ASSIMILATING SATELLITE SOIL MOISTURE AND FLOOD EXTENT MAPS INTO A FLOOD PREDICTION MODEL.

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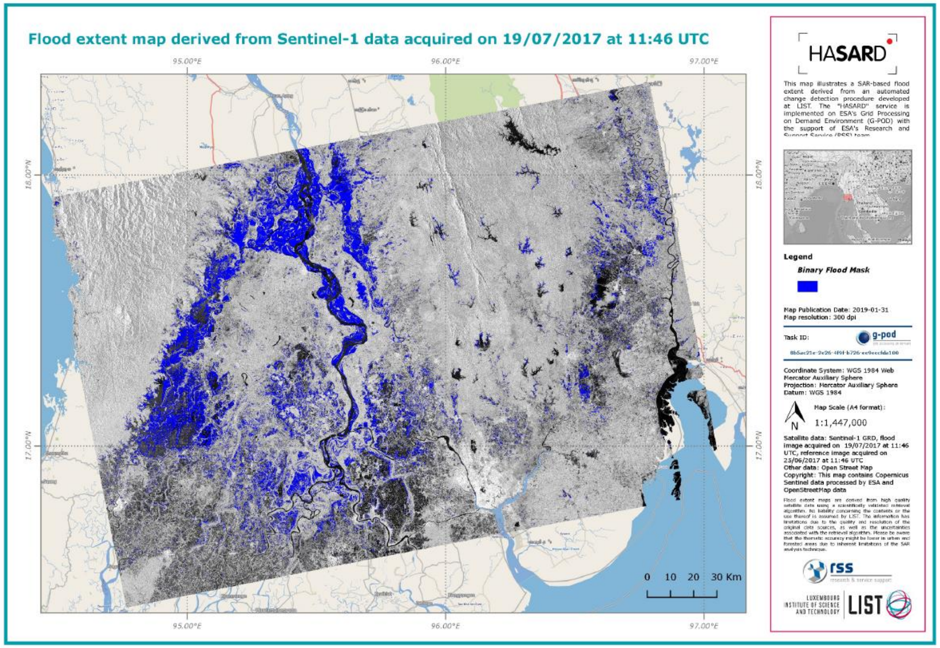
CONTEXT



A powerful tool for flood management and prediction: hydrological modelling

Need for observations to set up, calibrate and evaluate these models. Issues:

- Traditional observations are punctual (pb of representativeness).
- Observations are scarcely distributed and observation networks tend to be further reduced (e.g. stream gauges)
- Ground observations not always reliable during flood events.

=> Need for new observation techniques : good candidates : satellite SAR flood images, and satellite derived soil moisture products

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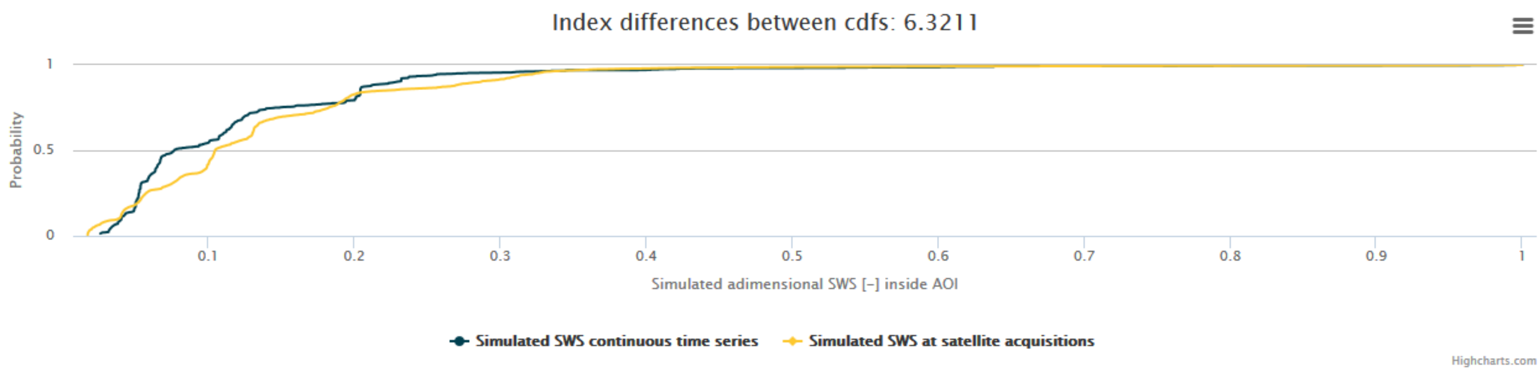
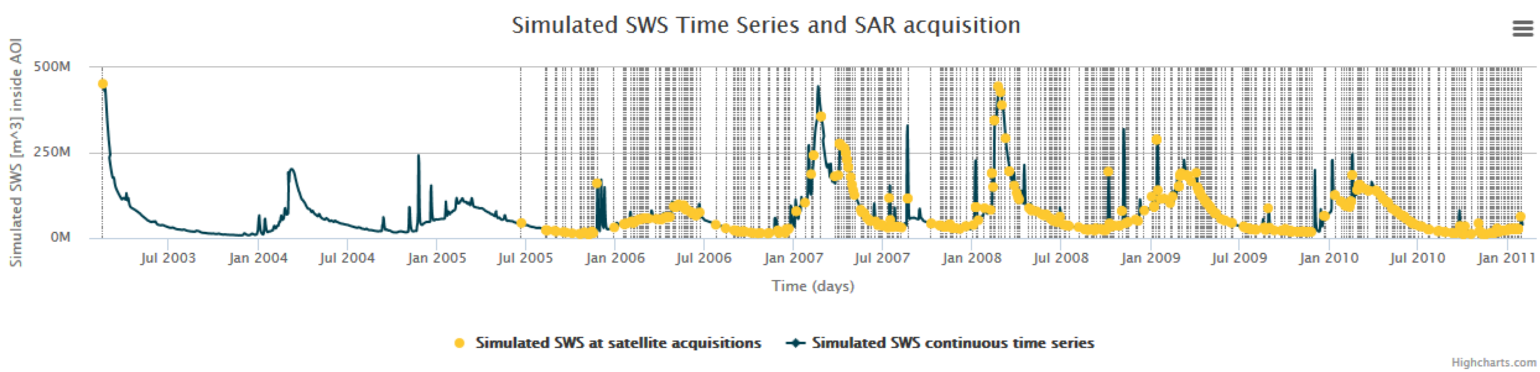
MORE AND MORE READILY AVAILABLE (RADAR) OBSERVATIONS

