ATMOSPHERIC CONTROL OF THE SURFACE ENERGY BUDGET

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LONG-TERM PROJECT GOALS

This project seeks to describe how heterogeneous surface fluxes that control ice growth are coupled to the atmosphere through radiative and sensible heat processes. Our hypothesis is that spatial and temporal variations in different air masses account for much of the climate variability that occurs in the Arctic.

OBJECTIVES

(1) We will combine AVHRR temperature estimates, surface temperature and radiation data from an array of drifting buoys, and vertical temperature and cloud data to estimate aggregate scale (100 km x 100 km) radiative and sensible heat fluxes for selected periods throughout the cold season (Tair < 0°, October through May) during SHEBA.

(2) We will assemble and evaluate information necessary to estimate lateral heat advection over the SHEBA region from gridded atmospheric data fields from the National Centers for Environmental Prediction (NCEP) and the European Center for Medium-Range Weather Forecasting (ECMWF). These gridded fields will be modified by data from the surface array and SHEBA core measurement program as necessary.

APPROACH

Field Measurements:

We will deploy 14 drifting buoys in a 300 km array in the Beaufort Sea (Figure 1). Four of the buoys are provided by the Joint Ice Center and two of the buoys are coordinated with McPhee/Morrison. All locations provide temperature data. An outer array of 3 buoys at 100 km radius (not shown) and 4 buoys at 50 km radius from camp measure sea-level pressure. These buoys provide the regional weather context for the experiment and bound the calculation of the surface temperature field. Four locations and the main camp provide long and short wave radiation measurements. Except for one radiometer pair, the radiometers are deployed in line to measure the spatial correlation of incoming radiation over distances of 10-75 km. Ice thickness gauges from CRREL (D. Perovich) will be collocated with the four radiation buoy locations. The two McPhee/Morrison buoys, one Japanese buoy, and three buoys located at 15 km from the camp will

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have oceanographic sensors. All pressure, temperature, and radiation sensors have been intercalibrated before the experiment.

Analyses:

The surface temperature field shown in Fig. 2 was derived from thermal infrared AVHRR data at 1 km resolution using techniques suggested by Lindsay and Rothrock (1994) and Key (1996). The image covers a (100 km x 100 km) area in the Beaufort Sea on 25 December 1992. This figure illustrates a surface temperature(ST) mosaic; the high-frequency variability in the image is due to leads and ice floes of various sizes. Soften your focus on the image, and a temperature gradient on the regional scale also appears, with warmer temperatures in the upper left corner and cooler temperatures in the lower right. This gradient is associated with an approaching frontal system.

How does the ST distribution over an 100 km x 100 km region compare to point measurements at the main camp? Is there a simple offset and stable distribution shape? Is the difference a function of air mass type? How does it change throughout the cold season? Is feature orientation important? We are left with the conclusion that there are conceptual difficulties with a traditional surface layer heat flux formulations over heterogeneous terrain such as Arctic sea ice.

The algorithms to derive geophysical parameters from the AVHRR data are contained in the Cloud And Surface Parameter Retrieval (CASPR) program developed by Key (1996). CASPR uses AVHRR data and local atmospheric temperature and humidity profiles to retrieve cloud properties, surface temperatures, and downwelling shortwave and longwave fluxes in the polar regions. This can be done for clear skies, but is more challenging for cloudy conditions. The ARM and SHEBA observations will be particularly valuable for validation of the satellite-derived surface temperatures under cloudy conditions. We will combine the high resolution CASPR output, the buoy data, and the high resolution vertical temperature and wind profiles in the boundary layer to estimate the aggregate scale radiative and sensible heat flux using bulk parameterizations. These estimates will be made for different weather conditions and compared to direct measurements at the central site. Comparisons will also be made to aircraft observations taken on specific days by other investigators. To diagnose the variability of the upwelling radiation, one must measure at more than one spot -- regional estimates are based on the actual variability of the surface temperature field. Downward radiation fluxes will be measured at four buoy sites and the central camp. We expect the downward fields to be more uniform than the upward fields, but the radiometer array can test this hypothesis.

