Hydro-DART: Ensemble Streamflow Assimilation with WRF-Hydro and the Data Assimilation Research Testbed
These are the researchers! I am the `pit crew'.
1. WRF-Hydro
2. A brief overview of ensemble assimilation
3. Hurricane Florence
4. DA results from an 80 member experiment
   • Model bias
   • Localization
   • Ensemble spread and Inflation
   • Gaussian Anamorphosis
5. Conclusion
Weather Research & Forecasting Hydrologic Model

Weather Forcing Engine

WRF-Hydro: [https://www.ral.ucar.edu/projects/wrf_hydro](https://www.ral.ucar.edu/projects/wrf_hydro)

NoahMP Land Surface Model

Terrain Routing Module

2-way coupling

NHDPlus Catchment Aggregation

Channel & Reservoir Routing Module

Forecast Products
Channel-Bucket-Only Ensemble Data Assimilation

* EAKF (Anderson, 2001)
* Enhanced Inflation (El Gharamti, 2018)

Python environment: [github.com/NCAR/wrf_hydro_py.git](https://github.com/NCAR/wrf_hydro_py.git)
What is Data Assimilation?

Observations combined with a Model forecast...

\[ \text{Observations} + \text{Model forecast} = \text{Analysis} \]

... to produce an analysis.

Overview article of the Data Assimilation Research Testbed (DART):
Ensemble DA in DART

1) Posteriors
2) Model Forecasts result in Priors
3) A forward operator (h) maps each model state to an expected observation
4) DA
5) observation increments and regression create new model states: Posteriors
Hurricane Florence made landfall near Wrightsville Beach, North Carolina at 7:15 a.m. ET September 14. The GOES East satellite captured this geocolor image at 7:45 a.m. ET.

Winds up to 150 mph (240 km/hr)
Damage: $24.23 billion
NOAA/NWS/NCEP/WPC

30+” of rain

Local point maximum rainfall may be higher than shown. See the NHC public advisories for the latest tropical cyclone information.
‘scale’ of Florence Domain

Bald Head Island, NC to Cape Lookout, NC 28531 Walk 147 miles, 45 h
Control: No Assimilation

Monthly mean of the model. The streamflow is driven by the precipitation.

More than 100 gauges, reporting every 15 mins.

Now, what happens when streamflow gauge data is incorporated through DA?
Assimilation happens every hour.

Correction along major reaches. DA is adding water to the stream channels.

Reach Stream Flow Ensemble Mean
Time-Avg (07 Sep - 07 Oct): Posterior - Control

Assimilation happens every 720 hourly assimilation cycles.
Large improvements to the amplitude and the phase compared to the control.
Prior greatly improves the model’s estimate.

Posterior provides almost a perfect match with the gauge streamflow data.

Difference between knowing what to do (like evacuating people) and not doing anything!
Taylor Diagram

Improvements: control->prior->posterior

NEITHER 1

ACCURATE, NO PRECISION

centered root mean square error

NEITHER 1

NEITHER 1

NEITHER 1

NEITHER 1

NEITHER 1

NEITHER 1

NEITHER 1

NEITHER 1

NEITHER 1

NEITHER 1
1. **Inflation**: As a way to increase ensemble uncertainty, adaptive both in space and time

2. **Pattern-based (Along-the-stream) localization**: To minimize sampling errors

3. **Gaussian Anamorphosis**: Variable transform to accommodate positive definite variables (with non-Gaussian distributions)
Inflation aims at making the model consistent with observations.

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Ensemble and observations are consistent. 
Florence Domain: localization

More than 50,000 links, more than 100 gages

Localization occurs along the reaches, not just based on horizontal distance. Upstream & Downstream.

Exploded view to show detail

100 km localization distance is used
Gaussian Anamorphosis Capability

Observation rejection is improved with GA.

Better fit to the observations on Sep. 17th.

Higher order moments are almost completely eliminated using GA.
Conclusion

We use DART to perform streamflow and flood prediction with WRF-Hydro (NWM) during Hurricane Florence.

DART greatly improved the streamflow estimates

Novel enhancements to the DA algorithm were required:
- Using pattern-based localization
- Spatially and temporally varying inflation
- Gaussian anamorphosis

Next Steps: Update soil moisture, groundwater and ice; force the coupled system with an ensemble of atmospheric forcing, ...
For more information:

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https://water.noaa.gov/about/nwm
Topography of North Carolina

Dorian (aside)

AQUA MODIS Infrared
2019/09/06 07:20:00Z NRL-Monterey
Gaussian -> NonGaussian positive

From: Penn State Stats 400 level online course.