THE ARM WEST ANTARCTIC RADIATION EXPERIMENT (AWARE)

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BACKGROUND

- The US Department of Energy Atmospheric Radiation Measurement (ARM) program, in collaboration with the National Science Foundation Division of Polar Programs (PLR), plans to deploy one of the most advanced suites of atmospheric science instrumentation to Antarctica beginning in November 2015 (Figure 1).
- A full ARM Mobile Facility (AMF) will be deployed at McMurdo Station in November 2015 and operate for an entire year (Central Facility).
- A smaller suite of key radiation, surface energy balance, and meteorological instruments will deploy to the WAIS Ice Camp in November 2015 and will operate for 75 days, throughout that station's field season.
- The scientific motivation is to acquire a atmospheric data set of unprecedented quality and completeness for the Antarctic, in support of efforts to explain the rapid warming of West Antarctica.
- Nicolas & Bromwich (2014) show that the West Antarctic warming trend discovered by Steig et al. (2009) extends as far as Ross Island and parts of East Antarctica (Figure 2).

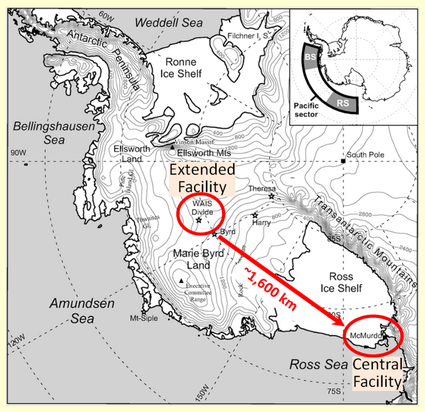


Figure 1. Location of the ARM Central and Extended facilities during AWARE (for definitions see www.arm.gov).

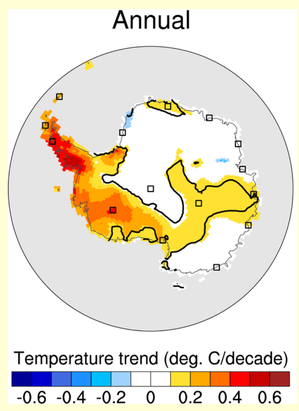
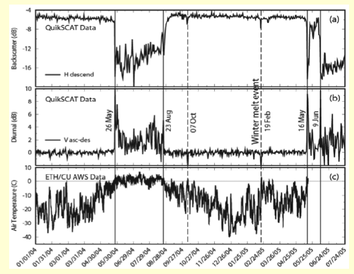


Figure 2. Annual average surface temperature trend (Nicolas & Bromwich, 2014).



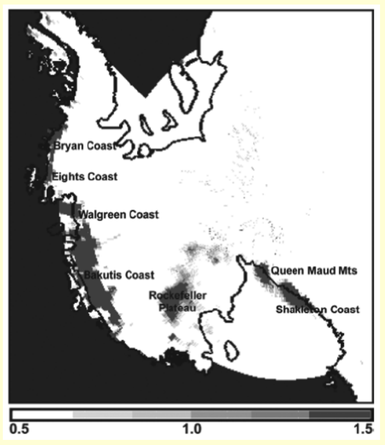


Figure 3. NASA QuikSCAT and SeaWinds scatterometer (QSCAT) data readily show surface melting events over ice sheets as a change in microwave signature; validated above for Greenland (Nghiem et al., 2007).

Figure 4 (above right). The extensive West Antarctic summer 2005 melt events recorded in QSCAT data (shown here in a grayscale depicting backscatter increase) emphasize the need to understand the atmospheric contribution to WAIS warming.

