# Advancing Climate Prediction at NCEP: Evaluation and Application of CFS

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# Acknowledgments


- Dr. Wanqiu Wang (CPC)
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- Dr. Bill Lapenta (EMC)
- Dr. Huug VandenDool (CPC)
- Ms. Lindsey Long (CPC)


# Outline

- **Climate Modeling and Prediction Advances**
  - Relationship to Symposium Theme
  - CFSv1 –vs – CFSv2
  - CFSv2 Operational Implementation
  - CFSv2 Reforecast Results
- **Applications**
  - Comparison of CFSv2 Reanalysis to other Reanalyses & Observations
  - Application of CFS for  Dynamic Hurricane Seasonal Prediction
- **CPC and the CIs**

# Climate Modeling and Prediction Advances

# Relationship to Symposium Theme

**This talk focuses on climate variability as captured by the Climate Forecast System (CFS), but satellite data is heavily used in the end-to-end System**

1. **Satellite data was assimilated to produce a Reanalysis of the atmosphere, ocean, sea ice and land over the 32-year period (1979-2010), which is required to provide consistent initial conditions for:**
2. **A complete Reforecast of the CFS over the 29-year period (1982-2010), in order to provide stable calibration and skill estimates of the new system, for operational subseasonal and seasonal prediction at NCEP**
3. **Satellite data is also used to Validate operational CFS forecasts**

# Climate Modeling and Prediction Advances at NCEP

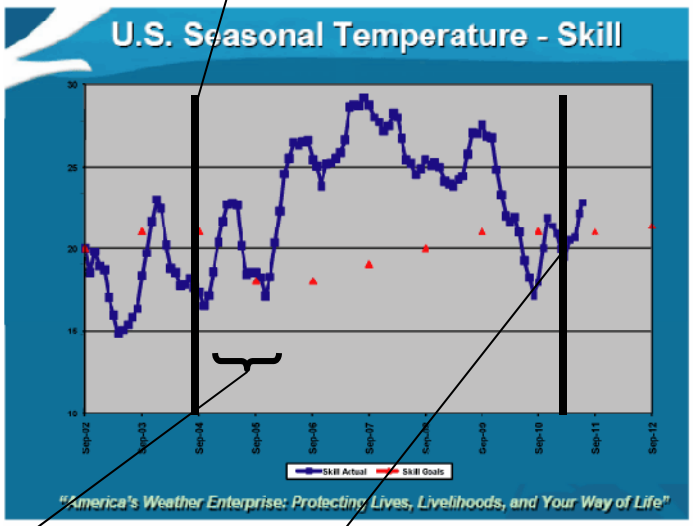
***Climate Forecast System*** **- NOAA's first dynamic, fully-coupled operational climate forecast model**

- **Version 1 operational since Aug 2004**
- **Version 2 operational in Mar 2011**
- **CFSv2 Reanalysis & Reforecasts (1979-present)**

***Climate Test Bed*** **– Accelerate the transition of Research to Operations (R2O)**

**Science Priorities:**

- **Climate model improvements**
- **Multi Model Ensemble prediction systems**
- **Climate forecast products**



# Advancement of Climate Forecast System (CFS)

## Implemented 30 March 2011

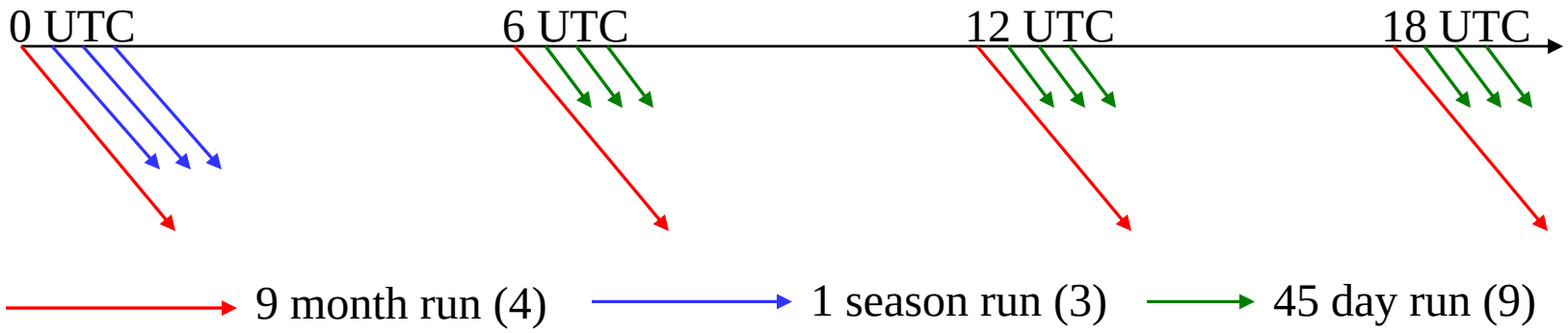
| Attribute | Operational (Since 2004) | March 2011 |
|---|---|---|
| Analysis Resolution | 200 km | 27 km |
| Atmosphere model | 2003: 200 km/64 levels<br>Humidity based clouds | 2010: 100 km/64 levels<br>Variable CO2<br>AER SW & LW radiation<br>Prognostic clouds & liquid water<br>Retuned mountain blocking<br>Convective gravity wave drag |
| Ocean model | MOM-3: 60N-65S<br>1/3 x 1 deg.<br>Assim depth 750 m | MOM-4 fully global<br>¼ x ½ deg.<br>Assim depth 4737 m |
| Land surface model (LSM) and assimilation | 2-level OSU LSM<br>No separate land data assim | 4 level Noah model<br>GLDAS driven by obs precip |
| Sea ice | Climatology | Daily analysis and 3-layer interactive sea ice model |
| Coupling | Daily | 30 minutes |
| Data assimilation | Retrieved soundings, 1995 analysis, uncoupled background | Radiances assimilated, 2008 GSI, coupled background |
| Reforecasts | 15/month seasonal output | 24/month (seasonal)<br>124/month (week 3-6) |

# CFSv2 Implementation

- CFSv2 became operational at NCEP (30 Mar 2011)
- Daily operational CFSv2 forecasts data archived by NCDC
- CFS Reanalysis and Reforecast (CFSRR) data for transition to new product stream
- Continue generation of CFSv1 data stream (thru June 2012).
- Data dissemination to non-NCEP users via the NOAA National Operational Model Archive & Distribution System (NOMADS)

# CFSv2 Operational Configuration

- 4 control runs per day (0, 6, 12 and 18 UTC) out to 9 months.
- 3 additional runs out to one season (0 UTC).
- 9 additional runs, out to 45 days (6, 12 and 18 UTC)
- 16 CFS runs every day



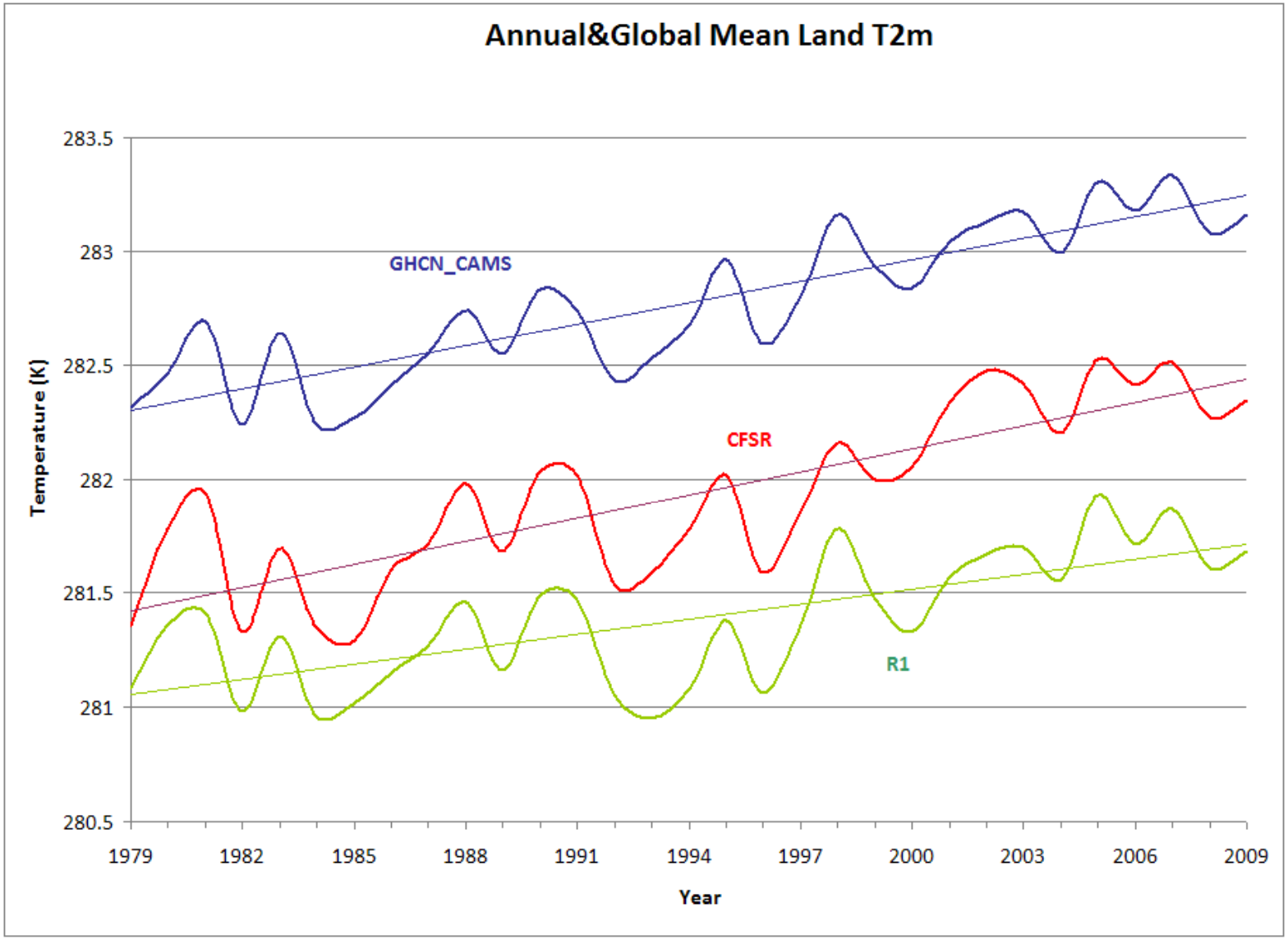

# CFSv2 Reanalysis and Reforecasts

- CFSv2 Reanalysis (1979-2010) – initialization
- CFSv2 Reforecasts (1982-2009) – calibration
- Data format change (GRIB 1 to GRIB 2) – NCEP provides scripts
- Status
  - CFS Reanalysis is publicly available at NCDC: http://nomads.ncdc.noaa.gov/data.php?name=access#cfsr
  - "First Look" Reforecast data (20 TB; calibration climatologies) publicly available at NCDC.
  - High Priority" Reforecast data (50 TB; 85 variables) publicly available at NCDC.
- CFSv2 "Lite Reanalysis" (1948-2010) underway

# An innovative feature of the CFSv2 Reanalysis is the use of historical concentrations of CO2 from the historical TOVS instruments

| Satellite Platform | Mission Mean (ppmv)b |
|---|---|
| TIROS-N | 337.10 |
| NOAA-6 | 340.02 |
| NOAA-7 | 342.96 |
| NOAA-8 | 343.67 |
| NOAA-9 | 355.01 |
| NOAA-10 | 351.99 |
| NOAA-11 | 363.03 |
| NOAA-12 | 365.15 |
| GEOS-8 | 367.54 |
| GEOS-0 | 362.90 |
| GEOS-10 | 370.27 |
| NOAA-14 to NOAA-18 | 380.00 |
| IASI METOP-A | 389.00 |
| NOAA-19 | 391.00 |

Courtesy: http://gaw.kishou.go.jp



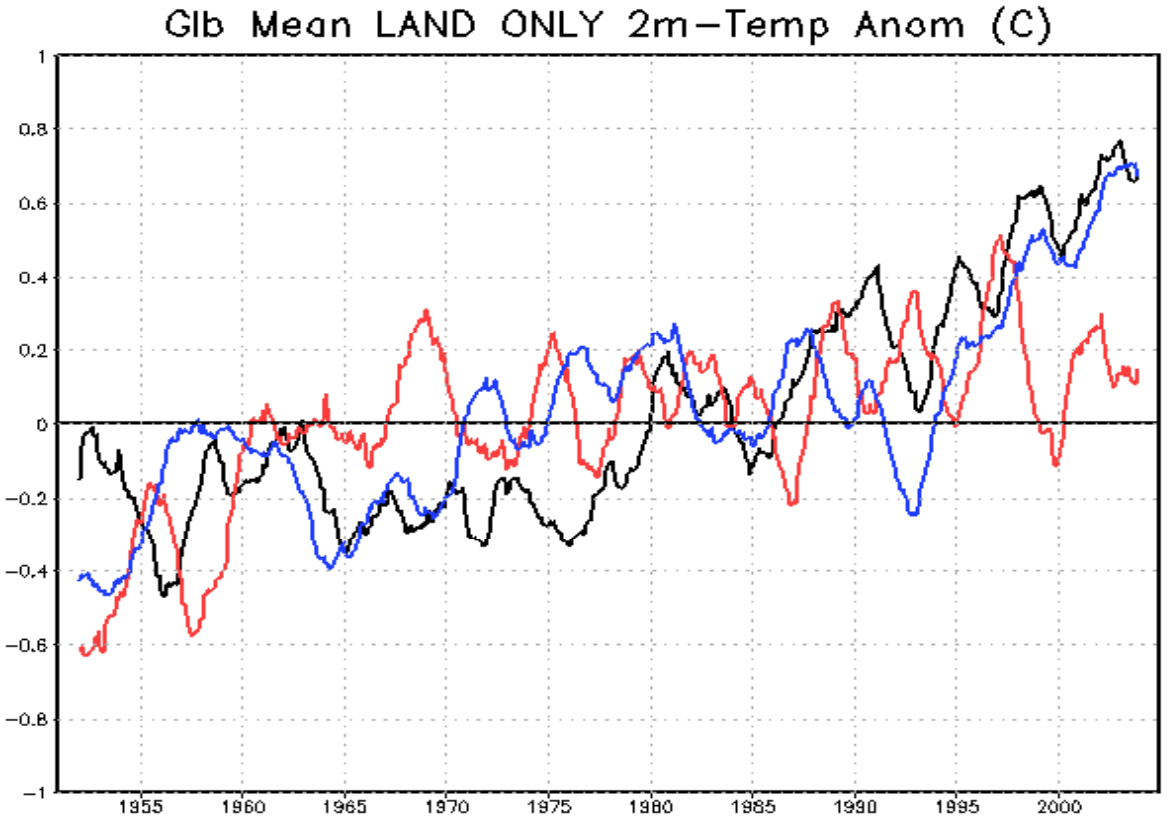

**The linear trends are 0.66, 1.02 and 0.94K per 31 years for R1, CFSR and GHCN_CAMS respectively.**



Huug van den Dool, CPC

# CFSv2 Capability to Recreate Decadal Temperature trend

| | |
|---|---|
| OBS | Observed temperature trend |
| CTRL | Coupled atmosphere-ocean 50 year run with constant CO2 |
| CO2 | Observed CO2 and aerosols in both troposphere and stratosphere |



