# Use of S-NPP VIIRS Data in Navy/DoD Operations

**NRL**

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**CIRA**

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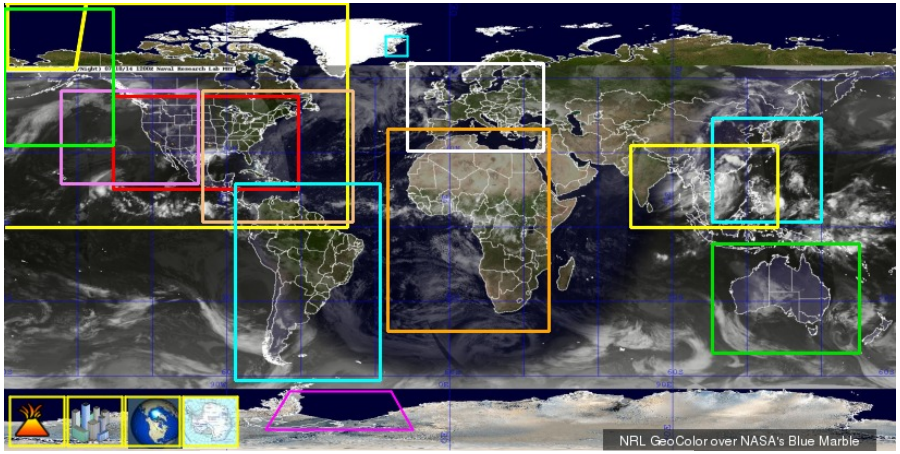
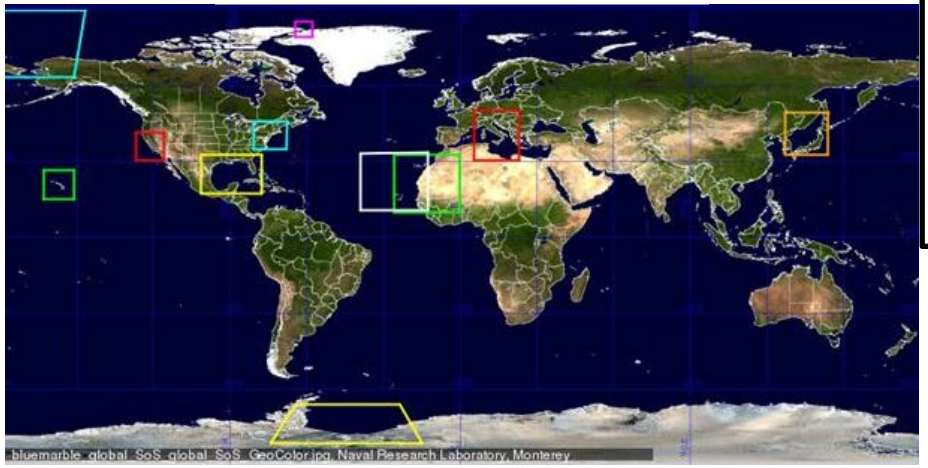
**Naval Research Laboratory**
**Marine Meteorology Division**

# VIIRS Imagery Demonstration

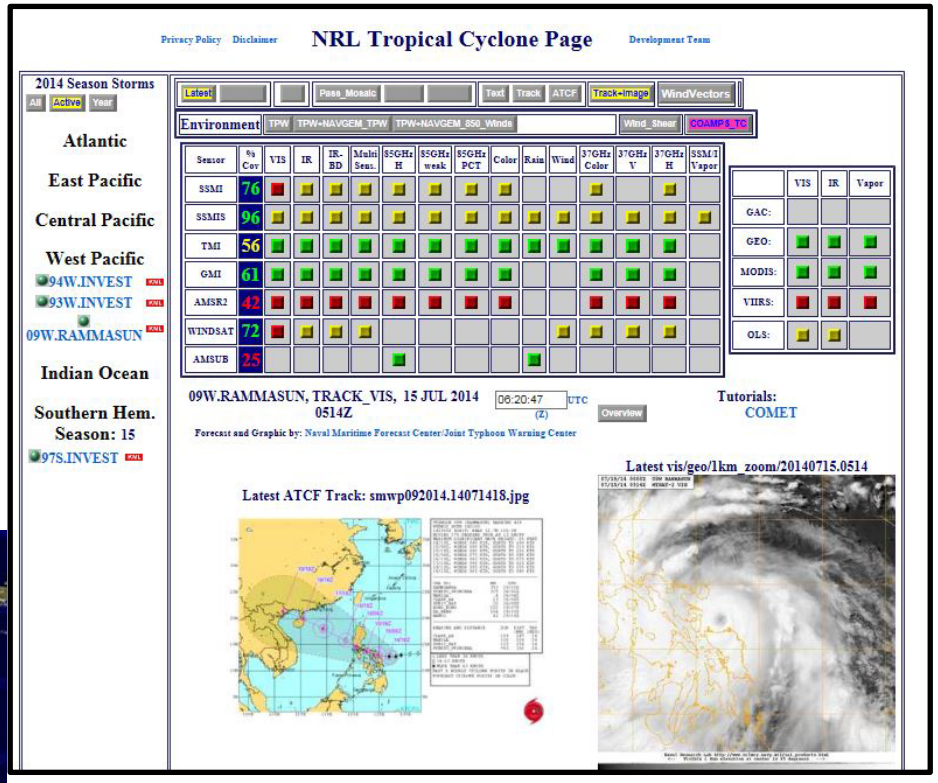
## NexSat



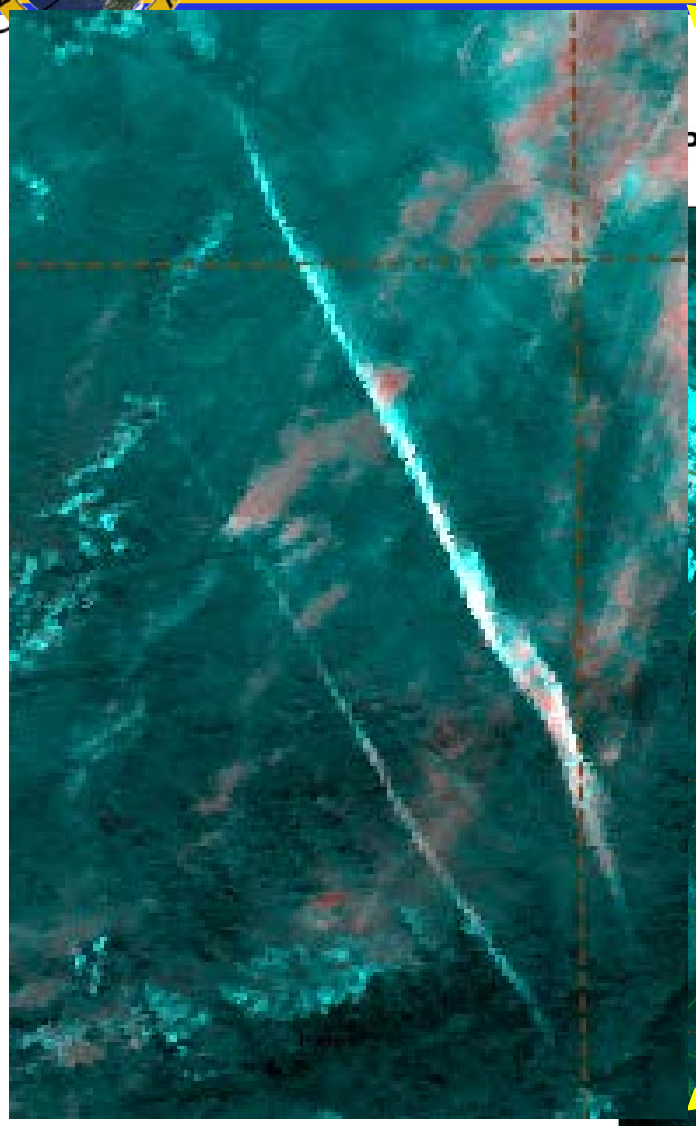

## VIIRS Demo

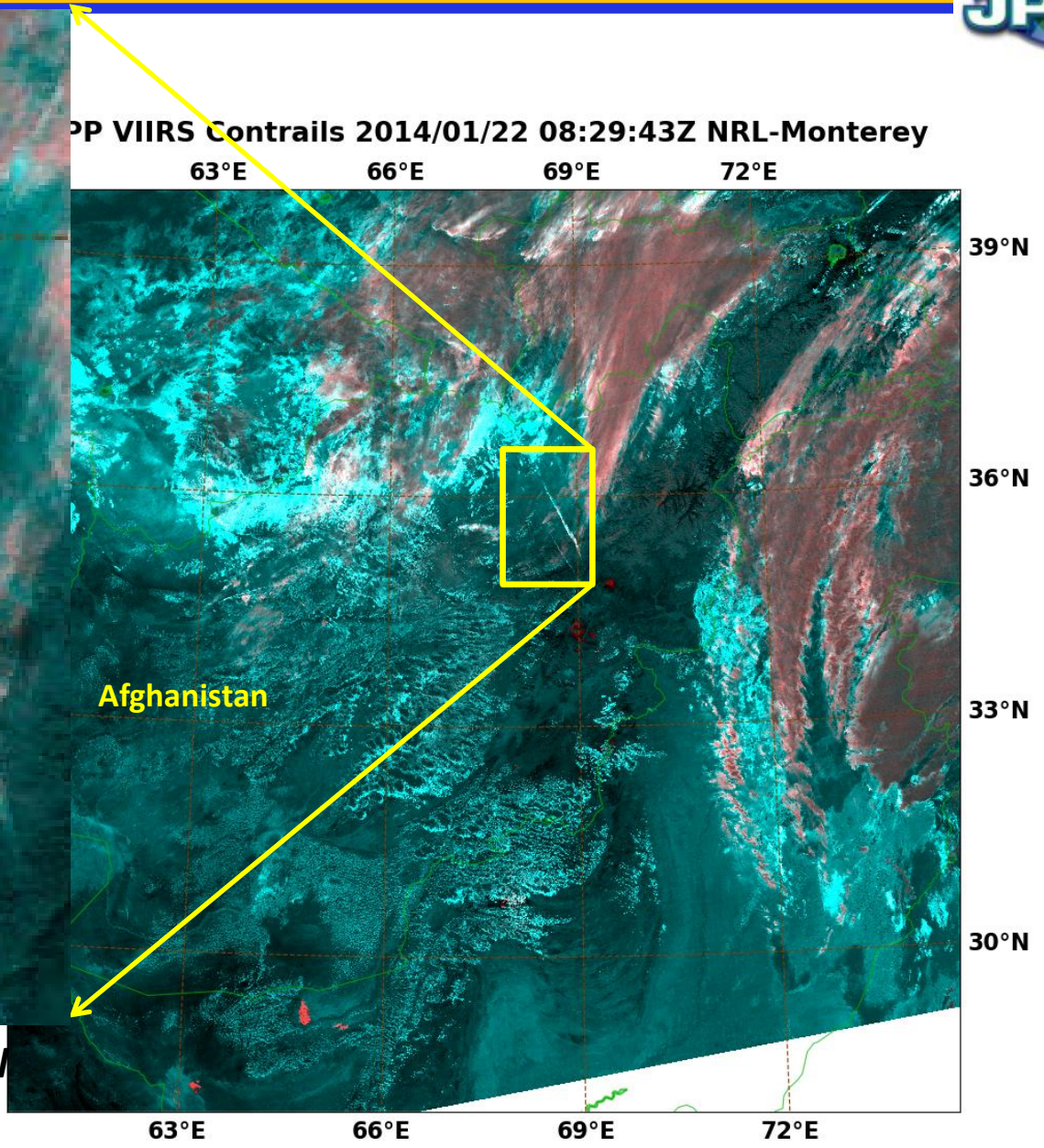



## TCWeb



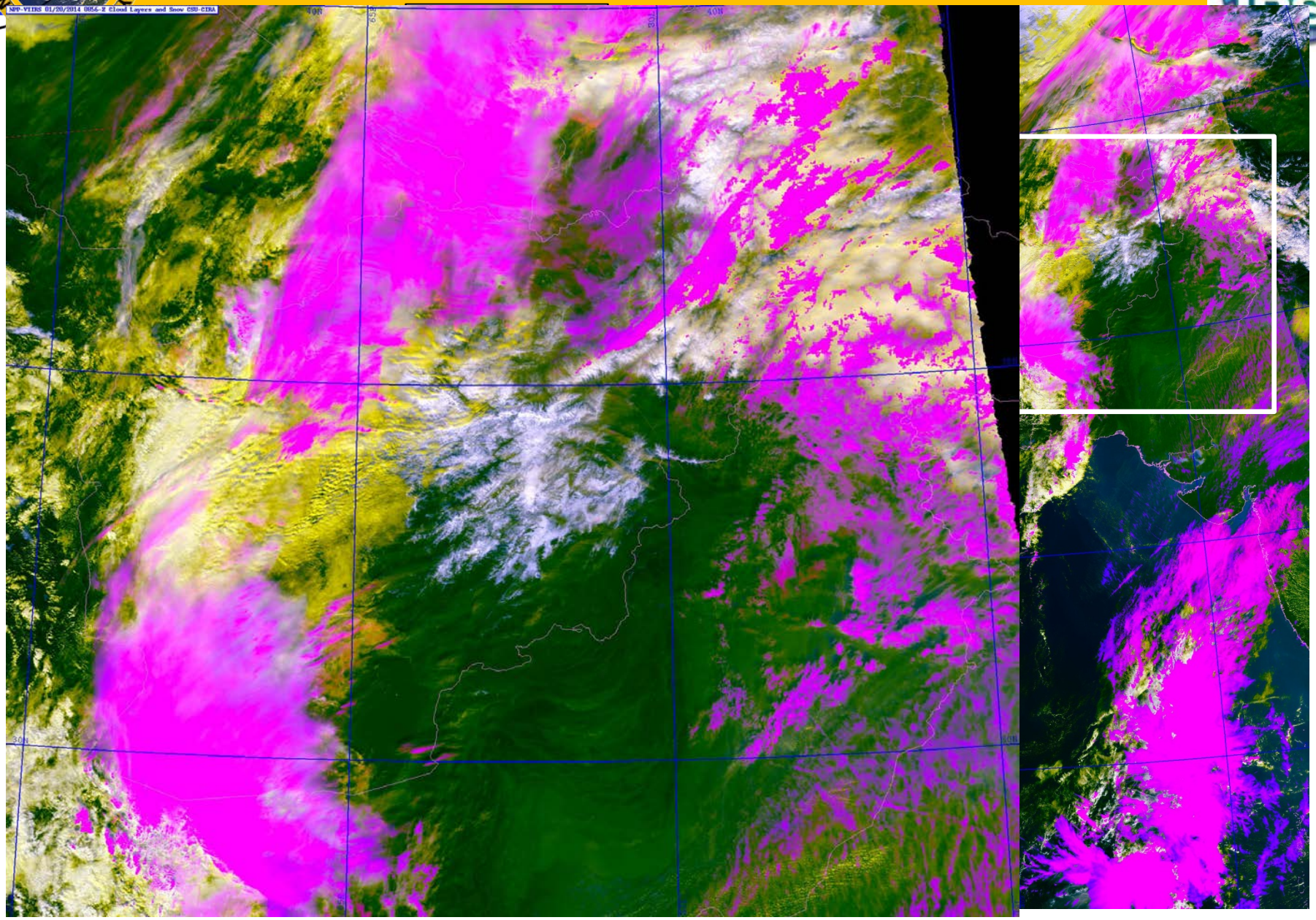
# VIIRS Contrail Detection






***Transitioned to Fleet Numerical for Operational use***

# Cloud/Snow Discrimination



# VIIRS (Blue-Light) Dust

***GOAL: Enhance and isolate lofted dust over desert (daytime) to reduce or avoid the problems associated with limited visibility in airborne dust.***

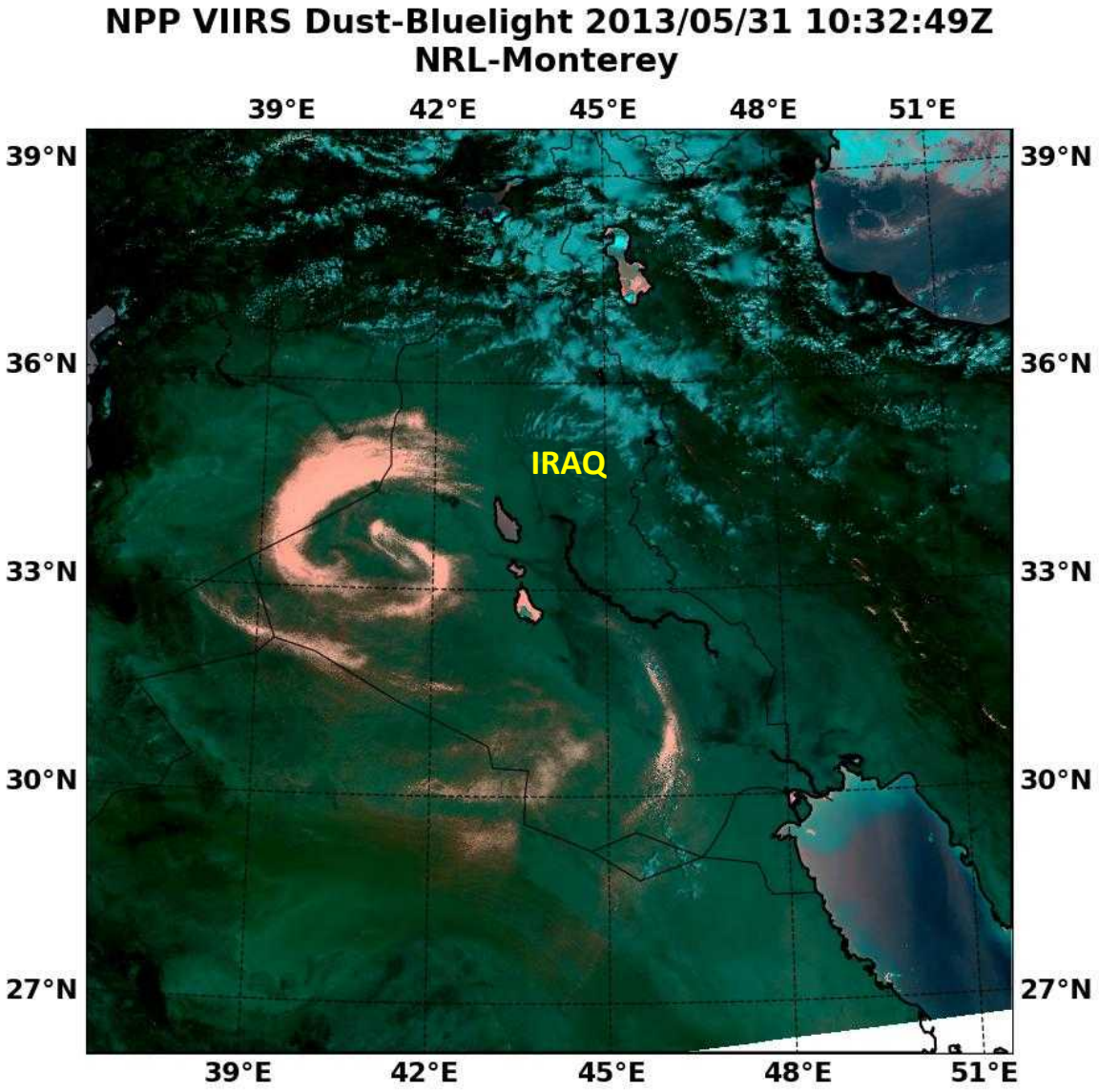
**NRL Dust Enhancement Algorithm uses a multispectral (7-band) function that takes advantage of these dust properties:**

- **Higher blue light absorption for dust**
- **Thermal contrast (dust and surface)**
- **IR split window difference (opposite in sign to Ci)**

***A false-color enhancement is created to isolate the lofted dust:***

**R: 7-band function (VIS/NIR/TIR)**
**G: Rayleigh-corrected green band**
**B: Rayleigh-corrected blue band**

***Transitioned to Fleet Numerical for Operational use***

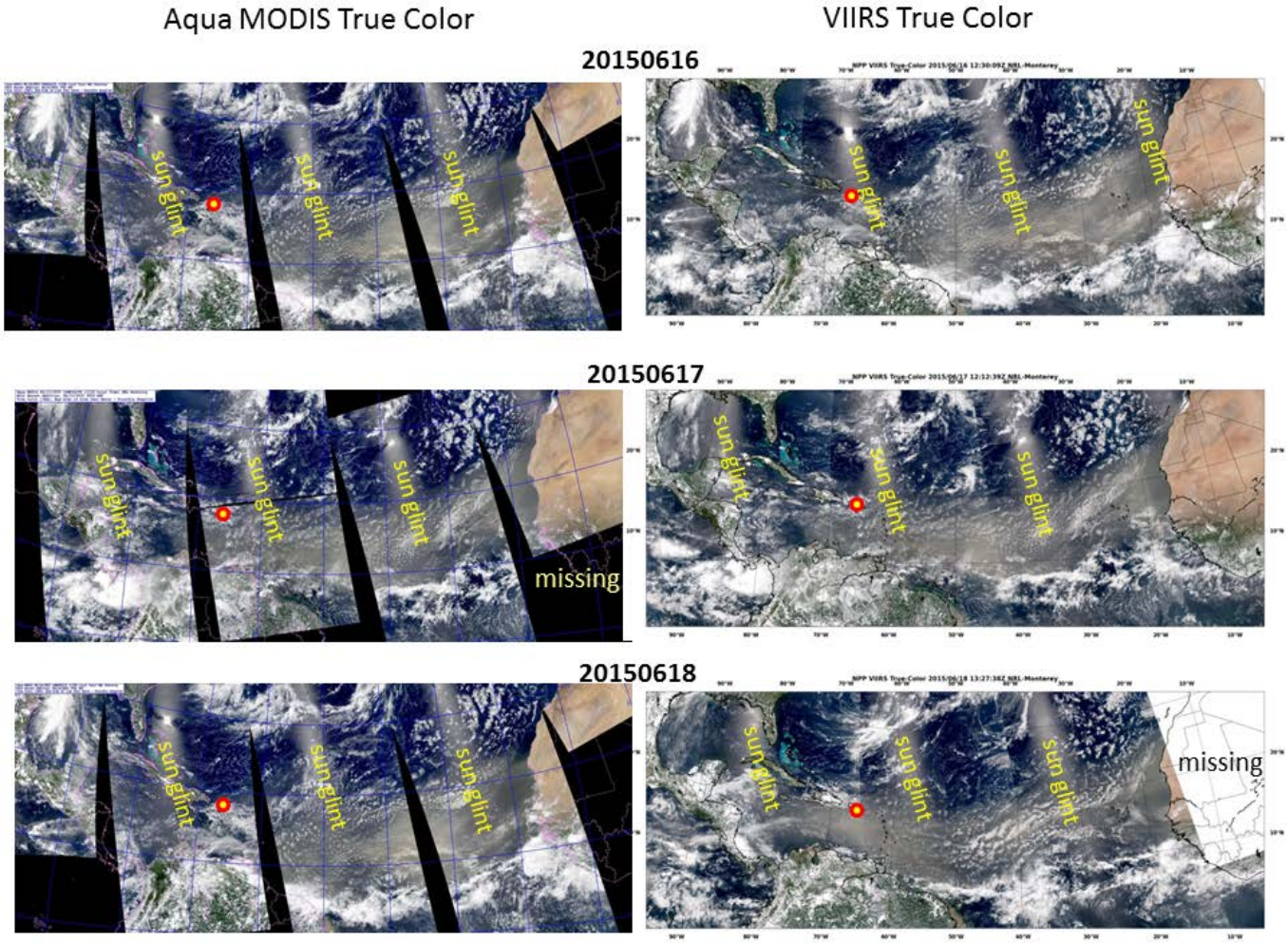


# Saharan Air Layer - Dust

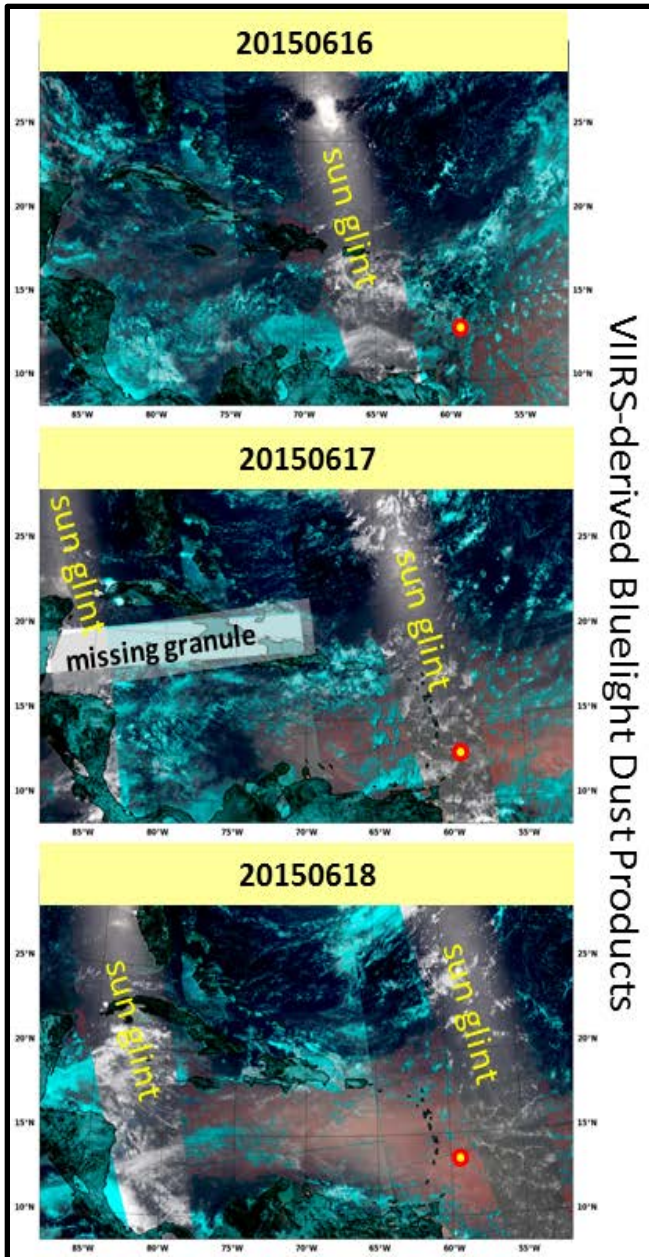
SAL borne dust is important for both visibility and health in the Caribbean.

VIIRS provides a significant improvement over MODIS for detection and assessment due to larger swath and improved resolution at scan edge.

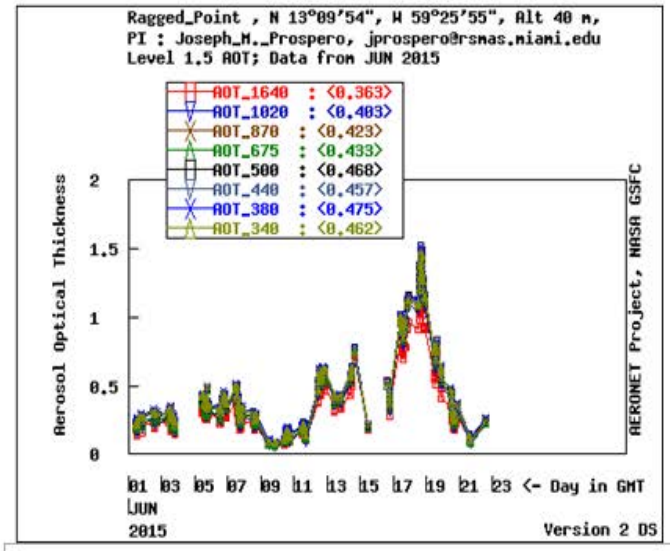
Monitored by the Puerto Rico NWS office.