INSTRUMENTATION

Balloon-Borne Sounding System (SONDE)	Atmospheric Profiling
Micropulse Lidar (MPL)	Cloud Physics
Microwave Radiometer, 23.834, 30, 89 GHz (MWR3C)	Cloud Physics
High Spectral Resolution Lidar with depolarization (HSRL)	Cloud Physics
Total Sky Imager (TSI)	Cloud Physics
Scanning ARM Cloud Radar, X-Band, 9.71 GHz (X-SACR)	Cloud Physics
Scanning ARM Cloud Radar, Ka-Band, 35.3 GHz (Ka-SACR)	Cloud Physics
Scanning ARM Cloud Radar, W-Band, 94 GHz (W-SACR)	Cloud Physics
Ka-Band ARM Zenith Radar (KAZR)	Cloud Physics
Vaisala Ceilometer (VCEIL)	Cloud Physics
Radar Wind Profiler at High Frequency (RWP)	Cloud Physics
Atmospheric Emitted Radiance Interferometer (AERI)	Spectral Longwave (LW) Radiation
Multifilter Rotating Shadowband Radiometer (MFRSR)	Spectral Shortwave (SW) Radiation
Downwelling Radiation Suite (SKYRAD)	Broadband SW & LW Radiation
Upwelling Radiation Suite (GNDRAD)	Surface Albedo and Energy Balance
Surface Energy Balance System (SEBS)	Surface Albedo and Energy Balance
Eddy Correlation System (ECOR)	Surface Energy Balance
Video Disdrometer (VDIS)	Surface Precipitation
Meteorological Instrumentation at AMF (MET)	Surface Meteorology
Cloud Condensation Nuclei Counter (CCN100)	Aerosol Observing System (AOS)
Ambient Nephelometer	Aerosol Observing System (AOS)
F(RH)/Wet Nephelometer	Aerosol Observing System (AOS)
Condensation Particle Counter (CPC)	Aerosol Observing System (AOS)
Hygroscopic Tandem Differential Mobility Analyzer (HDTMA)	Aerosol Observing System (AOS)
Particle Soot Absorption Photometer (PSAP)	Aerosol Observing System (AOS)
Ozone (Absorption Cell)	Aerosol Observing System (AOS)
Local Meteorology (Vaisala WXT520) for AOS	Aerosol Observing System (AOS)
Cimel Sunphotometer (CPHOT)	Aerosol Observing System (AOS)

Table 1. ARM Second Mobile Facility (AMF-2) instruments that will be deployed at McMurdo Station from November 2015 through September 2016.

Balloon-Borne Sounding System (SONDE)	Atmospheric Profiling
Micropulse Lidar (MPL)	Cloud Physics
Vaisala Ceilometer (VCEIL)	Cloud Physics
Microwave Radiometer, 23.834, 30, 89 GHz (MWR3C) *	Cloud Physics *
Total Sky Imager (TSI) *	Cloud Physics *
SIO Shortwave Spectroradiometer (Scott & Lubin 2014a)	Spectral Shortwave (SW) Radiation
Multifilter Rotating Shadowband Radiometer (MFRSR)	Spectral Shortwave (SW) Radiation
Downwelling Radiation Suite (SKYRAD)	Broadband SW & LW Radiation
Upwelling Radiation Suite (GNDRAD)	Surface Albedo and Energy Balance
Eddy Correlation System (ECOR)	Surface Energy Balance
Video Disdrometer (VDIS)	Surface Precipitation
Meteorological Instrumentation at AMF (MET)	Surface Meteorology

C-17s support McMurdo

LC-130s support WAIS

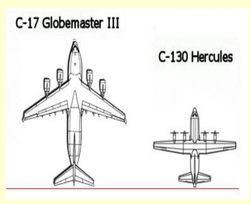


Table 2. ARM instruments that will be deployed at WAIS in November 2015. Although the AMFs have been deployed worldwide for several years, Antarctica poses the greatest logistical challenges to date for the ARM program. At WAIS, we are limited to a single LC-130 flight, but this still allows for a sophisticated suite of atmospheric and surface energy budget measurements never before made in West Antarctica.

(a) HSRL

(b) KAZR

(c) KASACR

(d) XSACR

Figure 5. Schematic of an AMF showing approximate surface footprint.

