Recent Advances in Ozone Data Assimilation at the GMAO - Towards a New Reanalysis

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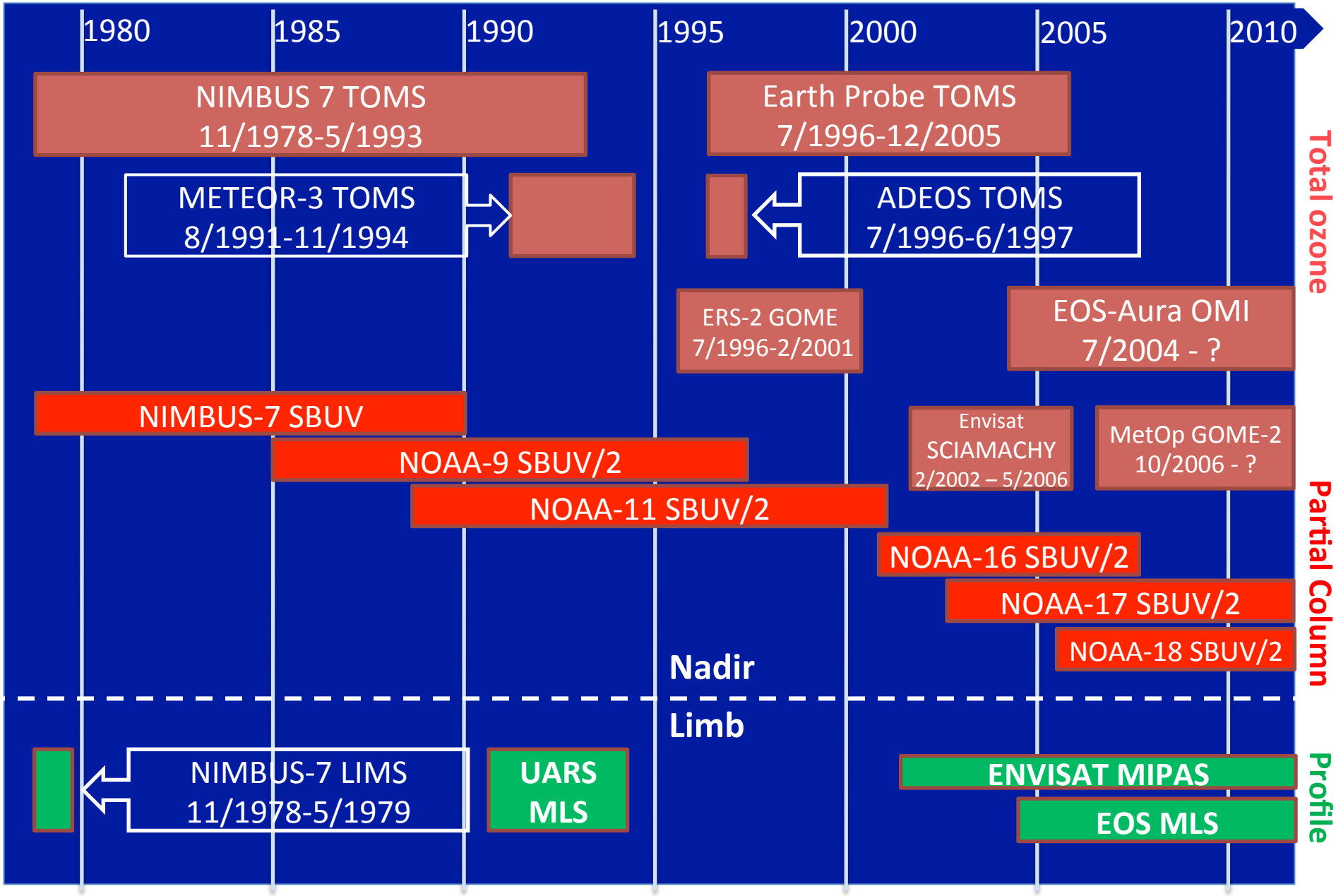
Plan of talk

The GEOS-5 Data Assimilation System

- Improving assimilated ozone between 500 and 50 hPa:
  - importance of SBUV data for reanalysis
  - sensitivity to background errors
- Assimilation of radiances from the **M**icrowave **L**imb **S**ounder on EOS-Aura:
  - progress to date
  - remaining work

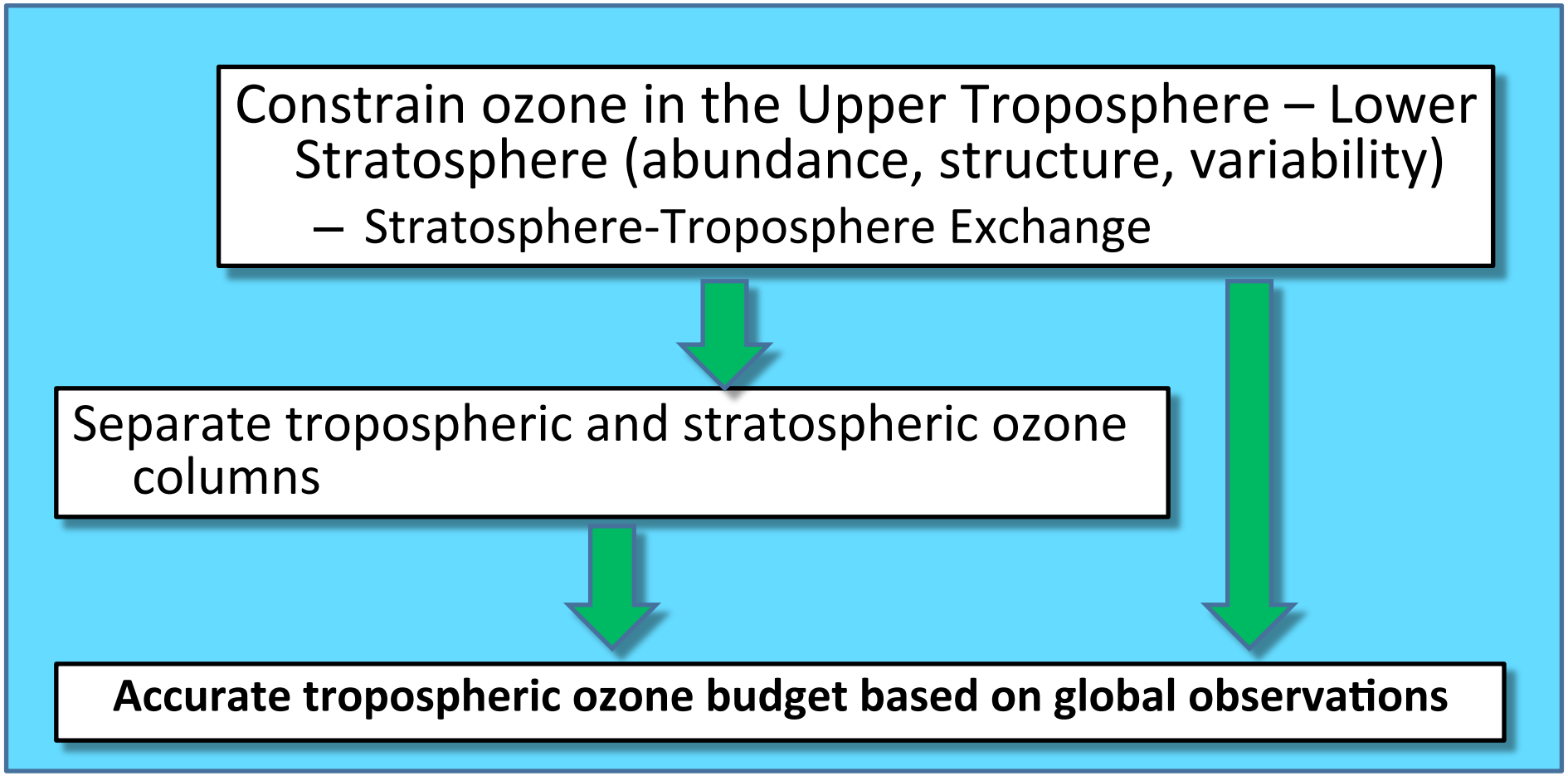
Ozone data for reanalysis: Continuity of SBUV ozone record



