Using remotely sensed soil moisture products to calibrate a large-scale groundwater model

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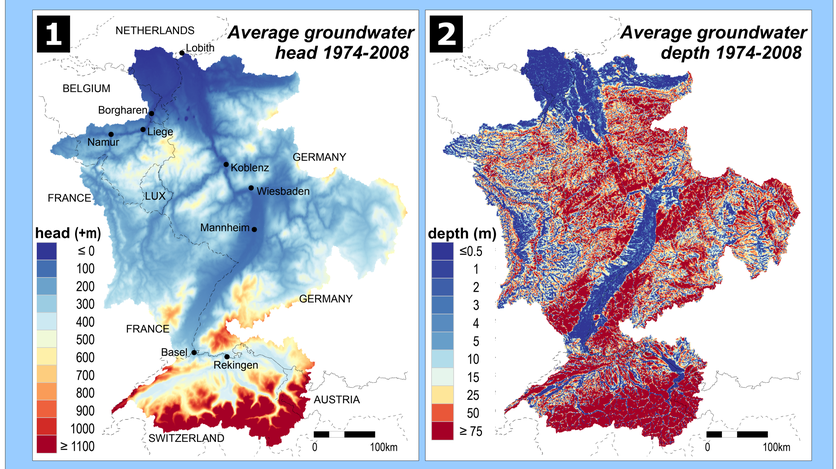
Can satellite signals be used for calibrating a groundwater model ?

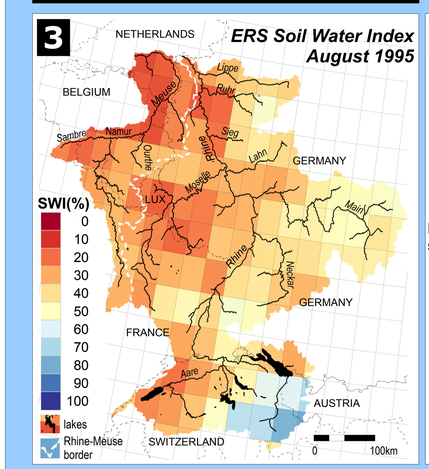
Study area: Rhine-Meuse basin



Figures 1 and 2 illustrate mean **groundwater heads and depths** for the period 1974-2008 based on the model of Sutanudjaja et al. (2011), that was built by using only global datasets.

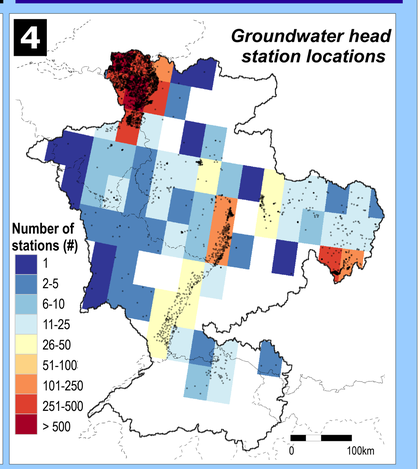
The basin has a good coverage of ERS SWI (Fig. 3) and ample in-situ groundwater head measurements (Fig. 4).

ERS Soil Water Index



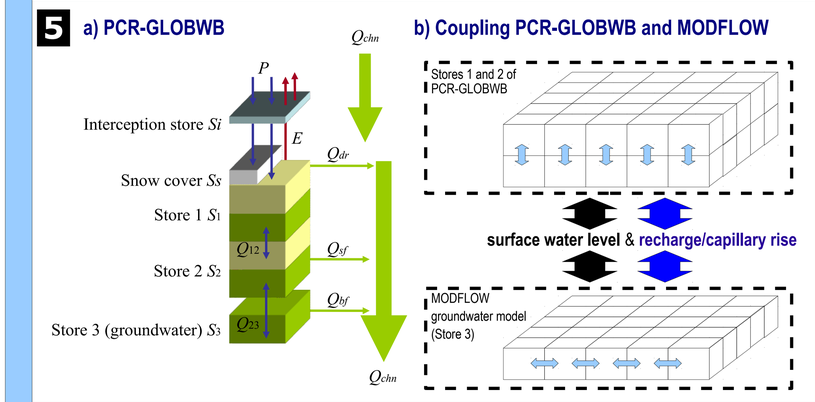
- Derived from European Remote Sensing (ERS) **active scatterometer** signals.
- Represent **soil moisture** contents (%) in **the first meter of soil**.