# CFSv2 Reforecast Results

- MJO Index
- 2-M Temperature
- Precipitation
- SST

# Definitions and Data

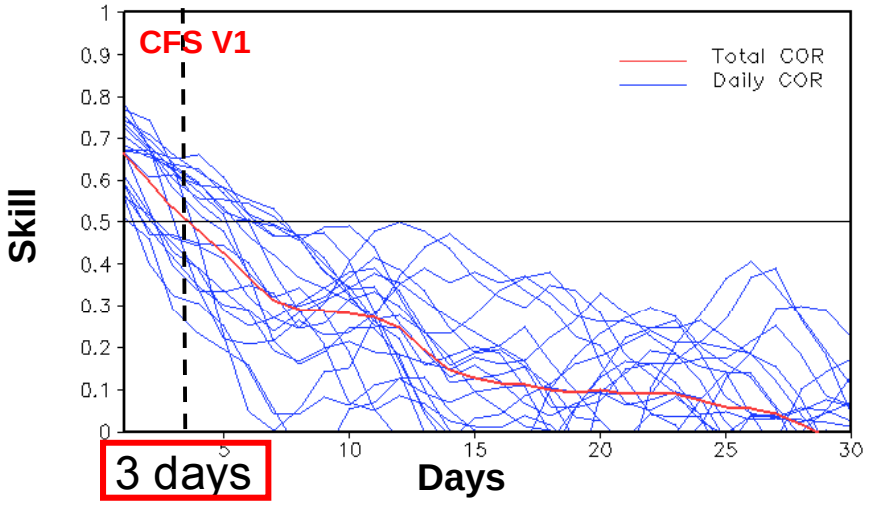
- WH: Wheeler Hendon MJO Index
- AC of ensemble averaged monthly means
- GHCN-CAMS (validation for Tmp2m)
- CMAP (validation for precipitation)
- OIv2 (validation for SST)
- 1982-2009 (28 years)
- Common 2.5 degree grid
- Variables/areas studied: US T, US P, global and Nino34 SST, global and Nino34 Prate.
- Two climos used for all variables within tropics

