Variability of Assimilated Ozone in the Upper Troposphere and Lower Stratosphere

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Ozone assimilation system

MODEL

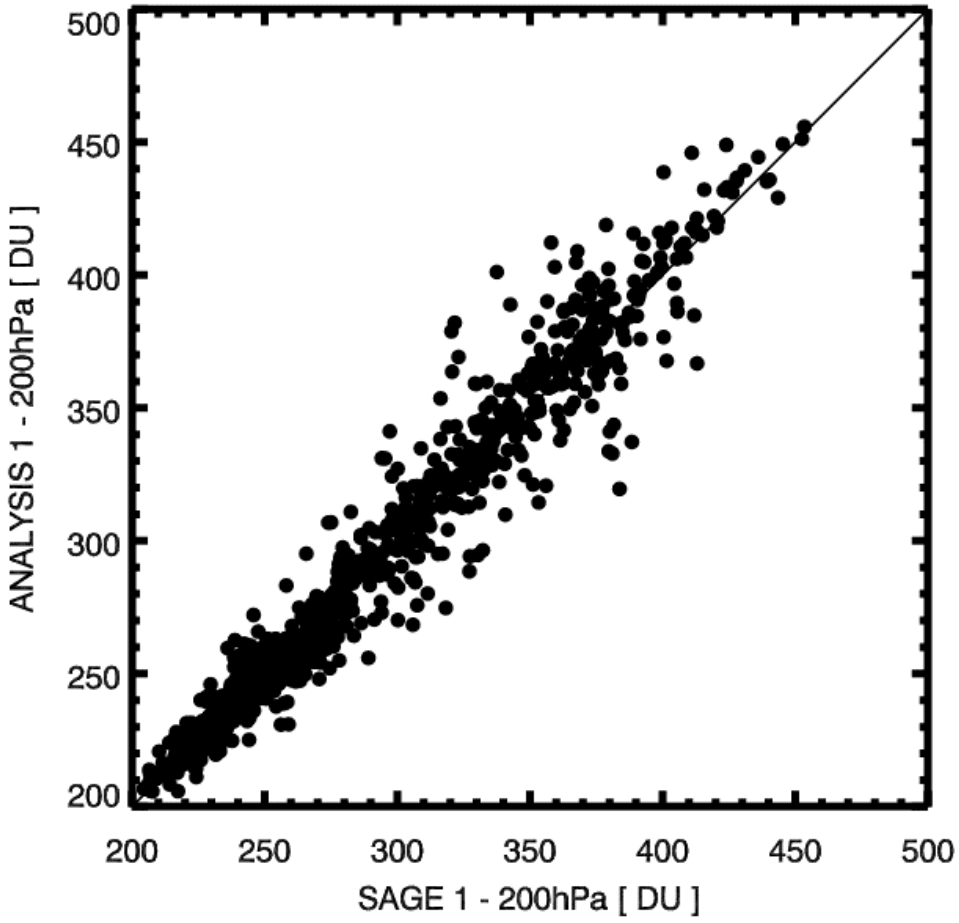
- transport within GEOS-4 **general circulation model** constrained by meteorological analyses
  - parameterizations for stratospheric photochemistry and heterogeneous ozone loss
  - a parameterization of the tropospheric chemistry

DATA

- The Microwave Limb Sounder (MLS): ozone profiles:
  - 20 levels 216 – 0.14 hPa
  - ~ 3,500 profiles a day, near global coverage
- Ozone Monitoring Instrument (OMI): US retrieved ozone total column (low reflectivity). Data averaged onto a 2°× 2.5° grid

- Data input and analysis output every 3 hours
- The model grid: 1°× 1.25° × 55 levels

Ozone assimilation system - validation

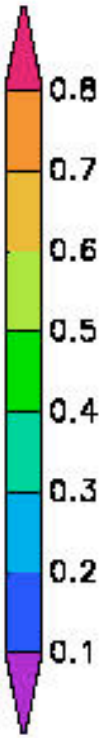


Data from SAGE II (January – March 2005) are integrated between 200 – 1 hPa and compared with those from collocated analysis

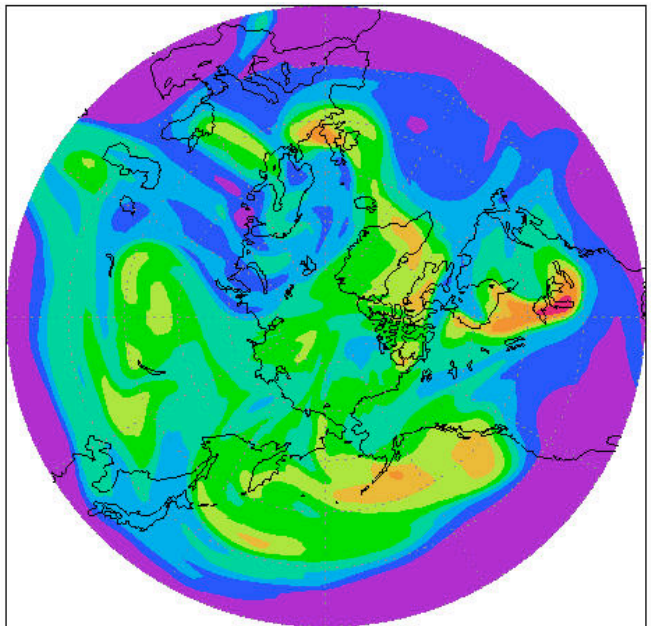
Relative RMS difference < 5%

I.Stajner et al. *Assimilated Ozone from EOS-Aura: Evaluation of the Tropopause Region and Tropospheric Columns* , submitted to J. Geophys. Res.

