Interactive Visualization of Ensemble Data Assimilation Forecasts for Hydrology Models

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Hydrology Forecasting

Predicting the behavior of water systems

Hurricanes

- Tropical storms, 75 mph to > 150 mph
- 2.5 trillion gallons of rain per day
- Flood rivers and lakes
- Damage to life and property

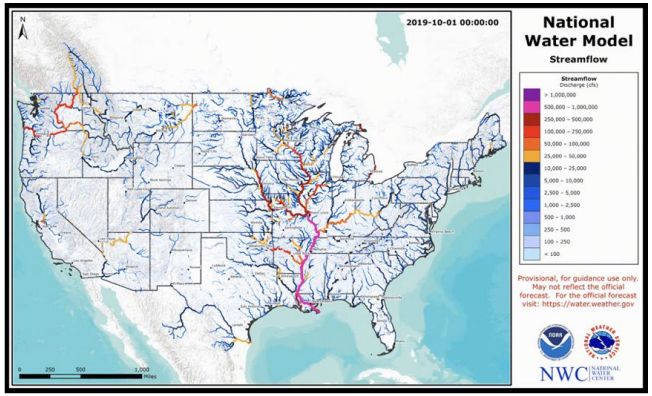
A family walking through a flooded street in Batabano, Cuba, on September 27, 2022, during the passage of hurricane Ian [Y. Lage, AFP]

Hurricane Ian: 150 deaths, > $112 billion in damages

A vehicle sits partially submerged in a flooded downtown following Hurricane Ian, in Orlando, Florida, September 29, 2022. [Gary Bogdon, EPA-EFE]

WRF-Hydro[1] Modeling System

- An open source community model
- Understand and predict water system behaviors
- Address issues relating to water availability, quality and hazards
- Used for forecasting floods during hurricanes Ian and Florence



