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High-spatiotemporal-resolution monitoring of reservoir water storage in the Lancang-Mekong River basin

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第18届
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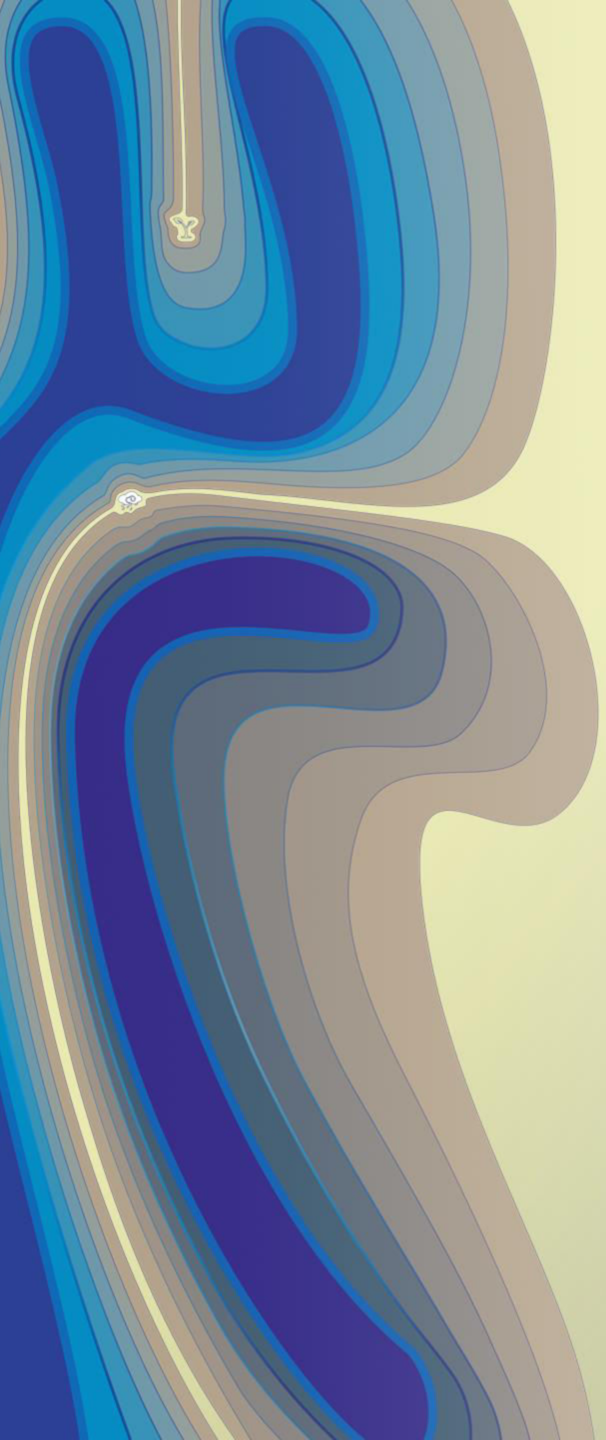
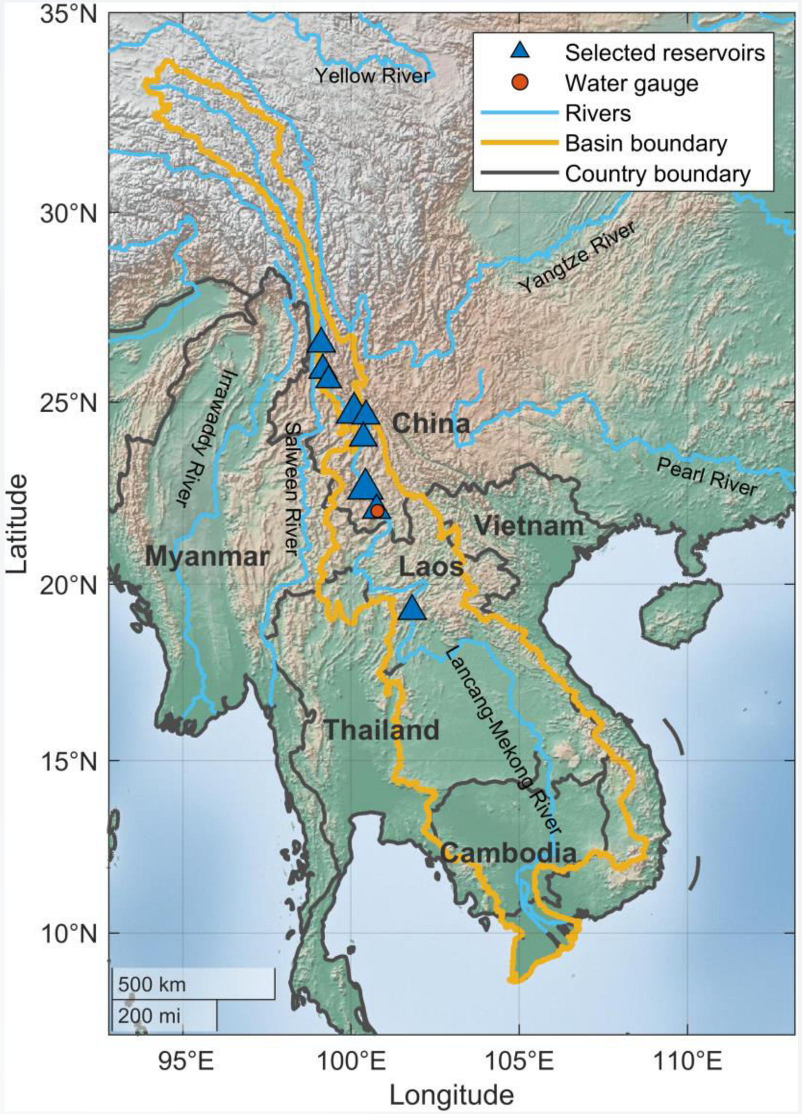


