TECHNISCHE UNIVERSITÄT DRESDEN

Fakultät Umweltwissenschaften, Fachrichtung Geowissenschaften, Institut für Planetare Geodäsie

The method of tailored sensitivity kernels for GRACE mass change estimates

Andreas Groh
Martin Horwath

EGU General Assembly 2016

DRESDEN concept
Exzellenz aus Wissenschaft und Kultur

In this talk

- We express GRACE mass change estimators in a unified framework.
- We explain how we design a GRACE mass change estimator for Antarctica, through a formal minimization of leakage + GRACE errors.
- We show the results. They will be made available as the products of an ESA Climate Change Initiative project.

(The separation of glacial isostatic adjustment is not in the focus of this talk)

General formalism

GRACE monthly solutions (Stokes coefficients)

$$\Delta c_{nm}^{\text{sat}}(t)$$

Estimator: linear functional

mass change estimate

$$\widehat{\Delta m(t)}$$

$$= 4\pi R^2 \sum_{n=0}^{n_{\max}} \sum_{m=-n}^{n} \tilde{\eta}_{nm} \, \Delta c_{nm}^{\text{sat}}(t)$$

$\times K_n$

or:

GRACE monthly solutions (EWH coefficients)

$$\Delta \kappa_{nm}^{\text{sat}}(t)$$

Estimator: linear funct. expressed by sensitivity kernel η

$$\widehat{\Delta m(t)}$$

$\div K_n$ $\times K_n$

$$= 4\pi R^2 \sum_{n=0}^{n_{\max}} \sum_{m=-n}^{n} \eta_{nm} \, \Delta \kappa_{nm}^{\text{sat}}(t)$$

Sensitivity kernel EWH

$$= \iint \eta(\lambda, \phi) \, \Delta \kappa^{\text{sat}}(\lambda, \phi, t) \, R^2 \, dA$$

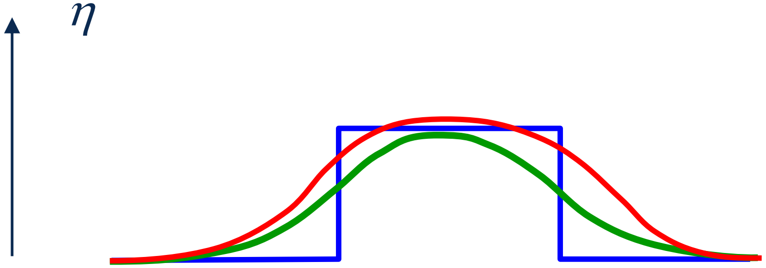
EWH: equivalent water height

$$K_n = \frac{2n+1}{1+k'_n} \frac{M}{4\pi R^2}$$

Regional (or direct) approach

$$\widehat{\Delta m(t)} = \iint \eta(\lambda,\phi)\,\Delta\kappa^{sat}(\lambda,\phi,t)\,R^2\,dA$$

equivalent water height (EWH)



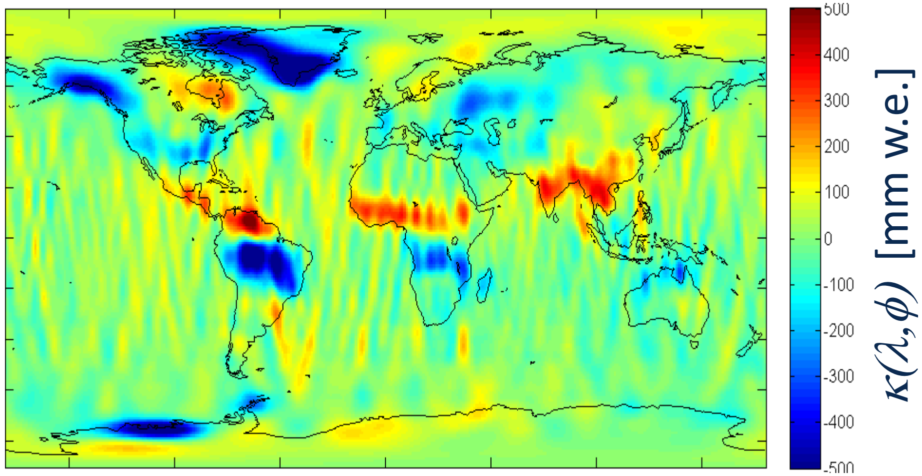
region function

=0 outside

=1 inside region

η . . . filtered region function

η . . . modified region function



Sensitivity kernel η : usually some heuristic modification of the region function

Filtering of GRACE solutions usually involved.

