DIHMS Final Meeting

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Probabilistic simulation and data assimilation with deterministic rainfall-runoff models

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Outline

- **Applicability of HPC to hydrometeorological flood forecasting**
  - The availability of high-performance computing offers new opportunities for operational hydrometeorological forecasting
  - Explore possible activities to be carried out during the DRIHM project

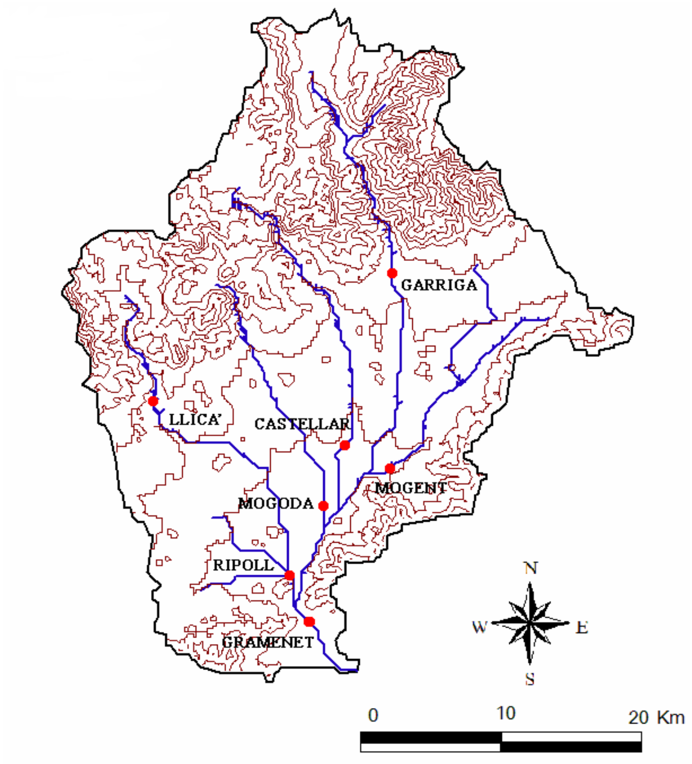
- **Real-time framework for probabilistic flash flood forecasting and data assimilation**
  - Case study: Besós basin (northeast Spain)
  - RIBS (Real-time Interactive Basin Simulator) model used in probabilistic way in real time.
  - Calibration through a probabilistic multiple-objective global optimization methodology.
  - Monte Carlo simulation for probabilistic simulation of an ensemble of basin states and response hydrographs at every step of the operational loop.

- **Data assimilation**
  - Assimilation of observed discharges in real time
  - Generation of new ensemble members through perturbation

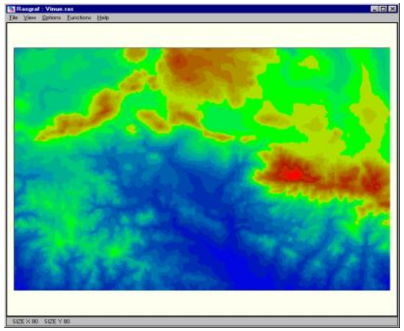
The Besós Basin

- Torrential basin of 1024 km^2
- Located near Barcelona city
- Significant flash-flood risk

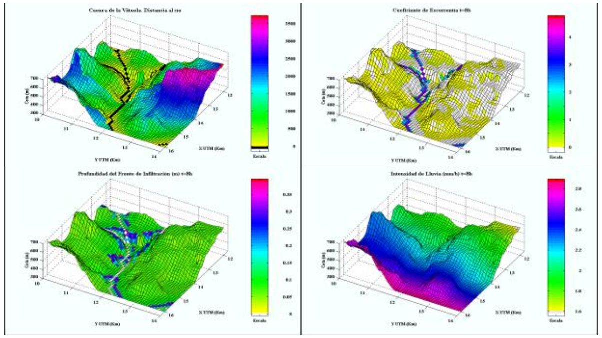
	Area (km^2)	L (km)	S (m/m)	t_c (h)
Mogoda	111	31.83	0.026	3.87
Llica	146	38.71	0.023	4.73
Garriga	151	26.41	0.026	3.36
Mogent	182	36.66	0.032	3.99
Montcada	221	43.24	0.015	6.15
Gramenet	1012	63.45	0.015	8.26



