of the outlet glaciers discharging ice along the eastern flank of the Peninsula from 64 south to 71 south, and along the former Wordie Ice Shelf in the west. Differential radar interferometry was employed to map the position of the glacier grounding lines. Estimates of ice thickness at the grounding line were obtained from hydrostatic equilibrium using existing topographic maps, or from direct measurement from radio echo sounding by BAS in 1994-2000 and CECS/NASA in 2002. The resulting glacier fluxes were compared to snow accumulation compiled by Turner et al. (2002) to deduce first-order estimates of the glacier mass balance. In places where ice shelves are known to have been retreating, we compared the 1996 velocities with older measurements as well as more recent estimates from ERS-1/2 (2000), Radarsat (2000-2003) and Aster (2002). On Fleming Glacier, we find a large increase in flow speed from 1972 to 1996, with no further increase after 1996, which suggests that the glacier did respond to the collapse of Wordie Ice Shelf several decades ago. On Drygakski glacier in the east, we confirm a large acceleration of the glacier following the collapse of Larsen B, as revealed by Rott et al. (2002), which is continuing to this date. We conclude on the effect of retreating ice shelves on the evolution of inland ice in this sector of Antarctica and on its impact on sea level rise.

C41A-08 0945h

The sea ice Thickness Distribution and Iceberg Size Distribution From AUV Measurements in the Northern Weddell and Eastern Amundsen Seas

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The AUV AUTOSUB 2 has been used on two campaigns in Antarctica. The first was in February 2000 at the northern edge of the Weddell Sea (63S, 50W), the second in March 2003 at the shelf break region of Pine Island Bay (71S, 102W). The aim in both cases for this project was to determine the sea ice thickness distribution on scales of 10's of km. In the first campaign the AUV was sent on missions of up to 80 km length at depths in the range 150-250 m. It was equipped with an upward looking scientific echo sounder operating at two frequencies as well as a full suite of oceanographic sensors including 2 CTD's, and both upward and downward looking ADCP's. The data allow derivation of the sea ice distribution and iceberg size distribution as well as recording under ice hydrographic data at very high spatial scales. We will show examples of the thickness data and give an example of the hydrographic data from a close approach to a small iceberg. In the second campaign the vehicle was substantially different and thickness data were obtained from upward looking ADCP data with shorter missions (30 km) but at shallower depths. In total the AUV has collected over 500 km of data for this project and is part of the Autosub Under Ice programme. The AUV will be sent to the Greenland Sea in 2003 and then back to Antarctica in 2004/5 for missions beneath the Filchner Ronne ice shelf.

C41B MCC: Level 2 Thursday 0830h

Monitoring, Measuring, and Modeling Snow Processes Posters *(joint with H)*

Presiding: **K Elder,** Rocky Mountain Research Station, U.S. Forest Service**; D Marks,** USDA Agricultural Research Service

C41B-0947 0830h INVITED POSTER

Snow Processes: Current Understanding and Future Prospects

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Snow processes are the key to understanding and describing the hydrology and climatology of cold regions and seasons. Snow is not simply a solid precipitation that can be treated like other hydrological inputs, but is redistributed, sublimated, and metamorphosed after snowfall and undergoes complex and rapid changes during melt. In open landscapes blowing snow erodes and transport surface snow from exposed surfaces through two-phase flow and redistributes the snow to more sheltered surfaces. During transport, significant sublimation loss may occur, making the process not just one of redistribution but ablation. Rapid changes to snow density, crystal size and spatial statistical properties occur during this phenomenon. In forested regions, snow interception by the canopy can store the majority of a mid-winter snowfall, and intercepted snow is exposed to high energy inputs, driving enhanced sublimation and melt. All snowpacks are subject to complex radiative, turbulent and conductive energy transfers which couple with snow mass transfer in manners that are not fully understood. It is increasingly realised however that simple flat plane assumptions in calculating coupled heat and mass transfer are not adequate for describing snow dynamics. Further, the non-linear aspects of most snow processes make their larger scale description highly dependant on the spatial distribution of boundary conditions and how these in turn are affected by the evolving snowpack state. The upcoming challenges in the study of snow processes still include improving the basic descriptions of these processes, yet new challenges have arisen in understanding and describing snow processes and their space-time dynamics over highly heterogeneous landscapes. The remarkable consistency of larger scale descriptions of snowcover evolution and spatial variation suggests that there are relevant principles of spatial organisation whose importance to snow phenomena has not been identified or explained.

C41B-0948 0830h POSTER

Estimation of snow water equivalent from sparse field measurements in Italian Alps

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The estimation of Snow Water Equivalent (SWE) is a far reaching matter in the hydrology of alpine rivers. SWE at the beginning of the melting season is often adopted as a boundary condition for snow melt models, low flows simulation and spring floods. Here, SWE snow measurements from alpine areas in central-northern Italy are analysed. Using 10-years snow depth registrations from a network of 28 stations, SWE is estimated and mapped on the observed area at the beginning of the melting season, set at April 1th. Because no systematic snow density measurements are provided at the given stations, sparse density measurements (about 200 over 5 years of observation) are used to find a relation between snow density, geo-morphologic features and the season, so as to provide SWE estimation at sites where only depth measurements are available. To enlighten regional features in SWE distribution, a Principal Component Analysis (PCA) is carried and two different regions are found. The covariance structure of the SWE field is assessed and an analysis is carried, to incorporate spatial and geomorphic attributes. A Kriging procedure is then carried and validated, showing proper estimation of SWE at ungauged sites. The Kriging methodology is then compared to other different, straightforward approaches used in the related bibliography, showing interesting performances. Then, areal estimation of SWE is provided, showing the Kriging procedure enhances systematic error in estimation from the other methodologies and also provides remedies for their correct application.

C41B-0949 0830h INVITED POSTER

Methods to Identify and Correct Snow Water Equivalent Pressure Sensor Measurement Errors to Improve Estimates of Water Stored as Snow

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Snow water equivalent (SWE) pressure sensor measurement errors significantly reduce the ability of water resource managers to accurately predict the amount of available SWE or snowmelt water runoff. SWE errors may occur when the snow/soil interface is at the melting temperature and the differential snowmelt rate between a SWE sensor and the soil exceeds the snow creep rate. A cold, dry snow cover overlying frozen soil will not exhibit SWE sensor errors because the snow and soil temperatures are both below the melting temperature. A delayed SWE sensor response may occur when the SWE accumulation rate exceeds the snow creep rate. Cold snow covers with many ice layers will have a relatively low creep rate while isothermal wet snow will have a relatively high creep rate. This is why a SWE sensor that exhibits a large error just before the onset of wet isothermal conditions will suddenly start to accurately measure SWE. By understanding the physical mechanisms that affect SWE sensor performance the occurrence of SWE errors can be identified and a variety of approaches to correcting them are possible. When only SWE sensor data are available, the occurrence of SWE errors can be identified by excursions in SWE, which can be corrected by interpolating from data on either side of the excursion. A delayed SWE sensor response to a snowstorm is related to the snow creep rate and can be corrected by shifting the SWE record to ensure that the start of the SWE increase and the storm agree. The SWE accumulation rate midway between the beginning and end of the storm should provide a good approximation of the storm's accumulation rate. When additional information on precipitation, snow depth, and snow core SWE are available then relatively simple comparison and interpolation methods can be used to correct errors. Ground temperature or heat flux data can be used to predict SWE sensor performance and correct SWE errors. Air temperature data and a heat flux model of snow and soil may be used to estimate data needed to correct SWE errors.