Content

- Introduction
- Data and Methods
- Results
- Discussion
- Conclusions

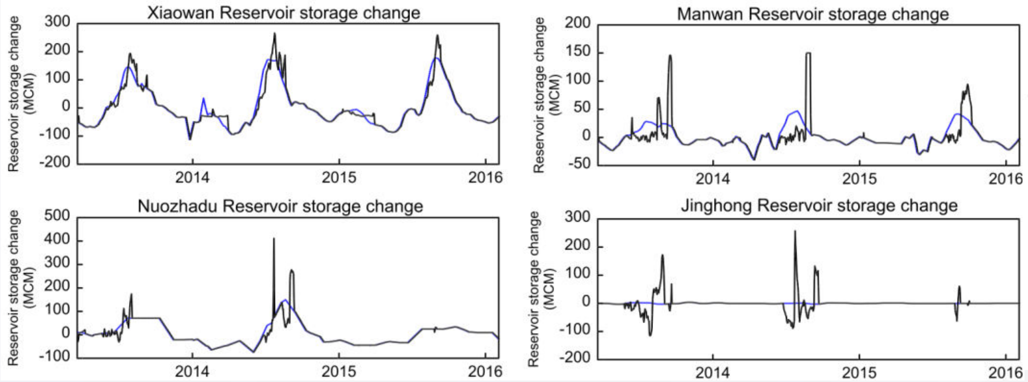
Introduction: Lancang-Mekong River



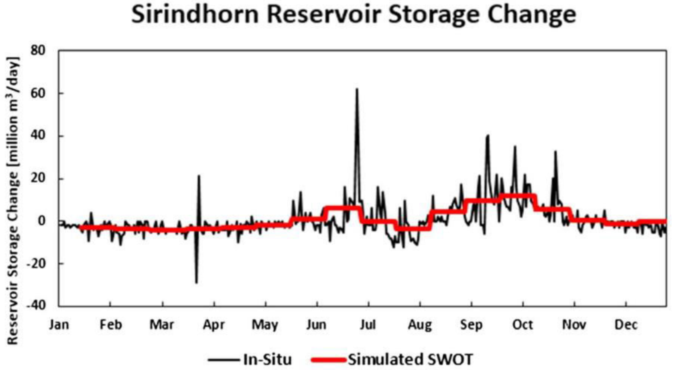
➢ Construction and operation of reservoirs in the Lancang-Mekong River (LMR) basin has a significant impact on river discharge

➢ Difficulty in obtaining in-situ measurements of reservoir water storage on the LMR

➢ Surface water extent (SWE), water surface elevation (WSE), and water storage of reservoirs can be derived from optical and synthetic aperture radar (SAR) images, and satellite altimetry



Han and Long et al. (2020)

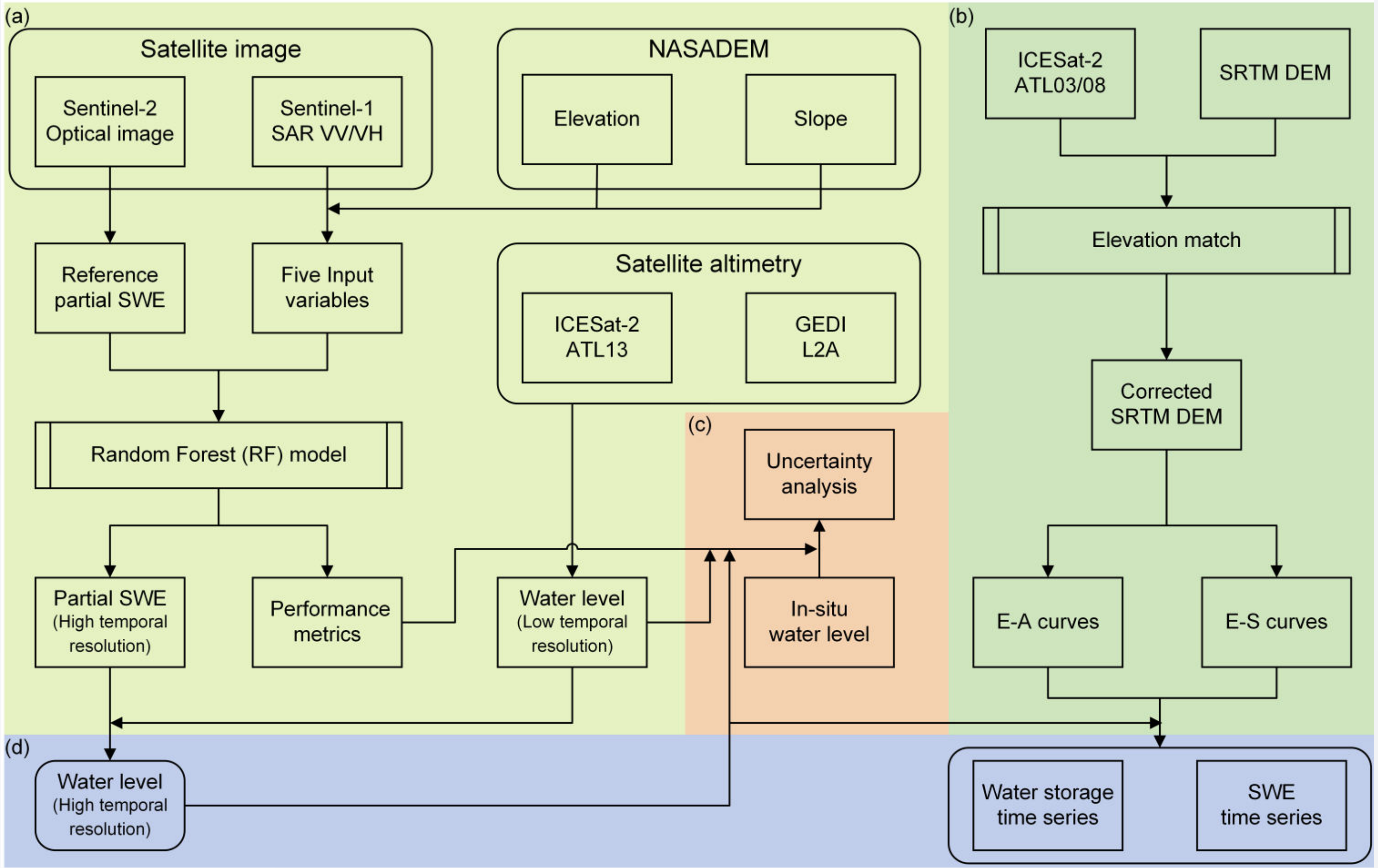


Bonnema & Hossain (2019)

➢ Complex terrain in the LMR causes large uncertainty in remote sensing monitoring of reservoir water storage

✓ Satellite altimetry, optical and SAR images, and DEMs were jointly used to obtain weekly water levels and water storages of the largest nine reservoirs on the main stem of the LMR during 2017–2021

