A Comprehensive Measurement Suite to Study Arctic Atmosphere Processes at MOSAiC

The US Department of Energy's ARM Mobile Facility

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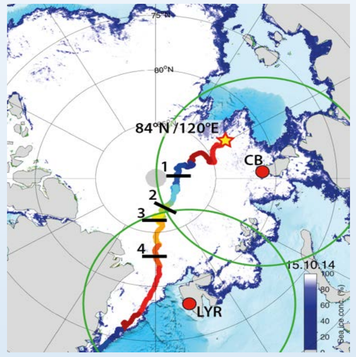
Polarstern in the sea ice

The **Multidisciplinary drifting Observatory for the Study of Arctic Climate (MOSAiC)** is an international initiative that aims to enhance understanding and model representations of Central Arctic coupled system processes to improve weather forecasting, climate prediction, sea-ice forecasting, and ecosystem assessment. It will provide unprecedented observations for process studies, model data assimilation, validation of satellite observations, and more.



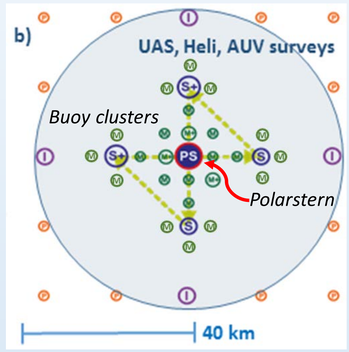
Year-long Drift Track (Forecast)
Fall 2019 – Fall 2020

Experimental Design

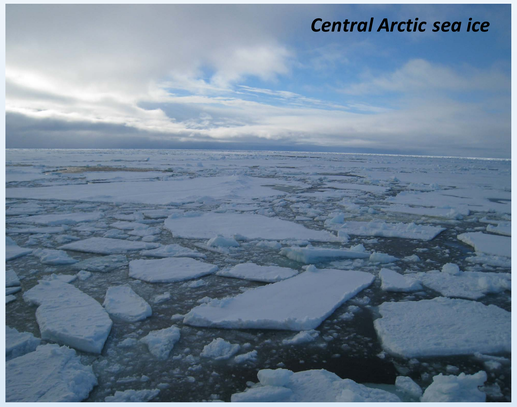
1) Central observatory onboard Polarstern drifting with the sea ice for a full year starting autumn 2019 to make comprehensive, coupled measurements in the atmosphere, sea-ice, ocean, and ecosystem.
2) Distributed network of autonomous and unmanned systems to provide key measurements on model grid-box scales (--->).
3) Coordinated multiscale modeling and analysis activities to develop process understanding, upscale, and synthesize knowledge.

MOSAiC Science Focus Themes

- Coupled system thermodynamics impacting ice energy budgets
- Coupled system dynamics impacting ice motion and deformation
- Key atmospheric drivers: Clouds, aerosols, ABL structure, precipitation
- Biogeochemistry and ecosystem processes in coupled system



Distributed Network of Observations

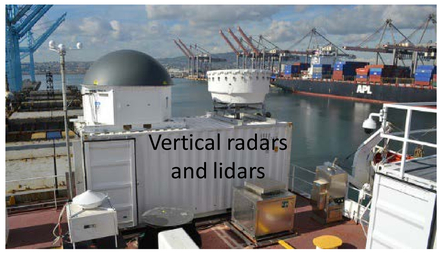


ARM Measurement Suite

The U.S Department of Energy **Atmospheric Radiation Measurement (ARM)** Program will install key atmospheric observations on and around the Polarstern during MOSAiC, including the ARM Mobile Facility II (AMF2) and Mobile Aerosol Observing System (MAOS). The baseline of instrumentation associated with these facilities is summarized here. These facilities have been previously installed on ships.

