CERFACS

CENTRE EUROPÉEN DE RECHERCHE ET DE FORMATION AVANCÉE EN CALCUL SCIENTIFIQUE

TERATEC 2020
Atelier « Données Satellite et environnement »

Estimation of River Discharges from SWOT Observations using Data Assimilation and hydraulic Models @CERFACS

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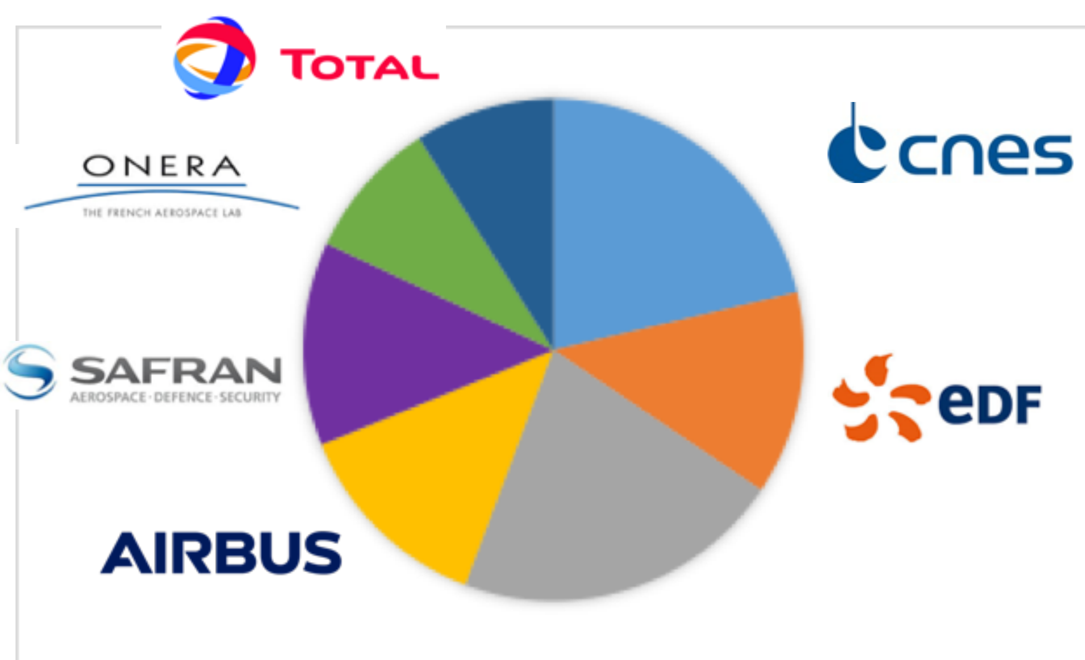
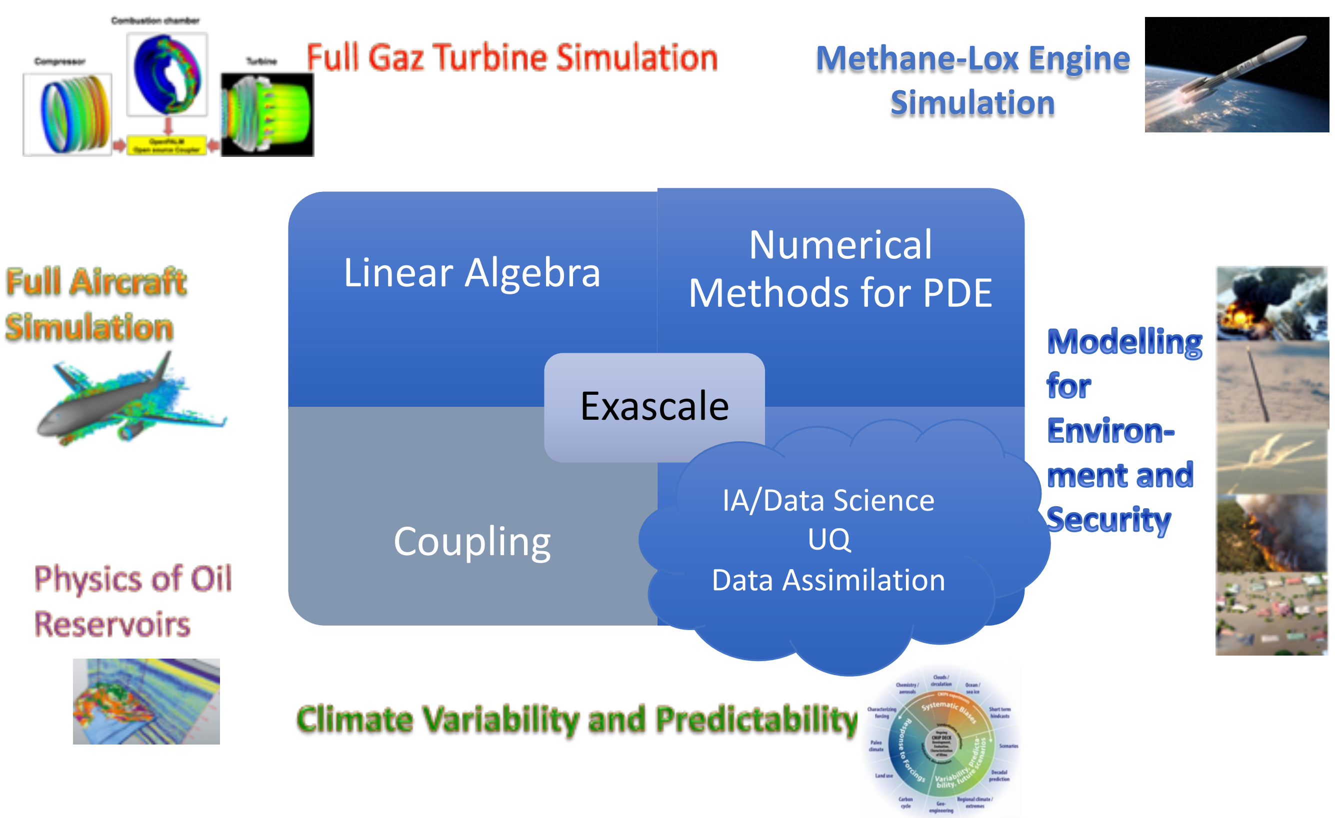
14/10/2020

CERFACS

- Cerfacs is a mutualized centre of research, development, transfer and training regarding simulation and High Performance Computing (HPC) for the benefit of its industrial and public shareholders on a set of major themes.
  - Cerfacs designs and develops innovative methods and software solutions to meet the needs of the aeronautics, space, climate, energy and environment sectors.
  - Cerfacs welcomes young scientists and offers high-level training in all its fields of expertise.





