

Objective guidance for intensity and structure analysis : Microwave, SATCON, scatterometers, ...

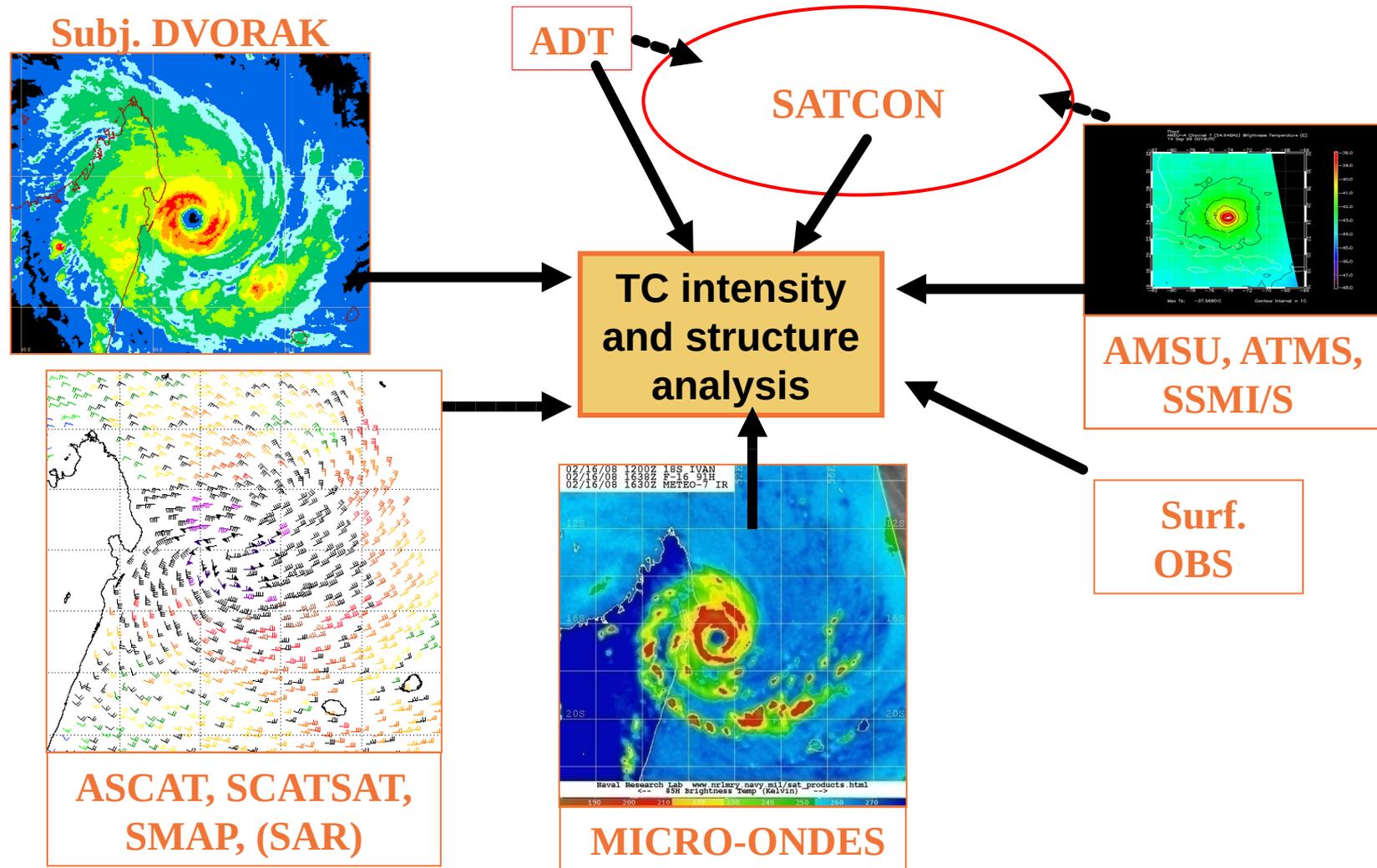
Sébastien Langlade Tarik Kriat

RA I WMO training course on tropical cyclones 2021

Intensity / Structure assessment : Overview

1. Microwave data
2. Objective Satellite guidance
3. Remote sensing of strong / extreme winds

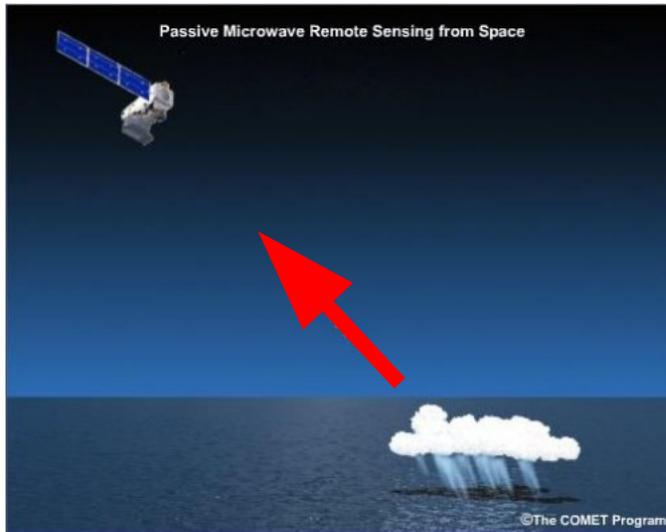
TC intensity / structure analysis in TC forecasting: an expertise



Intensity / Structure assessment : Overview

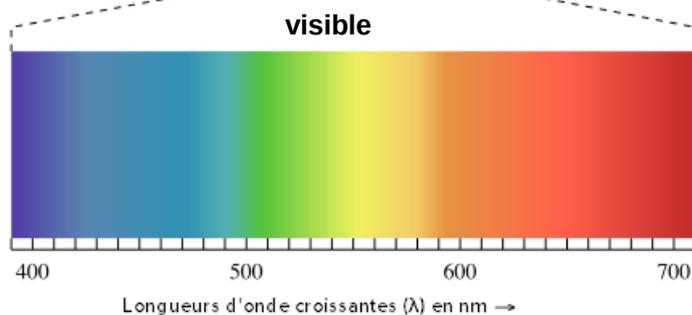
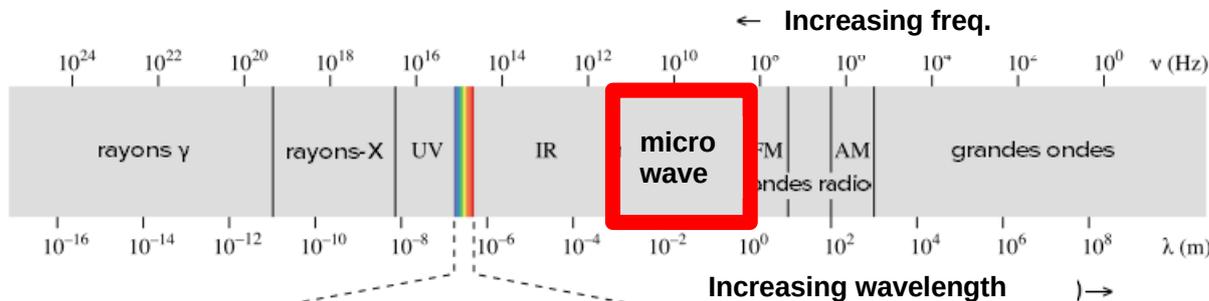
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Passive micro-wave imagery



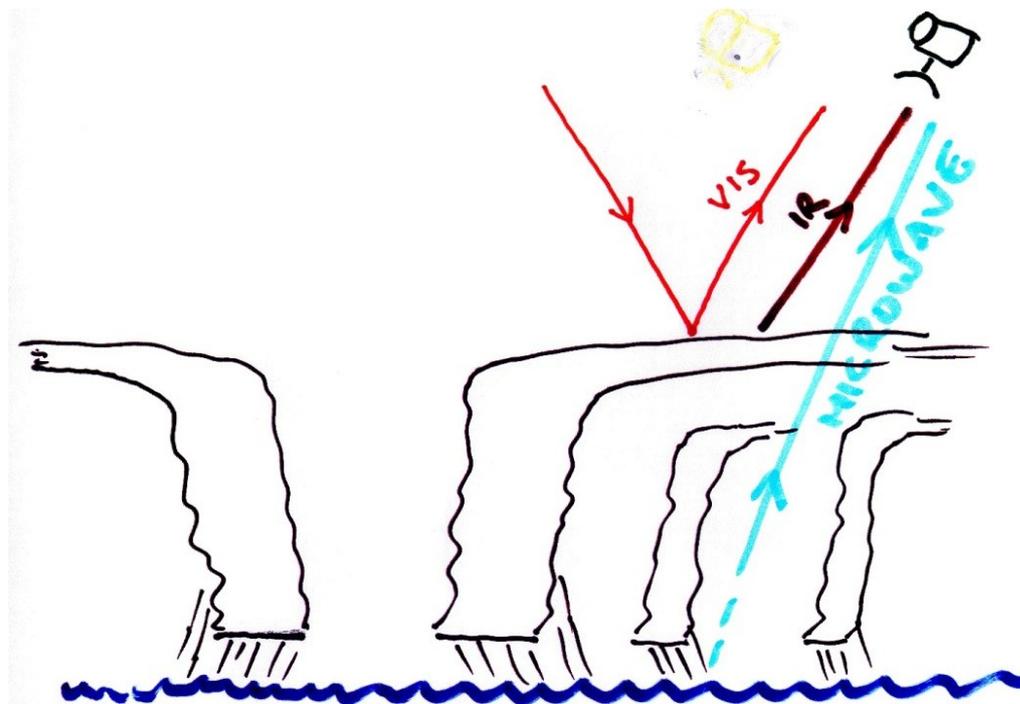
- Passive microwave imagers measure the radiation emitted in the 5-200 GHz microwave range.
- A brightness temperature (T_b) is measured which allows to quantify the radiative processes and the associated hydrometeors:

- Scattering / graupeln
- Emission / Absorption / liquid cloud water and water drops

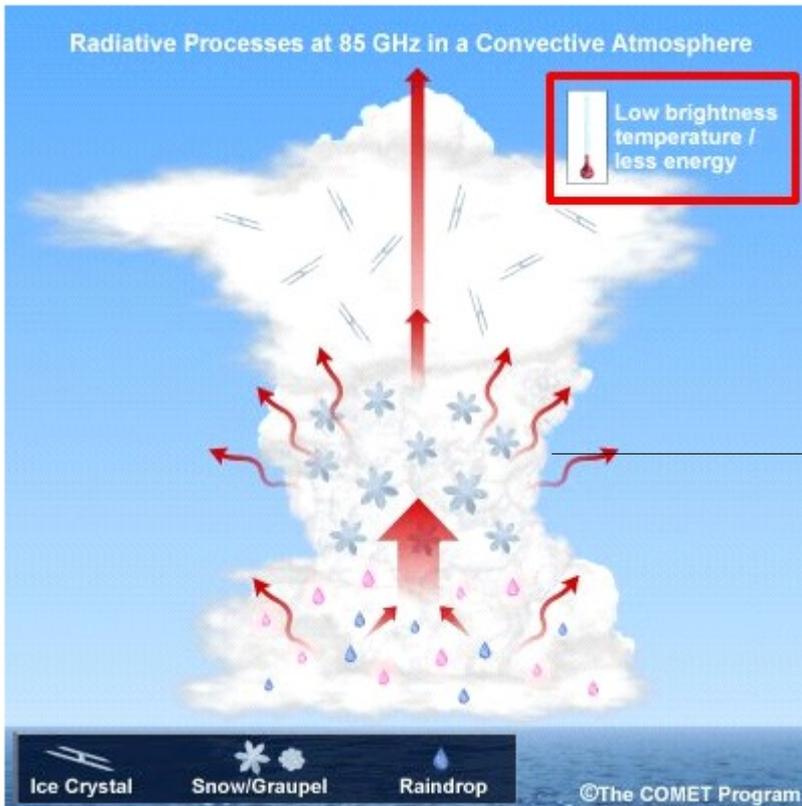


Passive micro-wave imagery

- Advantages:
 - see through cirrus clouds
 - detection in almost all atmospheric conditions
- Disadvantages
 - Wavelength + long than VIS or IR
 - less energy and less good resolution
 - Only on scrollers
 - More complex interpretation.



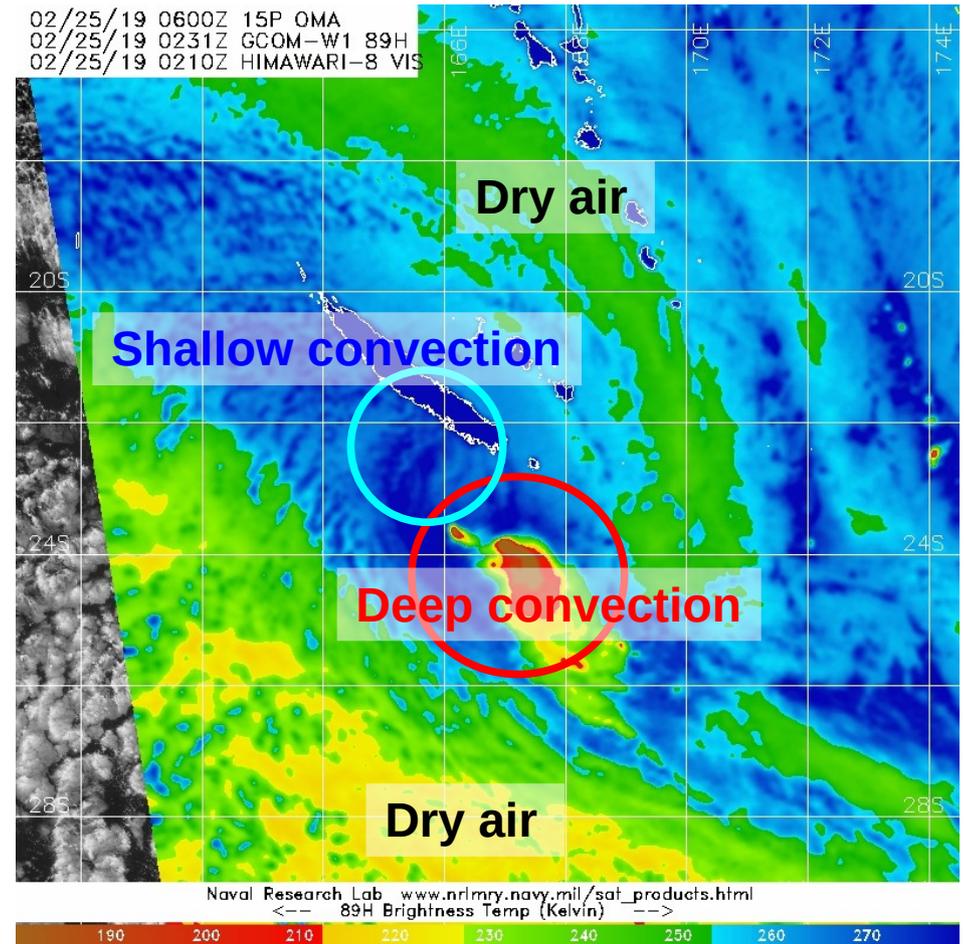
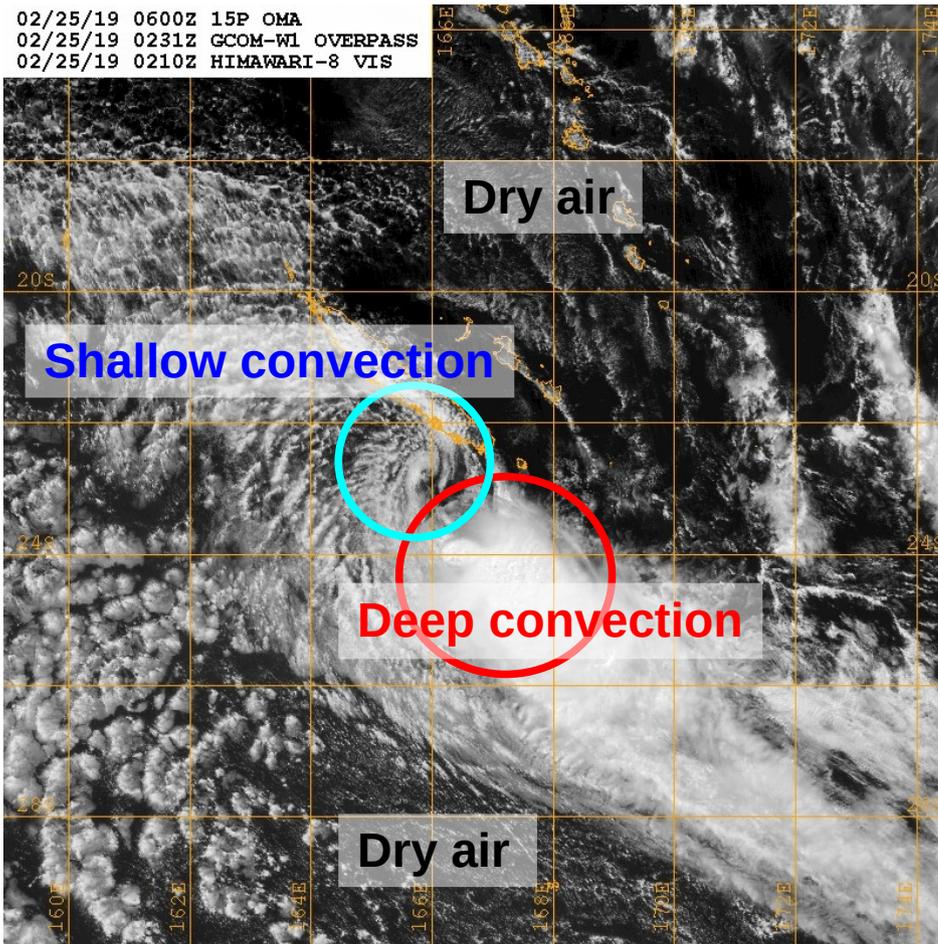
Passive micro-wave imagery



