Comparison of Snow and Liquid Water Mass Variability over North America from GRACE and Model Data

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INTRODUCTION

North America has an abundant supply of freshwater resources, but water demands, including those arising from climate changes, increase steadily over the years. GRACE can provide good knowledge of the continental water mass variability in support of studying flood-drought events, glacier melting, changes in precipitation and the hydrology cycle. The knowledge gained from GRACE can indispensably assist management of water resources on a continental scale. A first step towards this is the analysis of geoid changes due to annual and interannual liquid water and snow mass variations. Principal component analysis (PCA) is used to study the spatio-temporal behaviour of the geoid changes.

DATA

GRACE data - 19 monthly gravity field solutions from February 2003 to January 2005 available from CSR RL02 in terms of spherical harmonic coefficients up to degree 120.
A time series with respect to the two-year mean is constructed.

Hydrological model data -
The *CPC soil moisture model* (Fan and van den Dool 2004)
The *Land Dynamics (LaD) model* (Milly and Shmakin 2002);
The *Global Land Data Assimilation System (GLDAS)* model (Rodell *et al.* 2004)
The *Canadian Meteorological Centre (CMC)* snow depth data (Brashnett 1998).

METHODOLOGY

Monthly geoid changes synthesized from the residual (with respect to the two-year mean) harmonic coefficients

$$\Delta N(\theta,\lambda,t) = a\sum_{l=2}^{\infty}\sum_{m=0}^{l} W_l P_{lm}(\cos\theta)\left[\Delta C_{lm}(t)\cos(m\lambda) + \Delta S_{lm}(t)\sin(m\lambda)\right]$$

Relationship between the coefficients of the geoid change and surface load

$$\begin{Bmatrix}\Delta C_{lm}\\ \Delta S_{lm}\end{Bmatrix} = \frac{3\rho_w}{\rho_{ave}}\frac{1+k_l}{2l+1}\begin{Bmatrix}\Delta \hat{C}_{lm}\\ \Delta \hat{S}_{lm}\end{Bmatrix}$$

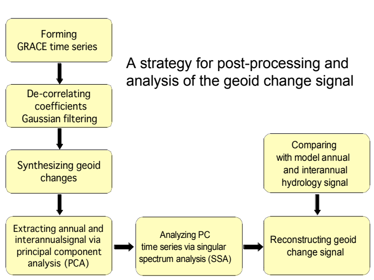
k_l = elastic Love number (Wahr *et al.* 1998)

ρ_w = density of water 1000 kg/m^3

ρ_{ave} = average Earth density 5517 kg/m^3

Algorithm for transforming harmonic coefficients

1. Spherical harmonic analysis of water equivalent data
2. Multiplication with degree-dependent factor
3. Synthesis to obtain space domain geoid

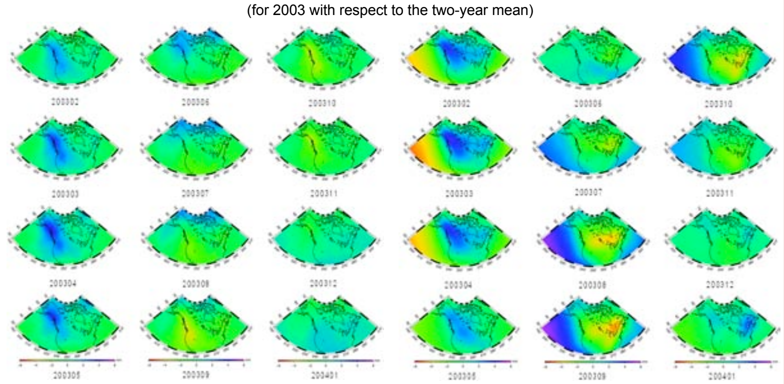


A strategy for post-processing and analysis of the geoid change signal

RESULTS

Reconstructed GRACE geoid changes **Annual and interannual GLDAS geoid changes**

(for 2003 with respect to the two-year mean)



Correlation coefficients of the loading EOF patterns from the liquid water storage models and GRACE.

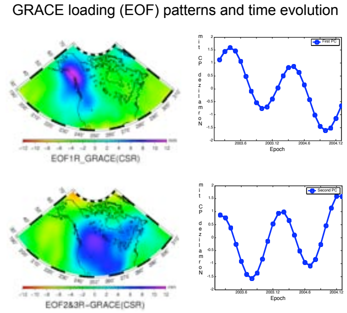
	GLDAS(1EOF)	LaD(1EOF)	CPC(1&2EOF)
GRACE(SCR) -2&3EOF	**0.84**	**0.74**	**0.84**

Correlation coefficients of the GRACE and hydrological models' geoid changes in April 2003.

	GLDAS	LaD	CPC
GRACE(SCR)	**0.64**	**0.60**	**0.16**

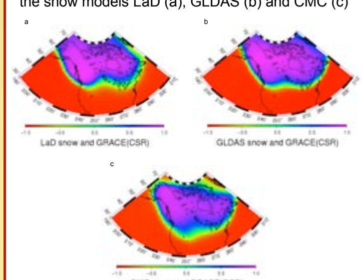
RESULTS (cont.)

GRACE loading (EOF) patterns and time evolution



The general geoid changes with an annual period at half wavelength of 300 km are extracted.

Correlation maps between GRACE and the snow models LaD (a), GLDAS (b) and CMC (c)



Derived from the coupled reconstructed GRACE and snow models' geoid changes.

DISCUSSION

The best correlation exists between the GRACE and GLDAS geoid changes. GLDAS is based on a sophisticated data assimilation procedure and has better global agreement with GRACE than the other two models.

The maximum positive signal is observed in the spring months of 2003 with a peak value in April (GRACE) and March (GLDAS). While the GLDAS model predicts positive geoid changes in Québec-Labrador, they are not observed in the GRACE reconstructed signal. Note, however, the well centered GRACE signal at southeastern Alaska with higher magnitude than the one predicted by GLDAS (see e.g., May 2003).

Existing interannual variations in water and snow masses not accounted for in the models, but observed by GRACE, may contribute to the discrepancies as well.

CONCLUSIONS

Principal component analysis is able to extract meaningful geoid change signal related to the continental hydrology cycle from a two-year GRACE time series.

The best agreement exists with the GLDAS continental water storage model.

GRACE is sensitive to water and snow mass variations in North America and provides useful and independent means for the validation and improvements of hydrological models.

ACKNOWLEDGEMENTS

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