List of abbreviations

TWS	Terrestrial Water Storage
GRACE	Gravity recovery and climate experiment
GHMs	Global hydrological models
LSMs	Land Surface Models
CSR-M	University of Texas Center for Space Research mascon solutions
JPL-M	Jet Propulsion Laboratory mascon solutions
WRR1	Water Resources Reanalysis 1 and 2
WRR2	
E2O	eartH2Observe
EU-FP7	European Union's Seventh Framework Programme
WATCH	WATer and global CHange
WFDEI	WATCH Forcing Data applied to the ERA-Interim data
MSWEP	Multi-Source Weighted Ensemble Precipitation
LISFLOOD	-
HBV-SIMREG	-
W3RA	Worldwide water Resources Assessment
SWABM	Simple Water Balance Model
WaterGAP3	Water – Global Assessment and Prognosis-3
HTESSEL	Hydrology Tiled ECMWF Scheme for Surface Exchanges over Land
JULES	Joint UK Land Environment Simulator
Surfex-Trip	Surface Externalisée-Trip

Table S1: Models overview and key changes from WRR1 to WRR2

	Model	Organization	Model Type	Evaporation	Runoff	Changes in WRR2	References
1	HBV–SIMREG	Joint Research Centre (JRC) GHM	GHM	Penman 1948	Beta function	n/a	Lindström et al. (1997)
2	LISFLOOD	Joint Research Centre (JRC)	GHM	Penman 1948	Saturation and infiltration excess	Improved soil layers, and groundwater abstraction	Van Der Knijff et al. (2010)
3	PCR-GLOBWB	Universiteit Utrecht (UU)	GHM	Hamon (tier 1) or imposed as forcing	Saturation and infiltration excess	Improved river routing and reservoir system, incorporated water consumption and groundwater abstraction	Van Beek et al. (2011)
4	SWBM	Eidgenössische Technische Hochschule (ETH)	GHM	Inferred from net radiation	Saturation and infiltration excess	n/a	Orth and Seneviratne (2013)
5	W3RA	Eidgenössische Technische Hochschule (ETH)	GHM	Penman 1948		Revised groundwater hydrology and soil equation incorporates enhanced parameter estimation, dynamic data assimilation, and water evapotranspiration not resulting from rainfall.	Van Dijk et al. (2014)
6	WaterGAP3	Universitat Kassel	GHM	Priestley–Taylor	Beta function	Integration of soil water evaluations and reservoir monitoring	Flörke et al. (2013)
7	HTESSEL	European Centre for Medium-Range Weather Forecasts (ECMWF)	LSM	Penman 1948	Saturation excess	Multilayer soil scheme, increased number of soil layers	Balsamo et al. (2009)
8	JULES	Centre for Ecology and Hydrology (CEH)	LSM	Penman 1948	Saturation and infiltration excess	Rainfall runoff dynamics, incorporating topographic gradient reliance in a saturated overflow discharge scheme	Best et al. (2011) Clark et al. (2011)
9	SURFEX-Trip	Metro France	LSM	Penman 1948	Saturation and infiltration excess	Improved groundwater. Land use, flood plains, snow and surface energy and plant growth	Decharme et al. (2010)

* Schellekens et al. (2017)

Correlation coefficient (R)

The correlation coefficient (R) is the frequently used statistic to quantify the patterns of similarity between two variables (f) and (r) which are defined at N discrete points (in time and/or space).

$$R = \frac{\frac{1}{N}\sum_{n=1}^{N}(f_n-\bar{f})(r_n-\bar{r})}{\sigma_f\,\sigma_r} \quad (3)$$

where $\bar{f}$ and $\bar{r}$ are the mean values and σ_f and σ_r are the standard deviations of “f” and “r”, respectively.

R reaches to 1 (maximum value) when for all n, $(f_n - \bar{f}) = \alpha(r_n - \bar{r})$, where α is a positive constant. In this instance, the two fields are not equal unless $\alpha = 1$, despite sharing the same centered pattern of variation. Therefore, it is unlikely that the two models have the same amplitude of variance as R alone.

