Can we use current geoid models for improving ocean state estimation

Grit Freiwald[1], Martin Losch[1], Wolf-Dieter Schuh[2] and Silvia Becker[2]

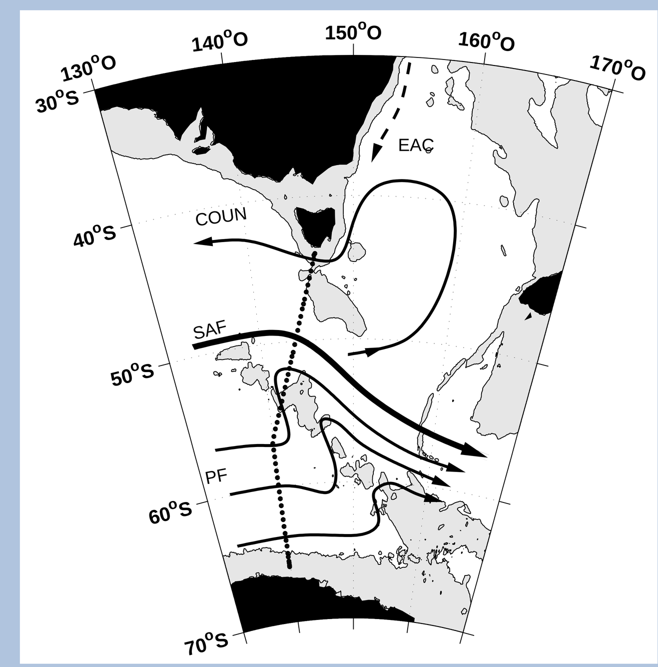
[1]Alfred Wegener Institute for Polar and Marine Research, Bremerhaven, Germany
[2]University Bonn, Institute of Theoretical Geodesy, Germany
Email: grit.freiwald@awi.de

1 Stationary inverse ocean models ...

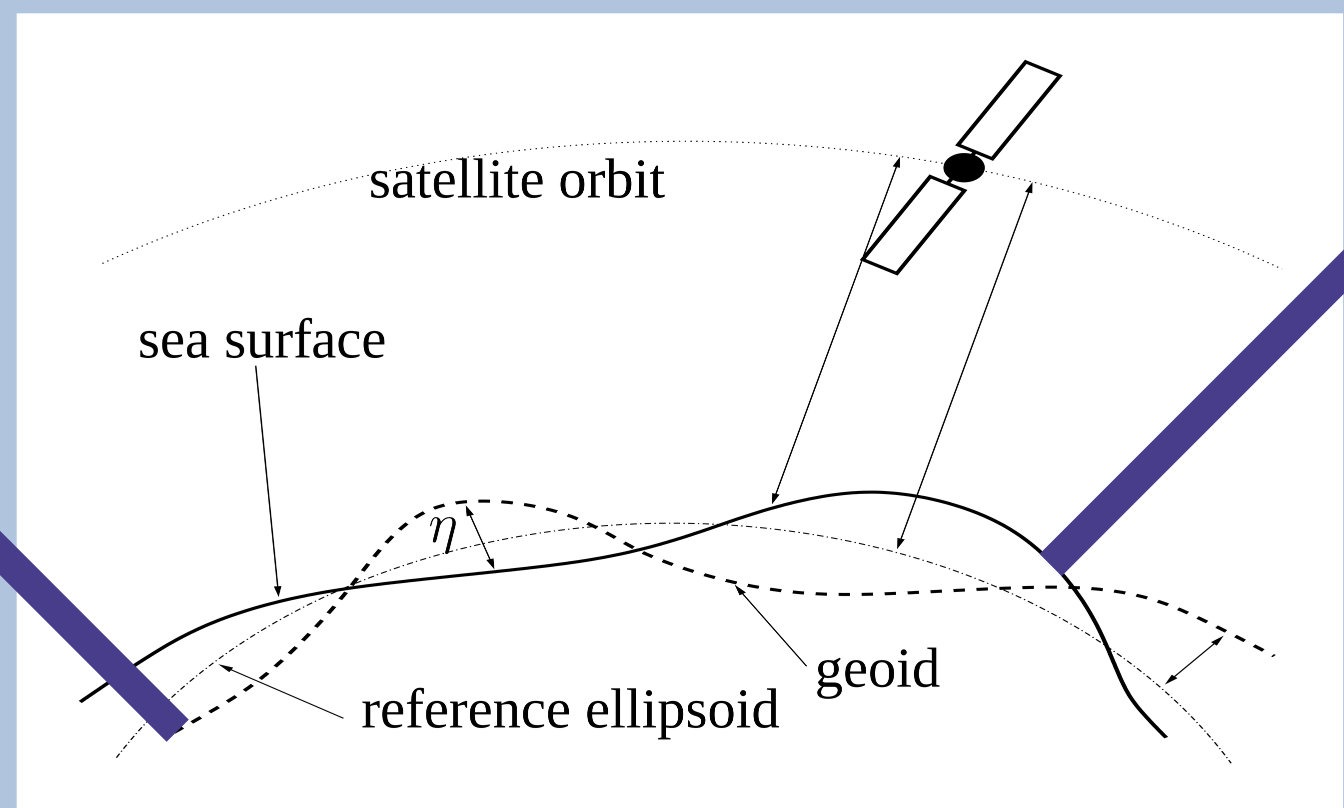
... compute oceanic flow fields from input variables such as temperature, salinity and current velocities v.
It is very expensive to measure mean velocities of ocean currents!
But surface velocity v can be determined by the geostrophic relation balance

