Determination of CERES unfiltered radiances using broadband radiation transfer simulations

Lusheng Liang[1] and Wenying Su[2]

1-SSAI; 2-NASA LaRc

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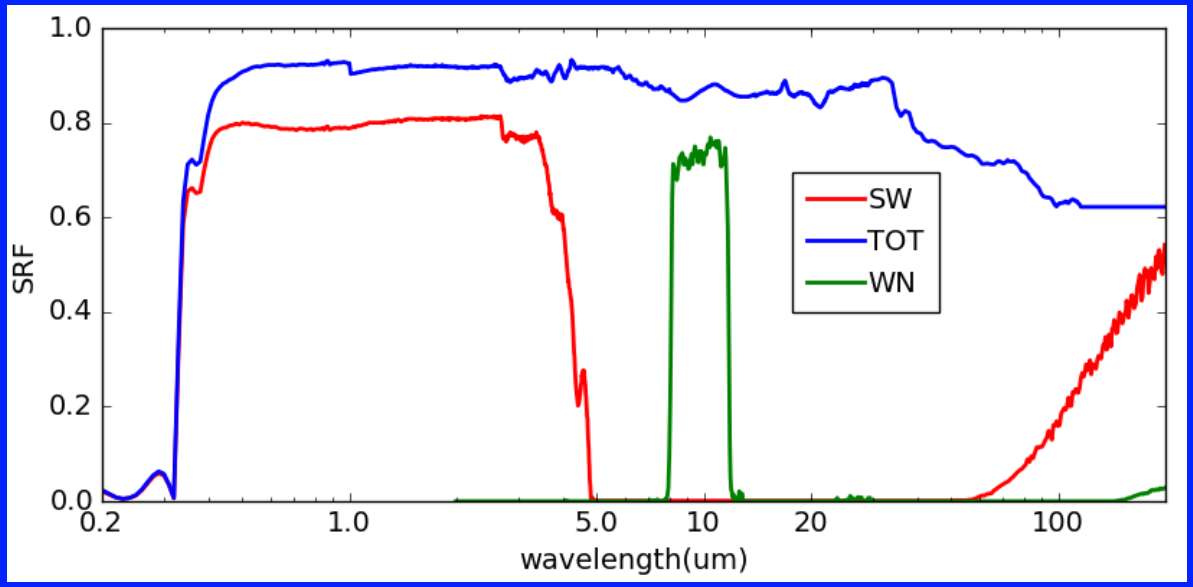
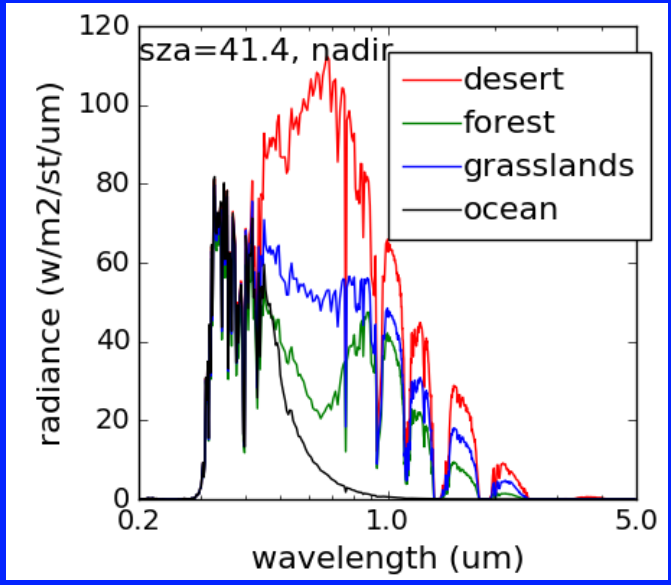
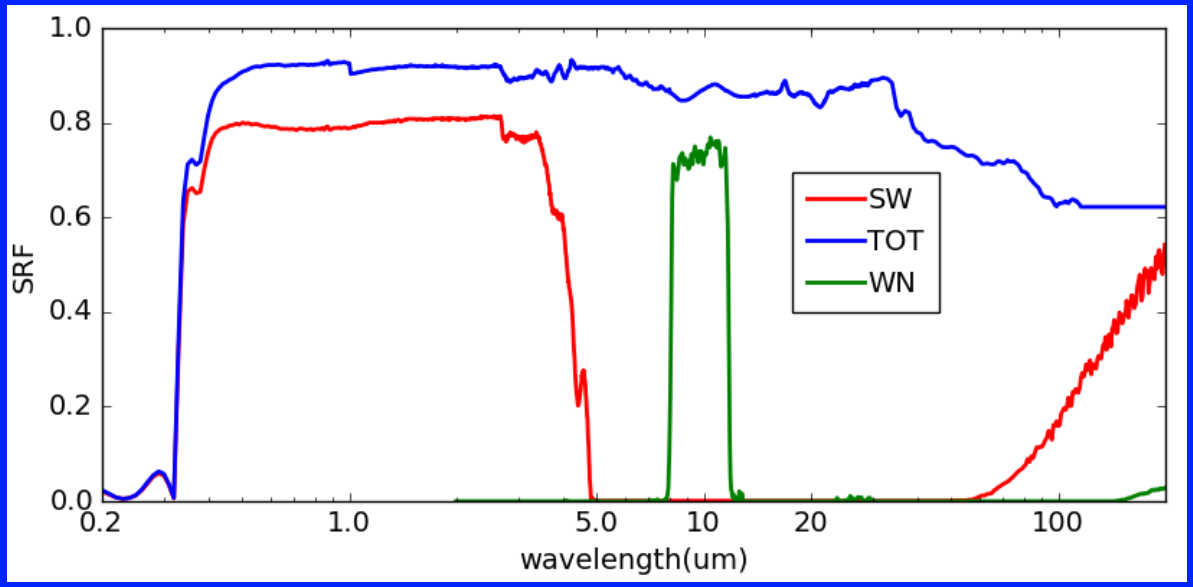
The response functions of CERES are NOT flat

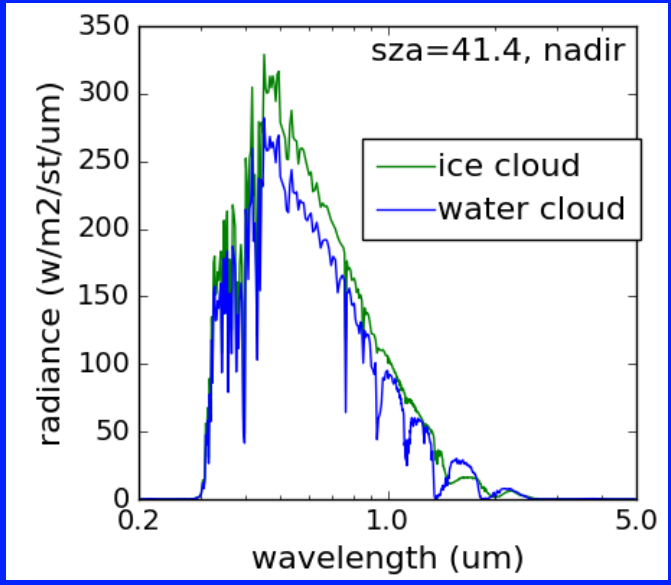




Clear sky over land

The response functions of CERES are NOT flat





Cloud ($\tau = 12$)

SW Radiance Unfiltering processes

(1). Unfiltered, reflected radiances are calculated from filtered, reflected radiances as:

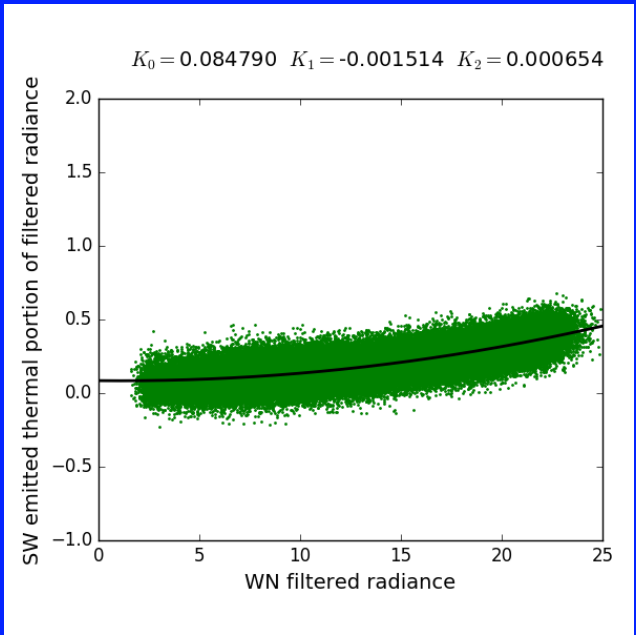
$$m_u^{SW_r} = a_0 + a_1 m_f^{SW_r} + a_2 \left(m_f^{SW_r}\right)^2$$

(2). The filtered, reflected radiances are calculated as:

$$m_f^{SW_r} = m_f^{SW} - m_f^{SW_e}$$

(3). The emitted thermal portion of the filtered radiance is calculated as:

$$m_f^{SW_e} = K_0 + K_1 m_f^{WN} + K_2 \left(m_f^{WN}\right)^2$$



Data extracted from the first day in each month in 2001 of Ed4 night time Terra FM1 and requiring SZA > 95 degrees to exclude the impact of twilight.