Data and Methods



Optical images + SAR images + DEMs

Random forest algorithm

Partial surface water extent

Satellite altimetry

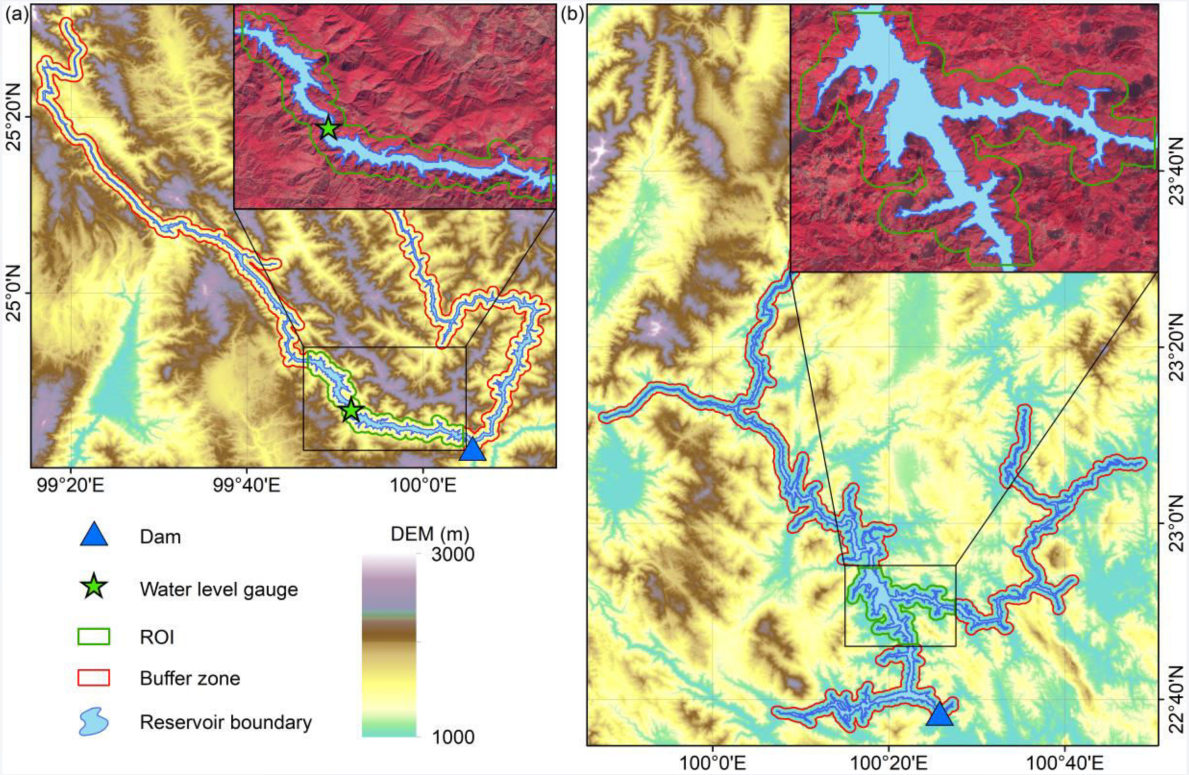
Water surface elevation

Corrected SRTM DEM

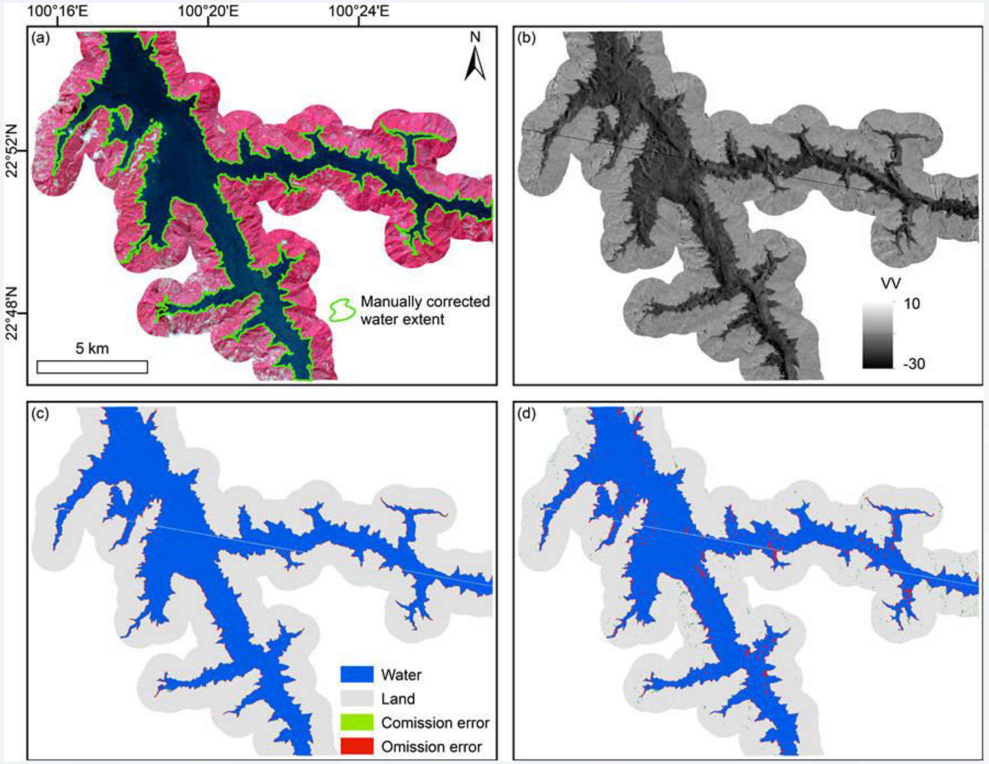
Water storage

- Sentinel-1/2 images and DEMs were jointly used to derive the partial SWE (weekly)
- Primely WSE of nine reservoirs were derived from ICEsat-2 (for seven reservoirs) and GEDI (for two reservoirs) data
- Weekly WSE time series were derived using partial SWE and satellite altimetry and water storage was finally obtain in combination with the elevation-storage (E-S) curves

