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Evaluation of an NMME-based Hybrid Prediction System for Eastern North Pacific Basin Tropical Cyclones

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Based on the previously developed model for the prediction of the Atlantic seasonal hurricane activity, the hybrid dynamical-statistical model utilizing the North American Multi-model Ensemble (NMME) has been expanded to predict hurricane activity for eastern North Pacific basin in further support of the NOAA's Hurricane Seasonal Outlook from the Climate Prediction Center (CPC). A hybrid dynamical-statistical model was first developed for the Atlantic using multiple linear regression relationships derived from forecasts and hindcasts with the NCEP Climate Forecast System v. 2 (CFSv2) and observational datasets (Wang *et al.* 2009). This project uses the data available through the NMME experiment, both real-time forecasts and hindcasts, which has shown that an ensemble approach improves skill over the individual CFSv2 system (Kirtman *et al.* 2014).

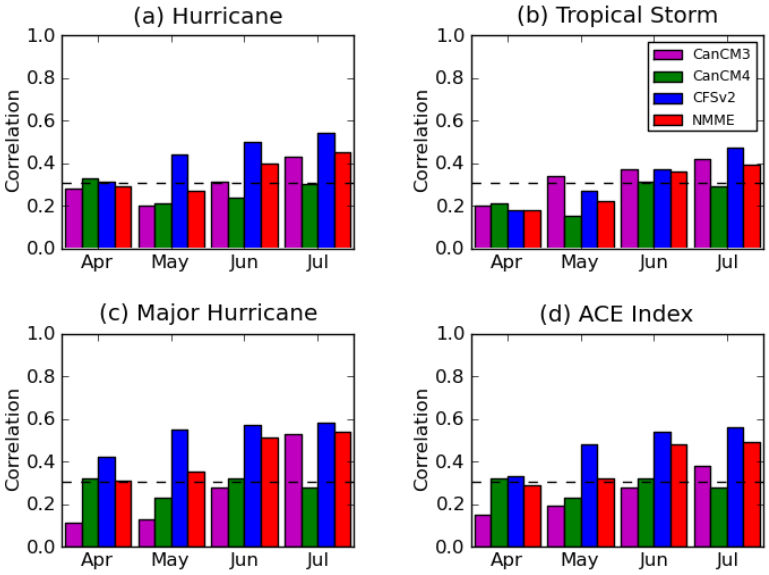

Fig 1 Hindcast prediction correlations for the eastern North Pacific basin for the four predictands: (a) hurricanes, (b) tropical storms, (c) major hurricanes and (d) the ACE index. Each model's (CFSv2, CanCM3/4, CCSM4) hindcast and the NMME hindcast using initialization months April through July were correlated with observed values are averaged over the 1982-2010 period. The dashed line denotes the 95% significance level.

Predictand	CanCM3	CanCM4	CFSv2	NMME
Hurricane	2.80	2.74	2.77	2.66
Tropical Storm	4.03	3.99	4.03	3.92
Major Hurricane	2.36	2.24	2.13	2.15
ACE Index	55.69	52.60	51.86	51.88

Table 1. Hindcast RMSE for April initial conditions averaged over the 1982-2010 period. The NMME and CFSv2 are the two models with the lowest RMSE values.

For the eastern North Pacific tropical cyclone (TC) activity forecasts, the selected predictors are the averaged July – September wind shear forecasts over the central tropical Pacific (10°S-7.5°N, 165°E-135°W) and sea surface temperature forecasts over the central North Pacific (20-36°N, 165°E-135°W) from a suite of four global climate models (GCMs): the CFSv2, Canadian Centre for Climate Modeling and Analysis Climate Model Versions 3 and 4 (CanCM3, CanCM4) and the NCAR Community Climate System Model Version 4 (CCSM4). The anomalous forecasts for shear and SSTs are used in unique regression relationships, fitted for each individual model to produce forecasts for four predictands: anomalous number of tropical storms,

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hurricanes, major hurricanes and accumulated cyclone energy (ACE) index for the full hurricane season, June through November. The anomalies are calculated using each model's 1982-2010 hindcast climatology. The NMME forecasts are an equally weighted average of the four model's forecasts. The forecasts skill was cross-validated over the 1982-2010 period.

