EGU2020

Effect of joint assimilation of GRACE and discharge observations on simulated water storages and fluxes

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IN A NUTSHELL

- **Research topic:** The global inland water resources can either be simulated with hydrological models or observed with satellites or in-situ stations. We combine both approaches and jointly assimilate GRACE-derived Total Water Storage Anomalies (TWSA) and in-situ GRDC discharge observations into the WaterGAP 2.2d Global Hydrological Model (WGHM) while simultaneously calibrating the most sensitive model parameters.
- **Method:** The data sets are assimilated separately and jointly with an Ensemble Kalman Filter for the Mississippi River Basin from 2003 to 2016. We then compare the simulated and observed TWSA and individual WGHM compartments as well as the simulated discharge against 62 observation stations.
- **Results:** The GRACE assimilation strongly pulls the TWSA simulations towards the observations and a simultaneous calibration strongly affects the individual WGHM compartments. The influence of the discharge assimilation depends on the chosen station but a calibration always increases the TWSA simulations. The joint assimilation strongly increases the snow and thus the TWSA simulations which is even intensified applying a calibration. The influence on the discharge simulations is diverse and the comparison with the 62 GRDC observations shows improvements and deteriorations.

MOTIVATION

Water resource management

Flood predictions

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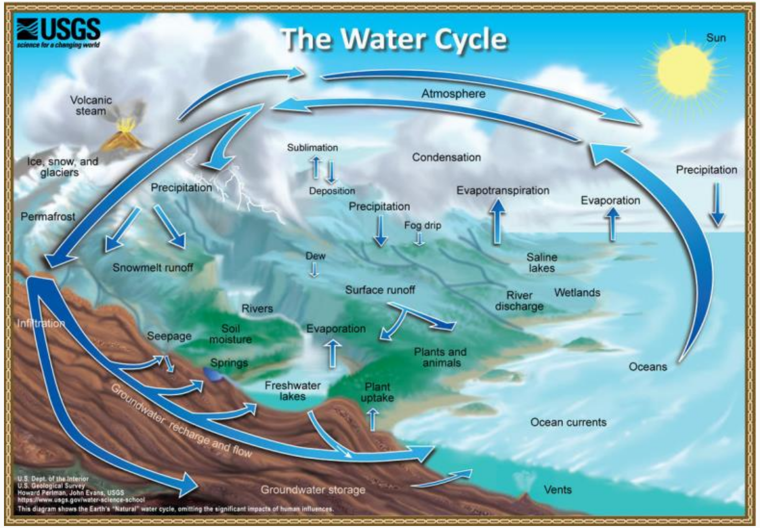
Drought predictions

- Several applications require a realistic representation of the global water cycle.
- Global hydrological models simulate continental water fluxes and individual storages. However, they poorly reproduce observations of discharge and Total Water Storage Anomalies (TWSA).
- To improve the realism of the simulations, observations are assimilated into hydrological models.



https://www.usgs.gov/media/images/water-cycle-natural-water-cycle

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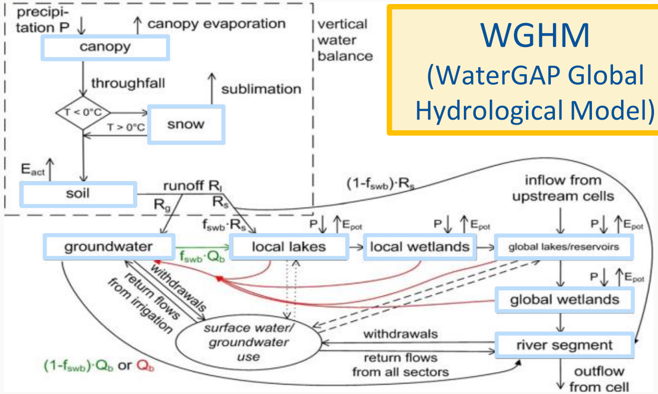
Global CDA