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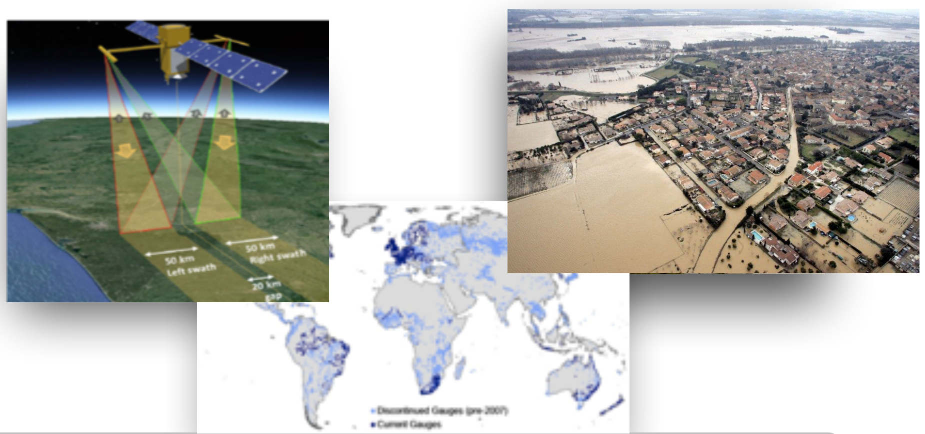
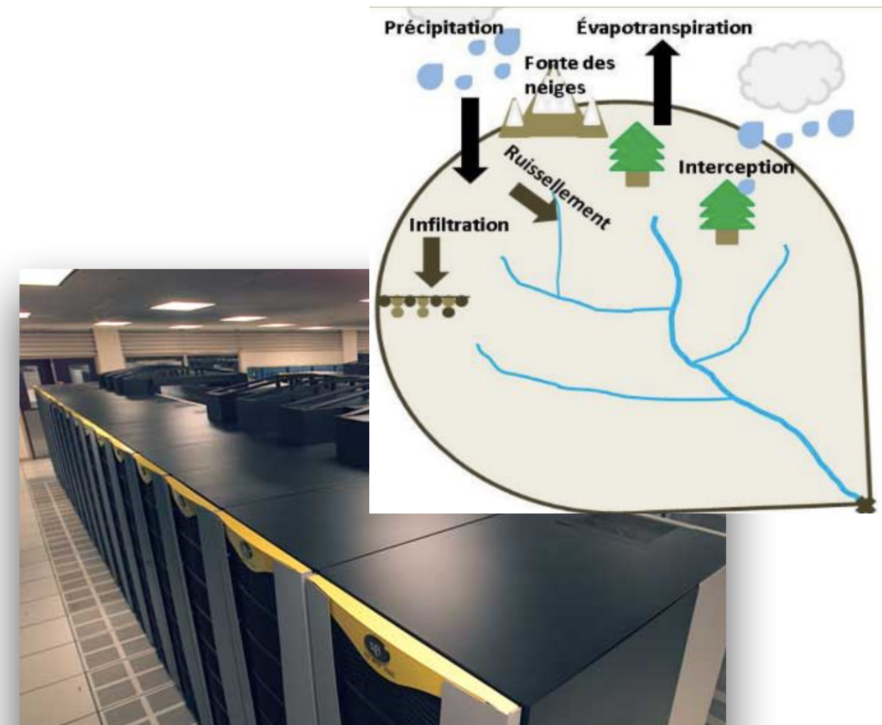
Challenges in hydrodynamics: Data Assimilation

Operational issue
How to predict river discharge for flood forecasting and water balance estimation?





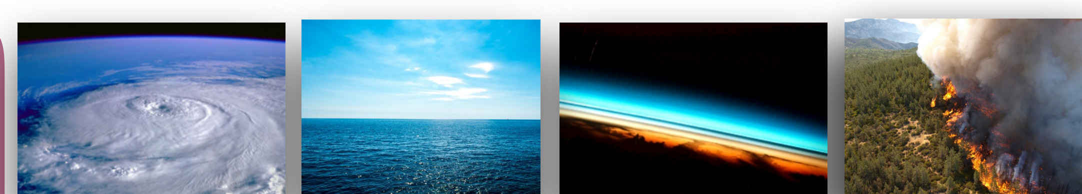
Observations

- in-situ : high frequency but sparse
- remote sensing : spatial coverage (SWOT) but low temporal coverage
- Various nature of errors

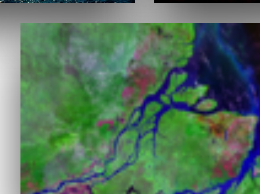
HPC Numerical simulations

- Simplified Navier Stokes equations 1D, 2D, 3D
- Limited information on bathymetry, topography, friction, hydrology, rainfall and maritim forcing

Data assimilation



Scientific issue
How to apply data assimilation to predict discharge and water level in rivers, estuaries and lakes ?



