Multisource data assimilation on two different classes of coupled surface/subsurface hydrology and water quality models

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Hydrology and water quality modeling

Many models simulate interactions between surface and subsurface hydrology and reactive solute transport : ISSHMs, such as CATHY [1,2,3,4], or more conceptual models, such as PESHMELBA[5,6]

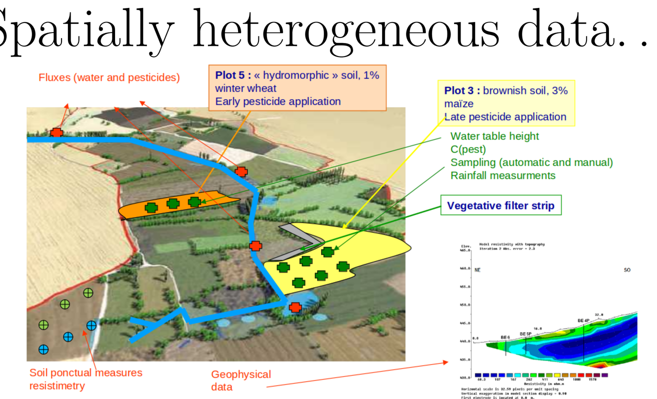
- based on nonlinear equations
- a large set of spatialized parameters
- many processes affecting pesticide transfer not (well) represented

⇝ **need for uncertainty quantification and reduction**

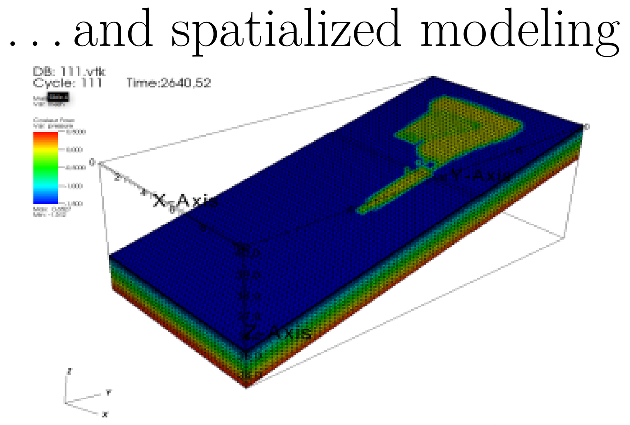
- in situ data on pesticides in a catchment are rare and heterogenous
- satellite images well describe data in space, but only water related

⇝ **very difficult to get the pesticides dynamics in situ**

Spatially heterogeneous data. . .



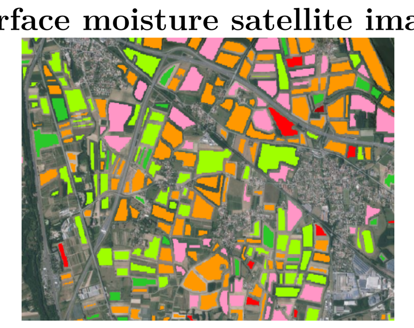
. . . and spatialized modeling



Coupled Data Assimilation techniques to:
- improve pesticide fluxes simulation
- estimate spatialized hydr. characteristics and other param.
- reduce the uncertainty (interactions, lack of knowledge, . . .)

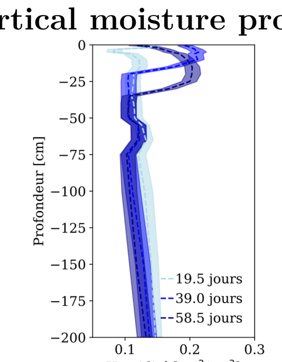
Multisource data on the Morcille catchment

Surface moisture satellite images



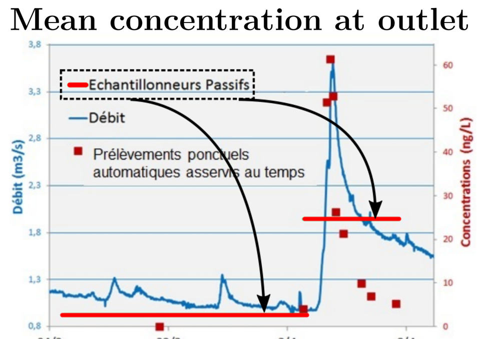
✓ Inversion of Sentinel1/Sentinel2 data (El Hajj et al., 2017)
✓ One value per plot
✓ Freq. = 6 days

Vertical moisture profiles



✓ TDR probe or ERT measures
✓ Ponctual (time and space)

