An update of OLR trend in the last two decades: what do CERES, AIRS, and CrIS tell us all together

Xianglei Huang[1], Xiuhong Chen[1], Norman Loeb[2], Seiji Kato[2], Qing Yue[3], Eric Fetzer[3], Qing Liang[4], Luke Oman[4], Stephen D. Steenrod[4]

1. University of Michigan 2. NASA Langley Research Center 3. JPL/Caltech 4. NASA GSFC

CERES Spring 2024 Science Team Meeting
May 15, 2024

Acknowledgements: CERES project

- We have had concurrent broadband and spectrally resolved measurements
  - CERES and AIRS on Aqua since Sep 2002
  - CERES and CrIS on S-NPP and JPSS1/2 since Feb 2012

- We also have had T & q well assimilated into ERA5 and MERRA-2 reanalyses
- We also have had cloud observations better than before
- Ozone monitoring and "nudged" simulations are also well-developed
- Other well-mixed GHGs are routinely monitored by NOAA

"Do we have a consistent picture from these observations-based datasets regarding the longwave radiative forcings and feedbacks in the last two decades?"

Some work presented here is still working-in-progress. Please do not cite.

MICHIGAN

Datasets (Jan 2003 - Dec 2022)

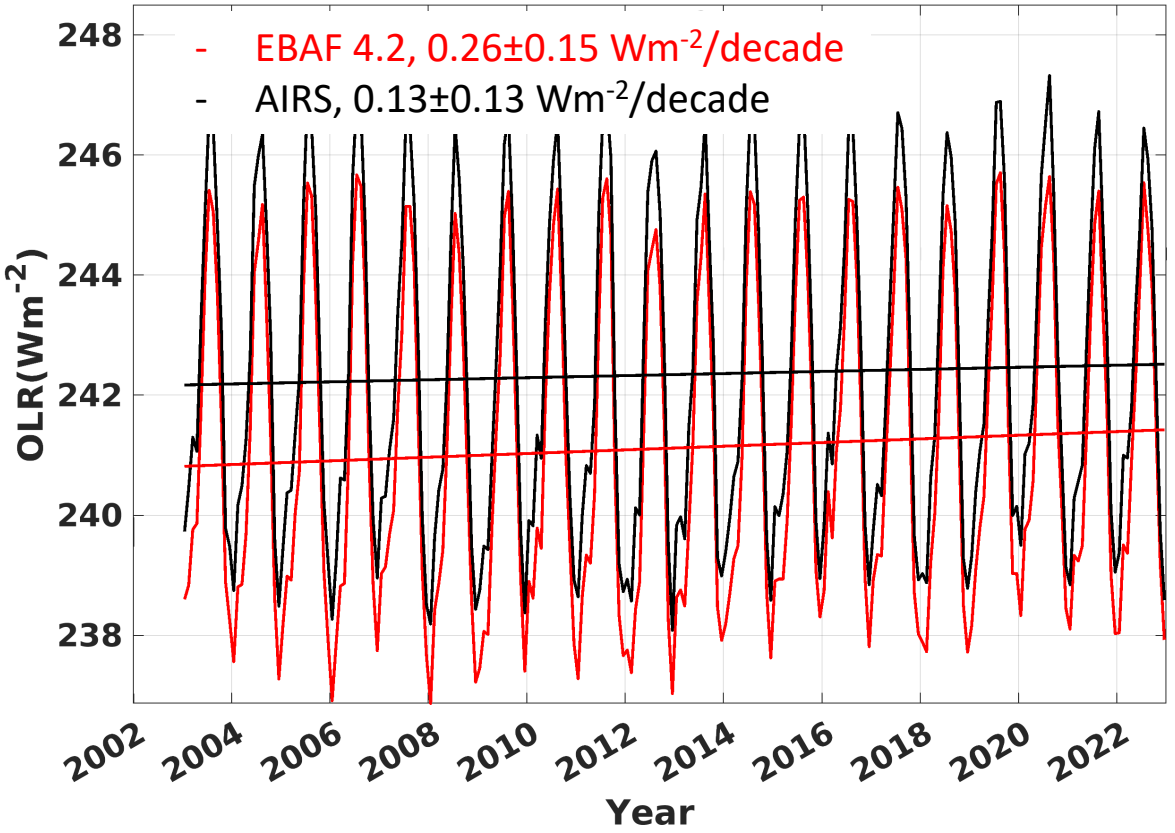
- CERES EBAF 4.2 AIRS L3 Spectral OLR product
  - 10cm^{-1} spectral flux derived from collocated AIRS and CERES measurements
- MODIS monthly-mean cloud state joint histograms
  - Derived from Eric Fetzer's MEASURES project
- ECMWF ERA5 reanalysis temperature and humidity profiles
- CO_2/CH_4/N_2O from NOAA GML
- O_3 from the NASA GEOS with the full chemistry version (GEOSCCM) with nudged meteorology
  - ~100km horizontal resolution, 72 vertical levels

MICHIGAN

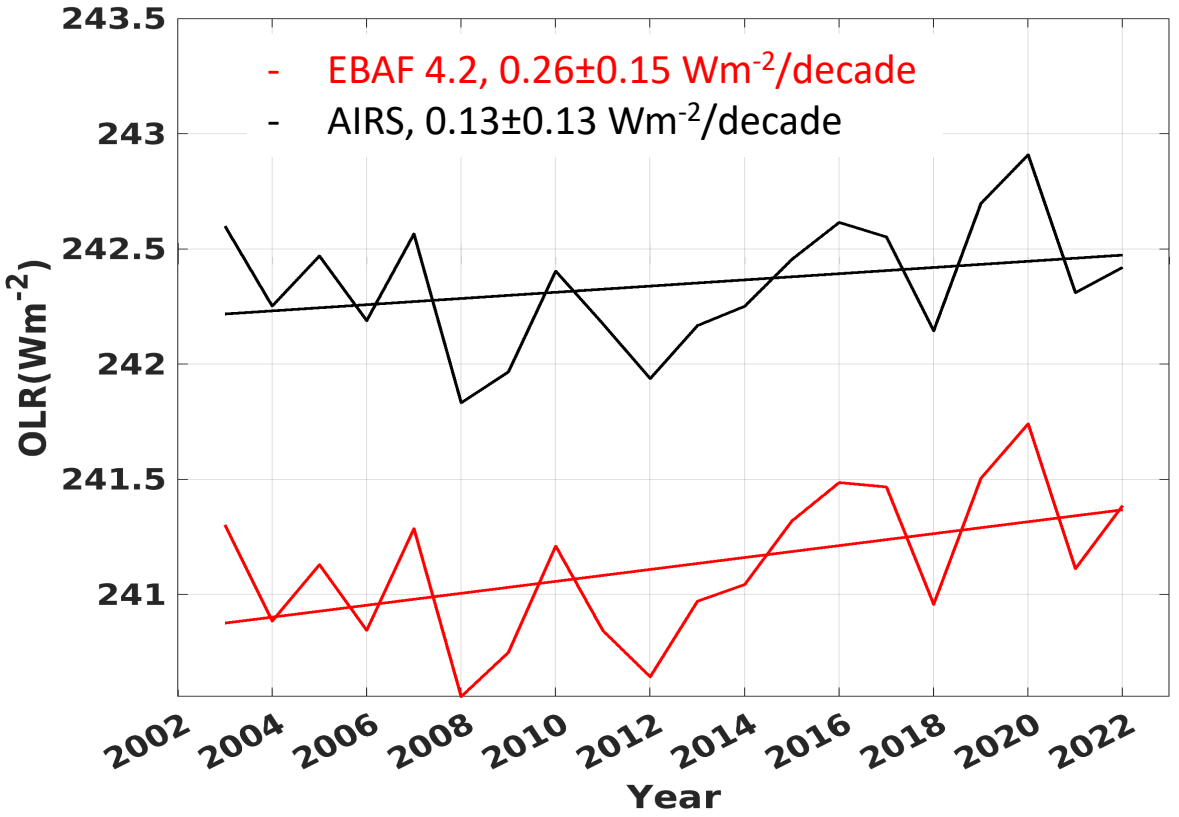
Global-mean OLR time series as inferred from CERES EBAF OLR and AIRS spectral OLR

Trends and uncertainties using Weatherhead's formula (1998, JGR)

Monthly-mean



Annual-mean



EBAF: 24-hour average

AIRS: equally weighted average of ascending and descending Aqua observations

What could be the reason(s) for the discrepancies, 0.26±0.15 vs. 0.13±0.13 Wm^{-2}/decade?

1. Sampling difference

   Check the long-term trend of collocated CERES-Aqua obs (prior to Feb 2022) vs. that of EBAF 4.2, no difference in linear trend

2. Uncertainty in inverting spectral radiance to spectral flux

   (1) Spectral ADM

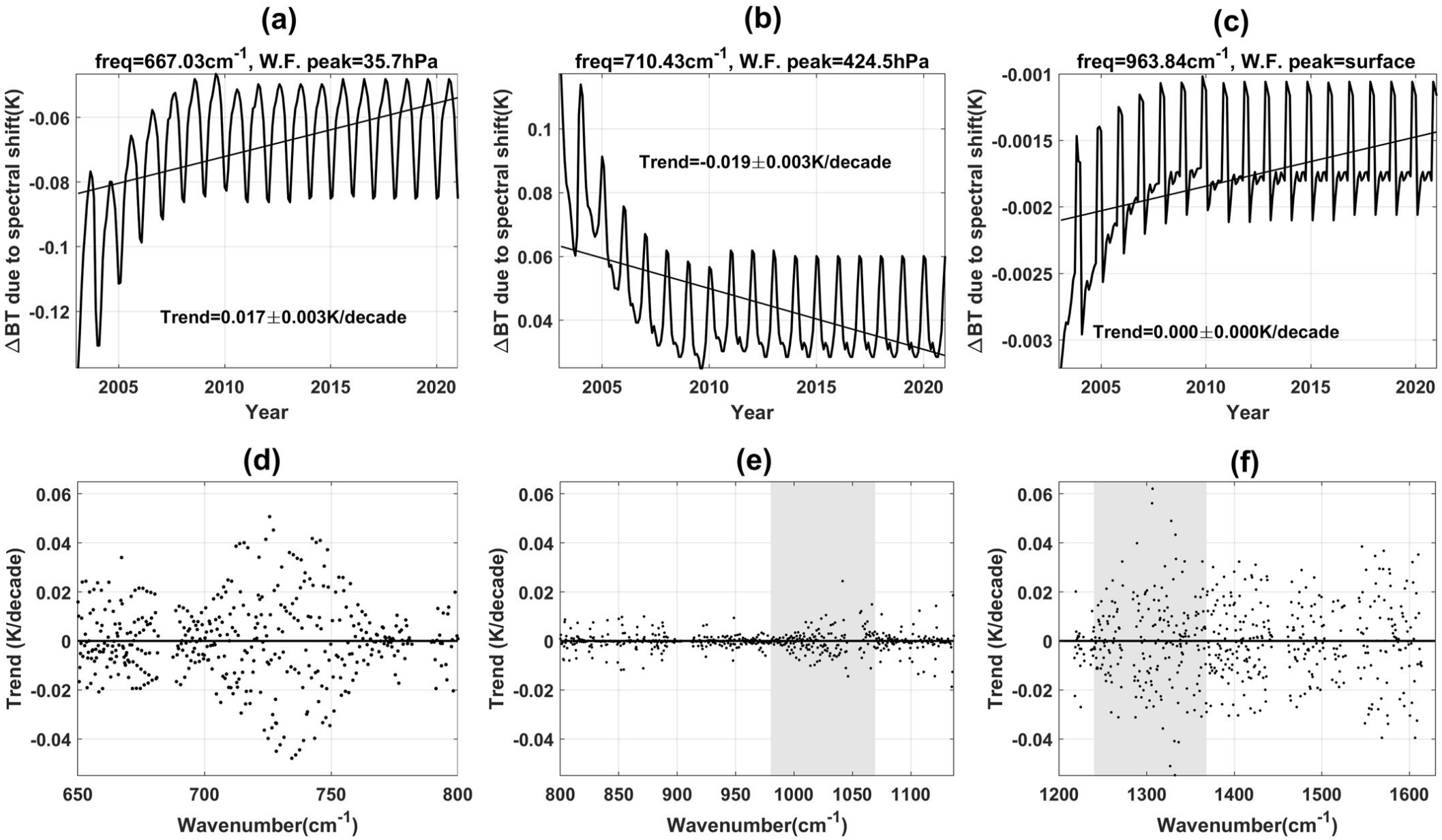
   (2) Extrapolation from mid-IR AIRS to far-IR region

