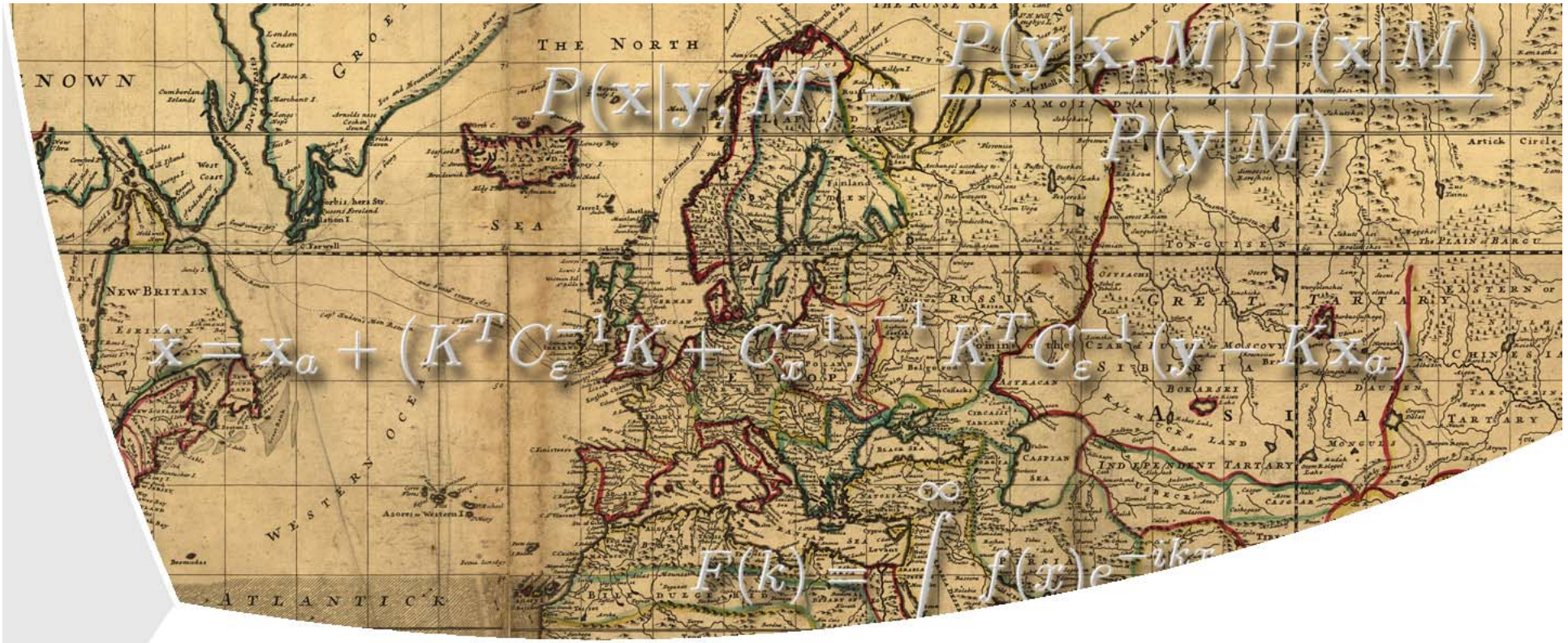

Ocean Surface Wind and Wave Retrieval Using C-and X-Band SAR

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Remote Sensing Technology Institute
German Aerospace Center (DLR), Oberpfaffenhofen

DLR Deutsches Zentrum für Luft- und Raumfahrt e.V.
in der Helmholtz-Gemeinschaft

Outline

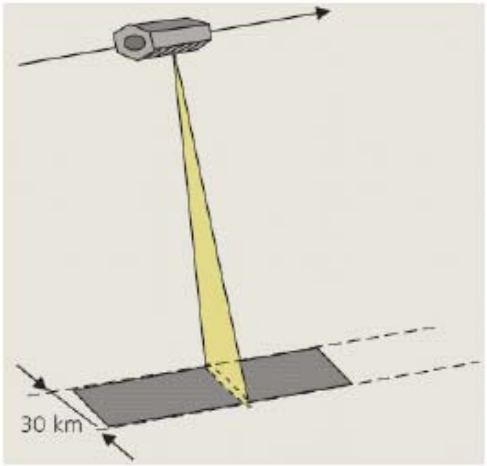
- XMOD parameters tuning
- NRCS simulation with XMOD
- Wind field retrieval with VV polarization TerraSAR-X data
- Wind field retrieval with HH polarization TerraSAR-X data
- Conclusion

TerraSAR-X

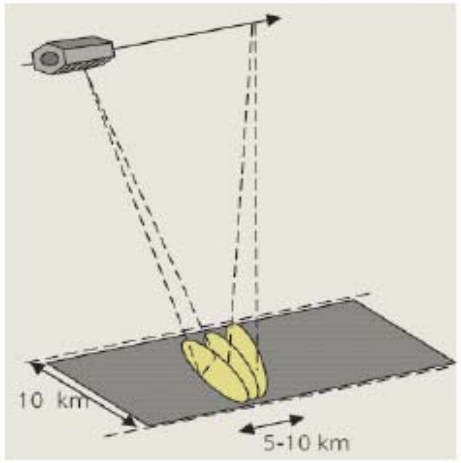
TerraSAR-X is a sun synchron satellite with a right side looking X-band synthetic aperture radar (SAR)

Wavelength	Scene extension	Incidence angle	Polarization	Resolution
0.031m	10,30,100 km	20°-60°	Single/**Multi**	2m-16m

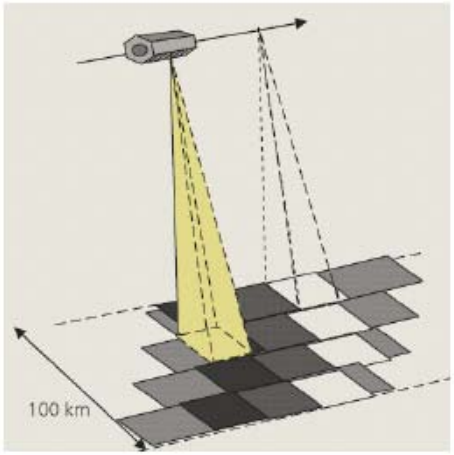
StripMap Mode



SpotLight Mode



ScanSAR Mode



Imaging geometry

Coastal wind field retrieval using SAR data X-Band

- CMOD -> XMOD

- Tuning data set:

SIR-C/X campaigns in April/October, 1994:

Spaceborne Imaging Radar-C/X-Band Synthetic Aperture Radar (SIR-C/X-SAR) flew on space shuttle Endeavour on mission STS-59 April 9-20, 1994. The instrument was scheduled for a second flight on shuttle mission STS-68 in October 1994.

SIR-C/X-SAR is a joint project of the National Aeronautics and Space Administration (NASA), the German Space Agency (DLR) and the Italian Space Agency (ASI).

Geophysical model function: XMOD

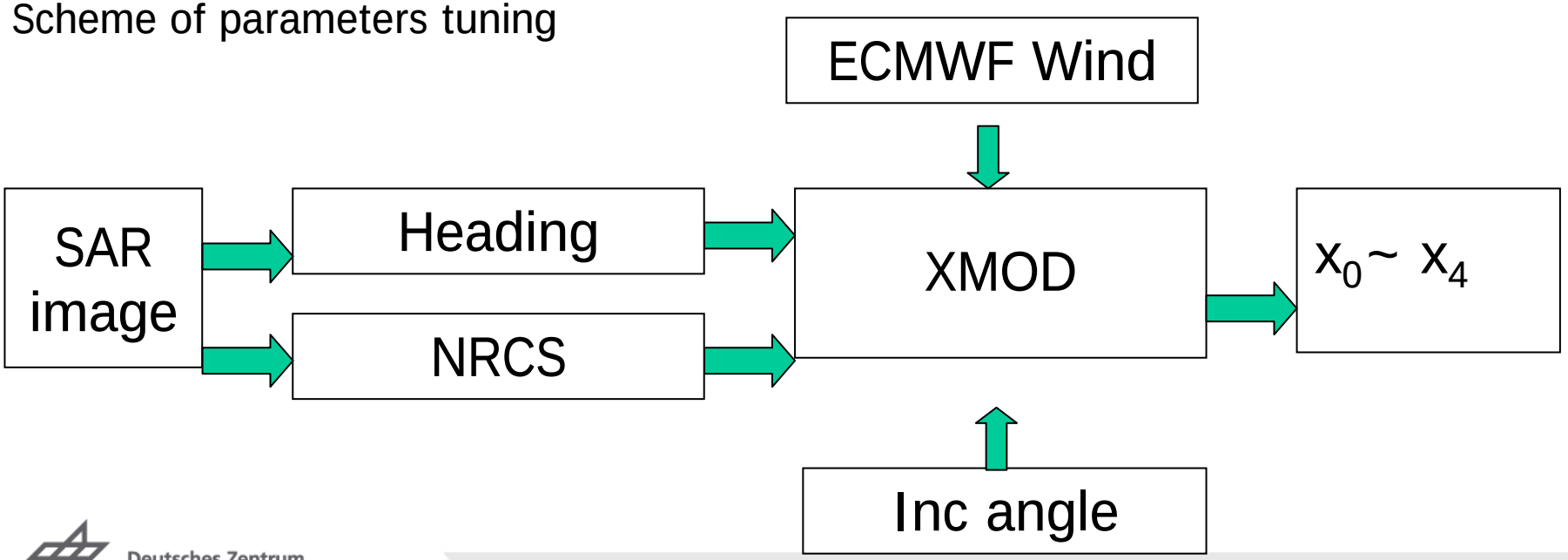
$$\sigma_0(U_{10},\theta,\varphi) = x_0 + x_1 U_{10} + x_2 \sin(\theta) + x_3 \cos(2\varphi) + x_4 U_{10} \cos(2\varphi)$$