Day–Night-All weather acquisitions

Synoptic view of large areas





MORE AND MORE READILY AVAILABLE (RADAR) OBSERVATIONS

esa grid processing on demand

European Space Agency

Day–Night-All weather acquisitions

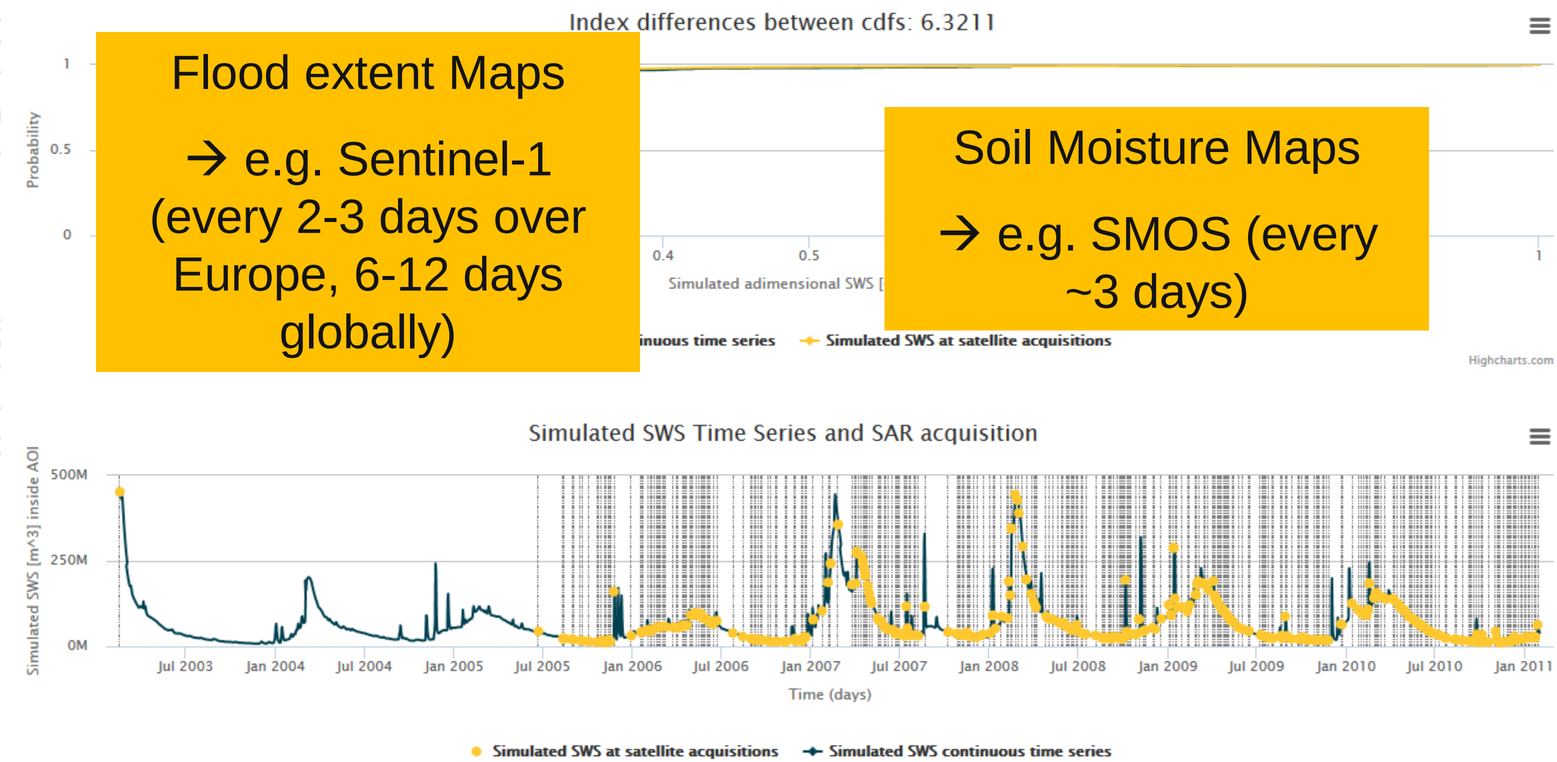
Synoptic view of large areas

Flood extent Maps

→ e.g. Sentinel-1 (every 2-3 days over Europe, 6-12 days globally)

Soil Moisture Maps

→ e.g. SMOS (every ~3 days)



Research question: Are these EO datasets sufficient for calibrating a distributed conceptual hydrological model ?