Challenges in hydrodynamics: remote sensing data

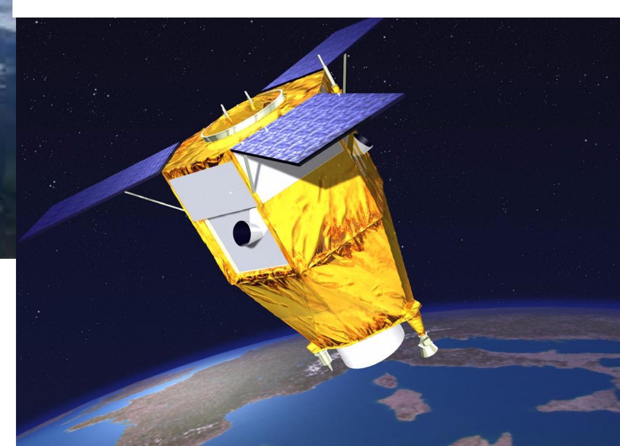
Estimation of river discharge

- Different spatial and temporal scales : large scale hydrology, river and estuaries hydrodynamics
- Complex physics with uncertain forcing at atmospheric, maritime and hydrologic boundaries

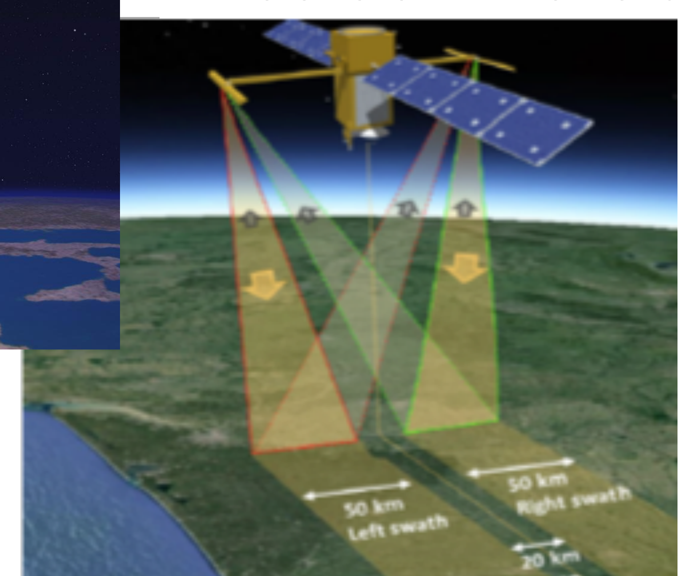
Combine Multi-sensor and Modeling approaches for monitoring the Multi-scale River hydrodynamics with Data assimilation algorithms (TOSCA Program from CNES)

Sentinel 1&2 (ESA-Copernicus)
Synthetic Aperture Radar + Optical imagery for environmental Earth observation from space

Pléïades
High-Resolution Optical Imaging Constellation
(CNES - Airbus DS)



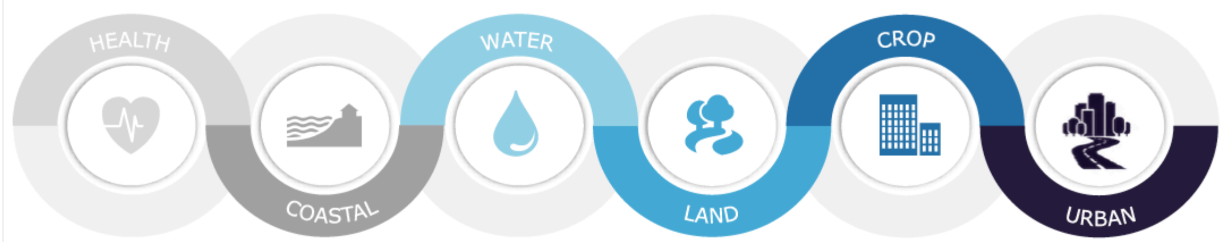
SWOT CNES-NASA (2021)
High resolution and global observation of water level with Ka-Band Radar Interferometer



Challenges in hydrodynamics: flood prediction and alter

Flood Detection and flood map prediction for Decision Support System (FloodDAM)

SCO SPACE CLIMATE OBSERVATORY



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@CERFACS: R&D for flood simulation and prediction

DATA

Huge volume of data

Heterogeneous data (time and space)

Various data servers

MODEL

Large computational time (ensemble)

Input data (topo, bathy, friction)

DATA ASSIMILATION

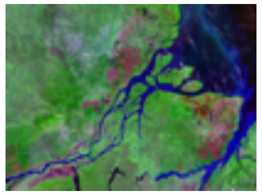
Identify major sources uncertainty

Correct models' parameters and states

@CERFACS :
Research and development for applied mathematics solutions dedicated to

- Discharge estimation in rivers
- Flood simulation and prediction, alert for DSS

Identify major sources uncertainty
Ensemble generation and uncertainty quantification

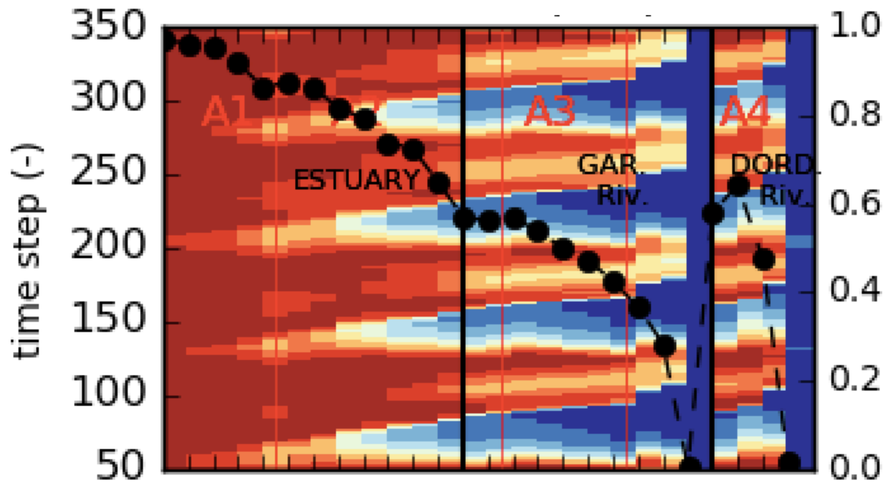


Objective: Sensitivity analysis and uncertainty quantification

Identify the control vector for assimilation with sensitive analysis using Monte Carlo

