Final Report for MAPP Project: GC15-204

Application of the NMME for the Intraseasonal Prediction of Tropical Cyclones over the Atlantic and North Pacific Basins

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Period of Activity: August 1, 2015 to September 30, 2016

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Objective

The objective of this project is to develop a suite of dynamical–statistical forecast models for intraseasonal forecasts of Atlantic and North Pacific basin tropical cyclone (TC) activities using the data from the NMME monthly forecasts.

1. Results and Accomplishments

1-1. Prototype testing with CFSv2

A set of prototype forecast systems has been developed using the dynamical seasonal forecasts from one of the NMME models, the NCEP CFSv2. The key scientific accomplishments are summarized below.

- We have established the empirical relationships between observed monthly TC activity and CFSv2 predicted ocean and atmosphere conditions with lead times from 0 month to 3 months for the tropical North Atlantic, tropical eastern North Pacific, and tropical western North Pacific basins, respectively. This is the physical basis for developing the hybrid dynamical–statistical forecasting systems for monthly TC activity.
- For each ocean basin, we have identified three potential predictors, including vertical wind shear (VWS), sea level pressure (SLP), and sea surface temperature (SST), which are the averages of these variables over the regions having high correlations with the observed monthly TCs (Please see Fig. 1 as an example for VWS).
- We have developed the hybrid dynamical–statistical model for forecasting monthly TCs for each ocean basin and assessed the forecast skill using different predictors.

The dynamical–statistical forecast system has been developed for predicting monthly TCs for the three northern ocean basins using multiple linear regressions. The forecast skill of the hybrid model has been evaluated based on cross-validations over the 1982–2010 hurricane seasons (May–November). The model has been run for each ocean basin with combinations of different predictors, including VWS, SLP, and SST.

Overall, the model has relatively high skills for the tropical North Atlantic and western North Pacific and relatively low skills for the tropical eastern North Pacific (Fig. 2). In different ocean basins, the highest forecast skill may be obtained using different predictors. In the Atlantic, for example, the model with two predictors, VWS and SST, shows the highest skill for all lead times. In the eastern North Pacific, using SST as the only predictor leads to the highest skills for all lead time forecasts.