$$v = \frac{g}{f}\frac{\partial \eta}{\partial x}$$

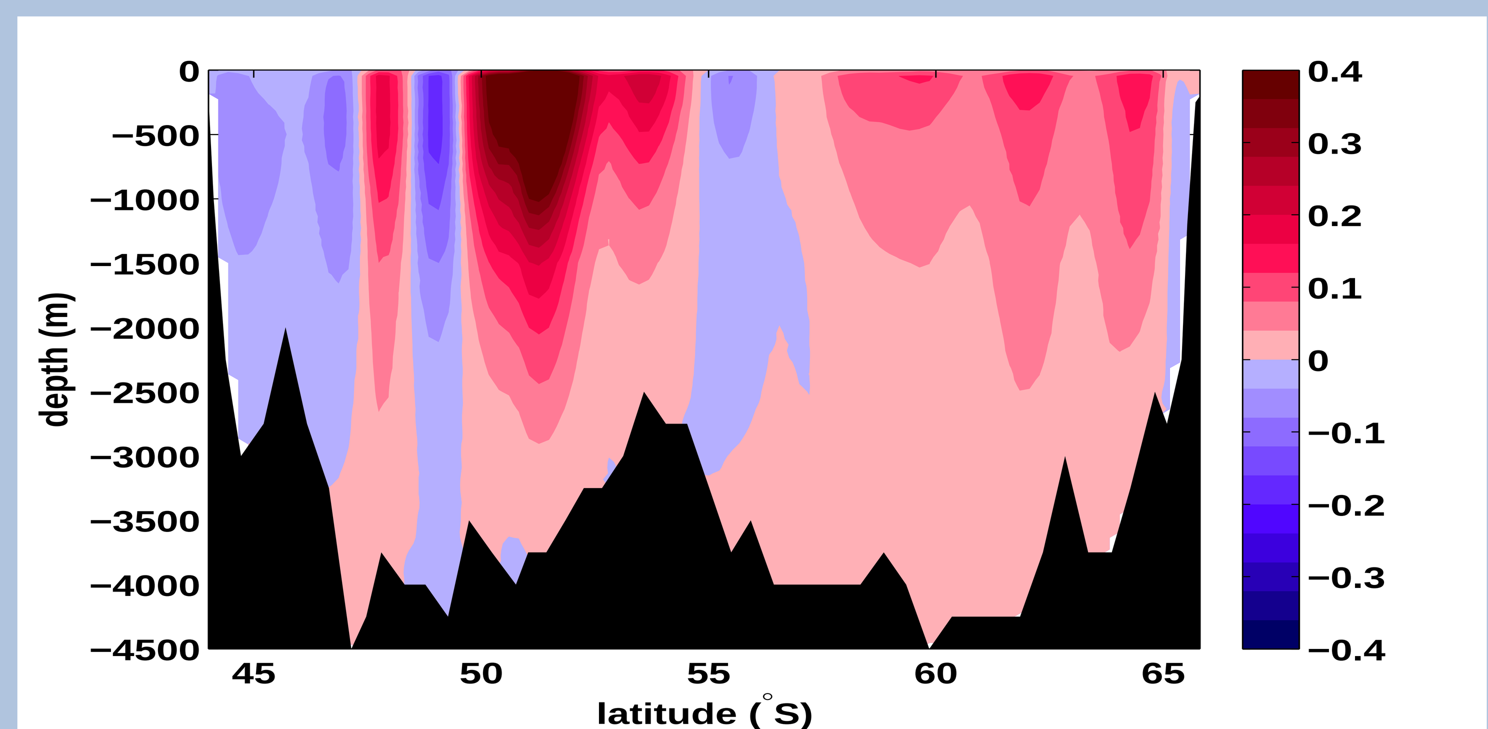
from the mean dynamic topography η
- the departure of the sea surface from the geoid.



