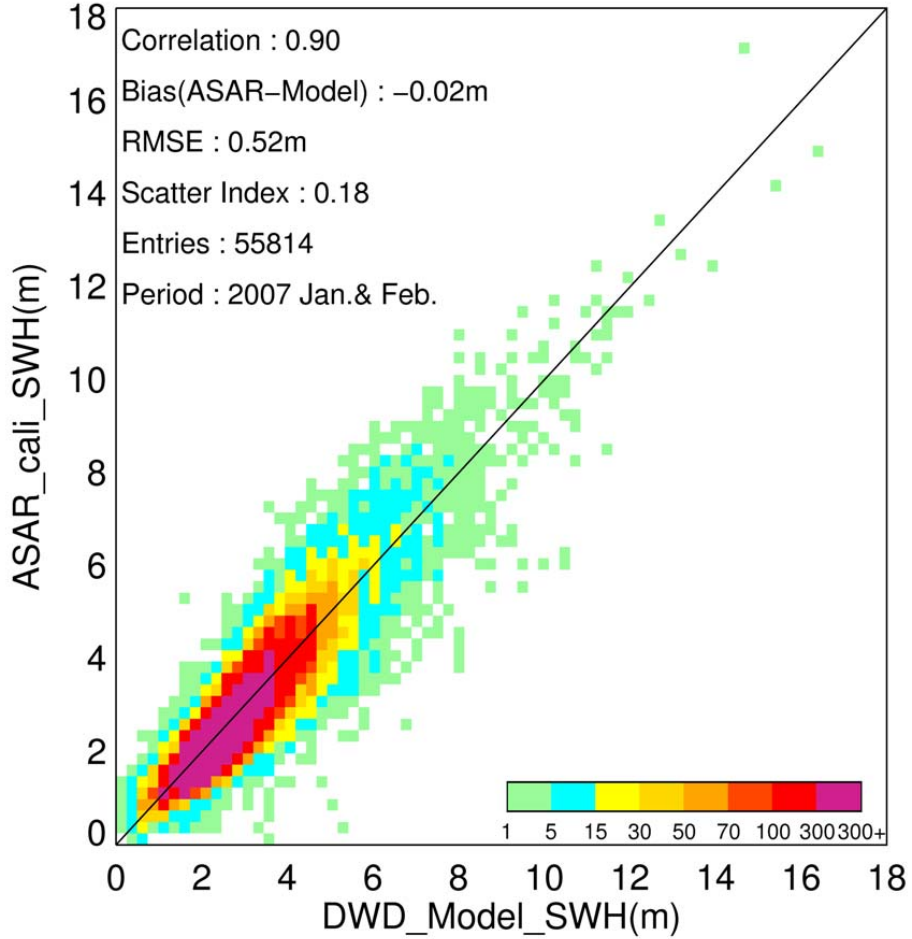
Validation of Coastal Wind and Wave Fields by High Resolution Satellite Data

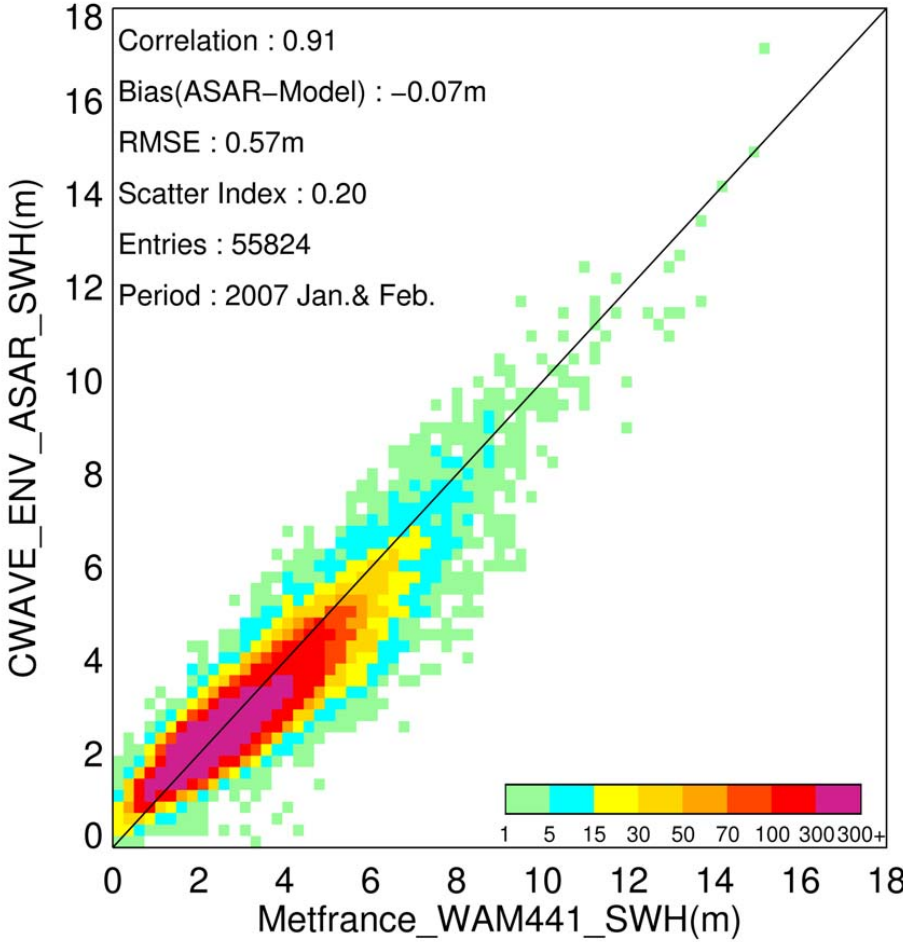
Susanne Lehner, Miguel Bruck, Andrey Pleskachevsky

German Aerospace Center

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

SWH by CWAVE from Global ENVISAT ASAR Data



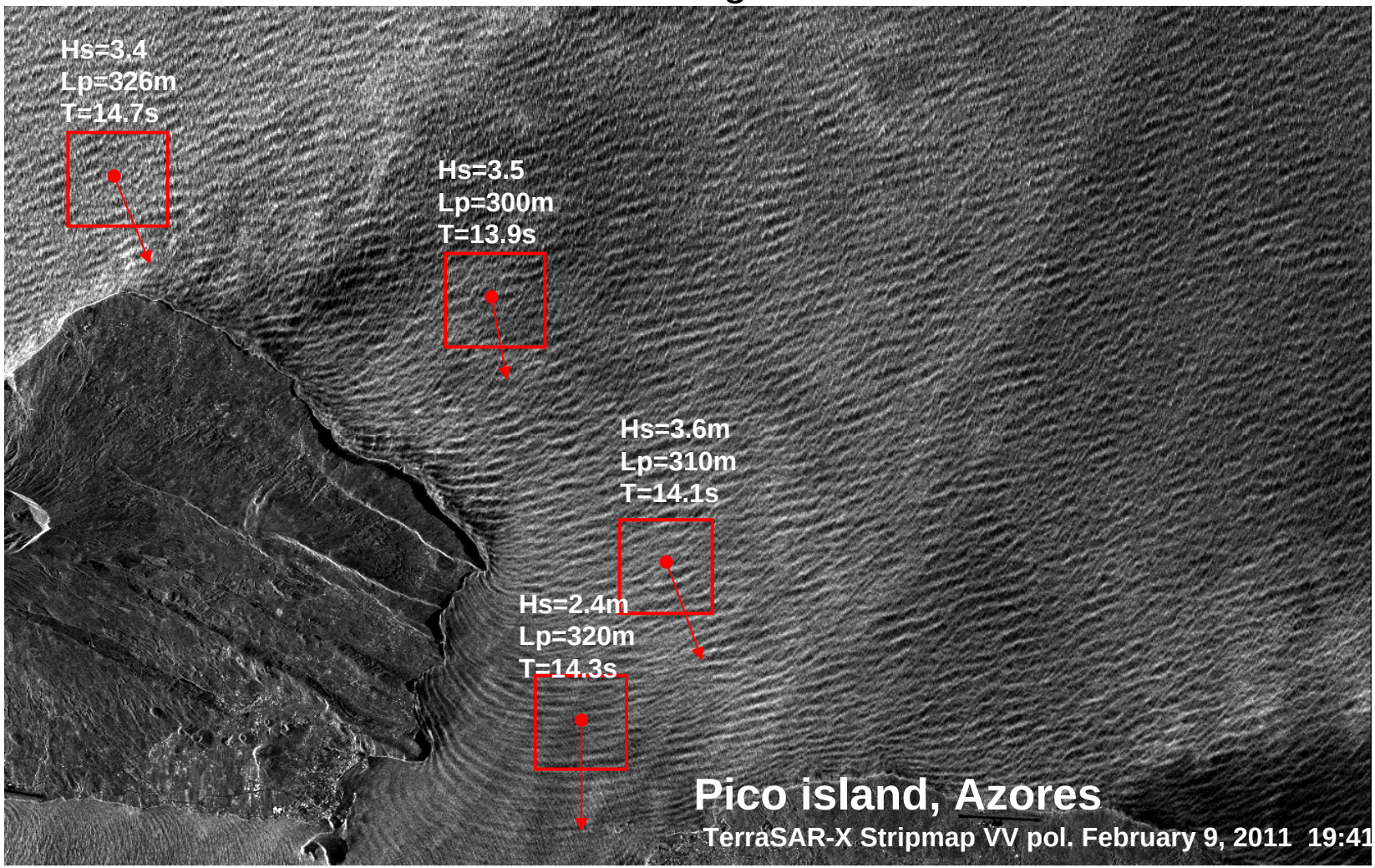


J. Schulz-Stellenfleth et al., JGR, X. Li et al., IEEE

Spatial variability of sea state (~300m) by TerraSAR-X images

Spatial variability of sea state (~300m) by TerraSAR-X images

XWAVE algorithm



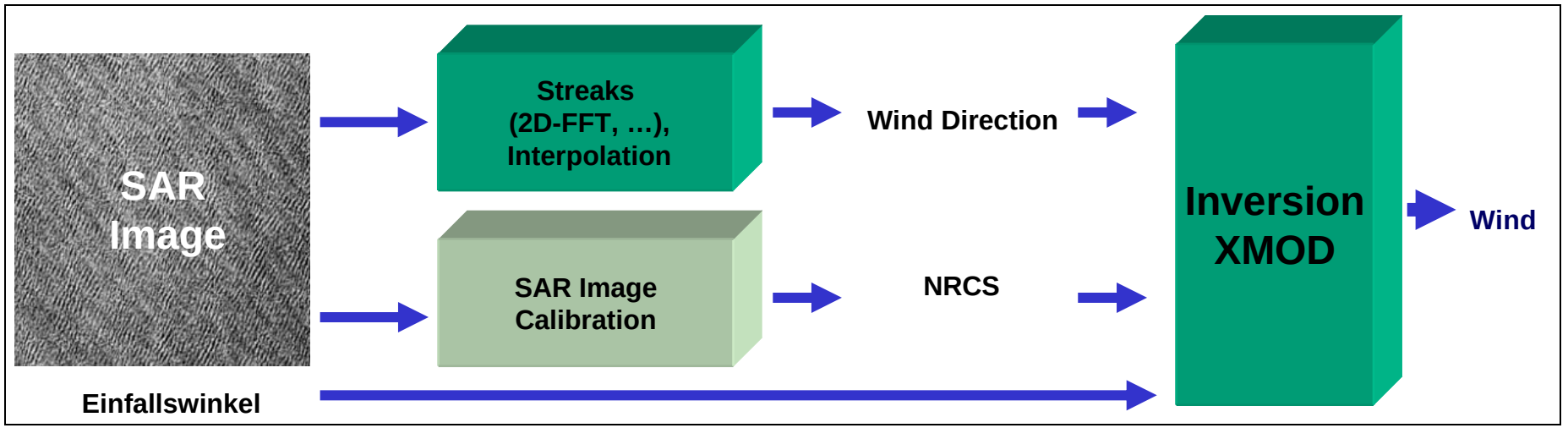
Horizon mask Neustrelitz for TerraSAR-X and ENVISAT

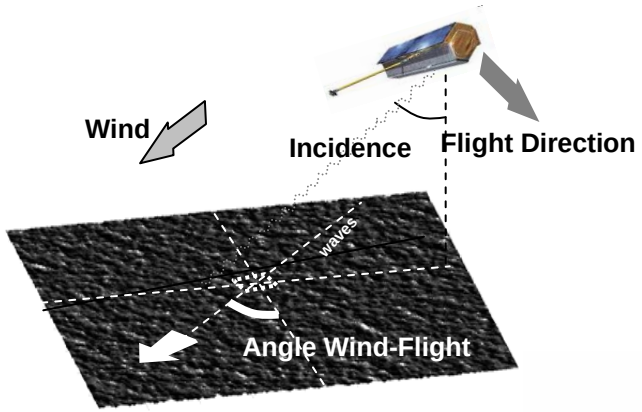
Near Real Time Services for TS-X in < 20 min in European MarSur Projects MARISS with EMSA, JRC, ESA, several European satellite providers

