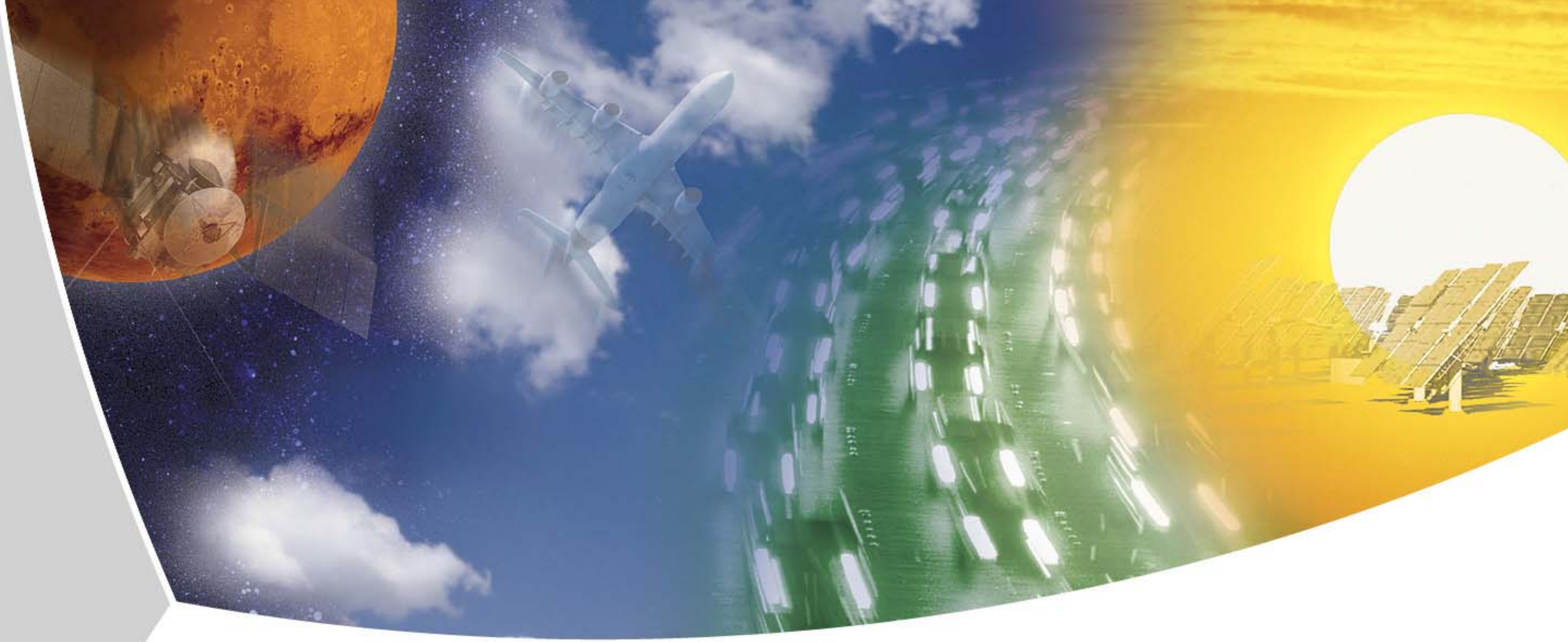


CONCEPTS FOR SPACE-BORNE AND GROUND-BASED RADAR SYSTEMS FOR TSUNAMI DETECTION

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

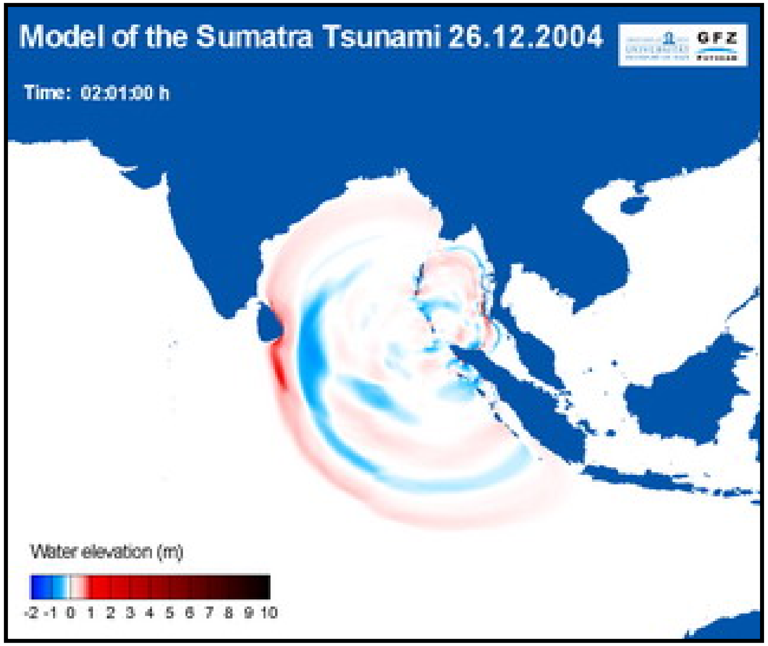
Geodätische Woche: 10.-12. Oct. 2006

Marquart – Galletti – Börner – Krieger – Schulz-Stellenfleth

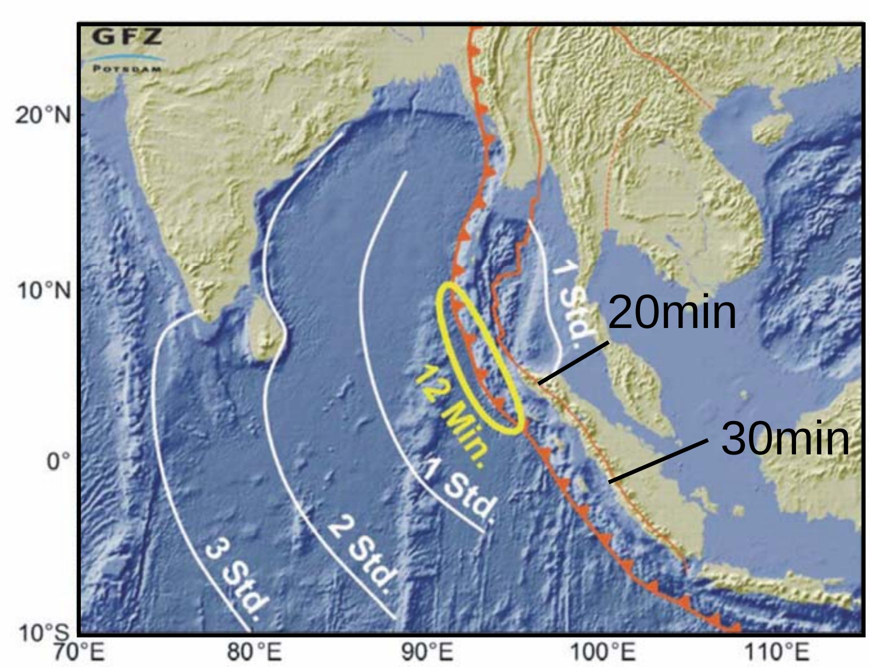
Contents

- GITEWS project
  - Motivation (Boxing Day Tsunami)
  - German-Indonesian Tsunami Early Warning System (GITEWS)
- Tsunami Geophysics
  - Measurable oceanographic observables
- Ground-Based Radars for Tsunami Detection
- Concept Design of a Spaceborne Radar for Tsunami detection

