P1.5 SURFACE RADIATION MEASUREMENTS IN ARCTIC POLYNYAS

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1. INTRODUCTION

While measurements of polar meteorology and ocean currents have received much attention in recent years, surface radiation data have lagged considerably. This is despite their importance to calculations of the surface heat budget, cloud radiative forcing, and albedo. Those in situ radiation time series which do exist are preponderantly coastal (eg at the North Slope of Alaska – Adjacent Arctic Ocean (NSA/AAO) site of the Atmospheric Radiation Measurement (ARM) Program; Stamnes et al, 1999) or located on stable platforms, limiting data return to seasonal information about local changes in short- and longwave radiation. The few datasets which have sampled regional and basin-scale radiation from floating ice stations and shipboard cruises report radiation values over a larger expanse but not necessarily over a more varied surface. For example, ice stations are necessarily located on multi-year floes which are less likely to melt through, while some ship operations are conducted entirely in open water or 10/10ths ice, depending on the scientific focus. Despite their inherent limitations, these combined data, both land and marine, are used to develop heat budget models for understanding air-sea-ice transfer and polar-optimized radiative parameterization schemes.

To improve our understanding of radiative exchanges at the surface and to optimize the applicability of algorithms in models by specifying the uncertainties, measurements representative of the rapidly varying cryosphere are necessary. Within and along the boundaries of polynyas, such variations occur on scales easily sampled by ship and aircraft as well as being appropriate to mesoscale modeling. In many cases, at least one of the polynya margins is bounded by land, where coastal-based data are relevant. Such a measurement scheme was employed during the North Water 1998 field season in the polynya occurring between Ellesmere Island, Canada and the Hayes Peninsula of Greenland (Barber at al., 2001). Simultaneous radiation data from well-calibrated sensors were recorded both at the Cape Herschel ice camp on the eastern polynya boundary and over the ice-ocean polynya surface from an ice-breaking research vessel during spring transition and summer melt. The time series from the two platforms were used to initialize a surface heat budget box model and test a number of clear-sky short- and longwave radiative parameterizations, which provided values for the calculation of cloud radiative forcing. Between the two sites substantial spatial variability existed, both in cloud cover and surface type, such that each radiation dataset was best represented by a different combination of short- and longwave schemes. As with all in situ polar data sets, these are likely to be dominated by regional effects. With larger, more extensive sets of measurements, it will be possible to determine more universal relationships between radiation and the changing polar environment.

During the International Polar Year (2007-2008), the opportunity can be seized to expand upon the scant, current knowledge of surface radiation. Numerous aircraft and shipboard experiments, both planned and proposed, should incorporate radiative measurements. Particular preference for polynya measurements, where the data return is optimized by the variations in surface cover and proximity to instrumented coastal sites (some of which may require enhancements to their sensors), is stressed.

2. BACKGROUND

For this to be successful, high-quality, long-term time series over a variety of surfaces and under changing sky conditions are necessary. An evaluation of polar-optimized clear-sky radiative parameterizations using measurements collected in four Arctic polynyas over an 8-year period indicate that the rms uncertainty in shortwave radiation (0.28 – 2µm) far outweighs that in the longwave (5-50 µm; Key, 2004). This is an interesting result, since pyrgeometer measurements have been a source of contention in radiation literature since they were first reviewed by Drummond et al. in 1970. Most of the debate was centered on technological, optical, and theoretical aspects of the measurement design, as well as the need for cold-temperature calibration,

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adequate characterization of the dome temperature, and proper ventilation of the sensor. Only recently, after decades of improvement, has the accuracy of the Eppley pyrgeometer approached requisite levels (2 Wm^{-2} rms uncertainty) for climate change monitoring (Fairall et al., 1999),

