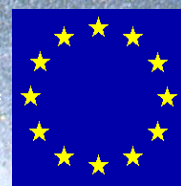
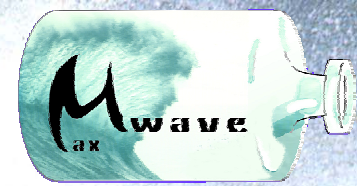
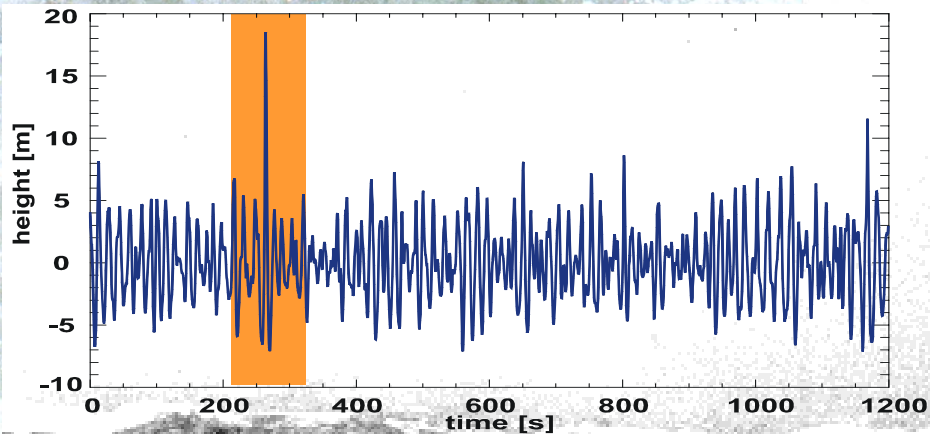


Radar Remote Sensing of the Sea Surface

Susanne Lehner



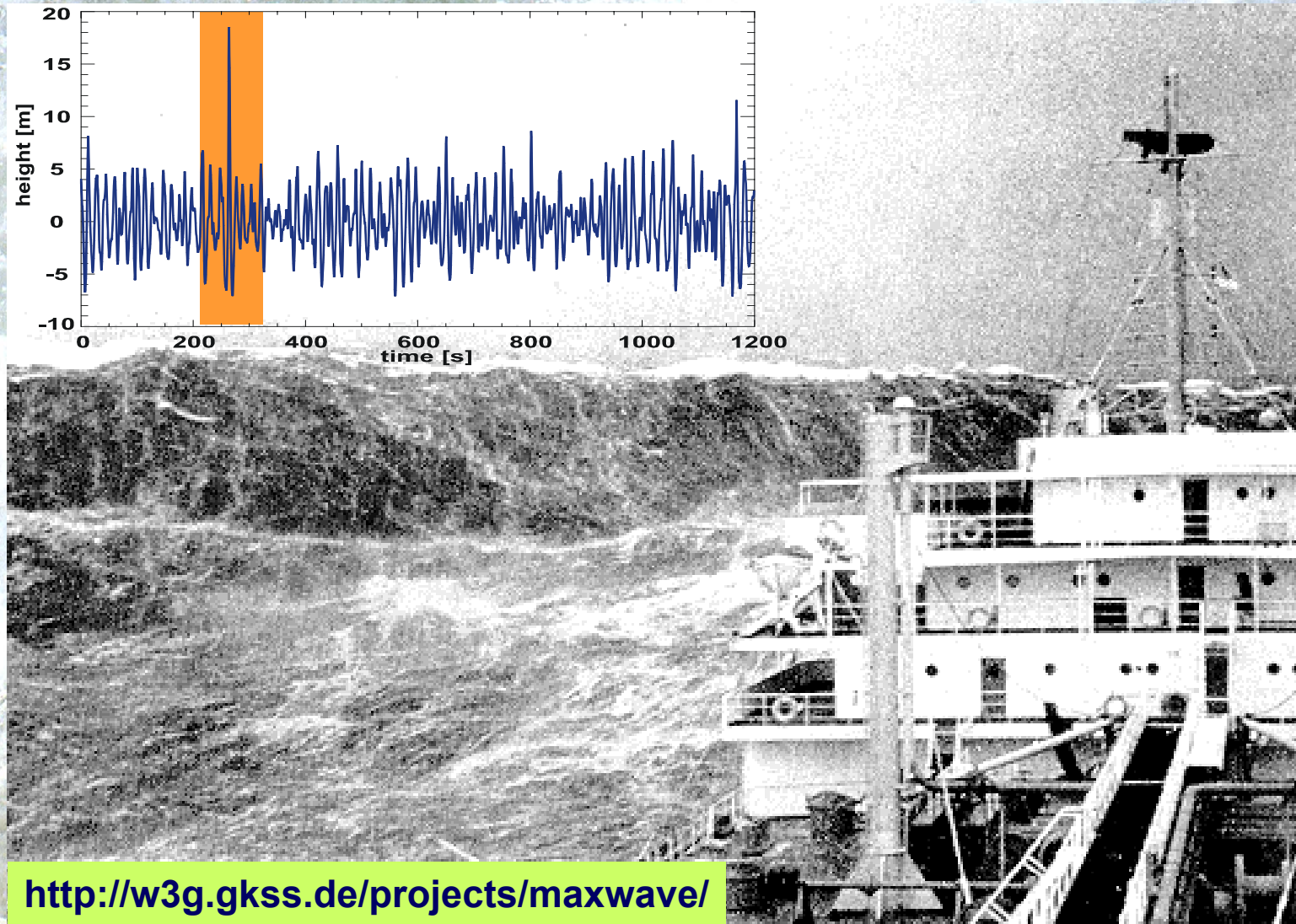
Forecasts and Statistics of Rogue Waves using Radar Data

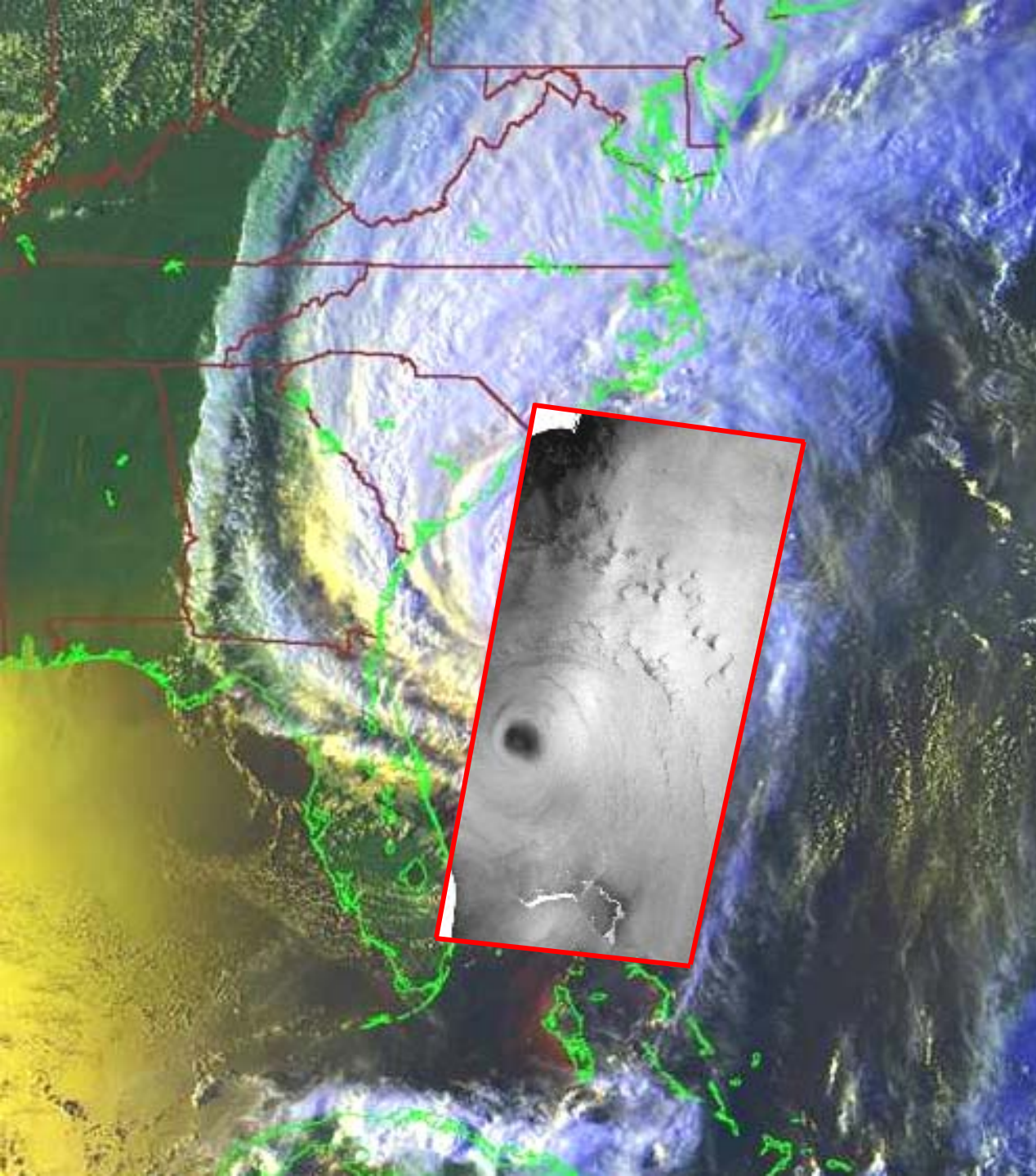


Partners:

