RIFUGIO - Rigorous Fusion of Gravity Field into Stationary Ocean Models

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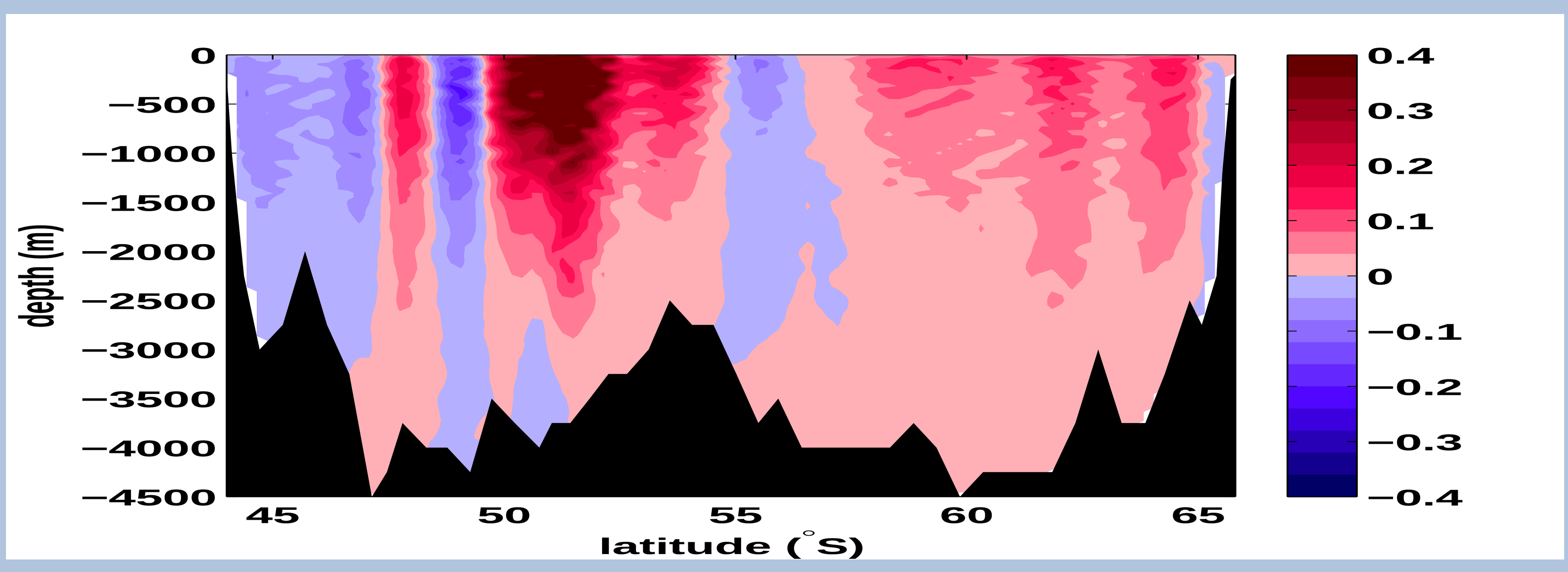
1 Stationary inverse ocean models ...

... compute oceanic flow fields from input variables such as temperature, salinity and current velocities v. It is very expensive to measure in-situ mean velocities of ocean currents!