3. Calibration/stability

   Much more difficult to assess

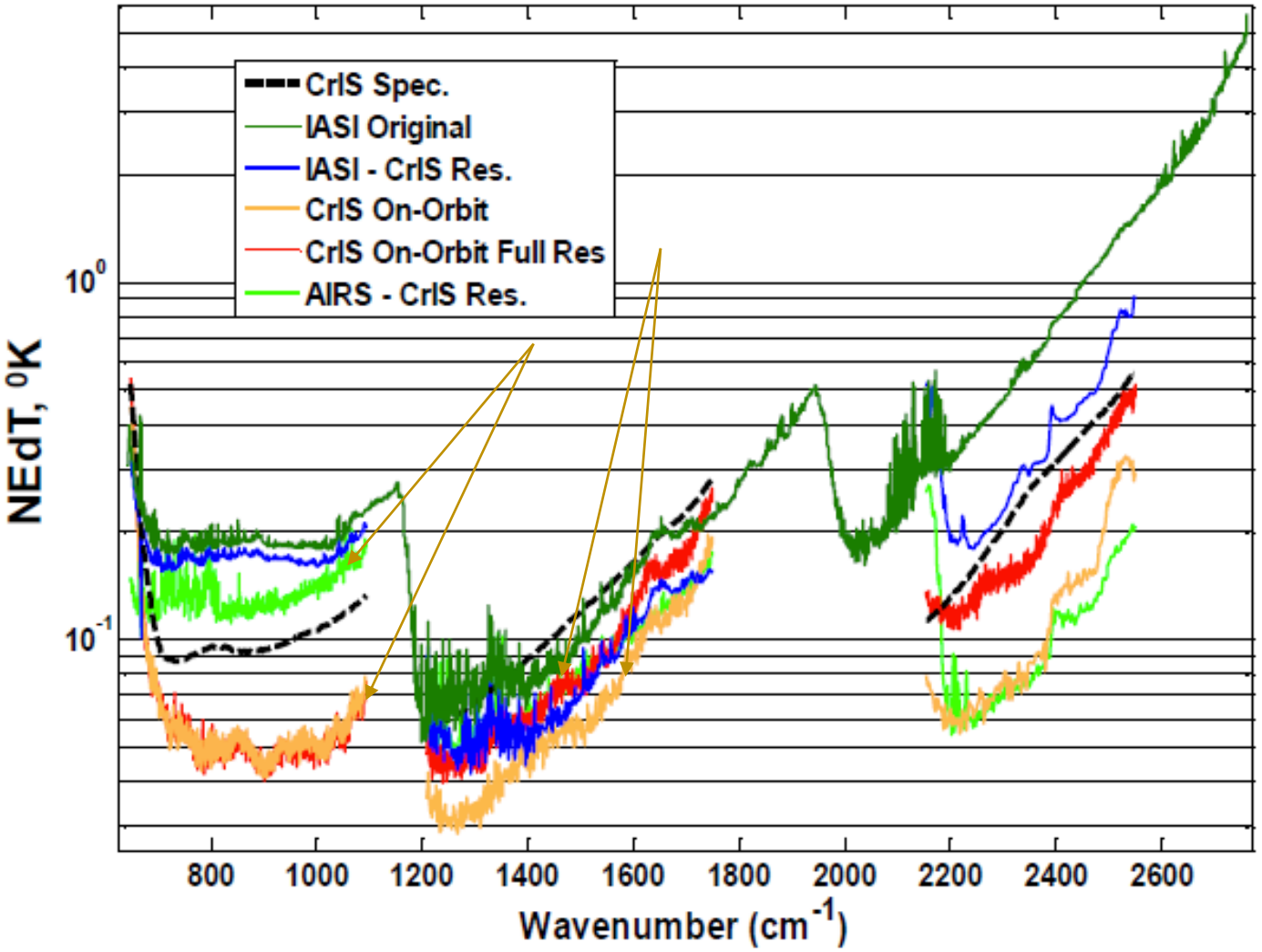
   Known issues and unknown issues

Secular drift of the AIRS SRF centroid: more stabilized after 2010



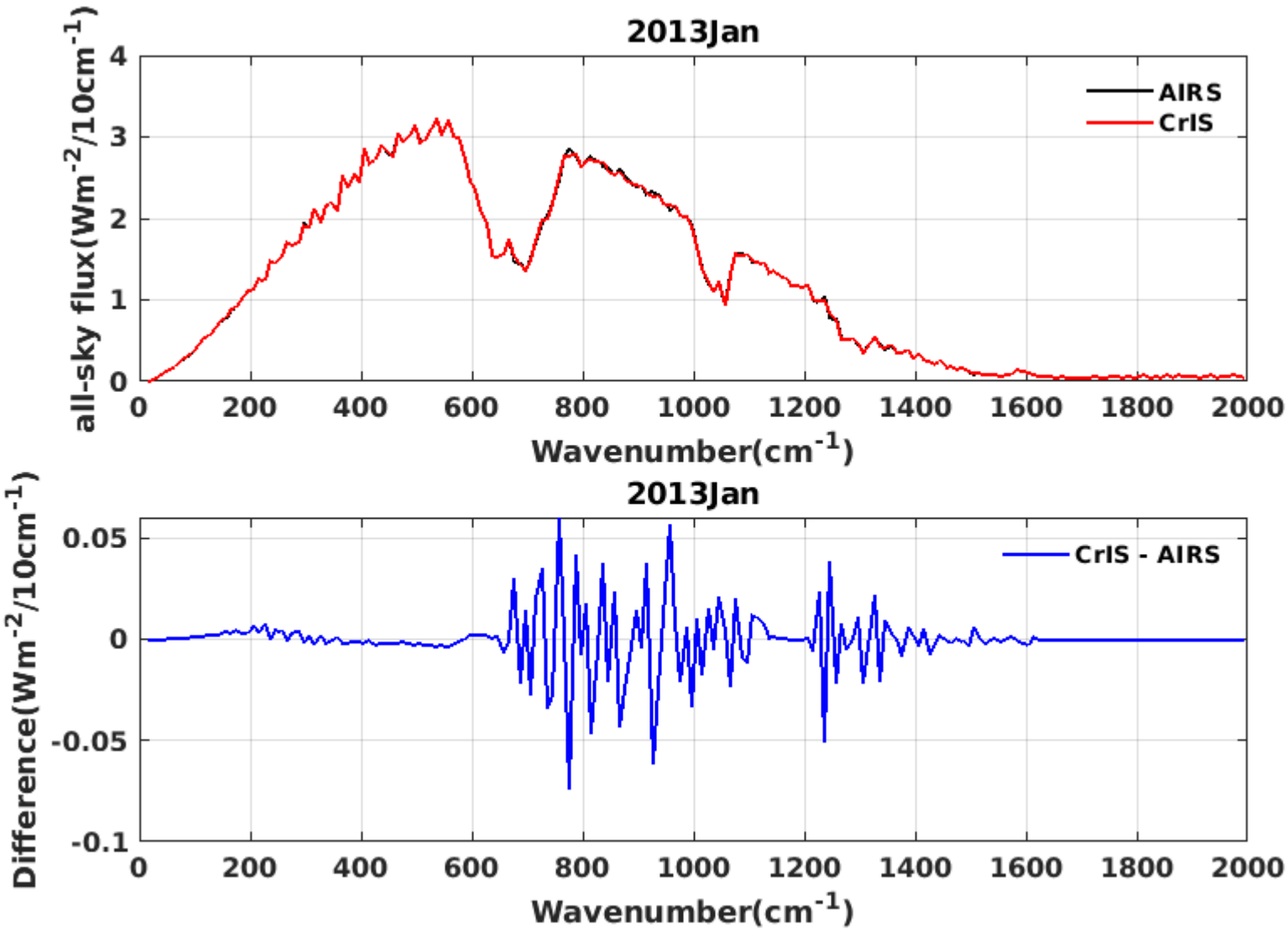
CrIS NEdT vs AIRS and IASI at native instrument resolution (T=270K)

In thermal IR, CrIS has smaller noise levels than both AIRS and IASI



Zavyalov et al, https://cimss.ssec.wisc.edu/itwg/itsc/itsc18/program/files/links/1.07_Zavyalov_po.pdf

Givens the AIRS and CrIS instrument performances, could we see sth different if we only use CrIS-era data?

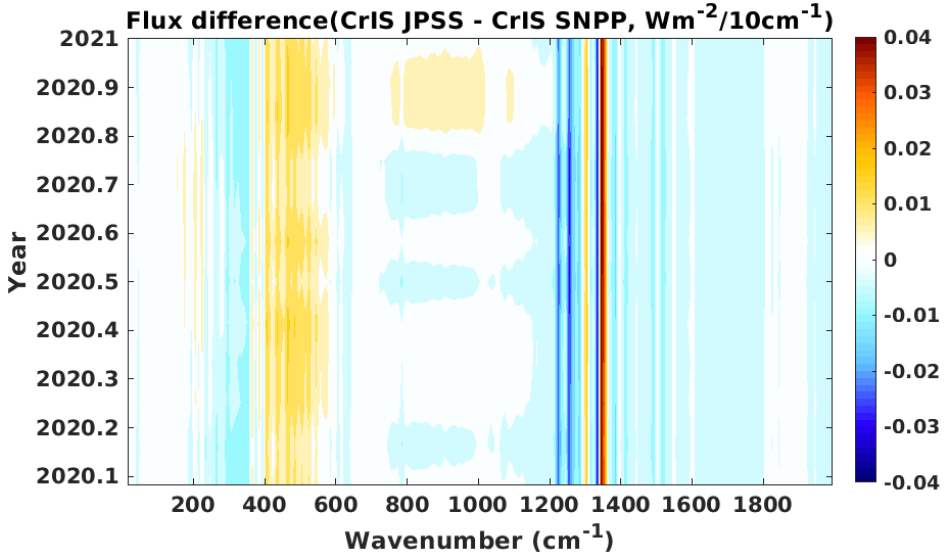


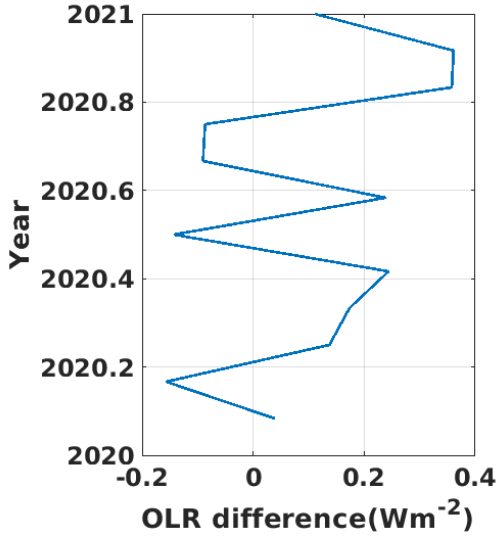
Issues with CrIS

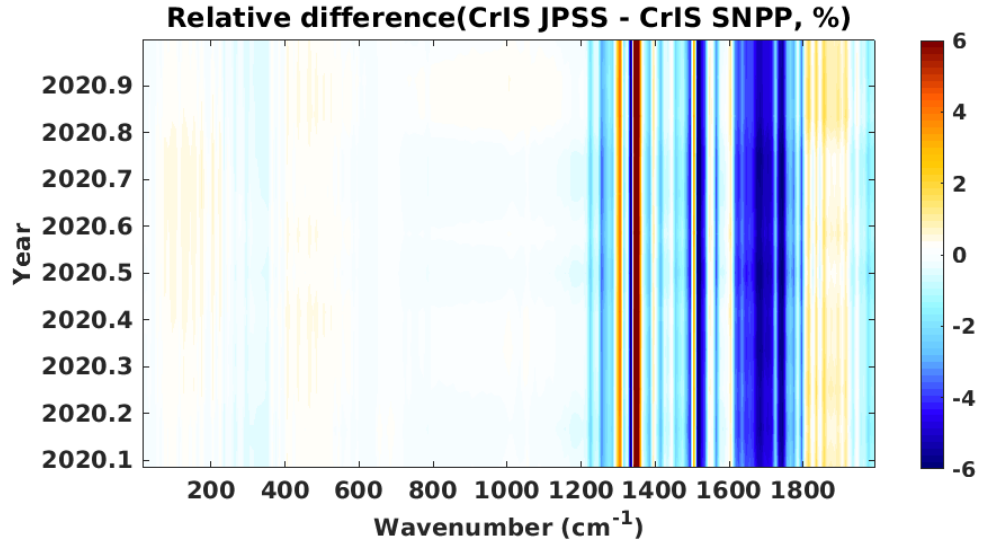
1. CrIS on S-NPP have issues in their mid-IR channels after 2021
2. CrIS on S-NPP and CrIS on JPSS-1 have differences

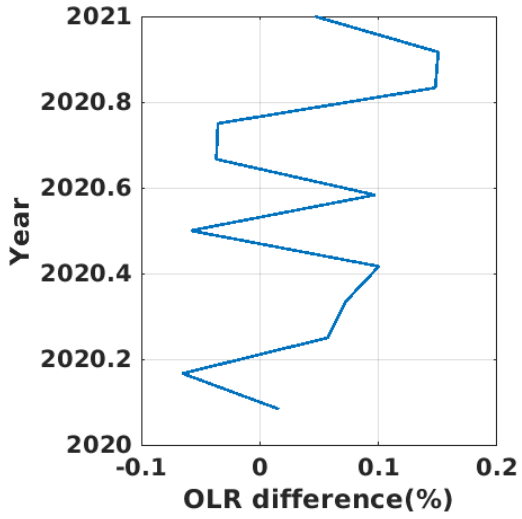
Our solutions: use CrIS on JPSS-1 after 2020 and CrIS on S-NPP before 2020; and make adjustments based on the overlapped measurements in 2020

Overlapped results in 2020 (global average)