Forward modeling (or mascon, or inverse) approach

GRACE monthly solutions

$$\Delta c_{nm}^{\text{sat}}(t)$$

Prescribed patterns *Patt. 1, ..., Patt. K*
with mass effects $\Delta m_1, \quad ..., \quad \Delta m_K$
e.g.
- mascons / point masses
- geophysically motivated patterns

Pseudo-observables $\boldsymbol{y}$ $\quad \boldsymbol{y}^{\text{sat}}(\boldsymbol{t})$
e.g.
$\boldsymbol{y}$ = filtered EWH on a grid, or
$\boldsymbol{y}$ = gravity at satellite height, or
$\boldsymbol{y}$ = Stokes coefficients

Least squares adjustment

$$\approx \boldsymbol{a_1(t)\, y_1} + \ldots + \boldsymbol{a_K(t)\, y_K}$$

GRACE mass change estimate $\widehat{\Delta m}(t)$

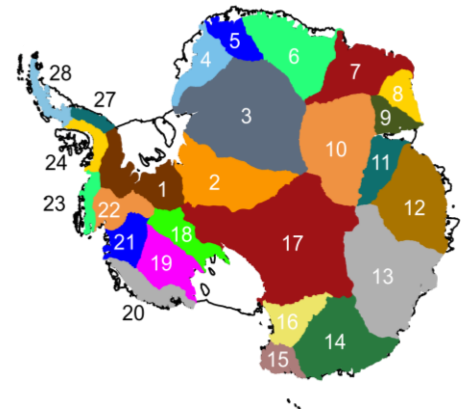
$$= \boldsymbol{a_1(t)}\, \Delta m_1 + \ldots + \boldsymbol{a_K(t)}\, \Delta m_K$$

Important note: Sequence of linear operations together constitutes a linear functional. It may be expressed, again, by a sensitivity kernel $\boldsymbol{\eta}$.
→ Forward-modeling approach is a realisation of the regional integration approach (e.g. Horwath & Dietrich, 2009; Jacob et al., 2012).

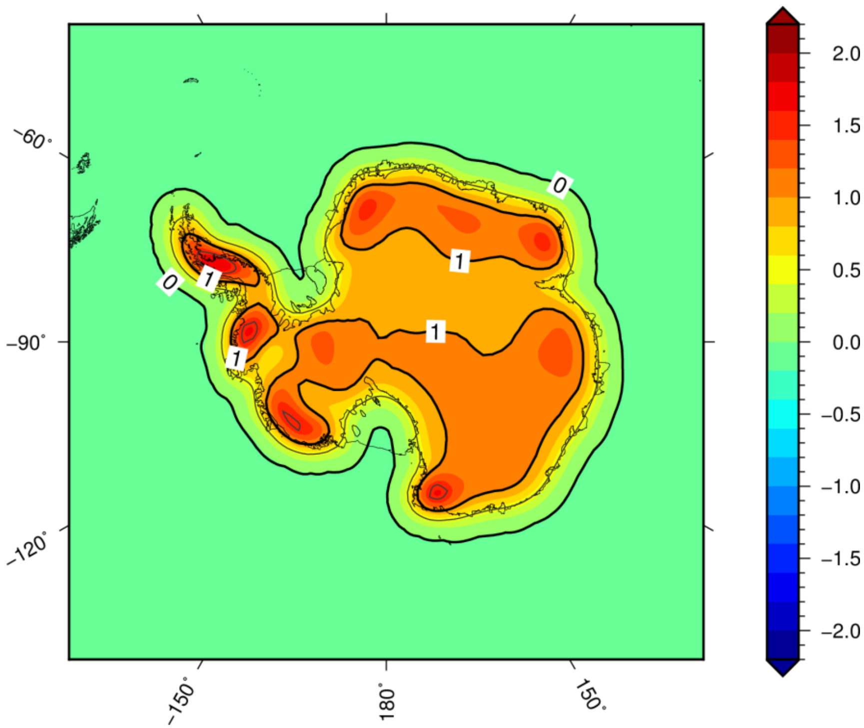
Forward modeling (or mascon, or inverse) approach

