



OUTLOOK FOR JPSS DATA AND PRODUCTS FOR TROPICAL CYCLONE ANALYSIS AND FORECASTING

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TCORF, March 13 2018. Miami FL

Outline

➤ CIRA/RAMMB JPSS applications:

Operational:

(1) Hurricane Intensity and Structure Algorithm (**HISA**)[operational]

Real-Time/Transitioning to Operations:

(2) Satellite eye-detection routine (**SEDR**) [TCRT,NAWIPS,SHIPS]

(3) Moisture In-flux Storm Tool (**MIST**) [real-time planned for 2019]

(4) VIIRS TC-centered imagery [TCRT, NAWIPS]

(5) Proxy-visible imagery [NAWIPS,SLIDER, AWIPS2]

➤ CIMSS JPSS applications:

Real-Time/Transitioning to Operations:

(6) TC Intensity Estimates (**TCIE**) [CIMSS SATCON PG]

(7) Satellite Consensus (**SATCON**) [CIMSS SATCON PG]

➤ TROPICS

TCRT CIRA/RAMMB TC-Real Time http://rammb.cira.colostate.edu/products/tc_realtime/
SLIDER <http://rammb-slider.cira.colostate.edu/>

CIMSS SATCON PG : http://tropic.ssec.wisc.edu/real-time/satcon/PG/satcon_pg.html

CIRA JPSS Applications

(1) CIRA's Hurricane Intensity and Structure Algorithm (HISA)

- provides satellite-based TC intensity estimates that are
 - global
 - objective
 - independent on Dvorak
- **Operational** on multiple satellites and instruments (NCO, NESDIS):
 - NOAA 15, 16, 18, 19, MetOp-A AMSU Statistical
 - NOAA18,19, MetOp-A,-B AMSU-MiRS
 - SNPP ATMS-MiRS
- Currently upgrading to run on:
 - NOAA-20 (JPSS-1, operational in 2019) ATMS-MiRS
 - TROPICS (2020) MW Radiometer
- Planned to upgrade to run on
 - MetOp-C (202?) AMSU-MiRS

(1) CIRA's Hurricane Intensity and Structure Algorithm (HISA)

- Purpose: provide satellite-based TC intensity estimates:
 - a) global, b) objective, c) independent on Dvorak
- operational on multiple satellites (NOAA, Metop, SNPP) and instruments (ATMS, AMSU)
- provides intensity estimates to NHC, CPHC, JTWC

INPUT

Retrievals
 $T(x,y,P)$
 $q(x,y,P)$

GFS
 T_{sfc}, P_{sfc}
 $Z(x,y, P_{100})$

Gradient Wind

$V(r,z)$
 $V_s(r)$

Statistical Model

V_{max}
 P_{min}
R34
R50
R64

Balanced 2d
winds at
standard P
levels

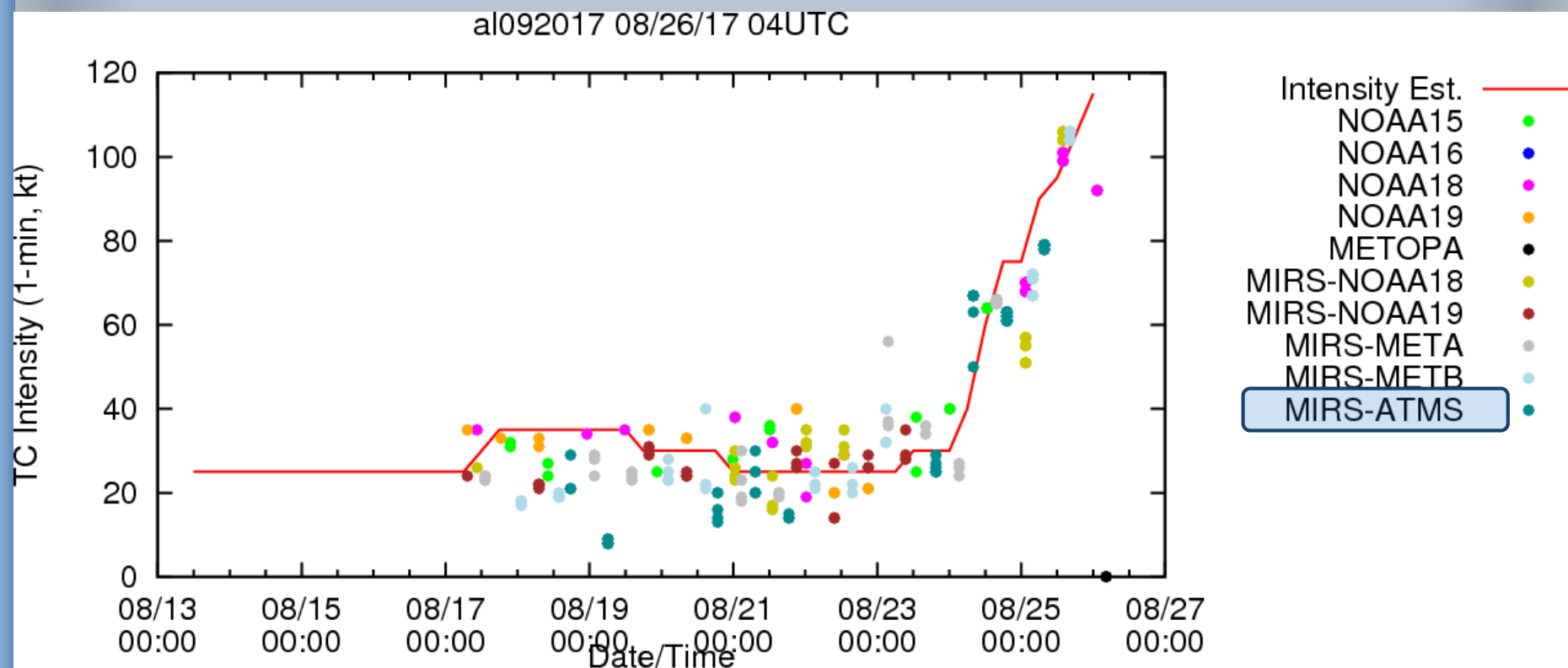
$V(x,y,P)$
 $V_s(x,y)$

OUTPUT

	ATMS-MIRS MAE	AMSU-MIRS MAE
Vmax (kts)	11.1 (1565)	13.2 (4346)
Pmin (hPa)	7.0 (1565)	8.4 (4347)
R34 (nmi)	20.0 (344)	24.9 (1044)
R50 (nmi)	12.0 (215)	10.6 (601)
R64 (nmi)	12.0 (134)	8.9 (336)

(1) HISA Maximum Sustained Wind

Major Hurricane HARVEY al09 2017



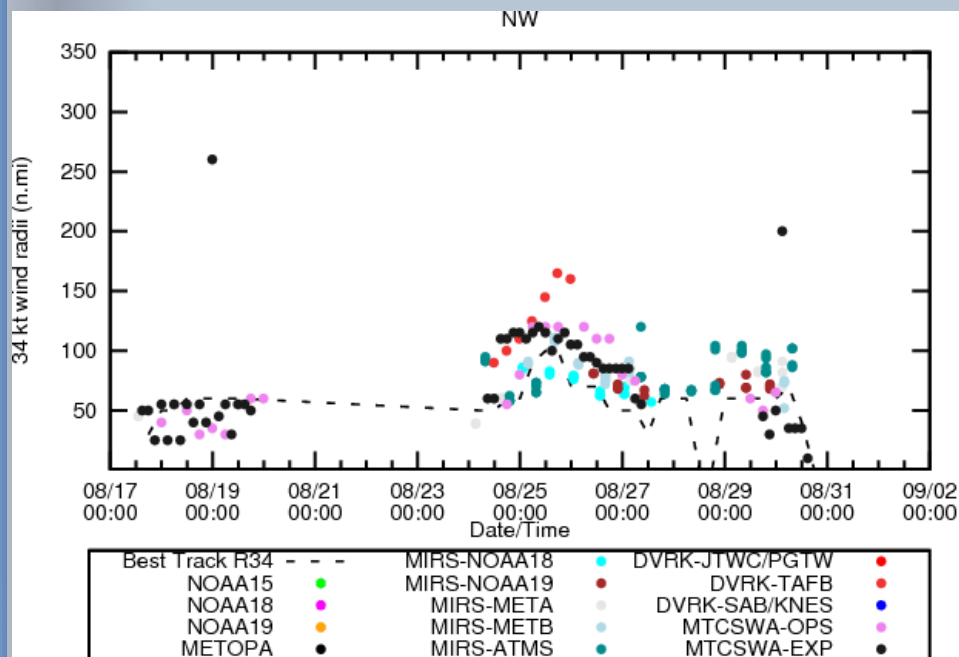
(1) HISA Fixes and 2-D Winds

Major Hurricane HARVEY a109 2017

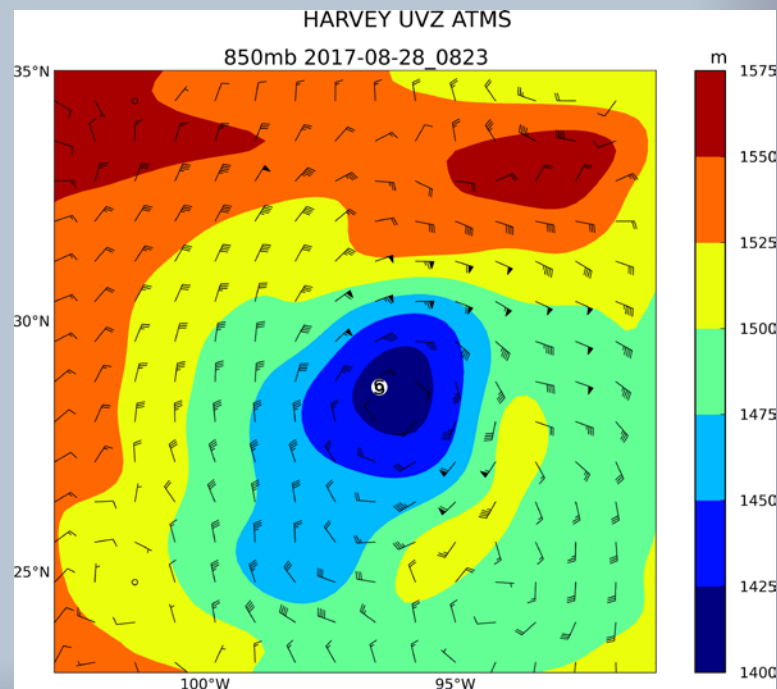
F-desk:

AL, 09, 201708240759, 30, ATMS, IPR, , 2243N, 9287W, , 1, 50, 2, 992, 2, MEAS, 34, NEQ, 67, 0, 0, 0, , , , 2, 63, , L, NSOF, OPS, , , , , 992, , SNPP01, 34, NEQ, 67, 0, 0, 0, , , , , , , , , , , , , 2, storm center extrapolated from t=-12 and t=0 adeck

HISA: 34-, 50-, 64- kt winds



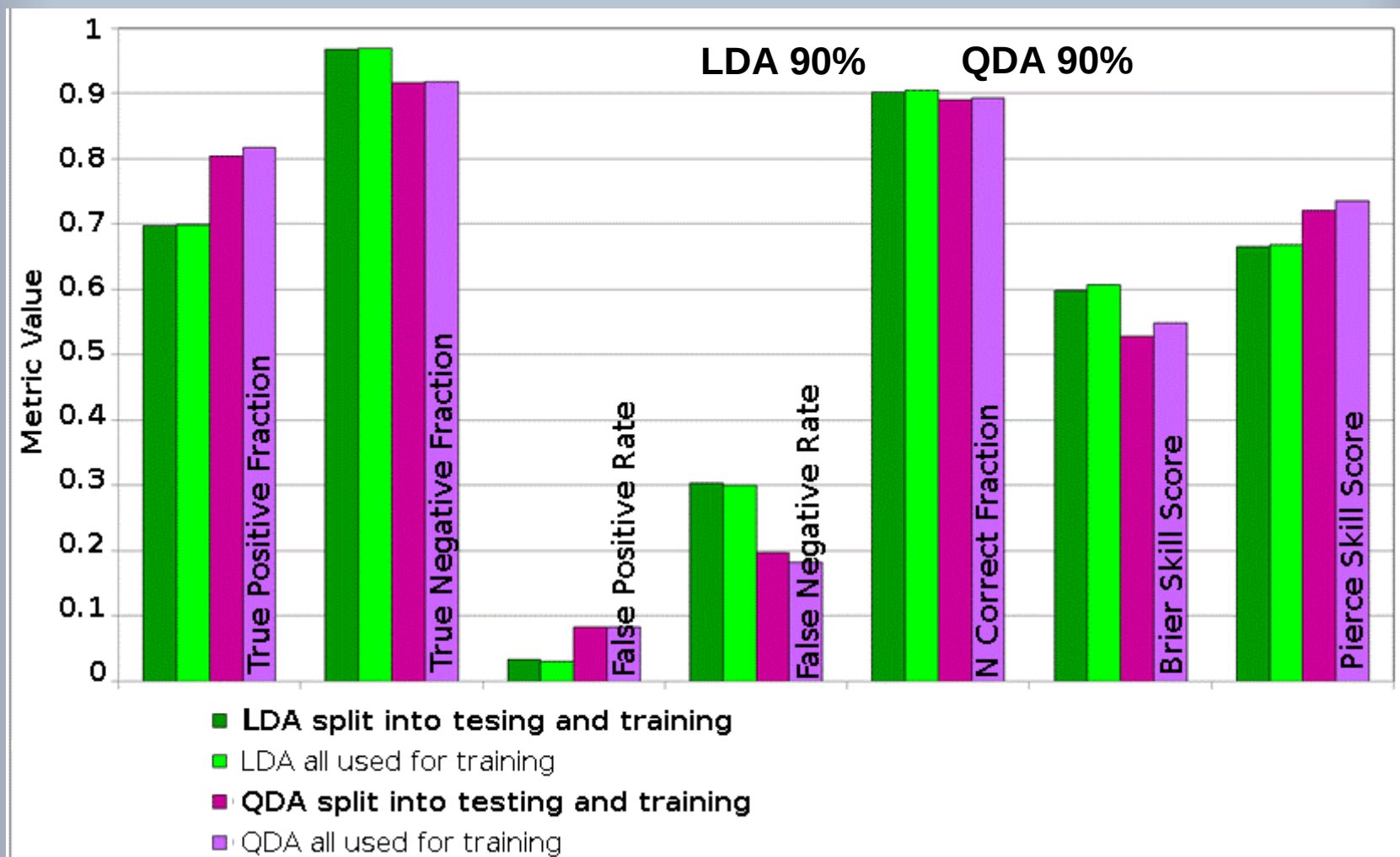
2-D Winds



(2) Satellite Eye Detection Routine (SEDR)

- TC eye formation is
 - fundamental to intensity analysis and forecasting
 - closely associated with RI
- SEDR:
 - **Purpose: objectively determine probability of the eye existence from IR imagery (GOES or VIIRS) to**
 - Replicate human-performed eye detection with objective procedure
 - Accuracy 90 % - similar to human accuracy (agreement between TAFB and SAB is 95%)
 - Make eye detection available at more times
- Use SEDR to:
 - Forecast eye formation
 - Predictor for SHIPS/LGEM and RII

(2) SEDR Verification

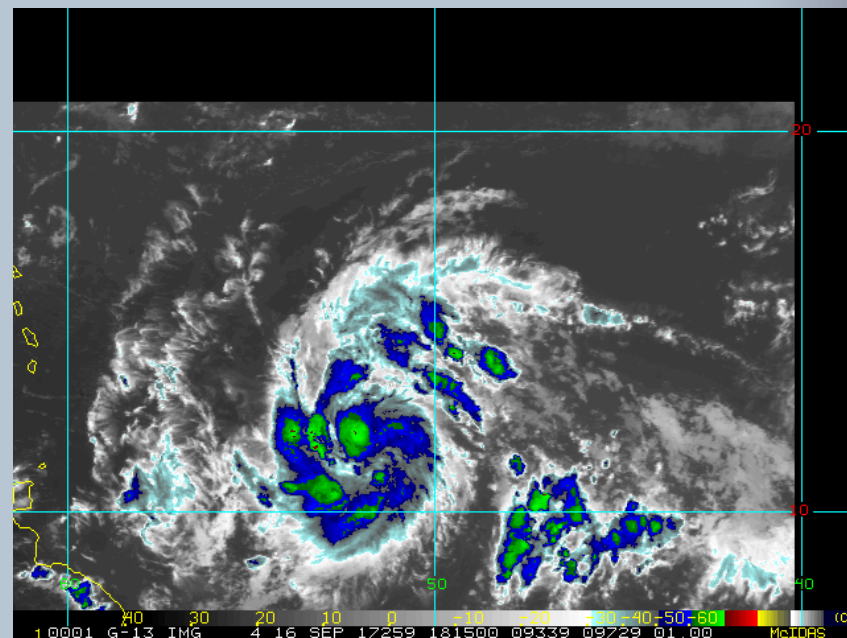
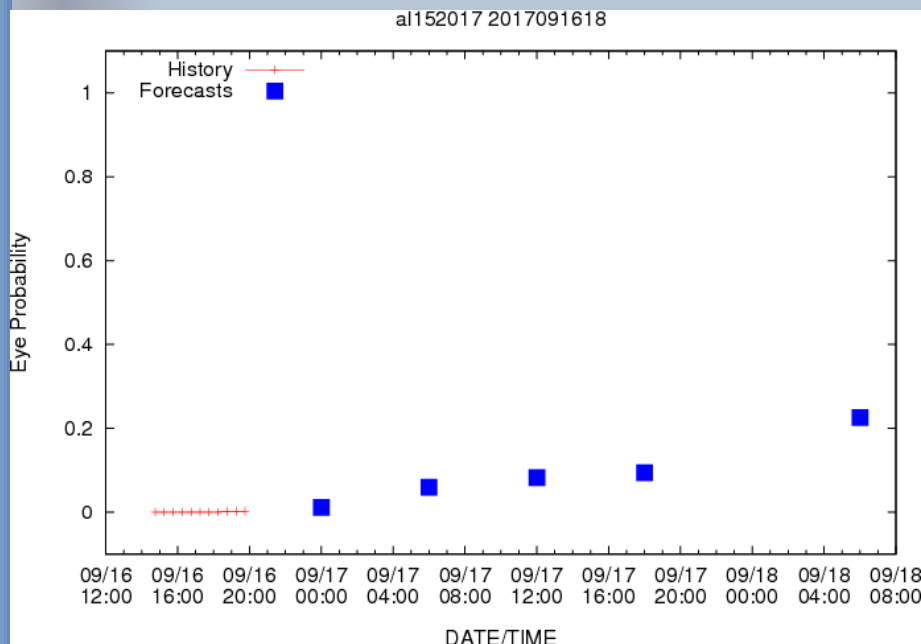


Performance is almost as good as human!

(2) SEDR in Real Time

Eye-existence probability and
6 – 36 h forecasts

Image at $t = 0$ h

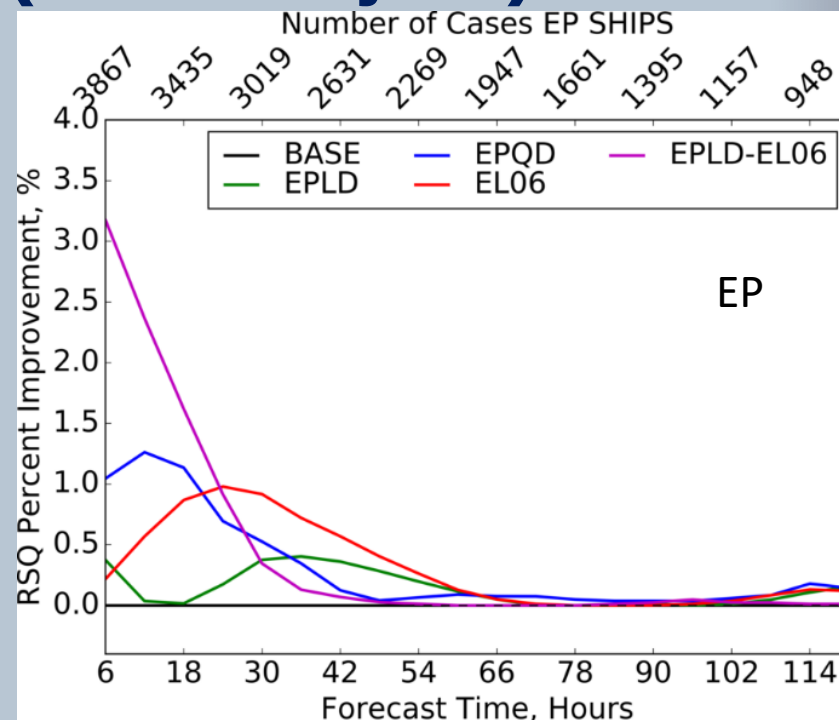
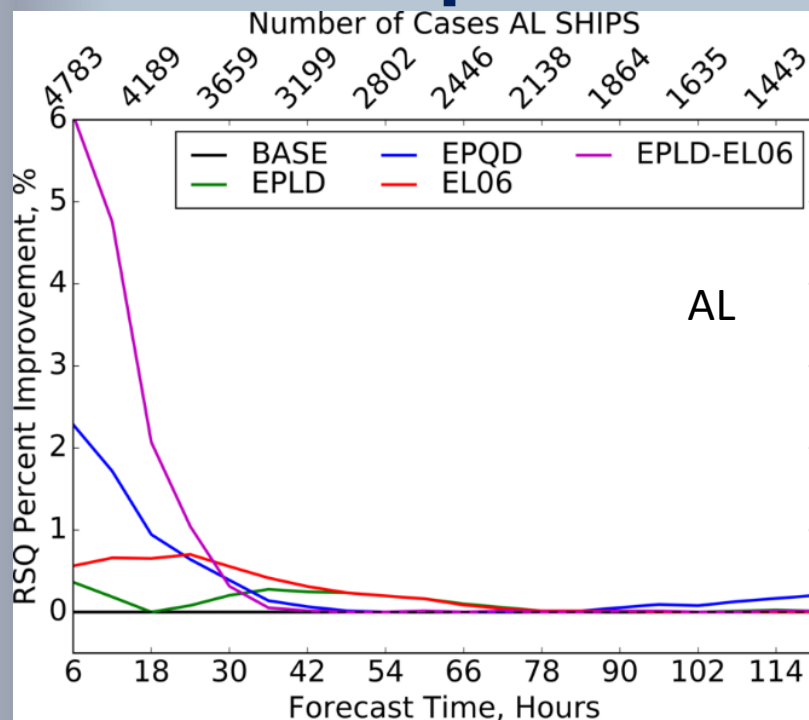


Major Hurricane MARIA 2017

Knaff and DeMaria (2017)

Available on CIRA/RAMMB TC-Real Time Page http://rammb.cira.colostate.edu/products/tc_realtime/

(2) SEDR: SHIPS/LGEM Forecast Improvement (JHT Project)



Predictor	Predictor description
EPLD	Eye-probability at FLT = 0 hr, LDA
EPQD	Eye-probability at FLT = 0 hr, QDA
EL06	Eye-probability at FLT = -6 hr, LDA
EL12	Eye-probability at FLT = -12hr, LDA

Predictors based of SEDR will be added to SHIPS/LGEM/RII as part of the JHT project

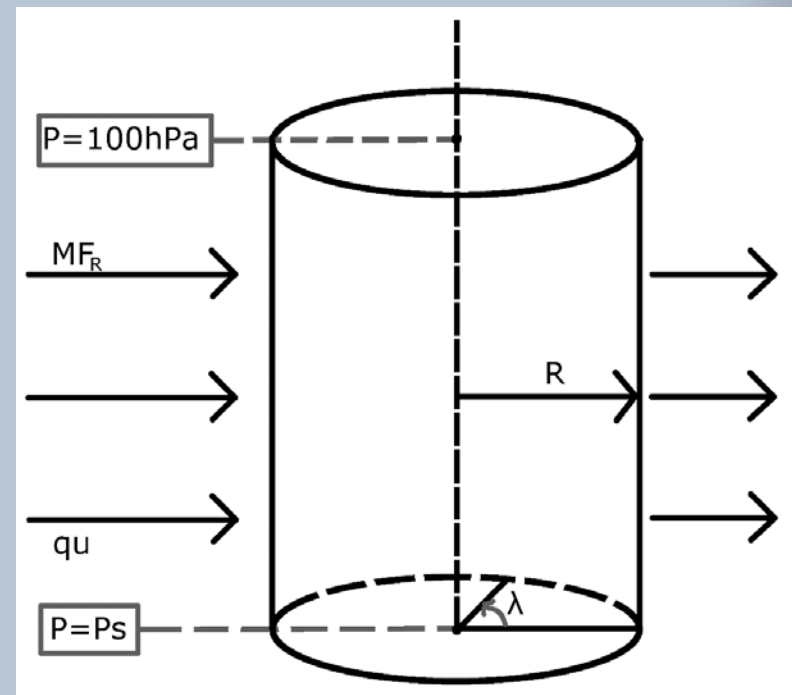
(3) CIRA's Moisture In-flux Storm Tool (MIST)

- **Dry air intrusions**
 - important for storm intensification since too much dry air inhibits convection
 - dry air mentioned in NHC forecast discussions:
 - 2016 - 23% of discussions
 - 2017 – 17%
 - cannot be readily quantified with existing applications and data
- **MIST:**
 - Purpose: detect and quantify dry air intrusions
 - Potential SHIPS and RII predictor ?

