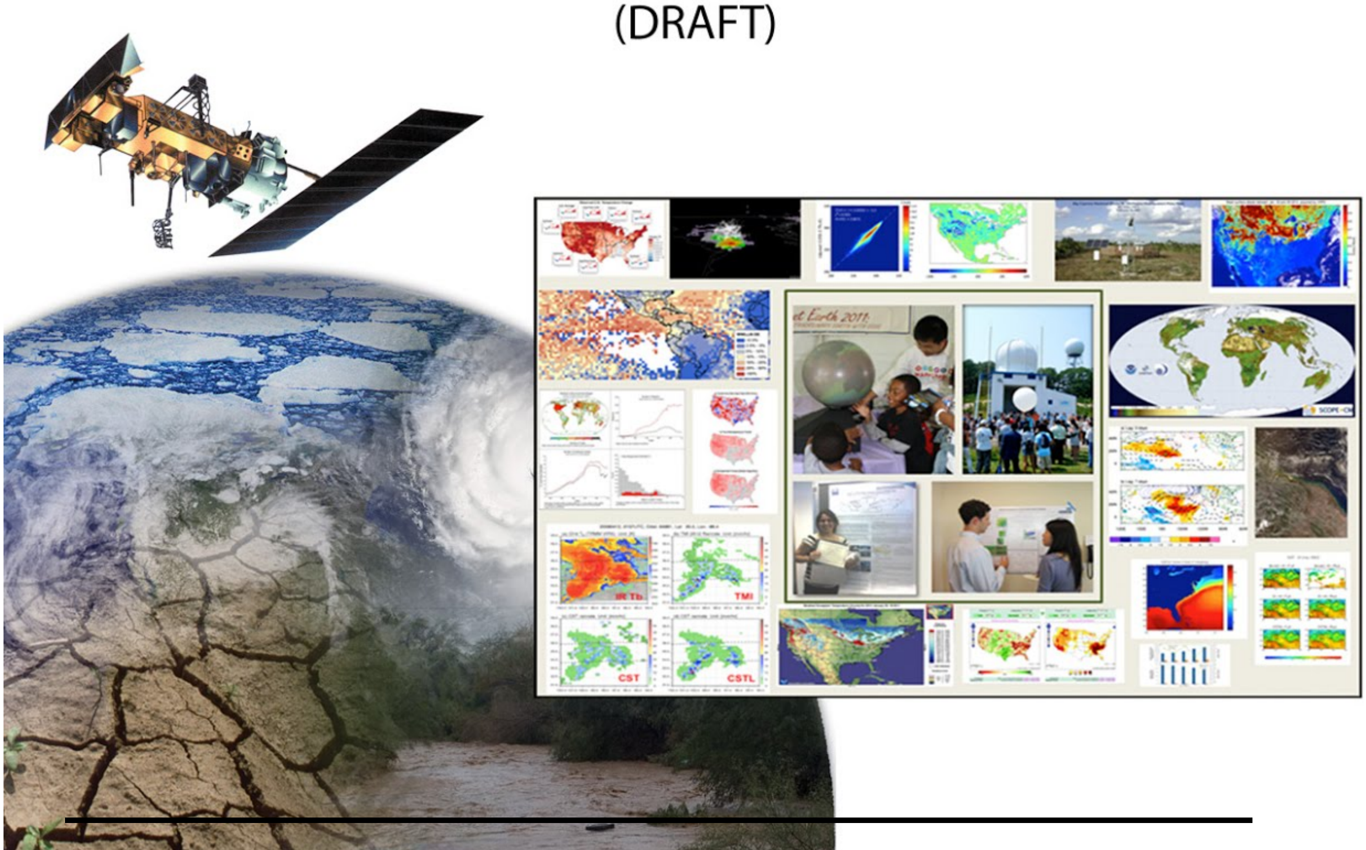
Cooperative Institute for Climate and Satellites

Mid-Term Review Report
November 2012
(DRAFT)



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EXECUTIVE SUMMARY

Over the past three years, CICS has undergone some of the most dramatic changes in its 29 years of existence. In mid-2009 the University of Maryland and NC State University were selected to operate the Cooperative Institute for Climate and Satellites (CICS). These two institutions anchor a consortium with more than 20 partner institutions across the U.S. CICS is the first experiment by NOAA and academic institutions to engage a geographically dispersed, diverse set of partners to address environmental change, their prediction, and potential impacts. In this report we document the scientific and societal impacts of this partnership.

The scientific vision of CICS centers on the observation, using instruments on Earth-orbiting satellites and ground networks, and prediction, using realistic mathematical models, of the present and future behavior of the Earth System. CICS' vision is consistent with NOAA's, and CICS scientists work on projects that advance all four of NOAA's Long-Term Goals. During this period CICS has strengthened its research and accomplishments under three major themes:

- **Climate and Satellite Research and Applications** incorporating the development of new observing systems, or new climate observables from current systems.
- **Climate and Satellite Observations and Monitoring,** focusing on: (a) development and improvement of climate observables from current systems, and (b) development of all continental and global fields of climate parameters that can be used for climate analysis and climate model initialization.
- **Climate Research and Modeling is** a research component bringing together (a) climate observables, modeling and validation in a comprehensive integrated whole, and (b) observational products with model development efforts to enable research into the improvement of forecasts of climate system variability on space scales ranging from regional to global, and time scales from a week or two to centuries.

CICS personnel have continued their strong efforts in remotely-sensed rainfall estimation, radiation algorithms and data sets, aerosol retrievals, data assimilation, the analysis of these data in climate studies, and incorporation into stand-alone and coupled models. Newly emerging thematic areas for CICS include regional ecosystems within a coupled context and observational analysis and synthesis.

In this document we have offered our perspective on the CICS' contributions to our relationship with NOAA. We expect to build upon our accomplishments over the next 6.5 years, and in the process to continue to conduct outstanding collaborative research, education and outreach.

I. CICS OVERVIEW

The Cooperative Institute for Climate and Satellites (CICS) is in the 4th year of the current Cooperative Agreement, and is in the process of undergoing a comprehensive review of its scientific and administrative activities. This document presents our responses to the questions posed by NOAA as a part of the review together with the necessary contextual background that will enable the reviewers to more fully appreciate the people and activities that comprise CICS. In the remainder of this section, we provide an overview of the organizational context and scientific approach of the Institute. The succeeding sections are organized around the responses to the review questions provided by NOAA.

A. The Cooperative Institute for Climate and Satellites

In 2009, the University of Maryland and NC State University were selected in a competition to form the Cooperative Institute for Climate and Satellites (CICS). CICS is a consortium of academic, non-profit and community organizations with leadership from the University of Maryland, College Park (UMCP) and North Carolina State University (NCSU) on behalf of the University of North Carolina (UNC) System. The two principal nexuses of CICS activity are located in College Park, MD (CICS-MD) and Asheville, NC (CICS-NC), and are hosted by UMCP and NCSU, respectively. CICS-MD is managed by the Earth System Science Interdisciplinary Center (ESSIC) at UMCP and CICS-NC is an Inter-Institutional Research Center with the UNC System, where it is known as the North Carolina Institute for Climate Studies (NCICS). Dr. Phillip Arkin is the Executive Director of CICS, Dr. Hugo Berbery the Director of CICS-MD and Dr. Otis Brown the Director of CICS-NC.

The range of expertise needed to support NOAA is broad and varied. It ranges from basic and applied research on the natural climate system, through study of the coupling of the Earth system to societal responses, and social science and policy research, to stakeholder engagement and communication with the body politic. It is clear that no one institution or even a small number of institutions can provide all the necessary academic expertise. Thus CICS was proposed as a consortium of partners with expertise covering the breadth of NOAA's portfolio. Currently CICS consists of 23 partners (figure A.1 lists the CICS Consortium members in addition to UMCP).

- University of North Carolina System
- Joint Global Change Research Institute
- Princeton University
- Howard University
- University of California at Irvine
- Columbia University
- City University of New York
- Climate Central
- Duke University
- University of Miami
- Oregon State University
- Colorado State University
- Remote Sensing Systems
- Renaissance Computing Institute of UNC
- Department of Energy Oak Ridge National Laboratory
- North Carolina Arboretum
- Centers for Climate Interaction
- Institute for Global Environmental
- Oak Ridge Associated Universities
- University of South Carolina
- Arizona State University
- University of Illinois

Institutions in GOLD are active: received funds, submitted proposals or actively discussing doing so

Figure A1: CICS Consortium members in addition to UMCP.

CICS' Vision and Mission derive from the historical expertise of the lead institutions and partners that comprise the CICS Consortium, together with NOAA's requirements. The CICS vision and mission are closely tied to the NOAA Strategic Goals.

CICS **vision** is to perform collaborative research aimed at enhancing NOAA's ability to use satellite and in situ observations and Earth System models to advance the national climate mission, including monitoring, understanding, predicting and communicating information on climate variability and change.

CICS **mission** is to conduct research, education and outreach programs in collaboration with NOAA to:

- Develop innovative applications of national and international satellite observations and advance transfer of such applications to enhance NOAA operational activities;
- Investigate observations and design information products and applications to detect, monitor and understand the impact of climate variability and change on coastal and oceanic ecosystems;
- Identify and satisfy the climate needs of users of NOAA climate information products, including atmospheric and oceanic reanalysis efforts;
- Improve climate forecasts on scales from regional to global through the use of observation-derived information products, particularly through participation in the NOAA/NWS/NCEP Climate Test Bed;
- Develop and advance regional ecosystem models, particularly aimed at the Mid-Atlantic region, to predict the impact of climate variability and change on such ecosystems; and
- Establish and deliver effective and innovative strategies for articulating, communicating and evaluating research results and reliable climate change information to targeted public audiences.

B. CICS Organization

As noted above CICS has two principal sites anchoring a broad consortium of more than 20 institutional partners. Each partner can have direct links with both anchors; however, specific linkages are dictated by the particular task to be performed. In the following we describe the organization of each anchor and their NOAA collaborators.

CICS-MD

CICS-MD is based upon the model and experience gained by UMCP through its management of the Cooperative Institute for Climate Studies in collaboration with NOAA beginning in 1983. ***CICS-MD focuses on the collaborative research in satellite observations and Earth System modeling conducted by the Center for Satellite Applications and Research (STAR) of NOAA/NESDIS and the National Centers for Environmental Prediction (NCEP) of NOAA/NWS.*** During the first several years of the award, CICS-MD has initiated additional collaborations with other NOAA units in the Washington, DC area, including the National Oceanographic Data Center (NODC) and the Air Resources Laboratory (ARL).

CICS-MD' host organization is the Earth System Science Interdisciplinary Center (ESSIC). ESSIC is in the College of Computer, Mathematical, and Natural Sciences (CMNS) of the University of Maryland, College Park. ESSIC seeks to better understand how the atmosphere-ocean-land-biosphere components of Earth interact as a coupled system and how human activities influence this system. ESSIC concentrates on four major research areas: climate variability and change; atmospheric composition and processes; the global carbon cycle (including terrestrial and marine ecosystems/land use/cover change); and the global water cycle. CICS-MD also includes strong participation from a number of UMCP departments, including Atmospheric and Oceanic Science (AOSC), Geographical Sciences (GEOG), and most recently Astronomy (ASTR).

Since CICS-MD includes UMCP faculty, staff and students from several units, we have found it helpful to define CICS-MD ***Members*** (see Appendix C) as faculty members who serve as Principal Investigators (PIs) of a CICS task, persons paid by a CICS task, and students and non-faculty employees who have been paid from a CICS task. The Satellite Climate Studies Branch (SCSB) of NESDIS/STAR is collocated with CICS-MD, and so we also include the Federal employees in the SCSB as CICS-MD members.

CICS-NC

CICS-NC is an Inter-Institutional Research Center (IRC) of the UNC System, referred to as North Carolina Institute for Climate Studies (NCICS). It is administered by North Carolina State University (NCSU) and affiliated with all of the UNC academic institutions as well as a number of other academic and community partners. ***CICS-NC focuses primarily on the collaborative research into the use of in situ and remotely sensed observations in climate research and applications that is led by the National Climatic Data Center (NCDC) of NOAA/NESDIS.*** CICS-NC also is engaged in productive collaborative research with other NOAA elements, including the ARL Atmospheric Turbulence and Diffusion Division. CICS-NC includes numerous partners from academic institutions with specific expertise in utilizing satellite observations in climate research, applications and models.

CICS Consortium

The CICS Consortium includes a wide range of research universities, non-profit organizations and community groups. Its role is to augment the capabilities of CICS and to extend its ability to conduct innovative and original collaborative research with NOAA. The CICS Consortium includes CICS-MD and CICS-NC. Figure B1 shows geographic distribution of the current consortium partners.

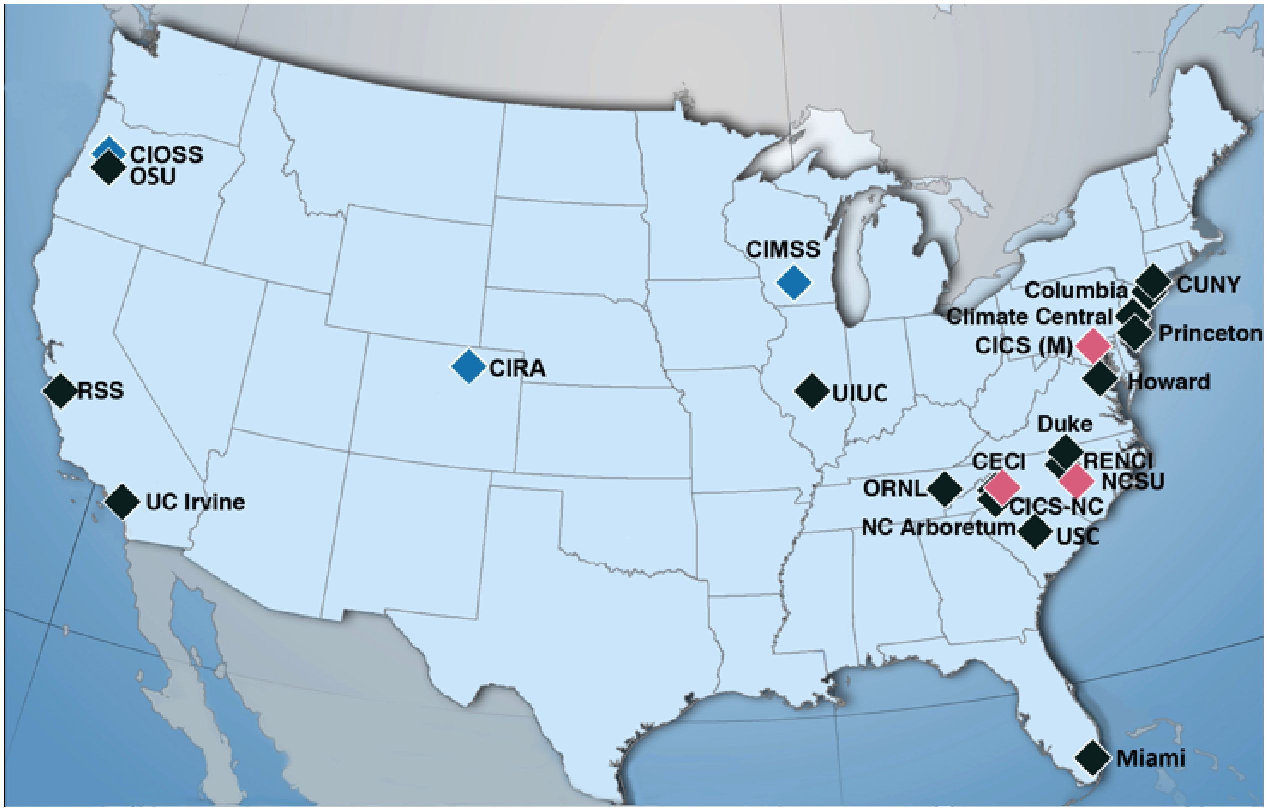


Figure B1: Institutional and geographical diversity of the CICS Consortium (2012). Black diamonds indicated CICS Consortium partners and red ones are the principal nexuses. Blue diamonds indicate the other NESDIS Cooperative Institutes.

CICS is arguably unique among NOAA Cooperative Institutes in its distributed consortial configuration. The initial membership of the Consortium was chosen to ensure a broad spectrum of expertise and experience appropriate to the proposed institute vision. Since CICS was established in 2009, some evolution in membership has occurred. A few of the initial members have found other methods to collaborate with NOAA, while others have been unable to identify a suitable niche. During the same period, several new partners have joined, extending the reach and capability of the Consortium.

The CICS Consortium provides NOAA with extraordinary opportunity to engage the extra-Federal scientific and user communities on research, development and outreach issues. It is a remarkably broad and flexible mechanism that enables NOAA to benefit from the collective wisdom and capability of its members.

C. CICS Administration

A Memorandum of Agreement (MOA) governing CICS organization and operation was concluded between UMCP and NOAA in 2011. The MOA describes the configuration and governance of CICS, and summarizes the functions of its several elements. The two principal anchors, CICS-MD and CICS-NC, are described, and the initial membership of the Consortium is defined. This MOA will expire at the end of the initial 5-year term of CICS.

CICS is led by Executive Director Dr. Phillip Arkin, who is assisted by Dr. Otis Brown, Director of CICS-NC and Dr. Hugo Berbery, Director of CICS-MD. The CICS Executive Board comprises senior officials representing UMCP, NCSU/UNC System and NOAA and provides advice and direction to CICS leadership on strategic and executive issues. The CICS Council of Fellows is the primary planning and consultative body for CICS and provides scientific advice to the Directors. Council members are drawn from CICS task leaders, NOAA collaborating scientists, and other eminent scientists from CICS partners and Consortium members.

CICS-MD is led by Research Professor Hugo Berbery of ESSIC and is hosted by ESSIC. CICS-MD includes research and professorial faculty members from ESSIC, AOSC, GEOG and ASTR, and supports a number of Research Associate and Faculty Research Assistant positions in each unit (see Appendix C). In addition, CICS-MD supports a number of graduate research assistants. CICS-MD financial and personnel operations are supported by the hosting unit, with ESSIC handling most of the responsibilities.

CICS-NC is led by Dr. Otis Brown and is hosted by the NCSU's Office of Research, Innovation and Economic Development. As noted earlier, CICS-NC is also the North Carolina Institute for Climate Studies (NCICS) and in that role represents a collaboration among all the institutions in the University of North Carolina System. It is co-located with NCDC in the Veach-Baley Federal Building in Asheville, NC.
NOAA support for CICS activities is handled through the 5-year Cooperative Agreement (CA) between NOAA and UMCP that implements the Cooperative Institute for the period July 1, 2009 through June 30, 2014. All activities at CICS-MD, CICS-NC and Consortium members are based on funds transmitted through the CA; activities not located at UMCP are funded through subcontracts. CICS-NC represents the largest set of subcontract activities, and is also responsible for the support of activities at a number of Consortium members through additional subcontracts. The ESSIC Business Office, directed by Mr. Jean La Fonta, manages the UMCP funding and accounting efforts.

The CICS award record since the original establishment of the Institute at UMCP in 1984 is shown in Figure C1. Given the critical role of climate monitoring and prediction in NOAA's mission, together with the developing connections to several of NOAA's principal scientific assets, we expect that CICS contribution to collaborative research and enhancement of operational capabilities in NOAA will continue to be significant.

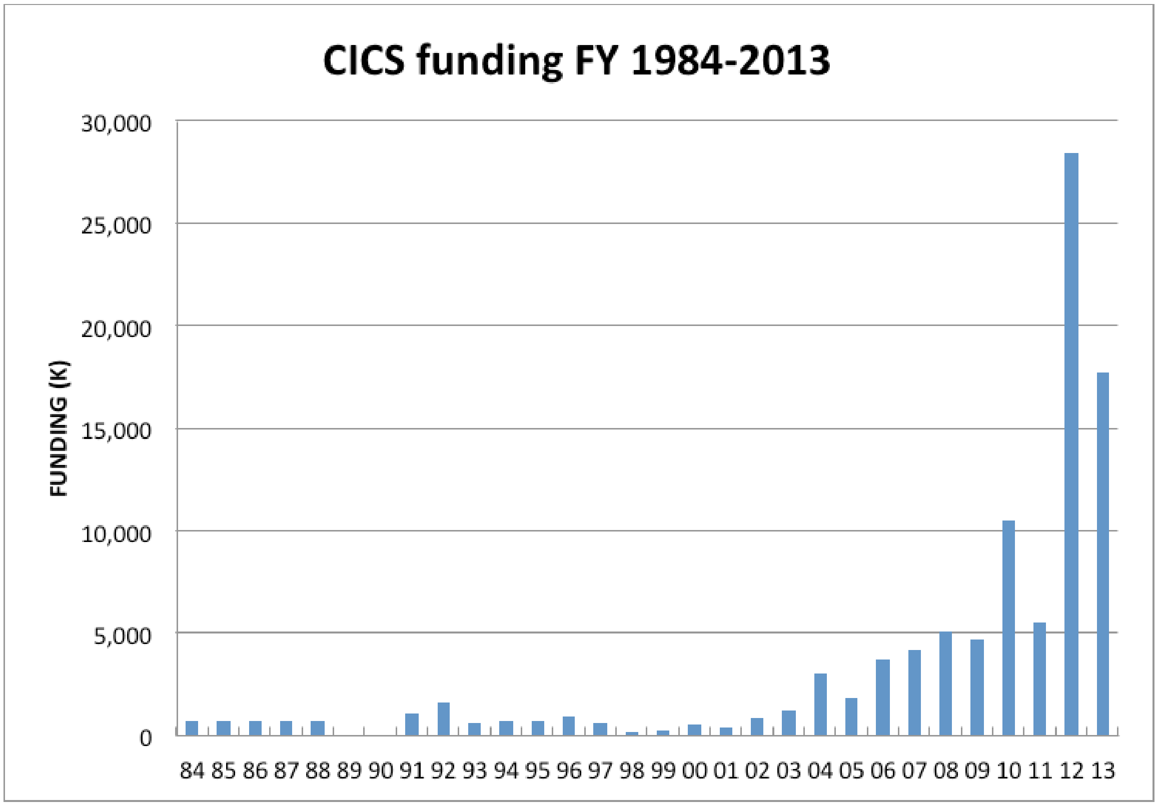


Figure C1: CICS Funding Profile in $1,000

II. SCIENCE PLAN

A. CICS Scientific Vision

What is the Scientific (Not Programmatic) Vision for the Institute?

The scientific vision of CICS centers on (a) the observation, using in situ and remote sensing observations, and (b) prediction, using realistic mathematical models, of the present and future behavior of the Earth System. In this context, observations include the development of new ways to use existing observations, the invention of new methods of observation, and the creation and application of ways to synthesize observations from many sources into a complete and coherent depiction of the full system. Prediction requires the development and application of coupled models of the complete climate system, including atmosphere, oceans, land surface, cryosphere and ecosystems. Since the component models are at greatly varying stages of maturity, hierarchies of less detailed models, together with uncoupled versions of the basic systems, must also be employed. Underpinning all of these activities is the fundamental goal of enhancing our collective interdisciplinary understanding of the state and evolution of the full Earth System.

The initial statement of CICS' Vision emphasized the observing, understanding and predicting of changes in the components of the Earth System. As research involving these aspects of NOAA's mission has advanced, the necessity of developing and implementing improved methods of communicating the relevant knowledge and information to communities of interest has become clear. CICS's Vision is evolving to accommodate this need, as illustrated by the increase in CICS projects related to user engagement, communication, and response to community needs.

B. Relation to the NOAA Strategic Plan

How is it related to the NOAA Strategic Plan?

The NOAA Next Generation Strategic Plan (see http://www.ppi.noaa.gov/ngsp/) states that NOAA's mission is:

- *To understand and predict changes in climate, weather, oceans, and coasts;*
- *To share that knowledge and information with others; and*
- *To conserve and manage coastal and marine ecosystems and resources.*

NOAA's vision centers on a holistic understanding of the interdependencies between human health and prosperity, and the intricacies of the Earth system. The objectives are: (a) a holistic understanding of the Earth system through research; (b) accurate and reliable data from sustained and integrated earth observing systems; and (c) an Integrated environmental modeling system.

NOAA's Long-term Goals are in four areas:

1. Climate Adaptation and Mitigation
2. Weather-Ready Nation
3. Healthy Oceans
4. Resilient Coastal Communities and Economies

These Goals are complemented by three supporting Enterprise efforts: Science and Technology; Engagement; and Organization and Administration. These Enterprise efforts represent activities that span the agency.

CICS' vision is closely aligned with NOAA's vision and goals, and CICS activities in the first 3.5 years of the Institute bear this out. Figure B1 shows the relationship of CICS support to the NOAA goals. CICS tasks contribute to all 4 of the NOAA Long-Term Goals, and in addition contribute significantly to NOAA's Enterprise activities.

Given the historical context that underlies the evolution of the CICS Scientific Vision and its tight coupling to NOAA's mission, the present close relationship is not surprising. A great deal of NOAA's mandate involves observing and predicting the behavior of the Earth System and finding ways to make the observations and predictions useful to the American public, topics that are central to CICS.

The CICS Vision as expressed in Section I.A maps closely to NOAA's interests as described in the NGSP. CICS strongly emphasizes the longer time scale aspects of NOAA's responsibilities, beginning approximately at the weather - climate interface and extending to centennial scales. CICS provides NOAA with mechanisms that enable the agency to conceive, plan and implement activities that span these aspects of its Mission.

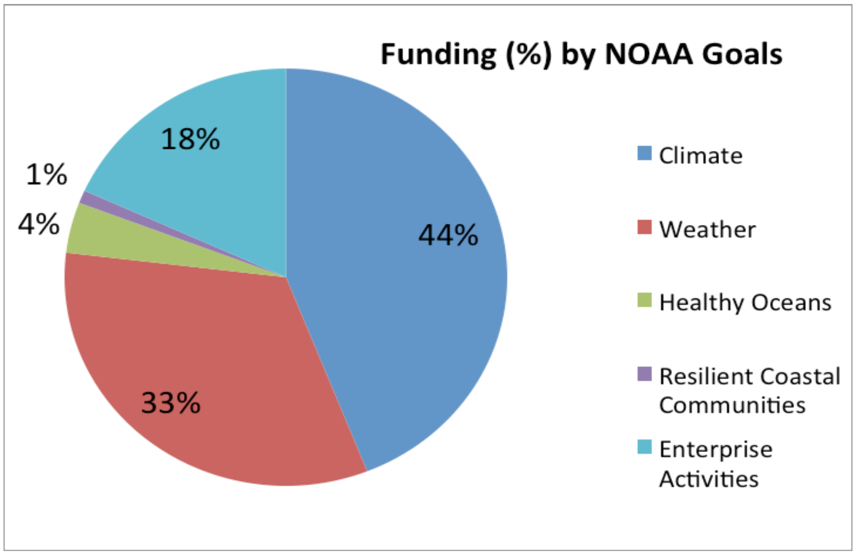


Figure B1: CICS Support by NOAA Goals (based on total support of $40.5M)

C. CICS Goals and Objectives

What are the goals and objectives?

CICS aims to advance NOAA's Earth observing, modeling, understanding, prediction and applications activities through extraordinary collaborative research with NOAA scientists.

The CICS corporate Vision is:

> **CICS performs collaborative research aimed at enhancing NOAA's ability to use in situ and satellite observations and Earth System models to achieve its long-term goals, including monitoring, understanding, predicting and particularly communicating information on climate variability and change.**

To fulfill this vision, CICS conducts research, education and outreach programs in collaboration with NOAA that accomplish the following goals:

- Developing innovative applications of national and international in situ network and satellite observations and assisting transfer of such applications to NOAA operational activities;
- Investigating observing systems and designing information products and applications to detect, monitor and understand the impact of climate variability and change on coastal and oceanic ecosystems;
- Identifying and fulfilling the in situ and satellite climate needs of users of NOAA climate information products, including atmospheric and oceanic reanalysis efforts;
- Improving climate forecasts on scales from regional to global through the use of satellite-derived information products, particularly through participation in the NOAA/NWS/NCEP Climate Test Bed;
- Developing and advancing regional ecosystem models, particularly aimed at the Mid-Atlantic region, to predict the impact of climate variability and change on such ecosystems; and
- Establishing and delivering effective and innovative strategies for articulating, communicating and evaluating research results and reliable climate change information to targeted public audiences.

In pursuit of these goals, CICS will:

- Engage in research on the use of in situ and satellite observations to advance the National climate mission, including monitoring, understanding, predicting and communicating information on climate variability and change in support of NOAA's mission and strategic goals.
- Mentor and train the next generation of researchers through research and educational opportunities.
- Provide educational and outreach opportunities in research on applications of satellite data and information to climate issues for both NOAA and the academic community.
- Disseminate and communicate research results for the general public, capitalizing on current advancements in technology, media and educational methodologies that address the unique nature and complexity of climate change science.

D. Measures of Progress

What criteria are used internally to measure progress in accomplishing these goals and objectives?

CICS advances towards its goals through the efforts of CICS scientists and their collaborators, supported by leadership. Rigorous quantifiable metrics are difficult to identify, and so CICS relies on a number of indices based on scholarship, support to NOAA, and engagement and outreach to the various communities of actual and potential users of CICS' information products. Our formal summary of progress is represented by the CICS Annual Report, published each year approximately on May 1 and containing summaries of our new and ongoing research efforts, as well as other relevant activities. The three Annual Reports completed during the first 3+ years of CICS (2010, 2011, 2012) are linked to from Appendix F. Section III of this review document contains illustrative examples and updates from each of the major research topic areas.

The following elements are used to evaluate CICS staff members and their contributions to the goals and objectives of CICS:

1. Scholarly Publications (peer reviewed only),
2. External and internal service relationships (national and international committees, meeting organization, etc.),
3. Recent scientific highlights and accomplishments,
4. Mentoring relationships,
5. Extramural research support (if relevant)
6. Graduate students supported through CICS
7. Collaborations with NOAA
8. Outreach and educational activities at K-12, undergraduate or graduate level, as well as private sector and general public
9. Products, articles, etc. developed through CICS support

Internal evaluation of progress within CICS is done in two ways: 1) through the annual evaluation of individual scientists by their respective academic units (ESSIC and other UMCP units for CICS-MD, and NCICS and other NCSU units for CICS-NC) and 2) through the several forms of CICS meetings. The annual meetings of the CICS Council evaluate the annual report and advise the Directors on scientific progress and future directions. CICS has had regular science meetings since its establishment. In these meetings, both CICS and NOAA scientists have the opportunity to present their active research to the peers and other interested scientists and program managers, and to receive helpful feedback. Other, less formal, gatherings take place frequently at both CICS-MD and CICS-NC in which young CICS scientists present progress updates on their projects and receive feedback. Finally, the CICS Executive Board, while it emphasizes managerial and strategic issues, is composed of scientists with relevant and extensive expertise, and often offers constructive high level advice regarding CICS progress.

The assessment of the success of individual CICS scientists is based, as is traditional in academic institutions, on the publication of scientific results in peer-reviewed journals and success in proposing research tasks to NOAA and other funding institutions. In addition, CICS scientists are evaluated on their contributions to the NOAA mission, in particular to the transition of research results into NOAA operational efforts, and on their success in engaging communities outside of the traditional scientific milieu. CICS as an institution is evaluated on the success of its contributing scientists.

CICS publications are listed in Appendix D and the number by year is shown in Figure D1. The full list indicates the great diversity and volume of our scientific work, and the large fraction of the publications that have our NOAA colleagues as co-authors demonstrate the successful collaborations that CICS has engendered. Many of these publications represent collaborative efforts that have led to enhancements in NOAA operational activities.

Figure D1: CICS Publications from July, 2009 to present.

E. Major Scientific Themes

What are the major scientific themes?

CICS seeks to better understand how the atmosphere-ocean-land-biosphere components of Earth interact as a coupled system and how human activities influence this system. To accomplish this, we study how to better obtain and integrate observations of the Earth System, and how to use models of widely varying complexity to understand the behavior of the system and to predict its future. CICS has three major research themes:

Theme 1: Climate and Satellite Research and Applications incorporates the development of new observing systems, or new climate observables from current systems.

Theme 2: Climate and Satellite Observations and Monitoring, focuses on: (a) development and improvement of climate observables from current systems, and (b) development of all continental and global fields of climate parameters that can be used for climate analysis and climate model initialization.

Theme 3: Climate Research and Modeling is the research component that brings together (a) climate observables, modeling and validation in a comprehensive integrated whole, and (b) observational products with model development efforts to enable research into the improvement of forecasts of climate system variability on space scales ranging from regional to global, and time scales from a week or two to centuries.

Research is conducted through in situ and remotely sensed observations, together with component and coupled ocean-atmosphere-land modeling. This multi-pronged approach provides a foundation for understanding and forecasting changes in the global environment and regional implications. Data assimilation and regional downscaling are used to link the observations and models, enabling us to study the interactions between the physical climate system and biogeochemical cycles from global to regional scales.

The CICS Themes are unchanged from the original submitted proposal. As CICS research has evolved since 2009, a set of Topic Areas (TA) have been identified as useful organizing devices. The table below illustrates the relationship between the Themes and the Topic Areas, and the Science Review (Section III) is organized around the TAs.

CICS Theme	CICS Scientific Topic Area
Theme 1: Climate and Satellite Research and Applications	• Climate and Data Assimilation • Land and Hydrology • Future Satellite Programs • Data Fusion and Algorithm Development • Calibration and Validation • National Climate Assessments • Education, Literacy and Outreach
Theme 2: Climate and Satellite Observations and Monitoring	• Land and Hydrology • Climate Data and Information Records and Scientific Data Stewardship • Surface Observing Networks • Consortium Projects • Climate Monitoring from Satellites • Future Satellite Programs • Data Fusion and Algorithm Development • Calibration and Validation • National Climate Assessments • Education, Literacy and Outreach
Theme 3: Climate Research and Modeling	• Climate and Data Assimilation • Land and Hydrology • Climate Monitoring from Satellites • National Climate Model Portal • Future Satellite Programs • Data Fusion and Algorithm Development • Calibration and Validation • National Climate Assessments • Education, Literacy and Outreach

Table 1: CICS Topic Areas and Science Themes

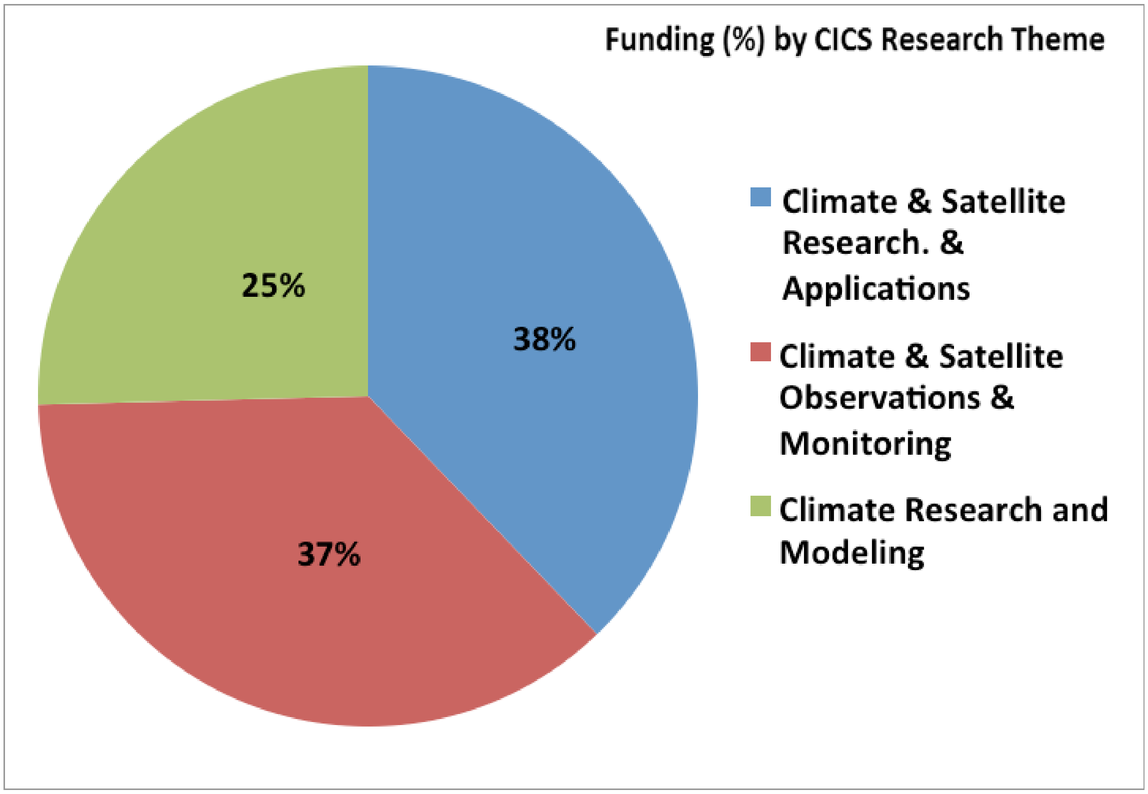


Figure E1: CICS funding for each Theme (some projects support more than one Theme)

Figure E1 shows the approximate funding from NOAA that applies to each of the Themes. Given their breadth, it is unsurprising that none of the CICS Themes is nearing completion. Some of the TAs that have been identified, such as Future Satellite Programs, have relatively clear life cycles and are evolving from the initial highly developmental stage toward implementation and operation, but ongoing activities related to ensuring quality and working toward improvements are expected to continue.

Within CICS, three new thematic areas are emerging: (a) Integration of observations and models, (b) Monitoring and predicting at the weather and climate interface, and (c) Climate literacy, education and outreach. All of these are growing from the existing Themes and TAs, and striving for organized structure and support.

F. Scientific Partnerships

What is your relationship to other NOAA entities?

CICS has extremely strong partnerships with the Center for Satellite Applications and Research (STAR) and the National Climatic Data Center (NCDC), both of NOAA/NESDIS, which are its two principal sponsors. CICS has a number of other strong linkages to NOAA laboratories and units in the Washington DC region and in Oak Ridge, TN, and in addition collaborates closely with other NOAA Cooperative Institutes and their NOAA partners.

The NOAA Center for Weather and Climate Prediction (NCWCP), which has been occupied since August 2012, and ESSIC, which hosts and houses CICS-MD, are located together in College Park at the UMCP's M-Square research park. CICS researchers and their NOAA collaborators work side by side in both locations. Figure F1 is a view of the new NOAA facility from the entrance. CICS-MD is headquartered in the ESSIC building (Figure F2), which is located approximately 400 meters from the NCWCP. The STAR Satellite Climate Studies Branch (SCSB) is collocated with CICS-MD in ESSIC. SCSB comprises 5 NESDIS scientists who work closely with many of the CICS-MD scientific staff. Other of the CICS-MD scientists collaborate with STAR scientists in the NCWCP; in some cases through physical location in the NOAA building and in others facilitated by the convenient proximity of ESSIC and the NCWCP.

Other CICS-MD scientists collaborate with the Climate Prediction Center and the Environmental Modeling Center of the National Centers for Environmental Prediction, and with the Joint Center for Satellite Data Assimilation and the Satellite Analysis Branch of NESDIS. A strong collaborative effort focused on air quality research joins CICS-MD scientists in the Department of Atmospheric and Oceanic Science with the NOAA Air Resources Lab headquarters unit located in the NCWCP. Elsewhere in the local area, CICS-MD scientists collaborate with the National Oceanographic Data Center and the Climate Program Office.

Figure F1: NOAA Center for Weather and Climate Prediction and ESSIC/CICS

Figure F2: ESSIC/CICS Building in M-Square Research Park

NESDIS NCDC and CICS-NC are collocated in Asheville in the Veach-Baley Federal Building Complex (Figure F3). CICS-NC scientists work in task teams within the various divisions of NCDC that directly support NCDC mission requirements. This working arrangement leads to strong collaboration between NOAA, CICS and contractor staff on a daily basis. These collaborations facilitate project development, initiation and execution as well as the publication of scientific results.

Figure F3: Veach-Baley Federal Complex -
NOAA’s National Climatic Data Center and CICS-NC

CICS-NC also has a strong collaboration with the Air Resources Lab Atmospheric Turbulence and DIffusion Division located at Oak Ridge, TN. This effort is focused on the installation, operation and research related to the Climate Reference Network, a major joint research project connecting scientists at ATDD, NCDC and CICS-NC.

A number of the CICS-NC staff have faculty appointments in the North Carolina State University College of Physical and Applied Mathematical Sciences (PAMS); see Figure F4. PAMS is currently undergoing organizational changes, and evolving into the College of Sciences with the additional of life sciences faculty. These appointments facilitate research collaboration, seminars across different campuses, mentoring of undergraduate and graduate students, and, are leading to development of new curriculum options for graduate programs in Raleigh. CICS-NC, starting summer 2013, will provide mentoring opportunities for students in the Climate Science and Society Professional Science Masters program, a joint undertaking program by NCSU and UNC Asheville.

Figure F4: Image of NCSU College of Sciences (PAMS).

What, if any, formal procedures do you have for joint planning?

CICS is involved in cooperative planning activities at a number of levels. Both NOAA and NESDIS coordinate annual meetings of the Cooperative Institute Directors. A broad range of issues are discussed at these meeting, including both events transpiring in the NOAA environment that will impact CI plans as well as inter-CI opportunities and challenges. The NOAA-wide meetings tend to focus, naturally, on issues that involve a majority of the CIs. The meetings of the NESDIS CI Directors are more focused on opportunities and challenges specifically relevant to CICS and those other CIs managed by and working most closely with NESDIS. The NESDIS CI Directors' meetings provide the opportunity to initiate and monitor the detailed, specific planning required to coordinate the broad research and development activities associated with the CIs roles in the GOES-R and JPSS programs.

CICS itself utilizes a number of methodologies for cooperative planning specific to our own research program. The Council of Fellows, which consists of approximately 36 CICS and NOAA scientists who are familiar with CICS research, meets at least annually to consider the CICS research portfolio. Focus groups drawn from the Council and including NOAA managers where appropriate are charged with evaluating CICS interaction with its NOAA partners and identifying innovative research opportunities. Three CICS Science Meetings, in 2010, 2011 and 2012, have provided fora for presentation of ongoing research and discussion of opportunities.

The CICS leadership weaves all these activities together, set priorities and coordinate interactions. The Executive Director, Phil Arkin, and the Directors of CICS-MD, Hugo Berbery, and CICS-NC, Otis Brown, participate in all of these processes and others, including direct conversation with NOAA scientists and managers, and develop action plans to ensure the successful conduct of the CICS research program.

III. SCIENCE REVIEW

What are the Institute's most recent scientific highlights and accomplishments?

The CICS Science Themes, as described in Section II E, are comprehensive and relatively nonspecific and specific research projects often span multiple themes. We have found it advantageous to group individual projects into Topic Areas based on common characteristics. Figure 1 illustrates the relationship between the Topic Areas and the CICS Science Themes. In this section, we present an overview of each Topic Area, together with illustrative examples of recent research results.