Velocity field from ocean model without MDT

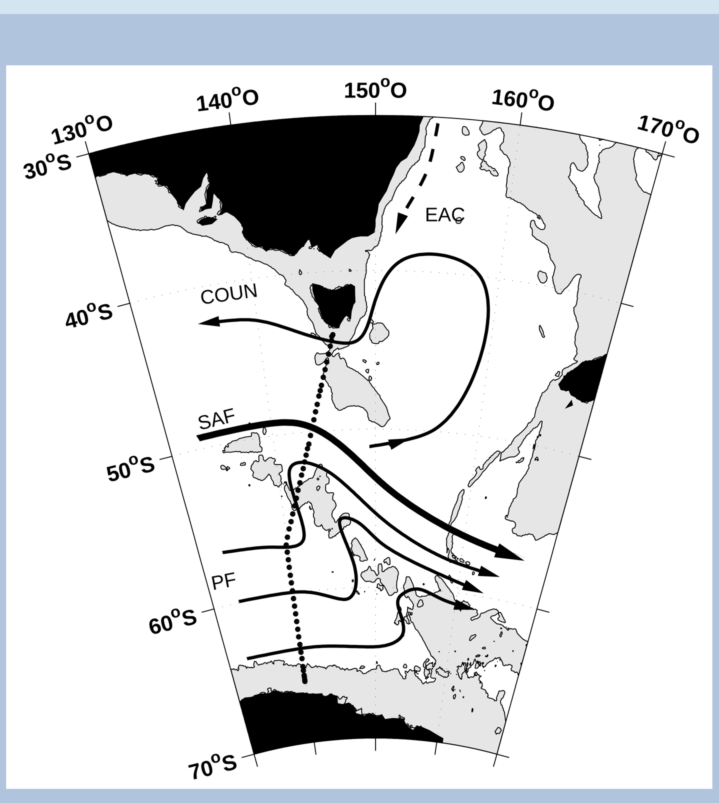
Mass transport across section: **159** $\pm$ **64 Sv**

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

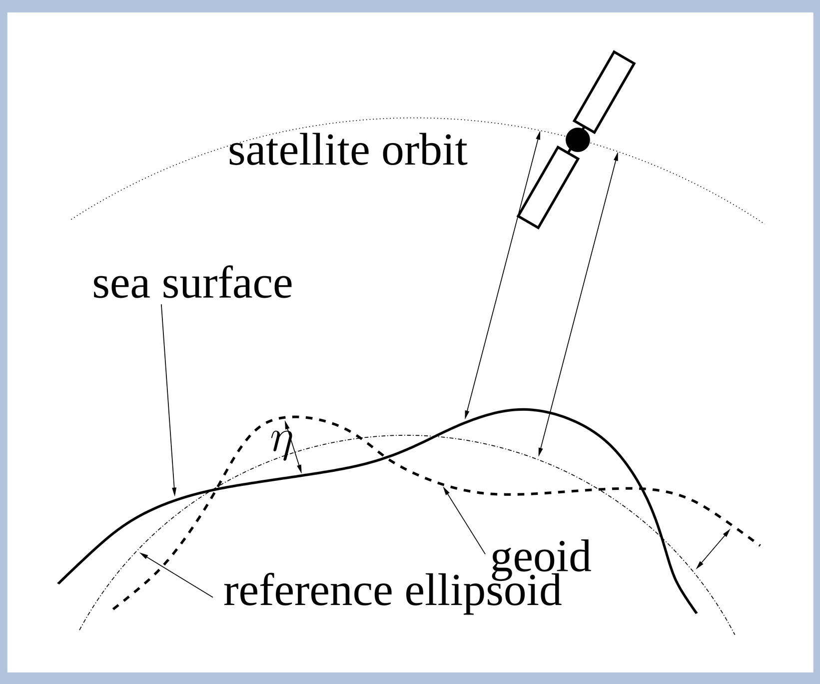
Surface velocities v can also be determined by the geostrophic relation balance

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

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



Section model FEMSECT Tasmania - Antarctica.



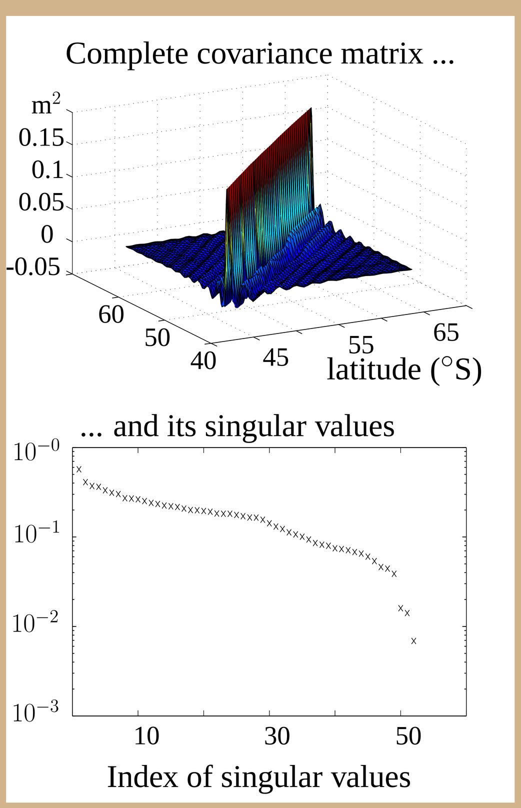
Mean dynamic topography (MDT)

