a medium such as snow because the assumption of independent scattering used in classical radiative transfer theory (CRT) is not valid. Validation of the DMRT approach requires a relationship between measured snow grain size and the DMRT approximation of snow grain radius as spherical particles with a mean radius of the log-normal particle-size distribution. This relationship is very important for a better understanding of snow modelling and for practical applications. DMRT simulations were compared with observations of microwave brightnesses at 18.7, 36.5 and 89 GHz (V and H polarizations) collected on February 19-25, 2003. Observation angles ranged from 30° to 70°. Model inputs included measured snow parameters except mean grain size. The average snow temperature, fractional volume and depth were held constant, together with the ice and soil permittivities. The minimum and maximum measured mean grain sizes were used to test the capabilities of the DMRT to reproduce the brightnesses as upper and lower limits. The sensitivity to the largest and smallest measured grain size in the three classes of minimum, medium and maximum observed grain sizes was also investigated. DMRT particle sizes yielding a best-fit to the experimental data for each date were computed. Results show that the measured brightnesses fall within the range of simulated brightnesses using the smallest and largest measured grain size values. The DMRT best-fit radii are comparable to the average radii for the medium observed grain sizes.

C42B-06 1505h INVITED

Sensitivity of 6.7 GHz Brightness to Snow Wetness

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We monitored dual-polarized 6.7, 19, and 37 GHz brightnesses of a snow pack at the Fraser, CO, site of the Cold Lands Processes Experiment (CLPX). Our contributions to CLPX include observations from the Truck Mounted Radiometer System (TMRS3) and the MicroMet Station (MMS) during winter and spring of 2003. Dual-pol 19 and 37 GHz brightnesses observed by satellite sensors are used operationally to estimate the Snow Water Equivalent (SWE) of dry snow on the prairie. The empirical algorithms that produce these SWE estimates fail when now packs contain liquid water. Our hypothesis is that a lower frequency brightness, like data from the 6.9 GHz channel of AMSR, in conjunction with a snow model could supplement 19 and 37 GHz brightnesses to yield SWE for wet snow packs. The retrieval process would be much like that used to estimate soil moisture. Our final measurements associated with CLPX occurred in May, 2003. We have processed and delivered our MMS data to the NSIDC archive, and are processing the TMRS3 data for delivery in fall, 2003. We will report our progress toward analyzing these brightness data during periods of wet snow pack.

C42B-07 1525h

Ground-Based FMCW radar measurements: a summary of the NASA CLPX data

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Frequency Modulated Continuous Wave (FMCW) measurements were made from the ground at one site (LSOS) during the 2002 campain and at 4 different sites during the 2003 CLPX campain. The system transmits a signal whose frequency varies linearly with time, and the transmitted and recieved signals are mixed before data aquisition to produce a signal which contains the differences in frequencies between the two signals. Measurements were made at C-, X-, and Ku-Band frequencies. Broadband (4GHz) measurements show a great deal of vertical stratigraphy within the snowpack, however narrowband measurements were also made to simulate airborne measurements. Experiments were also performed at different look angles, and metal reflectors were placed at various depths for calibration. All of the data collected during the NASA CLPX mission are summarized.

URL: http://ucsu.colorado.edu/~marshalh/CLPX.html

C42C MCC: 3002 Thursday 1600h

CLPX: Cold Lands Processes Field Experiment II *(joint with H)*

Presiding: **D Cline,** NOAA National Operational Hydrologic Remote Sensing Center**; K Elder,** Rocky Mountain Research Station, U.S. Forest Service

C42C-01 1605h

Analysis of airborne and spaceborne hyperspectral data for the 2003 Cold Land Processes Experiment

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Airborne and spaceborne hyperspectral data were collected during the first and second intensive observation periods (IOP) of the 2003 NASA/NWS Cold Land Processes Experiment (CLPX) in the Rocky Mountains of Colorado. These data were acquired to provide calibration and validation of snow cover products from the CLPX core passive and active microwave remote sensing measurements. The airborne data were measured by the NASA/JPL Airborne Visible Infrared Imaging Spectrometer (AVIRIS) during both IOPs of 2003. The spaceborne data came from the NASA EO-1 Hyperion imaging spectrometer in the middle of each IOP. Field spectra of calibration targets were collected near the time of acquisitions with an Analytical Spectral Devices FR field spectroradiometer. Core field measurements in the CLPX included stratigraphy of snow grain size. The imaging spectrometer data were atmospherically corrected to apparent surface reflectance using the HATCH model. Field spectra from calibration targets were used to calibrate the apparent surface reflectance data. The apparent surface reflectance data were then analyzed for subpixel snow covered area, grain size, vegetation covered area, and rock covered area using the Multiple Endmember Snow Covered Area and Grain size model (MEMSCAG). This model is a coupling of Multiple Endmember Spectral Mixture Analysis (MESMA) and the radiative transfer model DISORT. Grain size retrievals were compared with core CLPX measurements of surface grain size.