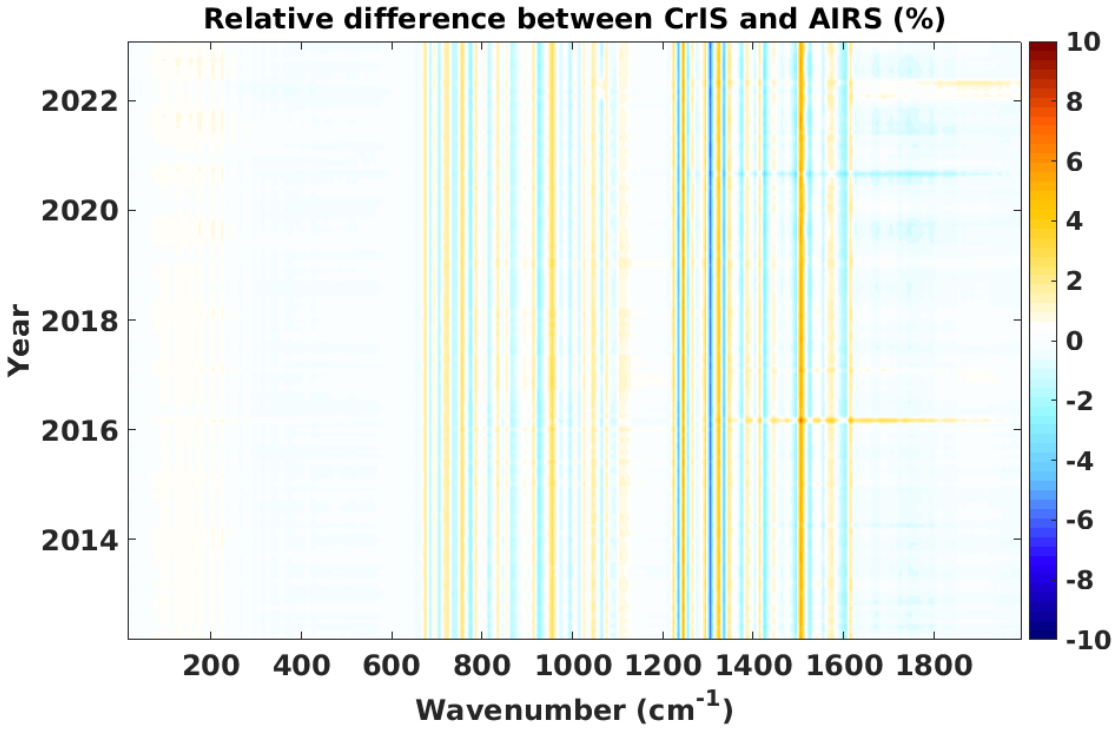


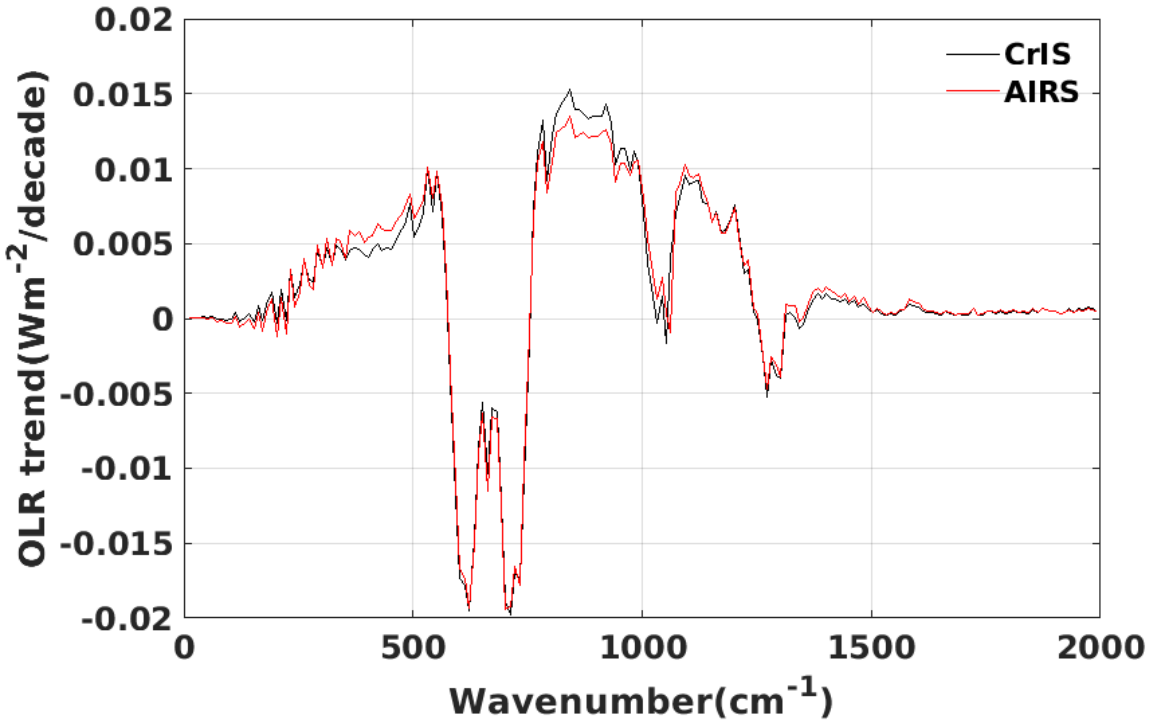






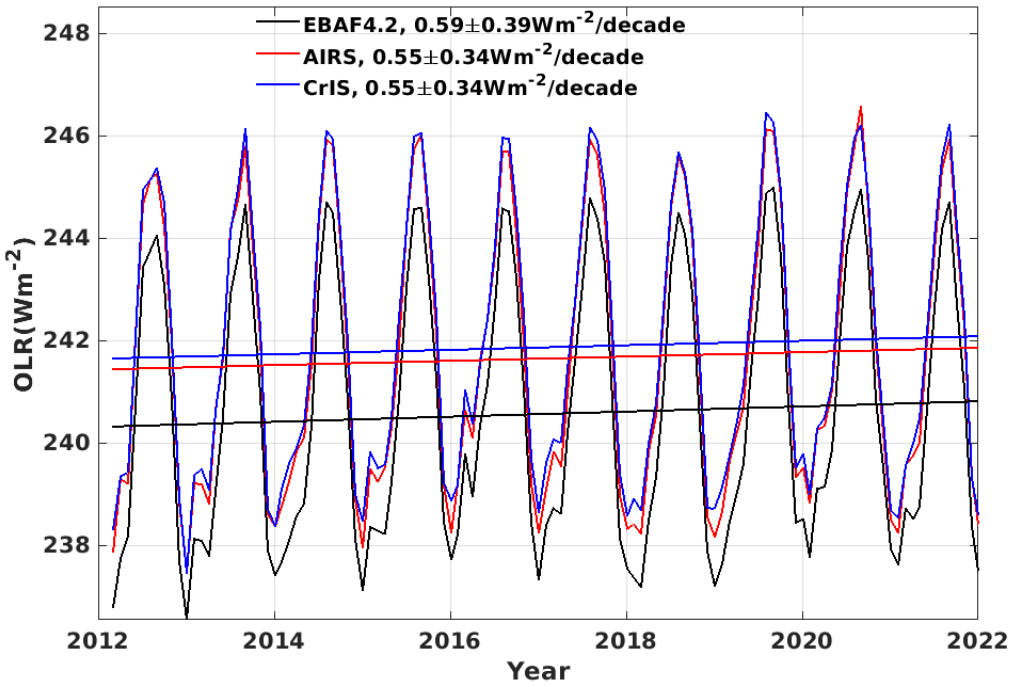
Spectral OLR from AIRS and CrIS: Feb 2012 to Jan 2023

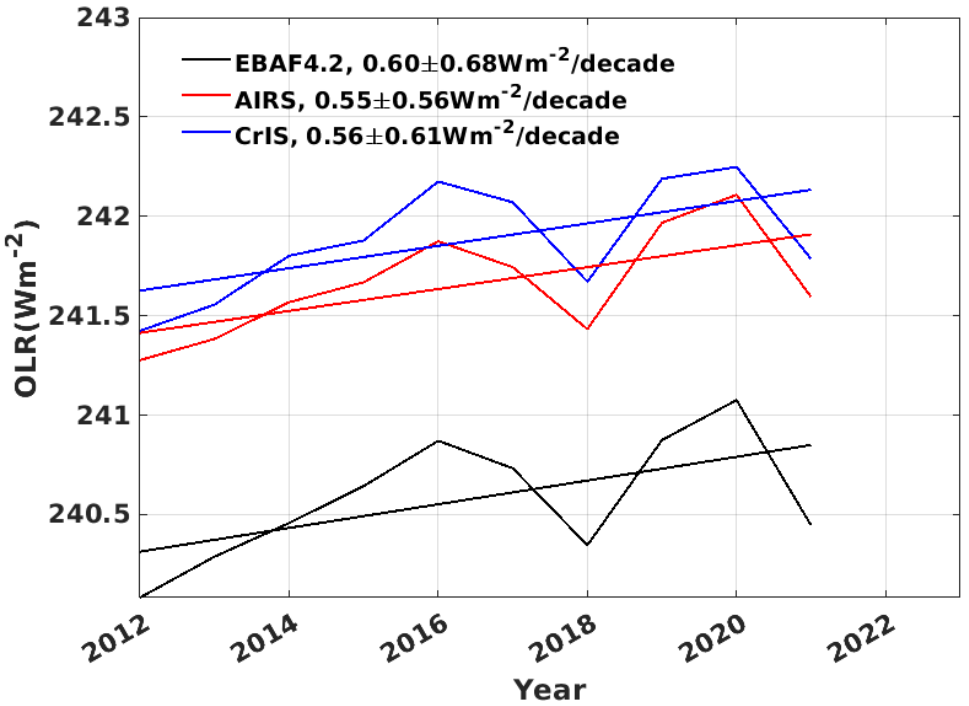




Trends from monthly-mean time series are calculated using trend_weatherhead.m
Trend ± 95% confidence interval is shown

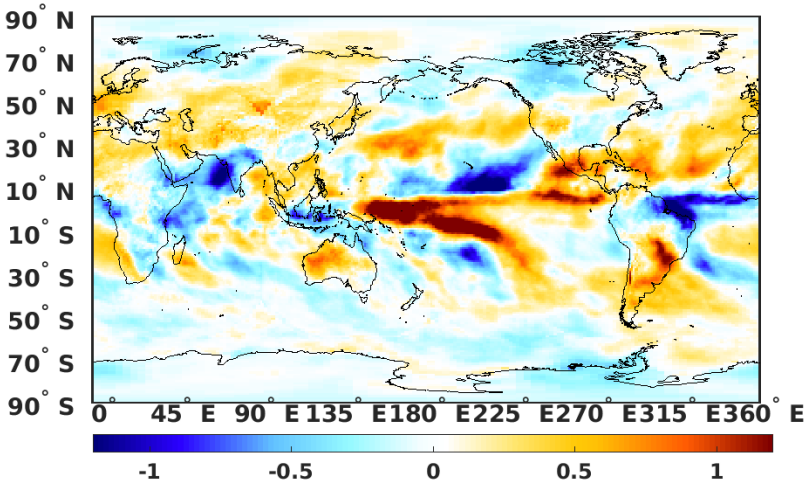
	$\frac{dF}{dt}$ from EBAF4.2 (Wm^{-2}/yr)	$\frac{dF}{dt}$ from CrIS (Wm^{-2}/yr)	$\frac{dF}{dt}$ from AIRS (Wm^{-2}/yr)	$\frac{d}{dt}[-RF] + [-\lambda]\frac{dT_{surface}}{dt}$	$\frac{d}{dt}[-RF]$ (Wm^{-2}/yr)	$-\lambda$ (Wm^{-2}/K)	$\frac{dT_{surface}}{dt}$ (K/yr)
201202 to 202201, global-mean	0.059±0.039	0.055±0.034	0.055±0.034	0.069	-0.021	2.699	0.034