2 Gravity field models: Ocean surface currents from MDT

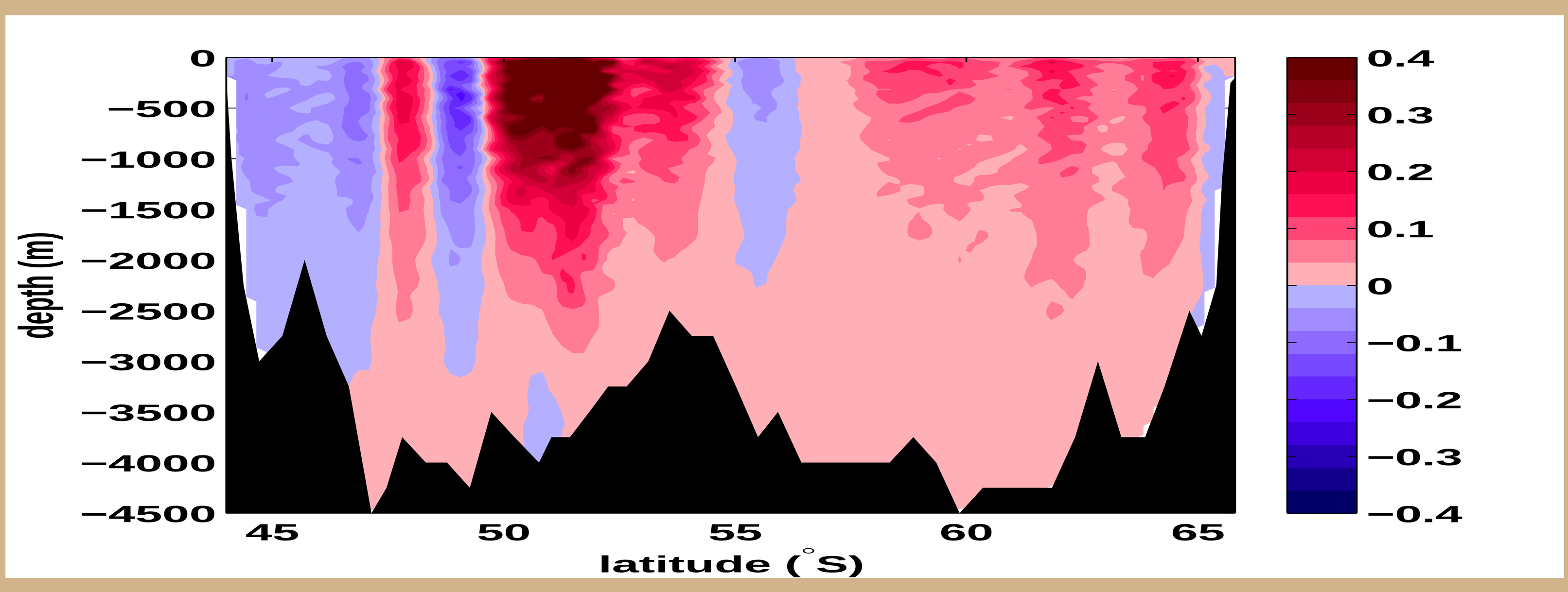
Global gravity field solutions are usually represented by spherical harmonic functions. To be used in an ocean model, the series has to be truncated and projected onto the finite ocean model grid. Due to neglecting small scales, the "omission error" occurs and leaks into large scales.

