AOMSUC-10

2–7 December 2019
Melbourne, Australia

10TH ASIA-OCEANIA METEOROLOGICAL SATELLITE USERS' CONFERENCE

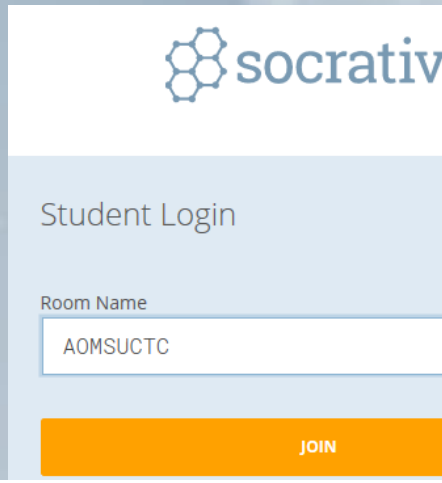
Tropical Cyclone applications of current and emerging scatterometers and radiometers

Joe Courtney

Bureau of Meteorology Perth

Socrative: b.socrative.com

Room: AOMSUCTC



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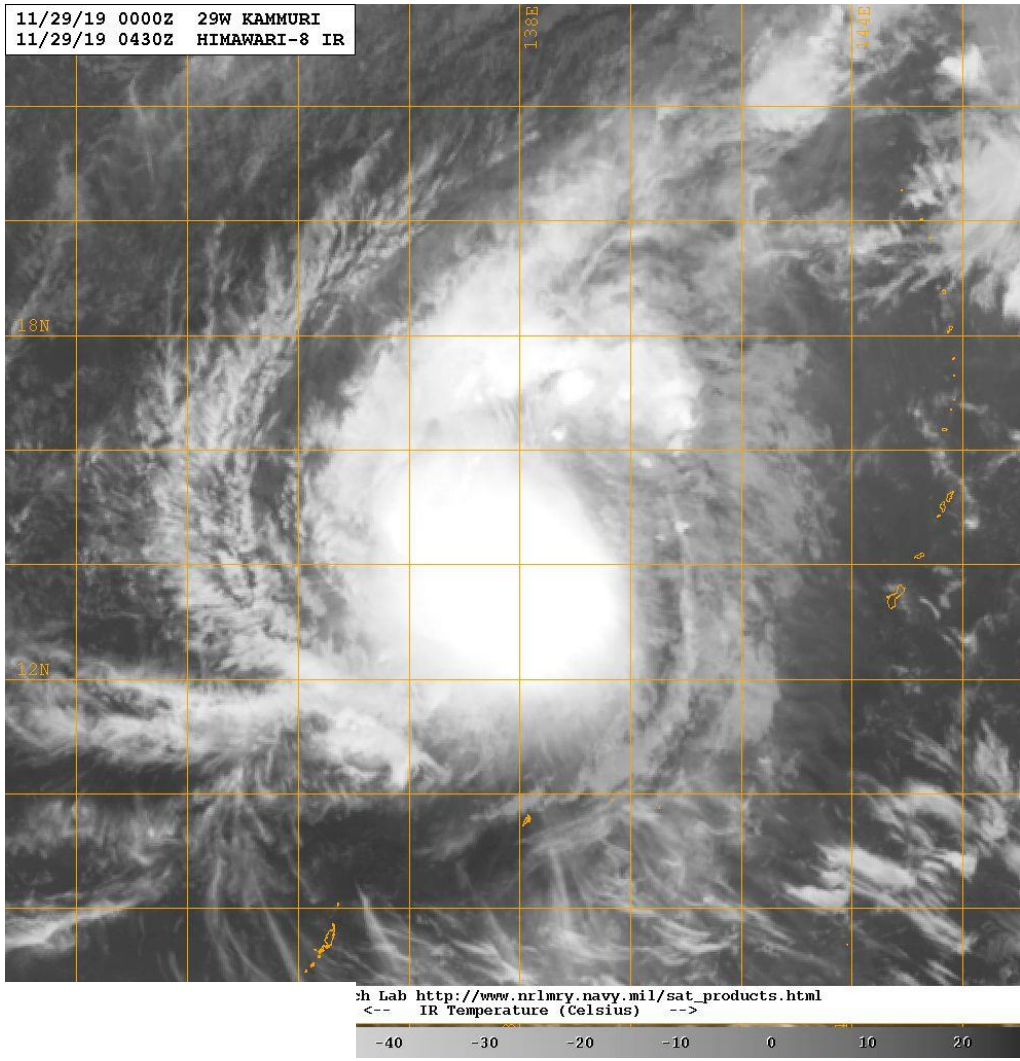
The forecasting challenge

Where is the centre?
How strong is it?
How far do gales extend?



TC Kammuri

29 November 2019

Credit: NRL https://www.nrlmry.navy.mil/TC.html

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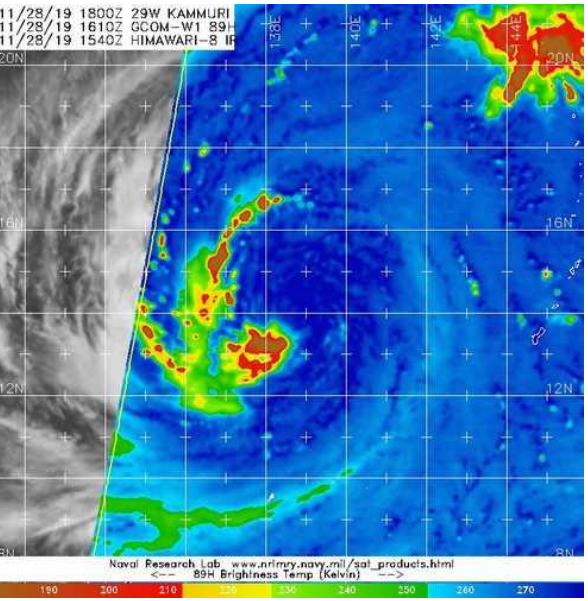
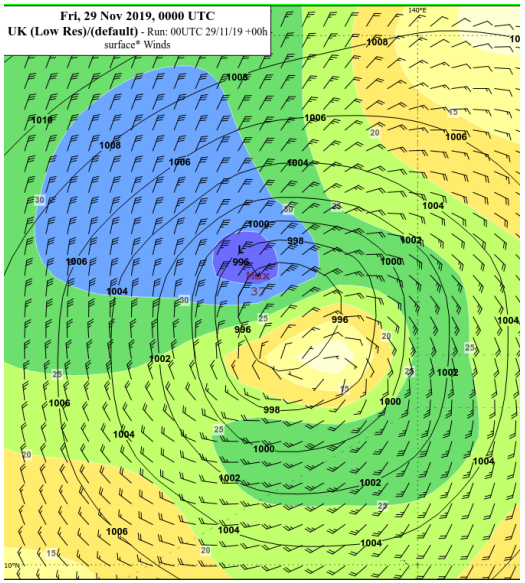
The forecasting challenge:

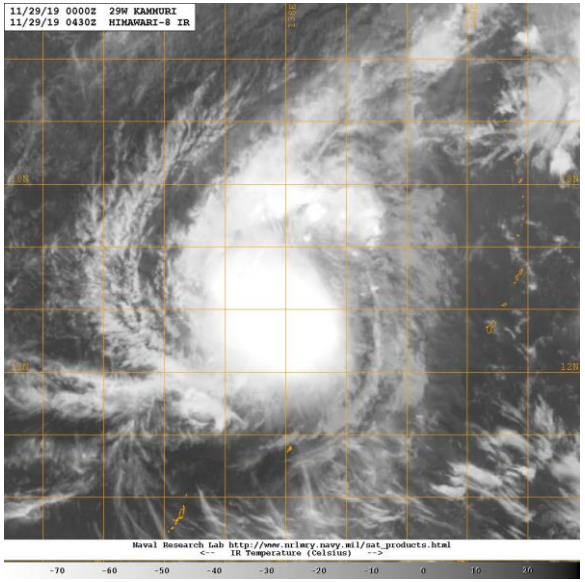
Where is the centre?
How strong is it?
How far do gales extend?

