Using high-resolution groundwater data for the validation of a global hydrological model: evaluating WaterGAP and calibration/data assimilation (C/DA) performance over France

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2) University of Rennes
3) GFZ German Research Center for Geodsciences
4) University of Bonn

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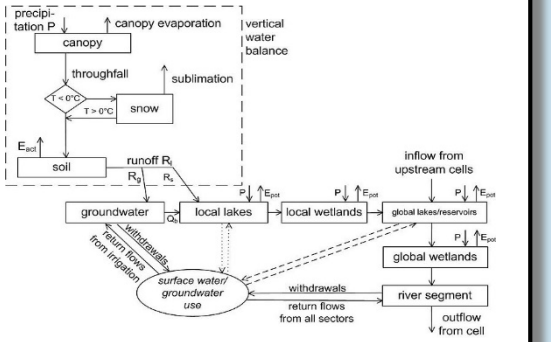
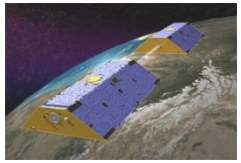
Study setup

WaterGAP Global Hydrology Model (WGHM)



Input data



GRACE

River discharge

This presentation

data assimilation

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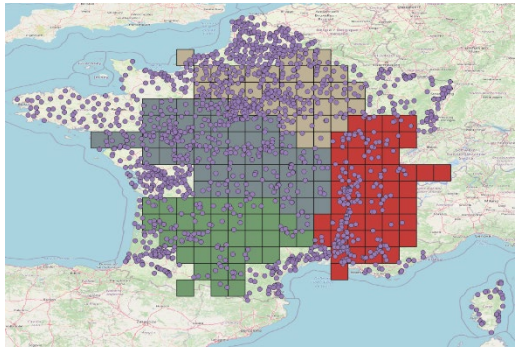
calibration

GFZ Helmholtz-Zentrum Potsdam

Validation of model output

Groundwater (GW) compartment



In-situ measurements in France

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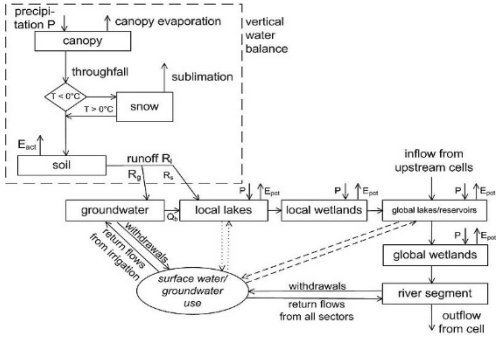

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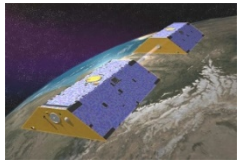

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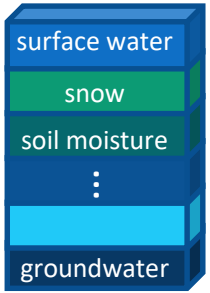

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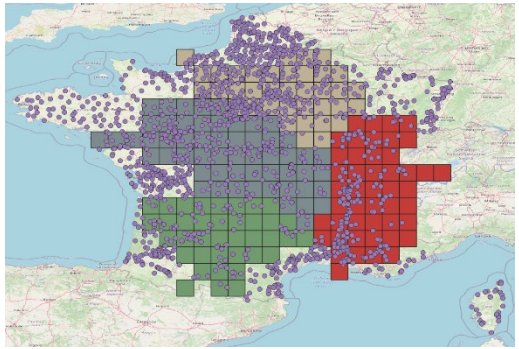


In-situ measurements in France

GW borehole distribution in France

Pre-processing of in-situ data:

~4000 boreholes

↓

Keep GRACE period
Remove bad timeseries
Remove domestic data
Remove outliers (iqr)