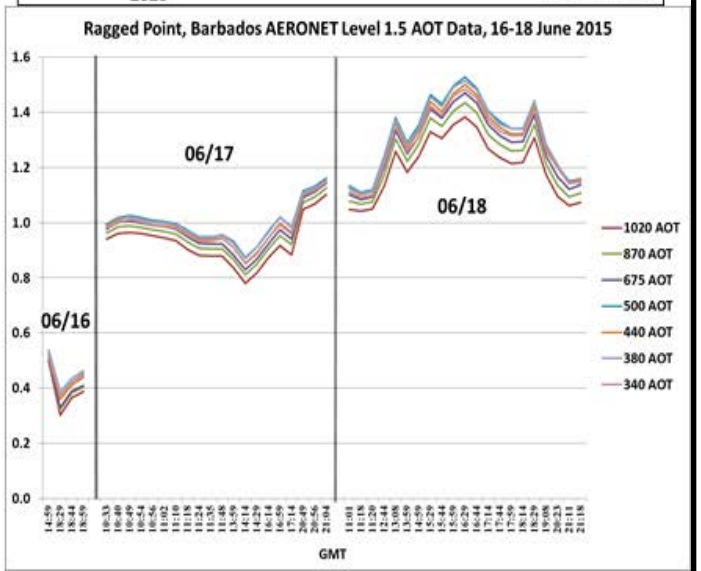


# Saharan Air Layer - Dust



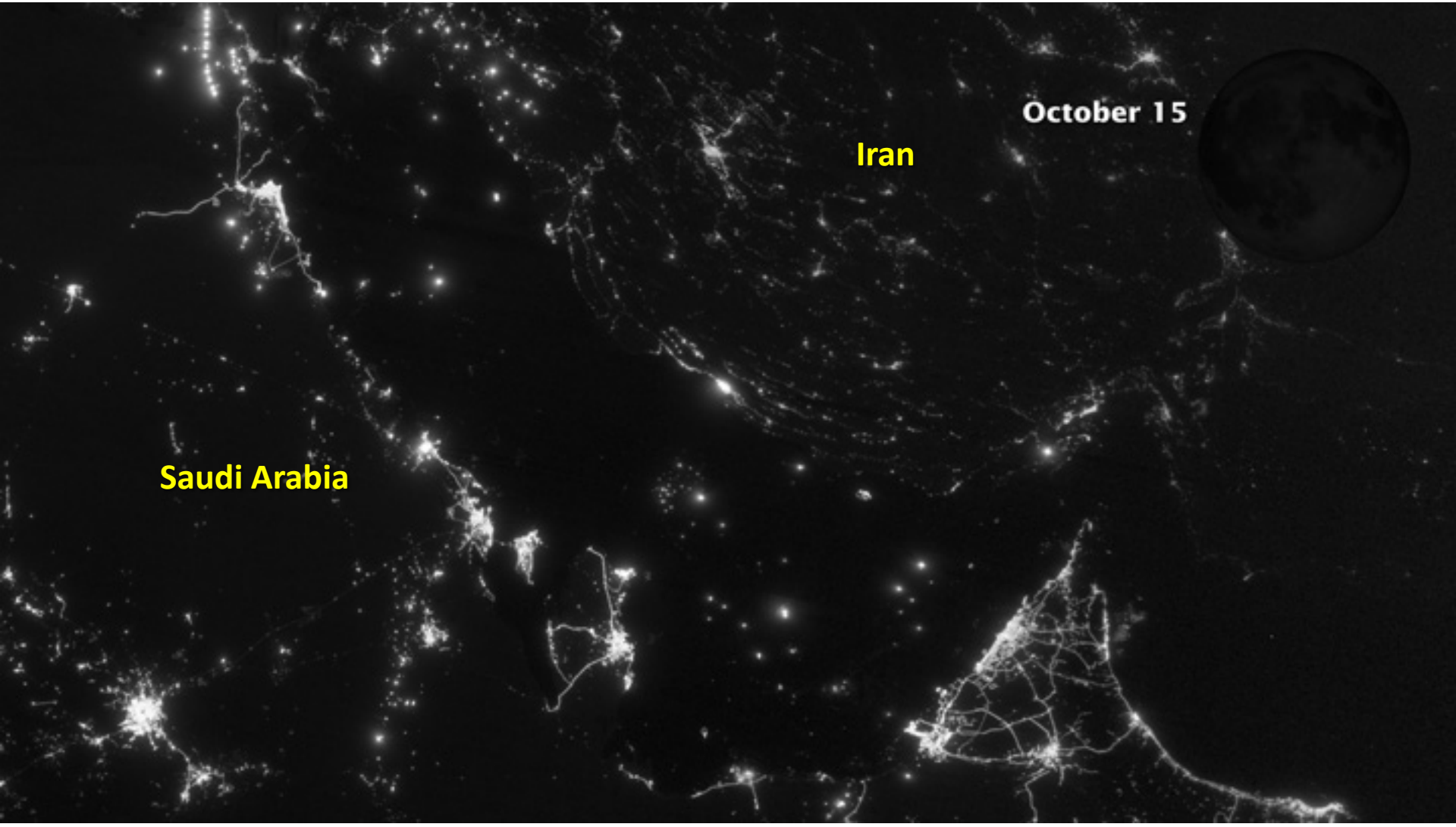

AERONET AOD at Ragged Pt, Barbados



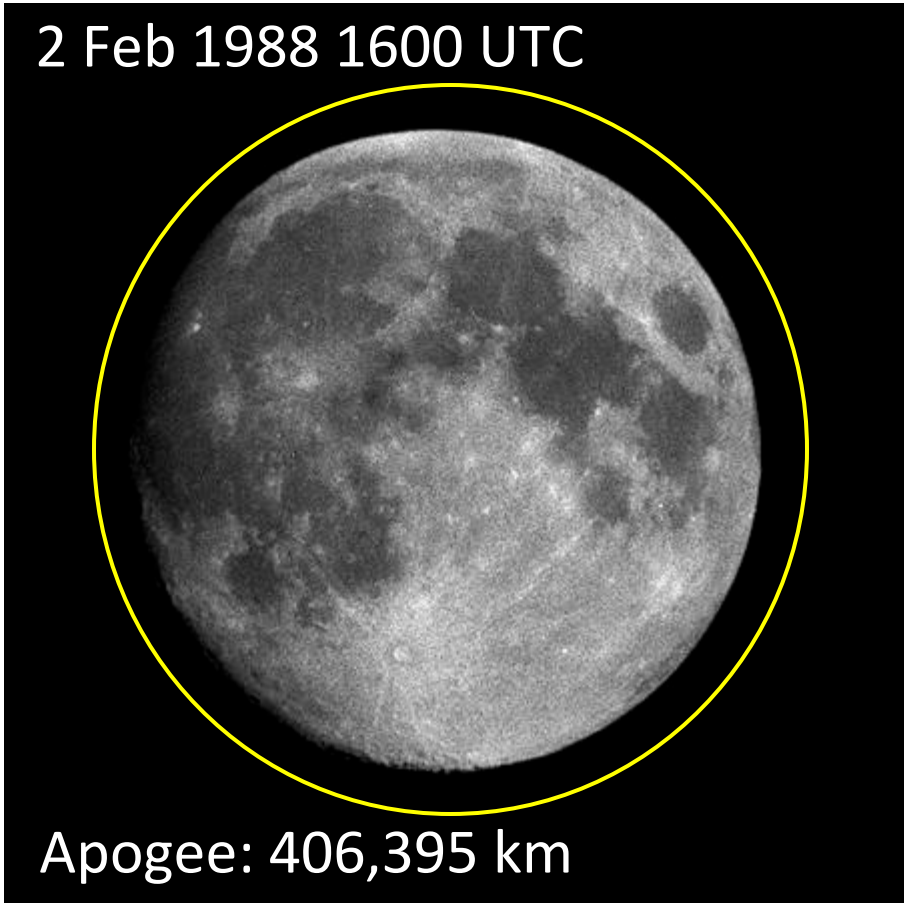



# The Lunar Cycle

## Sep 30 – Oct 15 2012



# The Lunar Cycle

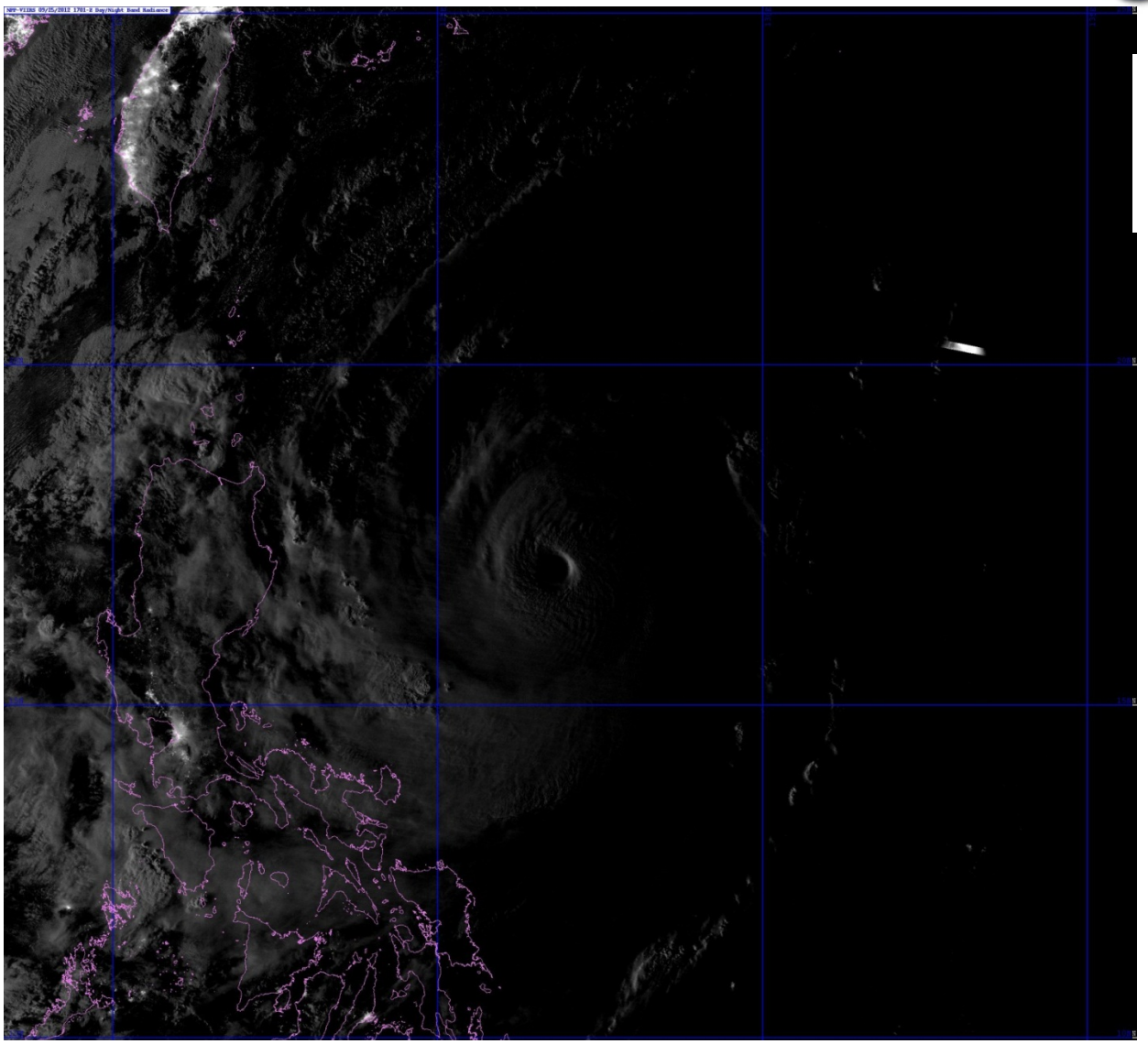
# Quantitative Lunar Reflectances

Lunar model is used to produce a form of near constant contrast (NCC) imagery.

Not applicable to the day/night terminator where solar signal is present.

Moon phase: 80%

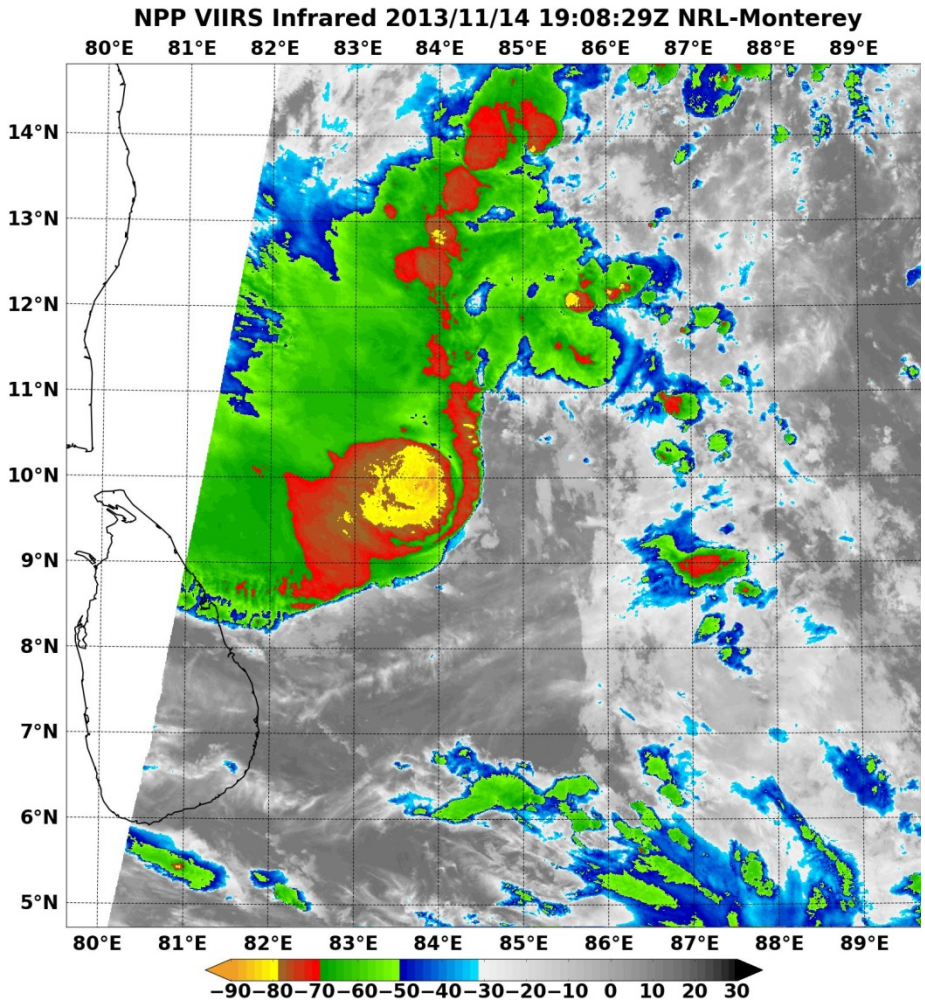
***Transitioned to Fleet Numerical for Operational use***