Construct SW unfiltering coefficients

(1). Calculate reflected, unfiltered broadband radiances

$$m_u^{SW_r} = \int_0^\infty I_\lambda^r \, d\lambda$$

(2). Apply CERES spectral response functions to calculate filtered broadband radiances

$$m_f^{SW_r} = \int_0^\infty S_\lambda^{SW} I_\lambda^r \, d\lambda$$

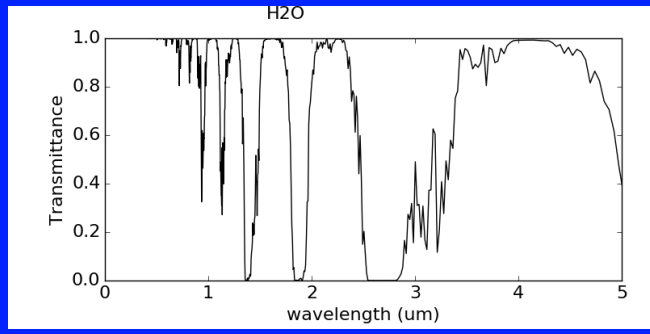
(3). Construct coefficients a0, a1, and a2 based on

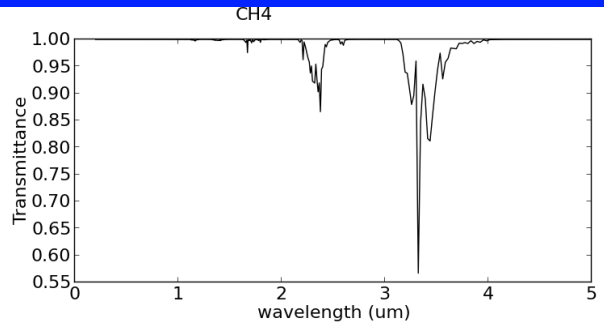
$$m_u^{SW_r} = a_0 + a_1 m_f^{SW_r} + a_2 \left(m_f^{SW_r} \right)^2$$

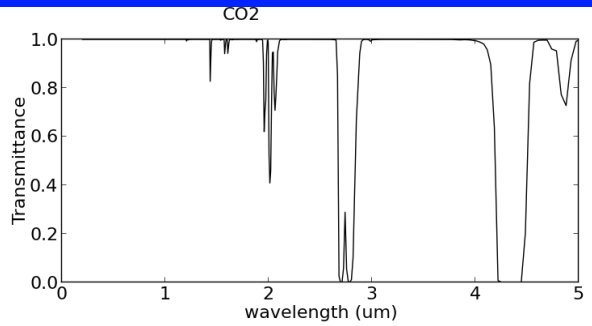
in every SZA-VZA-RAZ bin (6 SZA bins x 8 VZA bins x 10 RAZ bins).

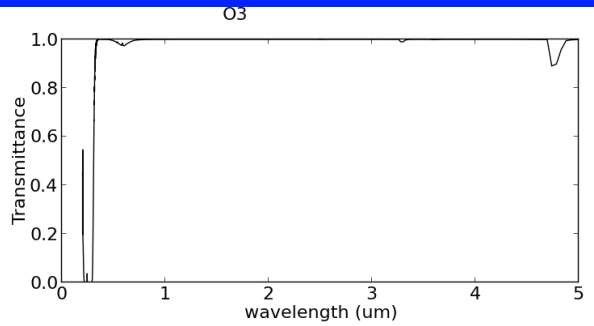
Model simulations: absorption of atmospheric gases in shortwave

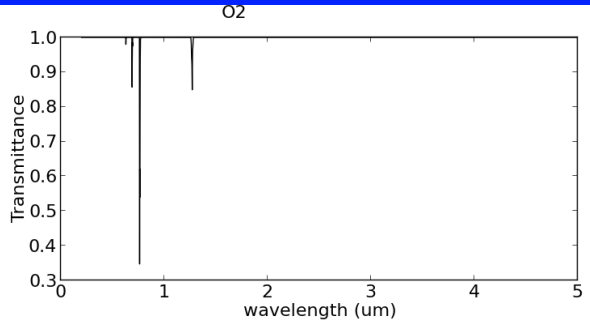
- Absorption properties of 7 major gases (H2O, O3, O2, CH4, CO2, CO and N2O) in atmosphere are all derived from line parameter database (aer_v_3.2 based on HITRAN 2008) of LBLRTM code;
- The previous version of broadband radiative transfer code considered absorption properties of H2O, and O2 derived from LBLRTM line parameter database and the that of O3 was derived from WMO's Atmospheric Ozone 1985.

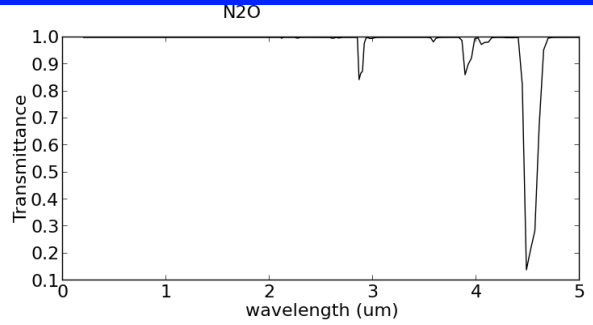


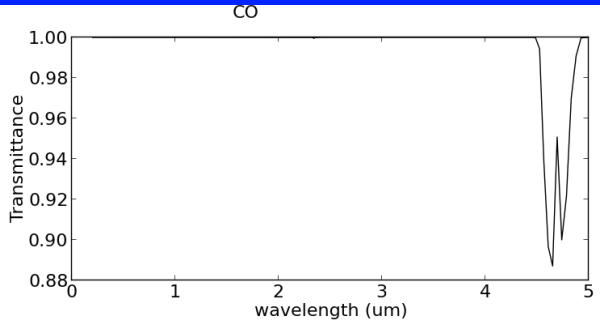






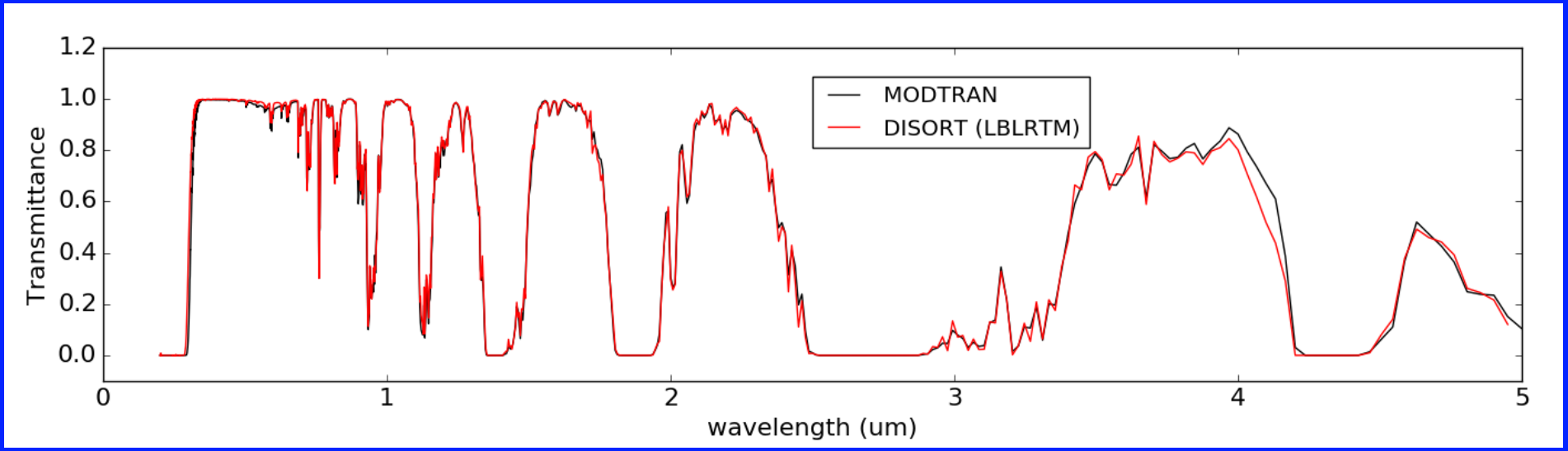






for the U.S. 1962 standard atmospheric profile

Compare transmittance calculated by DISORT to that by MODTRAN (tropic profile)



