Surface Atmosphere Radiation Budget (SARB) working group update

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Outline of this talk

• Edition 5 plan
  • MATCH aerosol
  • Langley Fu-Liou code update
  • MOA (temperature, specific humidity, and ozone profiles)
• Skin temperature impact on surface irradiance
Global monthly surface clear-sky downward shortwave anomalies

Selected Region: [-90.0 to 90.360]

Area Average Time Series (deseasonalized)

- August 2000: missing Terra data
- May 2003: Siberian forest fire??
- June 2011: Canadian smoke
- October 2015: Indonesian smoke
- August 2019: Siberian wildfire
- January 2020: Australian fire
- August 2021: Siberian wildfire

Standard deviation = 0.59 Wm$^{-2}$
Number of month $> 2\sigma$: 14 (out of 261)
8 occurred after 2010
5 occurred after 2019
Edition 4 MATCH

• Clear-sky total aerosol optical thickness is constrained by MODIS derived aerosol optical thickness (dark target and deep blue).

• Modeled dust optical thickness is too large
  • Modeled dust optical thickness is adjusted by MODIS optical thickness when MODIS optical thickness is available
  • Sometimes dust aerosol is used for smoke.

• Large fraction of sulphate and small fraction of sea salt over ocean.

• MATCH provides aerosols over polar regions
  • Transport of aerosol to polar regions is important.

• Aerosol under cloudy conditions largely depend on model but affects clear-sky cloud removed irradiances.
Australian fire event (January 2020)

Total aerosol optical thickness

Dust aerosol optical thickness

Glb mean(sd): 0.165 (0.123)  Mx/Mn: 0.0004/1.27

Glb mean(sd): 0.030 (0.049)  Mx/Mn: 0.0/0.552
Edition 4 sea salt and sulfate aerosols
Edition 5 MATCH

• A MODIS/VIIRS aerosol optical thickness assimilation module is going to be developed for NCAR Community Earth System Model (CESM), Community Atmosphere Model (CAM) 6

• Use 3-mode modal aerosol representation (MAM3, internal mixing) in CAM 6
  • Aitkin (SO4, SOA, and SS), accumulation (SO4, POA, SOA, BC, SS, and DST), coarse (SO4, SS, and DST).
  • Species include SO4 sulfate, SOA secondary organic aerosol, SS Sea-salt, POA primary organic aerosol, BC black carbon, and DST mineral dust.
  • Stratospheric aerosol (TBD)
  • Optical property of species in 4D (+ wavelength) are provided by CAM6 and used in Edition 5 Langley Fu-Liou RT model (Changes from Edition 4).

• Winds (u and v components) and T and q are nudged 3 hourly using GEOS.

• Current plan is to assimilate total AOT, fine and coarse mode fractions and/or AOT at multiple wavelengths.

• A Back-up plan is to use 4D aerosol fields and optical property form GEOS
Optical property input to Langley Fu-Liou code

These aerosol properties come from MATCH (CAM6) But can be replaced by GEOS-IT or R21C
Langley Fu-Liou RT code: gaseous absorption update

• Absorption cross sections are updated with HITRAN 2012 (line by line code, lblrtm v12.8, outputs were made by Lusheng Liang)
• Includes absorption by H2O, CO2, O3, O2, and CH4
  • CO2 absorption with variable CO2 concentrations can be computed for both shortwave and longwave
• Current version is participating in Correlated k-Distribution Model Intercomparison (CKDMIP, Hogan and Matricardi 2020)
Longwave Edition 5 vs. Edition 4 (mean of 5 standard atmospheres)

LW heating rate
Ed 5: red Ed4 Black

Graphs showing broadband LW heating rate and longwave flux.
Correlated K-Distribution Model Intercomparison Project (CKDMIP, Hogan and Matricardi 2020)

Mean bias 1.32 Wm-2
RMS 1.70 Wm-2

Mean bias 0.23 Wm-2
RMS 1.71 Wm-2

Courtesy of Robin Hogan
Edition 5 MOA plans

- Grid size
  - 1 deg by 1 deg (can be changed later)

- Vertical levels
  - same as GEOS product or same as Edition 4

- Use hourly mean surface skin temperature
  - Retrieved cloud properties are not very sensitive
  - Hourly mean is required to produce hourly mean surface irradiance

- Include GEOS cloud fraction
Surface skin temperature

• Sensitivity of surface irradiance to skin temperature bias
• Retrieved cloud properties are not very sensitive to skin temperature, except for nighttime cloud fraction.
• Sensitivity of upward longwave irradiance

\[ \Delta F_\uparrow = -F_{net} \frac{\Delta \varepsilon}{\varepsilon} + \varepsilon \left( 4\sigma T^4 \frac{\Delta T}{T} - F_\downarrow \frac{\Delta F_\downarrow}{F_\downarrow} \right) + \Delta F_\downarrow \]

