JHT Year-2 Mid-Term Progress Report: Improving Predictability of the Atlantic Warm Pool in Ocean Model for Assistance to Operational Hurricane Forecast

Chunzai Wang[1], Sang-Ki Lee[2], and Carlos Lozano[3]
[1] NOAA/AOML, Miami, FL 33149
[2] CIMAS/University of Miami, Miami, FL 33149
[3] NOAA/NCEP/EMC, Camp Springs, MD 20746

1. Introduction

This report is a summary of research conducted by the project personnel during the last 6 months period (August 1, 2010 - January 31, 2011). The rationale for the current project is the recent scientific finding that the Atlantic warm pool (AWP) — a large body of warm water comprised of the Gulf of Mexico, the Caribbean Sea, and the western tropical North Atlantic — may add a value for improving the simulation of Atlantic tropical cyclone (TC) in operational hurricane forecast models. In particular, recent studies using both observations and models have shown that a large AWP reduces the vertical wind shear and increases the convective available potential energy over the main development region for Atlantic hurricanes, and thus facilitates the formation and development of Atlantic TCs (Wang et al. 2006; Wang et al., 2008a, 2008b). Therefore, our ultimate goal is to improve the forecast of the formation and intensification of Atlantic hurricanes in NCEP/EMC operational model, by improving the simulations of the AWP in that model during the Atlantic hurricane season of June to November.

We have shown through our research during the JHT year-1 that HYCOM has a tendency to produce a large cold bias of up to 2degC in the AWP region. Such tendency is mostly hidden in the forced simulations because the model SST is damped toward the observations in the forced simulations. The cold AWP bias is revealed only when HYCOM is thermally coupled to the atmospheric mixed layer model (AML). This is because nonphysical thermal interaction, which may be caused by the ocean model bias in the forced HYCOM simulations, is not allowed in the thermally coupled HYCOM simulations. However, further model simulations suggest that such bias emerges very slowly. Over the AWP region, it takes about 4 ~ 5 months to develop a –1degC SST bias. Therefore, the cold AWP SST bias should not cause a serious problem in the 5-day forecast of the NCEP/EMC operational models.

2. Achievements

Nevertheless, we show in this report that the 5-day forecast error of RTOFS is as large as 2degC and usually negative. In particular, the cold SST error is largest in the deep tropics between equator and 10N, and in the southern Caribbean Sea. We suspect that the 5-day forecast error of RTOFS originates from a combination of many different sources, including the Cooper and Haines scheme, GFS weather forecast error, initialization, and 2DVAR data assimilation. It is demonstrated here that the application of a simple bias correction scheme could substantially reduce the 5-day forecast error of the RTOFS in the deep tropics and Southern Caribbean Sea.

2.1. *5-day forecast error in RTOFS during ASO*

Figure 1 shows the 5-day forecast error of RTOFS averaged during the each week of August 2010. It is clear that the 5-day forecast error is as large as 2degC and usually negative. In particular, the cold SST error is largest in the deep tropics between equator and 10N. A strong cold SST error is developed during the 4th week over the AWP region of the southern Caribbean Sea and the Gulf of Mexico. It appears that the SST error north of 30N away from the Gulf Stream is largely due to weather forecast error of GFS. Figure 2 is same as Figure 1 expect during September of 2010. As in Figure 1 for August 2010, the 5-day forecast error in this case is large and usually negative. It is still largest in the deep tropics (equator-10N). The southern Caribbean Sea (AWP region) is persistently cold. The eastern tropical North Atlantic SST is also too cold in this case. SST in this region is, however, very difficult to forecast since the mixed layer is very shallow there. In other words, small wind forecast error or ocean initialization error may result in a large SST error. Figure 3 is same as Figure 1 expect during October of 2010. The regions of large 5-day forecast error are persistently located at the deep tropics, southern Caribbean Sea, and the eastern tropical North Atlantic. However, the spatial structure and strength of the error are changed from the earlier periods. Nevertheless, they evolve rather slowly.