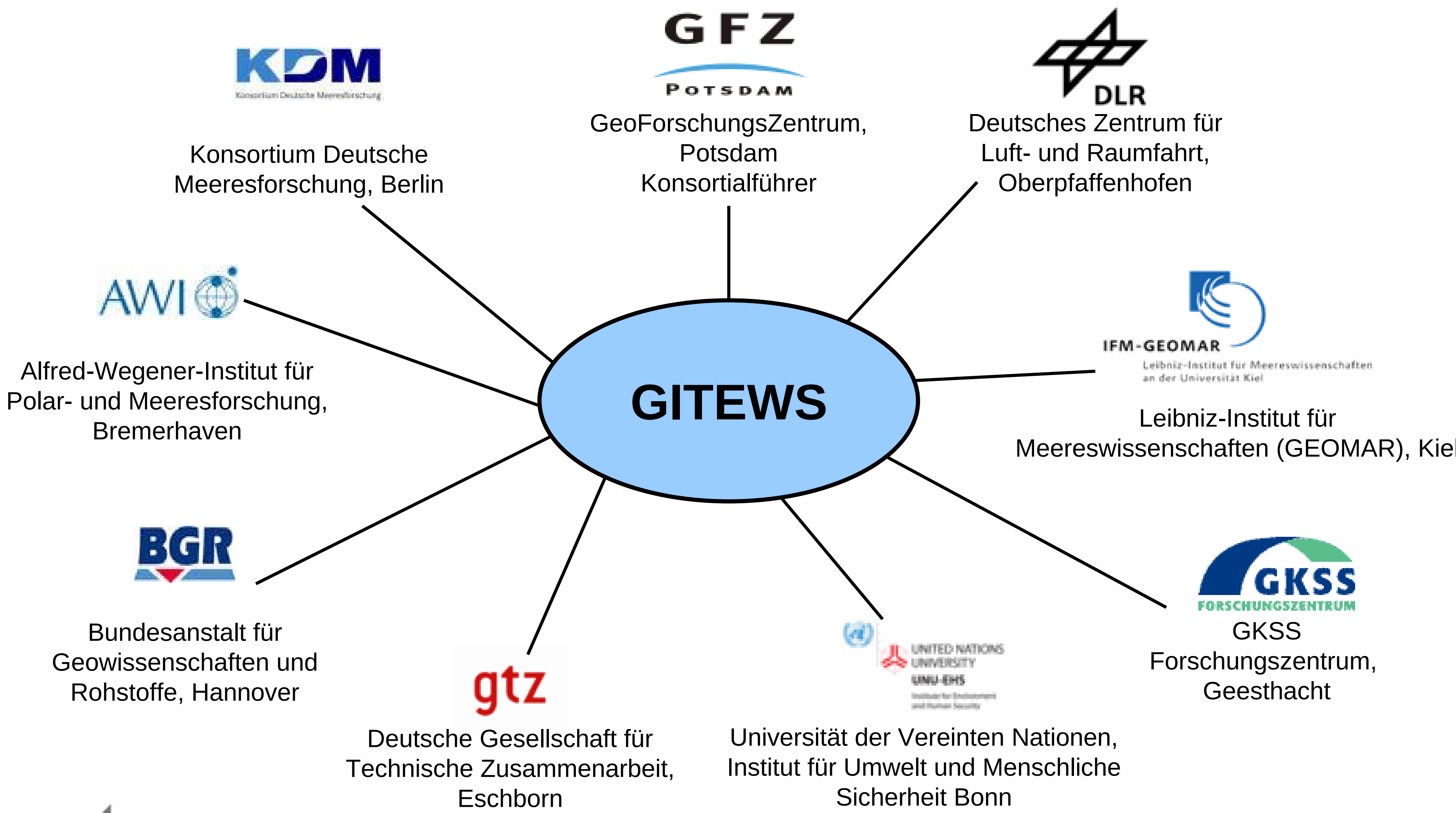
Boxing Day Tsunami (26.12.2004)