Table of ARM instruments for MOSAiC

	Instrument	Measurement	Deploy location	Science Justification	Priority
Aerosol	CCN100 (single column)	CCN concentration	Ship	Baseline characterization of cloud-available aerosols.	3
	Condensation Particle Counter (CPC)	Aerosol number concentration > 10nm	Ship	Baseline characterization of total aerosol concentrations	3
	Ultrafine Condensation Particle Counter (UCPC)	Aerosol number concentration > 2.5 nm	Ship	Concentration of small particles for identifying new particle formation; particle source attribution	2
	Hygroscopic Tandem Differential Mobility Analyzer (HTDMA)	Aerosol mass, size, and # distribution as g(RH), particle growth factor	Ship	Baseline characterization of aerosol size distributions; aerosol hygroscopicity	3
	Ultra High Sensitivity Aerosol Spectrometer (UHSAS)	Aerosol size distribution, 50nm – 1 micron	Ship	Baseline characterization of aerosol size distributions	3
	Ambient Nephelometer	Aerosol light scattering coeff at ambient RH	Ship	Aerosol scattering for direct aerosol radiative effects	3
	Wet Nephelometer	Aerosol light scattering coeff as f(RH)	Ship	Aerosol scattering for direct aerosol radiative effects	3
	Particle Soot Absorption Photometer (PSAP)	Optical transmittance of particles a 3 wavelengths	Ship	Aerosol absorption for direct aerosol radiative effects	3
	Time-of-Flight Aerosol Chemical Speciation Monitor (TOF-ACSM)	Aerosol mass spectrum measurements	Ship	Characterization of aerosol composition	3
	Single Particle Soot Photometer (SP2)	Black carbon mass concentration	Ship	Role of black carbon in Arctic	3
	NOx, NOy, CO, CH4, Ozone	Gas concentrations	Ship	Airmass source, age, transport, chemistry, carbon cycle	2
	Vaisala WXT520	P, T, RH, winds	Ship	Meteorological measurements	3
	Cimel Sunphotometer	Aerosol optical depth	Ship	Aerosol optical depth	3
Cloud and Atmosphere Profiling	Balloon-Borne Sounding System (radiosonde)	2-4 times daily profiles of P, T, RH, winds	Ship	Atmospheric thermodynamic state and BL structure, context	3
	Microwave Radiometer, 3 channel (MWR, MWR3C)	Liquid water path, Water vapor path	Ship	Atmosphere and cloud characterization	3
	High Spectral Resolution Lidar (HSRL)	Backscatter, depol ratio, cloud micro properties	Ship	Cloud property characterization; information on aerosol profiles	3
	Micropulse Lidar (MPL)	Backscatter, depol ratio, cloud micro properties	Ship	MPLNet, (May not be needed if HSRL is present)	0/3
	Doppler Lidar	Air motions, turbulence	Ship	Wind, turbulence for ABL characterization (*Not available)	3
	Total Sky Image (TSI)	Visible hemispheric photos	Ship	Visual documentation of cloud/sky	3
	Marine W-band ARM Cloud Radar (M-WACR)	Vertical radar moments and spectral	Ship	Cloud, precipitation properties; Cloud-BL dynamical interactions;	2
	Ka-band Scanning ARM Cloud Radar (Ka-SACR)	Radar moments; Cloud micro/dynamical properties; spatial coverage	Ship	Clouds and precipitation; Spatial organization of cloud properties.	2
	X-band Scanning ARM Cloud Radar (X-SACR)	Radar moments; spatial coverage; Polarimetry;	Ship	Clouds and precipitation; Spatial organization of cloud properties.	3
	Ka-band ARM Zenith Radar (KAZR)	Vertical radar moments and spectra	Ship	Cloud and precipitation property characterization; Cloud-BL dynamical interactions;	3
	Vaisala Ceilometer	Cloud base heights, backscatter	Ship	Robust cloud presence and height characterization	3
	Wind Profiler, 1290-MHz beam steerable (or 915 MHz)	Wind profiles	Ship or Ice	BL wind structure at high resolution (sub-optimal system for Arctic)	2
	Atmospheric Emitted Radiance Interferometer (AERI)	IR spectral radiance at zenith or other angles	Ship	Cloud property characterization, including cloud radiative properties	3
Surface Energy	Multifilter Rotating Shadowband Radiometer (MFRSR)	Solar irradiance at multiple wavelengths	Ice or Ship	Atmospheric / aerosol optical depth	3
	Upwelling Radiation (GNDRAD)	LW, SW upwelling broadband fluxes	Ice	Surface radiation/energy balance, albedo characterization	3
	Downwelling Radiation (SKYRAD)	LW, SW downwelling broadband fluxes & components	Ice or Ship	Surface radiation/energy balance, cloud radiative properties	3
	Eddy Correlation System (ECOR)	Surface turbulent fluxes, carbon dioxide.	Ice	Critical for turbulent component of surface energy balance	3
	Surface Energy Balance System (SEBS)	Up/down SW/LW radiation, soil moisture	----	--- (little added value beyond GNDRAD, SKYRAD)	0
Precip	2D Video Disdrometer (VDIS)	Precip DSD and fall speed	Ice	Precipitation mass/rate at the surface	3
	Rain Gauge, weighing bucket	Precipitation rate	Ice	Precipitation mass/rate at the surface	1
	Met. Instrumentation	P, T, RH, winds near surface	Ice	Met context for all measurements	3

