Project: **906**

Project title: **The role of convective available potential energy for tropical cyclone intensification**

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In the first phase of the project we were successful in completing simulations to test the sensitivity of a developing tropical cyclone under two distinct conditions which affect the amount of CAPE present. We conducted our sensitivity tests with the non-hydrostatic cloud resolving model CM1. This cloud model which was developed by George Bryan at NCAR (Bryan and Fritsch 2002; Bryan and Rotunno 2009) can perform simulations in axisymmetric and 3 dimensional configurations both of which we used in our numerical experiments. Here, the axisymmetric and 3-dimensional configurations are referred to as 2D and 3D, respectively.

We adopted the preconfigured namelists (both 2D and 3D) that were provided for tropical cyclone simulations with some changes to certain parameters. The grid spacing in 2D was set to 1km with 1500 grid points in the horizontal direction and 40 model levels in the vertical having a 500m grid spacing. In 3D mode the grid spacing was set to 2km with 600 grid points in the horizontal while the same vertical resolution is used. The Dunion sounding was adopted to provide the base state conditions. Two sets of experiments were conducted for both configurations, where in the first group the temperature profile of the sounding was adjusted so that there will be an increase of the temperature lapse rate by 0.5K/km and 1K/km, and a decrease by the same rate (Perturbed Atmosphere experiments). The second group of experiments investigated the effect of doubling, halving, quadrupling and quartering the surface transfer coefficient for enthalpy (*CE*).

To test the sensitivity of the tropical cyclone's intensification to CAPE (Convective available potential energy) we need to analyse its radial distribution at the time of maximum intensification. A tropical cyclone's most intense winds are located at a radius beneath the eyewall. In the eyewall air flows approximately along surfaces of constant angular momentum (Willoughby 1988). These surfaces are curved or slantwise which means the air flows up and outward. Schubert and Hack (1983) took full advantage of this fact and introduced the new coordinate, potential radius *R*, which allows one to investigate the flow, wind speed, from the perspective of potential radius as opposed to physical radius. In all cases the evaluations were done at the time of maximum intensification.

Figure 1 shows the time evolution of maximum wind speed for all simulations. Based on these we see that varying amounts of CAPE affects the intensification rate. In the perturbed atmosphere runs an atmosphere with a higher lapse rate is proving to be favourable for intensification while an atmosphere with a lower lapse rate is proving to hinder development. The intensification in the 2D runs is more rapid with steeper intensification rates. The experiments for the different values of *CE* we notice that increasing the value of *CE* causes rapid intensification in the 2D runs with a significantly higher intensification than the 3D while decreasing the value of *CE* causes a slow intensification. It is clear that CAPE is affecting the way the cyclone intensifies and to better understand this we analyse the CAPE distribution and windspeed at the time of maximum intensification (the black circle on the graphs).

Figure 2 shows the radial distribution of azimuthally averaged CAPE for the 3D runs for when we halved (0.5 x *CE*) and doubled (2 x *CE*) *CE* at the time of maximum intensification for each experiment. We notice that when the wind speed is at its greatest the amount of CAPE is either at its lowest or very low. However, moving outwards from 120km we see that the CAPE is high. CAPE has two peaks in figure 2a. Looking at figure 3 showing radial CAPE distribution for the Perturbed Atmosphere experiments, we see a similar pattern. At the radius where the wind speed is high, CAPE is low. This is only observed in figure 4a while in figure 4b both the windspeed and CAPE is low due to the fact that the atmosphere is unable to support the development of a tropical cyclone. Frisius and Schönemann (2012) noticed a similar relationship in the context of maximum intensity where inside the cyclone in the vicinity of maximum windspeed, slantwise CAPE was low and outside it was high. This led to the conclusion that the high amount of CAPE in the outer core of the cyclone affects the intensity of the cyclone.

