



# Use of the VIIRS Day-Night Band Imagery for Tropical Cyclone Analysis and Forecasting

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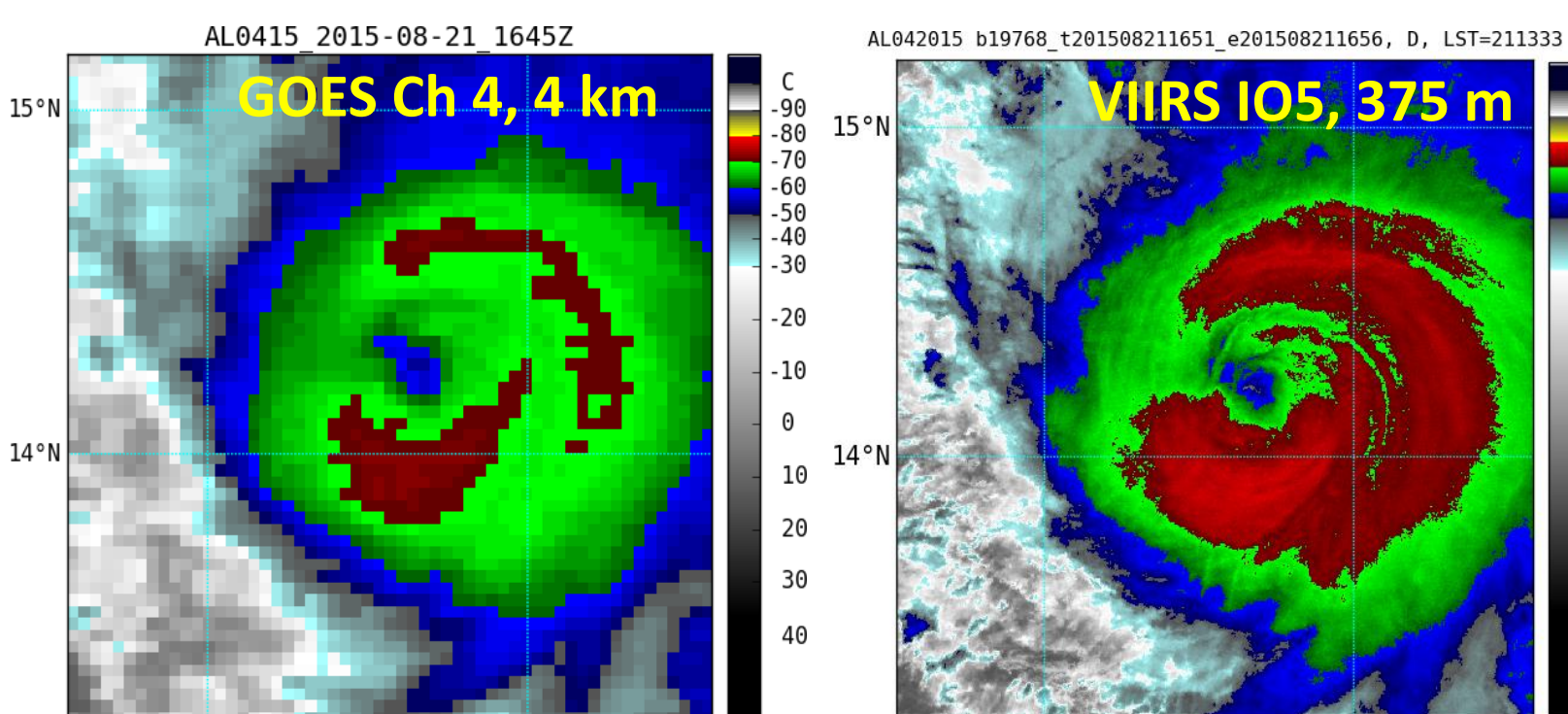
## Introduction

The Visible Infrared Imaging Radiometer Suite (VIIRS) is one of the five instruments on-board the Joint Polar Satellite System (JPSS) Suomi National Polar-Orbiting Partnership (S-NPP) satellite. There are 5 satellites in the JPSS program

- Current: **SNPP** (launched Oct 2011)
- Future: **JPSS-1/NOAA20** (spring 2017), **JPSS-2** (2022), **JPSS-3** (2026), and **JPSS-4** (2031)

### VIIRS has

- **16 Moderate Resolution Channels** (M-Band; 750 m resolution at nadir)
- **5 Imaging Resolution Channels** (I-Band; 375 m at nadir) and
- **Day-Night Band Channel** (DNB, 750 m across the scan, nominal bandwidth from 500 to 900 nm). VIIRS' DNB channel is a successor to the Defense Meteorological Satellite Program Operational Linescan System (OLS).