  30S-30N: 1982-1998 and 1999-2009

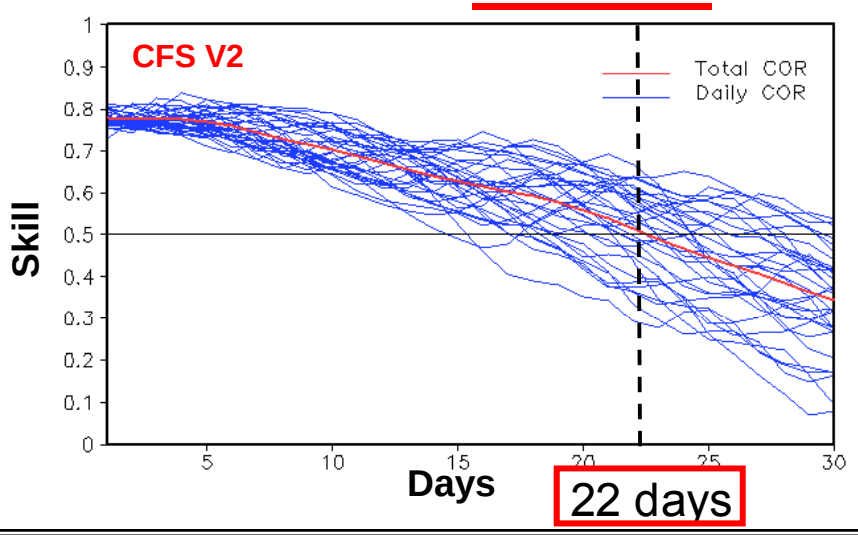
  Elsewhere: 1982-2009

# Preliminary Analysis Shows Improved MJO Signal in CFSV2

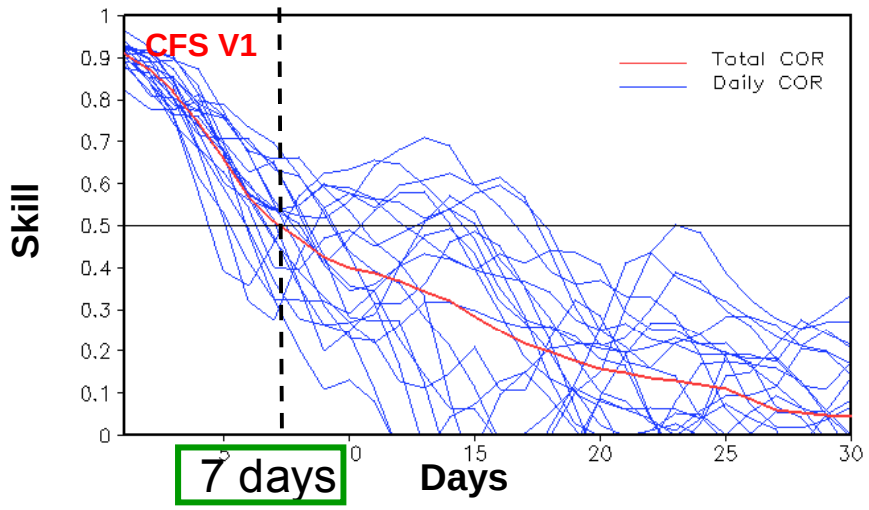
WH-MJO Index 09 Feb to 13 Mar



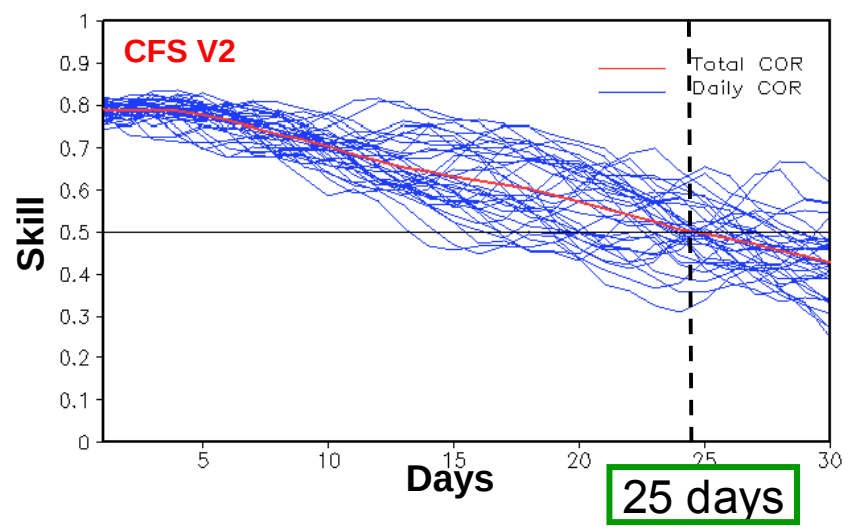

WH-MJO Index 09 Feb to 13 Mar



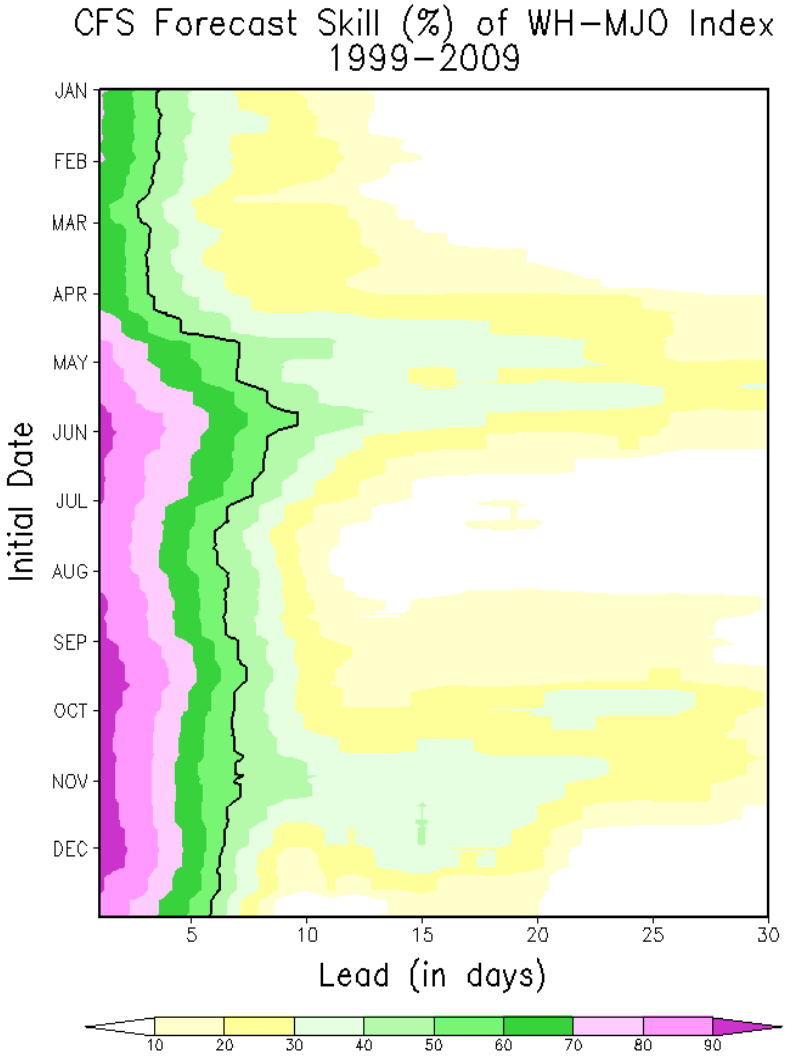

WH-MJO Index 09 Nov to 13 Dec

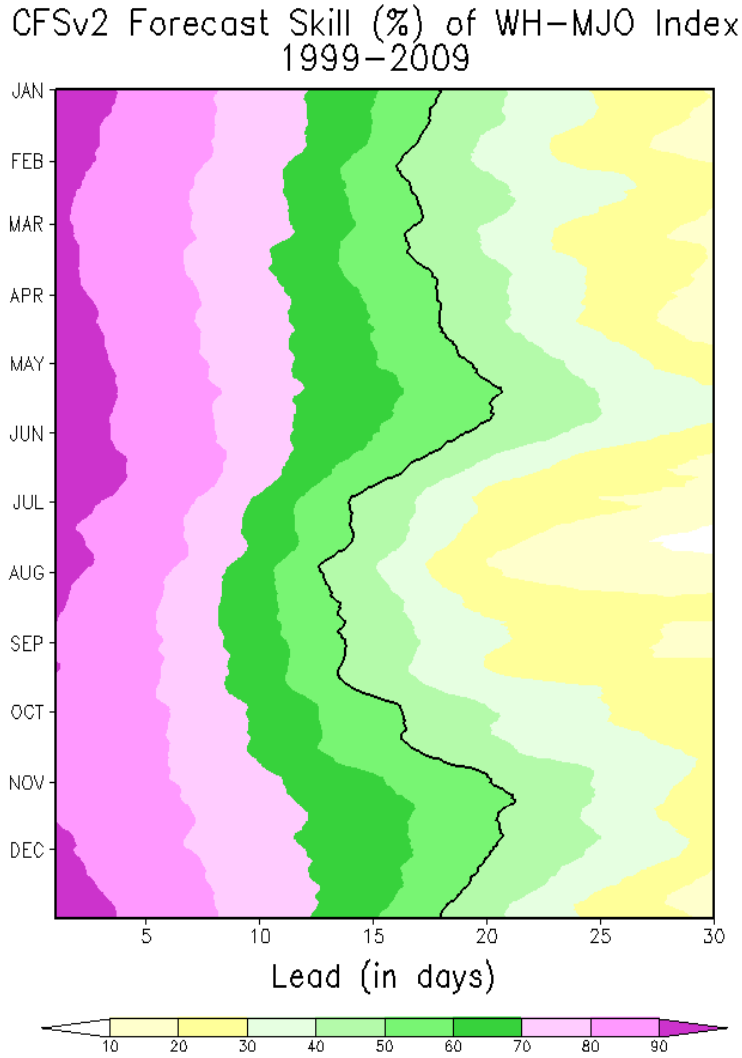



WH-MJO Index 09 Nov to 13 Dec



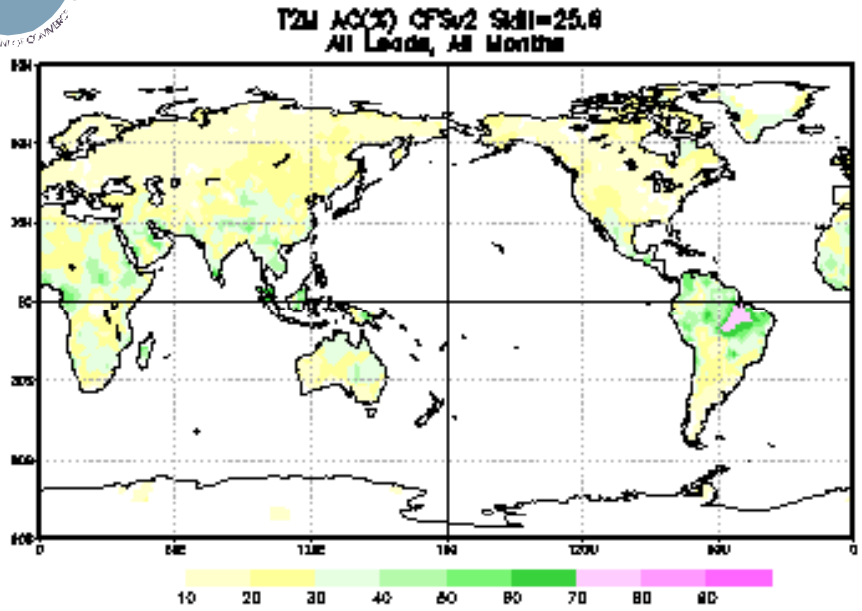
# Forecast Skill of WH-MJO index

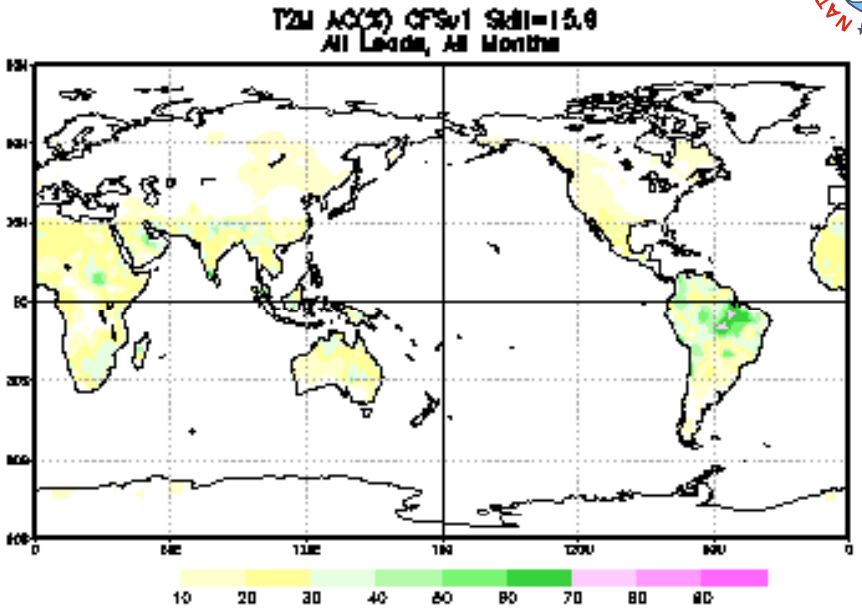


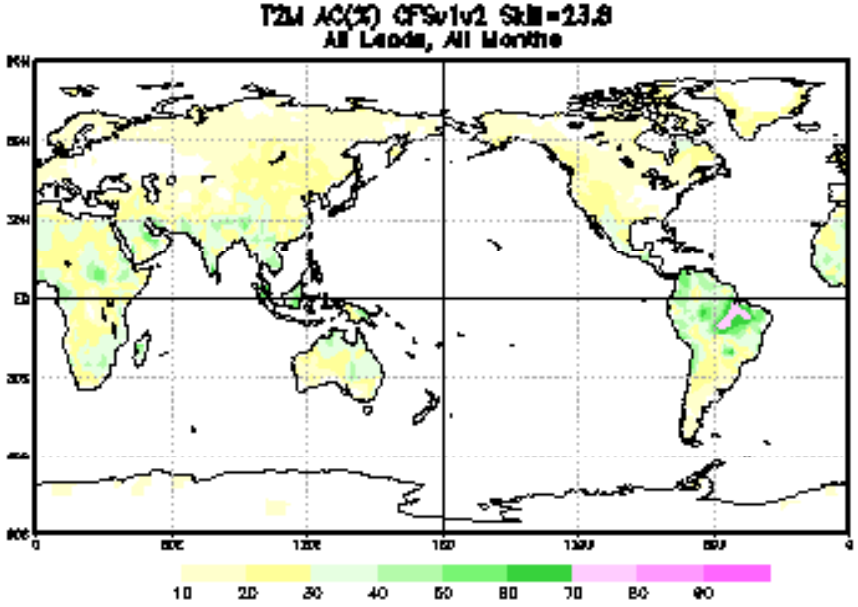






Qin Zhang and Huug van den Dool, CPC




**2-meter Temps AC**

**(All Leads, All Months)**

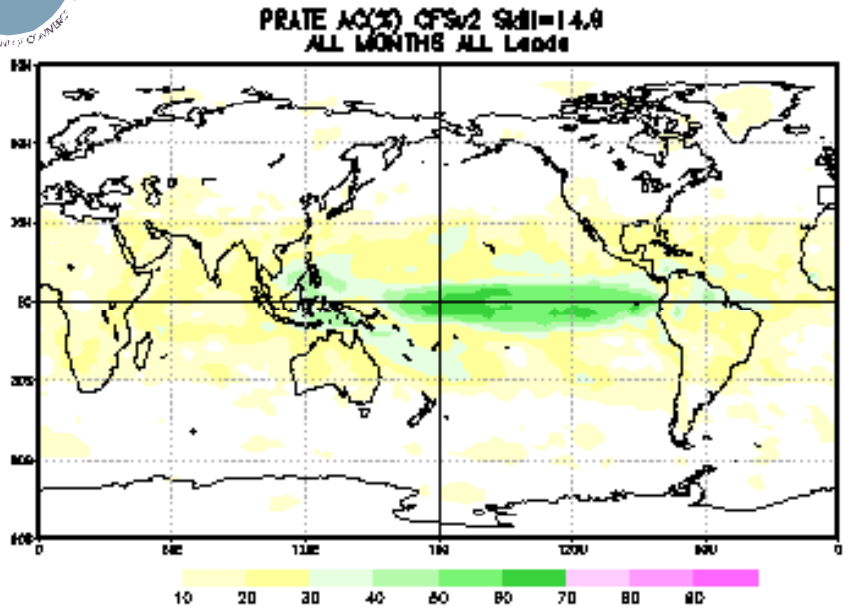
**CFSv2: 25.6**

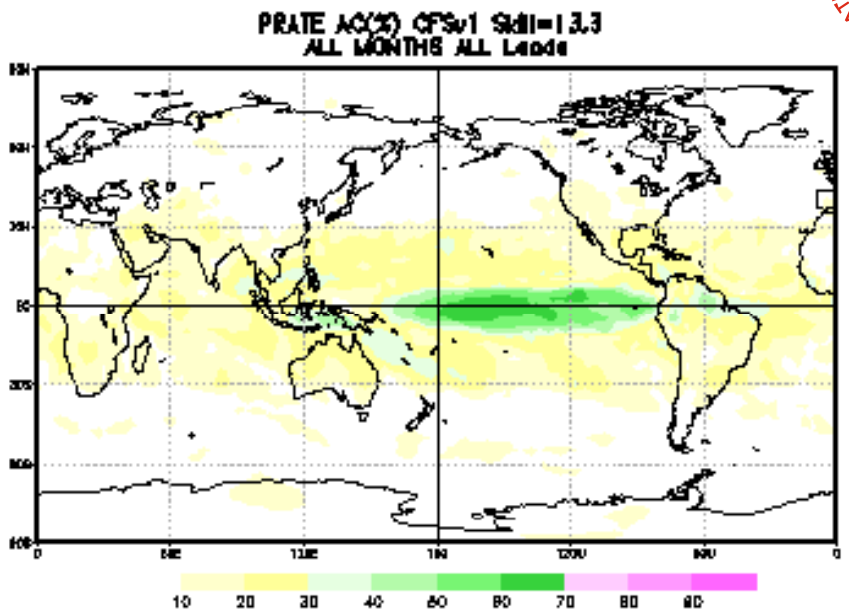
**CFSv1: 15.9**

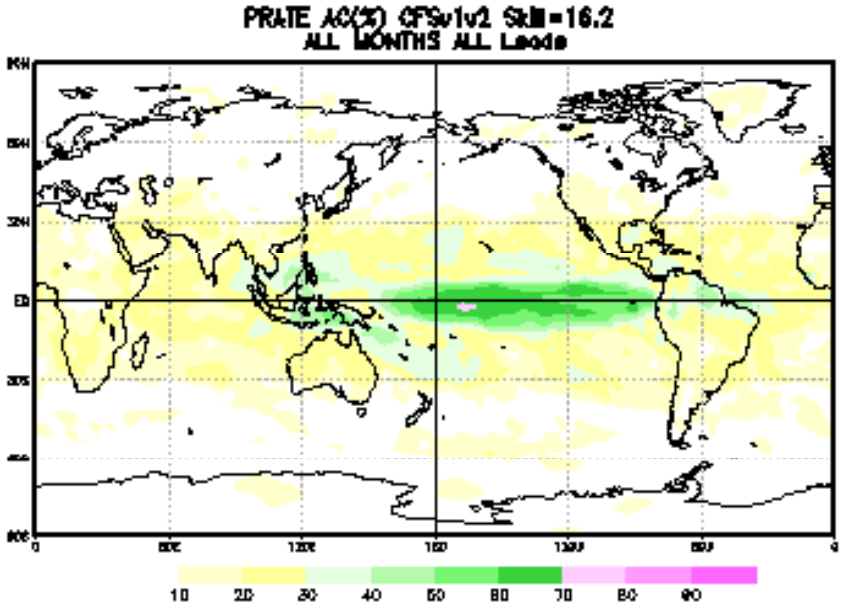
**CFSv1v2: 23.8**

**More skill globally for CFSv2**

HUUG VAN DEN DOOL. CPC/NCEP/NWS/NOAA




**Precipitation AC**

**(All Leads, All Months)**

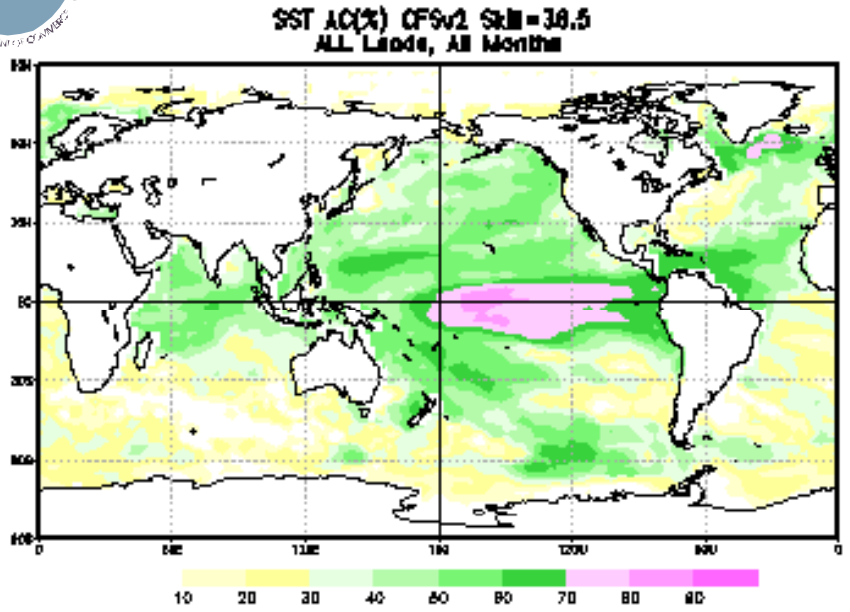
**CFSv2: 14.9**

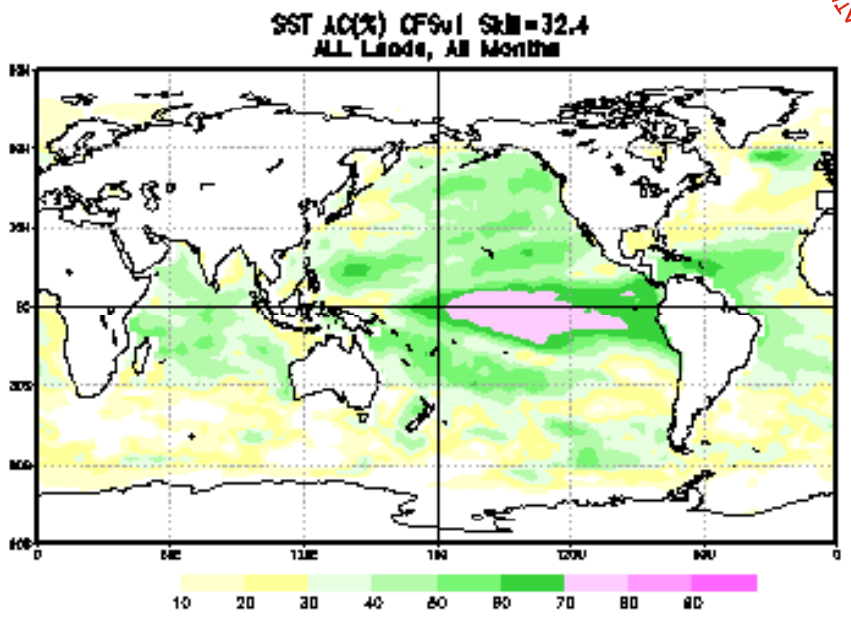
**CFSv1: 13.3**

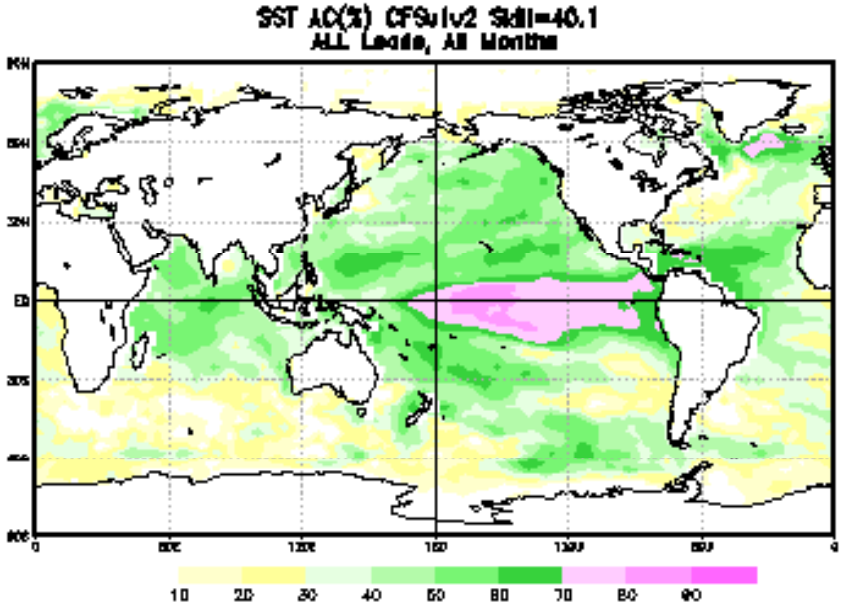
**CFSv1v2: 16.2**

**More skill in the Western Pacific for CFSv2**

HUUG VAN DEN DOOL, CPC/NCEP/NWS/NOAA




HUUG VAN DEN DOOL. CPC/NCEP/NWS/NOAA

**Sea Surface Temp AC**

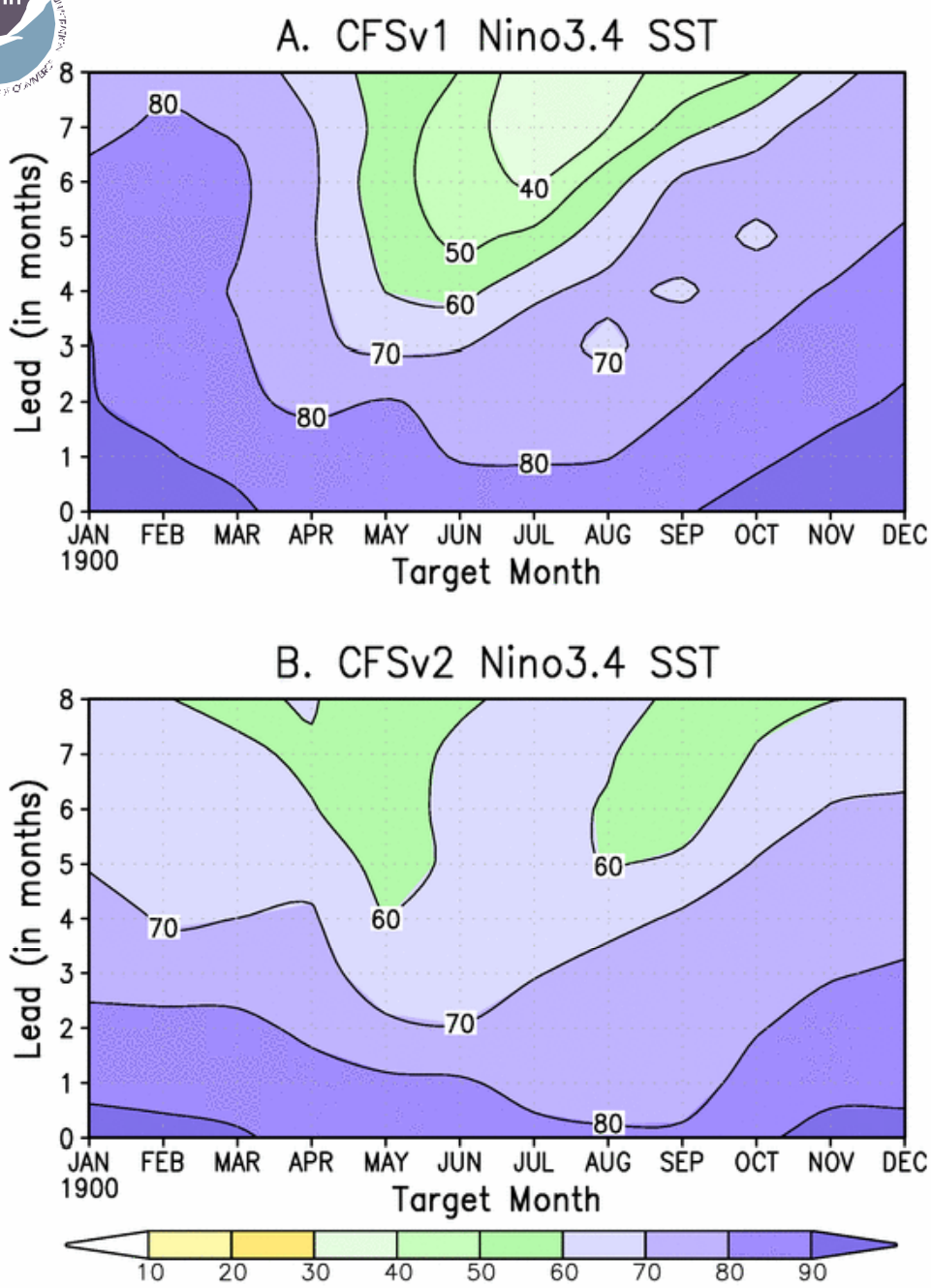
**(All Leads, All Months)**

**CFSv2: 36.5**

**CFSv1: 32.4**

**CFSv1v2: 40.1**

**More skill west of the dateline and over the Atlantic for CFSv2**




**Sea Surface Temperature Ensemble skill of Nino 3.4**

**CFSv1 has a problem in that it persists large winter anomalies into the spring (a critical ENSO season) and is reluctant to go to neutral, let alone to go from La Nina to El Nino or vice versa (as is common in spring).**

**The standard deviation for MAM is clearly improved in CFSv2.**
**There appears to be much less of a "spring barrier" in CFSv2.**



Huug van den Dool & Emily Becker, CPC

# THE BOTTOM LINE

## Anomaly Correlation: All Leads (1-8), All Months (10)

**Green is good** **Red is not good**

| Model | US T | US P | Nino34 SST | Nino34 Prate | Global SST (50N-50S) |
|---|---|---|---|---|---|