↓

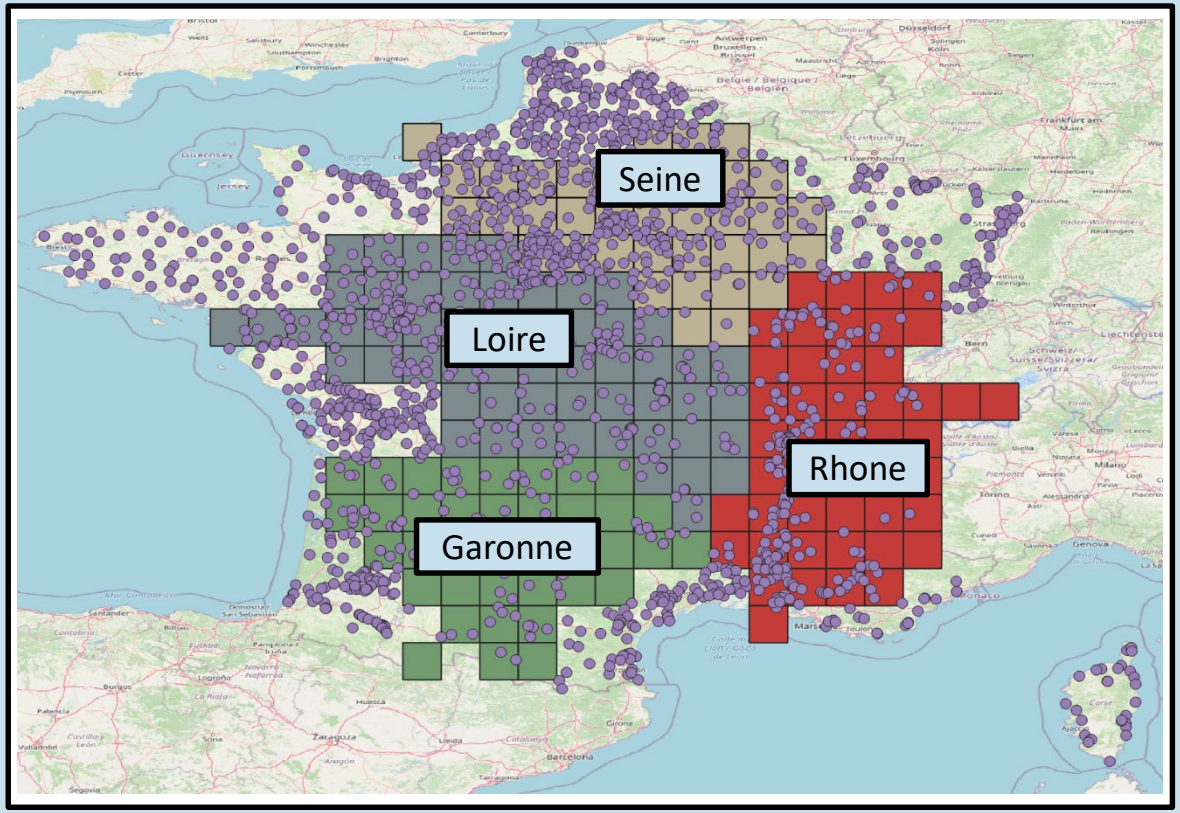
~3200 boreholes

↓

Keep unconfined aquifers

↓

1765 unconfined boreholes (purple dots)



(data obtained from ADES, France: https://ades.eaufrance.fr/)

Converting GW level to water storage

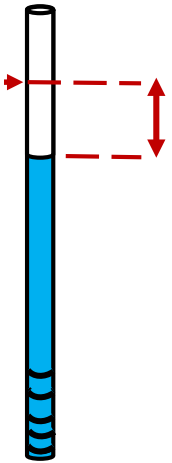
GW borehole unit

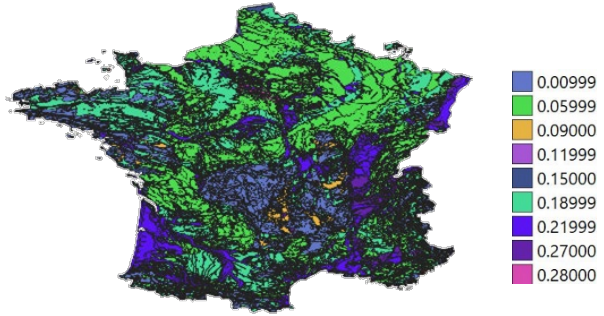
GW head variation $[m]$ * Porosity [unitless] * 1000 $[kg/m^3]$ = $[kg/m^2]$