U_{10} — wind speed

θ — incidence angle

φ — angle between wind direction and SAR look direction

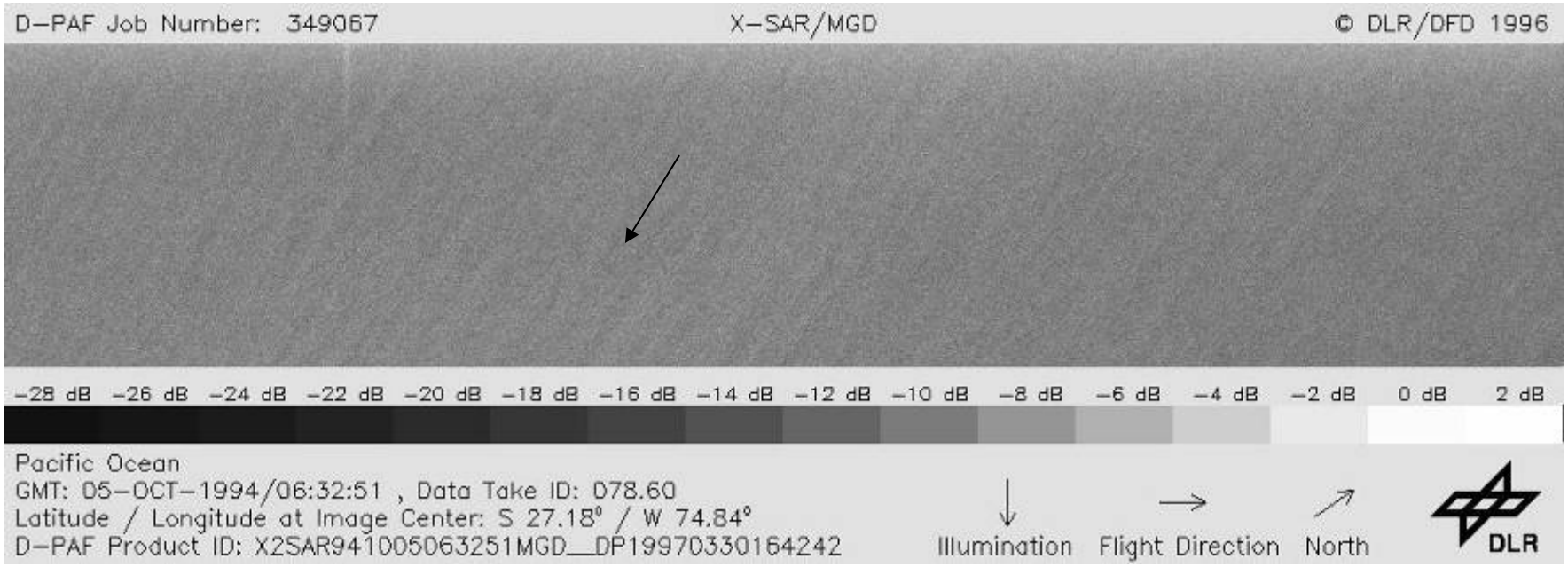
Scheme of parameters tuning



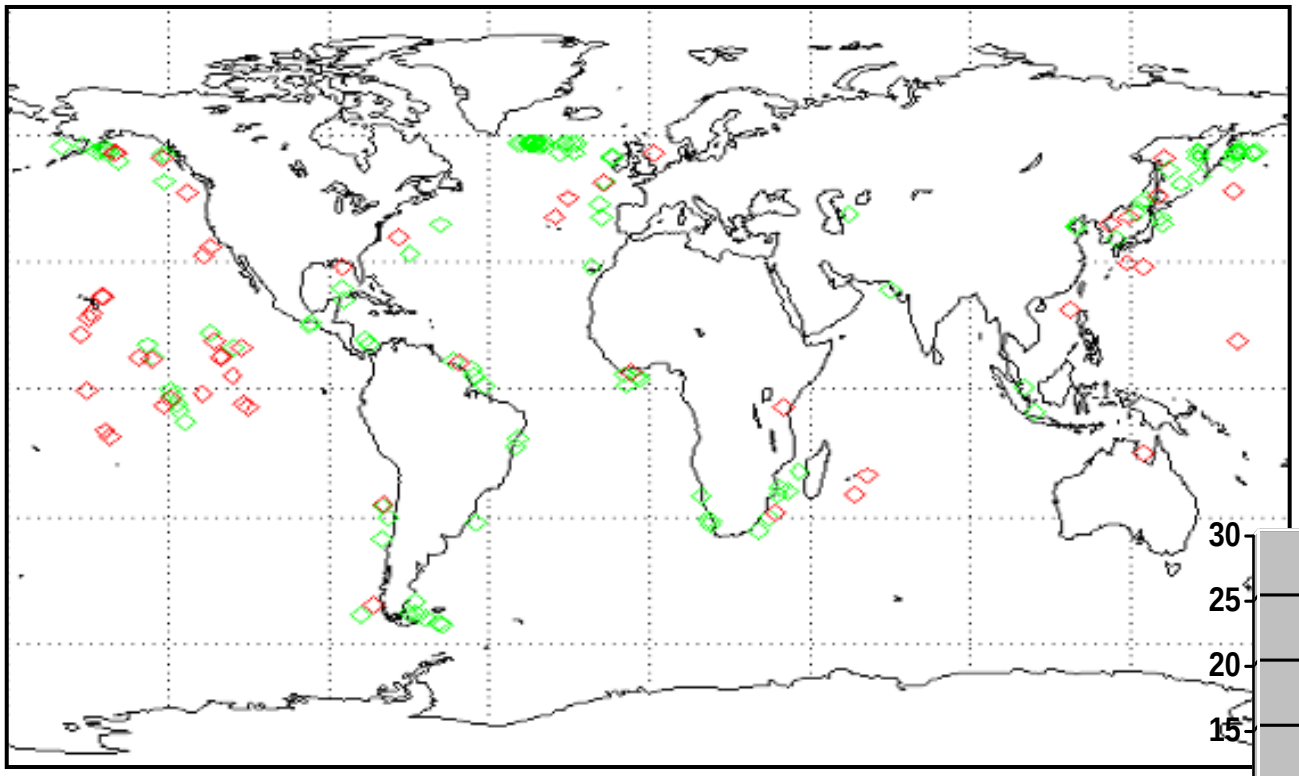
X-SAR Characteristics:

Wavelength	Scene extension	Incidence angle	Polarization	Resolution
0.031m	15-40 km	25°-60°	VV	30m

Printout of X-SAR Digital Quick Look from the Pacific Ocean

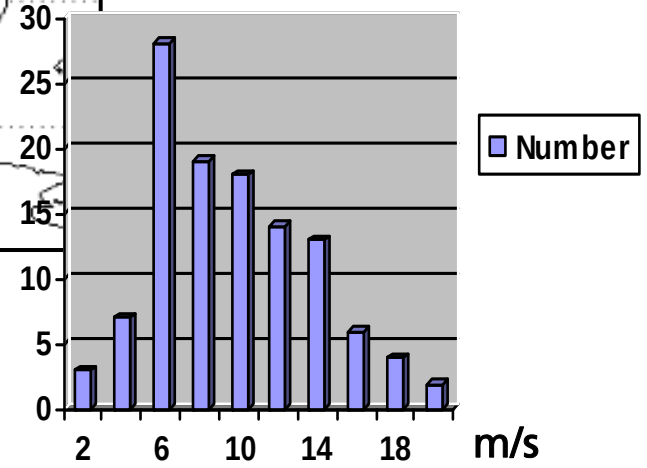


Locations of X-SAR Data Used:



Green: 114 data for parameters tuning

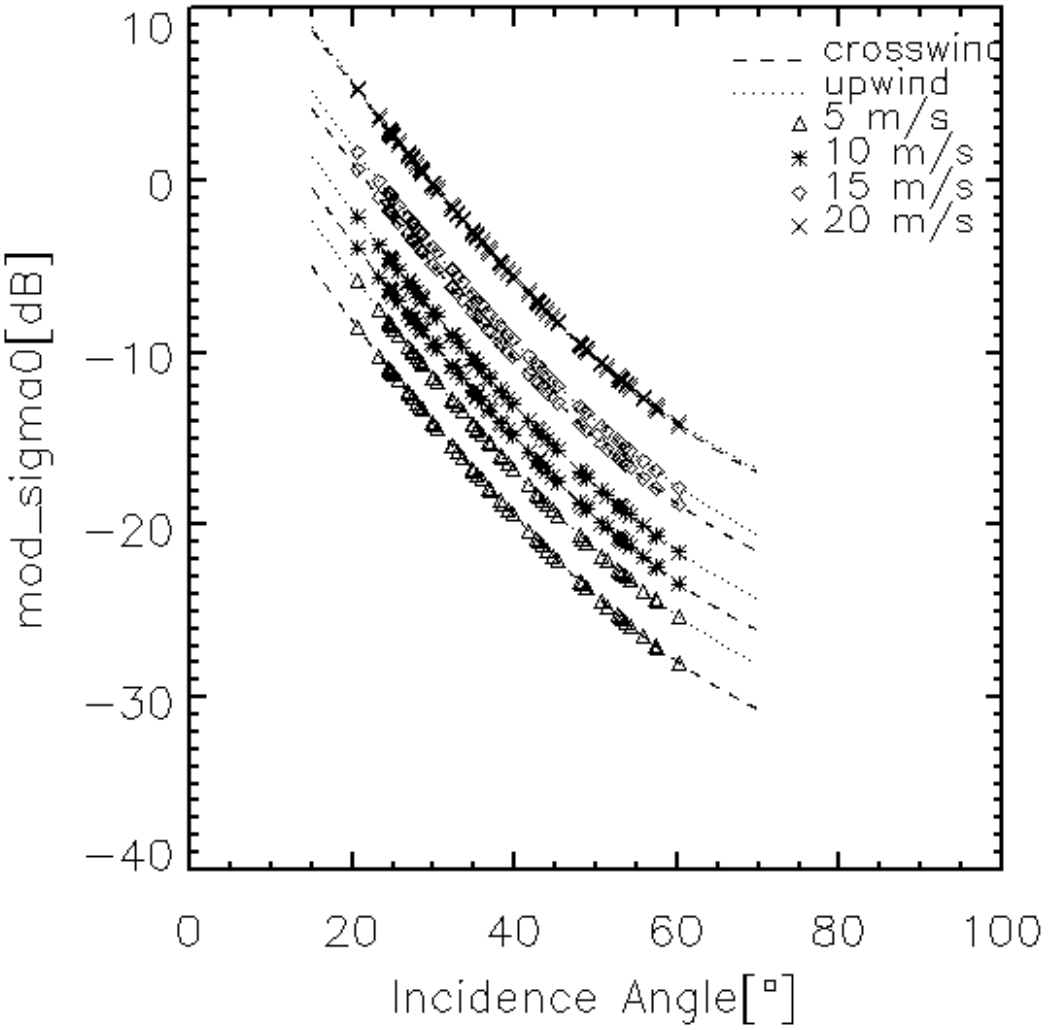
Red: 52 data for testing



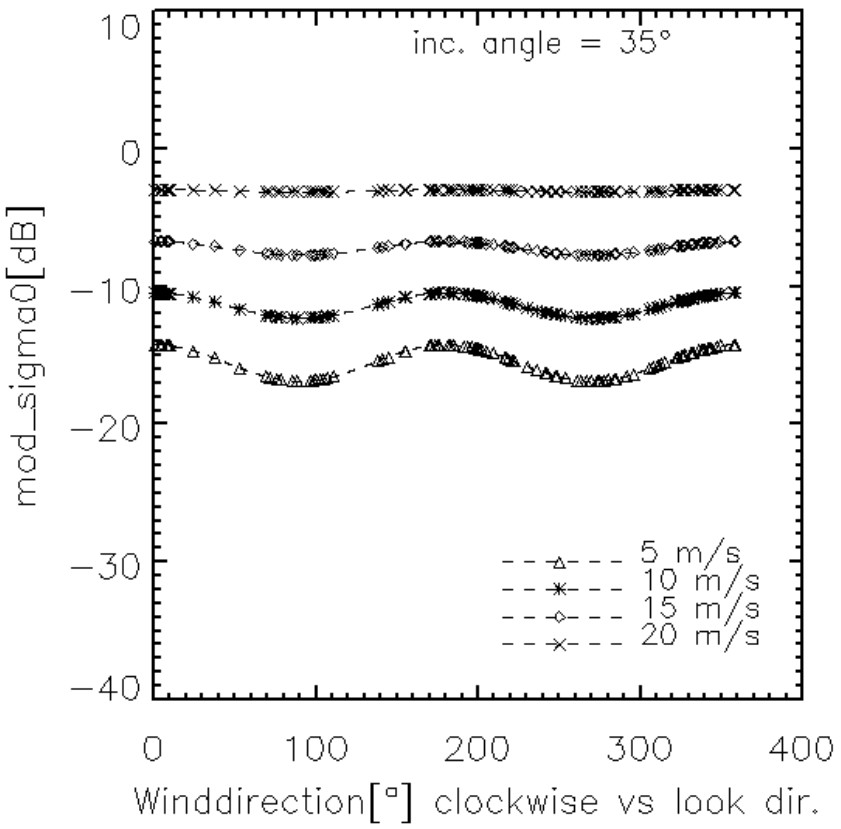
Histogram of different wind speeds for model tuning

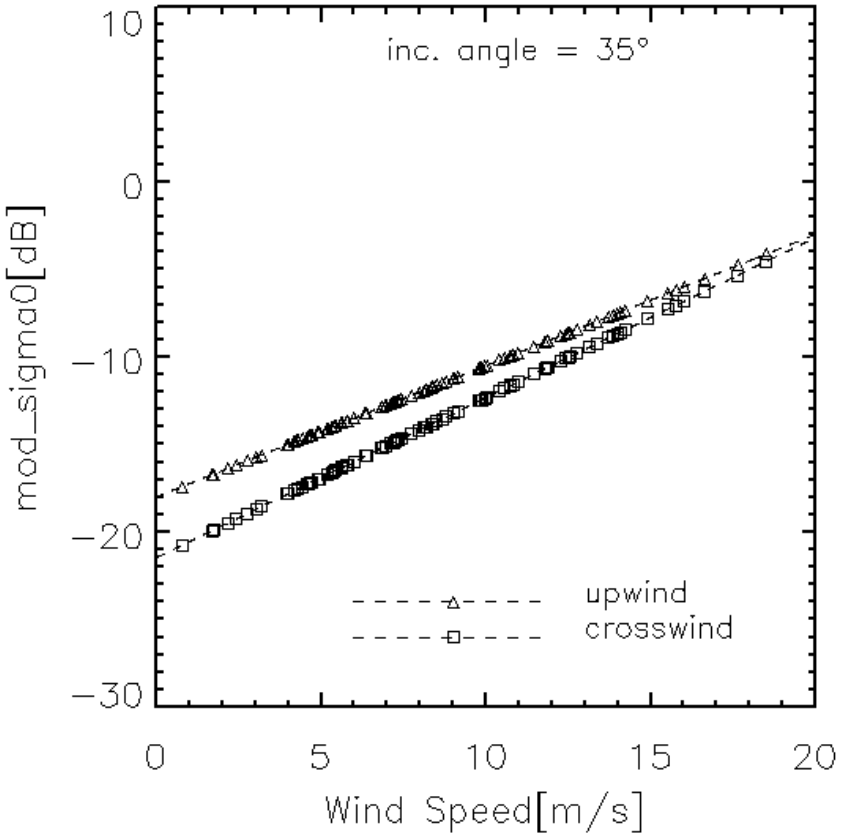
Around 90% of TSX incidence angle range covered