Tools:

IR/Vis; radar; Microwave; Observations (sfc/aircraft…), NWP/objective algorithms and scatterometers/radiometers







Credit: NRL https://www.nrlmry.navy.mil/TC.html

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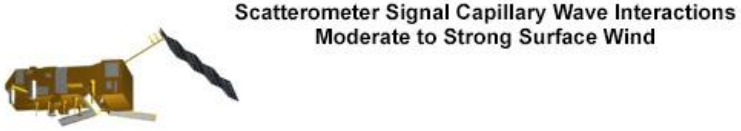
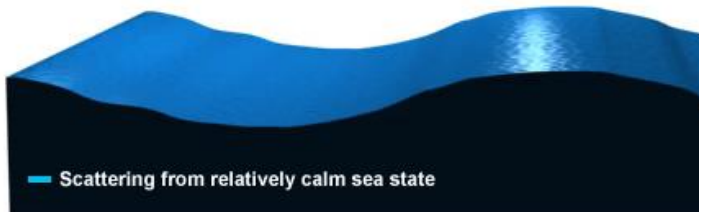
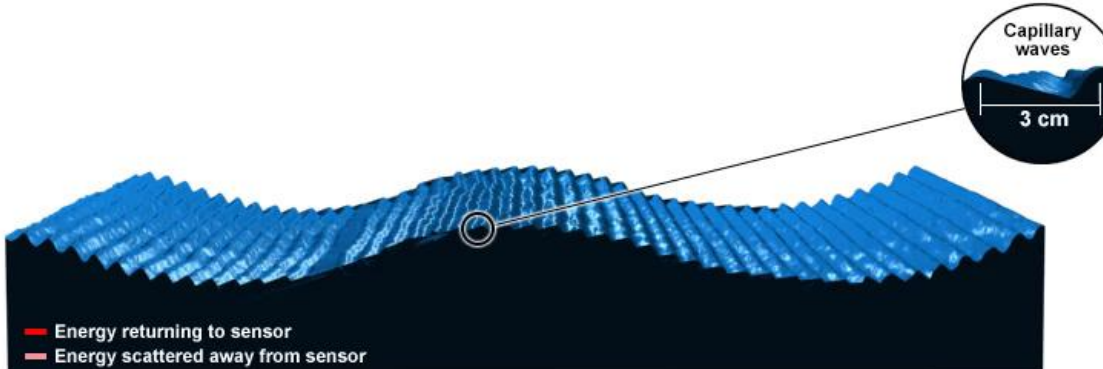
Scatterometry Theory:
active sensors measure backscatter
Bragg scattering

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







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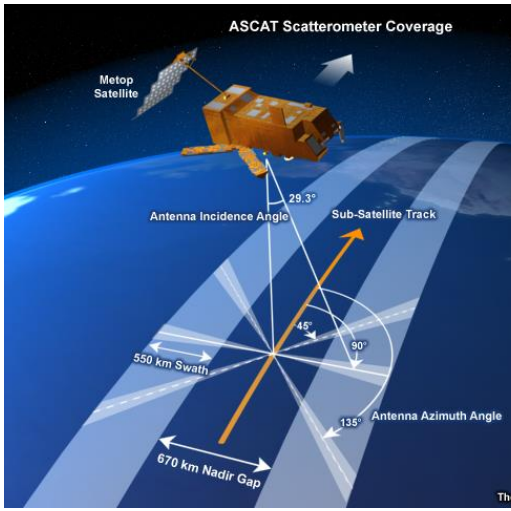
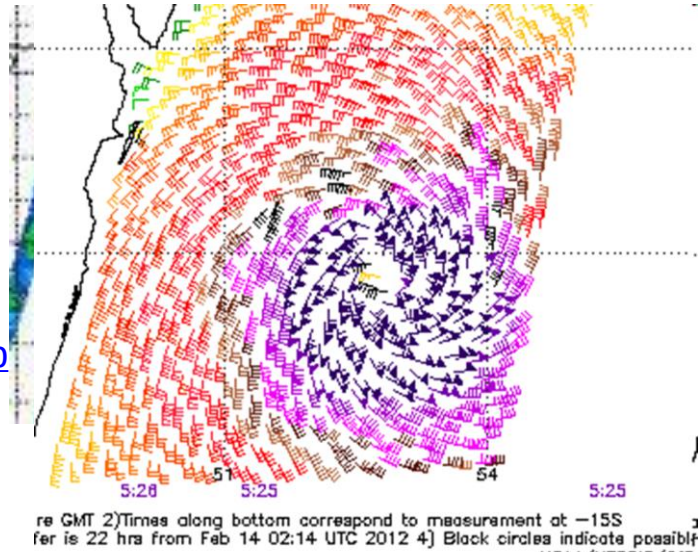
Advanced SCATterometer (ASCAT)

- 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
- 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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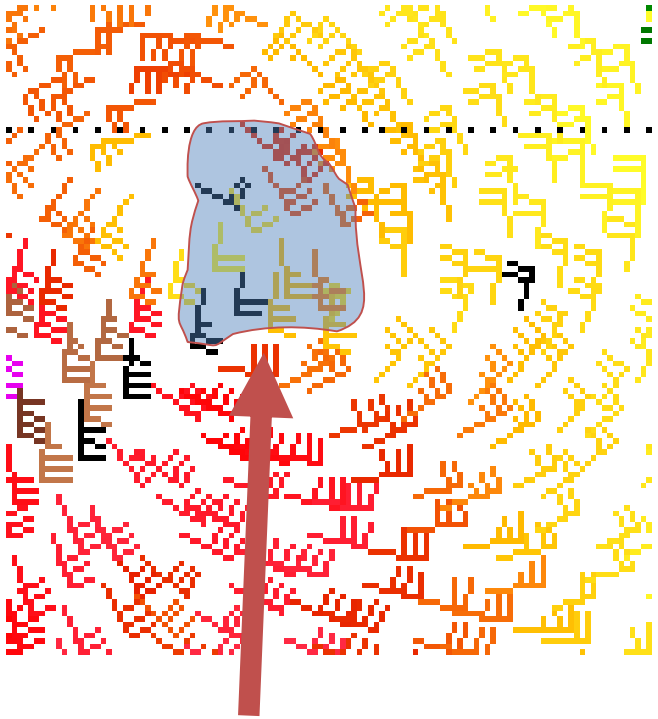
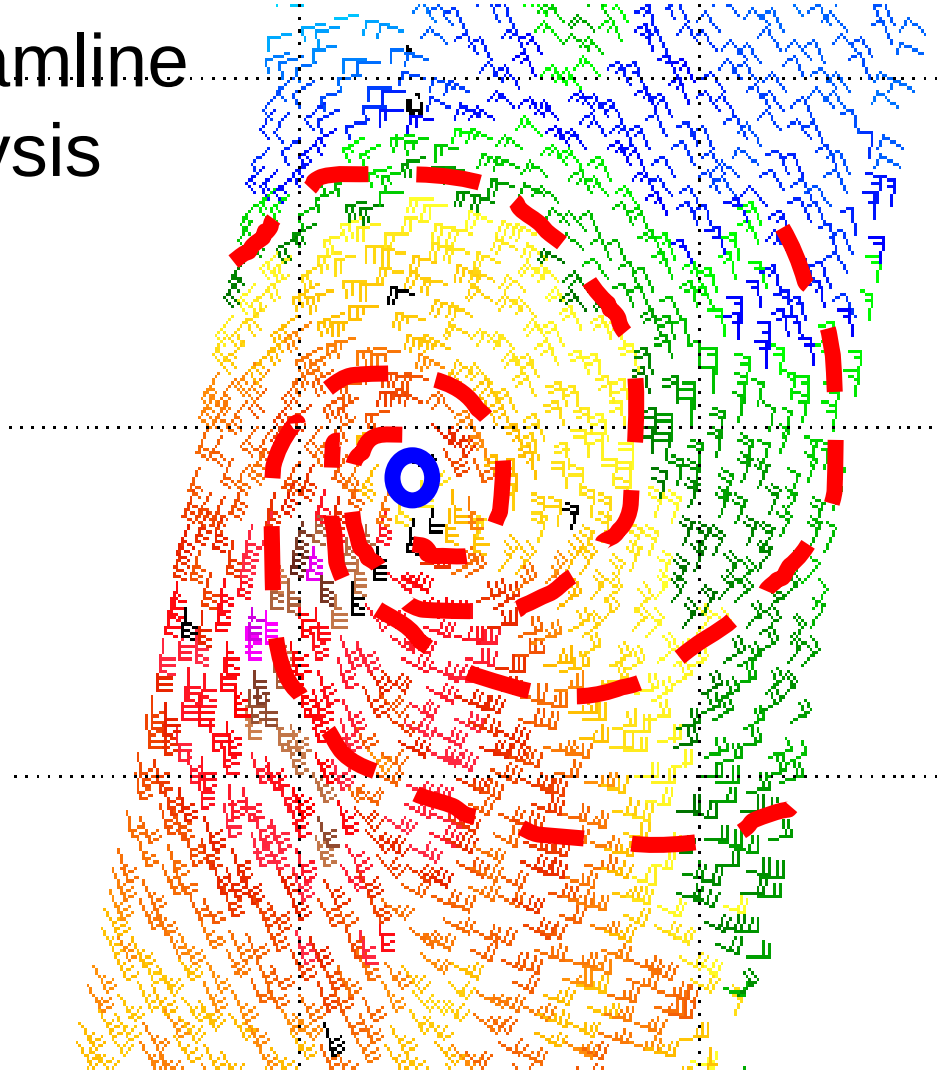
AScat - positioning