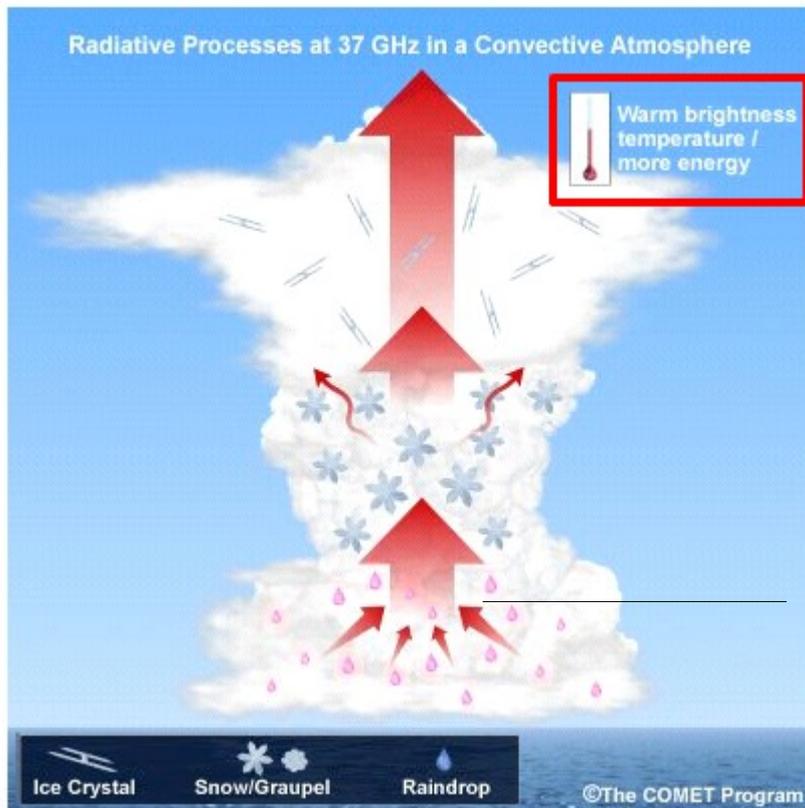
- 85GHz :
 - The signal is amplified in the presence of liquid drops
 - Scattering by icy particles
 - Deep convection associated with low T_b
 - Weak convection associated with high T_b

Passive micro-wave imagery

- 85GHz :



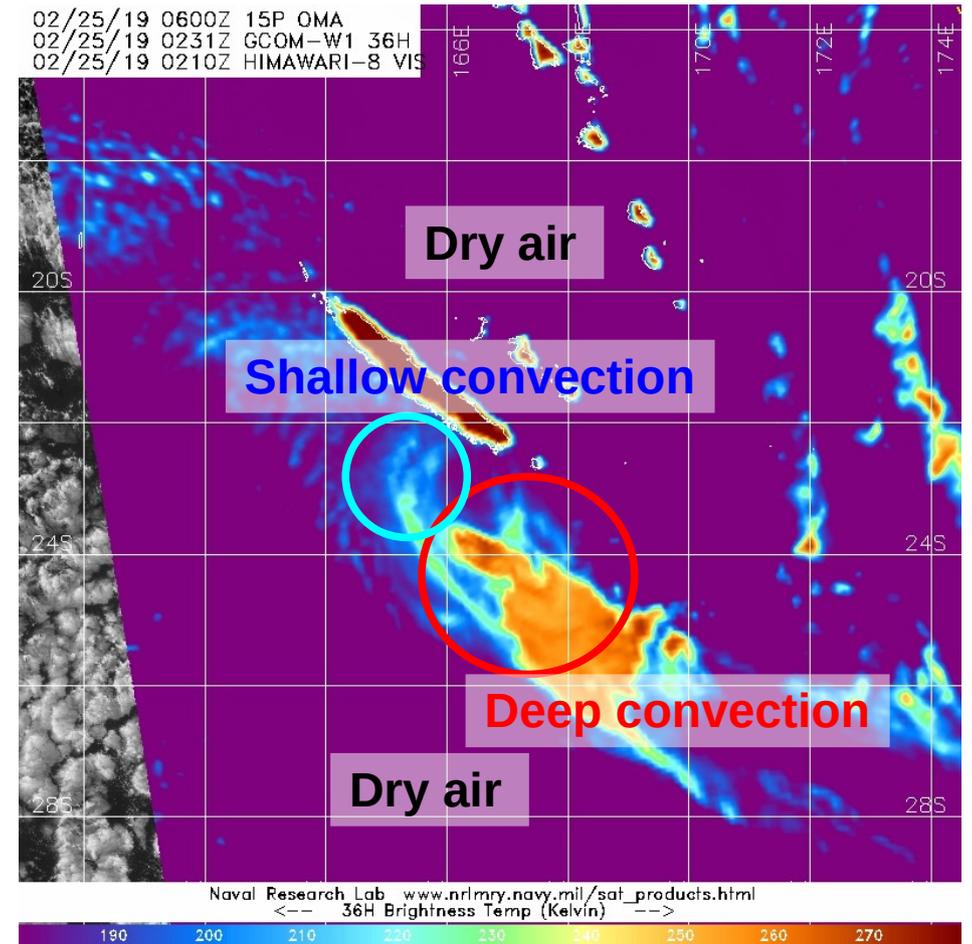
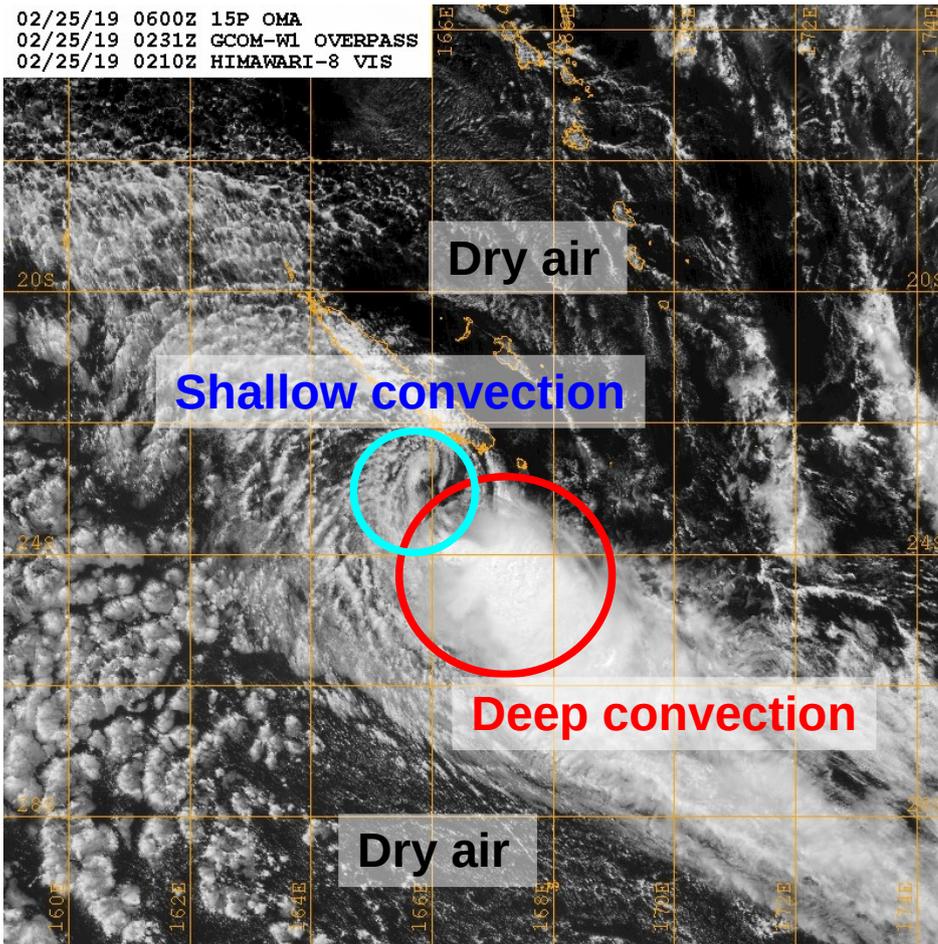
Passive micro-wave imagery



- 37GHz :
 - The signal is amplified by the liquid drops
 - No scattering by ice particles
 - Heavy rain associated with high T_b
 - Light rain associated with low T_b

Passive micro-wave imagery

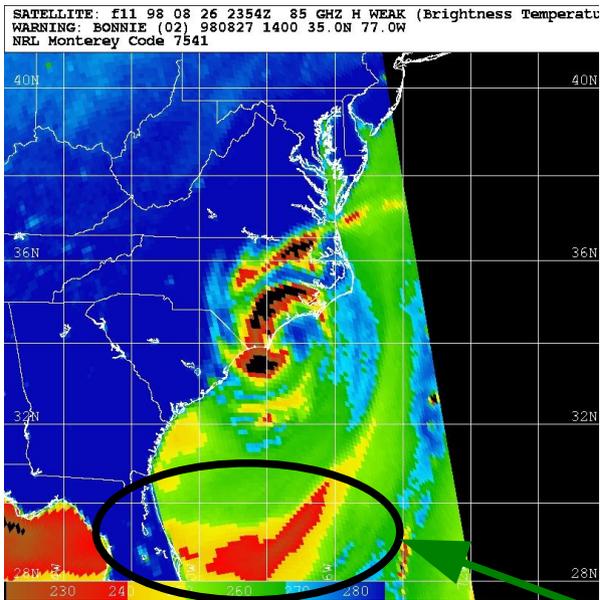
- 37GHz :



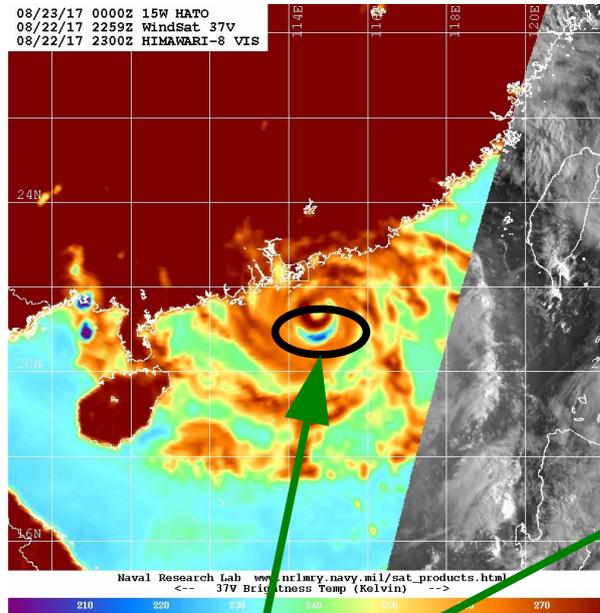
Passive micro-wave imagery

- Different products available on the [NRL/FNMOC](#) :
 - Polarised products :

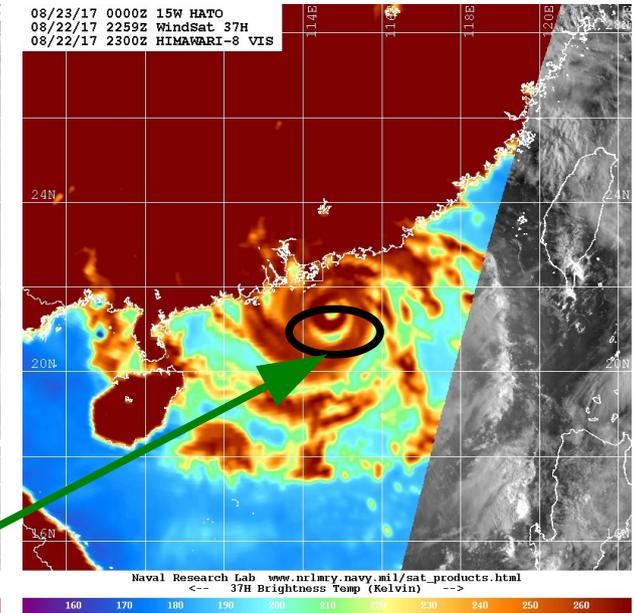
89h/89weak



37v



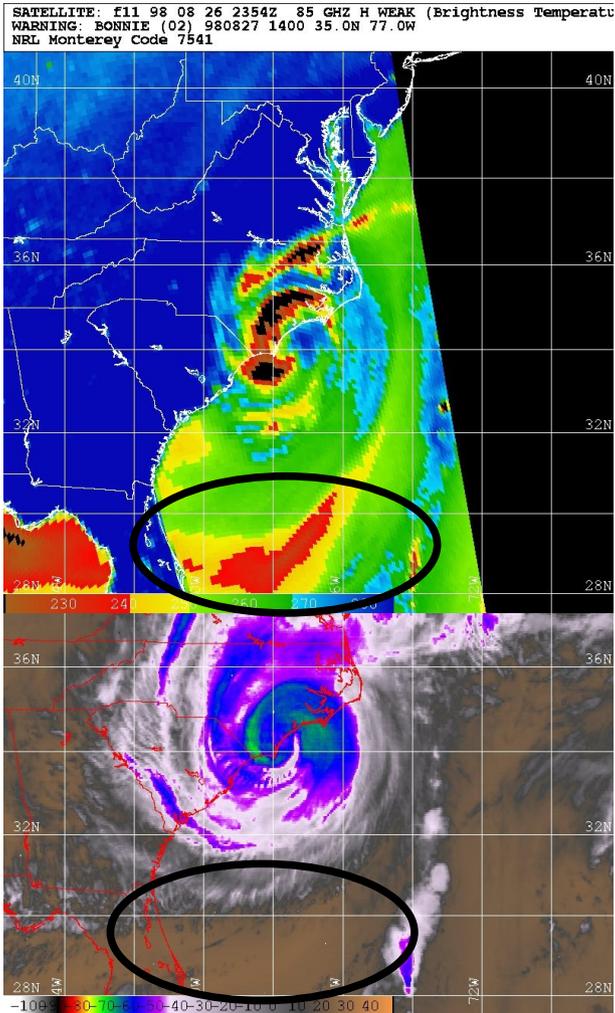
37h



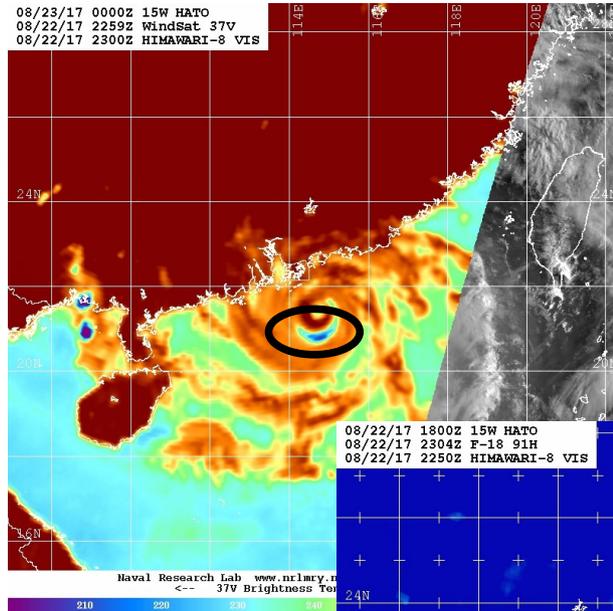
► But some biases :

