→ SEASAR 2018

Advances in SAR Oceanography

7–10 May 2018 | ESA–ESRIN | Frascati (Rome), Italy

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Analysis of the 2017 Hurricane Season IRMA observed by Sentinel-1 , RADARSAT-2 and TerraSAR-X

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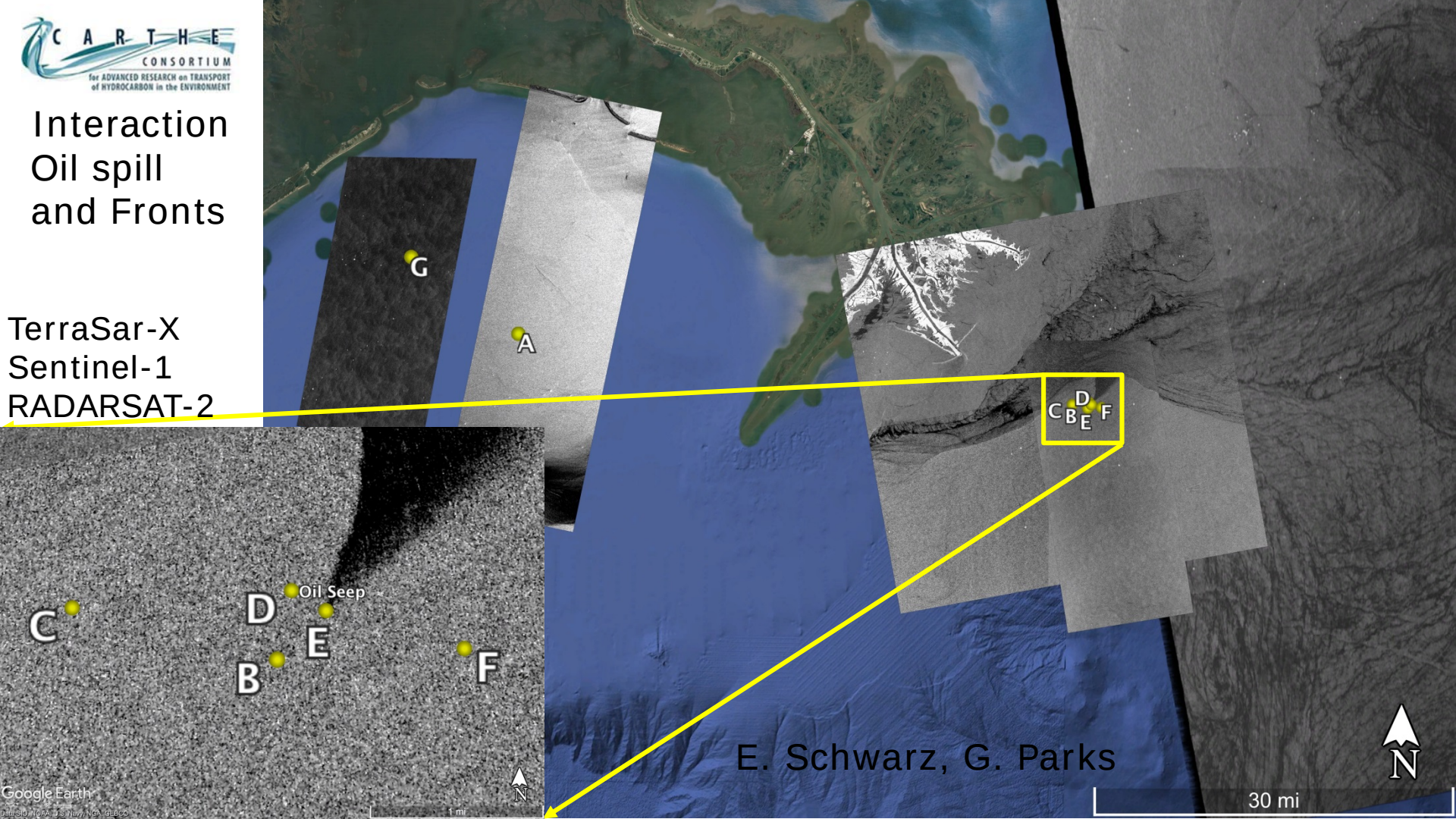
Interaction Oil spill and Fronts

TerraSar-X
Sentinel-1
RADARSAT-2



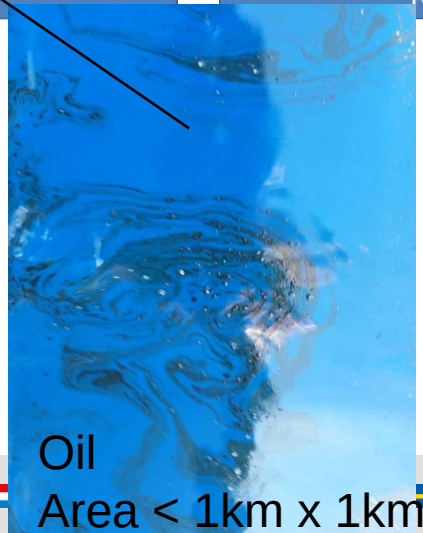
E. Schwarz, G. Parks

Aftermath: Oil Seep caused by Hurricane IVAN

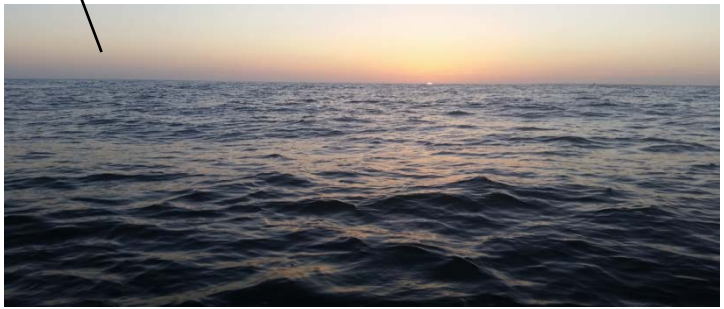
Radarsat-2 20th April 2017

TerraSAR-X 20th April 2017

Freshwater Front



Oil
Area < 1km x 1km



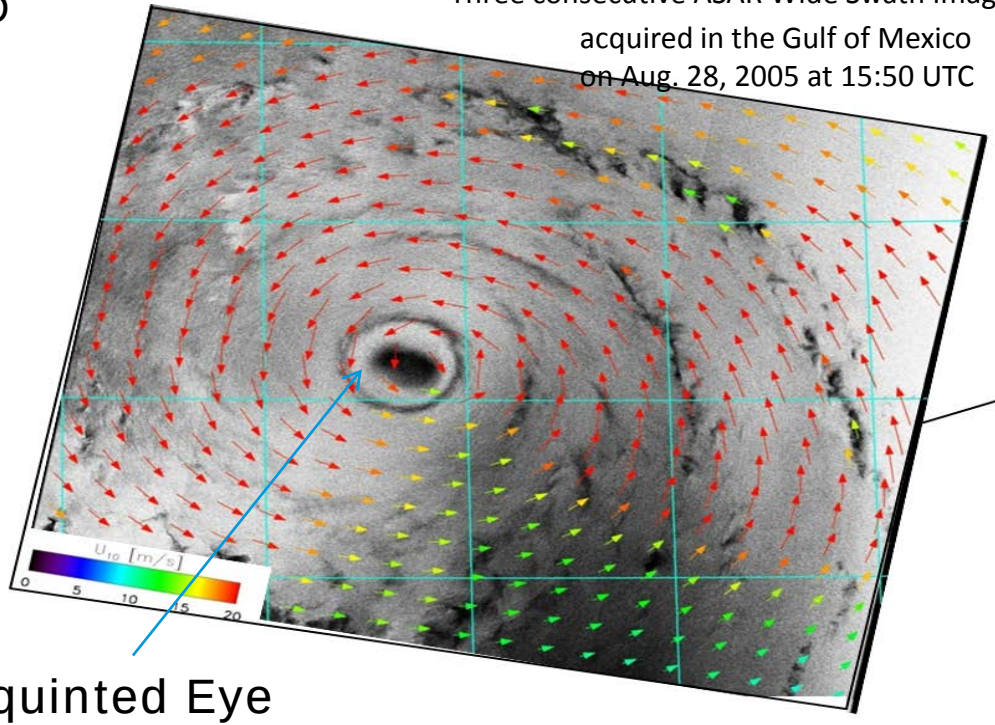
Slicks – Smooth Sea Surface

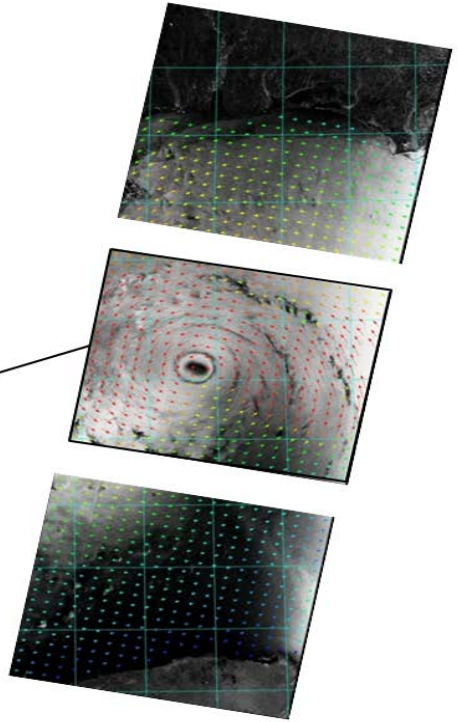
Wind field from SAR data: Hurricane Katrina

CMOD

Three consecutive ASAR Wide Swath Images acquired in the Gulf of Mexico on Aug. 28, 2005 at 15:50 UTC