XMOD NRCS depending on incidence angle, wind direction and wind speed

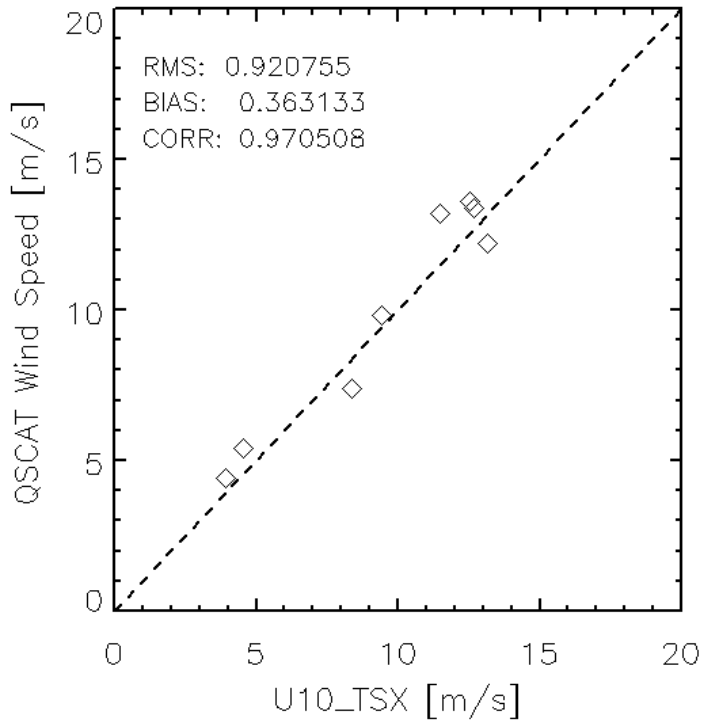


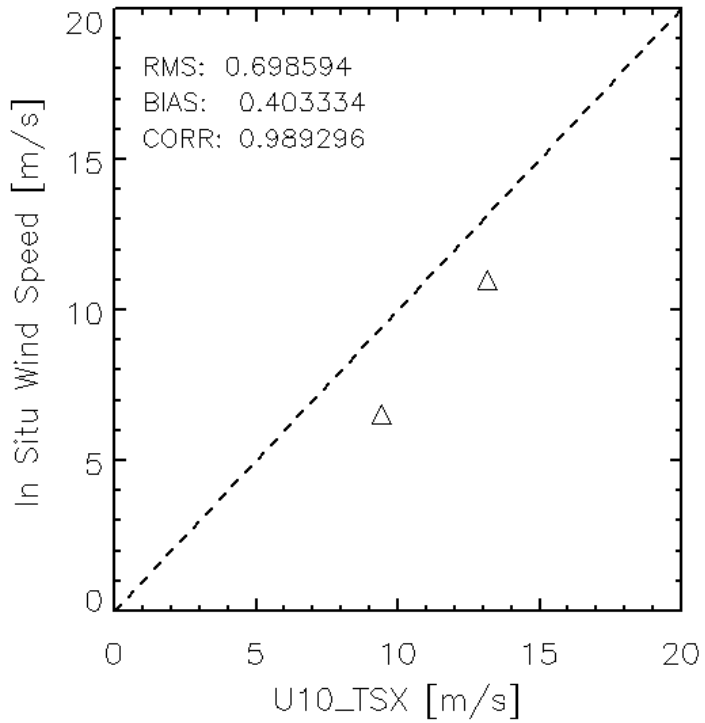
XMOD NRCS depending on incidence angle, wind direction and wind speed



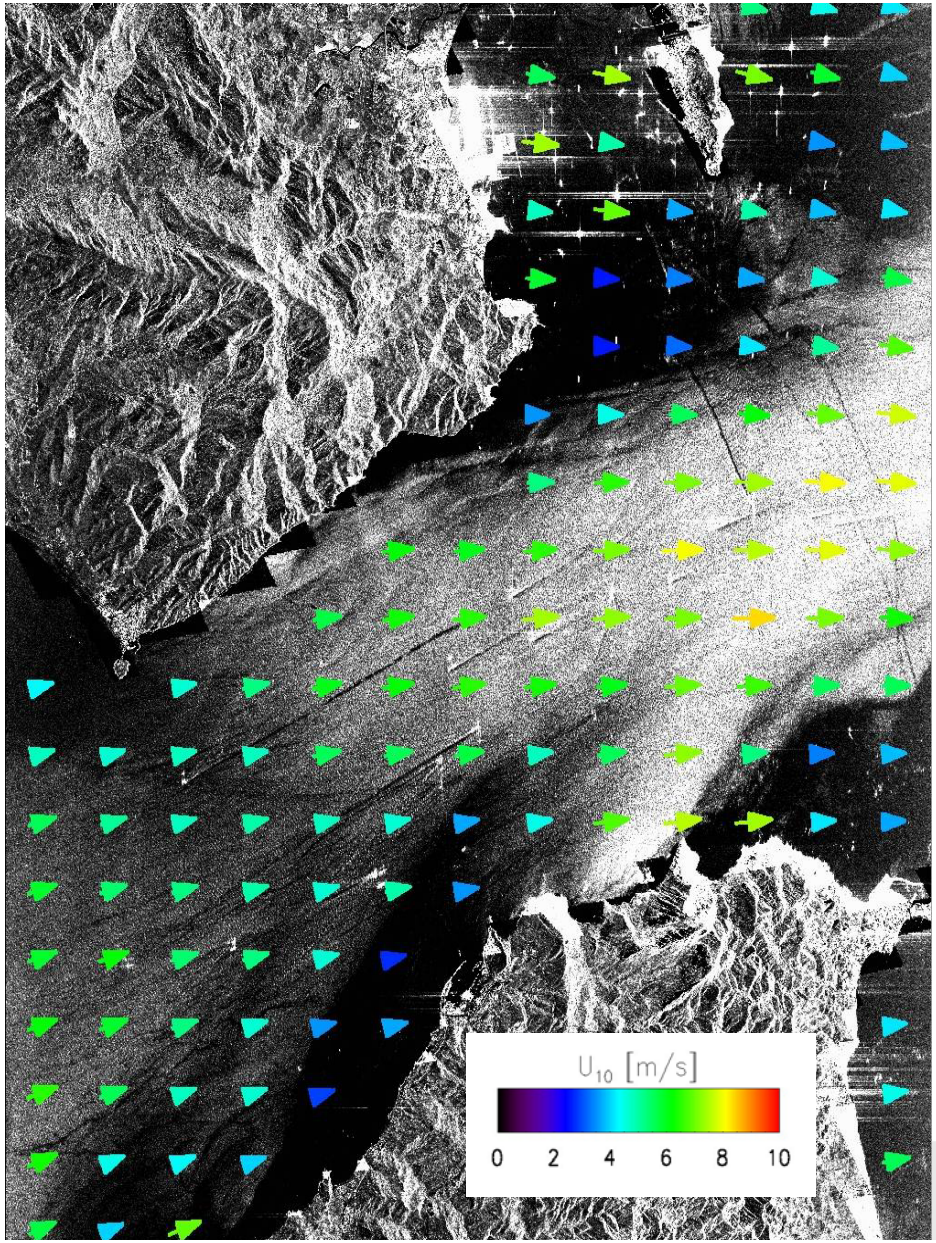


Comparison of XMOD1.2 wind speed to QSCAT and In Situ ones





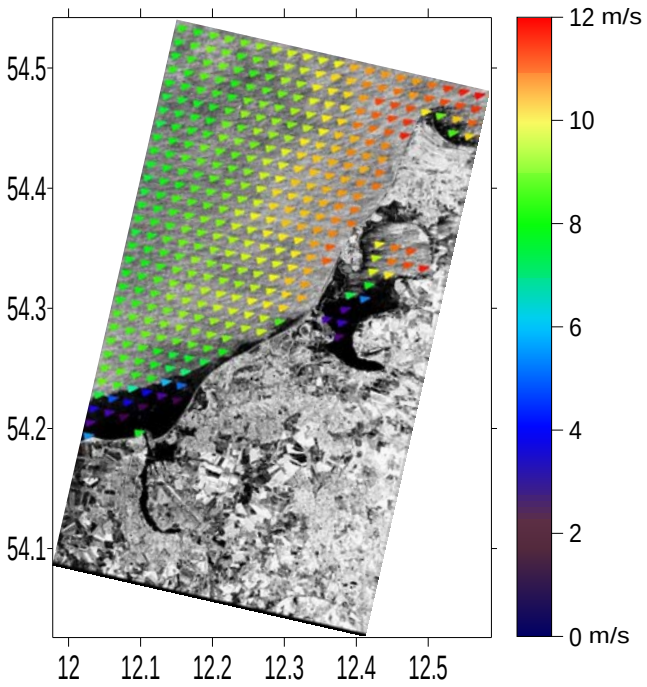
Coastal wind field retrieval using SAR data X-Band

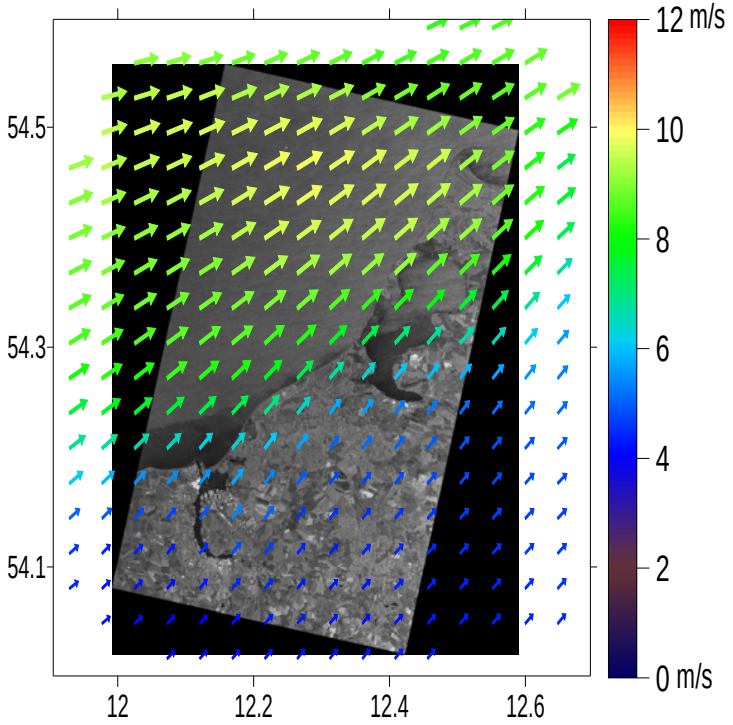


TerraSAR-X Stripmap mode scene acquired on July 9, 2007 at 06:29 UTC

XMOD Implementation on TerraSAR-X

Wind speed from VV Stripmap TerraSAR-X image

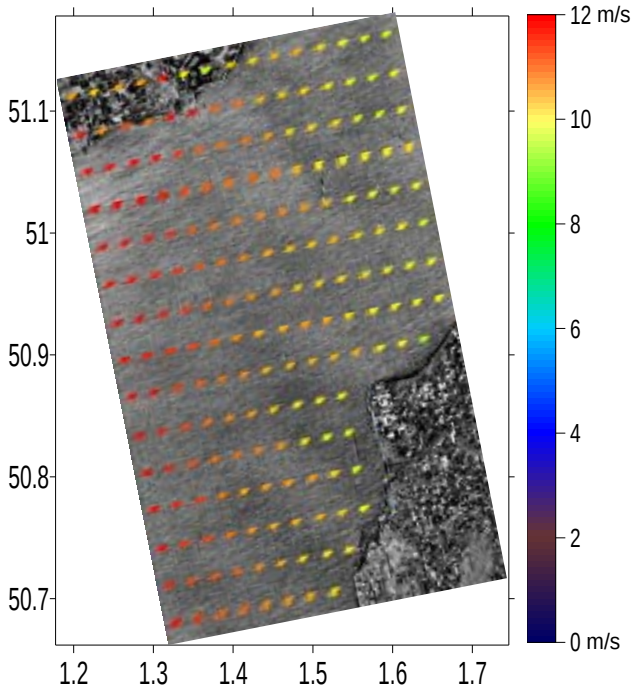




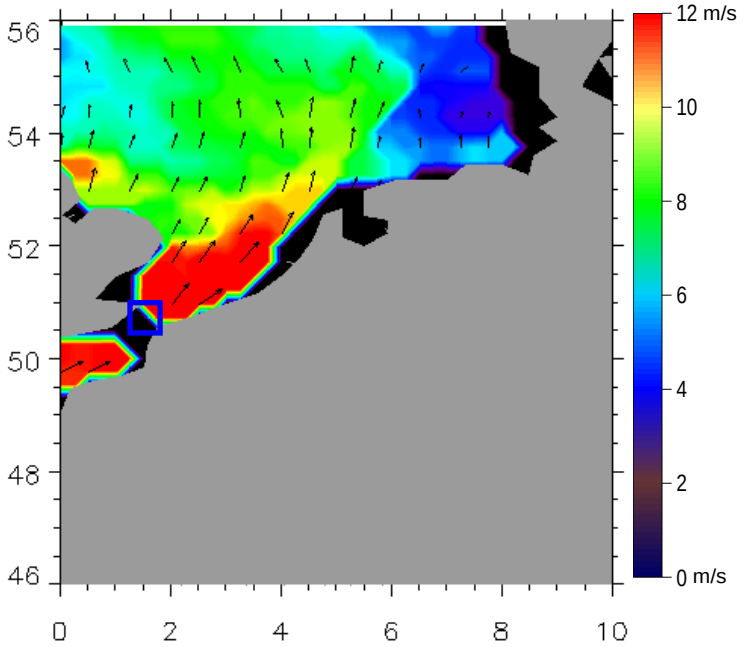
July 23 , 2007 at 05:33 UTC
over the Baltic sea