Water density

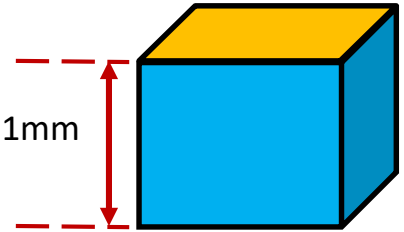
WaterGAP unit

Mean of timeseries GW head



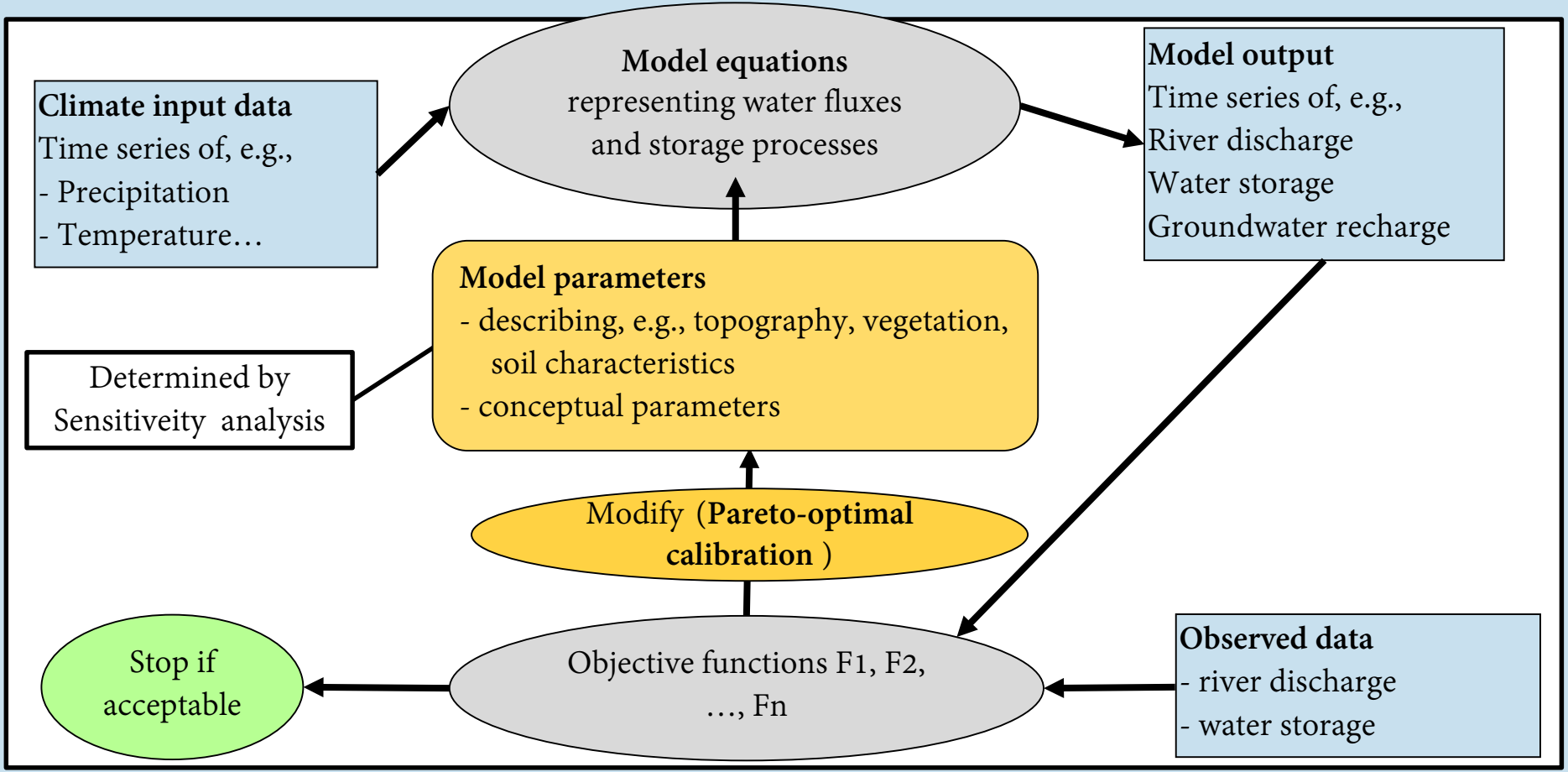


Gleeson et. al (2014)



height of 1 kg water on 1 m^2 area is 1 mm, so called equivalent water height (EWH)

Calibration Concept: POC (Pareto-optimal calibration)



POC setup

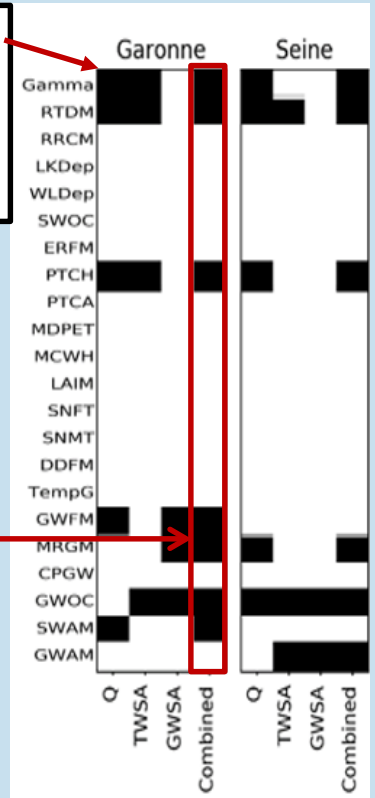
List of WGHM parameters

Acronym	Full name	Min	Max	Default
Gamma	Runoff Coefficient	0.3	3	0.7
RTDM	Root Depth Multiplier	0.5	3	1
RRCM	River Roughness Coefficient Multiplier	1	5	3
LKDep	Lake Depth	1	20	5
WLDep	Wetland Depth	1	20	2
SWOC	Surface Water Outflow Coefficient	0.001	0.1	0.01
ERFM	Evaporation Reduction Factor Exponent Multiplier	0.33	1.5	1
NRDM	Net Radiation Multiplier	0.5	2	1
PTCH	PT-Coefficient - Humid	0.885	1.65	1.26
PTCA	PT-Coefficient - Arid	1.365	2.115	1.74
MDPET	Max Daily PET	6	22	15
MCWH	Maximum Canopy Water Height	0.1	1.4	0.3
LAIM	LAI Multiplier	0.2	2.5	1
SNFT	Snow Freeze Temperature	-1	3	2
SNMT	Snow Melt Temperature	-3.75	3.75	0
DDFM	Degree Day Factor Multiplier	0.5	2	1
TempG	Temperature Gradient	0.001	0.01	0.006
GWFM	Groundwater Factor Multiplier	0.3	3	1
MRGM	Maximum Groundwater Recharge Factor Multiplier	0.3	3	1
CPGW	Critical Precipitation for GW - Arid Zone	2.5	20	12.5
GWOC	Groundwater Outflow Coefficient	0.001	0.02	0.01
SWAM	Net Surfacewater Abstraction Multiplier	-2	2	1
GWAM	Net Groundwater Abstraction Multiplier	-2	2	1
PrecipM	Precipitation Multiplier	0.5	2	1

Sensitivity analysis

Black boxes: Sensitive to Q (runoff), TWSA (total water storage) and GWSA (groundwater)

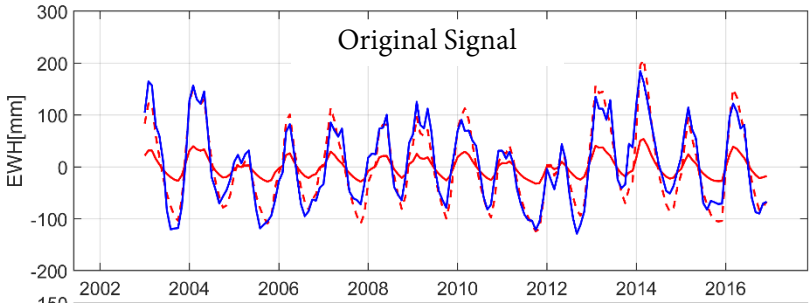
Combined: Selected parameters for calibration