(2) MIST Schematics

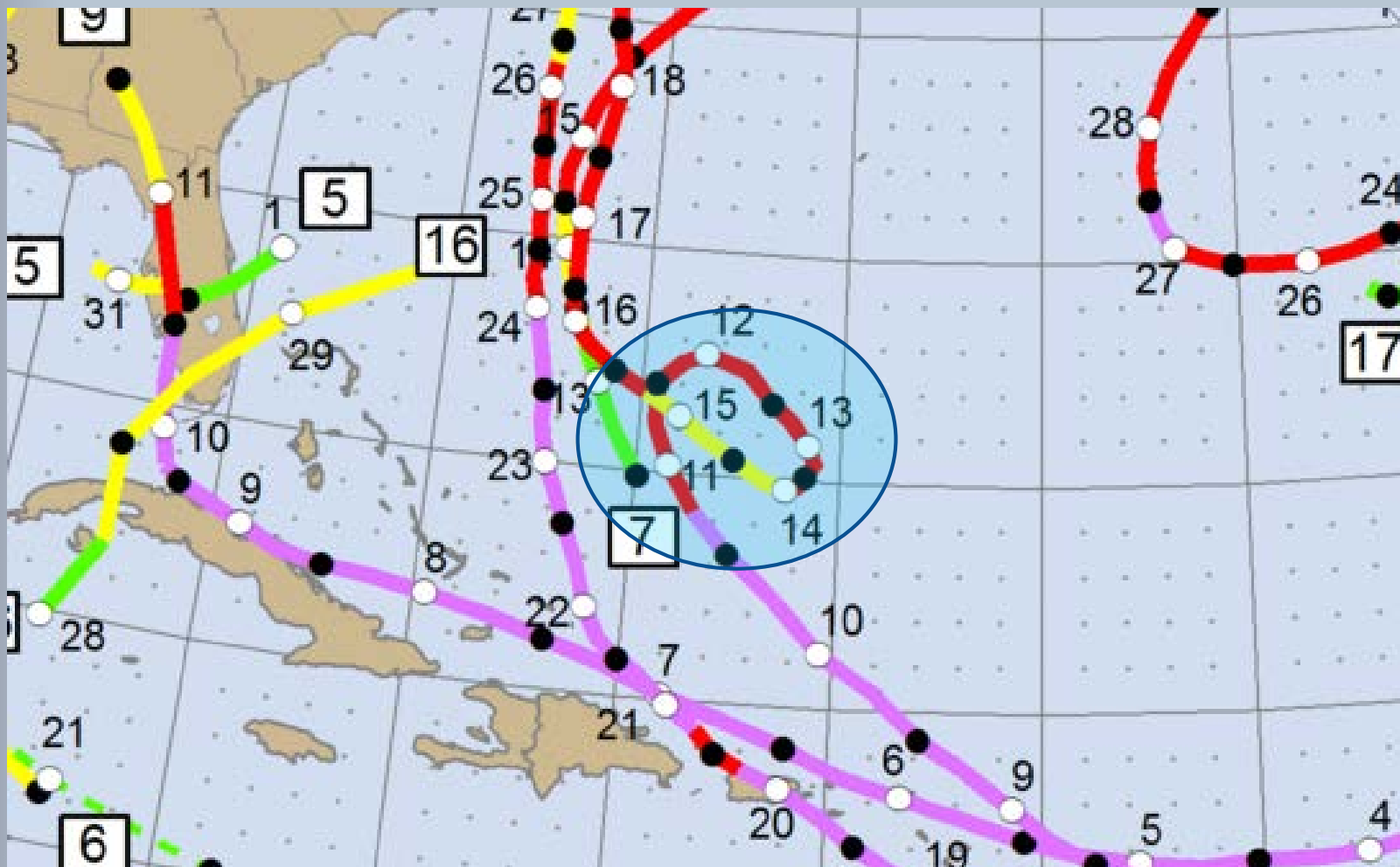
- **Standalone application**
 - detect dry-air intrusions
- **Test as RII predictor**

$$MF(R) = \frac{R}{g} \iint q(U_R - C_R) d\lambda dp$$



R – radius at which MF is evaluated; λ - azimuth; U_R – radial wind component ; q – mixing ratio; p – pressure; C_R – radial component of storm motion vector

(3) MIST: JOSE 2017



Jose: weakened from major hurricane to TC in the middle of its lifecycle, on Sep 14 - 15

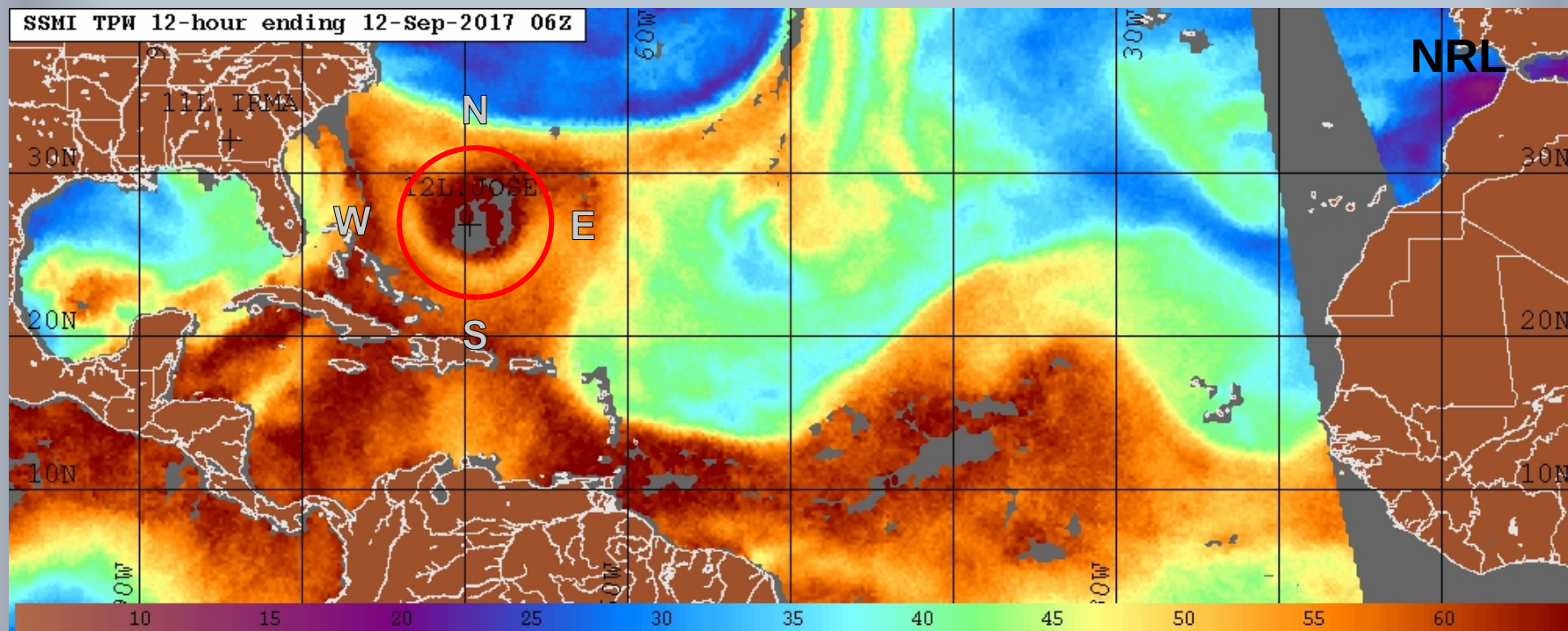
(3) MIST: JOSE 2017

ZCZC MIATCDAT2 ALL
TTAA00 KNHC DDHHMM

Tropical Storm Jose Discussion Number 39
NWS National Hurricane Center Miami FL AL122017
1100 PM AST Thu Sep 14 2017

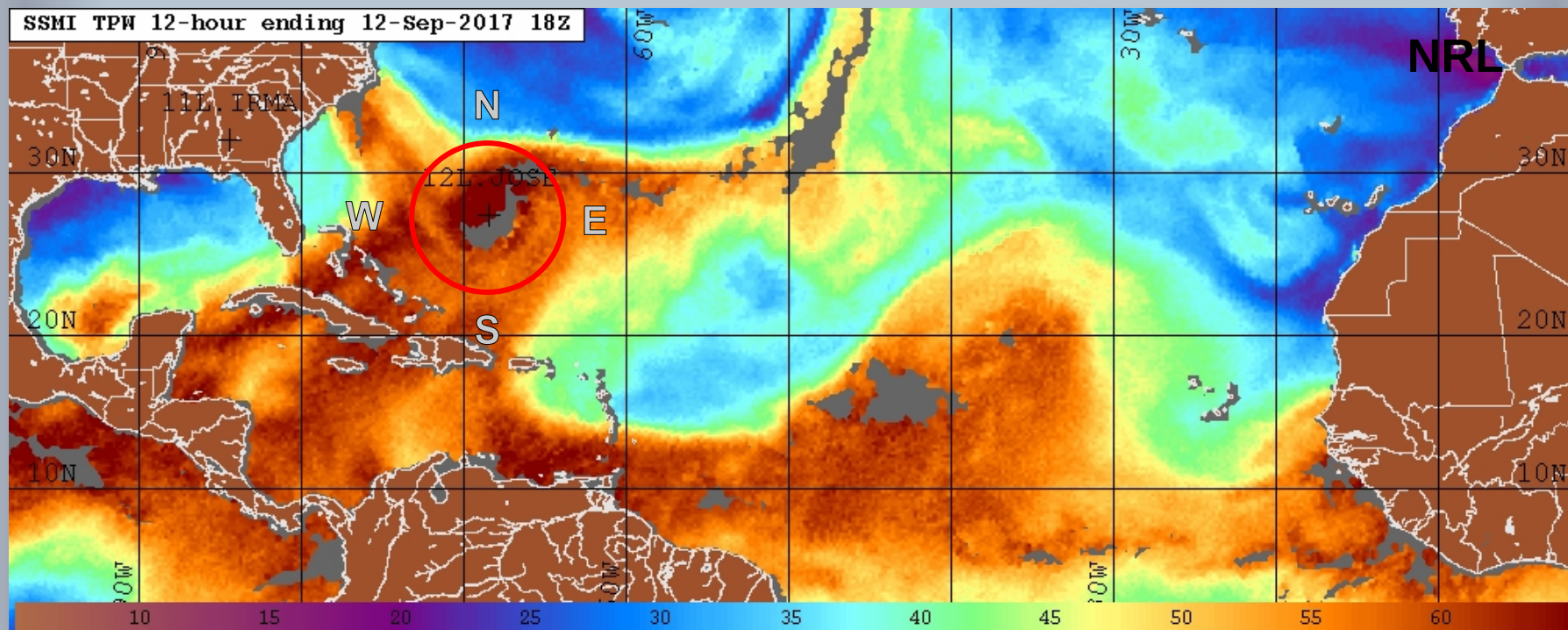
Although the shear affecting Jose for the past several days appears to be relenting, deep convection is still limited to the eastern semicircle of the cyclone, **perhaps in part due to dry air that was observed earlier today.** A blend a objective and subjective current intensity estimates still supports an intensity of 60 kt.

No change has been made to the intensity forecast, which remains near the multi-model consensus. Based on SHIPS diagnostics from the GFS and ECMWF models, **Jose should become embedded in a more humid environment beginning in about 12 h**, and this, along with warm SSTs, should support at least gradual strengthening.



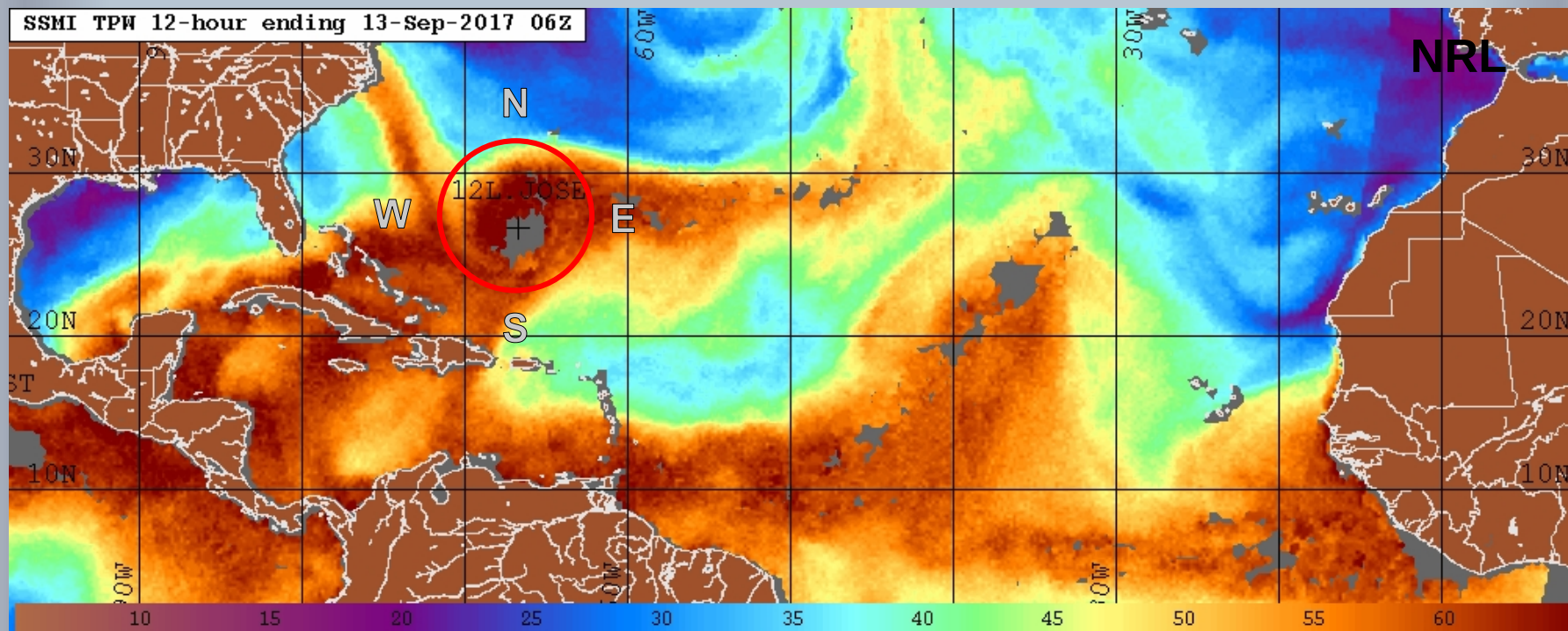
- TPW is commonly used to detect dry air intrusions

09/12 06 UTC
65 kt
delV = 0 kt in 24 hr



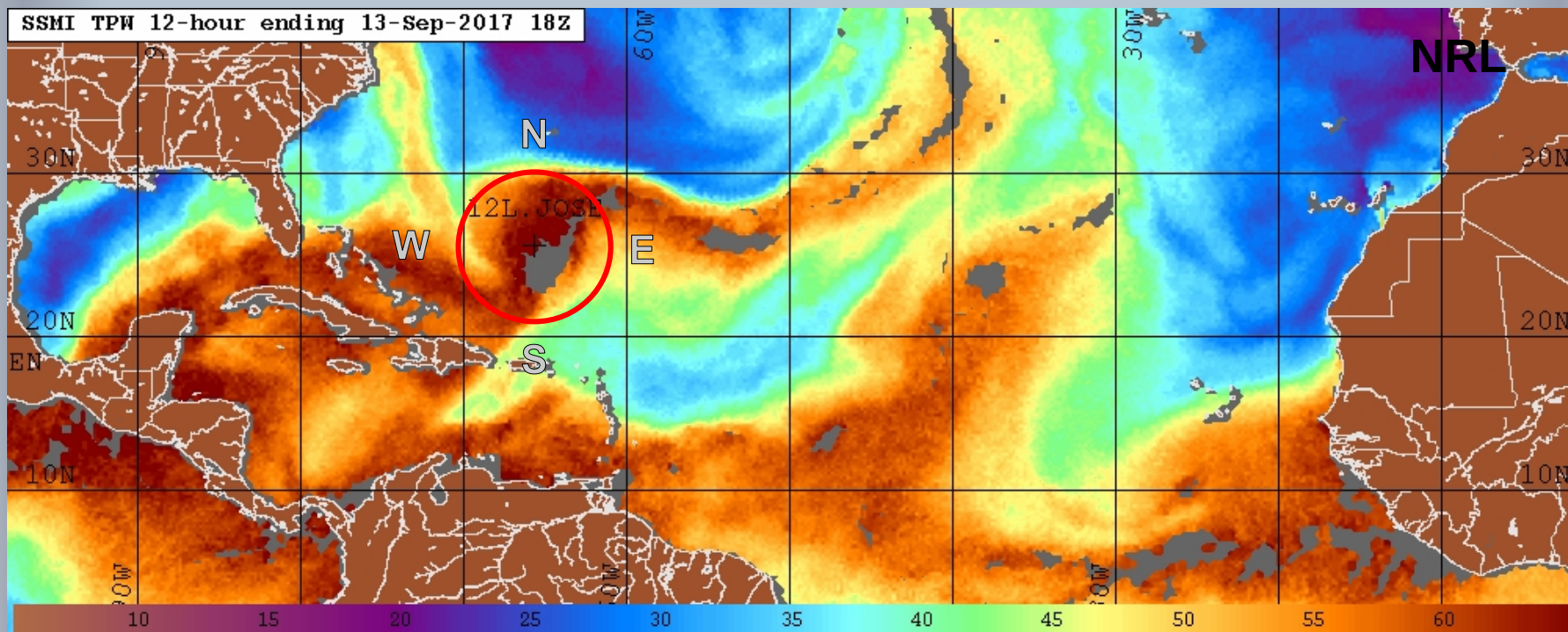
- TPW is commonly used to detect dry air intrusions