RMS difference (E)

RMS is the most frequently used statistic to quantify differences between two fields (f and r) and is defined by

$$E = \frac{1}{N}\sum_{n=1}^{N}\left[(f_n - \bar{f}) - (r_n - \bar{r})\right]^2 \quad (4)$$

The standard deviation of “f” (σ_f) is defined as following

$$E = \frac{1}{N}\sum_{n=1}^{N}(f_n - \bar{f})^2 \quad (5)$$

And of “r” (σ_r) is

$$E = \frac{1}{N}\sum_{n=1}^{N}(r_n - \bar{r})^2 \quad (6)$$

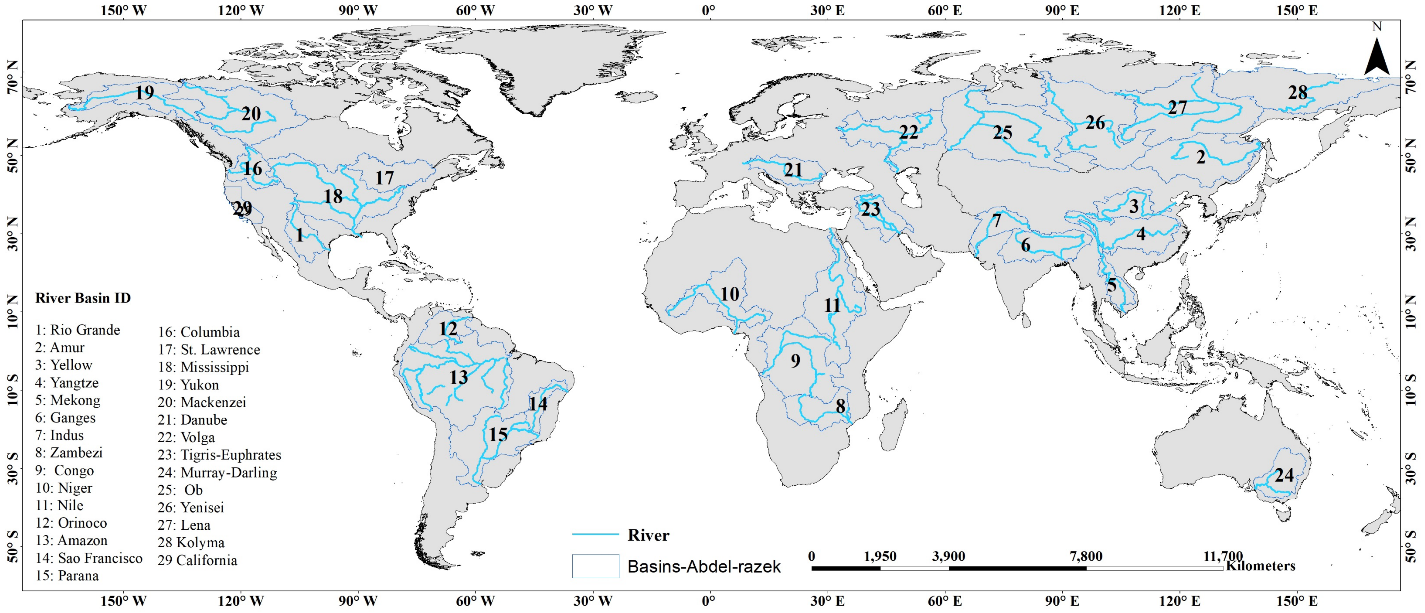

Figure S1: Selected 29 major global river basins.

Nine river basins including Amur (2), Saint Lawrence (17), Yukon (19), Mackenzie (20), Volga (22), Ob (25), Yenisei (26), Lena (27), and Kolyma (28) were selected from the boreal zone. Among them, five basins (i.e., Yukon, Mackenzie, Yenisei, Lena, and Kolyma) have heterogeneous climate conditions from polar to boreal and one basin (i.e., Saint Lawrence) is in boreal to temperate zones. Eleven river basins in the temperate zone were selected. Out of these, three basins i.e., Columbia (16), Mississippi (18), and the Danube (21) are located in the cold to temperate zone, and four basins i.e., Rio Grande (1), Euphrates (23), Murray-Darling (24), and California (29) in temperate to arid zone while four river basins Yellow River (3), Yangtze (4), Brahmaputra-Ganga (6), Indus (7) shares polar to the temperate and arid climate. Five basins, including Zambezi (8), Niger (10), Nile (11), São Francisco (14), and Prana (15), were selected from the arid zone and four major river basins in the tropical zone, including Mekong (5), Congo (9), Orinoco (12), and Amazon (13).

