Detectability of fast cloud adjustments in large-scale high-resolution simulations

O. Sourdeval[1], M. Costa Surós[2], S. Crewell[2], C. Carbajal Henken[3], C. Engler[4], J. Hesemann[5], C. Hoose[5], H. Rykba[6], J. Kretzschmar[1], and J. Quaas[1]

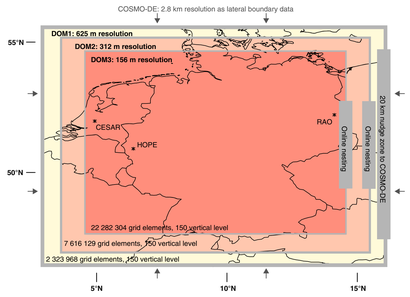
1 - Universität Leipzig, Germany; 2 - University of Cologne, Germany, UK; 3 - Frei Universität Berlin, Germany; 4 - TROPOS, Germany; 5 - Karlsruhe Institute of Technology, Germany; 6 - DWD, Germany

Motivations

- Cloud adjustments to anthropogenic aerosol perturbations remain an important source of uncertainties on global radiative forcing estimates. Joint modeling-observation efforts are needed.
- This study seeks to identify, quantify and better understand these effects through sensitivity analyses based on large-scale high-resolution simulations. Their detectability by spaceborne or ground-based observations is also assessed.

Model and experiment framework

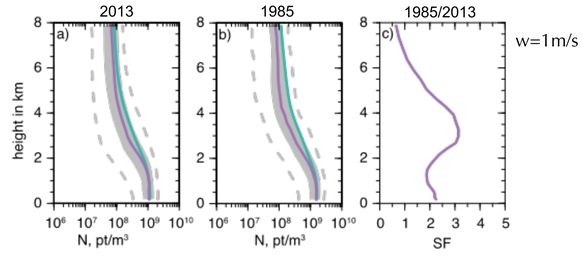
- The high resolution simulations are performed by ICON in a Large Eddy Model configuration



Characteristics of ICON-LEM (Heinze et al, 2017):

- 156-m of horizontal resolution, 150 vertical levels
- The domain covers Germany.
- We focus on a 24 hr simulation (02 May 2013)
- Two moment microphysics scheme with 6 hydrometeor classes (Seifert-Beheng)
- Aerosols are not yet interactive!

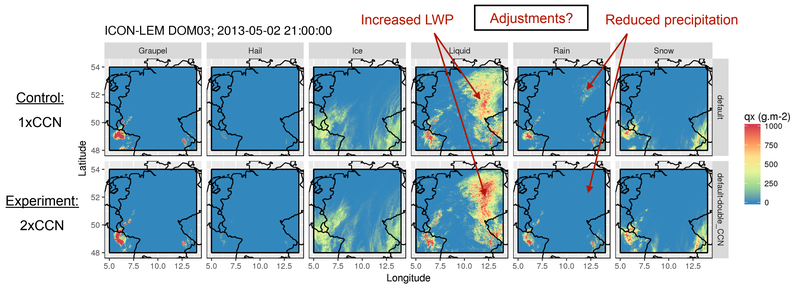
- The framework consists in analyzing the response of clouds, precipitation and radiation to a CCN (Cloud Condensation Nuclei) perturbation.
- Initial setup:
  - Control: 24 hr ICON-LEM simulation with CCN profiles representative of 02 May 2013
  - Experiment: Same as control with 2xCCN (~representative of 1985 concentrations), improvement in progress.
- 4D CCN fields (time and space varying) are obtained from simulated aerosol concentrations (COSMO-MUSCAT) for different updraft velocities and supersaturations (Abdul-Razzak and Ghan, 2000).



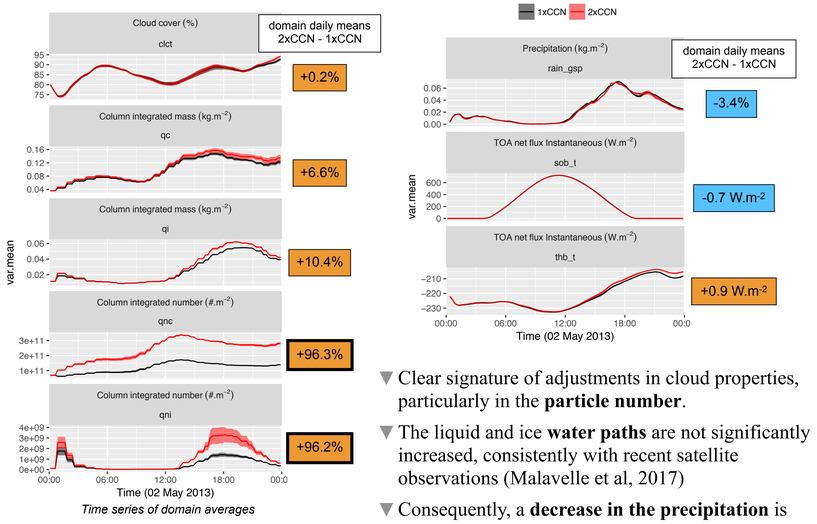
Domain average CCN profiles corresponding to w=1m/s

Cloud adjustments in ICON LEM simulations

- Adjustments in the spatial distribution of vertically integrated particle mass (6 hydrometeors).