The anomaly correlations between hindcast and observed tropical cyclone (TC) activity are shown in Figure 1 for three of the individual models and the averaged NMME suite. The CCSM4 was removed from the NMME mean due to low correlations in the hindcast analysis. The CFSv2 has the highest skill across the suite, followed by the NMME. The NMME however, reduces the RMSE for two of the predictands, tropical storms and hurricanes, when compared to the three individual models (Table 1). For the other two predictands,

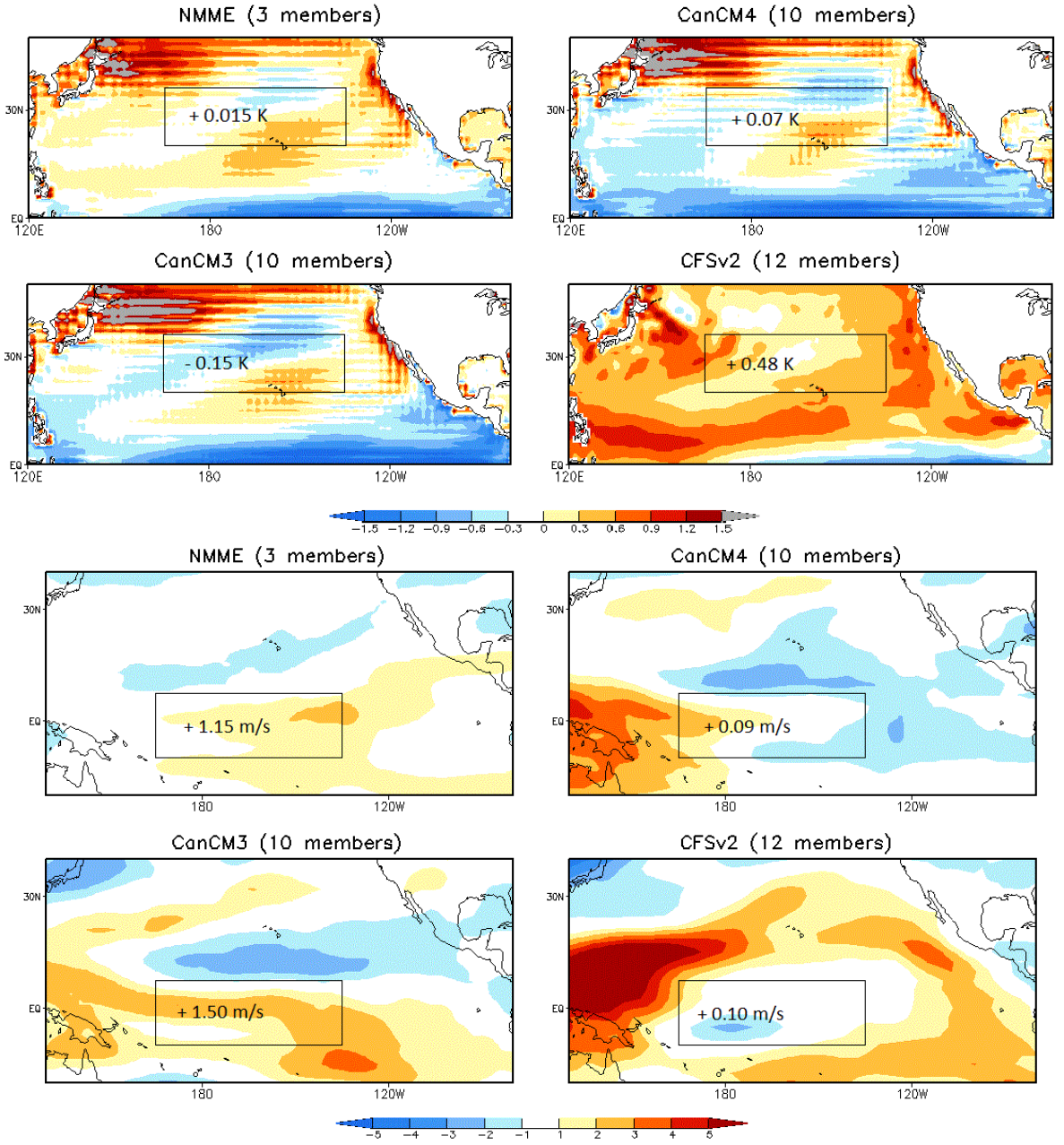

Fig 2. 2016 forecast of anomalous SST (a) and wind shear (b) for the July-September period from forecast runs with April 2016 initial conditions. The area of prediction is outlined and with area-averaged anomaly value displayed. This value was used as a predictor in the forecast, excluding the NMME suite mean. The NMME forecast is an equal-weighted average of each model's individual forecast.

the RMSE between CFSv2 and NMME are comparable. The hybrid model has the highest skill for the major hurricane predictand, followed by the ACE index.

The hybrid dynamical-statiscal model was tested in real-time, using the forecasts with April 2016 initial conditions from the CanCM3, CanCM4 and CFSv2 to predict for the 2016 eastern North Pacific hurriance season. The forecasts from the three individual models were averaged to create the NMME forecast for the 2016 season. The ensemble mean April 2016 forecasts of wind shear and SSTs from July to September are shown in Figure 2 for individual models, as well as for the NMME. The area of prediction used to construct the predictors is outlined in a black box, with the spatial average displayed. Both the CanCM3 and CanCM4 SST fields show warm anomalies in the central North Pacific, with cold anomalies to the north, while the CFSv2 SST field shows an overall warm signal for the North Pacific basin. The CFSv2 and CanCM4 wind shear fields show a slight enhancement, but mostly neutral signal for the central tropical Pacific, while the CanCM3 shows a stronger enhancement. The NMME averages for the SST field shows a near-normal forecast and the wind shear forecast is above-normal.