Wrong direction

Streamline analysis



Southern Hemisphere example

ASCAT positioning: ARCHER

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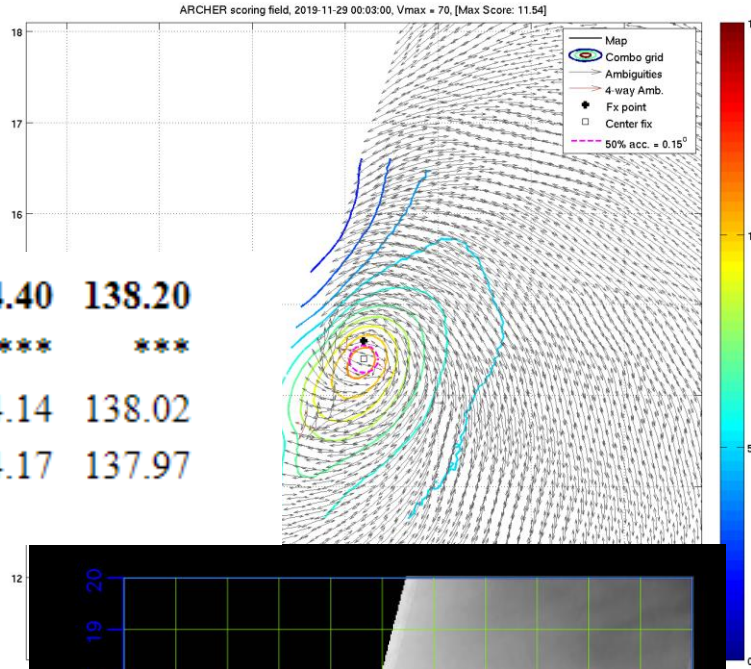
http://tropic.ssec.wisc.edu/real-time/archerOnline/web/index.shtml

Automatic and usually better than human eye

Kammuri 29W: 00Z 29/11/2019 ASCAT-A

http://tropic.ssec.wisc.edu/real-time/archerOnline/cyclones/2019_29W/web/summaryTable.html

20191129 00:03:00 *	Metop-A	ASCAT	70.0	14.40	138.20
20191128 23:30:00	Geo	Vis	70.4	***	***
20191128 23:30:00	Geo	NearIR	70.4	14.14	138.02
20191128 23:30:00	Geo	IR	70.4	14.17	137.97



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

NRCS from NOAA 'manati' web page:

via 'storm' option

eg : Kammuri: NRCS very clear!

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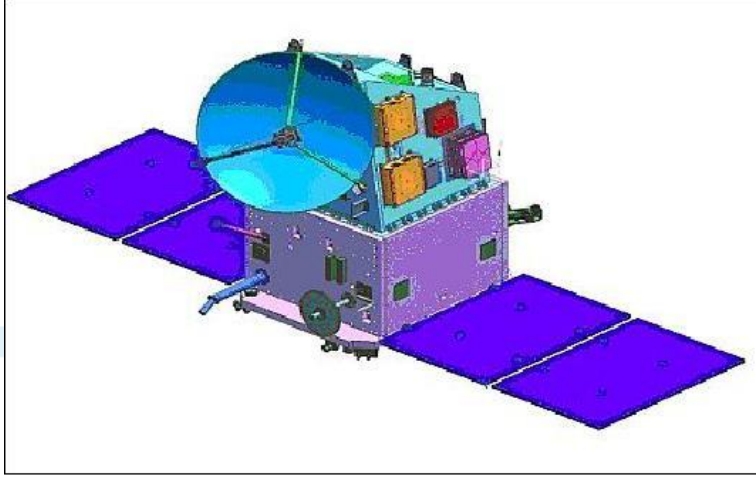
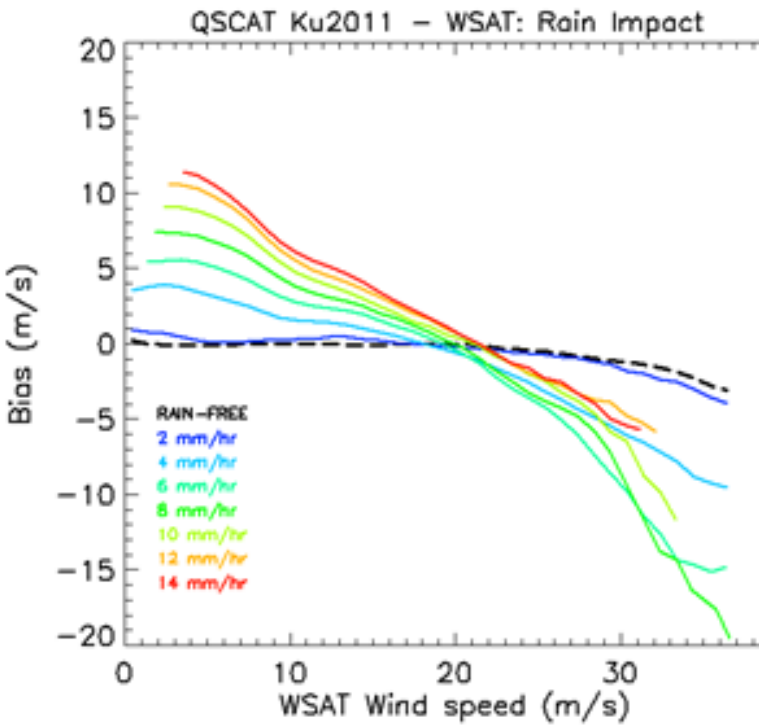
SCATSAT



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
Swathe 1440km

TC applications:
Good for gale radii
Issue: rain contamination for speed
Overestimates winds in mod/heavy rain (<50kn)
intensity not so great esp >~50kn



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

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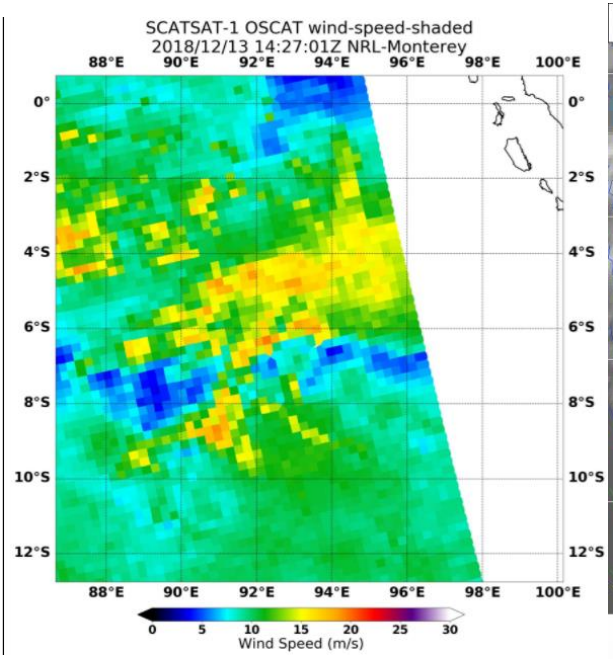
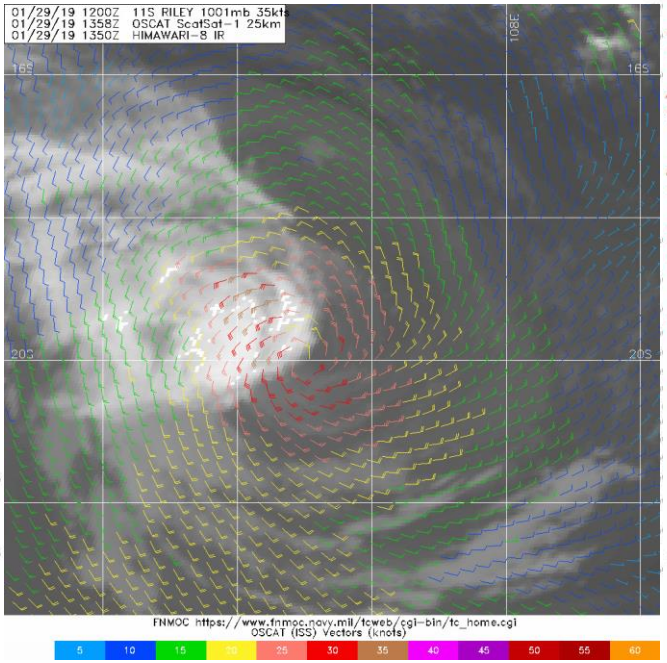
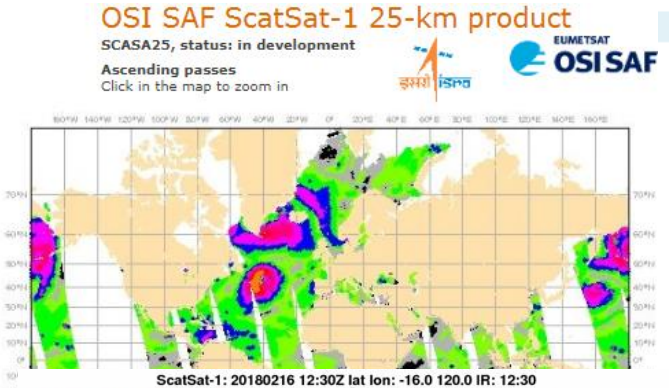
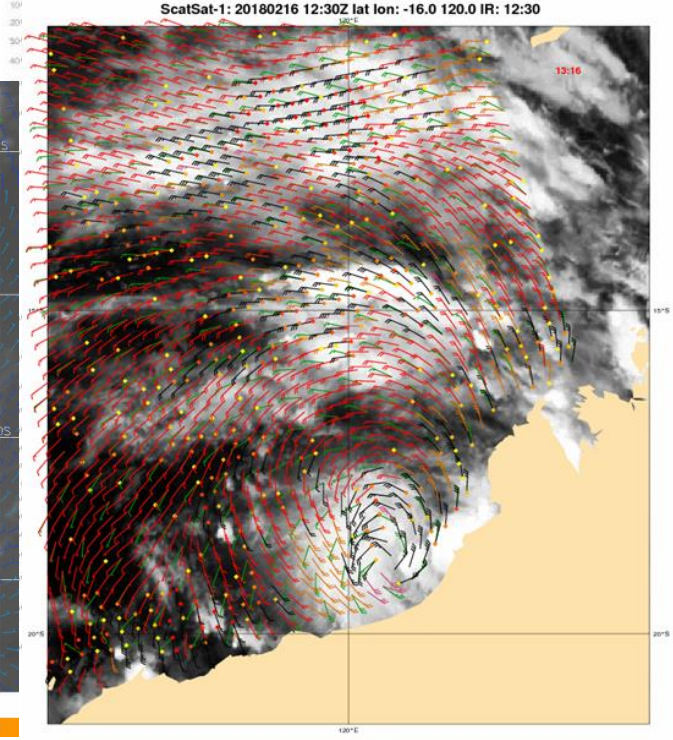
SCATSAT availability

