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

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Outline

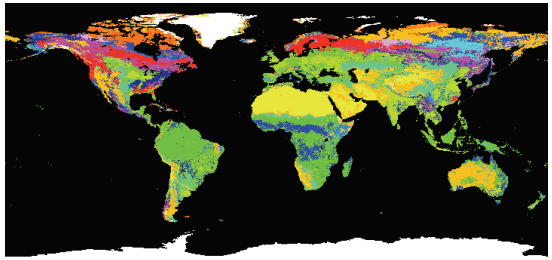
- Simulations using ECMWF ERA-interim reanalysis
  - Sensitivity of radiance averages to surface emissivity and spatial/temporal-varying GHG profiles
- Other related activities in my group
  - Synergy of AIRS and CERES
  - Longwave band-by-band CRF
  - Modeling capacity for sampling studies
  - Data analysis: AR5 sneak peak

Simulations with ERA-interim data

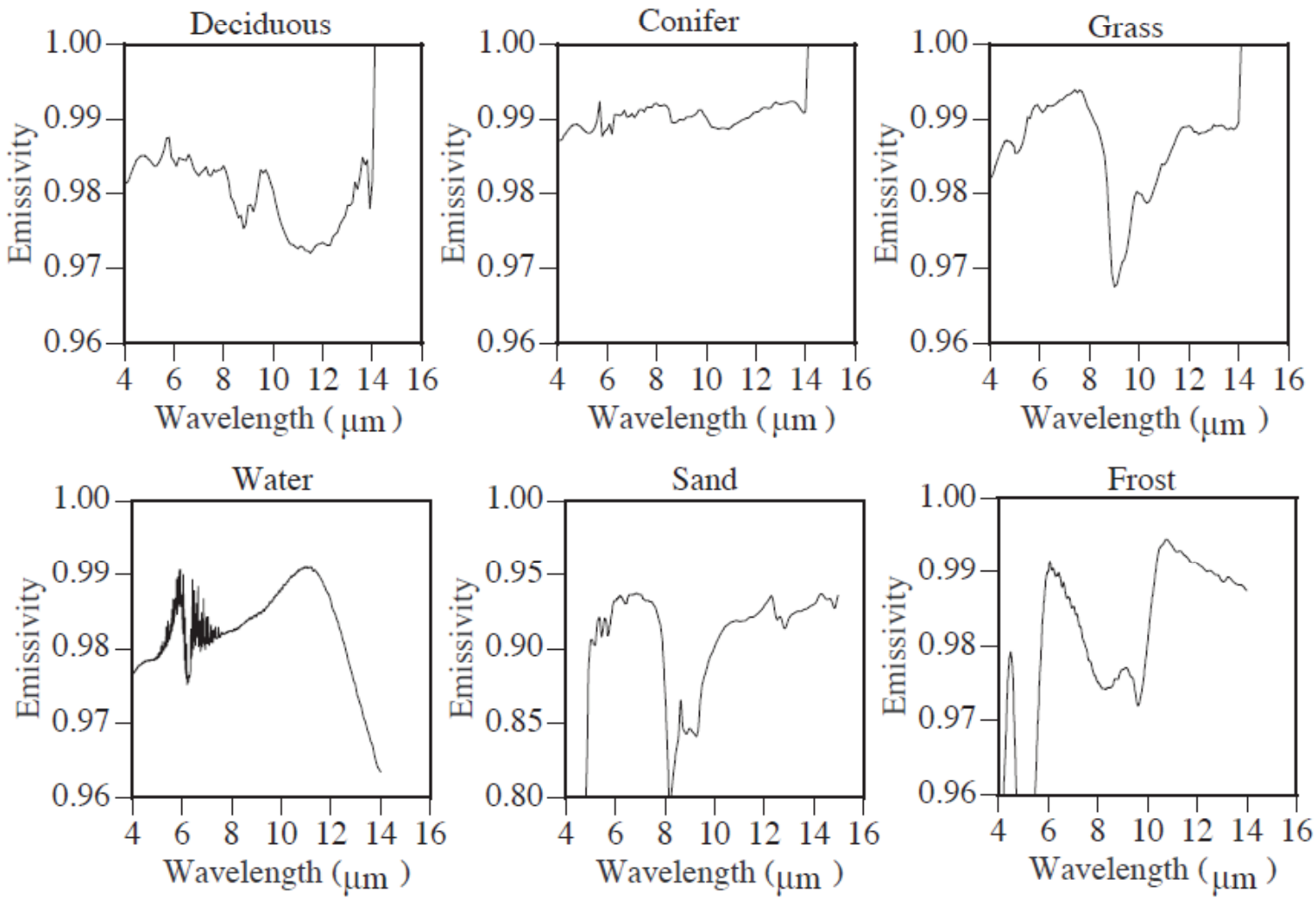
- Radiance simulator at UM
  - Modtran5-based RTA (0.1 cm^{-1})
  - Local cluster operated by university (total > 10,000 CPUs)
    - Flexible rental for exclusive use with minimal cost: can rent 1000-2000 CPUs over a short notice
    - Flexible configuration to "homogenize" nodes: big help for I/O demanding 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
    - CO_2, CH_4, N_2O, CO
      - 1: McClatchey profiles for difference seasons in mid- and high latitudes
      - 2. Mean seasonal cycles at 1990s from a CTM (MOZART)