Section model FEMSECT Tasmania - Antarctica.



Mean dynamic topography (MDT)



Velocity field from ocean model without MDT

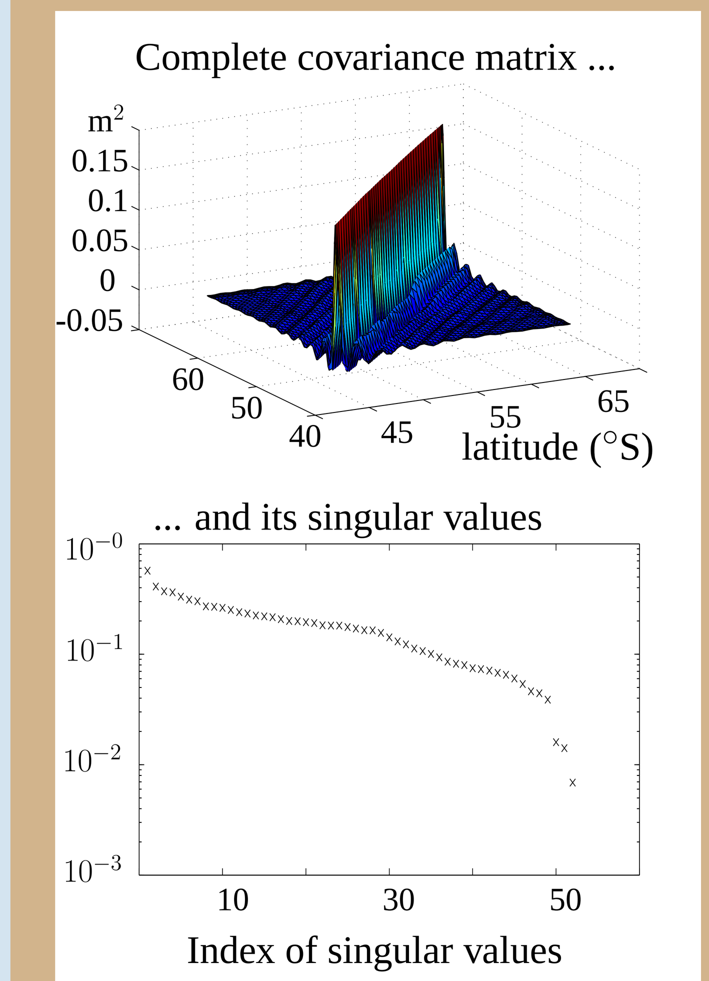
Mass transport across section: **159 ± 64 Sv**

Formal errors are calculated from inverting the Hessian of the cost function.

2 Gravity field models

Global gravity field solutions are usually represented by spherical harmonic functions. To be used in an ocean model, the series has to be truncated and projected onto the finite ocean model grid.
Due to neglecting small scales, the "omission error" occurs and leaks into large scales.

We show: The omission error should be taken into account!!



Error covariance matrix of complete geoid model

The omission error has considerable influence on the error covariance matrix whose inverse is used as the weighting matrix during the optimization.

Formal errors for transport across section

Mass transport across section: **174 ± 48 Sv**
(with geoid model and full omission error)

RESULTS:

- The omission error is not negligible for the overall error estimate.
- Considering the omission error reveals that GRACE data are not accurate enough for improving transport estimations by ocean models significantly.
- Assimilating mean dynamic topography (MDT) into the ocean model leads to high mass and heat transport estimations.