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C41B-0950 0830h POSTER

Snow Water Equivalent Predictions for Hydrologic Model Input and Simulation

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A multiple regression equation was developed to describe temporal and spatial variability of daily snow water equivalent (SWE) in Lake Tahoe's Incline Creek watershed. SWE maps of the basin are needed for parameterization of the physically-based Alpine Hydrochemical Model (AHM) to simulate basin hydrology and solute transport. SWE maps allow for calculation of snow covered area, snowfall, and potential snowmelt needed for AHM input. SWE data collected during 2002's peak snow accumulation were used in conjunction with data from three local SNOTEL stations to calibrate the regression equation. Calibration was conducted during a dry and average water year using the sum of least squares. The multiple-regression is dependent on elevation, aspect, slope, vegetation density and solar radiation and is normalized by the average SWE measured at the three SNOTEL sites. Basin-wide computations were done at 30 m resolution in ArcView to generate daily SWE maps. Normalized error was added to predictions from the regression equation to mimic the variability in the observed data. Verification was performed at the three SNOTEL sites for a wet year and another average year. Stream response is highly dependent on SWE distribution and associated melt rates such that hydrologic model results allow evaluation of the SWE interpolation technique.

C41B-0951 0830h POSTER

Distribution of Soil Dynamics in a Small Mountain Catchment

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Soil moisture in semi-arid regions dominated by winter precipitation is recharged as a bulk influx during spring melt and dries down quickly during the ensuing months. This timing in combination with various spatially distributed landscape properties produces distinct spatial soil moisture patterns. The patterns

must be recognized in a distributed manner to account for hydrologic processes of storage and redistribution. This research investigates the spatial correlation among distributed point measurements of soil moisture, and between soil moisture patterns and landscape properties such as topography, vegetation, and the spatial snowmelt patterns. We also evaluated data using a combined snowmelt-soil water model to provide spatially and temporally continuous estimates of net recharge and evapotranspirtation across the watershed. Recharge estimates were compared with measured streamflow measured at a weir at the base of the watershed. Reynolds Mountain East (RME) subcatchment in Southwestern Idaho is in an intermountain region exhibiting high variability in topography, vegetation, and snow distribution. RME encompasses an area of 0.6 km2 with 19 neutron probe access tubes distributed throughout the catchment. Two years of soil moisture data were collected with supporting climate and snow distribution data. In addition, leaf area index was measured for different vegetation types. The soil water regime is typically characterized by two regimes: the spring snow melt and summer dry down with a variable degree of recharge prior to snow fall in the during the fall. Distributed patterns of soil moisture have distinct correlation to snow and vegetation distribution.

C41B-0952 0830h POSTER

Measurements of Snow Deformation Using Particle Image Velocimetry Combined With Finite Element Simulations

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The rheological properties of snow are not well understood, however accurate constitutive relationships are necessary for various fields including vehicular movement over snow, calculating snow loads on structures, avalanche studies and military applications (Shapiro, et. al. 1997). Accurate deformation measurements combined with finite element modeling may help to improve constitutive models of snow under load. Measurements of deformation under band loading of snow samples of varying densities and crystal type were performed in the laboratory. The deformation caused by the loading was calculated using particle image velocimetry (PIV), in which particle paths are traced with a rapid sequence of digital photographs. PIV software allows accurate calculation of the strain field in the snow sample. These experiments are compared to a non-linear finite element model with interface elements (Marshall, 2002, Fall AGU: C11B-0996). Model parameters describing the constitutive properties of the snow sample are adjusted to provide the best fit to the measurements of deformation, which may lead to an improved understanding of the behavior of snow under a band load.

C41B-0953 0830h POSTER

Evaluation of snow process over short vegetation in land surface modeling

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Sublimation and snow melt process over short canopies are examined with a two- layer canopy model. The model's performance is evaluated with observation from the North Park Basin, Colorado, taken during the Cold Land Surface Processe s Experiment. The site is covered with a sage community with an average height of 30cm. Two cases with weak winds are selected for further examination. In the first case, the snow covers the ground surface but there is no intercepte d snow in the canopy. In the second case, the canopy is partially covered with intercepted snow. Improved representation of snow interception, subcanopy parameterization and the change of relative canopy height due to changing snow depth are implemented in the land surface model. The modified model better simulates both sublimation and sensible heat flux from the canopy and ground surface by giving more realistic energy partition between the ground and the canopy. It is shown that the modelled latent heat flux is sensitive to the intercepted snow amount because less intercepted snow leads to greater absorption of solar energy by the canopy, more buoyancy generation of turbulence above the canopy and possible stratification of the subcanopy. Hence, it is necessary to establish an appropriate treatment for intercepted snow amount in the model. **Key words**: sublimation, short canopy, subcanopy snow

C41B-0954 0830h POSTER

Snow accumulation, melt and runoff at the Arctic Treeline in Northern Canada

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The storage and release of water from the seasonal snowpack is an important component of the hydrologic cycle in NW Canada. Previous work has illustrated that the end of winter snowcover is spatially variable, and that the surface energy fluxes are also variable at a range of scales. Energy fluxes over the vegetated, complex terrain typical of the Arctic treeline in NW Canada, vary due to vegetation type (tundra vs. shrub tundra), and due to topographically induced differences in radiation regime, wind speed, and turbulent fluxes of sensible and latent heat. This spatial variability in both end of winter snow water equivalent and energy fluxes, results in the development of a patchy snowcover. The development of a patchy snowcover adds another element to the spatial variability in energy fluxes, and therefore melt, due to the local scale advection of sensible heat. This process results in an increase in sensible heat flux at the windward edge of snow patches. This paper will discuss the relative importance of the spatially variable snow cover and energy fluxes in controlling snowmelt rates, the resultant development of a patchy snowcover, and consider the implications to runoff, energy fluxes between the landsurface and the atmosphere, and methods to consider these processes in landsurface schemes and hydrologic models.

