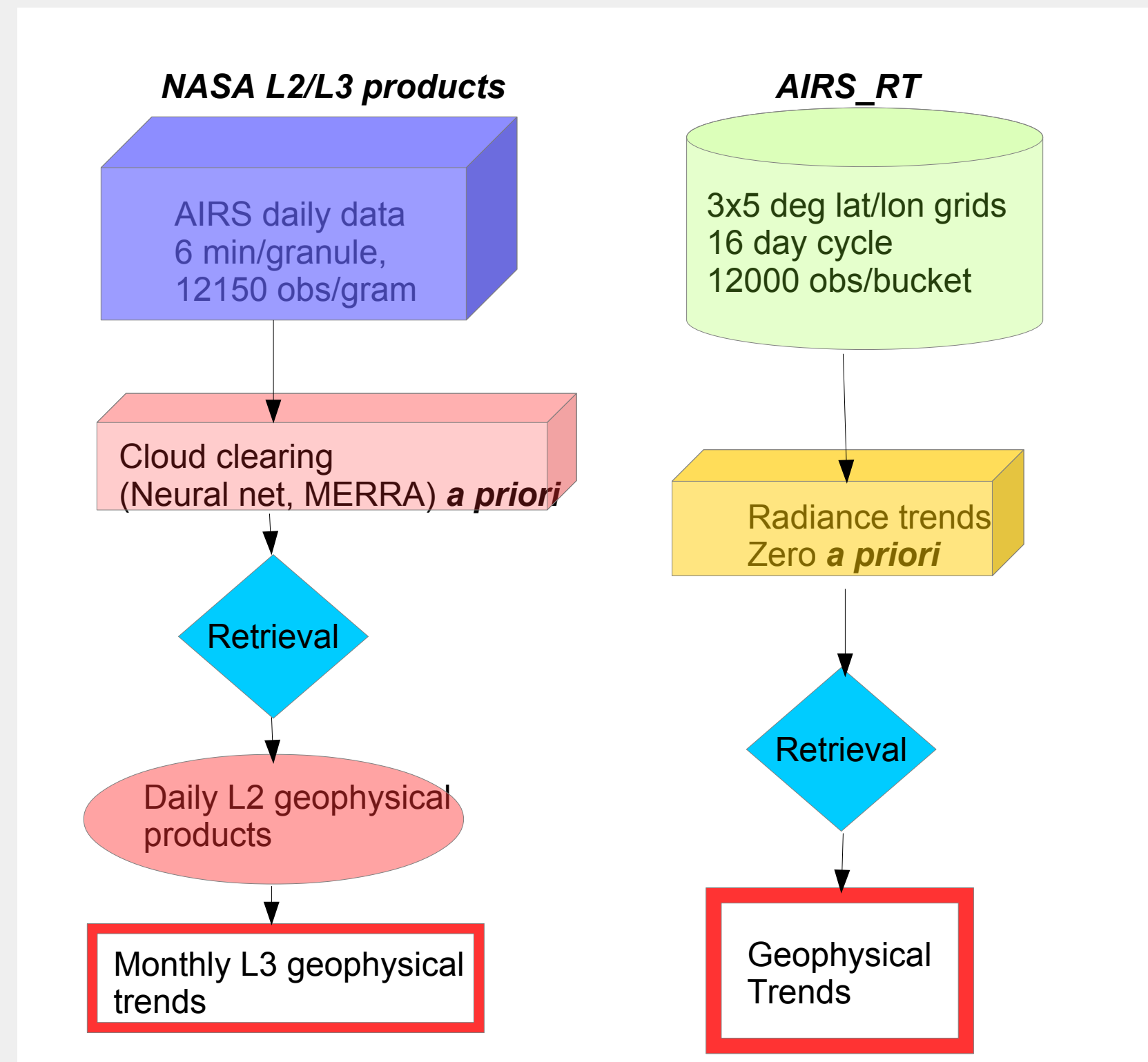


1. Infrared sensors

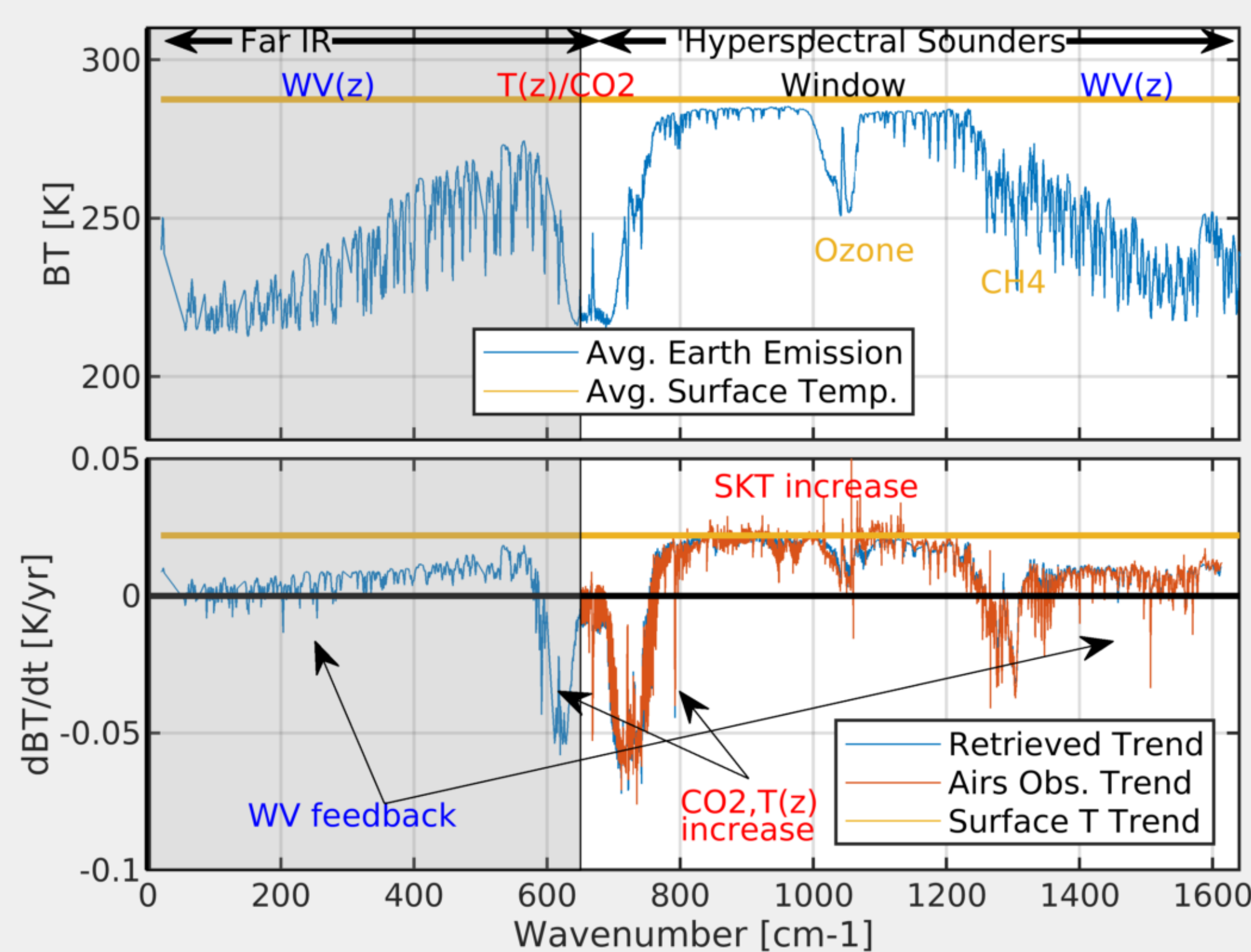
- ▶ New generation Hyperspectral sounders span 2002 - 2040+ in fixed 1.30 pm orbit
 - ▶ NASA's Atmospheric Infrared Sounder (AIRS 2002/09-present) 1.30 pm orbit
 - ▶ NOAA Cross Track Infrared Sounder (CrIS 2012/02-present) 1.30 pm orbit
- ▶ Full hyperspectral IR sounder channels allow retrievals of
 - ▶ $T_{surface}$, atmospheric $T(z)$, $WV(z)$ profiles, traces gases ($CO_2, CH_4, CFCs$) etc
 - ▶ cloud properties (phase, particle size, cloud amount, cloud top, fraction)
 - ▶ large aerosols (dust and volcanic ash, which are "infrequent")
- ▶ Outstanding sensor stability (≤ 0.002 K/yr)
- ▶ New product **CHIRP** provides homogeneous record with a single spectral response and radiometric offsets removed, providing a single 40+ year IR radiance record. We use this data set for **AIRS_RT** work shown here.