Trend of OLR from EBAF 4.2

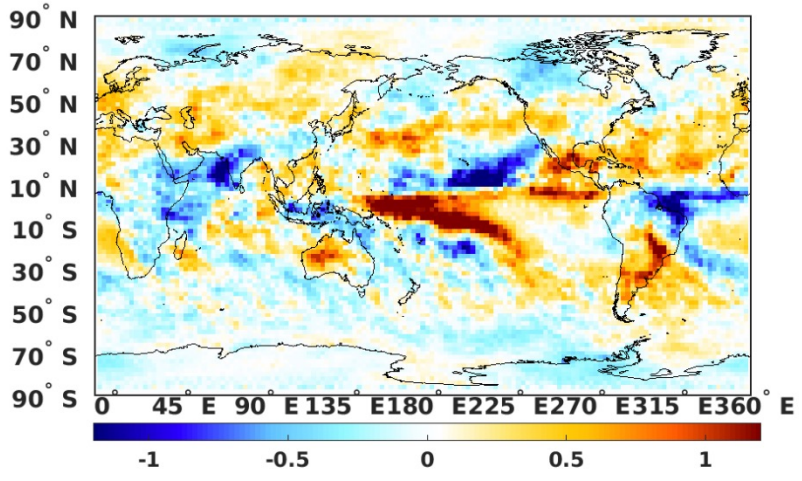
Mean = 0.059Wm^{-2}/yr



Wm^{-2}/yr

Trend of OLR from AIRS

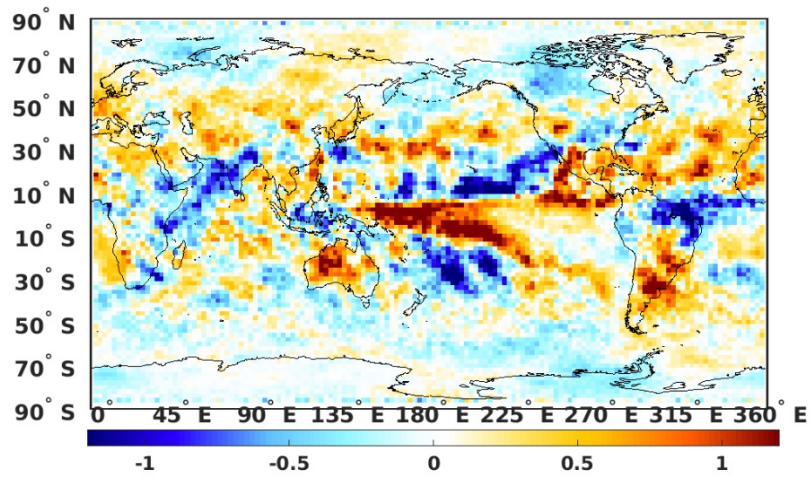
Mean = 0.055Wm^{-2}/yr



Wm^{-2}/yr

Trend of OLR from CrIS

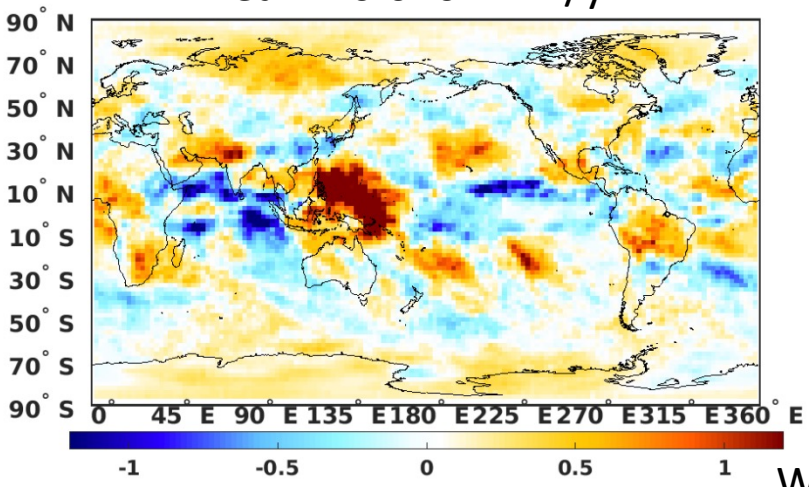
mean=0.055 Wm^{-2}/yr



Wm^{-2}/yr

Trend from feedback+forcing

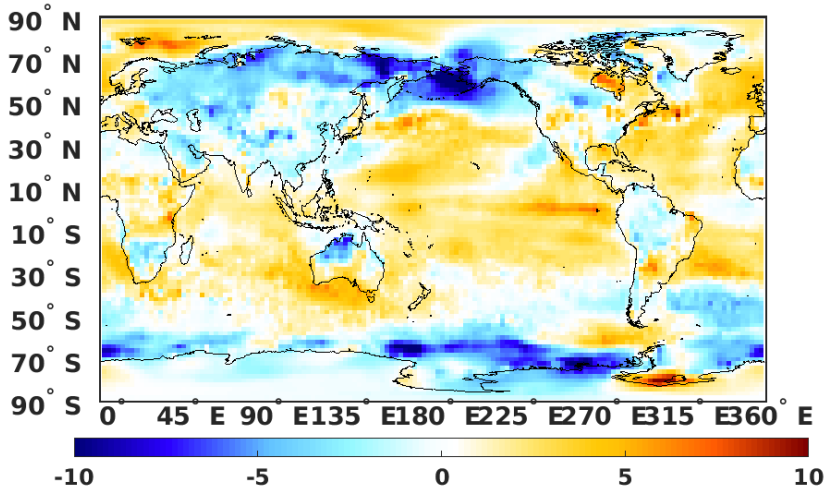
Mean = 0.070Wm^{-2}/yr



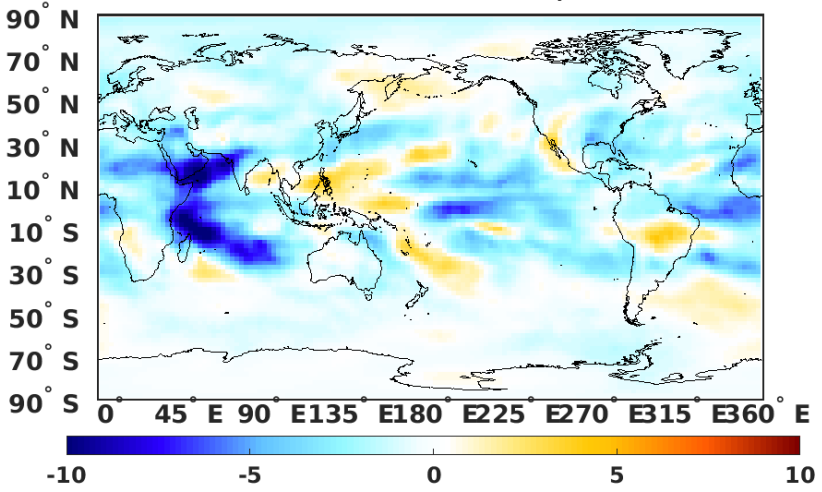
Wm^{-2}/yr

2012Feb-2022Jan (10years)

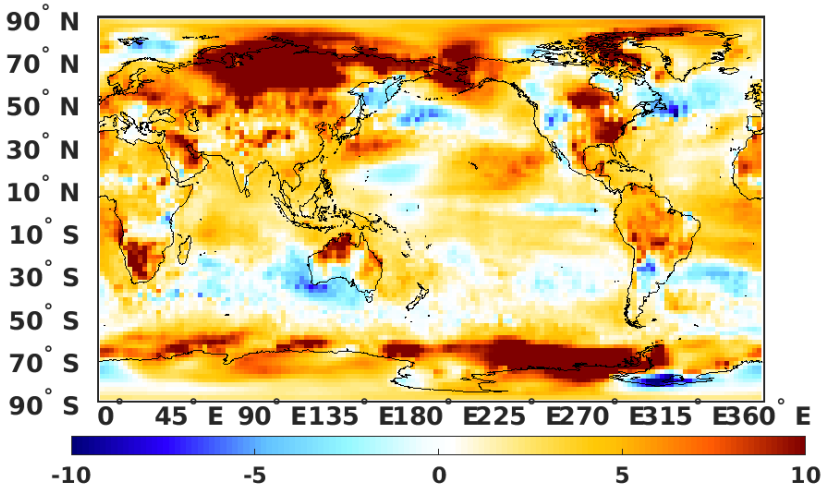
-LR=0.54Wm^{-2}/K



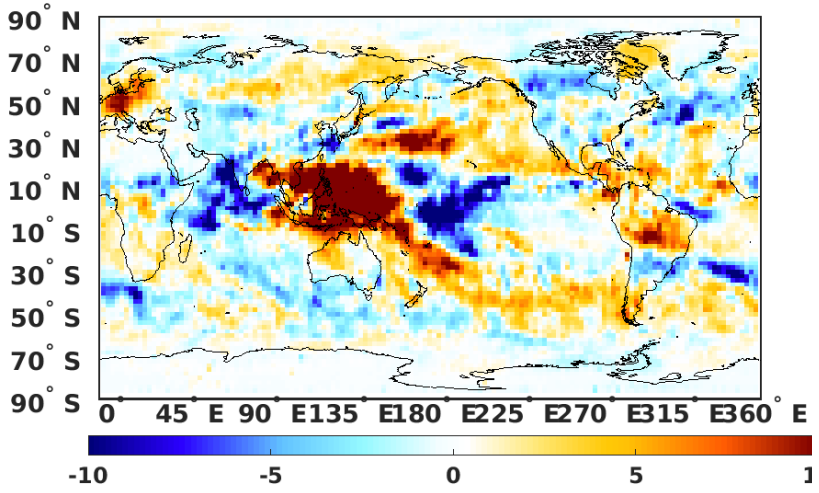
-WV= -1.30Wm^{-2}/K



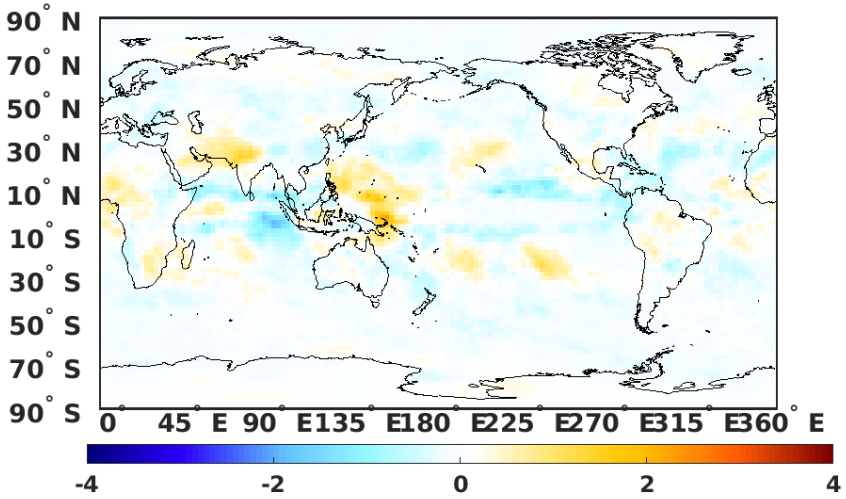
-Planck= 2.90Wm^{-2}/K



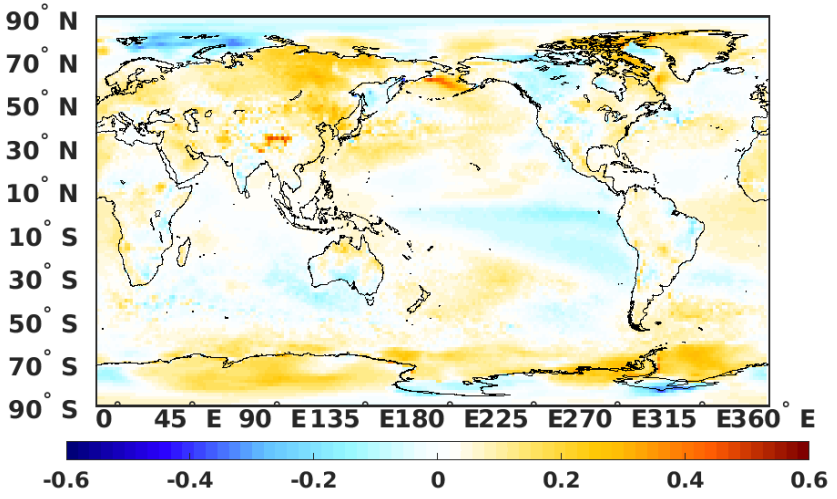
-cloud=0.65Wm^{-2}/K



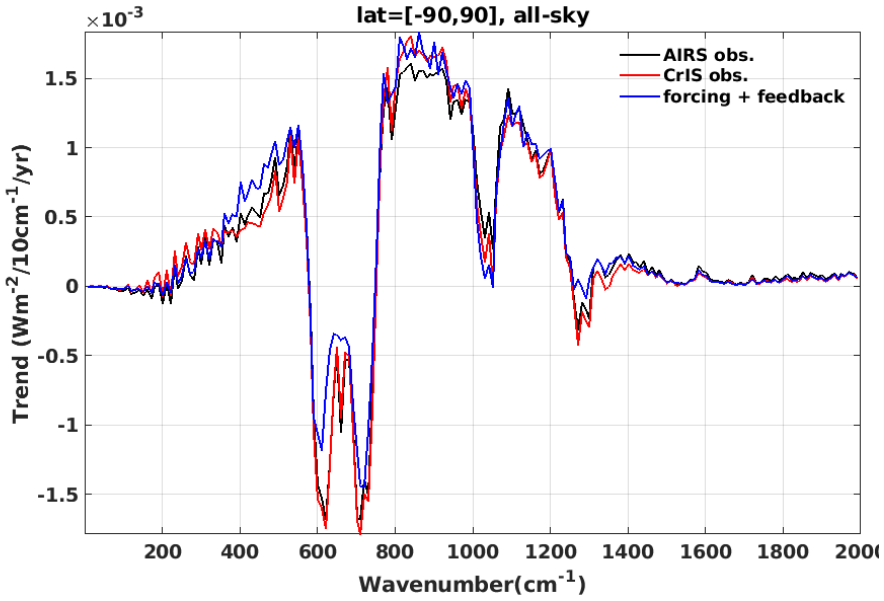
forcing (Wm^{-2}/K)