As the sensors are now of adequate quality to collect the data, their deployment in polar regions should be tailored to the platform or environment in which they are to be measuring. While simple plate-mounted Eppley pyranometers and pyrgeometers are appropriate to coastal and ice camp-type deployments, shipboard observations – especially in the rough waters of ice-free seas – and aircraft surveys require innovative designs to reduce motion and vibrational effects. Over the past decade, gimbaled radiation sensors have been used to record downwelling short- and longwave time series from ice-breaking vessels navigating polynyas. This design was used during the North Water Polynya Project in 1998 and 1999, collecting minute-averaged radiation data in open water, 10/10ths ice, and gradations of ice-water cover in between. During the 1998 NOW survey, a meteorological mast at a coastal fast-ice site, Cape Herschel, also provided detailed radiation data, which was useful for delineating the extent of the polynya's influence as well as comparisons of cloud forcing over ice and the dynamic polynya environment (Ananasso et al, 2005).

Quantifying the reflected radiative component has proved to be much more difficult, especially from ship-based platforms. The lack of unshadowed surfaces in and around the ship reduces the number of viable locations for measuring upwelling radiation, which is used to calculate net surface heat fluxes and albedo. Even when extended on a bowsprit angled over the undisturbed surface ahead of the CCGS *Pierre Radisson*, spray covered a downward-looking Eppley pyranometer dome. The spray turned to ice, cracking the dome, and allowing further spray to enter the sensor, corrupting the measurements. Near a ship moored in thick ice floes, the SHEBA (Surface Heat Budget of the Arctic) project successfully utilized a multi-tiered tower to mount upward and downward-looking radiation sensors for the collection of an annual cycle of radiative flux data. However, this array was in an accessible, quasi-stable environment where continuous maintenance of the tower was possible, particularly following precipitation events and after melt ponding began.

3. RESULTS

An analysis of data collected in four polynyas over an eight-year period demonstrated the radiative variability present in these ice-free areas of the Arctic (Key, 2004). While clouds were identified as efficient scatterers of incoming radiation and possible mediators of climate change, the dominant radiative forcing was realized by small changes in albedo associated with a melting or freezing snow-ice-water surface. Demarcation of snow-covered surfaces was of particular importance to upwelling radiation, which featured an 80 W•m-2 difference in shortwave radiation reflected from fresh snow (480 $W{\bullet}m^{-2}$) as opposed to bare ice (400 $W{\bullet}m^{-2}$) at small solar zenith angles. Variations in aerosol optical thickness and cloud microphysical parameters had a less profound but still climatologically relevant influence on the downwelling radiative signal.

4. CONCLUSIONS

These analyses and the data necessary to draw conclusions about the radiative relationship between a seasonally-changing ice-water-snow surface and the developing overhead cloud cover are few. During the proposed research associated with the upcoming IPY, it is recommended that some aspect of radiative measurement be included in the observational array. Field projects during this time will have varied scope, and therefore provide a range of conditions necessary for characterizing radiation at high latitudes. Reflected radiation and albedo observations are particularly lacking and will require innovative sensor and mounting designs to counter the limitations of field support vessels, including ships and aircraft. Ultralight gliders, which can carry small payloads, may provide one useful alternative for collecting these measurements.

Ultimately, instrumentation of coastal weather stations and IABP buoys would provide the long-term and wide area coverage that currently benefits surface air temperature and sea level pressure studies in the Arctic. Land and ice-based time series could be augmented by shipboard measurements collected by dedicated radiometers on icebreakers servicing northern communities. These and other ice camp, aircraft, and specialized site (e.g., ARM-NSA/AAO) data would serve to extend the SURFRAD network into the high latitudes, where the radiative complexities are greatest. With routine radiation measurements, improvements to radiative transfer routines, understanding of cloud-ice-snow feedbacks, quantification of multiple reflection and cloud radiative forcing, validation of CERES-type datasets, and construction of representative surface flux models will become possible, all of which lend themselves to more accurate characterization and forecasting of global climate change.

5. REFERENCES

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