An overview of true-color imagery products from space: ATS-3 to GOES-R

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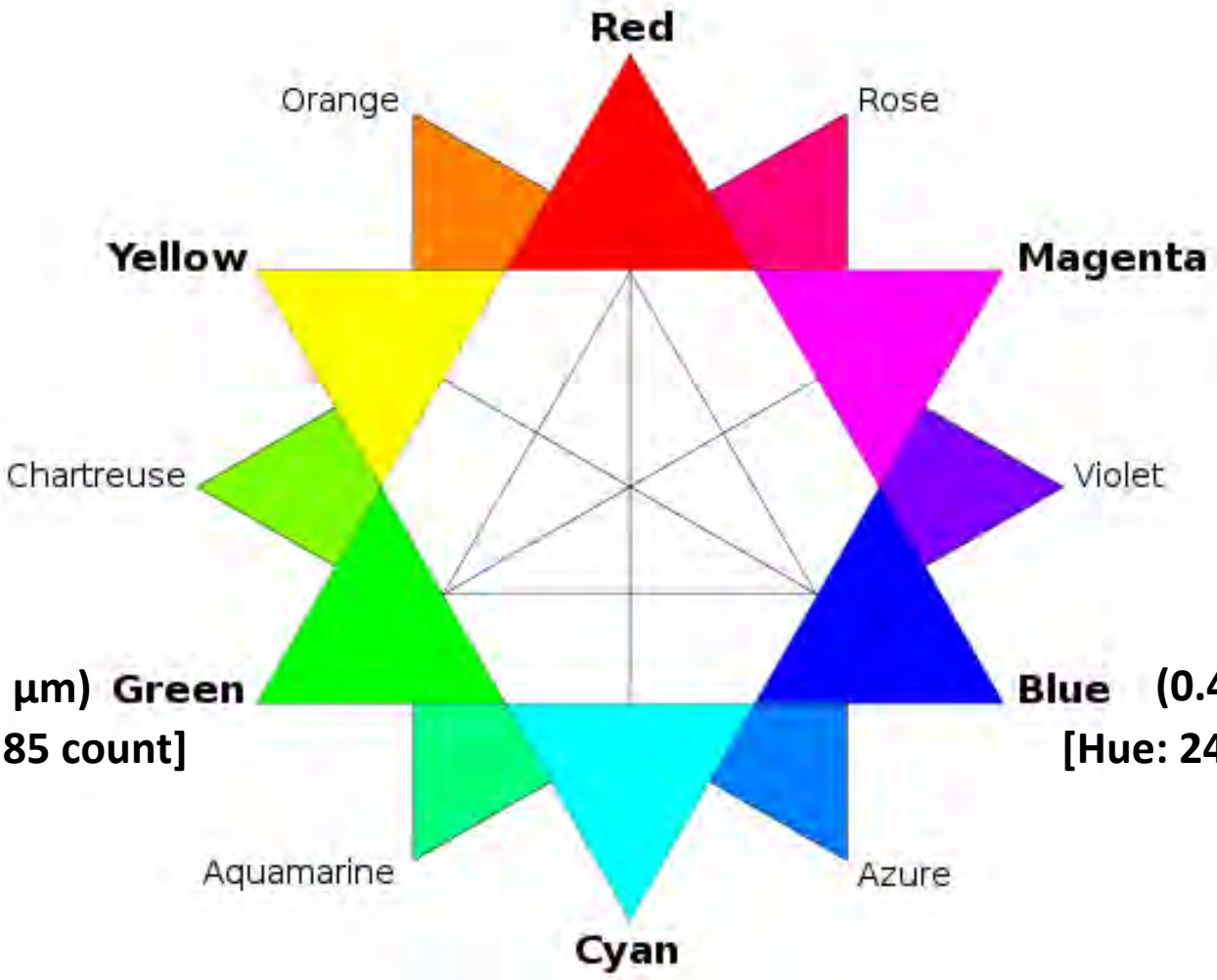
Color Wheel

[Hue: 360° - 255 count]
[Hue: 0° - 0 count]
(0.64 µm)

Hue: 0 to 360° or
0 to 255 counts



(0.55 µm) Green
[Hue: 120° - 85 count]

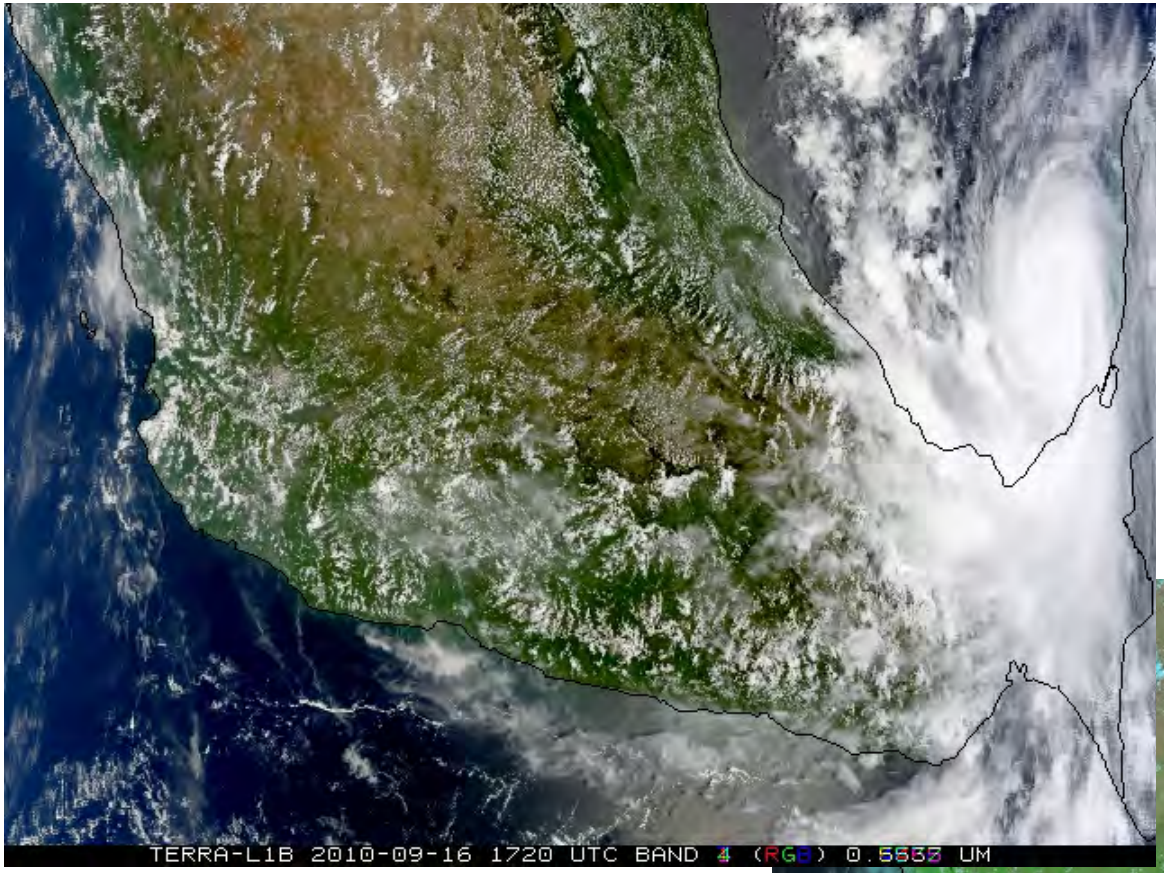
Blue (0.47 µm)
[Hue: 240° - 170 count]

True-color vs. RGB

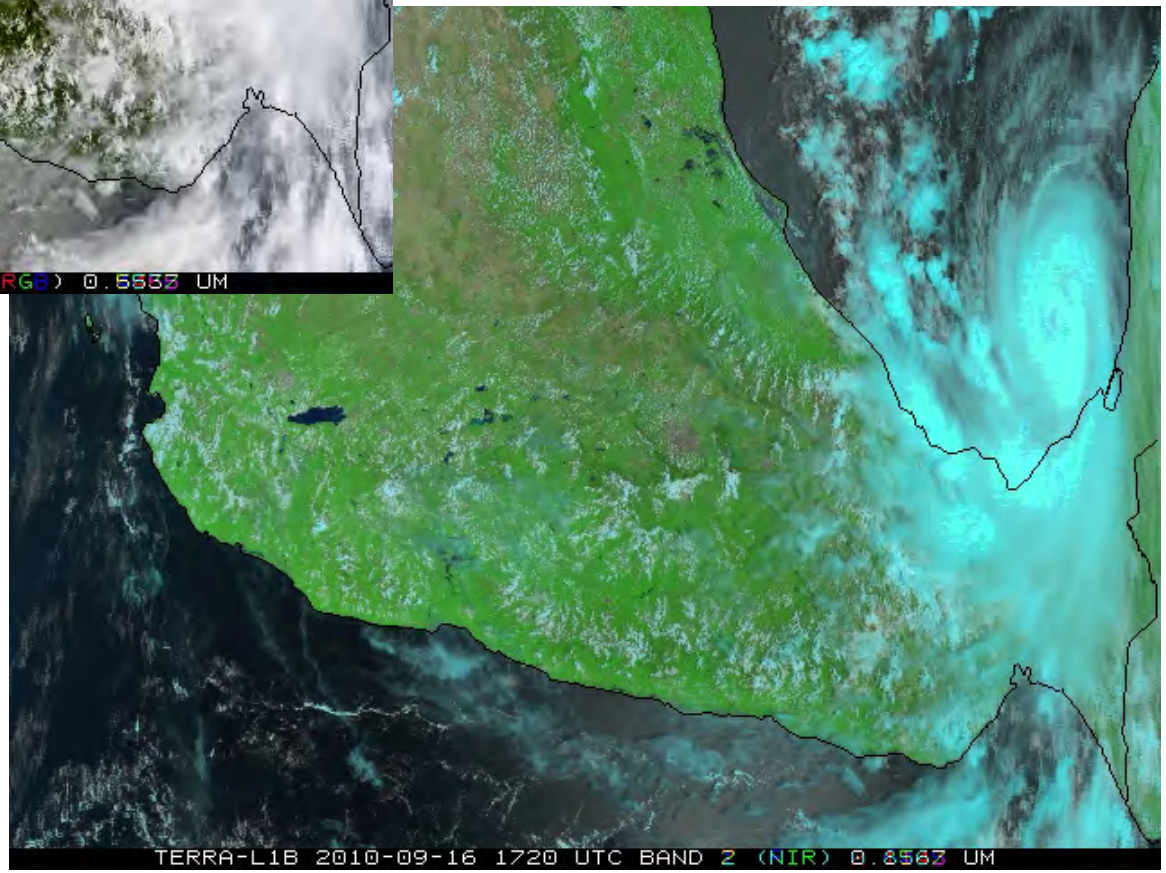
- **True-color** imagery is obtained by adding/ combining the Red, Green, and Blue visible/ reflective images.