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









NEW CFOSAT SCATterometer

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Similar characteristics to SCATSAT

- Joint Chinese French Oceanography SATellite : CFOSAT (2019),
- https://www.wmo-sat.info/oscar/instruments/view/918

OSCAR
Observing Systems Capability Analysis and Review Tool

- Channel: 13.3 GHz (5cm); Ku-Band (dual-pol)
- two passes per day (ascending/descending)
- Swathe 1000km
- Resolution: 25-50km
- TC applications:
- Lack of coverage in tropics an issue
- Good for gale radii and positioning
- intensity not so great esp >~50kn
- Available:
  KNMI http://projects.knmi.nl/scatterometer/tile_prod/tile_app.cgi

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NEW HY-2B SCATterometer

Similar characteristics to SCATSAT

OSCAR
Observing Systems Capability Analysis and Review Tool

- Satellite: HY-2B (2019),
- https://www.wmo-sat.info/oscar/satellites/view/545
- Channel: 13.2 GHz (5cm); Ku-Band
- two passes per day (ascending/descending)
- Resolution: 25-50km
- Swathe 1300km
- TC applications:
- Lack of coverage in tropics an issue
- Good for gale radii and positioning
- intensity not so great esp >~50kn
- Available
  KNMI http://projects.knmi.nl/scatterometer/tile_prod/tile_app.cgi

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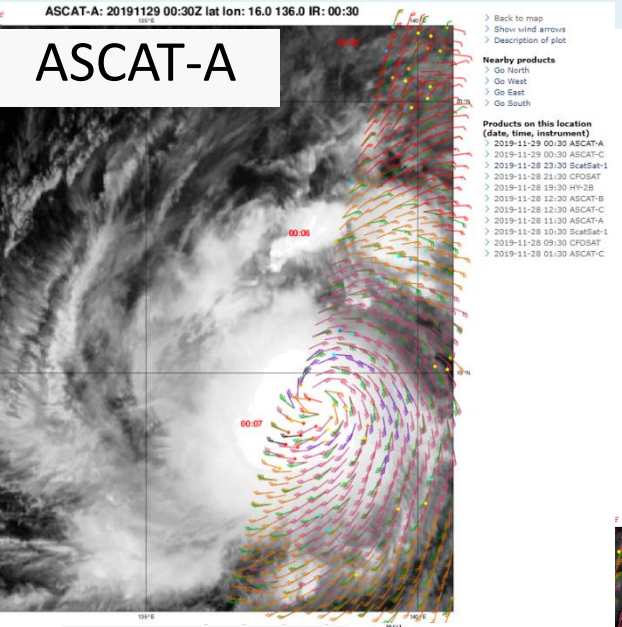
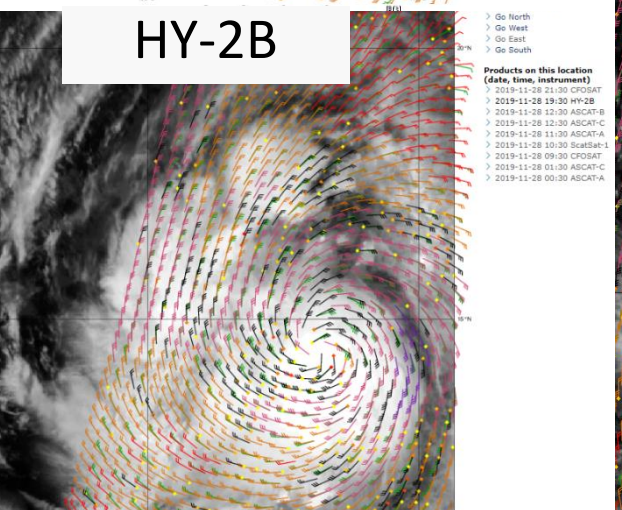
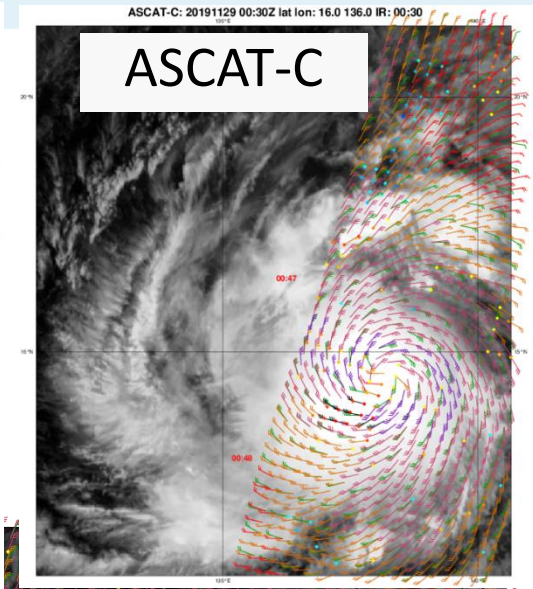
Coverage: HY-2B, CFOSAT-SCATSAT-ASCAT A, B, C

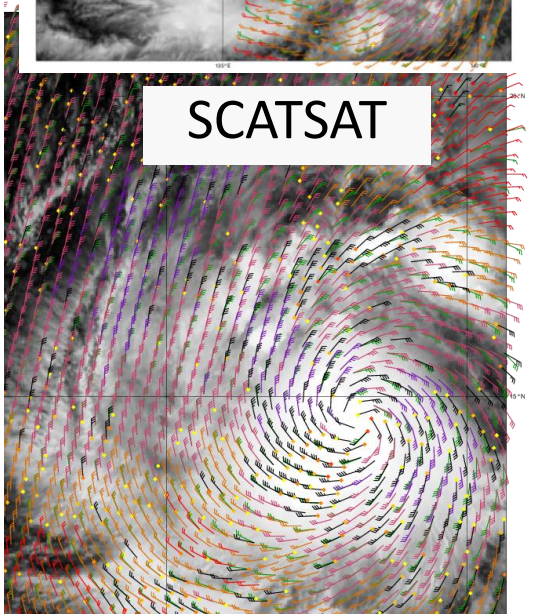
Case: Kamuri 3h window 28/22Z to 29/0120Z

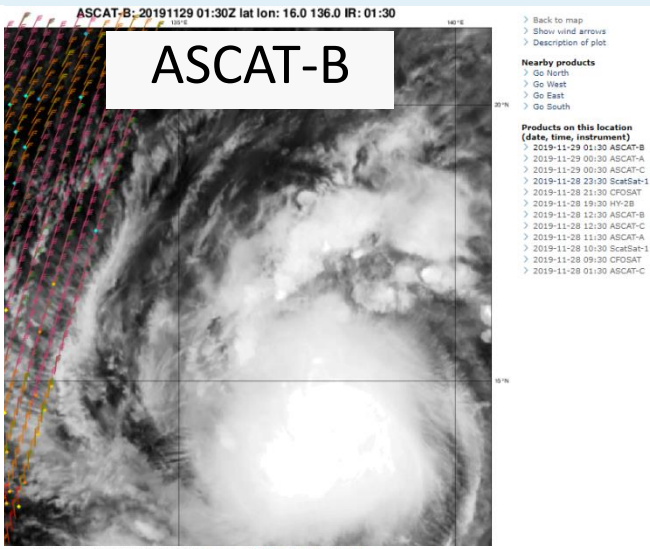
NOW: coverage 95% guaranteed 2 daily!!!