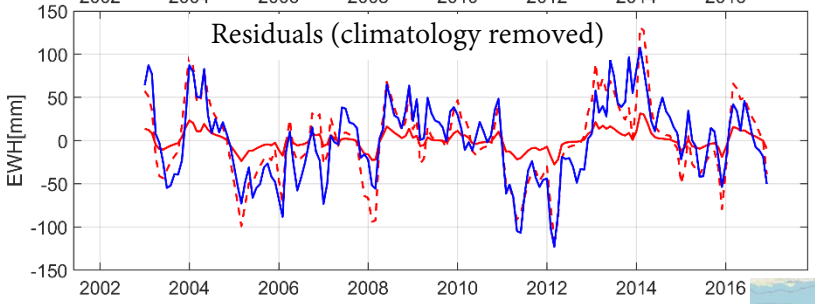


Results: Groundwater storage

Garonne basin average

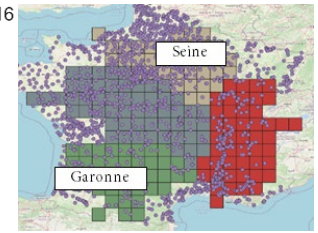
WGHM — in-situ — WGHM calibrated
WGHM scaled — WGHM calibrated scaled





= scaled WGHM GW storage

Correlation	WGHM
Original	0.94
Residuals	0.86



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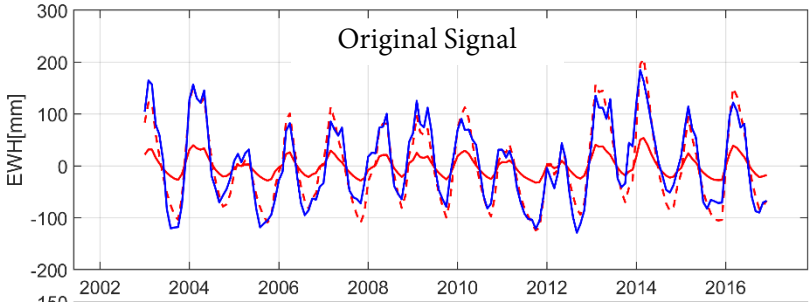

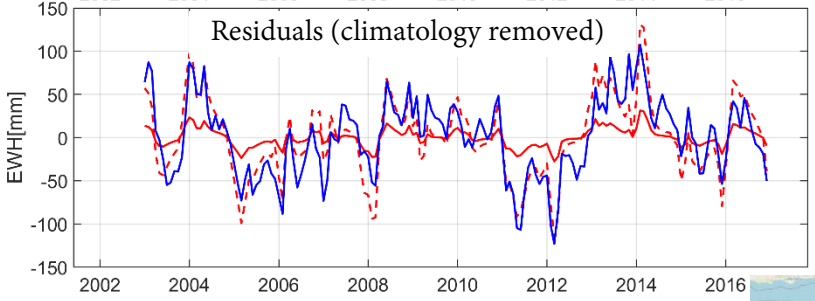

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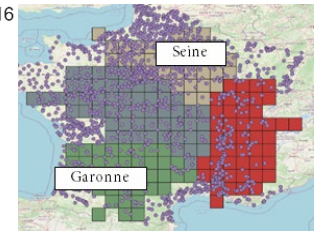

Very good correlation between model an in-situ data

- Both in the original time series…
- …and in the residuals (after removing climatology).

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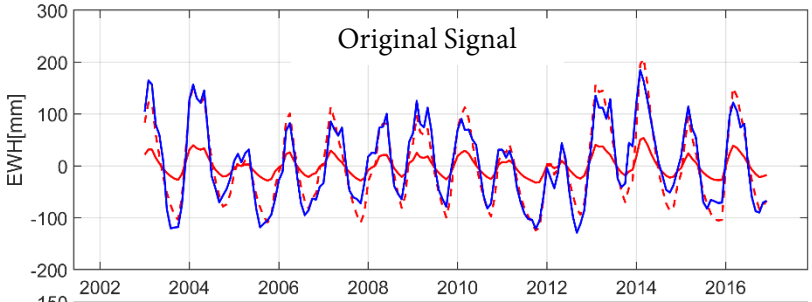

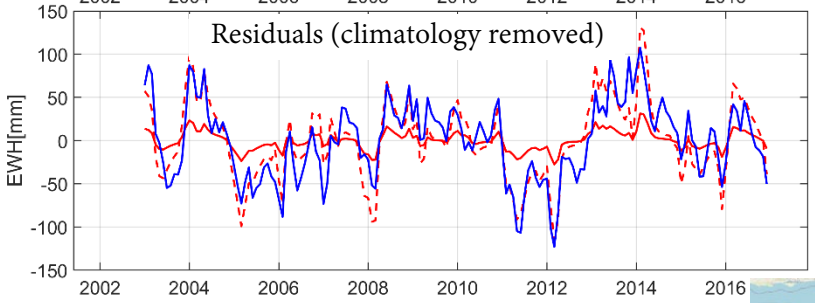

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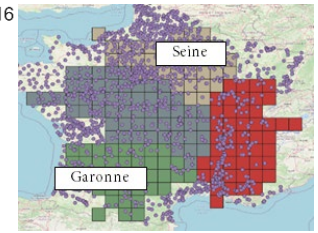

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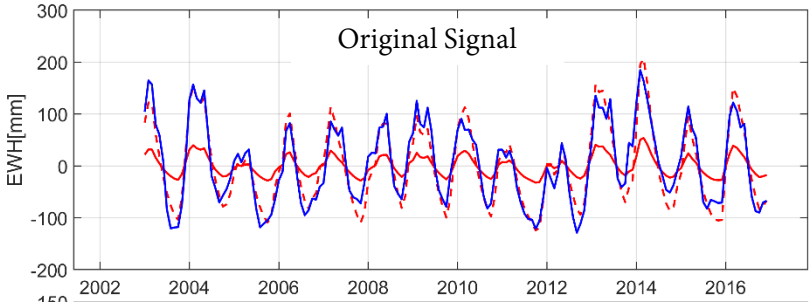