Groundwater head stations



- **Ground measurements** from various institutions in the Rhine-Meuse basin.
- Only time series from **the first upper aquifer** were used (> 5000 points).

Model used: PCR-GLOBWB-MOD

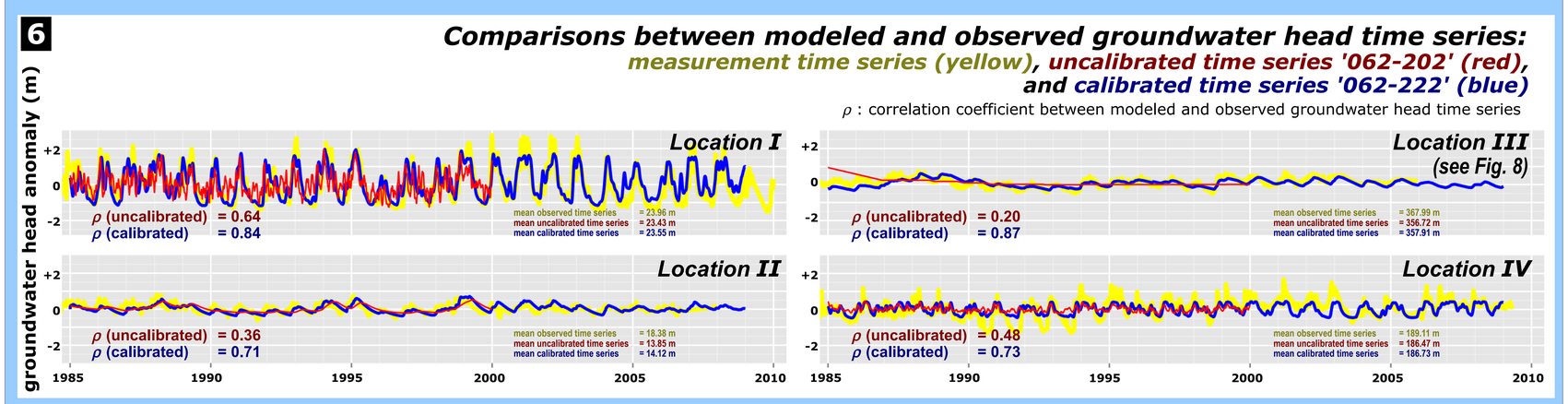


- daily resolution, 30 arc-second (~1km) resolution, built by using only global datasets
- a coupled model: **PCR-GLOBWB** & **MODFLOW** (to simulate groundwater lateral flow)
- **fully online coupling**: capillary rise is activated and baseflow is a function of head

Purpose:

To check whether a spaceborne soil moisture product called the **'ERS Soil Water Index (SWI)'** (Wagner et al, 1999) can be used to calibrate a coupled groundwater-land surface model.

Results:



- We ran more than 200 scenarios with varying values of upper soil and aquifer properties.
- Table 1 (variation of **KD**: aquifer transmissivities) and Table 2 (variation of **Ksat**: upper soil saturated hydraulic conductivities) present some examples.
- Unfortunately, the soil moisture performance indicator (**rho_SM**) is not sensitive to the variation of **KD** (aquifer transmissivity).
- **KD** is only sensitive to the discharge performance indicators (**NS** & **NS_LOG**), see Table 1.
- Ksat is sensitive not only to discharge results (**NS** & **NS_LOG**), but also to soil moisture results (**rho_SM**), see Table 2.