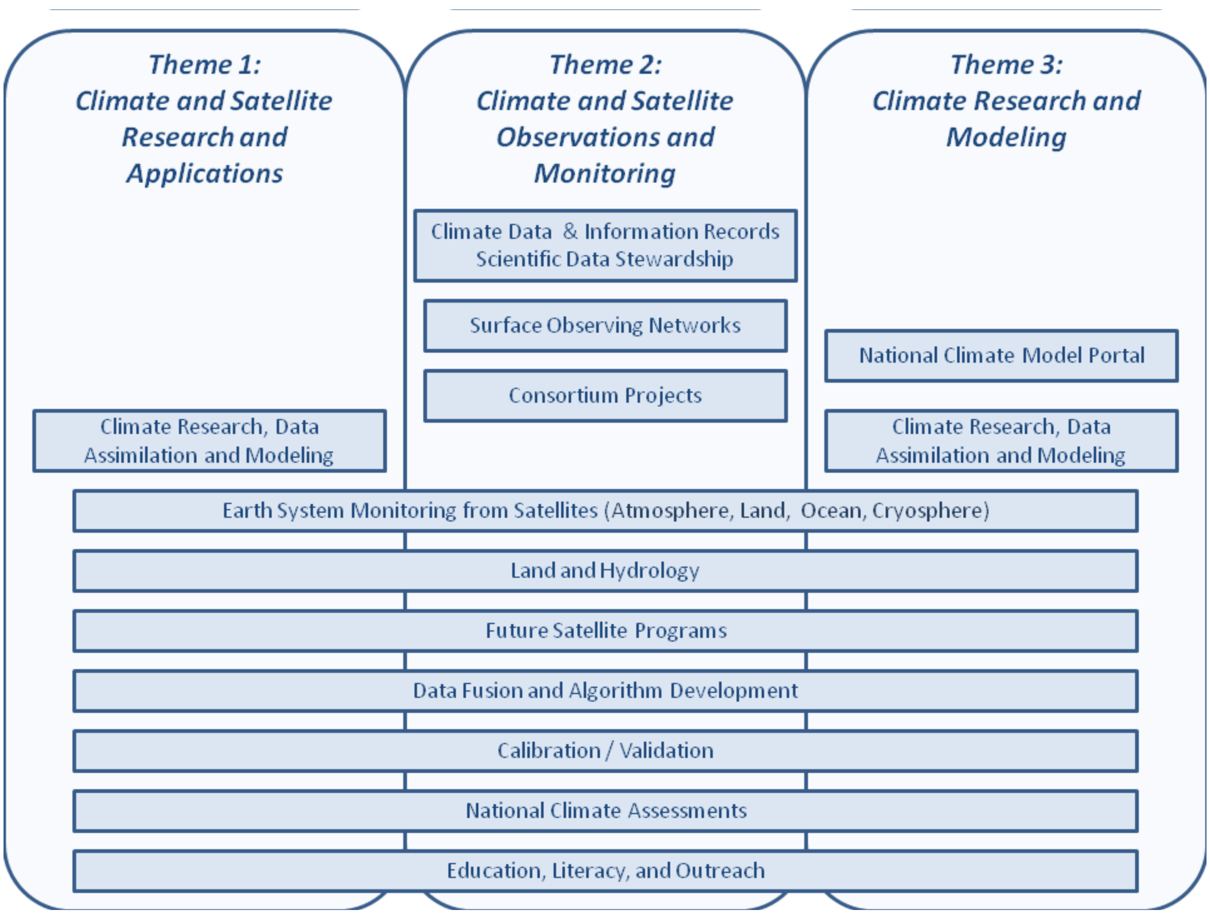


Figure 1: Relationship among the CICS Scientific Themes and the Topic Areas.

A. Data Fusion and Algorithm Development

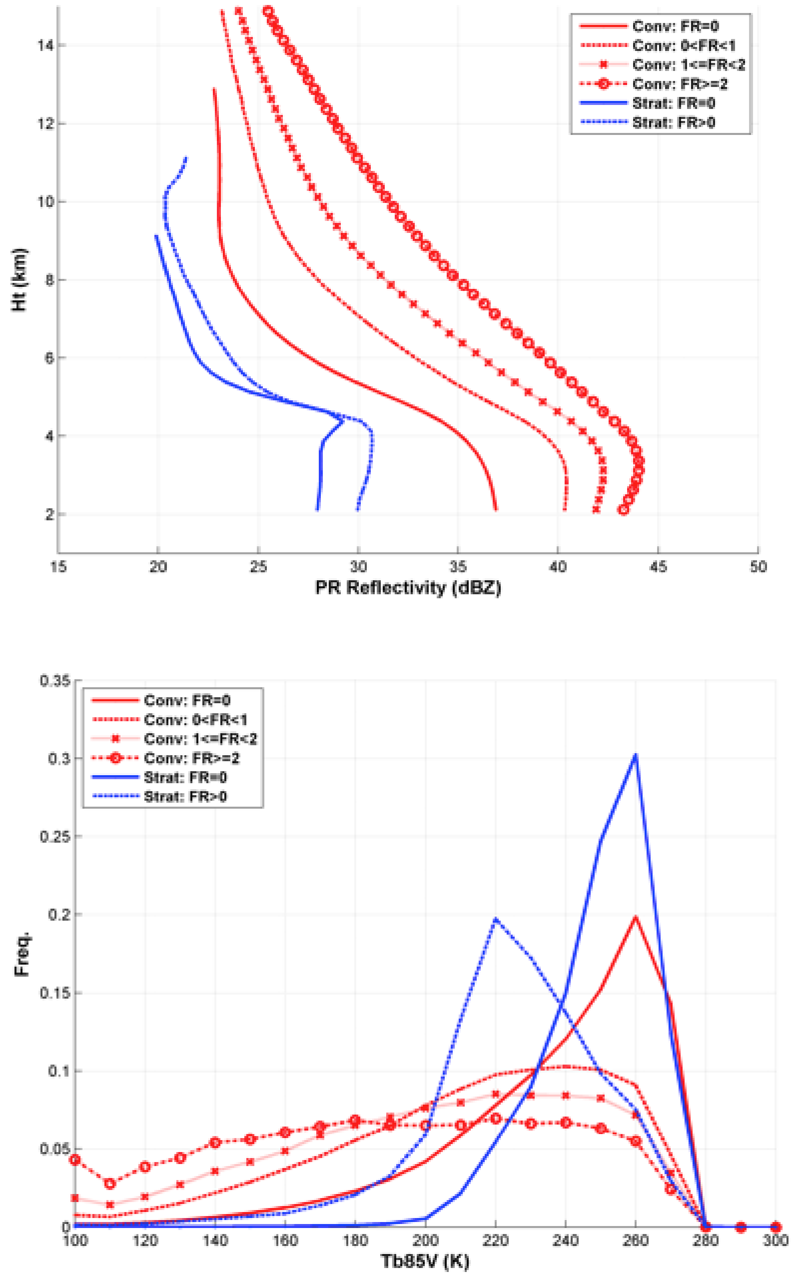
This Topic Area includes research projects that focus on the use of satellite and complementary observations to create geophysical data sets related to various aspects of the global climate system. Examples of ongoing research projects in this Topic Area are described in Section III A.

1. Combining GOES-R and GPM to improve GOES-R rainrate product (Nai-Yu Wang)
This project focuses on the multi-instrument and multi-platform synergy of combining GOES-R and NASA GPM to improve precipitation products. The proposed project has two objectives: 1) to improve microwave-based precipitation by connecting the ice-phase microphysics commonly observed by GOES-R GLM and GPM microwave instruments 2) to provide GOES-R rain-rate (QPE) algorithm a better microwave rain-rate calibration. Innovative strategy to make use of lighting and microwave data in identifying the convective and stratiform rain types are developed, which improves microwave-based convection definition and rain rate estimates. Because GOES-R ABI rainfall rate (QPE) algorithm requires the microwave-based rain rates as a calibration target (Kuligowski, 2009), the better microwave rain rates will improve the accuracy of GOES-R rainfall rate retrievals.

In this study, we investigate the viability of using lightning in conjunction with passive microwave to maximize the correlation between convective precipitation and PM measurements. The goal here is to use lightning information to improve PM's ability to discriminate convective and stratiform precipitation. Four years (2002-2005) of TRMM Microwave Imager (TMI), Lightning Imaging Sensor (LIS), and Precipitation Radar (PR) data are co-located for analysis and derivation of a robust and physically based convective and stratiform separation. The relationships between flash rates, PR reflectivity and 85 GHz TBs are illustrated in Figure A1. For convective pixels, the categories with higher lightning activity tend to have higher peak reflectivity (i.e., large size ice particles, Figure A1a), cooler *Tb85V* (i.e., large IWP, Figure A1b), and higher surface reflectivity (i.e., heavy surface precipitation, not shown here). The convective categories also tend to have deeper storm structures; i.e. the high reflectivity values (>40 dBZ) extend to greater heights, indicating strong updraft and convective activity.

Based on the distribution of lightning flash rates in the four years of TRMM TMI/PR/LIS data discussed in the previous paragraph, we stratify the data into 4 categories with increasing lightning activity this is equivalent to classify the data into categories with increasing convective activity. The convective fraction relationships for the 4 convective categories are trained using TRMM data from January 2002- December 2005.

The improvement in the TMI retrievals upon incorporating LIS information is most clearly observed in deep convective systems. For convective pixels, the mean bias in the convective ratio for TMI-LIS compared to PR is ~8% lower than the corresponding value for the TMI algorithm. Consequently, the mean rainrate bias relative to PR is reduced from ~17% to ~12% by adding LIS information to TMI. However, the RMS error in the TMI-LIS rainrate estimates is ~4.5% higher compared to the TMI estimates. This indicates that even though the TMI-LIS algorithm improves the mean biases (both in CSI and RR estimates), it appears to increase the variance of rainrate errors relative to PR. This may be due to the original *RRconv* and *RRstra* regressions. These *Tb85V – RR* relationships were not stratified by lightning categories. For future algorithm development, calculating *Tb85V – RR* convective and stratiform relationships might be the next step to better improve the impact of lightning on PM rain-rate algorithms. The overall rainrate improvement is 6%. A JGR journal publication is currently in press based on this work. (Wang et al., 2012).
(a)



(b)

Figure A1: (a) Median reflectivity profiles for convective and stratiform rain types separated by lightning activity, and (b) Tb85V histograms for each subset in (a), from Jan 2002 –Dec 2002.

References:

Wang, N-Y., K. Gopalan, and R. Albrecht, 2012: Application of lightning to passive microwave convective and stratiform partitioning in 2 passive microwave rainfall retrieval algorithm over land from TRMM, JGR-Atmosphere, in press.

2. Microwave and Diurnal Corrected Blended SST (Andy Harris)

CICS and NESDIS scientists are collaborating to develop new high-resolution (0.1°´0.1° and 0.05°´0.05°) global SST analyses using a recursive estimator to emulate the Kalman filter. The resulting analyses also include continuously updated uncertainty estimates for each analysis grid point. Since these analyses are entirely satellite-based, there is no explicit attempt to correct regional biases to an *in situ* standard. Instead, biases between individual datasets are corrected against the NCEP RTG_HR SST in a statistical manner, with certain assumptions of persistence and correlation length scale. The analysis is performed at three different correlation length scales, with the final result being interpolated based on local data density. This preserves mathematical rigor whilst mimicking the effect of a non-stationary prior. It also provides a solution to the problem of preserving resolution without introduction of excessive noise.

Thinned RTG data are also assimilated, but have negligible contribution to the final analysis where there is adequate density of other observations. The analysis performs well with the addition of new geostationary SST data, and the recent increase in resolution from 0.1°´0.1° to 0.05°´0.05° (see Figure A2), particularly with respect to the definition of features of oceanographic importance, such as mesoscale and coastal eddies.

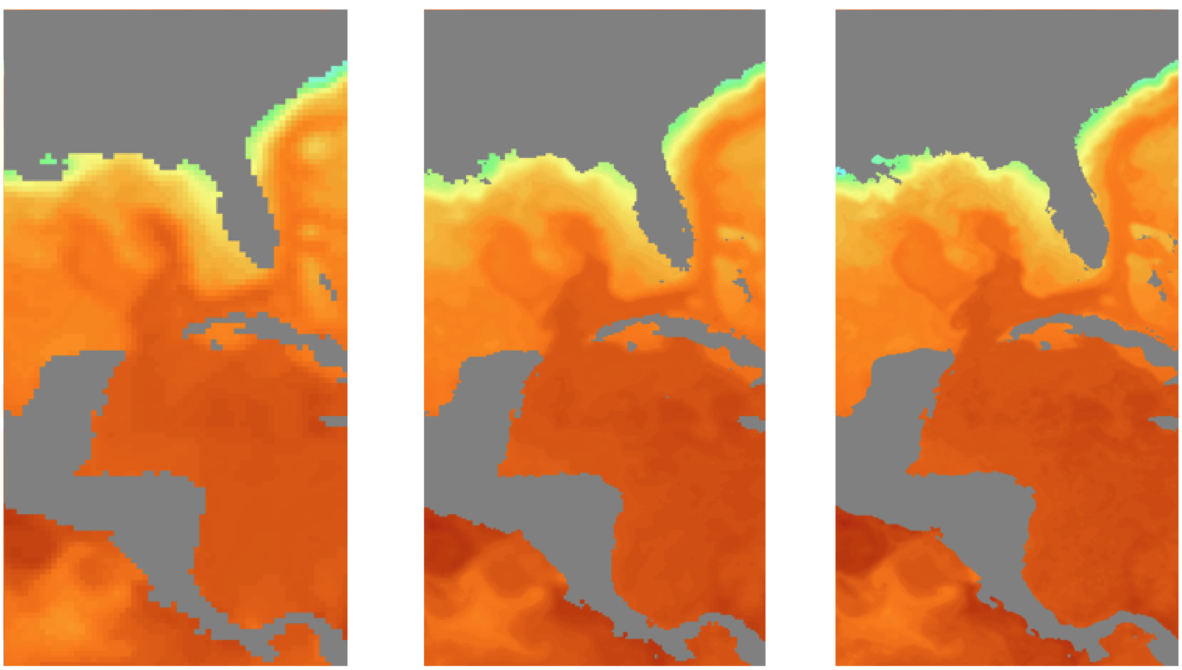


Figure A2: Comparison of Reynolds Daily OI ¼°×¼° SST analysis (left panel), POES-GOES Blended 0.1°×0.1° SST analysis (middle panel) and POES-GOES Blended 0.05°×0.05° SST analysis (right panel). Improved definition of shallow water regions in the vicinity of Abaco and other Caribbean islands, as well as coastal eddies in the Gulf Stream and Loop Current, is evident, particularly in the 1/20 degree product.

3. Investigations over Arctic Sea Ice using Satellite and Aircraft Altimetry (Sinéad L. Farrell)

Sea ice mass balance and thickness are leading indicators of the state of the climate system and the ongoing loss of Arctic sea ice has serious implications for the polar environment and climate. Satellite altimeter observations of sea ice thickness indicate a decrease in the overall volume of the ice pack during the last decade, indicating the loss of the thickest, multiyear ice in particular. Continuous monitoring of Arctic sea ice using satellite and airborne altimetry is necessary to determine whether these observations are part of a sustained negative trend, or a reflection of natural, inter-annual variability. Furthermore it is essential to validate the measurement capabilities of satellite altimeters using independent aircraft and field data. This project will quantify the ability of satellite altimeters on board ICESat, Envisat, CryoSat-2, and ICESat-2 to map the elevation and thickness of Arctic sea ice through analysis of data gathered by the NASA IceBridge airborne mission, which provides a yearly, multi-instrumented survey of key, rapidly changing regions of the Arctic sea-ice pack.

The 2011 field season was highly successful with three aircraft flights beneath satellite-borne radar altimeters, as well as overflights of direct sea ice field measurements in the Beaufort and Lincoln Seas. The team conducted a detailed inter-comparison of IceBridge airborne data collected in April 2009 during the joint NOAA/NASA Canada Basin Sea Ice Thickness (CBSIT) experiment, with in situ field measurements of sea ice and snow thickness that were acquired at the Danish GreenArc Ice Camp north of Greenland. Snow depth estimates from the Kansas University snow radar system were validated via comparison with the in situ measurements, with a demonstrated agreement between the datasets to better than 3 cm. Following the publication of these results (*Farrell et al.*, 2011a), a basin-scale analysis of snow thickness on Arctic sea ice, using measurements from the IceBridge snow radar system, was completed. Results from the 2009 Arctic campaign were used to derive trans-Arctic profiles of snow depth (Figure A3). This experiment demonstrated the first, routine measurement of snow thickness on sea ice from an airborne system (*Kurtz and Farrell*, 2011). Comparisons with a climatology of snow depth, compiled from over 40 years of in situ measurements (*Warren et al.*, 1999), revealed that snow on multiyear sea ice was consistent with historical values, while snow thickness on first year ice was ~50% lower than the climatology.

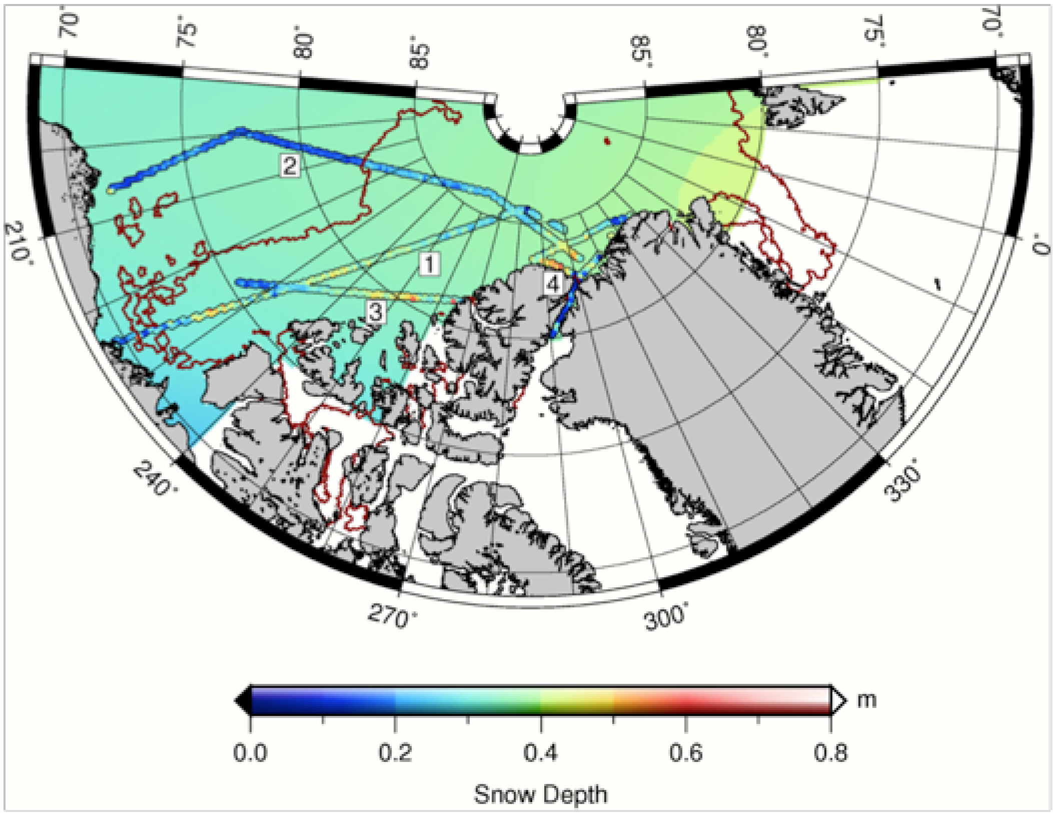


Figure A3: Trans-Arctic profiles of snow depth derived along 2009 IceBridge flight-lines, overlaid on a snow depth climatology from Warren et al., 1999.

B. Future Satellite Programs

This Topic Area includes research projects that focus on aspects of the development and implementation of new NOAA meteorological satellite systems. CICS participates in a number of projects related to two new systems: GOES-R and JPSS. Examples of ongoing research projects in this Topic Area are below.

(i) Scientific support for the GOES-R Mission

The planned Geostationary Operational Environmental Satellite-R (GOES-R) will include instruments to detect, measure or derive numerous atmospheric, land surface and oceanic parameters, including short- and long-wave radiation, rainfall, evapotranspiration (for drought monitoring), lightning occurrence, fire detection, aerosol optical properties, and cloud and precipitation products. CICS participates in collaborative research related to algorithm development, risk reduction and proving ground activities.

1. Risk Reduction Research for GOES-R Geostationary Lightning Mapper (Scott Rudlosky and CICS students)

The instrument complement on GOES-R will include the Geostationary Lightning Mapper (GLM). This instrument will provide regular and frequent depictions of lightning occurrence from geostationary orbit for the first time, offering a significant advance in the ability of scientists to observe and understand the role of lightning in severe weather, tropical storms, and climate.

CICS scientists participate in risk reduction and algorithm development activities and serve as subject matter experts supporting GLM science and applications development and as members of the GLM Risk Reduction Team. They have developed methods to ensure user readiness for GLM data by working with proxy data from other observing programs, including the Tropical Rainfall Measuring Mission (TRMM) Lightning Imaging Sensor (LIS), Lightning Mapping Arrays (LMA), and models. These algorithms utilize GLM proxies in a variety of nowcasting, severe storm identification, aviation weather, wildfire, and precipitation applications.

A recent collaborative study evaluated the World Wide Lightning Location Network (WWLLN) and Vaisala's Global Lightning Dataset (GLD-360) relative to TRMM/LIS observations (Figure B1) by determining the fraction of TRMM/LIS flashes that are observed by the various ground-based networks. This study also documented spatial variability in the various performance metrics, and provided performance statistics to Proving Ground partners that currently use these data.

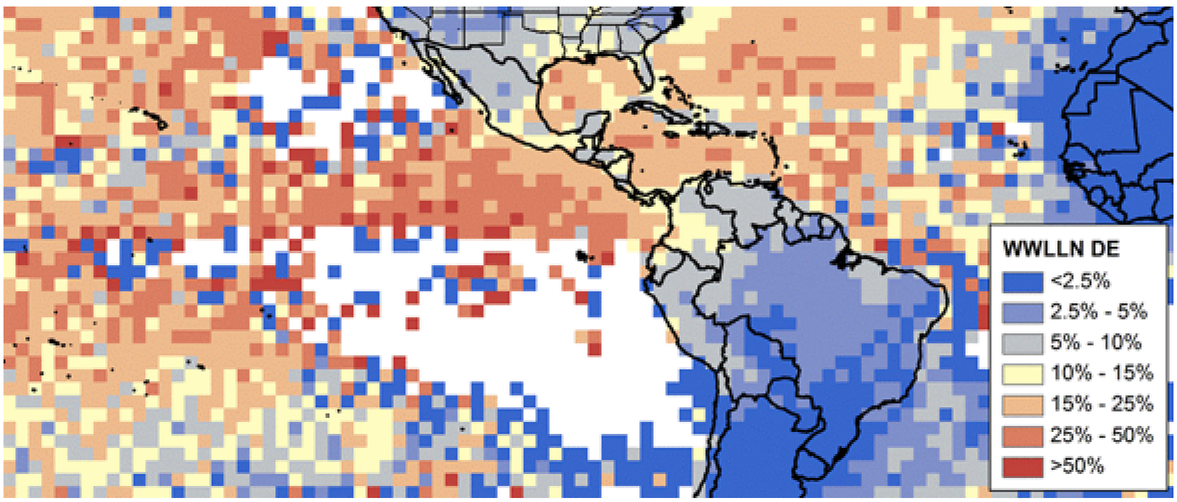


Figure B1: WWLLN Detection Efficiency relative to TRMM/LIS.

2. Combining GLM and ABI Data for Enhanced GOES-R Rainfall Estimates (Robert Adler, Weixin Xu, and Nai-Yu Wang)

This project seeks to combine information from the Geostationary Lightning Mapper (GLM) with the Advanced Baseline Imager (ABI) to produce a superior combined instrument rainfall product for GOES-R. This effort will make the GOES-R precipitation information uniquely important and provide the National Weather Service (NWS) and other users with timely, more accurate precipitation estimates from geosynchronous satellite data for use in supplementing ground-based estimates, especially in mountainous areas (e.g., western U.S.), surrounding waters, and in Mexico and Central and South America. The resulting improved rainfall estimates will be valuable for nowcasting in general, flash floods in particular, and estimation of rain potential of tropical cyclones.

This project first examined lightning-cloud-rain relationships with TRMM observations and derived useful lightning-cloud-rainfall relationships for the algorithm development (Xu et al. 2012). These findings and relationships are used to improve the rainfall estimation based on IR techniques, using the Convective/Stratiform Technique (CST) of Adler and Negri (1988) as a prototype approach.

An IR-lightning (CSTL) algorithm has been developed through coupling lightning measurements into the IR technique (CST) applied to the TRMM data. First, lightning flash locations are used to identify convective cores that are missed by the IR technique. Second, lightning occurrence is used to eliminate convective cores incorrectly identified by IR technique, helping to solve one of the biggest problems in geo-IR rain estimation. Quantitative rainrate-Tb and rainrate-lightning relations are then used to determine convective core area and rainrate. The stratiform rain area of mature systems is determined using a Tb threshold. Preliminary results show that CSTL improves CST in convective (heavy) rain retrievals by more than 30%. Lightning information can aid to identify convective cores missed by the IR-only technique (improving detection), eliminate misidentified convective cores (lowering false alarm), and more correctly assign heavy convective rainfall rate. The final IR estimated instantaneous rainrate is improved significantly after combining lightning information (see example in Fig. B2). Statistically, the correlation coefficients as compared to TRMM radar and passive microwave estimates increase with the lightning information from 0.32 and 0.52 to 0.53 and 0.76, respectively, indicating the value of the lightning information. Also, based on a few case studies, the CSTL also shows potential for improvement when compared with the Self-Calibrating Real-Time GOES Rainfall Algorithm (SCaMPR) (Kuligowski, 2002), a product similar to the GOES-R baseline algorithm.

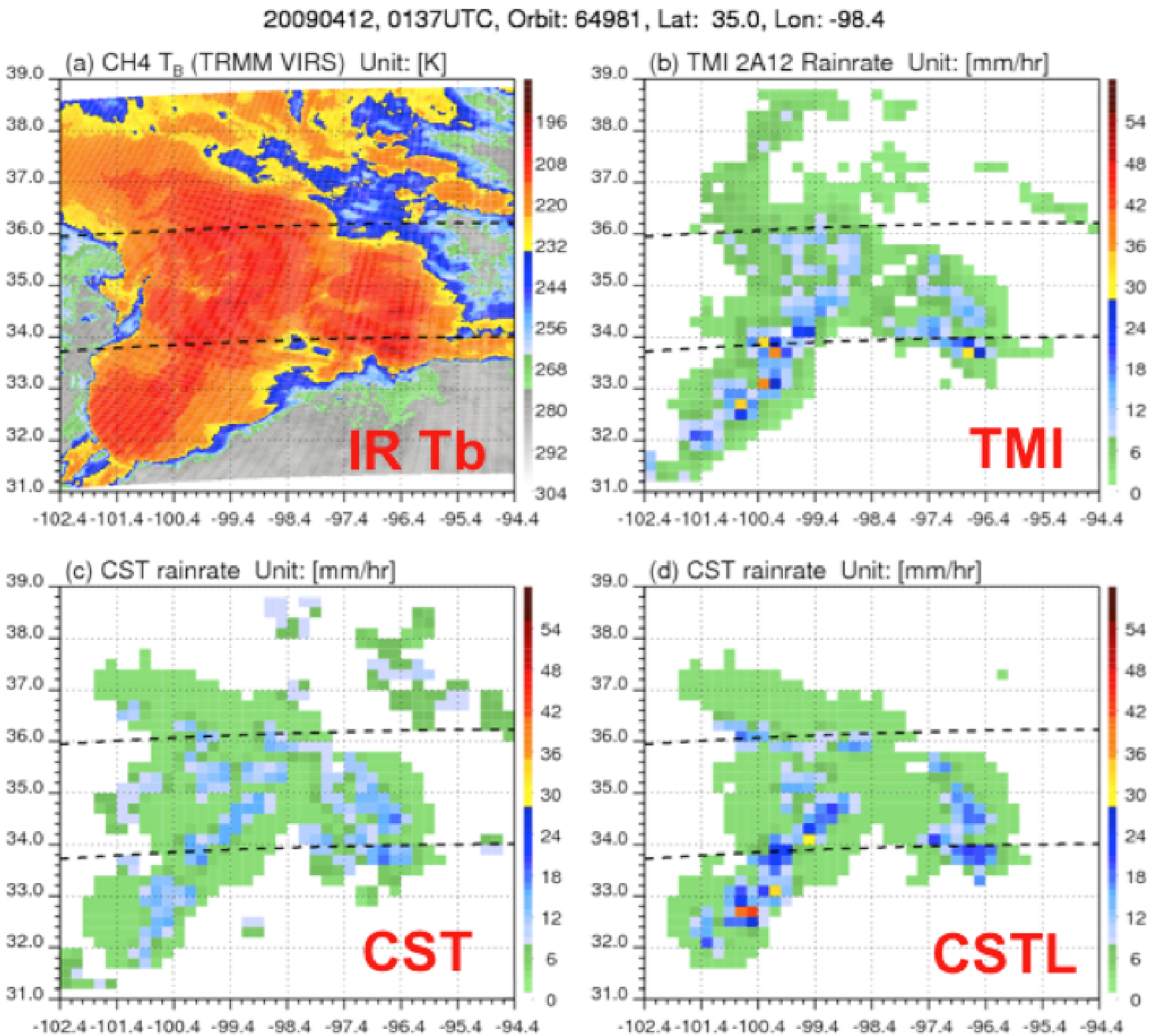


Figure B2: A snapshot of a mesoscale convective system: (a) TRMM VIRS Infrared brightness temperature, (b) TMI rain estimates, (c) CST rain estimates, (d) CSTL rain estimates. All the rain estimates are at 20-km resolution.

REFERENCES

Adler, R. F., and A. J. Negri, 1988: A satellite infrared technique to estimate tropical convective and stratiform rainfall. J. Appl. Meteor., 27, 30-51.

Kuligowski, R. J., 2002: A self-calibrating real-time GOES rainfall algorithm for short-term rainfall estimates. J. Hydrometeor, 3, 112–130.

Xu, W., R. F. Adler, and N.-Y. Wang, 2012: Improving Geostationary Satellite Rainfall Estimates Using Lightning Observations, I: Underlying Lightning-Rainfall-Cloud Relationships. J. Appl. Meteor. Climatol., in press.

3. Application of the GOES-R Land Surface Temperature Product for snowmelt mapping (Cezar Kongoli)

Land surface temperature (LST) lies at the heart of the surface energy balance and is a key variable in weather and climate models. The main goal of this project is development of a new application of the GOES-R LST product for snowmelt detection. A Snowmelt Detection (SD) application would be synergetic and an excellent addition to the GOES-R Flood/Standing Water (FSW) product, which in concert *would provide valuable information to hydrologists and forecasters* for *snowpack-runoff prediction and flood monitoring all-year round.* Another goal of this project is to enable the use of remotely sensed LST in surface energy balance modeling and land data assimilation schemes all-year round; At present, GOES LST land surface modeling applications are limited to snow-free landscapes. The methodology put forth is the development of a technique that uses GOES-derived LST in combination with snow fraction data and surface type to flag the melting snow component of the GOES pixel. GOES 12-14 series data are being used as proxy to derive LST. VIIRS data are also being used as proxy to examine the potential of GOES-R optical spectral measurements for improved day-time snow melt detection.

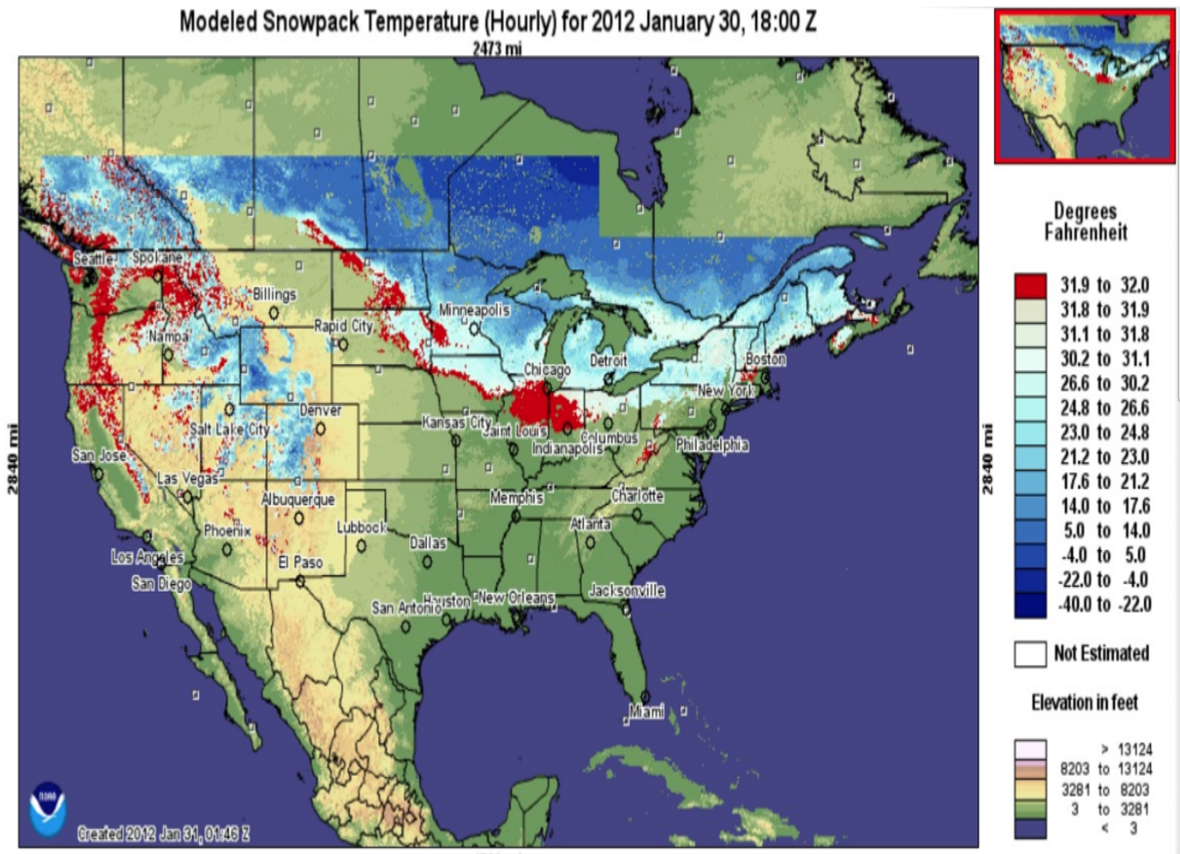


Figure B3: GOES-based potentially melting snow for cloud-free- and snow-flagged scenes.

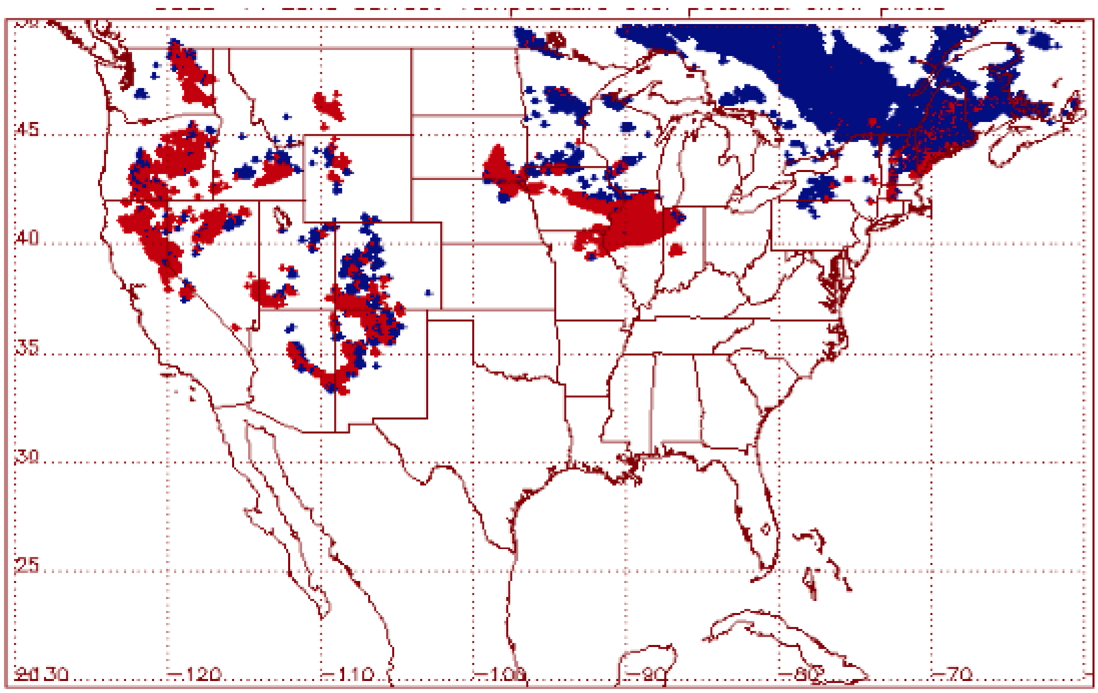


Figure B4: Modeled snow temperature (top image) from NOAA's National Operational Hydrological Remote Sensing Center (NOHRSC) snow analysis product and the potentially melting snow areas in red (bottom image) as identified using the operational GOES-14 LST product over cloud-free and snow-flagged scenes.

4. Development of Operational Algorithms & Software to Derive and Validate Snow Depth Product from GOES-R (Peter Romanov)

The final objective of this project consists in the development of algorithms and software to routinely produce and validate the Snow Depth (SD) product from GOES-R Advanced Baseline Imager (ABI) instrument data. To estimate the snow depth we use an empirical relationship between the snow depth and the snow fraction, derived by another group within the GOES-R Cryosphere Team. Snow depth retrievals are made only over plain non-forested areas. An external cloud mask is used to limit SD estimates to cloud-clear pixels only. The validation system for this product will provide routine estimates of the product accuracy. The validation approach consists in a direct comparison of derived snow depth with synchronous collocated observations of snow depth at ground-based meteorological stations.

A final version of the operational algorithm to estimate snow depth from GOES-R ABI was developed, tested and transferred to GOES-R Algorithm Implementation Team (AIT) in September 2011. The algorithm performance was tested with both current GOES-Imager data and with GOES-R proxy data that were generated by AIT from observations of Moderate Resolution Spectroradiometer (MODIS) onboard EOS satellites Terra and Aqua. As an example, Figure B5 presents a sequence of daily snow depth maps over US Great Plains and Canadian Prairies during the period of about two weeks. The product was generated with the GOES-R snow depth algorithm applied to the current GOES Imager data.

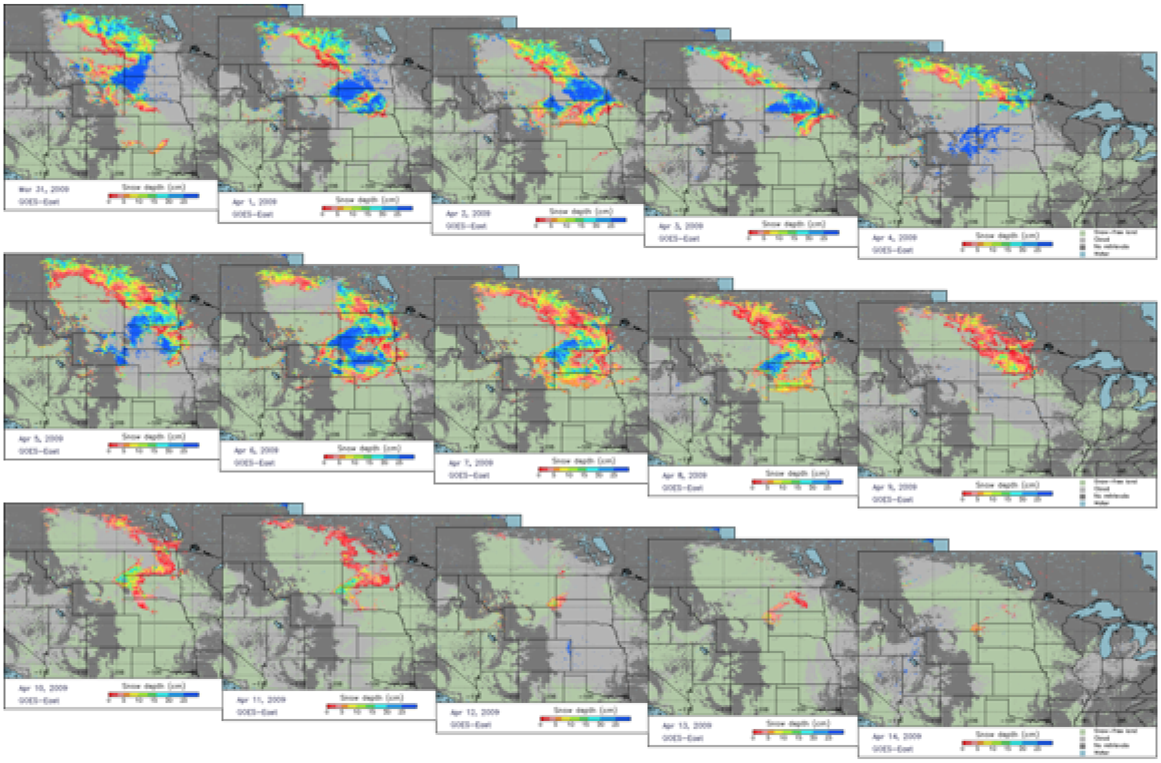


Figure B5: Example of the snow depth retrieval with the GOES-R ABI SD algorithm. The SD algorithm has been applied to the snow fraction derived from GOES-East Imager data.

(ii) Scientific support for the JPSS Mission

The Joint Polar Satellite System (JPSS) is the next generation of the U.S. polar-orbiting satellites that will provide continuity of observations for the existing NOAA Polar-orbiting Operational Environmental Satellites (POES) and for the new Suomi National Polar-orbiting Partnership (NPP) mission. The Suomi NPP satellite was launched on October 28, 2011, and the first JPSS spacecraft, scheduled for launch in 2016, will take advantage of technologies developed for the NPP satellite and its scientific instruments. Calibration methods developed for NPP will both improve the current operational data products and apply to the future JPSS measurements. CICS participates in collaborative research related to algorithm development, risk reduction and proving ground activities.

1. Research for Advanced Calibration of Joint Polar Satellite System (JPSS) Instrument (Slawomir Blonski)

The Visible Infrared Imager Radiometer Suite (VIIRS) on the NPP satellite is a 22-band multispectral imaging radiometer with a spectral range from 400 nm to 12 µm that includes both reflective solar bands and thermal emissive bands. Shortly after VIIRS acquired first imagery on November 21, 2011, evaluation of the image quality of the new datasets confirmed that the images display high dynamic range and low noise level, and are free of any spatial and radiometric artifacts from the applied sample aggregation (see an example in Figure B6). A more quantitative evaluation of image quality identified “striping” caused by non-uniformity of detector arrays. Differences of radiometric response among detectors were measured and used to initiate an update of calibration coefficients that reduce striping when applied to the imagery.

