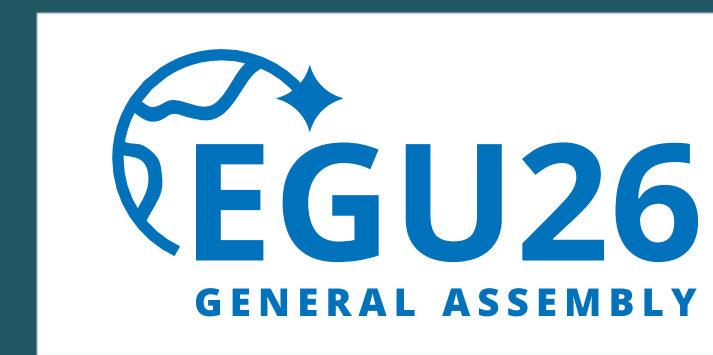


Does Hydrological Forcing Matter for GRACE Downscaling?

Evaluating hydrological forcing datasets for GRACE-based terrestrial water storage downscaling in Central Asia



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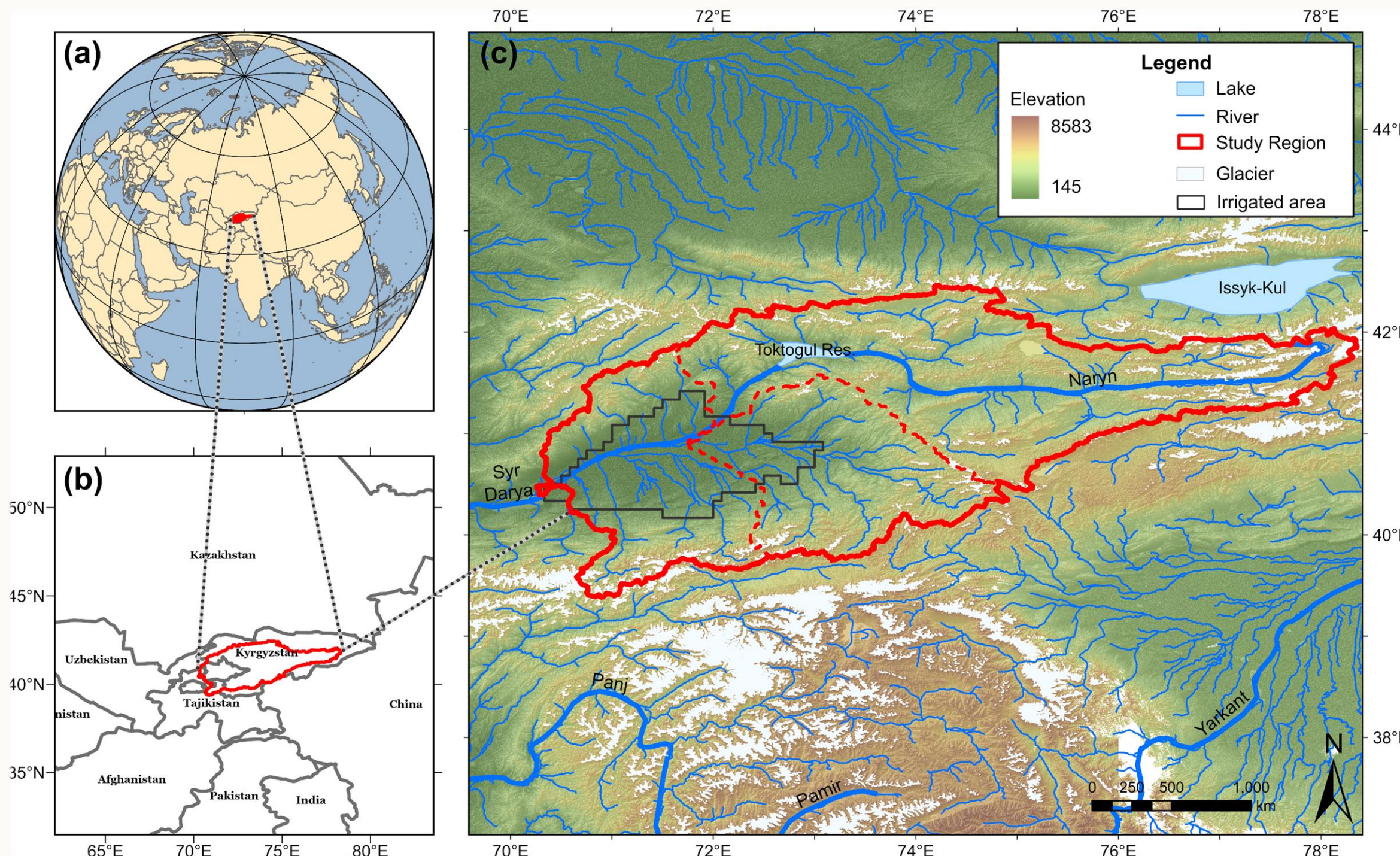
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1 Why downscale GRACE?