CMOD



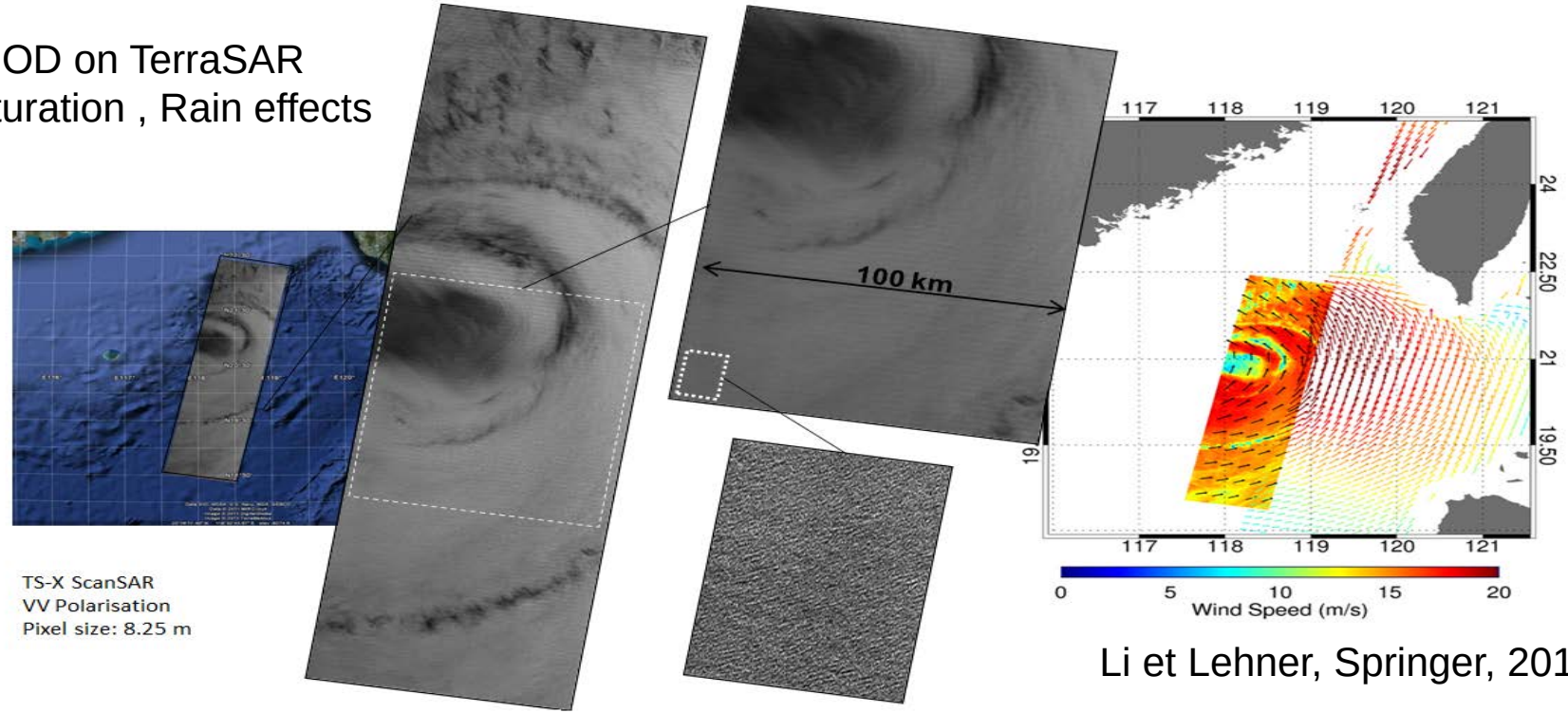


Squinted Eye

Reppucci et al., IEEE -> Saturation at 20 m/sec

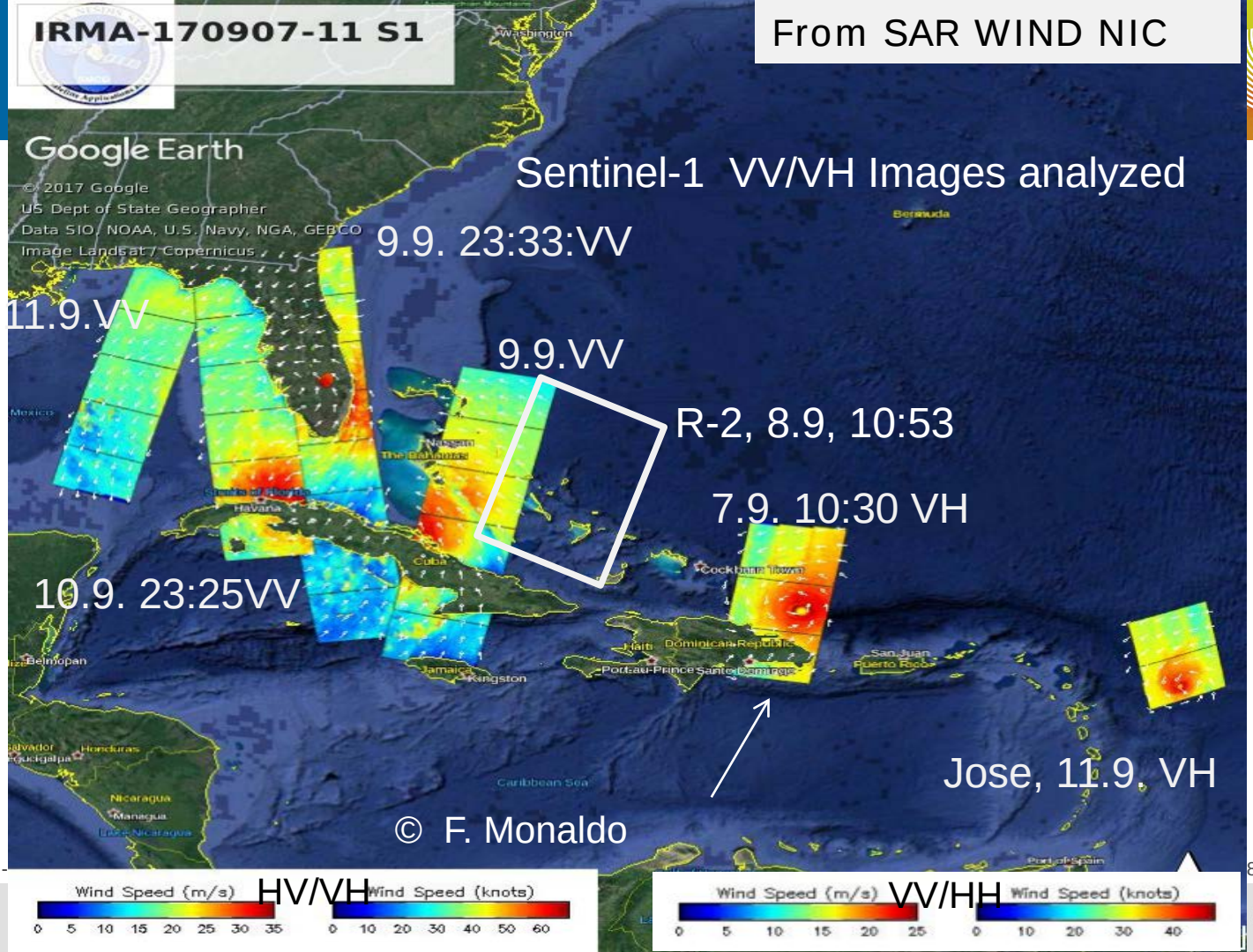
Wind field from SAR data: Typhoon MEGI

XMOD on TerraSAR
Saturation , Rain effects

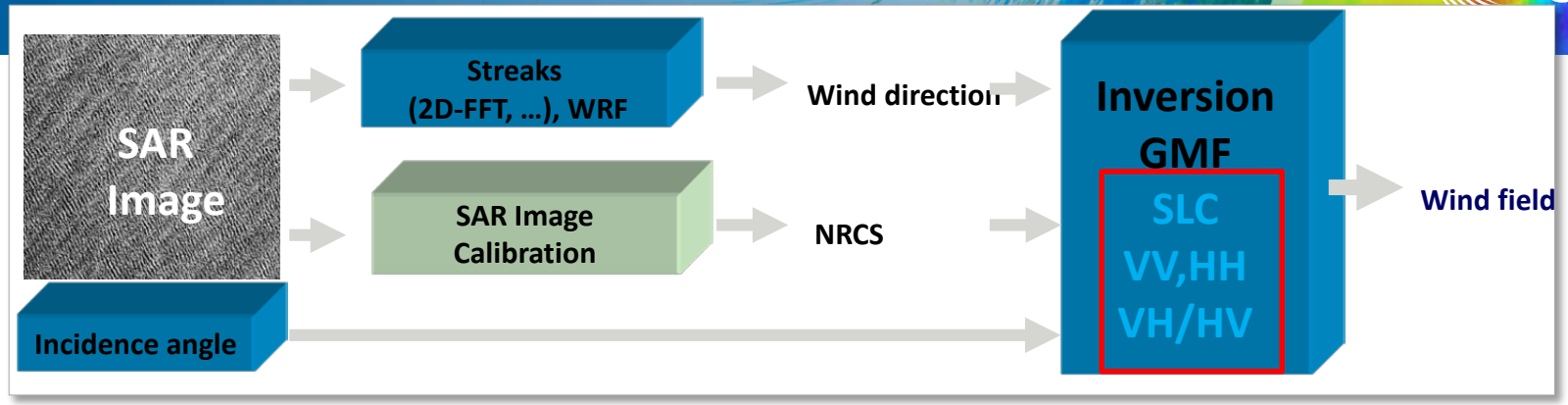


Li et Lehner, Springer, 2017

Tropical Cyclone Eye “MEGI” SSW measurement of Typhoon using TSX-SC data


IRMA-170907-11 S1
From SAR WIND NIC
Google Earth
© 2017 Google
US Dept of State Geographer
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image Landsat / Copernicus
Sentinel-1 VV/VH Images analyzed
9.9. 23:33:VV
11.9.VV
9.9.VV
R-2, 8.9, 10:53
7.9. 10:30 VH
10.9. 23:25VV
Jose, 11.9. VH
© F. Monaldo
Wind Speed (m/s) 0 5 10 15 20 25 30 35
HV/VH
Wind Speed (knots) 0 10 20 30 40 50 60
Wind Speed (m/s) 0 5 10 15 20 25
VV/HH
Wind Speed (knots) 0 10 20 30 40

SAR Sea Surface Wind Speed / Sea Surface Roughness Retrieval



Geophysical Model Function (GMF): $\sigma_0 = B_0(v,\theta)(1 + B_1(v,\theta)\cos\phi + B_2(v,\theta)\cos 2\phi)$

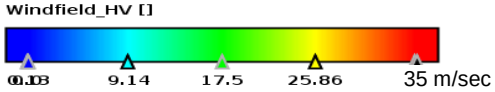
Radar band	GMF	Spaceborne SAR Sensors
C-band (5.6GHz)	CMOD4,CMOD5/5N	ERS/SAR,ENVISAT/ASAR, RADARSAT-1/2, Sentinel
L-band (1.3GHz)	LMOD1/2	JERS-1, ALOS PALSAR-1/2
X-band (9.6GHz)	XMOD	TerraSAR-X/TanDEM-X, Cosmo-SkyMed