09/12 18 UTC
65 kt
delV = 0 kt in 24 hr



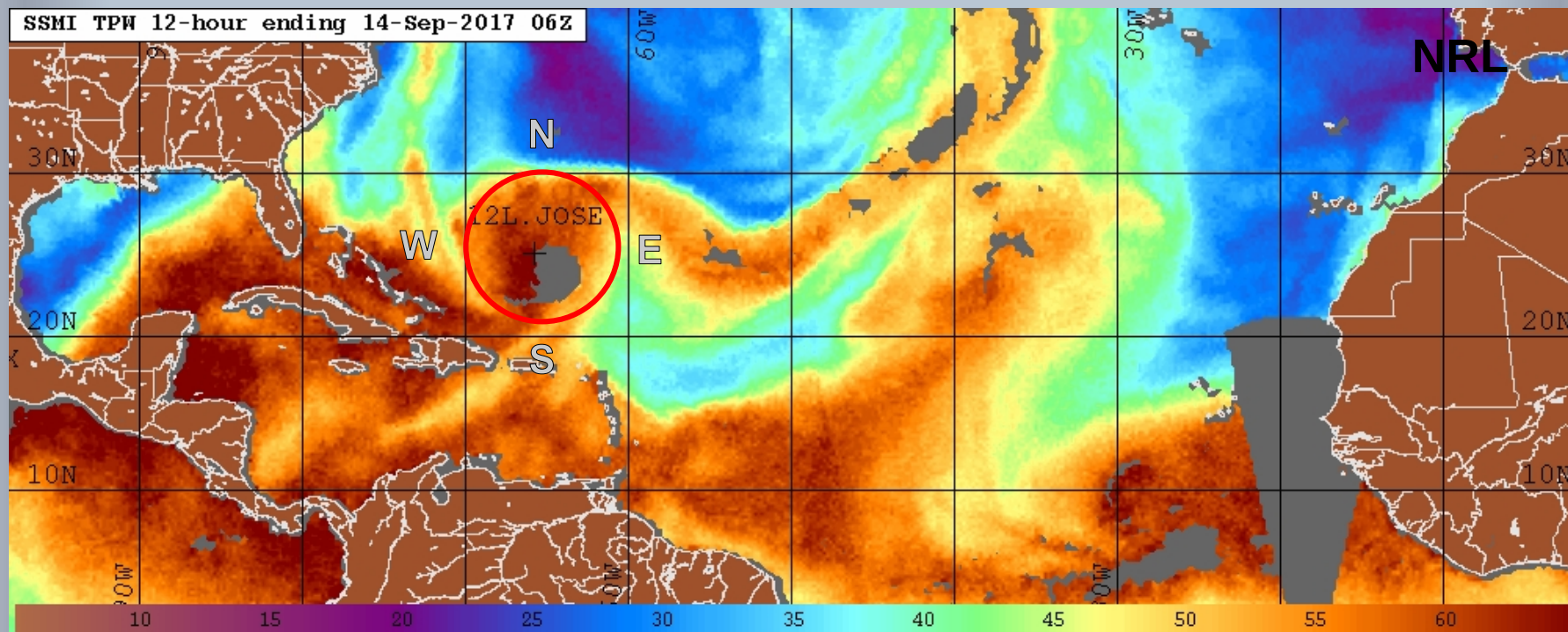
- TPW is commonly used to detect dry air intrusions

09/13 06 UTC
65 kt
delV = 0 kt in 24 hr



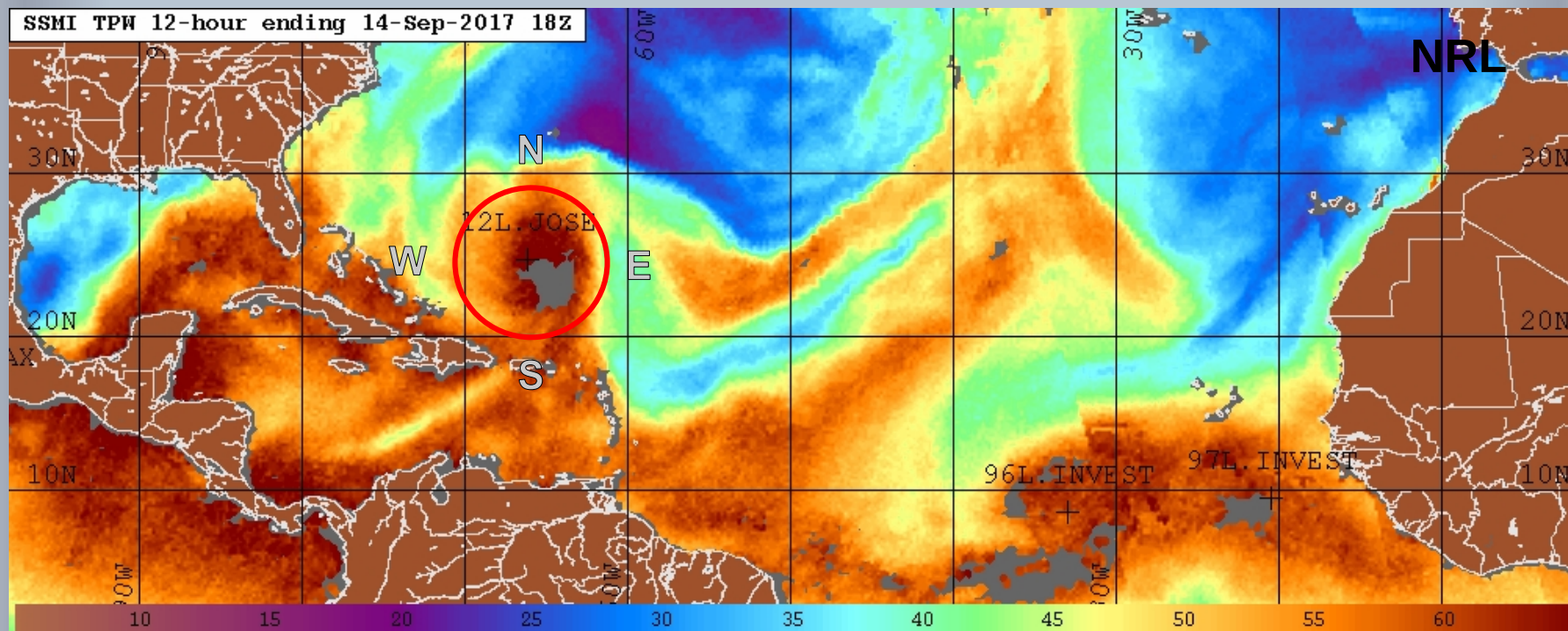
- TPW is commonly used to detect dry air intrusions

09/13 18 UTC
65 kt
delV = - 5 kt in 24 hr



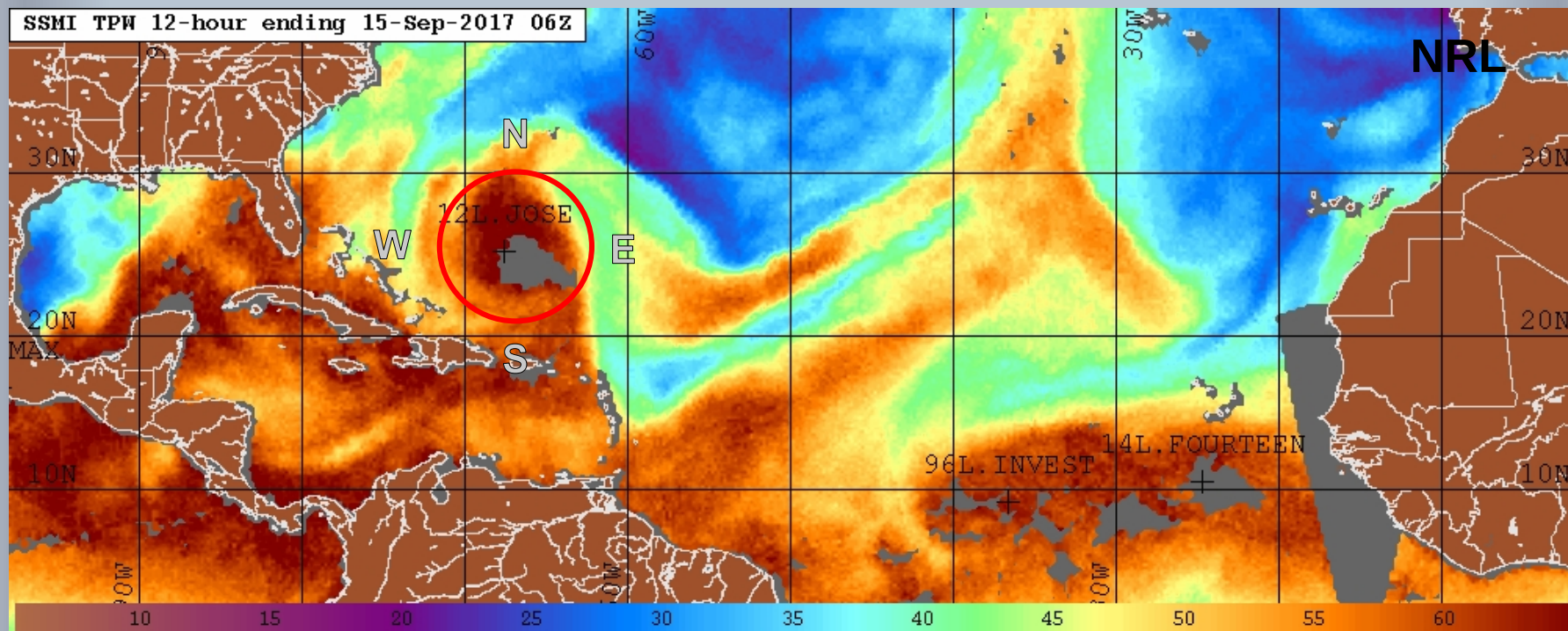
- TPW is commonly used to detect dry air intrusions

09/14 06 UTC
65 kt
delV = - 5 kt in 24 hr



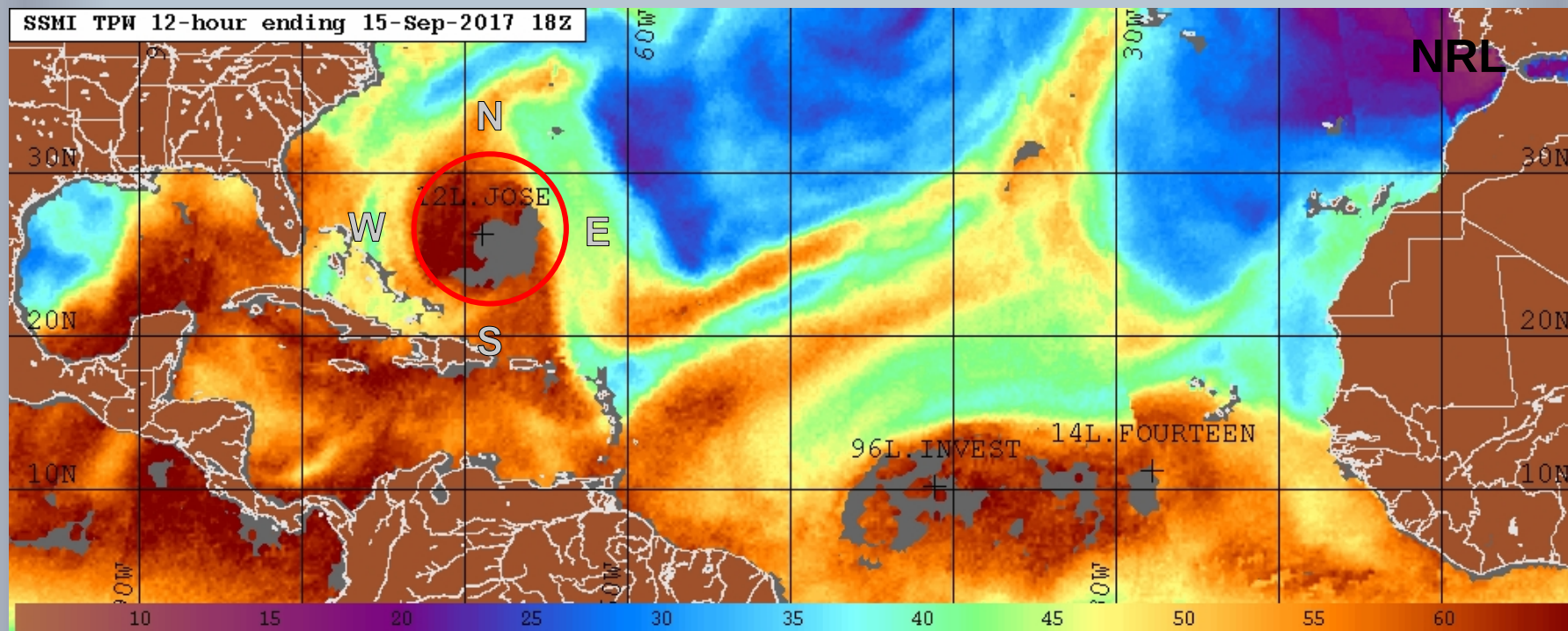
- TPW is commonly used to detect dry air intrusions

09/14 18 UTC
60 kt
delV = + 5 kt in 24 hr



- TPW is commonly used to detect dry air intrusions

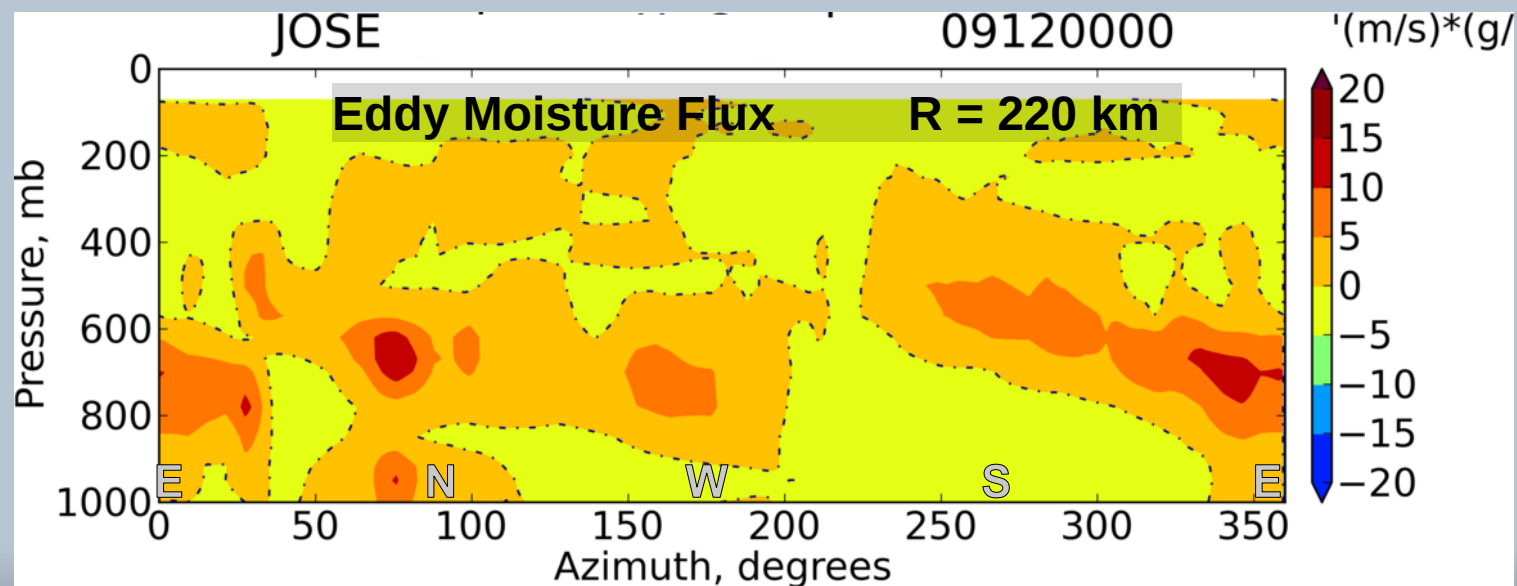
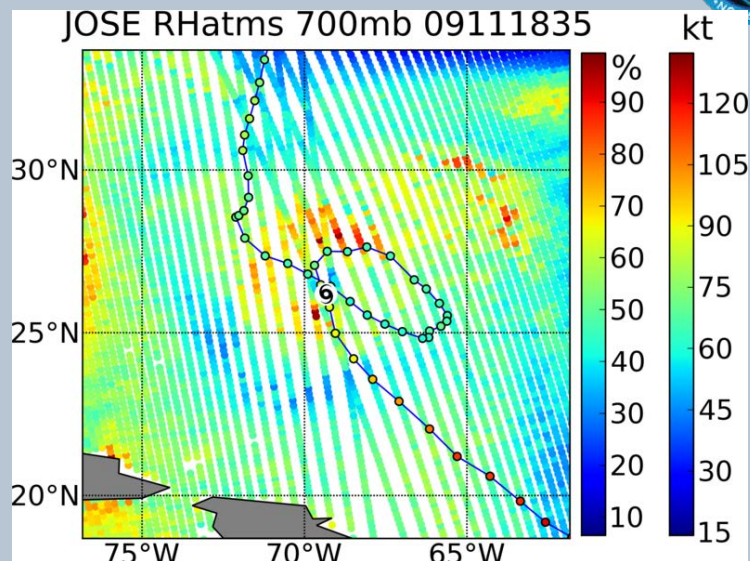
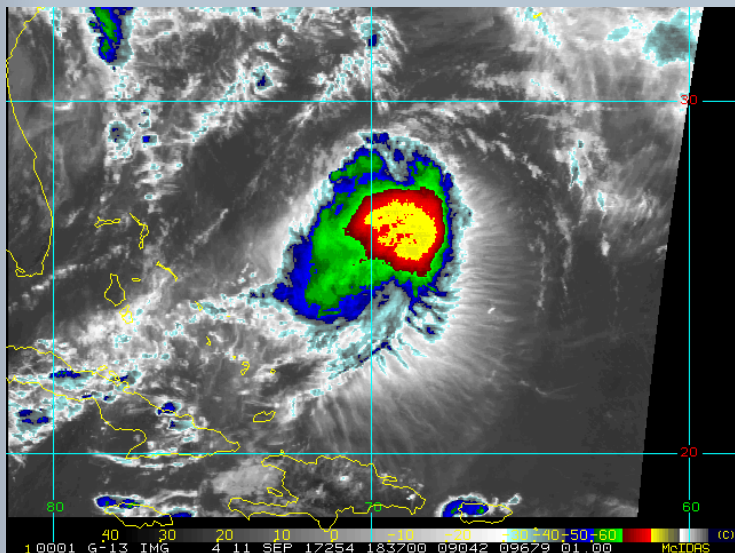
09/15 06 UTC
60 kt
delV = + 10 kt in 24 hr



➤ TPW is commonly used to detect dry air intrusions

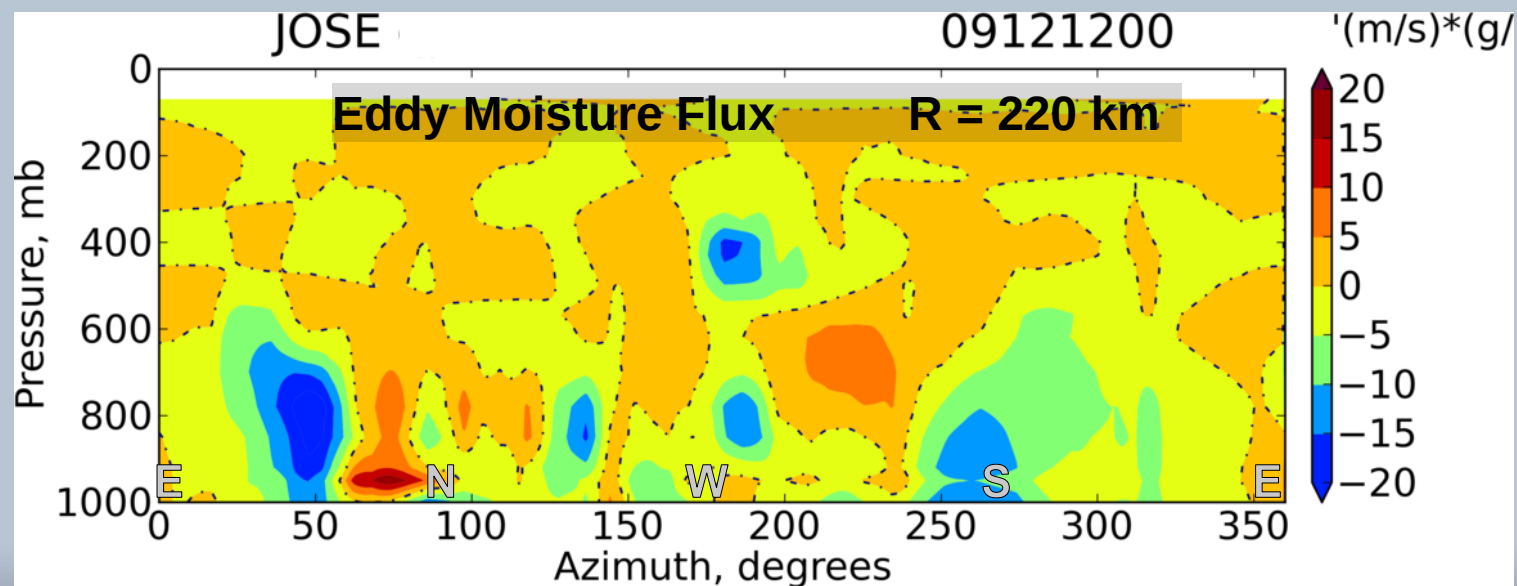
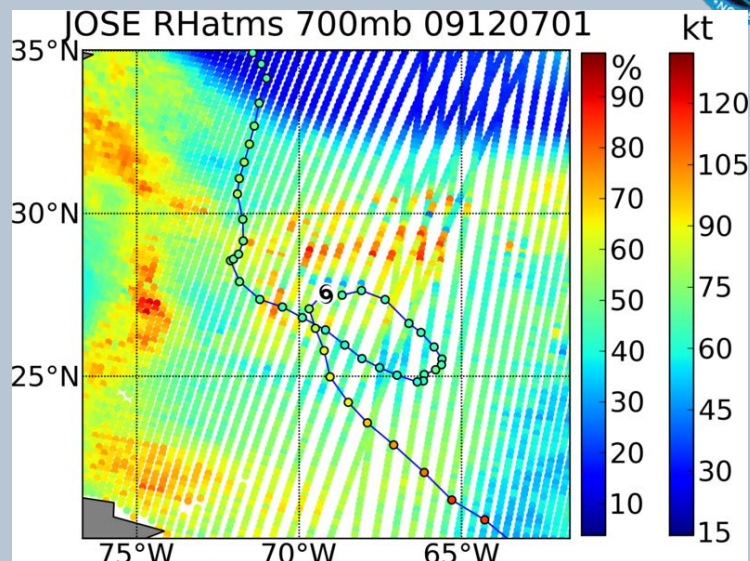
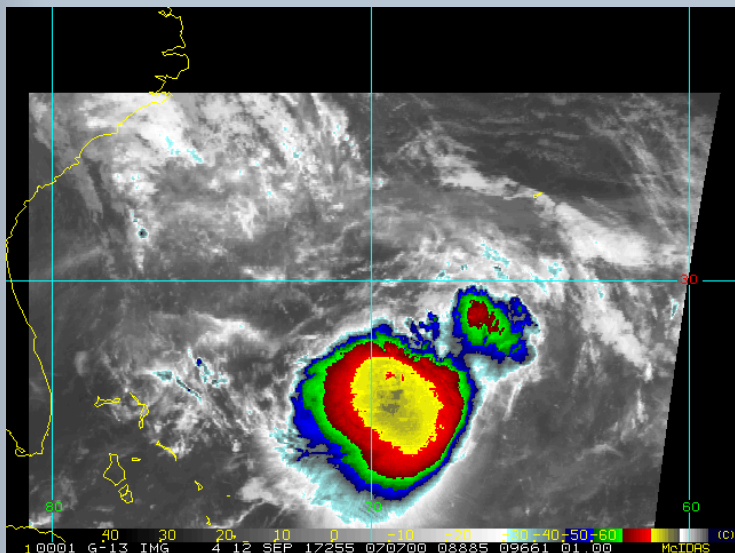
09/15 18 UTC
65 kt
delV = + 5 kt in 24 hr

