Regional scale ensemble streamflow assimilation with coupled WRF-Hydro and DART

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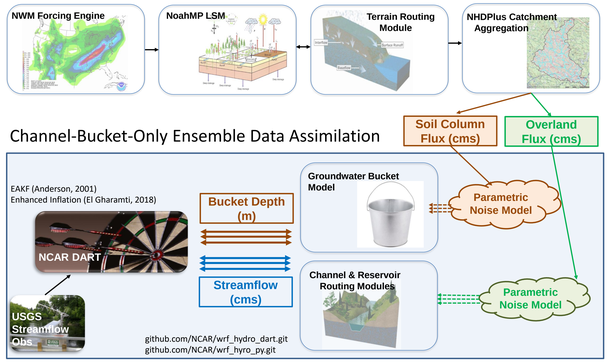
Abstract

The Data Assimilation Testbed Research (DART) has been coupled with the community WRF-Hydro modeling system, enabling ensemble data assimilation. The coupled Hydro-DART system uses state-of-the-art assimilation tools, including spatially and temporally varying adaptive inflation (to counter insufficient ensemble spread) and localization along stream channels (to eliminate spurious correlations). The system is also equipped with an efficient on-line estimation strategy of various physical and statistical parameters.

The Hydro-DART framework discussed here utilizes a channel-only capability of the WRF-Hydro model with an objective to demonstrate its robustness and high computational efficiency which can be appealing in operational settings. Uncertainty in the overland and groundwater channel-influxes is represented by incorporating stochastic perturbations. The assimilation framework provides streamflow and parameters estimates via the ensemble adjustment Kalman filter (EAKF). Here, we present preliminary results and the initial progress made on the implementation of the Hydro-DART framework. Testing is performed on regional case studies, looking at large-scale extreme flooding events such as *"Hurricane Florence."*

WRF-Hydro DART

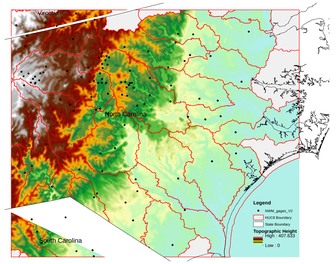
- ❑ We use a one-way-forced channel-bucket routing module which has been separated from the rest of the NWM configuration of the WRF-Hydro
- ❑ This decomposition allows ensemble operation of streamflow models



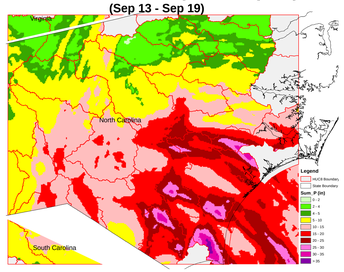
Case Study: Hurricane Florence

- Caused sever damage in the Carolinas in September 2018 primarily as a result of freshwater flooding
- Many places received record-breaking rainfall, and some places received more than 30 inches of rainfall
- Large storm surge along the coast causing widespread flooding
- Heavy rainfall caused widespread inland flooding
- Several cities were inundated such as Fayetteville, Smithfield, Lumberton, Durham, and Chapel Hill
- Major rivers spilled over their banks such as Neuse River, Eno River, Cape Fear River, and Lumber River

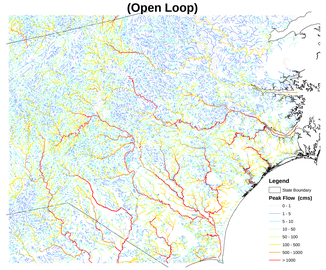
Topographic Height (m)



Accumulated Precipitation (mm)
(Sep 13 - Sep 19)

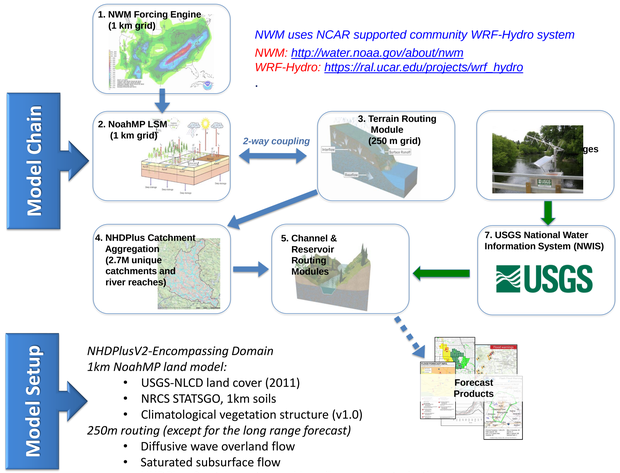


Peak Simulated Streamflow (cms)
(Open Loop)



National Water Model Configuration of WRF-Hydro

The National Water Model, an operational configuration of the WRF-Hydro model, provides streamflow forecasts for 2.7 million river reaches as well as other hydrologic states and fluxes. The NWM employs a nudging scheme in which more than 6000 USGS instantaneous streamflow observations are assimilated. This procedure is utilized as a way to provide initial states for different forecast configurations allowing forecasts for up to 30 days.