Our second objective is to investigate lateral heat flux over the SHEBA site. Figure 3 shows the 700 mb height field for different Januaries over the Beaufort Sea: 1988 has weak advection; 1989 has westerly winds with relatively warm advection, and 1990 has northerly winds with cold advection. We will analyze the gridded weather patterns from the European Center and the U.S. National Center for Environmental Prediction to investigate heat advection, similar to previous work. We plan to discriminate among the different processes that establish the Arctic cold pool and govern local vs. large scale variability.

ACCOMPLISHMENTS

All buoy equipment was obtained, calibrated and made ready for deployment in SHEBA. Considerable effort was required to integrate radiation sensors, GPS sensors, and other meteorlogical sensors from different suppliers.

SCIENTIFIC RESULTS

New Project.

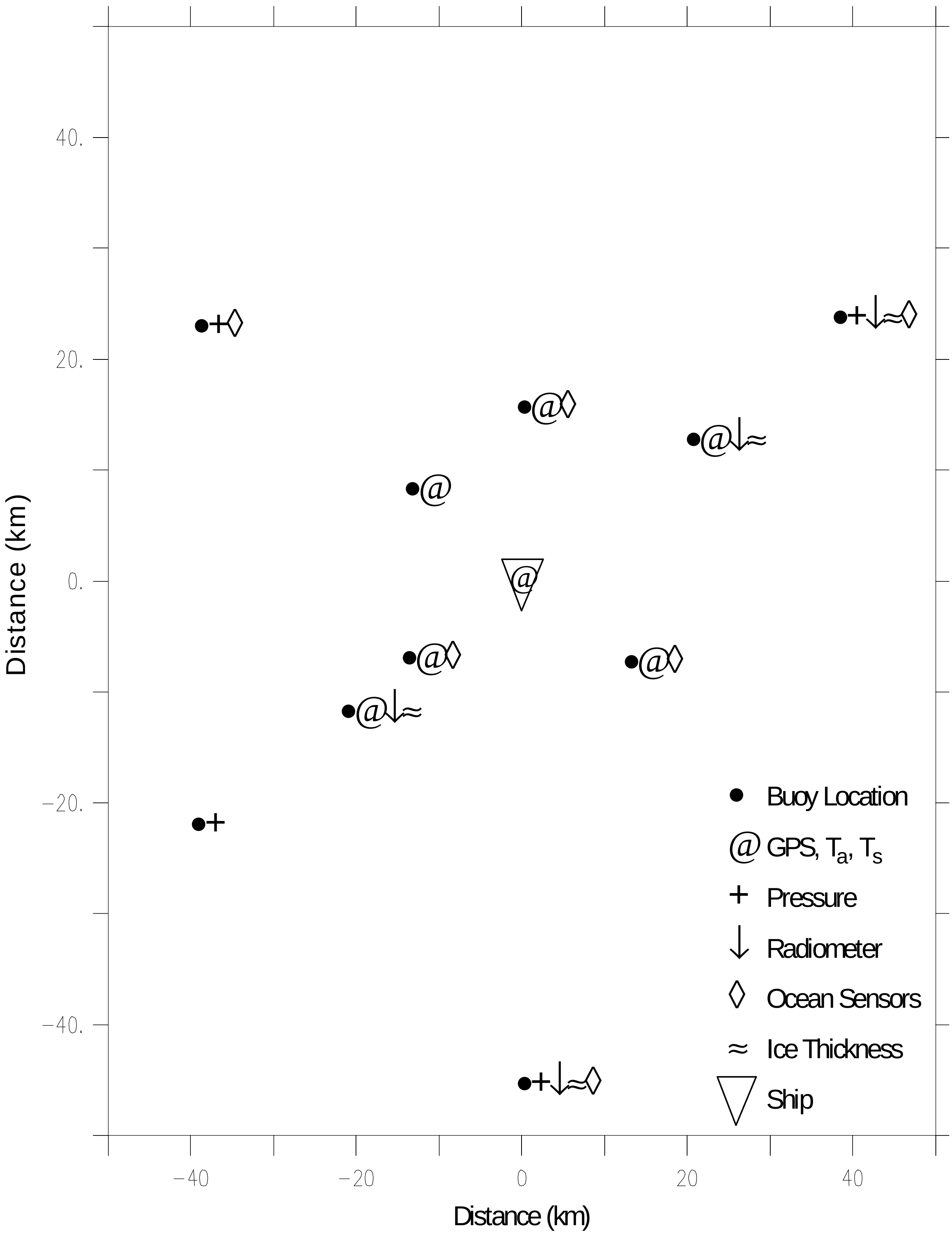
IMPACT ON SCIENCE/SYSTEMS APPLICATION

Throughout the cold season downward radition is the most important measurement for understanding the variability of the surface energy budget in the Arctic. There have been historical difficulties in making these measurements because of radiometer domes frosting and producing unreliable measurements. This project will make the first major use of autonomous buoy-based radiation measurements, based on an enclosure mechanism developed by Scientific Solutions.

REFERENCES:

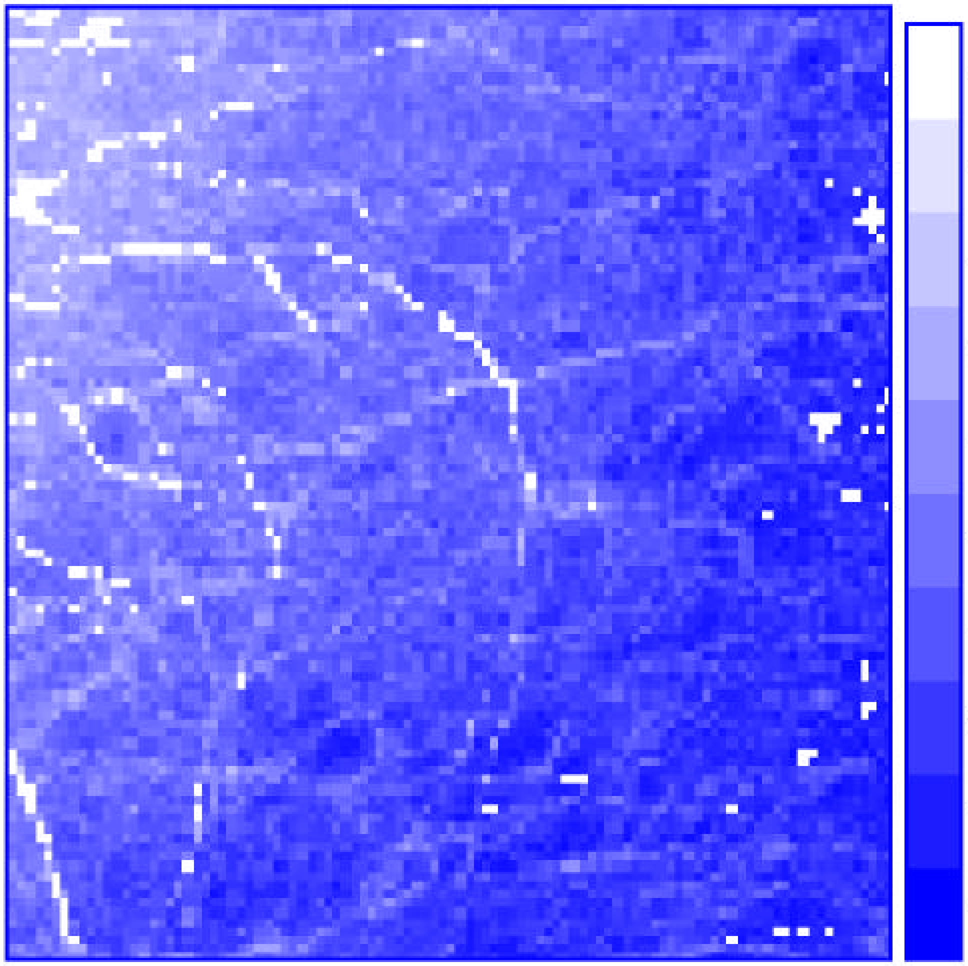
Key, J.R., 1996: The cloud and surface parameter retrieval (CASPR) system for polar AVHRR, Tech. Rep. 96-02, Department of Geography, Boston University, 37pp.

