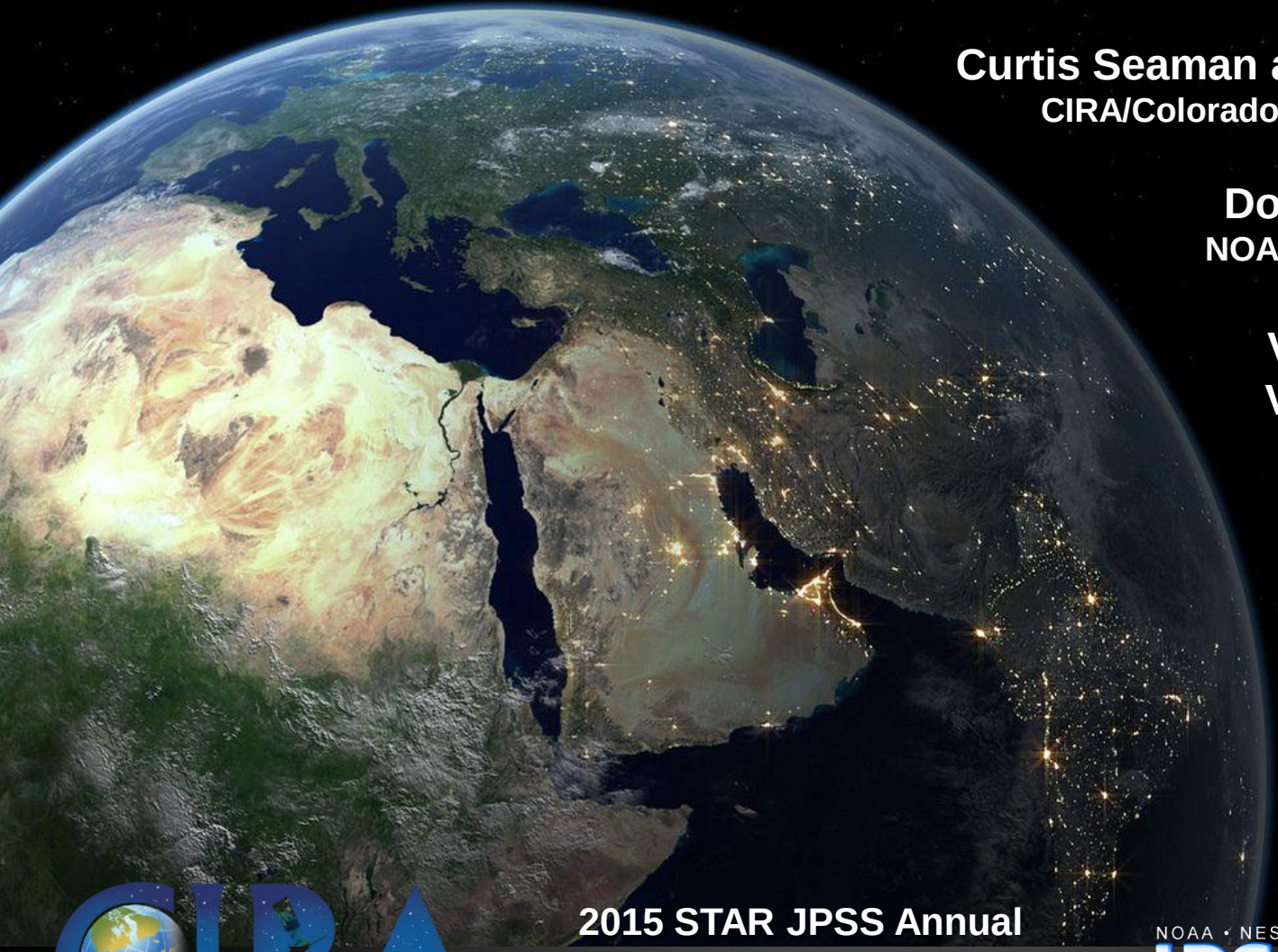
On the use of the VIIRS Day/Night Band and Near Constant Contrast Imagery



Curtis Seaman and Steven Miller
CIRA/Colorado State University

Donald Hillger
NOAA/NESDIS/STAR

VIIRS Imagery and Visualization Team

Cooperative Institute for Research in the Atmosphere

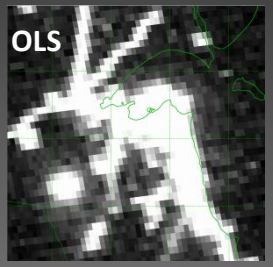
2015 STAR JPSS Annual Science Team Meeting
College Park, MD

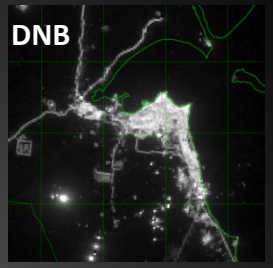
NOAA • NESDIS JPSS Joint Polar Satellite System

NOAA U.S. National Oceanic and Atmospheric Administration U.S. Department of Commerce

Image Credit: http://earthspacecircle.blogspot.com

DNB Advances Over Heritage



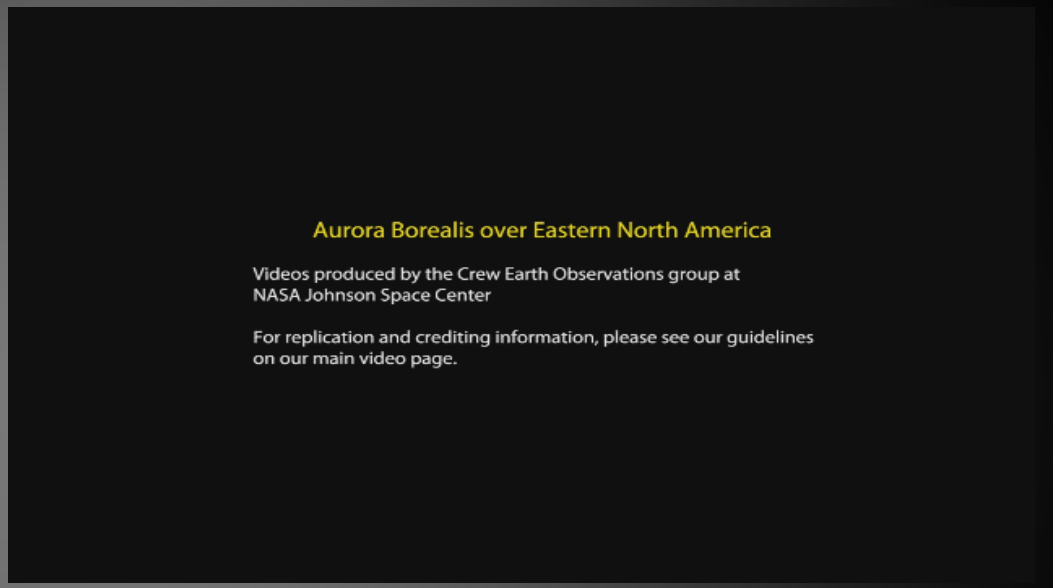


Attribute	DMSP/OLS*	VIIRS/DNB on Suomi NPP*
Orbit	Sun-synchronous, ~850 km	Sun-synchronous, 827 km
Nighttime Nodal Overpass Time	~1930 UTC	~0130 UTC
Swath Width	3000 km	3000 km
Spectral Response (FWHM)	Panchromatic 500-900 nm	Panchromatic 500-900 nm
Instantaneous Field of View	5 km (nadir) / ~7 km (edge)	0.740 ± 0.043 km (Scan) 0.755 ± 0.022 km (track)
Spatial Resolution (Ground Sample Distance)	2.7 km; 'smooth' data	< 0.820 km (Scan) < 0.750 km (track)
Minimum Detectable Signal	4×10^{-5} W m^{-2} sr^{-1}	3×10^{-5} W m^{-2} sr^{-1}
Noise Floor	~5×10^{-6} W m^{-2} sr^{-1}	~5×10^{-7} W m^{-2} sr^{-1}
Radiometric Quantization	6 bit	13 - 14 bit
Accompanying Spectral Bands	1	11 (night) / 21 (day)
Radiometric Calibration	None	On-Board Solar Diffuser
Saturation	In Urban Cores	None

DMSP = Defense Meteorological Satellite Program
OLS = Operational Linescan System

NPP = National Polar-orbiting Partnership (NOAA/NASA)
VIIRS = Visible/Infrared Imaging Radiometer Suite
DNB = Day/Night Band

Primary Sources of Light

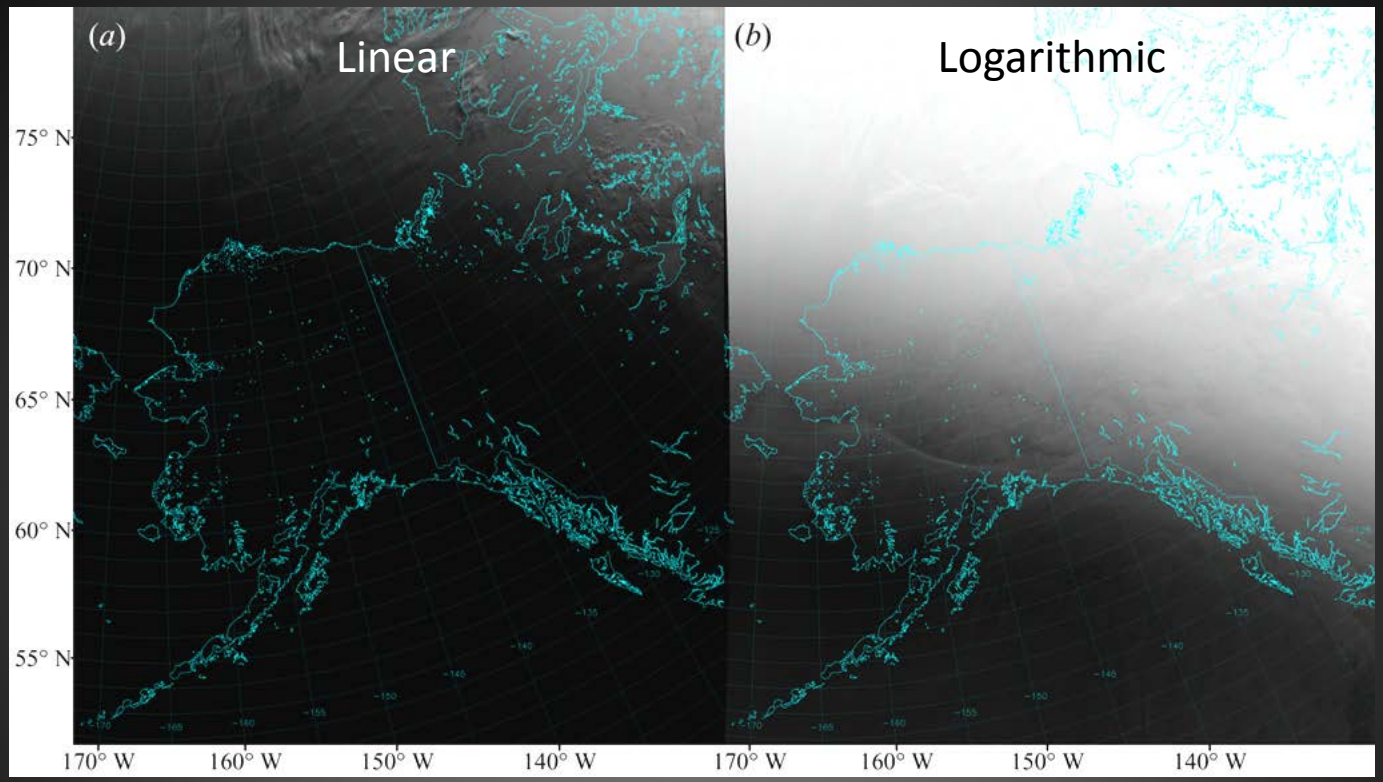


Credit: Robert Simmon (NASA)

