Some thoughts on the linearity of spectral radiances averaged over large spatial domain and long timescale

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Outline

• Simulations using ECMWF ERA-interim reanalysis
  – Sensitivity of radiance averages to surface emissivity and spatial/temporal-varying GHG profiles

• Other related activities in my group
  – Synergy of AIRS and CERES
  – Longwave band-by-band CRF
  – Modeling capacity for sampling studies
  – Data analysis: AR5 sneak peak
Simulations with ERA-interim data

• Radiance simulator at UM
  – Modtran5-based RTA (0.1 cm\(^{-1}\))
  – Local cluster operated by university (total > 10,000 CPUs)
    • Flexible rental for exclusive use with minimal cost: can rent 1000-2000 CPUs over a short notice
    • Flexible configuration to “homogenize” nodes: big help for I/O demanding jobs
  – Benchmark: 96 CPU, 6-hourly ERA-interim profiles, 1.5 ° by 1.5° resolution (120 lat 241 lon)
    – Nonscattering, 1cm\(^{-1}\) computing resolution: 2hr for 1 month, i.e. 1 day for 1 year of simulation
    – Nonscattering, 0.1cm\(^{-1}\) computing resolution: 20 hr for 1 month
    – 2-stream: a factor of 2~4
Simulations with ERA-interim data

• Radiance simulator at UM (contd.)
  – High spectral res. surface emissivity
    • Latest ASTER Spectral library v2.0
    • USGS 1km IGBP scene type (18 types, same as CERES/SARB)
  – Trace gases
    • 6-hourly ozone profiles from ERA-interim reanalysis
    • CO₂, CH₄, N₂O, CO
      – 1: McClatchey profiles for difference seasons in mid- and high latitudes
      – 2. Mean seasonal cycles at 1990s from a CTM (MOZART)
NOTE: no database gives $\varepsilon_\nu$ beyond 14 $\mu$m

From NASA/TP-1999-209362 By Wilber, Kratz, and Gupta
Applications of the simulators

• Test the impact of seasonality of trace GHGs and surface spectral emissivity on averaged radiances
  For clear-sky radiances
  – Control case: blackbody surface, constant GHG profiles
  – Ozone+ other minor GHGs case
  – Ozone + other minor GHGs + surface emissivity case
Control case: global mean clear-sky radiance 2006 Jan (1.0 cm$^{-1}$)
Deviation from the control case

- Ozone band affected most (and it is most complicated!)
- Slope in WN region also affected
- Ad hoc surface emissivity <714cm$^{-1}$
Other activities: AIRS and CERES synergy

- Huang et al. (2008) and Huang et al. (2010) developed and validated spectral ADM/algorithms for deriving 10-cm\(^{-1}\)spectral flux over the entire LW
  - Build spectral ADM based on CERES scene type def.
  - Compute spectral flux from collocated AIRS observation
  - For open oceans only in these studies
  - Extending to land surface now

<table>
<thead>
<tr>
<th>Year</th>
<th>Nighttime (W m(^{-2}))</th>
<th>Daytime (W m(^{-2}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>2003</td>
<td>0.80 ± 1.34</td>
<td>0.86 ± 1.72</td>
</tr>
<tr>
<td>2004</td>
<td>0.52 ± 1.29</td>
<td>0.79 ± 1.67</td>
</tr>
<tr>
<td>2005</td>
<td>0.93 ± 1.35</td>
<td>1.81 ± 1.81</td>
</tr>
<tr>
<td>2006</td>
<td>0.86 ± 1.38</td>
<td>2.10 ± 1.81</td>
</tr>
<tr>
<td>2007</td>
<td>0.83 ± 1.40</td>
<td>2.45 ± 1.87</td>
</tr>
</tbody>
</table>

Cloudy sky over the ocean

<table>
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<th>Year</th>
<th>Nighttime (W m(^{-2}))</th>
<th>Daytime (W m(^{-2}))</th>
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<tr>
<td>2003</td>
<td>1.63 ± 5.22</td>
<td>3.73 ± 5.94</td>
</tr>
<tr>
<td>2004</td>
<td>1.33 ± 5.16</td>
<td>3.00 ± 5.73</td>
</tr>
<tr>
<td>2005</td>
<td>1.75 ± 5.32</td>
<td>4.06 ± 6.03</td>
</tr>
<tr>
<td>2006</td>
<td>1.58 ± 5.42</td>
<td>4.35 ± 6.08</td>
</tr>
<tr>
<td>2007</td>
<td>1.50 ± 5.37</td>
<td>4.57 ± 6.06</td>
</tr>
</tbody>
</table>