Figure 6. "Flagship" AMF-2 instruments include (top left to right): (a) High Spectral Resolution Lidar (HSRL) for aerosol and thin cloud optical depth and depolarization for cloud phase; (b) Ka-band ARM Zenith Radar (KAZR) for cloud first three Doppler moments, spectral width, and vertical velocity with 30 m resolution to 20 km; (c) Ka- and X-band Scanning ARM Cloud Radars (KASACR & XSACR) for cloud volume observations with 1-degree beamwidth.

METEOROLOGICAL RELATIONSHIP BETWEEN WAIS AND ROSS ISLAND

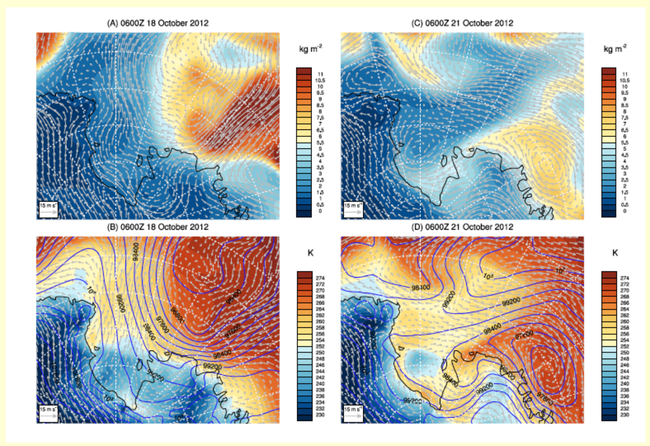


Figure 7. Although separated by 1600 km, the WAIS and Ross Island often have a close meteorological relationship. The above sequence of 700 hPa circulation, moisture flux, and 2 m air temperature shows a low pressure cell bringing moisture over the WAIS (e.g., Nicolas & Bromwich, 2011), which then makes its way down over the Ross Ice Shelf to Ross Island, between 18-21 October 2012. Clouds resulting from this WAIS air mass are seen in the MODIS satellite image in Figure 9.

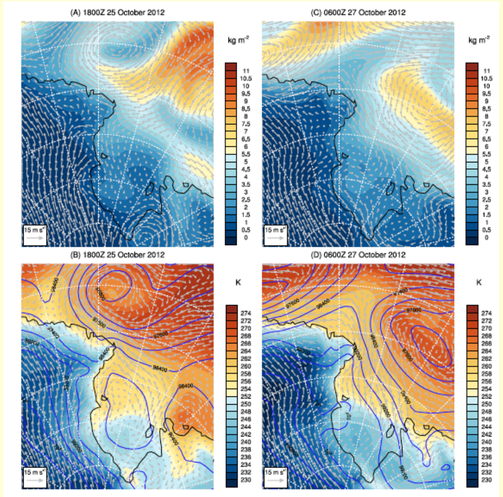


Figure 8. Continuation of this sequence showing a shift toward Northerly flow onto Ross Island, bringing moisture directly from the Ross Sea, between 25-27 October 2012.