- The Day/Night Band is sensitive to radiation (500-900 nm) over a range of intensity spanning 8-orders of magnitude from sunlight to new moon (airglow)
- This presents a particular challenge for Imagery

Global Nighttime Lights of the World (Chris Elvidge; NOAA/NGDC), Baugh et al. (2013)

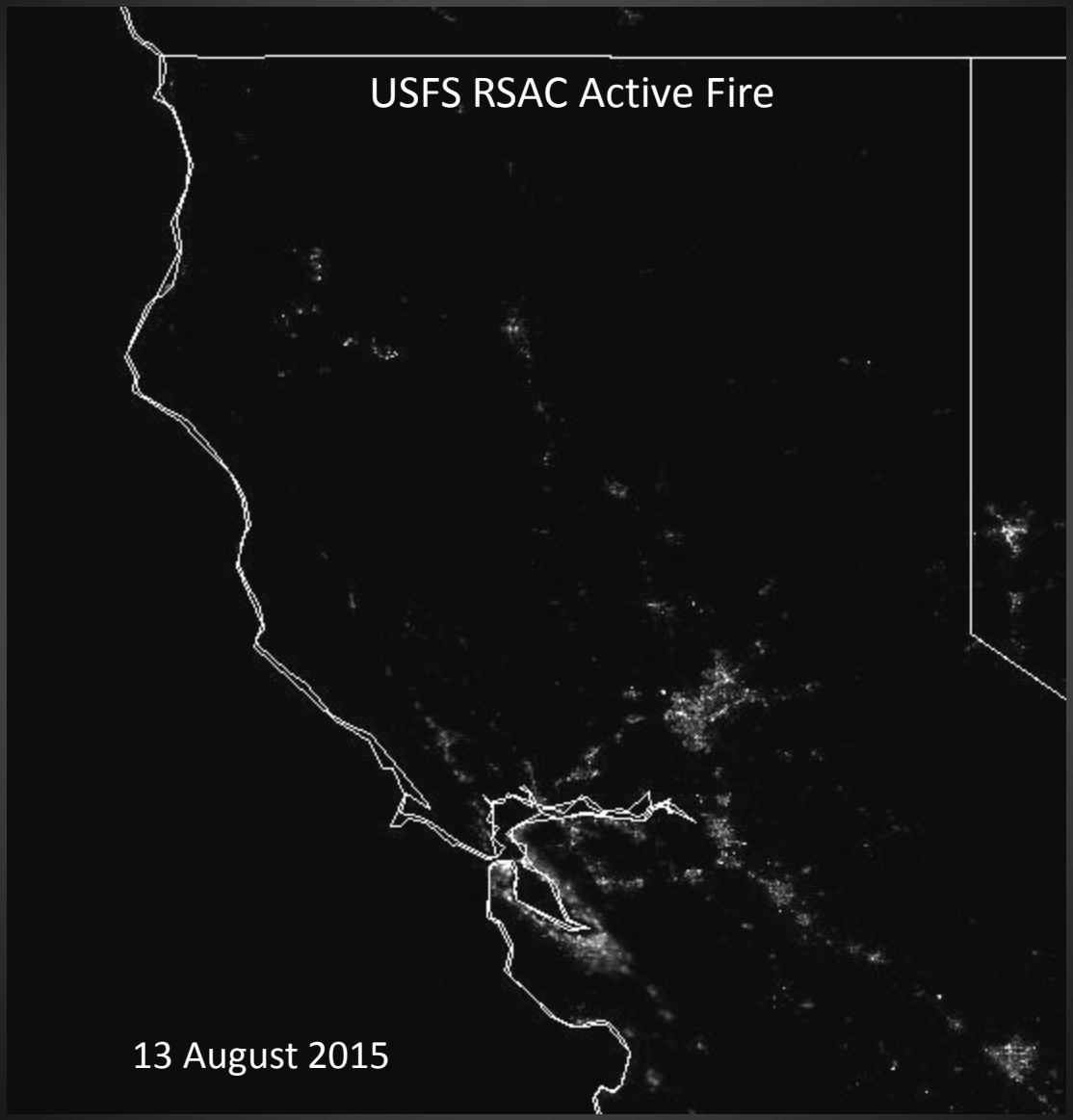
Displaying 8 orders of magnitude in 256 colors



1 May 2013

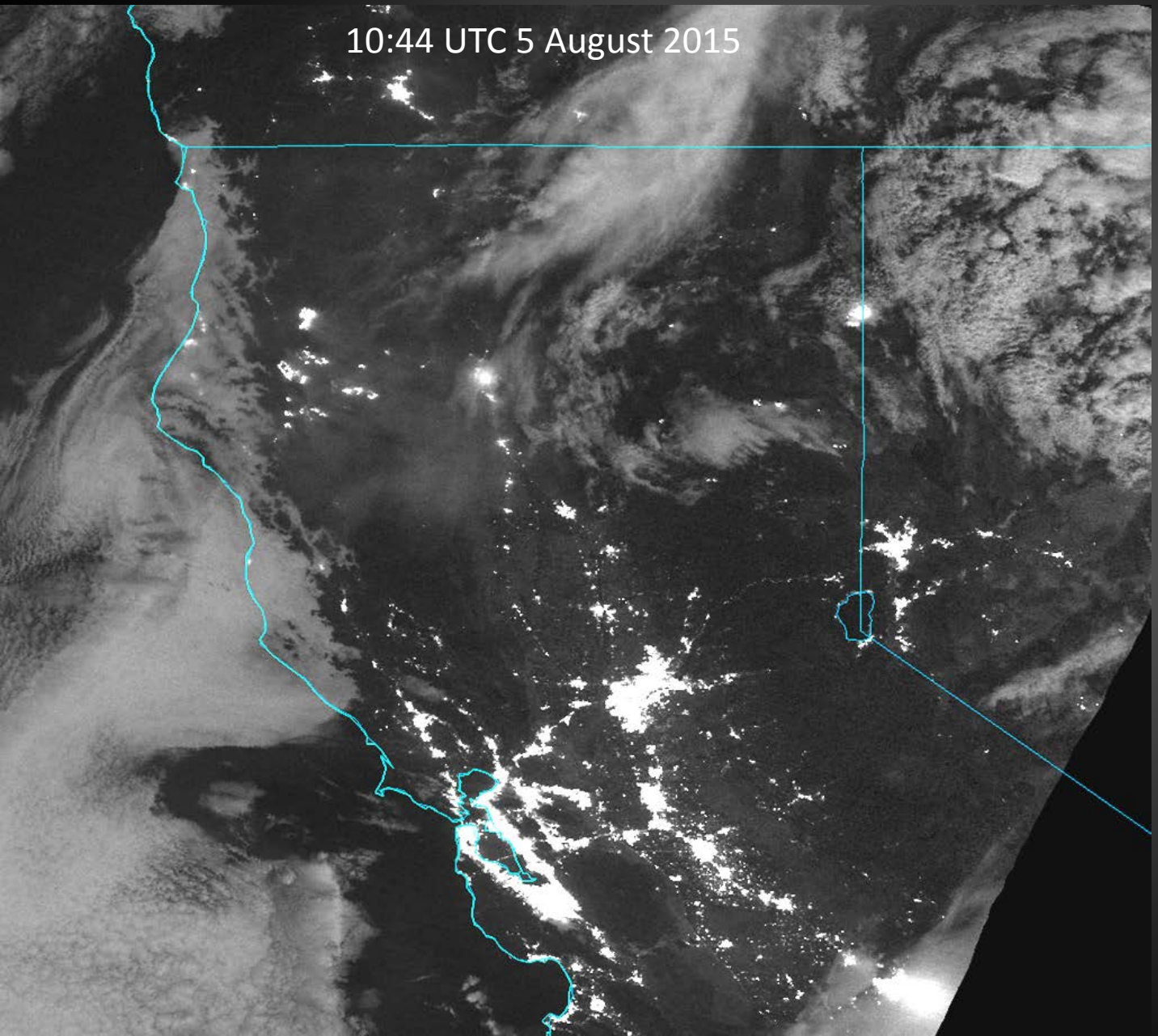
- DNB radiance values vary between ~10^{-2} and ~10^{-10} W cm^{-2} sr^{-1}
- Simple scaling methods fail to capture the full range of the data
- What is the best way to capture the full range in 256 colors?

Displaying 8 orders of magnitude in 256 colors



http://activefiremaps.fs.fed.us/imagery_viirs.php

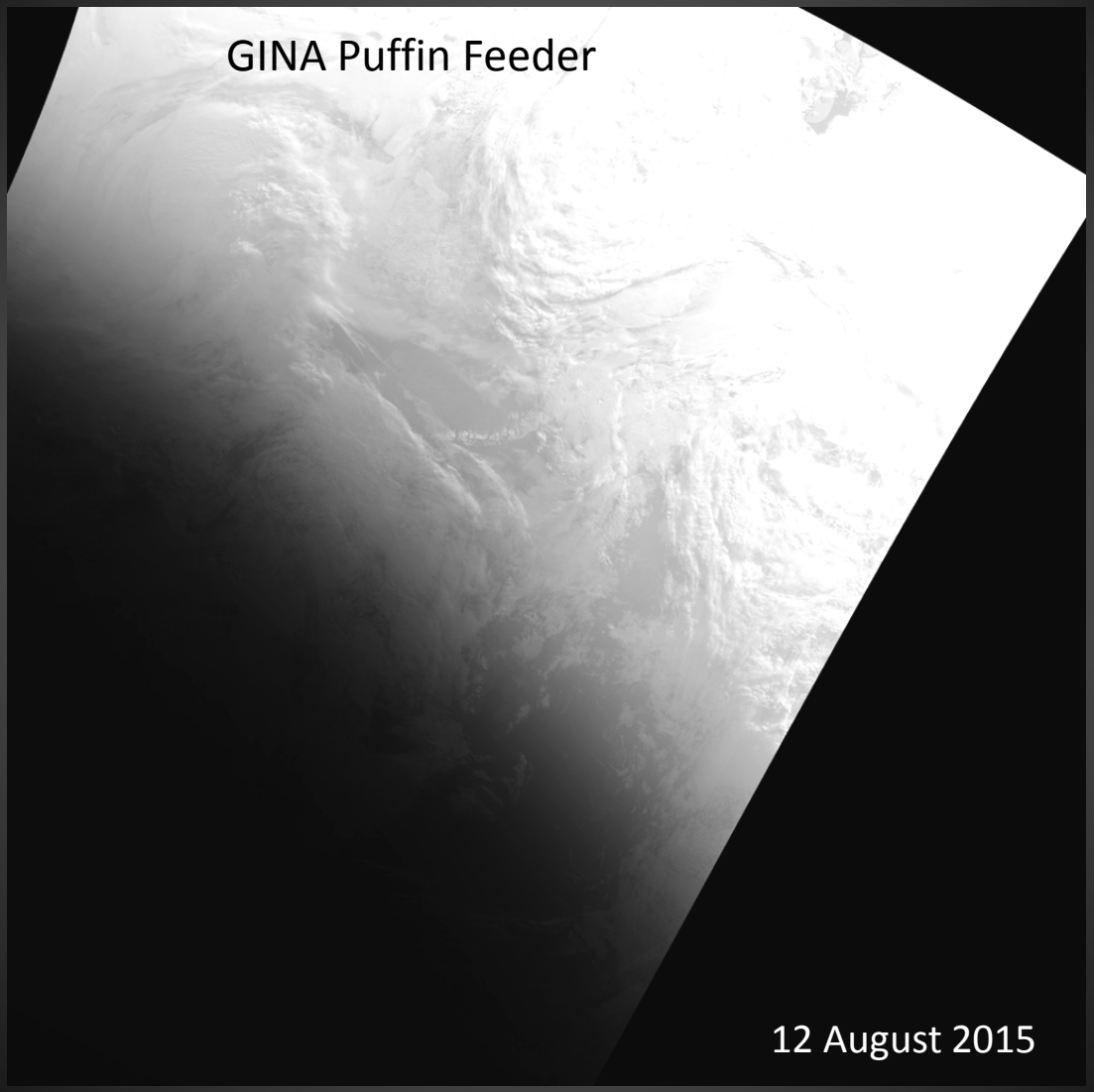
Missing Details



These images of the Northern CA wildfires show: bad scaling leads to misinformation.

