17.C4 A MINIMAL HURRICANE MODEL WITH A COUPLED MIXED LAYER OCEAN

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1. INTRODUCTION

The minimal 3-layer hurricane model of Zhu et al. (2001, henceforth referred to as ZSU) is coupled to a simple model of the ocean's mixed layer to provide a minimal coupled hurricane-ocean model for research. The model is being used to explore the sensitivity of hurricane intensification to ocean feedback.

2. MODEL COUPLING

The ZSU-model is used with the modified Arakawa convection scheme turned on. Representations of shallow convection and radiative cooling are included as well. The sea surface temperature SST which was constant in ZSU is predicted in this version by a simple ocean model.

The ocean model represents the tropical mixed layer and a motionless thermocline below. It follows the equations of Chang and Anthes (1978, henceforth referred to as CA), with the following changes: we added a prognostic equation for the temperature at the bottom of the mixed layer. This bottom temperature changes due to the vertical replacement of thermocline water, which is assumed to have a constant temperature gradient of 0.125 Km^{-1}. Horizontal advection is ignored, however. The initial thickness of the mixed layer is 100 m and the temperature at the bottom of this layer is 25°C. We added a second option for the mixing parameterization following Price (1981), henceforth referred to as PR, in which the mixing velocity depends on the local Richardson number calculated from the motion of the ocean's mixed layer. in contrast, in the CA model mixing depends only on atmospheric parameters. Our numerical techniques differ from CA: we use a flux-corrected transport type advection scheme to assure positive layer thickness and monotonic temperature advection.

The ocean model is driven solely by the shear stress, which is obtained from one of the usual bulk formulae for the drag coefficient. These formulae require the the horizontal wind at 10 m above the surface as input. The ocean model returns the sea-surface temperature to the atmospheric model as lower boundary condition. The horizontal velocities in the ocean are more than an order of magnitude smaller than in the atmosphere, thus the timestep is typically one order of magnitude larger than that of the ZSU model.

3. THE EXPERIMENTS

We restrict this investigation to the basic calculation where a weak vortex with 15 m s^{-1} maximum wind and a radius of maximum winds of 120 km is initiated on a beta-plane at 20° North in an environment at rest and over a tropical ocean at rest. In barotropic models the vortex drifts westwards and polewards.

4. OCEAN RESPONSE

The reference case (I) is run with no ocean. As the standard SST is 28°C we refer to it as NO28. The first two experiments concern the mixing parameterization used in the ocean model. The experiments are abbreviated CA and PR according to the mixing type used. There is a threshold criterion in PR, so that for weak winds there is no intrusion of colder waters from below into the warm top layer of the ocean. With CA, mixing sets in continously using CA rationale. As both formulations allow only a cooling of the top layer water by cold thermocline water intrusion,

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we performed experiments with a SST which is 0.5°C higher than the standard case (I), because the relative cooling effect is implicitly incorporated using a lower constant SST. Otherwise the comparison would only document the weaker development with a coupled ocean. As reference case (II) we performed a calculation with a constant SST of 28.5°C.

Both experiments CA and PR lead to regions of considerably lowered SST, which extend parallel and somewhat to the right of the track where the hurricane has passed several hours before. The cooling we calculated exceeds reported values in PR and other studies. The results of CA can be reproduced to to high degree with their parameters, however. This suggests that these low SSTs are not only an artifact of our model's numerical formulation. A more detailed analysis reveals that the shear stresses are larger for our evolved vortex than that of CA. The reason is partly our very broad vortex, but also the high wind speeds that are attained. An overall lower SST will lead to a delayed and weaker development, with core pressures not as deep as typical for hurricanes. As the shear stress is the only mechanism to drive the ocean, we reduced its effect in all experiments by reducing the 10 m wind that enters the shear stress calculation by taking 0.7 times the value of the wind speed in the middle of the boundary layer. Other authors suggest values around 0.8.

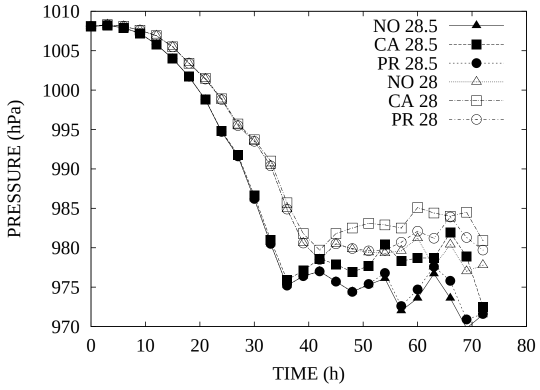

Figure 1: Minimum pressures for SSTs of 28°C and 28.5°C

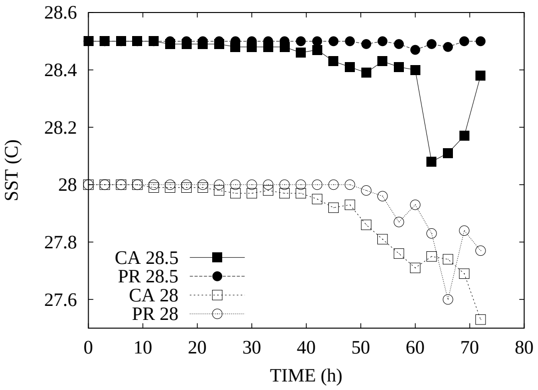

Figure 2: Averaged SST in the northeastern sector between 100 km and 300 km radius.

5. RESULTS

Figure 1 shows the central pressure which is attained, used as an indicator for intensity. The initial SST is either 28°C or 28.5°C. The tracks (not shown) are less regular than those in barotropic models. There is a strong dependence of the distribution of convection and grid-scale saturation on SST changes. Figure 2 shows the grid averaged SST in a sector between 0 and 90 degrees (northeastern sector) and a radius between 100 km and 300 km with the origin at the pressure center. In this sector the observed cooling is largest. Although the PR model predicts the lower SSTs, the CA model predicts a broader cooling region. Within 100 km the grid averaged SST cooling is only weak, as the cooling pattern lags behind the cyclone center.

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