| CFSv2 | 16.3 | 9.5 | 77.2 | 54.5 | 42.2 |
| CFSv1 | 9.5 | 10.3 | 71.8 | 52.8 | 37.7 |
| CFSv1v2 | 15.4 | 12.2 | 78.3 | 57.0 | 45.4 |
| CFSv1v2-CFSv2 | -0.9 | +2.7 | +1.1 | +2.5 | +3.2 |
| %tage change | (-5.8%) | (+22%) | (+1.4%) | (+4.4%) | (+7%) |

# Applications

## Comparison of CFSv2 Reanalysis to other Reanalyses & Observations

# Comparison of CFSv2 Reanalysis to other Reanalyses and Observations

1. CFSR

   Monthly mean fields.  Hourly precipitation

2. Other Reanalyses

   NCEP/NCAR **R1**, NCEP/DOE **R2**, ECMWF **ERA40**

3. Observations

   **Precipitation**: CMORPH, CMAP, GPCP, TRMM

   **T2m**: GHCN CAMS

# CFS Reanalysis

## What is it

- A global, high resolution, coupled atmosphere-ocean-land surface-sea ice dataset that provides the best estimate of the state of these coupled domains over the period 1979-2009.

## How it can be used

- Real Time Climate Monitoring
- Initial conditions for historical forecasts
- Estimates and diagnosis of the earth's climate state over the satellite data period for community climate research.

## Products

- CFSR products are available at hourly time resolution, 0.5 degree horizontal resolution, and at 37 standard pressure levels: includes sea-level pressure, winds, height, SST, precipitation and hundreds of others.


## The NCEP Climate Forecast System Reanalysis

Suranjana Saha, Shrinivas Moorthi, Hua-Lu Pan, Xingren Wu, Jiande Wang, Sudhir Nadiga, Patrick Tripp, Robert Kistler, John Woollen, David Behringer, Haixia Liu, Diane Stokes, Robert Grumbine, George Gayno, Jun Wang, Yu-Tai Hou, Hui-ya Chuang, Hann-Ming H. Juang, Joe Sela, Mark Iredell, Russ Treadon, Daryl Kleist, Paul Van Delst, Dennis Keyser, John Derber, Michael Ek, Jesse Meng, Helin Wei, Rongqian Yang, Stephen Lord, Huug van den Dool, Arun Kumar, Wanqiu Wang, Craig Long, Muthuvel Chelliah, Yan Xue, Boyin Huang, Jae-Kyung Schemm, Wesley Ebisuzaki, Roger Lin, Pingping Xie, Mingyue Chen, Shuntai Zhou, Wayne Higgins, Cheng-Zhi Zou, Quanhua Liu, Yong Chen, Yong Han, Lidia Cucurull, Richard W. Reynolds, Glenn Rutledge, Mitch Goldberg

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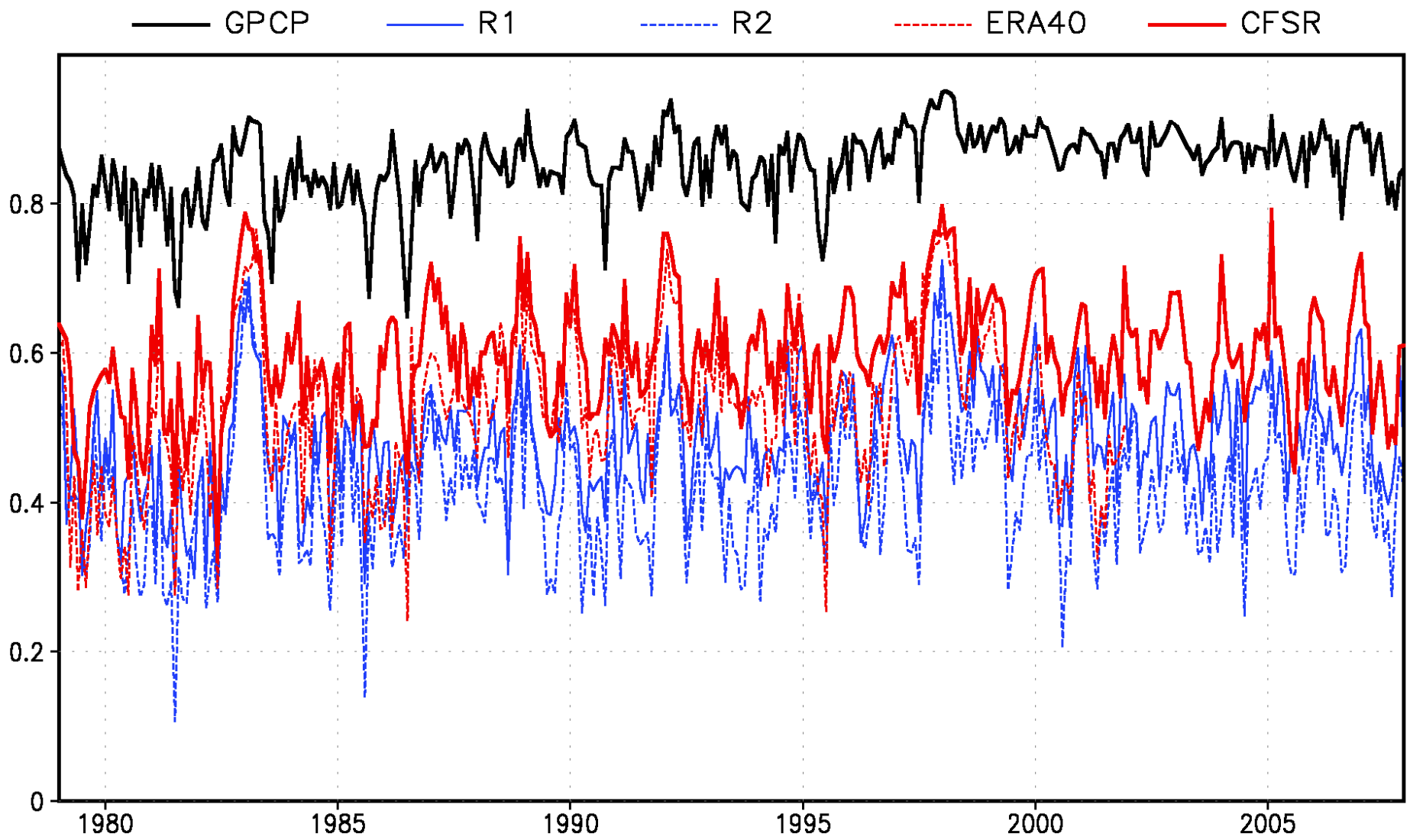
Volume 91, Issue 8, pp 1015-1057.
doi: 10.1175/2010BAMS3001.1

