2C.3 THE INTERACTION BETWEEN CONVECTION AN AFRICAN EASTERLY WAVES: A MODEL CASE STUDY

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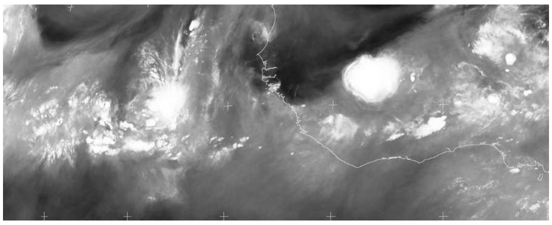
1. INTRODUCTION

The African easterly wave (AEW) out of which Hurricane Helene (2006) developed was generated over West Africa early in September 2006. It propagated westward and at around 15 UTC on 9 September convection occurred in the northern part of Burkina Faso.

The convective system grew rapidly into a mature mesoscale convective system (MCS) that began to decay slowly on 10 September in the early morning hours (Fig. 1). In the following, a new convective burst occurred in the region of the decaying westward moving system. In the late afternoon, it has a squall-line-like shape and moves from the continent to the Atlantic that is reached at around midnight. Over the eastern Atlantic the convective activity was relatively low. A few hours later several large convective outbursts occurred. On 12 September, 12 UTC, the system was organized enough to be classified a tropical depression. On 14 September, 00 UTC, it was upgraded a tropical storm and became Hurricane Helene on 16 September at 12 UTC.

The AEW is shown in Fig. 2. High values of relative vorticity at 700 hPa occur in the afternoon of 9 September at 3°W. The relative vorticity increases with time. From 14 September it is no longer the relative vorticity of the AEW but of the tropical storm. The convection is initiated ahead of the trough of this AEW and during all the changes in intensity and shape the convective systems keep this position.

20060910, 00 UTC



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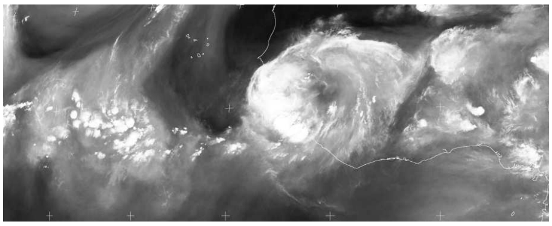
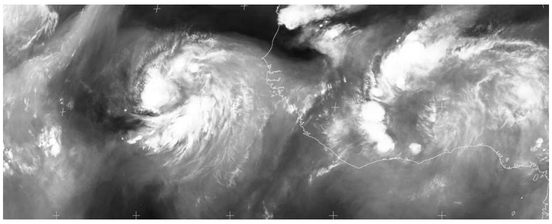
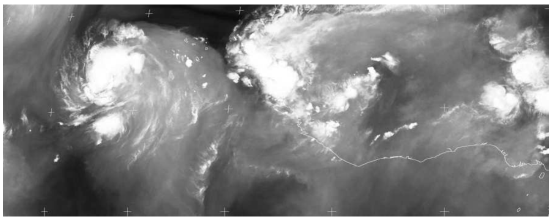


20060913, 00 UTC, Tropical Depression



20060914, 00 UTC, Tropical Storm



20060917, 00 UTC, Hurricane Helene

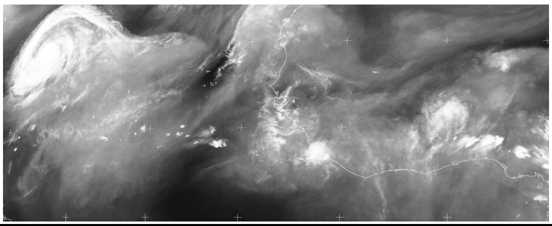


Fig. 1: Water vapour Meteosat images showing convection over West Africa and different stages of the cyclogenesis of Hurricane Helene (2006). (http://www.sat.dundee.ac.uk/abin/geobrowse/MSG/2006/9, Channel 5: water vapour 5.35 - 7.15 µm)

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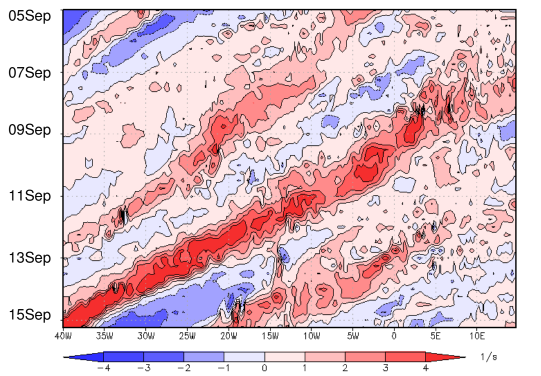


Fig.2: Hovmoeller plot of the relative vorticity at 700 hPa, averaged between 6°N and 16°N.

