Observing regional ice mass changes with GRACE

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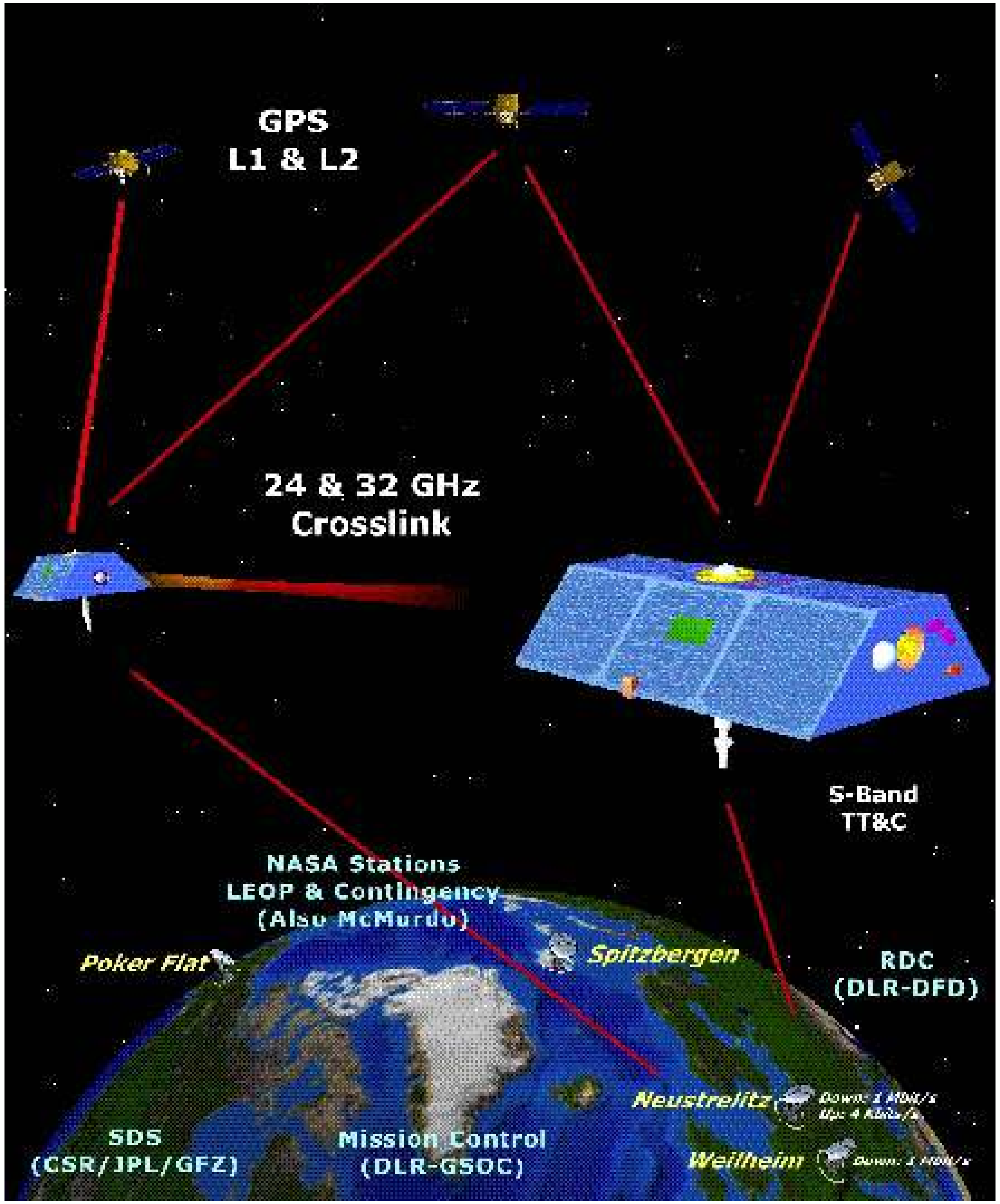
Observations of ice mass changes

terrestrial: hardly accessible terrain, continuous coverage impossible

satellite methods allow continuous observations, temporal and spatial

GRACE has been successfully used for Greenland, Antarctica and Alaska

GRACE **G**ravity **R**ecovery **A**nd **C**limate **E**xperiment



Content:

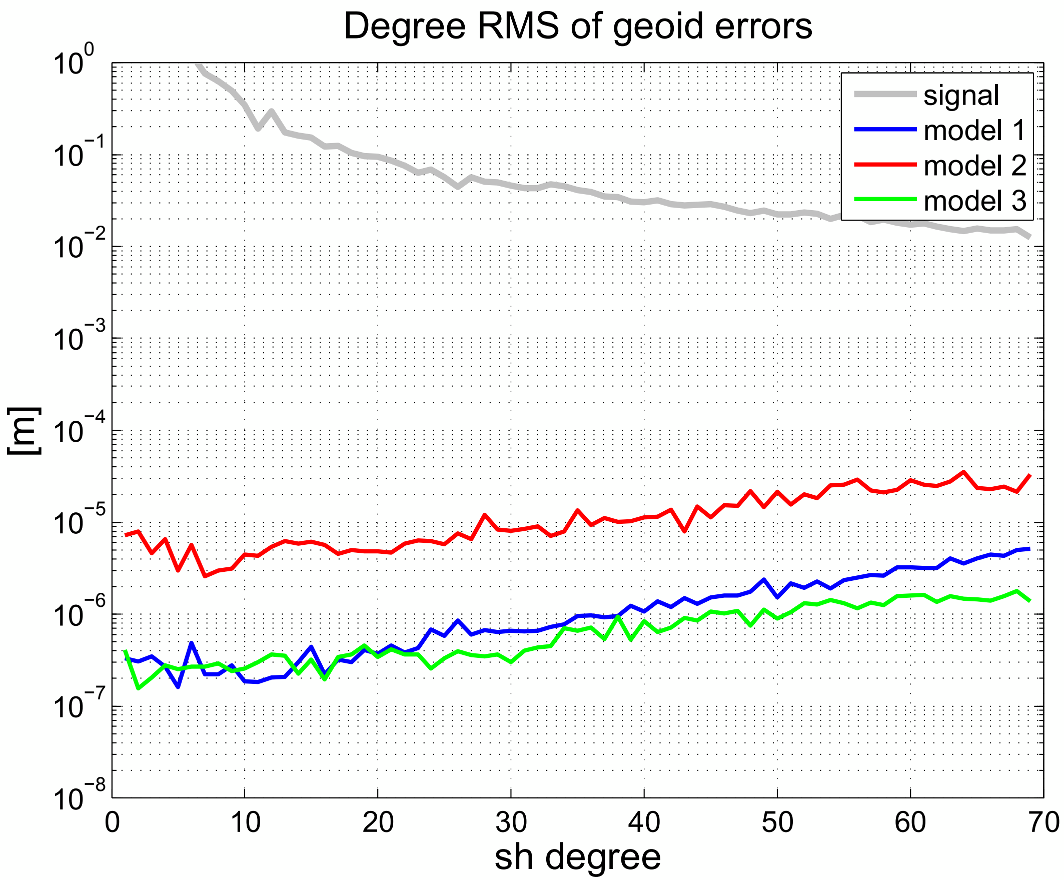
- Observability of signals from the cryosphere
- Spherical wavelets for regional modeling

Background

- very few terrestrial observations of glacier mass changes
- 8 years time series of observations from GRACE
- GRACE measurements have been successfully used for ice mass changes in Greenland and Antarctica
- A benchmark study in terms of regional GRACE data analysis for observations of glacier mass change was done by Luthcke et al[*]. They used 2° by 2° **mascons** to cover the Gulf of Alaska Glaciers.

