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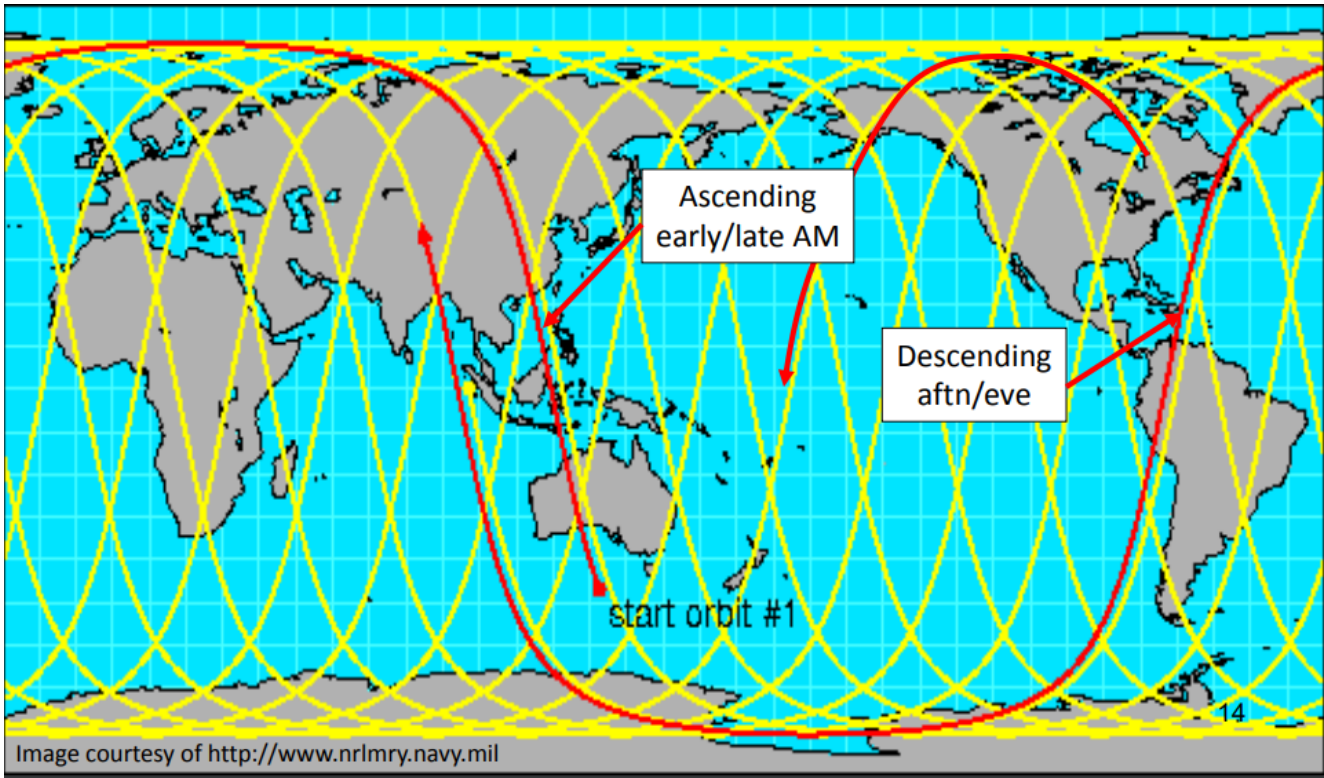
Polar orbiting satellites (cf Geostationary)
Sun-synchronous daily orbital path

~12hours to observe the entire earth

Same location twice daily (ascending /descending)

Low earth orbit (Geo at 36000km)

Delay in receiving data because of limited receiving stations



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Passive and Active instruments for measuring radiation

Passive Instruments:

– Receive radiation leaving the earth-atmosphere system

– Measure solar radiation reflected by land & atmosphere targets (visible light)

– Measure emitted and scattered IR radiation

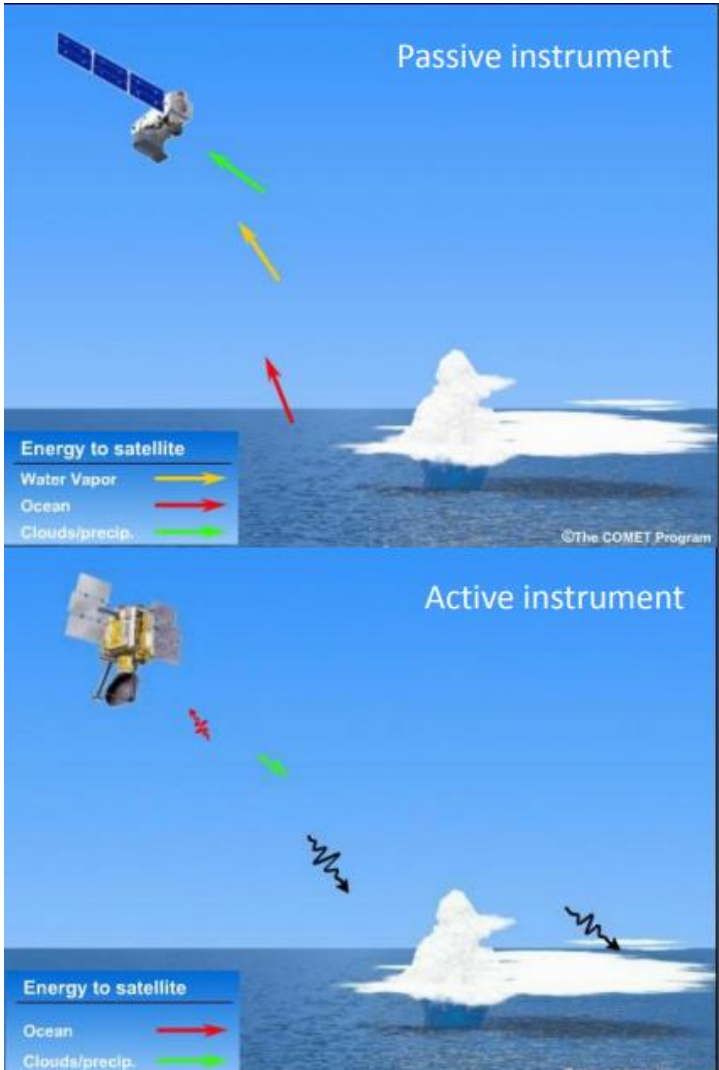
– Measure microwave radiation emission, scattering (ice); emission/absorption (liquid water in clouds) directly related to brightness Temperature

• Active Instruments:

– Send out pulses of radiation, usually at microwave frequencies

– Measure radiation returned to the sensor

– eg: radars; scatterometers



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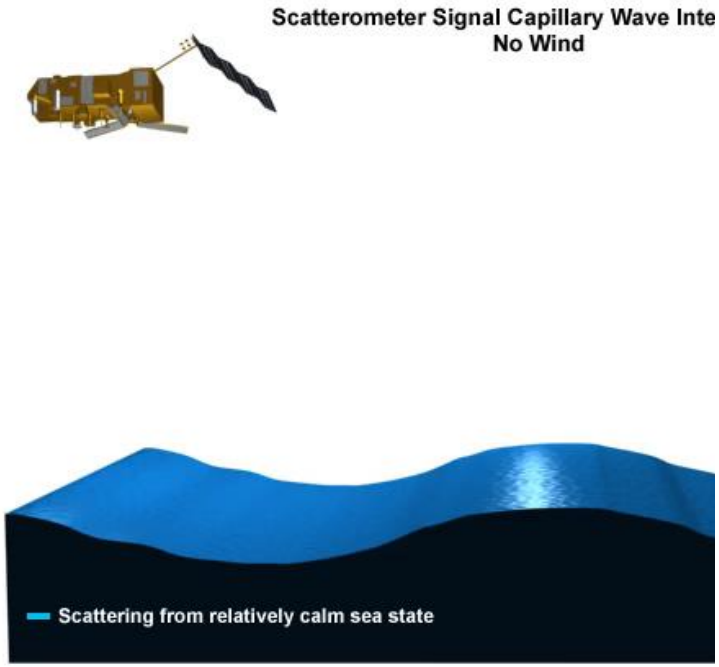
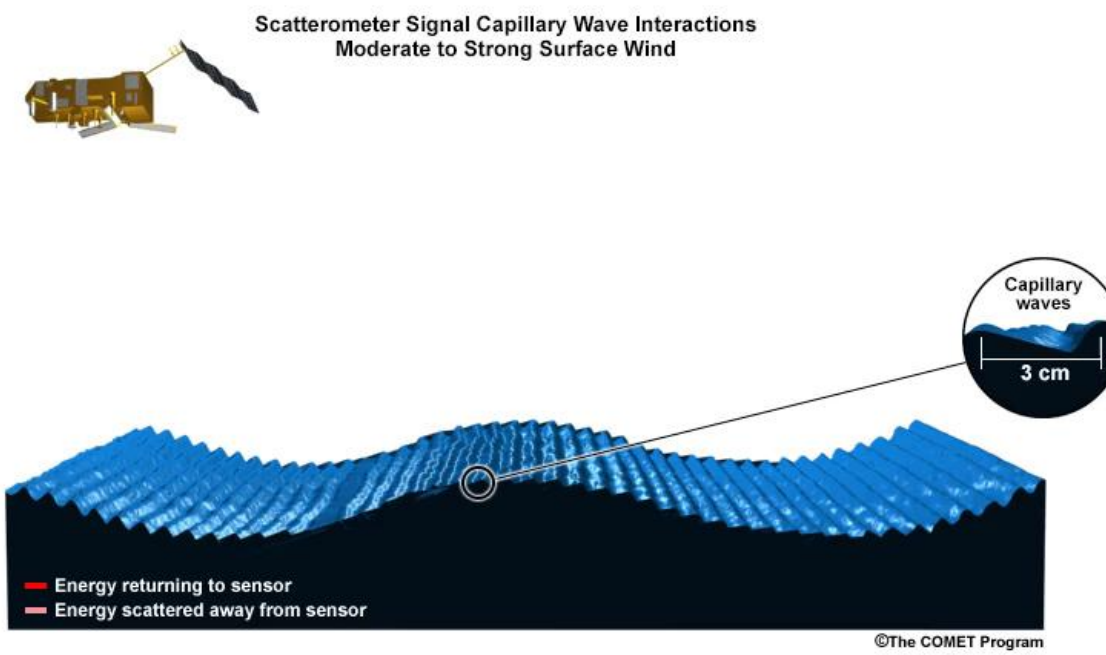
Scatterometry Theory: active sensors measure backscatter Bragg scattering

Sensors emit microwave energy and measure return signal
Small (2-4cm) capillary waves correspond to wind speed
Bragg scattering: energy at similar wavelengths scattered





Credit: COMET https://www.meted.ucar.edu/training_module.php?id=1093#.XElBfteWa71

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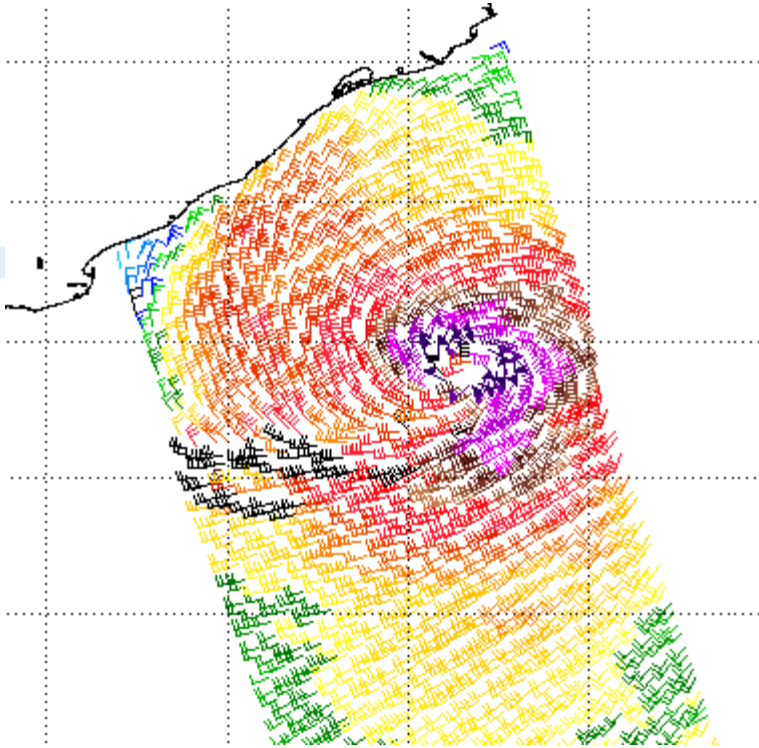
Scatterometry

http://manati.orbit.nesdis.noaa.gov/datasets/ASCATData.php



ASCAT: on METOP-A, B and C satellites

see:http://manati.orbit.nesdis.noaa.gov/datasets/ASCATData.php/

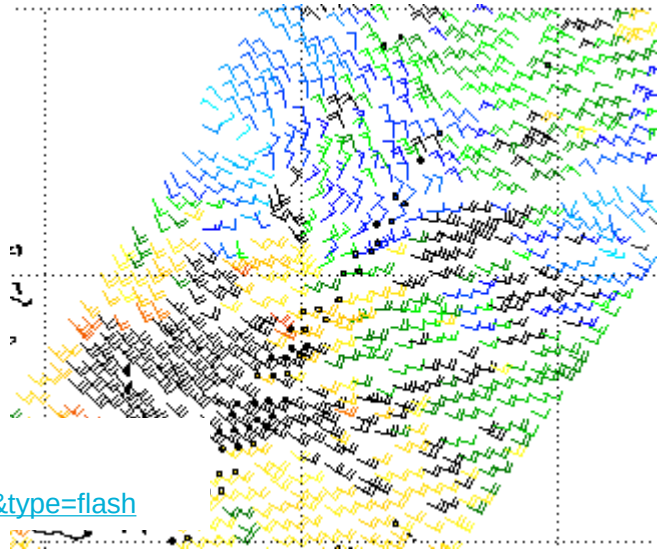
SCATSAT: more sensitive to heavy rain replaces OceanSAT similar to old Quickscat

Windsat: Very sensitive to heavy rain and so only useful in heavy rain-free areas.

AMSR-2: speed only – ok for gale extent

SMAP/SMOS:

SAR: high quality but not yet real-time in easy view



COMET Training package:
https://www.meted.ucar.edu/EUMETSAT/marine_forecasting/navmenu.php?tab=1&page=2-2-0&type=flash

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Advanced SCATterometer (ASCAT)

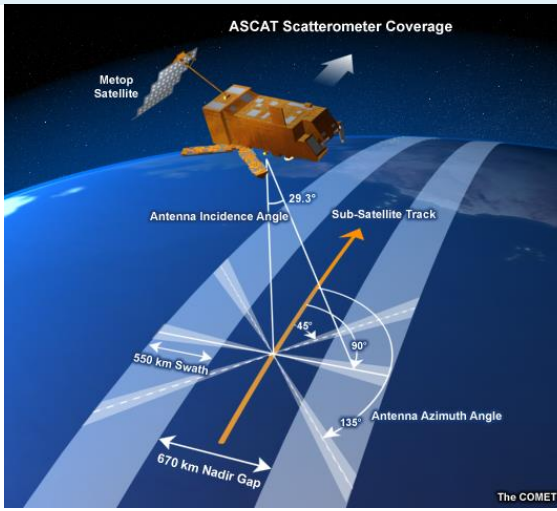
Satellite: MetOp-A (2007), B (2012), C (2018)

Channel: 5.25 GHz (5cm); C-Band

coverage: three antennas detecting two swathes 520km wide separated by ~600km underneath where insufficient energy comes back.

two passes per day (ascending/descending)

Resolution: 25-50km



TC applications:

Lack of coverage in tropics an issue

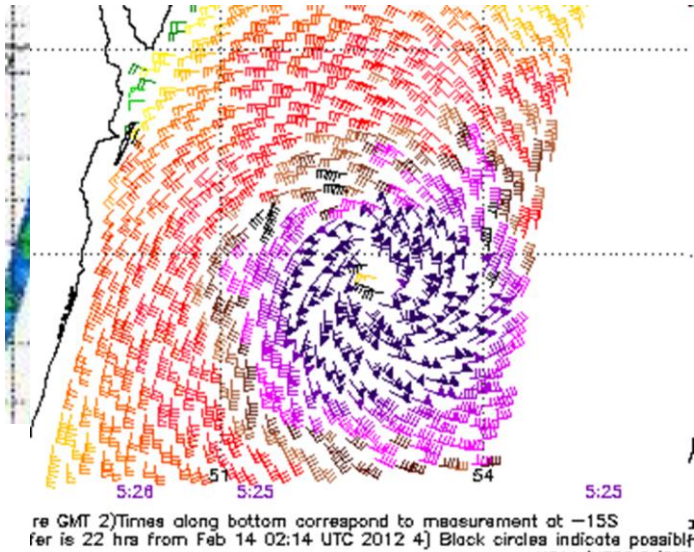
Excellent for gale radii and positioning

Excellent for intensity to ~50kn (i.e. weaker systems)

NOAA http://manati.orbit.nesdis.noaa.gov/datasets/ASCATData.php

KNMI http://projects.knmi.nl/scatterometer/tile_prod/tile_app.cgi

NRL: https://www.nrlmry.navy.mil/tc-bin/tc_home2.cgi



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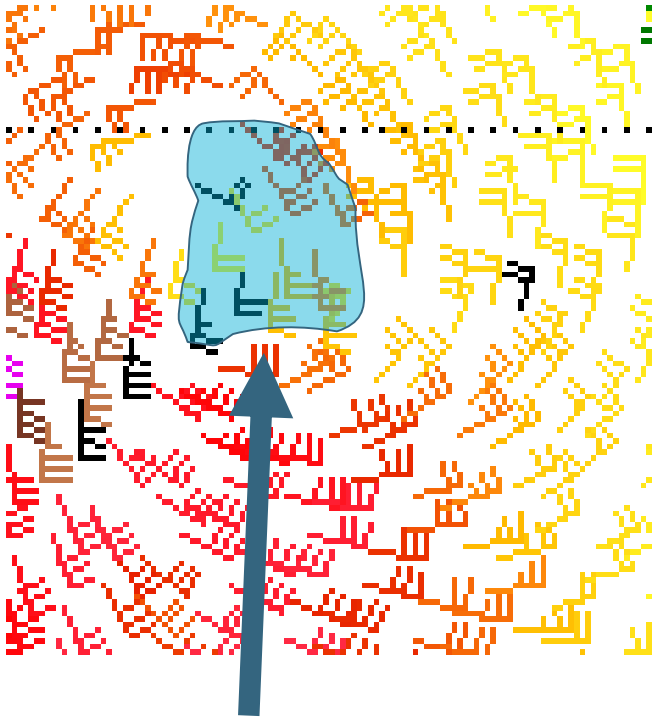
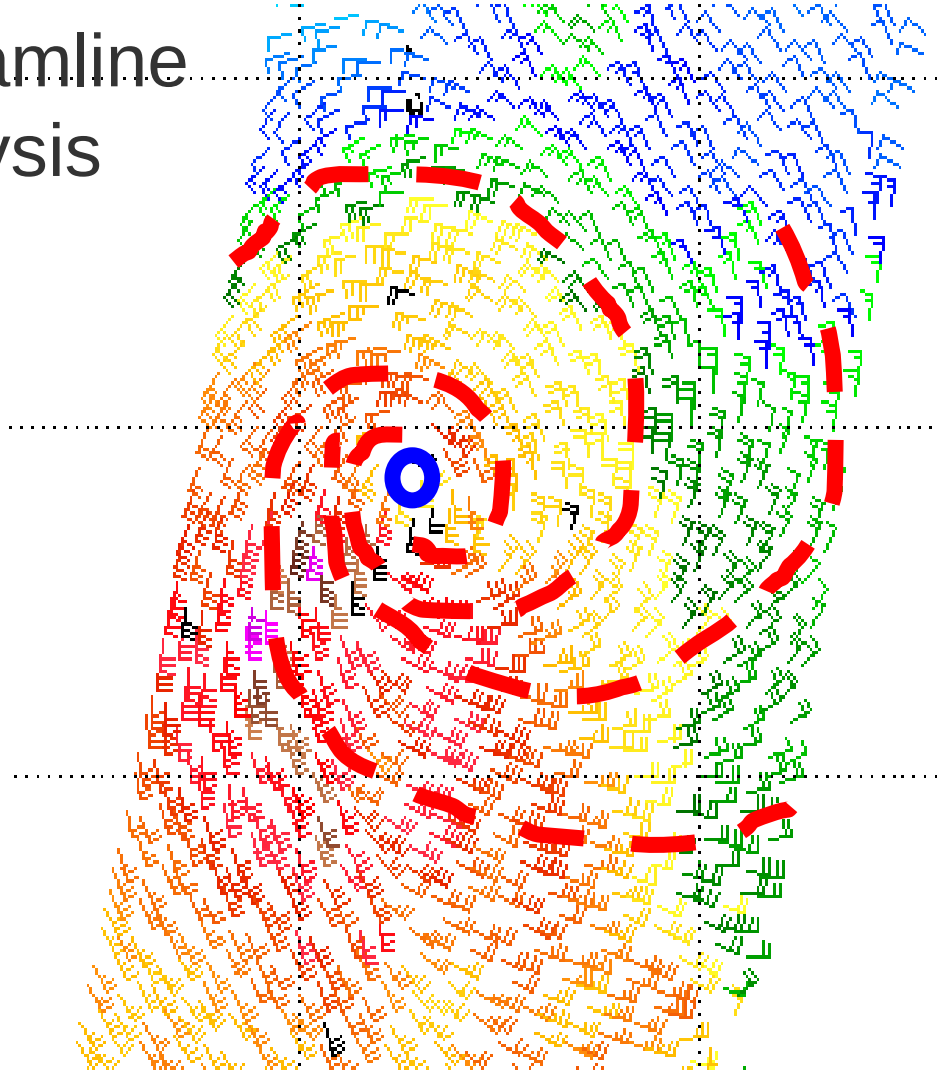
ASCAT - positioning