C41B-0955 0830h INVITED POSTER

Soil Heat and Water (SHAW) Model Validation During Snowmelt in a Forested and Regenerating Clearcut on a Colorado Subalpine Hillslope

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Perturbations to Central Rocky Mountain subalpine forests can significantly impact hydrological processes. Understanding interactions between subalpine forest and surface/subsurface hydrology at the process level is essential for the development and validation of hydrologic models. Measurements from two subalpine hillslopes are used to validate the Soil Heat and Water (SHAW) model. One hillslope is a naturally regenerating clearcut that was harvested in December 1984. Adjacently lies a second hillslope, which serves as the control and is forested with trees exceeding 80 years in age. Both plots are populated with lodgepole pine (Pinus contorta), subalpine fir (Abies lariocarpa) and Englemann spruce (Picea englemannii). Identical meteorological and hydrological measurements were made on both plots from January through June 2001. Meteorologic measurements include air temperature, relative humidity, incoming solar radiation, net radiation, wind speed and direction, soil temperature, and snow depth. Hydrologic measurements include snow water equivalent, soil moisture, snowmelt discharge at the base of the snowpack, and subsurface plot discharge. Precipitation was measured offsite in a nearby forest clearing. In addition to parameterizing the model, these measurements serve as critical validation points for model output. The model produced adequate results in both forest conditions.

C41B-0956 0830h INVITED POSTER

Measured and Predicted Solar Transmission Through Conifer Canopies

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Snow dynamics under forest canopies are strongly influenced by the large spatial variability of energy transfers in this environment. Transmission of solar radiation through a canopy is highly variable and depends on tree species, as well as canopy properties such as height, density, and leaf area. Modeling snow processes at the stand scale has proven challenging due to the highly variable structure of forest canopies controlling solar radiation incident at the snow surface. This study aims to describe and simulate the solar irradiance variability on the snow surface beneath two stands: an open, discontinuous conifer canopy, and a relatively uniform conifer canopy. The objectives are 1) to compare measured and predicted solar transmissivities based on field data and analysis of hemispherical photographs and 2) to evaluate the magnitude of the predicted solar fluxes and the timing of snow ablation using the snow model, SNOBAL, driven separately with both measured and modeled solar transmissivities. Field measurements were made during winters of 2002 and 2003 at the Local Scale Observation Site (LSOS) in Fraser, Colorado USA as part of the Cold Land Processes Experiment. The canopy structure of the trees in a 0.8 ha plot was measured in detail (species, tree location, height, crown height, diameter at breast height). We measured incoming global solar radiation at the snow surface, beneath uniform and discontinuous lodgepole pine canopies, using arrays of 10 upward looking pyranometers at each site. Incoming global solar radiation was measured above the canopy and used to calculate transmitted values. Hemispherical photographs taken, with a Nikon CoolPix995 digital camera equipped with a Nikon Fisheye Converter (183° FOV), at each pyranometer location (n=20) were analyzed with Gap Light Analyzer (GLA) software (Frazer, et al. 1999) to determine total solar transmissivity. Mean measured and predicted solar transmissivities compared well (r^2=0.86) in the discontinuous canopy site (0.27 measured vs. 0.29 GLA-predicted) and in the denser, uniform site (0.47 measured vs. 0.48 GLA-predicted). Our snow ablation modeling results suggest that using digital hemispherical images along with GLA software to determine a solar transmission factor can adequately represent the sub-canopy solar radiation incident on the snow surface.

C41B-0957 0830h POSTER

Coupling a Physically Based and Spatially Distributed Snowmelt Model with a Flowpath Model, Green Lakes Valley, Colorado Front Range

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Spatially distributed estimates of snow deposition and melt allow us to better understand the interaction between hydrology and topographic structure and climate in mountain basins. Here we report on initial efforts to add a physical based and spatially distributed energy balance snowmelt model, ISNOBAL to the XTOP_PRMS model, a flowpath model coupling the TOPMODEL and Precipitation Runoff Modeling System within the Module Modeling System (MMS). This procedure was demonstrated at the 8-ha Martinelli and the 220-ha Green Lake 4 (GL4) catchments in the Green Lakes Valley, Colorado Front Range. In the pilot study using a temperature index snowmelt algorithm in the XTOP_PRMS model, streamflow discharge measured in 1996 was used to calibrate parameters and streamflow

discharge was simulated from 1997 to 2000. The results showed that the discharge simulation was relatively successful at the 8-ha Martinelli catchment, with a Nash-Sutcliffe efficiency of 0.76. The *t*-test for paired means indicated that the prediction of discharge was not significantly different from the observation at $\alpha = 0.05$ ($n = 1611$, $p = 0.6$). However, the discharge simulation was relatively poor at the GL4 catchment, with a Nash-Sutcliffe efficiency of only 0.54. Moreover, the difference between the predicted and observed values was significant at $\alpha = 0.05$ ($n = 1611$, $p = 0.005$). It is believed that the poor performance of the XTOP_PRMS model at the GL4 catchment was due to use of the temperature index snowmelt algorithm as well as the coarse (daily) temporal resolution of the air temperature in the model. To resolve this problem, we report on our efforts to incorporate the hourly mode ISNOBAL with the XTOP_PRMS model within the MMS. High temporal resolution time-series images of climate surfaces such as air temperature, humidity, wind speed, precipitation, and solar and thermal radiation are generated using the Image Processing Workbench (IPW) and a combination of 3 to 5 point measurements, elevational gradients, and detrended Kriging. Through those efforts, we show that the discharge and flowpath simulations can be improved at both Martinelli and GL4 catchments.

C41B-0958 0830h POSTER

The Effect of Basin Scale on Diurnal Streamflow Timing in Snowfed Catchments

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The daily phase of diurnal cycles of streamflow is a measure of travel times in a basin. When indexed by the hour of maximum discharge each day, the phase represents the time from peak snow melt in the afternoon to the time most water reaches the gage, which ranges from a few hours to almost a full day later. Hourly discharge measurements from sixty basins in the western United States, with areas ranging from 1 to 10,000 km^2, illustrate how diurnal streamflow timing varies with basin size and gives insights into how observed diurnal cycles may be used to infer the progress of snowmelt within a given basin. The travel time increases with longer percolation times through deeper snowpacks, increases with longer travel times overland and along longer stream channels, and decreases with faster instream flow velocities. Correlations between diurnal timing and daily mean discharges help to identify which of these three factors dominates at a given basin scale. In basins with areas less than 30 km^2, snow properties that determine the travel times through the snowpack dominate diurnal streamflow timing. In particular, daily peak flows shift to earlier in the day as the snowpack thins and the mean discharge increases. Travel time, and thus diurnal timing, in basins larger than 30 km^2 but with main channel lengths less than 50 km is dominated by in-channel flow distances, so that the daily peak is delayed as snowmelt is increasingly drawn from the farther reaches of the basins. Diurnal timing in these basins is particularly susceptible to change in years when spring storms bring new snow to the basin and reset the geographic distributions of (and travel distances from) snowmelt. The drop in discharge due to colder temperatures is accompanied by earlier daily peak flows because the new snow has a shorter travel distance. Travel times in large basins with main channel lengths longer than 60 km are governed by stream velocities, with peak flows that arrive earlier as mean discharges and channel velocities increase. These observed patterns of diurnal timing can be reproduced by simple models that couple porous-medium flow through evolving snowpacks and free-surface flow in stream channels.

