A daily spatiotemporal estimator for downscaling GRACE gravity models for terrestrial water storage and groundwater storage estimation

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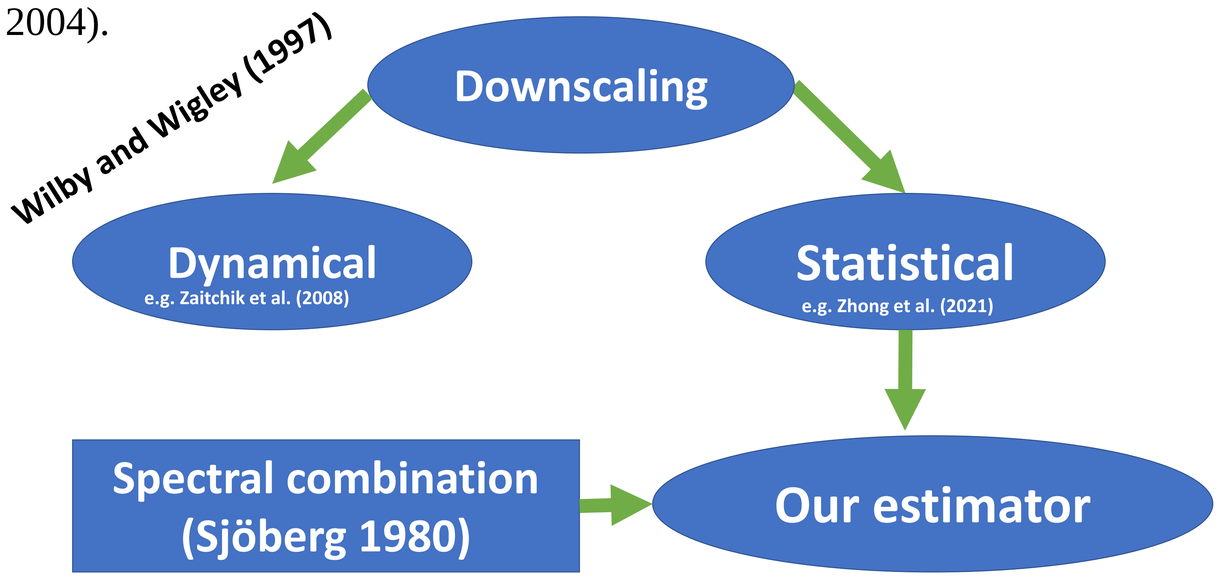
ABSTRACT

Because of the limited spatiotemporal resolution of the gravity field and climate experiment (GRACE) time-variable gravity models for water management authorities, an estimator is developed to downscale the monthly terrestrial water storage anomalies (TWSA), derived from GRACE gravity models, to a daily 0.25˚×0.25˚ spatiotemporal resolution. This new method spectrally combines the TWS of GRACE and daily hydrological models e.g. Global Land Data Assimilation System (GLDAS) to enhance quality of both low and high frequency of TWS signals in the estimated TWSA and Groundwater storage anomalies (GWSA). This estimator is applied over Canadian Prairies for a period of six-month. Comparison of the estimated GWSA with 75 Piezometric wells in the area shows a correlation of about 95% with a great consistency across the wells.

INTRODUCTION

The Gravity Recovery and Climate Experiment (GRACE, Tapley et al. 2005) is a satellite mission with twin satellites for precise determination of spatial and temporal variations in the Earth's gravity field. However, the ability of GRACE to monitor changes at smaller scales is limited for local water management authorities. Therefore, the gravity field models of GRACE need to be downscaled by involvement of hydrological data, like Global Land Data Assimilation System (GLDAS, Rodell et al. 2004).



OBJECTIVE

The objective of this study is to developed a new and simple estimator to spectrally downscaling GRACE models using hydrological models like GLDAS and apply it in Canadian Prairies.

METHODOLOGY

In order to downscale the monthly GRACE data to daily, the following estimator is proposed:

$$\tilde{T}_i^G = \sum_{n=0}^{\infty} a_n (k_n + \varepsilon_{k_n})(\bar{T}_n^G + \varepsilon_{\bar{T}_n^G})$$

where k_n is the ratio of the daily and monthly variation of the TWS, ε_{k_n} is the error spectra of this ratio. $\bar{T}_n^G$ is the spectra of monthly GRACE TWS, and $\varepsilon_{T_n^G}$ is their error spectra, a_n is the spectral coefficients of the estimator

$$\hat{a}_n = \frac{c_{i,n}}{k_n^2 \sigma_{\bar{T}_n^G}^2 + \sigma_{k_n}^2 c_{i,n}^2 + \sigma_{k_n}^2 \sigma_{\bar{T}_n^G}^2 + c_{i,n}}$$

RESULTS AND DISCUSSION

Figure 1 shows three selected days of 15th of August, September and October 2003 for visualisation of our downscaling process. The minimum GWSA is seen in Palliser's Triangle with about -45 mm, -62 mm, and -57 mm, respectively on these days.