Wrong direction

Streamline analysis



Southern Hemisphere example

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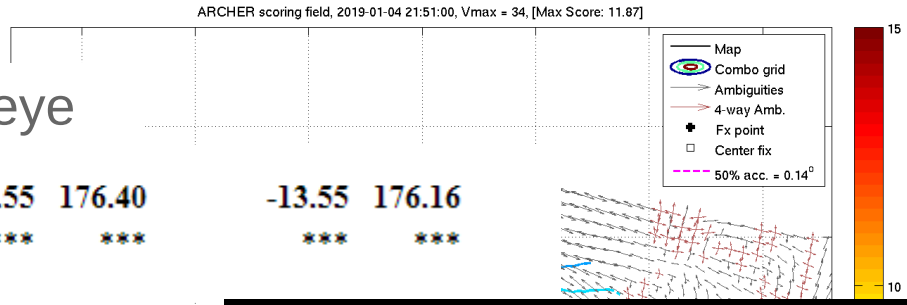
ASCAT positioning: ARCHER

http://tropic.ssec.wisc.edu/real-time/archerOnline/web/index.shtml

Automatic and usually better than human eye

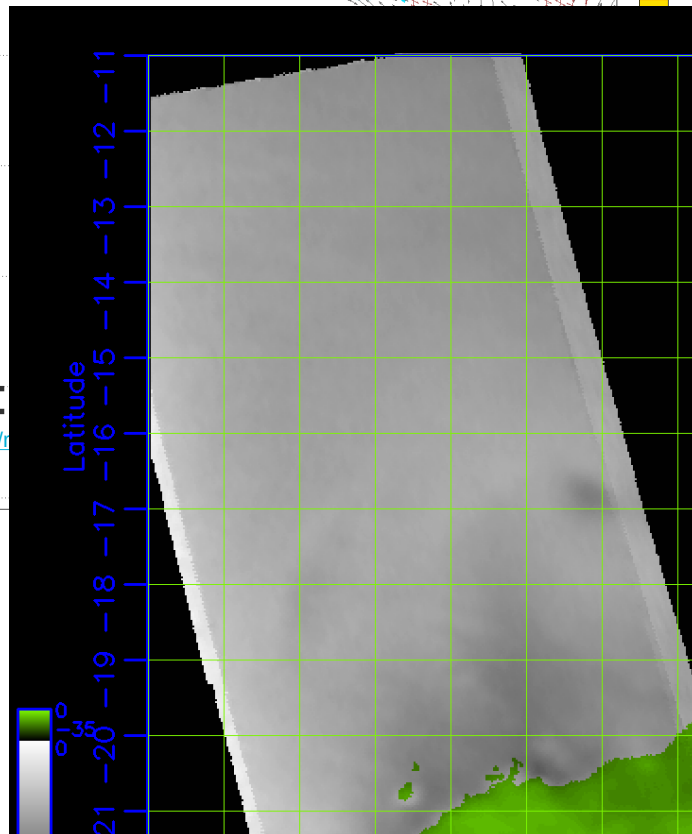
20190104 21:51:00 *	Metop-B	ASCAT	33.6	-13.55	176.40	-13.55	176.16
20190104 20:42:00	Metop-A	ASCAT	35.5	***	***	***	***



NRCS: scalar wind display can be the clearest indication of centre fix in the light wind area

Mona 09P:

http://tropic.ssec.wisc.edu/r



NRCS from NOAA 'manati' web page:

via 'storm' option

eg : Riley Jan2019: NRCS better than Archer

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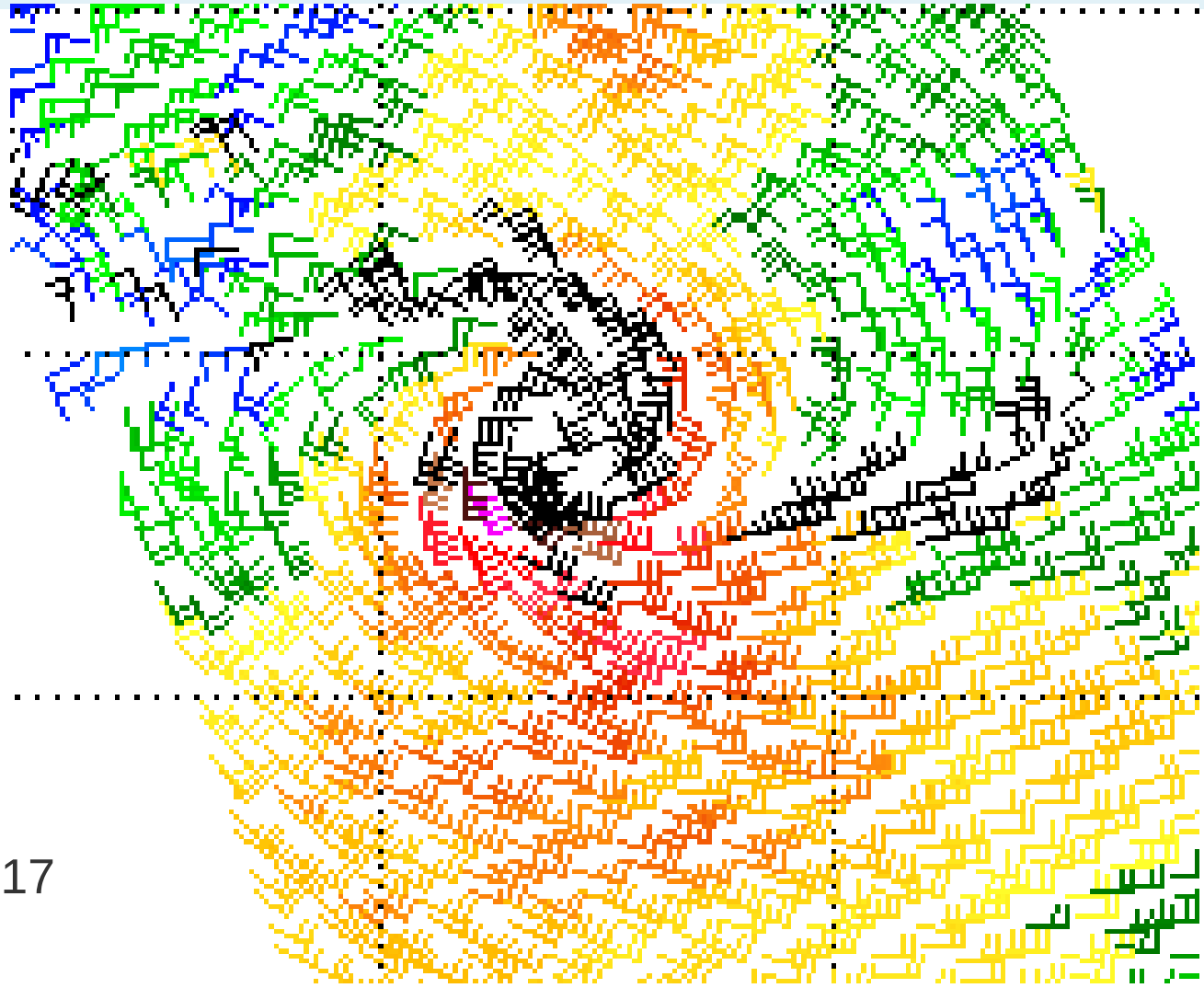
ASCAT case: Donna

Position?
Intensity?
Structure?



Donna: 10:35Z 3 May 2017

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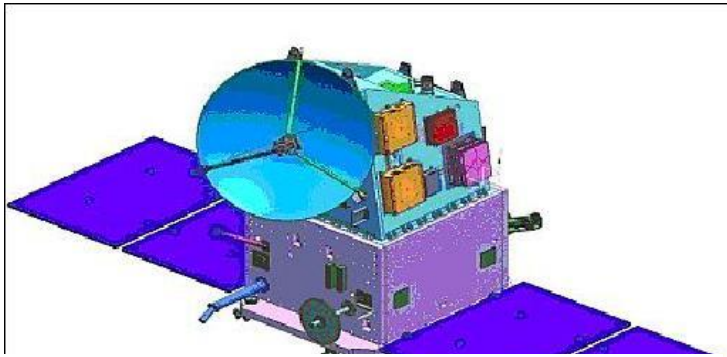
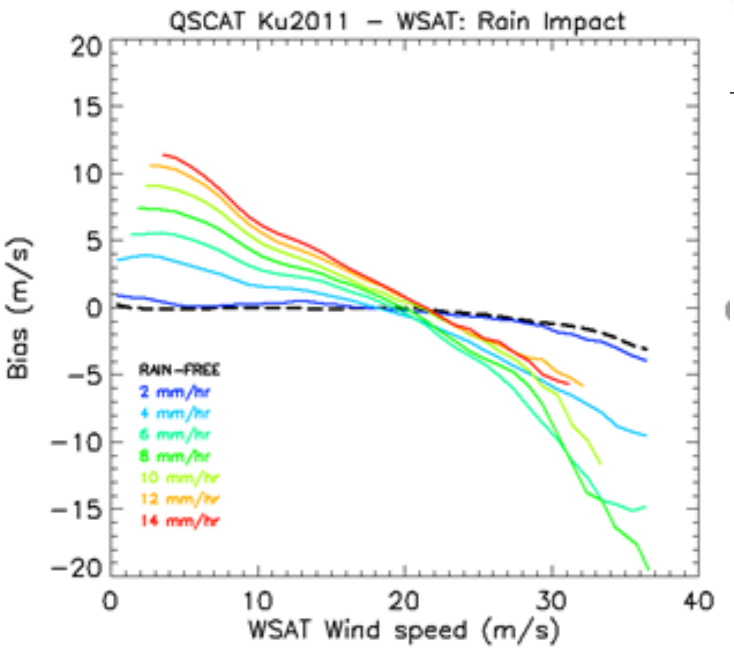
SCATSAT

SCATSAT-1 India (ISRO) continuation of OSCAT
Channel: 13.5 GHz (2cm); Ku-Band
coverage: 1800km wide (wider than ASCAT)
two passes per day(ascending/descending)
Resolution: 25-50km



TC applications:
Excellent for gale radii
Overestimates winds in mod/heavy rain (<50kn)
Ok for intensity to ~50kn



Images courtesy:
https://directory.eoportal.org/web/eoportal/satellite-missions/s/scatsat-1

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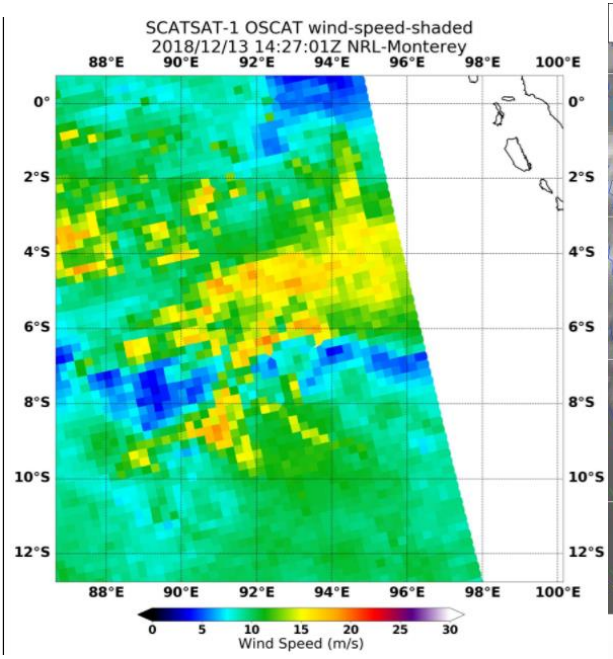
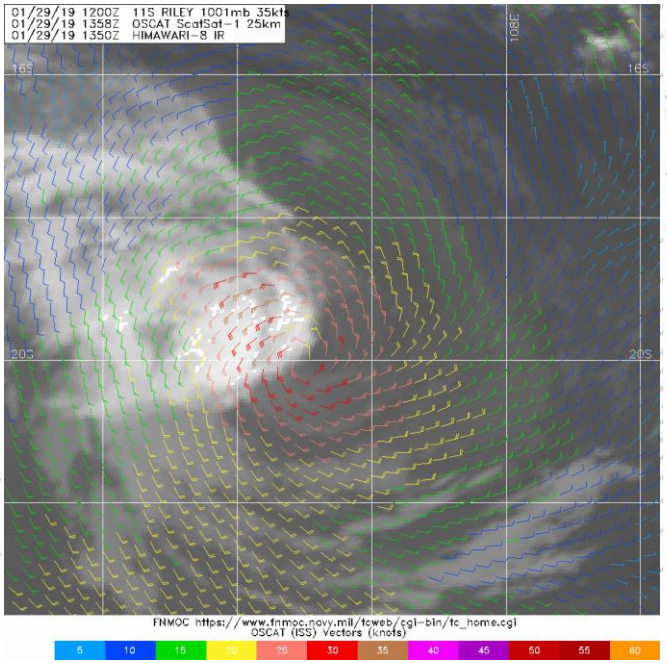
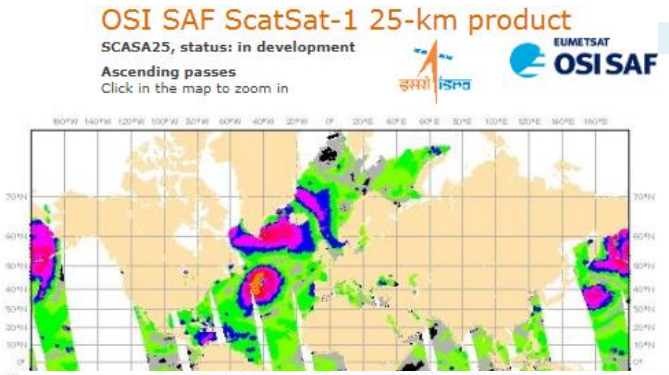
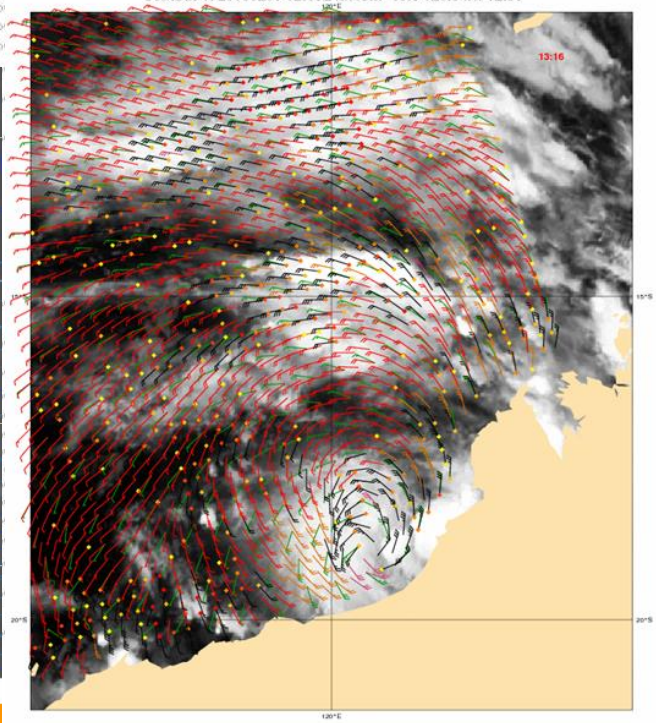
SCATSAT availability

1. KNMI http://projects.knmi.nl/scatterometer/tile_prod/tile_app.cgi
2. FNMOC: https://www.fnmoc.navy.mil/tcweb/cgi-bin/tc_home.cgi
3. NRL: speed only (irregular coverage currently)
4. Not yet NOAA-coming?
https://manati.star.nesdis.noaa.gov/datasets/ASCATData.php









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Exercise: accessing the information
Task: Find ASCAT/SCATSAT for Oma 15P ~18S 162E

Use:
1. NOAA https://manati.star.nesdis.noaa.gov/datasets/ASCATData.php
2. KNMI http://projects.knmi.nl/scatterometer/tile_prod/tile_app.cgi

Advanced :
3. Use NOAA 'Storm' option to centre on TC
4. FNMOC: https://www.fnmoc.navy.mil/tcweb/cgi-bin/tc_home.cgi

Question: Find the latest ASCAT and SCATSAT passes that move over Oma in the SW Pacific (off New Caledonia)
What time does the pass go over Oma?
What are the highest winds?
Comment on the extent of gales: which quadrant has the furthest extent of gales?