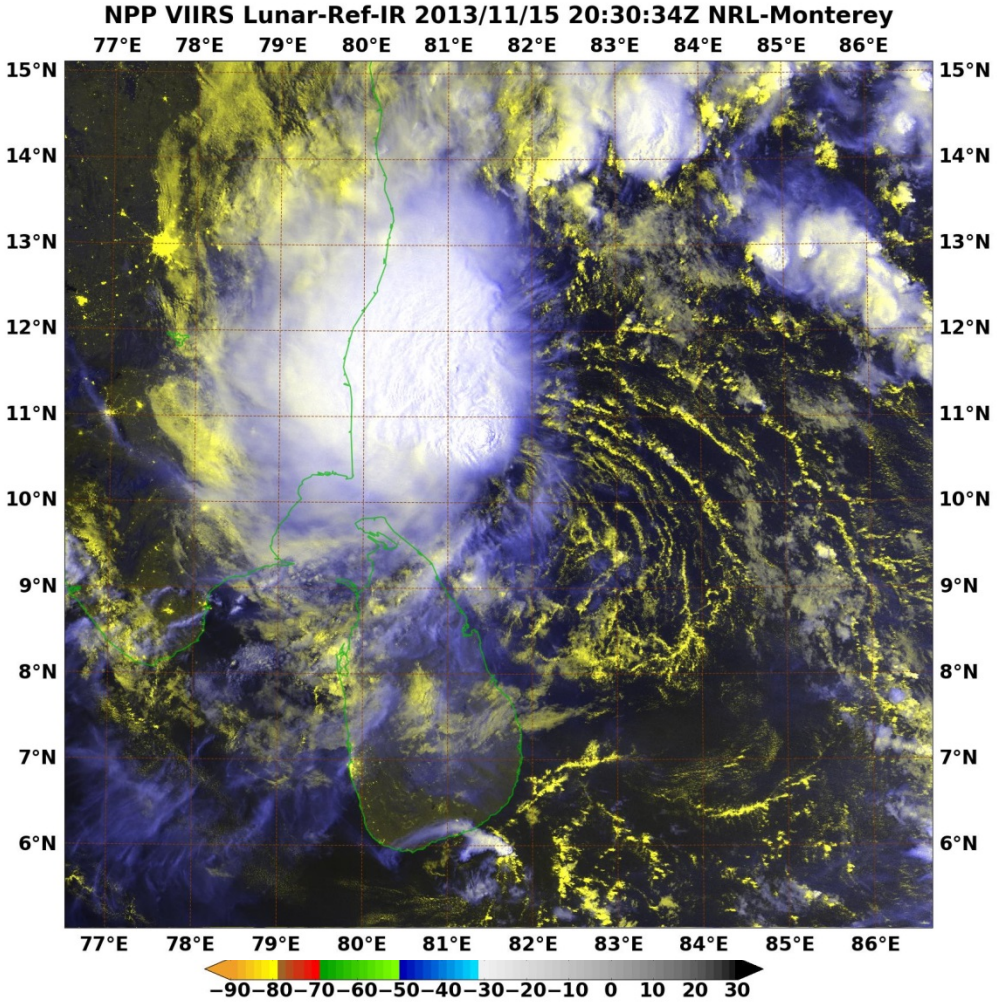


**Quantitative visible reflectance values: many applications**

# DNB Reveals Low-Level Features

## Typhoon Haiyan

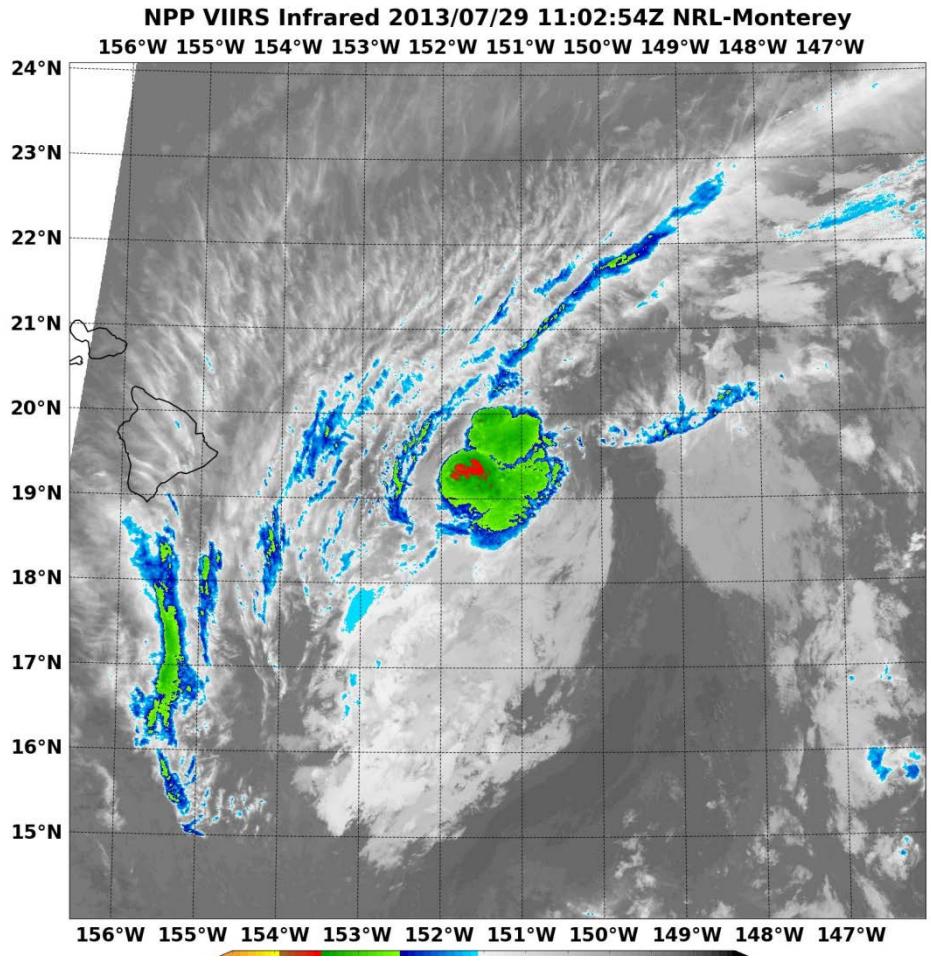


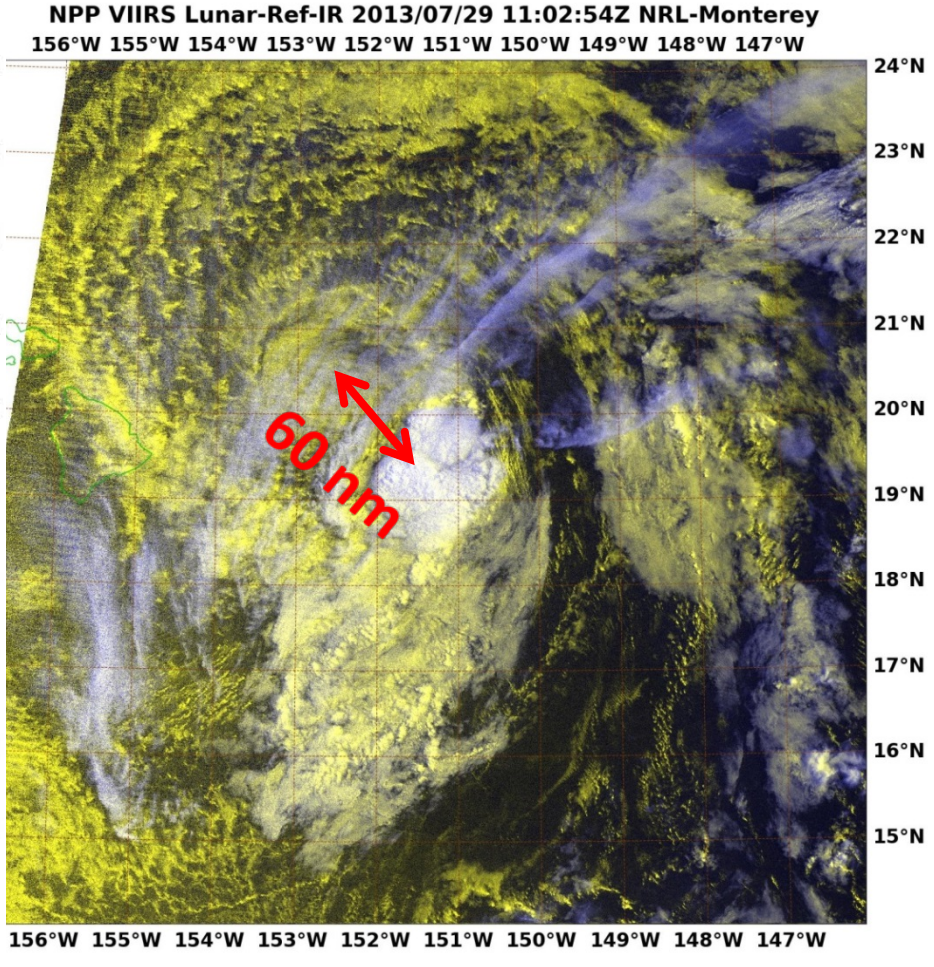




**LLCC “exposed” by VIIRS DNB lunar illumination**

# DNB Reveals Low-Level Features

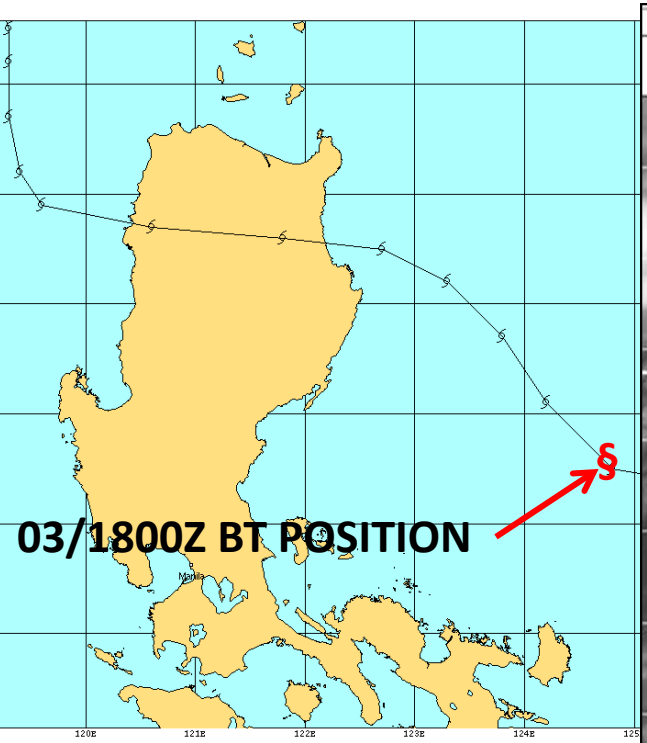
## Hurricane Flossie

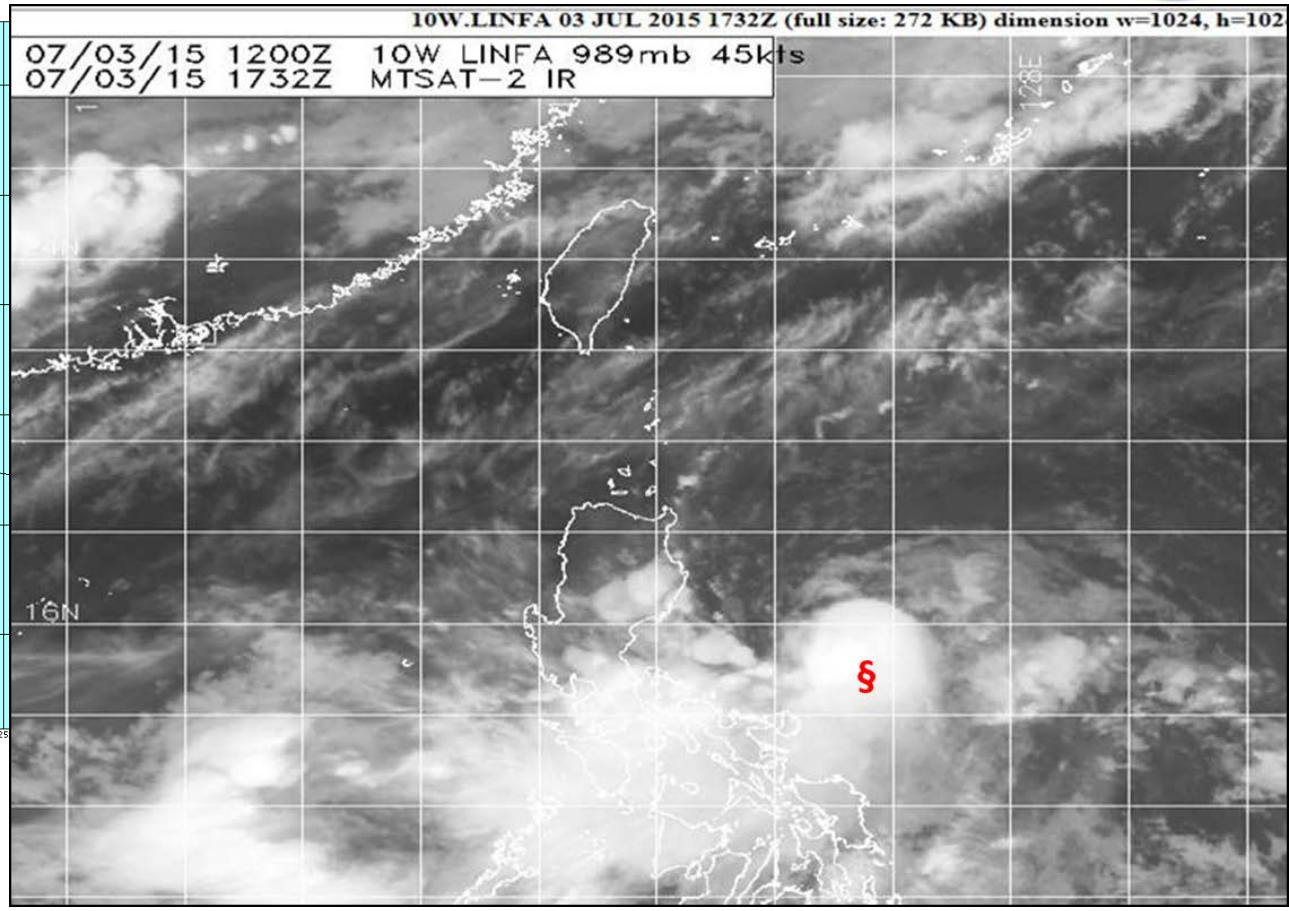



**VIIRS DNB dramatically altered CPHC Flossie forecast to the NW, directly impacting landfall and day 1-3 day warnings**

# Typhoon Linfa




**Infrared imagery provides low confidence of storm location.**

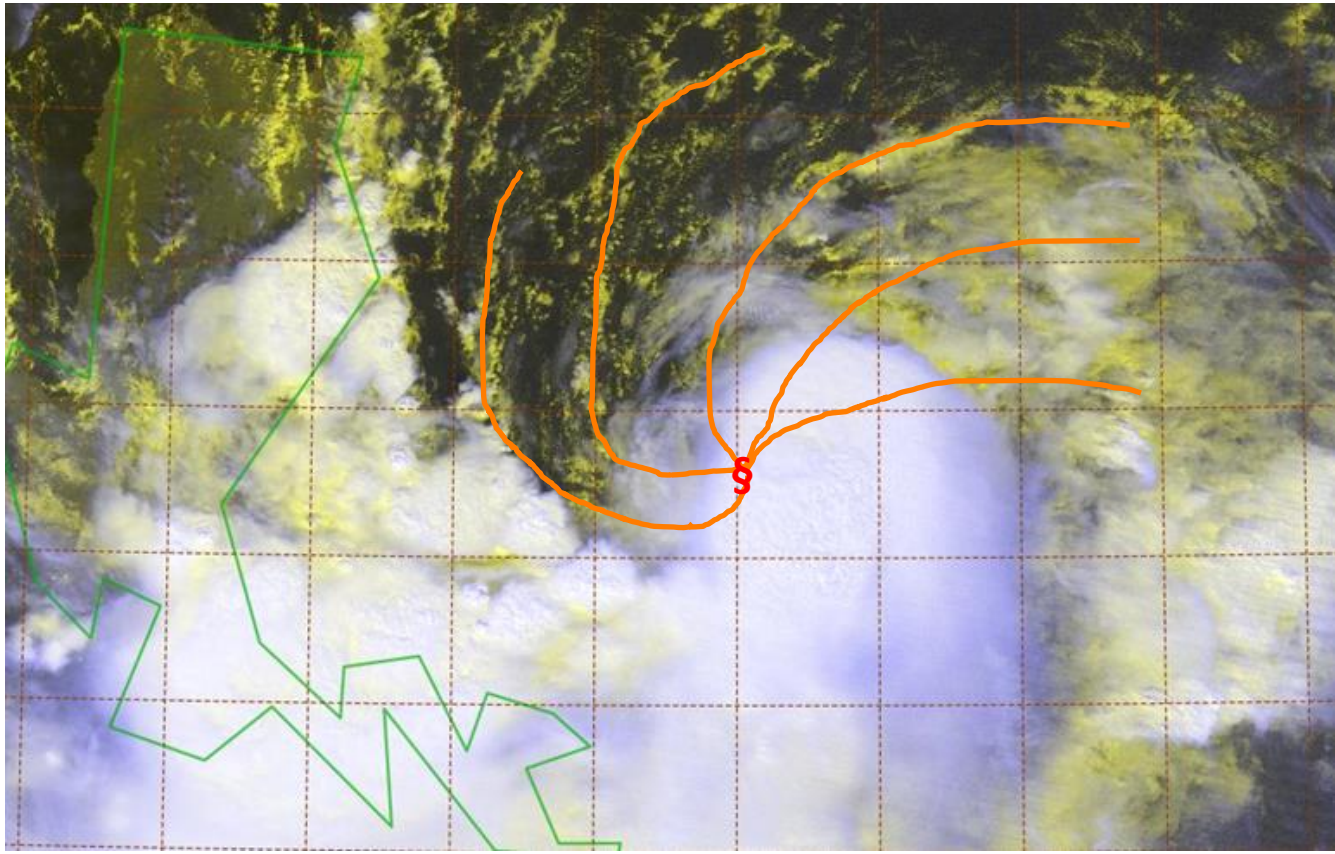
**No microwave imagery available at the time to improve confidence.**

# Typhoon Linfa

VIIRS allowed analysts to greatly improve upon IR-only storm center.

Low level cloud lines are easily traced to the storm center.

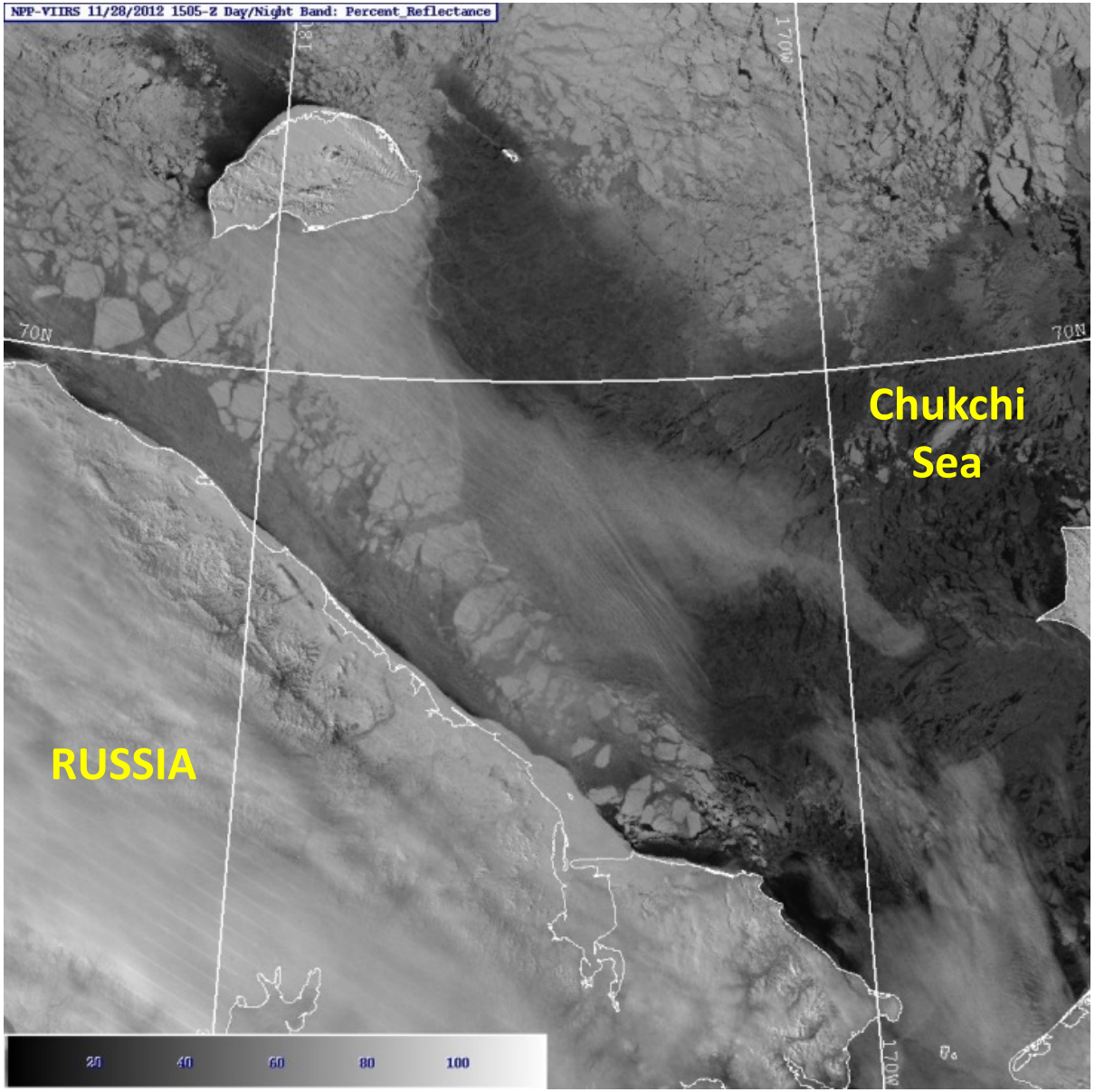
Without DNB, analysts would have favored a position under the deeper convection



**"Without the VIIRS image, TC position would have been derived from IR only, which would have placed the center further southeast ~20 miles"**

Courtesy of Capt. Brian Decicco and TSGT Ricky Frye, Joint Typhoon Warning Center

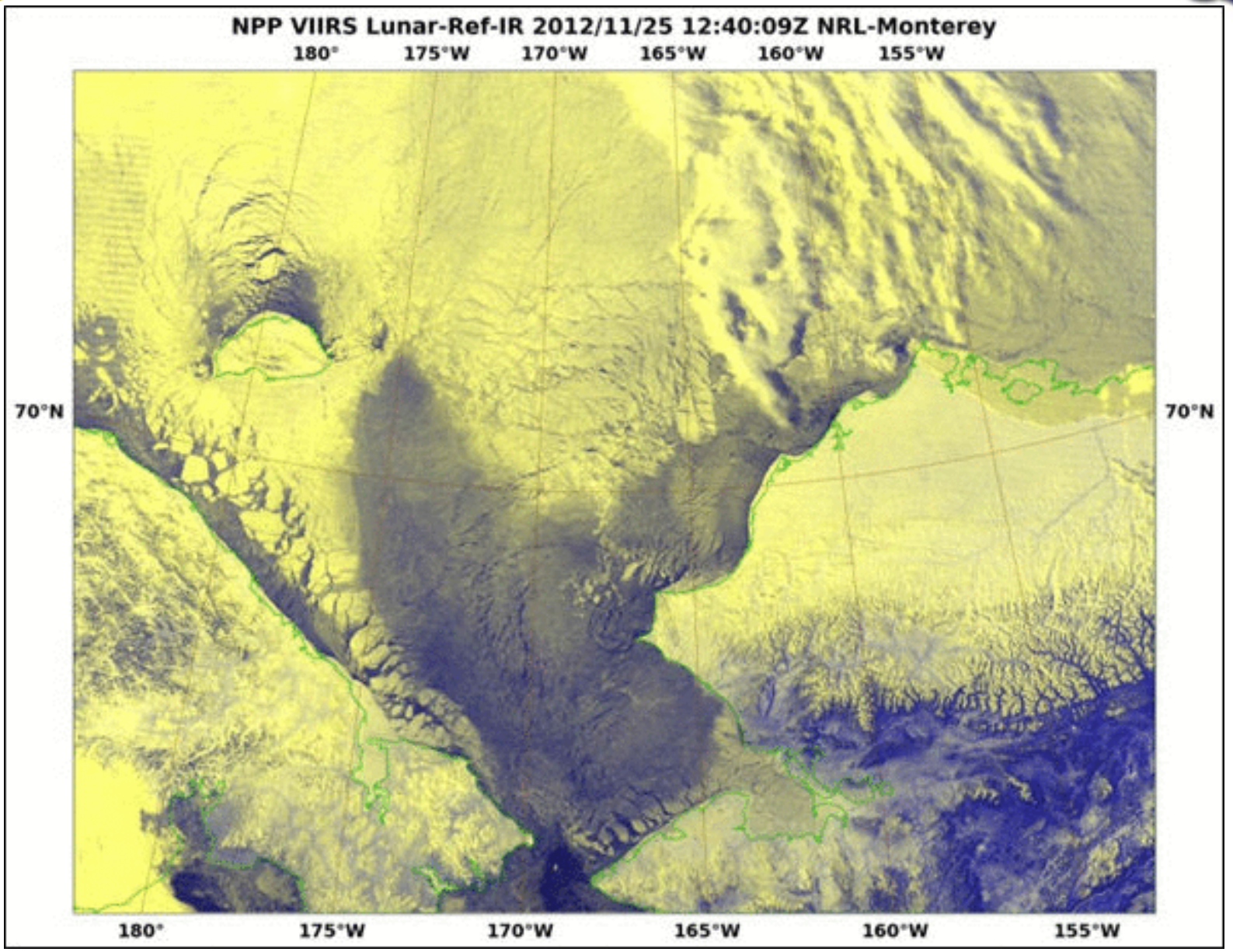
# DNB For Nighttime Sea Ice




**Lunar illumination passes through thin cirrus and reflects off sea ice below**

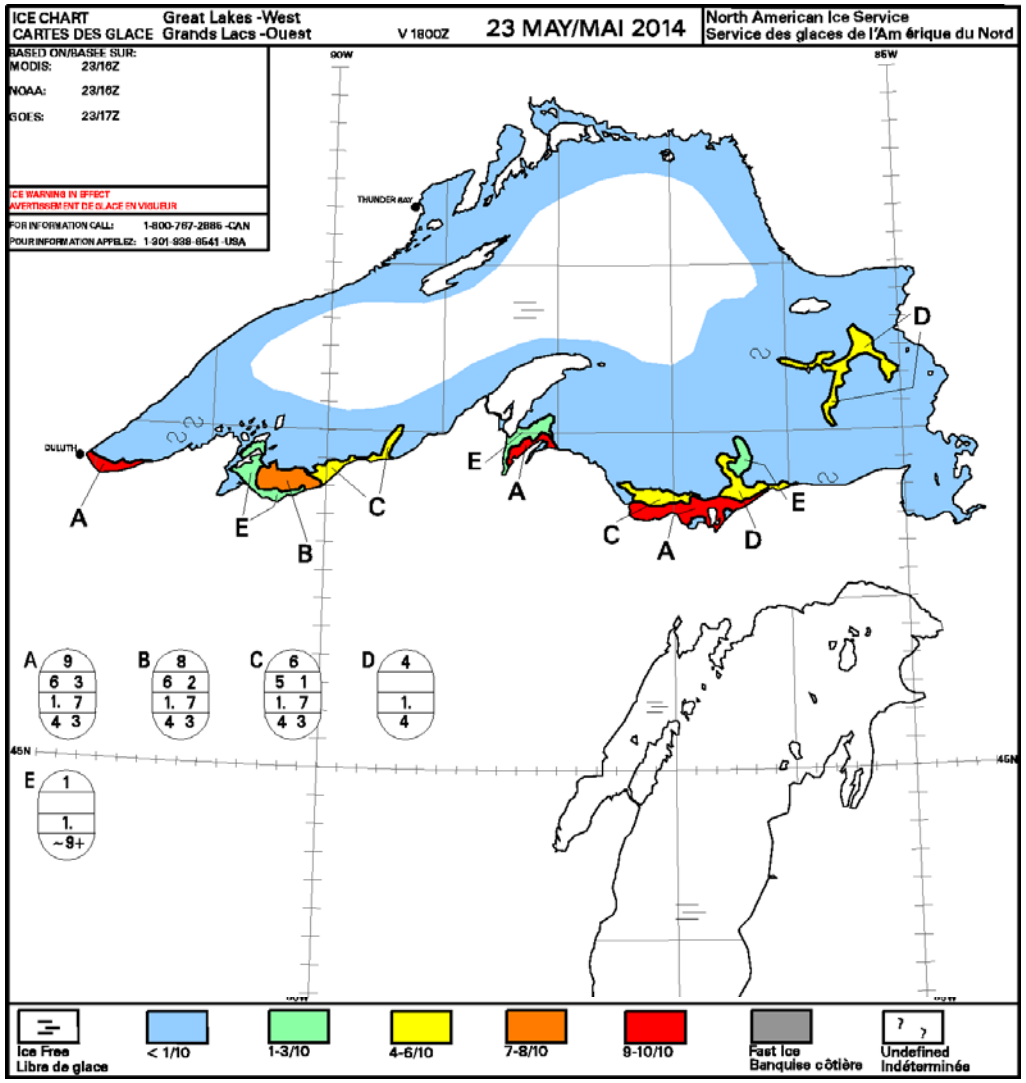
Cooperative Institute for Research in the Atmosphere

# DNB For Nighttime Sea Ice



# Great Lakes Ice Demo

**NIC**
**Great Lakes**
**Lake Ice Map**
**May 23, 2014**

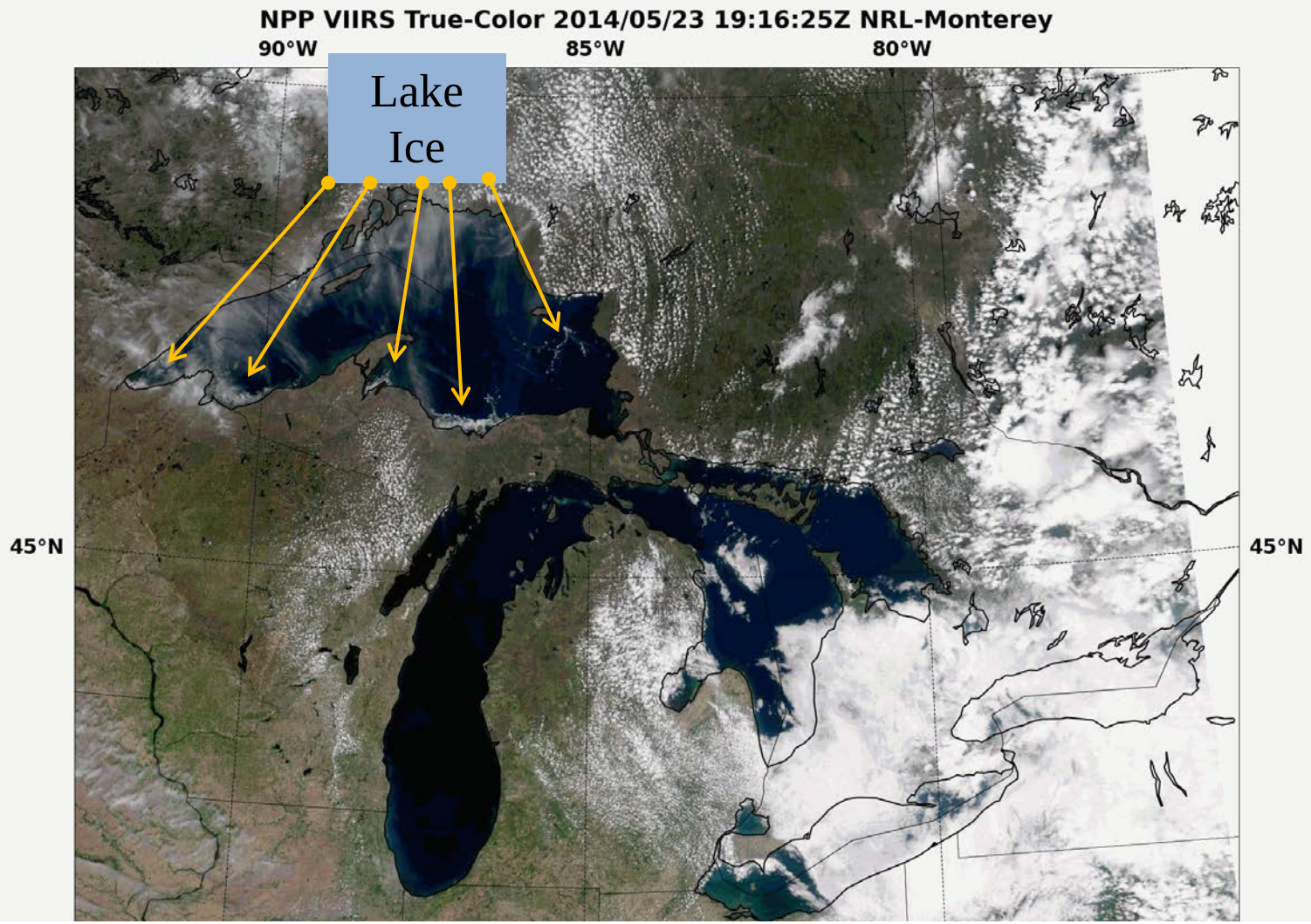



**< 1/10 (light blue), isolated lake ice near south shore and Michipicoten Island**

# Great Lakes Ice Demo

**VIIRS True Color Animation**

**May 23-30 , 2014**

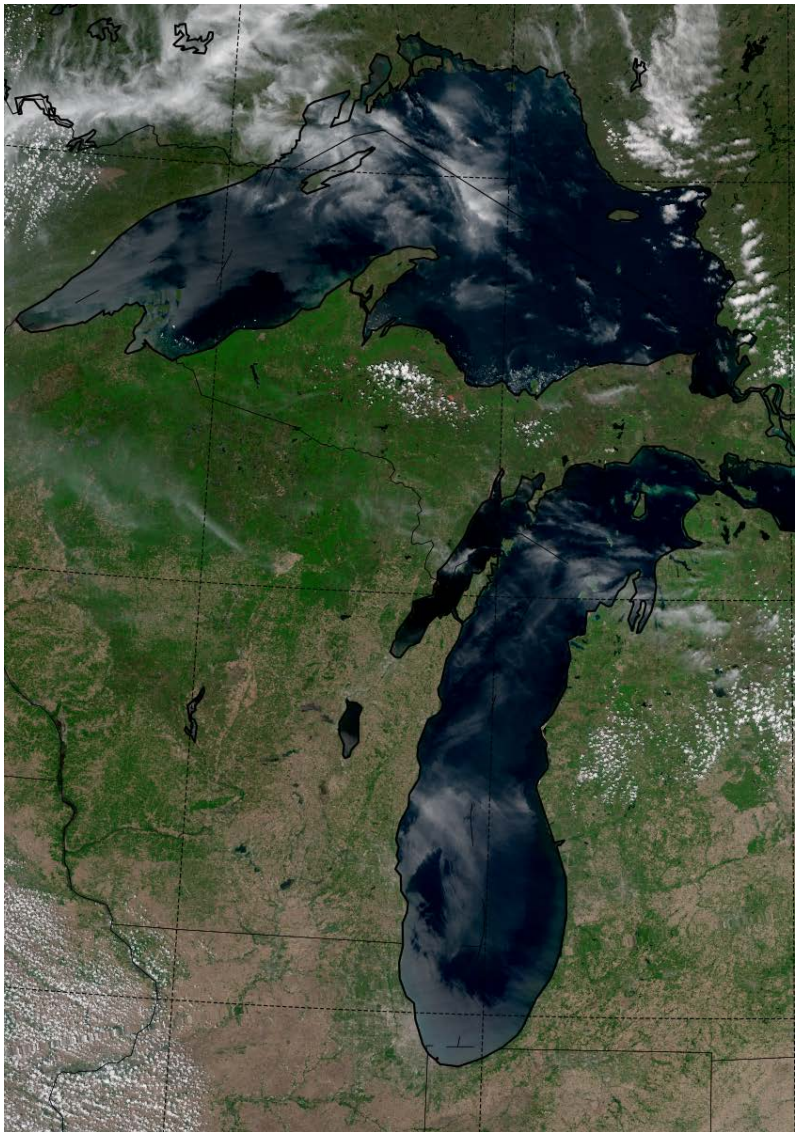



**Created Great Lakes VIIRS sea ice demo within 15 minutes of NIC request using GeoIPS software**

# Great Lakes Ice Demo

**May 24, 2015**

**May 30, 2015**



# NIC Use of VIIRS

NRL added seven polar domains in support of NIC operations.

