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PRELIMINARY DESIGN FOR ARCTIC ATMOSPHERIC RADIATIVE TRANSFER EXPERIMENTS

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If current plans are realized, within the next few years, an extraordinary set of coordinated research efforts focusing on energy flows in the Arctic will be implemented. All are motivated by the prospect of global climate change. SHEBA (Surface Energy Budget of the Arctic Ocean), led by the National Science Foundation (NSF) and the Office of Naval Research (ONR), involves instrumenting an ice camp in the perennial Arctic ice pack, and taking data for 12-18 months. The ARM (Atmospheric Radiation Measurement) North Slope of Alaska and Adjacent Arctic Ocean (NSA/AAO) Cloud and Radiation Testbed (CART) focuses on atmospheric radiative transport, especially in the presence of clouds, as well as on the formation, evolution and dissipation of clouds. ARM is led by the US Department of Energy (DOE). The NSA/AAO CART involves instrumenting a sizeable area on the North Slope of Alaska and adjacent waters in the vicinity of Barrow, and acquiring data over a period of about 10 years. This duration was chosen so as to include a large number of meteorological situations, spanning a wide range of conditions, in an ensemble collected as a basis for model algorithm development and validation. ARM also plans to participate in SHEBA. FIRE (First ISCCP [International Satellite Cloud Climatology Program] Regional Experiment) Phase III is a program led by the National Aeronautics and Space Administration (NASA) which focuses on Arctic clouds, and which is coordinated with SHEBA and ARM. FIRE has historically emphasized data from airborne and satellite platforms. All three programs anticipate initiating Arctic data acquisition during spring, 1997.

In light of this historic opportunity, we discuss a strawman atmospheric radiative transfer experimental plan that identifies which features of the radiative transport models we think should be tested, what experimental data are required for each type of test, the platforms and instrumentation necessary to acquire those data, and in general terms, how the experiments could be conducted. Aspects of the plan are applicable to all three programs.

The most obvious requirement for radiative transfer experiments is that selected aspects of the radiant energy field itself must be measured. The questions then are, which specific aspects? Over what spectral ranges? With what resolution? How accurately? Over what time periods? With what equipment? etc. etc. Similarly, it is clear that the relevant characteristics of the atmosphere need to be measured simultaneously with the radiation field in order to model radiative transport through the atmosphere. Comparable questions arise here. It is a little less obvious that the optical properties of the underlying surfaces must also be taken into account, but such is the case. Again, more questions.

The details of experimental design are driven by programmatic objectives as well as

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scientific imperatives. Whereas each of the arctic programs mentioned above share many of the same generic objectives, there are significant differences. ARM focuses on atmospheric radiative transport through both clear and especially cloudy atmospheres with the goal of substantially improving cloud-related GCM (General Circulation Model) algorithms for the purpose of improving the quality of GCM future-climate simulations. The SHEBA interest in radiative transfer is specific to the radiative influence on sea ice behavior. While FIRE to a large extent shares the interests of both of the other programs, it is also motivated by NASA's need to understand radiative transport as an aid to interpretation of satellite remote sensing data.

Here we limit the discussion to ARM, and consider only a few specific features of the strawman plan. Given ARM's programmatic objectives, ARM must concern itself with (among other things) surface and near-surface energy balance. The accuracy with which ARM needs to make radiometric measurements can be judged by considering the order of magnitude of the anticipated change in the energy balance due to the projected doubling in the atmospheric concentration of greenhouse gases within the next several decades -- on average, a few watts per square meter. In principle, radiometric measurements should be made to an accuracy corresponding to a small fraction of the anticipated greenhouse changes. Since making the necessary radiometric measurements to that accuracy may well be beyond present capabilities, it is important for ARM to push the state of the art in this regard.

It has been pointed out by Ellingson et al (1994) that at high latitudes during the polar night, a substantial fraction of the surface and near surface energy transfer occurs within the so-called "dirty window" spectral region (16-25 micrometers), a window which at lower latitudes is effectively closed by water vapor in the lower troposphere. Under polar night conditions, however, the atmosphere is so cold (and hence, dry), that this window opens up. The implication for the ARM NSA/AAO site is that radiometric measurements need to be extended to cover the dirty window region. It is of major importance to note that surface and near surface high latitude conditions during the polar night mimic the conditions which occur in the upper troposphere at lower latitudes, and that radiative transfer under these conditions is thought to play a critical role in greenhouse warming globally, not just at high latitudes (Lindzen, 1991). Hence, a well-conceived and well-executed experimental program at high latitudes will contribute to improved simulation of global, as well as high latitude radiant energy flows.

In the contemplated experiments, the importance of absolute humidity for radiative transfer makes it imperative that accurate humidity measurements be routinely made as a function of altitude at the NSA/AAO CART site. However, the low temperatures and resulting low absolute humidities are well known to make high quality humidity measurements difficult. Nevertheless, the difficulties must be overcome.

Finally, we note that in the Arctic, the surface optical properties change so dramatically during the annual cycle that their influence on surface and near surface energy balance must be more accurately taken into account than at lower latitudes, especially in the presence of clouds or other atmospheric scatterers. Measurement of time-dependent surface optical characteristics is less important at locations where either snow and ice do not occur, or where they are perennial. Fortunately, appropriate means for making such surface measurements have recently been under development (Tsay, 1994).

Many other elements enter into the strawman plan, but those elements discussed above suggest the plan development process we have adopted.

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