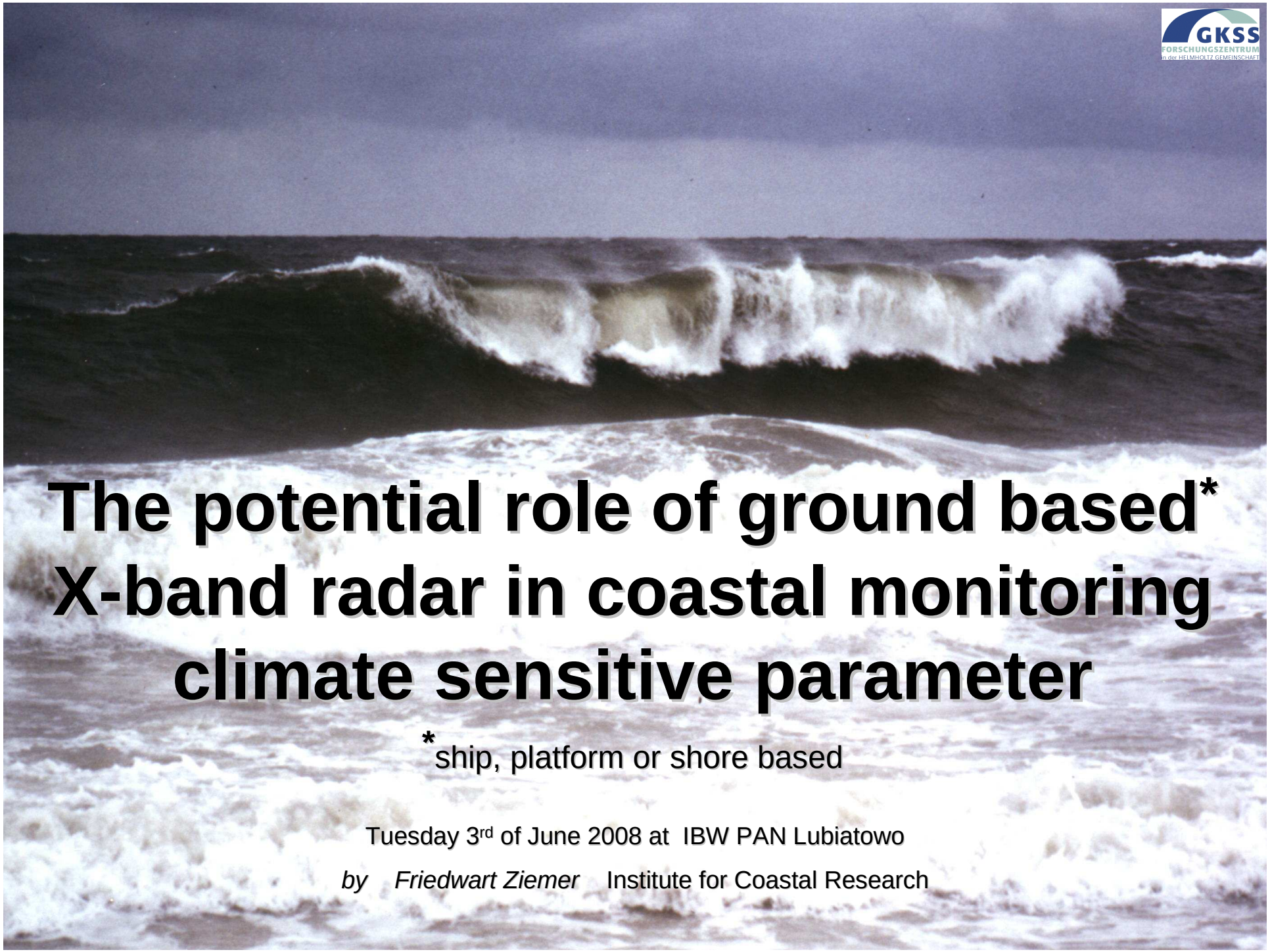

The potential role of ground based* X-band radar in coastal monitoring climate sensitive parameter

*ship, platform or shore based

Tuesday 3rd of June 2008 at IBW PAN Lubiatowo

by *Friedwart Ziemer* Institute for Coastal Research

Short History of Radar Hydrography at GKSS

- 1990 – 93 Calibration of the wave radar „WaMoS“ at the FP „Nordsea“ and onboard the ships „Gauss“ and „Planet“.
- 1991 – 95 Calibration and Validation of the „ERS - 1“ satellite on Gulfaks C.
- Since1993: First operational WaMos at EKOFISK.
- Since 1996 WaMoS is merchandised by a company.
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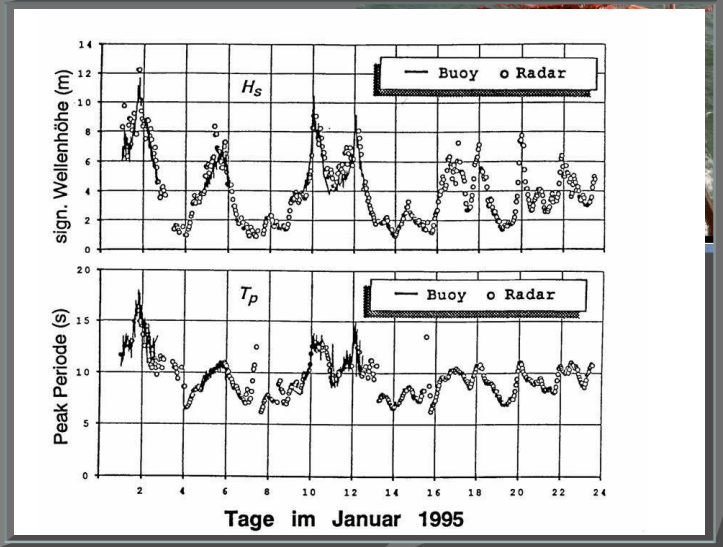
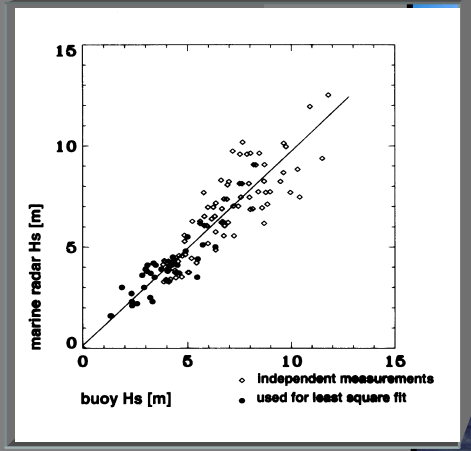
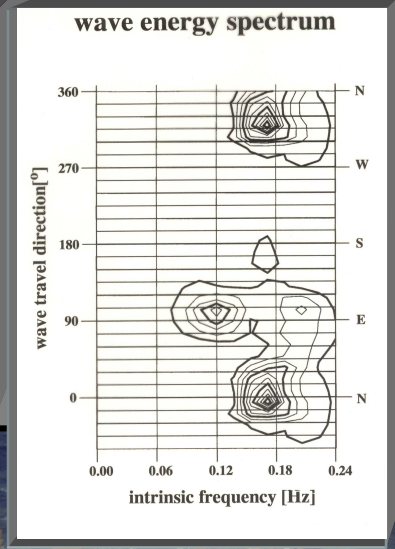
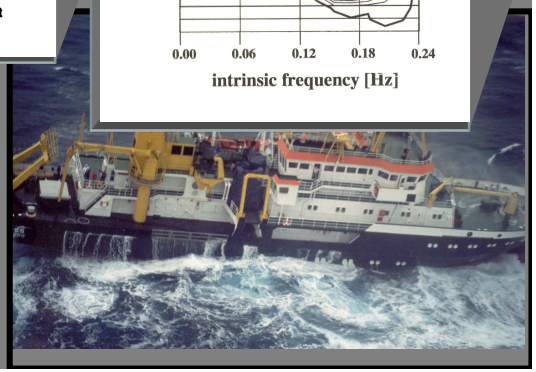
- Since 2000 development of coherent Doppler radar.
- Key words in actual research: morphodynamic, wave dissipation and others.









Radar Hydrography

outlook

Radar remote sensing has reached a level of maturity to become an important instrument in Earth observation on global, regional and local scales.

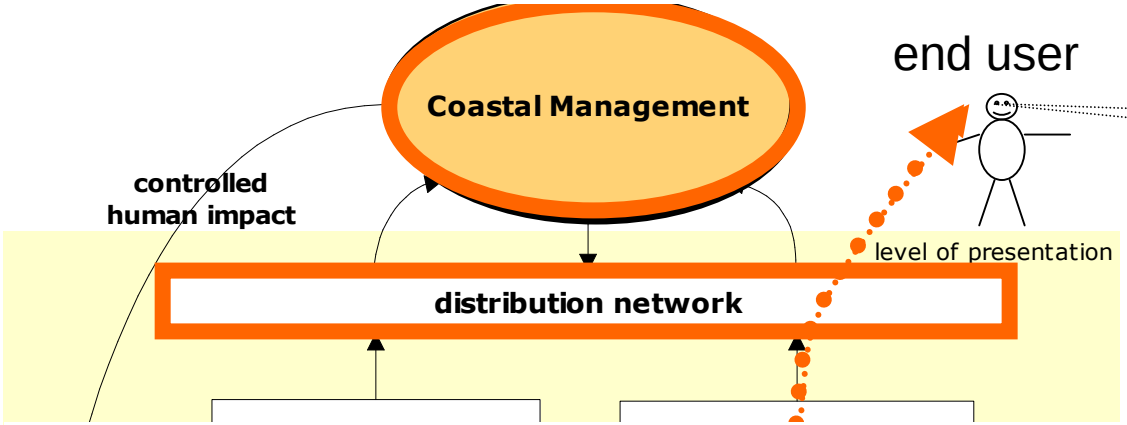
The scales are preset by the instrument‘s carrier: *satellite, airplane, ship or off- / onshore station.*

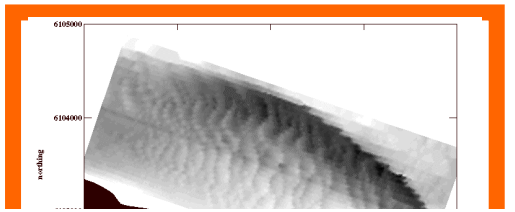
Radar Hydrography

outlook

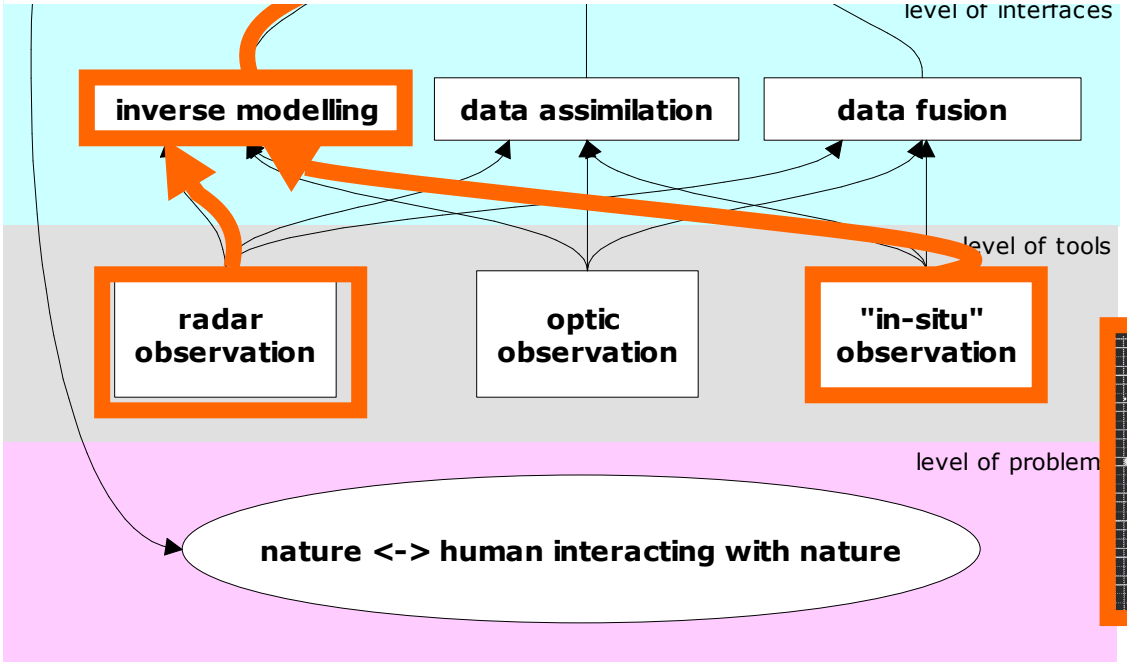
Indicators for the global change and its impact to the coastal surrounding are *wind*, *waves, currents*, *sea level, coastline, bathymetry*, *ice coverage* and others.

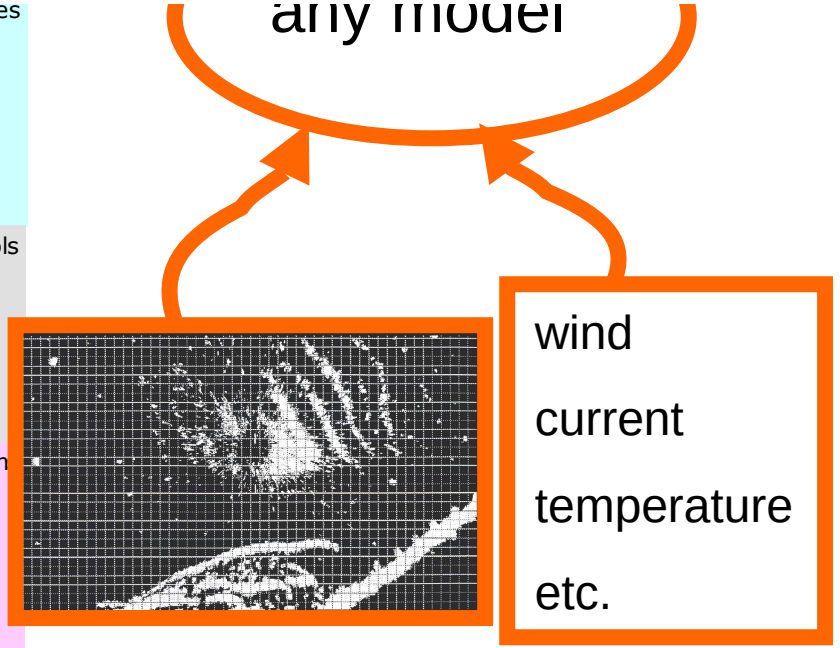
Radar can register the status and monitor the change of most of these parameter in coastal areas and in the open sea.



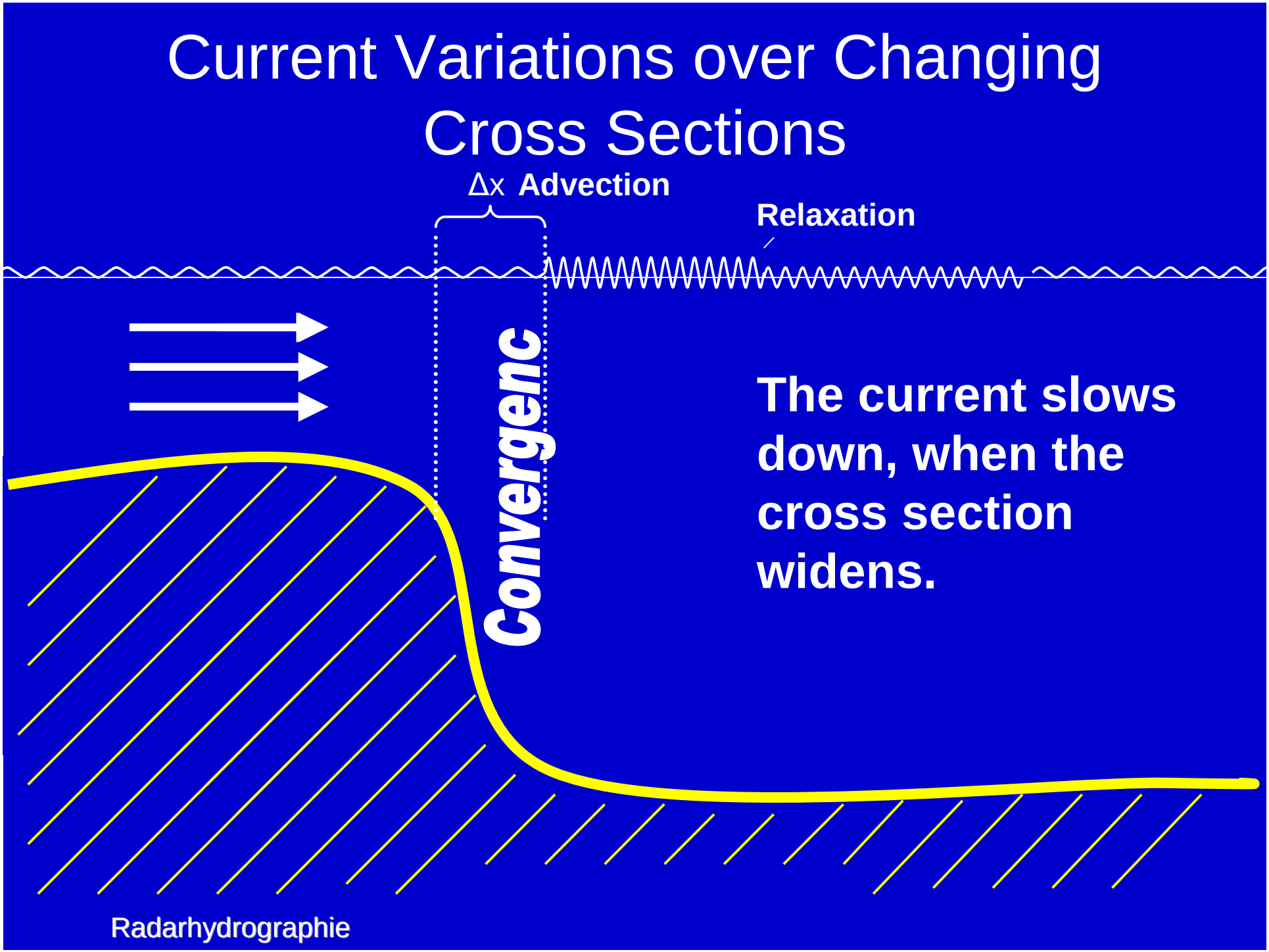


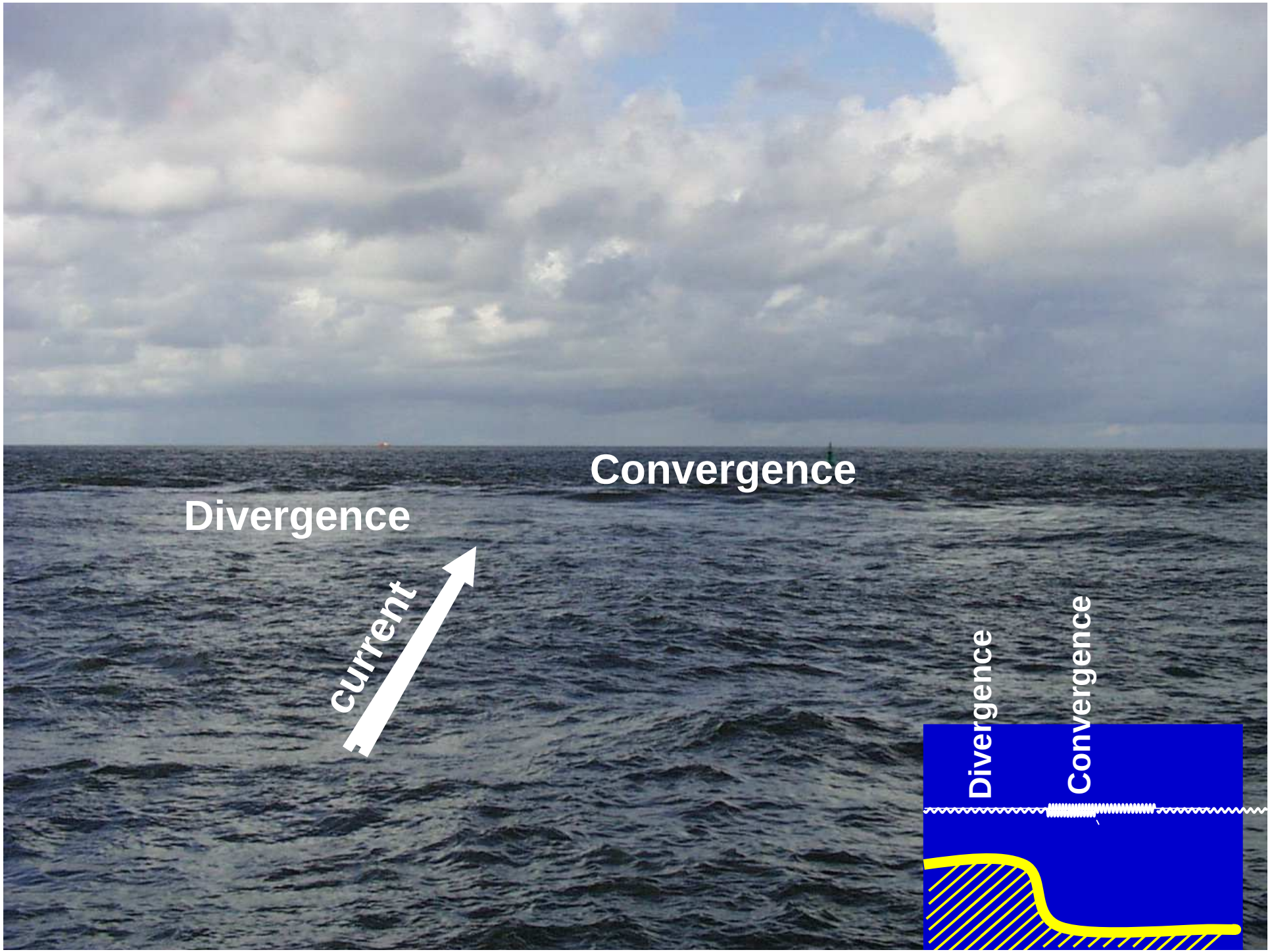
Integrated Monitoring for the Coastal Management