- GKSS
- DLR
- DNMI
- DNV
- IST
- K.U. Leuven
- MeteoF
- OSW
- TU Berlin
- UKMet

<http://w3g.gkss.de/projects/maxwave/>



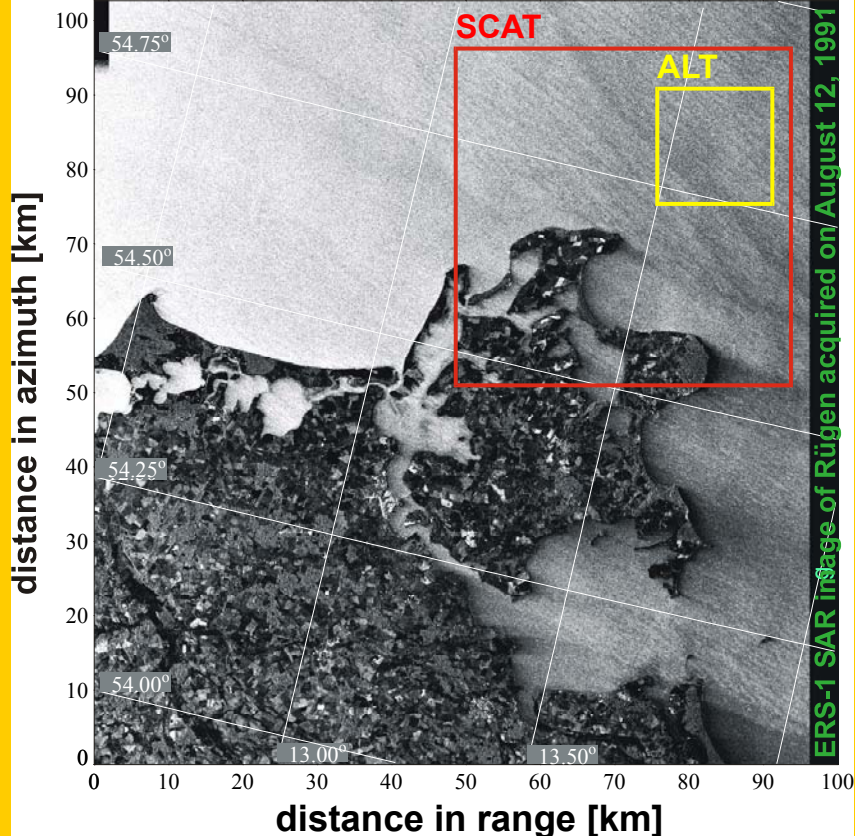
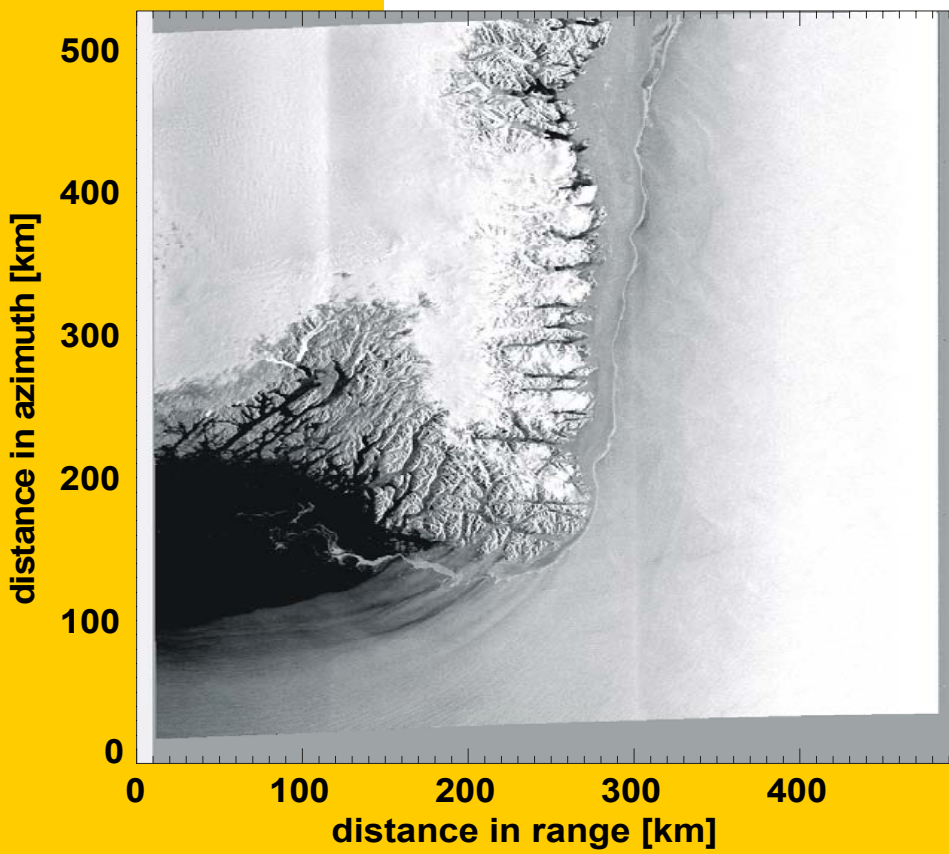
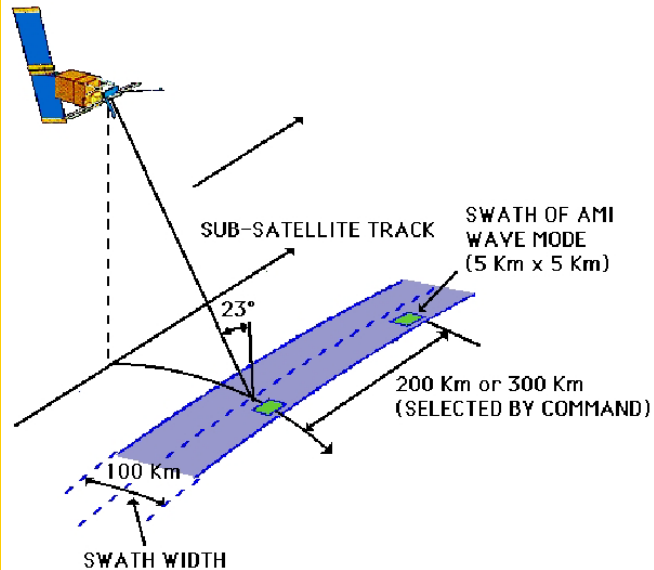


Hurricane Floyd
AVHRR NOAA-12
RADARSAT-1
ScanSAR
Sep 15, 1999



Vachon et Katsaros 2000

Synthetic aperture radar data



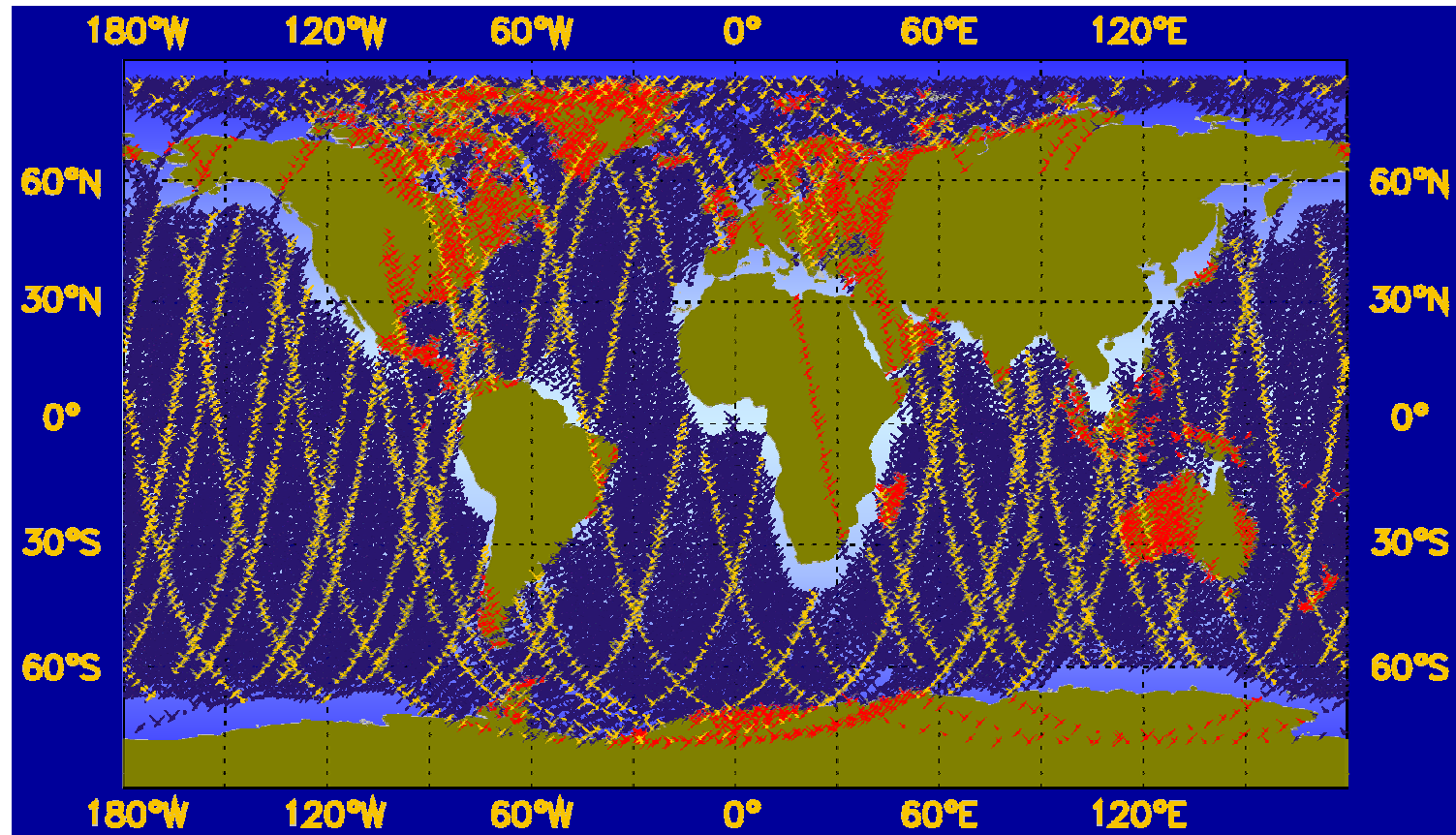
ERS-1 SAR image of Rügen acquired on August 12, 1991

Sensor: ERS-2 Processor: BSAR@IMF © ESA/DLR 2000

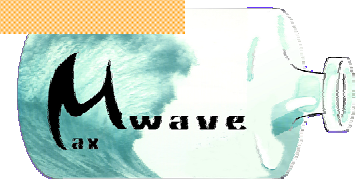
Raw Data ID: MSL08582-3-1-143
 UTC Time: 01-SEP-1998/23:51:04
 Coordinates: N 34.71° / W 22.92°
 Processing Date: 19-JUN-2000

Flight North

Global wave mode data



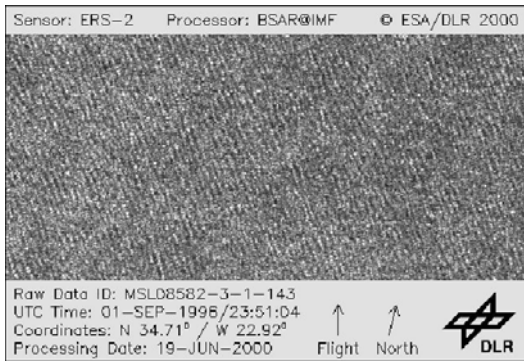
- 27 days of ERS-2 SAR imagerettes (34 310)
- Co-located to ERS-2 SCAT wind data
- Co-located to ECMWF Wind forecasts
- Co-located to ECMWF Wind analysis



ENVISAT cross spectra versus ERS wave mode data

Simulated ENVISAT wave mode data

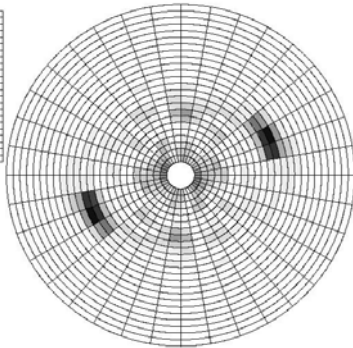
Imagette



Real part

wavelength [m]

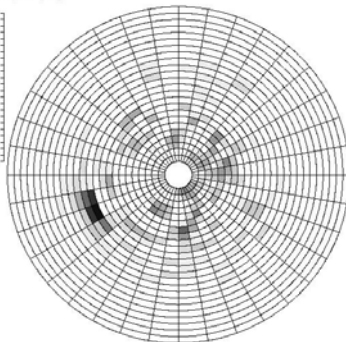
23.
33.
46.
65.
92.
130.
183.
257.
363.
511.
721.
1015.