From NASA/TP-1999-209362 By Wilber, Kratz, and Gupta

NOTE: no database gives ε_v beyond 14μm

Applications of the simulators

- Test the impact of seasonality of trace GHGs and surface spectral emissivity on averaged radiances

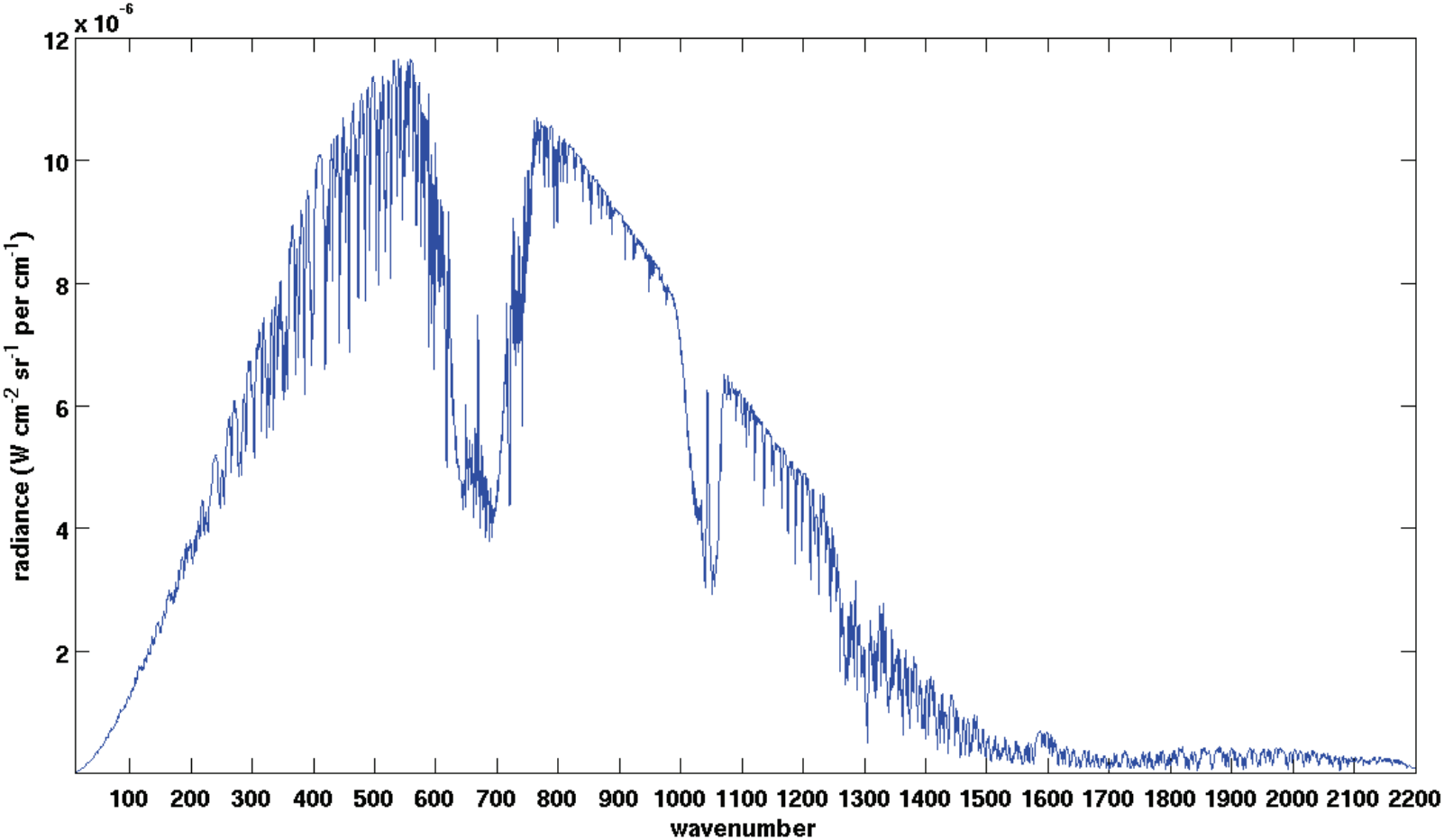
  For clear-sky radiances

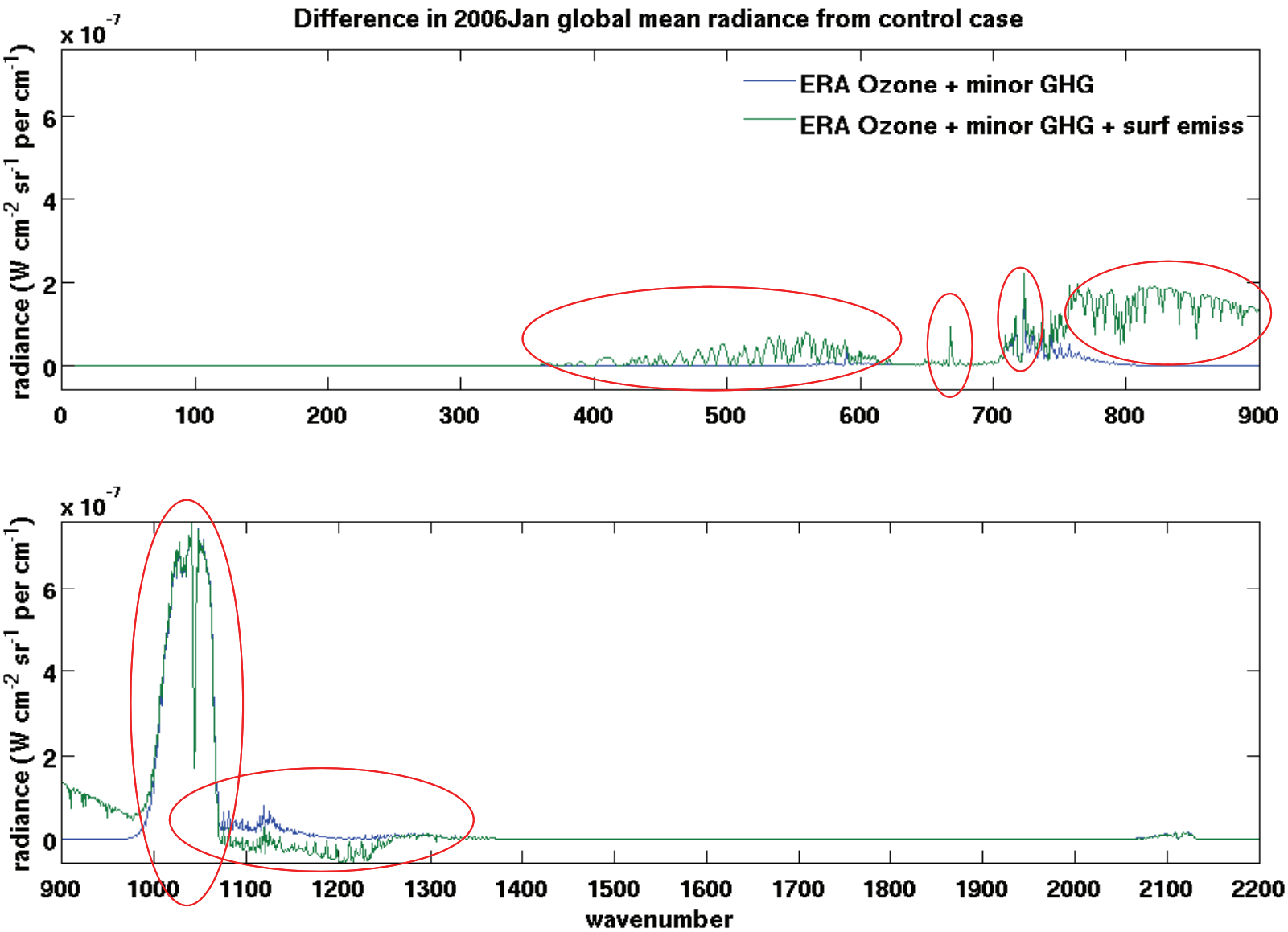
  – Control case: blackbody surface, constant GHG profiles

