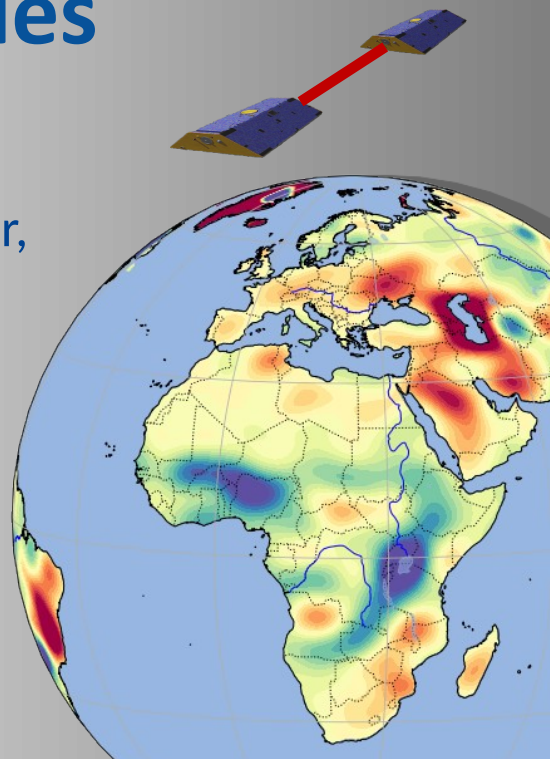
Strategies for assimilating GRACE/-FO terrestrial water storage anomalies into hydrological models

Anne Springer, Yorck Ewerdwalbesloh, Helena Gerdener,
Kerstin Schulze, Jürgen Kusche

Institute of Geodesy
Bonn University



DFG CRC 1502 DETECT

Assimilation of GRACE Terrestrial Water Storage Data into a Land Surface Model: Results for the Mississippi River Basin

BENJAMIN F. ZAITCHIK

GRACE Improves Seasonal Groundwater Forecast Initialization over the United States

AUGUSTO GETIRANA,[a,b] MATTHEW RODELL,[a] SUJAY KUMAR,[a] HIROKO KATO BEAUDOING,[a,b] KRISTI ARSENAULT,[a,c] BENJAMIN ZAITCHIK,[d] HIMANSHU SAVE,[e] AND SRINIVAS BETTADPUR[e]

Assimilating GRACE Into a Land Surface Model in the Presence of an Irrigation-Induced Groundwater Trend

Wanshu Nie[1], Benjamin F. Zaitchik[1], Matthew Rodell[2], Sujay V. Kumar[2], Kristi R. Arsenault[2,3], Bailing Li[2,4], and Augusto Getirana[2,4]

Assimilation of terrestrial water storage from GRACE in a snow-dominated basin

B. A. Forman,[1,2,3] R. H. Reichle,[1] and M. Rodell[4]

Estimating Terrestrial Snow Mass via Multi-Sensor Assimilation of Synthetic AMSR-E Brightness Temperature Spectral Differences and Synthetic GRACE Terrestrial Water Storage Retrievals

Jing Wang[1], Barton A. Forman[1], Manuela Girotto[2], and Rolf H. Reichle[3]

Determining water storage depletion within Iran by assimilating GRACE data into the W3RA hydrological model

M. Khaki[a,*], E. Forootan[b], M. Kuhn[a], J. Awange[a], A.I.J.M. van Dijk[d], M.A. Sharifi[e,f]

Revising precipitation – water storages – vegetation signatures with GRACE-based data assimilation

Helena Gerdener[a,*], Jürgen Kusche[a], Kerstin Schulze[a], Gohar Ghazaryan[b,c,d], Olena Dubovyk[b,c,e]

Improving drought simulations within the Murray-Darling Basin by combined calibration/assimilation of GRACE data into the WaterGAP Global Hydrology Model

M. Schumacher[a,b,c,*], E. Forootan[d], A.I.J.M. van Dijk[c], H. Müller Schmied[e,f], R.S. [illegible], J. Kusche[b], P. Döll[e,f]

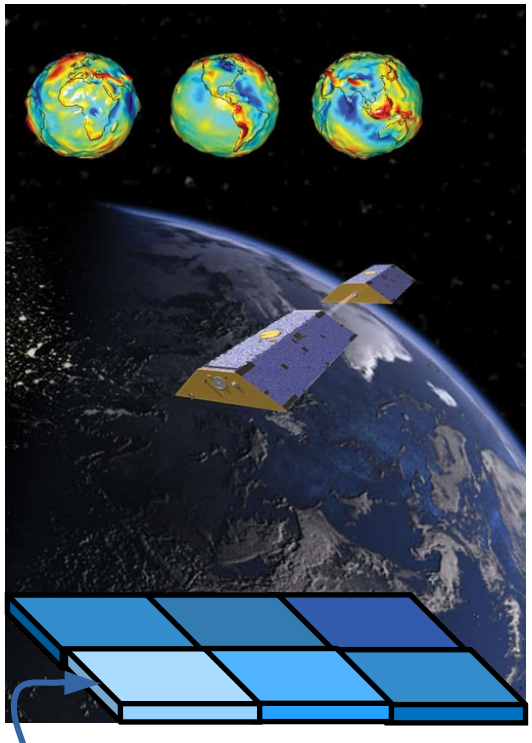
Accounting for spatial correlation errors in the assimilation of GRACE into hydrological models through localization

M. Khaki[a,*], M. Schumacher[b], E. Forootan[a,c], M. Kuhn[a], J.L. Awange[a], A.I.J.M. van Dijk[d]

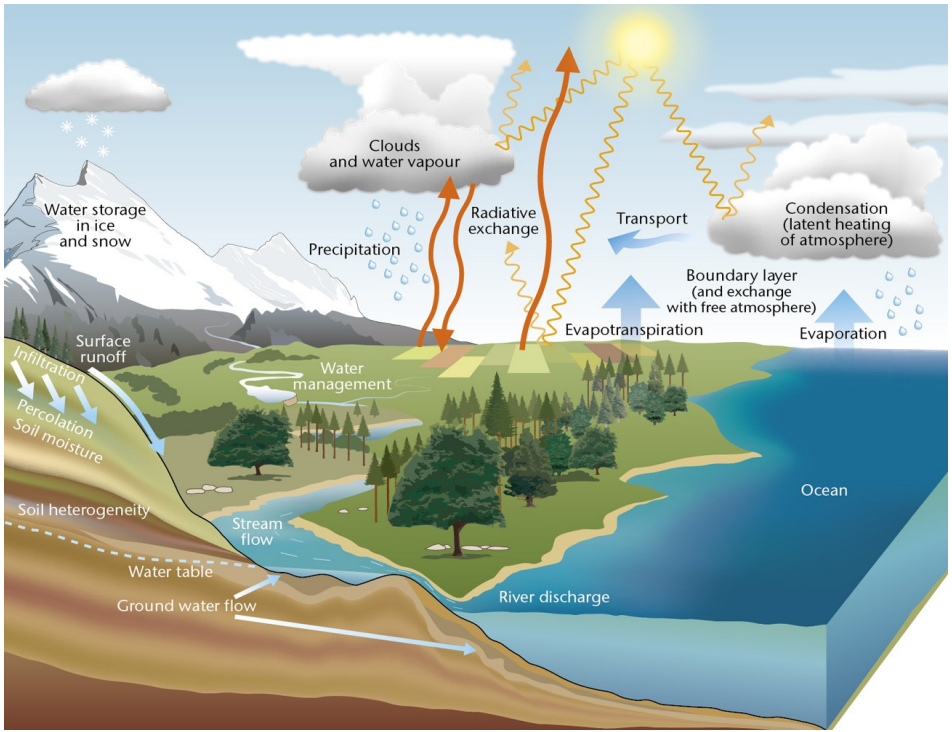
54

GRACE/FO – data assimilation publications

GRACE data assimilation



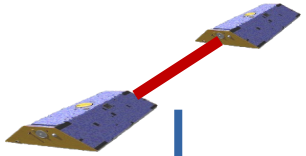
equivalent water height (ewh)



- snow
- ice
- surface waters
- wetlands
- canopy
- soil water
- soil ice
- groundwater

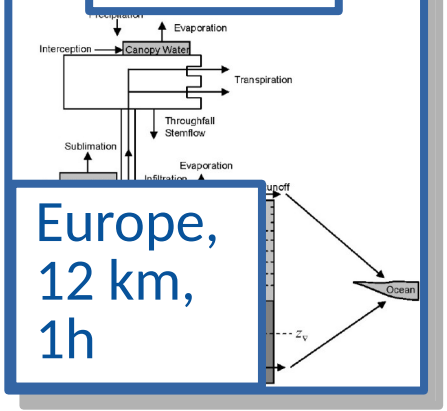
Spatial and temporal resolution mismatch!

GRACE DA in Bonn



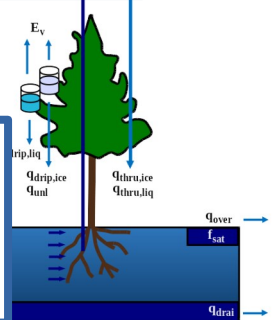
PDAF Parallel **Data Assimilation** Framework