C41B-0959 0830h POSTER

Survey, Analysis, and Modeling of McAfee Meadow Cirque, White Mountains, California

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A sub-meter resolution GPS was used to measure this glacial cirque. Some data was collected during April, 2003. Most data was collected after the snow melted in June and July. Some of the summer data was combined with the winter data to compute a snow survey with spot checks using a probe. An evaluation of this data collection technique is included. All of the data was used to analyze the surface using variograms. This data supplemented DEMs, Digital Elevation Model files from digitized 7.5 minute topographic maps to create a sub-meter precision map of the cirque. The beginnings of a computer model was constructed to use this map to simulate the creation of the cirque.

URL: http://home.apu.edu/~elulofs/AGU03/AGU03.htm

C41B-0960 0830h POSTER

Intercomparison of two models to simulate snowcover dynamics beneath forest canopies

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Numerical simulation of snowcover dynamics in mountain environments is complicated by the fact that forest canopies strongly affect the snow surface energy balance relative to open sites. A number of methods to simulate the affect of forest canopies on the snow surface microclimate have recently been developed and successfully applied across a range of canopy structures. A detailed comparison of two techniques to simulate snowcover processes beneath forest canopies is presented. One method uses empirically-derived canopy adjustment algorithms based on Beers Law to drive the 2-layer mass- and energy-balance model SNOBAL. The second model (SNOWCAN) contains a physically-based optical and thermal canopy radiation model that was recently coupled to a snow energy budget model based on the SNTHERM code. The two models were tested across a range of forest structures including deciduous, mixed deciduous-conifer, sparse conifer and dense conifer canopies. Both models accurately simulated the development and ablation of the seasonal snowcovers, however differences in the components of the energy balance were observed in all of the canopies. Simulated sub-canopy radiation components were relatively similar (within 10%) in the leafless deciduous canopy, but diverged strongly in canopies with higher leaf area indices. Simulated sub-canopy direct solar radiation was larger at high sun angles in the SNOBAL simulations relative to the SNOWCAN simulations. Maximum direct solar radiation differences between the two models approached a factor of 3 during clear, mid-day, late-season periods in the dense conifer canopies. In contrast, simulated sub-canopy thermal radiation was lower in the SNOBAL simulations relative to the SNOWCAN simulations. Maximum differences between the two models were approximately 10% during clear periods, and negligible during cloudy periods. Simulated sub-canopy diffuse solar radiation differences were generally within 2% for all canopy structures during all times of the year. During the ablation phase, the net snowcover radiation was generally higher, and turbulent fluxes were generally lower in the SNOBAL simulations relative to the SNOWCAN results. The results of this investigation indicate that differences in canopy parameterizations can lead to very similar estimated sub-canopy radiation due to counteracting differences in solar and thermal streams. Additional long-term sub-canopy radiation data are needed to improve simple empirical and physically-based canopy radiation models for spatially-distributed snowcover simulations in mountain environments containing a range of vegetation structures.

C41B-0961 0830h POSTER

Topographically Based Estimates of Historical and Future Snow Accumulations for Watersheds in Western North America

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Under forecast climate warming, alpine snowpacks may vary substantially due to regional warming that will likely decrease the accumulation of snow in the watershed. Snowmelt contributes more effectively to runoff than rainfall. Conversion of winter snowfall to rainfall will likely result in declining runoff. We used historical and future temperature and precipitation scenarios (Lapp et al, 2002) along with digital elevation models to estimate changes in snow spatial and temporal distributions over several key watersheds in the study region. The analysis is ongoing but initial results indicate increases in winter precipitation may counteract the impacts of warmer winters on spring snow water equivalent (SWE) in some years in some basins in the study region. However, basin SWE declines dramatically in areas where warming combines with declining winter precipitation.

C41B-0962 0830h POSTER

Modeling the Spatial Distribution of Snow in a Rugged Alpine Valley

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One of the most challenging problems in snow hydrology is understanding the spatial distribution of snow properties in montane catchments. Natural snow variability is extreme due to complex environmental controls. Many authors have found relationships between topographic parameters and snow distribution, but conclusions are based on datasets that span one or two years and it is not known whether the results are specific to the particular years of the study. Research was conducted in the Green Lakes Valley, an east-facing headwater catchment that abuts the Continental Divide and is part of the Niwot Ridge LTER. Snow depth surveys at maximum accumulation were conducted from 1997 to 2003. Snow distribution was modeled using a combined deterministic and stochastic approach. The deterministic trend component was modeled using three approaches: a constant trend, a linear combination of linear topographic parameters, and a linear combination of non-linear combinations of topographic parameters. The topographic parameters considered included elevation, slope, an index of total radiation, an index of wind exposure, and an index of snowdrift formation. Additionally, a multi-year dataset that includes all the measurements taken from 1997 to 2003 was analyzed, which increased the power of the statistical testing. Wind exposure was found to be a significant predictor of snow depth for every year of the study. Elevation, slope, and the index of radiation were found to be significant predictors for some years, but not for others. All terrain parameters were found to be significant for the multi-year dataset when the non-linear trend model was used. An exponential variogram was used to characterize the spatial correlation of residual errors. The range and variance of spatial correlation were found to be related to commonly measured indices of winter precipitation. Moreover, the correlation (R^2) of winter precipitation to the variance of spatial correlation increased from 0.745 for the simple model to 0.906 for the non-linear model. Similarly, the correlation of winter precipitation to the length of spatial correlation increased from 0.452 for the simple model to 0.647 for the non-linear model.

C41B-0963 0830h POSTER

Spatiotemporal Snowpack Distribution Across a Topographically and Ecologically Complex Landscape, Glacier National Park, Montana, USA

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Spatial and temporal variability in snowpack distribution at the watershed scale is the primary driver of many physical and ecological processes in mountain environments such as Glacier National Park. The USGS Global Change Research Program in Glacier National Park has been collecting snow data at 130 points along six survey routes in two 400 km2 watersheds since water year 1995. These data represent below-treeline snow conditions from two distinct climate regimes separated by the Continental Divide, as well as a broad range of elevations, aspects and land cover characteristics. Consistent relationships between snow water equivalent (SWE) at survey points and same-day SWE observations recorded at nearby SNOTEL automated snowpack reporting stations were used to produce modeled estimates of daily SWE at each survey point for water years 1995-2003. Analysis of both observed and estimated

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SWE values show that SWE variability across the landscape increases steadily over the course of the water year and peaks sometime between March and May, depending on the year. Observed and estimated SWE values also indicate that elevation is the dominant factor controlling the distribution of SWE across this topographically complex landscape, overshadowing other known factors such as variations in land cover and solar radiation. Elevation explains an average of 60 percent of the total variability in observed SWE (for all observations), increasing steadily from 45.5 percent in December to 64.4 percent in June. Modeled daily relationships between elevation and SWE will serve as a solid base for empirical models of distributed SWE in Glacier, though further exploration of the relationship between SWE and land cover, solar radiation, and other factors will improve the accuracy of these models.