2. Data and Analysis Outline

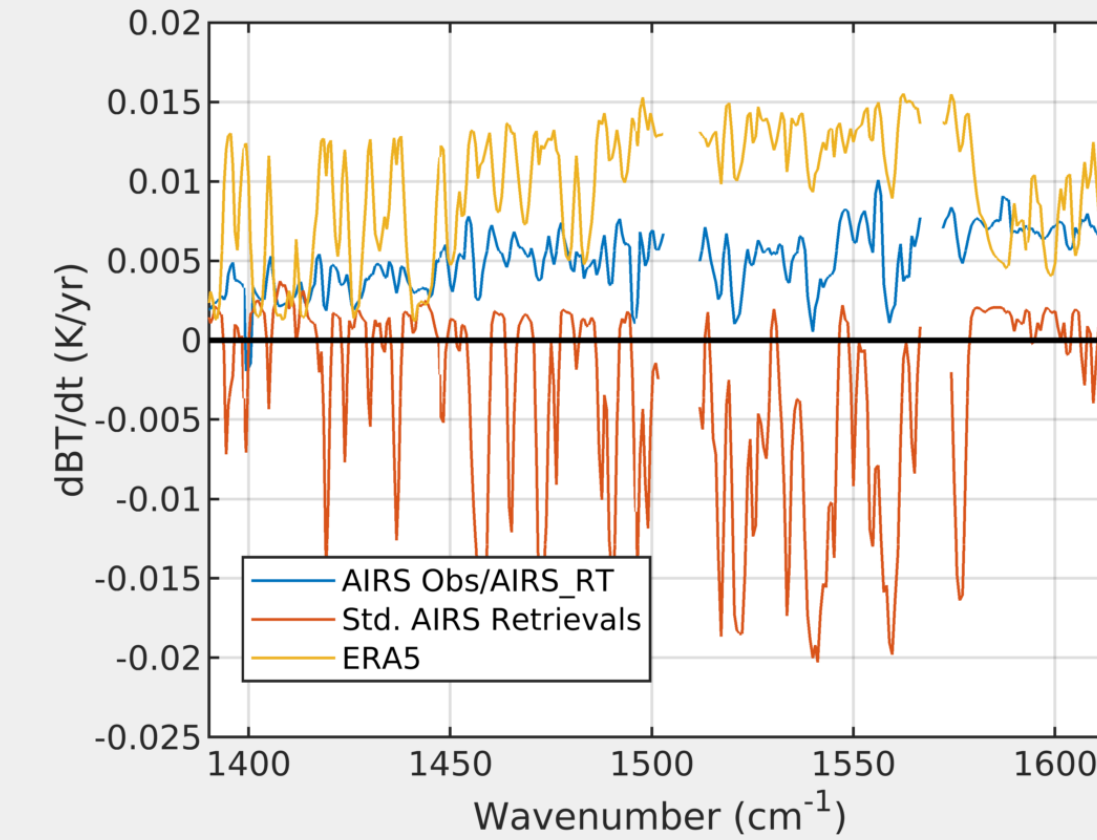


- ▶ AIRS L2 retrieved profiles quite sensitive to neural net or NWP *a-priori*; errors from these propagate into retrieved L2 products and L3 trends
- ▶ **Our approach uses the observed radiance trends and zero *a-priori* making errors very traceable**
- ▶ Binned data (21+ years!!!!) is **freely available on Amazon Web Services**
- ▶ Very fast, takes 30 minutes to redo entire dataset