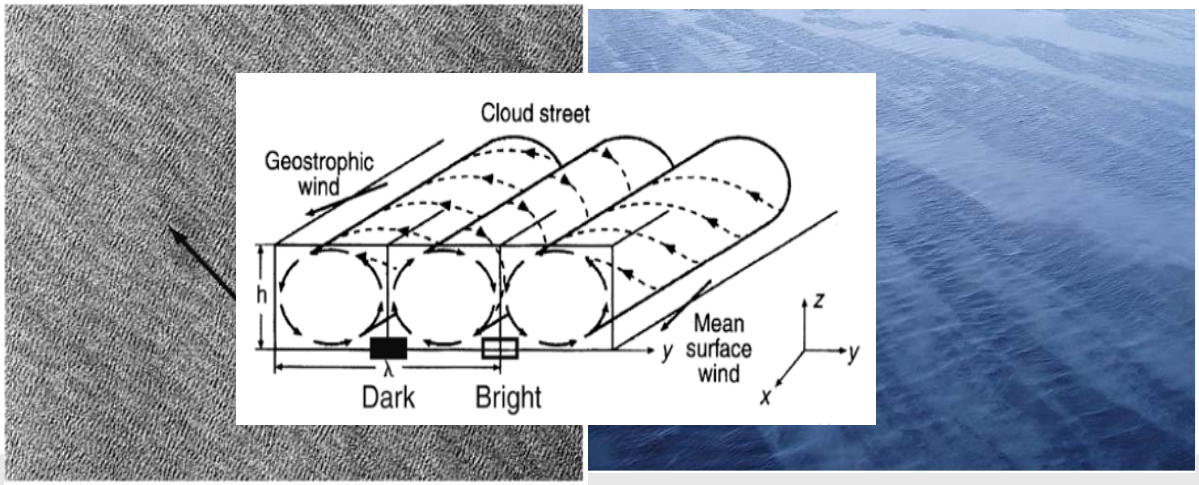
Wind Field: XMOD Algorithm

Geophysical Model Function GMF (Wind ⟷ Roughness of Sea Surface)

Connection between Radar NRCS, Wind Speed, Wind Direction and Incidence Angle







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➢ Development of the X-band GMF for sea surface wind field retrieval

XMOD1, linear inversion

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

XMOD2, non-linear inversion, comparable to CMOD GMF

$$\sigma_0(U_{10},\theta,\varphi) = \sum_{n=0}^{2} (A_n(U_{10},\theta,\varphi)\cos\{n\varphi\})$$

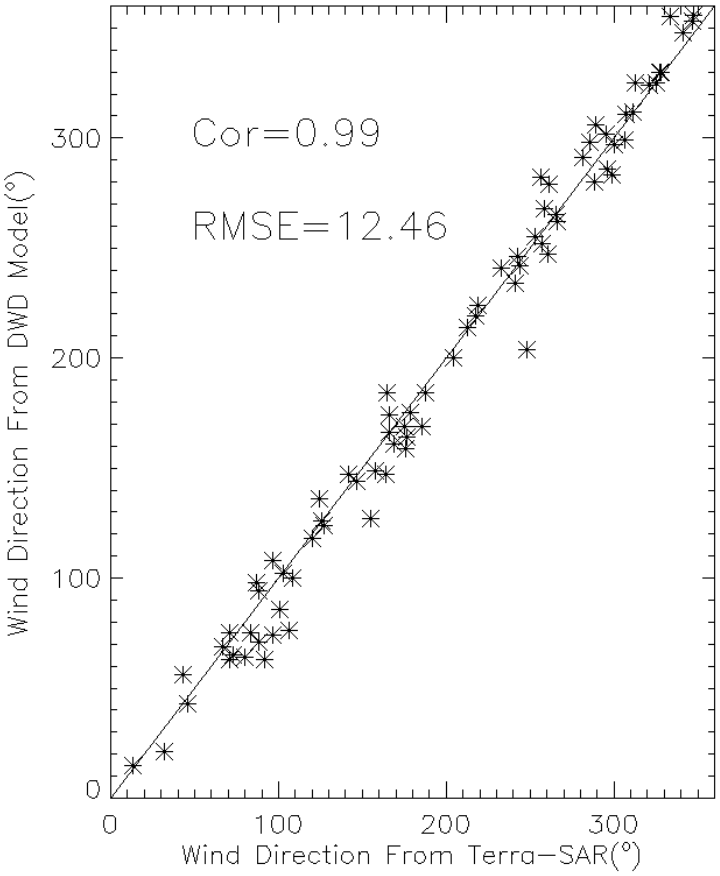
U_{10} — wind speed;

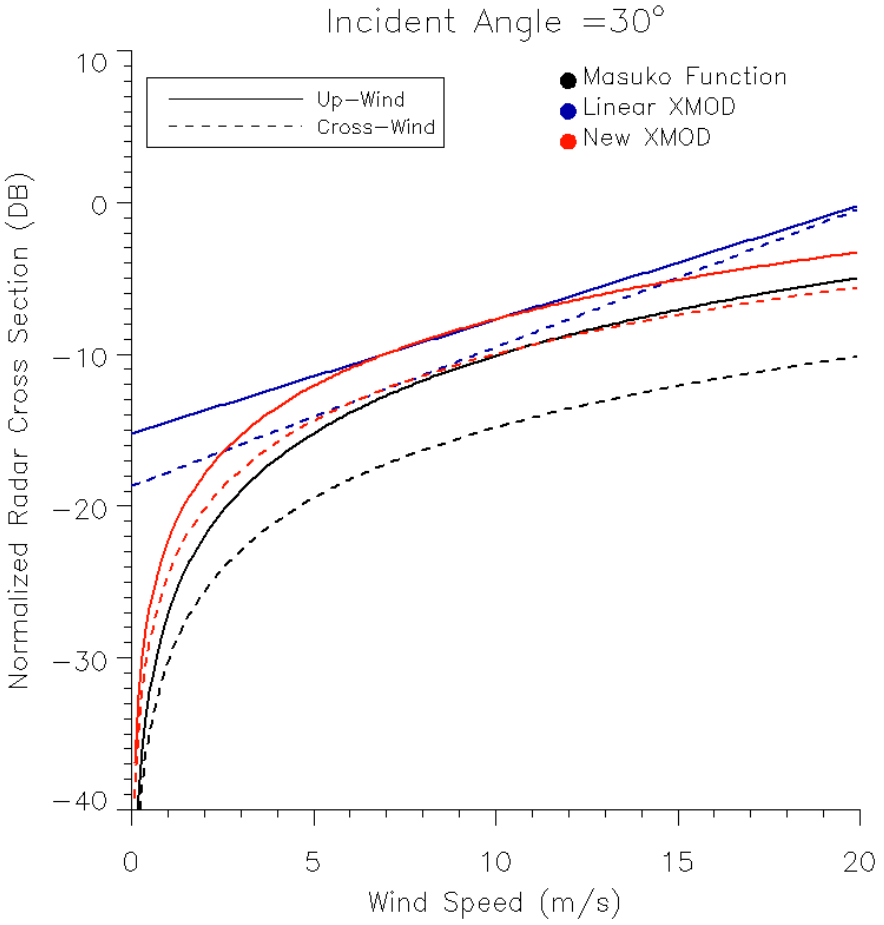
θ — incidence angle;

φ — angle between wind direction and SAR look direction

XMOD1, Y. Ren et al, IJRS, tuning dataset from X-SAR (shuttle mission)
XMOD2, X. Li et al, Spie 2011 (tuning onTS-X data)

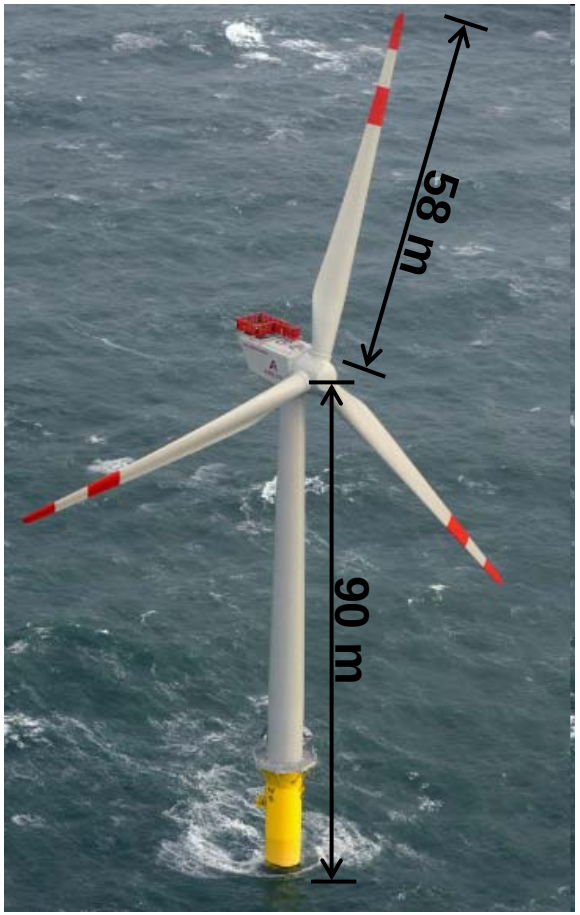
Comaprison of Wind Speed Algorithms





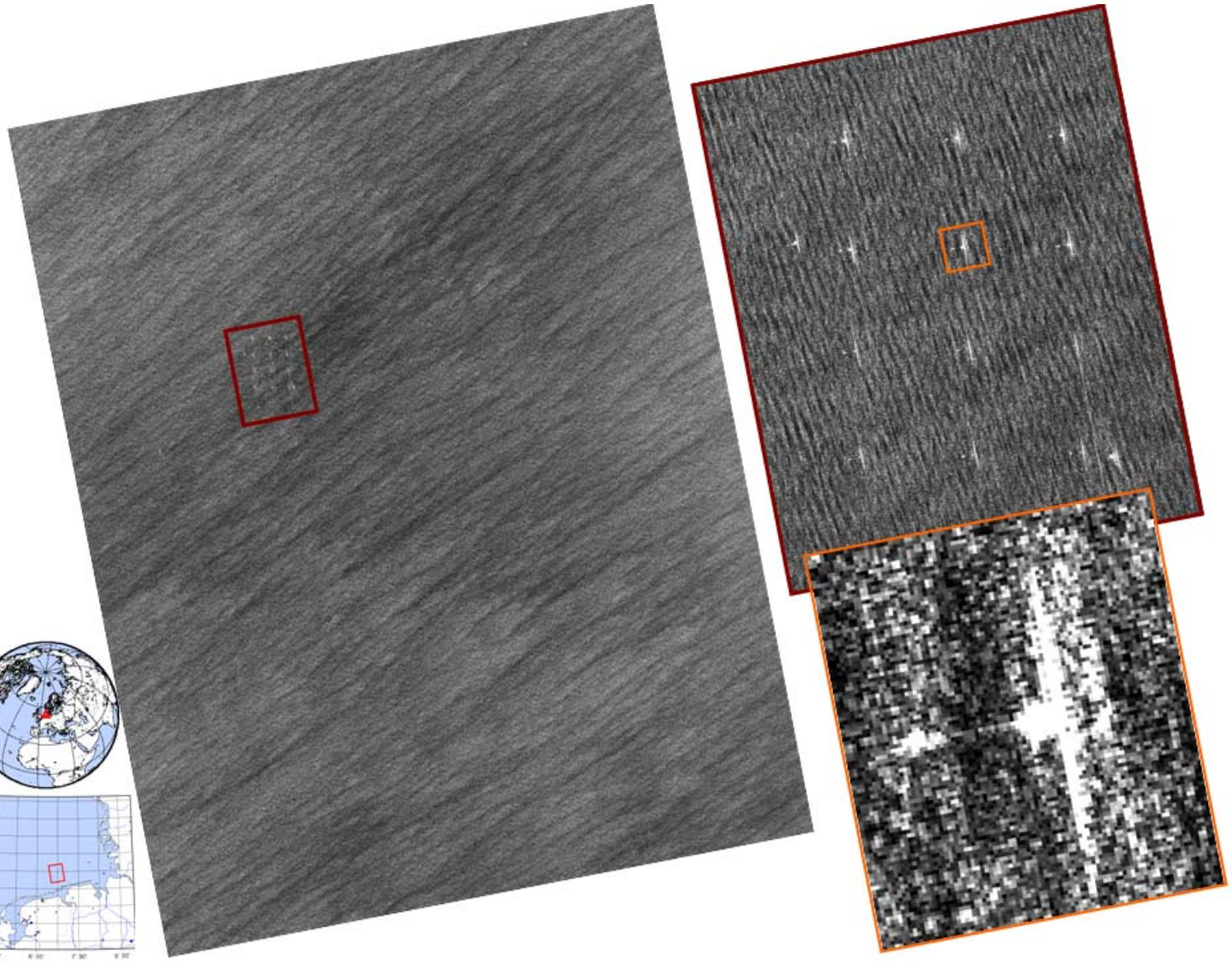
Case study over Alpha Ventus

Alpha Ventus is the first offshore wind farm of Germany, located at the North Sea