Passive micro-wave imagery

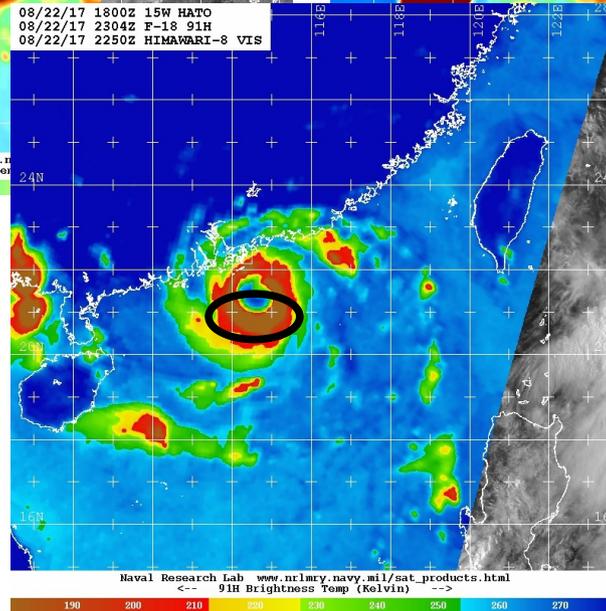
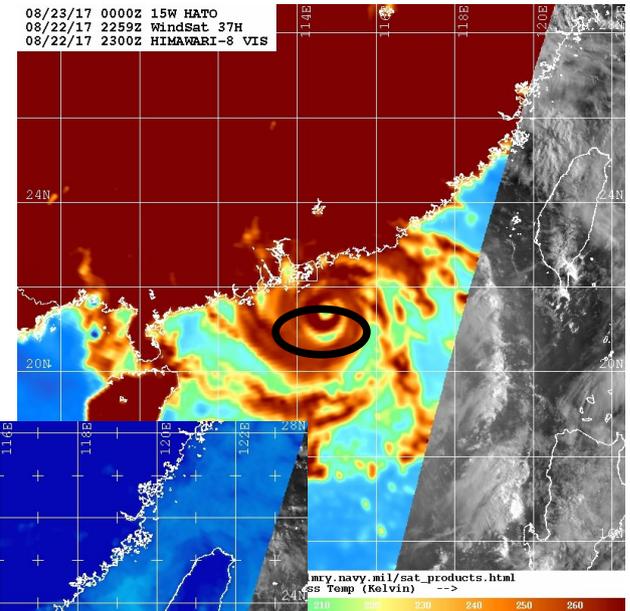
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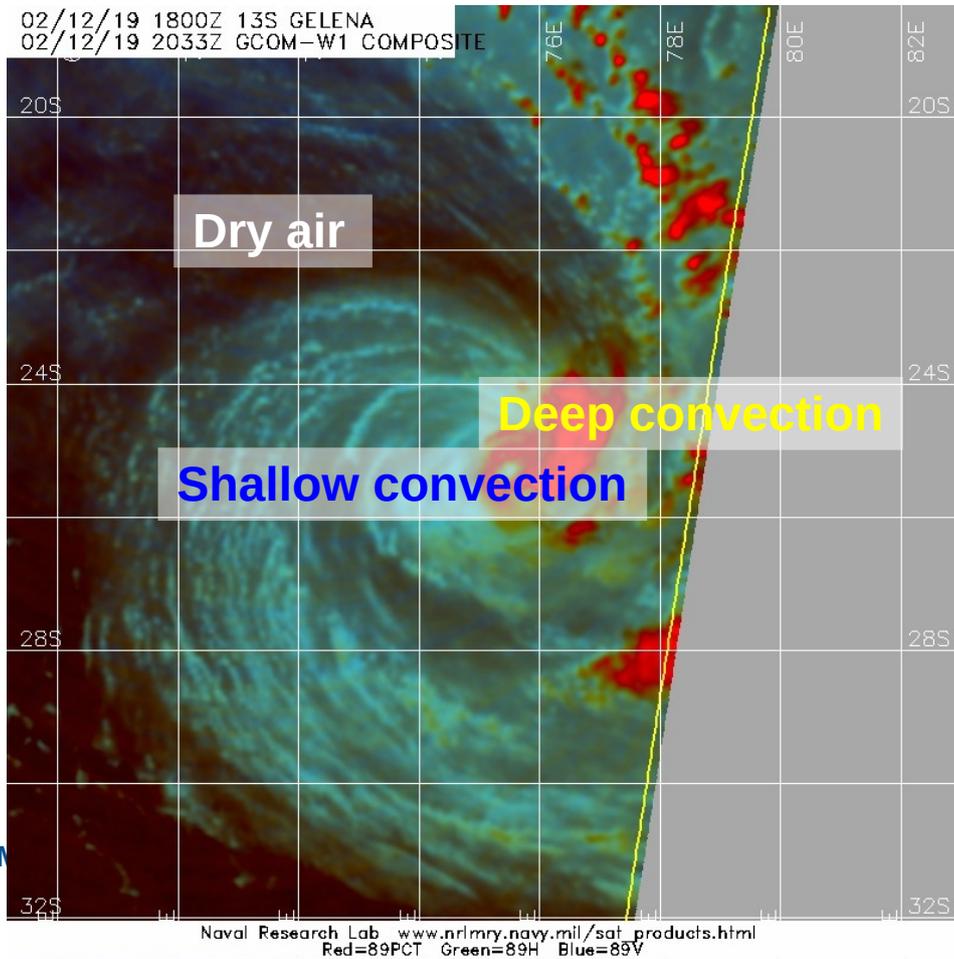
37h



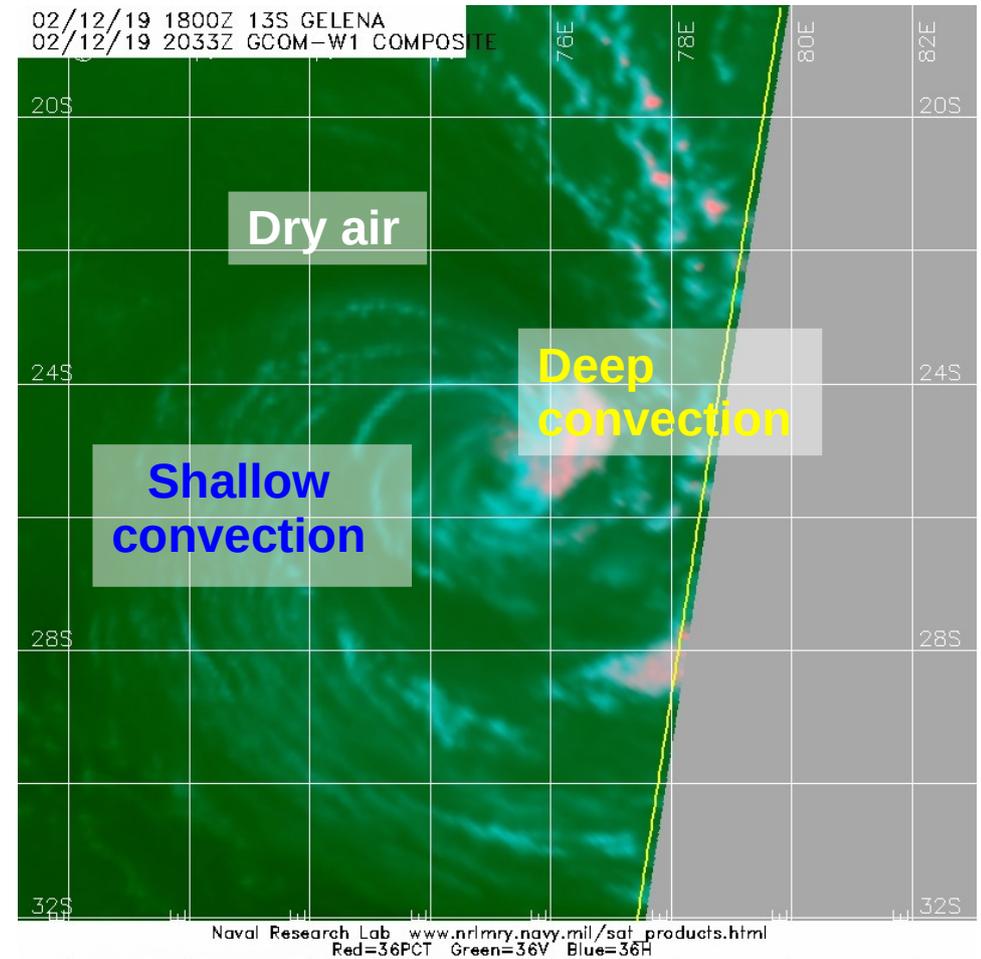
Passive micro-wave imagery

- Different products available on the [NRL/FNMOC](#) :
 - Composites (most used) :