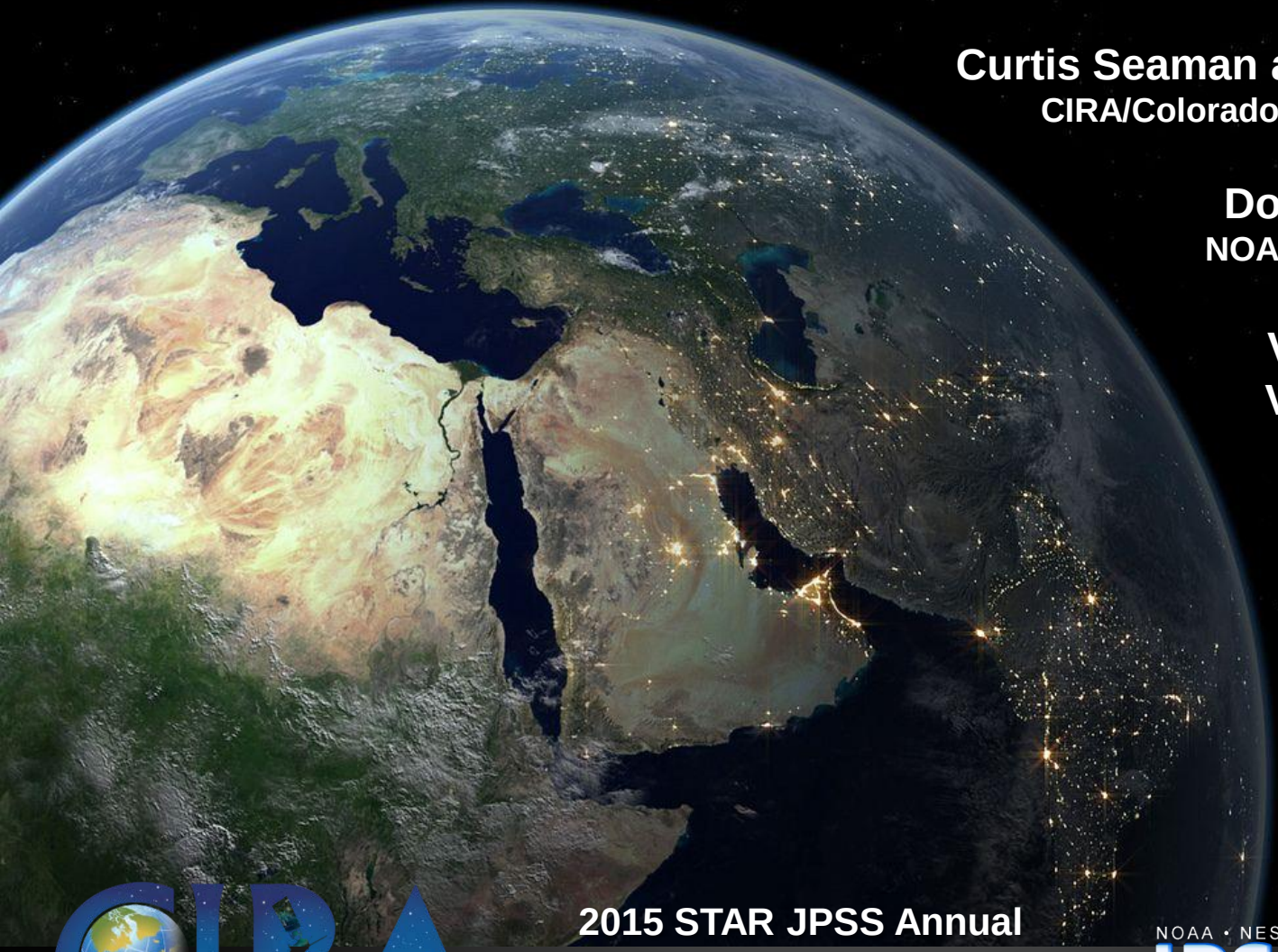
VIIRS frequently used as a component of sea ice analysis.

The NIC has since begun receiving an operational VIIRS feed.

# Summary

- VIIRS imagery is actively playing a role in operational analysis and forecasting.
- The DNB has directly influenced tropical cyclone forecasts on multiple occasions and is relied upon by JTWC and the CHPC.
- The National Ice Center has incorporated VIIRS into its workflow.
- Dust imagery derived from VIIRS has proven useful for detection and forecasting of SAL borne dust outbreaks in the Caribbean.
- Several algorithms based on VIIRS imagery have transitioned to FNMOC for operational use by the Navy.

# 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

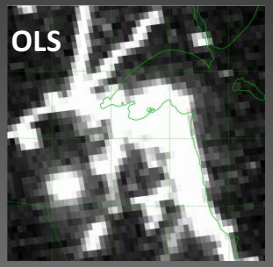
**2015 STAR JPSS Annual Science Team Meeting**
**College Park, MD**

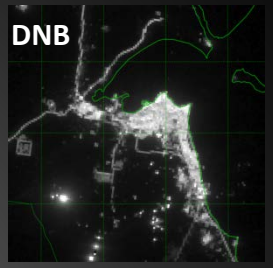
NOAA • NESDIS JPSS Joint Polar Satellite System

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

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

# DNB Advances Over Heritage



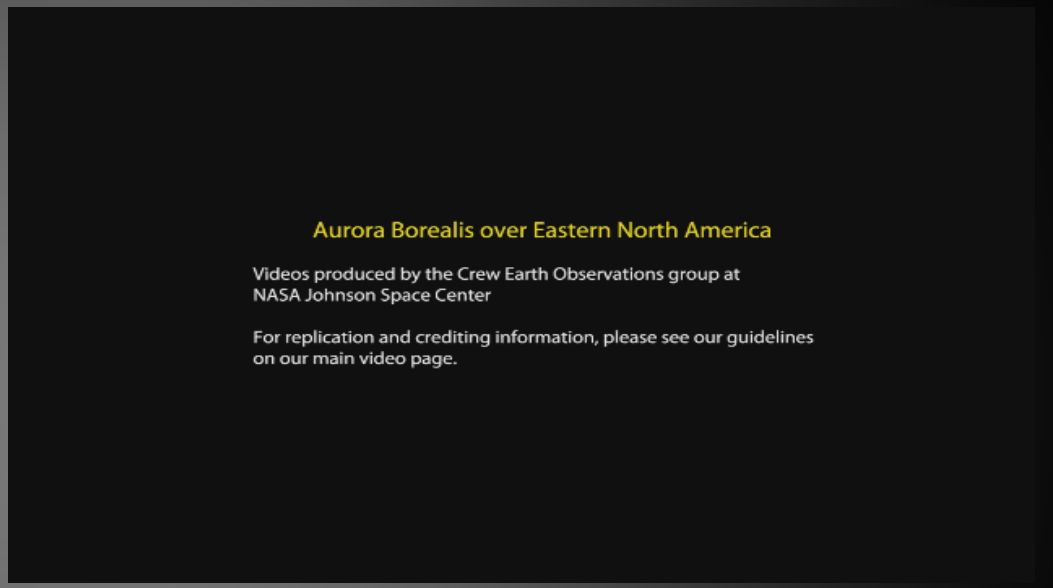




| Attribute | DMSP/OLS* | VIIRS/DNB on Suomi NPP* |
|---|---|---|
| Orbit | Sun-synchronous, ~850 km | Sun-synchronous, 827 km |
| Nighttime Nodal Overpass Time | ~1930 UTC | ~0130 UTC |
| Swath Width | 3000 km | 3000 km |
| Spectral Response (FWHM) | Panchromatic 500-900 nm | Panchromatic 500-900 nm |
| Instantaneous Field of View | 5 km (nadir) / ~7 km (edge) | 0.740 ± 0.043 km (Scan)<br>0.755 ± 0.022 km (track) |
| Spatial Resolution<br>(Ground Sample Distance) | 2.7 km; 'smooth' data | < 0.820 km (Scan)<br>< 0.750 km (track) |
| Minimum Detectable Signal | $4\times10^{-5}$ W m$^{-2}$ sr$^{-1}$ | $3\times10^{-5}$ W m$^{-2}$ sr$^{-1}$ |
| Noise Floor | ~$5\times10^{-6}$ W m$^{-2}$ sr$^{-1}$ | ~$5\times10^{-7}$ 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

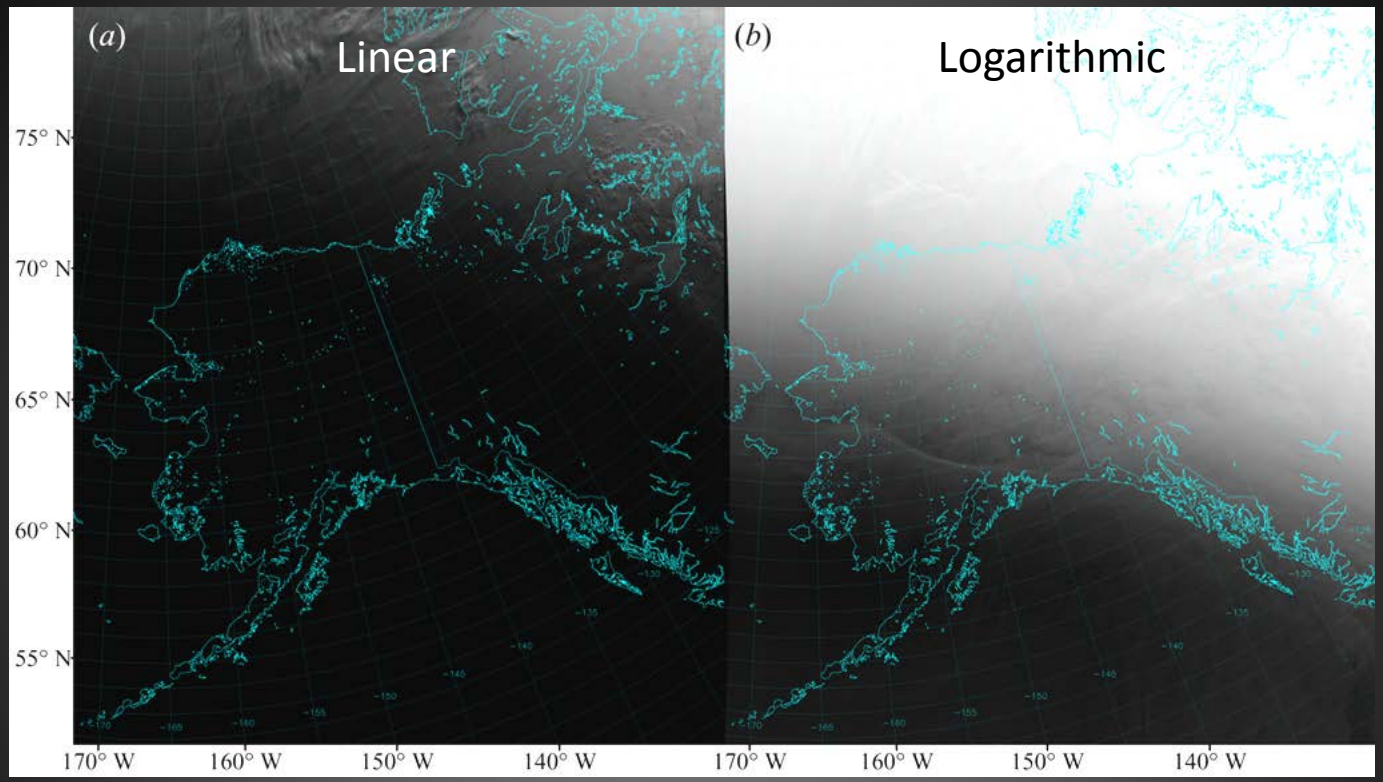




*Credit: Robert Simmon (NASA)*

- 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)*

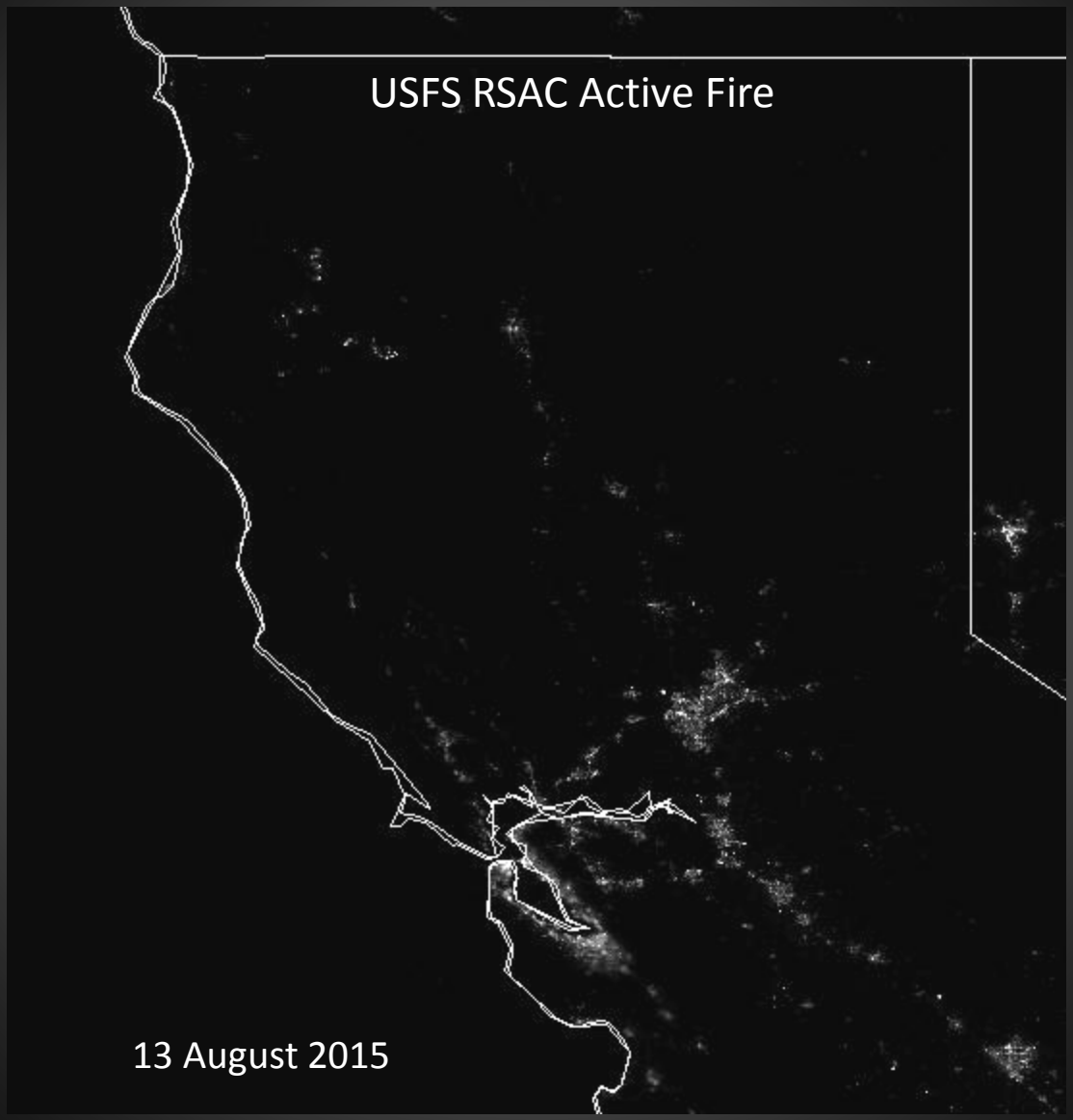
# Displaying 8 orders of magnitude in 256 colors




1 May 2013

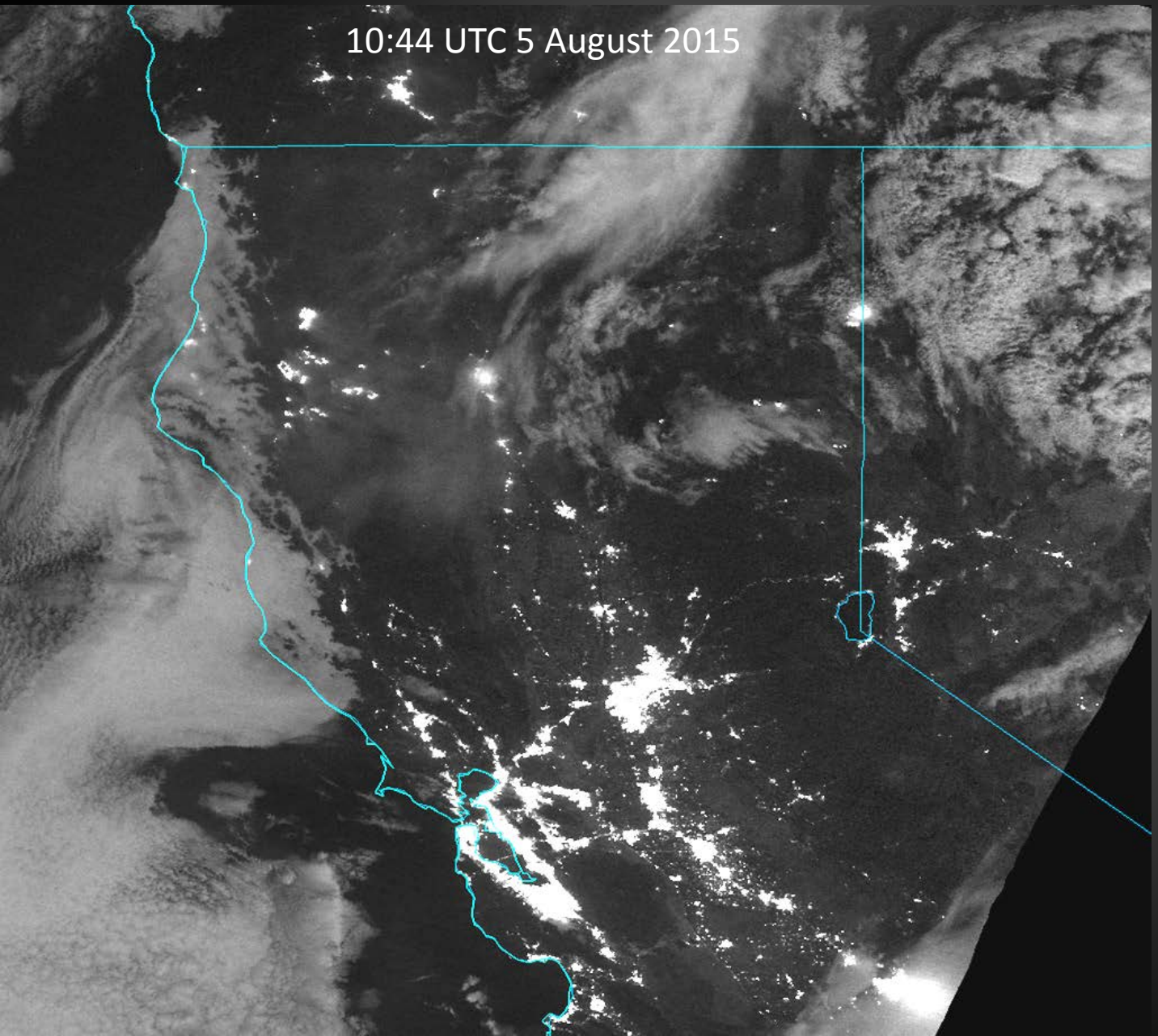
- DNB radiance values vary between ~$10^{-2}$ and ~$10^{-10}$ W $cm^{-2}$ $sr^{-1}$
- Simple scaling methods fail to capture the full range of the data
- What is the best way to capture the full range in 256 colors?

# Displaying 8 orders of magnitude in 256 colors




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

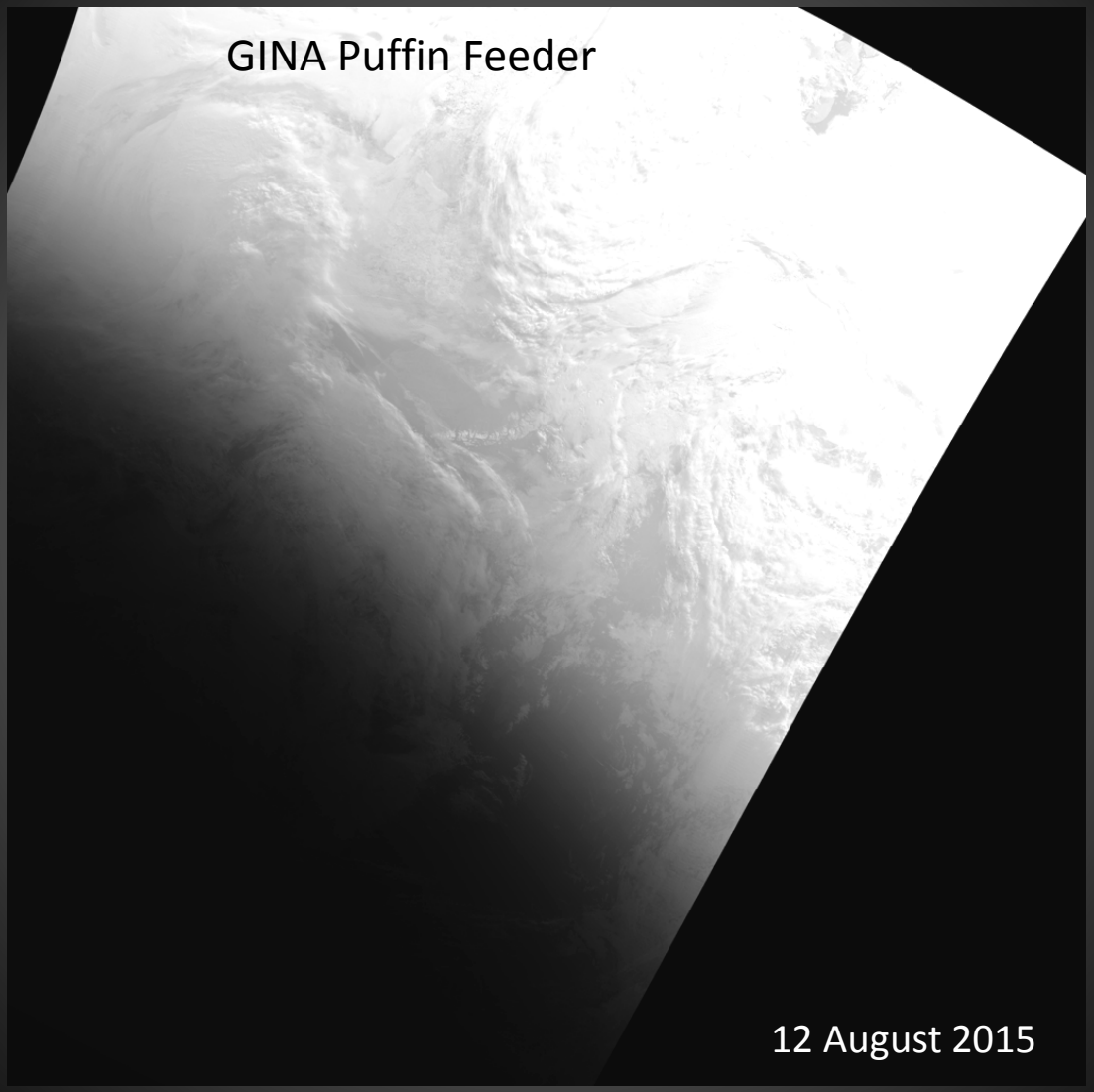
# Missing Details




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

Context is everything!

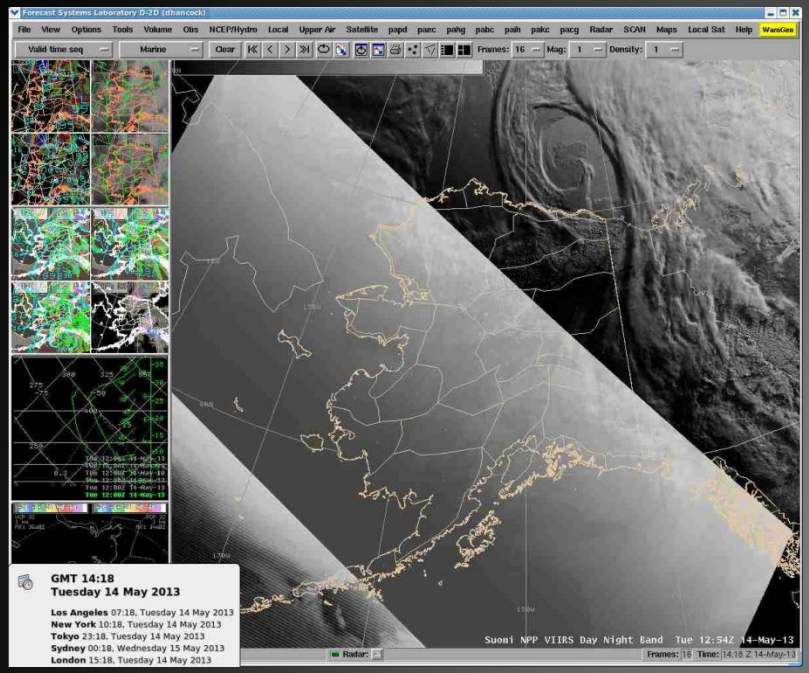
# Displaying 8 orders of magnitude in 256 colors

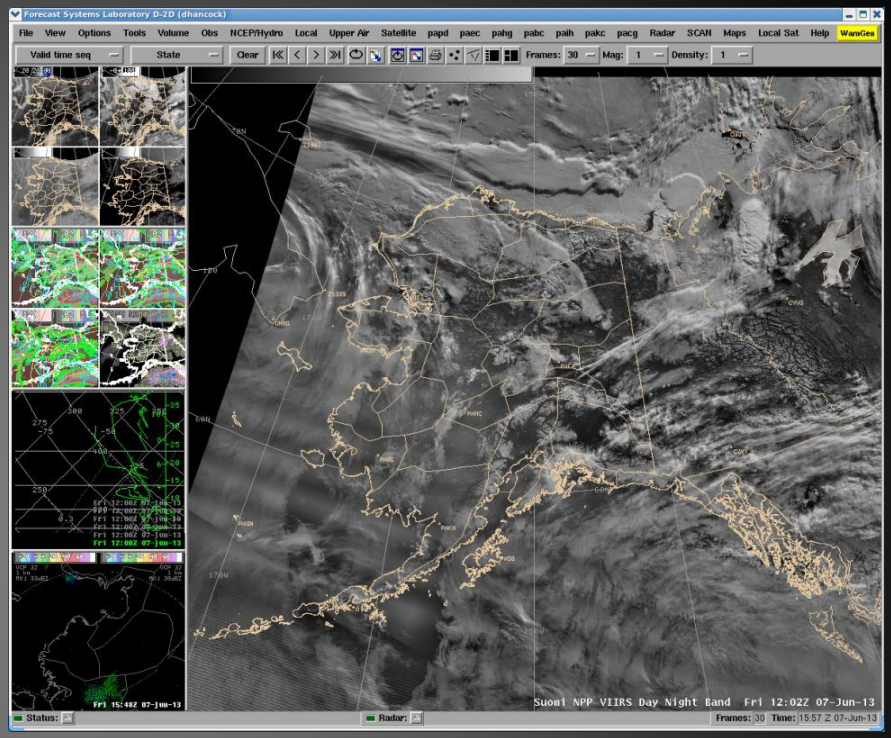



*http://feeder.gina.alaska.edu/*

# 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

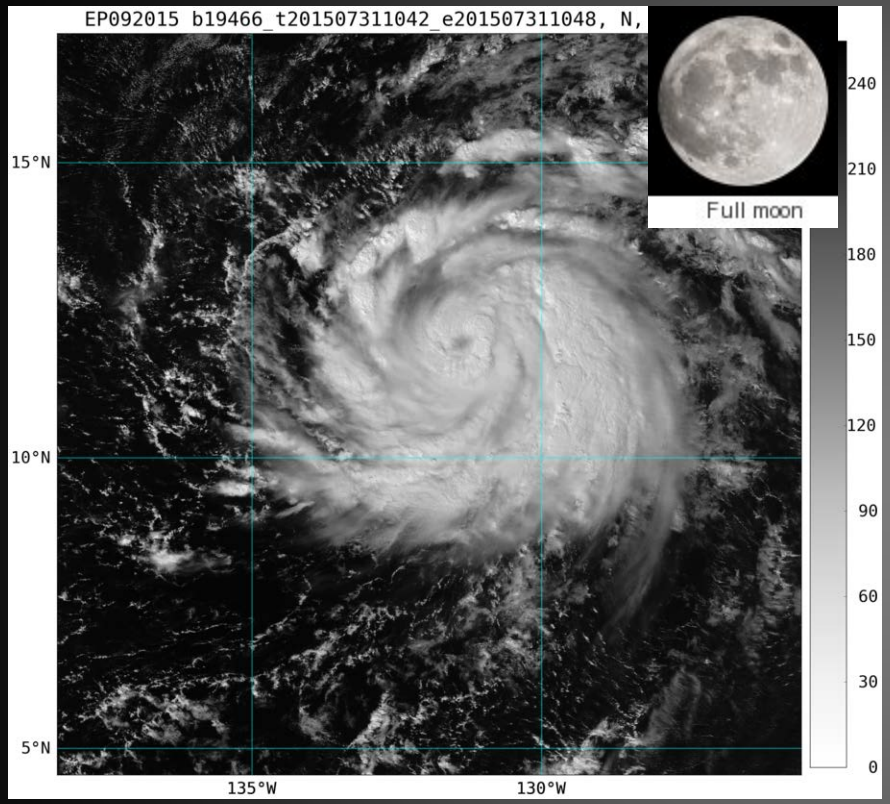
These algorithms have artifacts near the terminator