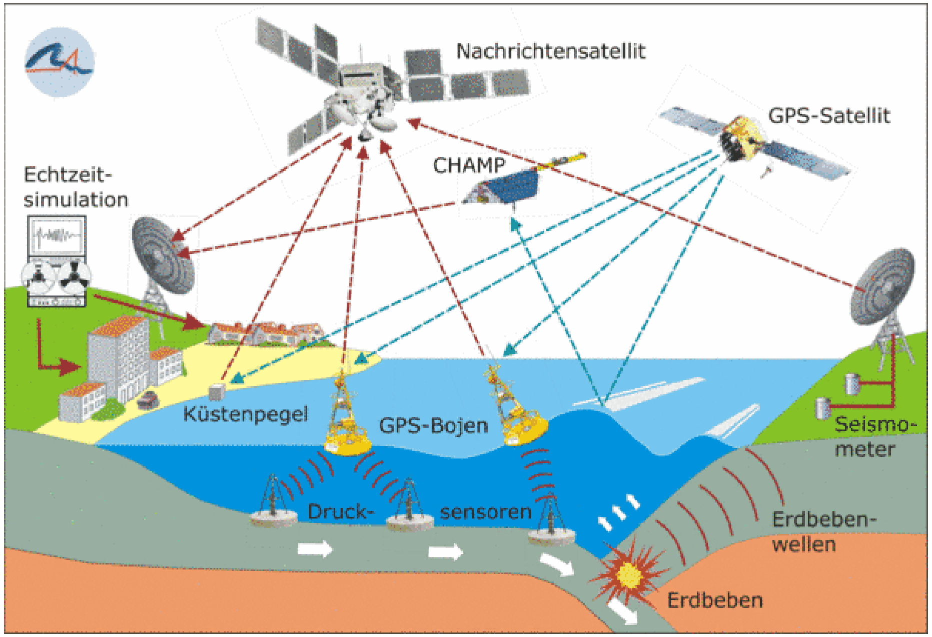
GFZ-Potsdam



German-Indonesia Tsunami Early Warning System



GITEWS Workpackages

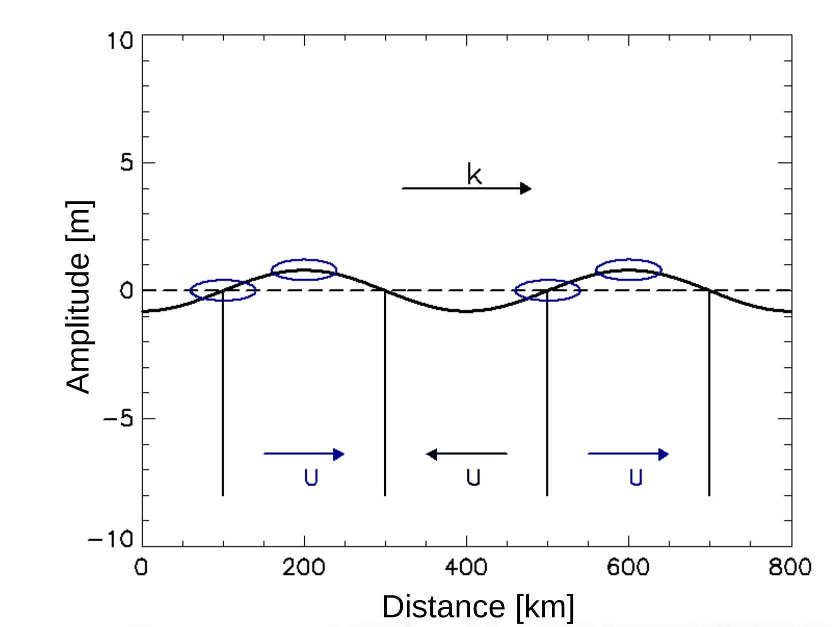


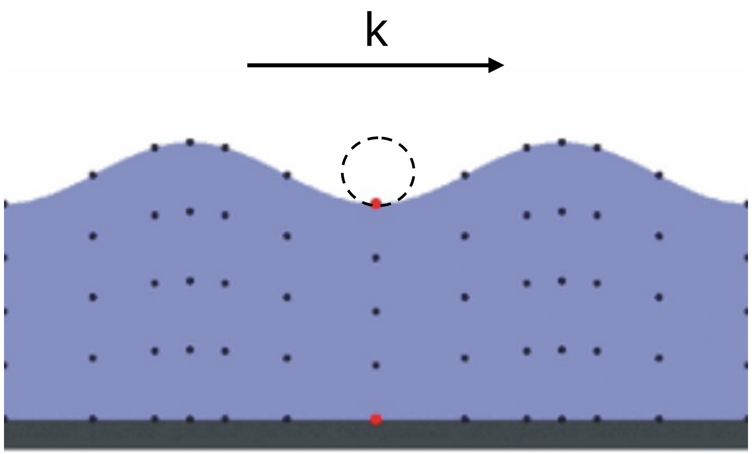
- Earthquake monitoring (WP 1000)
- Ocean Instrumentation (WP 2000)
- GPS Technology (WP 3000)
- Early Warning and Mitigation Center and Earth Observation Studies (WP 4000)
- Tsunami Modelling (WP 5000)
- Capacity Building (WP 6000)
- Project Management (WP 7000)

WP 4430
Studies on Ground-based HF and Microwave RADAR and new Space-borne microwave systems