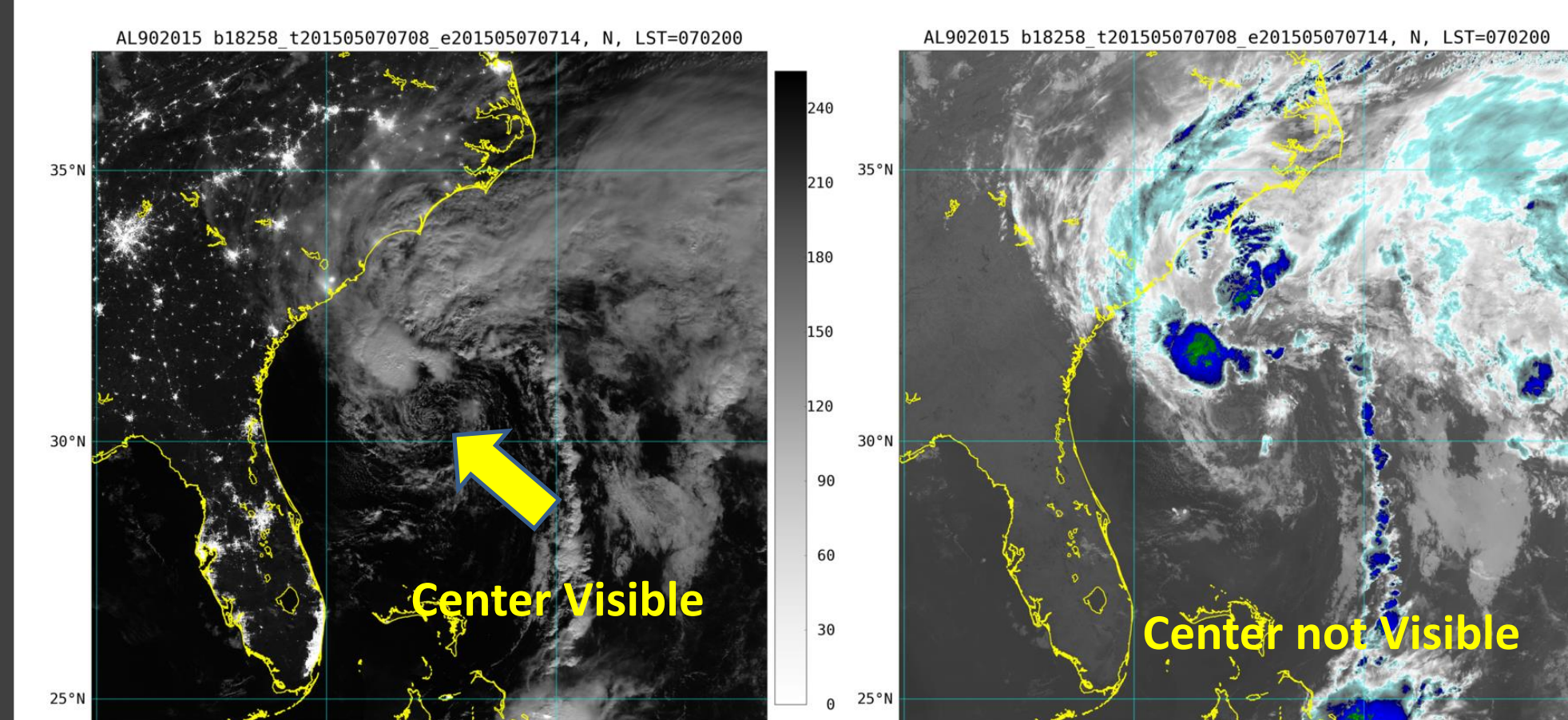
AL042015 Major Hurricane DANNY

- Global visible/infrared (IR) /DNB coverage **twice daily** (sun synchronous), 22 channels
- 3040 km swath width: **no gaps** between orbits!

