P2G.4 HURRICANE DEFLECTION BY SEA SURFACE TEMPERATURE ANOMALIES.

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ABSTRACT

To determine whether hurricane forecasts can be improved using high resolution sea surface temperatures, five-day hindcasts of the major 2005 hurricanes (Dennis, Katrina, Rita and Wilma) were made using the Met Office's Numerical Weather Prediction (NWP) model, using 40 km resolution (NWP) and 6 km (OSTIA) SST analyses. The use of OSTIA had little effect on Dennis, Katrina and Wilma, but slightly improved the hindcast of Rita. In the OSTIA run for Rita, the point of minimum surface pressure was deflected by 70 km. This deflection disappeared when a warm eddy captured by OSTIA was manually deleted, implying that Rita was deflected by the eddy. No deflection was seen (in vorticity) at 850 mb, implying that combined tracking methods could be useful. A further comparison of the curvature of all the trajectories with local SST gradients showed no significant correlation. However, steering by SST anomalies might be more detectable in areas where atmospheric steering is weaker, for example, in the eastern tropical Pacific.

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1 INTRODUCTION

Hurricanes cause much damage to coastal communities, and accurate and timely forecasts of landfall sites are important for planning. However, hurricane forecasts are not yet perfect. For example, the Met Office NWP model's 5-year running mean northern hemisphere hurricane position 72-hour error is 314 km.

A hurricane's trajectory is influenced mainly by the air flow in the middle troposphere, but other factors can also play a role. For instance Fovell and Su (2007) looked at the impact of cloud microphysics on the hurricane trajectory and found that uncertainties in this area could account for much of the variation in ensemble forecasts. The effect of sea surface temperature (SST) on hurricane intensity is well known. Palmen (1948) first showed that hurricanes require SSTs of over 26.6^{o}C to maintain themselves, and recent modelling studies have shown that hurricanes intensify over warm ocean eddies (Shay $et\ al.$, 2000), but the effect of SST on trajectory, considered here, has been less studied.

Agrenich (1984) compared 12 hurricane trajectories from the tropical Pacific with 1-degree resolution SST data and found that the hurricanes moved towards areas with higher SSTs. Dengler (1997) modelled an idealised hurricane moving northwestwards over a boundary between warm water in the south and colder water in the north and showed that the change in SST deflected the model hurricane to the east and Mandal *et al.* (2007) found that the inclusion of SST anomalies effected the trajectory of a cyclone simulated in the Bay of Bengal.

In this study four of the strongest hurricanes from the 2005 season were modelled using the Met Office's forecast model with 1) a 40 km resolution SST (NWP) and 2) a 6 km resolution SST (OSTIA), to investigate the impact of the SST on hurricane trajectories.

2 METHOD

The hurricanes studied here are listed in table 1. The model runs were made between the dates in columns 3 and 4 and were made with a version of the Met Office's NWP model, with 40 km resolution, 38 levels, and without assimilation.

Hurricane (2005)	Formed dd/mm	Start dd/mm	End dd/mm
Dennis	04/07	06/07	10/07
Katrina	23/08	25/08	29/08
Rita	18/09	20/09	24/09
Wilma	15/10	20/10	24/10

Table 1: Start & end dates of the model runs.

The Met Office NWP model's output files for each of the start dates (column 3) were used for initialisation, and the NWP SST analysis from that time was used. The Met Office's higher-resolution Operational Sea Surface Temperature and Sea-ice Analysis (OSTIA) analyses was interpolated onto the model grid and a monthly climatological SST was used to fill in lake SSTs which were not available from OSTIA. Although OSTIA was regridded to 40 km resolution it still included more information about SST patterns than the NWP SST since it utilises extra information from AATSR IR, SEVIRI IR, and TMI microwave satellite data that can penetrate clouds.

3 RESULTS

Figures 1a-d show the observed tracks (black lines with symbols), the original 2005 Met Office forecasts (red lines), the new hindcasts (without assimilation) using the 40 km SST analysis (green) and the 6 km OSTIA SST analysis (blue), all determined using the vorticity at 850 mb. The new hindcasts were better than the original forecast (red), especially for Wilma which lingered too long over the Yucatan peninsula in the 2005 run. The new hindcasts used a more recent version of the model with improved convection and boundary layer schemes and this may explain the improvement.

