Using atmospheric regimes to assess CMIP5 models biases in the Arctic Surface Energy Budget

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Global TOA All-Sky Radiation Anomalies
(CERES_EBAF_Ed4.0; 03/2000 – 11/2016)

Absorbed Solar

- Emitted LW

NET Radiation
Arctic surface energy budget: Current Status

Christensen et al. (2016; BAMS)
CMIP5 models disagree on key Arctic SEB components…

Boeke and Taylor (2016; JGR): Evaluation of the Arctic surface radiation budget in CMIP5 models
...many of which are cloud-related.

Boeke and Taylor (2016; JGR) Evaluation of the Arctic surface radiation budget in CMIP5 models
Methodology: Regime Definition

LTS bins: 2 K
Omega500 bins: 4 hPa day$^{-1}$

Data: CERES SFC_EBAF 4.0, MERRA-2, CMIP5 models (historical simulations)
CERES LWDN surface fluxes

Winter

Summer

Direction of increasing LWDN

Stronger variations in LW fluxes are found w.r.t LTS than omega500
CERES LWUP surface fluxes

Winter

Summer

Direction of increasing LWUP
CERES Surface LW CRE

Winter

Direction of increasing LW CRE

Summer

Regions of highest frequency of occurrence
CERES SWDN surface fluxes: Summer

**SWDN_all**

**SWDN_clr**
CERES Surface SW and Net CRE

Direction of more negative SW CRE
CMIP5 Ensemble LWDN surface fluxes

Winter

Summer

Red: CMIP5 > CERES
Blue: CERES > CMIP5
CMIP5 Ensemble LWDN_clr surface fluxes

Winter

Summer

Red: CMIP5 > CERES
Blue: CERES > CMIP5
CMIP5 Ensemble LWUP surface fluxes

Winter

Summer

Red: CMIP5 > CERES

Blue: CERES > CMIP5
CMIP5 Ensemble Surface LW CRE

Winter

Summer

Red: CMIP5 > CERES
Blue: CERES > CMIP5
CMIP5 Ensemble Surface SWDN

SWDN

CMIP5 > CERES

Red: CMIP5 > CERES
Blue: CERES > CMIP5
CMIP5 Ensemble Surface SWUP

**SWUP**

- **Red**: CMIP5 > CERES
- **Blue**: CERES > CMIP5
Certain regimes do indicate a shift from a net cooling to a net warming effect.
Takeaways…

• A regime approach allows a better assessment of the implications that of model processes on the surface energy budget as well as the implication of surface energy budget errors on processes.
• Results suggest a slew of relevant and important biases in CMIP5 relative to CERES.
• Using the regime framework shows significant gradients in the sensitivity of the surface energy budget terms to small changes in LTS.
CMIP5 Ensemble mean 950 hPa Air Temperature
CMIP5 Ensemble mean lower tropospheric IWC and LWC
CERES EBAF Total cloud fraction and optical depth
CERES Surface Net CRE

Certain regimes do indicate a shift from a net cooling to a net warming effect.
Surface energy budget biases can lead to compensating effects

From NICE data...

- Positive LWDN anomaly
- Rapidly warms sea ice surface, Increasing LWUP
- Increases upward sensible heat flux
- Alters near-surface temperature gradient