CLM3.5



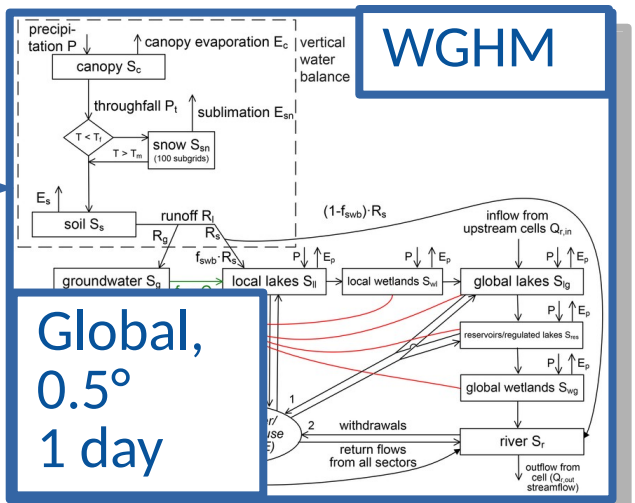
Europe,
12 km,
1h

CLM5



Europe,
12 km,
1h

WGHM

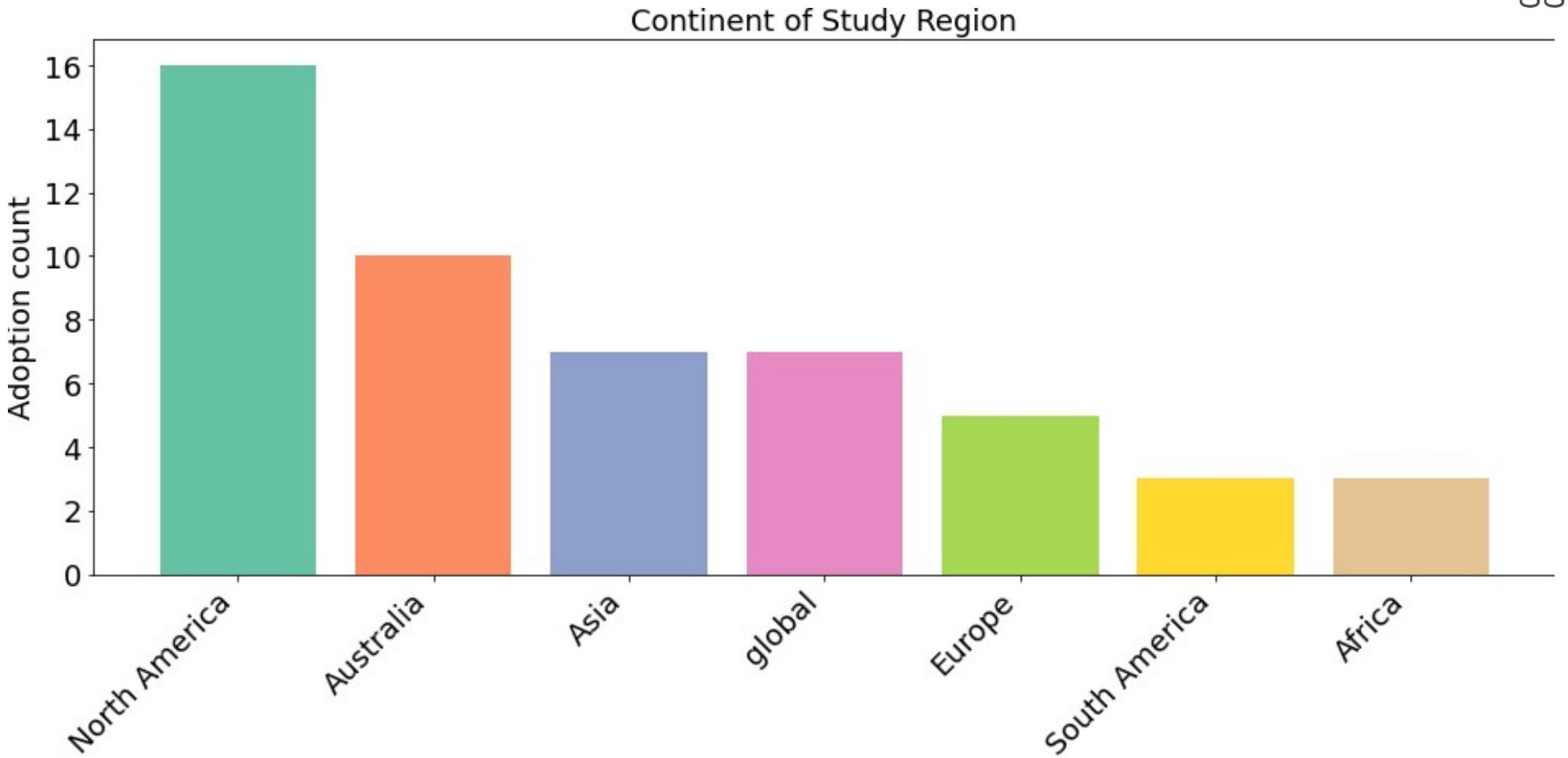


Global,
0.5°
1 day

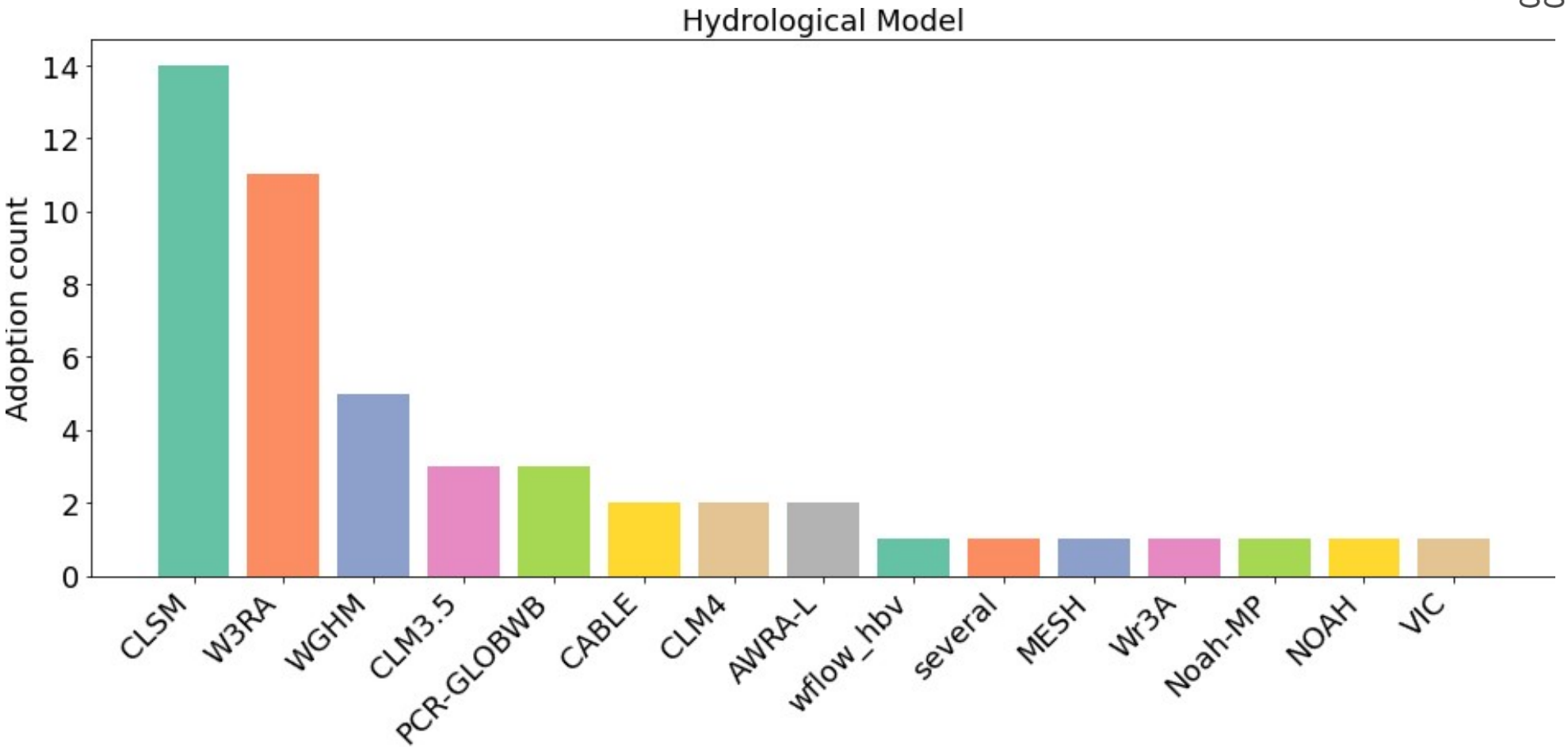
54

GRACE/FO – data assimilation publications

Spatial distribution of GRACE-DA studies

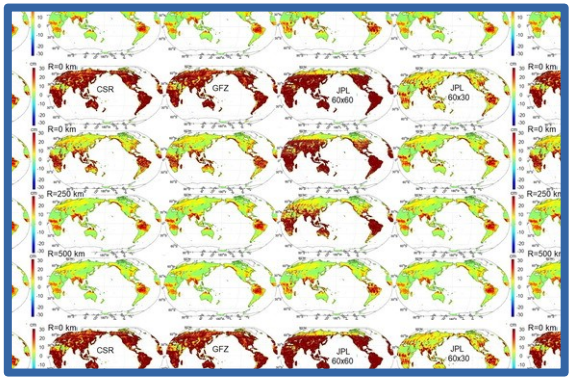


Employed hydrological models



GRACE DA choices

GRACE product and observation error

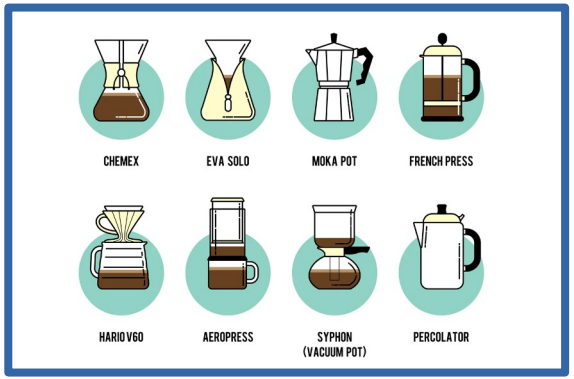


- Spherical harmonics (SH)
- Mascons
- Gridded level 3 product
- Line-of-sight gravity difference (LGD)