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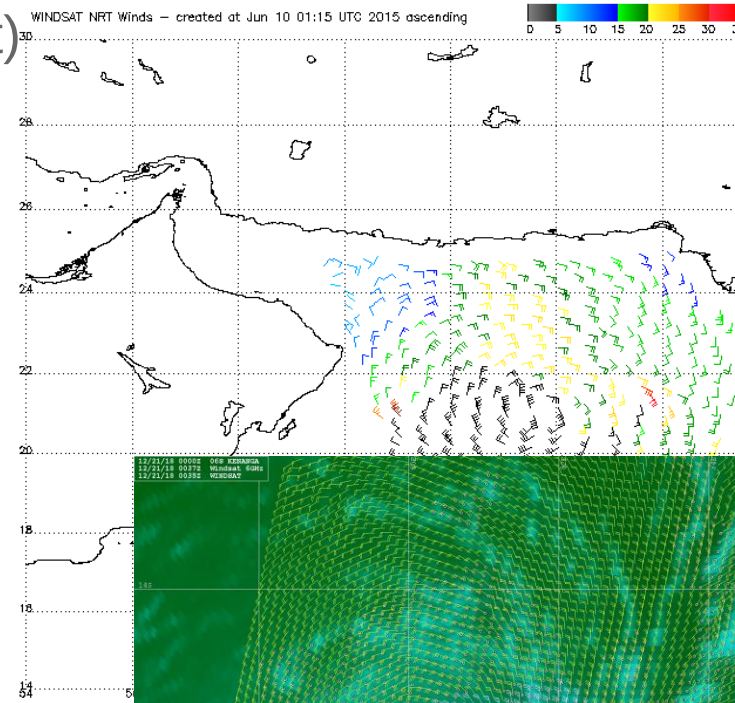
Radiometers (passive)
Windsat

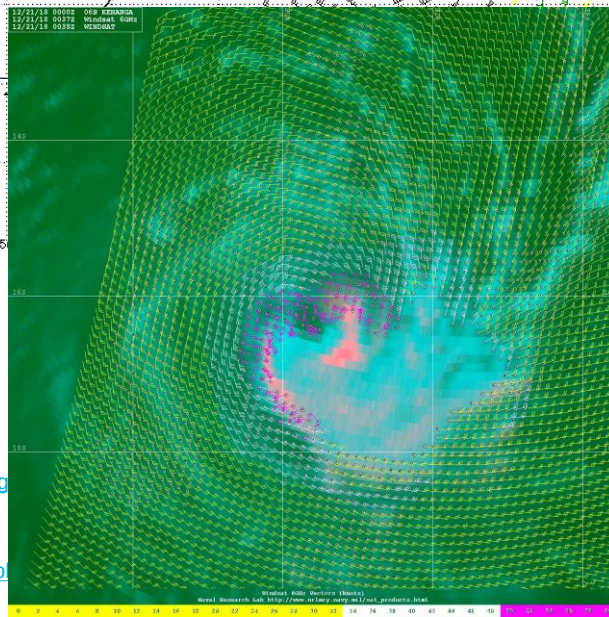
https://manati.star.nesdis.noaa.gov/datasets/WindSATData.php

Satellites: Coriolis (2003 extended lifetime! First)
Channel: 6.8-37 GHz
coverage: 1000km wide (>ASCAT, <SCATSAT)
two passes per day(ascending/descending)
Resolution: ~25km

TC applications:

Overestimates winds in rain, but solution to overcome speed in rainfall being worked on
Not useful for intensity
Sometimes for gale radii outside rain areas
NOAA: https://manati.star.nesdis.noaa.gov/datasets/WindSATData.php
NRL: https://www.nrlmry.navy.mil/tc-bin/tc_home2.cgi





Examples:1 Ashobaa Courtesy: NOAA
https://manati.star.nesdis.noaa.gov/windsat_images/windsat_storm/storm_id_image_new/2015/windsat15061001_01_ASHOBAA_as.png

2. Kenanga courtesy NRL
https://www.nrlmry.navy.mil/tcdat/tc19/SHEM/06S.KENANGA/ssmi/scat/scat_over_color37/20181221.0037.windsat.WINDSAT_6GHz_col
wind.06SKENANGA.3772_090pc_80kts-976mb_162S_804E_sft201812210000_bgt201812210035_bgn201812210000.jpg

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AMSR2 radiometer (passive)

https://manati.star.nesdis.noaa.gov/datasets//GCOM2Data.php

Satellite: GCOM (2012)

Channel: 10.7-36.5GHz

Coverage: 1450km (wider than ASCAT)

Two passes per day

TC applications:

Can be ok for extent of gales

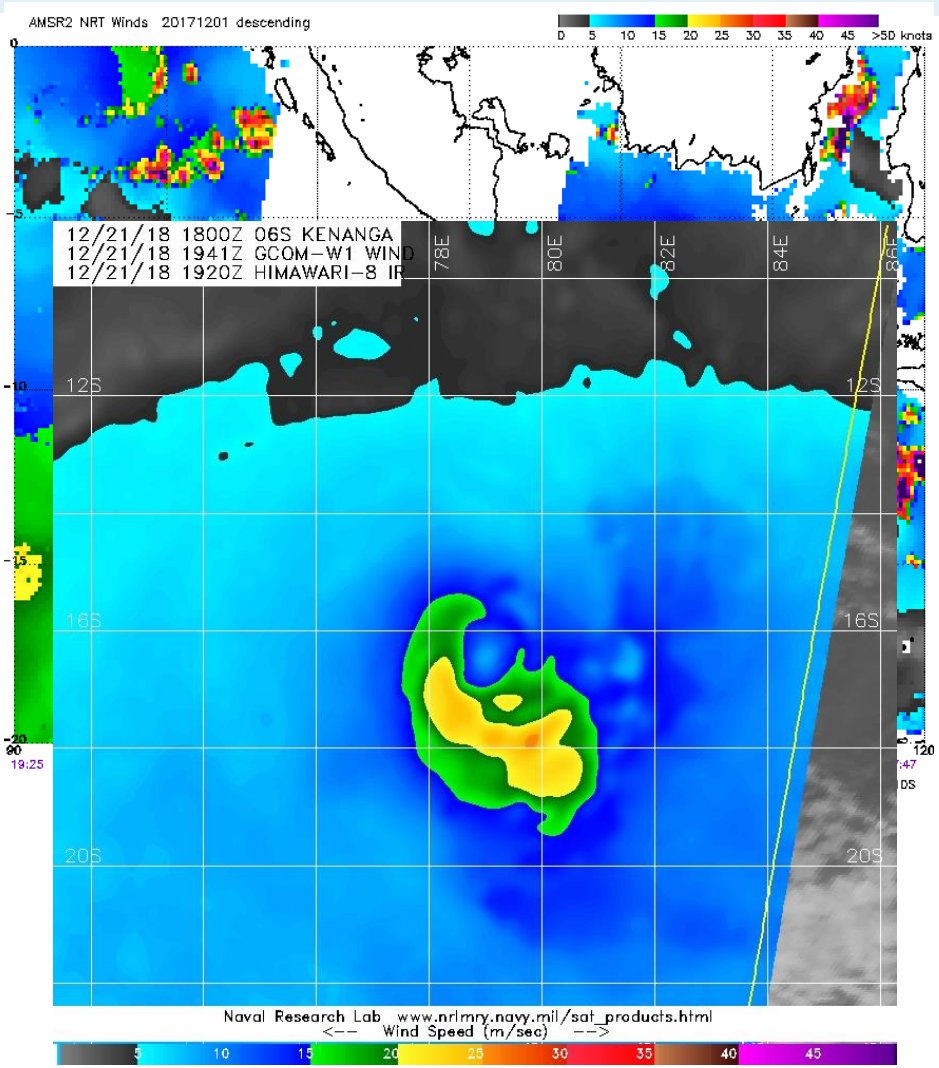
Speed only

Availability same as Windsat

NOAA and NRL

Solution to overcome speed in rainfall being worked on

ALSO SSMIS radiometer as well



Examples: 1. Dahlia Courtesy: NOAA
https://manati.star.nesdis.noaa.gov/gcom_images/arch/wdsp/GC2017335/zooms/WMBds57.png
2. Kenanga 2018 NRL

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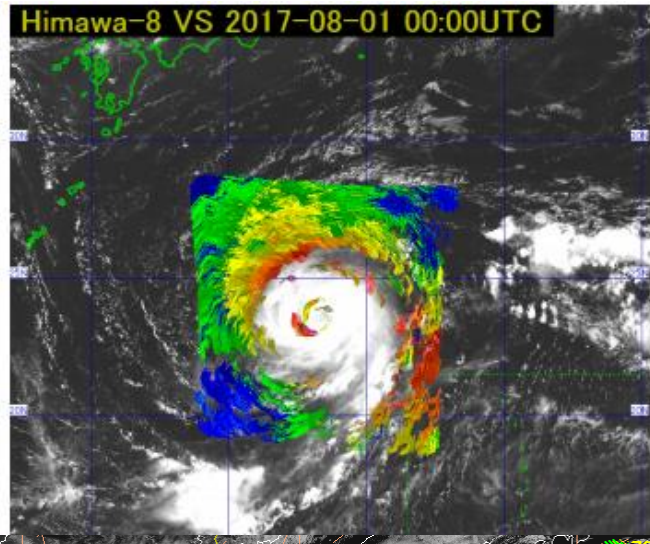
Geostationary satellites
AMV (Cloud drift winds) derived to surface
Rapid scan mode



Latest Geostationary:

Himawari-9:	10min;	rapidscan 2.5min for target*;
GOES-R:	10-15min;	rapidscan 1-5min;
FY-4:	15min	rapidscan 2.5min;
KOMPSAT-2A	10min	rapidscan 2.0min east Asia
Meteosat:	10min	rapidscan 2.5min Europe

Rapidscan best for surface winds

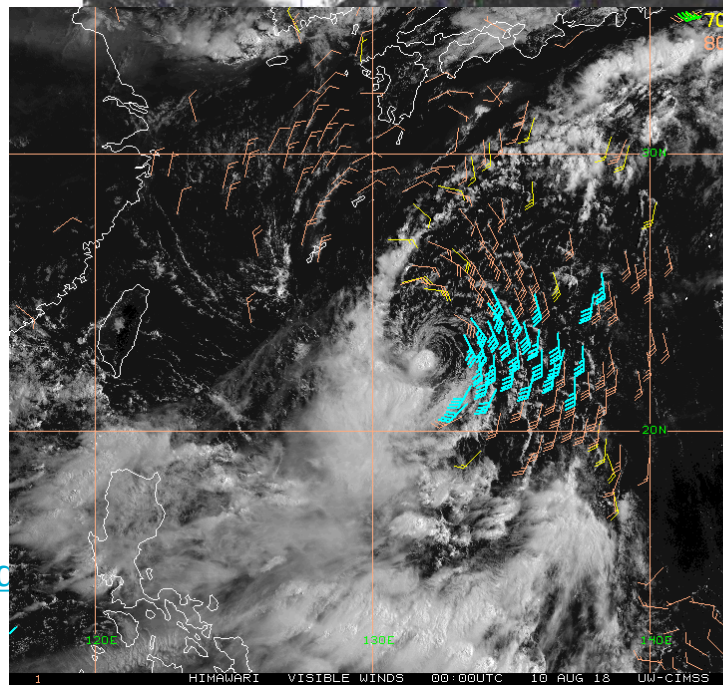
Requires low level cloud exposed so not for central cloudy regions near TC;

Useful for environmental flow and gale extent.

CIMSS: Surface Adjusted Vis/SWIR Winds

Acknowledgement: Bessho et al 2018 (IWTC-9)

https://www.wmo.int/pages/prog/arep/wwrp/tmr/documents/T5.2_ppt.pd



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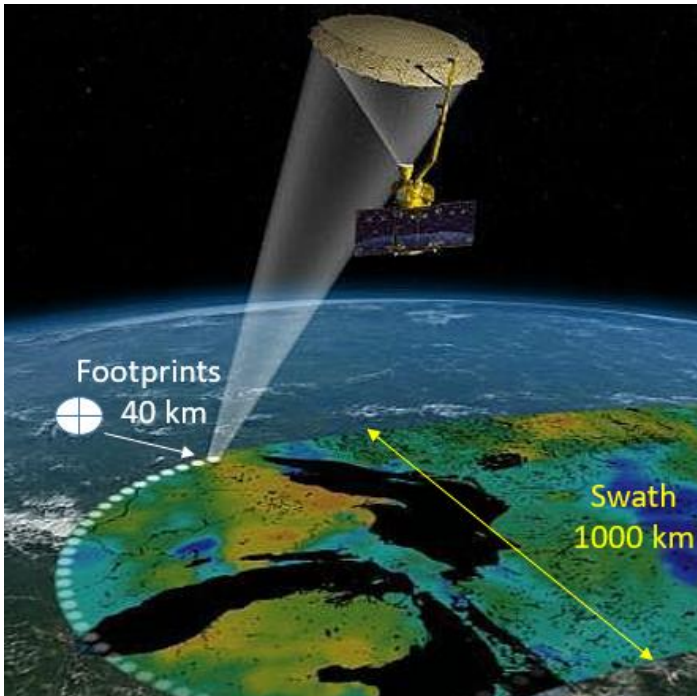
L-Band Radiometers:
SMAP (Soil Moisture Active Passive)
SMOS (Soil Moisture and Ocean Salinity)

http://www.remss.com/missions/smap/winds/

microwave ocean emissivity (sea foam) correlates to wind speed
mostly linear at high winds, no reduced sensitivity.
at L-band (21 cm) atmosphere is almost transparent so very small impacts of rain compared to C, X and Ku bands
L-Band 1.4GHz cf ASCAT C-Band 5.3GHz & SCATSAT Ku-band 13.5GHz
So can resolve high wind speeds
Satellite: SMOS (NASA 2009); SMAP (ESA 2012)
Coverage swathe 1000km SMAP; 1500km SMOS
Resolution 40km (winds averaged over footprint)

TC applications:
Intensity as resolves high wind speeds
40km resolution constraint for small RMW
Good for gale/storm/hurricane radii
Access for real-time an issue (SMOS N/A)



SMAP coverage image courtesy Meissner et al.2018

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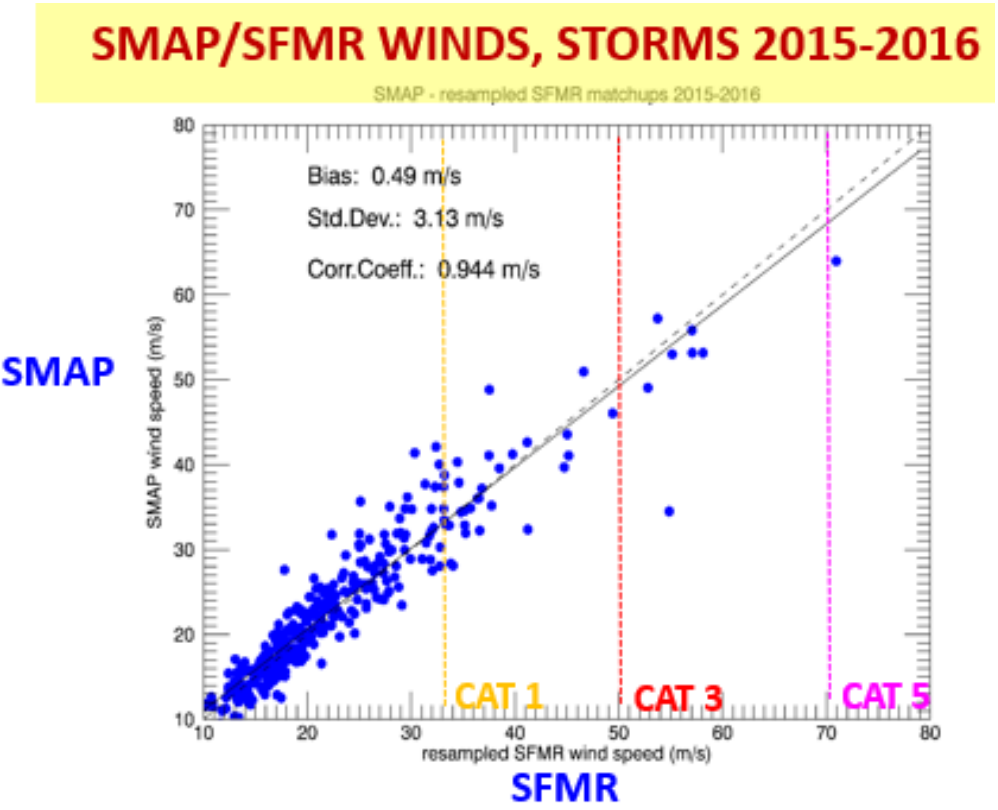
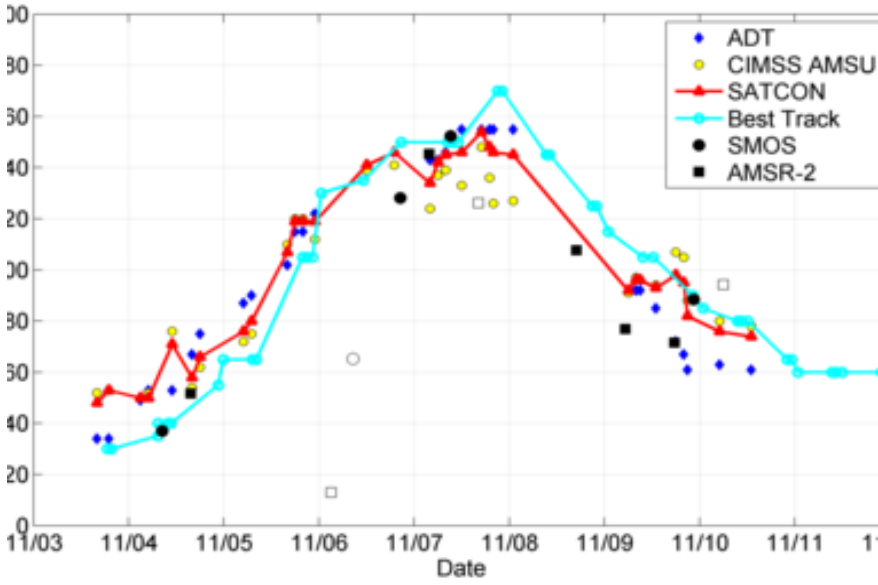
L-Band Radiometers: calibration accuracy within ~10 %

SMAP Vs SFMR calibration



SMOS Haiyan



http://www.smosstorm.org/

Acknowledgement: Meissner et al IWTC-IX

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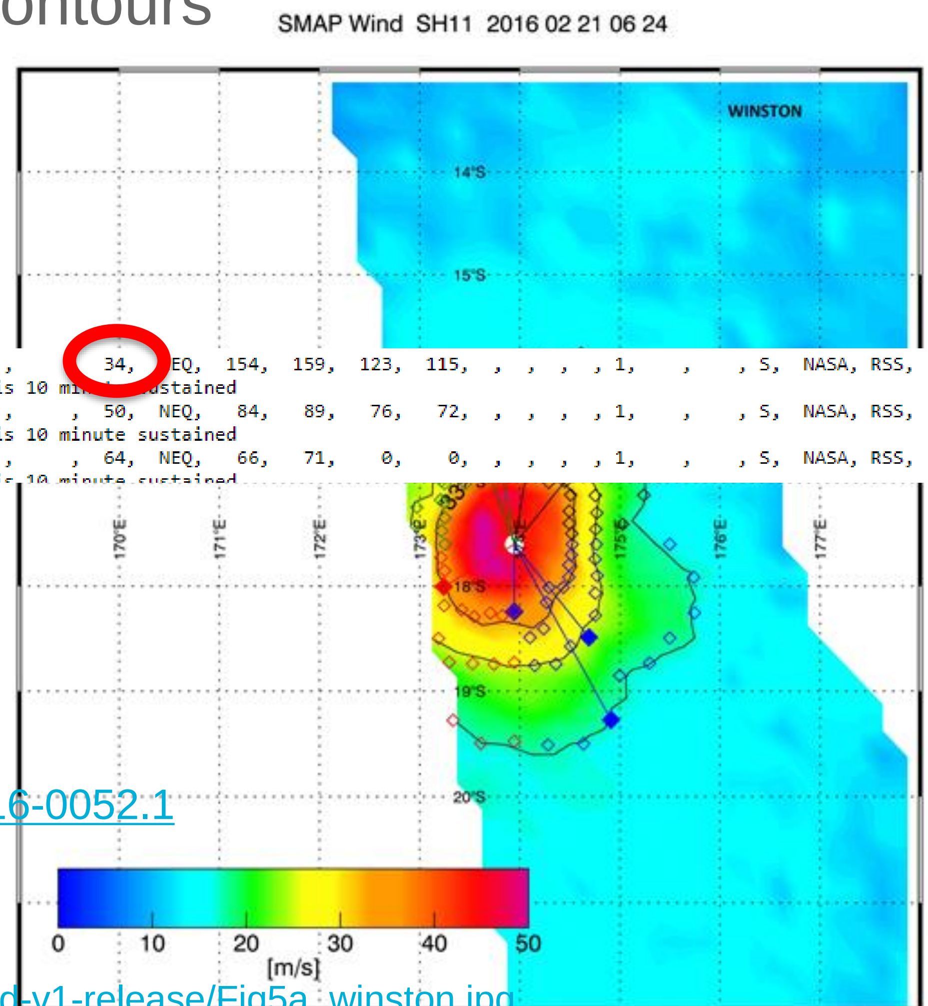
SMAP wind radii