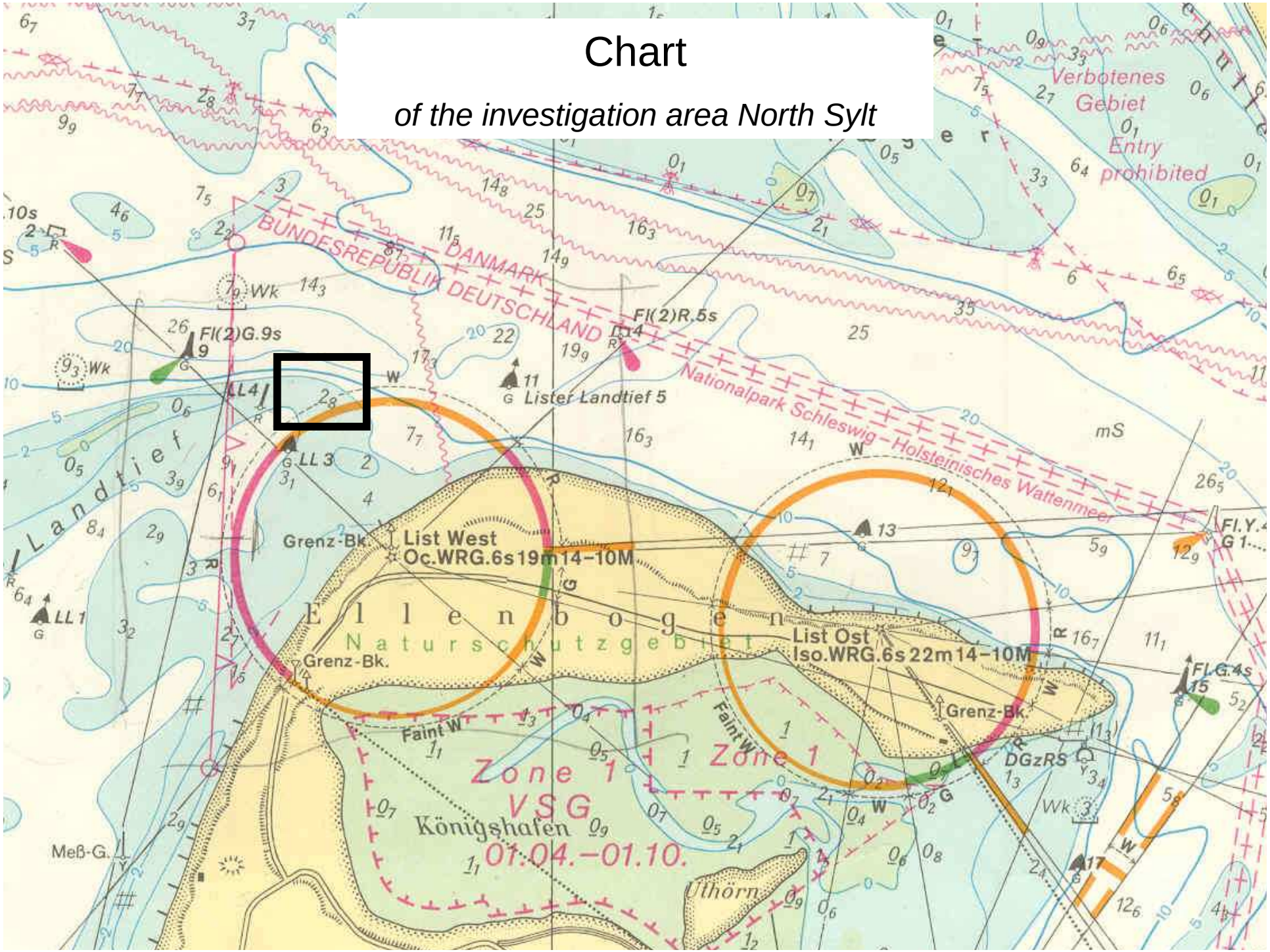
Current Variations over Changing Cross Sections



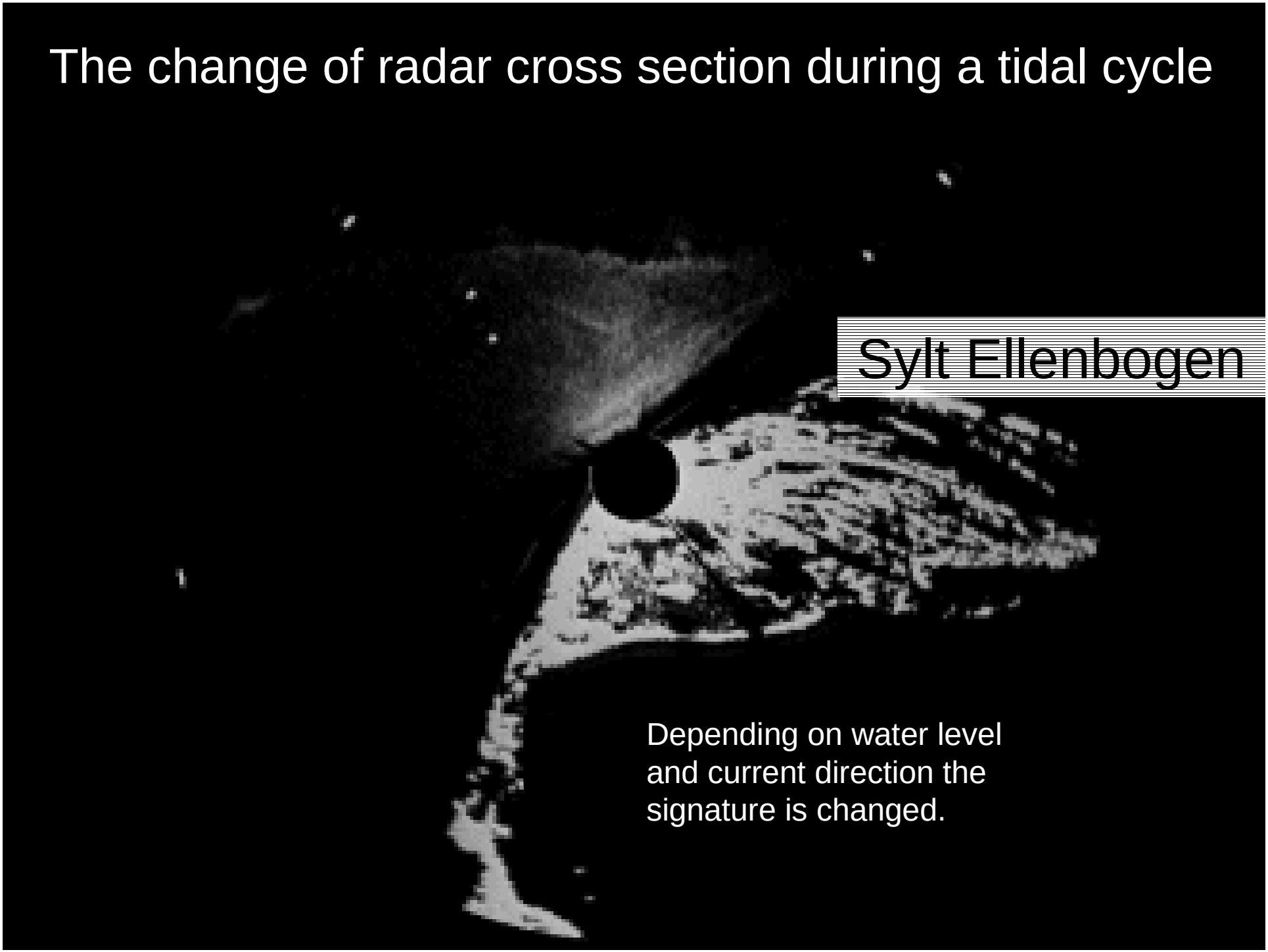

Convergence
Divergence
current
Divergence
Convergence

Chart

of the investigation area North Sylt

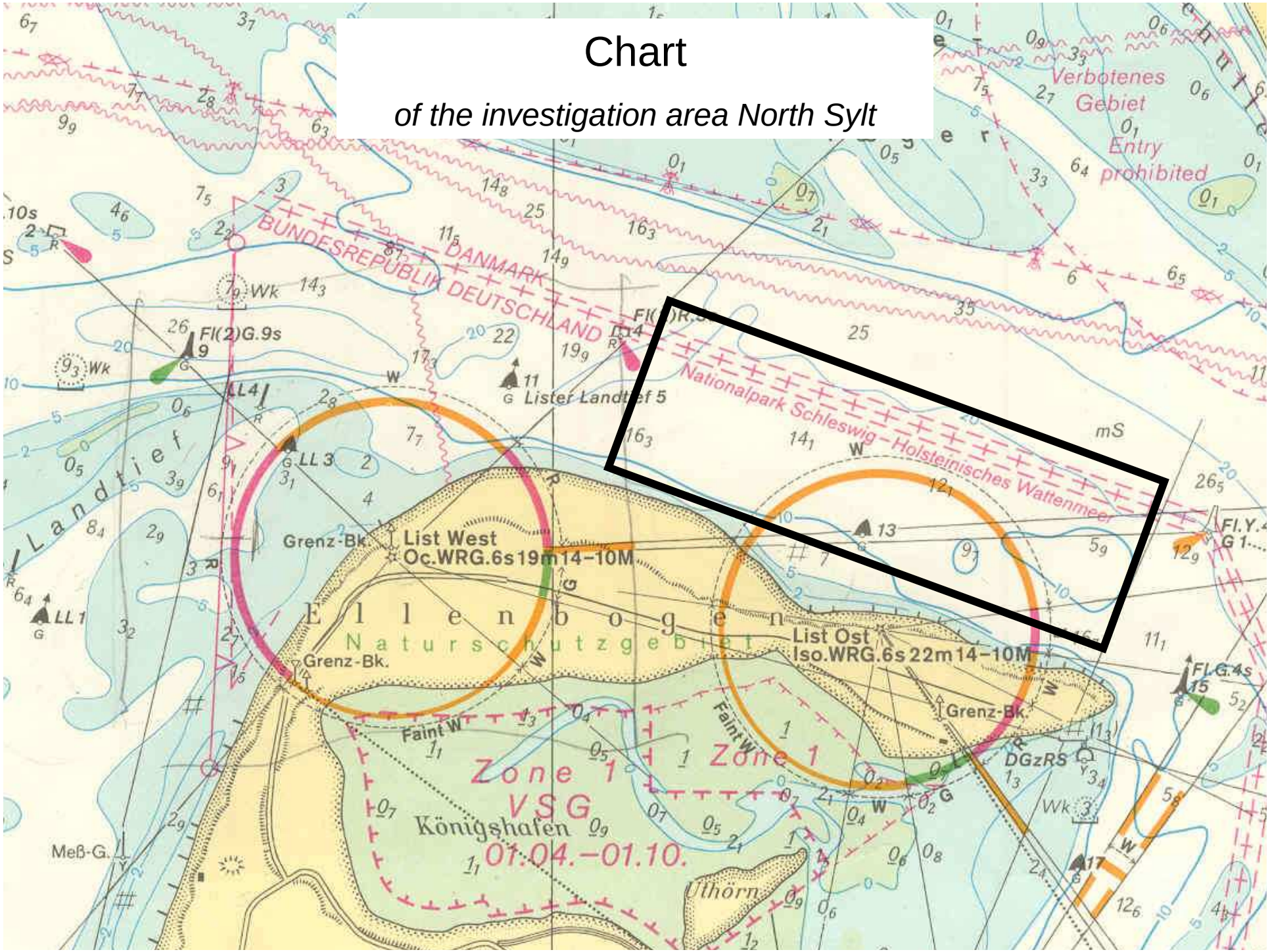


The change of radar cross section during a tidal cycle

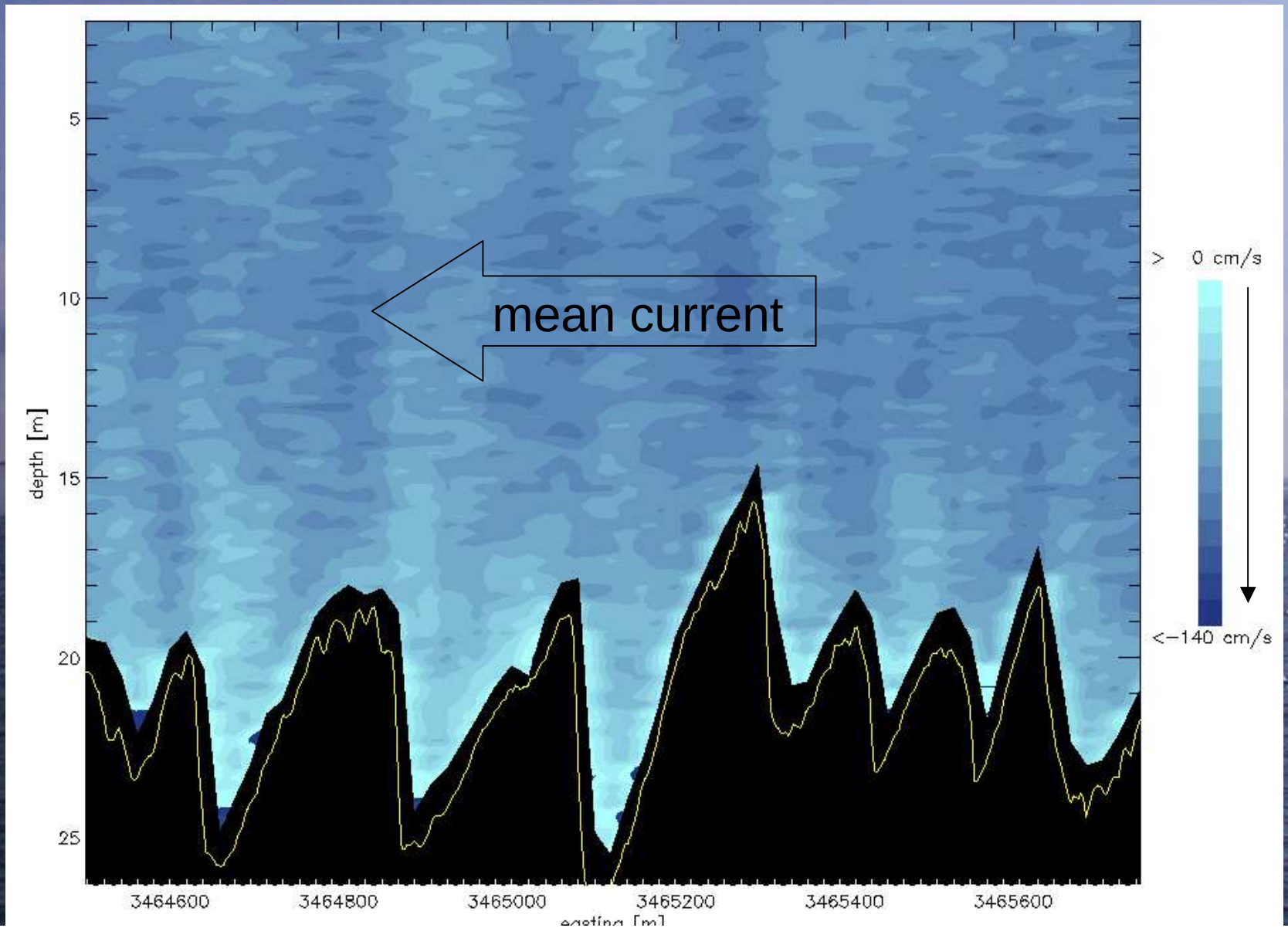


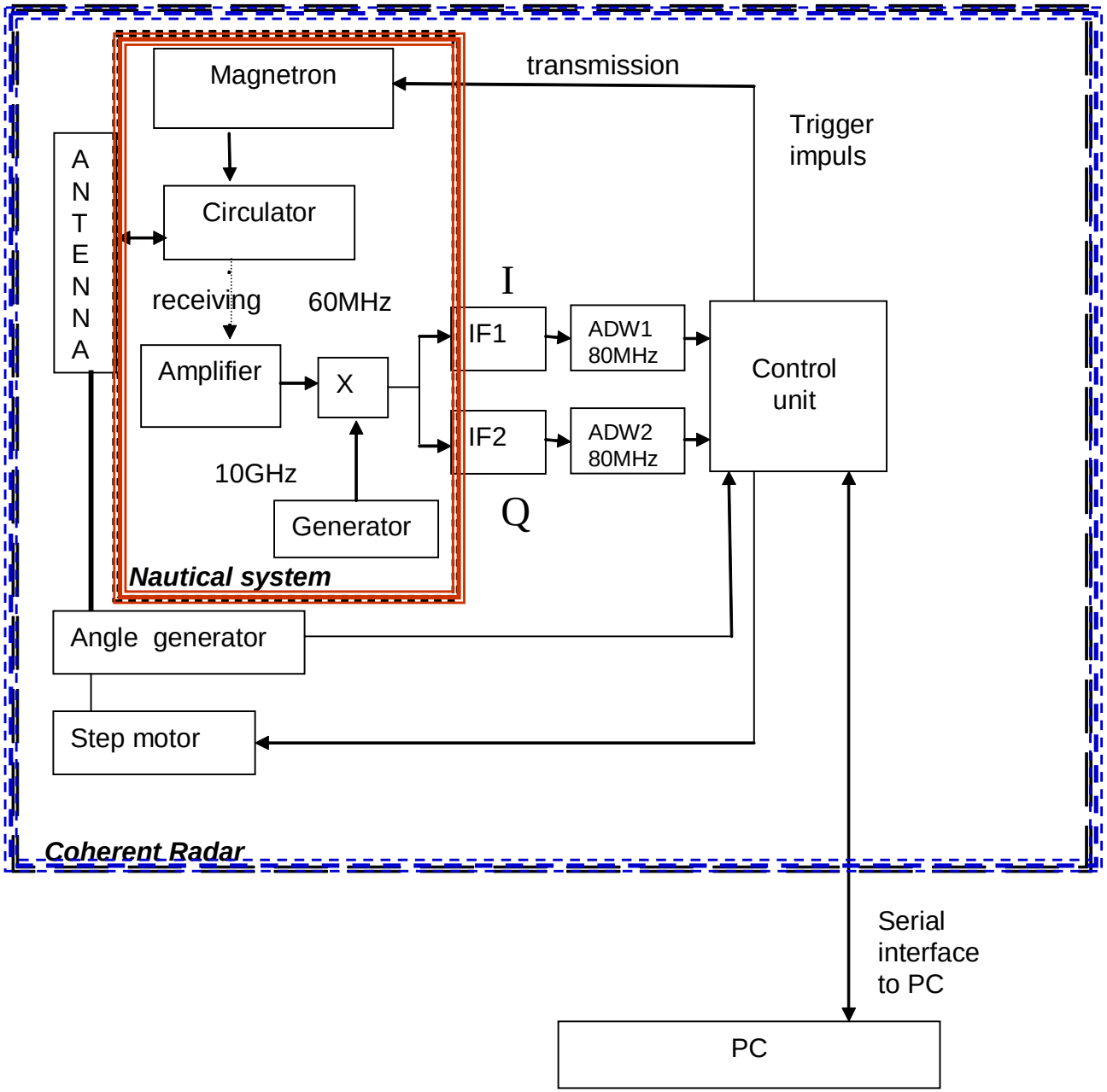
Chart

of the investigation area North Sylt



This ADCP profile demonstrates the steering of the current speed by the cross section.