- GRACE and GRACE-FO provide highly valuable large-scale observations of TWS, but their coarse spatial (~300 km) and temporal (~monthly) resolutions limit regional applications.
- Here, we downscale GRACE-based TWS changes (TWSCs) to daily, 1 km resolution over the Naryn – Kara Darya basins and Fergana valley in Central Asia by integrating GRACE with high-resolution hydrological forcing datasets^[1] and evaluate their performances.

2 Study region: Central Asia

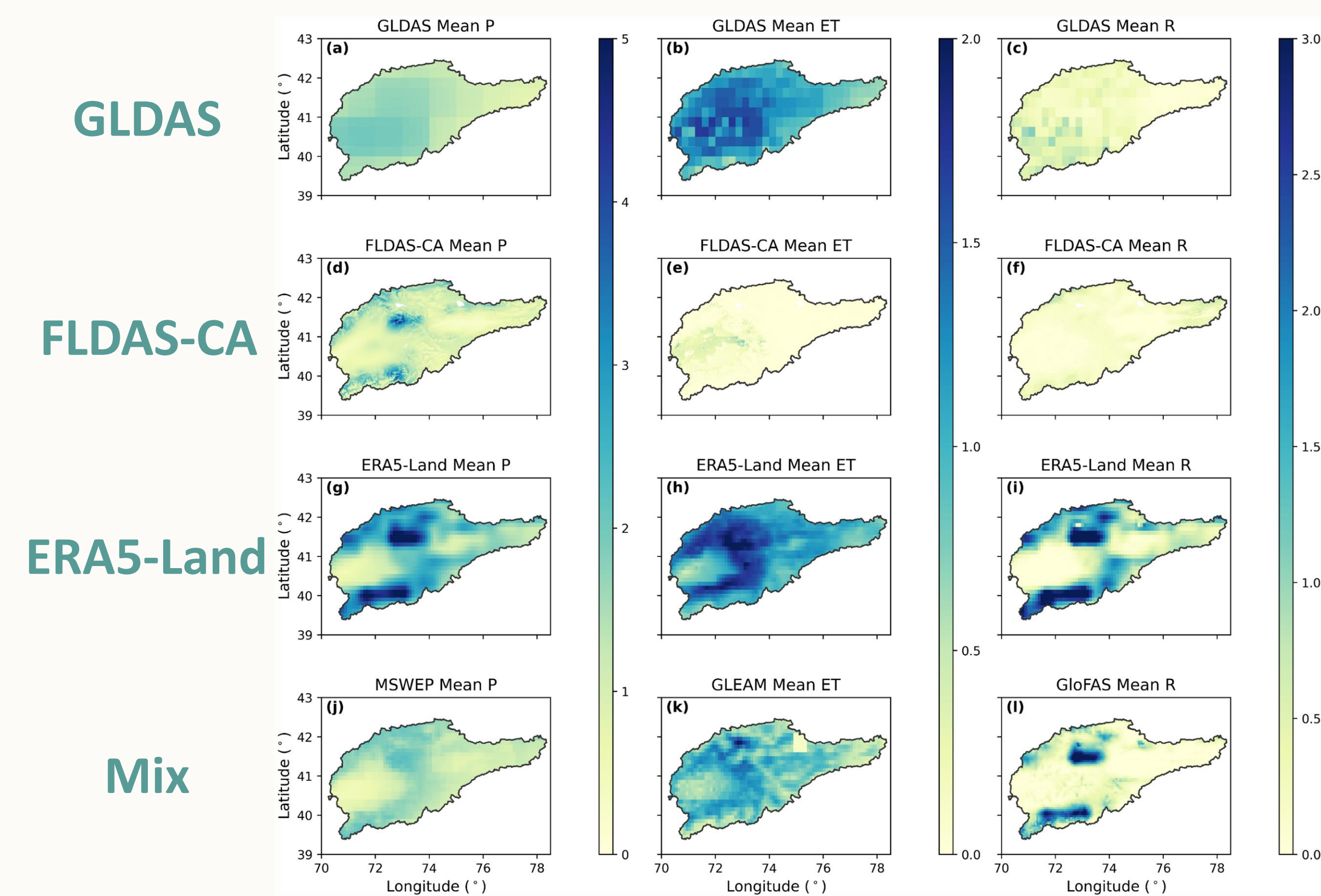


3 Research Questions

- How can GRACE-derived TWS be physically downscaled in space and time?
- To what extent does the choice of input hydrological forcing data affect the accuracy and robustness of downscaled GRACE products?
