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Assessing uncertainties of GRACE-derived terrestrial water-storage fields

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Conclusions:

GRACE-derived terrestrial water-storage (TWS) fields inverted from solutions of the Center for Space Research (CSR), the Jet Propulsion Laboratory (JPL), the German Research Centre for Geosciences (GFZ), and the *Groupe de Recherche de Géodésie Spatiale* (GRGS) present:

- uncertainties of 9.4, 13.7, 14.8, and 13.2 mm, respectively, at a global scale;
- at the basin scale (91 river basins), the CSR overperforms the other processing centers;
- results based on the "noise decoupling" problem were confirmed by a comparison with an ensemble solution from the four GRACE processing centers.

Aim:

To assess the quality of GRACE-derived TWS fields inverted from the Level-2 products (spherical harmonics coefficients - SHCs) provided by CSR, JPL, GFZ, and GRGS by using a generalized formulation of the three-cornered hat (TCH) method.

The noise decoupling problem (TCH):

The N-by-N covariance matrix of the individual noises $\mathbf{R}$, whose elements are the unknowns of the problem and should be determined, is related to $\mathbf{S}$, the (N-1)-by-(N-1) covariance matrix of the series of the differences, by:

$$\mathbf{S}=\mathbf{H}^{\mathrm{T}}\cdot\mathbf{R}\cdot\mathbf{H} \tag{1}$$

where

$$\mathbf{H}=\begin{bmatrix} 1 & 0 & \cdots & 0 \\ 0 & 1 & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & 1 \\ -1 & -1 & \cdots & -1 \end{bmatrix} \tag{2}$$

The system in (1) shows that there are N "free-parameters" to be estimated. Then, by partition of $\mathbf{R}$ as

$$\mathbf{S}=\mathbf{H}^{\mathrm{T}}\cdot\begin{bmatrix} \hat{\mathbf{R}} & \mathbf{r} \\ \mathbf{r}^{\mathrm{T}} & r_{NN} \end{bmatrix}\cdot\mathbf{H} \tag{3}$$

is sufficient to solve the underdetermined problem in (1) by isolating N "free-parameters", i.e., $\mathbf{r}=[r_{1N},r_{2N},\ldots,r_{N-1,N}]^{\mathrm{T}}$ and r_{NN}. Considering the nature of the problem, the objective function:

$$F(\mathbf{r},r_{NN})=\sum_{i:i<j}\frac{r_{ij}^2}{\left(\sqrt[N-1]{\det(\mathbf{S})}\right)^2} \tag{4}$$

constrained by

$$[\mathbf{r}-r_{NN}\cdot\mathbf{u}]^{\mathrm{T}}\cdot\mathbf{S}^{-1}\cdot[\mathbf{r}-r_{NN}\cdot\mathbf{u}]\leq r_{NN} \tag{5}$$

is a candidate in the minimization problem, where $\mathbf{u}$ is the N-1 vector of ones.

Methodology:

- GRACE Level 2 products from four different processing centres (CSR, GFZ, GRGS, and JPL) from August 2002 to June 2014 filtered with a DDK2 filter;
- The SHCs starting from degree (d) 3 and order (o) 0 up to d/o 60 were inverted into global TWS monthly fields at a resolution of 1 arc-degree, and used to compute basin-averaged series as well;
- Watersheds of the world larger than 10^5 km² (GRACE's resolution) extracted from the WRI Major Watersheds of the World Delineation were inverted to SHCs (d/o 60) and smoothed with DDK2.

Global comparison of the solutions:

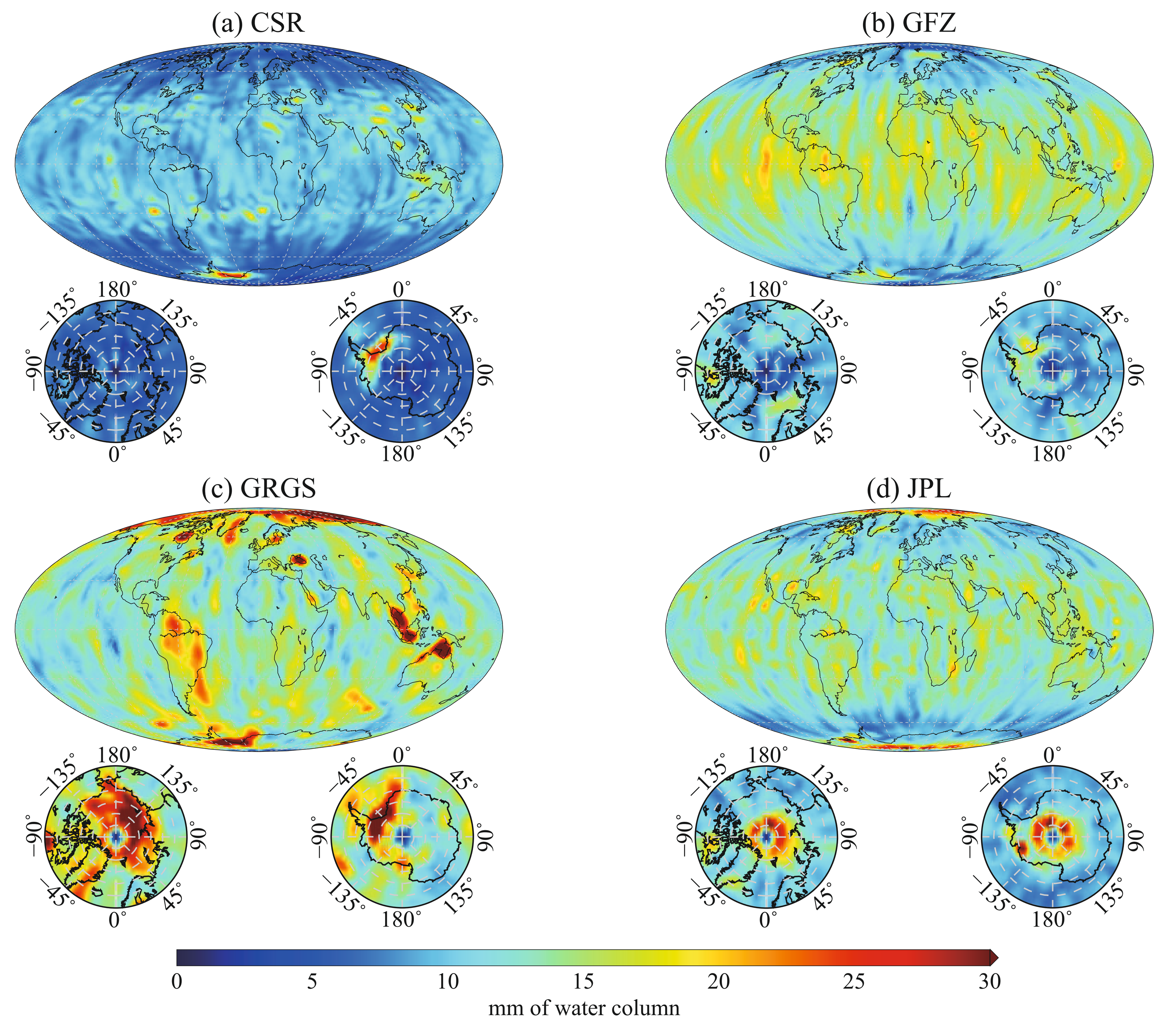

Fig. 1 - Uncertainties of the GRACE-TWS fields. The area weighted uncertainty for each GRACE processing ceter is CSR 9.4 mm (a), GFZ 13.7 mm (b), GRGS 14.8 mm (c), and JPL 13.2 mm (d).