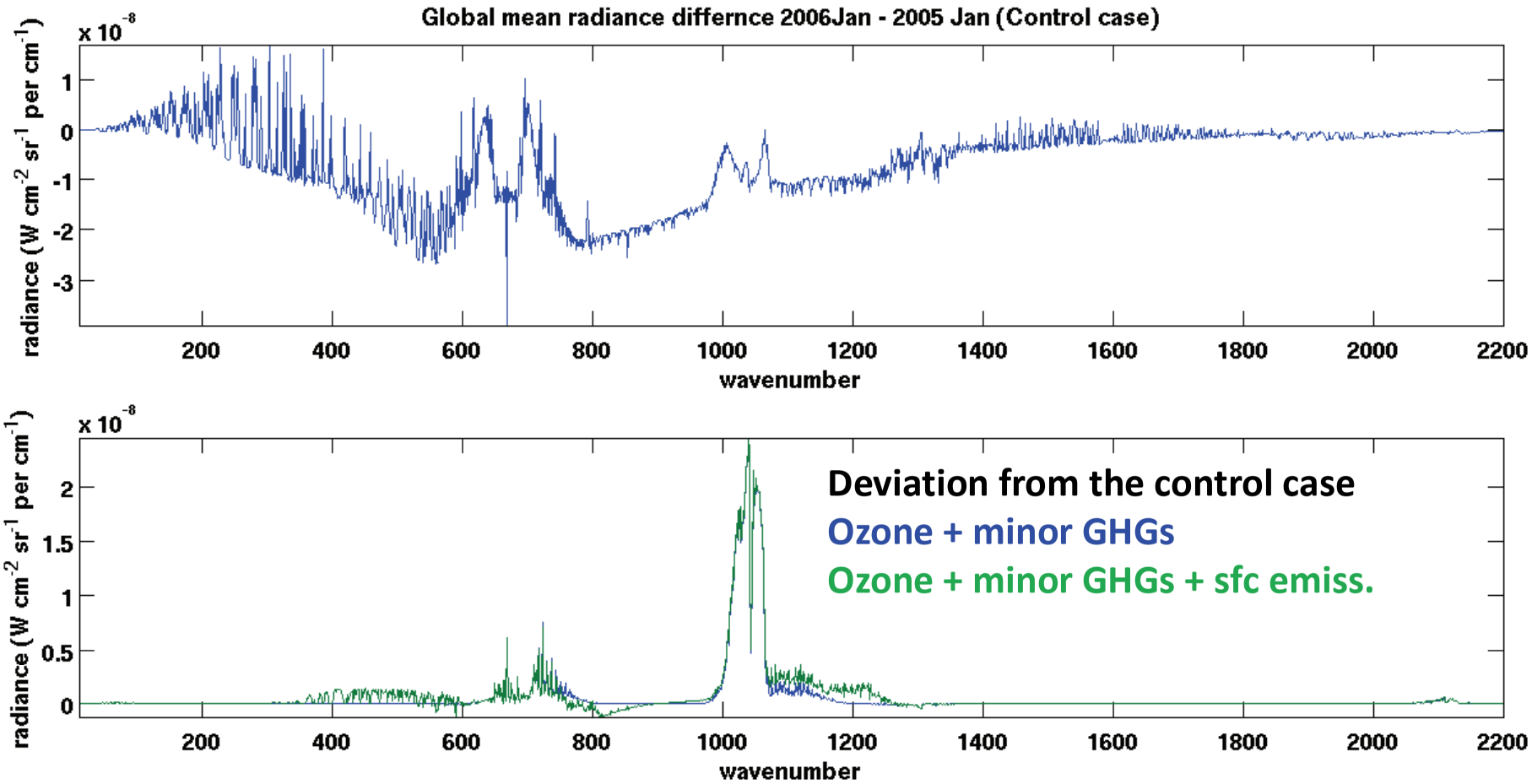
  – Ozone+ other minor GHGs case

  – Ozone + other minor GHGs + surface emissivity case

Control case: global mean clear-sky radiance 2006 Jan (1.0 cm^{-1})




Difference in 2006Jan global mean radiance from control case
x 10^-7
radiance (W cm^-2 sr^-1 per cm^-1)
ERA Ozone + minor GHG
ERA Ozone + minor GHG + surf emiss
0
2
4
6
0
100
200
300
400
500
600
700
800
900
x 10^-7
radiance (W cm^-2 sr^-1 per cm^-1)
0
2
4
6
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
2100
2200
wavenumber



- 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

	Nighttime ($W\ m^{-2}$)	Daytime ($W\ m^{-2}$)
2003	0.80±1.34	0.86±1.72
2004	0.52±1.29	0.79±1.67
2005	0.93±1.35	1.81±1.81
2006	0.86±1.38	2.10±1.81
2007	0.83±1.40	2.45±1.87

Clear sky over the ocean

Daytime drift corrected in CERES SSF Edition 3

$OLR_{AIRS_Huang_algorithm}$-collocated OLR_{CERES}

Cloudy sky over the ocean

	Nighttime ($W\ m^{-2}$)	Daytime ($W\ m^{-2}$)
2003	1.63±5.22	3.73±5.94
2004	1.33±5.16	3.00±5.73
2005	1.75±5.32	4.06±6.03
2006	1.58±5.42	4.35±6.08
2007	1.50±5.37	4.57±6.06