Color

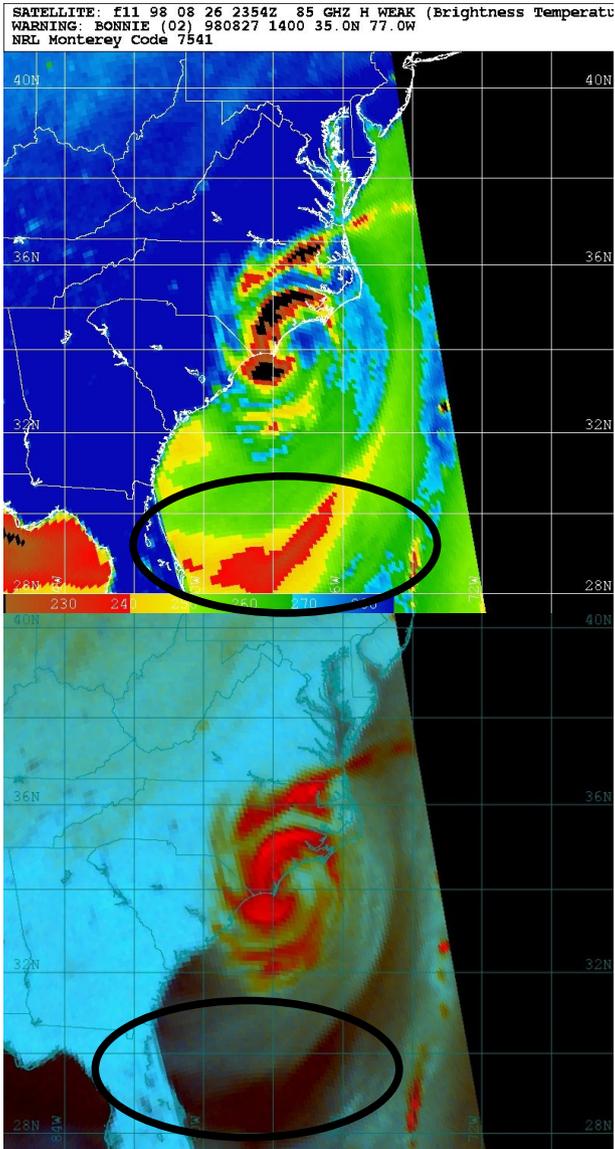


37Color

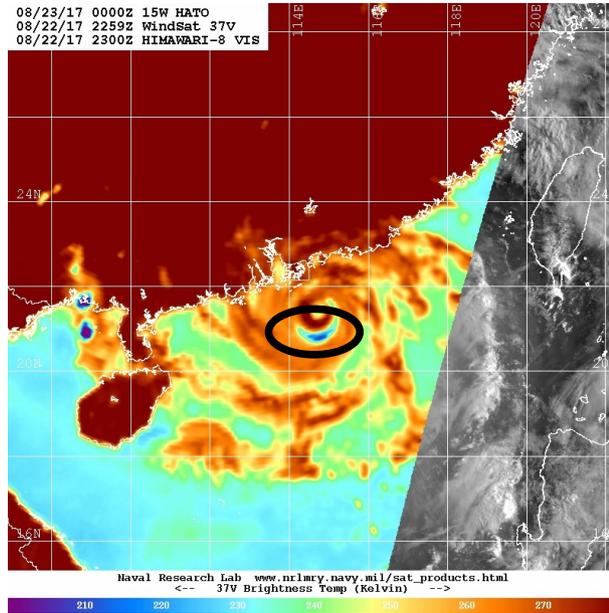


Passive micro-wave imagery

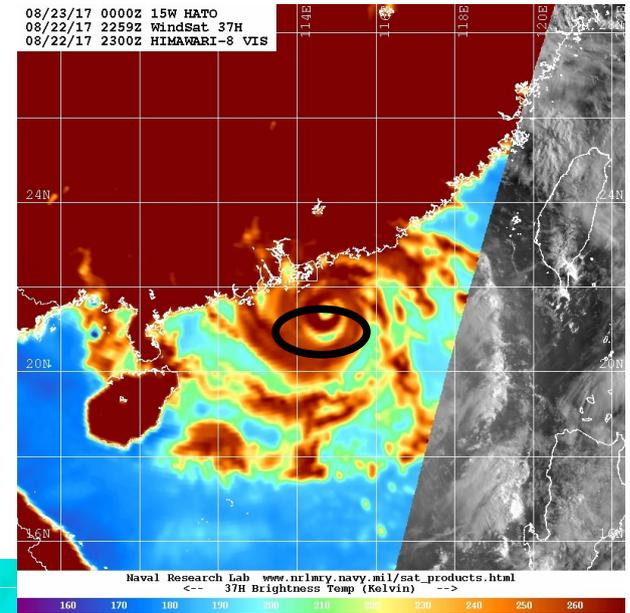
89h/89weak



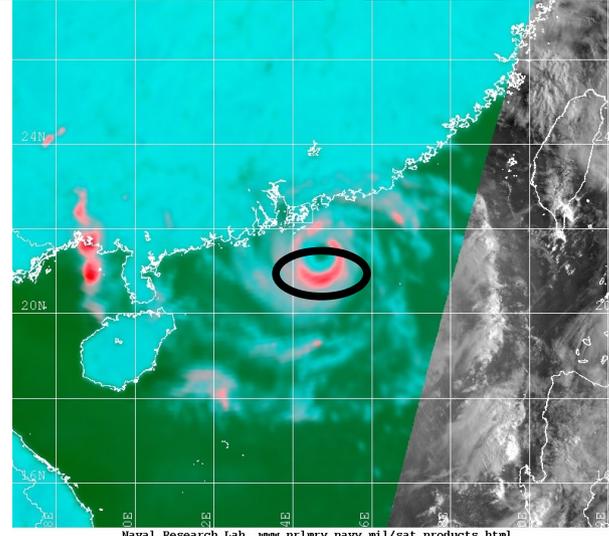
37v



37h



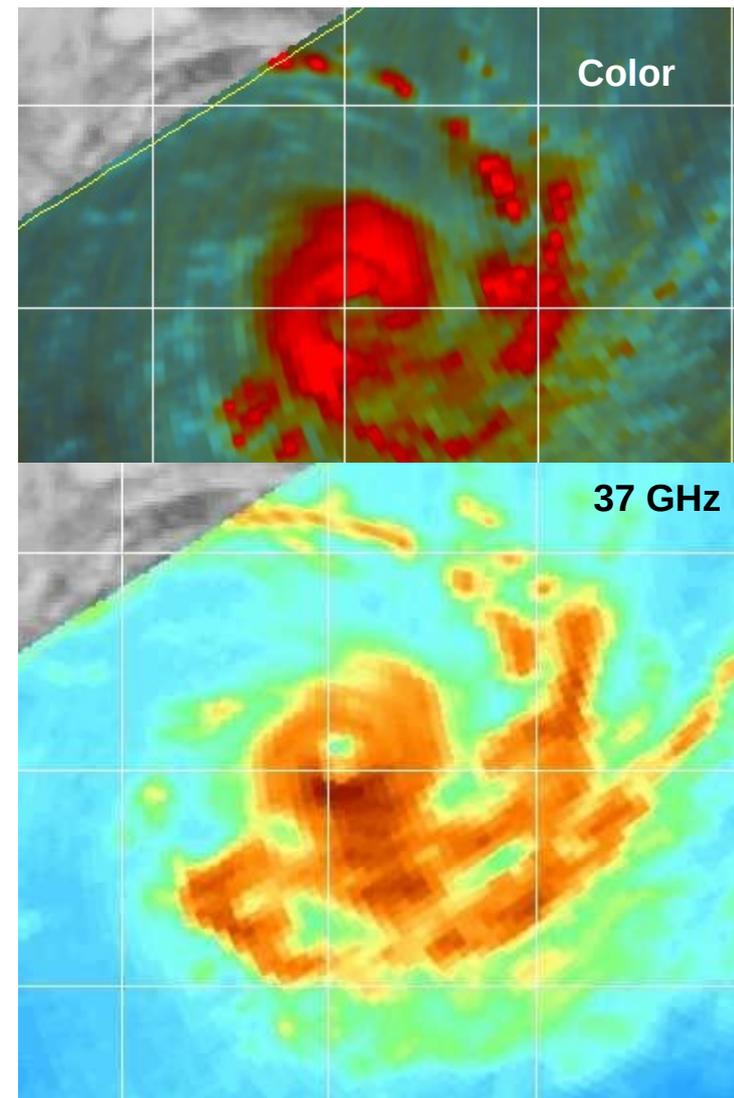
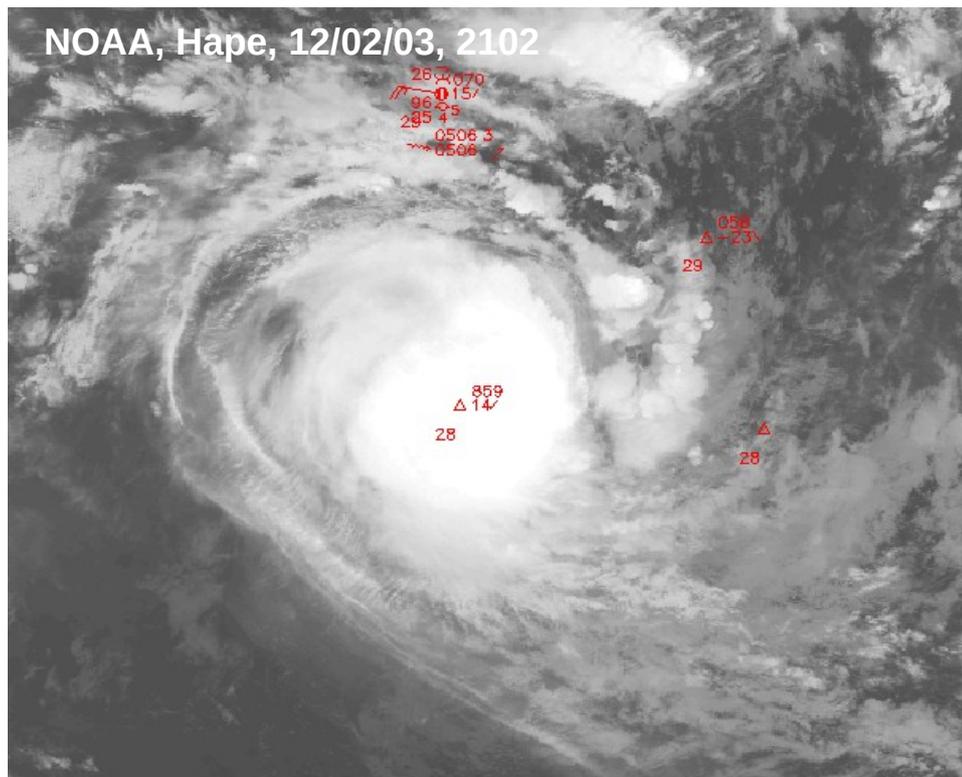
Color



37Color

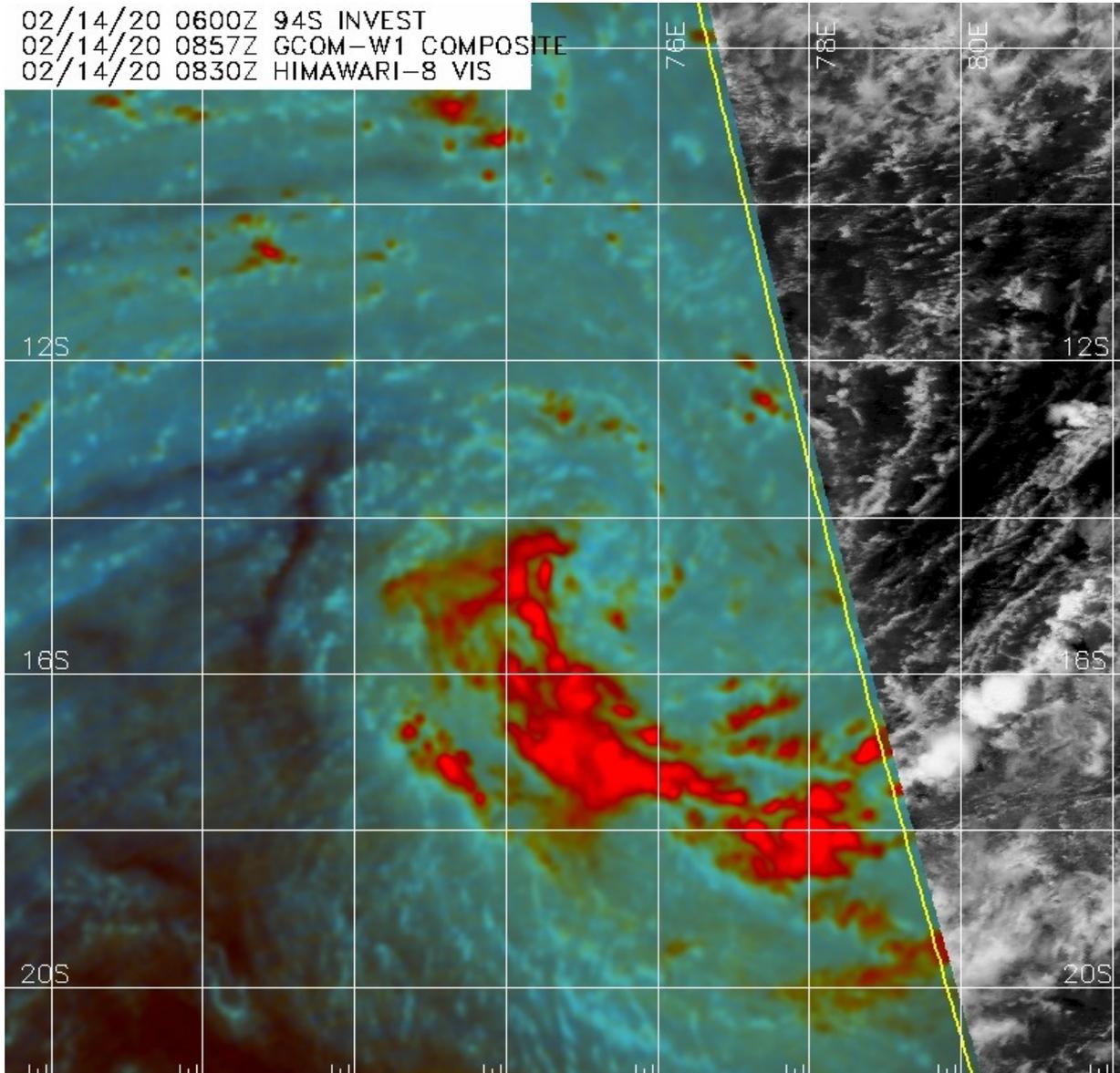
Passive micro-wave imagery

- Essential tool to locate the center precisely:
 - CDO/sheared cloud pattern
 - At the beginning/end of TC lifecycle



Passive micro-wave imagery

02/14/20 0600Z 94S INVEST
02/14/20 0857Z GCOM-W1 COMPOSITE
02/14/20 0830Z HIMAWARI-8 VIS

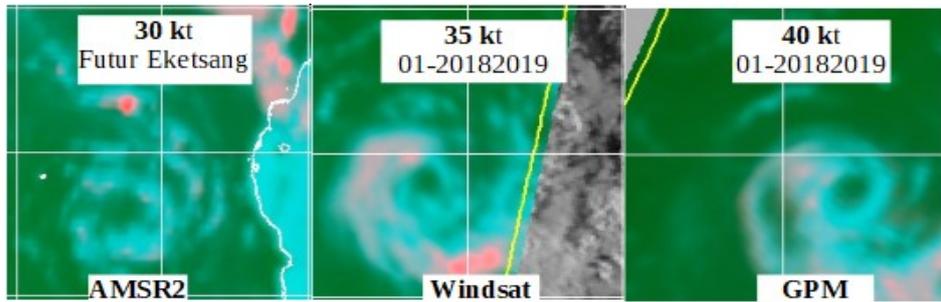


Where is the center ?

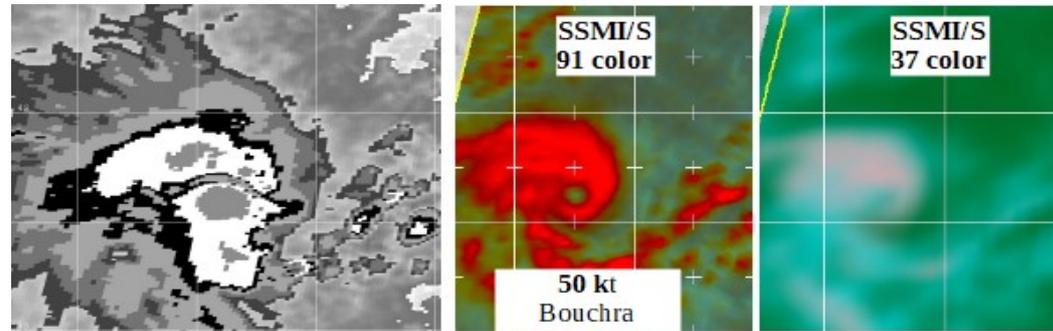
Early stage of Gabekile (février 2020)

Passive micro-wave imagery

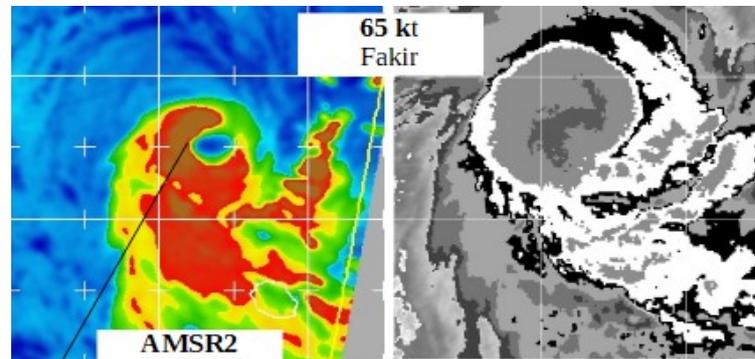
- Witness the inner-core structuring and intensification :



Well-defined eye in 37 GHz / No eye in 85 GHz / No eye in conventional imaging → MTS (gale force winds)



Well-defined eye in 85 GHz / vertical alignment / No eye in conventional imaging → STS (storm force winds)



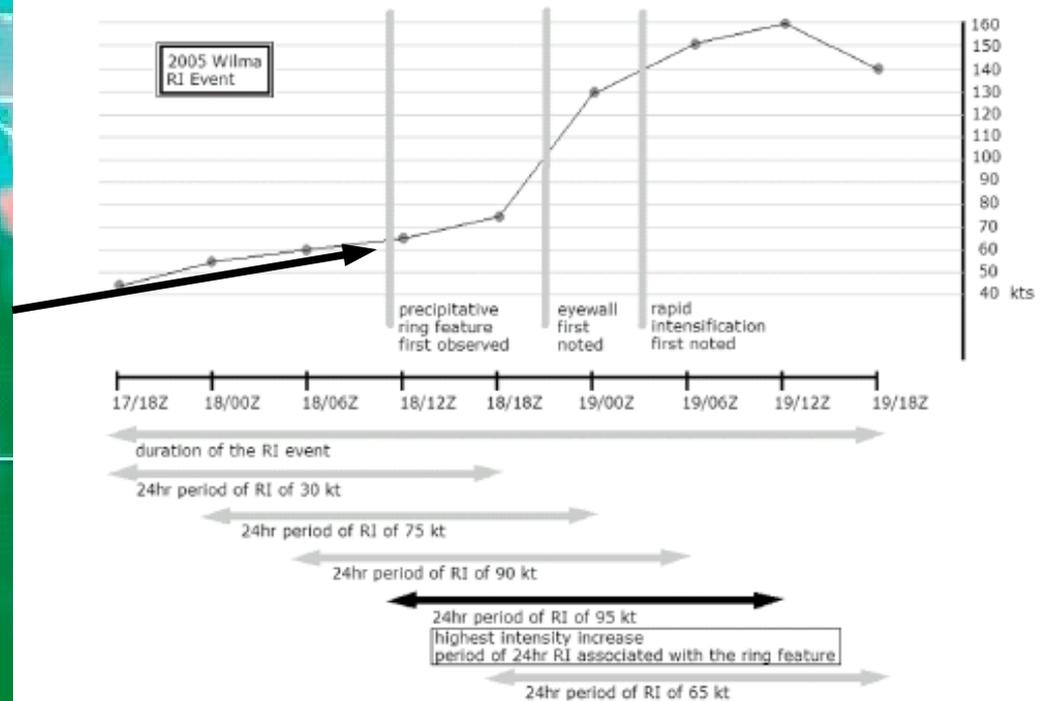
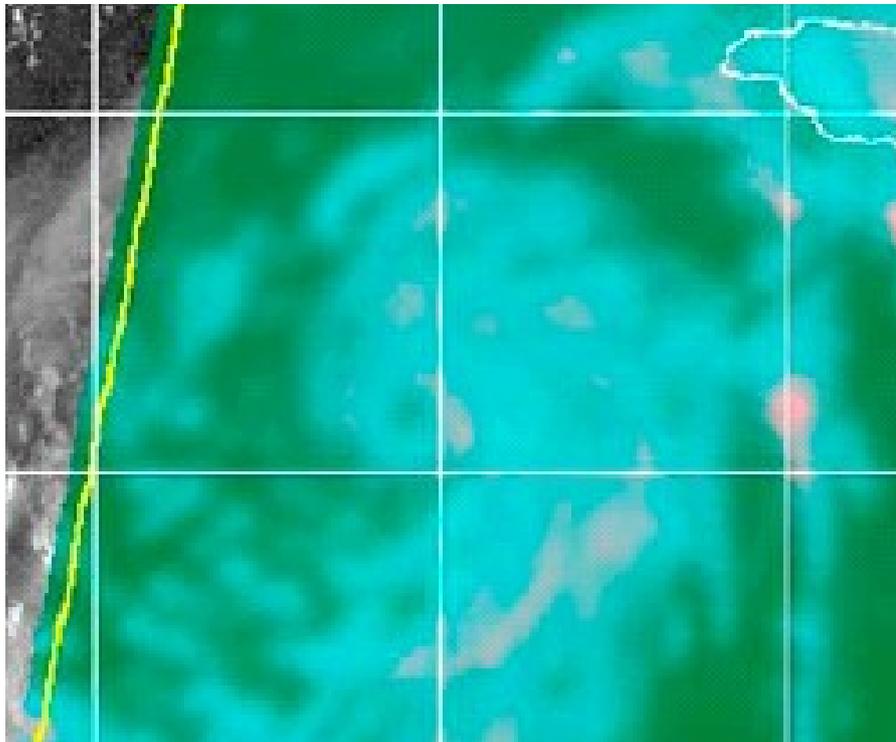
Well-defined eye in 85 GHz / Very low Tb on large part of RMW in 85 H / No eye in conventional imaging → TC (hurricane force winds)

