ACE-SPACE

Antarctic Circumnavigation Expedition: Study of Pre-industrial-like Aerosol Climate Effects

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Areas of contribution

Polar atmospheric processes

Modelling and forecasting

Polar-lower latitude linkages

Education

Observations

Summary

Aerosol-cloud interactions are the least understood anthropogenic influence on climate change (IPCC, 2013). A major cause of this limited understanding is the poorly quantified state of aerosols in the pristine preindustrial atmosphere, which defines the baseline against which anthropogenic effects are calculated. The uncertainty in aerosol induced radiative forcing (± 0.7 from a mean of -0.55 W/m2) is twice the uncertainty for CO_2 (± 0.35, mean +1.68 W/m2). Also, models grossly underestimate cloud solar reflectance there, by as much as 30 W/m2 during summer. We suspect it partly being due to poor representation of aerosol-cloud interactions.

This project aims at reducing the uncertainty in the effects of aerosols on climate change by exploring preindustrial-like conditions which can almost only be found in the Southern Ocean. To achieve this, we will conduct ship-based measurements of aerosol microphysical and chemical characteristics as well as measurements of trace gases modulating particle characteristics and combine these with on-board remote

sensing and satellite data of clouds to evaluate global climate models.

The Southern Ocean is the most pristine aerosol environment on Earth, but almost the entire region remains unsampled. The ACE expedition from December 2016 to March 2017 provides a unique and unprecedented opportunity to prove or dismiss this hypothesis.

Description

ACE-SPACE will advance our understanding of climate-relevant aerosol processes. These processes regulate the ability of aerosol to form cloud condensation and ice nucleating particles and hence modify the radiative properties of clouds. Aerosol-cloud interactions are the least understood anthropogenic influence on climate change. A major cause of this limited understanding is the poorly quantified state of aerosols in the pristine preindustrial atmosphere, which defines the baseline against which anthropogenic effects are calculated.
ACE-SPACE pursues an interdisciplinary approach of connecting on board in-situ and remote sensing measurements, satellite observations and global climate modelling. Expected results are:
a) Enhanced understanding of the aerosol properties, how trace gases modulate aerosol properties, and processes that are key to aerosol-cloud radiative forcing, including formation and growth of new particles and relevant chemical species e.g., from marine emissions.
b) Improving satellite retrieval over the Southern Ocean by linking in-situ cloud condensation and ice nuclei measurements through onboard remote sensing with cloud droplet number concentrations from satellite observations.
c) Evaluating and constraining global climate model simulations through use of the measured aerosol and cloud data, and understanding the implications for radiative forcing and the related uncertainty.

To achieve this, ACE-SPACE will participate in the Antarctic Circumnavigation Expedition (ACE) taking place between December 2016 and March 2017 onboard the Russian icebreaker Akademik Treshnikov. The expedition is planned to travel clockwise around Antarctica starting in Cape Town, South Africa, with stops at more than ten islands, Hobart, Tasmania, and Punta Arenas, Chile. The expedition will cover latitudes between 35° and 67° S. In addition, a subset of measurements will be conducted along the North-South transects from Bremerhaven, Germany, to Cape Town and back.
ACE-SPACE will host a suite of on-line measurements for the characterization of aerosol particles covering aerosol chemical composition, size distribution, CCN and IN activity amongst other which will be operated continuously. Off-line analyses of the same characteristics as well as of cloud and rain water chemistry together with trace-gases observations of CO, dimethyl-sulfate and isoprene will complement the measurements. Standard meteorological observations are covered by the onboard meteorological station.
The onboard measurement data will be used to constrain satellite data retrieval assumptions. Satellite retrievals are crucial for understanding clouds over the Southern Ocean as they provide long-term data with large spatial coverage. However, large errors exist in remote-sensing estimates of Southern Ocean mixed-phase and multilayer cloud properties, and precipitation. As linking in-situ measurements with cloud droplet number satellite retrievals allows relating aerosol properties to cloud radiative effects, it is highly desirable to minimize retrieval uncertainties. Ship-measured aerosols, precipitation and thermodynamic properties of the boundary layer will be expanded in the vertical by measurements of cloud base heights (ceilometer). Further, aerosol optical depth profiles will be taken with a sun photometer, and a “sky camera” will record cloudiness and cloud types. These datasets will be combined with satellite measurements of properties of boundary layer clouds such as cloud cover, liquid water path, geometrical and optical depth, and solar reflectance. We will use data products from the Moderate-Resolution Imaging Spectroradiometer (MODIS).

Modelling will be conducted with the Global Model of Aerosol Processes (GLOMAP), whereby the new measurements will be used to evaluate aerosol concentrations. We will exploit existing comprehensive uncertainty analyses based on this model to constrain its uncertainty. Presently uncertainties in modelled aerosol are essentially unconstrained over the Southern Ocean. Using our measurements will produce a set of model runs with a reduced uncertainty. Additionally, we will quantify how the reduction in uncertainty of pristine aerosol environments affects Southern Ocean clouds and the radiative impact on climate. We will run preindustrial and present-day simulations of the UKESM Earth System Model to quantify the anthropogenic radiative forcing using models before and after constraining pristine aerosol properties. We will quantify cloud radiative and microphysical properties, the top of atmosphere radiative fluxes and the radiative forcing, and demonstrate how the change in the modelled pristine aerosol affects these quantities. The results will enable us to assess the well documented shortwave radiation bias >55°S through the impact on cloud fraction.

ACE-SPACE contributes especially to YOPP's objective of "Gather[ing] additional observations through field programmes aimed at improving understanding of key polar processes" (objective 1) and thereby to the overarching goal to "Enable a significant improvement in environmental prediction capabilities for the polar regions". The project also aims to improve the representation of aerosol-cloud interaction, a key (polar) process, in models (objective 3) and the "linkages between polar regions and lower latitudes and assess skill of models representing these" (objective 6) by including modelling activities as a key component in the project. ACE-SPACE measurements will take place during the preparatory phase of YOPP which has the advantage of providing detailed information ahead of the intensive observing period. In terms of educational contributions, ACE-SPACE is involved in the "Maritime University" aboard the Akademik Treshnikov. Additionally, ACE-SPACE is highly complementary to SOCRATES (Southern Ocean Clouds Radiation Aerosol Transport Experimental Study, US, NSF) planned for Austral Spring 2018 to Fall 2019.

Timeline

2016-12-01 - 2017-03-25

Regional emphasis

Northern hemisphere: No

Southern hemisphere: Yes

Key project deliverables

Expected results are:
a) Enhanced understanding of the aerosol properties, how trace gases modulate aerosol properties, and processes that are key to aerosol-cloud radiative forcing, including formation and growth of new particles and relevant chemical species e.g., from marine emissions.
b) Improving satellite retrieval over the Southern Ocean by linking in-situ cloud condensation and ice nuclei measurements through on board remote sensing with cloud droplet number concentrations from satellite

observations.
c) Evaluating and constraining global climate model simulations through use of the measured aerosol and cloud data, and understanding the implications for radiative forcing and the related uncertainty.

Data sets:
- aerosol number concentration
- aerosol size distribution (sub- and super-micron)
- aerosol chemical composition based on mass spectrometric measurements
- CCN activity
- INP number concentration
- trace gas concentrations (e.g., CO, DMS)

Data management

ACE data base hosted by the Swiss Polar Institute - raw data? aerosol data will be available through the GASSP and likely EBAS databases - quality assured.
All data bases are open access.

Is data provided to WMO Global Telecommunication System

No

Real-time provision

no