3. IR Hyperspectral Trends shows LW Forcings and Responses



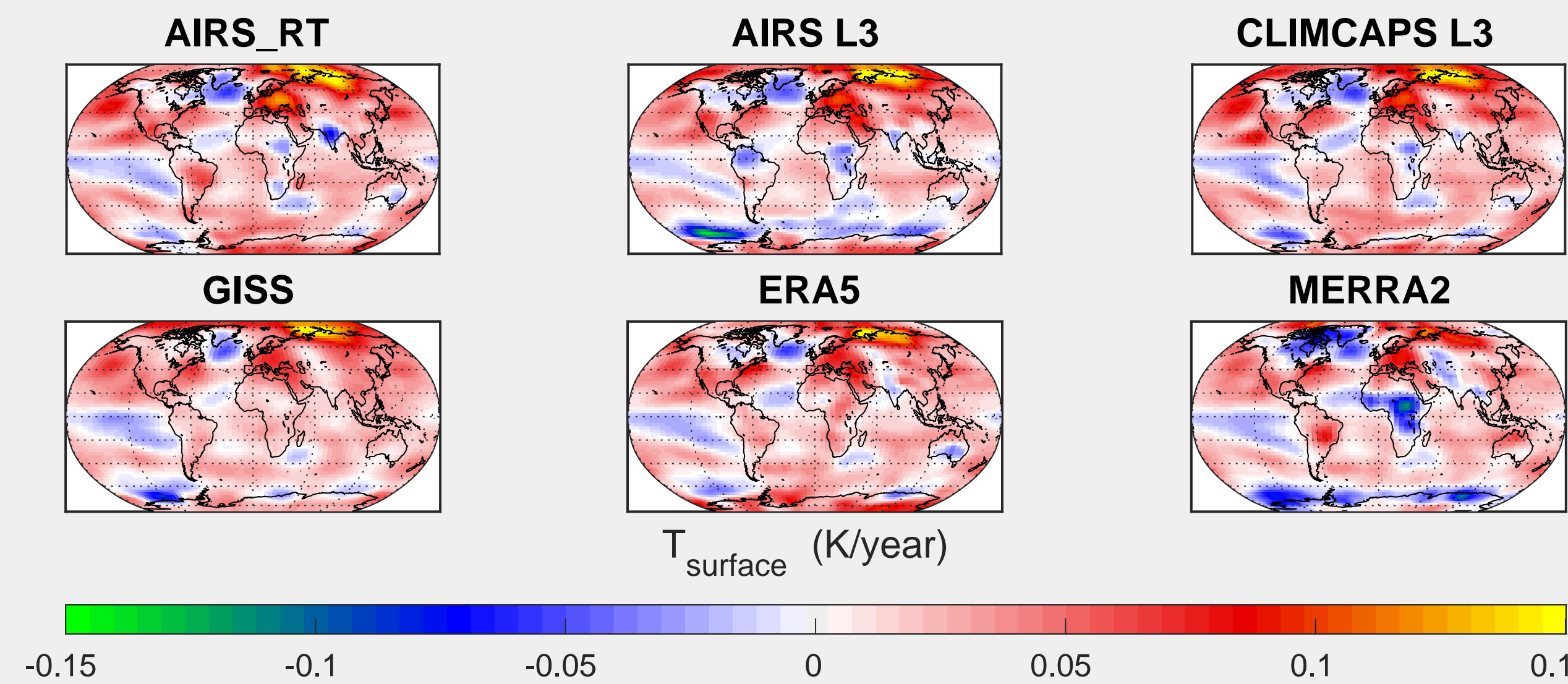
4. Spectral Closure is a Rigorous Test!



- ▶ Definitive test of accuracy: Convert (ERA5, MERRA2, etc.) fields to equivalent radiance trends and compare to the "truth", ie measured radiance trends.
- ▶ ERA5 WV feedback is lower than observed.
- ▶ AIRS retrievals very inaccurate

