A SHEBA Testbed for Evaluating the Simulation of High-Latitude Atmospheric and Cryospheric Processes

Gijs de Boer

CESM Polar Climate Working Group, 16 February, 2012
Introduction to SHEBA

SHEBA Objectives:

• Support the analysis and interpretation of physical processes that control the surface heat and mass balance and contribute to ice-albedo and cloud-radiation feedback mechanisms,

• Construct and test realistic models and parameterizations of these physical processes on the local and aggregate scales, and

• Provide initial condition, boundary conditions, forcing functions, and test data to support SHEBA modeling efforts.

(Uttal et al., 2002 [BAMS])
Introduction to SHEBA

SHEBA Measurements:

**Atmosphere:** Surface meteorology (T, RH, wind, cloud fraction, pressure, precipitation), 10m and 20m tower meteorology, surface fluxes (radiative, heat), cloud properties (height, thickness, phase, water path), radiosondes for upper air soundings, tethered balloon soundings*

**Ice:** Ice thickness, snow depth, ice stress, thickness distribution*, soot content*, spatial snow cover*, albedo*, ice motion*, melt pond fraction

**Ocean:** Temperature, salinity, conductivity, density, current, salinity flux, turbulent heat flux, lead temperature*, lead salinity*, optical properties*

*Seasonal only

Additional Datasets:

**Reanalysis products:** ERA-40, ERA-Interim, JRA, NCEP1, NCEP2 -- interpolated to the SHEBA ship location for the entire year.

**Satellite products**
Previous SHEBA Model Studies

Applications of SHEBA/FIRE data to evaluation of snow/ice albedo parameterizations

J. A. Curry and J. L. Schramm
Program in Atmospheric and Oceanic Sciences, Department of Aerospace Engineering Sciences, University of Colorado, Boulder

D. K. Perovich
U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire

J. O. Pinto
Program in Atmospheric and Oceanic Sciences, Department of Aerospace Engineering Sciences, University of Colorado, Boulder

Model Simulations of the Arctic Atmospheric Boundary Layer from the SHEBA Year

Michael Tjemestrøm, Mark Zagar and Gunilla Svensson

An improved single-column model representation of ocean mixing associated with summertime leads: Results from a SHEBA case study

Marika M. Holland
National Center for Atmospheric Research, Boulder, Colorado, USA
Planned Simulations

As part of the PCWG CSL Proposal:
- 2 degree FV CESM CAM5 DART for entire SHEBA year
- 1 degree FV CESM CAM4 DART for entire SHEBA year

Outside of the PCWG CSL Proposal:
- Single column CICE simulations driven by atmospheres from CAM4/5, reanalyses and observations
- WRF LES simulations of limited cases to evaluate transitions between cloudy and clear states
Processes Of Interest

Ice Cloud Macrophysics:

(Figure courtesy of J. Kay)
Processes Of Interest

Ice Cloud Macrophysics:  (Park et al., 2010 [J. Clim.])

In CAM5, macroscale ice cloud fraction diagnosed separately from liquid cloud fraction. For initially clear sky, ice cloud fraction within the grid box:

\[ CF_i = \min(1, RH_d^2) \]

Where:

\[ RH_d = \max \left( 0, \frac{RH_{ice} - 0.8}{0.3} \right) \]

For Liquid:

\[
CF_{liq, st} = \begin{cases} 
1 & \text{if} \quad RH_{liq} \geq 1 \\
1 - \left[ \frac{3}{\sqrt{2}} \left( \frac{RH_{liq} - RH_{cl}}{1 - RH_{cl}} \right) \right]^{2/3} & \frac{1}{6} (5 + RH_{cl}) \leq RH_{liq} \leq 1 \\
4 \cos \left[ \frac{1}{3} \left( \cos \left( \frac{3}{2\sqrt{2}} \left( \frac{RH_{liq} - RH_{cl}}{1 - RH_{cl}} \right) \right) - 2\pi \right) \right] & RH_{cl} \leq RH_{liq} \leq \frac{1}{6} (5 + RH_{cl}) \\
0 & RH_{liq} \leq RH_{cl}
\end{cases}
\]
Processes Of Interest

Ice Cloud Macrophysics:
Processes Of Interest

Ice Cloud Macrophysics:

Land

Ocean
### Processes Of Interest

**Ice Cloud Macrophysics:**

<table>
<thead>
<tr>
<th>Temperature (K)</th>
<th>RH</th>
<th>liq (%)</th>
</tr>
</thead>
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</tr>
<tr>
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<td>0.6</td>
<td>0.7</td>
</tr>
<tr>
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<td>0.7</td>
<td>0.8</td>
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<tr>
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<tr>
<td>270</td>
<td>1.0</td>
<td></td>
</tr>
</tbody>
</table>

**Land**

**Ocean**
Processes Of Interest

Ice Macrophysics:

(de Boer et al., 2010b [GRL])
Processes Of Interest

Ice Macrophysics:

For **liquid formation**, either water vapor supply rate (from surface or large scale advection) or large scale temperature advection must be large enough to overcome sink of water vapor due to depositional growth of ice clouds.

At moderate (-25C < T < -5C) temperatures, this does not appear to happen in observations.
Processes Of Interest

Atmospheric State Analysis

(Morrison et al., 2011 [Nature Geosci.])
Processes Of Interest

Atmosphere-Ice Interaction

GCM Simulation  \(\leftrightarrow\) Reanalyses  \(\leftrightarrow\) Atmospheric Observations

Evaluate

Clouds, Precipitation, Surface Radiation

Column CICE Simulation  \(\leftrightarrow\) Ice Observations
Processes Of Interest

Aerosol Cloud Interactions

(de Boer et al., 2012 [ACP])

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Discussion

What’s the point?
• Integrated effort within the PCWG
• Increased utilization of interdisciplinary dataset for model evaluation
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Considerations:
• Process understanding vs. climate understanding
• Representativeness of SHEBA year
• Lack of Aerosol Measurements
• Others?
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• Cryosphere?
• Ocean?(?)
• Atmosphere?
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• Cryosphere?
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• Atmosphere?

Integration into funded research projects (current or future)?
• DOE Cryosphere (funded)
• EaSM RFP on Decadal and Regional Climate Prediction using Earth System Models (Deadline 5/11/12)
• Others?
References


