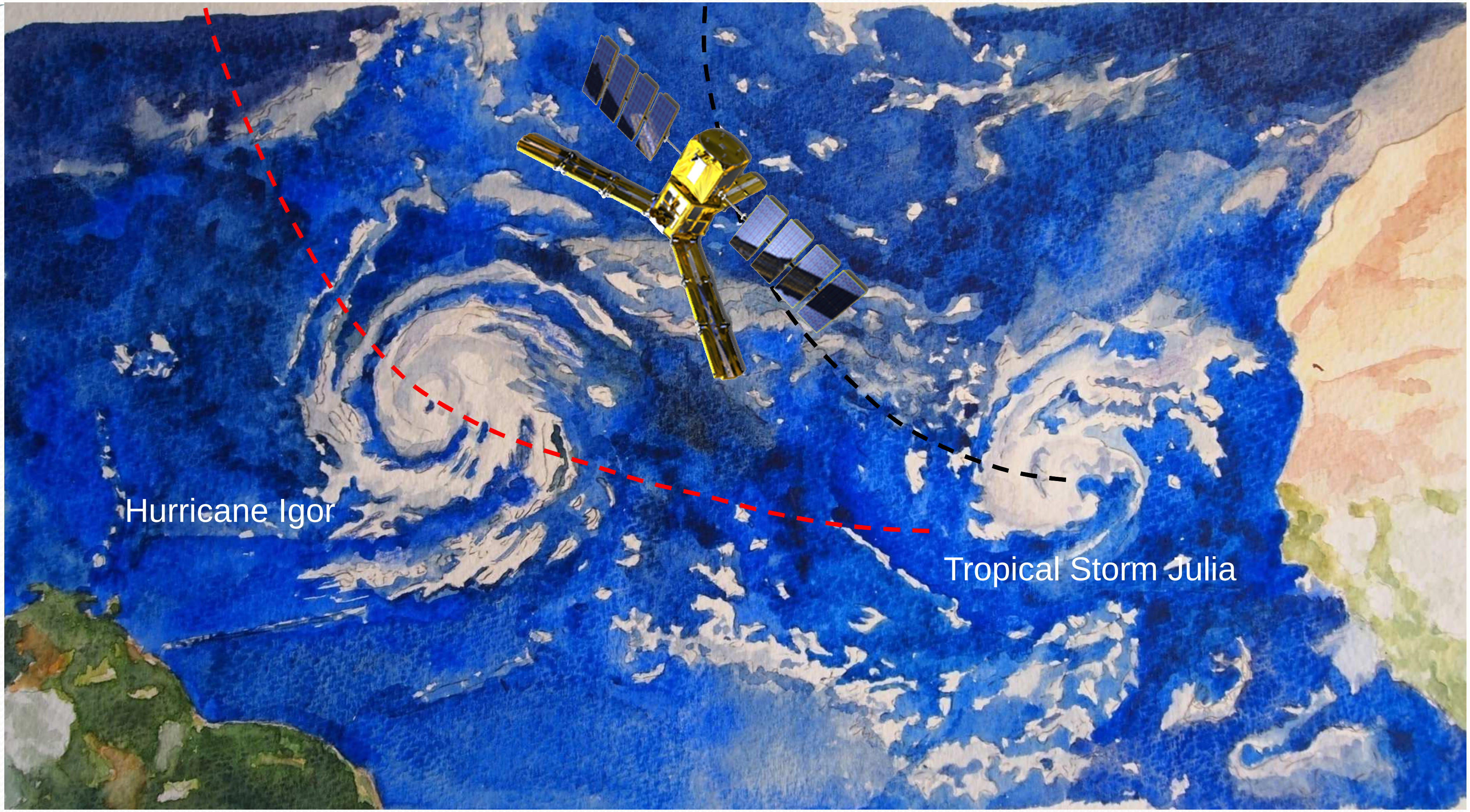
smos+ storms
support to science element

Severe Marine Weather Studies using SMOS L-band Sensor

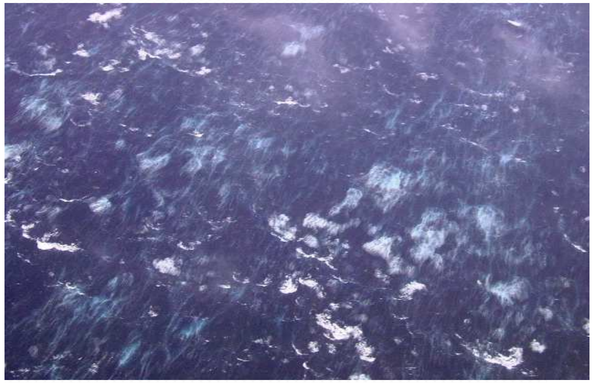


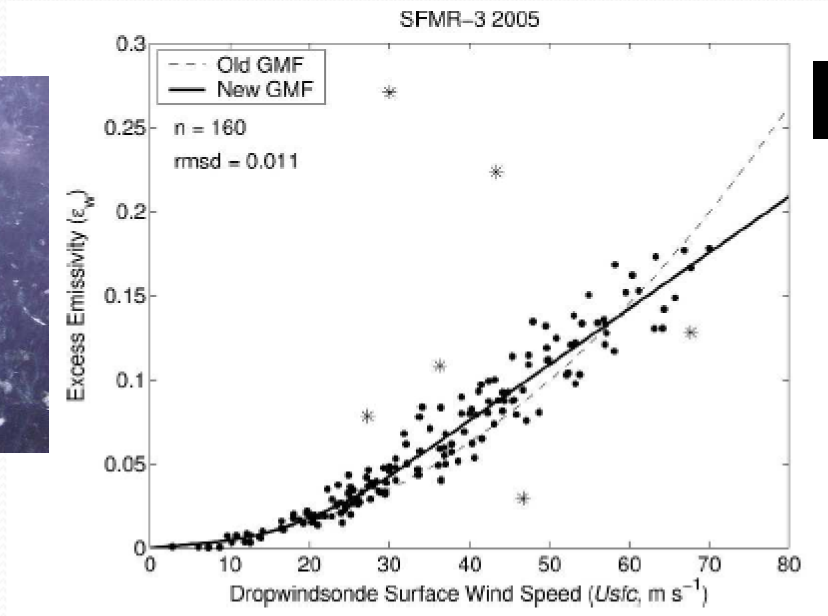
Nicolas Reul[1], J. Tenerelli[2], B.Chapron[1], Y. Quilfen[1], D. Vandemark and Y. Kerr[3]

Ifremer esa CLS

Wind speed retrieval in extreme winds : SFMR

Increase of the microwave ocean emissivity
with wind speed ⇔ surface foam change impacts





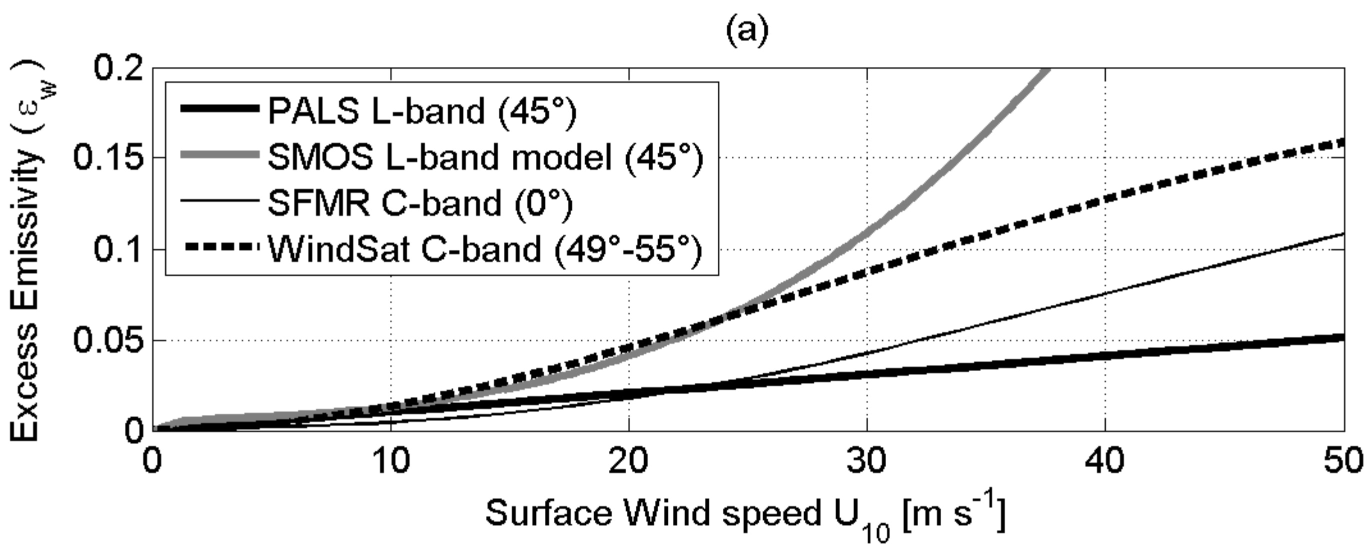
Hurricane hunter P-3

This information can be used to retrieve the surface wind speed in Hurricanes:

Principle of the Step Frequency Microwave Radiometer (SFMR) C-band:

NOAA’s primary airborn sensor for measuring Tropical Cyclone surface wind speeds since 30 year (Ulhorn et al., 2003, 2007).