- **RGB** imagery can refer to many types of **false-color** imagery that are obtained by using RGB techniques to combine images other than the Red, Green, and Blue images.

True-color vs. False-color (both are RGB)



True-color (Red, Green, Blue)
MODIS bands 1+4+3



False-color / RGB
MODIS bands 7+2+1
Also called natural color

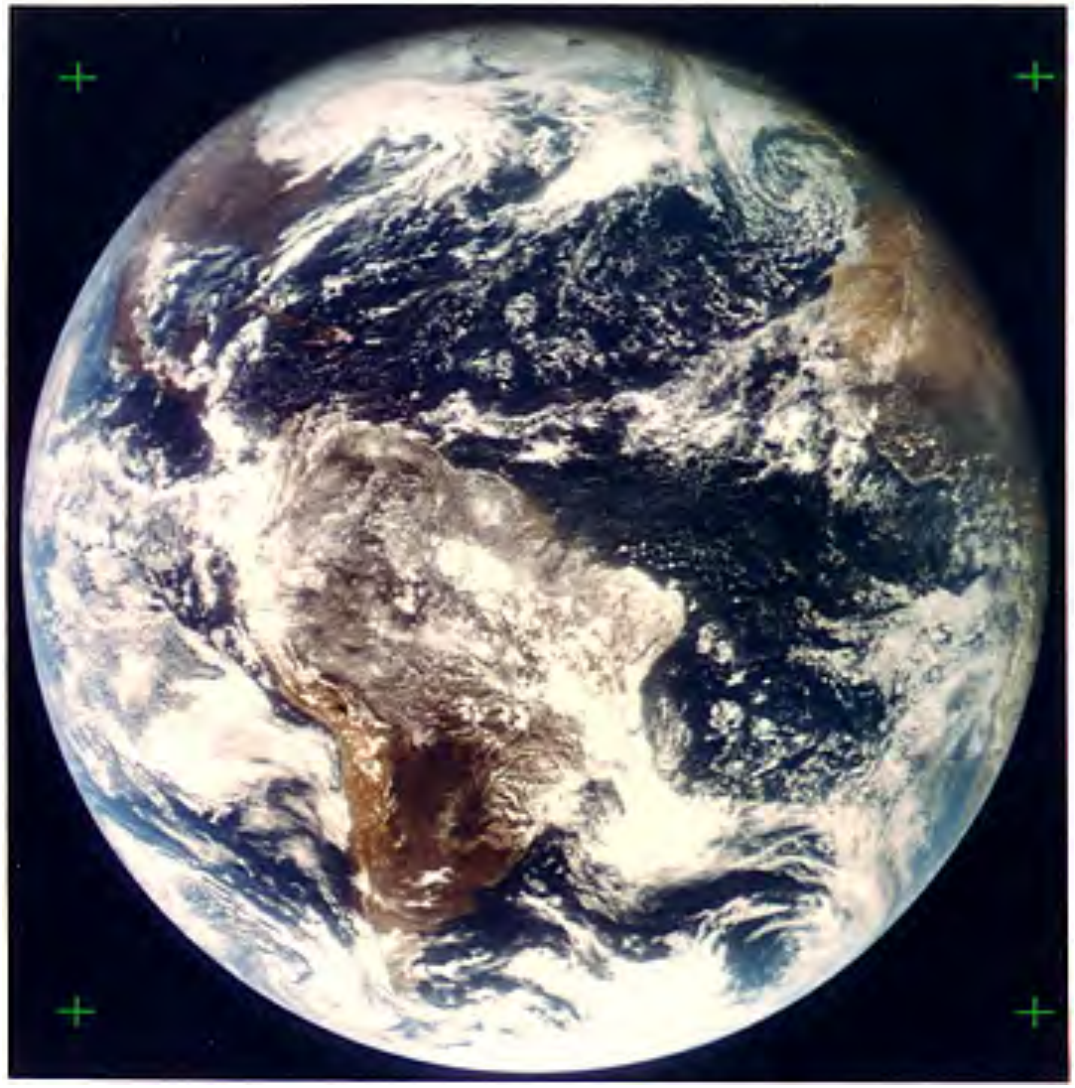
True-color from geostationary orbit

- 1967—1974/5
  - **MSSCC (Multicolor Spin-Scan Cloudcover Camera)** on **ATS-3** (Applications Technology Satellite)
  - (True-color was only available for the first 3 months.)

- ~2015
  - **ABI (Advanced Baseline Imager)** on **GOES-R**
  - (Green only as synthesized from Red, Blue, and Near IR bands)

- ~2014
  - **Modified ABI** on Japanese **MTSat-3** (Multi-functional Transport Satellite)
  - (Green directly available, along with Red and Blue bands)

The **Multicolor Spin Scan Cloud Camera (MSSCC) on ATS-3** (launched 5 November 1967) produced striking portraits of entire continents such as this view of South America (~ 4 km resolution @ nadir)

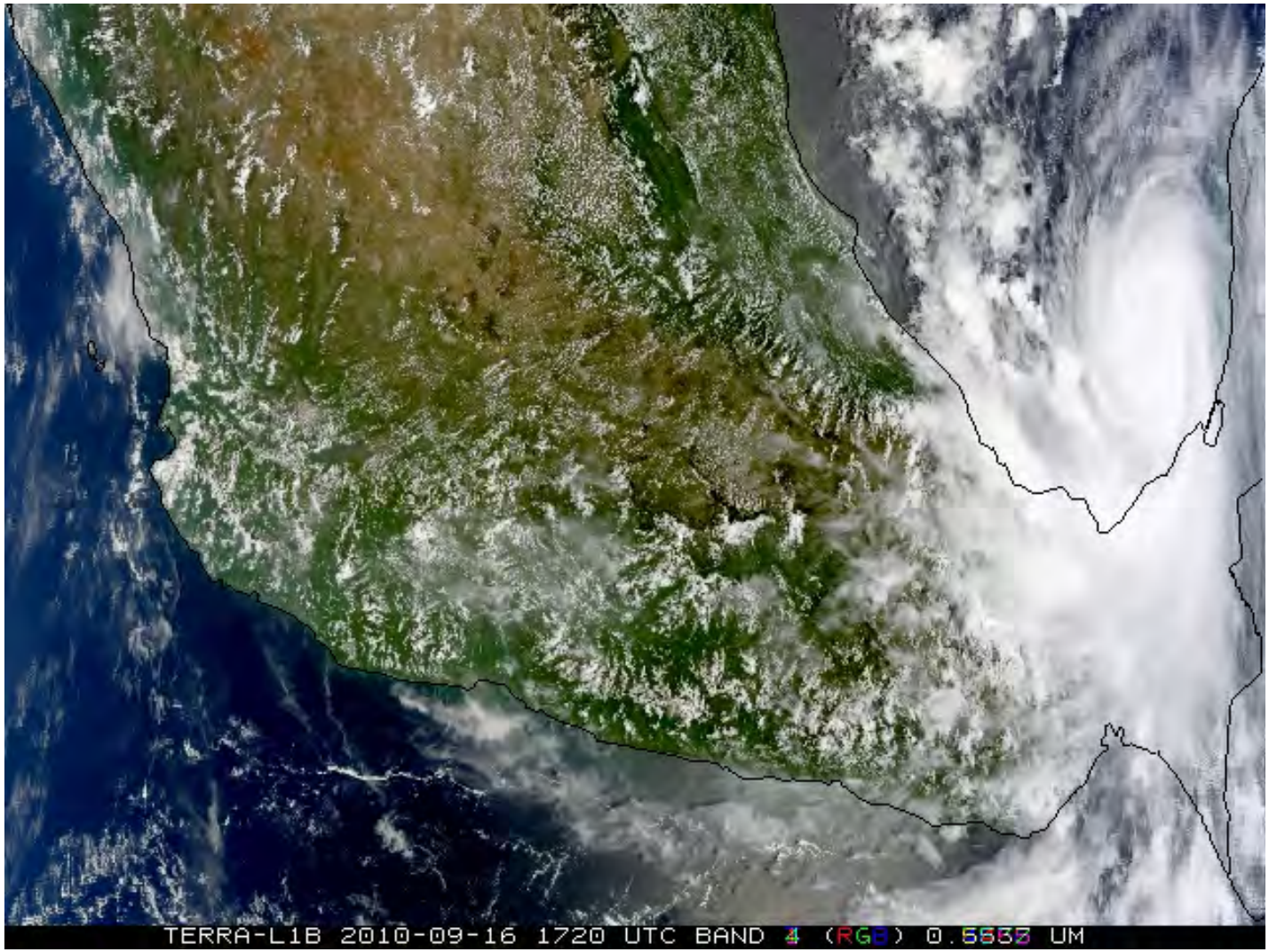


True-color from polar orbit

- 1997 — 2010
  - **SeaWiFS** (**Sea**-viewing **Wi**de **F**ield-of-view **S**ensor) on SeaStar / OrbView-2 satellite
- 1999 — present
  - **MODIS** (**Mod**erate resolution **I**maging **S**pectroradiometer) on EOS-Terra and EOS-Aqua satellites
- ~25 October 2011
  - **VIIRS** (**V**isible/**I**nfrared **I**mager **R**adiometer **S**uite) to be on NPP and JPSS series satellites