• Sensitivity of net longwave irradiance

\[ \Delta F_{\text{net}} = F_{net} \frac{\Delta \varepsilon}{\varepsilon} - \varepsilon \left( 4\sigma T^4 \frac{\Delta T}{T} - F_\downarrow \frac{\Delta F_\downarrow}{F_\downarrow} \right) \]
TOA and surface upward longwave irradiance

Mid-latitude summer atmosphere
Surface skin temperature = 295 K
Surface emissivity = 0.90
Clear-sky and all-sky surface net longwave irradiance
Clear-sky (total area) OLR: Computed (Ed.4 SYN) – Observed (EBAF)

Smaller OLR difference over desert
- Day-night skin temperature bias might partially cancel out
- Humidity bias, GEOS-541 upper tropospheric humidity has a positive bias
- Dust aerosol layer optical thickness and height (negative bias over ocean)

Adjusted skin temperature

Need to determine bias and correct bias error (work with the cloud working group)
Summary

• Treatment of gaseous absorption in Langley Fu-Liou code is updated for Edition 5 production
  • Newer HITRAN database (2016) and SW absorption varies with CO2 concentration.
• One of objectives of Edition 5 MATCH development is to improve aerosol type (fine and coarse mode)
• Importance of aerosols in computing clear-sky radiation budget change is emphasized
  • Large aerosol loading events occur more often
  • Transport of aerosol to polar regions and aerosol under cloudy conditions largely depend on model.
• Work with the cloud group to improve the impact of GEOS surface skin temperature bias to surface irradiance.
Publications


Back-ups
Edition 5

• Fu-Liou code
  • Edition 4 versus Edition 5 gaseous absorption
• MATCH
• MOA
  • 1deg by 1deg(?)
  • Cloud also uses hourly mean skin temperature (i.e. not instantaneous skin temperature
• Skin temperature impact on surface irradiance
• D1 CCCM (Seung-Hee Ham)
Recent activities

• Released Edition 4.1 EBAF through November 2021
• Released D1 version (revised from B1) of CCCM (jointly with the cloud working group)
• Generated MOA using GEOS-IT
• Implemented the algorithm and modernized (.pro to .py) to use AFWA ice age product after CLASS ice age product was terminated in August 2021
• Developed the SYN algorithm that uses no geostationary satellite data.
• Developed Edition 4 CRS production code and evaluated instantaneous surface fluxes
Validation

• Evaluated Edition 4 MATCH aerosol optical thickness (paper is under review) using AERONET, MODIS, and MERRA-2 aerosol optical thickness.

• Evaluated twilight cloud properties derived from geostationary satellites and their effects to surface fluxes

• Evaluated time series of surface flux anomalies derived from Aqua only (i.e. no geostationary satellite derived clouds) SYN.

• Validated CRS instantaneous footprint-scale Arctic surface downwelling broadband radiative fluxes against measurements conducted at the MOSAiC drifting observatory.

• Updated surface validation input files from binary files to netCDF files and developed a python code to generate the input files from surface observations.
Aqua only noGEO, Terra only no GEO, and Terra+Aqua noGEO SYN analysis

• Edition 4.2 EBAF uses SYN noGEO product
  • Adjust Terra only and NOAA 20 only climatology based on Terra+Aqua.
  • Use Terra only, NOAA20 only, and Terra+Aqua anomalies.

• Difference in climatology and anomalies
• Difference in surface irradiance trends
• Surface validation
Effect of skin temperature bias on the surface upward longwave irradiance

• Sensitivity of skin temperature derived from TOA radiance to surface emissivity
  • \( I = T [\varepsilon B_\lambda (T_{\text{skin}}) + (1 - \varepsilon) B_\lambda (T_{\text{eff}})] \)
  • \( \frac{\partial B_\lambda (T_{\text{skin}})}{\partial \varepsilon} = - \frac{B_\lambda (T_{\text{skin}}) - B_\lambda (T_{\text{eff}})}{\varepsilon} \)
  • Retrieved skin temperature is sensitive to emissivity under dry, clear, and daytime conditions

• Skin temperature bias gives
  • Cloud mask bias: Cloud mask is not very sensitive to skin temperature (Sunny’s result)
  • Cloud property bias (Sunny’s result)

• Skin temperature bias directly affects surface upward longwave irradiance
  • Comparison of clear-sky OLR with CERES (C3M or CRS??)
  • Run CRS with Sunny’s results??
[G-5.4.1 Anomalias] – [ERA-5 Anomalias]

- The differences between G541 and ERA5 are similar to those between G541 and MERRA-2.
- This implies that the differences are mainly driven by G541 problems.

Area weighted; climatology is obtained using 2003-2020

Temperature (K)

Water Vapor (g/kg)

Loss of MHS (microwave humidity sounder)
November 2019
Fewer instruments are assimilated so that the impact is larger in GEOS-5.4.1

Tropical standard ATM
Water vapor mixing ratio @ 400 hPa
~0.6 g/kg
~20 to 30% drift