Observational constraints on the vertical distribution of instantaneous ozone radiative forcing in chemistry climate models

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Radiative forcing from ozone

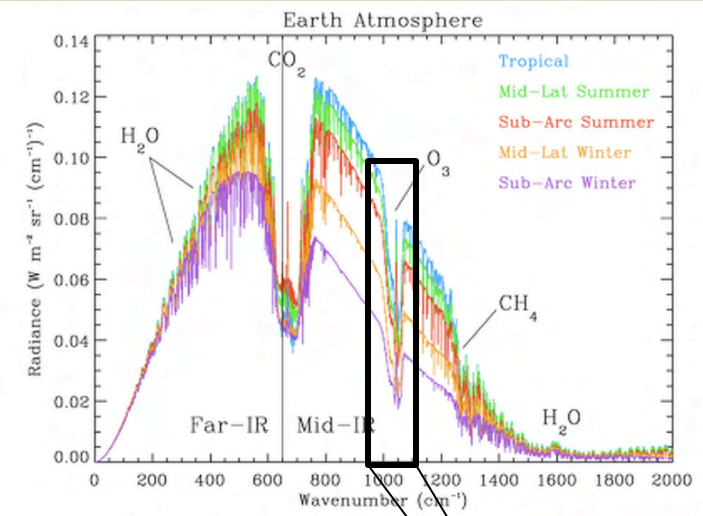
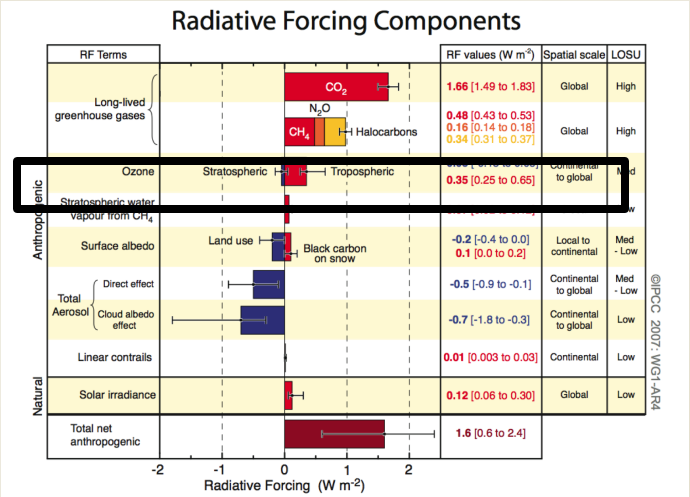


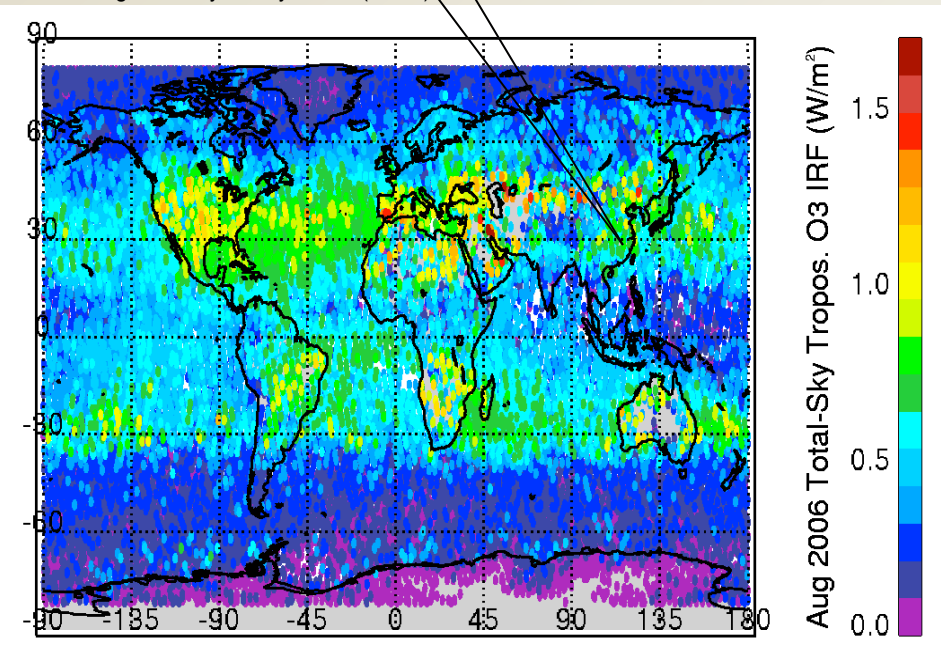
Fig. courtesy M. Mlynzcack (LaRC)