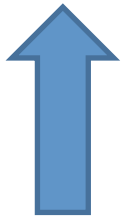
Examples of **SeaWiFS** true-color images (Florida and Alaska, respectively)

Example of **MODIS** true-color
Hurricane Karl, 2010-09-16 at 1720 UTC



Visible/reflective RGB bands on current and future satellites

	Geostationary				Polar-Orbiting	
	Current GOES Imager	Meteosat / MSG SEVIRI	GOES-R ABI	MTSat-3 Modified ABI	EOS MODIS	NPP VIIRS
Red	Red	Red	Red	Red	Red	Red
Green				Green	Green	Green
Blue			Blue	Blue	Blue	Blue



Missing Green band:

This is the challenge for generating high-temporal resolution true-color imagery over the U.S. for the foreseeable future.

GOES-R ABI Bands

	ABI Band	Central Wavelength (μm)	Wavelength Range (μm)	Band Explanation	Spatial Resolution (km) @ nadir
Reflective bands	1 (blue)	0.47	0.45 - 0.49	Visible/reflective	1
	X (green)	0.55	Synthesized	Visible/reflective	1
	2 (red)	0.64	0.59 - 0.69	Visible/reflective	0.5
	3	0.865	0.846 - 0.885	Reflective	1
	4	1.378	1.371 - 1.386	Cirrus	2
	5	1.61	1.58 - 1.64	Snow/ice	1
Emissive bands	6	2.25	2.225 - 2.275	Particle size	2
	7	3.90	3.80 - 4.00	Shortwave IR window	
	8	6.19	5.77 - 6.6	Water vapor	
	9	6.95	6.75 - 7.15	Water vapor	
	10	7.34	7.24 - 7.44	Water vapor	
	11	8.5	8.3 - 8.7	Water vapor, SO_2	
	12	9.61	9.42 - 9.8	Ozone	
	13	10.35	10.1 - 10.6	Longwave IR window	
	14	11.2	10.8 - 11.6	Longwave IR window	
	15	12.3	11.8 - 12.8	Longwave IR	
	16	13.3	13.0 - 13.6	Longwave IR	

How do we get true-color from GOES-R ABI?

- One method: put GOES imagery over a true-color background (as demonstrated on NexSat website)
- Or: synthesize the Green band from the other ABI bands
  - Regression
  - Look-Up-Table (LUT)

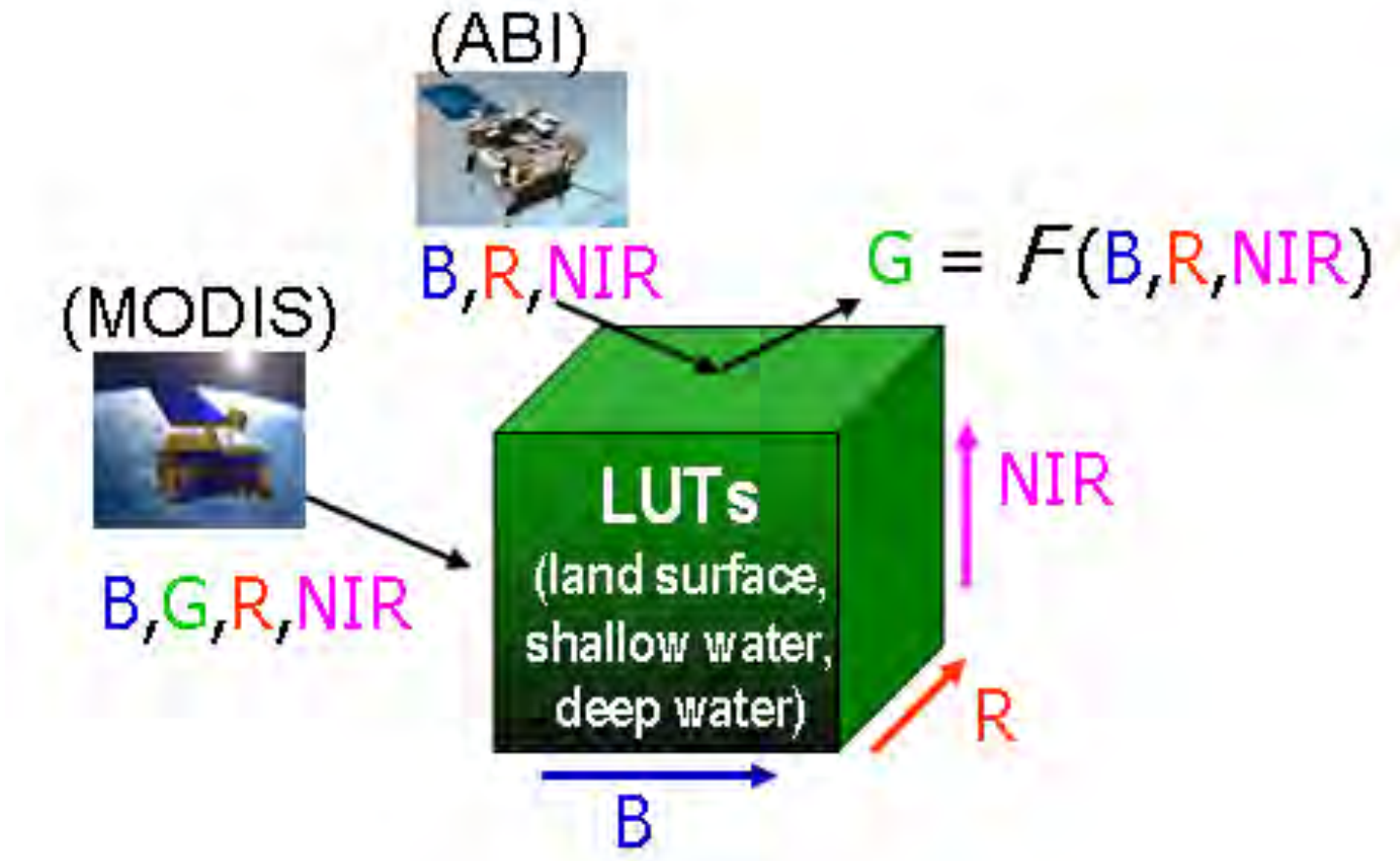
(Either method is trained on available true-color imagery, such as MODIS, where ABI-equivalent bands are available, as well as the Green band.)

One option: Put GOES over a true-color background (from MODIS)

'GeoColor' imagery from the *NexSat* website. The color background is composed of images from NASA's blue marble (MODIS data), with current GOES visible and infrared data overlaid via dynamic transparency factors.

Problem: Background is static, and does not represent current conditions.

Green Look Up Table (LUT) creation and use for ABI



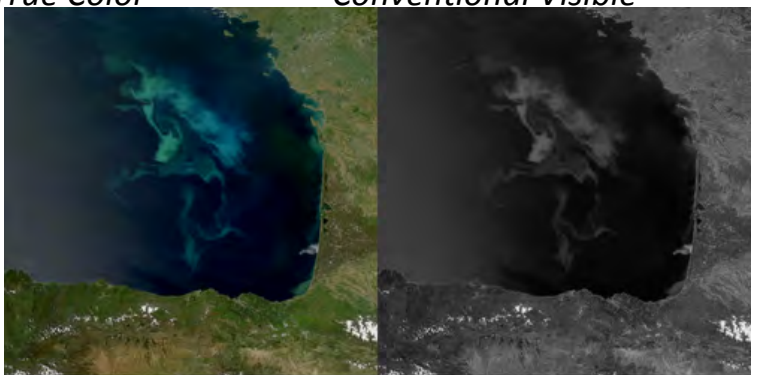
True Color for GOES-R ABI

- True color is the preferred format for basic satellite imagery presented at all circles (research, operations, and the general public) because of its intuitive appeal.
- Currently, only polar satellite systems offer true color capability, resulting in superb imagery but at poor temporal refresh.
- GOES-R series ABI's omission of the critical 0.55 μm (green) band precludes a native true color ability.
- A data fusion algorithm has been developed to '**synthesize**' the missing green band[1], allowing for approximate true color imagery from the GOES-R ABI.
- The algorithm has been demonstrated on NWP-based simulated ABI imagery[2].