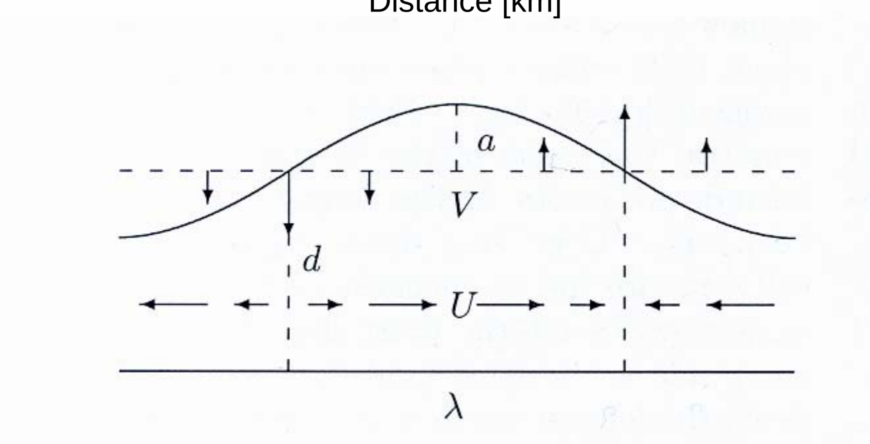
Geophysical Parameters

Tsunami parameters



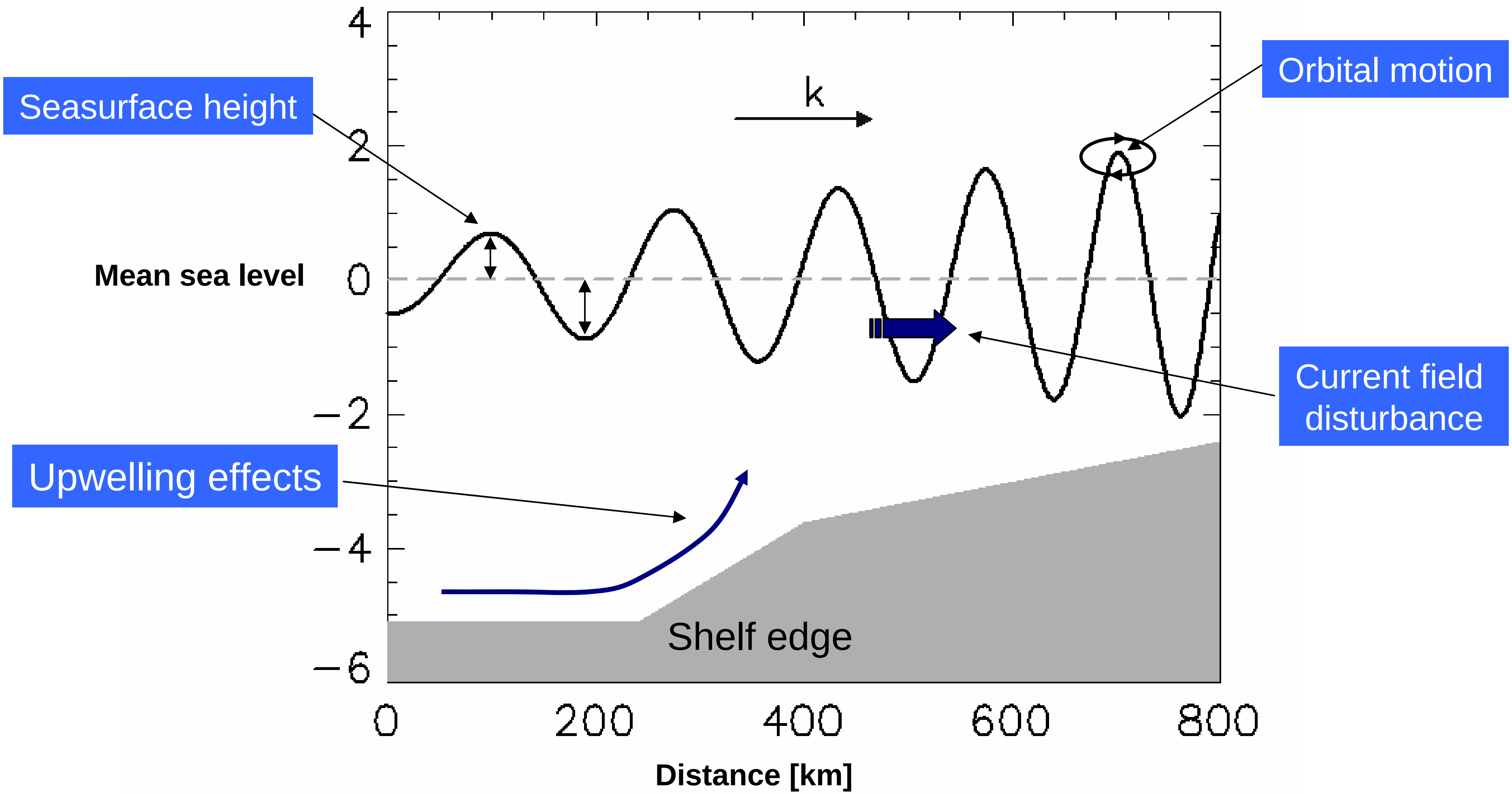


http://de.wikipedia.org/wiki/Tsunami



A: amplitude
d: water depth
U: horizontal velocity
V: vertical velocity
λ: wave length

Geophysical Parameters



Tsunami Scale

Benny Lautrup, *Tsunami Physics*
Kvant, Jan 2005

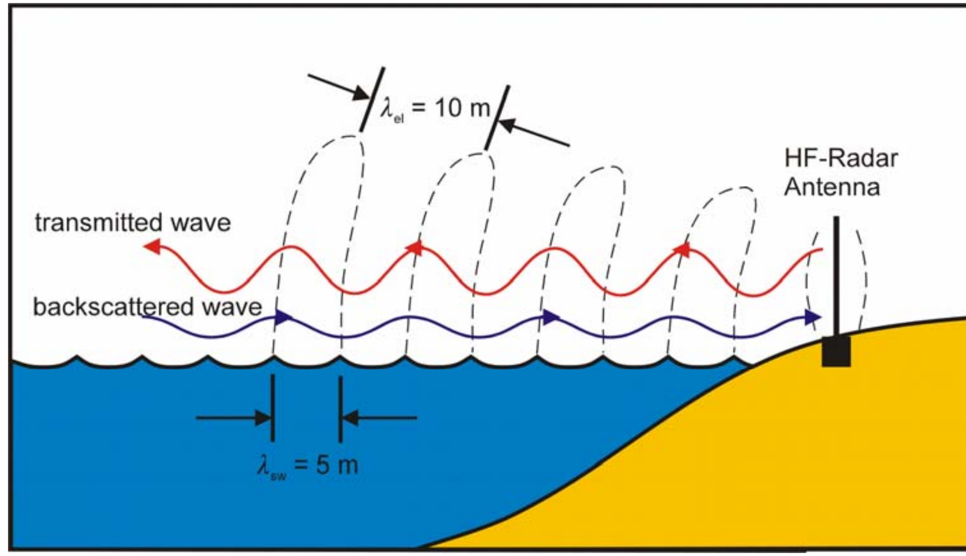
Deep Ocean	d=4000 m	λ=150 km	a=0.7 m	U=0.08 m/s
Coastal Area	d=40 m	λ=15 km	a=5 m	U=2.5 m/s

Tsunamis are more easily detectable in coastal areas

GROUND-BASED RADARS FOR TSUNAMI DETECTION:

HF RADARS

HF RADAR (Helzel GmbH)