Context is everything!

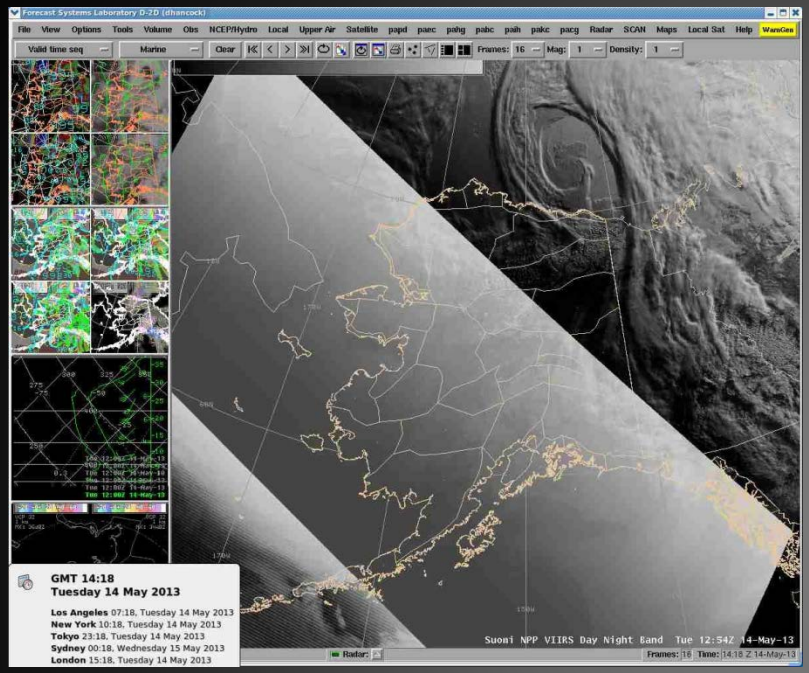
Displaying 8 orders of magnitude in 256 colors

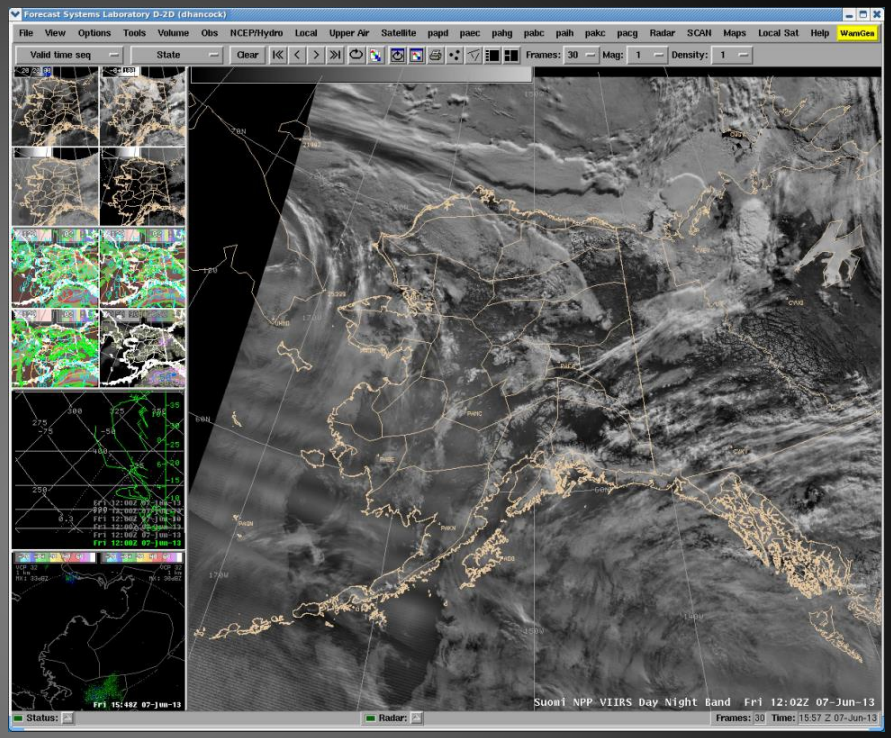


http://feeder.gina.alaska.edu/

Alaska Region WFOs

Image Credits: Eric Stevens, Alaska Region Satellite Liaison





Forecasters in the Alaska Region have been using imagery in AWIPS/AWIPS-2 that have been provided to them with a variety of scaling algorithms

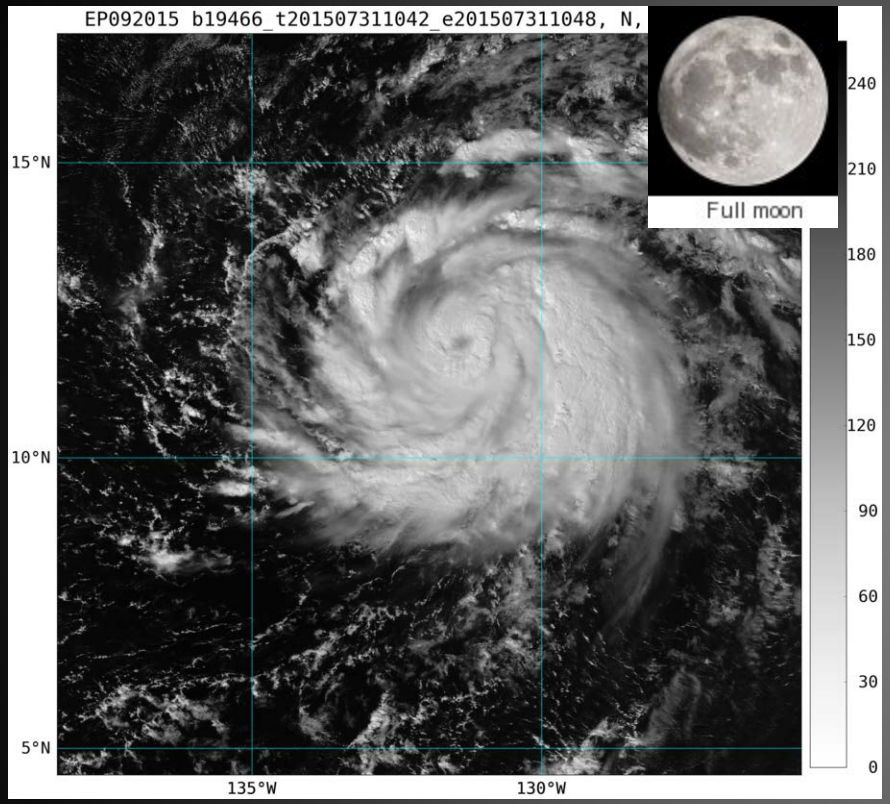
These algorithms have artifacts near the terminator

Remember: the terminator is always present in Alaska for “daytime” overpasses in Winter, “nighttime” overpasses in Summer

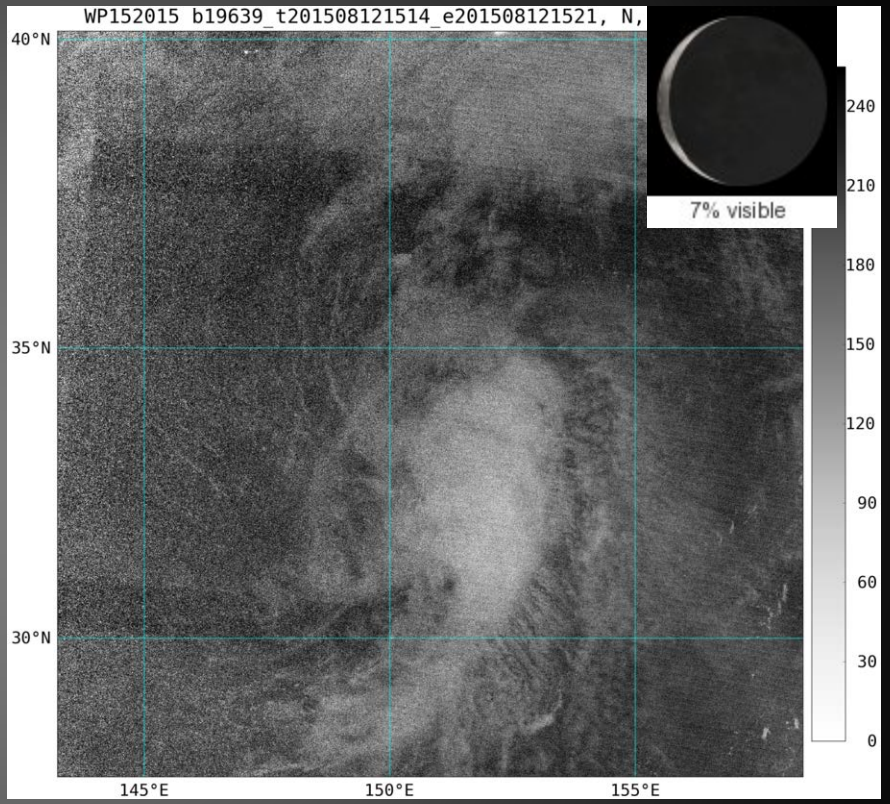
Displaying 8 orders of magnitude in 256 colors

CIRA median-based linear

Hurricane Guillermo (2015)



TD Molave (2015)



- Scaled between (median) x 8 and ((median) x 8)/256
- Works in the tropics – day and night, entire lunar cycle
- Fails near the terminator – no good for Alaska
- Likely use at NHC