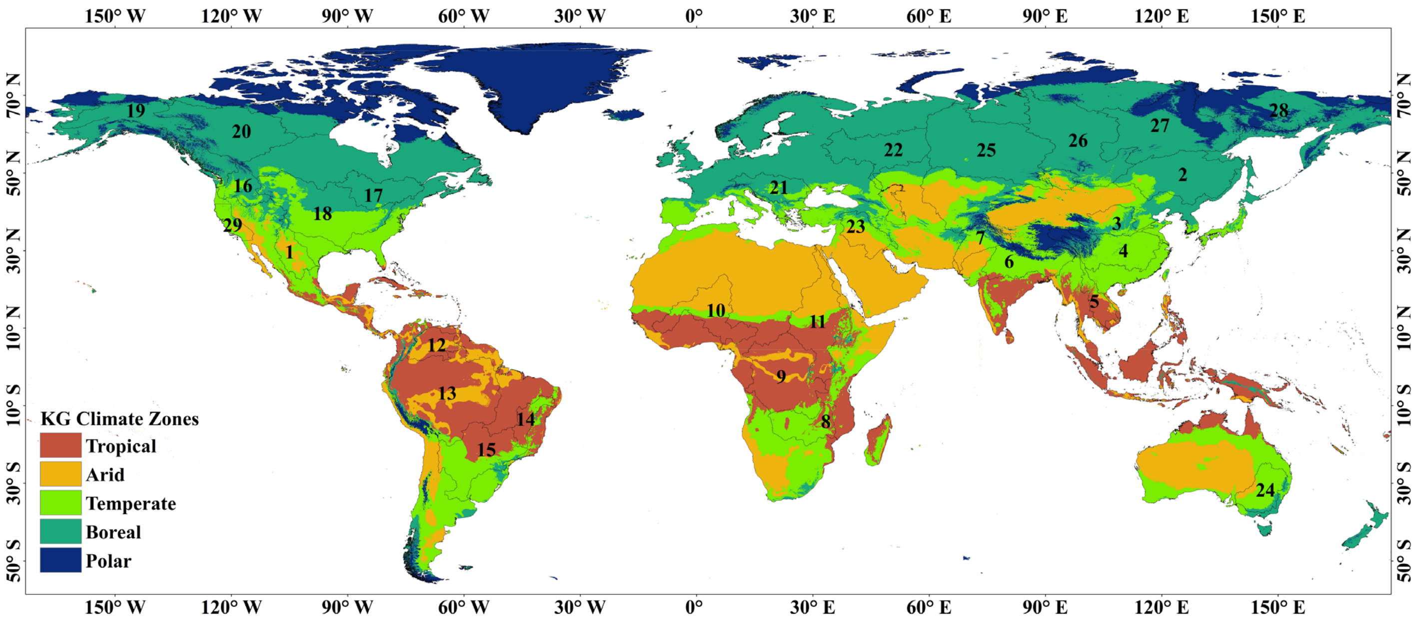

Figure S2: KGClim Climate Zones (1983-2013) classification