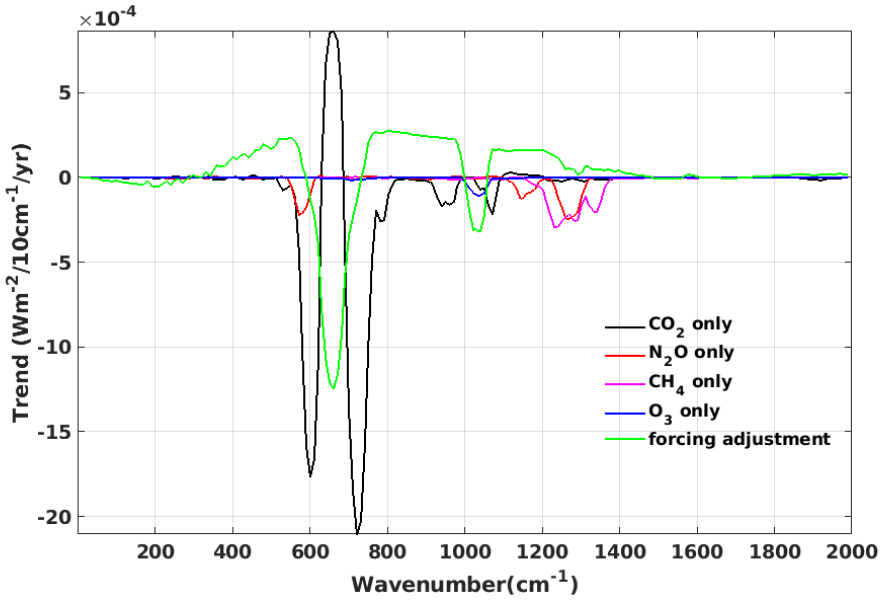


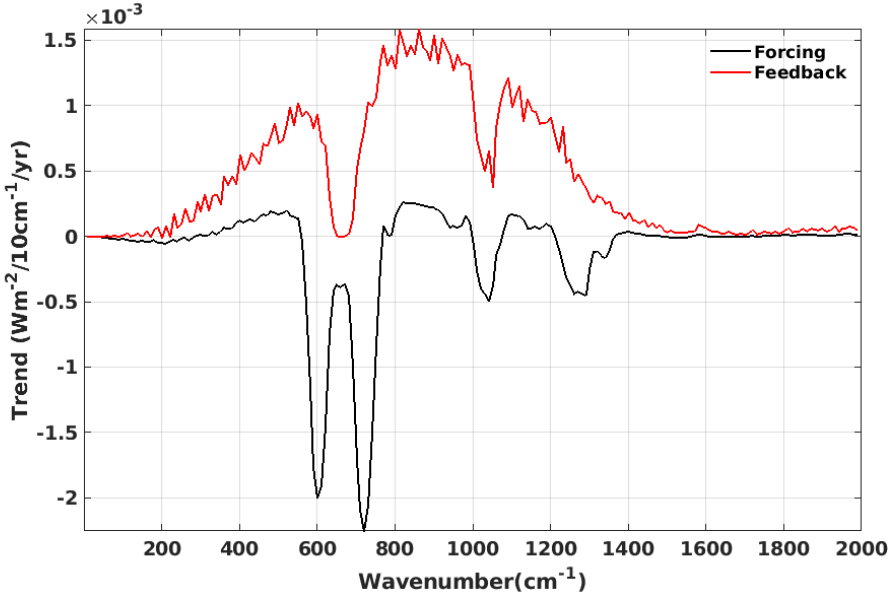
Ts trend (K/yr)

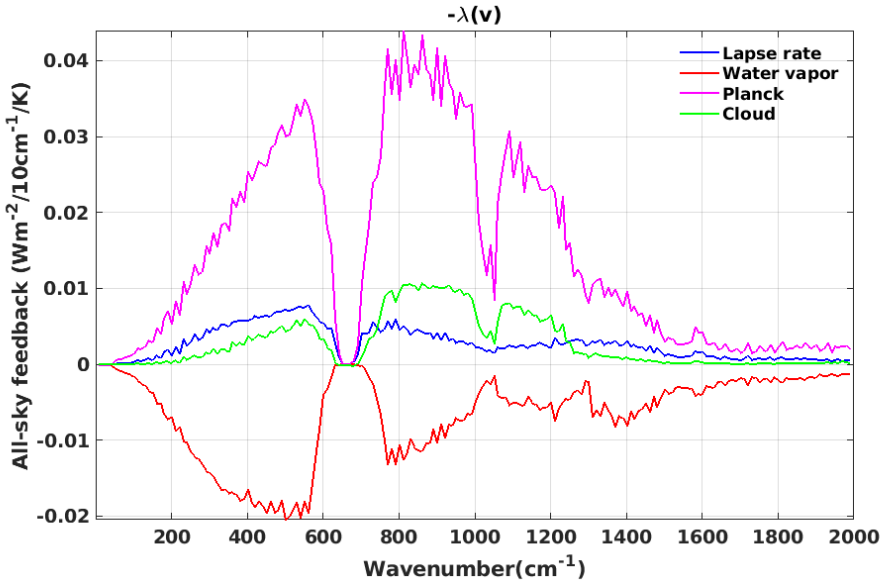


Upward positive (opposite to convention of feedback analysis)


lat=[-90,90], all-sky
×10^-3
AIRS obs.
CrIS obs.
forcing + feedback
Trend (Wm^-2/10cm^-1/yr)
Wavenumber(cm^-1)


×10^-4
CO2 only
N2O only
CH4 only
O3 only
forcing adjustment
Trend (Wm^-2/10cm^-1/yr)
Wavenumber(cm^-1)


×10^-3
Forcing
Feedback
Trend (Wm^-2/10cm^-1/yr)
Wavenumber(cm^-1)

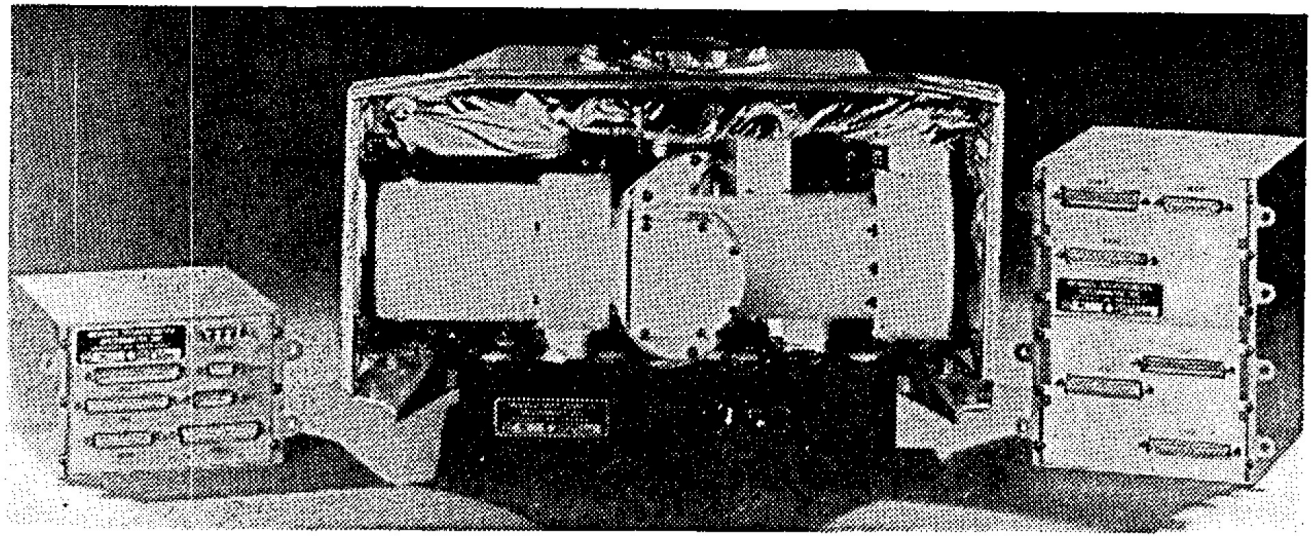

-λ(v)
Lapse rate
Water vapor
Planck
Cloud
All-sky feedback (Wm^-2/10cm^-1/K)
Wavenumber(cm^-1)

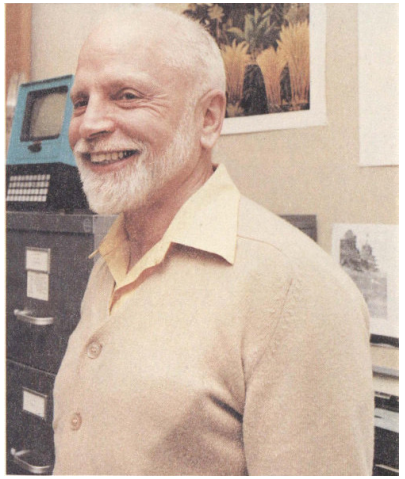
Conclusions and reflections

- We have enough data now to **start to**
  - looking the spectral dimension of the longwave radiative forcing and feedback from observations
  - painting the whole picture from concerted observations
- The agreements among CERES, AIRS, and CrIS are encouraging. Meanwhile
  - Interannual variability is not small
  - Continuity is the key as the secular signal starts to stand out of the internal fluctuation: gaps in observations will be a showstopper
- The synergy of multiple and complementary observations for future climate observing system
- So far the spectral OLR depends on extrapolation from the mid-IR to far-IR, and

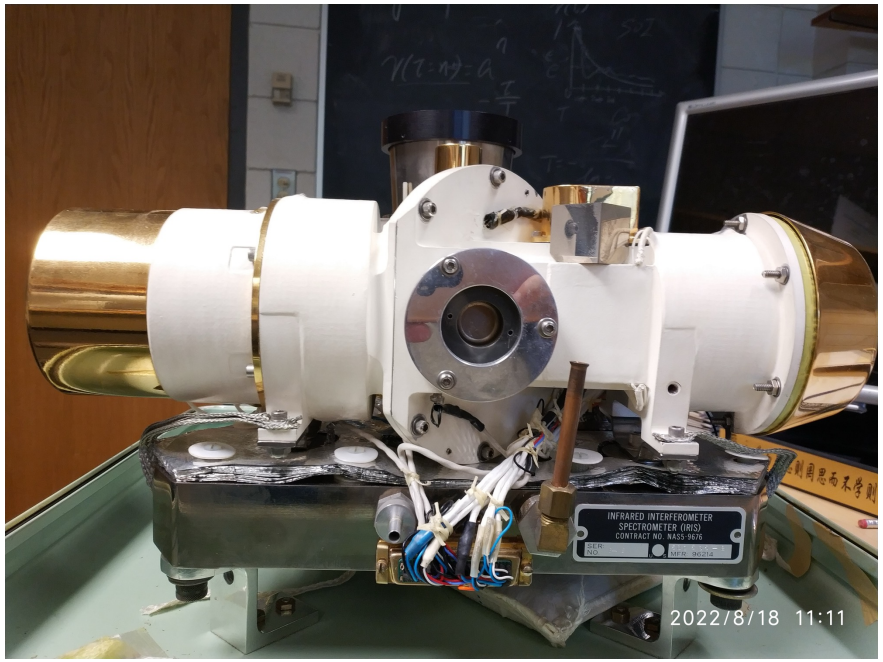
MICHIGAN

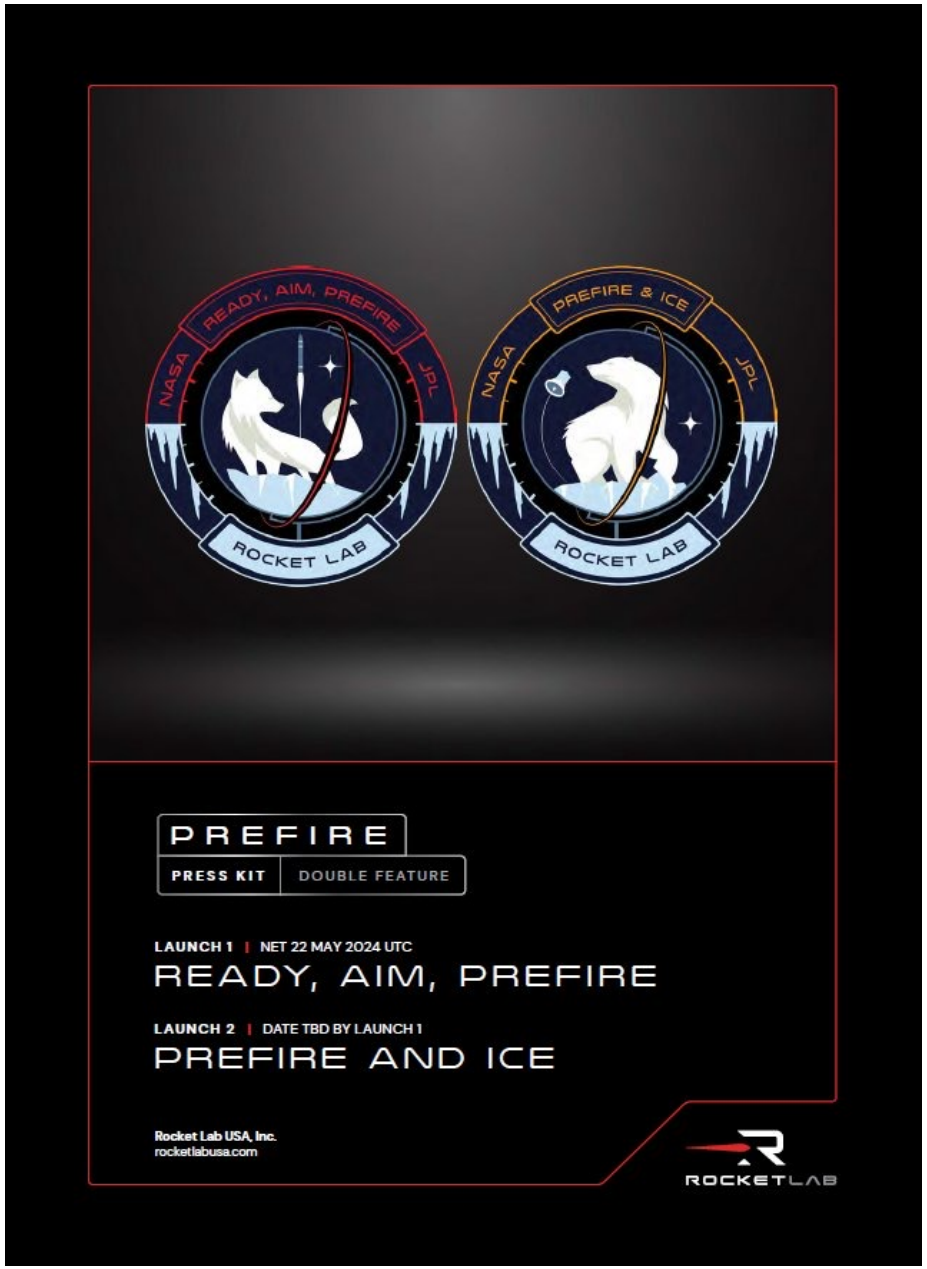
The last time we have global far-IR spectral measurements from space was Jan 1971…





Rudy Hanel (1922-2015)