Sobol index for the maritime boundary condition along the estuary

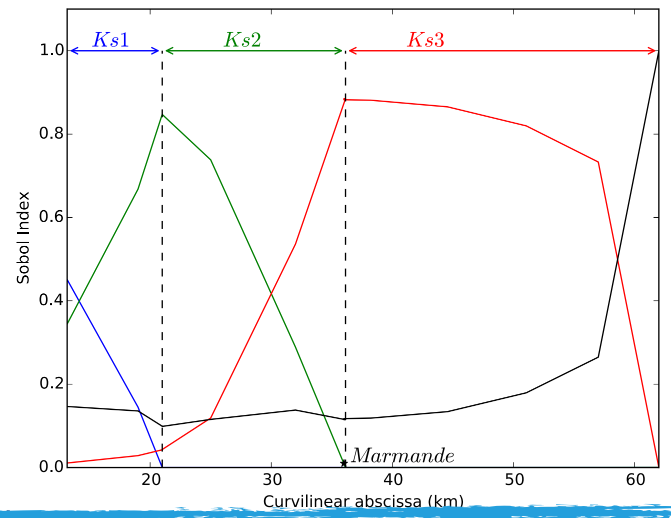
(Laborie et al, COMG 2019)



Reduce the cost of ensemble generation using a surrogate model

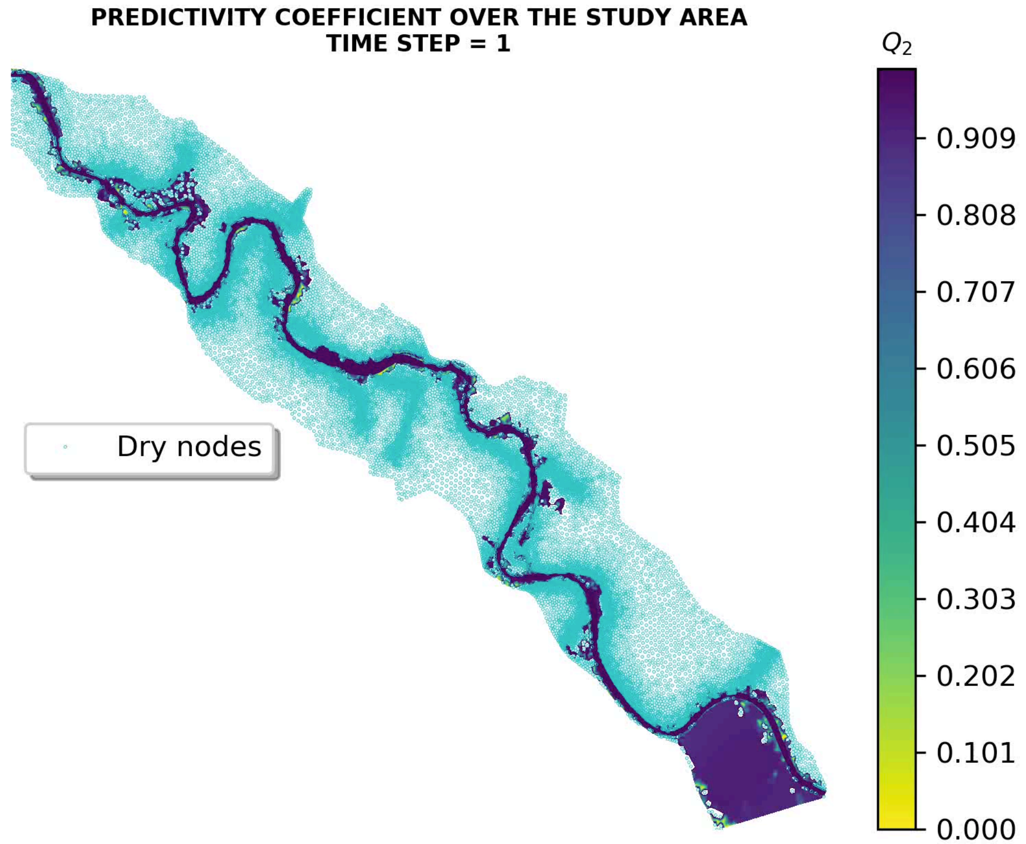
Sobol index for the friction coefficient blog the Garonne river

(El Moçayd et al., ENMO 2017, Roy et al., SERRA 2017)



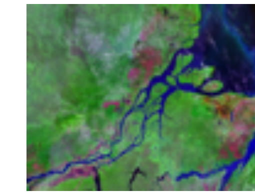
Mixture of surrogate experts for non linearities

Advanced surrogate modelling strategies to deal with discontinuity
Mixture of Expert: PhD S. El Garroussi on going@CERFACS



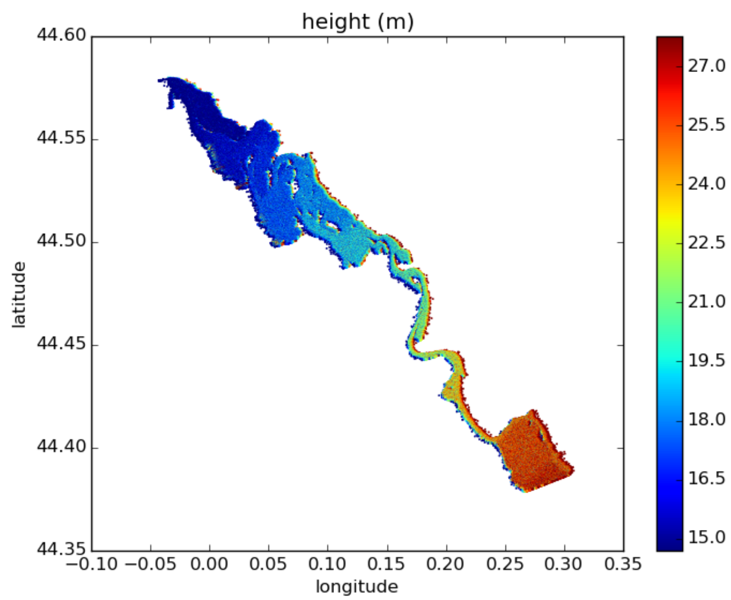
Correct models' parameters and states

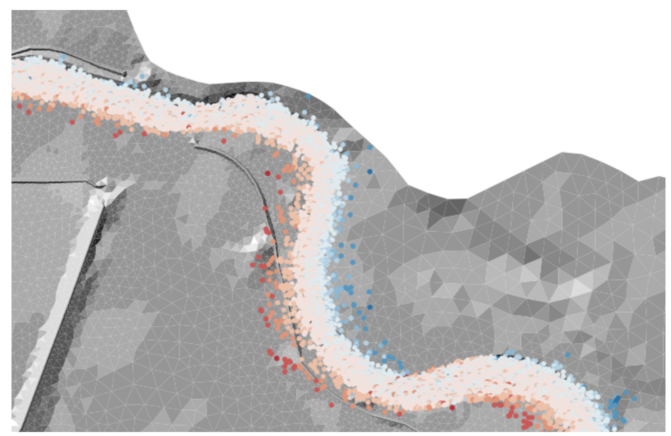
Discharge estimation with ensemble based data assimilation