Example: Sensitivity kernel that corresponds to forward modeling method where

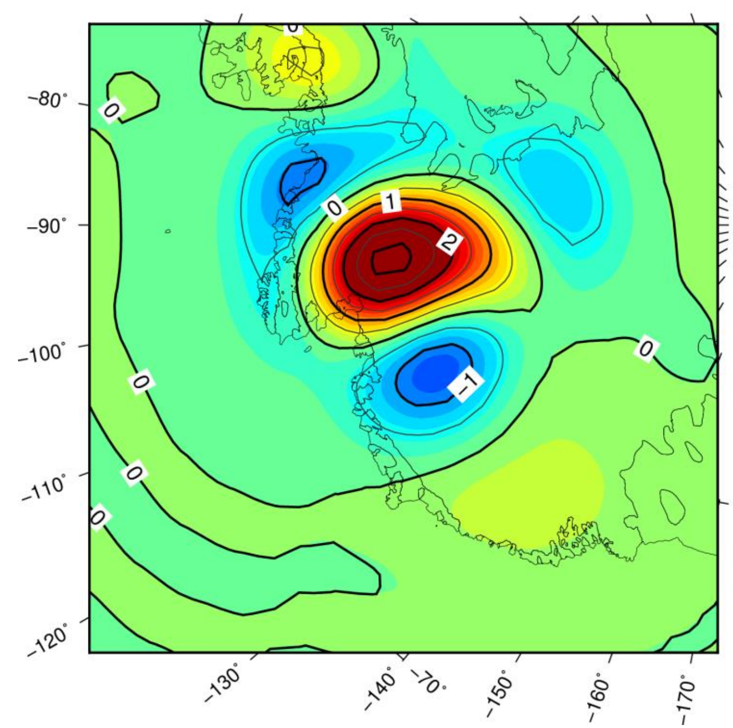
- pseudo-observables are filtered EWH coefficients
- Patterns are homogeneous mass changes over drainage basins



AIS



Basin 22



Realisation of tailored sensitivity kernels

Design the sensitivity kernel η by a formal minimization of the sum of the variances of

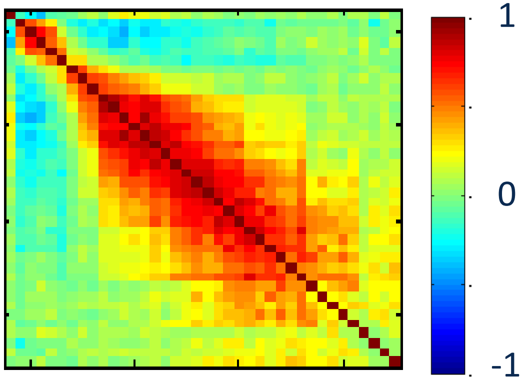
- GRACE error effect and
- Leakage effect

This requires information (maybe simple assumptions) on the variance / covariance of

- GRACE monthly solution errors
- geophysical signals that induce leakage

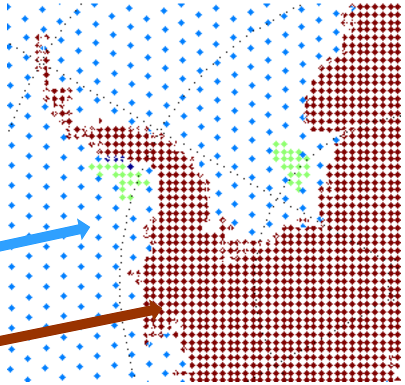
– empirical variance / covariance information derived from the month-to-month scatter

– GRACE release: ITSG-Grace2016 (TU Graz, prelim. version)



– different variances for the ice sheet and the far-field regions

– no spatial covariances (exception: Antarctic Ocean)