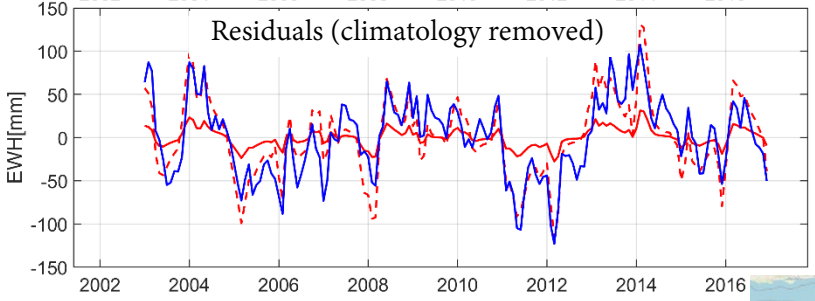

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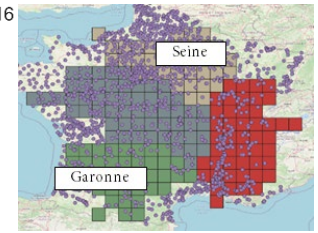

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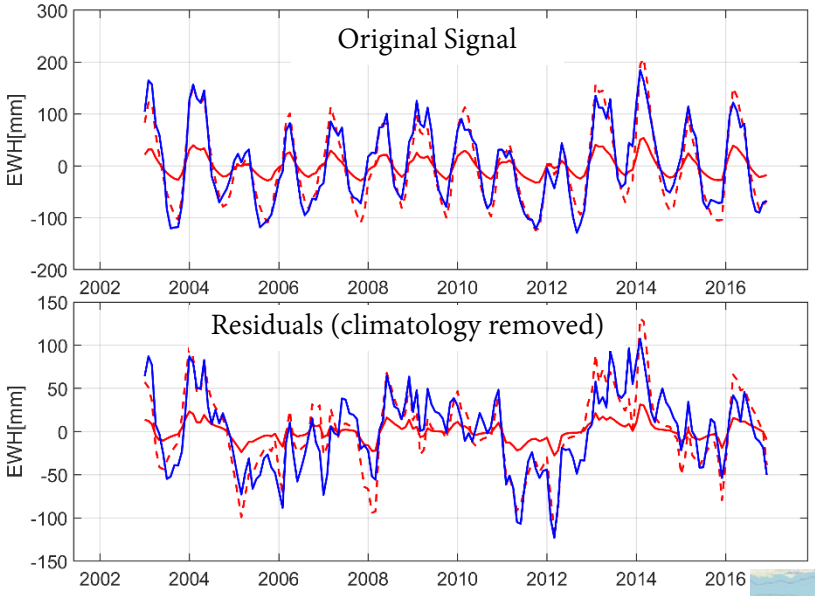

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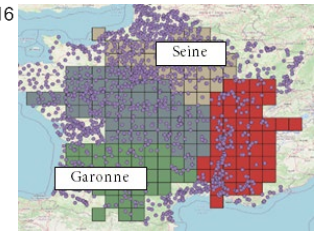

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Possible reasons for larger variability of in-situ data

- using porosity to convert from level to storage over-estimates storage
- spatial distribution of boreholes in productive aquifers
- spatial extent of aquifers not considered for basin averaging

Results: Groundwater storage

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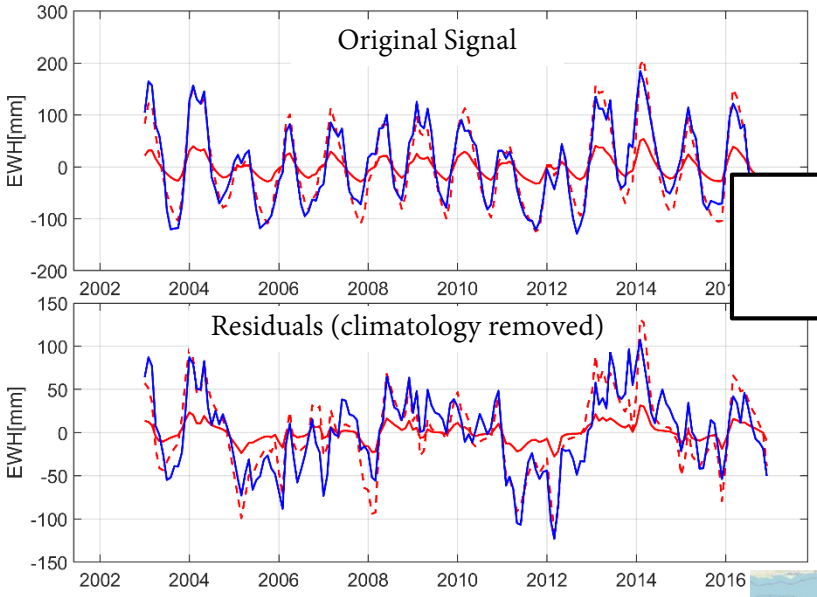
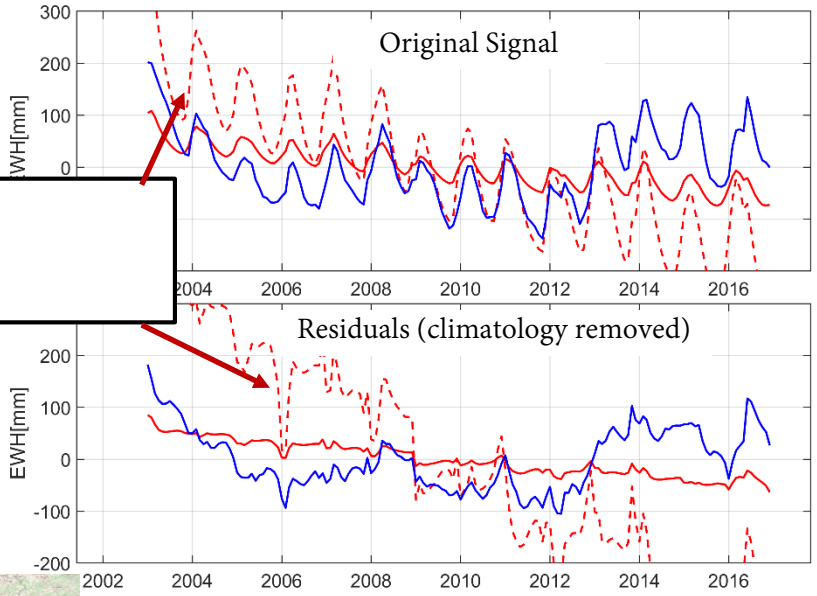
WGHM
scaled
in-situ
WGHM calibrated
scaled