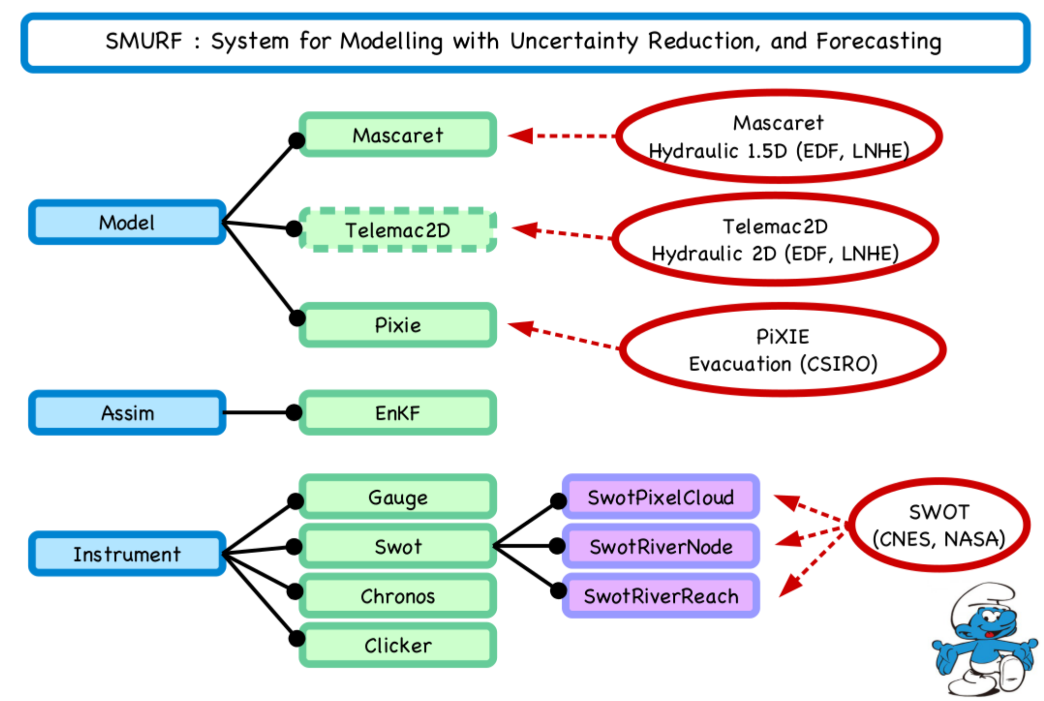
Objective: Assimilate SWOT-like observations with associated errors

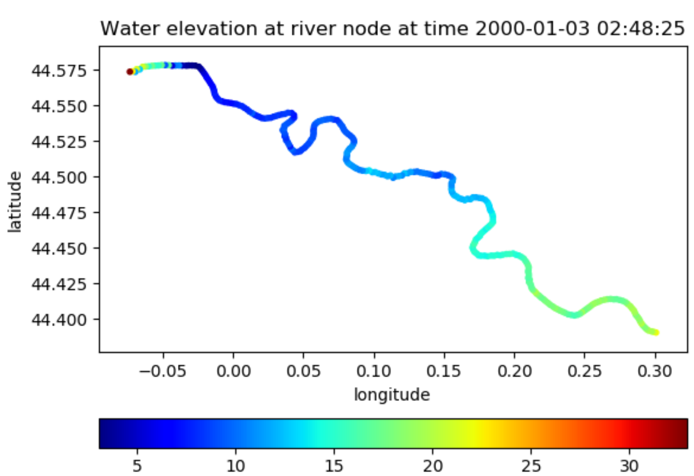
- Water height maps: pixelcloud with 50*50m pixel but large errors
- Water height values: at river nodes and river reaches from spatial averaging, small errors
- Wet/Dry front: flooding area retrieved from water height maps

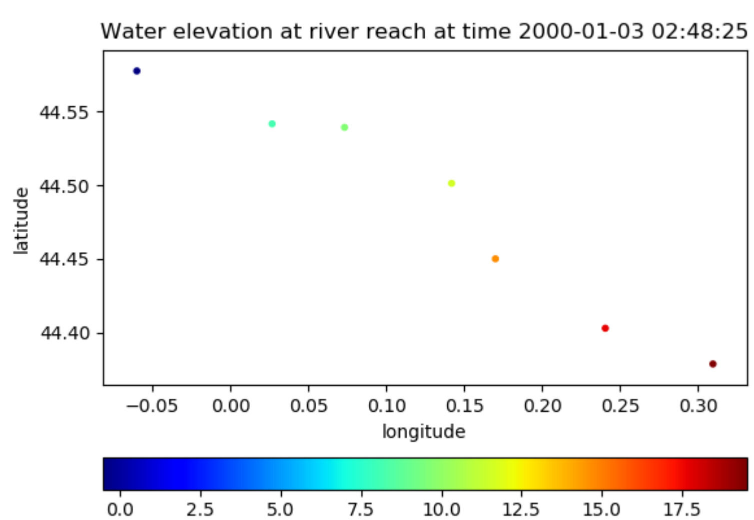




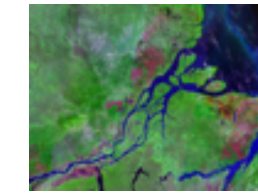
SMURF software @CERFACS (Py library dedicated to DA)







