The scientific utility of GMD surface radiation measurements

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• About 68% of the solar energy not reflected away is absorbed at the surface (Net SWdn)
• Somewhat balanced by the net LW at the surface
• The remaining net surface radiative is available for latent and sensible heat fluxes, etc.
Example Uses for Surface Radiation Observations

• Observational Studies
  – Instituted operational Radiative Flux Analysis
    • clear-sky and cloud macrophysical products
  – Magnitude and trends (John Augustine)

• Comparisons for Diagnosis and Development
  – Satellite
    • Have global coverage, but issues inferring surface radiation
  – Models
    • Also global coverage, but simplifications and assumptions
    • Weather forecast improvement (Kathy Lantz, Stan Benjamin tomorrow)
SURFRAD Seasonal Trends 1996-2017

Aggregate Winter Average: 2.9 Wm\(^{-2}\)/decade

Increasing tendency greater in summer than in winter, regionally dependent.

Aggregate Summer Average: 4.2 Wm\(^{-2}\)/decade

Decadal Slope:
- Winter: -0.8, -4.0
- Summer: +4.6, +6.7

Fort Peck: Winter -0.8, Summer +4.6
Penn State: Winter -4.0, Summer +6.7
Table Mountain: Winter +4.4, Summer +6.7
Bonneville: Winter +4.3, Summer +5.8
Desert Rock: Winter +3.2, Summer +5.8
Goodwin Creek: Winter +5.4, Summer +3.3
ISCCP FD - SURFRAD Comparison: MSCM

ISCCP-FD 280 km equal-area global grid

Meteorological Similarity Comparison Method

Comparing a 280 km X 280 km box to a point measurement somewhere in the box

If the box has 30% cloud cover and the point is experiencing 60% cloud cover, it does not make sense to compare them

Throw that comparison pair out!

Comparisons of ratio of direct over diffuse SW versus cloud fraction shows ISCCP low bias.

SURFRAD AOD shows ISCCP input AOD off by factor of 2.

Comparisons show much better agreement using half the original aerosol AOD as input to ISCCP retrievals.

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CERES SYN 1-deg surface irradiance

- From polar orbiting satellites from NASA only
- MODIS and MATCH for cloud and aerosol information
- Gridded Surface albedo, snow (land), and ice (water)
  - Snow surfaces still problematic
- Gridded ozone information used for absorption correction
- Reanalysis for atmospheric profiles and other meteorological information
- Most importantly – uses 3-hour cloud information from GOES to better account for diurnal cloud variations
CERES SYN 1-deg. vs 7 U.S. SURFRAD and 4 Antarctic Sites (2003 – 2014)

Continental US: Mean does well, (-3 LW, 0 SW) but still considerable point-by-point uncertainties.

Similar results with simulated GOES-R Series retrievals.

South Polar Sites (snow): Mean bias of 6 Wm\(^{-2}\), and considerable point-by-point uncertainties.
Surface Radiation Data Use: Models Estimating clear-sky climatologies Using BSRN sites

High resolution BSRN records (minute data)
* GMD associated with 1/3 of the BSRN sites that have contributed data to the BSRN Archive, operates 13 sites

SW clear sky algorithm
Long and Ackerman (2002) JGR
Takes into account magnitude and temporal variability of diffuse and total downward solar radiation

LW clear sky algorithm
Long and Turner (2008) JGR
Makes use of clear episodes detected by the SW algorithm and takes into account variability of downward longwave radiation, measured ambient air temperature and effective sky brightness temperature.

Clear sky BSRN data processed at ETH Zurich by Maria Hakuba with support from Chuck Long
SW down clear-sky evaluation: Biases from Observations

Individual CMIP5 Models

Biases of 39 CMIP5 models

Average bias of each model at 53 surface sites

Individual CMIP5 model biases averaged over 53 BSRN sites
Best estimates for global mean clear sky fluxes

**Surface clear-sky SW down**
GCM global means versus their biases averaged over BSRN sites

- **Clear sky global means in models (Wm\(^{-2}\))**
- **Corr. coeff.: 0.94**

- **Clearsky LW down:**
  - **247 Wm\(^{-2}\)**
  - **314 Wm\(^{-2}\)**

Model biases at observation sites (Wm\(^{-2}\))
Global All- and Clear-sky Estimates using Observations and Models

• New estimates for global mean radiation budget without cloud effects based to the extent possible on information contained in the direct observations from surface and space.