Seine basin average





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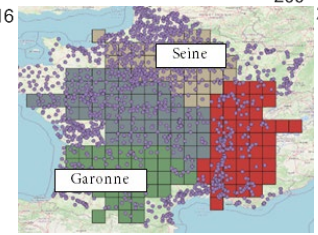

Correlation	WGHM
Original	0.38
Residuals	0.14

Results: Groundwater storage

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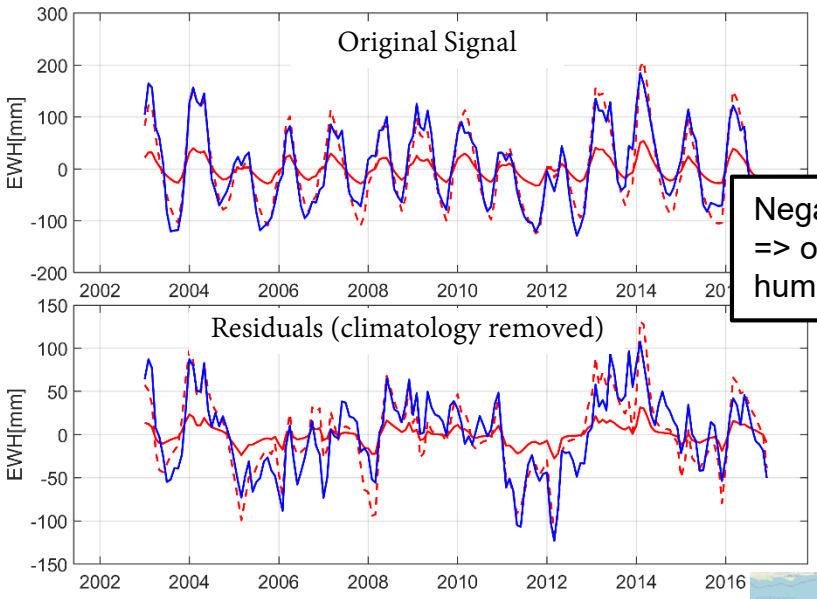
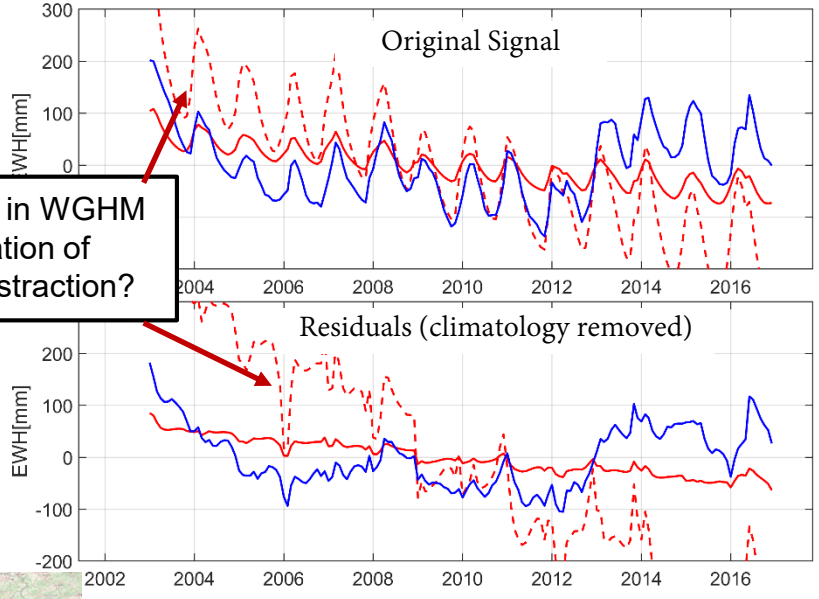
Seine basin average





Negative trend in WGHM
=> over-estimation of
human GW abstraction?

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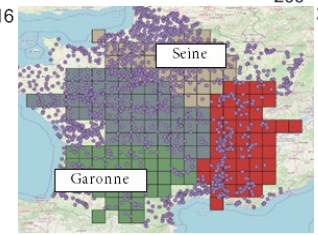