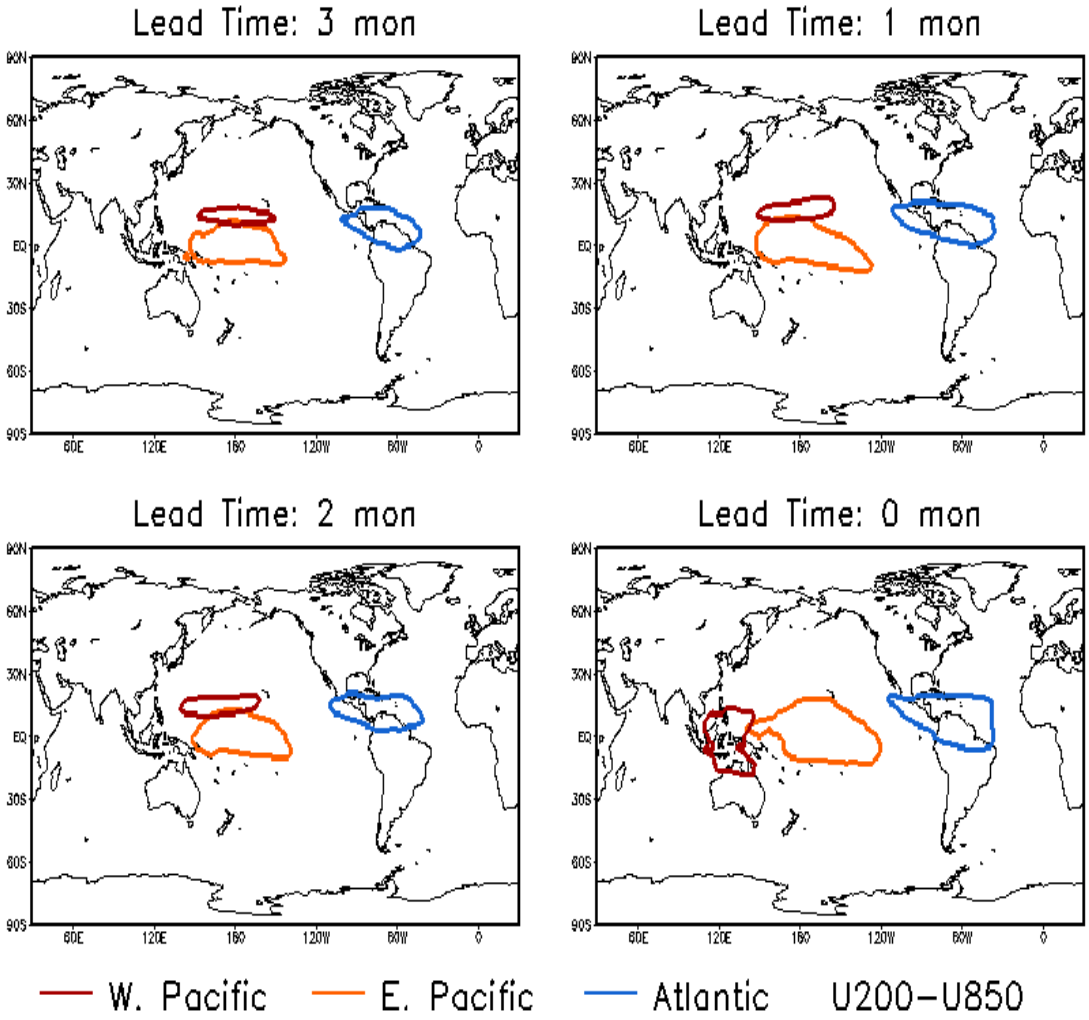

Fig. 1 Regions for constructing vertical wind shear (VWS) as a predictor for the three ocean basins based on the correlation maps between observed monthly TC activity over May–November 1982–2010 and CFSv2 hindcasts of vertical wind shear with lead times from 3 months to 0 month. The regions circled by blue, orange, and red lines are used for averaging VWS for the Atlantic and the eastern and the western North Pacific, respectively.