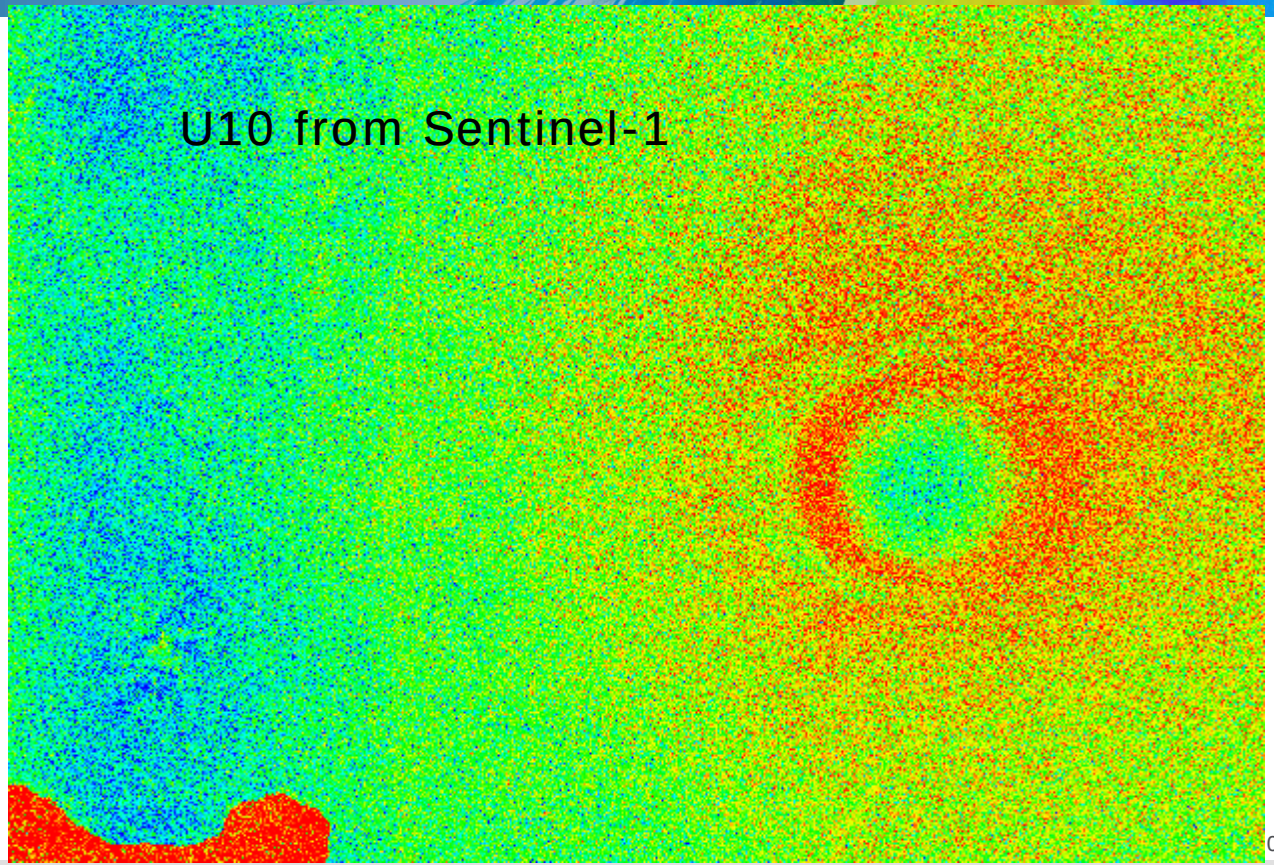
Alpers et al., Lehner et al, 1998 (ERS), Horstmann et al, Reppucci et al (ENVISAT), Li et al. TS-X

U_{10} derived from VH using empirical Algorithm

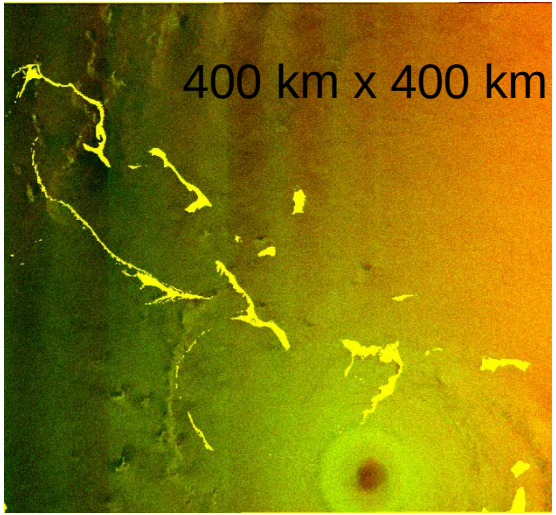
e.g., CPO for HV

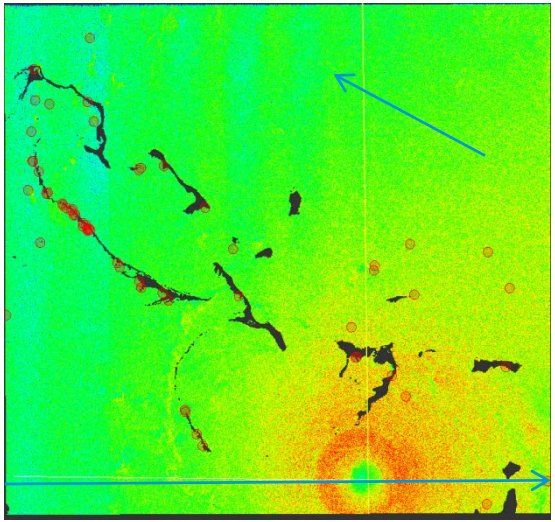
After,
Vachon et al.,
Zhang,Perrie et al,



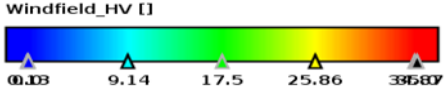


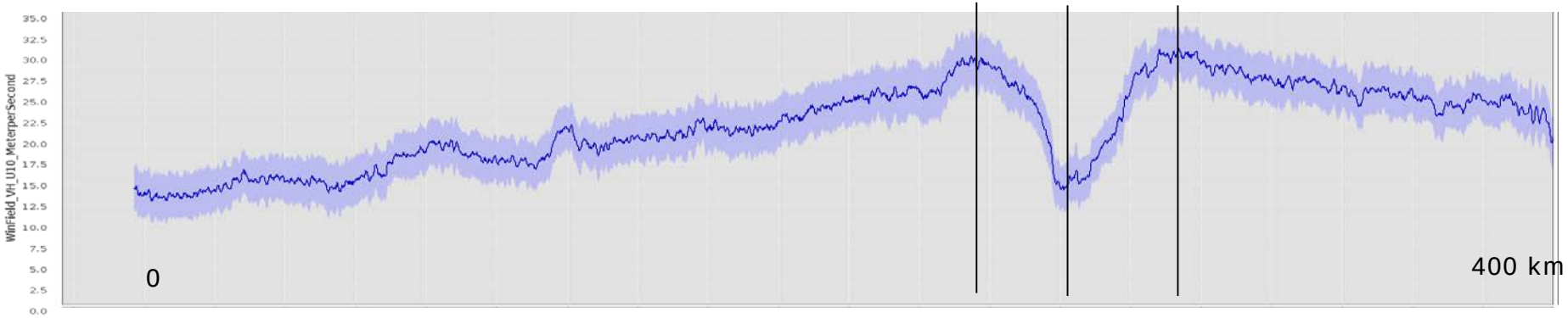
Hurricane IRMA over Bahamas by RADARSAT 2



