Interactive Visualization of Ensemble Data Assimilation Forecasts for Hydrology Models

Ameya Patil[1,2], Marlee Smith[1], Helen Kershaw[1], Moha Gharamti[1]

NCAR | NATIONAL CENTER FOR ATMOSPHERIC RESEARCH

UNIVERSITY of WASHINGTON

1. Ensemble Data Assimilation

- A sequential approach used to estimate the dynamical state of a system with its uncertainties
- Combines multiple sources of information, each having its own uncertainties, including:
  - model predictions with model bias uncertainty,
  - real-world observations with measurement uncertainty

  to get an improved estimate of the system state.
- Used for forecasting weather, floods, and even spread of diseases like covid.

Fig. 1 shows a schematic representation for forecasting the streamflow in a water body using ensemble data assimilation,, with the associated uncertainties.

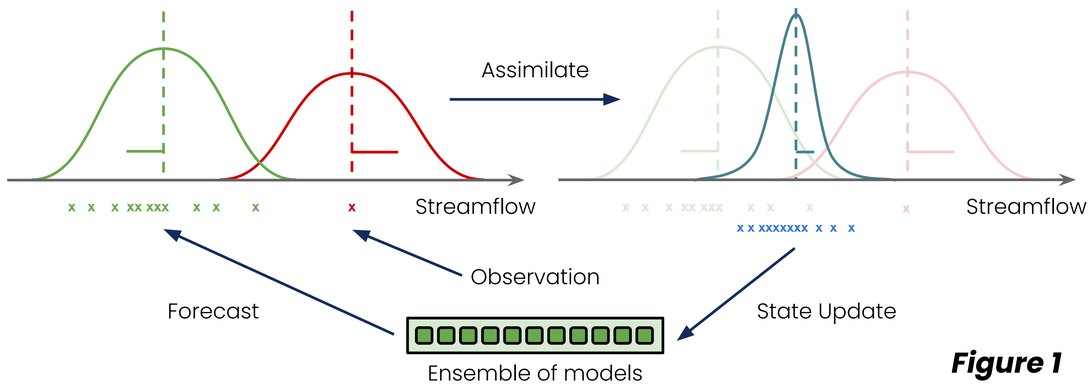


Figure 1

2. HydroVis

Problem: *Understanding and making reliable decisions based on ensemble forecasts* for Earth systems can be challenging due to the high dimension of earth system models, the various sources of uncertainties, and the massive volume of observation data. This becomes critical to plan precautionary measures, during extreme events like hurricanes.

Solution: *HydroVis* - interactive dashboard for easy analysis and assessment of the quality and uncertainty of ensemble data assimilation forecasts, for the ***WRF-Hydro*** hydrological flood forecasting system. This would in turn help in making reliable ensemble forecasts based decisions, in life critical situations.

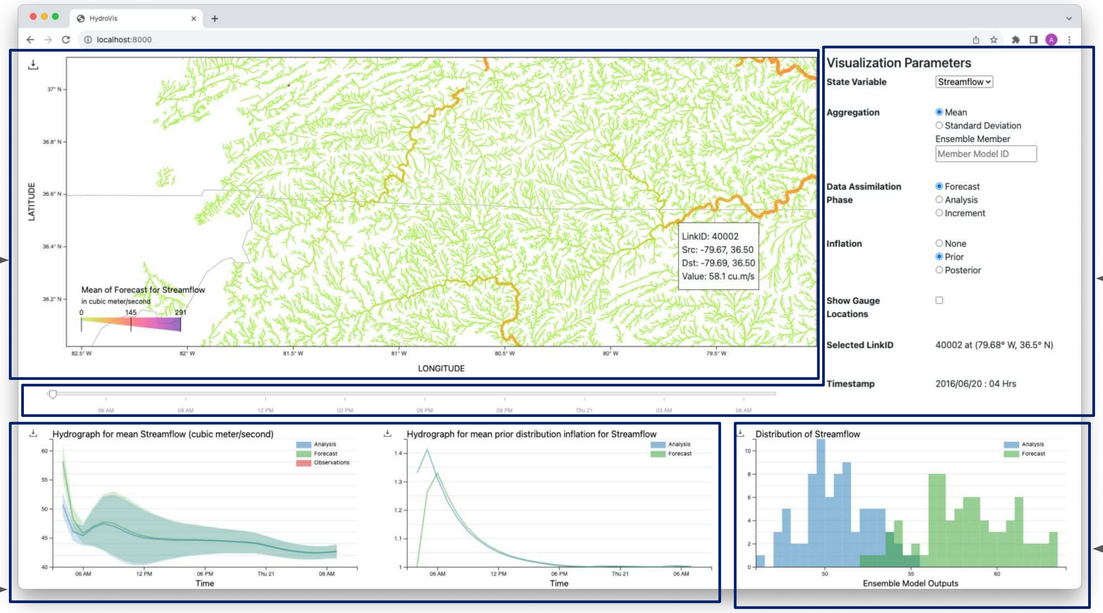
- Developed as a web application with Python Flask for the web server and D3.js for the visualizations.
- Uses open-source libraries with limited software dependencies for better portability across systems.
- Interfaced with the Data Assimilation Research Testbed (DART) developed at NCAR.

WRF-Hydro

NCAR | DART

Map visualization showing the geographic context for the water bodies of interest. Also acts as an interactive widget to select and view details for a specific water body.

Time-series plots showing the changes in forecasts, observations, refined estimates and inflation corrections applied to the models over time.



Control panel to:
- inspect different system variables,
- change aggregation to be applied,
- inspect data assimilation phases,
- inspect inflation corrections,
- view water body gauge locations,
- set desired timestamp.

Histograms to help assess the uncertainty of the estimated streamflow at locations of interest. This panel also provides insights on the nature of the underlying streamflow probability distribution: Gaussian, near or non-Gaussian.

Figure 2

3. Future Work

- Upgrade backend data store, implement data precomputation, caching and prefetching for better interactive performance.
- Add open loop data - forecasts ***without*** data assimilation, for comparative evaluation of the model performance.
- Add more visual constructs focusing on the uncertainties in the assimilation process and the forecasts, eg: swarm plot, hypothetical outcome plot, etc.
- Integrate within DART for real-time monitoring and analysis of the performance of both the forecasting models and the forecasts.

4. Acknowledgements

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1 - National Center for Atmospheric Research *{apatil, masmith, hkershaw, gharamti}*@ucar.edu

2 - University of Washington, Seattle (*ameyap2@cs.washington.edu*)