A consistent depiction of longwave broadband and spectral radiative forcing and feedback from two decades of observations

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 2023 Science Team Meeting
May 9-11, 2023

Acknowledgements: CERES project

- We have had concurrent broadband and spectrally-resolved measurements since 2002, i.e., CERES and AIRS on Aqua.
- We also have had T & q well assimilated into ERA5 and MERRA-2 reanalyses
- We also have had cloud observations better than before
- GHGs have been continuously monitored
- Ozone monitoring and "nudged" simulations are also well developed

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

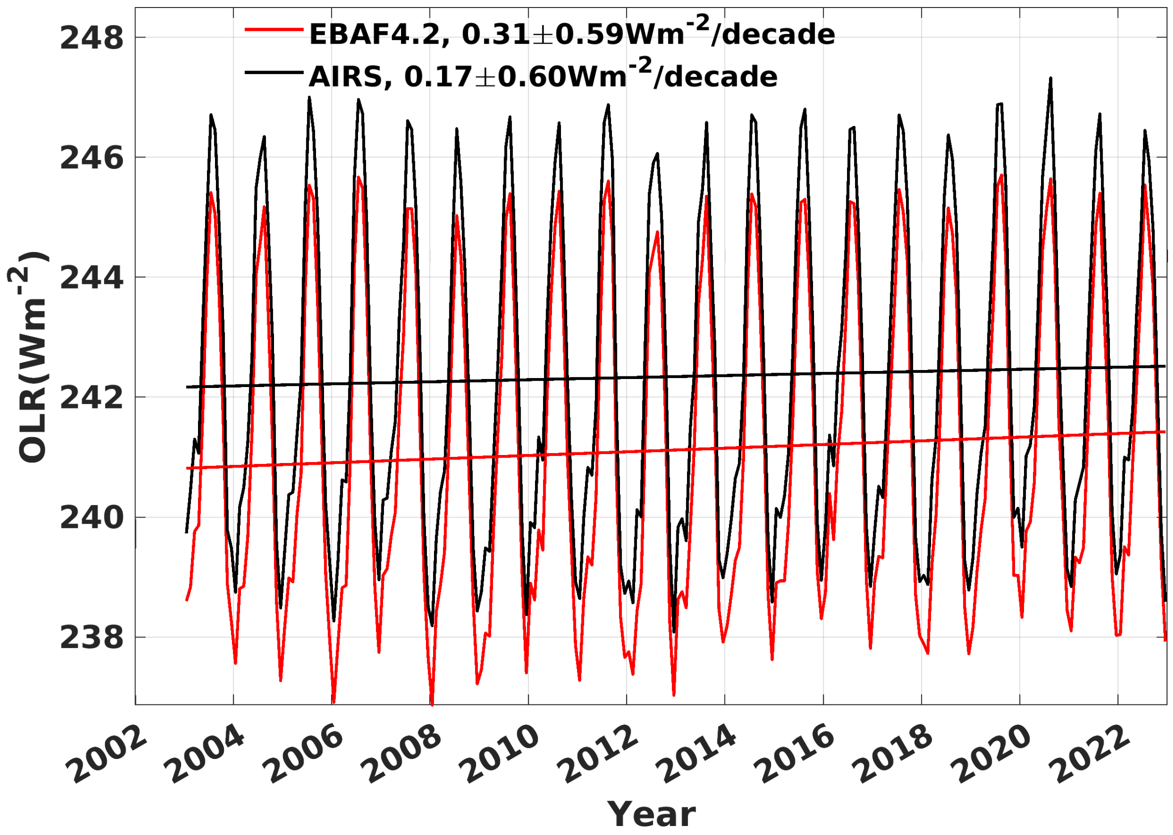
Some work presented here is still working-in-progress. Please do not cite.

Datasets (Jan 2003 - Dec 2022)

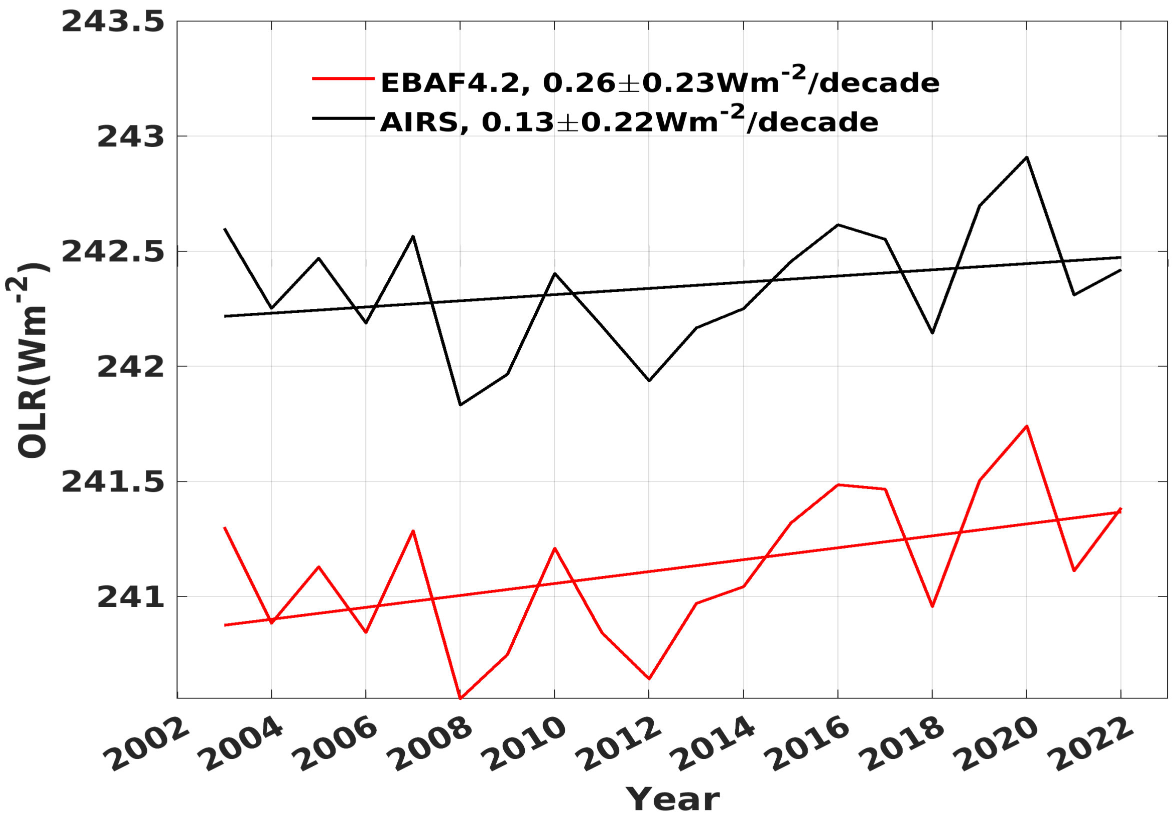
- CERES EBAF 4.2 AIRS L3 Spectral OLR product
  - 10cm^{-1} spectral flux derived from collocated AIRS and CERES measurements
- MODIS monthly-mean cloud state joint histograms
  - Derived from Eric Fetzer's MEASURES project
- ECMWF ERA5 reanalysis temperature and humidity profiles
- CO_2/CH_4/N_2O from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