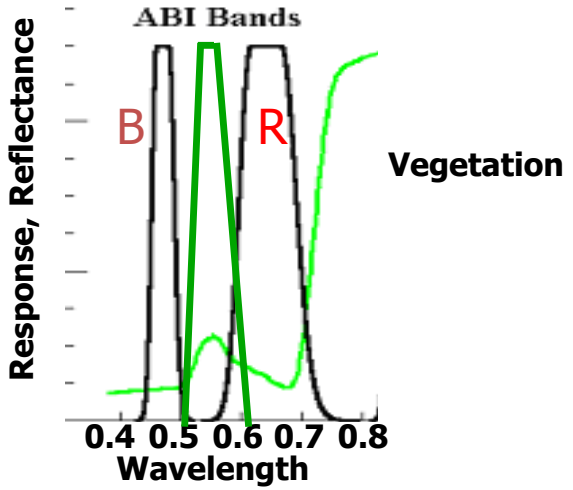
[1] Miller et al., IJRS, 2011 (In Press)

[2] Hillger et al., JARS, 2011 (DOI:10.1117/1.3576112)

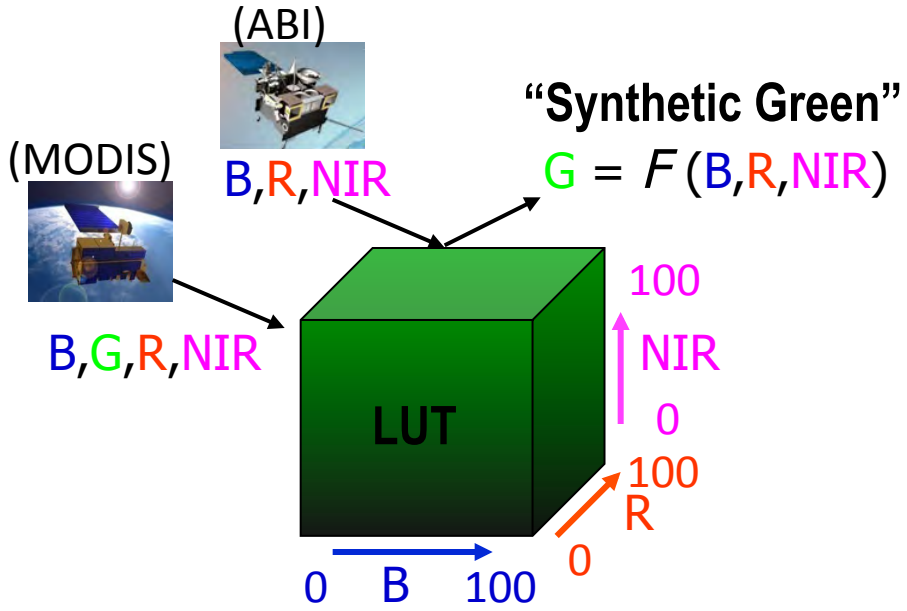
True Color *Conventional Visible*



Our last GEO-based true color capability: ~1967 (!!) on NASA's ATS-3 satellite

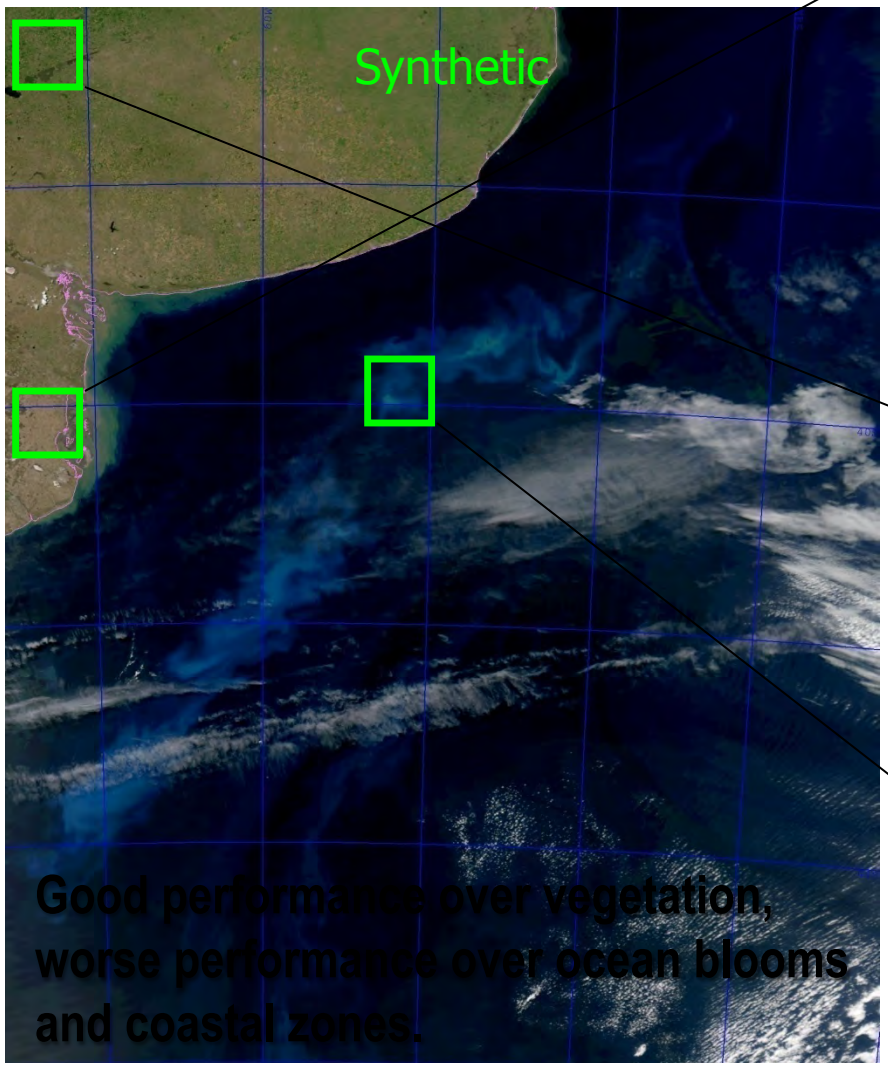


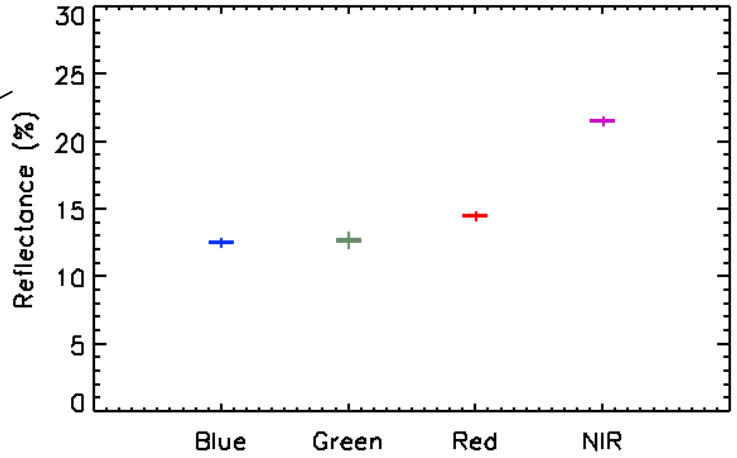
Synthetic Green Algorithm

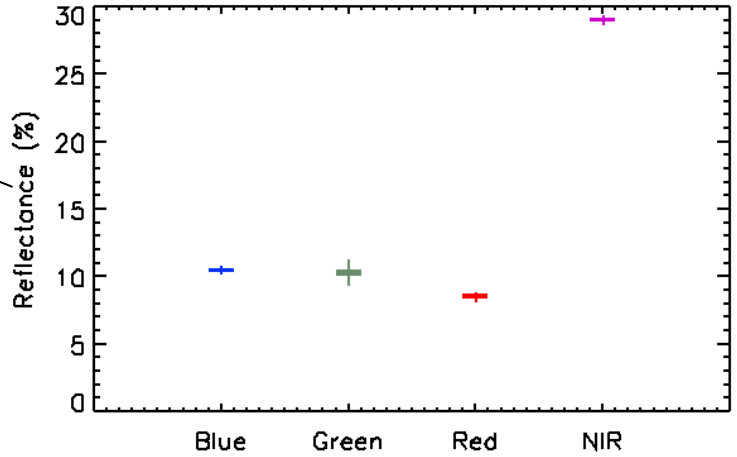


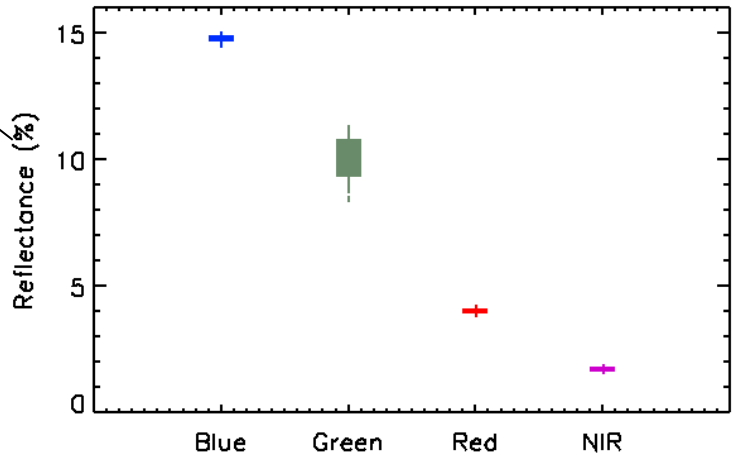
1. Begin with a sensor (MODIS) providing Blue (B), Green (G), Red (R), and Near-Infrared (NIR; 865 nm) information
2. Create a **Look-Up-Table** of G reflectance as a function of B, R, and NIR based on a global dataset (pre-corrected for Rayleigh scatter)
3. Synthesis Step: Consult the Look-Up-Table with new Blue/Red/NIR to estimate G
4. Use B, R, and the estimated G to produce a true color image