HIRLAM Model Forecast,
July, 23 2007 at 6:00 UTC

Wind speed retrieved by VV polarization stripmap TerraSAR-X data

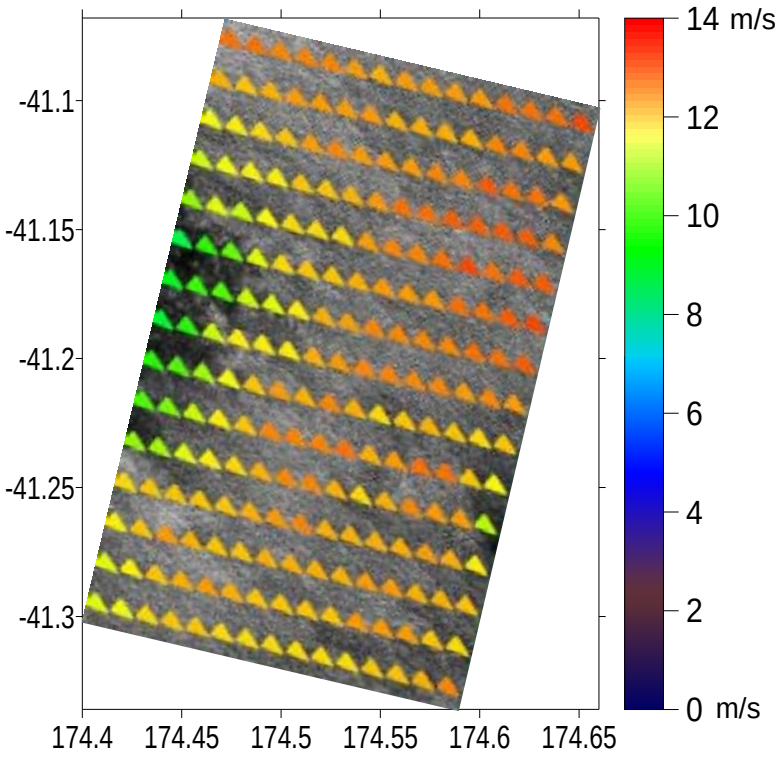


Jul. 2, 2007 at 17:35 UTC
over English Channel

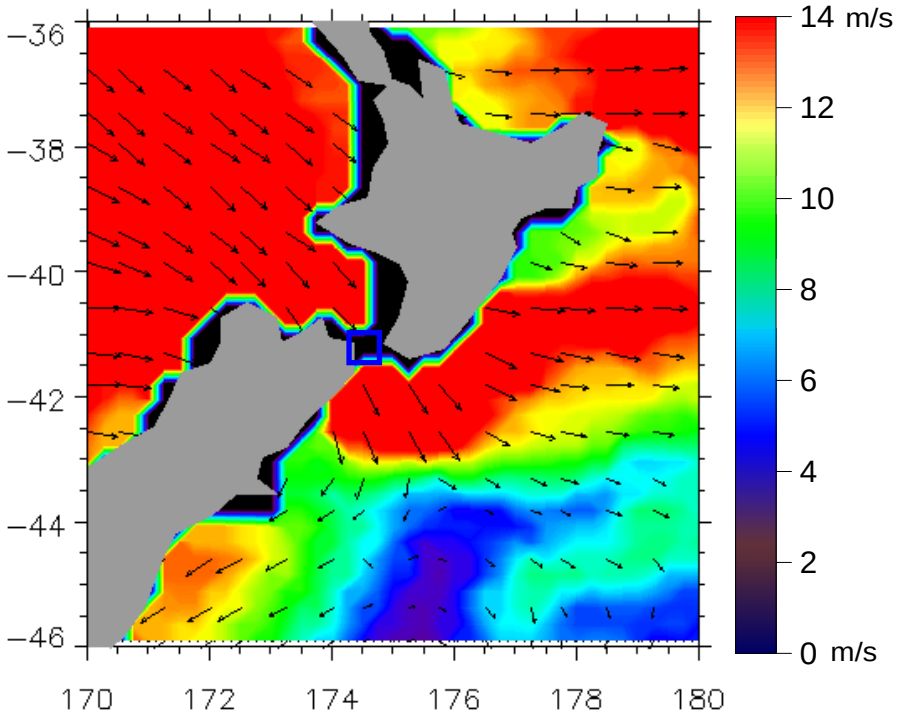


QSCAT , Jul. 2, 2007 at
19:30 UTC

Wind speed retrieved by VV polarization stripmap TerraSAR-X data

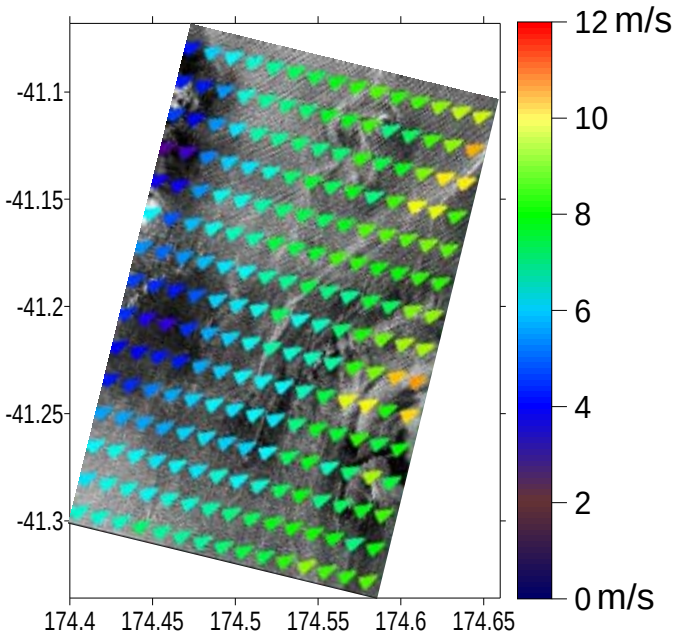


Aug. 14, 2008 at
17:45 UTC,Cook strait

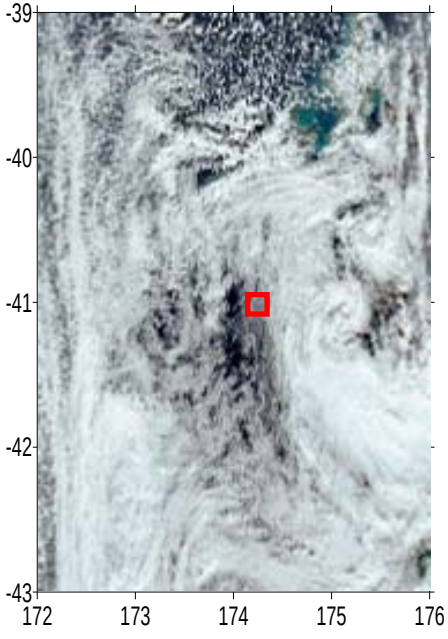


QSCAT , Aug. 14,
2008 at 18:30 UTC

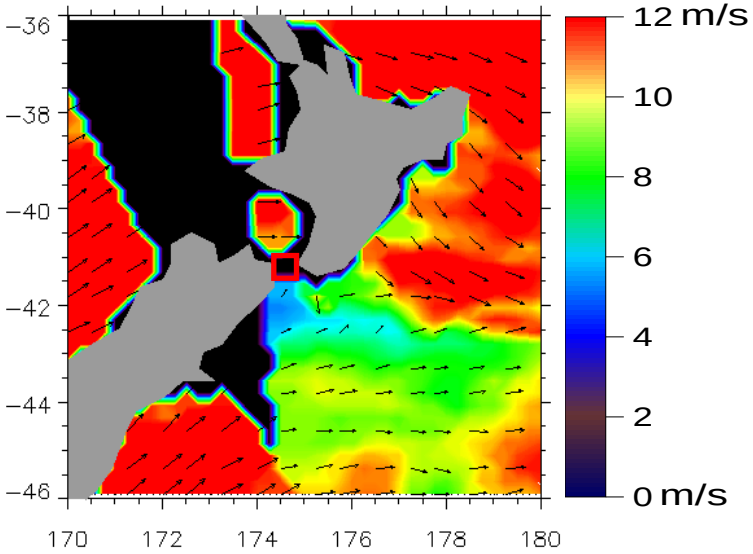
Wind speed retrieved by VV polarization stripmap TerraSAR-X data



Aug. 3, 2008 at 17:45 UTC over Cook Strait

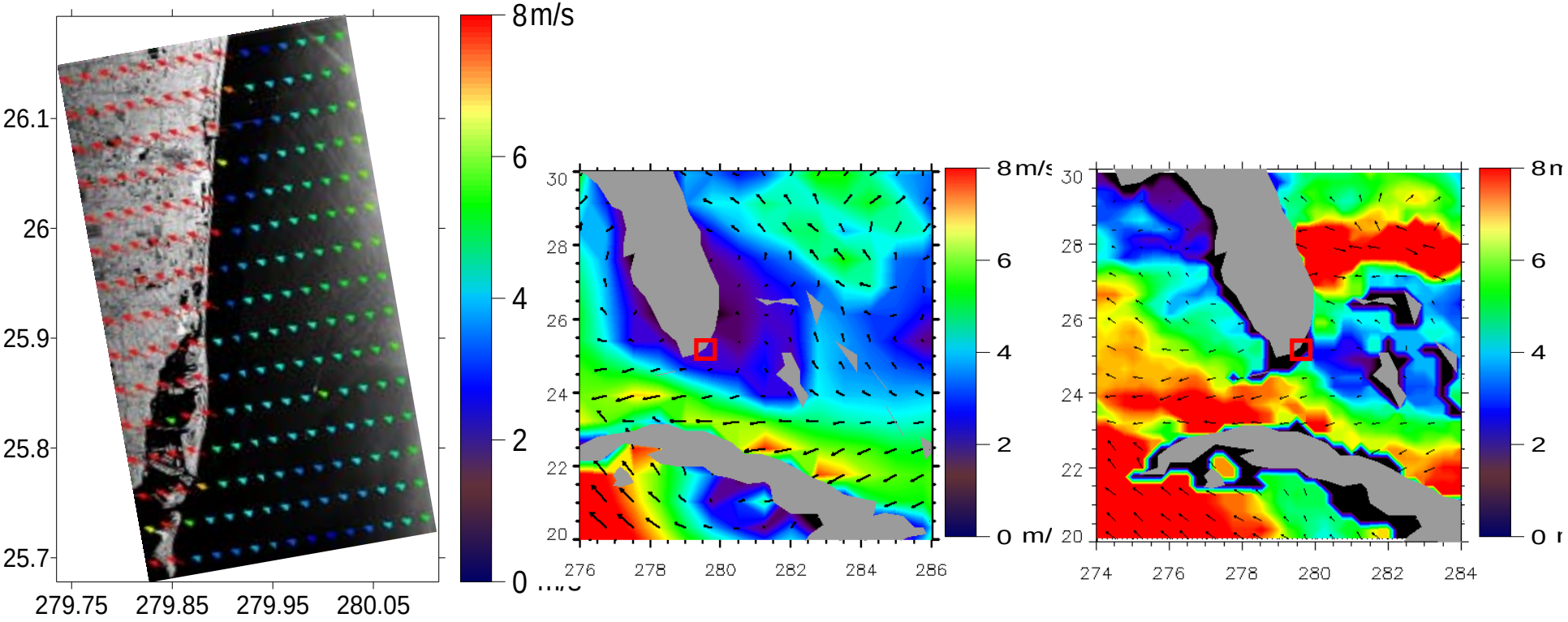


Satellite cloud imagery from MODIS over Cook Strait acquired on Aug. 3, 2008



QSCAT , Aug. 3, 2008 at 18:12

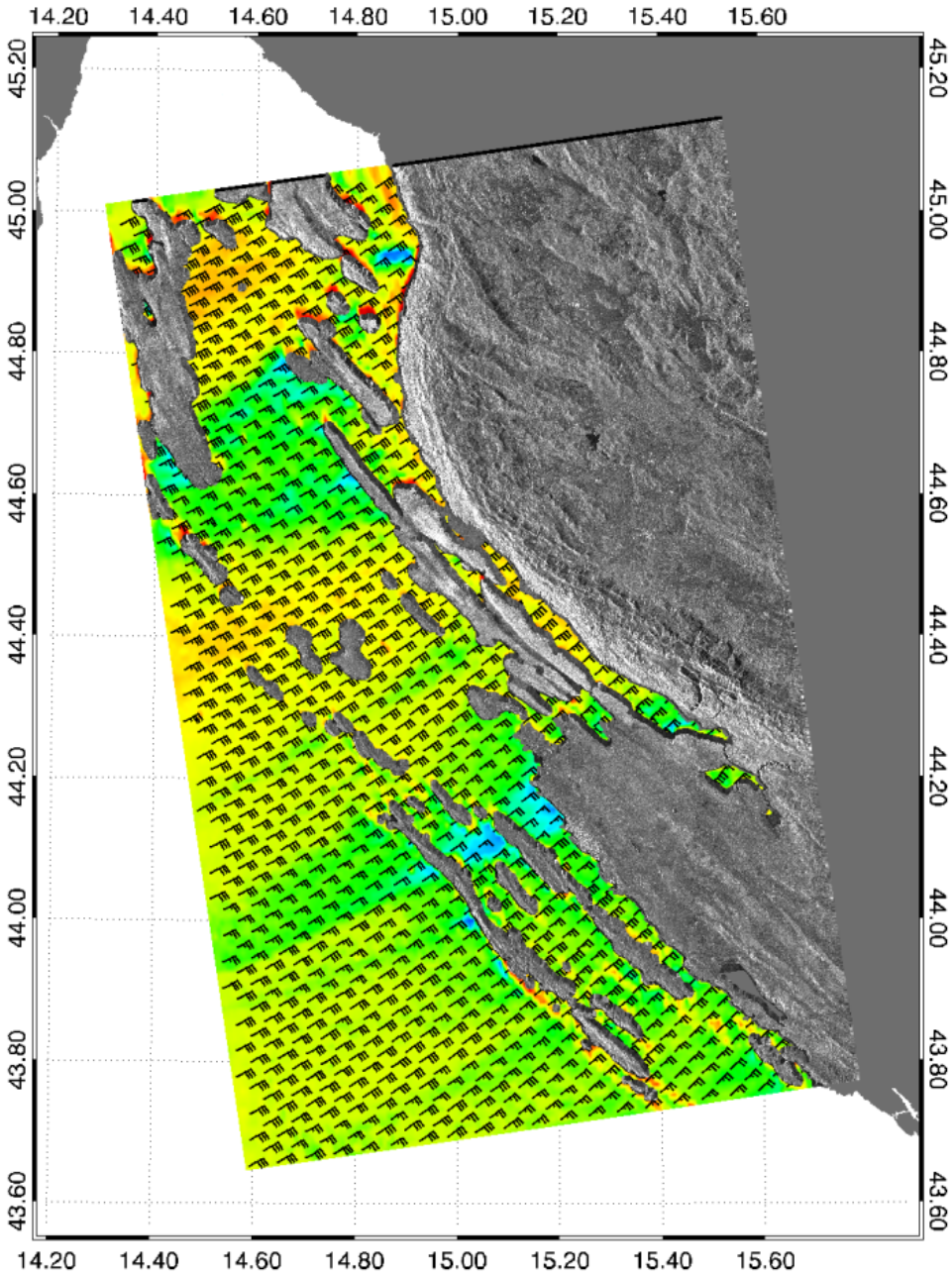
Wind speed retrieved by VV polarization stripmap TerraSAR-X data



