Stiftung Alfred-Wegener-Institut
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Rigorous Fusion of Gravity Field into Stationary Ocean Models (RIFUGIO)

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1 Stationary ocean models

compute oceanic flow fields from input variables like temperature T, salinity S and mean dynamic topography (that is the altimetric mean sea surface referenced to observations of the geoid) by using physical laws, for example:

Equation of state: density $\rho = \rho(S, T, p)$.

Geostrophy: surface velocity $v = \frac{g}{f}\frac{\partial \zeta}{\partial x}$.

S salinity
T temperature
p pressure
g acceleration due to gravity
f Coriolis parameter
ζ geopotential height

For the integration of the model equations some unfortunatelly unknown reference velocities are needed. As they cannot be directly determined by observations their estimation is a major problem in the solution process.

We will use 3 different model types:

- section model, FEMSECT
- box inverse model
- 3D inverse model, IFEOM

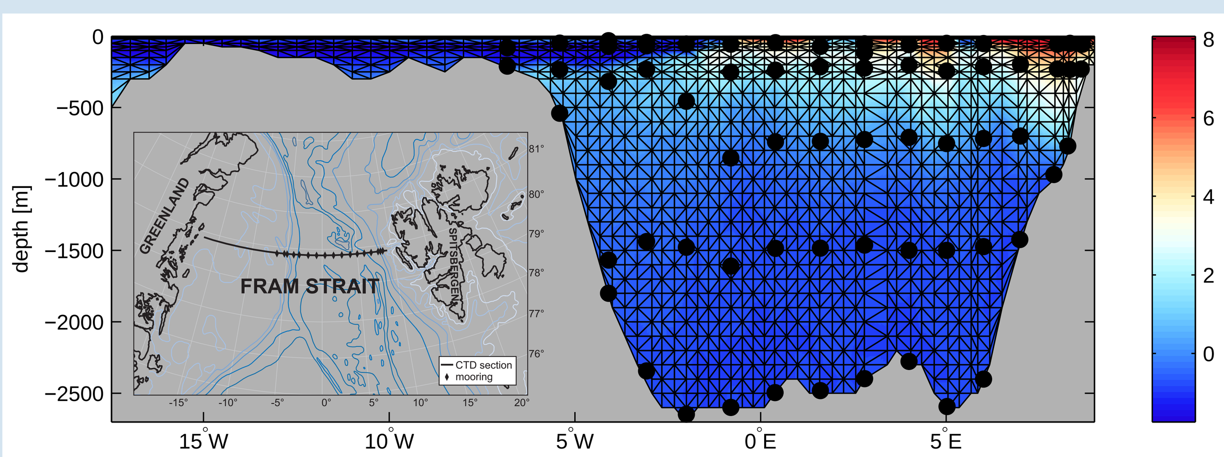

Figure 1: Example model grid for FEMSECT: Fram Strait.