Performance



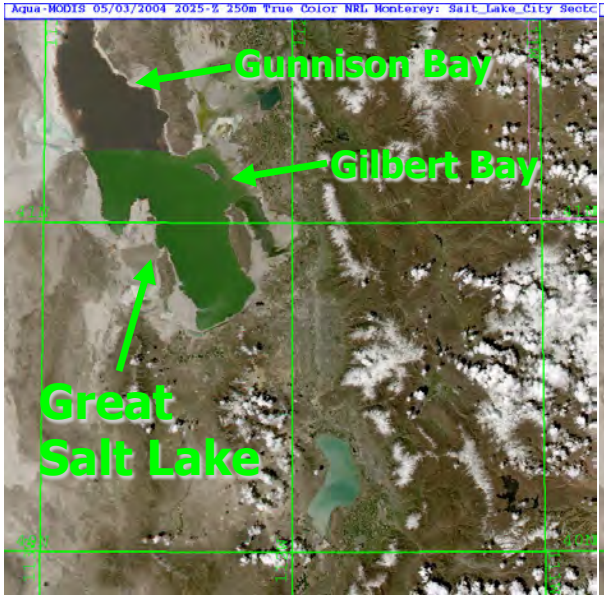




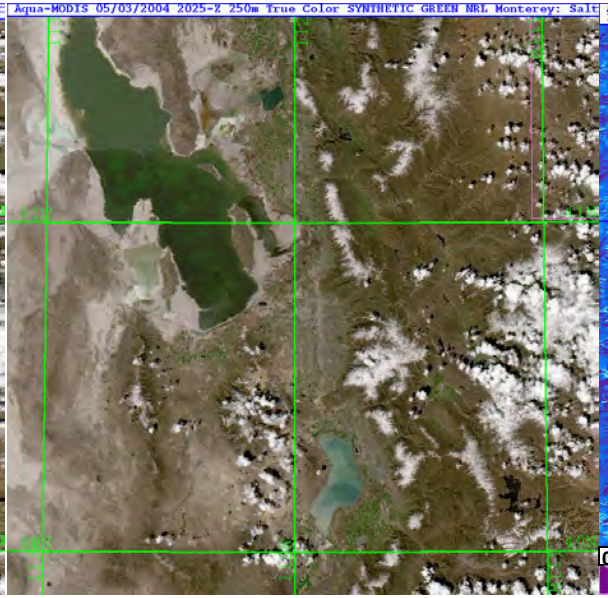


Comparisons

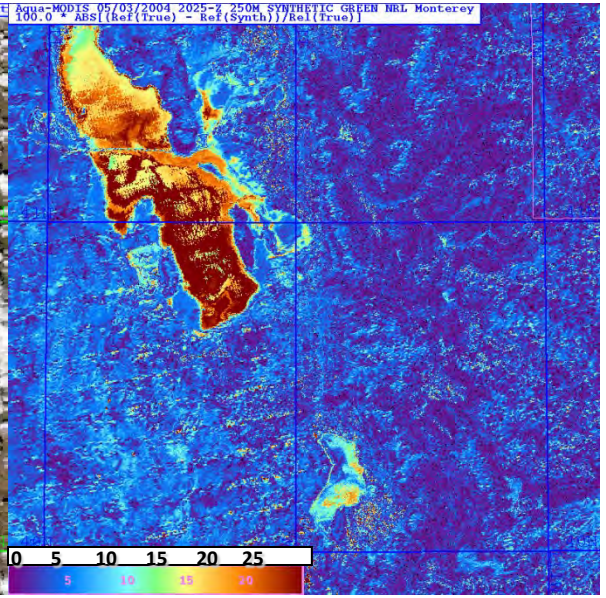
Truth



Approx



Relative Difference (%)

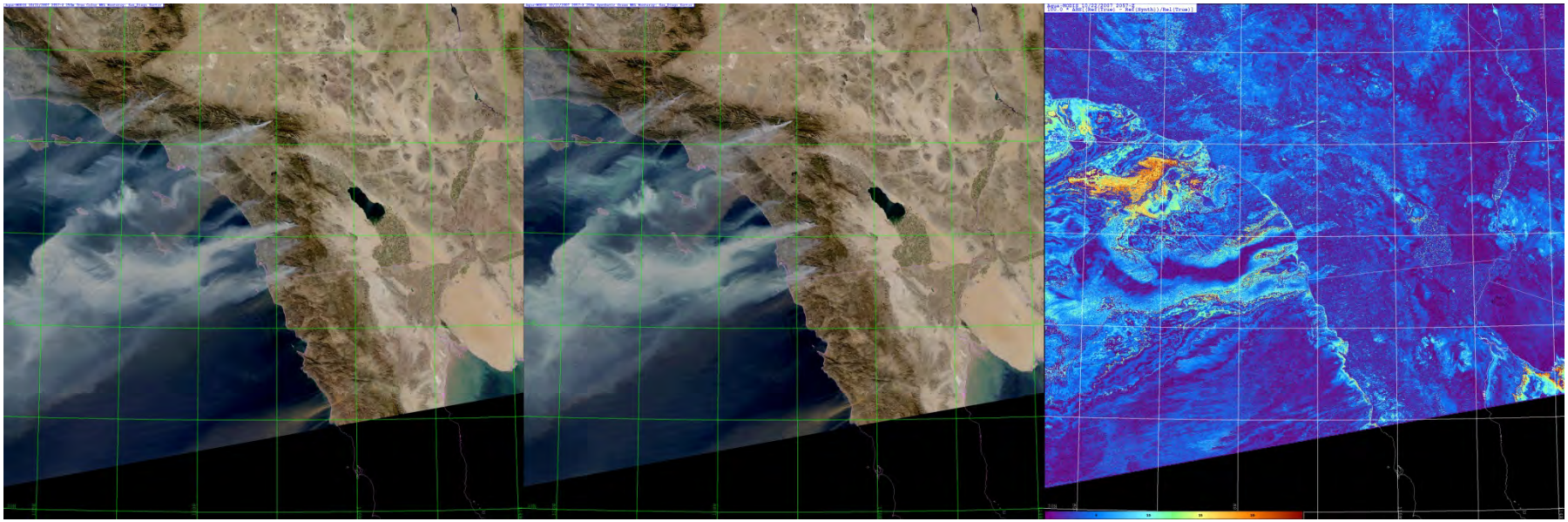


Comparisons

Truth

Approx

Relative Difference (%)