1. clear sky over ocean

SW clear sky over ocean: model simulations

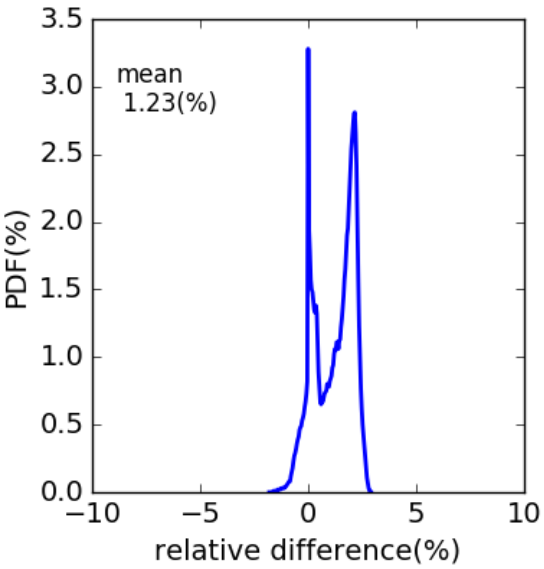
- 8 bins of aerosol optical depths: 0, 0.05, 0.09, 0.14, 0.30, 0.60, 1.0 and 2.0 of OPAC aerosols models
- Simulations are done for

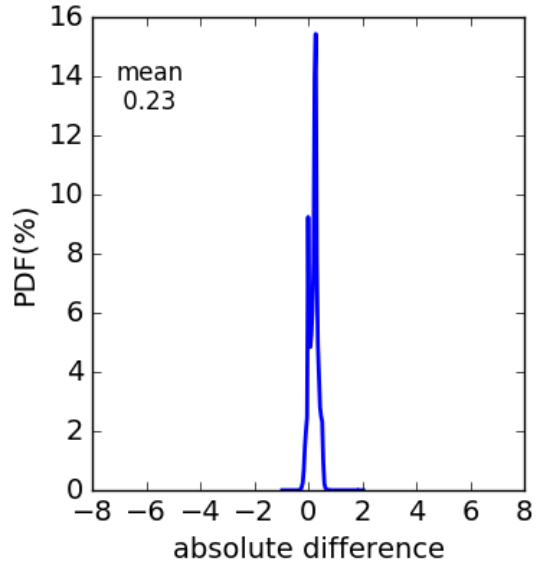
Atmospheric profile	Aerosol types
U.S. Standard 1962	maritime tropic, maritime polluted and maritime clean
Tropic	maritime tropic, dust
mid-latitude summer	maritime tropic
mid-latitude winter	maritime tropic
Subarctic summer	maritime clean
Subarctic winter	maritime clean

- 4 wind speeds: 0, 5, 9 and 15m/s

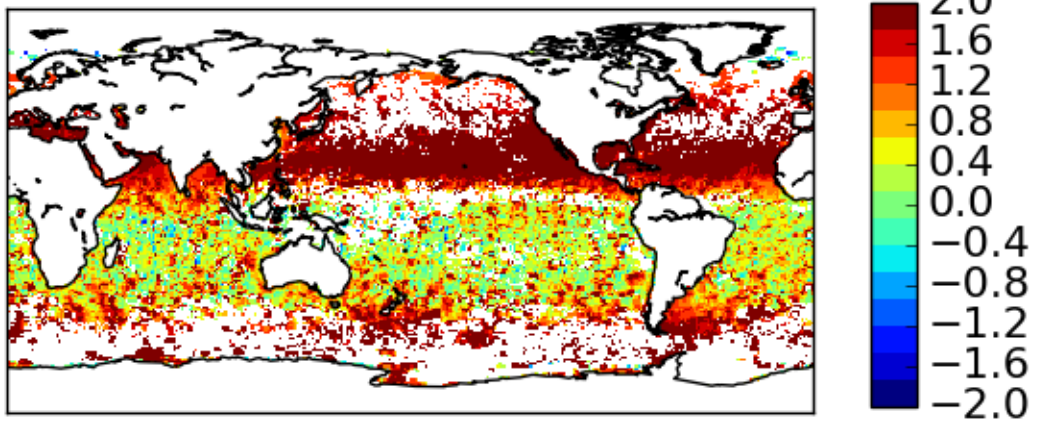
Compare unfiltered radiances (as calculated from DISORT) to that based on Ed4 coefficients

Terra FM1 2010 01

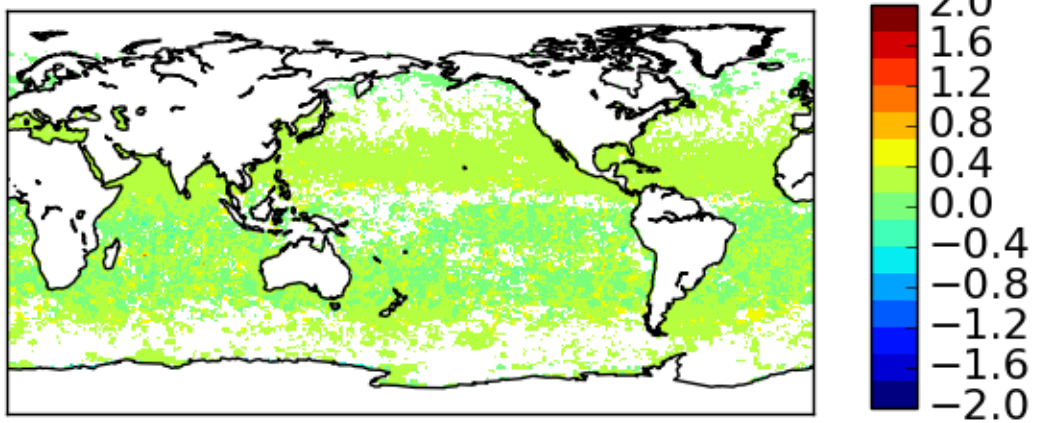




Relative difference (%)



Absolute difference (w/m^2/st)



2. clear sky over land

SW clear sky over land: model simulations

Land surface Bidirectional Reflectance Distribution Functions

At a given wavelength, the BRF at surface is calculated based on Ross-Li BRDF model

$$R = P_0 + P_1 K_1(\theta_0, \theta, \varphi) + P_2 K_2(\theta_0, \theta, \varphi)$$

where K_1 and K_2 are two kernels, and P_0, P_1, and P_2 are the BRDF parameters.

For every IGBP surface type:

- At wavelengths of MODIS 7 land bands (bands 1-7), the BRDF parameters were averaged from 10 years of MODIS observations (MCD43C1)
- The parameters at other wavelengths between 0.47 and 2.1um are calculated with spline interpolations
- The parameters at the wavelengths < 0.47 um or > 2.1 um are extrapolated and scaled along with the spectral reflectance from JPL spectral library 2.0.