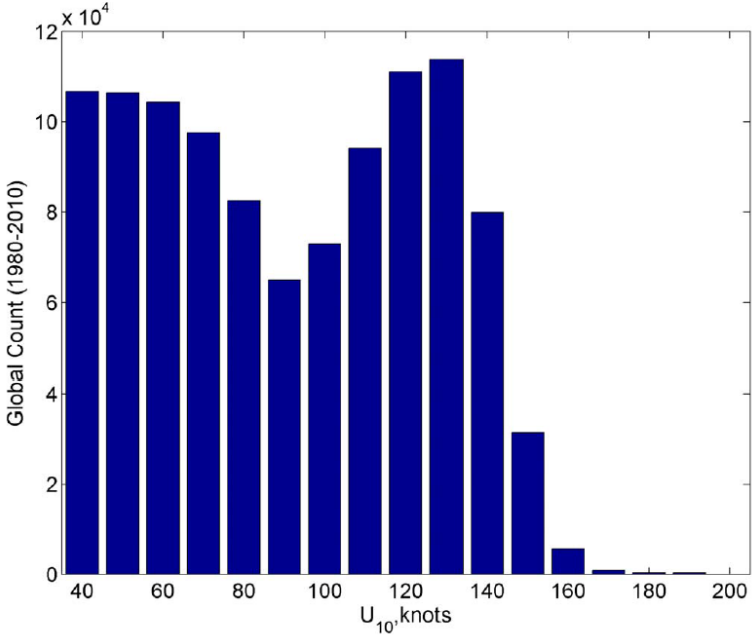


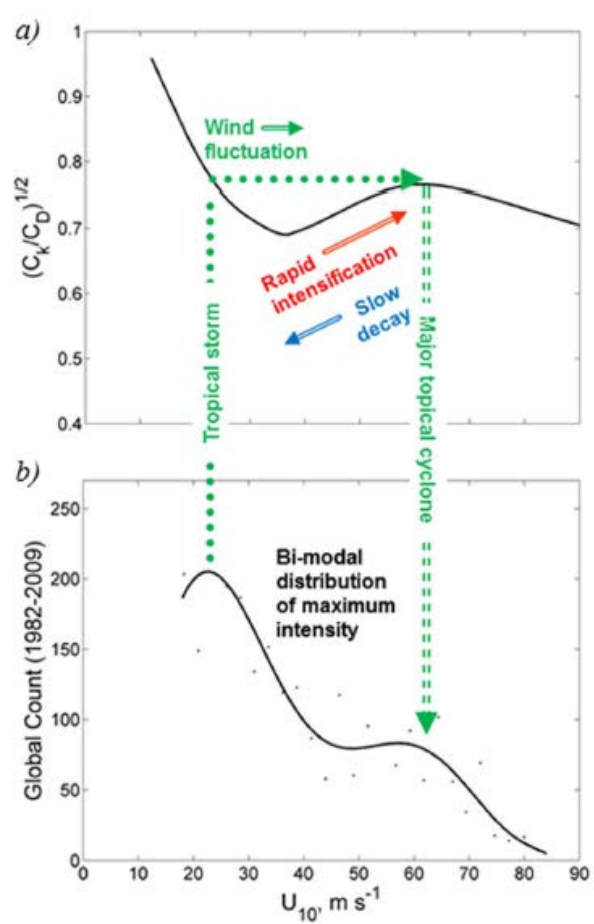
8 Sep 2017
10 53 UTC
R2 © MDA
HV





Bimodal distribution of Hurricanes

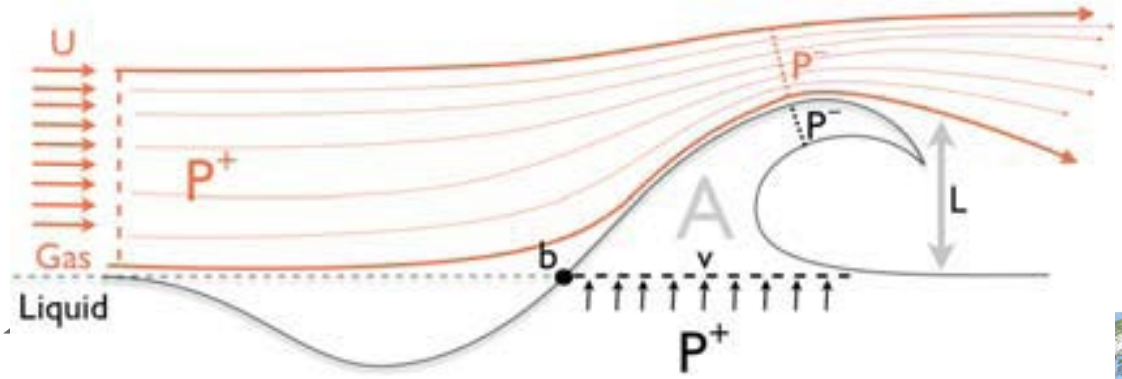




from Soloviev et. al.

Air-Sea Interface under Tropical Cyclones

- The disruption of the air-sea interface and spume generation under tropical cyclone conditions can be explain by the Kelvin-Helmholtz type shear-layer instability (Koga 1981).
- This instability is able to overcome the stabilizing force of gravity force and surface tension at the air-water interface above ~30 m/s wind speed, corresponding to transition to Category 1 hurricane

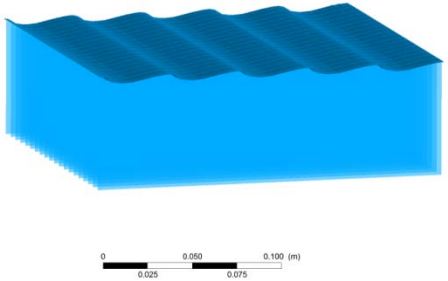


Soloviev et al, 2017

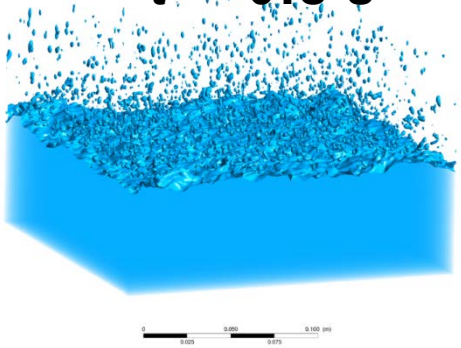
CFD simulation of the air-sea interface

***t* = 0 s**

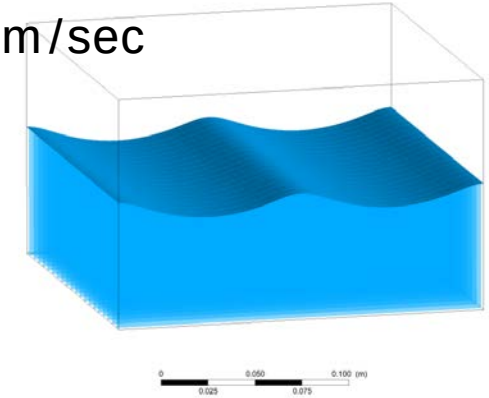
***t* = 0.3 s**



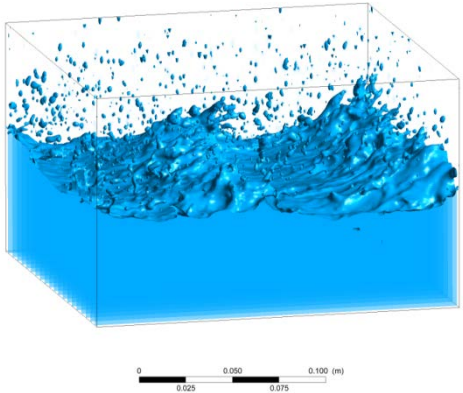
4 cm wavelength



U_{10} ~ 80 m/sec



10 cm wavelength

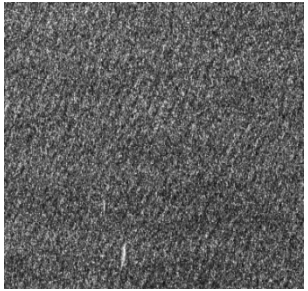


Spray is cause for increased amplification

SWH from SAR now official------ CWAVE

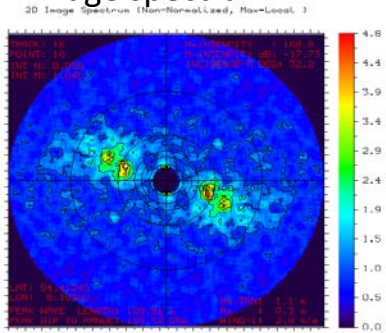
Wind Speed: New tuning of HV algorithm necessary

SAR subscene



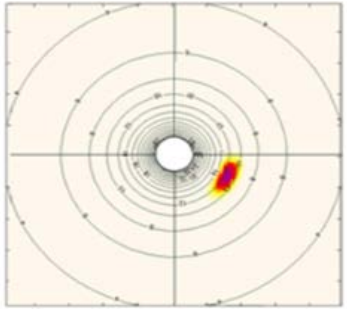
FFT

Image spectra



Transfer functions

wave spectra



integration

Integrated parameters:

direct estimation -

empirical functions
using also local wind information

Wave height,
mean period,
etc.

Image feature analysis
GLCM (Grey Level Occurrence Matrix)

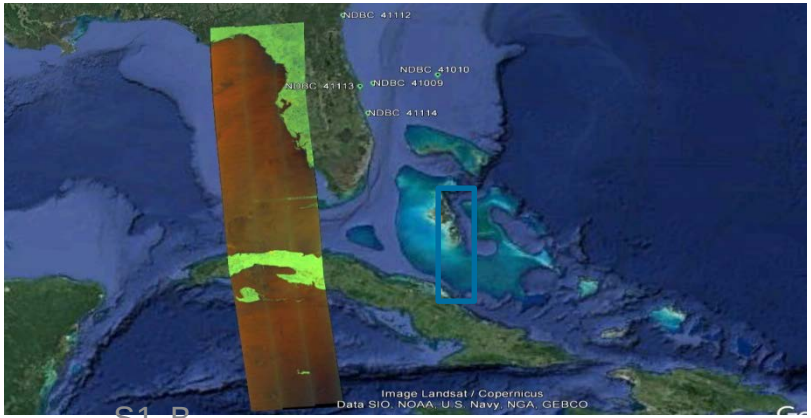
Entropy, Contrast, Correlation,
Dissimilarity, etc.,

