WIDE RANGE IN CLIMATE MODEL RADIATIVE TRANSFER CALCULATIONS OF TOP-OF-ATMOSPHERE FLUX SENSITIVITY TO TROPOSPHERIC OZONE AS COMPARED TO TES AND IASI SATELLITE DERIVED PRODUCTS

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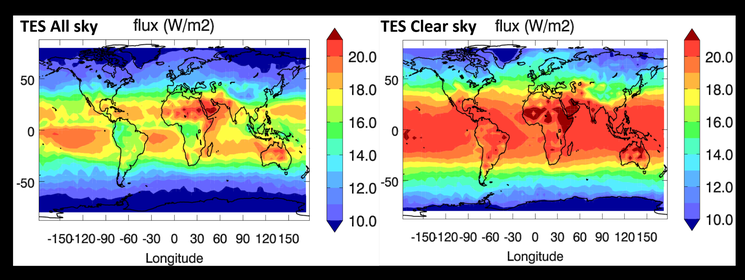
MOTIVATION

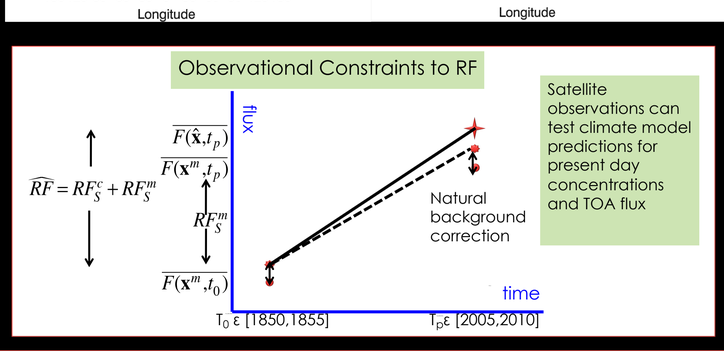
- Model simulated 9.6 μm ozone band TOA flux and flux sensitivity have never been evaluated by observations
- Biases in these quantities are sources of bias in ozone RF
- Ozone longwave radiative effect (LWRE) depends on temperature and relative humidity via atmospheric opacity
- Benchmarking present day ozone band flux and LWRE is important for understanding climate feedbacks that affect ozone forcing

Large range in model estimates for:

Direct Ozone RF

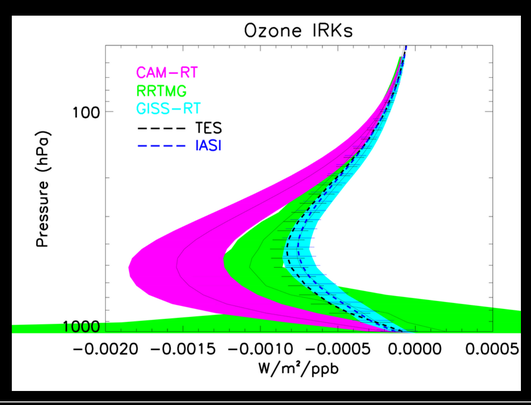
- Preindustrial-to-present day: 0.35 W/m² [0.25 to 0.65 W/m²]
- through 21st century: 0.89 W/m²





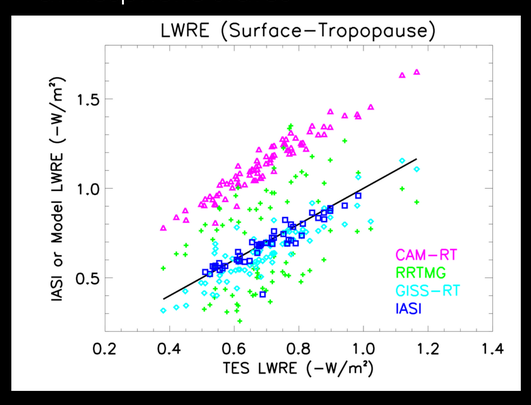
MODEL vs. DATA IRKs and LWRE

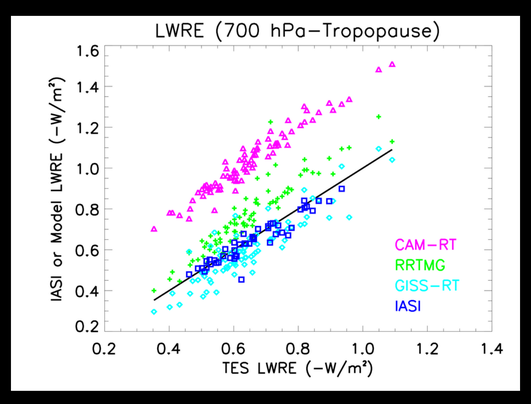
Climate RT Model	Institution	O3 bands (cm⁻¹)	References
CAM-RT (band)	NCAR	1000-1120	Lamarque et al., JGR, 2008 Conley et al., GMD, 2013
CAM-RRTMG (corr. K)	NCAR/AER	980-1080	Iacono et al., JGR, 2008
GISS-RT (band)	GISS/Duke U.	970-1010 1010-1070 1070-1210	Schmidt et al., J. Clim. 2006 Shindell et al., ACP, 2013