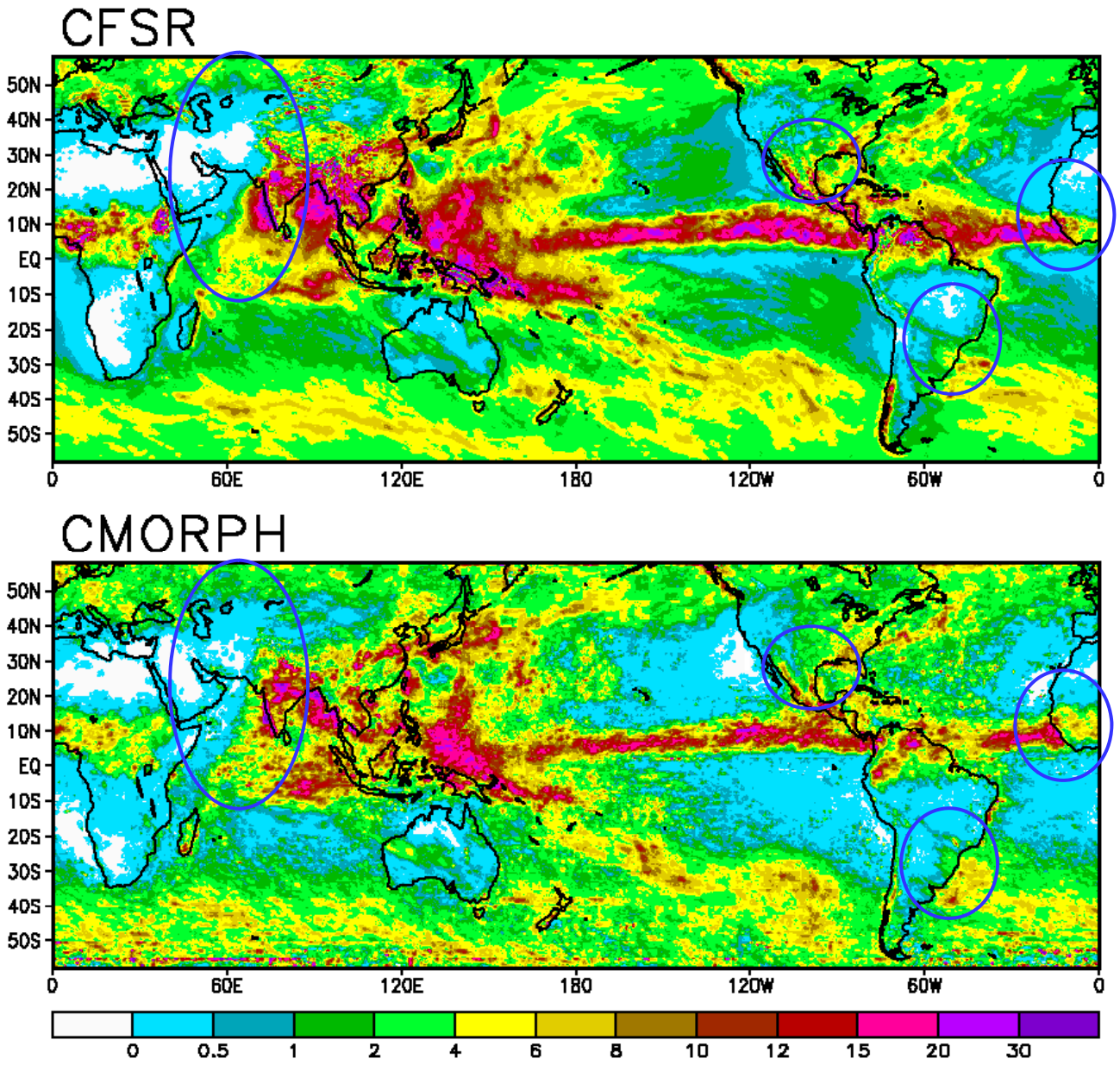
# Precipitation

# Monthly precipitation spatial correlation with CMAP



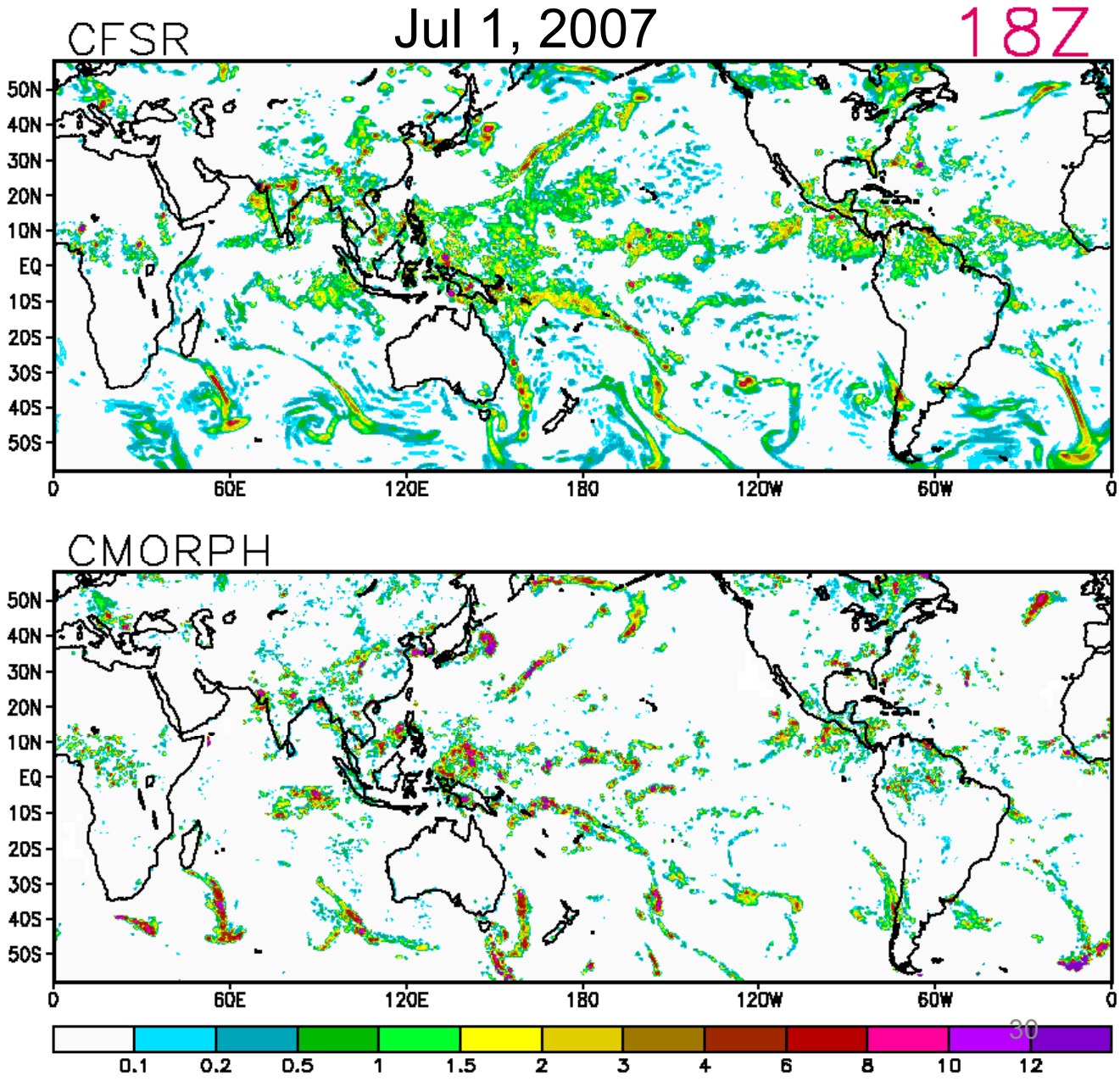
# Jul 2007 monthly mean precipitation on T382 grid

- Very reasonable overall spatial pattern in CFSR.
- Realistic local sharp changes.
- Reasonable North American Monsoon



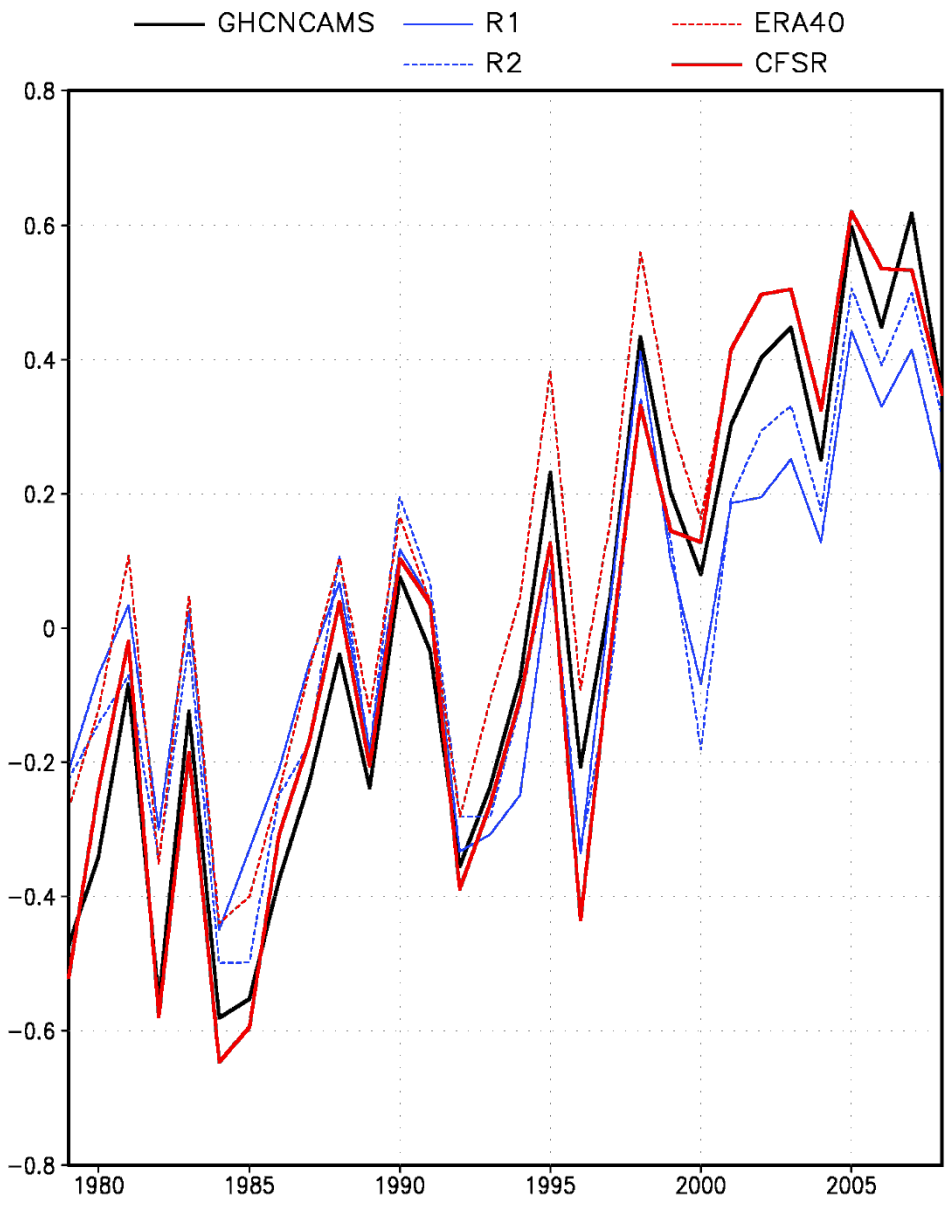
# Hourly precipitation on T382 grid

- CFSR captures the structure and evolution of individual weather systems, especially in mid-latitudes.
- In the tropics, the CFS tends to have larger areas of small precipitation rate.



# Surface air Temperature (T2m)

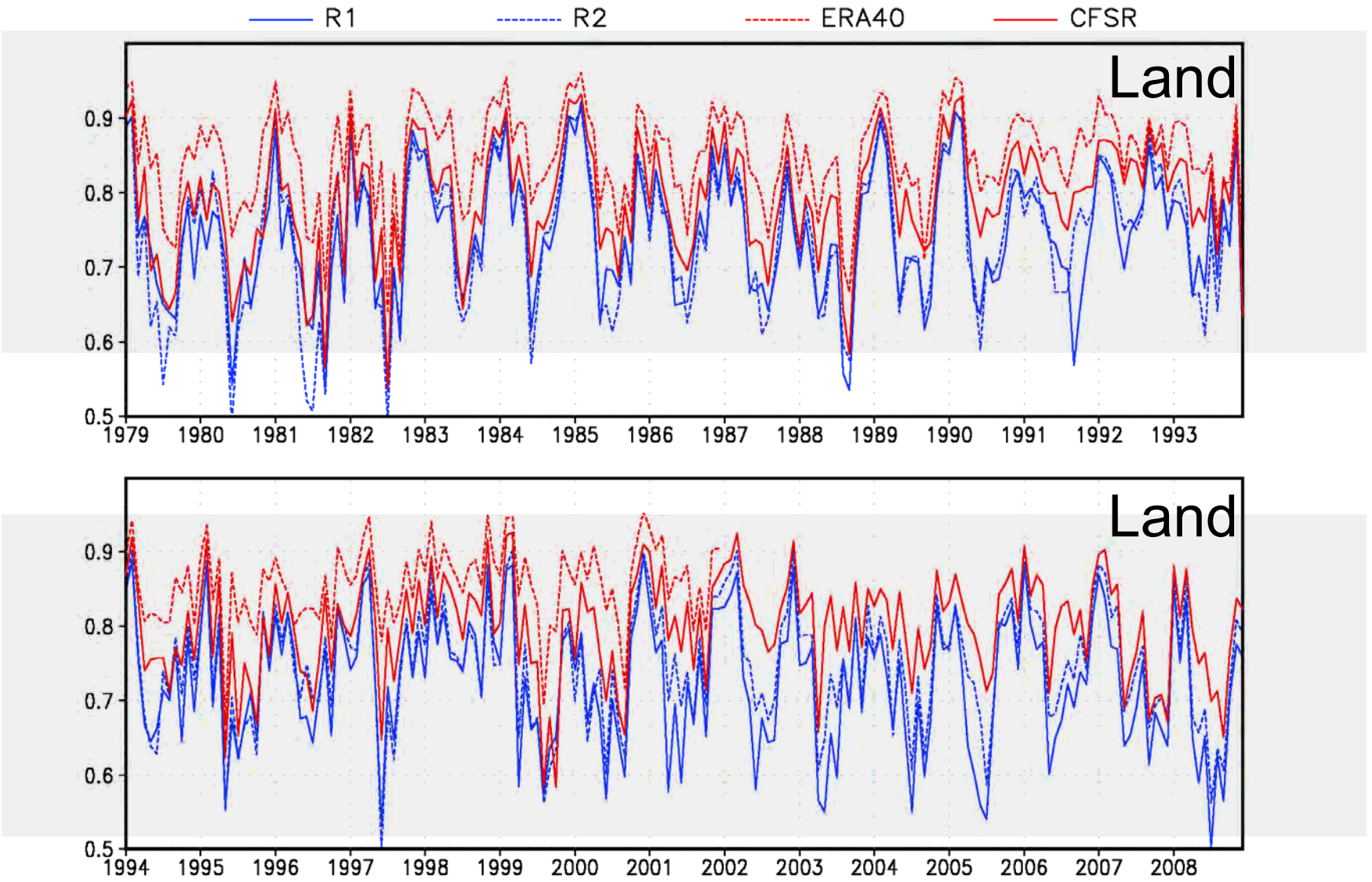
# Annual global mean anomalies over land (K)