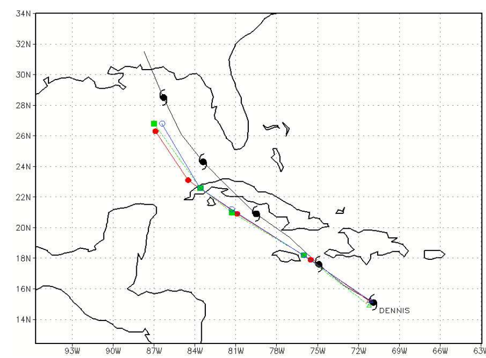

Figure 1a. The observed track of Dennis (black), the Met Office 2005 forecast (red circles), the new NWP-SST forecast (green boxes) and the OSTIA-SST forecast (open blue circles).

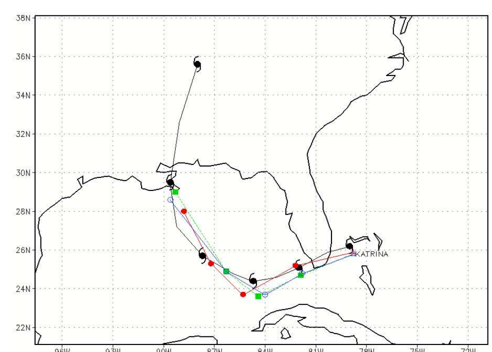

Figure 1b. As Fig.1a, for hurricane Katrina.

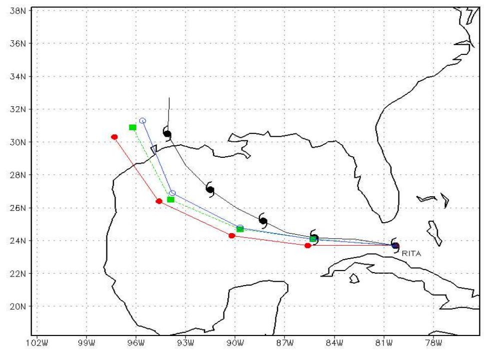

Figure 1c. As Fig.1a, for hurricane Rita.

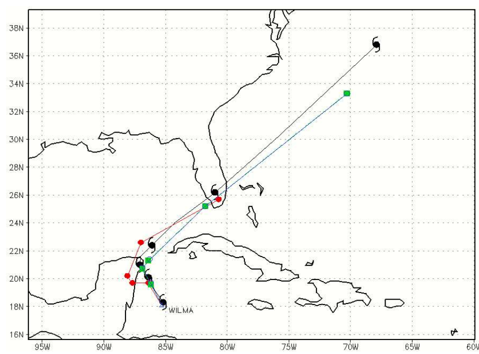

Figure 1d. As Fig.1a, for hurricane Wilma.

Figure 2a (right) reproduces the results for Rita in Fig. 1c but the centre of the hurricane is now defined as the point of minimum *surface* pressure. The NWP and OSTIA SST runs are shown by the dashed and dotted lines and differ by up to 70 km. The background colours show the difference between the OSTIA and NWP SST. OSTIA was warmer at at 89^{o}W, 27^{o}N, which is the location of a detached loop current eddy that can be seen in satellite images. Figure 3b shows the result of a model run in which the warm eddy (only captured by OSTIA) was deleted by reducing the SST by 0.25K over the area of the eddy, which was 36,000 km^2 (an area the size of Belgium, or Maryland). When this was done the NWP and OSTIA tracks were identical, which implies that in this case the warm ocean eddy in OSTIA deflected the model hurricane towards it, as seen also for slow moving Pacific hurricanes by Agrenich (1984).