GEOS-5 Data Assimilation System

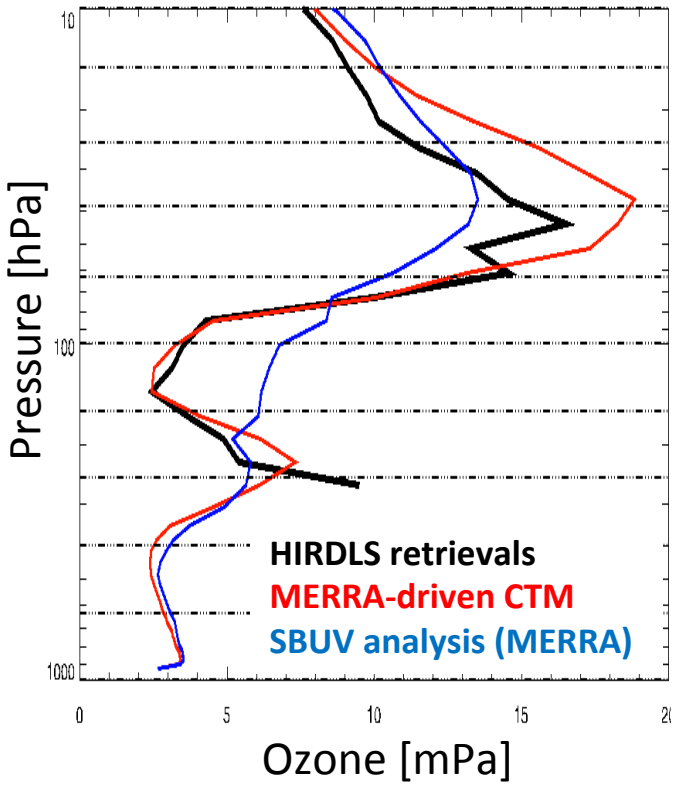
- **Atmospheric General Circulation Model:**
  - **Horizontal resolution: flexible - 2.5° to ¼°**
  - **72 layers from the surface to 0.01 hPa**
  - **Parameterized ozone chemistry (stratospheric P&L; dry deposition)**
- **3D-Var analysis:**
  - **Gridpoint Statistical Interpolation**
  - **developed in collaboration with NCEP**
- **Observations:**
  - **Conventional (surface, sondes, radar, aircraft, MODIS-derived winds,…)**
  - **Satellite radiance data (TOVS/ATOVS, AIRS, IASI, SSM/I, GOES, GPS-RO)**
  - **Ozone data (SBUV2, OMI, MLS retrievals)**
    - **"Efficiency factors" (averaging kernels for EOS OMI)**
    - **V8.6 SBUV partial columns**
  - **MLS radiances are being added**

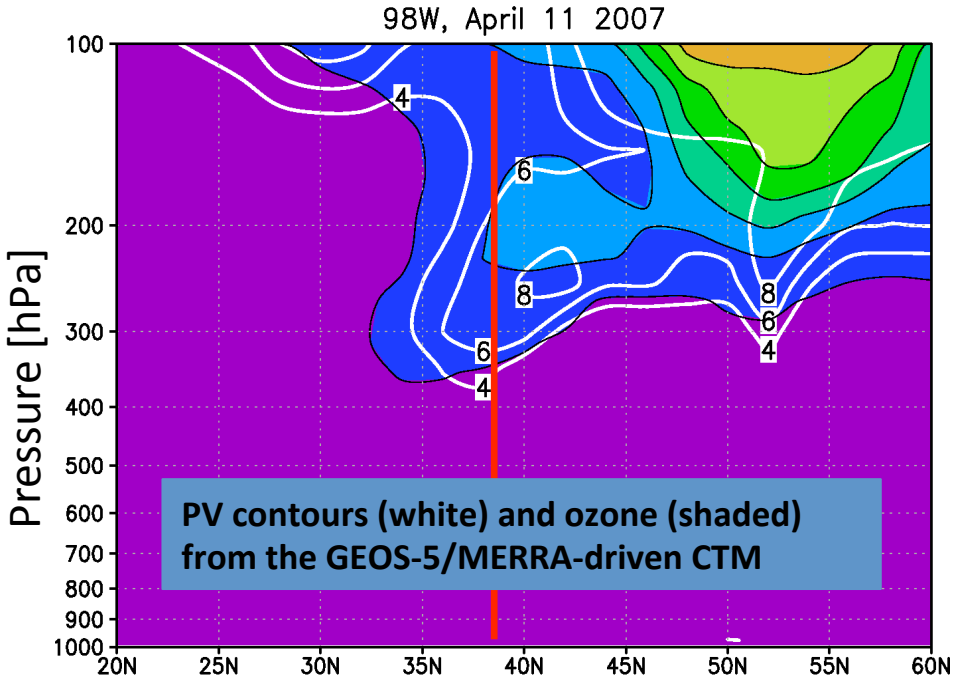
Ozone Assimilation in GEOS-5: Science Objectives