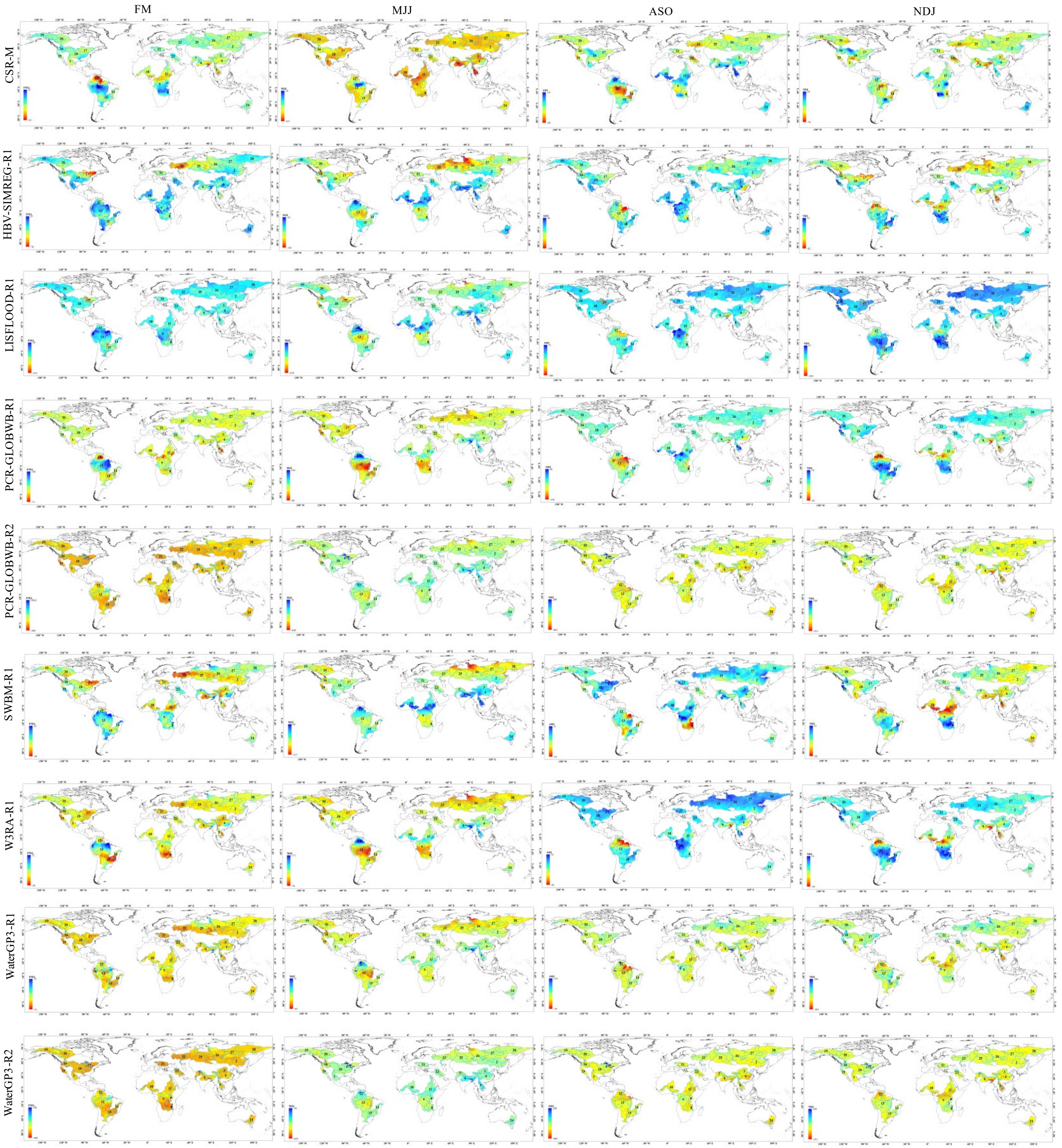

Figure S3: Seasonal maps for GRACE CSR-M and GHM R1 and R2

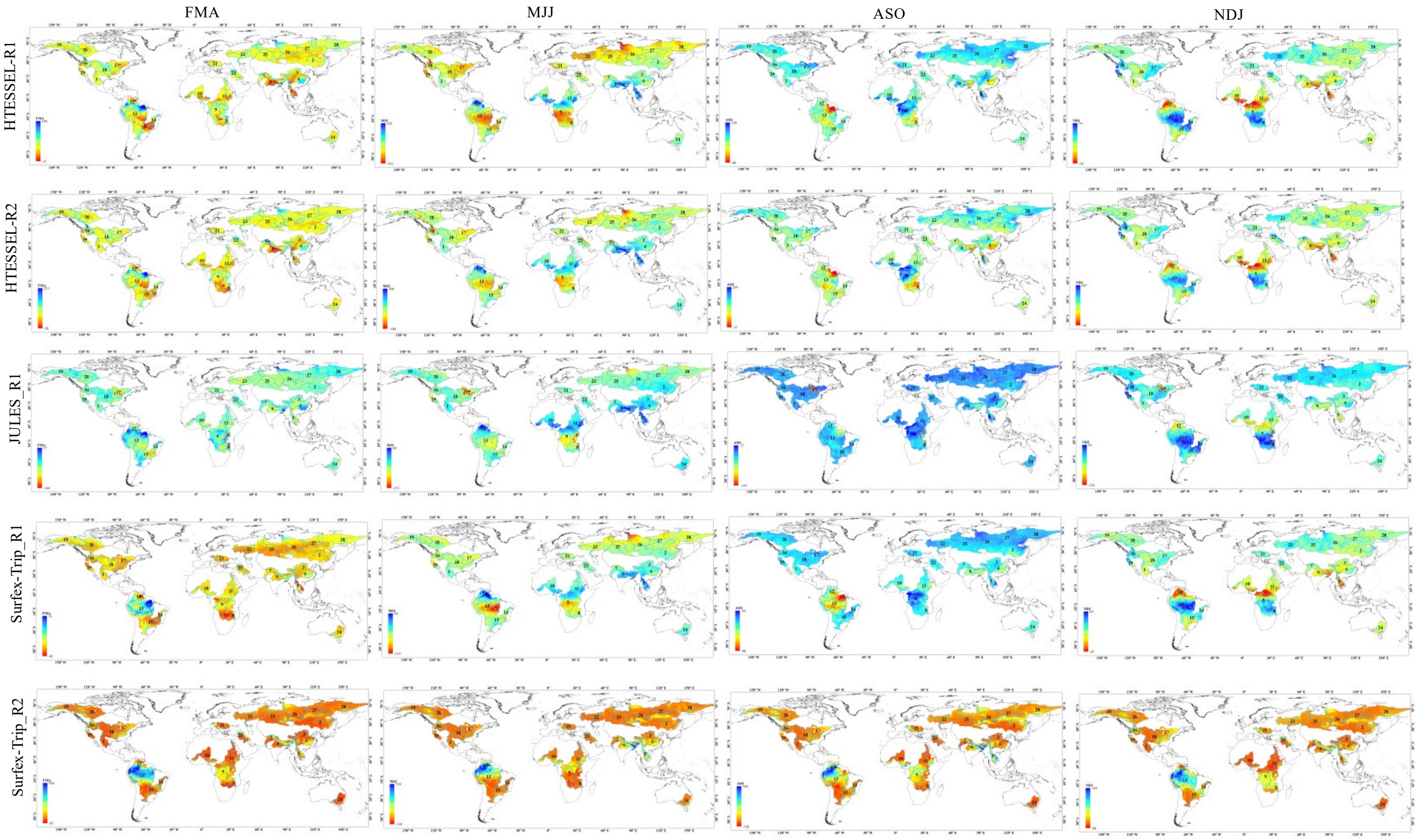