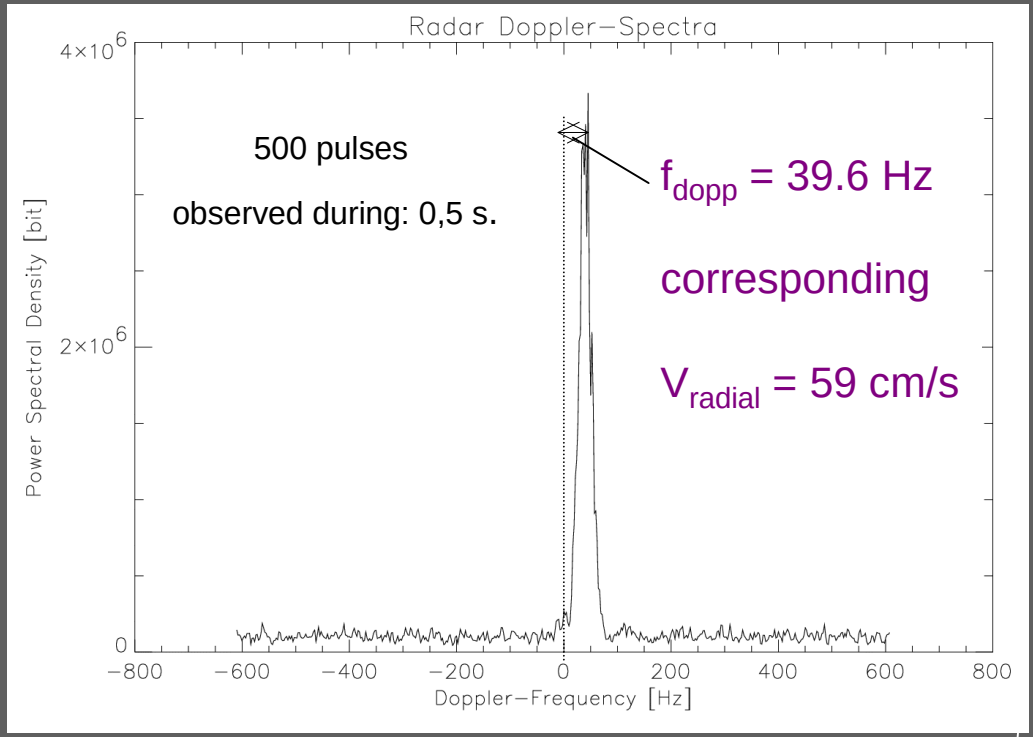


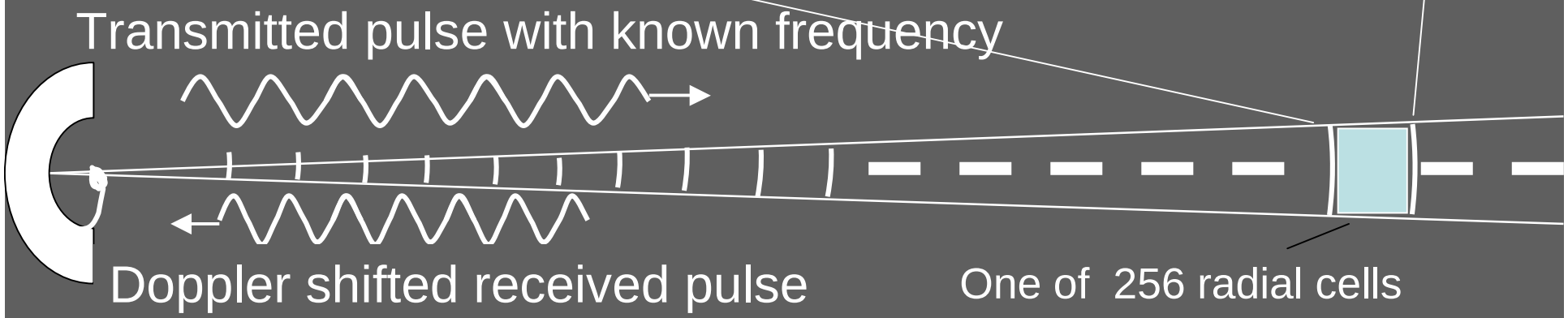


The first two bytes of the received signal contain the complex reference of the transmitted signal.

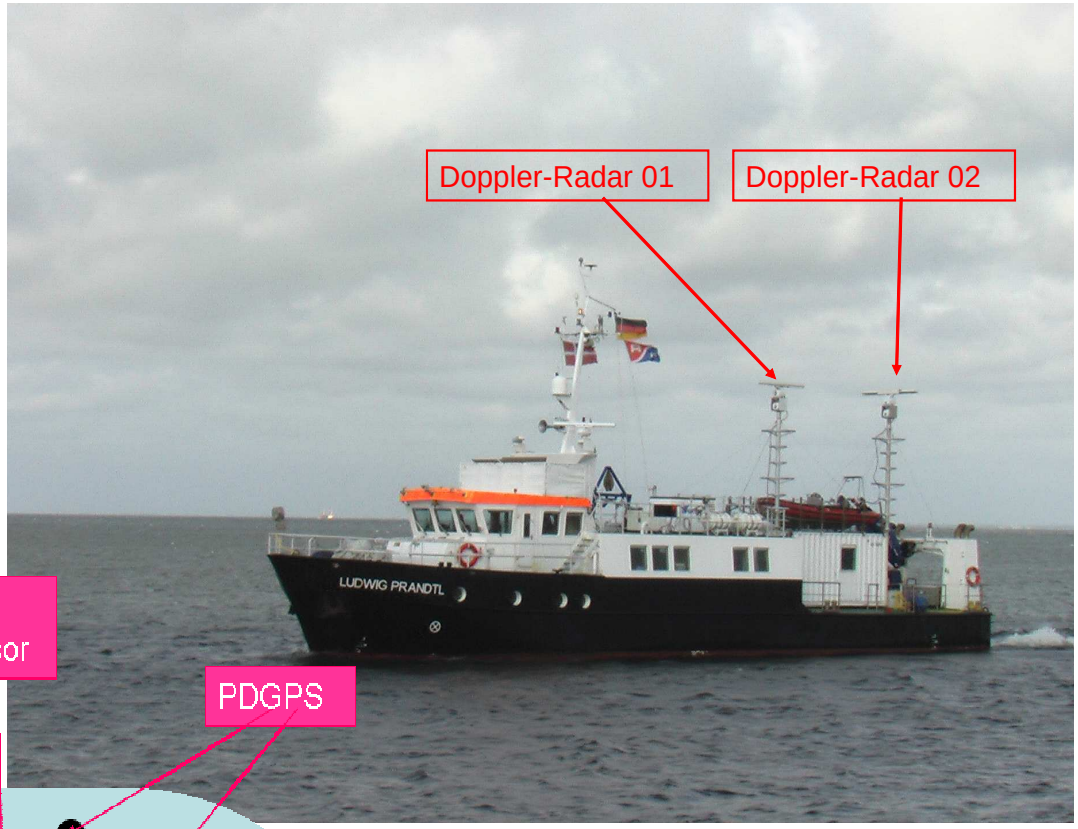
Doppler frequency shift

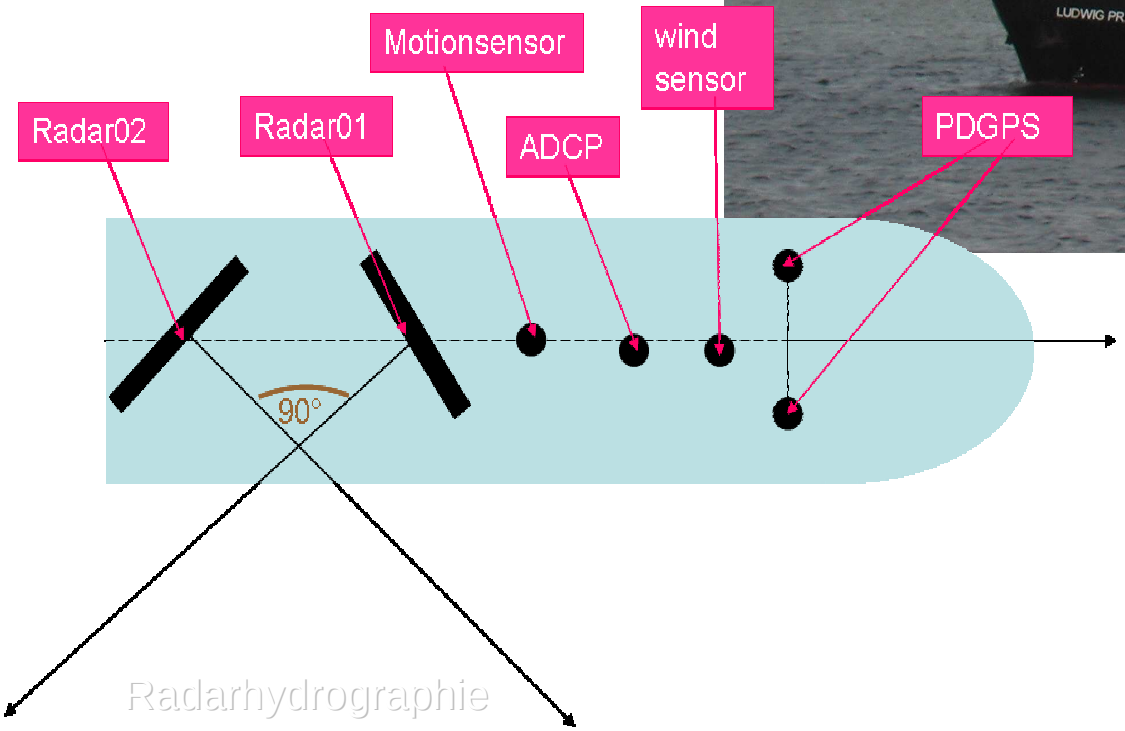
The Doppler shift is detected in 256 radial cells.

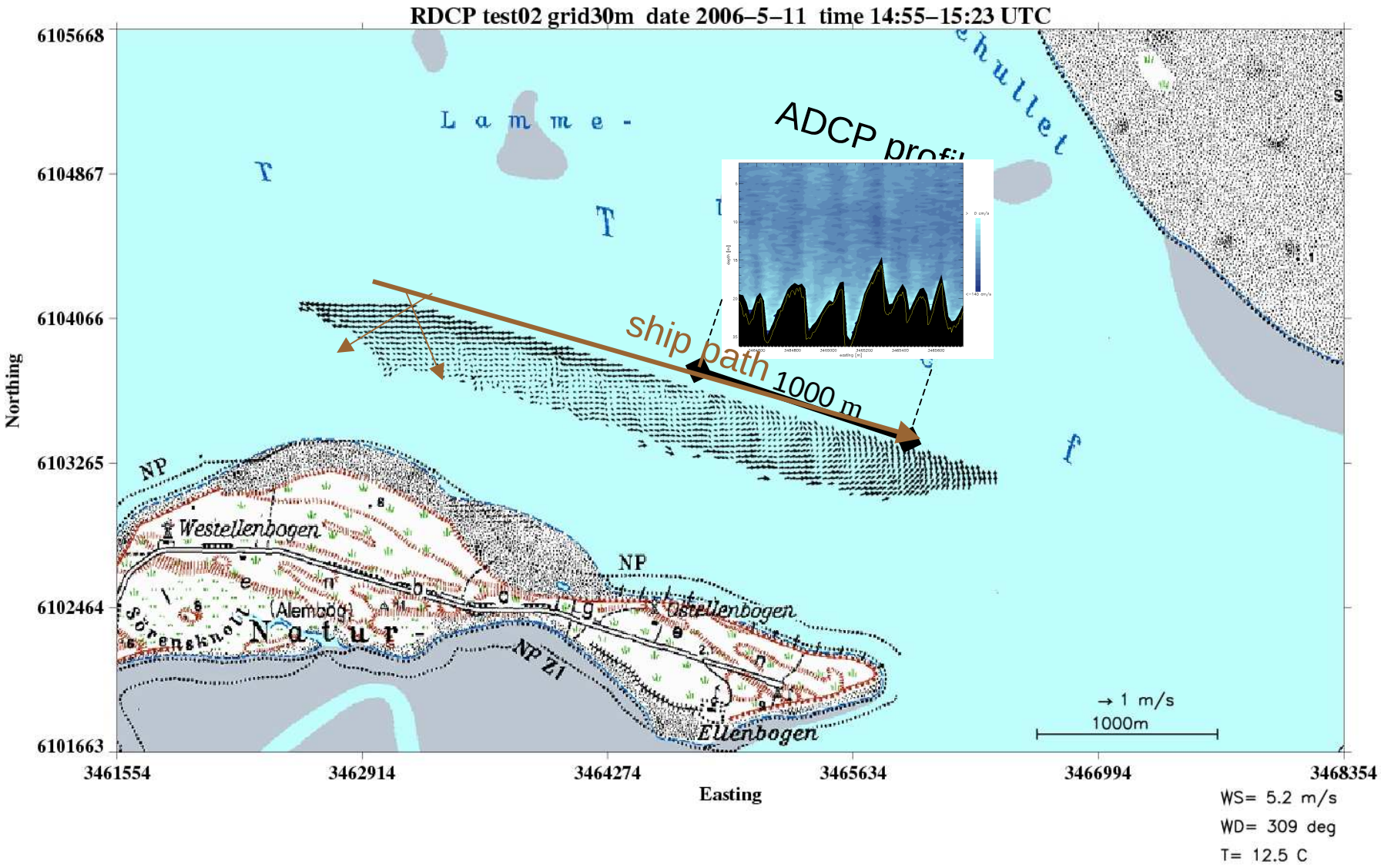




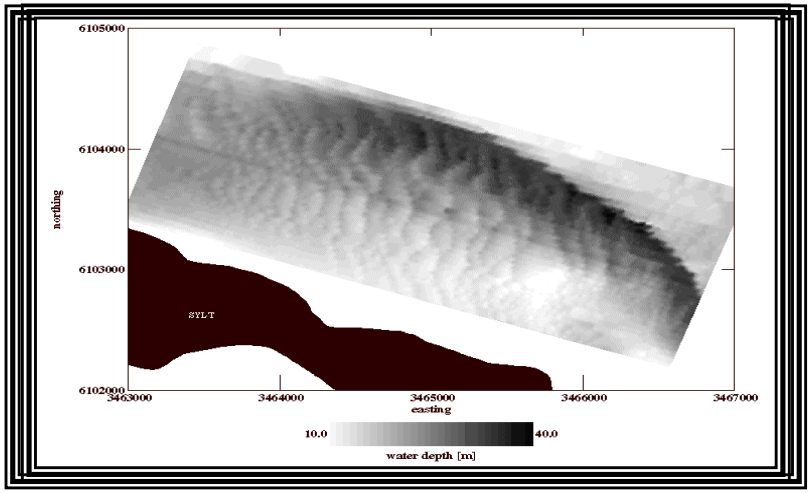
RDCP = Radar Doppler Current Profiler







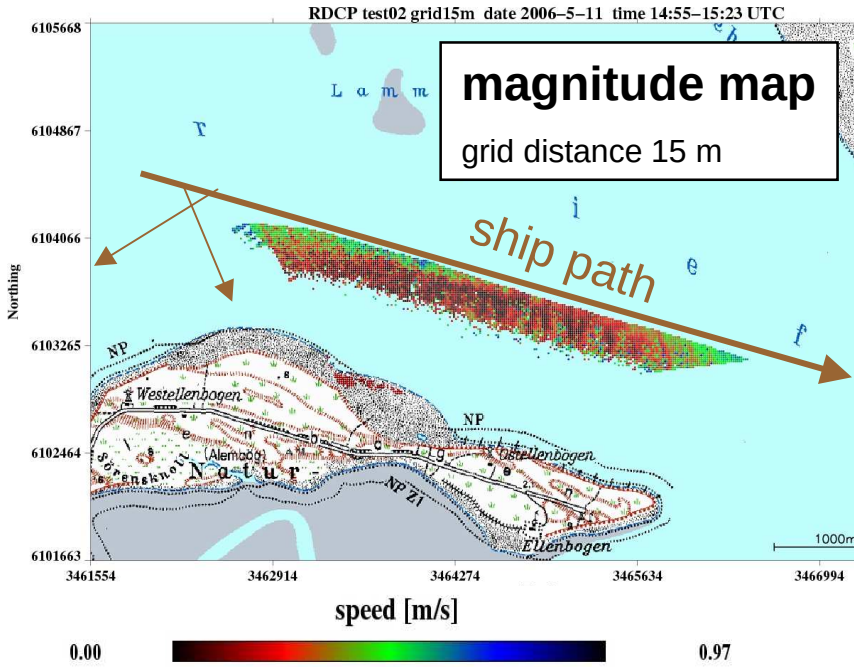
Bathymetry deduced from RDCP current maps

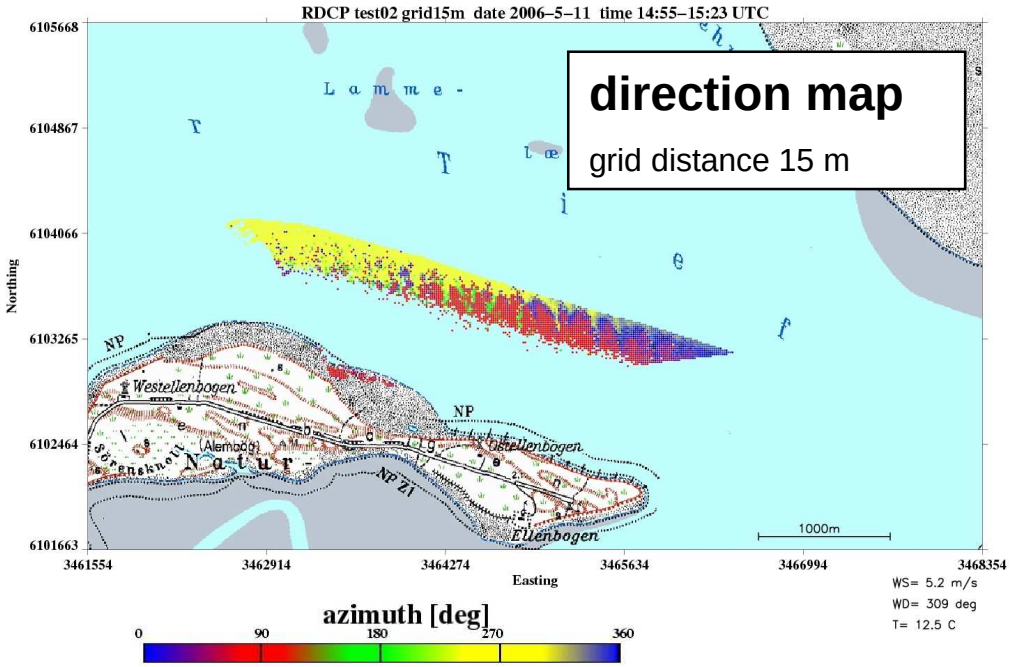


Time for acquisition is 20 minutes.

Length of path about 3 nm.

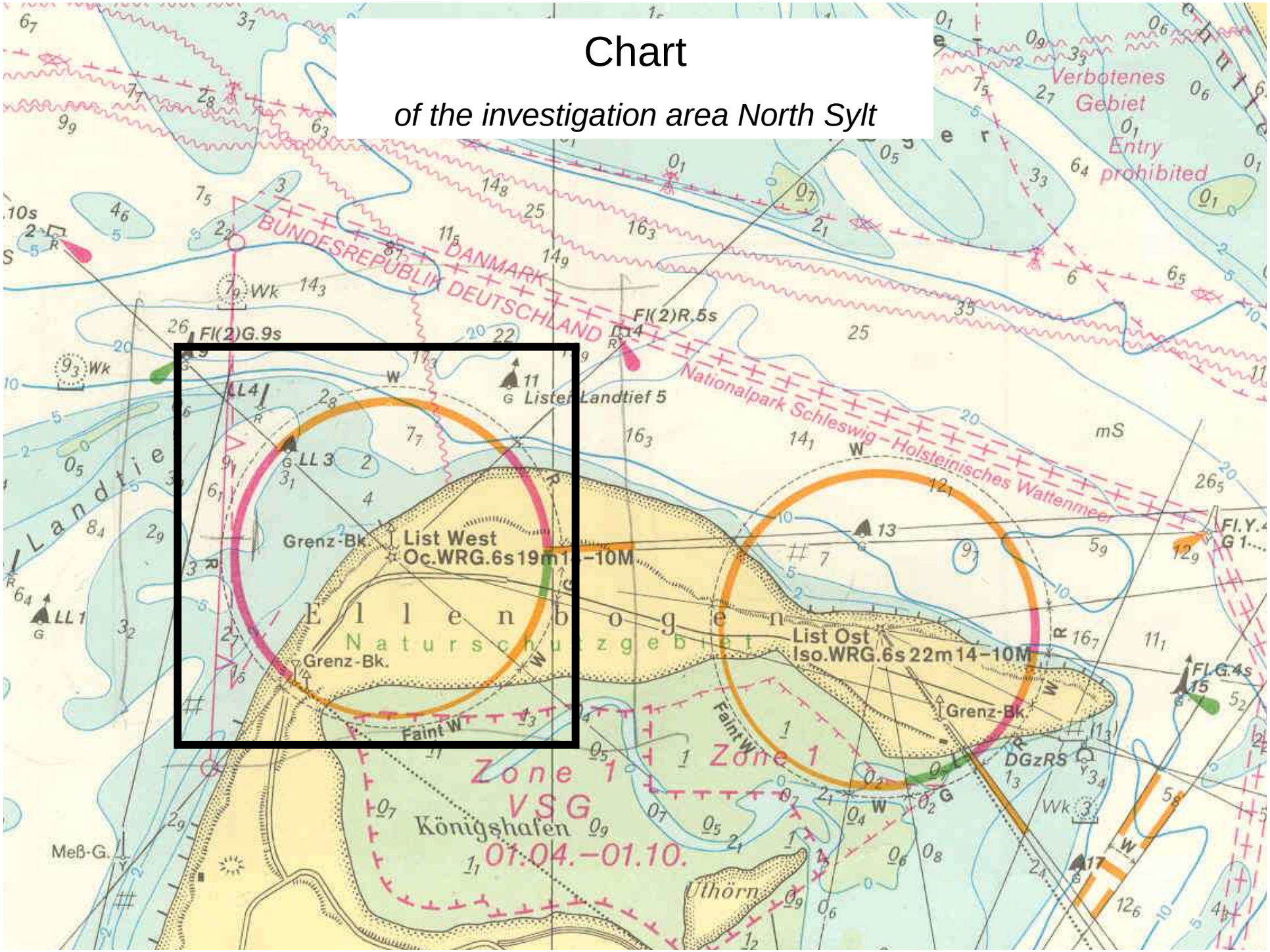
Width of stripe about 500 m.



