A SEASONAL HYDROLOGIC ENSEMBLE FORECAST SYSTEM OVER THE EASTERN U.S.

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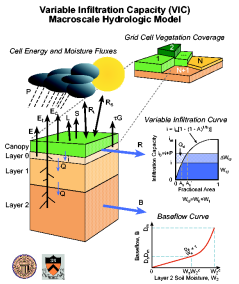
Introduction

"Progress in diagnosing, modeling and predicting seasonal climate variability represents a major scientific advancement of the 20th century, however, progress in the effective utilization of forecasts has lagged behind" (Goddard *et al.*, 2001). This research builds on an experimental seasonal hydrologic forecast system in the Ohio River basin to address a central scientific question of whether seasonal climate predictions have sufficient skill to provide useful hydrologic forecasts and water management information across the eastern U.S., as well as consider how seasonal hydrologic predictions can be made most skillful given the climate predictions, and how this skill can be quantified. The project focuses over the eastern U.S., and carries out the following two major activities:

1) The development of an expanded Eastern U.S. hydrologic ensemble forecast system that will include all basins east of the Mississippi main stem up to the mouth of the Ohio River.
2) An evaluation and analysis of the resulting seasonal hydrological predictions, with a focus on understanding the reliability of the ensemble forecasts and the overall uncertainty in the hydrologic ensembles due to model (seasonal climate and hydrologic) uncertainty, calibration uncertainty, data uncertainty, and so forth.

The project will enhance NOAA operational activities by extending current links to the NCEP-lead LDAS activities, by providing results useful for the NWS/HDL proposed water initiative and by demonstrating the usefulness of the seasonal hydrologic forecasts through application studies.

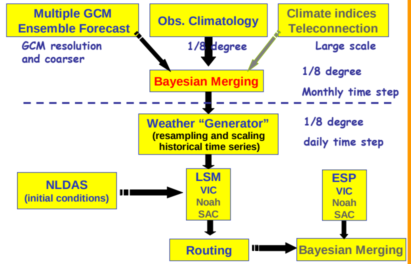
VIC Hydrologic Model



Variable Infiltration Capacity (VIC) model is a semi-distributed grid-based hydrological model with distinguishing hydrologic features such as the representation of subgrid variability in soil storage capacity as a spatial probability distribution. It has been widely applied to large continental river basins (Nijssen *et al.* 1997, Wood *et al.*, 1997 among many others) as well as continental scales (Naurer *et al.*,2001, Mitchell *et al.*, 2004, Sheffield *et al.*, 2004) and global scales (Nijssen *et al.* 2001 and Sheffield *et al.*, 2006). Its ability to simulate the hydrological processes has been well recognized. VIC model can be run in full energy balance mode as well as simple water balance mode with minimum inputs of daily total precipitation, daily minimum and maximum temperature, and wind. For the purpose of seasonal hydrological prediction, running VIC in the water balance mode with a daily time step is sufficient and also efficient.

Forecast Approach

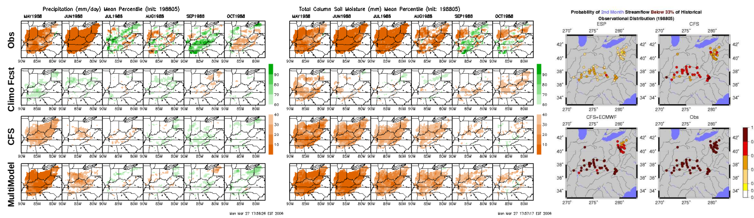
The central element of the forecast approach is the Bayesian merging that combines seasonal forecast from multiple climate model with observed climatology to achieve more reliable and skillful seasonal forecast. Spatial and temporal downscaling of climate model forecast is necessary for hydrologic applications and is done through the Bayesian merging approach and resampling of historical observations, which also creates the daily atmospheric forcing that is used to drive VIC model during the forecast period. NLDAS forcing is used to the provide estimate of initial conditions prior to the forecast.



Evaluation with A Multi-Year Hindcast Dataset

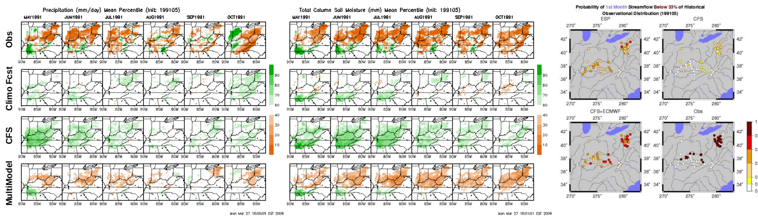
Hindcast (198805)

For this extreme event, climatologic forecast shows no skill in precipitation and soil moisture forecast. CFS-based forecast shows skill in the first few months. The multi-model-based forecast shows skill at longer lead times.