5MW Wind turbine

Case study over Alpha Ventus, Wind Farm North Sea

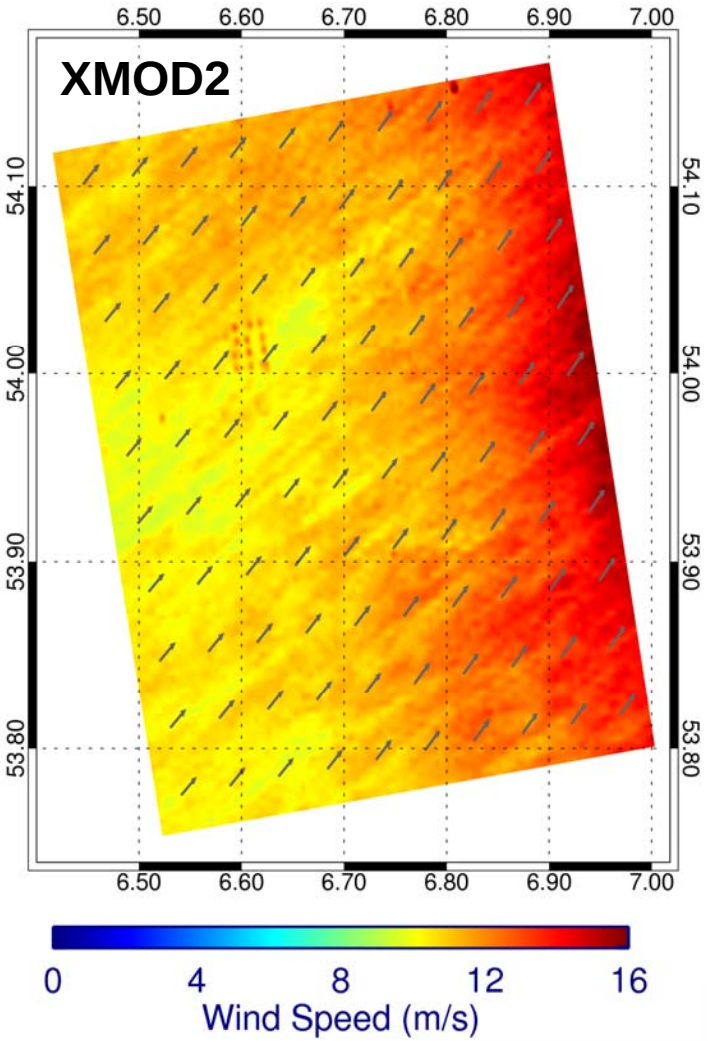


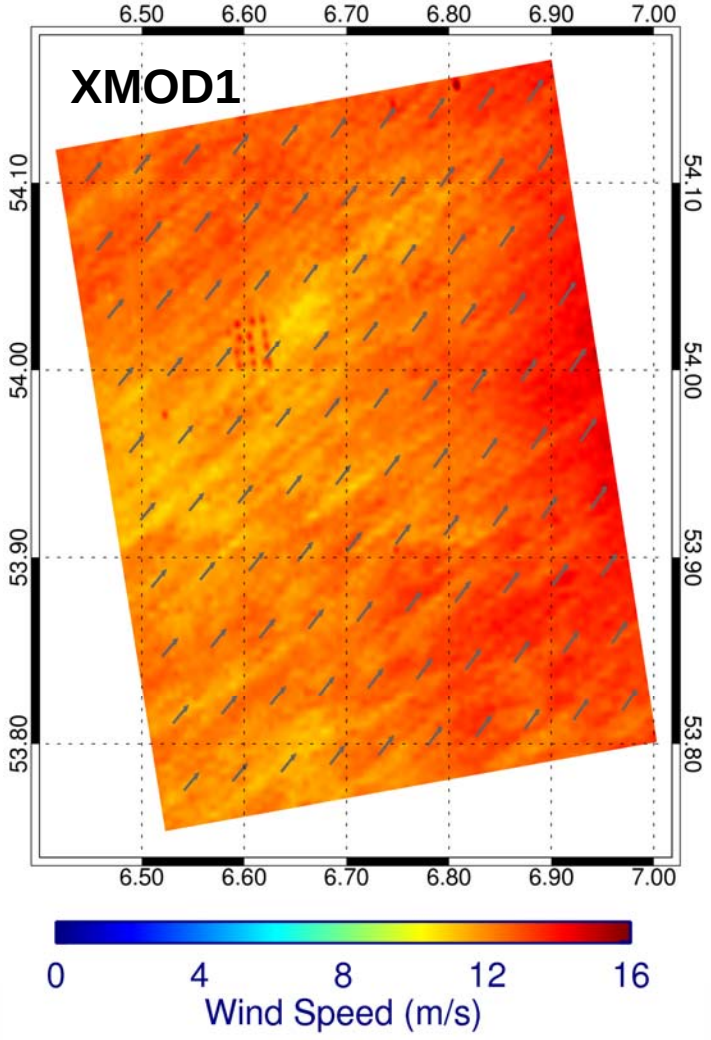
TS-X Stripmap
Aug.7, 2011
at 17:18 UTC

VV polarization,
spatial res. 3 m

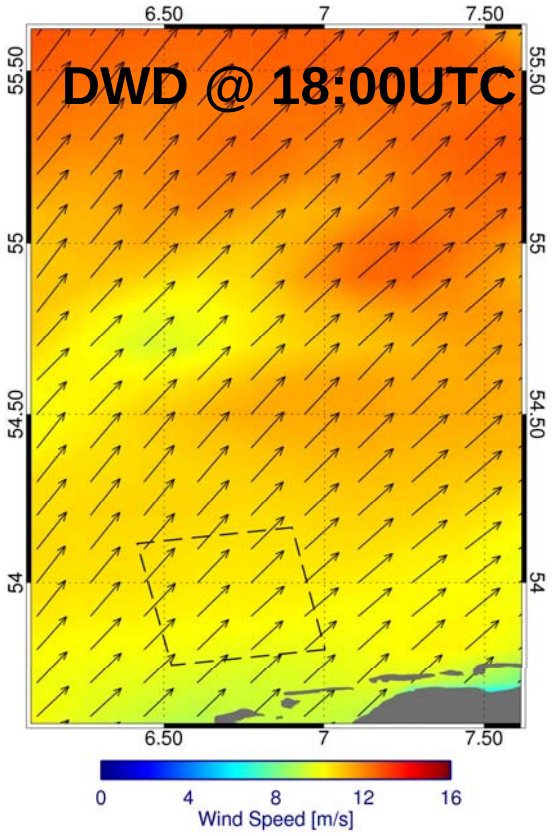
DLR Deutsches
für Luft- u
in der Helmh

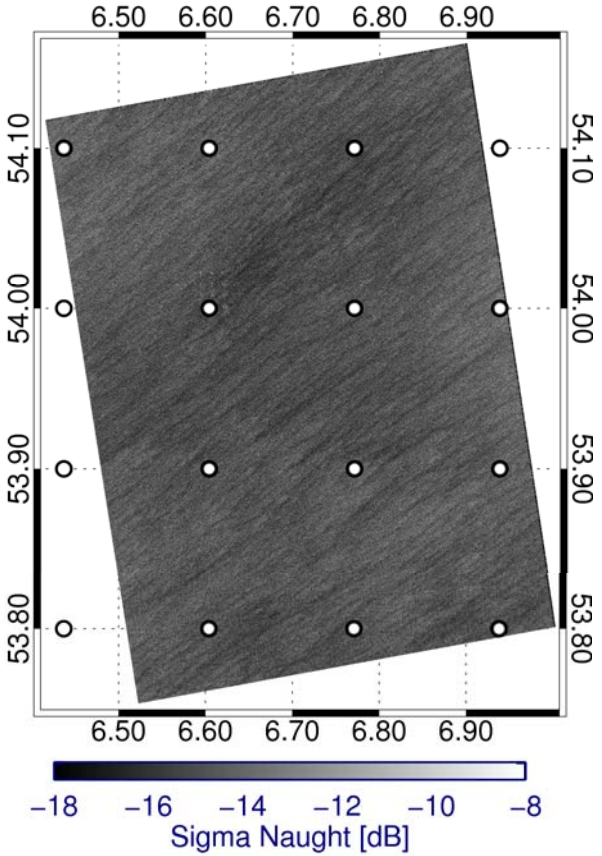
Sea surface wind field derieved from the TS-X data over Alpha Ventus

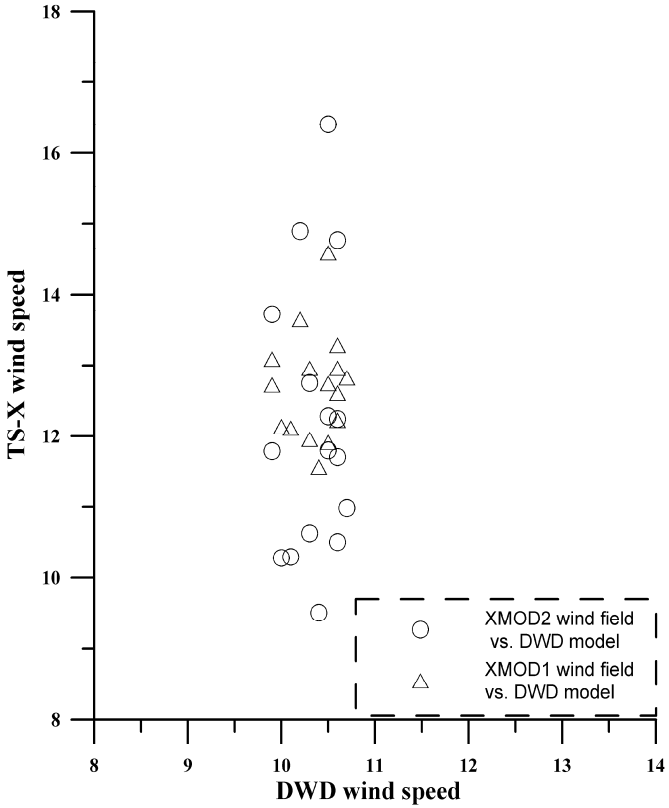




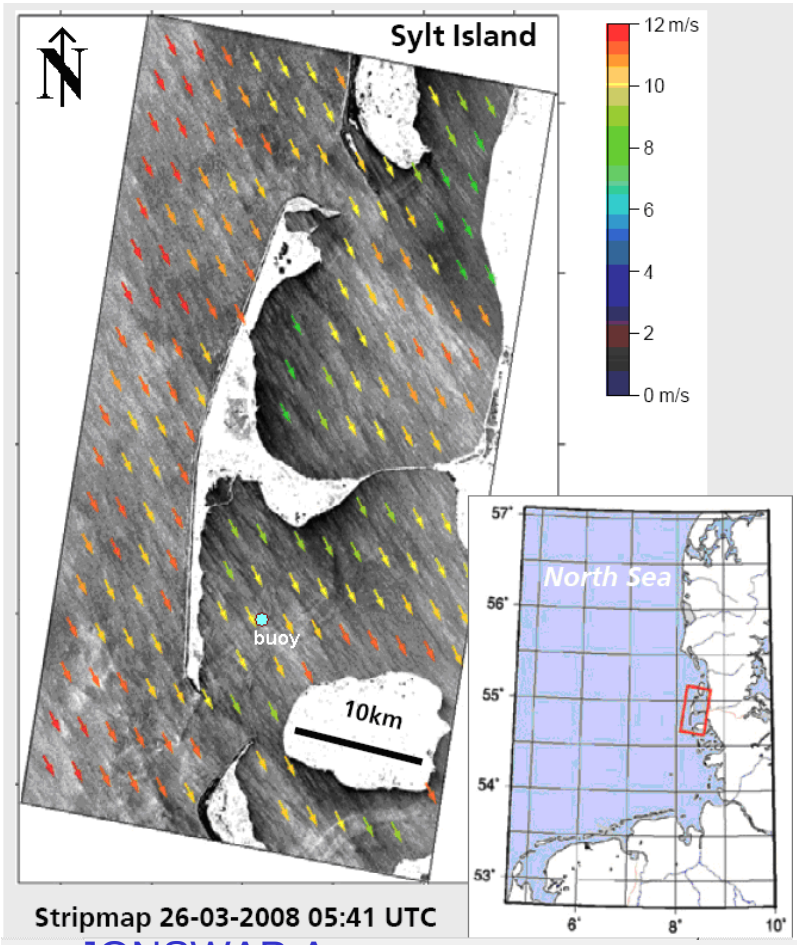
Comparison of TS-X wind measurements to DWD (global) model