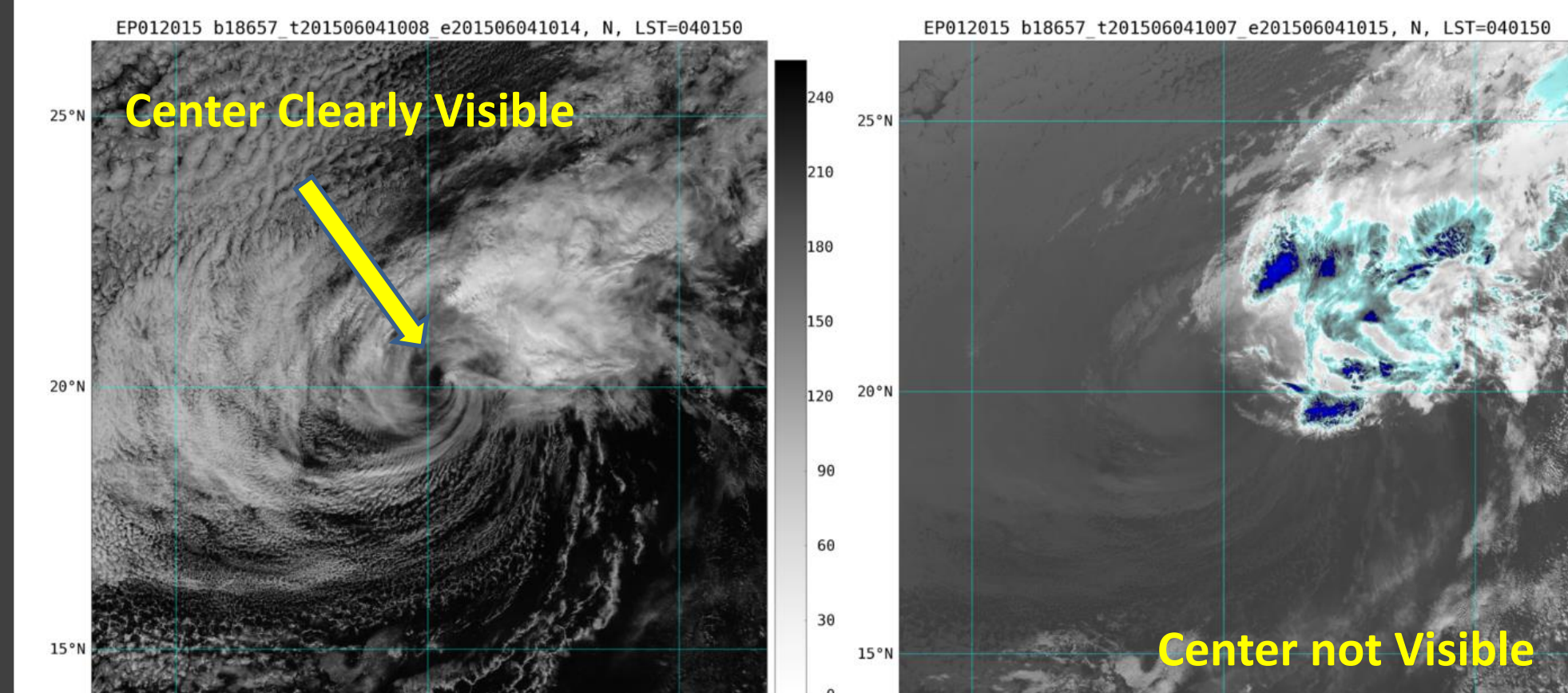
## VIIRS DNB Center Fixing

### Center Fixing

AL902015 INVEST (right before becoming Tropical Storm ANA)



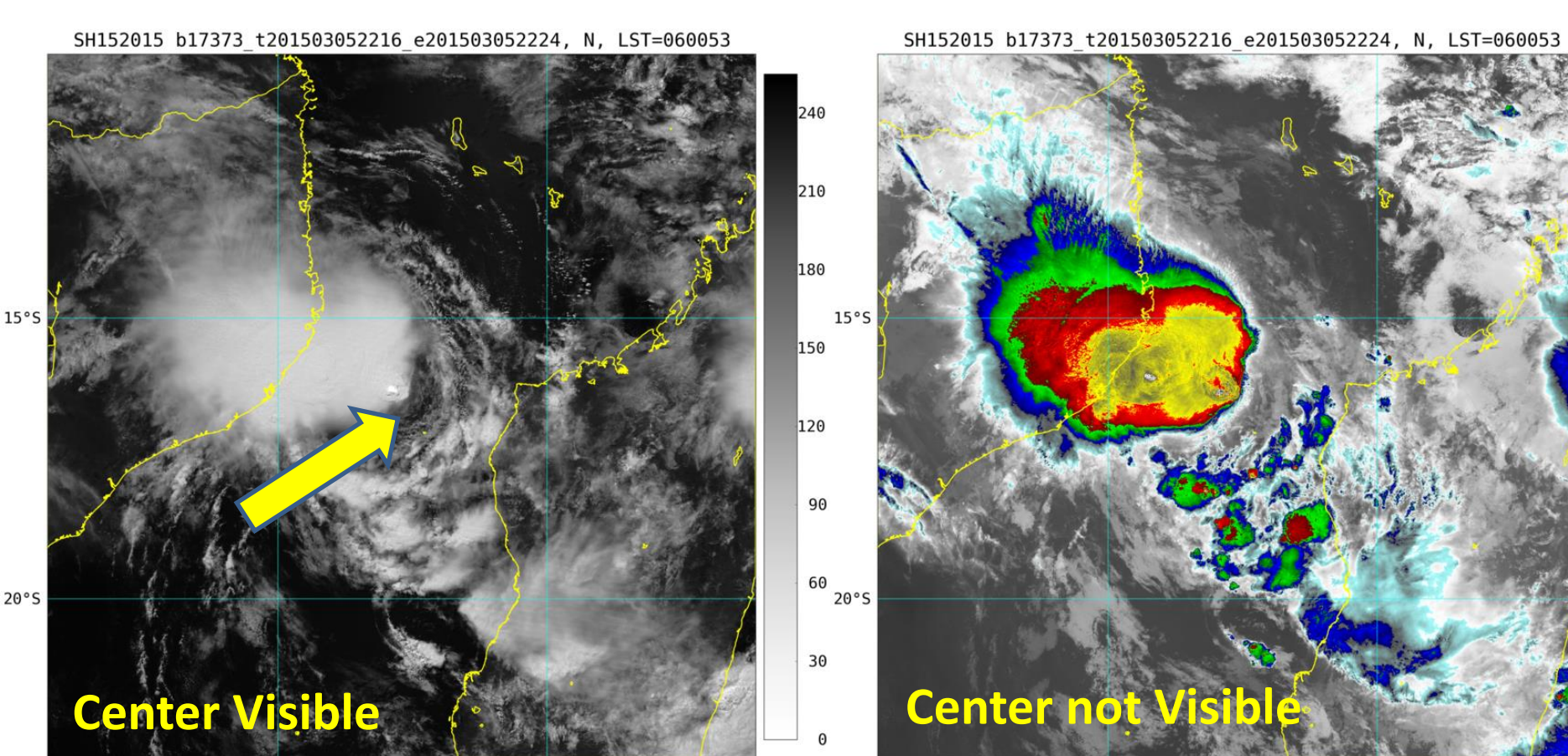
- Low level circulation center visible only on DNB image
- Hard to see the center location from the IR image alone