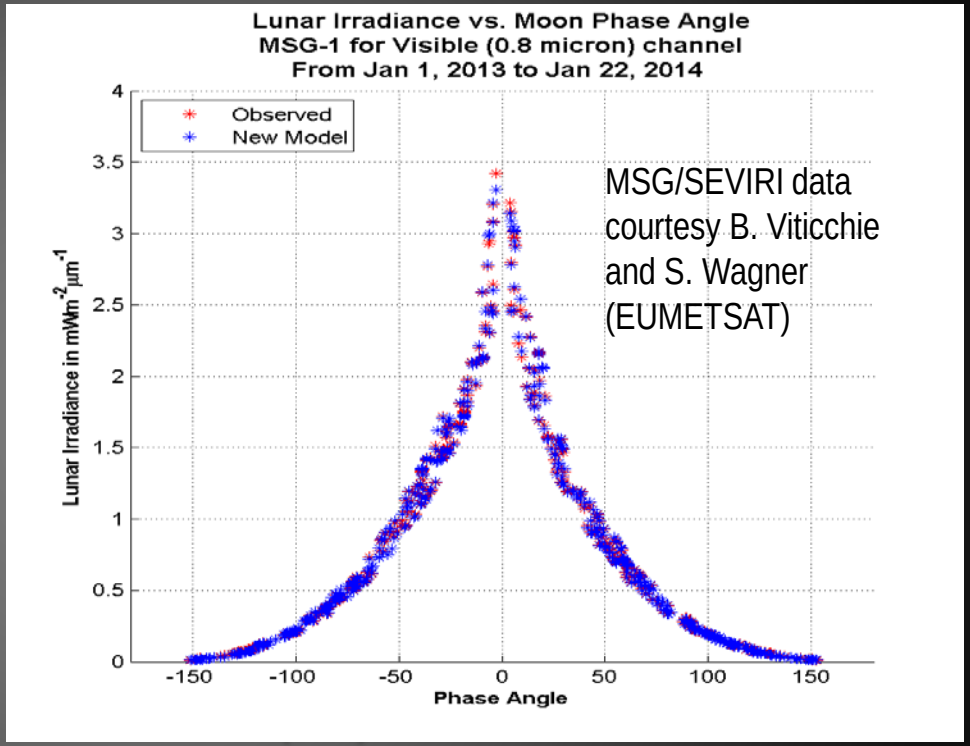
http://rammb.cira.colostate.edu/products/tc_realtime/

Visualizing the DNB: Lunar Irradiance Modeling

Mean: 384,401 km

Enables Calculation of Lunar Reflectance:

$$R_m = \pi I_m / (\mu_m F_m)$$

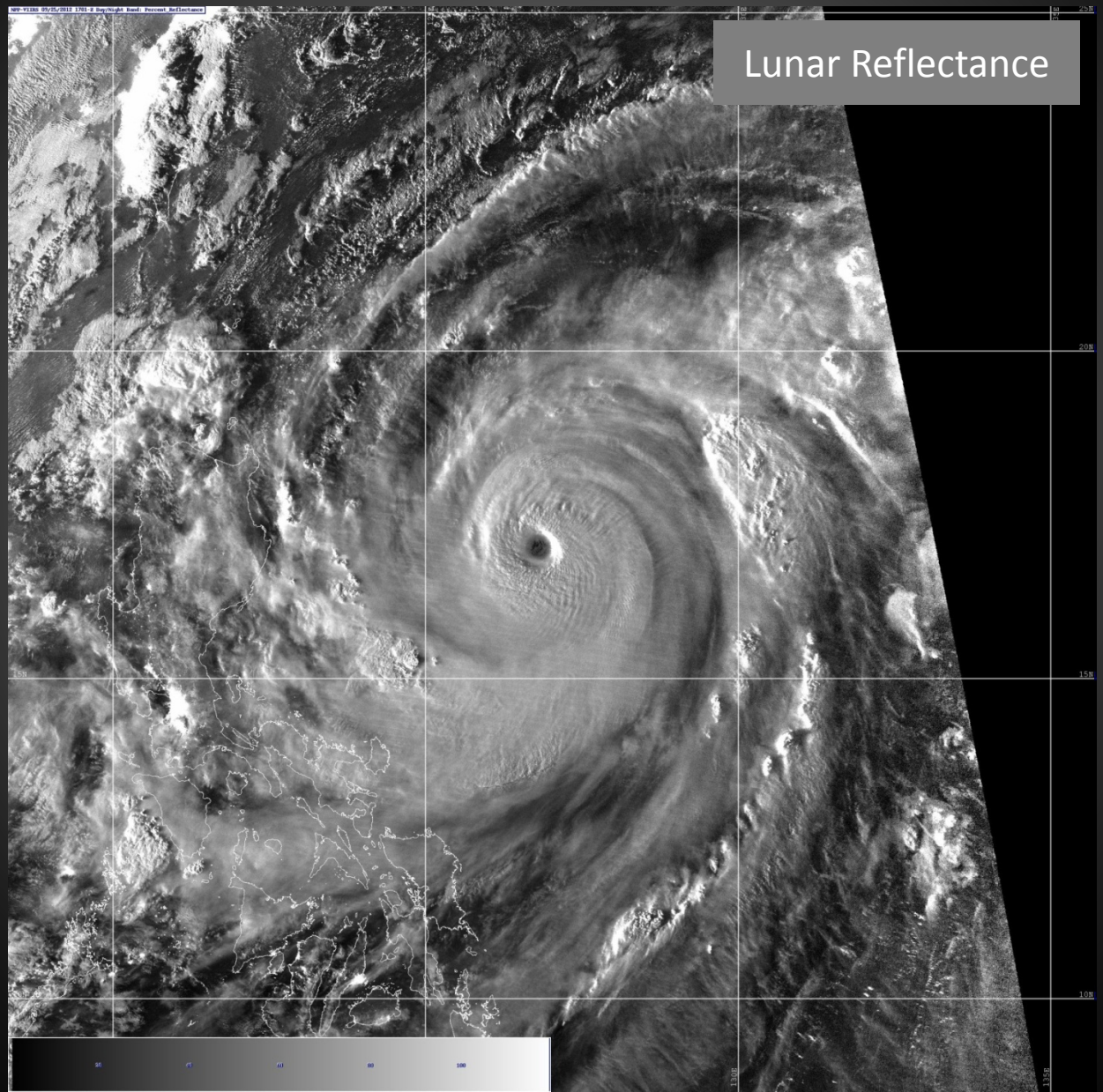


→ *Reduces 8 orders of magnitude range in radiance to <1 order of magnitude range in reflectance*

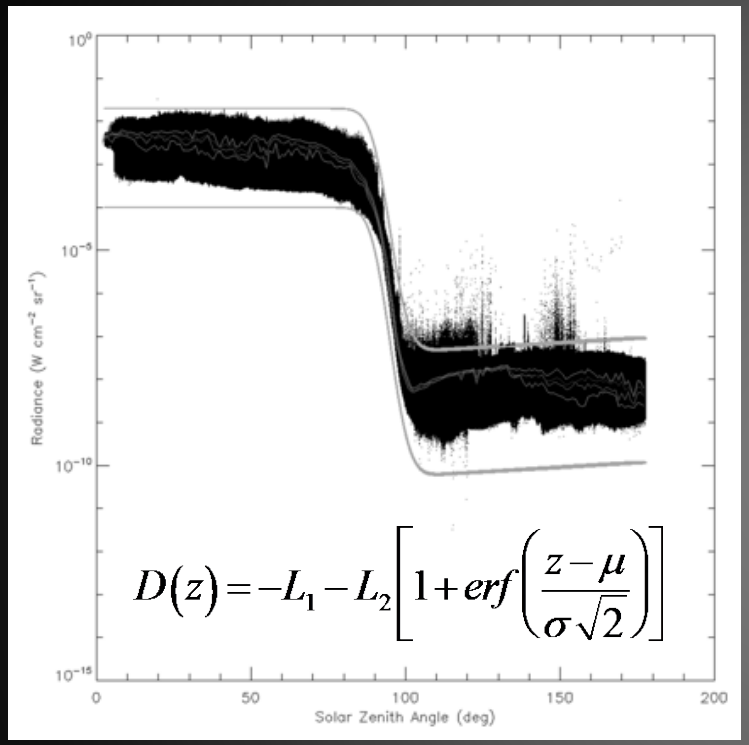
→ *Opens the door to possible quantitative applications involving the calibrated DNB observations of moonlight.*

Lunar Reflectance to Improve Imagery

Typhoon Jelawat: 9/25/2012 ~1700Z



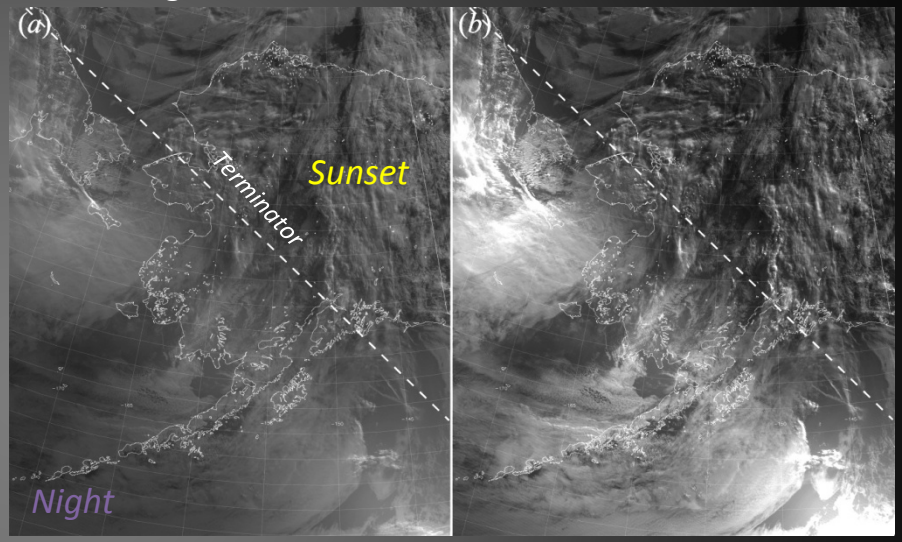
Visualizing the DNB: ERF-Dynamic Scaling



Seaman and Miller (2015) describe a non-linear log scaling based on the structure of the 'error function' (*erf*).