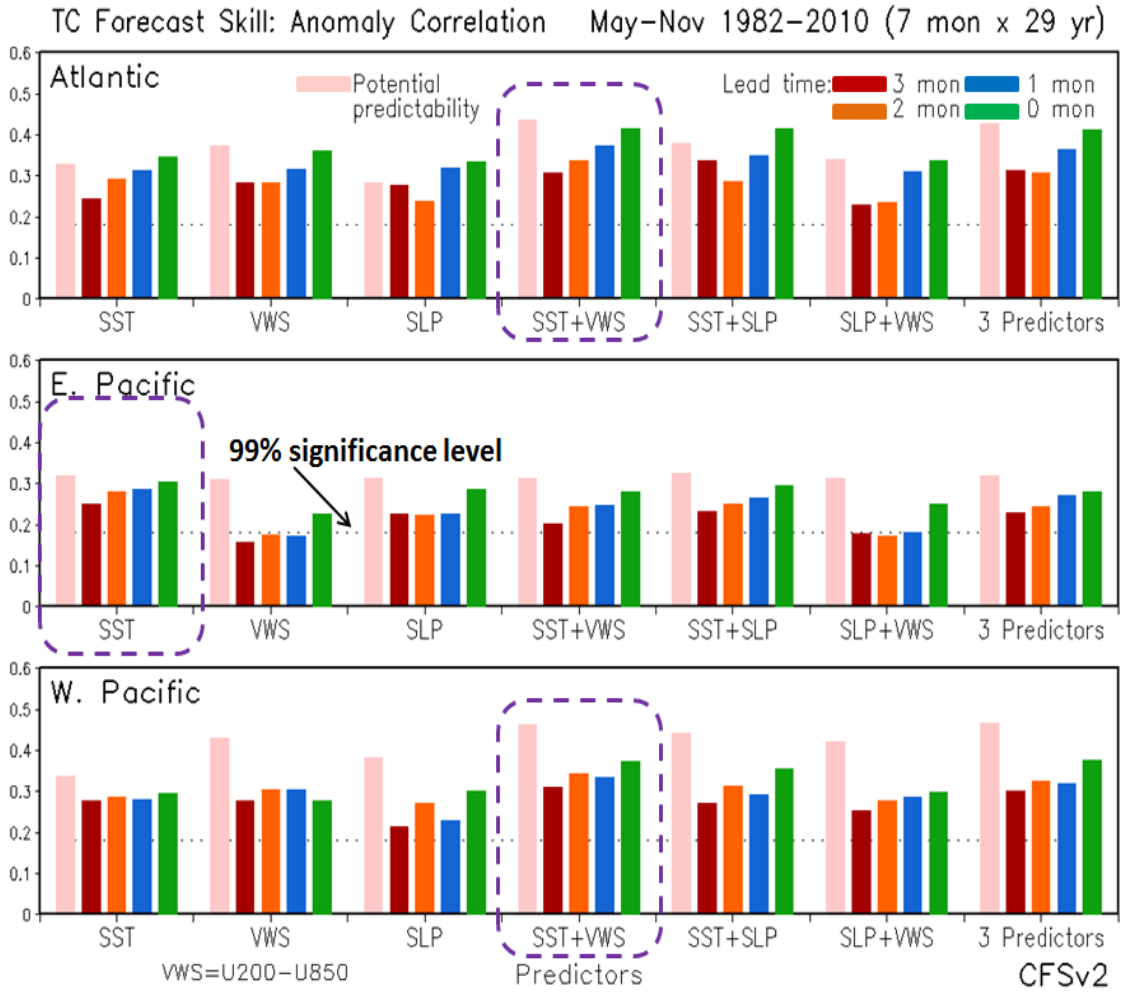

Fig. 2 Forecast skills for monthly TCs based on cross-validations over the 1982–2010 period for the Atlantic (top), the eastern Pacific (middle), and the western Pacific (bottom) using different predictors derived from the CFSv2 hindcasts with lead times from 3 months to 0 month. The box with dashed lines denotes the highest forecast skill in each ocean basin.

1-2. NMME Extension

The dynamical-statistical forecast model developed using the CFSv2 to forecast for the Atlantic and North Pacific basins' tropical cyclone (TC) activities was extended to include other models from the NMME. The other models included in the system are the NCAR CCSM4 and the Canadian models, CanCM3 and CanCM4. These models, and the CFSv2, are used to create a NMME forecast for TC activities on the monthly time scale for three basins: the Atlantic (ATL), the eastern North Pacific (ENP) and the western North Pacific (WNP). The forecasts are made for the hurricane season, which is defined here as May through November.

The three potential predictors, vertical wind shear (VWS), sea level pressure (SLP), and sea surface temperature (SST), were tested individually and in combination to assess the highest skill in forecasting TCs, which is shown in Fig. 3. The regions of high correlation established between the observed monthly TC activity and the CFSv2 potential predictors at each lead time for each basin were used for all models. The combination of VWS and SSTs were chosen as the best predictors and were used for all models at all lead times. Unique regression relationships were applied for each model and the forecasted anomalies are multiplied by the ratio of the standard deviations of each model hindcast and the observed TC anomaly interannual variability. The NMME forecast is an equally weighted average of each model's resultant forecasted anomalies added to the observed TC climatology.