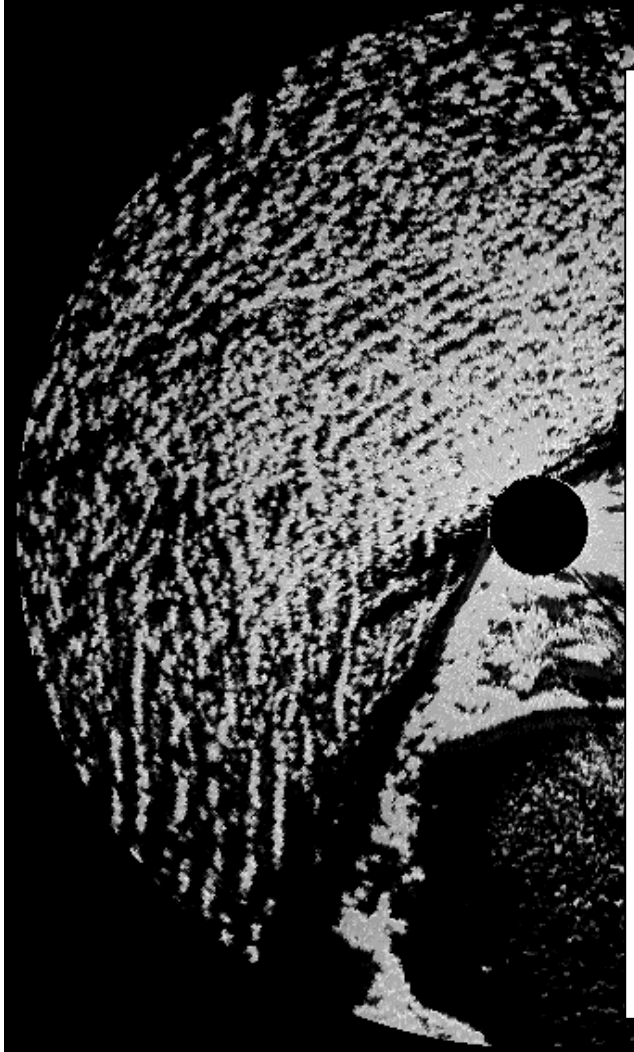


Chart

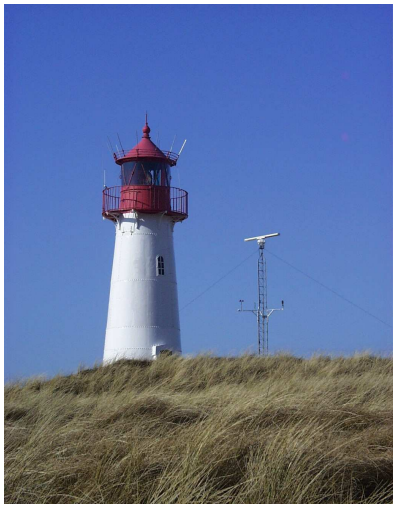
of the investigation area North Sylt

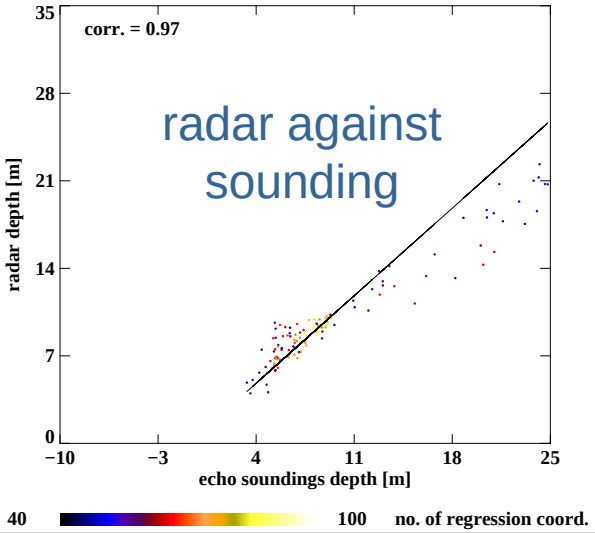


Land based radar



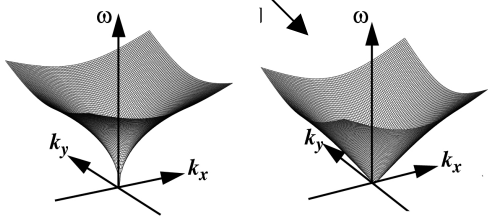
From a time series of wave field images (acquired during 10 minutes radar observation) the local change of dispersive waves is detected. This allows to deduce the local water depth by inverse modeling technique. For this procedure a (*national and international*) patent was awarded in 2003.





Influence of local depth h to Dispersion

$$\omega = \sqrt{gk \tanh(kh)}$$



$\tanh\left(2\pi \, h/\lambda\right)$

1

0.5

$\lambda = 4h$

$\lambda = h$

$\lambda = 10h$

h/λ

0.1

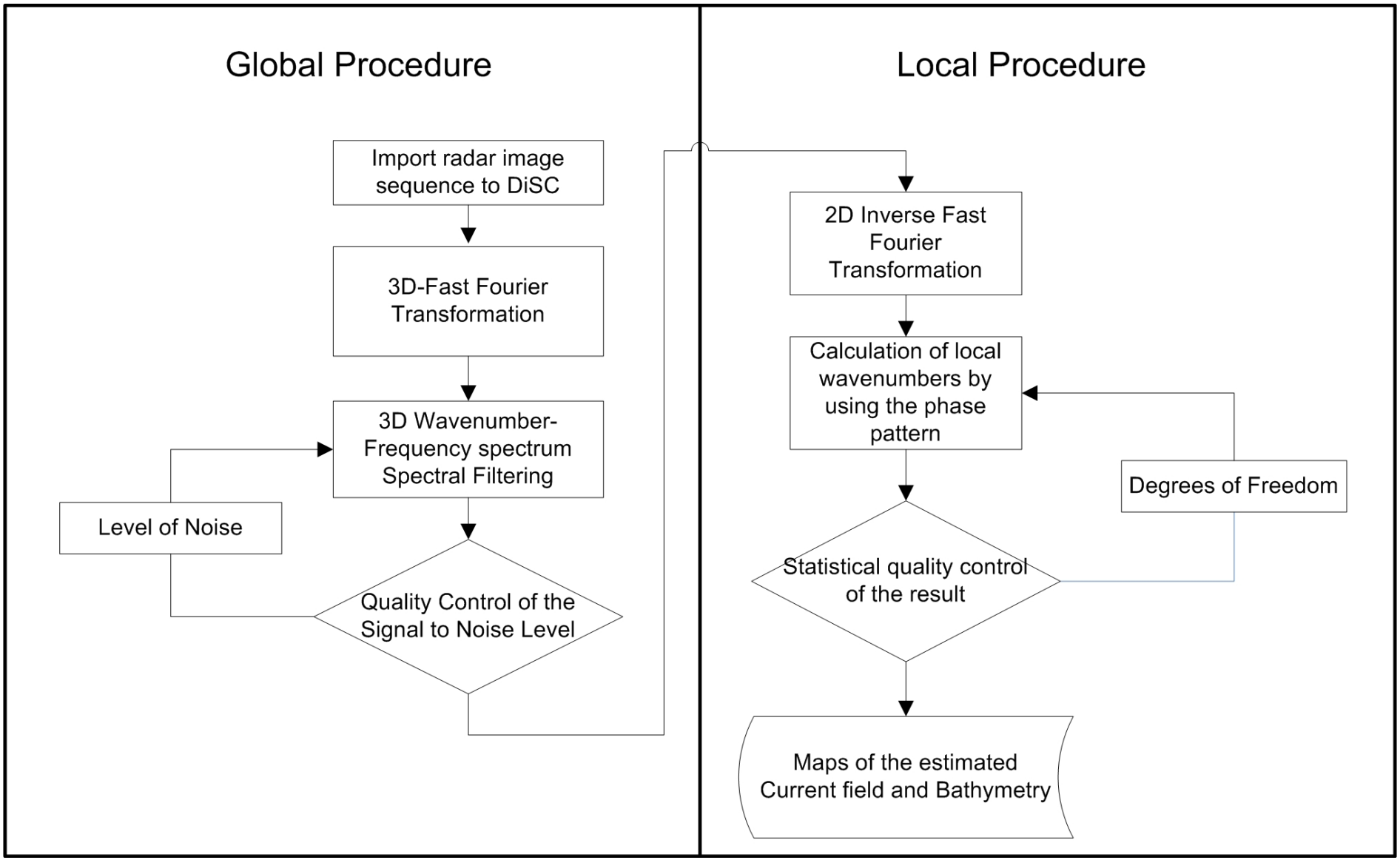
0.5

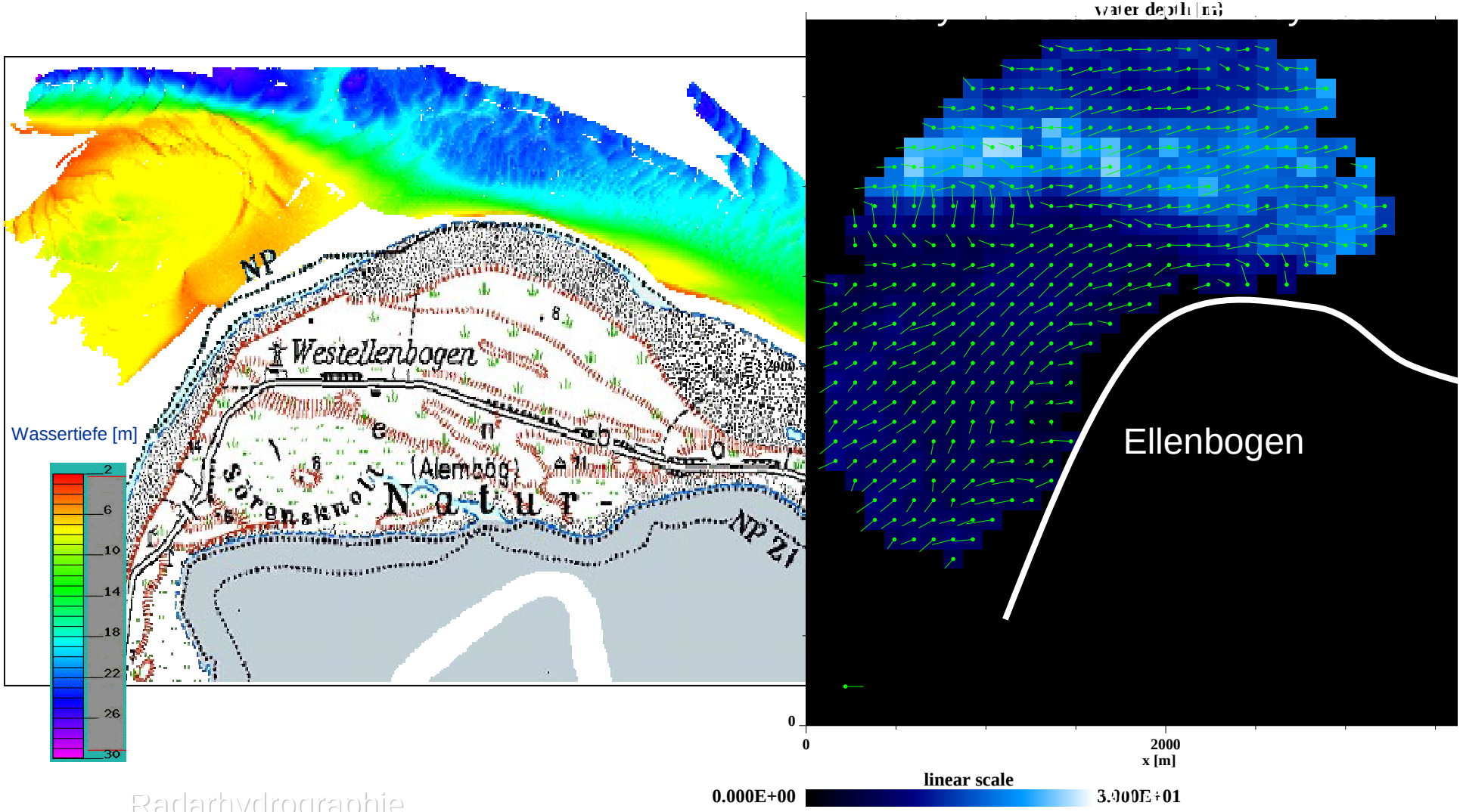
1

$\lambda = 20h$

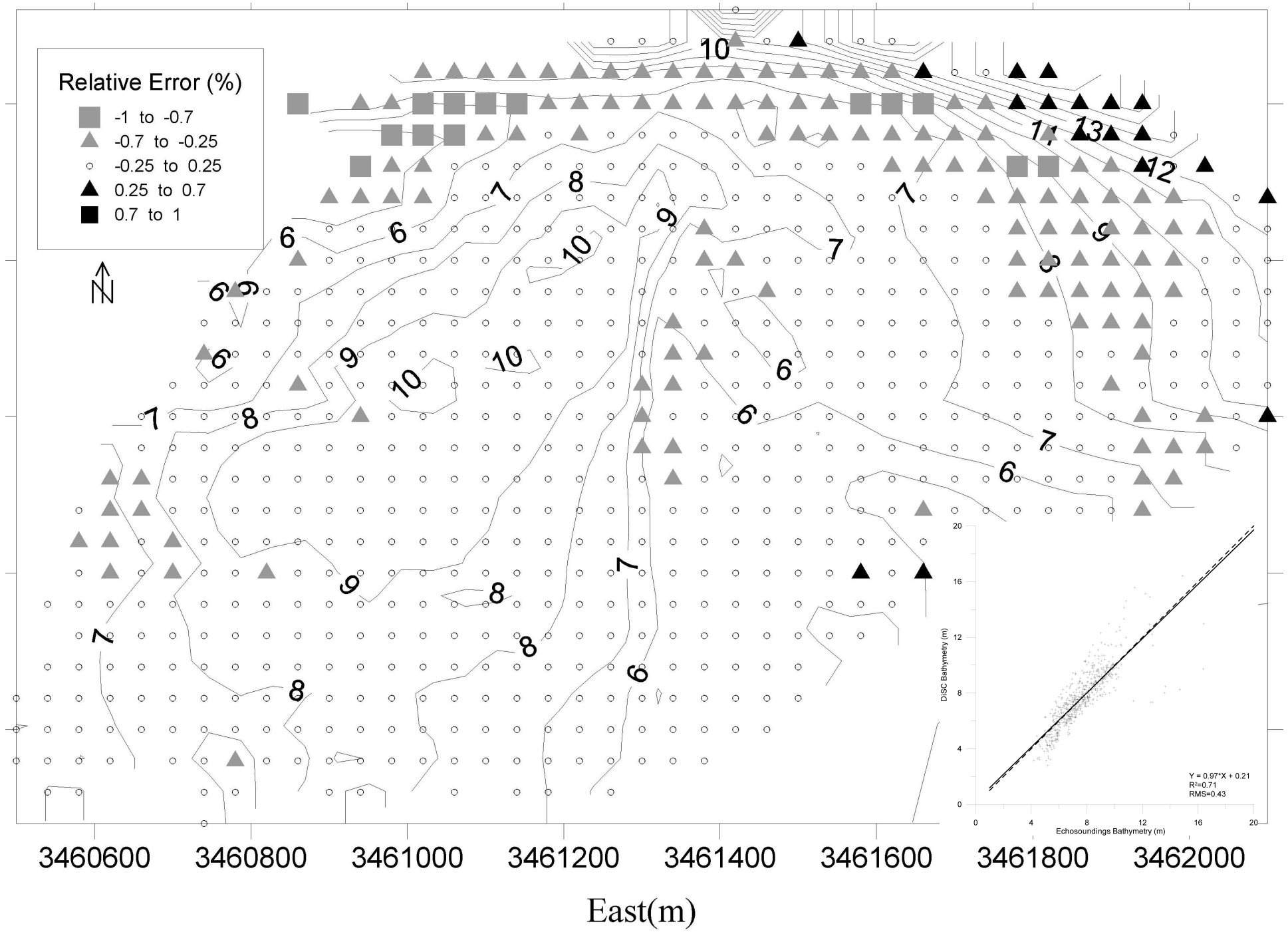
range of reasonable results

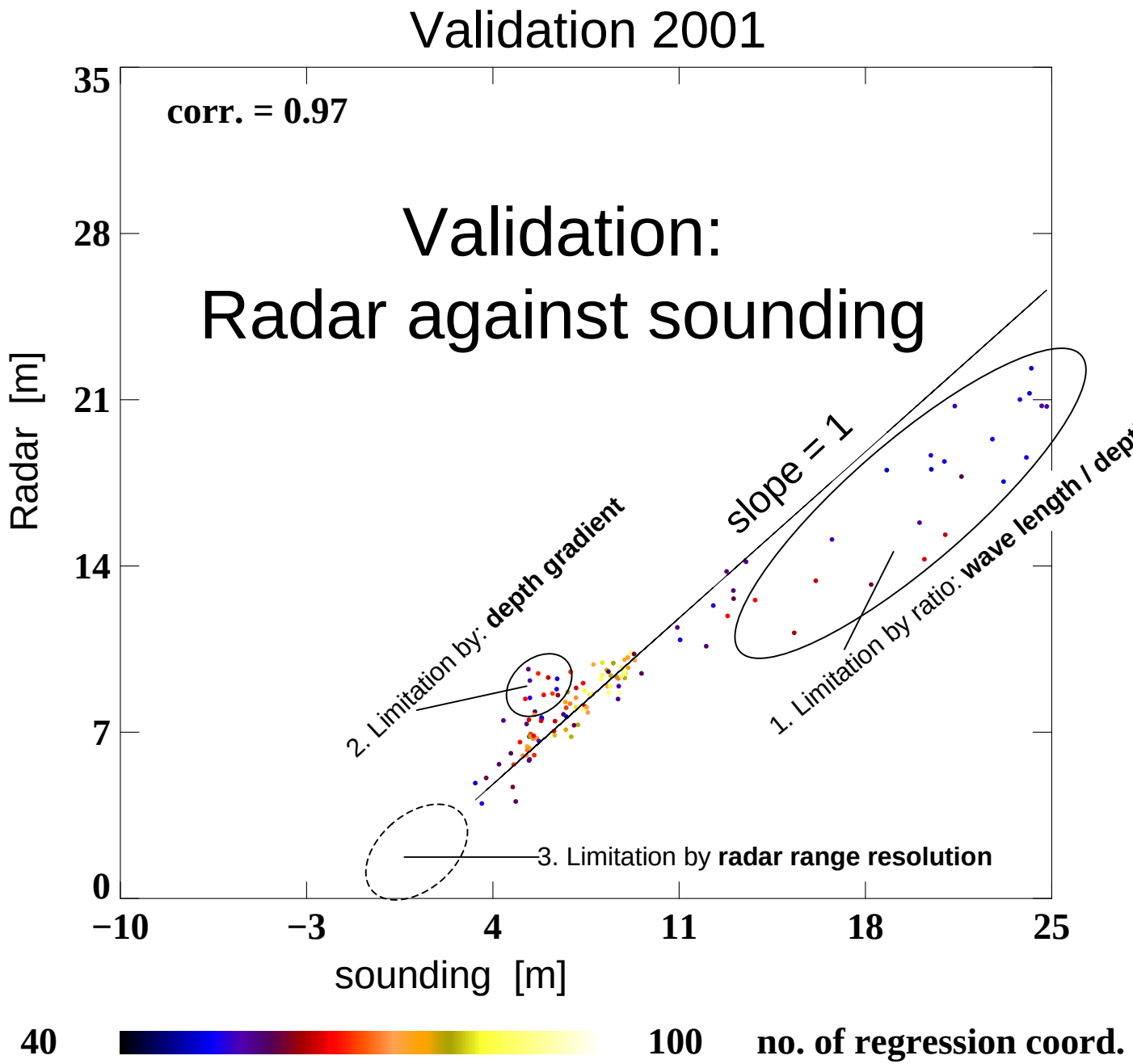
Flow chart of DiSC





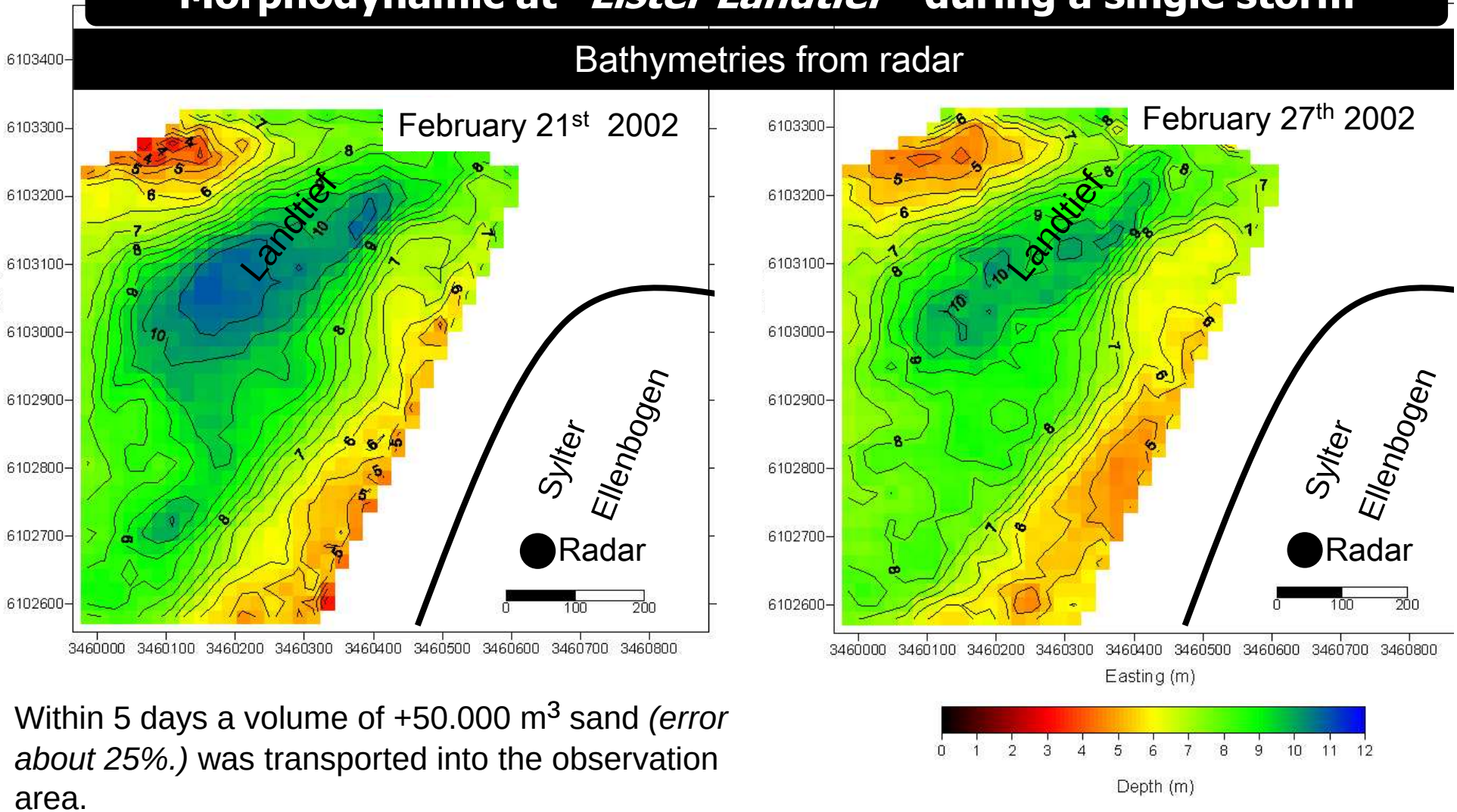
Radarhydrographie


Relative Error (%)
-1 to -0.7
-0.7 to -0.25
-0.25 to 0.25
0.25 to 0.7
0.7 to 1
N
DISC Bathymetry (m)
Echosoundings Bathymetry (m)
Y = 0.97*X + 0.21
R²=0.71
RMS=0.43
0
4
8
12
16
20
3460600
3460800
3461000
3461200
3461400
3461600
3461800
3462000
East(m)


Validation 2001
corr. = 0.97
Validation:
Radar against sounding
35
28
21
14
7
0
Radar [m]
−10
−3
4
11
18
25
sounding [m]
slope = 1
2. Limitation by: depth gradient
1. Limitation by ratio: wave length / depth
3. Limitation by radar range resolution
40
100
no. of regression coord.