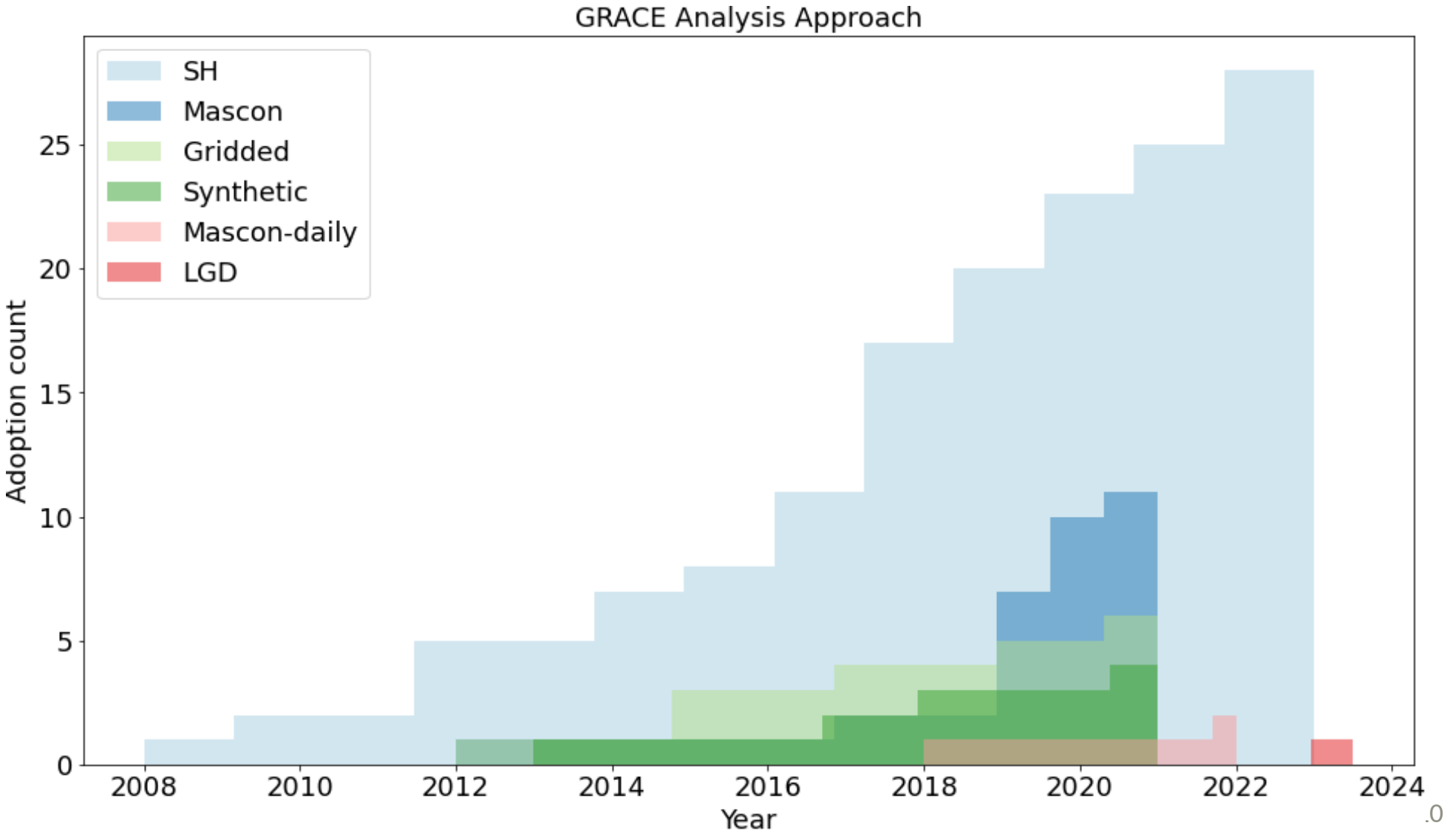
Geophysical corrections

- Glacial isostatic adjustment (GIA)
- Lakes / reservoirs
- Earthquakes
- Glaciers

Assimilation strategy

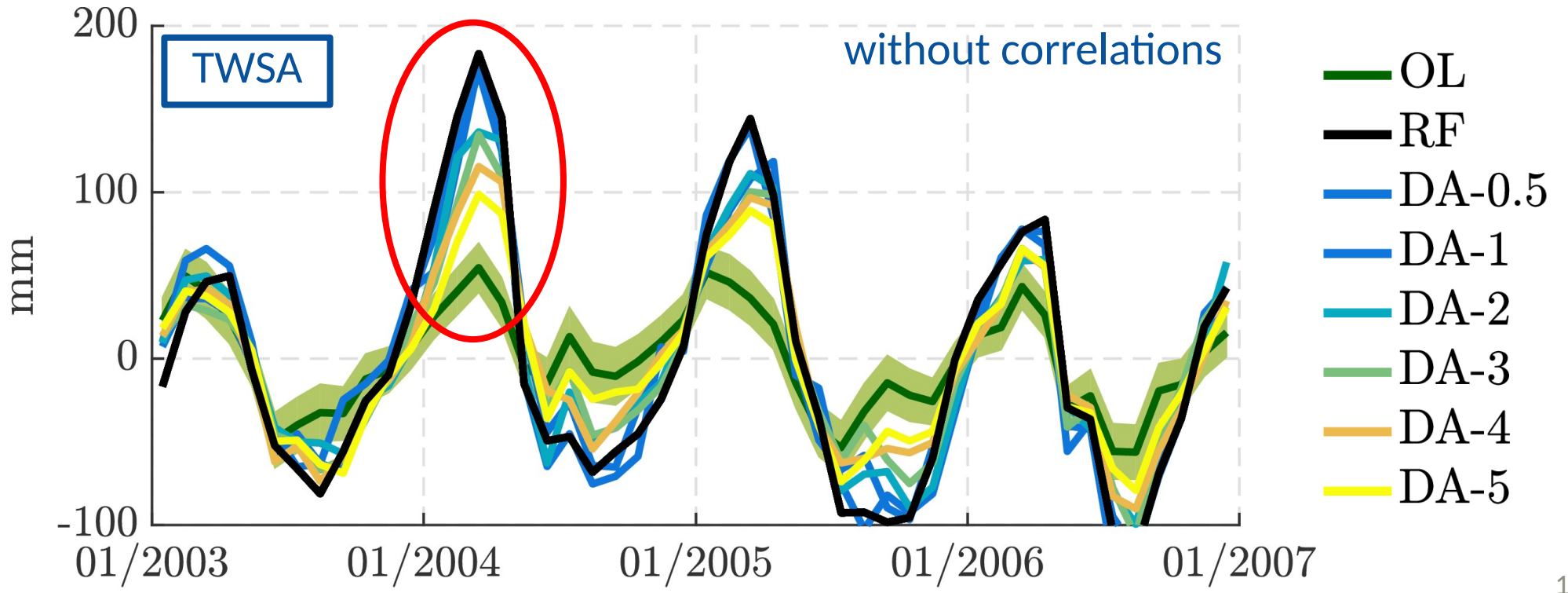


- Observation operator
- DA algorithm
- Application of increments


GRACE Analysis Approach
SH
Mascon
Gridded
Synthetic
Mascon-daily
LGD
Adoption count
0
5
10
15
20
25
2008
2010
2012
2014
2016
2018
2020
2022
2024
Year