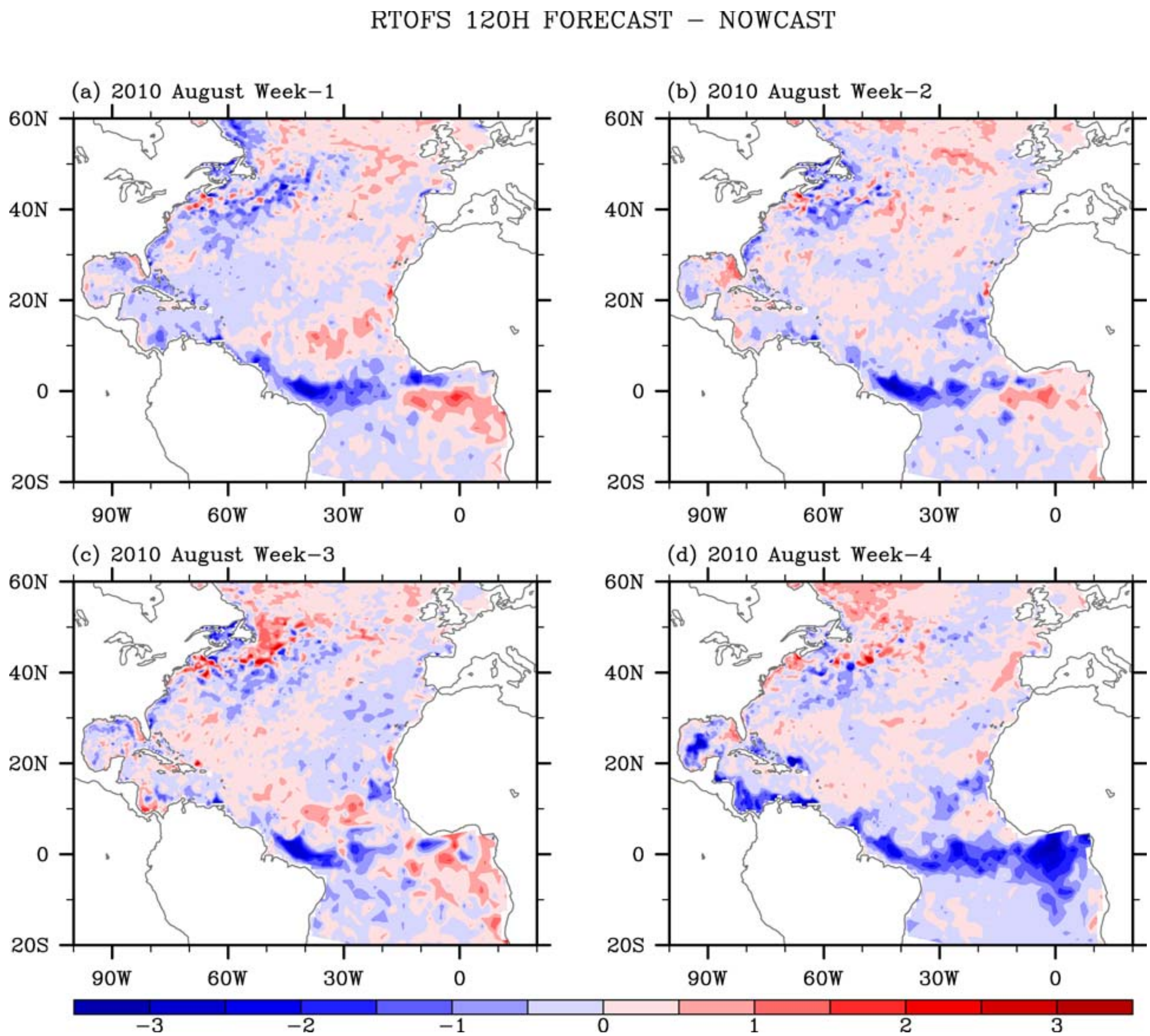

Figure 1. 5-day forecast error in RTOFS averaged during the each week of August 2010.