- How can downscaled products be validated in data-scarce regions?
- How can high-resolution TWSC estimates improve our understanding of regional hydrological processes?

4 Data Basis

Precipitation Evapotranspiration Runoff



Other datasets
 -- GRACE/-FO Level-3: JPL mass concentrations
 -- River network: HDMA database

5 Methods

Data pre-processing

Water balance-based daily TWSC estimates

Temporal downscaling

Monthly differences interpolated using splines

Spatial downscaling

Partial Least Squares regression

Post-bias correction

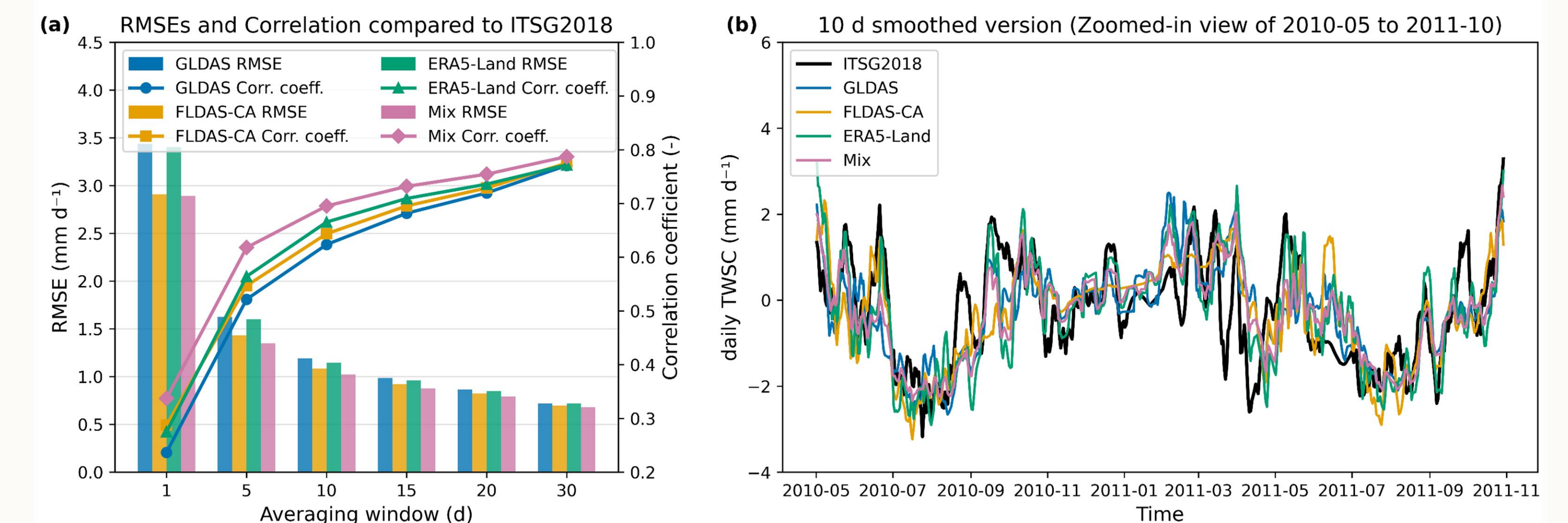
Land–river mask-based bias redistribution