(3) MIST: JOSE 2017



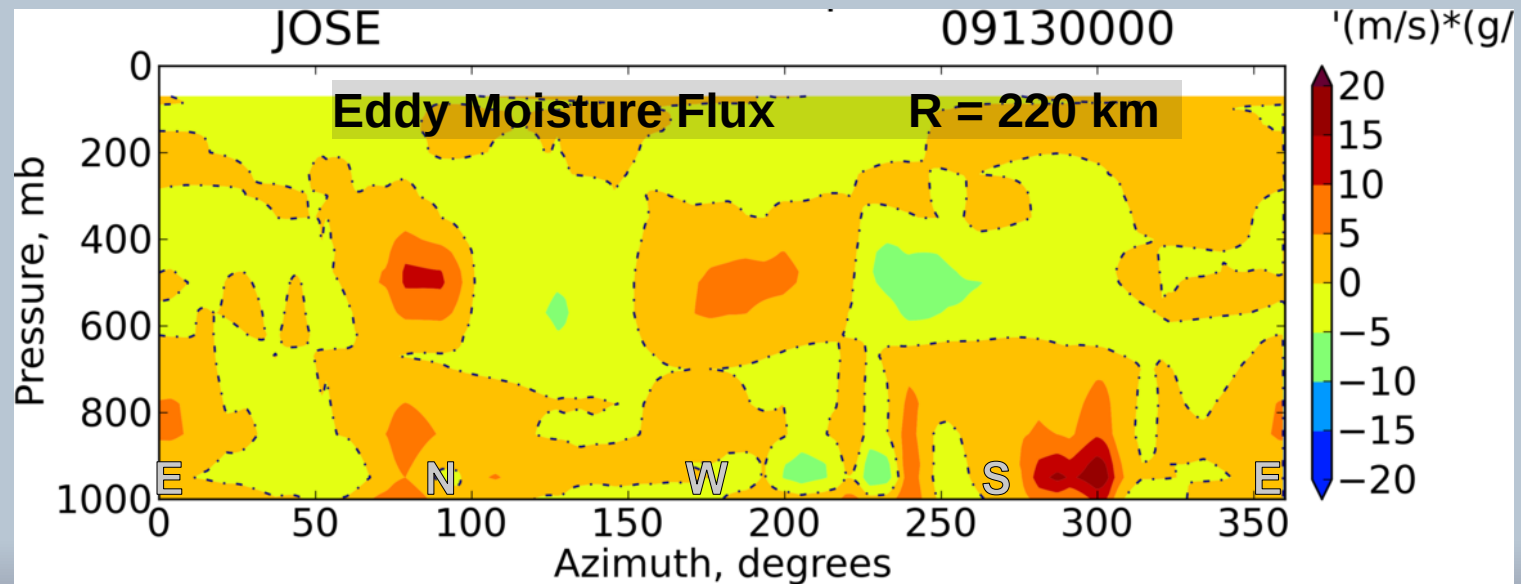
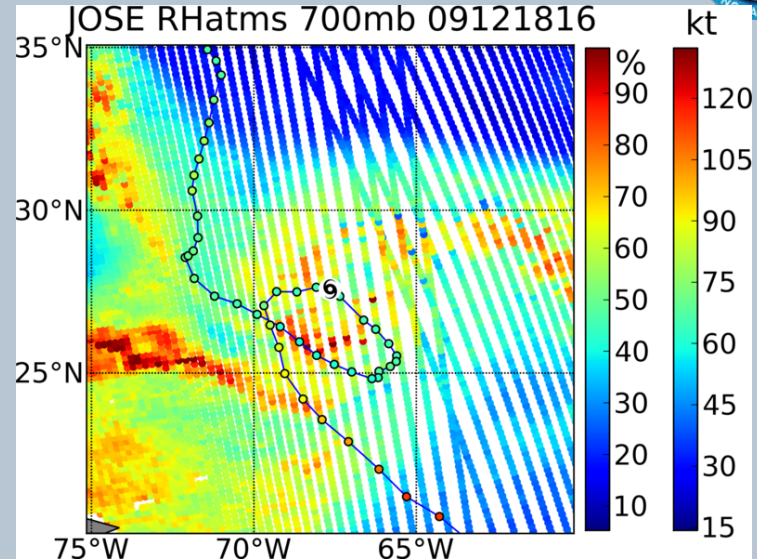
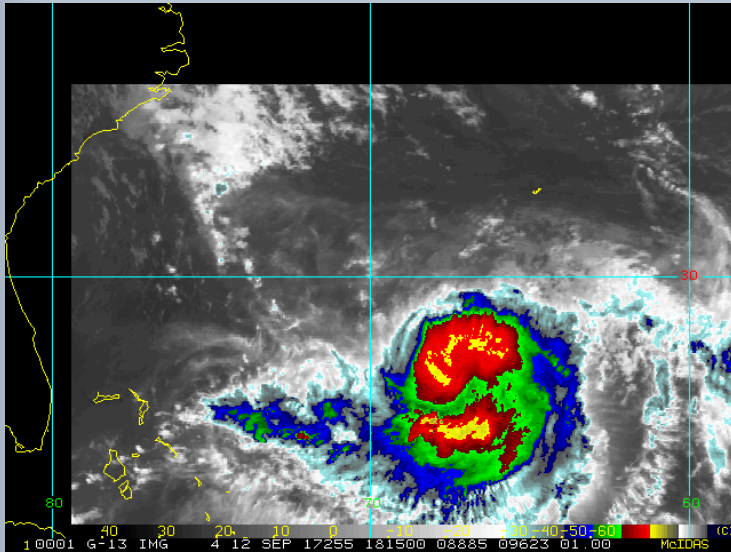
09/12 00 UTC 75 kt delV = - 10 kt in 24 hr

(3) MIST: JOSE 2017



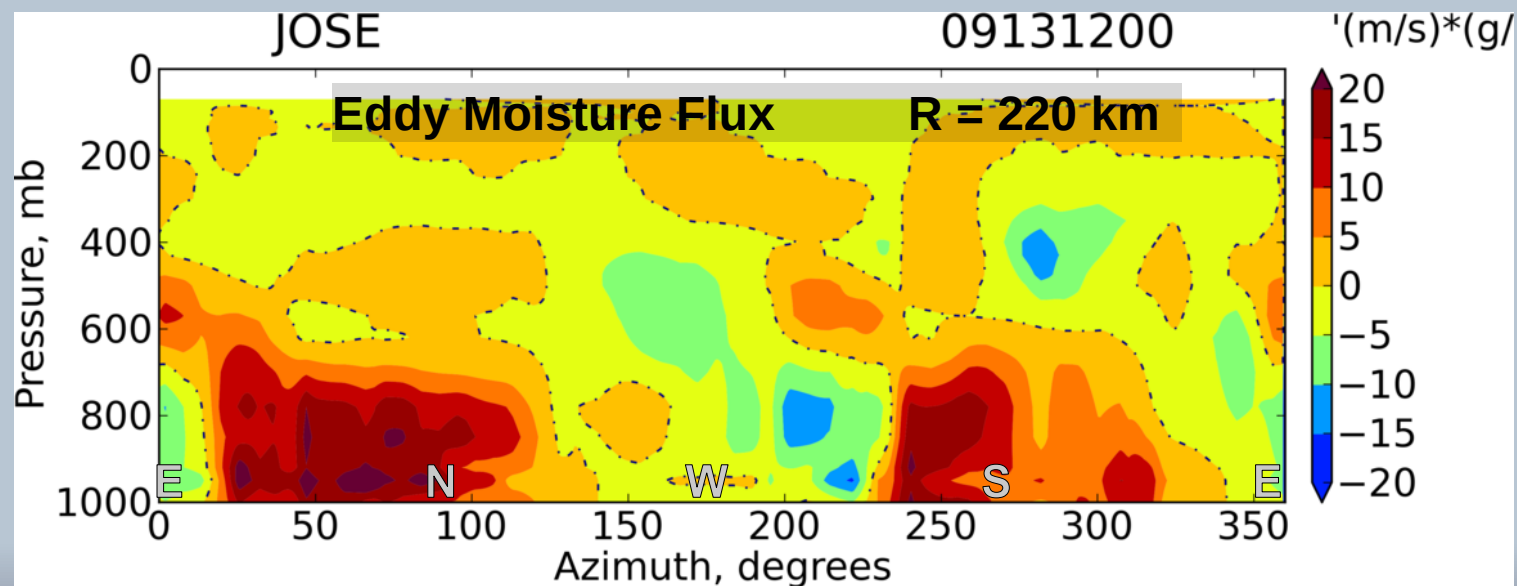
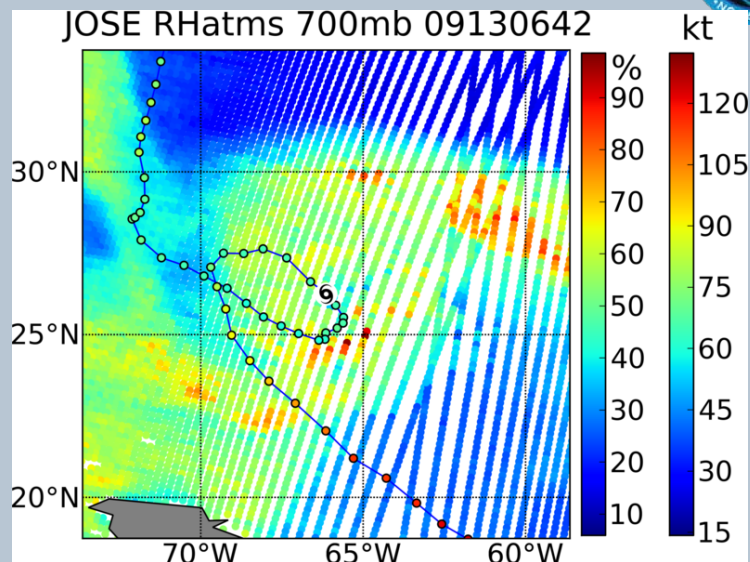
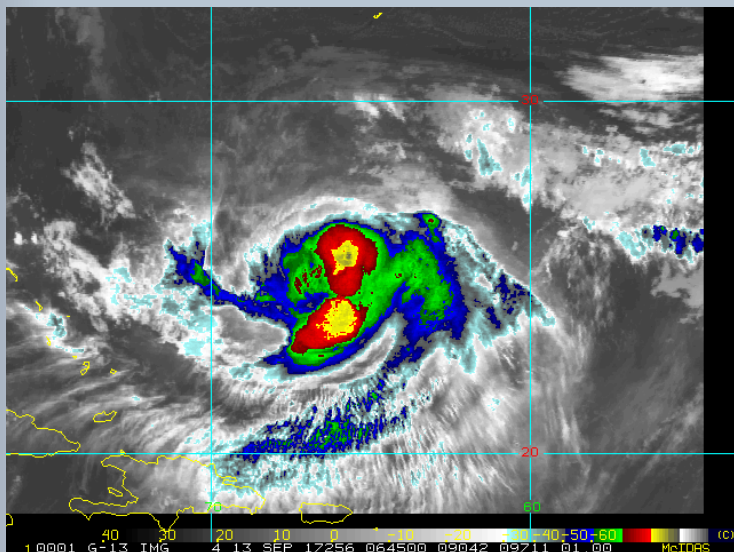
09/12 12 UTC 65 kt delV = 0 kt in 24 hr

(3) MIST: JOSE 2017



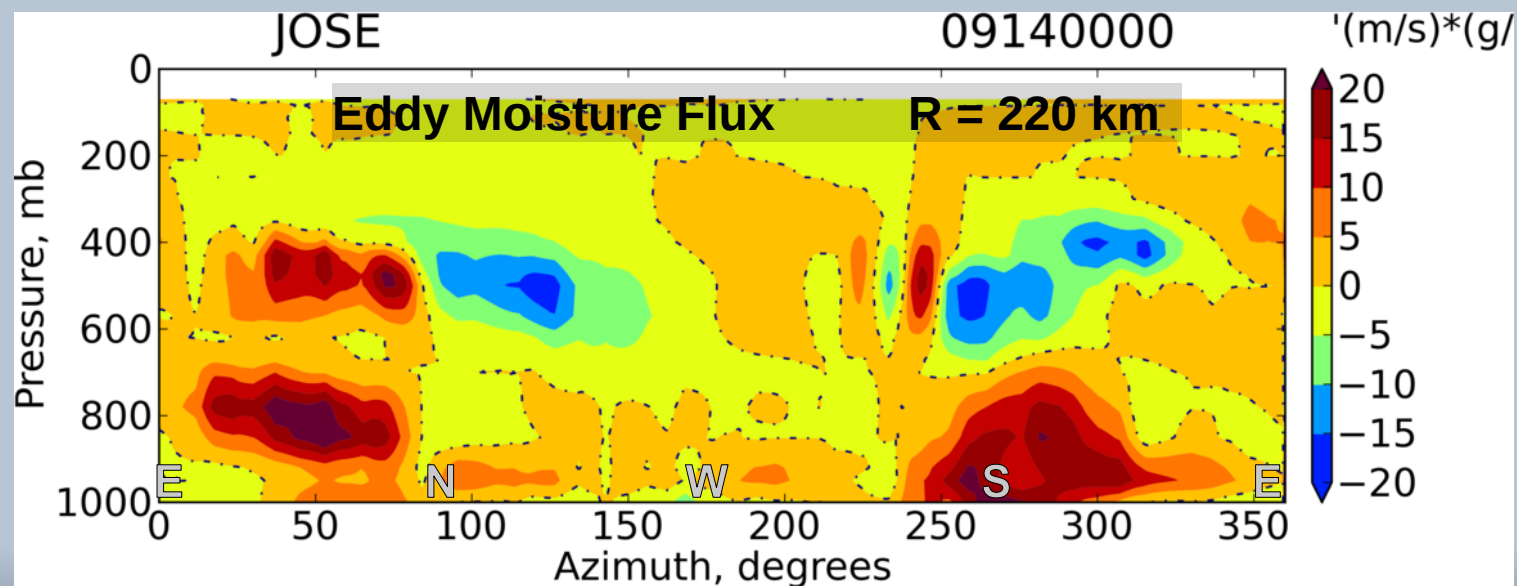
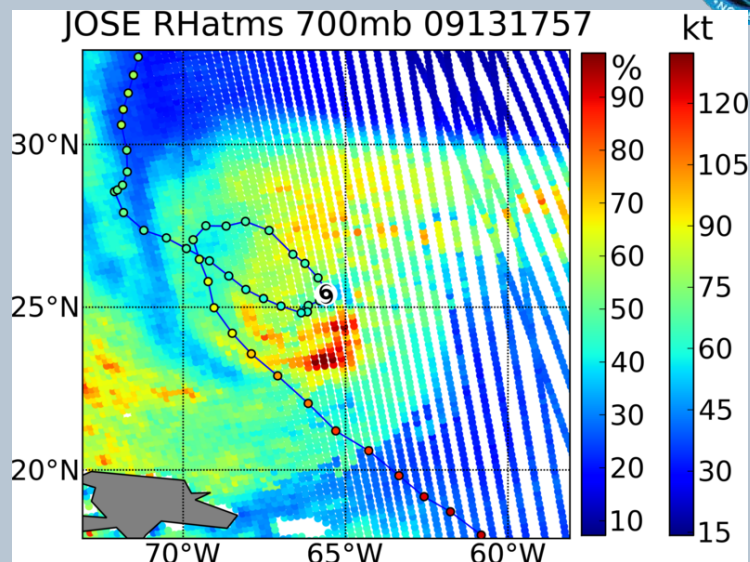
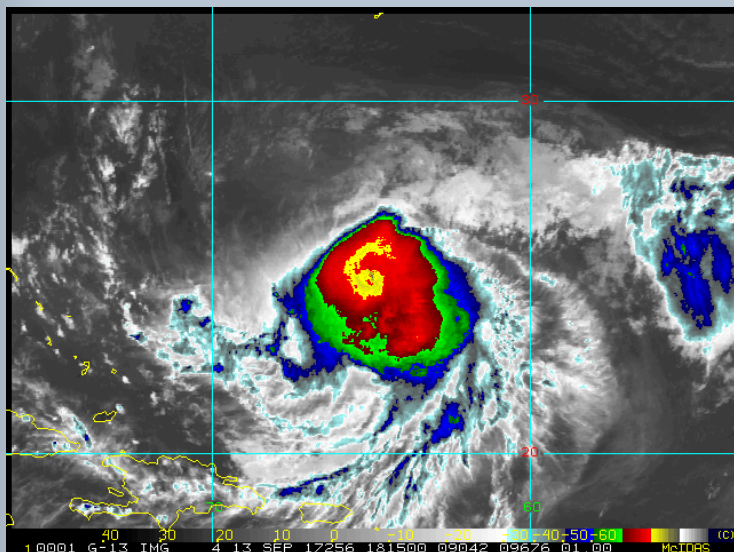
09/13 00 UTC 65 kt delV = + 5 kt in 24 hr

(3) MIST: JOSE 2017



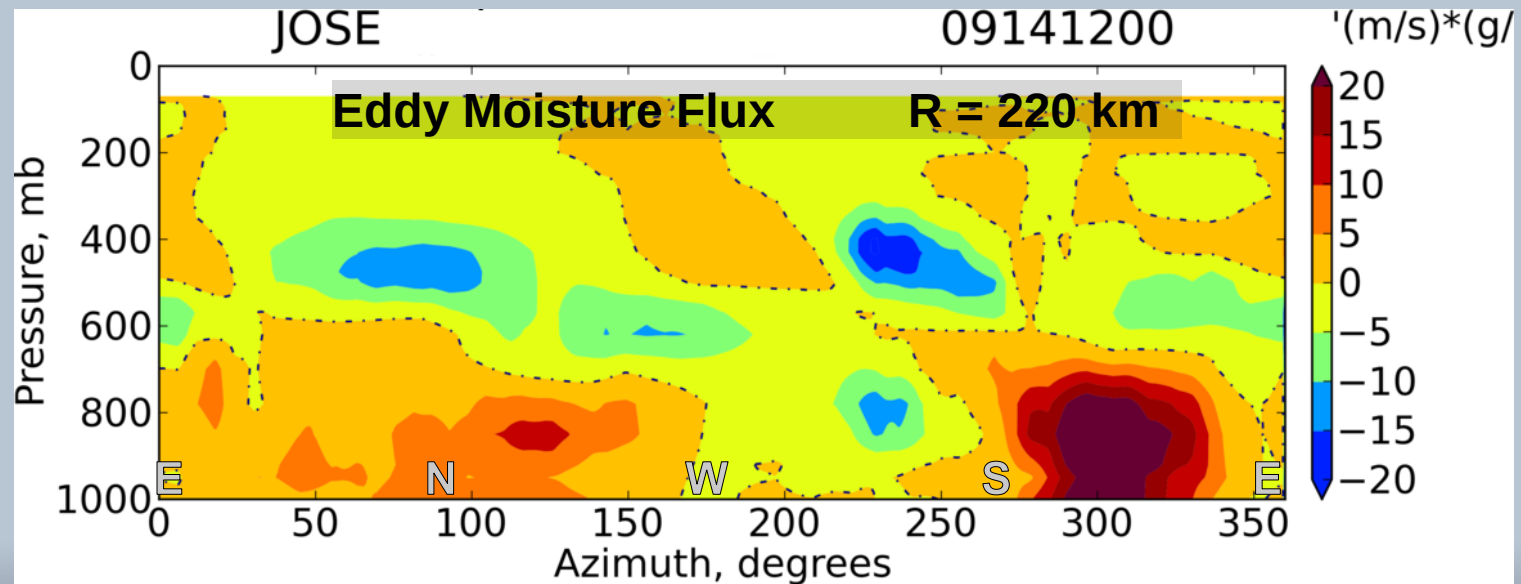
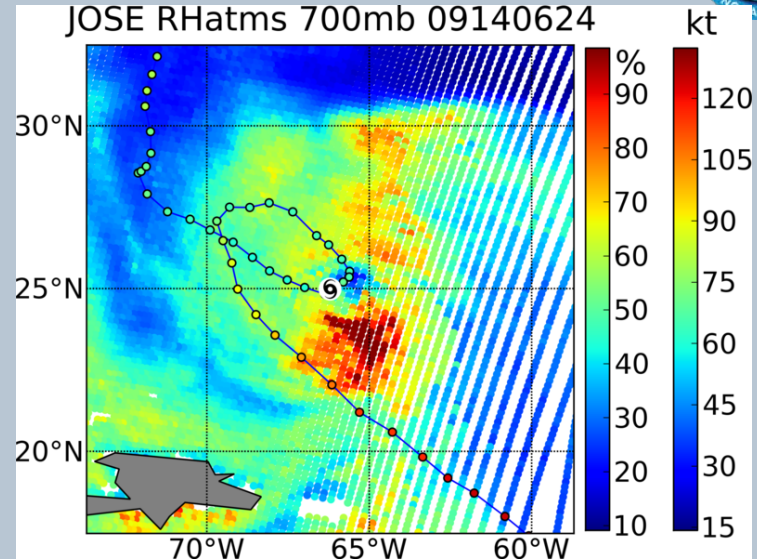
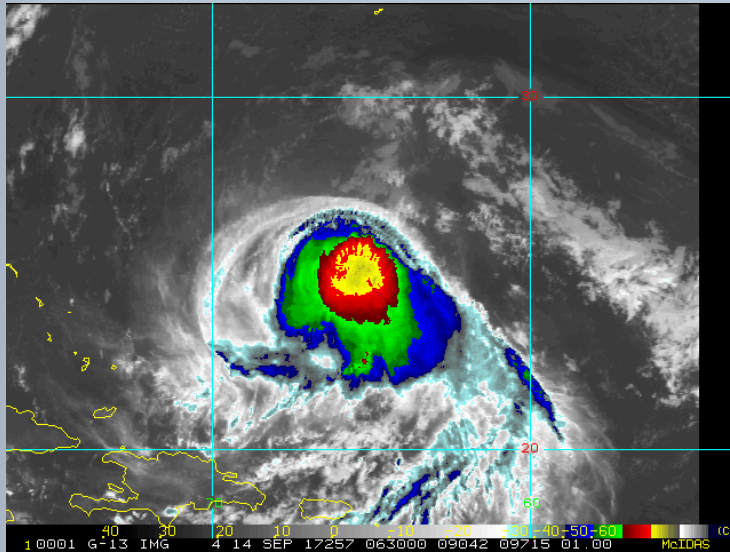
09/13 12 UTC 65 kt $\text{del}V = -5 \text{ kt in 24 hr}$