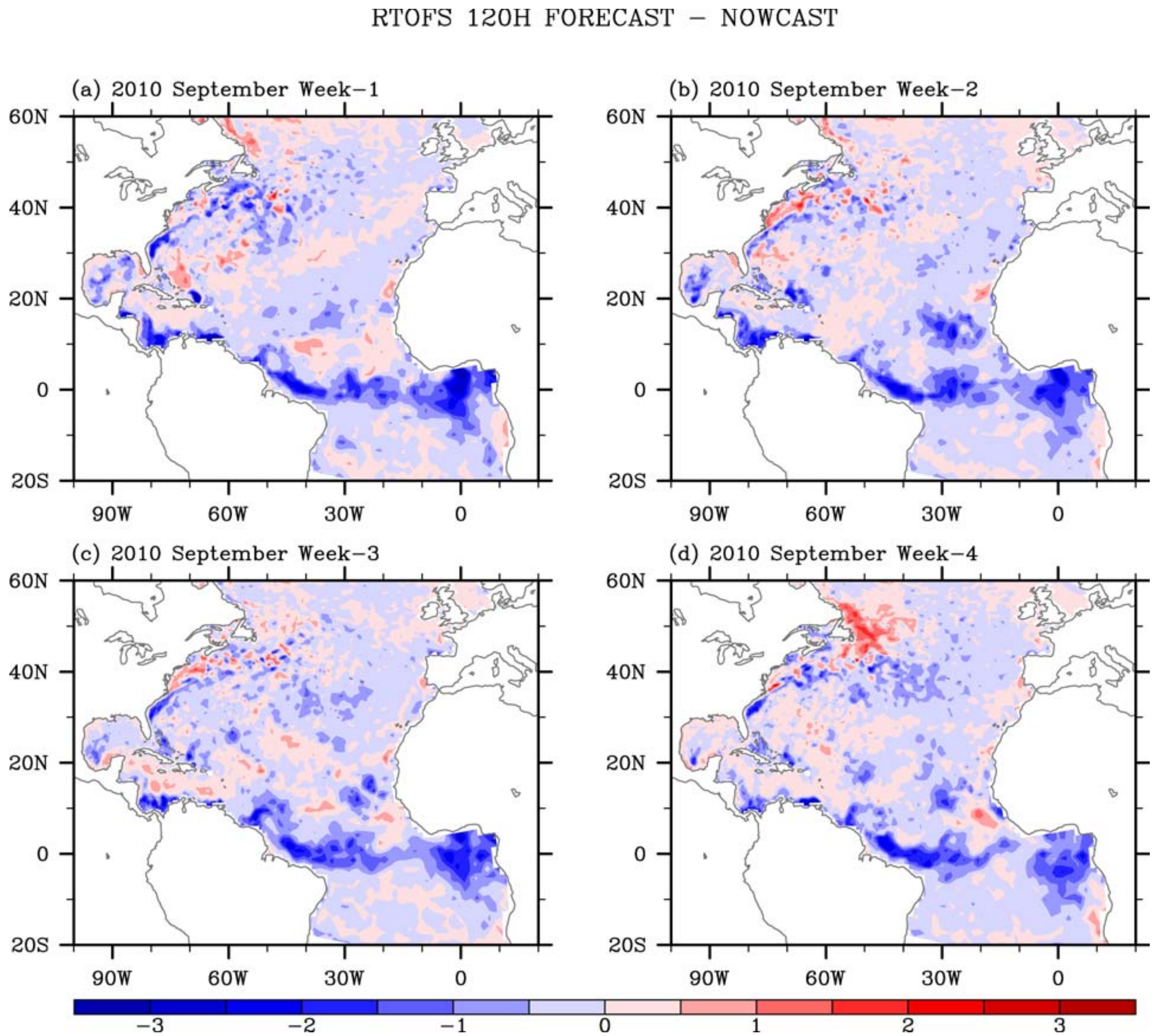

Figure 2. 5-day forecast error in RTOFS averaged during the each week of September 2010.

