Modelling aerosols and aerosol-cloud interactions in the Arctic

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D02

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1 Summary

Explore the **role of aerosol-cloud-radiation interactions in Arctic climate** by combining global and Arctic-focused GCM simulations and multi-climate-model analysis:

- Assess controls on aerosol transport to Arctic, incl. particle mixing, ageing and deposition
- Evaluate model representation of Arctic clouds and aerosol-cloud interactions
- Quantify aerosol direct/indirect climate forcing, dynamic effects, snow/ice albedo forcing
- Diagnose relevance of aerosol forcing for Arctic climate change

Hypothesis

Aerosols contribute to the observed Arctic Amplification through direct and indirect radiative effects, for which particle transport, ageing, deposition on snow/ice, and interactions with clouds are key factors.

2 Research rationale

Arctic aerosol

- Potentially important role in Arctic Amplification
- Direct and indirect effects on energy balance, atmospheric heating and dynamics
- Indirect effects presumably much stronger than direct forcing in latitudes
- Key role of Arctic low-level clouds
- Anthropogenic forcing highly sensitive and dependent on natural background
- Dramatic seasonal variations in surface albedo, snow/ice albedo forcing

Fig. 1: Plume of Alaska wildfire smoke over Greenland from NASA's Terra satellite on 27 July 2014

Challenges

- Large spread in climate model Arctic aerosol predictions: uncertainties in seasonality, stratification, deposition and processing of aerosol
- Changing sources & transport pathways (local vs. long range)
- Arctic low-level, multi-layer mixed-phase clouds challenging for climate models

New possibilities and ideas

- Comprehensive model approach: from studying regional processes – exploiting new measurements – to understanding climate context
- New flexible aerosol-climate model ICON-HAM2
- New developments in cloud microphysics and emission inventories
- Multi-model context (CMIP5/6) and relevance of aerosol forcing for Arctic climate change

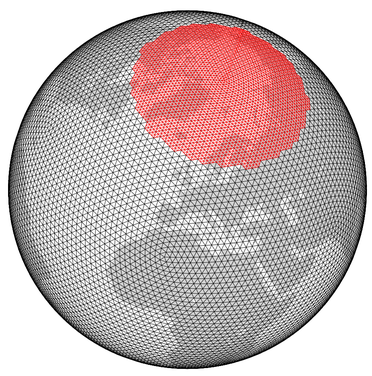


Fig. 2: ICON model grid with Arctic nest

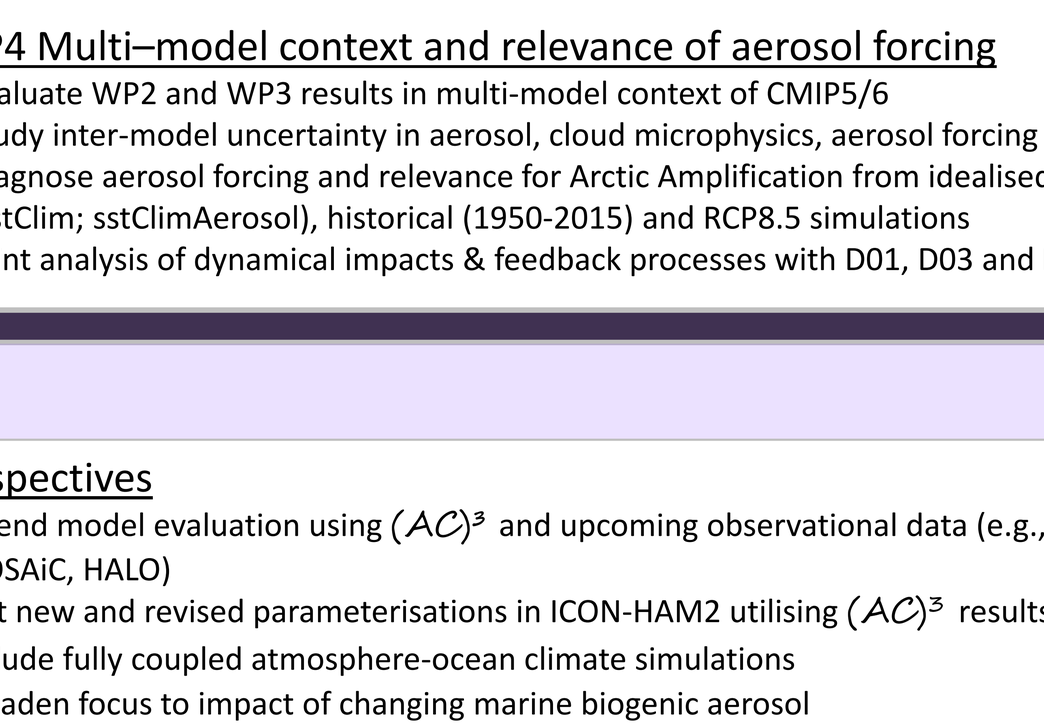
3 Research plan

WP1 Base case GCM simulations and initial evaluation

- Base-case simulations with ICON-HAM2 for WP1 and WP2:
  - Standard setup, prescribed SST/sea ice, 1-5 year periods for sensitivity studies
  - Nudged runs, 40-km global grid/13-km Arctic nest, 2006–15/$(AC)^3$ campaigns 2017/19
- Evaluation with B01/02, E04 data, CloudSat, CALIPSO, COPERNICUS re-analysis