(3) MIST: JOSE 2017



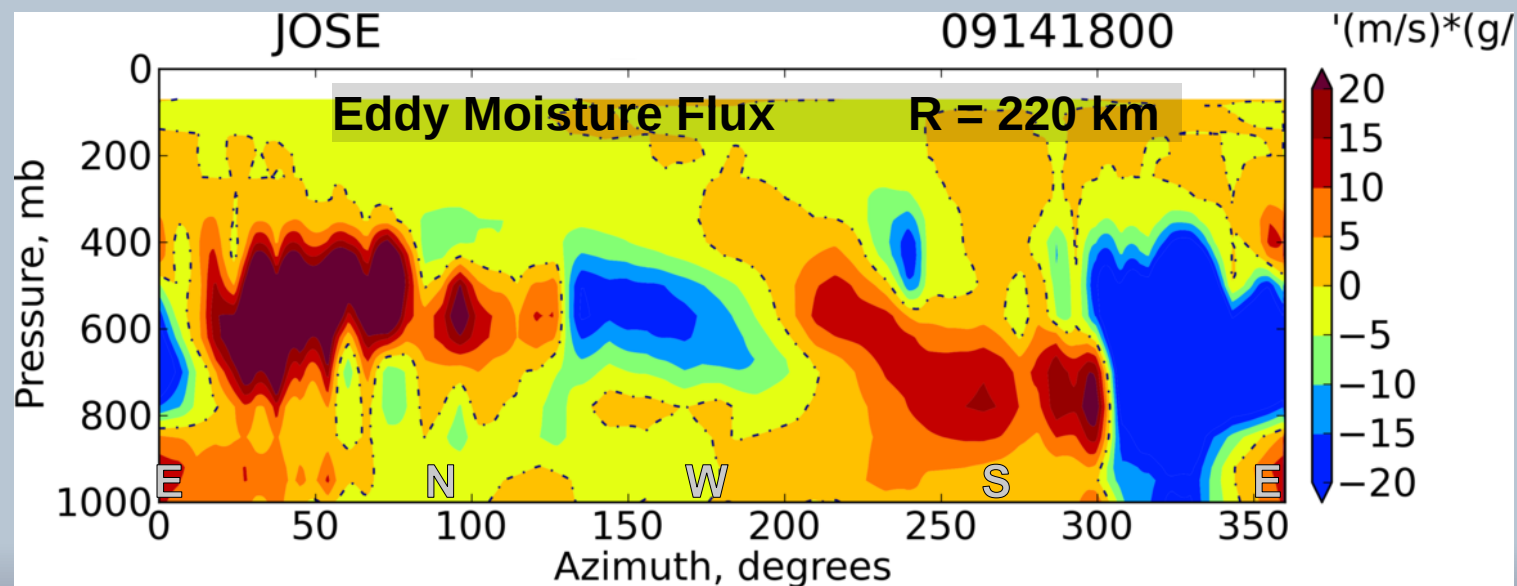
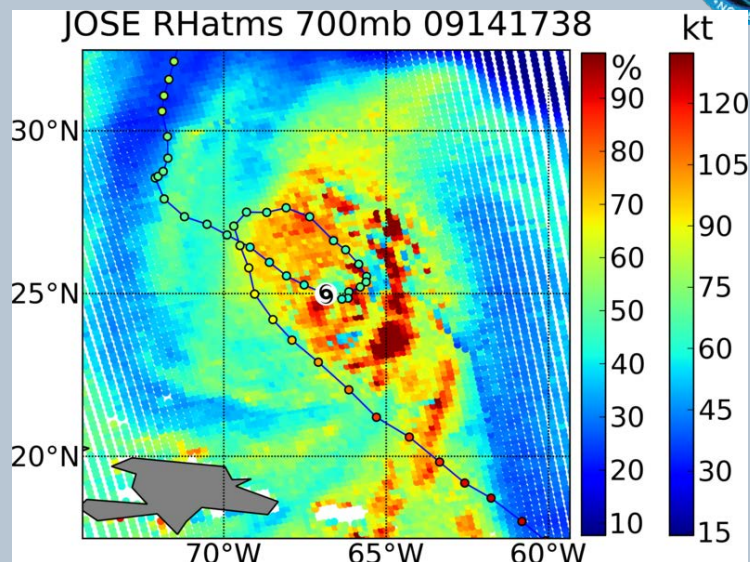
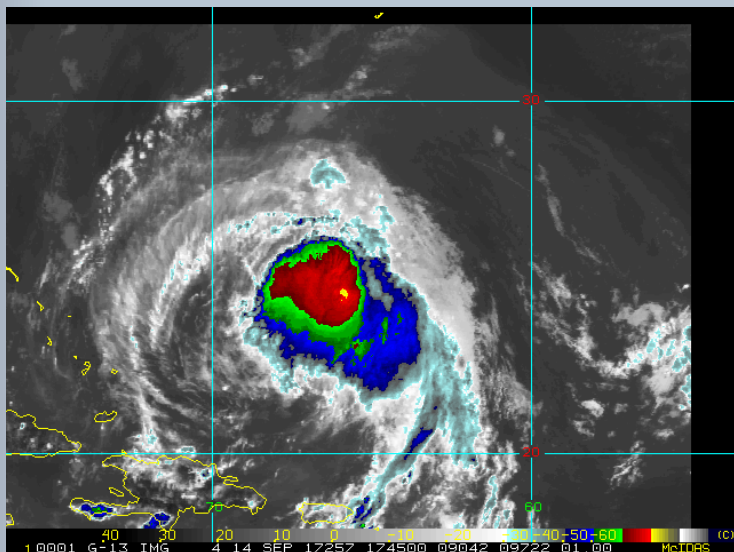
09/14 00 UTC 70 kt delV = - 10 kt in 24 hr

(3) MIST: JOSE 2017



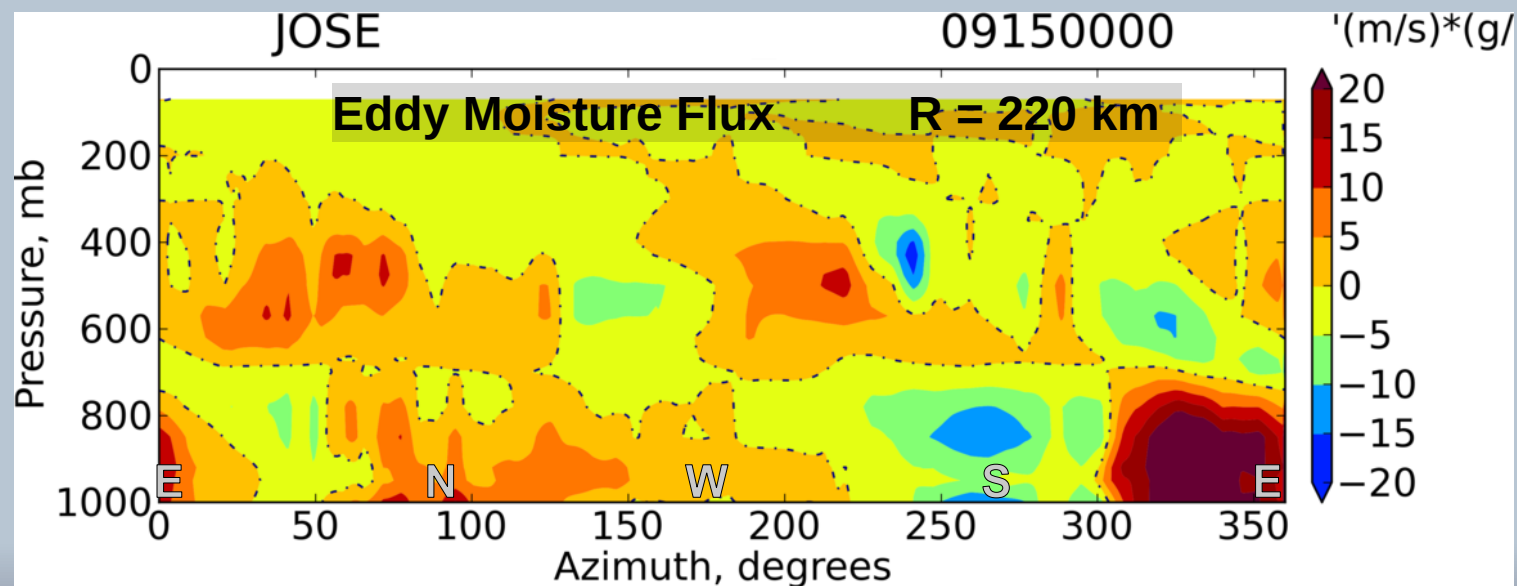
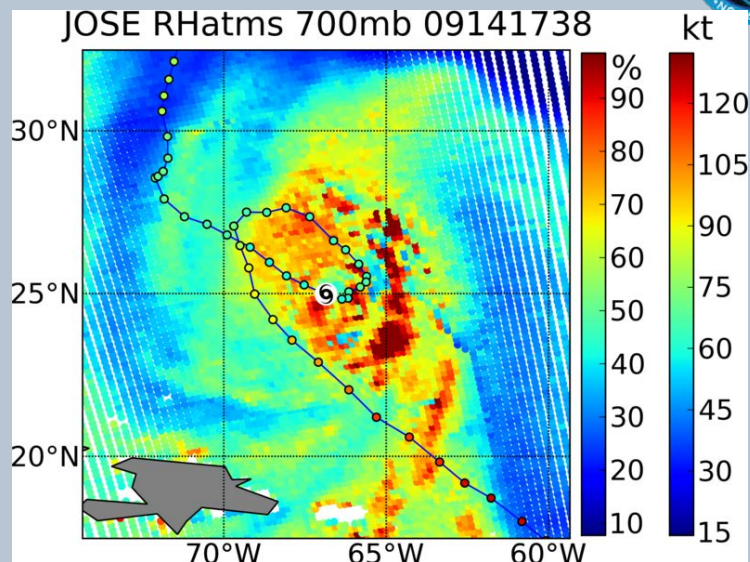
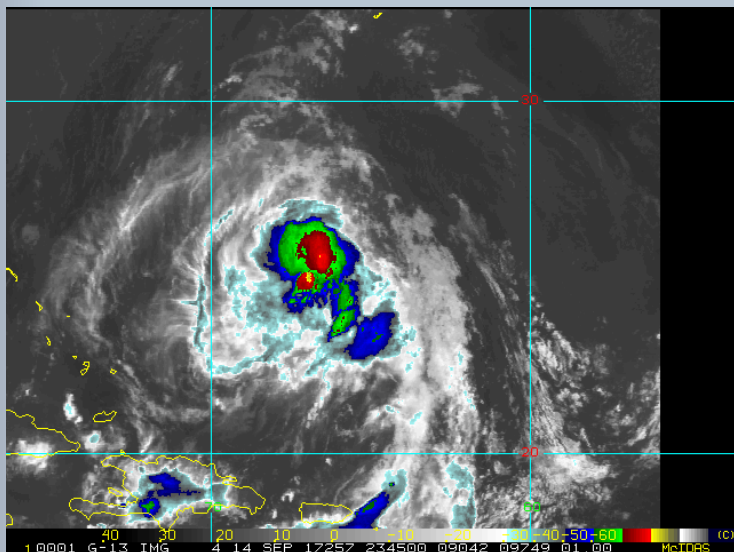
09/14 12 UTC 60 kt delV = 0 kt in 24 hr

(3) MIST: JOSE 2017



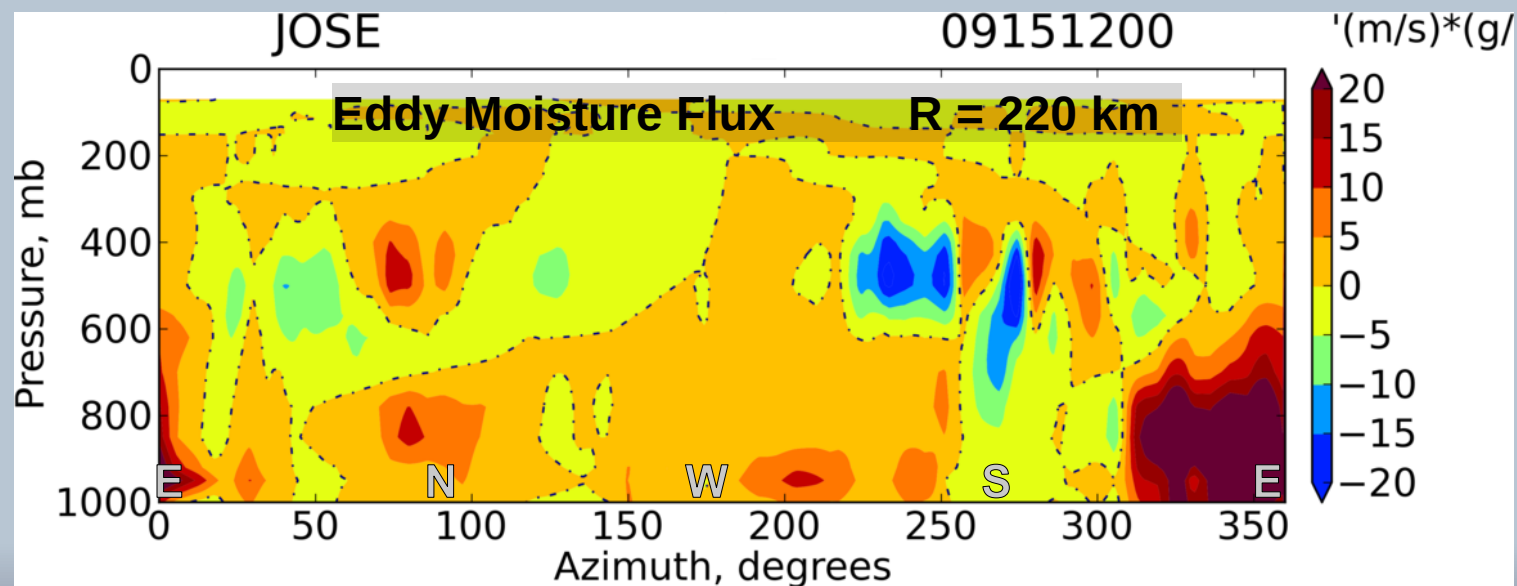
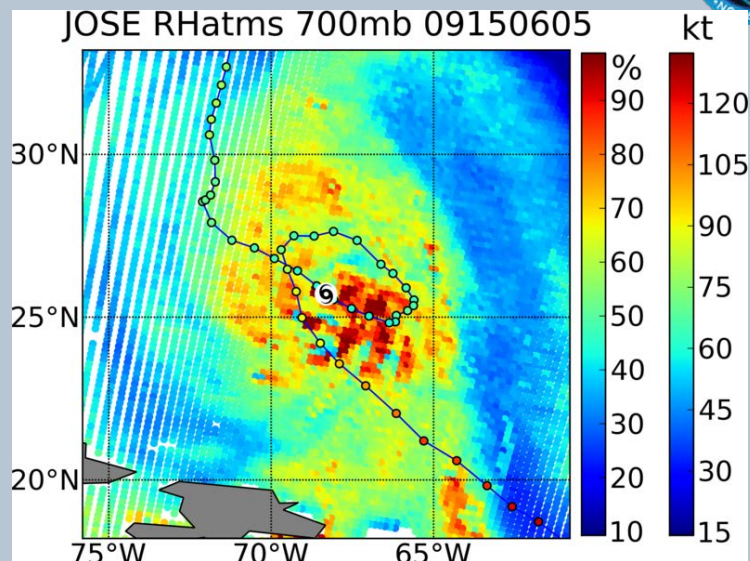
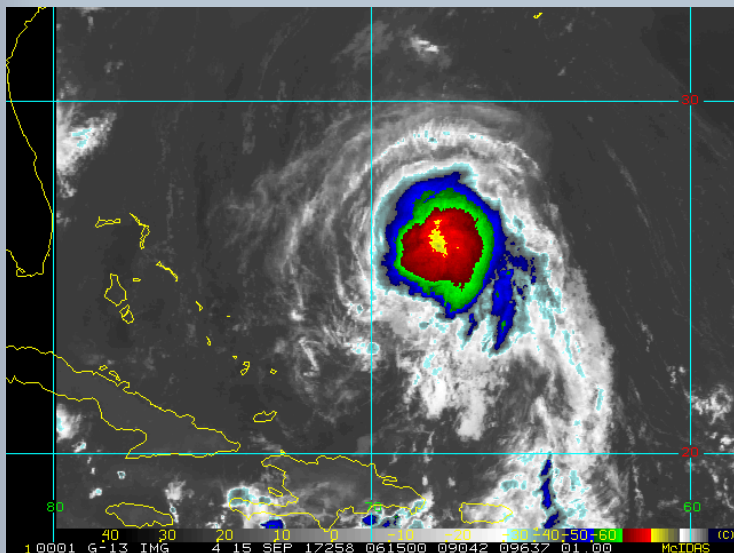
09/14 18 UTC 60 kt $\text{delV} = +5 \text{ kt in 24 hr}$

(3) MIST: JOSE 2017



09/15 00 UTC 65 kt delV = + 5 kt in 24 hr

(3) MIST: JOSE 2017



09/15 12 UTC 60 kt delV = + 10 kt in 24 hr

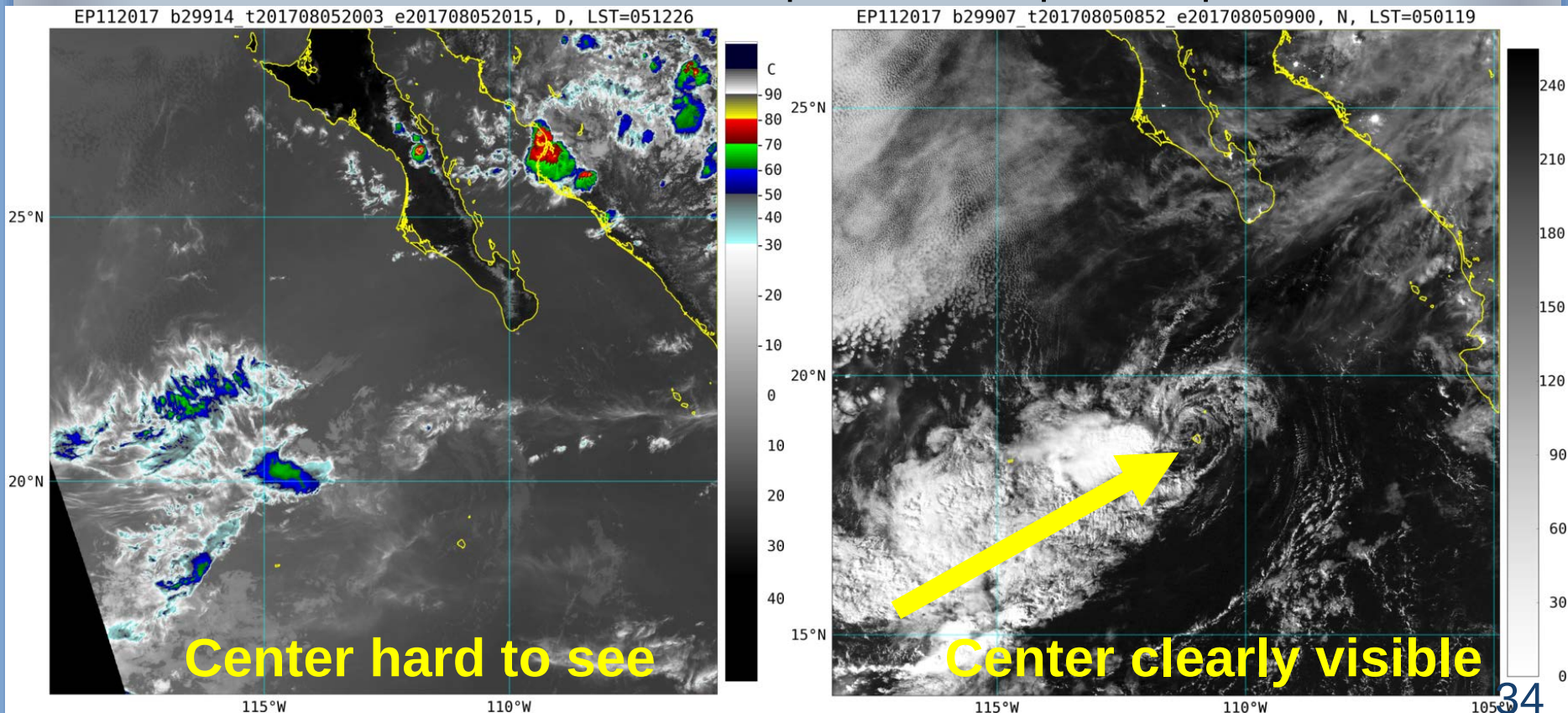
(4) VIIRS DNB

- VIIRS provides unique
 - Day Night Band (DNB) imagery
 - very high-resolution (375 m) visible and IR imagery
 - VIIRS imagery proved to be very useful for TC analysis and forecasting, especially for high-time center-fixing
- **CIRA's VIIRS TC-Centered DNB Imagery**
 - Uses CIRA's DNB scaling
 - Is available in near real-time at TC Real-Time page
http://rammb.cira.colostate.edu/products/tc_realtime
 - Considering using low-latency direct broadcast data
 - CIRA developed VIIRS TC-Centered database for post-season analysis
 - **Available in real-time on NHC's NAWIPS**

(4) VIIRS DNB center fixing

- Low level circulation center could be visible on DNB image, but hard to see on IR, especially if covered by cirrus
- DNB much higher resolution than microwave, allows more precise center fix