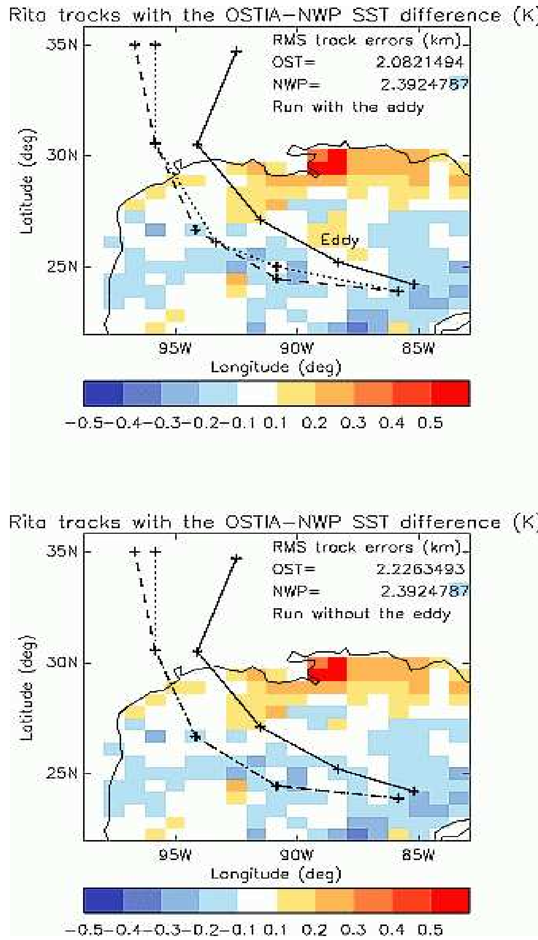

Figure 2a-b (above). The track of Rita determined using the minimum surface pressure, with (Fig. 2a) and without (2b) the eddy. The colours show the OSTIA-NWP SST difference. The solid line shows the observed track of Rita. The dashed and dotted lines show the forecasts made using the NWP and OSTIA SSTs. The lower plot shows the run in which the warm eddy was deleted. The two tracks are very close.

Figure 3 shows the model track using OSTIA with (red) and without (green) the warm eddy determined using the vorticity at 850 mb (the standard method of tracking). There is no significant difference, which suggests that the deflection seen in Fig. 2a would be missed using this tracking method.

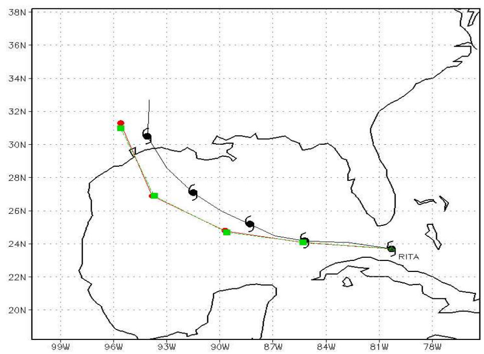

Figure 3. Difference in the tracks with and without the eddy using the vorticity at 850 mB.

4 CAVEAT

In order to determine whether the SST deflects hurricanes on a more regular basis, the observed curvature of the trajectories of all four hurricanes (taken from the Unisys website) were compared with the difference in SST between the hurricane centre and a point 100 km to the right of the hurricane velocity vector. However, no significant correlations were found, indicating that the deflection by the SST anomaly in the case of Rita may be a rare event.

Such deflections may be more detectable for intense SST anomalies, as seen in the case of Rita, or when other (atmospheric) steering effects on the hurricane are minimised. Agrenich, 1984, for example found a correlation in the Pacific, and the eastern Pacific from 5-15^{o}N might be a good place to look since it is noted for almost-straight tracks, suggesting that atmospheric steering effects are less important and influences from SST anomalies may be more detectable.

CONCLUSION

The effect of the higher-resolution OSTIA SST on hindcast error was small for Dennis, Katrina and Wilma, but slightly beneficial for Rita.

In the model, hurricane Rita was deflected at the surface towards a warm eddy by 70 km in just two days. However, a comparison of the curvature of all four trajectories with local SST gradients showed no significant correlations. Such deflections may be more detectable for intense SST anomalies, as seen in the case of Rita, or when atmospheric steering effects on the hurricane are weaker, for example in the eastern tropical Pacific.

Hurricane tracking at the Met Office uses the vorticity pattern at 850 mb, whereas the deflection of Rita described here was seen in the surface pressure. As a result similar deflections in other hurricanes may have been missed. Ideally, a combination of tracking methods could be used.

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