WP2 Aerosol transport and direct radiative properties

- Nudged ICON-HAM2 (WP1), latest inventories, scenarios for local emission trends
- Source partitioning and trajectory studies: optical and CCN properties of natural vs. anthropogenic aerosol, particle ageing; comparison to A01/02, B02, E02 data
- Quantify direct/semi-direct radiative forcing, parameterisation for BC-albedo forcing



WP3 Aerosol cloud–mediated radiative forcing

- Evaluate cloud microphysics in ICON-HAM2, identify optimum representation
- Evaluation using active satellite and B03/04 microphysical observations
- Assess effective radiative forcing of anthrop. aerosol, nudged ICON-HAM2 (WP1)
- Detection/attribution of anthropogenic aerosol effects from satellite/$(AC)^3$ data

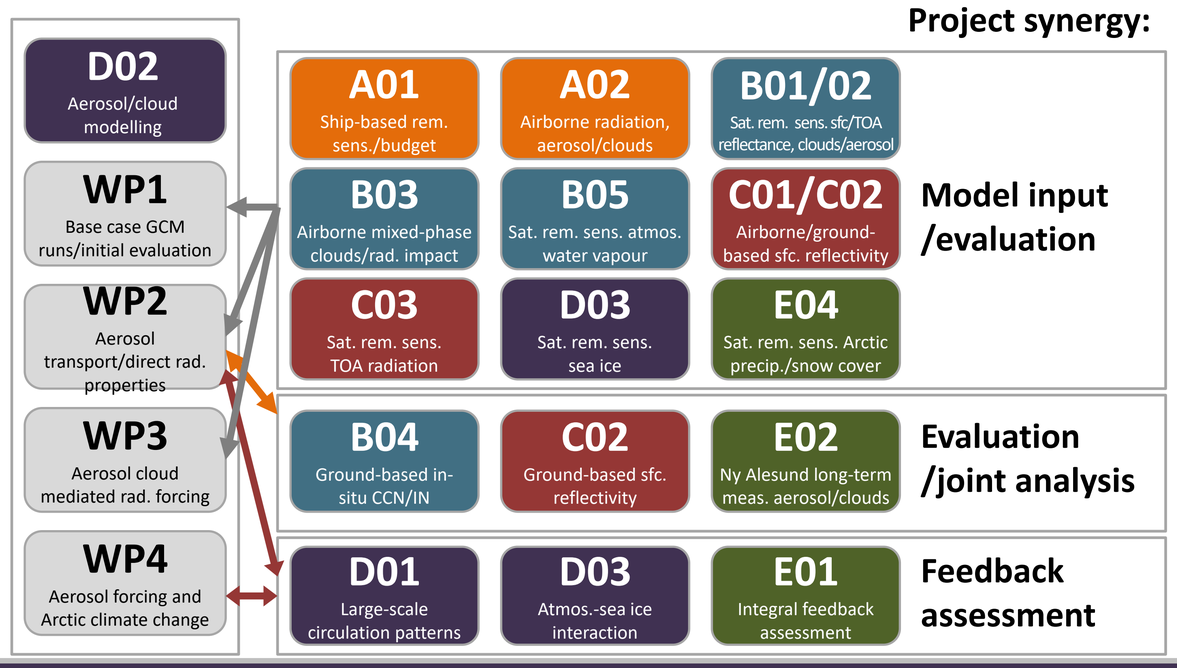
WP4 Multi–model context and relevance of aerosol forcing

- Evaluate WP2 and WP3 results in multi-model context of CMIP5/6
- Study inter-model uncertainty in aerosol, cloud microphysics, aerosol forcing
- Diagnose aerosol forcing and relevance for Arctic Amplification from idealised (sstClim; sstClimAerosol), historical (1950-2015) and RCP8.5 simulations
- Joint analysis of dynamical impacts & feedback processes with D01, D03 and E01

4 Role within $(AC)^3$ & perspectives

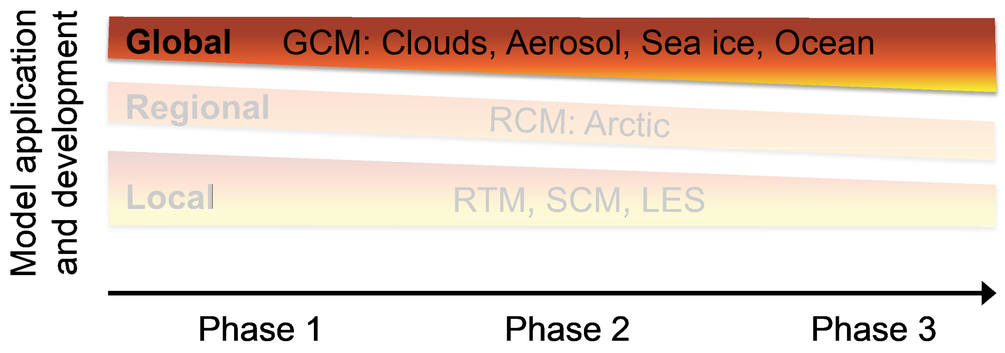
Collaboration within $(AC)^3$

- D02 provides spatio-temporal context to and interpretation of field observations
- D02 relies on data from $(AC)^3$ as input parameters and for model evaluation



Perspectives

- Extend model evaluation using $(AC)^3$ and upcoming observational data (e.g., MOSAiC, HALO)
- Test new and revised parameterisations in ICON-HAM2 utilising $(AC)^3$ results
- Include fully coupled atmosphere-ocean climate simulations
- Broaden focus to impact of changing marine biogenic aerosol



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