Higher variability in TS-X data

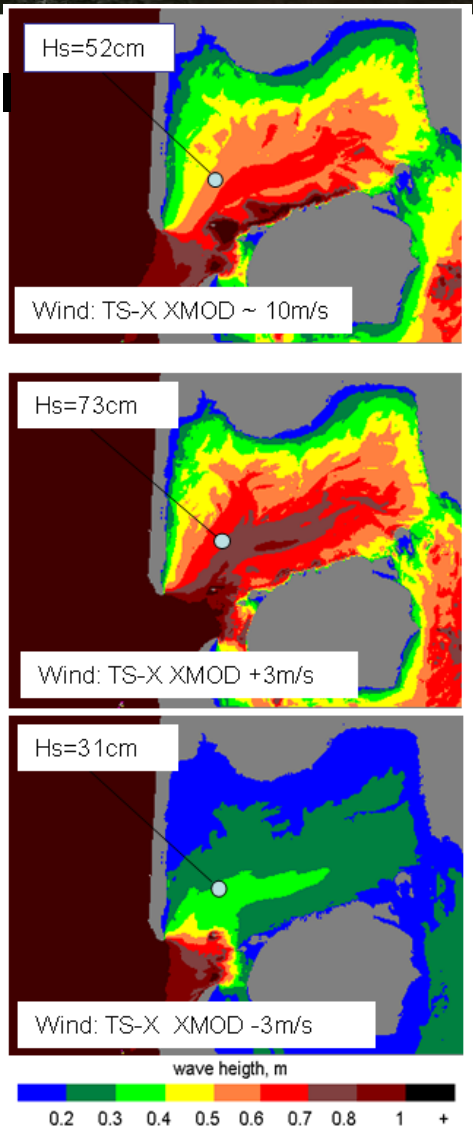


Wind Input K-Model

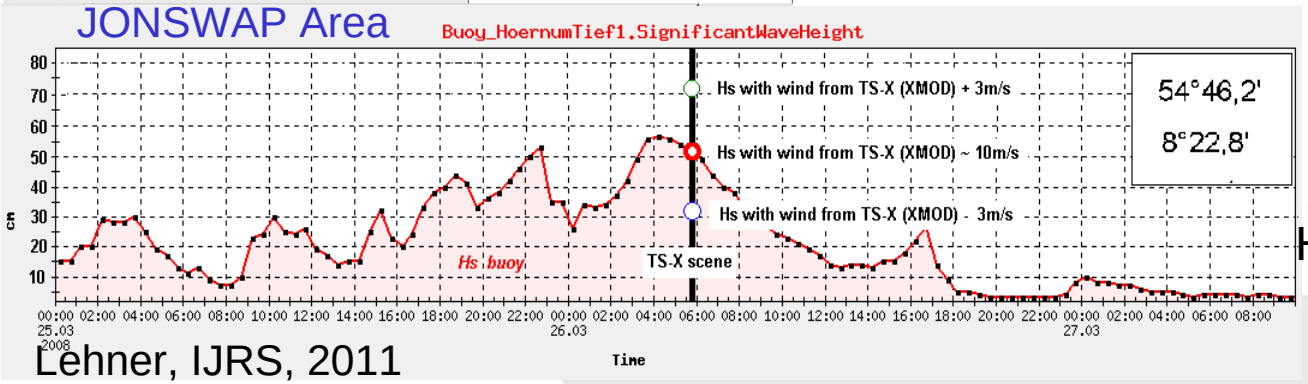
wind+3m/s

wind

wind - 3m/s



GKSS (HZG) buoy

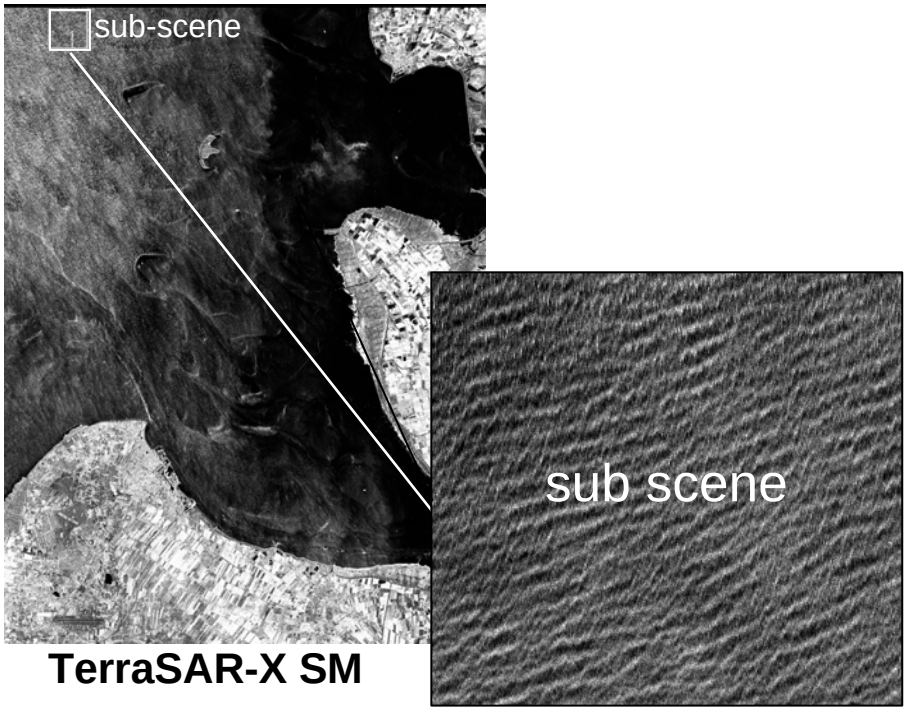


Lehner, IJRS, 2011

Hs modelled by K-model

buoy measurement

XWAVE: Sea State Parameters from TerraSAR-X Images



TerraSAR-X SM

Elbe estuary

$$m = \frac{I(i,j) - mean}{mean}$$

$$S = FFT(m)$$

$$E = \int_{k=\max}^{k=\min} S(k,\theta)\,dk\,d\theta$$

signal intensity I

↓

signal modulation ***m***

↓

image spectra ***S***

↓

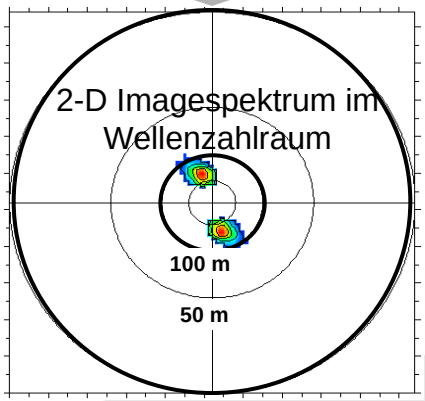
filtering, L_{min}, L_{max}

↓

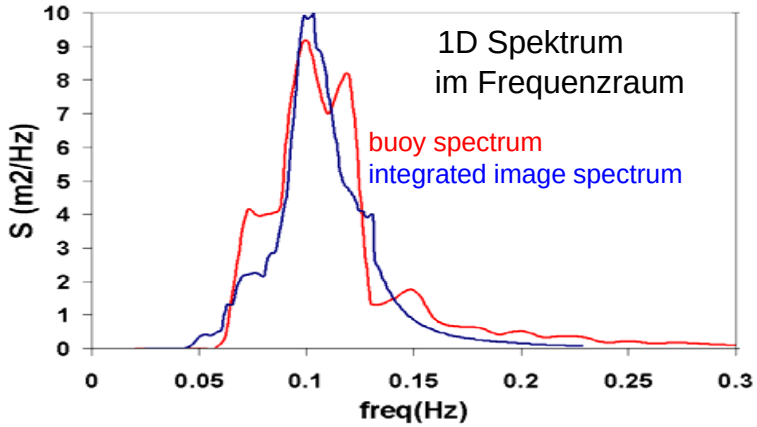
XWAVE function

↓

Parameters: H_s, L_p, T_p…

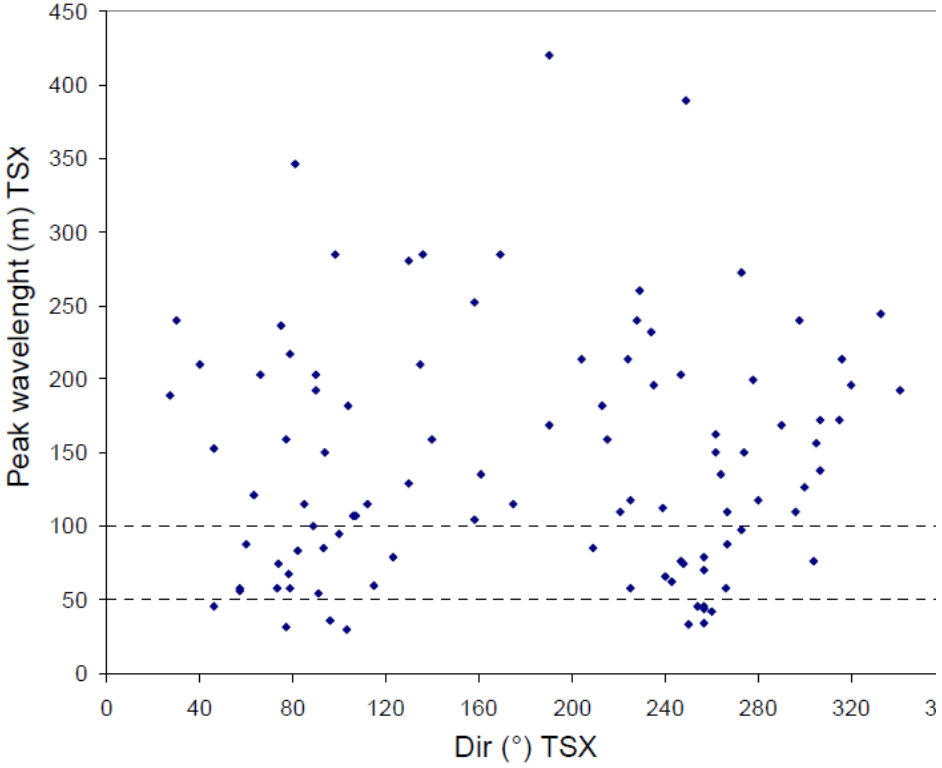


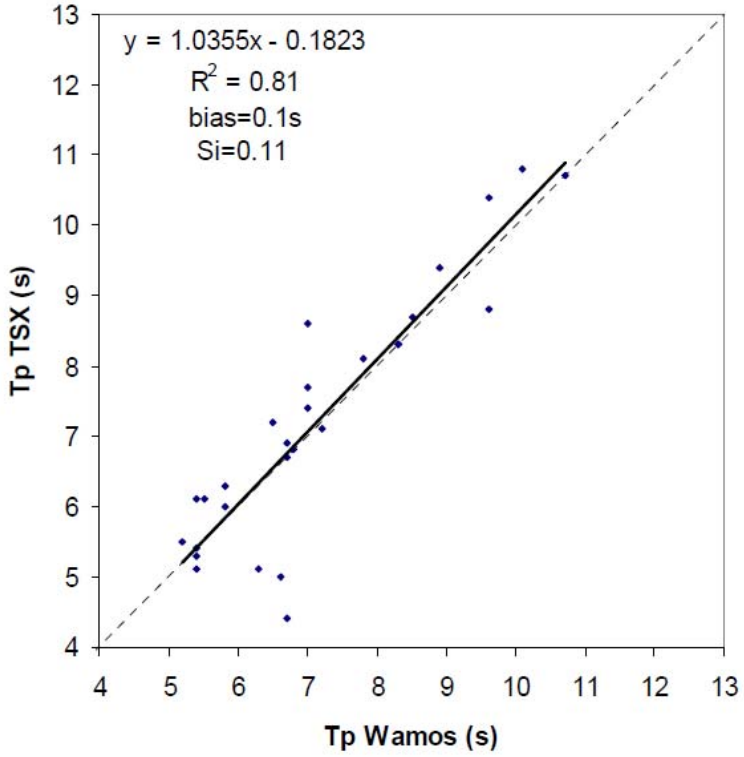
2D image spectrum



$|\cos\alpha|) + a_3$

Statitistics Wave Length XWAVE Empirical Algorithm





Collecting data set over NOAA buoys,
Image data have to be ordered for acquisition about 2 days in advance

XWAVE Algorithm: estimation of Significant wave height from TS-X data

based on analysis of image spectra and uses fitted parameters

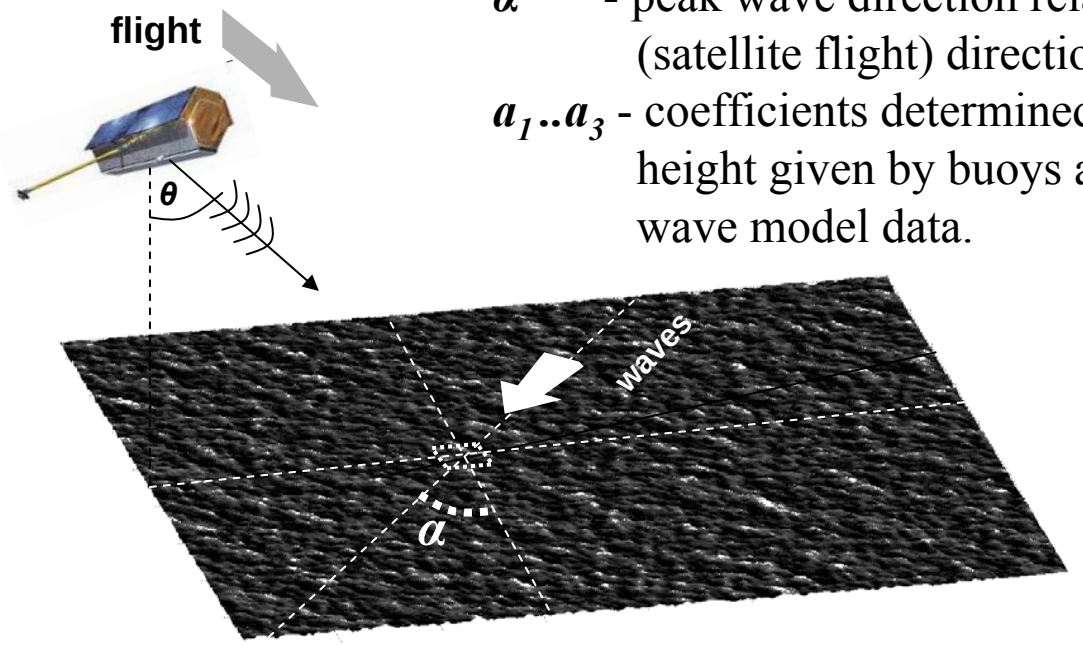
$$Hs = a_1 \cdot 4\sqrt{E \sin\theta (1.0 + a_2 \cos(\alpha))} + a_3$$

E - total energy calculted from the image spectrum in domain λ_{min} and λ_{max}.

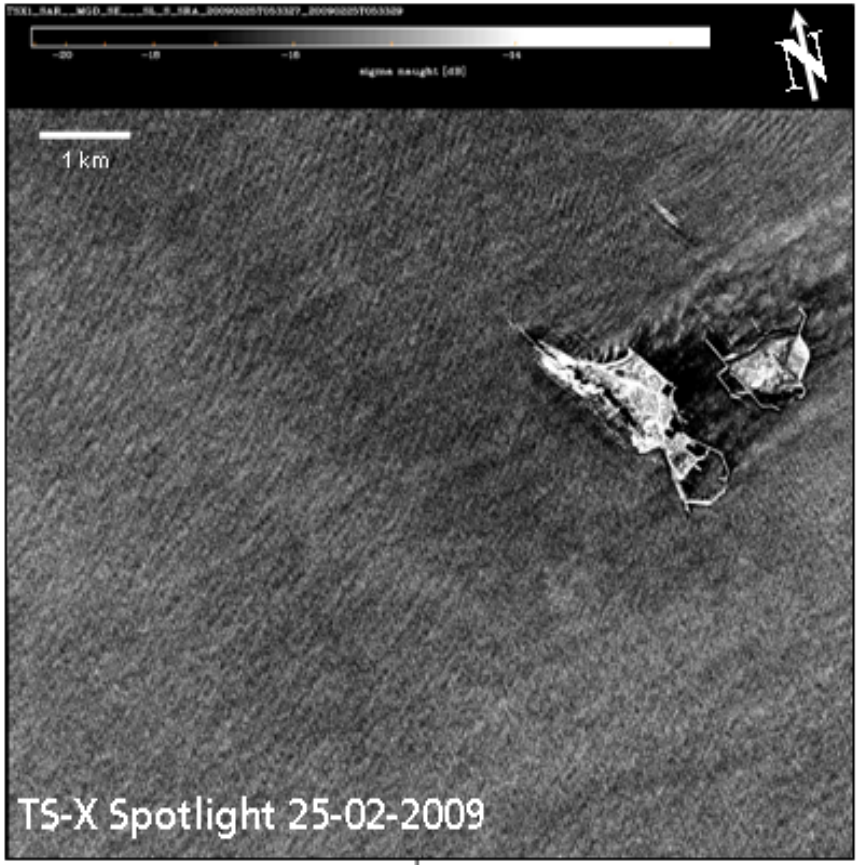
θ - the incidence angle

α - peak wave direction relative to azimuth (satellite flight) direction

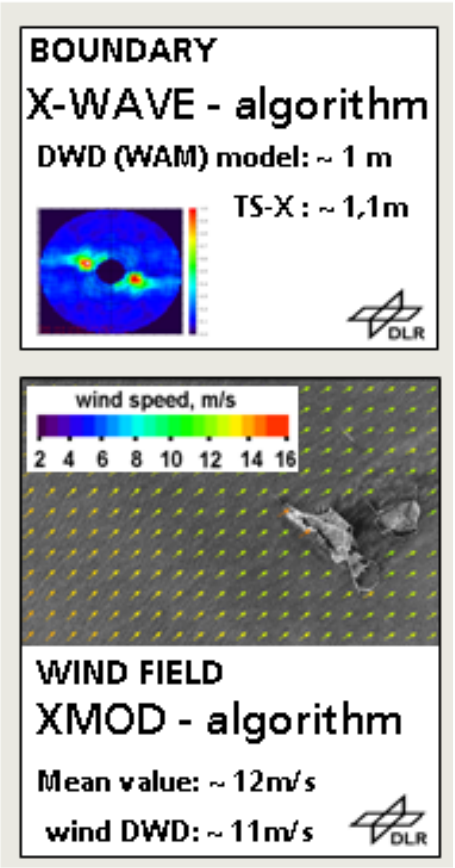
a_1..a_3 - coefficients determined by TS-X,TD-X data fitting with wave height given by buoys and DWD (German weather center) wave model data.