Lindsay, R.W., and D.A. Rothrock, 1994: Arctic sea ice surface temperature from AVHRR. *J. Climate*, *7*, 174-183.

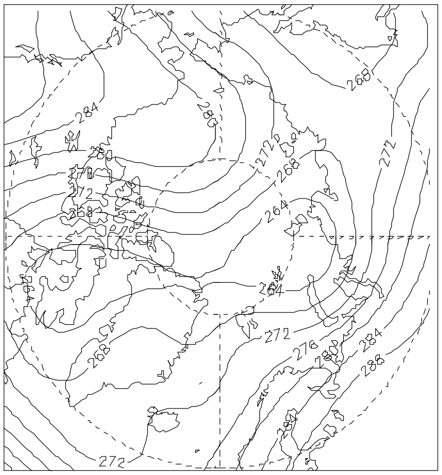


1. Positions of ARGOS buoys around SHEBA ship

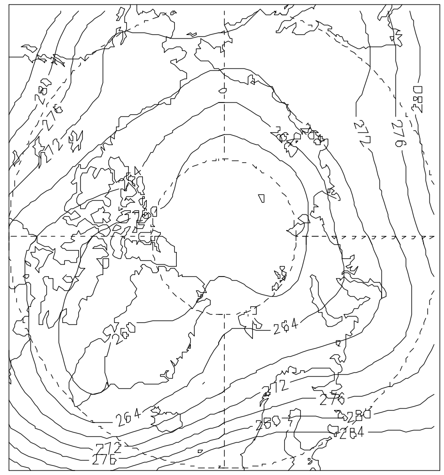
Surface Temperature in ° C 25 December 1992



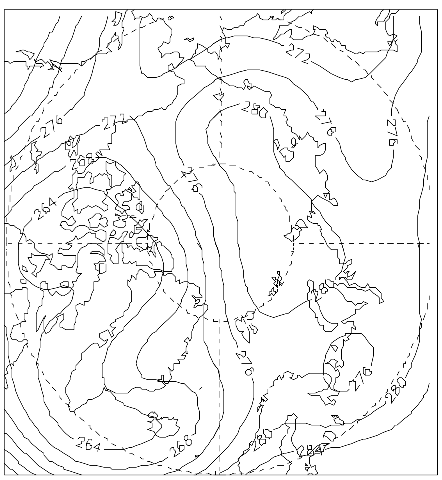
2. Derived from AVHRR thermal infrared data at 1 km resolution, this image covers a (100 km)^2 area in the Beaufort Sea centered at (74° N,140° W).



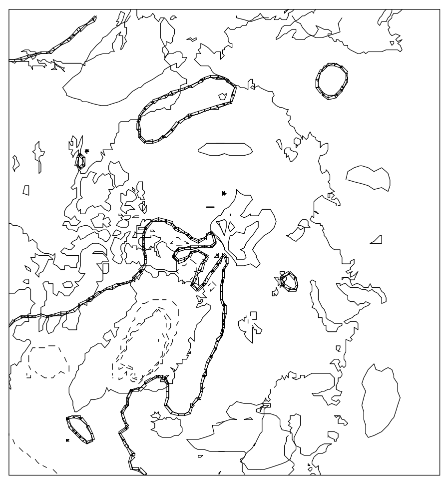
(a) NCEP 700 mb height for JANUARY 1988



(b) NCEP 700 mb height for JANUARY 1989



(c) NCEP 700 mb height for JANUARY 1990



(c) 700 mb height difference (NCEP minus NASA) for JANUARY 1990

3. This figure illustrates the large variability of the weather regime over the Beaufort Sea, as represented by the 700mb height field. The data are from the NCEP/NCAR Reanalysis and are contoured in dam. The different flow patterns lead to different advective heat fluxes over the SHEBA region. January 1988 (a) had a large blocking ridge over the Beaufort Sea, January 1989 (b) had westerly flow, and January 1990 (c) had northerly flow. The fourth panel shows the difference between the NCEP/NCAR Reanalysis and the NASA Reanalysis, plotted with a contour interval of 1 dam; with the exception of Greenland and near the pole, the two reanalyses are virtually identical although the analysis methods and data sources are different.