Excellent for R34, R48 and R64 contours
Near-real time for SMAP (~3h)

JTWC collab: file 'fixes' not 'aids'

```
SH, 15, 201803211043,  30, SMAP,        IR,  , 1500S, 10950E,      ,  , 137, 1     ,  ,       34, NEQ,  154,  159,  123,  115,  ,  ,  ,  , 1,    ,    , S,  NASA, RSS,
,    ,    ,    ,    ,    ,    ,    ,    ,  ,  ,  ,  ,  ,  ,  ,  ,  , 1, max. wind is 10 minute sustained
SH, 15, 201803211043,  30, SMAP,        IR,  , 1500S, 10950E,      , 1, 137, 1,     ,  ,    ,  50,  NEQ,   84,   89,   76,   72,  ,  ,  ,  , 1,    ,    , S,  NASA, RSS,
,    ,    ,    ,    ,    ,    ,    ,    ,  ,  ,  ,  ,  ,  ,  ,  ,  , 1, max. wind is 10 minute sustained
SH, 15, 201803211043,  30, SMAP,        IR,  , 1500S, 10950E,      , 1, 137, 1,     ,  ,    ,  64,  NEQ,   66,   71,    0,    0,  ,  ,  ,  , 1,    ,    , S,  NASA, RSS,
                                                                      1, max. wind is 10 minute sustained
```



Marcus: 137 kn

Meissner, Ricciardulli and Wentz:
https://journals.ametsoc.org/doi/10.1175/BAMS-D-16-0052.1

Winston: winds of 50m/s (>90kn)
http://images.remss.com/figures/announcements/smap-wspd-v1-release/Fig5a_winston.jpg

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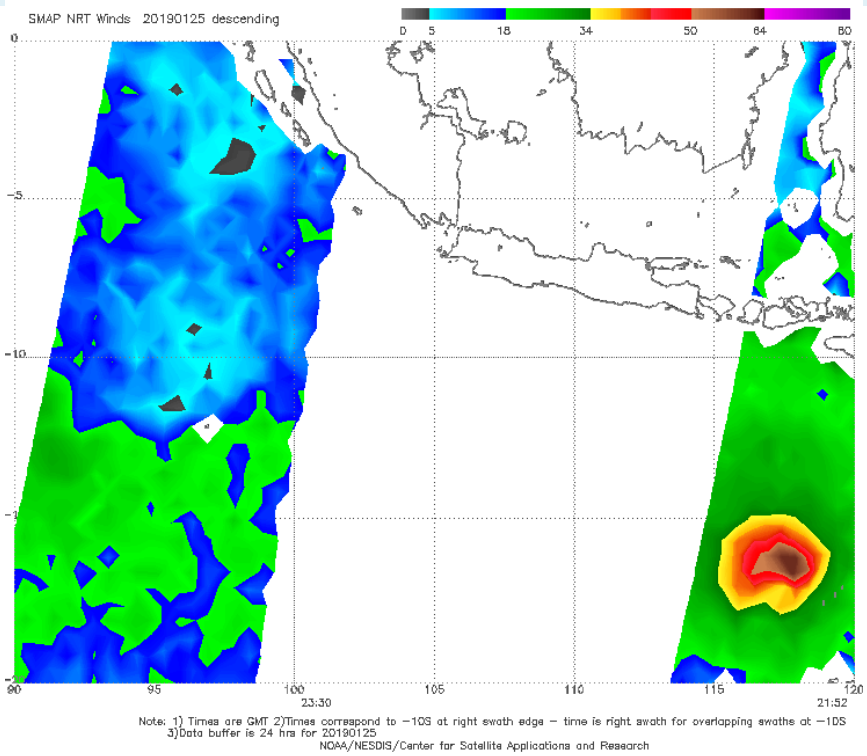
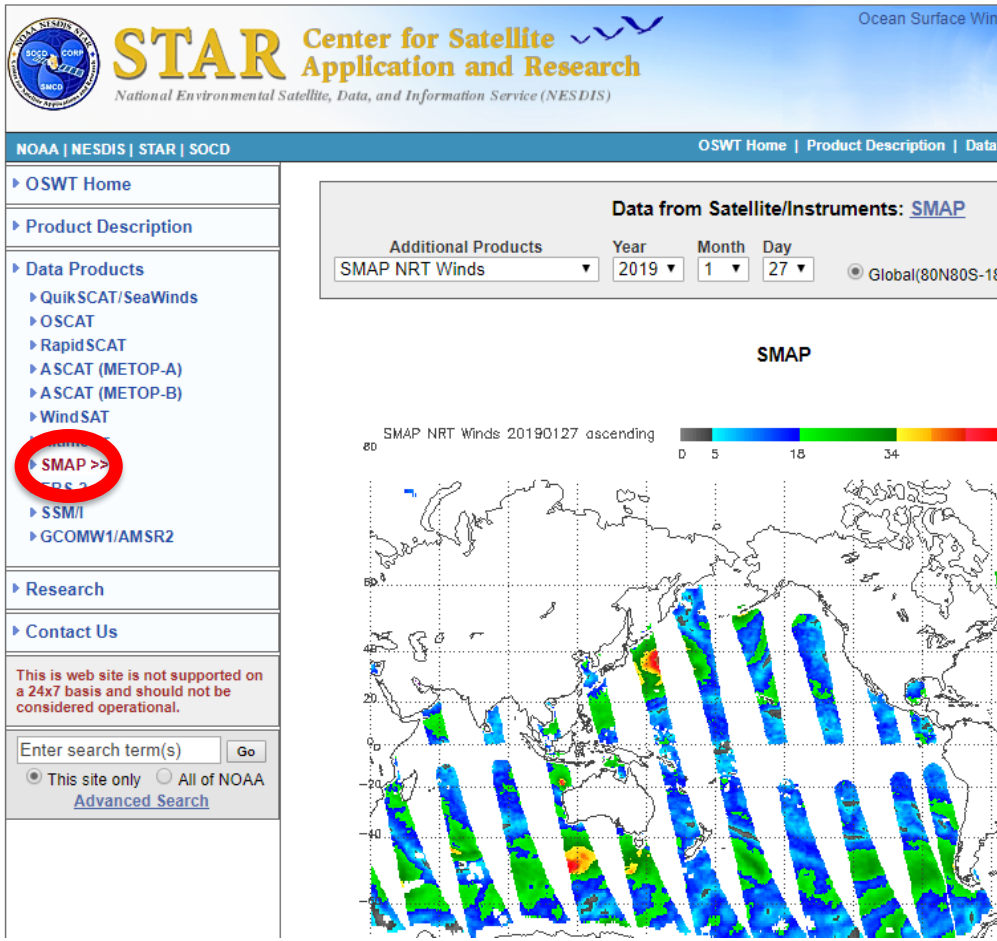
SMAP availability: NOAA manati

https://manati.star.nesdis.noaa.gov/datasets/SMAPData.php





Example: Riley 2330Z, 25 January 2019

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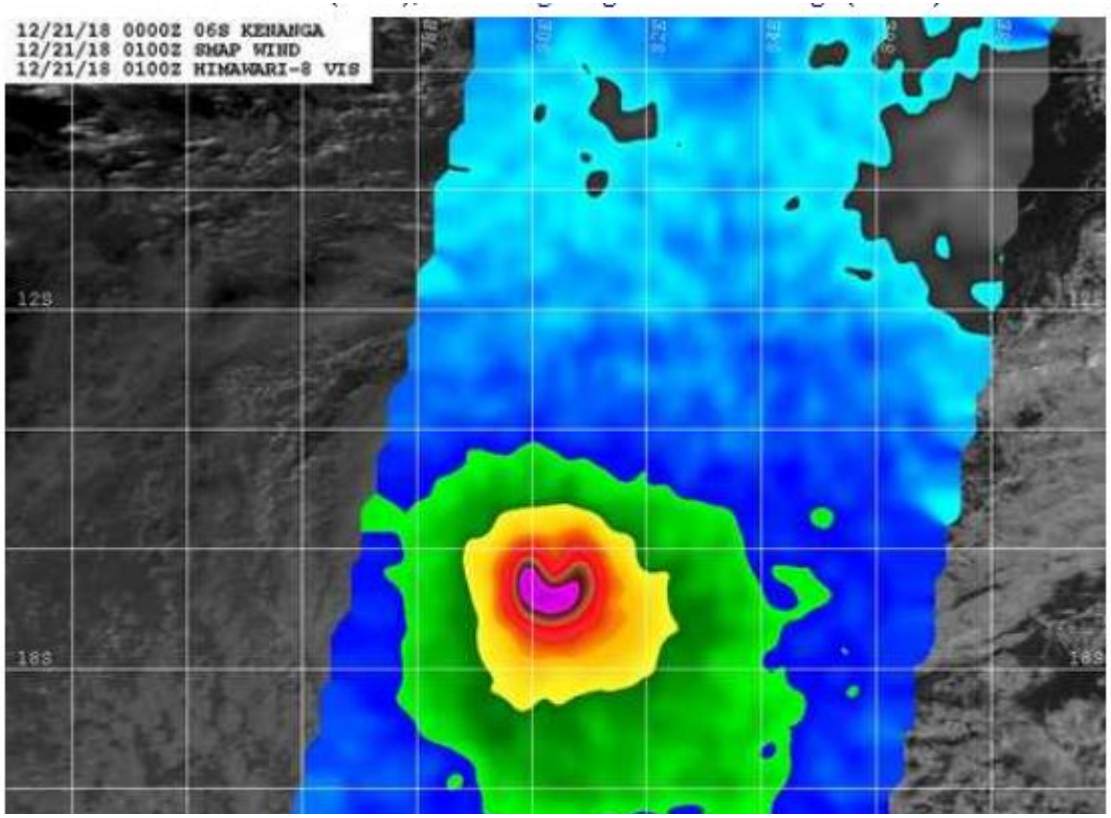
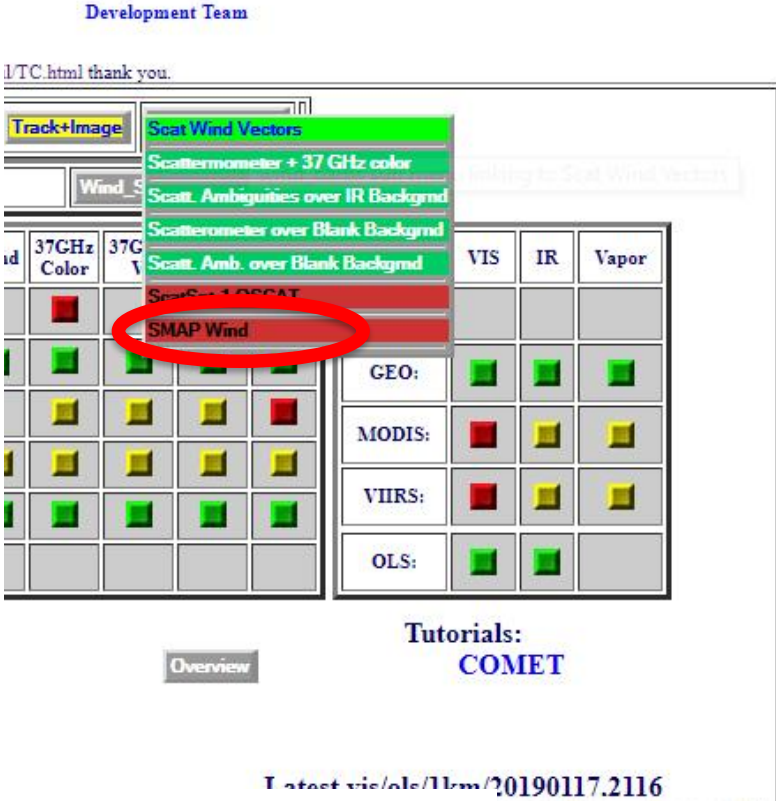
SMAP availability: NRL

https://www.nrlmry.navy.mil/tc-bin/tc_home2.cgi

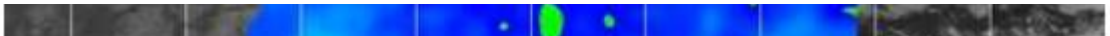
NRL: but currently not getting all the images (none for Riley 11S)





Example: Kenanga 2018 75kn

Courtesy: NRL https://www.nrlmry.navy.mil/tcdat/tc19/SHEM/06S.KENANGA/smap/wind/20181221.0100.smap.x.wind.06SKENANGA.80kts-976mb-163S-804E.054pc.jpg



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Exercise: accessing the information
Task: Find SMAP for Oma 15P

Use: 1. NOAA https://manati.star.nesdis.noaa.gov/datasets/ASCATData.php

Question: Find the latest SMAP pass that moves over Oma in the SW Pacific
Note: will have to change date to 18 Feb
What time does the pass go over Oma?
What are the highest winds?
Comment on the extent of gales: which quadrant has the furthest extent of gales?
How does this compare with ASCAT and SCATSAT from previous exercise?

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Microwave Imagery Interpretation

Why Microwave?

Satellites and access

Features of 37 and 85 frequencies

How to use both

Intensity

COMET microwave training

www.meted.ucar.edu

Acknowledgements: Roger Edson

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The Satellites Sensors

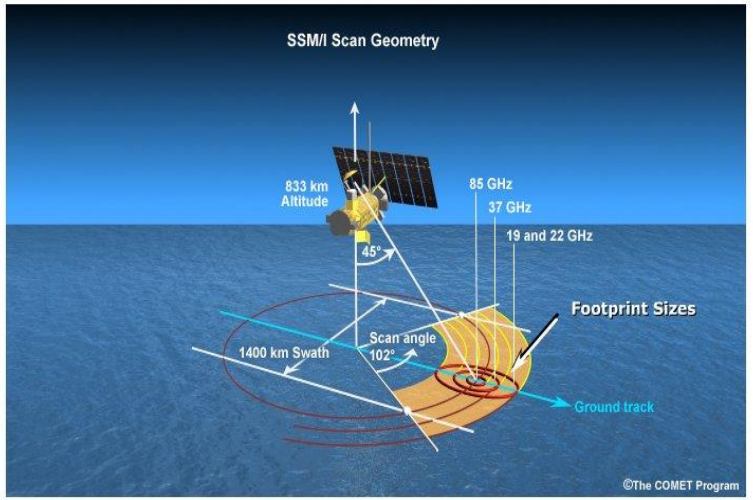
Passive sensing up–radiation from ocean/clouds in 19-24, 37, 85-91GHz ranges

- Polar Orbiting Conical Scanner

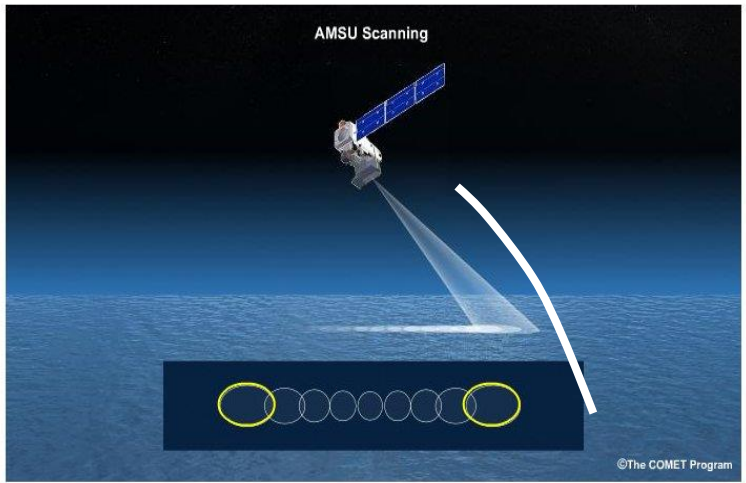
  SSMI, SSMIS, GMI, AMSR2, Windsat (37GHz)

  + more? TMI (TRMM),

- narrow scan widths but maintains footprint resolution across the entire scan
- 85GHz higher res than 37GHz



- Cross track AMSU (85GHz only)
- wider scan swaths but resolution degrades toward the edge of scan



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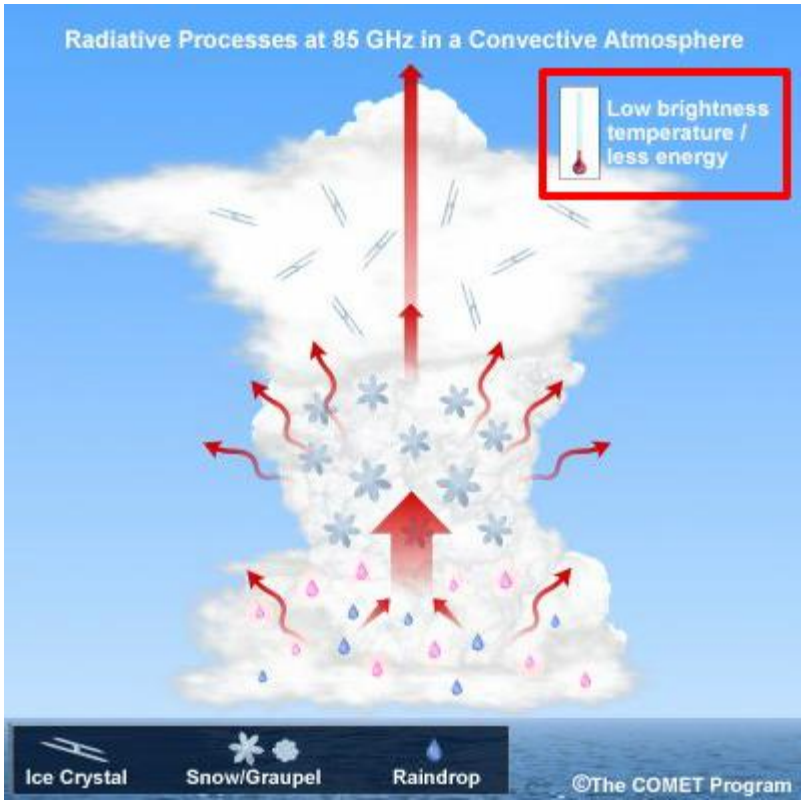
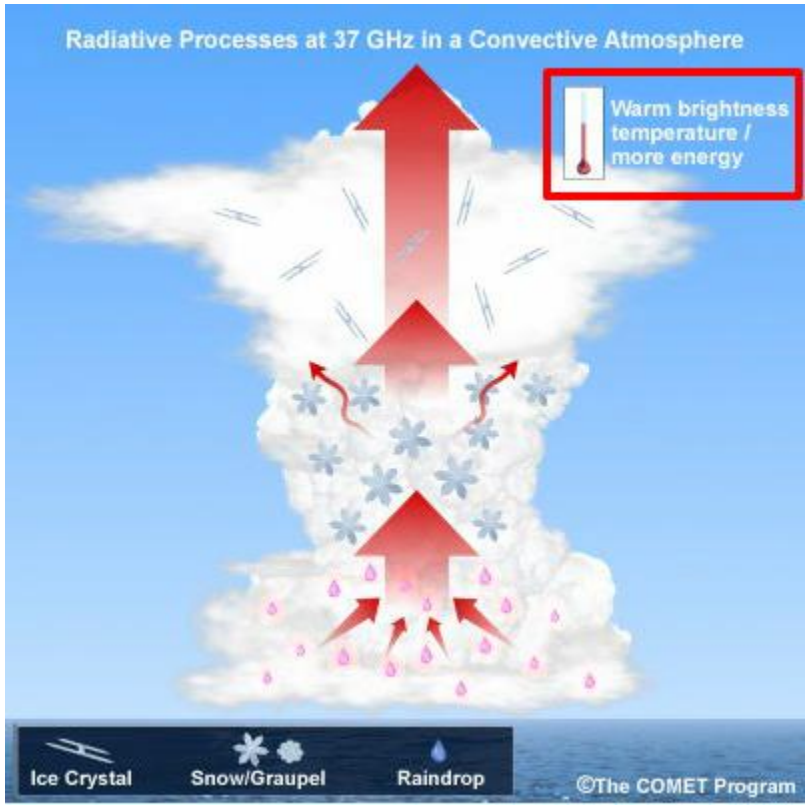
37-85 GHz differences

85GHz from ocean is absorbed & scattered by water droplets and further scattered by large water droplets and hail higher up in deep convection leading to low brightness temperatures.