Wind Excess Emissivity at High winds



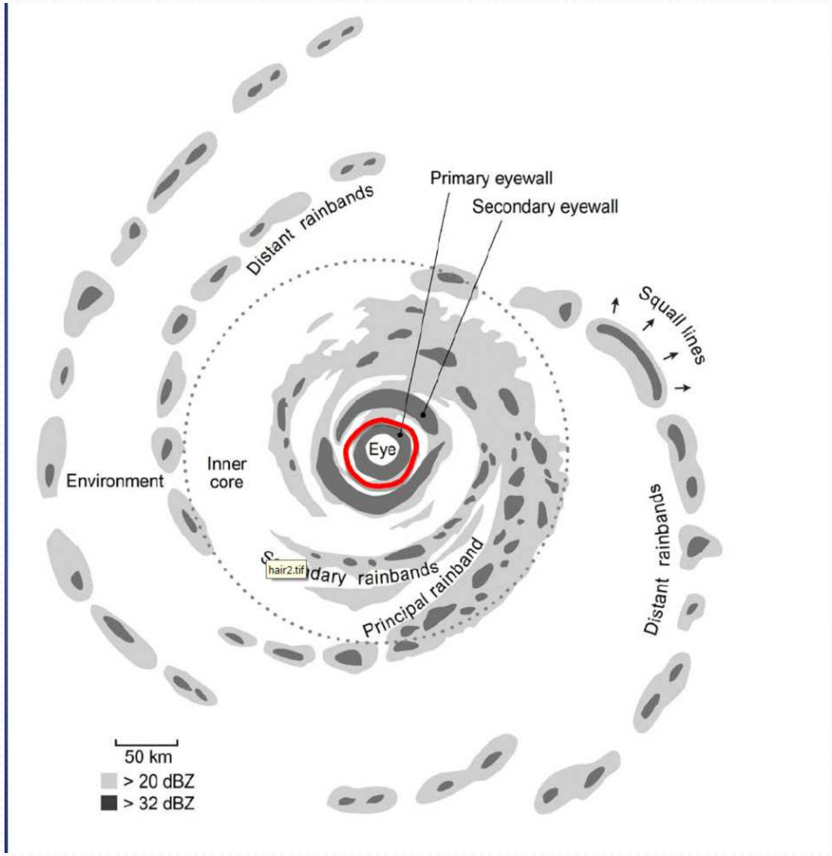
C-band: ~1K/m/s

L-band: 0.35K/m/s

C-band TB~3 times more sensitive to wind speed than L-band

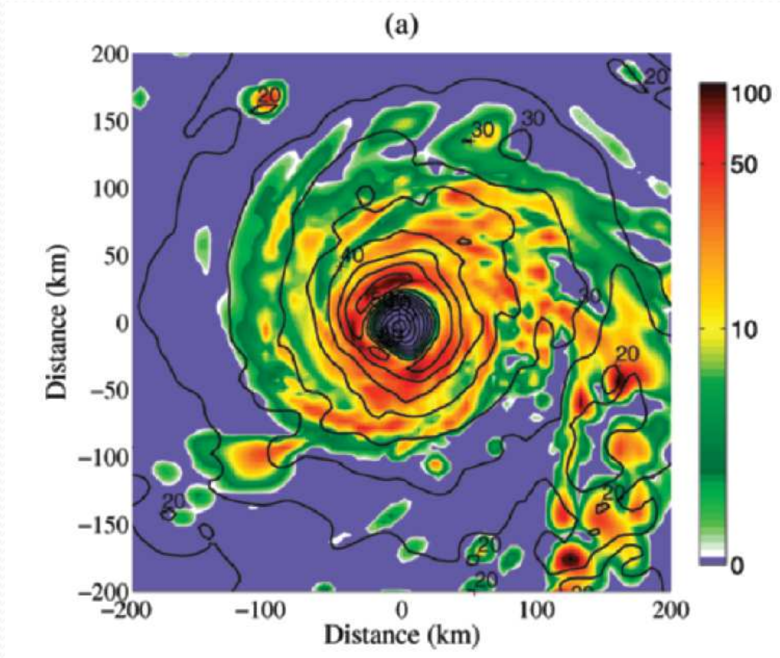
High winds in Hurricanes are very often associated with High rain rates

Rain Anatomy in a hurricane



Houze 2010

Rain rate [mm/h]

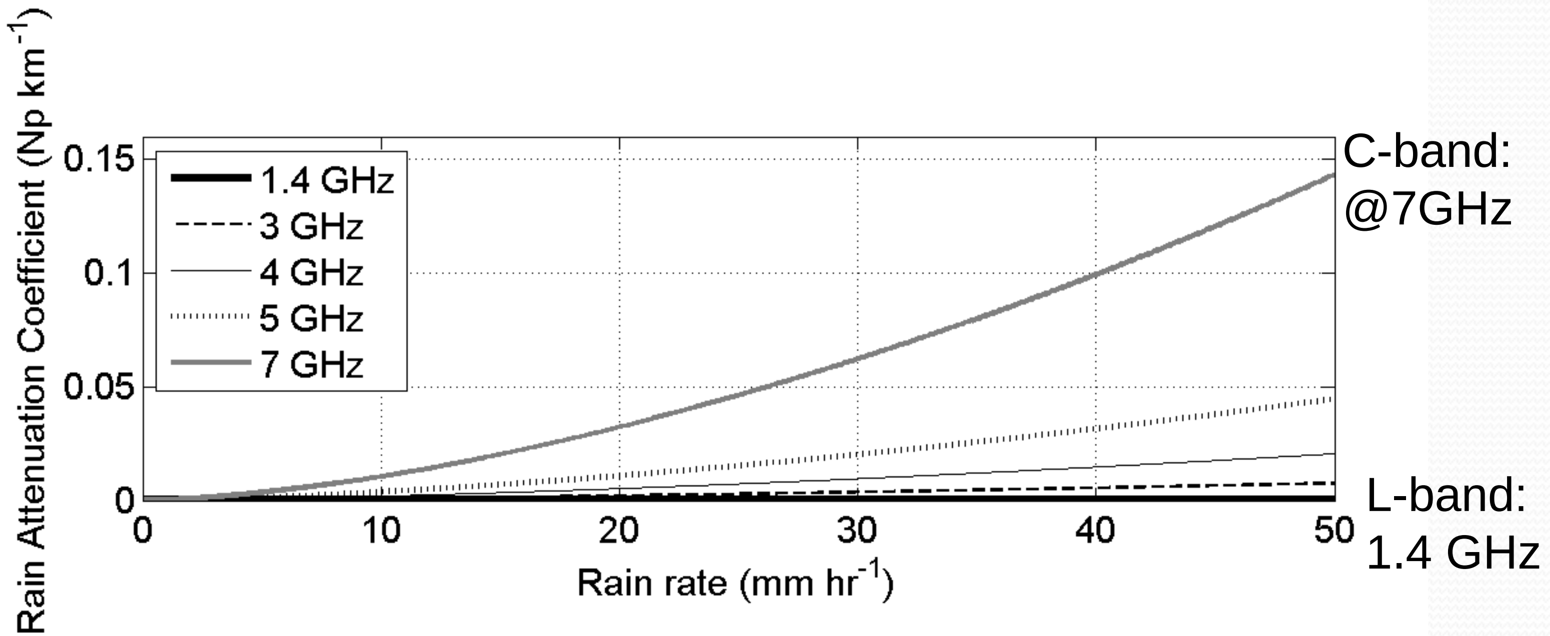


S.Shen and J. Tenerelli 2007

Rain attenuation at L-band

Because of the small ratio of raindrop size to the SMOS electromagnetic wavelength (~21 cm), scattering by rain is almost negligible at L-band, even at the high rain rates experienced in hurricanes.

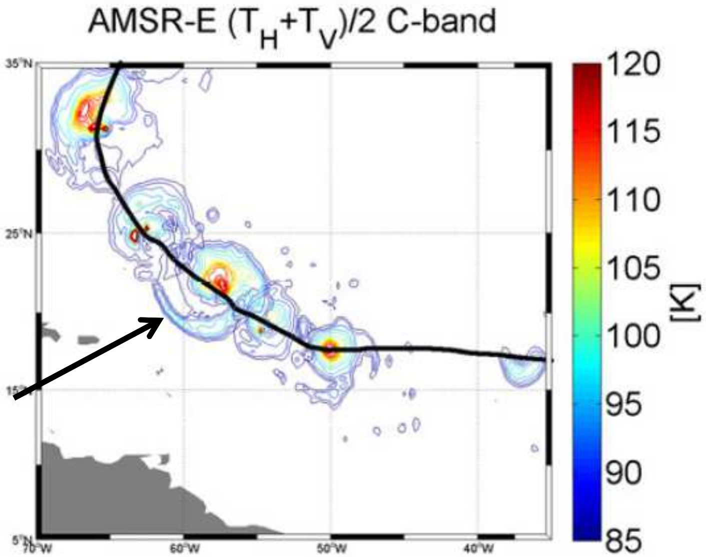
Rain impact at 1.4 GHz can be approximated entirely by absorption and emission (Rayleigh scattering approximation valid)

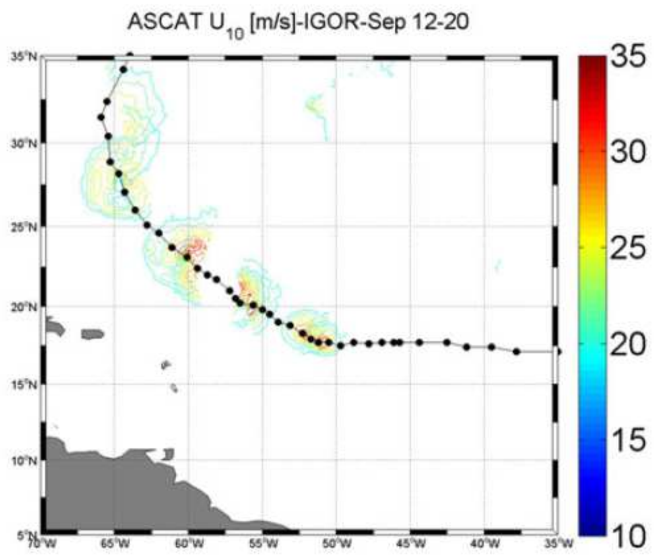


Rain impact Generally two order of magnitude smaller at L-band (1.4 GHz) than at C-band (5-7 GHz)

Limitations of current satellite MW observing systems Operating at frequencies ≥ C-band

Rain Bands Signatures At C-band





• Passive/active data are strongly affected by rain for f ≥ C-band

•Radar data saturates at high winds

=>very difficult to retrieve surface winds (for passive multiple frequency is required (SFMR))

As L-band is much less affected=>opportunity!

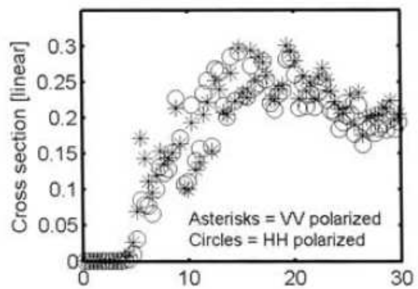
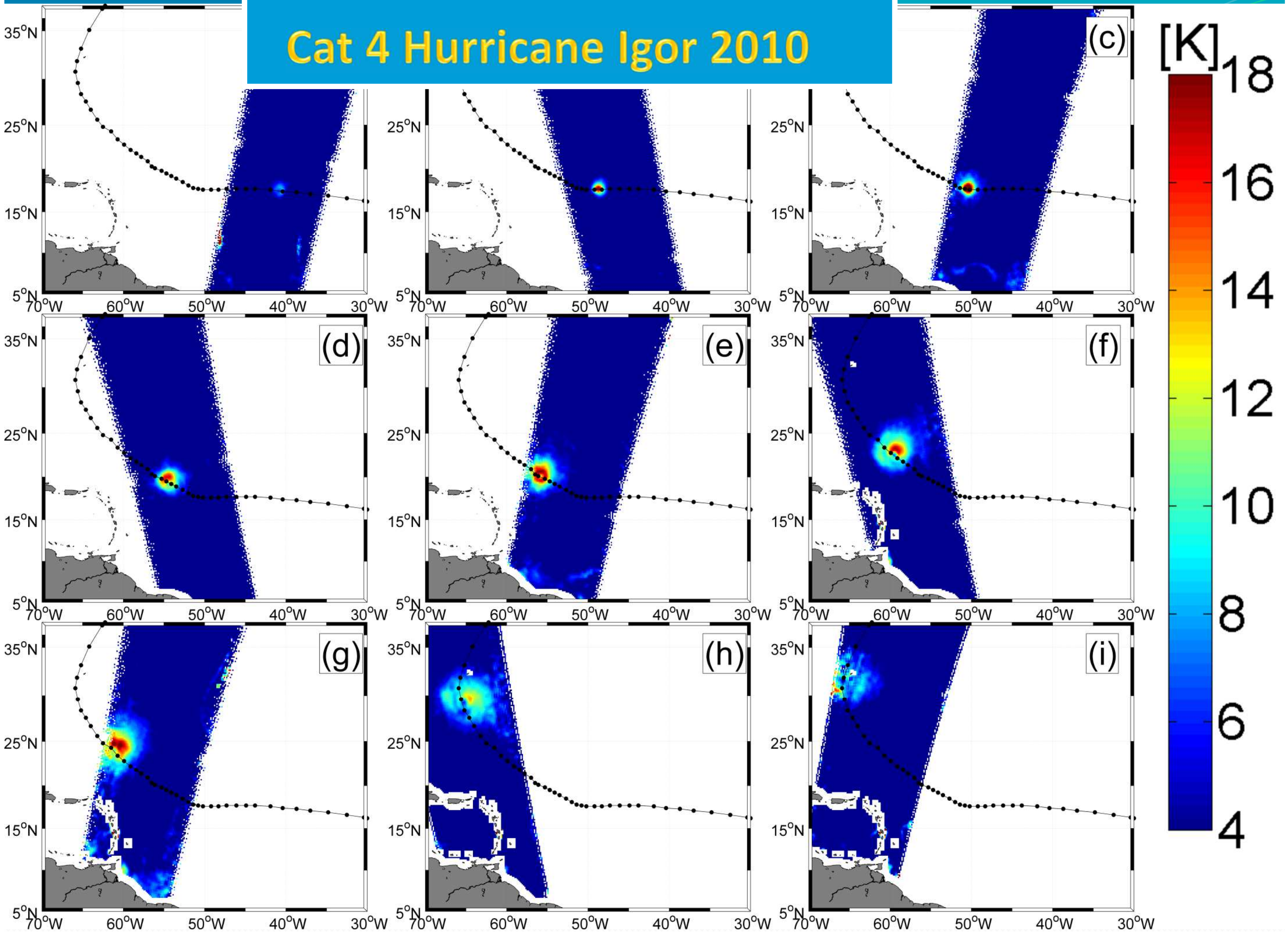
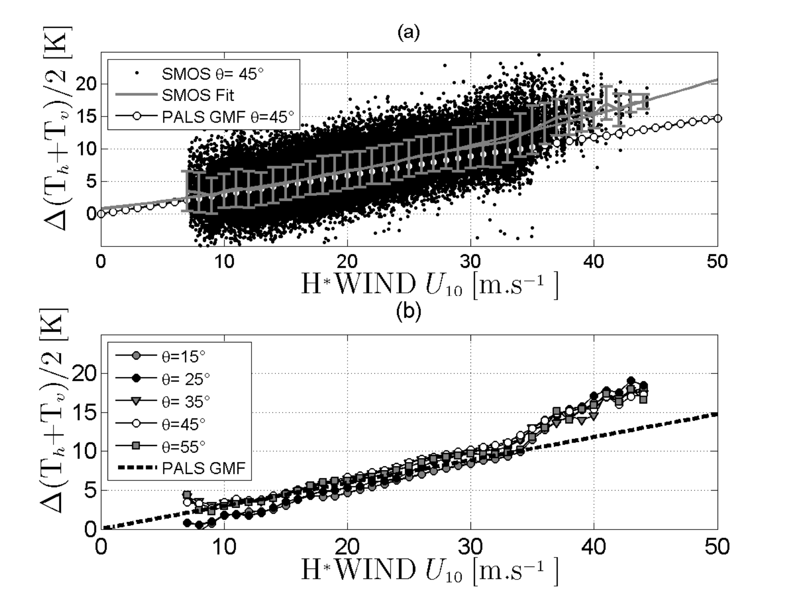