Products validation

Comparison with ITSG2018, soil moisture, other products

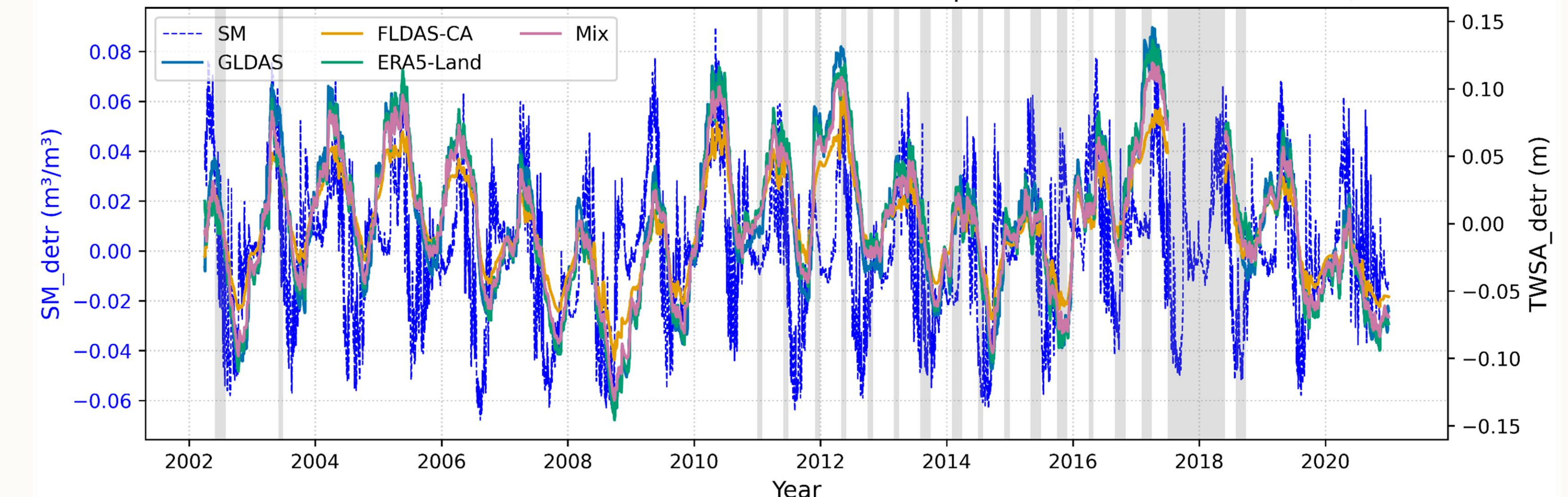
6 Key Results

Comparison of temporally downscaled daily TWSCs with ITSG-Grace2018 solution



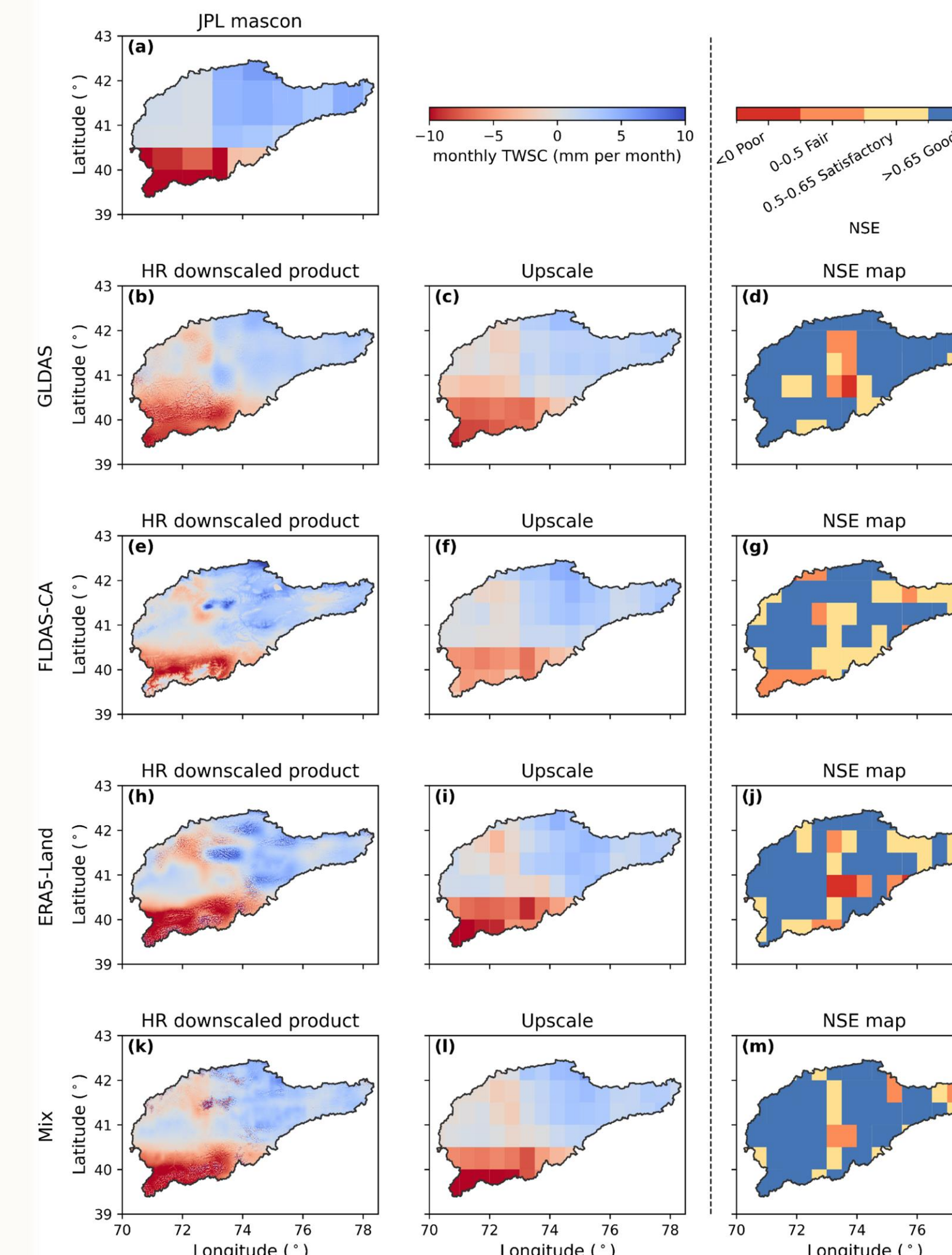
Sub-weekly variations are captured. The Mix downscaled result performs best.

Time series of soil moisture and TWSA from downscaled products (linear trend removed)



Physically meaningful correlations ($r \approx 0.5$). A time lag of about one month.

Monthly TWSCs on Oct. 2023 computed from JPL mascon and downscaled products



Take-home message

The Mix forcing achieves the best overall performance, showing:

- The highest correlation with ITSG2018 and generally satisfactory NSE against GRACE;
 - Correlations of 0.6 and 0.83 with the two existing downscaled products^{[2][3]}, respectively;
 - Capture of short-term hydrological events, such as the January 2006 snow event.
- These results highlight the importance of carefully selecting input hydrological datasets for downscaling applications.

References
 [1] Pellet, V., Aires, F., Alfieri, L., and Bruno, G.: A physical/statistical data-fusion for the dynamical downscaling of GRACE data at daily and 1 km resolution, *J. Hydrol.*, 628, 130565, 2024.
 [2] Gou, J., and Soja, B.: GRACE-SeDA: A Global Total Water Storage Anomaly Product with a Spatial Resolution of 0.5 Degrees From Self-Supervised Data Assimilation, *ETH Research Collection* [data set], 2023.
 [3] Li, F.: Global high-resolution (0.25°×0.25°) total water storage anomaly dataset derived by reproducing GRACE data, *Zenodo* [data set], <https://doi.org/10.5281/zenodo.17265162>, 2025.