Ice in Clouds Experiment– Dust (ICE-D)

Scientific Program Overview (SPO)

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The following testable hypotheses are proposed:

- Mineral dust particles dominate the CCN and IN population in the convective clouds off the west coast of Africa and their activities are strongly dependent on the source region and the nature and extent of the aging process undergone by them.
- The ice concentrations and the fraction of ice water content relative to the total condensed water content are directly related to the concentration or surface area of dust aerosols for the ICE-D clouds.
- The IN activity of dust depends upon its mineralogy and could be affected by minor constituents.
- The composition and size distributions of the dust and thus implicitly its nucleating ability is fairly uniform through deep layers in the vertical.
- Biological and carbonaceous particles contribute to primary ice nucleation in the ICE-D clouds, but do not dominate over dust.
- A secondary ice multiplication process that requires the presence of supercooled droplets larger than a threshold size in the presence of initially low ice concentrations is responsible for the glaciation of ICE-D Cu congestus clouds at temperatures warmer than -10^{o}C.

Important improved and new cloud particle probes (anti-shatter tips and algorithms, faster electronics) and aerosol composition probes will advance observations from earlier experiments and are likely to allow reliable comparisons between IN measurements and ice particle observations early in the development of the ice phase. Enhanced online and offline measurements to quantify the efficacy of ice nuclei with low ice nucleation efficiencies and the time dependence of nucleation will be measured using improved instruments and measurement techniques that are just finding their way into recent field campaigns. Given that the clouds to be focused on are relatively simple dynamically, weather forecast models (e. g., WRF, UK Met Office Unified Model) can be used to investigate the complex effects of dust aerosols on liquid and ice phase processes. On the basis of field observations, laboratory experiments in the AIDA chamber in Karlsruhe, Germany and elsewhere in association with the 2015 International Ice Nucleation Workshop (proposal to be submitted) will be designed and conducted to fully characterize the ice nucleating and CCN properties of surface dust samples deemed to be characteristic surrogates for airborne particles. This will also include effects of realistic surface coating or chemical ageing of the dust aerosols. The laboratory experiments have significantly more time and provide controlled conditions to explore the ice nucleating capabilities of the dust aerosols much more fully than is possible from aircraft or from measurements at the ground in Cape Verde.

Executive Summary

Mineral dust particles are efficient heterogeneous ice nuclei (IN) and potentially the most important aerosol for heterogeneous ice production in clouds in a global sense. Mineral dusts can also have an impact on cloud properties via action as cloud condensation nuclei (CCN). Observations of dust aerosols have largely focused on their role in modifying tropical cyclogenesis, as cloud condensation nuclei, their action as ice nuclei from laboratory studies, or indirectly from remote sensing measurements.

To improve the understanding and representation (in models) of dust-produced IN and CCN, we propose the Ice in Clouds-Dust (ICE-D) field program based out of Cape Verde, Africa from June 20-August 1, 2015. This location and time was selected because i) large dust concentrations and dust events generated over Africa are frequently observed; (ii) dust number concentrations are often high and with strong gradients compared to further downstream of the source (e. g., Caribbean region), providing high signal to noise ratio for IN and other measurement systems; iii) physical properties and mineralogical composition are diverse; iv) surface chemical affects (i.e., aging) are most rapid over the ocean; and v) large gradients in regional dust concentration provide for aircraft sampling under a wide range of conditions in a single flight, and vi) Cape Verde has an international airport with facilities that supported NASA DC8 research aircraft operations during the NASA AMMA field program.

The NSF/NCAR C130, with a complete set of particle composition and size spectrometers, CCN spectrometers and IN measurements, lidar, radar and dropsondes, will profile the lower atmosphere and collect in-situ cloud and remote sensing data in the vicinity of Cape Verde. Aerosol composition, size distribution, CCN and IN concentration measurements, and lidar and ozone profiling will be done at ground sites on Cape Verde. Additional U.S. and foreign aircraft proposals will also be submitted. On the basis of the field observations, laboratory experiments will be conducted with separate funding to fully characterize the ice nucleating properties of surface dust samples deemed to be characteristic surrogates for airborne particles. Improved statistical and physical characterizations of dust and its effect on clouds is the expected outcome of all measurements. A vibrant modeling component will be conducted as part of the project. ICE-D data will be used to constrain regional scale aerosol-cloud interaction modeling simulations carried out by university groups and the UK Met Office. Dust transport modeling products of the Office of Naval Research and the UK Met. Office will be available, and together with the ground-based observations and satellite imagery, will be used to assist ICE-D C130 flight planning and the post-experiment analyses.

Six hypotheses for testing are identified, centered on the role of mineral dust and other aerosols in modifying cloud microphysical, precipitation and feedback processes in cumulus clouds. Broader impacts center on understanding the complexities and resolving uncertainties of aerosol indirect effects on global climate, as well as supporting the educational training of the next generation of scientists.