Streamflow (cfs) simulation over CONUS for 2019-20 water year

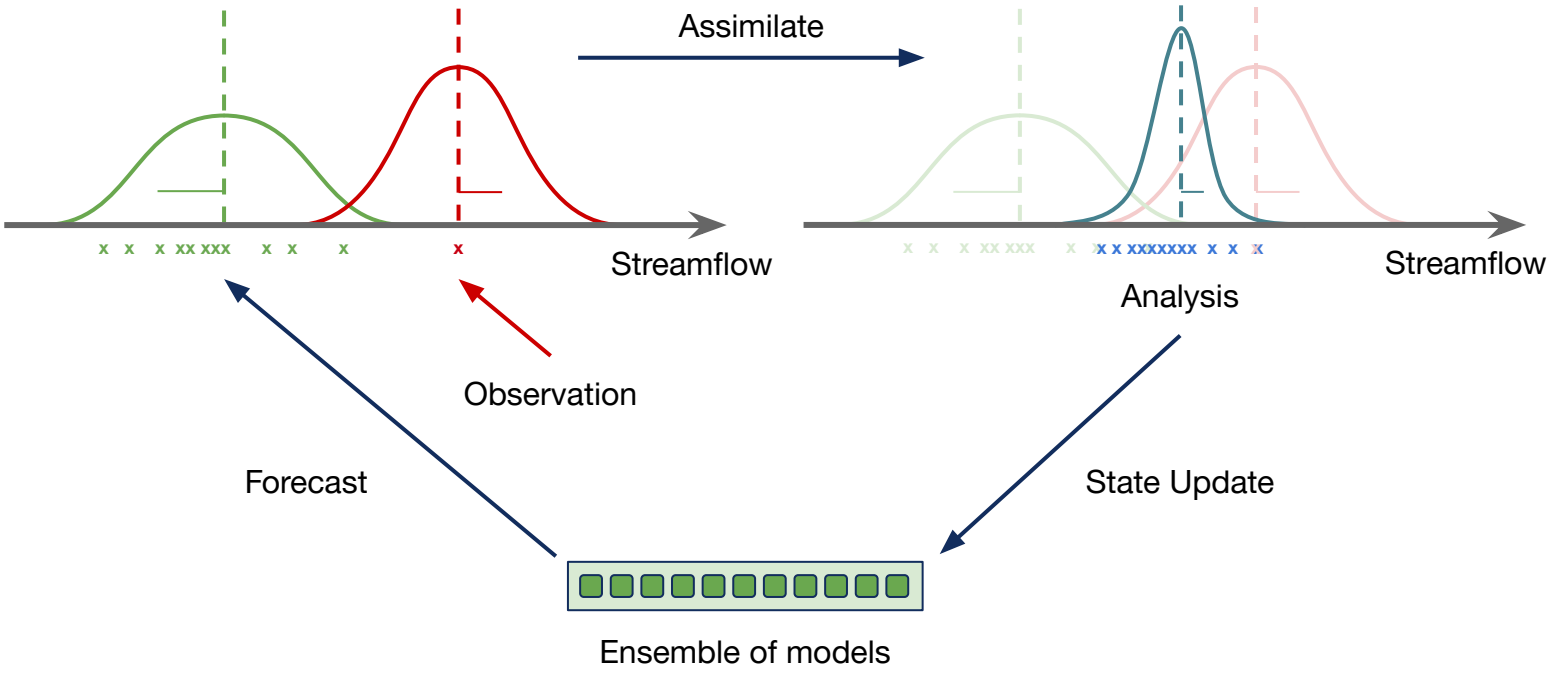
WRF-Hydro®

1 - https://ral.ucar.edu/projects/wrf_hydro

Interactive Visualization of **Ensemble Data Assimilation Forecasts** for Hydrology Models

What is Ensemble Data Assimilation Forecasting?

A sequential approach combining **multiple sources of information** about a system, with a **model of the system** to **estimate the dynamical state** of the system



Why is ensemble forecasting challenging?

- Huge number of data points to be processed
  - High dimensional models
  - Large number of observations
  - Data Assimilation Research Testbed (DART)[1] to the rescue!

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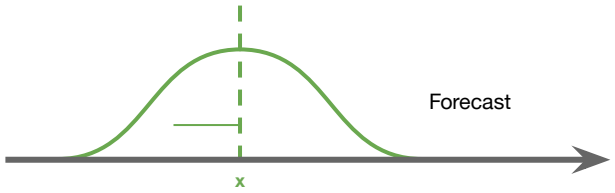
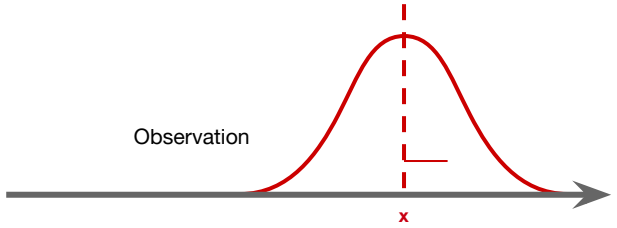
1 - https://dart.ucar.edu/

Why is ensemble forecasting challenging?

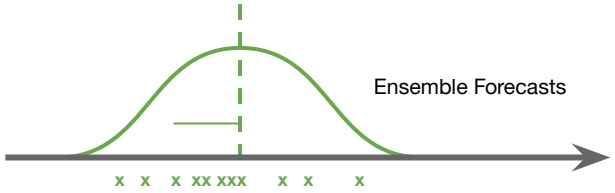
- Sources of uncertainty



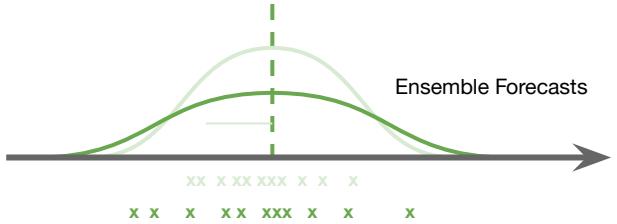
Model uncertainty



Instrument uncertainty



Initial value uncertainty



Inflation

Why is ensemble forecasting challenging?

- Huge number of data points to be processed
  - High dimensional models
  - Large number of observations
  - Data Assimilation Research Testbed (DART)[1] to the rescue!
- Multiple sources of uncertainty
- Highly critical when used with context

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Interactive Visualization of Ensemble Data Assimilation Forecasts for Hydrology Models

How do interactive visualization dashboards help?