Clear sky over the ocean

Daytime drift corrected in CERES SSF Edition 3
## Annual-mean CRF in 2004 (Tropical oceans)

<table>
<thead>
<tr>
<th></th>
<th>AIRS&amp;CERES observed CRF (Wm(^{-2}))</th>
<th>AM2 simulated CRF (Wm(^{-2}))</th>
<th>NASA GEOS-5 simulated CRF (Wm(^{-2}))</th>
<th>Canada CanAM4 simulated CRF (Wm(^{-2}))</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>LW broadband</strong></td>
<td>27.45 (100%)</td>
<td>28.13 (100%)</td>
<td>28.30 (100%)</td>
<td>27.27 (100%)</td>
</tr>
<tr>
<td><strong>H(_2)O</strong></td>
<td>5.36 (19.5%)</td>
<td>5.33 (19.0%)</td>
<td>5.08 (17.9%)</td>
<td>4.45 (16.3%)</td>
</tr>
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<td>0-560cm(^{-1}); &gt;1400cm(^{-1})</td>
<td>5.36 (19.5%)</td>
<td>5.33 (19.0%)</td>
<td>5.08 (17.9%)</td>
<td>4.45 (16.3%)</td>
</tr>
<tr>
<td><strong>CO(_2)</strong></td>
<td>4.18 (15.2%)</td>
<td>3.74 (13.3%)</td>
<td>5.15 (18.2%)</td>
<td>4.82 (17.7%)</td>
</tr>
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<td><strong>WN</strong></td>
<td>9.35 (34.1%)</td>
<td>10.03 (35.6%)</td>
<td>9.06 (32.0%)</td>
<td>8.78 (32.2%)</td>
</tr>
<tr>
<td>800-990cm(^{-1})</td>
<td>9.35 (34.1%)</td>
<td>10.03 (35.6%)</td>
<td>9.06 (32.0%)</td>
<td>8.78 (32.2%)</td>
</tr>
<tr>
<td><strong>O(_3)</strong></td>
<td>2.02 (7.0%)</td>
<td>1.68 (6.0%)</td>
<td>3.62 (12.8%)</td>
<td>3.73 (13.7%)</td>
</tr>
<tr>
<td>990-1070cm(^{-1})</td>
<td>2.02 (7.0%)</td>
<td>1.68 (6.0%)</td>
<td>3.62 (12.8%)</td>
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<td><strong>WN</strong></td>
<td>6.53 (23.8%)</td>
<td>7.34 (26.1%)</td>
<td>5.43 (19.1%)</td>
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<td><strong>H(_2)O NO(_2) CH(_4)</strong></td>
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Difference in one band could be as large as or even larger than the broadband difference

In collaboration with Jerry Potter, Lazaros Oreopoulos, et al.
Annual-mean CRF map: 1070-1400 cm$^{-1}$

GEOS-5: lower than obs. and a narrow range: 0.18-0.22
GFDL AM2: higher than obs.

In collaboration with Jerry Potter, Lazaros Oreopoulos, et al.
High-resolution GCMs and CRM

• GFDL HiRam model (50km resolution) [in collaboration with Ming Zhao at GFDL]
  – Reliable in simulating climatology of many variables (Zhao, 2009)
  – One year of 3-hrly output of TOA LW and SW fields and some ancillary fields: A data set for studying sampling issues.

• In-house modeling capability
  – AM2
  – Goddard Cumulus Ensemble (GCE) model: 1km-4km channel mode with MERRA initialization
AR5 model analysis: sneak peak

Difference in 5-year mean albedo (GCM all forcings run– CERES EBAF)

In collaboration with Jerry Potter
Recap

• To be realistic, time-varying ozone profiles have to be included. Its impact on global mean radiance is non negligible (or exclude ozone bands)

• Surface emissivity also affects global mean radiances. Impact on regional radiance could be even larger.
  – Moreover, land surface itself is changing over years.

• Connecting spectral radiances and spectral fluxes
  – Usages in GCM evaluations
  – Relations with the band-by-band (spectral) cloud feedback?