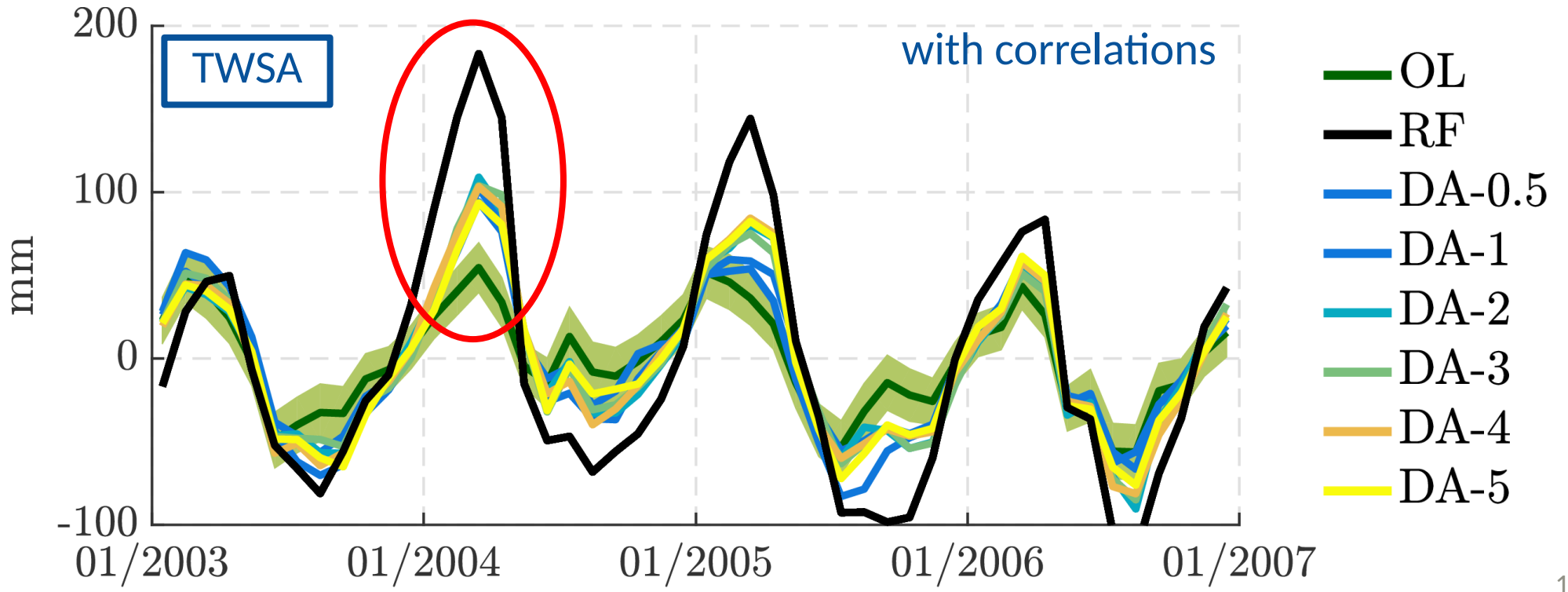
Observation grid and error model

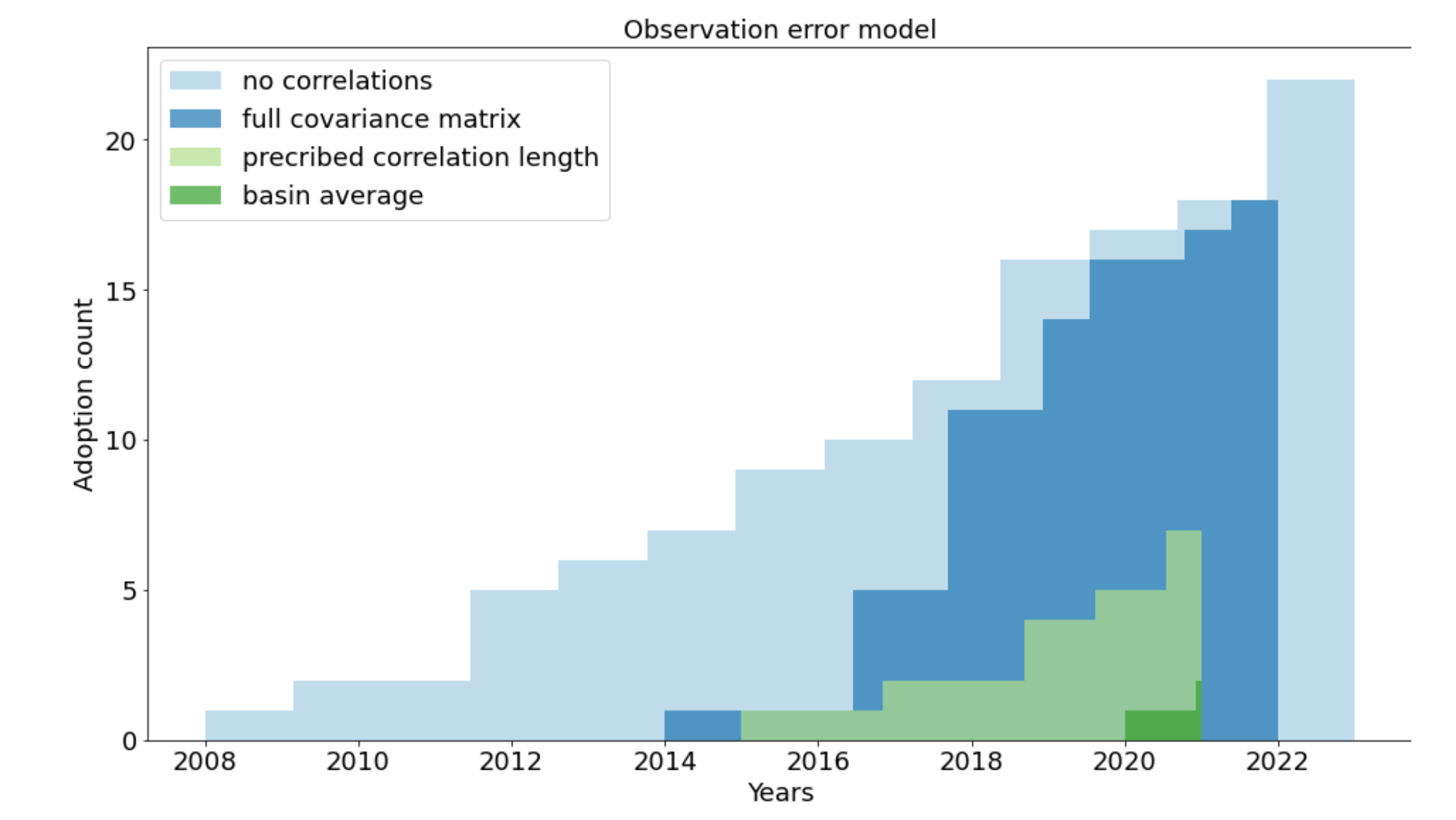
OSSE experiment with CLM3.5 over Europe (here: Daugava, Narva, Neva)

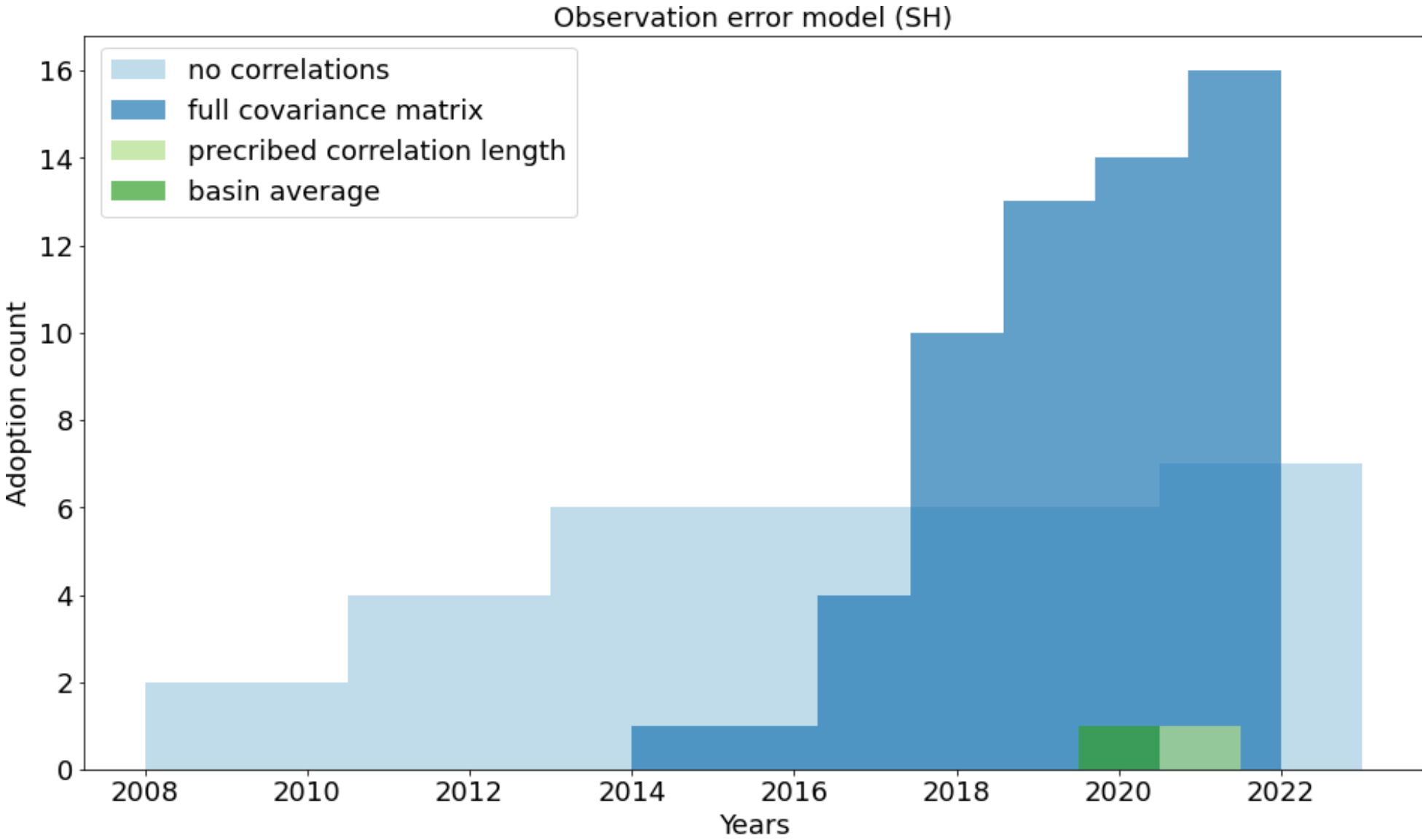


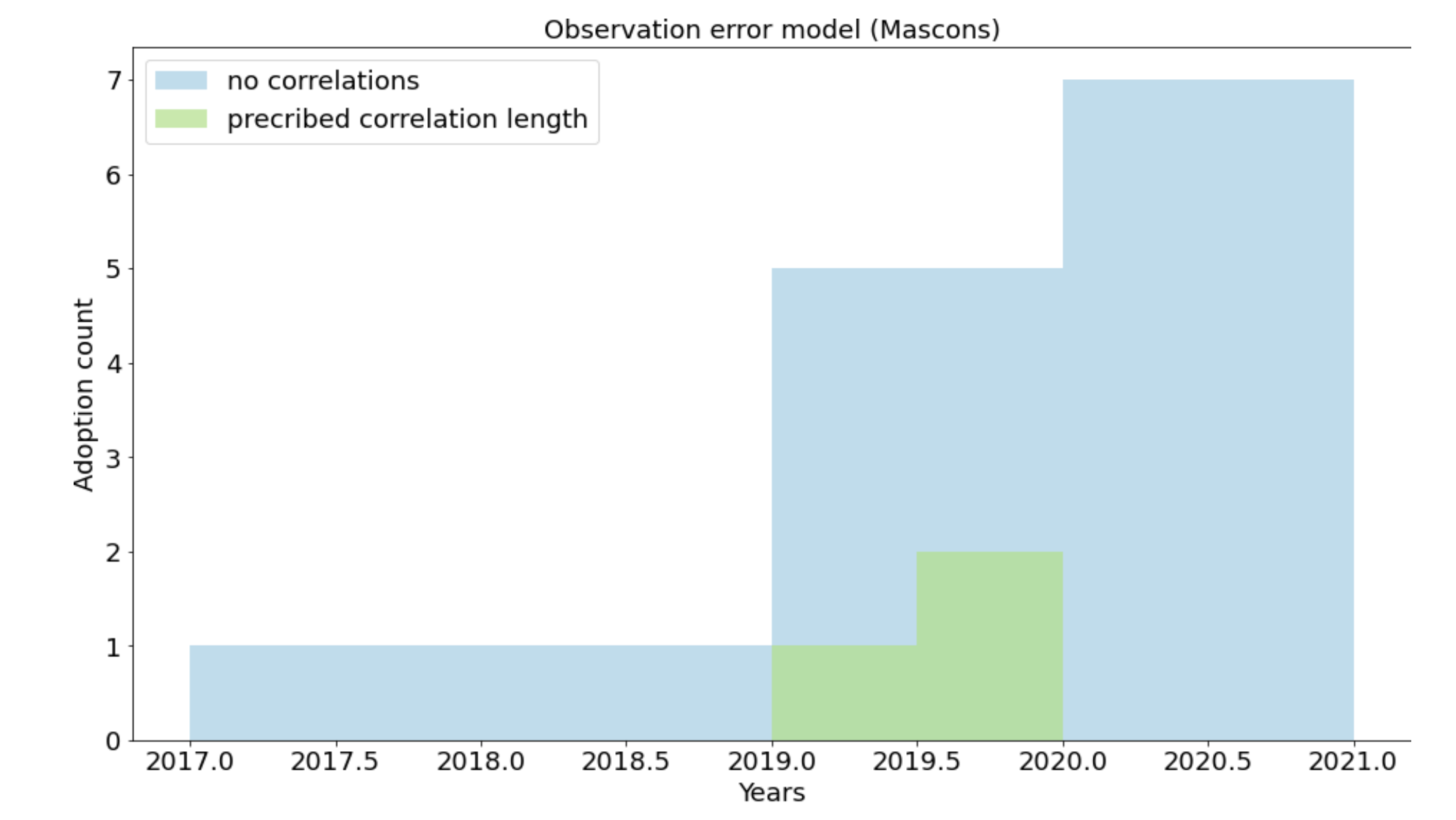
Observation grid and error model

OSSE experiment with CLM3.5 over Europe (here: Daugava, Narva, Neva)




Observation error model
no correlations
full covariance matrix
precribed correlation length
basin average
Adoption count
0
5
10
15
20
2008
2010
2012
2014
2016
2018
2020
2022
Years


Observation error model (SH)
no correlations
full covariance matrix
precribed correlation length
basin average
Adoption count
0
2
4
6
8
10
12
14
16
2008
2010
2012
2014
2016
2018
2020
2022
Years