Data and Methods



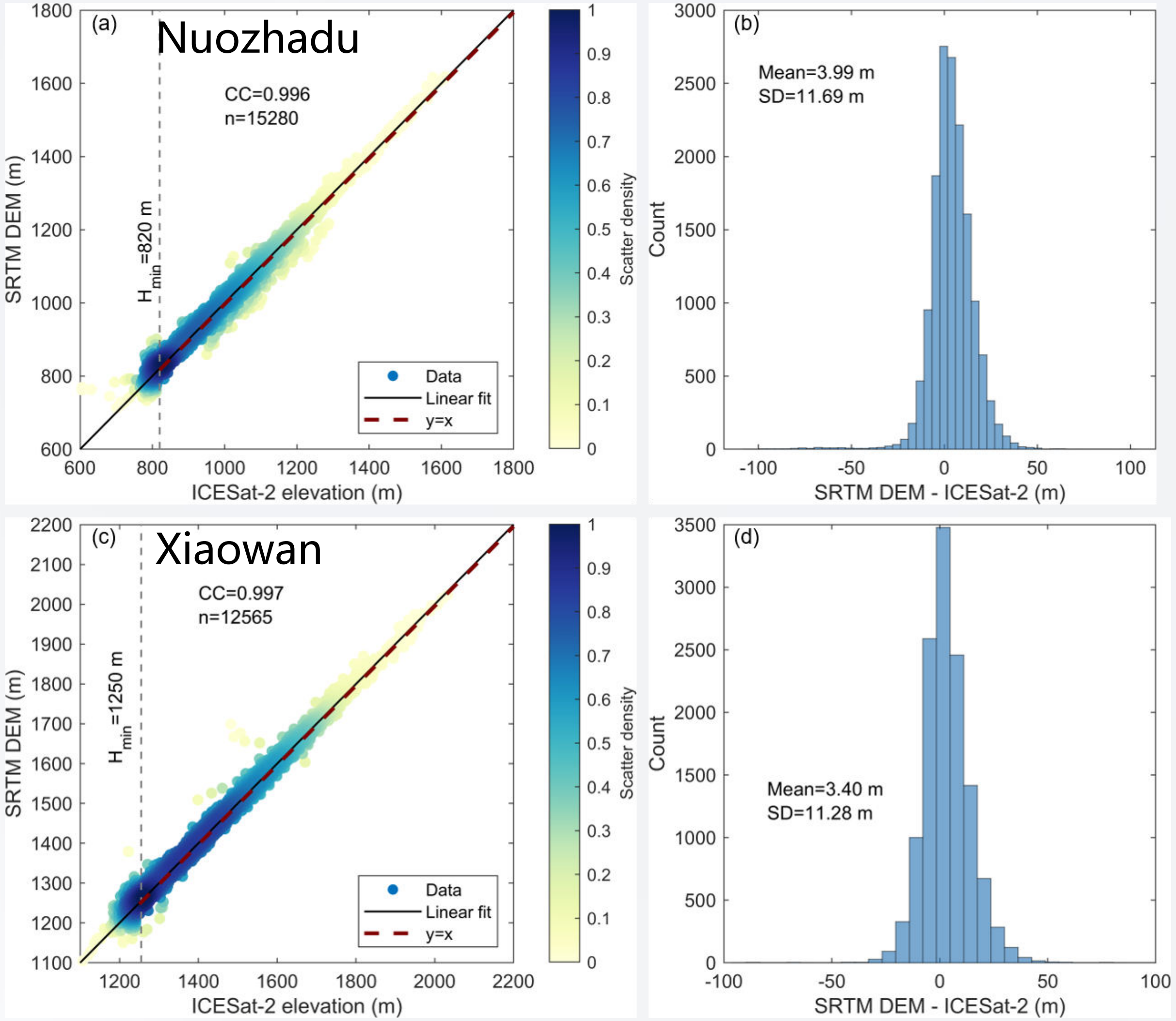
Regions of Interest in Xiaowan (left) and Nuozhadu (right) reservoirs



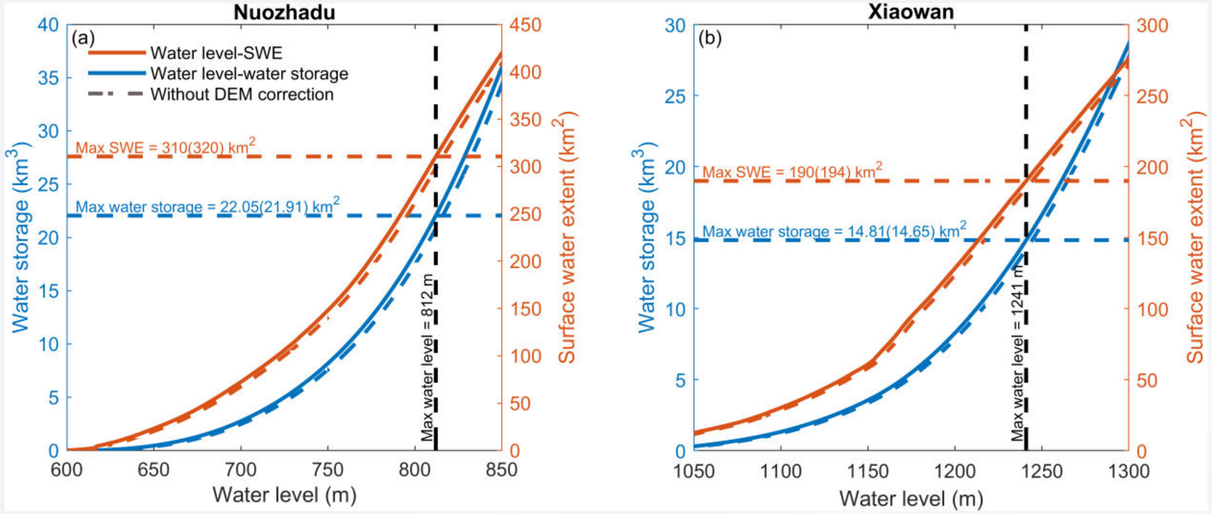
(a) Sentinel-2 image (b) Sentinel-1 SAR image
(c) Result of the RF model (d) Result of the Otsu algorithm

- ➢ Partial SWE of the reservoirs in the ROIs was derived using the Random Forest (RF) algorithm based on Sentinel-1/2 satellite images and NASADEM
- ➢ Sentinel-2 images were used to obtain accurate partial SWE as the reference for water classification of Sentinel-1 images and DEMs
- ➢ Input features of the RF model include VV/VH and median filtered VV/VH backscatter coefficients from Sentinel-1 images and slope and elevation form NASADEM

Data and Methods



Density scatterplots and histograms of differences between SRTM DEMs and ICESat-2 ATL03 elevations used as ground truth