- HF ground wave
- Backscattering from wave crests

→ Bragg Scattering

e.g. λ_{SW}=25m → f_{RADAR}= 12 MHZ → HF RADAR

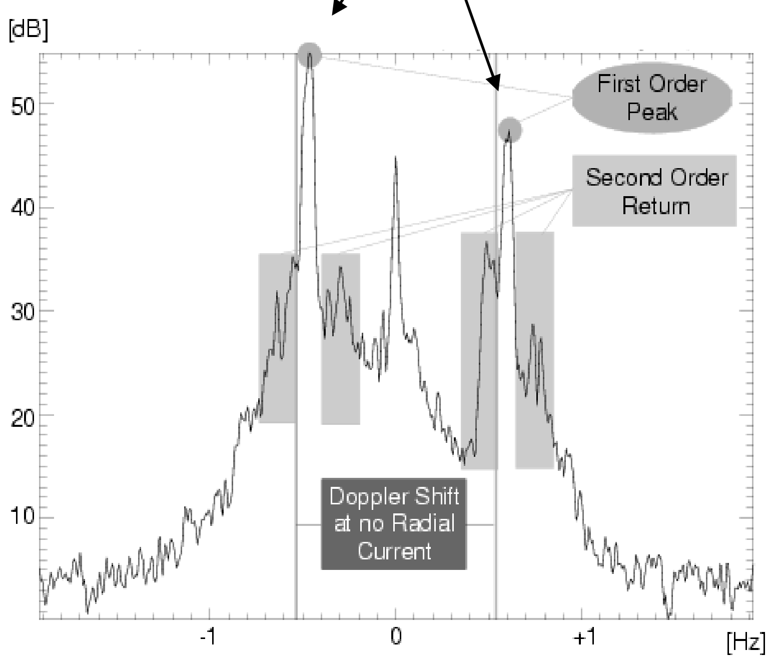
http://www.helzel.com

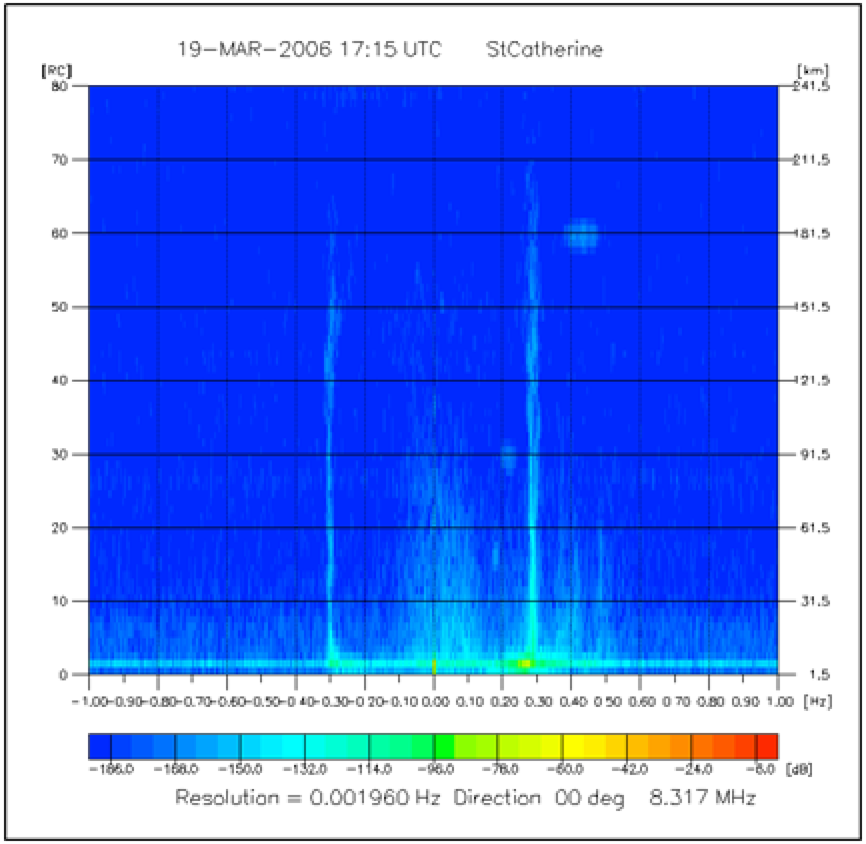
http://www.ifm.zmaw.de

Doppler Spectrum

1 Dim. Radial Component

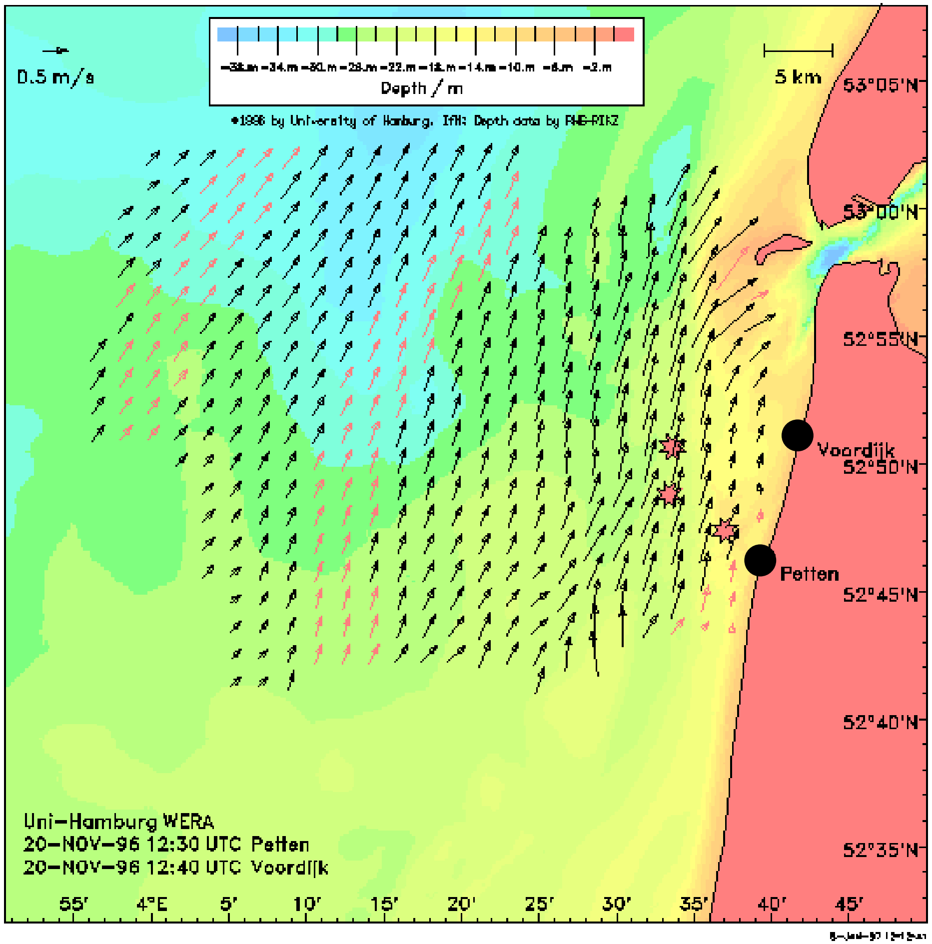
$$f_D = \pm \frac{k\, v_r}{\pi}$$





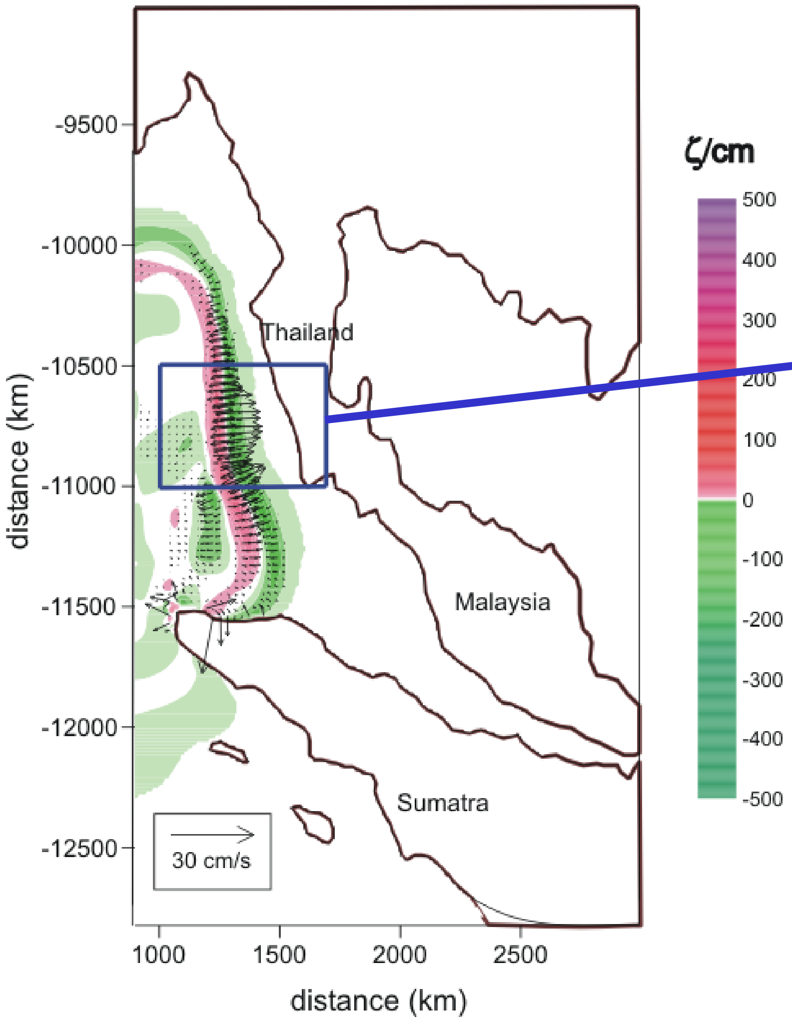
http://www.ifm.zmaw.de

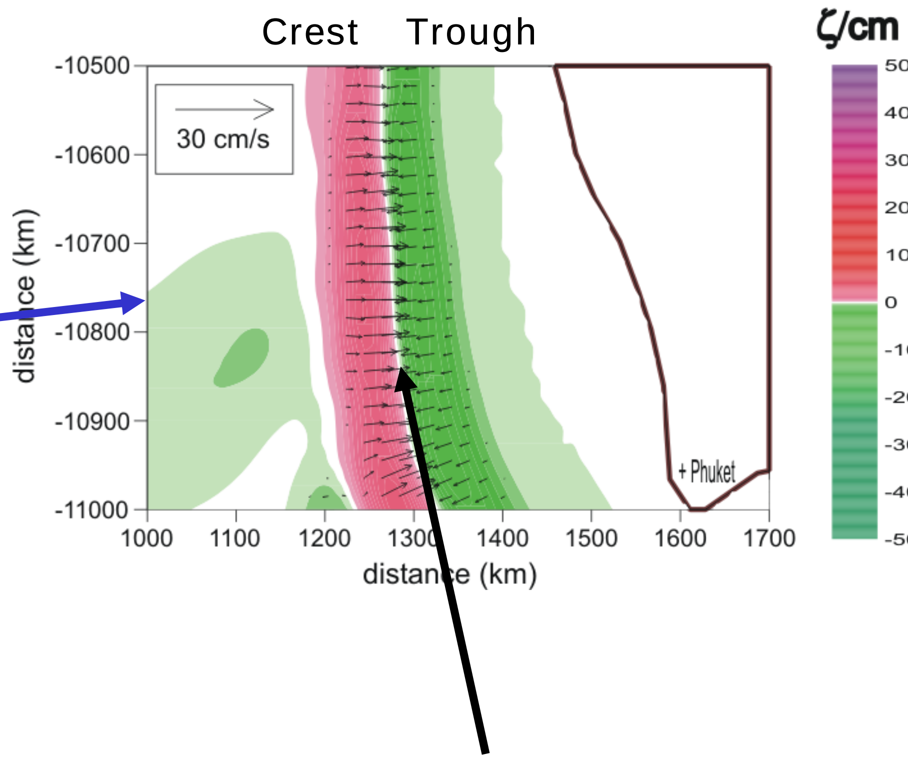
Current Field