Figure S4: Seasonal maps of LSM R1 and R2

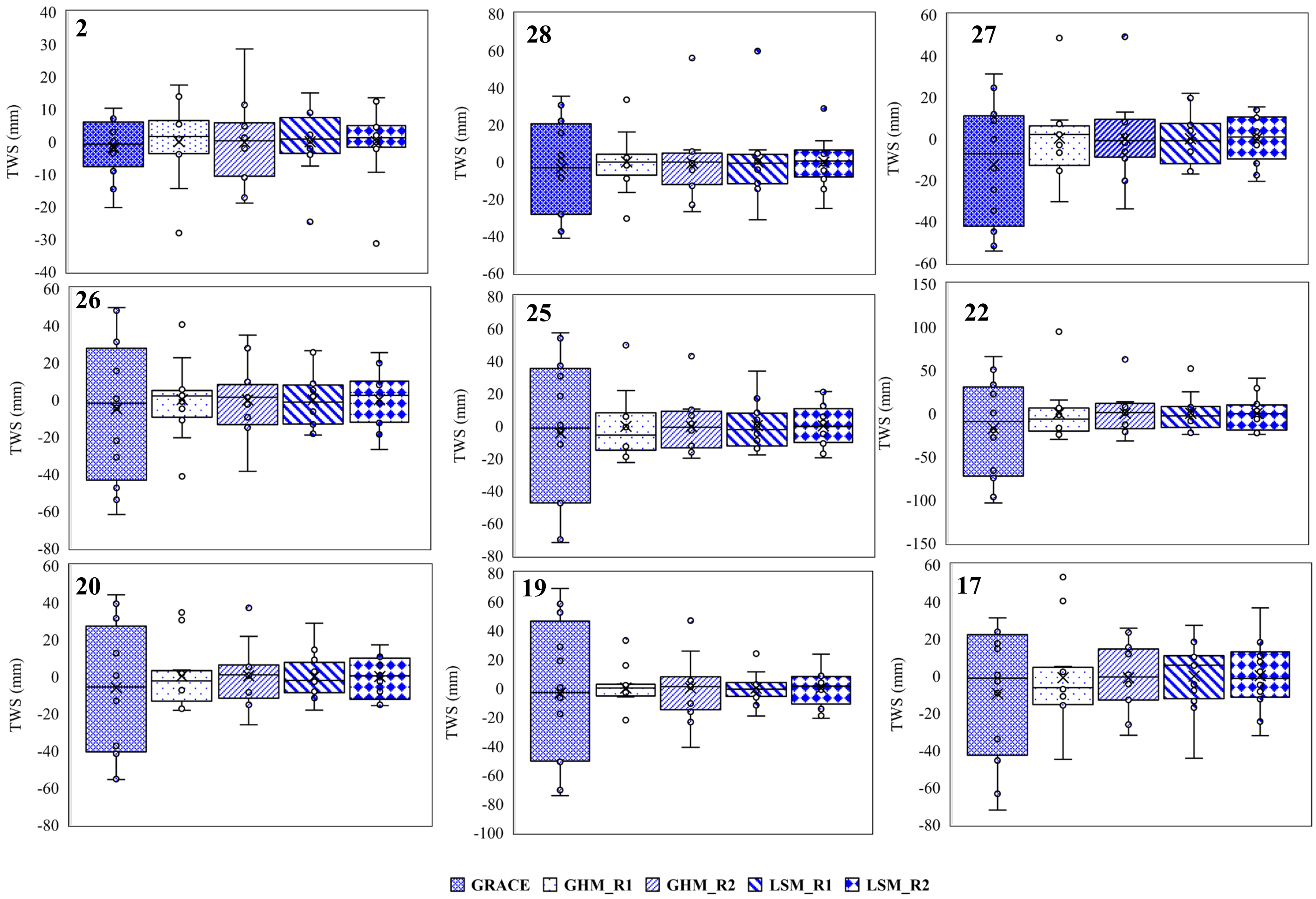

Figure S5: Distribution of GRACE and grouped model type (GHM or LSM) and forcing resolution (R1 and R2) in the Boreal zone.