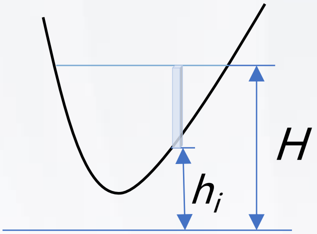


E-A and E-S curves of Xiaowan and Nuozhadu

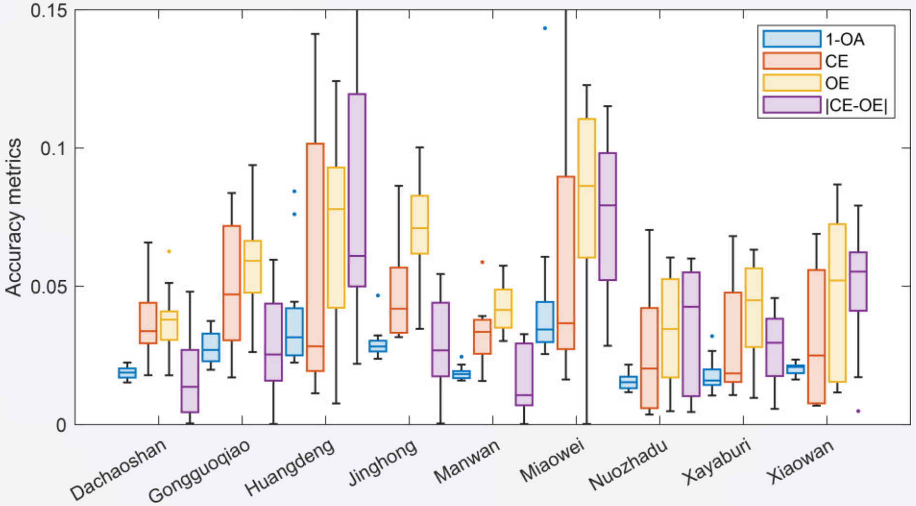
- ➢ The long wavelength error of the SRTM DEM (Rodriguez et al. 2006) causes ~ 4 m of error in the E-A and E-S curves
- ➢ ICESat-2 ATL03 geolocated photon data were used to correct the SRTM DEM in the nine reservoirs

$$A(H)=\sum_{i=1}^{N}\max\{\operatorname{sgn}(H-h_i),0\}\times 30\times 30$$

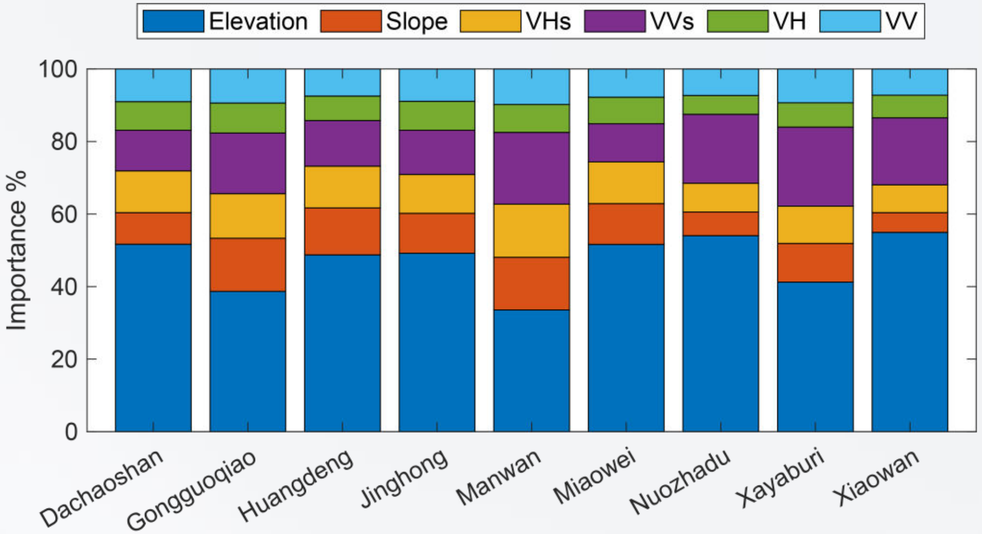
$$S(H)=\sum_{i=1}^{N}\max\{H-h_i,0\}\times 30\times 30$$



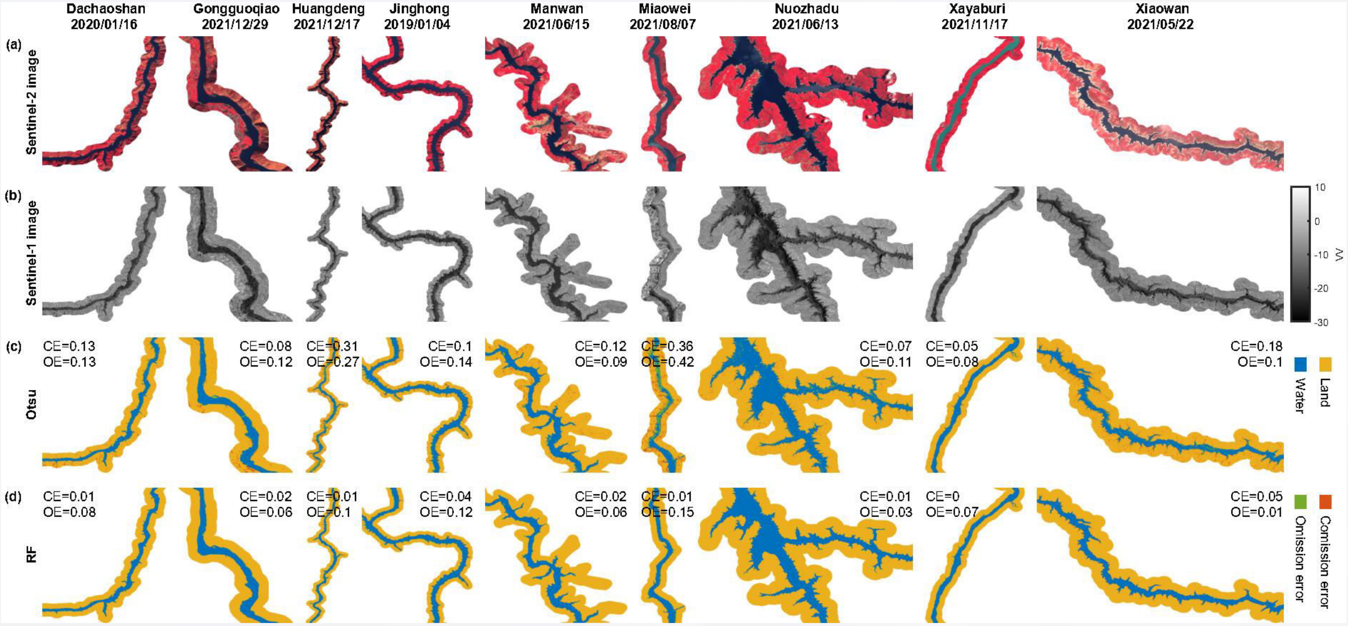
Results: Performance of the RF algorithm



