Winter Precipitation, Sublimation, and Snow-Depth in the Pan-Arctic: Critical Processes and a Half Century of Change

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► In its simplest form, the winter (below freezing) arctic surface moisture balance is given by

\[ \zeta = P - S \]  

where \( \zeta \) is the snow-water-equivalent depth, \( P \) is precipitation, and \( S \) is sublimation.

1) We have shown that we can measure \( \zeta \) in the Arctic (see the suite of Sturm and Liston publications).

2) Accurate precipitation (P) observations are very limited throughout the Arctic, because of precipitation gauge inaccuracies due to high winds and blowing snow, and the sparse station network.

3) Our knowledge of winter sublimation (S) is even worse. S is not routinely measured anywhere, and sublimation models require additional development and testing.
Fundamental questions concerning arctic winter sublimation rates and conditions remain unanswered. Resolving these is essential if we are to close local, regional, and/or pan-Arctic moisture budgets, because the evidence indicates that sublimation (S) can be a substantial fraction (between 15 and 50%) of the total winter precipitation.

Figure 1. Simulated 1995 Kaparuk basin (in arctic Alaska) (a) end-of-winter snow-water-equivalent (swe) depth distribution, and (b) fraction of winter precipitation returned to the atmosphere by sublimation (Liston and Sturm, 2002: J. Hydrometeorology).
PROPOSED WORK

► We will investigate winter sublimation processes in order to improve and develop models and methods that will allow us to evaluate $S$ in Equation [1] with accuracy and reliability over a wide range of atmospheric conditions.

► This knowledge, coupled with measurements of snow depth ($\zeta$), will then allow us to compute $P$ at stations where $P$ is either not reported, or where, more likely, it is inaccurate.

► We will apply this method to pan-Arctic station and gridded model data, producing records of $P$, $S$, and $\zeta$ for each station that, in some cases, will extend back 50 years.

Our research program has three components/tasks:

1) Investigate snow sublimation process over a wide range of environments on land and sea ice by making direct sublimation measurements;

2) Refine and enhance sublimation model components; and

3) Use 1) and 2) to compute $P$, $S$, and $\zeta$ values using pan-Arctic meteorological data spanning the last 50 years, and examine the resulting time series for trends in both time and space.
TASK 1: Snow Sublimation Processes: Eddy Correlation Measurements

► We will implement a multi-year field campaign using eddy correlation towers to measure surface fluxes of heat, moisture, and momentum over a wide range of snow, vegetation, sea ice, and atmospheric conditions.

► We will supplement our measurements by collaborating with J. Pomeroy and his group working at Trail Creek in the MacKenzie Basin, Canada, and with Y. Kodama, working in the Lena Basin, Russia.

► The measurements will be made along a transect extending from Fairbanks in the boreal forest, across the tundra of arctic Alaska, and on to the sea ice north of Prudhoe Bay.

Table 1. Eddy correlation tower instruments.

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Parameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Campbell CSAT3 Sonic Anemometer</td>
<td>$w', u', v', T'$</td>
</tr>
<tr>
<td>Campbell KH20 Krypton Hygrometer</td>
<td>$\rho_v'$ (vapor pressure)</td>
</tr>
<tr>
<td>Campbell/Vaisala HMP35CF Hygrothermometer</td>
<td>$T, RH$</td>
</tr>
<tr>
<td>Campbell SR50 Ultrasonic Snow Depth Gauge</td>
<td>Snow depth</td>
</tr>
<tr>
<td>REBS Q7 Net Radiometer</td>
<td>$Q^*$</td>
</tr>
<tr>
<td>REBS Soil Heat Flux Plate</td>
<td>$Q_g$</td>
</tr>
<tr>
<td>video camera</td>
<td>Exposed vegetation</td>
</tr>
<tr>
<td>2.5 KW generator</td>
<td></td>
</tr>
<tr>
<td>Campbell 5000 data logger</td>
<td></td>
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</tbody>
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TASK 2: Snow Sublimation Processes: Improving Model Physics

- We will develop a model of snow sublimation that incorporates the improvements and alternate physics suggested by our measurement program and literature reviews.

- This model will need to be capable of handling sublimation process from the boreal forest to the sea ice.

- The basis of the model will be the sublimation subroutine that is currently part of SnowTran-3D (Liston and Sturm 1998).

A Blowing and Drifting Snow Model (SnowTran-3D)
(Liston and Sturm (1998) J. Glaciology, 44, 498-516)
TASK 3: Evaluating Fifty Years of Arctic P, S, and $\zeta$

► We will generate a pan-Arctic sublimation and precipitation data set. The key to implementing this lies in having pan-Arctic data sets that will allow us to solve Equation [1] for precipitation, with the necessary data to model S as outlined in the previous sections.

► For this purpose, we will use three global atmospheric data sets (we welcome any others!):

1) Global Summary of the Day station data, 1973-present. This data set contains the following daily variables: average and daily maximum and minimum air temperature; station pressure; sea level pressure; average wind speed and maximum daily wind gust; dew point temperature; visibility; precipitation; and snow depth on ground.

2) NCAR/NCEP reanalysis products (1948 - present).

3) ECMWF global reanalysis (ERA). The latest ERA-40 reanalysis (covering the period middle 1957-2001, with products on approximately $1^\circ$ latitude-longitude grids), will be available (in 2003) for our proposed work.