37GHz from ocean is absorbed by cloud/ rain droplets – the radiated energy is NOT affected by large water droplets and hail higher up in deep convection leading to high brightness temperatures.



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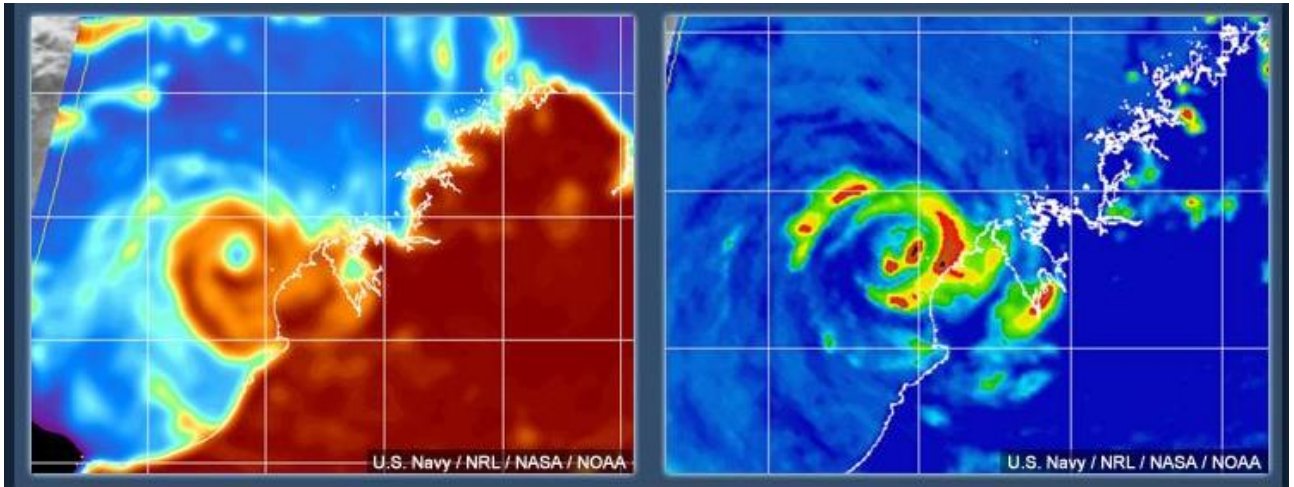
37 Vs 85 GHz – summary

- 37 GHz shows region of low-level clouds/rain and so clearly shows low-level circulation but doesn't distinguish deep convection from rain.
- 85-91GHz better shows deep convection but can not always see low-level circulation.

Use colour enhancement to resolve ambiguity between deep convection and clear ocean surface



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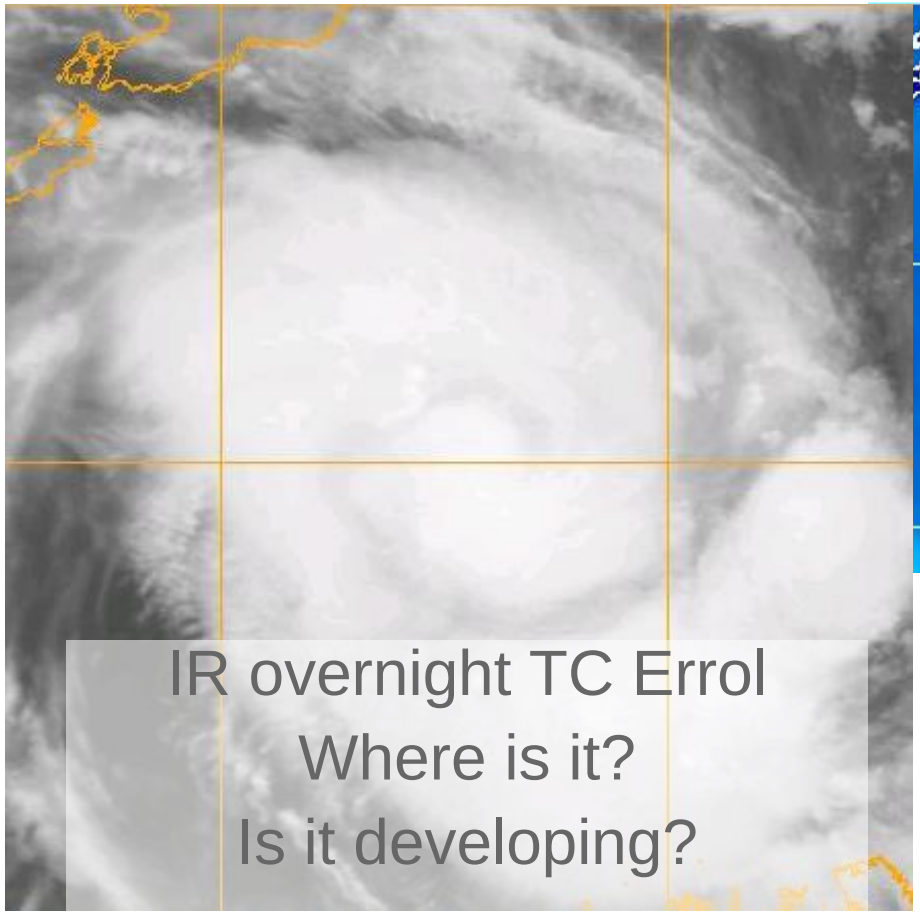
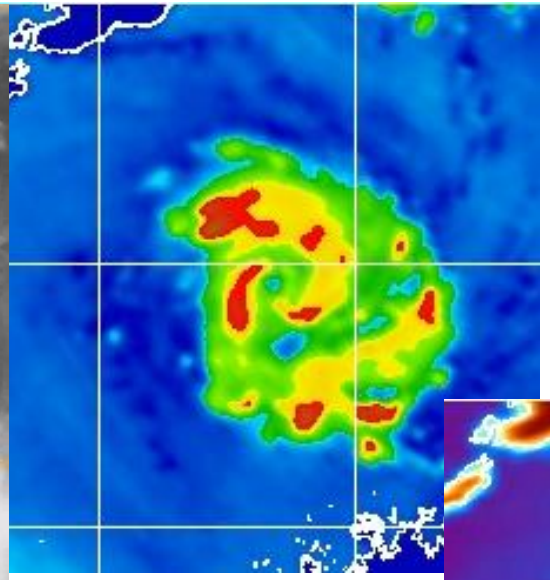
Why is microwave useful?

Microwave allows us to see through the high cloud and resolve details of the structure and low level circulation



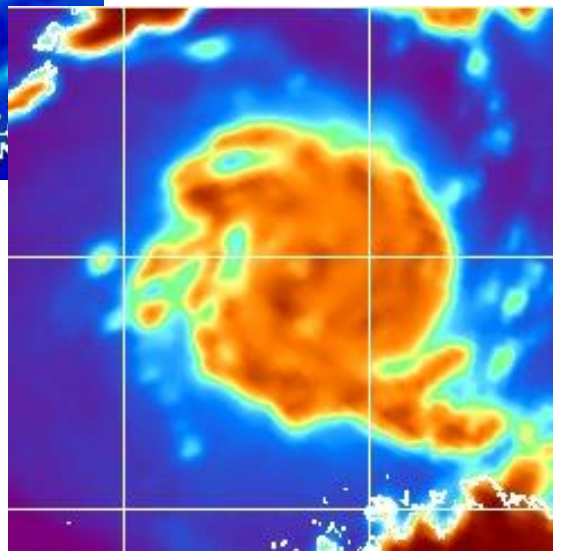
IR overnight TC Errol
Where is it?
Is it developing?



85-91GHz

Deep convection higher up

37GHz
low down



Availability: NRL web pages

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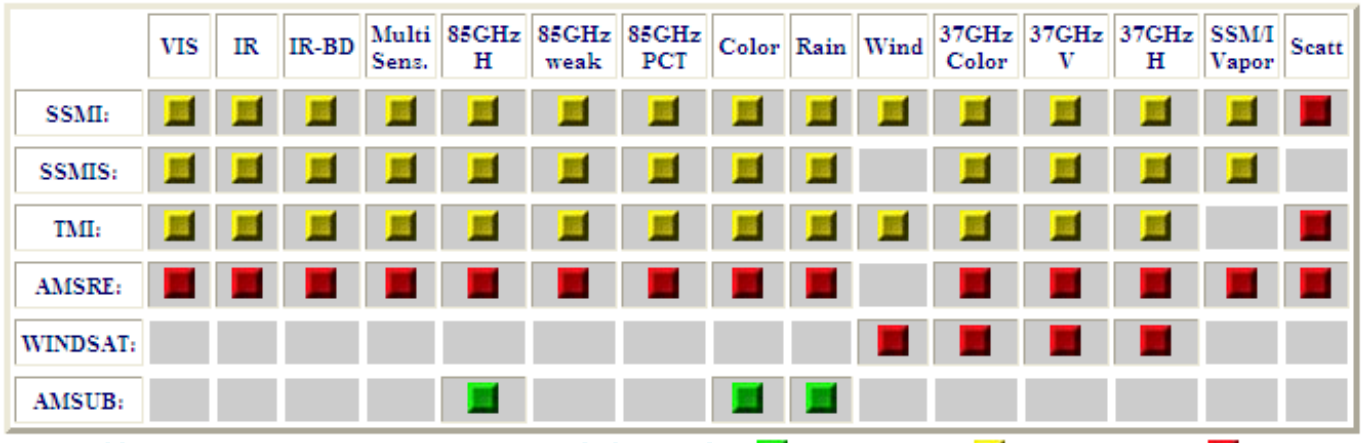
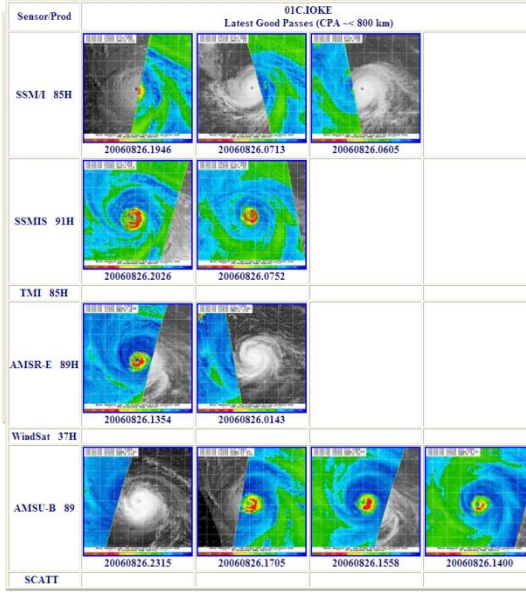
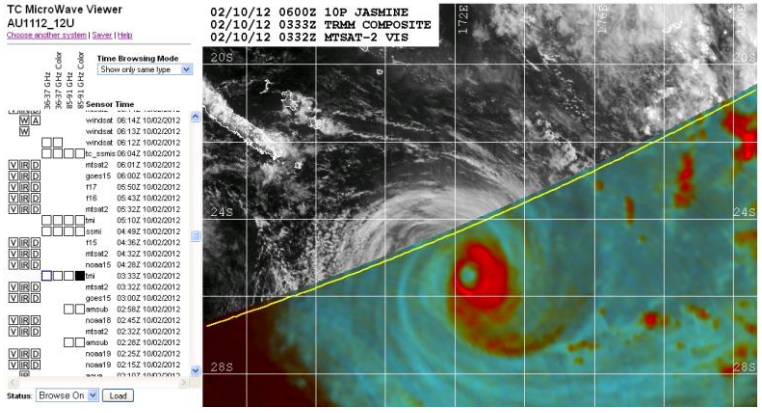




http://www.nrlmry.navy.mil/TC.html

Alternate Page at FNMOC www.fnmoc.navy.mil/tcweb/cgi-bin/tc_home.cgi

BoM Image viewer (web)



Advantages
navigation to get lat/lon;
distance to point;
ease of viewing - fast;
local archive.

Different presentations

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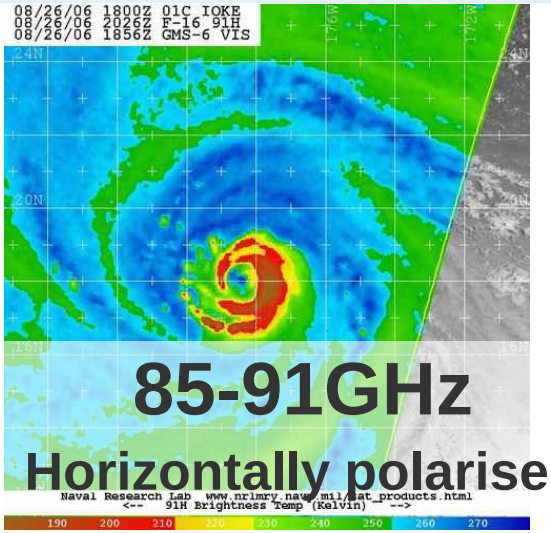
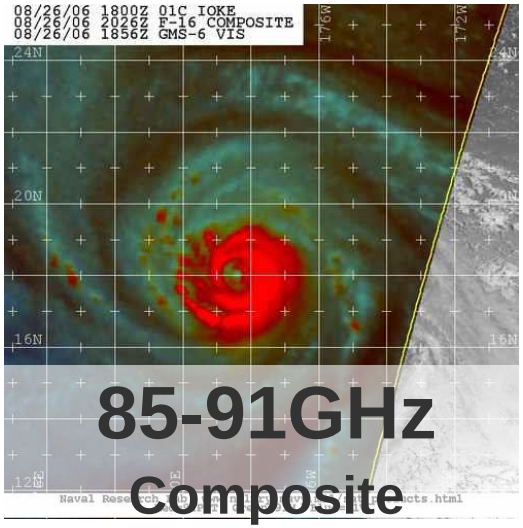
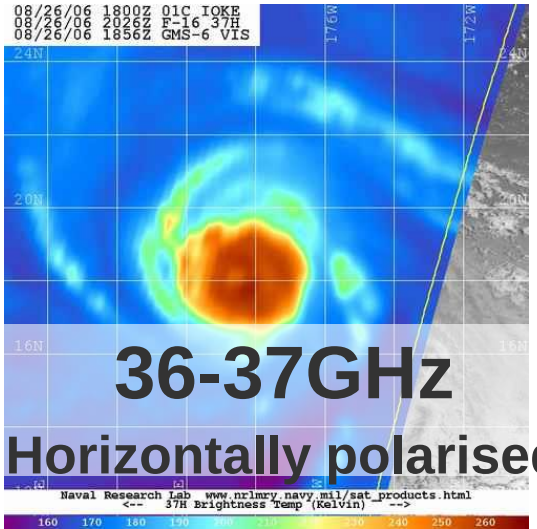
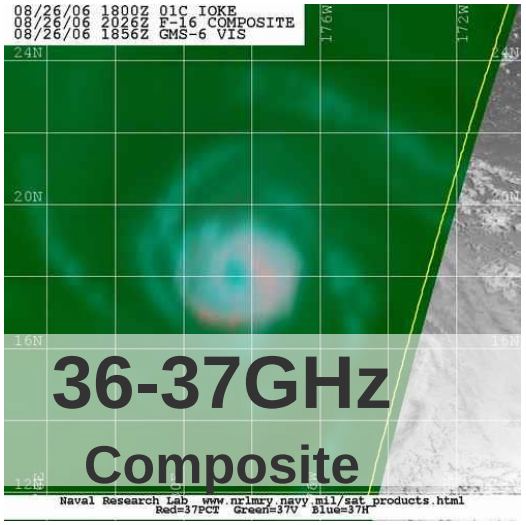


'color' Composite view combines horizontal and vertical polarisation and PCT so can 'correct' for known weaknesses







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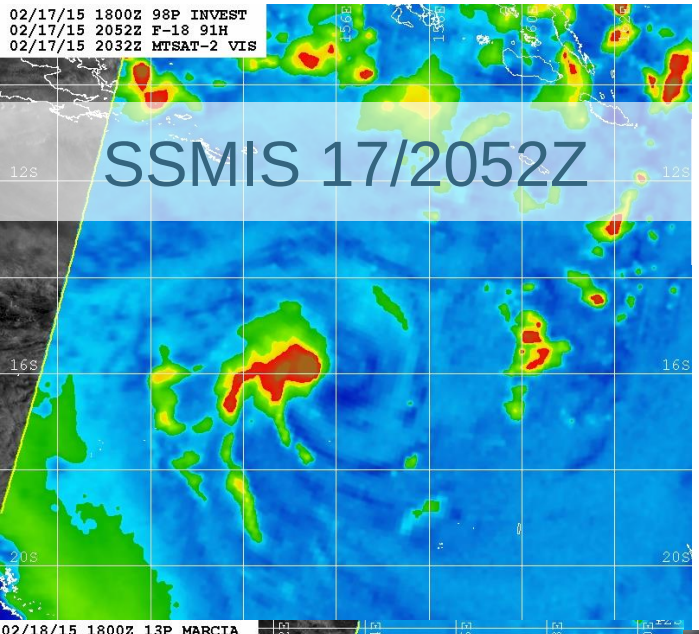
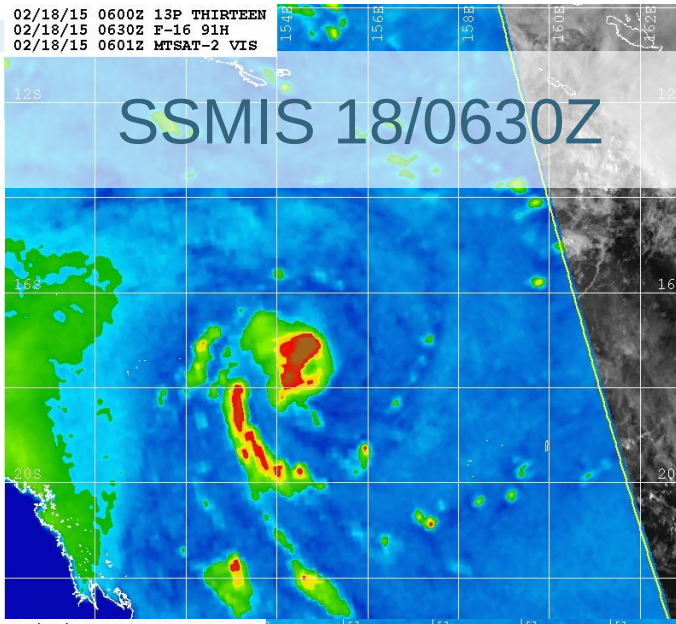
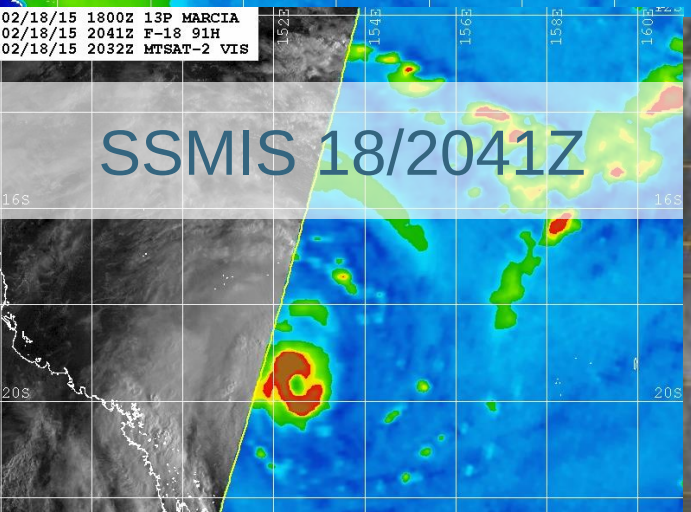
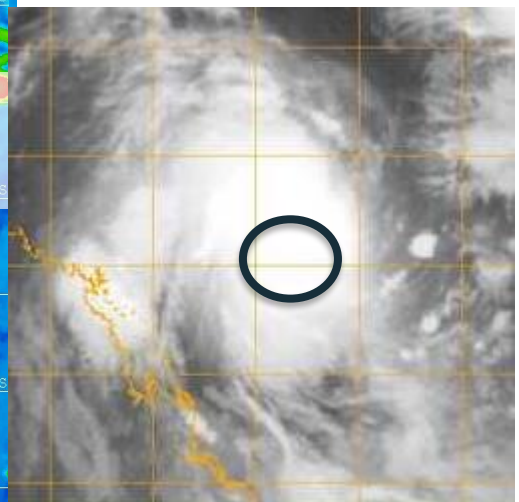
TC Marcia Development