Since it was observed that VIIRS sensor sensitivity in the near infrared and adjacent bands decreases with time more quickly than anticipated, radiometric response of the reflective solar bands has been closely monitored using both on-board calibrator solar diffuser measurements and data acquired over the Antarctic Dome C calibration site. Monitoring of VIIRS radiometric gains was implemented based on on-board calibrator data provided in intermediate product files and on such known sensor characteristics as spectral response functions, solar diffuser bidirectional reflectance distribution functions, and transmittance of the solar attenuation screen. Time series of the radiometric gains produced from the VIIRS sensor measurements of light reflected by the solar diffuser were then used to predict rate of future changes in VIIRS sensitivity and to estimate that the radiometric response degradation will level off within few months. VIIRS measurements of Earth surface reflectance at the Dome C site in Antarctica have shown that the observed degradation of radiometric response is not an artifact caused by the solar diffuser. Dome C is a CEOS-recommended standard site for satellite radiometric calibration and validation that is characterized by stable snow cover and reduced atmospheric effects. Temporal dependence of the Dome C data agrees well with the SD measurements (Figure B7) and supports the use of Dome C in validation of radiometric calibration updates that correct degradation of VIIRS radiometric sensitivity.

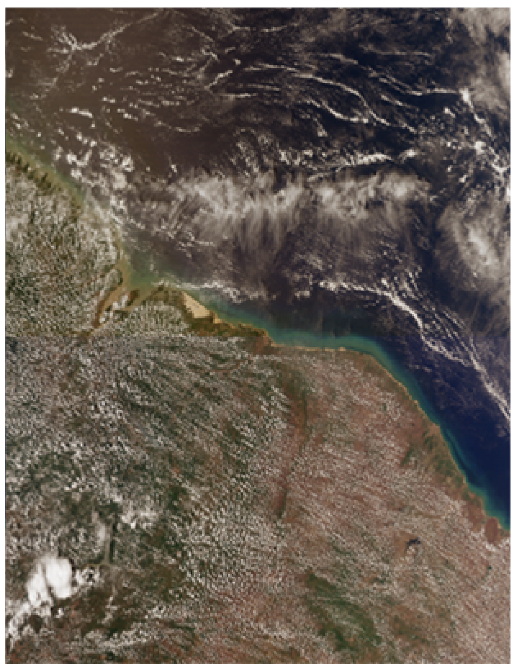


Figure B6: One of the first images acquired by the VIIRS instrument on board the Suomi NPP satellite on November 21, 2012.

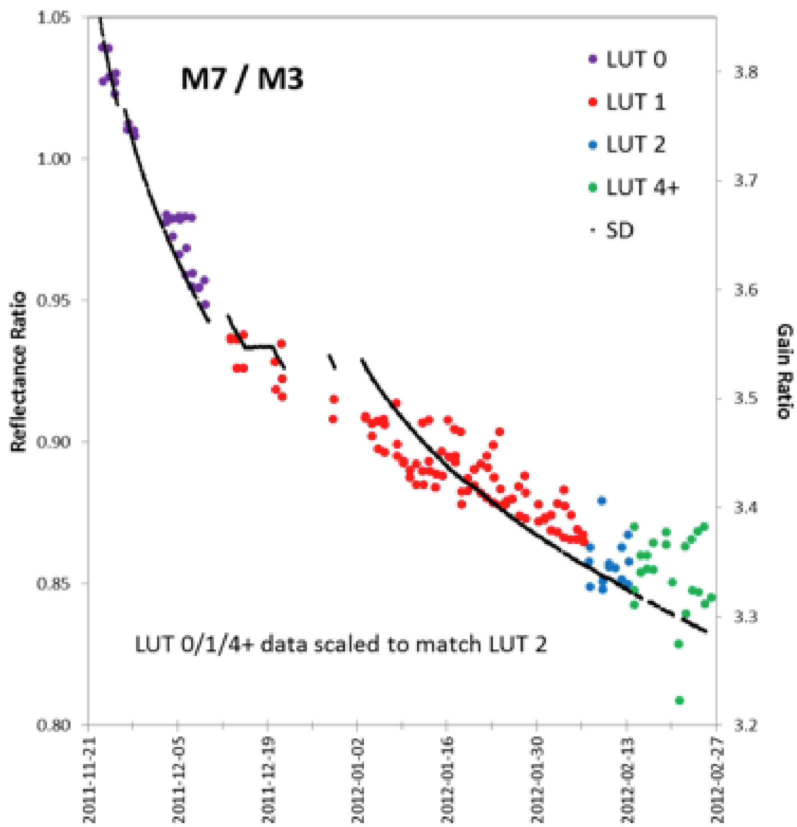
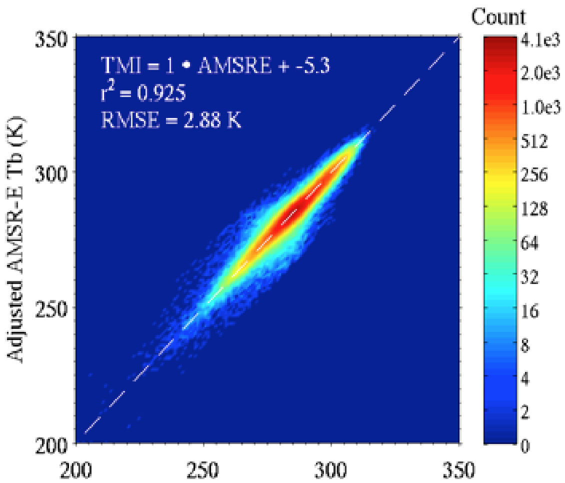


Figure B7: VIIRS Top-of-Atmosphere reflectance ratio for the Dome C site compared with on-board solar diffuser (SD) gain ratio for two bands: M7 (865 nm) and M3 (488 nm).

2. Development of JPSS AMSR-2 Hydrology Products (Patrick Meyers)

Measurements from polar orbiting satellites, particularly from microwave sensors, are useful as the basis for retrieval algorithms of hydrological parameters. This project focuses on the development of algorithms related to the hydrological cycle for the recently deployed AMSR-2 aboard the GCOM-W1 satellite operated by JAXA. AMSR-2 will provide a suite of parameters including rainfall rate, total precipitable water, cloud liquid water, and soil moisture by updating previous algorithm techniques. Precipitation is measured using the Goddard profiling algorithm (GPROF), which was developed for TRMM/TMI. AMSR-E and AMSR-2 brightness temperatures cannot be directly input into GPROF due to frequency differences with the TMI sensor, particularly the 85/89 GHz channels. To account for sensor differences, a linear regression technique was applied to adjust AMSR-E brightness temperatures to TRMM frequencies for clear and rain-likely conditions using collocated brightness temperatures (Figure B8). This correction dramatically decreased the frequency of rainfall observed at high mid-latitude elevations where snow was likely contaminating retrievals (Figure B9).



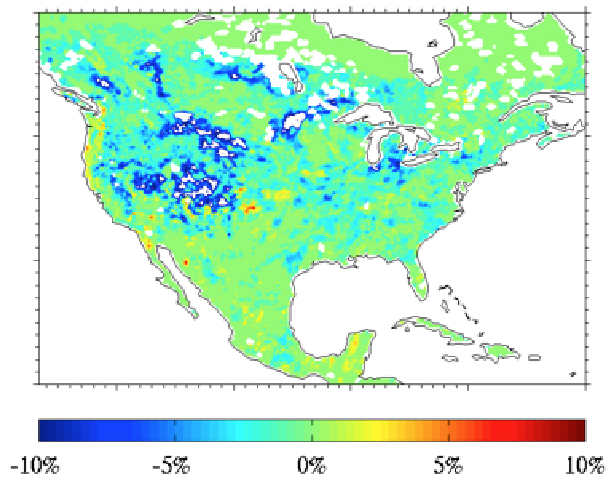


Figure B8: Adjusted AMSR-E 89V brightness temperature using linear regression correction. Shading represents the density of observations in 1°x1° bins (left panel)

Figure B9: Change in frequency of observation of precipitation by applying adjusted AMSR-E brightness temperatures for January 2010. The adjustment greatly reduced false alarms in the Rocky Mountains (right panel).

3. NPP/JPSS Global Space based Inter-Calibration System (GSICS) (Likun Wang)

This task provides cross-calibration support for Suomi NPP and JPSS instruments, including VIIRS, CrIS, and ATMS by using inter-calibration techniques to assess their spectral and radiometric calibration accuracy, preciseness, and stability. CICS scientists will work closely with the international community through WMO GSICS and CEOS Working Group CalVal (WGCV) to develop the best practices for inter-calibration and evaluate NPP instrument calibration using observations from multiple instruments in comparison with simultaneously collocated NPP and JPSS observations. Initial work has focused on validation of the CrIS Sensor Data Records (SDR) from Suomi NPP by comparing them with other two similar on-orbit infrared (IR) hyperspectral instruments, i.e. AIRS from Aqua and IASI from Metop-A and –B. An inter-calibration system has been implemented to directly compare temporarily coincident CrIS and IASI and CrIS and AIRS observations at orbital crossing points of satellites occurring at high latitudes, the so-called simultaneous nadir overpasses (SNO). The system can automatically extract the SNO spectra from two compared instruments and resample the spectra at the common spectral grids. Figure B10 illustrates the CrIS and IASI SNO case on September 2 2012 at the Southern Polar region. The extracted spectra from CrIS and IASI at water vapor absorption region well agree with each other and their brightness temperature difference is less than 0.1K. The above case clearly shows the ability to identify the NPP instrument on-orbit calibration uncertainties from the inter-calibration study.

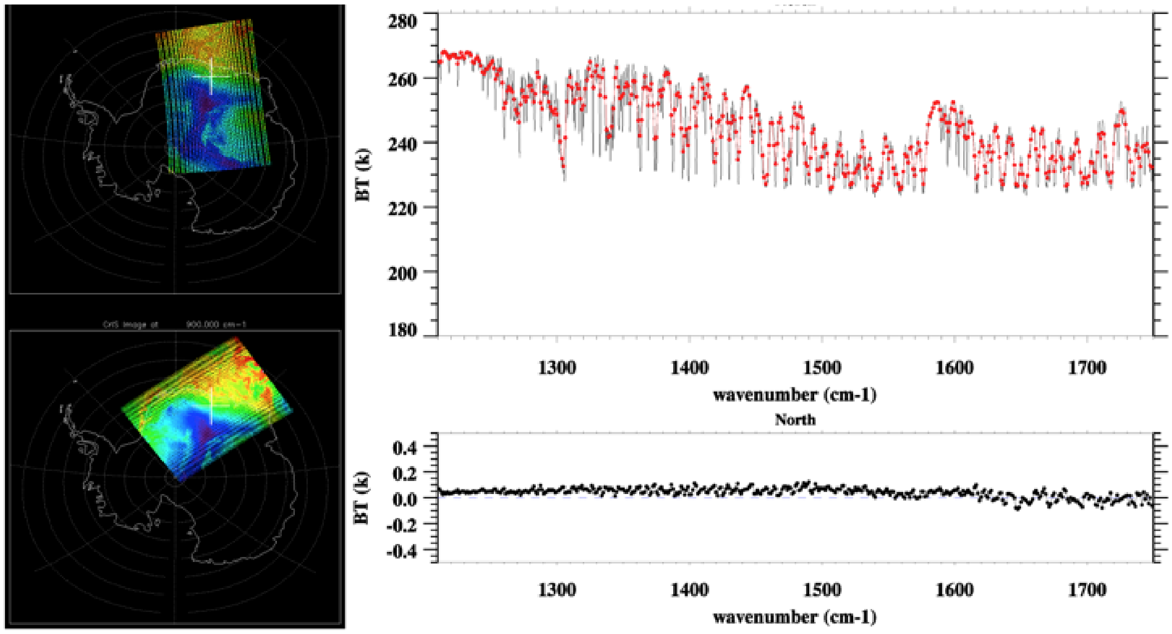


Figure B10: (Left) Simultaneous nadir overpass observations for IASI (top) and CrIS (bottom) indicated by the white plus symbols as well as (Right) the SNO spectra from IASI (black) and CrIS (red) and their BT differences (bottom).

C. Surface Observing Networks

NCDC manages several observing networks for NOAA as well as collecting, processing, analyzing and archiving datasets associated with them and other national and global networks. CICS-NC staff provide direct support for the processing and analyses of surface observations from these sources. In this section we highlight activities associated with these efforts.

1. Assessments, improving understanding of historical observations, detection and attribution, and instigation of future reference observations (Peter Thorne)

Assessments

Peter Thorne has served as a Lead Author on both the Working Group 1 contribution to the 5th Assessment Report of the Intergovernmental Panel on Climate Change and the 2013 National Climate Assessment. For IPCC he is section lead on the temperatures section of Chapter 2 (observations) as well as lead on a Chapter box and the frequently asked question "How do we know the world has warmed?". Within the National Climate Assessment he is a lead author on the climate science chapter. For the past three years he has also been an editor on the Global Chapter of the Annual State of the Climate Report published by BAMS. For the first two years as a CICS employee he took part in the media briefing on this activity on behalf of NOAA.

Improving understanding of historical observations

An international meeting was organized in September 2010 at the UK Met Office to address perceived shortcomings in global land surface temperature products. This led to an agreed international program - the International Surface Temperature Initiative (ISTI), chaired by Peter Thorne of CICS-NC. The Initiative envisaged an end-to-end process from improved fundamental data holdings through new dataset product creation, consistent benchmarking and assessment and serving to end-users. Significant advances have been made in the efforts to create a first version release of a monthly land surface temperature databank (Section C2).

Strong efforts to engage the meteorological community resulted in two plenary talks at the International Temperature Symposium 9 (organised by NIST) in March 2012 on the International Surface Temperature Initiative and the importance of meteorological community participation in climate more generally as well as talks on the GCOS Reference Upper Air Network (see below). A total of five accepted proceedings papers from this conference include CICS co-authorship.

Significant efforts have also accrued on other aspects of the surface temperature initiative. The International Surface Temperature Initiative has been featured in *Nature* and Peter Thorne interviewed by *New York Times, UK Guardian, LA Times, The Economist,* and *Discover Magazine* in this regard. Peter Thorne also sits on the scientific advisory panel of the UK National environment Research Council funded Earthtemp initiative.

An example of benchmarking approaches has been published in JGR considering the US land surface data record USHCN. The use of benchmarks, and an ensemble of plausible realizations of the NCDC pairwise homogenization algorithm used to create USHCN and GHCN yielded additional insights into the likely uncertainties in this record. The algorithm was shown to be reasonable but have a propensity to under-estimate the trend adjustment required in the presence of an overall systematically biased input data stream with a propensity for breaks of one sign. This is similar to known facets of the US surface raw data yielding a conclusion that we are far more likely to be underestimating than overestimating CONUS warming trends. Figure C1 illustrates how the algorithm performed on one example analog used in the JGR analysis.

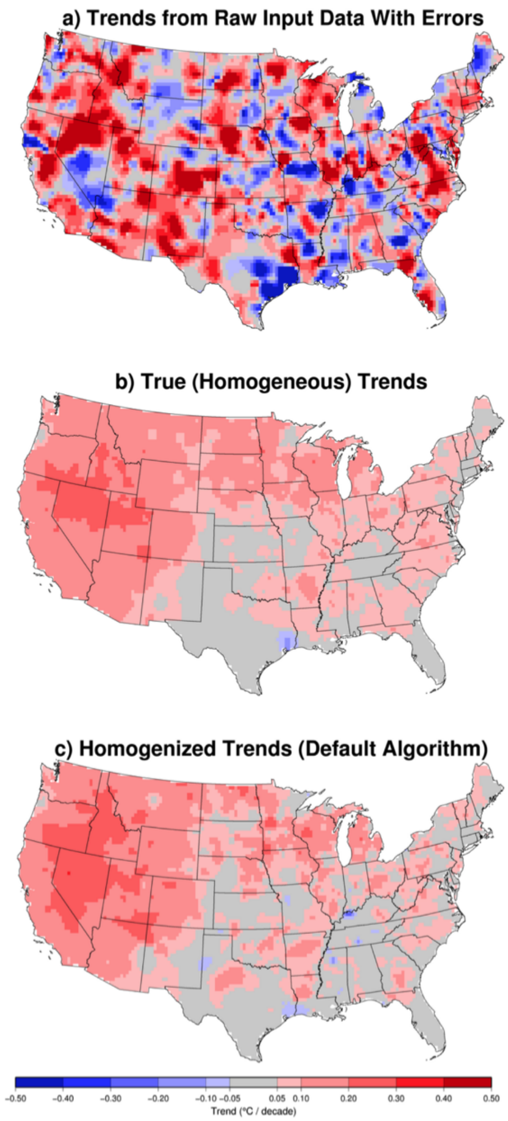


Figure C1. Example of application of the NCDC pairwise homogenization algorithm to an analog of the USHCN network. The top panel represents the 'bad' data presented to the algorithm, the middle panel represents the 'pristine' data and the lower panel is what the algorithm returned. See Williams et al., 2012, JGR for further details.

In addition to surface temperature activities the following have been achieved in this sphere over the current review period:

- Documentation of holistic parametric uncertainty estimates in the Hadley Centre's radiosonde temperature product (JGR, CICS lead)
- Construction of parametric uncertainty estimates for the Microwave Sounding Unit from Remote Sensing Systems and comprehensive comparison to radiosonde datasets and their uncertainties (JGR x2, CICS co-author)
- Construction of quality controlled synoptic surface observation dataset HadISD in cooperation with Hadley Centre and NCDC (COP, CICS co-author)

- Construction of surface humidity homogenized product (COPD, CICS co-author)
- Construction of tropospheric balloon-based humidity product with NCAR and Hadley Centre (J. Clim., CICS co-author)

Detection and attribution

Work under this area has been on two aspects, more traditional detection and attribution of long-term changes in climate, and the newer area of event attribution. Several papers have been published or are under active review looking at detection and attribution of temperature changes in the free atmosphere (JGR x2, 1 still under review, PNAS). In addition Peter Thorne was on the organizing committee for a meeting on extreme event attribution in Oxford, UK. This was organized under the joint auspices of the UK Government, UK Met Office, Oxford University and NOAA.

Instigation of future reference observations

The GCOS Reference Upper Air Network aims to create a network of global reference quality measurements with robust uncertainty estimates derived through an unbroken chain to absolute standards. Peter Thorne is the co-chair of the Working Group on GRUAN. Efforts continue to build up the GCOS Reference Upper Air Network. Regulatory materials have been prepared and vetted. Data has started flowing for the first product – radiosonde profiles – through NOAA NCDC. Significant progress has been made towards bringing additional measurements into the data stream including lidars, radiometers and GPS precipitable water. Three new sites have applied or are in the process of applying to join the network. Peter Thorne attended the NDACC (Network for the Detection of Atmospheric Composition Change) steering committee in October 2012 to further collaboration with this network. In December 2012, at the invitation of the EU, he will give a plenary talk in Brussels, Belgium, on the future of the European Observing System as part of preparations for EU FP7 funding calls.

2. Maintenance and Streamlining of the Global Historical Climatology Network – Monthly (GHCN-M) Dataset (Jared Rennie)

Since the early 1990s the Global Historical Climatology Network-Monthly (GHCN-M) dataset has been an internationally recognized source of information for the study of observed variability and change in land surface temperature. Version 3, which marks the first major revision to this dataset in over a decade, became operational in May 2011 and provides monthly mean temperature data for 7280 stations from 226 countries and territories. This version introduces a number of improvements and changes that include consolidating “duplicate” series, updating records from recent decades, and the use of new approaches to homogenization and quality assurance. Since its initial release, GHCN-M version 3 has undergone updates to incorporate monthly maximum and minimum temperature, improve processing run time and undertake bug fixes discovered as a result of a google summer of code student placement with the Climate Code Foundation which was facilitated by CICS-NC and NCDC staff. These have been documented in NCDC tech reports.

Efforts are underway to upgrade GHCN-M and release version 4. One of the major goals of this update is to add stations to improve capture of finer spatial and temporal scales. The *International Surface Temperature Initiative* (ISTI), a working group of climate scientists, meteorologists, and statisticians, is an effort to create an end-to-end process for land surface air temperature analyses. Their first goal is to create a single, comprehensive global databank of surface meteorological observations. The databank will be version controlled and seek to ascertain data provenance. There are multiple stages of the databank, including the original paper record, keyed data in its native format, and a merged dataset with duplicate source data reconciled. All data, along with its underlying code, will be publicly accessible, in order to be open and transparent.

Multiple sources of data, on monthly and daily timescales, have been submitted to NCDC and uploaded to the Databank site. Data sources range from digital images of the original paper copy (known as Stage 0) to keyed data in its native format (Stage 1). Data is converted into a common format and data provenance flags are added to every single observation (Stage 2). These flags are determined based upon information provided by the data sender. Some examples include whether an original paper copy is available, and if any quality control or homogenization was applied to the dataset prior to submission. Currently, there are 28 daily sources and 20 monthly sources that have been converted to Stage 2. In addition, all daily sources were converted into monthly averages, in order to make the monthly version of the databank more robust.

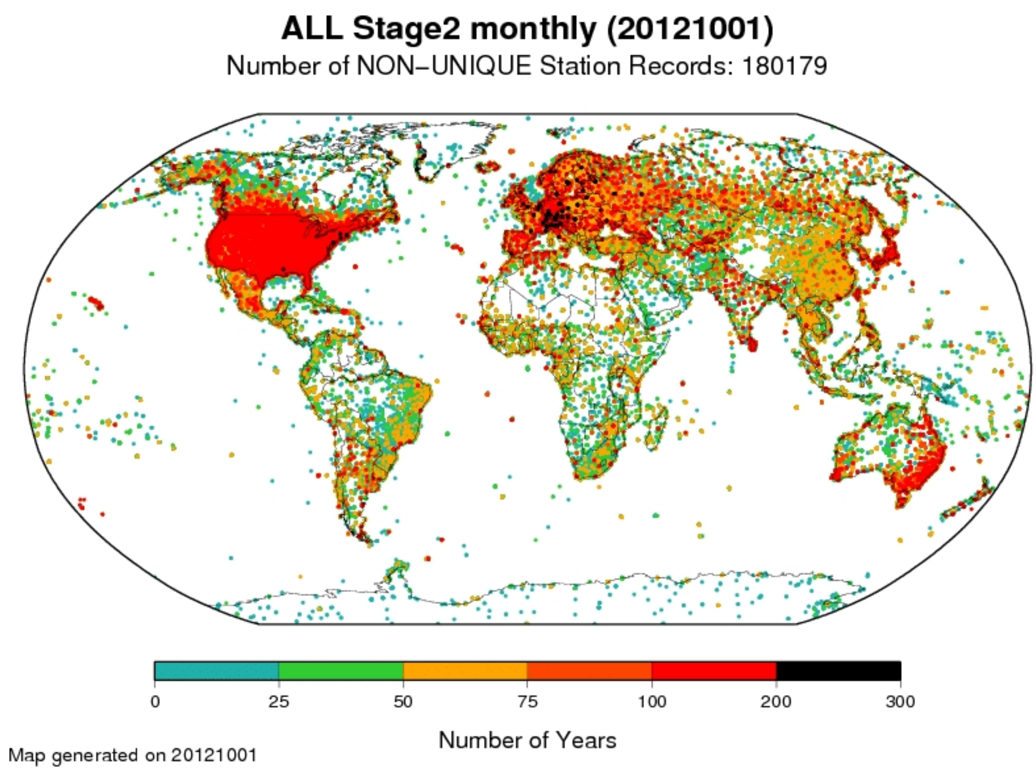


Figure C2. Location of Stage 2 monthly station records in the databank, along with their period of record.

Currently there are over 180,000 station records in Stage 2, which include the monthly sources, as well as the “monthly averaged” daily sources (see Figure C2). The algorithm to merge these sources into a single merged Stage 3 dataset with duplicates removed has been developed and made available to the public for analysis. This process occurs in an iterative fashion through all the sources, and comparisons are made to determine if a station match exists and a merge should occur. The approach is based upon metadata matching and data equivalence criteria. Metadata comparisons include the geographic distance between the stations, elevation difference, and an algorithm for station name similarity. Data comparisons include “goodness-of-fit” measures for overlapping data, and neighbor comparisons for non-overlapping data. Weighted priors are formed based upon bootstrapping techniques, and are then recombined to form a posterior probability of station match. Validation of each technique is applied using stations with known bias and noise and comparing output.

In October 2012, the consolidated Stage 3 dataset has been released to the public. Figure C3 displays graphical representations of the results. This release will be in beta for a period of 3 months where feedback is encouraged. Afterwards, the official first version release will be made operational, along with all code and data used in order to remain open and transparent. Using this operational dataset, updates to the GHCN-M quality assurance and homogeneity algorithms will be applied to account for higher spatial and temporal sampling. The goal is to release version 4 of GHCN-M by the end of the 2013 calendar year.

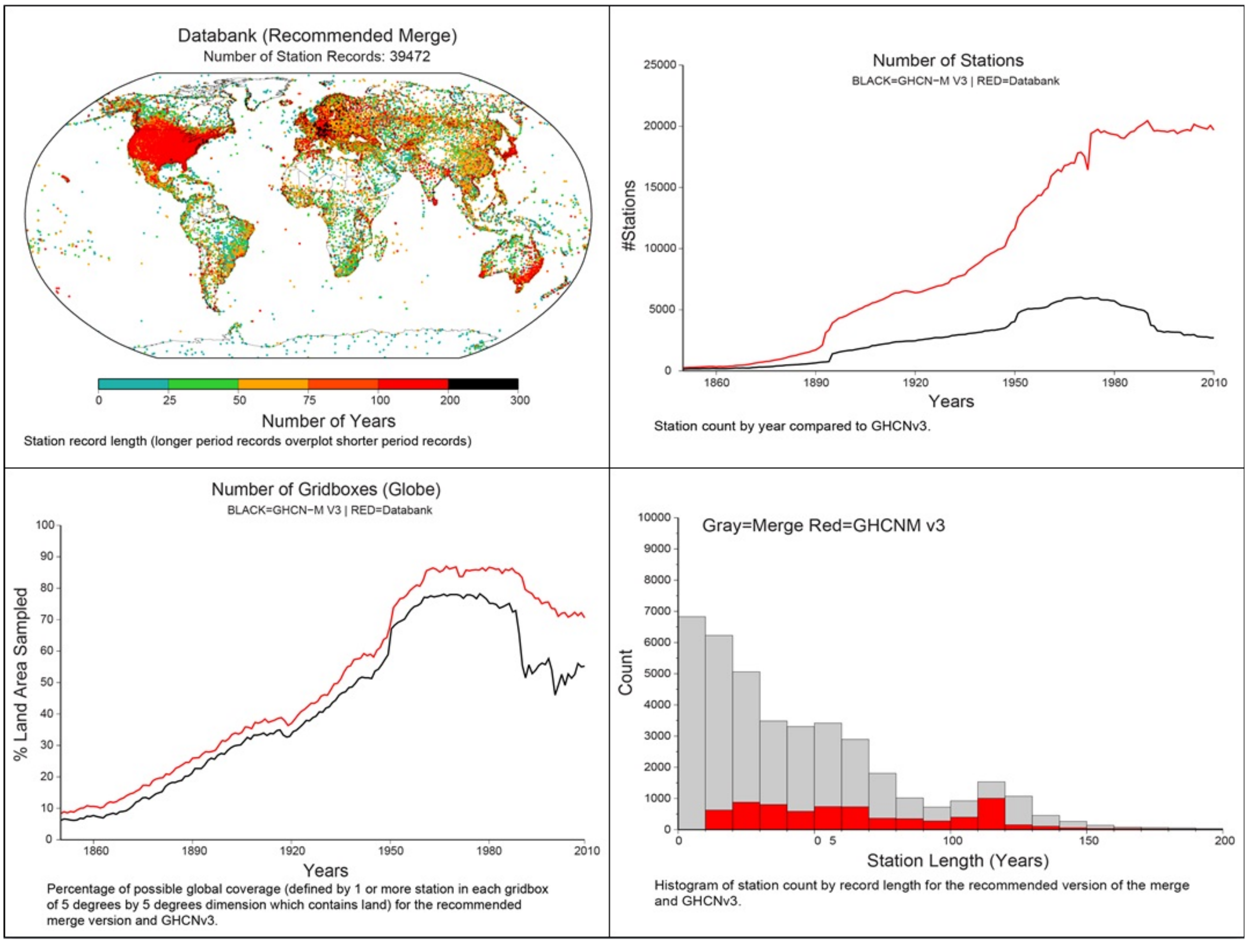


Figure C3. Graphical representation of Stage 3 merged product. Upper left: location of stations in dataset, along with their period of record. Upper right: time series of number of stations over time, compared to GHCN-M version 3. Lower left: time series of number of 5 degree X 5 degree gridboxes over time, compared to GHCN-M. Lower right: histogram of station count by record length, compared to GHCN-M. More information can be found at http://www.surfacetemperatures.org/databank.

3. Validation of US Climate Reference Network (USCRN) Soil Moisture and Temperature (Jesse Bell)

The US Climate Reference Network is a series of climate monitoring stations maintained and operated by NOAA (Diamond et al. 2012: see additional note below). To increase the network's capability of monitoring soil processes and accurately estimating drought, it was decided to add soil observations to the list of USCRN instrumentation. In the summer of 2011, the USCRN team completed the installation of all soil observational probes in the contiguous US. Each station, along with traditional measurements of surface air temperature, precipitation, infrared ground surface temperature, wind speed, and solar radiation, now also transmits relative humidity, soil temperature, and soil moisture measurements every hour. The data is maintained and stored at NOAA's National Climatic Data Center, while installation and maintenance is performed by NOAA's Atmospheric Turbulence and Diffusion Division (ATDD).

The goal is to produce high-quality soil datasets and use these data to research the relationship of soil observations to spatial change and develop drought-monitoring products. To ensure the network is providing quality data, there are a series of quality checks that must be performed before the data are made available to end-users. One task of this project is to improve the current quality assurance method to accurately determine faulty sensors for removal from the final soil products. Exploring the data record and researching ways to identify erroneous changes in the time series is the best way of improving the quality assurance procedure. In this report we will explore ways that we have improved the soil observations' quality assurance and promoted the networks abilities to potential users.

The completion of the network in 2011 required implementation of improved soil quality assurance. As the soil observations are transmitted hourly from 114 stations on a near real time basis via the GOES satellite, there are large amounts of data to observe for occurrences of faulty periods. The first step was to automate the quality assurance process and decide the proper checks to determine sensor health. After a thorough investigation, the decision was to proceed with certain statistical checks to ensure the automatic ingest could instantaneously flag and remove faulty time periods.

We investigated the appropriate range boundaries for determining when sensors are recording values that exceed sensor limits. Initial boundaries were determined by the largest physical limits of the sensor. We then examined the possibility of using specific soil conditions as a determinant of boundary limits. The results of this study were mixed. We were able to determine that specific boundaries can be produced, but some of the boundaries may unexpectedly remove actual measurements.

The next stage of development included incorporating a "bad sensor list" to the quality assurance process. The bad sensor list is a list of sensor time periods that are removed from the final products because these periods are not reliable. On a monthly basis, there is an automated evaluation of the data series using a set of statistical checks to determine bad periods in the data record. The unique triplicate design of USCRN soil observations at every depths allows for quick identification of faulty sensor measurements. These periods are then added to the bad sensor list for removal.

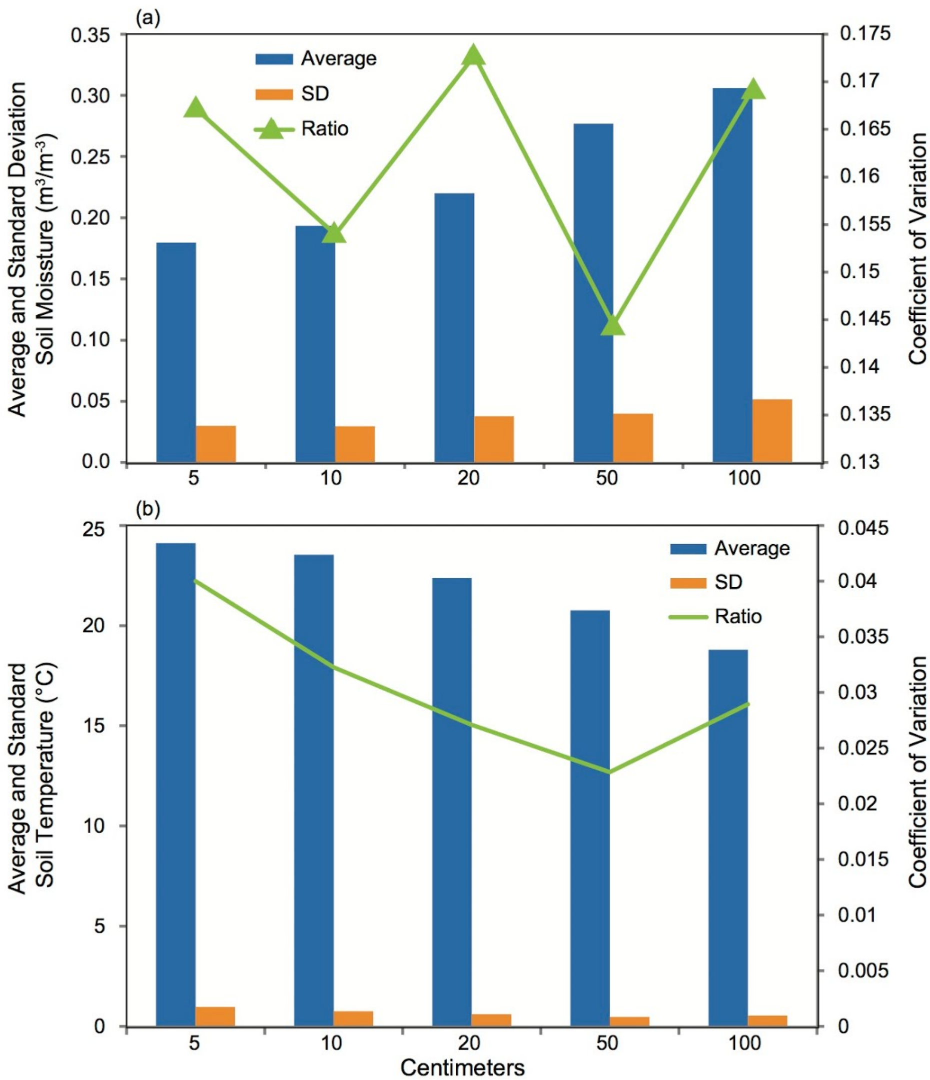


Figure C4. Soil climate means (blue bars) and standard deviations (orange bars) were produced from five soil depths across all stations recording measurements during the month of June 2011. Line graph (right axis) is the average coefficient of variation (CV): a) soil moisture %); b) soil temperature (°C).

In addition to improving the quality assurance of these data, we are examining spatial relationships that may assist in understanding the changes that occur between sensors (Figure C4). These relationships will not only help improve quality assurance, but also assist the scientific community in understanding spatial relationships of soil moisture and temperature (Figure C5). We are also developing drought-monitoring products to improve the usability of the data (*e.g.* plant available water).

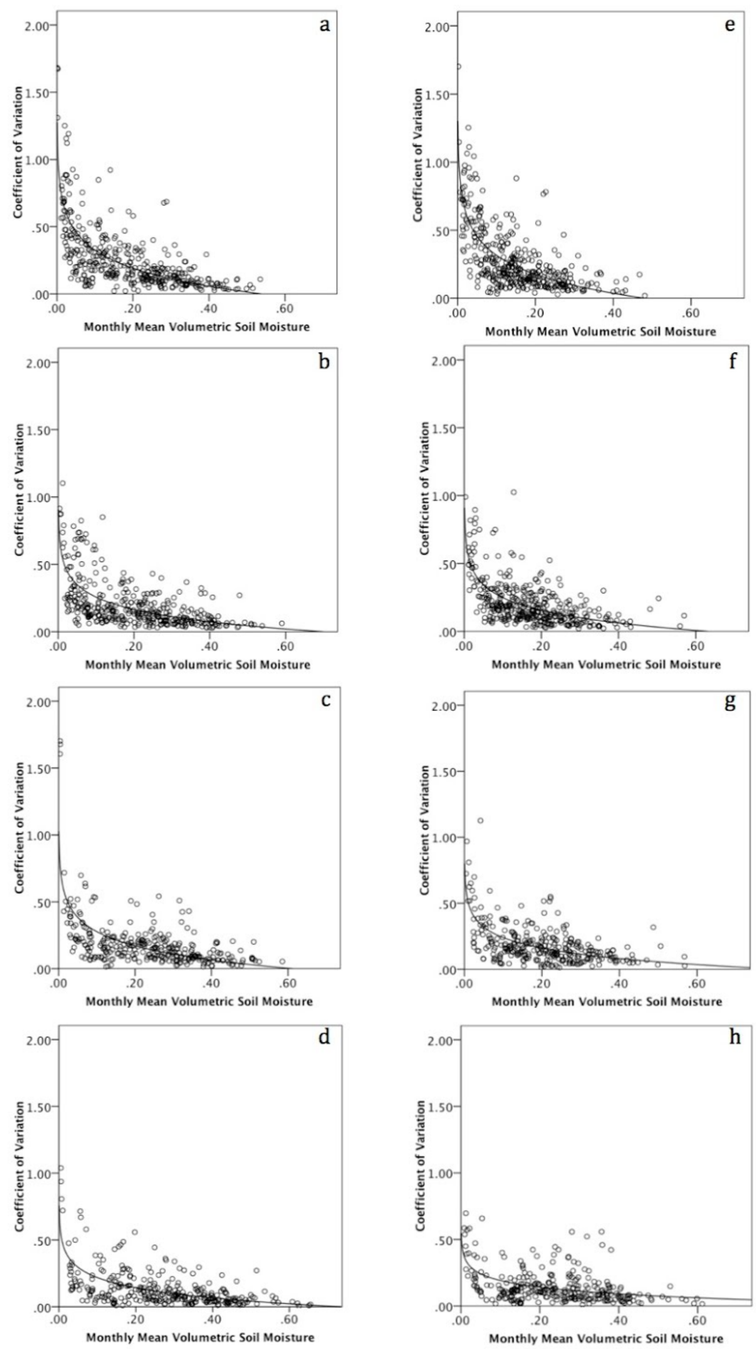


Figure C5. Distributions of coefficients of variation (CV) versus soil moisture means; 2011: (a) 5 cm, (b) 10 cm, (c) 20 cm, and (d) 50 cm; 2012: (e) 5 cm, (f) 10 cm, (g) 20 cm, (h) 50 cm. This figure shows the logarithmic relationships of mean monthly soil moisture and CVs of soil moisture by depth at all stations available for April-July 2011 and April-July 2012. Soil moisture CVs logarithmically decrease as the mean soil moisture increases at all depths analyzed.

Additional note: CICS-NC staff members in partnership with NCDC and ATDD helped construct an overview paper of USCRN, which is now accepted at the Bulletin of the American Meteorological Society. This is the first USCRN paper to thoroughly describe the function of the network, instrumentation at each station, and location of data access. The completion of this manuscript was possible because of CICS-NC staff involvement.

4. Collocated US Climate Reference Network (USCRN) and Cooperative Observer network (COOP) Temperature and Precipitation Comparisons (Ronald Leeper)

The USCRN was specifically engineered to detect and attribute climate signals over the next 50 years. From station placement, sensor selection, calibration standards, and redundancy, this network was designed to limit the effect of observational biases on data records. As a result of this architecture, the USCRN is one of the first networks to deploy temperature and precipitation in triplicate in addition to shielding precipitation gauges within both a small double-fence intercomparison reference (SDIFR) and double-alter shields.

As the USCRN data becomes more involved in climate focused tasks, differences between the traditional COOP and USCRN network design and the role of network architecture on observational differences will become increasingly relevant. The purpose of this study is to compare closely-collocated (within a km) USCRN and COOP temperature and precipitation observations and attribute the role of network design on commonly used climate metrics (growing degree days, growing season, etc...).

Due to well aspirated thermistors, USCRN daily maximum and minimum temperatures were generally cooler and warmer than COOP observations respectively. While the warm minimum temperature bias varied little from season to season, USCRN cool maximum temperature bias was typically amplified during summer months. Network temperature biases resulted in a slight increase in USCRN based growing season days and length over COOP.

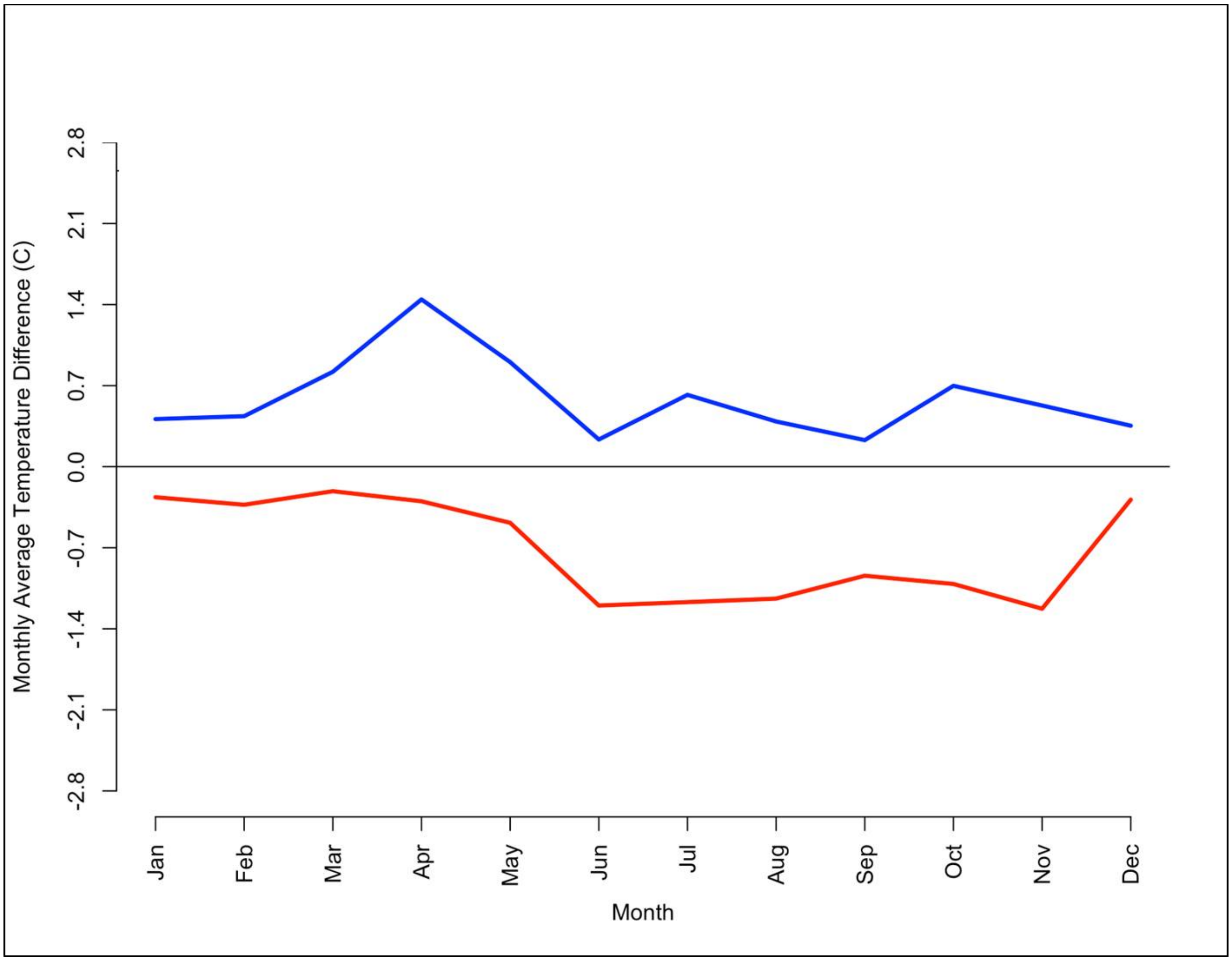


Figure C6: Monthly average temperature difference (USCRN minus COOP) for daily maximum (red) and minimum (blue) at the USCRN station in Holly Springs, MS.