The model has the highest skill for the North Atlantic basin, followed by the western North Pacific basin. The eastern North Pacific basin has the lowest skill (Fig. 5). When comparing this with the results from Fig. 3, the TC forecast skill chart shows that the eastern North Pacific does not gain skill from the inclusion of VWS as a predictor, while both the North Atlantic and western North Pacific basins show improvement. Both the VWS and SST were used as predictors for all basins for continuity in the model. The use of the ratio of standard deviations in the hindcast anomalies improves the model's ability to capture more of the relative maximum and minimum monthly anomalies over the time series, as well as trends of positive or negative TC anomalous activities over several years (Fig. 4).

A test for real-time forecasting (Table 1) was also run using forecasted VWS and SSTs from July and August 2016 from each model's forecasts as predictors for the 0- to 3-month lead times**.** Compared to the observations, the forecasts did capture most of the peak activity in each basin. The North Atlantic basin performed the best, while the western North Pacific and eastern North Pacific basins forecasts were under forecast. This year was unusual for TC activity because all three northern ocean basins had active seasons.

Fig. 3. Forecast skills for monthly TCs based on cross-validations over the 1982-2010 period for the 4 models. The Atlantic, eastern Pacific and western Pacific basins were evaluated separately at lead times 0-3 months.

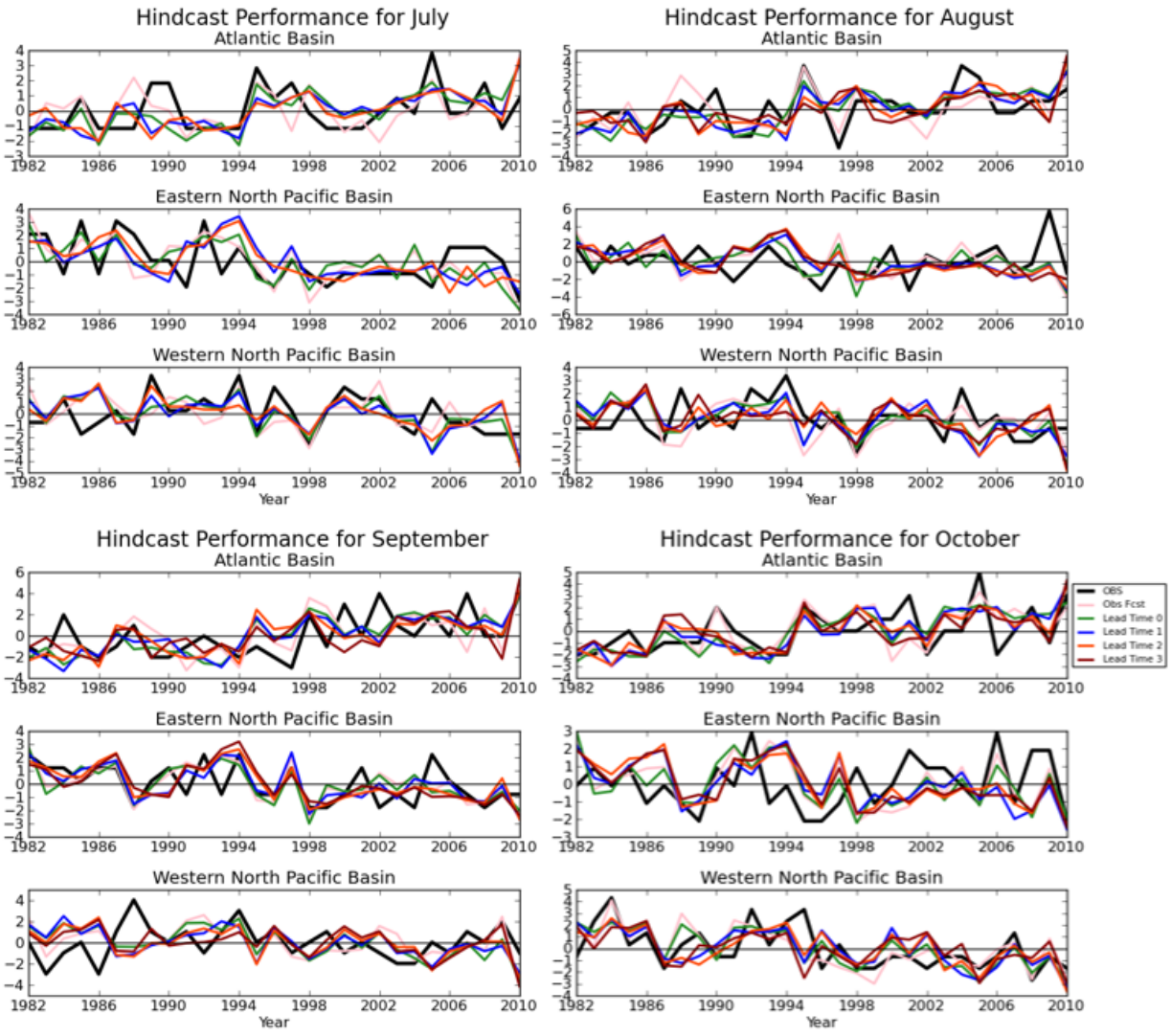

Fig. 4. Time series of the NMME forecasted TC anomalies over the 1982-2010 hindcast period for lead times 0 to 3 months, compared with the observational time series for July to October.

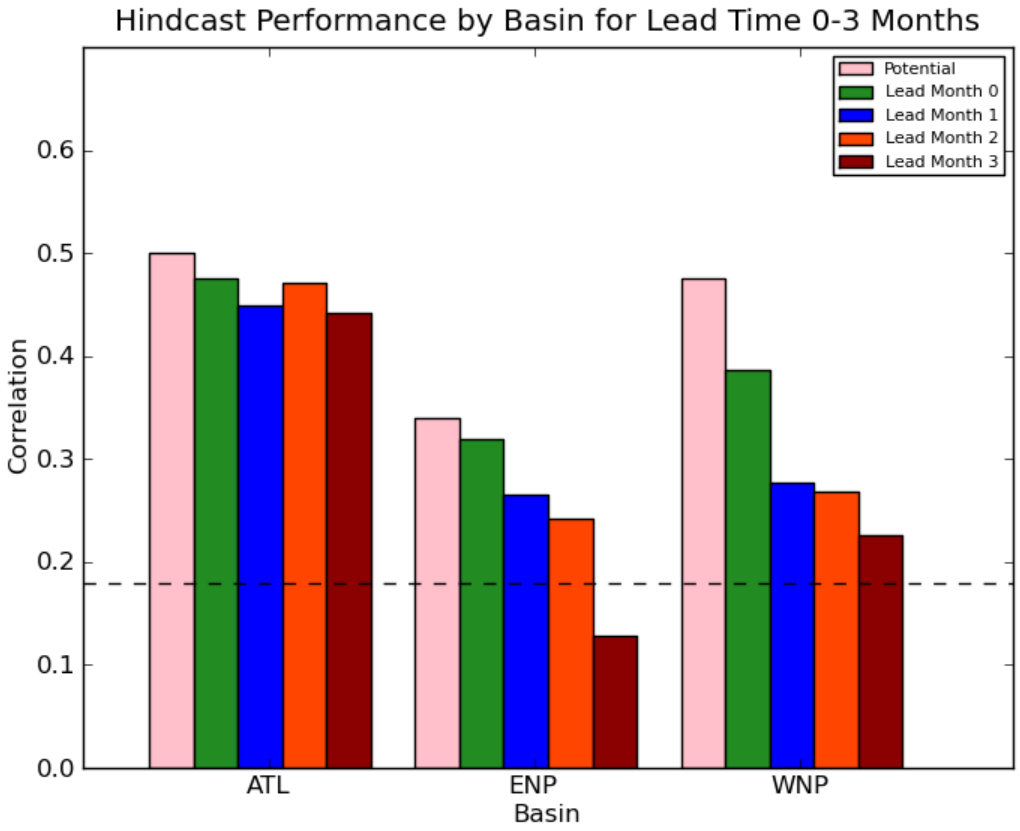

Fig. 5. Hindcast performance for the NMME average for each basin over the 1982-2010 period from May to November using wind shear and SSTs as predictors from 0 to 3 month lead times. The dashed line denotes the 95% significance level.

