Thoughts on the Application of TSIS/SORCE SSI in the IPCC CMIP Modeling Efforts

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Acknowledgements: NCAR Supercomputing Facilities
• This talk is about
  – How to use SSI observations (not TSI) in the climate model simulation
  – Compare SORCE/TSIS SSI observations with what have been used in the climate model simulation
    • What are the major differences?
  – What do such differences imply
    – Take-home message: coupled model is needed
    – Uncertainty in visible vs. Near-IR in SSI directly affects simulated high-latitude surface energy budget/climate
  – Preliminary model simulation results
  – I will focus on the troposphere-surface system: most relevant to our climate
    • I will use CESM v2, the flagship climate model from NCAR
Set-up the stage (I): climate model

- Climate models can be run with different configurations
  - Prescribed SST/sea ice runs (AMIP): only atmosphere and land can change
  - Coupled run: ocean can respond
    - Slab-ocean model run (SOM): only thermodynamic response
    - Fully-coupled run: dynamic and thermodynamic responses
  - Very different running cost
    - Most studies about sun-climate connection employed AMIP-type run
Set-up the stage (II): shortwave treatment in the climate model

• In atmospheric model
  – Use ~10 bands to cover UV+ Vis+ Near-IR
  – E.g. RRTMG_SW in the CESM: 14 bands (9 in Near-IR)

![Graph showing SSI difference for two models (CESM - TSIS and CESM - MUSIL) across different wavelengths (RRTMG-SW bands) with vertical bars representing the difference in SSI (Wm^-2) at various wavelengths ranging from 0.2 to 3.85 µm. The graph compares CESM - TSIS and CESM - MUSIL models across multiple bands.](image-url)
Set-up the stage (III): surface spectral reflectance Visible vs. Near-IR

**Actual measurement**

- Barren/desert
- Fresh snow
- Sea ice
- Forest

**Values in the CESM**

<table>
<thead>
<tr>
<th>Surface</th>
<th>VIS</th>
<th>NIR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry Snow</td>
<td>0.98</td>
<td>0.70</td>
</tr>
<tr>
<td>Wet Snow</td>
<td>0.88</td>
<td>0.55</td>
</tr>
<tr>
<td>Bare Ice</td>
<td>0.78</td>
<td>0.36</td>
</tr>
<tr>
<td>Melting Ice</td>
<td>0.71</td>
<td>0.29</td>
</tr>
<tr>
<td>Open water</td>
<td>NA</td>
<td>NA</td>
</tr>
</tbody>
</table>
Questions to be addressed

- Do we have the right VIS-vs-NIR specifications for the SSI used by the climate modeler?
- If not, how much can it affect the simulation
  - A model with allowable sea ice change is needed
  - Surface needs to respond here. Prescribed SST/sea ice won’t do the work
- Both can be investigated using SORCE/TSIS SSI measurements
<table>
<thead>
<tr>
<th>From</th>
<th>Download site</th>
<th>Time period and WV range</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Multiple Same-Irradiance-Level (MuSIL)</td>
<td>SORCE <a href="http://lasp.colorado.edu/lisird/data/musil_sim/">http://lasp.colorado.edu/lisird/data/musil_sim/</a></td>
<td>Apr.14,2003-Aug.29, 2017; 0.24 -1.6 µm</td>
<td>Total solar irradiance (TSI) record has an estimated relative uncertainty of about 5% of the measured solar cycle variability. Woods, et al, Decoupling Solar Variability and Instrument Trends using the Multiple Same-Irradiance-Level (MuSIL) Analysis Technique, Solar Phys., 293, A76, 2018.</td>
</tr>
</tbody>
</table>
Annual-mean difference on the RRTMG_SW bandwidth

2000-2014, CESM - EMPIRE

Total: 0.73 Wm$^{-2}$

- Compared to EMPIRE:
- The offset between VIS and Near-IR.
- Diff in one band can be much larger than that of TSI
Make solar spectral irradiance for CESM simulation

Control run dataset (Solar_avg_CESM_control.nc)
(1) do multi-year average from daily solar spectral irradiance of CESM
(2) scale it using TSIS total solar irradiance

TSIS run dataset(Solar_avg_CESM_TSIS.nc)
(1) Use TSIS measurements from 0.2-2.4 micron
(2) for <0.2 micron and >2.4 micron, the spectral shape is same as the control run dataset, but scaled to have the TSI identical to the control run dataset

Same TSI, but different SSI specification. Repeating every year.
Simulation Set-up

• Model version:
  – CESM 2.1.1

• Model components (compset=ETEST):
  – CAM6 physics; Sea ICE (cice) model version 5; DOCN slab ocean model; MOSART River runoff; Stub glacier (land ice) component (SGLC); Stub wave component (SWAV).

• Gases:
  – O3, OH, NO3, and HO2 are prescribed as the 3-D (lon-lat-lev) climatology for 2000 (averaged between 1995-2005), with a temporal resolution of 5 days.
  – Surface emissions for CO2, CH4, N2O, CFC11eq, CFC12 are the 2000 climatology (averaged between 1995-2005) with a temporal resolution of 1 month.

• Aerosol and precursor emissions: fixed at the 2000 level.

• Four-member ensemble runs

• Simulation period:
  – 2000-2019. Ensemble mean of the last 10 years (2010-2019) are used for the analyses.
Total difference = 0.005 Wm^{-2}
Annual-mean TOA Upward Flux

Annual-mean Surface Upward Flux

Zonal mean TOA Upward SW (TSIS-CTL)

Zonal mean Surface net Upward SW (TSIS-CTL)

Positive upward.

Hatched are significant at 5% level. Cancellation between green and N-IR bands
Orange parts are significant at 5% level.
Conclusions and Outlooks

- Visible-vs-NIR SSI is directly relevant to surface energy budget, more so at the high latitudes
- Their impact can only be correctly assessed with coupled models, not a prescribed SST/sea ice run
- A proof-of-concept simulation shows statistically significant changes in SH sea ice and $T_{\text{surface}}$
- SORCE/TSIS are where we can get observation-based constrains from
  - A new SSI dataset for climate modeling community?
- Future works:
  - Fully coupled runs
  - Time-dependent SSI variations
THANK YOU!
CESM spectral interval: 1, 3, 5, 7, 10, 30, 50 nm
TSIS spectral interval: 0.04~9 nm
Orange parts are significant at 0.05 level.
Orange parts are significant at 0.05 level.
Hatched are significant at 0.05 level.
ANN, JJA, DJF energy transport

Bold parts are significant at 0.05 level.
Hatched are significant at 0.05 level.