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CFSv2-based Hybrid Dynamical-Statistical Model for Week 3 to 4 Forecast of Atlantic/Pacific Tropical Storm Activity

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1. Introduction

Hybrid models have been utilized to predict tropical cyclone (TC) activity on the seasonal and monthly timescales. Subseasonal variabilities and variations, such as the Madden Julian Oscillation, can enhance or degrade the impacts of TC activity and the likelihood of TC formation. Due to successes in longer-lead forecasts, the NCEP Climate Forecast System v2 (CFSv2) has been used to create a dynamical-statistical model to forecast TC activity for weeks 3 to 4. This is a timescale that sees large variability and improving forecast skill for this time period will bridge a gap between the shorter-lead week-2 forecasts and the longer lead seasonal forecasts. With the improvement of CFSv2 in predicting MJO, the hybrid approach can be applied to predicting TC activity on a shorter timescale. The hybrid model was developed using multiple linear regression relationships derived from CFSv2 forecasts and hindcasts, and observational datasets, similar to that developed for seasonal forecasting (Wang *et al.* 2009). This project uses only CFSv2 data, rather than the North American Multi-model Ensemble, as seen with the seasonal forecasting (Harnos *et al.* 2017), due to availability of data on the daily basis.

2. Hybrid model

The model predicts for three northern ocean basins, the Atlantic, the Eastern North Pacific and the Western North Pacific, for 31 weeks of the hurricane season, defined as the first week of May through the last week of November. Three variables, vertical wind shear (VWS), sea level pressure (SLP) and 2-m temperature (T2m) from the CFSv2 dynamical forecasts were tested as predictors for the statistical model. Correlations between the three variables and observed weekly TC days were used to determine the regions of highest correlations for each variable. These area-averaged variables were used as potential predictors in the model to forecast weekly TC days, weekly ACE values and probabilistic forecasts. Multiple and simple linear regression approaches were used to evaluate the potential predictors, performing cross-validations with CFSv2 hindcast data to test each variable individually and all combinations of the three over the 1999 to 2014 period. The results from this test are shown in Fig 1. From this evaluation of forecast skill, 2-meter temperature and vertical wind shear were selected as the best predictors for the model. The same variables, averaged over different regions of skill, were used as predictors for all three basins.

Table 1 Correlations between the forecasted ACE and observed ACE are shown for week 3 and 4 of 2017 hurricane season for the three basins.

Week	WNP	ENP	ATL
3	0.277	0.474	0.658
4	0.402	0.607	0.657

Table 2 Heidke skill scores for the probabilistic forecast based on weekly tropical cyclones days are shown for weeks 3 and 4 of 2017 hurricane season for the three basins.

Week	WNP	ENP	ATL
3	-0.09	-1.36	0.07
4	0.14	-1.39	0.09

3. Forecasts of 2017 hurricane season

Real-time forecasts, both probabilistic and deterministic, were made for weeks 1 to 4 for the 2017 season. For the purpose of this project, we focused on weeks 3 to 4. The deterministic forecasts for the 2017 season are show in Fig. 2. The correlations between the observed and forecasted values are shown in Table 1. The Eastern North Pacific forecast captured some of the variability in the 2017 season; however, it did over-predict activity for much of the season. The Western