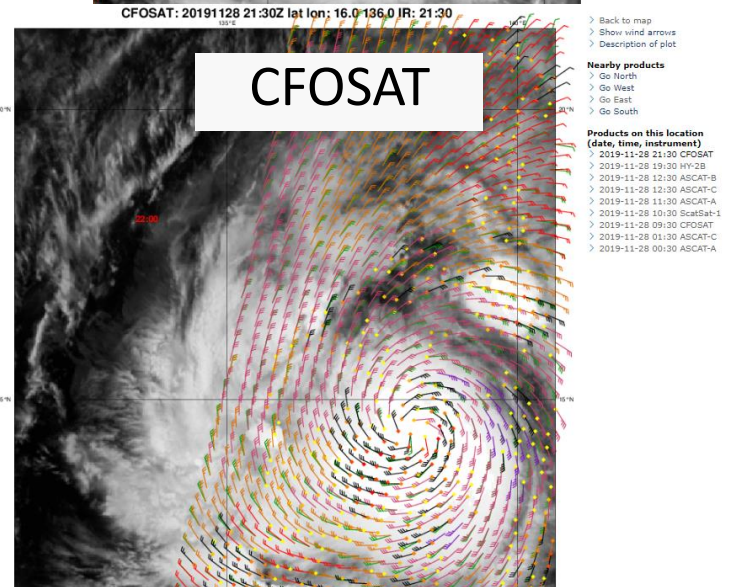












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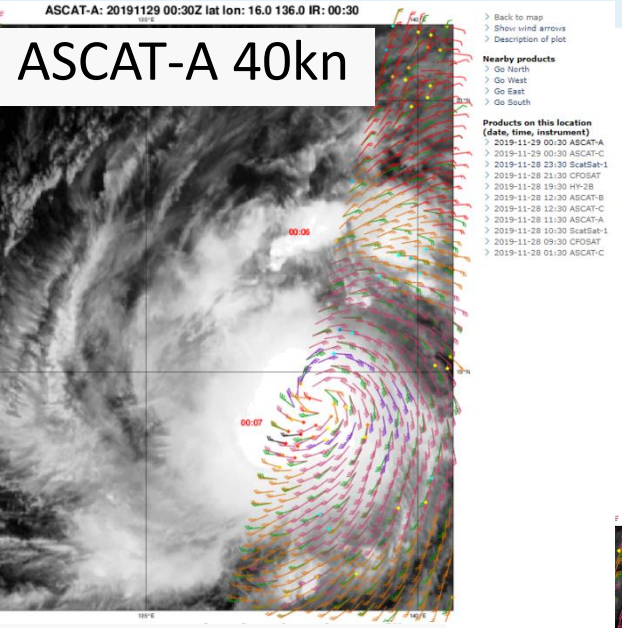
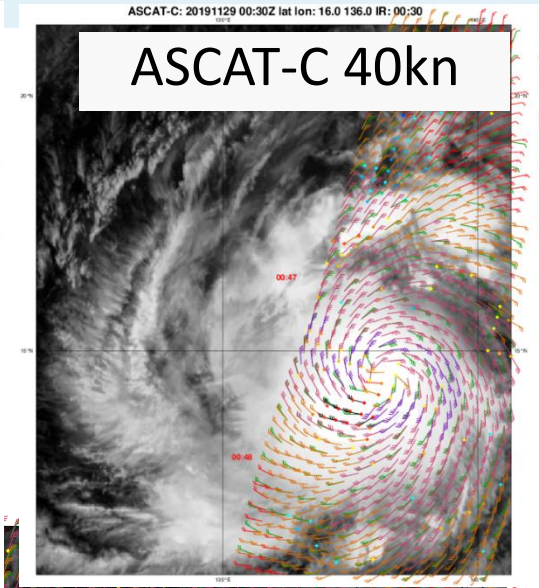
Case: Kamuri 00 UTC 29 November
What is the intensity ?
Refer Socrative.com

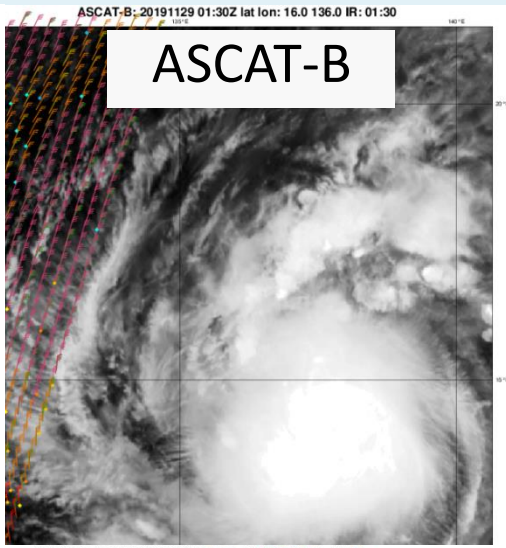
ASCAT-A 40kn



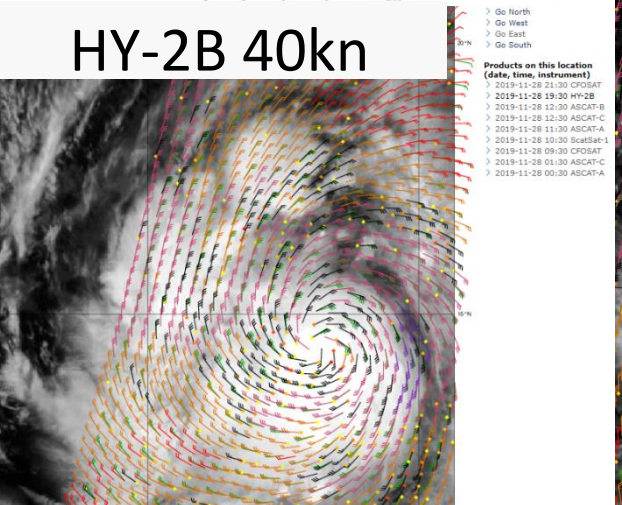
ASCAT-C 40kn



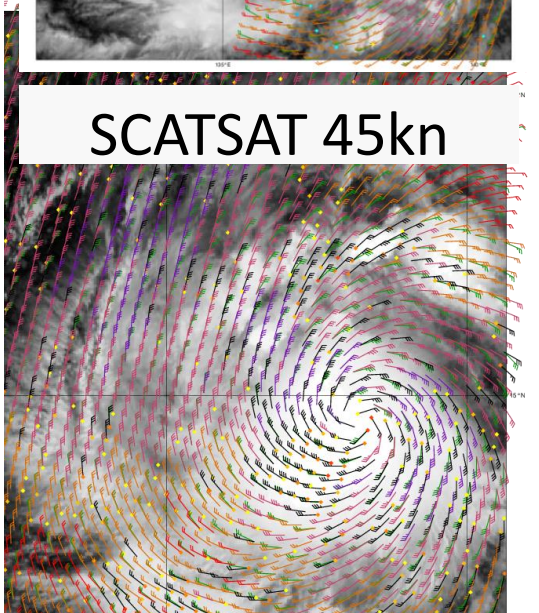
ASCAT-B



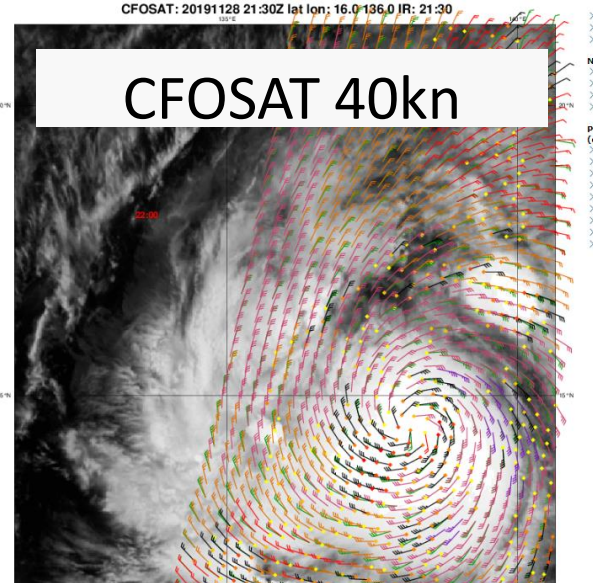
HY-2B 40kn



SCATSAT 45kn



CFOSAT 40kn



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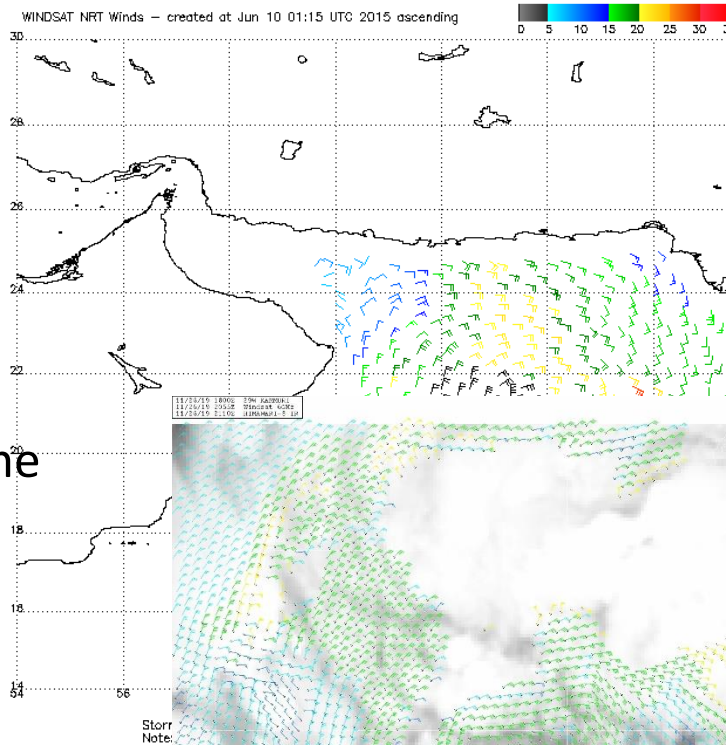
Radiometers (passive)
Windsat