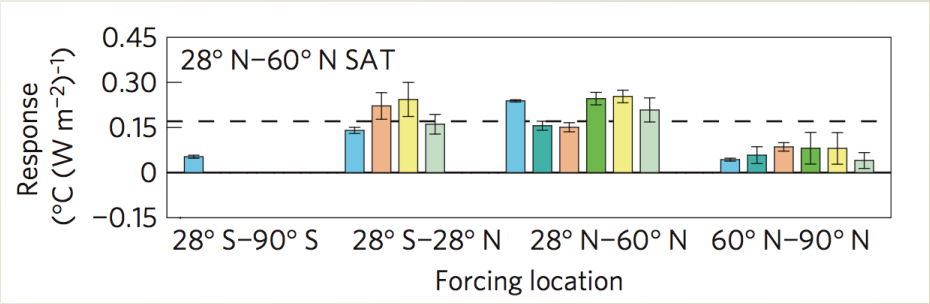
- Inter-model radiative forcing from ozone: .35 [0.25-.65] W/m^2 (IPCC AR4)

Radiative Forcing uncertainties:
- Pre-industrial background ozone
- Spatial distribution
- Vertical distribution



IPCC AR4

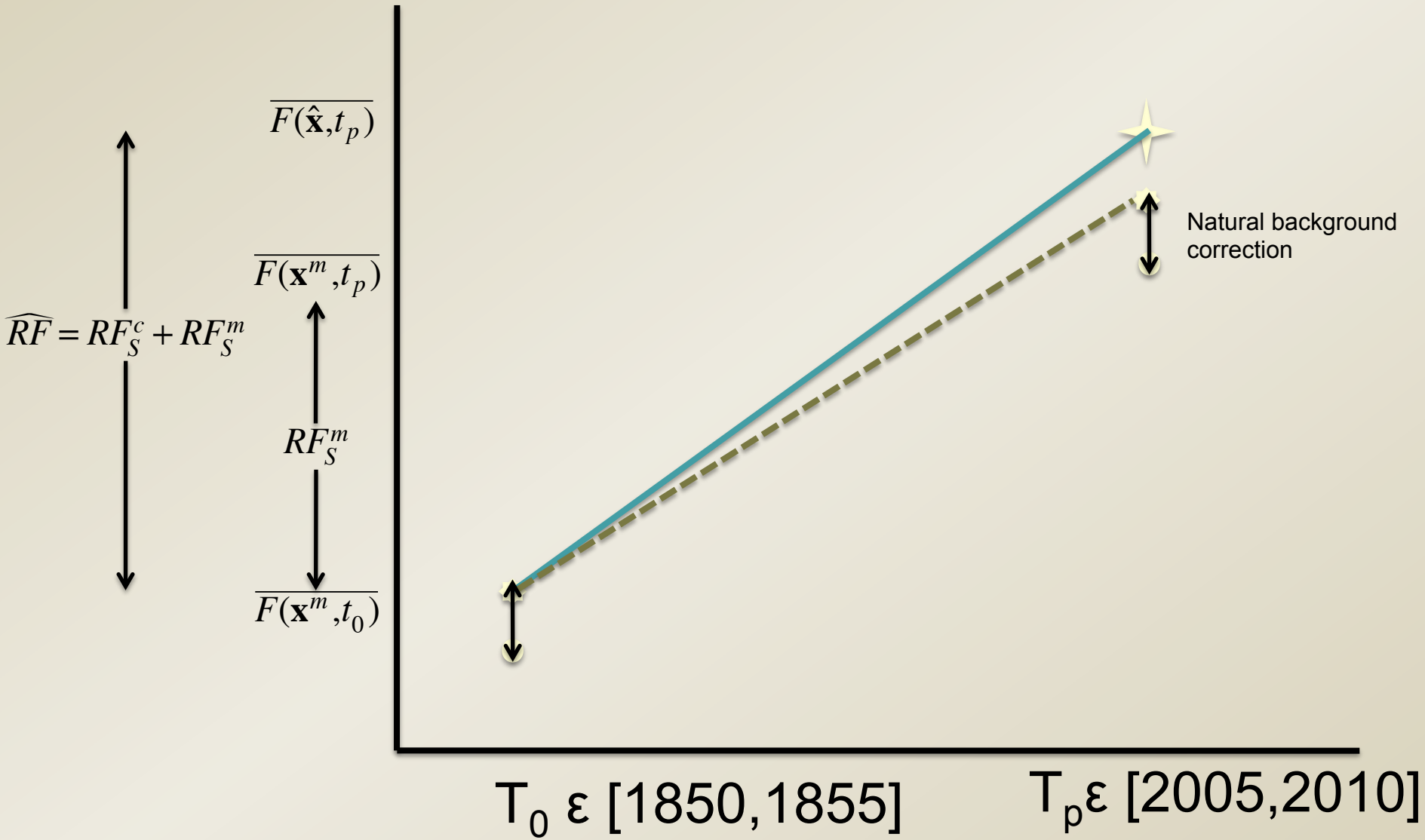




Shindell and Faluvegi, *Nature Geosciences*, 2008

The regional temperature response is a function of the forcing location

Satellite correction of PIP RF



Basic approach

Pre-industrial to present day radiative forcing with observed or retrieved present day concentrations

$$R\hat{F} = F(\hat{\mathbf{x}}, t_{pres}) - F(\mathbf{x}^m, t_{PI})$$

PIP RF with respect to climate model output

$$R\hat{F} = \underbrace{F(\hat{\mathbf{x}}, t_{pres}) - F(\mathbf{x}^m, t_{pres})}_{RF^c} + \underbrace{F(\mathbf{x}^m, t_{pres}) - F(\mathbf{x}^m, t_{PI})}_{RF^m}$$

