Model Evaluation in Central Greenland using a Comprehensive Set of Atmospheric and Surface Measurements

Nathaniel Miller (CU-ATOC, CIRES)
Matthew Shupe, Jan Lenaerts, Jennifer Kay, Ralf Bennartz, Ola Persson
Christopher Cox, David Noone, Von Walden, David Turner, Konrad Steffen

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ICECAPS
Atmospheric State and Cloud Properties
Shupe et. al. 2013, BAMS

Broadband Radiation
- Swiss Federal Institute (ETH)
- NOAA – Global Monitoring Division

Subsurface temperature, 10m, 2m measurements
- Closing the Isotope Balance at Summit (CIBS)

10m, 2m measurements
- NOAA – Global Monitoring Division
# Instrumentation

<table>
<thead>
<tr>
<th>Parameters Measured [≈heights]</th>
<th>Instrument</th>
<th>Project - Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atmospheric Temperature Profile</td>
<td>Vaisala RS92 Radiosondes</td>
<td>ICECAPS - MSF</td>
</tr>
<tr>
<td>Snow Temperature Profile</td>
<td>Campbell Scientific 107 Temp Probes</td>
<td>CIBS - 50m tower</td>
</tr>
<tr>
<td>Surface height</td>
<td>Campbell Scientific SR-50A Sonic Ranger</td>
<td>CIBS - 50m tower</td>
</tr>
<tr>
<td>Temperature [2m, 10m]</td>
<td>Logan RTD - PT139 special order</td>
<td>NOAA/GMD - met tower</td>
</tr>
<tr>
<td></td>
<td>Vaisala HMP 155 Temp probes</td>
<td>CIBS - 50m tower</td>
</tr>
<tr>
<td></td>
<td>Metek USA1 Sonic Anemometers</td>
<td>CIBS - 50m tower</td>
</tr>
<tr>
<td>Wind Speed [2m, 10m]</td>
<td>Metek USA1 Sonic Anemometers</td>
<td>CIBS - 50m tower</td>
</tr>
<tr>
<td></td>
<td>MetOne 010-CA Cup Anemometers</td>
<td>CIBS - 50m tower</td>
</tr>
<tr>
<td>Relative Humidity [2m, 10m]</td>
<td>Vaisala HMP 155 RH probes</td>
<td>CIBS - 50m tower</td>
</tr>
<tr>
<td>Water Vapor Mixing Ratio [2m, 10m]</td>
<td>Picarro L2120 spectrometer</td>
<td>CIBS - 50m tower</td>
</tr>
<tr>
<td>Barometric Pressure</td>
<td>Setra 270</td>
<td>NOAA/GMD - met tower</td>
</tr>
<tr>
<td>LW↓, LW↑</td>
<td>Kipp and Zonen CG4 pyrgeometers</td>
<td>ETH - Radiation Station</td>
</tr>
<tr>
<td></td>
<td>Eppley PIR pyrgeometers</td>
<td>NOAA/GMD - Radiation Station</td>
</tr>
<tr>
<td>SW↓, SW↑</td>
<td>Kipp and Zonen CM22 pyranometers</td>
<td>ETH - Radiation Station</td>
</tr>
<tr>
<td></td>
<td>Kipp and Zonen CM22 pyranometers</td>
<td>NOAA/GMD - Radiation Station</td>
</tr>
<tr>
<td>Liquid Water Path</td>
<td>RPG Microwave Radiometers - HATPRO and HF</td>
<td>ICECAPS - MSF</td>
</tr>
<tr>
<td>Precipitable Water Vapor</td>
<td>RPG Microwave Radiometers - HATPRO and HF</td>
<td>ICECAPS - MSF</td>
</tr>
<tr>
<td>Cloud Occurrence</td>
<td>Millimeter Cloud Radar - 35 GHz</td>
<td>ICECAPS - MSF</td>
</tr>
</tbody>
</table>
Temperature Profiles

![Temperature Profiles Diagram](image)

(a) 

(b)
Define a positive flux as warming the surface

\[ \text{SEB} = \text{SW}_{\text{down}} - \text{SW}_{\text{up}} + \text{LW}_{\text{down}} - \text{LW}_{\text{up}} + H_{\text{sensible}} + H_{\text{latent}} + C + S \]