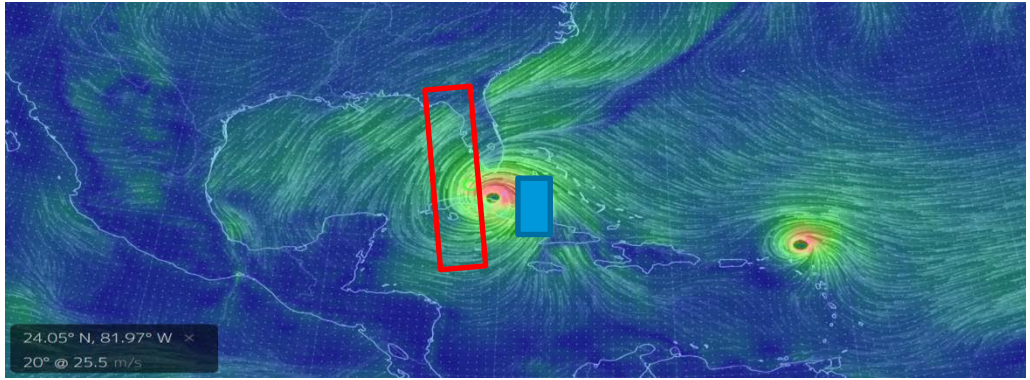
NN

: Hasselmann, Schulz-Stellenfleth, Lehner, Bruck, Pleskachevsky, Stopa, Ardhuin

Sentinel Images from 2017 IRMA landfall

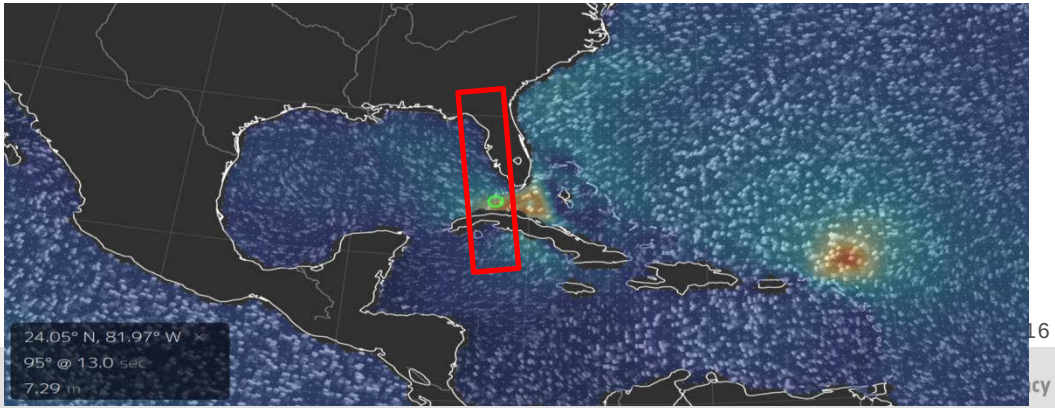
2017-09-09 23:33



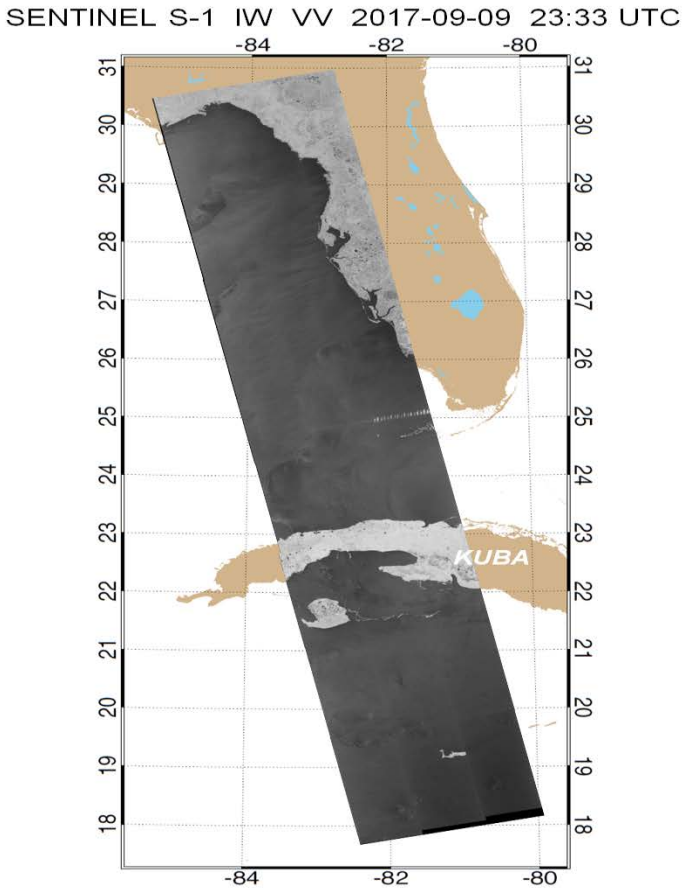


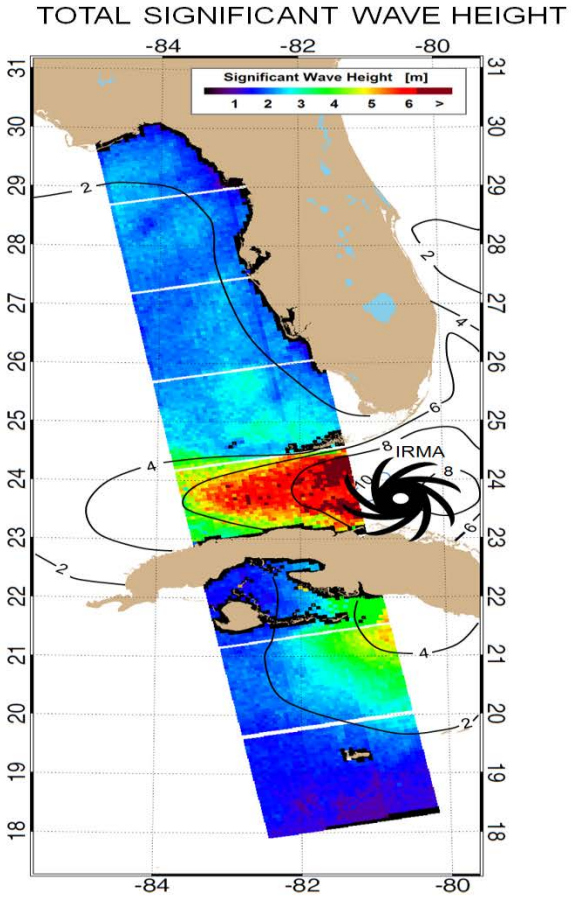
S1-B

2017-09-09 23:33:28
2017-09-09 23:33:57
2017-09-09 23:34:22
2017-09-09 23:34:47
2017-09-09 23:35:12
2017-09-09 23:35:37
2017-09-09 23:36:02
2017-09-09 23:36:27