**Linear Trend**
(K/decade)

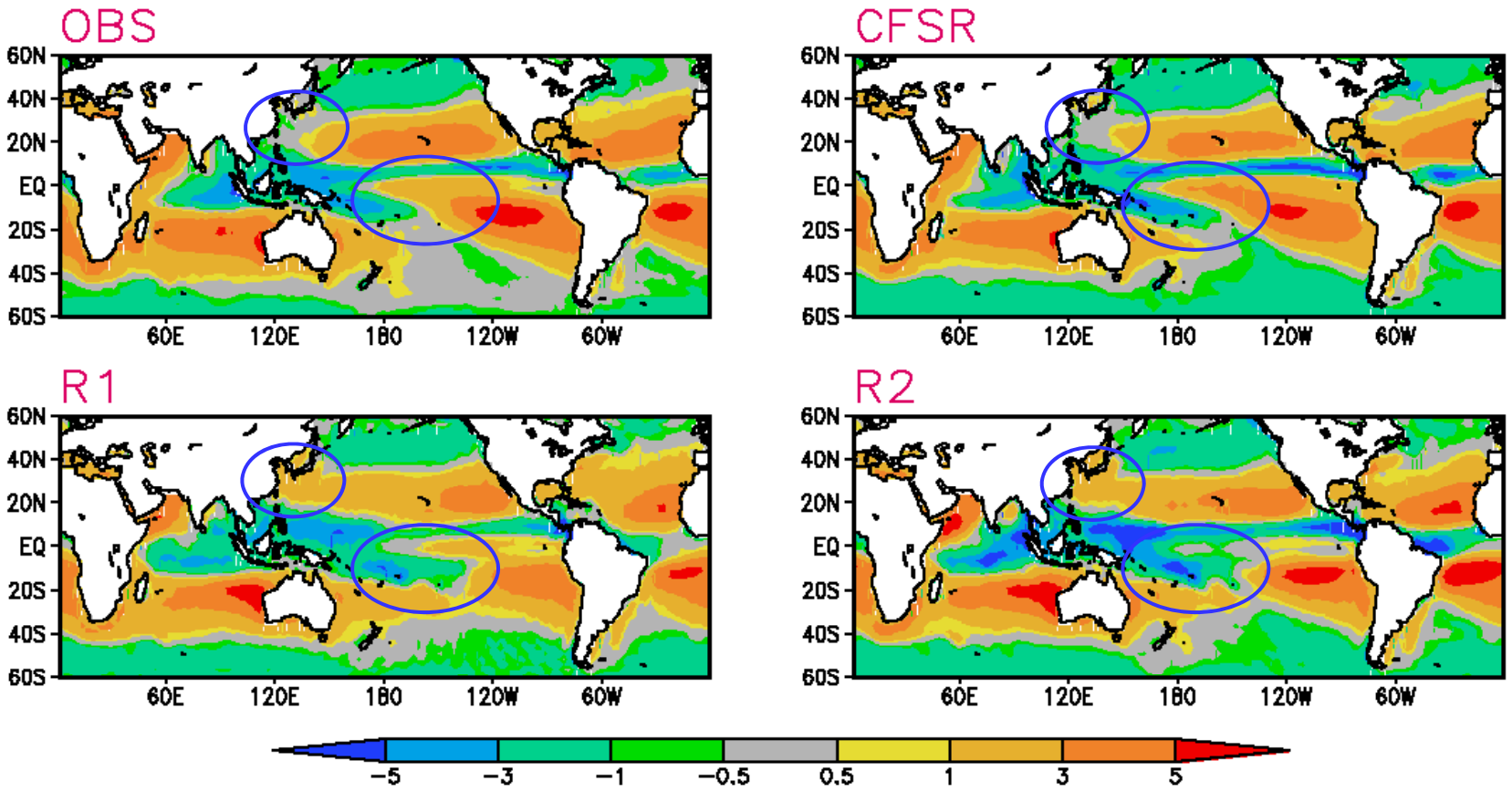
| | |
|---|---|
| GHCN | 0.35 |
| R1 | 0.19 |
| R2 | 0.24 |
| ERA40 | 0.26 |
| CFSR | 0.35 |

# Monthly T2m spatial correlation with GHCNCAMS



# E - P

# Annual mean E - P (mm/day)




More realistic E-P distribution in CFSR than in R1 and R2.

# CFSR Improvements

1. Captures local precipitation structures and evolution of individual systems.
2. Better representation of precipitation interannual variability.
3. Better representation of T2m interannual variability and long-term trend
4. More reasonable E-P distribution

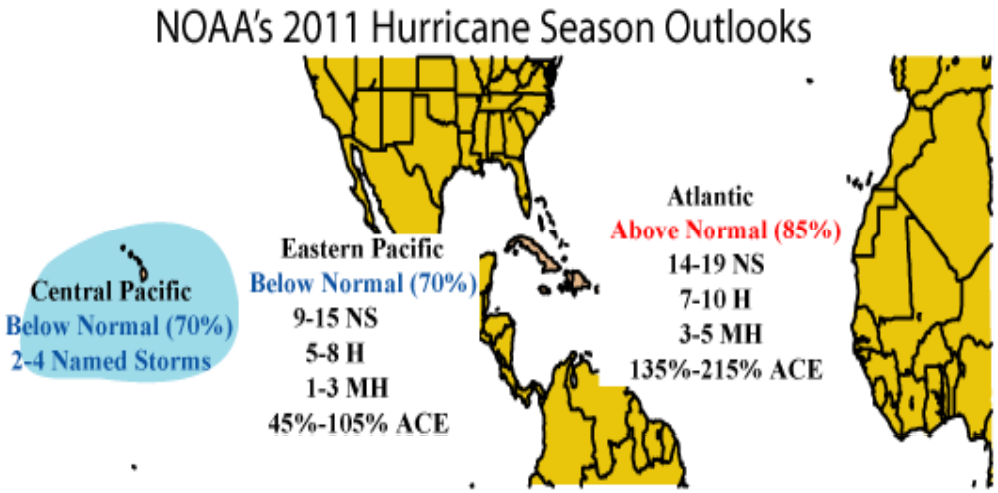
# Applications

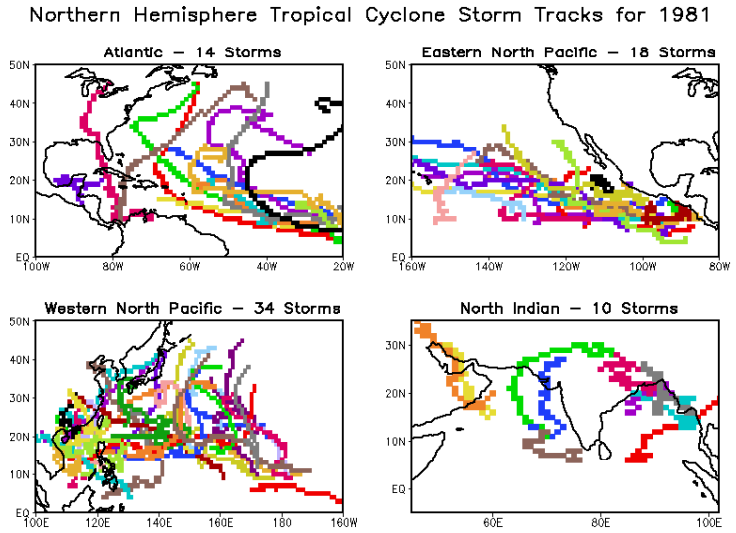
## Application of CFS for

## Dynamic Hurricane Seasonal Prediction

# Application of CFS for Dynamic Hurricane Seasonal Prediction

- CFS is used operationally (April+July) to produce an ensemble of high resolution runs in support of NOAA's Atlantic and Eastern Pacific Hurricane Seasonal Outlooks.
- CFS is able to reliably capture the net seasonal frequency and intensity of tropical cyclone activity in these basins.



# Datasets

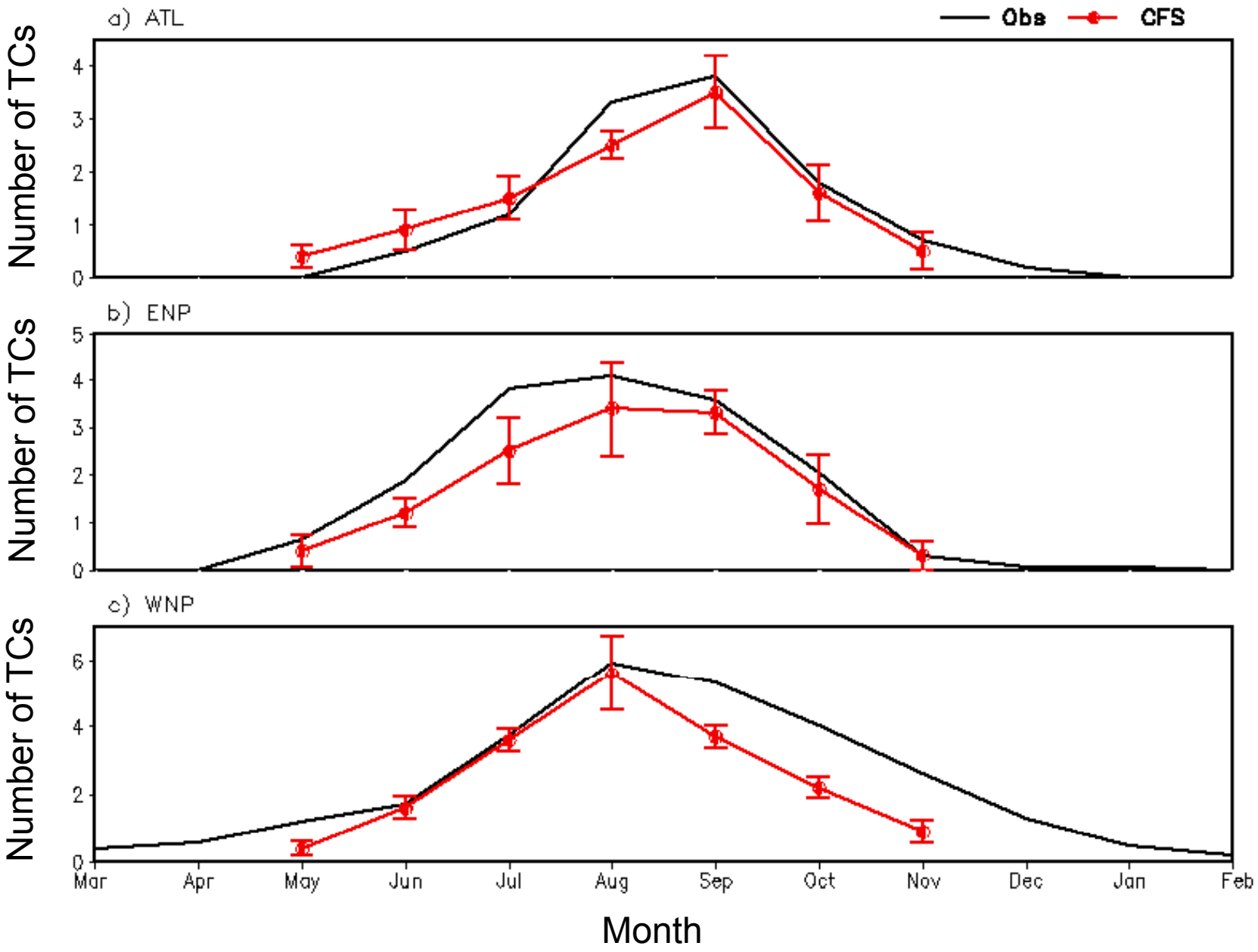
- CFS Hindcasts at T382
  - 5 Members: April 19-23 at 00Z
  - Output every 6 hours
  - 28 Years: 1981-2008

- Observations from HURDAT Best Track Dataset
  - Tropical depressions and subtropical storms are not included in the storm count.

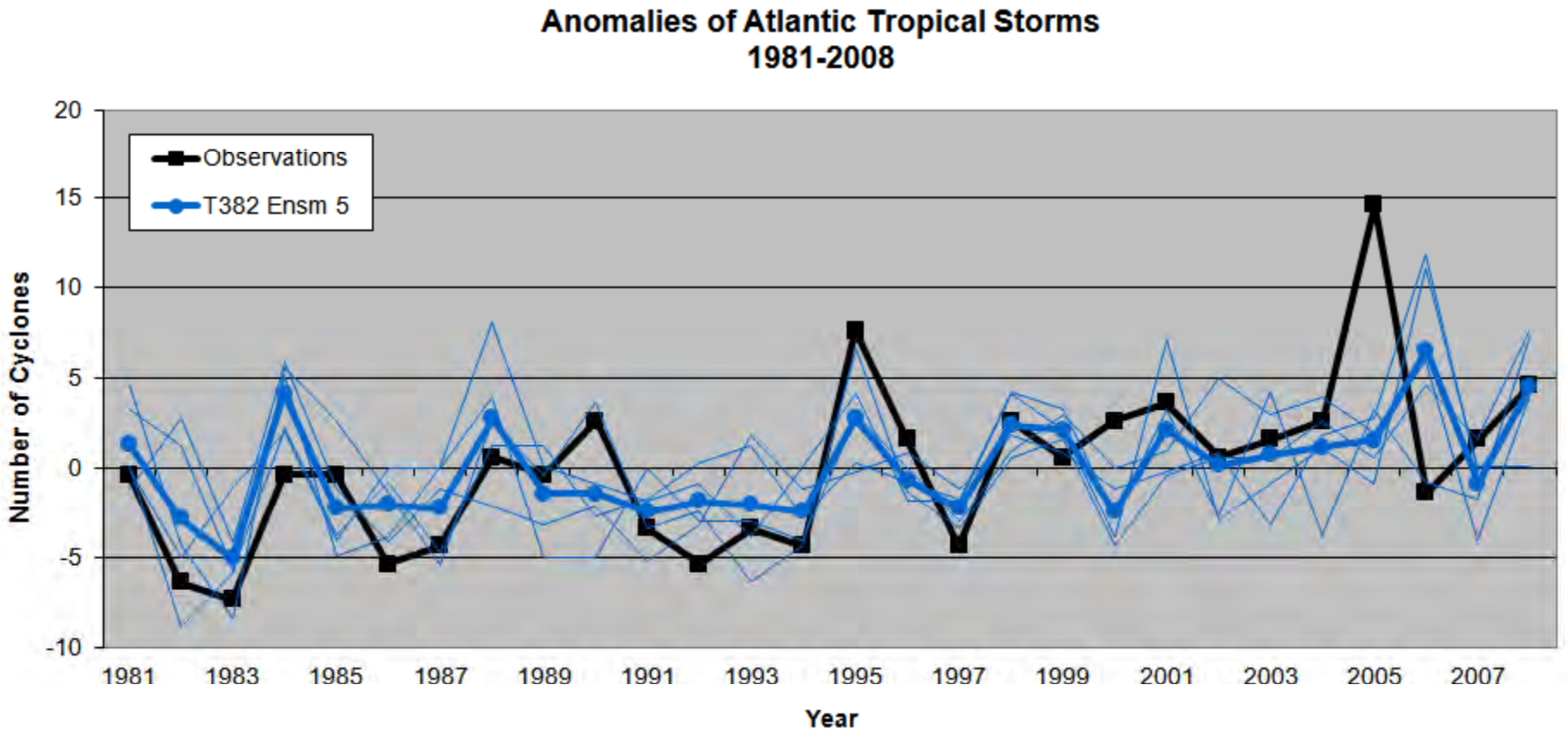
# Detection & Tracking Method

- Method based on Camargo & Zebiak (2002)
  - Point must meet 7 criteria to be considered a storm
  - Tracked forward and backward in time following vorticity maxima > $3.5 \times 10^{-5}$ $s^{-1}$