Taylor series expansion via IRK

$$R\hat{F} = \sum_i \mathbf{h}_i^{\mathrm{T}}(\hat{\mathbf{x}}_i - \mathbf{x}_i^m) + \mathbf{b}_i + RF^m$$

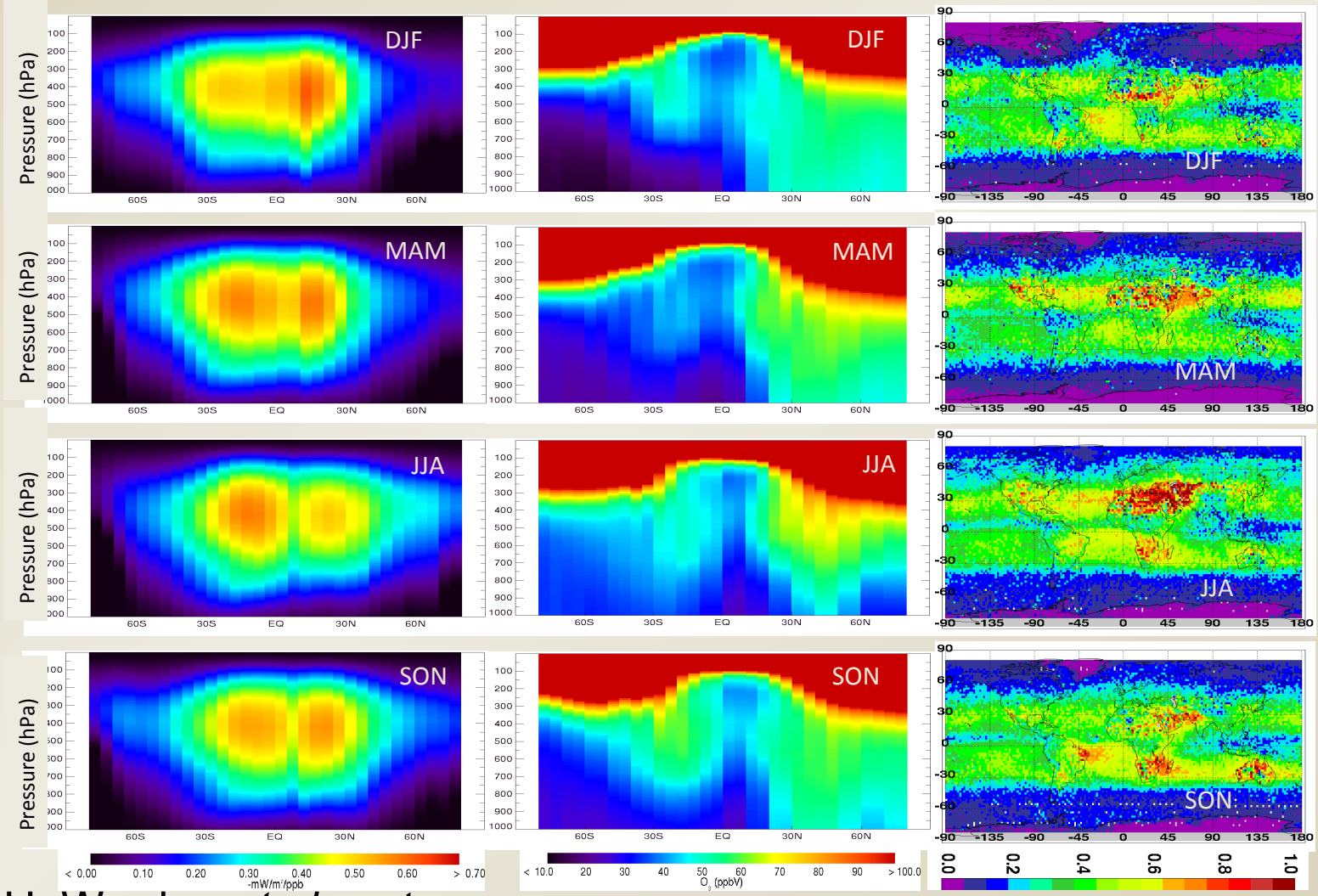
Challenges

- Satellite bias
- Satellite sampling
- Model background uncertainties

$\hat{\mathbf{x}}$ TES ozone
$\mathbf{x}^m$ model ozone
t_{pres} present day
t_{PI} pre-industrial

TES Seasonal Averages (2005-2009)

All-sky IRK (-mW/m^2/ppb) | O_3 (ppb) | Tropos. O_3 LWRE (W/m^2)

