Comparing the atmospheric planetary boundary layer (PBL) in a high-resolution model with ground-based observations: a detailed look at PBL clouds over JOYCE-CF

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HD(CP)² High definition clouds and precipitation for advancing climate prediction

1. Boundary layer clouds in a changing climate

Dufresne and Bony, (2008):
The representation of low level clouds in climate models is a major contribution to uncertainties in prediction of future climate.

Quaas et al., (2009):
The net response of PBL clouds to changes of aerosols or greenhouse gases contributes greatly and on very short time scales to the net radiative response of the atmospheric column.

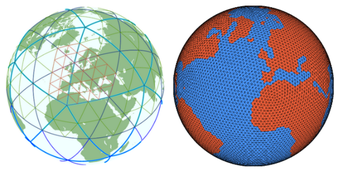
2. THE ICOsahedral Non hydrostatic atmospheric (ICON) model

To better describe clouds and their impact, recently a new model has been developed in Germany, with higher resolution compared to previous models and larger amount of clouds and turbulent motions resolved.

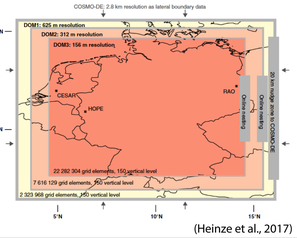
ICON has three main versions:

1) ICON – CLIMATE
Max-Planck Institute for Meteorology (MPI-M)
Hamburg, Germany

2) ICON – NWP
German Weather Service (DWD)
Offenbach, Germany



3) ICON – LEM
- **Domain size and topography**
- **LES type simulation** (resolutions of 625, 312, 156 m), no convection parameterization, resolved clouds, 3D Smagorinsky turbulence)
- **Forcing with analysis NWP data** (COSMO)
- **Open boundaries** (instead of periodic boundary conditions)
- **1 way nesting**
- **Microphysics:** 2 moments scheme from Seifert and Beheng (2006), for warm rain Seifert and Beheng (2001)



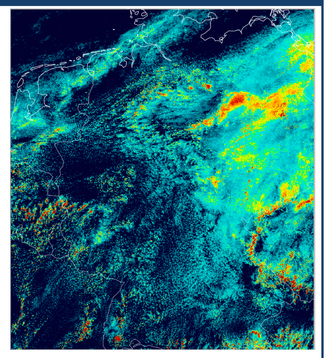
(Heinze et al., 2017)

3. Research questions

With ICON-LEM realistic cloud fields can be simulated: are they physically correct?

In particular:

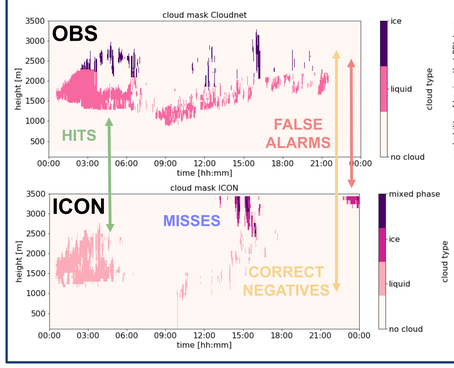
- Is ICON-LEM capable of reproducing the main low cloud features compared to observations?
- Do any major biases exist?
- If so, which model physics or cloud-/precipitation processes can they be attributed to?

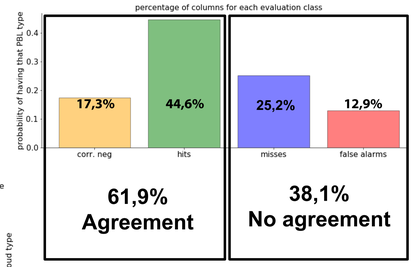


Snapshot taken at 12:15 from the 2nd May 2013.
Cloud water content from domain 3 at 156 m resolution of ICON-LEM.

4. Cloud mask for model and observations

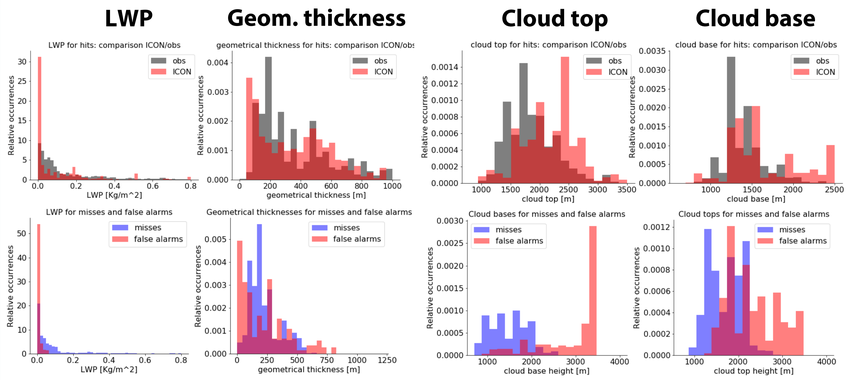
- The 2nd May 2013 is analyzed based on Cloudnet for the observations and on the cloud water content for the ICON-LEM model output.
- All observations are resampled on the model time grid (9 seconds)