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

Monthly-mean



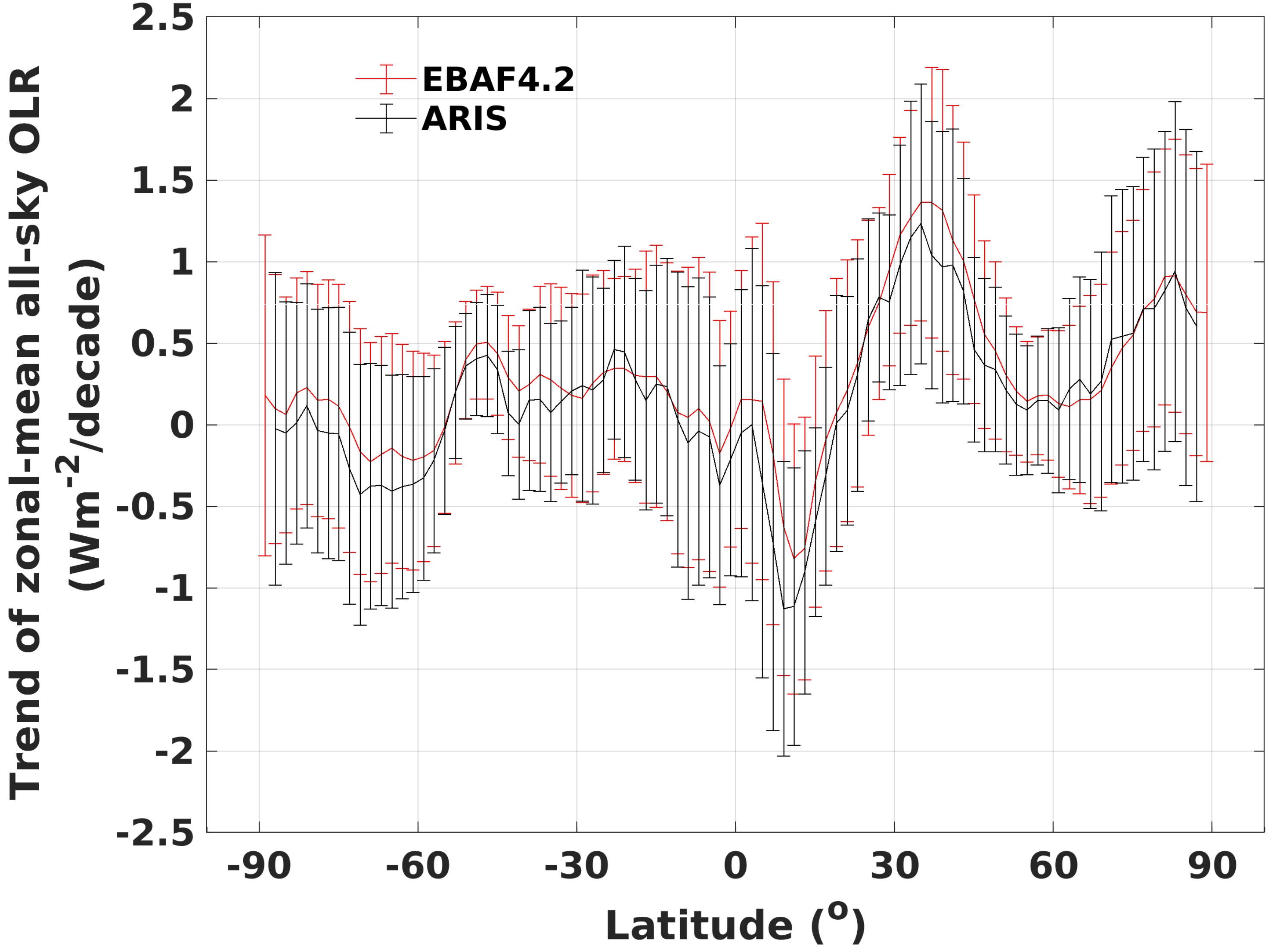
Annual-mean



EBAF: 24-hour average

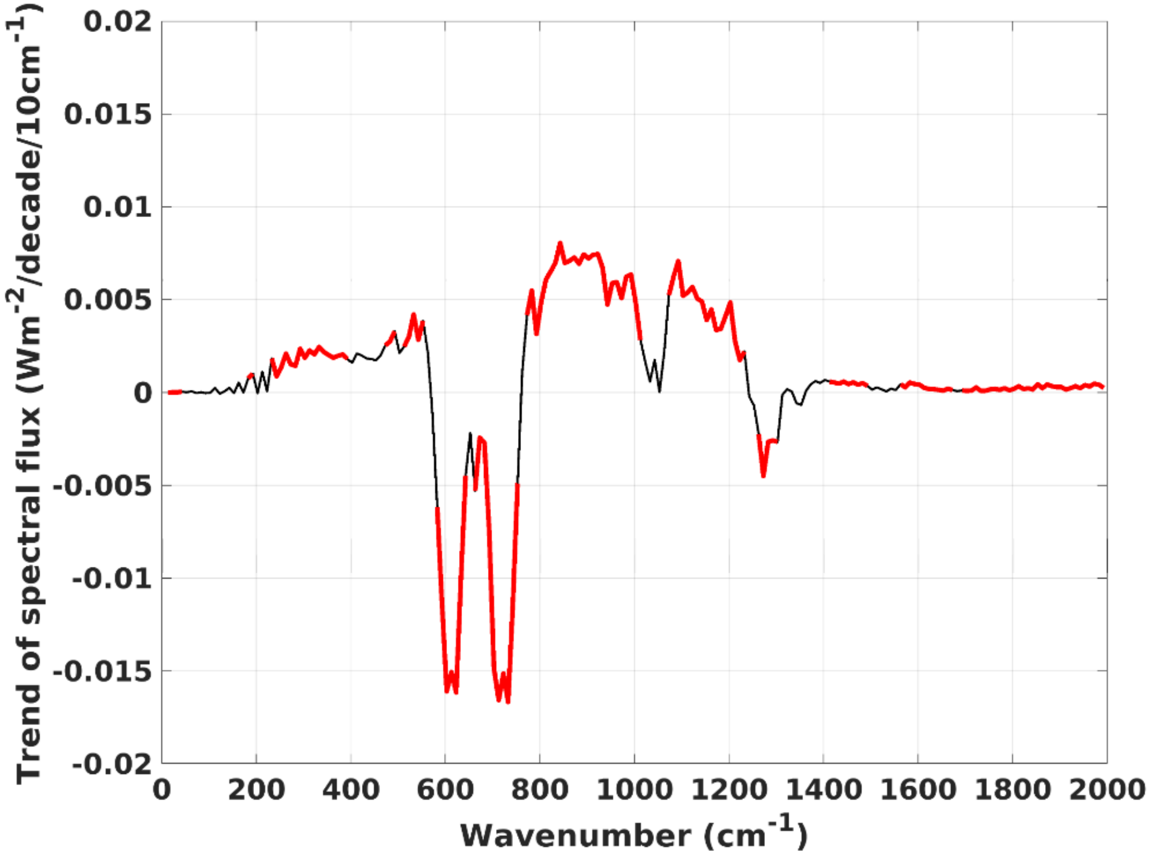