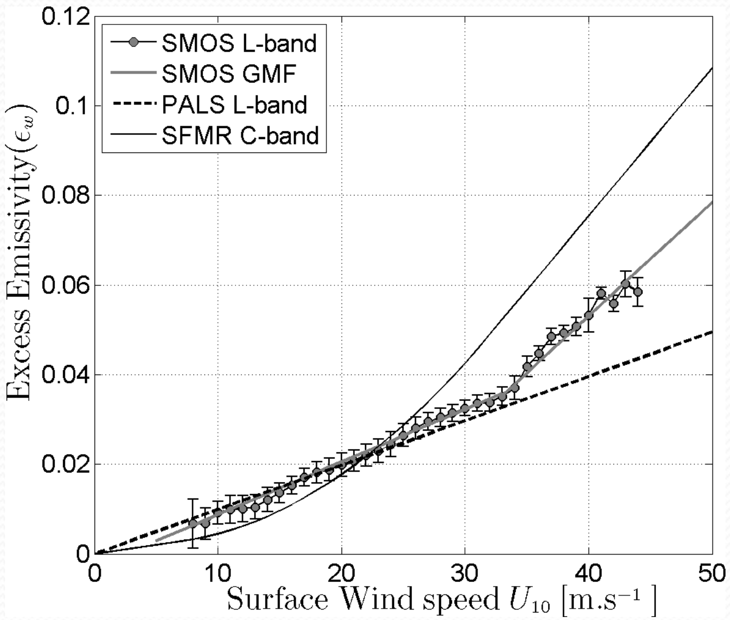
Figure 5. Normalized radar cross section (NRCS) versus centerline (0.3 m height) wind speed in the tank. Note that U_{10} is approximately $1.5U_{0.3}$.

Cat 4 Hurricane Igor 2010



Geophysical Model function: Tb=f(wind speed)





C-band

L-band:
0.7K/m/s
for hurricanes

0.3 k/(m/s)
below

$$\Delta I = \frac{\Delta(T_H+T_V)}{2} = 0.35\,U_{10}\text{-}1.3 \qquad U_{10} \leq 33\ \text{m.s}^{-1}$$

$$= 0.75\,U_{10}\text{-}14.5 \qquad U_{10} \geq 33\ \text{m.s}^{-1}$$

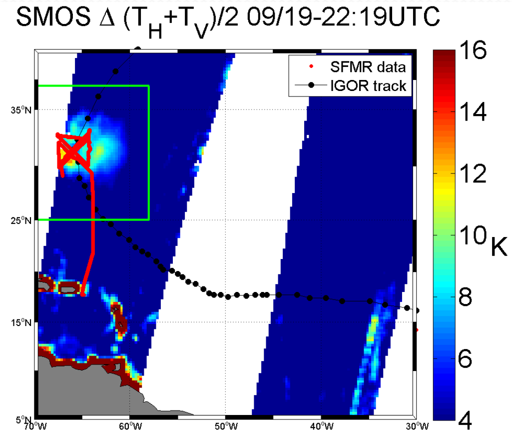
Development of a SMOS wind speed GMF based on Hwind products in IGOR hurricane

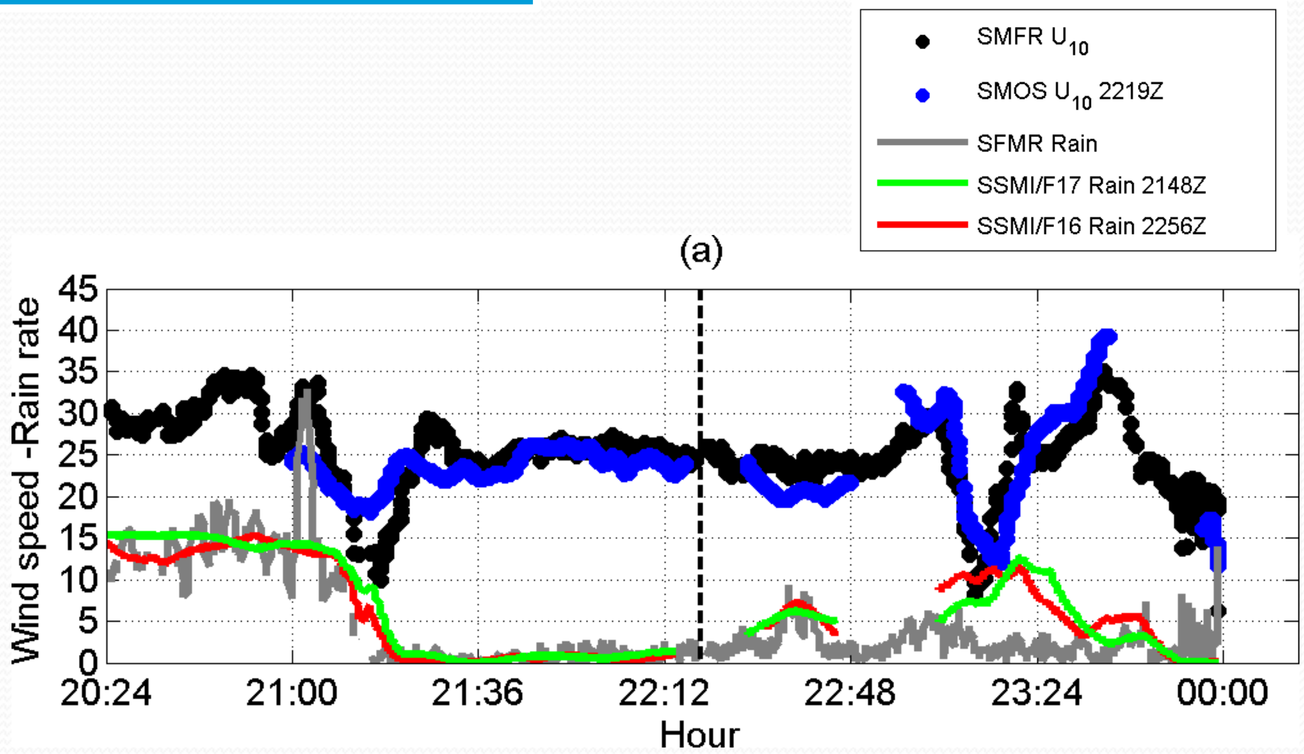
Bilinear L-band dependencies with surface wind speed