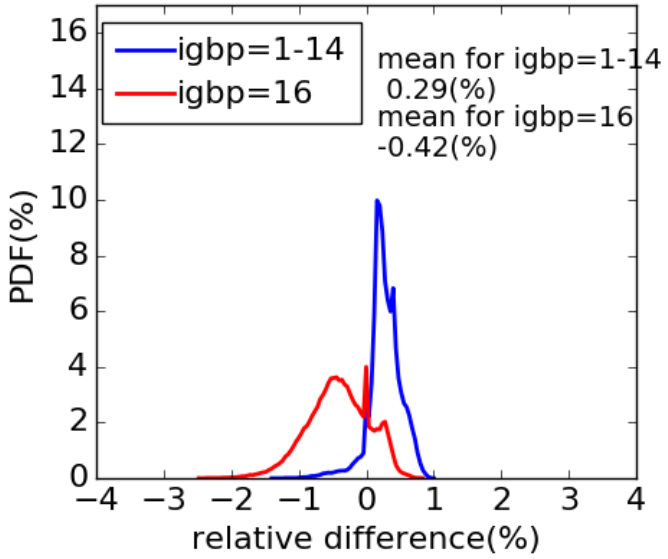
SW clear sky over land: model simulations

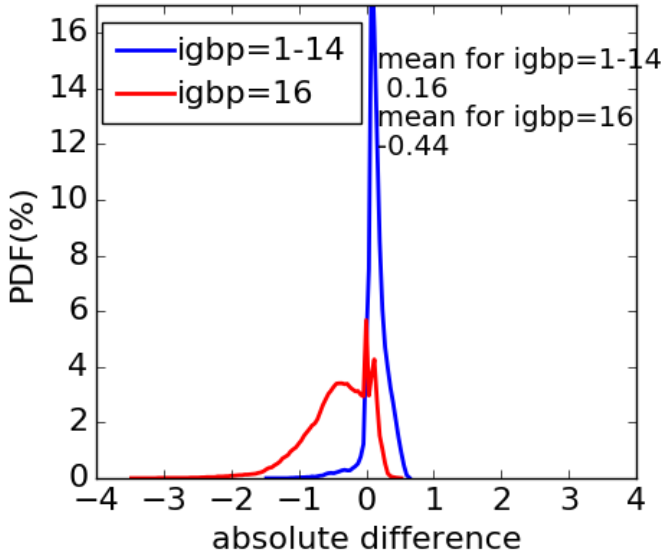
- Broad-band radiative transfer simulations are performed for land surface with IGBP 1-14 and 16
- 8 bins of aerosol optical depths: 0, 0.05, 0.09, 0.14, 0.30, 0.60, 1.00 and 2.00.
- Broad-band radiative transfer simulations are performed for

Atmospheric profile	Aerosol types
U.S. Standard 1962	Continental average, continental clean, dust, urban
Tropic	dust
mid-latitude summer	Continental average, urban
mid-latitude winter	Continental average

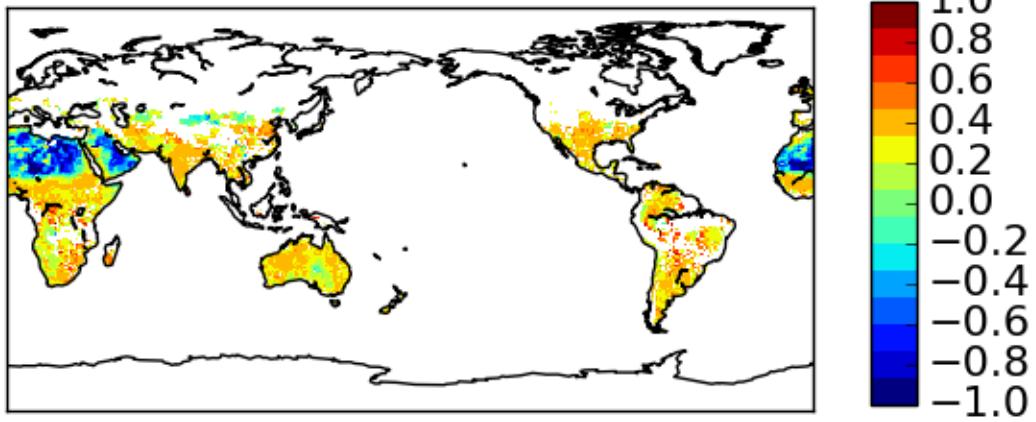
Compare unfiltered radiances (as calculated from DISORT) to that based on Ed4 coefficients

Terra FM1 2010 01

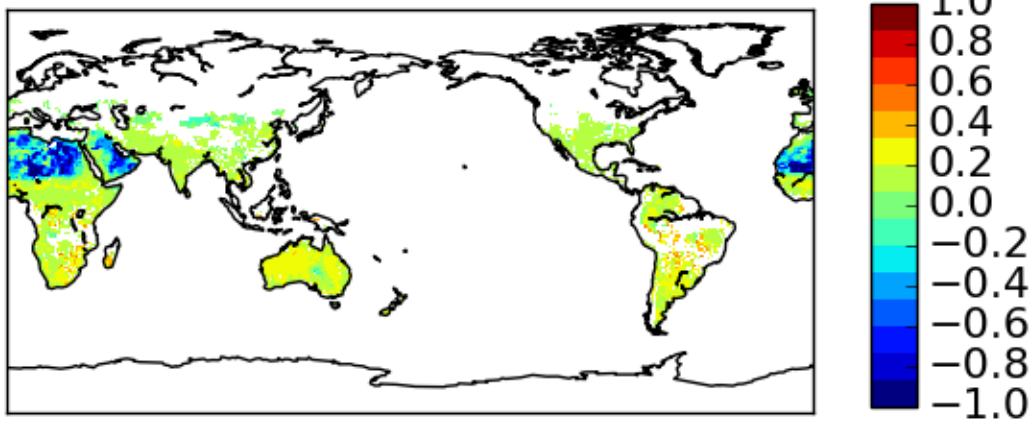




Relative difference (%)



Absolute difference (w/m^2/st)



3. cloud over ocean

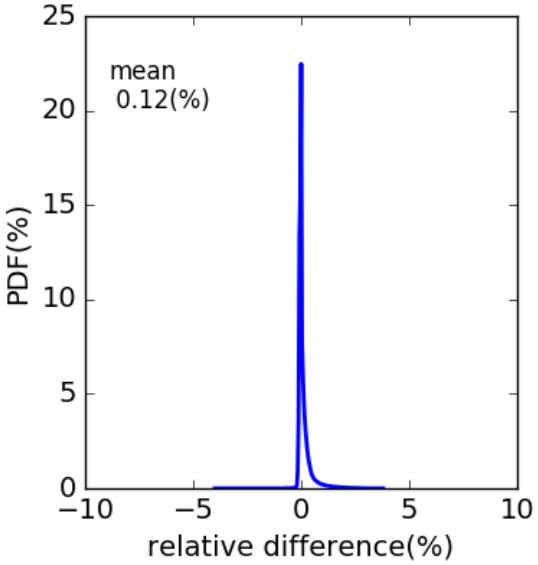
SW cloud over ocean: model simulations

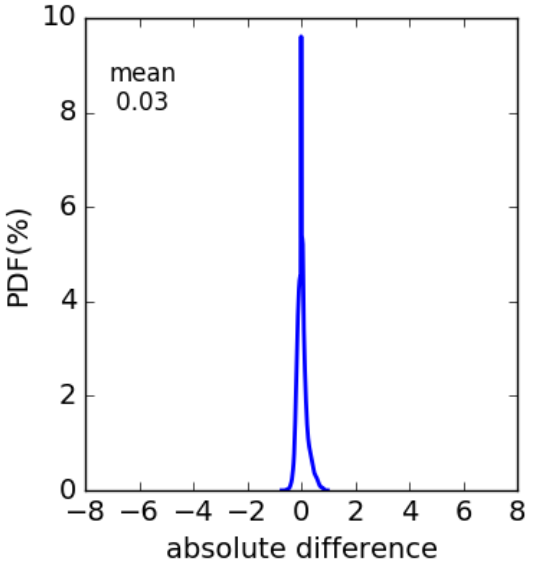
- Ping Yang's water and ice radiative properties (single-habit model for ice)
- 7 cloud optical depths: 1, 2, 4, 12, 14, 20, and 217
- 4 water cloud droplet diameters: 8, 20, 32 and 50 um
- 3 ice cloud crystal diameters: 21.86, 46.34 and 115.32 um (single-habit model)
- Cox-Munk ocean model
- 4 wind speeds: 0, 5, 9 and 15m/s
- Simulations are done for