Daily precipitation comparisons between USCRN and COOP were mixed and strongly influenced by time of observation (TOB) bias. After accounting for TOB by grouping consecutive days of precipitation into events, half of USCRN stations on average captured more precipitation than COOP. However during this analysis, inquires concerning potentially erroneous COOP observations were submitted for review. At present, over 64 mm of precipitation have been corrected in NCDC data records, which showcase the value of USCRN as a "reference" network.

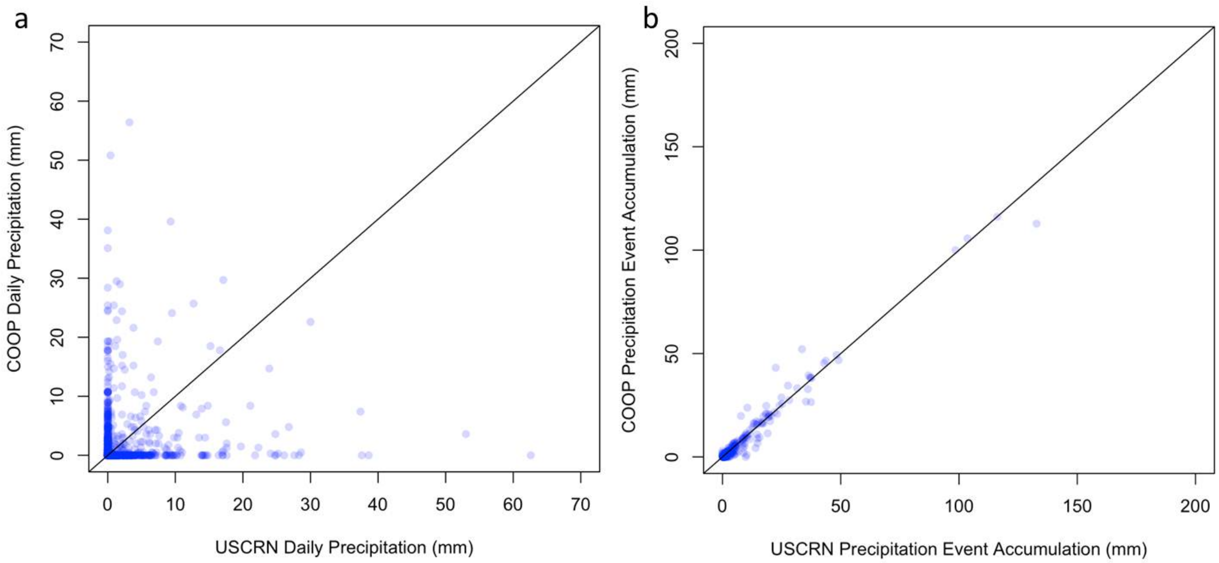


Figure C7. Observed daily (a) and event based (b) precipitation for USCRN and COOP stations at Harrison, NE.

5. Climate Monitoring and Research Support to the Atmospheric Turbulence and Diffusion Division of NOAA's Air Resources Laboratory (Mark Hall, ORAU)

ORAU is assisting NOAA/ATDD and NOAA/NCDC in the installation of new USCRN and USRCRN stations and annual routine maintenance visits to the existing USCRN and USRCRN sites. ORAU is also assisting with the regular calibration of various sensors deployed at the monitoring sites.

One of the primary *foci* for the ATDD/ORAU partnership has been sustaining NOAA's climate observing systems and developing research efforts that will enhance our understanding of a changing environment in the different ecosystems within the United States.
NOAA designated the USRCRN for modernization to better meet its mission of providing the nation with data regarding the state of a region's climate quality. To ensure the most accurate data are collected throughout the network, ORAU completed the installation of 74 new USRCRN stations in the southwest climate region. The pilot project is part of NOAA's goal to install ~500 USRCRN stations.

ATDD/ORAU is leading the installation, calibration, and maintenance of the new, automated stations that will collect temperature and precipitation data every 5 minutes. Each new station includes triple redundant temperature and precipitation sensors for reliability. Additionally, the station is expandable to allow for any future interest in measuring soil temperature, soil moisture, snowfall, and snow depth. The first stations were installed in early October 2010, with an additional 50 stations added in FY 2011. The ultimate goal is for both the USRCRN and the USCRN to work together to deliver accurate, high-quality data to users studying climate trends.
In FY2011 ATDD/ORAU was selected to expand the USCRN into Alaska. ORAU personnel are involved in site surveys, Arctic capable equipment, calibration and installation, operational test and evaluation, station commissioning, and life cycle operations and maintenance (O&M). The establishment of at least 29 Alaskan climate reference observing stations will enable the United States to have the same level of climate monitoring capability in Alaska compared to the national monitoring of temperature and precipitation trends in the lower 48 states (e.g., ability to track with at

least 99% temperature and 98% precipitation accuracy for decadal trends). The Alaskan CRN is a NOAA legacy contribution to the International Polar Year (IPY) and the nation. The AKCRN is a most important part of the integrated national and global climate-observing system. AKCRN monitoring will significantly improve the understanding and knowledge of climate variability and change, which can often be more pronounced and detected earlier in high latitudes.
The Alaska CRN station near Tok, Alaska was installed in August 2011, which brought the total number of completed stations to 9. An additional 5 locations were surveyed for future installations. Figure C8 illustrates the USCRN Network. Figures C9a and C9b illustrates sites in Grande Teton National Park and the Big Cypress National Preserve.

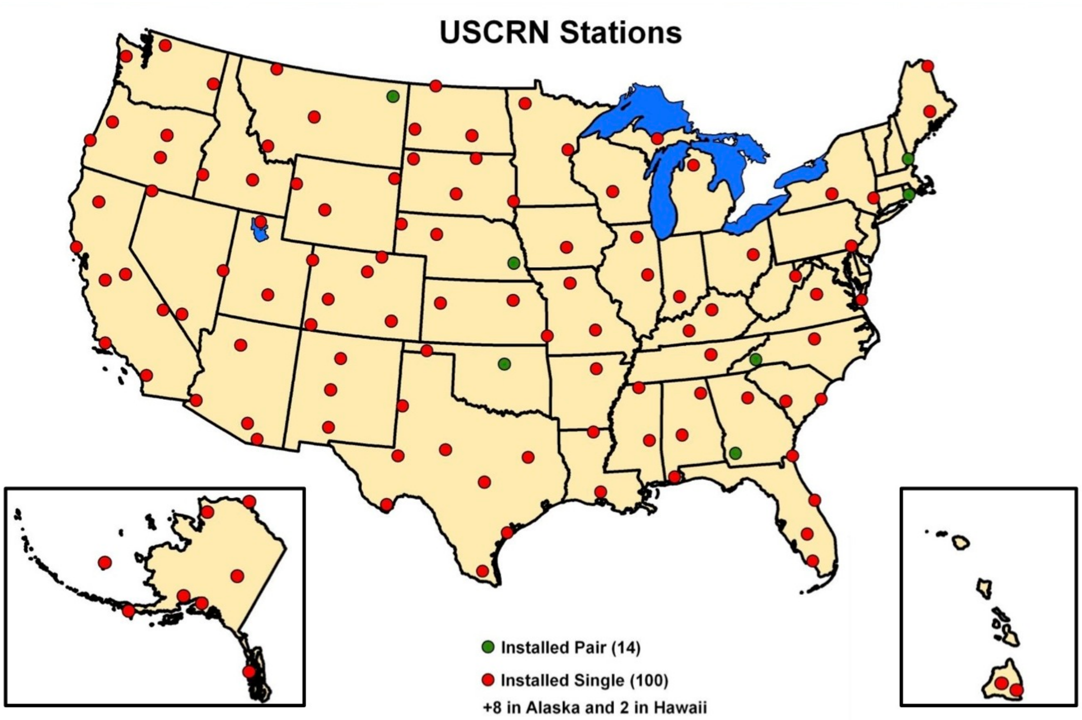


Figure C8: USCRN Network

Figure C9a: USCRN Site in Grande Teton National Park

Figure C9b: USCRN Site in Great Cypress National Preserve

D. Land and Hydrology

This Topic Area includes research projects that focus on the validation of algorithms that derive land surface products from observations taken by the Suomi NPP satellite. Additional research activities focus on algorithm enhancement and refinement. Examples of ongoing research projects in this Topic Area are below.

1. NPP/VIIRS Land Product Validation Research and Algorithm Refinement: Land Surface Albedo (Chris Justice, Shunlin Liang).

This work emphasizes the validation and refinement of the NPP/VIIRS land surface albedo (LSA) algorithm. LSA, together with ice surface albedo and ocean surface albedo, are combined into one final product --VIIRS surface albedo EDR. LSA is generated from two types of algorithms: Dark Pixel Sub Algorithm (DPSA) and Bright Pixel Sub Algorithm (BPSA). DPSA uses the Bi-directional Reflectance Distribution Function (BRDF) information from the 16-day gridded albedo IP to first calculate spectral albedo and then convert spectral albedo to broadband albedo using empirical models. BPSA directly estimate broadband albedo from VIIRS TOA radiance. In addition to land pixels, surface albedo over sea ice pixels is also calculated from a similar direct estimation approach. Three main activities were part of the current research:

Pre-launch evaluation and validation work. We participated the cal/val rehearsal before the launch of NPP. During the rehearsal, we tested the data delivery system and evaluated the proxy data using the MODIS albedo products.

Verifying VIIRS albedo codes. The VIIRS albedo EDR codes have been included in the latest release of ADL (Version 3.1). We tested the codes on our local computational environments and programmed to handle the input and output of the albedo codes. The intermediate products of DPSA are stored in a special format called GIP. In GIP files, 2-D images are stored in 1-D land-pixel-only arrays to save storage.

Evaluating the actual NPP/VIIRS albedo EDR. After the launch, we started evaluating the actual VIIRS albedo products. Once the albedo EDR is available, multiple days' data covering the continental US are downloaded and evaluated. Data from different paths are first re-projected and mosaicked to one daily map. The overlapping region has the values of the mean of the multiple scenes. Figure D1 shows a composite map by averaging the albedo EDR of the ten days.

Based on the evaluation, we found: 1) surface albedo EDR products have values over both ocean and land; 2) the seasonal snow is captured in the albedo map; 3) albedo from the different paths are relatively consistent, so the mosaic image has no unnatural boundary; 4) "Data gap" is a problem, since albedo is produced for cloud-free pixels; 5) missing strips exist; 6) some values without physical meaning (<0 or >1) are produced. Due to the special sampling design, the albedo EDR has some missing values at the edge of scanning lines, called "bow-tie" effects. We developed codes of interpolation to mitigate the effects.

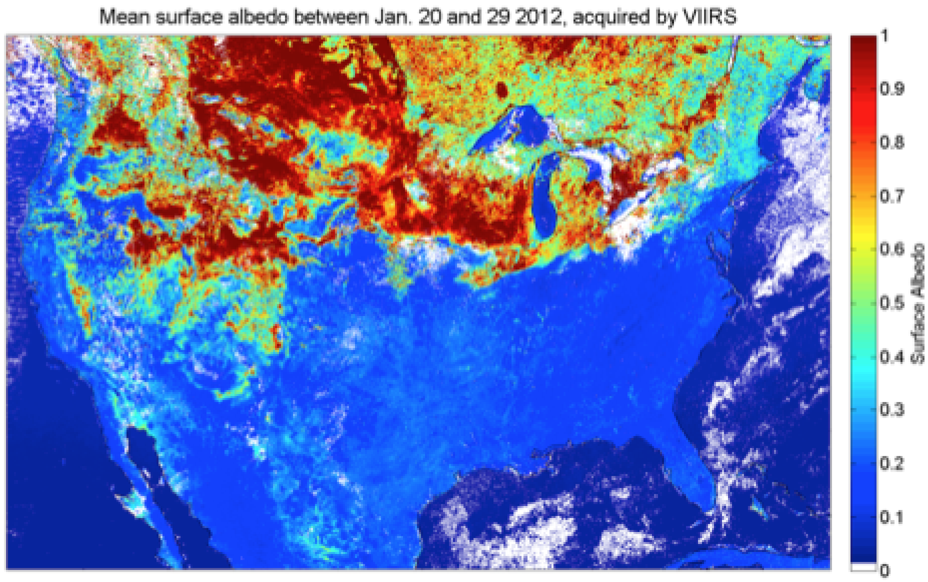


Figure D1: Mean surface albedo from VIIRS for January 20-29, 2012.

2. A Terrestrial Surface Climate Data Record for Global Change Studies (Eric Vermote)

The overall objective of this project is to produce, validate and distribute a global land surface climate data record (CDR) using a combination of mature and tested algorithms and the best available land imaging polar orbiting satellite data from the past to the present (1981-2011), and which will be extendable into the JPSS era. The data record consists of one fundamental climate data record (FCDR), the surface reflectance product. Two Thematic CDRs (TCDRs) are also be derived from the FCDR, the normalized difference vegetation index (NDVI) and LAI/fAPAR. These two products are used extensively for climate change research and are listed as Essential Climate Variables (ECVs) by the Global Climate Observing System (GCOS). In addition, these products are used in a number of applications of long-term societal benefit. The two TCDRs are used to assess the performance of the FCDR through a rigorous validation program and will provide feedback on the requirements for the Surface Reflectance FCDR.

Several improvements have been applied to the dataset, improved geolocation, calibration, cloud mask, and aggregation scheme. The AVHRR data record compared favorably to the MODIS coincident data record (used as a reference) as it has been verified for NOAA16 during the 2003-2004 period (figure D2). We have also started the generation of the LAI/fAPAR product and the product compared well to the climatology developed by Frederic Baret at INRA (see Figure D3), the Boston University algorithm for LAI/fAPAR have also been implemented and is under testing. We have developed the code for the processing of the 1 km AVHRR data that will be used to process the 1992-1998 AVHRR HRPT record. We have used the Climate Data Record in application of societal benefit (Yield prediction for agriculture). We have started transitioning the code and dataset to NOAA NCDC in Asheville.

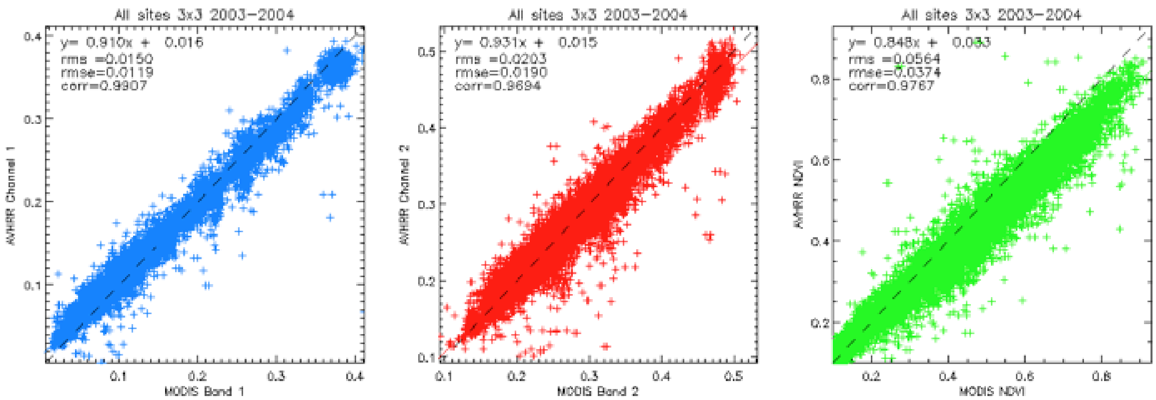
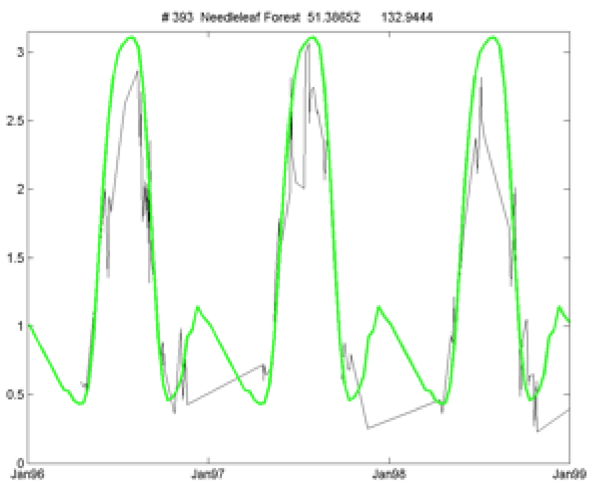


Figure D2: Comparison of MODIS (x axis) with AVHRR (y axis) for 2003-2004 for 150 sites. Left panel with the blue crosses is channel 1, center panel with red crosses is channel 2, right panel with green crosses is NDVI.



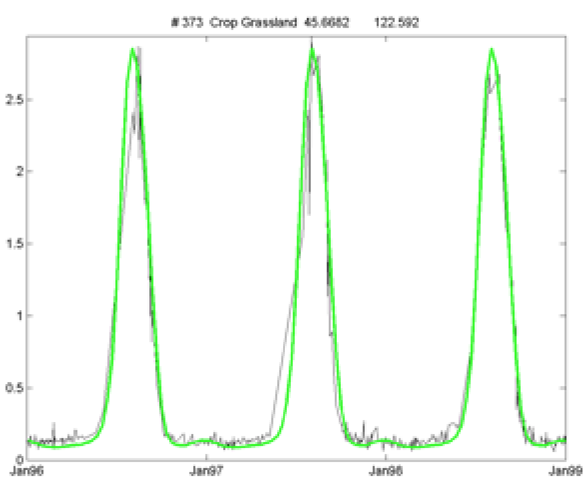


Figure D3: Two sites extracted from the comparison of the LAI product generated by this project for NOAA14 (black line) over 420 sites with the INRA LAI climatology (1999-2007).

3. NPP/VIIRS Land Product Validation Research and Algorithm Refinement: Active Fire Application Related Product (Wilfrid Schroeder, Evan Ellicott, and Louis Giglio)

The goal of this project is to assist the Joint Polar Satellite System (JPSS) in the development, evaluation, validation, and implementation of an improved Visible/Infrared Imager/Radiometer Suite (VIIRS) active fire algorithm in the early post-launch period. Development of an active fire product from VIIRS that would more closely resemble the Moderate Resolution Imaging Spectroradiometer (MODIS) product will provide data continuity with intrinsic scientific merit (figure D4). The revised VIIRS active fire algorithm incorporates the same capabilities of the latest version of the MODIS fire product (Collection 6), including fire detection data (two-dimensional scene classification product [mask]) and characterization retrievals (e.g., fire radiative power [FRP]). The Collection 6 MODIS algorithm offers improvements over the baseline VIIRS algorithm, which is simply a straightforward "port" of the MODIS Collection 4 algorithm with no specific changes made for VIIRS. Among other improvements, the Collection 6 algorithm employs dynamic potential fire thresholds to better capture small, cool fires, an additional rejection test to help eliminate false alarm errors in small forest clearings in the Amazon, and expands processing over the open ocean and other large water bodies to permit the detection of offshore gas flaring.

We began a preliminary evaluation of the VIIRS fire product with the onset of valid thermal data in late January 2012. This process has been streamlined using customized software for parsing and analyzing (both qualitatively and quantitatively) VIIRS and near-coincident Aqua MODIS fire pixels. Our results are communicated to the mission's program officers and engineers and actions are taken to address problems related to upstream mission components (e.g., Level 1B data). Initial findings include the identification of erroneous Level 1B data aggregation processing that was impacting the active fire algorithm performance, and of the occurrence of large clusters of spurious fire pixels caused by corrupted Level 1B input data.

Development of a prototype VIIRS code using Collection 6 MODIS algorithm includes tuning of algorithm parameters to account for the different radiometric characteristics and spatial resolution of the VIIRS sensor. We have begun testing specific algorithm enhancements to exploit the unique (and sometimes superior) characteristics of the VIIRS sensor. Validation of the VIIRS active fire product is being pursued using reference data acquired with fire-imaging airborne sensors.

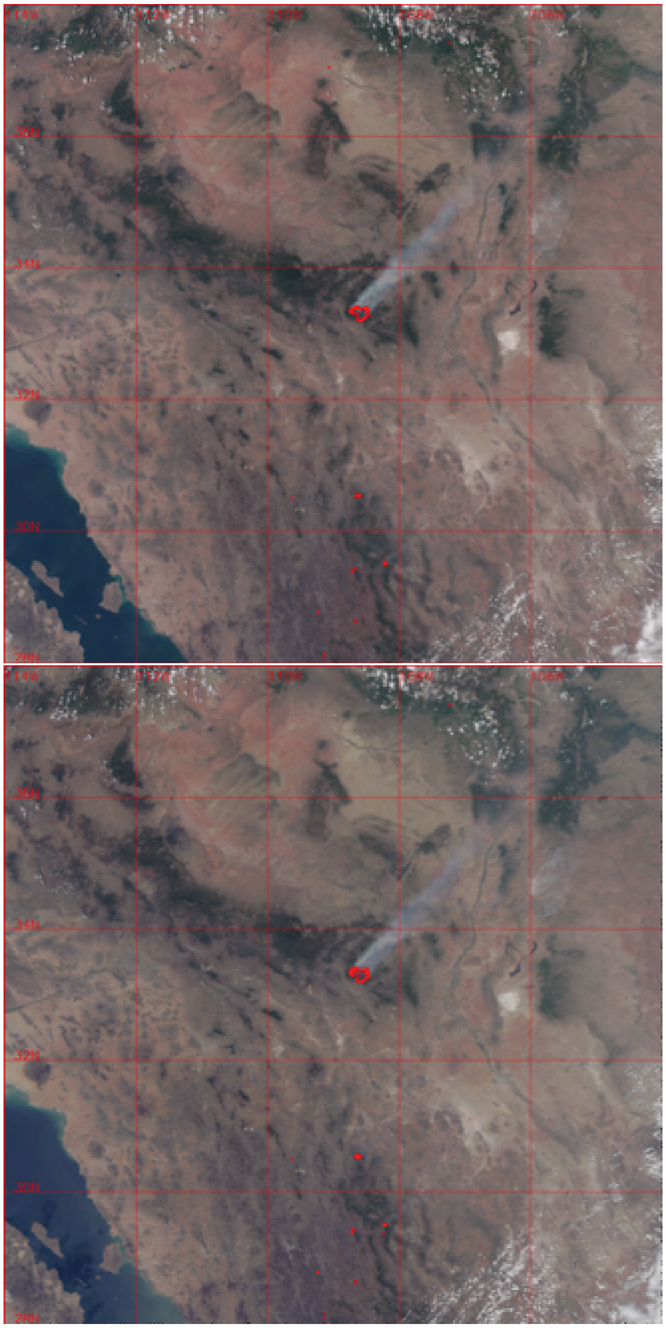


Figure D4: NPP/VIIRS (top) and Aqua/MODIS (bottom) near-coincident imaging of Whitewater Baldy Complex Wildfire in New Mexico (center of image). VIIRS (MODIS) image acquired on 25 May 2012 at 1955 UTC (2035 UTC).

E. Calibration and Validation

This Topic Area includes research projects that focus on the calibration and validation of satellite radiance data as well as products of algorithms that derive geophysical parameters from those data. Examples of ongoing research projects in this Topic Area are below.

1. A Recalibration of the AVHRR data record to provide an accurate and well parameterized FCDR (Jonathan Mittaz)

The Advanced Very High Resolution Radiometer (AVHRR) is a critical instrument for climate change studies because different versions of the AVHRR sensors have been available continuously for over 30 years and continue to be used to the present day. To use the AVHRR for climate change studies, however, accurate and stable radiances are required, or at the very least the biases and trends have to be well understood. Unfortunately these are not available with the current operational calibration, and work done by us and others has already shown significant biases and errors of up to > 0.5K. Further, analysis done by the University of Miami as part of the Pathfinder project shows that for at least one AVHRR (NOAA-16) significant time varying calibration problems are producing large time variable SST biases (Figure E1). These issues of both large biases and time variable calibration problems will severely limit the use of the AVHRR for climate change studies if left uncorrected.

In order to address the problems with the current AVHRR calibration we have developed a completely new physically based calibration methodology which has been able to find and highlight the complex sources of bias and error in both the pre-launch and in-orbit data for the AVHRR. By including effects such as stray light and instrument temperature drifts we have shown that it is possible to remove much of the source of error seen in AVHRR radiances and under certain circumstances provide a nearly zero bias pre-launch calibration. We have also shown that the new calibration also has the capability of predicting instrument gain during times when the on-board calibration data are affected by solar and/or Earthshine contamination - solar contamination has been a significant problem for many NOAA platforms as their equator crossing times drift.

The baseline for this new calibration are matches with the (A)ATSR satellite series and we have developed new match code which deals with variations in observed instrument footprints. Critical to this work is an understanding of any biases/problems with the (A)ATSR sensors themselves and we have undertaken a detailed study comparing IASI (Infrared Atmospheric Sounding Interferometer) with the AATSR. Preliminary results show that while in general the 11μm channel has a simple and small (0.06K) bias, the 12μm channel shows a strong and large trend as a function of scene temperature. At cold (<240K) temperatures there is also evidence of a time variable bias of order 0.1K which may be due to fundamental errors in the AATSR calibration methodology. This is the first time to our knowledge that such strong trends as well as time dependent biases have been reported in the AATSR and we are in the process of contacting the AATSR calibration team to work on a solution. While more work (and more data) needs to be analyzed, we have used these results to both correct the 12μm AATSR data as well as limit our matches to scene temperatures >240K when doing our AVHRR recalibration.

With the (A)ATSR caveats described above we are currently in the process of moving through the AVHRR series starting with the more modern AVHRRs to derive a new calibration scheme to the complete historic AVHRR data record to fix calibration biases and contamination effects and therefore provide an accurate and clean AVHRR FCDR. We have begun systematically analyzing data from different AVHRRs to derive new calibrations to create a database of AVHRR/ATSR matched data to be used in determining the new AVHRR calibration and have derived new calibrations for four AVHRRS, NOAA-16 to NOAA-18 and MetOp-A. For NOAA-16 we have had to do extra work involving a significant amount of research and data analysis due to large time dependent biases. Figure E1 shows examples of the correlation between the radiance bias and the blackbody temperature for NOAA-16 and shows that the bias is, to first order, linearly correlated with the BB temperature. However the plot also shows that the radiance bias is not a simple function of temperature but the dependence varies over time. The two periods shown in Figure E1 correspond to different behaviors in the thermal state of the instrument and show that the radiance bias behavior seen in NOAA-16 is complex.

At the moment the full solution to the behavior of the radiance bias with respect to the thermal state has not been completed. However, as the lower plot of Figure E1 shows, even a simple correction can significantly help in the retrieval of geophysical parameters from NOAA-16 and we are close to arriving at a solution to the problem.

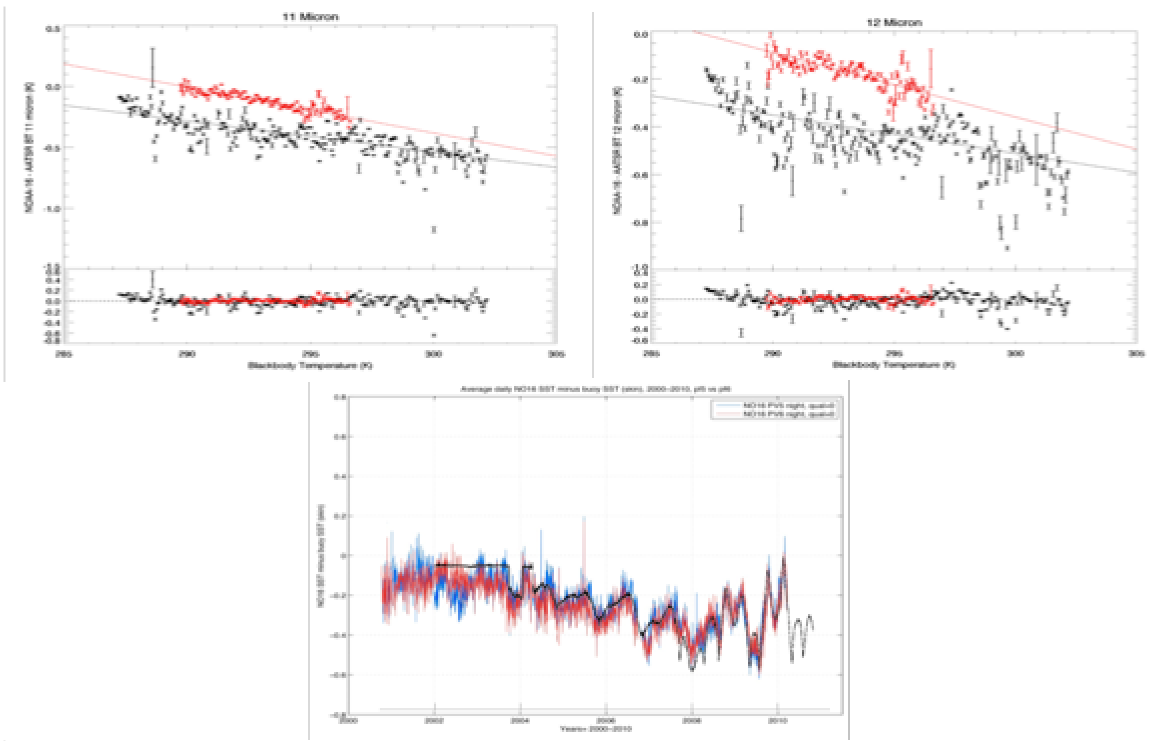


Figure E1: Top two panels show the correlation between instrument temperature and radiance bias (relative to the AATSR) for the AVHRR on-board NOAA-16 for the 11 and 12mm channels. The red data points correspond to data over the time period 2004-2007 and the black data points correspond to the time period 2008-2011 and show that the bias time dependence changed in 2008. The lower panel shows an example of the SST bias caused by not correcting for the time dependent bias (based on Pathfinder V6.0 data, Evans (private communication)) together with an estimate of the expected SST bias based on a simple time dependent radiance bias model. The agreement shows that the radiance bias for NOAA-16 is indeed related to the instrument temperature.

2. Addition of MiRS Precipitation Products from the ATMS Instrument to the STAR Precipitation Cal/Val Activity (John Janowiak)

CICS has implemented and continued the development of the US calibration/validation project (http://cics.umd.edu/~johnj/us_web.html). This activity compares a wide range of satellite-derived precipitation estimates and model forecasts over the US against both the US stage 4 radar and the CPC daily gauge-based analyses. Recently this project was expanded to incorporate MiRS precipitation products from the ATMS instrument into the evaluation activity.

As of early 2012, only a few samples of MiRS precipitation products that were derived from the ATMS instrument aboard the NPP satellite were available (figure E2). We downloaded all of the MiRS granules for a sample day, gridded the precipitation estimates to a 0.25o degree latitude/ longitude grid that matches the "Stage IV" radar reference data, plotted the individual swaths and compared them to an independent precipitation analysis (CMORPH) to ensure that we processed the data properly. We then modified the product evaluation software to incorporate the MiRS/ATMS estimates so that when the estimates become available on a routine basis, the evaluation process will be ready to accept them.

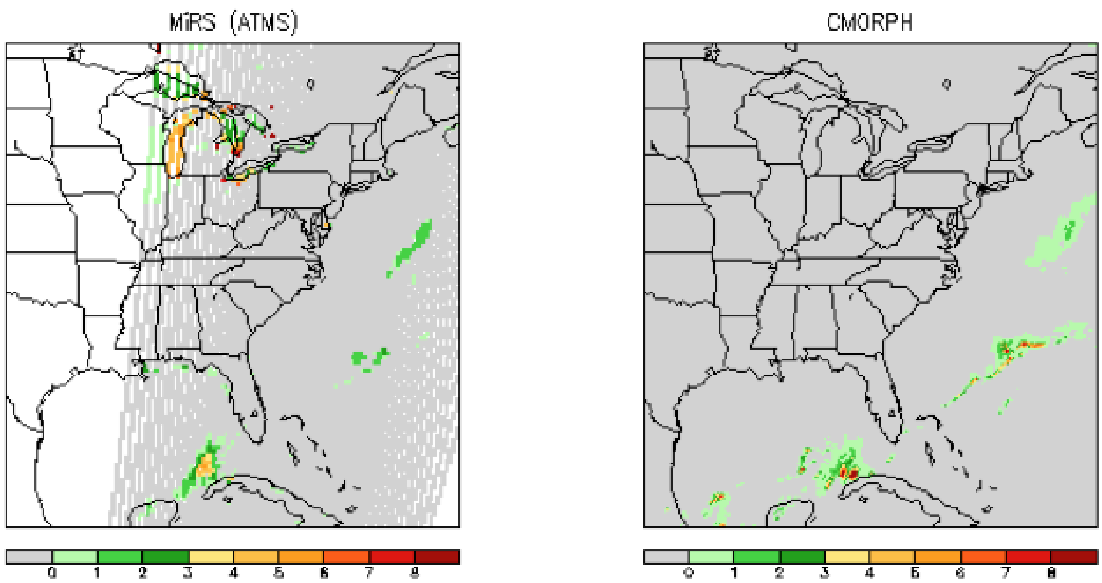


Figure E2: Plot of precipitation (mm/hr) for MiRS (from ATMS instrument; left) and CMORPH (right) for 8 U.T.C. on January 29, 2012.

3. Development of validation tools and proxy data for GOES-R ABI Air Quality Proving Ground for the Northeast (NY Metro Region) (Barry Gross)

The Air Quality Proving Ground (AQPG) has been developed as a means to test current ABI aerosol algorithms and to demonstrate performance based on realistic proxy datasets. It is also the case that aerosol retrievals are most complex over brighter surfaces and in particular urban centers. This difficulty is particularly a concern due to population impacts and local sources making monitoring more critical. Since the aerosol retrieval product for GOES-R ABI builds on the heritage of the MODIS algorithm, the algorithm suffers some of the difficulties that MODIS has in retrieving aerosols over urban areas. In particular, the current surface parameterizations used cannot be considered optimal and more regional algorithms are needed to assess the GOES-R ABI algorithm. The purpose is therefore to create the most realistic proxy datasets on the ABI channels that can provide robust tests of the algorithm in the NYC area.

In order to make an assessment, we have constructed TOA radiances using the 6SV radiative transfer code for the current MODIS bands (B1/B3/B5/B7) but using the GOES-R ABI geometry in an urban region to assess the performance of planned aerosol retrieval algorithms using realistic urban aerosol fields. The aerosol model was chosen to be urban fine mode and the AOD spatial distribution was chosen to model realistic emission sources that might occur (figure E3a). The surface albedo model was taken from season averaged MODIS-ASRVN retrievals (no simulated clouds however).

The MODIS TOA reflectance data were then ingested into the MODIS operational inversion algorithm (IMAPP) and the MODIS AODs were calculated. The results (figure E3b) demonstrate that the current retrieval algorithm at high resolution (2 km) leads to significant over biases that would lead to strong overestimates of surface PM2.5. We have recently run the 6SV code to generate LUT's for the GOES-R ABI spectral channels. Efforts to include land classification data into the MODIS data stream are being tested and can remove much of the over-biased observed.

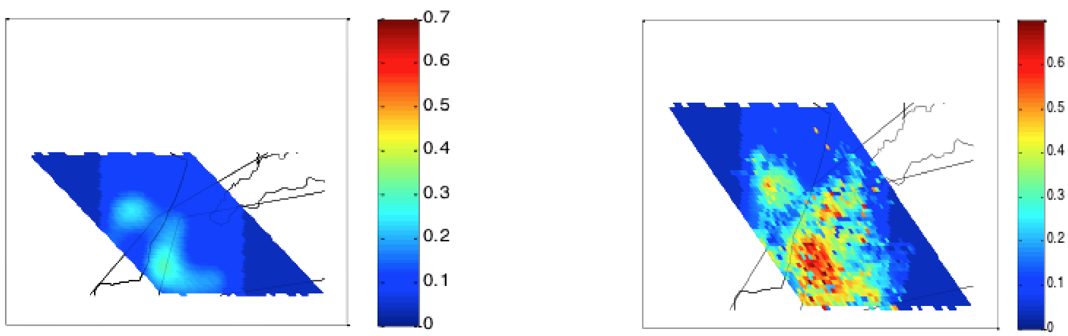


Figure E3: Assessment of errors using GOES-R ABI PROXY data sets. a. Input Aerosol Optical Depth Input Distribution, b. Retrieved using current MODIS C005 surface parameterization.

F. Climate Data and Information Records and Scientific Data Stewardship

Stewardship of environmental information for climatic purposes is a primary focus at NCDC. CICS and its partners are involved in multiple activities that improve the quality of archived information at NCDC and/or make it more accessible. This section highlights several projects in this area - a complete list is in Appendix F.

1. Assessment of Calibration of the Visible Channel of Geostationary Satellites in the ISCCP B1 Data (Anand Inamdar)

This task is the assessment of the current Visible channel calibration of the International Satellite Cloud Climatology Project (ISCCP) B1 geostationary satellite data. The ISCCP B1 data represents geostationary imagery at 3 hourly and 10 km spatial resolution retrieved from the global suite of geostationary meteorological satellites (GOES over the US, Meteosat over Europe, GMS over Japan, INSAT over Indian sub-continent) covering the period 1983 until present. There are three main channels in the ISCCP B1, consisting of the visible, infrared window and water vapor. While the latter two have been already calibrated, the focus of this task is visible channel calibration.

Visible channel calibration is currently managed by the Meteorological Center in France through normalization with the concurrent Advanced Very High Resolution Radiometer (AVHRR) solar channel on the afternoon NOAA polar-orbiting satellite at the same viewing geometry. However, certain discrepancies have been discovered in the calibration of some of the GOES, Meteosat and MTSAT series satellites and there is also an absence of any calibration prior to 1983. The objective of the present work is to fill in these calibration gaps and perform a uniform calibration for all the geostationary satellite visible channels from 1979 until present, through cross-calibration with the MODIS-quality AVHRR visible channel Climate Data Record (CDR) product recently made available by NOAA. This will enhance the quality of the recently rescued ISCCP B1 data, especially since it will be employed in a future reprocessing of the ISCCP cloud climatology resulting in a higher spatial resolution of the cloud properties and surface radiation budget. The ISCCP B1 data has been successfully employed in hurricane research and is currently being used in the evaluation of the global geostationary surface albedo project.

The processing of the calibration for all geostationary meteorological satellites through match-up with the AVHRR solar channel reflectance in the PATMOS-x data (CDR) is almost complete for the period 1979 – 2009 for the GOES, Meteosat, MSG, GMS and MTS series. The previously reported cumulative histogram matching technique has been implemented through deriving an optimized set of matching criteria. The time series of calibration slopes for selected GOES, MET and GMS series are shown in Figs. 1-3. The slope of the calibration slope time series is a measure of the degradation of the visible sensor during its lifetime. While the slopes of calibration curves follow the ISCCP calibration closely for the most part, there are individual differences, such as that for GOES – 7 (Figure F1) during the post-Pinatubo eruption period (after 1992). Also the calibration for GOES-11 (not shown) reveals a big offset, as also that for the MTS-1 (Figure F1) in addition to the excessive noise characterizing the ISCCP calibration.

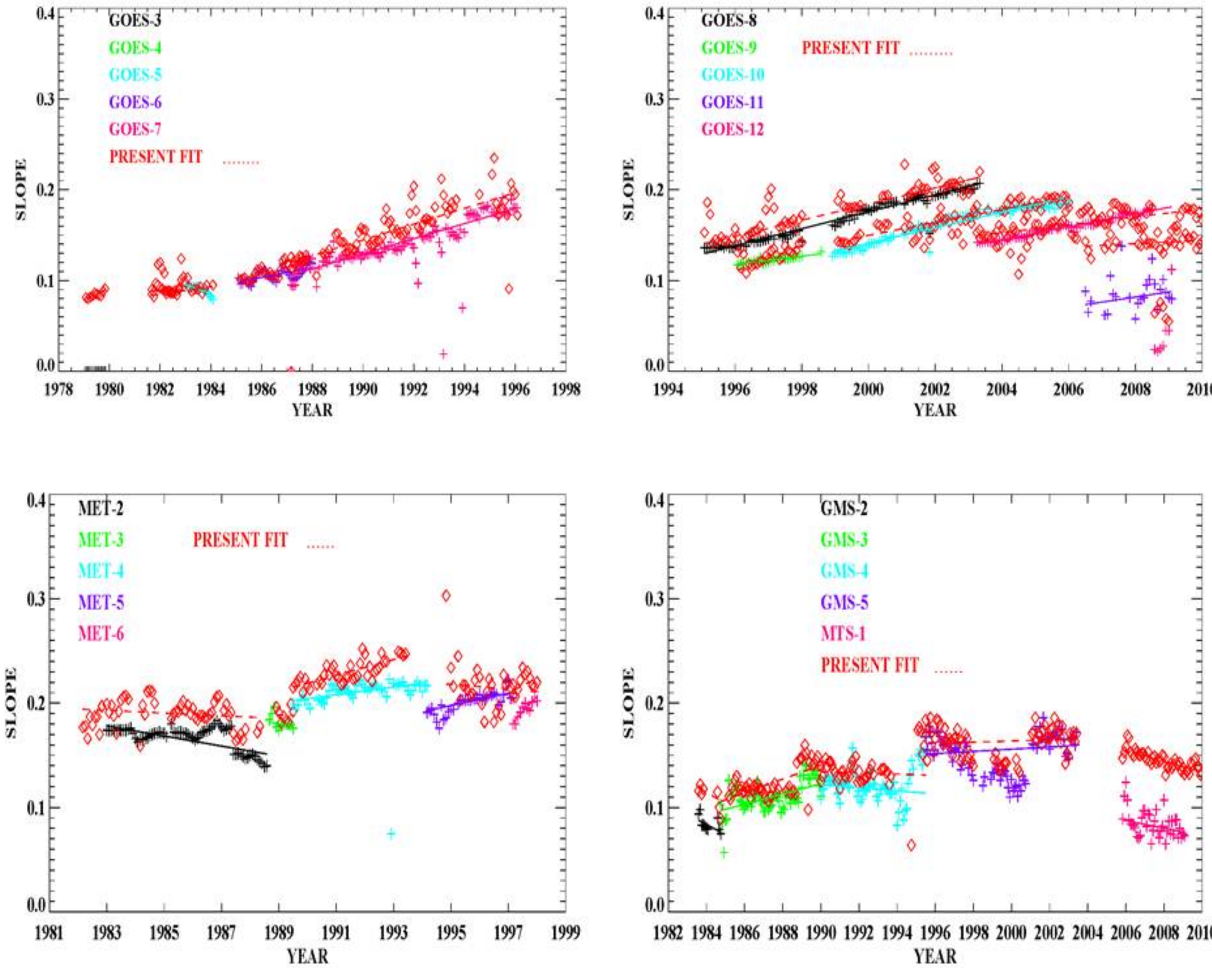


Figure F1: Time series of calibration slope for GOES, METEOSAT, GMS, and MTSAT-1 (1982 – 2004). The '+' symbols and the solid lines refer to the ISCCP and the diamond symbols and the associated regression fit line (dashed) are from the present calibration approach.