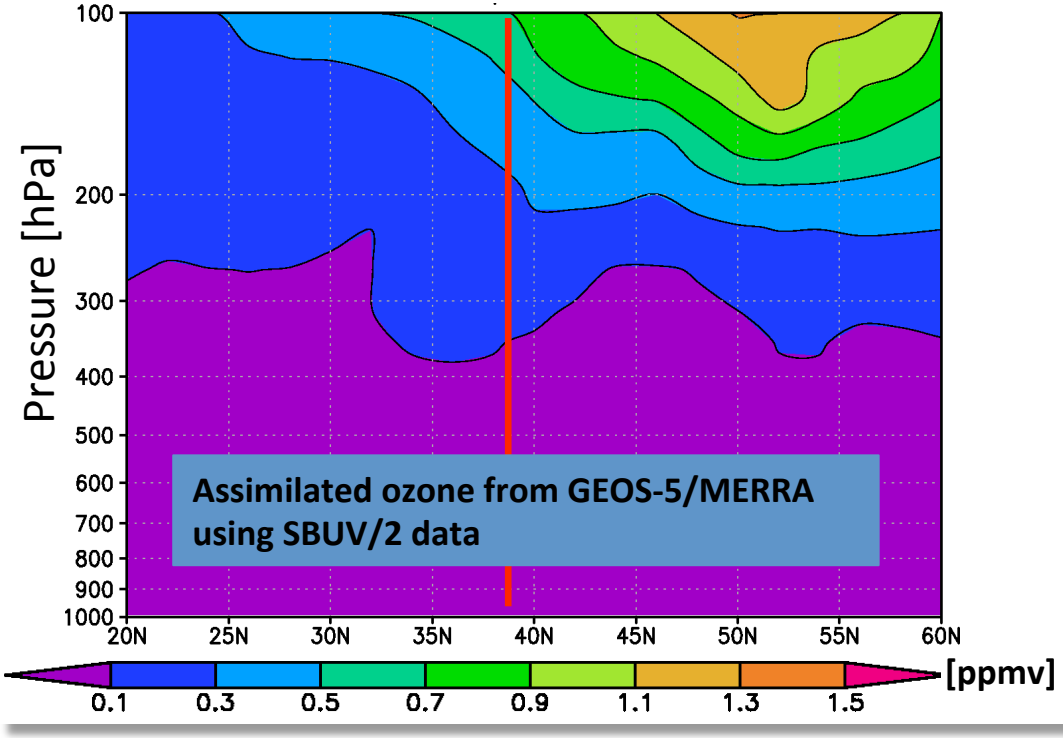


Transport using assimilated winds leads to realistic ozone profile structure in the UTLS

Assimilation of SBUV in GEOS-5/ MERRA does not show this vertical structure: smoothing from the assimilation process







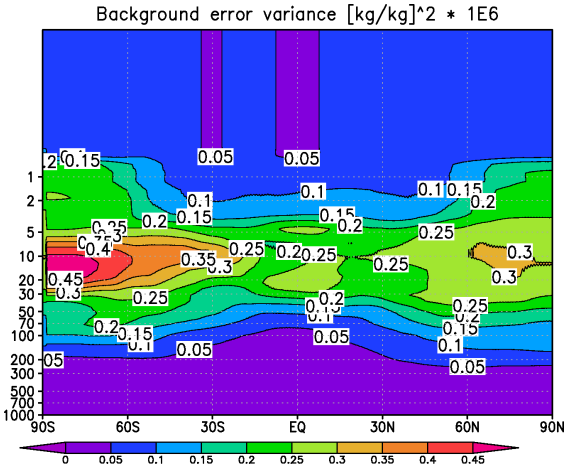
So...

How can we take advantage of data without damaging transport-induced small-scale structures?

Background errors

GEOS-5/MERRA

- NMC Method
- 2-D lookup table of variances and correlation length scales
- High ozone gradients in the UTLS are not resolved
- **Statistics-based; real-time dynamics not accounted for**



Alternate approach

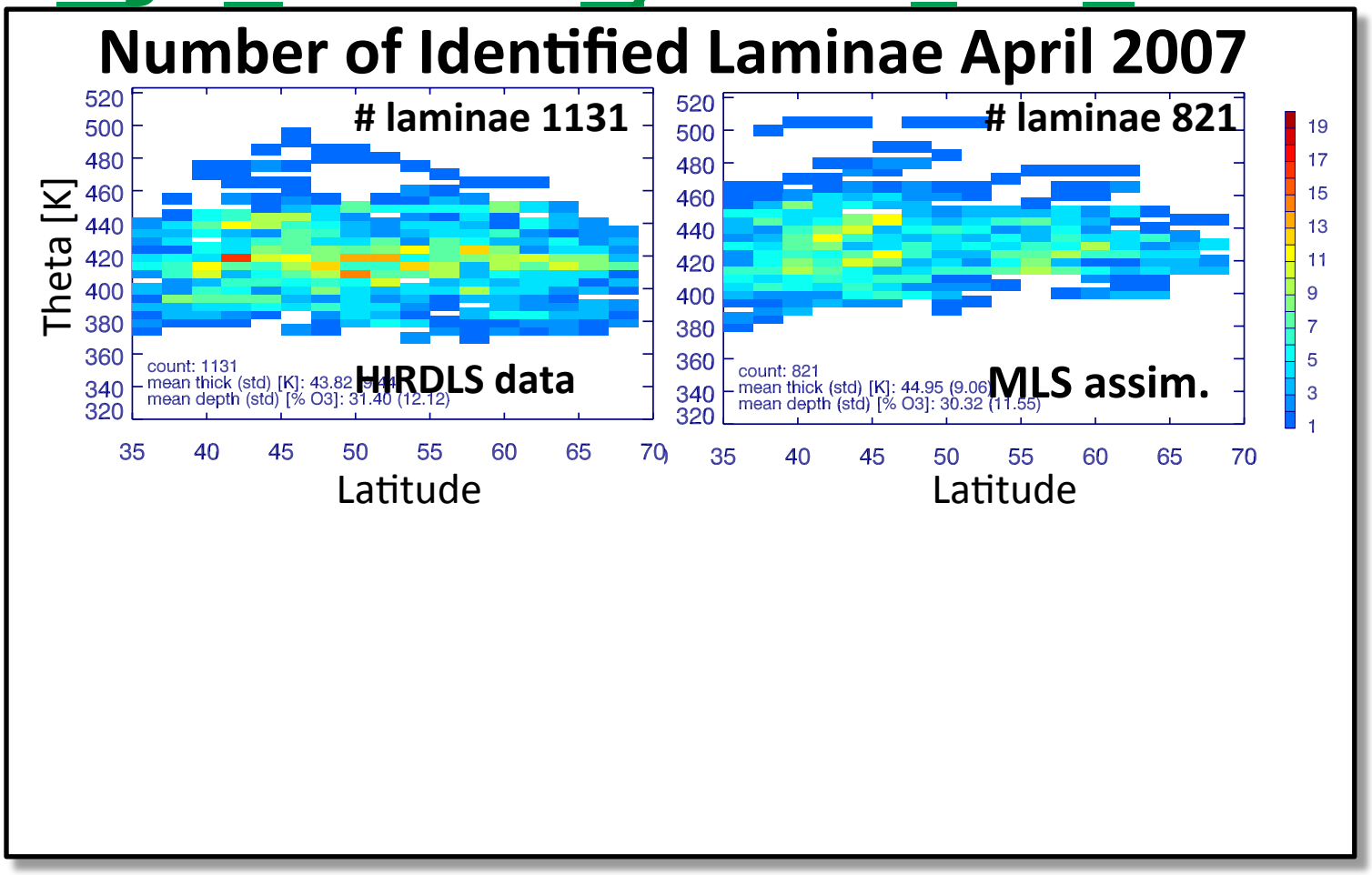
- Proportional method
- A possible candidate for σ^2:

$$\sigma^2 = \alpha \times [O_3]_{[mol/mol]}$$

$[O_3]$ – background ozone
α – specified parameter

- **Process-based**

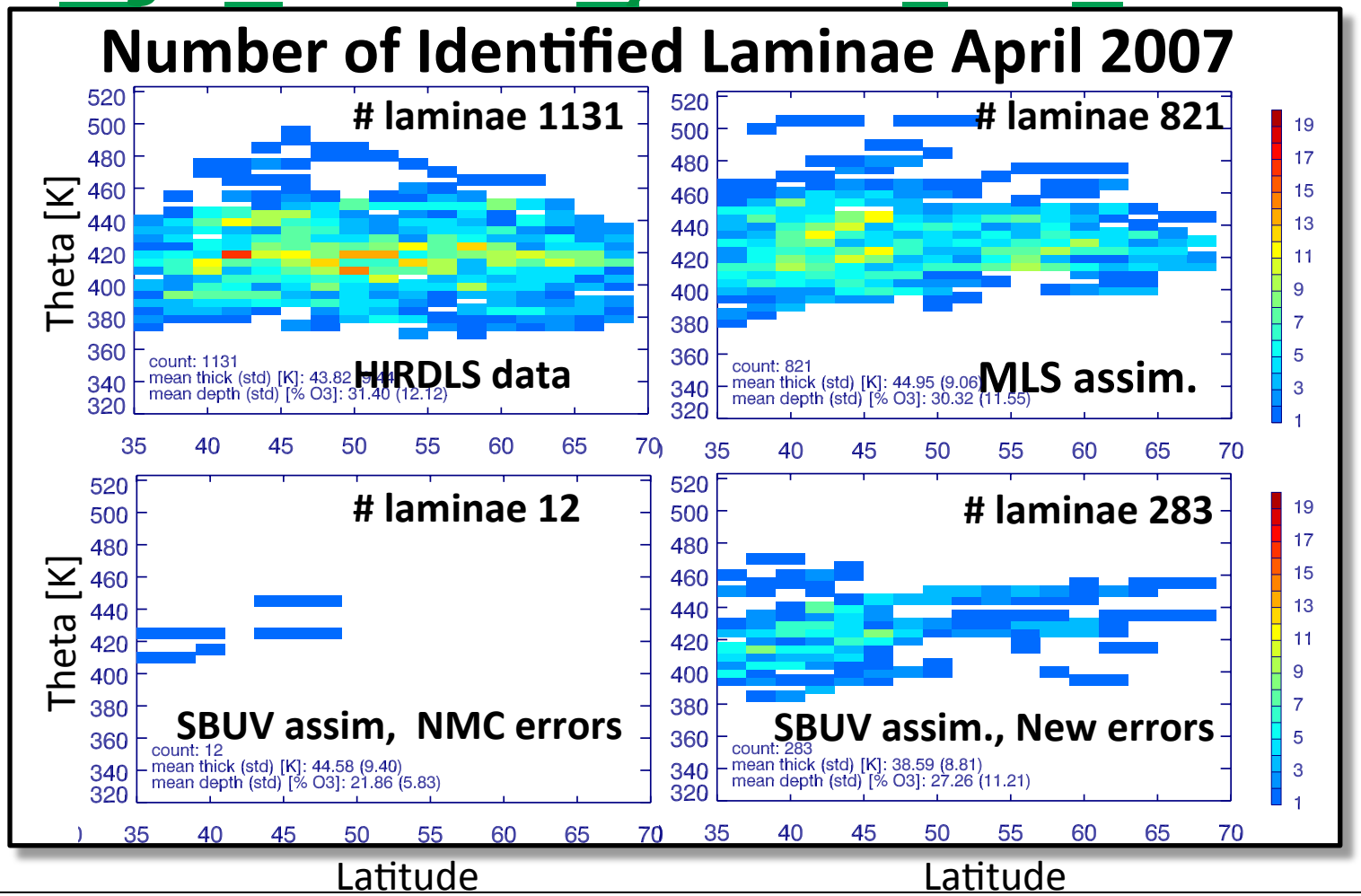
UTLS ozone laminae in GEOS-5 – comparison with High Resolution Dynamics Limb Sounder



- Some of the laminae reported by HIRDLS may be spurious
- GEOS-5 DAS was run at a coarse resolution (2°×2.5°)

The challenge: get with SBUV what we can get with higher resolution limb data

UTLS ozone laminae in GEOS-5 – comparison with High Resolution Dynamics Limb Sounder



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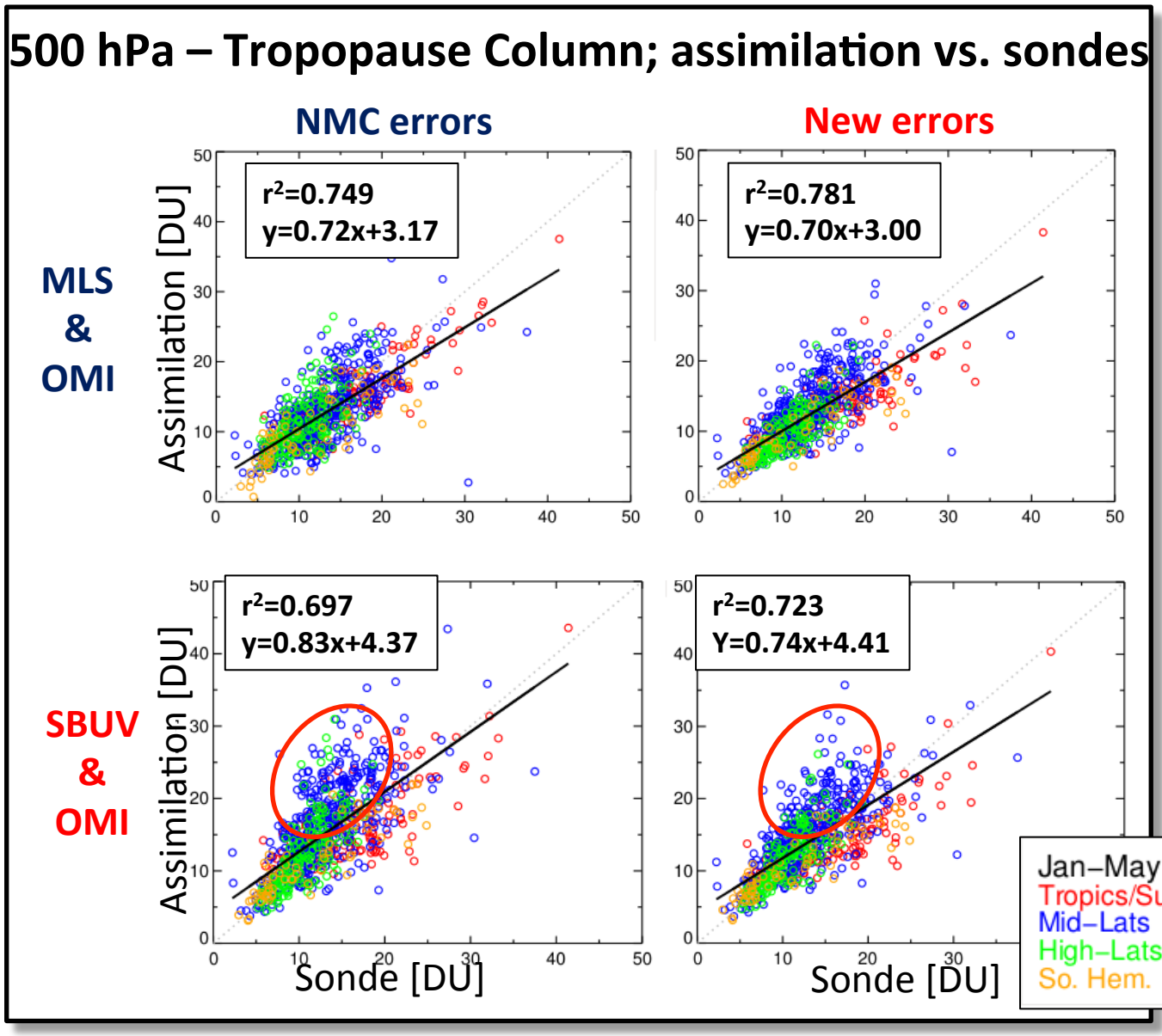
Upper tropospheric (500hPa-tropopause) ozone columns – comparison with ozone sondes