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

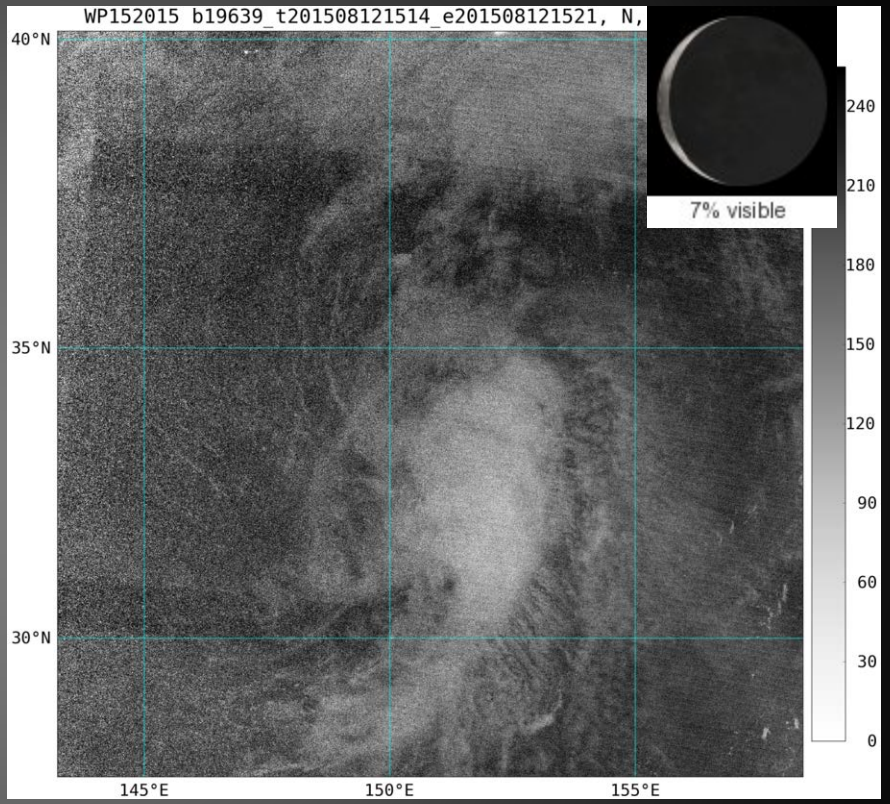
# Displaying 8 orders of magnitude in 256 colors

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

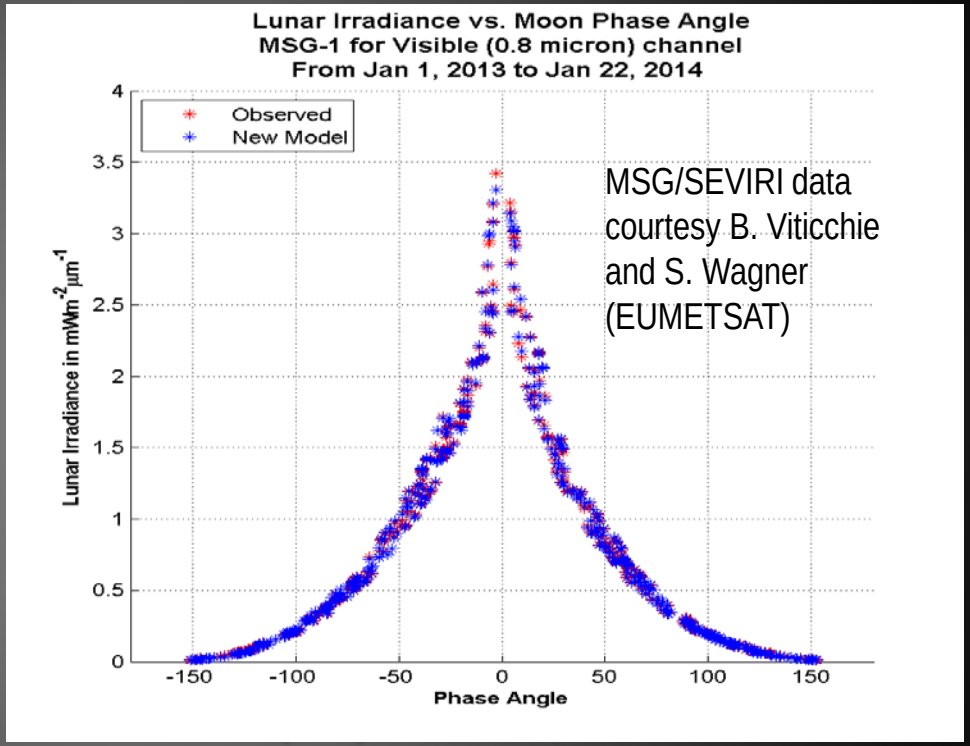
*http://rammb.cira.colostate.edu/products/tc_realtime/*

# Visualizing the DNB: Lunar Irradiance Modeling


Mean: 384,401 km

Enables Calculation of Lunar Reflectance:

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

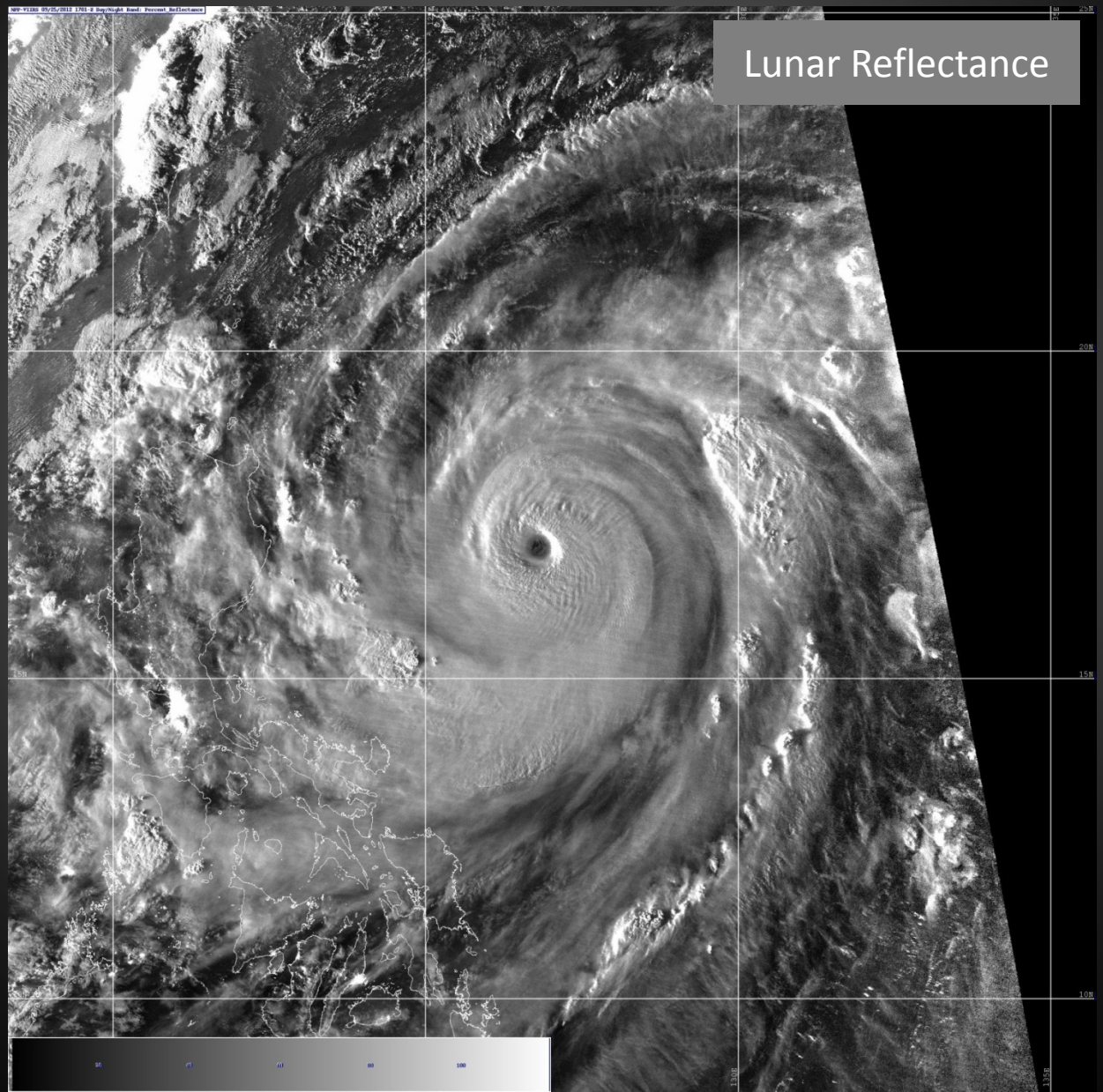



→ *Reduces 8 orders of magnitude range in radiance to <1 order of magnitude range in reflectance*

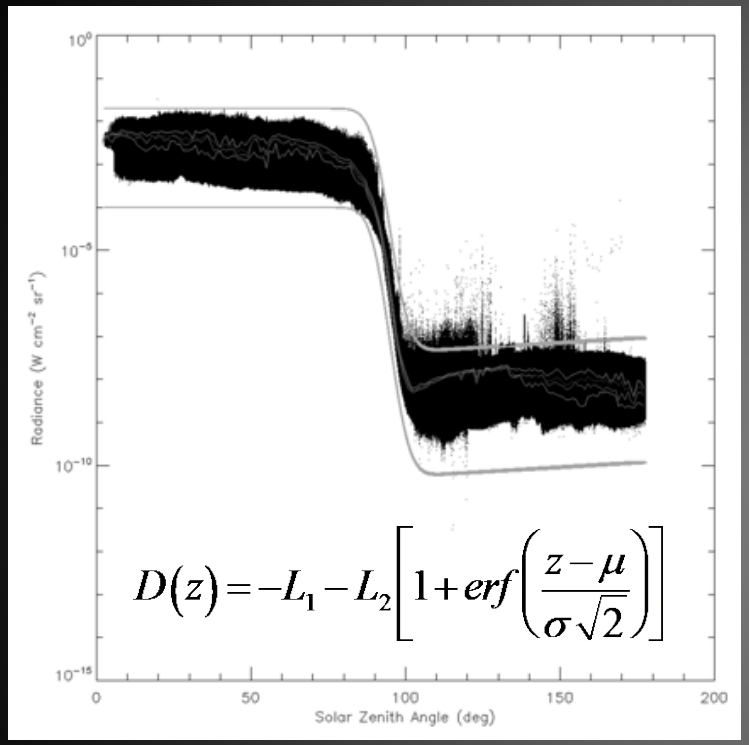
→ *Opens the door to possible quantitative applications involving the calibrated DNB observations of moonlight.*

# Lunar Reflectance to Improve Imagery

Typhoon Jelawat: 9/25/2012 ~1700Z



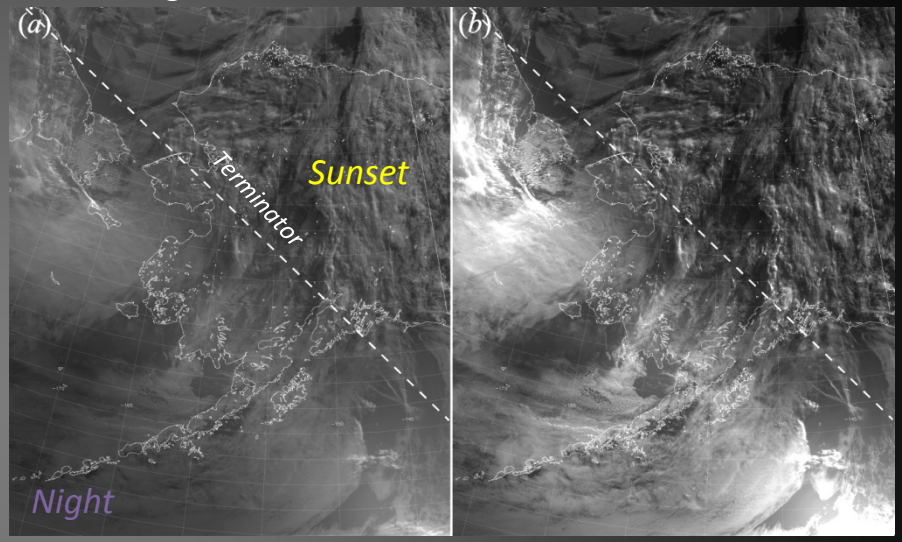
# Visualizing the DNB: ERF-Dynamic Scaling




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

ERF Scaling

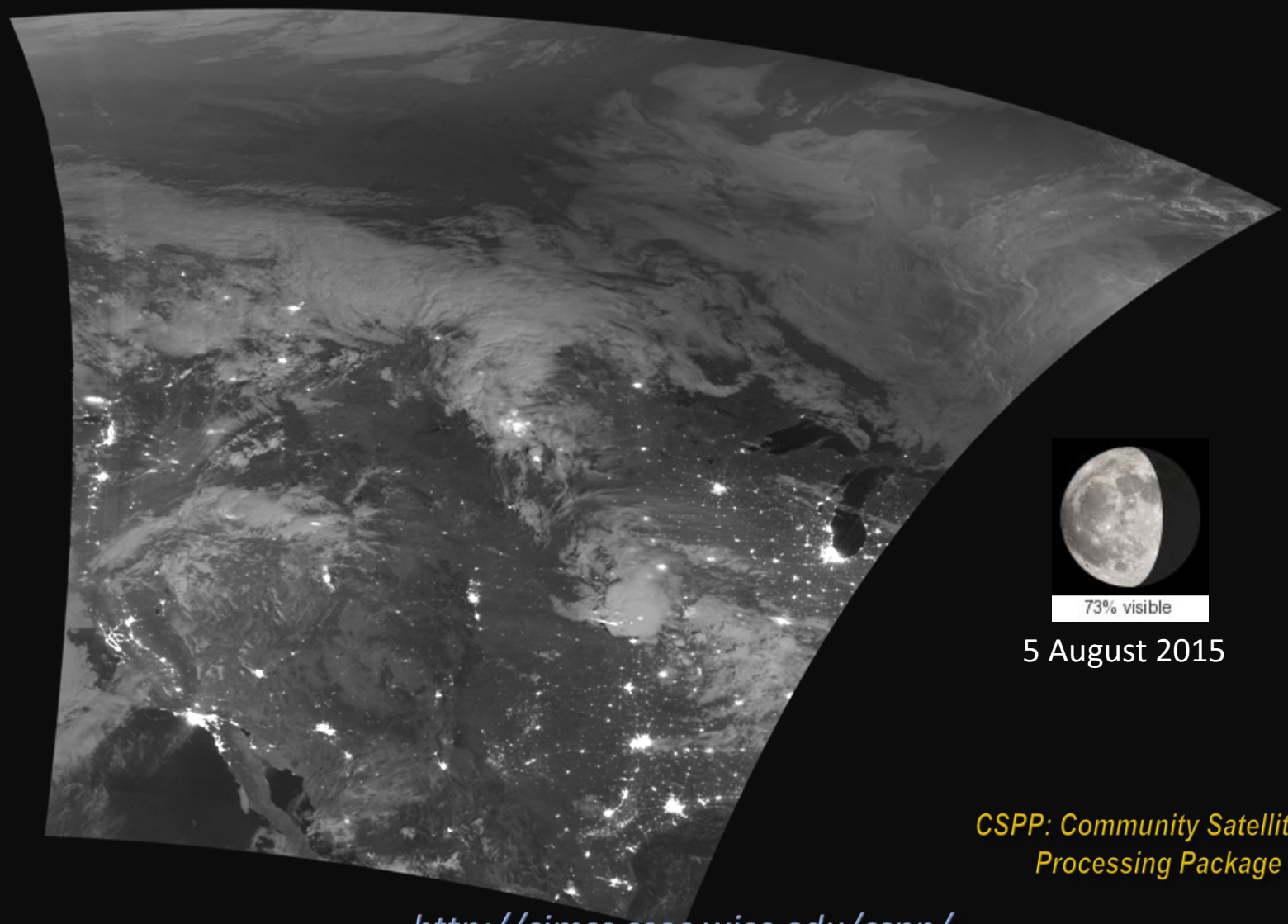
NCC Product




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





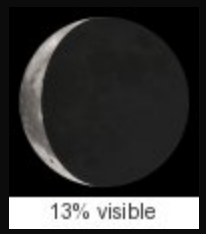

5 August 2015

*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/

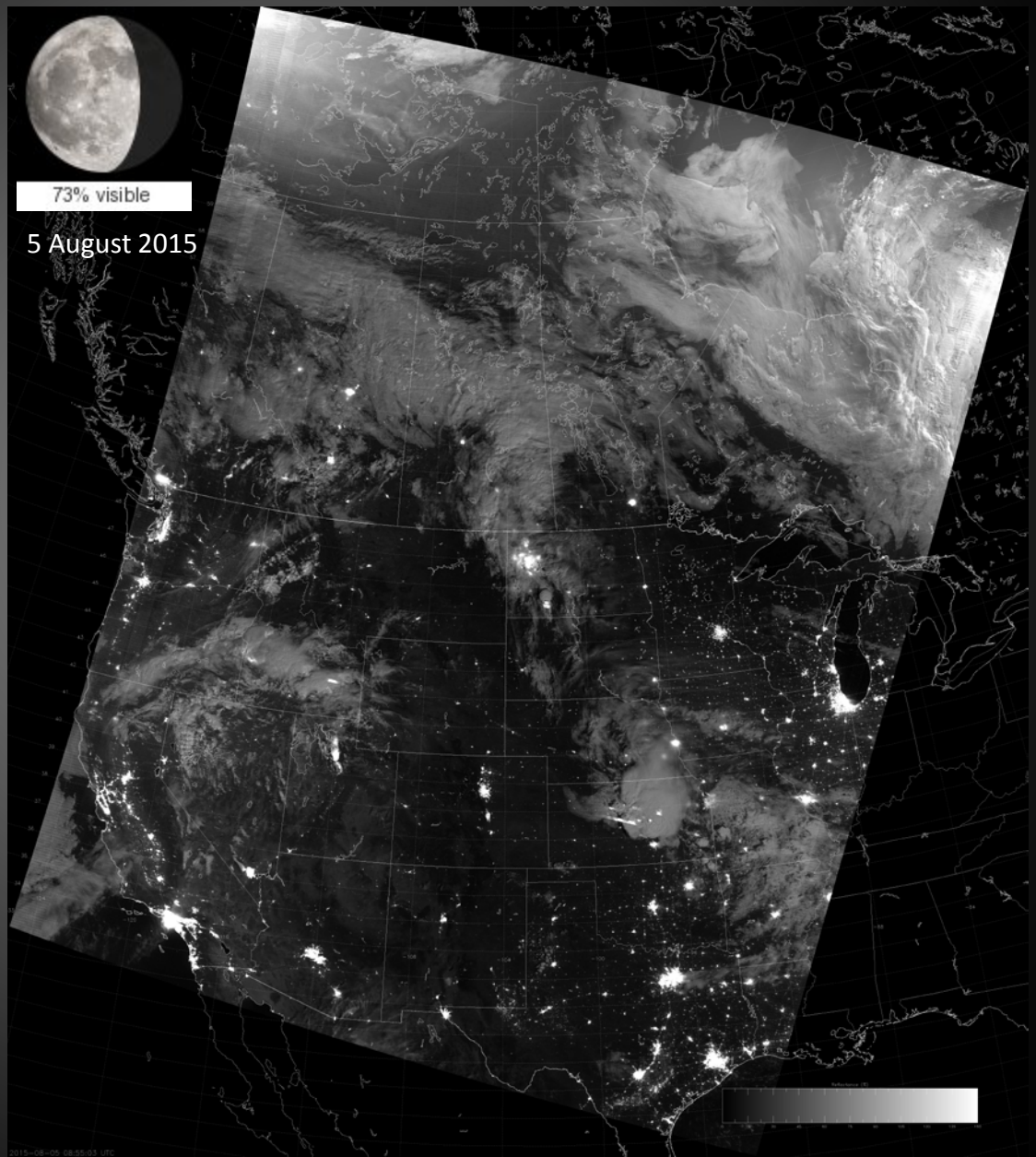
# Visualizing the DNB: Near Constant Contrast EDR

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

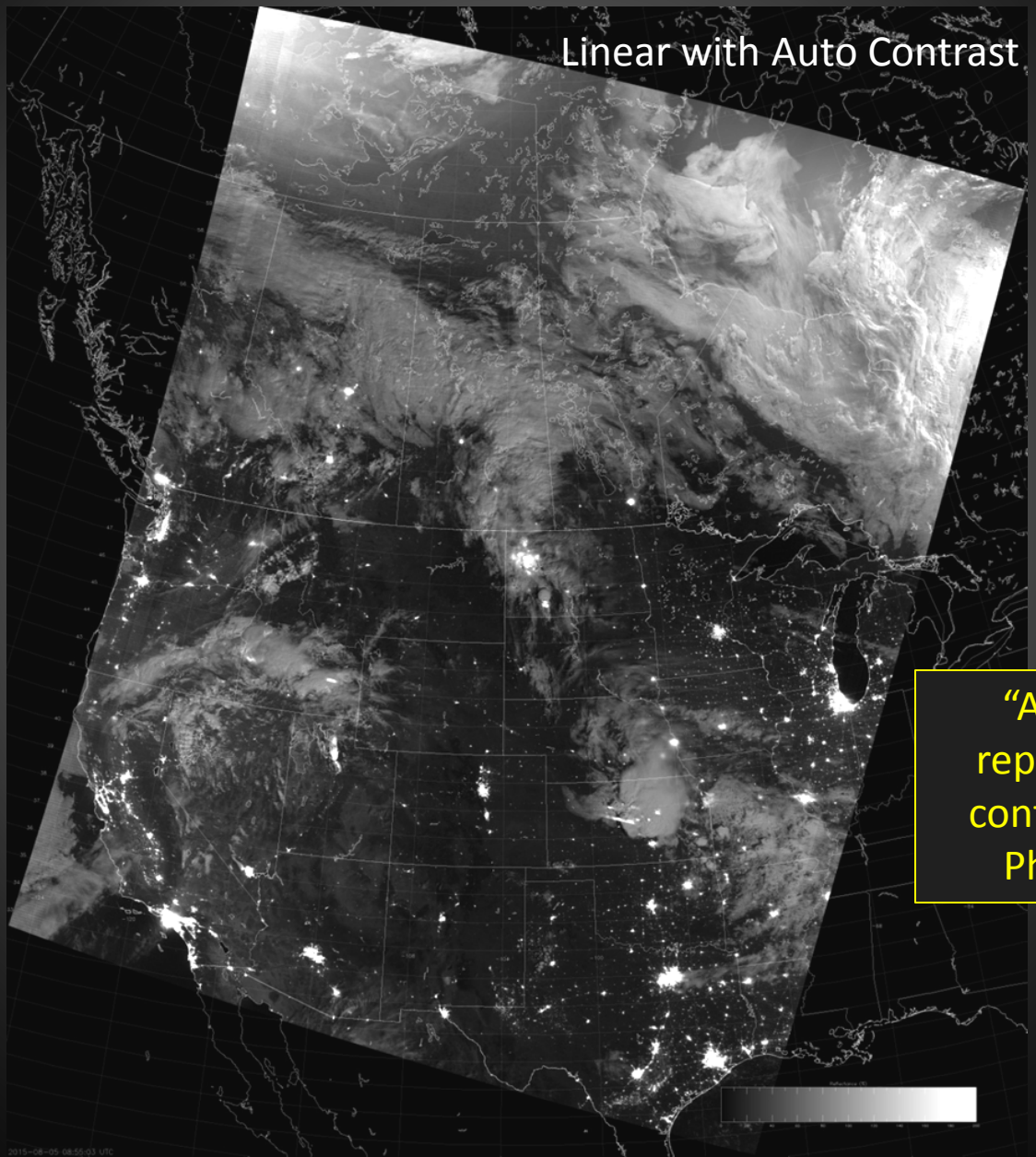
- Original assumptions based on DMSP OLS have been corrected for DNB so NCC now works as intended