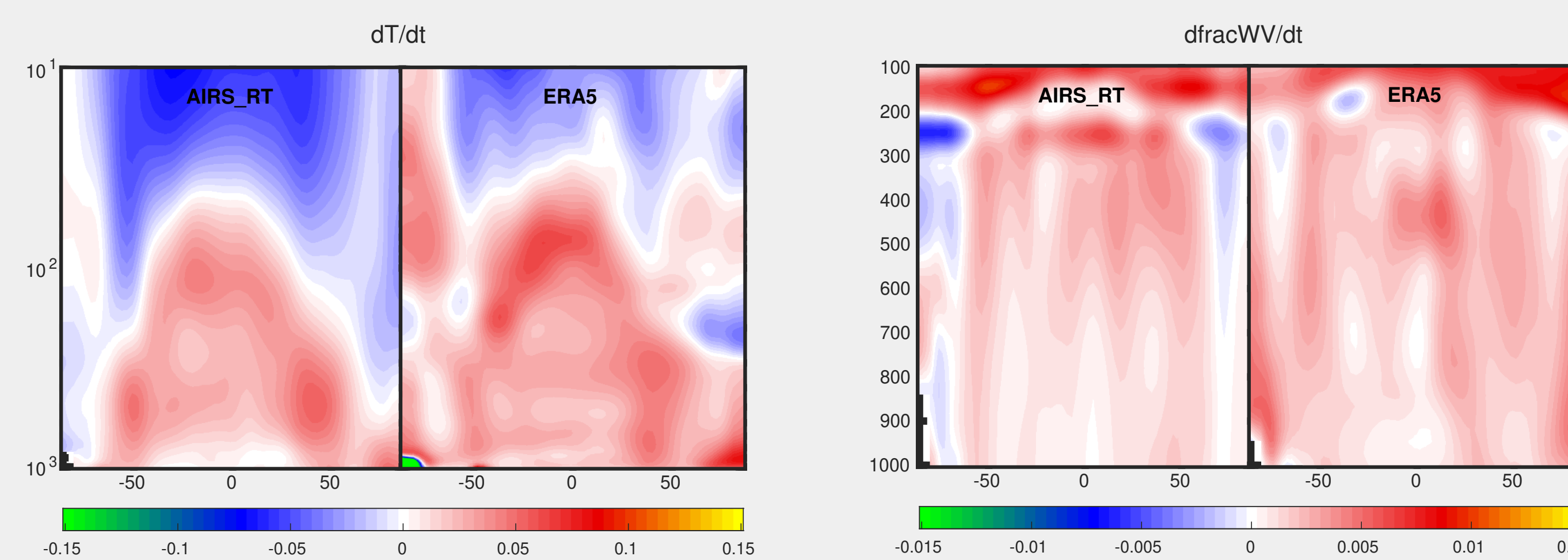
5. Surface temperature trends

- ▶ Surface Temperature Trends, Day+Night, "validate" the spectral closure
- ▶ Profile T/H₂O can only be accurate if simultaneously derived surface trends are accurate
- ▶ AIRS_RT compares very favorably with ERA5 and GISS and CLIMCAPS.
- ▶ Some Differences over continental tropical regions. Global averages very similar for ERA5, GISS and AIRS_RT (within 10)
- ▶ Cosine averaged trend +0.020 K/yr (ERA5, GISS = +0.022, +0.021 K/yr)