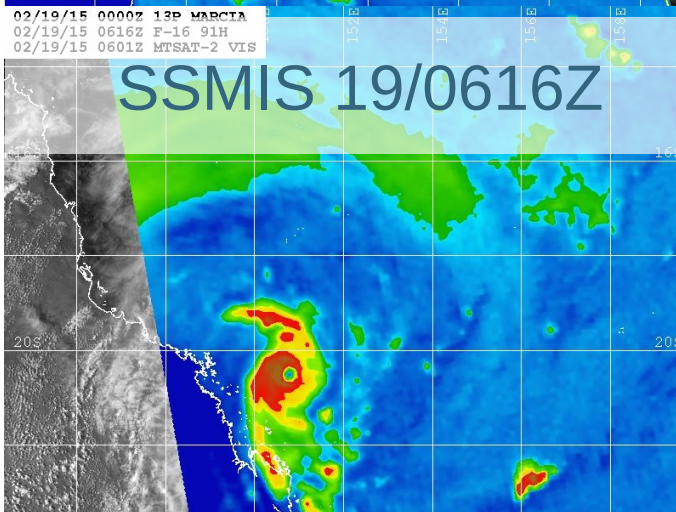


91GHz SSMIS over 34h









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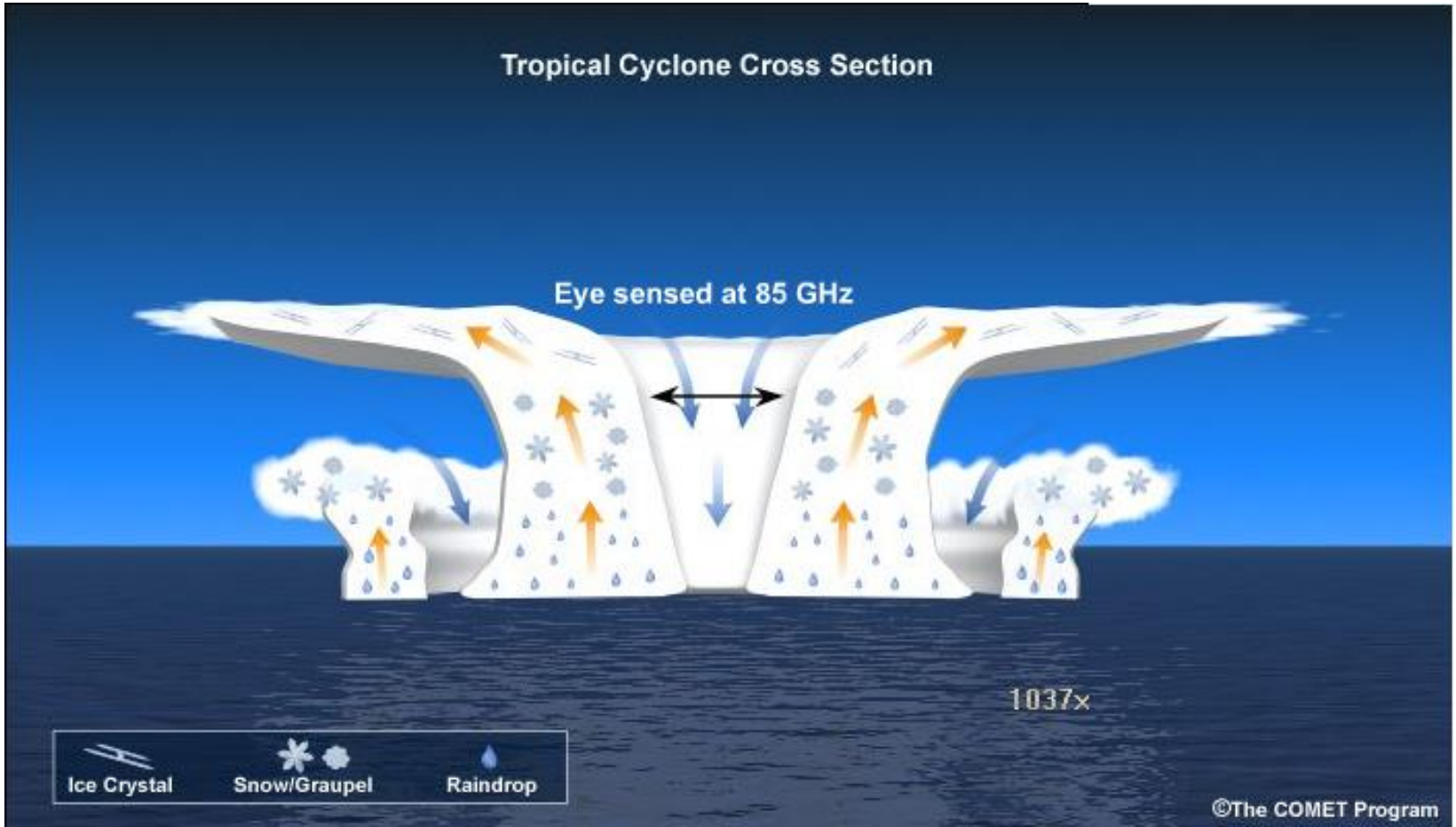
37 Vs 85 GHz

Eye looks bigger on 85 GHz as 85GHz represents conditions higher up.



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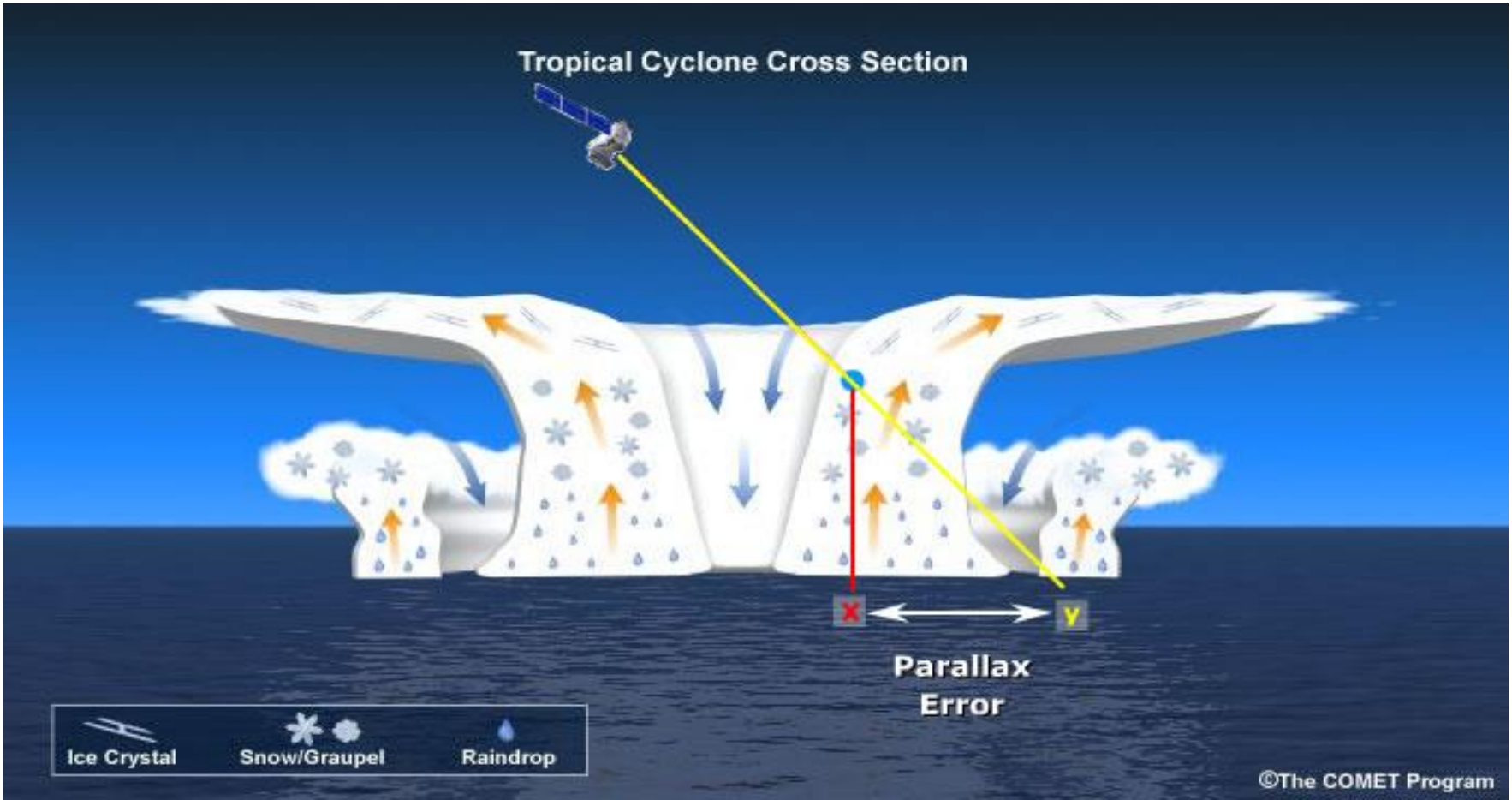
Parallax at 85-91 GHz
Need to correct position

Note: Not to scale



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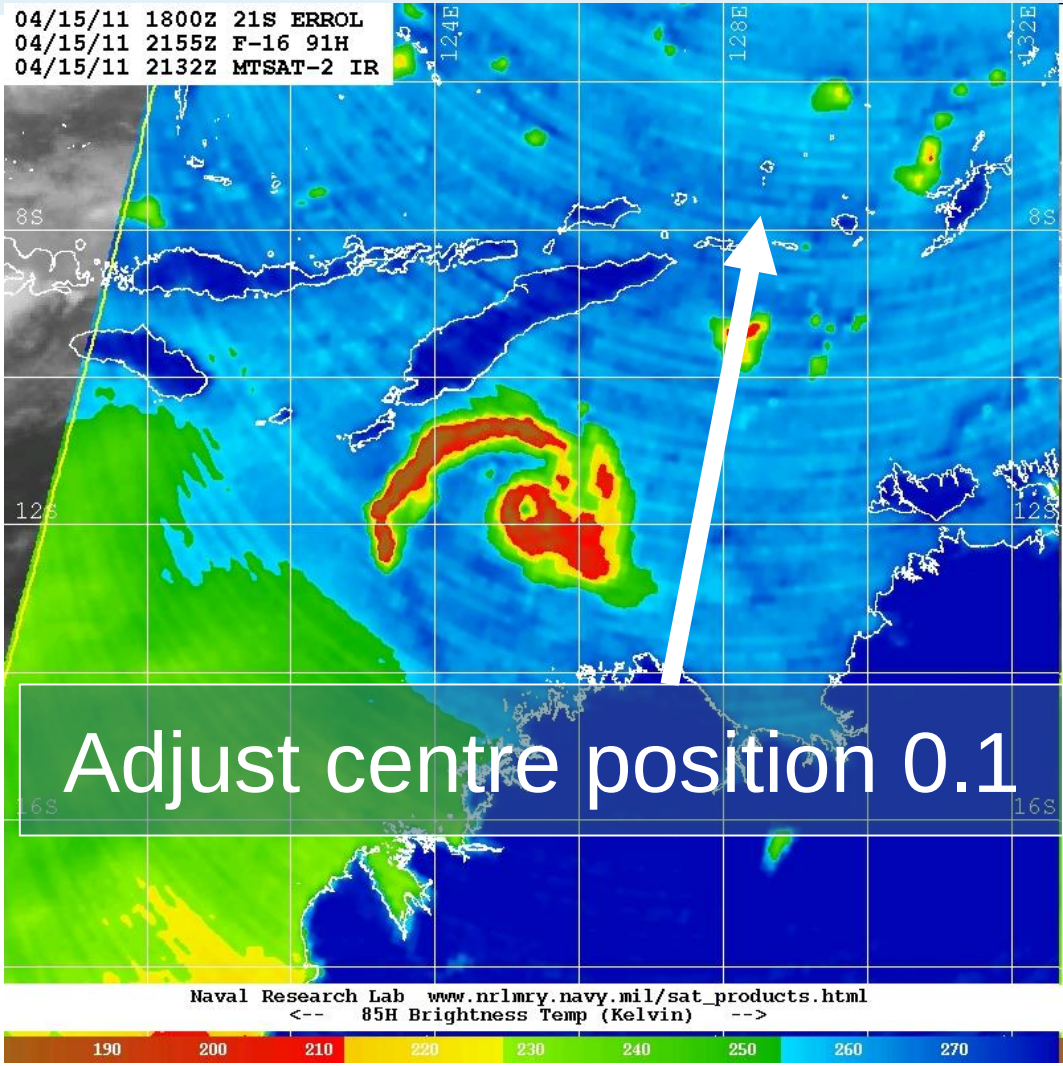
Parallax for 85-91GHz

Which direction is the satellite travelling?

Which way is the parallax correction?



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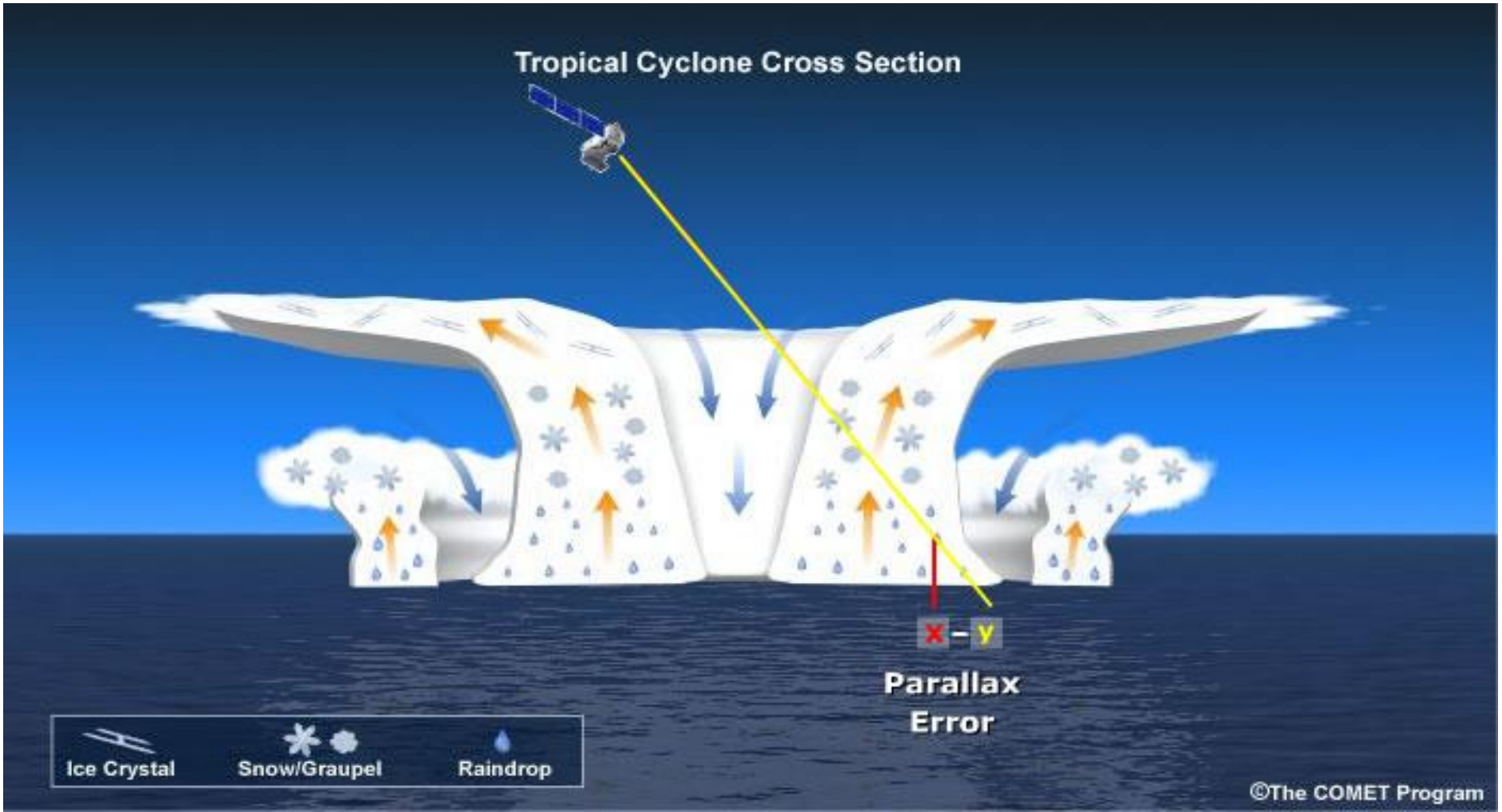
Parallax at 37 GHz