Mean concentration at outlet

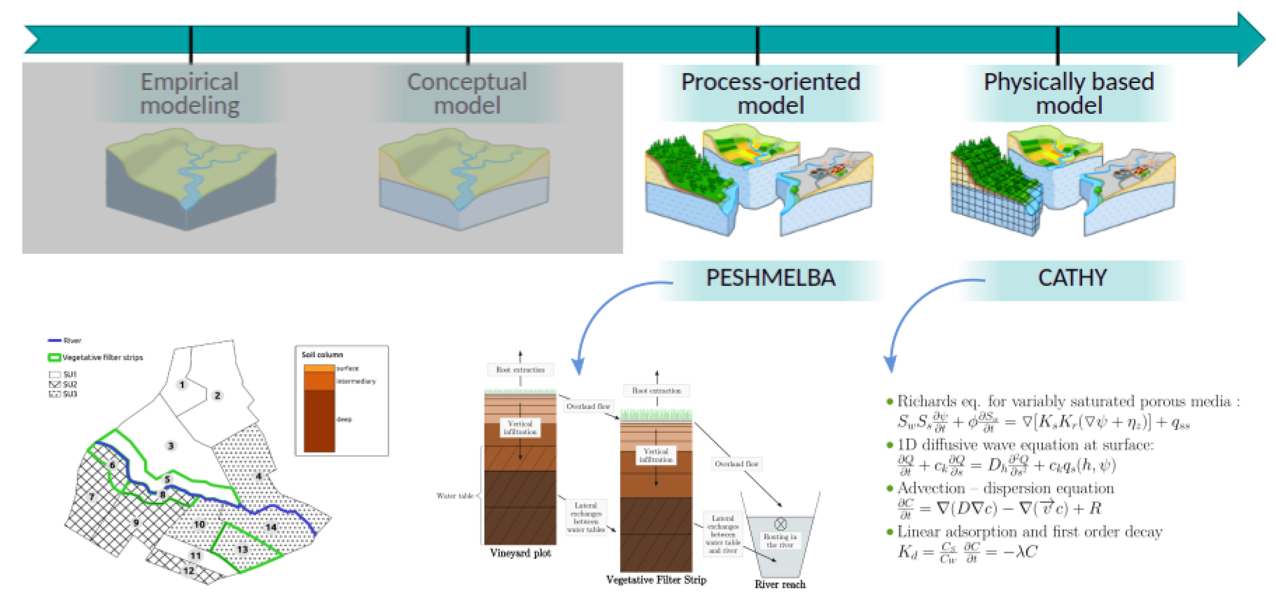


✓ Passive samplers for example
✓ Variable period of integration

References

[1] Camporese, M. et al., 2010. 10.1029/2008WR007536 [2] Weill, S. et al., 2011. 10.1016/j.advwatres.2010.10.001 [3] Gatel, L. et al., 2019. 10.3390/w12010121 [4] Gatel, L. et al., 2019b. 10.1016/j.envsoft.2018.12.006 [5] Rouzies et al., 2019. 10.1016/j.scitotenv.2019.03.060 [6] Rouzies et al., 2023. 10.5194/gmd-16-3137-2023 [7] Rouzies et al., 2025. 10.5194/hess-2024-219 [8] Emerick & Reynolds, 2013. 10.1016/j.cageo.2012.03.011