C41B-0964 0830h POSTER

Improving the Snowmelt Simulation in NCEP Noah LSM

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Snowmelt is one of the most important cold-season land processes, because snowmelt strongly links surface thermal dynamics and hydrological processes. Accurately predicting the timing of snowmelt is critical for determination of the land-surface budgets of energy and water, though it is very difficult and challenging. An early bias in spring snowmelt was found to be a common problem for the NCEP Noah LSM in several uncoupled experiments (North American Land Data Assimilation System (NLDAS), PILPS-2d, PILPS-2e, and Rhone/GLASS), owing mainly to the albedo over snow cover being too low during this transient period. In the present study, through rerunning the Noah LSM for the PILPS-2d experiment, it is found that the low albedo bias during snowmelt is mainly caused by 1) an overly small snowdepth threshold (water equivalent) in the function relating snow cover fraction to snowdepth, and 2) lack of temporal resolution of vegetation greenness, which is one of the major factors to determine snow albedo in the original algorithm of the Noah LSM. After modifying both of these two factors, the snow albedo formulation as well as snowmelt timing has been improved significantly in PILPS-2d. Because PILPS-2d is only one site experiment, we will rerun 1-3 cold seasons of the retrospective NLDAS with the latest version of the Noah LSM, including aforementioned revised snow albedo formula plus some other upgrades such as albedo diurnal adjustment and patchy snow treatment of evaporation to verify that the same improvement of snowmelt timing can be extended to continental scales. The operational NESDIS daily N. Hemisphere 23-km snow cover analysis will be used to verify the control and experimental executions of the Noah LSM in the retrospective NLDAS.

C41B-0965 0830h INVITED POSTER

Scale Dependence Between Hydrologic and Atmospheric Models

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A disparity tends to exist between the scales simulated by atmospheric models intended as input for hydrologic modeling and those at which hydrologic modelers simulate processes especially snow accumulation and depletion in mountainous terrain. Two different models are used to generate input atmospheric data at various scales to drive a snow hydrology model and test the sensitivity of the snow processes at various forcing scales. One of the input atmospheric models is the nested grid atmospheric model, RAMS, developed at Colorado State University. The second input model uses IPW (Image Processing Workbench) to distribute measured climatic variables over complex landscapes. The snow energy balance model is the grid based ISNOBAL. The simulations are performed in the Reynolds Creek Experimental Watershed (RCEW) in the Owyhee Mountains of South-Western Idaho. RCEW is well instrumented with distributed rain gauges, meteorological sites, snow pillows, and discharge weirs. A Rain-on-Snow flooding event is used for the simulations which occurred during the end of December 1996 and the beginning of January 1997. The analysis is showing that atmospheric grids on the order of tens of kilometers miss much of the detailed atmospheric dynamics controlling snowfall in the complex terrain of the Owyhee Mountains and lead to incorrect hydrologic results if simplistic downscaling techniques are used. The detailed variability in the precipitation gauges is on the order of a kilometer or less and the snow pack variability is on even smaller scales. It is hypothesized that atmospheric forcing need to be modeled down to scales on the order of 1 kilometer and then redistributed by wind effects to accurately depict the complex conditions in mountainous terrain.

C41B-0966 0830h POSTER

Comparing Local Analysis Prediction System (LAPS) Diagnoses with Observations

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Meteorological forcing data are necessary to drive many of the spatial models used to simulate atmospheric, biological, and hydrological processes. Unfortunately, many areas (e.g., high elevation mountains, deserts) lack meteorological data and available point observations are not always suitable for landscape or regional applications, especially in mountainous regions. The local analysis prediction system (LAPS, http://laps.fsl.noaa.gov/) is a meteorological diagnostic tool that employs observations (meteorological networks, radar, satellite, soundings, and aircraft) to generate a spatially distributed, three-dimensional, representation of atmospheric features and processes. Data produced by LAPS include wind speed, wind direction, surface temperature, relative humidity, surface pressure, precipitation, and cloud cover, among others. Because LAPS is a spatially distributed representation of meteorological observations, it provides valuable opportunities for users that require local (10 km horizontal grid increment) meteorological data to drive distributed land surface and ecosystem models over large regions (1.29 x 10^6 km^2). As with any diagnostic representation, it is important to ascertain how LAPS outputs deviate from a variety of observations at different spatial and temporal scales. Since many observations are integrated into LAPS, they can not be used to assess diagnostic performance. Fortunately, a number of observations exist that are not used in the LAPS system. These observations include GLOBE (http://www.globe.gov), the cold lands processes experiment, (CLPX, http://www.nohrsc.nws.gov/~cline/clp.html), and other observation networks that generate comparable data to those employed in LAPS. Independent data sets were collected and compared with LAPS outputs from 1 September 2001 to 1 September 2003. The best model and observed correlations were tied to relative humidity and air temperature. Poorer relationships were identified among observed wind speed and direction data. The relationships among LAPS diagnoses and observed data with respect to site locations, local land cover, temporal resolution of observations, and season of the comparison are described with respect to LAPS diagnoses and observed data, and example applications of the LAPS data are provided.

C41B-0967 0830h POSTER

The Effect of Illumination and Viewing Geometry and Forest Canopies on the Estimation of Snow Cover Using Remote Sensing

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With the exception of cloud cover, the largest obstacle to producing a global daily snow cover product using remotely sensed data is the presence of the forests, which cover much of the seasonally snow-covered portion of the world. The presence of the forest canopy influences the radiance received by the sensor in such a way that the proportion of viewable snow within a pixel changes as a function of forest properties, topography and viewing position. To explore the potential effects of sun angle and viewing geometry of satellite systems such as NOAA AVHRR and MODIS on snow cover estimation, a program has been written to estimate viewable gap fractions (VGF) across landscapes based on the Li-Strahler geometric-optical (GO) bidirectional reflectance distribution function (BRDF) model. It computes a VGF map for a specified illumination and viewing geometry using maps of forest cover and species and terrain images of slope and aspect. This study explores the effect of illumination and viewing geometry and forest properties on the VGF for the Fool's Creek Intensive Study Area (ISA) in Fraser Experimental Forest, Colorado. Intensive field measurements of the required parameters for the GO model and maps of forest properties are used to generate maps of viewable gap fractions. Hemispherical photos are used to validate model results. The results improve our understanding of the way forest canopies influence the estimation of snow cover using remotely sensed data.