The new background error scheme leads to increased sonde – assimilation correlations (N. mid to high lattitudes)

Summary of Part 1

The new background error covariance model substantially improves the structure of ozone laminae in the UTLS and the agreement of partial ozone columns with sonde observations when assimilating partial-column data from SBUV/2

Assimilation of radiances from the EOS Microwave Limb Sounder

- **Uses the MLS Callable Forward Model developed at JPL**
- **Implementation in GEOS-5 is a close collaboration with the MLS tea**

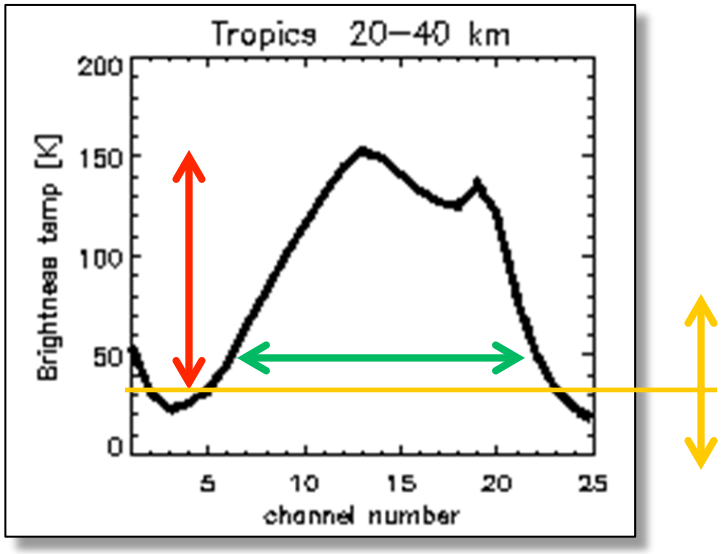
This is work in progress…

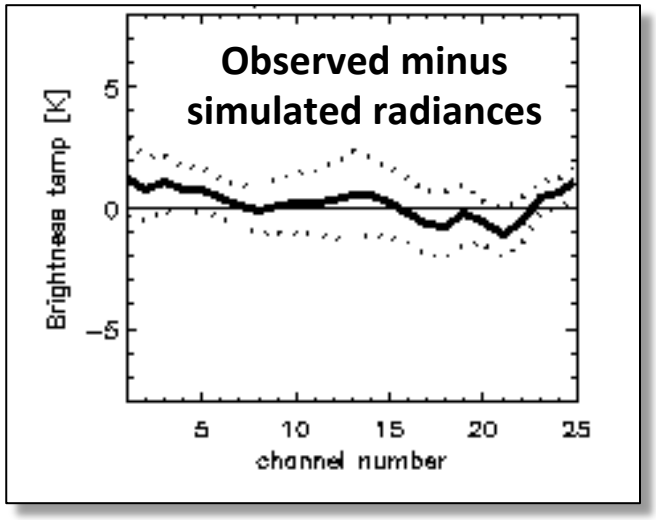
Results presented here are from 8-day (August 1 – 8th 2009) test experiments at 2.5° resolution

Motivation

- **Future reanalysis: data will not depend on a priori from older versions of GEOS**
- **Operational analyses: possibility of assimilating MLS in near real time (if computationally feasible)**
- **Based on earlier results with retrieved MLS data we expect that the radiance assimilation will improve**
  - **Ozone in the UTLS**
  - **Temperature in the upper stratosphere**

Information from MLS radiances





- **Contrast**: ozone concentration
- **Breadth**: tangent pressure
- **Position**: baseline/extinction

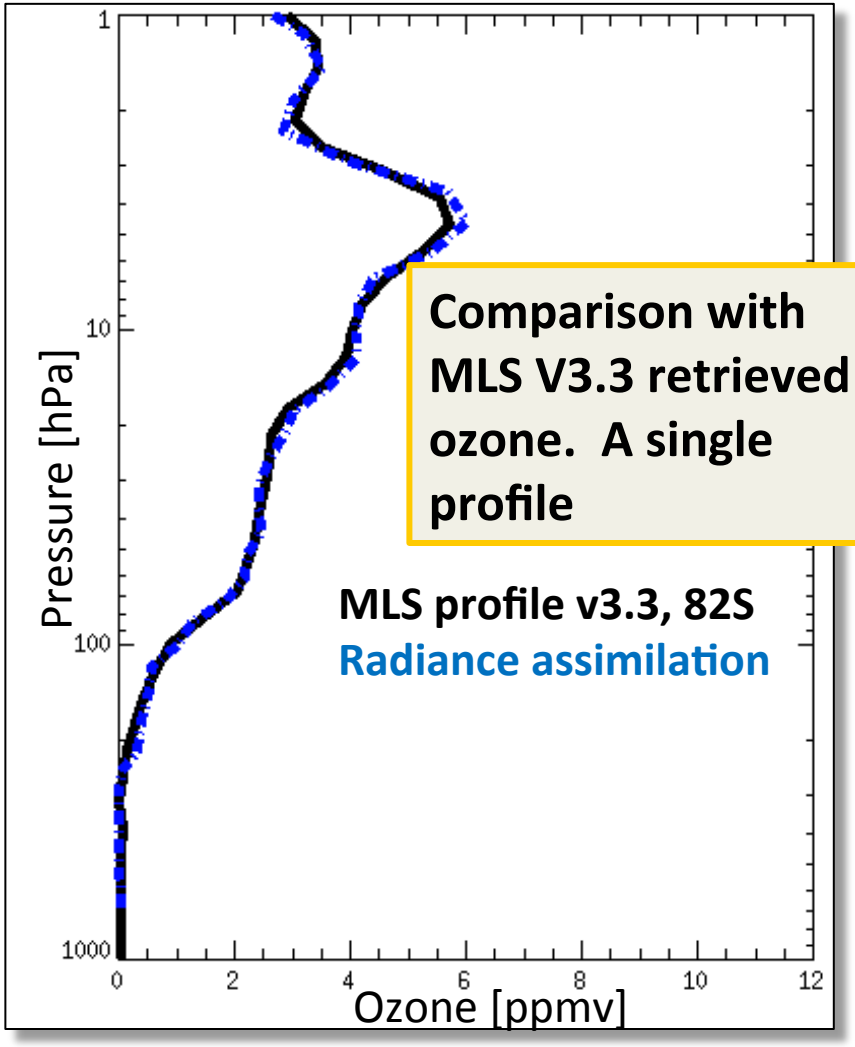
We need all three pieces.