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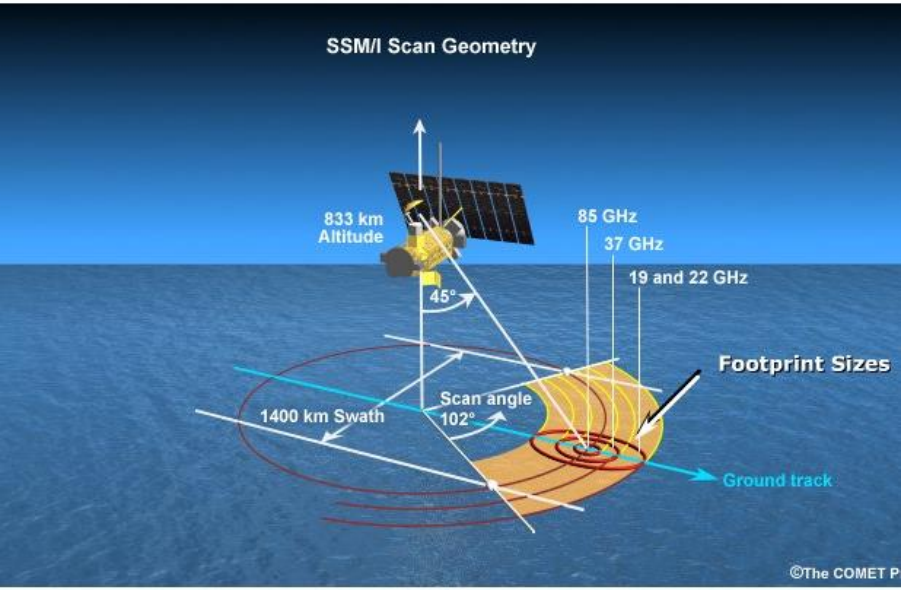
37 Vs 85 GHz – Eye size & Parallax

Parallax error:

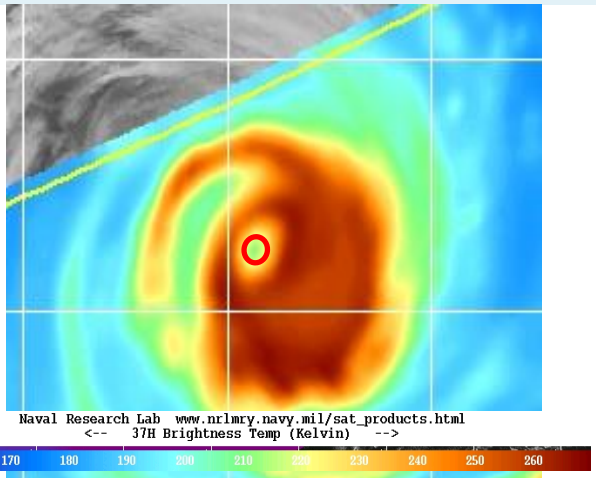
37 GHz - 5 km or less

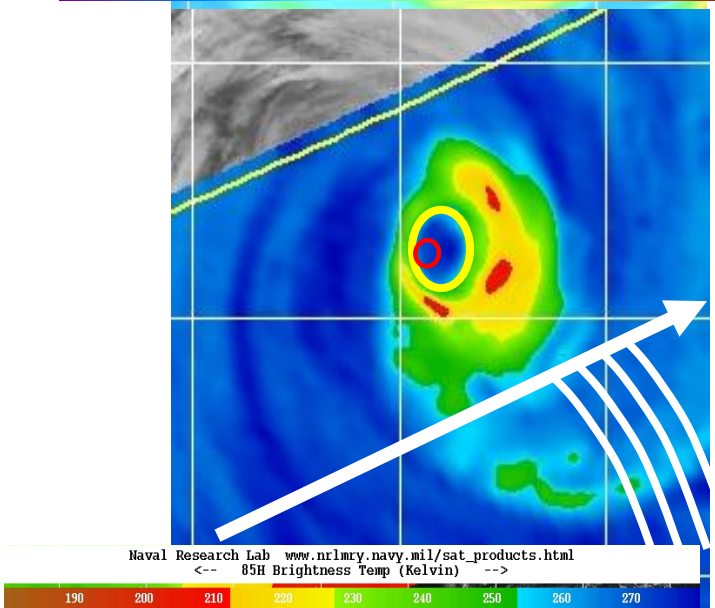
85-91 GHz - 10-20 km



Correction back towards satellite

motion is parallel to edge; use 85 windscreen wiper effect to determine direction





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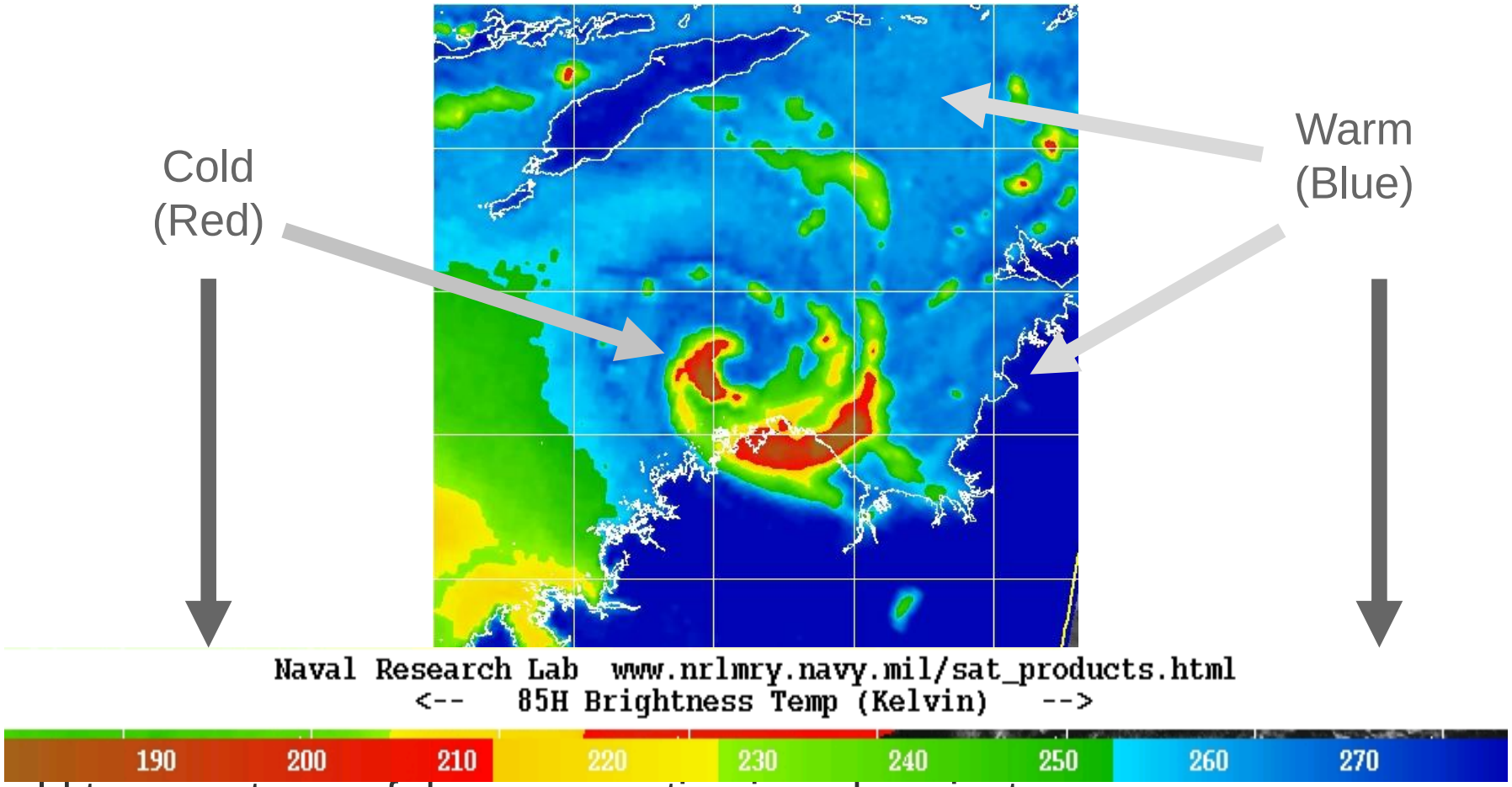
85 GHz



cold temperatures of deep convection in red against a warmer ocean background (and land) in blue.

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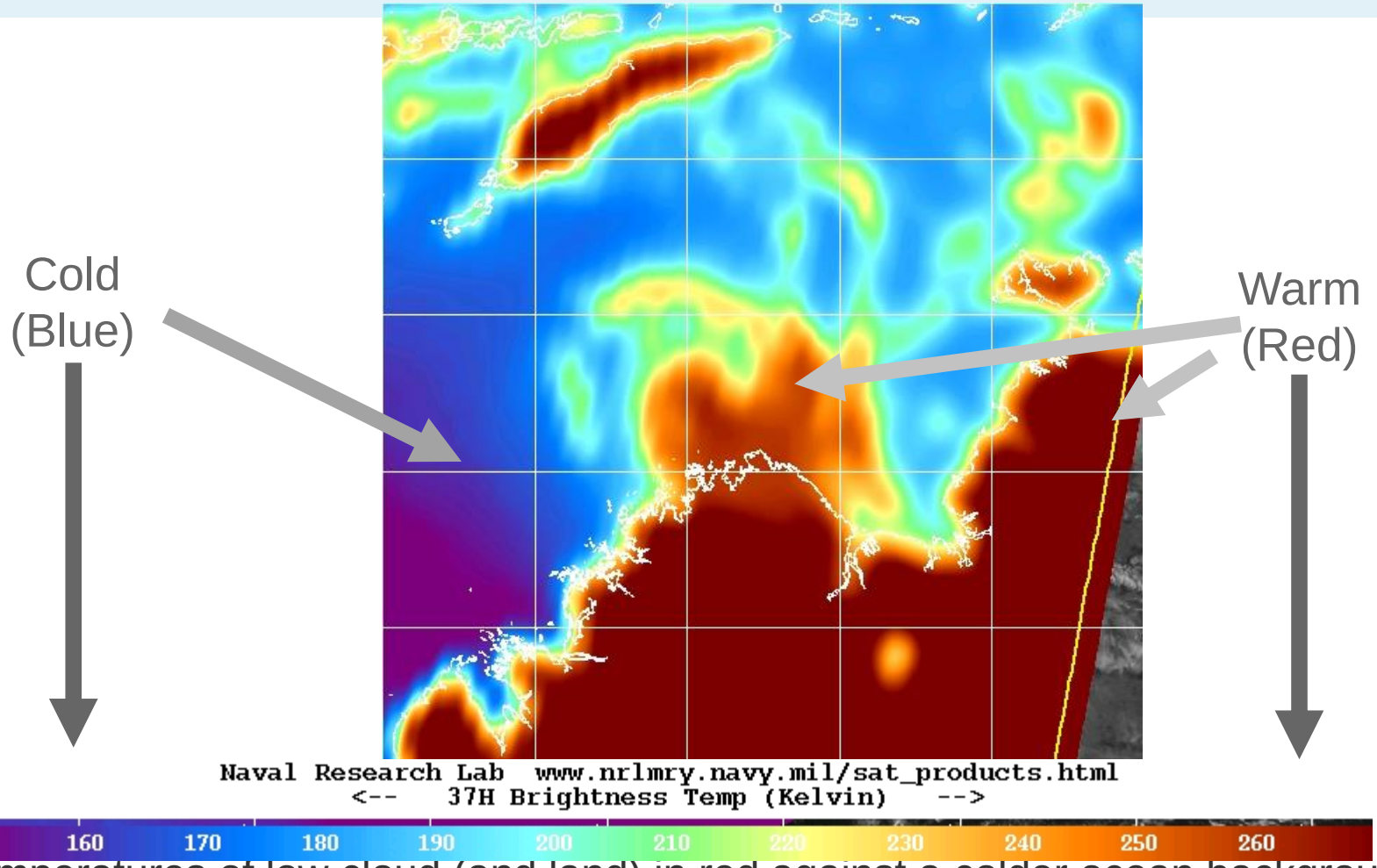
37 GHz



warm temperatures of low cloud (and land) in red against a colder ocean background in blue.

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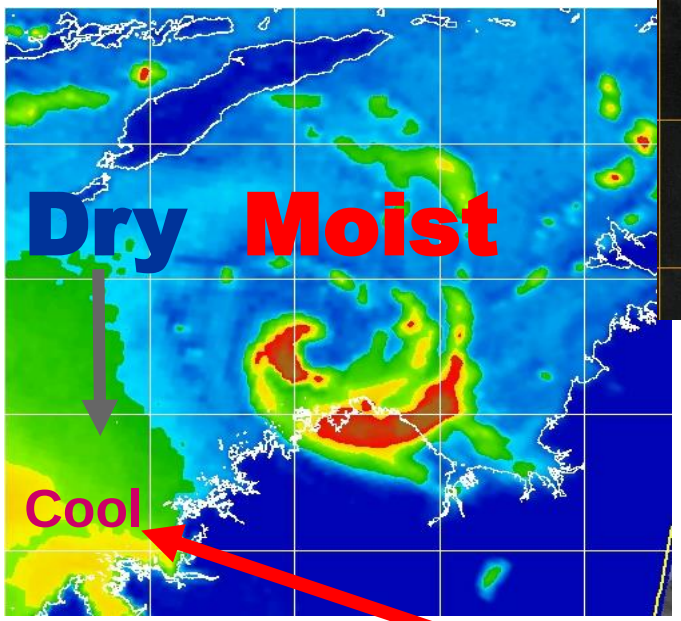
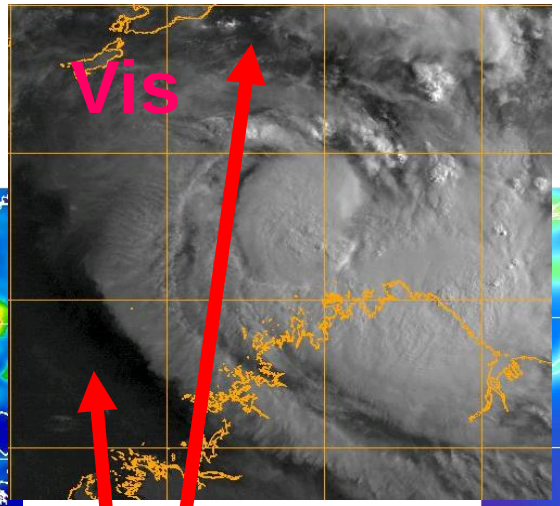
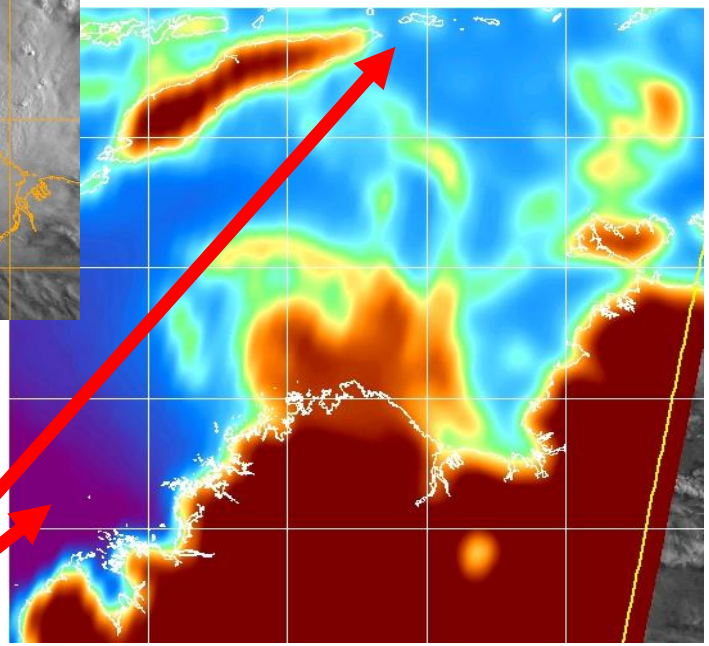
Viewing Interpretation--*Oceans*

*Oceans Appears Cool in 85GHz



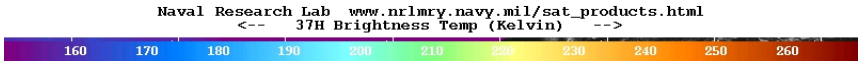


*Oceans Appears Cold in 37GHz



OCEAN

Cold Cool Warm



Cold Warm

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85-91GHz Summary

At 85 GHz, energy emitted from the ocean surface is rapidly depleted in lower to middle portions of convective clouds due to scattering by water drops and large ice particles

Advantages:

Can penetrate cirrus and reveal internal storm structure such as eyes and convective bands;

Distinguishes deep convection from lightly raining cloud features;

Offers higher spatial resolution than at 37GHz;

Limitations:

Can not always see low-level circulation;

Cold ocean may look like deep convection – needs colour enhancement to resolve ambiguity ocean and cloud;

Parallax errors when viewing deep convection (10-20km);

Not available on Windsat;

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37GHz Summary

At 37 GHz, abundant energy emitted by water droplets lower in the convective cloud is largely unaffected by ice particles higher in the cloud

Advantages:

Can penetrate cirrus and reveal detail within the storm core missed by 85GHz such as eyes;

Shows regions of low level clouds/rain;

Small parallax error compared to 85GHz;

Limitations:

As deep convection not distinguished well from low clouds then inner core may be poorly defined;

Lower spatial resolution than on 85GHz;

Some scattering in very intense convection resulting in false signal – needs colour enhancement to resolve this detail;

Not available on AMSU-B;

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Summary

- There are different techniques used to find the centre: use all available and the best;
- Microwave images:
  - 37GHz low level – generally best for positioning
  - 85-91GHz highlights convection in mid-levels
  - Use 'color' composite views to help distinguish ocean/low cloud from higher cloud.

Q Microwave is most useful for determining the centre when …

Q Microwave is least useful for determining the centre when …

Exercises: Gita Feb 2018 09P

Where would you put the centre?
What imagers were most useful?
What other information would help?