- The operating frequency is the most important parameter for long range
- The lower the operation frequency the longer the range
- A center frequency of 10MHz results in a Bragg wave length of about 15m
- f [5-15MHz] → Range [100-200km]

Current Field Simulation





Strong ocean current signature

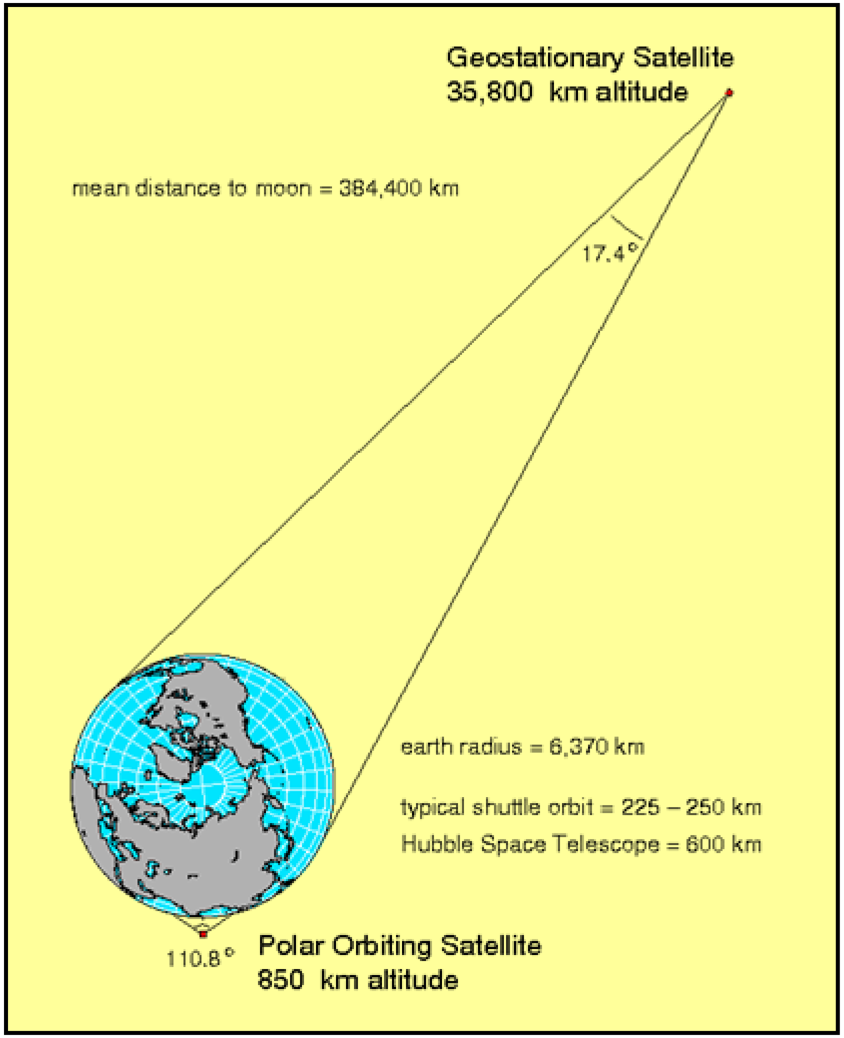
along the Tsunami front !

Institute of Oceanography (IfM) Hamburg

DLR CONCEPT
FOR TSUNAMI DETECTION:

GEOSTATIONARY INTERFEROMETER

Why a geostationary orbit ?