ERF Scaling

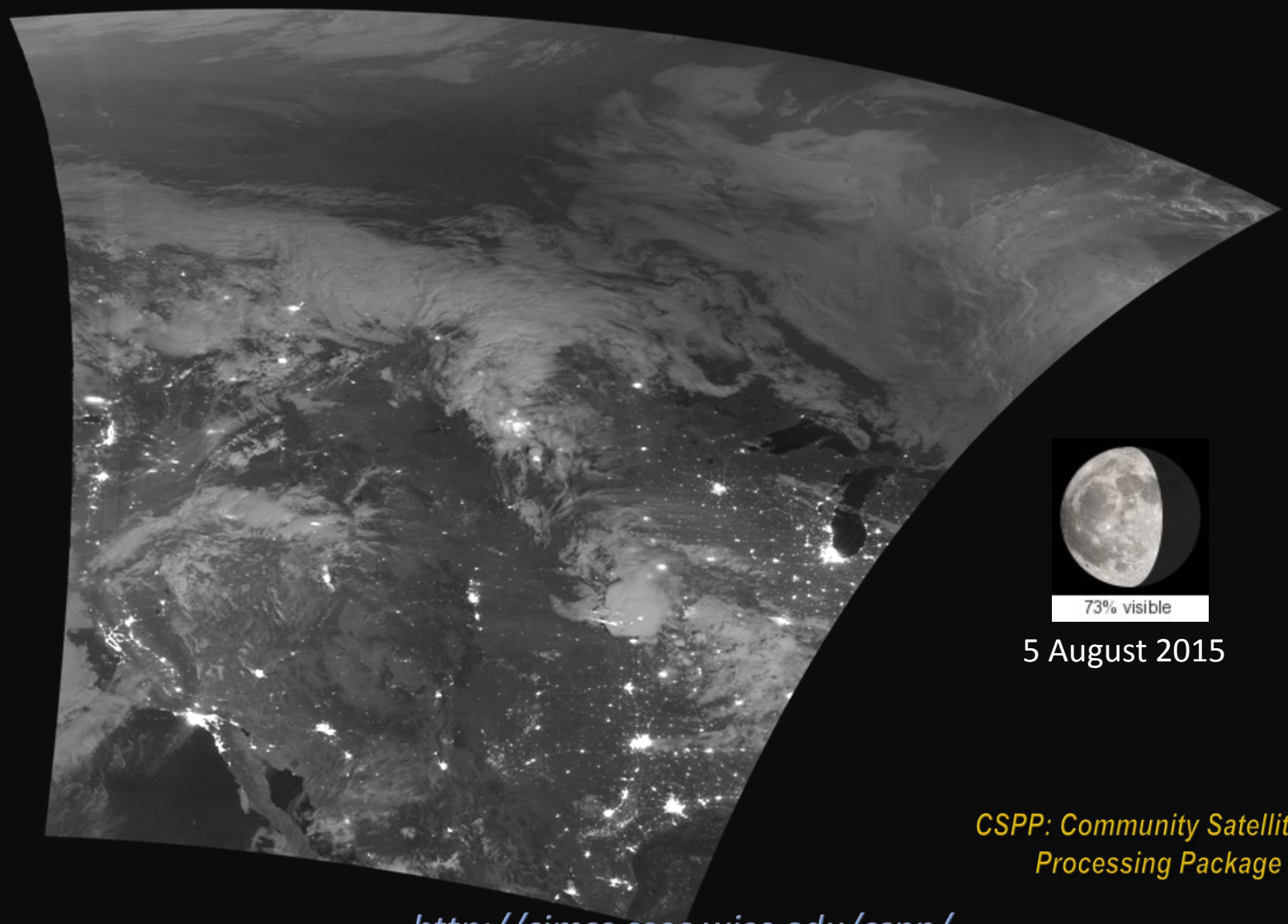
NCC Product



Strength: produces imagery with nearly constant contrast across the day/night terminator. (ERF-Dynamic Scaling is as good as, or better, than NCC in these cases.)

Visualizing the DNB: CSPP and CIRA algorithms

CSPP/CIRA ERF-Dynamic Scaling



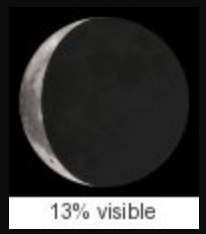
5 August 2015

CSPP: Community Satellite Processing Package

http://cimss.ssec.wisc.edu/cspp/

Visualizing the DNB: CSPP and CIRA algorithms

CSPP/CIRA ERF-Dynamic Scaling



11 August 2015

http://cimss.ssec.wisc.edu/cspp/

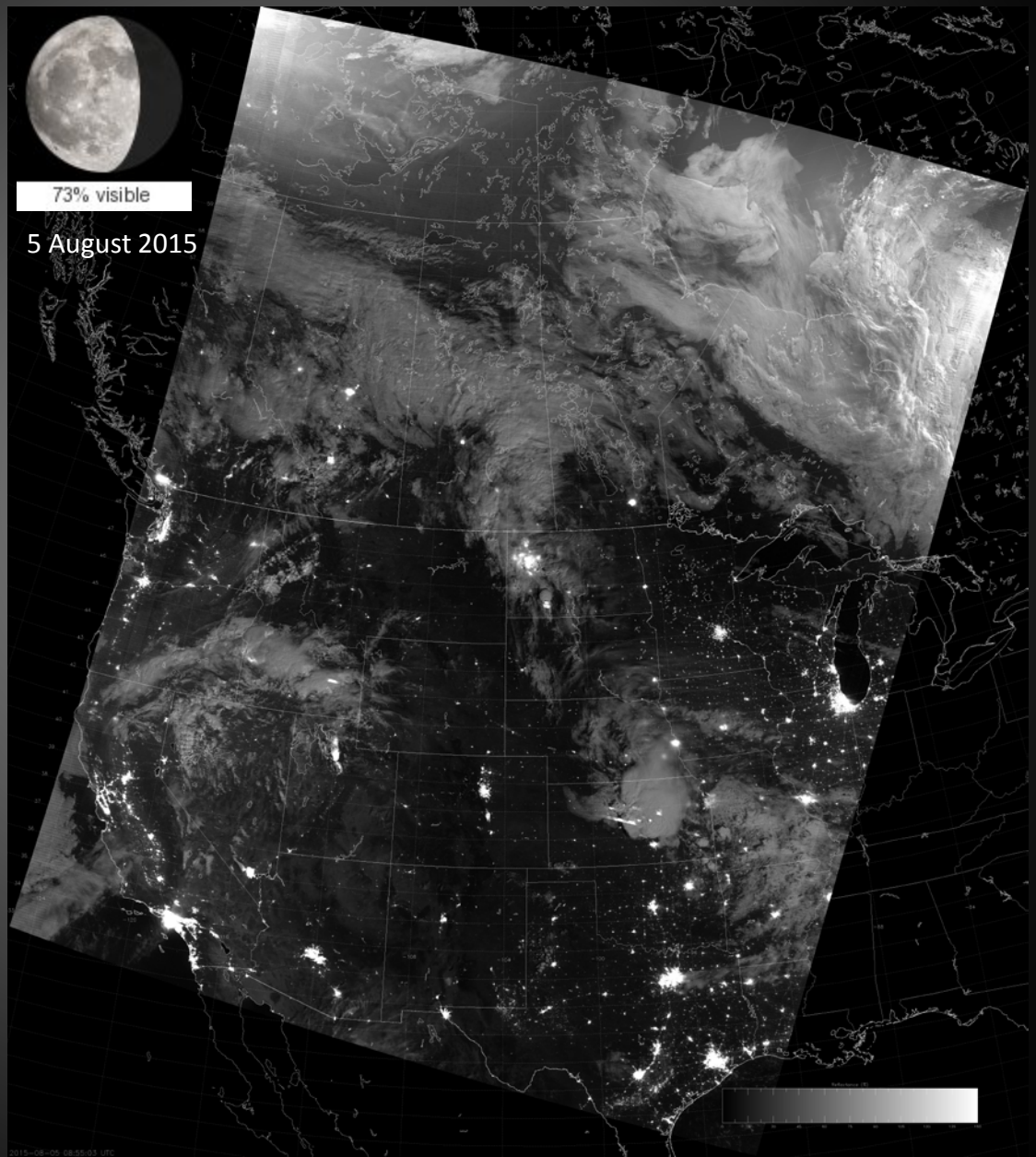
Visualizing the DNB: Near Constant Contrast EDR

- The NCC EDR converts from DNB radiance to “pseudo-albedo” by constantly adjusting the gain based on solar-lunar-satellite geometry (GVVSSE/GVVSLE tables)

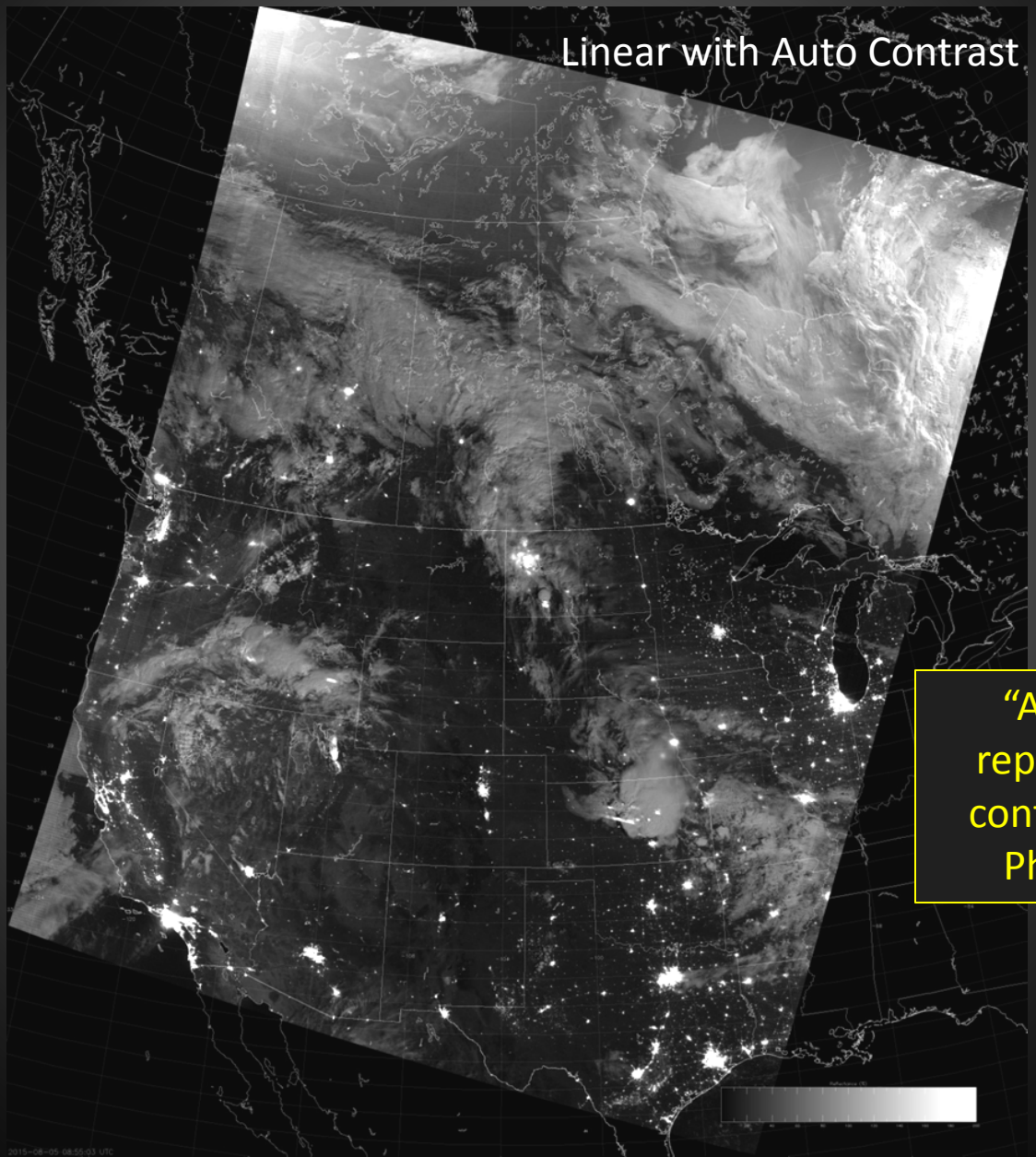
- Original assumptions based on DMSP OLS have been corrected for DNB so NCC now works as intended

- NCC will be available in AWIPS soon

- Values are allowed to vary from -10 to +1000, which presents its own challenges