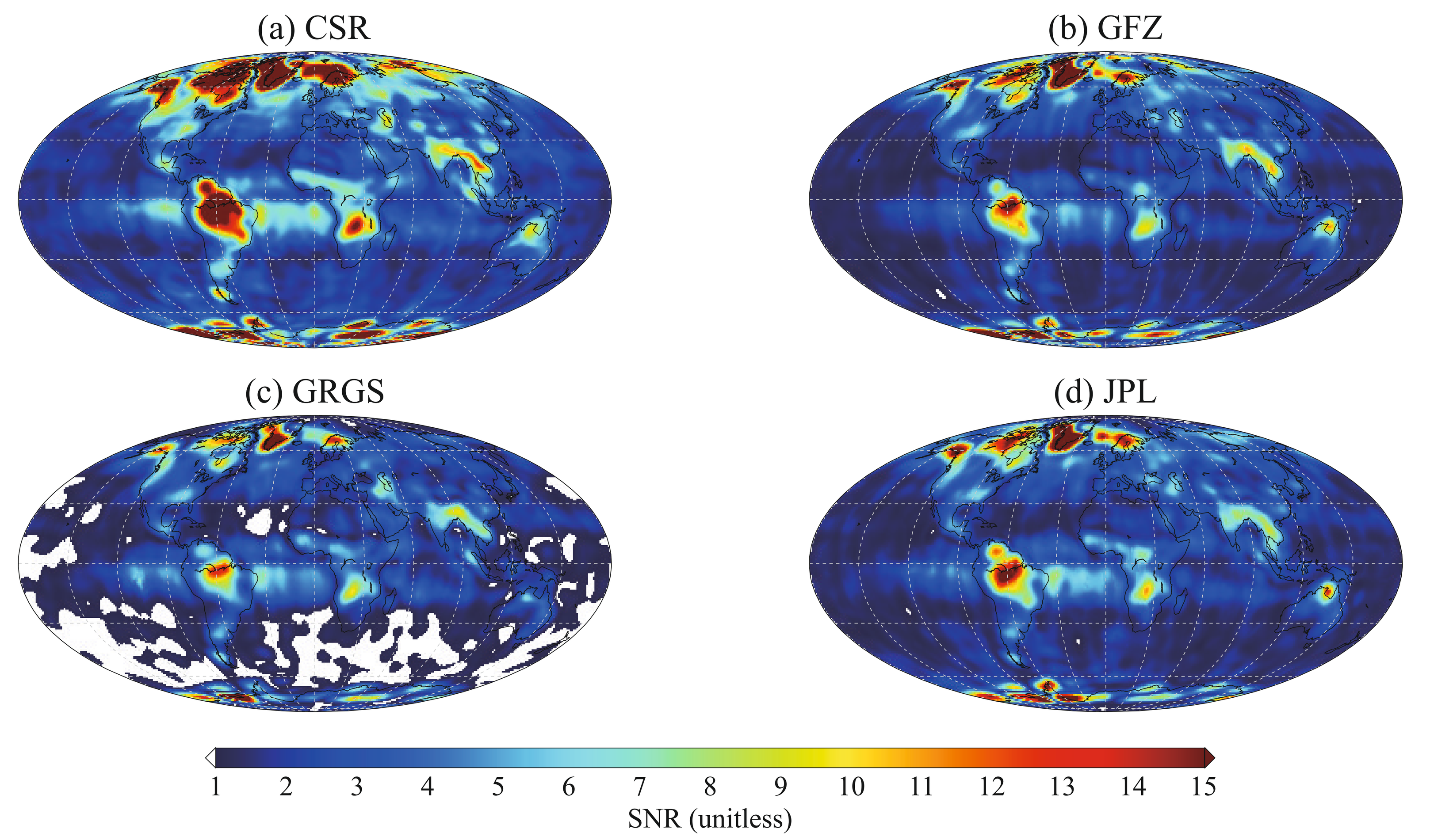

Fig. 2 - Signal-to-noise (SNR) based on the standard deviation of each time series and the uncertainties based on the TCH results (Fig. 1). The area weighted SNR value for each GRACE processing ceter is CSR 4.2 (a), GFZ 2.9 (b), GRGS 2.3 (c), and JPL 2.9 (d). The SNR values < 1, which indicate more noise than signal, were masked out in white.