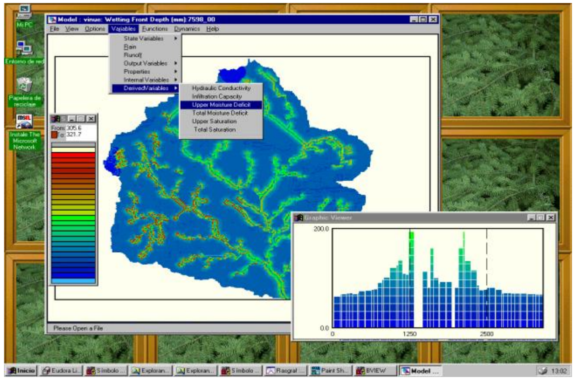
RIBS: Distributed rainfall-runoff model



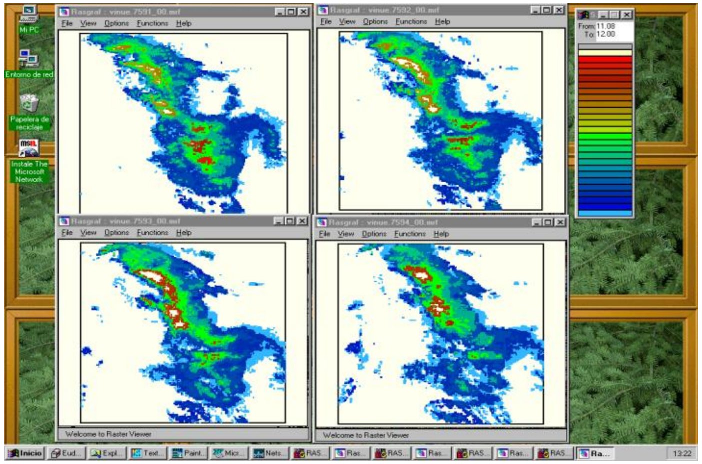
Digital Terrain



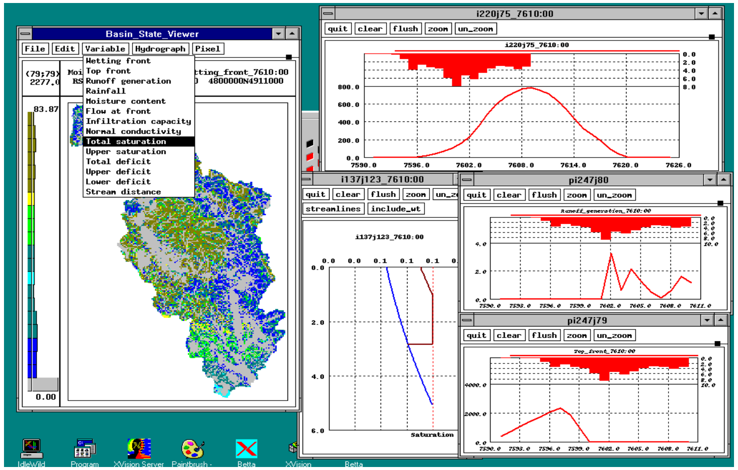
Distributed variables



Runoff (mm/h)



Rainfall (mm/h)



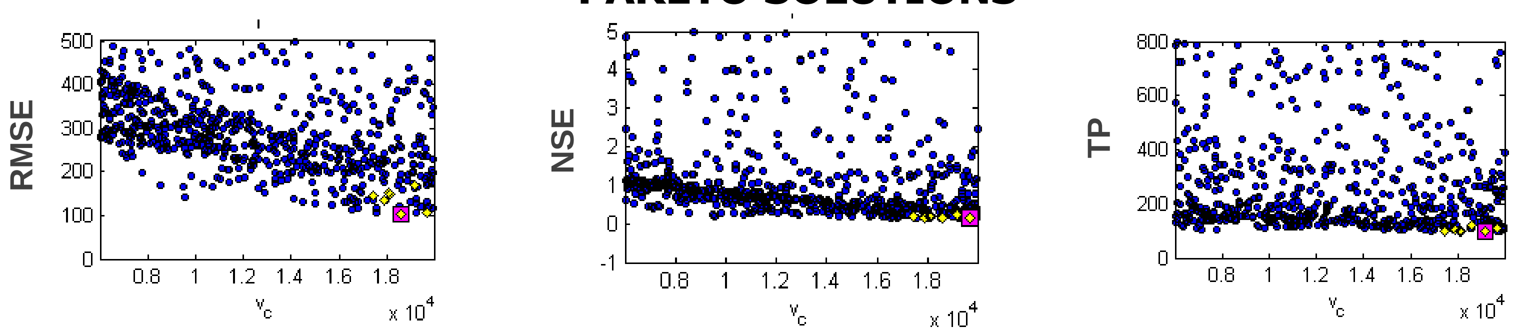
Results (m^3/s)

Probabilistic calibration of RIBS

- **Local soil parameters (Brooks-Corey parameterization)**
  - **K_{0n} normal hydraulic conductivity in surface [mm·h^{-1}]**
  - **θ_s saturation moisture.**
  - **θ_r residual moisture.**
  - **ε porosity of the soil**