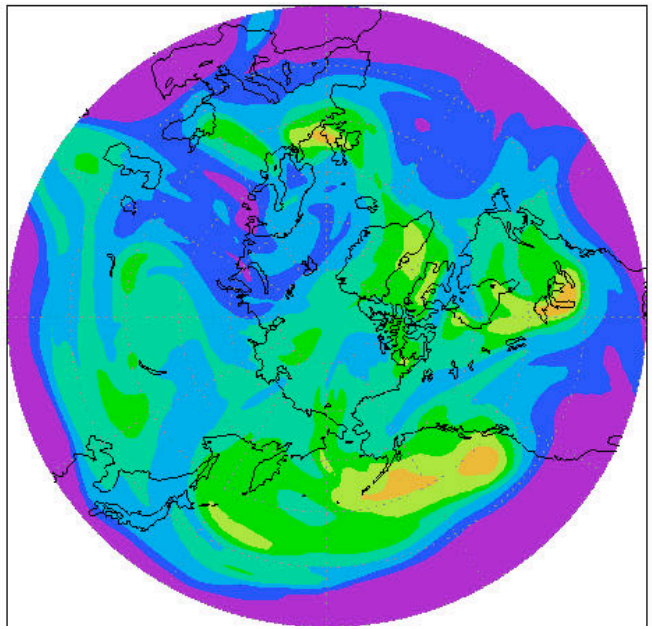
Model vs. assimilation



Model at 200 hPa
Dec 31 12Z



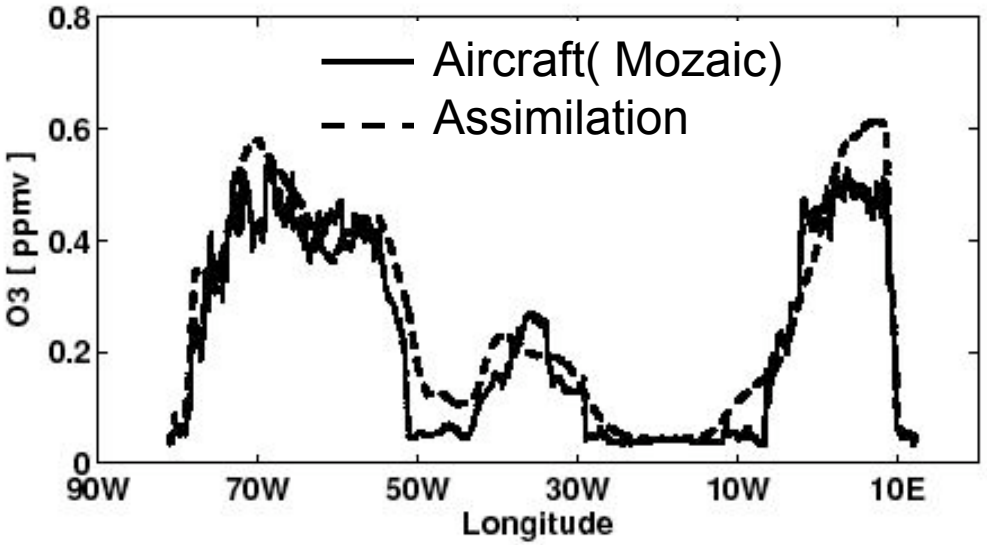
assimilation



Morphology of the fields is very similar, the difference is in values in specific regions and tracer gradients.
The field structure is by and large determined by dynamics

Questions

- **How does assimilation impact the structure of the ozone field, e.g. Does it introduce or erase features?** (see Birner, T., D. Sankey, T. G. Shepherd, *The tropopause inversion layer in models and analyses*, Geophys. Res. Lett., 33, L14804)
- **What spatial scales are properly represented by assimilation? At what scales can assimilation reproduce variability of the ozone field?** (stemming from S. E. Strahan and J. D. Mahlman, *Evaluation of the SKYHI general circulation model using aircraft N2O measurements: 2. Tracer variability and diabatic meridional circulation*, JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 99, NO. D5,)