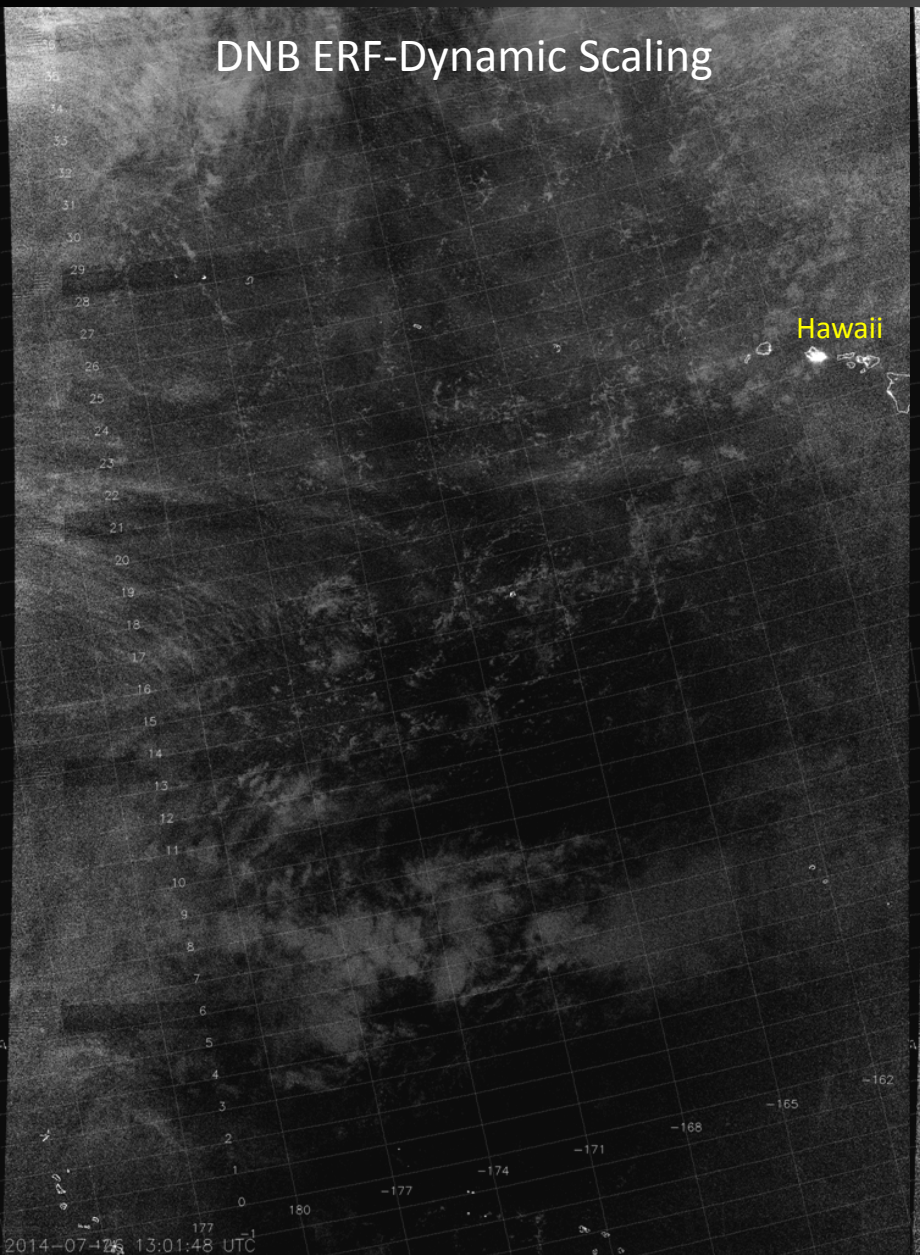


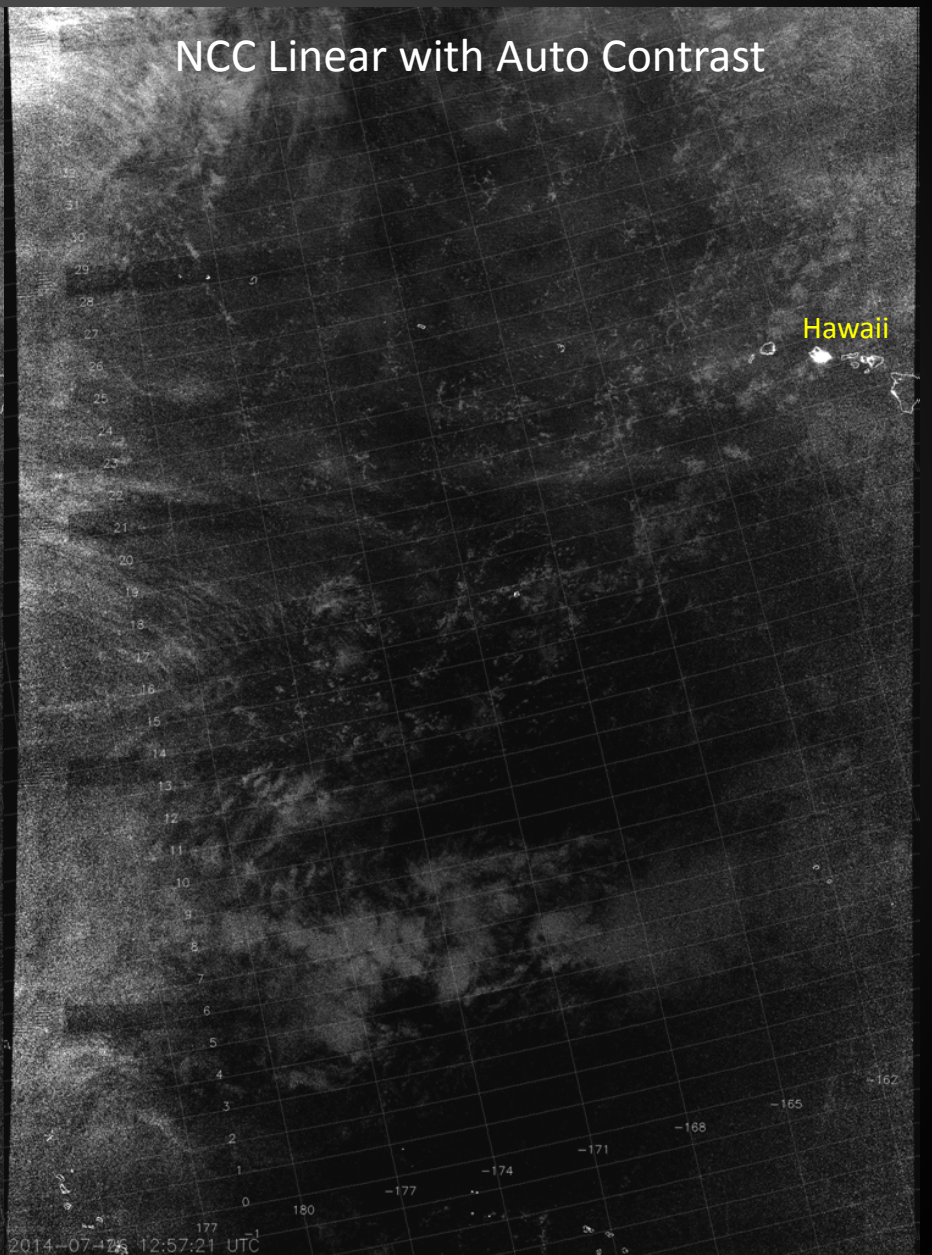
Scaling the NCC: with moon



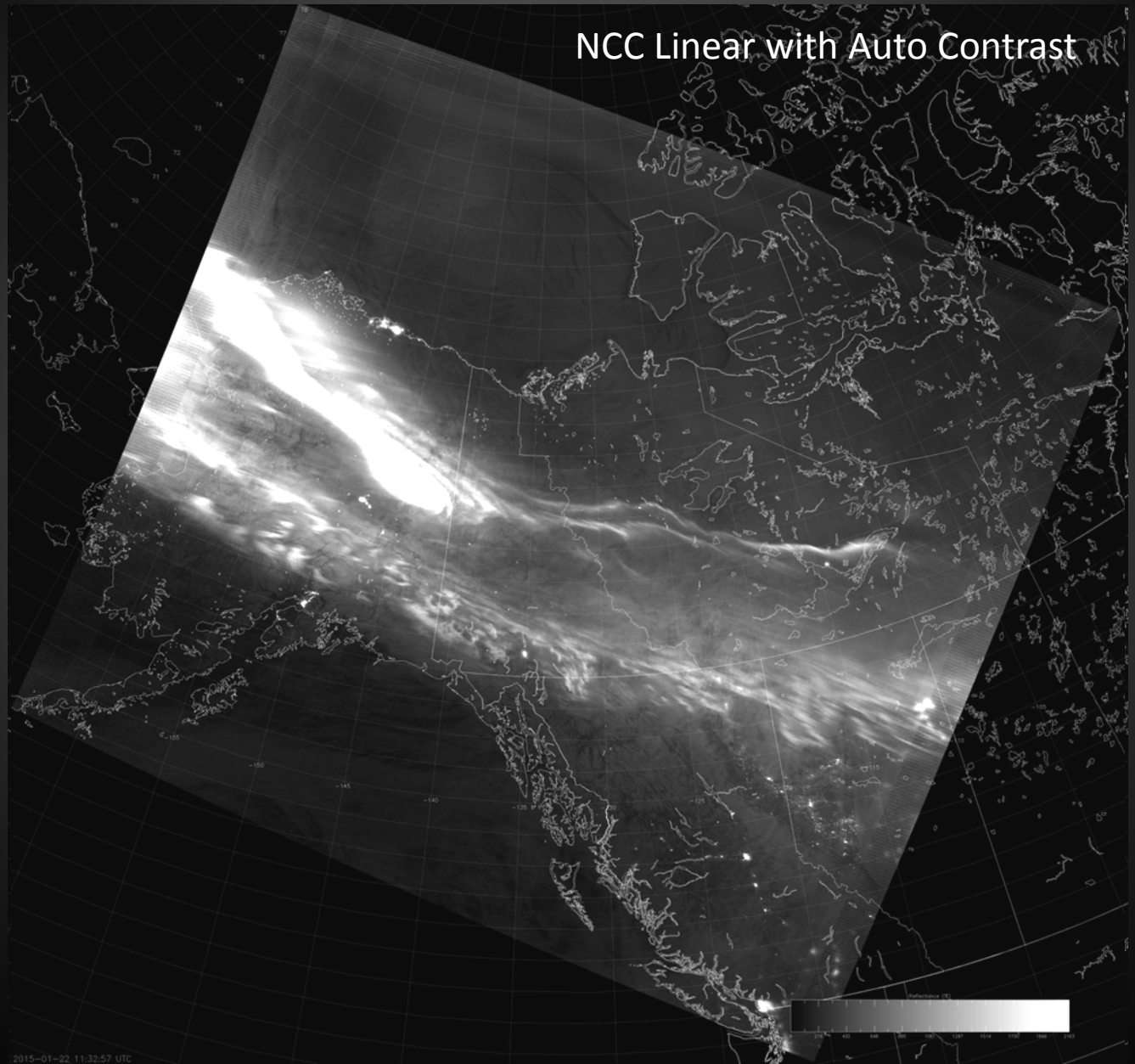
"Auto Contrast" replicates the auto contrast function in Photoshop, etc.