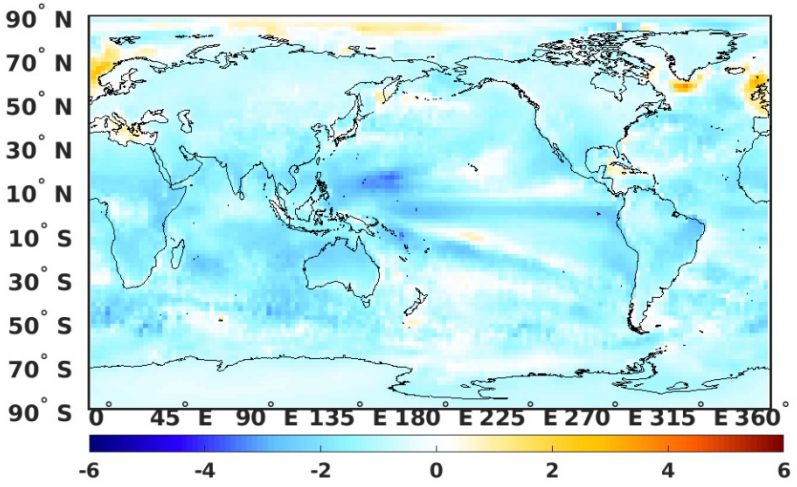




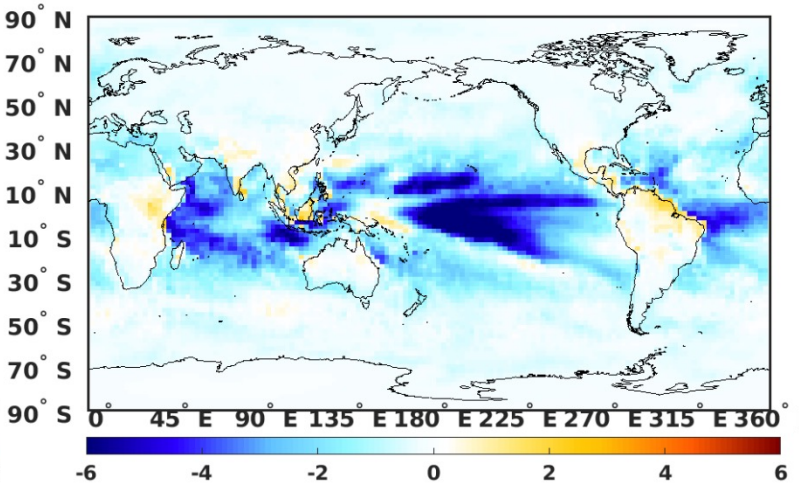
(NASA Pre-launch press conference at 3pm today)

Thank You!

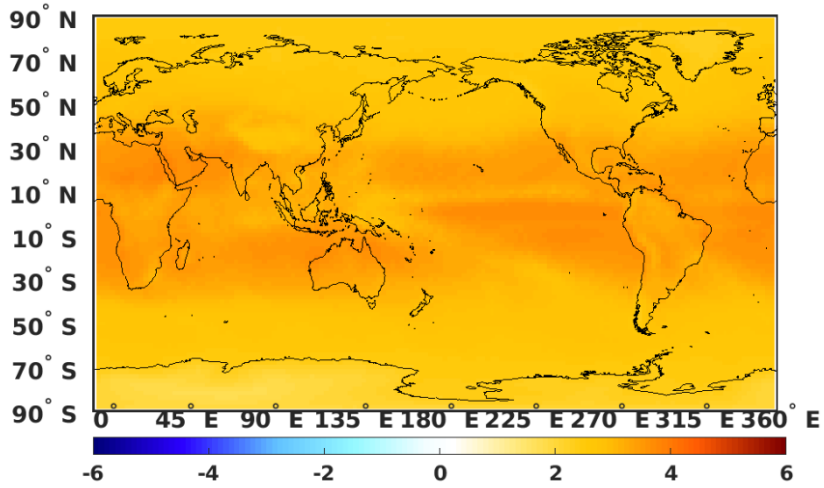
-LR=-1.14Wm^{-2}/K



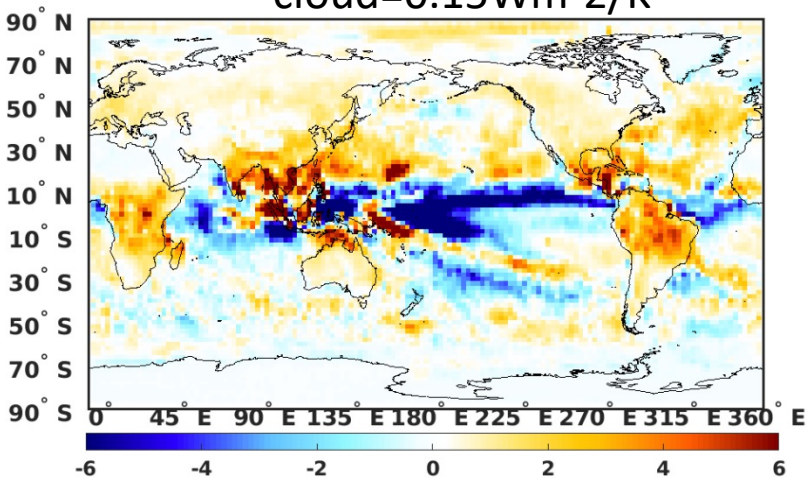
-WV =-1.05Wm^{-2}/K



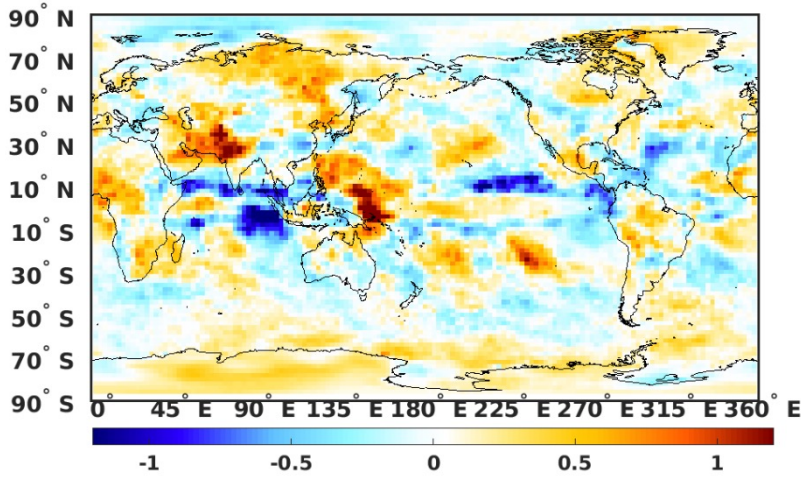
-Planck =3.07Wm^{-2}/K



-cloud=0.15Wm-2/K



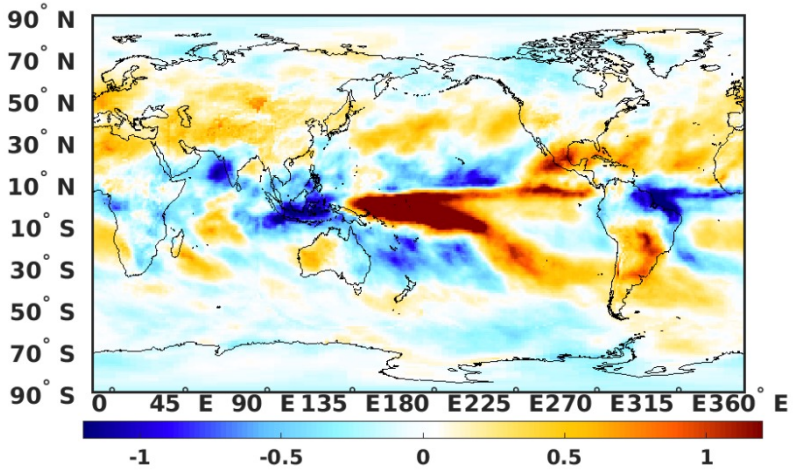
Total feedback*Ts trend+forcing=0.035



Feedback is computed using grid-by-grid Ts

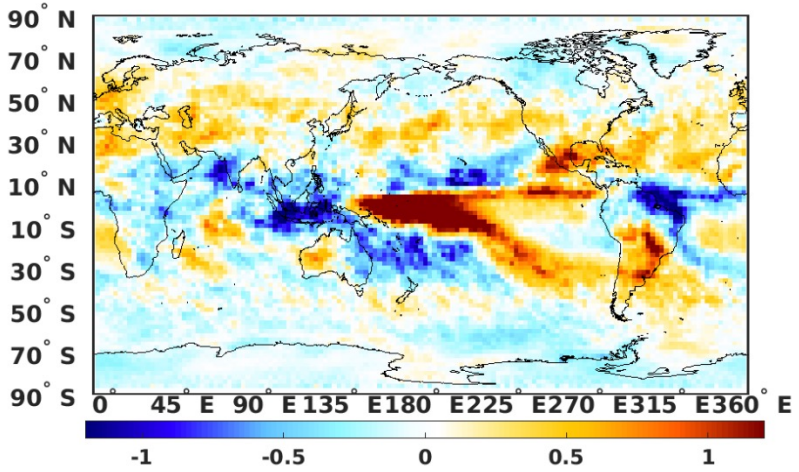
Trend of OLR from EBAF 4.2

Mean = 0.054Wm^{-2}/yr



Trend of OLR from AIRS

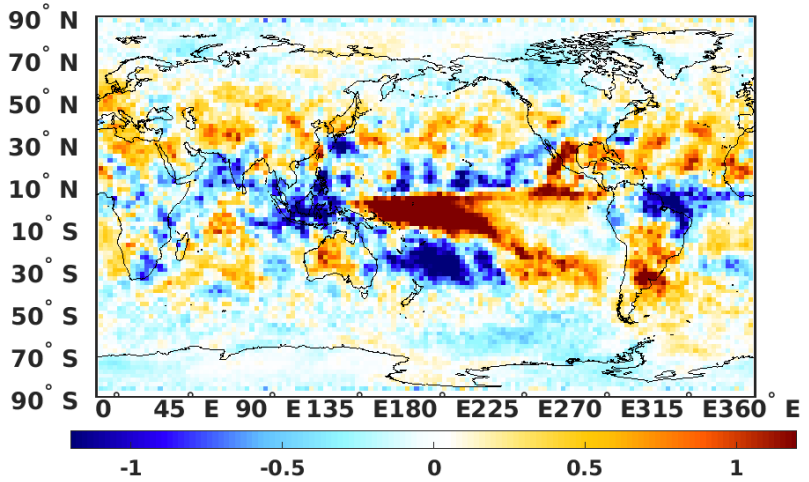
Mean = 0.042Wm^{-2}/yr



Wm^{-2}/yr

Trend of OLR from CrIS

mean=0.041 Wm^{-2}/yr



Wm^{-2}/yr

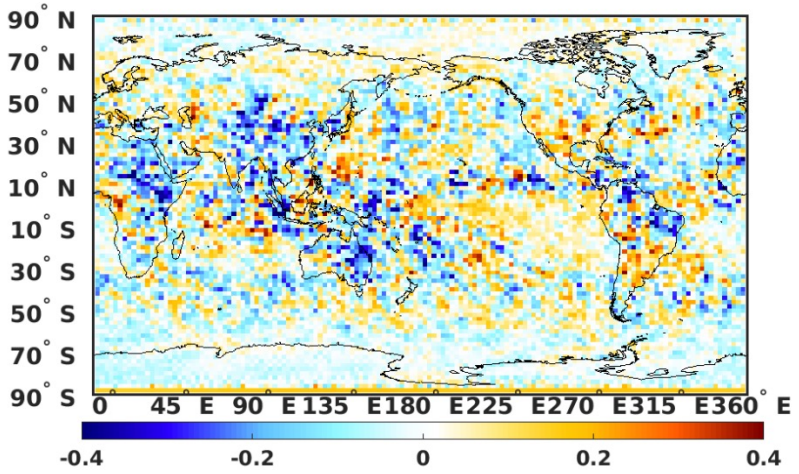
All-sky

2012Feb-2023Jan (11years)

For CrIS flux, it is derived from Suo-NPP over 2012-2018 and JPSS-1 over 2019-2023