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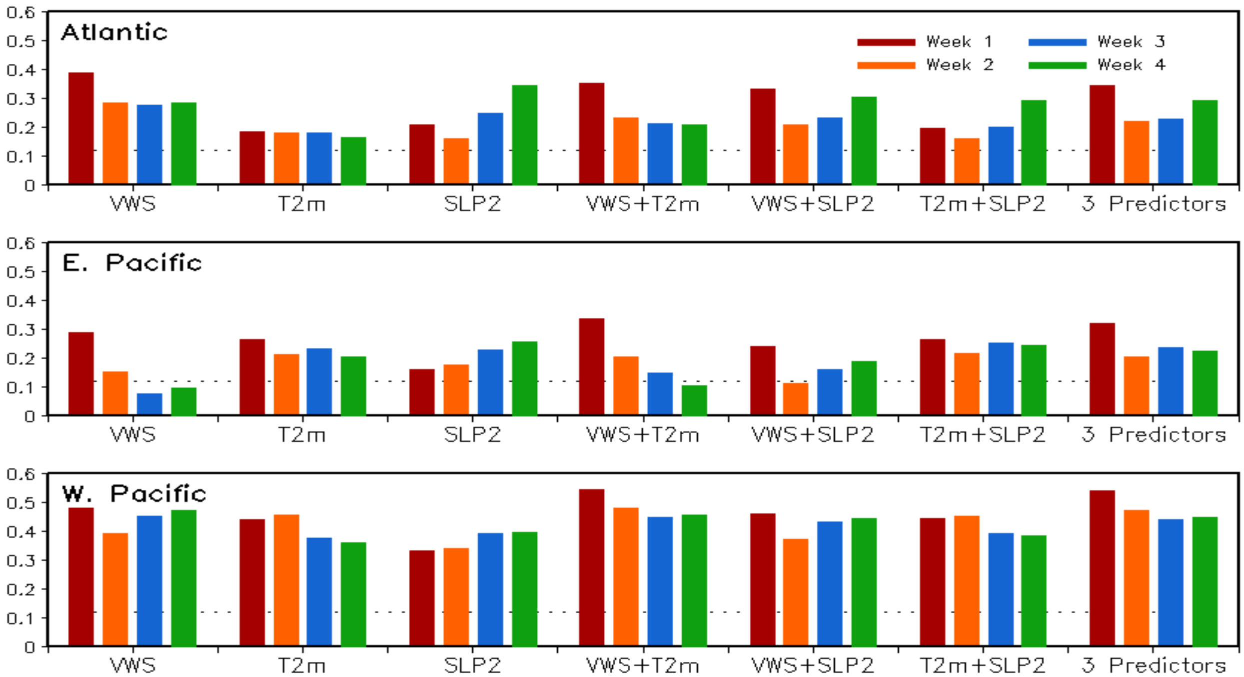
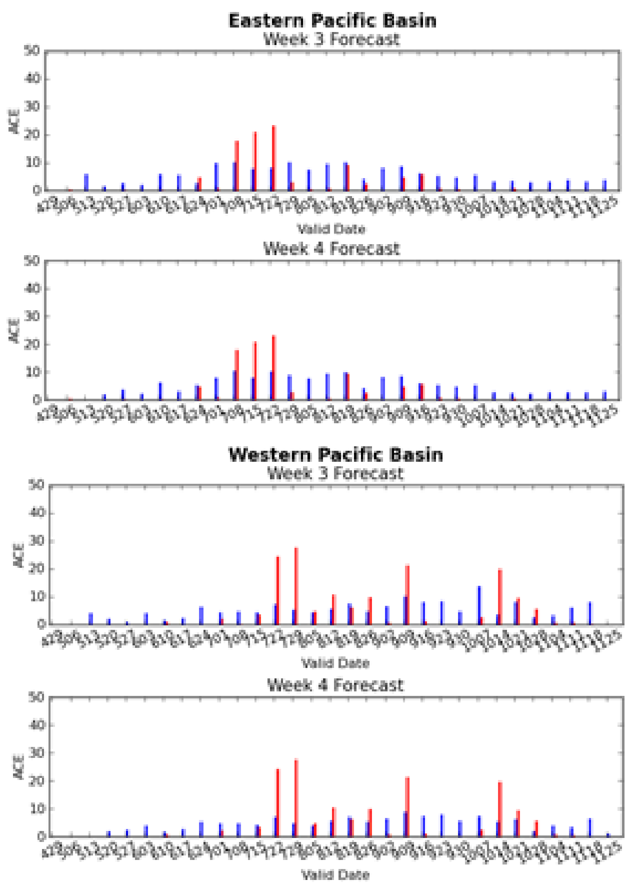


Fig. 1 Forecast skill for weekly TC activity is shown using the different potential predictors, as well as combinations. These are based on cross-validations over the 1999-2014 period.



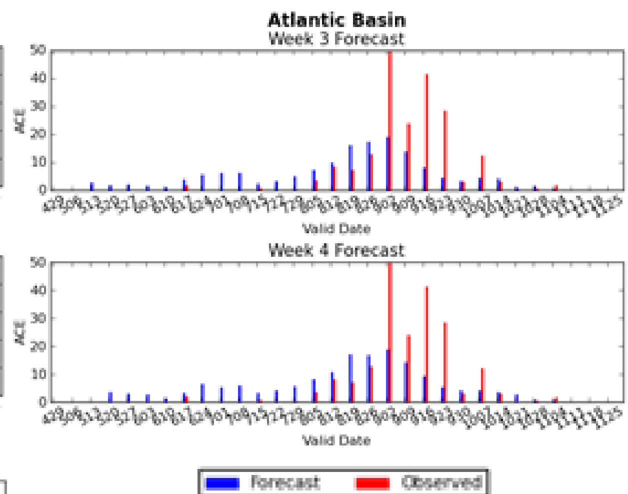


Fig. 2 The deterministic weekly ACE forecasts are shown for the 2017 season, with the forecasted weekly ACE values in blue and the observed values in red for the Atlantic, Eastern Pacific and Western Pacific basins. VWS and T2m were used as predictors.

North Pacific basin was under-forecast by the model, specifically in the middle of the season. The latter part of the season was actually over-predicted by the model. The model did the best in the Atlantic basin in terms of capturing the peak of activity for the season, though it did fail at capturing the extreme values in the observations. The highest correlations between observed and forecasted activity are for the Atlantic basin, followed by the Eastern North Pacific and Western North Pacific. Overall, week 4 has a higher correlation than week 3 in almost all the basins.