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

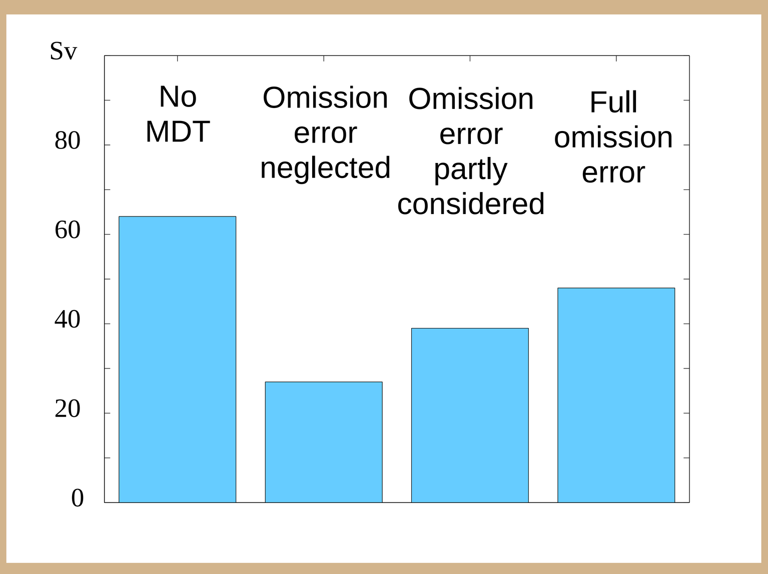
The omission error has considerable influence on the error covariance matrix whose inverse is used as the weighting matrix during the optimization.



Error covariance matrix of complete geoid model



Velocity field from ocean model with MDT



Formal errors for transport across section

Results:

- Mass transport across section: **174** $\pm$ **48 Sv** (with full omission error)
- 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.

$\Longrightarrow$ We expect significant improvements from GOCE with low omission error!

3 Ocean surface currents from ice drift: an alternative approach

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

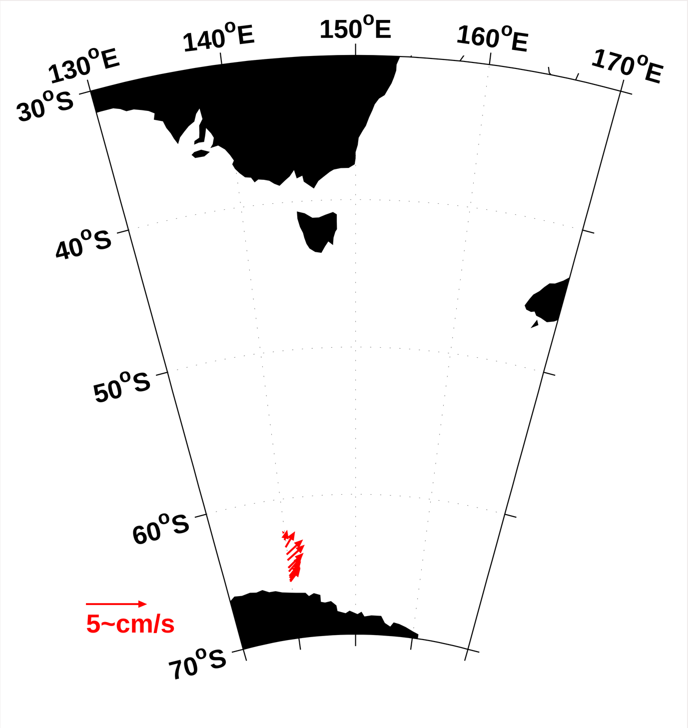
$$\begin{bmatrix}\bar{c}_u\\ \bar{c}_v\end{bmatrix} = \begin{bmatrix}\bar{U}\\ \bar{V}\end{bmatrix} - F \cdot \begin{bmatrix}\cos\theta & -\sin\theta\\ \sin\theta & \cos\theta\end{bmatrix}\begin{bmatrix}\bar{u}\\ \bar{v}\end{bmatrix}$$