AIRS: equally weighted average of ascending and descending Aqua observations

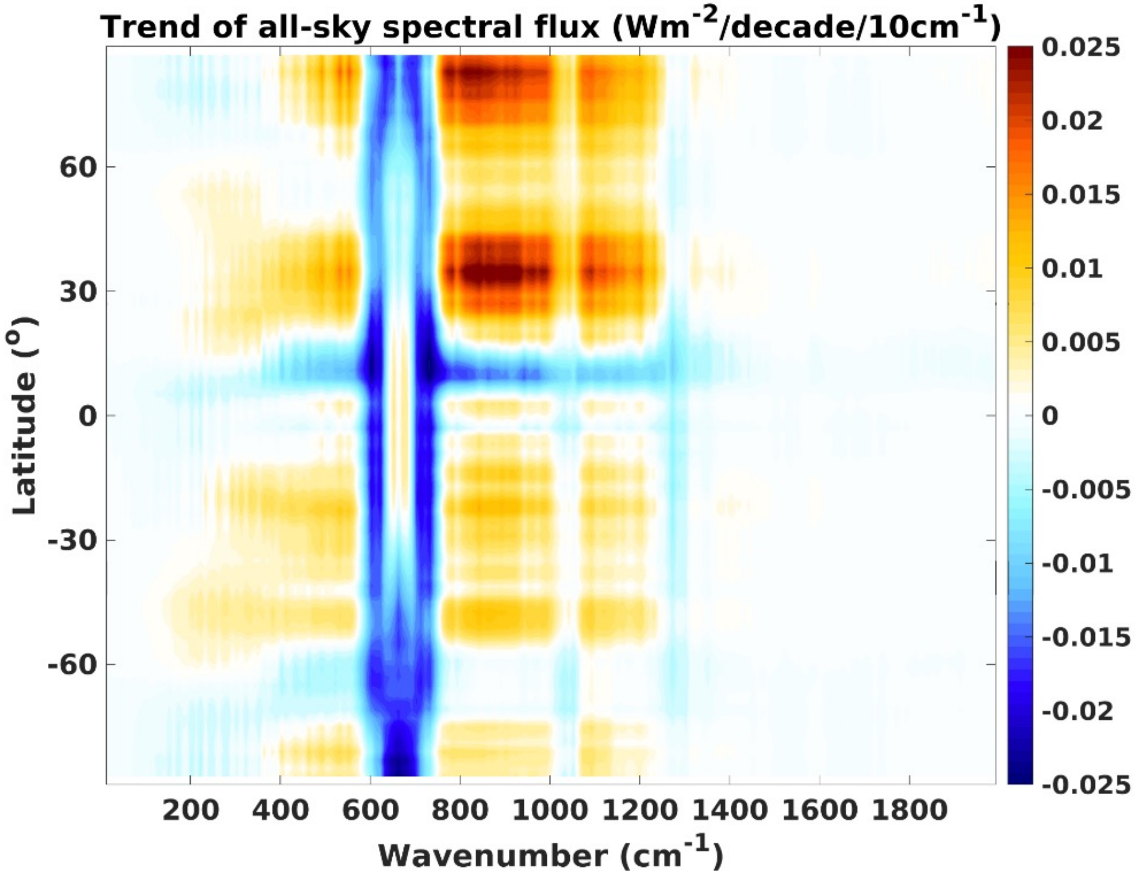
Zonal-mean Trend



Update to EBAF 4.2
Trend computed using the same period (2003 to 2021, annual trend)