C41B-0968 0830h POSTER

Monitoring Mountain Snow Pack Evolution using Near Surface Optical and Thermal Properties

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Variability in regional climate can affect snow covered area, amount, and timing of yields. Monitoring is particularly important in the semi-arid western United States. In order to assess the impact of regional climate variability on water resources, there is a need for improved assessment of changes in snow pack properties as they indicate the degree and timing of snow pack melt. Detecting the evolution and spatial distribution of surface melt requires extracting diagnostic information about the evolving spring time snow pack using retrieved radiative surface information from satellites. We have examined a theoretical approach for monitoring the state of the snow pack using surface indicators such as visible reflectance and temperature. This was accomplished through the development of a Near Surface Moisture Index (NMSI), which models relative moisture through construction of a feature space using visible band and a thermal band. A simple analytical RT model for computing directional hemispherical reflectance and emissivity derived from the delta-eddington approximation to the equation of radiative transfer was used to produce the NMSI. Snow near surface grain size could be a proxy for characterizing the evolution of surface conditions during ablation periods. Modeled reflectance and emissivity, as a function of grain size, over MODIS channels 4, 6, and thermal band passes were used to produce the NMSI feature space constructed from the Normalized Difference Snow Index (NDSI) on the adscissa and brightness temperature (Tb) on the ordinate. As grain size increases, the dynamic range or sensitivity of NDSI is reduced, with saturation occurring approximately around 400-450ìm grain radius. Tb for various grain sizes at fixed kinetic temperatures at 245, 250, 255, 260, 265, and 273 Kelvin and ndsi as a function of grain size were used to construct a theoretical NMSI feature space. An index from such a feature space may be designed considering that an optimal index would be constructed with isolines situated perpendicular to the displacement features within the modeled feature space. Displacement vectors ideally are indicative of the change in the surface snow pack through an increase in NDSI and Tb. Field data of snow surface and depth properties will be used to confirm if such an approach would be viable for monitoring snow pack evolution from combined TERRA/AQUA daily MODIS acquisitions during the melt season.

C41B-0969 0830h POSTER

Seasonal and Interannual Variability in Colorado River and Rio Grande Snowcover Patterns: 1995-2002

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Snow covered area (SCA) maps gridded at 1-km^2 were analyzed to assess the persistence of snowcover in the Southwestern U.S. The maps used were derived from AVHRR scenes using a three-part cloud masking procedure and spectral unmixing algorithm, and give fractional snow cover per 1-km^2 pixel. Areas with persistent snowcover exceeding 25% SCA were relatively reproducible from year to year, corresponding to higher elevations. However, there were different January through June patterns of snowcover persistence during recent drought years as compared to previous years. Differences reflect both seasonal timing of snowfall and different temperature patterns. The annual maximum snow extent, or area with any snowcover during the year, exhibited significant interannual variability, and was not well correlated with maximum snow water equivalent. Cloud persistence over the January through June snow season also showed significant interannual variability, and was in part responsible for differences in the apparent SCA. There were as few as 3 and as many as 18 cloud-free days when snow on all or part of the area of interest could be mapped.

C41B-0970 0830h POSTER

Time Series of Snow Covered Area for Hydrologic Response Units of the Tom River Basin, Russia, from Satellite Imagery, 1980-1985

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The seasonal snowpack dynamics of the Eurasian mountains and Siberian plains play a critical role in the freshwater fluxes of northern rivers into the Arctic Ocean. This study is part of a larger project whose goal is to analyze the freshwater discharge of the Ob' River (Russia) to the Arctic, using satellite remote sensing and hydrologic modeling on a daily time step. Using AVHRR Polar Pathfinder imagery obtained from the National Snow and Ice Data Center (NSIDC), time series of snow cover (accumulation through depletion) are created for hydrologic response units (HRUs) of the Tom River, a tributary of the Ob'. Sub-watersheds and HRUs of the Tom watershed are delineated using digital elevation and land use/land cover data within a Geographical Information System. All digital data are reprojected to the equal area azimuthal EASE-Grid of the NSIDC imagery. Daily remotely-sensed snow images for 1980 to 1985 are overlaid on the HRUs to give time series of percent snow cover for each HRU. These time series are compared with model-generated HRU snow cover, allowing us to evaluate the performance of the model's snow sub-routines in a spatially distributed manner. This study will contribute to better modeling and understanding of snow accumulation and depletion processes, which serve as important and climate-sensitive controls on the fresh water fluxes of Arctic river basins.

C41B-0971 0830h POSTER

Inter-Decadal Variations of the Near-Surface Freeze/Thaw Cycle of Soils in the Northern Hemisphere

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Understanding of the near-surface freeze/thaw cycle of soils is prerequisite for evaluating the impact of cold season/cold region processes on surface and subsurface hydrology, regional and global climate, carbon exchange between the atmosphere and the land, and the terrestrial ecosystem as a whole. Change in the freeze/thaw cycle of soils is also a good indicator and integrator of climate and environmental change. A frozen soil algorithm was developed at the National Snow and Ice Data Center to detect the near-surface soil freeze/thaw cycle over snow-free and snow-cover land surface. The frozen soil algorithm consists of two parts: (i) over snow-free land areas, passive microwave satellite remote sensing algorithm was used to detect the near-surface soil freeze-thaw cycle; (ii) over snow-covered land areas, a one-dimensional numerical heat transfer model with phase change was used to detect soil freeze-thaw status under snow cover. The frozen soil algorithm has been validated with the accuracy of approximately 83 percent in the contiguous United States. The frozen soil algorithm was applied to investigate the near-surface soil freeze-thaw status in the Northern Hemisphere for the period from 1978 through 2002. Passive microwave satellite remote sensing data of SMMR and SSM/I are used in the analysis. The timing, area extent, frequency, and length of the near-surface soil freeze period are investigated. The preliminary results indicate that the maximum area extent of frozen ground can be up to 60 percent of the exposed land surface with significant inter-annual variations in the Northern Hemisphere. The duration of the seasonally frozen ground ranges from less than one month in the south to over eight months in high altitude and latitude regions. The actual number of days of soil freezing varies from a few weeks to more than several months. The near-surface soil freeze/thaw cycle is characterized by low frequency (less than 5 times per winter) and long duration (greater than 2 months per cycle) at high elevation and latitude regions, by high frequency (greater than 10 times per winter) and short duration (less than 2 weeks per cycle) in the middle latitudes, and by low frequency (less than 5 times per winter) and short duration (less than 2 weeks per cycle) in lower latitude regions. The time series (1978-2002) analysis indicates that in general maximum area extent decreased and the last date of soil freezing in spring became earlier, while there were significant variations from different regions.