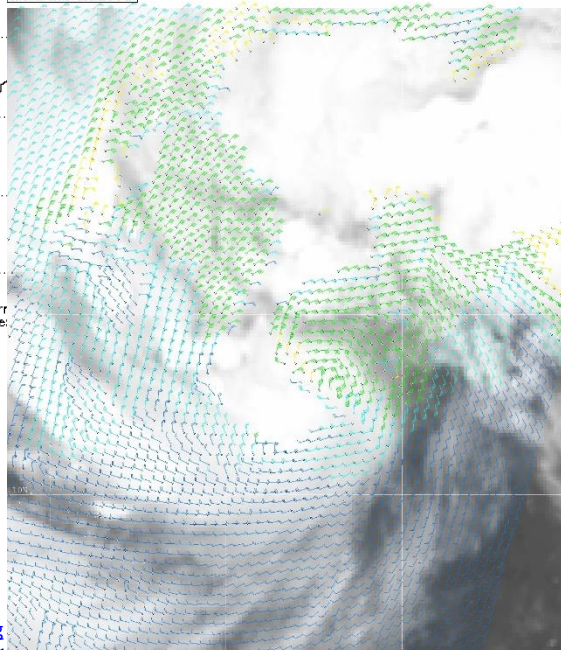
https://manati.star.nesdis.noaa.gov/datasets/WindSATData.php

Satellites: Coriolis (2003 extended lifetime!)
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. Kammuri courtesy NRL https://www.nrlmry.navy.mil/tc-bin/tc_home2.cgi?AGE=Prev&ACTIVES=19-SHEM-01P.RITA,19-WPAC-29W.KAMMURI,19-IO-90A.INVEST,19-SHEM-91S.INVEST,19-WPAC-95W.INVEST,19-WPAC-96W.INVEST&PHOT=yes&ATCF_BASIN=wp&SIZE=Full&NAV=tc&ATCF_YR=2019&ATCF_FILE=/SATPRODUCTS/kauai_data/www/atcf_web/public_html/imag

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AMSR2 radiometer (passive)

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

Satellite: GCOM (2012)

Channel: 10.7-36.5GHz

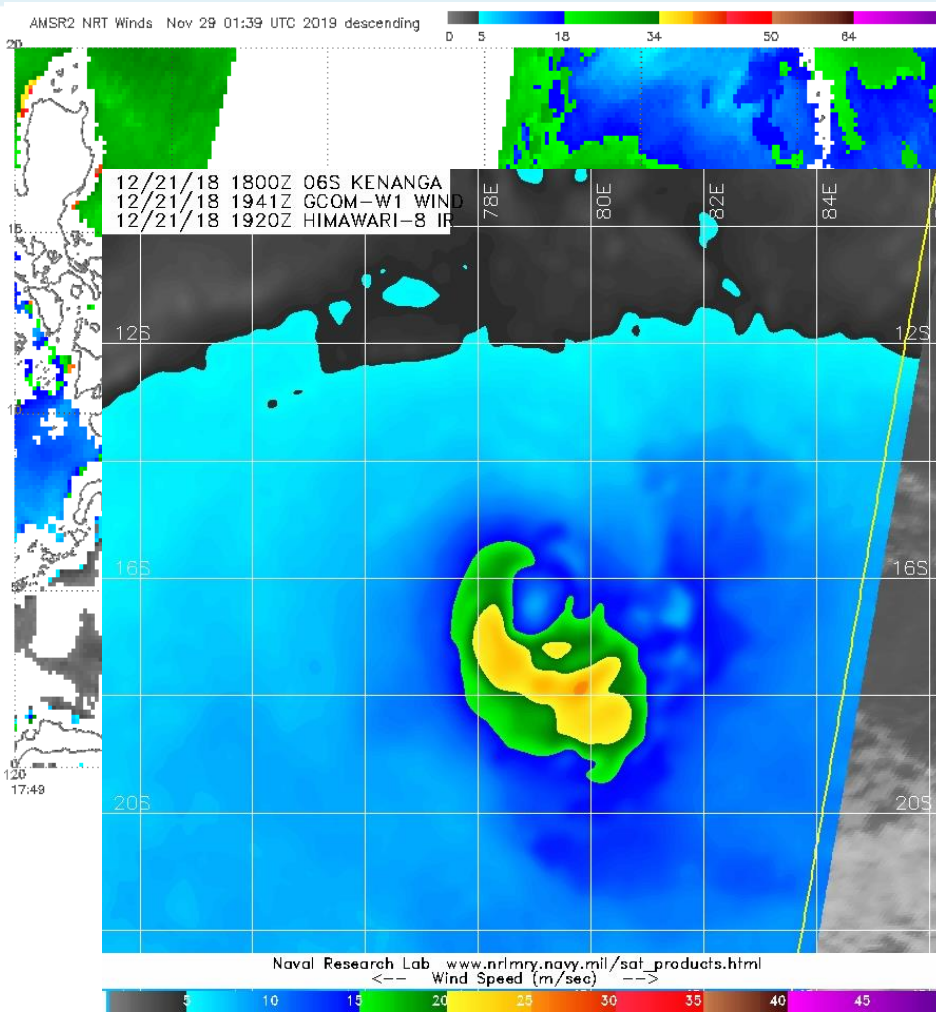
Coverage: 1450km (wider than ASCAT)

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. Kammuri Courtesy: NOAA
https://manati.star.nesdis.noaa.gov/gcom_images/cur/wdsp/zooms/WMBds62.png

2. Kenanga 2018 NRL

L-Band Radiometers:

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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.

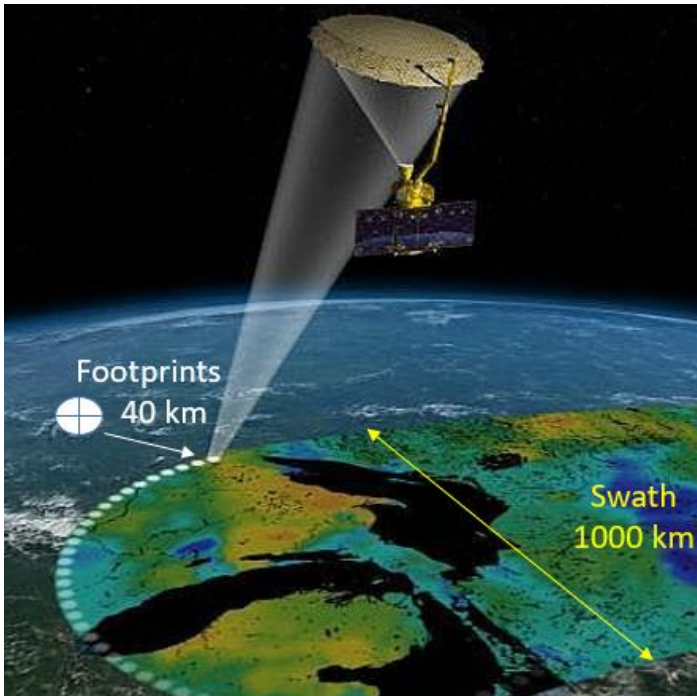
at L-band (21 cm) atmosphere is almost transparent so very small impacts of rain compared to C, X and Ku bands

