The Integration of Probabilistic Precipitation Forecasts from the National Blend of Models into NOAA's National Water Model: A Case Study of Hurricane Beryl

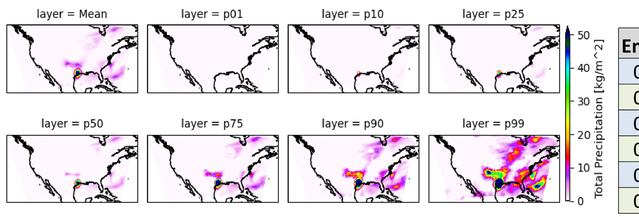
Amir Mazrooei[1], Yongxin Zhang[1], Ishita Srivastava[1], Ryan Cabell[1], Alyssa McCluskey[1] and David Gochis[2]
1) NSF National Center for Atmospheric Research, Boulder, CO. 2) Airborne Snow Observatories, Boulder, CO, USA

Introduction

The U.S. National Water Model (NWM) built on the NCAR's WRF-Hydro modeling system simulates and forecasts streamflow for over 3 million stream reaches across the CONUS and its territories. The NWM Medium-Range forecast configuration (10-day ahead) currently relies solely on deterministic QPF from the Global Forecast System (GFS). The NOAA's National Blend of Models (NBM) is a sophisticated forecasting tool that combines output from multiple weather models to produce highly detailed and accurate predictions. This study explores the use of NBM Precipitation Quantile Mapping and Dressing (QMD) probabilistic precipitation forecasts QPF06 to force NWM for MR forecasting.

Pre-processing the NBM-QMD Dataset: Construct Ensemble Precipitation Forecasts

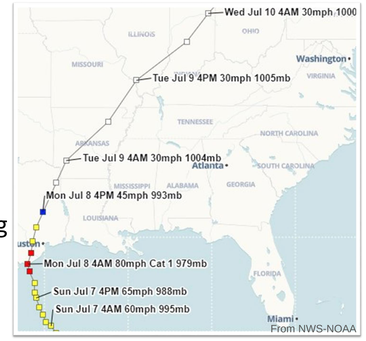
NBM-QMD dataset are obtained from NOAA's servers. Within this dataset, the probabilistic precipitation forecasts are available in 100 percentile layers (e.g., p01), as well as an additional layer reflecting the QMD-Mean. However these layers can not be directly used in the water model since p01 implements the driest conditional precipitation and p99 forces the wettest possible rainfalls all over the CONUS. So to reconstruct realistic precipitation ensembles for the water model, we compute the weighted mean of a selection of the QMD percentile layers, while the assigned weights are balanced around the middle 50th percentile. With this respect, 6 ensemble members were generated as it is shown in the table below. This is a new configuration option added to the NOAA's *Meteorological Forcing Engine (MFE)*, which handles these pre-processing steps and outputs NWM meteorological forcing files.

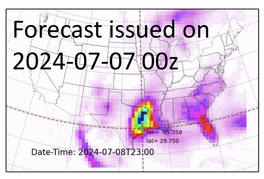


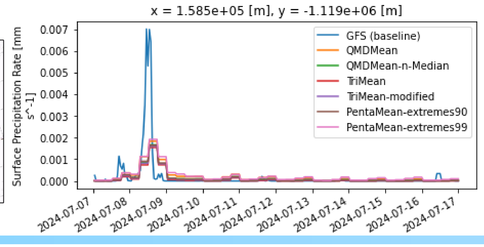
		Weights assigned to QMD layers							
Ens #	Ensemble Member Name	*Mean*	*p01*	*p10*	*p25*	*p50*	*p75*	*p90*	*p99*
01	QMD-mean	1	-	-	-	-	-	-	-
02	QMD-mean-n-median	0.5	-	-	-	0.5	-	-	-
03	TriMean	-	-	-	0.25	0.5	0.25	-	-
04	TriMean-modified	0.2	-	-	0.2	0.4	0.2	-	-
05	PentaMean-extremes-90	-	-	0.1	0.2	0.4	0.2	0.1	-
06	PentaMean-extremes-99	-	0.1	-	0.2	0.4	0.2	-	0.1

Hurricane Beryl was a devastating tropical cyclone that impacted the Gulf Coast of the United States in late June and early July 2024. The storm formed on June 28, 2024, and quickly intensified, reaching Category 5 status by July 1. Beryl continued its destructive path, making landfall near Matagorda, Texas, on July 8 as a Category 1 hurricane, resulting in at least 36 deaths and causing between $28 billion and $32 billion in damage.

Figures below show the QPF06 probabilistic forecasts sourced from NBM-QMD, offering critical insights into the expected rainfall distribution, intensity, and timing associated with the storm. It is shown that the "QMD-Mean" and the "PentaMean-99" are the wettest ensemble members, while the "TriMean" member has the driest rainfall over the sampled grid cell over Houston urban area.