Morphodynamic at "*Lister Landtief*" during a single storm

Bathymetries from radar

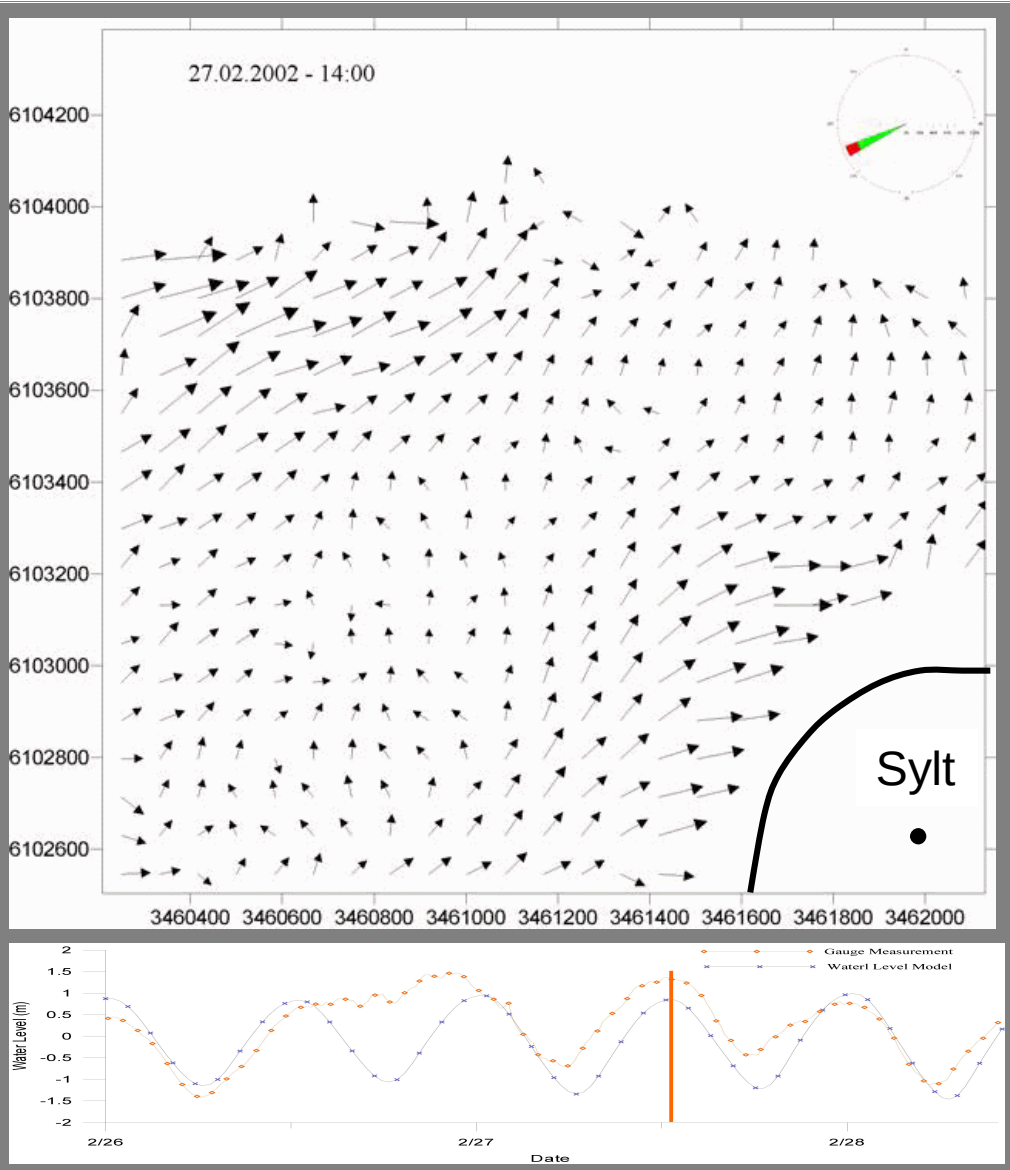


Within 5 days a volume of +50.000 m^3 sand *(error about 25%.)* was transported into the observation area.

Current Field

Normal Tide Conditions

The radial range of the area is about 1 nm.



Radar Hydrography

summary

By means of direct observation and inverse modeling important hydrodynamic field parameter can be deduced.

The feature of area covering observation makes the radar to be an indispensable instrument in monitoring ocean and coastal waters especially to manifest changes.

Thank you !

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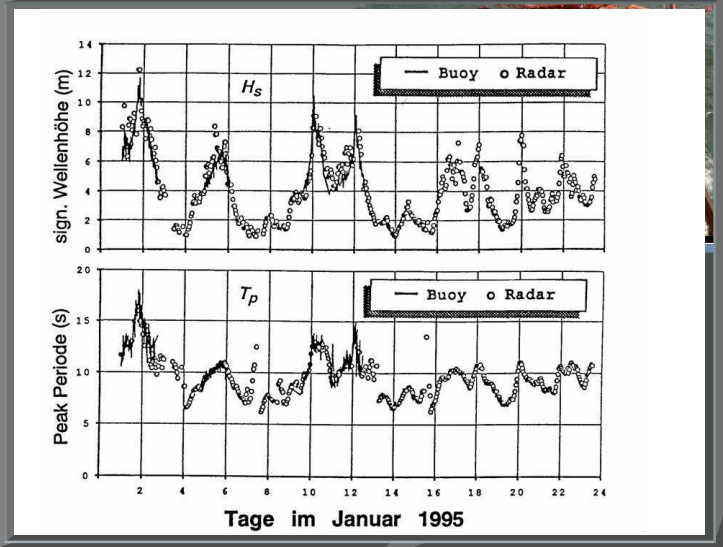
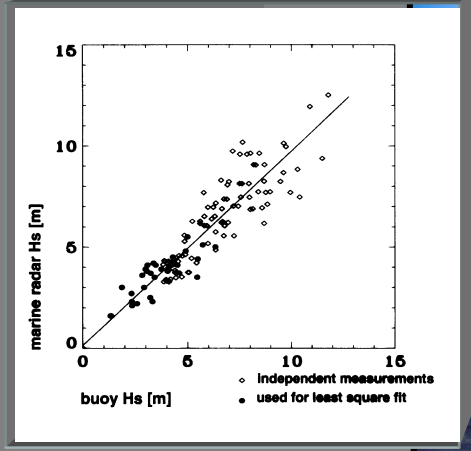
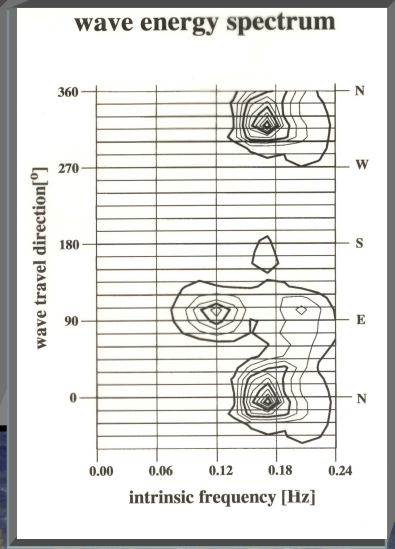
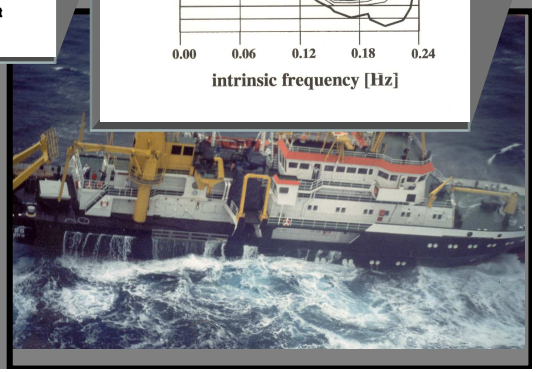
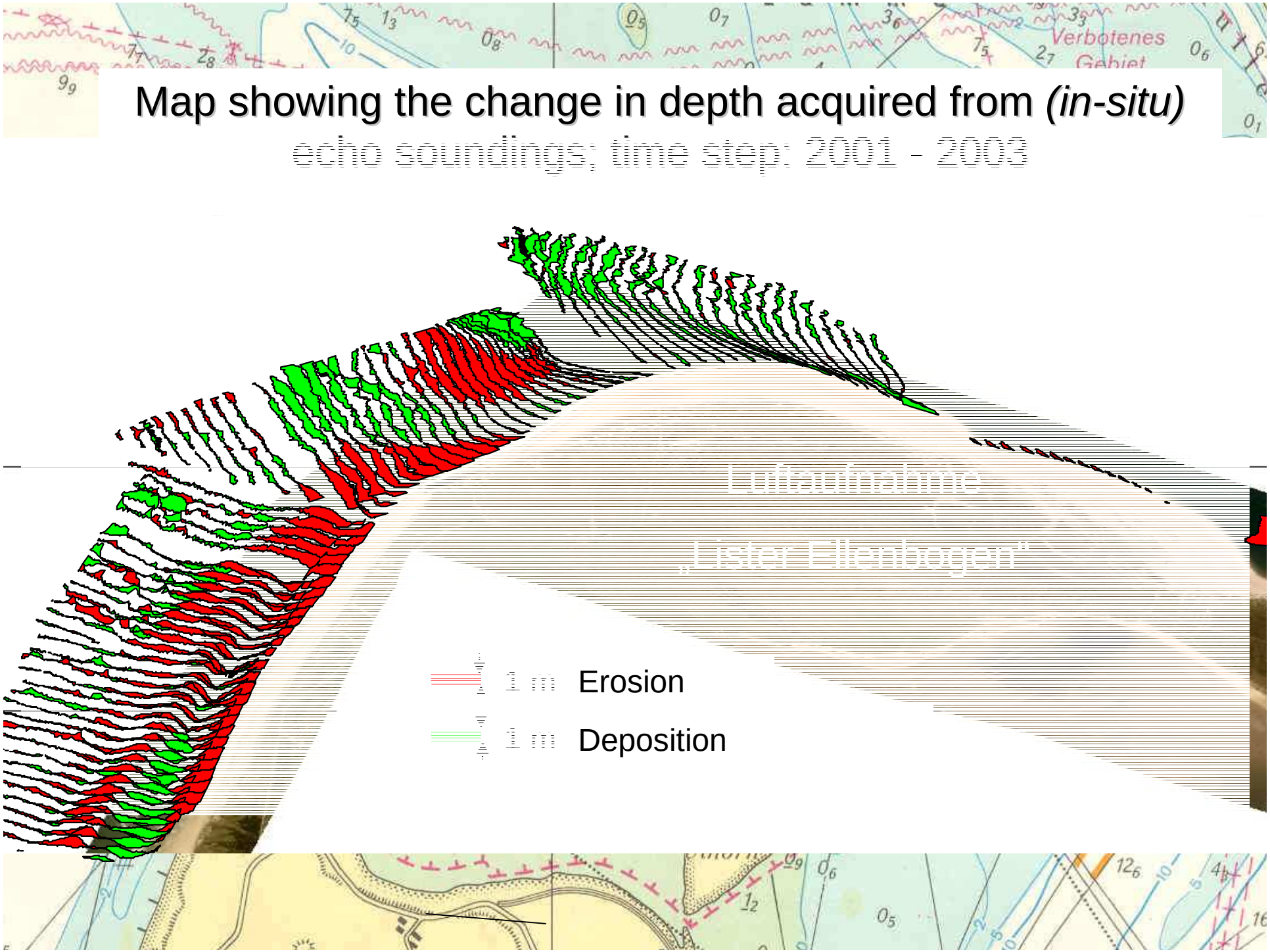




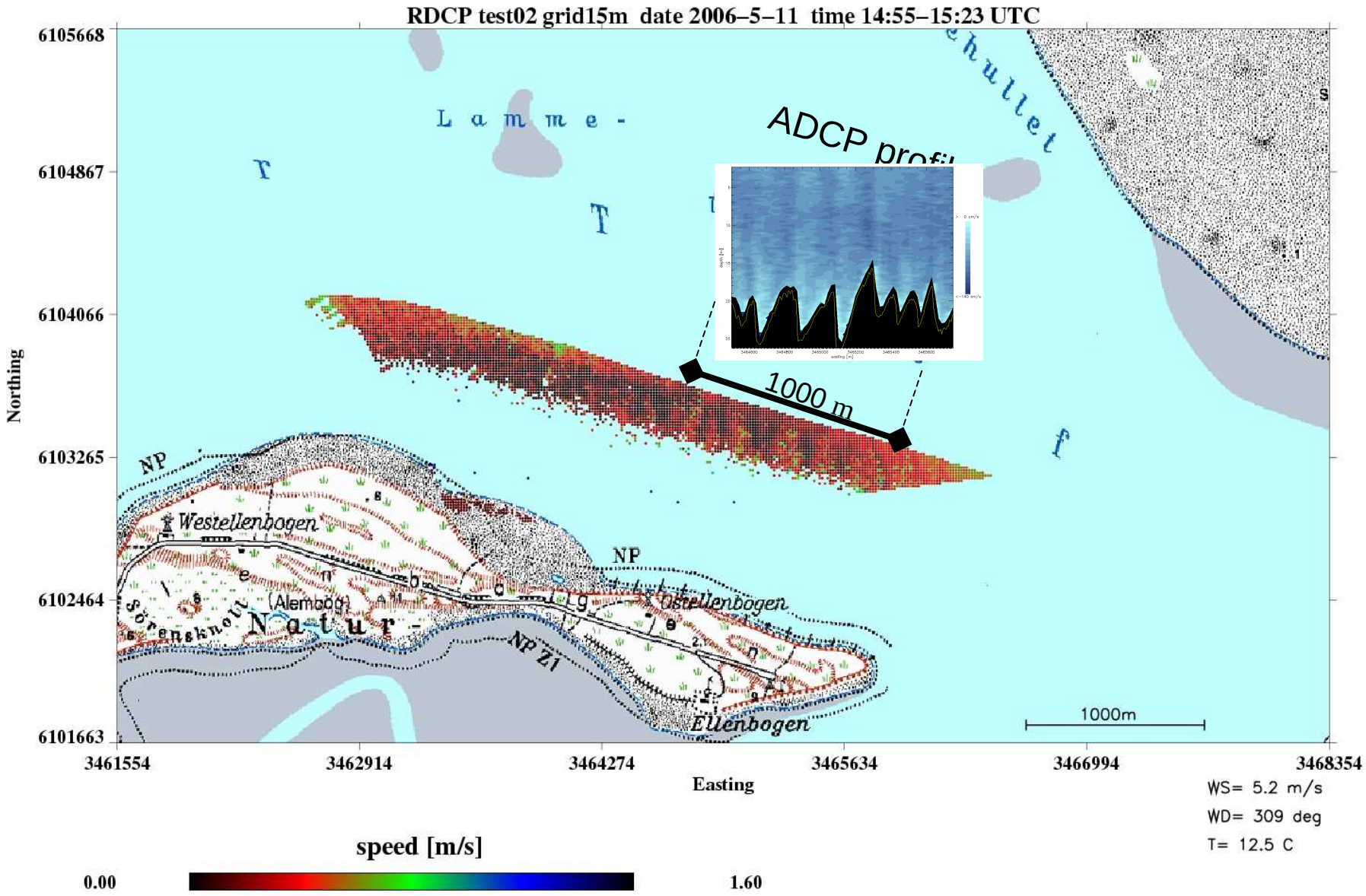




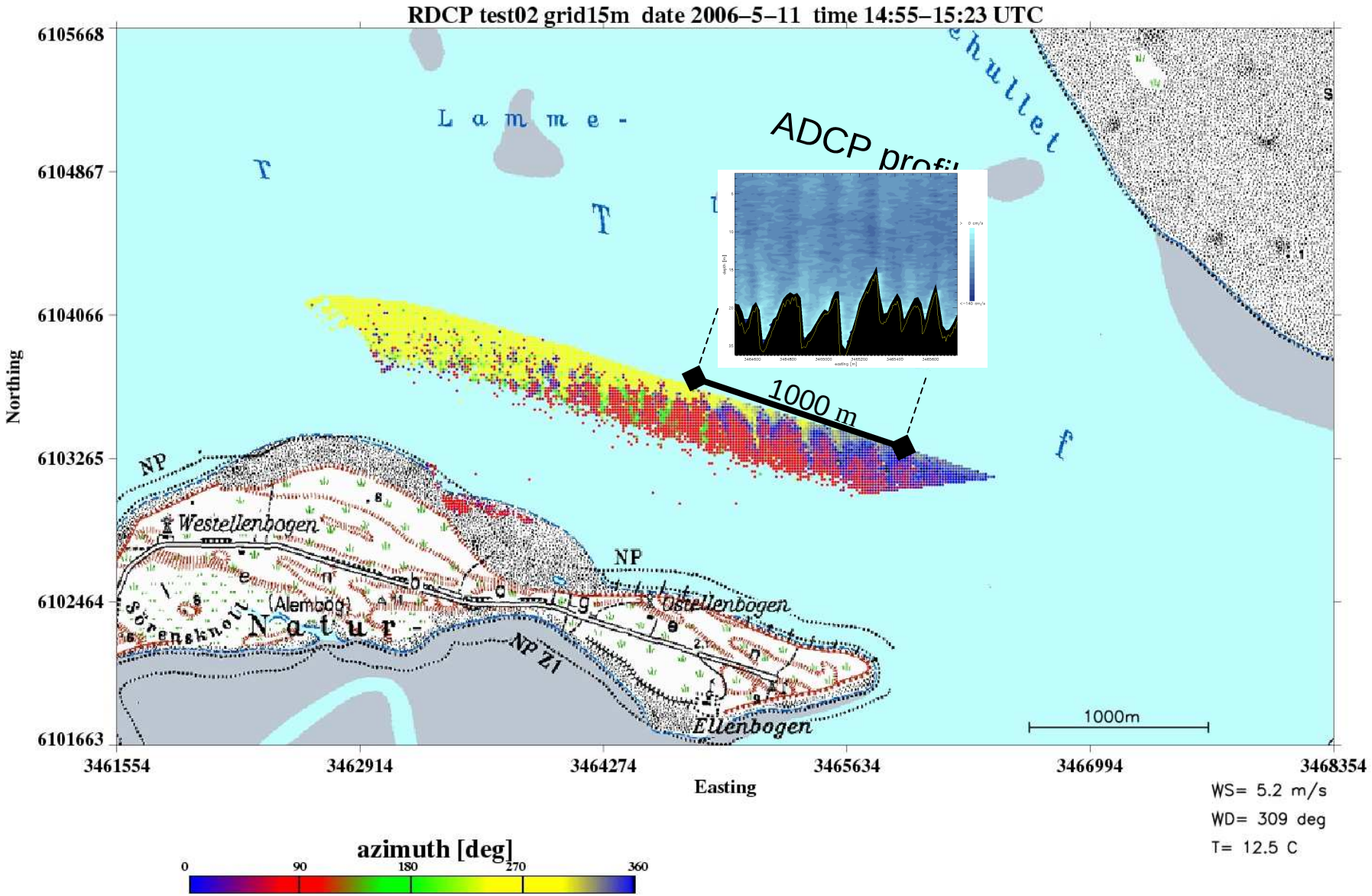
Map showing the change in depth acquired from *(in-situ)* echo soundings; time step: 2001 - 2003



Laufende Arbeiten: Strömungskartierung Betrag (HW+3*h*)

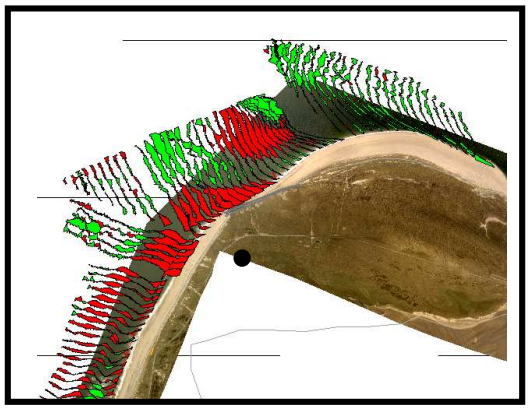


Laufende Arbeiten: Strömungskartierung Richtung (HW+3*h*)