Process-oriented vs physically based model



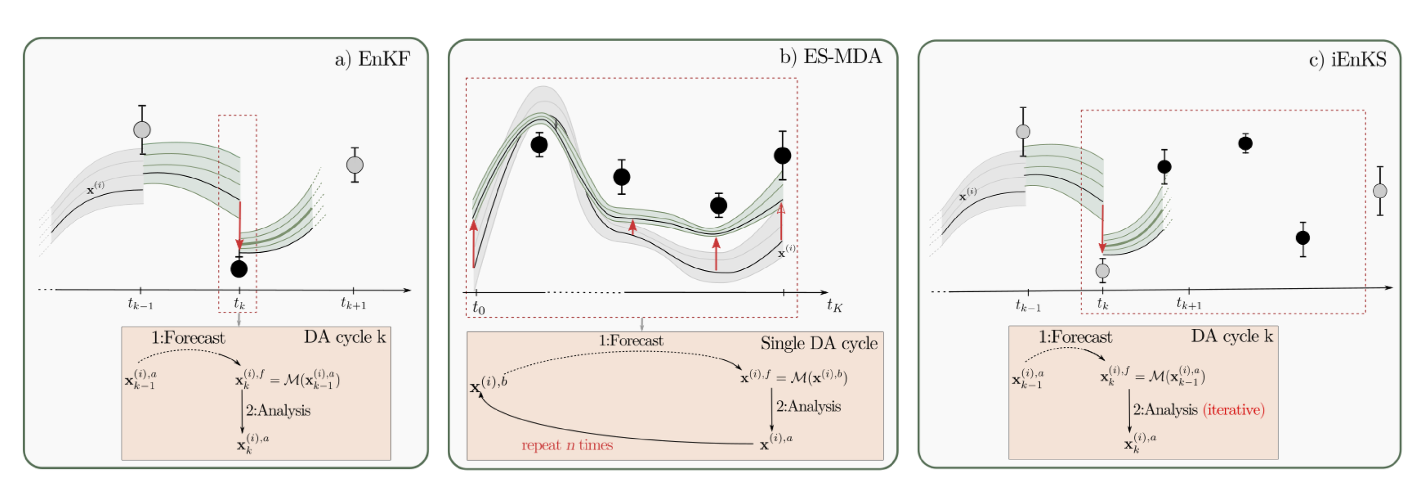
GSA indicates a significant impact of hydrodynamic characteristics on solute transfer in both models [4,5]. It will be important however to explore the influence of critical differences between the models :

- ≠ in **meshing**: nonuniform landcape units at coarse spatial discretization vs. uniform and much finer resolution (DEM cells)
- ≠ in **process** representation and coupling (water, solutes) => can lead to more/less unsteady or unstable numerical behaviors
- ≠ in **coupling** methods for surface/subsurface and vertical/lateral exchanges => can lead to contrasting surface/subsurface correlations, thus affecting surface DA impact on deep soil
- ≠ in model and obs. **error** definitions needed to solve the DA problem

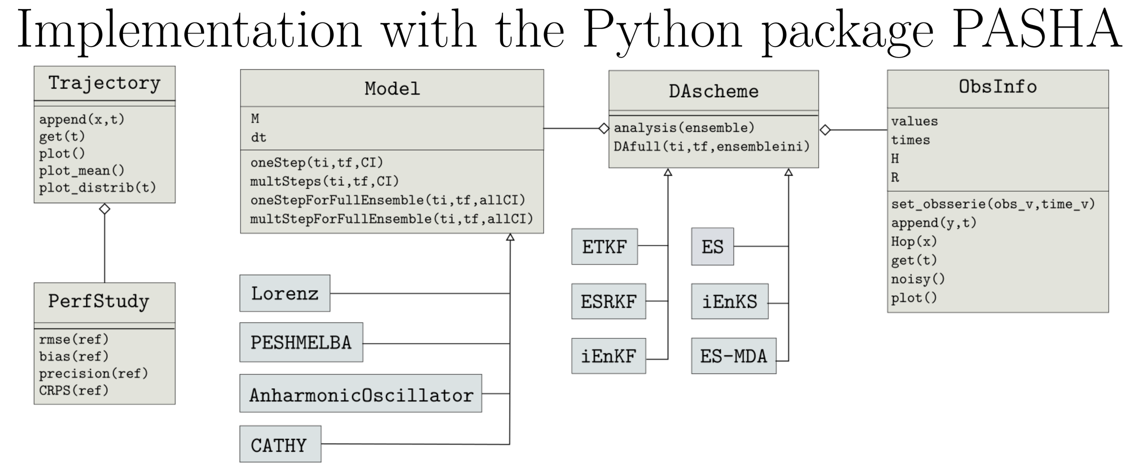
⇝ **Key Question:** How does modeling approach affect data assimilation?

⇝ Use of consistent methods and setups to evaluate both models and assimilation techniques