Table 2 details the forecasts from each individual model and the NMME averages, alongside the observations from the 2016 eastern North Pacific hurricane season. The CanCM3 and CanCM4 forecasted a near-normal season, as well as the NMME averaged forecast. The CFSv2 forecasted a below-normal season. For the eastern North Pacific, the 2016 hurricane season was classified as above-normal. All of the models underforecasted the 2016 season. The CanCM4 model was the closest in forecast, with a near-normal season on the top-end of the prescribed ranges for each predictand. The CFSv2, while performing the best in the hindcast evaluations, had the lowest performance in the real-time prediction. During the summer of 2016, the eastern Pacific was undergoing a shift in the ENSO cycle, after a record-high El Niño in 2015-16. Many of the models forecasted a shift to a La Niña phase duing the summer of 2016 in the Eastern Pacific (also seen in Fig. 2), which remained in a neutral state. The La Niña phase typically brings a near-normal or below-normal hurricane season to the Eastern Pacific, which could explain the underforecasted season by the models.

Variable	CanCM3	CanCM4	CFSv2	NMME	Observations
Hurricanes	7-9 (8)	8-9 (8)	5-7 (6)	6-8 (7)	12
Tropical Storms	13-15 (14)	15-16 (15)	11-14 (13)	13-15 (14)	18
Major Hurricanes	3-4 (3)	3-4 (4)	1-3 (2)	2 – 4 (3)	5
ACE	93-117 (105)	100-124 (112)	45-98 (71)	79 – 113 (96)	144

Table 2. The NMME-based hybrid prediction of the 2016 TC season over the ENP basin. The forecasted ranges are shown, with the average forecast in parentheses. The hybrid system with April ICs predicts a near-normal season. The observed totals of July – September 2016 fall into the above-normal ranges based on the basin climatology.

The hybrid statsical-dynamical model created for the eastern North Pacific basin showed skill over the hindcast period. Even though the CFSv2 showed more skill in the hindcasts than the NMME average, it showed the lowest skill overall in the real-time forecast for the 2016 season. Other models from the NMME project may be explored, as hindcast and variable datasets become available and are analyzed. Including more recent years in the training period for 2016 could also improve the forecasting skill, as three out of the five past years have been above average for TC activity in the eastern North Pacific. The NMME hybrid model is expected to continue to be of use in developing a comphrensive NOAA Hurricane Seasonal Outlook.

References

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