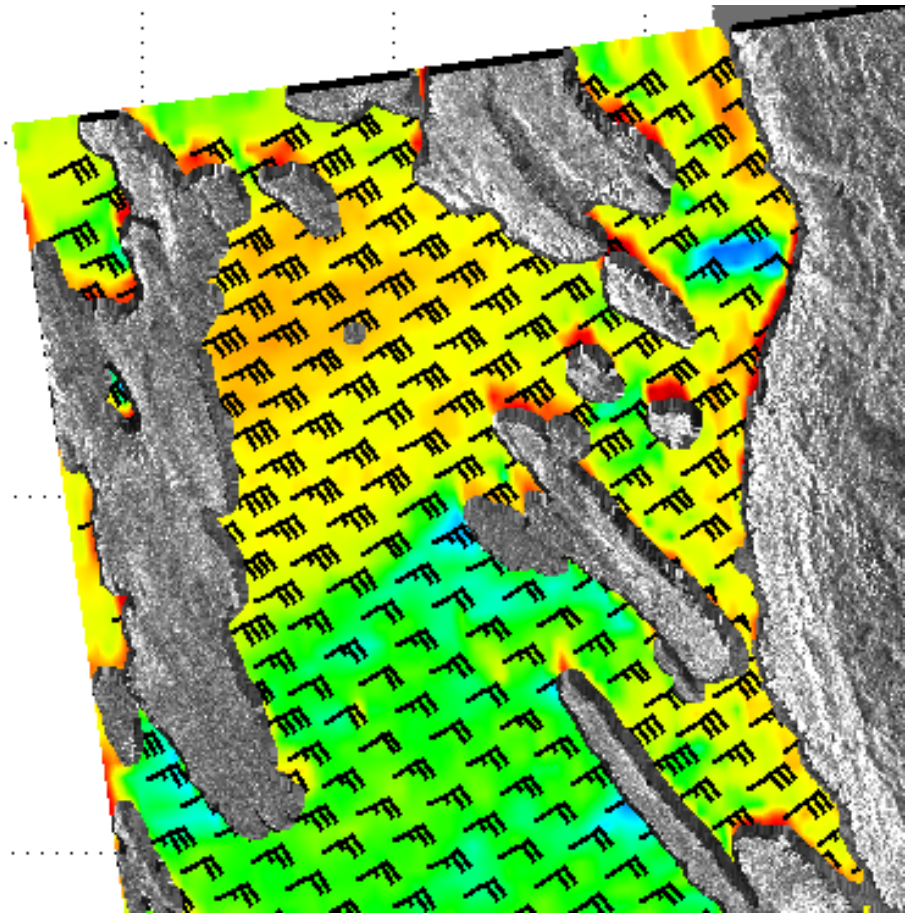
on May 23, 2008 at 23:21 UTC over Miami

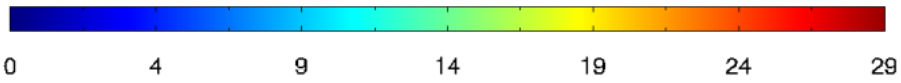
DWD Model, May 24, 2008 at 00:00 UTC

QSCAT , May 24, 2008 at 23:42 UTC



9 March 2010, TSX-1 ScanSAR





Coastal wind field retrieval using SAR data X-Band HH Polarisation

Model : Polarization ratio from Thompson

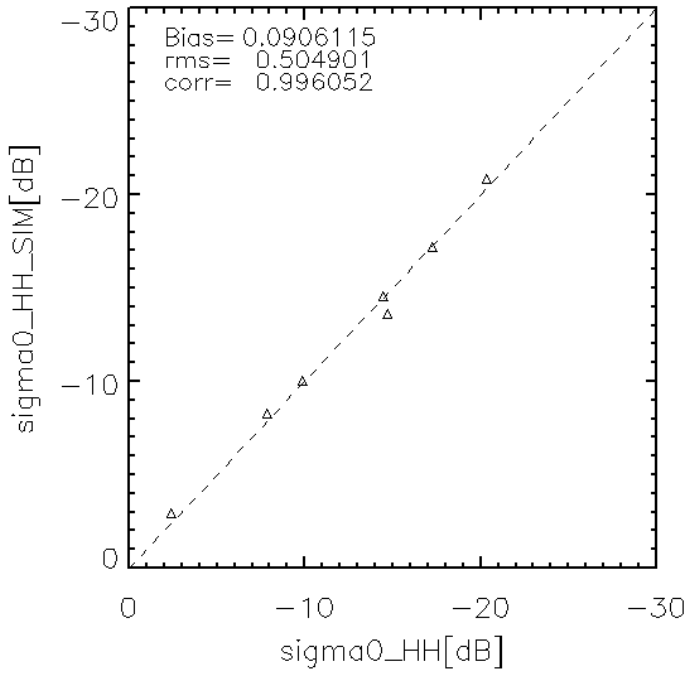
TerraSAR Dual-pol ⟹ $$P(\theta) = \frac{\sigma_0^{VV}}{\sigma_0^{HH}} = \frac{(1+\alpha\tan^2\theta)^2}{(1+2\tan^2\theta)^2}$$ ⟹ **α =1.73**

Polarisation ratio from Mouche:

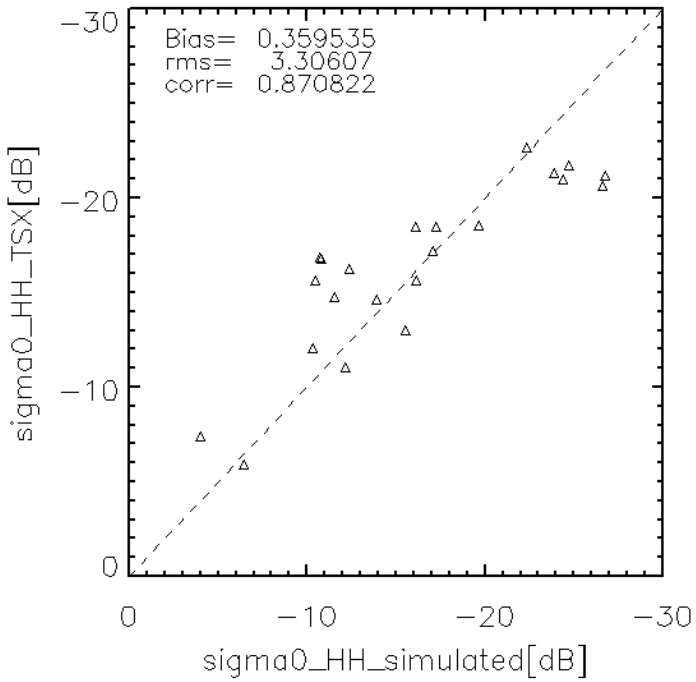
TerraSAR Dual-pol ⟹ $$P(\theta) = \frac{\sigma_0^{VV}}{\sigma_0^{HH}} = A\exp(B\theta) + C$$ ⟹ **A=0.0248**
B=0.1057
C=1.43878

Model 1: Polarization ratio model from Thompson

$$P(\theta) = \frac{(1+\alpha\tan^2\theta)^2}{(1+2\tan^2\theta)^2}$$



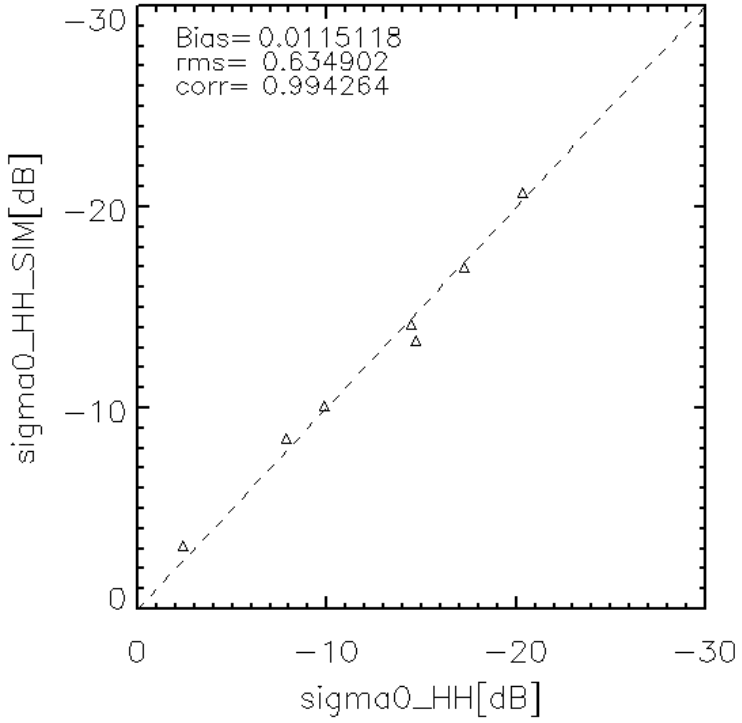
Model 1-1 turned by Dual-Polarization mode



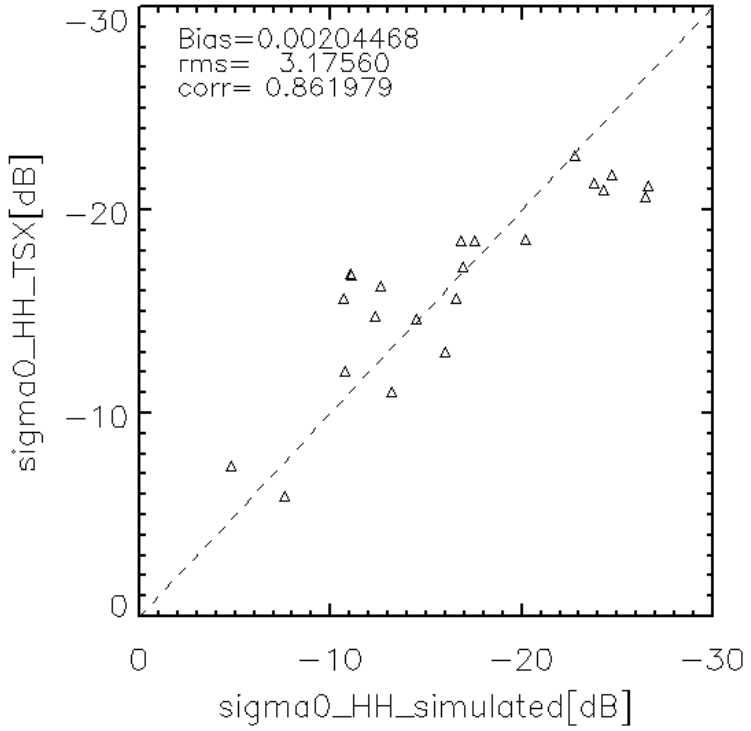
Model 1-2 turned by HH single Polarization mode

Model 2: Polarization ratio from Mouche

$$\mathrm{P}(\theta) = \mathrm{A}\exp(\mathrm{B}\theta) + C$$

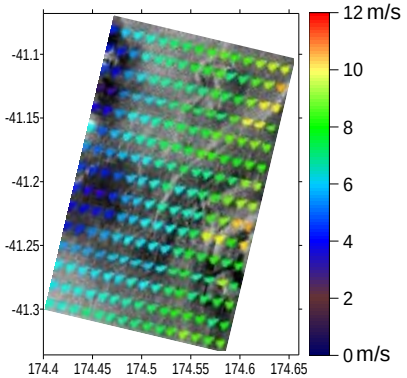


Model 2-1 turned by Dual-Polarization mode

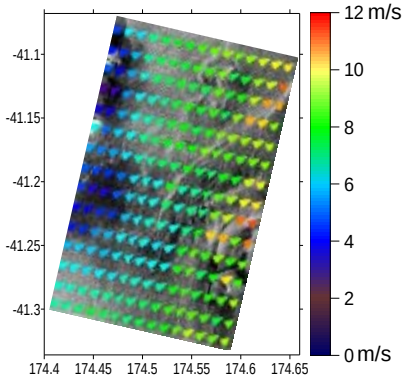


Model 2-2 turned by HH single Polarization mode

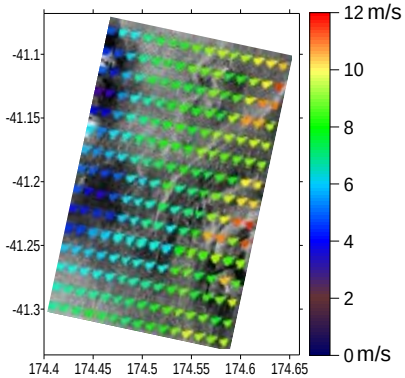
Wind fields retrieved with polarization ratio models