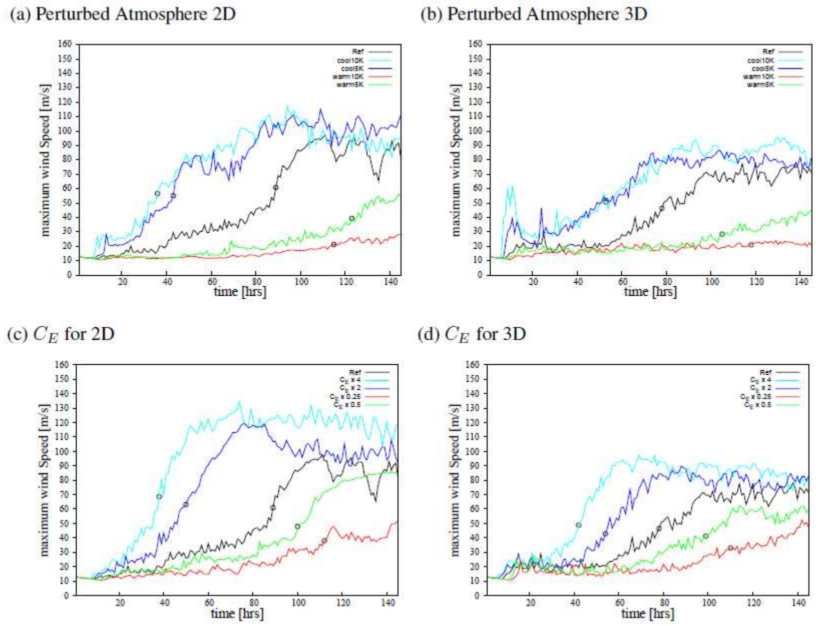

Figure 1: Evolution of maximum wind speed over six days for i) a perturbed atmosphere in a) 2D and b) 3D and for ii) different values for *CE* in c) 2D and d) 3D.

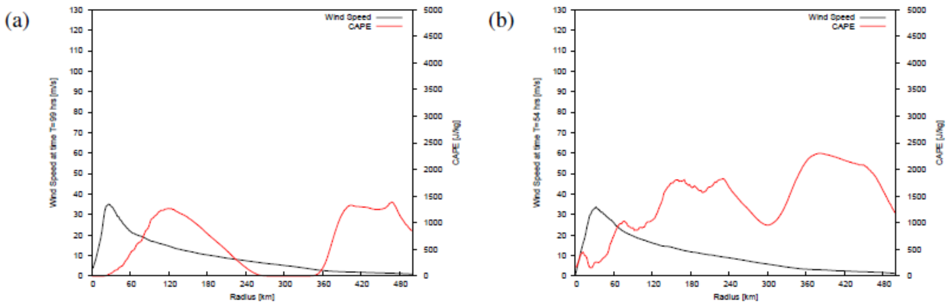

Figure 2: Radial distribution of azimuthally averaged CAPE (red curve) and wind speed (black curve) for the 3D experiments at the time of maximum intensification for a) 0.25xCE experiment and b) 2xCE experiment.

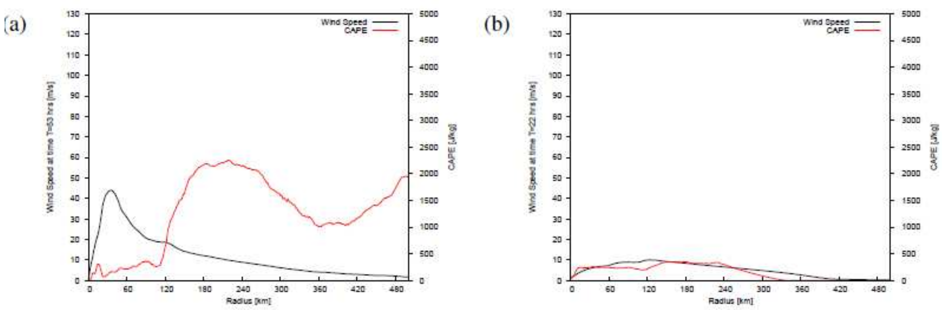

Figure 3: Radial distribution of azimuthally averaged CAPE (red curve) and wind speed (black curve) for the 3D experiments at the time of maximum intensification for a) the high lapse rate experiment and b) low lapse rate experiment.

Based on these results we see that CAPE is affecting the cyclone and that further tests and investigations need to be conducted so that we can better understand how CAPE fits into intensification. These tests will be conducted using CM1 but with a convective adjustment scheme so that we can test the WISHE theory out where a tropical cyclone develops under conditions of zero or negligible CAPE. Besides the studies based on CM1 we also employ the simpler axisymmetric Ooyama model (Ooyama 1969) to understand better the dynamics of intensification and the role of CAPE.

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