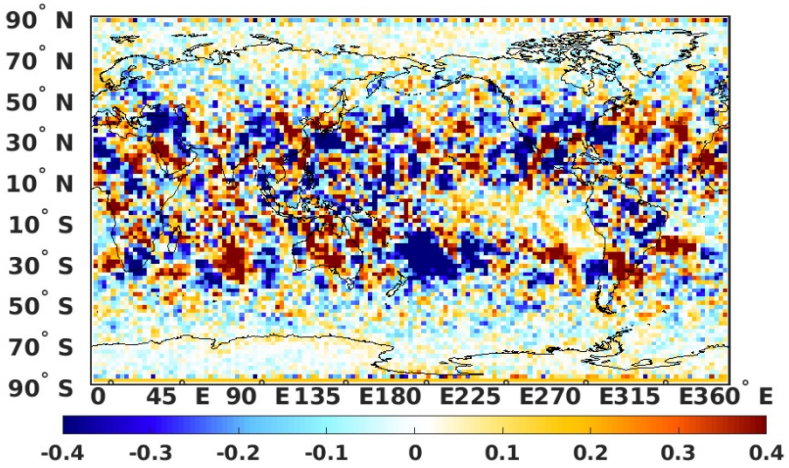
Trend of OLR (AIRS – EBAF4.2)

mean=-0.012Wm^{-2}/yr

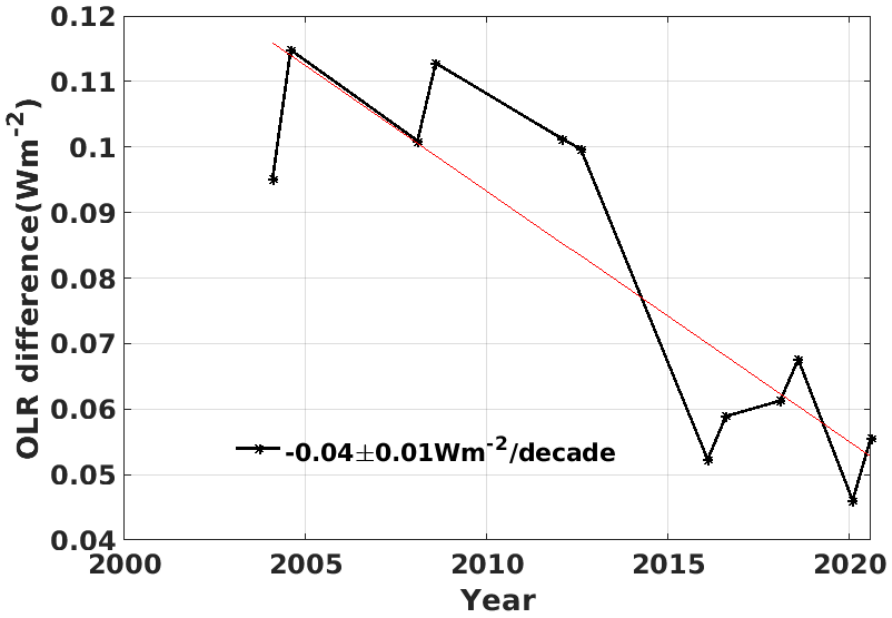


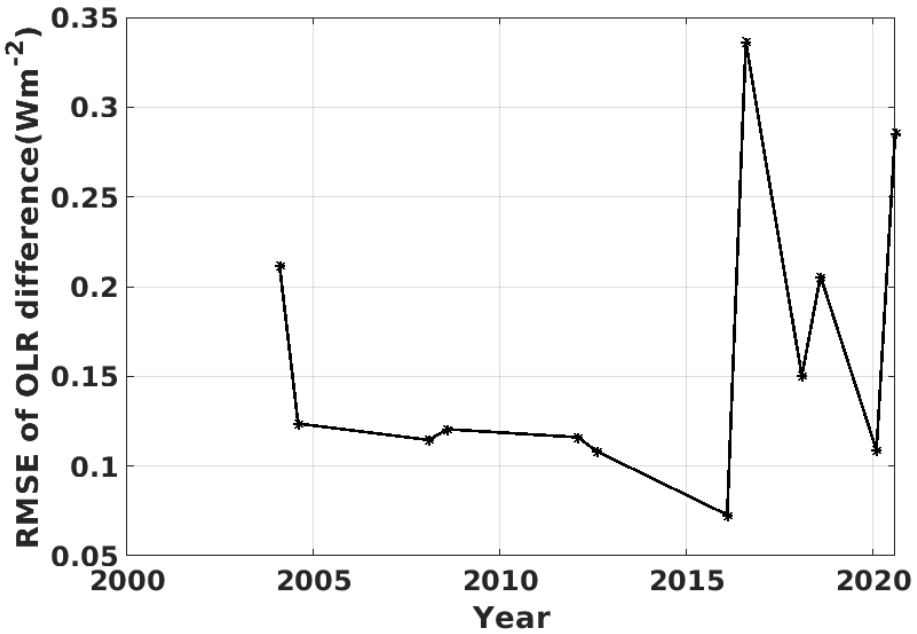
Trend of OLR (CrIS– EBAF4.2)

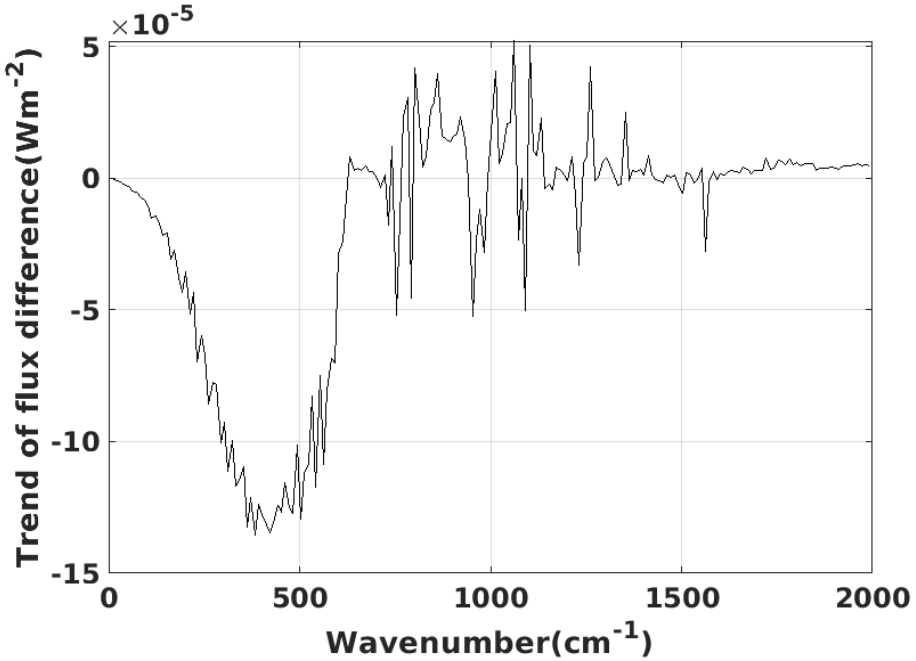
mean=-0.013Wm^{-2}/yr



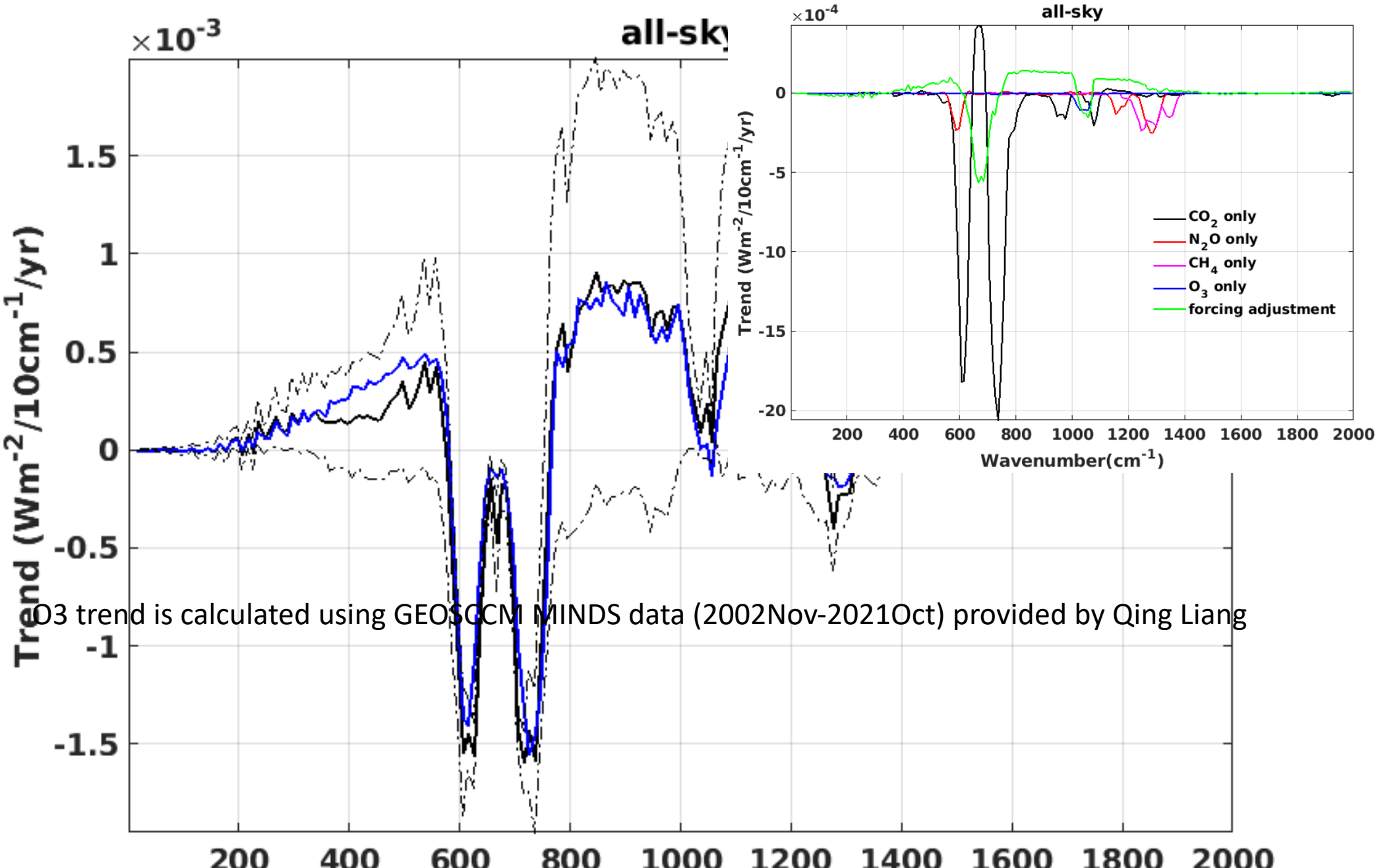
OLR difference (AIRS L1C – AIRS L1B) and the trend of the flux difference



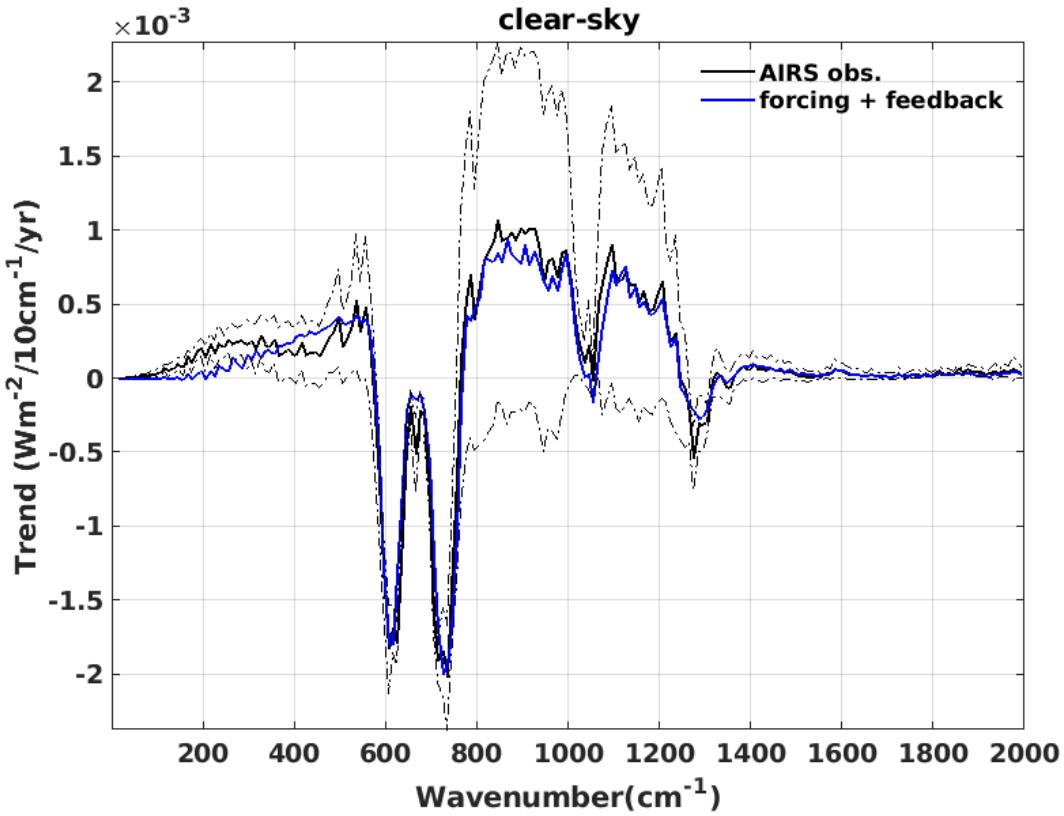


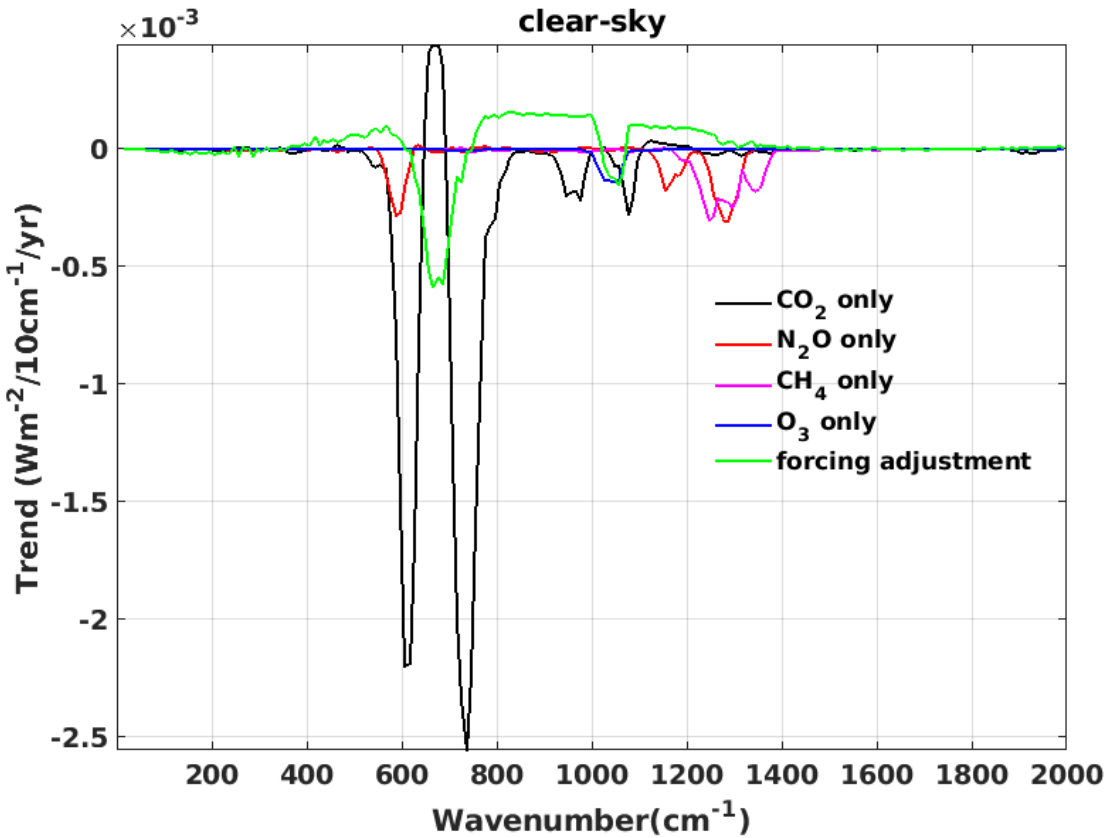


The flux trend from AIRS L1B is 0.14Wm^{-2}/decade,
So the flux trend from AIRS L1C would be about 0.10Wm^{-2}/decade