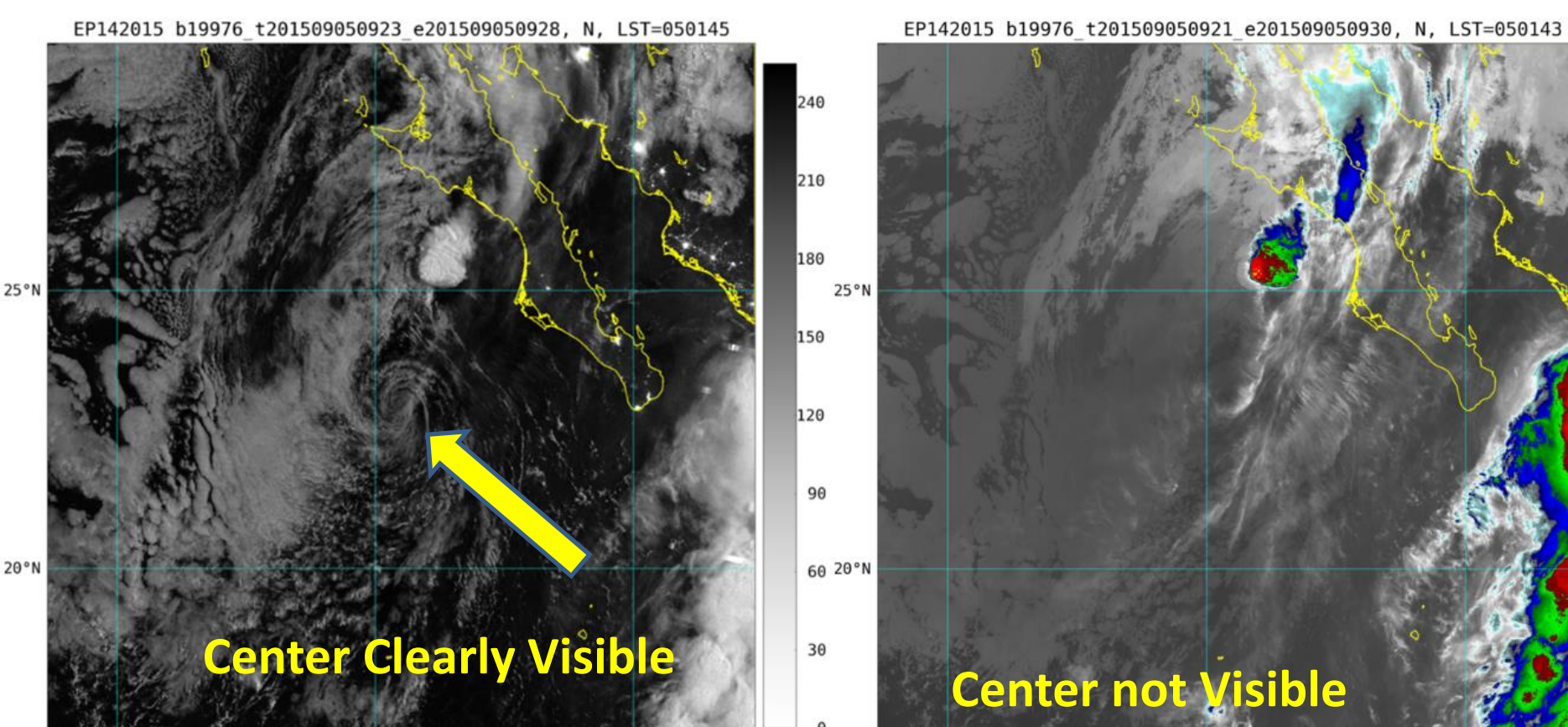
EP012015 Major Hurricane ANDRES

### Center Fixing

SH152015 Tropical Cyclone FIFTEEN



- Low level circulation center visible only on DNB image
- Hard to see the center location from the IR image alone



EP142015 Tropical Storm KEVIN

## Comments on Center Fixing

- The center is typically the **starting point for intensity estimation**
- Location is **important for warnings** and the running of guidance
- Weaker storms often have **multiple centers**
- Storm **symmetry is often poor in weaker systems** making center fixing challenging
- Sheared tropical cyclones have **displaced centers** which are difficult to find at night

## CIRA Tropical Cyclones Near Real Time DNB Imagery

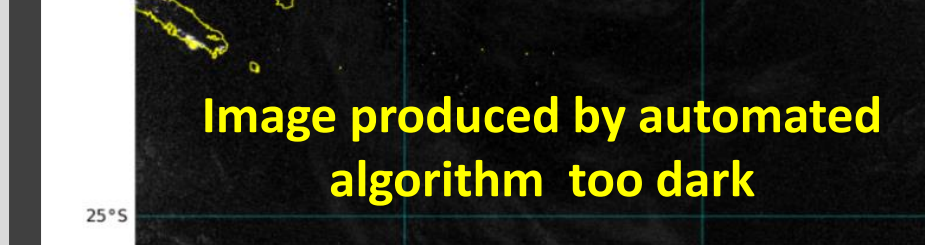
An experimental near real-time application displaying storm-relative VIIRS DNB, visible, and IR imagery in the vicinity of TCs has been developed and is available on RAMMB-CIRA's TC Real Time page: [http://rammb.cira.colostate.edu/products/tc\\_realtime/](http://rammb.cira.colostate.edu/products/tc_realtime/)

- 3 VIIRS products available online:
  1. Alternating DNB (at night) and VIS (during day) [2 hr latency]
  2. DNB imagery during both day and night [1.5 hr latency]
- 3. VIIRS high-resolution IR band I05 (11.45μm) [2 hr latency]
  - Product description: [http://rammb.cira.colostate.edu/products/tc\\_realtime/about.asp](http://rammb.cira.colostate.edu/products/tc_realtime/about.asp)