# Seasonal Cycle

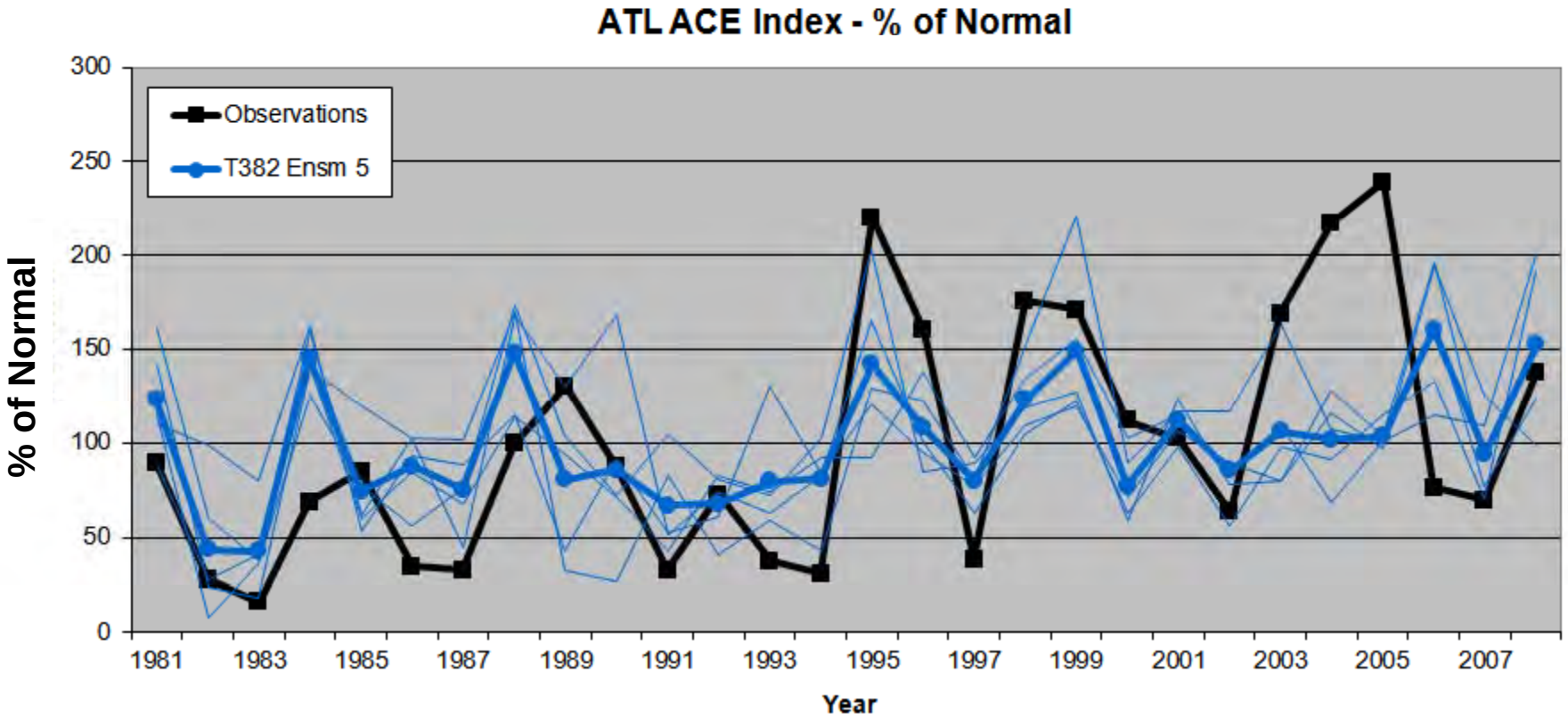


# ATL Interannual Variability




| T382 | Correlations |
|---|---|
| April Ensm 5 | 0.62 |

# ATL Basin ACE Index




The ACE Index measures the amount of energy produced by the storm during its lifetime. It is the summation of the surface winds squared, taken every 6 hours of the storm's duration.

| T382 | Correlations |
|---|---|
| April Ensm 5 | 0.63 |

# Tropical Storm Count Statistics

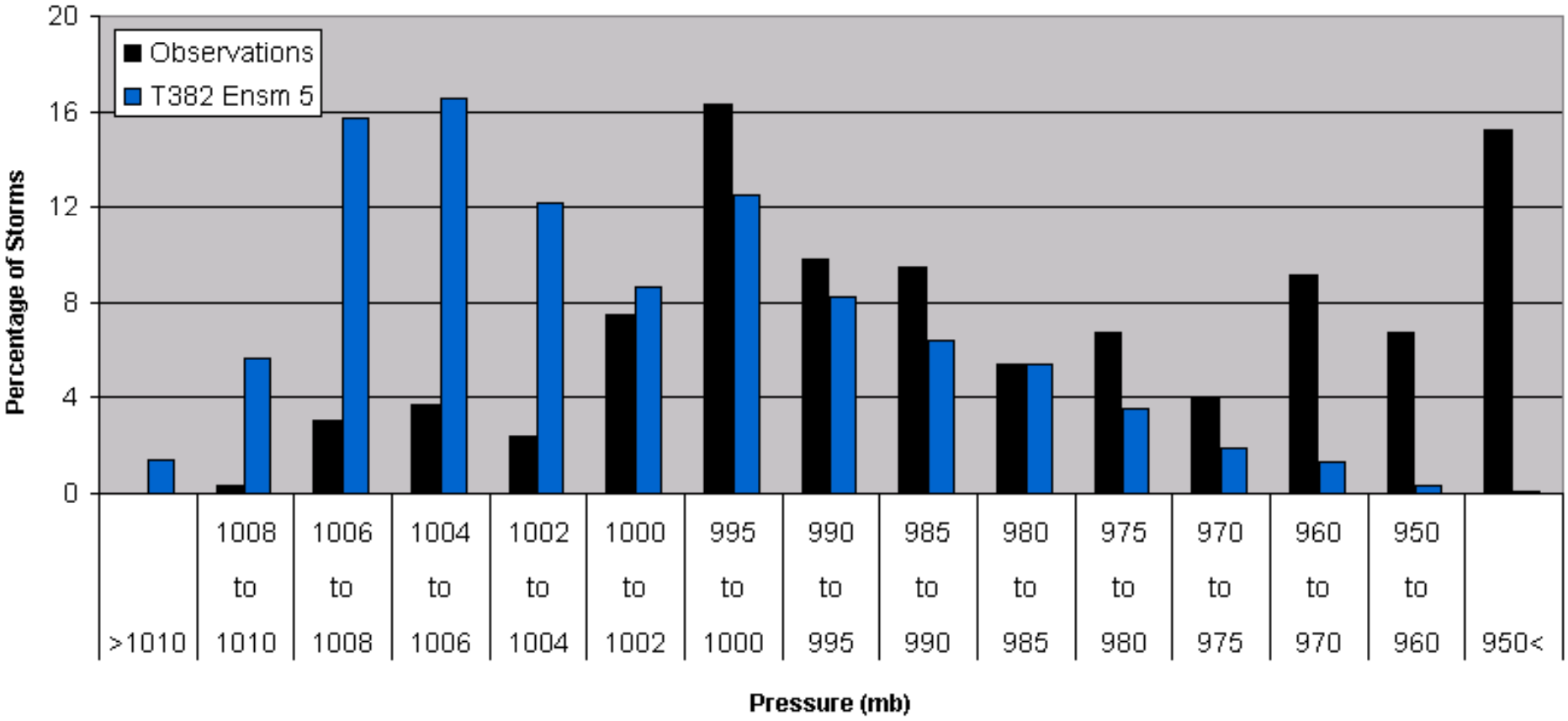
| **ATL** | Mean | Median | Standard Deviation |
|---|---|---|---|
| Observations | 11.4 | 11.5 | 4.8 |
| T382 Ensemble | 10.9 | 10.1 | 2.8 |

| **ENP** | Mean | Median | Standard Deviation |
|---|---|---|---|
| Observations | 16.1 | 16.5 | 1.8 |
| T382 Ensemble | 12.9 | 13.1 | 4.1 |

| **WNP** | Mean | Median | Standard Deviation |
|---|---|---|---|
| Observations | 24.2 | 23.5 | 4.0 |
| T382 Ensemble | 18.0 | 18.5 | 4.1 |

The CFS tends to underestimate the number of storms in each basin, especially the Western North Pacific.

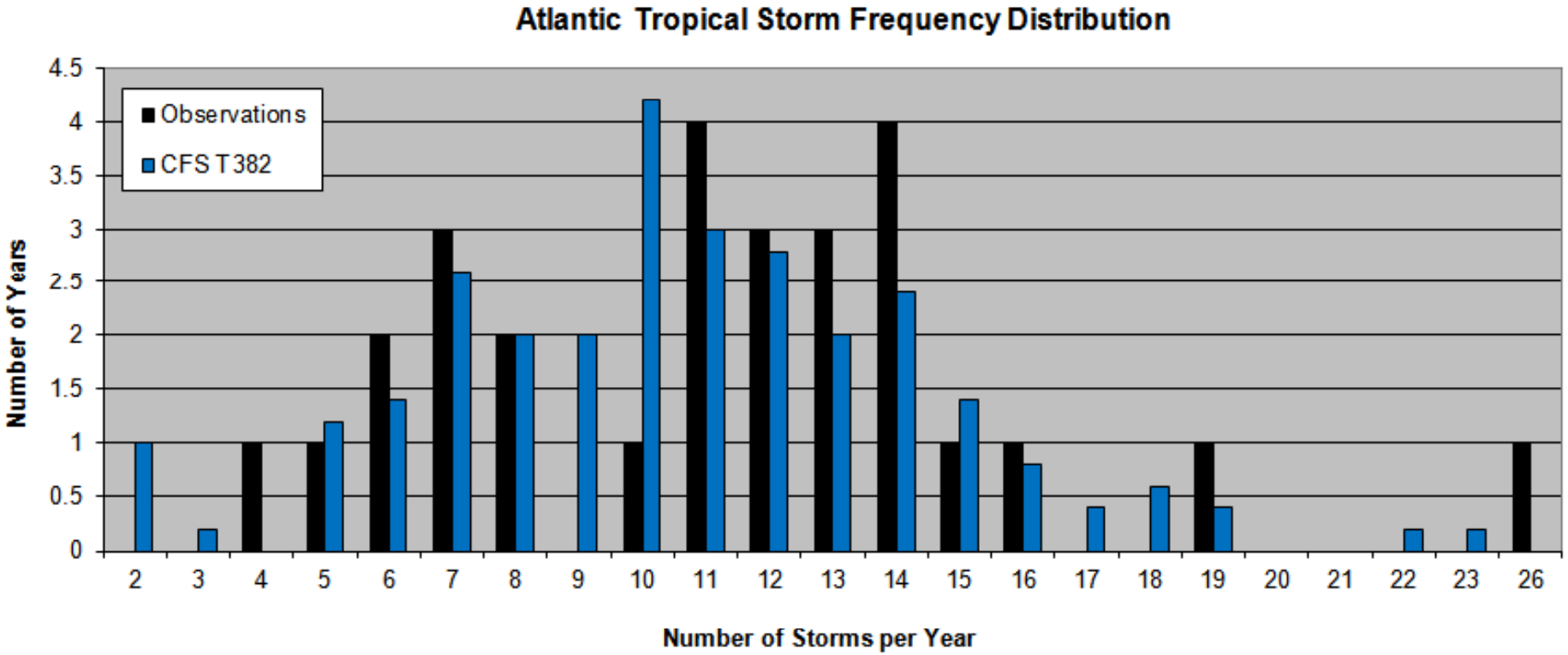
# Frequency of Minimum Pressure - ATL




CFS Minimum Pressure Range: 1017 - 950 mb

OBS Minimum Pressure Range: 1009 - 882 mb (Wilma, 2005)

# Storm Frequency Distribution - ATL



# Summary of Results for Atlantic

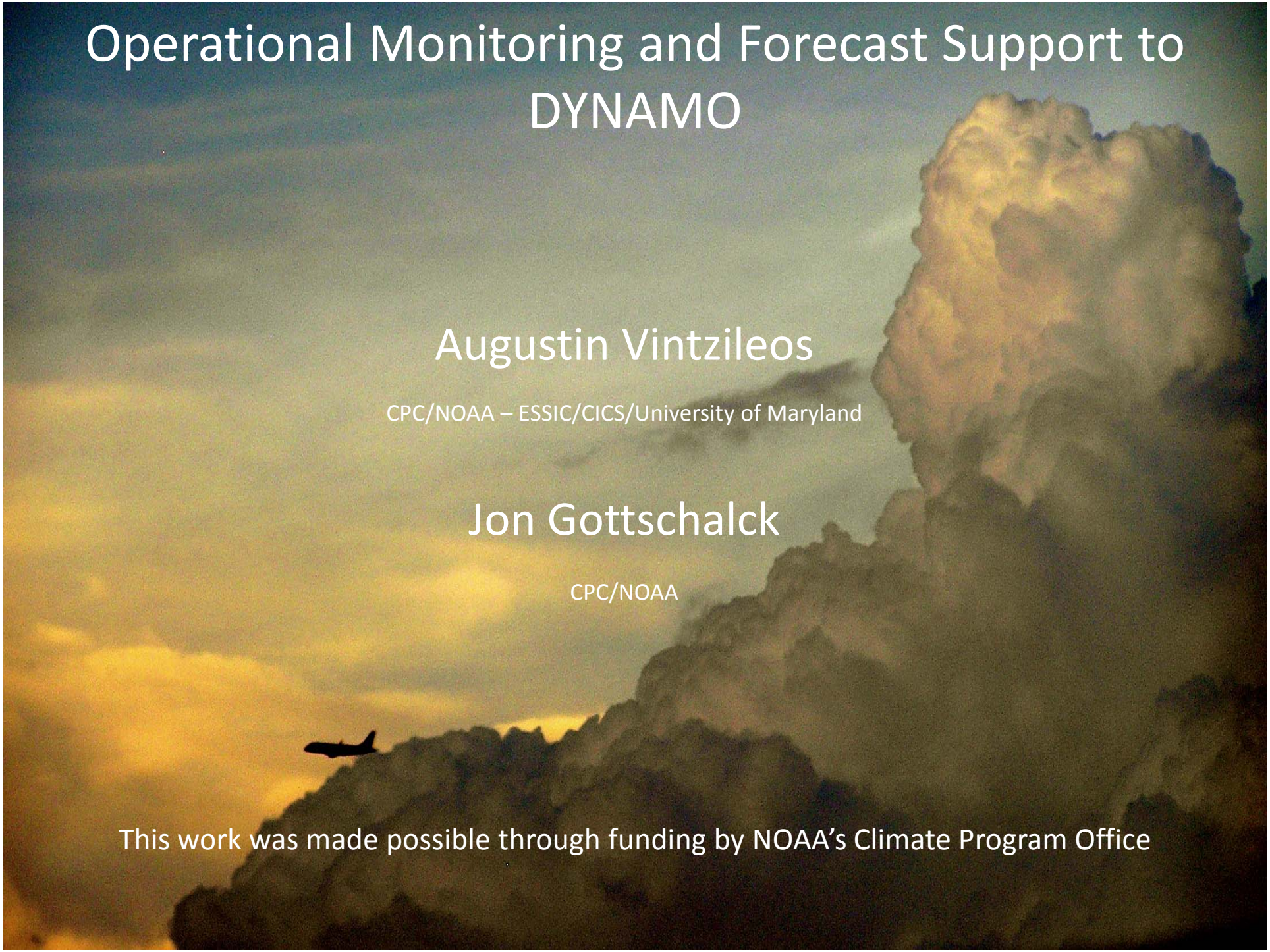
- CFS Reforecasts at T382:
  - Captures annual cycle in number of TCs
  - Produces statistically significant Interannual variations in the number of TCs and accumulated cyclone energy
  - Tends to underestimate the total number of TCs per season
  - Tends to underestimate the minimum central pressure range