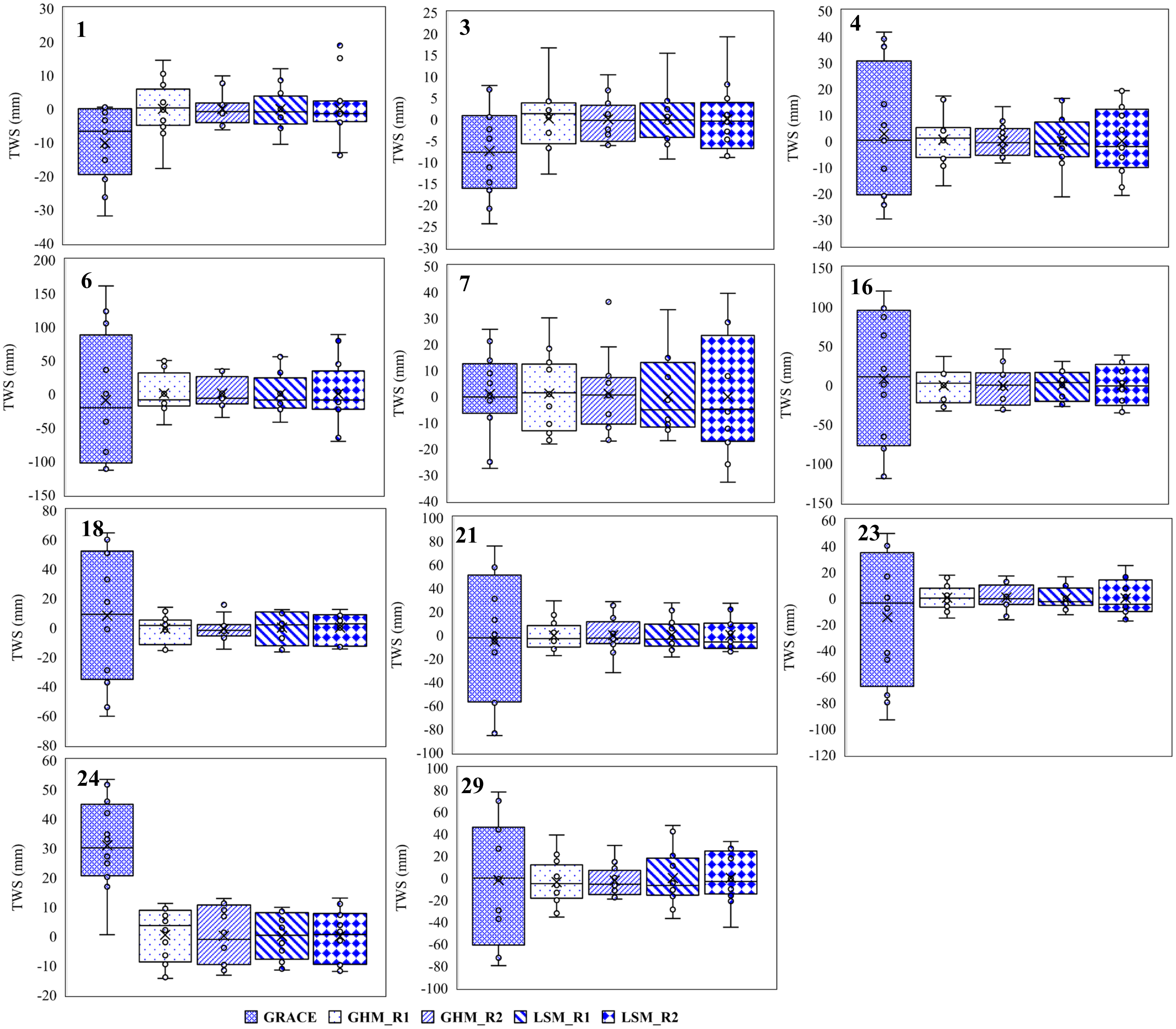

Figure S6: Distribution of GRACE and grouped model type (GHM or LSM) and forcing resolution (R1 and R2) in the Temperate zone.