Hindcast (199105)

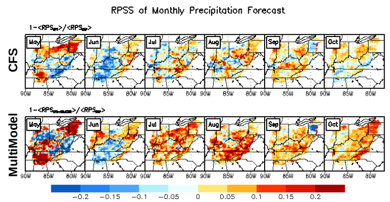
In this case, climatologic forecast still shows no skill in precipitation and soil moisture forecast. CFS-based forecast gives wrong forecast while multi-model-based forecast corrects the CFS forecast and shows significant skill over all lead time.



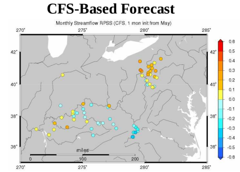
Cross-validation

Using a 19-year hindcast dataset (May to Oct of 1981-1999) over the Ohio River basin, we cross-validate and evaluate the performance of the forecast system. RMS error is used as the metric to quantify the forecast skills when the ensemble mean is used as the deterministic expression of the forecast. RPS (ranked probability score) is used as the metric to quantify the forecast skills when the forecast is interpreted in a probabilistic manner.

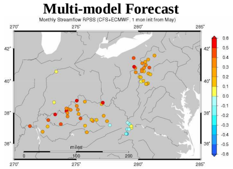
The CFS-based forecast and Multi-model-based (CFS+DEMETER) are compared with the climatological forecast, and they both show better skills than the climatological forecast in precipitation, soil moisture and streamflow (below). Over most of the Ohio River basin, the improvement in forecast skill is most significant in the first few months.



CFS-Based Forecast



Multi-model Forecast

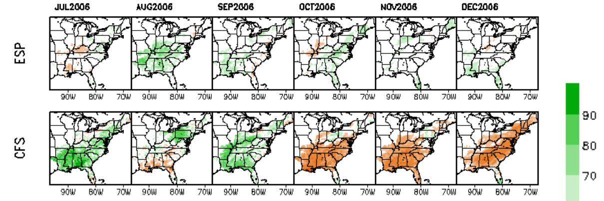


Positive values indicate an improvement in forecast skill with respect to climatological forecast.

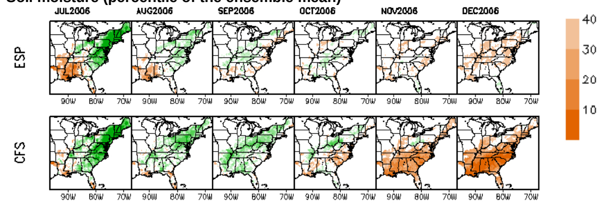
Realtime Drought Monitoring and Seasonal Forecast

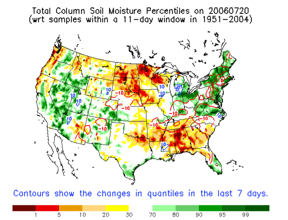
We have developed realtime drought monitoring capability (right top) over the CONUS and it provides more details than the office US drought monitor (right middle) and is more consistent with the USGS realtime streamflow stage information (right bottom). Using such a nowcast as the initial condition and seasonal forecast from CFS, we release a 6-month seasonal hydrologic forecast over the eastern US (below), including precipitation, soil moisture and streamflow.

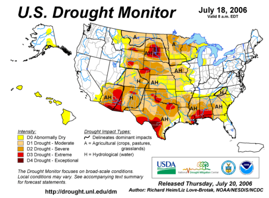
Precipitation (percentile of the ensemble mean)

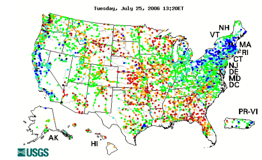


Soil moisture (percentile of the ensemble mean)









Summary

•Our current Bayesian merging approach is able to bring in useful information from climate seasonal forecasts to form the best estimates.
•Although limited, the skill from the Bayesian merging can be amplified with conditional selection of analogs in historical data.
•Multi-model-based forecast is better than single model-based forecast in general, therefore it is necessary to develop a multi-model framework for future seasonal predictions.
•Forecast becomes less certain with the increase of lead time, the probabilistic forecast moves towards climatological distribution as lead time increases.
•Our future plan is to merge our approach with the approach developed by Univ. Washington, hence providing a unified approach for the entire U.S.

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