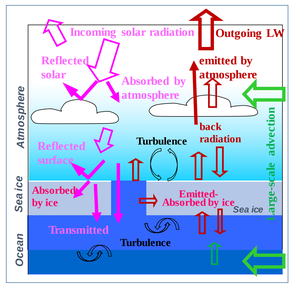


ARM's global network. The facilities deployed on MOSAiC will be similar to other observations made around the globe by the ARM program at both long-term fixed sites (Central US, Northern Alaska, Azores) and mobile installations (Germany, California, India, China, Niger, Antarctica, etc.)

MOSAiC-ARM Science Themes

Surface Energy Budget (SEB) of Sea Ice

- Surface radiative and turbulent heat fluxes. Radiation is a backbone of ARM for >20 years
- Process relationships relating different flux terms in the atmosphere-surface system
- The role of important feedbacks (i.e., ice-albedo)
- Assess annual evolution (albedo, radiative balance, etc.)

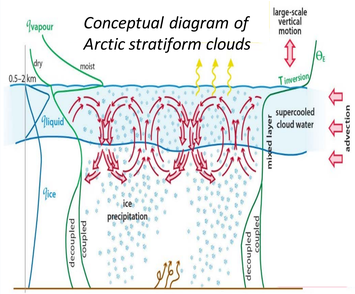


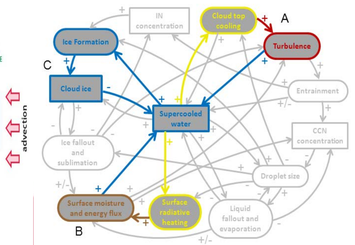
Arctic Energy Budget showing key terms in the coupled system

The SEB strongly controls the sea-ice mass budget

Cloud and Precipitation Processes

- Cloud phase and its drivers, mixed-phase processes and persistence
- Dynamical-microphysical-radiation interactions
- Cloud radiative effects on a variable albedo surface
- Links between local cloud-precip processes and large-scale advection
- Partitioning of snowfall/precip modes



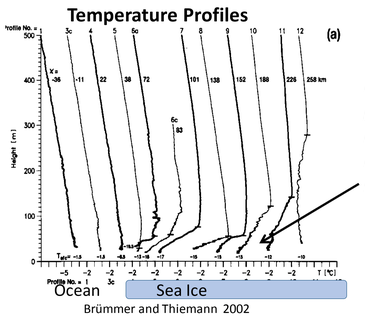


Complex web of cloud processes support long-lived liquid-containing clouds

First deployment of a scanning radar over the Arctic sea ice

Atmospheric Boundary Layer

- Seasonal and conditional evolution of BL structure, including stable boundary layers
- Coupling between surface and free troposphere, including role of clouds
- Profiling wind and turbulence
- Momentum transfer to the sea ice

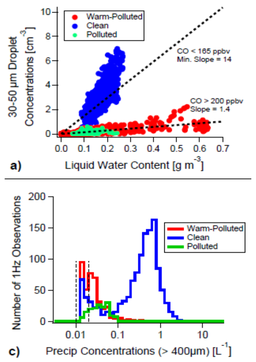


Dropsonde profiles show how ABL is modified over sea ice.

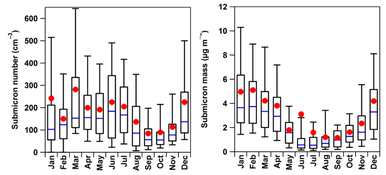
The ABL serves as a critical interface for energy transfer with the sea ice

Aerosol Properties and Cloud Interactions

- Annual cycle of aerosol number and composition
- Aerosol-gas interactions influencing nucleation and growth
- Particle composition and its link to cloud activity
- Black carbon in the atmosphere and on the surface
- Major dearth of central Arctic aerosol observations, especially in winter



<<<< Aerosol number impacts the properties of cloud liquid and cloud ice.



Annual cycles of aerosol number & mass at Barrow. What do these look like over the central Arctic Ocean?

Aerosol perturbations can play an important role in Arctic clouds, since the clouds are often not opaque in the IR