In the current implementation only ozone is assimilated.

We use previously retrieved tangent pressure data.

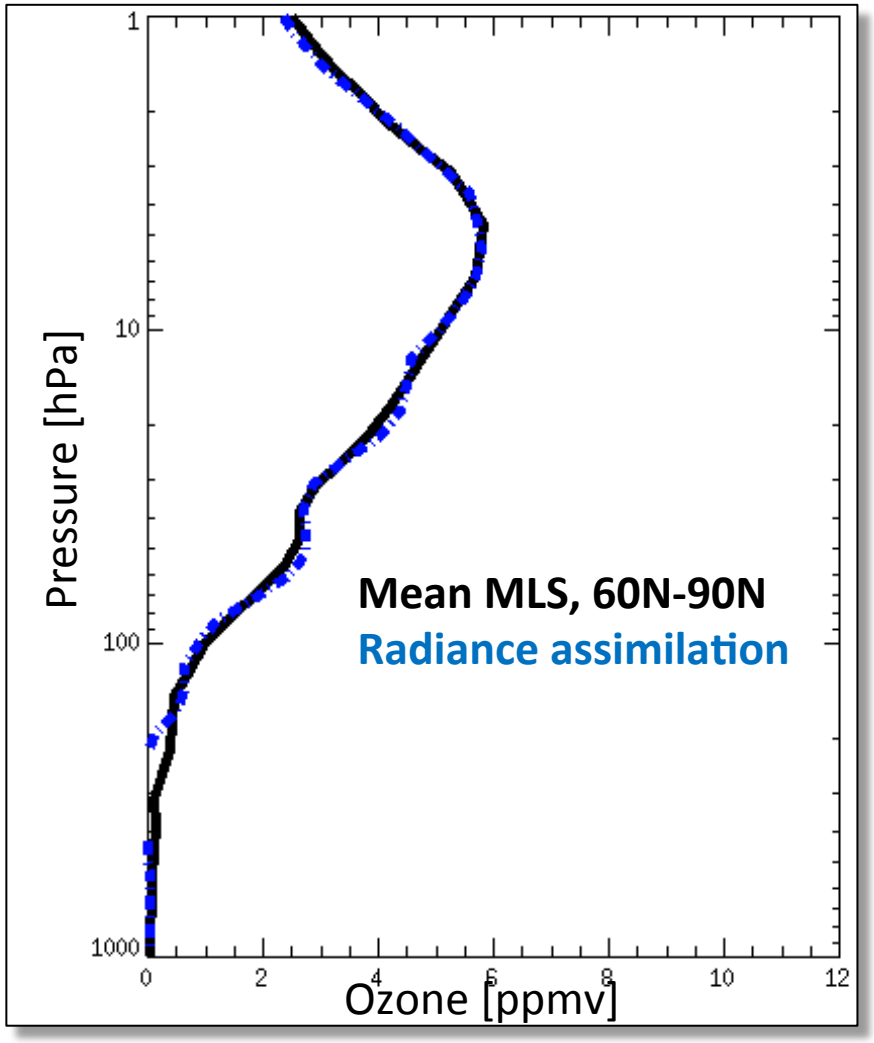
Implementation of online baseline retrieval is underway

Some results



Comparison with MLS V3.3 retrieved ozone. A single profile

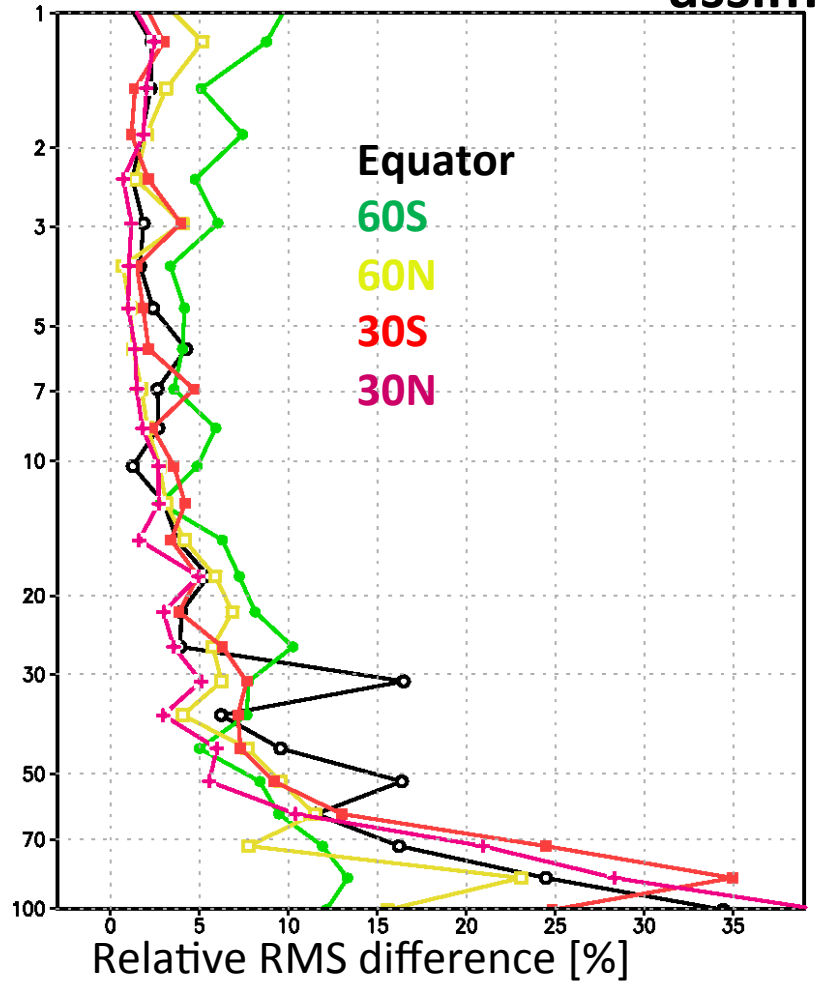
MLS profile v3.3, 82S
Radiance assimilation