THE CONCEPTUAL HYDROLOGICAL MODEL

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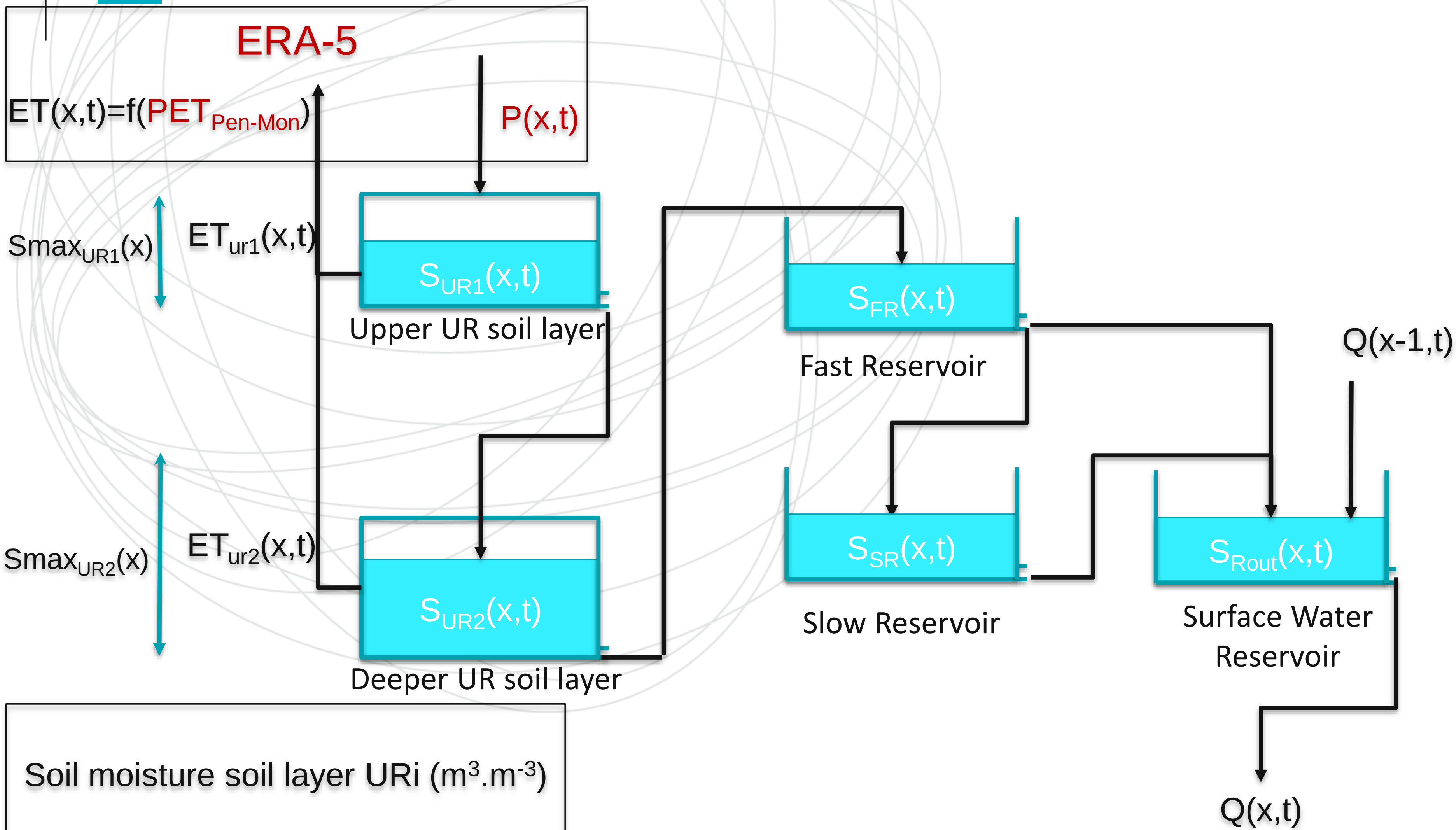
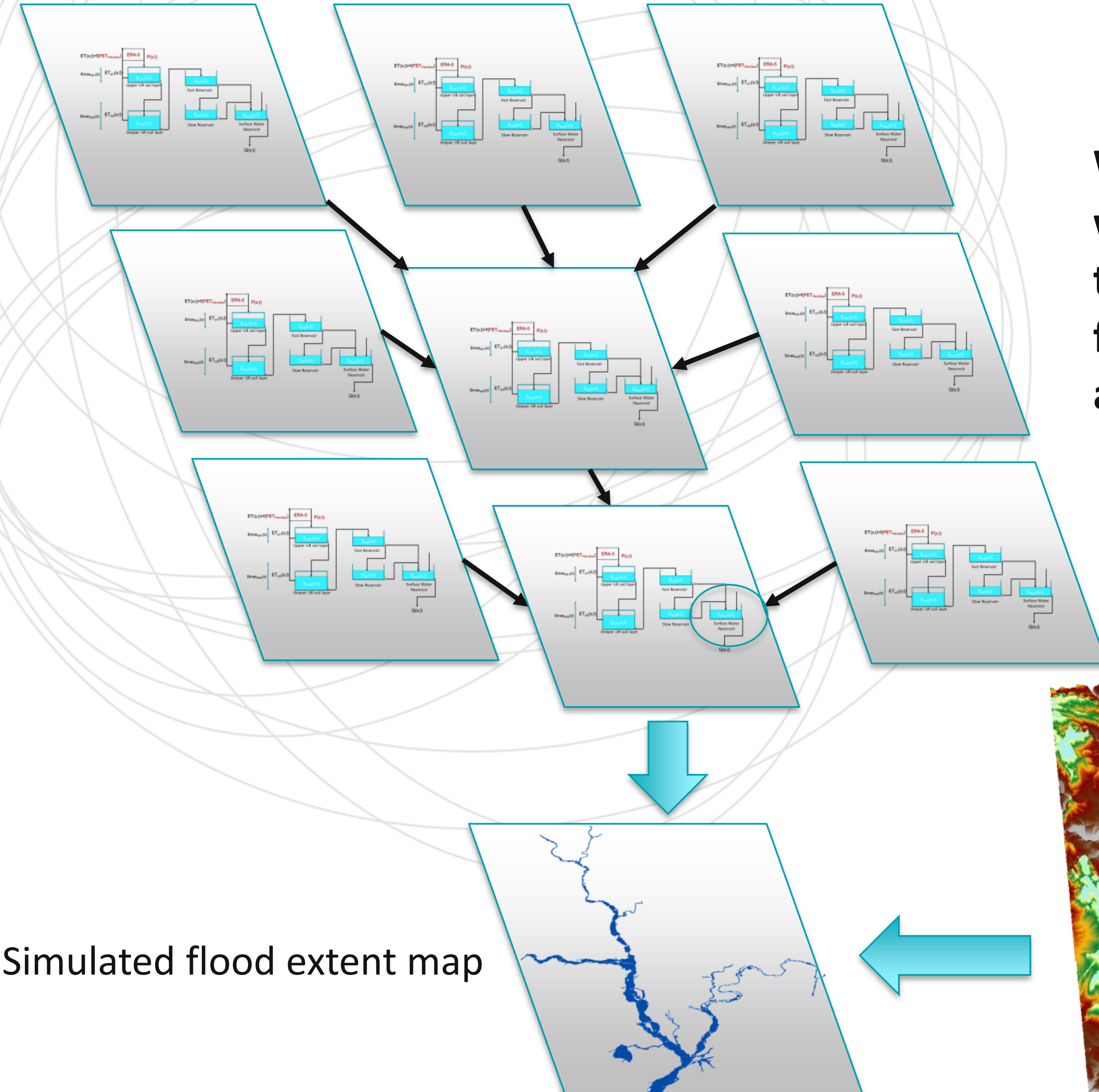
THE MODEL STRUCTURE



Soil moisture soil layer URi ($m^3.m^{-3}$)

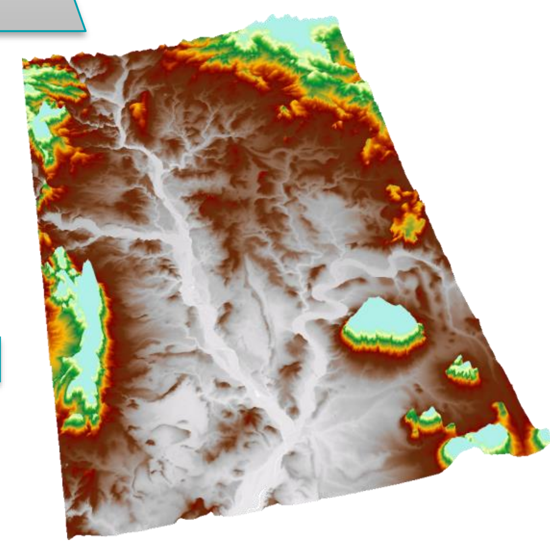
$$SM_{uri} = EFC_{uri} * S_{uri}/Smax_{uri}$$

THE MODEL STRUCTURE



We distribute Surface water volume over topography to obtain flood extent maps and flooded area

Topography information



Simulated flood extent map

ASSIMILATION DESIGN

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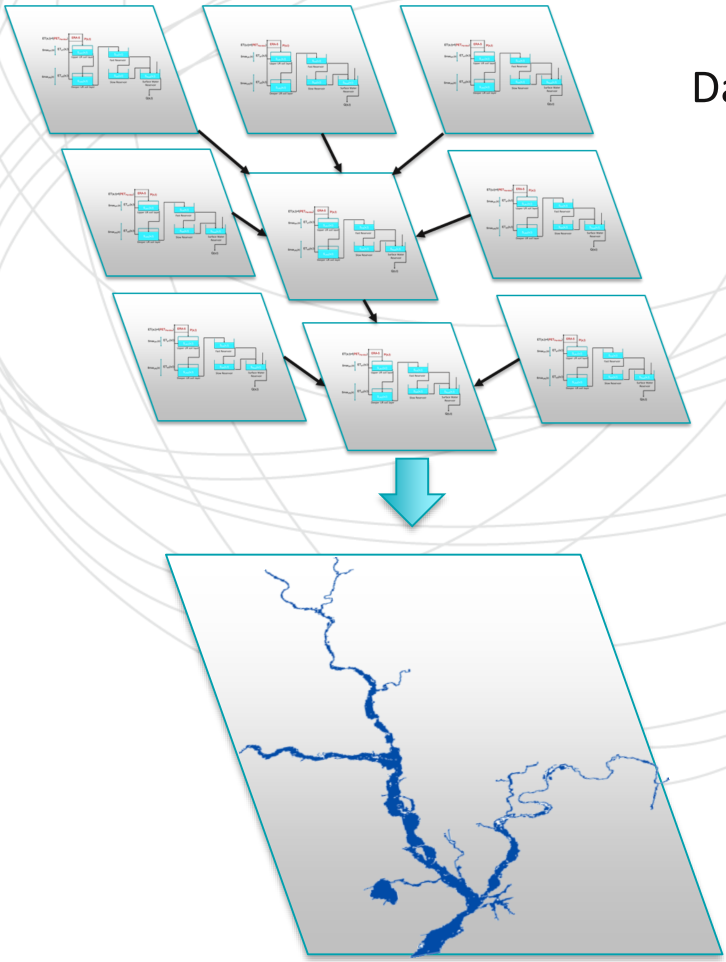
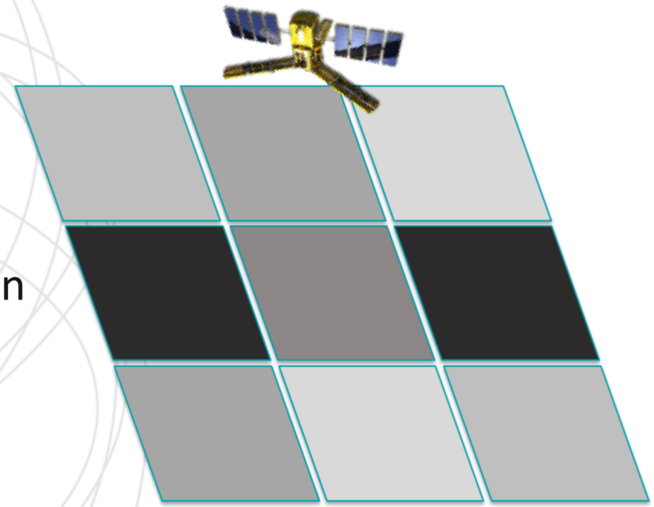
ASSIMILATION DESIGN: THE OBSERVATION

