Assimilating GRACE data into hydrological models

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Bundesministerium für Bildung und Forschung







Outline

Data assimilation: concept

Kalman filter and ensemble Kalman filter

- Adaption to specific problem: assimilating GRACE into hydrological model (WGHM)
- What do you have to think of, that might not be told in the textbook?

Example: Assimilation results



Data assimilation: Concept













So we want to combine model results and observations.

What does this mean?



Figure modified from: Introduction to Data Assimilation for Scientists and Engineers O. Thual, *Open Learn. Res. Ed. INPT 0202* (2013) 6h

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The update minimizes a combination of distances => cost function

$$J(\blacksquare) = \frac{1}{2} \| \blacksquare - \bullet \|_{C}^{2}$$

distance between update
and model prediction











(Ensemble) Kalman filter

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iual compartments: $O(\blacksquare)$

Kalman (1960)

















Ensemble Kalman filter



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Empirical model covariance matrix C_{xx}



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Empirical model covariance matrix C_{xx}



Variances of model predictions



Variances of model predictions



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- uncertainties of TWS in each GRACE evaluation cell
- correlations between TWS in different cells



- uncertainties of TWS in each GRACE evaluation cell
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GRACE observation covariance matrix

- uncertainties of TWS in each GRACE evaluation cell
- correlations between TWS in different cells



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- correlations between TWS in different cells



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One more aspect: Parameter calibration





Calibration parameters



Update calibration parameters together with water storage states => extend state vector **x** by (a subset of the) calibration parameters

calibration AND assimilation in one step => C/DA approach

Advantage: parameters that fit "better" to reality can improve the model beyond the data period

Update calibration parameters together with water storage states => extend state vector **x** by (a subset of the) calibration parameters

calibration AND assimilation in one step => C/DA approach



Parameter calibration





Examples: Assimilation results

Examples for assim. GRACE into hydr. models HCU

Not a

^{complete} list...

Zaitchik et al. (2008)

- first use of EnKF(smoother)
- basin averages for GRACE
- simple GRACE error model
- improved agreement of assimilated model to measured groundwater

The same approach was used by:

Forman et al. 2012

- snow dominated basin

Houborg et al. 2012

- focus on drought monitoring

Li et al. 2012

- validation against measured discharge
- European river basins

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Forman et al. (2012): Mackenzie Basin



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Li et al. (2012): Europe

Li et al. (2012): Europe

- Model: NASA CLSM
- Ensemble Kalman Smoother



Li et al. (2012): Europe

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Girotto et al. 2016

gridded GRACE data + SMAP

Kumar et al. 2016

- gridded GRACE data + distributed errors

Schumacher (2012) Eicker et al. (2014)

- C/DA approach
- strict error propagation
- gridded GRACE data
- model: WGHM

Schumacher et al. (2016)

- Impact of GRACE error information

Schumacher (2016)

- PhD thesis on data assimilation

Schumacher et al (2017, submitted)

 drought assessment in the Murray– Darling basin (Australia)

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Schumacher et al. 2017 (submitted)

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- drought assessment in the Murray– Darling basin (Australia)

Tangdamrongsub et al. (2017)

 use of full GRACE covariance matrices

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(Kumar et al. 2016)

Kumar et al. (2016): USA



Summary

Data assimilation: concept

- combining observations and model results
- to better describe reality
- to separate the integral GRACE signal (space, time, vertical)

(Ensemble) Kalman filter

- adaption to specific problem: assimilating GRACE into hydrological model
- challenges:
 - uncertainties of model not known (=> ensemble approach)
 - ill-conditioned covariance matrices of model and observations
 - choice of GRACE discretization (grid size)
- parameter calibration within the same step as assimilation (=> C/DA approach)

Some assimilation results

Outlook

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Combining data and models will be come more and more important in the future to make better use of the data and to understand the processes governing global change!

Thank you very much for your attention!

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