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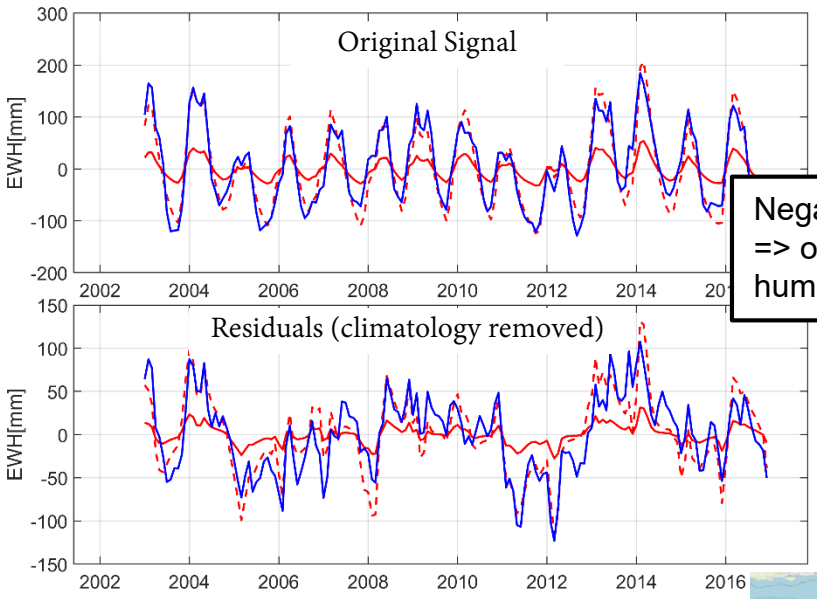

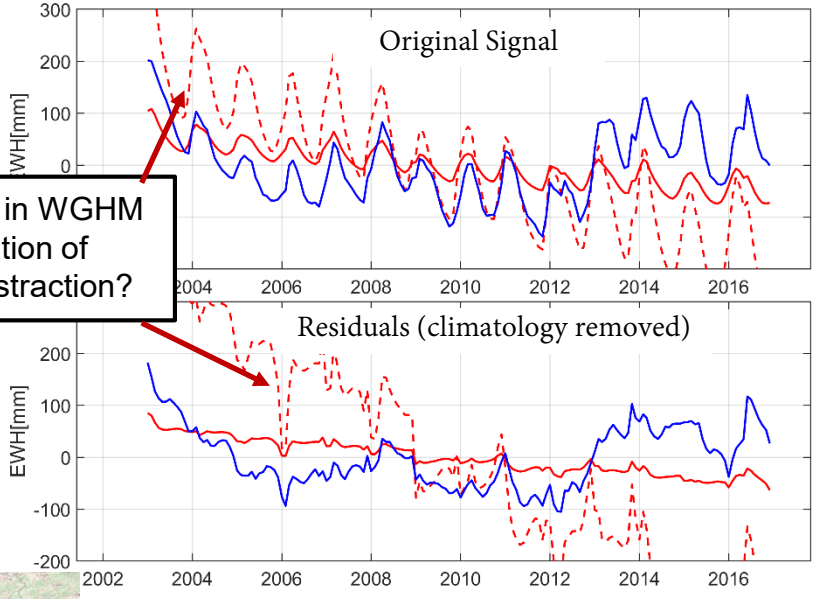

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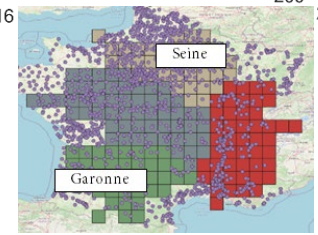

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Low
correlation

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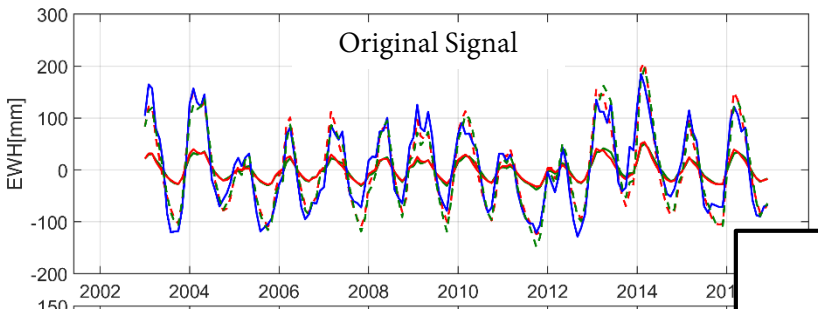