Scaling the NCC: no moon





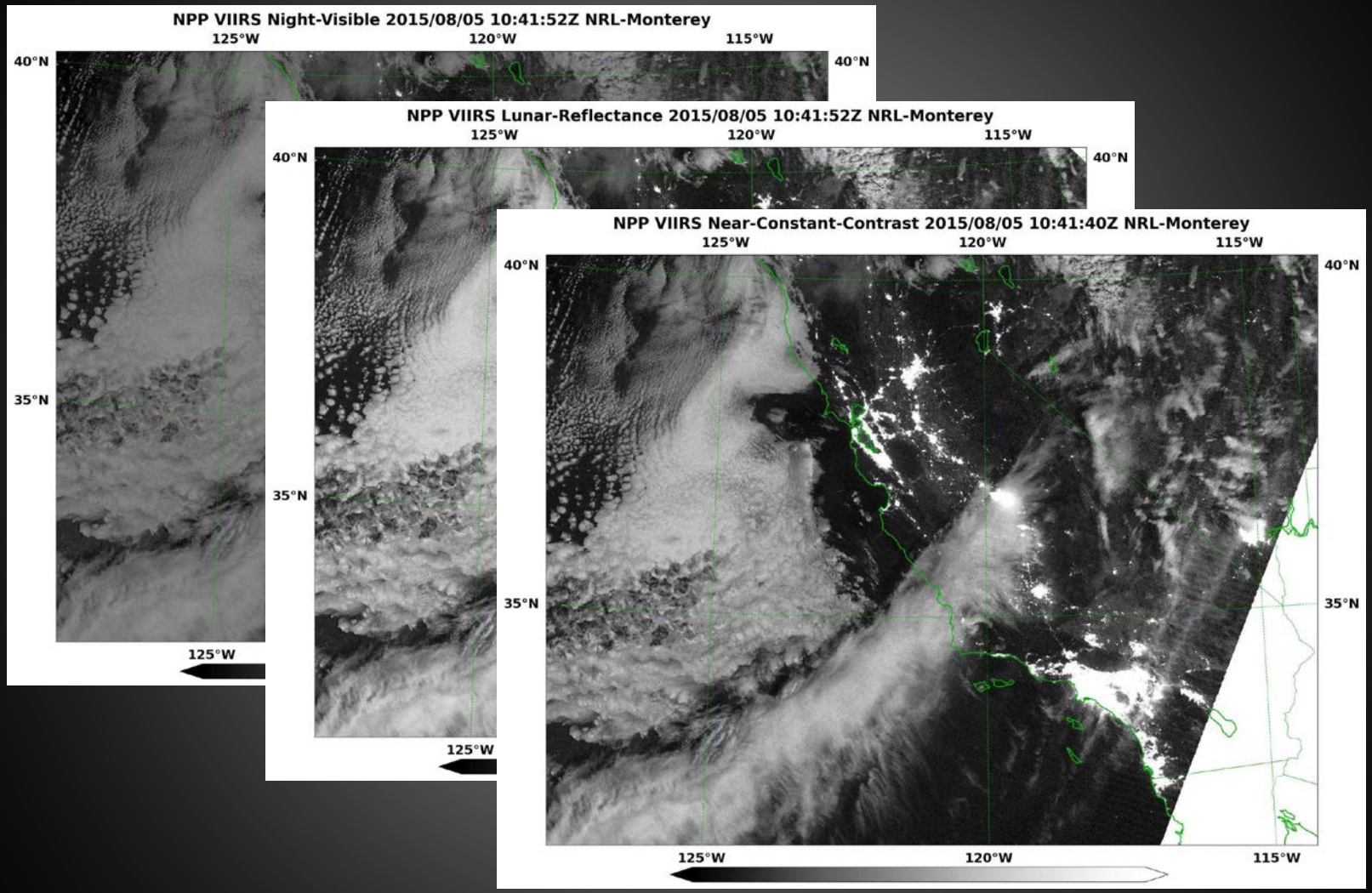
Scaling the NCC: auroras



Conclusions

- The Day/Night Band is a revolution for science *and* imagery processing.
- Users of visible imagery have never had to account for such a broad range in values before.
  - Training required
- Is there a one-size-fits-all scaling method?
  - Histogram Equalization
  - CSPP Adaptive
  - Median-based Linear
  - ERF-Dynamic Scaling
  - Near Constant Contrast EDR
  - Lunar Reflectance
- Scaling Near Constant Contrast imagery between 0 and 1 does not work in all situations.
  - NCC scaling must adjust to fit the observations just like DNB scaling algorithms
- Auto Contrast algorithm for NCC imagery shows promise, needs further development

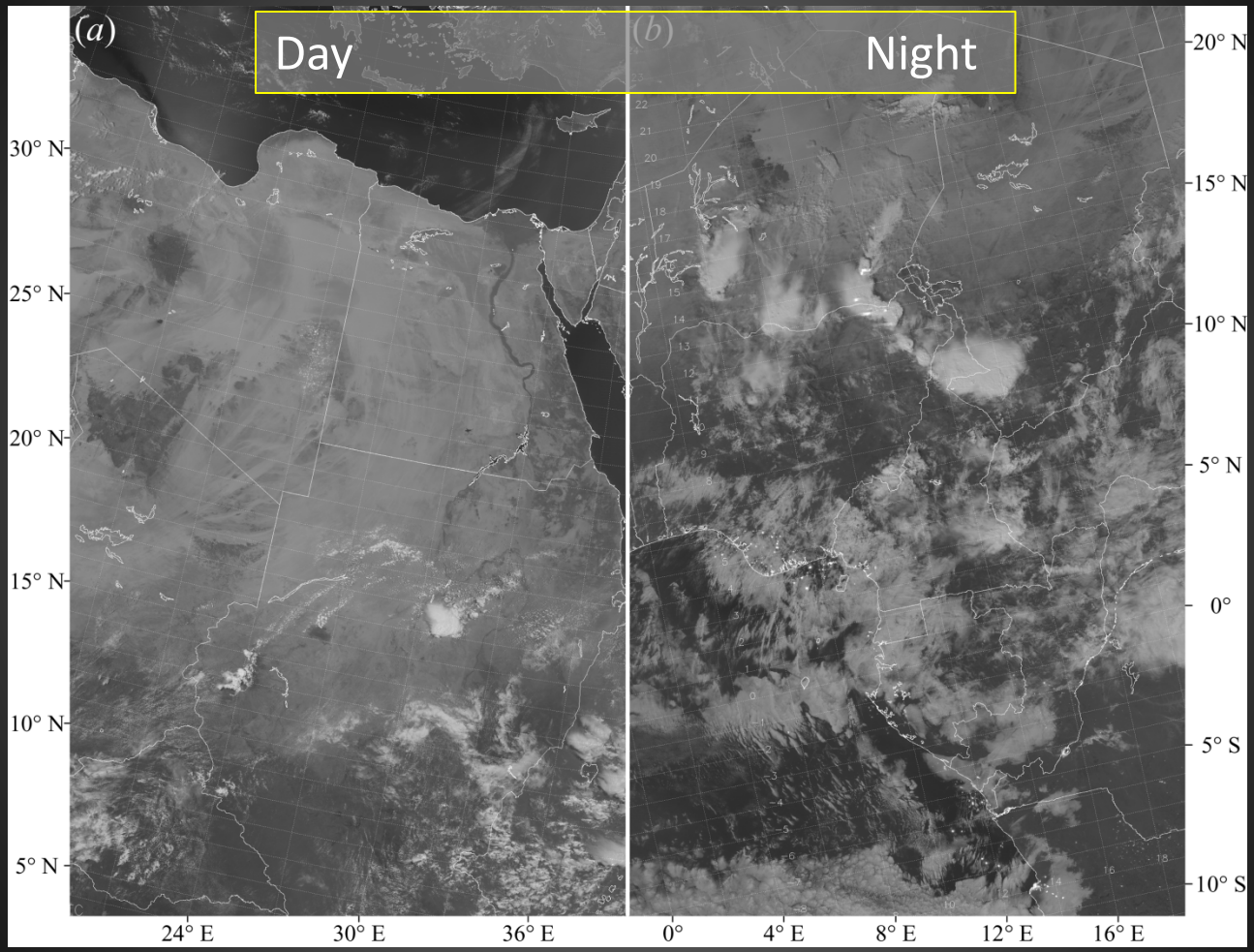
Naval Research Laboratory (NexSat)



Near Constant Contrast EDR

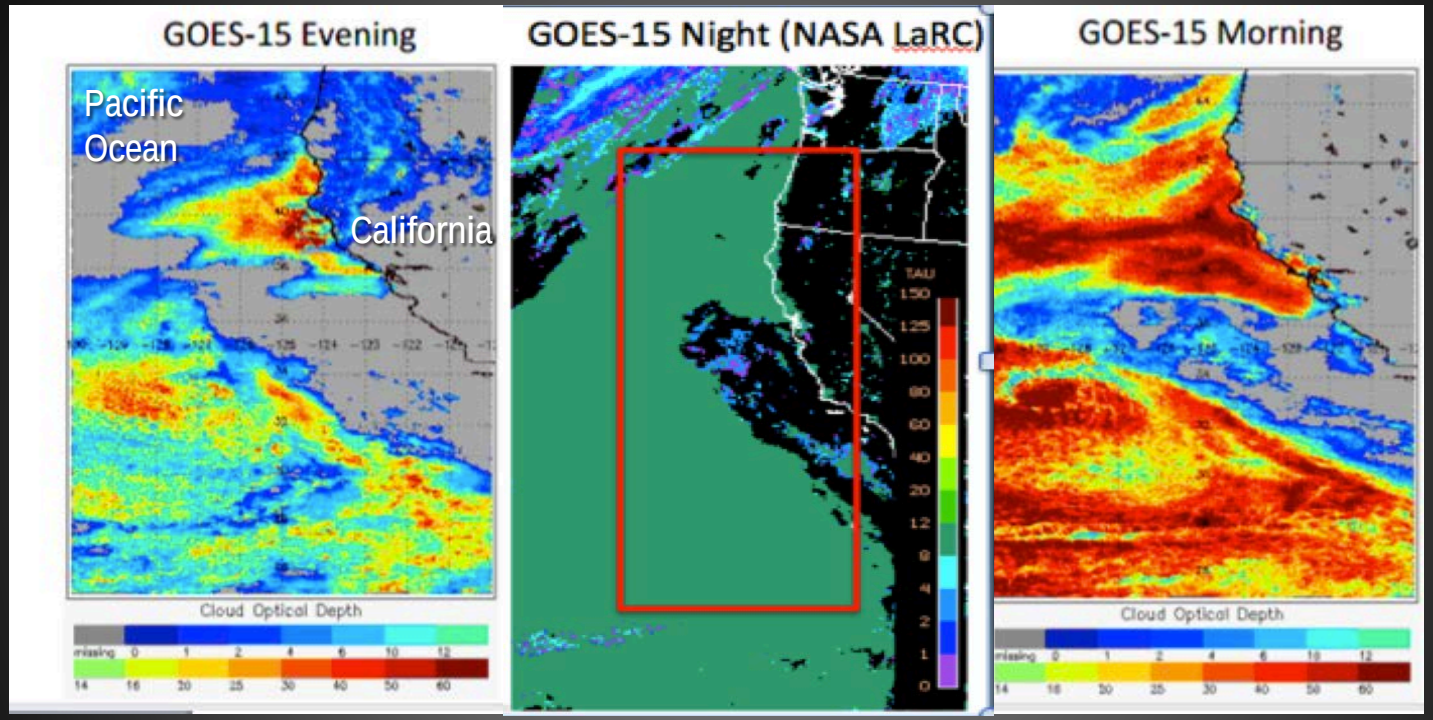
http://www.nrlmry.navy.mil/NEXSAT.html

Visualizing the DNB: ERF-Dynamic Scaling



The other goal is to produce images at night with the same level of contrast as daytime images. (Full moon case shown here.)