Imaginary Part

wavelength [m]

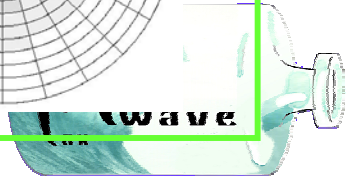
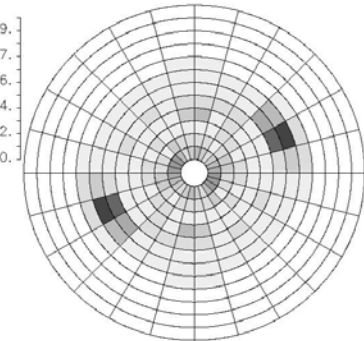
23.
33.
46.
65.
92.
130.
183.
257.
363.
511.
721.
1015.



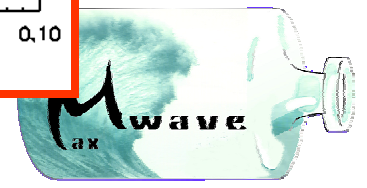
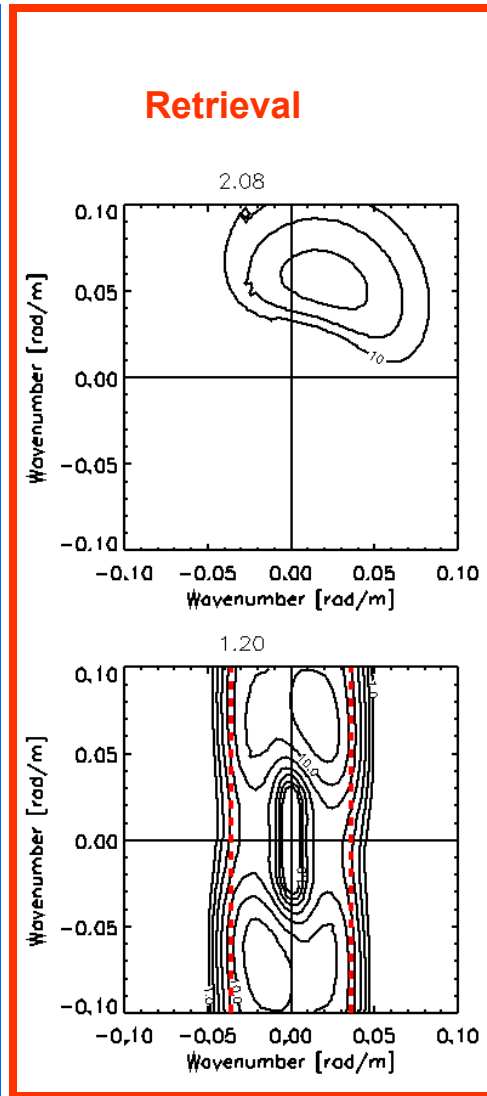
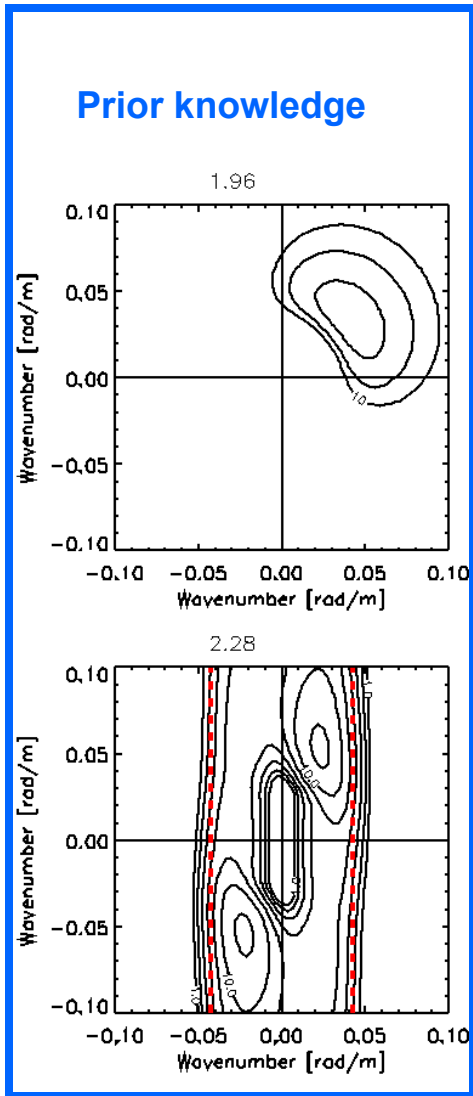
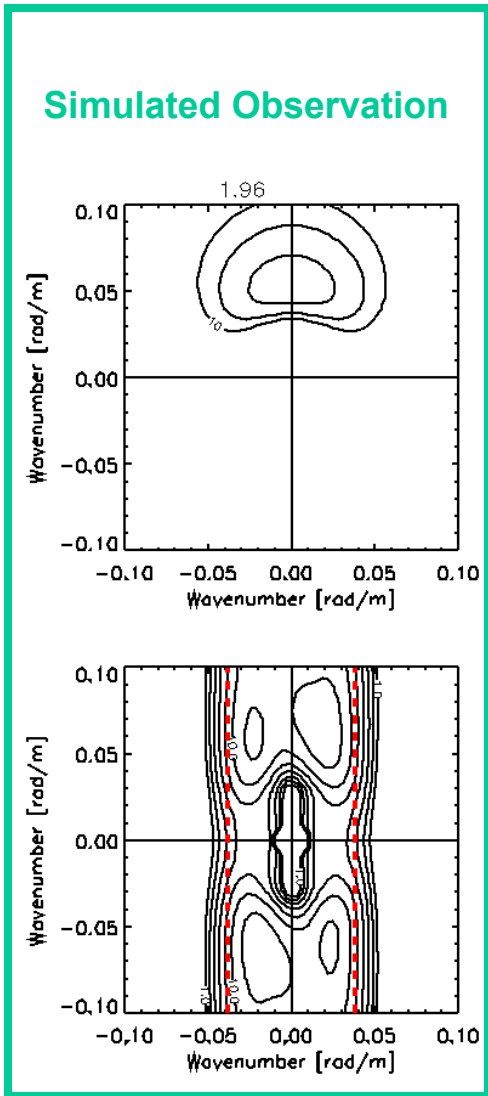
ERS UWA spectrum

wavelength [m]

109.
207.
306.
404.
502.
600.