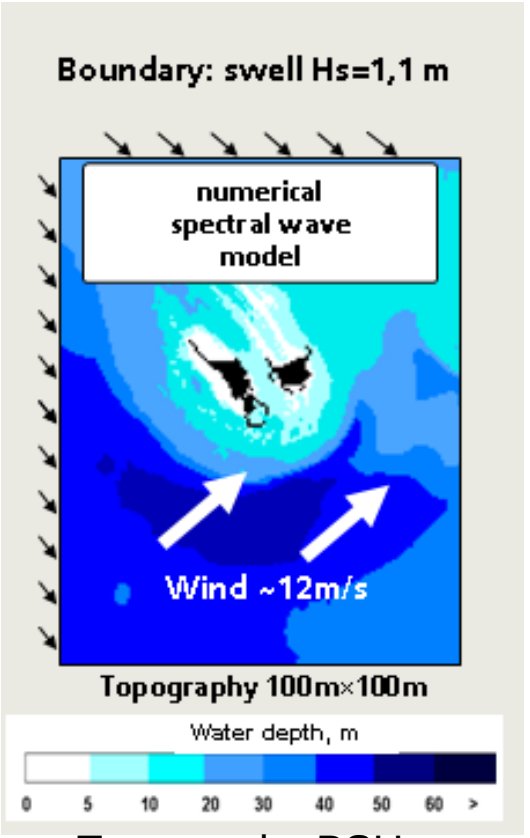


Modelling of Sea State over Helgoland with K Model and boundary conditions from TS-X



North Sea, Helgoland

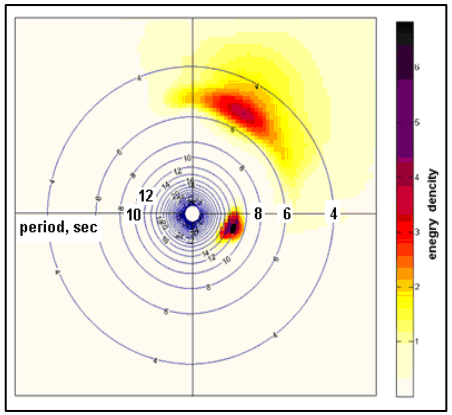




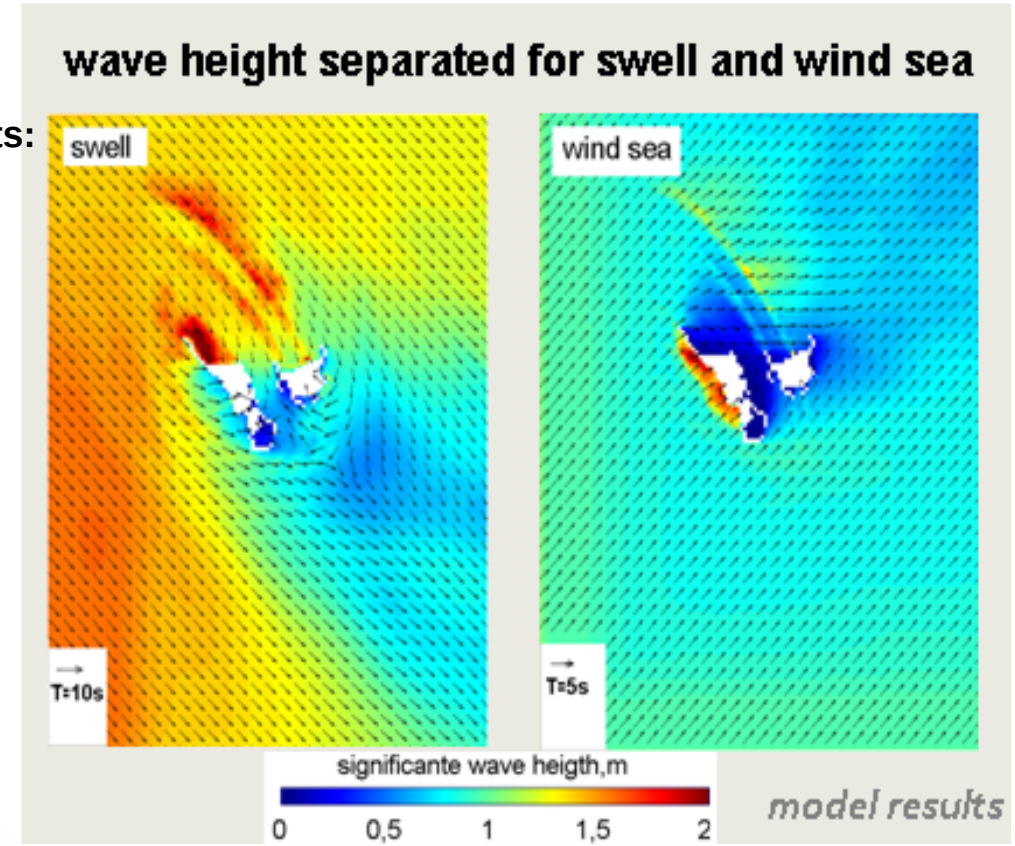
Lehner et al. IJRS, 2011

SWH from K-Model with boundary conditions from TS-X

- **The wind field: XMOD**
- **boundary spectra include two parts:**
  - swell (obtained using XWAVE)
  - wind sea (JONSWAP spectra)



Boundaty spectra from TSX
XWIND , XWAVE

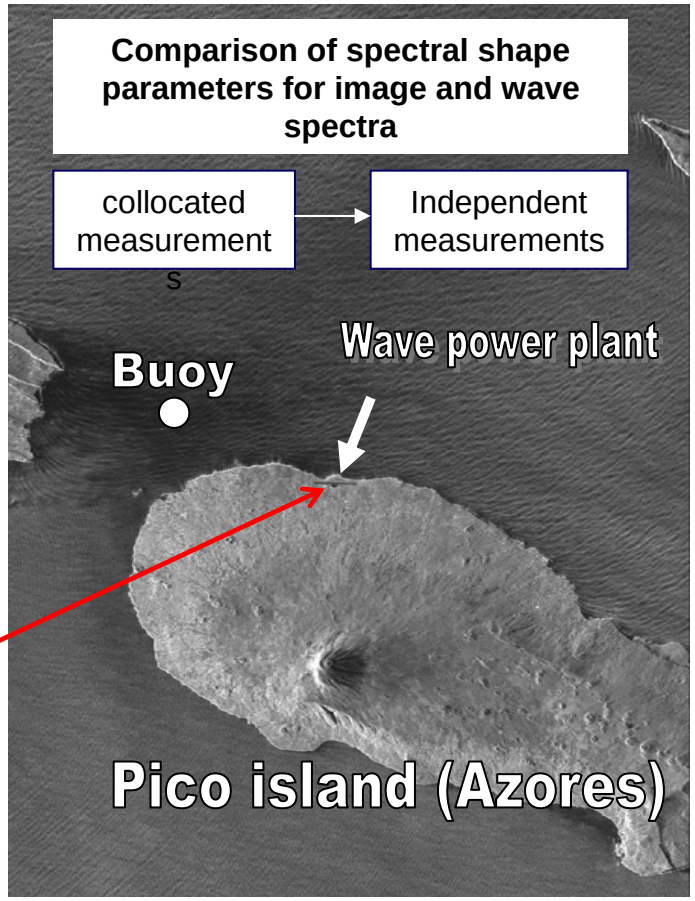


Application: Sea-State spatial Variability and Wind Field estimation using TerraSAR-X Synthetic Aperture Radar Data