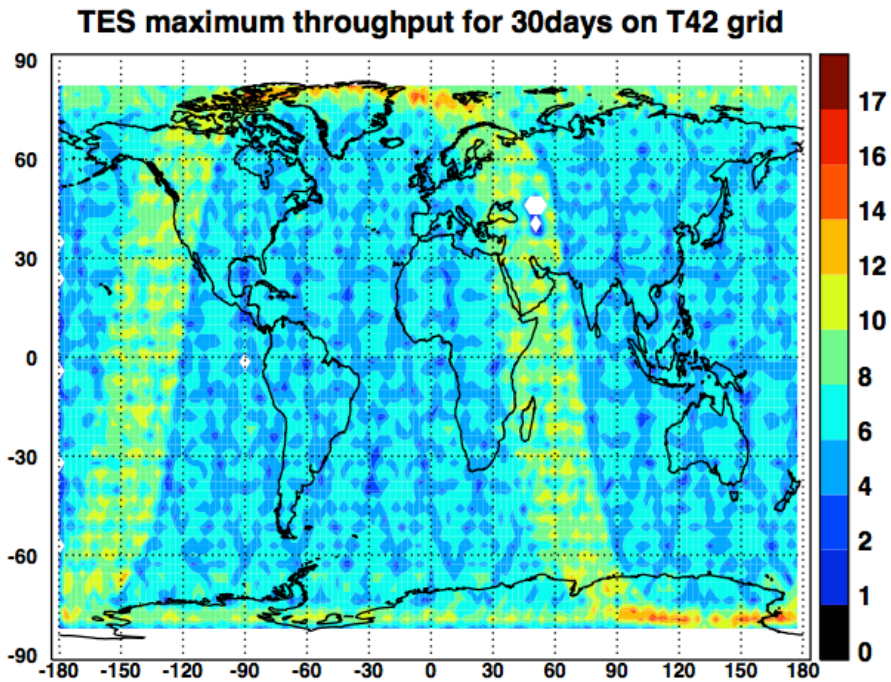


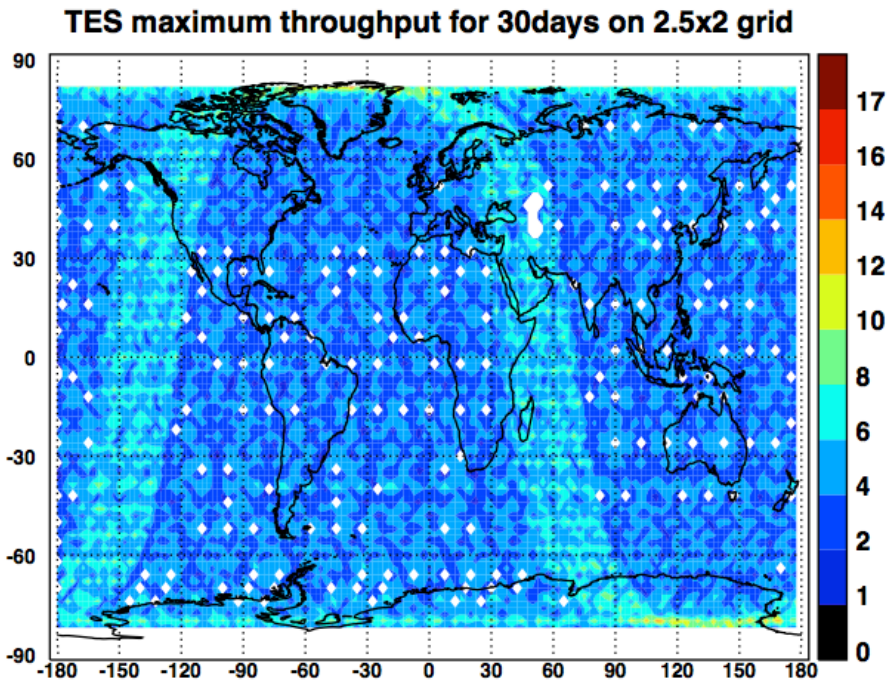
Long wave radiative effect (LWRE) in W/m^2