Test of inversion scheme using simulated observations



5 x 10 km wave mode imagettes

70601163033

70601163504

70601163935

70601164405

70601170235

70601170706

70601171207

70601171637

70601172108

70601174047

70601174518

19970601163534

19970601164005

19970601164435

19970601170305

19970601170736

19970601171237

19970601171707

19970601172138

19970601174117

19970601174548

19970601163604

19970601164035

19970601164506

19970601170335

19970601170806

19970601171307

19970601171738

19970601172208

19970601174147

19970601174618

19970601163634

19970601164105

19970601164536

19970601170405

19970601170836

19970601171337

19970601171738

19970601172238

19970601174217

19970601174718

19970601163704

19970601164135

19970601164606

19970601170435

19970601170906

19970601171407

19970601171738

19970601172238

19970601174247

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19970601163734

19970601164205

19970601164636

19970601170505

19970601170936

19970601171437

19970601171738

19970601172238

19970601174318

19970601174818

19970601163804

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19970601171738

19970601172238

19970601174348

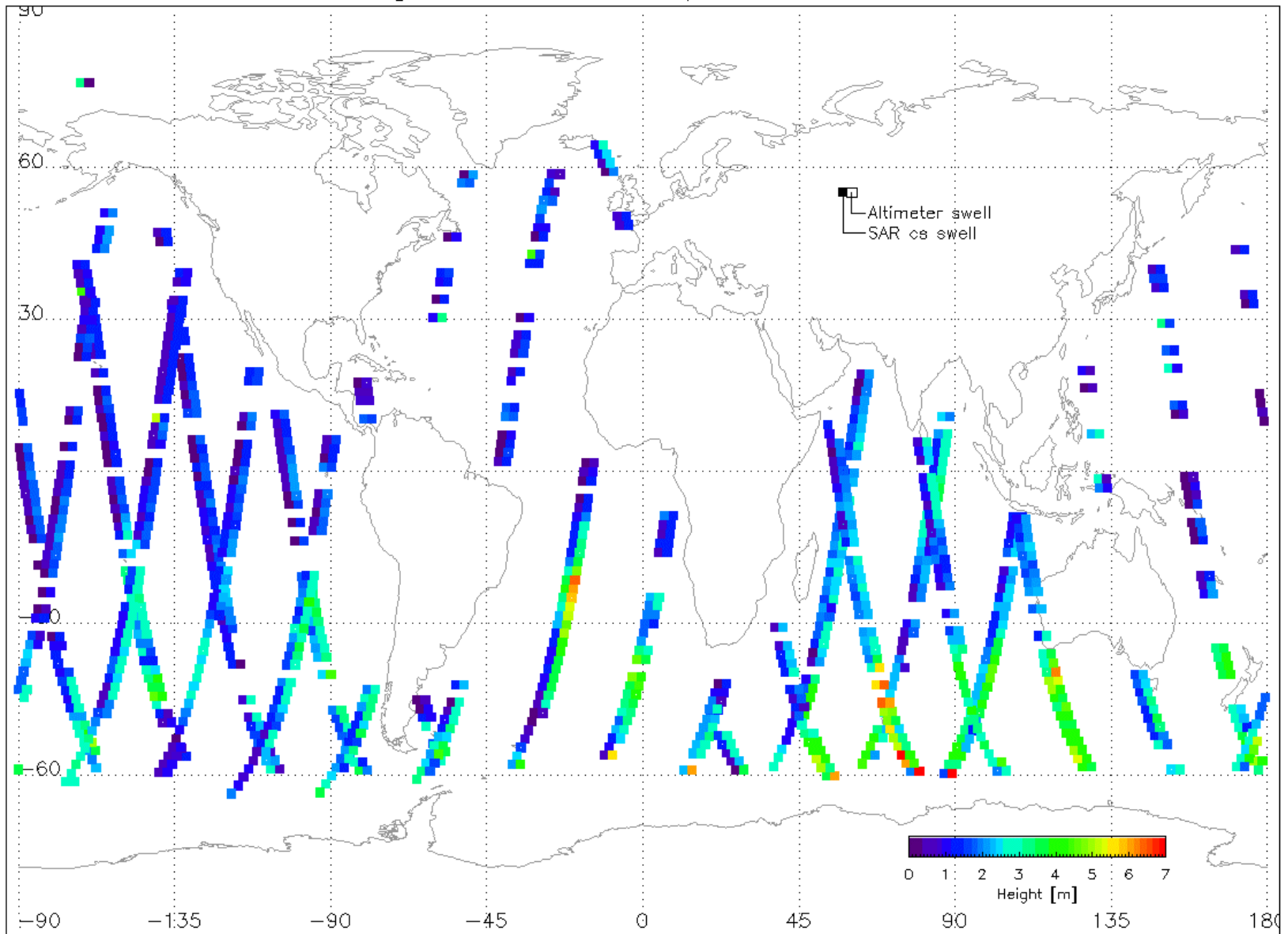
19970601174849

Radar ASAR

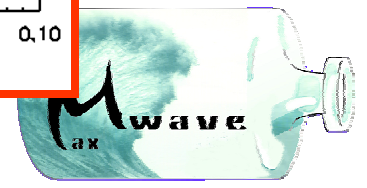
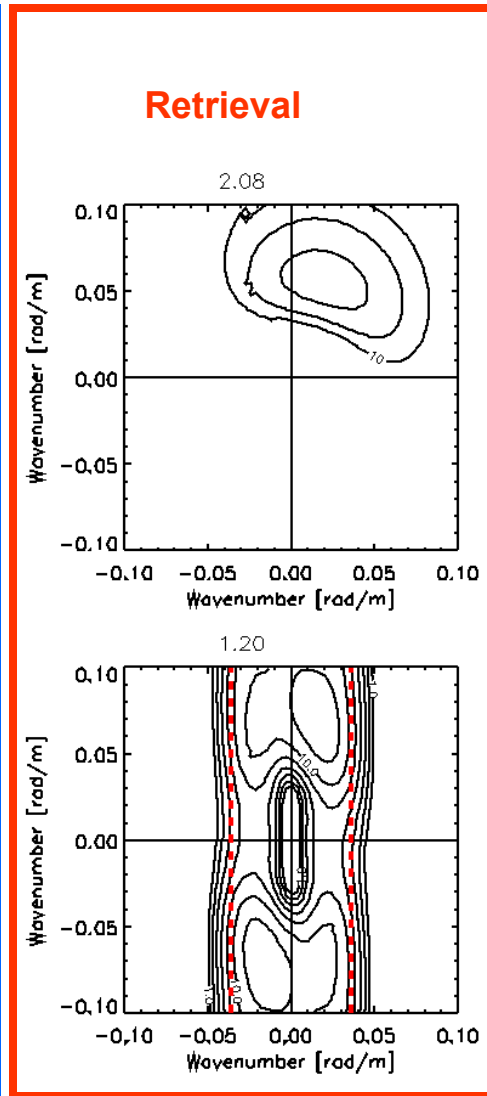
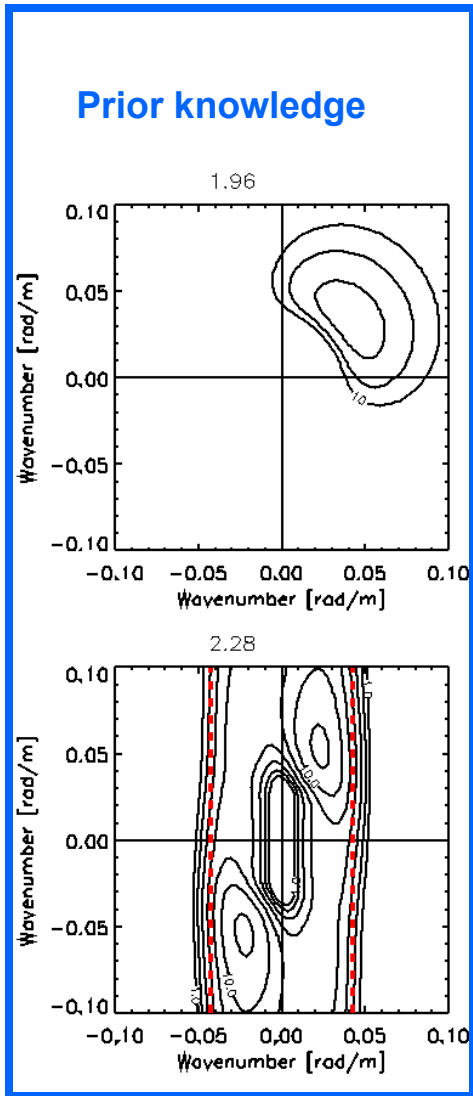
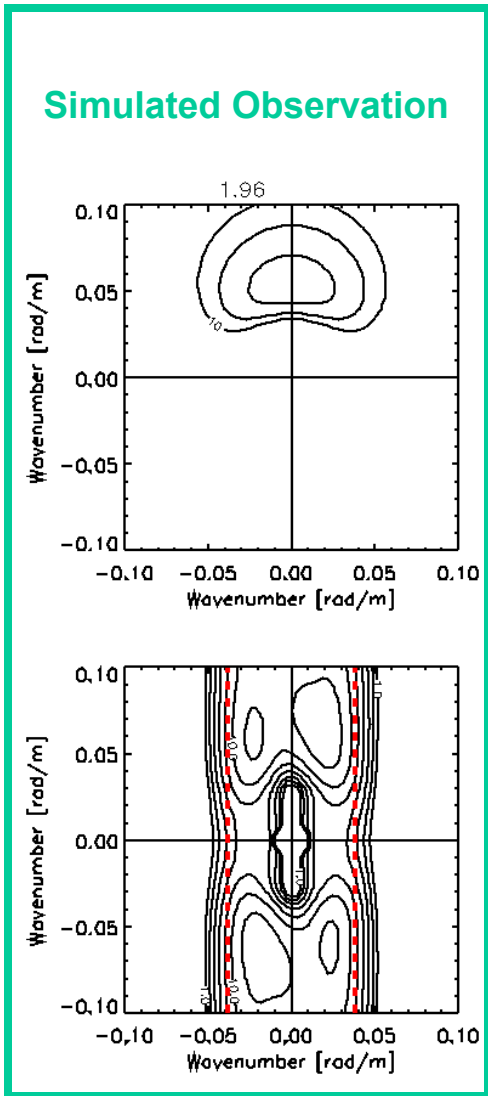
Wind / Sea State

From India to Antarctica June 1, 1997

August 22, 1996 – Comparison SAR to RA



Test of inversion scheme using simulated observations

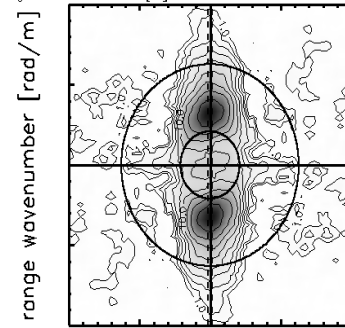


Comparisons of radar and model data sets

- Example

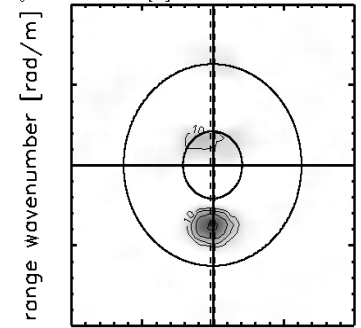
- Inconsistency between SAR observation and WAM forward simulation
- Wave length 233 m / 142 m
- Wave direction 284° / 104°

lat: -38.2 lon: 351.5 date: 19960821102313
heading: 194.0 cut-off [m]:4168.3



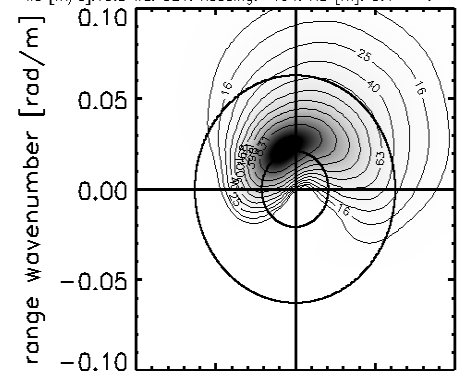
-0.10 -0.05 0.00 0.05 0.10
azimuth wavenumber [rad/m]

lat: -38.2 lon: 351.5 date: 19960821102313
heading: 194.0 cut-off [m]:4168.3

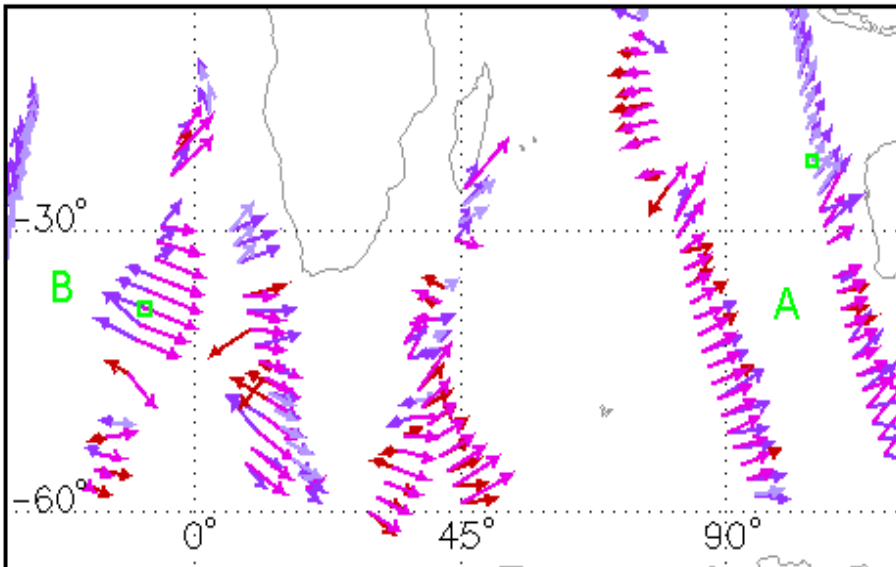


-0.10 -0.05 0.00 0.05 0.10
azimuth wavenumber [rad/m]

lat: -38.2 lon: 351.5 date: 19960821120000
ws [m/s]:13.5 wd: 321. heading: 194. HS [m]: 5.4



-0.10 -0.05 0.00 0.05 0.10
azimuth wavenumber [rad/m]