Discharge estimation with ensemble based data assimilation

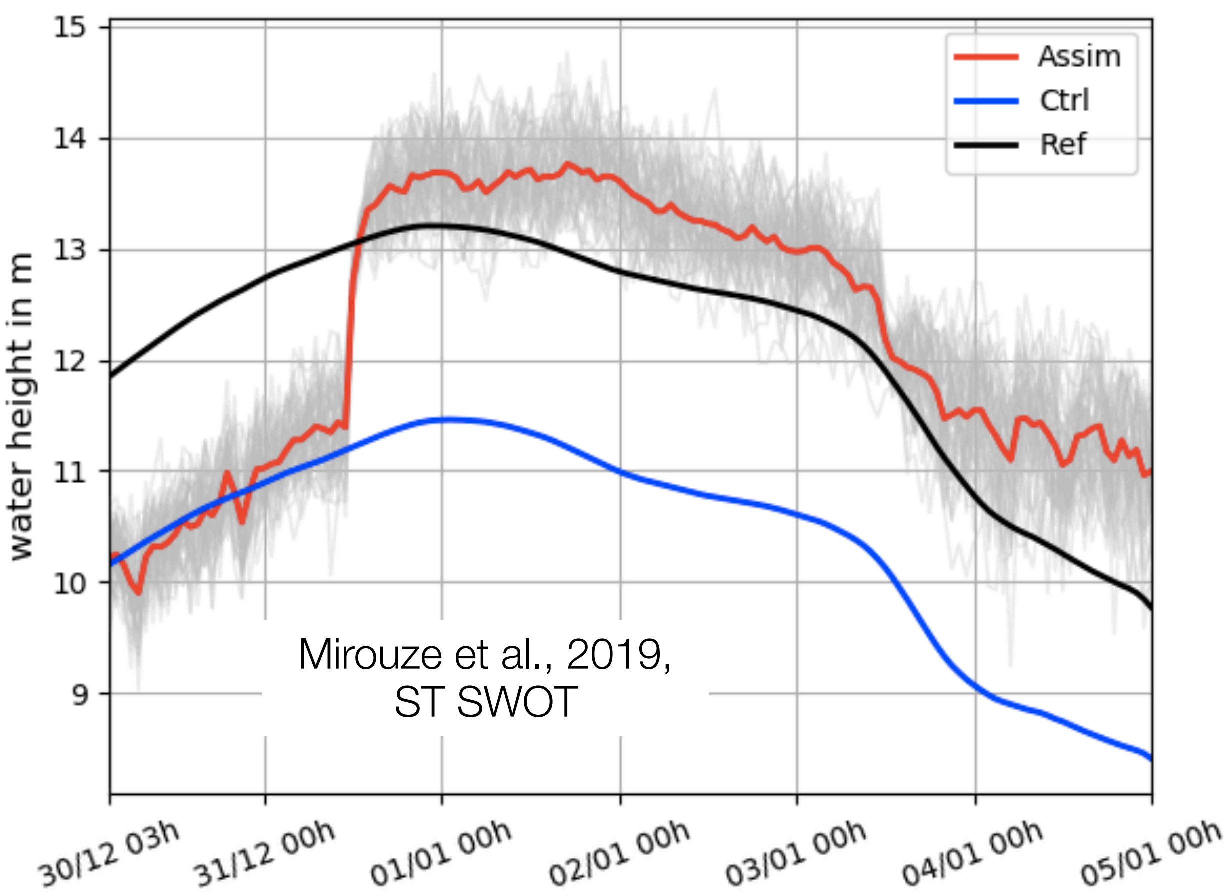


Assimilation of SWOT-like data in Hydrodynamics

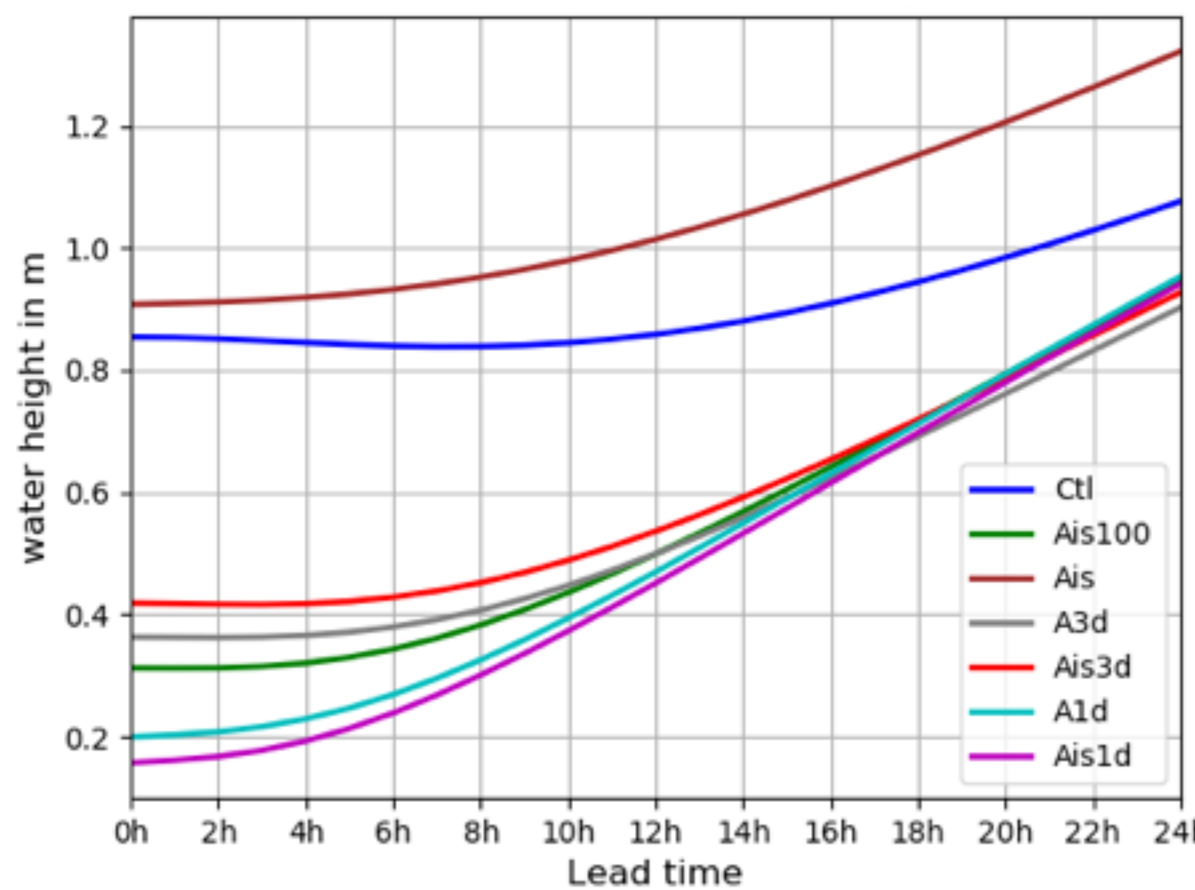
TOSCA-CNES Propal on Discharge estimation
(2020-2024)