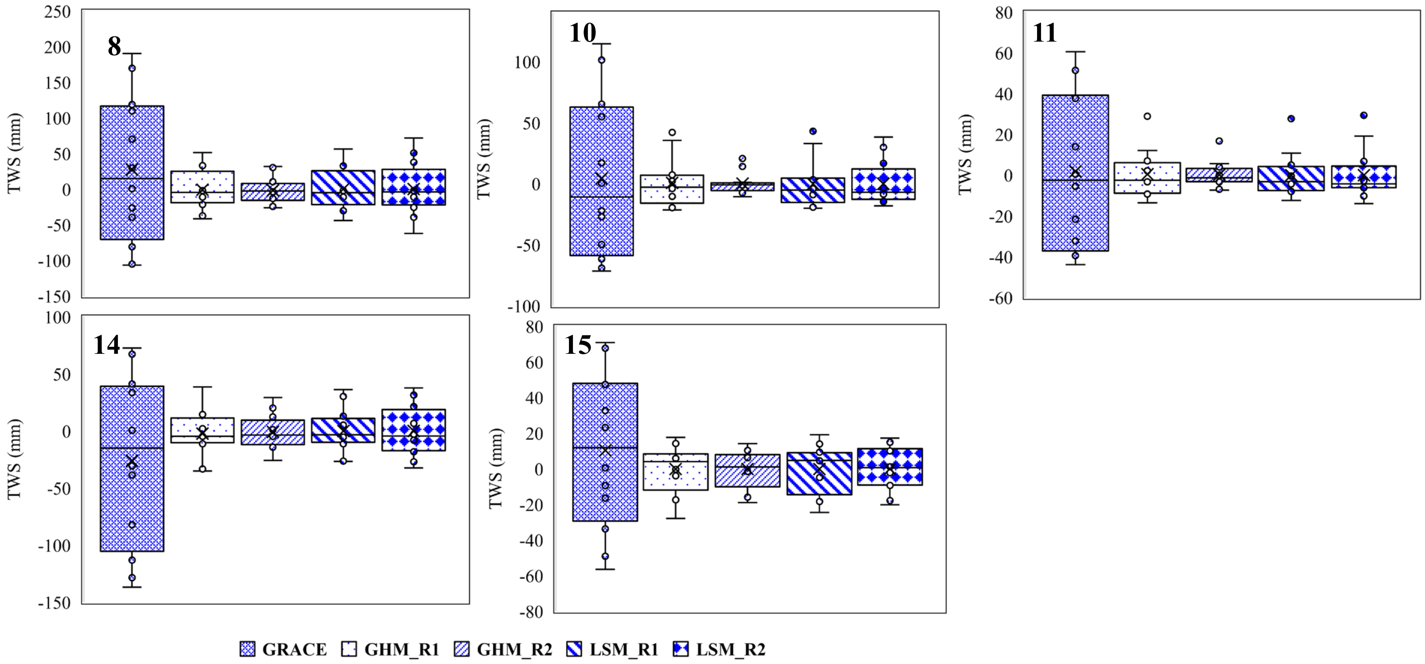

Figure S7: Distribution of GRACE and grouped model type (GHM or LSM) and forcing resolution (R1 and R2) in the Arid zone.

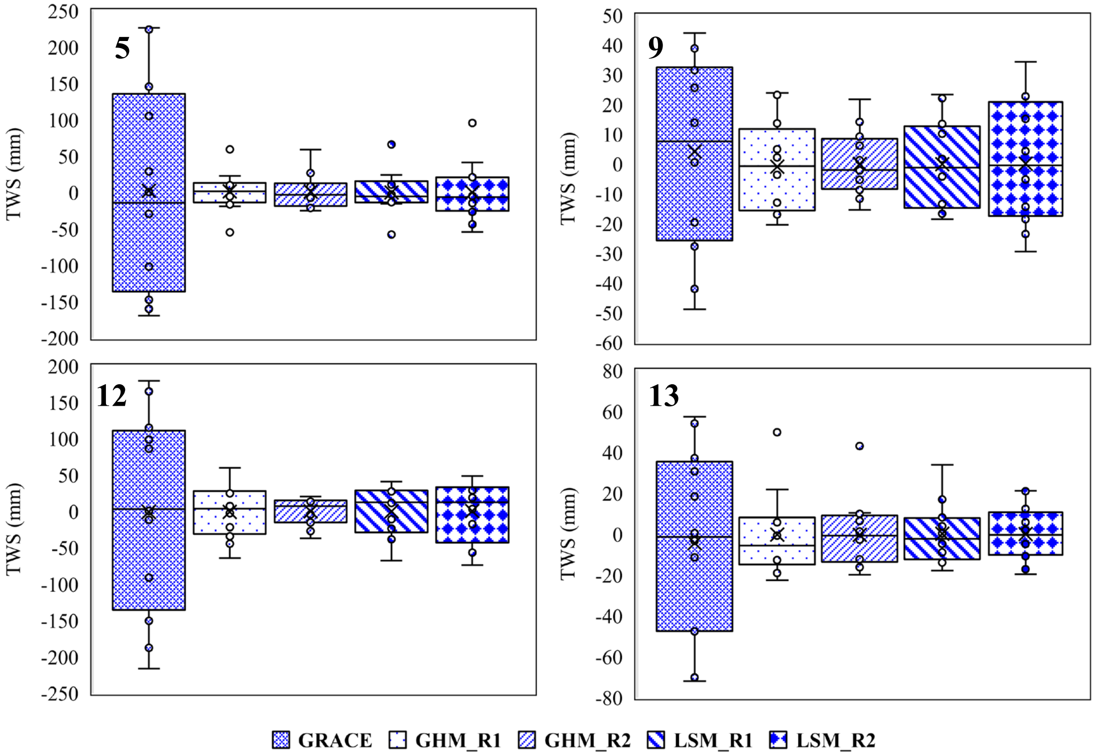

Figure S8: Distribution of GRACE and grouped model type (GHM or LSM) and forcing resolution (R1 and R2) in the Tropical zone.