$\frac{dF(v)}{dt}$ AIRS spectral OLR trend: global and zonal-mean (2003-2022)





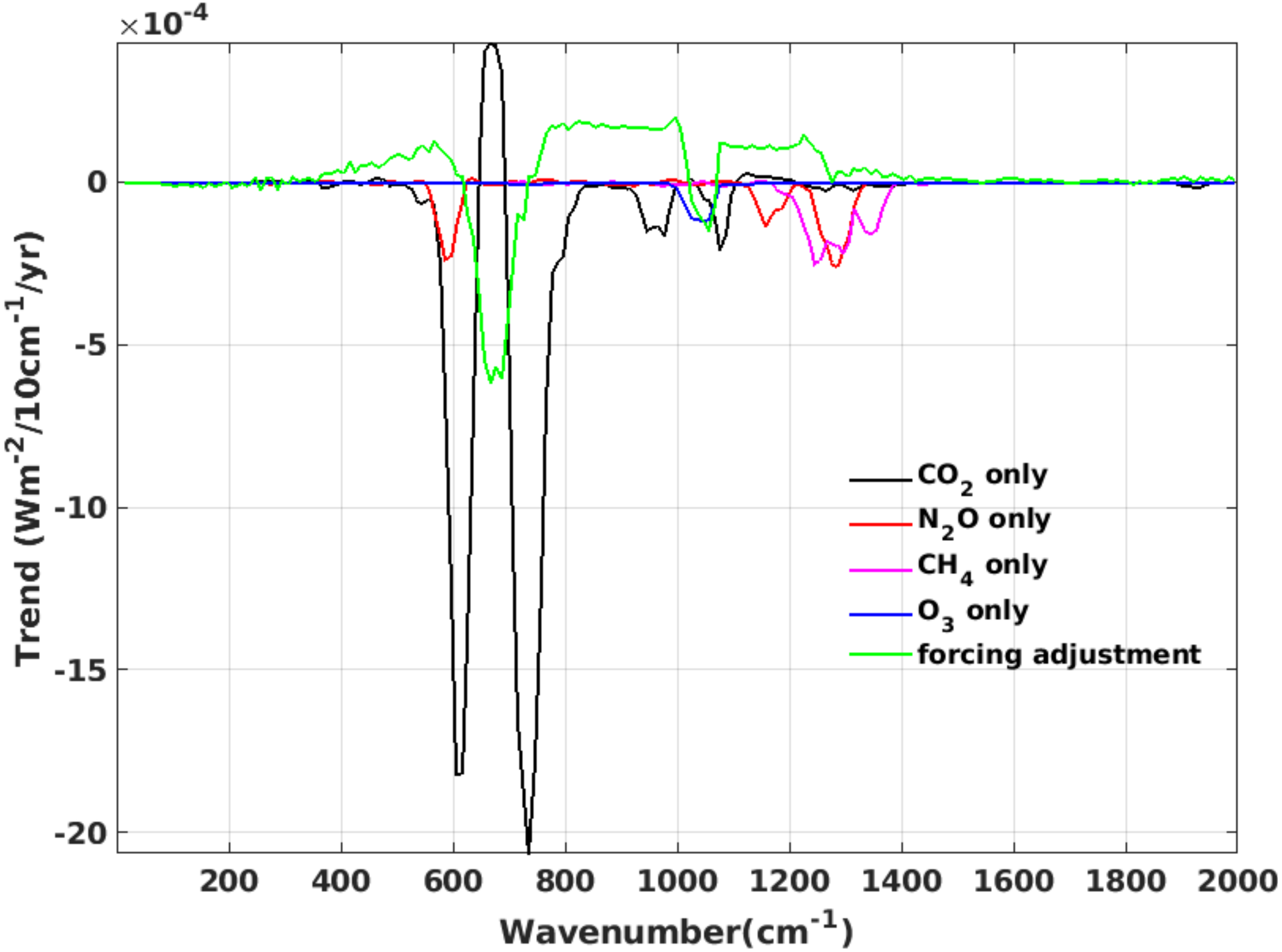
Decompose to the spectral radiative forcing and spectral feedback

$$\frac{dF(v)}{dt} = \frac{d}{dt}[-RF(v)] + [-\lambda(v)]\frac{dT_{surface}}{dt}$$