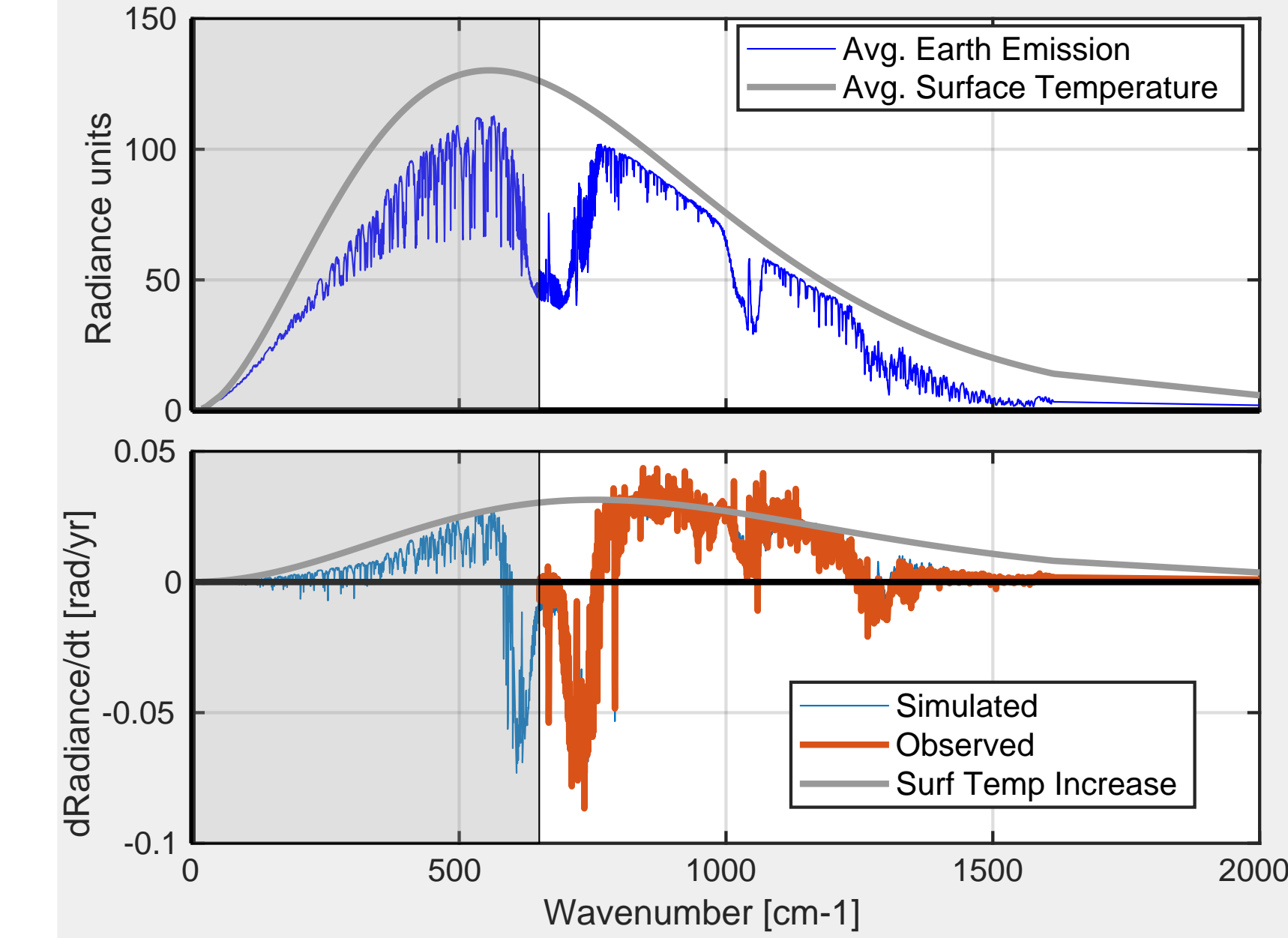


6. Atmospheric T/WV trends

- ▶ Sounders most accurate in free trop. for H₂O, free trop. + strat. for T(z)
- ▶ AIRS_RT ~ ERA5 in troposphere, but quite different in polar stratosphere
- ▶ AIRS_RT has slightly lower (positive) WV trends, except in polar upper trop, as seen from spectral closure
- ▶ AIRS V7 water vapor trends (not shown) are VERY different from these two
- ▶ AIRS V7 temperature trends (not shown) similar to AIRS_RT in polar regions



