The representation of clouds in the non-hydrostatic weather forecast model HARMONIE

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Introduction

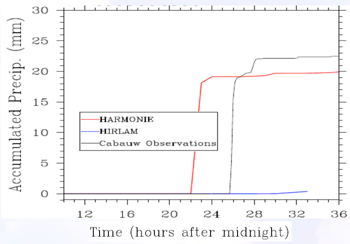
HARMONIE is a next generation non-hydrostatic weather forecast model. HARMONIE can be operated at a very fine horizontal spatial grid resolution (~ 1 km), and explicitly resolves vertical convective motions.

Objectives

The first phase of this KvK **IMPACT** project aims to address whether HARMONIE provides more accurate weather predictions than HIRLAM, in particular for those meteorological circumstances that may hinder aircraft operations at Schiphol airport. To this end a detailed comparison of model results with observations is made.

Case 1: Deep convection

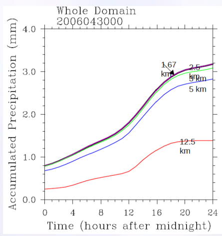
Cases: April 30, 2006 , 25-26 May 2009 (Weather Alarm case)
Analysis: Time series of precipitation for various areas (whole domain, Schiphol area, Cabauw Point), daily averaged precipitation for various areas, wind strength at Schiphol and around precipitation clusters
Sensitivity studies: Domain size, resolution
Verification: Ground based Observations/Rain Radar



A comparison of HARMONIE and HIRLAM output with data from Cabauw indicates that HARMONIE is much more successful at predicting the storm on 25-26 May 2009 than HIRLAM. In particular, HARMONIE predicts well the general shape of the rainfall pattern, with a large amount of rain over one hour and slight rainfall a few hours later (see Figure above). HIRLAM predicted *no* rainfall at all over the time of the storm. Though the rainfall rate is predicted fairly well, the onset of the precipitation in HARMONIE is 3 hours too early.

Case 2: Cold pools

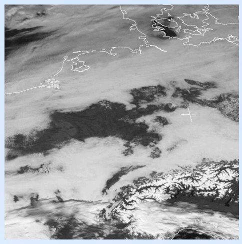
Cases: April 30, 2006 , July 9 2007
Analysis: Divergence of vertical wind (dw/dz), temperature, moisture, precipitation, wind gusts around these clusters and correlations between these parameters, if any.
Sensitivity studies: Domain size, resolution



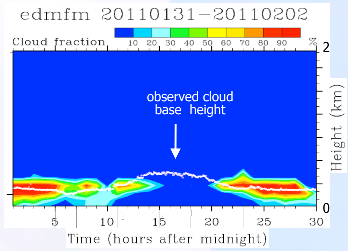
Cold pools develop if rain evaporates which leads to a subsequent cooling of air. Because cold air is heavier than warm air this cooled air will sink down. If there is a lot of evaporation of rain, this can trigger intense downdrafts which can eventually reach the ground surface.
Various runs with different horizontal grid resolutions demonstrate that HARMONIE can resolve the dynamical structures of cold pools provided that the horizontal resolution is finer than 2.5 km. This is nicely illustrated from the Figure above which displays the domain averaged rainfall amount as a function of horizontal grid resolution.

Case 3: Stratocumulus

Case: January 30-February 1, 2011
Analysis: Total cloud cover, liquid water path, cloud base and top heights
Sensitivity studies: Domain size, resolution
Verification: MSG satellite (LWP, cloud cover, cloud top height)



Stratocumulus clouds are only a few hundreds of meters thick. Despite their relative shallowness, they reflect back to space more than 50% of the downwelling solar radiation, and can cause a poor visibility if their cloud base is very close to the ground surface. In addition, in the wintertime period stratocumulus clouds may produce freezing rain.



The satellite image of 31 January 2011 12 UTC shows a horizontally extended stratocumulus cloud deck covering the Netherlands. As the condensed water amount in low clouds is typically very small, on the order of 0.1 g/kg, it is notoriously difficult for weather and climate models to capture these clouds well. In practice this means that if the total water specific humidity is only 0.1 g/kg off, or the temperature just a few tenths of a degree Celsius too high, an unsaturated, clear atmosphere will be predicted (De Roode, 2007). Indeed, the amount of stratocumulus and persistence of the observed stratocumulus cloud deck is underpredicted in various European weather forecast models, like the ECMWF, COSMO, and DWD. Also in HARMONIE the stratocumulus cloud deck disappears for a couple of hours around noon-time. A preliminary analysis of the boundary layer humidity indicates that it is a bit too low during the clear air period. This could possibly be due to a surface moisture flux that is too small, or because of excessive entrainment of dry air present just above the cloud top. To verify these hypotheses, in addition to other ones that relate to data assimilation, the contribution of the vertical turbulent transport to the tendencies of heat and moisture as computed by the new EDKF scheme will be investigated.

Preliminary conclusions

- It is demonstrated that a non-hydrostatic set up of the model helps to more realistically capture deep convection as compared to HIRLAM.
- Although the stratocumulus cloud deck does not persist in the HARMONIE results in contrast to the observations, various other tests with EDMF/EDKF parameterization scheme show promising results with regard to the representation of low clouds.

References

De Roode, S. R., 2007: The role of eddy diffusivity profiles on stratocumulus liquid water path biases. *Monthly Weather Rev.*, **135**, 2786-2793.
Siebesma A.P. , P.M.M. Soares and J. Teixeira, 2007: A combined Eddy Diffusivity/Mass-flux approach for the convective boundary layer. *J. Atm. Sci.*, **64**, 1230-1248.

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