Ocean Wave Height under Hurricane IRMA

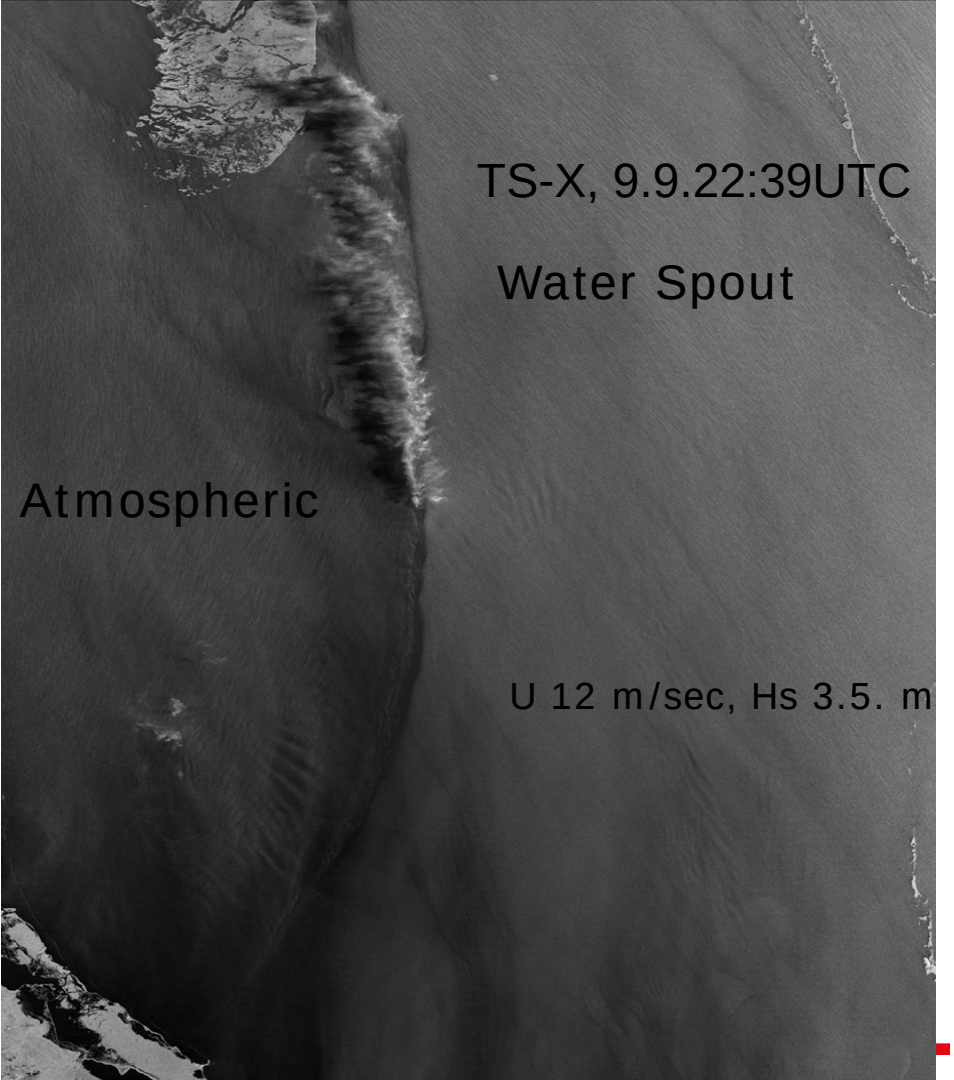


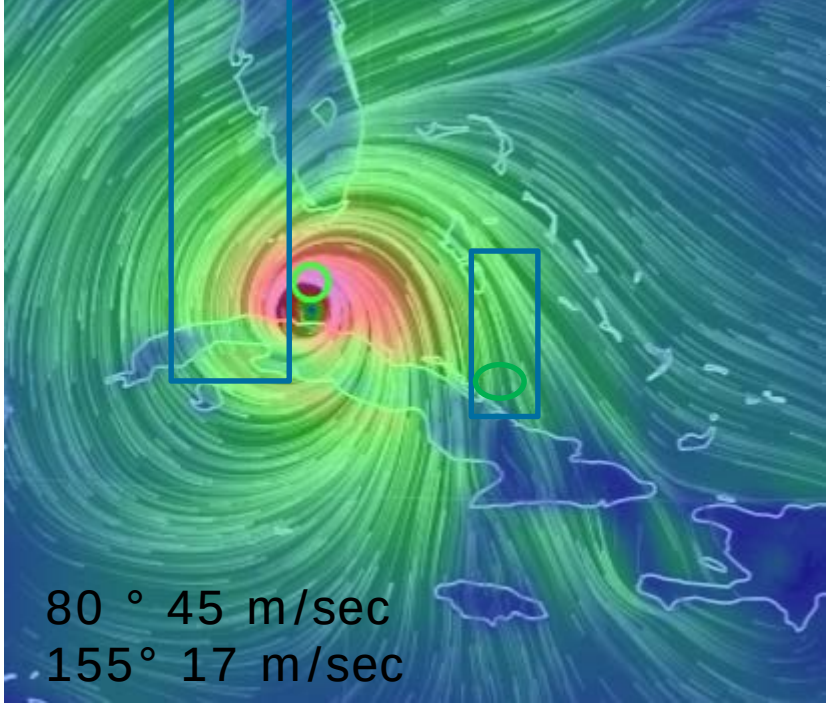


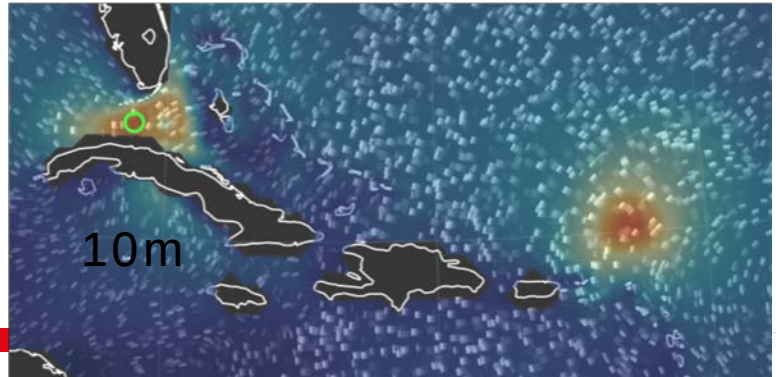
ESA News
Pleskachevsky et al,

EUSAR 2018

10m WW3


TS-X, 9.9.22:39UTC
Water Spout
Atmospheric
U 12 m/sec, Hs 3.5. m

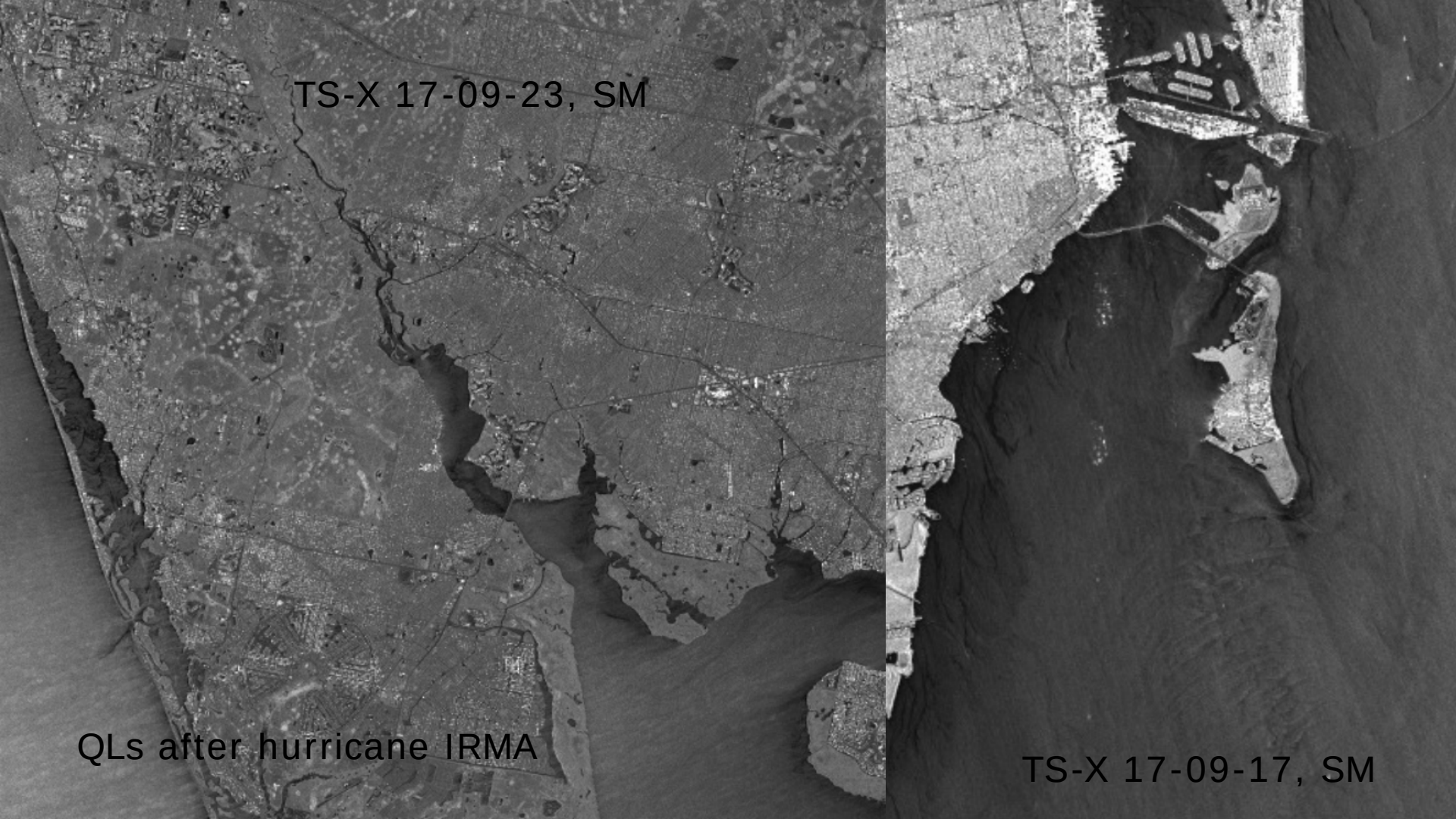

80 ° 45 m/sec
155° 17 m/sec


10m

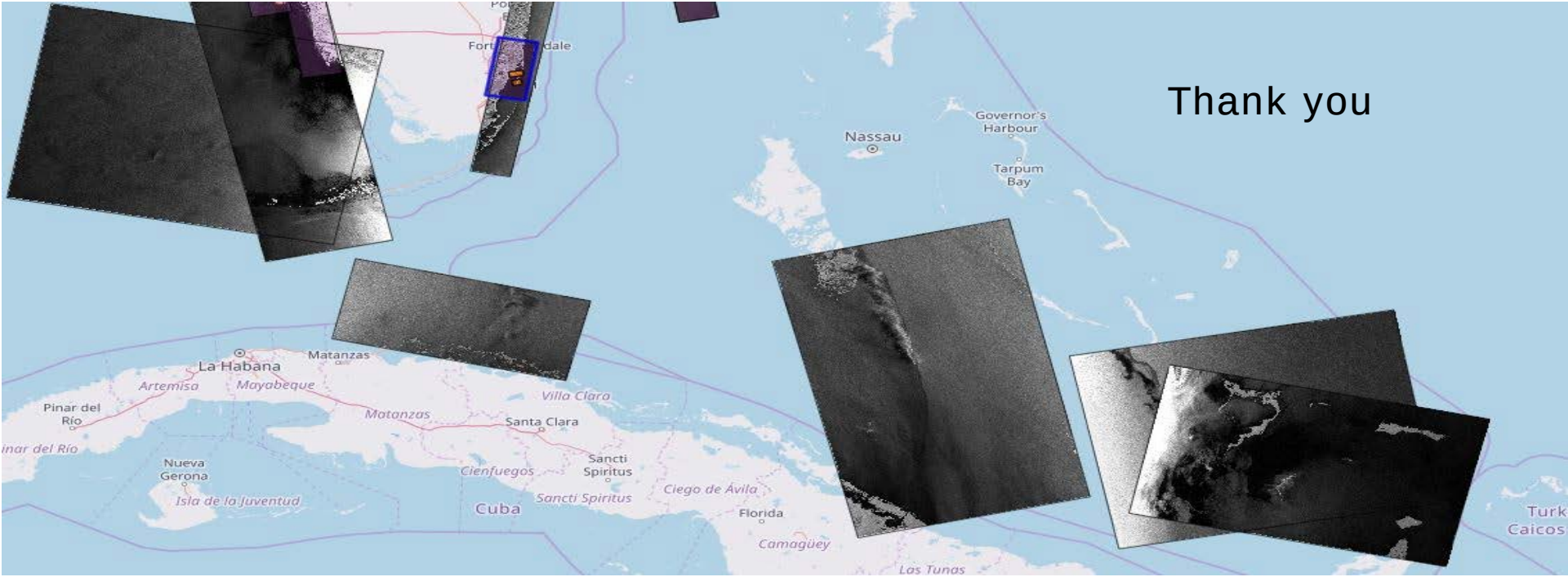
Summary:

- Derive Wind Speed u10 and Sea State Parameters using empirical algorithms. Significant wave height and dominant period measurable <20 % SI
- Wind Speed measurements saturate at low 20 m/sec depending on range, HV channel is used to overcome this problem, retuning HV
- Sentinel data freely available on ESAs website (SLC) fantastic dataset acquired, OCN not always available; WV and IW mutually exclusive, RADARSAT complex data not available
- TS-X saturates, shows high res small scale features of the wind field like water spouts, ocean waves – and rain (scatterers) in the air, no dual pol was acquired,
- NN algorithms developed for TS-X wind speed, sea state on QLs
- Roughness from SAR imagery may explain bimodal distribution and rapid intensification of hurricanes

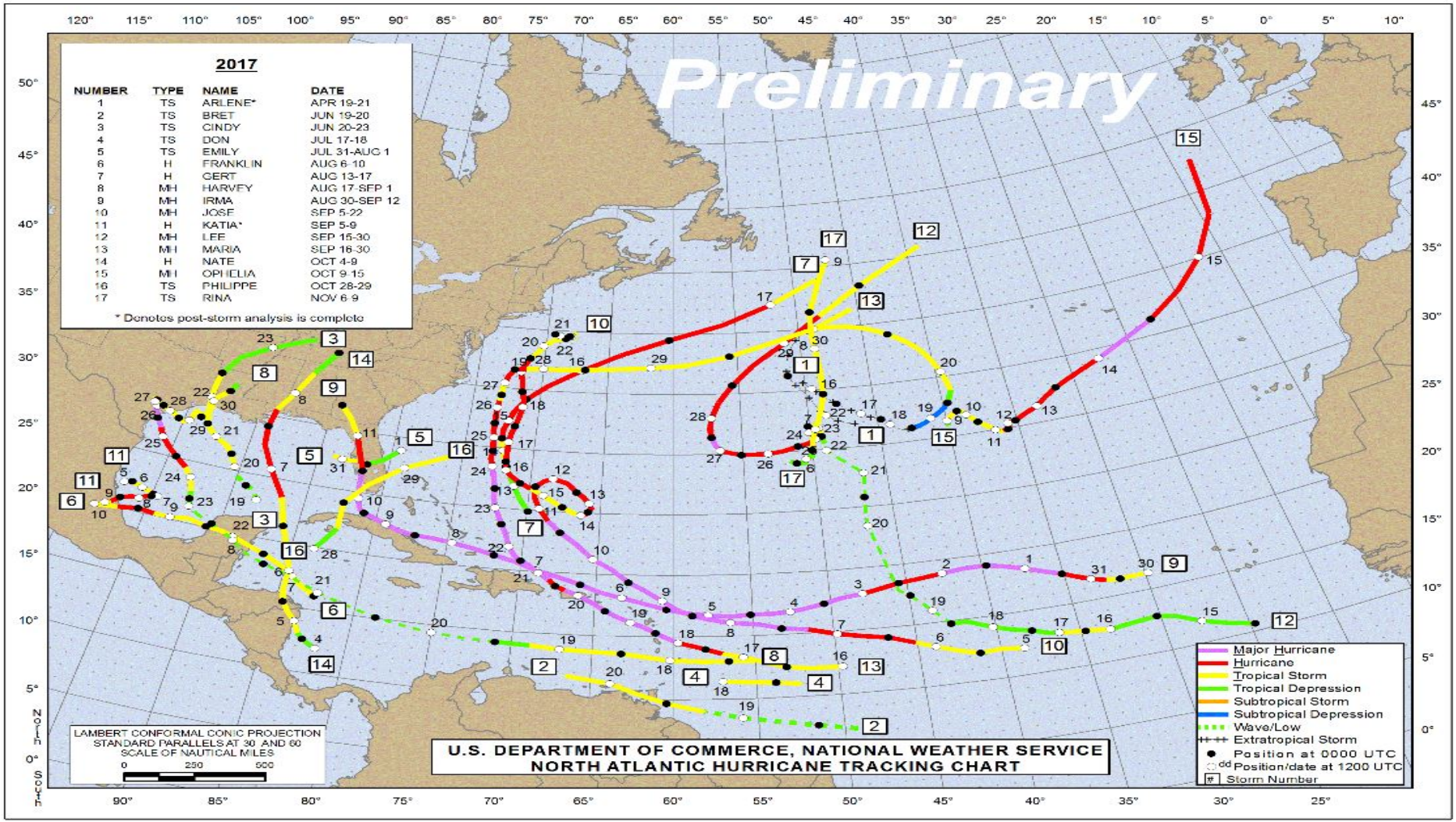
- Special Issue Remote Sensing (after Oceans Conference) on Remote Sensing of Sea Surface Roughness : Please submit !!!!