[*] S.B. Luthcke, A.A. Arendt, D.D. Rowlands, J.J. McCarthy, and C.F.Larsen. Recent glacier mass changes in the gulf of alaska region form GRACE solutions. Journal of Glaciology, 54(188), 2008.

Simplified error analysis - K-band range rate



model 1:
num. derivative of realistic range errors

model 2:
white noise 10^{-7} on range rate

model 3:
white noise 10^{-8} on range rate

$\Rightarrow$ We assume white noise in the order of 10^{-8} m/s on the range rate.

Glaciological signals and measurements with GRACE

Forward modeling: A point mass of 2,5 Gt causes a range rate of 10^{-8} m/s in one overflight.

Error propagation according to $y = b + m \cdot x + a \cdot \sin(\omega t + \phi)$ with $\omega = 2\pi/\text{year}$ gives:

accuracy individual measurement	years	uncertainty mean b (Gt)	uncertainty trend m (Gt/a)	uncertainty amplitude a (Gt)
2,5 Gt (10^{-8} m/s)	1	0,92	1,65	0,80
	5	0,27	0,093	0,27
	8	0,21	0,045	0,21
	10	0,19	0,032	0,19
	15	0,15	0,018	0,15

Examples for glaciological mass changes

- Svalbard, Austfonna ice cap: Annual mass balance $\mathbf{-3 \pm 1}$ **Gt/a** (Dowdeswell et al., 2008 [1])
- Alps, total mass loss: about $\mathbf{-1}$ **Gt/a** (Zemp et al., 2006 [2])
- Mass changes of individual glaciers in the Alaska Range and the Tien Shan: from $\mathbf{3,8 \cdot 10^{-5}}$ **Gt/a** to $\mathbf{0,4}$ **Gt/a** (Dyurgerov et al., 2002 [3])
- **GRACE K-band measurements**: Error propagation gives an uncertainty of **0,045 Gt/a** for the trend estimated from a 8 years time series

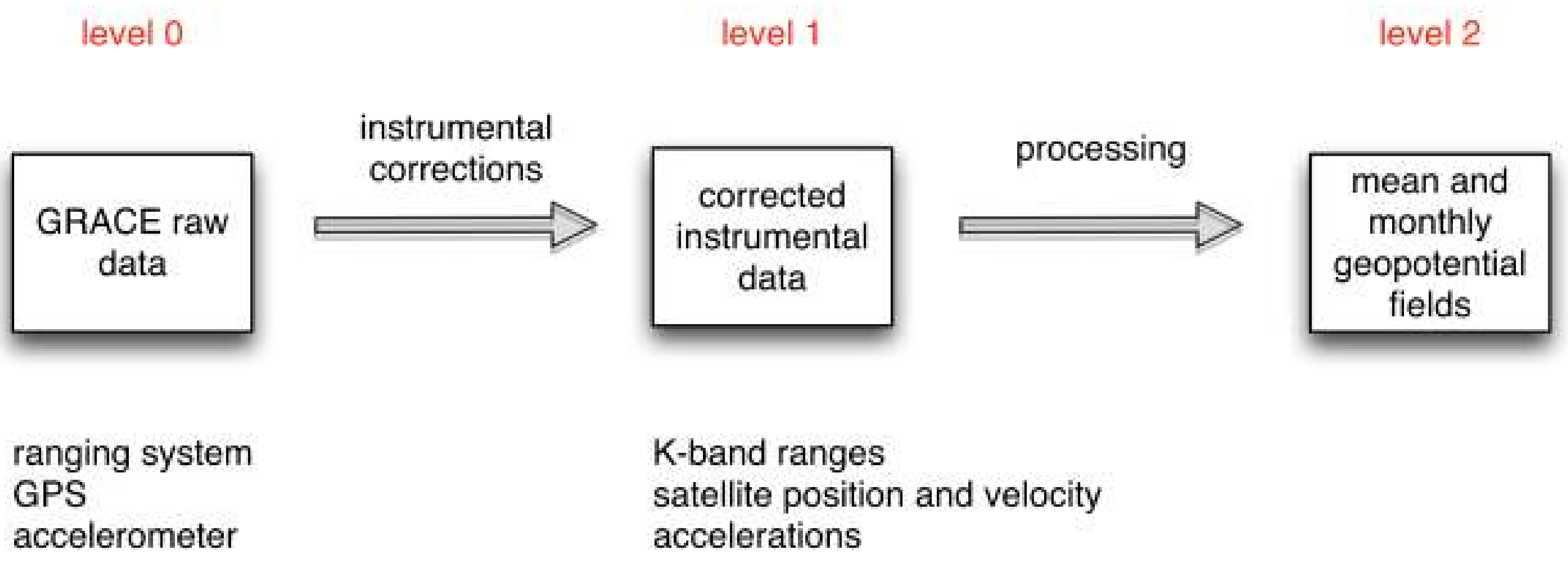
[1] J. A. Dowdeswell, T. J. Benham, T. Strozzi, and J. O. Hagen. Iceberg calving ux and mass balance of the austfonna ice cap on nordaustlandet, svalbard. Journal of Geophysical Research, 113, 2008.