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Determine position and uncertainty at:

a. 1216UTC on 12/02/2018 _____

b. 18UTC on 11/02/2018 _____

c. 0304UTC on 10/02/2018 _____

d. 1426UTC on 09/02/2018 _____

e. 1240UTC on 08/02/2018 _____

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Exercises: Gita Feb 2018 09P

Where would you put the centre?
ASCAT

https://manati.star.nesdis.noaa.gov/datasets/ASCATData.php:

a. 0852UTC on 12/02/2018 _____

b. 2024UTC on 11/02/2018 _____

c. 2044UTC on 10/02/2018 _____

d. 2104UTC on 09/02/2018 _____

e. 2124UTC on 08/02/2018 _____

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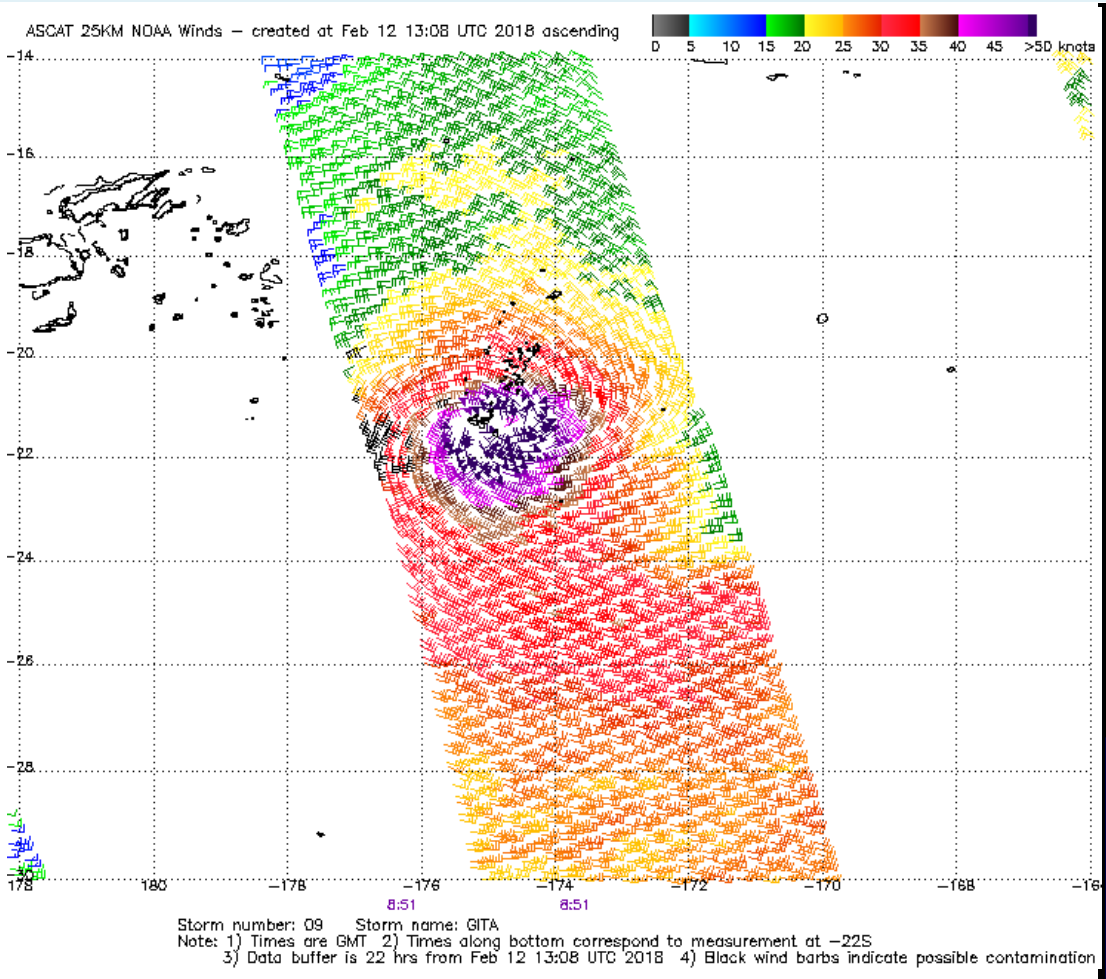
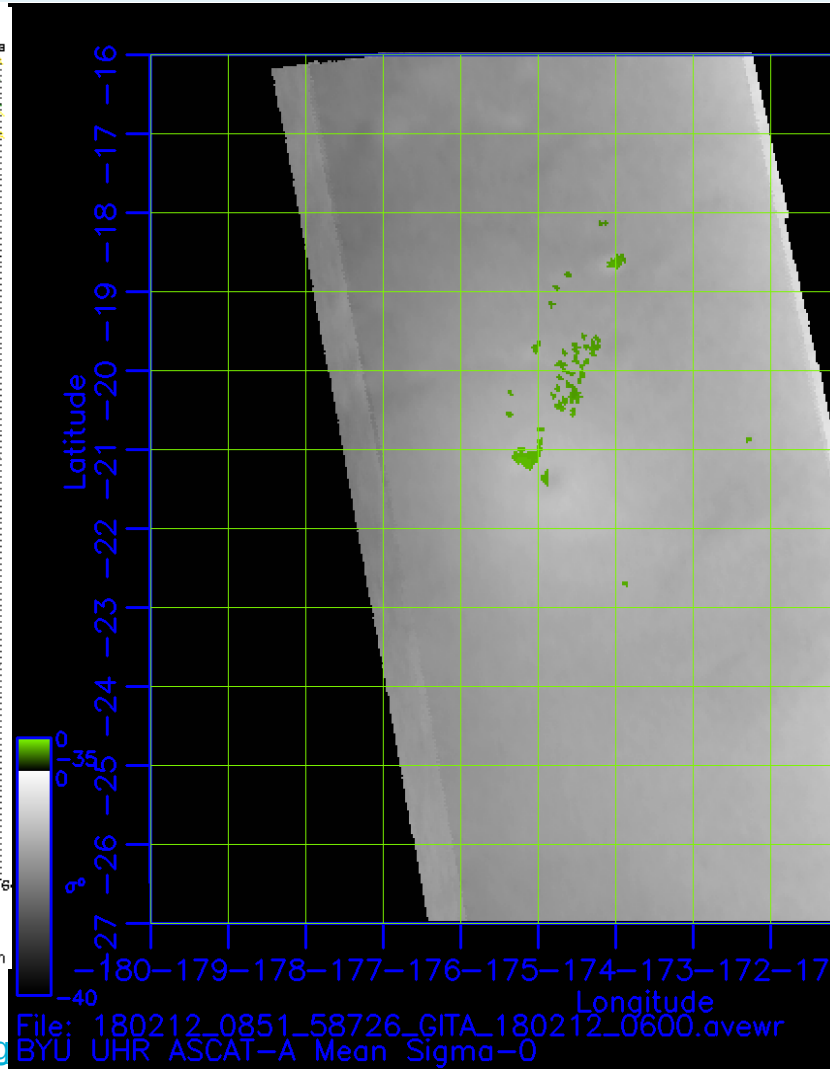
Scatterometry exercise: Gita
a. 12/0852 UTC





https://manati.star.nesdis.noaa.gov/ascat_images/ascat_storm/byu_sh_imag

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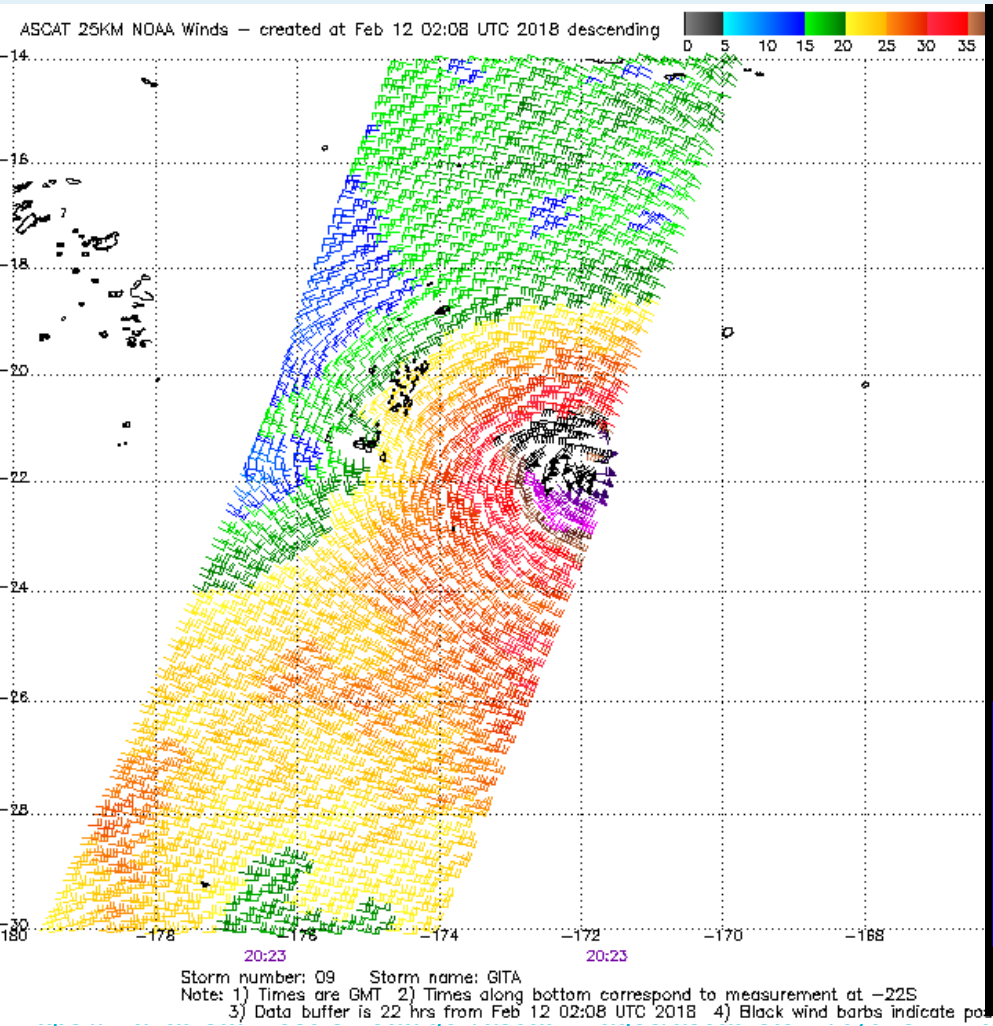
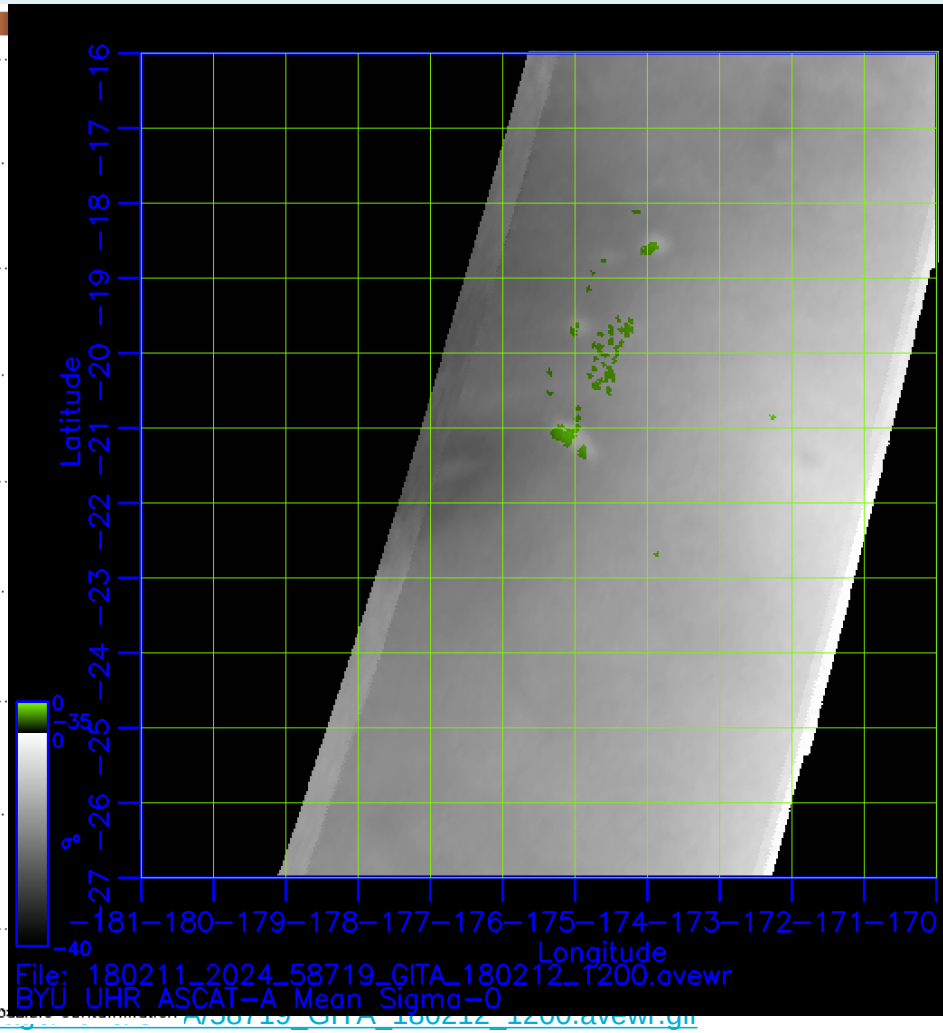
Scatterometry exercise: Gita
b. 2024UTC on 11/02/2018





https://manati.star.nesdis.noaa.gov/ascat_images/ascat_storm/ascat_25km/storm_sh_image/2018/ascat2518021202_09_GITA_ds.png

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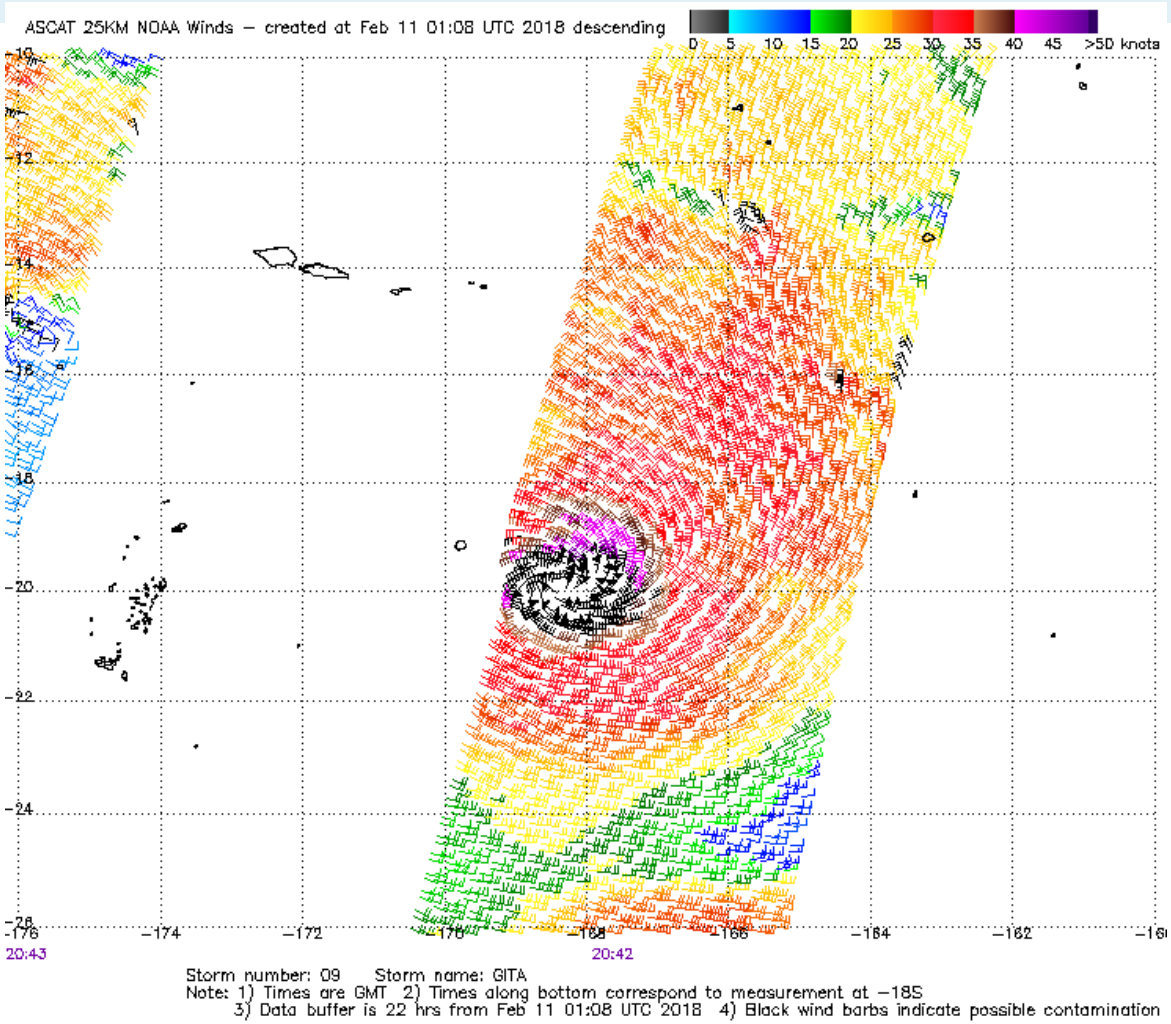
Bureau of Meteorology

Scatterometry exercise: Gita
c. 2044UTC on 10/02/2018



https://manati.star.nesdis.noaa.gov/ascat_images/ascat_storm/ascat_25km/storm_sh_image/2018/ascat2518021000_09_GITA_ds.png
https://manati.star.nesdis.noaa.gov/ascat_images/ascat_storm/ascat_25km/storm_sh_image/2018/ascat2518021101_09_GITA_ds.png

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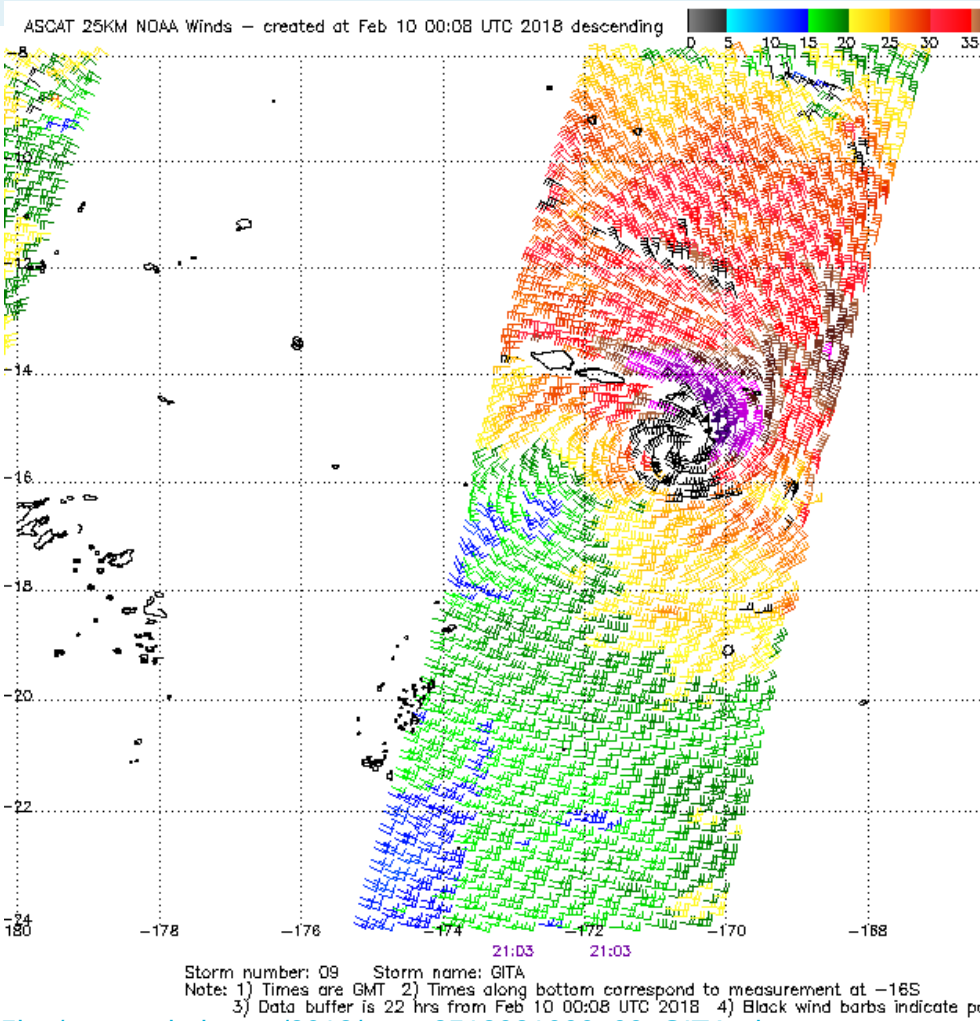
Scatterometry exercise: Gita
d. 09/2103 UTC



https://manati.star.nesdis.noaa.gov/ascat_images/ascat_storm/ascat_25km/storm_sh_image/2018/ascat2518021000_09_GITA_ds.png
https://manati.star.nesdis.noaa.gov/ascat_images/ascat_storm/byu_sh_image/2018/GITA/58719_GITA_180212_1200.avewr.gif

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Scatterometry exercise: Gita
e. 2124UTC on 08/02/2018

11/02/18 2024

https://manati.star.nesdis.noaa.gov/ascat_images/ascat_storm/byu_sh_image/2018/GITA/58719_GITA_180212_1200.avewr.gif

https://manati.star.nesdis.noaa.gov/ascat_images/ascat_storm/ascat_25km/storm_sh_image/2018/ascat2518021000_09_GITA_ds.png