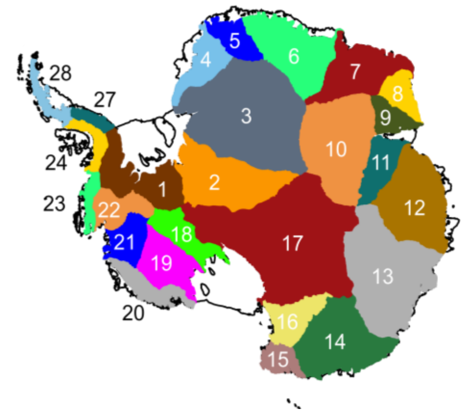


std = 0.2 Gt

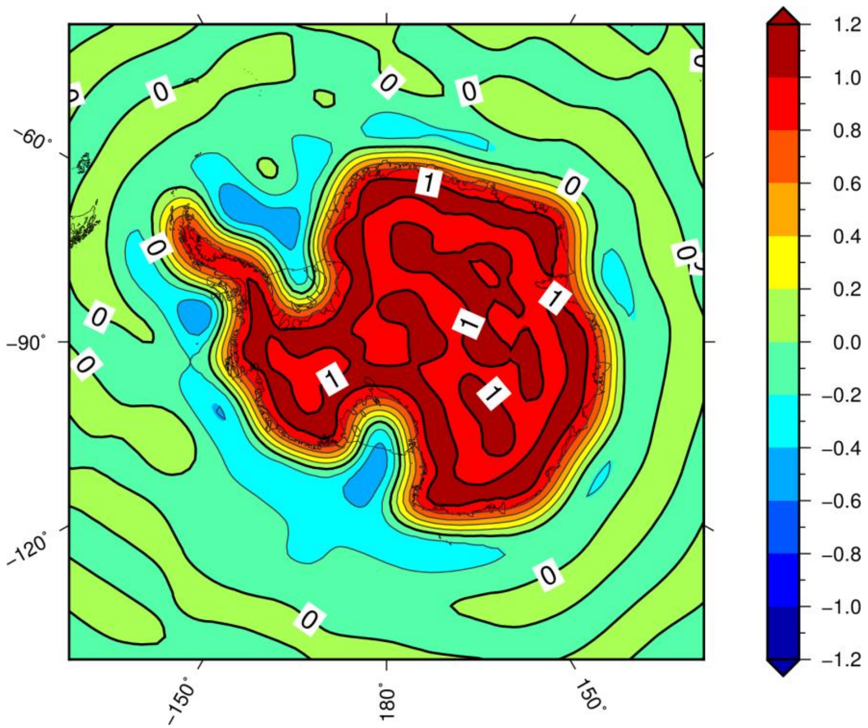
std = 1.0 Gt

Resulting tailored sensitivity kernels

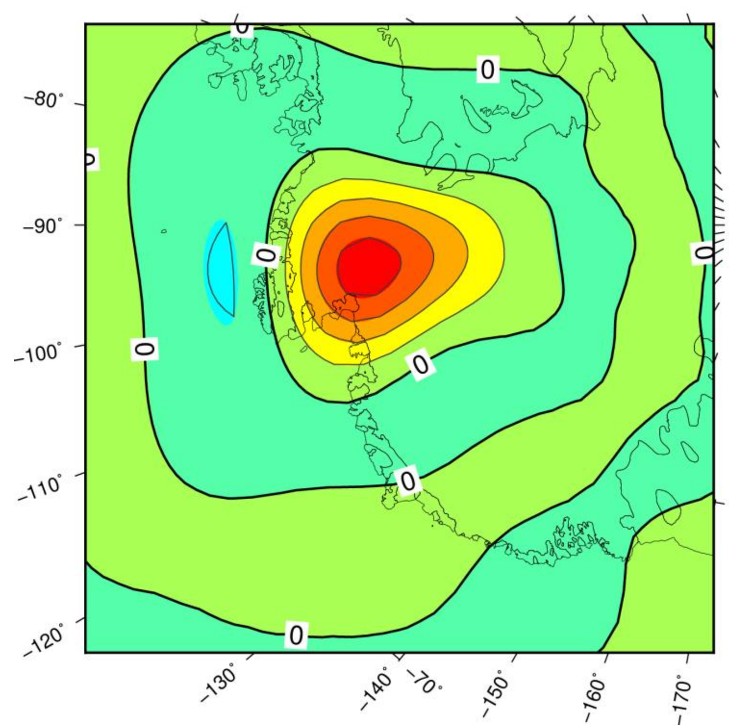
Sensitivity kernels for the integration over the entire AIS or individual drainage basins



