Validating CERES Surface Irradiance in the Arctic with Airborne Radiometer Measurements from the ARISE Campaign

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CERES Science Team Meeting Spring 2017
Arctic Radiation-IceBridge Sea & Ice Experiment

Based in Fairbanks, Alaska during September 2014

From the NASA C-130:

- Measure spectral and broadband radiative fluxes
- Quantify surface characteristics, cloud properties, and other atmospheric state parameters under a variety of Arctic atmospheric and surface conditions
- Coincide with satellite overpasses as often as possible
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- Coincide with satellite overpasses as often as possible

Naval Research Laboratory Broadband Radiometers (BBR):

- SW up and down – modified Kipp and Zonen CM-22 pyranometers
- LW up and down – modified Kipp and Zonen CG-4 pyrgeometers
- estimated uncertainty ~ 3-5%
CERES SYN and Existing Arctic Validation

Clouds and the Earth’s Radiant Energy System Edition 4A
Synoptic Dataset (CERES SYN):

• Hourly SW and LW up-welling and down-welling computed surface fluxes on a 1°x1° grid
• Cloud properties from MODIS
• Atmosphere from GEOS 5.4.1
• Tuned to CERES TOA measurements
CERES SYN and Existing Arctic Validation

Clouds and the Earth’s Radiant Energy System Edition 4A Synoptic Dataset (CERES SYN):

- Hourly SW and LW up-welling and down-welling computed surface fluxes
- Cloud properties from MODIS
- Atmosphere from GEOS 5.4.1
- Tuned to CERES TOA measurements

Current estimate of uncertainty in the Arctic (monthly mean):
- Down welling SW: 12 Wm\(^{-2}\)
- Down welling LW: 21 Wm\(^{-2}\)
Comparing CERES SYN and BBR

3 Comparisons:
1. CERES SYN and BBR:
   - Compare the mean SYN SW and LW, upwards and downwards irradiances with corresponding mean measured BBR irradiances.
Comparing CERES SYN and BBR

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1. CERES SYN and BBR:
   • Compare the mean SYN SW and LW, upwards and downwards irradiances with corresponding mean measured BBR irradiances.

2. Model irradiances and BBR
   • Use the Langley Fu-Liou radiative transfer model, with standard CERES inputs to calculate irradiances at aircraft level collocated with each 1-min averaged BBR measurement.
   • Gives “SYN-like” fluxes with same spatial and temporal sampling as BBR
Comparing CERES SYN and BBR

3 Comparisons:

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   • Gives “SYN-like” fluxes with same spatial and temporal sampling as BBR

3. Model irradiances with additional aircraft observations and BBR
   • Use the Langley Fu-Liou radiative transfer model, replacing some of the standard CERES inputs with ancillary measurements taken from the aircraft.
   • Tests the effect of changing inputs on the comparison
CERES SYN and ARISE

September 9th

September 13th
Scene Conditions

September 9th

Aqua 20:59

Terra 22:17

Aqua 22:37

Terra 23:55
Scene Conditions

September 9th

<table>
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September 13th

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<tr>
<td>Aqua 22:12</td>
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Comparison between CERES and BBR - 9th

\[ \Delta F = 19.0 \quad (6.4\%) \]

\[ \Delta F = -16.9 \quad (-39.5\%) \]

\[ \Delta F = 22.5 \quad (8\%) \]

\[ \Delta F = 11.8 \quad (6.8\%) \]
Comparison between CERES and BBR - 9th

**LW Up**

\[ \Delta F = 19.0 \quad (6.4\%) \]

**SW Up**

\[ \Delta F = -16.9 \quad (-39.5\%) \]

**LW Down**

\[ \Delta F = 17.0 \quad (5.7\%) \]

\[ \text{RMS} = 17.2 \]

\[ \Delta F = 22.5 \quad (8\%) \]

\[ \text{RMS} = 17.8 \]

**SW Down**

\[ \Delta F = -6.3 \quad (-14.7\%) \]

\[ \text{RMS} = 23.8 \]

\[ \Delta F = 11.8 \quad (6.8\%) \]

\[ \text{RMS} = 51.9 \]

**Comparison between CERES and BBR - 9th**

\[ \Delta F = 4.7 \quad (1.7\%) \]

\[ \text{RMS} = 17.8 \]

\[ \Delta F = 29.5 \quad (17\%) \]

\[ \text{RMS} = 51.9 \]
Comparison between CERES and BBR - 13th

ΔF = -45.0 (-19%)

ΔF = 42.4 (20%)

ΔF = -35.9 (-11%)

ΔF = 9.2 (3.2%)

RMS = 9.7

ΔF = 13.0 (6.2%)

ΔF = -40.5 (-17.1%)

RMS = 21.1

ΔF = 8.4 (2.6%)