2. MODEL SIMULATIONS

The weather prediction model (COSMO4.0) of the Detuscher Wetterdienst (DWD) is used to simulate the AEW out of which Hurricane Helene developed and the imbedded convection.
The initial and boundary conditions are taken from 6-hourly European Centre for Medium-range Weather Forecasts (ECMWF). A COSMO run with a horizontal resolution of 28 km covers the large domain in Fig. 3 and the different runs with a resolution of 2.8 km are shown by the red boxes. The model region is centred on the convective system. The position of the box is adjusted for every new run. In the high-resolution model runs the parameterization off convection is turned of and a 72-h forecast are carried out.

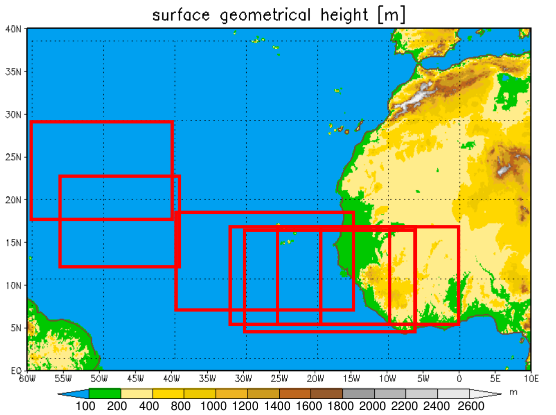
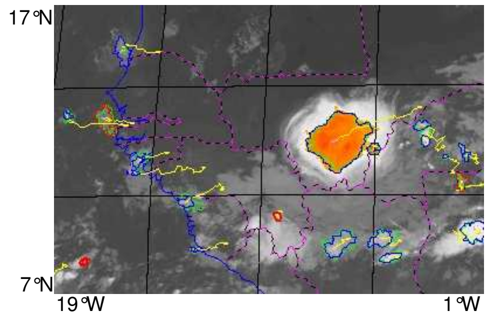


Fig. 3: The surface geometrical height in m is shown as well as the different model regions for the 2.8-km runs.

The model source code was adapted for the moisture, temperature and momentum budgets.

The AEW is well represented in the 28-km model run. The main difference to the ECMWF analysis is that the region of maximum vorticity is not as broad. Nevertheless, the model computes the observed AEW satisfactorily.



12h forecast initiated at 9 Sep 2006, 12 UTC

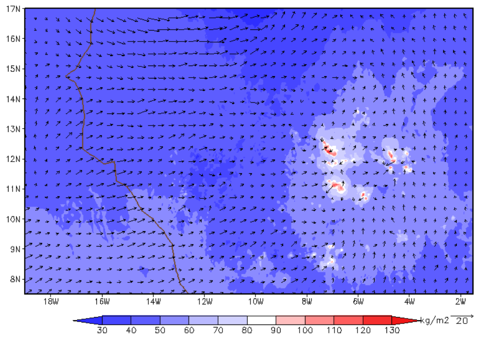


Fig. 4:Top: The RTD Product of Météo France, where the brightness temperature is shaded. Bottom: The vertical integral of humidity, cloud water and ice (kg/m^2) as well as the wind speed at 1000 hPa.

The model regions can be divided into four categories: (a) over land, (b) over land and water, (c) over the ocean and (d) the tropical cyclone.
The comparison between the model results for all regions with the RTD Product from Meteo France and satellite images showed an overall good agreement. An example for the region over land is given in Fig. 4 and for the region over the Atlantic in Fig. 5. In both cases the convective systems occur at the same place and move with the same speed as in the satellite images. This gives us confidence to use the simulations as a basis for budget calculations.

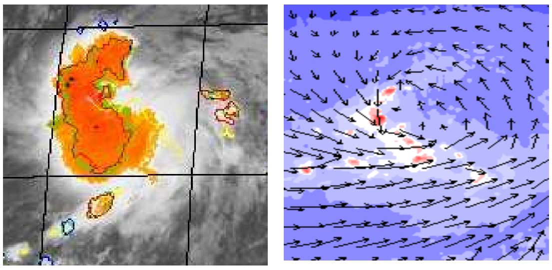


Fig. 5: The same as Fig. 4, but for the simulation initiated on 12 September 00 UTC. The displayed time is 12 UTC, 12 hours after the initialisation. The same colour code applied as in Fig. 4.