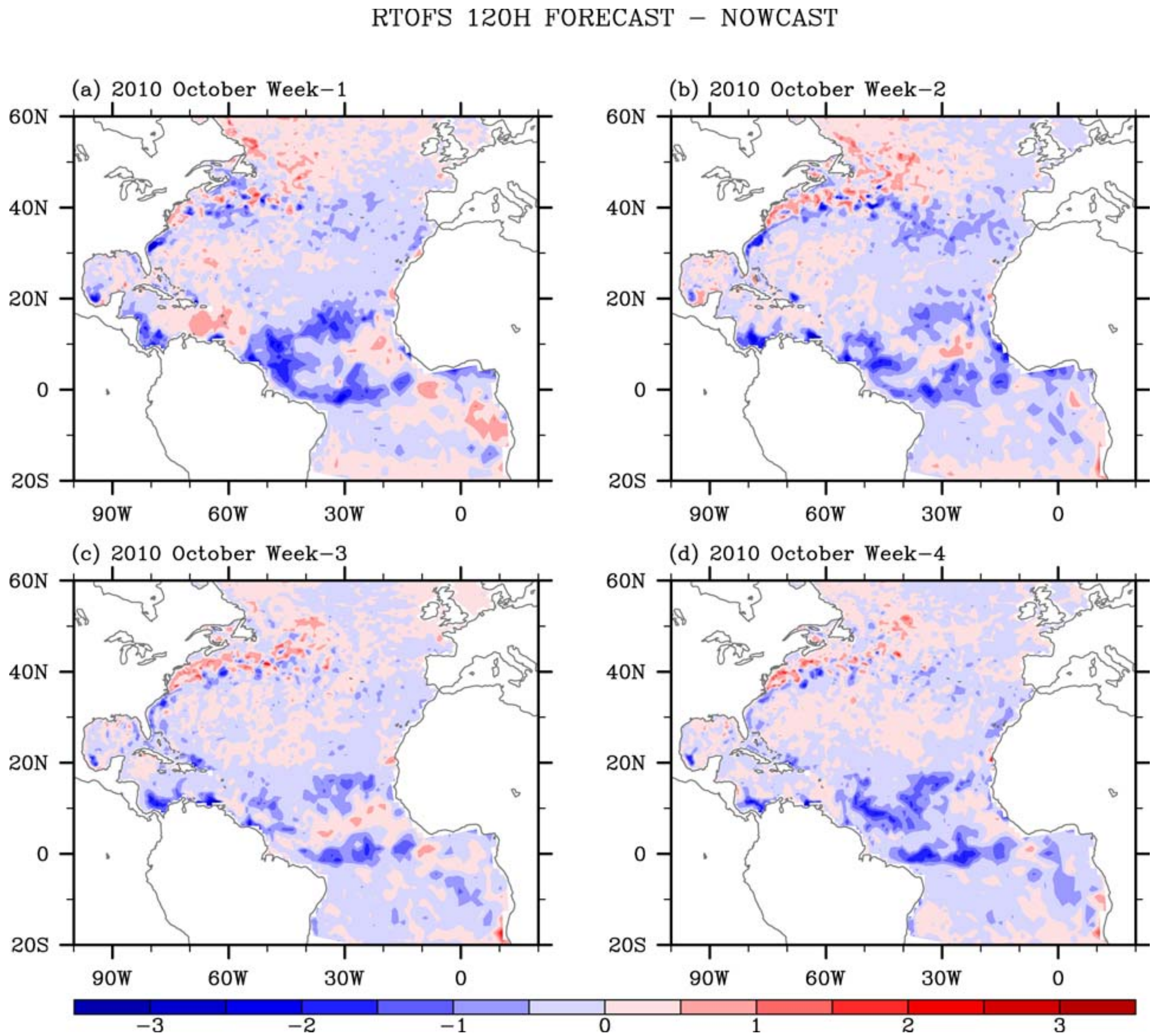

Figure 3. 5-day forecast error in RTOFS averaged during the each week of October 2010.

Since the 5-day forecast of RTOFS is used, although indirectly, to initialize the HyHWRF every 6 hours, the 5-day forecast error of RTOFS may be potentially introduced to the HyHWRF to negatively affect the hurricane track-and-intensity forecast. However, we found that the SST bias in HYCOM should remains very small within 5-day forecast. Therefore, the 5-day forecast error of RTFS should originate from other sources, that includes

1) Cooper and Haines scheme to project the SSH data to profile data;
2) GFS weather forecast error;
3) Initialization;
4) 2DVAR data assimilation.