- NCC will be available in AWIPS soon

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

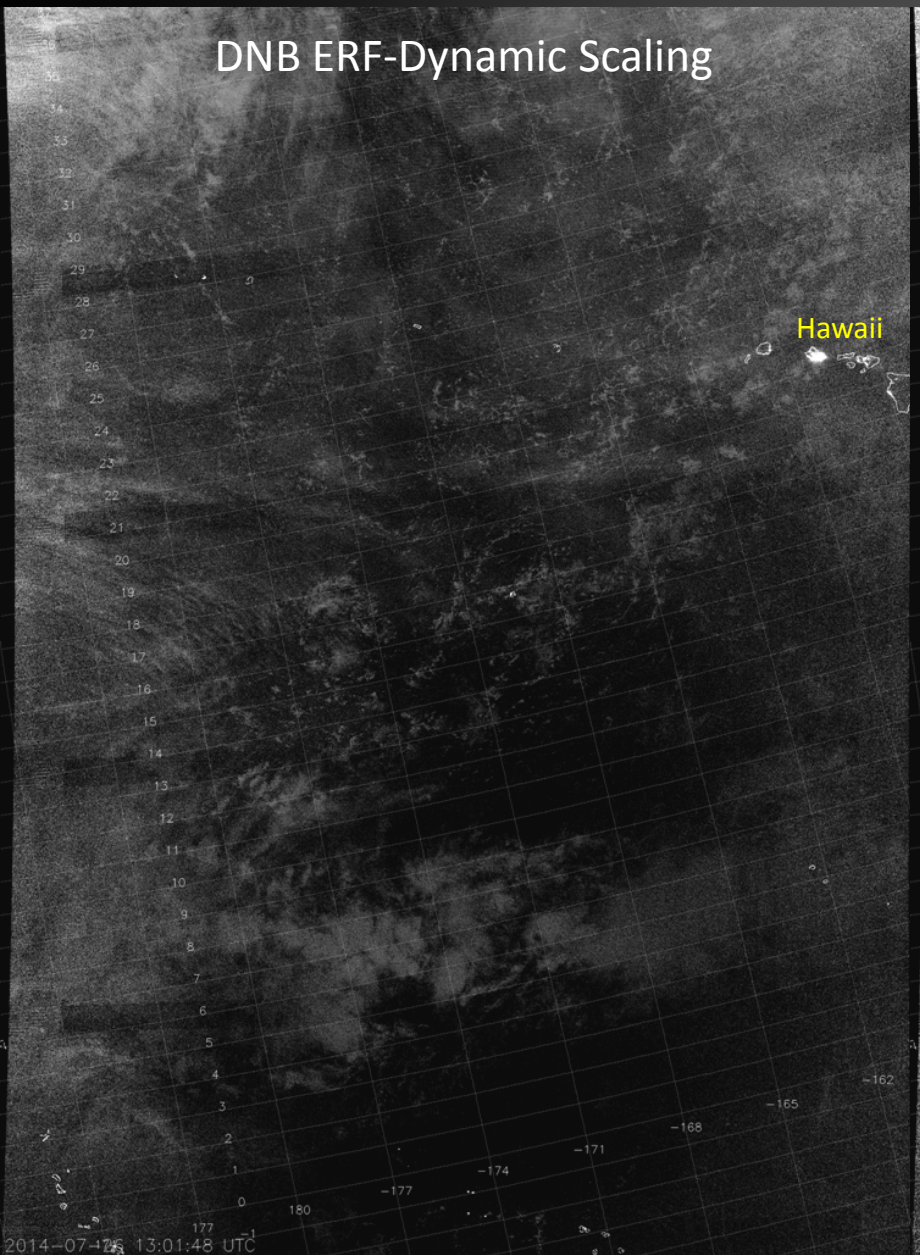


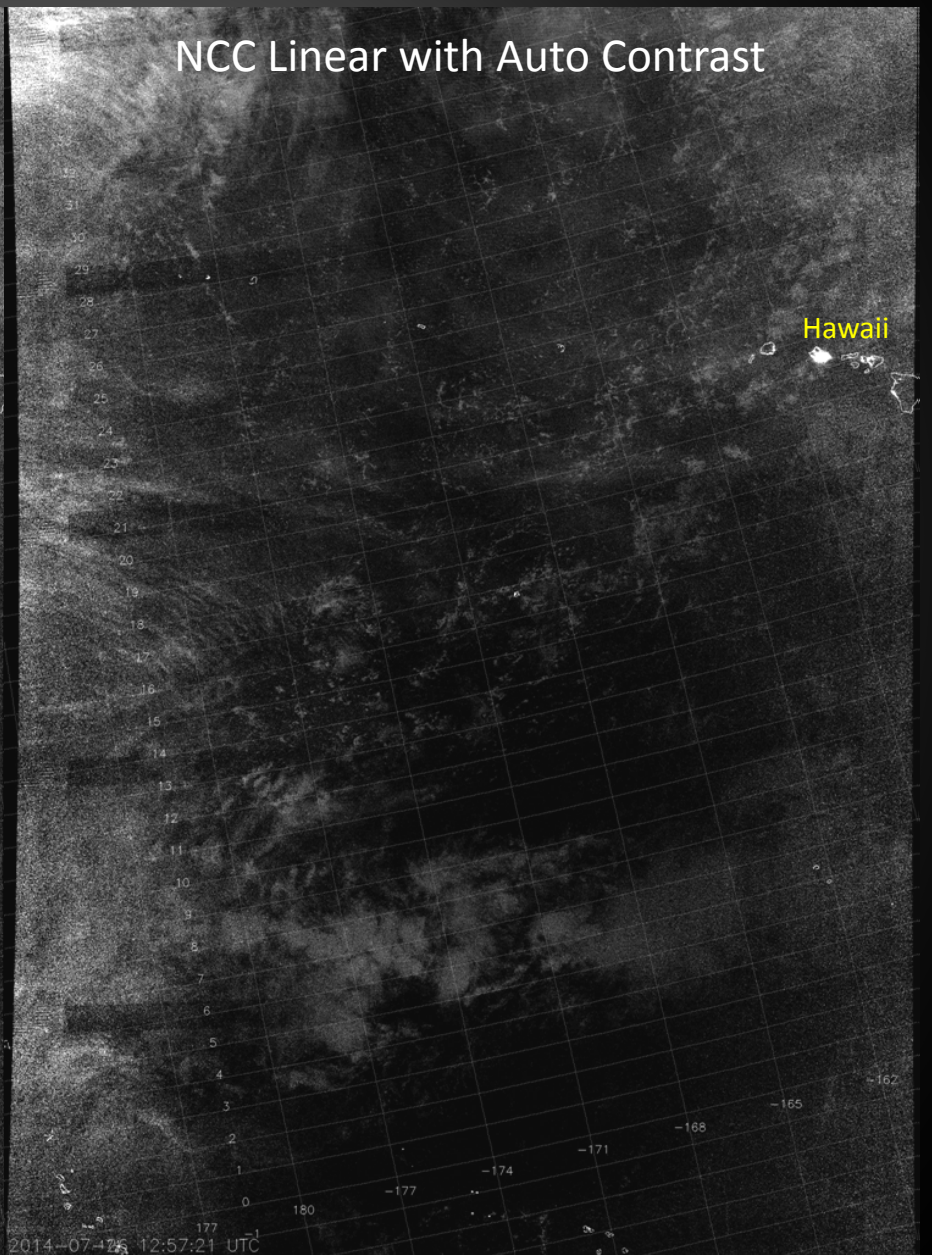
# Scaling the NCC: with moon



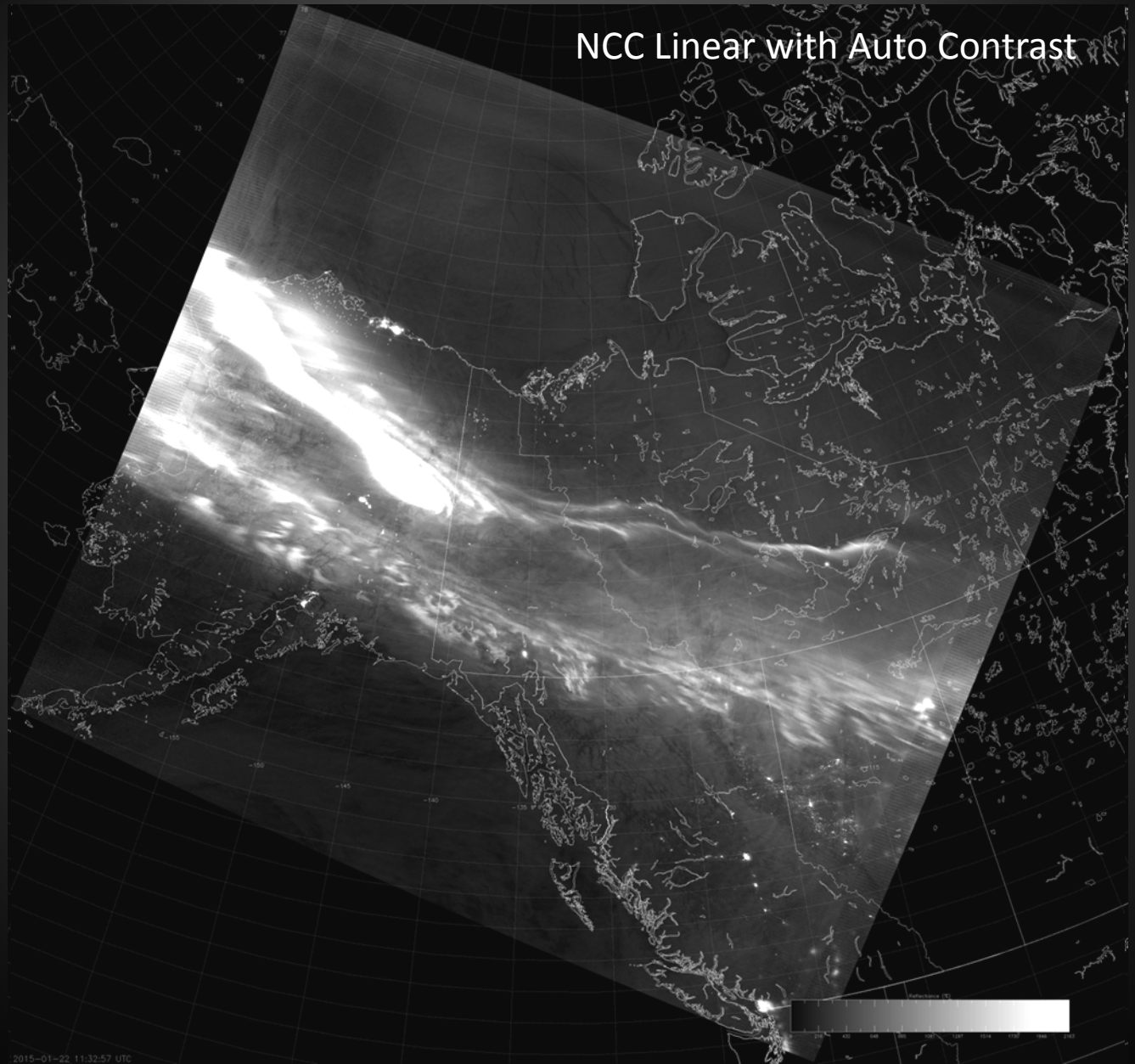

"Auto Contrast" replicates the auto contrast function in Photoshop, etc.

# Scaling the NCC: no moon



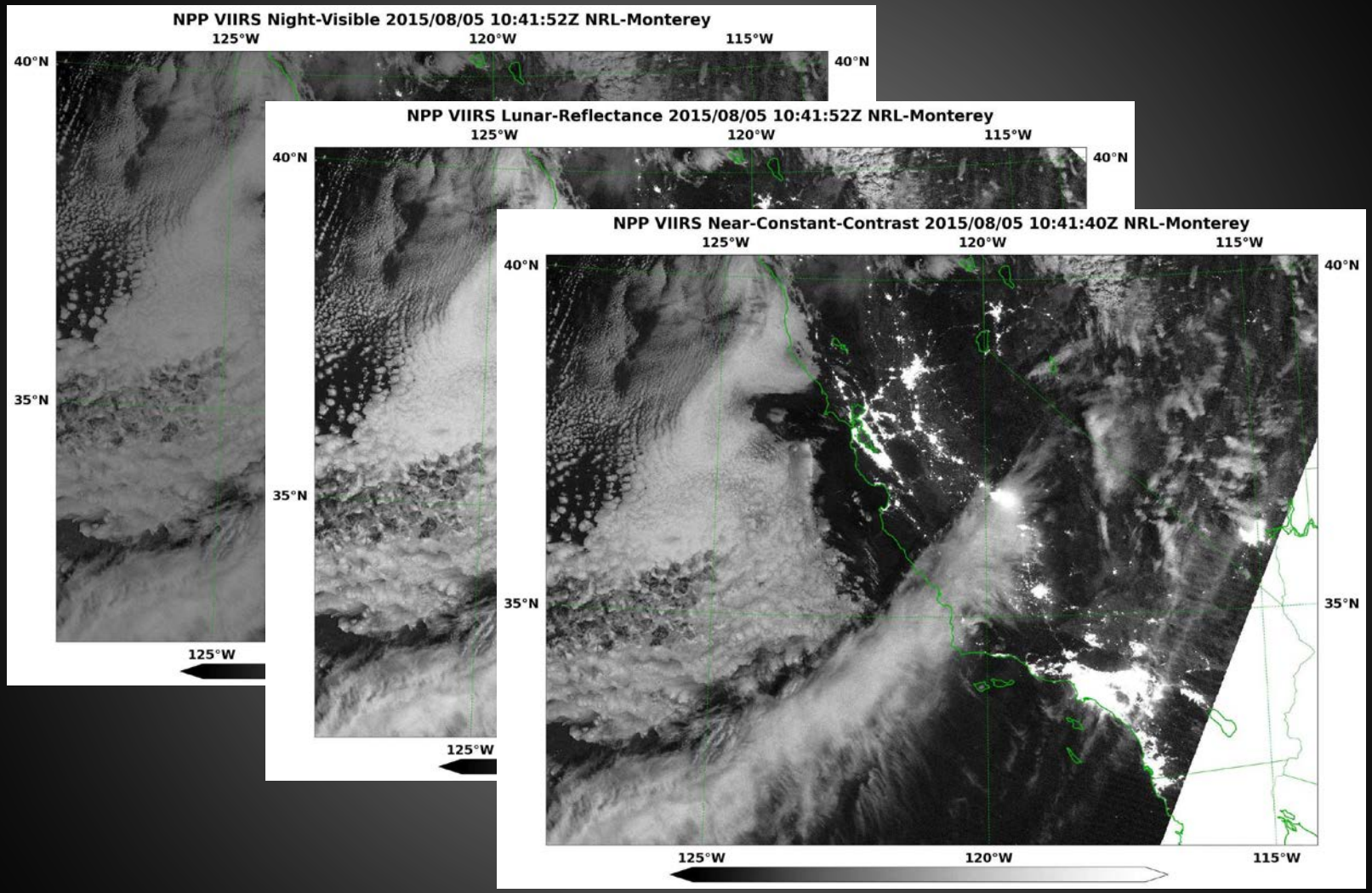
# Scaling the NCC: auroras



# 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

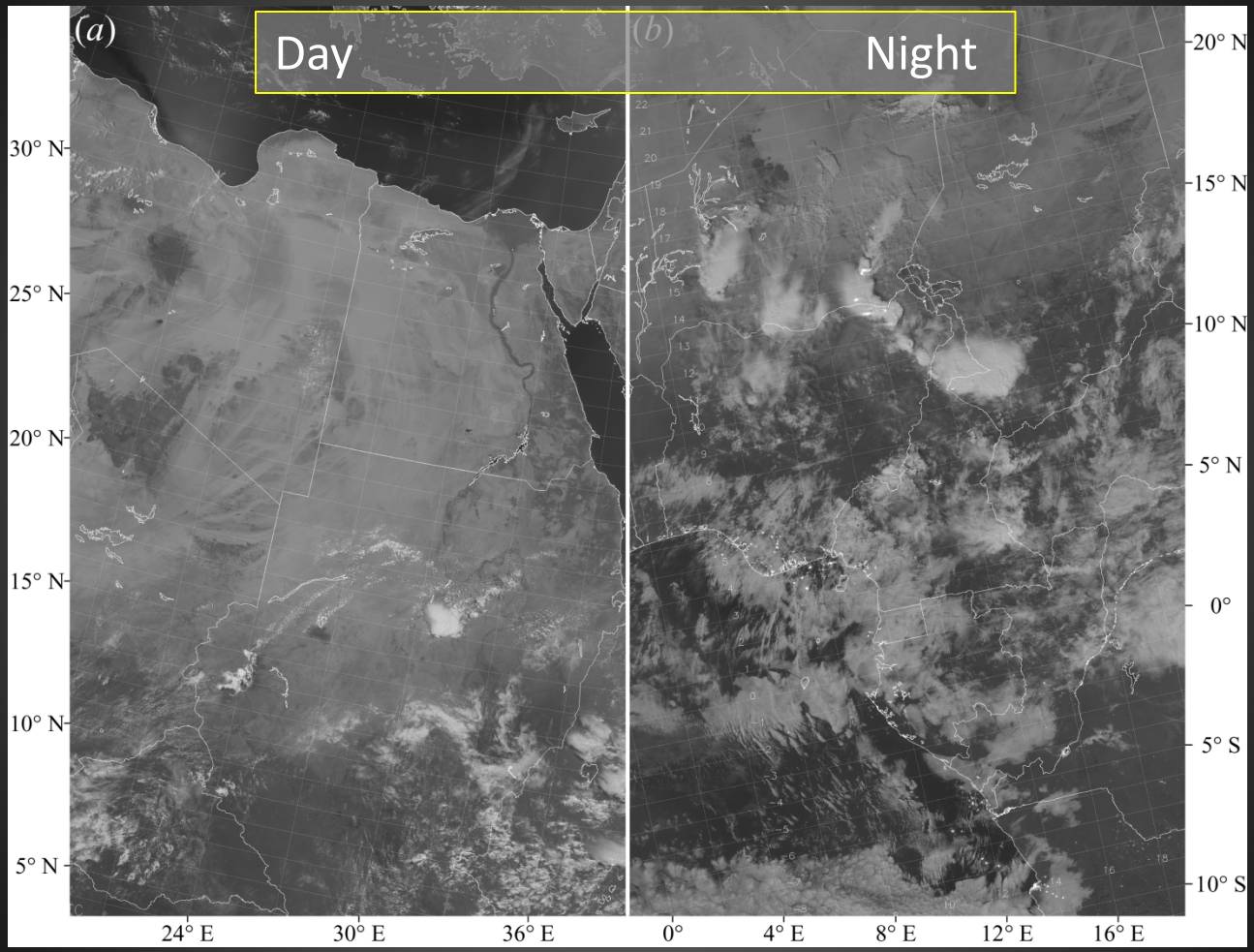
# Naval Research Laboratory (NexSat)




Near Constant Contrast EDR

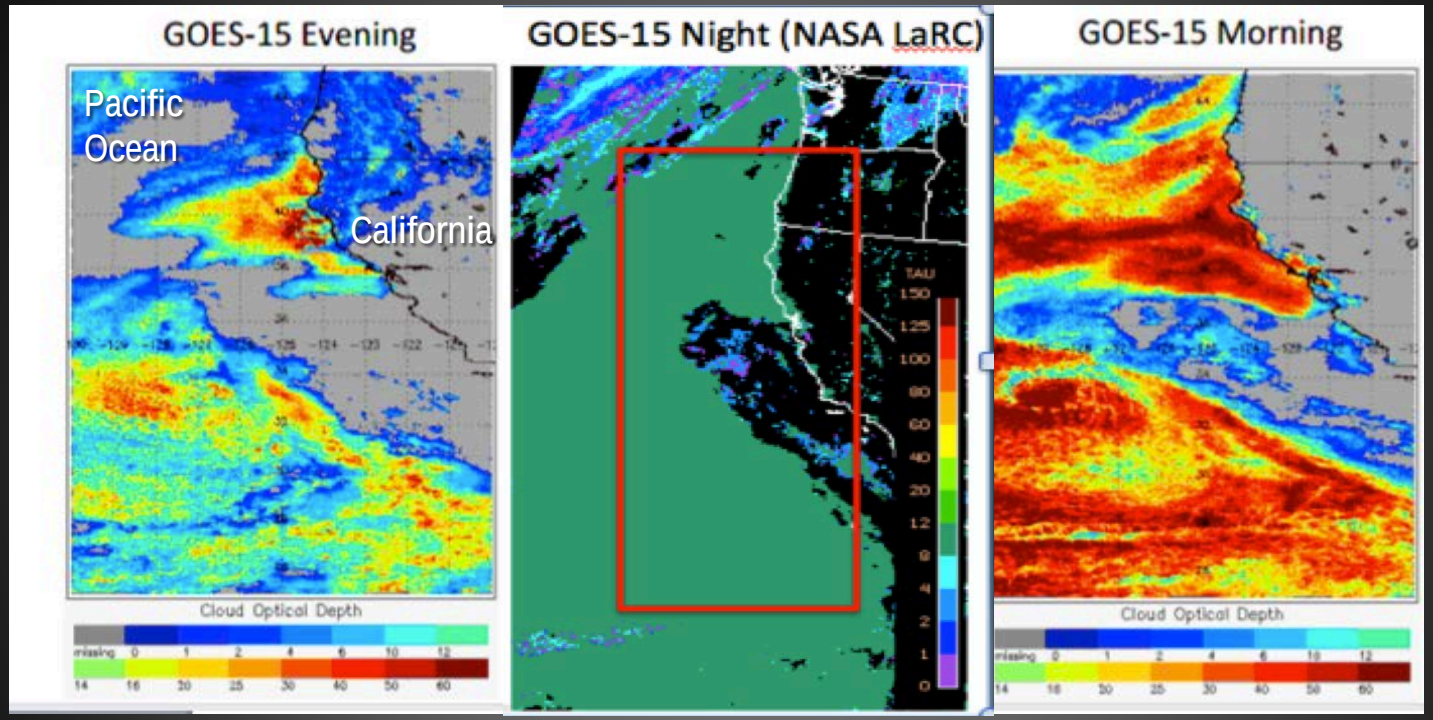
*http://www.nrlmry.navy.mil/NEXSAT.html*

# 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



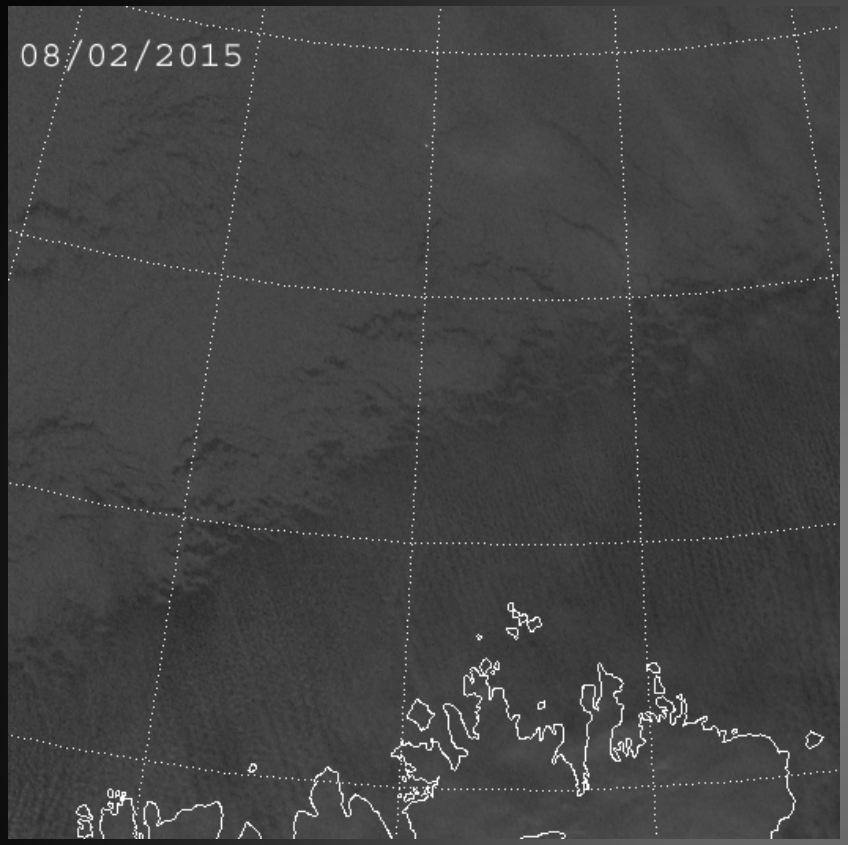

06:30PM 01:30AM 09:30AM

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

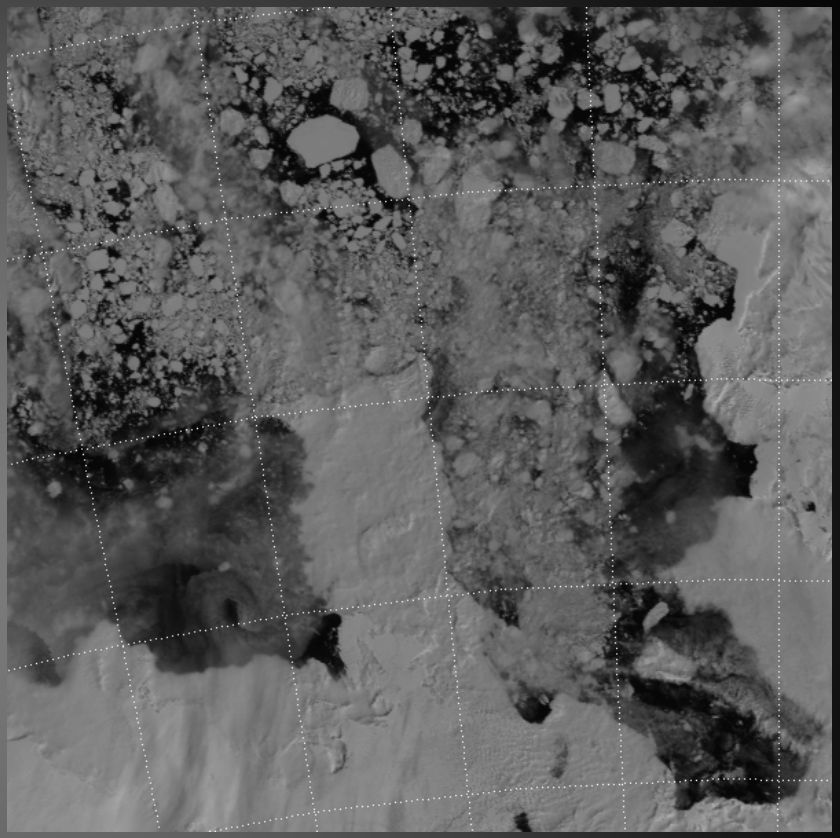
Shortwave Infrared Split-window Technique (SWIT)

Walther et al. (2013)

# Scaling in Action

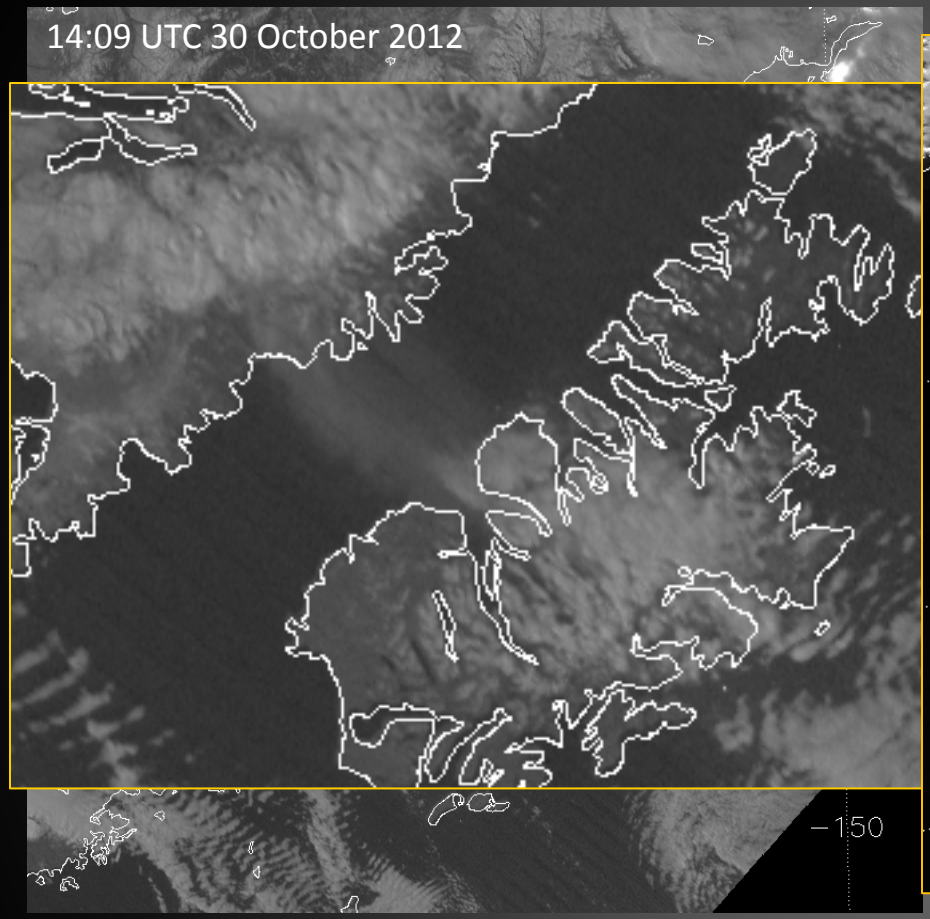



ERF-Dynamic Scaling with Auto Contrast
(moonless nights and twilight)

