

SUPPLEMENT TO INDIRECT AND SEMI-DIRECT AEROSOL CAMPAIGN

The Impact of Arctic Aerosols on Clouds

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TABLE S1. Instruments and measurements at the Atmospheric Radiation Measurement Program (ARM) Barrow, Alaska, site during the Indirect and Semi-Direct Aerosol Campaign (ISDAC) experiment.

Instrument	Measurements/derived quantities
Radiosonde	Profiles of temperature, humidity, and winds
Microwave radiometer	Water vapor path and liquid water path
Profiling microwave radiometer	Temperature and humidity
915-MHz radar wind profiler/Radio Acoustic Sounding System (RASS)	Winds and virtual temperature profile
Vaisala ceilometer	Cloud-base altitude
Millimeter cloud radar	Cloud liquid water and cloud ice content profiles
Micropulse lidar (polarized)	Backscatter profile and depolarization ratio
Atmospheric Emitted Radiance Interferometer (AERI)	Downwelling high-resolution infrared radiance spectra, profile of temperature and humidity, water path, optical depth, cloud thermodynamic phase, and effective radius of ice and water
Cimel sunphotometer	Aerosol optical depth
Normal incidence multifilter radiometer	Aerosol optical depth
Pyrgometer (3.5–50 μm)	Infrared broadband radiative fluxes

TABLE S1. Continued.	
Instrument	Measurements/derived quantities
Total precipitation sensor (TPS)	Precipitation rate and amount
OTT disdrometer	Precipitation rate, amount, reflectivity, and drop size distribution
Humidified nephelometer	Aerosol scattering as function of relative humidity
Particle soot absorption photometer (PSAP)	Aerosol absorption
Condensation nuclei counter	Total particle number
Passive cavity aerosol spectrometer probe (PCASP)	Accumulation mode size distribution
Droplet Measurement Technologies (DMT) cloud condensation nuclei (CCN) counter	CCN concentration (one supersaturation at a time)
Daily chemical analysis	Submicron mass and ion concentration
Ice particle counter (IPC)	Ice particle concentration
DMIST visibility sensor/camera	Visibility
FD12P precipitation sensor	Precipitation amount, type, rate, and extinction
Sentry visibility sensor	Extinction and visibility
VRG101 precipitation instrument	Precipitation rate and amount
Fog measuring device (FMD) droplet spectra	Cloud droplet size distributions
DSC Vaisala surface temperature sensor	Surface temperature
DSC Vaisala surface condition sensor	Surface precipitation phase and relative humidity
3D Young anemometer	3D wind and 16-Hz turbulence
SR50 snow depth sensor	Snow depth
ASD spectroradiometer	Shortwave spectral irradiance
Tandem differential mobility analyzer	Aerosol hygroscopicity

TABLE S2. Instruments installed on the National Research Council (NRC) Convair-580 during ISDAC. Although most probes installed on each flight, a few probes were exchanged and only used for specific flights [e.g., two-dimensional probes with new tips were designed to reduce shattering, the SPEC fast forward scattering spectrometer probe (FSSP), and the cloud imaging probe (CIP)].	
Instrument	Measurements and/or derived quantities
Rosemont 102 probes (three)	Temperature
National Center for Atmospheric Research (NCAR) reverse-flow probe	Temperature
NRC of Canada position measurement system	Aircraft positions, attitudes, etc.
NRC wind measurement system	Winds and gusts
EG&G chilled mirror hygrometer	Humidity
LICOR LIC2G2 water vapor/CO ₂ instrument	Humidity
Buck Research CR-2 chilled mirror hygrometer	Humidity
Rosemount 858 gust probe	Vertical velocity
Rosemount Icing Probe (RICE)	Presence of supercooled water
Nevzorov liquid water content (LWC)/total water content (TWC) probe	Liquid water content and total water content
Particle Measuring System (PMS) Commonwealth Scientific and Industrial Research Organisation (CSIRO) King Probe	Liquid water content