2.2 *Application of a simple adaptive bias correction*

Although the spatial structure and strength of the 5-day forecast error change in time, they tend to repeat during a certain period and evolve rather slowly. Therefore, if we assume that the current 5-day forecast error repeats in the next 5-day forecast, we can remove that error in the next 5-day forecast, as shown in the schematic figure (Figure 4).

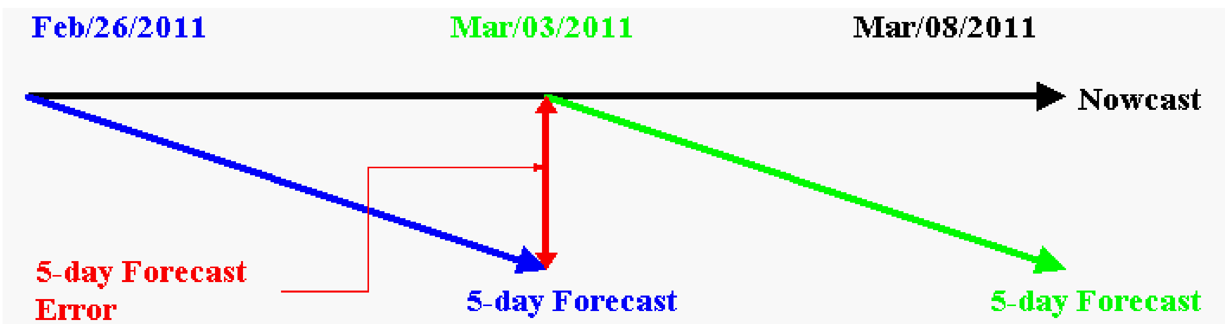

Figure 4. This schematic figure explains the main idea of the adaptive bias correction scheme used in this study. Assume that today is March/03/2011. Then, we can compute the 5-day forecast error of March/03/2011 (i.e., Nowcast on March/03/2011 - 5-day forecast of March/03/2011). When we make 5-day forecast of March/08/2011, we can remove the 5-day forecast error of March/03/2011.

Figure 5 shows the mean and root mean squared error (RMSE) of the 5-day forecast of RTOFS along with the RMSE of the bias-corrected 5-day forecast during August 2010. It is clear that if the adaptive bias correction is applied, the 5-day forecast error is significantly reduced over the deep tropics. However, the RMSE is slightly increased in the high latitude, probably because GFS weather forecast error is amplified there. Figure 6 (September 2010) and 7 (October 2010) also show that the RMSE can be significantly reduced in the southern Caribbean Sea. Figure 8 and 9 show that the 5-day forecast RMSE is very large near and entrance of the Caribbean Sea during August and September 2009. The adaptive bias correction significantly reduces this error. As shown in Figure 10, during October 2010, the 5-day forecast error is relatively small everywhere. Even in this case, the RMSE is reduced in the southern Caribbean Sea and the deep tropics when the adaptive correction is applied.