See H. Worden *et al* poster

TES sampling density

Aghedo *et al*, ACP 2011

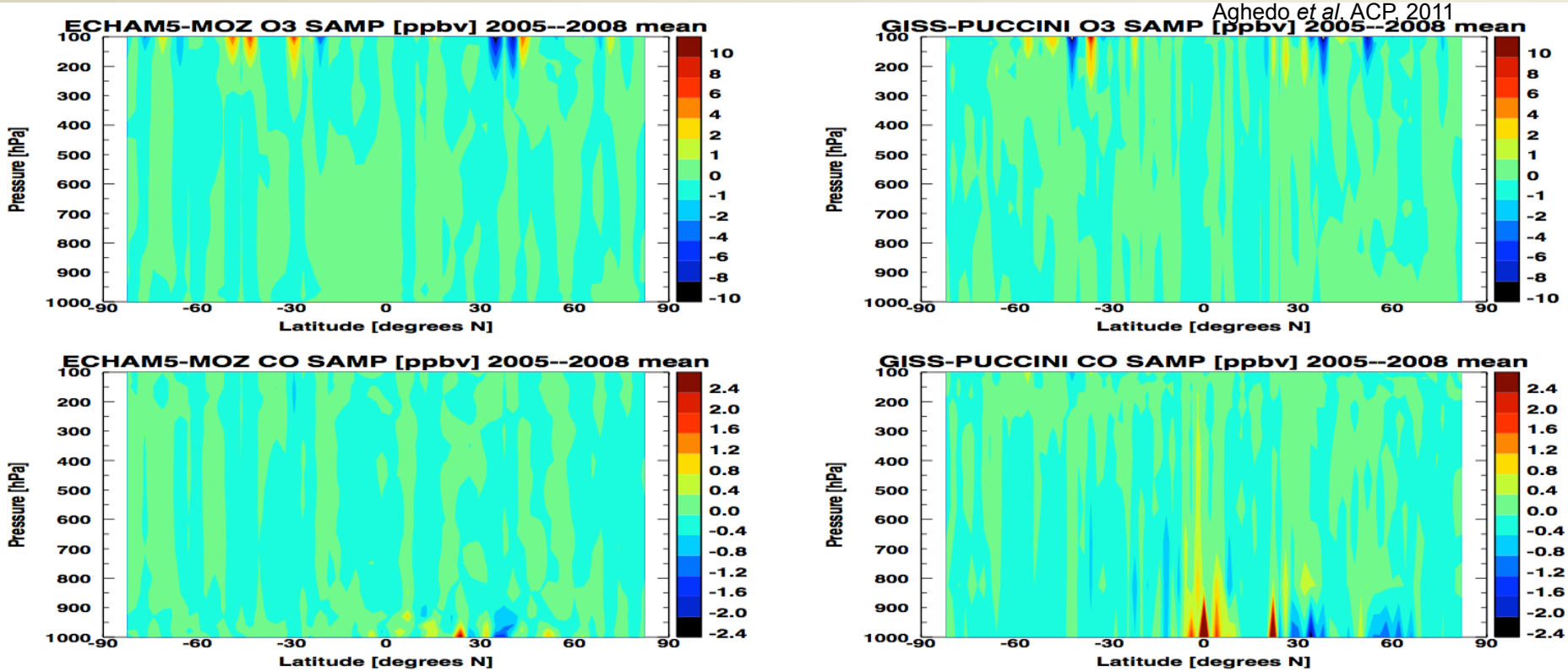




TES spatial sampling is sparse.
IR sounding provides twice day temporal sampling.
For RF calculations, larger domains are sufficient.
What is the impact on ozone climatology?

Effect of satellite sampling

Aghedo *et al*, ACP, 2011



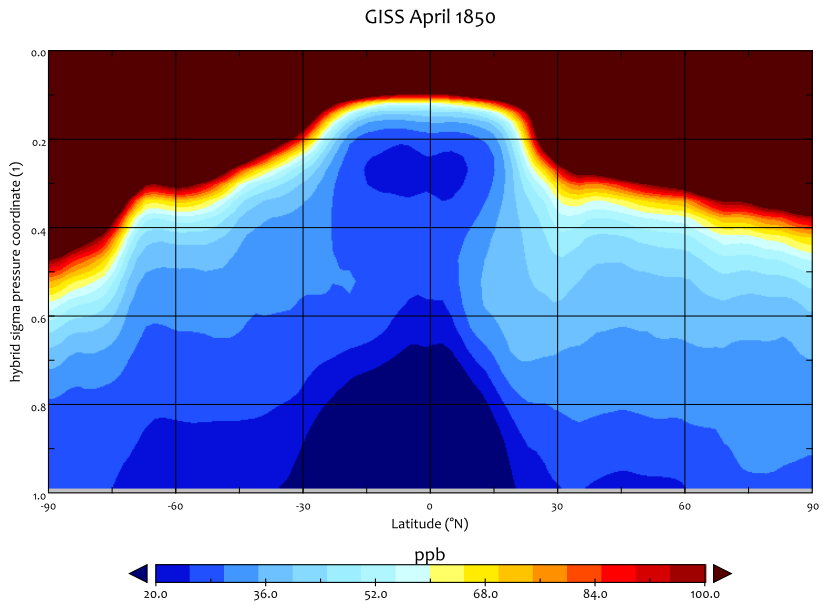
Comparison of model sampled at TES locations to model time series

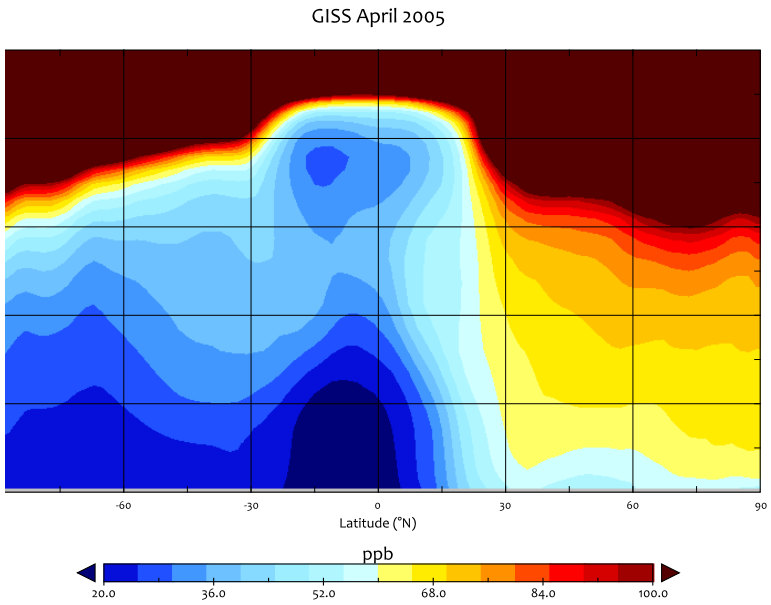
Remarkably, climatology is captured to within 1 ppbv