POD	FAR	BIAS	ACC	PODF
0.64	0.22	0.82	0.62	0.43

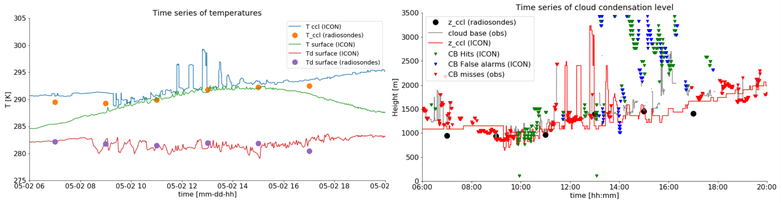
5. Characteristics of hits, misses and false alarms



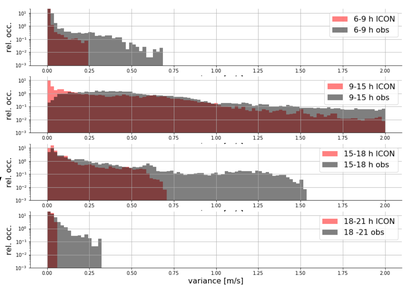
- Clouds detected as hits and misses have typical PBL clouds characteristics
- "Fake clouds" (false alarms) are thin, very high and with small LWP values

6. Physics behind misclassified columns

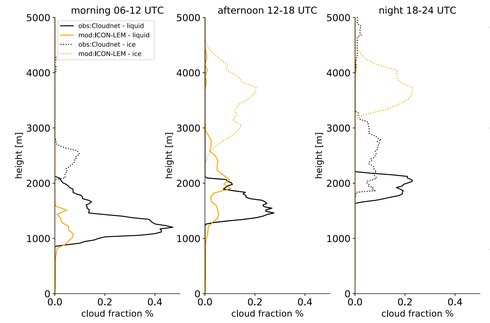
Analysis of thermodynamics (Convective Condensation Level (CCL)) and dynamics (variance of vertical velocity)



- The model shows a pretty good agreement for T_{CCL} with radiosondes.
- The surface temperatures is approximately equal to T_{CCL} from 9:00 to 15:00.
- Clouds are missed between 8:00 and 10:00 and in the spikes region.
- The presence of a cloud aloft at 2500 m between 14:00 and 17:00, decoupled from the PBL is causing some falsely assigned hits.
- The interval with largest variances in vertical velocity in ICON corresponds to the time interval in which most clouds are identified as HITS (9:00 to 15:00)
- The lack of formation of clouds after 15:00 which we saw in the previous slide corresponds to a decrease of the variance of w in ICON between 15:00 and 18:00.



7. Diurnal evolution of cloud fraction profiles in the PBL



- Observations show that clouds form at the top of the PBL and raise during the day with the PBL development. In the last part of the day clouds are decoupled from PBL.
- ICON-LEM captures well the cloud base height in the first part of the day, but misses some clouds especially in the turbulent PBL development between 12:00 and 18:00.
- ICON-LEM is not able to represent the decoupled liquid cloud in the last part of the day

8. Conclusions and future work

- A method for comparing one-to-one ground-based observations and model output has been tested on one case study. ICON-LEM reproduces the major part of PBL clouds even if some are missed and some "fake" clouds with small LWP are generated.
- Good agreement among Z_{CCL} from radiosondes and ICON-LEM despite some rare spikes at noon is found; cloud formation does not seem to be strictly coupled to the thermodynamics of the Z_{CCL},
- Clouds fraction is lower in the model, especially in the early morning during the first PBL development, in occurrence of spikes of Z_{CCL} and after 15:00 when the variance of the vertical velocity decreases compared to observations.

References:

*Dufresne, J. and S. Bony, 2008: An Assessment of the Primary Sources of Spread of Global Warming Estimates from Coupled Atmosphere–Ocean Models, J. Climate, **21**, 5135–5144, https://doi.org/10.1175/2008JCLI2239.1*
*Quaas et al., 2009: Aerosol indirect effects–general circulation model intercomparison and evaluation with satellite data, Atmos. Chem. Phys., **9**, 8697–8717, www.atmos-chem-phys.net/9/8697/2009/*
Heinze et al., 2010: Large-eddy simulations over Germany using ICON: a comprehensive evaluation, Q.J.R. Meteorol. Soc., 143: 69-100. doi:10.1002/qj.2947

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