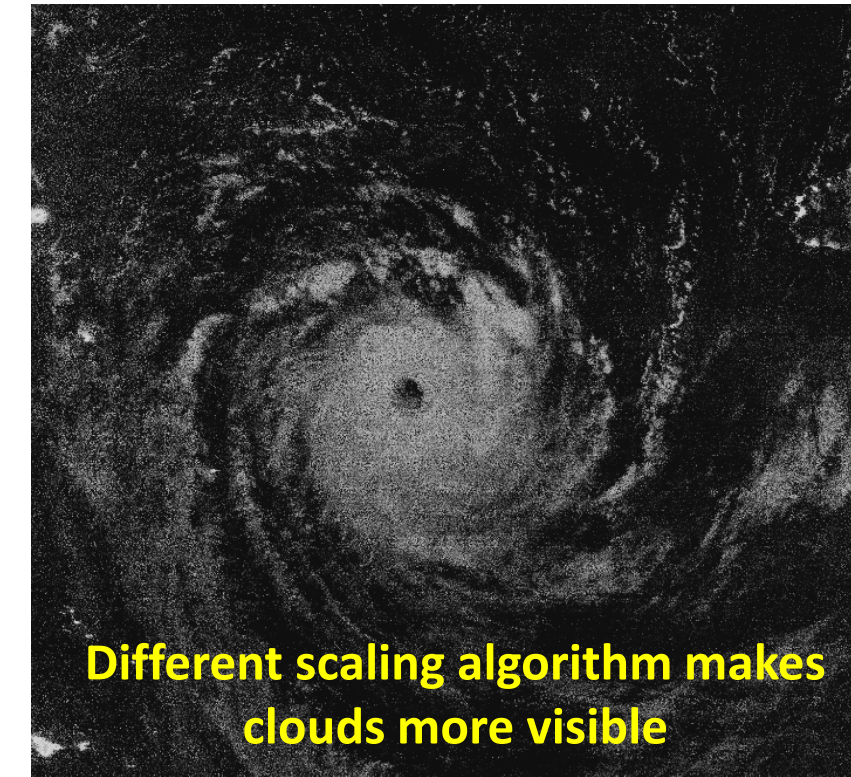
The low-latency, storm-centered VIIRS imagery from the CIRA TC Real Time Page, which in some cases produces better results compared to Near Constant Contrast (NCC) imagery, has been utilized in the National Hurricane Center (NHC) Proving Ground and has shown utility for TC analysis.

### Future Imagery Improvements

- Getting more data with lower latency
- Consider getting direct readout VIIRS data
- Direct readout will have **~15 minutes latency for AL and EP**
- Working with NHC TSB on providing to them VIIRS TC Imagery in real time



SH062016 Tropical Cyclone ULA



- Developing new and testing existing algorithms to improve quality of DNB imagery in difficult conditions such as
  - Low illumination (e.g. around new moon)
  - Presence of many bright light sources (e.g. city lights)

## VIIRS Day/Night Band Channel (DNB)

- **2nd generation of 'low-light visible' sensors**
- Detected **radiances span over 8 orders of magnitude**
- DNB **produces visible-like imagery at night** using illumination from the moon, auroras, anthropogenic sources, and night glow
- **Sensitivity**
  - Maximum: **full sunlight** reflection (order  $10^{-2}$  W cm<sup>-2</sup> sr<sup>-1</sup>)
  - Minimum: **airglow** at night (order  $10^{-10}$  W cm<sup>-2</sup> sr<sup>-1</sup>)
  - Includes: **reflected moonlight**, **auroras**, and **nightglow**
  - Can detect a single isolated street lamp from orbit (~834 km) (Miller et al. 2013)
- Image quality may change significantly depending on the amount of light available

## VIIRS DNB for Tropical Cyclone Forecasting

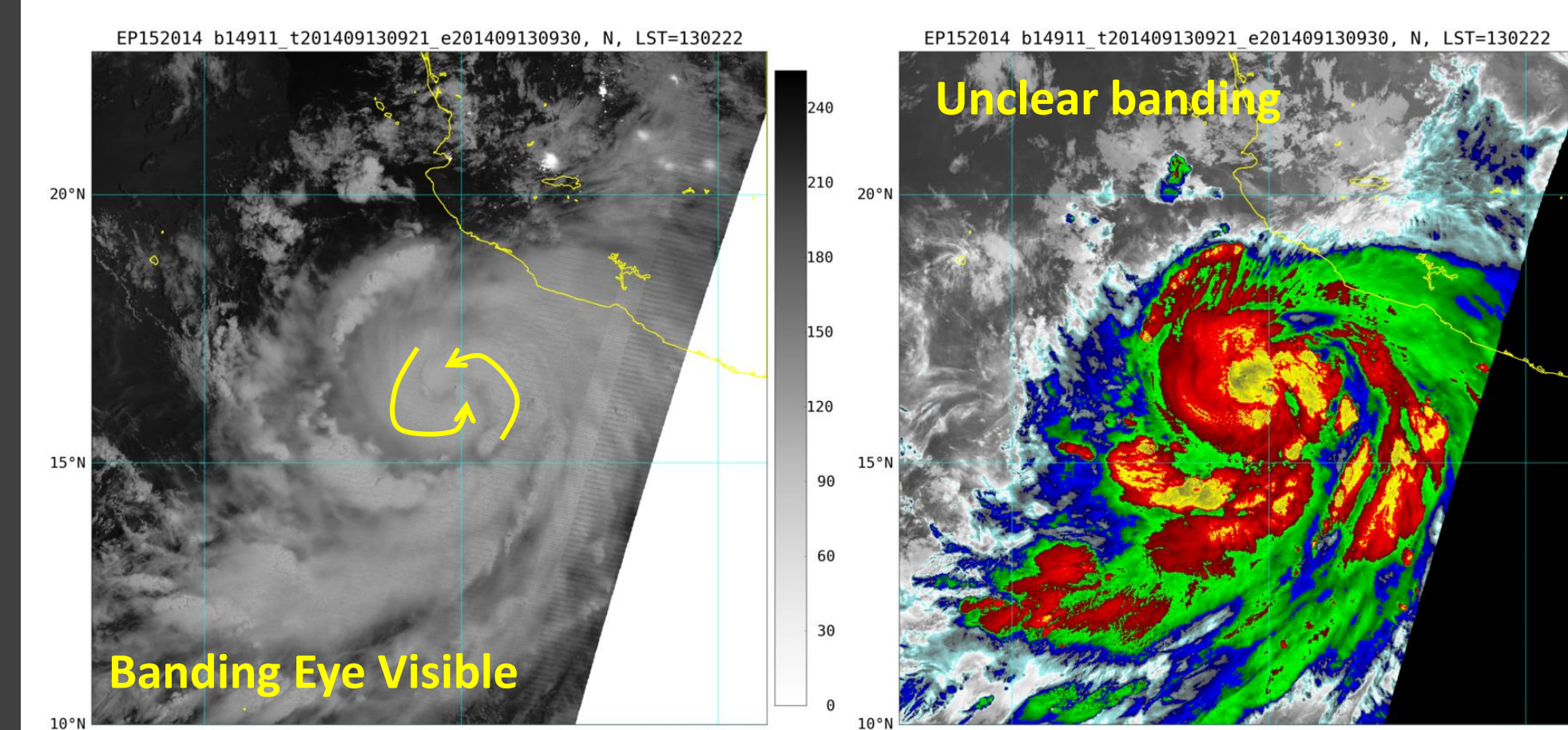
The **unique DNB data have multiple applications for tropical cyclone (TC) analysis and forecasting** and can be critical for operational forecasters.

