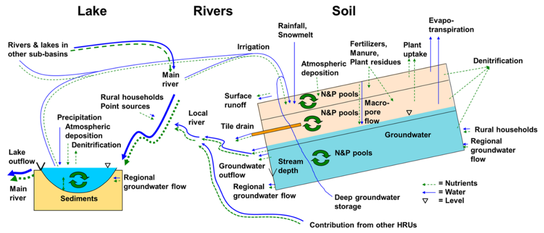
Accounting for discharge simulation performances and observation quality for modelling sediment at global scale

Alban de Lavenne, Alena Bartosova, Johan Strömqvist and Berit Arheimer
SMHI, Norrköping, Sweden (alban.delavenne@smhi.se)

Water quality modelling is very often constrained beforehand by the performance of discharge modelling. When the model is set up at global scale, this discharge performance and observations data quality usually greatly varies in space. This work proposed a calibration strategy that aims to address this issue.

WW-HYPE hydrological model



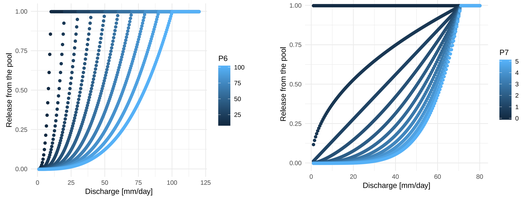
A simple sediment module

We extend the WW-HYPE model *(http://hypeweb.smhi.se)* recently set up at a global scale *(Arheimer et al. 2019)* to simulate sediment fluxes. We calculate eroded particles from soil based on HBV-sed model using erosion index, slope and rainfall:

$$MSed = Slope^{P1_G} \times Prec^{P2_G} \times P3_G \times P4_L \times P5_S$$

Parameters: General ($P1_G$,$P2_G$, $P3_G$), land use ($P4_L$) soil ($P5_S$).

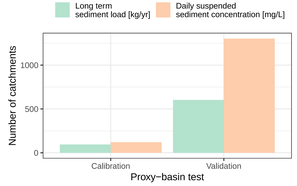
After the detachment, those particles are stored in a pool and released to surface waters using two additional parameters ($P6_G$ and $P7_G$).



A multi-objective calibration strategy

The dataset

Two measurement types:
- S_L: long term average sediment load [kg/yr]
- S_C: daily suspended sediment concentration [mg/L]



Original dataset: GLORICH, Vanmaercke et al. (2014), Land2Sea database (Peucker-Ehrenbrink Bernhard, 2018) and FAO data.

Multi-objective optimisation

Calibration optimises one objective function per dataset:
- AKG : Weighted average of a rescaled KGE for S_C data:

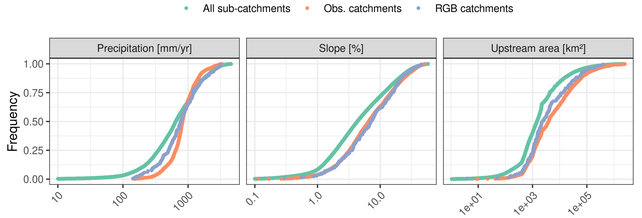
$$sum\ (\ w_i\ *\ KGE\ /\ (2\text{-}KGE)\ )\ /\ sum\ (w_i)$$

- SMB : Weighted average of a Rescaled Bias for S_L data:

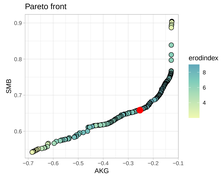
$$sum\ (\ w_i\ *\ |Sim\ -\ Obs\ |\ /\ (Sim\ +\ Obs)\ )\ /\ sum\ (w_i)$$

Selection of Representative Gauged Catchments

Representativeness of the different land use, rainfall and slope distribution, observation type, continent at global scale is maximised.

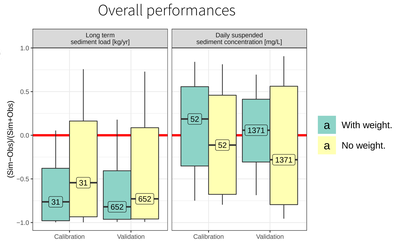


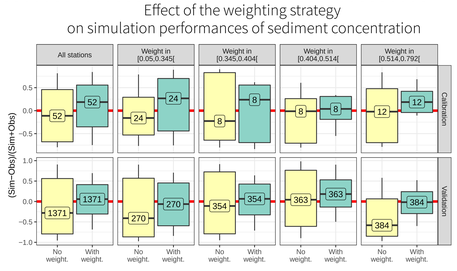
Parameter space is explored using caRamel R packages and one solution on the Pareto Front is selected geometrically using the shortest distance to the best value of both criteria.

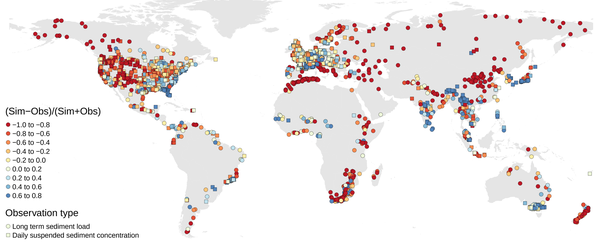


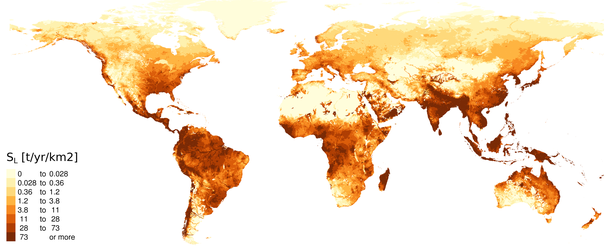
Model simulation results

- The proposed calibration strategy enables to improve the robustness of the model (better performances on validation sites)
- The model fits more easily sediment concentrations but underestimates sediment loads overall







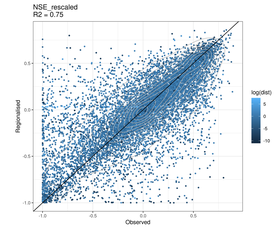


Evaluation of the monitoring stations

Regionalisation of discharge simulation performance

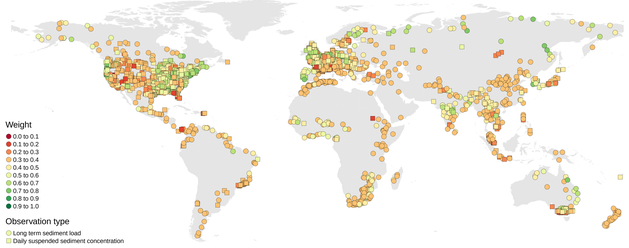
Because discharge observation is not always available at sediment monitoring stations, the C_{2M} criteria is estimated from the 5 neighouring gauged catchments weighted by the inverse Ghosh distance

C2M = NSE / (2-NSE)



Weighting of sediment monitoring stations

The weight w_i of each monitoring station is the average of 2 scores:
- a score on discharge simulation performance using regional C_{2M}
- a score on sediment data quality (based on the amount of data and representativeness of the station location by the model)



Conclusion

- The calibration strategy addresses the issue of data quality and lack of discharge simulation performance inherent to global scale modelling.
- An explicit awareness about how much each monitoring stations can be trusted for model calibration enables to improve model robustness.
- The multi-objective framework highlights discrepancy between concentration and loads estimates that still needs to be addressed.

References: *Arheimer et al. Global catchment modelling using World-Wide HYPE (WWH), open data and stepwise parameter estimation, Hydrol. Earth Syst. Sci. Discuss., in review, 2019.*

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