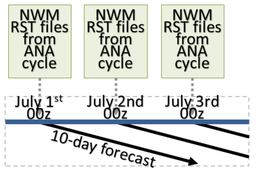




	mean	std	25%	50%	75%	max
QMD_mean	0.000194	0.000348	0.000026	0.000076	0.000192	0.001835
QMD_mean_n_median	0.000134	0.000304	0.000013	0.000038	0.000098	0.001668
TriMean	0.000096	0.000284	0.000000	0.000000	0.000038	0.001549
Modified-TriMean	0.000116	0.000296	0.000005	0.000015	0.000069	0.001606
PentaMean-extremes-90	0.000125	0.000310	0.000000	0.000016	0.000089	0.001648
PentaMean-extremes-99	0.000229	0.000361	0.000064	0.000117	0.000214	0.001925

Water Model Experimental Setup

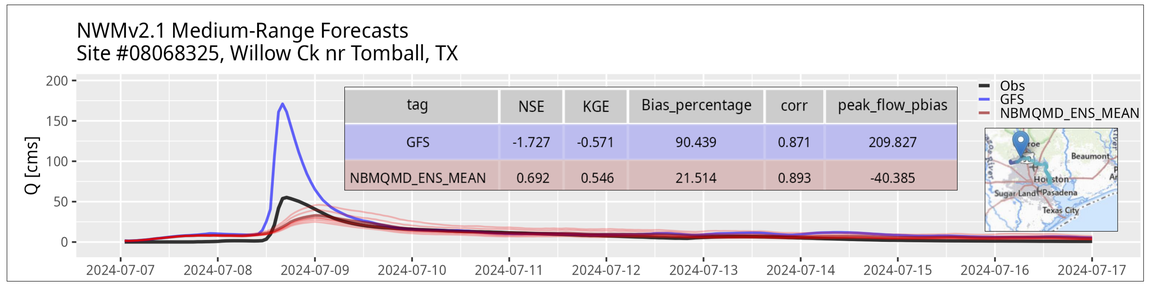
About **20 Medium-Range Forecasts** issued on 00z every day over the period **2024-June-28 to 2024-July-19**. NWM is restarted based on daily restart files at 00z.For each MR forecast issue date, NWM has been executed 6 times with different ensemble members of the processed NBM-QMD probabilistic forecasts.



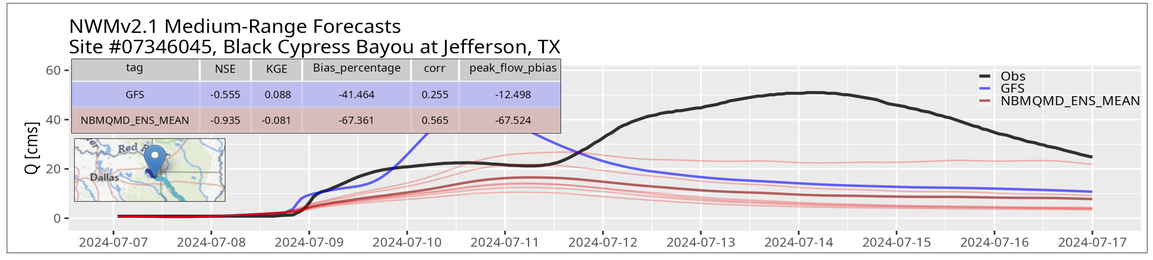
NWM Probabilistic Forecasting, Source of NWM Forcing fields:							
Run Tag	Ensemble Size	Total Precip (RAINRATE)	2-m Air Temp (T2D)	Wind (U2D & V2D)	Radiations (SW & LW)	Humidity (Q2D)	Pressure (PSFC)
GFS (baseline)	1	GFS	GFS	GFS	GFS	GFS	GFS
GFS_QMDNBM_APCP	6	NBM-QMD (APCP)	GFS	GFS	GFS	GFS	GFS

Evaluation of Hydrologic Forecasts

- Below is a sample hydrograph showing good performance of MR ensemble forecasting using NBM-QMD probabilistic climate forecasts over a sample river basin in Texas during Beryl storm. GFS-based streamflow forecasts have a strong positive bias, particularly during peak flow event, however the error in peak flow timing is minimal. On the other hand, NBMQMD-based streamflow forecasts are more accurate in terms of flow volume and have better NSE and KGE verification metrics, though the peak flow timing is off by hours.



- Another sample hydrograph showing bad performance of MR ensemble forecasting using either GFS climate forecasts or NBM-QMD probabilistic climate forecasts over a sample river basin in Texas during Beryl storm. Note again that the GFS-based streamflow forecasts are better than the NBMQMD-based ones in terms of peak flow timing and biases.



- Future research will compute and summarize the skill in streamflow forecasting and the gain by incorporating NBM probabilistic forecasts over the U.S. states affected by Beryl hurricane.