Reul et al., JGR, 2012

Comparison at SFMR transects

NOAA hurricane Hunter flight

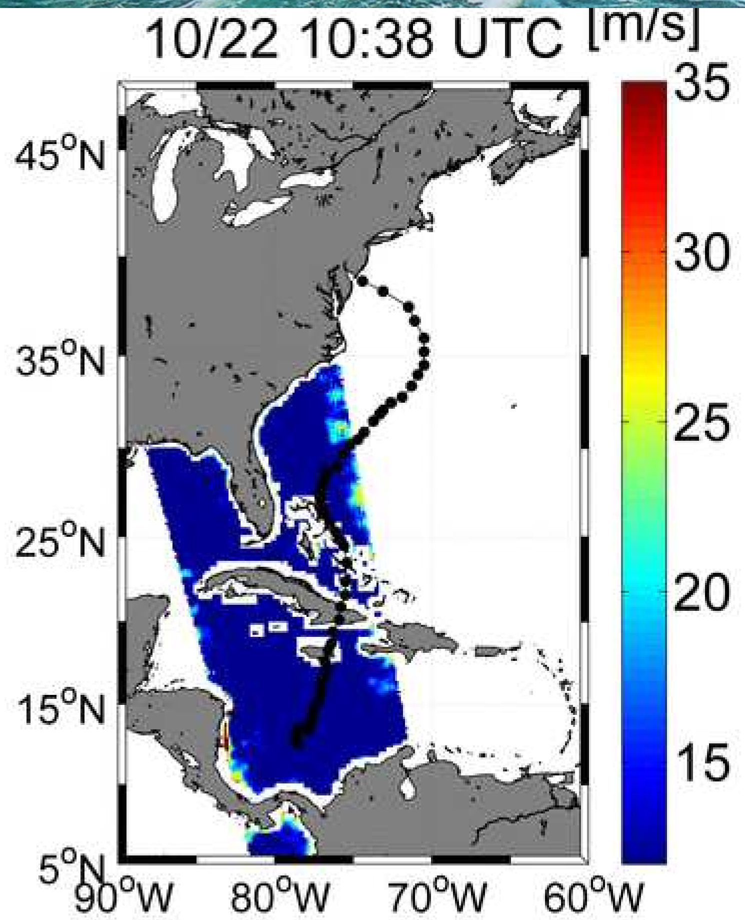


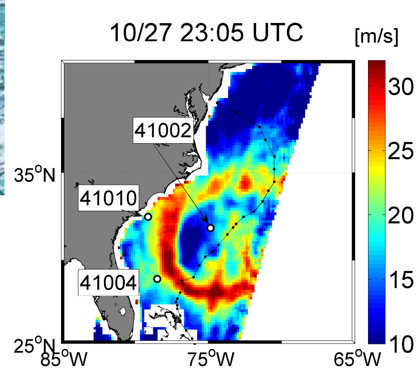


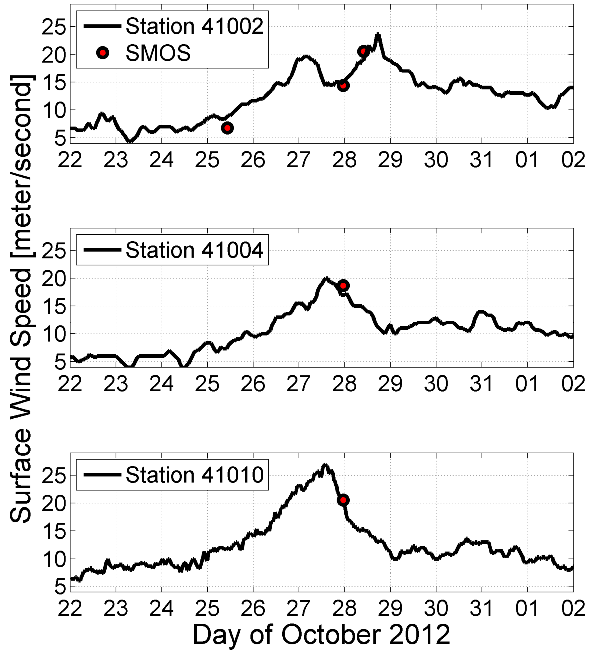
SuperStorm Sandy Viewed by SMOS

Validation with buoy data

Hurricane Sandy Oct 2012

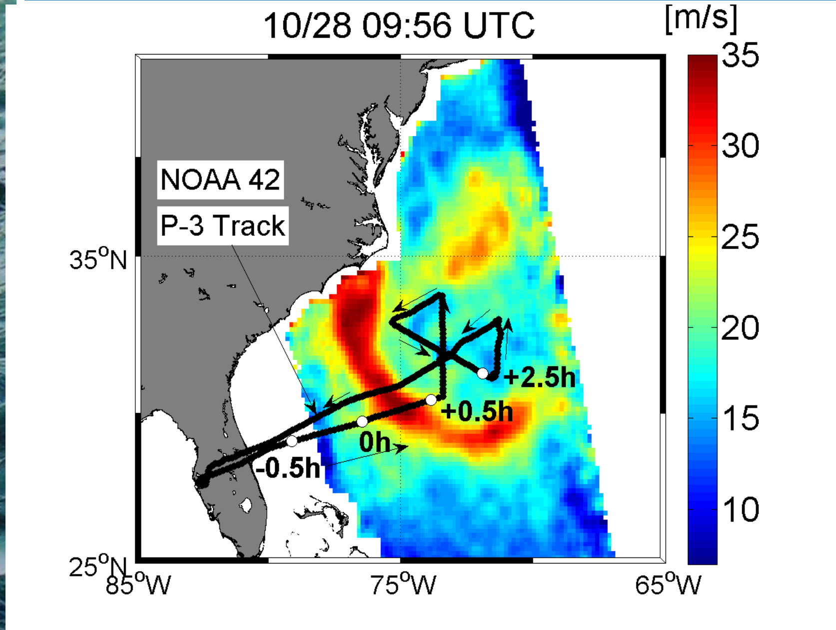






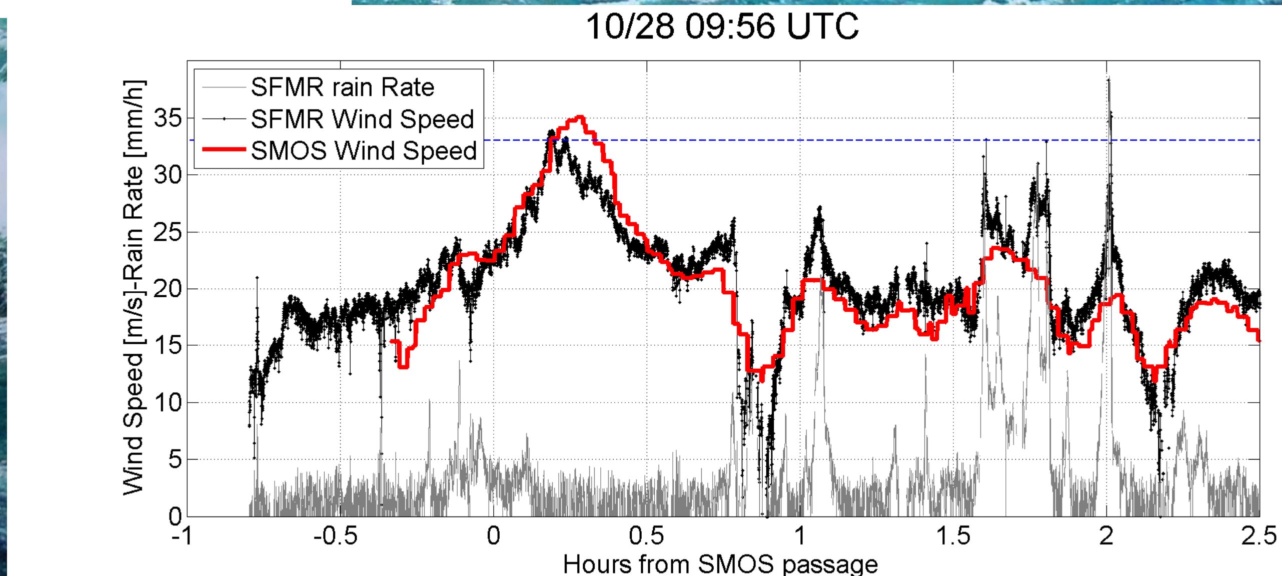
Hurricane Sandy

Validation with NOAA hurricane hunter Aircraft Data (C-band)SFMR

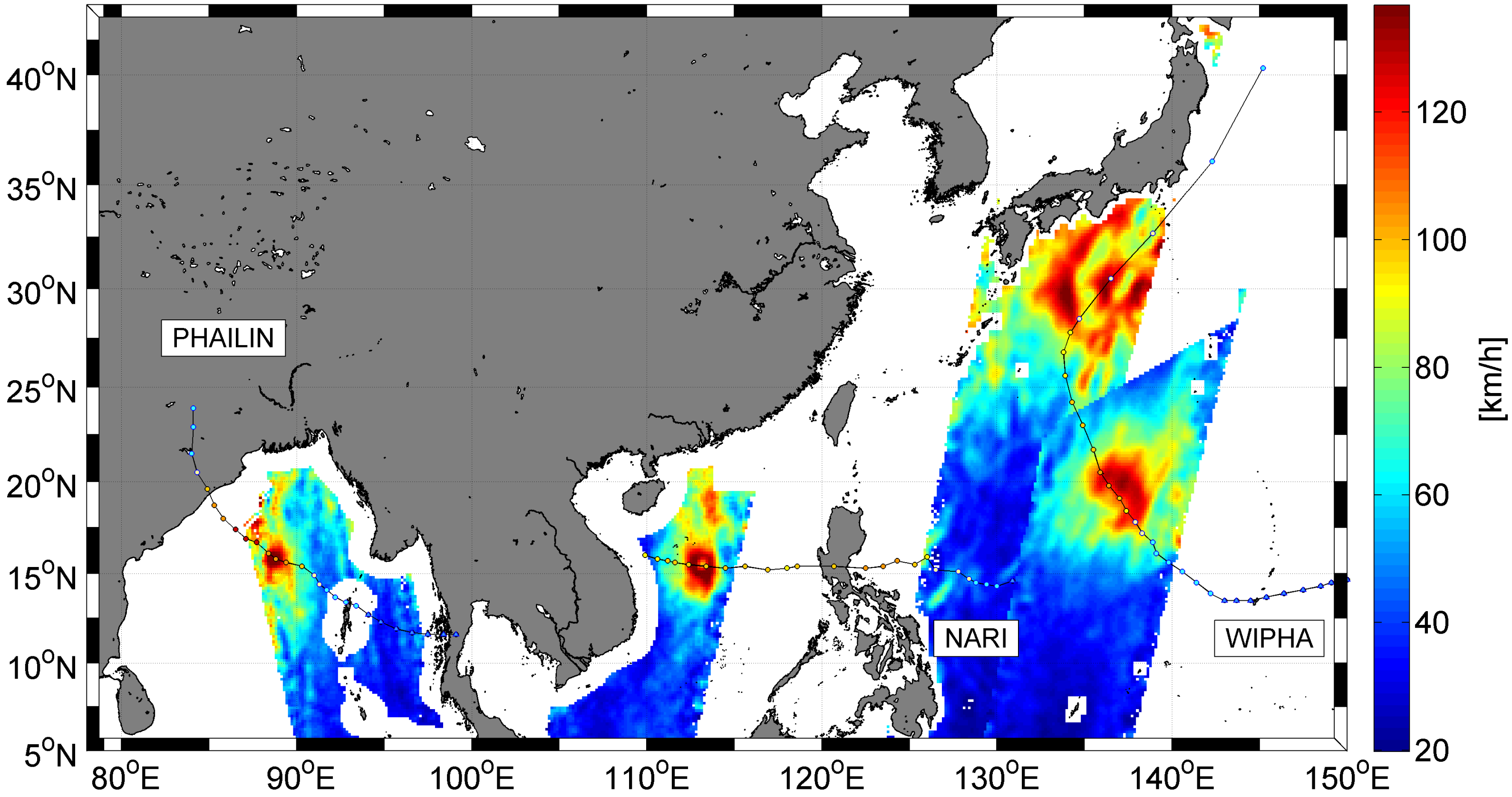


SMOS winds

Accuracy
~<3 m/s



Example of Typhoon samplings: Oct 2013



Legend: Surface wind speed in km/h estimated from SMOS brightness temperature data acquired between the 10th and the 15th October 2013 under Typhoons Phailin (Bay of Bengal 11th Oct), Nari (South China Sea, 13 oct) and Wipha (Western Pacific, 13 th & 15th). The Typhoons eye tracks are indicated by small magenta dotted curves. Credits: ESA, Ifremer & CLS.