NWM uses NCAR supported community WRF-Hydro system

NWM: http://water.noaa.gov/about/nwm

WRF-Hydro: https://ral.ucar.edu/projects/wrf_hydro

Model version : WRF-Hydro V5.0.1 which is equivalent of NWM V2.0 beta version.

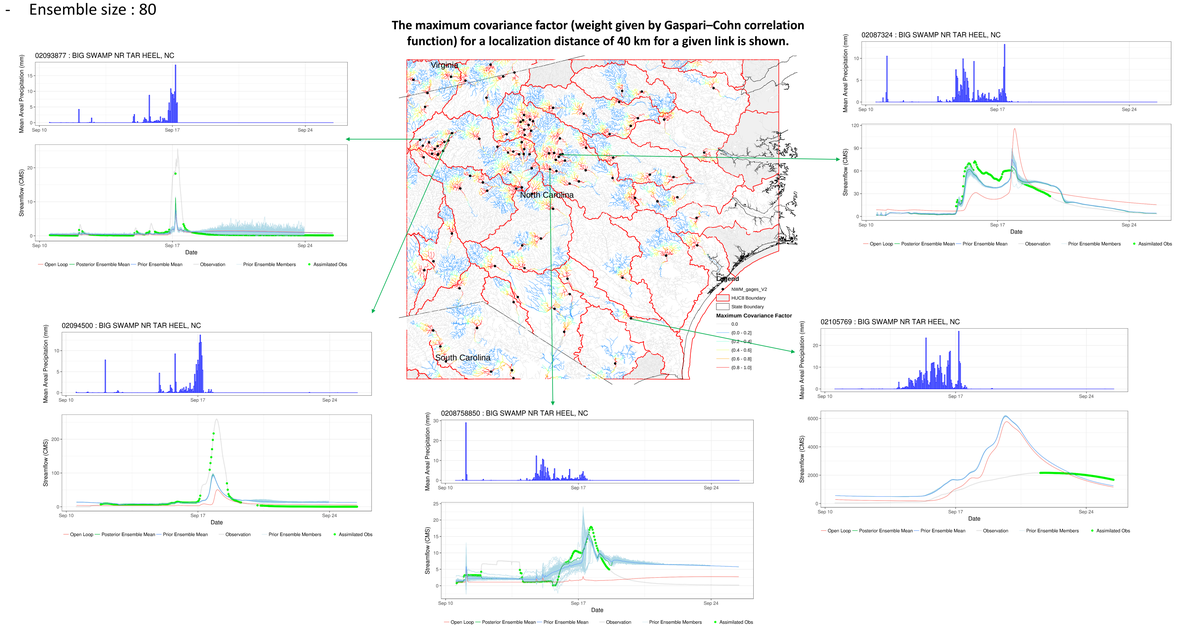
Docker container available as part of the training material: https://ral.ucar.edu/projects/wrf_hydro/training-materials

Preliminary Results

Experiment specification:

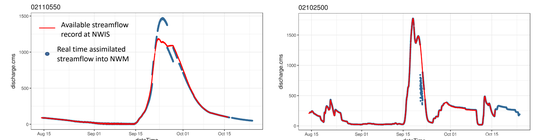
- Sequential data assimilation: Ensemble adjustment Kalman filter (EAKF)
- Inflation: Recently proposed enhanced adaptive inflation algorithm (El Gharamti, 2018)
- Localization: *A new 'Along-the-stream' localization.* The observations only affect a restricted length of upstream and downstream stream sections. Unlike Euclidean-based localization techniques, the proposed pattern-based localization ensures that streams from different watersheds are not updated with potentially unrelated streamflow data
- Parametric noise model: To maintain 'realistic' variability across the ensemble, parametric noise models are imposed on the overland flux and groundwater flux contributions to the channel model
- Ensemble size : 80

The maximum covariance factor (weight given by Gaspari–Cohn correlation function) for a localization distance of 40 km for a given link is shown.

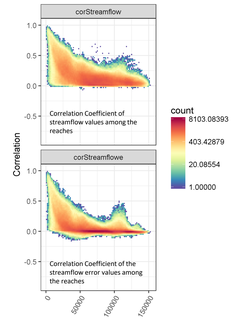


Conclusions and Ongoing Work

- HydroDART, an ensemble based channel-bucket only DA module for the WRF-Hydro, was developed and evaluated for a regional domain.
- A better understanding and formulation of the streamflow observation uncertainty is required.



- Localization scheme: the initial maximum distance of the links that get updated is 40 km. More testing will be done to find the optimized localizations distance.
- Performance of the Channel-Bucket Ensemble DA would be compared with the existing NWM DA scheme.



References

- Anderson, J. L., 2001. An Ensemble Adjustment Kalman Filter for Data Assimilation. Monthly Weather Review, 129, 2884-2903.
- El Gharamti M., 2018. Enhanced Adaptive Inflation Algorithm for Ensemble Filters. Monthly Weather Review, 2, 623-640.