"-" here to indicate upward positive

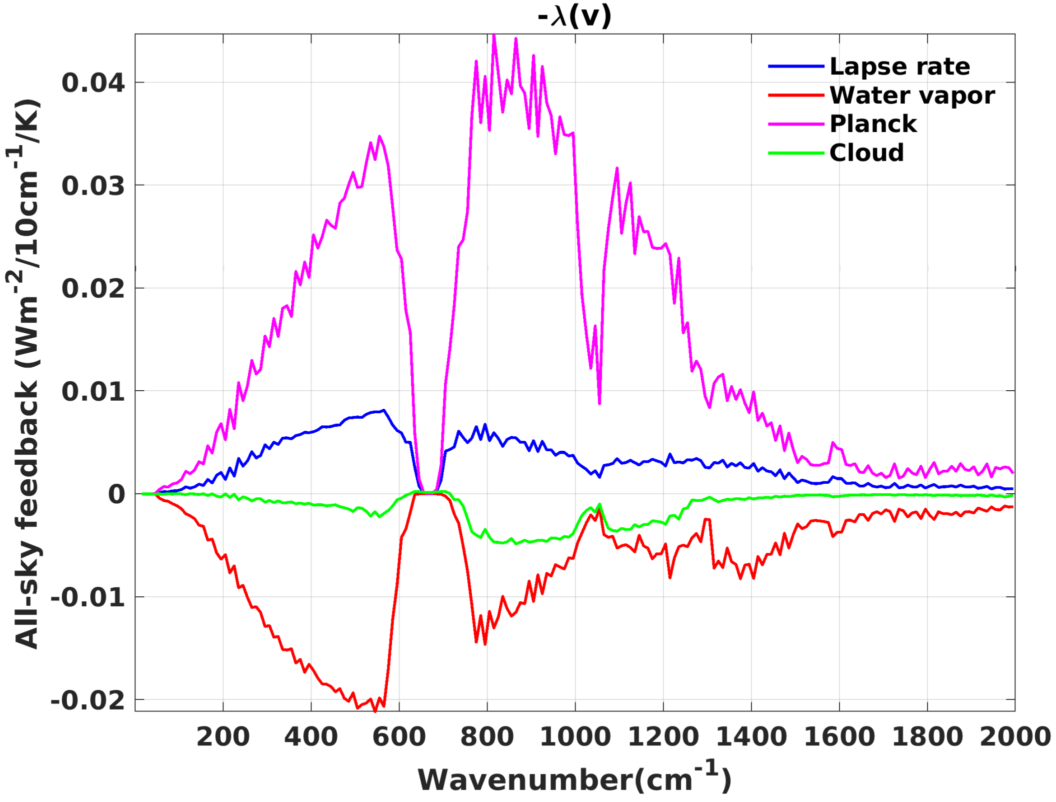
- $\frac{d}{dt}RF(v)$: computed using time-varying CO_2, CH_4, N_2O, and O_3 with PCRTM and ERA-5 meteorological fields
  - It is ERF, so fast adjustment is estimated using a CESM-AMIP run with varying GHGs
- $\frac{dT_{surface}}{dt}$:global-mean surface temperature trend from ERA5
- $\lambda(v)$: spectral radiative feedback estimated with spectral radiative kernels (Huang et al., 2014; Yue et al., 2016; Huang et al., 2019), ERA5 fields, and MODIS cloud fields.

$\frac{d}{dt}[-RF(v)]$: ERF with adjustment derived from an CESM-AMIP simulations (2003-2022)

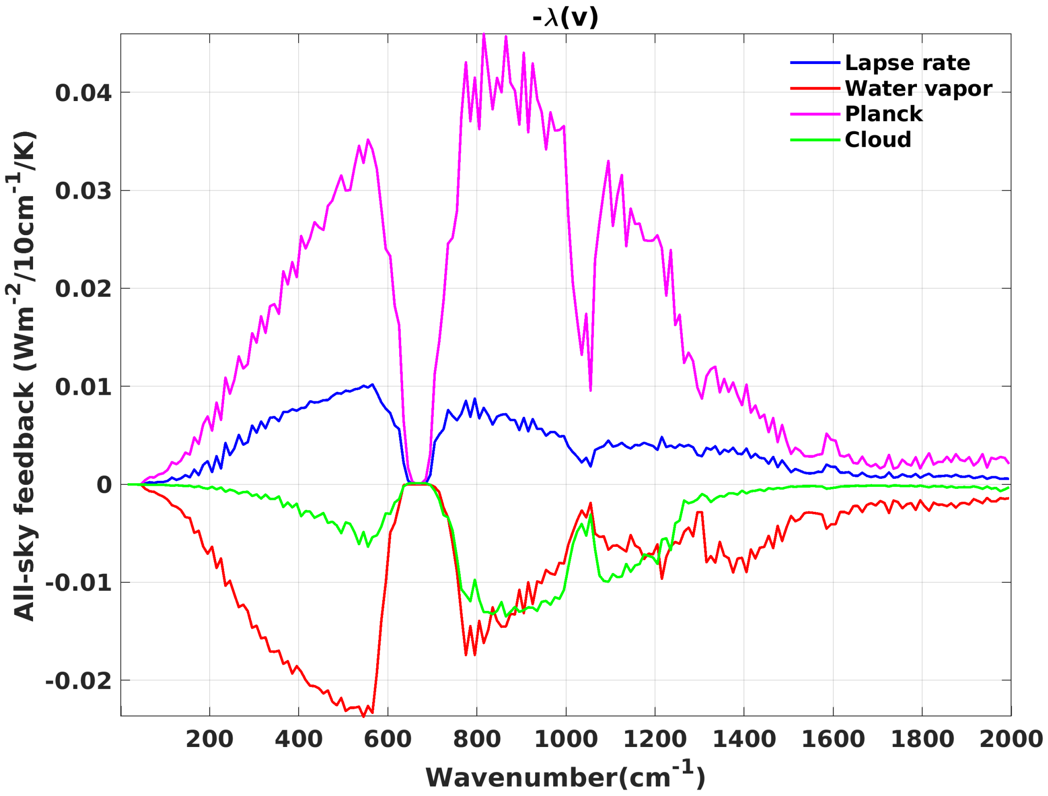


$-\lambda(v)$: the short-term feedbacks (year-to-year variations)