Haiyan Super Typhoon Signature in SMOS data

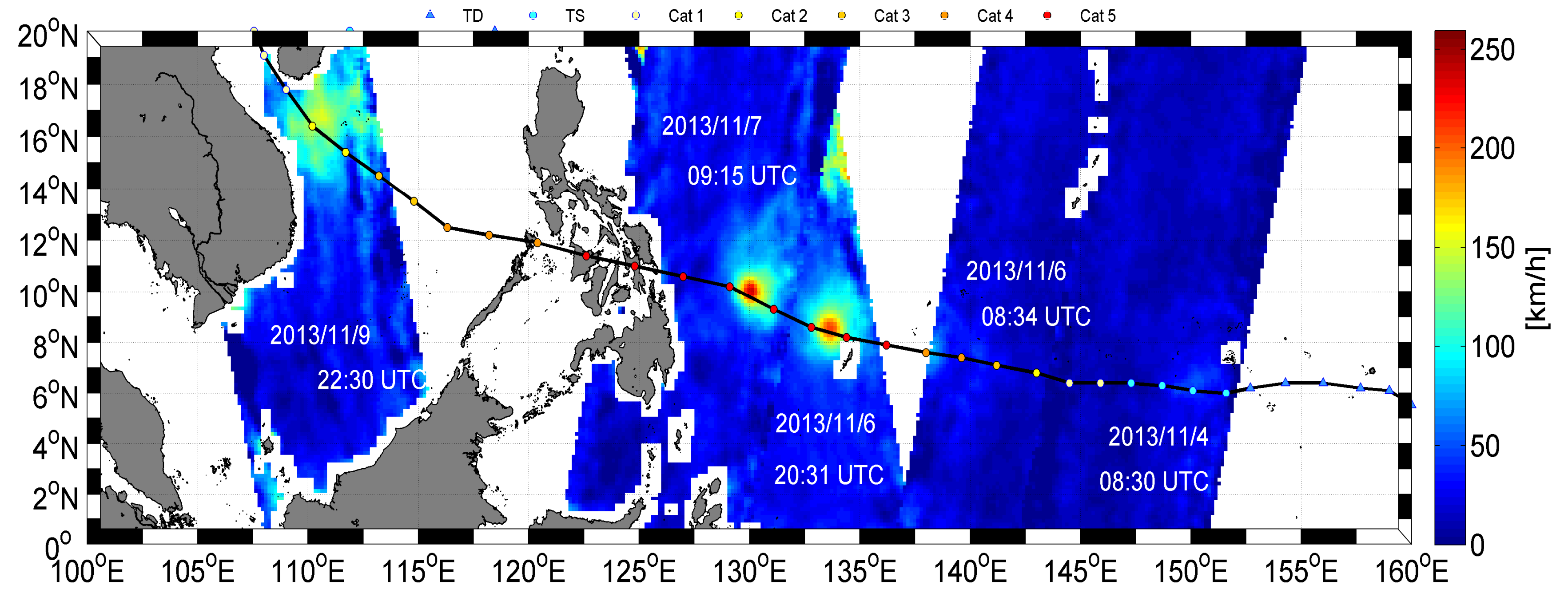
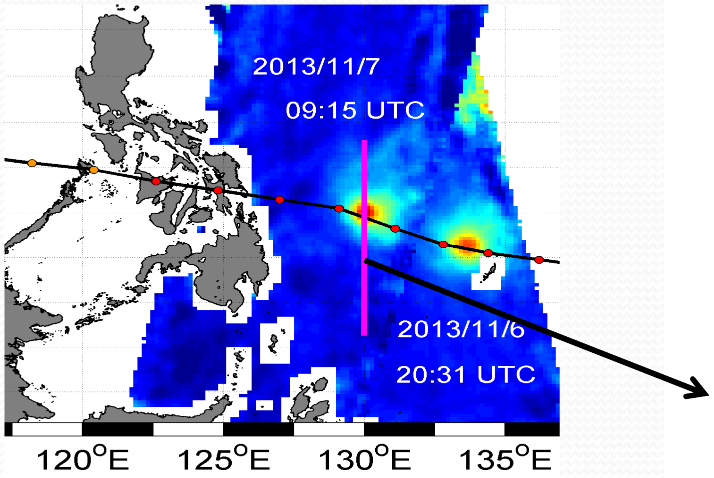
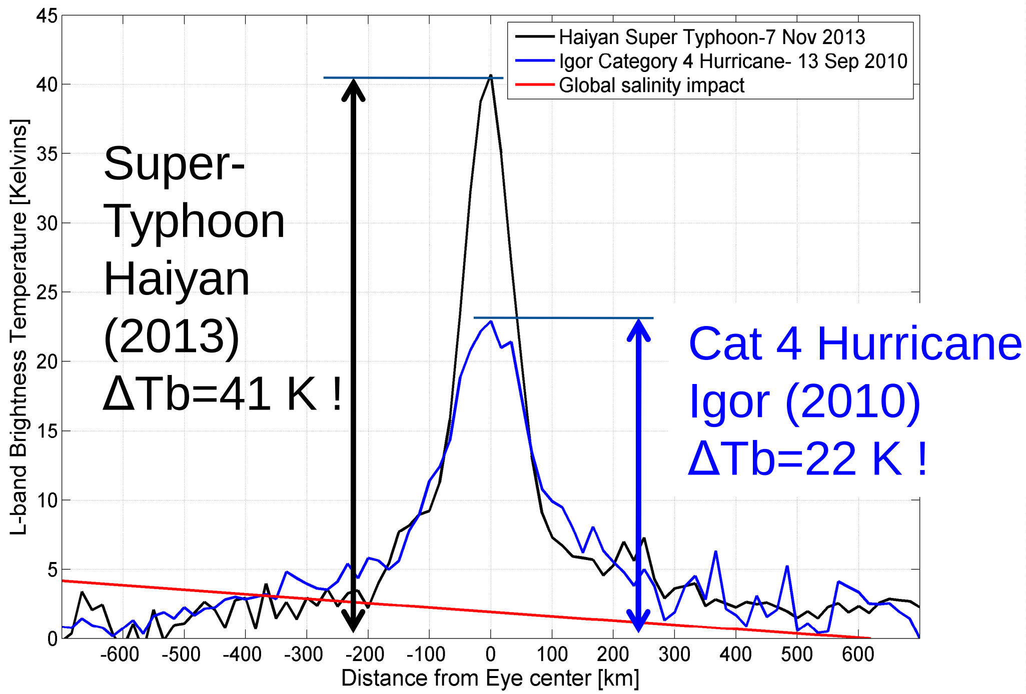


Figure 1: SMOS retrieved surface wind speed [km/h] along the eye track of super typhoon Haiyan from 4 to 9 Nov 2013.

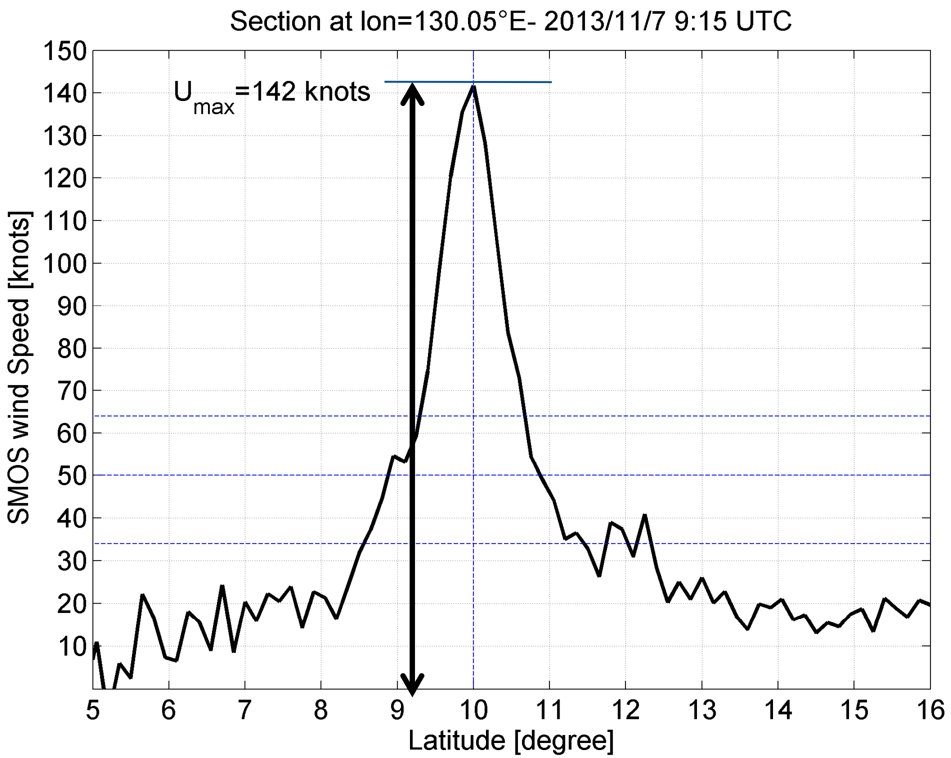
Haiyan Super Typhoon Signature in SMOS data



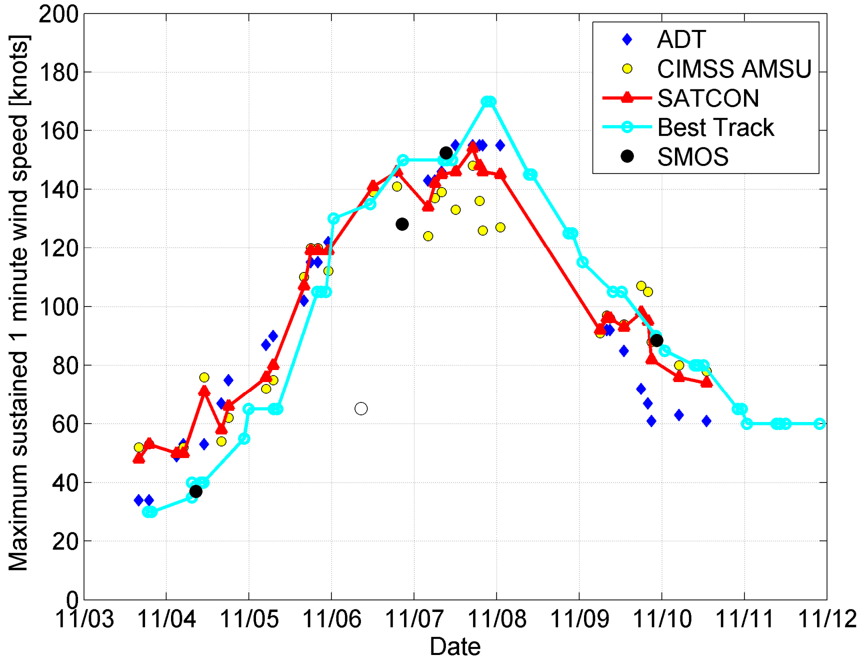


Haiyan Typhoon in 2013:
The brightest natural source of L-band radiation ever measured over the oceans
=>an unprecedented natural extreme

Haiyan Super Typhoon Signature in SMOS data



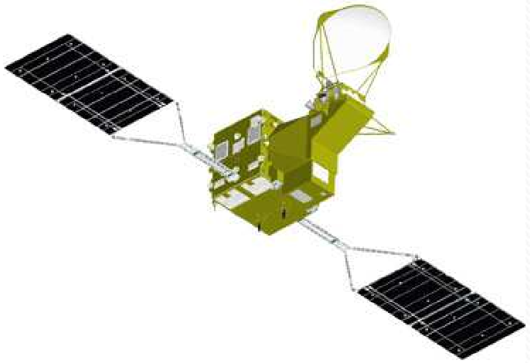
Surface wind speed deduced from the SMOS estimated excess brightness temperature.



Maximum sustained 1 minute wind speed estimated during Haiyan Typhoon. From SMOS data (black filled dots) compared to Advanced Dvorak Technique (ADT=blue diamond), CIMSS (yellow filled dots), SATCON (red) and Best Track from NHC (cyan).

Excellent agreement between SMOS max winds estimates and other traditional Datasets (Dvorak, Best track,..)