RMS = 27.4

ΔF = 9.9 (3.4%)
Comparison between CERES and BBR - 13th

**LW Up**
- \( \Delta F = 9.9 \) (3.4%)
- \( \text{RMS} = 9.7 \)

**LW Down**
- \( \Delta F = 42.4 \) (20%)
- \( \text{RMS} = 21.1 \)

**SW Up**
- \( \Delta F = -45.0 \) (-19%)
- \( \text{RMS} = 47.6 \)

**SW Down**
- \( \Delta F = -35.9 \) (-11%)
- \( \text{RMS} = 27.4 \)
Including Ancillary Aircraft Observations

Atmospheric Temperature – 9th

Skin Temperature – 9th
## Sea Ice Datasets

<table>
<thead>
<tr>
<th></th>
<th>NSIDC Near-Real time Snow and Ice Extent (NISE): Ed4A</th>
<th>NSIDC/NOAA Climate Data Record of Passive Microwave Sea Ice Concentration (CDR): CDR-ICE</th>
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<tr>
<td><strong>Instrument/Radiances</strong></td>
<td>SSMI, SSMIS on DMSP F13 and F17 19.4, 37.0 GHz Tb - NESDIS</td>
<td>SSMI, SSMIS on DMSP F13 and F17 19.4, 37.0 GHz Tb - RSS</td>
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<tr>
<td><strong>Algorithm</strong></td>
<td>GSFC NASA Team</td>
<td>Combination of GSFC NASA Team and GSFC Bootstrap</td>
</tr>
<tr>
<td><strong>Resolution</strong></td>
<td>25 Km</td>
<td>25 Km</td>
</tr>
<tr>
<td><strong>Quality Control</strong></td>
<td>Low Forward processing only</td>
<td>High Consistent algorithm over time series Grid cell uncertainty estimates and quality flags</td>
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Changing Sea Ice Data Source

Sea Ice Fraction – 9th

Sea Ice Fraction – 13th

- CDR
- NISE
Use LVIS provided images from nadir camera.

Classify pixels into either:

a) Ocean
b) Thin ice
c) Sea ice
Sea Ice Data Source Validation

2014/09/13 11:36:32

Use LVIS provided images from nadir camera.

Classify pixels into either:

a) Ocean
b) Thin ice
c) Sea ice
Sea Ice Data Source Validation
Sea Ice Data Source Validation

<table>
<thead>
<tr>
<th>Data Source</th>
<th>Sea Ice</th>
<th>Sea Ice + Thin Ice</th>
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<tbody>
<tr>
<td>CDR</td>
<td>Bias = 6.92</td>
<td>RMSE = 13.47</td>
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<tr>
<td>Sea ice</td>
<td>Bias = 0.76</td>
<td>RMSE = 2.27</td>
</tr>
<tr>
<td>NISE</td>
<td>Bias = 1.66</td>
<td>RMSE = 12.53</td>
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<tr>
<td>Sea ice</td>
<td>Bias = -4.50</td>
<td>RMSE = 6.62</td>
</tr>
<tr>
<td>Sea ice + thin ice</td>
<td>Bias = 0.76</td>
<td>RMSE = 2.27</td>
</tr>
<tr>
<td>Sea ice + thin ice</td>
<td>Bias = -4.50</td>
<td>RMSE = 6.62</td>
</tr>
</tbody>
</table>
Comparison between CERES and BBR - 9th

**LW Up**
- \( \Delta F = 19.0 \) (6.4%)
- \( \text{RMS} = 7.6 \)

**LW Down**
- \( \Delta F = 7.1 \) (2.4%)
- \( \text{RMS} = 22.5 \) (8%)

**SW Up**
- \( \Delta F = -16.9 \) (-39.5%)
- \( \text{RMS} = 25.4 \)

**SW Down**
- \( \Delta F = 2.1 \) (4.9%)
- \( \text{RMS} = 11.8 \) (6.8%)

**RMS**
- \( \Delta F = -2.7 \) (-1%)
- \( \text{RMS} = 7.6 \)

- \( \Delta F = 2.1 \) (4.9%)
- \( \text{RMS} = 25.4 \)

- \( \Delta F = 11.8 \) (6.8%)
- \( \text{RMS} = 17.4 \)

- \( \Delta F = 31.7 \) (18.3%)
- \( \text{RMS} = 53.7 \)
Comparison between CERES and BBR - 13th

Δ\( \bar{F} \) = 9.9
(3.4%)

Δ\( F \) = 9.9
(3.4%)

Δ\( F \) = 42.4
(20%)

RMS = 8.4

Δ\( F \) = 16.0
(7.6%)

RMS = 22.0

Δ\( F \) = -31.2
(-13.1%)

RMS = 49

Δ\( F \) = -35.9
(-11%)

RMS = 27.4

Δ\( F \) = 4.6
(1.4%)

RMS = 27.4
Summary

• First attempt at using aircraft observations to validate CERES surface products in the Arctic Ocean.

• We have a limited number of data points to compare with, but we can make some conclusions:
  • Differences between the SYN fluxes and BBR can be large.
  • *But* spatial and temporal sampling is important, and after accounting for that we generally get agreement to within the uncertainty for the LW.
  • The SW has worse agreement – more dependent on cloud retrievals and surface type.
  • Including atmospheric and skin temperature measurements from the aircraft generally reduces the differences between observed and calculated fluxes – highlighting the importance of accurate re-analysis datasets.
  • Sea ice dataset is important for the accurate modelling of upwelling SW flux. But determining which sea ice dataset is correct is difficult.
Including Ancillary Aircraft Observations

Atmospheric Temperature – 13th

Skin Temperature – 13th