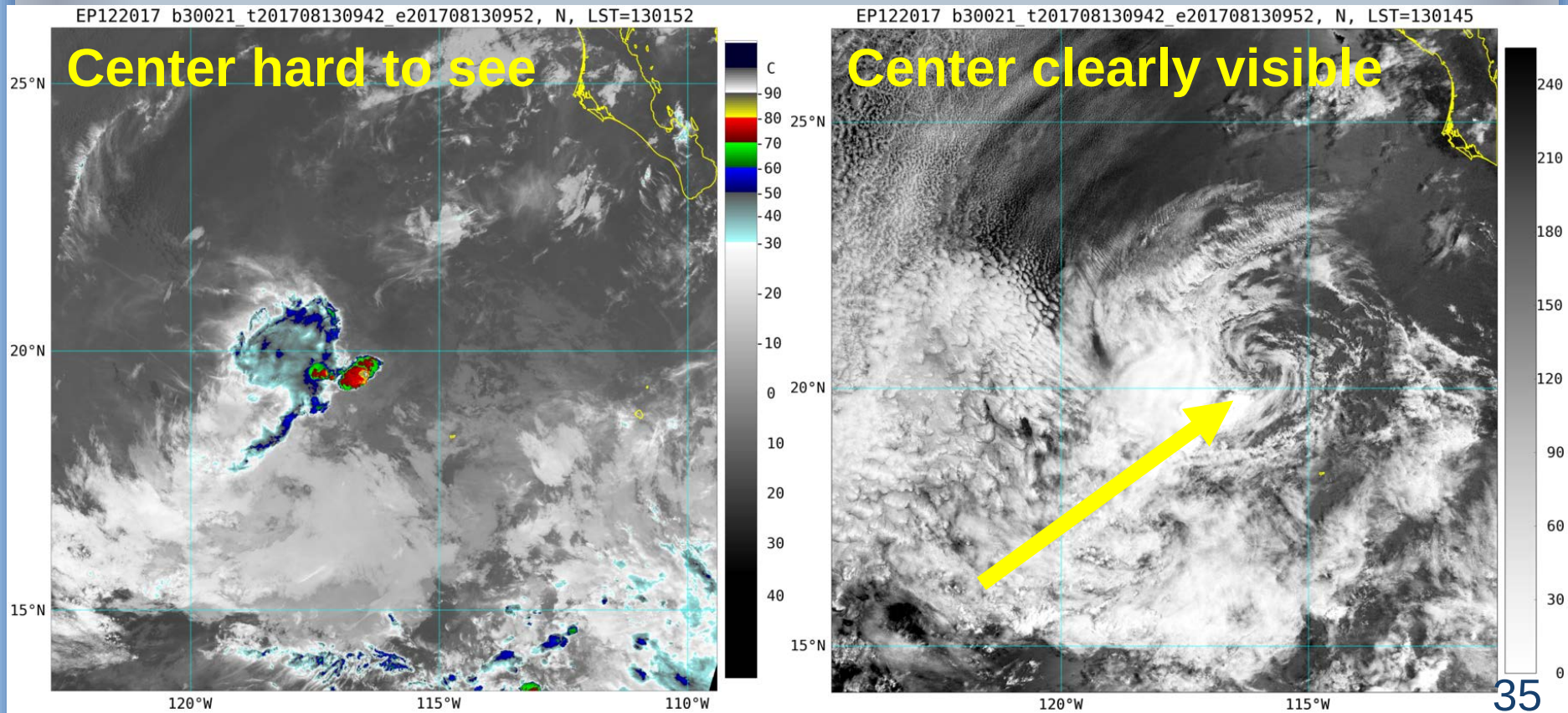
ep112017 Tropical Depression ELEVEN



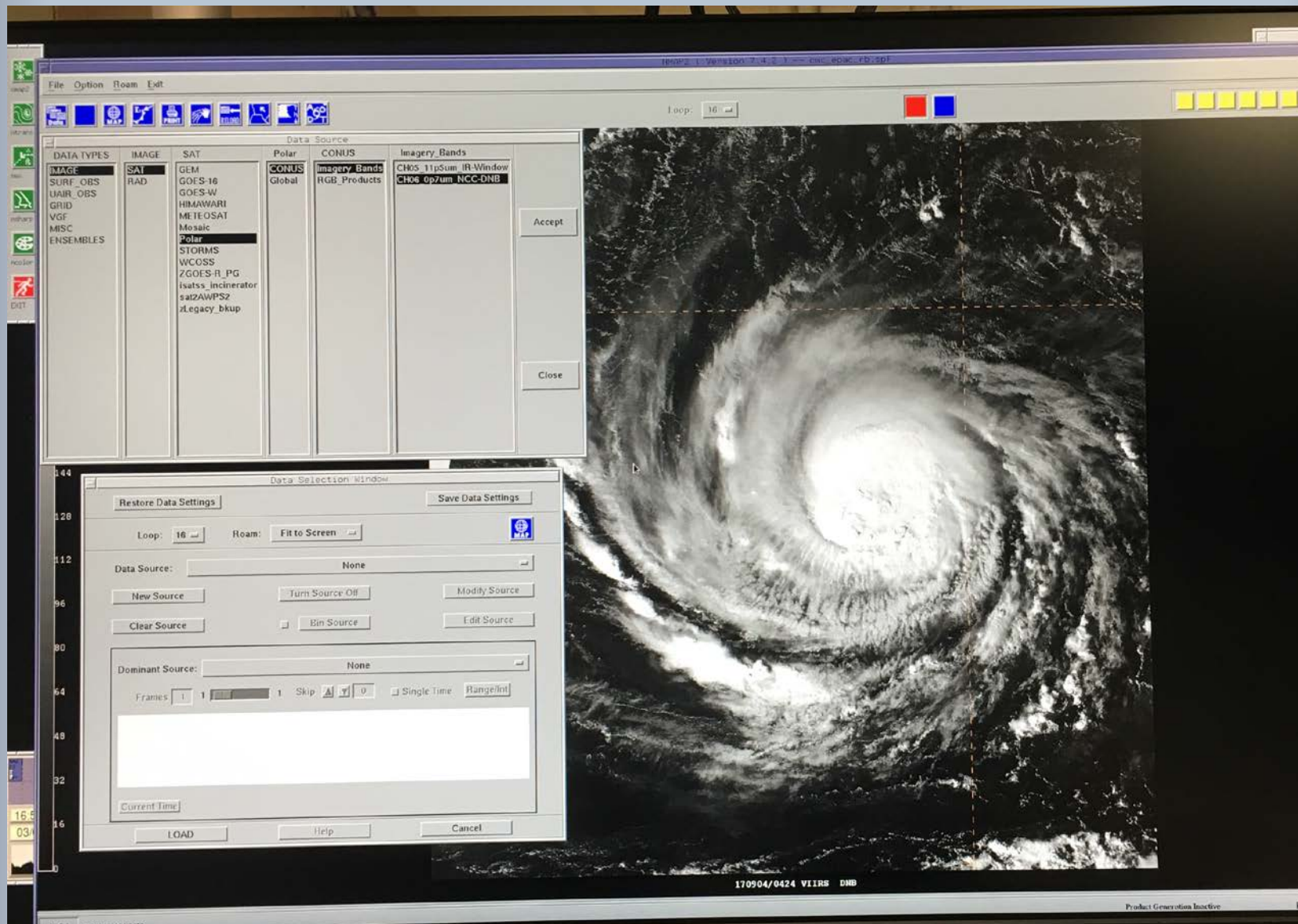
(4) VIIRS DNB center fixing

- Low level circulation center could be visible on DNB image, but hard to see on IR, especially if covered by cirrus
- DNB much higher resolution than microwave, allows more precise center fix

ep122017 Tropical Storm JOVA



(4) VIIRS DNB: NHC's NAWIPS

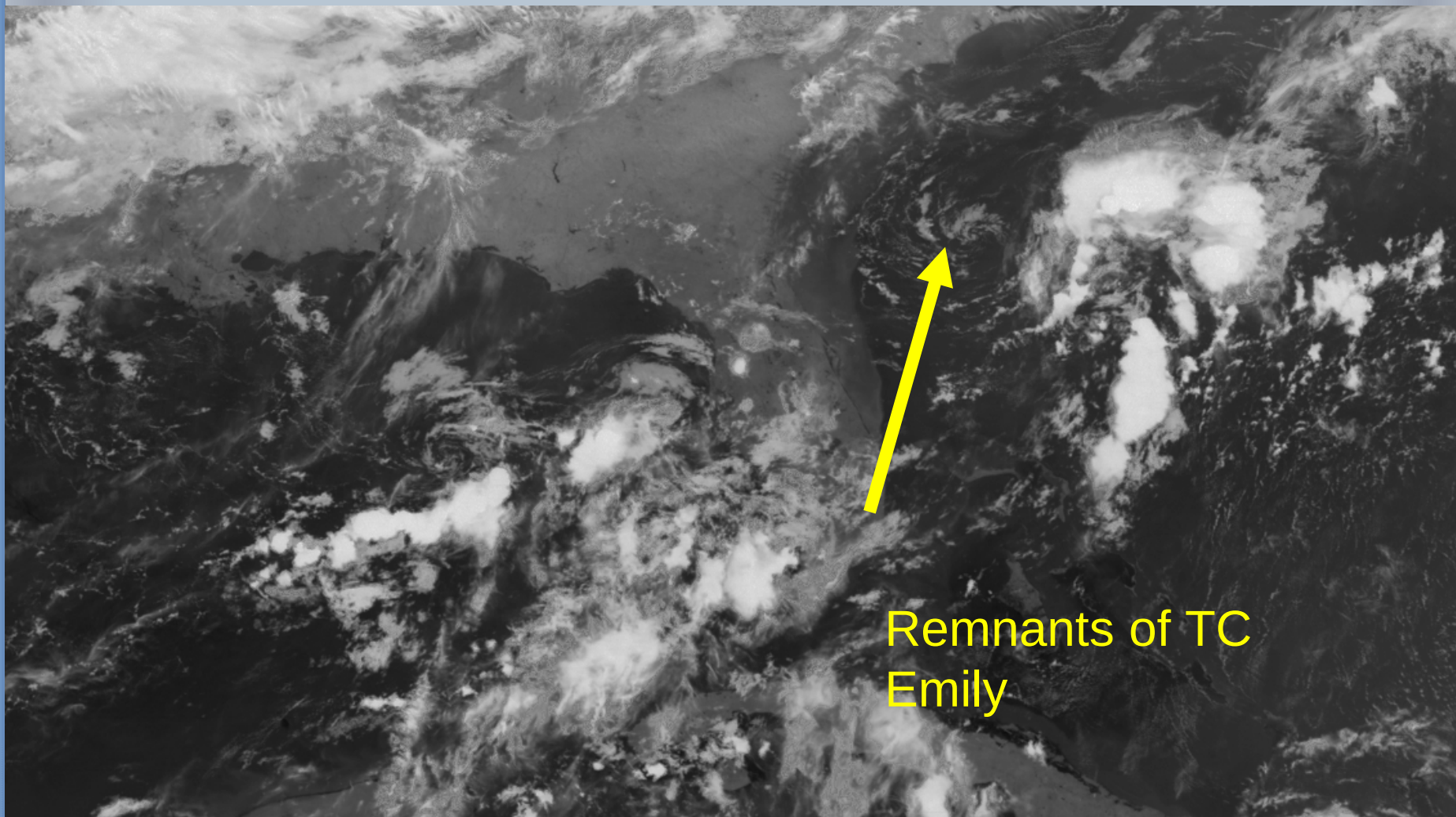


(5) Proxy-Visible Imagery

- Legacy NHC high-time “visible ”product:
 - 3.9 μm channel combined with 10.35 μm (“fog” product)
- **Proxy-visible imagery:**
 - Developed using **VIIRS DNB radiances**
 - Uses GOES-16 channels to make **full disk continuously available at night** proxy-visible imagery
 - Can be also used with GOES-17 and Himawari-8
 - **dynamically combines 3.9 μm with long-wave IR channels, depending on the background**
 - allows to see low-level clouds at larger ranges of the backgrounds surfaces and SSTs compared to existing products

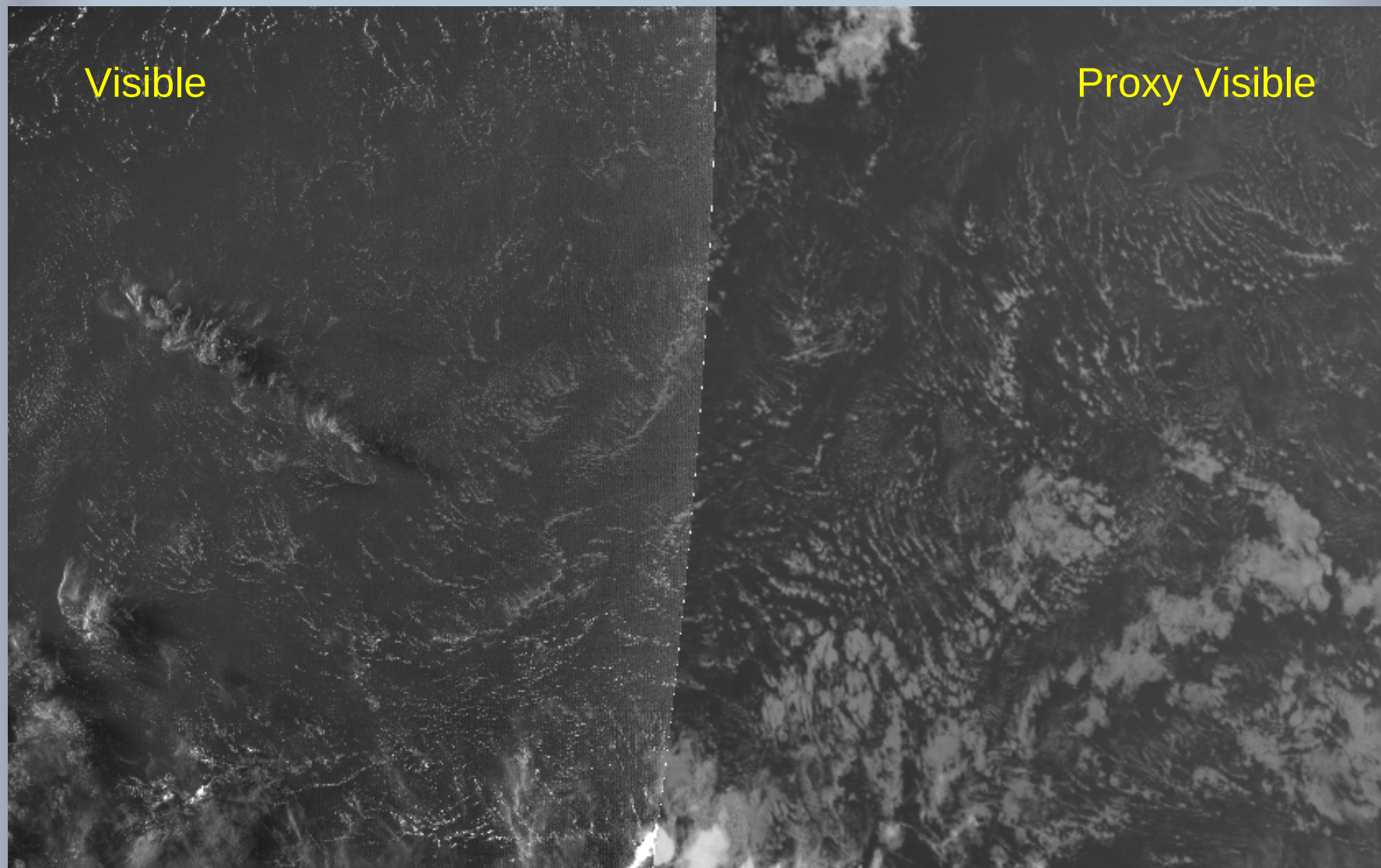
(5) Proxy Visible Imagery

GOES-16 – low level clouds

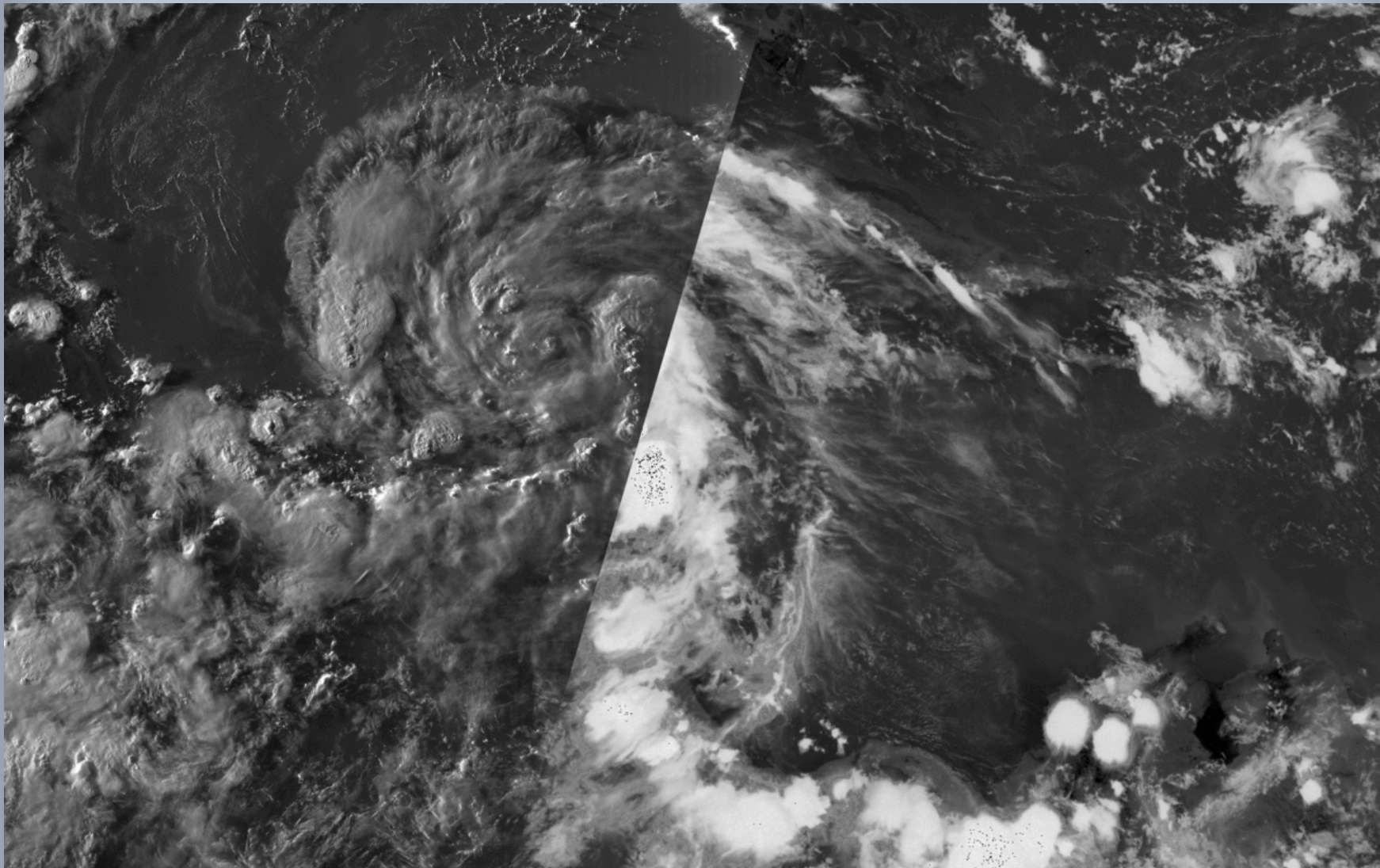


Remnants of TC
Emily

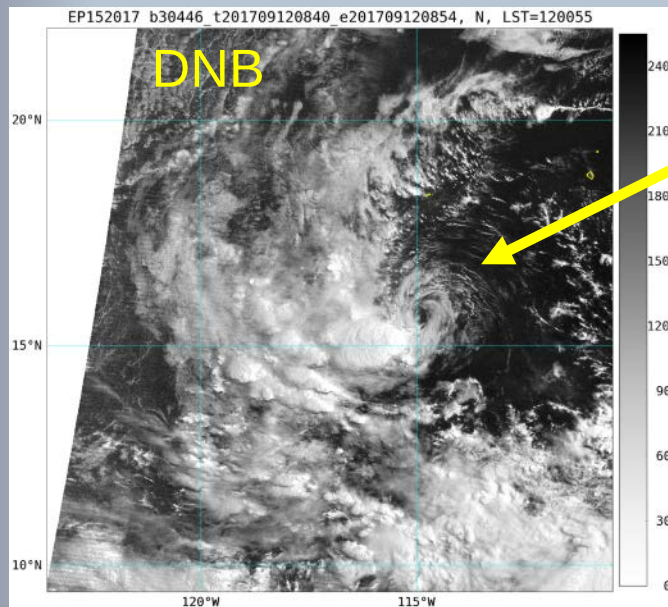
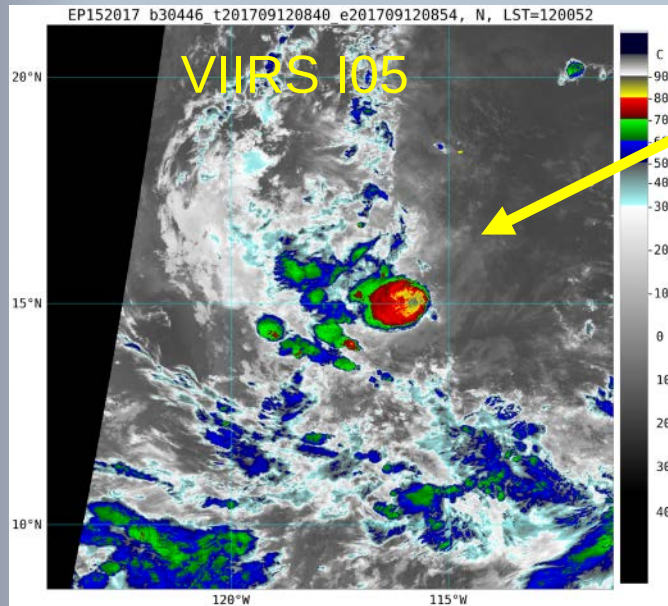
(5) Proxy Visible Imagery Day/Night Terminator