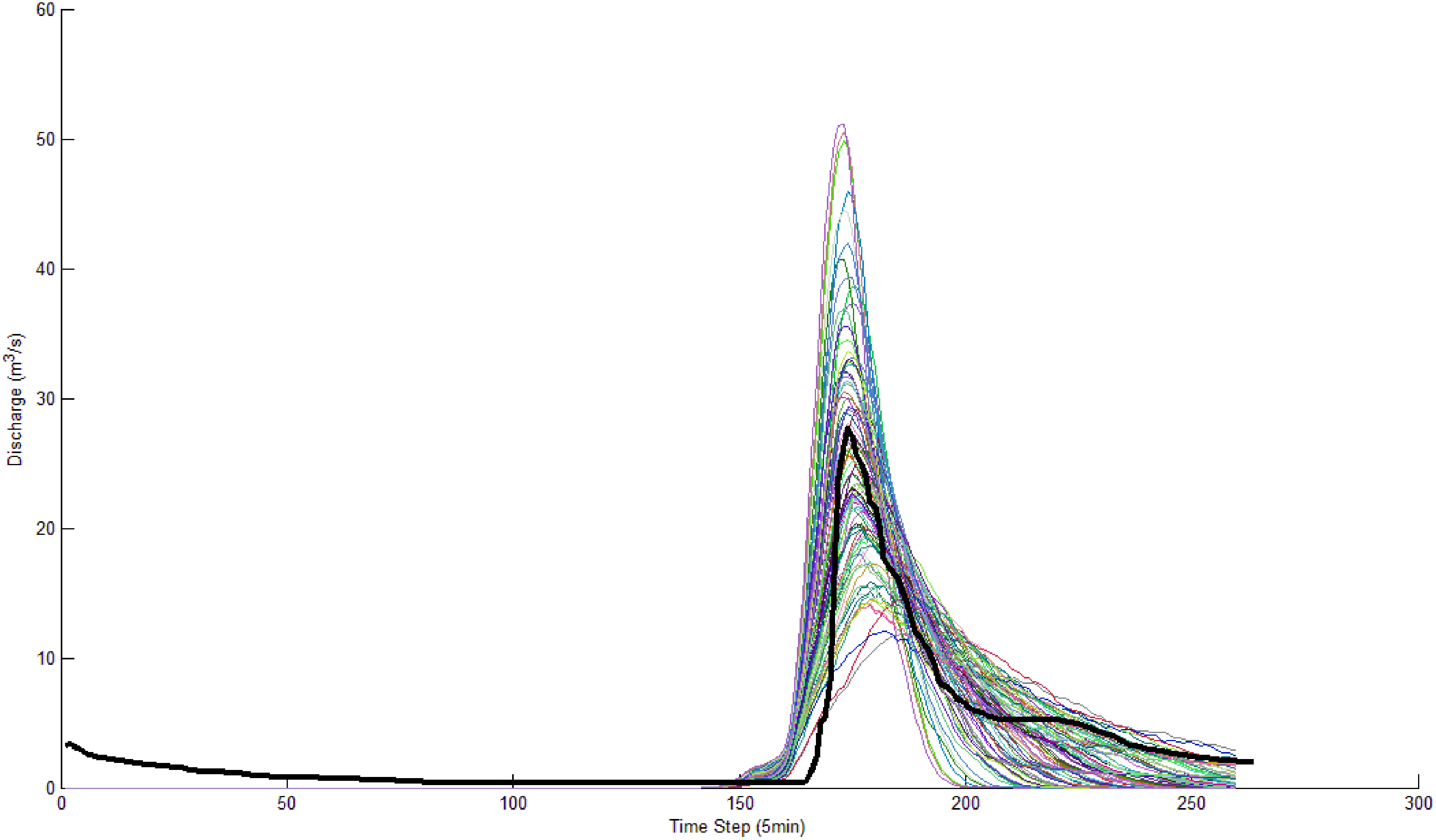
- **Global hydrological parameters:**
  - **f variation of hydraulic conductivity in depth [mm^{-1}]**
  - **a anisotropy ratio between hydraulic conductivities in the two main directions [-]**
  - **K_v ratio between flow velocity in channel and flow velocity in hillslope [-]**
  - **C_v mean flow velocity in channel [m·h^{-1}]**