Data assimilation methods



Implementation with the Python package PASHA



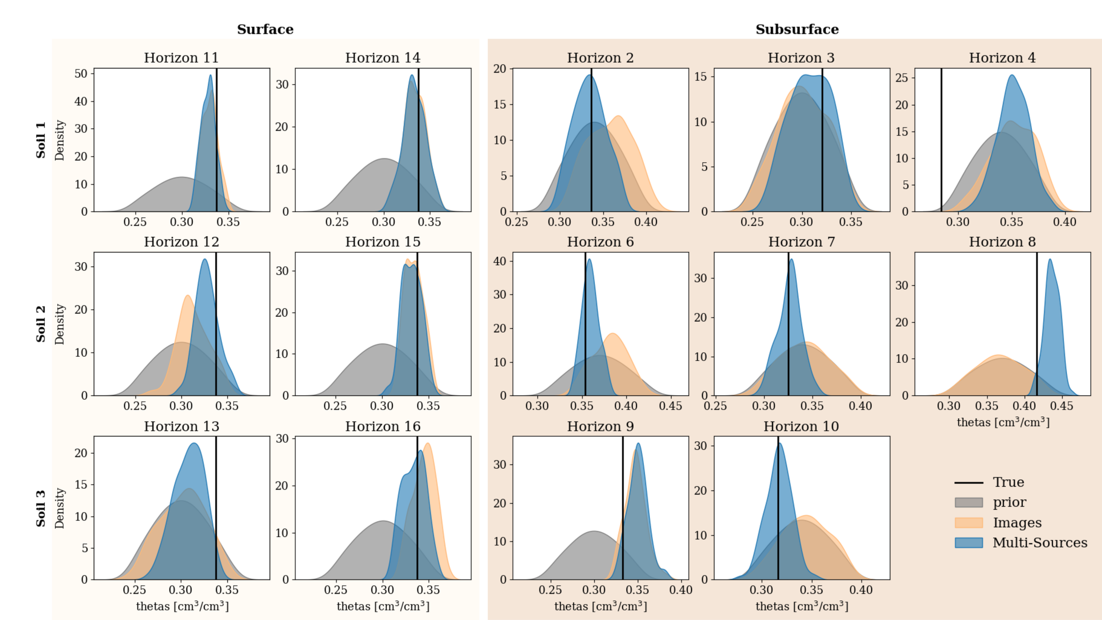
PASHA = PedAgogic StocHastic data Assimilation `https://forgemia.inra.fr/emilie.rouzies/pasha/`

Results: First DA tests with a simpler model

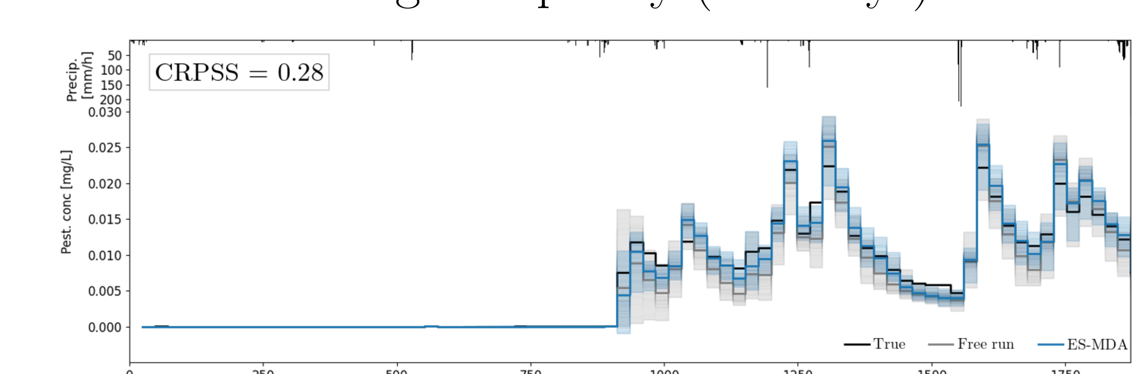
The framework was tested on PESHMELBA at the catchment scale [5], on several DA methods [7]: EnKF, ES-MDA, iEnKS

- spectrum of available ensemble methods (ens. filters, hybrid ens./var. smoothers and long window ens. smoothers)
- use the available observations in different ways.

⇝ **The most performant *in this context* is ES-MDA [8]**



- DA of **satellite surface moisture images** gives good correction of surface variables and parameters, but with a limited impact (or even negative) in the subsurface
- Adding **subsurface observations** improves moisture estimates at all depths on all plots of the same type
- Significant impact of assimilating **integrated concentration of pesticides** if data at high frequency (< 5 days) and accurate



⇝ **Strongy-coupled DA assimilation efficiently corrects pesticide concentration**

Conclusion

- Twin experiments provide answers to what can be estimated from which data, the sensitivity to obs. accuracy and frequency
- Multisource DA with a simpler model demonstrates the relevance to pesticide transfer ⇝ Next step : set the DA framework on CATHY
- How will DA methods behave on CATHY ? New virtual obs.?
- How to properly account for observation error correlations in image assimilation?