3. CONVECTION OVER LAND

The contribution of the diabatic terms, i.e. moist processes (SQ), radiation (RAD) and turbulence (MTD) as well as their sum (SRD=SQ+RAD+MTD) is shown in Fig. 6 for the box from 9.5-5.5°W, 9.5-14.0°N, and 975-200 hPa. The tendencies are averaged over 3 h. The meteorological situation is that one large convective system belonging to the MCS which is initiated over Burkina Faso is near its peak convective activity. The heating rate profile has its maximum between 500 and 600 hPa. The moist processes contribute most to diabatic heating. The impact of radiation is fairly small, but the turbulence has a marked influence especially between 700 and 600 hpa. Here two small peaks occur that appear to be related to the strong shear near the AEJ.

By comparing the total diabatic heating and the absolute vorticity we conclude that the PV increases between the surface and 650 hPa. Then it varies from 650 to 520 hPa due to the jet influence, and decreases above up to 350 hPa.

4. CONVECTION OVER WATER

The box region from 22-17.5°W, 10.5-14.0°N and 975-200 hPa includes a large and very active convective cell over the Eastern Atlantic. It can be seen that the relative vorticity profile has its maximum between 700 and 750 hPa, whereas the maximum of the sum of the diabatic heating terms is much broader and occurs between 700 and 600 hPa. The moist processes entirely dominate the whole profile. The impact of radiation is negligible, and the turbulence shows peaks near the surface as expected.

The diabatic tendencies result in a strong increase in PV up to about 700 hPa. The PV tendency is small between 700 and 600 hPa, and between 600 and 300 hPa the PV decreases.

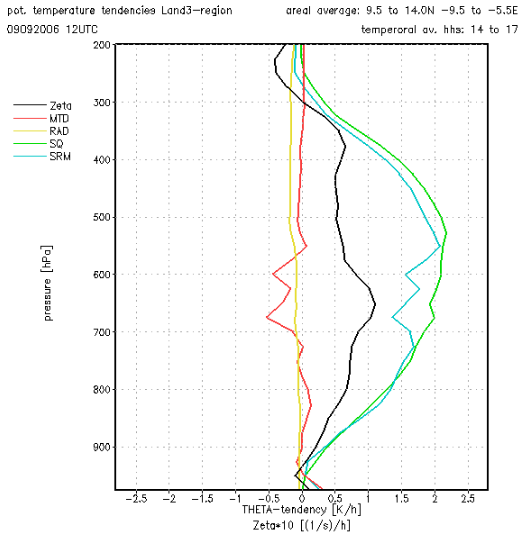


Fig. 6: Averaged profiles of the potential temperature tendencies (K h^{-1}) due to turbulence (MTD, red), radiation (RAD, yellow), moist convection (SQ, green), and the sum of SQ, RAD and MTD (SRM, turquoise). The relative vorticity (ZETA) is black.

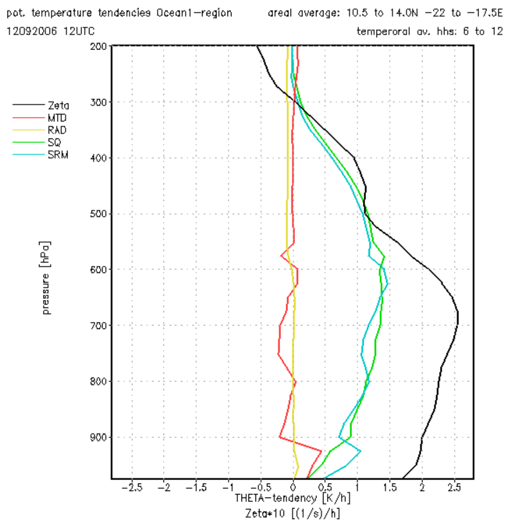


Fig. 7: The same as Fig.6, but for a different region.

The relative vorticity is much stronger in the case over water and the relatively high values reach the surface. Over land, the near surface values are around zero. The time of the over-water profile is shortly before the system became a tropical depression and it already had a pronounced cyclonic rotation near the surface.

5. SUMMARY AND OUTLOOK

The high-resolution model simulations with COSMO4.0 for different model regions showed that the model is able to simulate the AEW and different stages of convective systems. Thus these simulations provide a basis for temperature, humidity and potential vorticity budget calculations. We see that there is an increase in PV below the jet and a decrease above.

In the future, the relative vorticity and potential vorticity budgets will be analysed in more detail.
As the Saharan Air Layer (SAL) is present during the whole observation period, model simulations with COSMO-ART (Aerosol and Radiative Trace gases) will be carried out to study the affect of SAL on the interaction between convection and the AEW. Lagrangian calculations will be conducted to investigate where the dry air close to the system originates.

6. ACKNOWLEDGEMENTS

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