PARETO SOLUTIONS

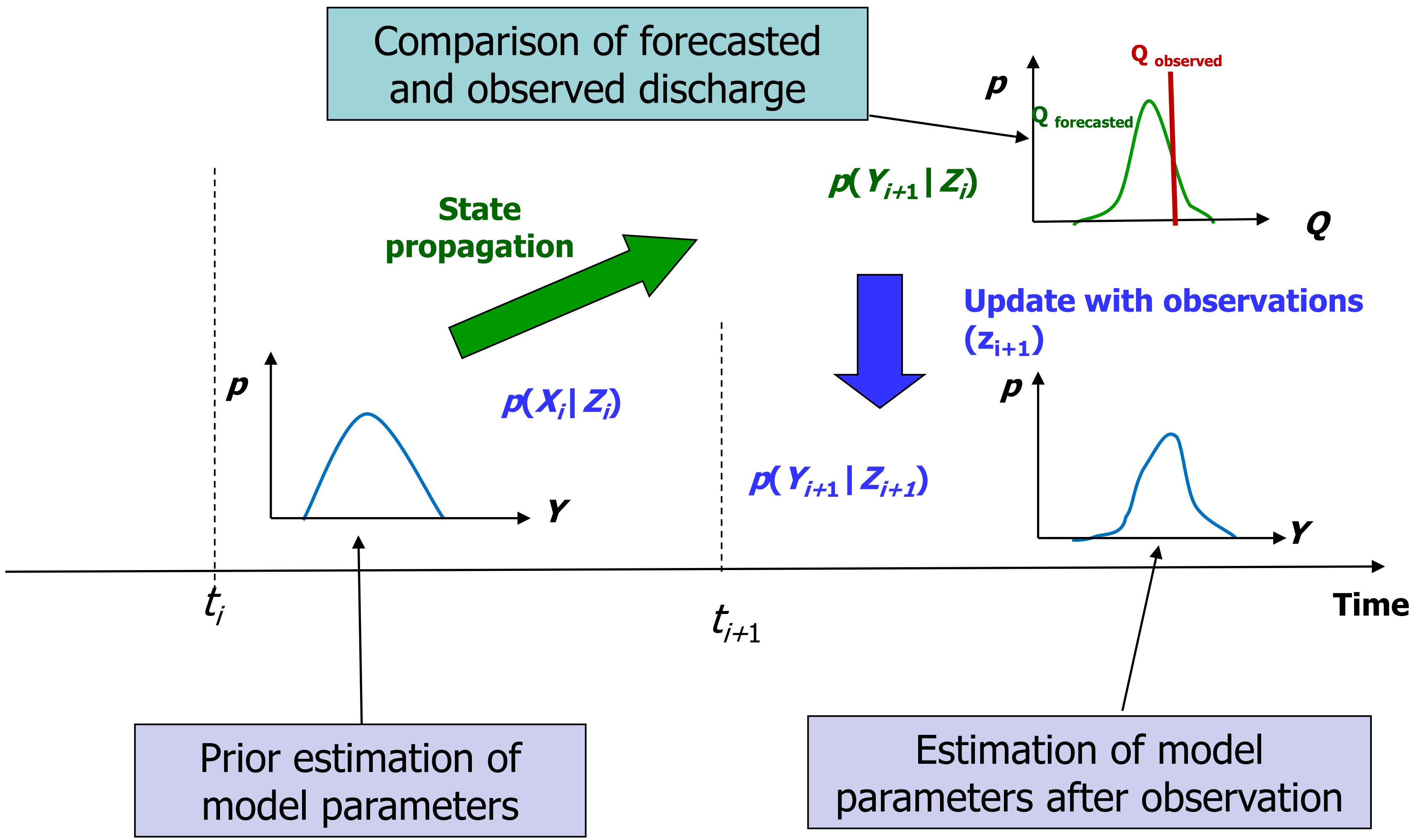


	$log_{10}(f)$	Cv	Kv
Minimum	0.00007	3	13849
Maximum	0.1	18	19941
Mean	-2.17	10.33	17761.67
Variance	1.03	16.53	2616997.33
Standard deviation	1.02	4.07	1617.71
Coefficient of Skewness	-0.45	0.0046	-0.90