GISS model

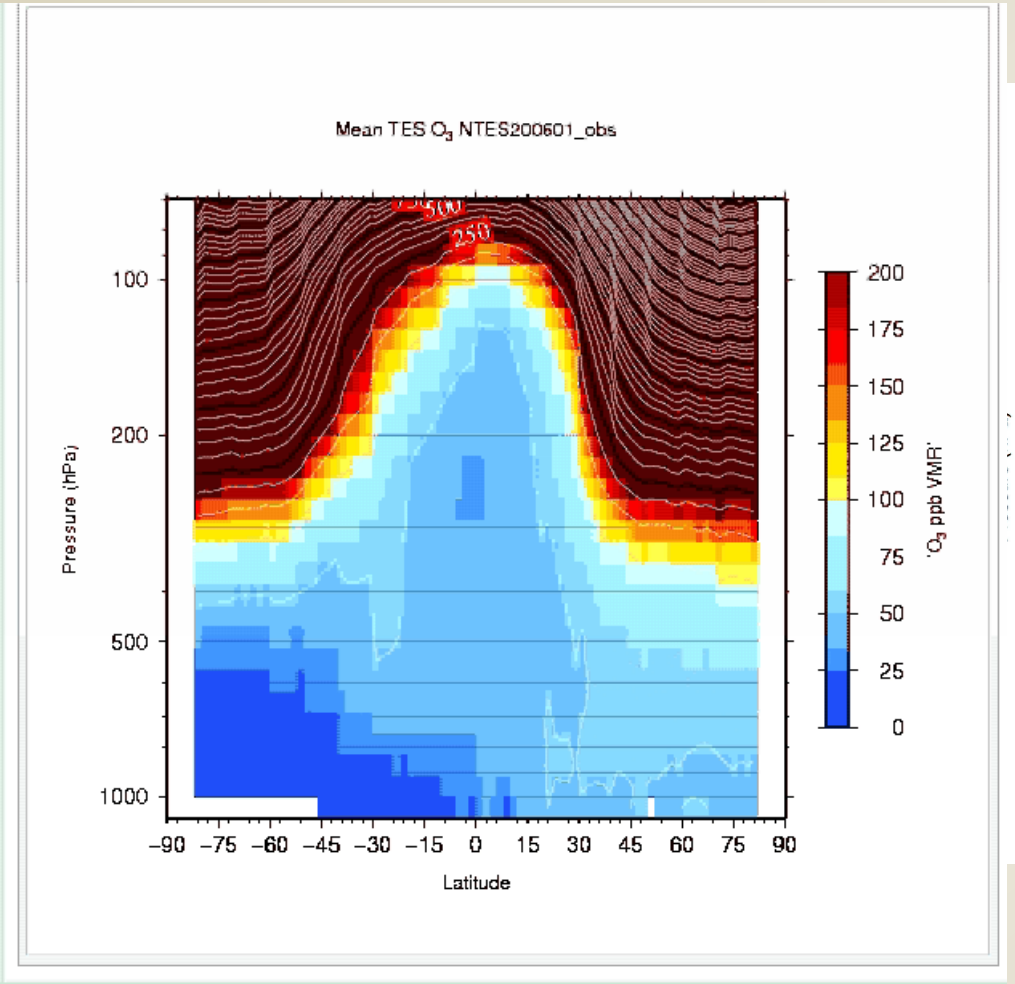
NASA GISS-PUCCINI (Shindell *et al*, JGR 2006)