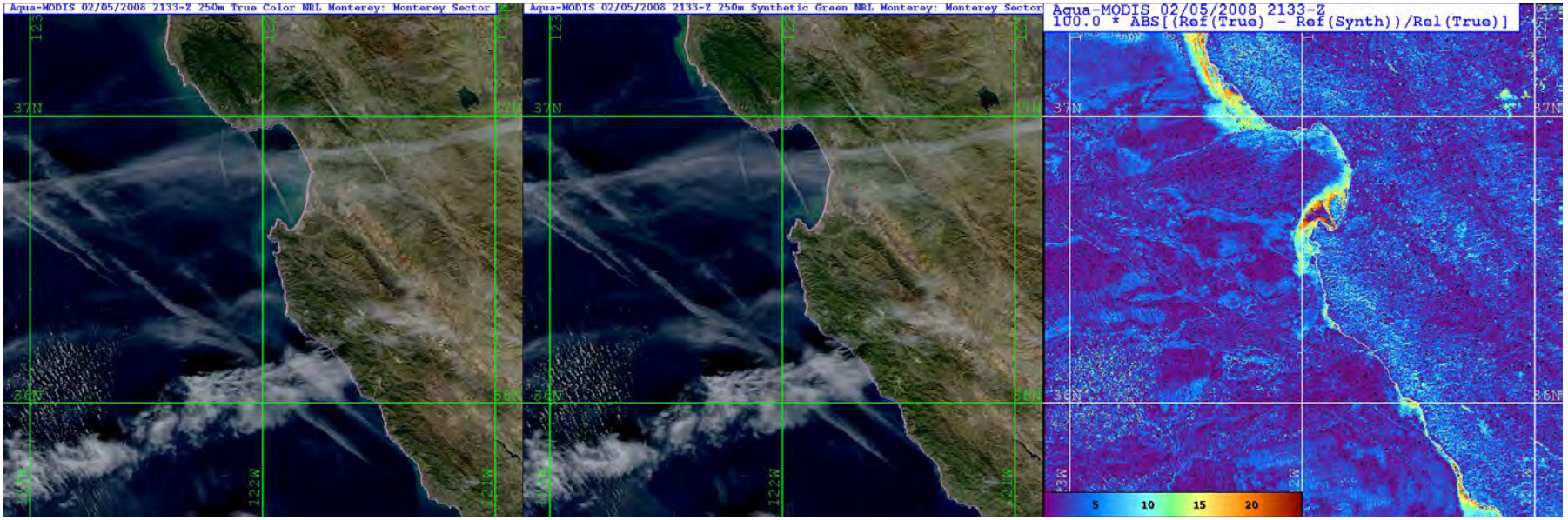


Comparisons

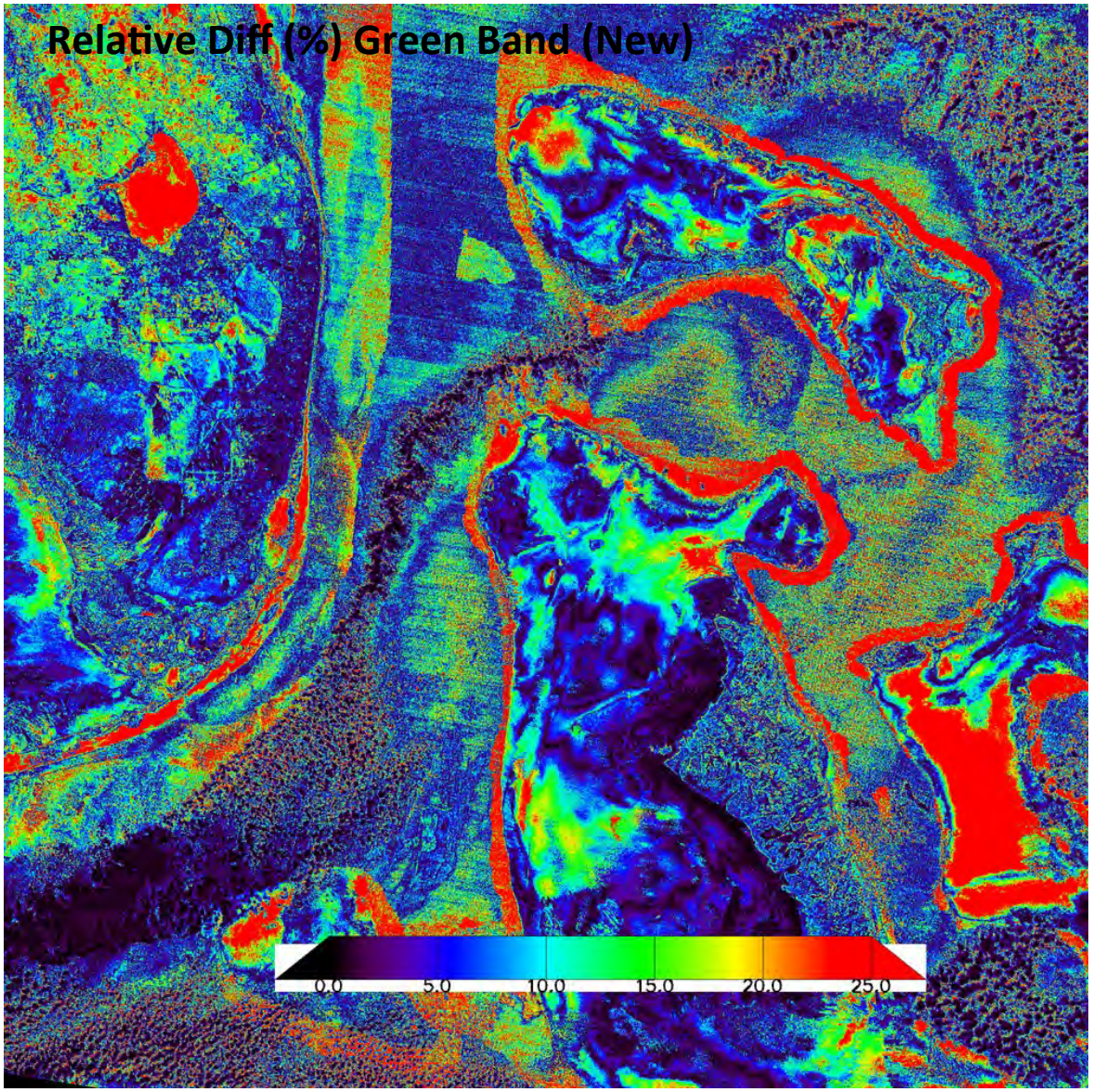
Truth

Approx

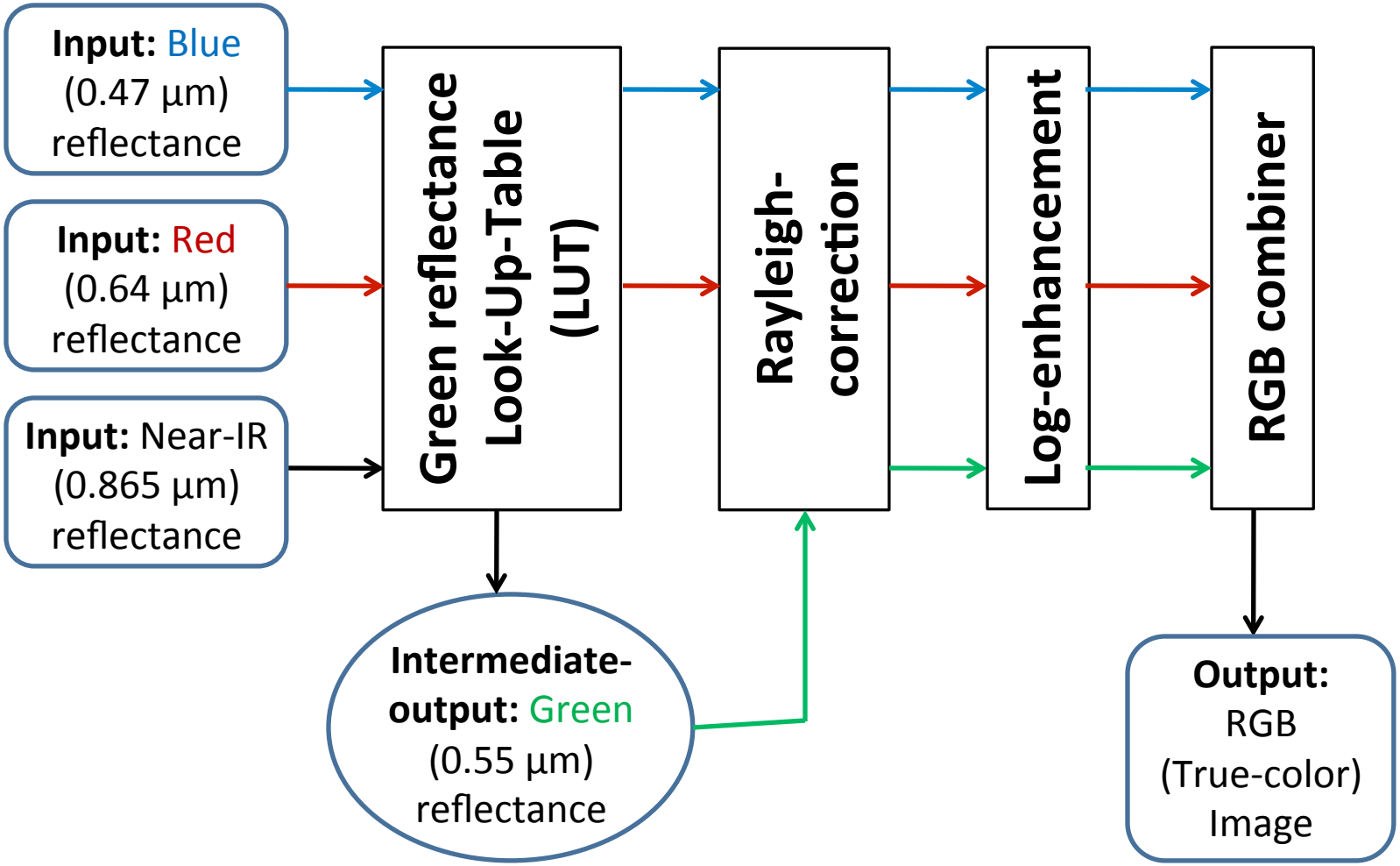
Relative Difference (%)