Naval Research Lab www.nrlmry.navy.mil/sat_products.html
 <-- 89H Brightness Temp (Kelvin) -->

190 200 210 220 230 240 250 260 270

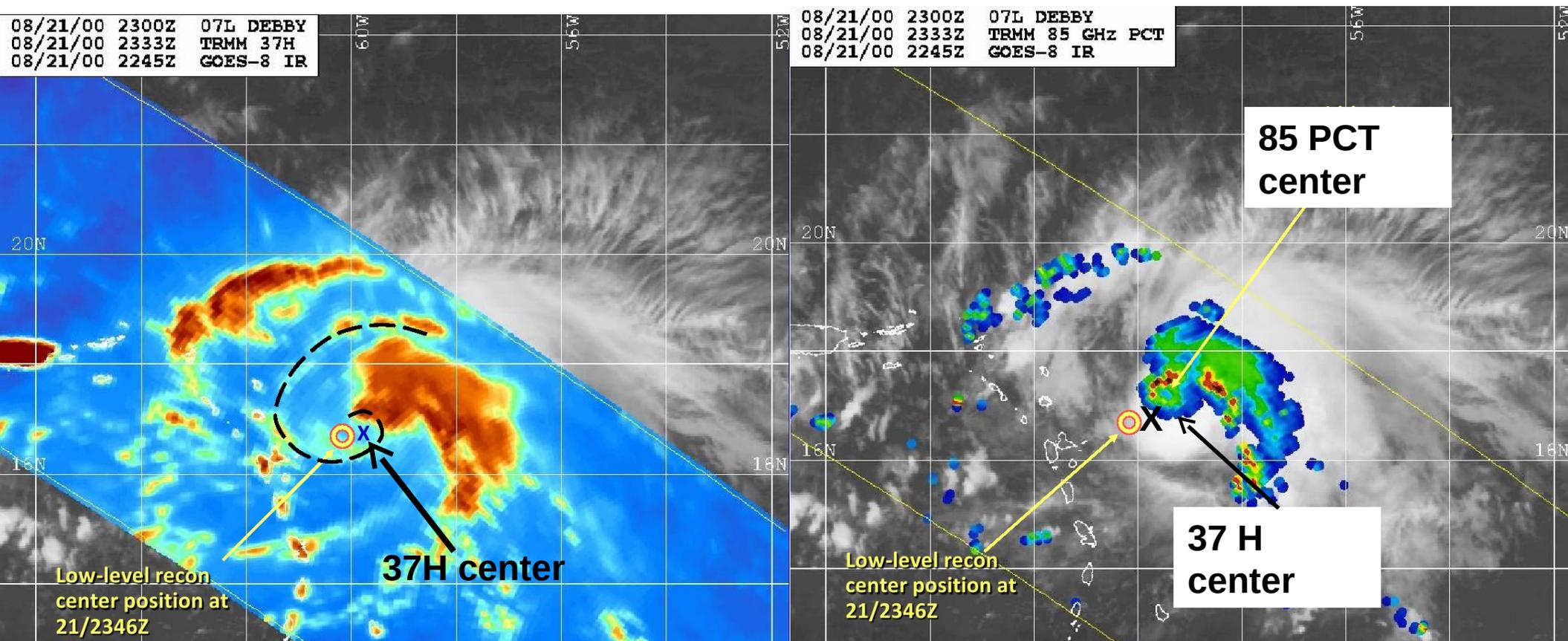
Passive micro-wave imagery

- Rapid intensification predictor (Cyan ring)
 - Kieper (2012): risk of rapid intensification within 24 hours



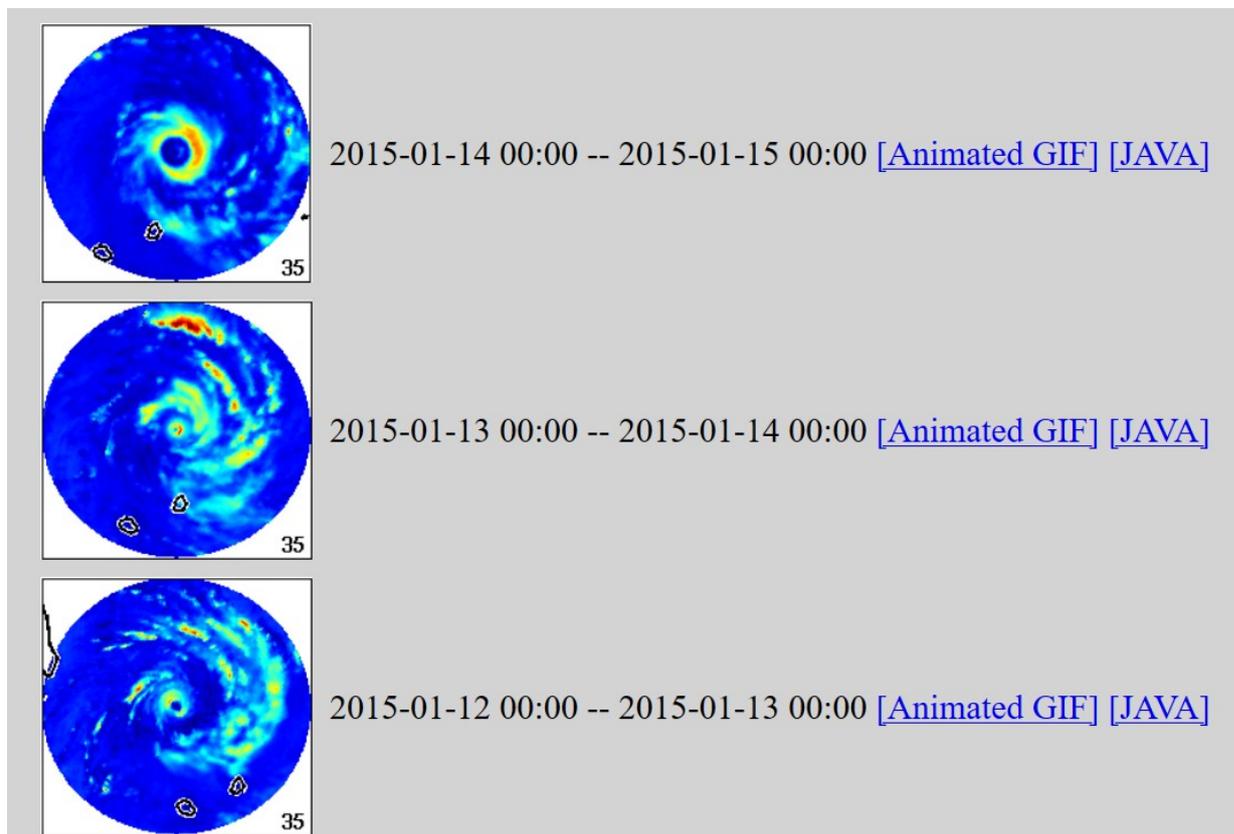
Passive micro-wave imagery

- Revealing the tilt of the cyclonic vortex in a sheared environment.



Passive micro-wave imagery

- MIMIC-TC :
 - Morphing animation of 89GHz data:
 - ▶ Bansi 2015



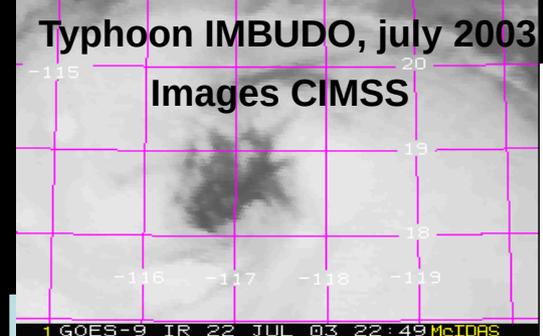
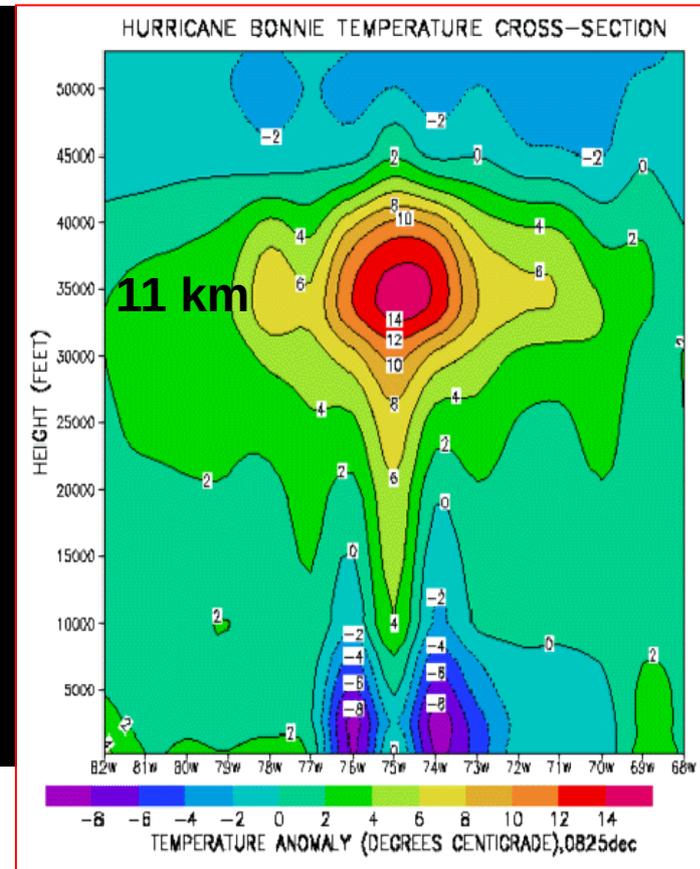
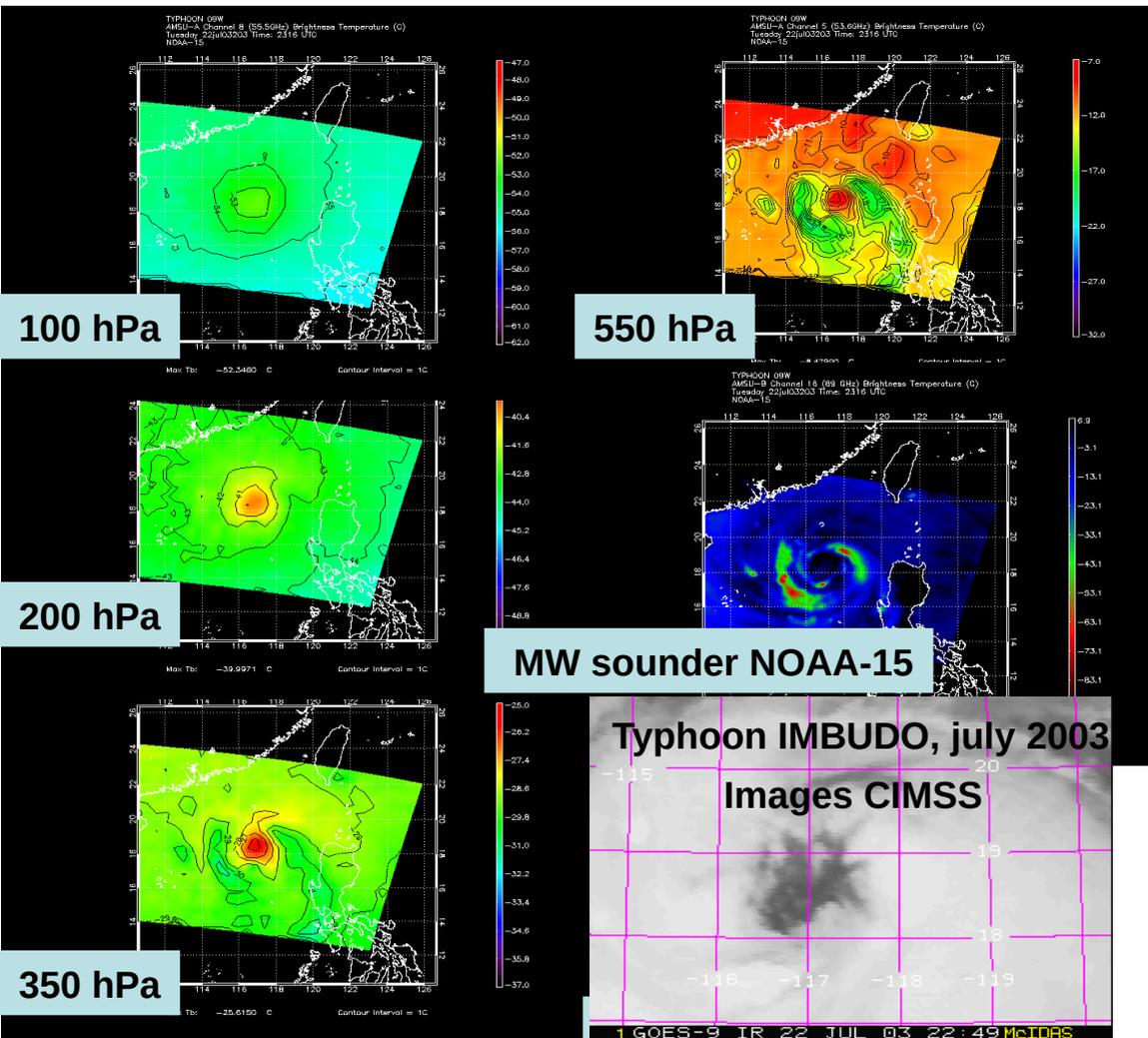
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Microwave sounders

- AMSU, ATMS, SSMIS :

An objective way to estimate the intensity of a system based on the magnitude of the warm core as seen by a sounder



Microwave sounders

- AMSU :
2 institutes develop operational algorithms : CIMSS, CIRA

Western North Pacific/Indian Ocean

Select Named Storm:

- 16W
- 17W USAGI
- 16W MANYI
- 13W TORAJI
- 14W KONG-REY
- 13W
- 12W TRAMI
- 11W UTOR
- 10W MANGKHUT
- 09W JEBI
- 08W CIMARON
- 07W SOULIK
- 06W RUMBIA
- 05W BEBINCA
- 04W LEEPI
- 03W YAGI
- 01B
- 02W
- 01W

AMSU-B
89 GHz

AMSU-A
CROSS SECTION

AMSU algorithm change log

What is the CIMSS AMSU Tropical Cyclone Intensity Algorithm?