Towards Merged SMOS-AMSR-2-SMAP High wind products



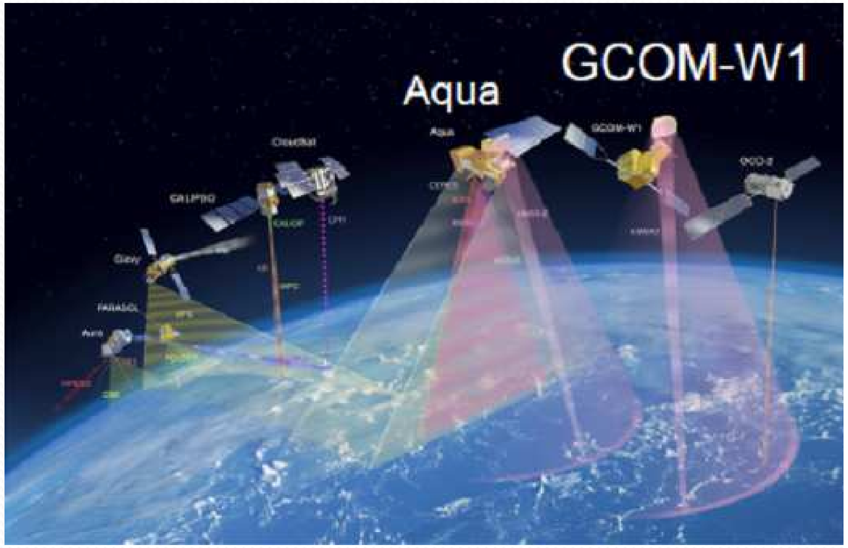
On 18 May 2012 Japan launched a new passive microwave instrument with the largest in the world diameter of antenna - Advanced Microwave Scanning Radiometer (AMSR2) onboard Global Change Observation Mission – Water satellite (GCOM-W1 "Shizuku")

Additional channel

Better than AMSR-E

AMSR2 Channel Set				
Center Freq. [GHz]	Band width [MHz]	Polarization	Beam width [deg] (Ground res. [km])	Sampling interval [km]
6.925 / 7.3	350	V & H	1.8 (35 x 61)	10
10.65	100		1.2 (24 x 41)	
18.7	200		0.65 (13 x 22)	
23.8	400		0.75 (15 x 26)	
36.5	1000		0.35 (7 x 12)	
89.0(A&B)	3000		0.15 (3 x 5)	5

Same as AMSR-E

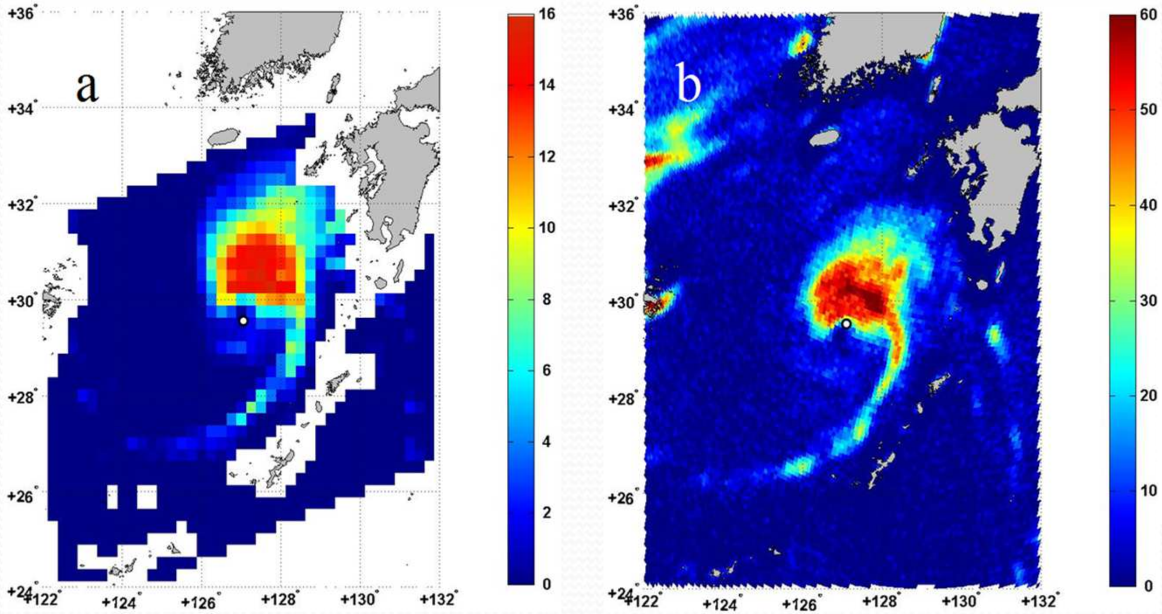


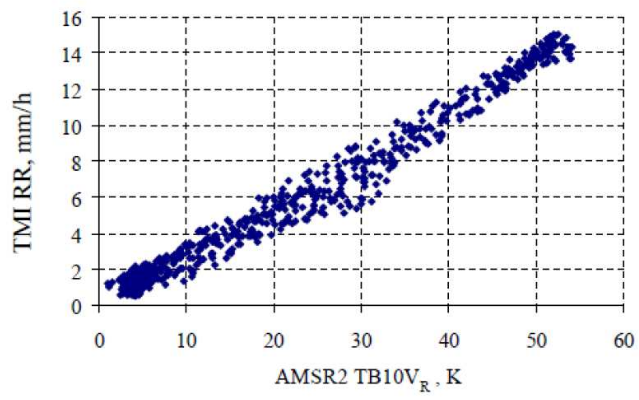
Potential accuracy for SWS retrievals is 1 m/s

AMSR2 all weather wind speed retrieval algorithms

Zabolotskikh E et al. GRL, 2014

Over most rainy atmospheres rain radiation at 10.65, 7.3, and 6.9 GHz can be parameterized in terms of $\Delta T_B{}^V{}_{7,6}$ and $\Delta T_B{}^V{}_{10,7}$. and related to rain rate (RR). After subtraction of the rain part from the total T_B rain-free SWS can be applied.

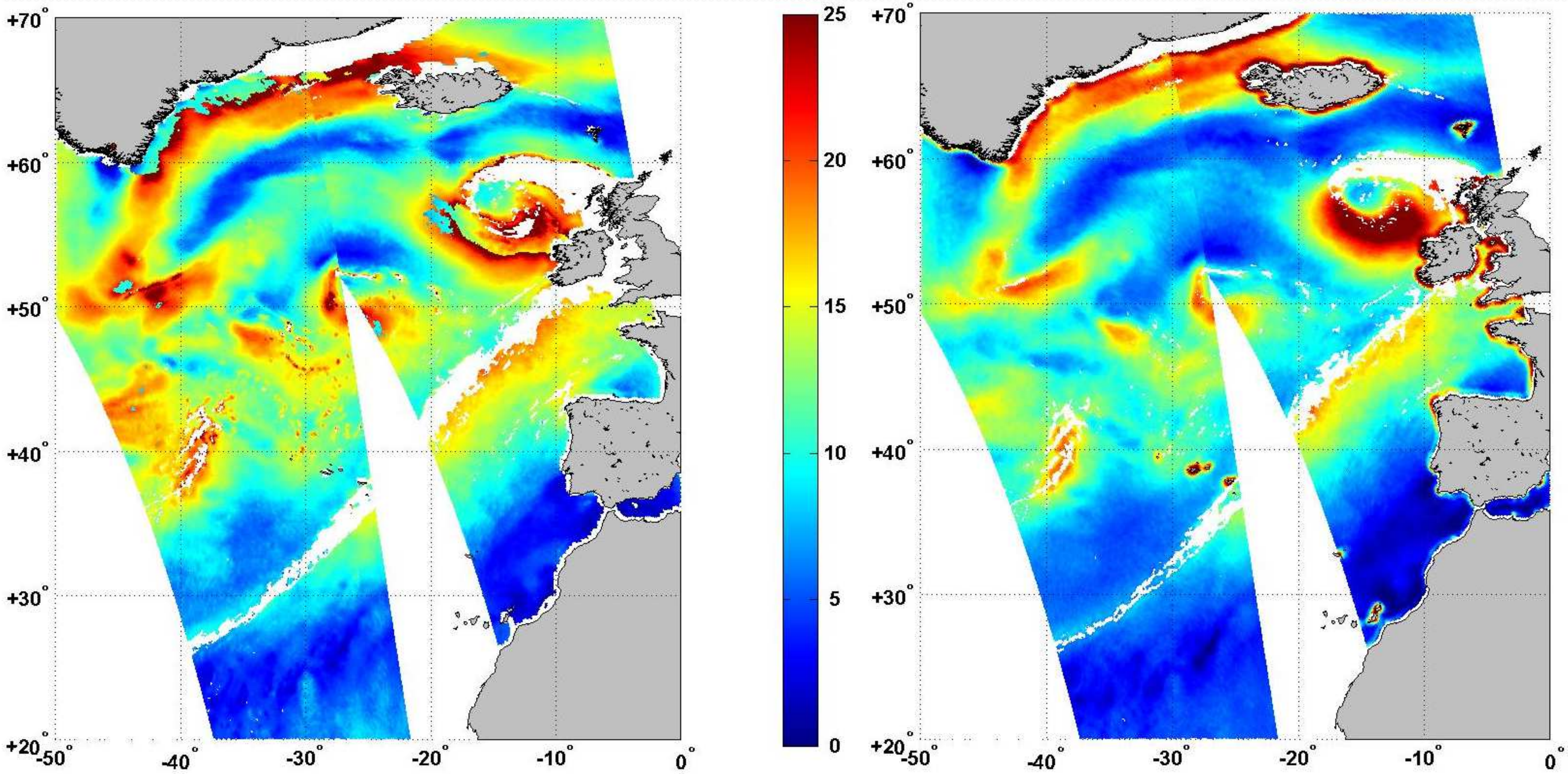




(a) TMI rain rate field (mm/h) for the typhoon Danas on 7 October 2013 (http://www.remss.com/) at ~ 18:36 UTC; (b). AMSR2 derived rain brightness temperature (K) at 10.65 GHz vertical polarization at ~ 17:14 UTC. White dots indicate the center of the typhoon at ~ 17:14 UTC

Towards Merged SMOS-AMSR-2-SMAP High wind products

Surface wind speed (SWS) in the extratropical cyclone 29 January 2013



AMSR2 JAXA standard product

AMSR2 new algorithm

Zabolotskikh E et al. GRL, 2014

AMSR2 wind speed retrieval algorithm applied to Haiyan

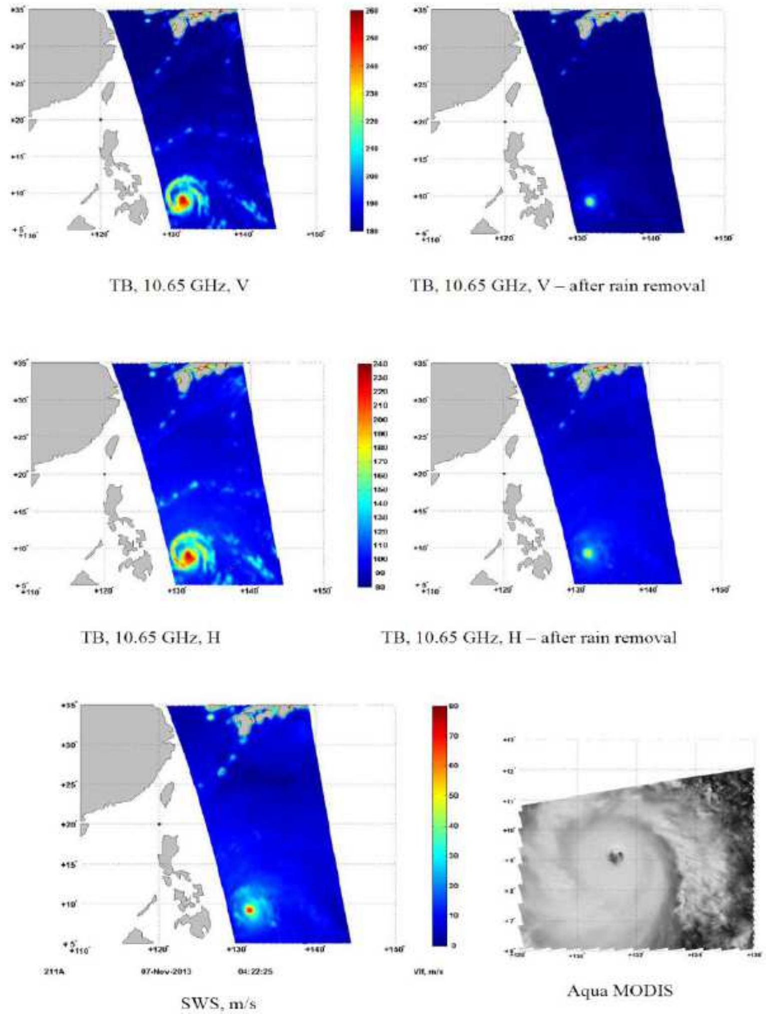


Figure 19: Rain effects removal algorithm applied to AMSR2 X-band Tb for an overpass of super Typhoon Haiyan as the surface wind speed reached maximum values of 150 knts on the 7 Nov 2013.