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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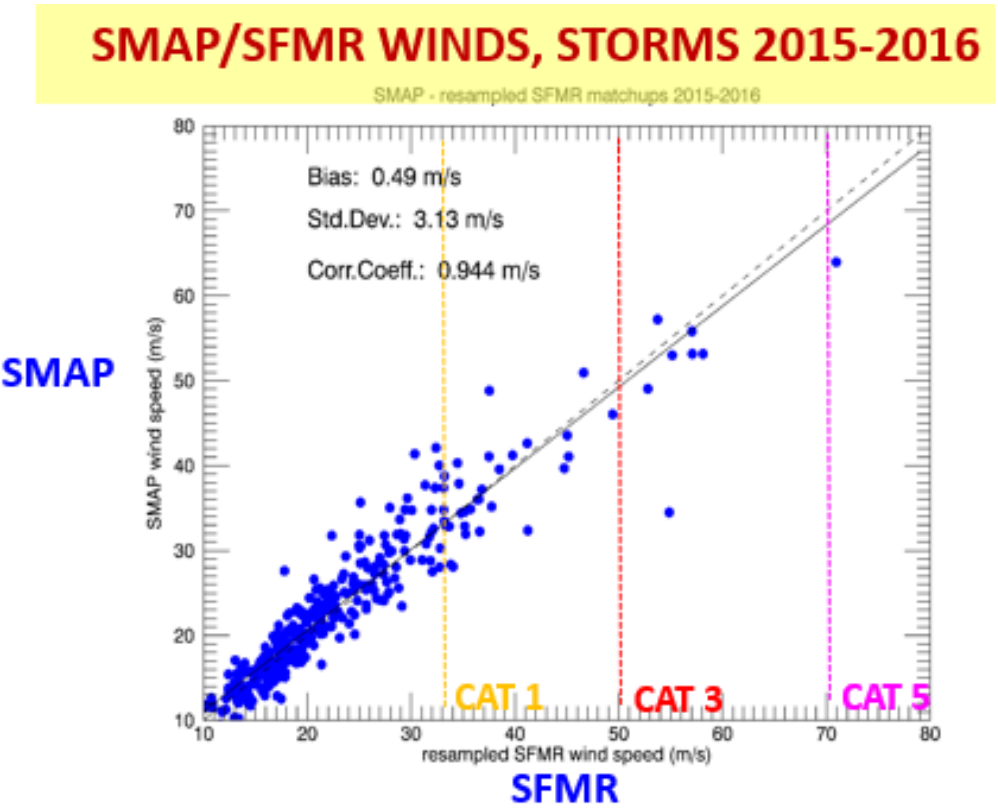
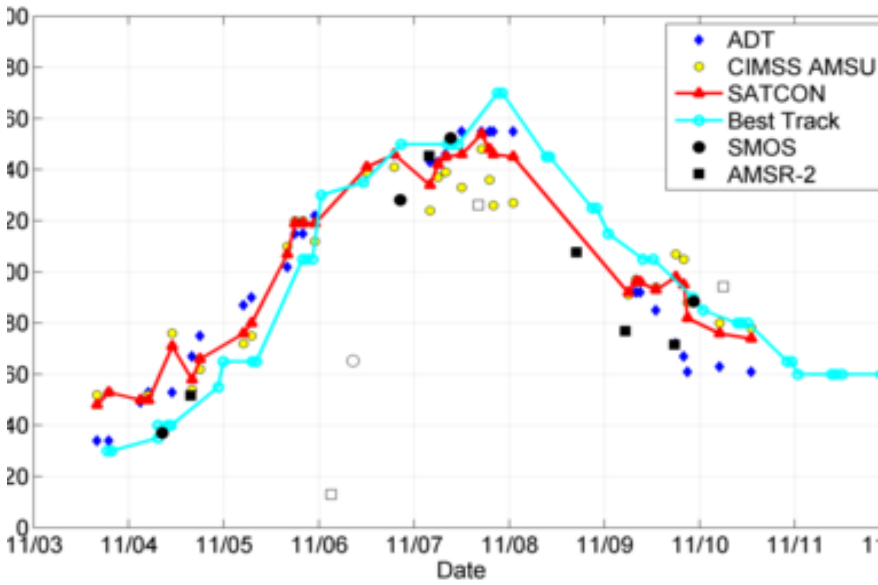
L-Band Radiometers: calibration accuracy within ~10 %

SMAP Vs SFMR calibration



SMOS Haiyan



http://www.smosstorm.org/

Acknowledgement: Meissner et al IWTC-IX

SMAP wind radii

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

JTWC collab: file 'fixes' not 'aids'

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SH, 15, 201803211043,  30, SMAP,      IR,  , 1500S, 10950E,     ,  137, 1      ,  ,      34, EQ,  154,  159,  123,  115,  ,  ,  ,  , 1,    ,    , S,  NASA, RSS,
 ,   ,   ,   ,   ,   ,    ,   ,   ,  ,  ,  ,  ,  ,  ,  ,  ,  ax. wind is 10 mi      ustained
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,
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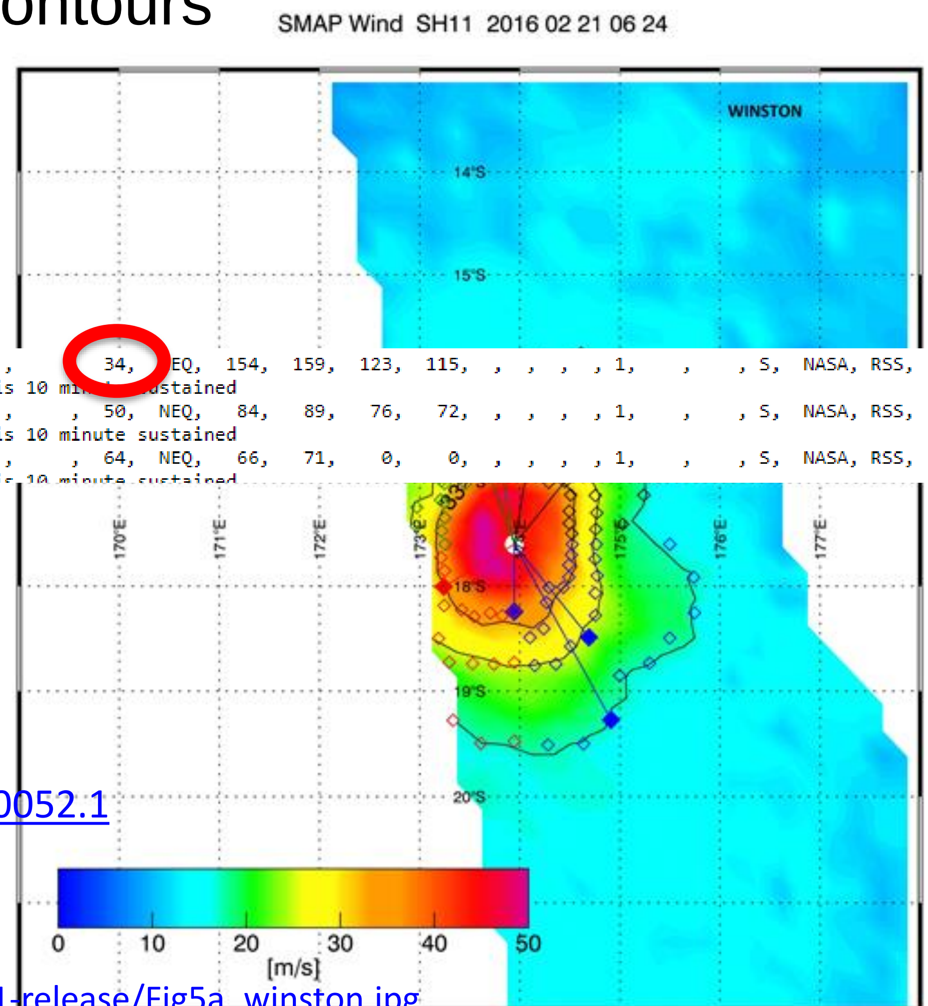
Marcus: 137 kn



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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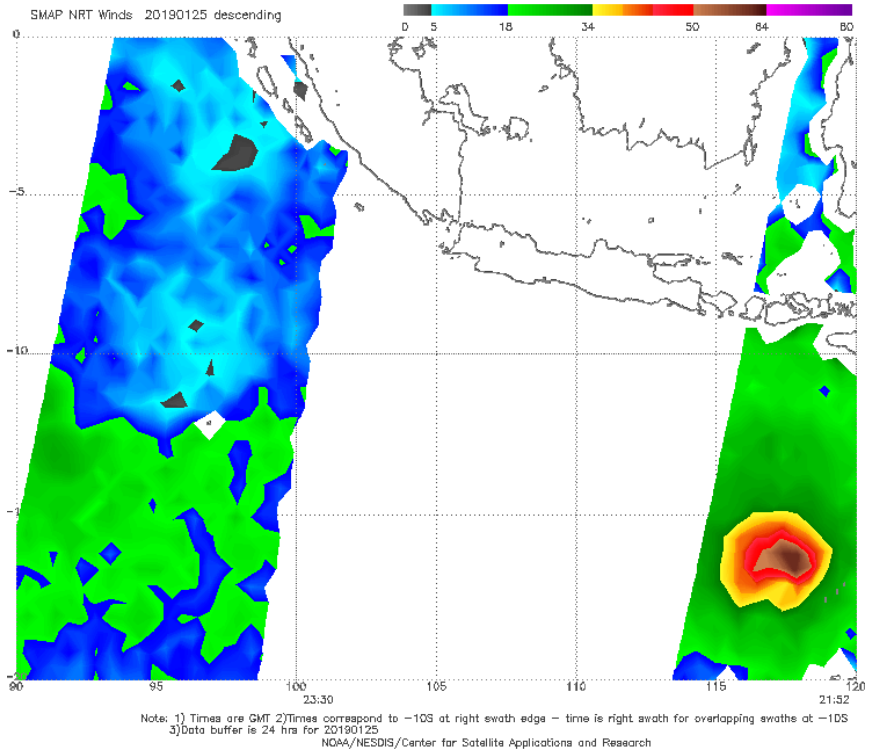
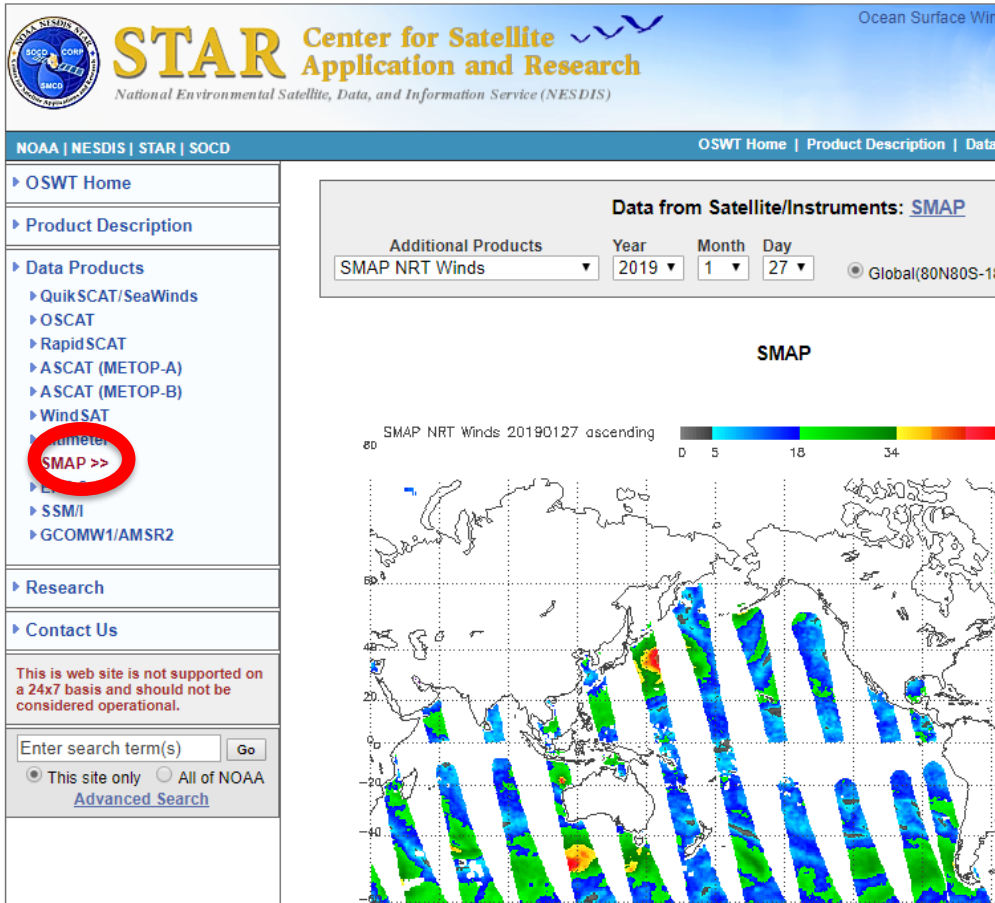
SMAP availability:

1. NOAA manati https://manati.star.nesdis.noaa.gov/datasets/SMAPData.php
2. NRL https://www.nrlmry.navy.mil/tc-bin/tc_home2.cgi
3. REMSS (not real time though) http://images.remss.com/smap/



Example: Riley 2330Z, 25 January 2019



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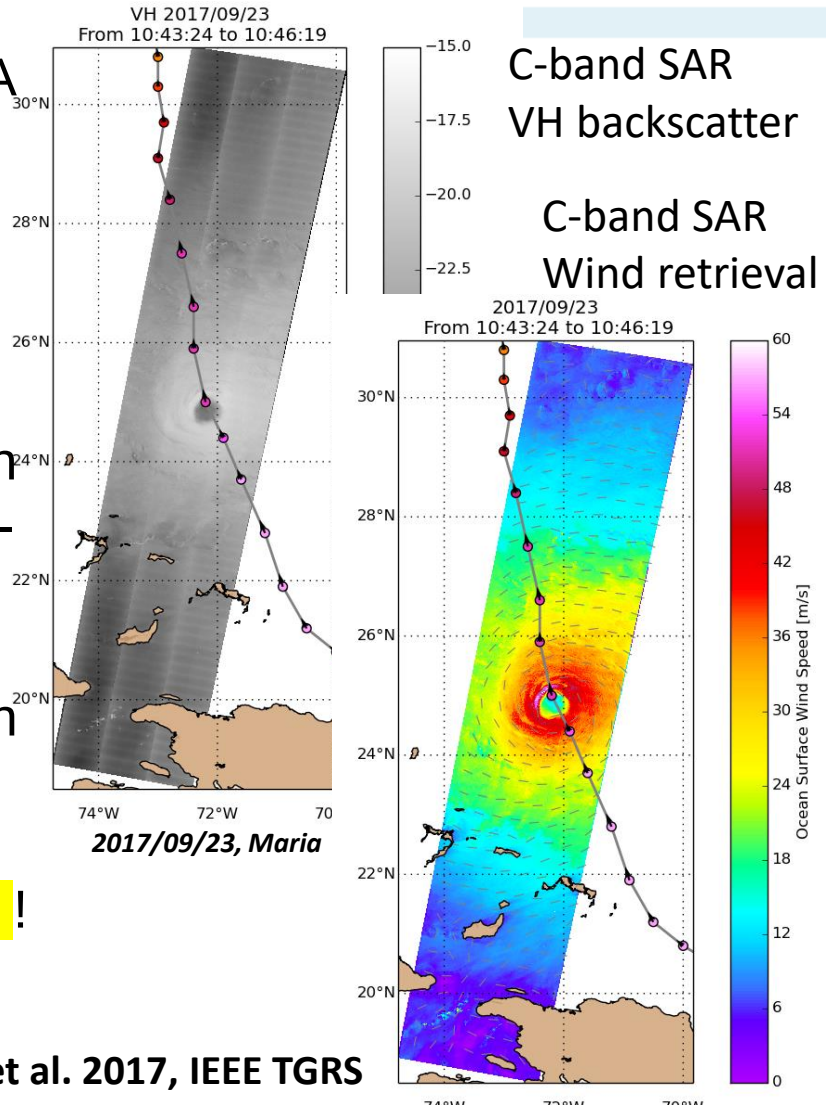
SAR C-Band Synthetic Aperture Radar

https://www.wmo.int/pages/prog/arep/wwrp/tmr/documents/IWTC-9_Subtopic_5-1.pdf

Satellites: Sentinel 1A, 1B (C,D coming) (ESA Copernicus program)
RadarSat-2 (Canada); Gaofeng-3 (China)
Coverage: ~400km
Resolution: <150m !!

Co-polarization: similar to ASCAT good <65kn
Cross-polarization: good for high winds like L-Band. No sensitivity to direction.
Skill: high (~SFMR)
Technique will be added to second generation (SG) scatterometers (EUMETSAT)

Issue: research mode only so not operational !



2017/09/23, Maria

Mouche et al. 2017, IEEE TGRS

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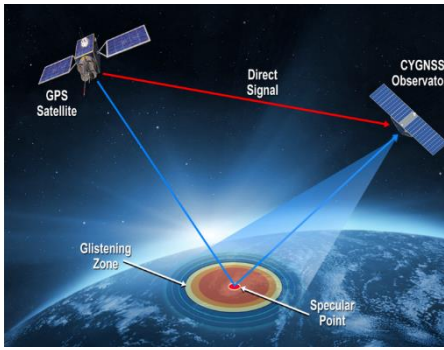
FUTURE

(CY)GNSS Cyclone Global Navigation Satellite System Reflectometry

navigation signals reflected from sfc using constellation of 8 micro-satellites (LOE 35deg.inclination), carrying a bi-static scatterometer receiver of GPS signals scattered by ocean.



'TROPICS' Time-Resolved Observations of Precipitation structure and storm Intensity with a Constellation of Smallsats

MetOp-SG (second generation)

CIMR: Copernicus Imaging Microwave Radiometer

L & C-band radiometer follow-on project in EU

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Challenges

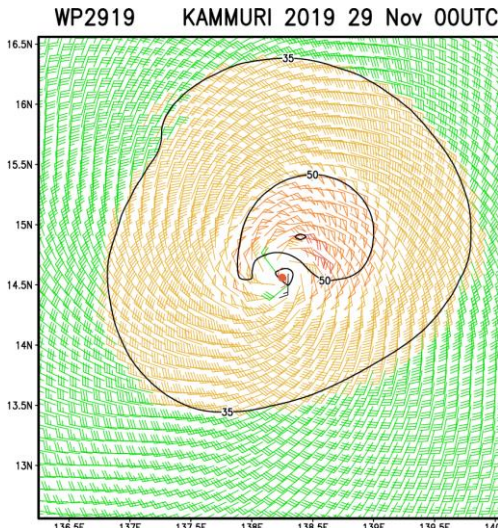
Forecasters: integrate all of this information into the forecast process – time is the killer.

Satellite people: share this data in real-time

Systems people: get the data into viewing software – current 'nightmare for forecasters (need navigation for measuring!)

Researchers: include this info into methods/techniques (SATCON, ARCHER, CIRA MSSWA …)

NWP people: assimilate this information into NWP



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Summary & Questions

Sensor	Band	Best	Challenge	Useful in ops
ASCAT (A, B, C)	C-band	Gale radii; Intensity <55kn	Coverage tropics	YES YES YES
SCATSAT HY-2B CFOSAT	Ku-band	Gale radii;	rain contamination	YES
SMAP	L-Band	Resolves high winds; Wind radii	Availability; 40km resolution	When avialable
Windsat/ AMSRE2/SSMIS	Passive radiometers	Gale radii	useful outside convection	somewhat
SAR	C-band	150m res; high skill <65kn	400km swathe; <65kn for now.	NOT YET
CyGNSS	GPS scatter	8 satellites	Small footprint; noisy	NOT YET
TROPICS	Passive radiometers	constellation	Into future; low quality	NOT YET
CIMR; MetOp-SG	combined	Skill at all intensity	Into future	After 2022/25