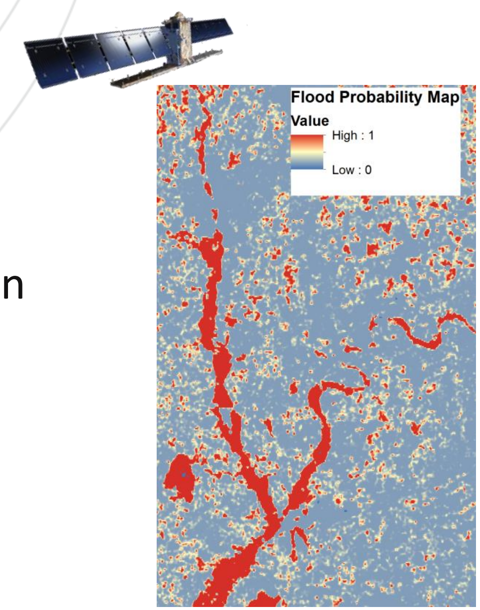


Data Assimilation



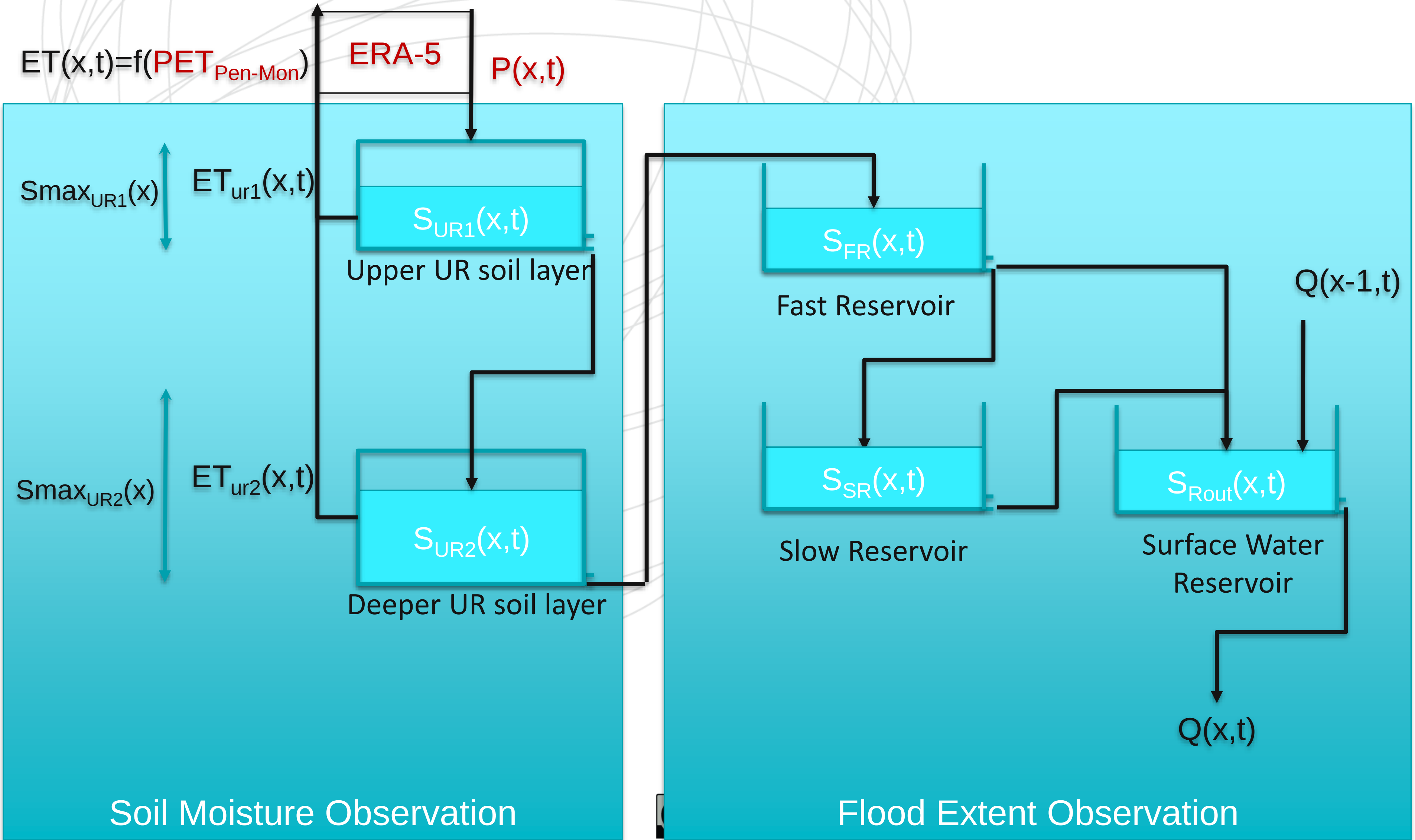
Satellite soil moisture maps

Data Assimilation



Satellite flood extent maps

THE ASSIMILATION DESIGN
PARAMETER UPDATING STRATEGY



THE ASSIMILATION DESIGN: A TEMPERED PARTICLE FILTER

Bayes Theorem: $$\boldsymbol{p(\theta|o)} = \frac{\boldsymbol{p(o|\theta)}}{\boldsymbol{p(o)}}\boldsymbol{p(\theta)} = \prod_{n=1}^{K} \frac{\boldsymbol{p(o|\theta)^{\varphi_n-\varphi_{n-1}}}}{\boldsymbol{p(o)}}\boldsymbol{p(\theta)}$$

$$0=\varphi_0 < \varphi_1 < \varphi_2 < \cdots < \varphi_K = 1$$

First Guess (32 random parameter sets)