Sand displacement observed since 2000 (*Lister Landtief)*

Lotungen 2000 - 2003

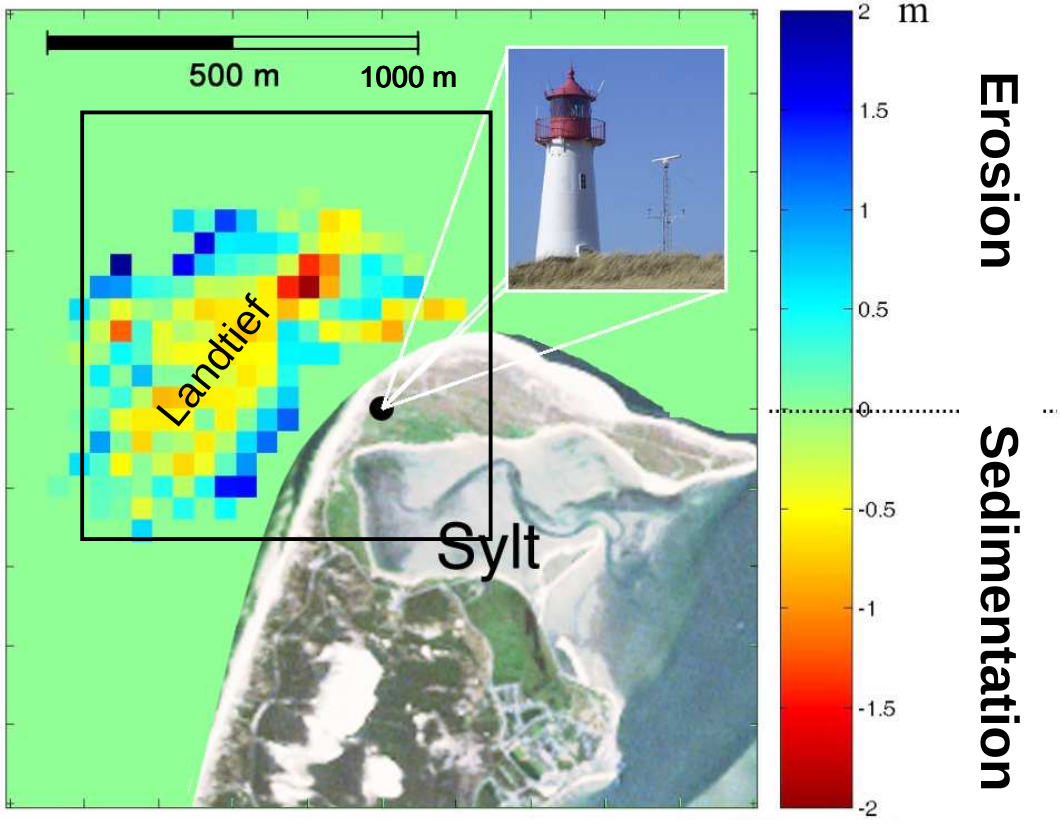


1 m Erosion

1 m Deposition

Daten ALR-Husum (2004)

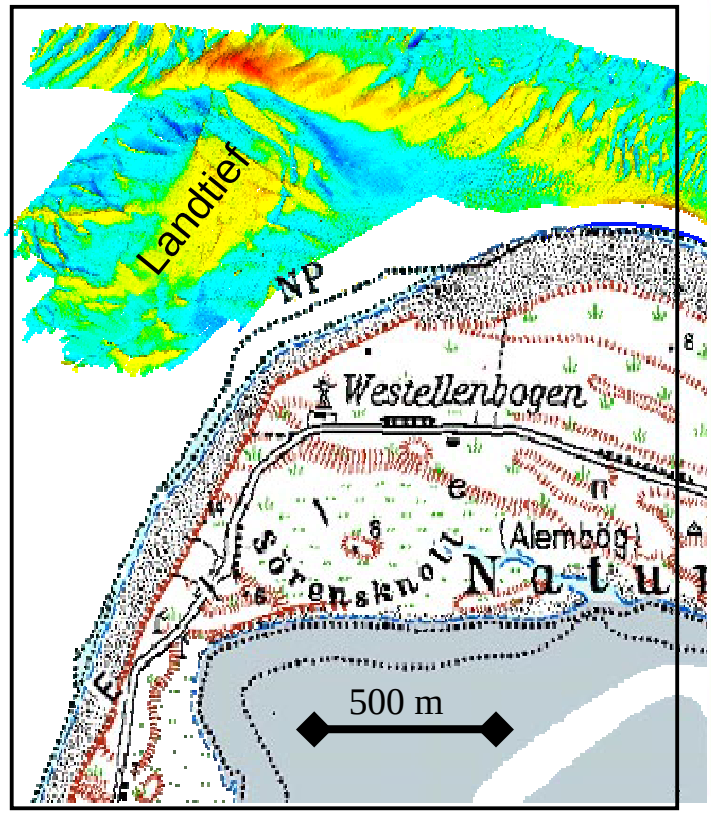
Radarmessungen 2001 - 2003



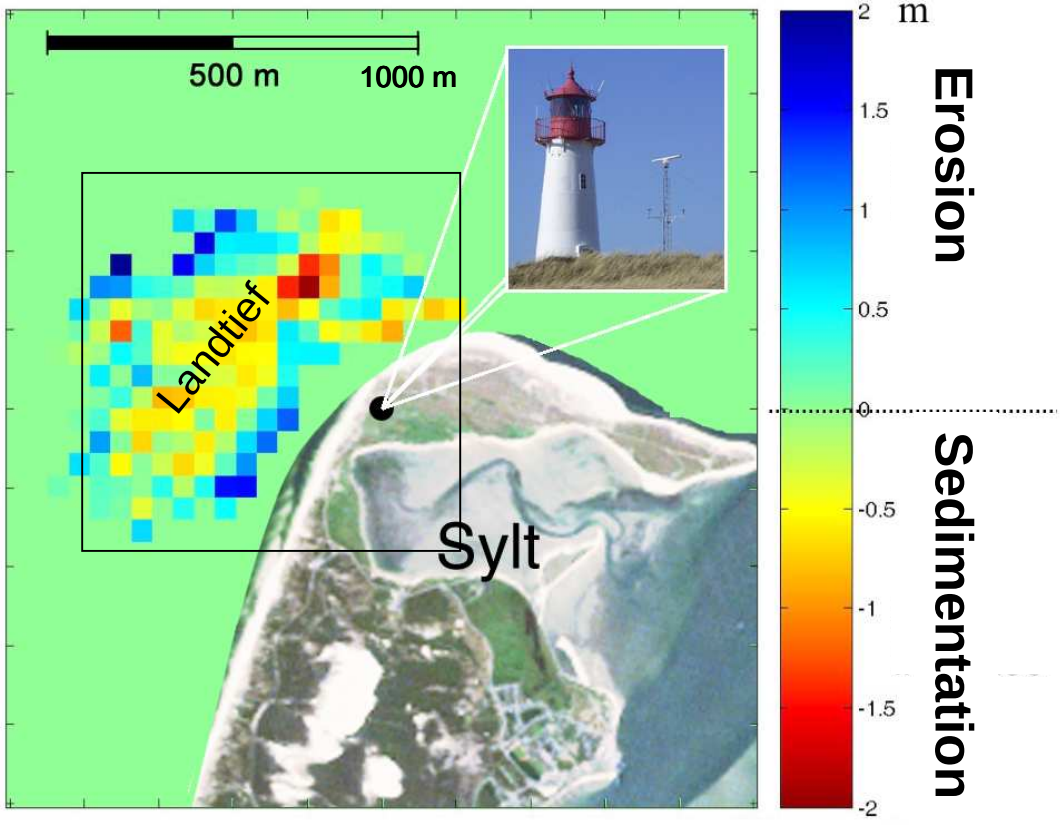
Bathymetry from sounding

Displacement of Sand in the *Lister Landtief* since 2000

Soundings 2001 - 2004



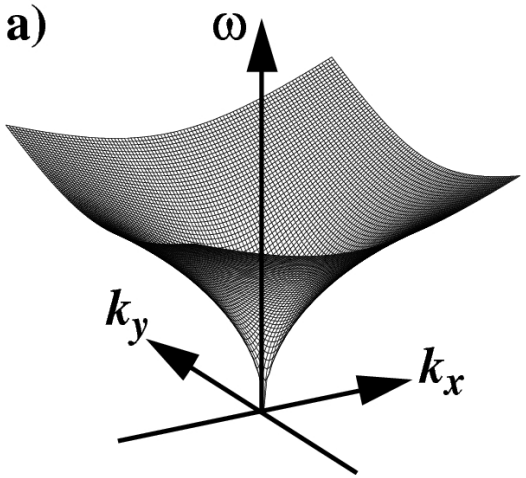
Radar observation 2001 - 2003



Insight in the background

The isotropic Dispersion and the non isotropic Dispersion

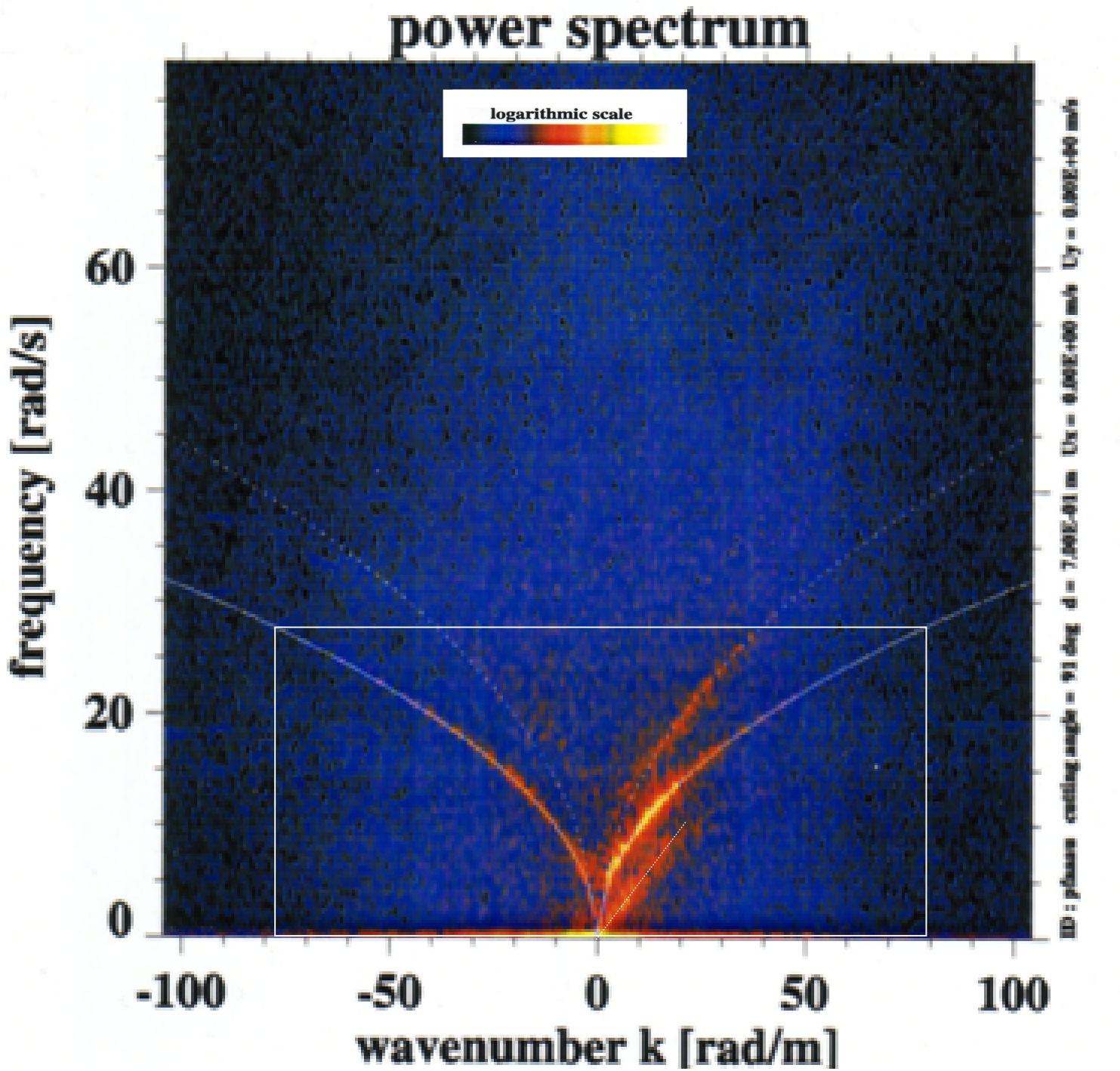
$$\omega = \sqrt{gk}$$



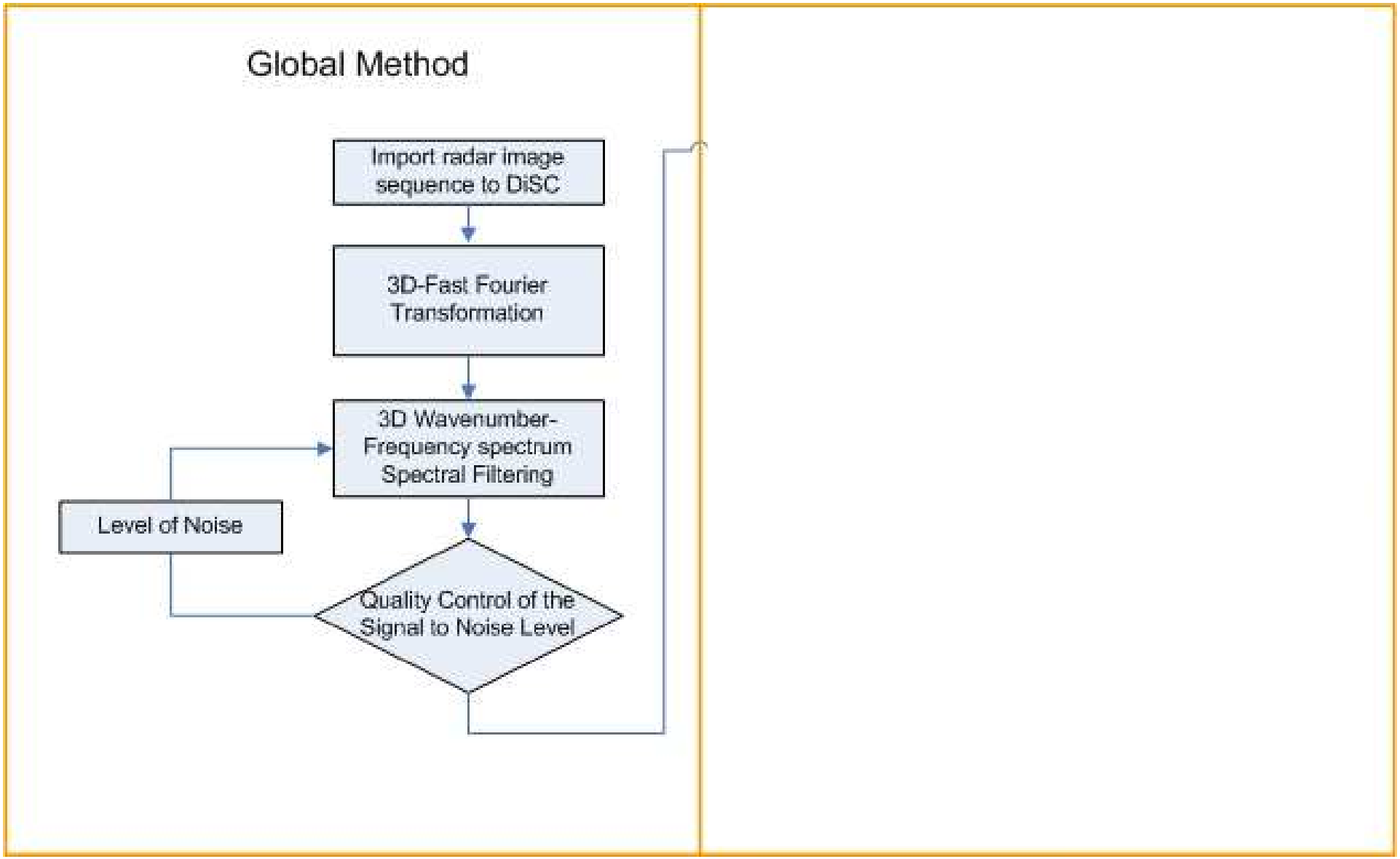
Undisturbed Dispersion over deep water

Dispersion over shallow depth

Dispersion under the influence of current

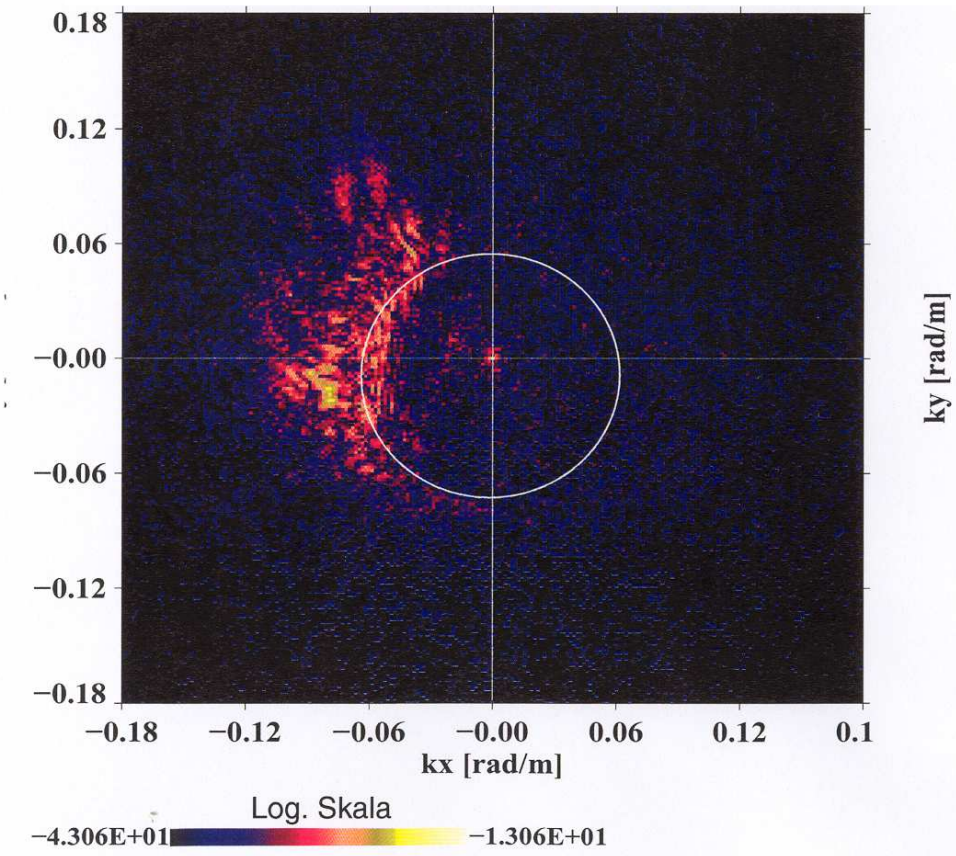

power spectrum
logarithmic scale
frequency [rad/s]
60
40
20
0
-100
-50
0
50
100
wavenumber k [rad/m]

Flow chart

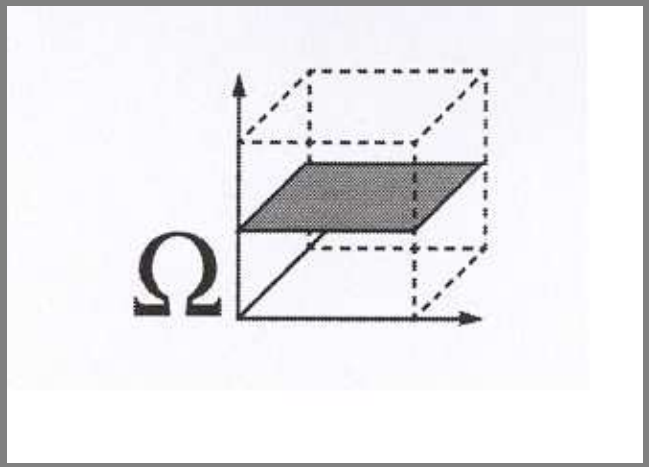

Global Method
Import radar image sequence to DiSC
3D-Fast Fourier Transformation
3D Wavenumber-Frequency spectrum Spectral Filtering
Level of Noise
Quality Control of the Signal to Noise Level

