What do we mean by ice sheet mass trends?

Martin Horwath TU München, Institut für Astronomische und Physikalische Geodäsie / Centre of Geodetic Earth System Research (CGE) Munich, martin.horwath@bv.tum.de

Summary

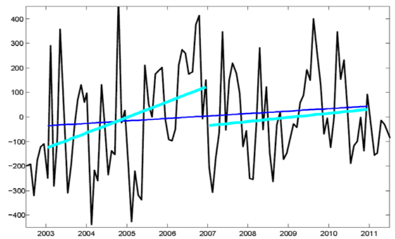
To assess ice sheet mass changes from GRACE or altimetry, simple mathematical functions like
- linear (+ seasonal)
- linear + quadratic (+ seaonal)

are commonly adjusted to time series *M*(*t*) of mass changes. The adjusted parameters (such as the linear trend) are communicated as main results.

This approach is challenged here.

Observed ice sheet changes do not obey the assumed simple mathematical relation. Consequently, trends adjusted to different periods are inherently different. Moreover, the fitted trends do not necessarily represent a best estimate of the actual change during the period of interest. This discrepancy not only limits interpretation of the results but also complicates comparison with different methods (like the budget method) that typically aim at quantifying the actual change during a particular period.

We are increasingly able to specify the actual temporal evolution of ice mass. The recommendation is to do so.



Antarctic mass time series from GRACE[1]. (No GIA correction is applied, since the focus here is not on the absolute trend numbers.)

Linear fit to 8 years

Independent fits to 4-year subperiods

Real-life example of problems with assuming a linear behavior: The adjusted trend in both 4-year subperiods is larger than the adjusted trend over the 8-year period.

Acknowledgments

Discussions with participants of the ESA/NASA project IMBIE (Ice Sheet Mass Balance Inter-comparison Exercise) have inspired this work.

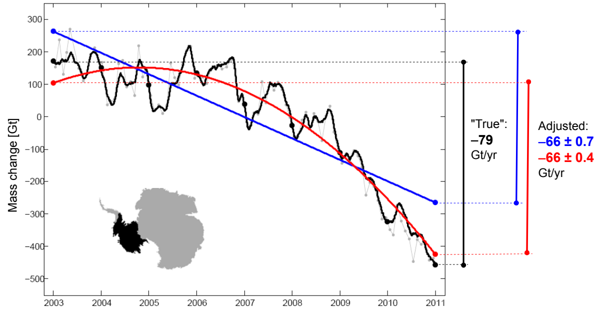
References

1) from CSR Release 04 monthly solutions

2) Horwath M, Legrésy B, Rémy F, Blarel F, Lemoine J-M (2012): Consistent patterns of Antarctic ice sheet interannual variations from ENVISAT radar altimetry and GRACE satellite gravimetry. Geophys. J. Int. doi: 10.1111/j.1365-246X.2012.05401.x

3) Horwath M, van den Broeke M R, Legrésy B, Sasgen I, Bamber J, Blarel F (2012): Antarctic surface mass balance variations reflected by regional atmospheric modeling, satellite altimetry, and GRACE. Talk on thursday afternoon, Session "Remote sensing of snow and ice"

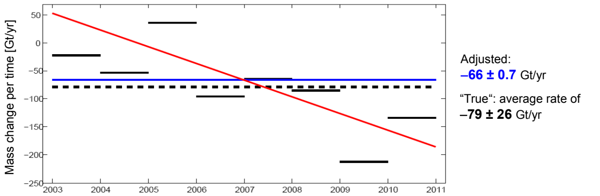
4) van den Broeke M, Bamber J, Ettema J, Rignot E Schrama E, van de Berg WJ, van Meijgaard E, Velicogna I, Wouters B (2009): Partitioning recent Greenland mass loss. Science 326:984-986, doi:10.1126/science.1178176.



Synthetic time series of mass change in West Antarctica. They are ***fictive***, but designed to be consistent with GRACE results[1]. (No GIA correction applied)

Linear fit (fitted together with annual and semiannual function).

Quadratic fit

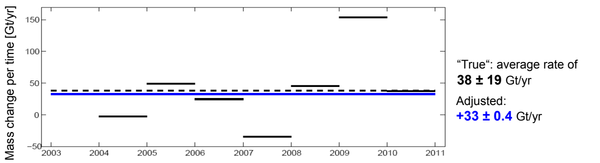


Change per year over individual years

Change per year over the total of 8 years

Mass rates according to the above least-squares fits

Concepts to assess ice mass changes: synthetic scenario for West Antarctica



Same as above, but for Dronning Maud Land

Arguments for the simple mathematical function fit and their counter-arguments

→ *Observation noise needs to be averaged out.*

← The quality of GRACE (and altimetry) results is evolving significantly. Now, deviations from a simple mathematical function are mostly signal rather than noise [e.g. Horwath et al. 2012a,b].

→ *A mathematical function fit involves smaller uncertainties of the results*

← Results and their uncertainties are of limited use if derived under invalid assumptions. A usual assumption for the formal error and the significance of trends is the absence of temporal correlation in the "noise" superimposed to the trend. This assumption is clearly violated by inter-annual signals. It is also violated if the original time series are filtered (smoothed) to render results "more significant".

→ *The interest is in the long-term signal rather than in the actual variations during the observation period.*

← This argument needs clarification.
- What is meant by "long-term signal"?
- What is the basis for assuming that this signal follows a simple mathematical model at any temporal scale? (For example, presently observed changes in Greenland do not appear to have long-term continuity backwards in time[4].)
- Is the long-term signal really distinct in nature and separable from shorter-term signals?

Recommendations

Use observations to describe the ice mass evolution as independent as possible from a-priori assumptions about how it behaves.

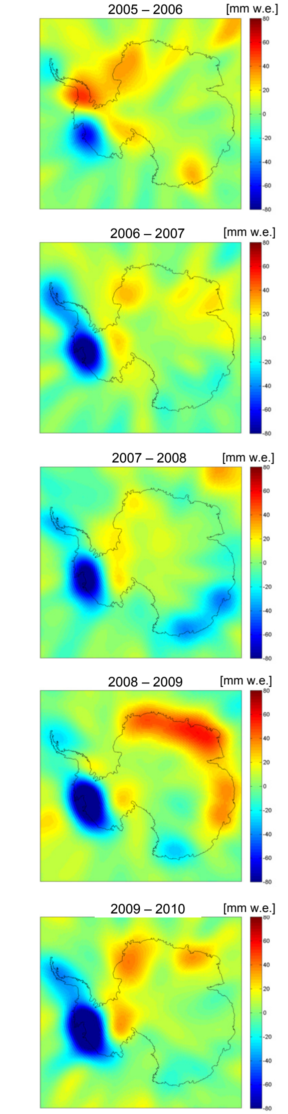
Specify estimates of actual changes between the start and the end of a considered period.

The necessary degree of averaging of observational data should be chosen as a compromise between error reduction and signal fidelity.

Questions (answers and comments welcome)

Optimal methods to estimate ice mass changes need to base on statistical properties of the geophysical signal and of observation errors. What do we currently know about both of them?

What are the experiences with similar trend assessments in neighbor disciplines (climate science, sea level studies, etc.)?



GRACE changes year to year: There is rich signal beyond a unique trend.

Shown are surface mass differences between consecutive annual means from the new GRACE Release 05 monthly solutions by GFZ.