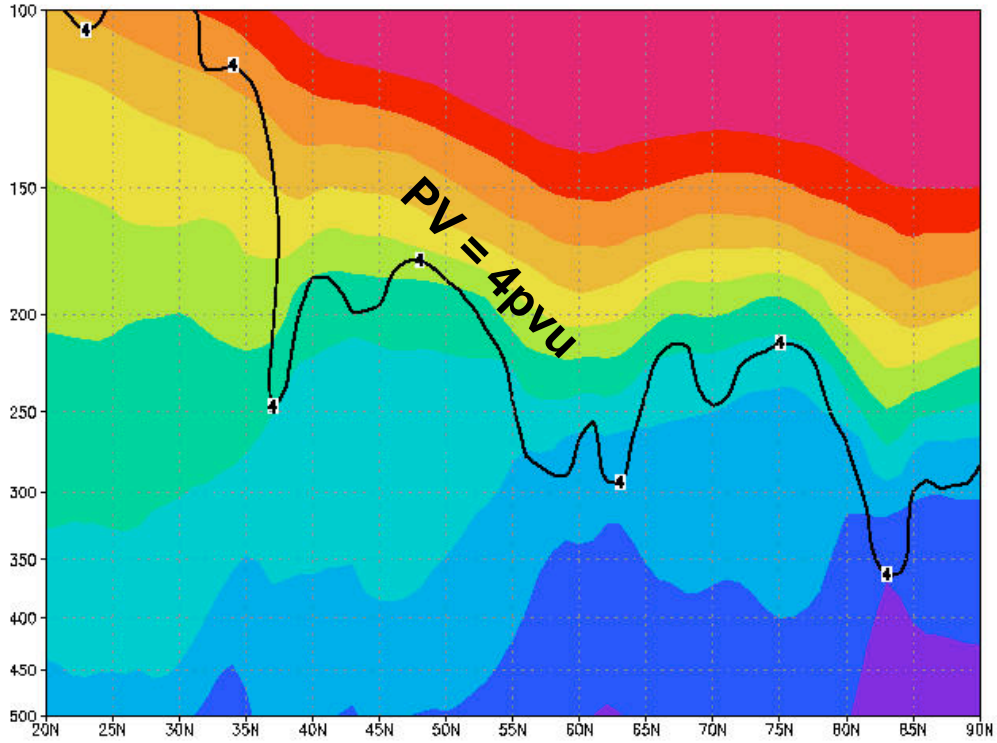


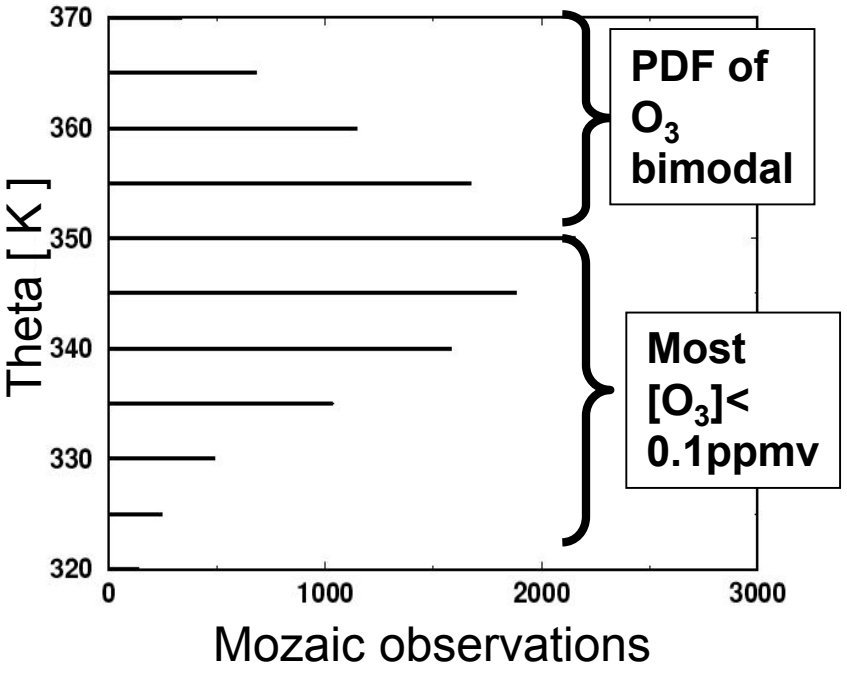
Mozaic

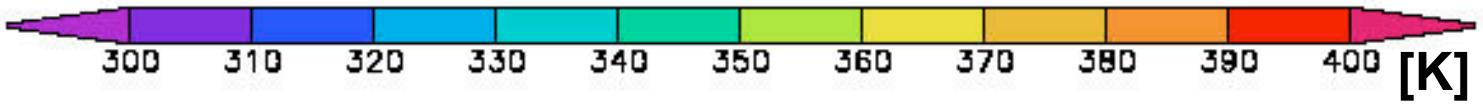
- High frequency (~10 sec) measurements of **ozone**, CO, temperature by instruments onboard commercial aircraft. Thouret, V., A. Marenco, J. A. Logan, P. Nédélec, and C. Grouhel (1998a), Comparisons of ozone measurements from the MOZAIC airborne program and the ozone sounding network at eight locations, *J. Geophys. Res.*, 103(D19), 25,695–25,720.
- Averaging within model grid boxes is applied in order to degrade aircraft data resolution to that of the model. The number of aircraft data within a grid box is of the order of 100
- Comparisons are done between the averaged Mozaic and analysis (model) interpolated in space and time.

Upper Troposphere – Lower Stratosphere (UTLS)