- **Primary DNB TC applications:**
  - ❖ Aid in **center location/fixing** (most useful for weaker systems)
  - ❖ **Eye detection**
- **DNB also detects:**
  - ❖ **Instantaneous lightning**
  - ❖ **Nightglow**
- The DNB's nighttime capabilities are **especially important for weaker TCs** that tend to be less organized, have multiple circulation centers, and are generally more difficult to locate.
- For example DNB imagery can be used to
  - **determine the presence of the eye** in cases when the eye is small or is obscured by thin cirrus and not obvious in infrared (IR) imagery
  - **perform center-fixing** and has been used by forecast centers to refine nighttime storm center locations
- The DNB has also proven **especially useful for sheared systems** when the low-level circulation center is exposed and/or elongated and is hard to determine from the IR imagery or animations of IR imagery.

## VIIRS DNB Eye-detection, Lightning, and Nightglow Waves

### Eye-detection

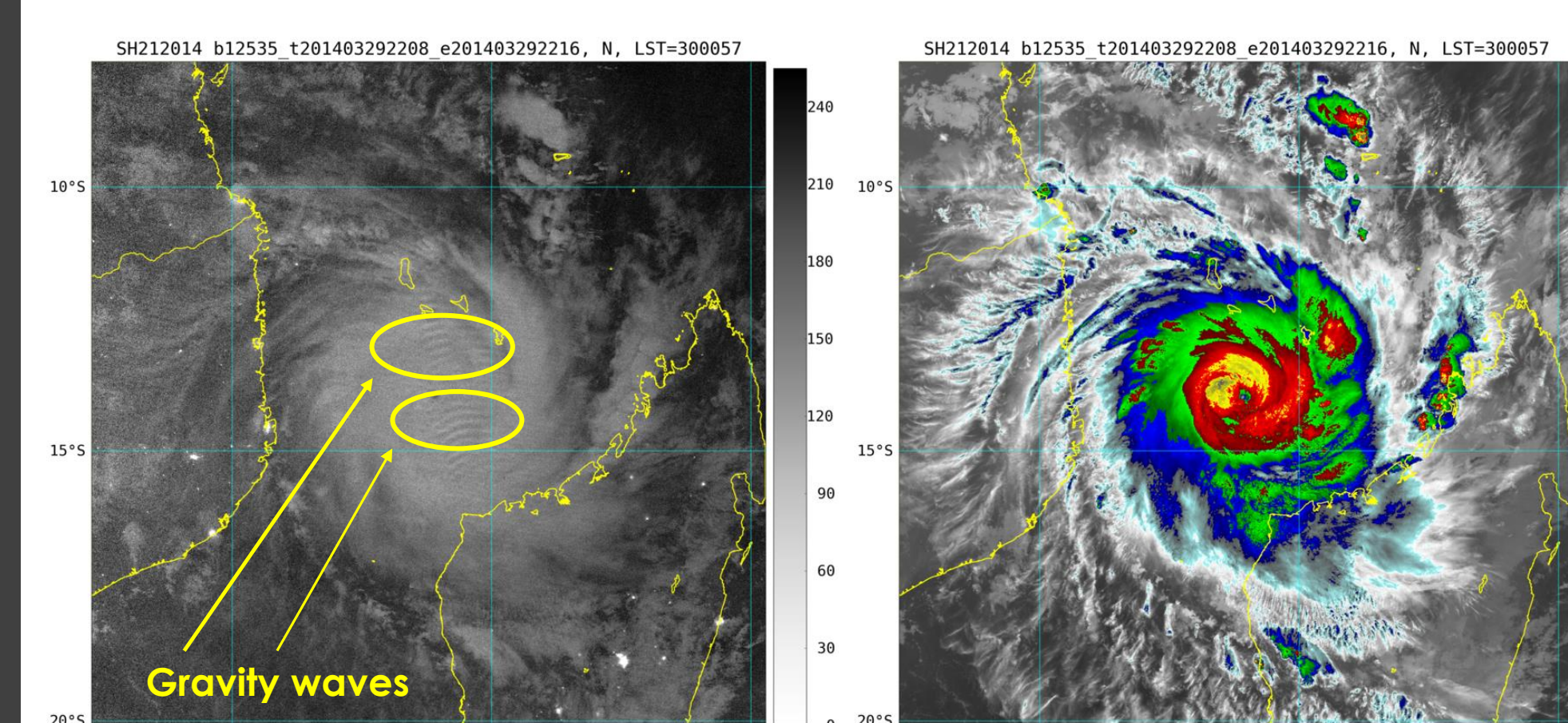
EP152014 Major Hurricane ODILE



- Banding eye apparent in the night-time DNB image
- No banding indicated in the IR image alone