Accuracy and uncertainty of the RF algorithm for nine reservoirs



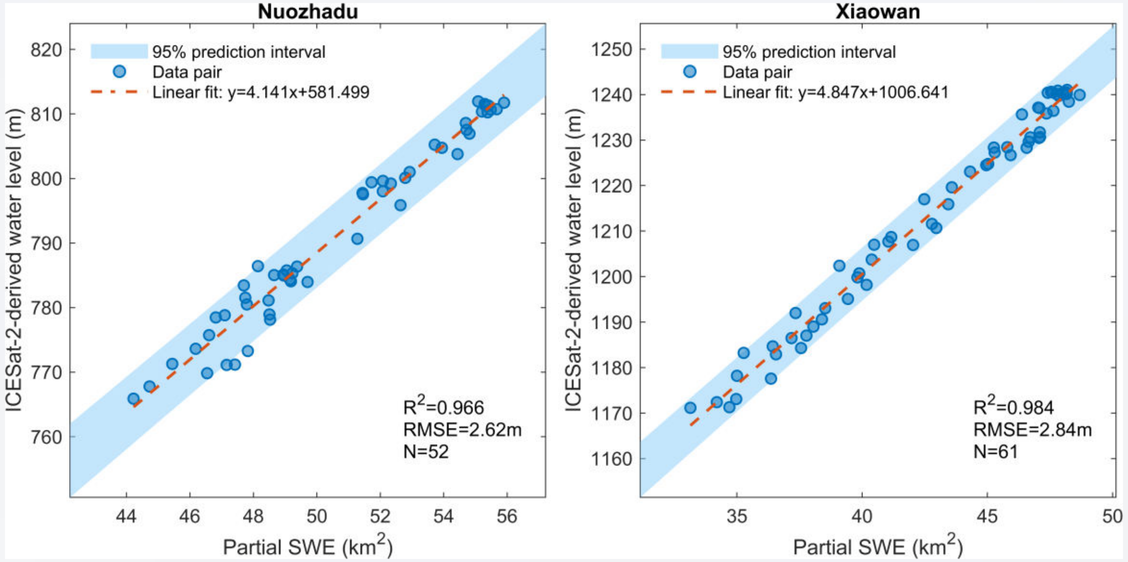
Importance of the features used in the RF algorithm



Comparison of accuracy of partial SWE extracted by the RF algorithm and Otsu algorithm for nine selected reservoirs

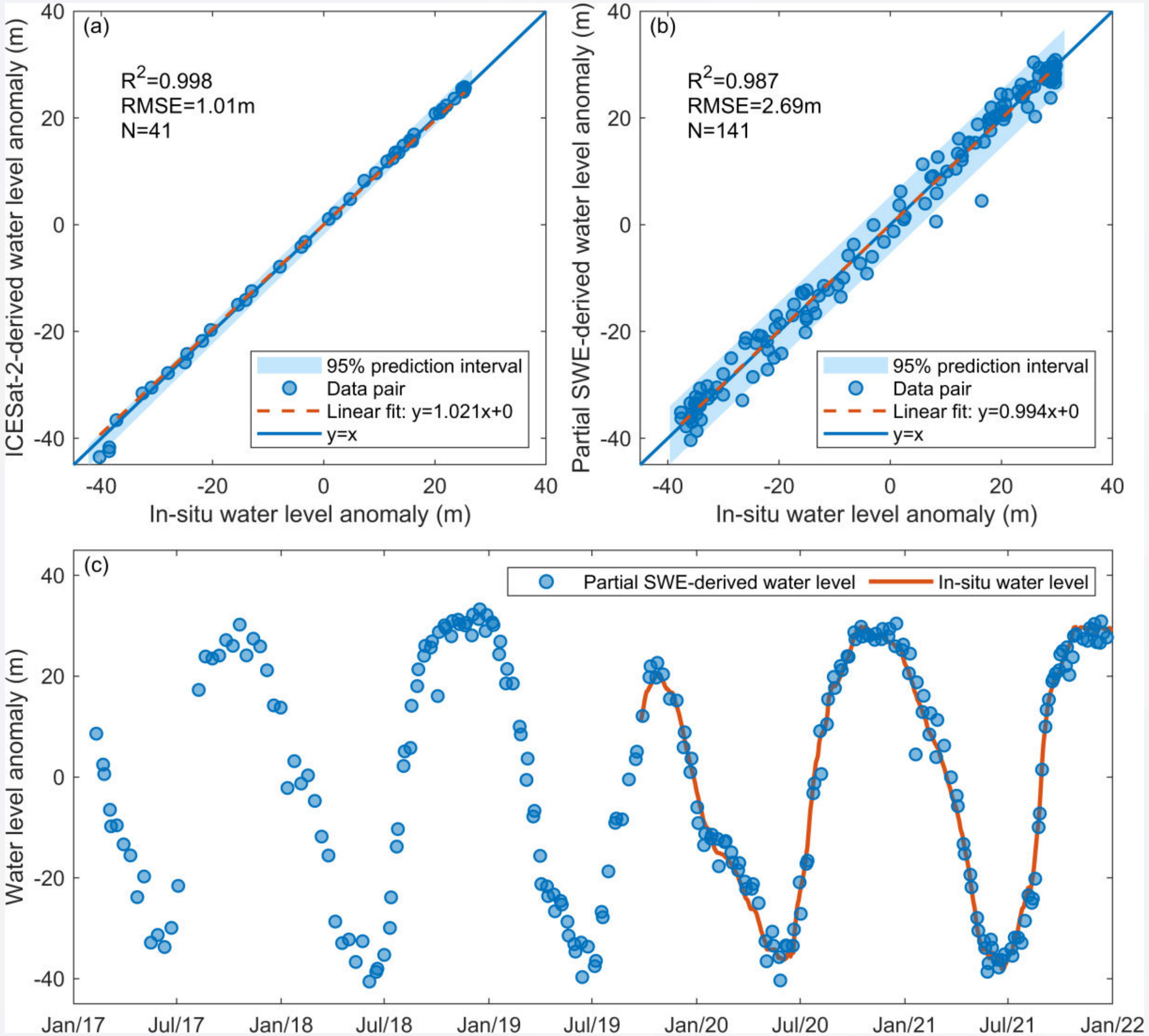
- ➢ In most cases, the overall accuracy of the RF algorithm exceeds 95%
- ➢ In the RF algorithm, the elevation is the most important feature, followed by the median filtered VV backscatter coefficient
- ➢ The overall performance of the RF algorithm is significantly better than that of the Otsu algorithm, especially in reservoirs under complex terrain (e.g., Huangdeng and Miaowei)