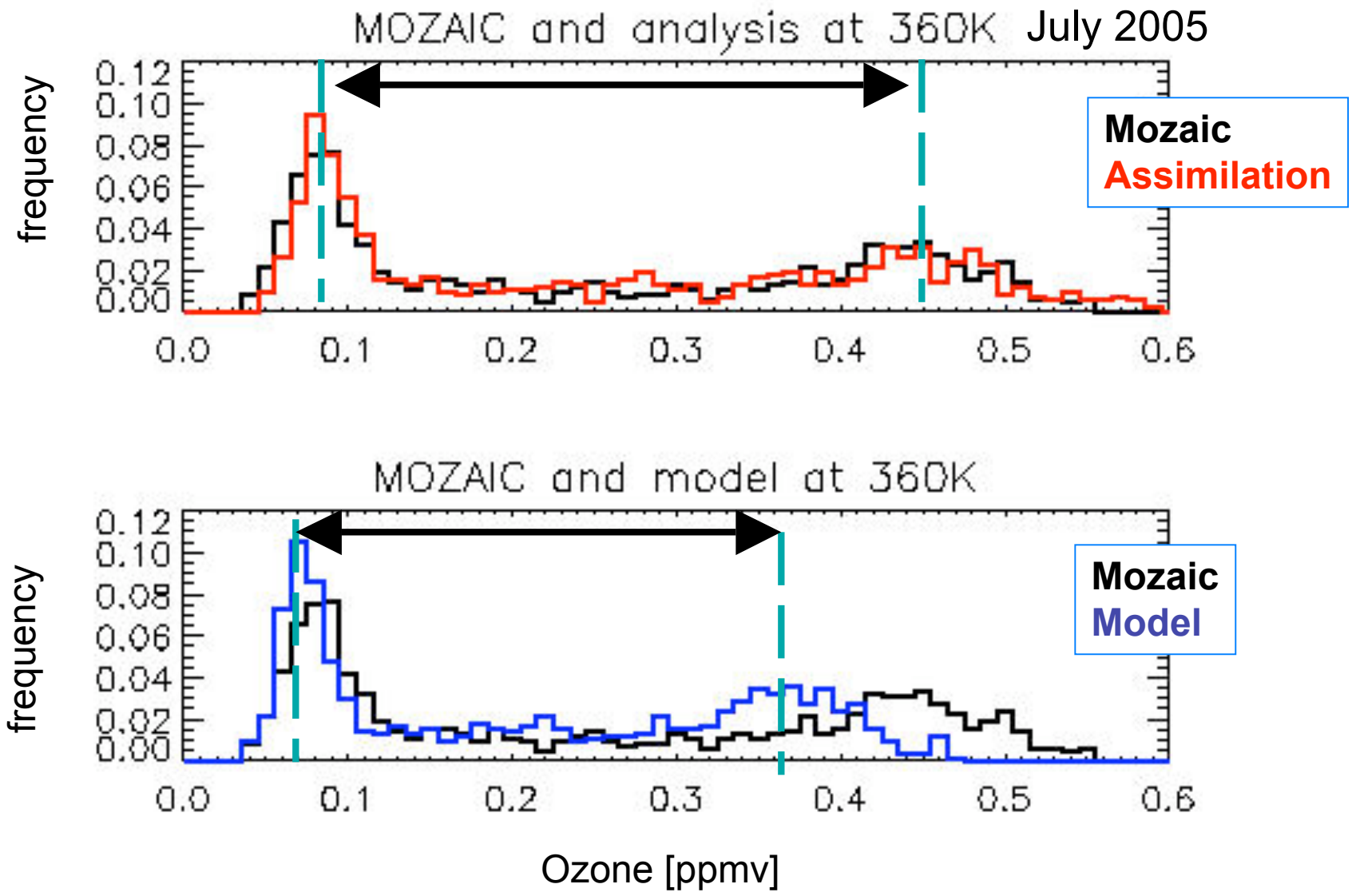
July 1st 90W - 0° mean PV and Theta





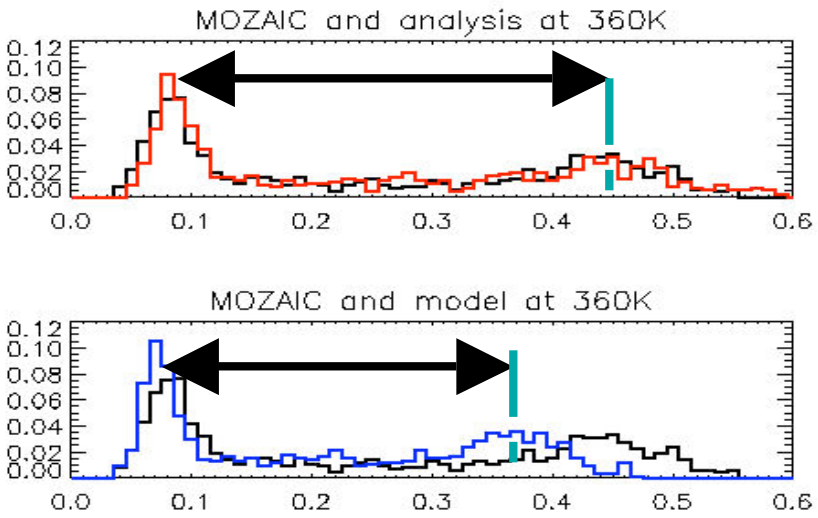


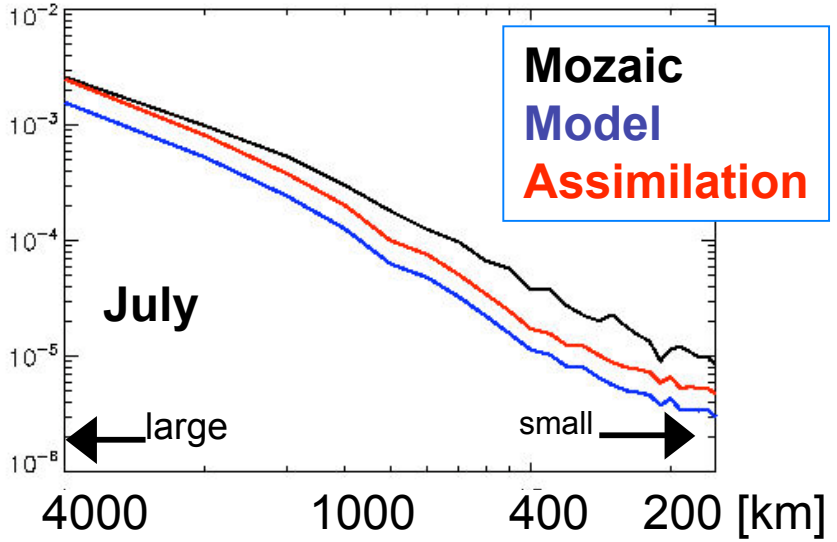
Distribution of ozone in the UTLS



Variability in terms of power spectra

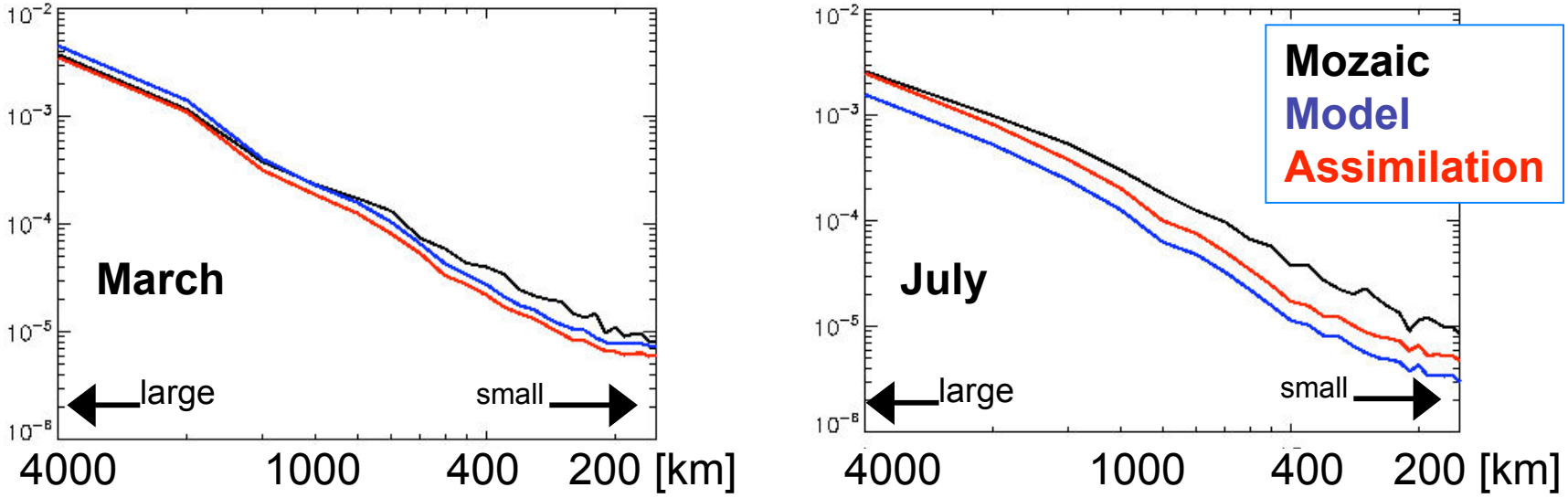
Power spectra of ozone mixing ratio are calculated from 4000 km long flight segments and interpolated model/analysis