### Nightglow Waves

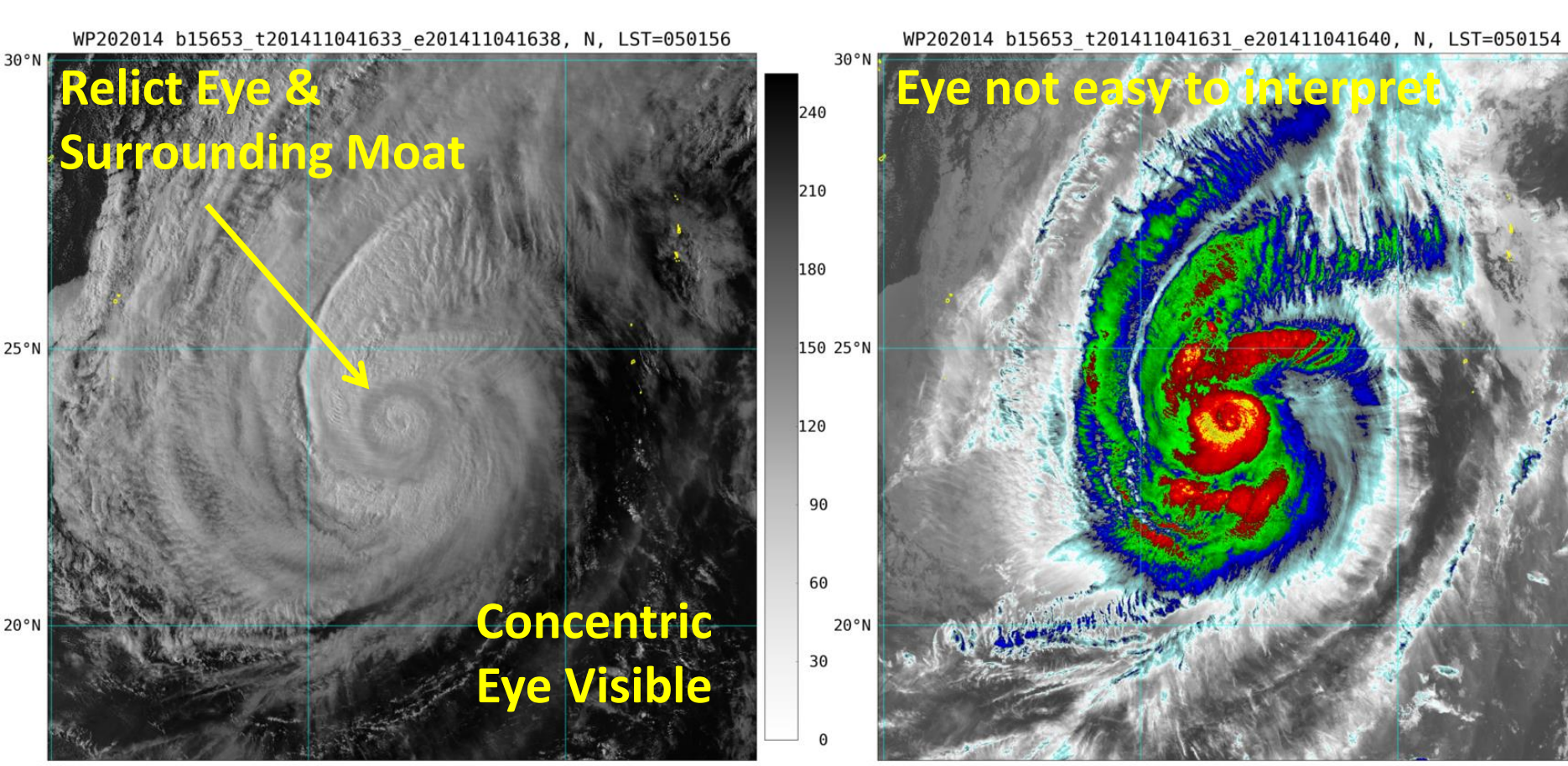
SH212014 Tropical Cyclone HELLEN



- Gravity waves observed in nightglow on DNB images (Yue et al. 2014)