Observation error model (Mascons)
no correlations
precribed correlation length
Adoption count
0
1
2
3
4
5
6
7
2017.0
2017.5
2018.0
2018.5
2019.0
2019.5
2020.0
2020.5
2021.0
Years

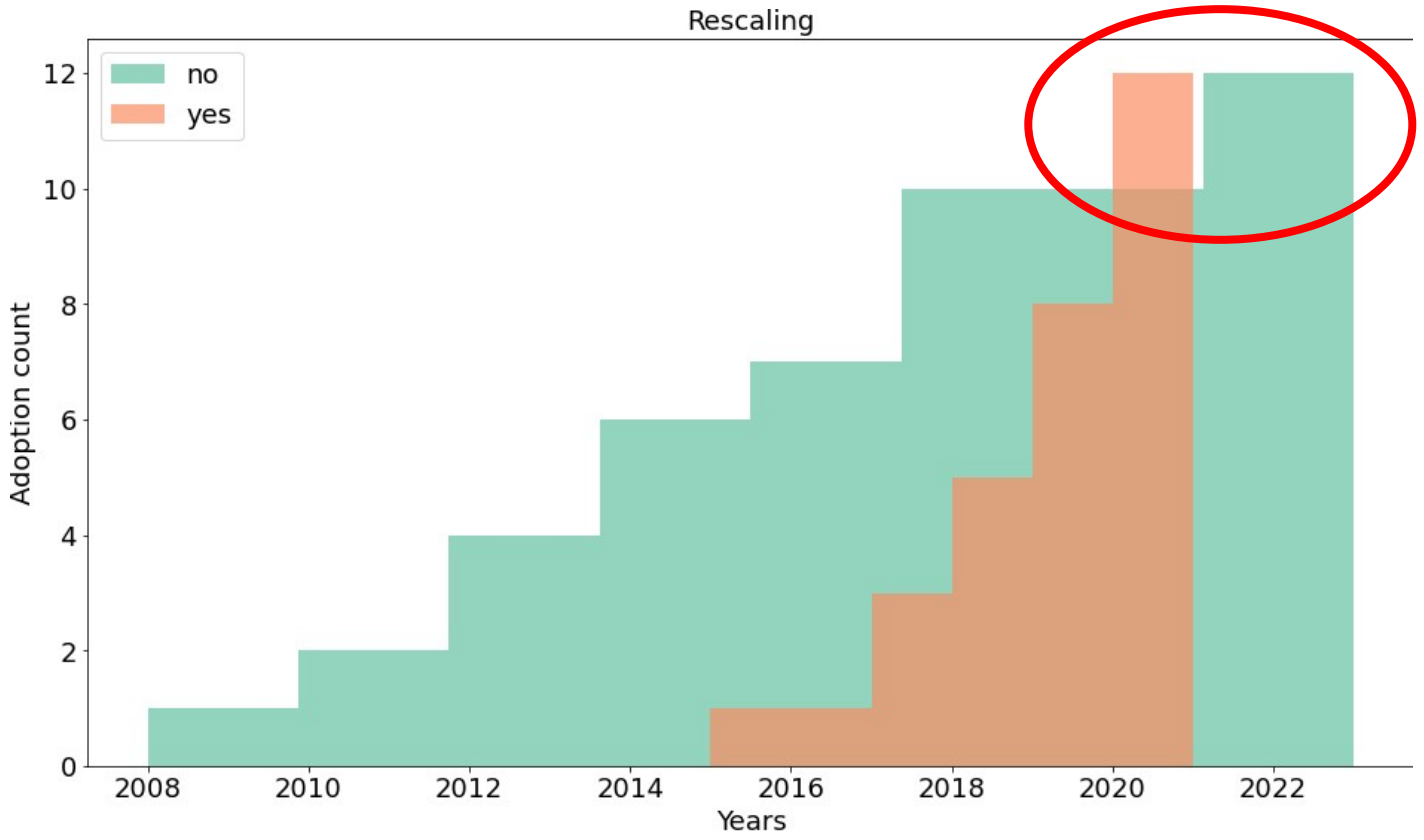
GRACE product and observation error

	Pros	Cons
SH	• No geophysical constraints • Full error covariance matrices	• Filtering and signal attenuation • Preprocessing necessary
Mascons	• No filtering necessary	• A priori constraints • Only diagonal error covariance
Gridded	• Ready to use	• Limited error information • Prescribed processing options
LGD	• Direct use of GRACE Level 1b data • High temporal resolution	• Exploratory approach • Sophisticated modeling steps

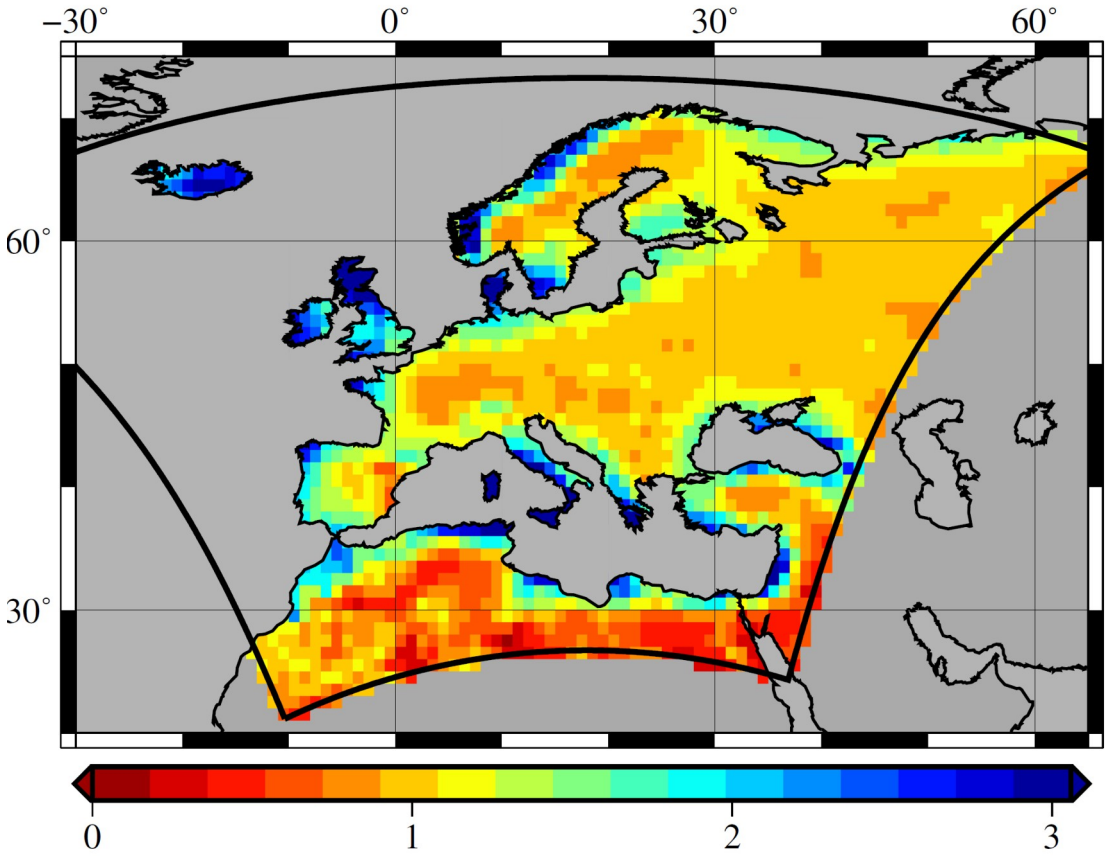
Filtering / Rescaling (SH solutions)

- **Filter**, but not rescale
- Apply **rescaling factors after filtering** to account for signal attenuation
- Rescale filtered GRACE TWSA to the **model variability**
- Filter modeled TWSA in the **observation operator**

Rescaling filtered SH solutions



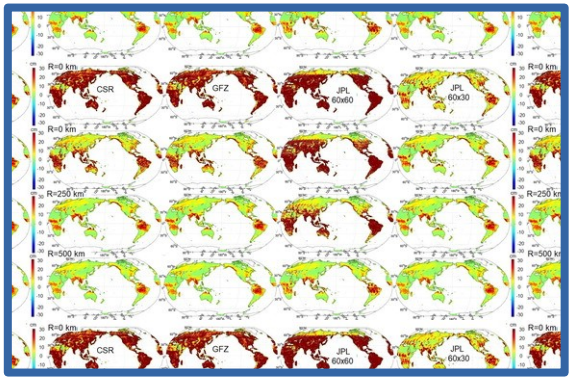
Rescaling



Rescaling factors over Europe computed from an ensemble of 5 global hydrological models.

GRACE DA choices

GRACE product and observation error

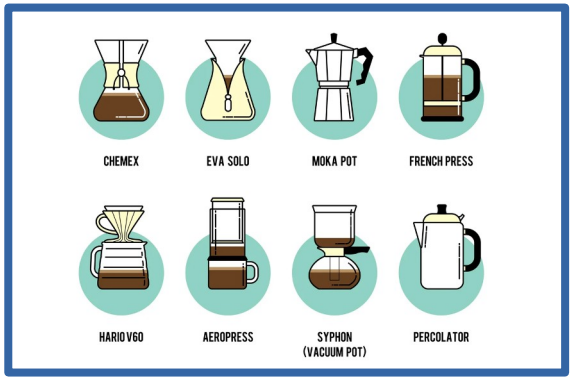


- Spherical harmonics (SH)
- Mascons
- Gridded level 3 product
- Line-of-sight gravity difference (LGD)