↓

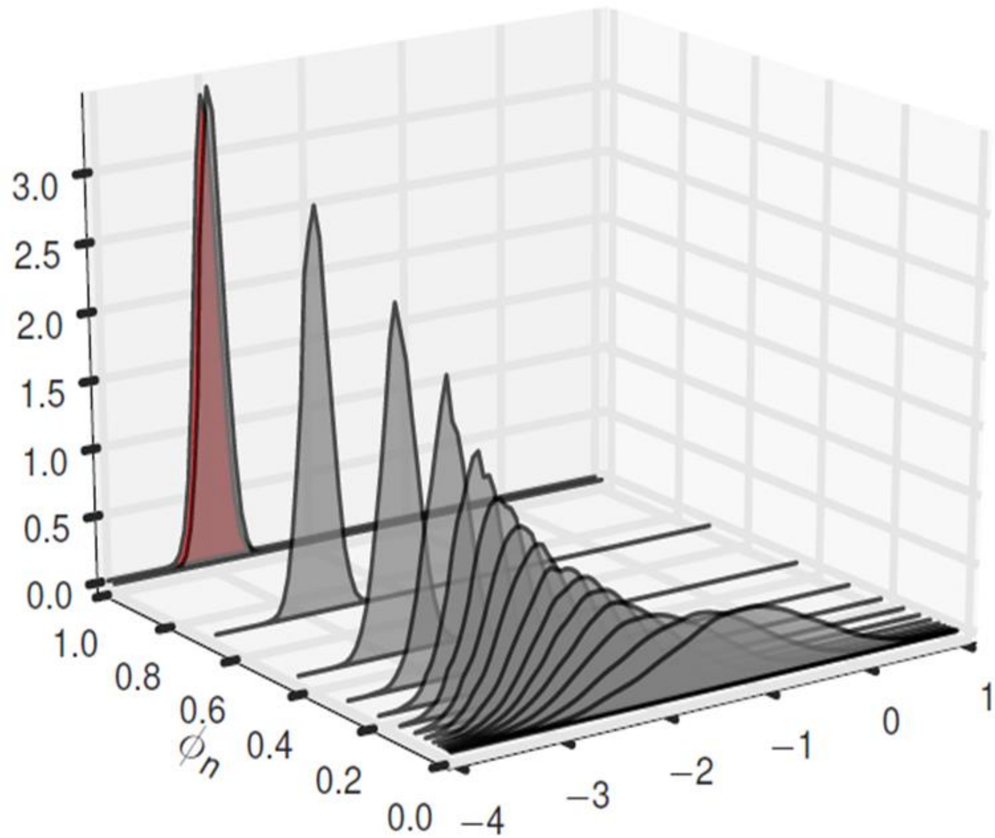
Particle weight computation using φ_1-φ_0 (φ_1 so that Neff=N/2)

↓

Particle Resampling

↓

Particle mutation using a Random Walk Metropolis Hasting algorithm



After Herbst et al., 2019

THE ASSIMILATION DESIGN: A TEMPERED PARTICLE FILTER

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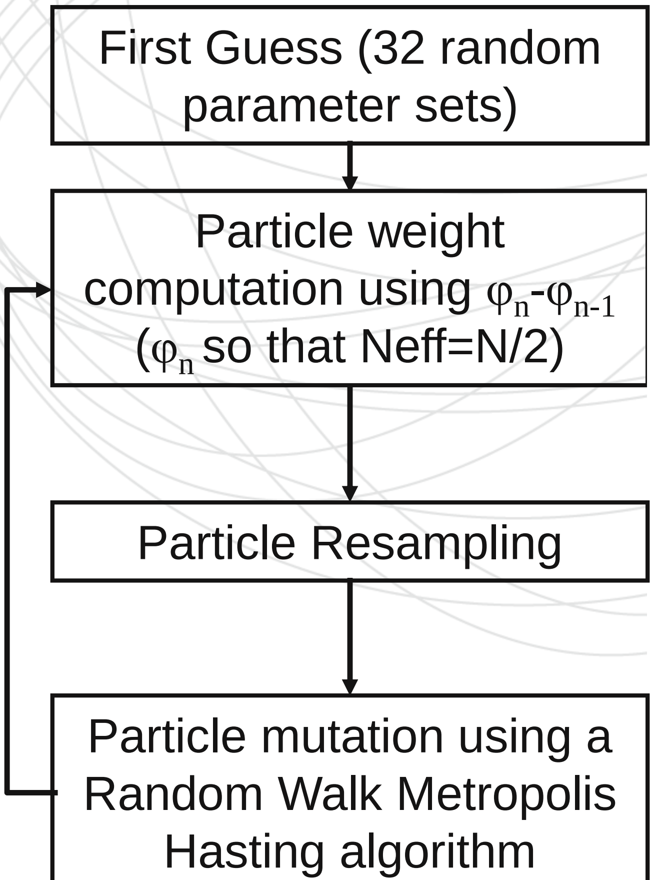