Wave length [m]
colorcoded

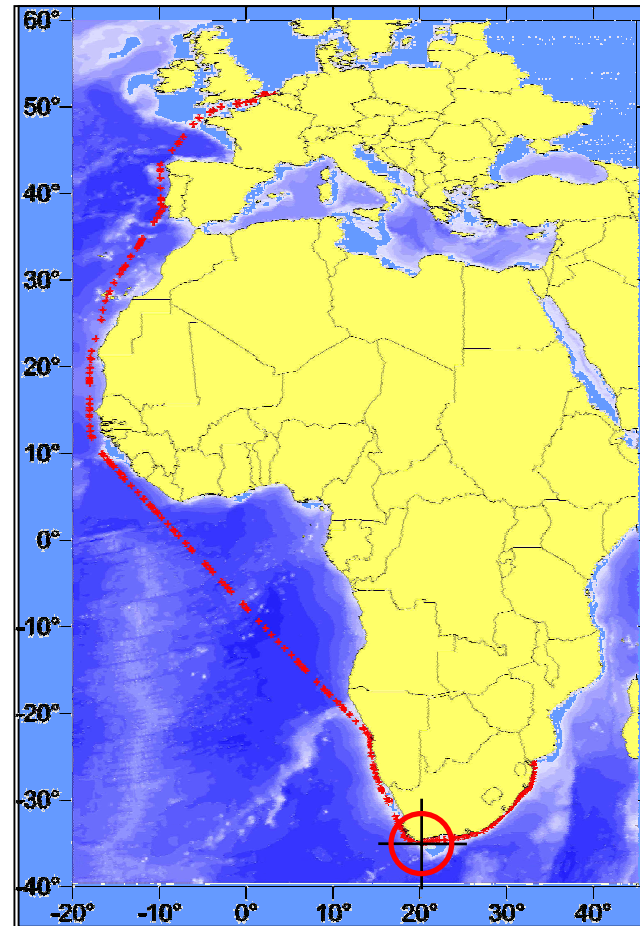
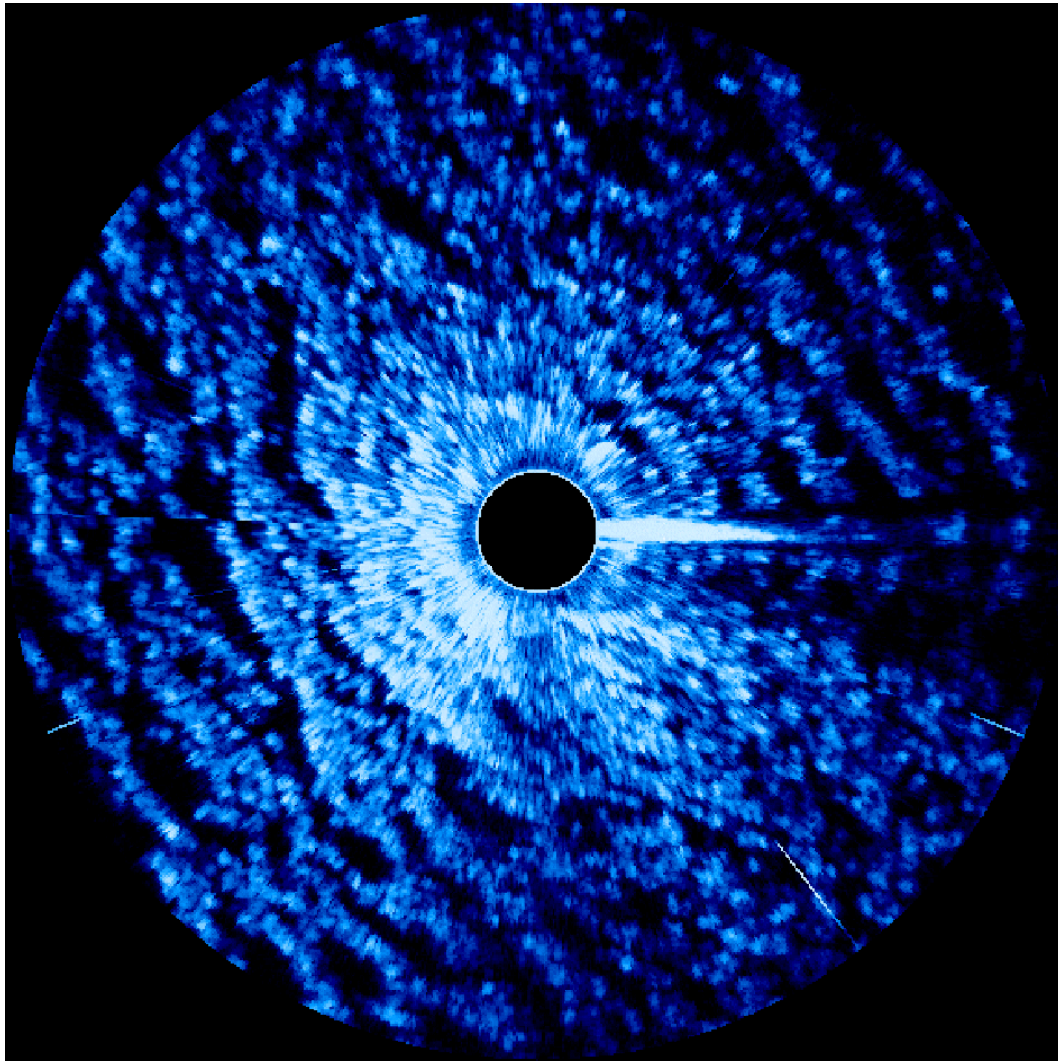
—→ < 20
—→ < 50
—→ > 50

SAR cs WAM forw.

Standard deviation

0 10 20

WAMOS measurements on GreyFox



Parameters Determined :

Hs – 2D wave spectra –

Operational, commercially available, certified

Wind Speed and Direction

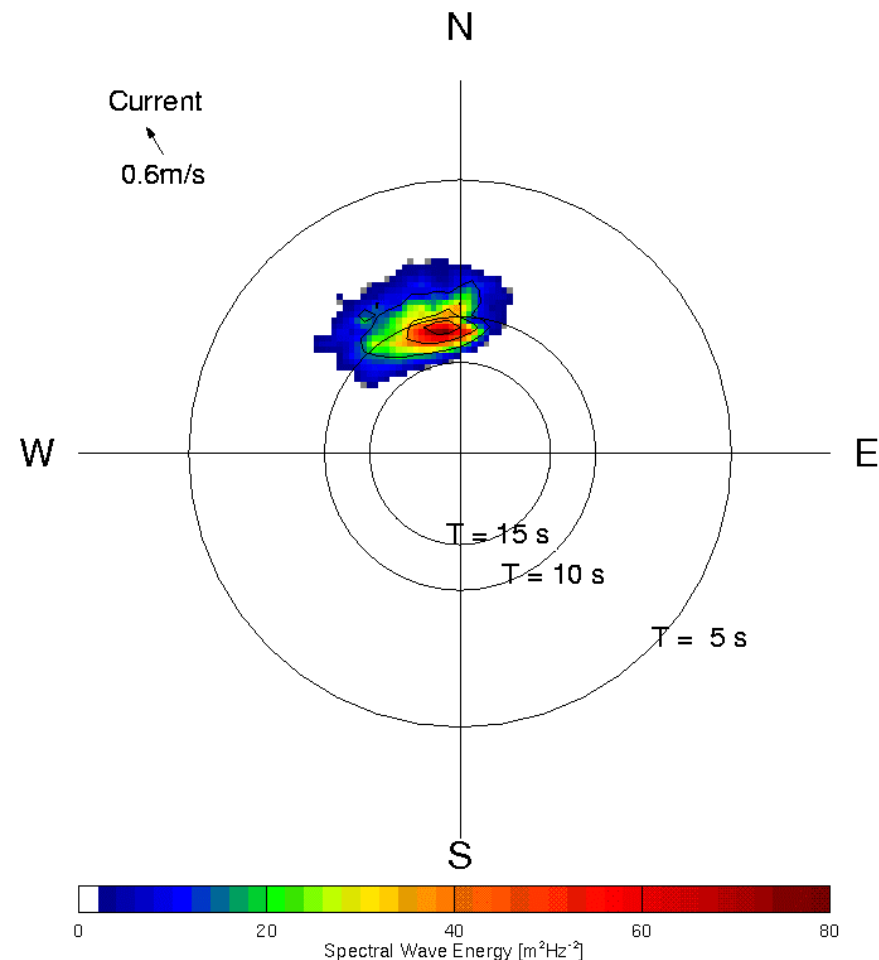
New – image information:

Single wave detection

Wave Height - Extreme Waves

Groupiness

Crest Length



New Algorithms for WAMOS/SAR :

Inversion Methods

For individual wave height from radar intensity

Wavelet Methods

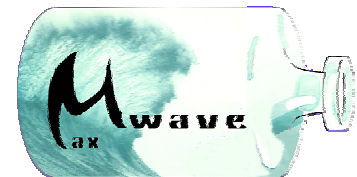
for single wave detection, groupiness, crest length