All components available for 1 year
July 2013 – June 2014

- **Broadband Radiation** - Swiss Federal Institute (ETH)
- **Sensible heat Flux** - Bulk Aerodynamic method (Persson et. al. 2002, JGR) and Eddy Covariance method
- **Latent Heat Flux** - Gradient 2-level method Stability Functions from Cullen 2003
- **Conductive Heat Flux (C)** - Thermistor String
- **Heat storage (S)** - Thermistor String
Annual Diurnal Cycle

(a) Total Radiative Flux

(b) Sensible Heat Flux

(c) Conductive Heat Flux

(d) Latent Heat Flux

Hour of the Day [UTC]

Month of Year

Wm$^{-2}$
High year round cloud fraction – 86%
- Ice-clouds are important to CRF
- LW CRF magnitude corresponds to the presence of liquid-bearing clouds
Surface albedo important for CRF

Central Greenland is a unique Arctic location

Miller et. al. 2015, J. Climate
Dong et. al. 2010, JGR
Shupe and Intrieri 2004, J. of Climate
Kay and L’Ecuyer 2013, JGR
Influence of Liquid-bearing Clouds and Insolation

Forcing terms

SZA < 70°, ws < 8 m s⁻¹
SZA > 90°, ws < 8 m s⁻¹

(a) Downwelling LW + net SW [W m⁻²]
(b) Surface Temperature [°C]
(c) Upwelling LW [W m⁻²]
(d) Bulk Richardson number
Response to Forcing terms
Response to Forcing terms

[Diagrams showing scatter plots with regression lines and slopes labeled: (a) slope = -1.010, (b) slope = 0.699, (c) slope = -0.101, (d) slope = -0.106, (e) slope = -0.0337.]
Annual responses

![Graph showing annual responses to (LWdown + SWnet)](image)

- LH + SH + C + S - LWup
- SH
- LH
- C
- S
- LWup

July 2013 - June 2014

All available data
SEB responses to CRF

(a) Cloud Radiative Forcing
\((-1.0) \times \text{SH response}\)
\((-1.0) \times \text{LH response}\)
\((-1.0) \times \text{G response}\)
\text{LWup response}

(b)
Forcing

LWdn + SWnet [W m$^{-2}$]

Albedo [SWup/SWdn]

ERA-I
ERA-I: 1year
Obs: 1year
Obs

LWP [g m$^{-2}$]
Community Earth System Model
Beta07 – CAM6, CLM5

LH + SH + G - LWup
SH
LH
G
-LWup

Obs: July 2013 - June 2014
Obs: All available
CESM: 1-year

Response of energy flux(es) to (LWdown + SWnet)

Month
J F M A M J J A S O N D
Climate Forecast System Reanalysis

![Graph showing response of energy fluxes to LWdown + SWnet

- LH + SH + G - LWup
- SH
- LH
- G
- LWup

Observations: All available

Respons of energy fluxes to LWdown + SWnet

Month: J F M A M J J A S O N D

Values: -1.2 -1.0 -0.8 -0.6 -0.4 -0.2 0.0

Graph represents the response of energy fluxes to LWdown + SWnet for different variables over time, with observations from all available sources and CFSR data from January 2011 to October 2016.
Conclusions

• Highly emissive GIS corresponds to a large response of the surface temperature
  – Strong radiative cooling under clear skies
  – Clouds can induce a warming of the surface on the same order as that of insolation due to the GIS being highly reflective in the shortwave

• Response of the non radiative SEB terms
  – Ground heat flux is the largest response
  – SH flux response is fairly constant throughout the annual cycle.
  – LH flux response is largest in the summer

• Process-based relationships indicate where there are deficiencies in representing GIS surface temperature variability.

• Data available - https://arcticdata.io/catalog/#view/doi:10.18739/A2Z37J
Thank you

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- David Noone’s project - Closing the Isotope Balance at Summit (CIBS)

- The Swiss Federal Institute (ETH) provided the ETH broadband radiometer measurements.

- Additional broadband radiation measurements, and near-surface meteorological tower data are provided by the National Oceanic and Atmospheric Administration’s Global Monitoring Division.

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