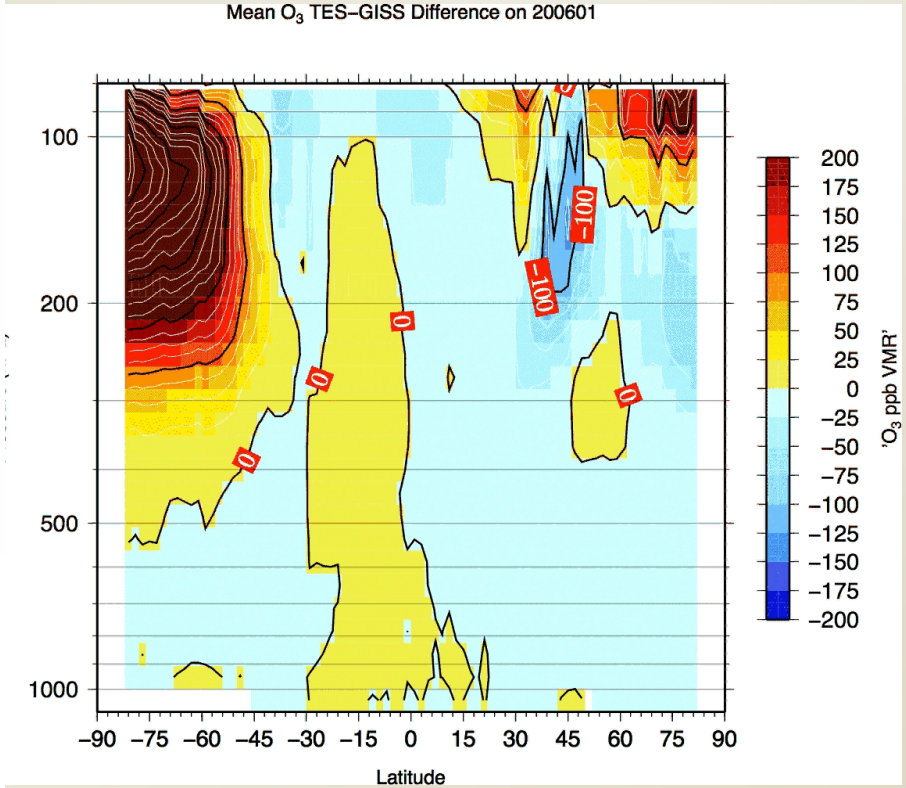
- PUCCINI tropospheric and stratospheric chemistry
- 2 x 2.5 grid, 40 vertical levels (up to 0.1hPa), gridded monthly mean
- Fully coupled ocean-atmosphere historical run.
- Prescribed SST.
- AR5 anthropogenic, aircraft, and agricultural (Lamarque *et al*, 2011); GFED biomass burning