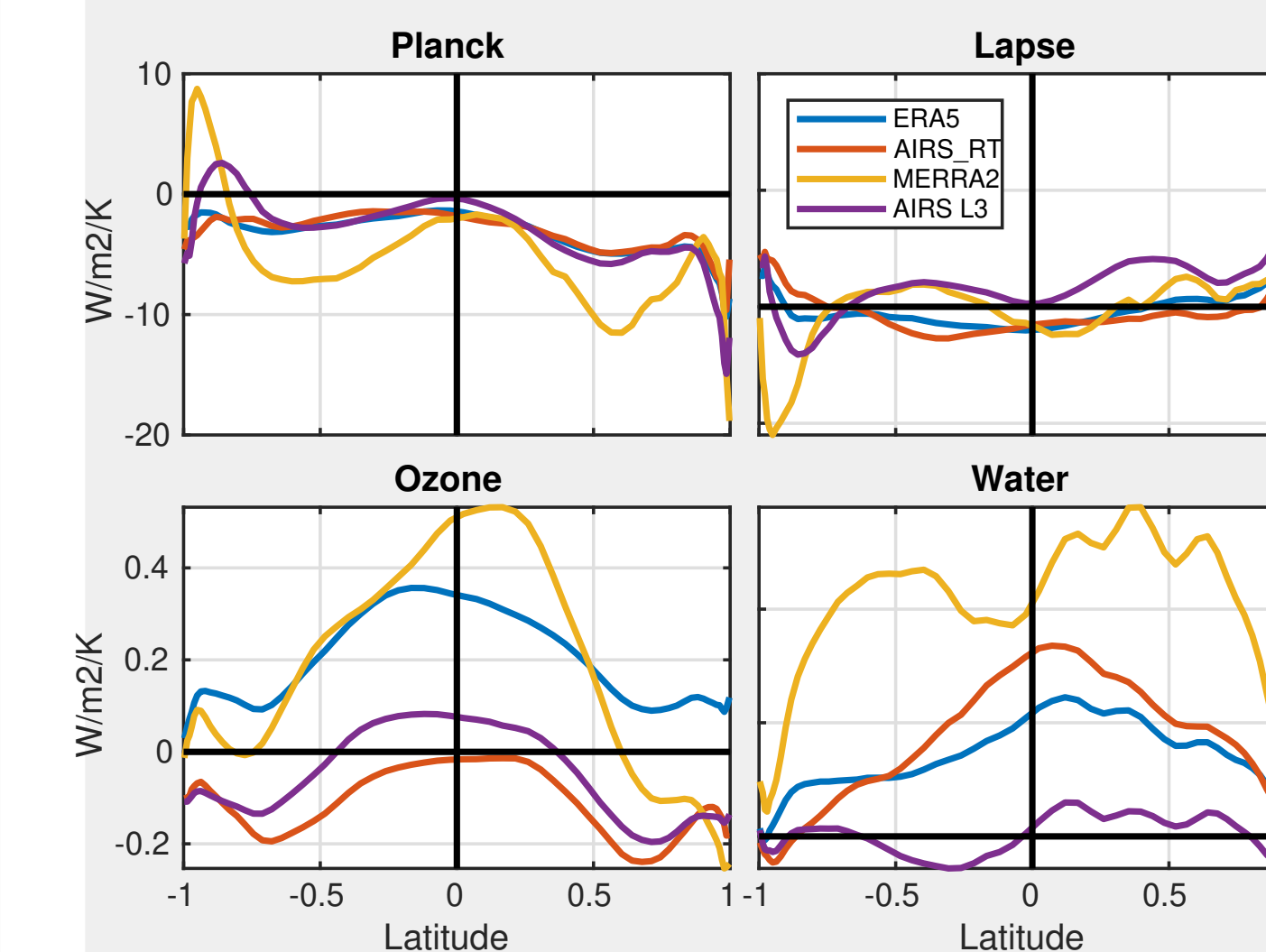
7. Relevance to clear sky OLR



- ▶ Far-IR WV emission dominates atmospheric cooling, esp. in descending tropical regions
- ▶ AIRS observed mid-IR WV senses same WV profile region important in FIR
- ▶ AIRS_RT trends shown previously used to compute OLR trends, so possible OLR calculation errors are not very important.

8. Longwave clear sky feedbacks

- ▶ We used average monthly ERA5 profile to set base clear sky OLR using *ecRad*
- ▶ Perturb the profile using geophysical trend, recompute clear sky OLR
- ▶ Compute feedbacks using One sided OLR change equations from Nadir Jevanjee *et. al.* "Simpsons law and spectral cancellation" GRL 2021



	Planck	Lapse	Ozone	WV	Total
AIRS_RT	-3.50	0.40	-0.12	1.22	-2.10
ERA5	-3.49	0.20	0.17	1.18	-1.94
MERRA2	-3.98	-0.19	0.12	3.40	-0.54
AIRS L3	-3.48	1.38	-0.07	-0.02	-2.59

Uncertainties on order of ± 0.30 W/m²/K per component
 Best overall agreement is AIRS_RT and ERA5 Spectral cancellation means summed values uncertainty about ± 0.10 W/m²/K

9. Conclusions

	ERA5	MERRA2	AIRS_RT	AIRS	CLIMCAPS
SKT trend K/yr	0.022	0.011	0.020	0.015	0.024
Feedbacks W/m2/K	-1.94	-0.54	-2.10	-2.59	-1.21

- ▶ **Observed Hyperspectral Radiance Trends → Geophysical Trends → Clear sky feedback decomposition**
 - ▶ Used $\delta(RH) \sim 0$ to retrieve of thermodynamic trends from observed spectral trends
 - ▶ General features of dSKT/dt, dT(z)/dt and dWV(z)/dt agree with NWP (ERA5, MERRA2)
 - ▶ Ongoing comparisons of our clear sky OLR trends against CERES show good agreement.
 - ▶ Ongoing comparisons of downwelling clear sky ILR trends also in good agreement.
- ▶ **Key advantages of our method include**
 - ▶ using only AIRS channels known to be stable
 - ▶ no *a-priori* information used, covariance matrices are tikonov and/or based on trend uncertainties
 - ▶ speed : takes a few hours to add recent 16 day timesteps, retrieval is less than 30 minutes
 - ▶ spectral closure : can compare observations versus model simulations
- ▶ Plan to include cloud effects in future anomaly timeseries geophysical retrievals