C42C-02 1620h

Comparing simulated and measured sensible and latent heat fluxes over snow

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Verifying simulated sensible and latent heat fluxes over snow has seldom been attempted because of the difficulty in direct measurement. Recent development of more robust eddy correlation (EC) systems allowed us to directly measure fluxes of heat and water vapor over snow during the 2003 NASA Cold Lands Processes Experiment. Measurements were made from February through melt-out of the snowcover in mid-June, 2003, at the Local Snow Observation Site (LSOS) in the Fraser Experimental Forest in Colorado. The measurement system was located in an open stand of pines, along with two additional meteorological measurement systems which monitored radiation, temperature, wind, humidity, snow and soil temperature, and snow depth. Precipitation was measured at the near-by USFS climate monitoring station. Th ough the EC system was operated continuously for nearly 5 months, reliable data are available only during relatively clear periods between storms. The point model SNOBAL was used to simulate the snowcover energy and mass balance over this same period of time. Measured fluxes follow the same trends as simulated with sensible heat flux being toward the snow and latent heat flux away from the snow. However, the magnitude of the simulated fluxes were less than those measured by the EC system. This measurement effort shows the need to better tune the EC system to conditions over snow, particularly during storms and condensing conditions. It also indicates that snowcover energy balance simulations are sensitive to wind measurement errors under low-wind conditions such as that found below a forest canopy.

C42C-03 1635h

Snow Cover Distribution Modeled From NASA Cold Land Processes (CLPX) Field Measurements

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Snow distribution was modeled over nine 1-km square field sites in Colorado. The sites were measured as part of the NASA Cold Land Processes Experiment (CLPX) during the winters of 2002 and 2003, at the end of February and March in both years. In each field site more than 500 snow depth and 16 snow pit locations were identified for sampling. Due to logistics and safety, all sites were not measured in some cases. We have distributed snow depth and density over all nine sites for all four sampling dates using a combination of methods including classification and regression trees, and geostatistics. The maps of snow depth, density and water equivalent were produced as a baseline for comparison of other estimation methods, applications such as runoff modeling, and as a tool for sensor and algorithm development for remotely sensed data collected during the CLPX field campaigns. Sites used in the study varied greatly in terms of physiography and climate. Sites included a wide range of elevation, land use, and vegetation cover from grassland to thick forest. Resultant snowpacks ranged from shallow, intermittent and discontinuous snow cover to deep snowpacks.

C42C-04 1650h

Snow Water Equivalent in the Mesocell Study Areas, Cold Land Processes Field Experiment (CLPX)

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One goal of the NASA Cold Land Processes Field Experiment (CLPX) was to estimate the mean snow water equivalent (SWE), and its associated uncertainty, for each of the three 25-km by 25-km Mesocell Study Areas (MSA). The principal purpose of these estimates is to serve as "ground truth" to validate single-footprint SWE retrievals from the EOS Advanced Microwave Sounding Radiometer (AMSR-E) and to compare with various models. Many factors make accurate estimation of SWE over areas of this size (625-km2) challenging. The large spatial variability of SWE within areas of this size demands a very large number of ground observation to adequately represent the mean and variation. Limited accessibility and logistical constraints prohibited this approach. Instead, airborne gamma radiation measurements were used to measure SWE throughout each MSA. This technique, used operationally by the National Weather Service, is based on the attenuation of natural terrestrial gamma radiation by the atomic mass cross-section of water (ice or liquid) contained in the snowpack and the upper 20-cm of soil. The background gamma radiation is measured in the fall, then the radiation is measured again when snow is present. The attenuation characteristics are well-known, making this a reliable approach to measuring the total SWE + soil moisture present. To separate these two components, soil moisture is estimated. Initial real-time SWE estimates for the three MSA were based only on rough estimates of soil moisture characteristics. In subsequent analysis, we have used soil moisture data collected during each of the flights to

refine the SWE estimates for each MSA. These new estimates are discussed, together with the uncertainty associated with estimated SWE for each MSA.