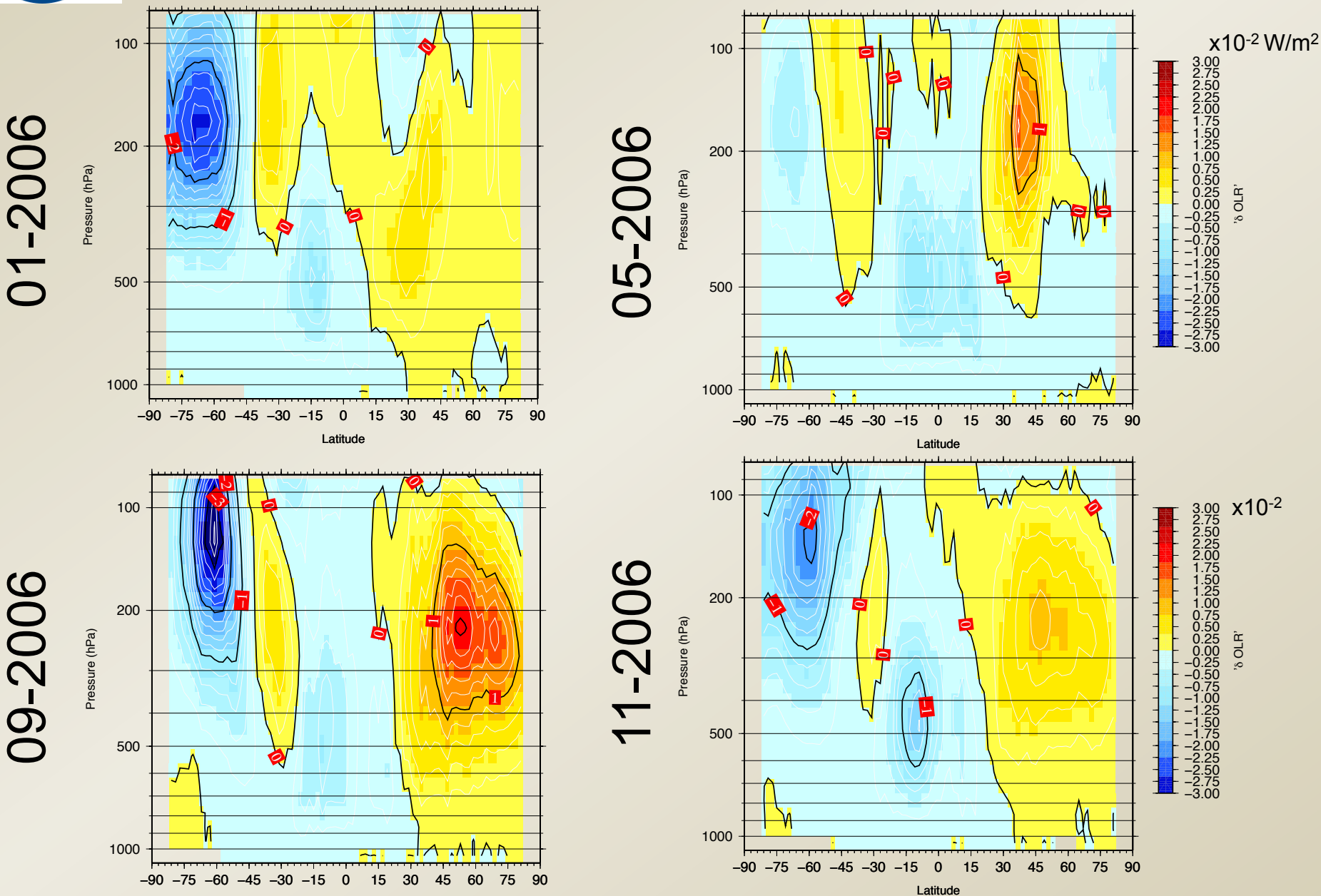
TES/GISS comparisons





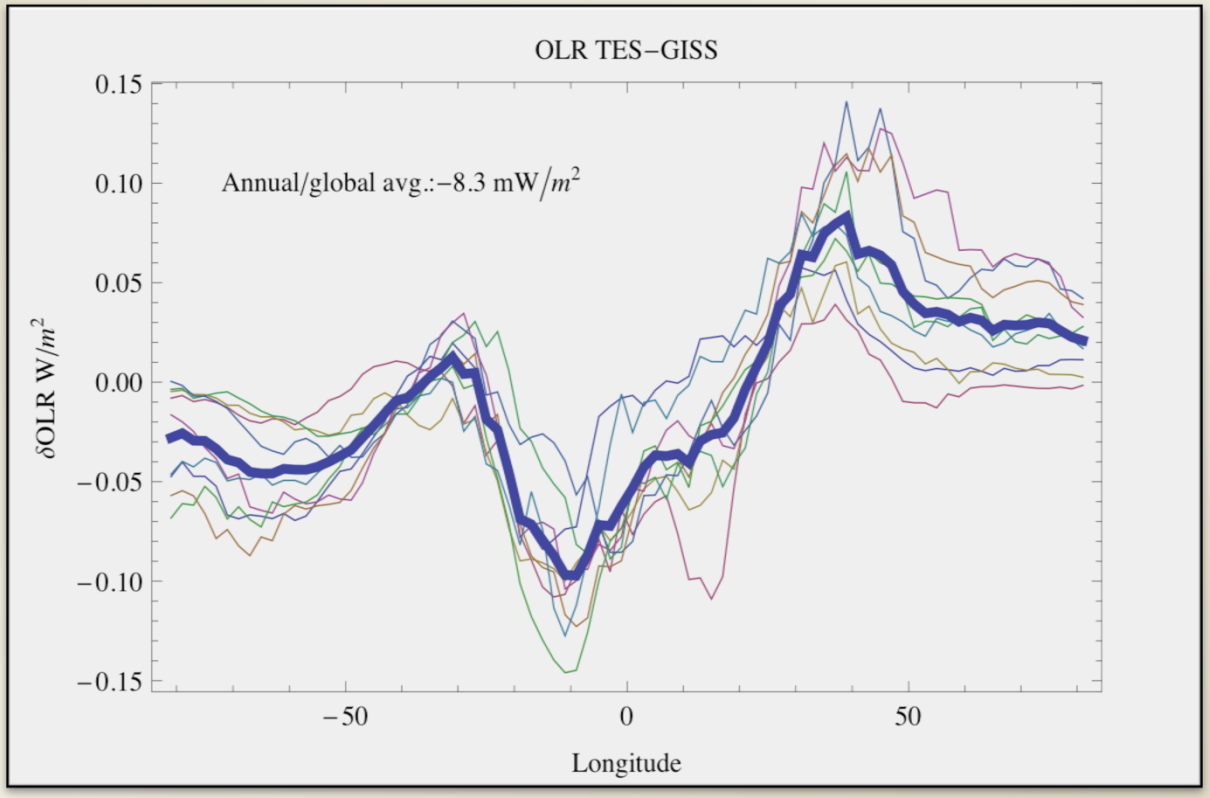
Significant differences > 200 hPa at high latitudes.
Suggests strat-trop exchange is too strong
GISS SH ozone is too weak.

TOA OLR: TES-GISS W/m²



Zonal differences

Vertically integrated OLR differences up to q < 150 ppb



Significant zonal structure in OLR:

- Overestimate in NH
- Underestimate in SH

Regional differences in OLR on the order of historic ozone RF

Remarkably, global mean agrees well. Relative to PIP RF (0.35 W/m^2), ~ 2% difference.

But is it for the right reason?

Conclusions

- TES ozone and ozone IRK provide critical new data for chemistry-climate model radiative forcing evaluation.
  - These data can provide insight into present day ozone RF and processes impacting pre-industrial ozone
- TES/GISS comparisons for 2006 show significant discrepancies in lower stratosphere with implications for STE.
- Ozone radiative effect is too high in NH trop, too low in SH, likely due to incorrect background.
- Global mean in ozone radiative effect in good agreement, but for the wrong reasons.
- For regional radiative forcing studies, the impact of these errors need to studied.