Calibration of the geostationary imager visible channel in the ISCCP B1 data is almost complete for the GOES, Meteosat, MSG, GMS and MTSAT series for the time period 1979-2009. Gaps in calibration and existing discrepancies in some of ISCCP calibration have been addressed, and the present calibration conforms to the MODIS standard.

2. Implementation of Geostationary Surface Albedo (GSA) Algorithm with GOES Data (Jessica Matthews)

We are implementing the Geostationary Surface Albedo (GSA) algorithm for GOES data on behalf of NOAA to contribute to an international effort in collaboration with EUMETSAT and JMA in support of the Sustained, Coordinated Processing of Environmental Satellite Data for Climate Monitoring (SCOPE-CM). This effort signifies the first such attempt to use the same core algorithm across internationally operated geostationary satellites to produce a climate data record for this variable.

Surface albedo is the fraction of incoming solar radiation reflected by the land surface, and therefore is a sensitive indicator of environmental changes. To this end, surface albedo is identified as an Essential Climate Variable (ECV) by the Global Climate Observing System (GCOS). In support of SCOPE-CM, NCDC is implementing the GSA algorithm for GOES data in collaboration with EUMETSAT and JMA. Currently, the GSA algorithm generates products operationally at EUMETSAT using geostationary data from satellites at 0° and 63°E and at JMA using 140°E geostationary data. To create the stitched global Level 3 product as illustrated in Figure F2, NCDC is tasked with implementing the algorithm for GOES-E (75°W) and GOES-W (135°W).

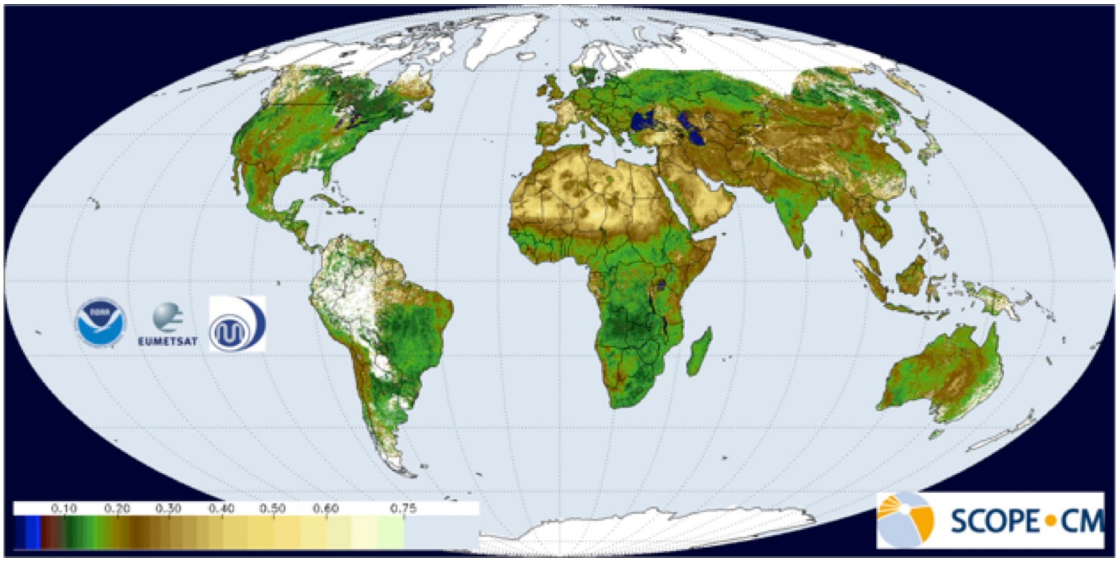


Figure F2: This figure illustrates the Level 3 global broadband surface albedo product proof of concept for the period of May 1-10, 2001. (Figure care of A. Lattanzio).

Previously the GSA algorithm was run with GOES data only for viability studies with 10 days of data. To effectively and efficiently generate products with this algorithm over large time periods, much effort was extended to understand the application to GOES data specifically. The effort may be divided into two general categories: Operations and Science. Examples of Operations tasks include: porting code developed in the EUMETSAT computing environment to be functional in the NCDC computing environment, code development to work with GOES data format imagery, code development for ancillary NWP input data, etc. Examples of Science tasks include: calibration of GOES data, evaluation of the effect of different spatial and temporal resolutions of GOES as compared to the resolutions of EUMETSAT and JMA satellites, validation of the algorithm as applied to GOES data with external data sets, development of uncertainty bounds for the product, etc.
To date, much of the effort for this project has been directed towards implementation of an operational algorithm at NCDC. The 32-bit core algorithm has been successfully ported to the 64-bit computing environment at NCDC. We have developed a code package to convert GOES formatted imagery into the required binary input for the core algorithm. And, we have developed a preliminary code package to convert the binary product output into netCDF4 format for archival.

In August 2011 NCDC hosted a weeklong visit by the team of collaborators from EUMETSAT. During this productive visit a number of tasks were accomplished. Most notably the first successful test runs of the algorithm were completed with GOES imagery at NCDC, signifying a major milestone for the project. Figure F3 illustrates the results of these first successful tests. Other issues addressed during this visit include discussions on: GOES scene selection choices, calibration techniques, current error estimation routines, conversion of outputs to netCDF format, inclusion of ancillary inputs, and generation of globally stitched and gridded Level 3 products.

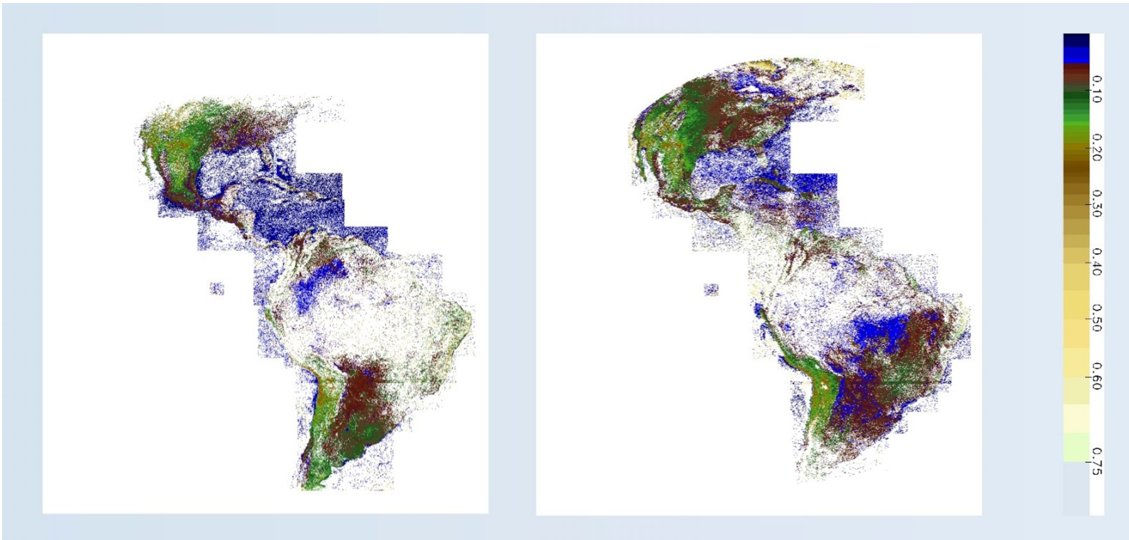


Figure F3: Directional hemispherical reflectance (DHR) for a solar angle of 30°, also called the black sky albedo. Both panels used GOES-E (GOES-8) data as input. The left and right panels are for January 1-10, 2000 and June 29-July 8, 2000, respectively.

In September 2012, we delivered all products for GOES-E and GOES-W for the SCOPE-CM requested period of 2000-2003. This is the largest reprocessing of GOES data undertaken at NCDC, working with 45 TB of input data. The work made use of the CICS computing facility, processing in only weeks, using nearly 70 parallel streams. We are currently analyzing the resultant products. Future validation work will utilize MODIS and in situ GSA observations. Pending validation, the algorithm will be implemented for the entire historical record of GOES data (1979-present). We also plan to develop an uncertainty analysis technique for the GSA products and to study the sensitivity of the final albedo products to scene selection and calibration methodology. Other planned scientific investigation includes researching possible angular and seasonal patterns in RPV parameters.

3. High Resolution SST Analysis (Richard Reynolds)
A two-stage SST analysis is being developed to best utilize the improved coverage of low-resolution microwave satellite data along with the restricted coverage and high resolution of infrared satellite data. Also an objective method is being designed to improve the signal-to-noise ratio of the final product.

During the last year the work on the objective determination of small-scale feature resolution in SST analyses has been completed. The purpose of this effort is to objectively determine the resolution capability and accuracy of SST analysis products. Ocean model SST fields are used in this study as "true" SST data and subsampled based on actual infrared and microwave satellite data coverage. The subsampled data are used to simulate sampling errors due to missing data. In a separate case, additional noise is added to the model data to also simulate random errors. Two different SST analyses are considered: a 2-stage optimum interpolation (OI) analysis and the high-resolution Operational SST and Sea Ice Analysis (OSTIA). Comparisons of the 2-stage OI and OSTIA show important differences. The OI tends to show reproduce small-scale features more accurately than OSTIA when the high-resolution data coverage is good. However, the OI also tends to produce more small-scale noise than OSTIA when the high-resolution data coverage is poor. The paper recommends that an improved analysis be developed with variable resolution and with noise variance that is more constant in space and time.

A draft paper is in the final stage of editing. The paper is entitled "Objective determination of feature resolution in two sea surface temperature analyses" by R. W. Reynolds, D. B. Chelton, J. Roberts-Jones, M. J. Martin, D. Menemenlis, and C. J. Merchant. Reynolds spent a month this summer at Oregon State University working with Professor Dudley Chelton on earlier drafts. During the coming year the objective determination paper will be finalized and will be submitted to the Journal of Climate in November 2012.

Figure F4 is an image of SST model data and SST analyses for July 1993 for the Gulf Stream. The left panels show the full high-resolution model data (top), the second high-resolution stage of the 2-stage OI (middle) and OSTIA (bottom) analyses of the full model data. The right panels show the equivalent versions using the reduced model data (see text). The color scale is in degrees C. Features in the full data (Model-Hi-Full) are captured by the OI-Hi-Full with some slight smoothing. OSTIA-Full is similar but clearly shows heavier smoothing of the model data, e.g., note that the tight eddy gradients in the model data are reduced by the OSTIA processing. The reduced high-resolution model data and analyses show that it is difficult to do a high-resolution analysis near 40°N and 55°W where there are no high-resolution model data. Because small-scale features tend to evolve relatively quickly, the under sampling of this variability in the simulated IR data manifests as noise in the Model-Hi-Red SST fields. This date was actually a time with reasonably good coverage compared with other days. The missing data are the reason that the OI-Hi-Red field is noticeably noisier than the OI-Hi-Full. Differences between the reduced and full versions of OSTIA are much smaller. Because the OSTIA analysis procedure lowers the analysis resolution, as noted above, the input data are effectively smoothed and the impact of any missing data is not as strong as it is for the OI analysis procedure.

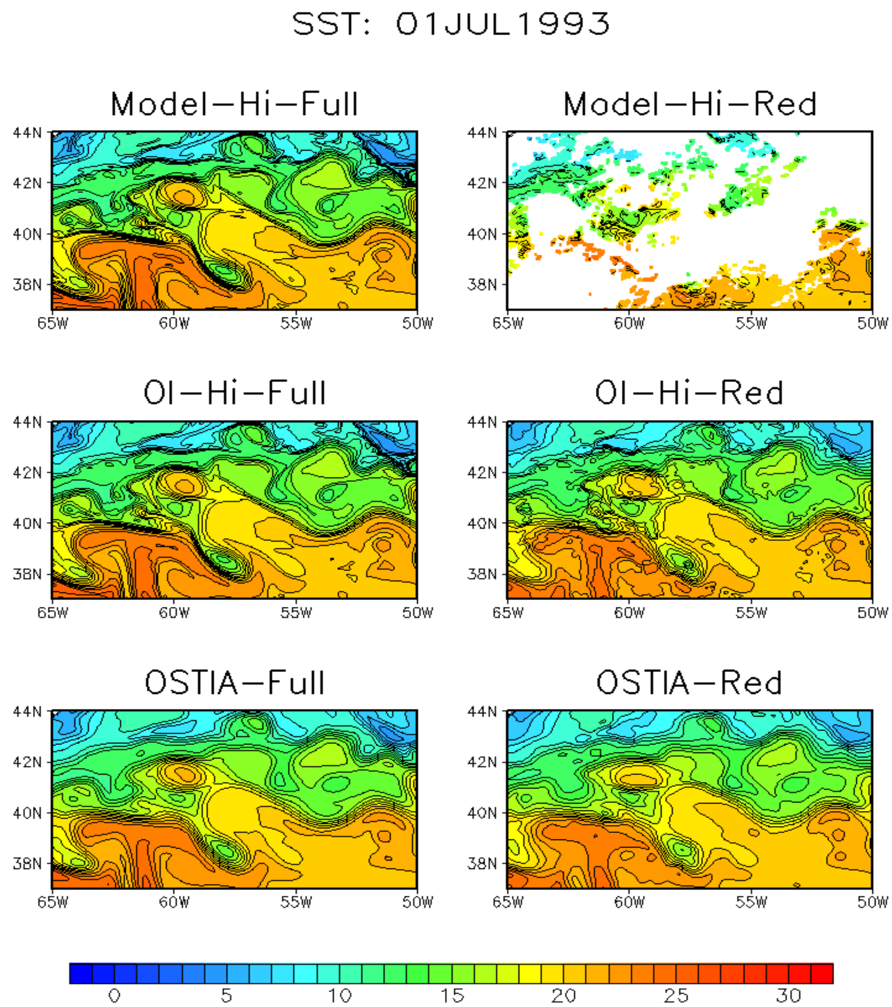


Figure F4: SST model data and SST analyses for 1 July 1993 for the Gulf Stream.

4. NPP VIIRS Land Surface Temperature product validation (Pierre Guillevic)
The goal of this project is to assist the JPSS program in the evaluation and improvement of the VIIRS Land Surface Temperature (LST) retrieval algorithm.

NOAA will soon use VIIRS - on Suomi NPP and soon on JPSS platforms - as its primary polar-orbiting satellite imager. Employing a near real-time processing system, NOAA generates a series of Environmental Data Records (EDRs) from VIIRS data. The VIIRS Land Surface Temperature EDR estimates the surface skin temperature over all global land areas and provides key information for monitoring Earth surface energy and water fluxes. Because both VIIRS and its processing algorithms are new, NOAA is conducting a rigorous calibration and validation program to understand and improve product quality.

This task is focused on the development of a new validation methodology to estimate the quantitative uncertainty in the LST EDR, and contribute to improving the retrieval algorithm. It employs a physically-based approach to scaling up point LST measurements currently made operationally at many field and weather stations around the world. The scaling method consists of the merging information collected at different spatial resolutions within a land surface model to fully characterize satellite products at moderate resolution (km x km scale). The approach is used to quantify scaling issues over terrestrial surfaces spanning a large range of climate regimes and land cover types, including forests and mixed vegetated areas (see Figure F5 for a graphic representation of the scaling challenge). First results show that VIIRS LST EDRs verify JPSS program quality requirements over vegetated areas - bias and precision specifications of VIIRS LST EDRs are 1.5K and 2.5K. However, VIIRS agrees better with scaled-up field data than with non-scaled field observations. With NOAA's Atmospheric Turbulence and Diffusion Division and the University of Tennessee Space Institute, airborne LST measurements at high resolution (10m) are performed to describe the LST spatial variability within a satellite pixel and improve the validation process.

Upcoming research activities include developing a routine validation platform based on operational field stations from NOAA's observational network: US Climate Reference Network (USCRN) and Surface Radiation Budget (SURFRAD). Ultimately, this validation approach should lead to an accurate and continuously-assessed VIIRS LST products suitable to support weather forecast, hydrological applications, or climate studies. It is readily adaptable to other moderate resolution satellite systems, such as the Geostationary Operational Environmental Satellite R Series (GOES-R).

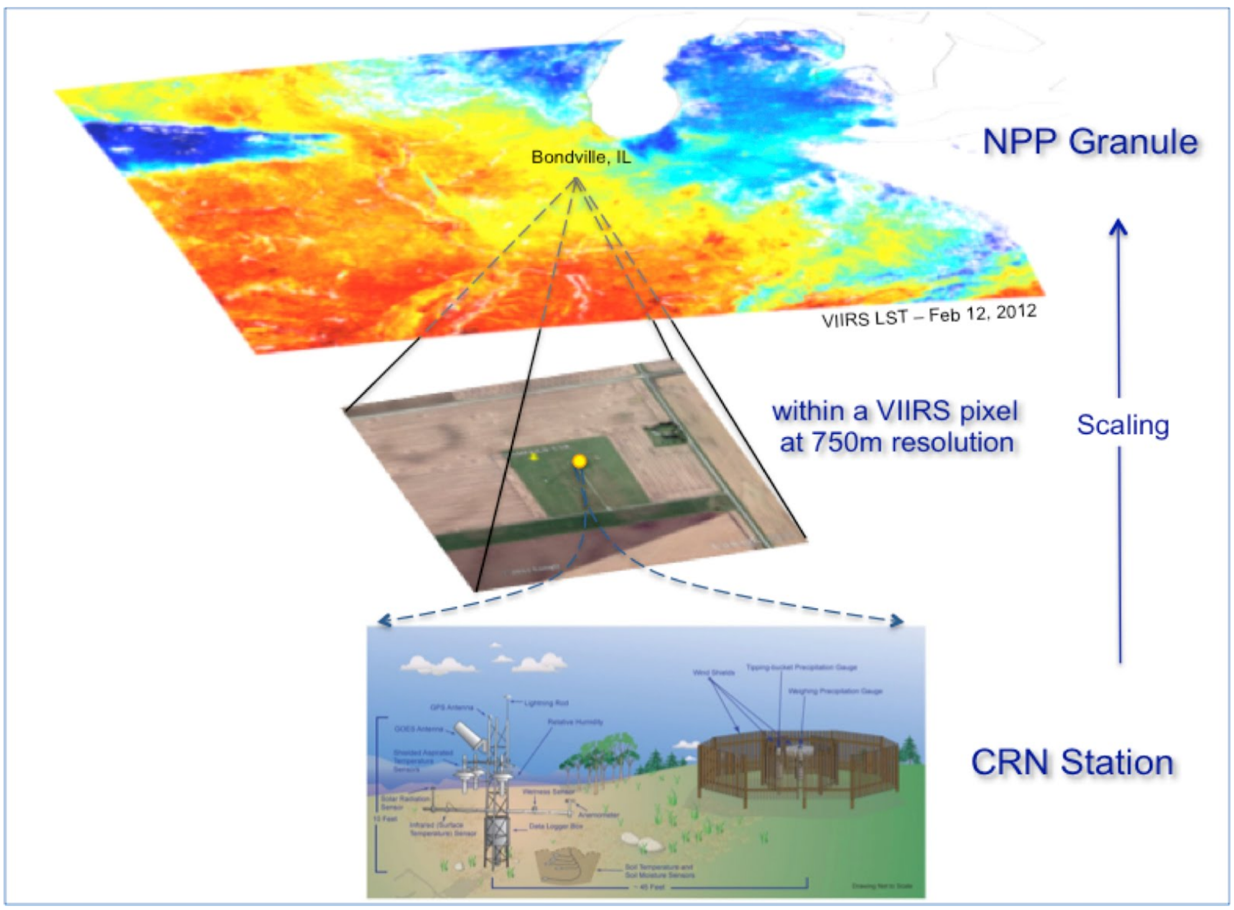


Figure F5: Representation of the scaling issue when using the NOAA's Climate Reference Network (CRN) to validate LST EDR from Suomi NPP VIIRS.

5. Precipitation Re-analysis using NMQ/Q2 (Scott Stevens, Ryan Boyles (NCSU))
This project involves the development of a re-analyzed, homogenous precipitation record for the continental United States using radar, surface gauge, and satellite platforms and methods developed at the National Severe Storms Laboratory in Norman, OK.
This work is part of an effort to create a high resolution, spatially and temporally homogenous precipitation record based on existing data collected from NOAA's array of NEXRAD radars and surface precipitation gauges distributed throughout the United States. With large coverage over the United States and very high temporal frequency (<10 minutes), radar offers the ability to see at a much higher spatial and temporal resolution than gauge networks or satellites alone.

NSSL is developing and testing a 2nd generation Quantitative Precipitation Estimate (QPE) (called Q2) that provides 1-km spatial resolution with 5-minute temporal resolution. NSSL uses Q2 to provide experimental flash flood guidance in near real time, but Q2 could also serve as a climate data record for the continental US (CONUS). NOAA needs a central archive for accurate, high-quality, precipitation information at high temporal and spatial resolutions to support local-scale climate analysis and climate monitoring. NSSL is working with NCDC through this CICS-NC project to develop a Q2 re-analysis to provide a 14-year period of record of precipitation for the CONUS.

The development of a high-resolution precipitation dataset will allow those in both research and operations to have access to information which can increase our understanding of the role of environment on rain and snowfall, allow for small-scale studies of land-surface relationships (e.g. topography, land use) on precipitation-producing systems, and provide localized estimates of precipitation for hydrology needs and drought monitoring.
Using the NMQ/Q2 software from Norman, OK, the reanalysis has been completed over a pilot domain covering nine radars in North and South Carolina. This has resulted in the process being adapted from its current real-time use at NSSL to a re-analysis mode that can be run on parallel computing systems, using archived NEXRAD data as input. Work is ongoing to expand the reanalysis to cover all of the CONUS.

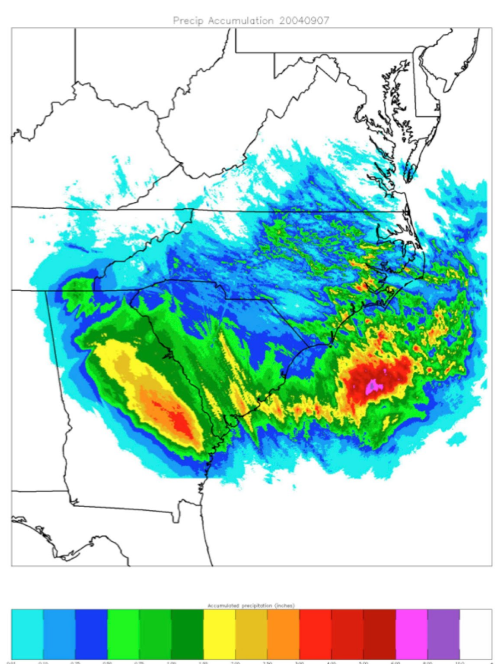


Figure F6. 24-hour precipitation accumulation over the Carolinas region for September 7, 2004, during the rainfall associated with Hurricane Frances.

The resulting five-minute, 1-km resolution precipitation estimate obtained from this process can be quickly accumulated into precipitation totals over any desirable time period. Figure F6 shows the radar-only precipitation estimate for September 7, 2004, over the Carolinas region, as the remnants of Hurricane Frances inundated the area. While this image shows estimates using radar alone, the process, in its full capacity, will allow for the integration of gauge networks, lightning data, and eventually satellite based estimates of precipitation.

Figure F7 demonstrates the full-scale ability of this process and shows a five-minute, radar-based rainrate for a morning in October 2012, covering CONUS. This product, along with a suite of derived products, is generated for the entire domain every five minutes. This mosaic is creating by merging together quality-controlled radar reflectivities from more than 130 NEXRAD radars around the United States. A dynamically-variable calculation is made to convert the three-dimensional radar reflectivities into a meaningful precipitation rate.

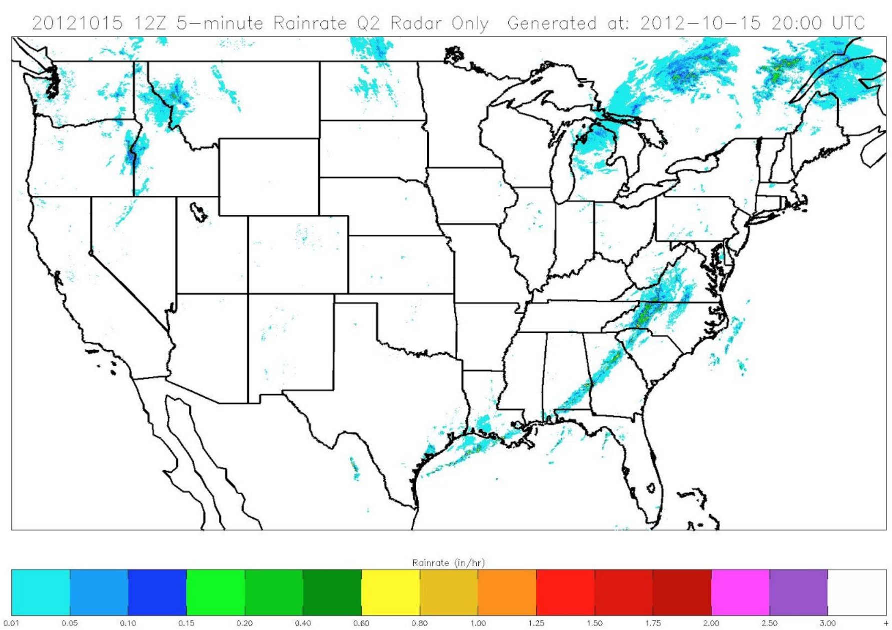


Figure F7: 5-minute radar-derived rainrate for the Continental US on the morning of October 15, 2012.

6. Characterization of Precipitation Features in the Southeastern United States Using a Multisensor Approach: Quantitative Precipitation Estimates (Olivier Prat)

We use a multi-sensor approach to characterize precipitation features at high spatial and temporal resolution. Focused over the Southeastern United States, this work aims at representing a proof of concept and a first step toward the development of rainfall climatologies at high spatial and temporal resolution. More broadly, this work is part of an on-going effort at NCDC to provide high-resolution precipitation estimates for hydrological applications and to derive trends in the evolution of precipitation patterns over time.

The primary goal of this project is to investigate long-term precipitation characteristics in the Southeastern United States at fine spatial and temporal resolution using a multi-sensor approach. The frequency and spatial distribution of precipitation extremes are evaluated using an ensemble of satellite and radar rainfall estimates. We use the precipitation reanalysis from the National Mosaic and Multi-Sensor Quantitative precipitation Estimates (NMQ/Q2), in order to derive yearly, seasonal, and sub-daily precipitation trends at high resolution (1-km/5-minute) for the period 1998-2010 with an attention to intense precipitation events.

This particular task is focused on the comparison of satellite observations from the Tropical Rainfall Measurement Mission (TRMM) and ground based (NMQ/Q2) precipitation estimates in terms of precipitation intensity, accumulation, diurnal cycle, event duration, precipitation type (stratiform/ convective), and precipitation systems (localized thunderstorms, mesoscale convective systems, tropical storms). In addition we investigate the impact of the spatial and temporal resolutions on each of these quantities, as well as the ability of satellite products to capture extreme precipitation events.

To date, we developed a precipitation climatology using the TRMM satellite suite of products such as TRMM Precipitation Radar (TPR 2A25: 5 km/daily) and TRMM Multisatellite Precipitation Analysis (TMPA 3B42: 25 km/3 hr) for the period 1998-2010. We compared TRMM satellite data with precipitation estimates at fine scale derived from the NMQ/Q2 (National Mosaic and Multi-Sensor QPE) for the pilot domain centered over the Carolinas. Current work consists in extending the domain of study to the Southeastern United States and CONUS. From this work, two manuscripts were submitted for publication. A first manuscript focussed on the quantification of the rainfall contribution originating from tropical cyclones in the Southeastern United States (Prat and Nelson 2012. J. Climate. In press). A second manuscript investigated the yearly, seasonal, and diurnal precipitation trends and the impact of the spatial and temporal resolutions on those variables (Prat and Nelson 2012. Atmos. Res. Submitted).

Figure F8 displays a comparison of the instantaneous rain-rate and the 3-hourly rain accumulation derived from the different sensors (NMQ/Q2, TMPA, TPR) in the case of the tropical cyclone Frances (2004). We note comparable patterns between satellite (TMPA, TPR) and ground based NMQ/Q2 estimates for the rainfall distribution and the rainbands. As expected we have a much higher resolution with estimates derived from NMQ/Q2. We also note important local differences due to beam blocking effect (NMQ/Q2) and to different rain rates estimation algorithms, sensor sensitivity, characteristics and technical limitation, or the number of NEXRAD sites processed (9 in the figure).

Figure F9a displays the average daily precipitation for summertime at 1km resolution derived from NMQ/Q2 from 1998 to 2010. We note higher rainfall along the coast (sea breeze effects) and over ocean (Gulf Stream). We also note over the mountains the beam blocking effect with those characteristics lines starting from the radar site location. In western North Carolina, we observe a very low daily accumulation because neither of the two radars located in TN and SC is able to fully capture rainfall events. Figure 9b presents the differences between the satellite estimates TMPA 3B42 and NMQ/Q2 re-gridded at 25-km. Larger differences are observed in Western North-Carolina and upstate South Carolina with a lower daily rain rate on the order of 75% for the radar based product NMQ/Q2 as the result of the beam blocking effect. Over the coastal Carolinas, we note a higher daily accumulation on the order of 75% observed by NMQ/Q2 that corresponds to sea breeze effects captured by NMQ/Q2 due to a higher spatial resolution than TMPA 3B42 for which those localized events are harder to capture.

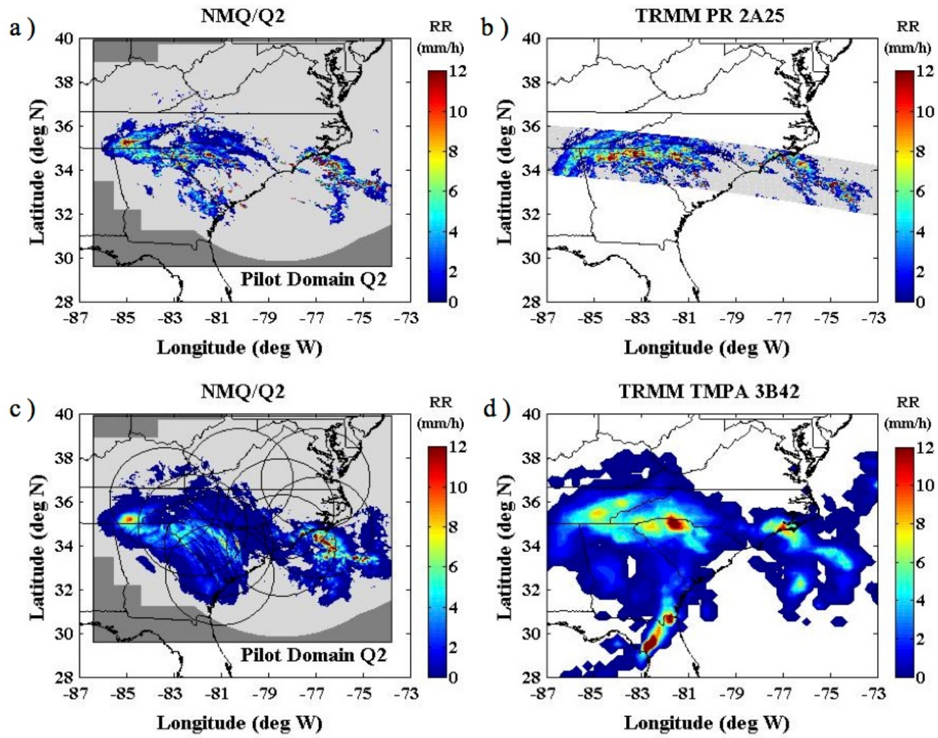


Figure F8: Hurricane Frances on 09/07/2004. Instantaneous rain-rate at 1235 UTC for: a) NMQ/Q2 (1 km), and b) TPR 2A25 (5 km). Three-hourly averaged rain-rate c) NMQ/Q2(1 km) and d)TMPA 3B42 (25 km)

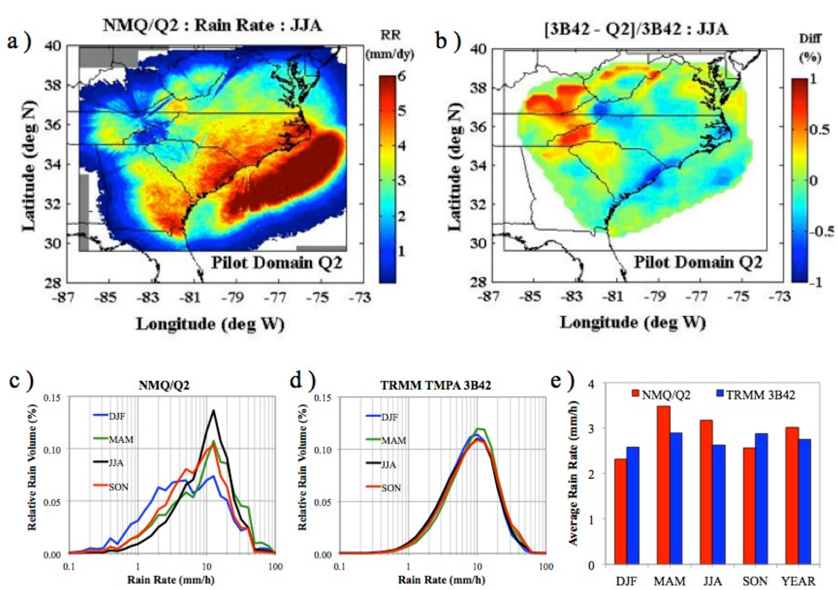


Figure F9: a) Mean precipitation derived from NMQ/Q2 (1 km), and b) differences between NMQ/Q2 and TMPA 3B42 (25 km) for summer (JJA). Seasonal PDFs derived from: c) NMQ/Q2, and d) TMPA 3B42. e) Seasonal and annual average rain-rate for NMQ/Q2 and TMPA 3B42.

Figures F9c and F9d display the seasonal PDFs for the relative rain volume derived from NMQ/Q2 (Fig. 2c) and TMPA 3B42 (Fig. 2d) respectively over the same area corresponding to the actual footprint of the nine radars. In both cases we note that a rain rate around 10 mm/h hour contributes the most to the rain volume. We observe a higher seasonal variability for NMQ/Q2 than for TMPA 3B42, which displays very similar PDFs throughout the year regardless of the seasonal characteristic of precipitation. Furthermore, the PDF for summer derived from NMQ/Q2 is shifted towards higher rain intensity, mainly due to the presence of summertime convection activity over the area. In addition, we note that winter PDF derived from NMQ/Q2, indicates a more widespread rain rate contribution from 2mm/h to 10 mm/h, when compared to TMPA 3B42, and that is due to cold precipitation such as snow or mixed phase.

Finally, Figure 9e displays the seasonal average rain rate (i.e. integration of the area under the curves). We observe a lower rain intensity of about 11% between NMQ/Q2 and TMPA 3B42 during the cold season (winter and fall), and a higher rain intensity of about 17% between NMQ/Q2 and TMPA 3B42 during the warm season (summer and spring) with globally a higher annual rain rate of about 9% for NMQ/Q2 (radar only) when compared to satellite estimates TMPA 3B42.

7. Comparison of ground based temperature measurements with satellite-derived phenology (Jesse Bell and Jessica Matthews)

This research is a comparison of satellite-derived phenology with ground-based temperature metrics. The goal of this task is to determine which air or soil temperatures are better indicators for estimating the timing of growing season at 39 stations located within the contiguous U.S.

Climate observations of growing season are essential for understanding plant phenology and physiological development. Consequently, the most accurate definition of growing season is important for understanding ecosystem processes, agricultural development, and drought status. Air temperature, as it is one of the most commonly recorded climate variables, is traditionally used to define the onset and end of the growing season when phenology measurements are not available. Because below ground activity has been shown to be a predominant indicator of vegetative growth, research is being conducted to determine if soil temperature is a better metric for calculating plant phenology than air temperature. Using air and soil temperature measurements from the U.S. Climate Reference Network (USCRN), we are comparing the remotely-sensed MODIS normalized difference vegetation index (NDVI) derived growing season metrics with different ground-based temperature thresholds to determine which in situ temperature variable provides the most accurate estimation of growing season.

The goal of this task is to determine the in situ temperature measurement(s) that best relates to the onset and end of satellite-derived growing season. The approach includes an investigation of 39 USCRN stations that have two complete years (2010-2011) of air and soil temperature data. MODIS NDVI data, from both AQUA and TERRA, are used to calculate start of season (SOS) for each USCRN station in the study. Four satellite images geo-located nearest to each station were extracted for all of 2010 and 2011. Two different methods for calculating SOS were used on this imagery: a local threshold based on yearly minimum and maximum NDVI values (ratio), and slope based estimates from exponential functional fits to NDVI data (exponential). The NDVI SOS estimates were then compared to the air and soil temperature thresholds (0^oC, 5^oC and 10^oC) derived from the ground based measurements. We hypothesize that the use of remotely-sensed data will help to determine the most accurate method for calculating growing season and assist in developing plant-based indices for each USCRN station.

The USCRN calculations of growing season, based on the three temperature thresholds, for the 39 stations in the study have been analyzed for 2010 and 2011. Soil temperatures were found to cross the temperature threshold significantly earlier in the year than air and surface temperatures (~20 days). As expected, the estimated growing season length progressively begins earlier with increasing depth (5cm 10cm, 20cm, and 50cm) of the soil measurements. These results were compared with NDVI-derived SOS.

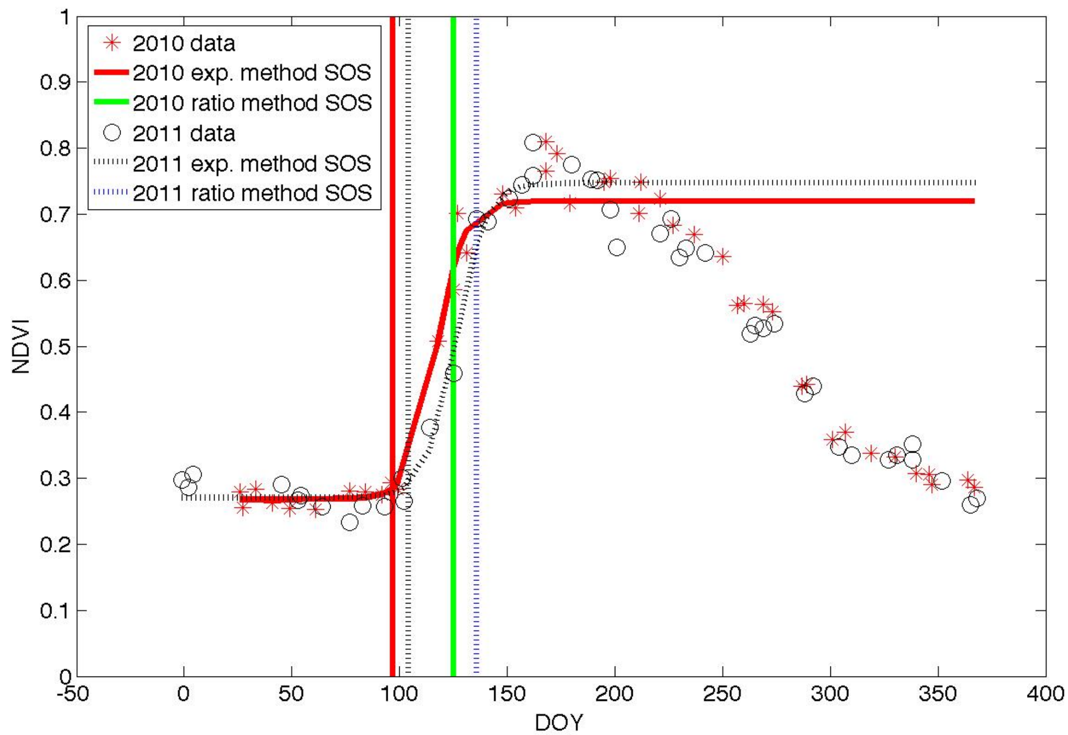


Figure F10: MODIS NDVI data for the pixel containing the Manhattan, Kansas USCRN station in 2010 and 2011. The vertical lines are an indication of the SOS estimate from NDVI data using the ratio and exponential methods.

MODIS NDVI data were analyzed for the pixel containing each of the 39 USCRN stations in the study. Two methods to calculate SOS from NDVI data are currently being evaluated for each station. Figure F10 illustrates an example comparison of the results of the two methods at the Manhattan, Kansas USCRN station. The first method (ratio) translates NDVI into a ratio based on the annual minimum and maximum NDVI measurement. An arbitrary threshold (0.5) was then used to establish the SOS. The other method used exponential curve fitting. After the curves were fitted to the NDVI time series, the derivatives with respect to time were calculated and the mean slope value was defined to be the threshold value. SOS was then determined to be the time-point associated with the first day where the threshold was crossed in the time series. These procedures are currently being evaluated to determine which is the more accurate method to estimate SOS from NDVI data for each of the 39 locations during the 2010 and 2011 growing seasons, and also how these SOS estimates compare to the SOS estimates from ground-based temperature methods (see Figure F11).