- Variability is underestimated in model and analysis
- Higher amplitudes in assimilation are likely a reflection of bias correction in the stratosphere

Variability in terms of power spectra



- In March the opposite is true: stratospheric ozone in assimilation is lower than in model yielding smaller amplitudes
- In all months, analysis and model spectra appear to have the same slope

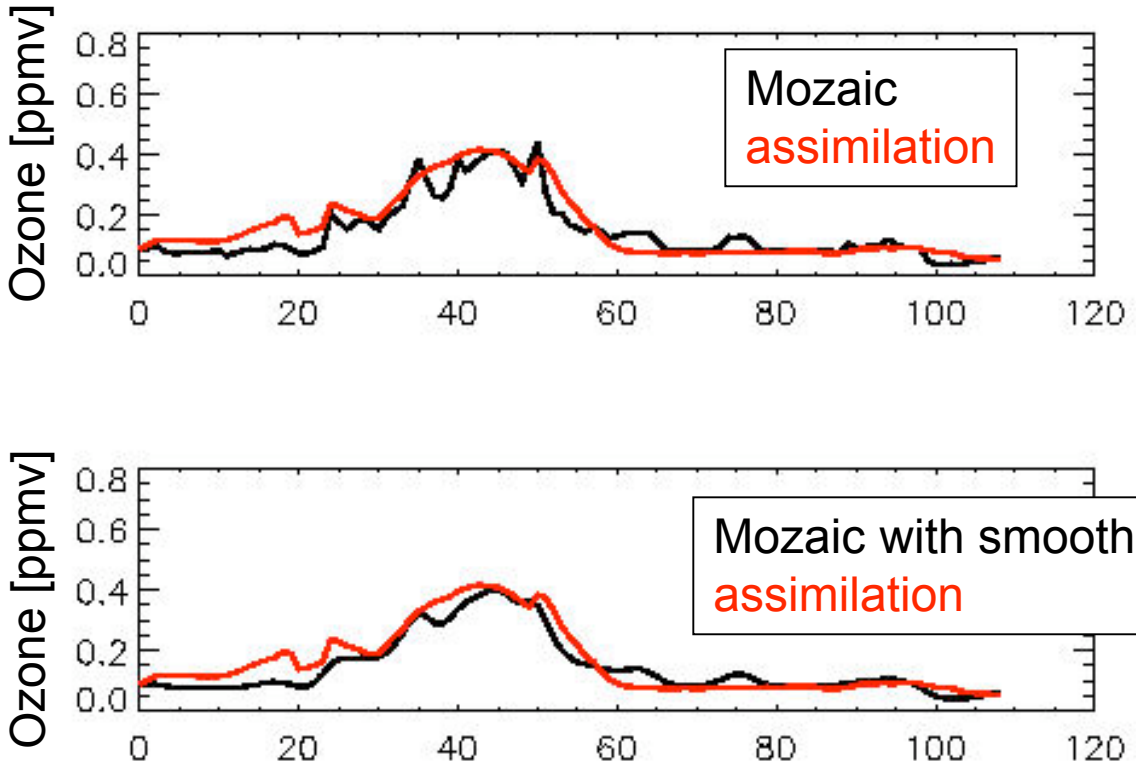
How does assimilation impact the structure of the ozone field?

- Field structure is determined by model dynamics rather than by constituent assimilation
- No evidence of features introduced or removed by assimilation
- Assimilation affects tracer variability by modifying high and low modes in distribution of the tracer

(consistent with, e.g. Wargan et al., *Assimilation of ozone data from the Michelson Interferometer for Passive Atmospheric Sounding*, Quarterly Journal of the Royal Meteorological Society, vol. 131, Issue 611, 2005)

Now take a look at small scale variability of ozone
and how it is represented in assimilation