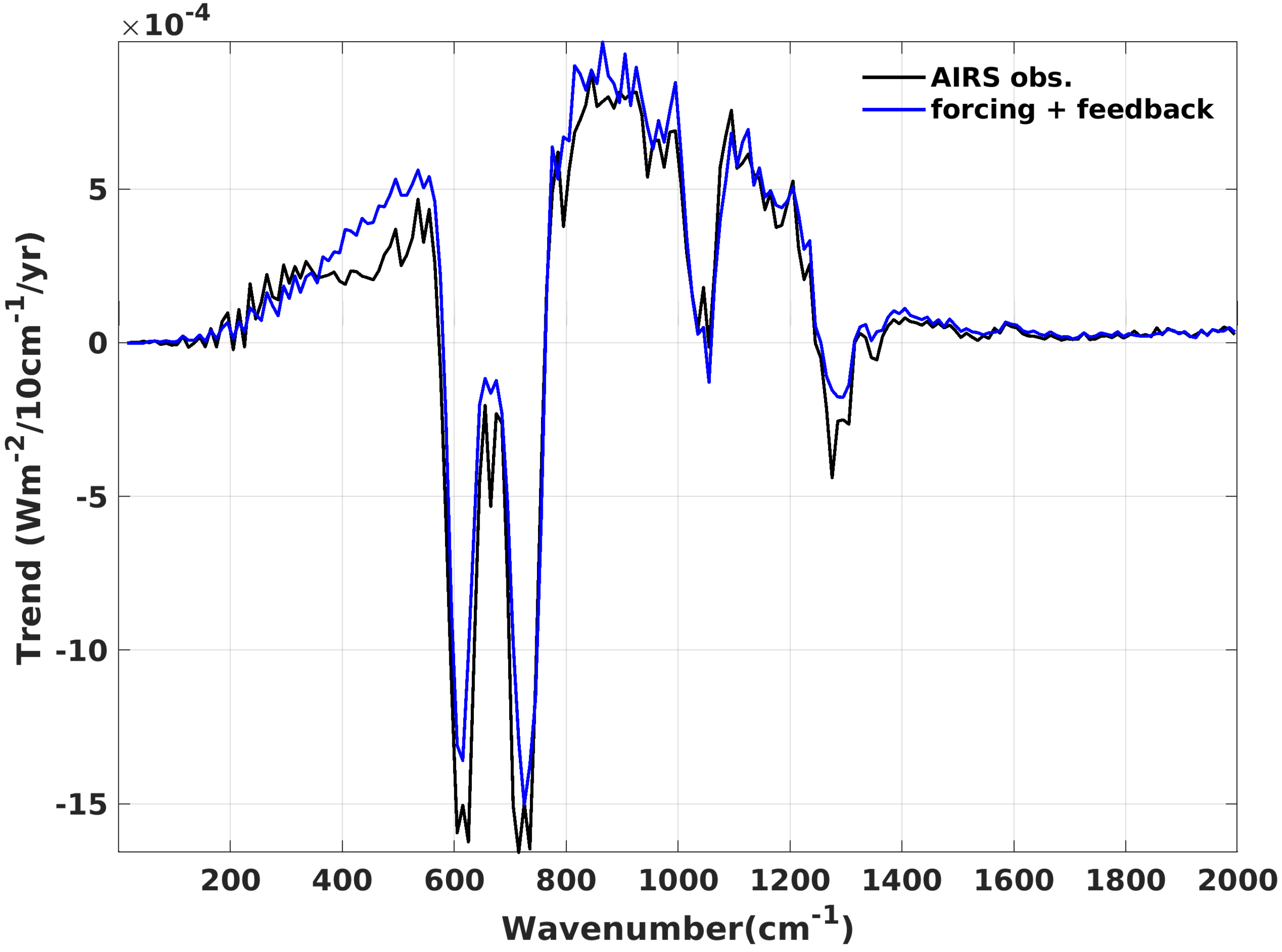
2003 to 2022



2008 to 2019



Spectral trend vs. Forcing + Feedback （2003 - 2022）



Spectral to broadband estimates

- $\frac{dF(v)}{dt} = \frac{d}{dt}[-RF(v)] + [-\lambda(v)]\frac{dT_{surface}}{dt}$

	$\frac{dF}{dt}$ from EBAF4.2 (Wm^{-2}/decade)	$\frac{dF}{dt}$ from collocated CERES (Wm^{-2}/decade)	$\frac{dF}{dt}$ from AIRS (Wm^{-2}/decade)	$\frac{d}{dt}[-RF(v)] + [-\lambda(v)]\frac{dT_{surface}}{dt}$ (Wm^{-2}/decade)	$\frac{d}{dt}[-RF]$ (Wm^{-2}/decade)	$-\lambda$ (Wm^{-2}/K)	$\frac{dT_{surface}}{dt}$ (K/decade)
2003 to 2021	0.31±0.64	0.33±0.60	0.19±0.65	0.28	-0.22	1.84	0.27
2003 to 2022	0.31±0.59	0.25±0.55	0.17±0.60	0.28	-0.22	1.96	0.25

2022: Hunga Tonga eruption; Aqua spacecraft anomaly since April; EBAF switched to NOAA20