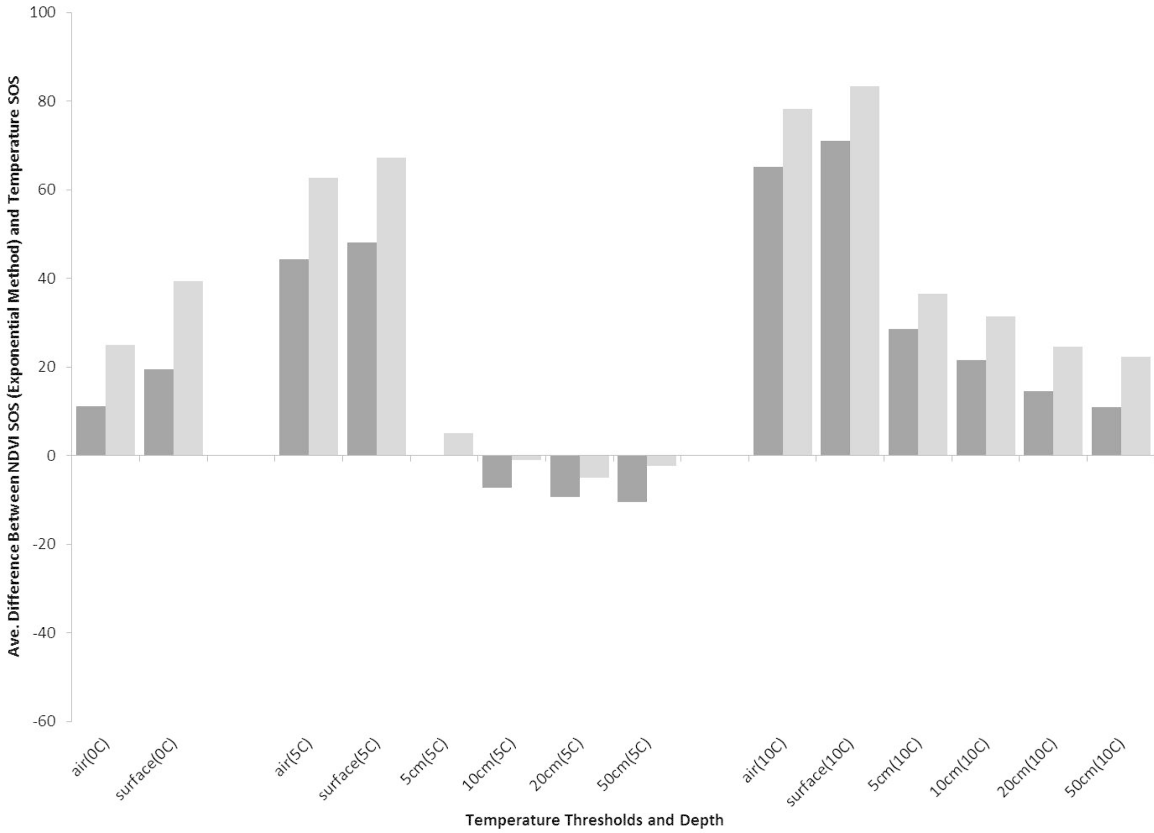


Figure F11: Comparison of the average difference between temperature-derived SOS at various depths and temperature thresholds with NDVI-derived SOS using the exponential method. Dark grey bars indicate 2010 and light grey bars indicate 2011. Soil temperatures using the 5^{o}C threshold have the strongest agreement with the NDVI-derived SOS.

8. The Madden–Julian Oscillation and Extratropical Impacts (Carl Schreck)

Intraseasonal forecasts of 7–30 days are valuable to many sectors. For example, the energy industry relies on such forecasts to meet upcoming energy demand. Divergent circulations from the tropics play a critical role in driving weather patterns on these timescales. Two key sources of tropical variability are the Madden–Julian Oscillation (MJO) and equatorial waves. They have traditionally been identified using proxies for tropical convection like outgoing longwave radiation (OLR). That method works well in regions like the Indian Ocean and the Western Pacific where the convection is particularly vigorous. However, the signals become more difficult to track in the Western Hemisphere and the subtropics.

NOAA's CDR Program has recently produced a homogeneous 32-year dataset of upper tropospheric water vapor (UTWV) from the high-resolution infrared radiation sounder (HIRS). This new dataset shows promise for identifying the MJO and equatorial waves in regions that are less convectively active. In the subtropics, for example, UTWV identifies the subsidence drying that occurs poleward of the MJO's convection. These signals, which are absent from OLR, uniquely highlight the interactions between the MJO and extratropical weather patterns.

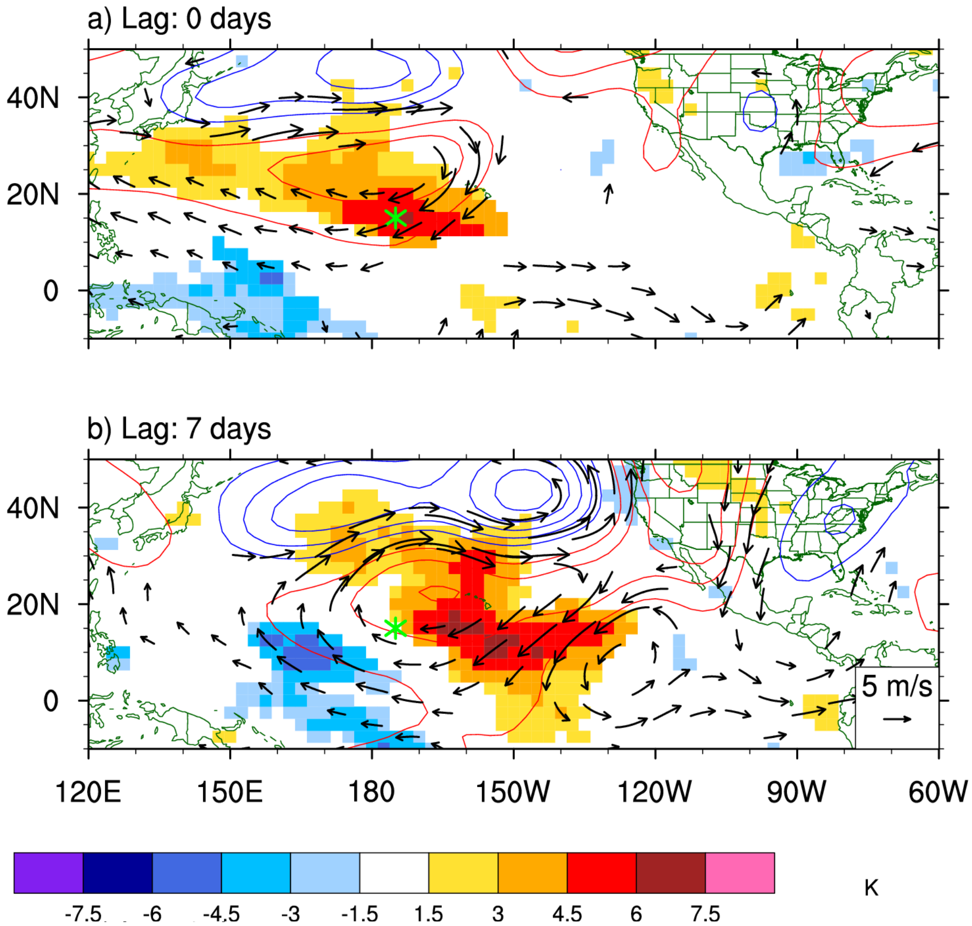


Figure F12: Lagged composite of UTWV (shaded), 200-hPa geopotential height (contours), and 200-hPa winds based on 27 events from November–April with a +2 standard deviation MJO-filtered UTWV anomaly at 15°N, 175°W. Contours are drawn every 20 m with positive values in red, negative values in blue, and the zero contour omitted. Shading and vectors are only drawn for anomalies that are significant at the 95% level.

Figure F12 shows an example of one such interaction. The shading identifies UTWV anomalies associated with the MJO. The contours and vectors indicate the coincident 200-hPa height and wind anomalies. The dry anomalies (warm shading) near Hawaii represent the MJO's enhancement of the subtropical ridge. This pattern leads to an amplified weather regime over North America seven days later (bottom panel). These signals could be useful for long-range forecasts of extreme temperatures, and they cannot be replicated using conventional measures of the MJO.

A new website (http://monitor.cicsnc.org/mjo/) was developed for daily monitoring of the MJO and equatorial waves using both OLR and UTWV. It has been tailored to meet the needs of forecasters at NOAA's Climate Prediction Center (CPC). Additional diagnostics were developed to support forecasts for the DYNAMO (Dynamics of the MJO) field campaign that was conducted over the Indian Ocean from October 2011 to March 2012. Now we are collaborating with members of the energy industry to develop new diagnostics and statistical models. The ultimate goal will be improving forecasts of energy demand over North America using the tropical UTWV and OLR signals.

9. Providing SSM/I Fundamental Climate Data Records to NOAA (Frank Wentz, Remote Sensing Systems)

The Special Sensor Microwave Imagers (SSM/I) are a series of 6 satellite radiometers that have been in operation since 1987. These satellite sensors measure the natural microwave emission coming from the Earth's surface. These emission measurements contain valuable information on many important climate variables including winds over the ocean, the moisture and rain in the atmosphere, sea ice, and snow cover. However, the extraction of this information from the raw satellite measurements is a complicated process requiring considerable care and diligence. The first step in the process is the generation of Fundamental Climate Data Records (FCDR) of the sensor measurements in term of antenna temperatures and brightness temperatures. Since the first SSM/I was launched in 1987, Remote Sensing Systems (RSS) has been providing SSM/I data to the research and climate communities. The RSS SSM/I datasets are generally recognized as the most complete and accurate SSM/I FCDR available.

The primary objective of this investigation is to make a high-quality SSM/I FCDR with supporting documentation more widely and easily available to the User Community. This is being accomplished by converting the RSS data to a netCDF4 format and then providing it to NCDC/NOAA for archiving and distribution.

The bulk of this investigation was the Year-1 work described in our previous Progress Report. In Years 2 and 3, we are providing User support for the SSM/I FCDR. This support includes: (1) the continue processing of the F15 SSM/I, (2) a complete reprocessing of all SSM/I data when Version 7 is finalized, (3) converting the RSS binary format into the netCDF4 format, and (4) supporting Users inquiries and feedback and attending meetings and conferences.

Whereas the generation of the V6 FCDR was part of RSS's commercialization program, the development and generation of the V7 FCDR was mostly paid for by NASA. This NASA support is acknowledged here and will be acknowledged on the NCDC/NOAA web site hosting the V7 FCDR.

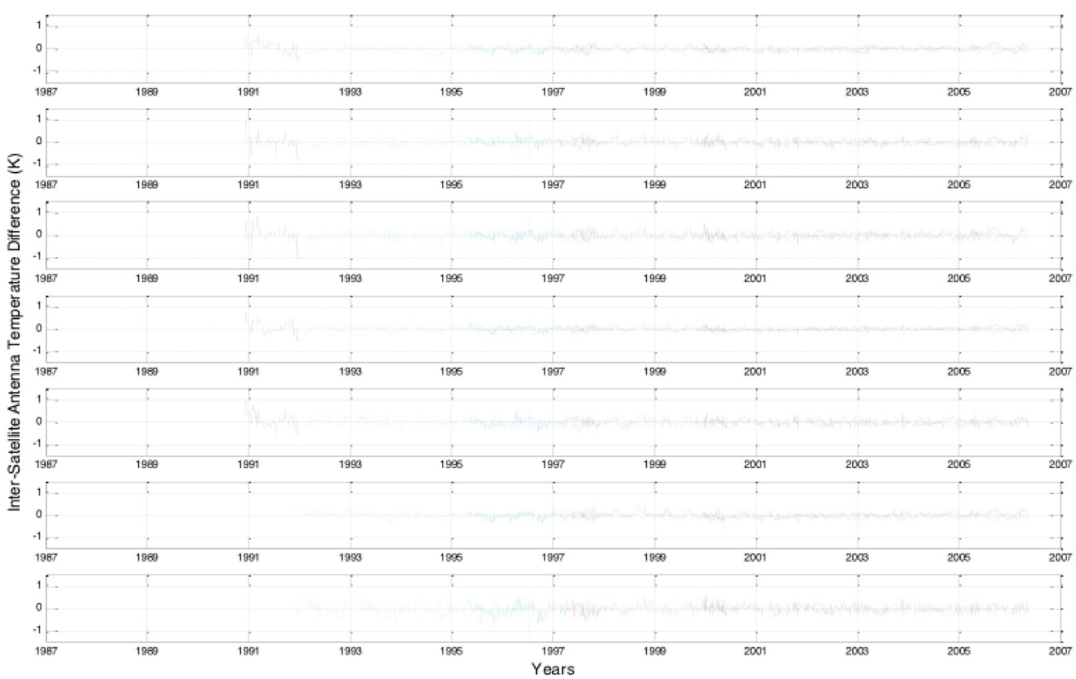


Figure F13: TA differences for 11 overlap periods after applying all the corrections. Each overlap period is shown in a different color with the color-coding. The 7 frames show the 7 channels going *from 19V at the top to 85H at the bottom in the order indicated. These results are for the evening portion of the orbit.*

black	red	green	blue	magenta	cyan	orange	black	red	green	blue
F08	F08	F10	F10	F10	F11	F11	F11	F13	F13	F14
F10	F11	F11	F13	F14	F13	F14	F15	F14	F15	F15

Table 1. Color-coding for figures displaying the 11 inter-satellite overlap periods.

We originally intended to deliver the V7 SSM/I data in Year 2. However, we encountered some unexpected complications in calibrating the SSM/Is. These complications have been resolved, and the result is a significantly improved product as compared to V6.

The primary improvements include:

1. The inter-calibration of the 6 SSM/Is is now accomplished by adjusting the antenna pattern correction (i.e., the coefficients that convert antenna temperature to brightness temperature) rather than simply adding offsets. This is a more physical way of doing de-biasing and should provide a consistent calibration over both ocean and land.
2. The new V7 radiative transfer model (RTM) eliminated the need to adjust the SSM/I earth incidence angles to achieve proper calibration, particular for the F10 SSM/I. The incidence angle dependence of the V7 RTM precisely matches that exhibited by the observations, thereby eliminating any need to adjust the incidence angle.
3. Corrections are made for solar radiation intrusion into the SSM/I hot load
4. Geolocation of the 6 SSM/Is was verified and in some cases fine-tuned.
5. The overall calibration is now consistent with other microwave imagers such as WindSat, AMSR-E and SSM/IS.

The V7 calibration for the 6 SSM/I was completed in March 2012 and the V7 FCDR will be converted to netCDF and delivered to NCDC/NOAA in April/May 2012. A technical report describing the V7 calibration method will be also provided. This will complete this investigation.

G. Earth System Monitoring from Satellites

This Topic Area includes research projects that focus on the derivation and curation of data sets that describe crucial aspects of the Earth System, as well as the application of those data sets and ancillary information in the detection and monitoring of significant climate events. Examples of ongoing research projects in this Topic Area are below.

1. CICS Support for the National Oceanographic Data Center (Gregg Foti and James Reagan). CICS participates in the archiving and delivery by NOAA/NODC of ocean data products that are derived from sensors operating in space. These include sea surface temperature, ocean altimetry, ocean vector winds and other products derived from these measurements. The satellite team adds value by providing metadata, making the data discoverable, performing quality assurance and providing scientific and technical support to users of these data (http://www.nodc.noaa.gov/SatelliteData/).

The Coral Reef Temperature Anomaly Database (CoRTAD) product quantifies global-scale stressors that are widely deemed responsible for the decline of coral reefs. CoRTAD, using support from the NOAA Coral Reef Conservation Program, uses SST from NOAA's Pathfinder program to develop weekly SST averages, thermal stress metrics, SST anomalies (SSTA), SSTA frequencies, SST Degree heating weeks and climatologies. CoRTAD version 4 beta (see example in Figure G1) has been completed. Improvements over previous versions of CoRTAD include:

- CoRTAD 4 is now in NetCDF format, which is preferred by ocean modelers and much of the oceanographic community.
- CoRTAD 4 contains vastly enriched metadata.
- CoRTAD 4 uses the latest Pathfinder data, version 5.2.
- CoRTAD 4 now goes back to the last 2 months of 1981 and now contains 2010 data.
- CoRTAD 4 has slightly higher spatial resolution at 8192 x 4096 global pixels.
- CoRTAD 4 uses an improved land mask.

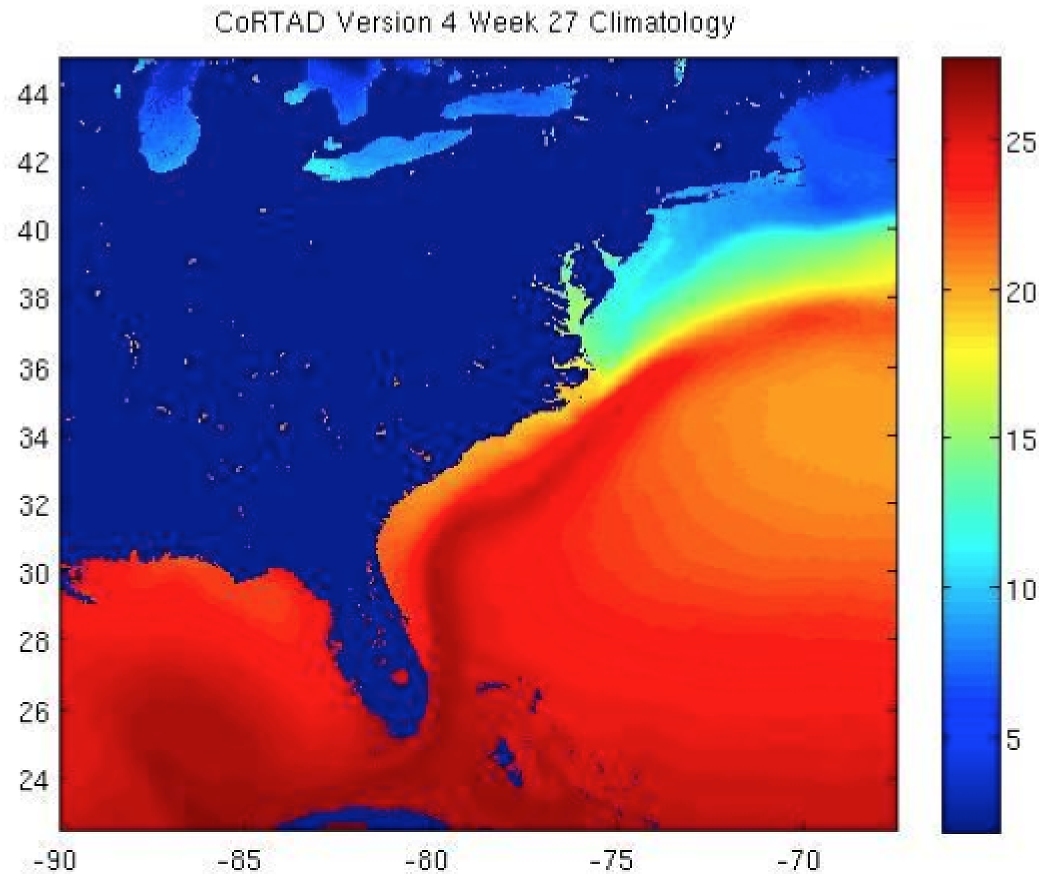


Figure G1: CoRTAD version 4 sea surface temperature climatology for Eastern North America. Week 27 for years 1982 through 2010 using Advanced Very High Resolution Radiometer (AVHRR).

2. A GOES thermal-based drought early warning index for NIDIS and dual assimilation of microwave and thermal infrared satellite observations of soil moisture into NLDAS for improved drought monitoring (Chris Hain, Shunlin Liang)

Evapotranspiration deficits in comparison with potential ET (PET) rates provide proxy information regarding soil moisture availability. In regions of dense vegetation, ET probes moisture conditions in the plant root zone, down to meter depths. Our group has spearheaded use of anomalies in the remotely sensed ET/PET fraction (*fPET*) generated with ALEXI as a drought monitoring tool that samples variability in water use, and demonstrating complementary value in combination with standard drought indices that reflect water supply. Additionally, our research group has demonstrated that diagnostic information about SM and evapotranspiration (ET) from microwave (MW) and thermal infrared (TIR) remote sensing can significantly reduce soil moisture (SM) drifts in LSMs such as Noah.

The two retrievals have been shown to be quite complementary: TIR provides relatively high spatial resolution (down to 100 m) and low temporal resolution (due to cloud cover) retrievals over a wide range of vegetation cover, while MW provides relatively low spatial (25 to 60 km) and high temporal resolution (can retrieve through cloud cover), but only over areas with low vegetation cover. Furthermore, MW retrievals are sensitive to SM only in the first few centimeters of the soil profile, while in vegetated areas TIR provides information about SM conditions integrated over the full root-zone, reflected in the observed canopy temperature. The added value of TIR over MW alone is most significant in areas of moderate to dense vegetation cover where MW retrievals have very little sensitivity to SM at any depth. This synergy between the two different retrieval techniques should provide a unique opportunity for the development of a dual assimilation system with the potential to improve drought assessments from the NLDAS suite of land surface models.

Our research group has developed all necessary routines to automatically download and process all necessary inputs needed for the generation of ALEXI ESI maps over the CONUS. The real-time system is currently running in a beta-mode at NOAA-NESDIS-STAR and has begun delivery of weekly ALEXI ESI maps to end-users at the Climate Prediction Center and the National Drought Mitigation Center, beginning April 2012. Real-time and retrospective (back to 2000) ALEXI ESI maps will also be made available to the user community at the following website which was developed in the past year and is shown in Fig. G2: http://hrsl.arsusda.gov/drought.

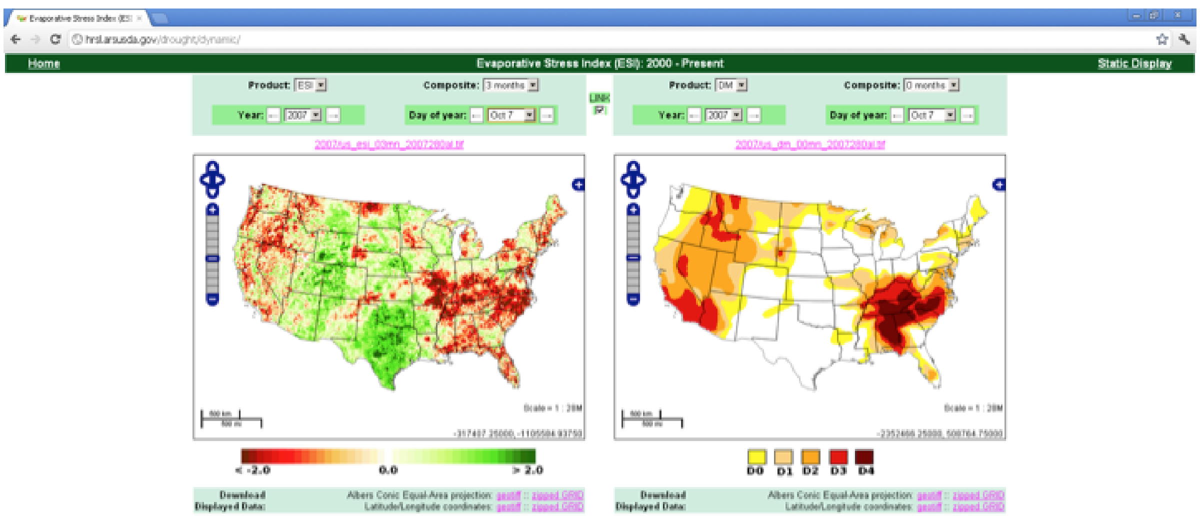


Figure G2: Screenshot of the ALEXI ESI website (http://hrsl.arsusda.gov/drought).

Additionally, during the past year our research group has begun the initial steps towards the implementation of TIR (ALEXI) and microwave soil moisture in a dual assimilation framework within the Noah LSM. All necessary inputs have been downloaded and archived needed for the assimilation simulations and include AMSR-E LPRM surface SM retrievals and TRMM 3B42RT 3-hour precipitation for the 2003 to 2011 study period. An initial set of assimilation experiments has been completed during the period of 2005-2008 to assess assimilation performance, using a retrieval error representation based on the fraction of green vegetation cover. Initial results show that each TIR and MW SM, in isolation, has the ability to correct precipitation errors from the TRMM 3B42RT forcing, as compared to an open-loop simulation. However, when both SM products are assimilated, little additional improvement is noted (relative to each in isolation), the cause of this result is currently being investigated and may be related to the current retrieval/model error covariance presentation.

3. The Development of AMSU Climate Data Records (CDRs) (Wenze Yang; Chabitha Devaraj; Isaac Moradi)

Current passive microwave sounder data, used in hydrological applications, are derived from POES satellites for which the primary mission is operational weather prediction. These data are not calibrated with sufficient stability for climate applications. A properly calibrated FCDR needs to be developed to enable the utilization of these data for TCDR and Climate Information Records and to extend their application into the JPSS era (e.g., POES/AMSU to NPP/ATMS to JPSS/ATMS). Once developed, TCDRs for water cycle applications (precipitation, water vapor, clouds, etc.) will be developed for use as key components in international programs such as GEWEX, CEOS and GPM. This project will focus on the development of AMSU FCDRs for the AMSU-A window channels (e.g., 23, 31, 50 and 89 GHz) and the AMSU-B/MHS sensor.

A pronounced asymmetric cross-scan bias of the AMSU-A window channels was discovered, and it severely impacted water cycle product generation. Several approaches, including vicarious cold and hot reference calibration techniques, are applied to characterize the cross-scan bias. The bias pattern appears to be stable through several years of data examined from the same satellite but is quite different among those onboard the different NOAA (NOAA-15, NOAA-16, NOAA-17, NOAA-18, and NOAA-19) and EUMETSAT (MetOp-A) satellites. The scan bias may be caused by sensor polarization misalignment or cross-polarization, even after the radiance/brightness temperature data have been geocorrected with regard to geolocation and view angles. Based upon the characterization information, two-point and three-point correction approaches are proposed; both approaches provide promising results for AMSU-A window channels at brightness temperature level and product level and outperform the current operational correction approach, which is essentially a one-point correction (Yang et al., 2012).

The impact of the cross-scan asymmetry of to the hydrological product is illustrated in Figure G3. Compared to the uncorrected CLW image, the corrected version has a much more coherent cloud structure above the vast ocean area at mid- and high-latitudes of Southern Hemisphere (Figure G3a, b). The corrected 31.4 GHz emissivity (Figure G3d) also exhibits much improvement in its cross-scan symmetry than the original (Figure G3c). This is most noticeable in the 15°N to about 37°N latitude bands where the lower emissivity is asymmetric at the two limbs in the original image but becomes comparable after correction. This serves as the first step toward a more stable fundamental and thematic climate data record to be used in hydrological and meteorological applications.

References:

Yang, W., Meng, H., Ferraro, R. R., Moradi, I., and Devaraj, C. 2012. Cross-scan asymmetry of AMSU-A window channels: Characterization, correction, and verification. IEEE Trans. Geosci. Remote Sens., No. 99. doi:10.1109/TGRS.2012.2211884.

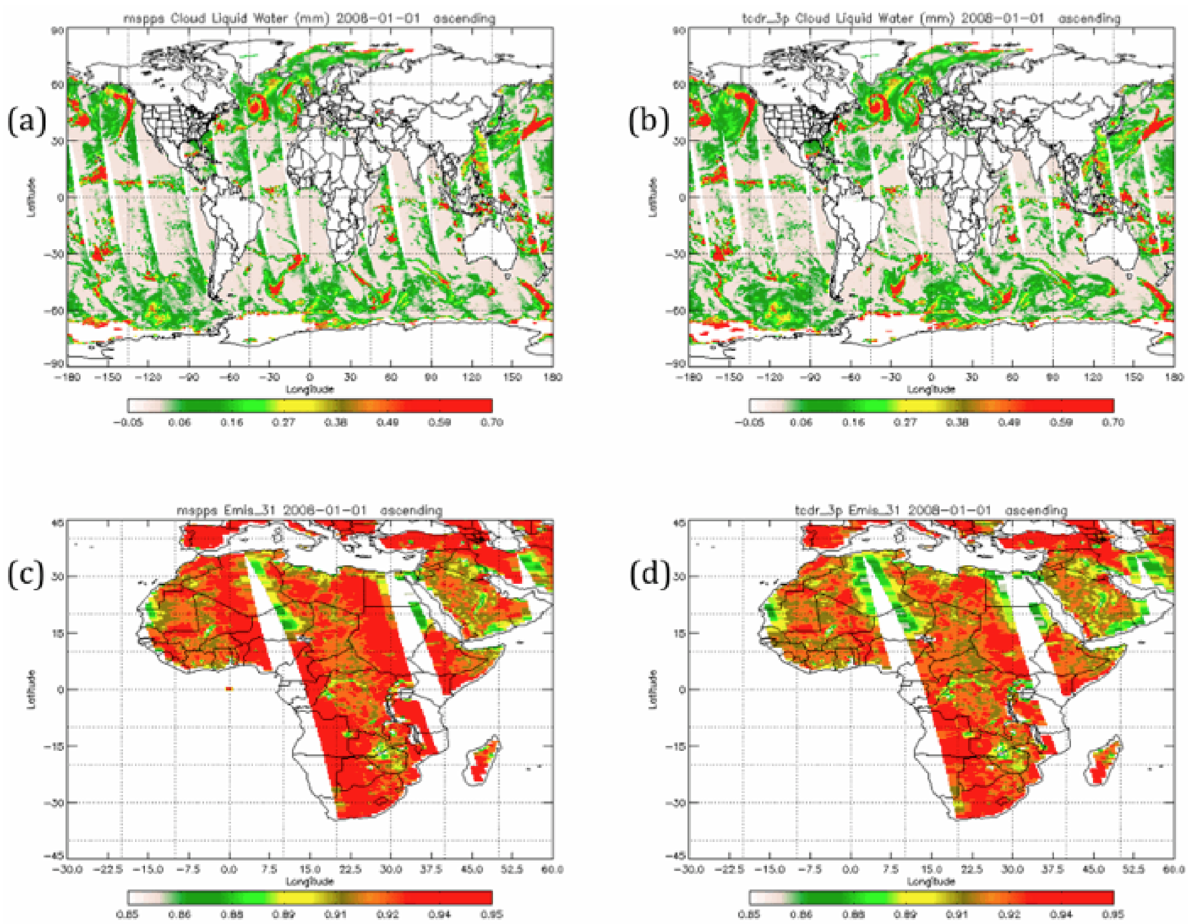


Figure G3: Geographical distribution of cloud liquid water (upper panels) and land surface emissivity at 31.4 GHz (lower panels), derived through MSPPS. Images (a) and (c) are the original products; and (b) and (d) are with asymmetry correction. For clarity, the 31.4 GHz emissivity is shown over the continent of Africa instead of the entire globe.

H. Climate Research, Data Assimilation and Modeling

This Topic Area includes research projects that focus on the integration through data assimilation of information, particularly in the form of satellite-derived data sets and models of the Earth System and its components and the use in research that aims to improve understanding of the physics of the global climate. Examples of ongoing research projects in this Topic Area are below.

1. CICS Support of CPC's Climate Monitoring and Prediction Activities (Augustin Vintzileos)

CICS scientists support various research activities at the Climate Prediction Center (CPC) of NCEP/NWS/NOAA. In this example, we engage with CPC staff in a number of monitoring, forecasting and diagnostic roles involving the Madden-Julian Oscillation (MJO) and its impacts on global and U.S. weather statistics at forecast lead times of Week-1 and Week-2. A major effort to improve the understanding of the MJO and consequently its prediction was the DYNAMO observational campaign during 2011/2012. This campaign proved to be very successful as three major MJO events occurred during its field program. The PI was involved with DYNAMO from its earliest stages as a member of the DYNAMO Science Steering Committee as well as a co-PI of a proposal funded by NOAA to provide operational real-time monitoring and forecast support to DYNAMO. He collaborated with scientists from all observational components of DYNAMO (aircraft, oceanography, radar and radiosondes) to define a set of variables to forecast/monitor for facilitating decision making by scientists in the field as well as aiding updates on the current status of the MJO to the field on a regular basis.

He designed and implemented algorithms that provided a suite of monitoring/forecasting products to the campaign operations with a success rate of more than 99% and participated in weekly conference calls to ensure the success of the program. The tools developed for the DYNAMO campaign are already being generalized and transitioned to benefit operational CPC forecast products. An example of operational monitoring and forecast products is provided in Figure H1 in which the observed weekly mean OLR is compared to its climatological distribution and Figure H2 in which the GFS weekly forecast is compared to the observed climatological distribution. An interface for clearly and succinctly displaying these and other forecast tools is nearing completion.

The PI led the effort for a team at NCEP (CPC, EMC and NCO) to draft and submit a follow-on proposal to make use of the obtained DYNAMO field data during 2011-2012 for future data denial experiments and in which the goal is to better understand the physical mechanisms for MJO onset and decay.

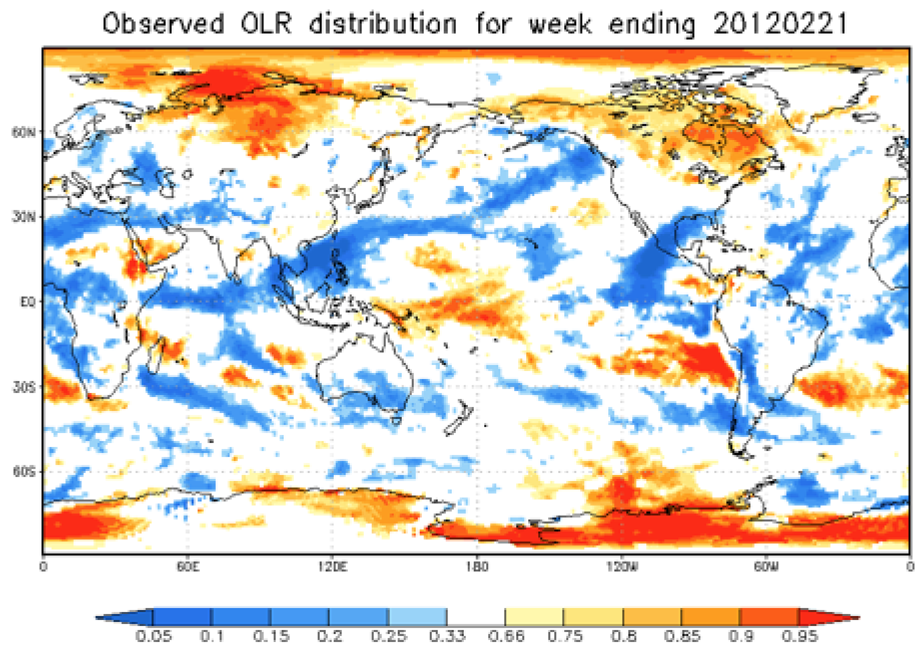


Figure H1: Percentiles of weekly observed OLR for the lowest 33% of the climatological distribution (blue colors) and for the upper 33% (red colors). In this particular example, the combined influence of the ongoing La Nina event and MJO activity are evident and are used as data for quantitative verification for forecast products.

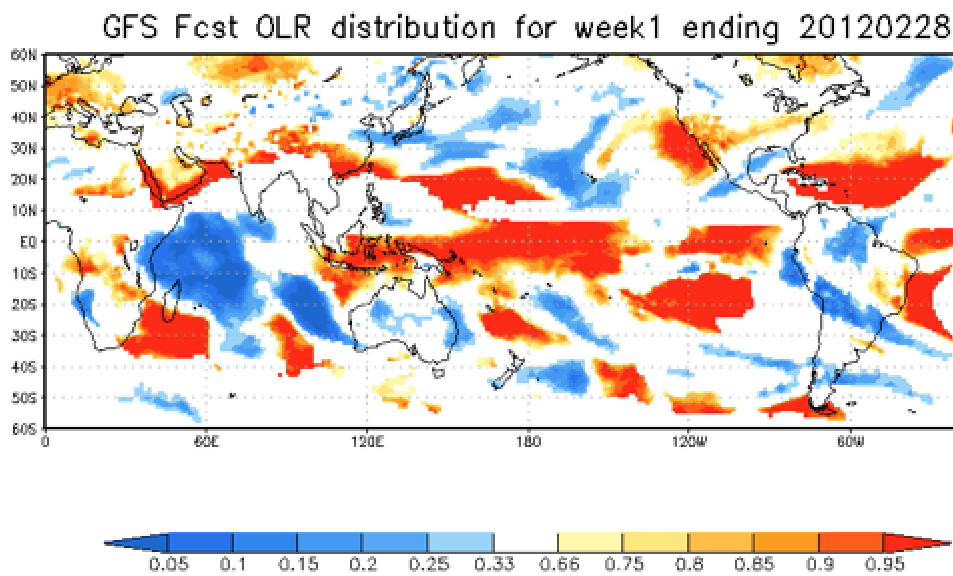


Figure H2: As in Figure H1, except for a weekly forecast from the GFS. In this example, a strong MJO signal dominates the Indian Ocean. At this stage of tool development, no bias correction is yet applied.

2. Exploration of an advanced ocean data assimilation scheme at NCEP (Jim Carton, Eugenia Kalnay and Steve Penny)

This project explores improvements to the 3DVar filter used in the Global Ocean Data Assimilation System (GODAS) by developing a hybrid filter in collaboration with NCEP. For the ensemble component of the hybrid filter, we have joined the University of Maryland's Local Ensemble Transform Kalman Filter (LETKF) with NOAA's Geophysical Fluid Dynamics Laboratory's Modular Ocean Model (MOM4p1) currently used for GODAS. LETKF provides time-dependent estimates of the forecast error covariance and facilitates assimilation of new observational data types.

A series of studies comparing LETKF and SODA indicate significant improvement using LETKF. For example, figure H3 shows the impact of using LETKF relative to a more conventional optimal interpolation data assimilation scheme in analyzing heat storage in the upper 500m. Figure H4 shows the temperature observation minus forecast differences and observation minus analysis differences for several experiments indicating that the error levels are substantially reduced when LETKF is used. The manuscript describing this work has been completed and is under submission (*Penny et al., 2012*).

To construct the 3DVar / LETKF hybrid assimilation, we may explore the approach of *Wang et al.* (2007a,b; 2008a,b) in which the error covariance matrix is determined as a weighted average of the original 3DVar and the flow-dependent error covariance determined by LETKF. Several principles should guide the design of the hybrid filter: it should build on the current 3DVar with minor software extensions; the results must be at least as good as the 3DVar, even before any tuning;

and additional computation time should be significantly less than for a full ensemble Kalman Filter or 4DVar at the equivalent spatial resolution.

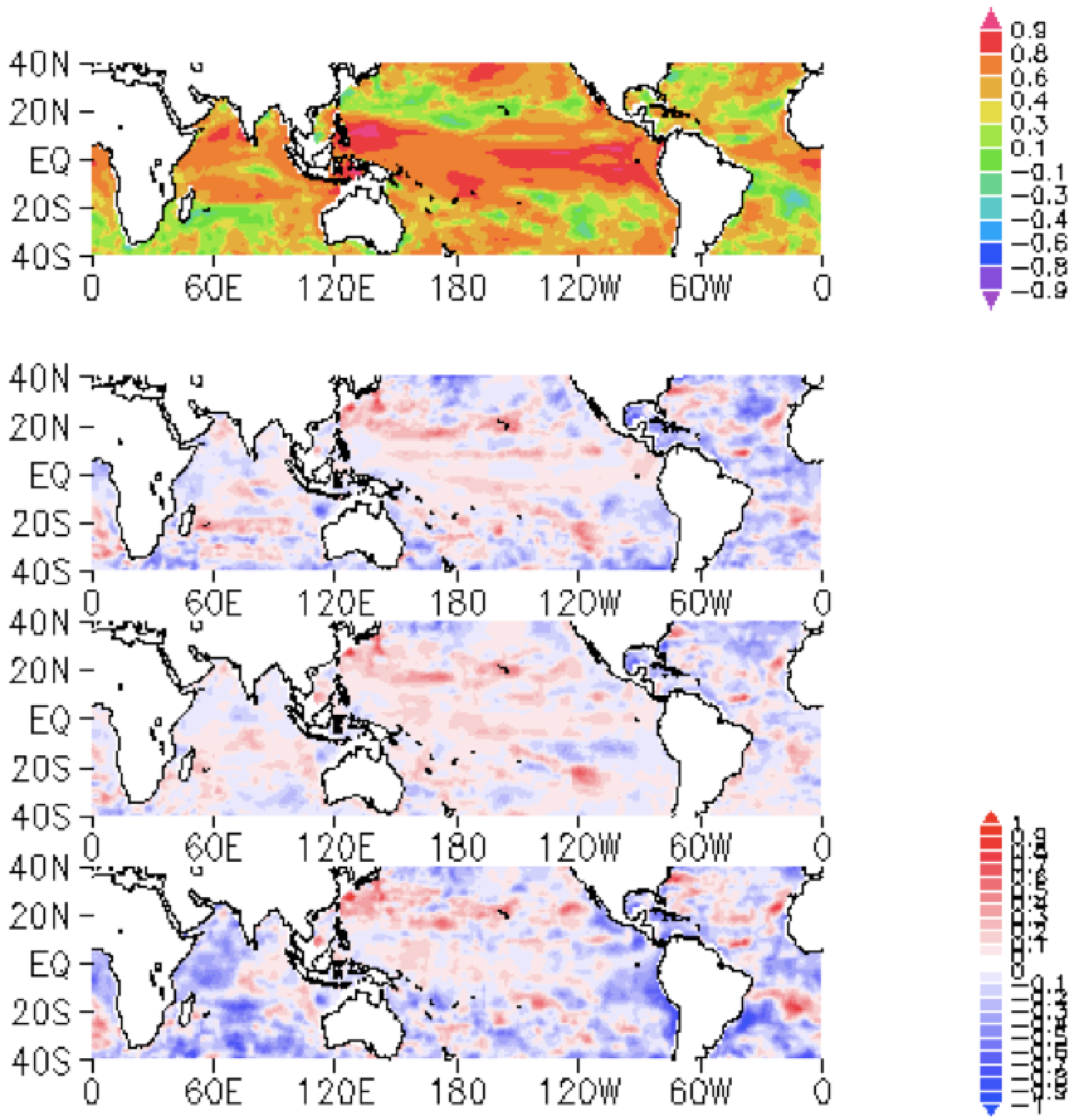


Figure H3: Improvement in correlation between monthly average top 500 m heat content and altimetry sea surface height from 1997-2003 versus nature run (a simulation with no data assimilation) for: SODA (second panel), LETKF-IAU (third panel) and LETKF-RIP (fourth panel). Seasonal cycle is included.

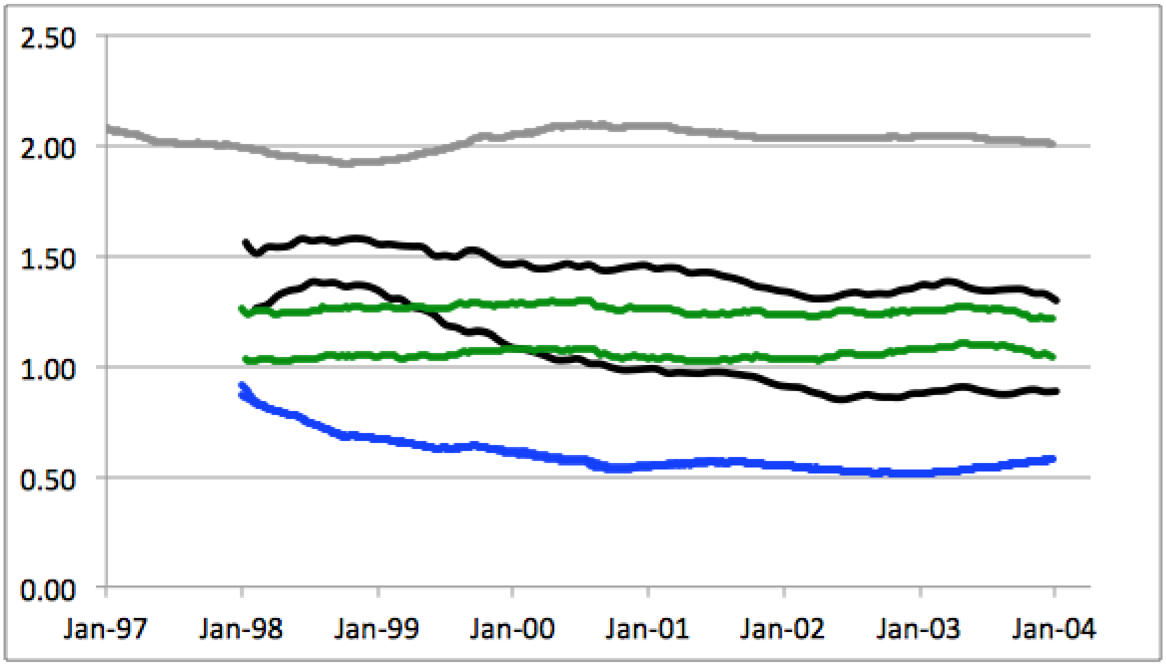


Figure H4: Comparison of RMS observation-minus-forecast and observation-minus analysis differences for global data assimilation experiments using Optimal Interpolation (similar to 3DVar, green) and the Local Ensemble Transform Kalman Filter (black, IAU; blue, running in place) for the seven-year period 1997-2003. Grey line shows results from simulation. Vertical axis is temperature (oC). Here differences are summed over all depths.