- **Spatial variability is observed by TS-X imagery**

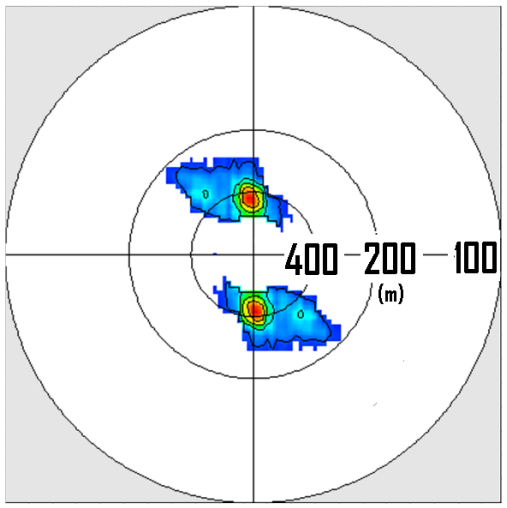
- **Wind field estimated**

sea state at wave power plant differs from the one at the buoy location

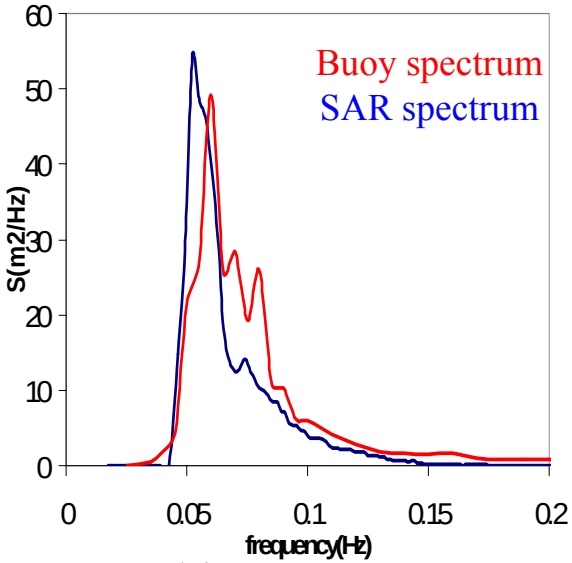


Example: Pico island, Sea State near Pico Wave Farm

SM, VV polarization,
February 14, 2011



2d spectrum

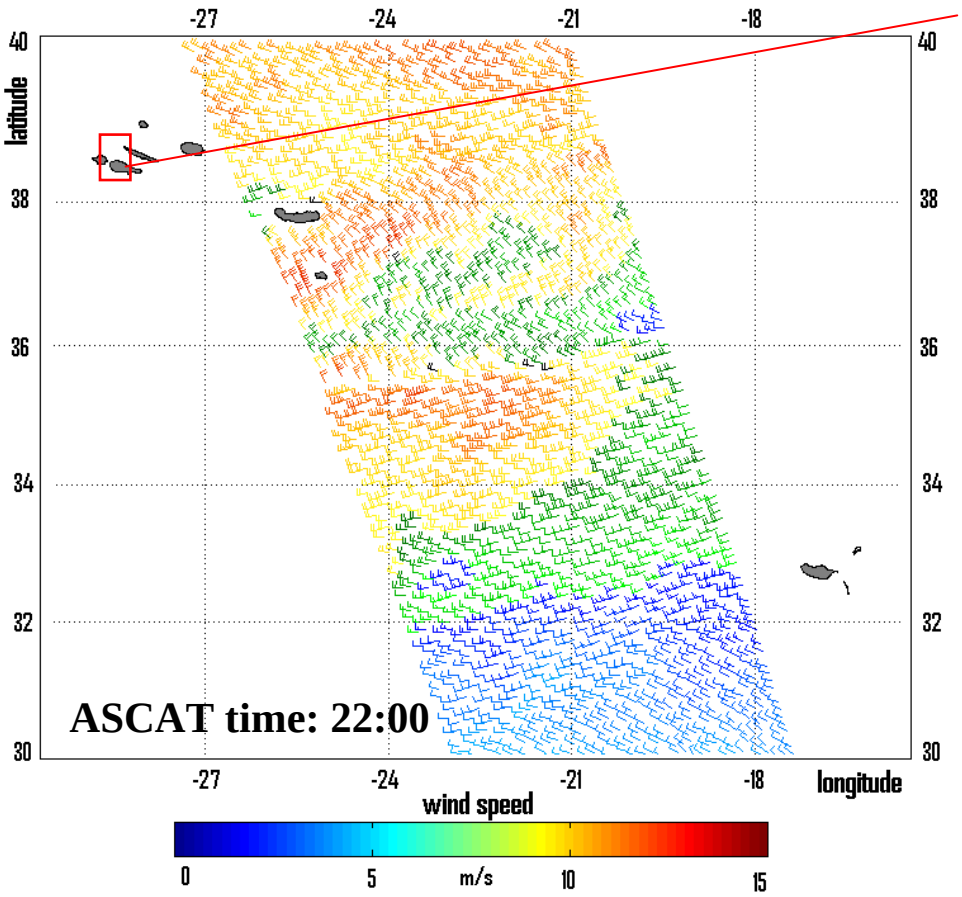


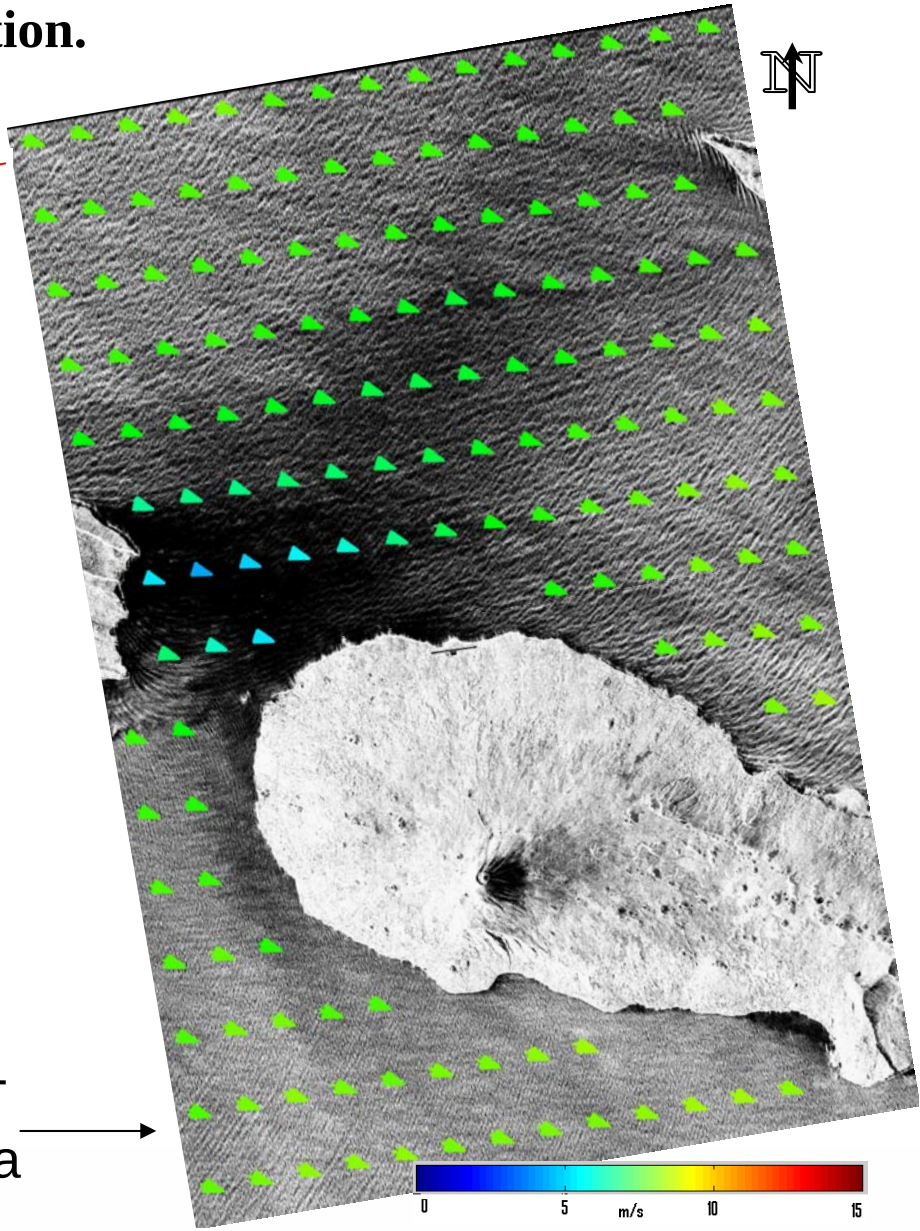
1d frequency spectrum

2011-02-14	H_s (m)	Tp (s)	T_{02} (s)	T_{-10} (s)	θm (°)
Buoy 19:30	4.7	16.7	11.6	14.2	347
TS-X 19:41	4.3	18.1	11.8	14.6	351

M.Bruck et al, EWTEC, 2011

Pico island: TD-X Stripmap VV polarization.
February 14, 2011 19:49



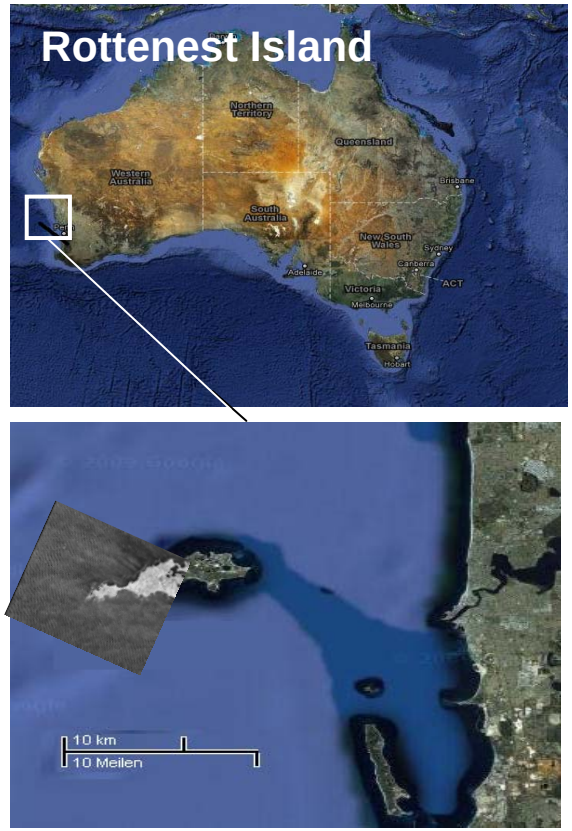


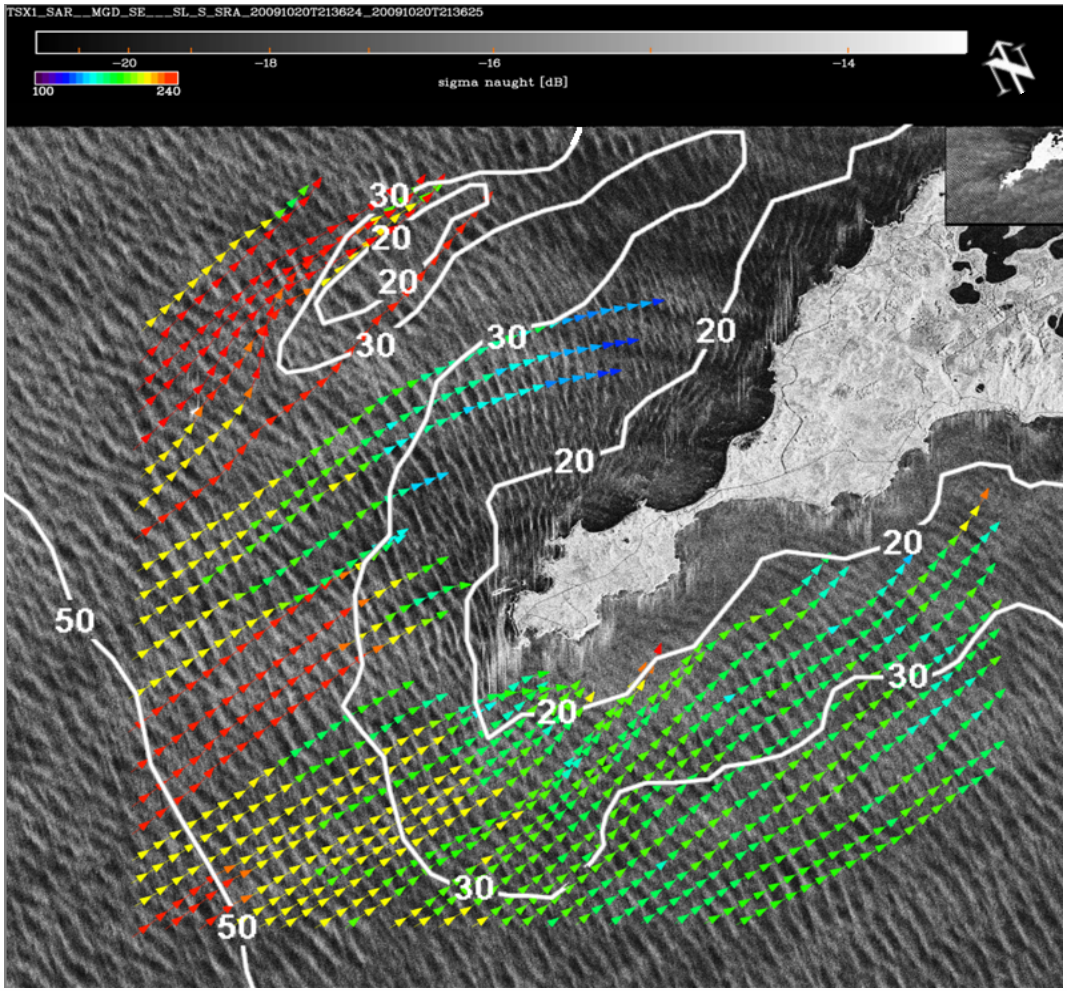
Wind vectors derived by the ASCAT

Wind speed derived from TS-X data

Determination of Underwater Bathymetry

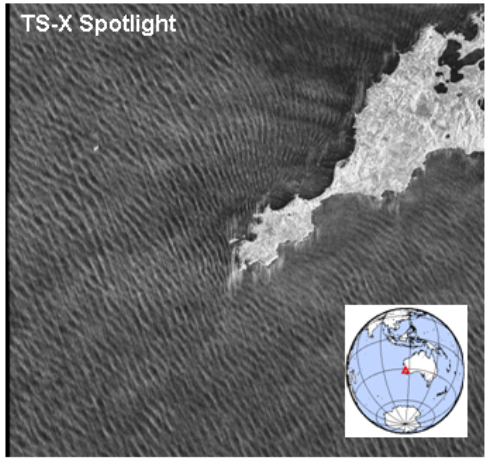
using Dispersion Relation





A. Pleskachevsky et al., Ocean Dynamics

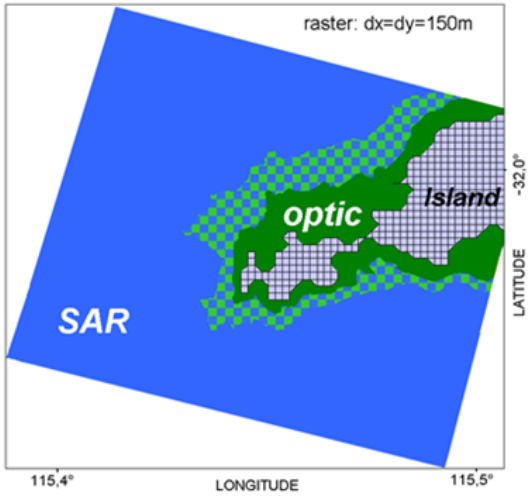
Underwatertopograpy from TerraSAR SAR and Optical



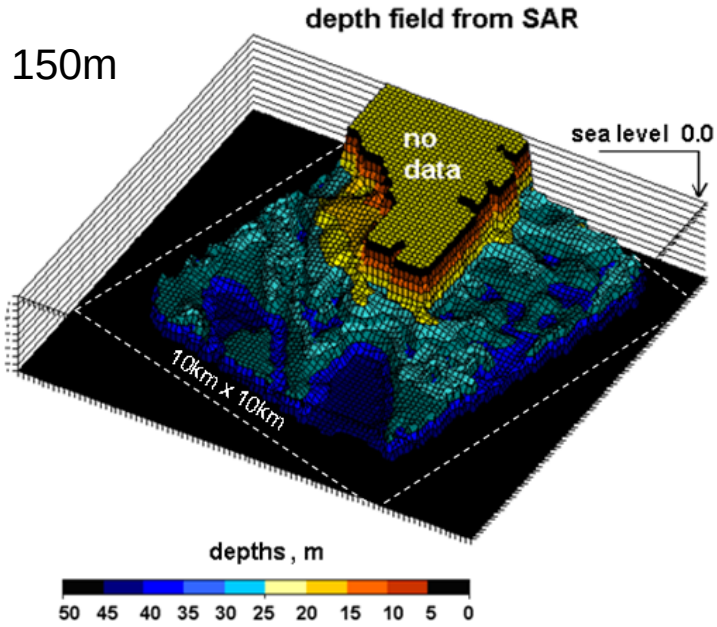
Optical and SAR data:
fusion and synergy

