Phase Characterization of Southern Ocean Clouds using HIAPER Cloud Radar (HCR) and High Spectral Resolution Lidar (HSRL) Observations: results from SOCRATES

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From 15 January to 24 February 2018, the NSF/NCAR Gulfstream-V High-Performance Instrumented Platform for Environmental Research (HIAPER) flew over the Southern Ocean to observe fine-scale features and structures of clouds as part of the Southern Ocean Clouds, Radiation, Aerosol Transport Experimental Study (SOCRATES). The aircraft primarily sampled low-level boundary layer mixed-phase clouds in the cold sector of Southern Ocean extratropical cyclones. Climate models often underestimate shortwave radiation reflected by near-surface cloud cover during the Austral summer due to difficulties in representing mixed-phase and supercooled liquid water. Understanding these cloud properties and processes is critical to accurately simulating them in the climate system.

Each research flight during the field campaign consisted of an initial high-altitude flight leg between Tasmania and approximately 60˚ south, after which the aircraft descended to make in situ measurements in the boundary layer. During the high-altitude flight legs, the HIAPER Cloud Radar (HCR) and High Spectral Resolution Lidar (HSRL) were pointed at nadir and were able to remotely sense cloud properties and cloud top phase. During twelve of the high-altitude flight legs, dropsondes were deployed in order to sample the thermodynamic environment. Thermodynamic fields measured by the dropsondes were overlaid on the radar and lidar cross sections.

An algorithm has been developed that uses these radar, lidar, and dropsonde data to characterize cloud top phase and ice particle production as a function of cloud top temperature during SOCRATES. Cloud tops were classified as containing liquid if they had low particle linear depolarization ratios and a high backscatter coefficient, and as ice if a high linear depolarization ratio was present. Many liquid-topped clouds had plumes of precipitation falling from cloud top. These plumes were classified as ice phase if the precipitation fell through the 0˚C isotherm and a definitive bright band and/or a distinct jump in particle fall velocity was present.

Results indicate that nearly all clouds sampled during the SOCRATES field campaign had liquid containing cloud tops. Most cloud tops sampled had temperatures between -10˚C and 0˚C supporting the existence of supercooled liquid water and mixed-phase cloud processes. Of the clouds sampled, approximately one in fifteen had a definitive bright band present. Ice production at relatively warm environmental temperatures was also occurring indicated by a definitive bright band even when cloud top temperatures were as warm as -2˚C. The sources of these radar, lidar, and thermodynamic characteristics/observations will be detailed and discussed.

Keywords: HIAPER Cloud Radar, Southern Ocean , SOCRATES