C42C-05 1705h

Use of LIDAR for Measuring Snowpack Depth

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Airborne LIDAR measurements were made near the date of peak snow accumulation in Colorado as part of the NASA Cold Land Processes Experiment (CLPX). LIDAR (LIght Detection And Ranging) overflights were repeated in the late summer following the experiment to obtain a baseline on the terrain in the areas where wintertime LIDAR data were collected. These areas were also measured for many snowpack parameters, including snow depth, by field crews near the winter overflight date. The surfaces generated by differencing the two LIDAR images produced a high-resolution spatial map of snow depth. The results were compared to point measurements of snow depth collected by the field teams. Results were also compared to modeled continuous distributions of snow cover to obtain differences in volume of snow predicted over the study sites. Absolute accuracy of the LIDAR data was evaluated using portions of the LIDAR imagery that was snow free during both overflights. The CLPX field campaign made onsite measurements at nine 1-km square study sites. Site characteristics varied greatly from subalpine to alpine, from thick forest to grassland, and from complex to flat terrain. The observed snowpacks varied between the deepest found in Colorado to shallow, discontinuous snow cover.

C42C-06 1720h

Comparison of simulated spectral bidirectional reflectance function of snow-covered austral summer sea ice with measurements

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The bidirectional reflectance distribution function (BRDF) is an important geophysical variable that provides patterns of surface directional reflectance due to direct beam incidence. Information of BRF is required to derive surface albedo from remote sensing data sets. Also, albedo under various conditions can be evaluated by integration of BRFs. Knowledge of BRF of snow covered sea ice surface is especially important because sea ice exerts a strong positive feedback effect on the surface energy budget, and snow covered sea ice exhibits a strong anisotropic pattern when the solar incidence angle is large. However, it is difficult to obtain a complete data set of snow-covered sea ice surface BRDF through field measurement because of the general paucity of clear sky conditions and the narrow range of solar incidence angles that occur during measurement. The information gap can be filled through validation of the modeled results from radiative transfer simulations. We performed a simulation of snow covered sea ice surface BRF using a multi-layered azimuth- and zenith-dependent plane parallel radiative transfer code. Combined with Mie scattering algorithm, the code takes the measured snow grain sizes, densities and thicknesses of individual layers as input, and generates snow-covered sea ice surface spectral BRF as output. The simulated surface spectral BRF is then compared with measurements. The discrepancies between the model simulation and measurements are analyzed and causes inferred.

URL: http://www.asf.alaska.edu/∼ *sli*

C42C-07 1735h

Remote Sensing of pan-Arctic Snowpack Thaw Using the Seawinds Scatterometer

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Springtime snowmelt is a major hydrological event across the pan-Arctic. Melt is typically simulated using time series climate data which, given a sparse network of Arctic meteorological stations, may not accurately capture detailed between-station spatial and temporal variability. Remotely-sensed estimates of snowpack freeze/thaw state offer the potential of more complete spatial coverage across remote, undersampled areas such as the terrestrial Arctic drainage basin. We compared the timing of spring thaw de termined from approximately 25 km resolution daily radar backscatter data with observed daily river discharge time series for 52 basins (5000–10,000 km^2) across Canada and Alaska for the spring of 2000. Algorithms for identifying critical thaw transitions were applied to daily backscatter time series from the Seawinds scatterometer aboard NASA QuikSCAT. Radar-derived thaw shows general agreement with discharge increases in basins with moderate–high ($>\sim 120$mm) runoff due to snowmelt. Average absolute difference in those basins was 16.2 days. Good correspondence is found across higher latitude basins in western Canada and Alaska, while the largest discrepancies appear at the driest watersheds with lower snow and daily discharge amounts. Extending this analysis to the entire pan-Arctic drainage basin, we compare scatterometer-derived date of the final spring thaw event with snow cover disappearance from composited satellite visible-band snow cover data. Good agreement is found across much of the pan-Arctic, with distinct zones of larger discrepancies across mainly southern parts of the basin. The largest disagreement occurs across south-central Asia and is likely due to high tree cover and topographic complexity. Stronger backscatter response in the signal-to-noise ratio is seen with higher snow cover, low–moderate tree cover and low topographic complexity. This analysis suggests that active radar instruments such as the Seawinds scatterometer offer the potential for monitoring high-latitude snowpack thaw and may lead to a better understanding of the timing and linkages between snowmelt and hydrologic response.

C42C-08 1750h

Parameterization of Forest Canopy Properties over Snow using MISR

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The presence of a forest canopy complicates our understanding of the processes of snow accumulation and ablation. Quantifying snow interception by forest canopies requires estimates of canopy density and geometry. Remote sensing data from the Multi-angle Imaging SpectroRadiometer (MISR) have been used to characterize surface structure through a parametric approach. The RPV parametric model relates the anisotropic surface reflectance to vegetation stand density and the degree of sub-pixel heterogeneity. Here, we show preliminary results using MISR 275m data acquired over snow-covered landscapes in Saskatchewan and Colorado. The shape of the bidirectional reflectance distribution function over varying vegetation of coverage amounts and geometries changes from bowl-shaped to bell-shaped, indicating strong potential for the use of multi-angle data in characterizing vegetation in conjunction with snow cover mapping.