Geophysical corrections

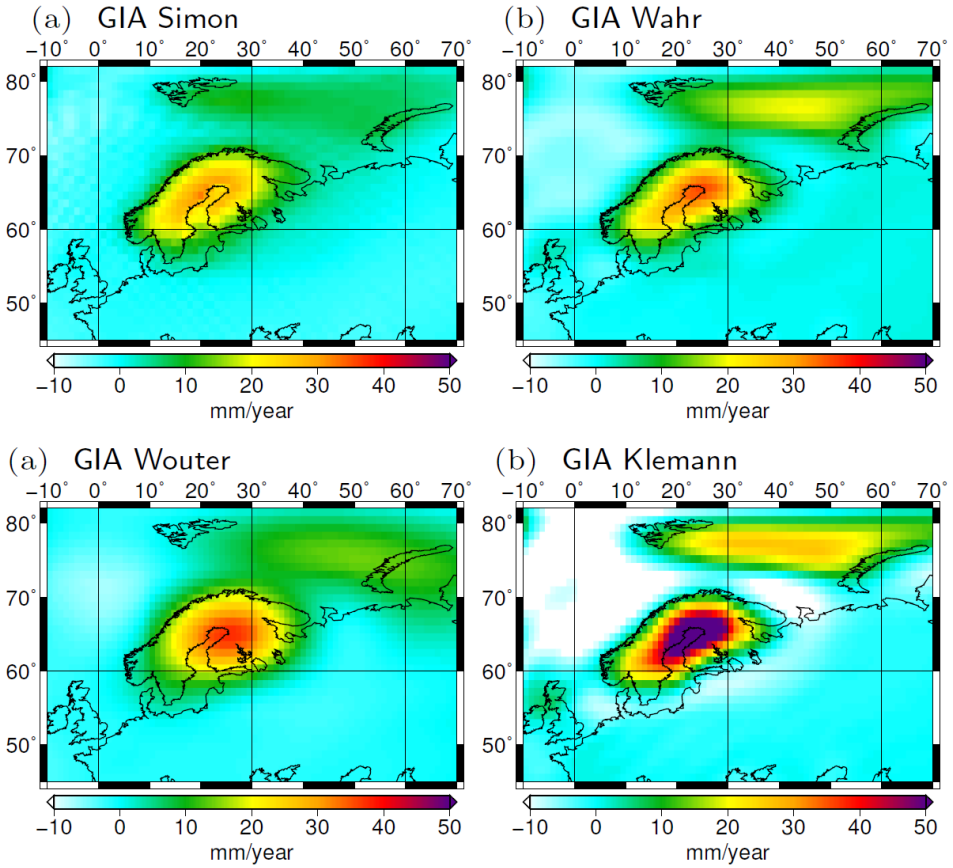
- Glacial isostatic adjustment (GIA)
- Lakes / reservoirs
- Earthquakes
- Glaciers

Assimilation strategy



- Observation operator
- DA algorithm
- Application of increments

Glacial isostatic adjustment (GIA)

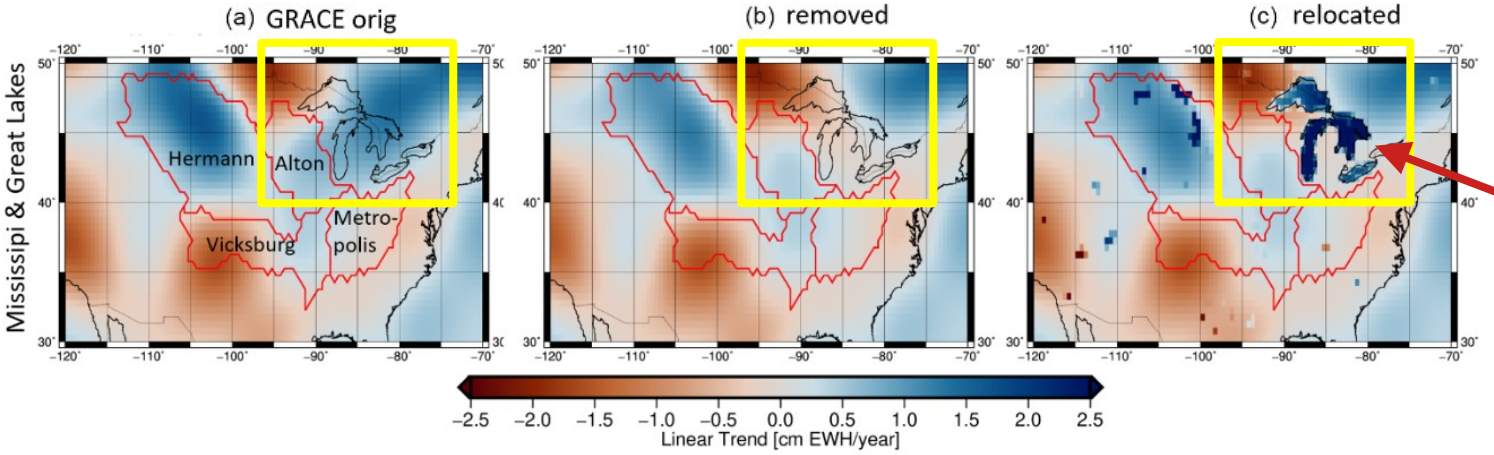


- GIA models have large differences.
- Errors can be as large as the signal.
- Which model should be used?
- What about error information?
- What is the impact on DA results?

Lake and reservoir leakage correction

Lakes / reservoirs in GRACE TWSA DA frameworks

- Leakage effect of localized water bodies present in GRACE-derived TWSA.
- During DA neighboring grid cells of surface water bodies might be affected.
- **Possible solution**: Global correction and relocation data sets based on satellite altimetry.



©https://en.wikipedia.org/wiki/Great_Lakes_region

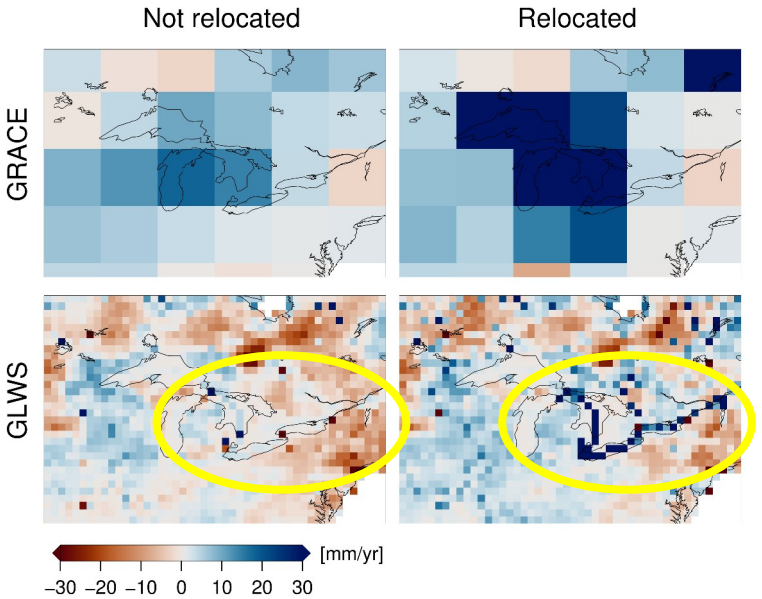
RECOG RL01: correcting GRACE total water storage estimates for global lakes/reservoirs and earthquakes

Simon Deggim[1], Annette Eicker[1], Lennart Schawohl[1], Helena Gerdener[2], Kerstin Schulze[2], Olga Engels[2], Jürgen Kusche[2], Anita T. Saraswati[3], Tonie van Dam[4], Laura Ellenbeck[5], Denise Dettmering[5], Christian Schwatke[5], Stefan Mayr[6], Igor Klein[6], and Laurent Longuevergne[7]

Lake and reservoir leakage correction

Trend assessment of the Great Lakes region

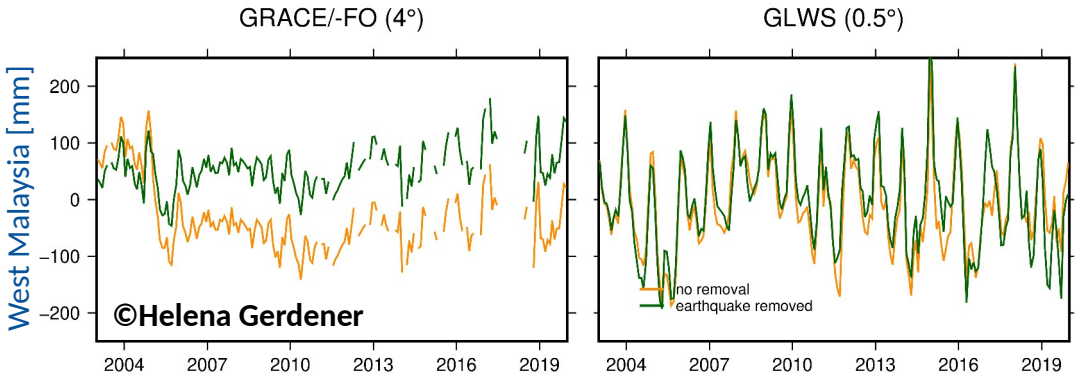
- Larger trend signal for Lake Erle, Huron and Ontario.
- Almost no changes of trends for Lake Superior and Lake Michigan.
- Coarse 4° GRACE/-FO resolution might bias relocation.



https://geology.com/maps/lakes/great-lakes/

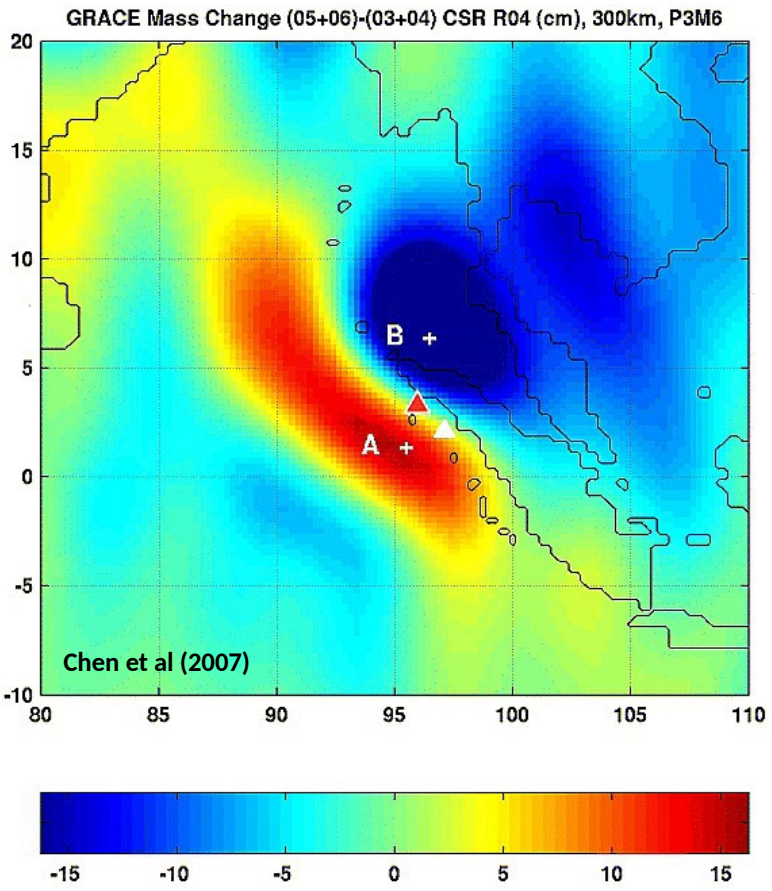
Earthquakes

- Missing corrections for Earthquakes might induce erroneous signals into hydrological models during data assimilation.
- Global correction data sets might be useful.