Probabilistic simulation

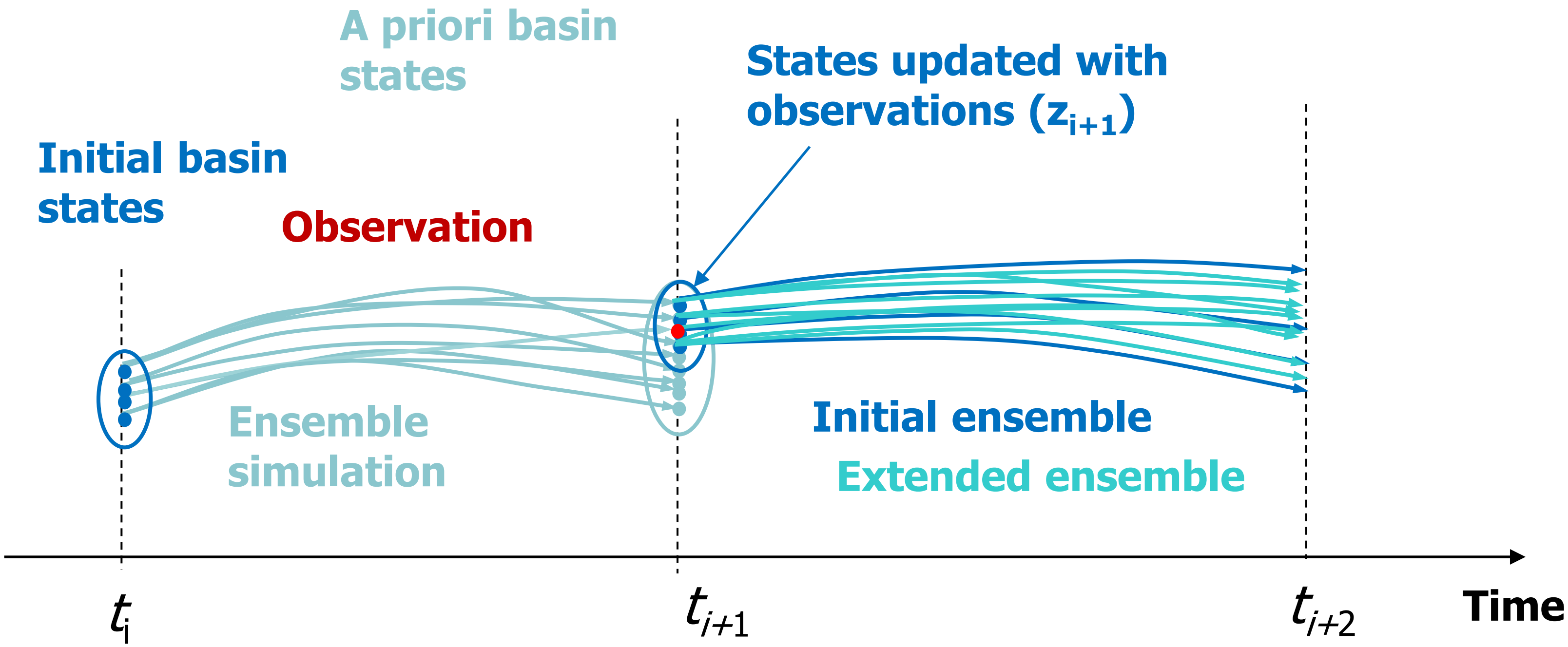


Real-time model parameters update

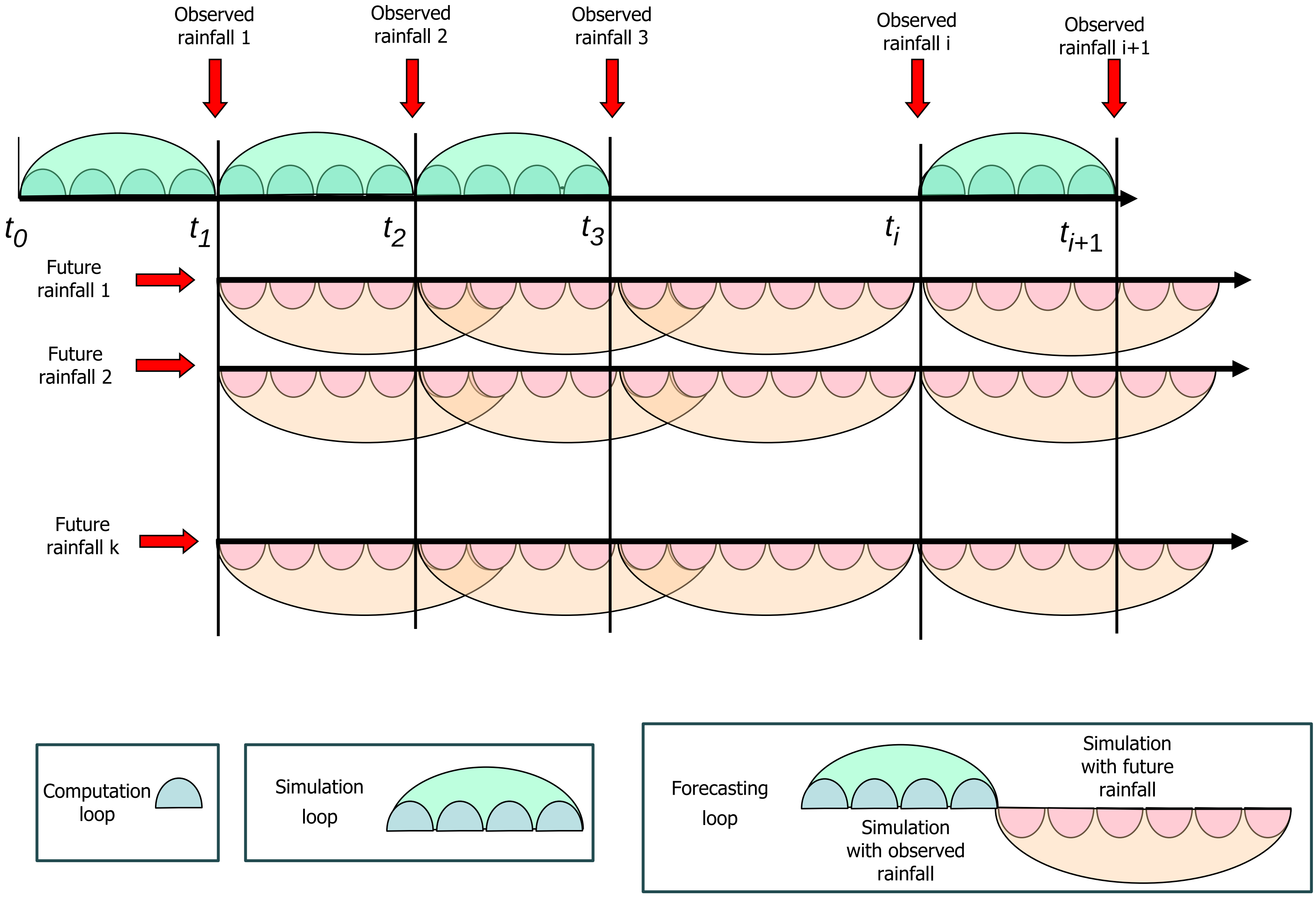


Uncertainty propagation loop

- State variables
- Model parameters
- Combination of both



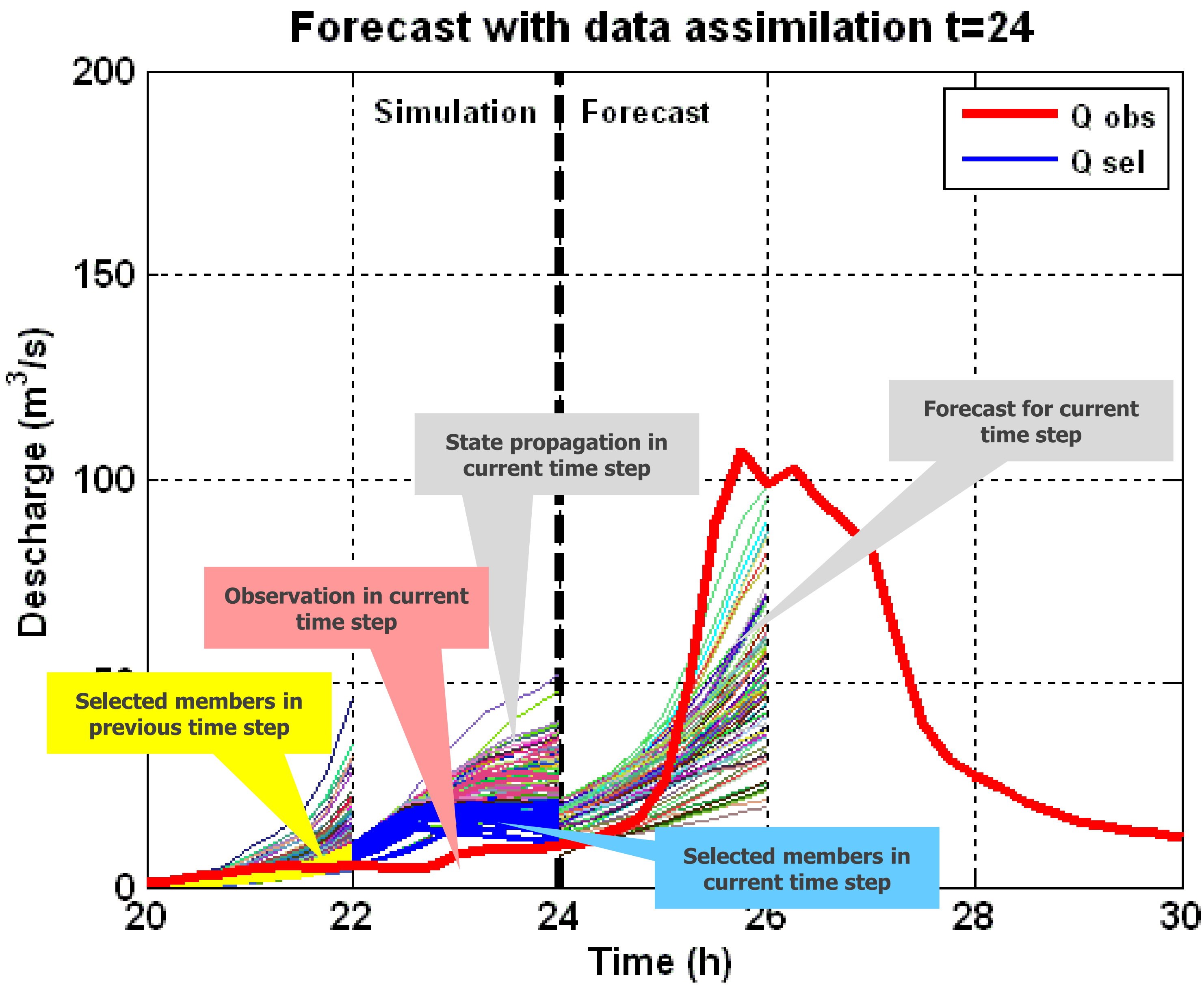