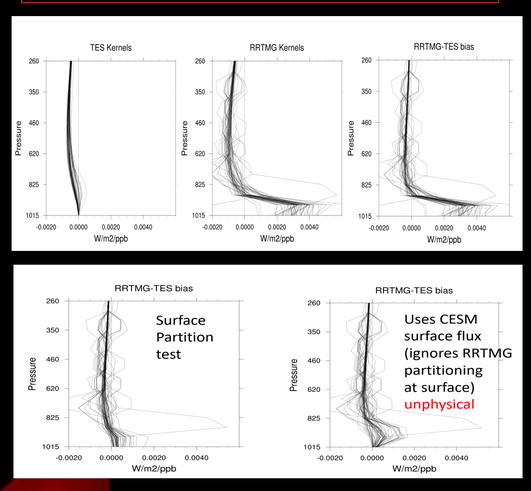
Model and satellite average IRKs with standard deviations indicated by color spread (models) and bars (TES and IASI). Model calculations used atmospheric states from TES retrievals on 2011.07.15 from 81 cloud-free ocean observations, 29°S – 48°N. TES IRKs are slightly larger on average than IASI due to daylight observations times.

Comparisons of model and IASI LWRE to TES LWRE for 2011.07.15 atmospheric states





Diagnosing issue with RRTMG IRKs

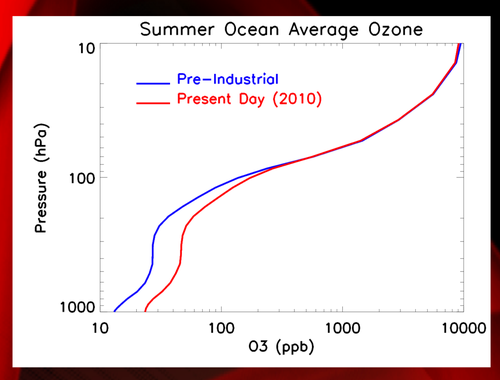


Tests to diagnose causes of surface layer bias in RRTMG. Left panel uses surface layer line-by-line results for radiance partitioning instead of the nominal 706 hPa. However, this could change the net out-going flus. Right panel ignores the RRTMG portioning in the surface layer and uses the CESM surface flux, which would produce unphysical results if applied in the model.

Statistics for LWRE (700 hPa to Tropopause) comparisons to TES

Model/IASI	Correlation R^2	Slope	Offset
CAM-RT	0.97	1.12	-0.31
RRTMG	0.92	1.16	-0.01
GISS-RT	0.90	0.98	0.02
IASI	0.94	0.88	-0.06

SIMPLE RF CALCULATION WITH IRKS

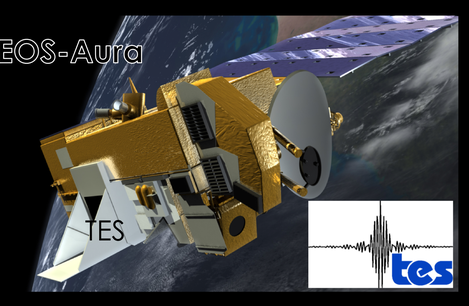


Pre-Industrial and present day O3 profiles from CAMChem (Lamarque et al., ACP, 2010) for NH summer, ocean scenes

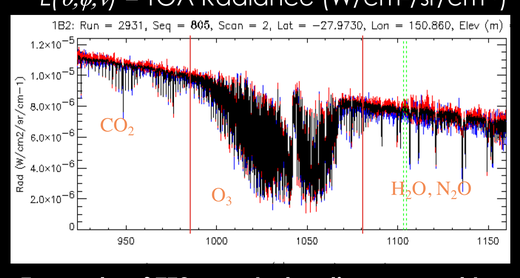
RF (W/m²) for ΔO_3 at tropopause

TES	IASI	GISS-RT	CAM-RT	RRTMG
0.24 ± 0.04	0.23 ± 0.04	0.22 ± 0.03	0.41 ± 0.08	0.27 ± 0.18

WHAT TES AND IASI MEASURE

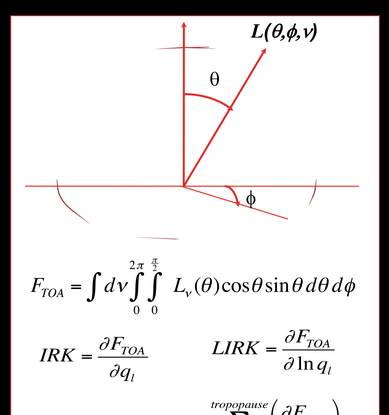


$L(\theta,\phi,\nu)$ = TOA Radiance (W/cm²/sr/cm⁻¹)



Example of TES spectral radiance used to retrieve O_3 vertical profiles.