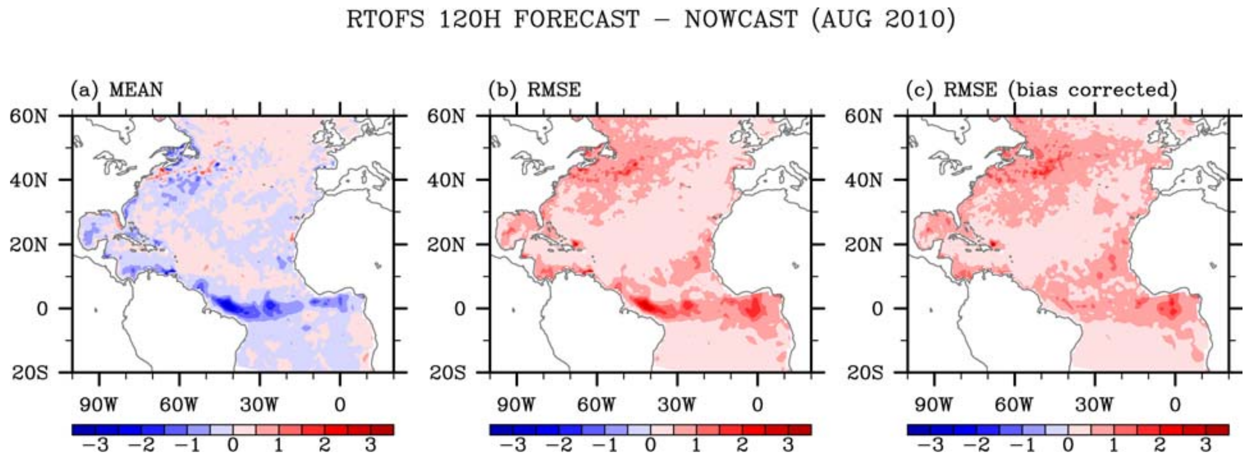

Figure 5. (a) Mean and (b) RMSE of the 5-day forecast of RTOFS along with (c) RMSE of the bias-corrected 5-day forecast during August 2010.

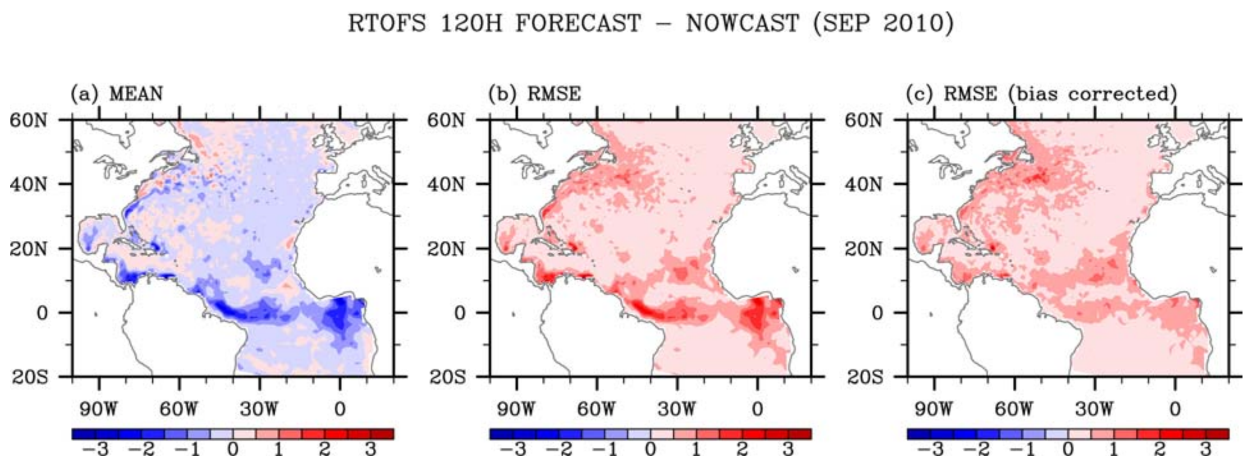

Figure 6. (a) Mean and (b) RMSE of the 5-day forecast of RTOFS along with (c) RMSE of the bias-corrected 5-day forecast during September 2010.