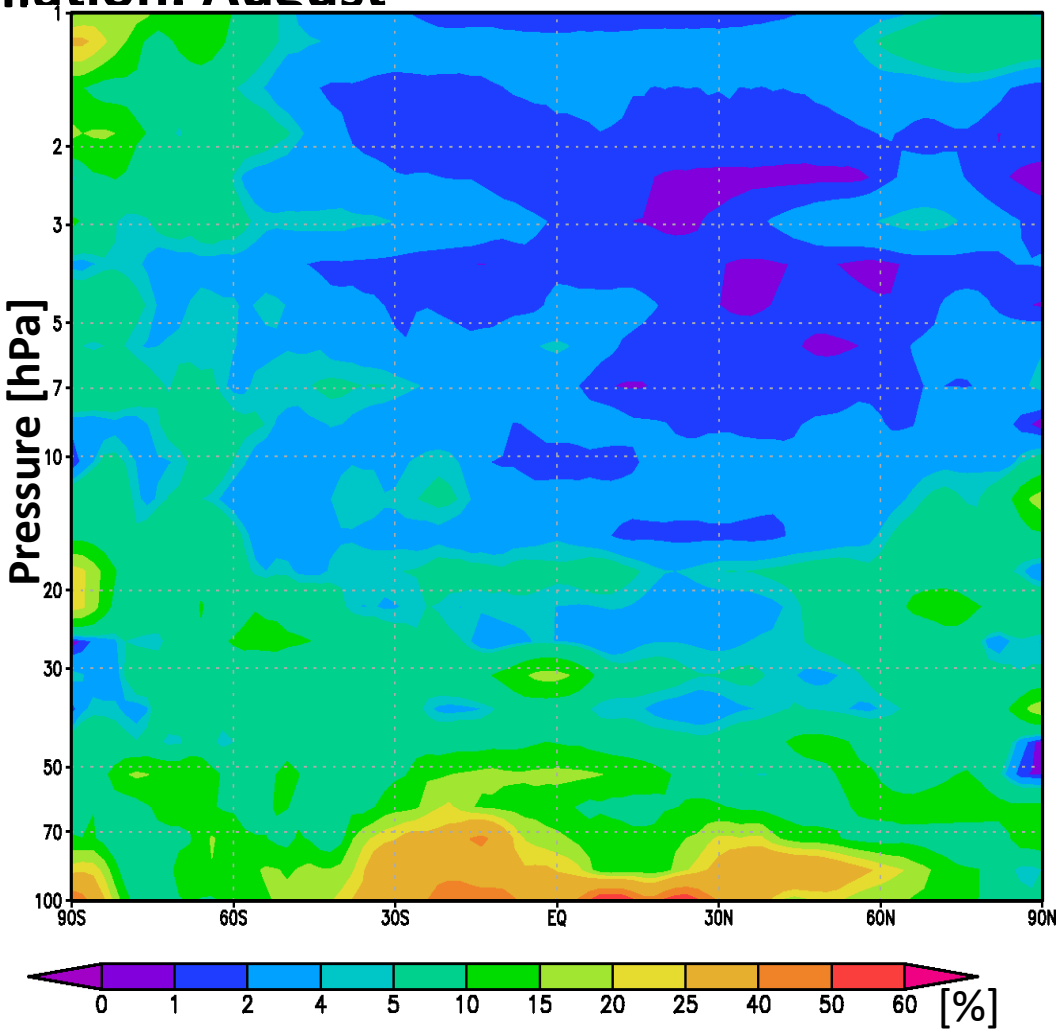


Mean MLS, 60N-90N
Radiance assimilation

Reasonable agreement in mid- and upper stratosphere – sanity check passed

Relative RMS difference: Assimilation of MLS v3.3 minus radiance assimilation. August





Agreement within 5% in mid to upper stratosphere except southern high latitudes.

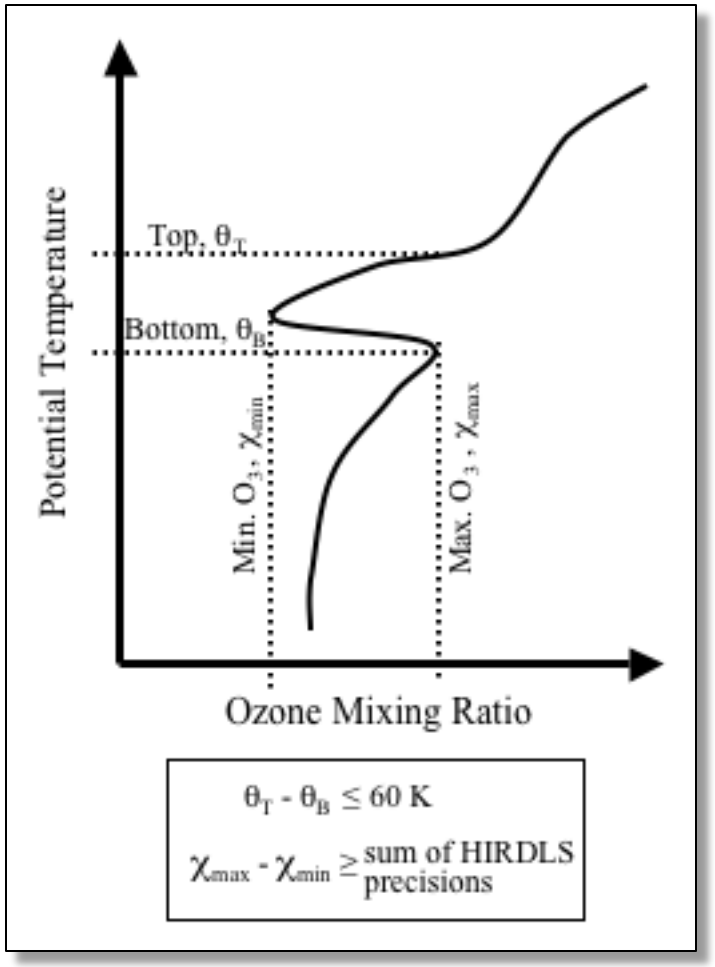
The lower stratosphere is expected to improve once online retrieval of "extinction" is implemented

Summary

- **Background error covariances matter! A new scheme improves the representation of the assimilated UTLS ozone in GEOS-5**
- **The MLS Callable Forward Model has been incorporated in GEOS-5 for band 7 (ozone)**
  - **Preliminary tests show agreement with MLS V3.3 within 5-10% in the middle and upper stratosphere**
- **Work in progress**