SMOS versus AMSR2 SWS in Haiyan

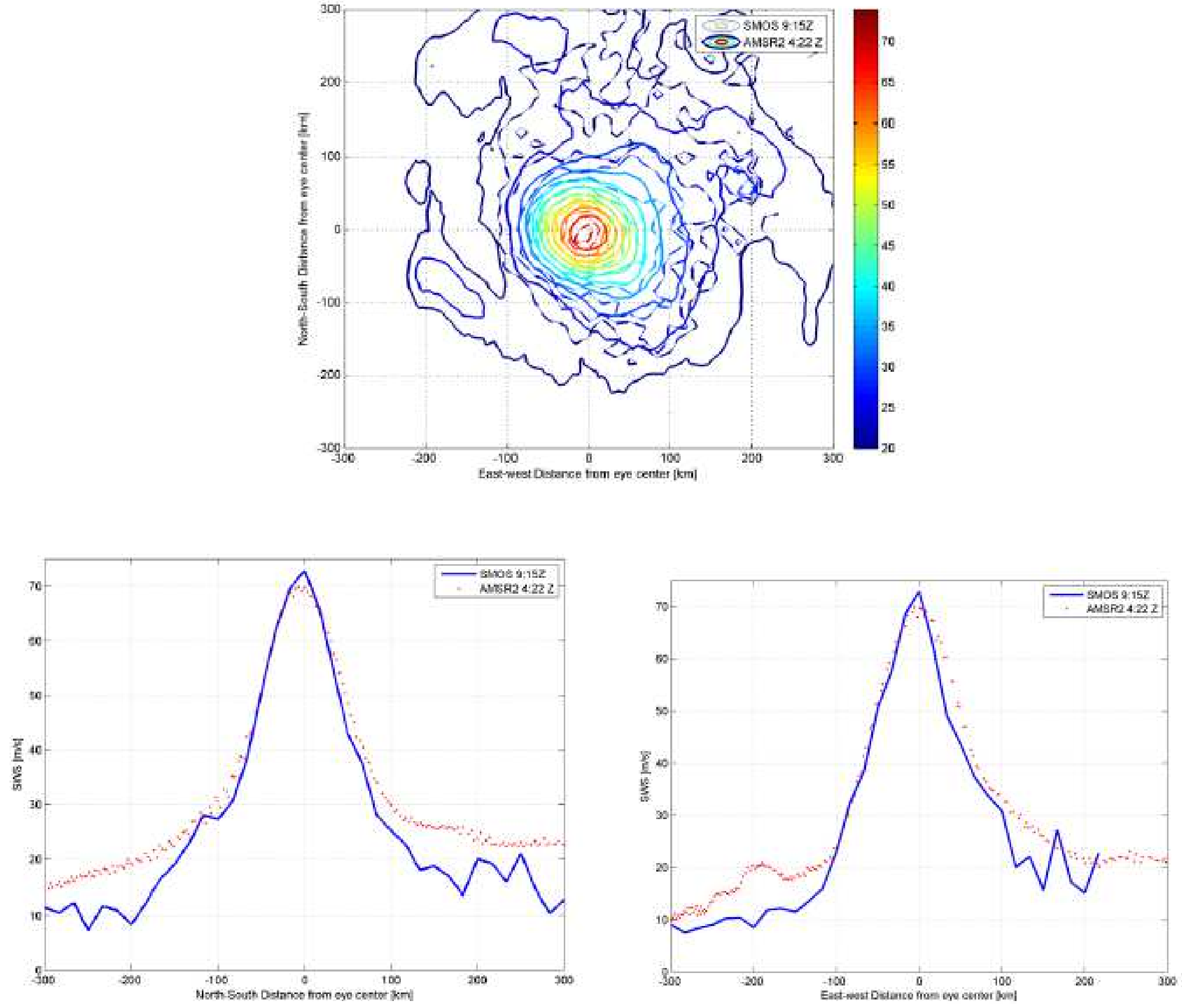
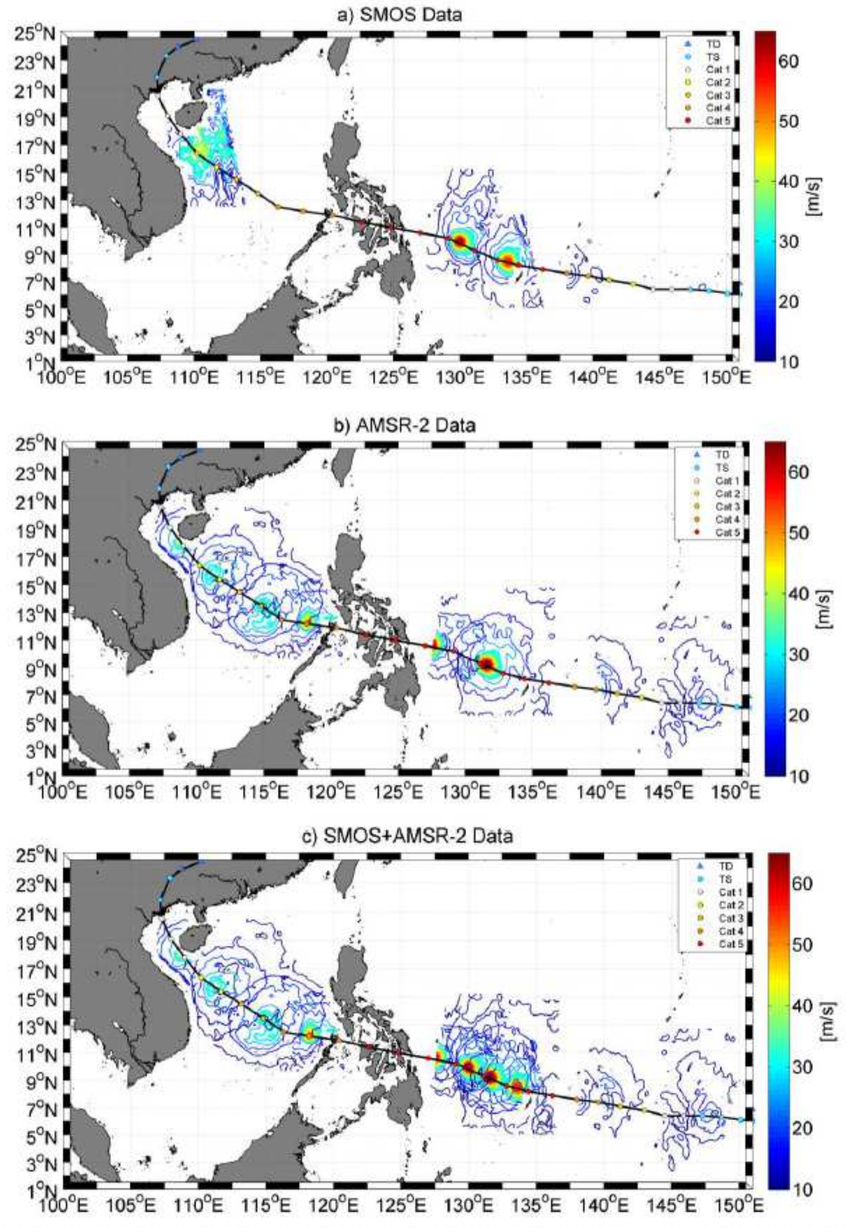


Figure 20: Top: *Superimposed contrours of SMOS (dashed) and AMSR2 (filled) surface wind speed fields estimated 5 hours apart as the sensors overpassed the super Typhoon Haiyan on the 7 Nov 2013. Bottom: North-South (left) and East-West (right) sections of the retrieved wind speed through the storm (blue=SMOS; red=AMSR2).*

Towards Merged SMOS-AMSR-2-SMAP High wind products



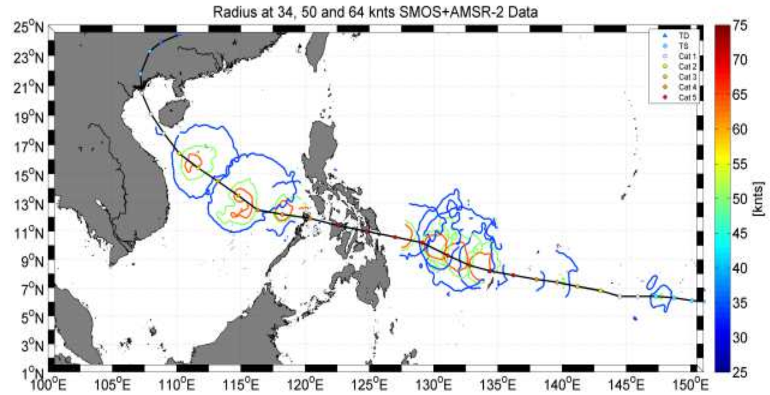


Figure 22: *Contours of the merged SMOS+AMSR2 retrieved winds over Haiyan at the threshold levels of 34 (blue), 50 (green) and 64 (orange) knots.*

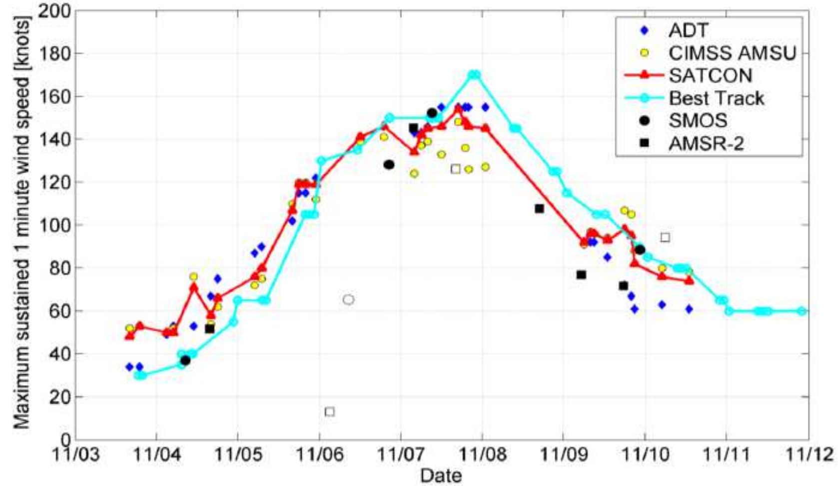


Figure 23: *Maximum sustained 1 minute wind speed estimated during Haiyan Typhoon. From SMOS data (black filled dots) and AMSR2 (black filled squares) compared to other top-of the atmosphere measurements. Note the empty circlesand squares correspond to the SMOS or AMSR2 measurements for which only a small portion of the cyclone signal was intercepted.*

Towards tracking Extra-Tropical Storms with SMOS & AMSR2

SMOS (L-band)+ AMSR-2 (C-band)