Current Intensity

CIMSS/NESDIS-USAF/NRL AMSU TC Intensity Estimation:
 SUPER TYPHOON 17W
 Thursday 19sep13 Time: 2052 UTC
 Latitude: 18.00 Longitude: 126.23
 Storm position corresponds to AMSU-A FOV 9 [1<--->30]

Estimated MSLP:	924 hPa
Estimated Maximum Sustained Wind:	124 kts
Estimate Confidence:	Good (+/- 10mb +/- 12kts)

Storm is sub-sampled: Bias correction applied is -13 hPa
 Channel 8 (~150 hPa) Tb Anomaly: 4.71
 Channel 7 (~250 hPa) Tb Anomaly: 4.71
 RMW: 11 km
 RMW Source is: MW
 Environmental Pressure: 999 (Climo)
 Satellite: NOAA-15
 ATCF data for Month: 09 Day: 20 Time (UTC): 0000

For imagery, go to <http://amsu.ssec.wisc.edu/nwpac32.html>
 For all comments and questions <mailto:chrisv@ssec.wisc.edu>

201317W IMBD: 0919 183Z: 2013 Time(UTC): 2052 NOAA-15
 AMSU-A Brightness Temperature Anomaly (Storm Center-Environment)
 Vertical red line indicates approx location of TC/Insect
 Approx latitude of cross section is 18.50

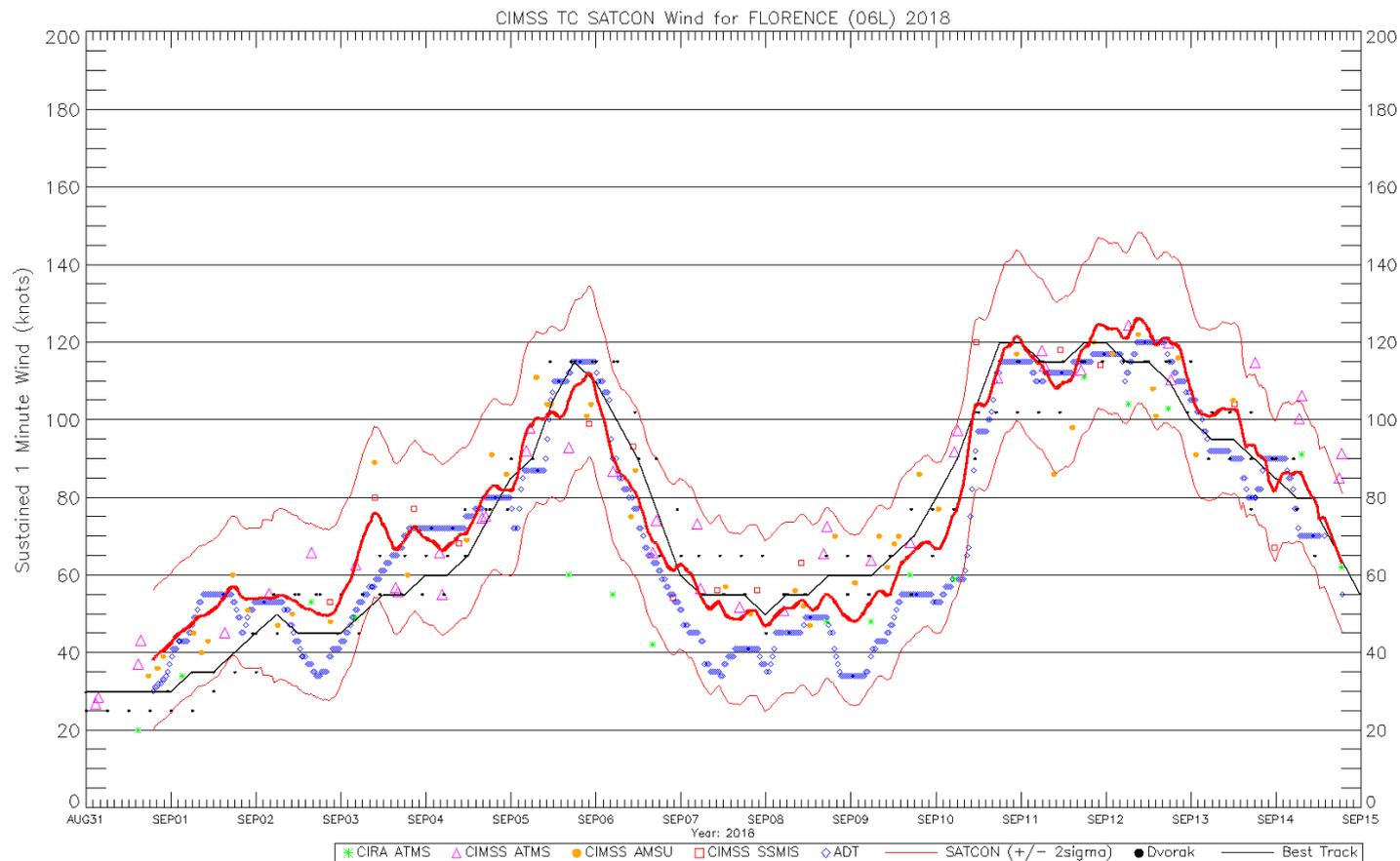
Pressure (hPa)

Longitude

Contour Interval = 0.5K

Weighted consensus of objective satellite estimates

- **SATCON** : **SAT**ellite **CON**sensus → estimates of TC Vmax/MSLP
 - Calibrated consensus of several objective intensity estimators: ADT (automatic Dvorak) & Probes (AMSU, SSMIS, ATMS)
 - Optimized for cloud configuration / TC life cycle



Weighted consensus of objective satellite estimates

- **SATCON** : SATellite CONsensus
 - Better scores than its components (2006-2015)

N = 4097	CIMSS AMSU	CIMSS ADT	SSMIS/ ATMS	SATCON
BIAS	-3.9	-1.6	-2.2	-0.2
AVG ERROR	9.7	10.0	8.6	7.2
RMSE	12.5	12.8	11.2	9.1

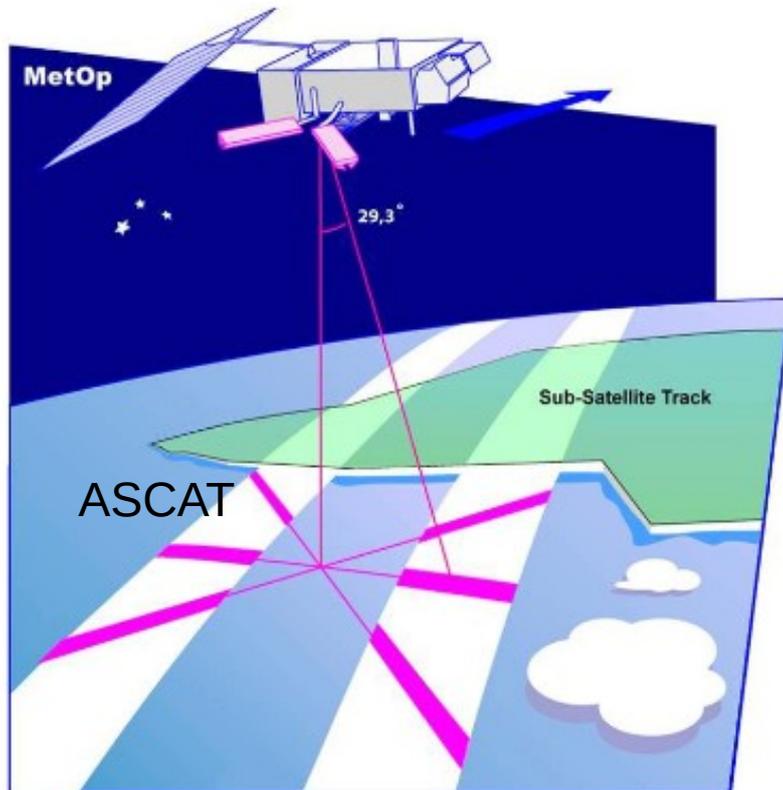
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Remote sensing of strong / extreme winds

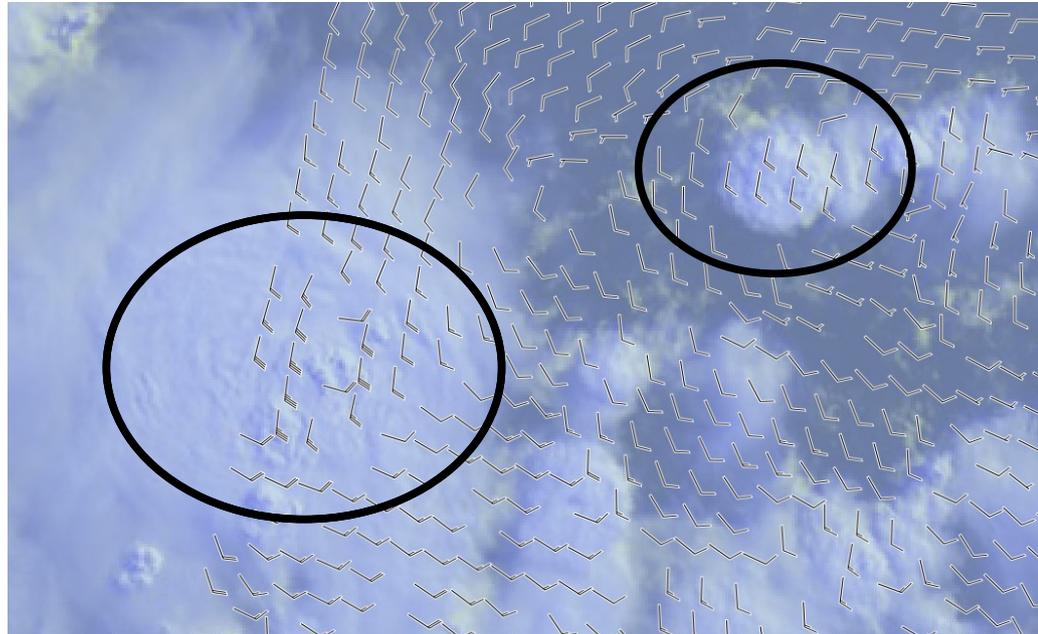
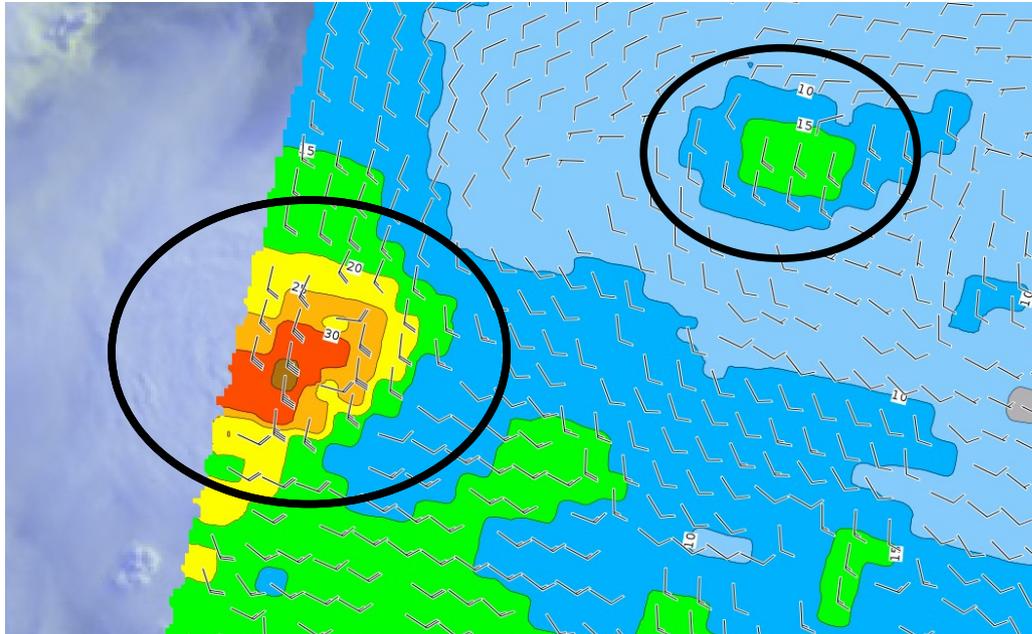
■ Principle :

- Diffusiometer: microwave radar measuring the signal backscattered by capillary and gravity waves on the sea surface
- The analysis of the signal backscattered by the same ocean surface seen from different angles by the satellite allows to calculate the strength and direction of the wind.
- The measurement is disturbed by any phenomenon that destroys the capillary waves: rain, very weak or very strong winds.
- Wind direction ambiguity: removed with model data

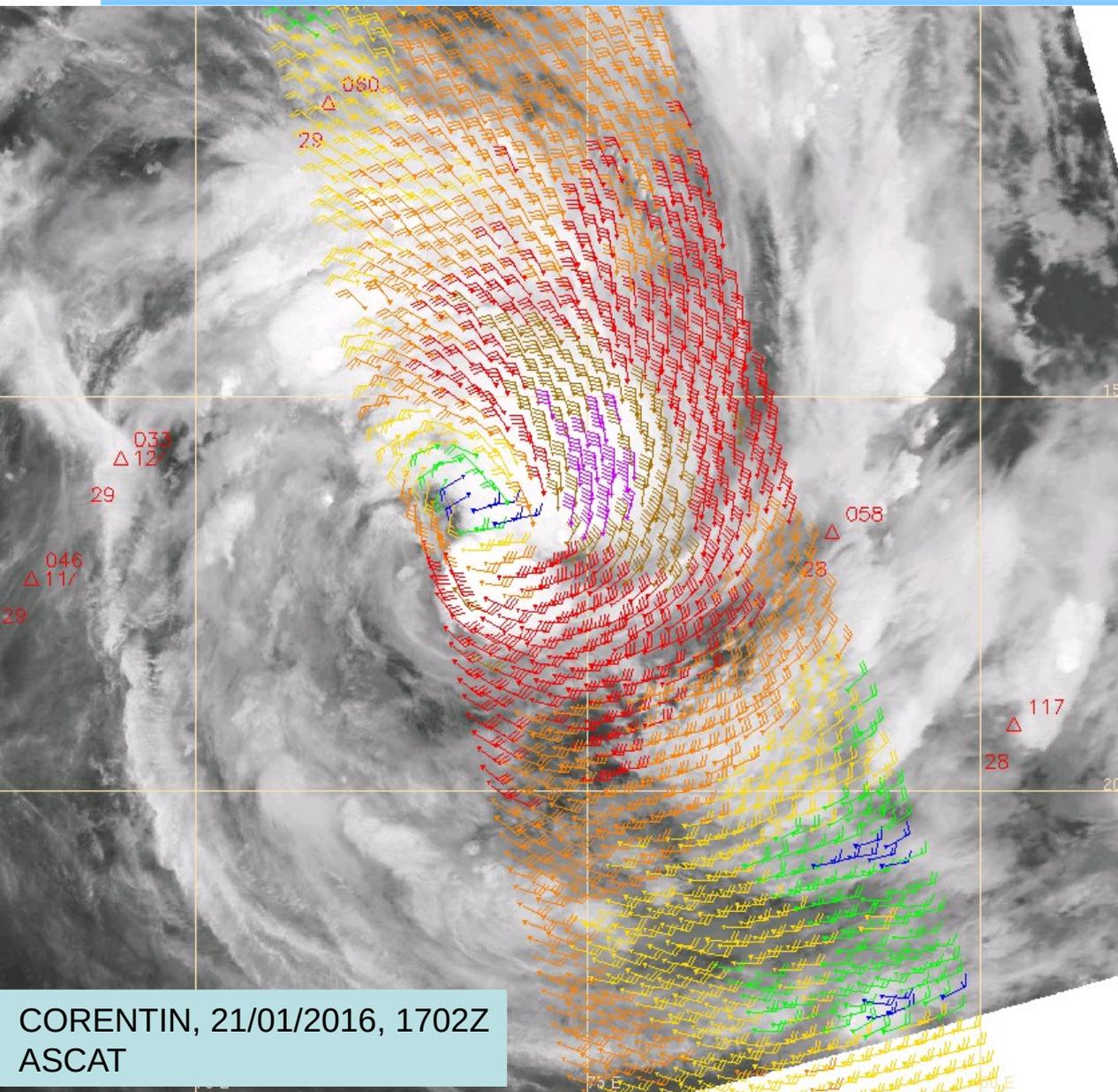


Remote sensing of strong / extreme winds

Example of the influence of heavy rainfall in light wind conditions → erroneous measurements



Remote sensing of strong / extreme winds



- ASCAT A, B and C (Metop - EU)
Best resolution at 12.5 km
Passage ~06Z and ~18Z
→ **ASCAT-A discontinued on 15/11/21**