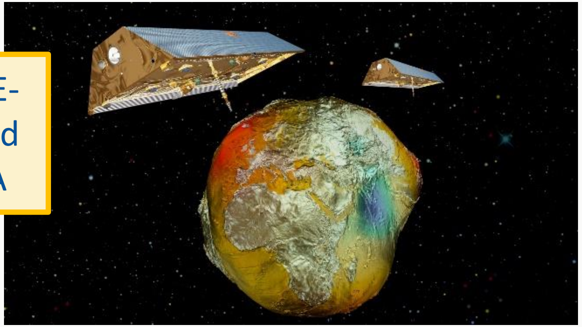
METHODOLOGY



WGHM
(WaterGAP Global
Hydrological Model)

Calibration
and/or
assimilation
(C/DA)

GRACE-
derived
TWSA



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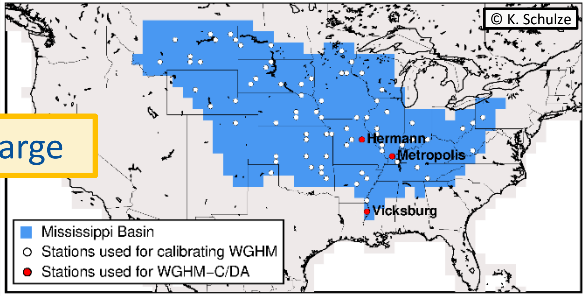
Research area: Mississippi River Basin (MRB)

discharge



GRDC - The Global Runoff Data Centre, 56068 Koblenz, Germany

- The WGHM (Müller Schmied et al. 2014) considers 10 individual compartments on a global 0.5°x0.5° grid.
- We couple the WGHM with the Parallel Data Assimilation Framework (Nerger and Hiller 2013) and apply an Ensemble Kalman Filter (Evensen 1994) to assimilate GRACE-derived TWSA and discharge observations considering 30 ensemble members.
- Regarding the discharge, we assimilate the observations of 3 GRDC discharge stations (red) and use 59 stations for validation only (white)

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METHODOLOGY

Global CDA

- The state vector of the Ensemble Kalman Filter includes all WGHM compartments of all grid cells within the MRB
- Different DA approaches
  - **GRACE:** We compare the sum of all WGHM compartments with the GRACE-derived TWSA
  - **Discharge:** We compare simulated and observed discharge to derive the EnKF increments which influence the compartments in the state vector
- **Joint assimilation:** Multiple update steps are applied successively before integrating the model for the next time step
- **CDA:** The considered parameters are included in the state vector

We calibrate the 6 most sensitive of the 24 WGHM parameters

GRACE-derived TWSA = Canopy + Snow + Soil + Groundwater + Local lakes + Local wetlands + Global lakes + Reservoirs + Global wetlands + River

1. Root depth multiplier
2. Runoff coef.
3. River roughness coef. multip.
4. Lake depth
5. Wetland depth
6. Surfacewater outflow coef.
7. Evapotranspiration reduction factor exponent multiplier
8. Net radiation multiplier
9. Priestley-Taylor coef. (humid)
10. Priestley-Taylor coef. (arid)
11. Max. daily PET
12. Max. canopy water height per leaf area
13. Specific leaf area multiplier
14. Snow freeze temperature
15. Snow melt temperature
16. Degree day factor multip.
17. Temperature gradient
18. Groundwater factor multip.
19. Max. amount of groundwater recharge
20. Critical precipitation for groundwater recharge
21. Groundwater outflow coef.
22. Net abstraction of surfacewater multiplier
23. Net abstraction of groundwater multiplier
24. Precipitation multiplier