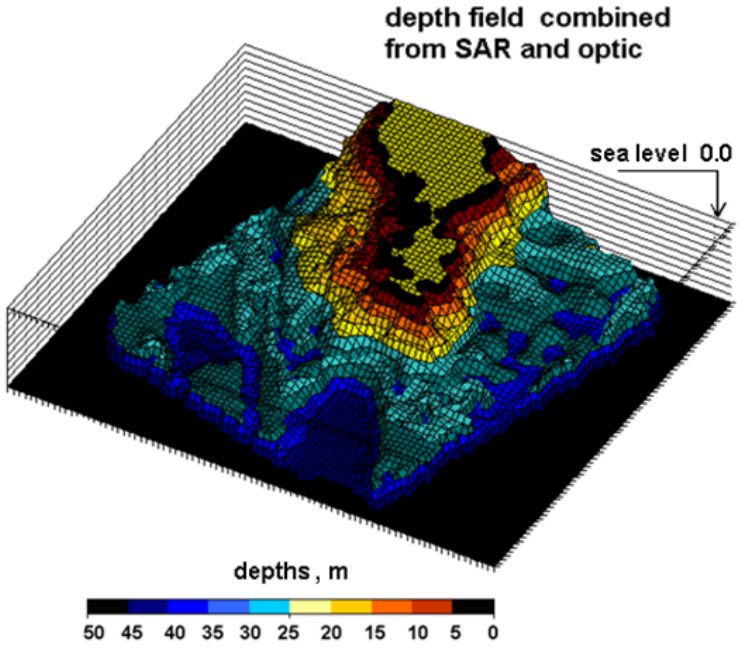
areas

- depths from optical data
- optical & SAR: synergy
- depths from SAR



Grid size 150m

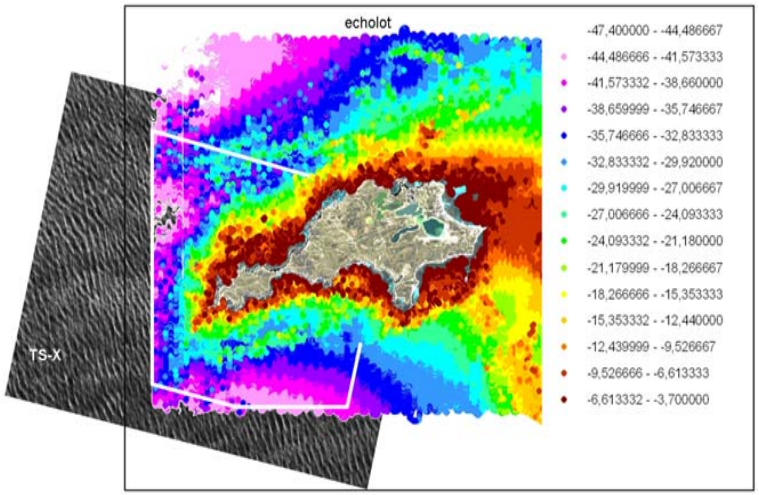




DLR

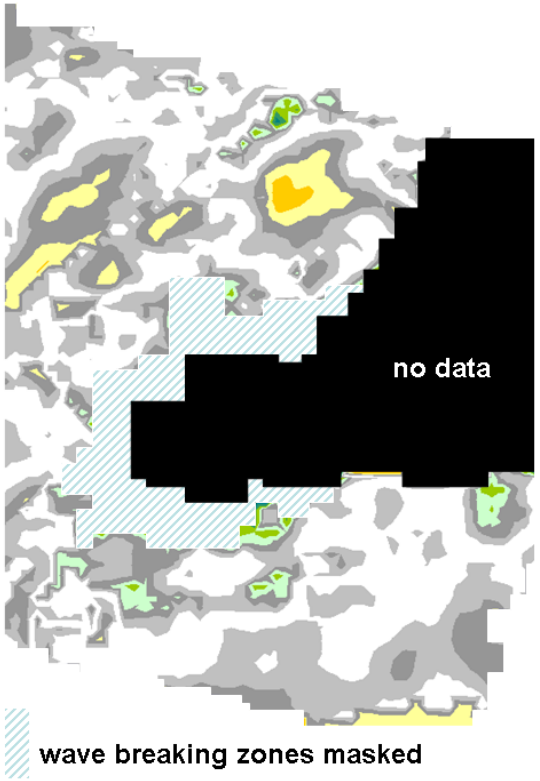
Determination of Underwater Bathymetry

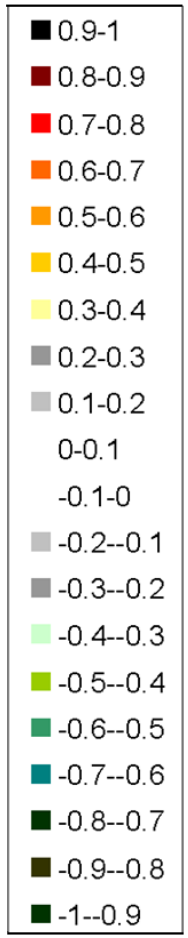
Validation



A.Plekachevky et al
Oceandynamics, 2011

$$\text{relative deviation} = \frac{D_{MESS} - D_{TSX}}{D_{MESS}}$$





Summary

Obtained information on the highly variable wind field and sea state in coastal areas using high resolution TerraSAR data

Use information from refraction to obtain underwater bathymetry

Methods

- Estimation by XMOD and XWAVE algorithm
- Comparison/Validation of wind field sea state parameters derived from TS-X SAR data with *in-situ* buoy measurements.
- Characterization of sea sate using integrated sea state and spectral shape parameters

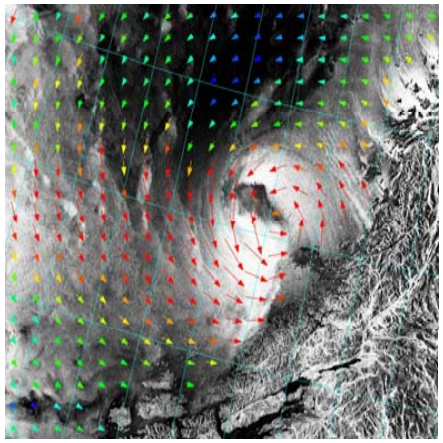
Goal

Real Time Satellite Services for North Sea, Baltic Sea, Mediterranean in cooperation with DWD

NRT Maritime Monitoring Services in European Framework, EMSA, JRC, FRONTEX

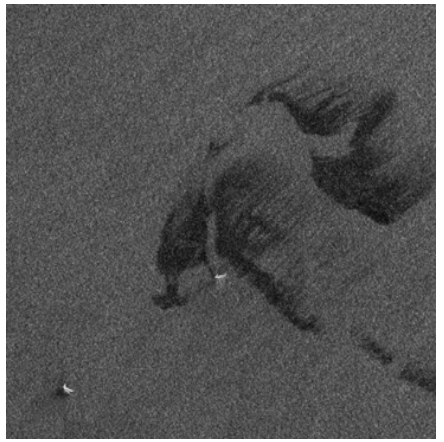
Thank you for your attention !

ENVISAT

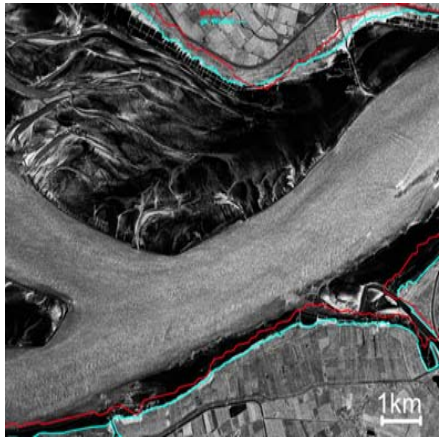


Wind

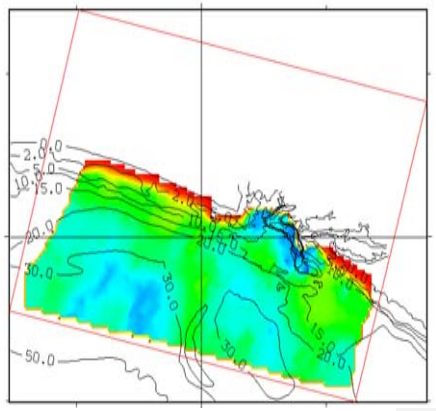
Sea State



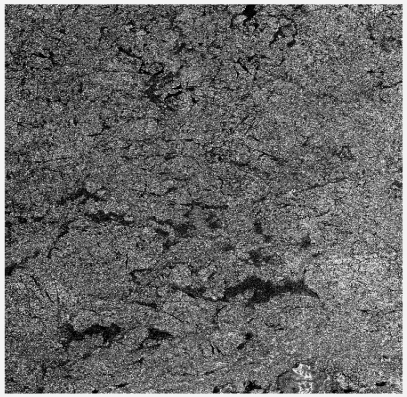
Oil



Land-Water Line

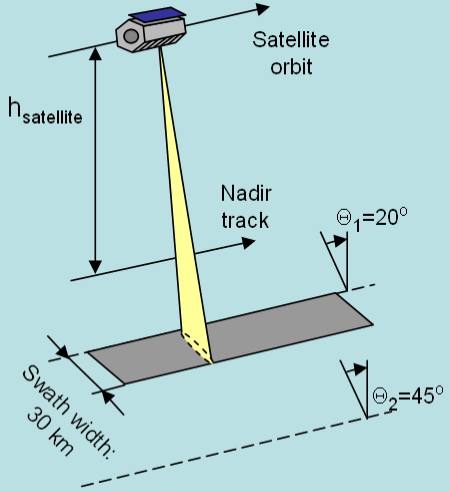


Bathymetry



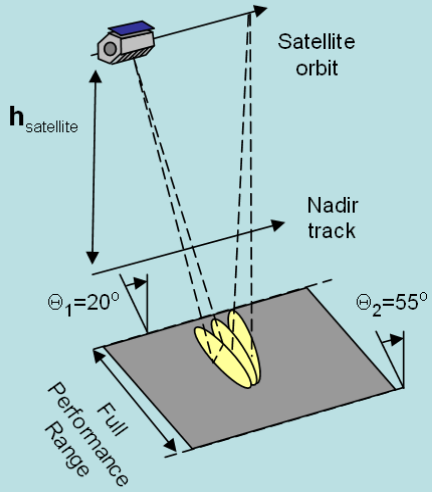
Sea Ice

TerraSAR-X Nominal Imaging Modes



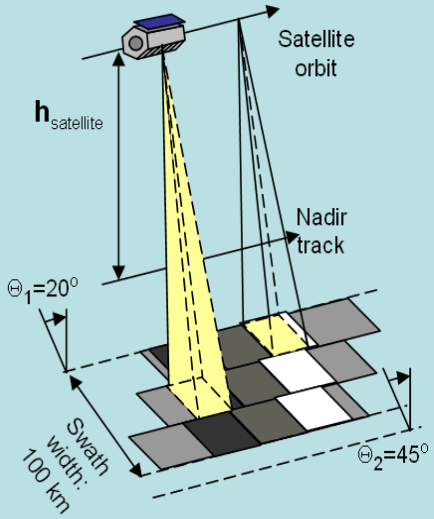
StripMap Mode

Resolution: 3 m ´ 3 m
Scene Size: 30 km ´ 50 km
[Range ´ Azimuth]
Coastal NRT < 20 min



SpotLight Mode

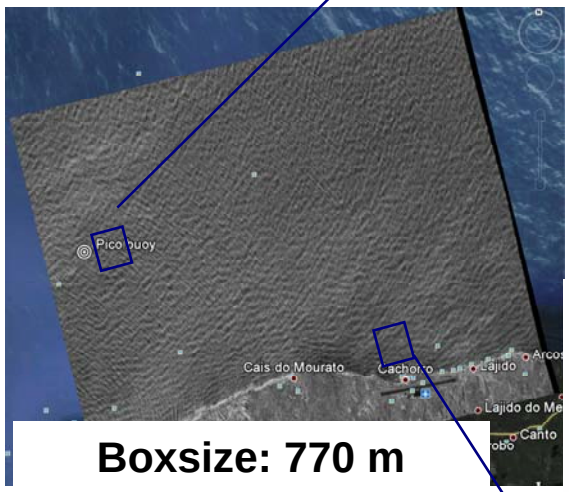
Resolution: 1 m ´ 1,5... 3,5 m
Scene Size: 10 km ´ 5...10 km
[Range ´ Azimuth]
Harbour, breakwaters, platforms



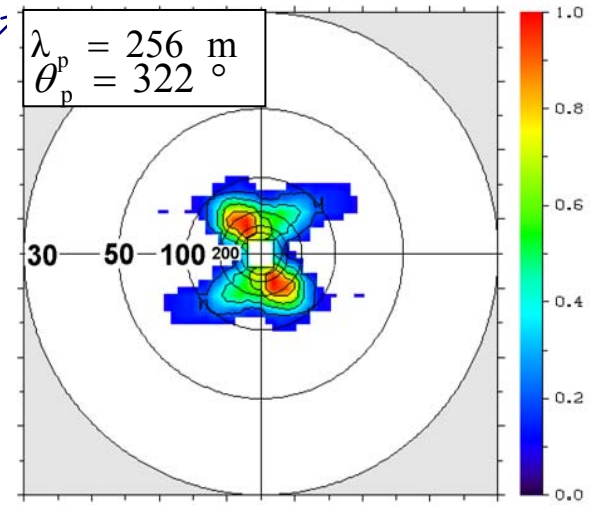
ScanSAR Mode

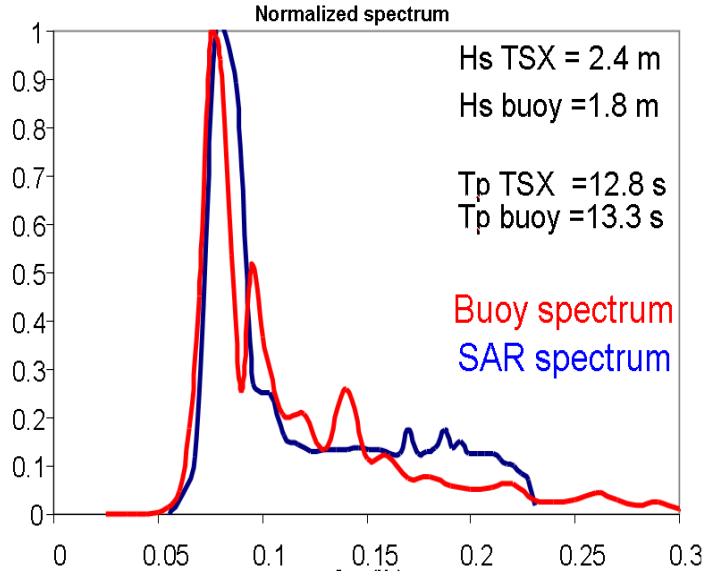
Resolution: 16 m ´ 16 m
Scene Size: 100 km ´ 150 km
[Range ´ Azimuth]
Ships , sea ice

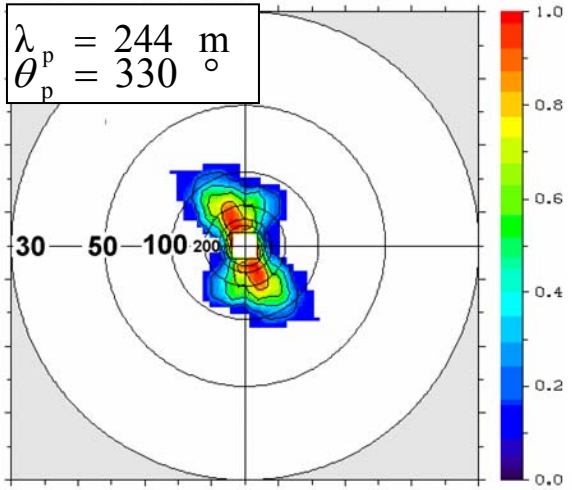
Pico island: Spotlight VV polarization, 27 March 2010 19:41