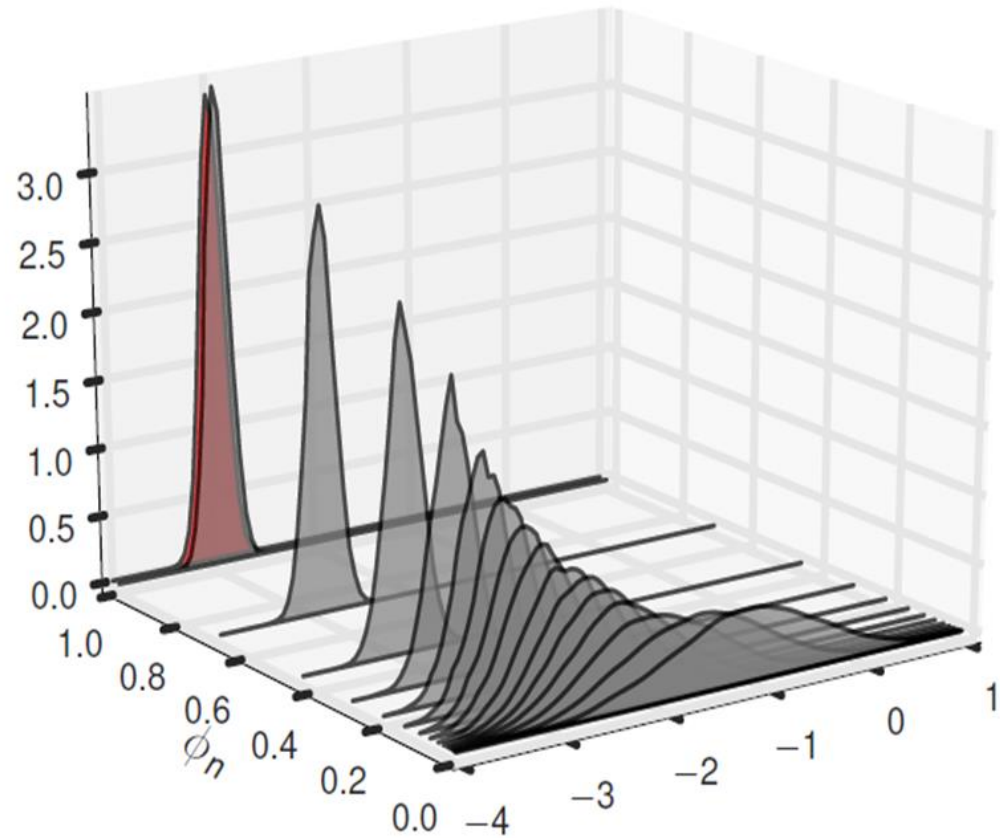

After Herbst et al., 2019

SYNTHETIC TWIN EXPERIMENTS

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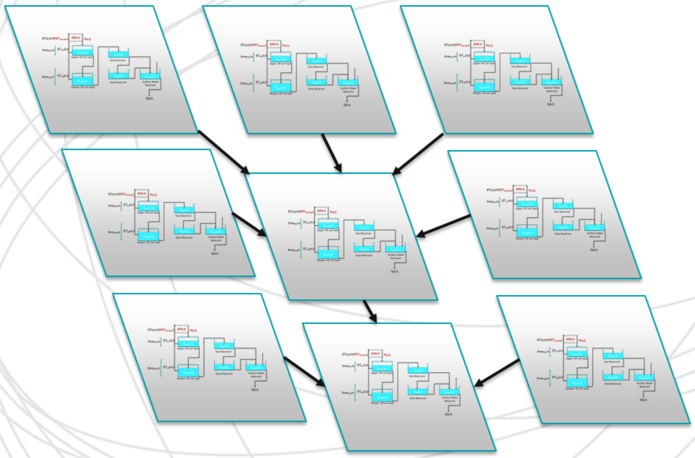
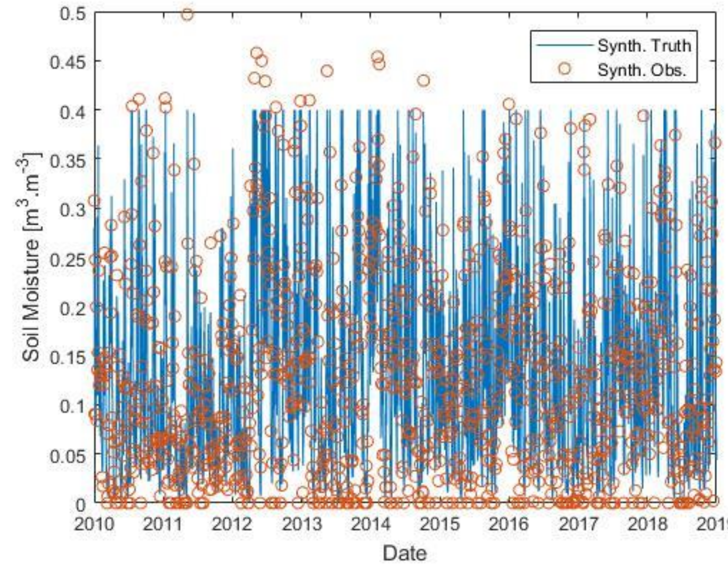
SYNTHETIC TWIN EXPERIMENTS: SYNTHETIC TRUTH AND OBSERVATION

Model forward run (9 years, hourly)



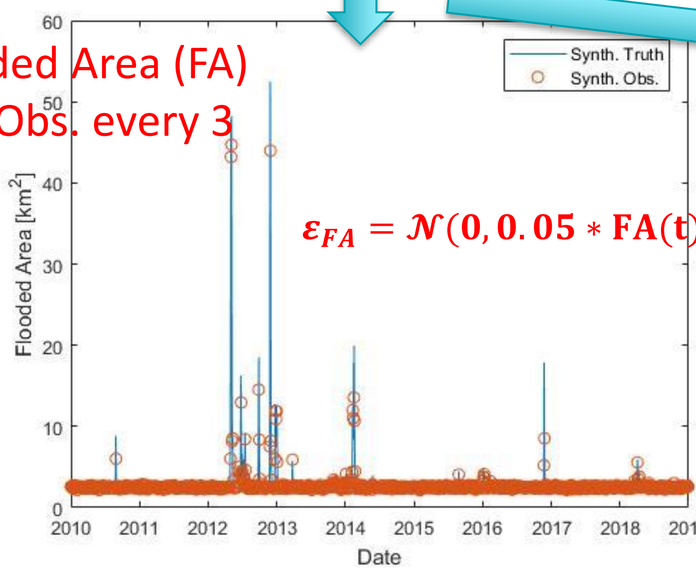
Soil moisture (SM): One Obs. every 3 days