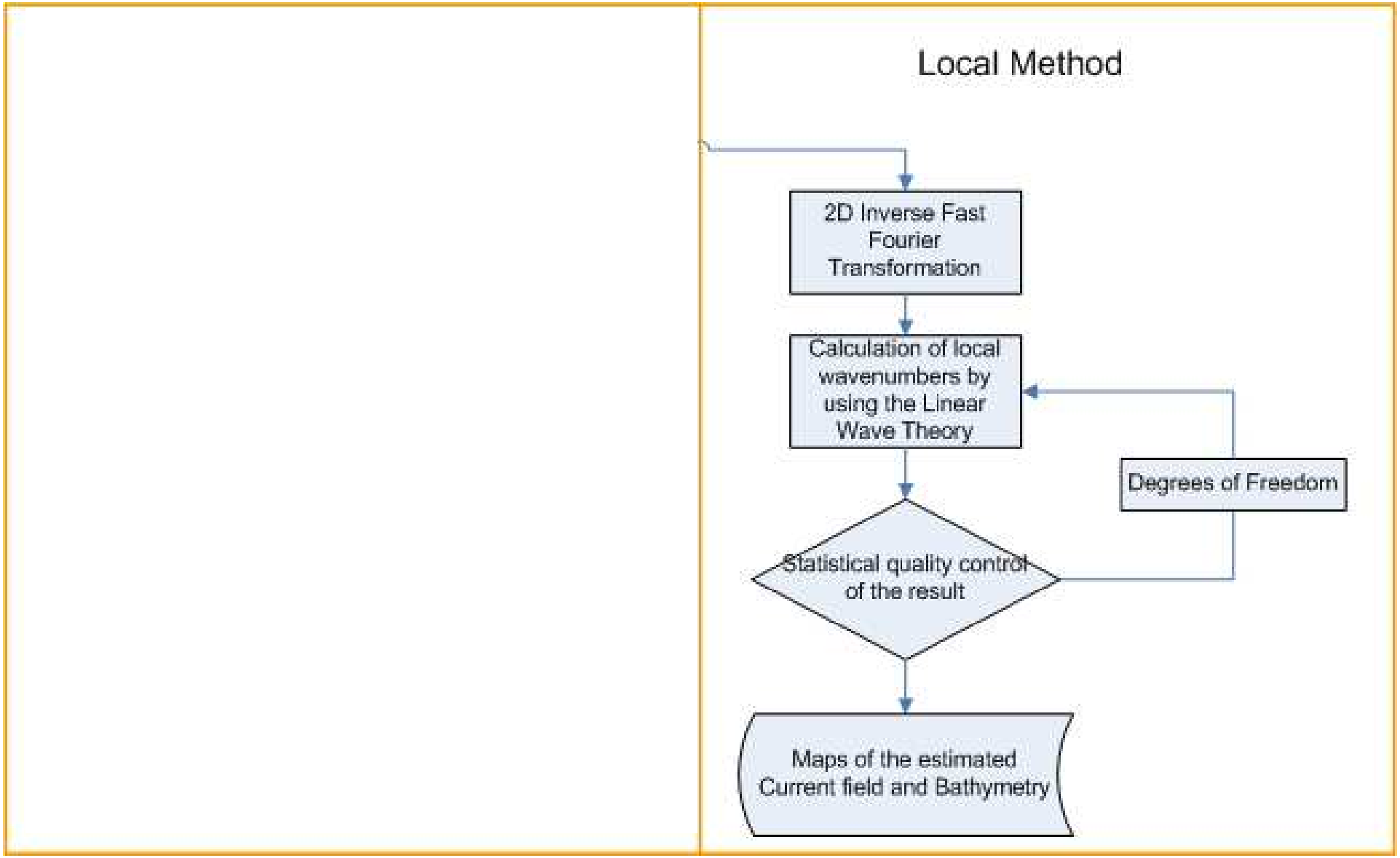
Power within one wave number plane at a fixed frequency

Power from the full image
2000 m * 2000 m



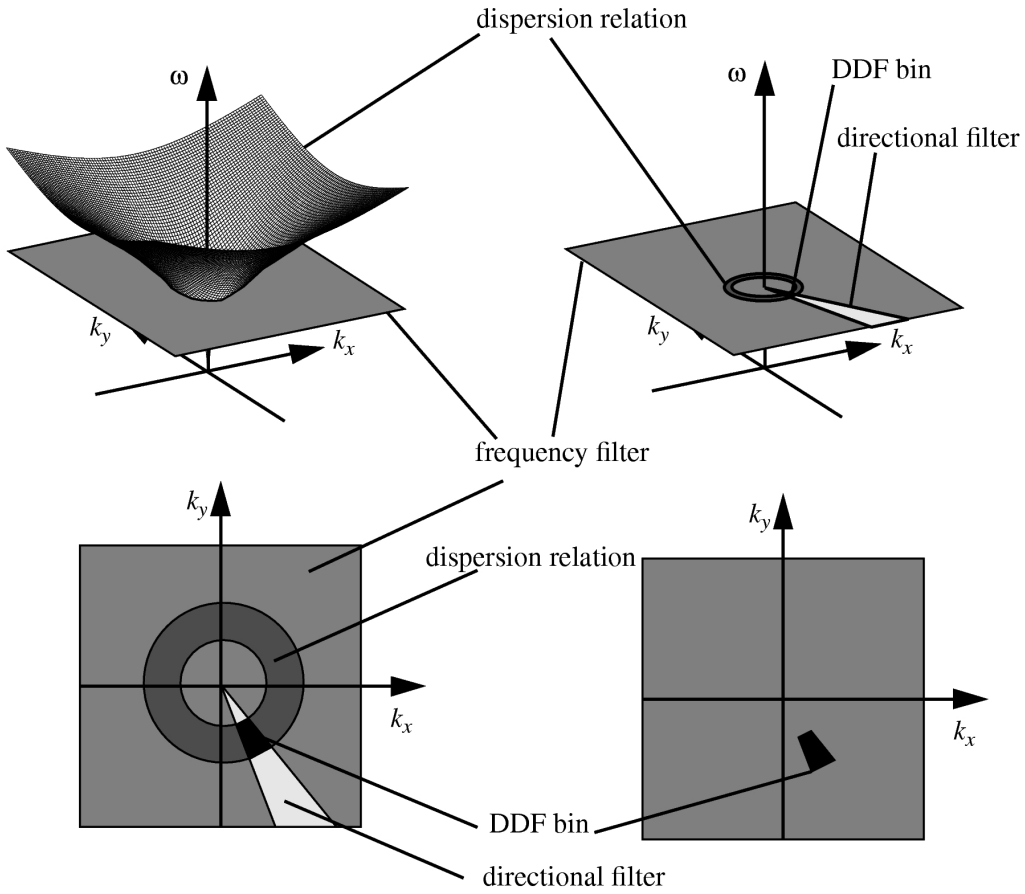
view direction

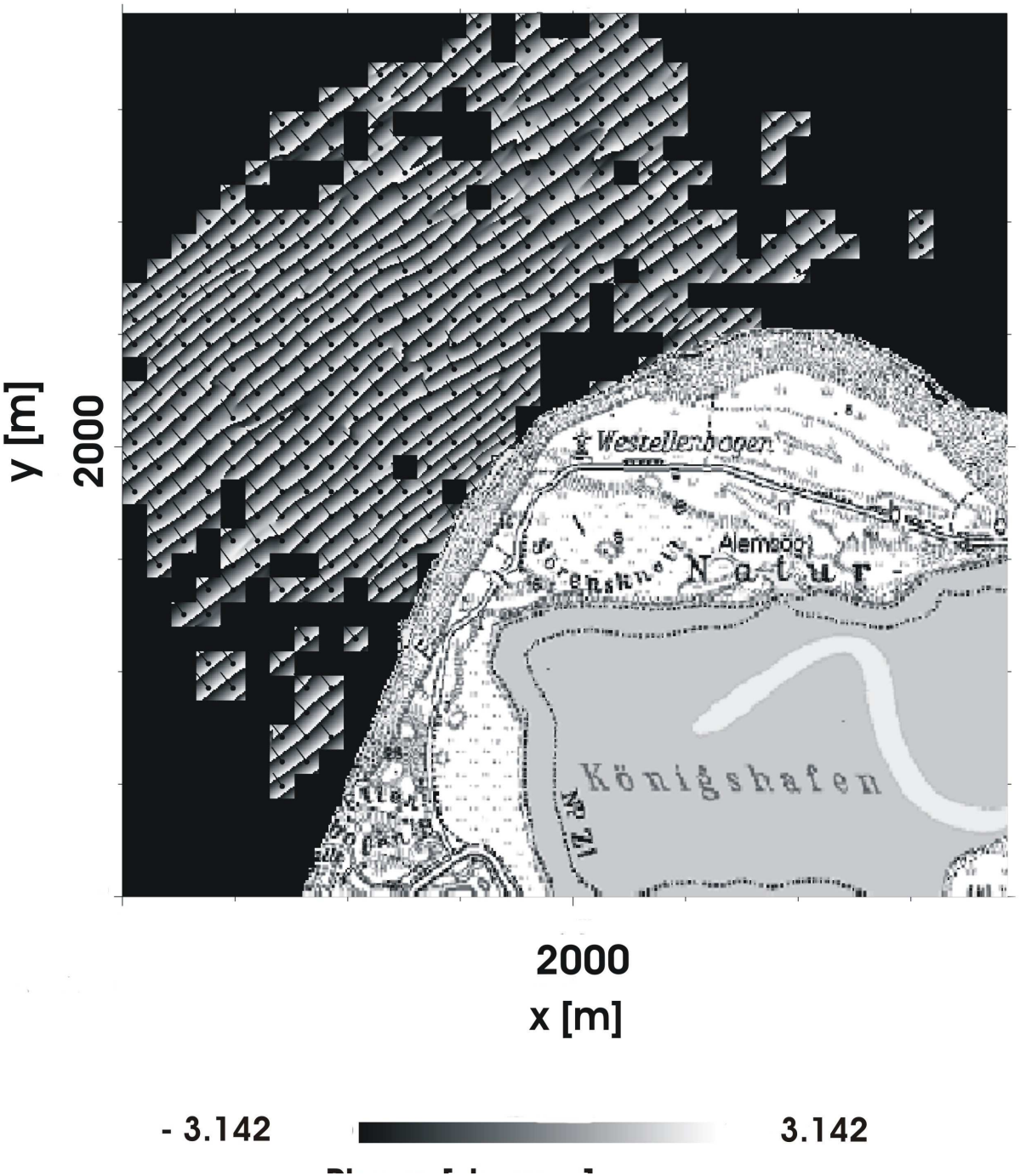



Local Method
2D Inverse Fast Fourier Transformation
Calculation of local wavenumbers by using the Linear Wave Theory
Degrees of Freedom
Statistical quality control of the result
Maps of the estimated Current field and Bathymetry

Radarhydrographie

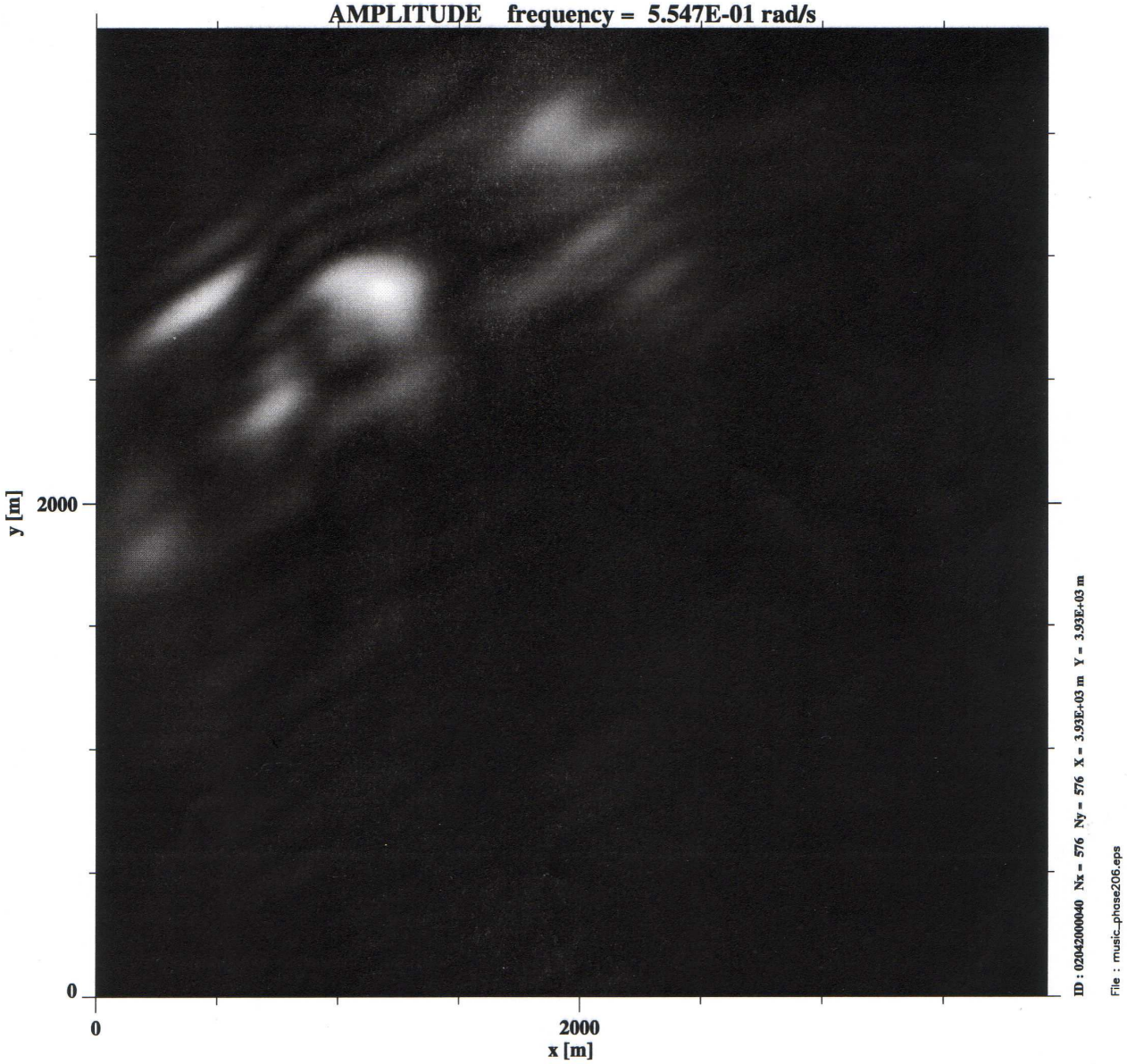
The definition of filter bins.



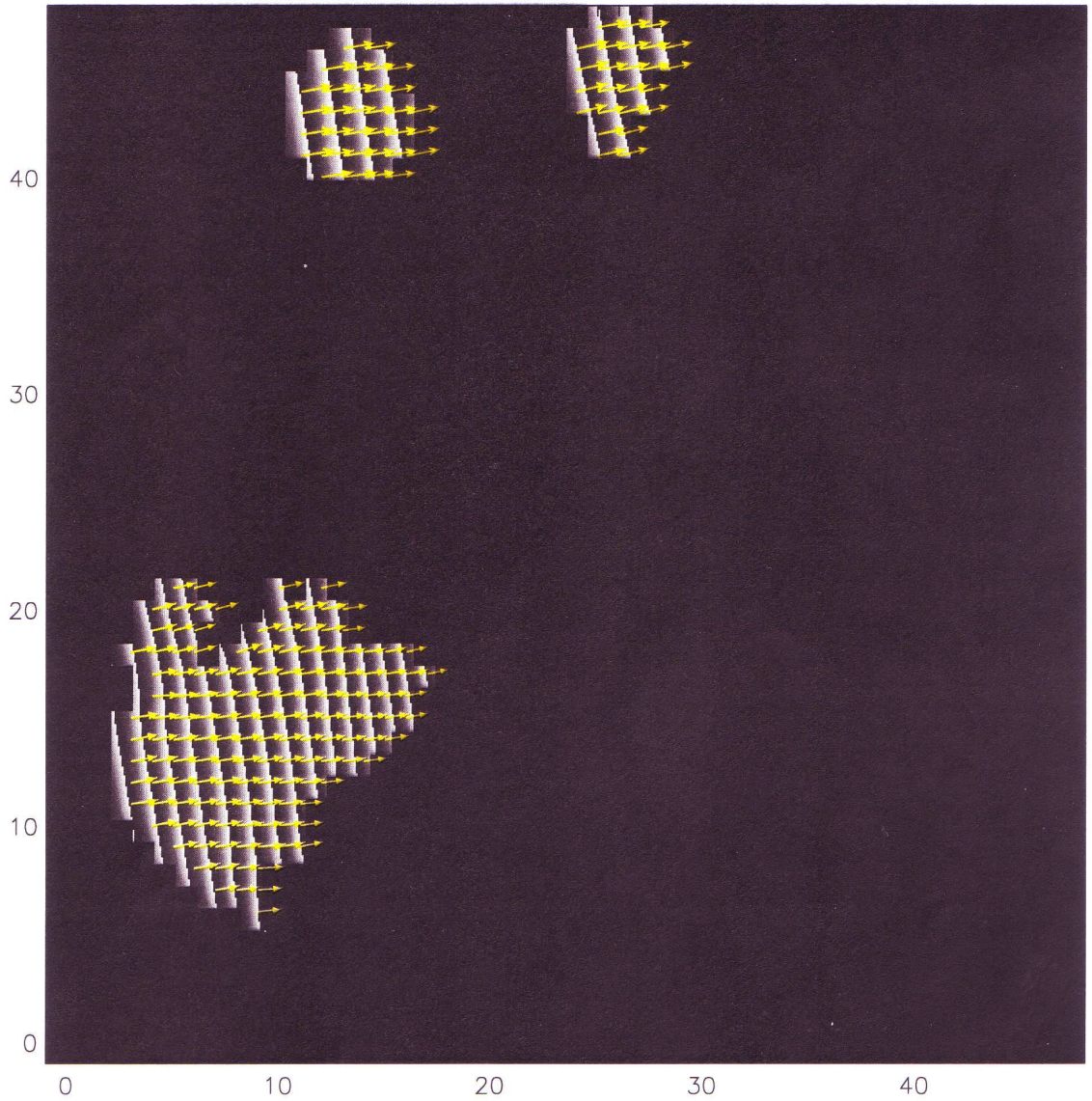


Example for a phase map.

The re-transformed wave structures do have the same phases and speeds. The wave number differs locally depending on depth.



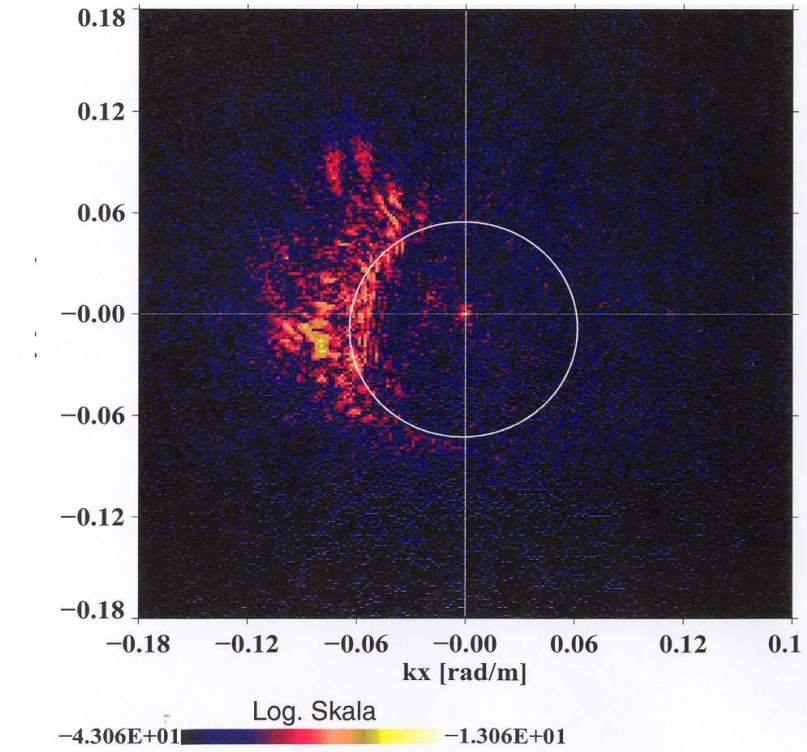
Example for a power map, pointing by its value to the locations with considerable contribution to the power in the actual bin.



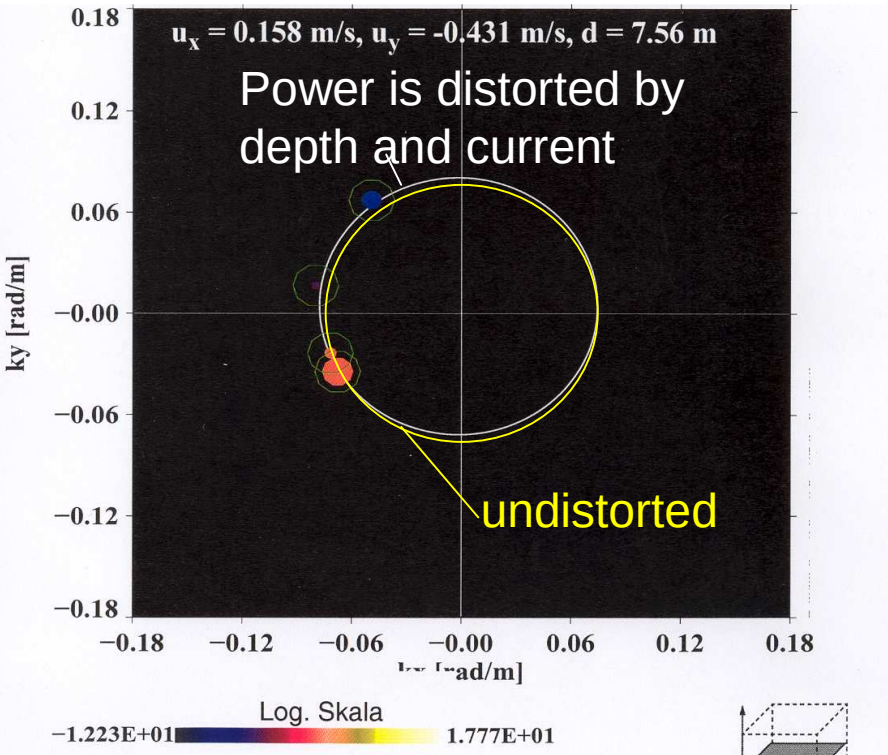
Merging phase and significance we get the locations that contributed to the power within the individual bins.