Atmospheric profile	Clouds
U.S. Standard 1962	Water and ice
Tropic	Water and ice
mid-latitude summer	Water and ice
mid-latitude winter	Water and ice

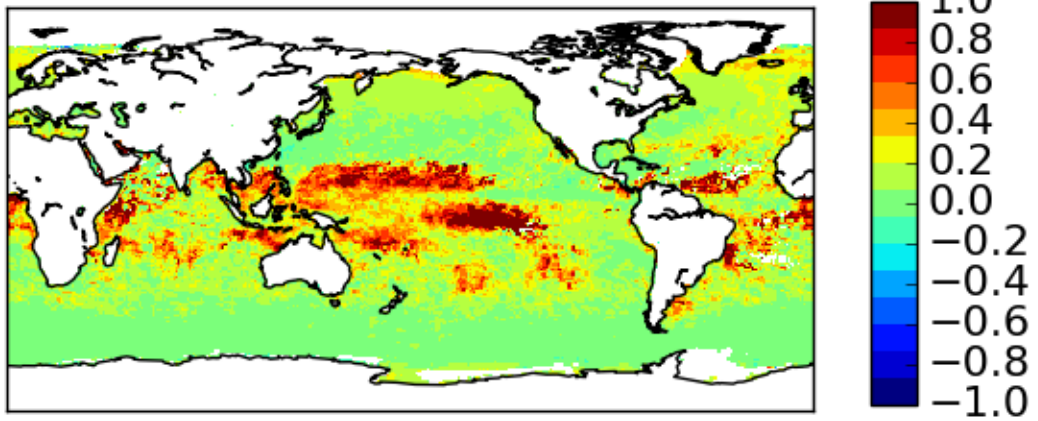
Compare unfiltered radiances (as calculated from DISORT) to that based on Ed4 coefficients

Terra FM1 2010 01

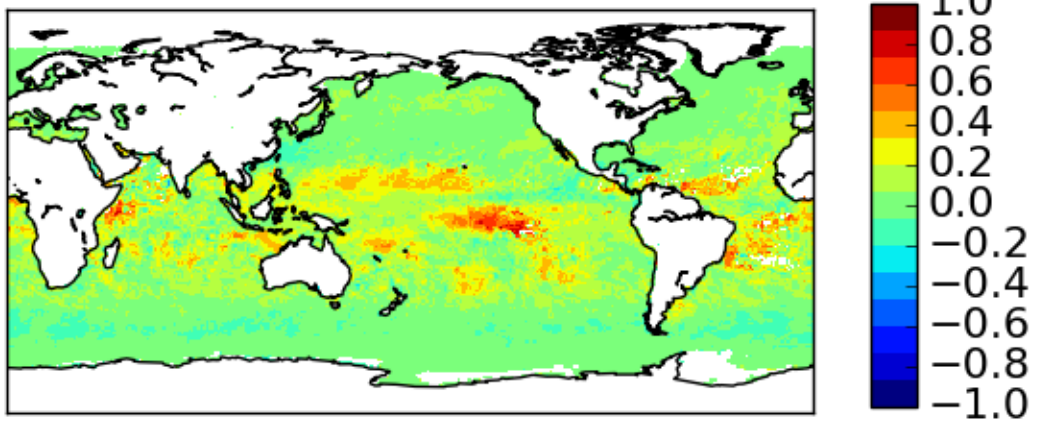




Relative difference (%)



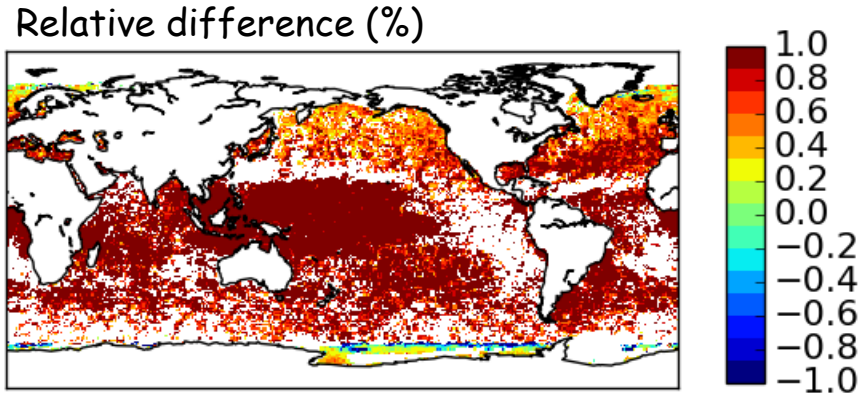
Absolute difference (w/m^2/st)



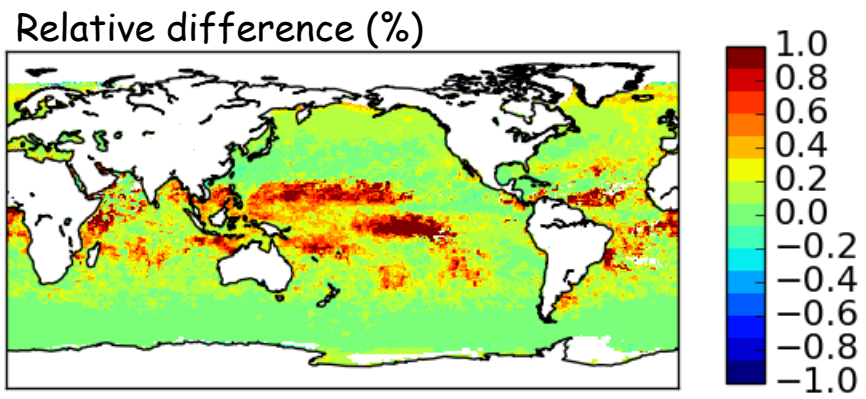
Compare unfiltered radiances (as calculated from DISORT) to that based on Ed4 coefficients