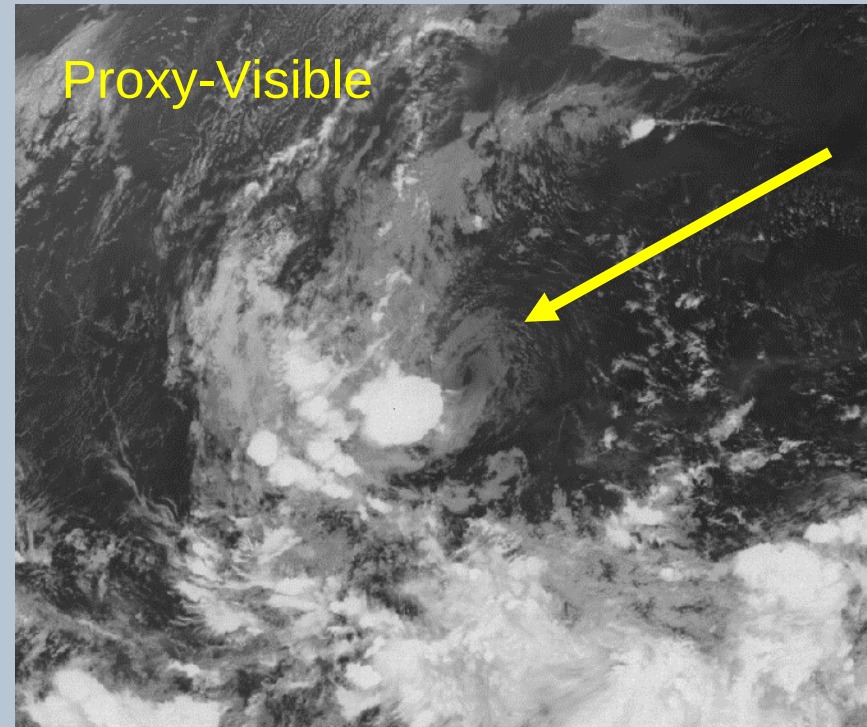
Hurricane Franklin, Aug 08 2017



(5) Proxy – Visible: detecting LLCC

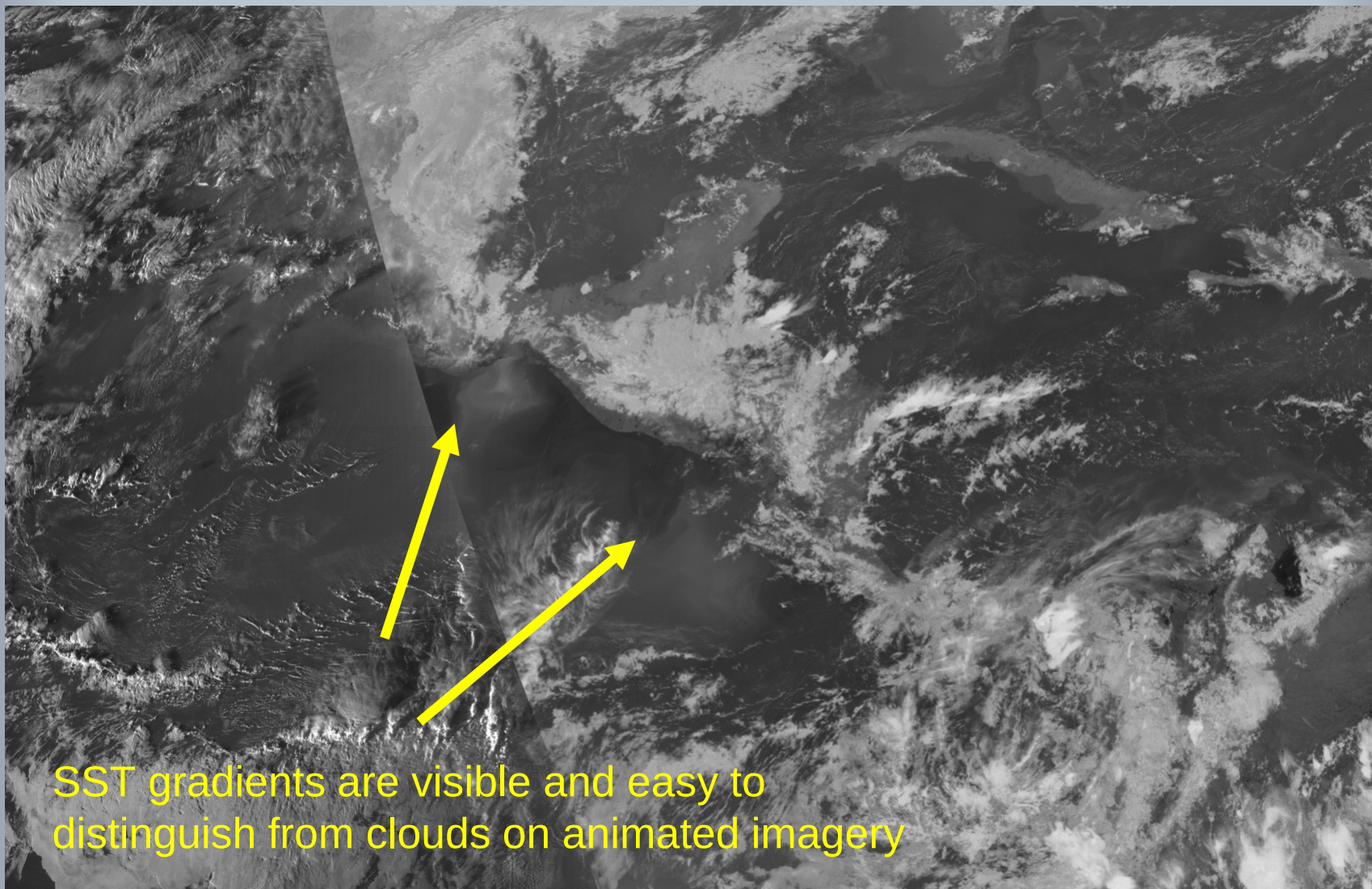


ep152017 Major Hurricane OTIS



In many cases LLCCs that are not visible on IR imagery can be seen on proxy-visible almost as well as on DNB, even without animation

(5) Proxy- visible: SST gradients

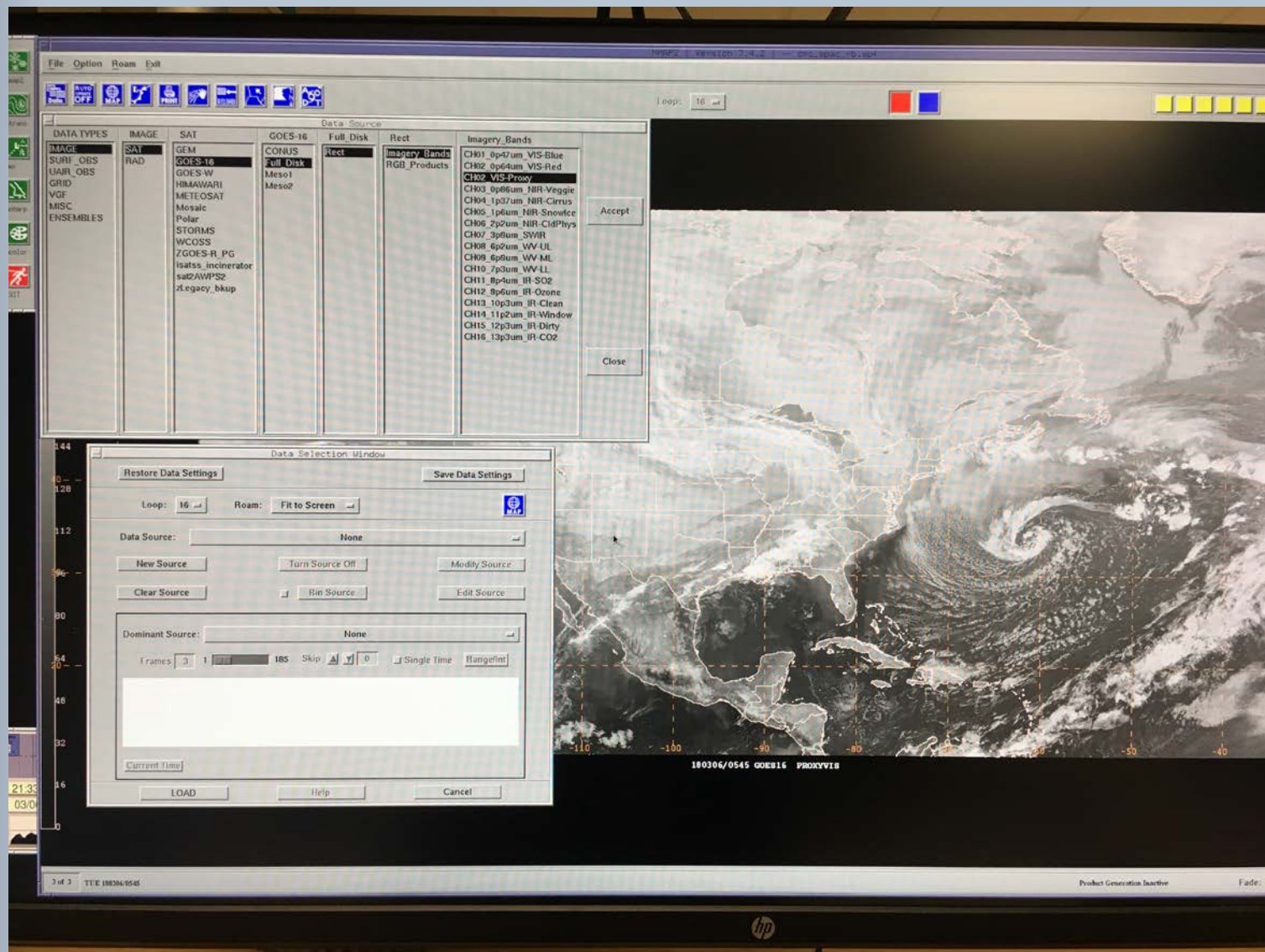


SST gradients are visible and easy to distinguish from clouds on animated imagery

(5) Proxy Visible: Next Step

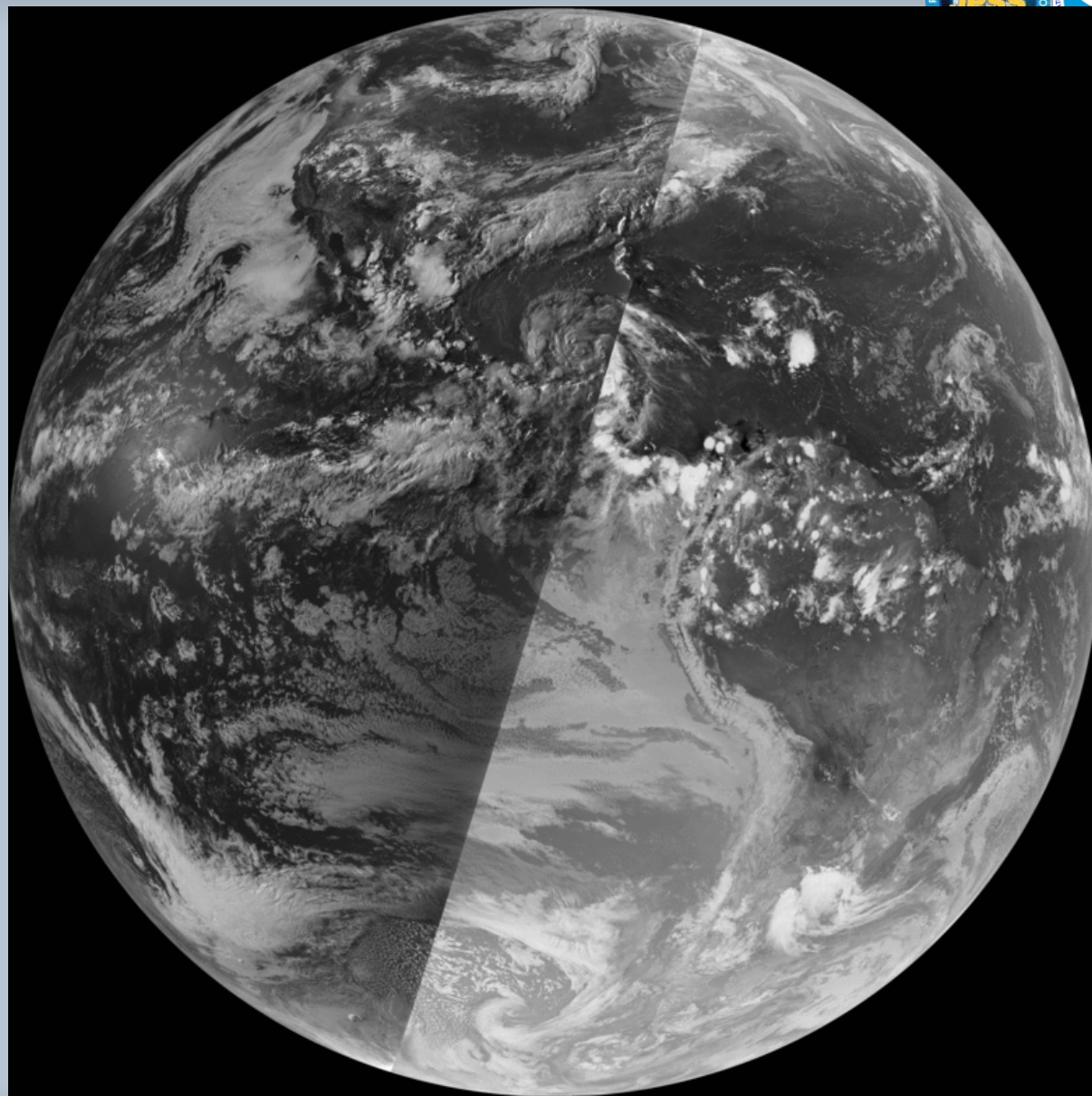
- Available on NHC's NAWIPS for GOES-16
- Will be available on SLIDER later this month:
- Next year:
 - GOES-17
 - AWIPS2 version
 - Himawari-8 - ?

(5) Proxy-Visible: NHC's NAWIPS



Proxy Visible Imagery On SLIDER

GOES-16 Full Disk



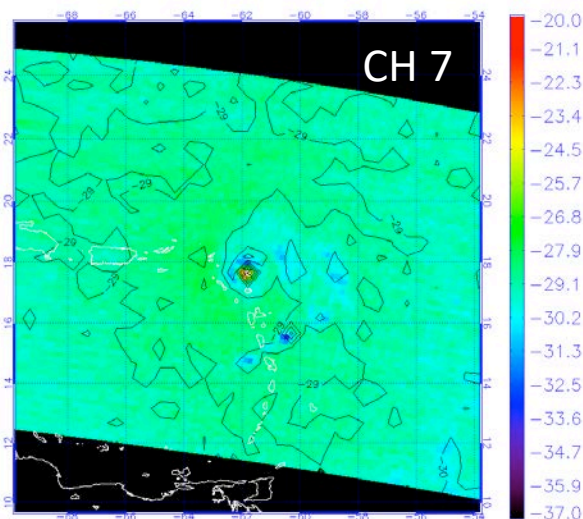
Summary:

CIRA JPSS Applications

- **HISA** operational and available to NHC, CPHC, and JTWC
- **SEDR**: adding to SHIPS, RII (as JHT project)
- **MIST**: will be available in real-time next year
- **VIIRS** TC-Centered DNB and I05: on NHC's NAWIPS
- **Proxy-Visible**: on NHC's NAWIPS; on SLIDER (end of March; currently on SLIDER2) <http://rammb-slider.cira.colostate.edu>
- **CIRA/RAMMB TC real-time page**
http://rammb.cira.colostate.edu/products/tc_realtime/
 - Available: VIIRS DNB, SEDR, HISA
 - Coming soon: MIST
- **CIRA/RAMMB SLIDER**: <http://rammb-slider.cira.colostate.edu/>
 - Proxy Visible - April 2018

CIMSS JPSS Applications

201711L IRMA
SNPP-ATMS Channel 7 (53.596GHz) Tb (C)
0906 0535

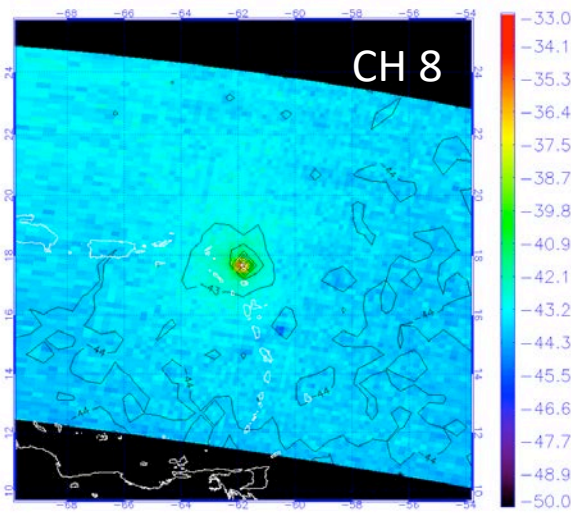


Max Tb (C): -22.4

Contour Interval = 1C

University of Wisconsin - CIMSS

201711L IRMA
SNPP-ATMS Channel 8 (54.94GHz) Tb (C)
0906 0535

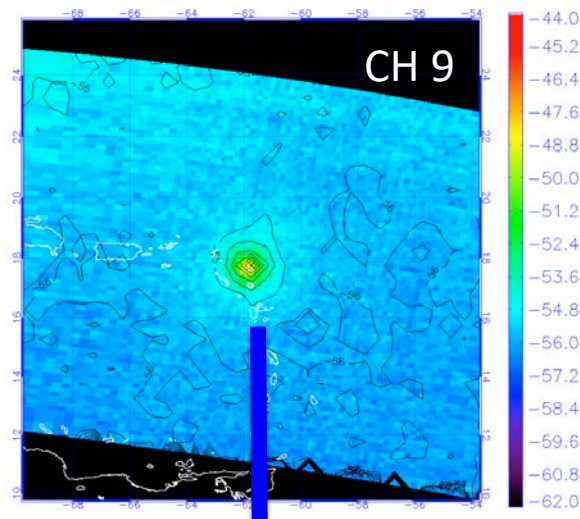


Max Tb (C): -35.6

Contour Interval = 1C

University of Wisconsin - CIMSS

201711L IRMA
SNPP-ATMS Channel 9 (55.5GHz) Tb (C)
0906 0535



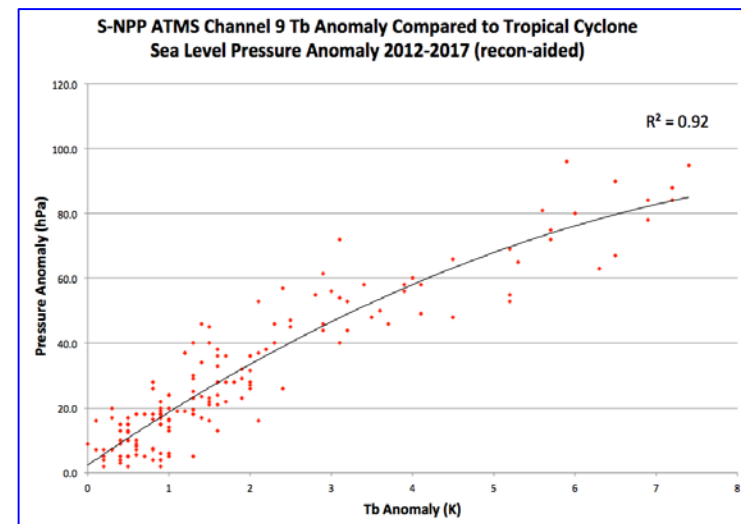
Max Tb (C): -48.7

Contour Interval = 1C

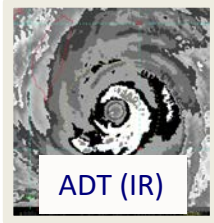
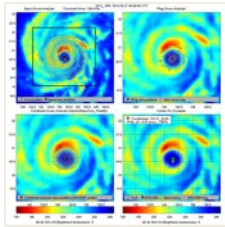
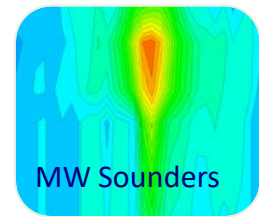
University of Wisconsin - CIMSS

- Regression-based approach using channel 7-9 Tb anomalies
- Correct for known resolution bias using TC eye size
- Derive Vmax from sounder-derived pressure anomaly, inner core Tb gradient, TC size (outer closed isobar diameter), and latitude.

N =228	ATMS Vmax	ATMS MSLP
Bias (knots)	-1.0	-0.1
Abs Error	8.4	5.6
RMSE	10.8	7.5



Objective estimates of TC intensity in near real-time. Compliments the current subjective Dvorak estimates



Multiple estimates from 4 different algorithms all with unique error characteristics



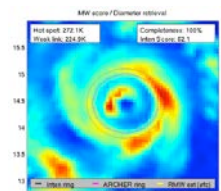
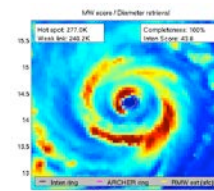
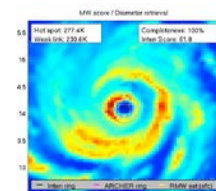
Merge into single estimate more skillful than the members or a simple average

SATCON

- Current members are CIMSS AMSU, SSMIS and ADT along with the CIRA ATMS algorithm (currently limited to eyes > 40 km in diameter)
- Final Vmax estimate is corrected to account for TC eye size, eyewall strength (organization and robustness) and storm motion. Eye size and eyewall strength come from CIMSS ARCHER.