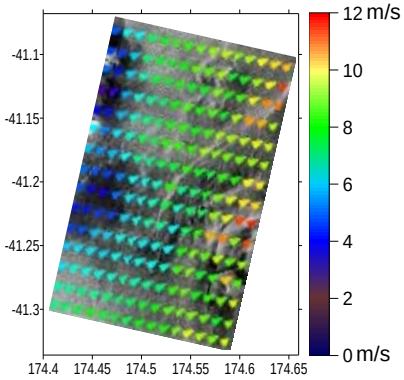
1) VV



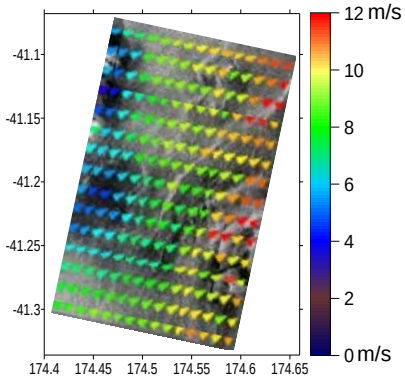
2) HH, Model 1-1



3) HH, Model 2-1



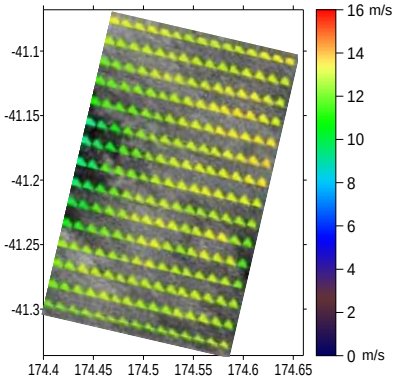
4) HH, Model 1-2



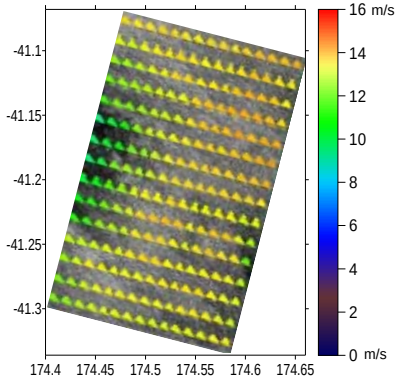
5) HH, Model 2-2

Wind speed from VV and HH polarization TerraSAR-X data acquired on Aug 3, 2008 at 17:45 UTC over Cook Strait

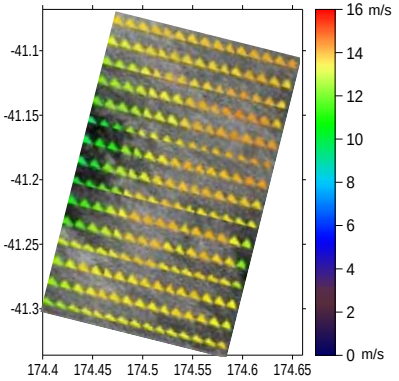
Wind fields retrieved with polarization ratio models



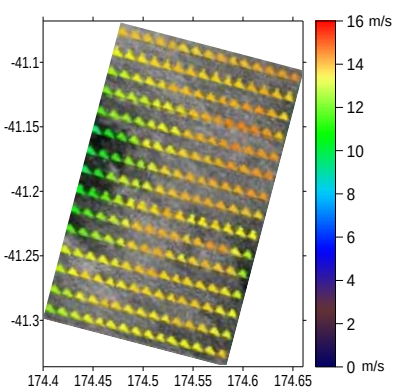
1) VV



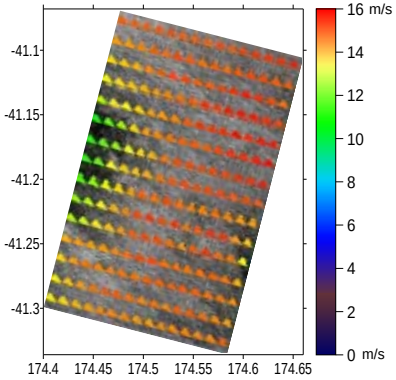
2) HH, Model 1-1



3) HH, Model 2-1



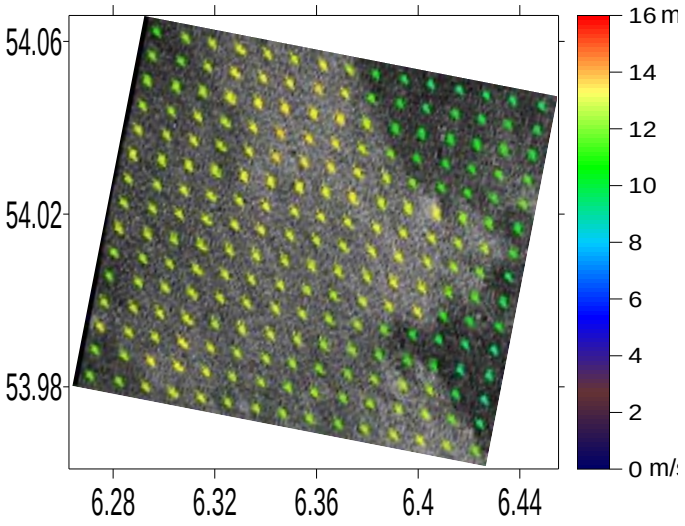
4) HH, Model 1-2

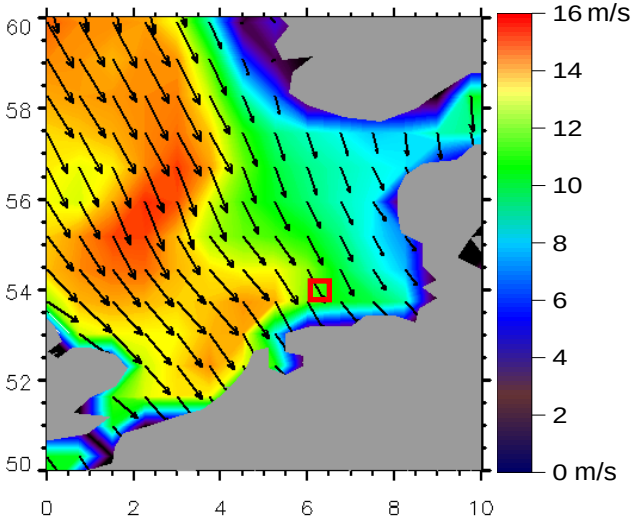


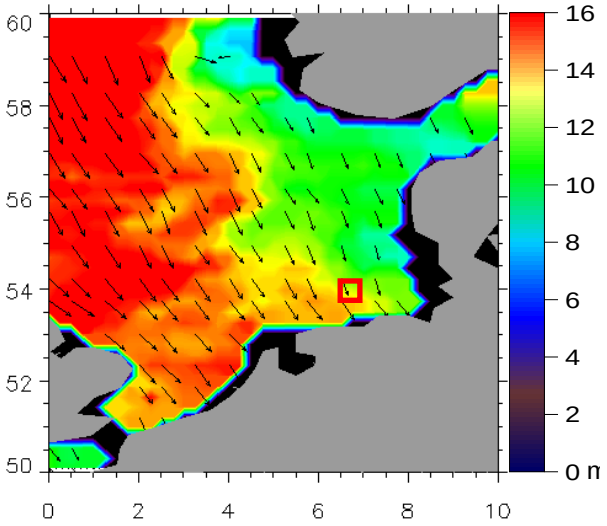
5) HH, Model 2-2

Wind speed from VV and HH polarization TerraSAR-X data acquired on Aug14, 2008 at 17:45 UTC over Cook Strait

Wind speed retrieved by HH polarization spotlight TerraSAR-X data





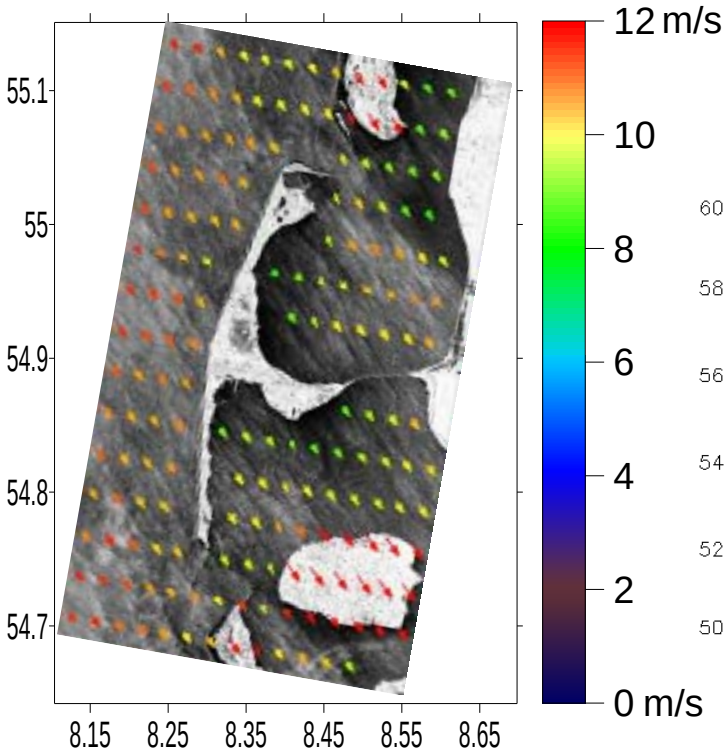


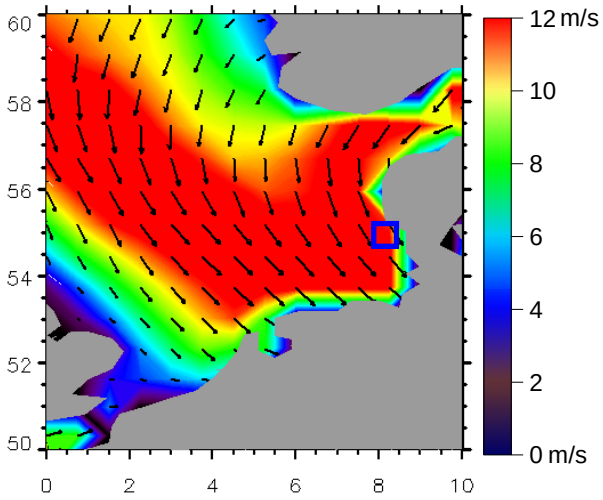
Mar. 25, 2008 at 05:59 UTC over German North Sea