[2] M.Zemp, W. Haeberli, M. Hoelzle, and F. Paul. Alpine glaciers to disappear within decades? Geophysical Research Letters, 133, 2006.

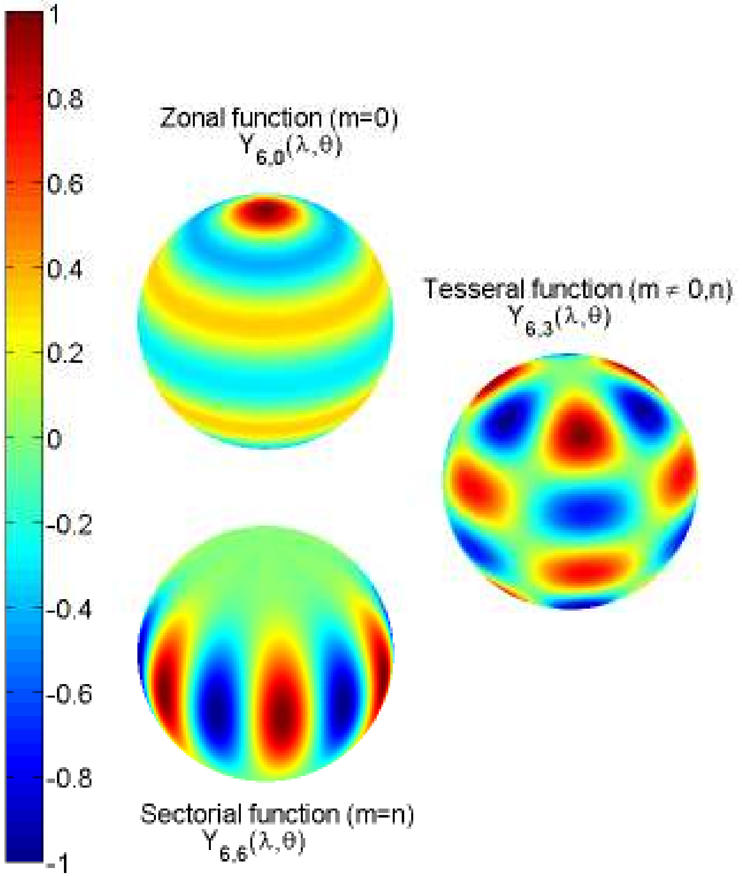
[3] M. Dyurgerov, M.Meier, and R. Armstrong. Glacier mass balance and regime: Data of measurements and analysis. Occasional Paper, (55), 2002. Institute of Arctic and Alpine Research, University of Colorado.