Basin scale comparison of the solutions:

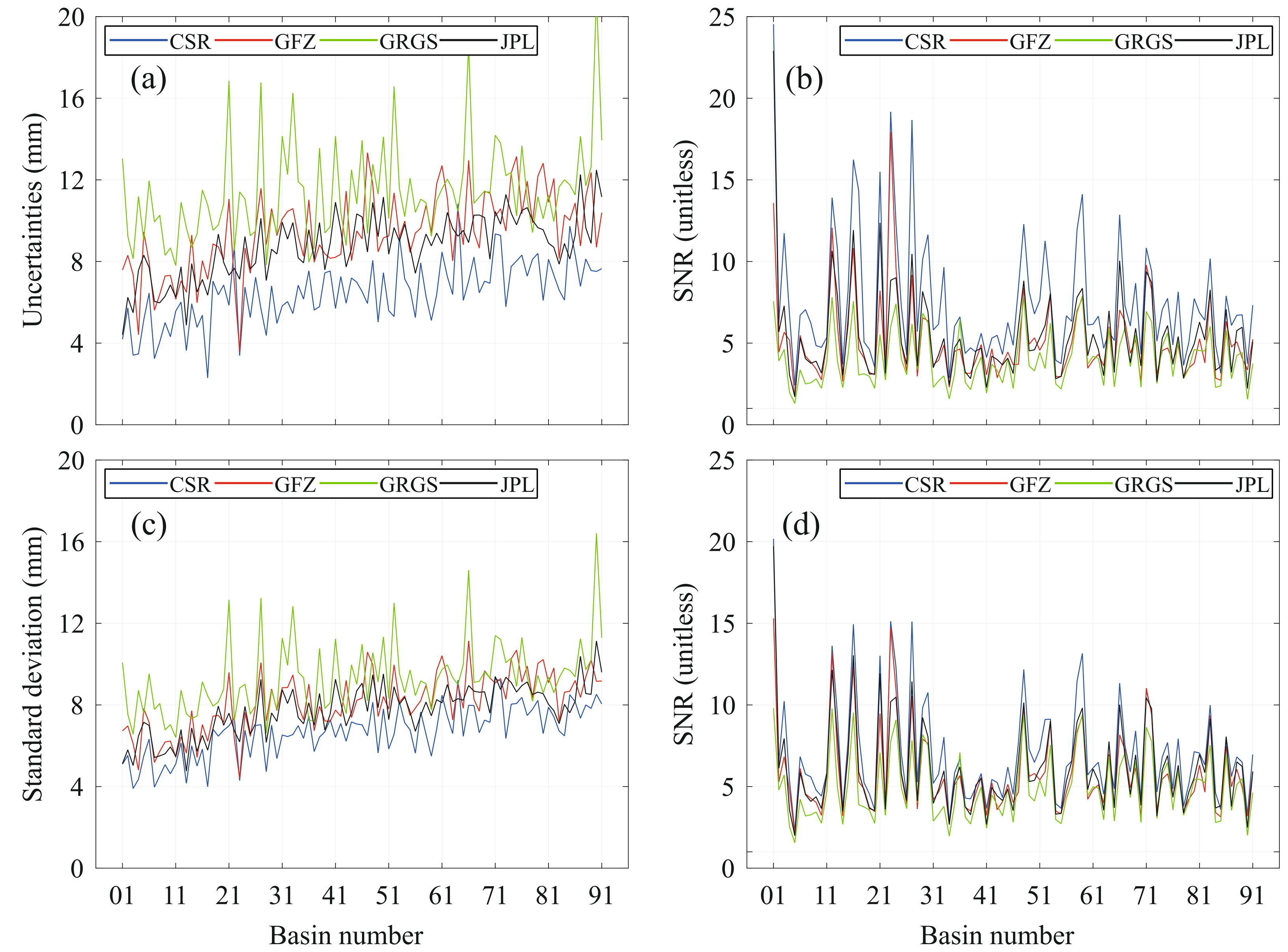

Fig. 3 - (a) The TCH-based uncertainties and (b) SNRs for the 91 watersheds. (c) The ensemble mean based standard deviations and (d) the SNRs. The basin numbers are sorted according to the area of the basin from largest to smallest (Amazon 01 and Rio Salado 91).