Real-time operational loop



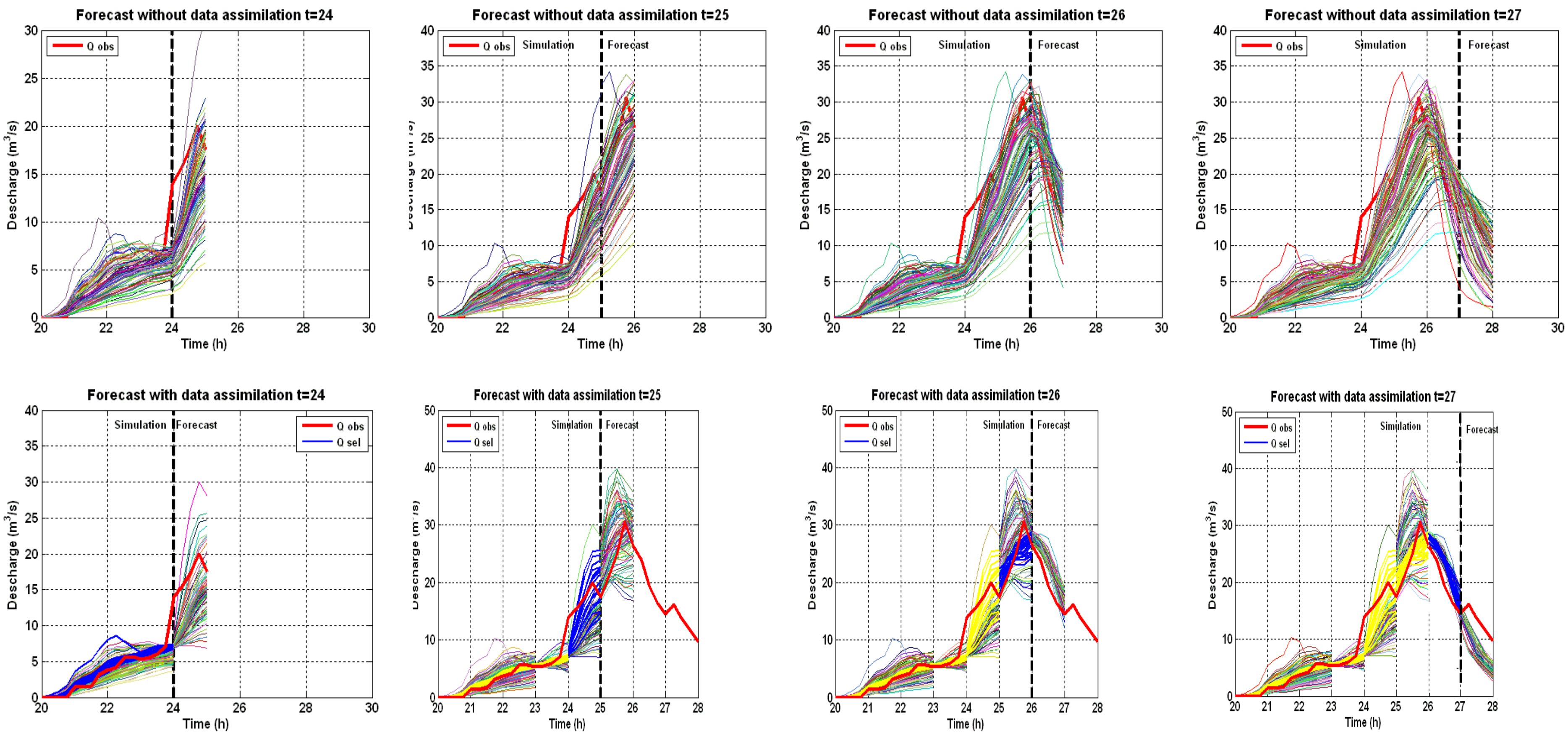
Tentative implementation

- **Probabilistic simulation**
  - Ensembles of 100 members sampled from a priori distribution of model parameters
- **Observation**
  - Observations taken only at one streamflow gauge
  - Observations considered 100% reliable
  - Verification trough NSE in last two hours
- **Model update**
  - Selection of 20 “best” ensemble members
  - Generation of 80 more members through perturbation of model parameters
- **Rainfall forecast**
  - Only one “perfect” rainfall forecast