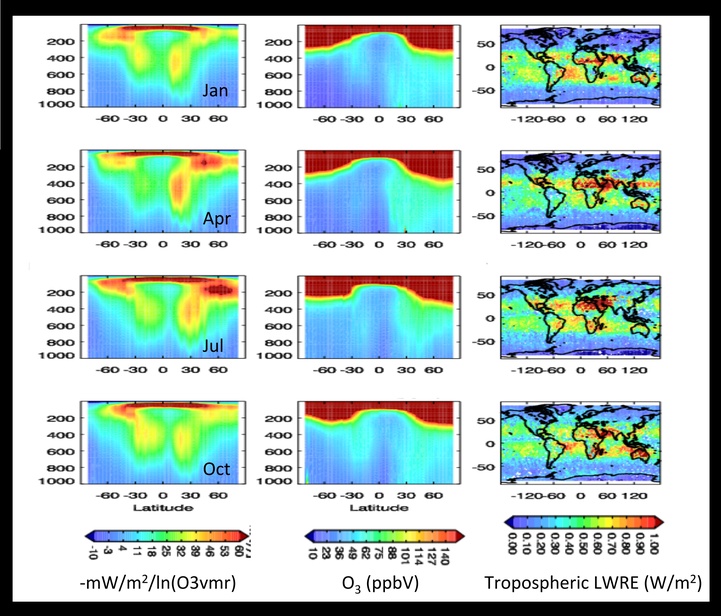
	TES	IASI
Instrument	FTS	FTS
Spectral resolution	0.1 cm⁻¹	0.5 cm⁻¹
Spectral coverage	652 to 2251 cm⁻¹	645 to 2760 cm⁻¹
NeΔT	0.30K @ 300 K	0.15K @ 280K
Footprint size	8.5 x 5.3 km²	12km diameter
Sampling coverage	Sparse global coverage (16 days)	global coverage twice per day
Orbit alt.	705 km	817 km
Eq. x-ing	13:30 LST	9:30 LST



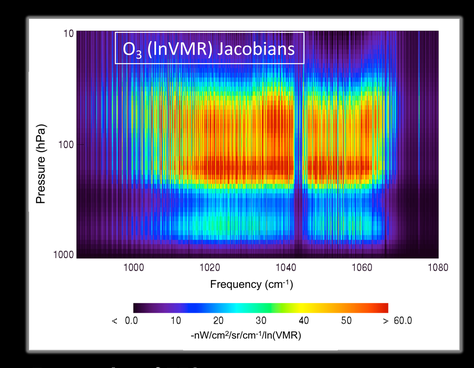
$$F_{TOA} = \int d\nu \int_0^{2\pi}\int_0^{\frac{\pi}{2}} L_\nu(\theta)\cos\theta\sin\theta\, d\theta\, d\phi$$

$$IRK = \frac{\partial F_{TOA}}{\partial q_l} \qquad LIRK = \frac{\partial F_{TOA}}{\partial \ln q_l}$$

$$LWRE = \Delta F_{TOA} = \sum_{l=surface}^{tropopause}\left(\frac{\partial F_{TOA}}{\partial q_l}\right) q_l$$



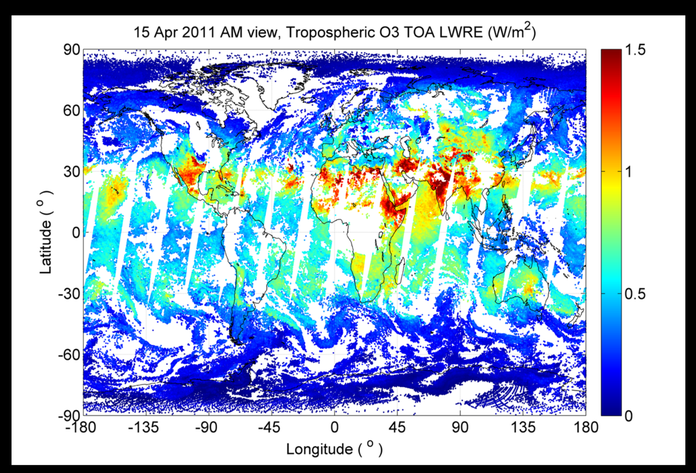
TES monthly averages for LIRK, O3 and LWRE



Example of TES Jacobian matrix used in O_3 retrieval and for O_3 IRKs.

$$\frac{\partial L_{TOA}(\nu)}{\partial q_l} = \frac{1}{q_l}\frac{\partial L_{TOA}(\nu)}{\partial \ln q_l}$$

IASI LWRE for a single day



CONCLUSIONS

- TES and IASI IRKs can be compared to model calculations to assess errors in radiative transfer and estimates of radiative forcing.
- We find a large spread in IRKs for the model calculations examined here, with only the GISS-RT model matching well with TES and IASI.
- The RRTMG radiative transfer model, using a correlated-K approach, produces kernels that increase the outgoing long-wave flux with an increase in ozone in the lowest layers. Although mostly canceled by the IRK in the mid – upper troposphere, it leads to large errors in the RF calculation.

IRK References

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Acknowledgments

NASA ROSES funding NNX14AE84G.

http://tes.jpl.nasa.gov/ http://smsc.cnes.fr/IASI/