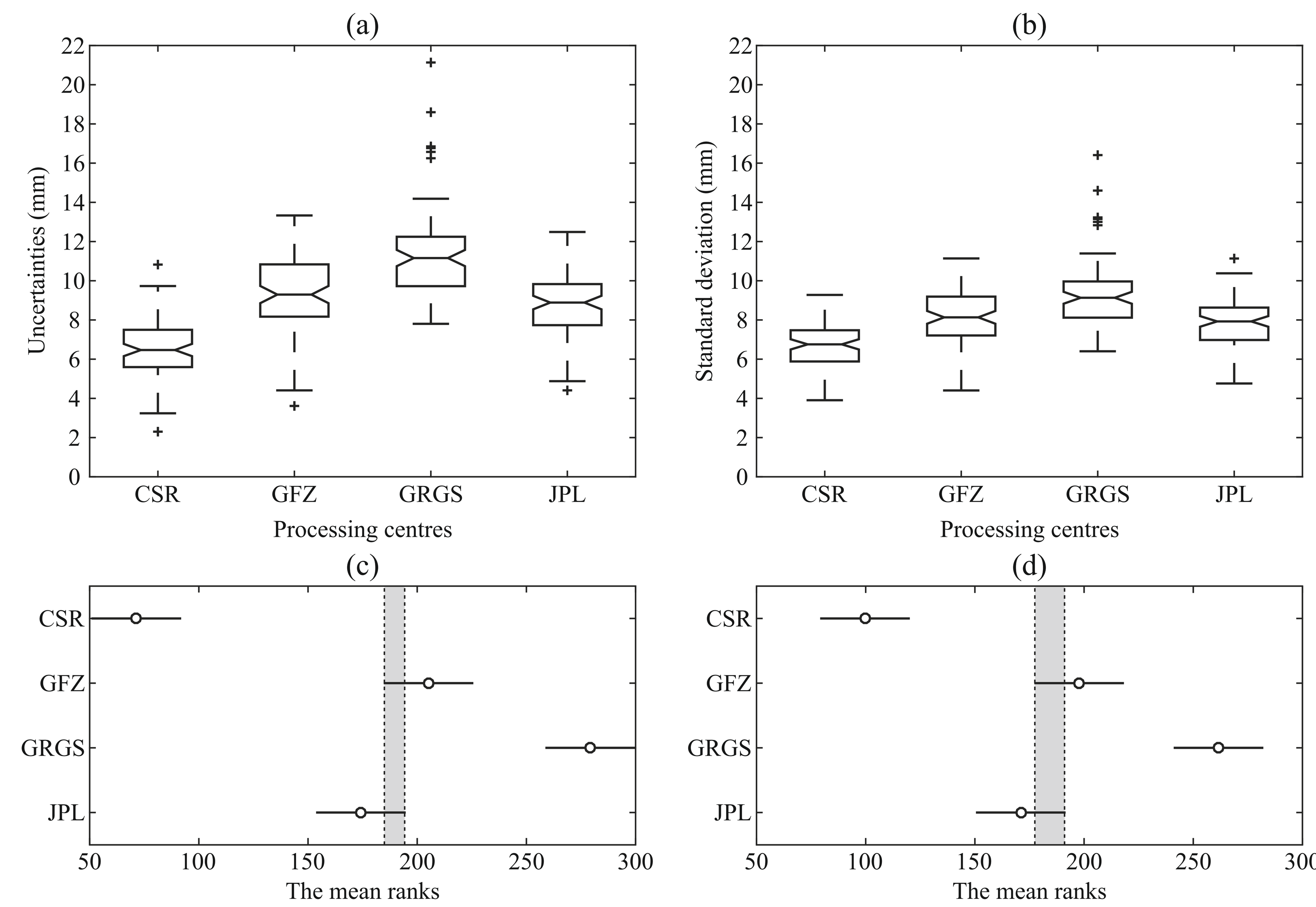

Fig. 4 - Box plot summaries of the error estimates based on (a) TCH and (b) ensemble mean. The performance rankings of the four solutions based on (c) TCH and (d) the ensemble mean for the 91 river basins. The lower *x*-axis values in (c) and (d) indicate superior performance.

✉For caveats and such, please, contact me at:
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Reference:
Ferreira VG, Montecino HDC, Yakubu CI and Heck B (2016) Uncertainties of the Gravity Recovery and Climate Experiment time-variable gravity-field solutions based on three-cornered hat method. *Journal of Applied Remote Sensing*, 10(1), pp 015015-(1-20). doi: 10.1117/1.JRS.10.015015

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