TS-X 17-09-23, SM
QLs after hurricane IRMA
TS-X 17-09-17, SM

IRMA Acquisitions from TerraSAR-X

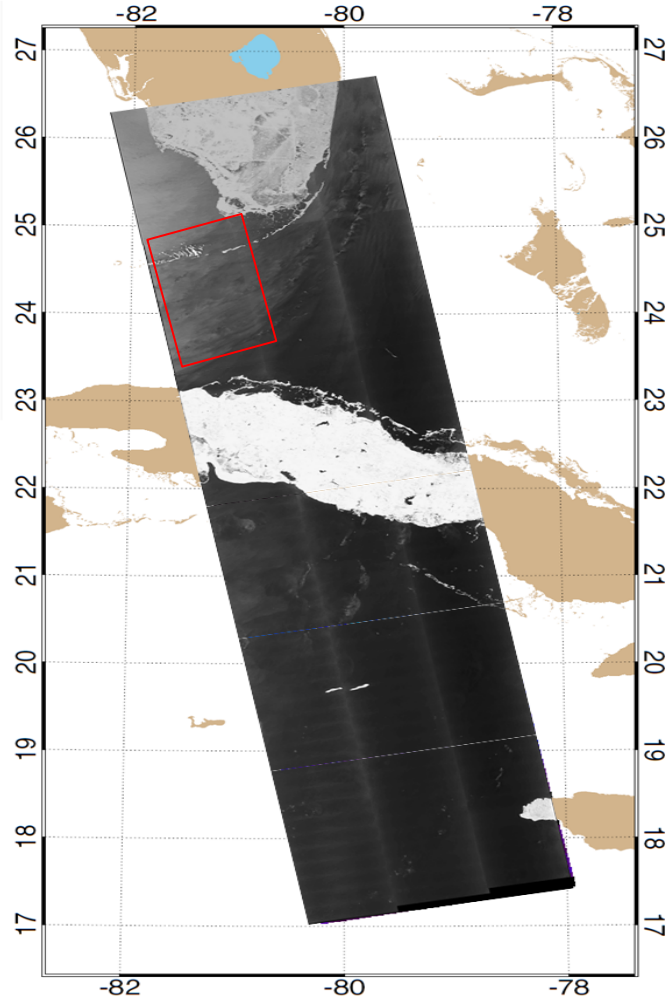


– Backup

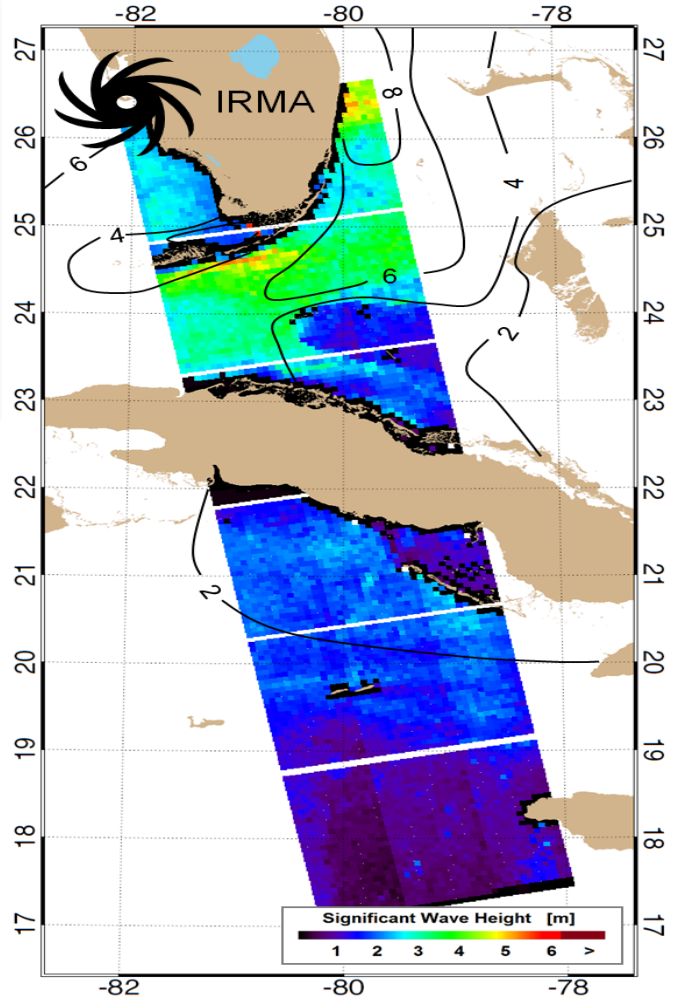

Preliminary
2017
NUMBER TYPE NAME DATE
1 TS ARLENE* APR 19-21
2 TS BRET JUN 19-20
3 TS CINDY JUN 20-23
4 TS DON JUL 17-18
5 TS EMILY JUL 31-AUG 1
6 H FRANKLIN AUG 6-10
7 H GERT AUG 13-17
8 MH HARVEY AUG 17-SEP 1
9 MH IRMA AUG 30-SEP 12
10 MH JOSE SEP 5-22
11 H KATIA* SEP 5-9
12 MH LEE SEP 15-30
13 MH MARIA SEP 16-30
14 H NATE OCT 4-9
15 MH OPHELIA OCT 9-15
16 TS PHILIPPE OCT 28-29
17 TS RINA NOV 6-9
* Denotes post-storm analysis is complete
LAMBERT CONFORMAL CONIC PROJECTION
STANDARD PARALLELS AT 30 AND 60
SCALE OF NAUTICAL MILES
0 250 500
U.S. DEPARTMENT OF COMMERCE, NATIONAL WEATHER SERVICE
NORTH ATLANTIC HURRICANE TRACKING CHART
Major Hurricane
Hurricane
Tropical Storm
Tropical Depression
Subtropical Storm
Subtropical Depression
Wave/Low
Extratropical Storm
Position at 0000 UTC
dd Position/date at 1200 UTC
Storm Number
North
South