TABLE S2. Continued.	
Instrument	Measurements and/or derived quantities
Vibrameter	Total water content
DMT cloud droplet probe (CDP)	Cloud size distributions (2–50 μm) attached to Counterflow Spectrometer and Impactor Probe (CSI) above
Korolev cloud extinction meter	Cloud extinction
DMT Cloud, Aerosol and Precipitation Spectrometer (CAPS)	Cloud size distributions: Cloud and Aerosol Spectrometer (CAS; 1–50 μm) and CIP2 (25–1550 μm)
DMT CIP1	Cloud size distributions (15–960 μm)
Stratton Park Engineering Company (SPEC, Inc.) cloud particle imager (CPI)	2.3- μm -resolution images of cloud particles
SPEC 2D-S cloud spectrometer	Cloud size distributions and images (10–1280 μm) and two independent orthogonal views of particle population
PMS FSSP-100	Cloud size distributions (3–45 μm)
PMS FSSP-300	Cloud size distributions (0.3–20 μm)
PMS two-dimensional cloud probe (2DC)	Cloud size distributions and cloud images (25–800 μm)
PMS two-dimensional precipitation probe (2DP)	Precipitation size distributions and precipitation images (200–6400 μm)
PMS 2DC Gray	Grayscale images of cloud particles, 15–960 μm
TSI 3775	Total aerosol concentration ($D > 4 \text{ nm}$)
TSI 7610	Total aerosol concentration ($D > 11 \text{ nm}$)
PMS PCASP-100X	Aerosol size distribution (~100–3000 nm)
DMT CCN counter	CCN concentration
Continuous flow diffusion chamber (CFDC)	Ice nuclei (IN) concentration
Radiance PSAP	Mass of black carbon in air
DMT three-laser photoacoustic and nephelometer (PASS-3)	Light absorption of aerosols at three wavelengths
TSI 3563 nephelometer	Optical scattering properties
Single Particle Laser Ablation Time (SPLAT) of flight mass spectrometer	Single particle size-resolved composition of refractory and nonrefractory material
Time-Resolved Aerosol Collector (TRAC), two samplers	Sampling of airborne particles with $0.1 < D < 2.5 \mu\text{m}$ for spectromicroscopy laboratory analysis
Counterflow virtual impactor	Separation of residual aerosol
DMT ultra-high-sensitivity aerosol spectrometer	Aerosol size distribution for $55 < D < 1000 \text{ nm}$
Tecran continuous Hg analyser	Mercury
TECO model 49 ozone analyzer	Ozone
Modified TECO model 48 CO analyser	Carbon monoxide
Heitronics KT19.85 infrared thermometer	Nadir narrow-field IR temperature below aircraft
Broadband visible radiometers	Broadband hemispheric visible radiation, zenith and nadir view, 305–2800 nm
Broadband pyrgeometer (Epply 3.5–50 μm)	Broadband hemispheric infrared fluxes, zenith and nadir view
ProSensing up-looking G-band radiometer	Multichannel radiometer centered on 183.31 GHz, measuring downwelling microwave radiance
Ka-band up- and down-looking radar	Cross sections of radar reflectivity
NRC Airborne W- and X-Band (NAWX), dual polarization, Doppler-ized, up/down/side looking	Cross sections of radar reflectivity and size-looking reflectivity/Doppler velocity fields

TABLE S3. List of applications being explored with the ISDAC data.

Application	Input data	Instrument	Validation data	Instrument
CCN closure	Aerosol size distributions	PCASP	CCN concentration	DMT CCN
Droplet number closure	Aerosol size distributions and vertical velocities	PCASP and gust probes	Droplet number concentration	CDP, CAS, FSSPs
Cloud extinction closure	Cloud particle size distributions	CDP, CAS, FSSPs, 2DC, CIP, 2DP	Cloud extinction	Extinctionmeter
Cloud water closure	Cloud particle size distributions	CDP, CAS, FSSPs, 2DC, CIPs, 2DP	TWC	CSI and Nevzorov probe
Cloud modeling	Aerosol size distributions, ice nuclei concentrations, radiative fluxes at model top, profiles of horizontal and vertical velocities, temperature and moisture, and surface fluxes and large-scale forcing	PCASP, CFDC, pyrgeometers, European Centre for Medium-Range Weather Forecasts (ECMWF) reanalysis	Cloud particle size distributions, liquid water and total water content, precipitation and cloud extinction	CDP, CAS, FSSPs, 2DC, CIPs, 2DP, LWC probes, Nevzorov probe, CSI, extinction meter, hot plate rain gauge, etc.
Semidirect effect	As for cloud modeling, plus aerosol absorption and scattering	As for cloud modeling, plus PSAP and nephelometer	As for cloud modeling	As for cloud modeling
Relation between IN and aerosol composition	Ice crystal concentration	CFDC	Size-resolved aerosol composition	Single particle mass spectrometer
Relation between IN and ice crystal concentration	Ice crystal concentration, temperature, and humidity	CFDC	Crystal size and habit and cloud particle size distributions	CPI, CDP, CAS, FSSPs, 2DC, CIPs, 2DP
Aerosol extinction retrieval	Aerosol extinction	Micropulse Lidar (MPL)	Aerosol scattering and absorption	Nephelometer and PSAP
CCN retrieval	Aerosol backscatter and scattering, relative humidity retrieval, surface CCN, and humidification function	MPL, RASS, surface CCN, and nephelometer	Cloud condensation nuclei concentration	DMT CCN
Millimeter cloud radar (MMCR) retrievals	Derived profiles of liquid water and ice water content	MMCR	Liquid water and total water content	LWC probes, Nevzorov probe, and CSI
Microwave radiometer (MWR) retrievals	Derived liquid water path and retrieval of liquid water content	MWR	Liquid water content	King probe and
Nevzorov probe				
AERI retrievals	Derived droplet and crystal optical depth, liquid and ice water path, and droplet and crystal effective radius	AERI	Liquid water and total water content, cloud particle size distributions, and cloud extinction	
	LWC probes, Nevzorov probe, CSI, CAS, CDP, FSSPs, CIPs, 2DC, 2DP, and extinction meter			
Analytical Spectral Devices (ASD) retrievals	Cloud optical depth, cloud water path, and effective radius	ASD spectroradiometer	As for AERI	As for AERI