I. National Climate Assessments

1. Technical Support Unit (TSU) for the National Climate Assessment (Kenneth Kunkel)
NOAA is participating in the high-level, visible, and legally mandated National Climate Assessment (NCA) process. The NCA is being conducted under the auspices of the Global Change Research Act of 1990, which calls for a report to the President and Congress that evaluates, integrates, and interprets the findings of the federal research program on global change every four years. Currently, a report is being prepared for release by the end of 2013, under the auspices of the US Global Change Research Program (USGCRP). NOAA's National Climatic Data Center (NCDC) and many parts of NOAA have provided leadership on climate assessment activities for over a decade.

To support this broad NOAA effort, CICS has provided most of the staff of a technical support unit (TSU) located at NCDC to provide scientific, graphical, coordination, technical and strategic support for the NCA. The TSU has already provided many critical products and contributions. These contributions included the production of regional climatologies and outlooks for all eight regions of the NCA, authorship of parts of the 2013 draft report, the development of data management strategies and tools, strategic interagency planning, workshop support, Federal Advisory Committee meeting support and web system development, as well as many other contributions.

The following sections describe in more detail the following major activities of the TSU: (2) Scientific Support, (3) Data Management Strategy and Tool Development, and (4) Technical Support for production of the 2013 report.

2. National Climate Assessment Scientific Support Activities (Kenneth Kunkel, Peter Thorne, Laura Stevens, Liqiang Sun, Andrew Buddenberg)
A broad array of science activities have been pursued to support the NCA, and specifically, to provide information for the 2013 report, including (a) development of written technical input on regional analysis of historical climate data, (b) development of written technical input on regional analysis of climate model simulations of the future, (c) authorship of parts of the 2013 draft report, and (d) research on assessment-relevant topics. The outcome of the first two activities was a set of nine large reports which were provided to the 2013 report authors and to federal agencies. These reports comprise over 650 pages, nearly 500 figure panels, and 59 tables. In the development of these reports, many regional experts were engaged and the resulting documents include 32 individual authors. There are meant as a resource not only for 2013 report, but also for federal agencies and others needing information for adaptation and mitigation applications.
Regional Analysis of Historical Climate Trends
An analysis of historical climate variations and trends was completed, focused around eight U.S. regions defined for the 2013 report. This analysis examined trends in mean temperature and precipitation, metrics of extreme temperature and precipitation, freeze-free season length, and variables of more regional interest, such as lake ice in northern regions. For example, a new adjusted temperature data set was used to assess long-term changes for the U.S. This (Figure I1) indicates that the last decade was the warmest on record in all regions of the U.S. It also indicates the last 21 years were warmer than the reference period of 1901-1960 everywhere except for parts of the southeast U.S.

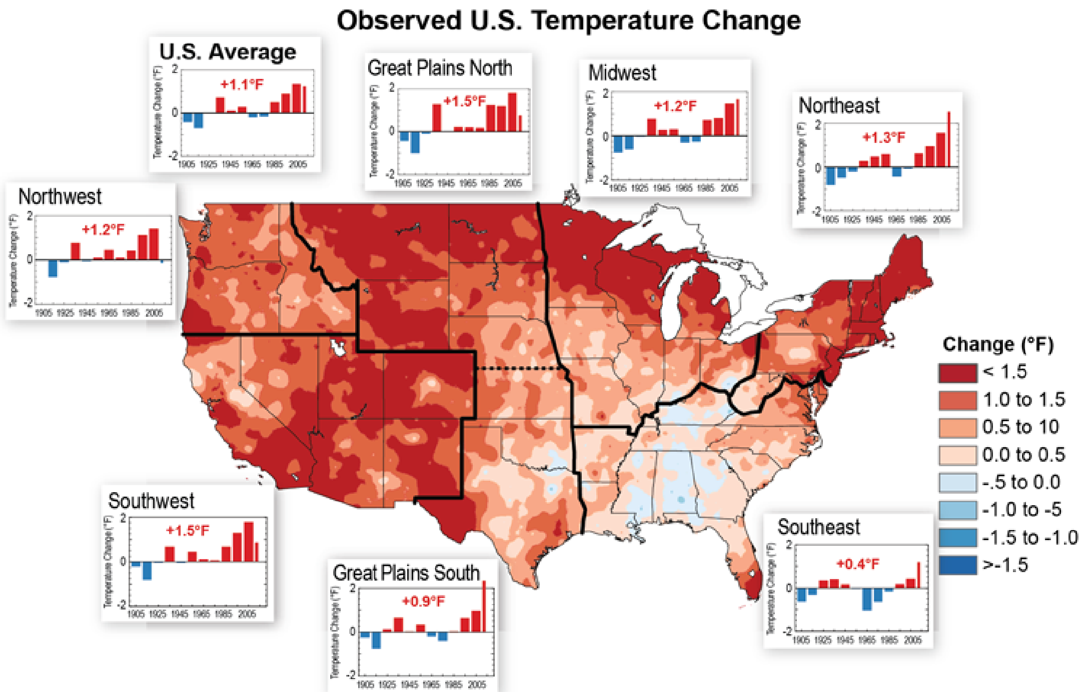


Figure I1: Temperature changes over the past 21 years (°F) (1991-2011) compared to the 1901-1960 average. (Graphs) Average temperature changes by decade (relative to the 1901-1960 average) for each region. The far right bar is for the single year of 2011. The 2001-2010 decade was the warmest on record in every region. The number on each graph is the average temperature increase for 1991-2011 relative to 1901-1960.

Regional Analysis of Climate Model Simulations of Potential Future Scenarios

Climate model simulations of the 21st Century for the A2 and B1 scenarios were analyzed and summarized. The analysis examined the CMIP3 suite of global climate models, statistically downscaled versions of the CMIP3 models, and regional climate model simulations from the North American Regional Climate Change Assessment Project. The results were included in the nine documents described above.

One example analysis is shown in Figure I3, comparing models and observations in the southeast, one of the few areas globally to not exhibit any 20th Century warming (see Fig. I1). The data were processed using 1901-1960 as the reference period to calculate anomalies. During the first half of the 20th century, the observed annual values vary around the model mean because that is the common reference period. These values occasionally fall outside the 5th/95th percentile bounds for the model simulations. During the 1950s, the observed values decline substantially but this does not occur in the model simulations. After about 1960, the observed values are generally within the 5th/95th percentile bounds but on the lower end of the distribution. The rate of observed warming after 1960 is similar to that of the multi-model mean. A few values are below the 5th percentile bound while none are above the 95th percentile bound after 1960.

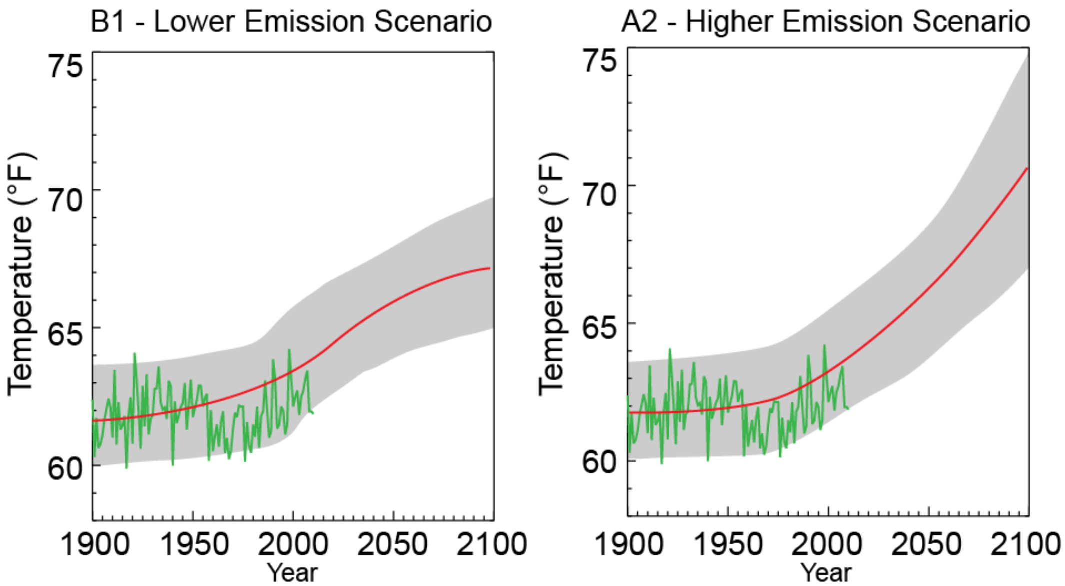


Figure I3: Time series of mean annual temperature for the Southeast region from observations (green) and from all available CMIP3 global climate model simulations (red and shaded). Red represents the mean and the shaded boundaries indicate the 5 and 95% limits of the model simulations. Model mean and percentile limits were calculated for each year separately and then smoothed. Results are shown for the low (B1) emissions scenario (left) and the high (A2) emissions scenario (right). A total of 74 simulations of the 20th century were used. For the 21st century, there were 40 simulations for the high emissions scenario and 32 for the low emissions scenario. For each model simulation, the annual temperature values were first transformed into anomalies by subtracting the simulation's 1901-1960 average from each annual value. Then, the mean bias between model and observations was removed by adding the observed 1901-1960 average to each annual anomaly value from the simulation. For each year, all available model simulations were used to calculate the multi-model mean and the 5th and 95th percentile bounds for that year. Then, the mean and 5th and 95th percentile values were smoothed with a 5-year moving boxcar average.

Authorship of Parts of the 2013 draft NCA Report

Kenneth Kunkel and Peter Thorne were assigned as two of the lead authors on three sections of the 2013 draft NCA report: the Climate Science Chapter, the Climate Science Appendix, and the Commonly Asked Questions Appendix. Dr. Kunkel was also assigned as one of the lead authors of the Agenda for Climate Change Research Chapter. Drafts of all of these sections were completed by early summer of 2012. Revision of these drafts is ongoing.

Trends in Extratropical Cyclone Occurrence (Kenneth Kunkel)

Research relevant to the ongoing national climate assessment was conducted on several topics, mainly related to trends in storms and extreme events. One prominent activity was research on the the nature of changes in extratropical cyclone (ETC) occurrence using a new reanalysis data set that extends back into the late 19th Century. Preliminary results point to some significant shifts in the spatial distribution and frequency of ETCs from the late 19th to the early 21st Century in the Northern Hemisphere. Most importantly, trends in ETC activity computed over more than 100 years are in some cases *opposite* in sign to those computed since 1950. The ratio of the number of high latitude to mid latitude ETCs was higher in the late 19th/early 20th Centuries; on the surface, this implies a shift in the mean track of ETCs to the south during the latter two-thirds of the 20th Century. Indeed, the mid-latitudes of North America and the Atlantic became more active after the 1930s.

3. National Climate Assessment Data Coordination Activities (Ana Pinheiro Privette)

Data Management for the NCA (Ana Pinheiro Privette)
CICS NC is supporting the NCA by providing leadership on the data management aspects of the program, specifically by helping design the data management strategy and help define the data policy and data archiving regulations for the National Climate Assessment.

Tools and Infrastructure to Support the NCA (Ana Pinheiro Privette, Andrew Budenberg)
CICS NC staff are helping the design and implementation of several tools to support the NCA process. Those include several web-based systems and can be divided into three categories:

1. **NCA Collaborative Tools:** These are tools that promote a more effective collaboration process between the different players of the NCA process and include the *NCA Authors Workspace* (completed), *NCA Indicators Workspace* (under development), and the *Report Integration Workspace* (completed)
2. **NCA Information Dissemination Tools:** These include tools that make the NCA related content available to the public such as the *Scenarios Webpage* (under development)
3. **NCA Input Tools:** These include tools that allow for public participation into the NCA process such as the *NCA Technical Input Upload System* (completed) and the *Review and Comment System* (under development).

Support for the Global Change Information System (Ana Pinheiro Privette)
The USGCRP Global Change Information System (GCIS) is an unified web-based source of authoritative, accessible, usable, and timely information about climate and global change for use by scientists, decision makers, and the public. CICS NC is supporting the development of the USGCRP Global Change Information System (GCIS) by helping with the design and implementation of the vision.

4. Technical Support for Production of the 2013 NCA Report
CICS NC is further supporting the production of the 2013 NCA report by providing *S*cience Writing, Editing and Graphic support to the process of creating the 2013 NCA report. This involves help editing all the report chapters and conceptualize, develop, and refine the figures for the report. The CICS NC staff also advises and helps implement the communication and outreach strategy for the assessment and multimedia production for NCA content visualization.

J. National Climate Model Portal

1. NOAA's National Climate Model Portal (NCMP) (Jay Hnilo)
Climate model and observational data is becoming too large to continually transfer. We have developed tools to help scientists perform calculations and off load smaller more meaningful data for direct examination.

The National Operational Model Archive and Distribution System (NOMADS) is a Web-services based project providing both real-time and retrospective format independent access to climate and weather model data. NOMADS was established to specifically address the growing need for this remote access to high volume numerical weather prediction and global climate models and data and to facilitate climate model and observational data inter-comparison issues. The National Climate Model Portal (NCMP) continues to be developed to extend the technologies and capabilities currently operational in NOMADS. NCMP, in close coordination with the NOAA Climate Service Portal (NCSP) will serve as an on-line resource to both improve models for modelers, and to convey key aspects of complex scientific data in a manner accessible to both climate and weather modelers and to non-specialists or other particular user communities. NCMP activities in the coming contract year will include: 1) continuing development of a requirements specification process, functional requirements, and preliminary design document; 2) additional proof of concept model-to observational capability using existing but enhanced tools and applications; 3) a downscaling proof-of-concept capability; 4) a user interface portal and community workspace into NOAA's suite of Climate and Weather Models; and (5) the development of on-line climate model diagnostic tools and resources.

Initial work emphasizes the development of diagnostic tools. In this initial phase we have developed tools that regrid, change time models, extract average annual, seasonal, diurnal cycles from data as well various statistical measures and the extraction of station data equivalents from gridded data. Other capabilities we are developing are the examination of anomalies, measures of extreme events, climate sensitivity, decadal trends and ratios of variances.

We have implemented a set of first look diagnostics that allow one for example to simply run a python script and extract station data equivalents from large gridded data (e.g., CFSR). As our website continues to evolve we will be serving such scripts and showing small plots of the output. These tools can be readily applied to both observational estimates (e.g., re-analyses) as well as model data. From models we have started to calculate derived values and diagnostics from the large IPCC (e.g., AR4) data holdings and will eventually serve these calculated values on the website. We have used these tools to support both the US National Assessment and continuing sectoral engagements at NCDC. We support via generation of plots submitted to the projections tab off the climate dashboard.

Below is an example of the annually averaged global surface temperature for all participant AR4 models.

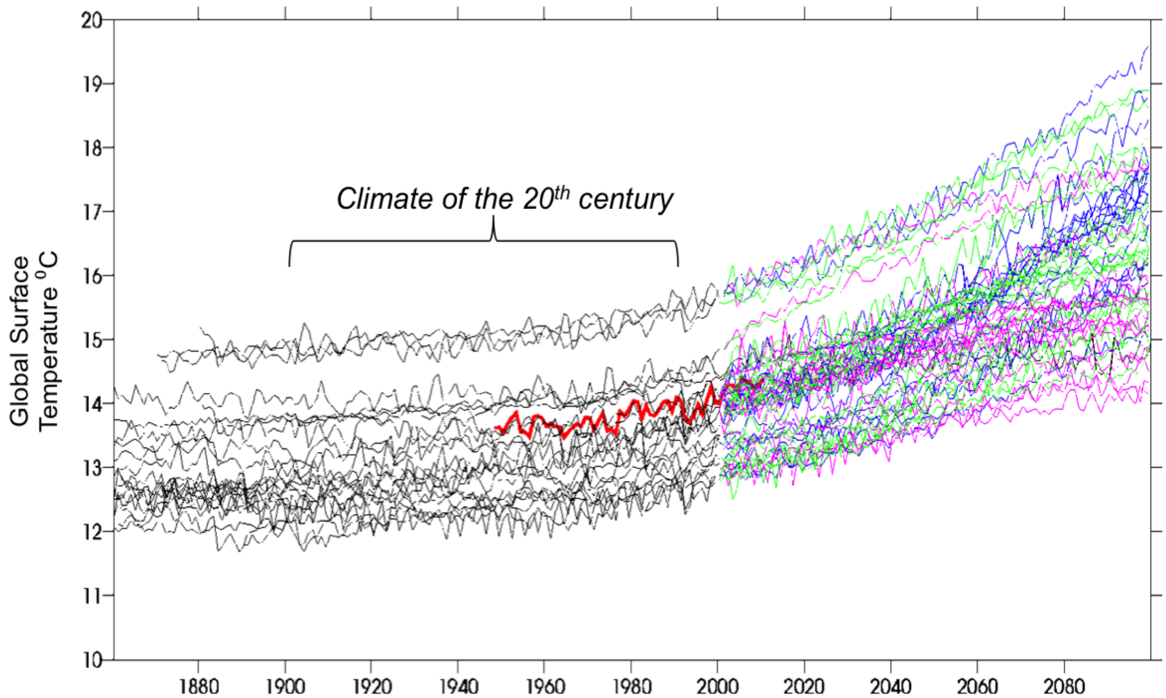


Figure J1: Globally averaged surface temperature (C) for all participant models and scenarios for the IPCC AR4. The climate of the 20th century run is in black, the SRESA2 scenario in blue, The SRESA1B in green and the SRESB1 in purple. An observational estimate the NCEP/NCAR reanalysis is in thicker red.

Out tool development and implementation when complete will allow one to dynamically generate figures and offload processed data files. Shown below Figure 2, is an example of these tools. We show the seasonal values of all participant models who submitted surface temperature for the AR4 models. We regrid all output to the same spatial grid, extract JJA and DJF for each model, average all participant runs for two time periods 1970-2000, for the climate of the 20th century (20c3m), and the period 2050-2059, for the high emission scenario (SRESA2). We show the entire globe differences for SRESA2 – 20c3m, for these two seasons below. The chosen color scale is the same in each showing the preferential warming (by a factor of two) in the projected winter season. Our hope is that these calculations and capability will be of interest to continuing adaptation and mitigation work within NOAA as well as external users.

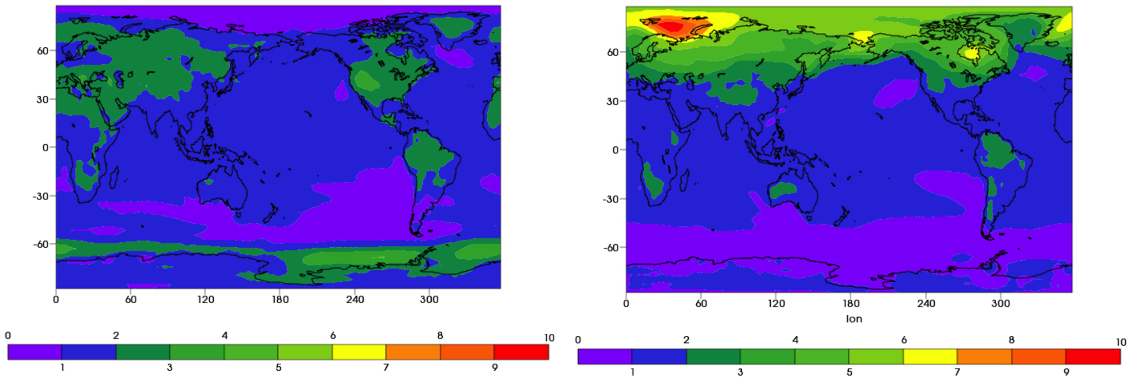


Figure J2: Seasonally Averaged Participant Member Surface Temperature Output Differences for the high emission scenario (SRESA2), and the climate of the 20th century run (20c3m) calculated as (SRESA2 – 203cm) for JJA(left) and DJF(right), in degrees C. Participant members in SRESA2 scenario are 19, and for the 20c3m are 24.

K. Consortium Projects

1. Maps, Marshes and Management: Ecological Effects of Sea Level Rise in NC (Thomas Allen, ECU)

The overall goal of this project is to provide information and practical tools to draw upon prior NOAA-funded ecological research on sea-level rise in NC in order to enhance coastal management and decision-making for ecological restoration, shoreline erosion abatement (e.g., living shoreline site suitability), and planning for sustainability of wetlands undergoing sea-level transgression. Accomplishments in this early phase of the project include organizing a stakeholder advisory group, completing a data and project tool inventory, needs and capability assessment for web map applications, and hosting a workshop for interested partners in the digital online atlas component.

The NOAA Ecological Effects of Sea-Level Rise project funded by NOAA CSCOR Sea-Level Rise Program launched multiple basic and applied science investigations of wetland responses to sea-level rise, sedimentation rate measurement, and landscape simulation modeling. This follow-on synthesizes and expands selected results of this research in conjunction with collaborating managers (Albemarle-Pamlico National Estuary Program/APNEP, NC Division of Coastal Management, and The Nature Conservancy.)

A volunteer advisory committee was established prior to the proposed work and confirmed once the project funding was announced, including Dr. Brian Boutin (*The Nature Conservancy*, NC Coastal Climate Change Adaptation Program), APNEP staff (Director Dr. Bill Crowell, Dean Carpenter, and Bill Hawhee) and Tancred Miller (Policy Analyst, NC DCM.)

A geospatial analyst was hired and has conducted a review of alterative available web map portals and compiled the templates and software installation. Hardware for long-term and high-bandwidth operational use is currently being assessed. New software pending release in summer 2012 will also be evaluated for enhanced functionality.

Initial prototype maps have been installed on a test server with a website (not disclosed to the public while under development; http://www.ecu.edu/renci/coastalatlas/).
The preliminary maps compile shoreline and sea-level rise inundation products from the prior EESLR project and ongoing work at ECU.

A workshop was held on February 13 at ECU to solicit feedback on the plans and broader coastal atlas initiatives that might be pursued. Fourteen representatives attended from outside ECU from cooperating institutions and the advisory committee. A recent outcome of this meeting is the leveraging forthcoming from NC DCM in its NOAA and Governor's South Atlantic Alliance initiatives. In addition, the group identified the ECU Joyner Library as a prospective partner. An initial meeting between library staff and the ECU team has prompted additional meetings and closer involvement so that research and discovery could be enhanced in a coastal atlas project.

In compiling geospatial data content for the atlas, the team has obtained all available NC ocean shorelines, access to estuarine shoreline GIS data under development, seamless LiDAR DEMs, and a map of vulnerable low-lying lands produced in-house. The latter layer has already been shared with our APNEP management partner for evaluation of human and environmental health vulnerabilities, and a presentation and publication are in review.

A presentation on the project was given to the NOAA-in-the-Carolinas annual meeting, held in Charleston, SC, on March 15-16th. The map produced as a baseline for sea-level rise was also accepted for publication in the forthcoming annual *ESRI Map Book* (Figure K1) due out this summer. Future work includes: refining of draft web map portals for shoreline erosion and sea-level rise; development of decision-support tools and interactive capability; and, finally the focus will turn to the higher order analysis of model incorporation via the online GIS (e.g., MEMII or similar spatially enabled marsh response modeling, currently restricted to site-based modeling.

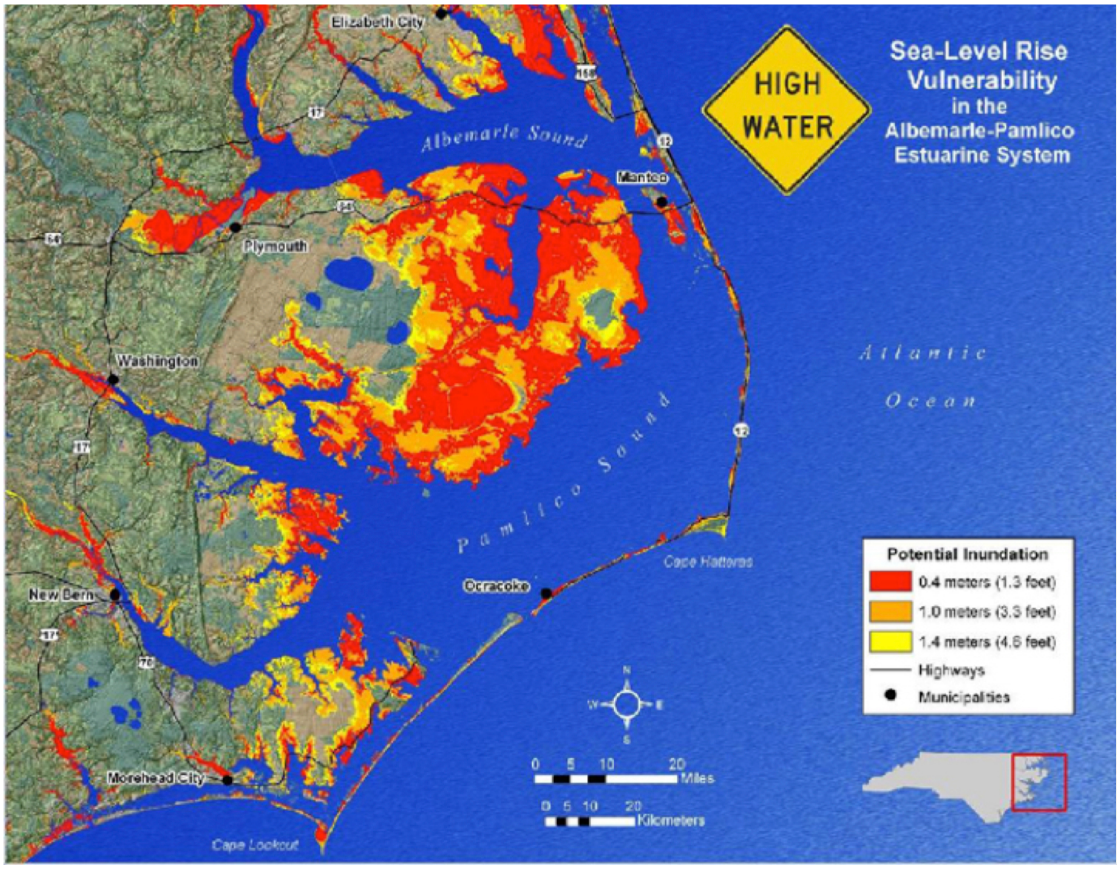


Figure K1: Sea-Level Rise Vulnerability Map to be published in ESRI Annual Map Book (2012).

2. Prototypes of Weather Information Impacts on Emergency Management Decision Processes (Ken Gallupi, RENCI)

This year's objectives focuses on prototyping products and services for improving the communications of weather and climate information to emergency managers application in critical decision-making. The project infuses social sciences with technology into a guidance that can be applied to for understanding customer needs for information. The methods have been applied to various weather events and the utility of current and future products and services.

This work results from collaboration between University of North Carolina at Chapel Hill, Institute for the Environment and the Renaissance Computing Institute, the HQ of the National Weather Service Office of Science and Technology, and East Carolina University Department of Geography. This portion of the report focuses on the East Carolina University (ECU) component, but in the context of the overall goal of the research, which is to understand how to improve NWS weather and climate decision support to the emergency management (EM) community to save lives and protect property. ECU served as the social science lead institution for the project with primary responsibility for developing the means to infuse social science research into NWS operations to 1) to understand the EM decision processes for risk and crisis management, 2) to understand what is effective translation of scientific information into knowledge for decision making, 3) to understand how collaborative technologies can facilitate knowledge exchange and situational understanding, and 4) to demonstrate prototyping methods fusing together social sciences, physical sciences, and technological advances to advance decision support. To accomplish our work, we employed an incremental and iterative research and development process with EM decision-makers guiding the process.

The work of the second year focused on the Risk Paradigm as the linking mechanism between the National Weather Service and emergency management. The paradigm is a process oriented structure so the year's objectives concentrated on infusing social science into operations by 1) prototyping products and services that improve the communication and utility of weather and climate information in EM processes, 2) developing guidance for National Weather Service field personnel to understand EM requirements and to develop improved products and services using the 4-Step Method, and 3) exploring improved approaches to communicating weather and climate knowledge to emergency managers. We applied the 4-Step Methodology developed during year one to understanding NWS-EM processes for a tropical weather event to validate its utility. The method uses social sciences to understand decision making contexts, identify gaps and needs in current practices, explores improvements to product and services through prototyping, and validates findings to make recommendations for operational changes. Documenting the methodology is ongoing and being tested with forecast offices to transfer the method to weather personnel for operational utility, and to explore the methodology application to a range of event types, geographic areas, and customer needs.

To identify critical needs of emergency managers in the risk paradigm to make decisions, a 4-Step method was developed in year 1. The steps include 1) identify the context and timelines of critical decision making, 2) identify current practices of preparing and gathering critical knowledge to make decisions, and identify gaps of needs, 3) prototype approaches and products that improve knowledge transfer between the NWS and EM communities, and 4) validate new products and services in operations. The method was applied in year one to winter weather, and in year two the method was applied to a second use case for tropical weather. In Year 2, we undertook focus groups, surveys of representatives of various Emergency Support Functions, and interviews. After Hurricane Irene, we were able to talk to emergency managers and to carry out surveys of local decision-makers about the products they used. Some of the findings from these efforts include:

- Tropical storm force winds arrival time in a jurisdiction was the most critical parameter needed but does not readily exist in a product.
- Products with least reported use and confidence are Slosh MEOW and MOM and Storm Surge Forecasts
- Issues with communication effectiveness are in need of exploration
  - Network and flow of information
  - Differences in knowledge and needs
  - Differences in definitions (impact, hazard, risk)
- Even within EM Community, one size does not fit all. For example, some prefer text and others graphics.
- Understanding of decisions made and timing of those decisions is critical to developing the most useful products and services (Figure K2)
- Web pages are heavily used so context, timing, and consistency are important

Figure K2: Critical Decision Timeline During Hurricane Irene.

We have also worked with NWS personnel in Montana as they prepared for and held focus groups with school officials regarding winter weather school closings. Documenting the 4-Step methodology for use by Weather Service personnel is on-going. The method is being applied by test WFOs to applications in other regions of the country in Montana and the Midwest. Refinements to the guidance document are being made as needs to clarify the approach are uncovered.

The current phase of the work is to conclude in June 2012. The work will conclude with the following outputs (ECU working in conjunction with the Institute for the Environment):

A documented 4-Step methodology that can be applied by any WFO, region, or national center to better identify and understand the needs of emergency management for weather and climate information in their decision making. The guidance can be developed into a training program by the NWS or allow individual groups to apply as they see fit to improve their operations.

The method is being applied to help evaluate a change in the Impact-Based Warning for tornadoes and severe weather in the Central Region. The project will set up the context for identifying how high-impact information can be produced and used more effectively. Surveys and other methods of collecting baseline and post-event effectiveness information will be developed. This work will serve as a case study for applying the results of this project to other issues of climate and weather information exchange.

3. Spatio-temporal patterns of precipitation and winds in California (Sandra Yuter, NCSU)

The predictability of flooding associated with atmospheric river storms in California is dependent on the repeatability of the spatial pattern of precipitation as a function of environmental characteristics that can be reliably forecast. Initial work indicates considerable variability in the spatial distribution of precipitation frequency among similar atmospheric river storms. One area of consistent frequent rainfall is the Plumas National Forest in the Feather River Basin.

Atmospheric rivers (ARs) are narrow corridors of enhanced water vapor transport within extratropical cyclones. When they arrive in California, ARs contribute significantly to the water supply and flood generation in the State. Although focused research during the last few years has yielded quantitative linkages between ARs and both regional water supply and extreme precipitation events, questions remain regarding the modification and redistribution of water vapor and precipitation in ARs by California's coastal mountains and Sierra Nevada. Previous work indicates that all recent flooding events on the US west coast were associated with an AR but not all ARs yielded flooding. Several factors can potentially turn an AR event into a flooding event. There is limited understanding of the relative roles of atmospheric stability, barrier jets, and small-scale ridges along the windward slope on watershed precipitation totals.

A key missing piece on the role of ARs in flooding events is knowledge of the detailed spatial distribution of precipitation over the windward slopes of the Sierra Nevada for each AR event and for groupings of AR events with similar environmental variables. The proposed work will utilize operational radar data from six National Weather Service WSR-88D radars (KBHX, KBBX, KRGX, KDAX, KMUX and KHNK) to construct a radar echo precipitation climatology of AR events for a 10 year period. A long-term radar echo climatology is needed since existing rain gauges provide only incomplete information on precipitation in this region, particularly over rugged mountainous terrain.

Upper air soundings were analyzed from two California sites to characterize the range of environments of AR events; 439 soundings from KDAK (Oakland, CA; soundings every 12 hours during AR events from Oct 1997 – Apr. 2011) and 68 soundings from KLHM (Lincoln, CA; soundings ~4-6 hours during events from Dec. 2010 – Mar 2011). Typical AR storms, (between the 25th and 75th percentiles) are stable, have cross-barrier wind speeds of 0 to 7 m/s and freezing level heights between 2.5 and 4 km. Higher freezing levels > 4 km are associated with higher stability and higher cross-barrier wind speeds.

A methodology was developed to "stitch" together precipitation frequency maps from the six radars to obtain a regional map. This method was applied to several test case storms. The Plumas National Forest in the Feather River Basin is a location of frequent rainfall during many AR storms, which is consistent with previous work that showed localized wind convergence in this area.

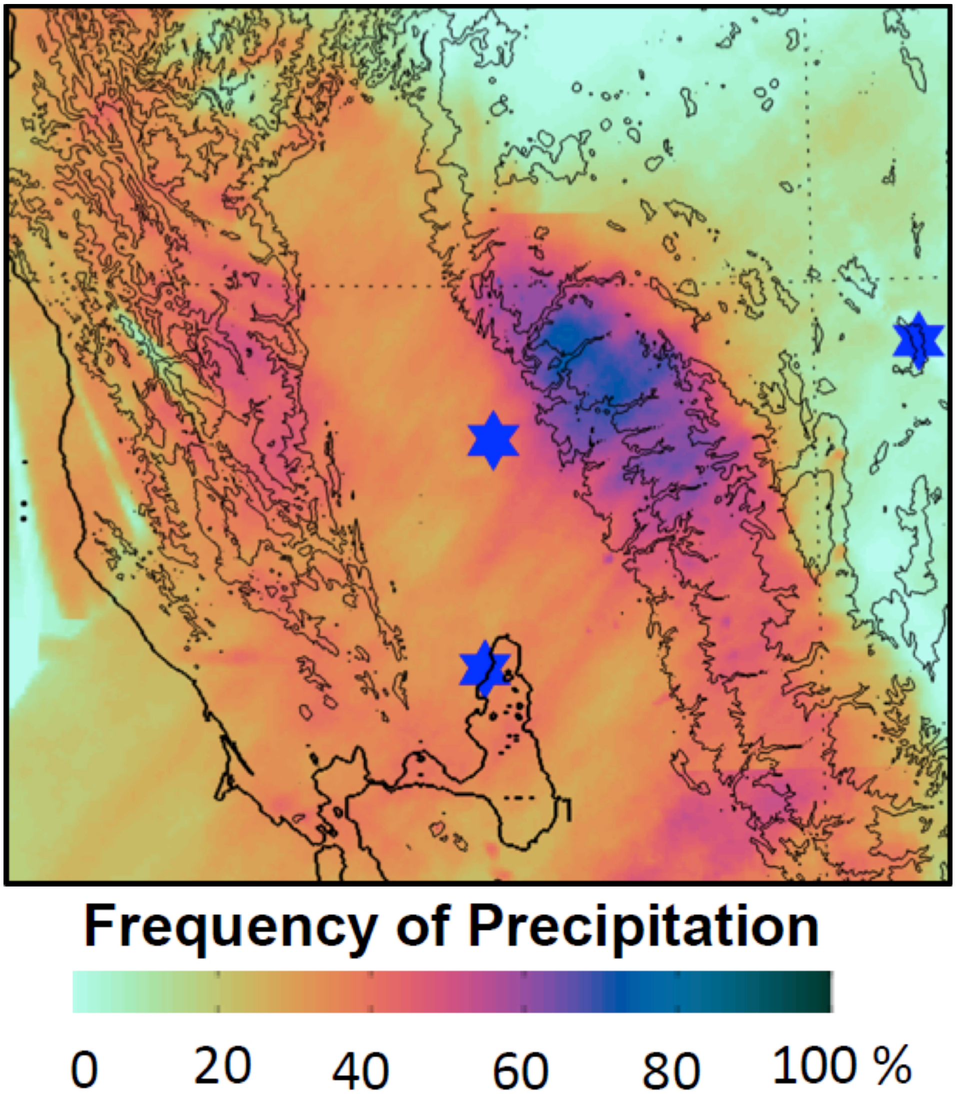


Figure K3: Detail from precipitation frequency map from 8 Feb 2007 AR storm showing region of higher frequency in the Plumas National Forest. Stars indicate locations of National Weather Service WSR-88D radars.

IV. EDUCATION, LITERACY AND OUTREACH

A. Educational Activities and Opportunities

What types of educational activities/opportunities (K-12, undergraduate and graduate students) does the Institute offer on an ongoing basis?

CICS supports NOAA's commitment to the development of a society that is environmentally responsible, climate resilient and adaptive and utilizes effective, science-based problem-solving skills (e.g. STEM based learning) in education. CICS scientists and educators participate in NOAA's climate education programs to advance the development of strong and comprehensive education and outreach activities about climate and oceanic and atmospheric sciences.

Through CICS education, literacy and outreach activities, CICS scientists involve students in climate science and enable students and teachers to explore and understand large volumes of climate data that NOAA collects about the Earth. Working collaboratively with other academic and public partners, stakeholders, private sector, CICS supports and engages in various educational and outreach-related activities to advance the following areas:

- Increase awareness of climate science and changes in the climate system
- Grow the understanding of how climate data is collected, observed, analyzed, and used in research purposes
- Increase awareness of climate datasets and products and how educational teachers/ professors can make use of climate data products for teaching climate science
- Demonstrate capacity building across public, private and academic arenas on the various impacts of climate change
- Increase the connection to private sector understanding and use of climate data and information for their strategic and operational use

Education, literacy and outreach are all important elements of the CICS mission. CICS engages in the improvement of both formal and informal education approaches to these areas of foci, as both of these approaches are important to the development of climate-literate citizens and a climate-adaptive society. These activities are broadly grouped within K-12 Education, Undergraduate Education, Graduate and Postdoctoral Education, Opportunities in Education Outreach and Private Sector Engagement. Below are key highlights of the various activities CICS has engaged in over the past three years.

K-12 Education

CICS reaches out through various activities to K-12 students to help advance climate science, literacy and education particularly focusing in on STEM skillsets. Over the past years, CICS scientists have given presentations, led lectures, taught courses, developed curricula, lent equipment, and mentored high-school students.

CICS scientists' activities include mentoring at local elementary schools, serving either as guest or regular scientists to discuss weather and oceanography lessons, and using the Magic Planet (animated globe for environmental data display) spherical display. One scientist (Stephanie

Scholaert-Uz of CICS-MD) supported building and maintaining the McKinley Elementary School rain garden, where she conducts semi-annual outdoor lessons with K-5 students. At least one senior high school student did a summer internship at the institute.

CICS partners with NOAA's NCDC and the NC State University Science House to provide K-12 educational outreach for climate and Earth system science. The Science House serves over 5,000 teachers and over 36,000 students annually from six offices spread across the state of North Carolina. The Science House leads teacher professional development sessions that focus on understanding the Earth system, the changing nature of the climate and its impacts, resource management and sustainability. The Science House supports students and teachers by providing climate materials, teaching techniques, and sharing cutting edge research from climate scientists. Laboratory equipment is loaned out to participating teachers at no cost. Students can use this equipment to collect local data, which can then be compared with various data from the National Climatic Data Center.

The Science House has engaged in two educational activities in partnerships with CICS-NC and NCDC. The first one is targeted to developing educational materials to enhance the exhibit *"Highlighting 150 Years of Weather Observations in Asheville"* at Asheville's Colburn Earth Science Museum. The other activity involves the development of an educational curriculum using NCDC's climate data, where specific climate dataset will be used for teaching exercises for teachers across the U.S. Through this educational engagement, CICS also hopes to increase their understanding of teachers' needs for climate information so they make effectively teaching climate science to their students.

CICS-NC Director of Literacy and Outreach, Jenny Dissen, and postdoctoral researcher, Carl Schreck, reviewed and supported the publication of "Monitoring the Climate System with Satellites," a 2-hour module, jointly funded by NOAA/NESDIS and EUMETSAT, that describes the unique role that environmental satellites play in monitoring the Essential Climate Variables (ECVs) that are key for measuring the climate system. Module was distributed to over 50,000 K-12 teachers.

Each summer since 2009 CREST organizes a Weather Camp (partially funded by CICS) where about 8-10 high school students spend one week on the campus of CCNY and 1 week at the NWS office on Long Island learning about weather concepts, operations and future college and job careers in STEM fields.

Undergraduate Education

The two main branches of CICS in Maryland and North Carolina support undergraduate education through mentoring, advising, and teaching students.

CICS-NC supports undergraduate student research activities and student internships. Currently, an undergraduate research project in the Applied Mathematics program is being overseen. CICS-NC has also undergraduate student internship programs where two UNC Asheville students have been engaged in supporting CICS staff over the past 2011-2012 year.

CICS-MD is closely linked to the University of Maryland's Departments of Geographical Sciences (GEOG), and Atmospheric and Oceanic Science (AOSC), where many CICS scientists are either members or affiliated researchers. Both Departments offer undergraduate degrees, and AOSC also offers a Professional Masters degree. The Department of Physics also offers a BS degree with a concentration in Atmospheric Sciences. CICS personnel are involved in teaching courses like Geography 415 (Land Use, Climate Change, and Sustainability) and AOSC 432, undergraduate atmospheric dynamics course and AMSC 460, undergraduate scientific computation course. For the last two summers, CICS has hosted an undergraduate student in Maryland to train her in scientific methods applied to climate studies. Given the growing interest in students as well as scientists, the intent is to expand this activity.

Other CICS researchers are engaged in teaching courses and classes at other universities. For example, James Reagan has helped create an alumni mentorship program at Cornell University for Atmospheric Science undergraduates, while Cezar Kongoli has mentored one undergraduate student at American University during her admission and one-year study abroad academic program at Oxford University, UK. He is currently mentoring one undergraduate student from American University on her graduate degree program in environmental management at Oxford University, UK.