backup

Lamina Identification With EOS HIRDLS O_3 Data

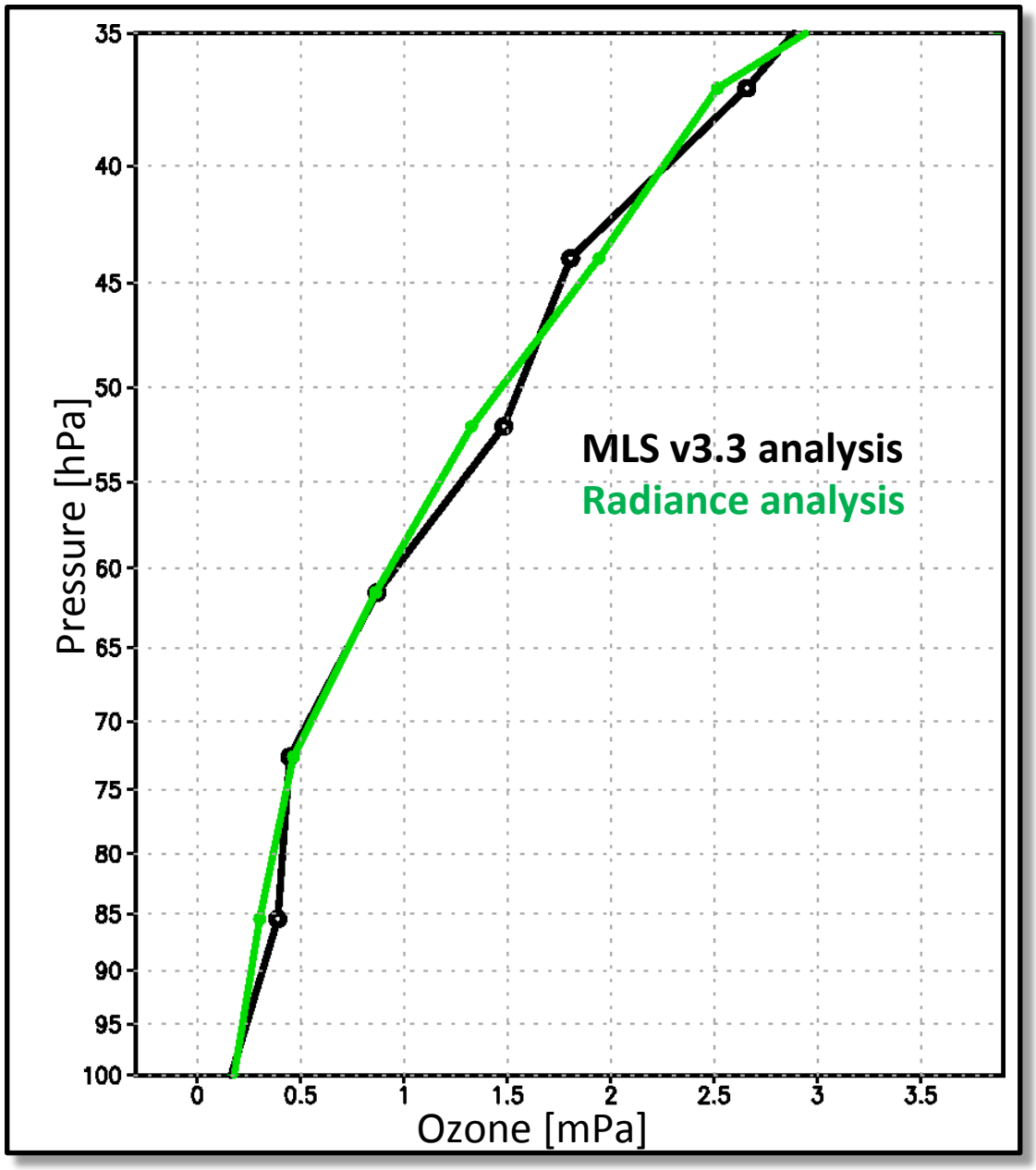


High Resolution Dynamics Limb Sounder

- Infrared sounder
- ~1 km vertical resolution
- capable of resolving laminae

- Interpolate to theta (only above 260 hPa)
- Average profiles in 2° latitude bands
- Determine lamina bottom and top
- Apply thickness and magnitude criteria
- Lamina must be coherent across 3 mean profiles

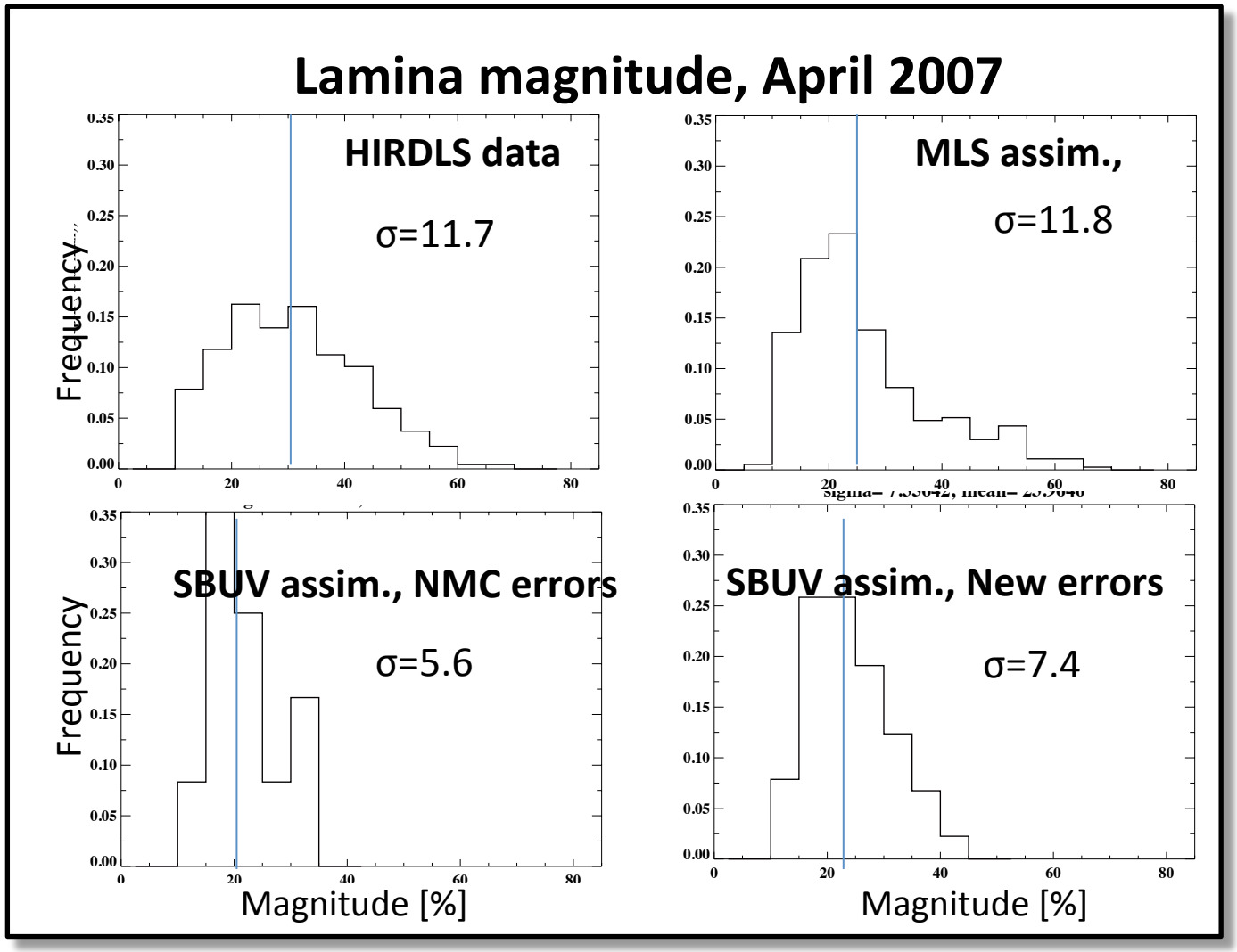
Lower stratospheric zonal mean profile at the equator



The MLS v3.3 analysis (assimilation of retrieved MLS ozone) exhibits oscillations in the tropical lower stratosphere – even in the zonal mean.

These are not seen in radiance assimilation

Representation of the UTLS ozone – comparison with High Resolution Dynamics Limb Sounder



PDFs of (Max ozone - Min)/Max [%] for each identified lamina

Better representation of the magnitude low ozone laminae with the new background errors.