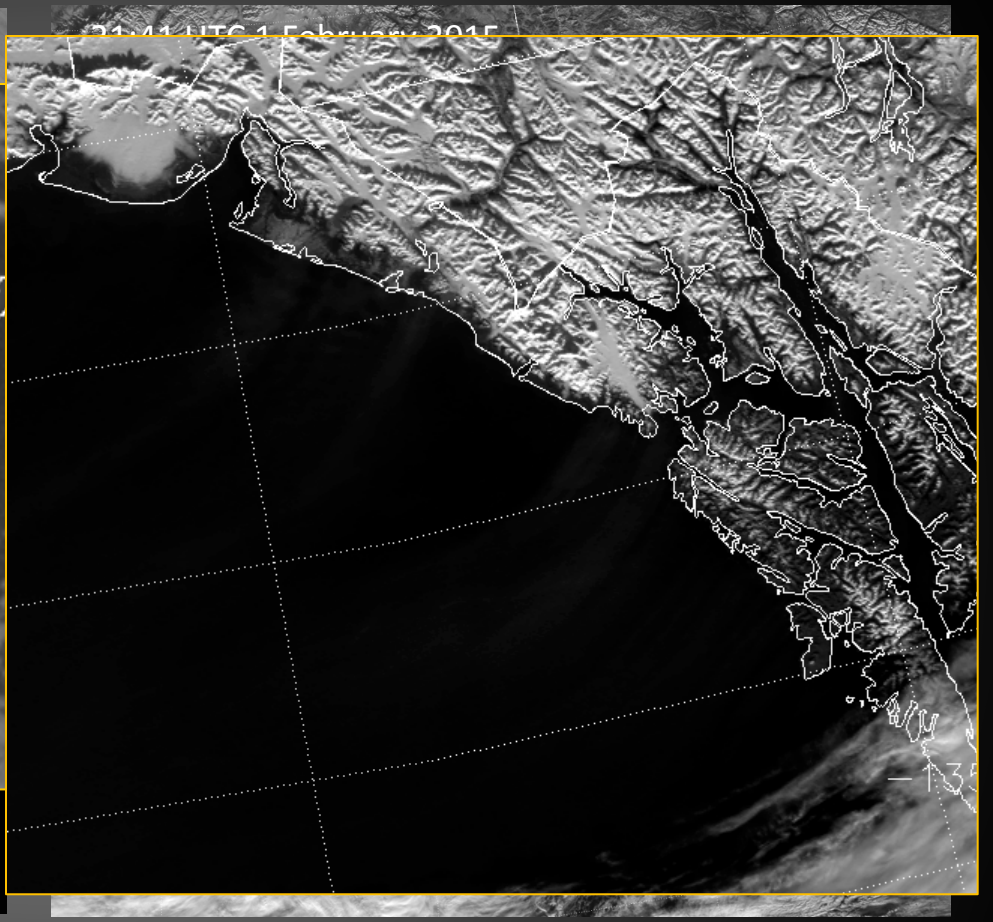


Near Constant Contrast EDR (0 to 2)
(daylight and twilight)

# 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

# Using VIIRS DNB to Detect Natural (and other) Disasters

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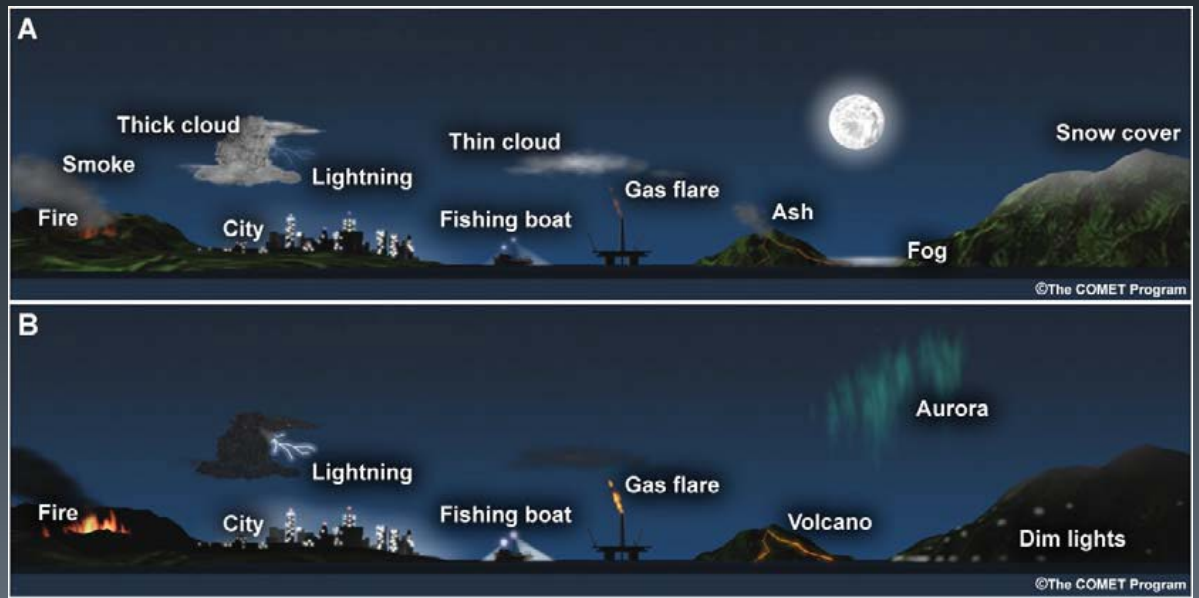
[1] Cooperative Institute for Meteorological Satellite Studies (CIMSS)
[2] Cooperative Institute for Atmospheric Research (CIRA)
[3] NOAA/RAMMB

# Overview

- Day Night Band Overview
- Why is DNB is useful for disaster detection
- Examples of interest
  - Hurricanes/Typhoons
  - Fires
  - Volcanos
  - Other natural and human disasters
- Conclusions

# Day/Night Band (DNB) overview

- The DNB measures visible radiances from both the Earth and atmosphere
- Wavelength of 0.7 μm, 742m x 742m pixel size
- Receives visible data from via reflection and emission sources (natural and anthropogenic )
- Sufficiently sensitivity to observe the reflected emissions of nocturnal airglow (nightglow); which are emissions originating primarily from ~85-95 km and starlight (Miller et al 2012), which is within upper boundary of the mesosphere (~50-85km)



# Why is DNB useful for disaster detection

- Can provide visible imagery at night
- Can be combined with other channels to produce unique nighttime products
- Publicity
  - Noted on national and international news, social media
- Being used by National Weather Service
  - Public Awareness
  - Improved forecasting

Examples of interest

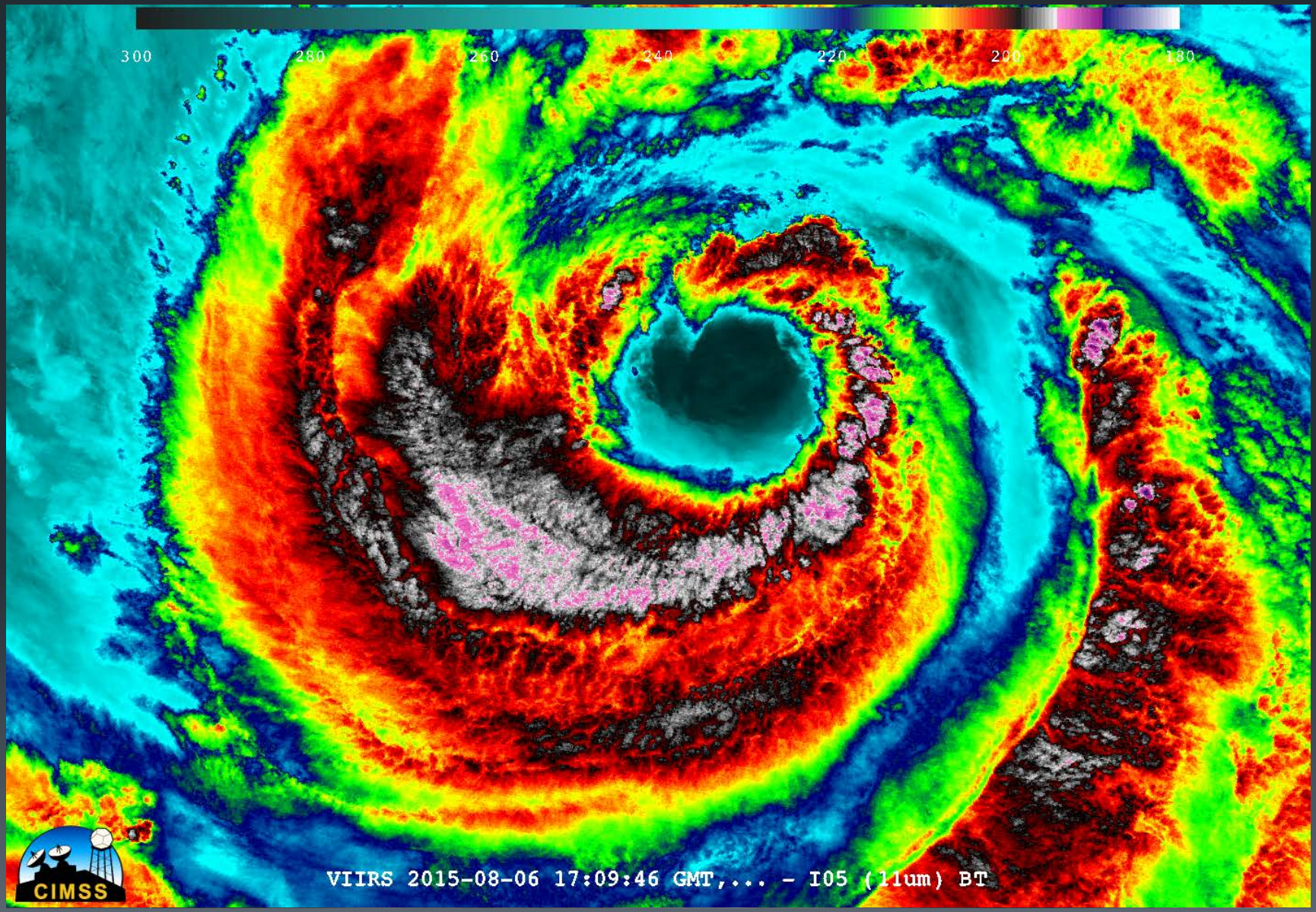
# Hurricanes, Typhoons

# Tropical Cyclones

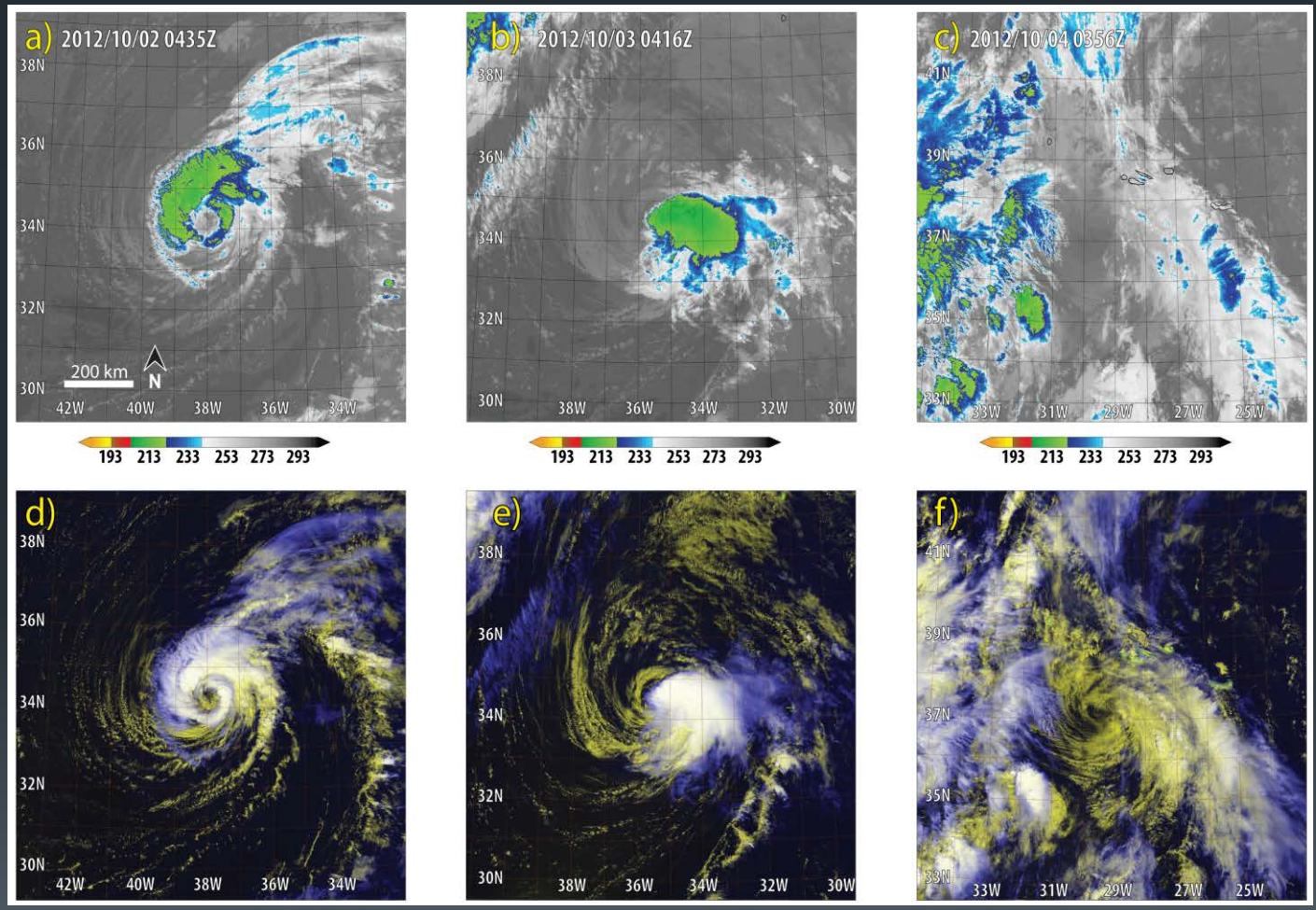
- Tropical cyclones occur in the major ocean basins of the world and pose a significant threat to coastal communities

- Numerous aspects of low light imagery from the DNB which can be useful to forecasters
  - Inner-eye-wall low cloud mesovortices, sometimes not seen from thermal infrared observations
  - Detection of eye-wall lightning for remote storms
  - Lunar reflection-based observations of low-level circulation
    - Already used by the NWS in at least two cases in Hawaii (Flossie, Ela) to re-center storm center
  - Post-storm analysis

# Typhoon Soudelor



# Tropical Cyclones:
## Exposed Low-Level Circulation (Nadine, 2012)




Miller, S.D.; Straka, W., III; Mills, S.P.; Elvidge, C.D.; Lee, T.F.; Solbrig, J.; Walther, A.; Heidinger, A.K.; Weiss, S.C. Illuminating the Capabilities of the Suomi National Polar-Orbiting Partnership (NPP) Visible Infrared Imaging Radiometer Suite (VIIRS) Day/Night Band. *Remote Sens.* **2013**, *5*, 6717-6766.

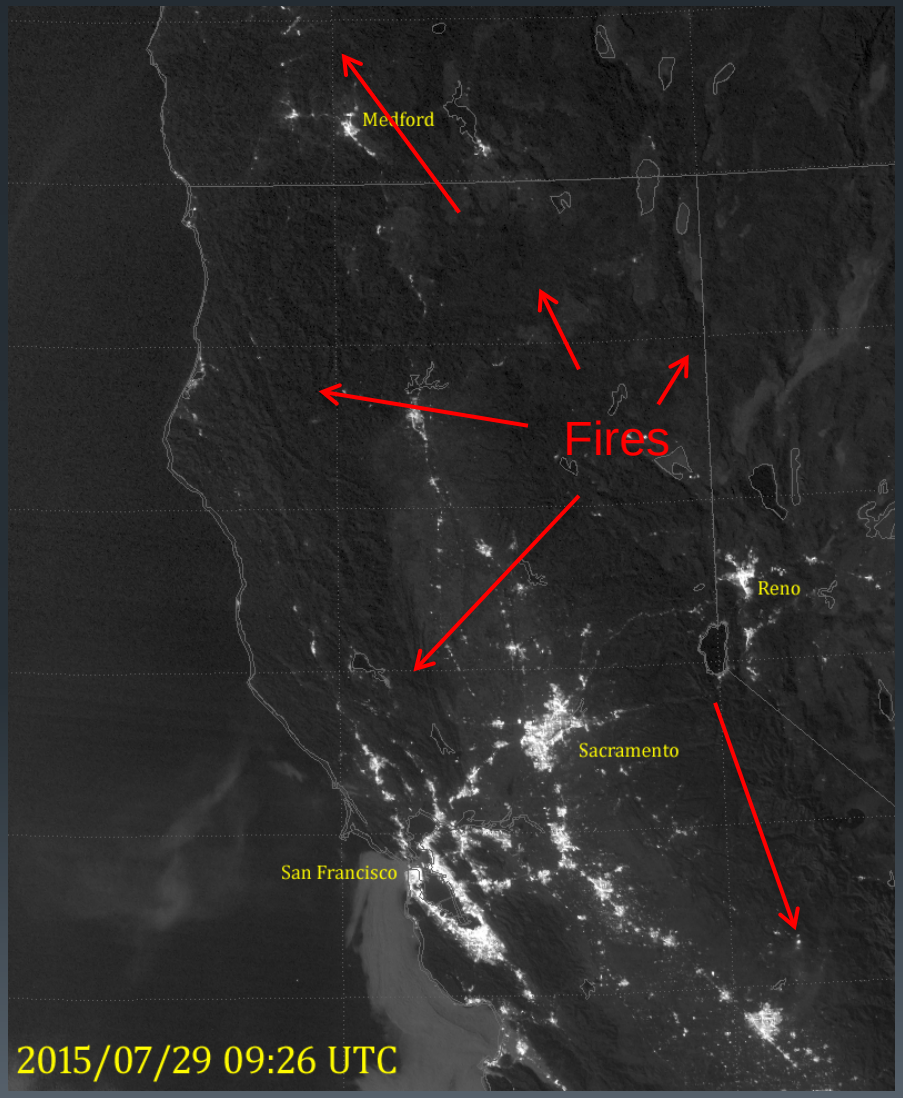
Examples of interest

# Fires

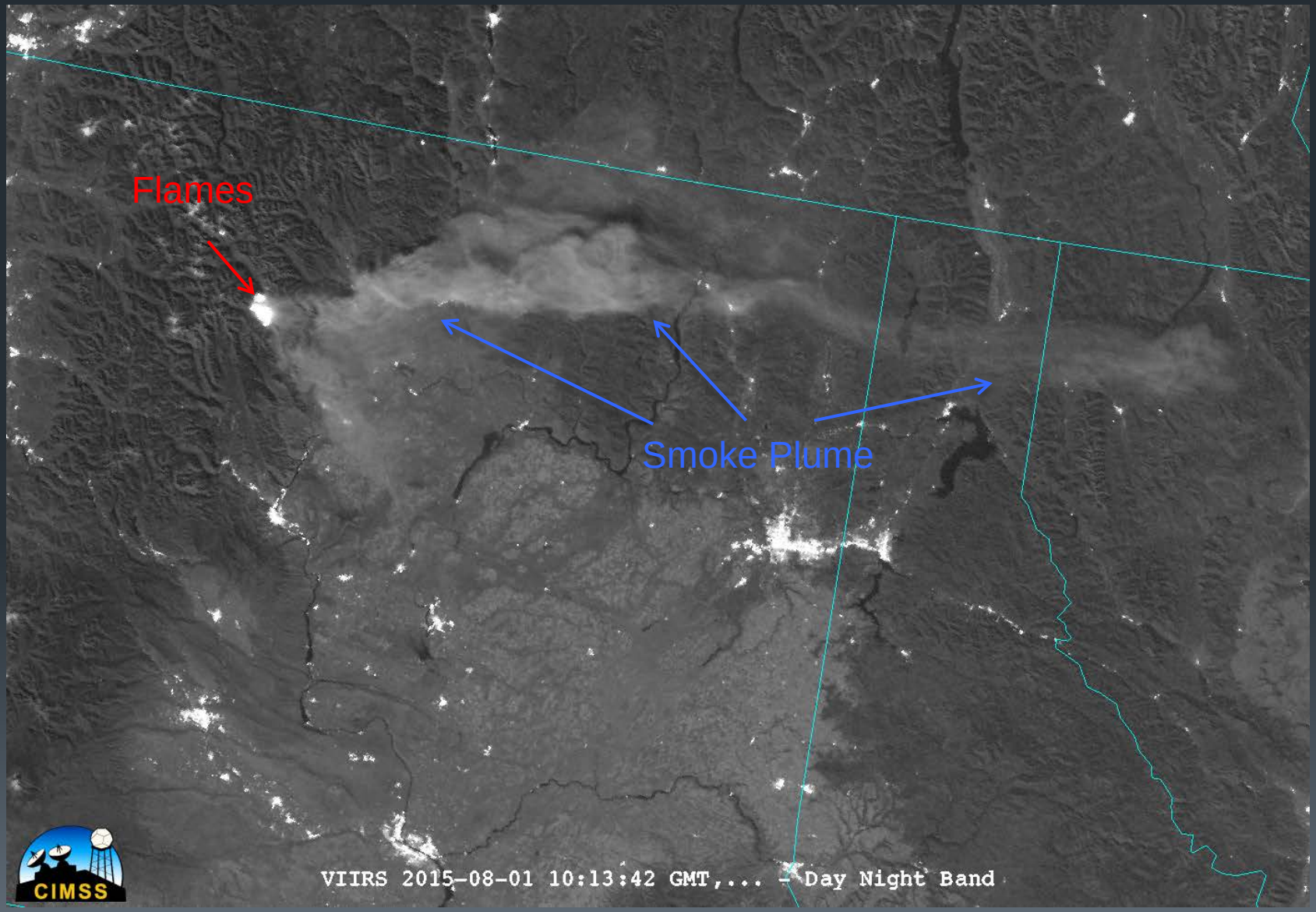
# DNB for fire detection

- Traditionally the 3.9μm (M13) channel was used for nighttime fire detection
  - Requires multiple thresholds over various surface type
- The DNB can be used directly to visually see smoke and fire locations
  - Useful public informational tool (Facebook, Twitter)
- The DNB along with other channels can be combined to develop improved night time fire detection algorithm
  - Example: VIIRS Nightfire product - Elvidge, C.D.; Zhizhin, M.; Hsu, F.-C.; Baugh, K.E. VIIRS Nightfire: Satellite Pyrometry at Night. *Remote Sens.* **2013**, *5*, 4423-4449.

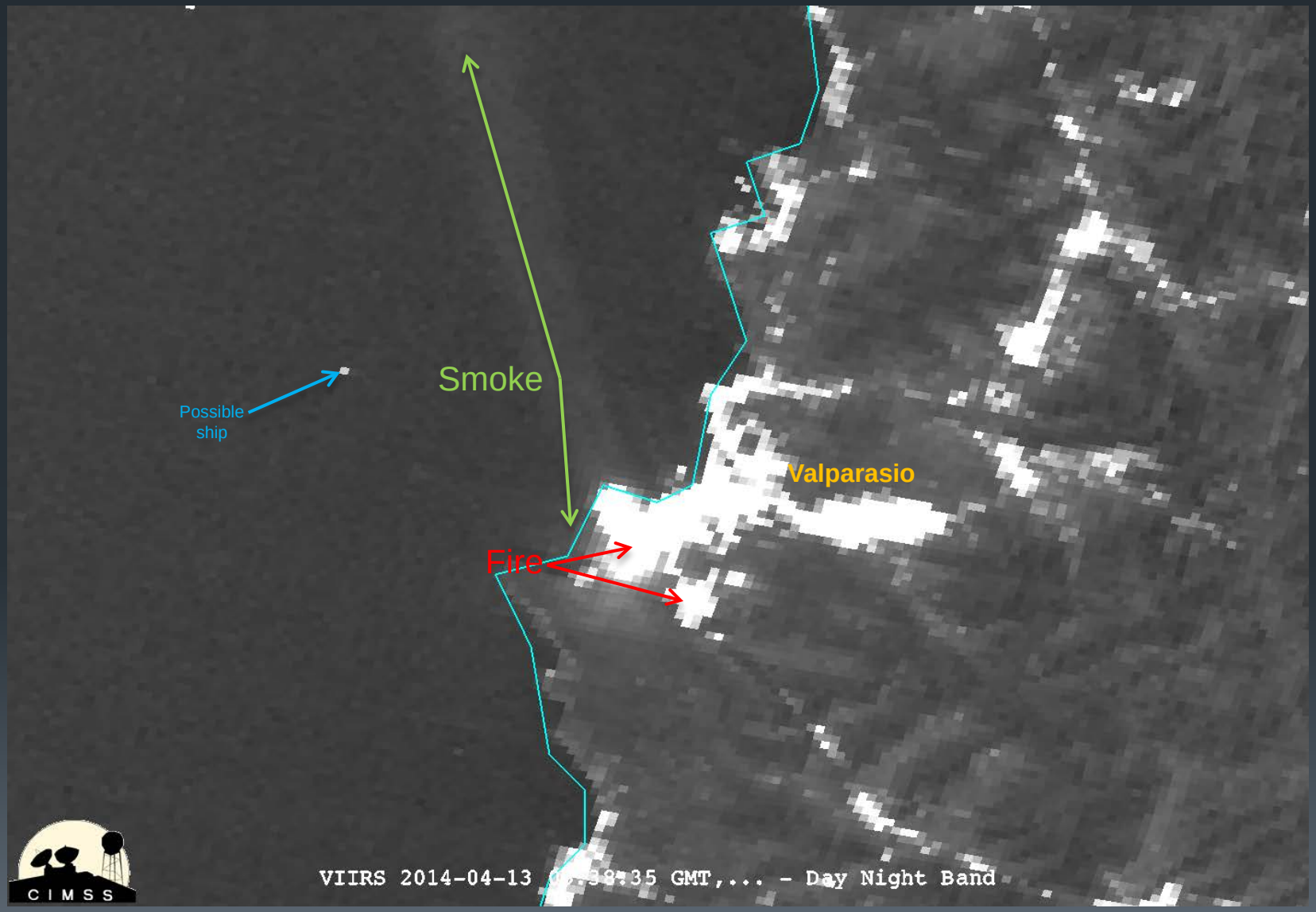
# California Multi-Night Loop



# Wolverine Fire



# Valparasio, Chile Fire



Examples of interest

# Volcanos

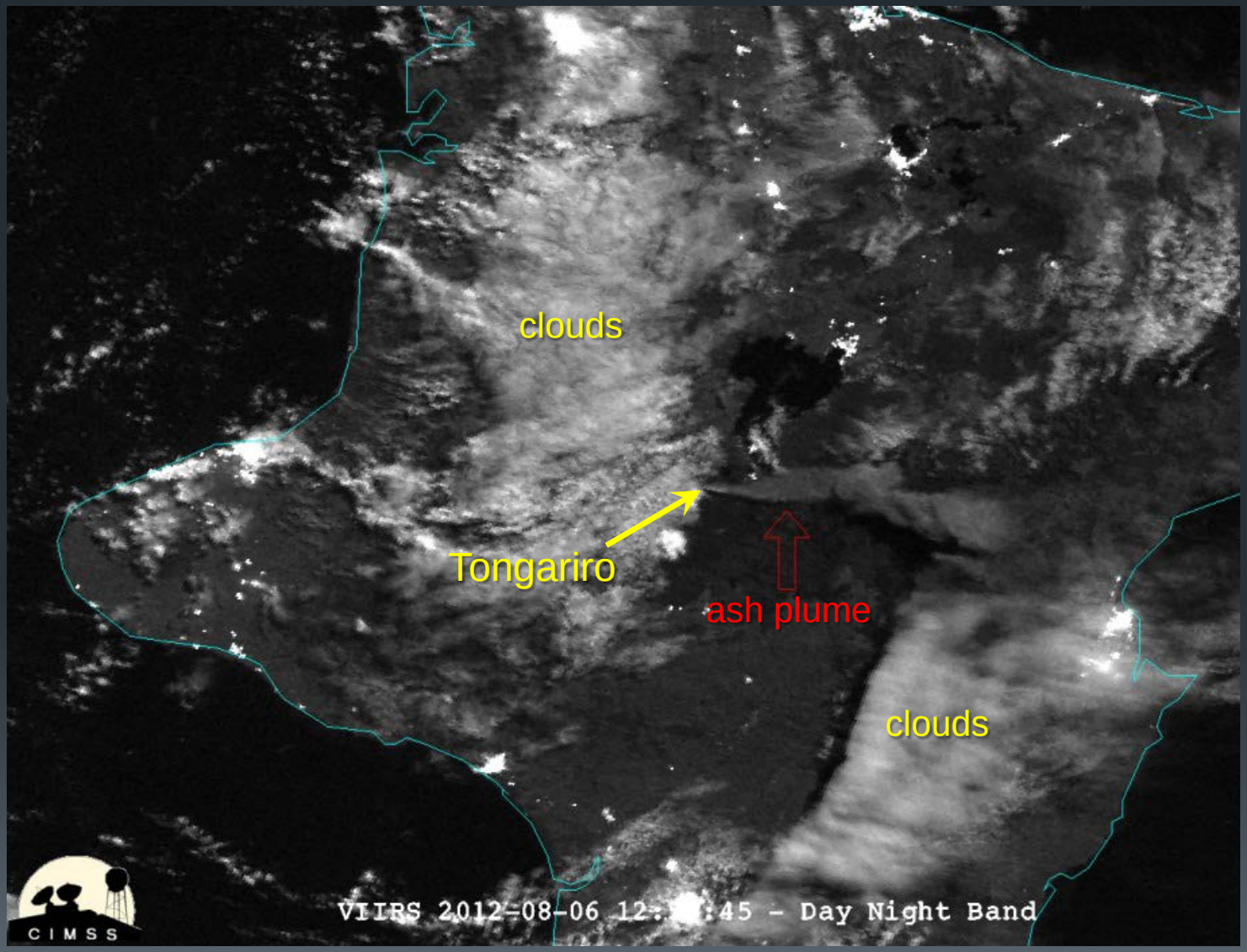
# DNB uses with Volcanos

While not a substitute for multi-spectral ash detection algorithms, the DNB can still provide useful insights during and after volcanic eruptions, both during moonlit and moonless nights