Terra FM1 2010 01

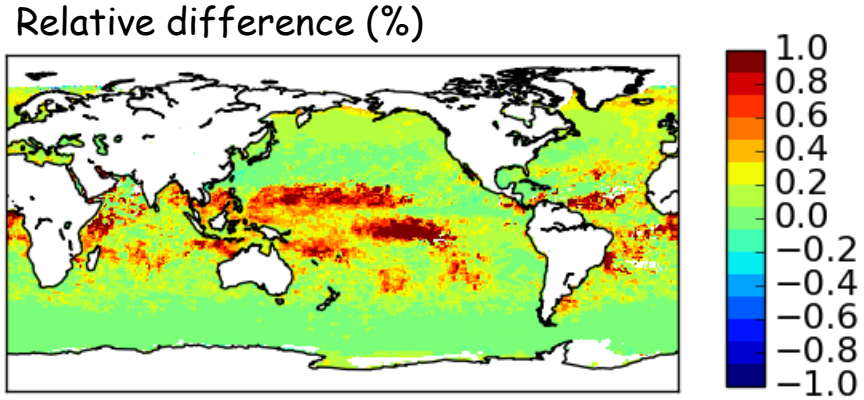
$\tau < 2$



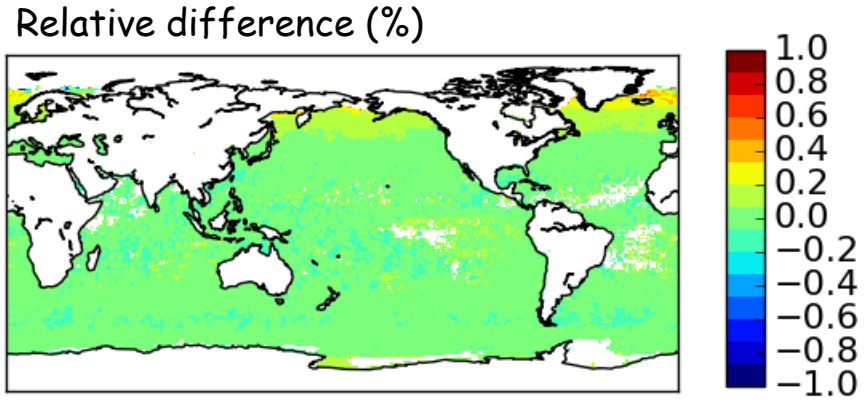
$\tau = 2$-4



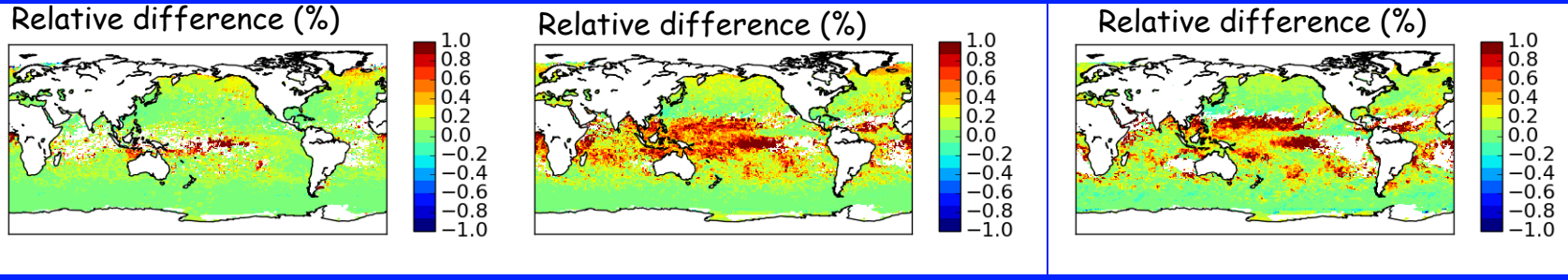
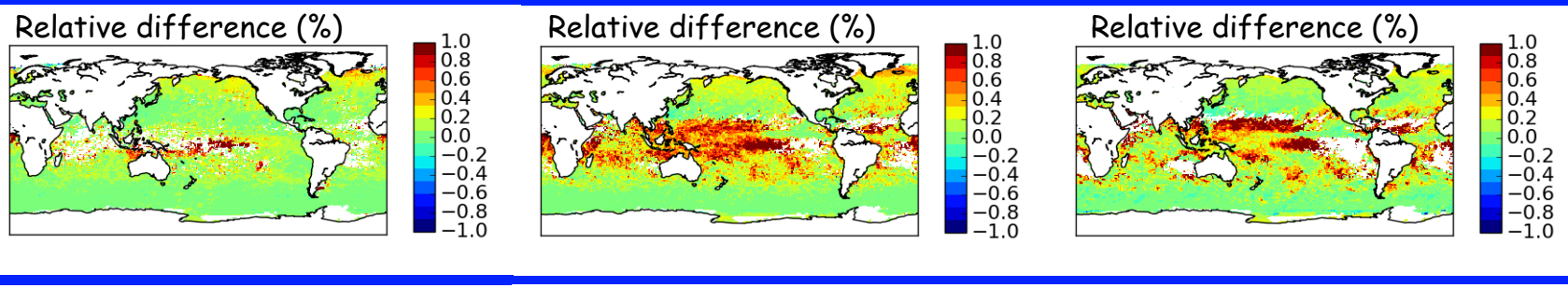
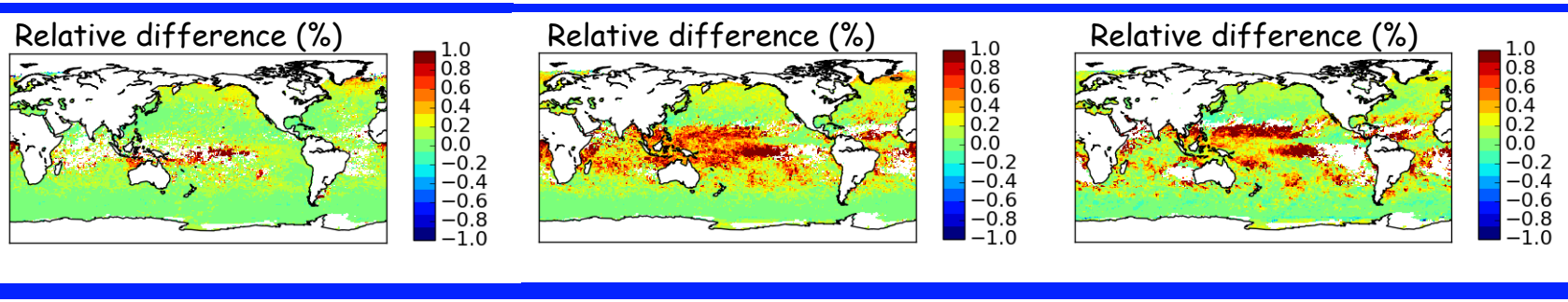
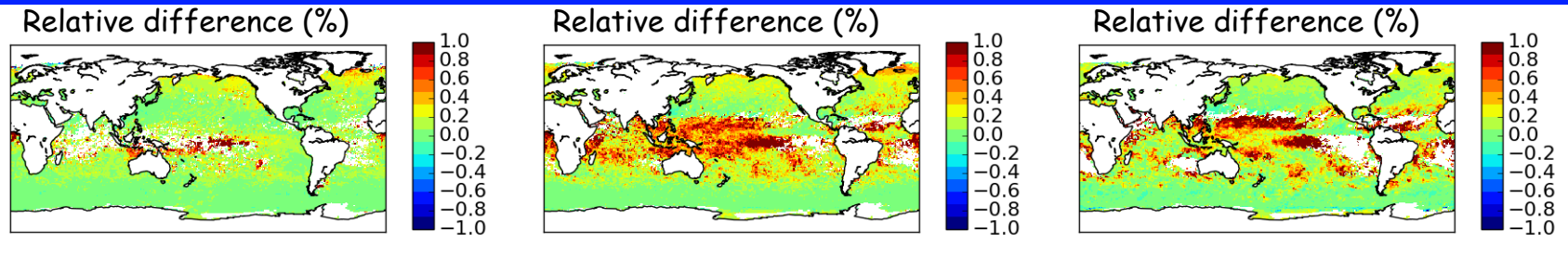
$\tau = 4 - 10$



$\tau > 10$



Compare unfiltered radiances (as calculated from DISORT) to that based on Ed4 coefficients

	Water cloud	Mix cloud	Ice cloud
$\tau < 2$			
$\tau = 2 - 4$			
$\tau = 4 - 10$			
$\tau > 10$			

4. cloud over land

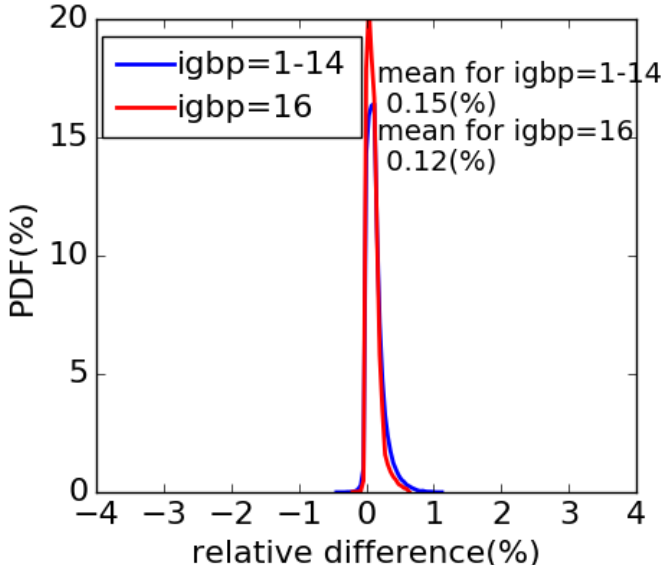
SW clouds over land: model simulations

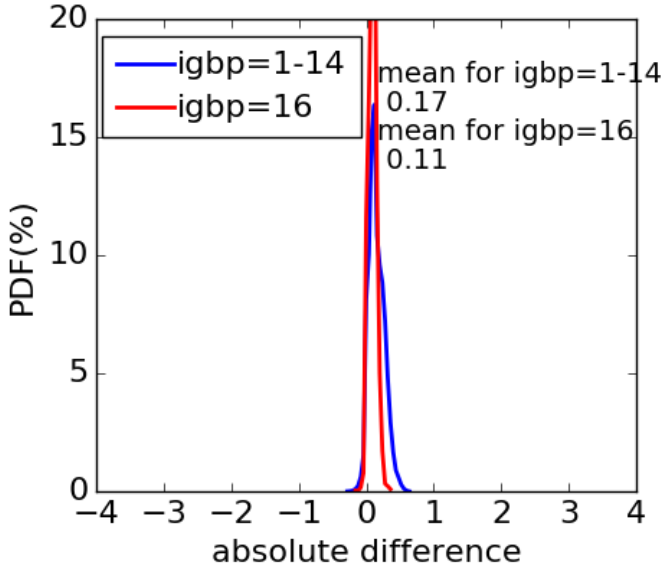
- Ping Yang's water and ice particle radiative properties (single-habit model for ice)
- 7 cloud optical depths: 1, 2, 4, 12, 14, 20, and 217
- 4 water droplet diameters for water clouds: 8, 20, 32 and 50 um
- 3 ice particle diameters for ice clouds: 21.86, 46.34 and 115.32 um (single-habit model)
- IGBP surface type 1-14 and 16
- Simulations are done for