CREST carries out a Summer Outreach program where more than 20 HS students are involved each summer for 8-weeks (leveraged through CREST) to work on various research projects. Some of the research results are then incorporated in the material for UG junior level class “Remote Sensing and Satellite Imagery”. UG of the senior level are involved in the senior design class developing instrumentation related to the coastal platform.

CREST personnel incorporated Radiative Transfer Examples into Graduate / Undergraduate Courses including Optical remote Sensing, Earth Surveillance and the Undergraduate Introduction to remote Sensing, and components of Graphyte were prototyped as projects in an undergraduate web-development class, other components of the web service were prototyped in a graduate Web-Service class.

Special summer courses are being taught at CREST by CICS tasks leaders on topics such as Geographical Information System and MatLab for students from Summer REU and Education Outreach Programs for High School and Senior Students. Four undergraduate students from the CE department learned how to download, read, and process GOES IR, CALIPSO, and CloudSat data for using in GOES-R project, in summers of 2011 and 2012. Educating one REU undergraduate and one high school student to learn how to acquire, read, and process satellite (GOES & MODIS) data, understand some of the cloud physical properties.

Graduate and Postdoctoral Education

As part of enhancing and supporting graduate students and postdoctoral students, CICS engages in several activities that span from support of postdoctoral fellows in innovative research, mentoring of graduate students and early career staff, support through fellowships, and advancing research effort through delivering seminars and presentations.

CICS scientists offer early career mentoring of students and participate in advisory panels. CICS has an extensive mentoring program for graduate students where they participate in review of students’ research, provide supervisory and mentorship support and aid in early career development areas. CICS supports postdoctoral fellows working in Maryland and North Carolina, and through selected support enables postdoctoral fellows to travel and present at a variety of state and national conferences, e.g., the American Geophysical Union Annual Meeting, the American Meteorological Society Annual Meeting and the Climate Diagnostics and Prediction Workshop that is part of CPC activities.

In addition, CICS-NC Director of Literacy and Outreach, Jenny Dissen, supported NCDC's scientist and meteorologist Marjorie McGuirk to collaborate with UNC Asheville's Masters in Liberal Arts Program Climate Change and Society to modify their current professional certification program and build a robust curriculum in partnership with NC State University.

CICS also engaged in interdisciplinary activities for education and outreach support. For example, Ms. Dissen served on a panel on energy, environment and climate at Harvard University for their Science Policy Careers Symposium, held on May 2, 2012 to provide support and share career experience to postdoctoral students in a career in science policy. Cezar Kongoli (CICS-MD) has supervised two students at the Department of Environmental Studies of American University (Washington DC) in the areas of remote sensing of coastal wetlands and statistical modeling and analysis of marine ecosystem health.

Many CICS scientists support and advice PhD students in different programs at the Universities in Maryland and North Carolina. In Maryland, there are about 20 graduate students involved in CICS research while in North Carolina about 5 graduate students working in CICS themes.

CICS scientists often provide lectures, deliver seminars, and give numerous presentations on their research areas. Since 2009, CICS researchers have published more than 300 peer-reviewed papers and given hundreds of presentations across a large number of conferences/meetings/workshops on the topics of climate research and applications, satellite and observation monitoring, and climate modeling. Staff members also serve on proposal review boards, and have conducted many reviews of papers for journals. For a full list of seminars and scientific visitors, please refer to the Appendix H; for a full list of presentations and invited talks, please refer to Appendix I.

CICS scientists participate in the annual CoRP Symposium, and CICS helps to support CUNY/CREST graduate students participation as well. CICS also facilitates summer visits by CUNY/CREST students to NESDIS Cooperative Institutes to obtain hands-on experience on useful software and techniques relevant to their research projects. This summer exchange program has led to increased visibility and employment opportunities for students and early career scientists and provides excellent candidates for open positions in NOAA and the CI's.

Opportunities in Education Outreach

Several future opportunities exist to grow education outreach across the K-12, undergraduate and graduate audience. CICS-MD strives to extend the involvement in the AOSC undergraduate program to allow for summer internship opportunities as well as serve in an advisory role to select early career staff or graduate students. In the near future, they plan to develop a similar activity with GEOG.

CICS collectively plans to expand K-12 outreach through both in-state programs and with other non-profit organizations to provide mentoring to high school students for careers in physics, climate science, satellite information, earth science, climate science communications, etc. CICS-NC plans to partner with the North Carolina School of Science and Mathematics to support special projects week to their junior and senior students in these topics.

At the graduate level, CICS aspires to establish a NOAA-oriented graduate student fellowship program similar to the collaboration between ESSIC and NASA/Goddard. Beginning in 2002, GSFC funded the first year of a graduate assistantship in Earth Science in one of the Departments of Atmospheric and Oceanic Science, Geology, and Geography, and a second assistantship on computational Earth Science. After the first year, the student's assistantship cost was split 50-50 between the University Major Professor and a GSFC scientist serving as thesis co-advisor.

B. Current and Planned Literacy and Outreach Efforts

What are the current and planned literacy and outreach efforts?

There is a need to advance climate science and climate change literacy for decision makers as they explore practical and cost-effective approaches to leverage available resources. Provision of climate data for applications and decision capabilities, which can factor into strategic, planning and operational decisions, requires partnerships across public, private and academic organization. CICS engages in several meaningful climate literacy and outreach activities to private sector as well as the general public. These activities are often in conjunction with CICS partners who have particular areas of expertise. Key highlights of accomplishments in literacy and outreach are framed under these areas:

- Advancing climate literacy for private sector partnerships through interdisciplinary activities, including outreach to energy industry, insurance industry, plant sector, and executive roundtable sessions
- Outreach to the TV meteorologists and other media interested in climate information
- Providing operational support to activities in NOAA organizations like NCDC in advancing their outreach with the Sectoral Engagement Team, communication with the Communications Officer and literacy with the Education Lead
- Outreach and literacy activities to the general public
- Developing communication and informational materials on the CICS activities and progress to share with CICS partners and to inform the general public

Climate literacy activities require developing frameworks, delivering presentations, engaging in relationship building and capacity- building activities, enabling catalytic support of innovation in uses of climate data, engaging in individual and executive-level roundtable discussions, as well as providing ongoing operational support to NOAA organizations like NCDC, NODC and CPC.

Outreach and Engagement with Private Sector through Interdisciplinary Activities

As part of the AMS's 1st Conference on Climate Adaptation, CICS-NC developed and executed a special forum and seminar activity called "Value Added Opportunities," where leaders of NOAA, including Dr. Kathryn Sullivan, NCDC Director Tom Karl, and CICS-NC showcased examples of scientific data simulations and visualizations to highlight collaborative efforts of artists, scientists and educators working together for value added opportunities of climate data.

CICS-NC Director, Otis Brown, and Jenny Dissen presented at NC State's Forum on Entrepreneurial Opportunities Associated with Climate Change Informatics, as part of their Office of Research, Innovation and Economic Development. Designed to create a structured and informal discussion about the intersection between Climate Change and the need for new types of businesses built around informatics, this engagement has lead the creation of a new venture start-up called *Global Climate Analytics* where NC State professors/entrepreneurs have teamed with venture capitalists and NC State's ORIED to create a tool and service to make global climate data and analytical tools about global climate data readily accessible to consumer and business users, through a consumer cloud-based search engine. Activities are in development stages.

In collaboration and partnership with NCDC's Climate Services and Monitoring Branch, Jenny Dissen has lead the development of an ongoing framework and approach for advancing the climate data applications through a new activity called Dataset Discovery Day. This two-day workshop allows NCDC to discuss their data products and CICS-NC to discuss application opportunities in various sectors. Information on Dataset Discovery Day can be found on the CICS-NC website: http://cicsnc.org/events/ddd/

CICS-NC has established a relationship with *Duke Energy* to understand the impacts of changing climate normals on their energy load forecast. This spurred a research activity in developing profiles of optimal climate normals for each climate division in North Carolina, which has enabled further dialogue with the company on impacts to their operational activities. The engagement with *Duke Energy* has also led to the development of an workshop on Alternative Climate Normals that took place April 24-25, 2012 , where regulatory agencies, science community and business leaders discussed the impacts of changing normals on business and opportunities in potentially enabling change in current regulations to allow flexibility for businesses to apply alternative normals. Information on this workshop can be found at this website: http://cicsnc.org/meetings/cnws/

Through collaboration with Institute for Global Environmental Strategies (IGES) President, Nancy Colleton, CICS-NC has participated in stakeholder engagement activities to better understand climate information needs. This research a) examined mechanisms and models for private sector engagement; b) assessed various business and economic strategic forecasting needs; and c) further examined the specific climate information needs and potential economic impacts of climate change on plant-based businesses.

Through the Climate Information Responding to User Needs (CIRUN) the University of Maryland is working with partners to mobilize a national effort to build the capacity to predict changes in advance on time scales of seasons to decades, and to convert these predictions into information that government and industry can use to plan and adapt. CIRUN was created with the vision of developing and piloting effective ways to provide actionable information about environmental change to the user community. Central to the agenda is the building of links between climate scientists, other disciplines, companies which deliver specialized information, and decision makers in the private and public sectors. CIRUN focuses on doing so through the following activities: (a) pilot projects to deliver actionable information; (b) a program of workshops; (c) a public lecture series; (d) support for interdisciplinary proposals to federal agencies; (e) an active web site; and (f) development of a database of potential collaborators in all the components of the information supply chain.

CIRUN examples:

- Lost in Translation: Linking Climate Science to Local Communities in Maryland and the Chesapeake Bay: On April 23, 2112, CIRUN helped co-sponsor an all-day workshop at UMUC (University of Maryland University College, College Park campus). The workshop was organized by the Maryland SeaGrant Program and by the Center for Watershed Protection.
- April 25/26, 2012 , Antonio Busalacchi and Steve Halperin participated in an Executive Roundtable in Asheville, NC, on climate private sector engagement and strategic forecasting.
- Chesapeake Bay Workshop: Integrating Climate and Environmental Information with Disease Surveillance to Address Pathogens and Algal Toxins of Concern to Public Health, a CIRUN workshop, jointly sponsored by the NOAA Oceans and Human Health Initiative (OHHI) and the NOAA Climate Program Office, was held at ESSIC on February 21/22, 2012. Scientists from the ocean climate community, and public health officials from State Departments of Health and Departments of Natural Resources in Delaware, Maryland, Virginia and Washington met for two days to discuss methods of providing reliable and actionable

monitoring data, forecasts and models for climate and naturally occurring aquatic biological hazards to public health officials, with a focus on dangerous vibrio and harmful alga blooms (HABs) in the Chesapeake Bay.

Outreach to TV Meteorologists

Through a collaborative partnership project with *Climate Central,* a CICS consortium member, CICS-NC has worked with Heidi Cullen in a grant program that established the routine relevancy of climate science information and provide the climate context to extreme weather events. Climate Central seeks to raise climate literacy by showcasing the findings of the upcoming National Assessment report.

In the past year, *Climate Central* focused on extreme weather, adaptation strategies, and media training for select NCDC scientists. *Climate Central* highlighted how NCDC data and tools can be used to better understand and manage climate and weather-related risks on seasonal to decadal and longer timescales through two video series. They have delivered 5-part series of roughly 2 minute video segments called Extreme Weather 101 which featured NCDC scientists and local TV meteorologists on the topics of drought, extreme heat, snowstorms, tornadoes and climate and precipitation and floods. In addition, they produced a 2-minute video segment called *Tell Me Why*

Outreach to the General Public

CICS reaches out to the general public and to communities of interest in a variety of ways. The University of Maryland sponsors an annual event called Maryland Day (http://www.marylandday.umd.edu/), during which activities such as CICS are offered the opportunity to reach a large audience, of order 70,000 visitors, in a campus-wide open house. For the last several years, CICS has had a strong presence in the ESSIC exhibit at Maryland Day. Most of the personnel in CICS support Maryland Day activities and CICS gets to "show off" many of its talented researchers, as well as promote the NOAA mission to the general public.

CICS-MD has been using a visualization technique called The Magic Planet" to reach out to the public. The Magic Planet displays datasets of weather and climate moving across its surface. The images displayed are used to educate visitors of all ages, school groups or other expert audiences about earth systems and how they relate to the environment. CICS makes presentations at Maryland Day, the Maryland Science Center in Baltimore, and the National Zoo. Furthermore, a supplemental target was to promote the use of *Earthnow,* a web-based blog operated by the same research institutes, among docents (staff and volunteers) that carry out presentations at SOS sites in museums and science centers across the country (and around the globe).

To fulfill this task, training sessions were held bi-weekly at the Maryland Science Center (MSC) in Baltimore, Maryland. The project identified supplemental methods to promote the public's learning, interest and focus on earth science, short-term weather and long-term climate change; such methods included (a) podcasting some of the *Earthnow* content and including it in automatic SOS playlists, (b) promoting the use of local stories and topical events in SOS presentations and *Earthnow* posts (by using local sources, working closely with museum staff and data providers and developers) and (c) creating future docent training material based on feedback received by an online survey of docents, as well as on the systematic observation of the public's engagement and perception (opinion) of the SOS live presentations.

CICS recently supported the launch of *CycloneCenter.org*, a joint activity with NCDC, UNC Asheville and Zooniverse, that enables the public to help analyze the intensities of past tropical cyclones around the globe. General public is able to log in and answer questions about that image as part of a simplified technique for estimating the maximum surface wind speed of tropical cyclones. This example of public collaboration will perform a large number of classifications in just a few months—something it would take a team of scientists more than a decade to accomplish. The end product will be a new global tropical cyclone dataset that provides 3-hourly tropical cyclone intensity estimates, confidence intervals, and a wealth of other metadata that could not be realistically obtained in any other fashion.

CICS also supported the successful world-premiere launch of the video game *Fate of the World* and the corresponding film *Gaming the Future*, which demonstrates global strategy games as an effective educational and scenario-building tool to discuss impacts of climate change. The film can be viewed here: http://www.cicsnc.org/people/jenny-dissen/progress-update/

As part of AMS 1st conference on Climate Adaptation, CICS-NC supported the display of art called *Pillars of Climate* (Steve McIntyre, June 30, 2011) to advance interdisciplinary connections between climate science and communications. Created through an art competition at the University of North Carolina Asheville (UNCA) through the Climate Change and Society course of study within the Master of Liberal Arts program at the University of North Carolina Asheville, two young artists created “Pillars of Climate” as an installation that investigates the issues of perception and dissemination of data in climate change. The art display is one example of blending science, communication, and outreach, highlighting the shift towards making science data visible, accessible and meaningful.

Communication and Informational Updates on CICS

CICS-MD and CICS-NC both distribute their *Circulars*, a semiannual publication that reports on CICS-MD / CICS-NC vision and mission, its research themes and brief description of select research progress being done at the institute. These circulars are shared with the respective university partners across the various offices to keep the department heads and professors updated on the research progress. They are also shared with participants at CICS organized workshops or science meetings.

CICS web sites continue to be developed to enhance CICS outreach to all interested sectors. CICS has a dedicated web page that serves as a focused presentation of CICS-specific research projects and results. An independent website, climateandsatellites.org, intended to provide a comprehensive description of the CICS Consortium has been established and is in the process of being enhanced. This site provides the background, mission and vision statements for CICS, as well as links to Consortium participants.

Both CICS-MD and CICS-NC maintain dedicated sites for their own activities that also include cross-links with others CICS sites using a consistent “look and feel. CICS-MD considers its current site obsolete and is in the process of redesigning it. The final version is expected to be in place in the coming months. CICS-NC website is active and updated to reflect progress and news/events.

CICS website: http://climateandsatellites.org
CICS-MD website: www.essic.umd.edu/cics-md/
CICS-NC website: www.cicsnc.org

In addition, CICS contributes news items to the ESSIC and AOSC web pages and blogs, where significant research accomplishments are described, and to the ESSIC Newsletter, an occasional publication describing the accomplishments of our scientists.

A new blog was launched on the ESSIC website titled “It’s Severe – Unique Perspectives on Extreme Weather”. This outreach effort aims to introduce the public to the unique methods and datasets that CICS/ESSIC scientists use to examine extreme weather events (thunderstorms, fires, floods, blizzards, etc.). The blog also serves as a seed for NESDIS, CICS, and ESSIC scientists to begin exploring new multi-sensor, multi-platform applications.

The College of Computer, Mathematical and Physical Sciences (CMPS), of which CICS is a part, issues a quarterly newsletter to a wide audience, and CICS, when appropriate, contributes items describing notable accomplishments and events.

Additional outreach through communication occurs through seminar participation. CICS scientists participate in the AOSC, ESSIC, and NCSU MEAS seminar series, as well as give seminars and presentations at other institutions. Appendix H contains a sampling of CICS Researchers’ invited talks and their participation in giving seminars.

C. Engagement with NOAA

How are research results from the Institute shared with NOAA as well as the broader scientific community?

Sharing Research Results

Research results from CICS are disseminated in a number of ways. During the initial stages of work, CICS scientists engage in frequent conversations with their NOAA colleagues with similar interests. In some cases, the NOAA scientists are directly involved in conducting or overseeing the work, but even for tasks in which they are less directly involved, collegial discussion is the norm. The co-location of SCSB scientists at CICS, as well as the co-location of some CICS scientists at STAR/NESDIS and NOAA/NCDC greatly facilitates this exceedingly valuable interaction. These conversations are not limited to CICS and STAR/NCDC scientists, of course, which improve their ability to inform and engage the broad research community.

CICS has and continues to provide formal and informal operational support to review of NCDC’s activities in Communications, including items related to NCDC’s operational and strategic plan activities, review of Communications Strategy, and review of various outreach information displayed on the climate.gov website. CICS supports NCDC’s Divisions through collaborating on NCDC work plans and approaches to identify users and applications of satellite climate data records and in supporting milestone celebrations such the SUOMI-NPP Launch, which is one of the first intersections of the in-situ and satellite-based observing platforms.

CICS-NC is supporting NCDC in building a center-wide engagement and outreach strategy and collaborates in research findings such as determining NCDC’s volume of requests for information and NCDC’s customer profile. The analysis is now part of the NCDC Overview and Briefing Discussion, and demonstrates that businesses, consultants and legal industry are the largest customer group of NCDC’s data.

CICS scientists frequently participate in the organization of scientific workshops on topics of high interest and relevance to NOAA. CICS also relies on traditional formal and semi-formal scientific vehicles for communicating interim and final results. These include seminars, informal publications, reports, formal publications and workshops. Please refer to the appendices for more information on workshops organized by CICS.

The annual CICS Council meeting provides a means where research results are shared with NOAA line organizations. The Council meetings also serve to identify and promote new activities in which CICS can better interact with NOAA.

The NESDIS Cooperative Institute Directors' meetings provide an opportunity to communicate research results not only with NOAA, but also colleagues at the other Cooperative Institutes.

Synchronizing CICS and NOAA Research Interests

How are NOAA's research interests conveyed to the Cooperative Institute?

NOAA conveys its research interests to CICS in numerous ways. At the highest, most strategic level, the NOAA Strategic Plan provides the essential context that identifies NOAA's goals and desired outcomes, and the Annual Guidance Memorandum specifies the most urgent and compelling priorities. A more explicitly research-oriented perspective is offered by the Five-Year Research Plan and the 20-Year Research Vision that NOAA has published during 2005. Other planning documents that are created by NOAA and the Line Offices in the course of defining and implementing programs are valuable as well.

On a more immediate level, the NESDIS Cooperative Institute Directors' meetings that were instituted in 2003 have been very useful in enhancing understanding of NESDIS' research interests. In addition, the SCSB Chief participates in regular meetings with the CICS Director and Deputy Director, and the meetings of the CICS Executive Board and Council of Fellows, which bring together senior managers and scientists from NOAA and CICS, are extremely helpful.

CICS-NC routinely participates in seminar series and presentations at NOAA's NCDC, as well as NCSU MEAS Department. CICS-NC has installed a new video teleconferencing capability to enhance and promote increased communications. CICS-NC works closely with Director of Communications, Steve Townsend, from NCSU PAMS (College).

NOAA seeks to ensure that societies and communities are informed and knowledgeable about the Earth's climate system and the impacts of climate change and variability. Equally important is providing support for critical decisions on adaptation and mitigation options. Building a climate-adaptive and resilient society also means integrating and applying the knowledge from basic and applied research to applications, such as building frameworks and systems into our economy, infrastructure, energy security, etc. It is vital to expand efforts that integrate social sciences with physical sciences, particularly as there are significant gaps in bridging the climate change information from a physical analysis to connecting with the broader impacts and opportunities analysis. NOAA can not address all of society's needs associated with these challenges. Government, academia and private enterprise all have roles in addressing these challenges.

These needs require an understanding and fostering of climate literacy and societal impacts at various levels, ranging from K-12 to sophisticated executive level business decisions, which include socio-economic and security considerations. There are significant challenges in climate education and literacy, as academic programs at undergraduate and graduate levels do not sufficiently describe the end-to-end risk and opportunities posed by a changing climatic system on societal systems. Certainly, this is also a gap in today's private sector market, as arguably most senior level decision-makers continue to be perplexed in how to most efficiently and effectively address and understand climate change.

NOAA may choose to consider options in sustaining and building a more robust education, literacy and outreach initiatives to establish a new skilled workforce prepare to address current and future challenges and opportunities of climate change.

V. SCIENCE MANAGEMENT PLAN

A. Identifying and Implementing Intellectual Opportunities

How does the Institute identify new intellectual opportunities?

Intellectual opportunities for CICS collaborative research arise from a number of sources with varying degrees of formality. Typically these opportunities surface from discussions between CICS staff, academic partners, private sector end-users and government scientists. The venues can be formal, such as the CICS Council of Fellows, Agency Announcements of Opportunity and the Federal Register. Conversely they can be much more informal ones, such as professional society meetings, weekly seminars at CICS and/or NOAA units, or visits with agency program managers. Co-location of the CICS centers at College Park and Asheville with major NOAA facilities, the NOAA Center for Weather and Climate Prediction (NCWCP) and the National Climatic Data Center (NCDC) facilitates routine meetings and exchanges between CICS, federal and contract staff and the opportunity for informal meetings. Co-location also facilitates interactions between the CICS leadership and NOAA program managers for information exchange, which can also lead to research opportunities. Recent opportunities identified through these mechanisms include:

- Research and development projects associated with JPSS and GOES-R
- Analysis of data from Suomi-NPP instruments
- Development of the National Calibration Facility
- Global temperature products analyses
- Outreach and Engagement

While it would accelerate the innovation process to have an internal research and development resource line set aside for seed funding startup activities, virtually all CICS resources are devoted to specific ongoing projects, education and outreach efforts, or to internal management of the Institute. In practice, the avenues for support of new initiatives are new NOAA budget resources and occasional support from STAR and/or NCDC management based upon convincing evidence of exceptional intellectual opportunity. One of the highest priorities for new Task 1 funding is to provide seed support to foster the development of new concepts. The CICS scientific staff is bright and creative, and frequently generates such new ideas.

B. Human resources

What is the demographic structure of the Institute employees?

CICS has grown significantly since its inception, with CICS-NC being built *ab initio* over the past 3 years to 35 staff members combined with substantial growth in the CICS-MD staff to address JPSS and GOES-R challenges. This growth has given CICS unique opportunities to recruit a diverse staff of domestic and international scholars and engineers with skill sets targeted on NOAA's Long Term Goals.

The most recent demographic survey of CICS employees in terms of ranks and educational achievement was completed for the 2012 Annual Report and is reproduced in Table 2. Significant expansion in the number of CICS scientists has occurred since then, as can be seen in the list of

CICS personnel in Appendix C.

Category	Total	BS	MS	PhD
Research Scientist	26	-	-	26
Visiting Scientist	1	-	-	1
Postdoctoral Fellow	16	-	-	16
Research Support Staff	14	1	13	-
Administrative	5	3	2	-
Total (> 50% support)	62	4	15	43
Undergraduate Students	2	-	-	-
Graduate Students	12	-	-	-
Employees that receive < 50% NOAA funding (not including students)	10	-	-	10
Located at NOAA facility (NCWCP, Silver Spring or NCDC)	38	1	9	28
Obtained NOAA employment within the last year	2	-	-	2

Table 2: CICS Employees

Human resource development is vital for CICS, from recruiting through training, rewards and ensuring a productive and welcoming workplace. Both the principal nexuses of CICS are administered by large public universities, UMCP and NCSU, and benefit from mature sets of policies and procedures that govern personnel matters. Within that context, both CICS-MD and CICS-NC have evolved processes that facilitate smooth and effective functioning in all aspects of employment matters.

In general, recruitment is driven by the needs of the research or outreach project being staffed in combination with the effort to entrain the best possible candidates. On other occasions, CICS has the opportunity to recruit widely and hire the best candidates as students or postdoctoral researchers. A wide variety of techniques are employed in searching for candidates, including public and focused advertising, individual contacts, and promotion from within, always with attention to equity issues.

Training and rewards are important tools in the CICS workplace. Specific procedures are handled according to the processes of the host university, and, at UMCP, by the individual units in which the CICS employees work.

C. Finances

What is the state of the financial health of the Institute (Provide a budget summary and identify imbalances or needed adjustments)?

CICS is in excellent financial health, with exceptional growth in both funding commitments from NOAA and expenditures in the 3.5 years since its establishment. Total funding is readily determined through the UMCP monitoring system, and is shown by year in Figure C1. The large increase in funding from 2009 to the present results from three main factors:

- The increase in CICS work is related to the development of the GOES-R and JPSS satellite systems;
- The expansion in research, research to operations transitions and outreach related to the Climate Data Record Program, National Climate Assessment and public/private sector engagement activities; and
- The move of NOAA employees from multiple locations to the new National Center for Weather and Climate Prediction in College Park.

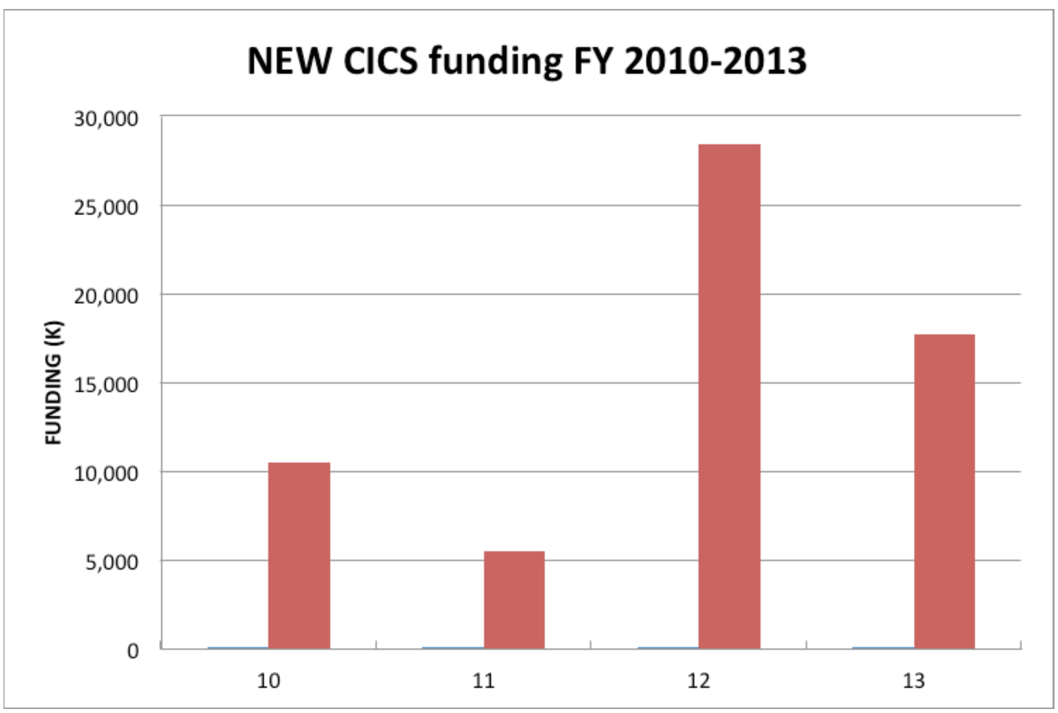


Figure C1: Total awards in CICS for UMCP fiscal years (July-June) 2010-2013, with FY 2013 estimated from annualized first quarter values.

Expenditures have grown at a slower but more regular pace, as CICS employees have been hired for projects initiated based on new NOAA requirements.

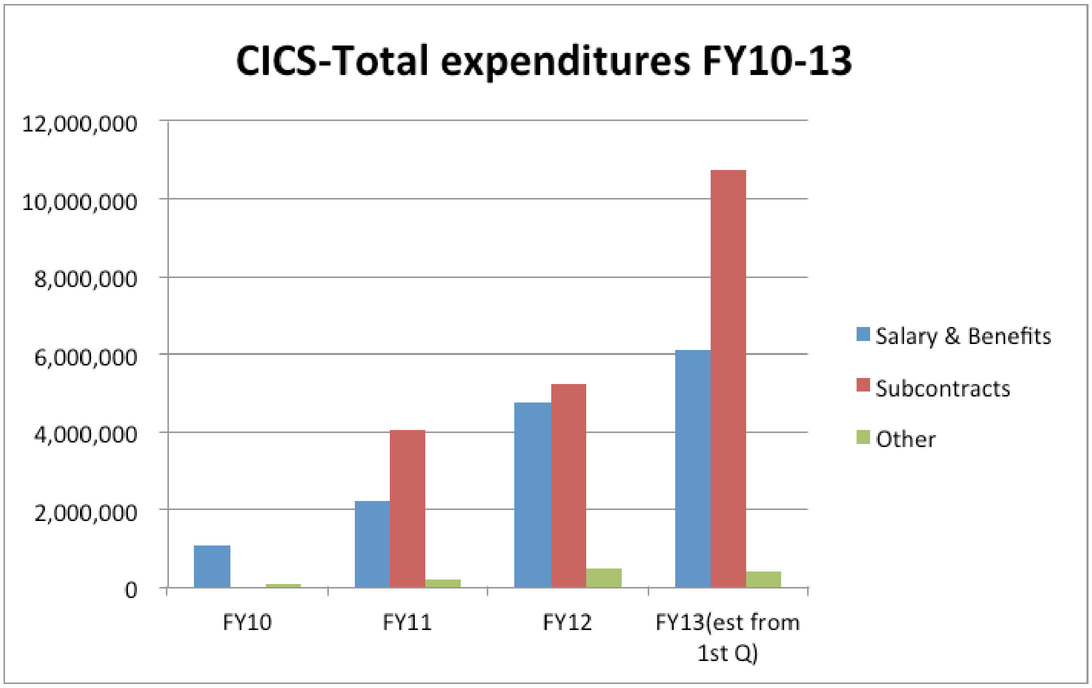


Figure C2: Total expenditures in CICS for UMCP fiscal years (July-June) 2010-2013, with FY 2013 estimated from annualized first quarter values.

Figure C2 provides estimated expenditure growth over the report period. Note that the annualized 2013 value for subcontracts may be exaggerated, since subcontract invoicing is less regular that local expense tracking. The central role of subcontracts in CICS is clear from Figure C2. This is driven by the NCSU subcontract, see below.

Figure C3 shows the expenditures at NCSU for the same period. Note that the annualized values for FY 2013 may overstate the likely values for the full year.

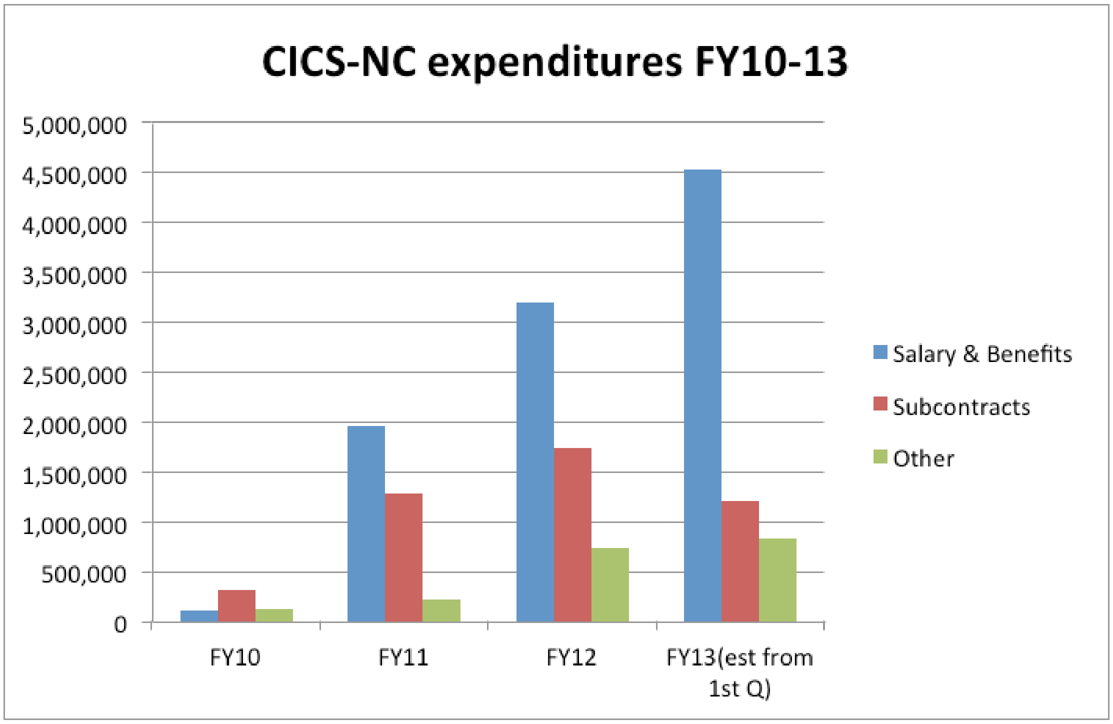


Figure C3: Total expenditures in CICS-NC for NCSU fiscal years (July-June) 2010-2013, with FY 2013 estimated from annualized first quarter values.

CICS poses very significant administrative and infrastructure challenges for its management and host institutions. The large number of individual projects supported under a single award requires a level of fiscal record keeping and oversight at both UMCP and NCSU that is far beyond that of typical research projects, even very large ones. All expenses associated with each individual task must be monitored both from the university perspective and from that of the NOAA sponsor. This level of effort requires significant support from the host university, which is possible because of the cost sharing committed to during the development of the CICS proposal.

CICS primary financial goal is stability and excellent stewardship to ensure that resources for its activities are available and adequate for its needs. The rapid growth over the initial 3.5 years of the project has certainly challenged the leadership and supporting staff. With excellent support from UMCP and NCSU and conscientious attention to best practices, we believe that we are in a strong position to achieve our financial objectives.

D. Issues

Are there any issues in interacting with NOAA or the Universities that require attention?

CICS outstanding challenges derive from stability of support in an era of tight budgets and insufficient resources to address administrative support and innovative ideas. To the present, host university cost share commitments have enabled CICS to manage this difficult situation. However, the same budget pressures that affect NOAA create stress on UMCP and NCSU, and a long-term solution will require creative and collaborative thinking. The largest NOAA Cooperative Institute, CIRES at the University of Colorado, has faced similar challenges in growing its activities and we have begun to investigate the possibility of capitalizing on their experience to streamline CICS operations.

In a broader sense, the balancing of basic and applied research is a continuing challenge, as is execution of plans for workforce development and engagement and outreach. We have had several successes in the latter areas with NOAA supporting a number of postdoctoral fellows and providing one-time support for engagement and outreach. However, there is no sustaining support line for either activity. Enhancement of Task I support levels would assist with seed funding of innovative ideas and we look forward to the NOAA Research Council acting on recommendations to do so.

Similarly, support for student fellowships, vital to the training of the next generation of NOAA scientists and staff, has been difficult to obtain. In the CICS proposal (Appendix B), CICS-MD committed to support two graduate research assistantships each year, one using Task I funds and the other supported through cost-sharing. However, the funding sources have not kept pace with costs, placing this vital effort in jeopardy.

Finally, since Cooperative Agreements are managed similarly to grants by NOAA, there is continuing fiscal pressure to show immediate costing of allocated resources. Unfortunately the late arrival of funding in the federal fiscal year has become the norm, and, thus costing and outcomes almost always lag NOAA's expectations. Moving cooperative agreement funding forward in the fiscal cycle would help the university partners in addressing NOAA's needs and expectations.

VI. SUMMARY, OPPORTUNITIES and CHALLENGES AND NEXT STEPS

A. Summary

The Cooperative Institute for Climate and Satellites (CICS) was established on July 1, 2009 as a collaborative effort including UMCP, NCSU, the UNC System, and nearly 20 other academic, private and non-profit organizations. CICS works with NOAA organizations in the Washington DC area and in Asheville NC to conduct outstanding collaborative research to advance the shared vision of CICS and NOAA. CICS' primary partnerships are with the Center for Satellite Applications and Research (STAR) and the National Climatic Data Center (NCDC), but include elements of the National Centers for Environmental Prediction, the Air Resources Laboratory, and the National Oceanographic Data Center (others are under discussion).

The scientific vision of CICS centers on the observation, using ground- and space-based instruments and networks, and prediction, using realistic mathematical models, of the present and future behavior of the Earth System. This vision is consistent with and supportive of NOAA's vision, and CICS scientists work on projects that advance NOAA objectives in all four of the agency's Long Term Goals. CICS currently comprises more than 100 scientists and staff located primarily in CICS-MD at UMCP and in CICS-NC, which is hosted administratively by NCSU and is collocated with NCDC. These scientists work on a large number of individual research projects in collaboration with NOAA scientists and program managers.

CICS has a strong focus on education, literacy, outreach and user engagement. Both CICS-MD and CICS-NC support educational efforts from the K-12 realm through undergraduate, graduate and postgraduate training. CICS directly supports a number of graduate students and postdoctoral fellows at UMCP and NCSU, and participates in a number of course offerings.

B. Challenges and Opportunities

CICS faces a wide variety of challenges that range from pressure on the Federal budget to the difficulties inherent in guiding a massive multi-institutional activity with a plethora of priorities. Here we describe a few of the most important challenges and the opportunities they present.

The most intellectually exciting challenges relate to CICS' role in advancing the community-wide effort to improve our ability to observe, understand and predict variations in the Earth System on time scales ranging from weeks to centuries, and to communicate the knowledge gained to broad communities to whom that information is vitally relevant. Basic scientific challenges and the allied opportunities include:

- How do we best integrate observations and models so as to obtain the most accurate possible depiction of the current and past state of the Earth System? CICS' expertise in satellite and in situ observations, the development of integrated analyses of parameters such as precipitation, and data assimilation position us well to contribute to solving this problem.
- How can we improve predictions of large-scale variability in the ocean-atmosphere system on time scales from a few weeks to many decades? This problem requires advances in

initialization of couple models and in understanding and modeling the physics of coupled oscillation, areas in which CICS scientists and their collaborators have extensive experience.
- How can we advance coupled Earth System prediction capabilities on regional domains? This problem requires extensive model development coupled with better definition of boundary and initial conditions. CICS scientists have contributed to these developments already and are well positioned to play a central role in ongoing research and development.

Communicating knowledge to communities outside of those involved in the fundamental science has proven exceptionally challenging. Physical scientists who create the majority of the advances in fields such as satellite observations and physical modeling are not generally skilled in interacting with social scientists and the general public, and yet that is exactly the skill most needed to learn what information is required and how it must be presented so as to make it useful. For example:
- How should predictive information be presented to ensure both utility and appropriate use? Climate and Earth System predictions are probabilistic, but useful and convincing presentation of such information is challenging. CICS scientists and communicators are well positioned to advance such efforts.
- Actionable information is required for societal applications based on climate information, but how can appropriate actions be determined given specific situations and the limitations on available information? CICS scientists and outreach experts in the Consortium are actively engaged in investigating this and associated issues.

CICS represents a locus of numerous activities among many elements of NOAA, about 20 academic, nonprofit and private organizations, and other Federal agencies. Institutional interactions, given this large number of participants, are a major challenge for CICS. At the same time, CICS has the opportunity to facilitate solutions to many complex problems that are nearly intractable without the linkages that CICS offers.
- NCEP/EMC models and projects generate enormous quantities of information in the form of model output. However, NCEP IT resources are not scaled to serve these data sets to the research and experimental communities that could benefit from their availability. By virtue of its collaborations with both NCEP and NCDC, CICS may be able to facilitate the necessary exchange and data hosting efforts.
- A large number of Federal agencies, as well as state and local organizations, have vital interests in obtaining up to date, authoritative, climate information. On occasion, interagency efforts are impeded by incompatible procedures. CICS can provide a neutral forum for such interactions on topics ranging from the design of new observing systems to the distribution and application of forecast information.

As a nation, the US faces huge challenges due both to our commitments domestically and internationally and to the impact of extreme environmental events on society. One early and obvious impact of these challenges is the pressure to reduce spending on any less than immediate priorities. Since this includes the types of collaborative research and outreach activities that are the core of CICS efforts, we expect financial resources to shrink, or at least fail to keep pace with costs and expanding mission.
- Can CICS do more with less? What should be the role of Cooperative Institutes in an era of shrinking budgets and expanding requirements? The situation is daunting, but by offering hiring options and innovative approaches, CICS can provide mechanisms for NOAA to improve its agility and responsiveness in science and outreach efforts.
- Can CICS continue to provide exceptional support to NOAA in its core mission areas while at the same time streamlining its management and administrative procedures so as to permit increased investment in student and postdoctoral support and in pilot projects to test bright

new ideas? With the support of our host universities and NOAA, and taking advantage of the best practices from the CI community, we believe we can.

Every challenge presents an opportunity. Above we have identified many significant challenges, but each one is associated with one or more opportunities to enhance the support that CICS provides to NOAA. Certain overarching opportunities are worth emphasizing:

- CICS is well positioned to help NOAA streamline the human resource pipeline by advancing K-12 and higher education in relevant subject areas, providing a fertile environment for young scientists to develop their skills, and by helping NOAA identify the best of those young scientists for its future needs.
- CICS has the experience and expertise to improve and expand data assimilation education and research, thereby providing the essential foundation for the advances in Earth System modeling, ecosystem modeling and climate data analysis required to meet National needs.
- CICS has established the outreach capability necessary to support NOAA in reaching out to social scientists, local communities, private sector decision-makers and the general public to enable them to survive and thrive in an era of environmental hazard and risk.

In this document we have offered our perspective on the CICS' contributions to our relationship with NOAA. We expect to build upon our accomplishments over the next 6.5 years, and in the process to continue to conduct outstanding collaborative research, education and outreach.

APPENDICES

APPENDIX A	**List of Acronyms**
APPENDIX B	**Proposal**
APPENDIX C	**CICS Personnel**
APPENDIX D	**List of Publications**
APPENDIX E	**Participation in NOAA Service Activities**
APPENDIX F	**Scientific Reports**
APPENDIX G	**CICS Presentations, Posters and Invited Talks**
APPENDIX H	**CICS Seminars**
APPENDIX I	**CICS Organized Workshops**
APPENDIX J	**CICS Memorandum of Understanding**

A full list of these items will be provided separately by October 29, 2012.