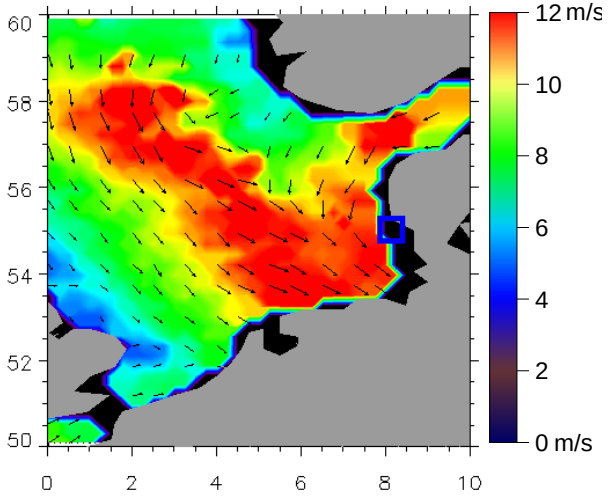
DWD Model, Mar. 25, 2008 at 06:00 UTC

QSCAT, Mar. 25, 2008 at 05:12 UTC

Wind speed retrieved by HH polarization stripmap TerraSAR-X data





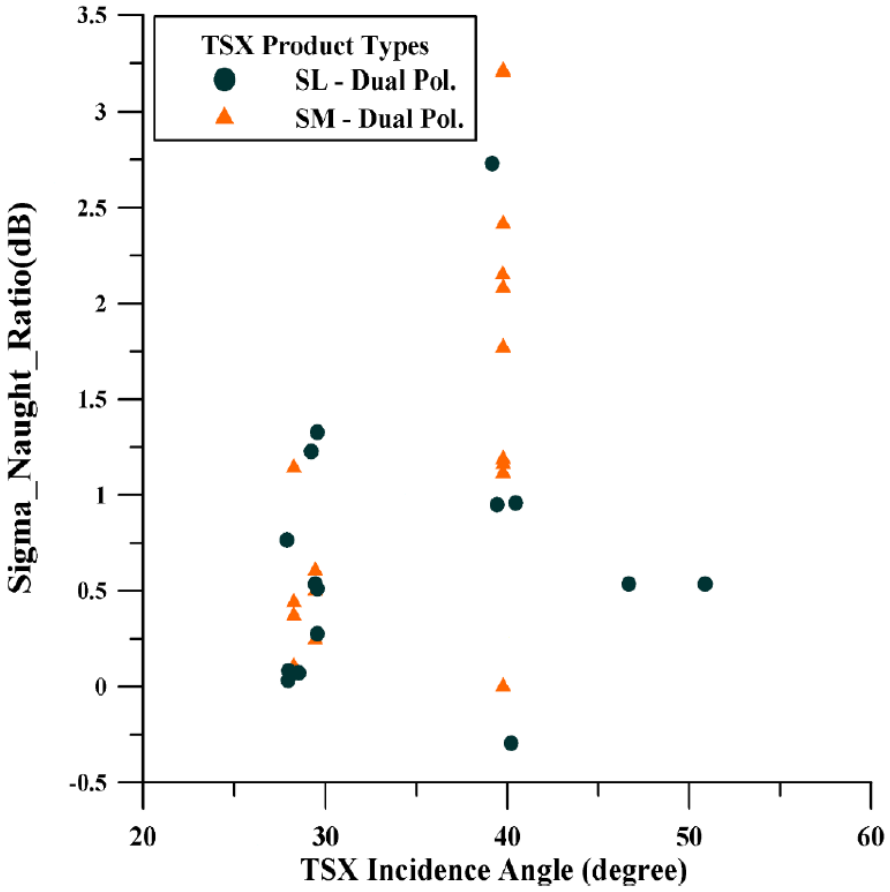


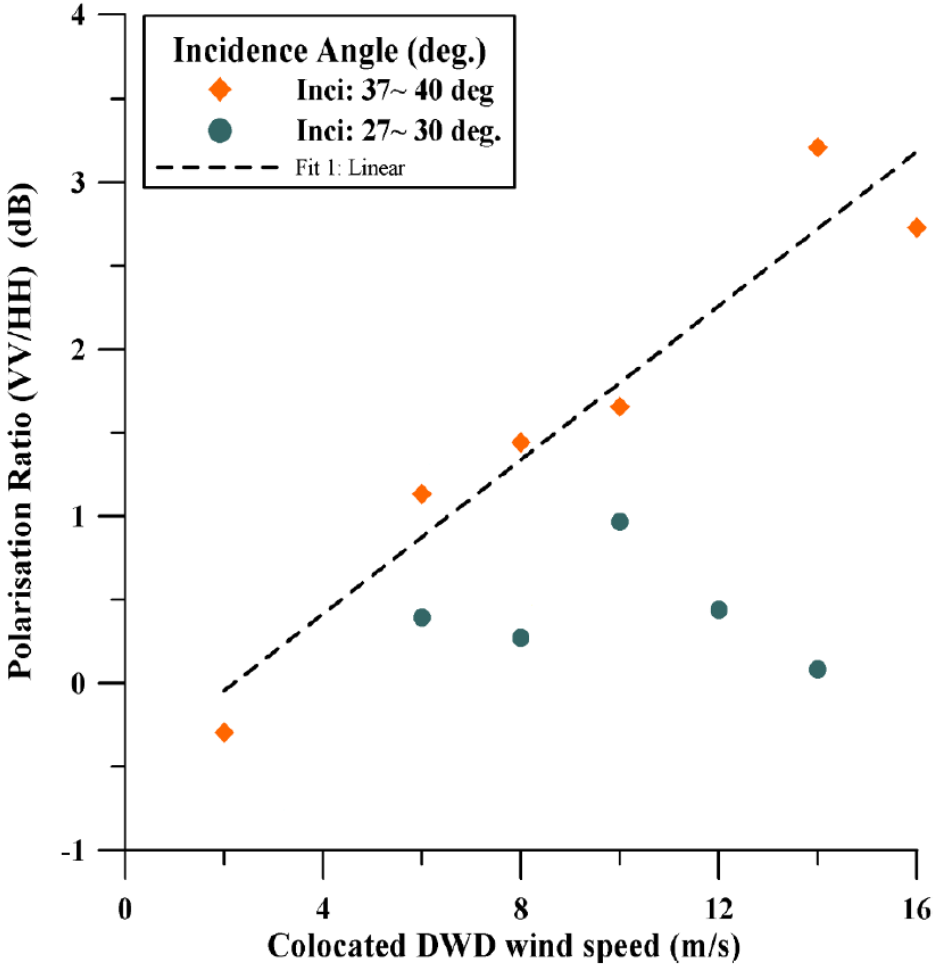
Mar. 26, 2008 at 05:41 UTC over Sylt Island

DWD Model, Mar. 26, 2008 at 06:00 UTC

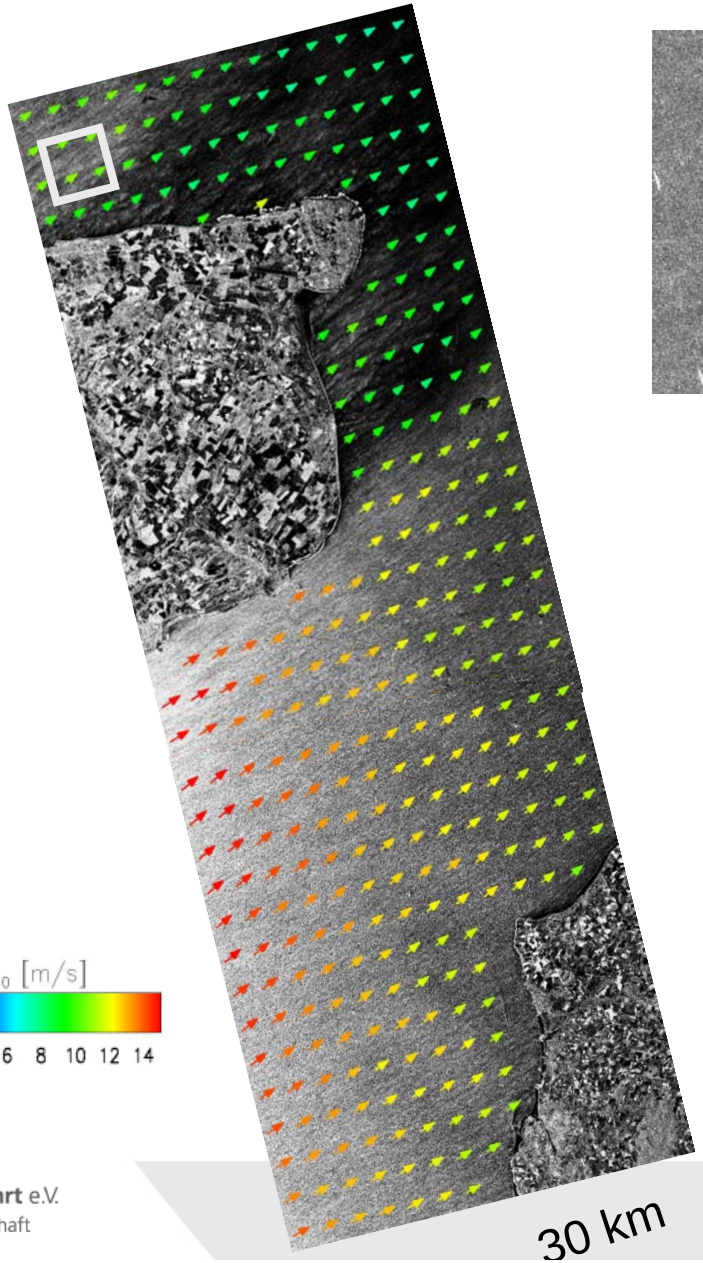
QSCAT, Mar. 26, 2008 at 04:48 UTC

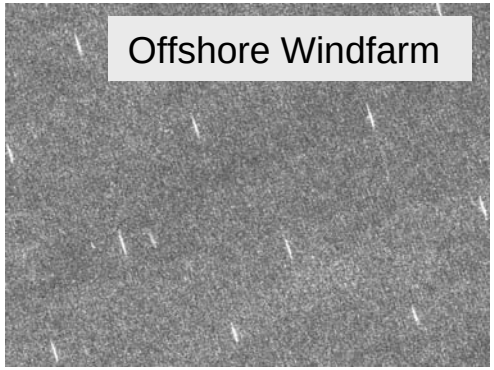
Polarization Ratio (VV/HH) Dependency on Incidence Angle and Wind Speed