a)

July 2016 IC's						
Atlantic Basin						
Month	CFSv2	CanCM3	CanCM4	CCSM4	NMME	OBS
July	3.4	3.6	2.8	4.9	3.7	0
August	8.5	5.9	5.2	6.2	6.4	4
September	9.0	6.3	5.5	6.6	6.9	7
October	4.5	2.9	2.8	4.2	3.6	2
Eastern North Pacific Basin						
Month	CFSv2	CanCM3	CanCM4	CCSM4	NMME	OBS
July	2.1	0	0	0	0.5	8
August	4.1	1.8	2.9	1.7	2.6	6
September	3.4	1.2	2.3	1.2	2.0	5
October	0	0	0.2	0	0.1	1
Western North Pacific Basin						
Month	CFSv2	CanCM3	CanCM4	CCSM4	NMME	OBS
July	1.8	0.8	2.1	0	1.2	4
August	5.9	3.4	4.3	2.7	4.1	9
September	6.0	4.5	4.2	3.0	4.4	6
October	4.8	3.0	3.5	2.3	3.4	5

b)

August 2016 IC's						
Atlantic Basin						
Month	CFSv2	CanCM3	CanCM4	CCSM4	NMME	OBS
August	4.3	7.0	5.5	7.0	6.0	4
September	6.7	7.3	6.0	6.9	6.7	7
October	3.1	4.1	3.5	4.6	3.8	2
November	0	1.7	1.8	2.8	1.6	1
Eastern North Pacific Basin						
Month	CFSv2	CanCM3	CanCM4	CCSM4	NMME	OBS
August	3.5	0	0	0	0.9	6
September	2.0	1.7	2.2	1.2	1.8	5
October	0	0	0.5	0	0.1	1
November	0	0	0	0	0	2
Western North Pacific Basin						
Month	CFSv2	CanCM3	CanCM4	CCSM4	NMME	OBS
August	6.4	3.2	4.0	1.2	3.7	9
September	4.9	2.2	3.8	2.0	3.2	6
October	3.3	2.3	2.5	1.8	2.5	5
November	1.6	0.4	0.8	0.8	0.9	3

Table 1. Real-time TC forecasts using a) July 2016 and b) August 2016 initial conditions for the 0-to 3-month lead times for each basin with corresponding observations.

Highlights of Accomplishments

- Developed a hybrid dynamical-statistical model for forecasting monthly TC activity based on the dynamical seasonal forecasts of 4 global climate models and tested each separately for forecast skill using the three potential predictors, VWS, SLP and SST, averaged over the regions of high correlations defined by the CFSv2 model.
- Hindcast datasets from the 1982-2010 period were created using the chosen 2 predictors of forecasted VWS and SSTs from the 4 models. These were cross-validated against observations and compared to a hindcast dataset using observed SSTs and VWS over the 1982-2010 period.
- An equally weighted NMME hindcast dataset was also tested for significance against the observational dataset. To capture more variability in the hybrid dynamical-statistical model, the forecasted anomalies from each model were multiplied by the ratio of the standard deviation of observed TC anomalies to the hindcast TC anomalies.
- The hybrid dynamical-statistical model was tested for a portion of the 2016 Hurricane Season, using the forecasts in months of July and August as predictors. The 0- to 3-month lead forecasts show variability that captures the peak month of each basin.
- It is planned to continue the real time prediction of monthly TC activity using this NMME based hybrid prediction system for the 2017 hurricane season in support of the CPC Global Tropics Hazards Outlook extension.

Publications

A manuscript based on this work is being prepared for publication. This final report is submitted somewhat late in January, 2017 due to delayed hiring of a support staff (Ms. Christina Finan) in March 2016 and data issues involved in processing real time forecast data for the 2016 tropical storm season.

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