Small scale variability

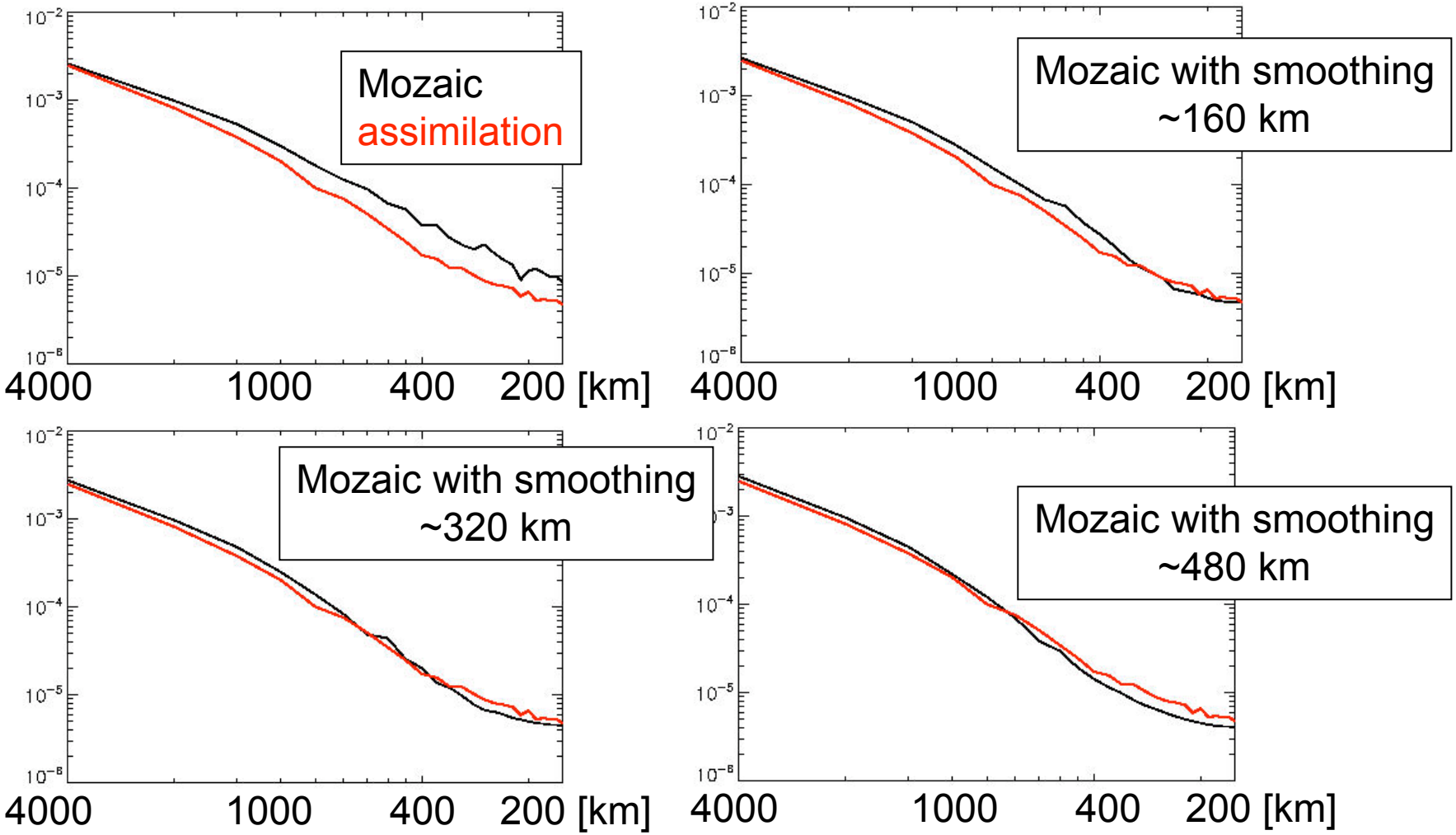


Aircraft data exhibit larger variability at small scales, even after averaging

A compactly supported Gaussian-like smoother decreases variability of aircraft data. Here 480 km smoothing is applied

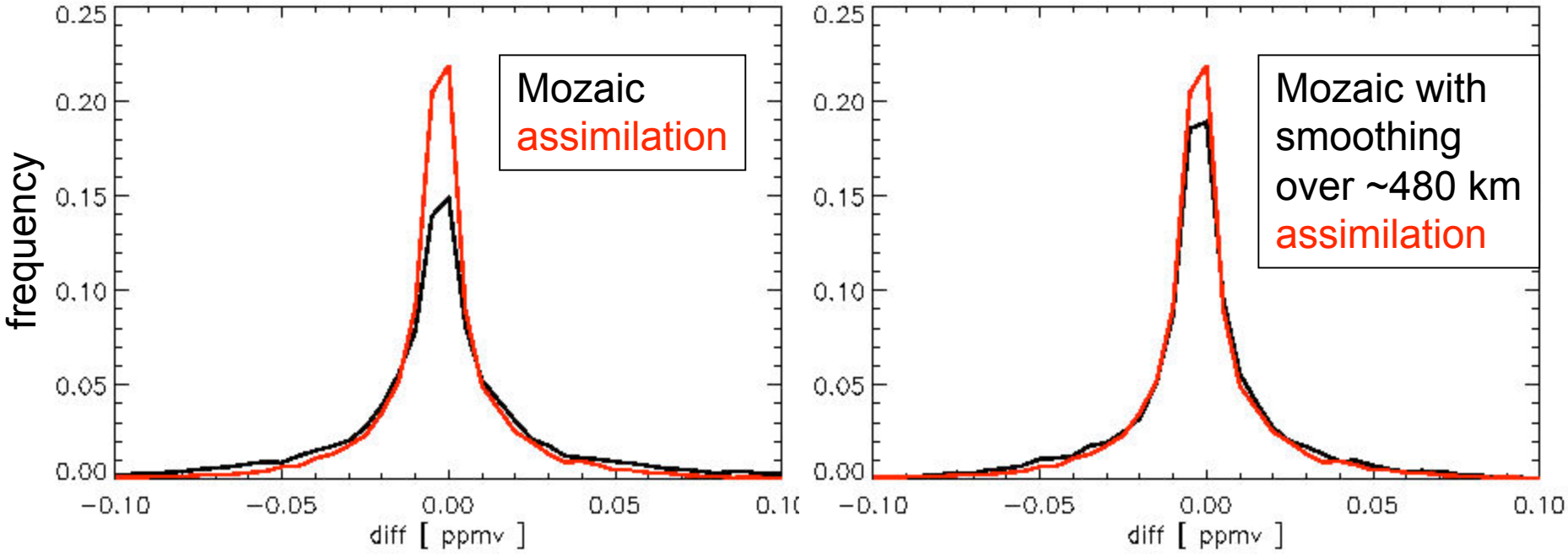
Question: What scales are properly represented by assimilation?
Or
How much smoothing will bring the aircraft data close to analysis?

Small scale variability – power spectra



Small scale variability – tracer differences

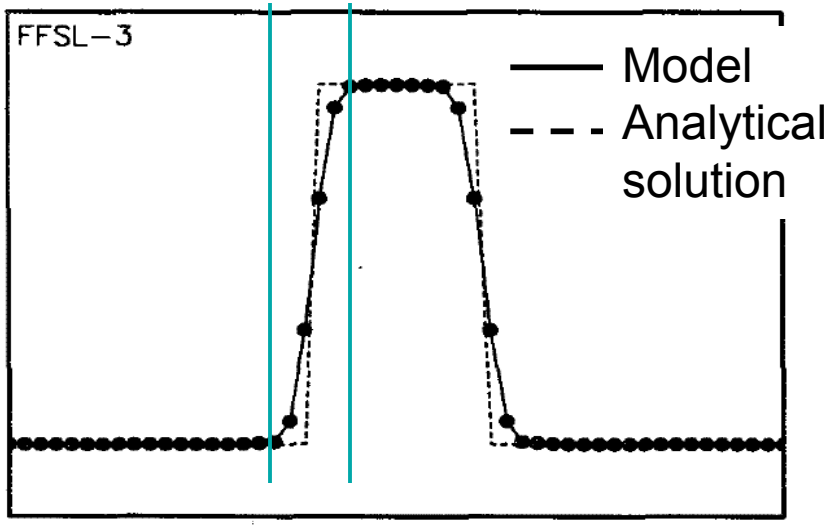
Distribution of ozone mixing ratio differentials. Differences are taken along flight tracks over separation of ~80 km.