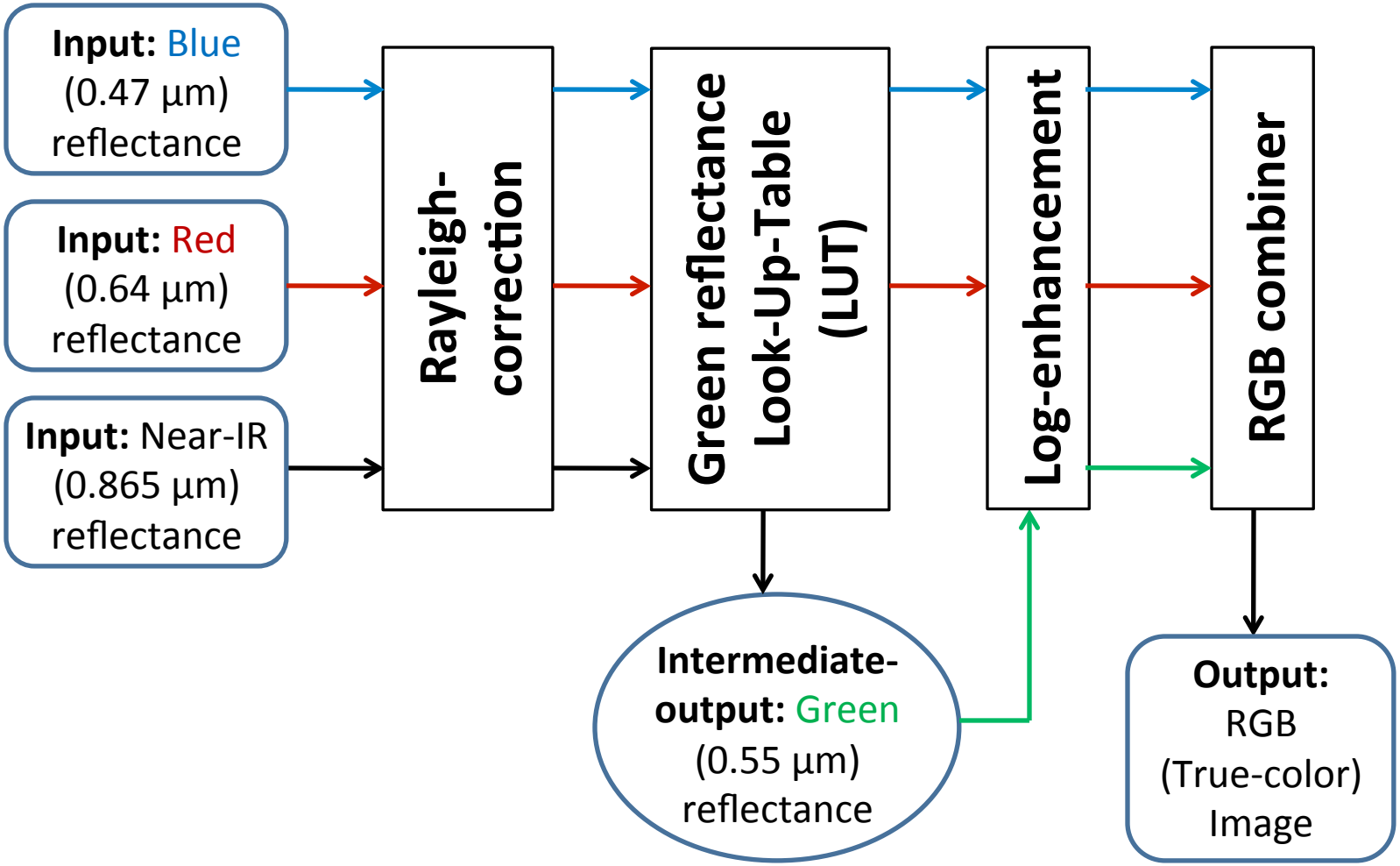
Class-Dependent LUTs



Green synthesis using available visible/reflective bands 1



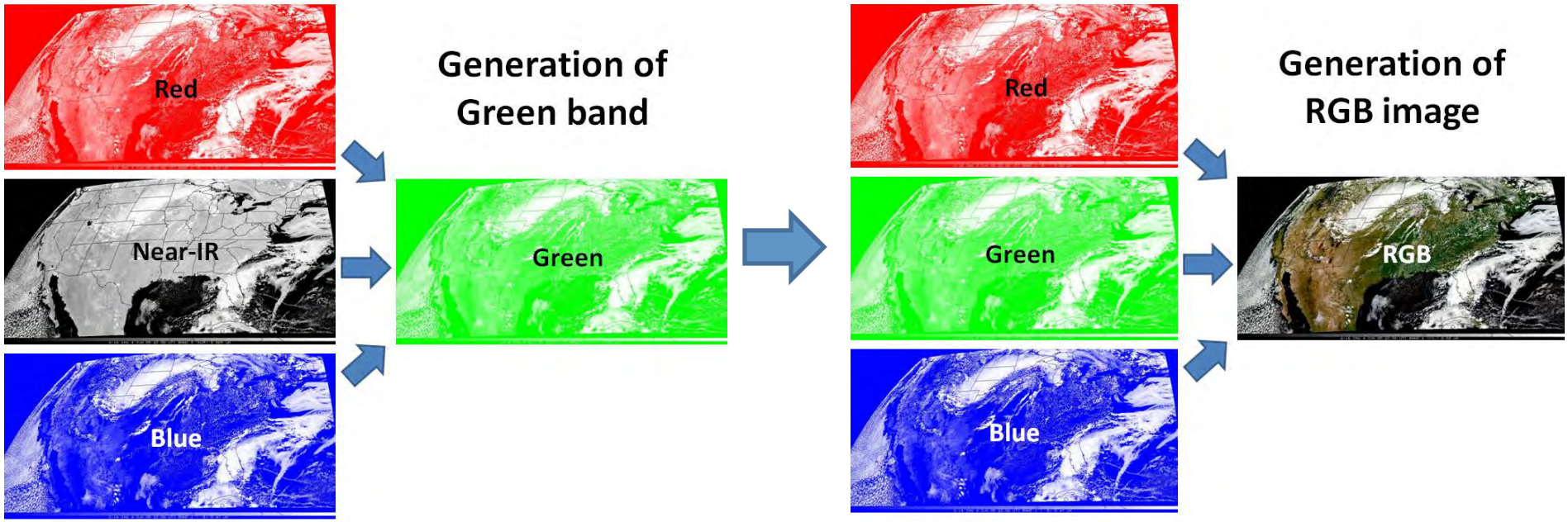
Green synthesis using available visible/reflective bands 2



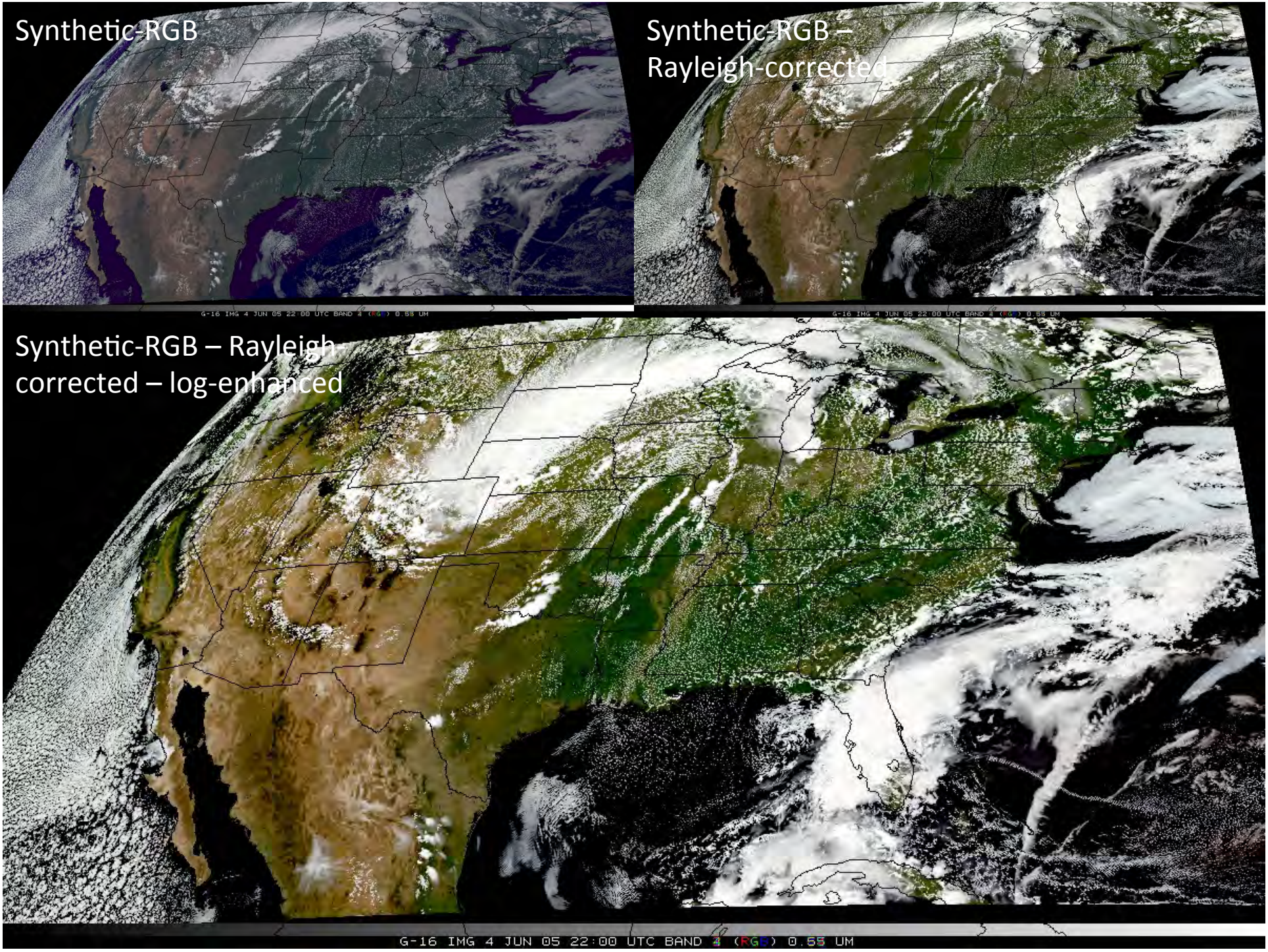
Schematic for generating missing (synthetic) Green and RGB images for GOES-R ABI

Step 1: **Green** from Red, Near-IR, and Blue bands, using a MODIS-trained LUT*.