Merits of the densification of the water level observation network with SWOT using EnKF data assimilation with MASCARET on the Garonne river

Assimilation of in-situ water level data at Marmande and daily SWOT-like 5km-reach averaged



Global water height RMSE with respect to reference for the ensemble mean of the DA experiments



Conclusions and perspectives

On going

Uncertainty Quantification and Data assimilation of in-situ and remote sensing observations for 1D-2D hydrodynamics for river discharge estimation and flood plain modelling

Perspectives

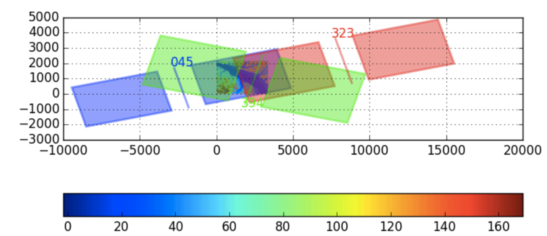
- Use WSE maps, water masks and flood edge data from Sentinel/Pléïades
- Machine Learning to reconstruct incomplete SWOT data taking advantage of overlapping swathes zones

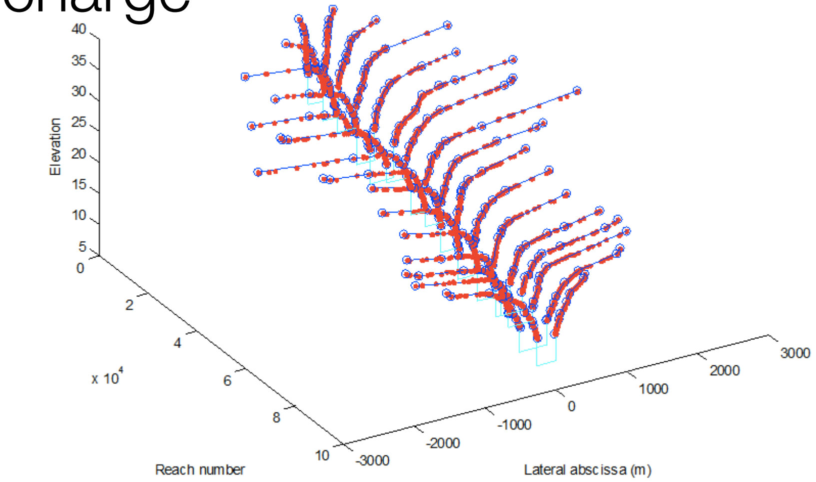
Thank you for your attention

SWOT observations and SWOT-like obs. with SWOT-HR

Generate synthetic data: SWOT-HR simulates the expected KaRIN measurement over simulated areas from hydrodynamic model outputs

Objective: Build and improve hydrodynamic models to estimate discharge

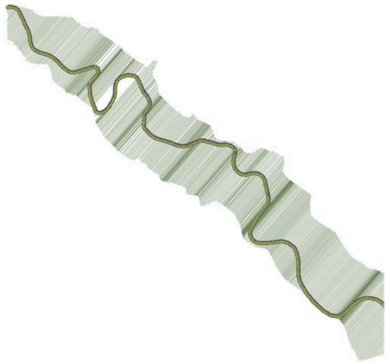


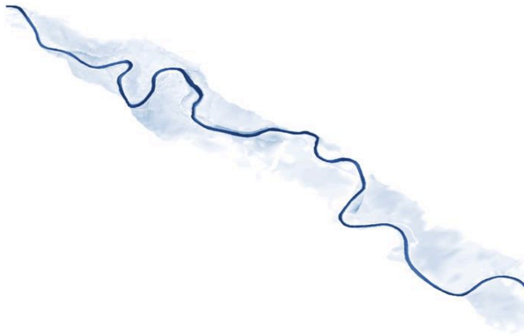


Retrieve bathymetry for SWOT measurements to build 1D and 2D hydrodynamic models

Compare SWOT observations to model outputs

- Map 1D model outputs onto 2D grid as SWOT-HR inputs with SIG
- Map 2D model outputs from unstructured grid to 2D structured grid as SWOT-HR inputs with interpolation tools



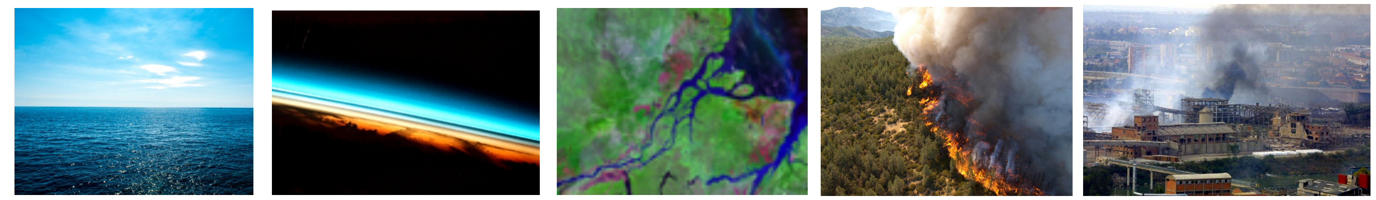


(left) Transect for 1D-2D mapping for discretized river center line with QGIS-Python script.
(right) Interpolated water depth from 1D MASCARET model ouputs to 2D bathymetry and flood plain for the Garonne River reach between Tonneins and La Réole.