- The probability distribution functions are fat-tailed
- The Mozaic data yields higher standard deviation than assimilated data
- When a smoother is applied to Mozaic data standard deviation decreases
- More smoothing will decrease it further but it will worsen Mozaic-analysis agreement as shown in power spectra plots

What spatial scales are properly represented by assimilation?

- Variability of assimilated ozone at small spatial scales is underrepresented as compared with aircraft data
- Degrading data resolution through smoothing brings its variability closer to that of assimilation as seen in power spectra and ozone difference PDFs
- The length scale that gives the best agreement is ~480 km (6 model grid cells)



It may take 6 grid-cells to resolve a jump.

The transport of a rectangular wave in a 50-cell domain.
S.J. Lin, R.B. Rood, *Multidimensional Flux-Form Semi-Lagrangian Transport Schemes,* Month. Weather Review 124, 1996

Why does analysis (and model) show less small scale variability than aircraft data?
Possible answers

- Accuracy of transport using assimilated winds (e.g. need to use time averaging in GEOS-4 to avoid noise contained in instantaneous winds)
- Inadequate gravity wave spectrum in analyzed winds
- Aircraft data have too much small scale variability for some reason
- ...?

Summary

- Assimilation affects tracer variability by modifying high and low modes in distribution of the tracer
- Field structure is determined by model dynamics rather than by constituent assimilation. No evidence of features introduced or removed by assimilation
- Variability of assimilated ozone at small spatial scales is underrepresented as compared with aircraft data.
- Degrading data resolution through smoothing brings its variability closer to that of assimilation as seen in power spectra and ozone difference PDFs.The length scale that gives the best agreement is ~480 km (6 model grid cells)