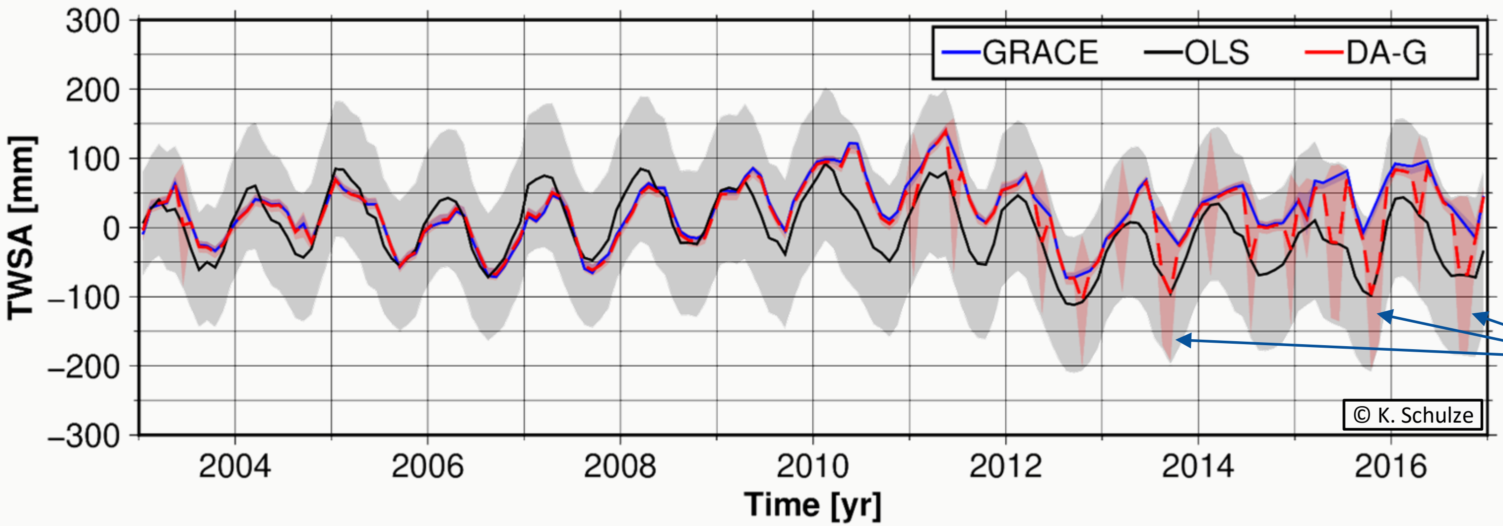
STUDY SET UP

We compare the simulations of an Open Loop Simulation (OLS, ensemble-based WGHM simulation) with different C/DA results

Assimilated observations	DA	CDA
GRACE-derived TWSA	DA-G	CDA-G
1 discharge station only: Hermann, Vicksburg, or Metropolis	DA-H, DA-V, DA-M	CDA-H, CDA-V, CDA-M
Jointly all 3 discharge station	DA-HVM	CDA-HVM
Jointly GRACE-derived TWSA and all 3 discharge stations	DA-GHVM	CDA-GHVM