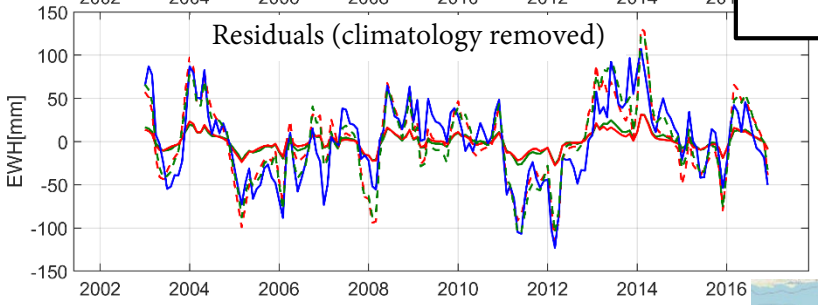

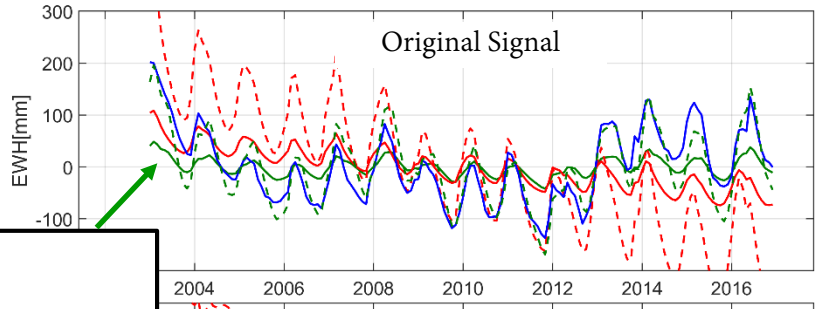

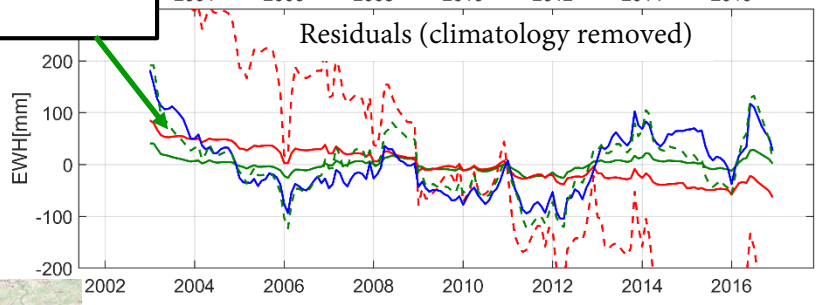

Correlation	WGHM	calibrated
Original	0.94	0.94
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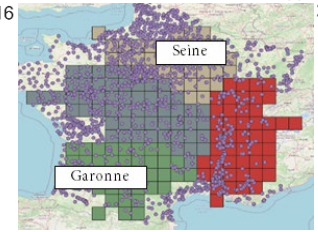

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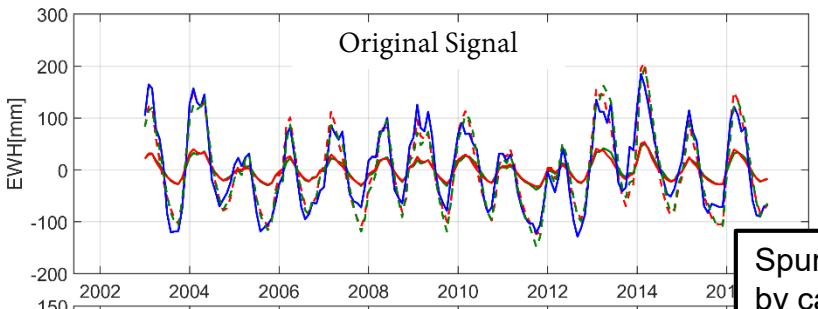
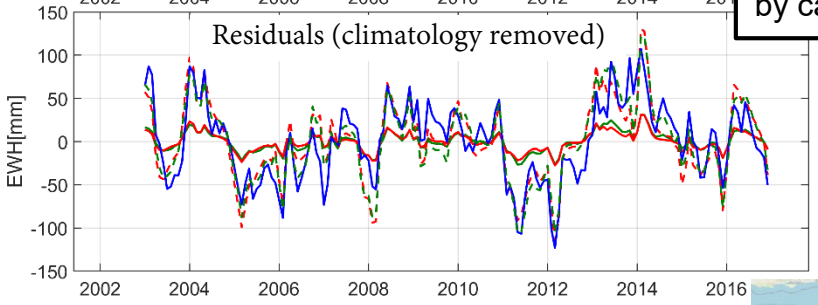
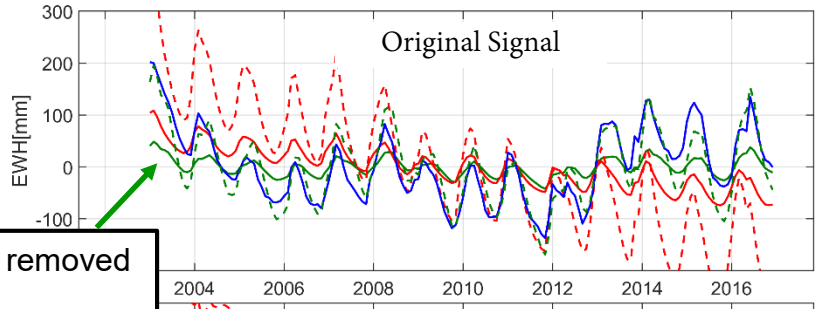
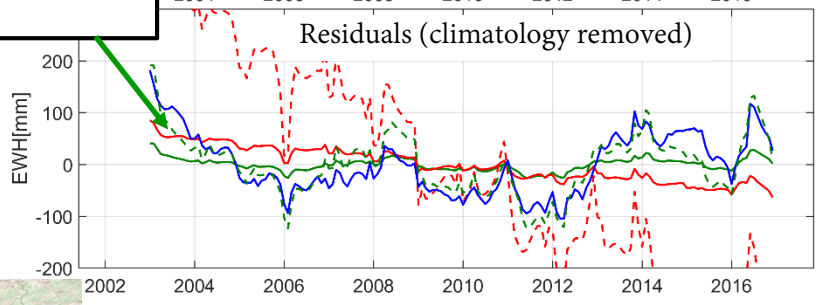






Spurious trend removed by calibration



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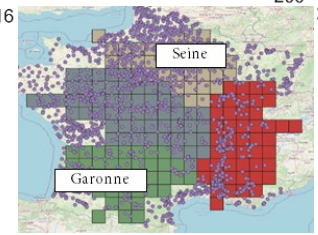
Original	0.94	0.94
Residuals	0.86	0.89



Correlation	WGHM	calibrated
Original	0.38	0.89
Residuals	0.14	0.89

Take home messages

- We present **in-situ data groundwater storage in France** used for the validation of WGHM model output before and after model calibration.
- **Sensitivity analysis** reveals most sensitive paramters with respect to river discharge, total water storage and groundwater
- **Multi-criterial calibration of WGHM** using GRACE total water storage anomalies and river discharge carried out for Garonne and Seine river basins.
- **Calibration removes spurious groundwater trend** in the Seine basin, which was likely due to overestimated groundwater use in the standard version.
- Higher groundwater storage amplitudes of in-situ data might be due to
  - using porosity to convert from level to storage over-estimates storage
  - spatial distribution of boreholes in productive aquifers
  - spatial extent of aquifers not considered for basin averaging

  => To be further investigated.