- Make fast and reliable data driven decisions
- Interactivity < 500 ms response time
- For ensemble data assimilation forecasts
    - Inspect different forecasted variables
    - Understand the uncertainty in the forecasts
    - Investigate the performance of selective models in the ensemble
    - Investigate the performance of data assimilation process
    - Understand contextual significance of the forecasts

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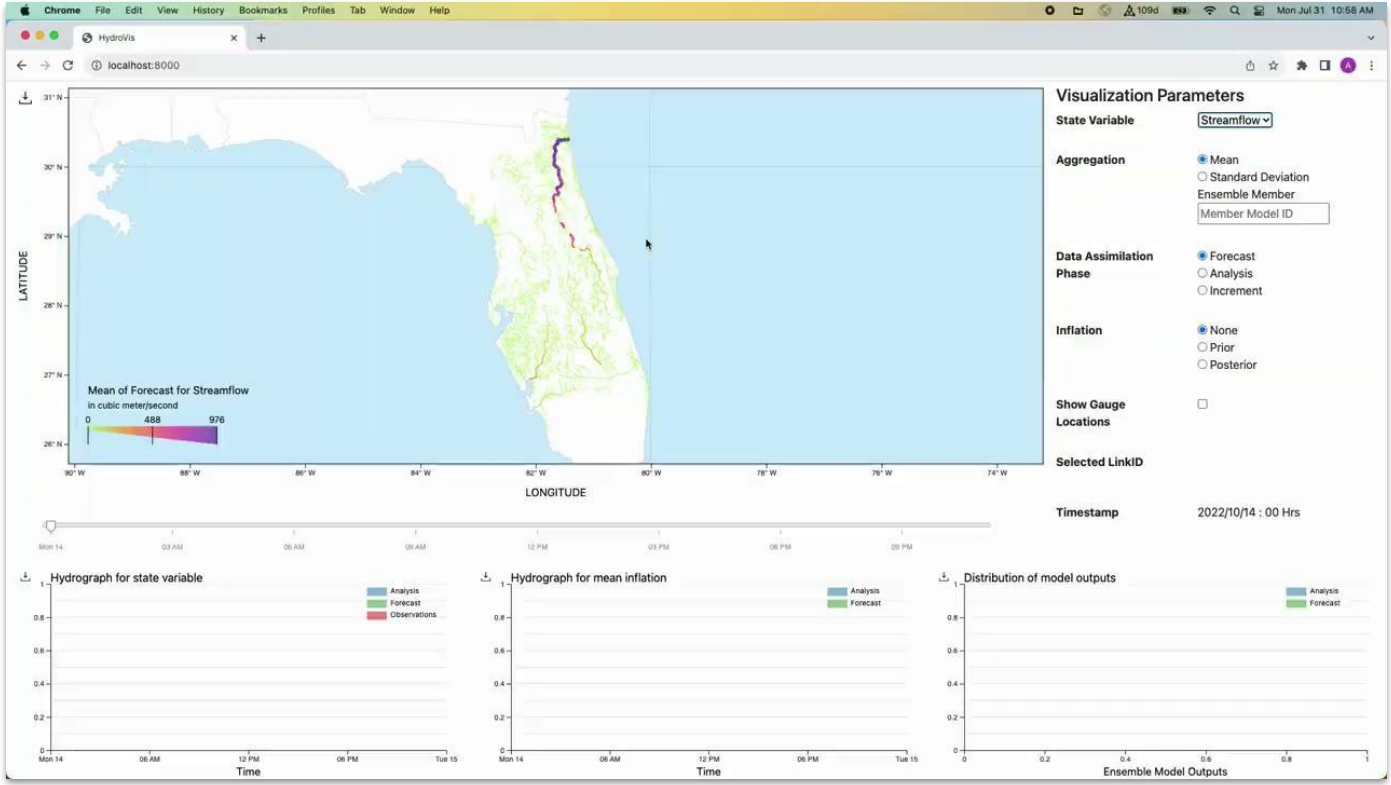
HydroVis