RECOG RL01: correcting GRACE total water storage estimates for global lakes/reservoirs and earthquakes

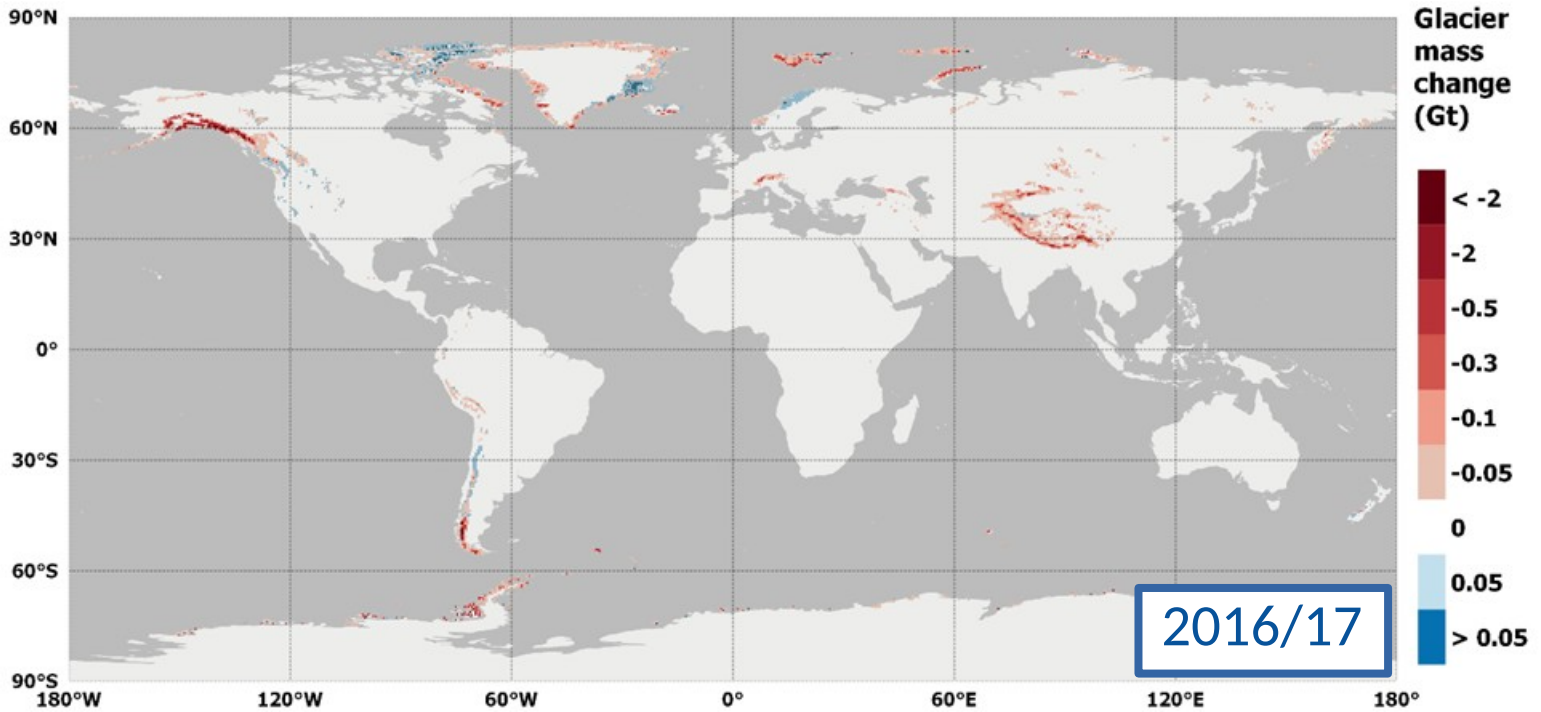
Simon Deggim[1], Annette Eicker[1], Lennart Schawohl[1], Helena Gerdener[2], Kerstin Schulze[2], Olga Engels[2], Jürgen Kusche[2], Anita T. Saraswati[3], Tonie van Dam[4], Laura Ellenbeck[5], Denise Dettmering[5], Christian Schwatke[5], Stefan Mayr[6], Igor Klein[6], and Laurent Longuevergne[7]



Mass change induced by the Sumatra-Andaman earthquake (2004) and the Nias earthquake (2005)

Glaciers

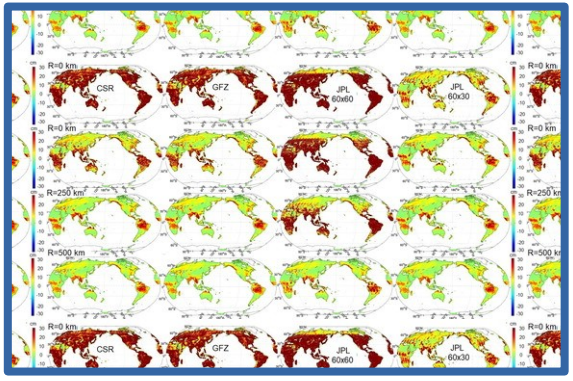
- Glacier mass changes are not included in hydrological models.
- Glacier mass changes observed by GRACE might affect other storage compartments.
- Global glacier mass change products including uncertainties have become available and could be used for correction.



Glacier mass change gridded data from 1976 to present derived from the Fluctuations of Glaciers Data base (produced at the WGMS on behalf of CCCS)

GRACE DA choices

GRACE product and observation error

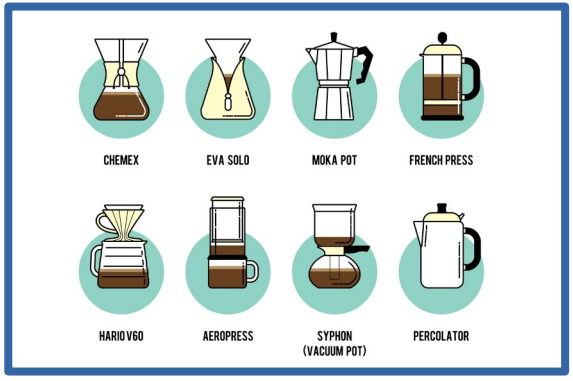


- Spherical harmonics (SH)
- Mascons
- Gridded level 3 product
- Line-of-sight gravity difference (LGD)

Geophysical corrections

- Glacial isostatic adjustment (GIA)
- Lakes / reservoirs
- Earthquakes
- Glaciers

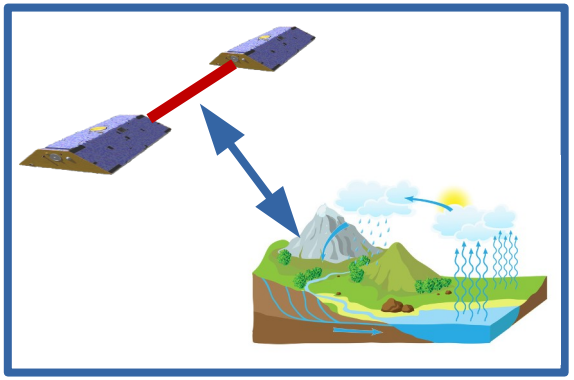
Assimilation strategy



- Observation operator
- DA algorithm
- Application of increments

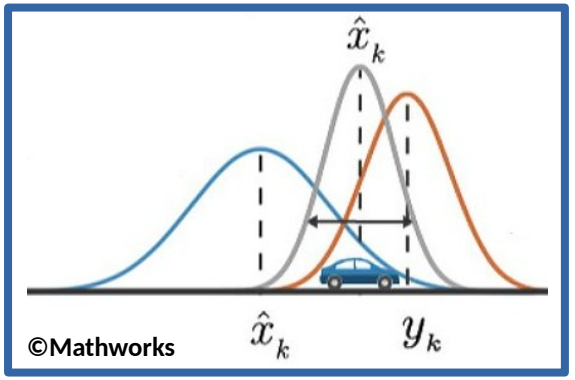
DA strategy CLM-PDAF

Observation operator



- **Monthly average**
- Average of 3 selected days to mimic GRACE observation period

DA algorithm

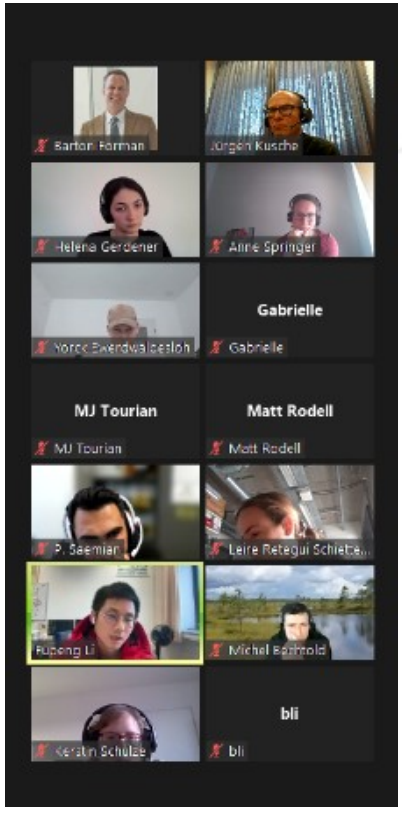


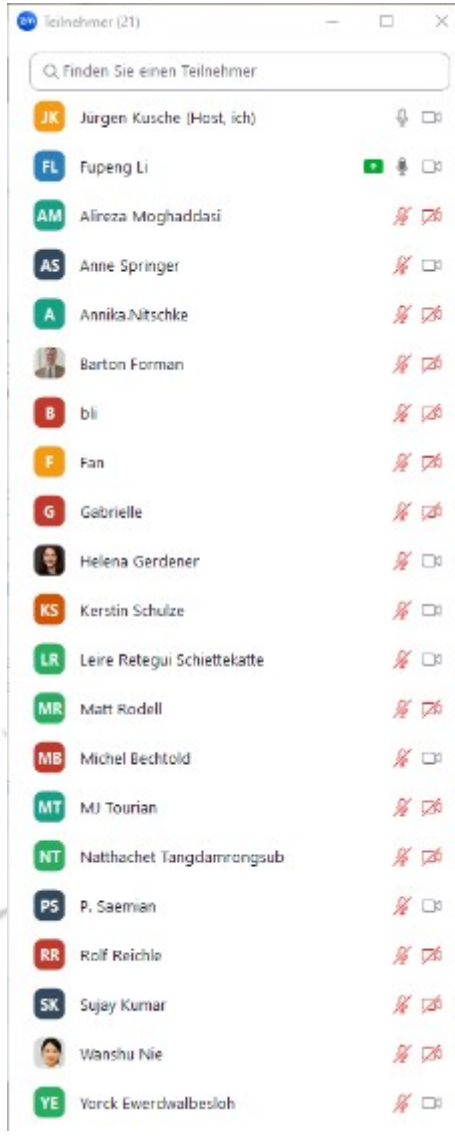
- Global filters (e.g., EnKF)
- Local filters, here: **LESTKF** (Local Error Subspace Transform Kalman Filter)
- Other options, such as Particle Filters