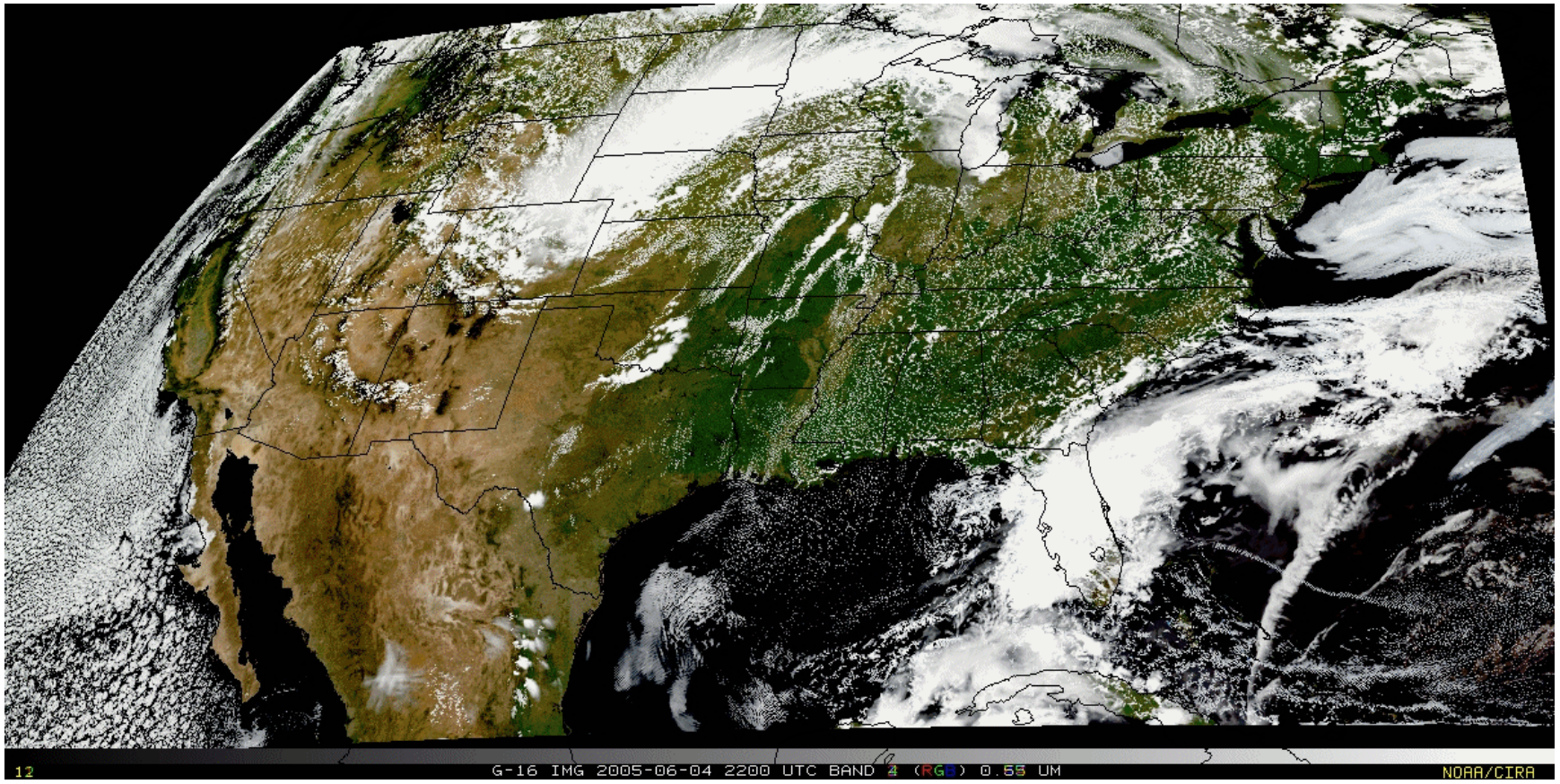
Step 2: **RGB** from Red, Green, and Blue bands.



*Synthetic-Green is produced using a Look Up Table (LUT) trained on MODIS imagery, which includes the necessary Red, Green, Near-IR, and Blue bands.


Synthetic-RGB
Synthetic-RGB – Rayleigh-corrected
Synthetic-RGB – Rayleigh-corrected – log-enhanced
G-16 IMG 4 JUN 05 22:00 UTC BAND 4 (RGB) 0.65 UM

Simulated **Advanced Baseline Imager (ABI)** data from GOES-R turned into true-color imagery by synthesizing the Green band from the Red, Blue, and Near-IR bands of ABI.



VIIRS on NPP / JPSS

- **True-color imagery** will be directly available (No need for Green synthesis)
- VIIRS imagery can be used as training data for improvements to Green synthesis for GOES-R ABI

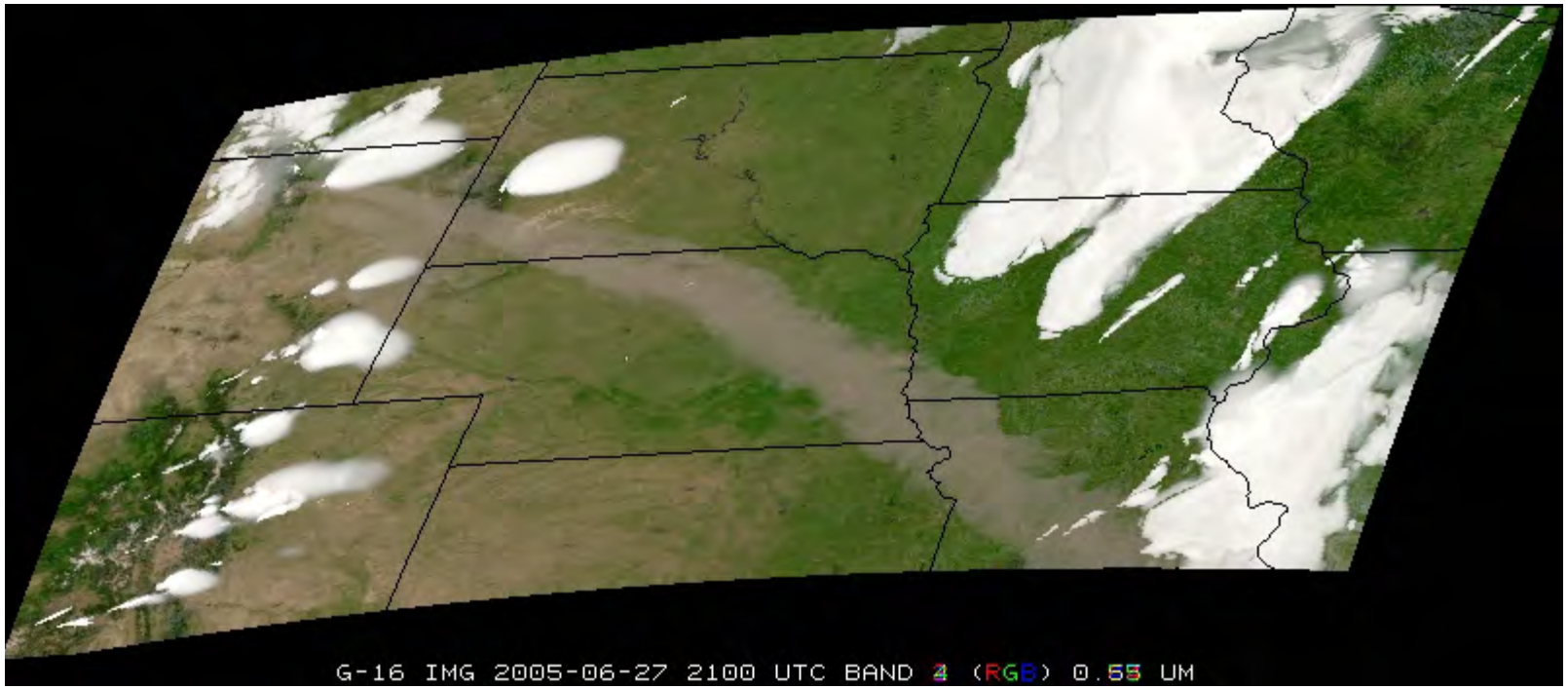
VIIRS Bands and Bandwidths

VIIRS Band	Central Wavelength (μm)	Wavelength Range (μm)	Band Explanation	Spatial Resolution (m) @ nadir
M1	0.412	0.402 - 0.422	Visible	750 m
M2	0.445	0.436 - 0.454		
M3 (blue)	0.488	0.478 - 0.488		
M4 (green)	0.555	0.545 - 0.565		
M5 (red)	0.672	0.662 - 0.682		
M6	0.746	0.739 - 0.754	Near IR	
M7	0.865	0.846 - 0.885		
M8	1.240	1.23 - 1.25	Shortwave IR	
M9	1.378	1.371 - 1.386		
M10	1.61	1.58 - 1.64		
M11	2.25	2.23 - 2.28		
M12	3.7	3.61 - 3.79	Medium-wave IR	
M13	4.05	3.97 - 4.13		
M14	8.55	8.4 - 8.7	Longwave IR	
M15	10.763	10.26 - 11.26		
M16	12.013	11.54 - 12.49		
DNB	0.7	0.5 - 0.9	Visible	750 m across full scan
I1 (red)	0.64	0.6 - 0.68	Visible	375 m
I2	0.865	0.85 - 0.88	Near IR	
I3	1.61	1.58 - 1.64	Shortwave IR	
I4	3.74	3.55 - 3.93	Medium-wave IR	
I5	11.45	10.5 - 12.4	Longwave IR	

True-color imagery is not just a pretty picture!

- Ocean color analysis has used true-color for years, to determine ocean/coastal health.
- Color imagery is indicative of vegetation extent and drought monitoring.
- Color also extends into the analysis of aerosols, such as smoke and ash, and airborne particulates like dust.
- Modeling of ash plumes into realistic imagery, leads to understanding of its detectability.

Example of a simulated ash plume overlaid on simulated ABI imagery, as seen in true-color



synthetic-RGB – Rayleigh-corrected – log-enhanced

Natural Color Imagery of Tropical Cyclones: Algorithms that create natural color imagery over tropical cyclones has been created for the GOES-R Proving Ground (PG) demonstration at NHC. These natural color images are created using adjacent MODIS granules, have a Rayleigh correction applied, are remapped to a 2-km Mercator projection and are posted on the RAMMB TC-Realtime website (http://rammb/products/tc_realtime/) along with other TC products.