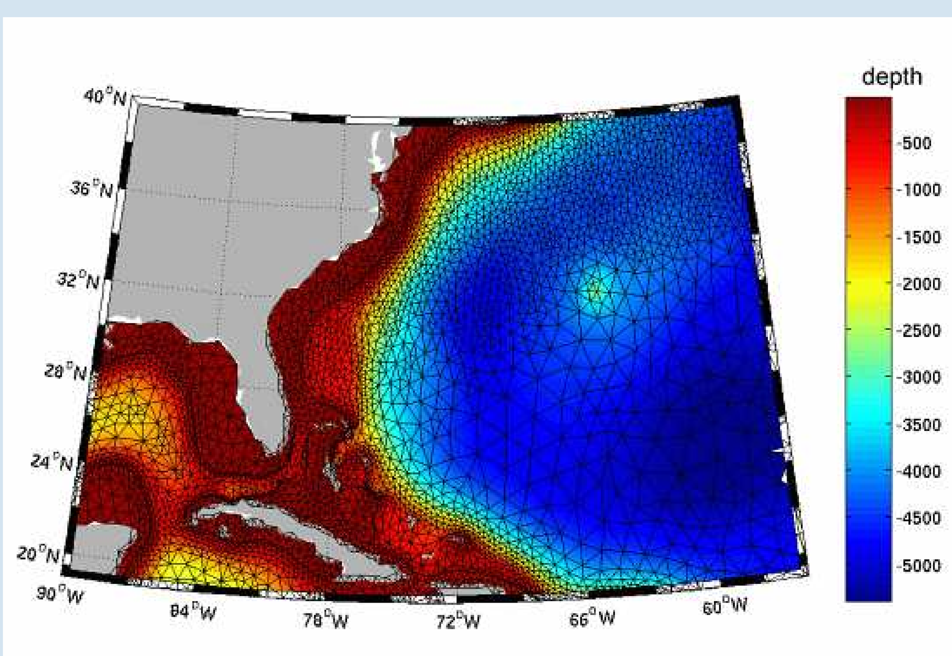

Figure 2: Example model grid for FEOM: Northwest Atlantic.

The models work with geographically gridded data, for example spatial resolution $\frac{1}{30°}$.

References

[1] Schuh, W.-D., Losch, M. (2008). Rigorous Fusion of Gravity Field into Stationary Ocean Models (RIFUGIO): Application for a research grant within DFG-SPP 1257.

[2] `http://de.wikipedia.org` (2009).

[3] `http://www.awi.de` (2009).

2 Satellite missions

such as GRACE (Gravity Recovery And Climate Experiment) and GOCE (Gravity Field and Steady-State Ocean Circulation Explorer) provide global and high resolution measurements of gravity with unprecedented accuracy.
From these observations geoid models can be constructed that are independent of altimetric measurements.

Figure 3: Satellite GOCE.

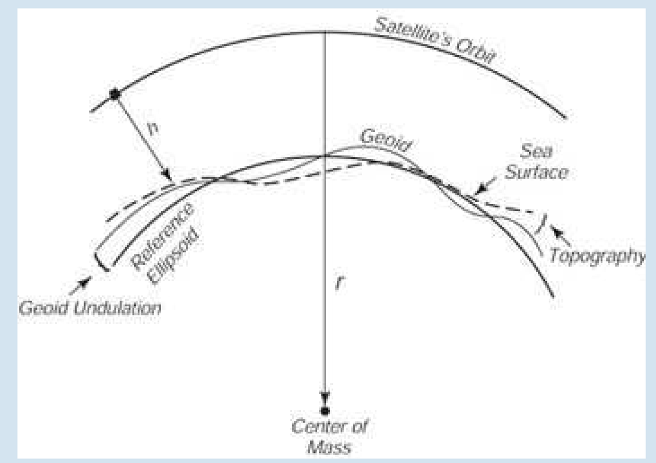

Figure 4: Ocean currents produce the oceanic topography, the departure of the sea surface from the geoid.

5 Goal of the project

For the Bonn group

- to combine the complete gravity field models with altimetric data and
- to derive a full error propagation and a regular covariance matrix.

For me at the AWI

- to integrate this information into stationary ocean models and
- to assess the effects of this data combination on improving ocean models.

4 Transform is needed!

- The transfer of the geoid model onto the discrete model fails in general:
  the band limited gravity field model represents only incomplete information in space domain
  $\Longrightarrow$ part of the signal is lost
- Previous approaches with different filters cannot quatinfy the amount of lost signal.
- Transform is needed for:
  - parameter values: **geoid heights**, gravity anomalies, ...
  - error variance and covariance information
- Complete gravity field models were designed by the Bonn geodesy group in a previous project. They form a complete basis of the entire space. Therefore the gravity model can be represented in the frequency domain (spherical harmonics) as well as in the space domain (data grids) without loss of information and a complete error description.