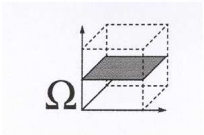
Example for the localisation of power within a given grid cell

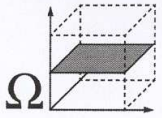
Power from the full image
2000 m * 2000 m



Integrated power for one frequency level
for one 40 m * 40 m grid cell

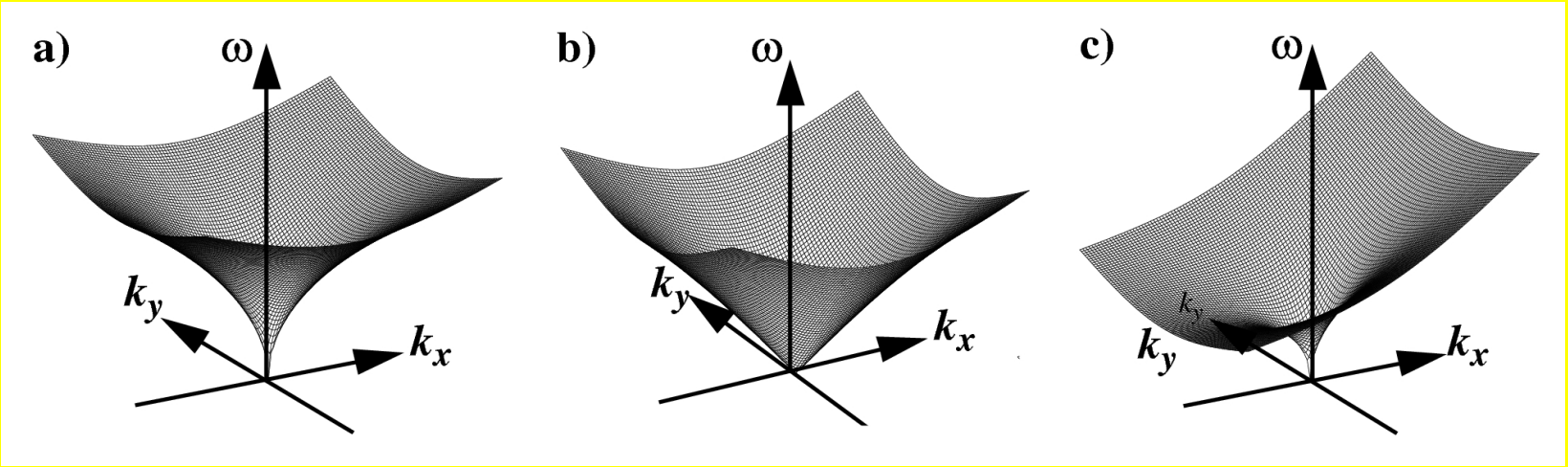






The localization procedure

- By integrating the power of all directions and all frequencies we receive a 3D-spectrum for each grid cell.
- For each localized spectrum the deviation from dispersion is deduced.



Range of application

limitations

1. Ratio wave length to local water depth

- *the deeper the water the longer the needed waves*

$$\lambda / h \leq 1 / 4$$

2. The local gradient in bathymetry

$$\partial / \partial x \left(h(x) \right) \leq 0.5m; where\, \partial x \approx 30m$$

- *flat sea bottom provides accurate results*
- *slopes in the bottom cause an over estimation of radar depth*

3. Radar range resolution

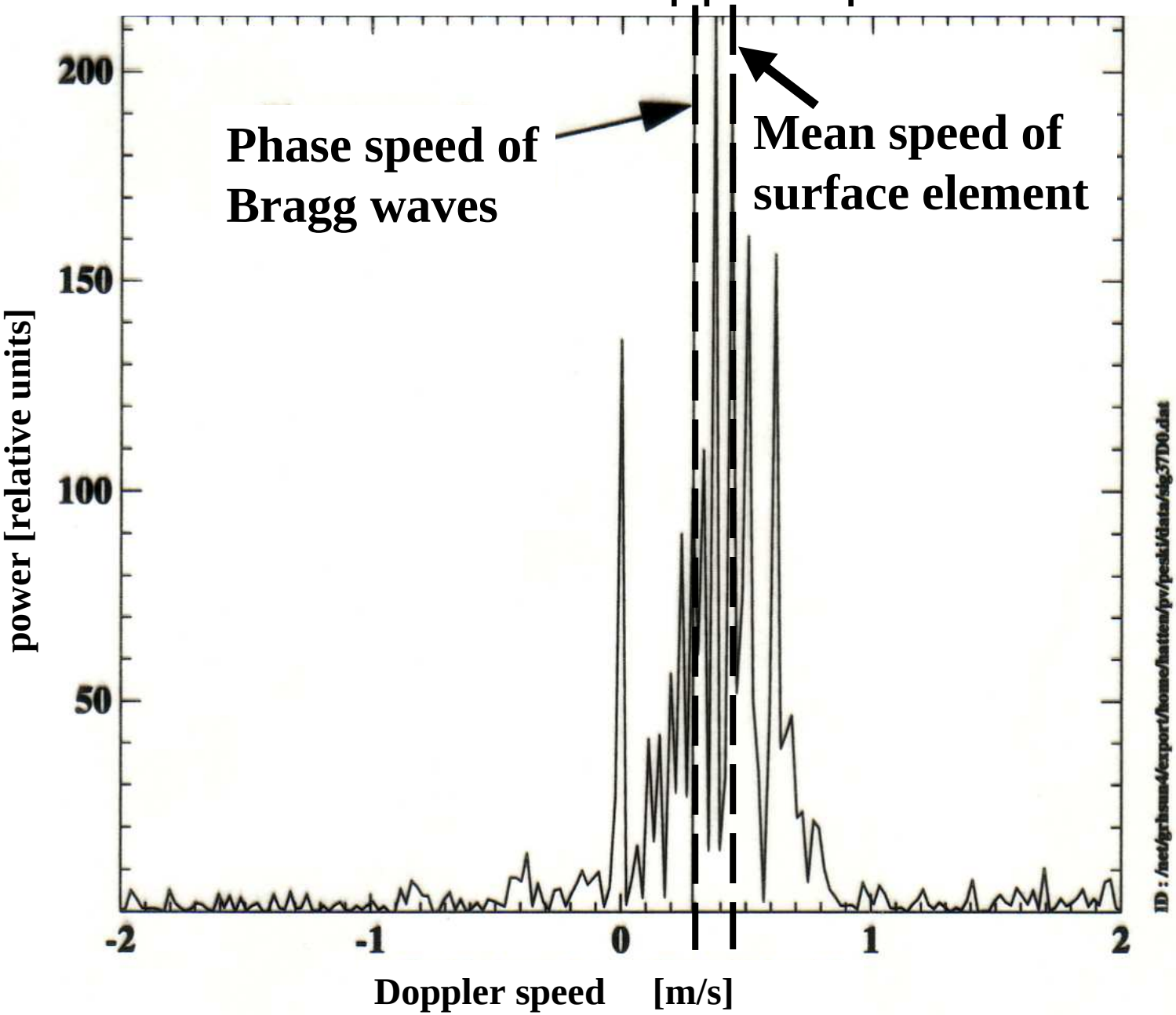
- *For the detection of the local wave number the corresponding wave should be sampled about 4 times*

$$\lambda_{shortest} \approx 4\Delta r$$

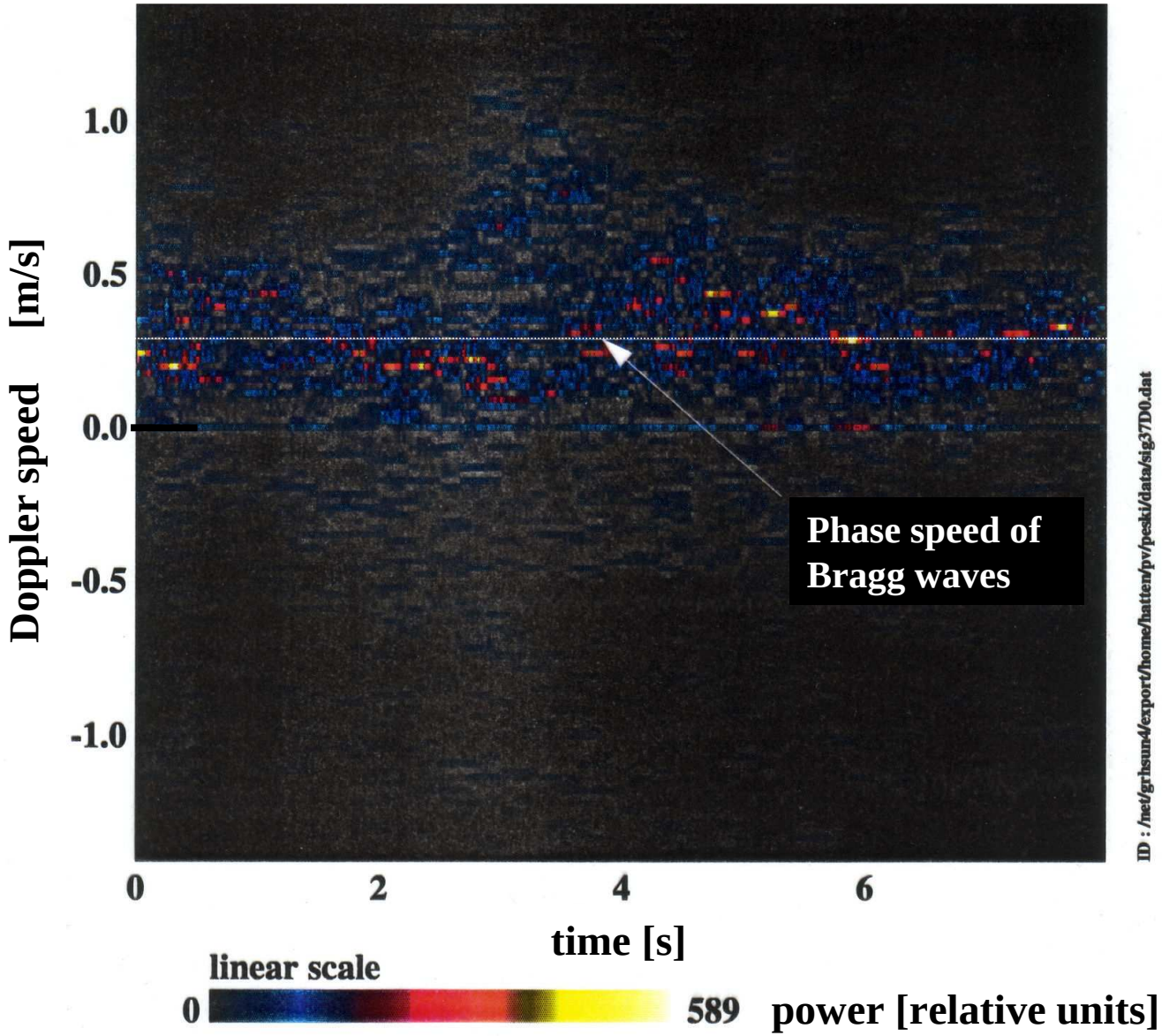
$$for: \Delta r = 7.5m \rightarrow \lambda_{shortest} \approx 30m$$

$$\rightarrow h_{local} \geq 3.0m$$

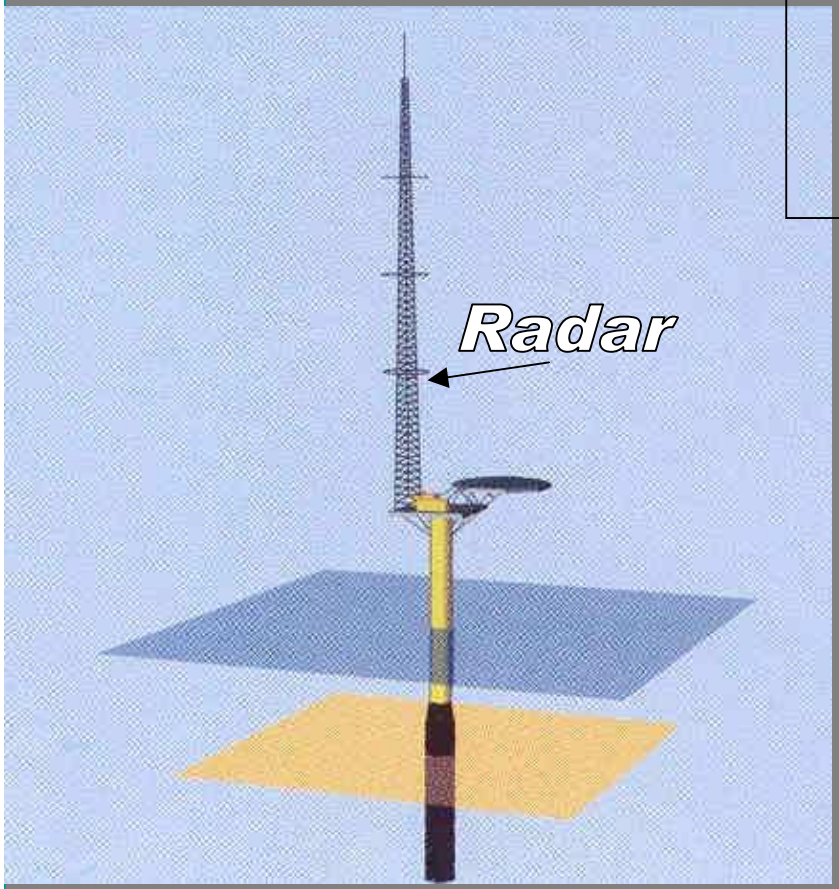
An individual Doppler spectrum



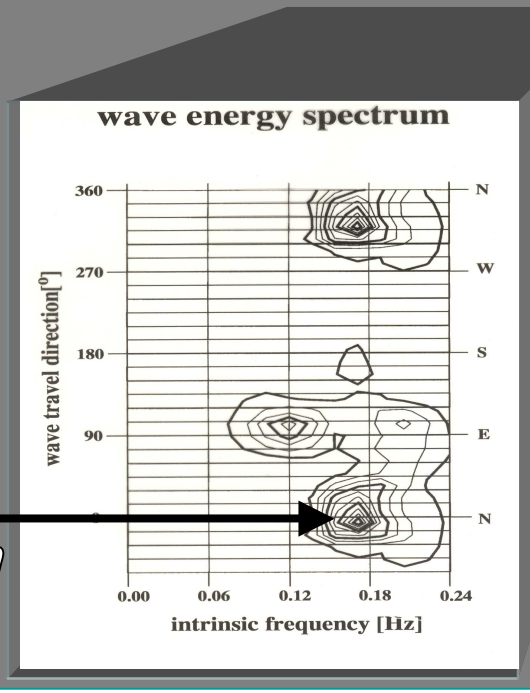
Time series of Doppler spectra of a moderate sea state



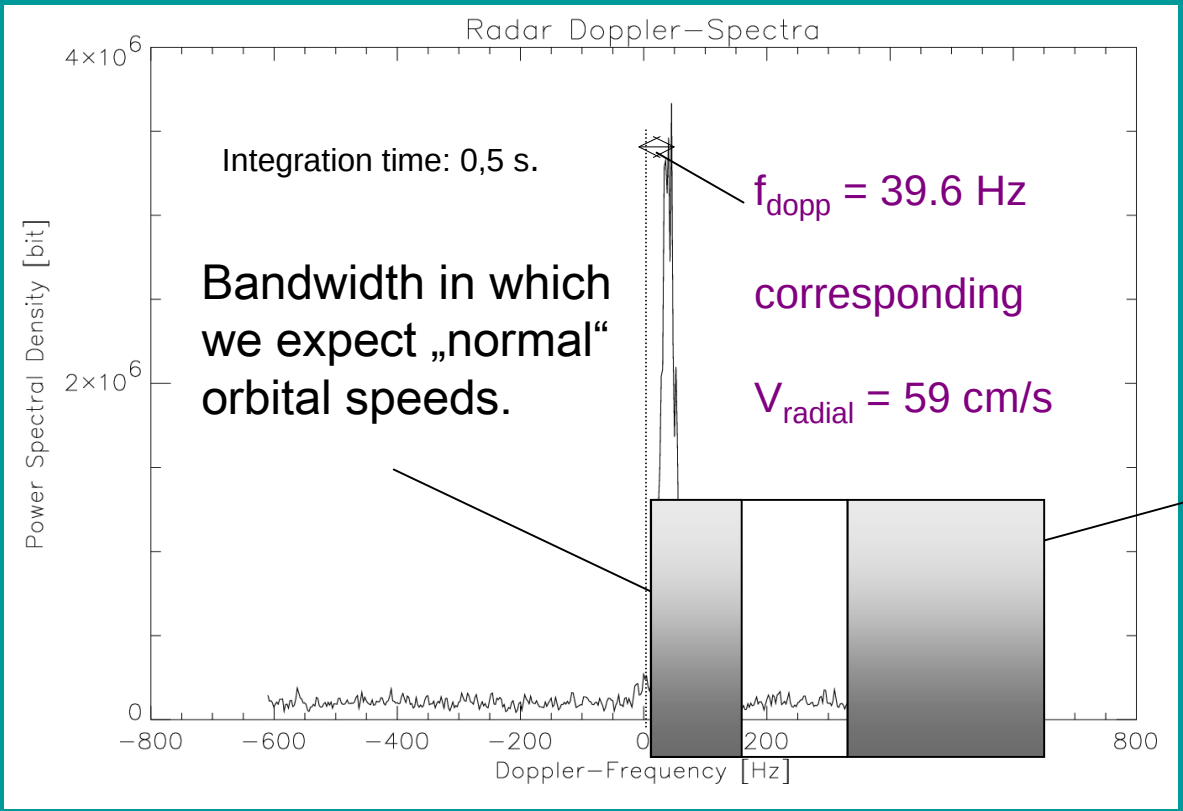
1. Step: To know the directional wave spectrum we conduct a WaMoS measurement to find the best view direction for the antenna of the coherent measurement.



antenna
view direction



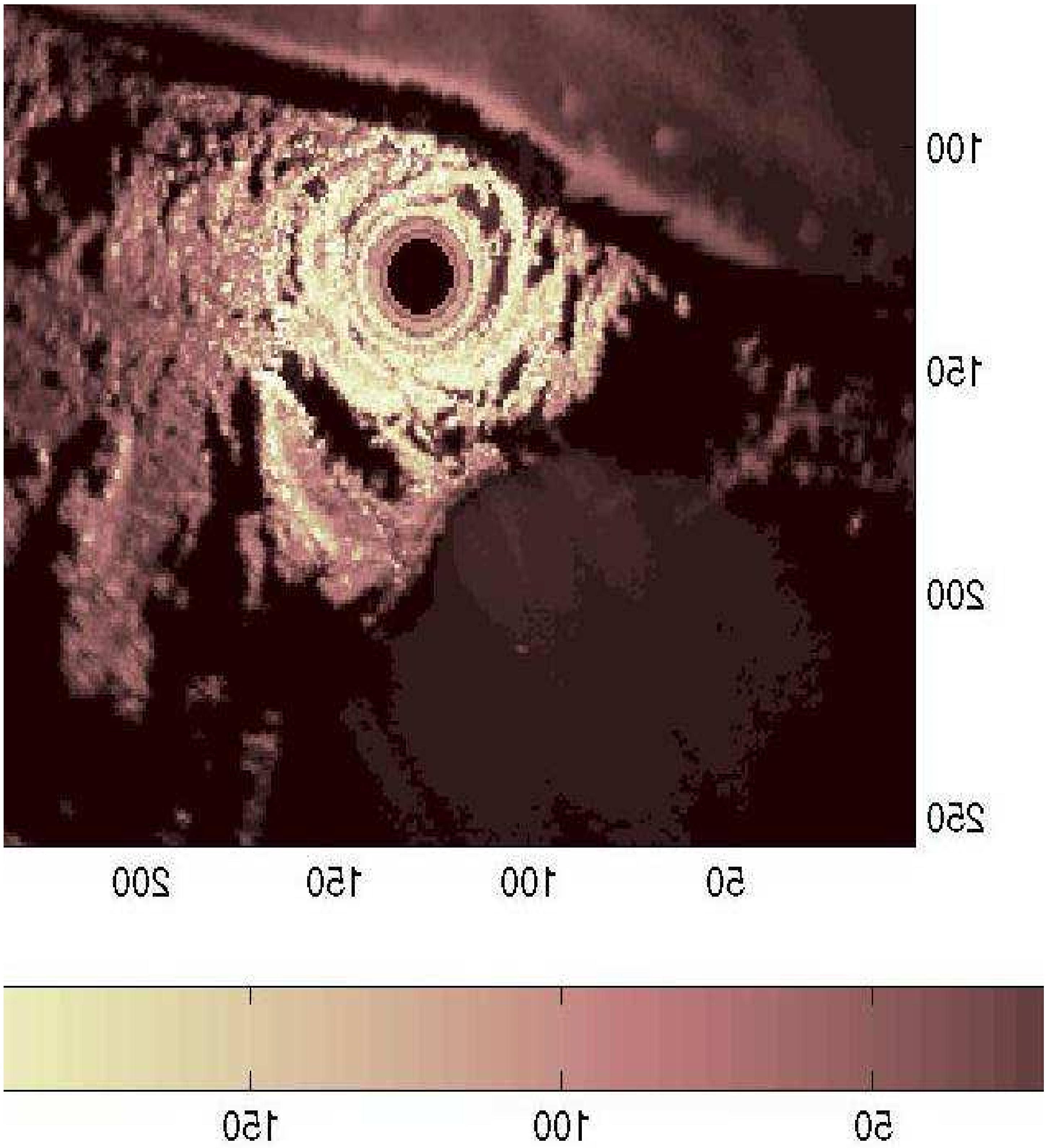
The spectral analysis of the coherent signal will as well provide the positions and speeds of breaking waves.



The bandwidth corresponds to a wave of 3 m height and an 10 s period.

$$v_{Orbital} = \pi H / \tau$$

Bandwidth in which we expect ***breaking*** events.


100
150
200
250
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50