# CPC and the CIs

# How is CPC involved with CIs?

- Historically: long-standing relationship with CICS
- Thematically: CPC mission links closely to CICS science themes
- Practically: CICS provides a useful alternative mechanism for sponsoring visitors and collaborative science at CPC
- CPC would like to enhance relationship with the other CI's
- 3 Examples of CPC-CICS coordination

# Operational Monitoring and Forecast Support to DYNAMO




Augustin Vintzileos

CPC/NOAA – ESSIC/CICS/University of Maryland

Jon Gottschalck

CPC/NOAA



This work was made possible through funding by NOAA's Climate Program Office

# What is DYNAMO?

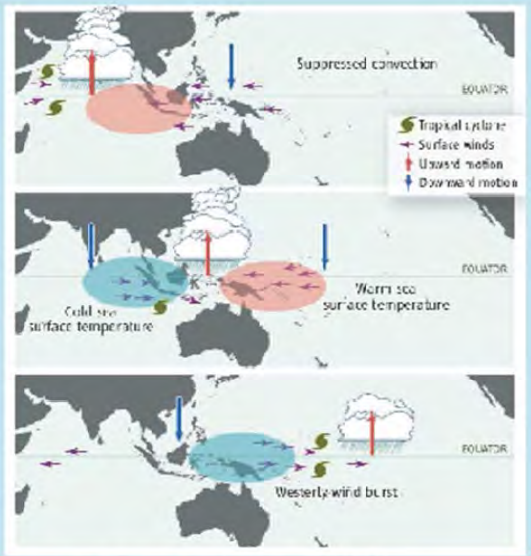
**DYNAMO** – *Dynamics of the Madden-Julian Oscillation (MJO)* – is a US research program for improving our understanding of MJO initiation and our capability of forecasting it.

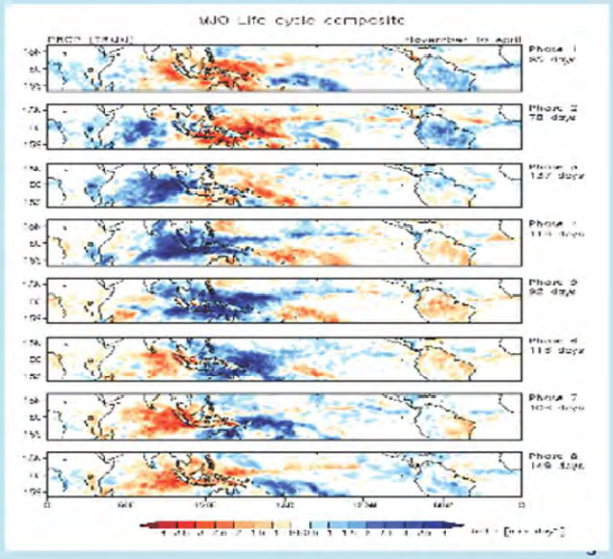

US agencies supporting DYNAMO: NOAA, NSF, ONR, DOE, NASA

DYNAMO is the US participation in *CINDY2011*.

## What is the MJO (Madden-Julian Oscillation)?

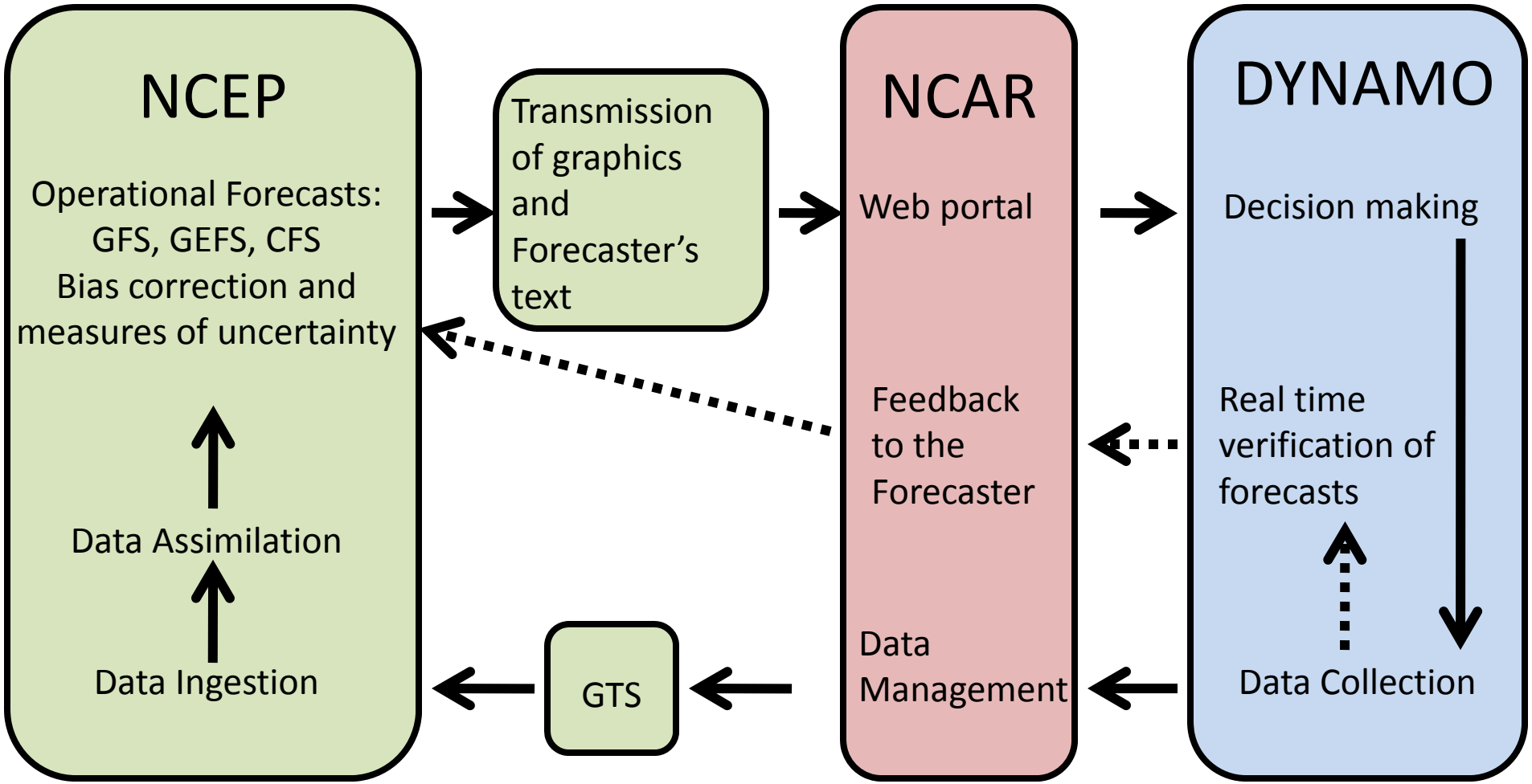
- Period: 30 – 80 days (intraseasonal)
- Eastward propagation speed: ~5m/s
- Main action center: equatorial Indian Ocean and western Pacific




Hartmann and Hendon (2007)

# Comprehensive Operational Forecast Support to DYNAMO: Work funded by NOAA/CPO



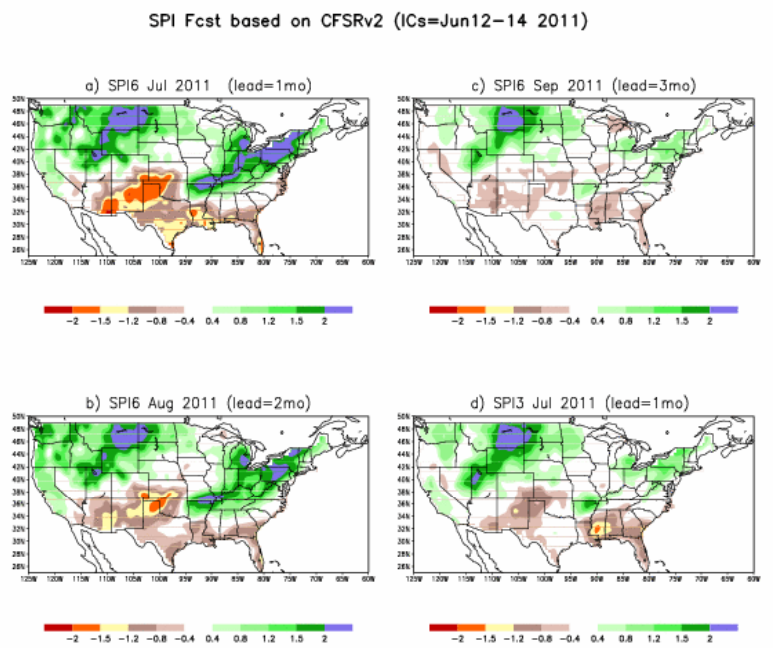

Gottschalck and Vintzileos (2011)

# CPC –CICS/ESSIC Drought Monitoring and Prediction Efforts

Kingtse Mo (CPC) and Li-Chuan Chen (CICS/ESSIC)

**Drought Monitoring and Prediction Tasks**

- **Develop next generation Drought Monitor and Seasonal Drought Outlook products (e.g. experimental monthly drought outlook for NIDIS)**
- **Deliver regional drought information to users via briefings (e.g. Monthly Drought Briefing) and web pages**
- **Research to improve objective drought forecast products based on the CFSv2**



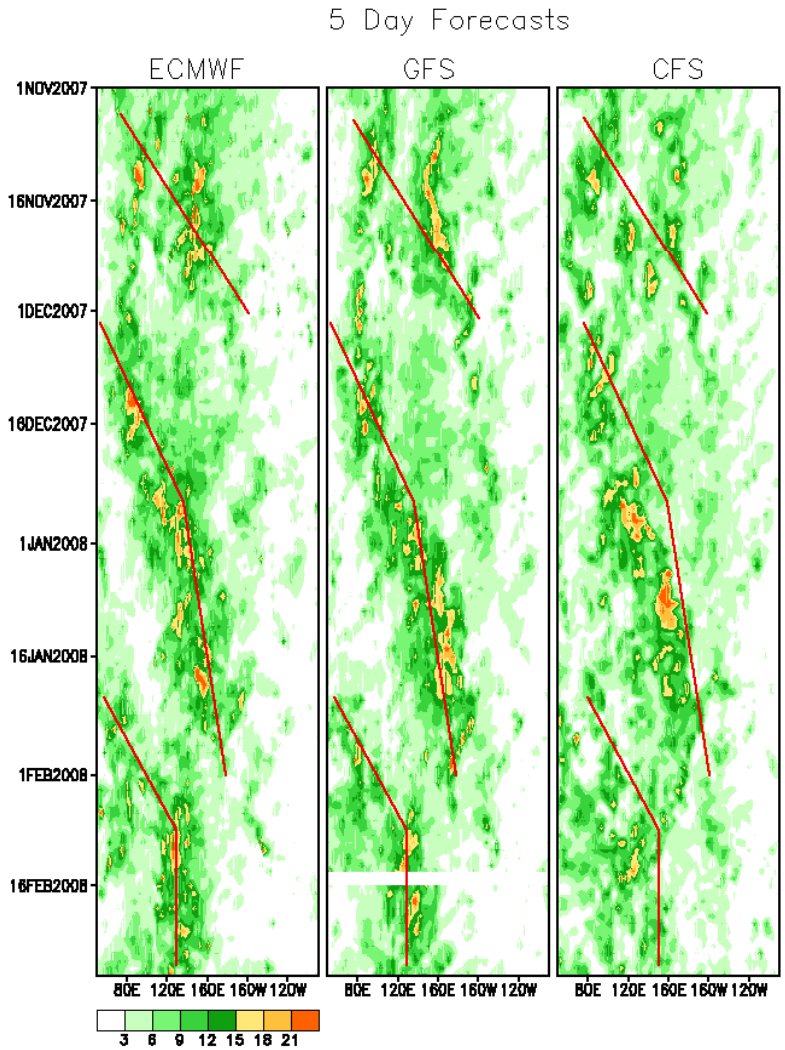

3-mo and 6-mo Standardized Precipitation Index (SPI) based on operational seasonal precipitation forecasts from CFSv2 are used for

✓ monthly drought briefing

✓ monthly and seasonal Drought Outlook.

# CPC – CICS/ESSIC
# Reliability of Precipitation Forecasts during MJO Events

**Hovmoller Diagram of Precipitation (15ºN-15ºS)**




red lines show evolution from observations ("CMORPH")

"5-day forecasts look good (even out to 10-day forecasts, … although the evolution shows increasing lag with increasing forecast projection)".


Janowiak[1], Bauer[2], Wang[3], Arkin[1], Gottschalck[3], 2010: An Evaluation of Precipitation Forecasts from Operational Models and Reanalyses Including Precipitation Variations Associated with MJO Activity. *Mon. Wea. Rev.* (in press)



[1] CICS/ESSIC
[2] ECMWF
[3] CPC

# Enhancing the Role of CI'S at CPC

- Expand use of CI'S to hire scientists (i.e. postdocs or contractors) who enhance the provision of applied research, observations, analysis, services and stakeholder input that contributes to CPC mission
- Collaborate with CI-affiliated researchers on topics of mutual interest
- Coordinate joint visiting scientist programs
- Coordinate summer intern programs
- Coordinate joint seminar series
- Potentially: CPC and CICS relationship could serve as a model for NWS engagement with the NOAA CIs