C41B-0972 0830h POSTER

Snow Cover Depletion and Soil Moisture Recharge at Three Cold Land Processes Experiment (CLPX) Meteorological Sites

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With increasing concern regarding water supply in arid and semiarid regions, knowledge of water resources in the Earth's cold regions is critical. Snow-cover depletion and soil moisture recharge are elements used in hydrologic modeling and climate modeling, as well as remote sensing applications. Modeled snow-cover depletion and soil moisture recharge are important parameters in hydrologic forecasting. We evaluate the ability of a one-dimensional mass and energy balance model (SNTHERM.89) to predict snow-cover depletion and to test the accuracy of Fast All season Soil STrength (FASST) in modeling the evolution of soil moisture recharge based on data from three NASA Cold Land Processes Experiment (CLPX) sites. The objective is to evaluate the model's ability to predict observations at three CLPX sites: Buffalo Pass (near Steamboat Springs, CO); St. Louis Creek (in the Fraser Experimental Forest, CO); and Illinois River (located in North Park, CO). The three sites were chosen for their diverse climatic and physiographic differences. The Buffalo Pass site has a deep snowpack with discontinuous forest cover dominated by Englemann spruce (Picea englemannii) and alpine fir (Abies lasiocarpa). The St. Louis site has a moderate snowpack depth and forest cover dominated by lodgepole pine (Pinus contorta). The Illinois River site is irrigated grassland with no forest cover.

C41B-0973 0830h POSTER

Spectral Signatures of Snow Depth Time Series

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Studies of complex systems have demonstrated that system behavior can be characterized from analysis of a single observable parameter. Initial results from this study suggest that one measured variable, change in snow depth, exhibits nonlinear behavior characteristic of a self-organizing complex system. Investigation of the behavior of this parameter provides insight into the complex nature of the seasonal snow system and sources of nonlinearity in system interactions. A pilot study, using data from a single observing station, demonstrated a "$1/\mathcal{F}$" power spectrum in a time series of change in snow depth, a time scaling consistent with self-organization in a complex system. Further, this "$1/\mathcal{F}$" power spectrum existed only within the accumulation (positive depth change) subset of the data, while the ablation (negative depth change) subset exhibited a "white noise" spectrum; this suggests that complex atmospheric dynamics and resultant precipitation patterns are significant forcing agents potentially driving nonlinear interactions in the seasonal snow system. To further explore the dynamics revealed by the change in snow depth parameter, a second analysis has been undertaken, using data from several observing stations. Snow depth measurements are used from meteorologic stations implemented through the NASA Cold Lands Processes Experiment (CLPX) in the 2001/2002 and 2002/2003 snow seasons. The data is averaged to produce an hourly measurement interval, and detrended by first difference to remove seasonal accumulation trends, leading to the "hourly change in snow depth" parameter used for analysis. Power spectra for each of the time series in the study display a range of frequency exponents consistent with the pilot study results, in that the ablation subset tends toward a white noise signature, while the accumulation subset commonly shows "$1/\mathcal{F}$" scaling.

C41B-0974 0830h POSTER

Wavelet analysis of Snow course data within the Sierra Nevada Mountains

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In recent years, an analytical method known as wavelet analysis has received increasing applications in geophysical fields (Foufoula-Georgiou and Kumar 1994). Wavelet analysis can be used to identify the time and frequency regime in data while still maintaining the time coordinate. By applying the wavelet analysis method to the Mount Shasta snow course for the time period from 1937-1997 using the continuous 1-D wavelet toolbox in MATLAB, we found that several frequency regimes are present within the signal. The inter-annual noise dominates the frequency regime below the seven-year scale, but there is a relatively consistent 9-13 year oscillation that is present within the snow data. This frequency regime is also observed to shift to lower scales as the time series progresses, possibly indicating a shift in the climate variability due to climate change. In addition, analyses of the depth and the water content data exhibit nearly identical wavelet images. We are currently in the process of identifying other climate variables that may exhibit similar periodicity with the continuous 1-D wavelet analysis, such as the PDO and ENSO. Preliminary results show that by analyzing the hydrologic variables of the Sierra Nevada snowpack depth and/or water content using the wavelet method, we may be able to provide useful insights into the synergy and expression of climate change and variability within the California Sierra Nevadas.

C41B-0975 0830h POSTER

An Analysis of Snow Processes Within a Regional Climate Model

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The Penn Sate-National Center for Atmospheric Research fifth-generation Mesoscale Model (MM5) driven by a 6-hourly reanalysis dataset from the National Centers for Environmental Prediction has been used to study the impact of snowpack on climate variability and the mechanisms of snowmelt over the Sierra Nevada region. The analyses of a one way nested 48km to 12km model run during the 1998 snowmelt season (April - June) showed that the underestimated snowpack resulted when there was stronger precipitation and higher temperature. An observed daily snowpack dataset collected from the automated Snowpack Telemetry system was assimilated in the model to improve its performance. The results showed that the assimilation processes greatly reduced the warm bias because the energy used to increase the temperature in the original model run was consumed by snowmelt. The cooled surface led to a more stable simulated atmospheric structure, reduced the intensity of spring storms, and therefore, suppressed the exaggerated precipitation. In the meantime, both atmospheric and land-surface conditions affected the snowmelt rate in the region studied. The faster snowmelt positively correlated with high pressure, which resulted in stronger downward solar radiation due to fewer clouds and brought warm air from the tropical Pacific Ocean to the region. The

variation of vegetation fraction also strongly affected the snowmelt because it modified surface albedo and changed the radiative forcings on the snow surface. However, the exaggerated snowmelt was produced by the land-surface model in the version of MM5 used in this study because of the lower simulated surface albedo and the neglect of the effects of vegetation fraction on snowmelt. Thus, a realistic physically based land-surface scheme in a meso-scale model is crucial to predictions of snowmelt, which is essential to the climate variability and water resources in the Sierra Nevada region.

URL: http://esd.lbl.gov/RCC

C41C MCC: Level 2 Thursday 0830h

International Polar Year 2007-2008 III Posters *(joint with A, B, G, H, OS, PP, S, ED, GC)*

Presiding: **C Elfring,** Polar Research Board, The National Academies**; S Drobot,** Polar Research Board, The National Academies

C41C-0976 0830h POSTER

Measurement of Key Polar Climate Variables in IPY4 Through Deployment of an International Fleet of Robotic Vehicles

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At the present time sea ice thickness distribution is understood to be a crucial variable that is descriptive of polar climate in a complex, integrative sense such that its determination over time is a significant priority. As it happens, the sea ice distribution is also a challenging determination given ideal circumstances of platforms and instrumentation, and these circumstances are not reliably extant. The standard approaches to sea ice information, ice-capable ships and satellites, do not at this time provide a workable strategy; ships cannot supply the coverage and satellites have not been equipped with proper instrumentation, which is in fact just now entering development phase. A strategy with promise for obtaining sea ice thickness in addition to other significant surface variables is the deployment of instrumented robotic vehicles; a particularly useful vehicle design is the Inflatable Rover under consideration for use on Mars. These vehicles can travel a 1-3 kilometers per hour powered by solar energy and can thus accomplish a major traverse in a 100-day deployment. The program we put forward calls for an international fleet of suitably designed rovers, each measuring useful variables relating to ice, snow, atmosphere, radiation, etc. In addition the rovers could collaborate in such tasks as monitoring each others activities, aiding in calibration and maintenance, and the like. Each rover could involve 2-3 co-investigators from different institutions and countries. Rover data would be satellite linked allowing K-12 monitoring of progress of the fleet. This IPY4 project integrates new technology into polar science, would engage the public and schoolchildren, could serve as a means of international cooperation, and all the while collects valuable climate change data. This work performed under contract to NASA.