Model results



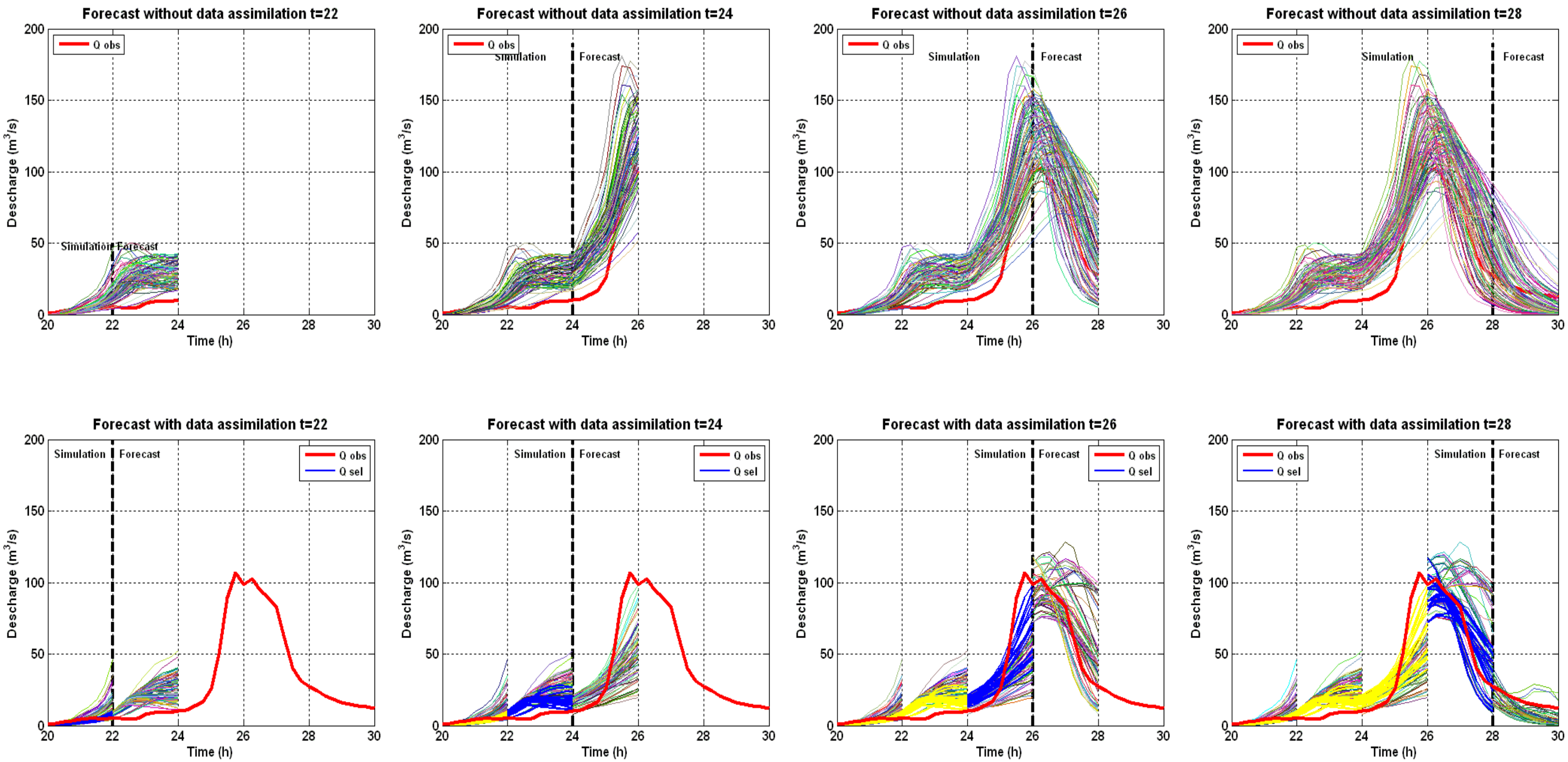
Forecast in Mogoda



NSE$_f$				
Forecast	**t=23**	**t=24**	**t=25**	**t=26**
No data assimilation	-0.13	-8.31	0.04	0.59
With data assimilation	-0.08	-6.95	0.44	0.59

CR (α = 5%)				
Forecast	**t=23**	**t=24**	**t=25**	**t=26**
No data assimilation	0.80	0.40	1.00	1.00
With data assimilation	0.80	0.60	1.00	0.20

Forecast in Ripoll



NSE$_f$				
Forecast	**t=22**	**t=24**	**t=26**	**t=28**
No data assimilation	-66.45	0.62	0.46	-1.23
With data assimilation	-34.06	0.29	0.80	-2.30

CR (α = 5%)				
Forecast	**t=22**	**t=24**	**t=26**	**t=28**
No data assimilation	0.11	0.44	1.00	1.00
With data assimilation	0.11	0.56	1.00	1.00

Conclusion

- **Distributed rainfall-runoff models**
  - Distributed rainfall-runoff models are a good option to include basin variability for real-time modeling
  - They can be calibrated probabilistically
  - Very demanding in computational terms (HPC is required)

- **Ensemble-based probabilistic simulations**
  - Simple way to make probabilistic predictions
  - They can include variability in rainfall, parameters or basin states
  - Realistic way to show different sources of model uncertainty explicitly

- **Real-time model update**
  - There are many possible alternatives for data assimilation
  - The approach seems promising and worthwhile trying