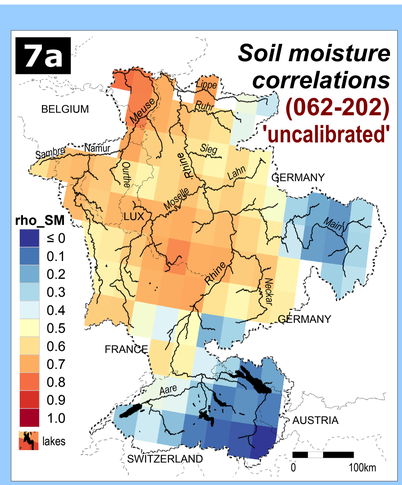
Table 1

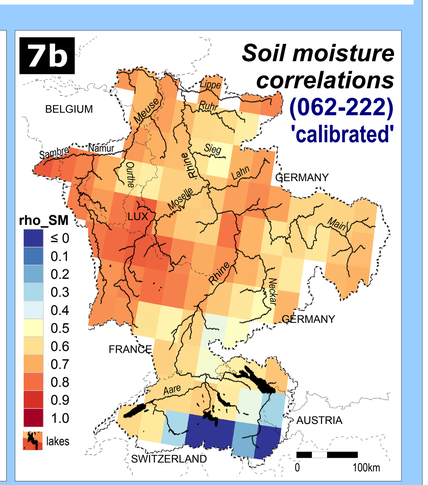
Code	KD	Ksat	NS rho_SM	NS Rhine	NS Meuse	NS_LOG Rhine	NS_LOG Meuse
062-222	very low	normal	0.58	0.48	0.43	0.52	-1.03
072-222	low	normal	0.58	0.56	0.52	0.26	-3.58
052-222	normal	normal	0.58	0.52	0.52	-0.05	-5.59
092-222	high	normal	0.58	0.34	0.36	-1.15	-11.13

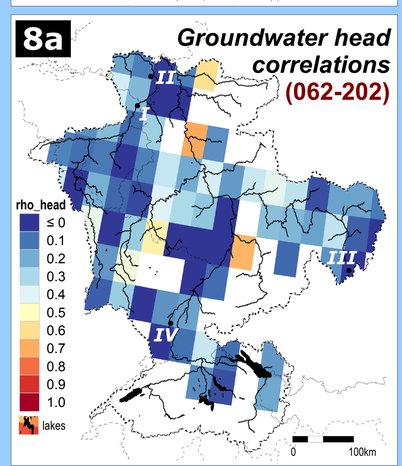
Table 2

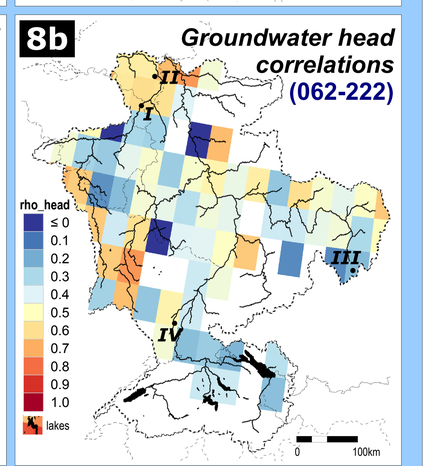
Code	KD	Ksat	NS rho_SM	NS Rhine	NS Meuse	NS_LOG Rhine	NS_LOG Meuse
062-202	very low	low	0.48	-3.83	-1.98	0.08	-0.26
062-222	very low	normal	0.58	0.48	0.43	0.52	-1.03
062-232	very low	high	0.47	-0.03	0.13	-0.03	-2.03

KD : aquifer transmissivities
Ksat : upper soil saturated hydraulic conductivities
rho_SM : correlation coefficient between modeled soil moisture time series and (observed) ERS SWI time series
NS : Nash-Sutcliffe model efficiency coefficient based on discharge values
NS_LOG : Nash-Sutcliffe model efficiency coefficient based on logarithmic discharge values









The European Remote Sensing Soil Water Index (ERS SWI) time series (Fig. 3), providing spatio-temporal soil moisture expressions, may be able to infer groundwater behaviors. We explored the possibility of using them to calibrate a coupled groundwater-land surface model called the PCR-GLOBWB-MOD (Fig. 5). We implemented a brute force calibration procedure by running several scenarios with varying parameter values (Tables 1 and 2). Results indicate that **ERS SWI can be used to calibrate such groundwater models by indirectly tuning groundwater recharge through changing the saturated conductivities** (K_{sat}). It is shown that the scenarios with good soil moisture performances also show good performances of their resulting groundwater heads (Figs. 6, 7 and 8). However, there are limitations to calibrate such models by using only ERS SWI. The aquifer transmissivities (KD) are sensitive to the discharge results (Table 1). Discharge observations are therefore also required for a more accurate model calibration.