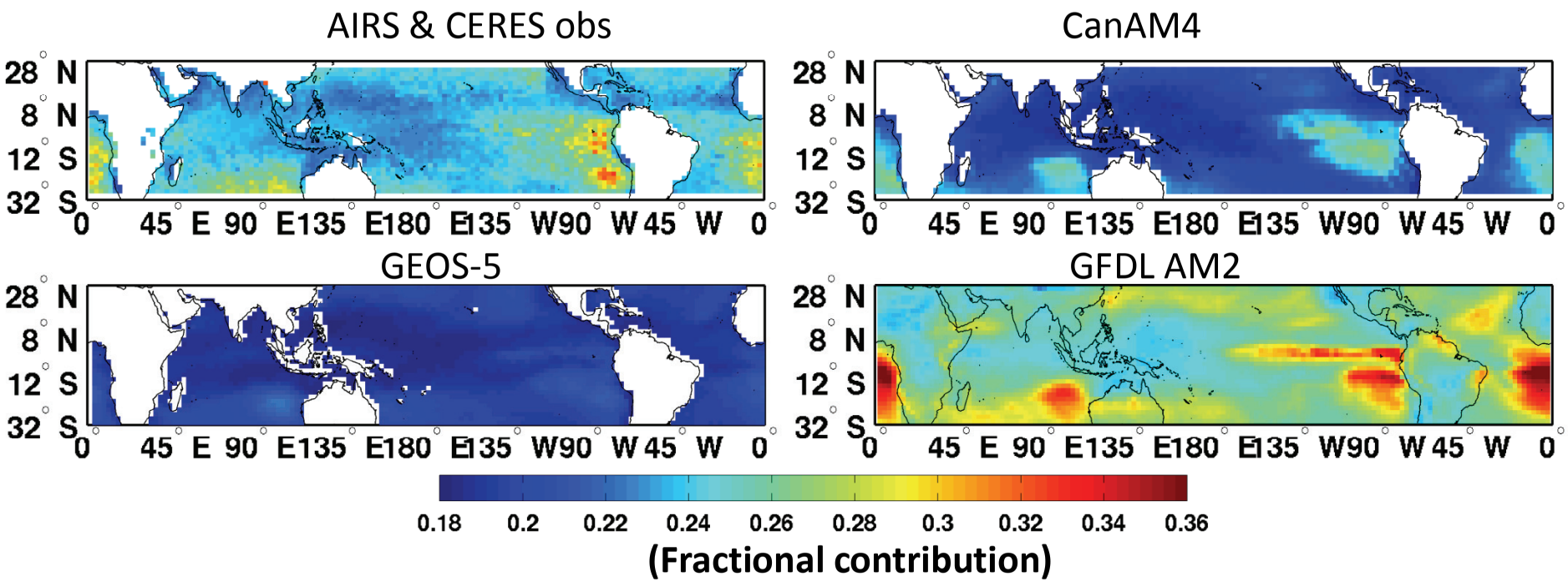
Annual-mean CRF in 2004 (Tropical oceans)

		AIRS&CERES observed CRF (Wm^{-2})	AM2 simulated CRF (Wm^{-2})	NASA GEOS-5 simulated CRF (Wm^{-2})	Canada CanAM4 simulated CRF (Wm^{-2})
			AR4 AGCM	AR5 AGCMs	
	LW broadband	27.45 (100%)	28.13 (100%)	28.30 (100%)	27.27 (100%)
H_2O	0-560cm^{-1}; >1400cm^{-1}	5.36 (19.5%)	5.33 (19.0%)	5.08 (17.9%)	4.45 (16.3%)
CO_2	560-800cm^{-1}	4.18 (15.2%)	3.74 (13.3%)	5.15 (18.2%)	4.82 (17.7%)
WN	800-990cm^{-1}	9.35 (34.1%)	10.03 (35.6%)	9.06 (32.0%)	8.78 (32.2%)
O_3	990-1070cm^{-1}	2.02 (7.0%)	1.68 (6.0%)	3.62 (12.8%)	3.73 (13.7%)
WN H_2O NO_2 CH_4	1070-1400cm^{-1}	6.53(23.8%)	7.34 (26.1%)	5.43 (19.1%)	5.48 (20.1%)

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.