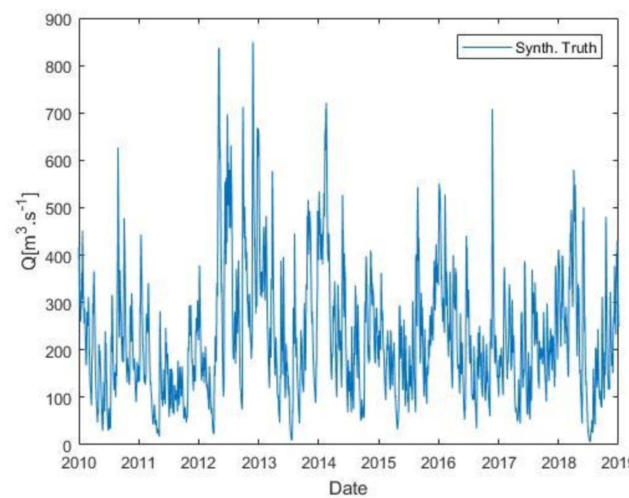


$\varepsilon_{SM} = \mathcal{N}(0, 0.04)$

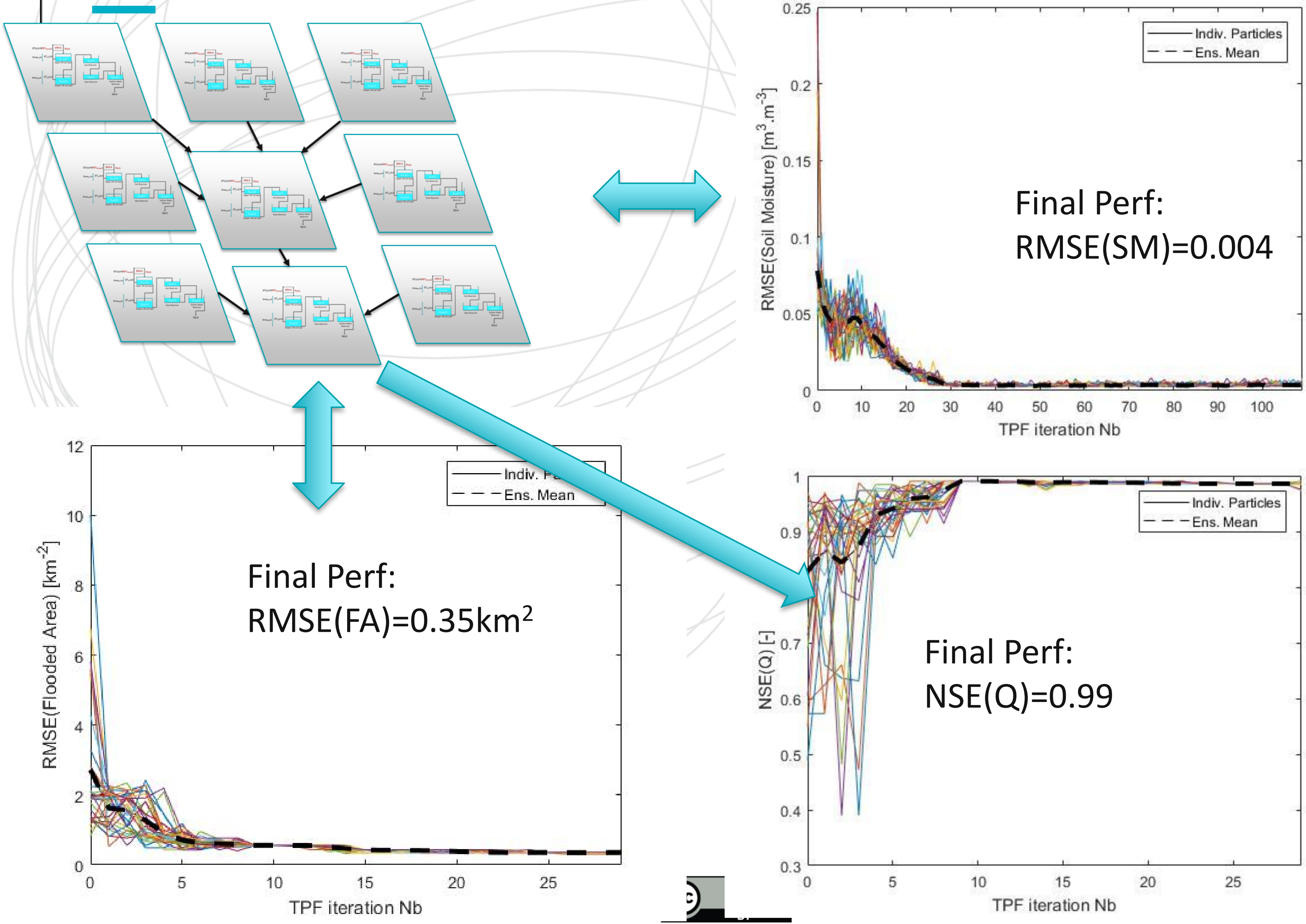
Flooded Area (FA)
One Obs. every 3 days

$\varepsilon_{FA} = \mathcal{N}(0, 0.05 * \mathrm{FA}(t))$

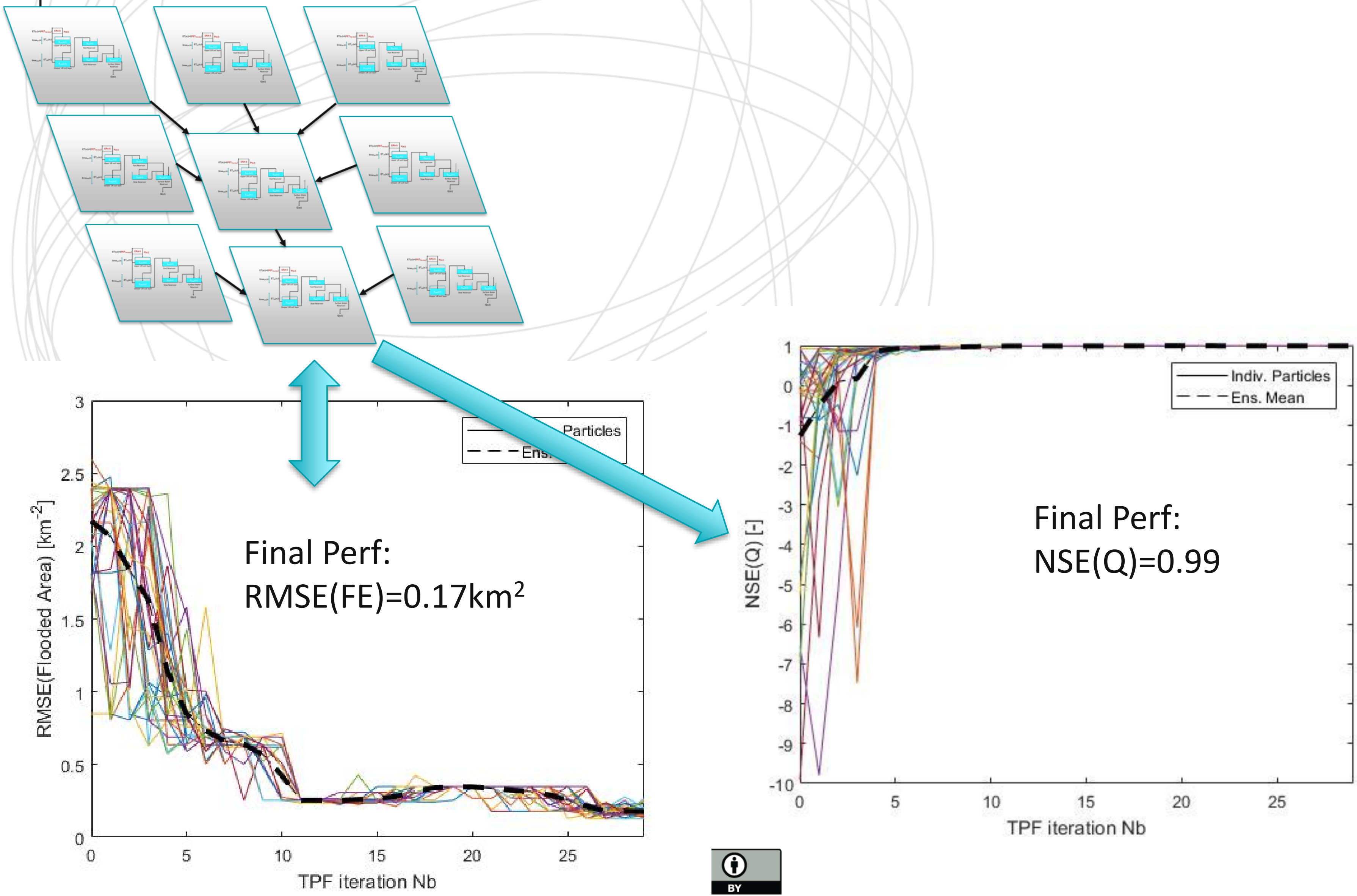




SYNTHETIC TWIN EXPERIMENTS: MODEL CALIBRATION USING SM+FA

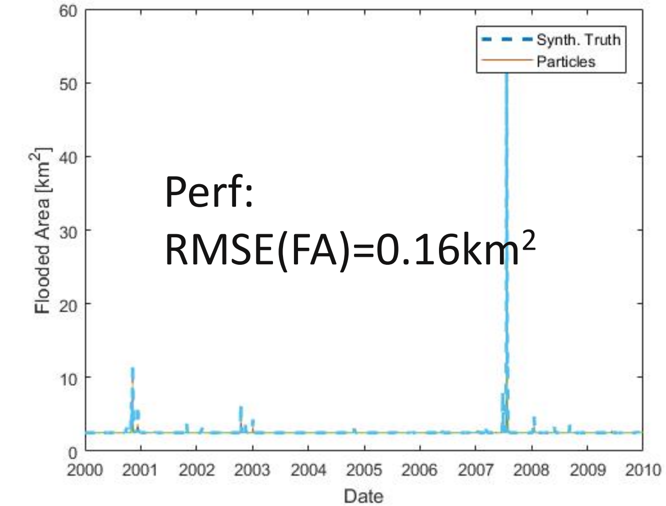


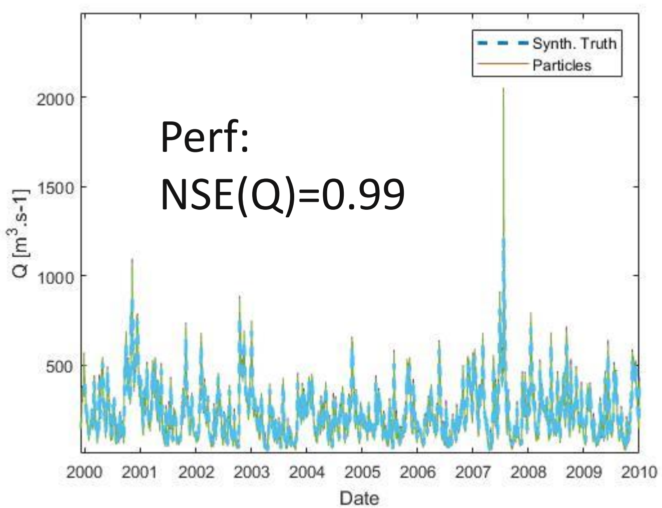
SYNTHETIC TWIN EXPERIMENTS: MODEL CALIBRATION USING FA ONLY



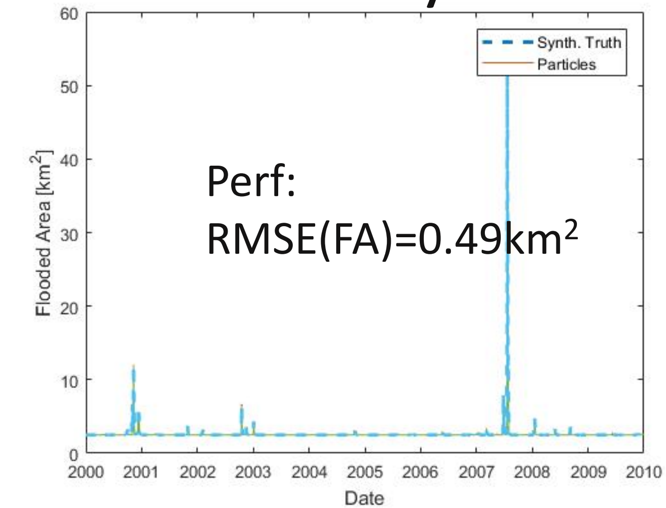
SYNTHETIC TWIN EXPERIMENTS: CALIBRATED MODEL EVALUATION

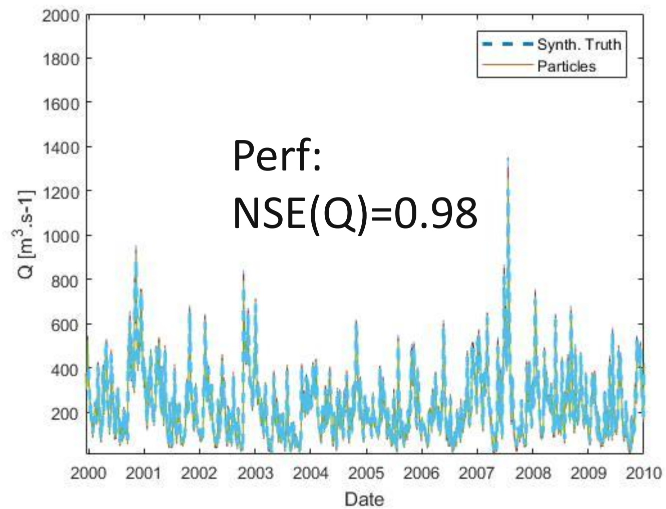
SM+FA





FA only