YES, but

- improvements are not as large as expected
- other methods lead to similar results
- further refinement of geoid models is required for ocean modeling

3 Ocean surface currents from ice drift

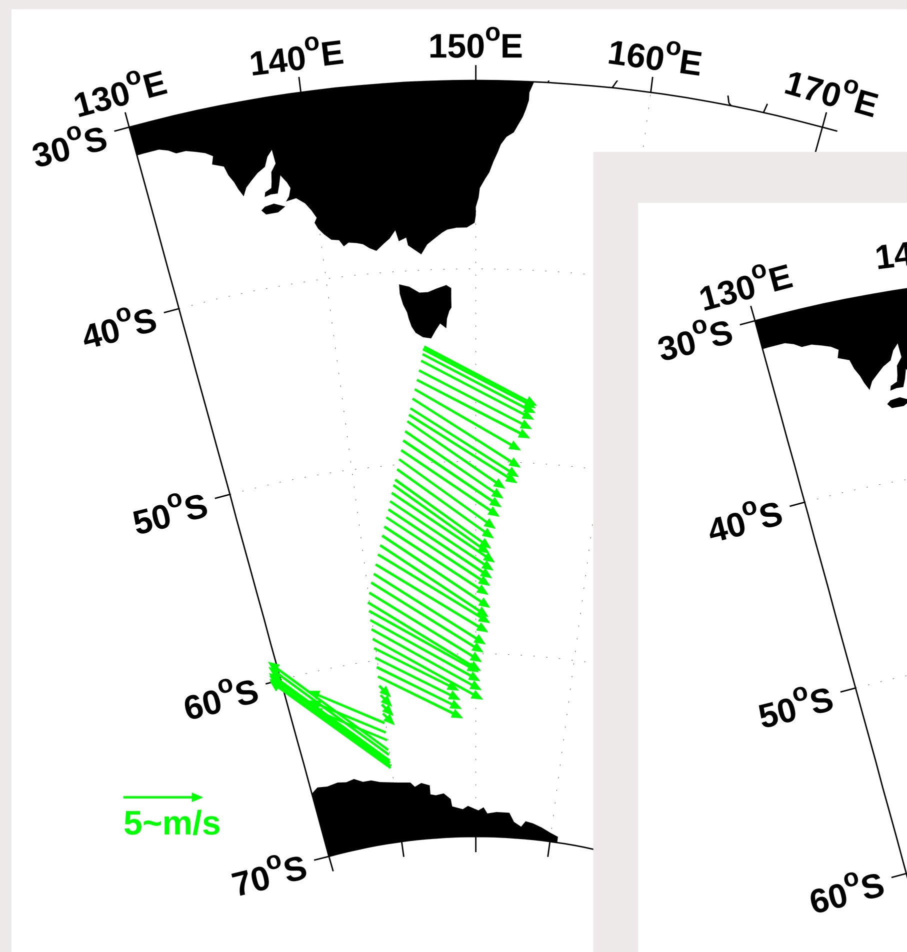
The presence of sea ice at high latitudes impedes altimetric measurements. But satellite imagery allows for detection of mean sea ice motion, whose features are mainly attributable to atmospheric forcing.
Surface ocean currents beneath the ice cover can be derived by subtracting the wind effect from the ice motion via

$$\begin{bmatrix} \bar{c}_u \\ \bar{c}_v \end{bmatrix} = \begin{bmatrix} \bar{U} \\ \bar{V} \end{bmatrix} - F \cdot \begin{bmatrix} \cos\theta & -\sin\theta \\ \sin\theta & \cos\theta \end{bmatrix} \begin{bmatrix} \bar{u} \\ \bar{v} \end{bmatrix}$$