• Combined with all sky budgets allows for estimation of global mean surface, atmosphere and TOA cloud radiative effects.
Summary

• Knowledge of the surface radiative energy budget is essential to understanding the Earth-Atmosphere system

• GMD is associated with over 1/3 of the sites that have submitted data to the BSRN Archive

• These data are being used:
  – not only for climatological and trend studies
  – also in conjunction with model and satellite products for evaluation and diagnoses
  – and combined scientific studies

Thank You

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Following are Extra
Complete net surface radiative cloud forcing and cloud macrophysical properties without using any measurements typically used as input for model calculations or satellite retrievals

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Meas./Retr.</th>
<th>Comments</th>
</tr>
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<tbody>
<tr>
<td>Downwelling Total SW</td>
<td>Measured</td>
<td>Unshaded Pyranometer</td>
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<tr>
<td>Clear-sky Total SW</td>
<td>Retrieved</td>
<td>Long and Ackerman, 2000, JGR</td>
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<tr>
<td>Diffuse SW</td>
<td>Measured</td>
<td>Shaded Pyranometer</td>
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<td>Clear-sky diffuse SW</td>
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<td>Long and Ackerman, 2000, JGR</td>
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<td>Direct SW</td>
<td>Measured</td>
<td>Sun Tracking Perheliometer</td>
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<td>Clear-sky direct SW</td>
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<td>Long and Ackerman, 2000, JGR</td>
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<td>Upwelling SW</td>
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<td>Pyranometer</td>
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<tr>
<td>Clear-sky Upwelling SW</td>
<td>Retrieved</td>
<td>Long, 2005, ARM</td>
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<td>Downwelling LW</td>
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<tr>
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<td>Clear-sky Upwelling LW</td>
<td>Retrieved</td>
<td>Long, 2005, ARM</td>
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<tr>
<td>Clear-sky periods</td>
<td>Retrieved</td>
<td>Long and Ackerman, 2000, JGR [daylight only]</td>
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<tr>
<td>LW Effective Clear-sky periods</td>
<td>Retrieved</td>
<td>Long and Turner, 2008, JGR [24-hour, may be high clouds present that do not affect LW]</td>
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<tr>
<td>Air Temperature</td>
<td>Measured</td>
<td>Temperature sensor</td>
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<td>Relative Humidity</td>
<td>Measured</td>
<td>Humidity sensor</td>
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<tr>
<td>Total Sky Cover</td>
<td>Retrieved</td>
<td>Long et al., 2006, JGR [daylight only]</td>
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<tr>
<td>Cloud Vis optical depth</td>
<td>Retrieved</td>
<td>Barnard and Long, 2004, JAM; Barnard et al., 2008, TOASJ [Skycover&gt;90% only]</td>
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<tr>
<td>Cloud SW transmissivity</td>
<td>Retrieved</td>
<td>Long and Ackerman, 2000, JGR [daylight only]</td>
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<tr>
<td>Cloud radiating temperature</td>
<td>Retrieved</td>
<td>Long, 2004, ARM [LW Scv&gt;50% only]</td>
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</table>
New GOES-R surface irradiance

- 6 shortwave channels on the new Advanced Baseline Imager (ABI) – improves inference of surface and atmospheric properties
- Onboard calibration to check calibration drift
- ABI algorithm for surface SW more sophisticated than current GOES
- 4 km, 5-min. resolution over CONUS, 15-min full disk

GOES-R ABI surface SW algorithm tested with 10 years of MODIS data
Less bias in cloudy conditions