AIS



Basin 22

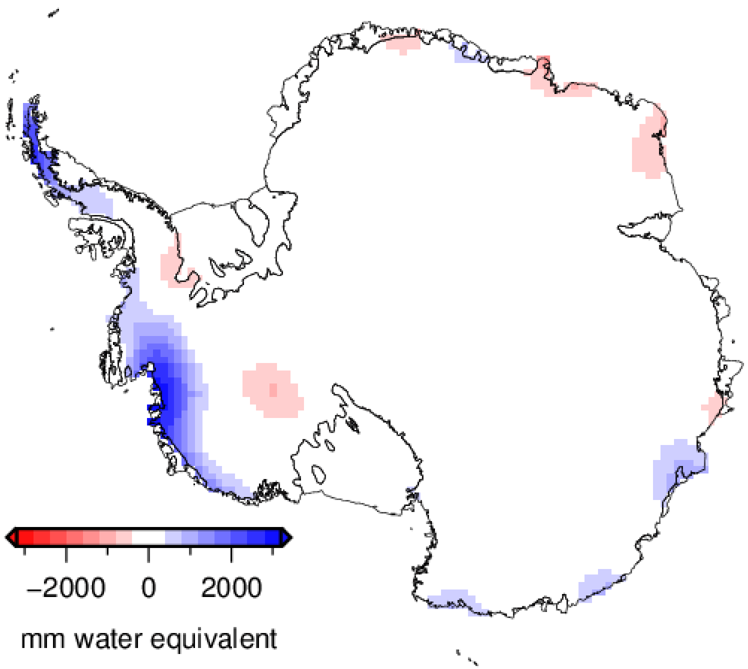


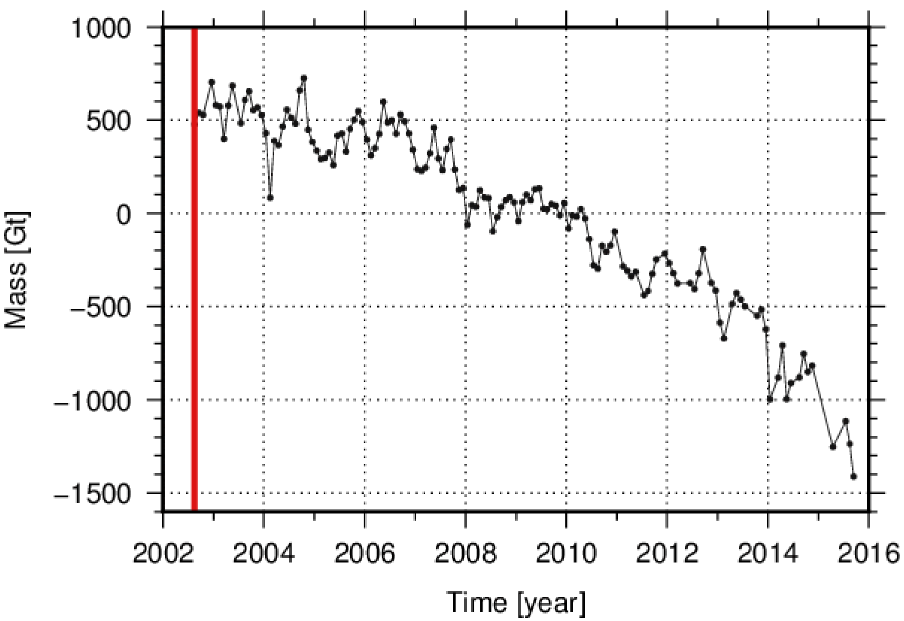
Application of tailored sensitivity kernels

Application of the derived sensitivity kernels to monthly GRACE solutions
ITSG-Grace2016 (prelim. version) – no explicit filtering

ITSG-Grace2016: see Talk by Klinger et al., Wednesday, 20 April, G4.2

Monthly time series of gridded and integrated mass changes of the
Antarctic Ice Sheet





Conclusions and outlook

New approach to directly tailor a mass change estimator by a formal optimization procedure

Method applied to generated Gravimetric Mass Balance (GBM) products within ESA's Climate Change Initiative project "Antarctic Ice Sheet CCI"

Product release: 9 May 2016, ESA Living Planet Symposium, Prague

Poster X4.187 by Horwath et al., Wednesday, 20 April, CR1.1,

Outlook

Incorporation of improved error models

Consideration of signal correlations

Thank you for your attention

TECHNISCHE UNIVERSITÄT DRESDEN
Fakultät Umweltwissenschaften, Fachrichtung Geowissenschaften, Institut für Planetare Geodäsie

The method of tailored sensitivity kernels for GRACE mass change estimates

Andreas Groh
Martin Horwath

EGU General Assembly 2016

DRESDEN concept
Exzellenz aus Wissenschaft und Kultur