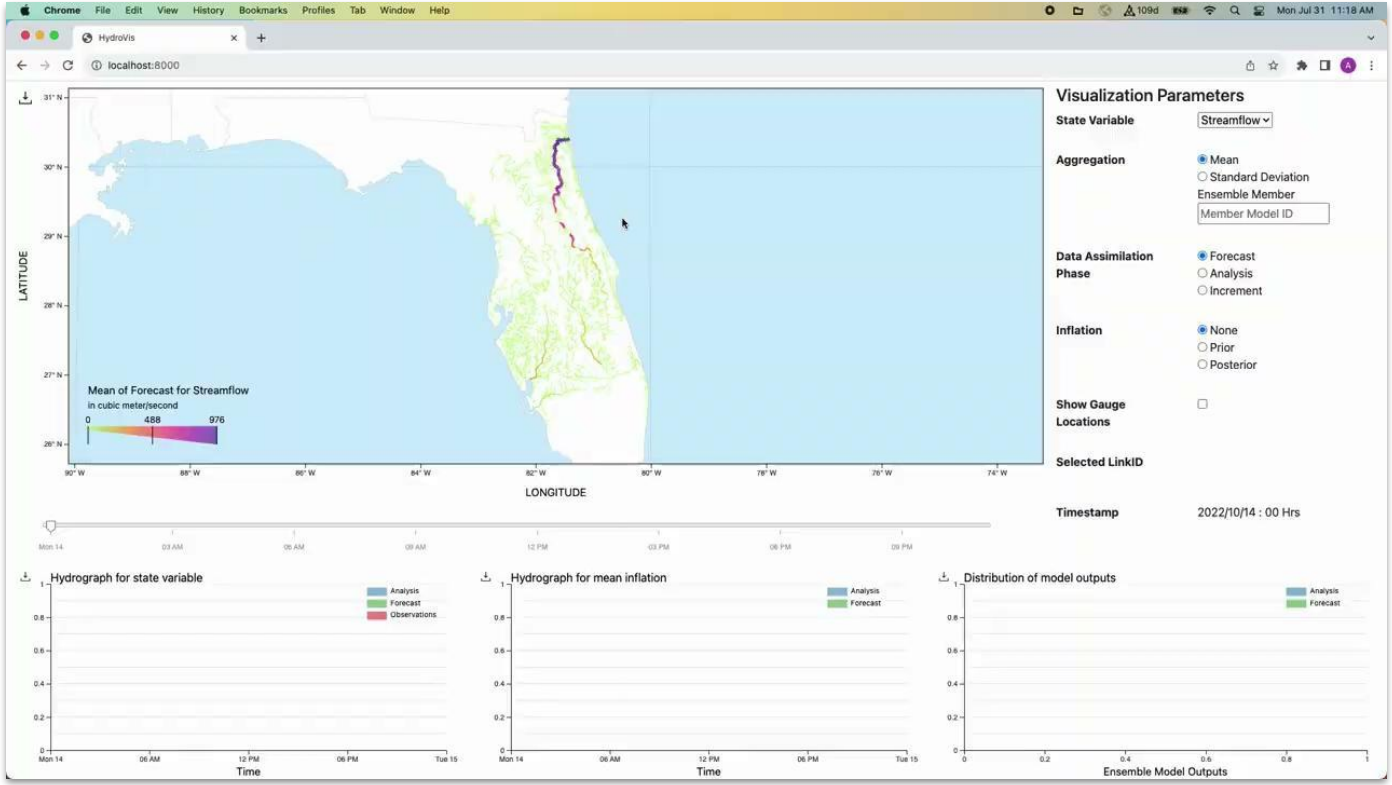
HydroVis

Map Visualization



HydroVis

Distribution Plot

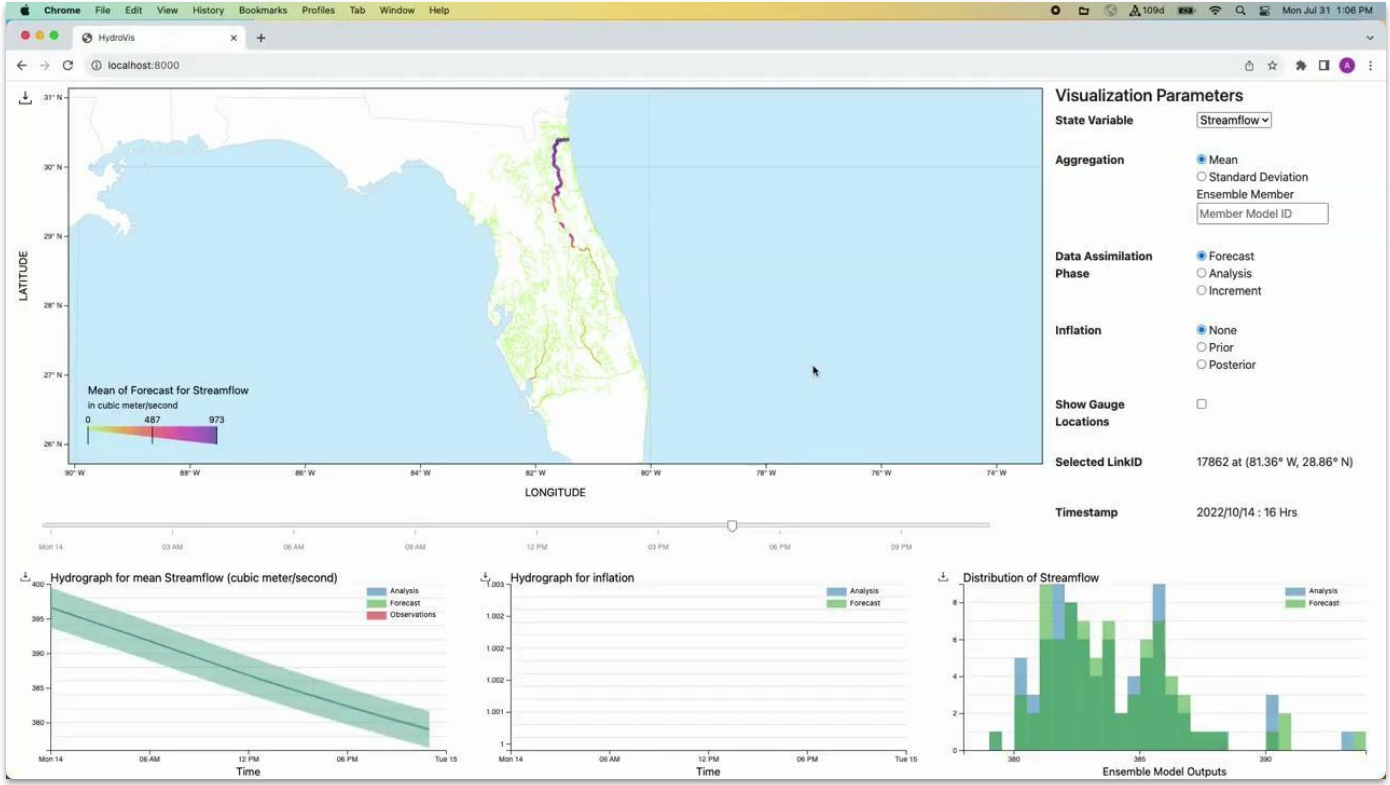


HydroVis

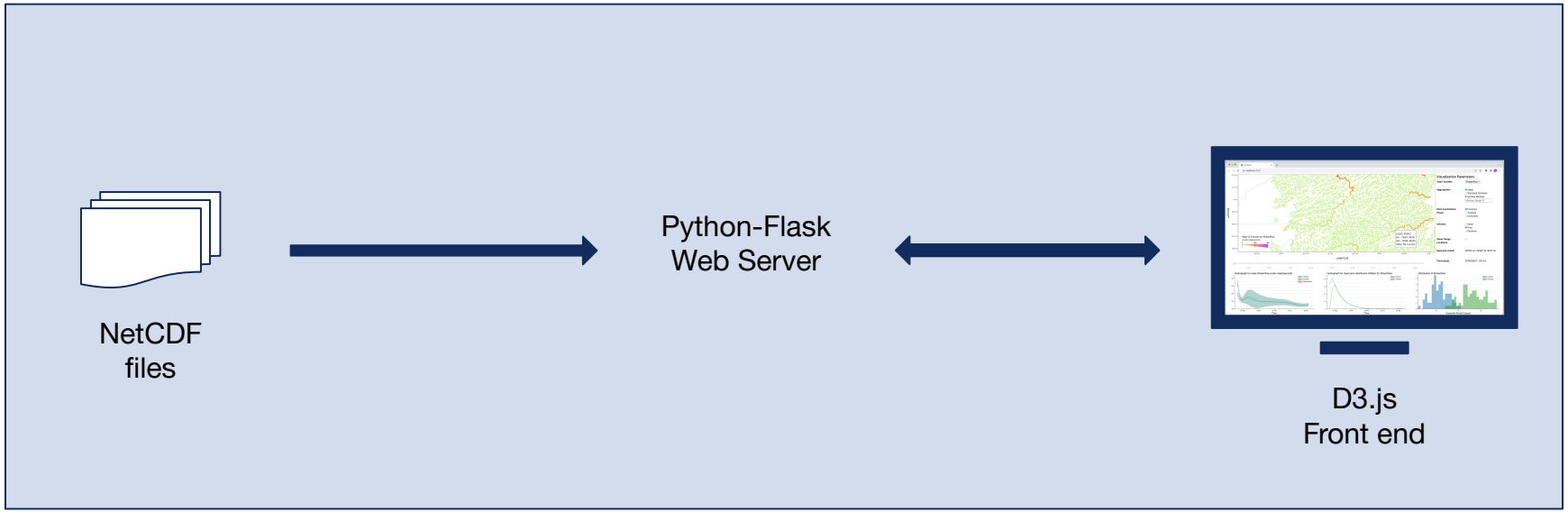
Hydrograph Plot

HydroVis

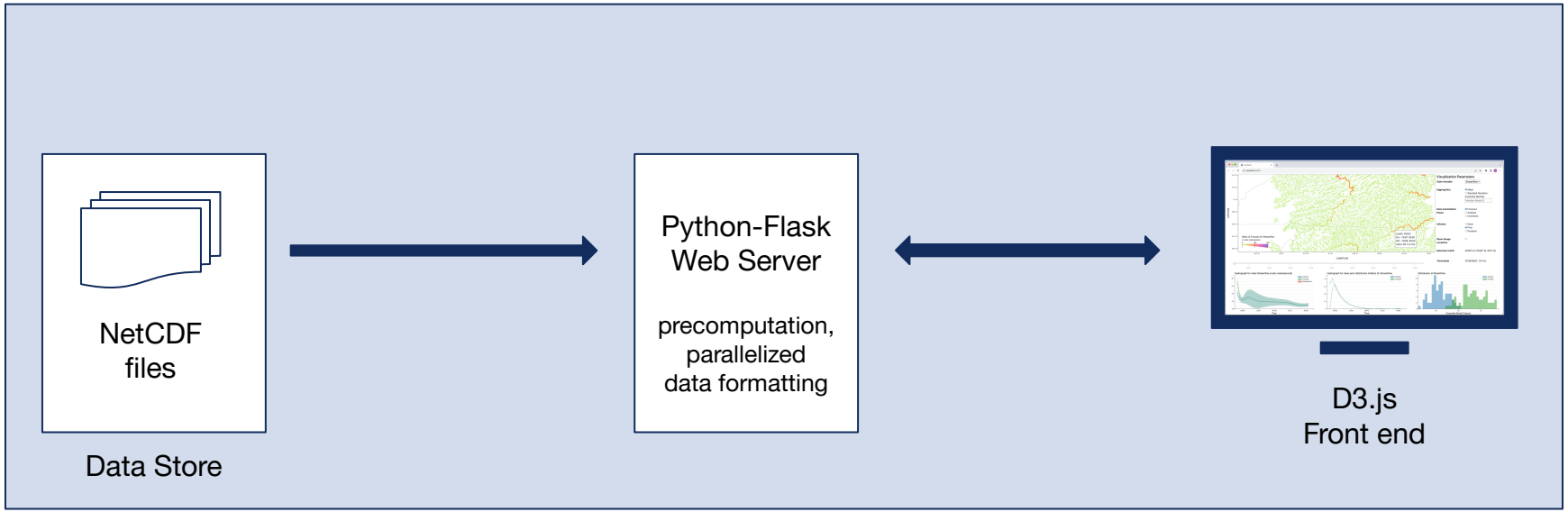