- Temporal evolution of domain average bulk quantities

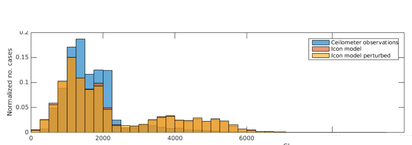


Time series of domain averages

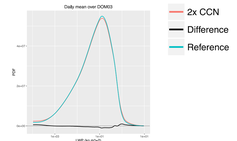
- Clear signature of adjustments in cloud properties, particularly in the **particle number**.
- The liquid and ice **water paths** are not significantly increased, consistently with recent satellite observations (Malavelle et al, 2017)
- Consequently, a **decrease in the precipitation** is observed.
- These results remain preliminary due to an issue in the radiation calculation, which didn't account for changes in particle numbers (no Twomey effect)

Detectability in observations

- Can the adjustments found in ICON-LEM be detected?
  - Use of data from **supersites** and **satellite** measurements.
  - Comparisons to initial 1xCCN and 2xCCN simulations. Is one more realistic than the other?



Comparison of cloud base heights measured from supersite kilometers and simulated by ICON 1xCCN and 2xCCN.

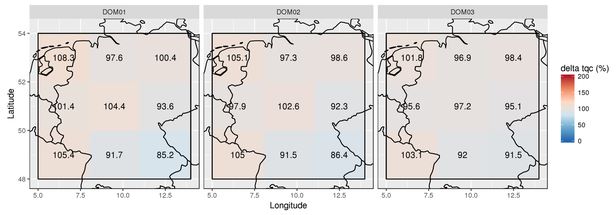


Daily mean PDF of LWP from ICON-LEM;

- The detectability of these adjustments from satellite seems difficult. Accurate retrievals of the **Nd and Ni** are needed.

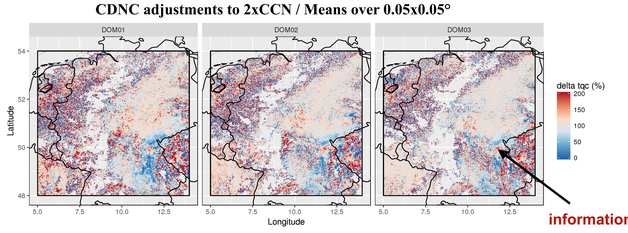
CDNC adjustments to 2xCCN / Means over ~3x3°

Spatial average of CDNC burden ($tq_c > 1$ g.m^{-2}), delta=exp-control (%); 06:00:00 UTC



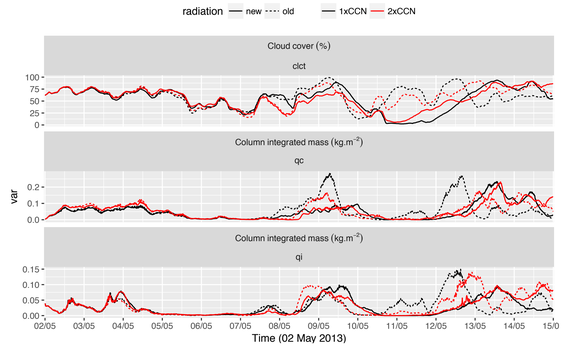
Is there information in the adjustment patterns at high resolution that could be detected per satellite?

CDNC adjustments to 2xCCN / Means over 0.05x0.05°

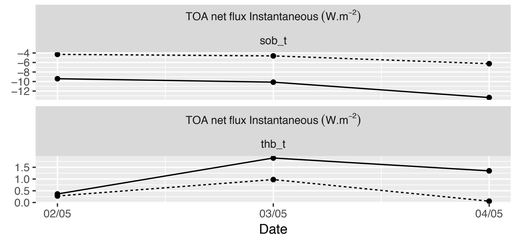


Representativeness for global adjustments

- Similar runs (1xCCN and 2xCCN) were made with ICON-NWP.
  - 14 days simulations from 02 May 2013 and no restart. Different initialization (IFS).
  - New and old radiation modules were tested.
  - 0.25°x0.25° over DOM03 domain.



- Analyses of daily mean adjustments to 2xCCN in T-AMIP with updated radiation.



- **Impact on SW net TOA fluxes**: -5 W.m^{-2} with old radiation (adjustment effects) and -10 W.m^{-2} with new module (Twomey + adjustments).
- Different from LEM (old radiation predicted -0.7 W.m^{-2}).
- This suggests about half Twomey and half adjustment contributions to the ERF.
- Roughly agrees with literature studies (e.g. Cherian et al 2014: -4W.m^{-2}/decade between 1990 and 2005)

Printed at the University Computer Center of Leipzig