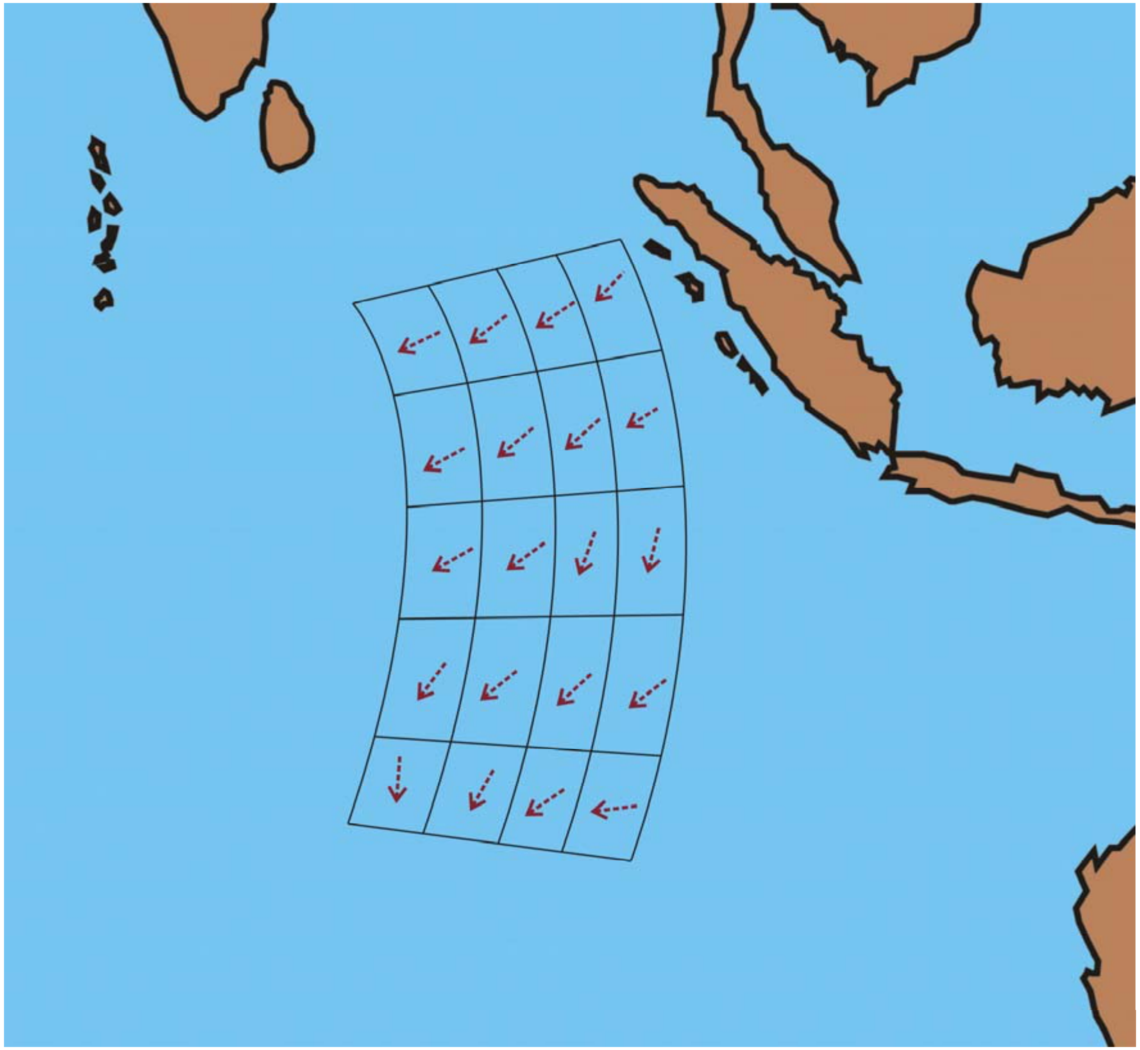


- Huge Field of View:
  Covers virtually every oceanic trench up to 50° latitude
- Continuous Monitoring for early warning
- While waiting for the next tsunami, other applications are possible:
  - ✓ Ocean Current measurements
  - ✓ Wave measurements
  - ✓ Global Ocean Circulation
  - ✓ Wind measurements