Results: Performance of partial SWE-derived WSE



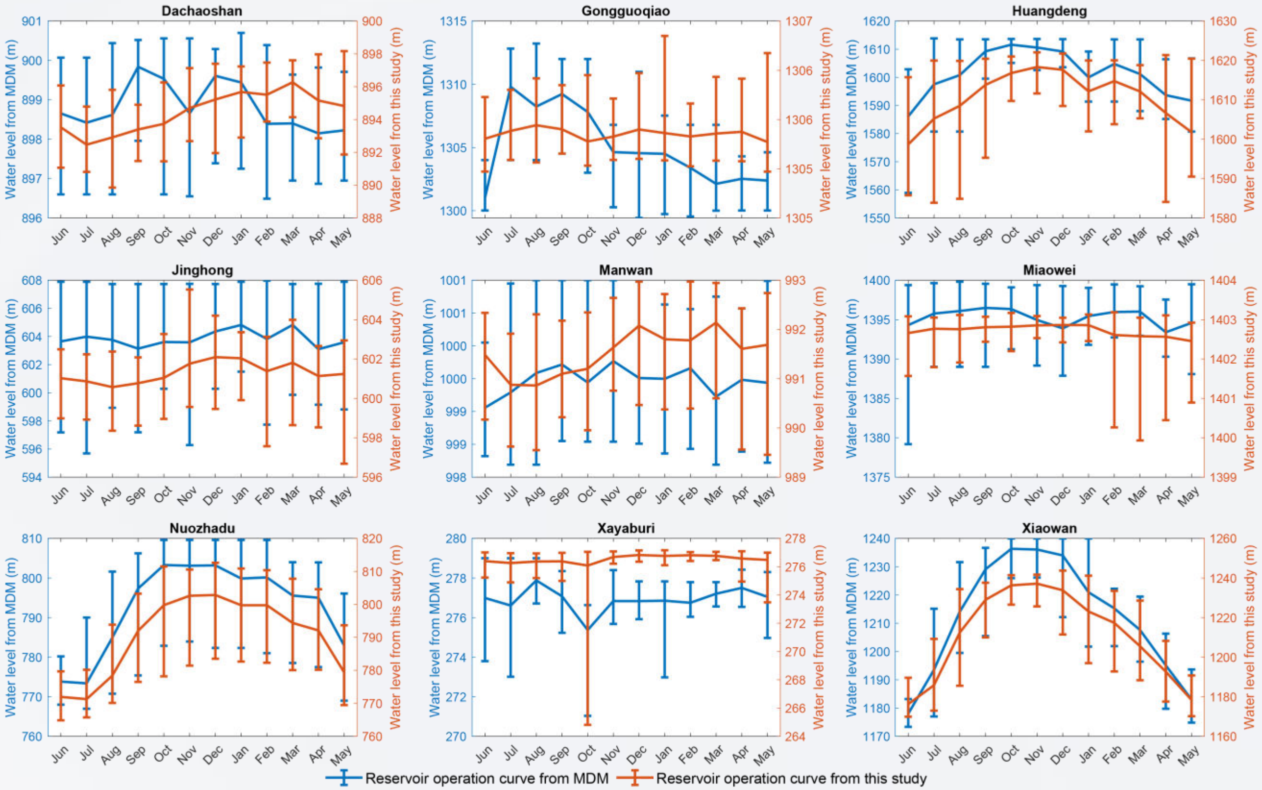
Correlation between partial SWE and ICEsat-2-derived water level

- ➢ Satellite altimetry-derived water level shows high accuracy but relatively low temporal resolution (~ 1 month)
- ➢ The correlation between partial SWE and satellite altimetry-derived water level can be used to transform partial SWE (weekly) into water level
- ➢ Water level estimates from partial SWE are very close to in-situ water levels (R^2 = 0.987 and RMSE = 2.69 m)