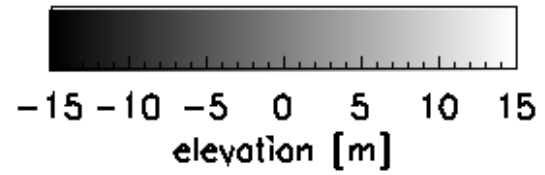
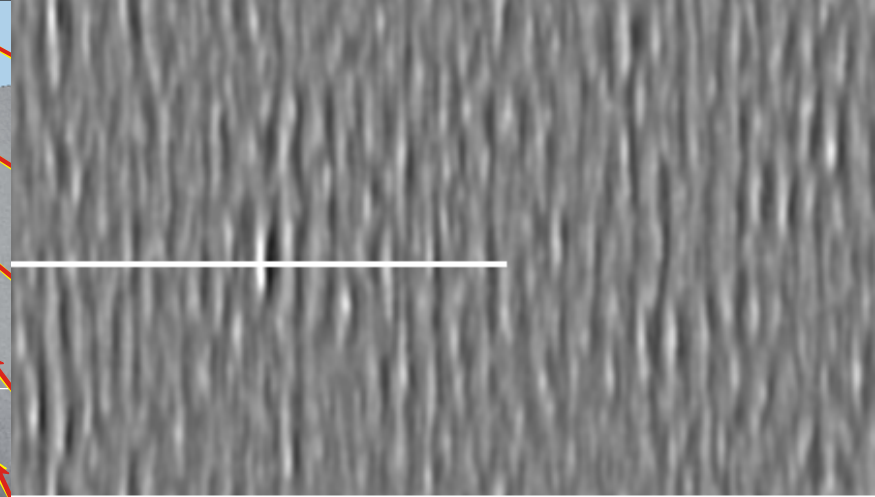
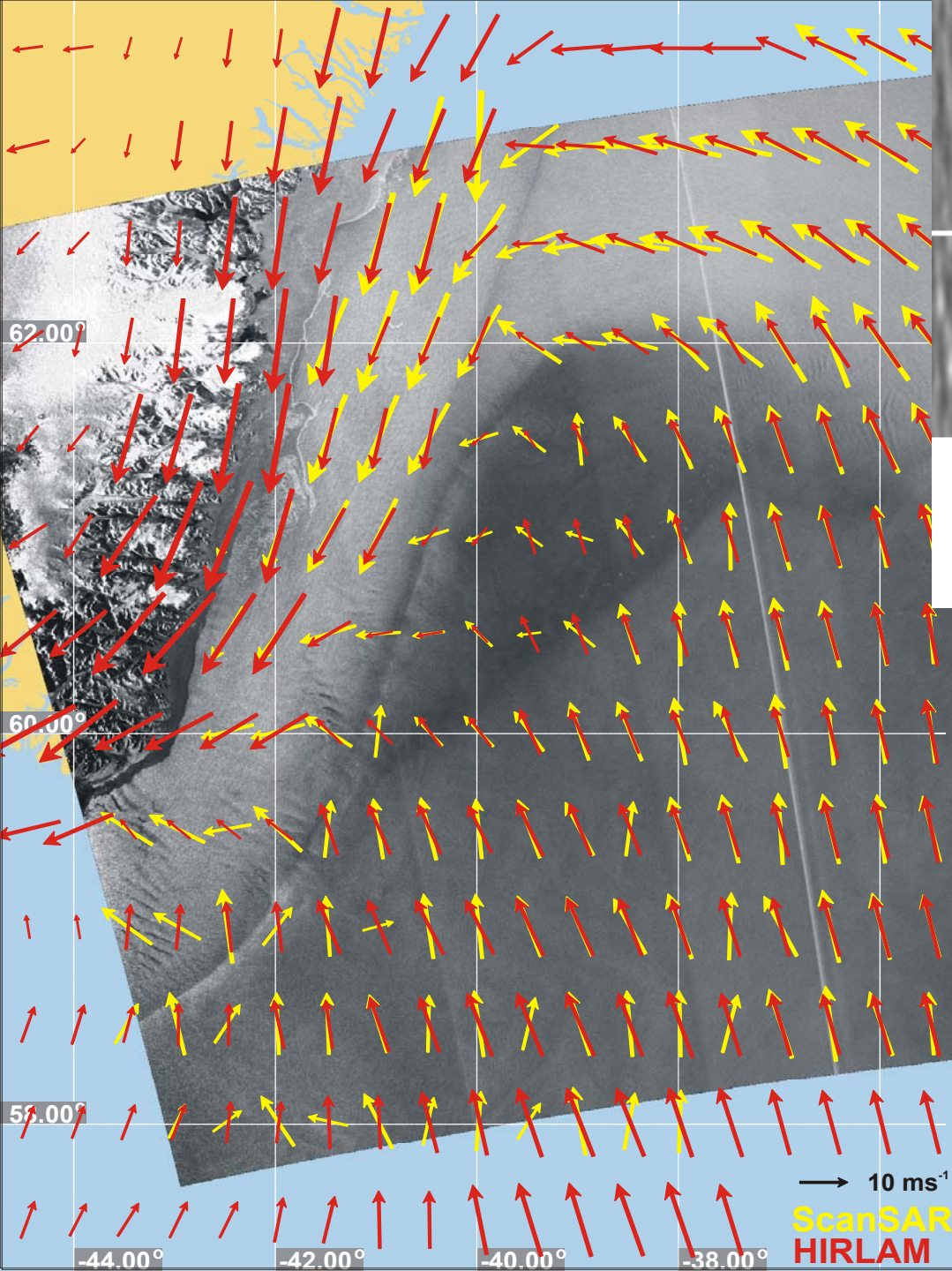
Hilbert Transformation

for determination of the envelope, groupiness,
individual instantaneous wave height

Gradient Methods, CMOD

Windfields



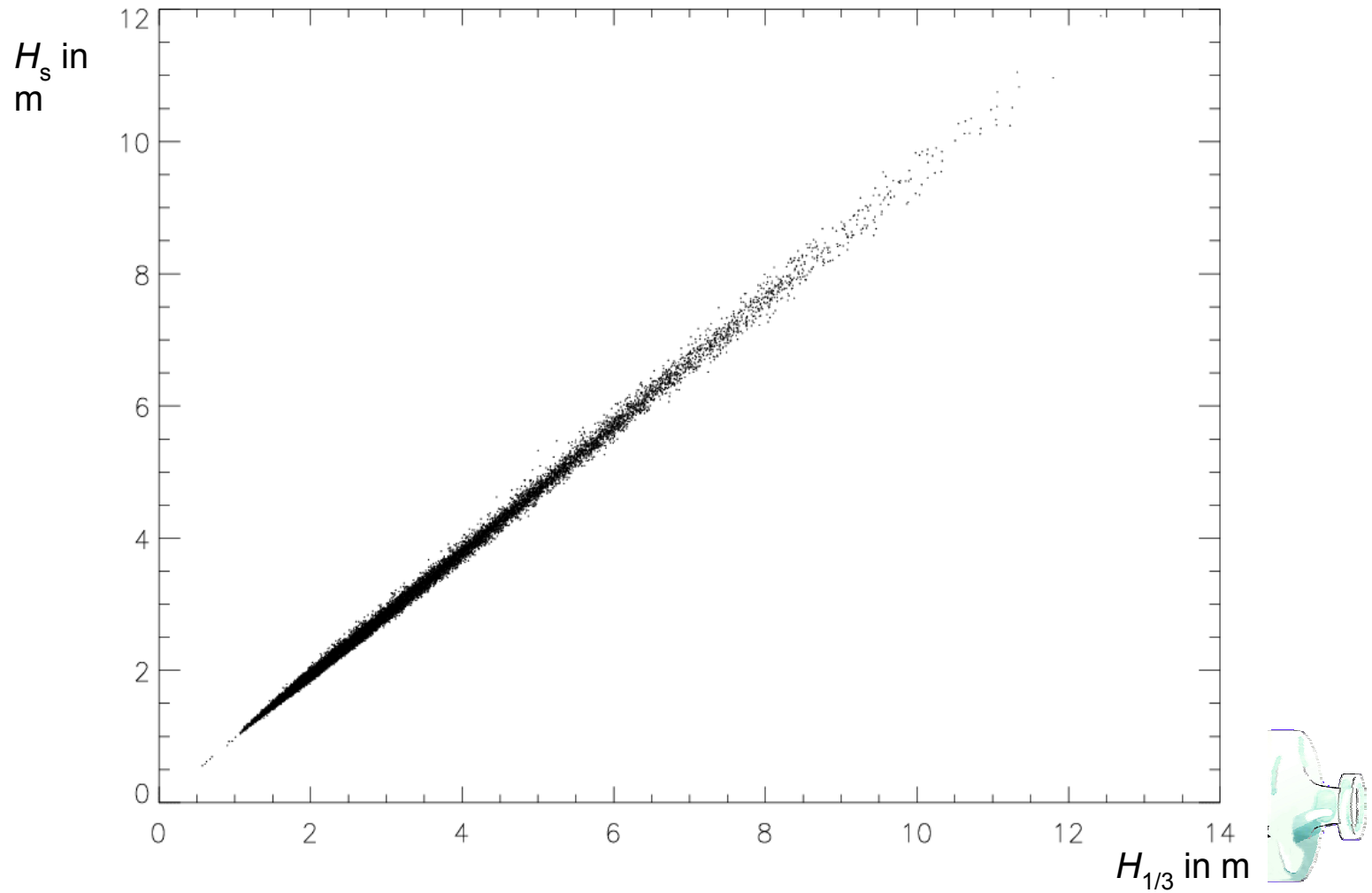


Satellites/Instruments

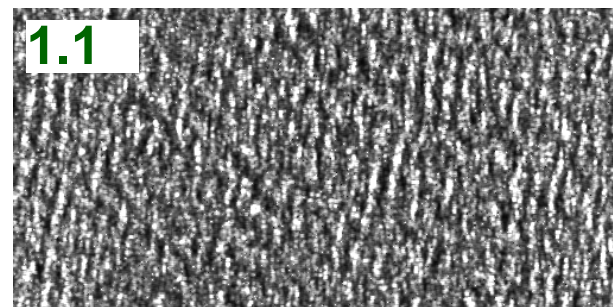
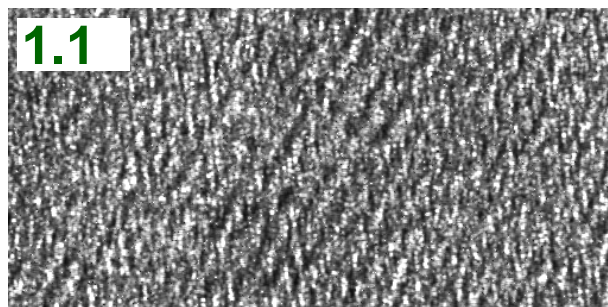
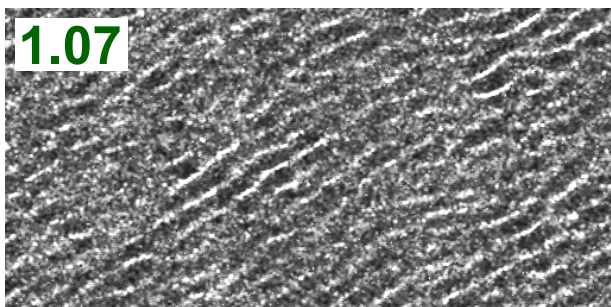
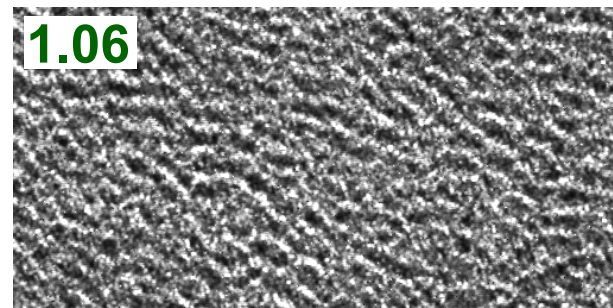
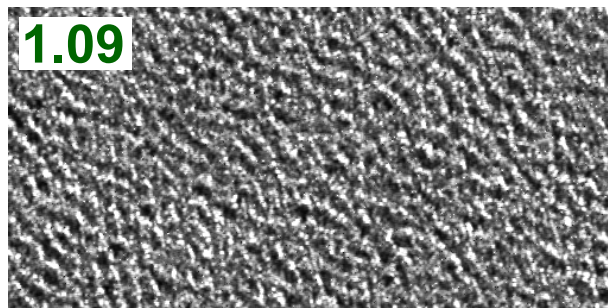
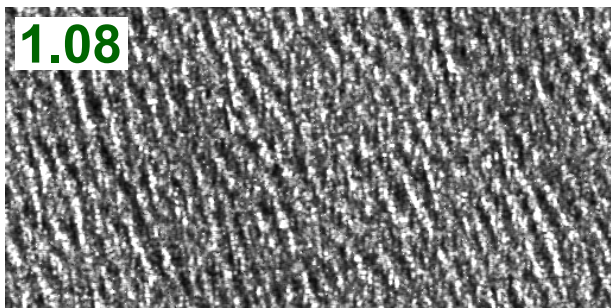
- ERS 1/2
- ENVISAT
- RADARSAT
- TERRA SAR