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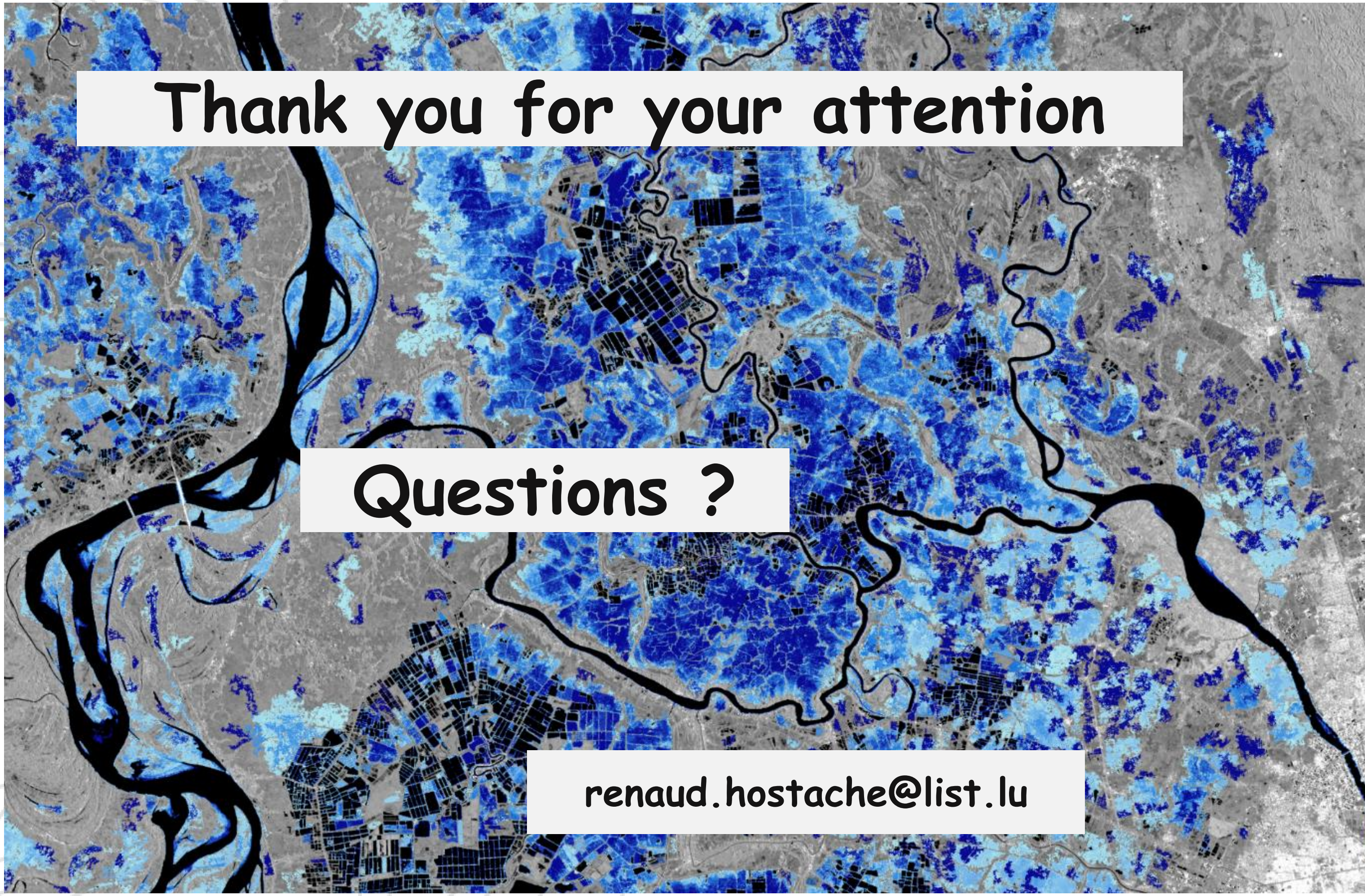
CONCLUSION & NEXT STEPS

- We carried out a synthetic experiment using a TPF of the joint assimilation of satellite flooded area and soil moisture observation
- The results are really promising as the calibrated model is predicting surface runoff accurately both during the calibration and the validation periods
- This opens the floor for applications at large scale over poorly gauged areas

Next steps:

- To further investigate the added value of soil moisture data
- To carry out real test case experiments



Thank you for your attention

Questions ?

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