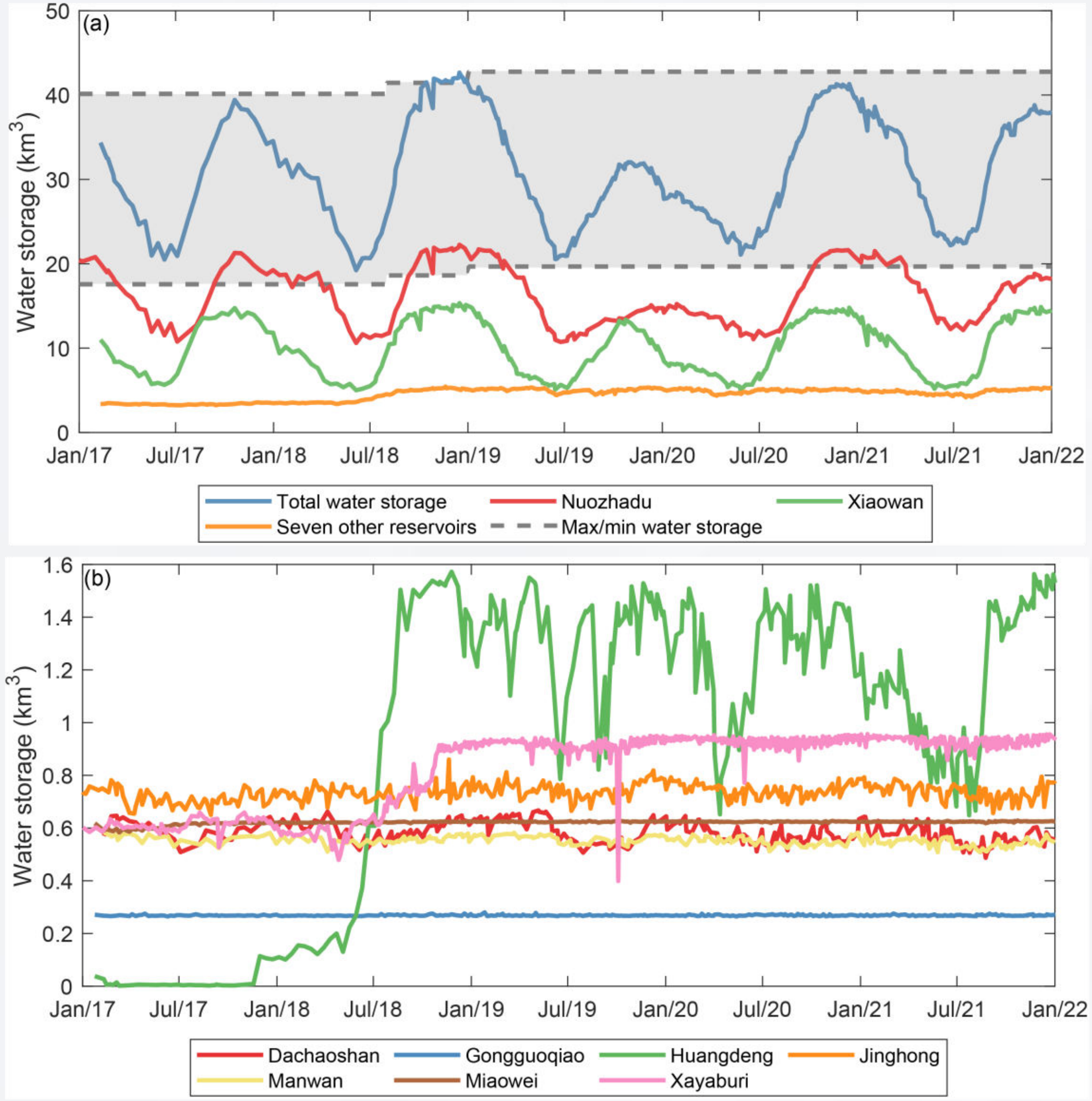


Comparison between water levels derived from ICESat-2 (a) and partial SWE (b, c) with in-situ measurements in the Xiaowan Reservoir

Results: SWE and water storage changes



Reservoir operation curves from this study and the Mekong Dem Monitor



Water storage changes in nine reservoirs

- Most reservoirs store water in the wet season (June to November) and release water in the dry season (December to May)
- The two largest reservoirs (Nuozhadu and Xiaowan) control the changes in reservoir water storage on the main stem of the LMR
- Storage change in the Huangdeng Reservoir accounts for the majority of total storage change of the seven relatively small reservoirs

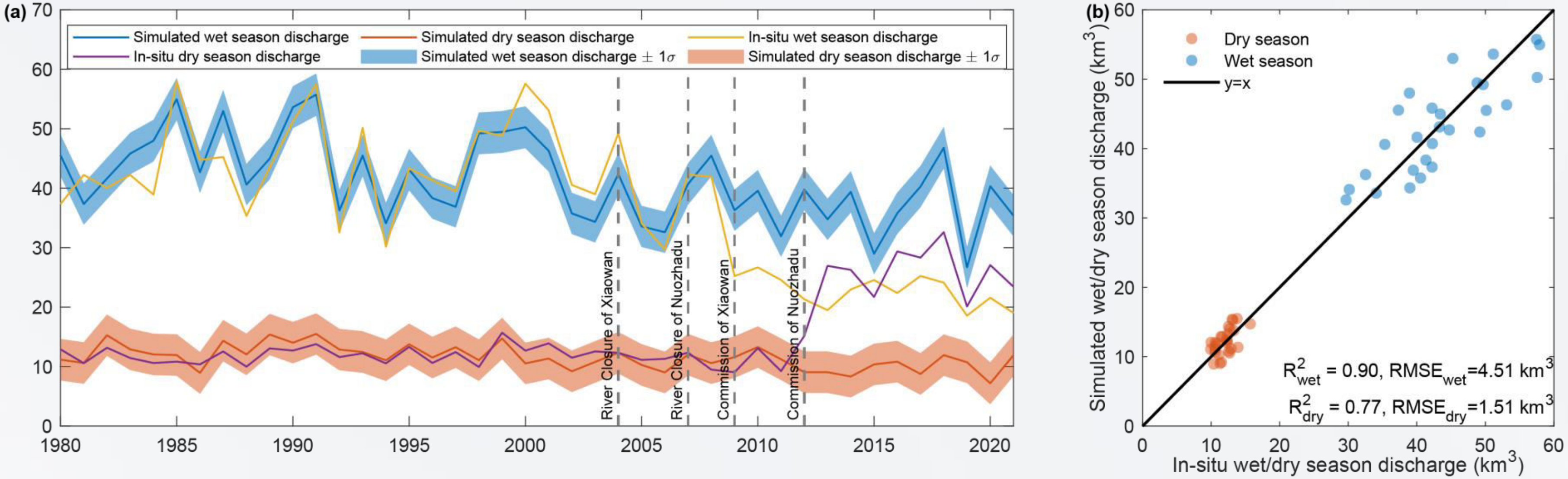
Discussion

- ➢ How to separate contributions of reservoir operation and climate change to changes in streamflow of the LMR?

A linear regression was considered between in-situ (Jinghong Station, the outlet station of the Lancang River) and ERA5-land runoff:

$$\hat{Q} = a * \sum_{i=1}^{N} R_i + b$$

(1980–2007 for calibration)



Wet/dry season streamflow from ERA5-land simulated (natural) and in-situ measurements

- ✓ Reservoir storage changes in the wet/dry season account for 42%/148% of simulated natural wet/dry season streamflow during 2017–2021
- ✓ Compared to the baseline period (1980–1986), contributions of reservoir operation to changes in streamflow during the wet and dry seasons are -33%±5% and 146%±18%, respectively

Conclusions

- ➢ Multisource remote sensing (i.e., Sentinel-1/2 images, ICESat-2/GEDI altimetry data, and DEMs) can be used to achieve high accuracy ($R^2 = 0.987$ and normalized RMSE < 5%), high-spatiotemporal-resolution monitoring (~ 7 days/10 m) of water levels and storage of reservoirs in the LMR
- ➢ The developed method of estimating reservoir water storage combines the advantages from satellite altimetry (high accuracy) and optical and SAR images (high temporal resolution)
- ➢ Reservoir storage changes in the wet/dry season account for 42%/148% of simulated natural wet/dry season streamflow during the recent five years (2017–2021), indicating that reservoir operation reduces risks of flooding in the wet season and markedly increases dry season streamflow

Thanks for your attention & comments！