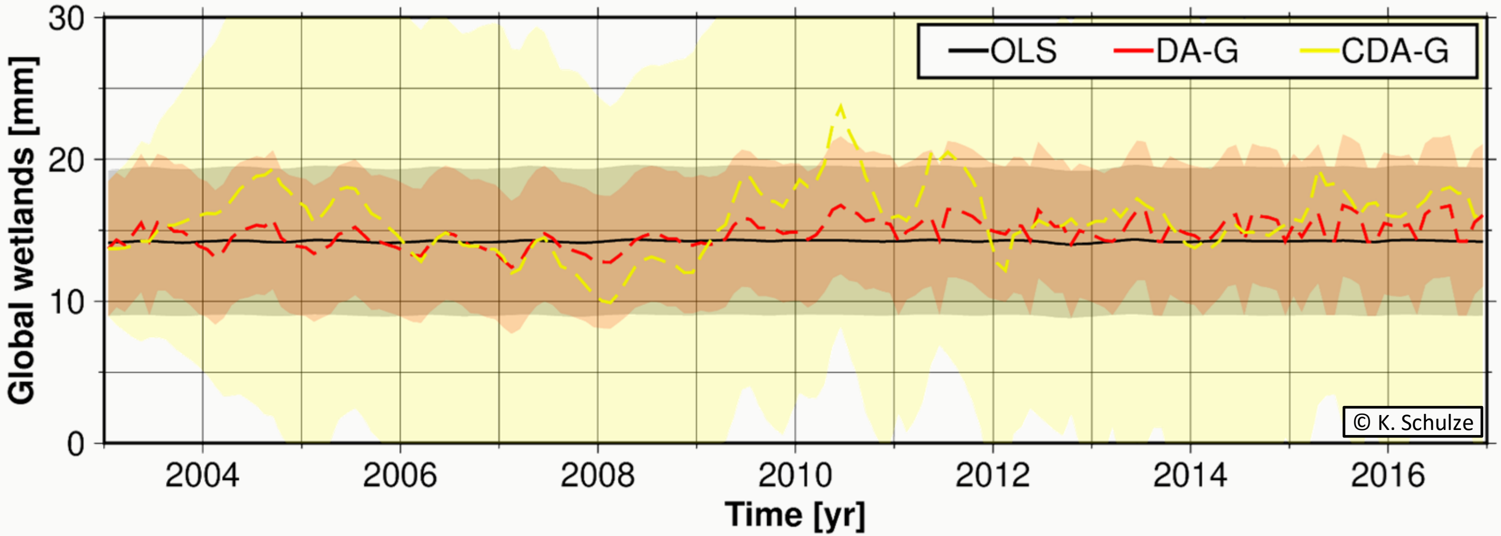
regarding the TWSA, individual WGHM compartments, and discharge.

During the assimilation of GRACE-derived TWSA, the TWSA simulations are strongly pulled towards the observations as the observations show much lower uncertainties than the model predictions. This was also shown in previous studies, e.g. Schumacher et al. (2018).