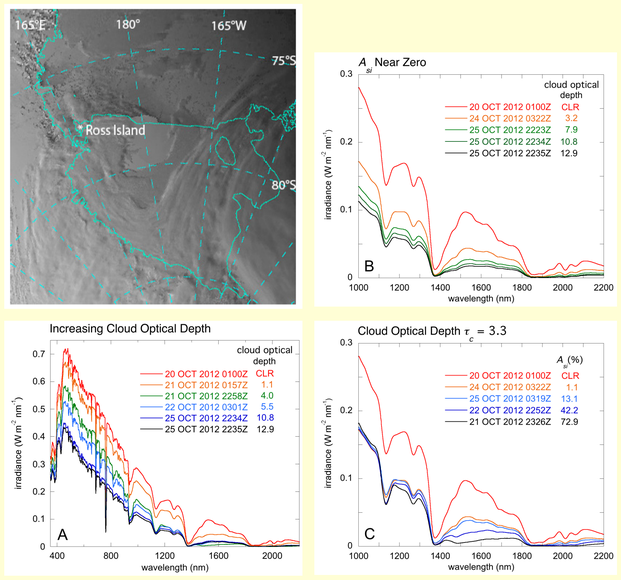


Figure 9. Using shortwave spectral surface irradiance data (A) at Ross Island in 2012 (AWARE will repeat these measurements), Scott & Lubin (2014) studied cloud optical properties arising from the meteorological scenarios of Figures 7 & 8. Clouds originating from the WAIS have a strong NIR spectral signature of ice water (C), in contrast to liquid water on subsequent days (B).

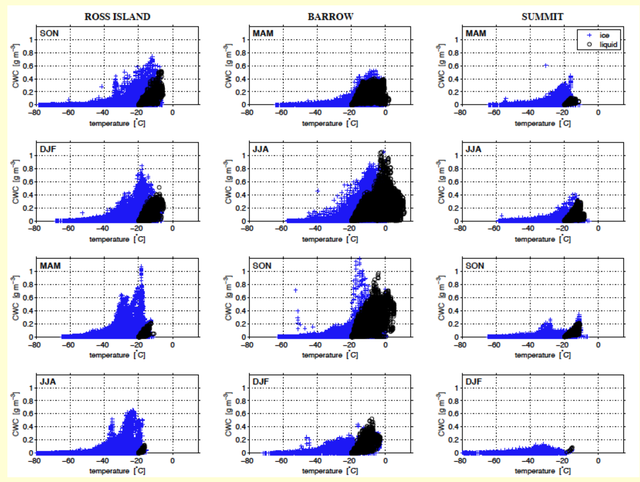


Figure 10. In addition to the WAIS warming problem, Antarctica provides unique manifestations of mixed-phase cloud microphysics. Here NASA CloudSat and CALIPSO retrievals of cloud liquid and ice water over Ross Island are contrasted with two Arctic sites. Even in the colder Antarctic environment, clouds contain more ice water at any given temperature. AWARE measurements will make valuable contributions to climate model validation and improvement not possible with existing Arctic data (Scott & Lubin, 2015)

REFERENCES

Nghiem, S. V., K. Steffen, G. Neumann, and R. Huff, 2007: in *Dynamic Planet: Monitoring and Understanding a Dynamic Planet with Geodetic and Oceanographic Tools*, IAG Symp., Cairns, Australia 22-26 Aug. 2005 (P. Tregoning and C. Rizos, eds.), 31-38.

Nicolas, J. P, and D. H. Bromwich, 2011: Climate of West Antarctica and influence of marine air intrusions. *J. Climate*, **24**, 49-67, doi: 10.1175/2010JCLI3522.1.

Nicolas, J. P., and D. H. Bromwich, 2014: New reconstruction of Antarctic near-surface temperatures: Multidecadal trends and reliability of global reanalyses. *J. Climate*, **27**, 8070-8093.

Scott, R. L., and D. Lubin, 2014: Mixed-phase cloud radiative properties over Ross Island, Antarctica: the influence of various synoptic-scale atmospheric circulation regimes. *J. Geophys. Res.*, **119**, doi:10.1002/2013JD021132.

Scott, R. L., and D. Lubin, 2015: Unique manifestations of mixed-phase cloud microphysics over Ross Island and the Ross Ice Shelf, Antarctica. *Geophys. Res. Lett.*, in review.

Steig, E. J., D. P. Schneider, S. D. Rutherford, M. E. Mann, J. C. Comiso, and D. T. Shindell, 2009. Warming of the Antarctic ice-sheet surface since the 1957 International Geophysical Year. Nature, **457**, 459-462, doi:10.1038/nature07669.

DATA MANAGEMENT

AWARE data will reside at the ARM archive (www.arm.gov) immediately after collection, reduction, and quality control from the field. ARM data are publicly available in a robust data archive that is easily accessible in common formats. There is no proprietary period for any researcher, and we encourage broadest possible use of data from this campaign.

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