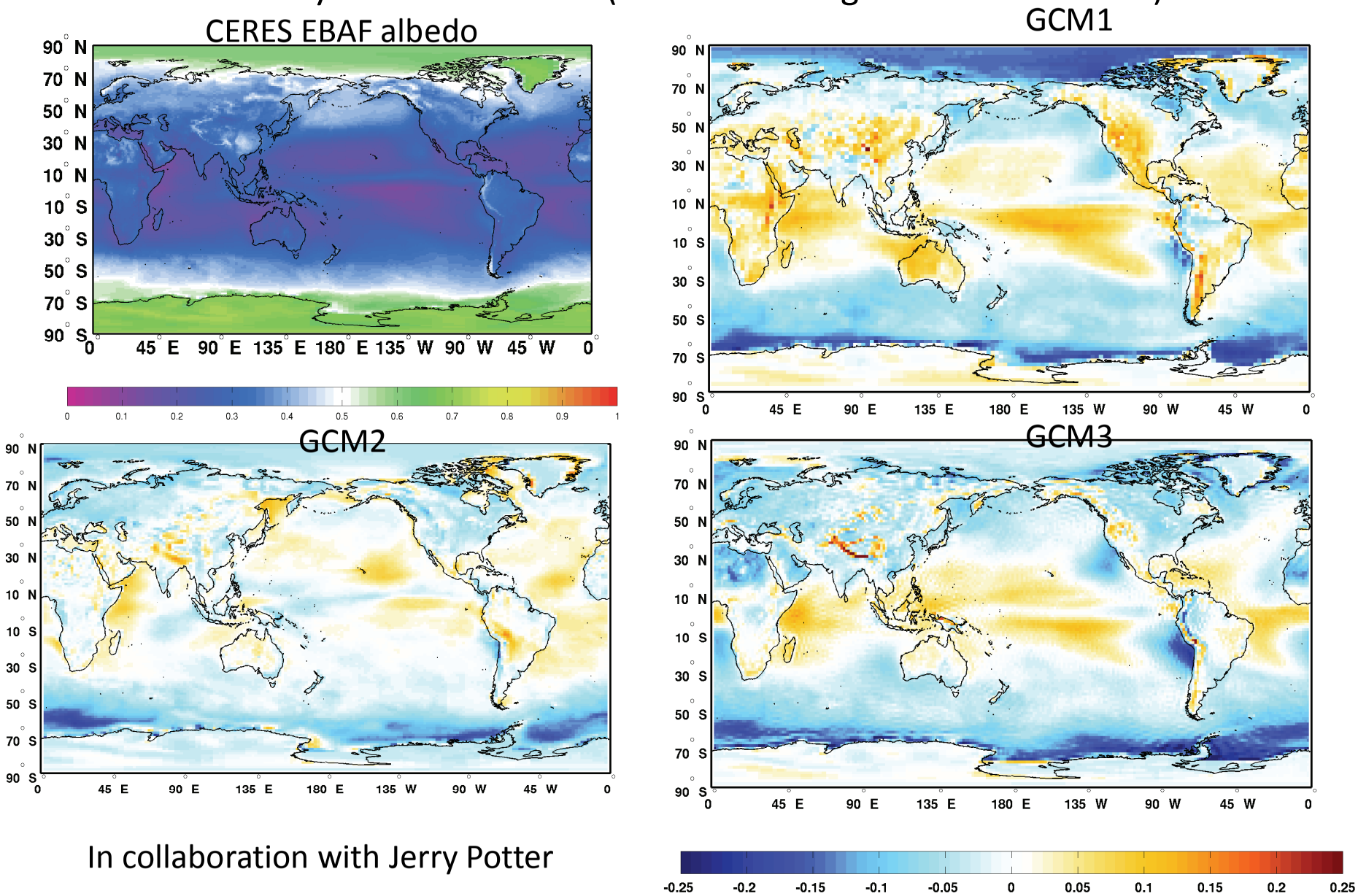
In collaboration with Jerry Potter, Lazaros Oreopoulos, et al.

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 initilization

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?