D
•
C
2

SENTINEL S-1 IW VV 2017-09-10 23:25 UTC

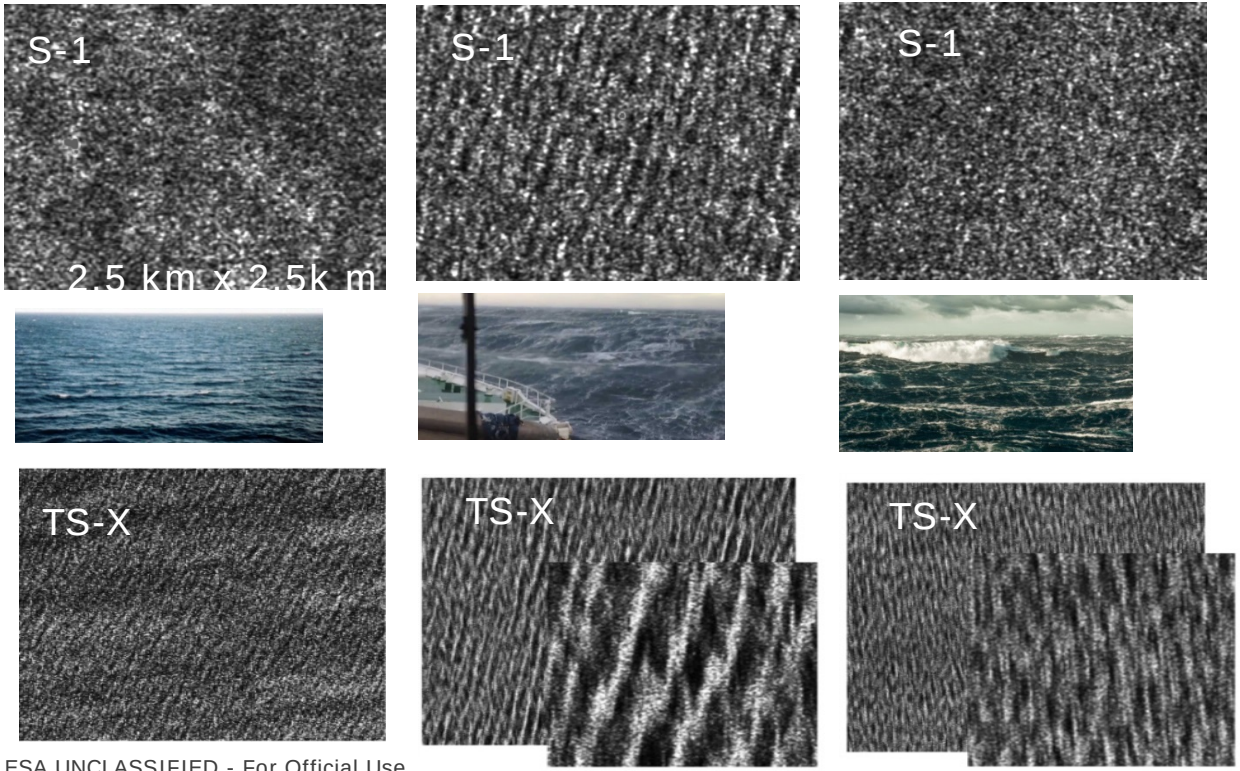


TOTAL SIGNIFICANT WAVE HEIGHT



Sea Surface by different Sensors

Hs ~ 0.5m | **Hs ~ 4m** | **Hs ~ 7m**



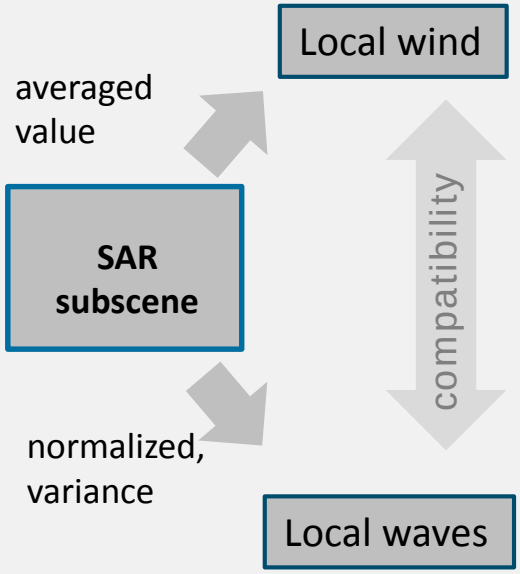
calm (swell) | **moderate** | **strong**

Fig. 13: Sea surface imaging by SAR: different sensors

SENTINEL S-1 IW VV 10m Pixel, C-band

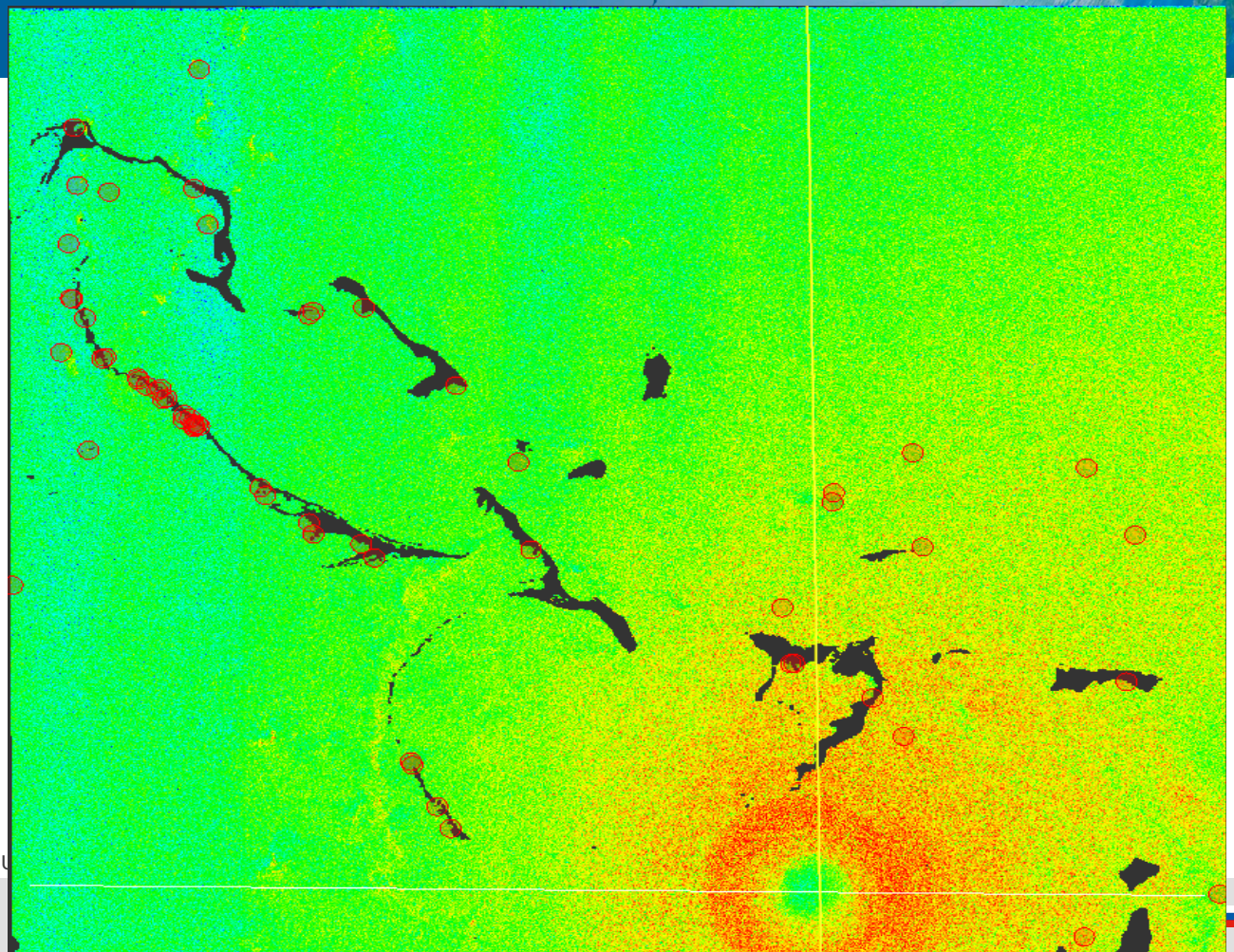
TerraSAR-X StripMap VV 1.25m Pixel, X-band

Principle
wind and sea state estimation



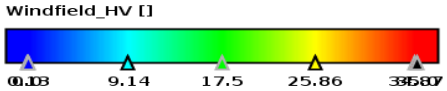

20kmx20km
In 2017 several SAR images of hurricane acquired by ESA‘s project SHOC
Dominican Republic
2017-09-07 10:30
SENTINEL-1 VV
Hurrican e Irma from SAR

Windfield from RADARSAT-2, IRMA

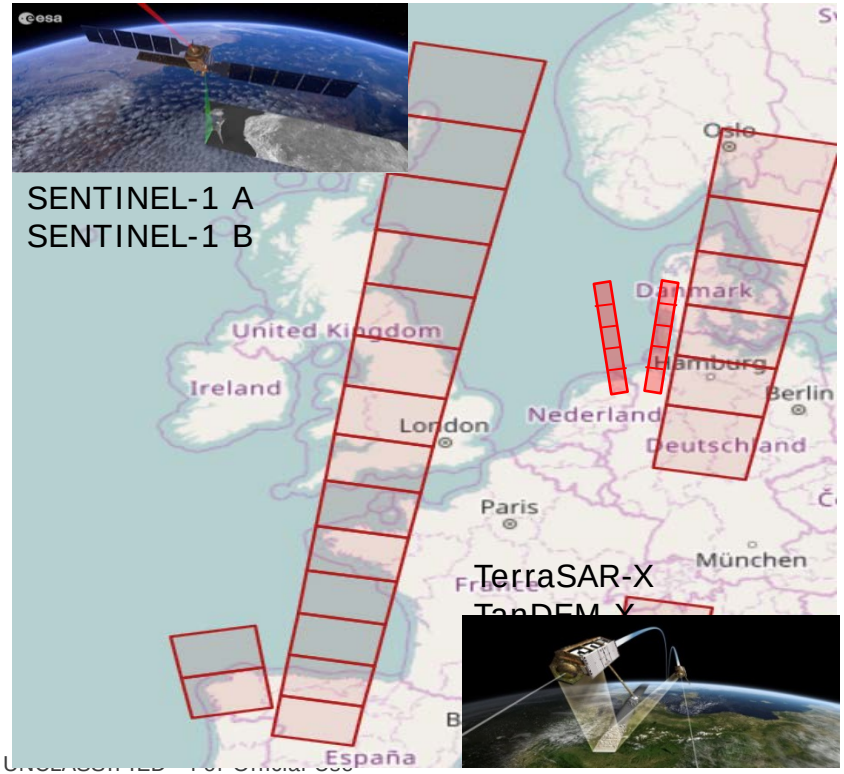


8 Sep 2017
10 53 UTC
HV, ground range
R2 © MDA

Dots SNAP result
ship detection

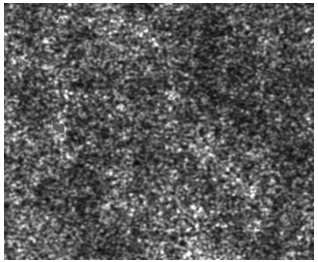


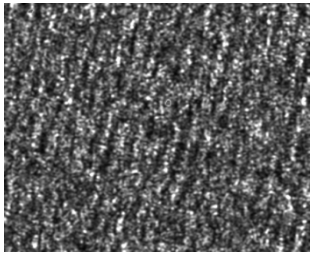
Different SAR Satellites, Radar Frequencies



Differences: resolution, bands, platform altitude, ground speed

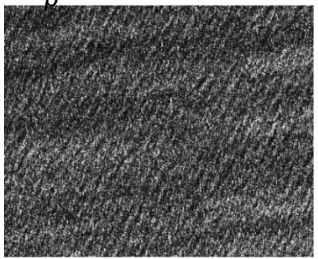
Sentinel-1 A/B IW 250km 10m pixel res.

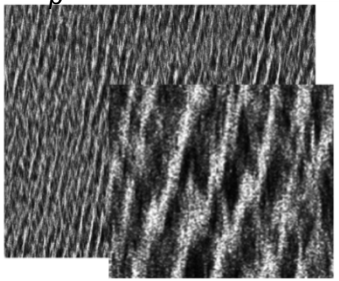




H_s~1.5m
L_p~ 80m

H_s~3.5m
L_p~250m





TerraSAR-X StripMap 30km 1.2m pixel res.

Fig. 14: Sea surface imaging by SAR: different sensors and coverage

Example SENTINEL S1 VALIDATION Measurements

EAST ATLANTICS & North Sea ~300 IMAGES ~ ~40 buoys **~900 collocations**

USA EAST COAST ~300 IMAGES ~ 15 buoys ~**400 collocations**

USA HAWAI 49 IMAGES 4 buoys ~**60 collocations**