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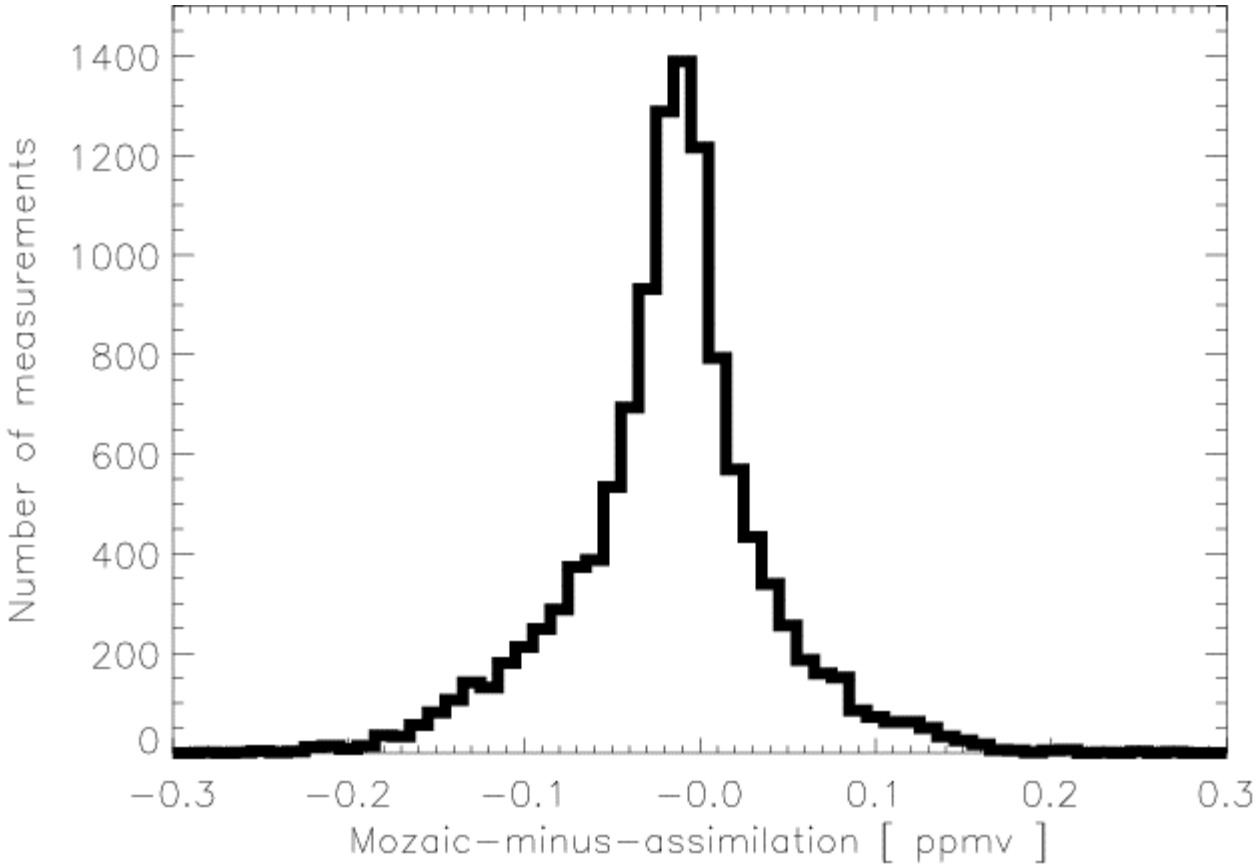
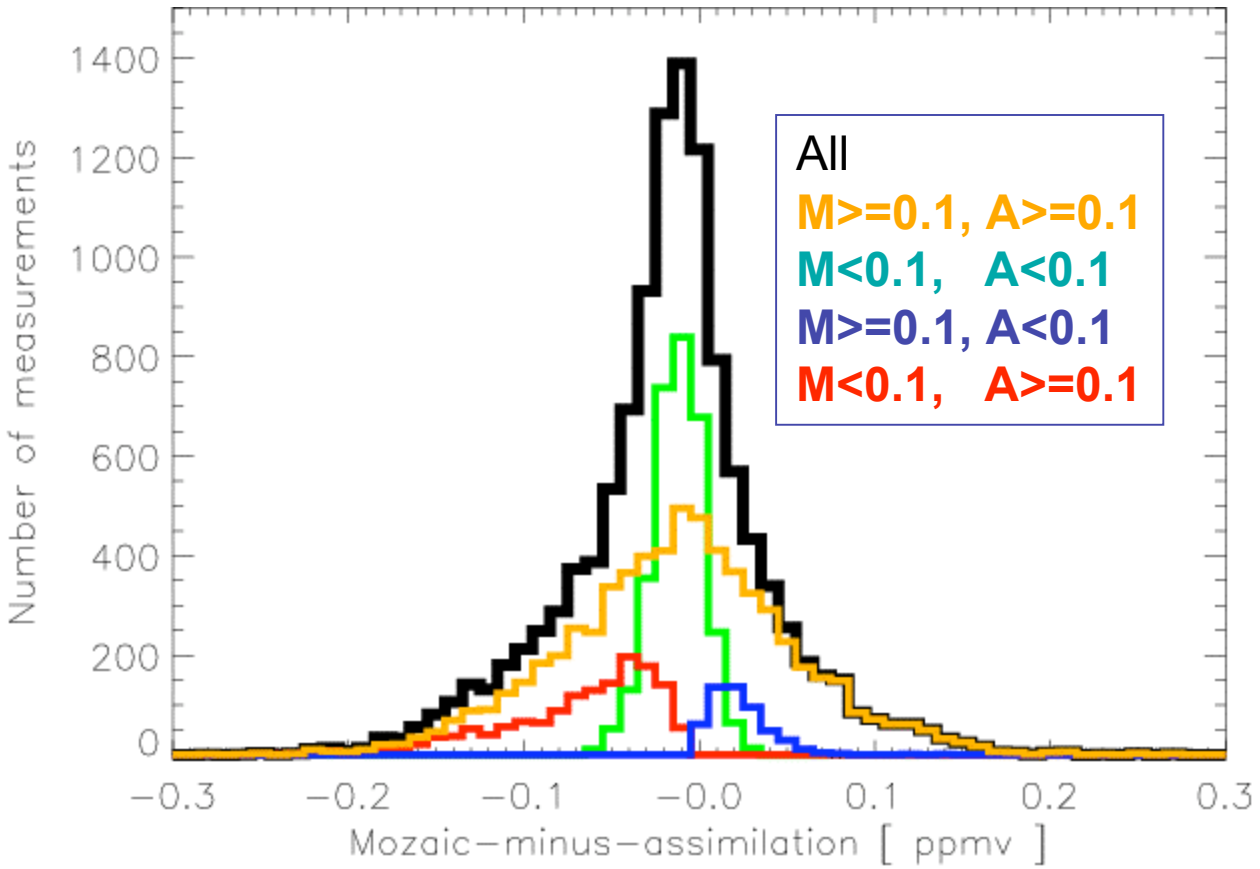
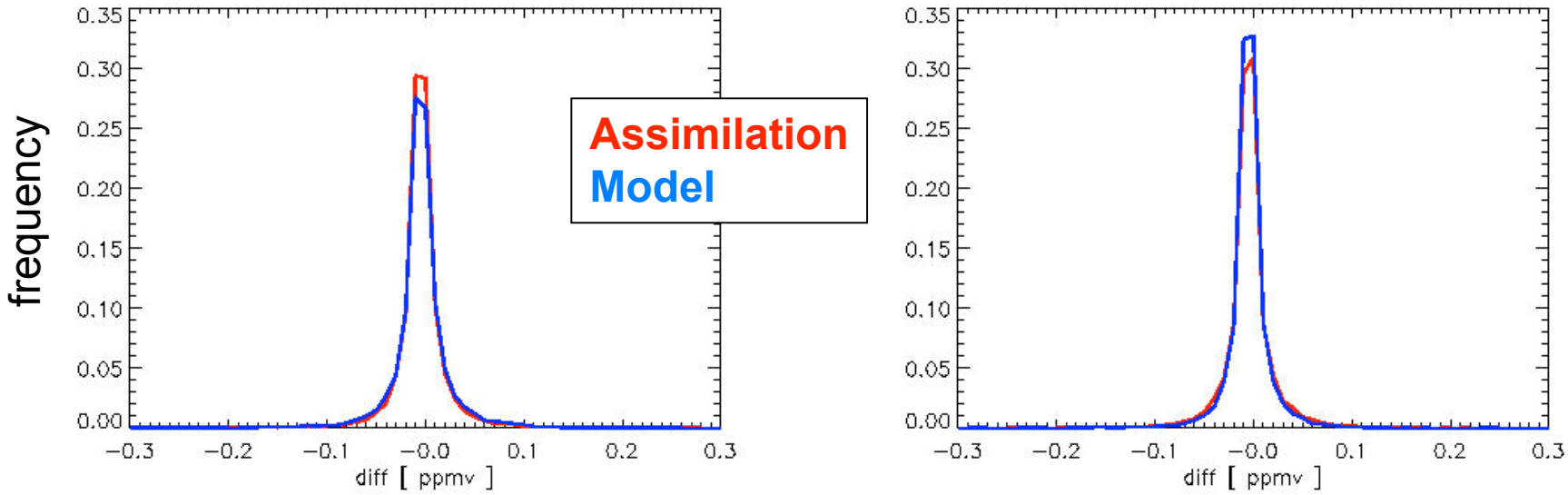
Mozaic minus analysis



Mozaic minus analysis



Variability in terms of two-point differentials



Topic

- How well is the variability of ozone represented in
  - Assimilation
  - Model
- This study focuses on the Upper Troposphere/Lower Stratosphere (UTLS) layer where there exist ample aircraft data that can be used for comparison