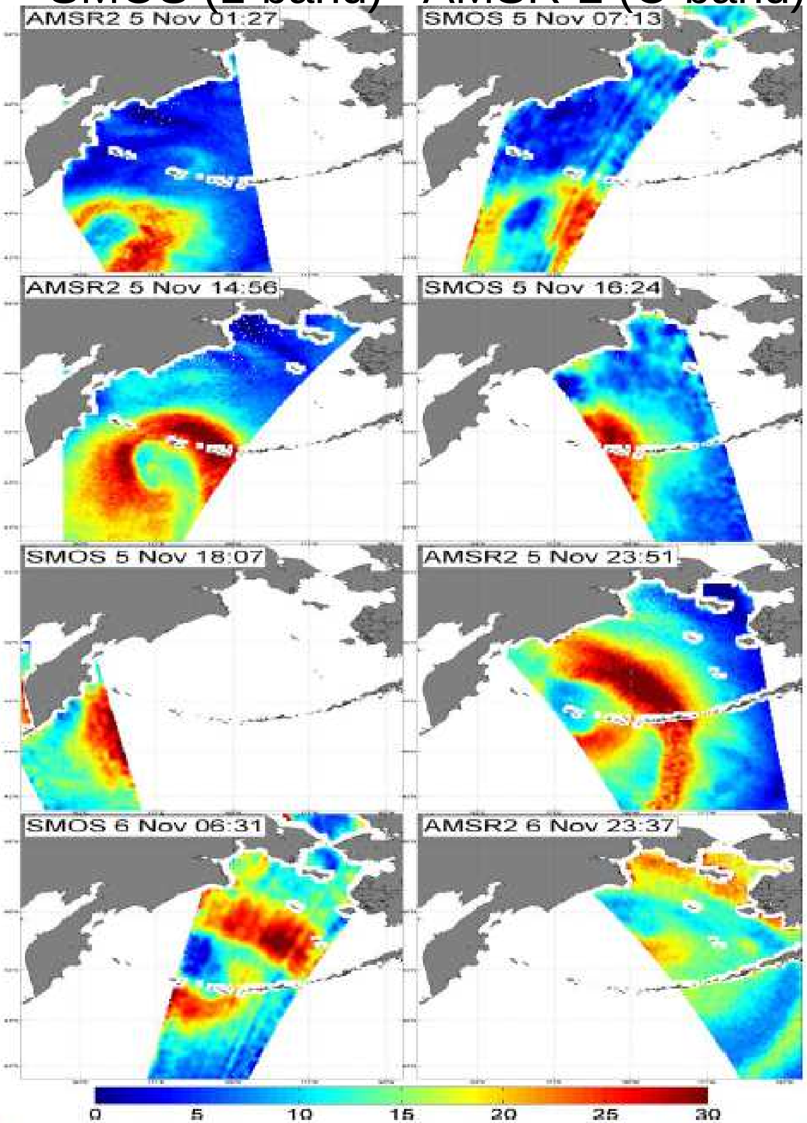


Figure 23: An Example of Extra-Tropical Storm sampling by SMOS and AMSR2 for 5 and 6 Nov 2013 (colorbar in units of m/s).

Ascat

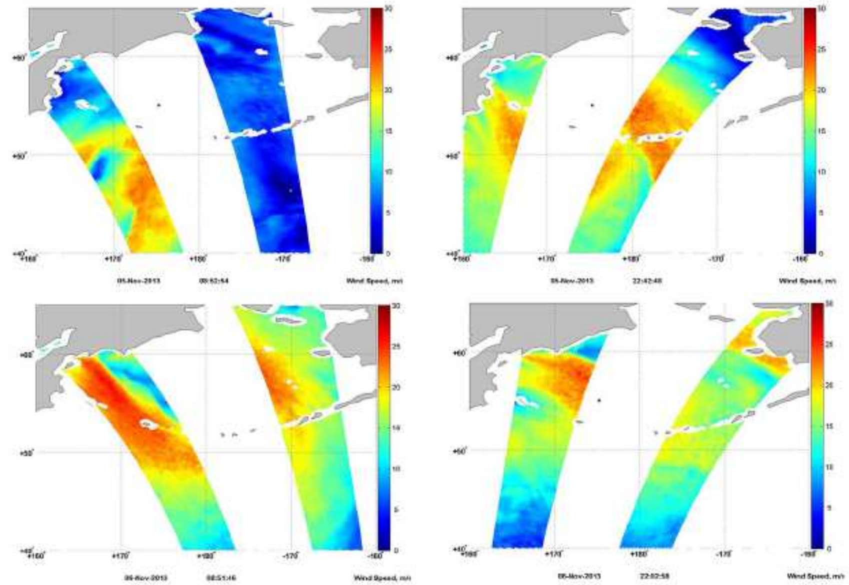


Figure 24: Sampling of the previously analysed Extra-Tropical Storm by METOP/Ascat from 5 to 6 Nov 2013 (m/s).

Summary (1)

- We evidenced clear SMOS brightness temperature signal associated with the passage of Hurricanes

- By analysing SMOS intercept with Hurricane Igor in 2010 and collecting an ensemble on auxilliary wind speed informations, we developed a Geophysical Model Function relating the SMOS Tb estimated at the surface (corrected for atmosphere) to the surface wind speed.

- We have shown that SMOS can allow to retrieve important structural surface wind features within hurricanes such as the radius of wind speed larger than 34, 50 and 64 knots. These are Key parameters to monitor tropical cyclone intensification

Ascat can provide R34 but not R50 & R64=>SMOS does

SMOS clearly outperform ASCAT & ECMWF in the Igor case in area far from Aircraft observations

Summary (2)

▪ **The potential effect on rain at L-band was analyzed:**
Below hurricane force (33 m/s)
=>some Rain impacts on the Tbs were found but small
(errors on wind speed < 5 m/s)

At very high winds, lack of rain-free data to firmly conclude but certainly weaker than at C-band

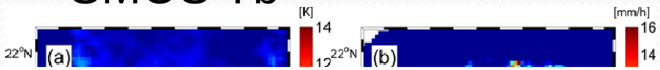
▪An empirical wind speed retrieval algorithm was developed
▪The latter was tested against an independant Hurricane: the Cat-1 Hurricane Sandy in 2012. SMOS wind speed retrievals were compared to NODC buoy data and SFMR wind speed:

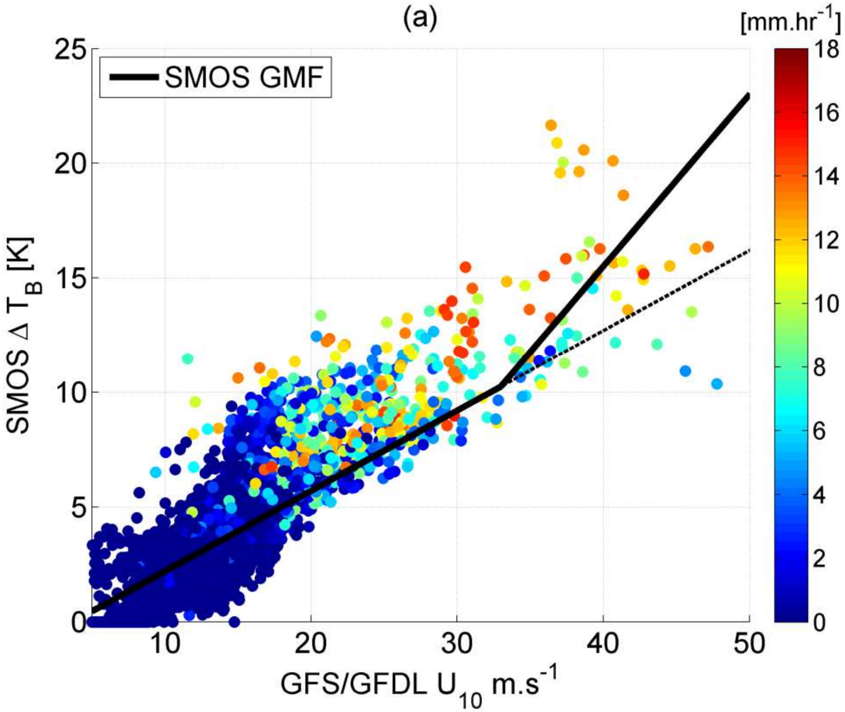
▪Agreement within ± 3 m/s was found

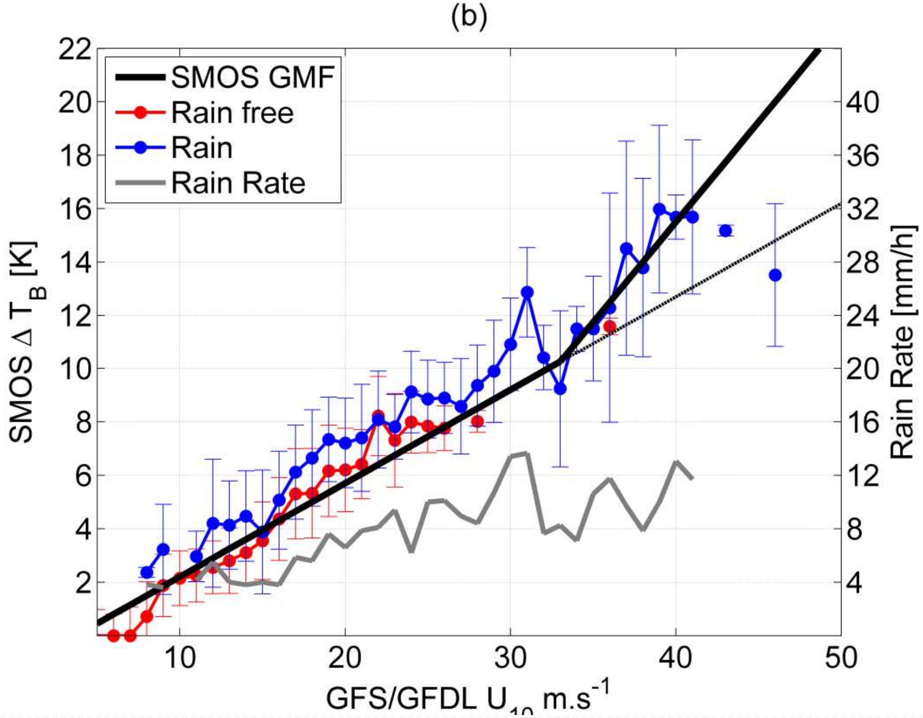
▪Main instrumental limitations are spatial resolution, RFI & land contamination

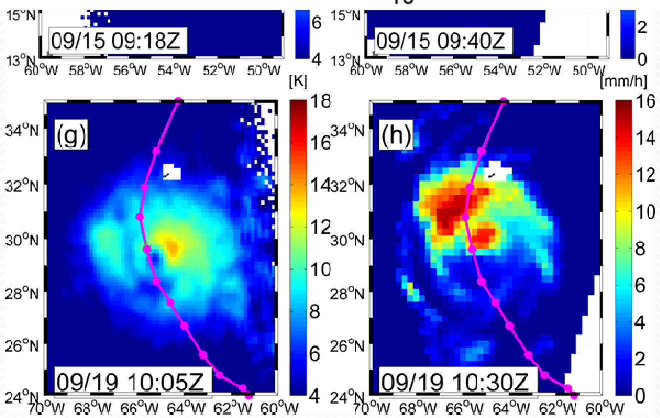
Potential rain Impact at L-band

SMOS Tb   Rain rates









SSM/I F16

Below hurricane force (33 m/s)
=>some Rain impacts but small
(errors on wind speed < 5 m/s)

At very high winds, lack of rain-free data to conclude