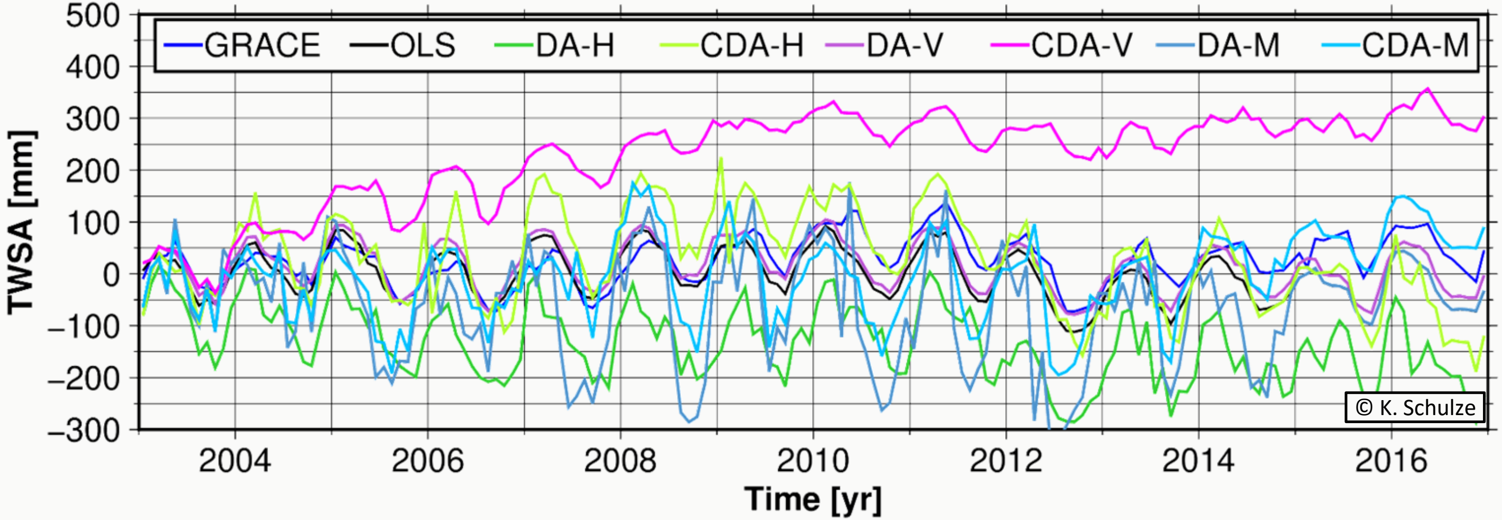
Data gaps within the GRACE-TWSA

Simultaneously calibrating the parameters does not affect the TWSA simulations but strongly influences the simulations of individual compartments, e.g. the global wetlands. Overall, the CDA has a stronger effect on the surface than on the non-surface compartments.



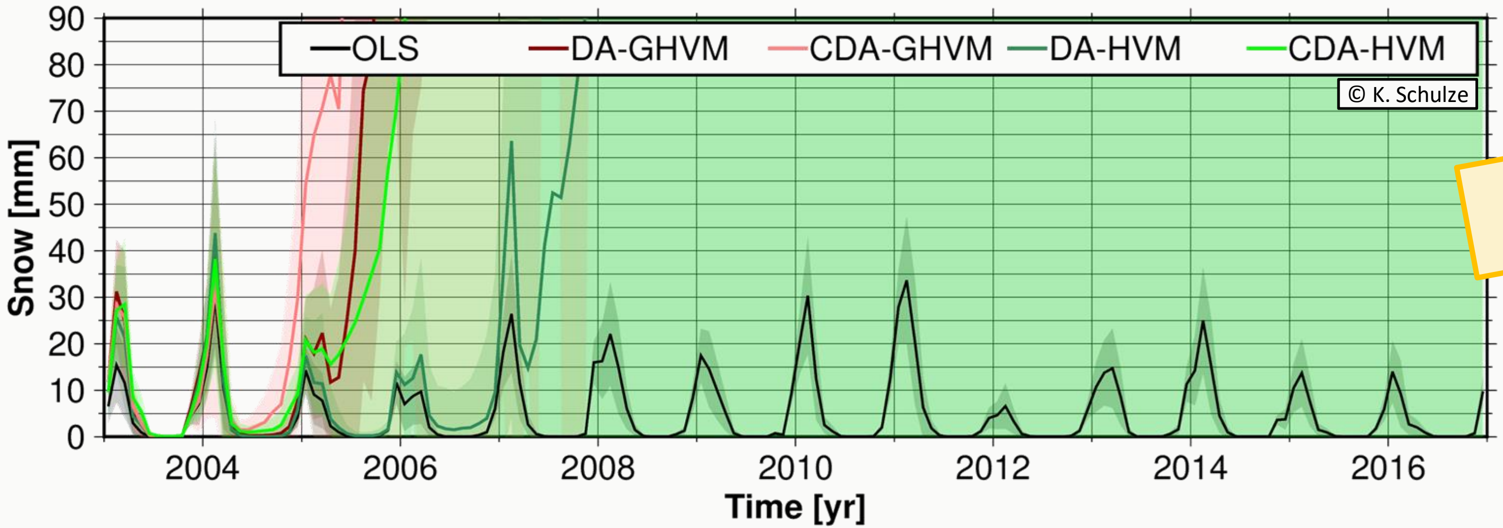
C/DA-DISCHARGE

- The influence of assimilating discharge observations depends on the chosen station. The assimilation of observations at the Hermann and Metropolis station reduce the simulated TWSA while the assimilated Vicksburg observations lead to similar results like the OLS.
- A simultaneous calibration generally increases the TWSA simulations compared with the DA-only.