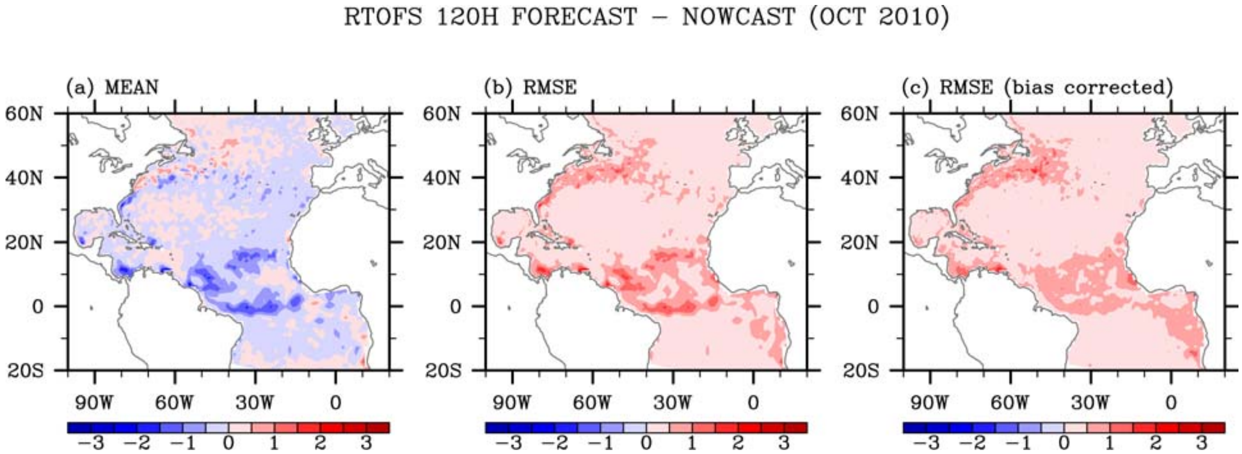

Figure 7. (a) Mean and (b) RMSE of the 5-day forecast of RTOFS along with (c) RMSE of the bias-corrected 5-day forecast during October 2010.

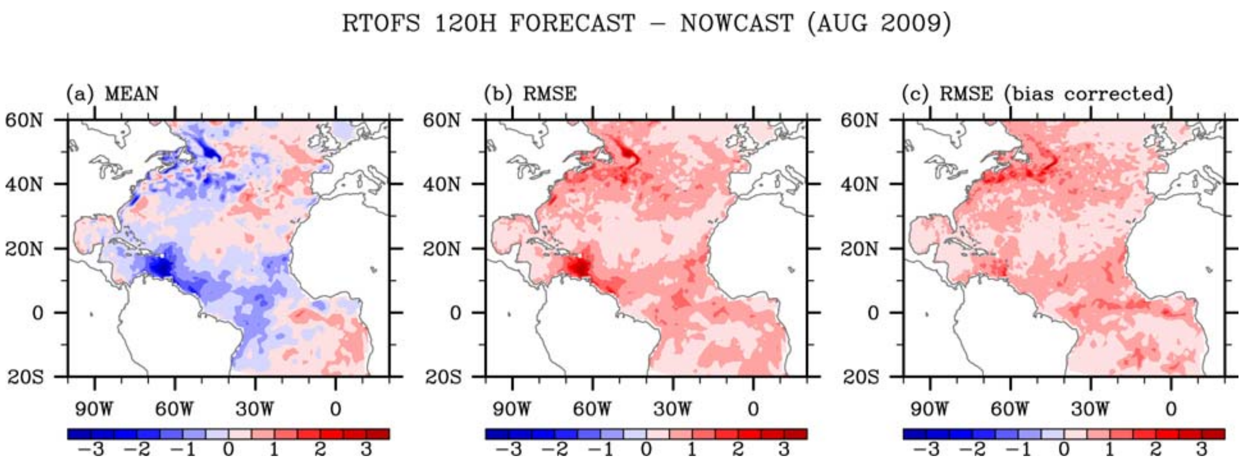

Figure 8. (a) Mean and (b) RMSE of the 5-day forecast of RTOFS along with (c) RMSE of the bias-corrected 5-day forecast during August 2009.