Atmospheric profile	Clouds
U.S. Standard 1962	Ice and water

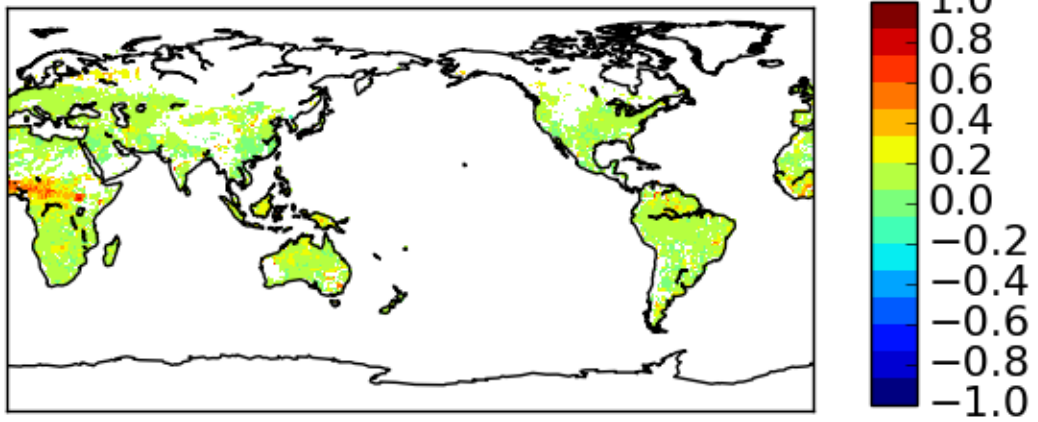
Compare unfiltered radiances (as calculated from DISORT) to that based on Ed4 coefficients

Terra FM1 2010 01

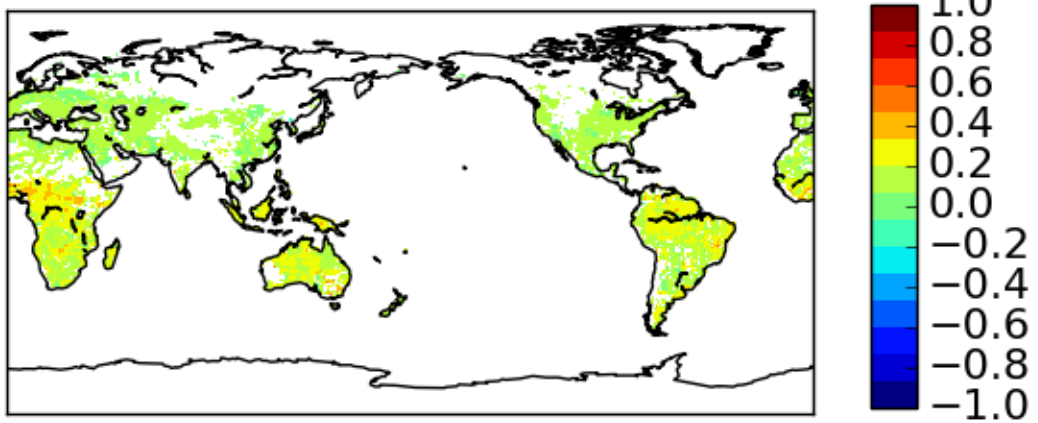




Relative difference (%)



Absolute difference (w/m^2/st)



5. Clear sky over snow and ice

SW clear sky over snow and ice: model simulations

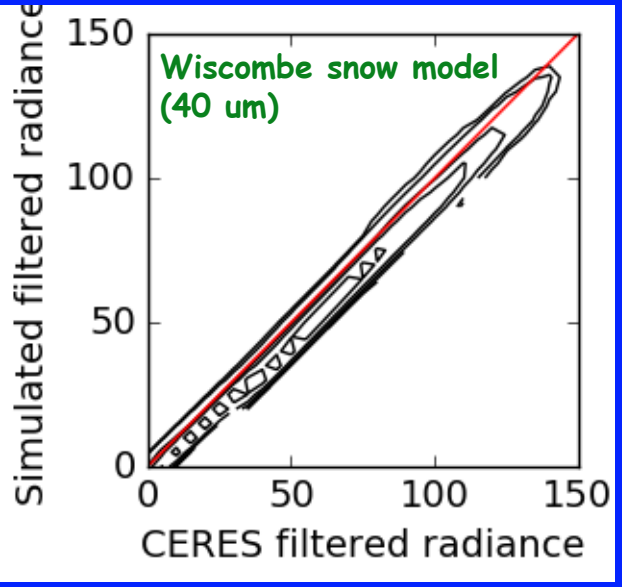
- Broad-band radiative transfer simulations are performed for

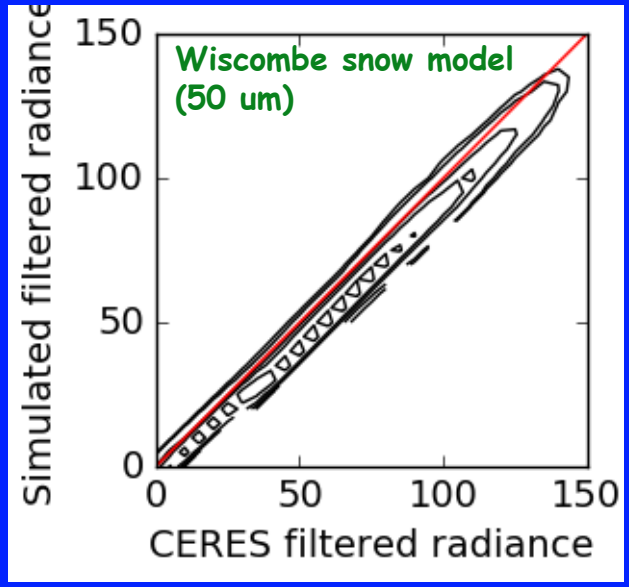
Atmospheric profile	Clouds
Subarctic summer	Continental clean
Subarctic winter	Continental clean

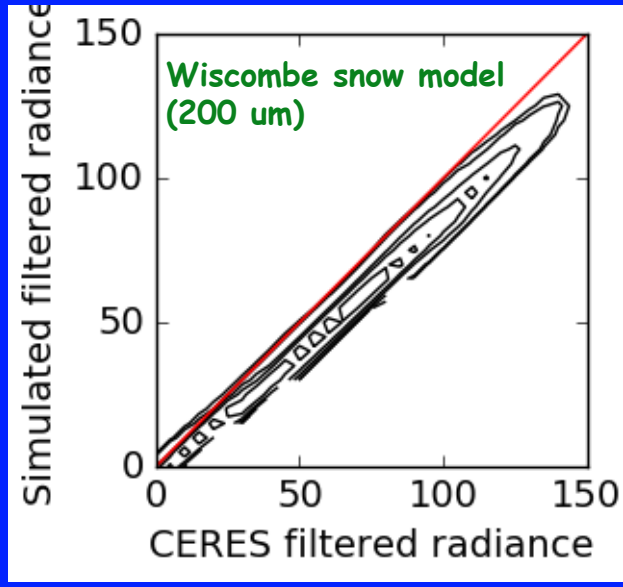
- 5 aerosol optical depth bins (0, 0.05, 0.14, 0.30, 0.60 and 1.00)