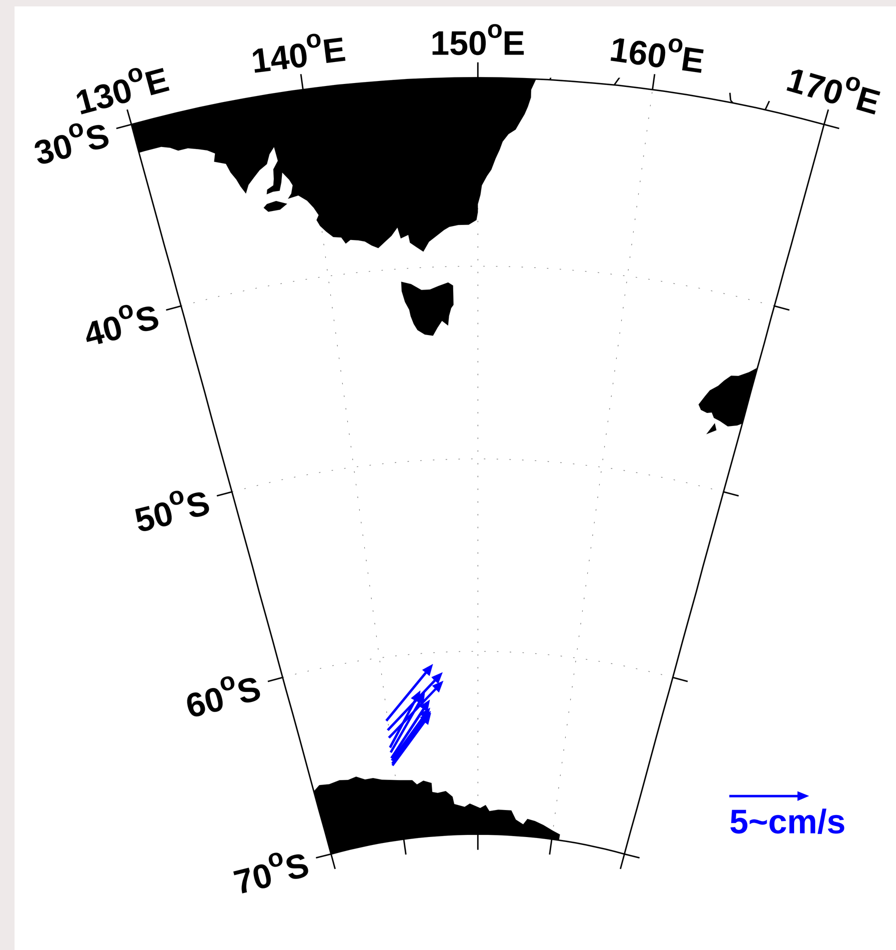
with turning angle $\theta = \arctan\left[\frac{\sum u'V' - \sum v'U'}{\sum u'U' + \sum v'V'}\right]$ and

$$F = \frac{\cos\theta \sum u'U' + \sin\theta \sum v'U' - \sin\theta \sum u'V' + \cos\theta \sum v'V'}{\sum u'^2 + \sum v'^2},$$

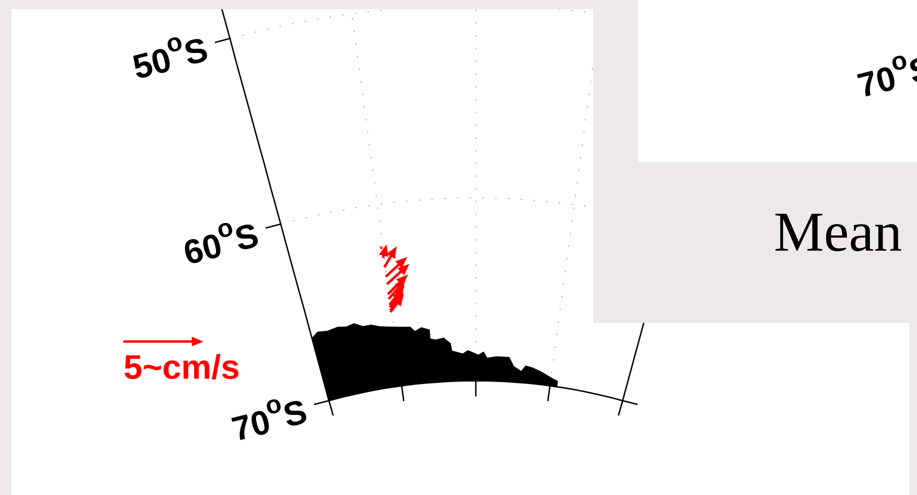
called the speed reduction factor. $u' = u - \bar{u}$ etc.
(N. Kimura: Sea Ice Motion in Response to Surface Wind and Ocean Current in the Southern Ocean, JMSJ 2004.)



Mean NCEP wind field



Mean ocean surface current



Mean ice drift data

Mass transport across section: **173 ± 46 Sv**
(with ice drift model)

RESULTS:

- Transports are higher than expected and
- Error reduction is of same scale as with geoid model.