Application of increments

- **At last day of month**
- At first day of month and loop
- Loop and apply fraction of increment to each day
- Temporal downsampling of GRACE TWSA

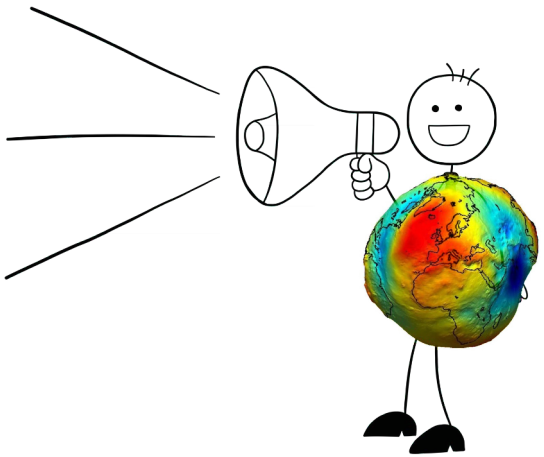
GRACE/-FO DA workshop Jan. 2024





Insights

- A standard assimilation procedure has yet to emerge with
  - standard error representations (correlations are important!)
  - standard geophysical corrections,
  - and standard assimilation algorithm.

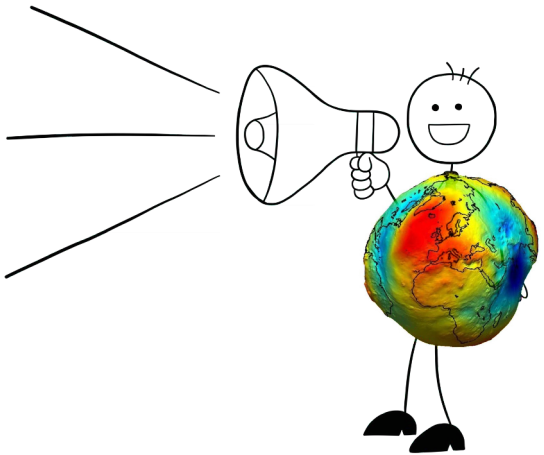


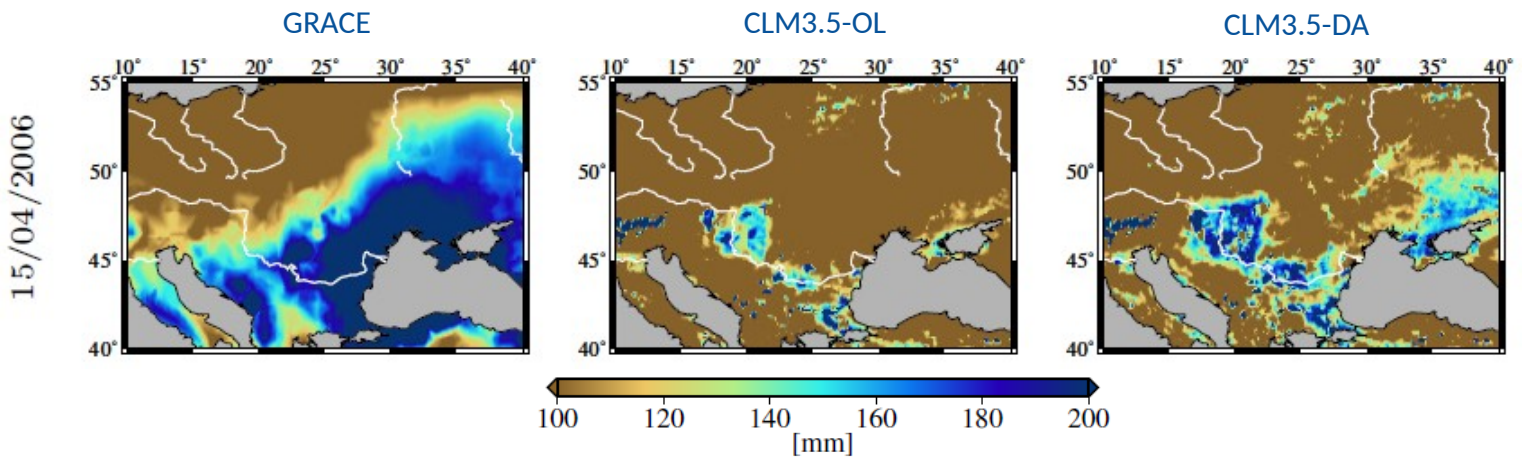
Funded by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation - SFB 1502/1–2022 - Projektnummer: 450058266

Insights

- A standard assimilation procedure has yet to emerge with
  - standard error representations (correlations are important!)
  - standard geophysical corrections,
  - and standard assimilation algorithm.

- In Bonn, we currently study
  - the representation of extreme events.





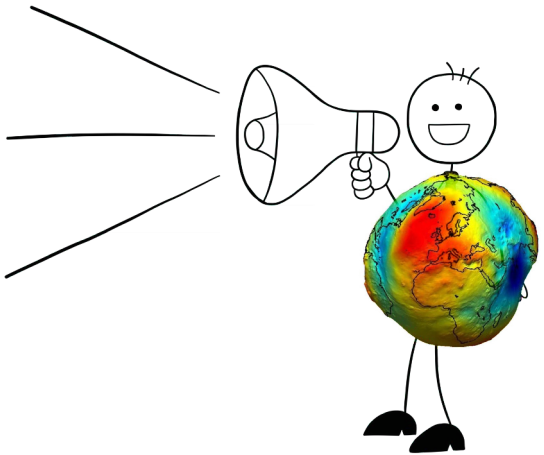
Danube flooding in spring 2006

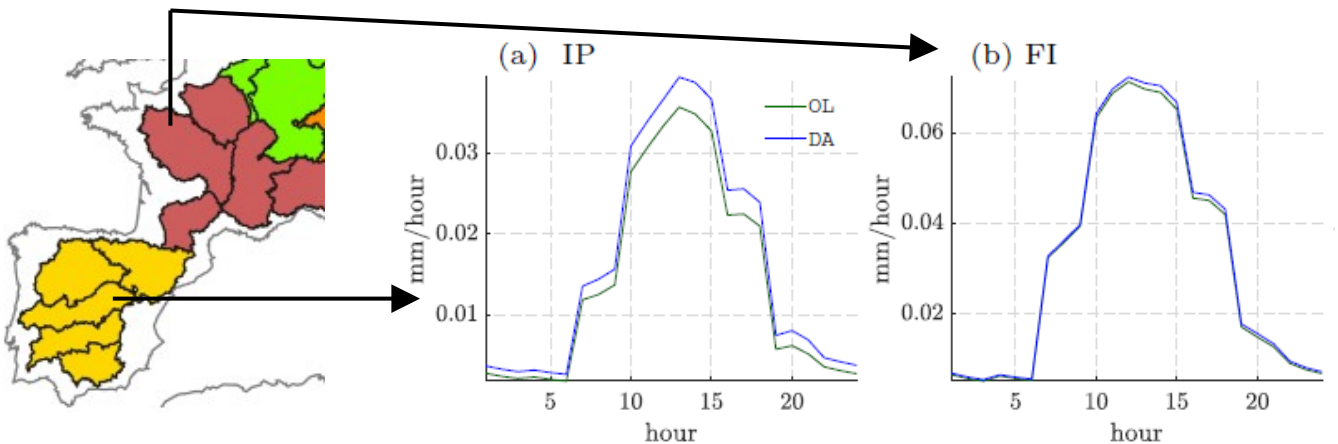
Funded by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation - SFB 1502/1–2022 - Projektnummer: 450058266

Insights

- A standard assimilation procedure has yet to emerge with
  - standard error representations (correlations are important!)
  - standard geophysical corrections,
  - and standard assimilation algorithm.

- In Bonn, we currently study
  - the representation of extreme events.
  - the impact of GRACE data assimilation on water fluxes.



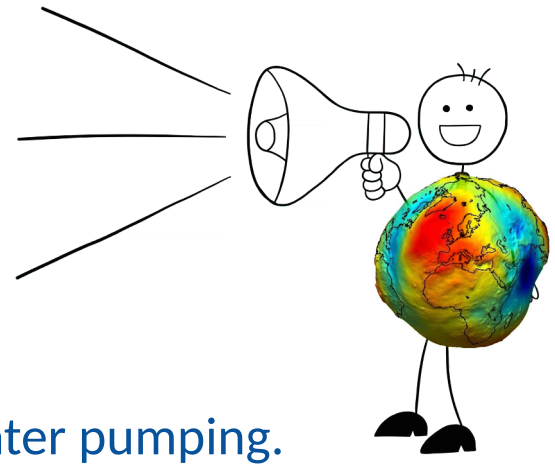


Daily cycle of evapotranspiration in August 2005

Funded by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation - SFB 1502/1–2022 - Projektnummer: 450058266

Insights

- A standard assimilation procedure has yet to emerge with
  - standard error representations (correlations are important!)
  - standard geophysical corrections,
  - and standard assimilation algorithm.



- In Bonn, we currently study
  - the representation of extreme events.
  - the impact of GRACE data assimilation on water fluxes.
  - anthropogenic influences on water storages through groundwater pumping.

Oral | Thursday, 18 Apr, 17:25–17:35 (CEST) Room 2.44

The Impact of GRACE Data Assimilation on Water Storage Dynamics in CLM3.5 and CLM5

Yorck Ewerdwalbesloh, Anne Springer, and Jürgen Kusche
University of Bonn, Institute for Geodesy and Geoinformation, APMG, Bonn, Germany

DFG CRC 1502 DETCT

Funded by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation - SFB 1502/1–2022 - Projektnummer: 450058266