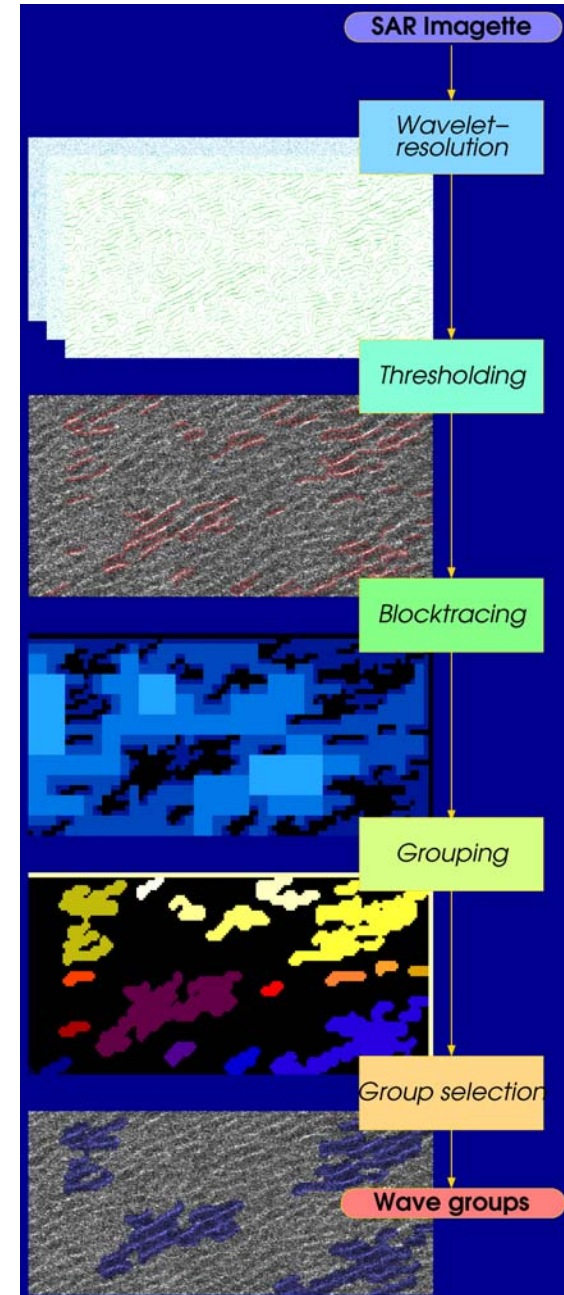
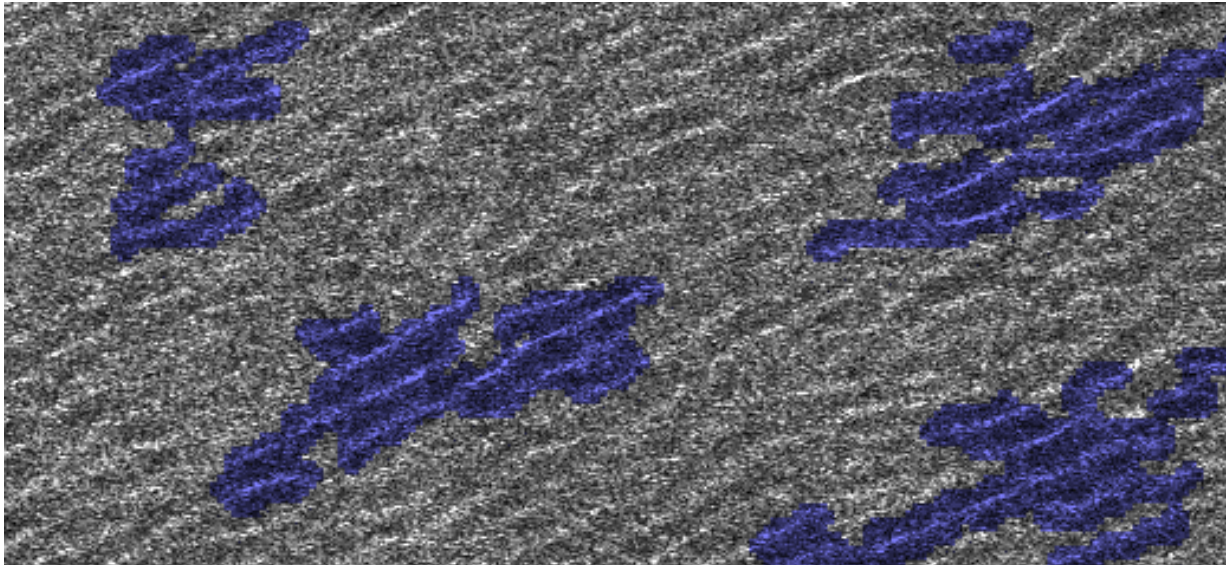
Correlation $H_{1/3}$ to H_s