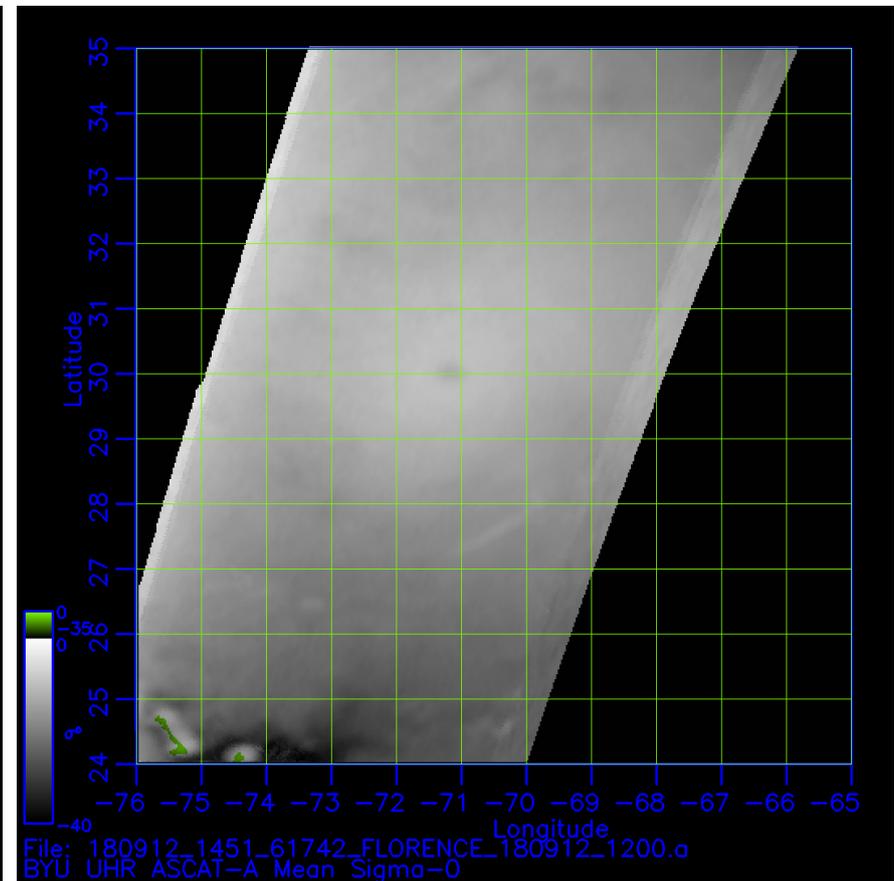
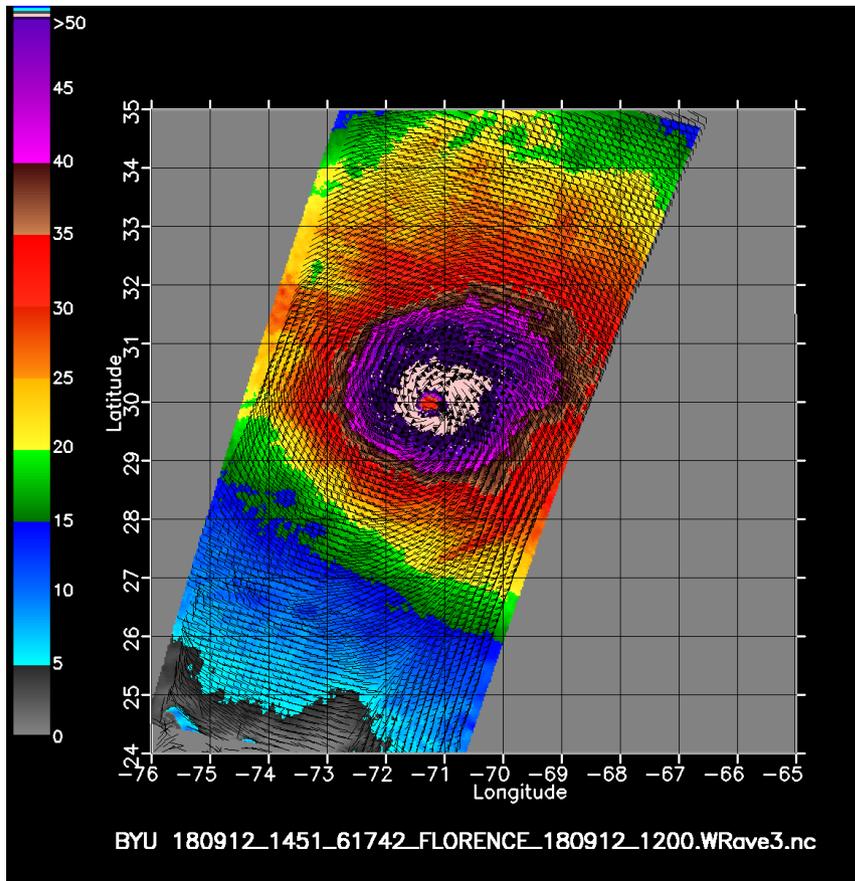
- HSCAT 2B, 2C - (HY 2B, 2C - CHINA)
Best resolution at 25 km
Status : development
Passage to ~00Z ~12Z

Interest in cyclone monitoring :

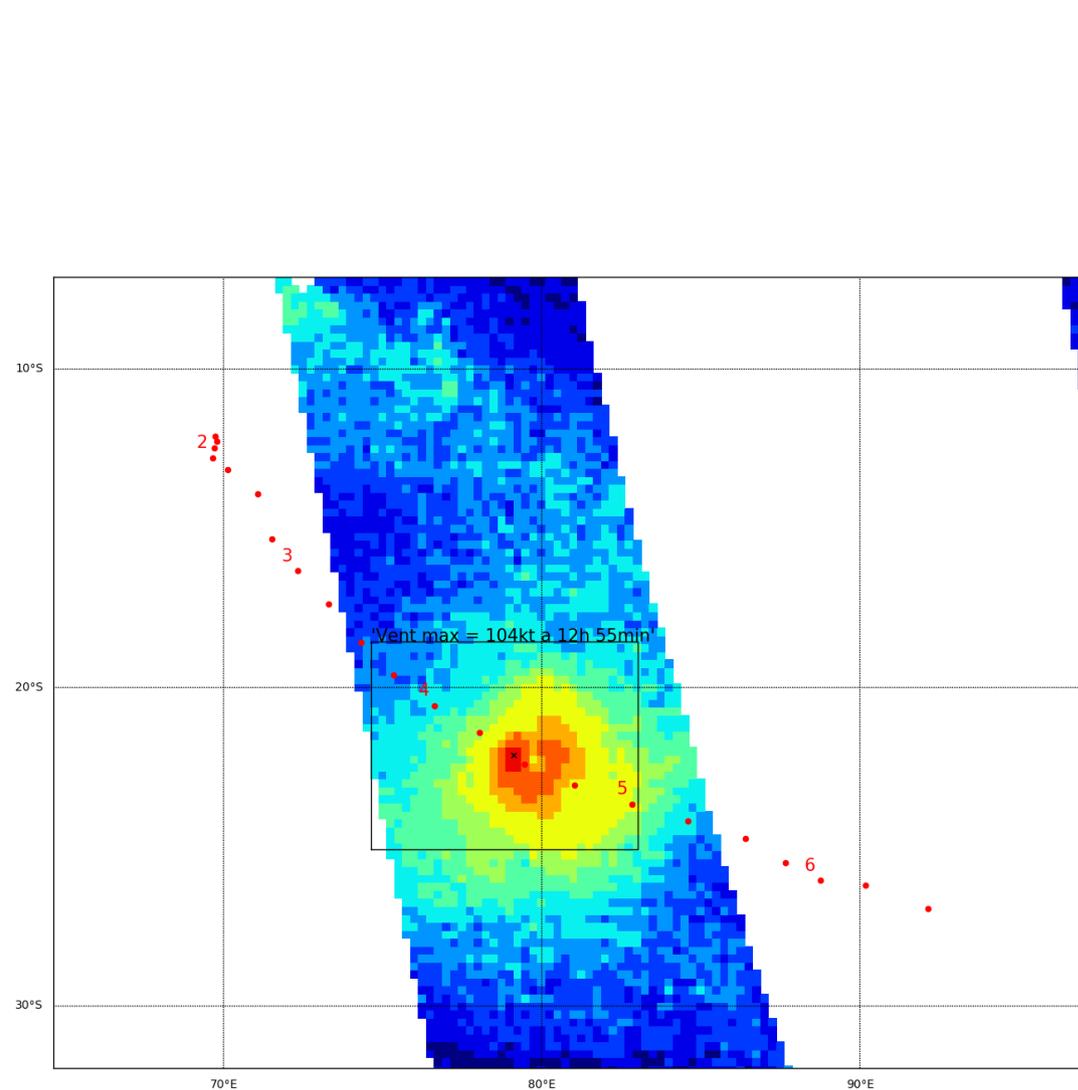
- Center fixing
- Intensity (range: 20 → 40 kt, can be used to assess the existence of storms or even hurricanes winds), but **beware resolution regards to system size**
- Winds radii assessment (near gale, gale, ~ storm force winds)

Remote sensing of strong / extreme winds

- **Manati** : High resolution product based on backscattered signal (windspeed retrieval)



Remote sensing of strong / extreme winds SMOS/SMAP (Soil Moisture Active Passive)



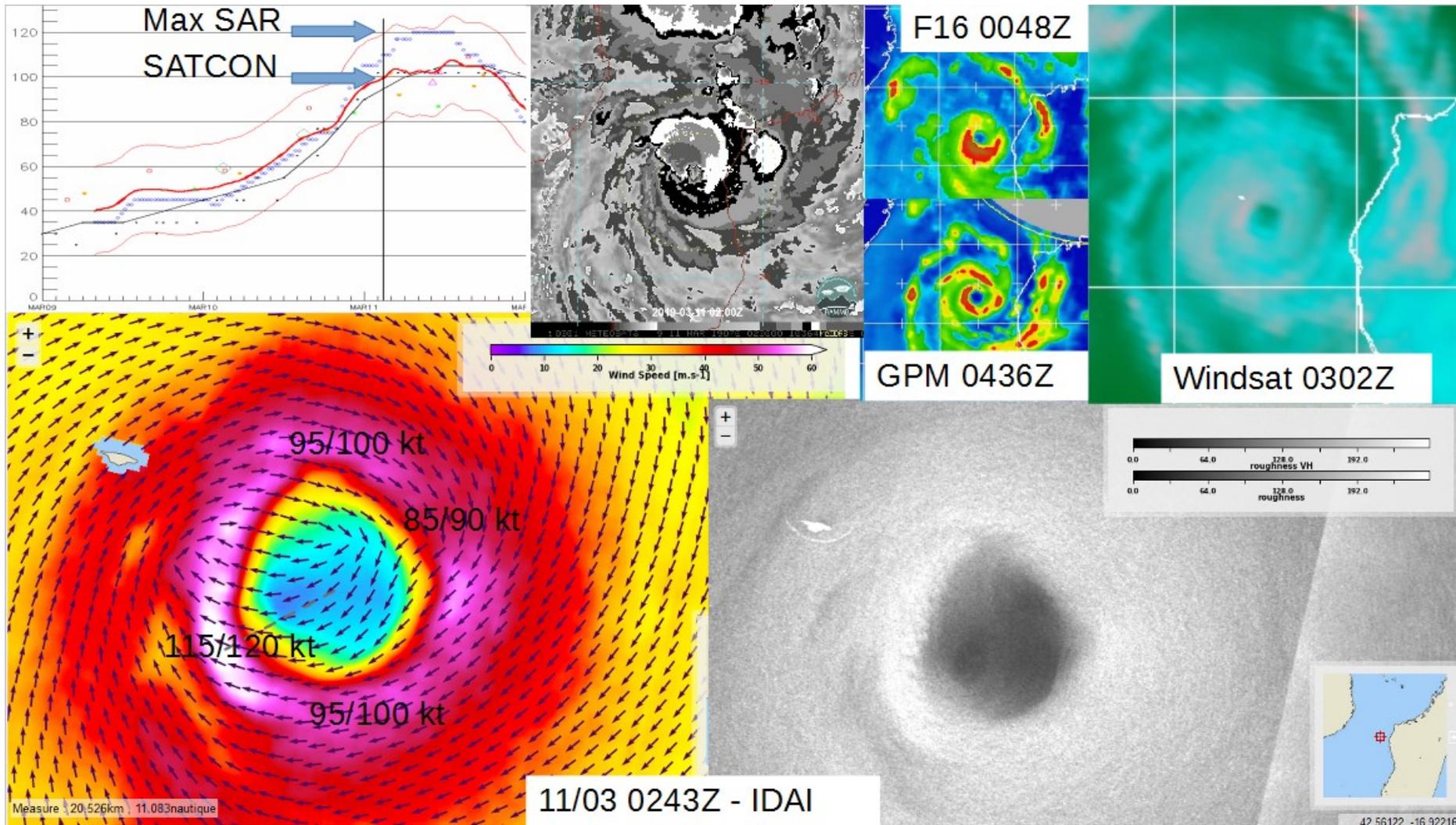
→ Passive low freq microwave radiometer sensitive to very high winds while being less affected by rain

→ Loose resolution (~40 km) but calibration to be able to estimate winds over 100 kt ...

→ Several hours between the satellite pass and the availability of wind products ...

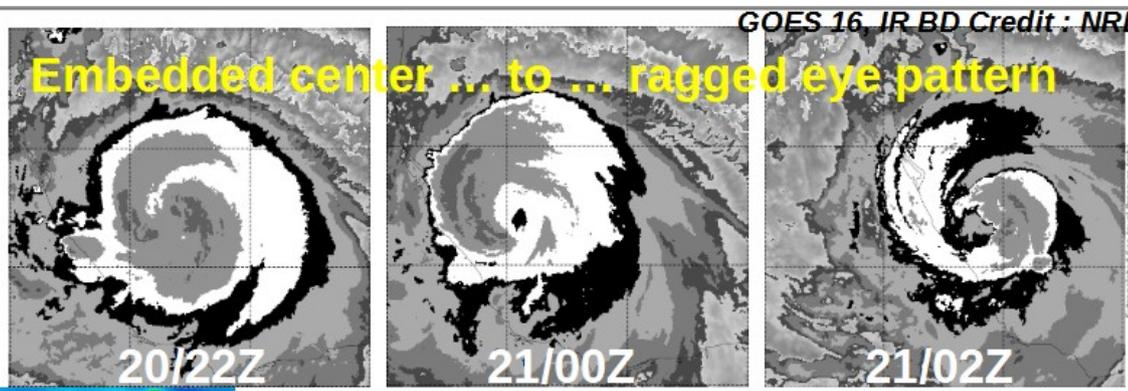
Remote sensing of strong / extreme winds