Article | Open Access | Published: 20 April 2023

Direct observation of Earth's spectral long-wave feedback parameter

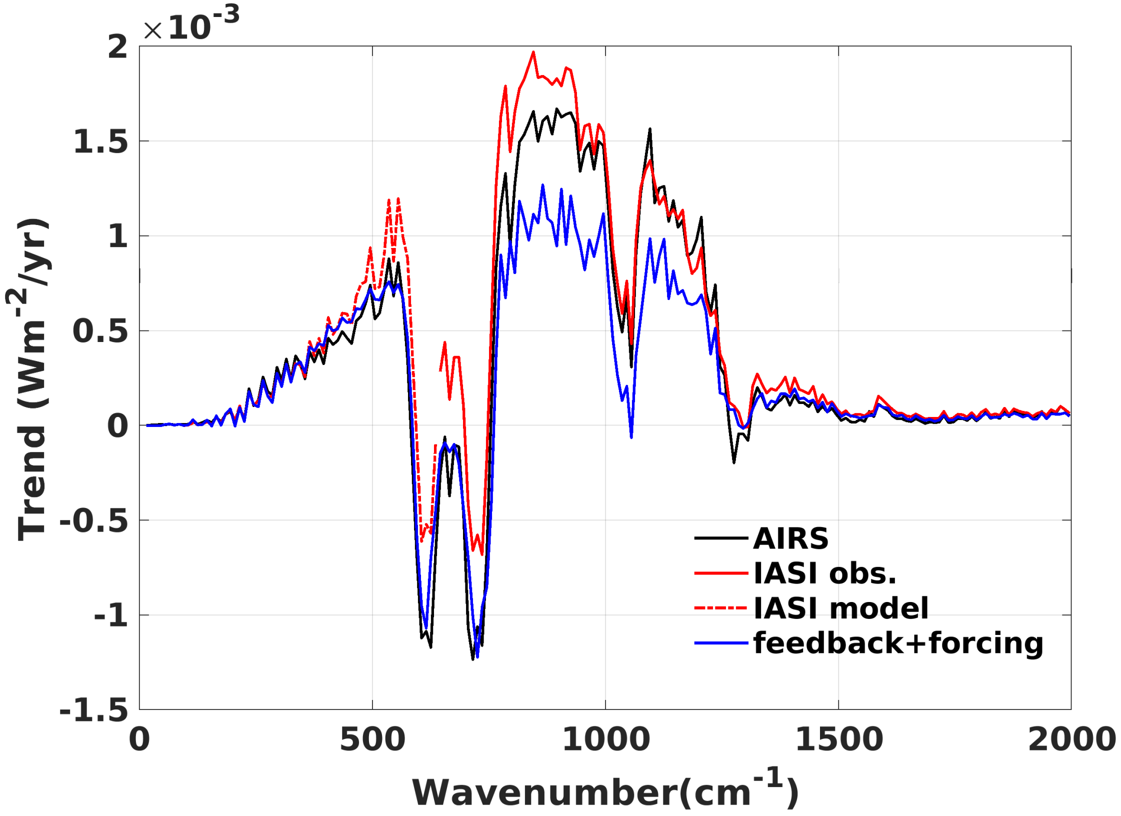
Florian E. Roemer, Stefan A. Buehler, Manfred Brath, Lukas Kluft & Viju O. John

Nature Geoscience (2023) | Cite this article

Abstract

The spectral long-wave feedback parameter represents how Earth's outgoing long-wave radiation adjusts to temperature changes and directly impacts Earth's climate sensitivity. Most research so far has focused on the spectral integral of the feedback parameter. Spectrally resolving the feedback parameter permits inferring information about the vertical distribution of long-wave feedbacks, thus gaining a better understanding of the underlying processes. However, investigations of the spectral long-wave feedback parameter have so far been limited mostly to model studies. Here we show that it is possible to directly observe the global mean all-sky spectral long-wave feedback parameter using satellite observations of seasonal and interannual variability. We find that spectral bands subject to strong water-

Spectral trend vs. Forcing + Feedback (2008-2019)