C41C-0977 0830h POSTER

Polar Ocean-Atmosphere-Sea Ice-Snowpack Interactions, and Global Change

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Studies of atmospheric and snow composition over the past few decades have revealed that there is very active exchange of gases and particles between the atmosphere and the surface in polar regions. Furthermore, it is now known that solar radiation can greatly modify the nature of these exchange processes, both in terms of the rates, and in terms of the nature of chemical species that are exchanged. For example, it is known that NOx, carbonyl compounds, and molecular halogens can be chemically/photochemically produced in snowpacks and sea ice, followed by their emission into the atmosphere where they can influence the abundance of radiatively active gases like O3, particles, and persistent organic pollutants. Given that the coverage of snow and sea ice is changing, a more quantitative understanding of these processes is necessary, to enable more reliable prediction of the future state of the atmosphere. Here we will discuss new internationally coordinated research activities (including the Ocean-Atmosphere-Sea Ice-Snowpack (OASIS) program) aimed at improving our understanding of chemical species exchange between the polar surfaces, oceans, and the atmosphere, and how they relate to the International Polar Year.

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The IGAC Air-Ice Chemical Interactions (AICI) Task and the IPY

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The new structure of IGBP focuses on study of the three main compartments (land, ocean, and atmosphere) and the exchanges and interactions between them. The cryosphere - ice, snow and permafrost - occurs in all three of these compartments. It forms a large proportion of the surface separating the land and ocean from the atmosphere: a seasonal maximum of 40% of land is covered by snow or ice, while several percent of the ocean is sea-ice covered. Recent observations in the Arctic and in Antarctica indicate that the snowpack is photochemically active, producing and emitting to the atmosphere a variety of photochemically active compounds such as HCHO and other carbonyl compounds, NOx, HONO, molecular halogens, and alkyl halides, which can significantly impact the composition of the overlying atmosphere. It is known that ozone can be photochemically destroyed within the snowpack, and in the overlying atmosphere as a result of photochemistry involving halogen species generated within and emitted from the snowpack. Because global change will result in changes to snow cover, and because these processes are currently ill-defined and thus difficult to predict with accuracy, an international coordinated effort regarding the role of ice and snow in atmospheric composition is needed. We have created the Air-Ice Chemical Interactions (AICI) project, as a new task within the IGBP IGAC Project. In this paper, we will discuss AICI, its structure, function, and future plans, in relation to the following scientific questions:

- How will changing amounts of sea ice, snow cover, and atmospheric ice alter atmospheric chemistry and composition and are there important feedbacks to climate?
- What are the present regional emissions and losses over snow, ice and sea ice, and how could they alter with changing climate?

Until now, our knowledge of polar tropospheric chemistry has been limited to a few, mainly coastal sites. The IPY offers an opportunity for a coordinated effort to determine the spatial and seasonal structure of the phenomena that have been observed. This could be done through concerted observations at manned stations, from airborne platforms, and using a network of autonomous sensors deployed throughout the Arctic and Antarctic.

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The Arctic Grand Challenge: Abrupt Climate Change

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Trouble in polar paradise (Science, 08/30/02), significant changes in the Arctic environment are scientifically documented (R.E. Moritz et al. ibid.). More trouble, lots more, "abrupt climate change," (R. B. Alley, et al. Science 03/28/03). R. Corell, Arctic Climate Impact Assessment team (ACIA), "If you want to see what will happen in the rest of the world 25 years from now just look what's happening in the Arctic," (Arctic Council meeting, Iceland, 08/03). What to do? Make abrupt Arctic climate change a grand challenge for the IPY-4 and beyond! Scientifically:Describe the "state" of the Arctic climate system as succinctly as possible and accept it as the point of departure.Develop a hypothesis and criteria what constitutes "abrupt climate change," in the Arctic that can be tested with observations. Observations: Bring to bear existing observations and coordinate new investments in observations through an IPY-4 scientific management committee. Make the new Barrow, Alaska, Global Climate Change Research Facility a major U.S. contribution and focal point for the IPY-4 in the U.S Arctic. Arctic populations, Native peoples: The people of the North are living already, daily, with wrenching change, encroaching on their habitats and cultures. For them "the earth is faster now," (I. Krupnik and D. Jolly, ARCUS, 2002). From a political, economic, social and entirely realistic perspective, an Arctic grand challenge without the total integration of the Native peoples in this effort cannot succeed. Therefore: Communications must be established, and the respective Native entities must be approached with the determination to create well founded, well functioning, enduring partnerships. In the U.S. Arctic, Barrow with its long history of involvement and active support of science and with the new global climate change research facility should be the focal point of choice Private industry: Resource extraction in the Arctic followed by oil and gas consumption, return the combustion products as greenhouse gases to their regions of origin. Thus multinational company operations are affected by their own activities. There is a strong, convincing case, that these industrial giants must be involved in Arctic partnerships of the grand challenge. A most instructive, very successful example is the collaboration by the chemical companies after the discovery of the polar ozone holes, followed by the replacement of the culprit chlorofluorocarbon compounds. Public relations and involvement/education: The IPY offers a unique opportunity to showcase and drive home, into homes, the seriousness of the issue, Hollywood/Madison Avenue/ NASA style, nothing else will do. Ultimately we need to be mindful that "civilizations are ephemeral compared to species. -What we need is a primer on science, clearly written and unambiguous in its meaning-a primer for anyone interested in the state of the Earth and how to survive and live well on it." (James Lovelock, Science, 08/05/98). - Let's start in the Arctic-NOW.

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Observing the Arctic From Space: Educational Opportunities for an International Polar Year

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Recommendations for an International Polar Year (IPY) will require integrated circumpolar research projects using present and advanced technologies. The IPY will offer exceptional opportunities for participation by indigenous residents of the Arctic. Educational outreach will be an essential component of IPY programs, to improve science competence and citizen awareness through participation in IPY projects and utilization of educational products. An important and practical objective of IPY educational outreach is to recognize that the earth is a system and that it is best from space that we can acquire seasonal and secular atmospheric, terrestrial and oceanic environmental data. Acquisition of reliable ground truth data in support of remote sensing of geophysical and geochemical variables will be essential, especially with broad long-term coverage in the polar regions. It should be an essential element of the IPY program. In the United States NASA has developed a strategy for long-term monitoring of some key parameters needed to bring us closer to the answers we need regarding climate change in the Arctic and polar regions. Technology consists of a group of five polar satellites that make a suite of earth observations referred to as the "A-Train". Data from this group of satellites, as well as from the Orbital Carbon Observatory (OCO) and older Quikscat and new Seawinds radar missions, will provide focus for an education program based not only on the acquisition of polar data but also on how these data correlate with global observations. We recommend that an educational outreach secretariat be developed for each national program that will involve the indigenous people