JOINT C/DA

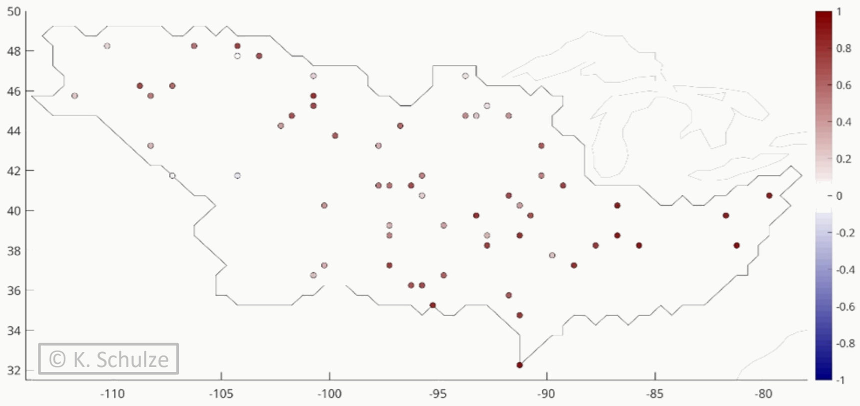
- While the other WGHM compartments are not influenced strongly, the joint assimilation strongly increases the snow compartment after the first assimilation months. These increases also affect the TWSA. Why the snow compartment is affected that strongly is ongoing research.
- The simultaneous calibration intensifies the effect on the snow compartment.



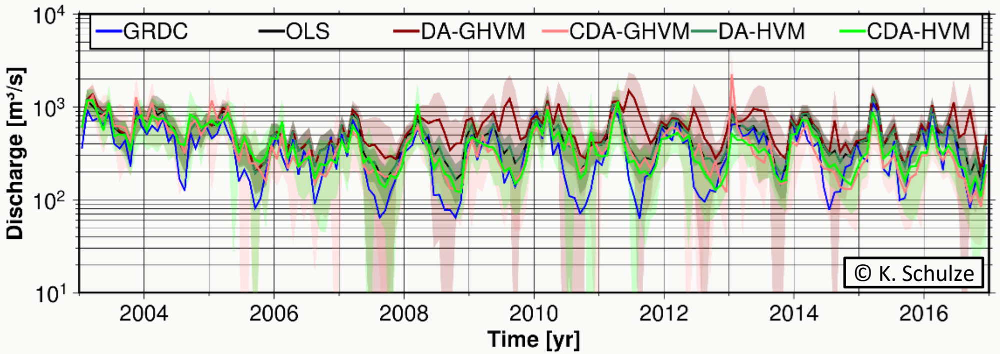
Ongoing research

VALIDATION AGAINST DISCHARGE STATIONS

The comparison of the OLS simulations with 62 GRDC observation stations shows a higher discharge correlation in the eastern Mississippi River Basin than in the western part.



Some discharge simulations are not affected or even deteriorated due to the C/DA, but some stations also show a better representation of the observations, e.g. the station in Kanawha Falls (West Virginia, USA). Here, especially the joint CDA approaches show strong improvements when taking in-situ discharge observations as reference.



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SUMMARY

Global CDA

- We coupled the WGHM with the Parallel Data Assimilation Framework and applied an Ensemble Kalman Filter to assimilate GRACE-derived TWSA and observed in-situ discharge.
- Our approach enables the joint assimilation of several data sets as well as a simultaneous calibration.

	DA	CDA
GRACE-derived TWSA	TWSA simulations are strongly pulled towards the observations	No effect on the TWSA simulations but on individual WGHM compartments
Single discharge stations	Influence depends on the chosen station	TWSA simulations are increased compared with the DA results
Joint approaches → Ongoing research	Strong increase of the snow simulation after the first months	The effect on the snow compartment is intensified

- The C/DA leads to diverse influences on the discharge simulations. A comparison against 62 discharge stations within the Mississippi River Basin shows improvements but also deteriorations depending on the station. In the East, simulations and observations generally fit better than in the West.

LITERATURE

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