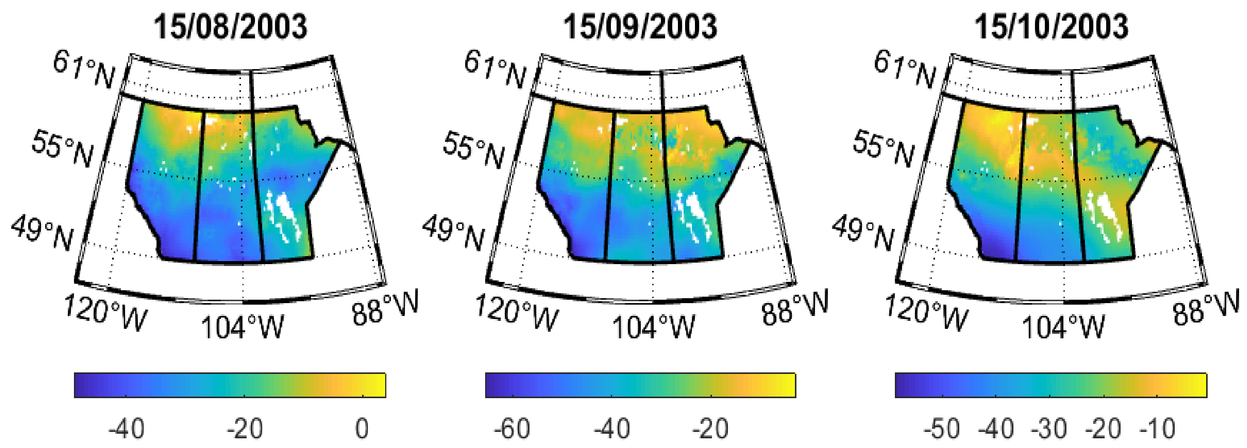


Figure 1. Daily downscaled groundwater storage anomalies (GWSA) over Canadian Prairies [mm]

VALIDATION AND CONCLUSION

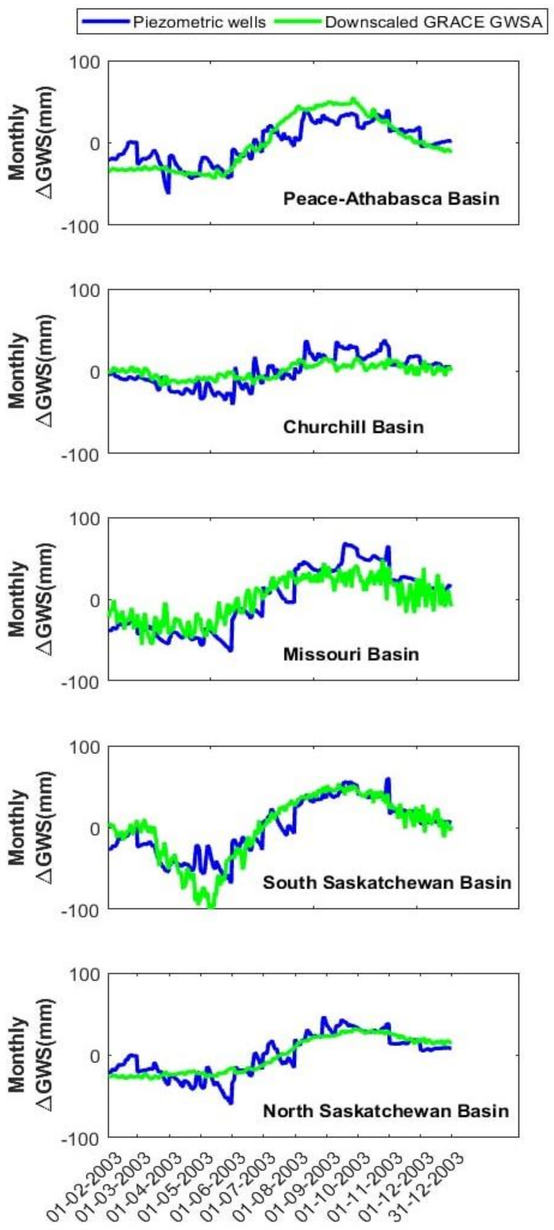


Figure 2. Daily downscaled groundwater storage anomalies (GWSA) of five well and our downscaled GWSA [mm]

Figure 2 shows the GWSA of some selected wells and our downscaled one.

The GWSA of 60 in-situ Piezometric wells in Alberta are used for validation of our products. The root mean squares error (RMSEs) and correlation ρ of their differences are:

10.6 < RMSE < 47.8 mm (60)
RMSE < 20 mm (15, 25%)
RMSE< 30 mm (44, 75%)
43% < ρ < 92% (60 wells)
40% < ρ < 50% (3 wells, 5%)
50% < ρ < 60% (10 wells, 16%)
60% < ρ < 70% (9, 15%)
70% < ρ <80% (15, 25%)
80% < ρ<90% (21, 35)
90% < ρ < 100% (2, 4%)

The first number in the parenthesis is number of wells and the second is the percentage out of total wells.

Our result shows that our products have high correlations and consistency across wells, confirming the successful excellent performance of our proposed method.

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