CIMSS ARCHER 89 GHz Wimmers and Velden, 2010

N =155	SATCON	Dvorak
Bias (knots)	-1.2	-1.7
Abs Error	6.0	6.5
RMSE	7.8	8.8



TC undergoing eyewall replacement cycle. Eye diameter shifts to outer ring

Retain smallest eye diameter and strongest eyewall signal within three hour window of intensity estimates for CIMSS SSMIS, AMSU and ATMS

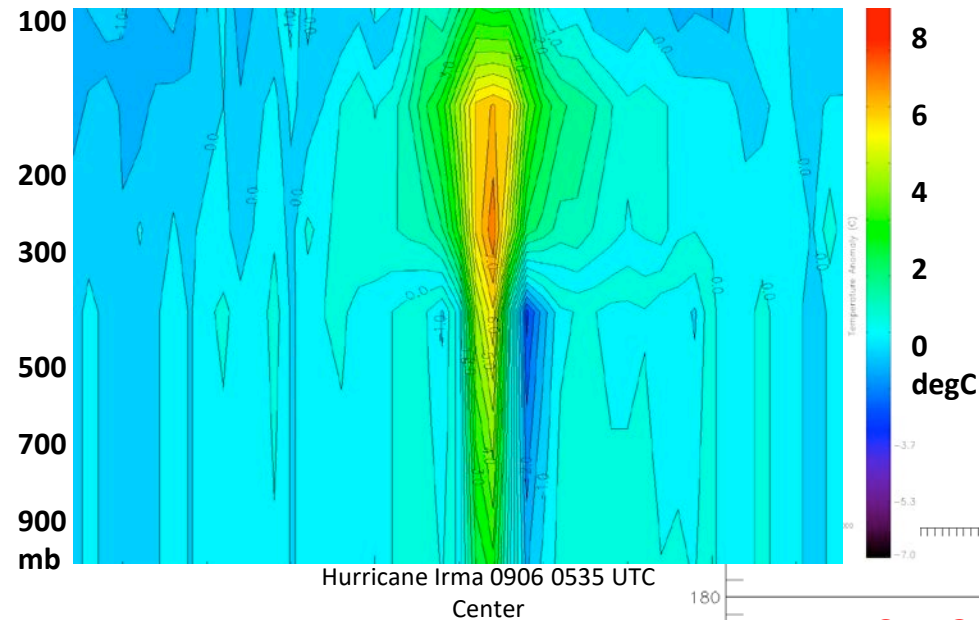
2016 Independent performance evaluation
Dvorak is average of all available TC fixing agencies



S-NPP ATMS and SATCON Intensity Estimates for Hurricane Irma



ATMS Height/Thermal (Brightness Temp) Cross-section



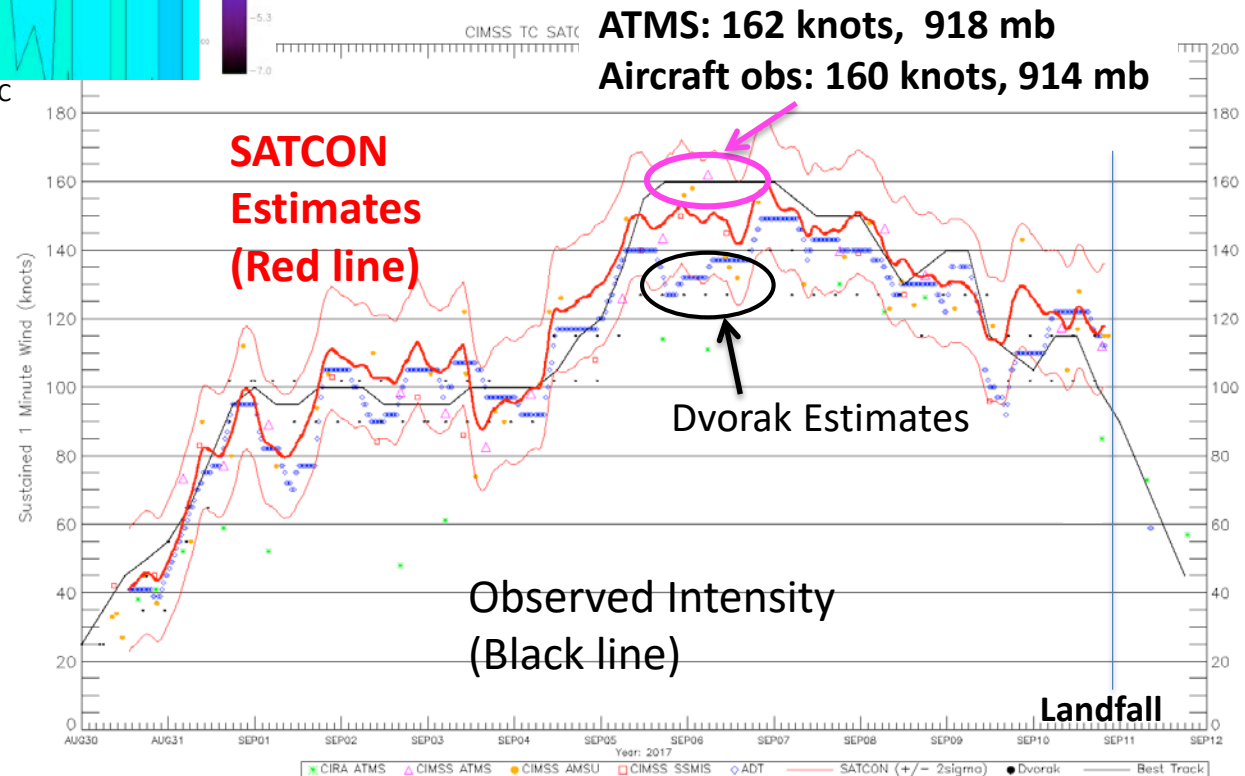
Observed upper-tropospheric warm core strength is related to Hurricane surface intensity (MSLP and Max winds)

Intensity estimates for Irma (Max Wind)
ATMS is only method that captures peak intensity

Experimental Objective SATellite CONsensus (SATCON) Intensity Estimate

Provider: UWisc - CIMSS
Storm: TROPICAL CYCLONE IRMA
Date: 06 Sep. 2017 Time: 05:35 GMT
Latitude: 17.69N Longitude: 61.95W

Estimated MSLP: 923 hPa
Estimated Maximum Sustained Wind: 150 kts
ADT MSLP: 930 hPa MaxW: 135 knots
AMSU MSLP: 910 hPa MaxW: 158 knots
ATMS MSLP: 918 hPa MaxW: 162 knots



UW-CIMSS SATCON Proving Ground Demonstration

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UW-CIMSS SATCON Proving Ground Demonstration Page

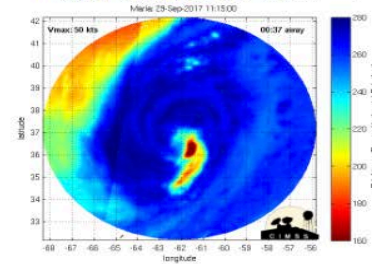
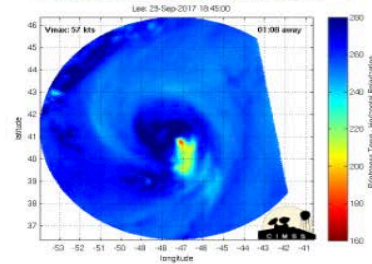
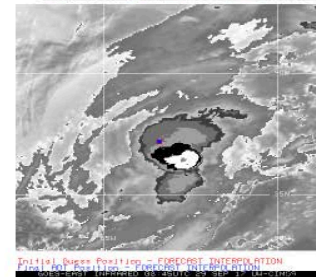
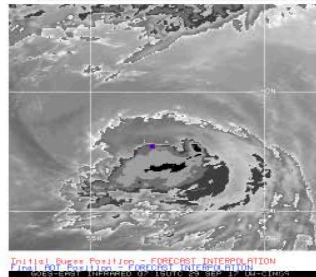
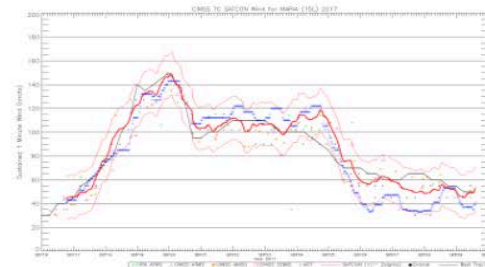
Product Developers: Derrick Herndon and Chris Velden

ACTIVE STORMS: LEE (14L) MARIA (15L)

Current Intensity Estimates

Atlantic
14L LEE 58 knots 982 hPa
09291036 UTC

15L MARIA 51 knots 982 hPa
09291410 UTC



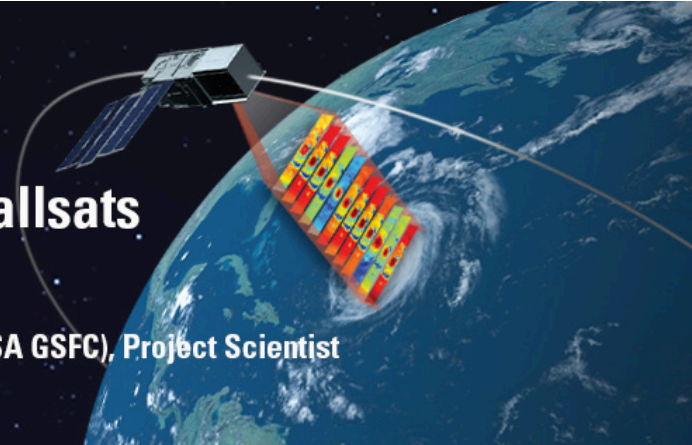
Satellite-Based Hurricane Intensity Estimation in the JPSS/GOES-R Era



Time-Resolved Observations of Precipitation Structure and Storm Intensity with a Constellation of Smallsats

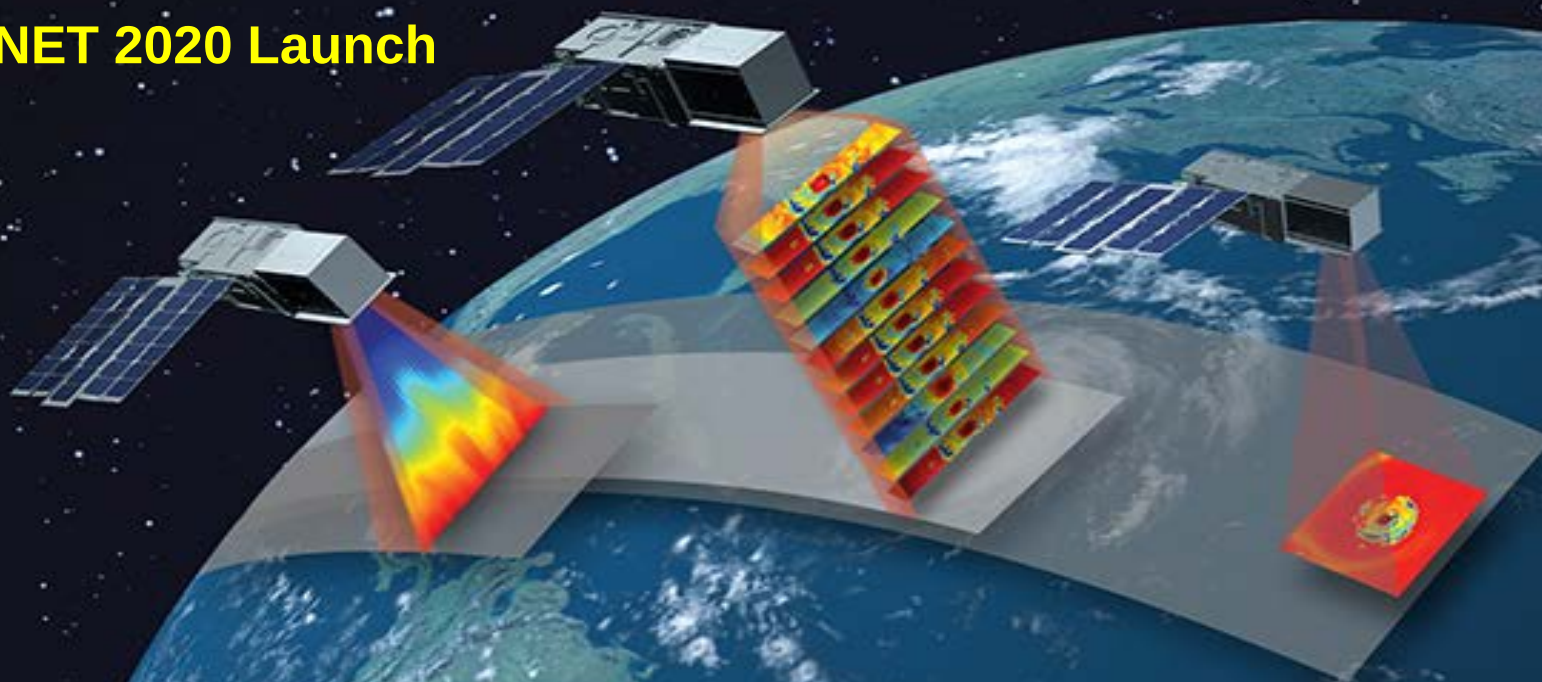
MIT Lincoln Laboratory (lead organization)

William J. Blackwell, Principal Investigator. Scott Braun (NASA GSFC), Project Scientist



**NASA Earth Venture
NET 2020 Launch**

**TROPICS will
provide better
than 60-minute
refresh over
entire tropical
cyclone belt**



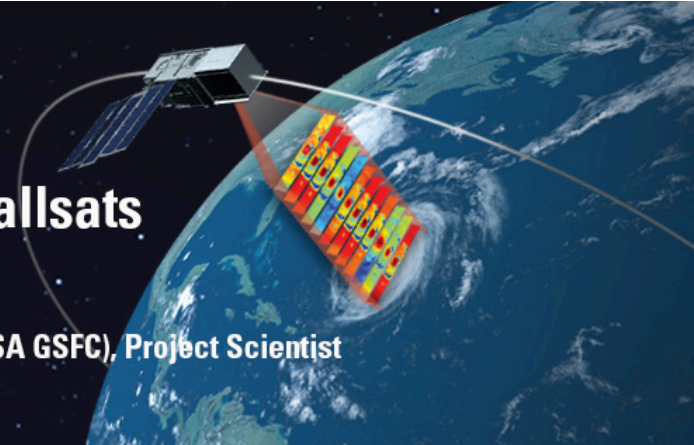
The NASA TROPICS CubeSat Constellation Observatory
Six satellites; cross-track MW sounders with 12 channels (90-205 GHz)



Time-Resolved Observations of Precipitation Structure and Storm Intensity with a Constellation of Smallsats

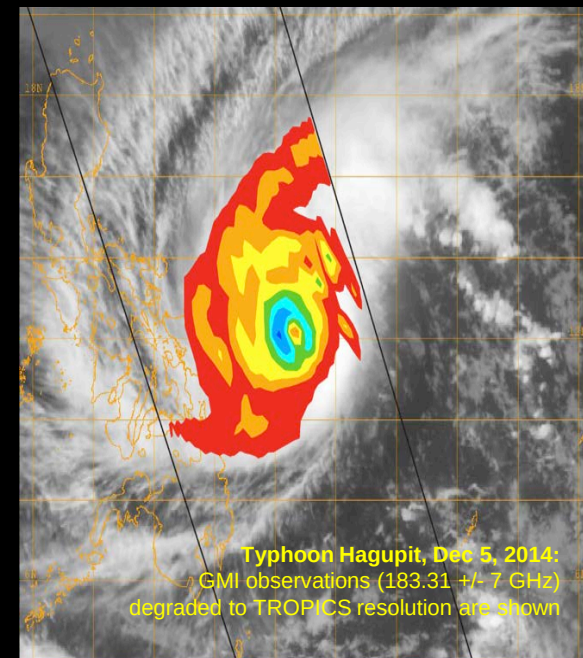
MIT Lincoln Laboratory (lead organization)

William J. Blackwell, Principal Investigator. Scott Braun (NASA GSFC), Project Scientist

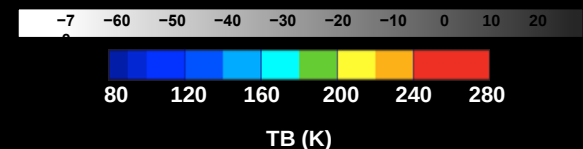


- TROPICS will be the first demonstration that science payloads on low-cost CubeSats can push the frontiers of spaceborne monitoring of the Earth to enable high-priority science
- Seven temperature channels near 118.75 GHz
- Three water vapor channels near 183.31 GHz
- Two imaging channels: 90 and 205 GHz
- Spatial resolution on par or better than ATMS
 - 25 km nadir resolution for temperature
 - 15 km nadir resolution for water vapor
 - 95% antenna beam efficiency (measured)
- 24-hr data latency (could be improved with additional investment in ground segment)
- MicroMAS-2a demonstration mission on-orbit and working well (public data release planned)

12/05/14 0600Z 22W
HAGUPIT
12/05/14 0801Z MTSAT-2-IR



Naval Research Lab http://www.nrlmry.navy.mil/sat_products.html
← IR Temperature (Celsius) →



<https://tropics.ll.mit.edu>

TROPICS Products and Expected Performance

Product	Threshold Requirement (Uncertainty)	Baseline Requirement (Uncertainty)	Expected Performance (CBE) (Uncertainty)
Temperature Profile	2.5 K	2.0 K	1.5 K
Moisture Profile	35 %	25 %	16.3 %
Rain Rate	50 %	25 %	18.3 %
Min Sea-Level Pres.	12 hPa	10 hPa	7.8 hPa
Max Sustained Wind	8 m/sec	6 m/sec	5.4 m/sec

Data to be publicly available from the NASA GES DISC



WISCONSIN
UNIVERSITY OF WISCONSIN-MADISON



Goddard
SPACE FLIGHT CENTER

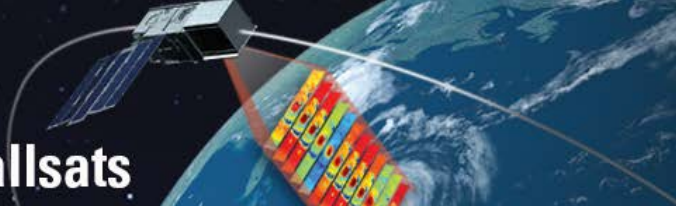


Tufts
UNIVERSITY





Time-Resolved Observations of Precipitation Structure and Storm Intensity with a Constellation of Smallsats

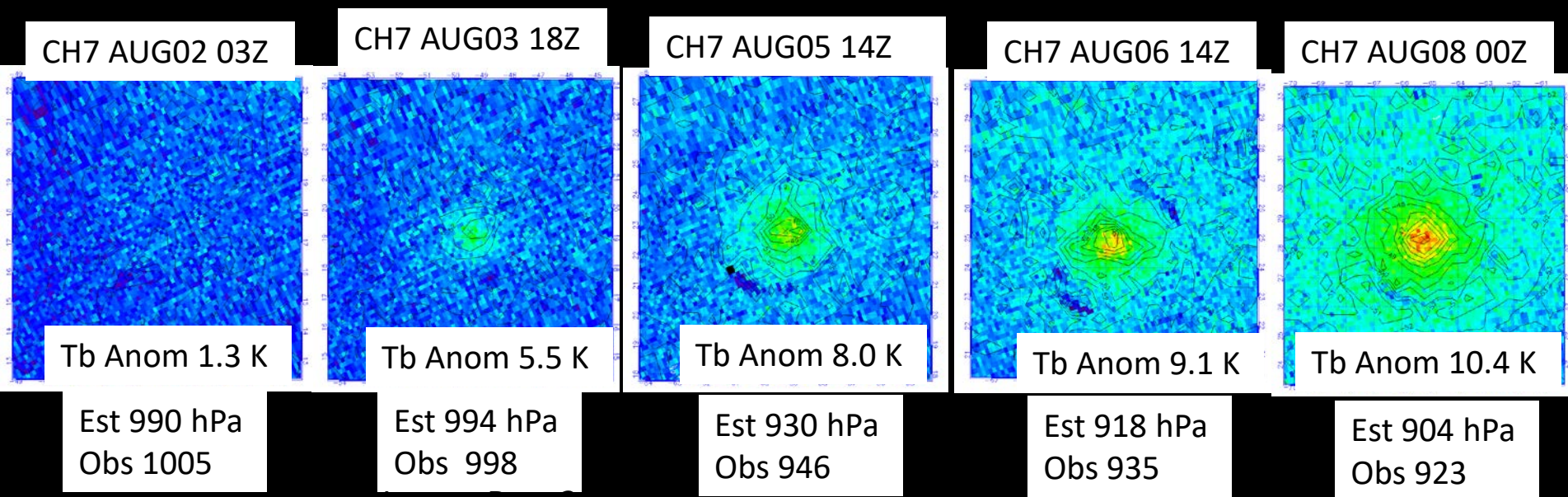


TROPICS TC Intensity Estimation CIMSS and CIRA

CIMSS (TCIE) and **CIRA (HISA)** TC Intensity Algorithms developed with AMSU and ATMS data will be used with TROPICS MW sounders to estimate

- TC Maximum Sustained Wind
- TC Mean Sea Level Pressure

CIMSS: Nature Run 2005 TROPICS CH7 TC Intensity Estimates



<https://tropics.ll.mit.edu>

Summary

TC intensity estimates : SSMIS, AMSU, ATMS, TROPICS

- **CIRA: HISA** operational and available to NHC, CPHC, and JTWC
- **CIMSS: TCIE**

TC Intensity estimates and SHIPS/RII Predictors:

- **SEDR**: adding to SHIPS, RII (as JHT project)
- **MIST**: plan to make available in real-time next year

VIIRS Imagery:

- **VIIRS TC-Centered DNB and I05**: on NHC's NAWIPS
- **Proxy-Visible Imagery**: on NHC's NAWIPS; on SLIDER (end of March)
<http://rammb-slider.cira.colostate.edu>

Online Resources:

- **CIRA TC real-time**: http://rammb.cira.colostate.edu/products/tc_realtime/ , **SLIDER**
- **CIMSS SATCON Demo**: http://tropic.ssec.wisc.edu/real-time/satcon/PG/satcon_pg.html
- **TROPICS** <https://tropics.ll.mit.edu>

Future Work

- JPSS-1 (NOAA-20) launched in November, 2017)
- Highlights from 3 Newly funded JPSS TC projects:
 - CIRA:
 - Combined VIIRS and Proxy-Visible product
 - Expand MIST to AMSU and NOAA20; display on NAWIPS
 - Develop ATMS application to track warm-core changes related to RI
 - Microwave automated eye-detection and determining RMW
 - Use quantitative estimates from JPSS to improve SHIPS/LGEM and RII
 - CIMSS:
 - Real-time TCIE with NOAA-20 ATMS in SATCON
 - Integrate SATCON and ARCHER into GeoIPS which would allow to run it at NHC, CPHC, and JTWC
 - Test SATCON input to SHIPS
 - NRL:
 - Implement at NHC, CPHC, and JTWC the GeoIPS – the unified MW processing system.