SAR (Synthetic Aperture Radar) = Ascat HD

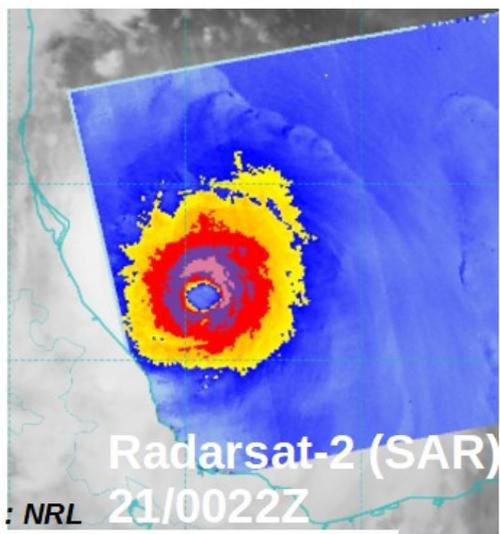
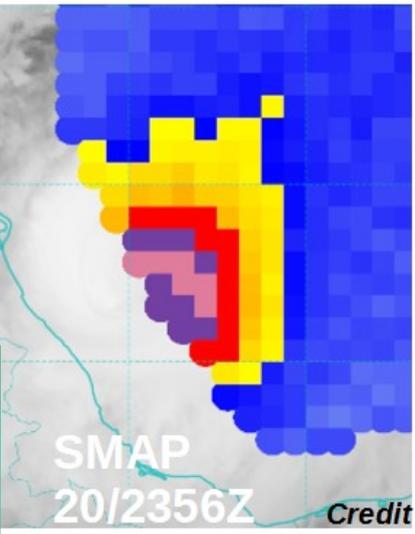
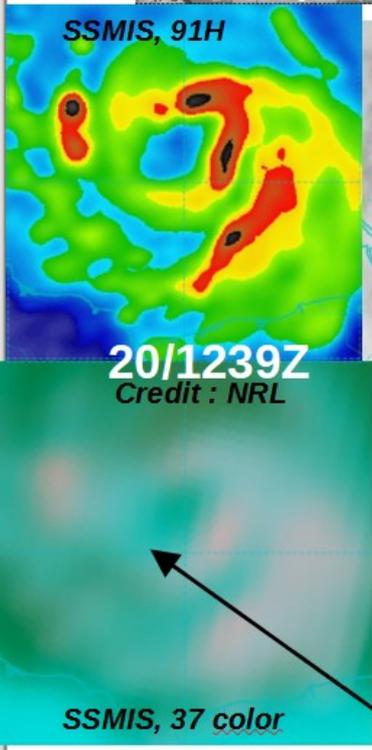
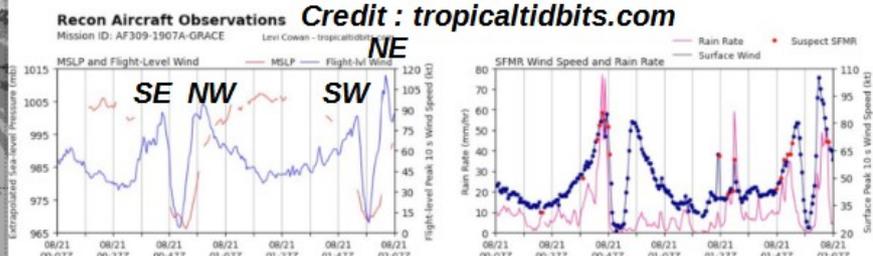


Remote sensing of strong / extreme winds

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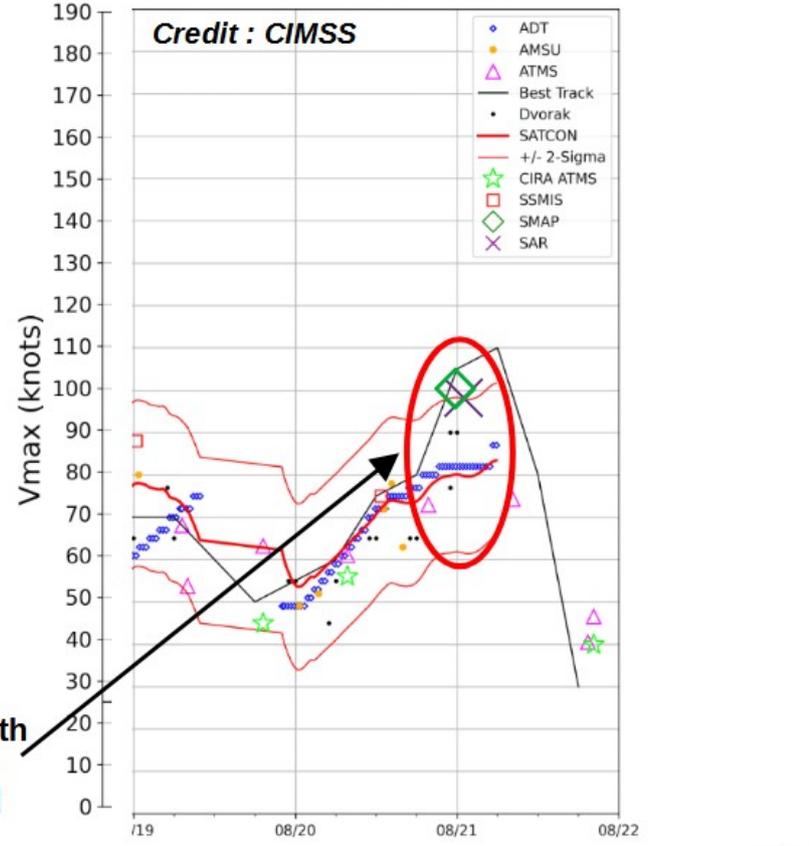


Hurricane GRACE August 2021, NATL

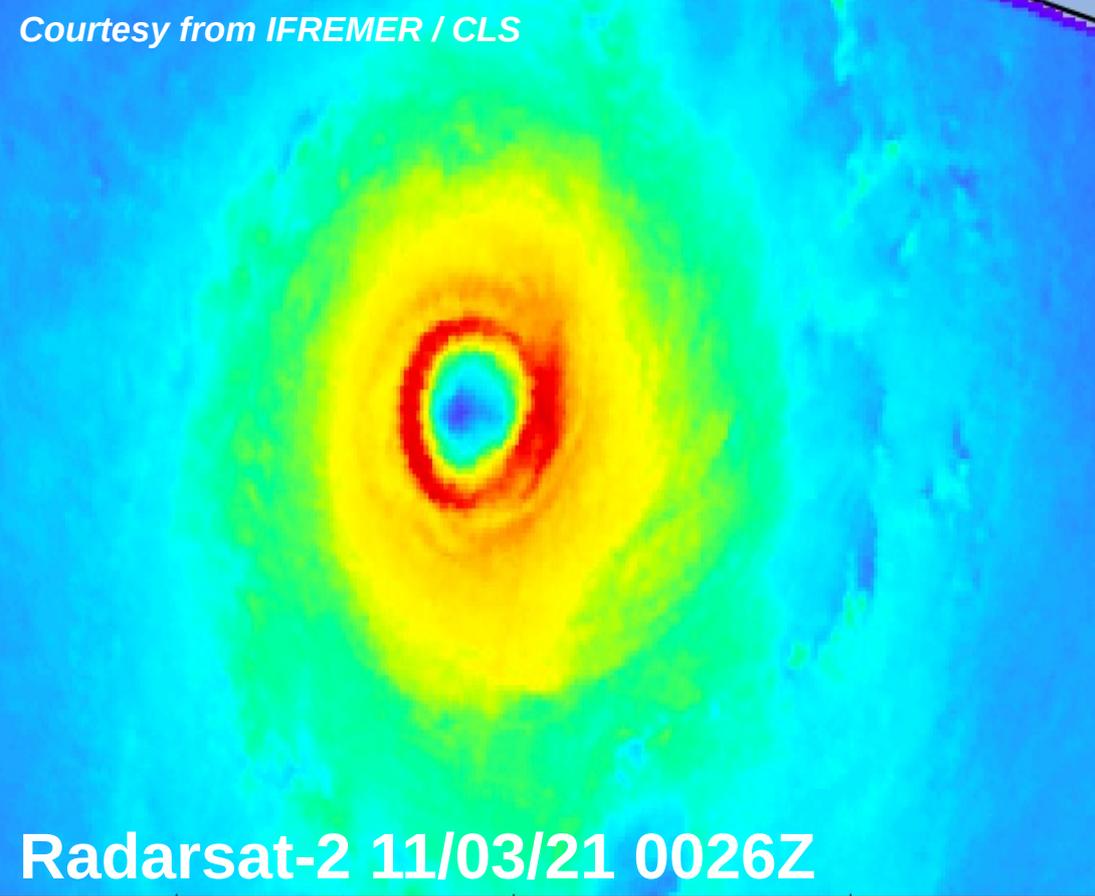


Early sign of RI on 37 GHz imagery (cyan ring)

SAR/SMAP agree with aircraft obs, obj/sub guidance lag behind

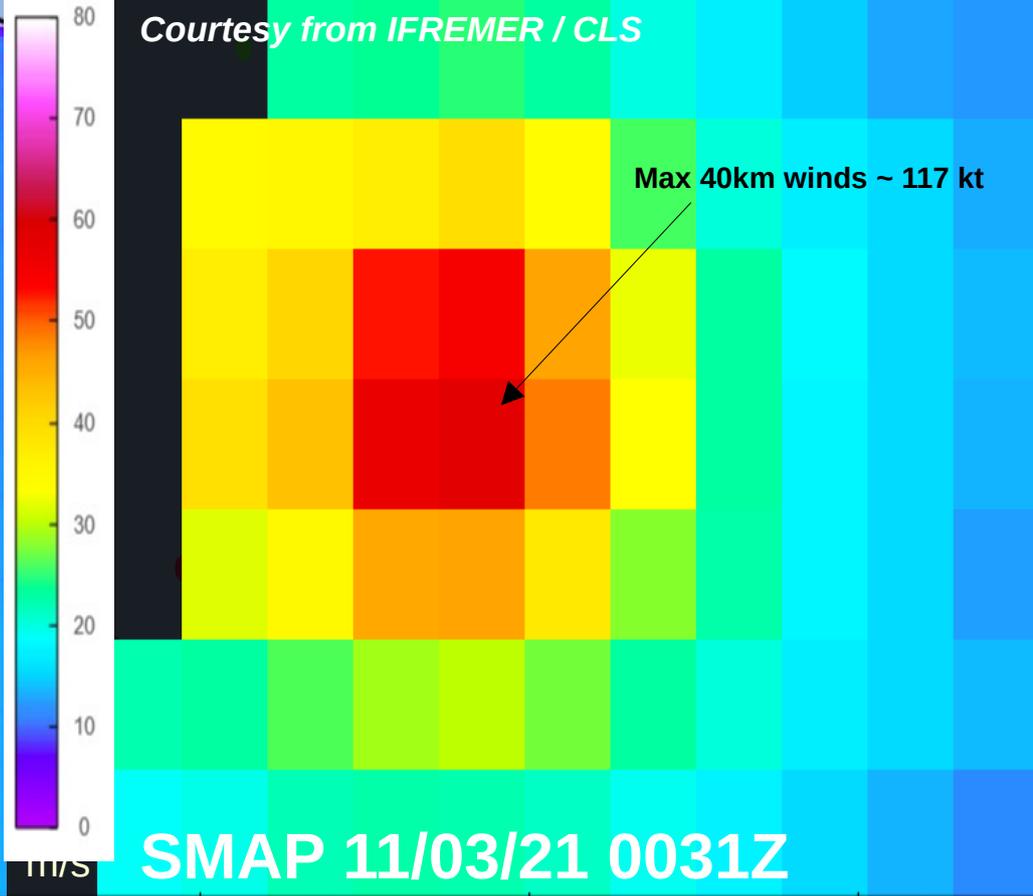


Courtesy from IFREMER / CLS



Radarsat-2 11/03/21 0026Z

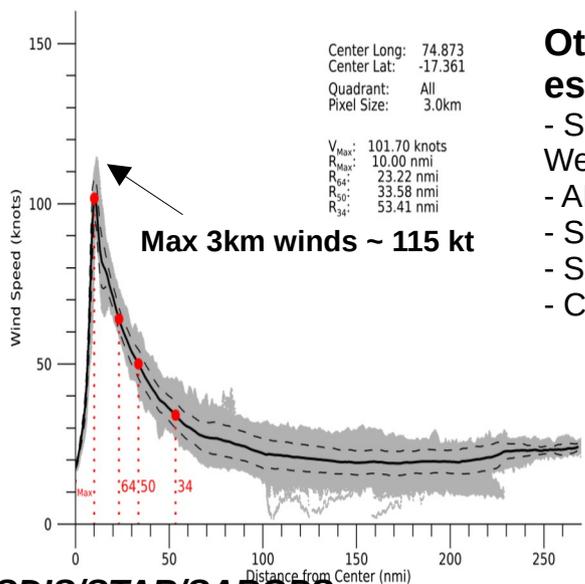
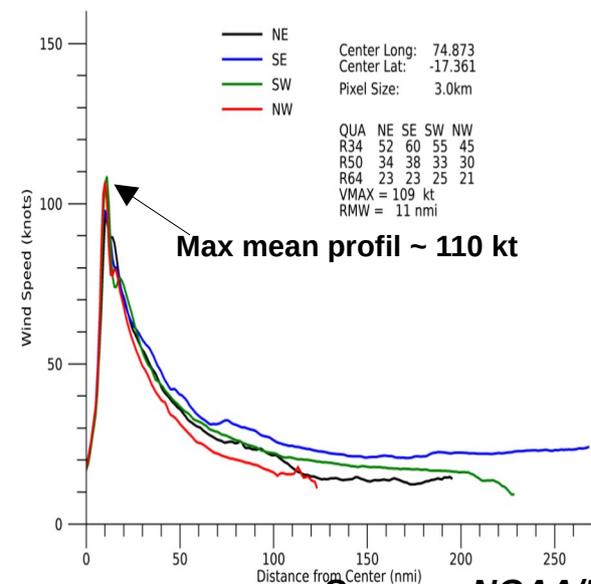
Courtesy from IFREMER / CLS



SMAP 11/03/21 0031Z

Mean Winds by Quadrant: SH242021 / HABANA
11 Mar 2021 00:26 UTC

SAR Derived Wind Speed: SH242021 / HABANA
11 Mar 2021 00:26 UTC



Other aids near 11/00Z for TC HABANA intensity estimate :

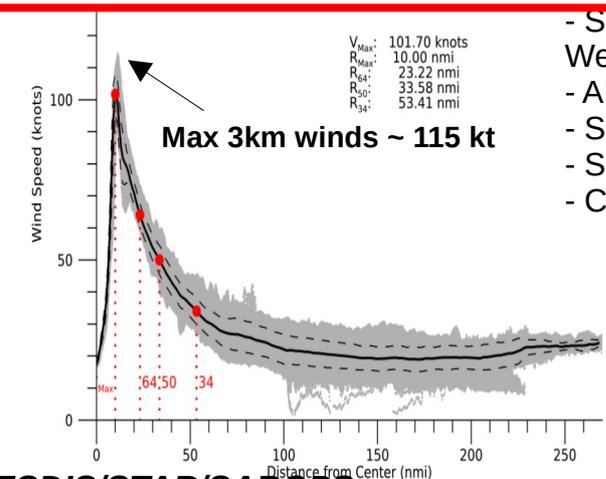
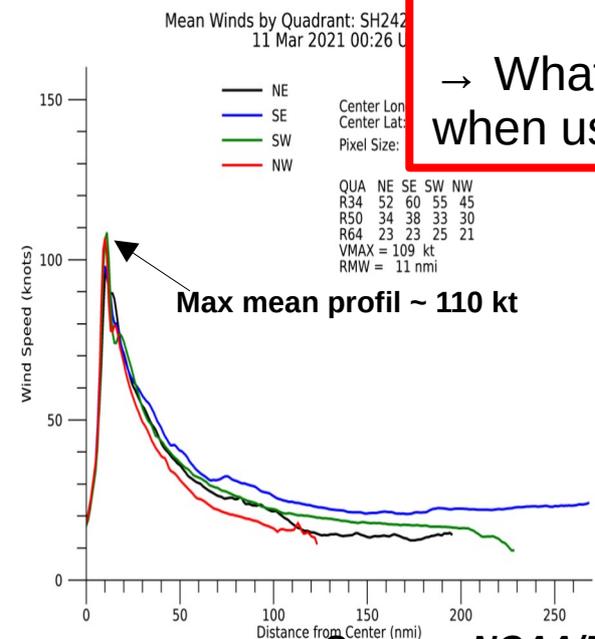
- Subj Dvorak : Ci from 6.5 (**127 kt 1'**) to 7.0 (**140 kt 1'**)
- Weakening trend (FT FMEE 6.0 / PGTW 6.5)
- ADT ~ **120/125 kt (1')**
- SSMIS / AMSU (shortly after) : resp. **130+ kt (1')** / **110/115 kt (1')**
- SATCON ~ **120/125 kt (1')**
- CIMSS ATMS (shortly before) : **115/125 kt (1')**

Source : NOAA/NESDIS/STAR/SAROPS

Radarsat-2 1

Remote sensing of extreme winds conditions era has begun
This is great news ! ... **BUT** some open questions remains :

- Estimation of error bars due to calibration/measure issues
- How do we define the intensity of a TC in the sense of a best-track (6 hrs sampling) ?
- What is the appropriate way to deal with wind averaging period when using SMAP/SMOS/SAR winds ?



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TC intensity / structure analysis in TC forecasting: an expertise