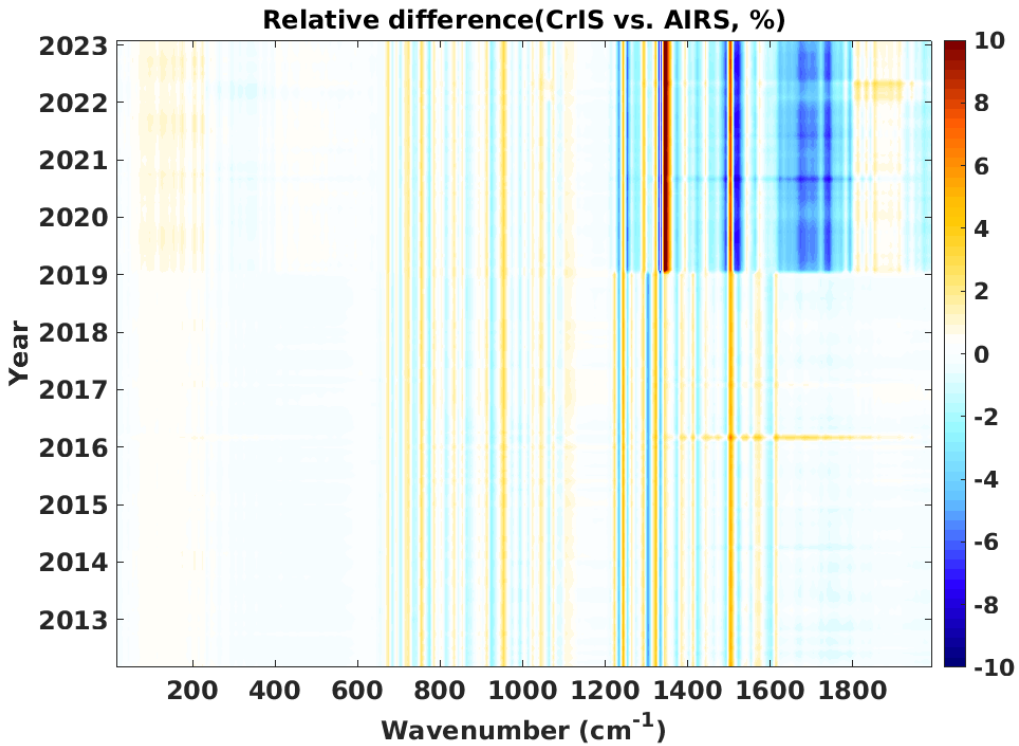


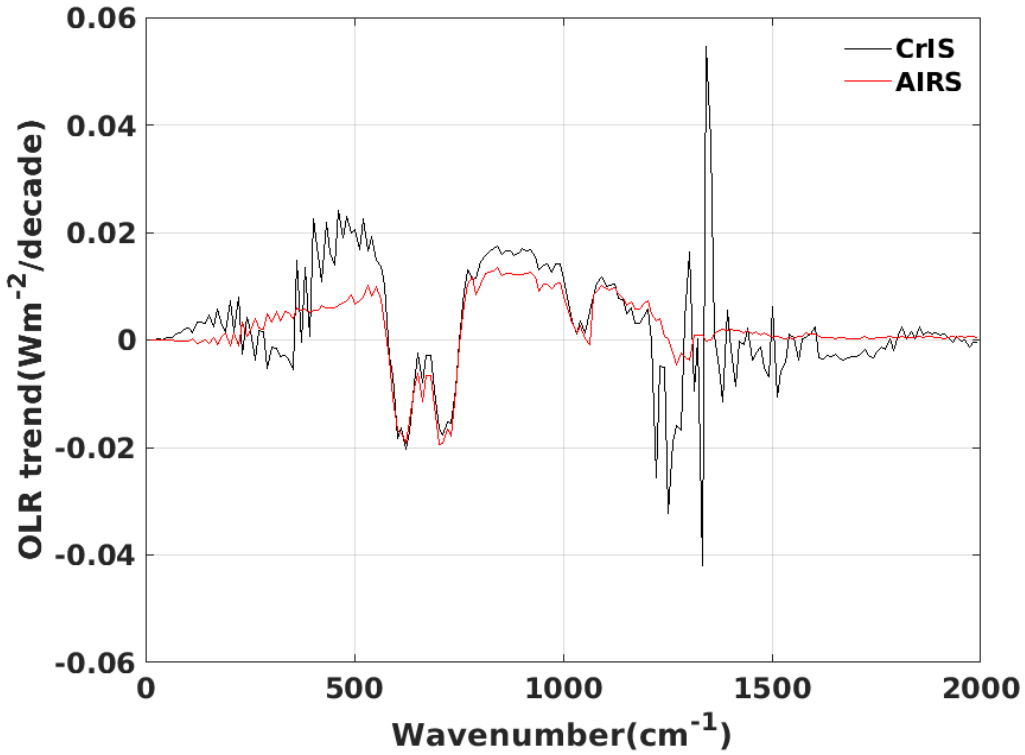
O3 trend is calculated using GEOSCCM MINDS data (2002Nov-2021Oct) provided by Qing Liang

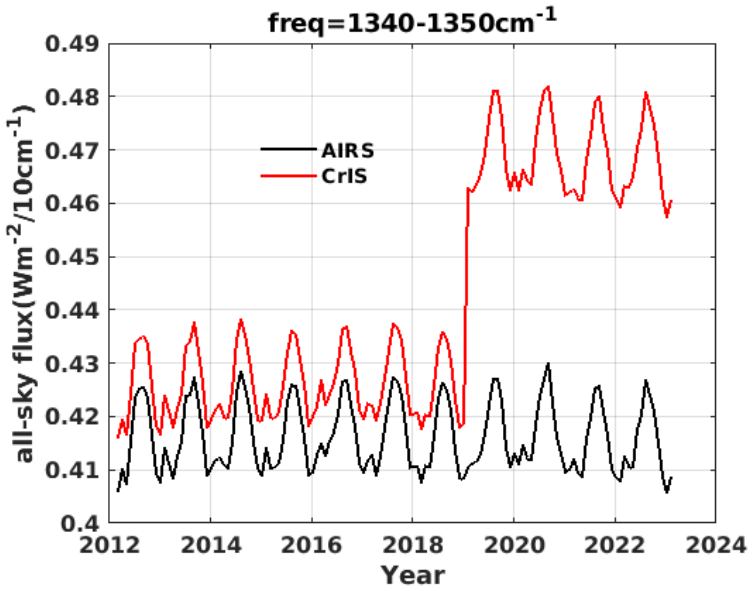

clear-sky
×10^-3
AIRS obs.
forcing + feedback
Trend (Wm^-2/10cm^-1/yr)
Wavenumber(cm^-1)


clear-sky
×10^-3
CO2 only
N2O only
CH4 only
O3 only
forcing adjustment
Trend (Wm^-2/10cm^-1/yr)
Wavenumber(cm^-1)

Global-mean

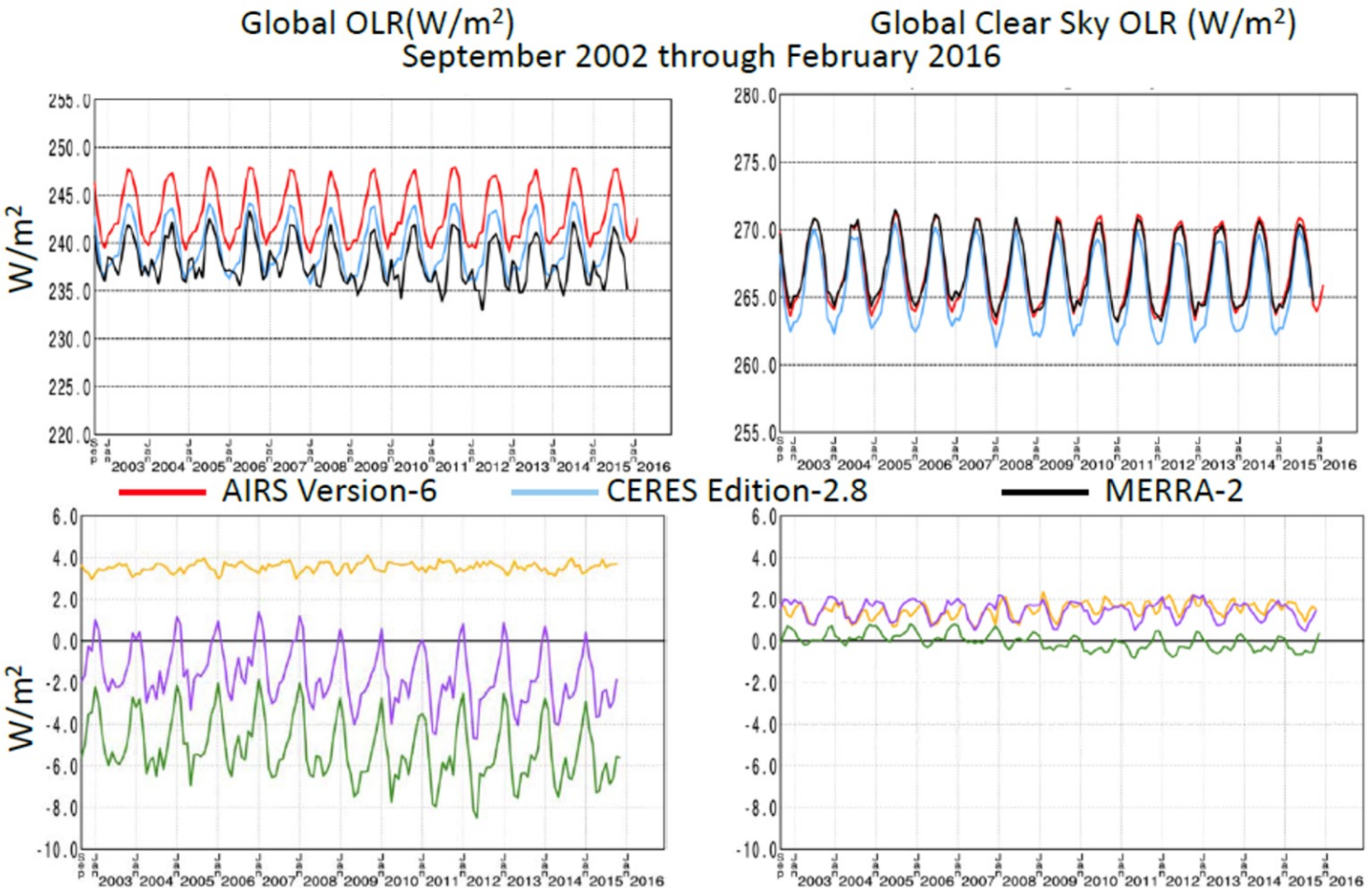






For CrIS flux, it is derived from Suo-NPP over 2012-2018 and JPSS-1 over 2019-2022

https://www.dropbox.com/s/k07jeqmmugw4bng/Screenshot%202023-05-04%20at%2012.19.49%20AM.png?dl=0



AIRS and CERES OLR time series differ in time by a small constant value. MERRA-2 OLR agrees reasonably well with CERES but the differences have an annual cycle and a negative drift. MERRA-2 Clear Sky OLR agrees better with AIRS than with CERES, but also has a small negative drift.

Joel Susskind, Jae Lee, and Lena Iredell

833

Table 2

	Global Mean	Tropical Mean	N. Hemisphere Extra-tropics	S. Hemisphere Extra-tropics
AIRS 1:30 PM	0.0024±0.0189	-0.0163±0.0361	0.0432±0.0406	-0.0008±0.0257
AIRS 1:30 AM	0.0110±0.0163	-0.0029±0.0312	0.0510±0.0343	-0.0012±0.0261
AIRS 1:30 AM/PM	0.0064±0.0174	-0.0100±0.0335	0.0469±0.0370	-0.0013±0.0256
CERES	0.0112±0.0179	-0.0063±0.0345	0.0554±0.0366	0.0020±0.0259

834