Principle of along track interferometry

$$\Delta\varphi_{\text{meas.}} = \varphi_1 - \varphi_2$$

Wide Swath Pattern Mearurements

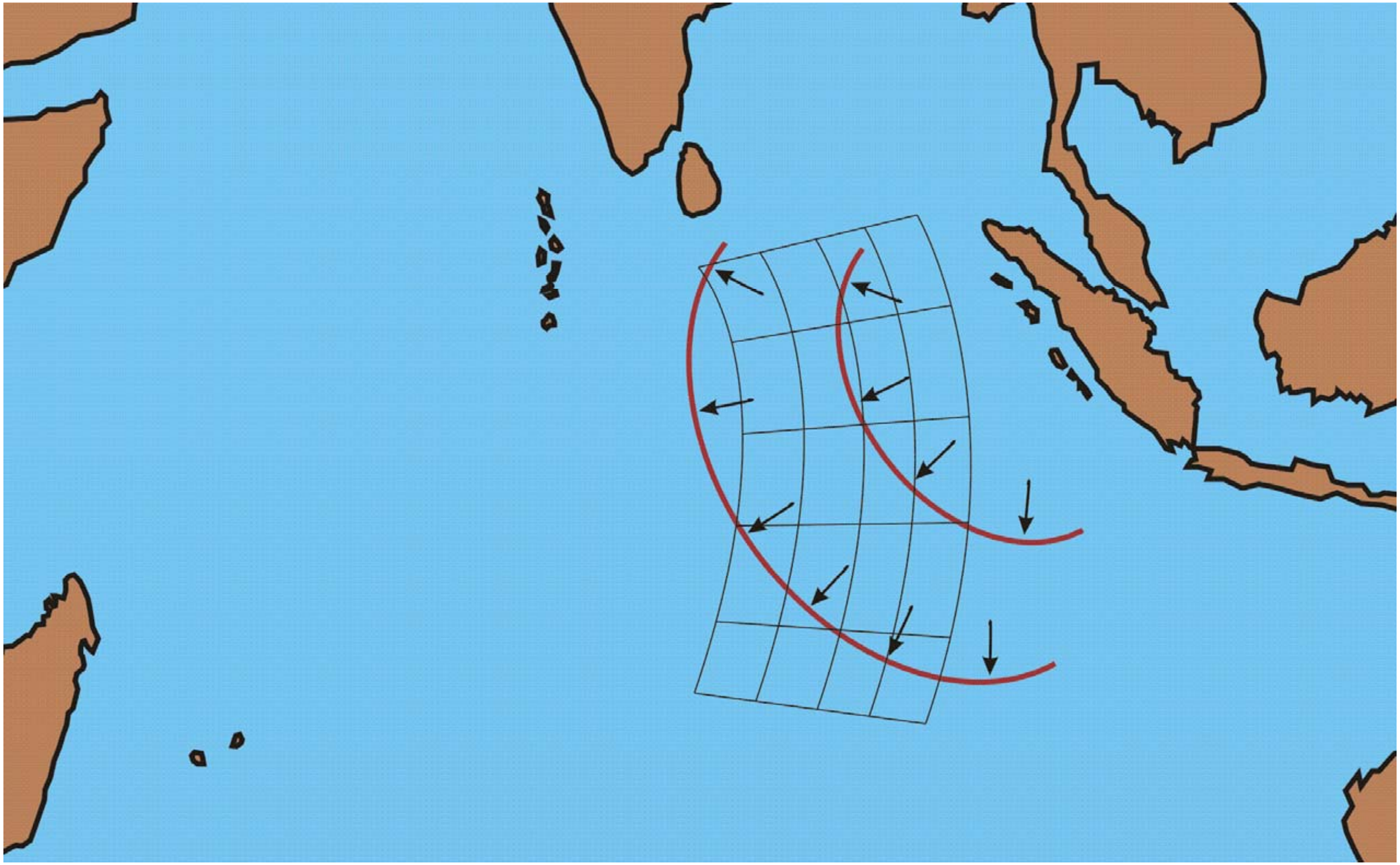


Current field

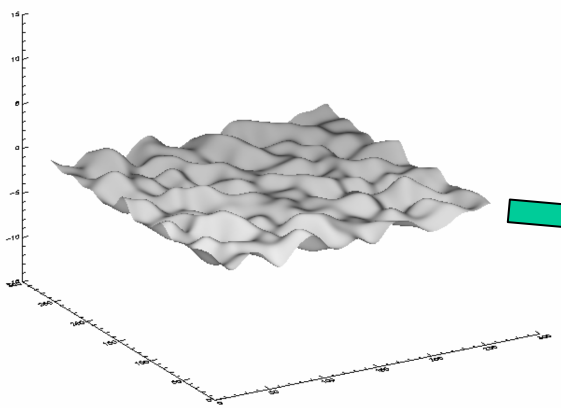
Tsunami

Resulting motion

Tsunami Wavefront



Modeling the Problem



Coherent target

$$\Delta\varphi_{measured} = 2\pi\tau\nu$$

[Goldstein and Zebker 87]

Incoherent target

$$\Delta\varphi_{measured} = \arg\left(\frac{1}{\sigma}\int_{-\infty}^{+\infty} e^{i2\pi\tau\nu} S(\nu)\,d\nu\right)$$

[Thompson and Jensen 93]

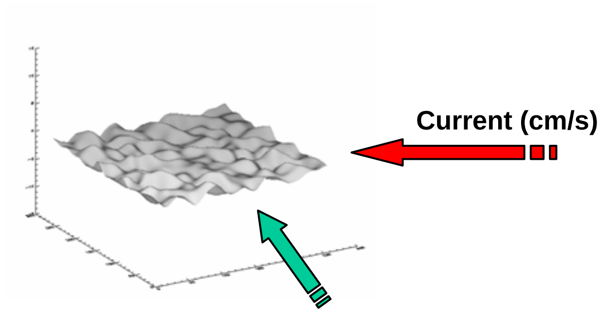
The resolution cell is occupied by a moving surface with scatterers moving on it.

Local currents and a tsunami displace the surface. (first order contributions)
Wind driven waves act as scatterers on the surface. (second order contribution)

Detection is achieved by comparing different measurements →

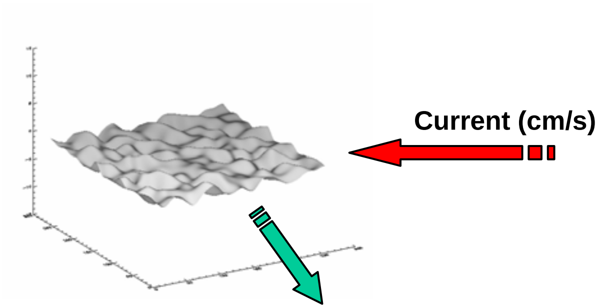
Tsunami Orbital Motion Detection

First semiperiod



$$\Delta\varphi_{measured} = \Delta\varphi_{current} + \Delta\varphi_{tsunami} + \Delta\varphi_{speckle} + \Delta\varphi_{noise}$$

Second semiperiod



$$\Delta\varphi_{measured} = \Delta\varphi_{current} - \Delta\varphi_{tsunami} + \Delta\varphi_{speckle} + \Delta\varphi_{noise}$$

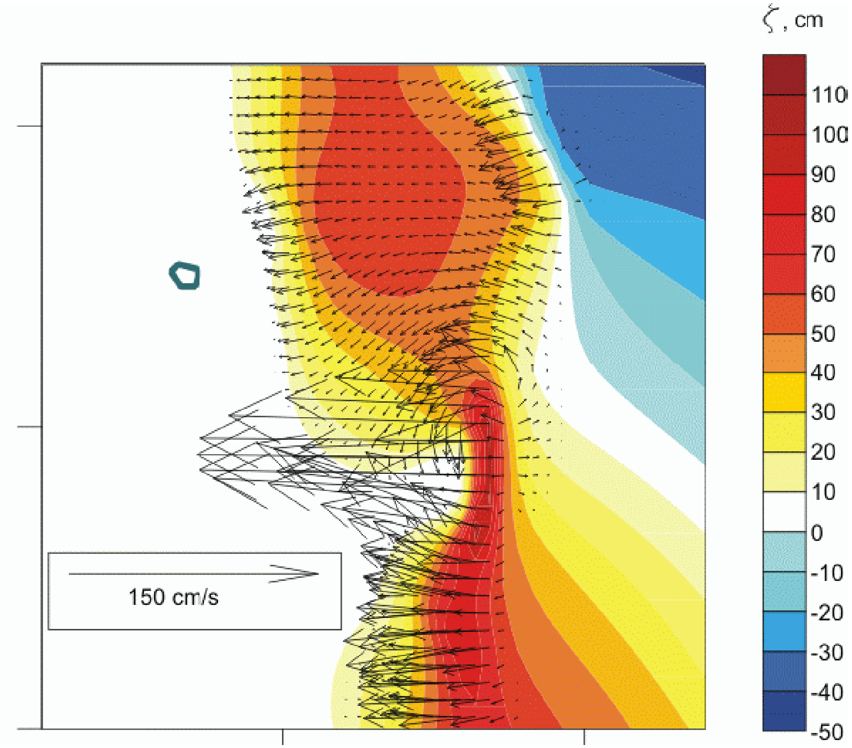
Current velocities:	~ cm/s (typical) 1-2 m/s (maximum)
Tsunami induced displacements:	~ cm/s

- The line of sight velocity difference should be in the order of cm/s.

Detection Strategy in the Continental Shelf

Even easier !

- Tsunamis induce anomalous current patterns when they impact the continental shelf



Simulation results
(courtesy UniHamburg)

Outlook

- We can draw on knowledge from many interferometric missions
  AIRSAR, ESAR, SRTM, TanDEM-X
  Mature technology for operational purposes
  Technology evolution, not revolution
- The Geostationary Interferometer makes available:
  Long time series
  Averaging over thousands of samples should improve the accuracy from 10 cm/s (standard ATI doppler accuracy) to 1cm/s (for tsunami detection)
- Digital Beamforming and Subspace Methods for azimuthal superresolution are being studied to limit antenna size
- Experimental validation of Doppler Accuracy Improvement upon averaging

Thanks for your

Attention !