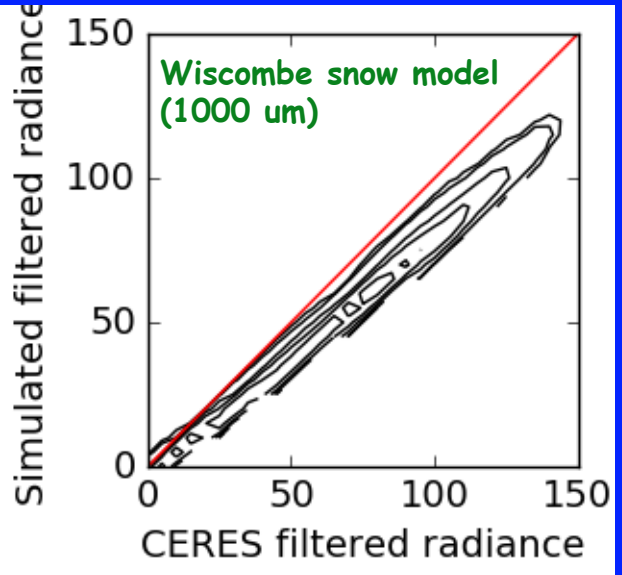
- Simulations are done for surface characterized by:
  1. MODIS BRDF model for igbp=15 and 20
  2. Wiscombe snow model (snow granular size=40um, 50um, 200um and 1000um)

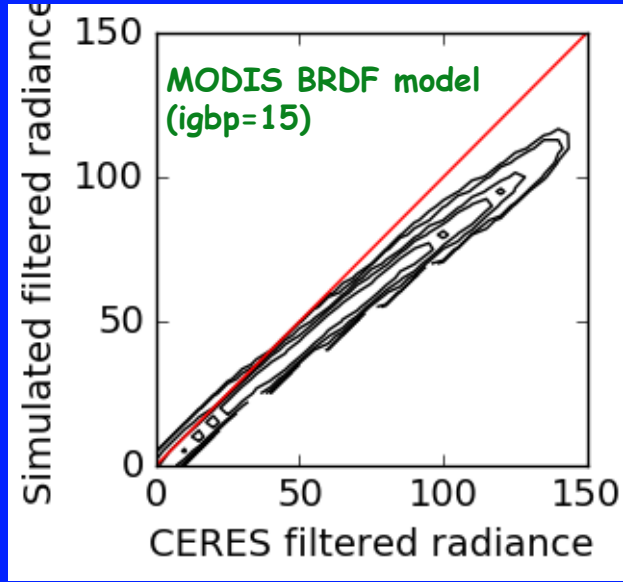
Compare filtered radiances (as calculated from DISORT based on subarctic summer atmospheric profile) to that of Ed4 for Terra FM1 Jan, 2010





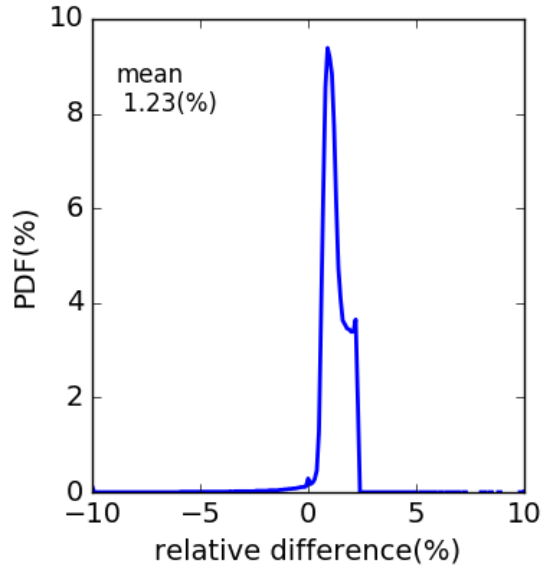


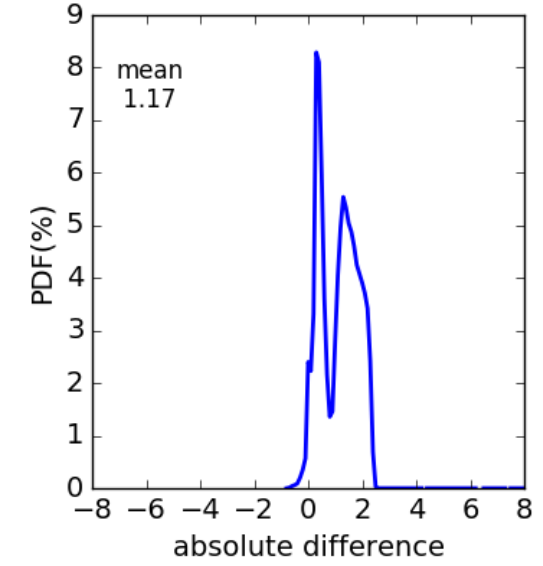




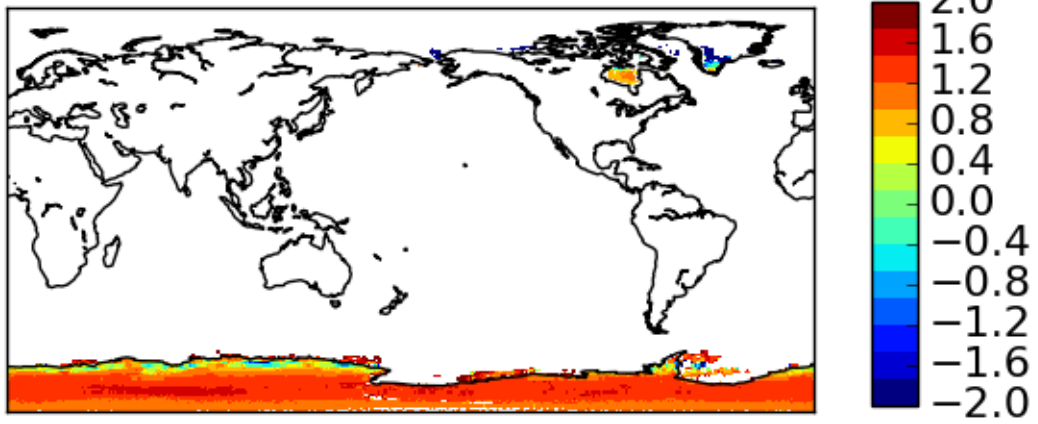
Compare unfiltered radiances (as calculated from DISORT based on Wiscombe snow model with snow granular size=40,50 and 200um) to that based on Ed4 coefficients

Terra FM1 2010 01

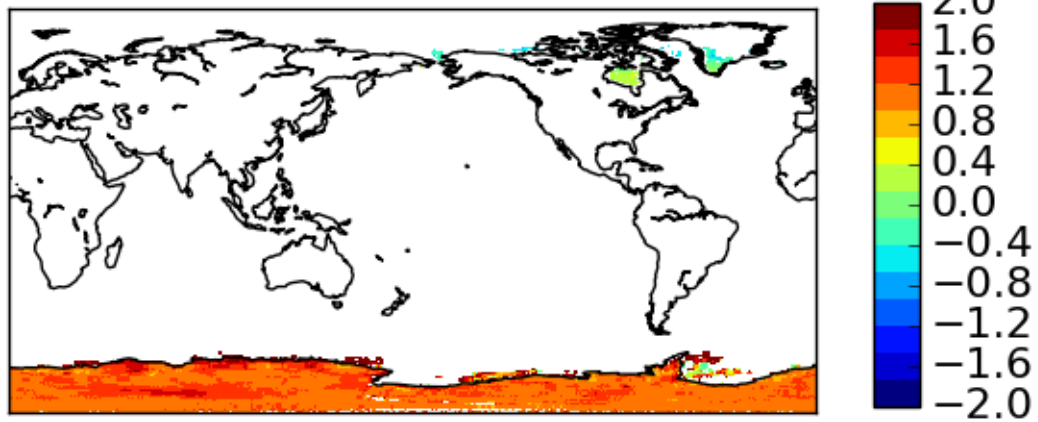




Relative difference (%)



Absolute difference (w/m^2/st)



Future work

- Continue to perform error/uncertainty analysis.
- Finalize CERES unfiltering radiance for shortwave.
- Examine CERES unfiltering radiance for longwave.
- Prepare to apply the new unfiltering radiance in the next version of CERES product.