User Interface Controls



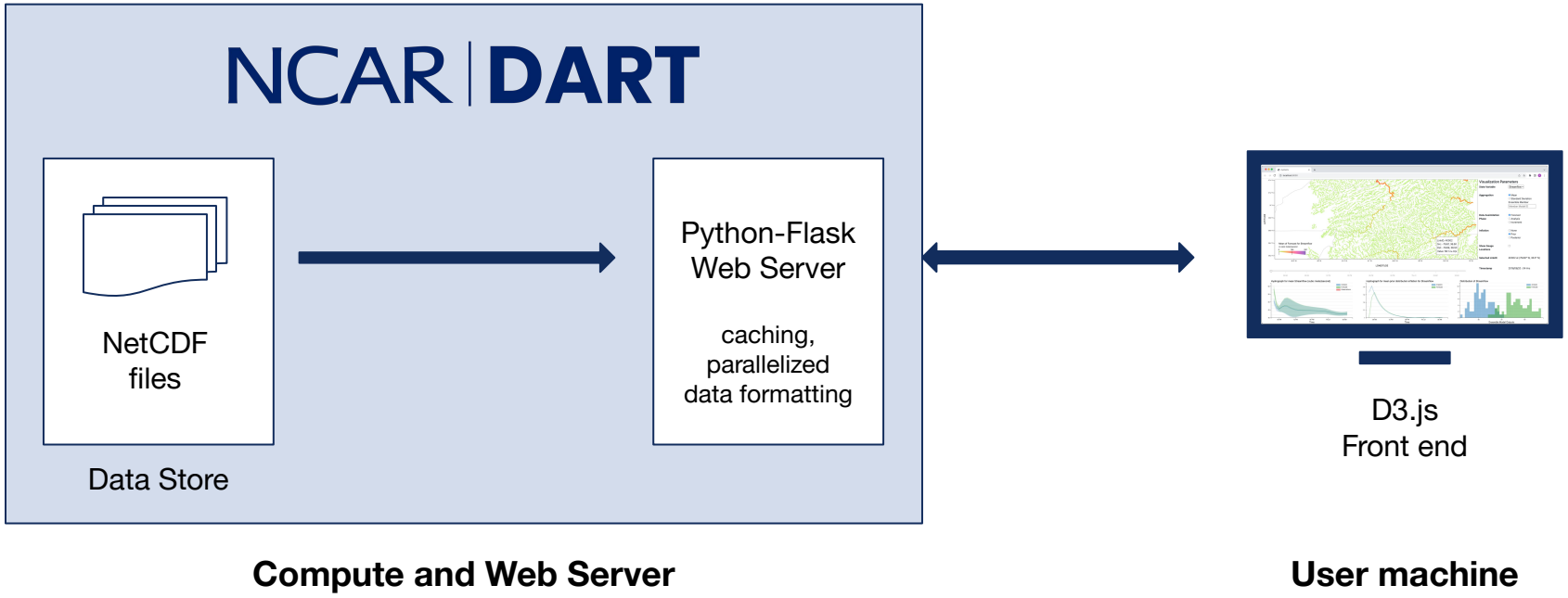
How is HydroVis designed?



Future Work


NetCDF
files
Data Store
Python-Flask
Web Server
precomputation,
parallelized
data formatting
D3.js
Front end
User machine

Future Work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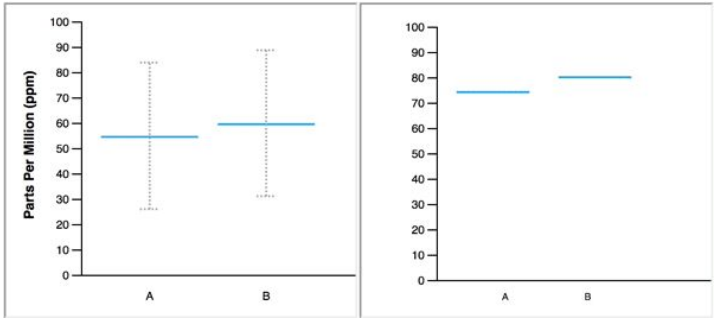
NetCDF files
Data Store
Python-Flask Web Server
caching, parallelized data formatting
D3.js
Front end
Compute and Web Server
User machine

Future Work

Visualization changes

- Open loop data to gauge the efficacy of data assimilation

- Uncertainty visualization constructs
  - hypothetical outcome plots



D3.js
Front end

User machine

Acknowledgements

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DAReS

Summer Intern Cohort and Managers

CISL and NCAR