Solar forcing for CMIP6

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Outline

• Part 1: Partial review of Matthes et al. 2016 GMD paper detailing CMIP6 recommendations

• Part 2: Progress in testing new forcing in WACCM
Part 1: Matthes et al. (2016)

- GMD paper published 6/6/2016 describes the recommendation for radiation and particle forcing.

- Radiation: total solar irradiance (TSI) and solar spectral irradiance (SSI), and F10.7cm radio flux,

- Particle forcing (new!): geomagnetic indices Ap and Kp, and ionization rates from solar protons, electrons and galactic cosmic rays.

- Data available at http://solarisheppa.geomar.de/cmip6

CESM Workshop, Breckenridge, June 20-23, 2016
Irradiance forcing

- Fixed and variable PI control
- Daily and monthly historical (1850–2014)
- Future (2015–2300), with an additional extreme Maunder Minimum-like sensitivity scenario
- TSI and SSI time series are defined as averages of two (semi-) empirical solar irradiance models: NRLTSI2/NRLSSI2 and SATIRE-TS
TSI historical

Matthes et al., GMD, 2016

weaker secular trend

Stronger change in recent minima

CESM Workshop, Breckenridge, June 20-23, 2016
Solar cycle amplitude

Matthes et al., GMD, 2016
Particle forcing

- geomagnetic indices Ap and Kp (used in WACCM for thermospheric processes, upper boundary)

- ion pair production rates (IPR) from solar protons, energetic electrons and galactic cosmic rays (used in WACCM and CAM-CHEM for NOx and HOx production)

- IPR on geomagnetic latitude and height
Geomagnetic forcing

Matthes et al., GMD, 2016
Past and future projections for particle forcing

![Graphs showing past and future projections for particle forcing](image_url)
Geomagnetic field variations

• 1850–1900: gufm1 model (Jackson et al., 2000)

• 1900–2015: International Geomagnetic Reference Field (IGRF-12; Thébault, 2015)

Part 2: Testing new forcing in WACCM

- CESM1(WACCM) version 1.0
  - Same model as used in CMIP5 (1.9° x 2.5°)
  - Interactive land / ocean / sea ice
  - Year 2000 fixed greenhouse gas concentrations
- 22-year integration using 1960-2005 average SSI (no solar cycle)
- 2 sets of integrations
  - NRLSSI v1: **CMIP5-SSI**
  - SOLARIS (NRLSSI v2 + SATIRE)/2: **CMIP6-SSI**
- Here the focus is on analysis of annual means (taken over the whole integration)
Change in SSI relative to 11-yr cycle

CESM Workshop, Breckenridge, June 20-23, 2016
Change in SSI relative to 11-yr cycle

~1 W/m$^2$ decrease in the stratosphere

~1 W/m$^2$ increase in the troposphere

Figure credit: S. Solomon
Comparison with solar-cycle

Hood et al., QJRMS 2015

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Ozone difference (CMIP6 – CMIP5)/CMIP5

Data Min = -4.3, Max = 1.8

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Hood et al., QJRMS 2015

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Solar Forcing for CMIP6 (v3.1)


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Thanks for your attention. Questions?
Appendix F: Projection of Historical Solar Cycles in Future Scenarios

Table 4. Historical solar cycles used for construction of future cycles (starting on 2015-01-01).

<table>
<thead>
<tr>
<th>Current cycle nb.</th>
<th>Historic cycle nb.</th>
<th>Start current cycle yyyy-mm-dd</th>
<th>Start hist. cycle yyyy-mm-dd</th>
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<td>1901-12-14</td>
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<td>2293-08-19</td>
<td>1944-02-23</td>
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</tbody>
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HOx={H, OH, HO2} difference (CMIP6 – CMIP5)/CMIP5

6th International HEPPA-SOLARIS Meeting, 13-17 June 2016, Helsinki, Finland
## Summary

<table>
<thead>
<tr>
<th>TSI</th>
<th>W/m²</th>
<th>SW heating</th>
<th>T</th>
<th>P(Ox) = JO₂</th>
<th>O₃</th>
<th>P(O¹D) = JO₃</th>
<th>HOx</th>
<th>H₂O</th>
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<td>TSI</td>
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<td>TBD!</td>
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<td>&lt;200</td>
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<td>200-300</td>
<td>-0.5</td>
<td>-0.3 K/d</td>
<td>-1.7 K @ 50 km</td>
<td>-4% @ 50 km</td>
<td>+1.5% @ 50 km</td>
<td>-4% &gt; 40 km</td>
<td>-2% 40 km</td>
<td>~-10% 80 km</td>
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