3 Gravity field models

Gravity fields, on global scale, are usually represented by an expansion into spherical harmonic functions.

$$f(\theta, \varphi) = \sum_{n=0}^{\infty} \sum_{m=-n}^{+l} c_{nm} Y_{nm}(\theta, \varphi)$$

Example: $$Y_{1,-1}(\theta, \varphi) = \sqrt{\frac{3}{8\pi}} \sin(\theta) e^{-i\varphi}$$

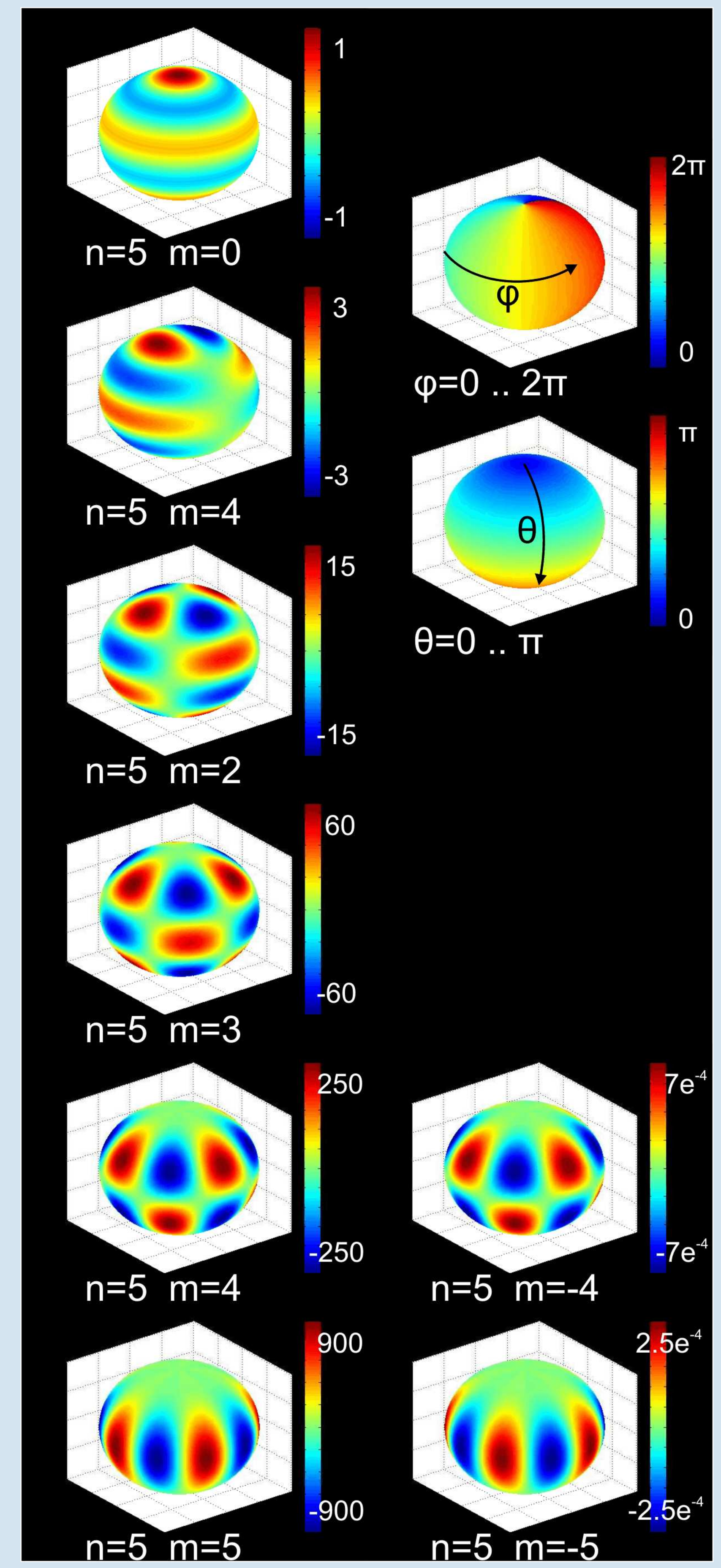

Figure 5: Some spherical harmonic functions.

Typically the accuracy of the geoid models decreases with increasing degree and therefore the model is restricted to a subdomain in frequency space.

Spatial resolution of $\frac{1}{30°}$ corresponds to degree and order **10800**.