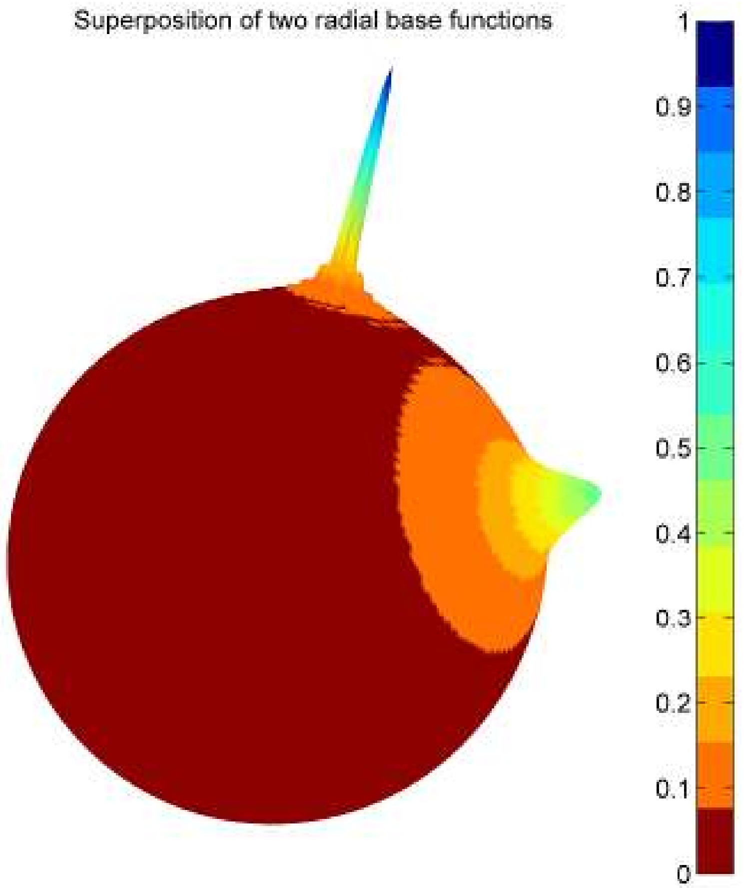
GRACE (**G**ravity **R**ecovery **A**nd **C**limate **E**xperiment)

Data products:



Spherical harmonics vs radial base functions





Source: Webpage university of Stuttgart, Institute of Geodesy, http://www.uni-stuttgart.de/gi/research/projects/project8/index.en.html

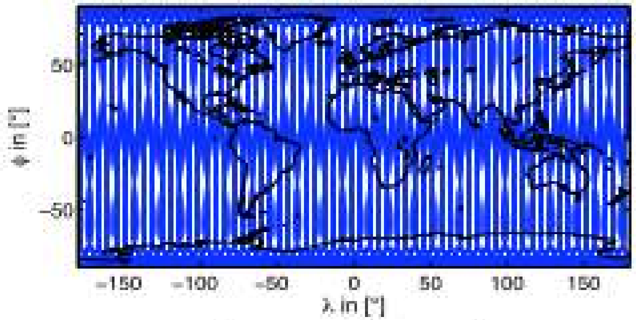
Summary and future work

glaciological signal

↕ ?

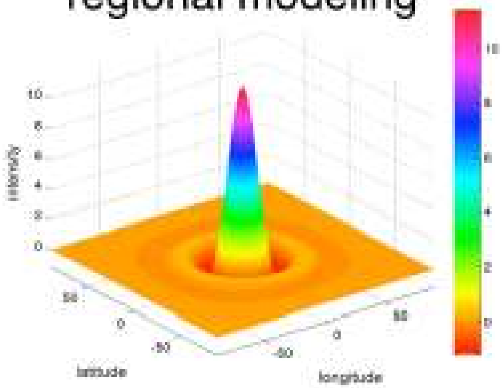
glaciological signal

upward
continuation



observations at
orbit height
+
other gravity signals
+
noise

data analysis and
regional modeling



⇨ possibility to
combine different data
sets in a multi-
resolution
representation