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 ice drift data (Polar Pathfinder, NSIDC)

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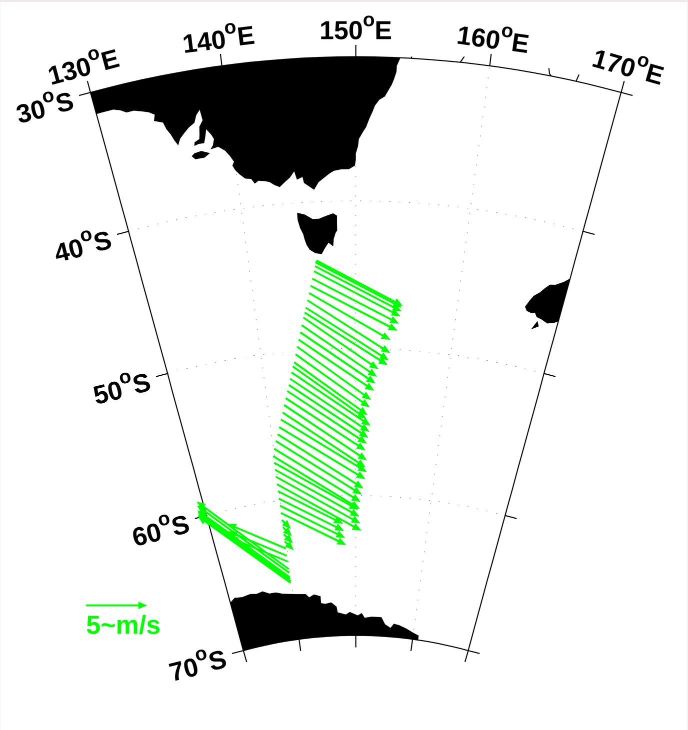

Mean wind data (NCEP reanalysis)

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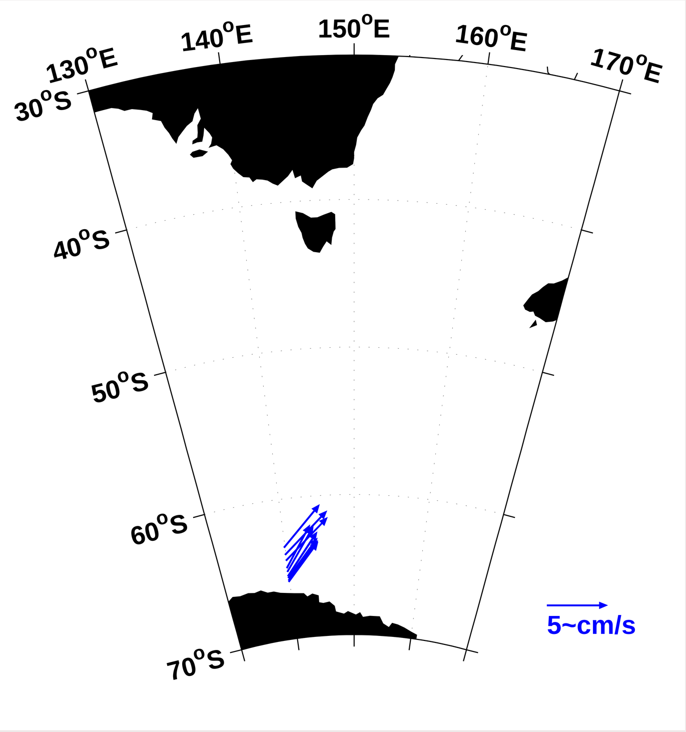

Mean ocean surface current

Mass transport across section: **173** $\pm$ **46 Sv** (with ice drift model) $\Longrightarrow$ Error reduction is of same scale as with geoid model.

To improve this estimate, we would need:

- refined radar imagery
- improved image processing techniques
- more reliable wind field
- error variance/covariance information!

This is far from being realized.

$\Longrightarrow$ Therefore, we hope for GOCE to improve the MDT method!