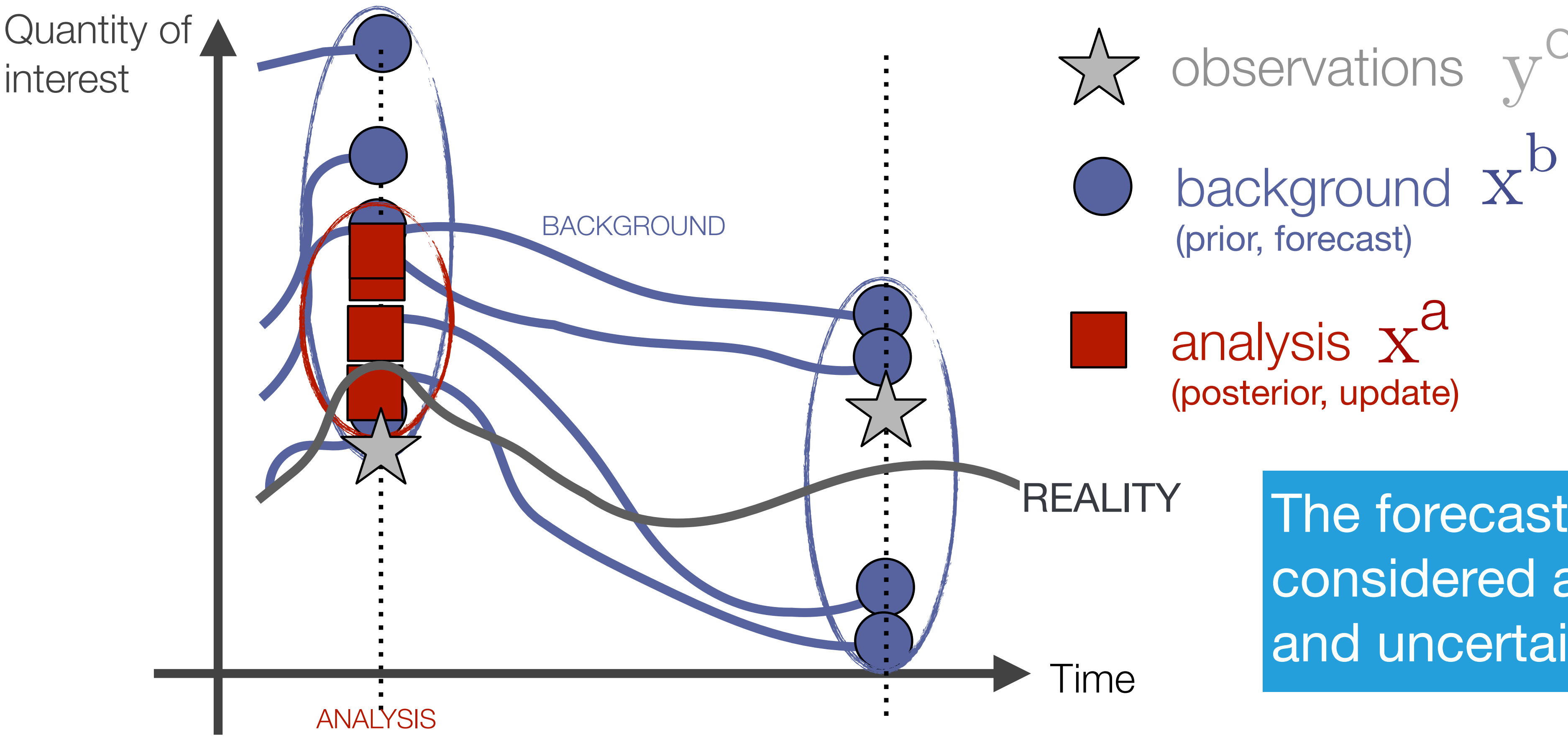
Perspective: Reconstruction of missing SWOT data

- Artificial Intelligence
- algos: CNN, Gradient Boosting, MLP

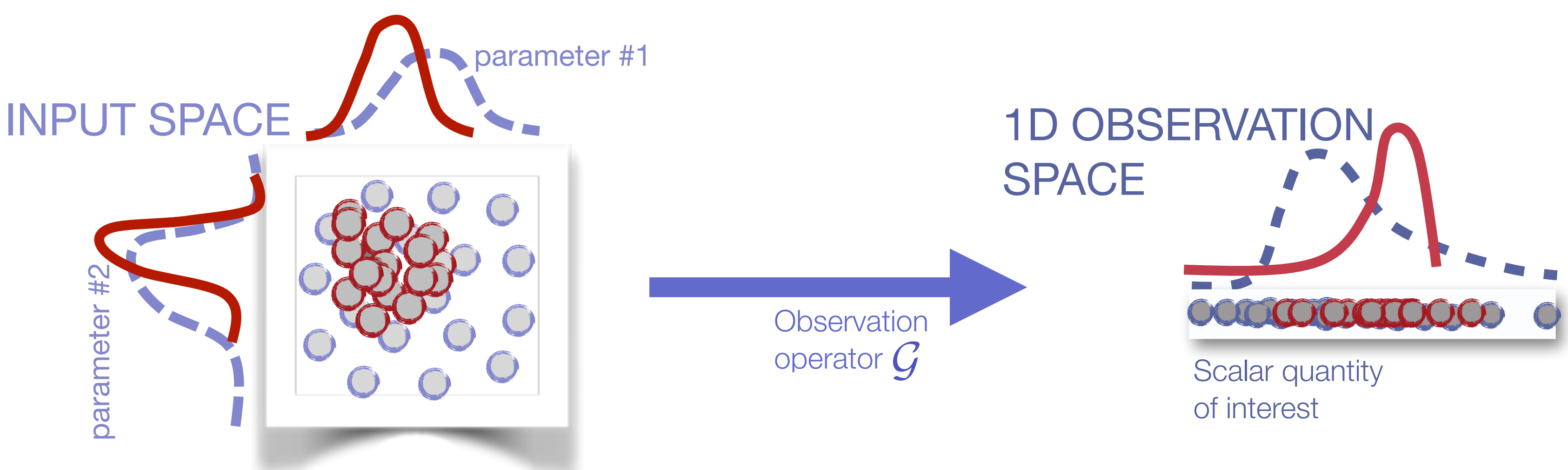
Overview



Stochastic viewpoint



The forecast step can be considered as a sensitivity analysis and uncertainty quantification step.



Important questions

Choice of perturbed variables
Size/variety of the ensemble
Sampling strategy
Physical model sensitivity