### Eye-detection

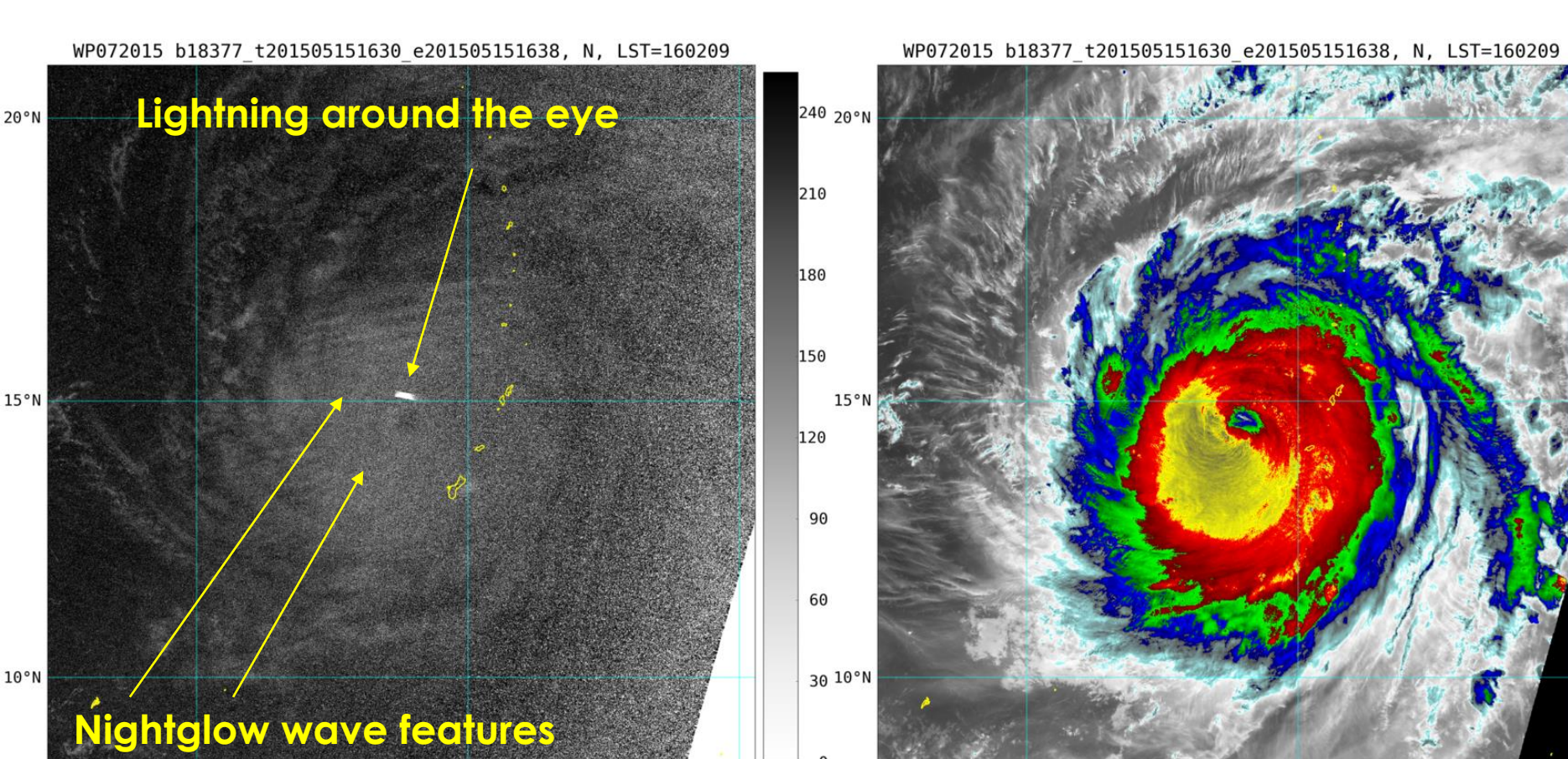
WP092014 Typhoon RAMMASUN



- Concentric eye is evident in night-time DNB image
- The concentric nature of the eye is more difficult to infer in the IR

### Nightglow Waves and Lightning

WP072015 Typhoon DOLPHIN



- Lightning strikes near the eye - peaking intensity? (DeMaria et al. 2012)

## Further Information about VIIRS

### COMET:

- Introduction to VIIRS Imaging and Applications [https://www.meted.ucar.edu/training\\_module.php?id=1075#.VYw4dPIViko](https://www.meted.ucar.edu/training_module.php?id=1075#.VYw4dPIViko)
- Suomi NPP: A New Generation of Environmental Monitoring Satellites <http://www.meted.ucar.edu/satmet/npp/navmenu.php?tab=1&page=3.2.0&type=text>

### VISIT:

- VIIRS Satellite Imagery in AWIPS. [http://rammb.cira.colostate.edu/training/visit/training\\_sessions/viirs\\_satellite\\_imagery\\_in\\_awips/](http://rammb.cira.colostate.edu/training/visit/training_sessions/viirs_satellite_imagery_in_awips/)
- VIIRS Imagery Interpretation of Super Typhoon Vongfong [http://rammb.cira.colostate.edu/training/visit/training\\_sessions/viirs\\_imagery\\_interpretation\\_of\\_super\\_typhoon\\_vongfong/](http://rammb.cira.colostate.edu/training/visit/training_sessions/viirs_imagery_interpretation_of_super_typhoon_vongfong/)

### CIRA:

- Suomi NPP (National Polar-orbiting Partnership) VIIRS Imagery and Visualization Team <http://rammb.cira.colostate.edu/projects/npp/>

## References

- DeMaria, M., R. T. DeMaria, J.A. Knaff and D.A. Molenaar, 2012: Tropical cyclone lighting and rapid intensity change. *Mon. Wea. Rev.*, **140**, 1828-1842.
- Hawkins J., J. Solbrig, S. Miller, M. Surratt, K. Richardson, and G. Chirokova, 2016: Tropical Cyclone Characterization via Lunar Illumination. *In preparation*.
- Miller, S. D., W. Straka, III, S. P. Mills, C. D. Elvidge, T. F. Lee, J. Solbrig, A. Walther, A. K. Heidinger, and S. C. Weiss., 2013: Illuminating the capabilities of the Suomi NPP VIIRS Day/Night Band. *Rem. Sens.*, **5**, 6717-6766; doi:10.3390/rs5126717.
- Yue, J., S. D. Miller, L. Hoffmann, and W. C. Straka, III, 2014: Stratospheric and Mesospheric concentric gravity waves over Tropical Cyclone Mahasen: Joint AIRS and VIIRS satellite observations. *J. Atmos. Solar-Terr. Phys.*, doi:10.1016/j.jastp.2014.07.003.