Coastal wind field retrieval using SAR data X-Band HH Polarisation



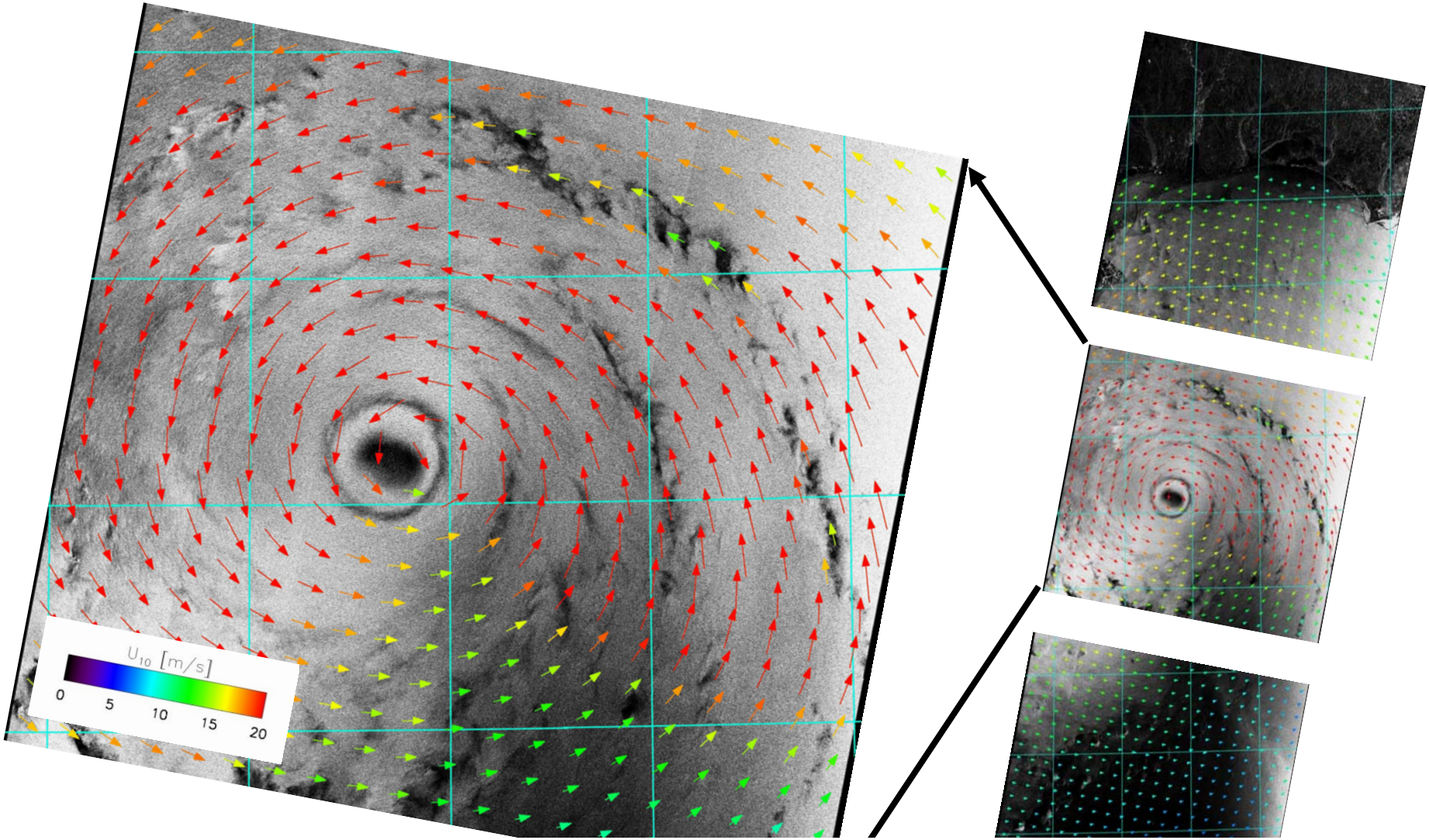


30 km x 100 km
TSX HH Stripmap
2. Juli , 2007,
7:35 UTC

Conclusion

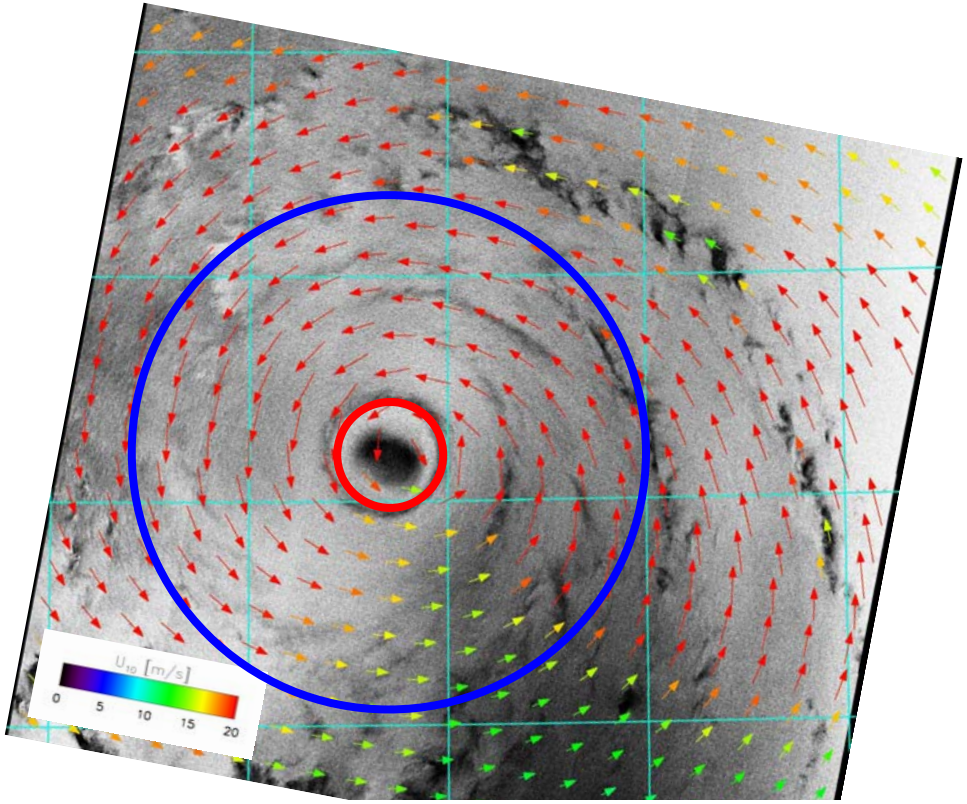
- An X-Band GMF (XMOD) was established for VV polarized data which for incidence angle of 20°~60° and wind speed in the range 2m/s~20 m/s can describe the relationship between X-band radar cross section, wind speed, wind direction and incidence angle accurately. The model is developed for X-SAR data and is valid for TerraSAR-X also.
- Retrieved wind fields from TerraSAR-X show meaningful results up to the coast reflecting local variations.
- For TerraSAR-X, XMOD was extended to HH polarized data by fitting the polarization ratio $\sigma_{VV} / \sigma_{HH}$
- The wind comparison of HH TerraSAR-X data with QSCAT shows encouraging results. For high incidence angles, the polarization ratio is wind speed dependant.
- Further cases have to be investigated in order to establish a trustable error estimate.

Wind field retrieval using SAR data



Three consecutive ASAR Wide Swath Images (right) acquired in the Gulf of Mexico on Aug. 28, 2005 at 15:50 UTC
Left: center scene (400x400km), „wind field“-resolution appr. 150m, pixelsize 75m

Wind field retrieval using SAR data



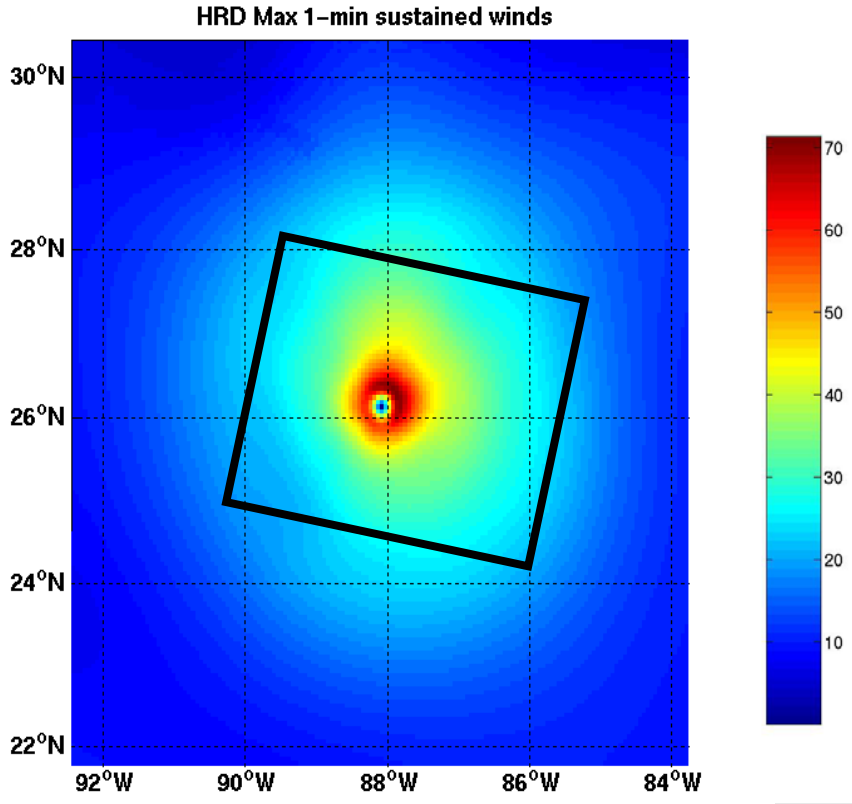
Red: radius of maximum wind speed (according to HRD)
Blue: radius of hurricane force winds (according to HRD)

SAR shows an underestimation of wind speed

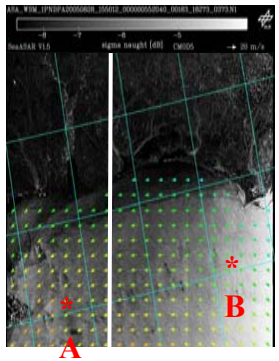
- mainly due to strong rain contamination and effects due to severe sea state

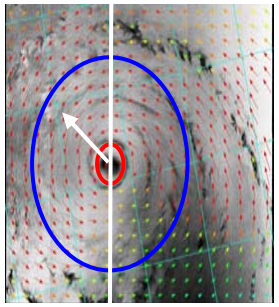
Reppucci et al., TGARS. April 2010

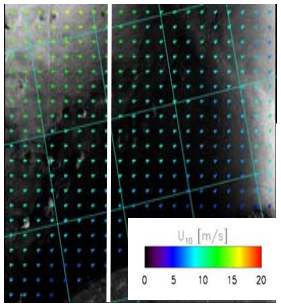
Reanalyzed wind speed of hurricane Katrina, processed by NOAA HRD



Wind field retrieval using SAR data







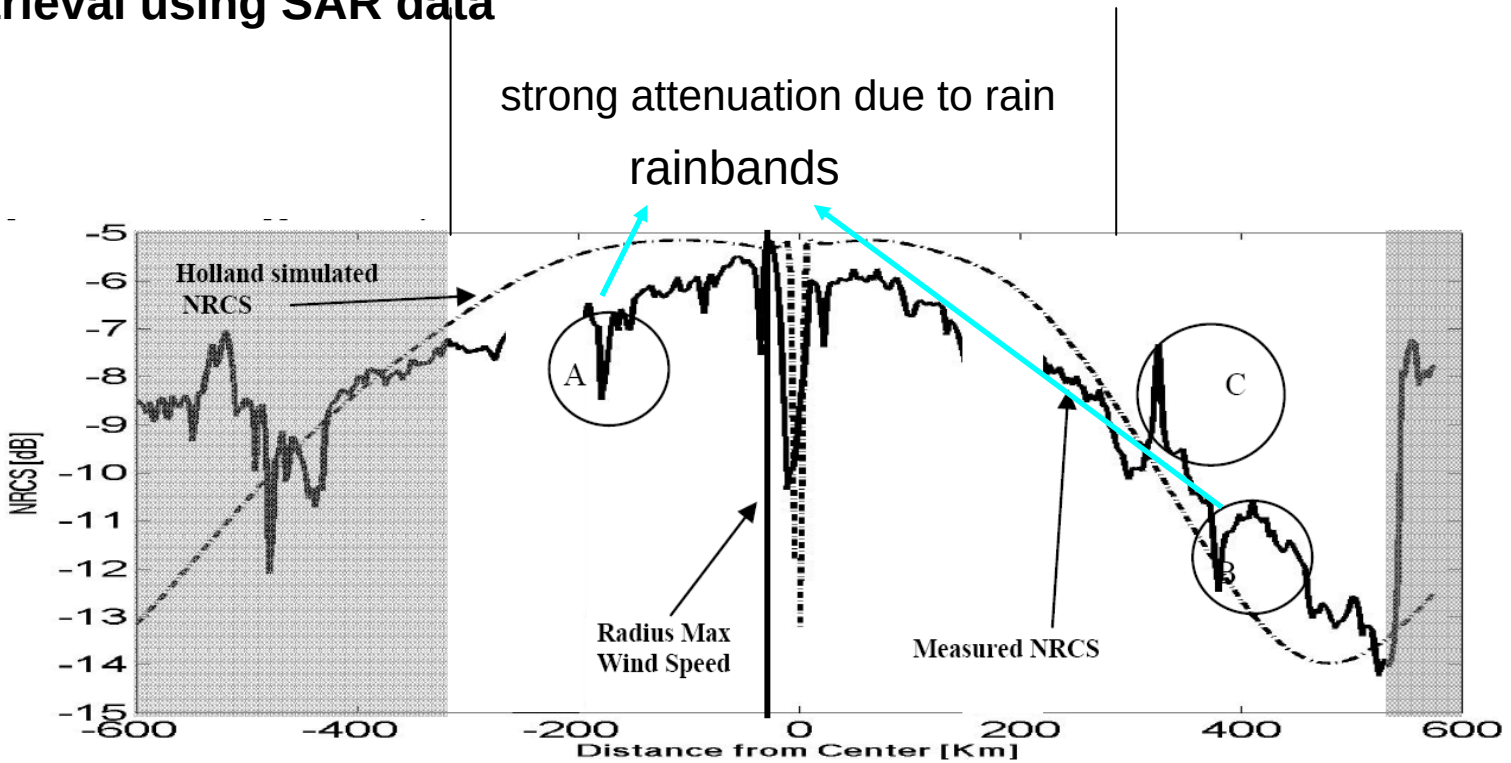


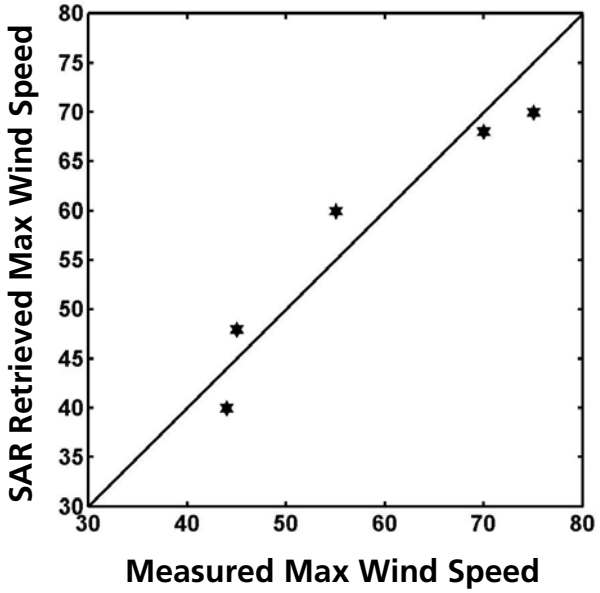
Figure 10: Along track cut of Fig 1(solid) and simulated NRCS (dash dotted) using the Holland model. Gray parts correspond to land acquisition.

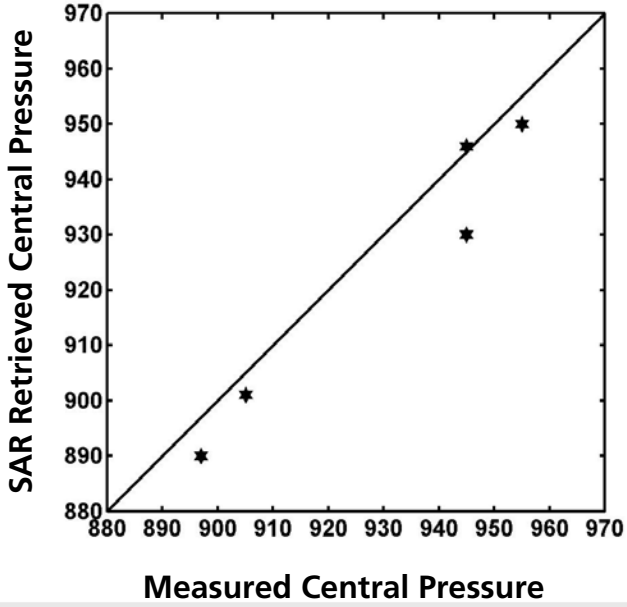
damping: arises from attenuation of the microwaves by raindrops in the atmosphere, from a modification of the sea surface roughness induced by the impact of raindrops and by wind field variations associated with the rain band.

The area of enhanced backscattering “C” is due to a thunderstorm cell

Wind field retrieval using SAR data

	Acquisition Time	Image center Coordinates	Measured Max Wind Speed	SAR Retrieved Max Wind Speed	Measured Central Pressure	SAR Retrieved Central Pressure
Hurricane Katrina	28-08-05 15:50	26,1° N, 87.7°W	70 *m/s*	68 *m/s*	905 *mb*	901 *mb*
Hurricane Rita	22-09-05 03:45	23.5° N, 85.5°W	75 *m/s*	70 *m/s*	897 *mb*	890 *mb*
Typhoon Kiko	09-09-05 01:11	18.3° N, 131° E	45 *m/s*	48 *m/s*	955 *mb*	950 *mb*
Typhoon Kiko	11-09-05 01:46	29.4°N, 124.2°E	55 *m/s*	60 *m/s*	945 *mb*	930 *mb*
Typhoon Songda	06-09-04 13:23	28.8° N, 128.4°E	44 *m/s*	40 *m/s*	945 *mb*	946 *mb*





Thanks!