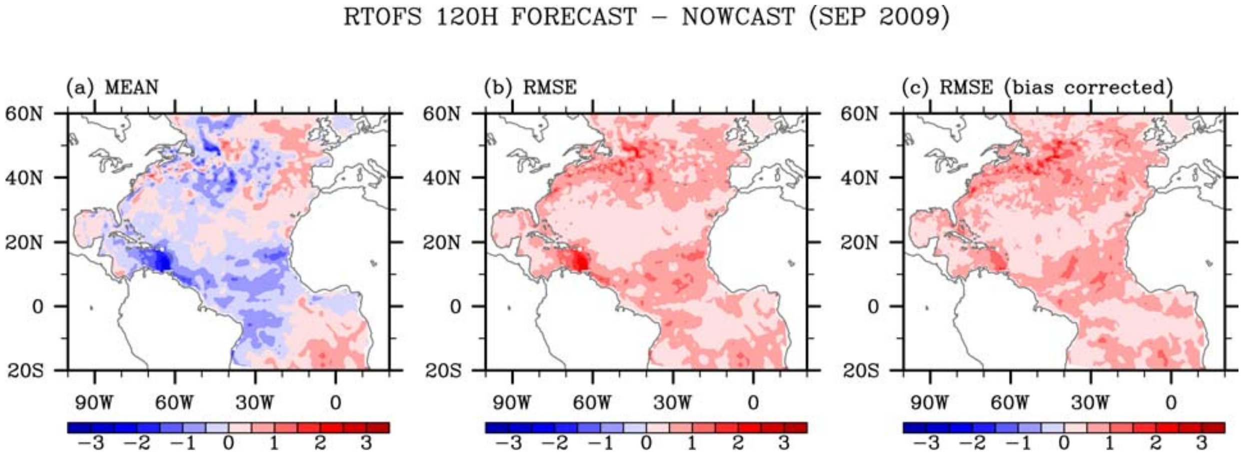

Figure 9. (a) Mean and (b) RMSE of the 5-day forecast of RTOFS along with (c) RMSE of the bias-corrected 5-day forecast during September 2009.

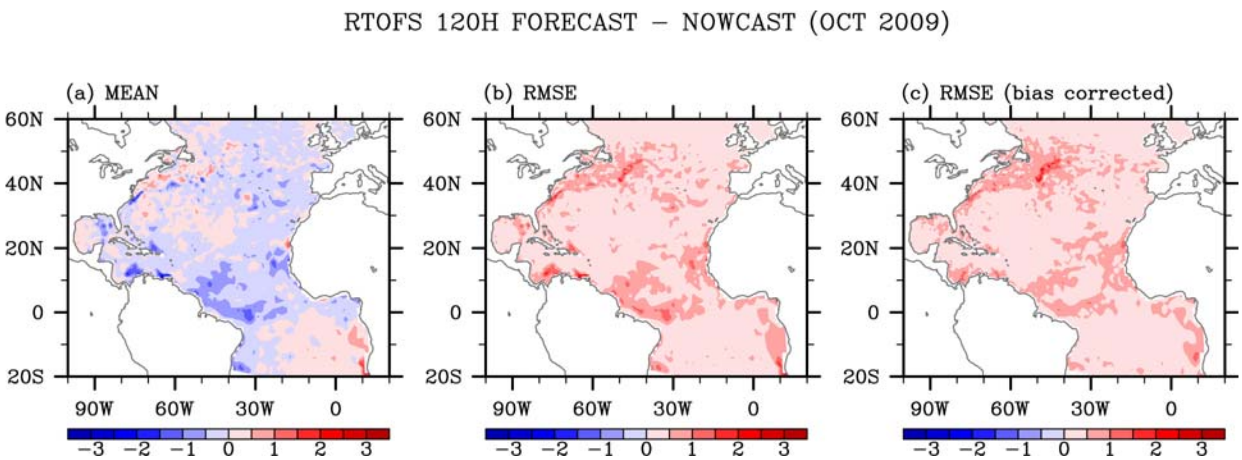

Figure 10. (a) Mean and (b) RMSE of the 5-day forecast of RTOFS along with (c) RMSE of the bias-corrected 5-day forecast during October 2009.

For actual implementation of the adaptive bias correction scheme, a corrective surface flux (Qcor) can be computed using the following equation and added to the model's heat equation:

$$\mathrm{Qcor} = \frac{\rho_w c_{pw}}{\mathrm{d}_1}\frac{1}{5}\sum_{\mathrm{i}=1}^{5}\frac{\Delta\mathrm{SST(i)}}{\Delta\mathrm{t(i)}}$$

i means i – day forecast

ΔSST(i) is i - day forecast error

Δt(i) is the time interval of the i - day forecast

d_1 is the model thikness of the first layer

The adaptive bias correction should not be applied poleward of 30N because GFS weather noise is amplified when the adaptive bias correction scheme is applied there. It is important to point out that the adaptive bias correction scheme does not depend on the details of the model configuration or data assimilation scheme used. Therefore, if implemented, this scheme will automatically adapt to the future changes in RTOFS.

In summary, it is demonstrated here that the application of a simple bias correction scheme could substantially reduce the 5-day forecast error of the RTOFS in the deep tropics and Southern Caribbean Sea. Since NCEP/EMC is currently exploring to use NAVY-MODAS to replace Cooper and Haines' scheme, we will explore how the 5-day forecast error is improved when NAVY-MODAS is used.