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Satellite measurement of surface winds for TCs: Current and emerging imagers

Use drawing pen to tick your answers

Sensor	Haven't heard of it	Heard of it but haven't used it	Use it operationally
ASCAT			
SCAT-SAT			
SMAP			

VLAB 19 February 2019

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

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

Joe Courtney

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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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Advanced SCATterometer (ASCAT)

Satellite: MetOp-A (2007), B (2012), **C (2018)** (A&B 1h offset)

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

Southern Hemisphere example

Streamline analysis

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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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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 soon
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

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,      , 1, 137, 1,      ,  ,      34,  NEQ,  154,  159,  123,  115,  ,  ,  ,  , 1,    ,    , S,  NASA, RSS,
,    ,    ,    
```

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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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SMAP availability: REMSS
http://images.remss.com/smap/

Data available from RSS
Images available on RSS in low res format (for time being)
http://images.remss.com/smap/smap_data_daily.html

Latency takes several hours
Post processing for higher accuracy

Example: Riley 2330Z, 25 Jan 2019

https://journals.ametsoc.org/doi/pdf/10.1175/BAMS-D-15-00291.1

SMAP/SMOS availability: ATCF example

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JTWC/NHC get SMAP and SMOS into ATCF automatically
Used for radii analysis

Yutu, Oct 23, 2018

SMAP: NetCDF4
www.remss.com/missions/smap/

15 kn
25 kn
34 kn
50 kn

SMOS: NetCDF but 3-5h latency
ftp://smoswind:icebigwindsea@ftp.ifremer.fr

Courtesy Meissner et al 2019

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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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Reflectometry (CY)GNSS

Cyclone Global Navigation Satellite System Reflectometry

AIM: To Measure ocean surface wind speed in all precipitating conditions

How**:** navigation signals reflected from surface using constellation

Design**:** 8 micro-satellites in low-earth orbit (35deg.inclination), each carrying a bi-static scatterometer receiver of GPS signals scattered by the ocean surface.

Challenges: noisy observations and resolution
Requires modelling to connect to TC tracks
Small footprint
Not operational but data on :
https://worldview.earthdata.nasa.gov

Advantages: more frequent temporally (8 satellites)
Resolution 25km

Morris and Ruf 2017, J. Appl. Meteor. Climat.

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CyGNSS

Small footprint
Florence,11/9/2018,
~ 21UTC

Courtesy: Mary Morris mary.g.morris@jpl.nasa.gov.

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CyGNSS data on NASA JPL site

worldview.earthdata.nasa.gov

Currently ~3day latency and uncertainty on quality, no time stamp

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Future: 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 <65km
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 !

C-band SAR
VH backscatter

C-band SAR
Wind retrieval

2017/09/23, Maria

Mouche et al. 2017, IEEE TGRS

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Future: SAR C-Band Synthetic Aperture Radar

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

SAR potential operational use

- There is no international strategy to maximize acquisitions over TCs.
- Requires international efforts to go from “experiments” to “operational services”.

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Future: 'TROPICS'

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

CUBESAT constellation: small satellites (<4kg) and cheap (short lifecycle)
12 channels 90-206GHz
Consortium approach NASA/MIT etc
First launch

Lower quality sensors but higher frequency when many deployed

https://directory.eoportal.org/web/eoportal/satellite-missions/content/-/article/tropics

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Longer term 2022+
MetOp-SG (second generation)
CIMR: Copernicus Imaging Microwave Radiometer
L & C-band radiometer follow-on project in EU

CIMR is one of the 6 High Priority Candidate Mission (HPCM) for the Expansion of the Copernicus Space Component (adding to the Sentinels 1-6).
Combined L and C bands provides extra capabilities

Characteristics (To be Confirmed)

- Conically scanning multi-frequency microwave radiometer
- ~95% global coverage every day; - swath 1800 km
- **Launch: 2025+ timeframe if selected by EU**

Channels (GHz, all H&V):	**1.4,**	**6.9,**	**10.65,**	**18.7**	**36.5**
Resolution (km):	**≤55**	**10**	**≤10**	**≤5**	**≤5**
NEΔT (K @150K):	**≤0.3**	**≤0.2**	**≤0.3**	**≤0.3**	**≤0.7**

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Summary

Sensor	Band	Best	Challenge	Useful in ops
ASCAT	C-band	Gale radii; Intensity <55kn	Coverage tropics	YES
SCATSAT	Ku-band	Gale radii; 1800km swathe	Winds deep convection	YES
SMAP	L-Band	Resolves high winds; Wind radii	Availability; 40km resolution	yes
Windsat/ AMSR2/SSMIS	Passive radiometers	Gale radii	Beyond convection	a bit
Himawari AMV	Vis/IR	High temporal res	needs rapidscan Beyond convection	Some parts Not S.H. yet
CyGNSS	GPS scatter	8 satellites	Small footprint; noisy	NO
SAR	C-band	150m res; high skill <65kn	400km swathe; <65kn for now.	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

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SPARE: Current and emerging satellite methods to estimate TC surface winds

1. Review of existing scatterometers and radiometers

   ASCAT, SCATSAT; WINDSAT; AMSR2, SSMIS ~~QSCAT; RapidScat~~;

2. Geostationary satellite surface derived winds.

3. 'New' and Emerging sensors

   L-Band Radiometers (**SMAP** and SMOS)

   C-Band Scatterometers (SAR)

   CyGNSS-R (Global Navigation Sat. system Reflectometry)

   TROPICS (2020?); MetOp SG (2022+); CIMR (2025?)

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Acknowledgement: Meissner et al. IWTC-9
https://www.wmo.int/pages/prog/arep/wwrp/tmr/documents/IWTC-9_Subtopic_5-1.pdf
COMET: https://www.meted.ucar.edu/training_module.php?id=1093#.XElBfteWa71

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