Inhomogeneous wave fields

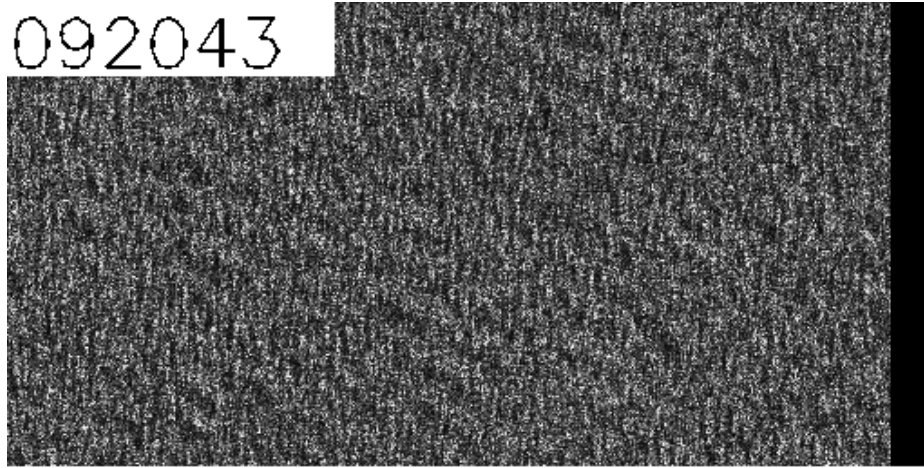


Groupiness

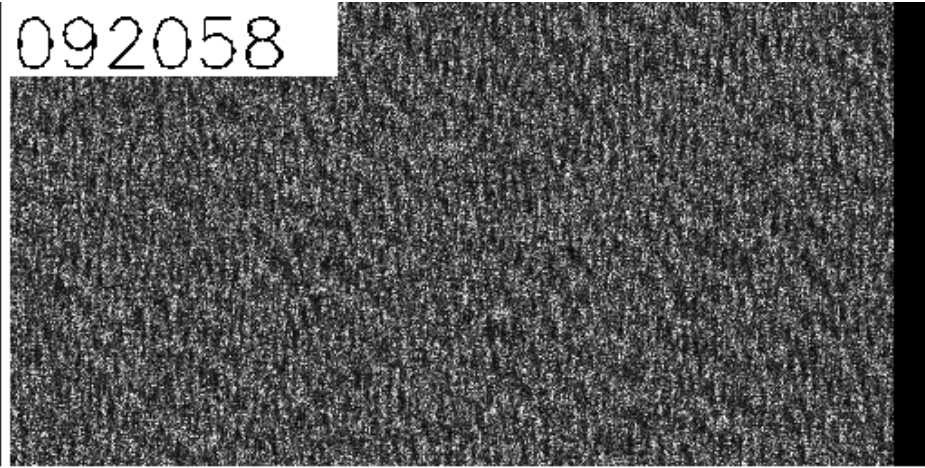


Future: Daily ENVISAT Imagerettes

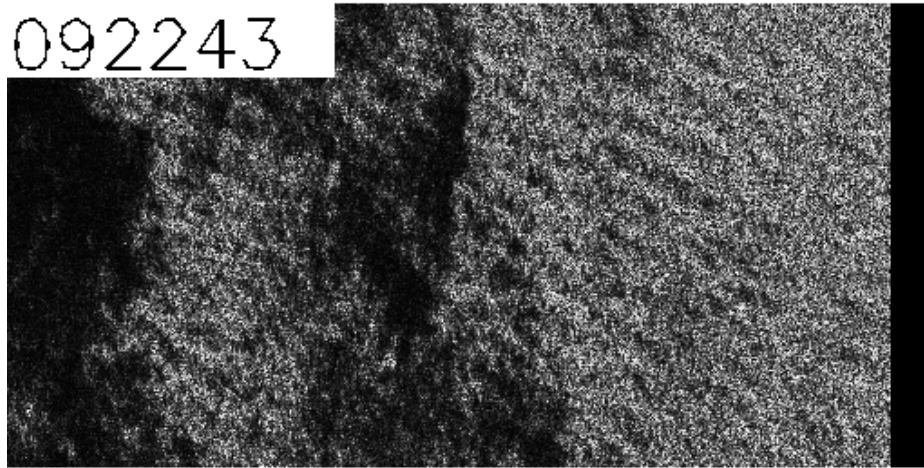
092043



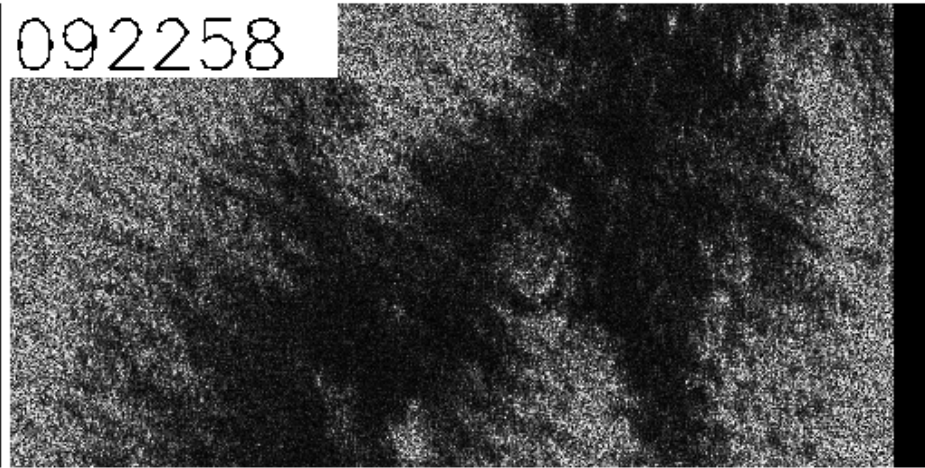
092058



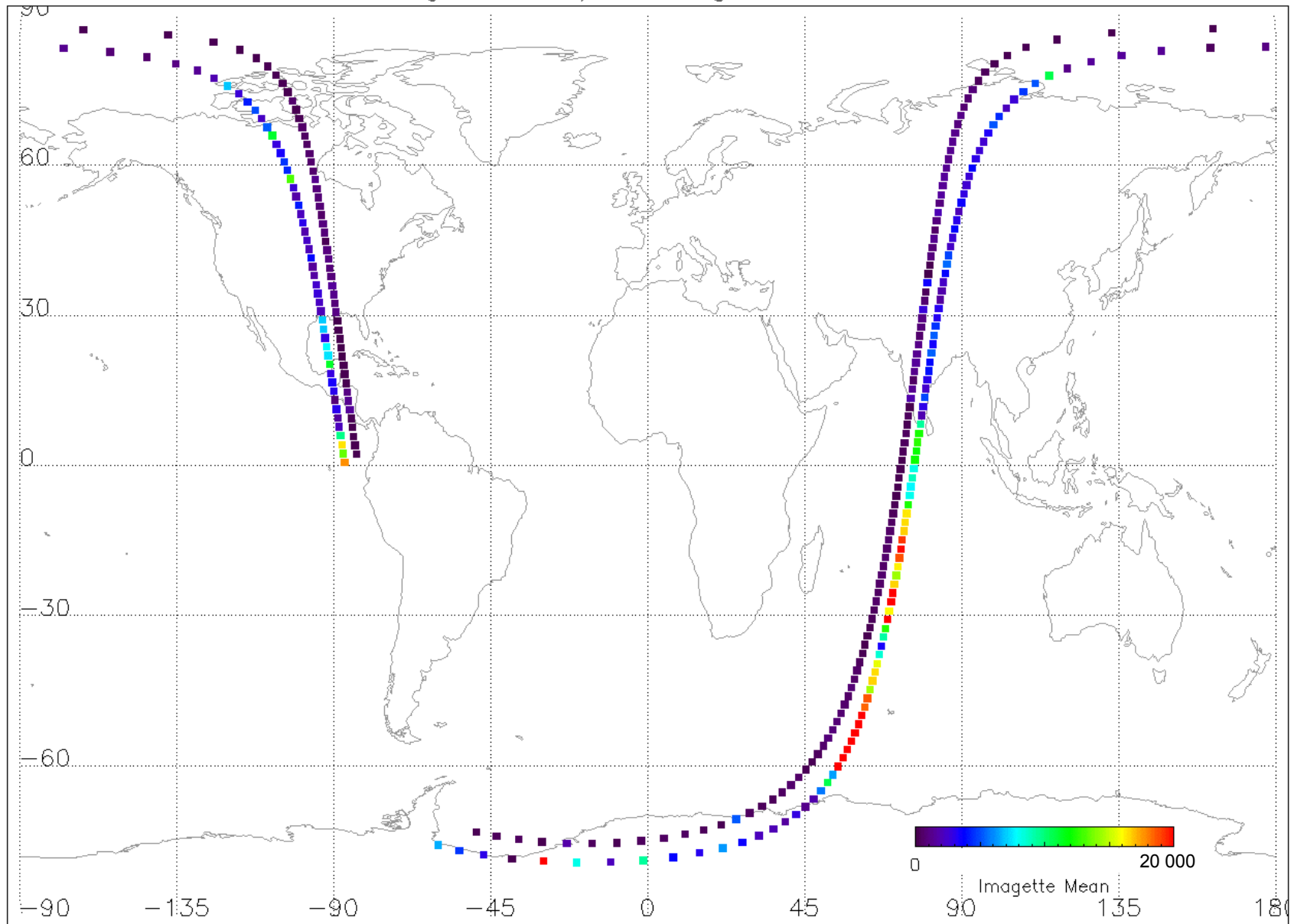
092243



092258



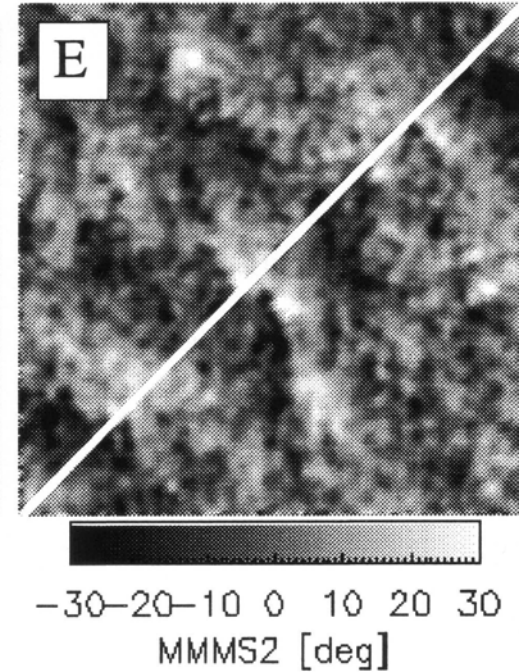
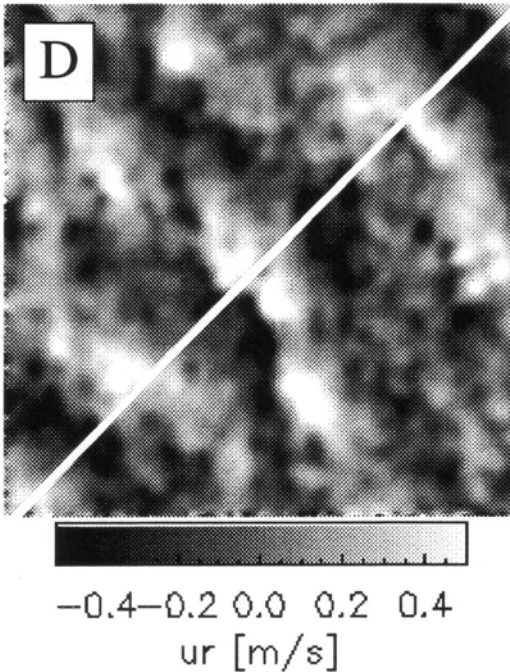
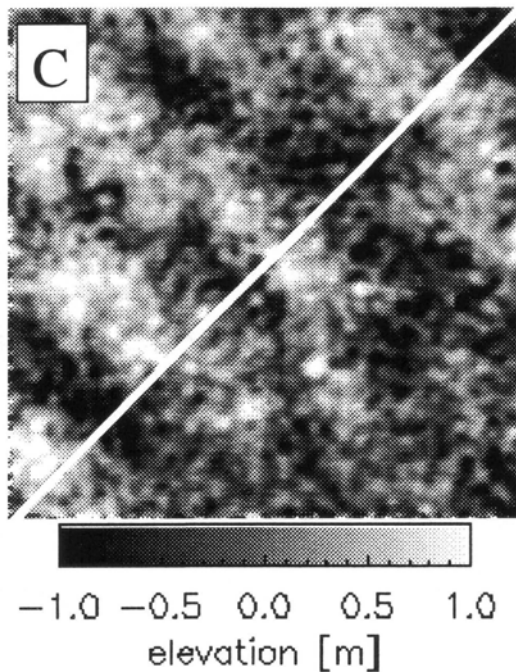
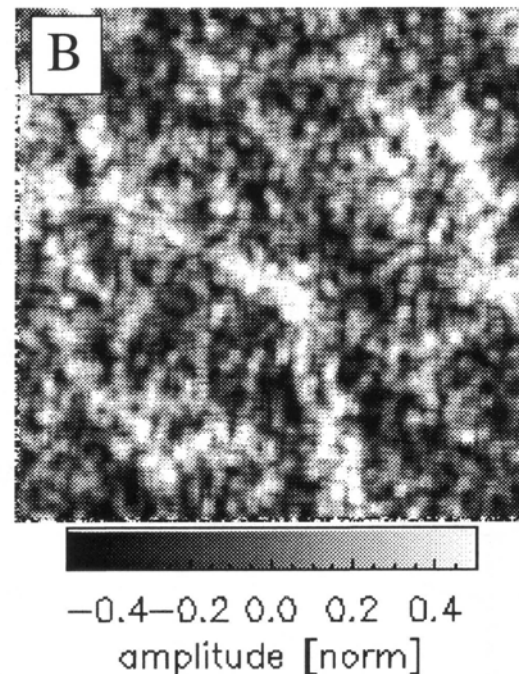
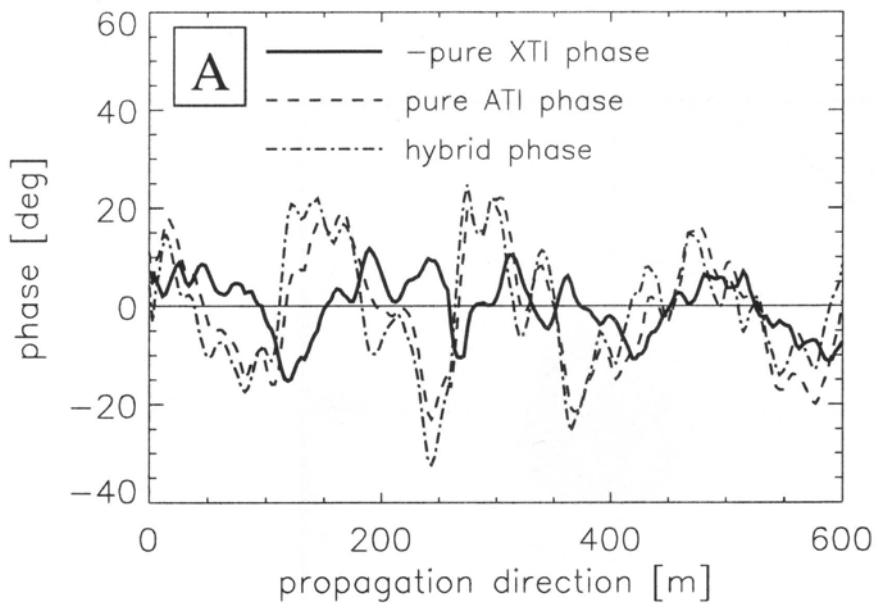
ENVISAT imagettes IS1/IS7, August 3, 2002, 3:55 UT



Radar Measurements of Extreme Waves

Gijon Experiment , 9.11.2000





Altimeter :

Conclusions:

Joint evaluation altimeter T_p – SAR swell

Individual return pulse

Satellite Radar:

RADARSAT/ENVISAT Hurricane/Tropical Storms

ERS1/2 wave mode global 5x10km - 10 years

New: ENVISAT data - daily – Hogben Radar Atlas

Cryosat for ocean waves?

TerraSAR, coastal studies

SWIMSAT

Airborne interferometric Radar: Gijon Experiment

Joint evaluation wave height - orbital velocity, currents