The probabilistic forecasts for weeks 3 and 4 for the 2017 season are shown in Fig 3. The results are for the entire 2017 31-week season, from late April until the end of November. Heidke skill scores for weeks 3 and 4 are shown in Table 2. The hybrid statistical-dynamical model developed for forecasting week 3 and 4 had varied results for the three basins in the probabilistic real-time forecasts through the 2017 season. The Eastern North Pacific had the lowest skill, with negative Heidke skill scores for both weeks 3 and 4. The probabilistic forecast for the Eastern North Pacific basin was above normal for almost the entire season. Further diagnosis into this case is needed to determine what caused such a bias in the probabilistic forecast, when observations were near normal, if not below average. The Western North Pacific had the best skill overall in week 4, but was slightly negative skill for week 3. The Atlantic basin was the most consistent over the two weeks, with a slight positive skill score. In the hindcast evaluation (Fig. 1), the Western North Pacific had the most skill, followed by the Atlantic and then the Eastern North Pacific. The probabilistic forecasts also show a similar pattern, which was to be expected.

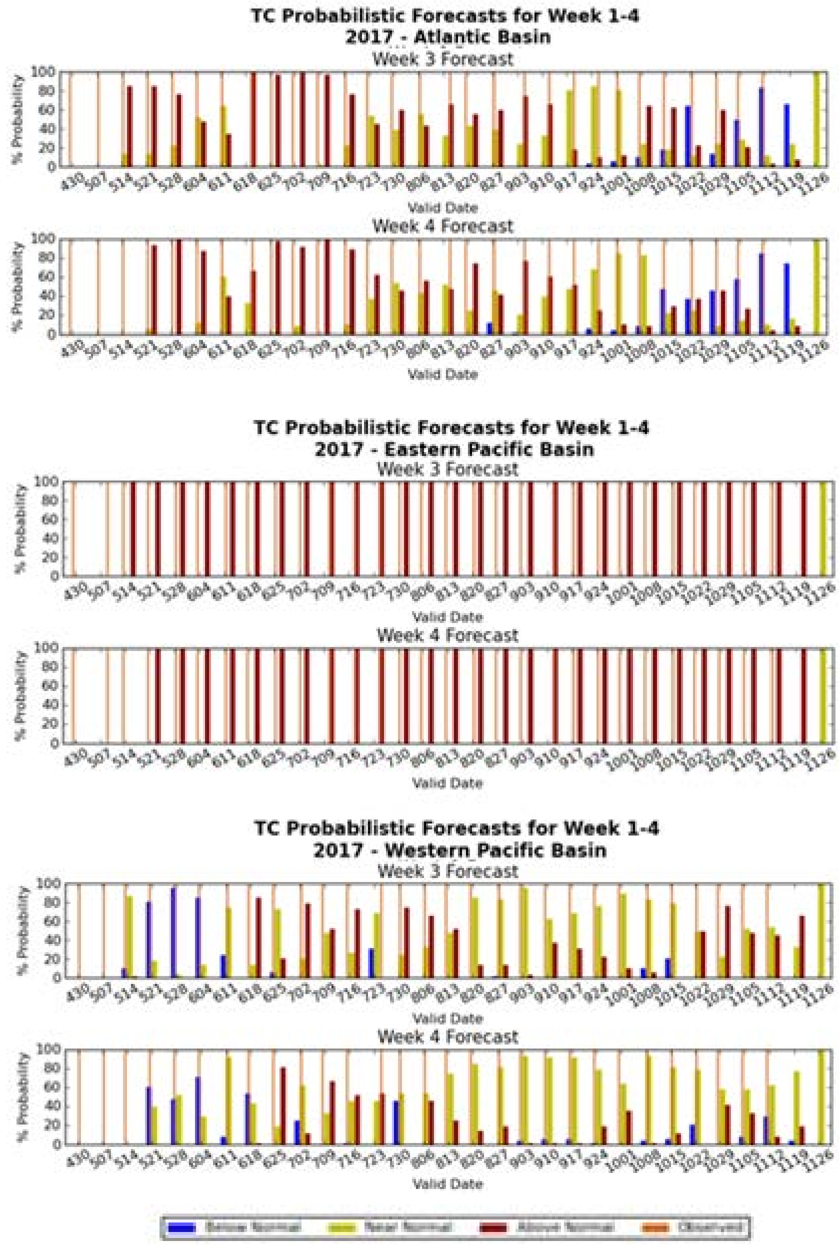


Fig. 3 The probabilistic forecasts for weeks 3 and 4 for the 2017 season are shown for the Atlantic basin, the Eastern Pacific basin and the Western Pacific basin. Above normal activity is shown in red, near normal in yellow and below normal in blue. Observations are shown in brown, and overlap the category that was observed. Above normal activity is defined as one standard deviation above the mean and below normal activity as one standard deviation below.

4. Future plan

This model will continue to be evaluated and optimized to provide a useful tool to forecasters for the week 3-4 time period. For further improvement, using different combinations of predictors for each basin could yield better results, most specifically for the Eastern North Pacific. Sea level pressure was shown to add skill in the hindcast evaluations for this basin. Another issue highlighted in the real-time forecast was the model's inability to the capture extreme values seen in observation. Measures to increase the variability are being considered. Other possibilities considered will be including more recent years in the training period, as well forecasting for weeks 3 and 4 as one time period. Eventually, the goal is to transition this product to an operational framework to act as guidance for week 3-4 tropical forecasts.

References

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