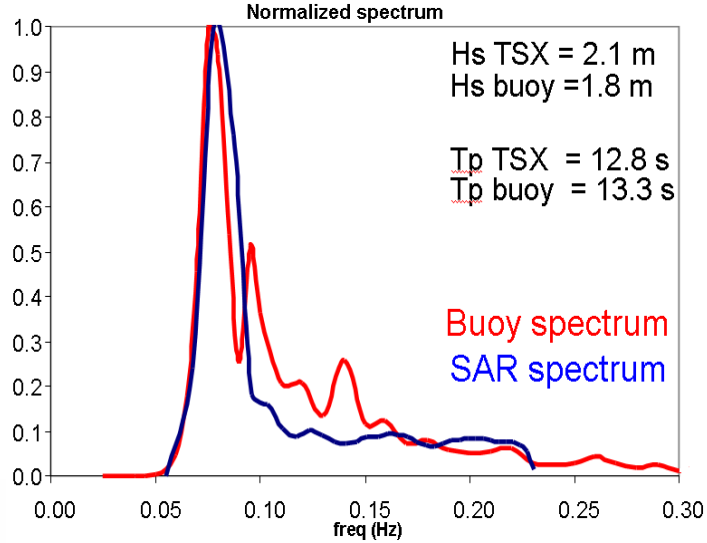


Boxsize: 770 m

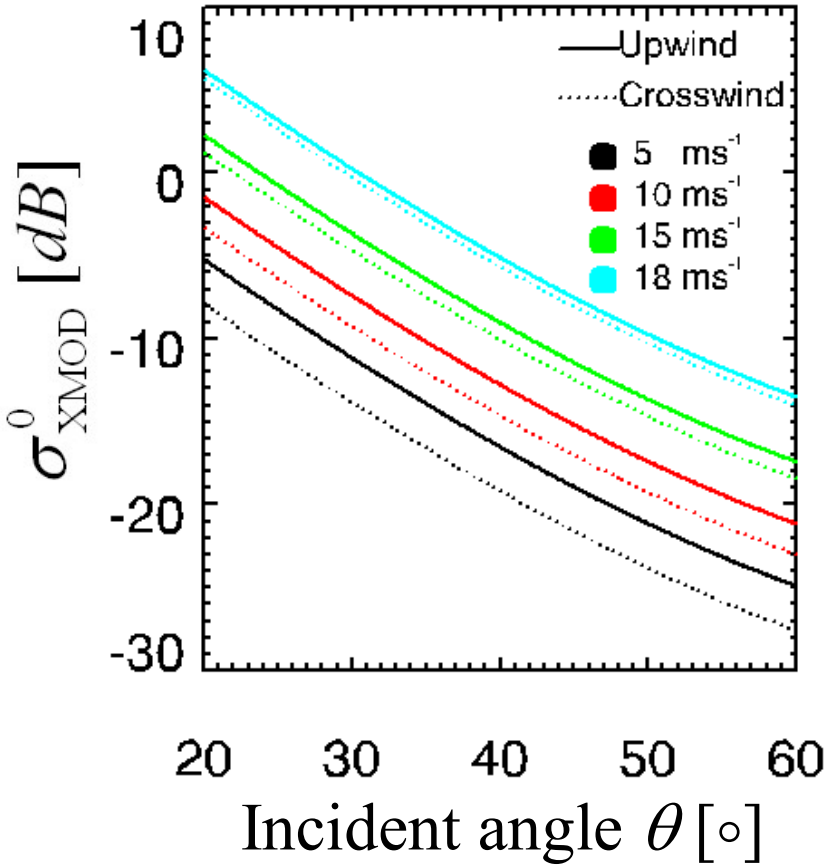


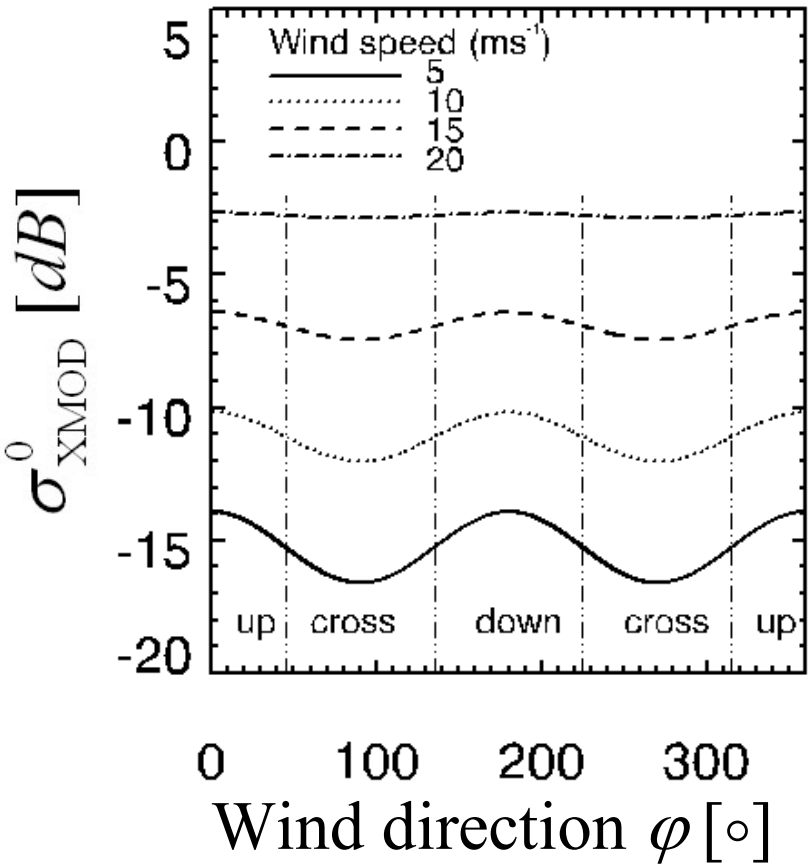






Wind Field Algorithm XMOD 1.0





NRCS by XMOD dependent on
Incidence angle and wind direction (at angle of 35°).

Y. Ren et al IJRS, PORSEC 2010

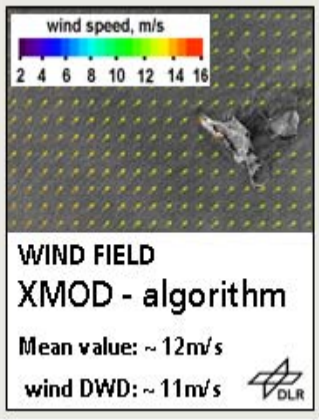
Implementierung aus SAR abgeleiteter Parameter in numerische Seegangsmodelle

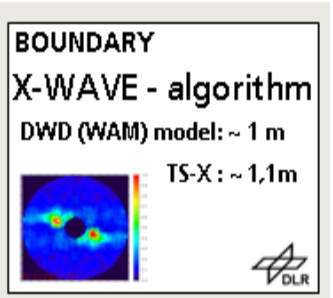
TerraSAR-X Szene

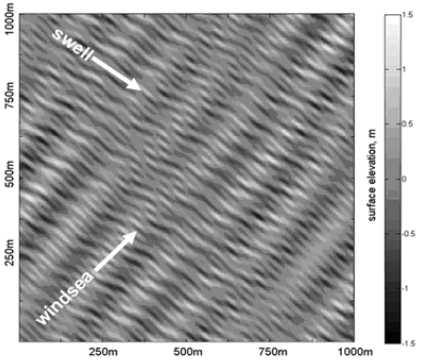
Wind und Randwerte

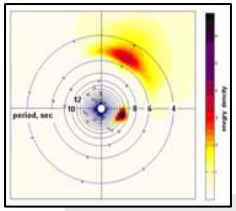
Topographie und Seegangsmodell

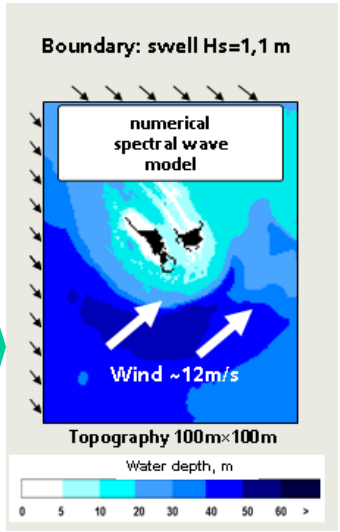
Seegangsmodel Ergebnisse

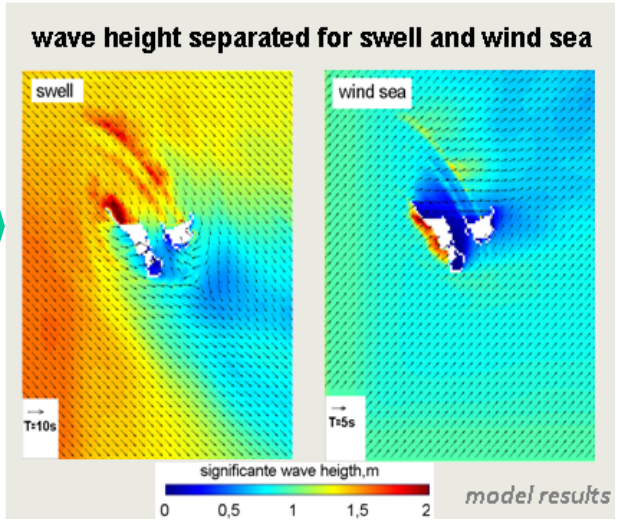








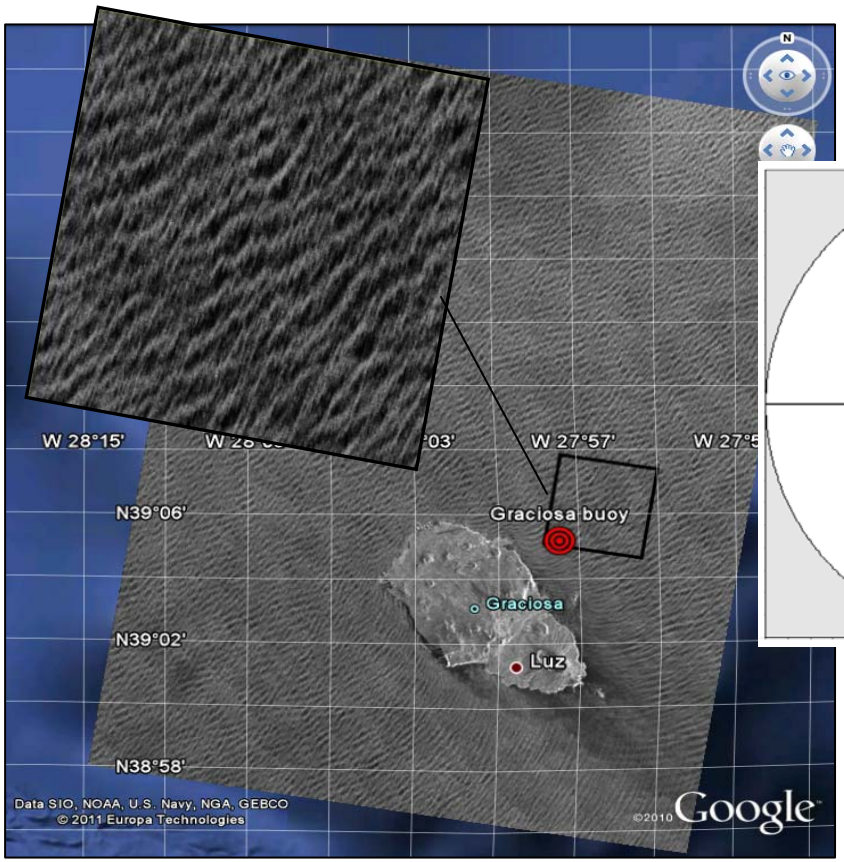


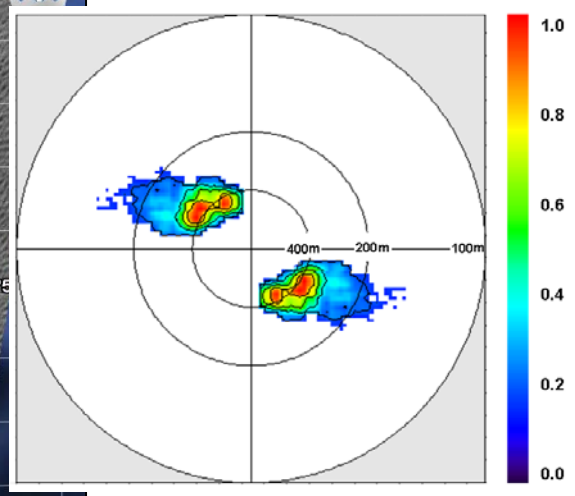


Randspektrum aus zwei Teilen:
- Dünung (XWAVE)
- Windsee (JONSWAP)

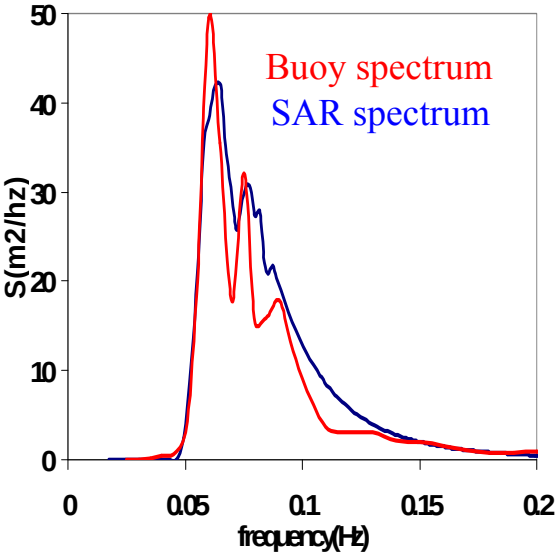
Windfeld: XMOD Algorithmus
Seegang: XWAVE Algorithmus

Graciosa island: Stripmap VV polarization February 13, 2011





2 D spectrum



1 D spectrum

2011-02-13	H_s (m)	T_p (s)	T_{02} (s)	T_{-10} (s)	θ_m (°)
Buoy 8:39	4.8	15.4	9.7	12.9	341
TSX 7:55	5.2	15.4	7.4	13.5	310