Lunar Reflectance to Retrieve Cloud Properties at Night



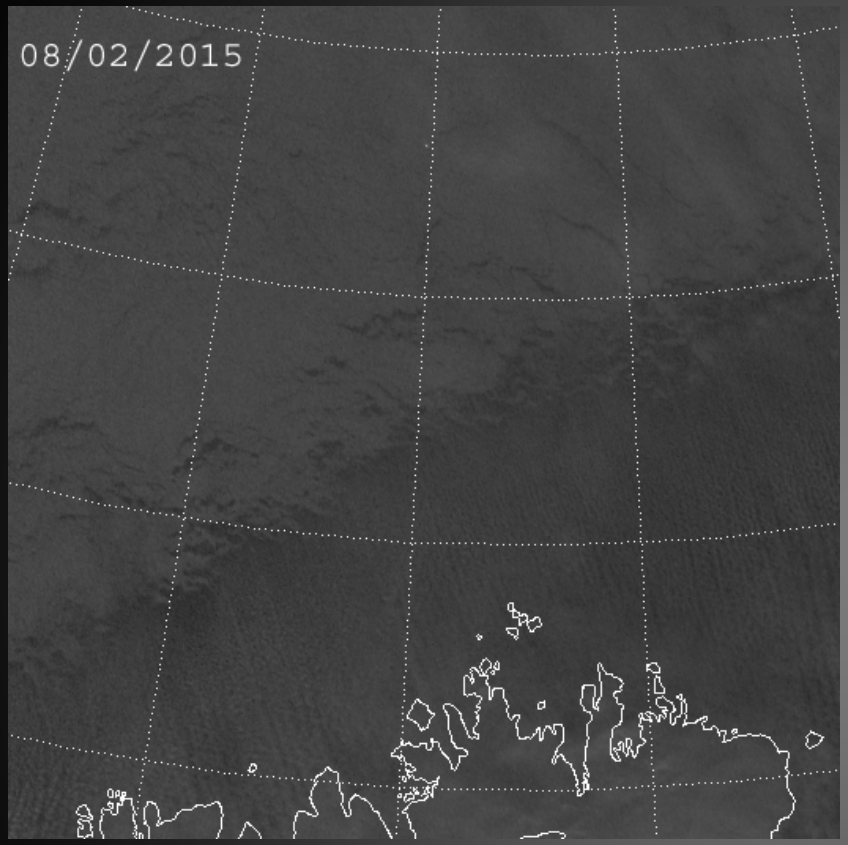
06:30PM 01:30AM 09:30AM

DNB-based Nighttime Cloud Optical & Microphysical Properties (NCOMP)

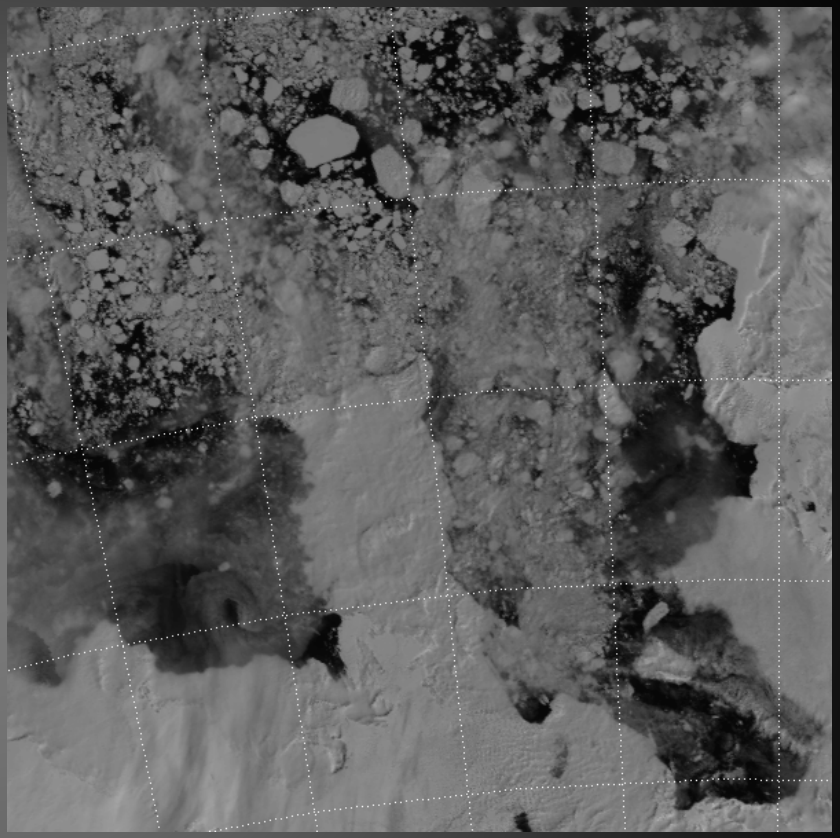
Shortwave Infrared Split-window Technique (SWIT)

Walther et al. (2013)

Scaling in Action

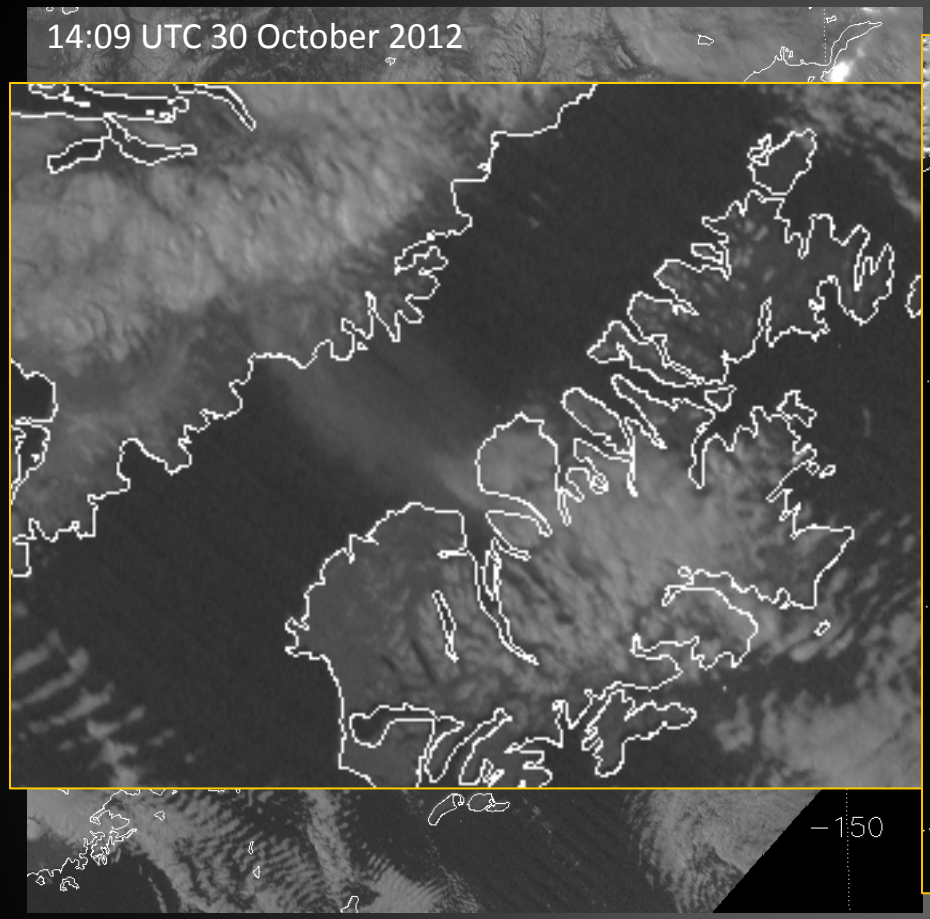


ERF-Dynamic Scaling with Auto Contrast
(moonless nights and twilight)

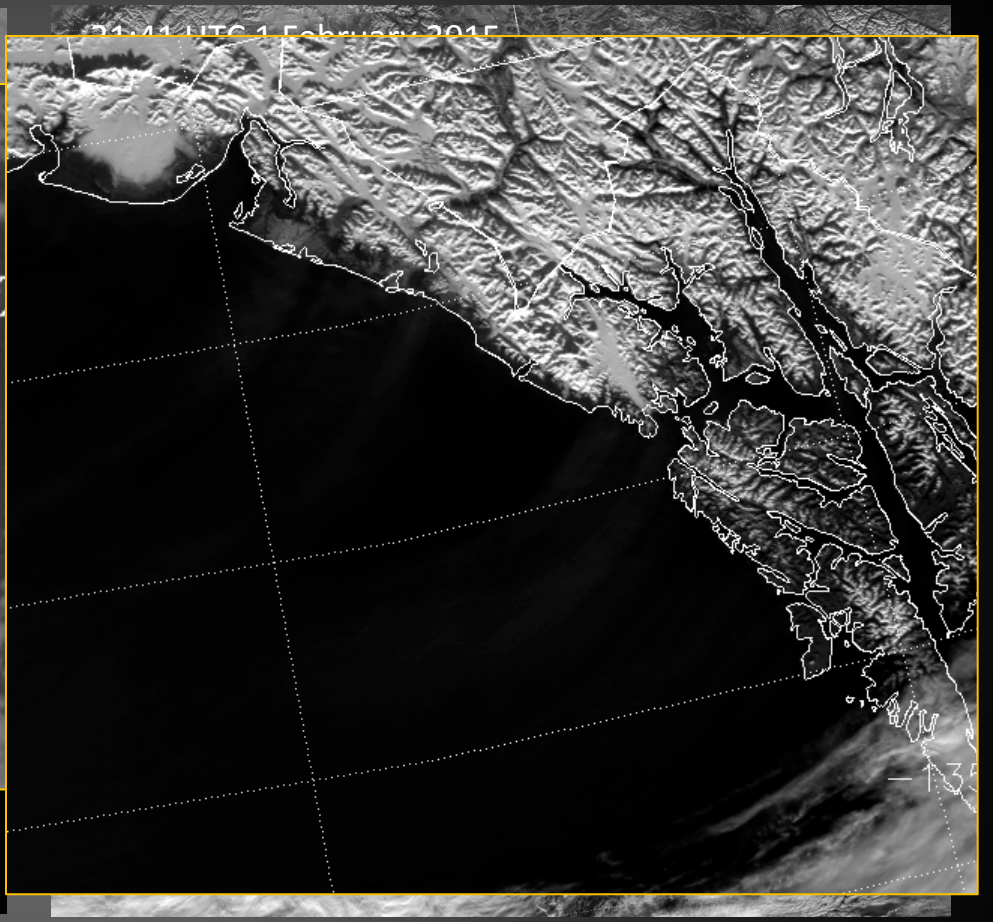


Near Constant Contrast EDR (0 to 2)
(daylight and twilight)

Ash and Dust



Volcanic ash leftover from the 1912 eruption of Novarupta is lofted over Kodiak Island in strong winds



Sightings of “glacial flour” provide forecasters an opportunity to “see the wind” and warn mariners