A mesoscale model for aerosol-cloud interaction studies WRF-PMCAMx-UF with insights to secondary ice production

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1. Introduction

- Aerosol-cloud interaction is complex, leading to uncertainties in climate prediction.
- Especially, capturing the correct amount of ice and liquid particles in mixed-phase clouds is challenging in climate models.
- Chemical Transport Models (CTMs) are used to study this interaction by simulating aerosol distribution and composition.
- We developed a coupled version of Weather Research and Forecasting model (WRF) version 4.2.1 and PMCAMx-UF CTM through prognostic cloud droplet number as well as investigated the effects of coupled model to secondary ice production (SIP).

2. Materials and methods

COUPLING APPROACH:

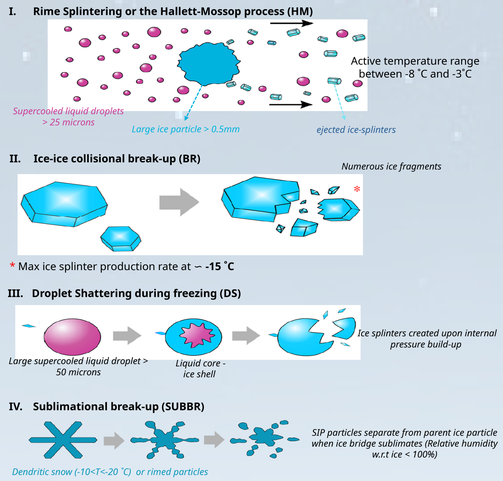
I. Cloud droplet number was prognostically calculated within WRF using the Morales and Nenes (2014) activation scheme for each grid cell and time step over a given simulation horizon (1 day) using the PMCAMx-UF aerosol distributions integrated over the WRF vertical velocity distributions.

II. Ice crystal numbers were computed adding SIP processes (Hallett-Mossop, collisional break up, droplet shattering and sublimational break up of snow and graupel) to WRF model following Georgakaki et al. (2023).

III. The droplet and ice fields were implemented back to WRF to calculate the new meteorological and aerosol fields.

IV. Steps I.-III. were iterated until convergence (by iteration 3) of droplet number and ice crystals were observed.

Simulation name	Details
CTRL	Prescribed number of droplets (250 cm^{-3}) (control simulation)
NDROP3	Prognostic number of droplets (250 cm^{-3} as initial), no SIP
SIPoff	Prescribed number of droplets (100 cm^{-3}), no SIP
SIPon	Prescribed number of droplets (100 cm^{-3}), with SIP
SIPoff3	Prognostic number of droplets (100 cm^{-3} as initial), no SIP
SIPon3	Prognostic number of droplets (100 cm^{-3} as initial), with SIP



SIMULATION PERIOD & MODEL EVALUATION:

- We evaluated cloud properties from each simulation against SEVIRI satellite and aerosol characteristics against several ground-based station observations (K-puszta, Värriö, Finokalia, Hyytiälä, Melpitz, Ispra, Aspvreten and Vavihill) obtained from the ACTRIS network data.
- In addition, we evaluated the effects of SIP processes for prescribed and prognostic droplet cases to satellite observations.
- The simulations focused on European region for 8th until 16th of June, 2012.

3. Results

- Decrease in small particles and increase in large particle numbers observed with prognostic droplets which showed a better agreement with all ground station observations (**Fig. 1**).
- Prognostic droplets decreased cloud droplet number concentration (CDNC) and liquid water path (LWP) (**Fig. 2a-b**), leading to positive radiative forcing.
- Prognostic droplet simulation showed better CDNC performance compared to prescribed droplet simulation (**Fig. 2a**).
- Addition of SIP processes increased ice water path (IWP) in temperature regions -20 to -40 regions, showing a better agreement with the satellite observations (**Fig. 2c**).

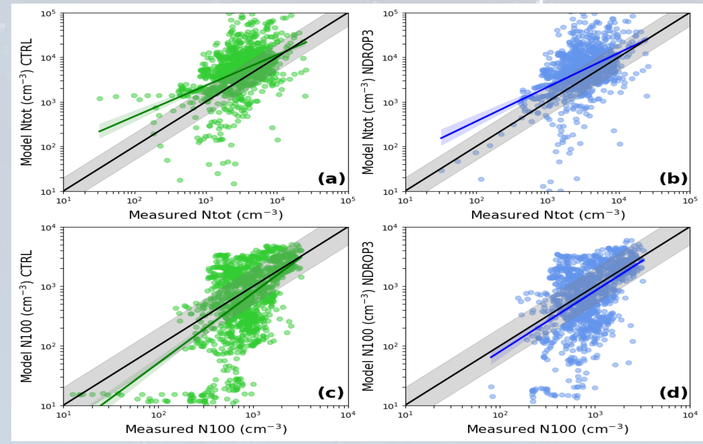


Fig 1: Measured and modelled total particle number, Ntot (a-b) and number of particles with diameter larger than 100 nanometers, N100 (c-d) on ground level from NDROP3 (blue) and CTRL (green) simulations.

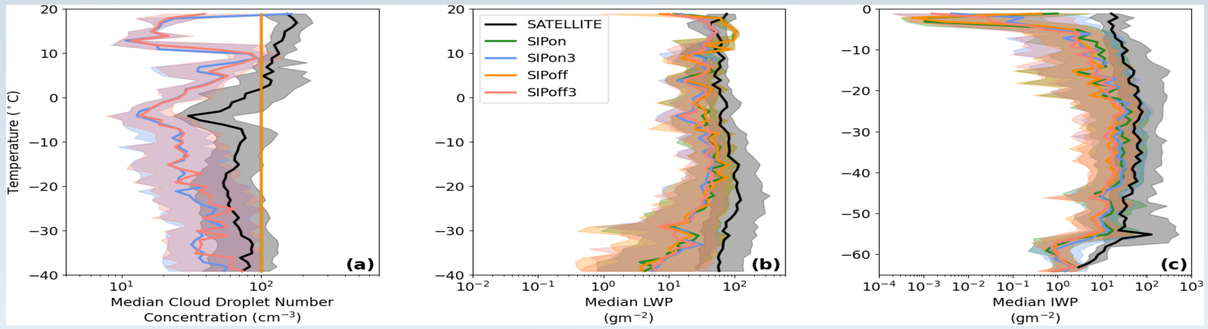


Fig 2: Temperature spectrum over the European region of median cloud top CDNC (a), LWP (b) and IWP (c) from prognostic SIP (blue), prescribed SIP (green), prognostic non-SIP (red) and prescribed non-SIP (yellow) droplet simulations as well as the satellite observations.

4. Conclusions

- Adding prognostic droplets increases the prediction capability of the model in terms of large particle numbers.
- Models with SIP processes and prognostic droplets slightly outperformed non-SIP and prescribed droplet cases in terms of CDNC and IWP compared to satellite observations.

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Acknowledgements:

Funding for this study was provided by the European Research Council (ERC) project "PyroTRACH" (Grant agreement No. 726165) and the European Union's Horizon Europe project "CleanCloud" (Grant agreement No. 101137639)

ERC_PyroTRACH
European Research Council
Established by the European Commission
CleanCloud
Horizon 2020 European Union Funding for Research & Innovation