Examples:

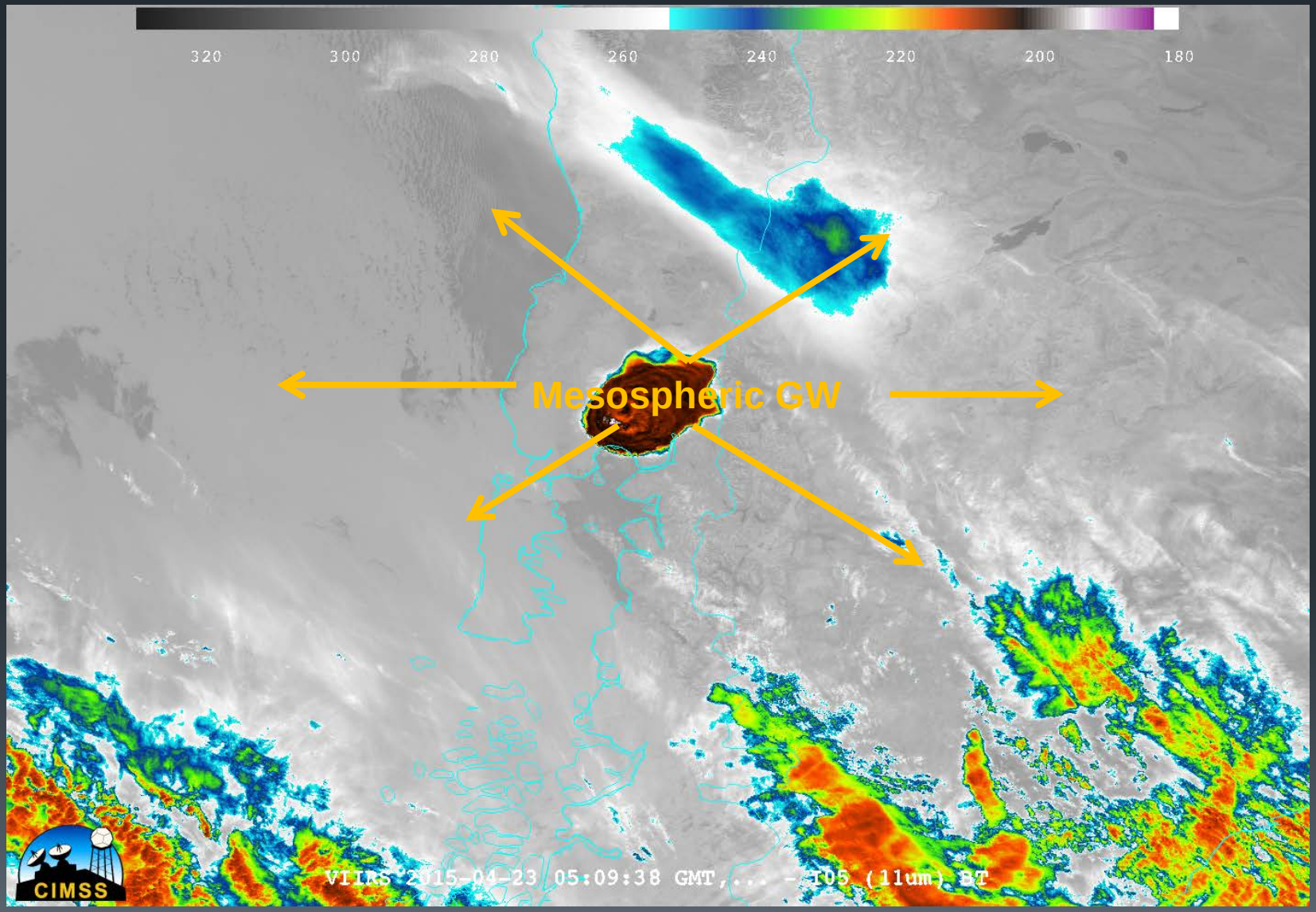
- Secondary, visible source for ash detection
- Monitoring of growth of lava field
- Shockwave detection

# Volcanic Ash



# Volcanic shockwave

Calbuco volcanic eruption, March 2015



# Iceland volcanos

Examples of interest

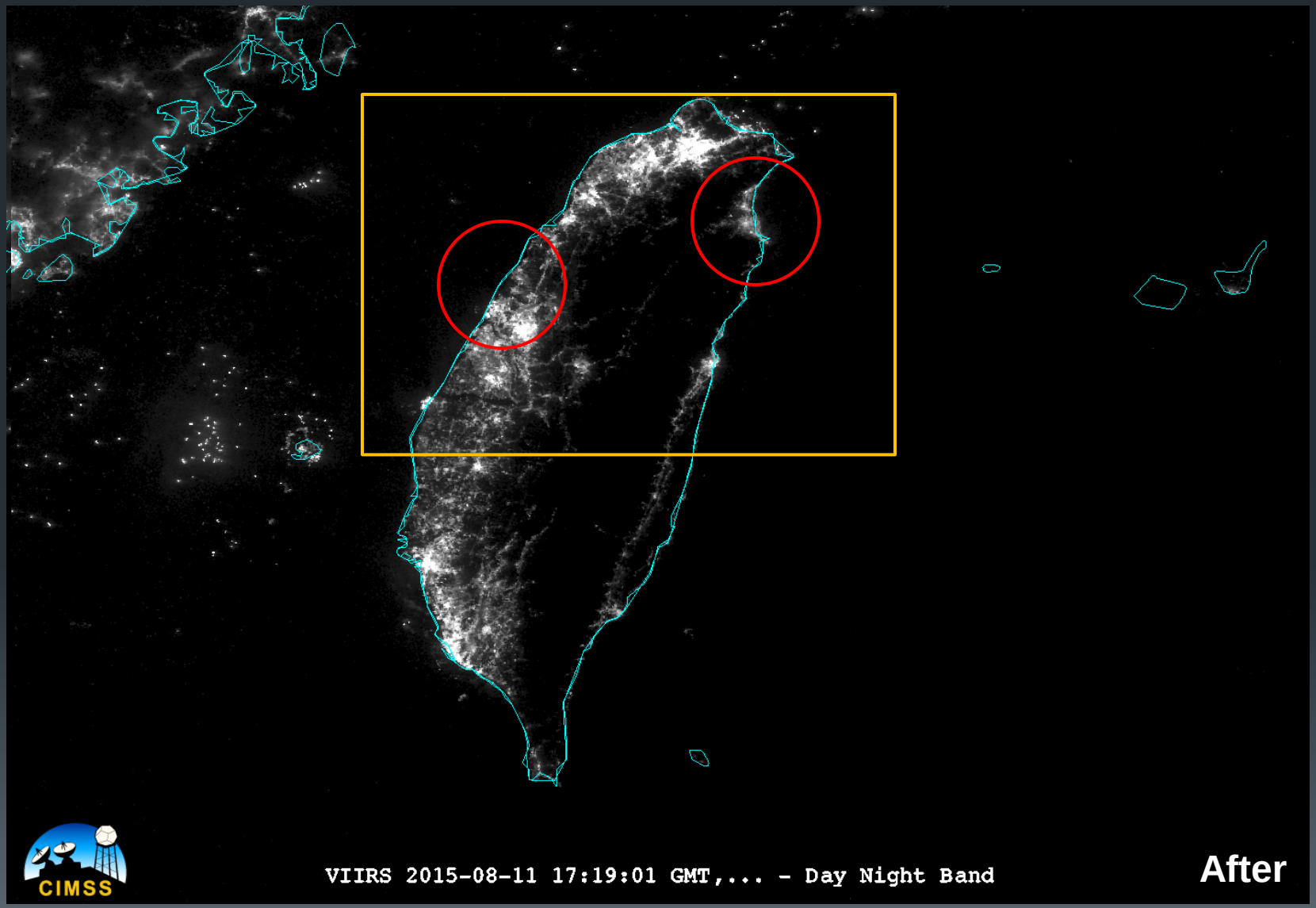
# Other natual/human disasters

# Other natural/human cause events (disasters) detected by DNB

- Post-case power outage analysis
- Severe Weather
  - Visible overshooting top detection
  - Lightning detection
- Monitoring of accidental and purposeful human caused incidents

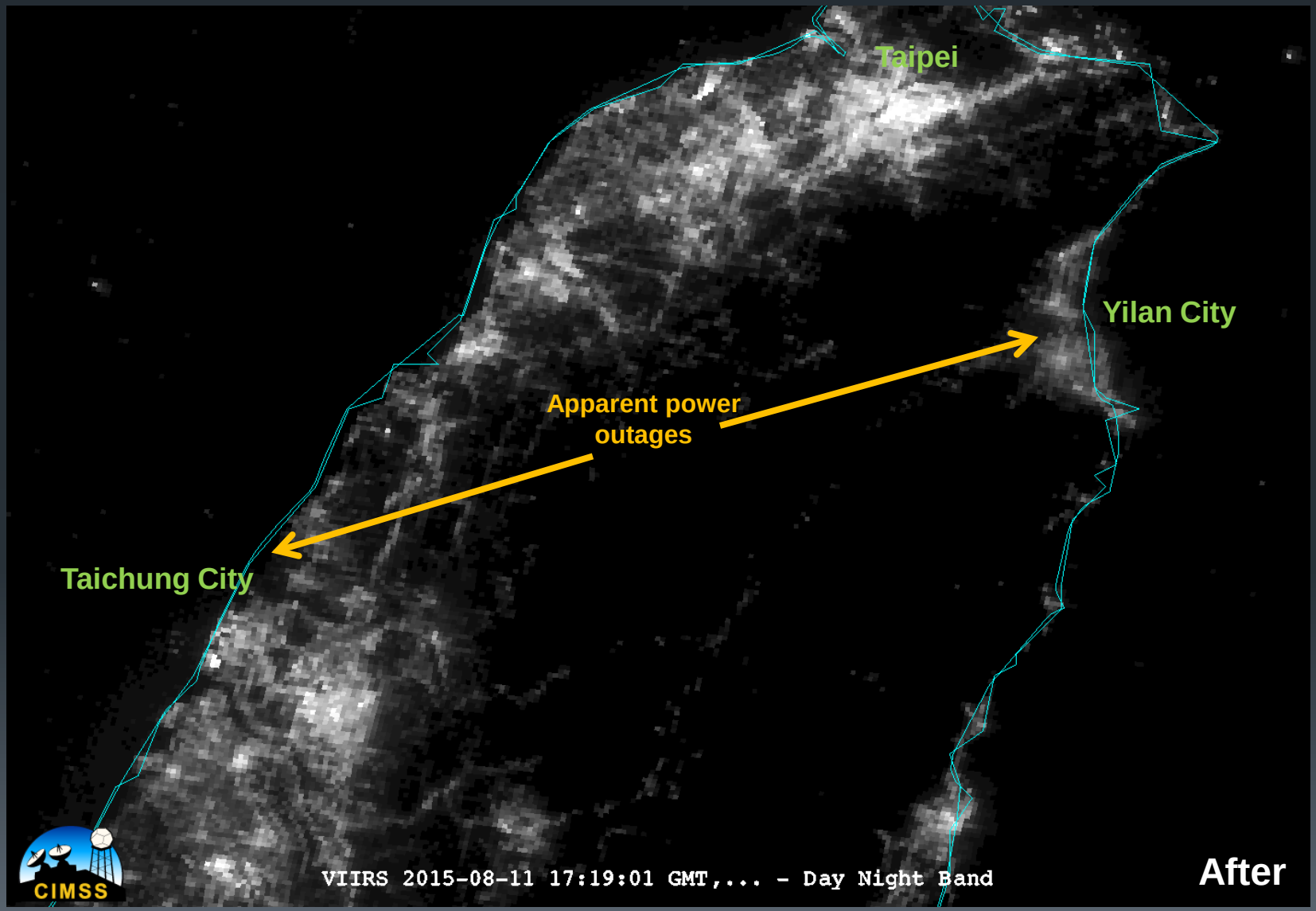
# Post Case power outage analysis

## Taiwan - Typhoon Soudelor

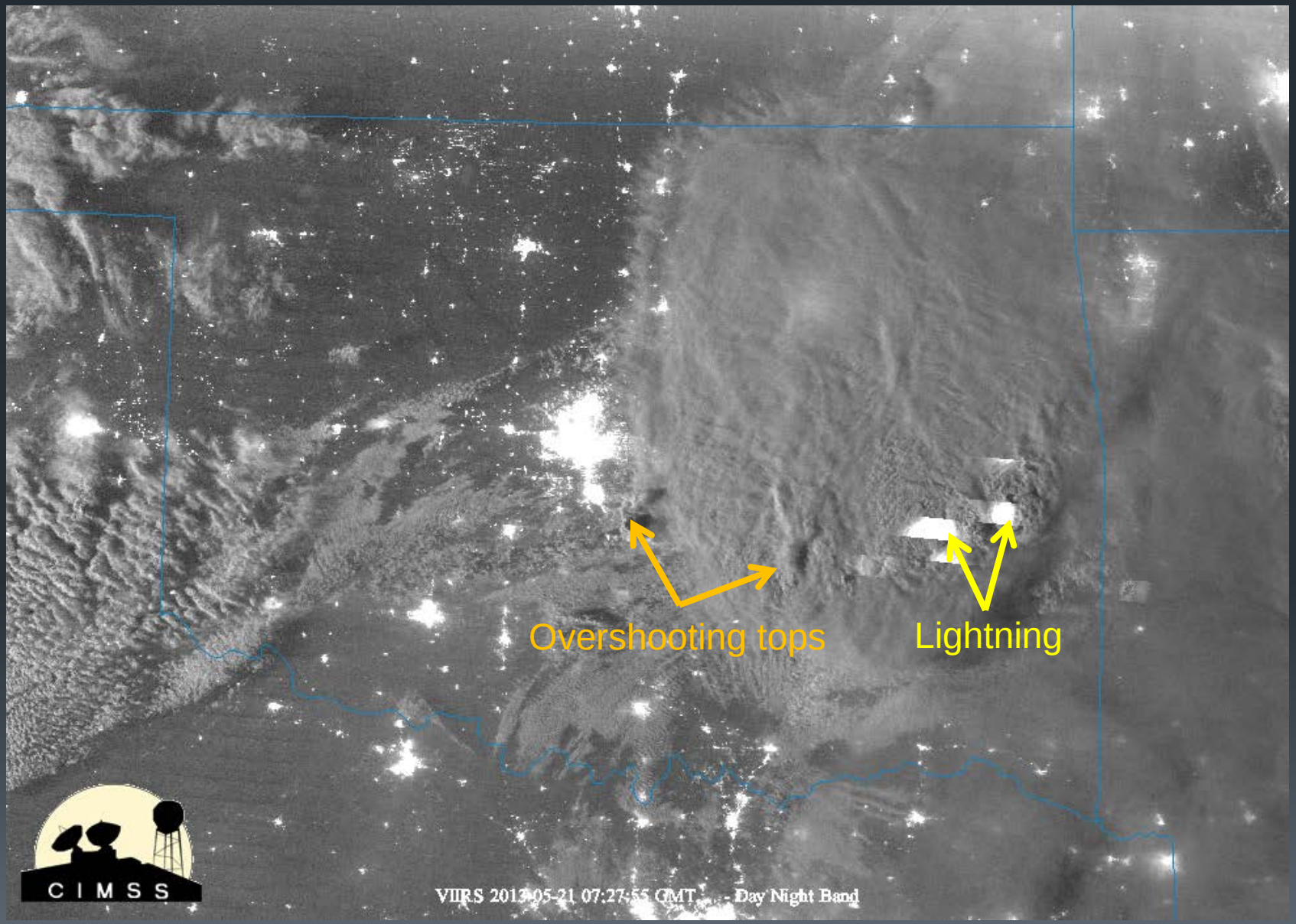


# Post Case power outage analysis

## Taiwan - Typhoon Soudelor

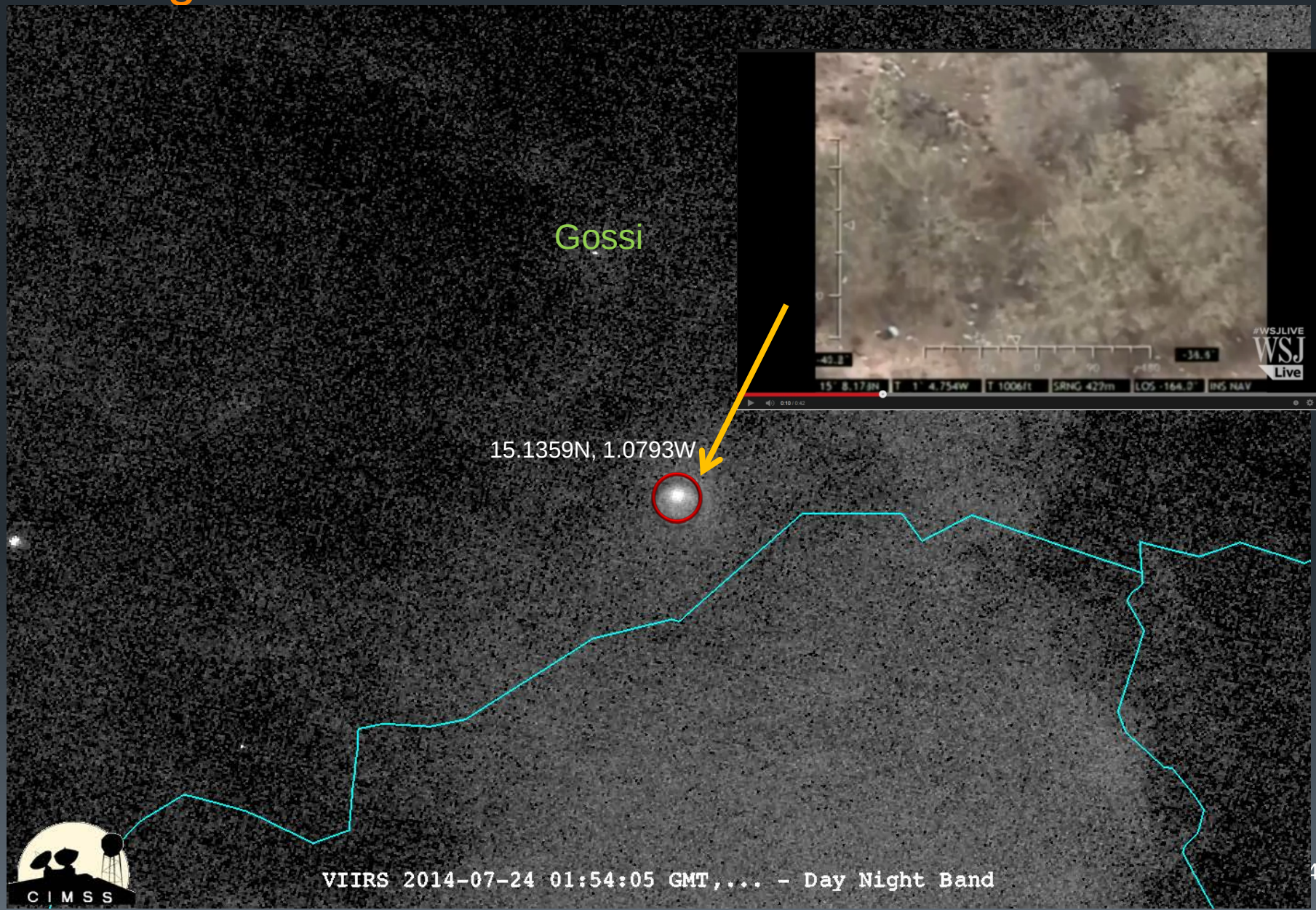


# Severe Weather



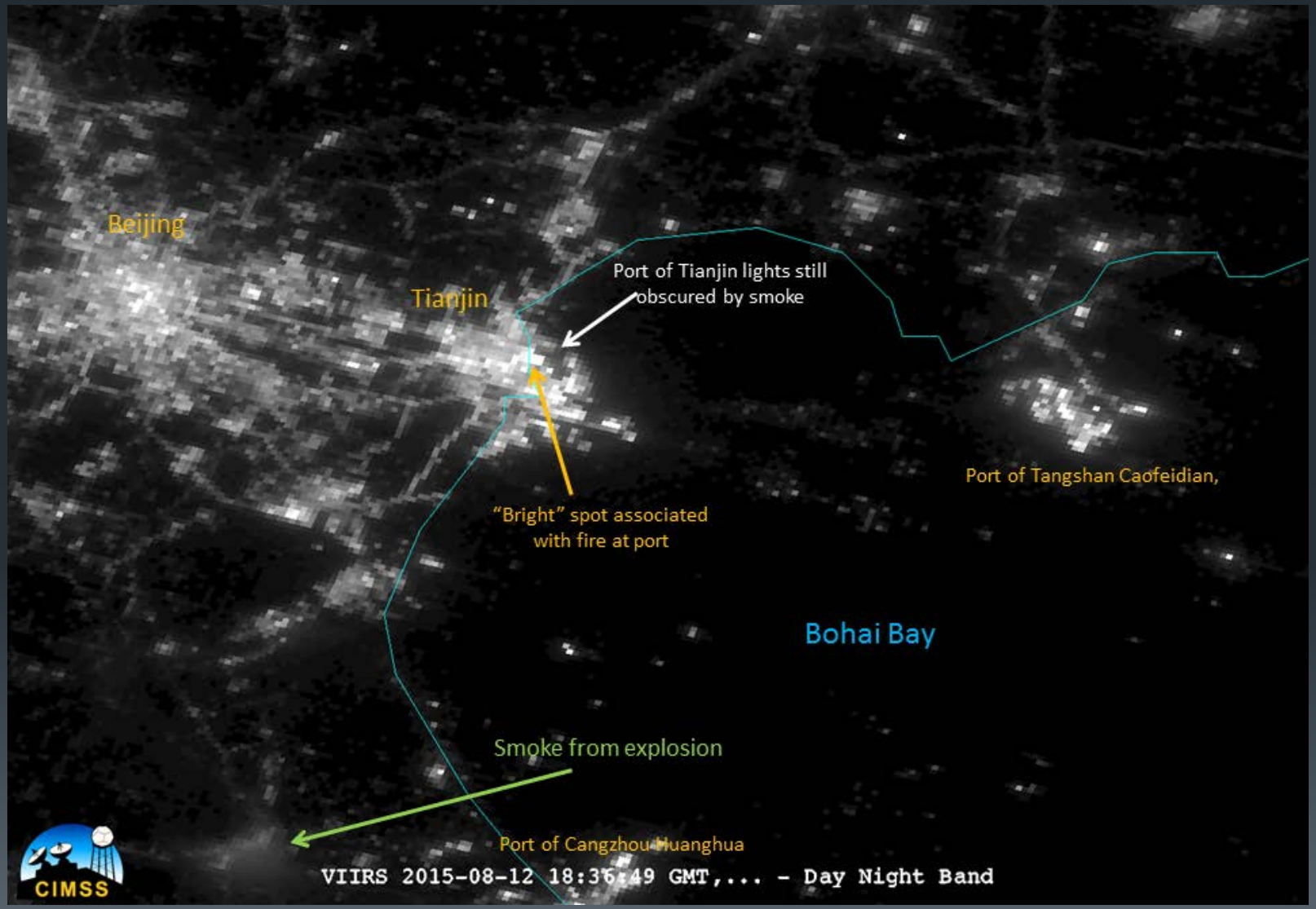
# Severe Weather related

## Air Algérie 5017



# Human made disasters

## Tianjin Port Explosion



# Other natural/human cause events (disasters) detected by DNB

- Monitoring of Sea Ice changes
  - Kiska Sea rescue
- Fog
- Monitoring of large scale dust storm events in the Middle East
- Monitoring of accidental and purposeful human caused incidents
  - Examples:
    - Monitoring of smoke plumes/fires from Tikrit/Baiji, Iraq refineries
    - Erie, IL pipeblast
    - Hercules 265  blowout
    - Lac-Mégantic rail disaster

# Summary

- The DNB provides the unique capability to provide visual imagery both during the day and at night
- Visible imagery can be used for public awareness via social and traditional media
- The DNB can provide qualitative and quantitative information of various disasters
- DNB imagery has been used in a number of *operational* cases during various natural disasters
- DNB imagery can be used for near-realtime analysis and monitoring of human-made disasters