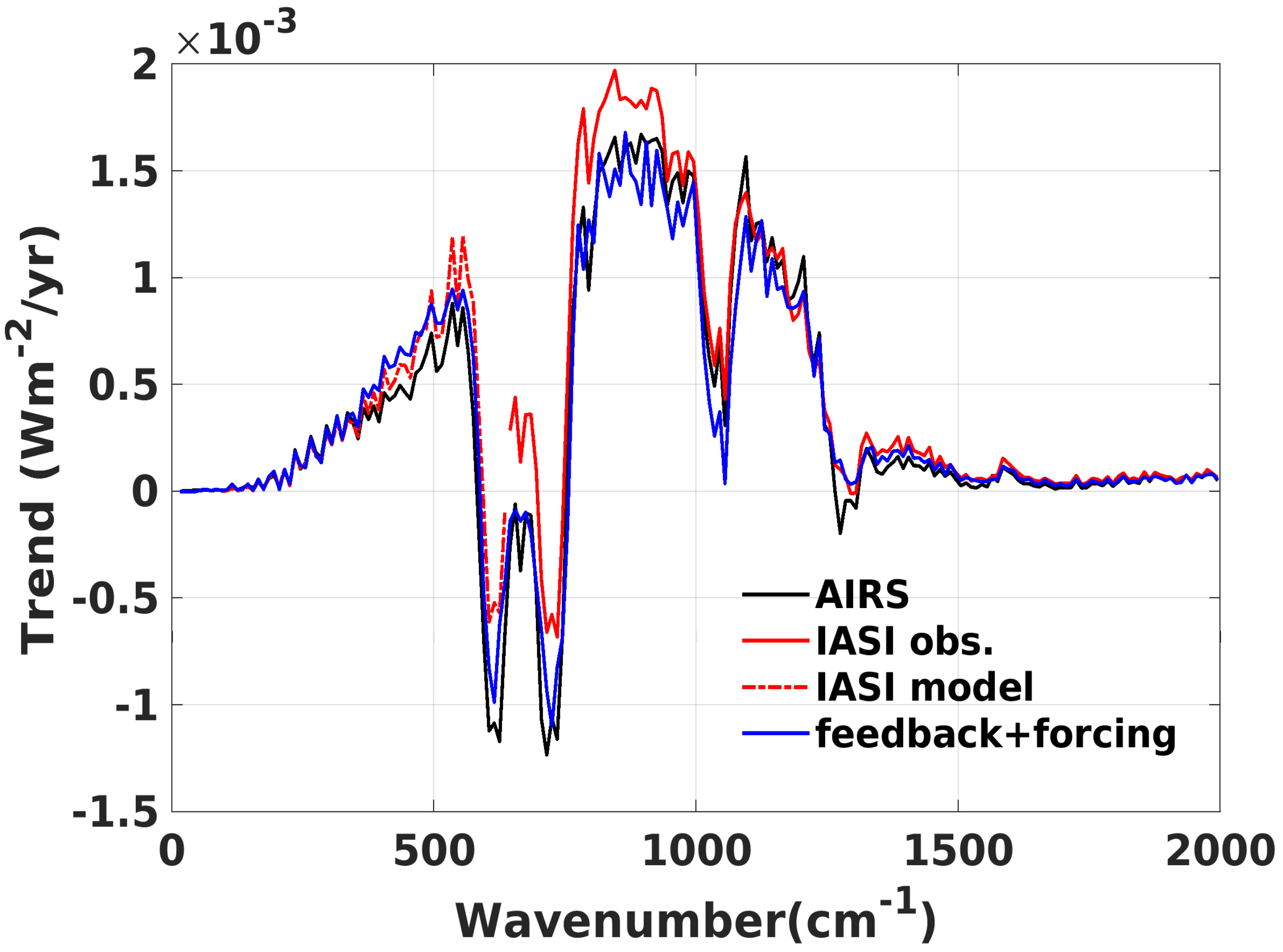


	2008 to 2019
$\frac{dF}{dt}$ from EBAF4.2 (Wm^{-2}/yr)	0.081±0.125
$\frac{dF}{dt}$ from collocated CERES with AIRS (Wm^{-2}/yr)	0.072±0.120
$\frac{dF}{dt}$ from AIRS (Wm^{-2}/yr)	0.067±0.128
$\frac{dF}{dt}$ from IASI (Wm^{-2}/yr)	0.089±0.129
$\frac{d}{dt}RF(v) + [-\lambda(v)]\frac{dT_{surface}}{dt}$ (Wm-2/yr)	0.050
$\frac{d}{dt}RF$ (Wm^{-2}/yr)	-0.026
$-\lambda$ (Wm^{-2}/K)	1.587
$\frac{dT_{surface}}{dt}$ (K/yr)	0.047

The lower feedback+forcing is due to cloud feedback

Cloud feedback is calculated from 2008 to 2019

Spectral trend vs. Forcing + Feedback (2008-2019)



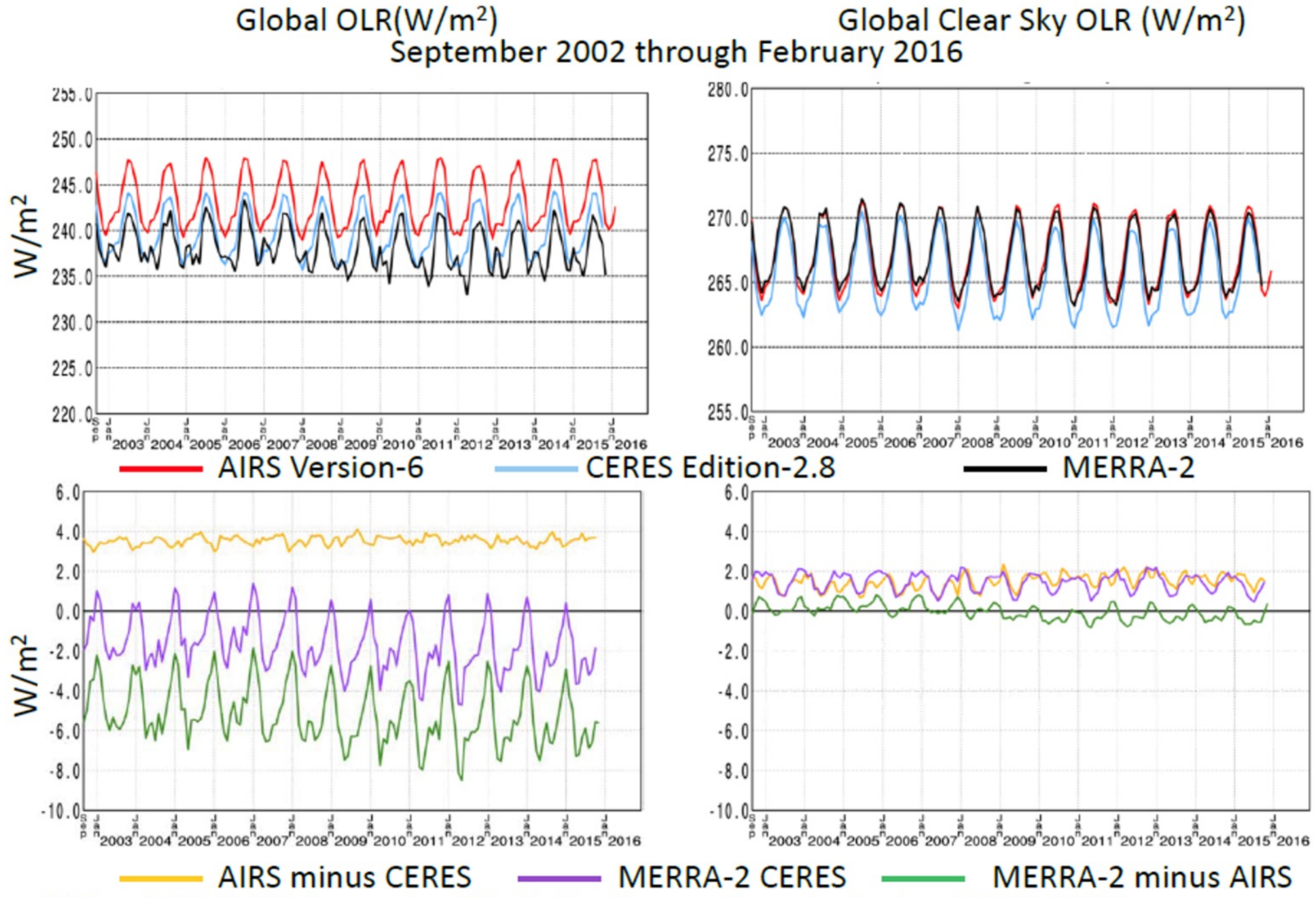
Cloud feedback is calculated from 2003 to 2022

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
- 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
  - Cloud feedback in response to CO_2 is most difficult to estimate from observations; other LW feedbacks likely can be estimated confidently from current observations.

Backup

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

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