

Limb ozone data assimilation in GEOS-5: MLS and OMPS-LP

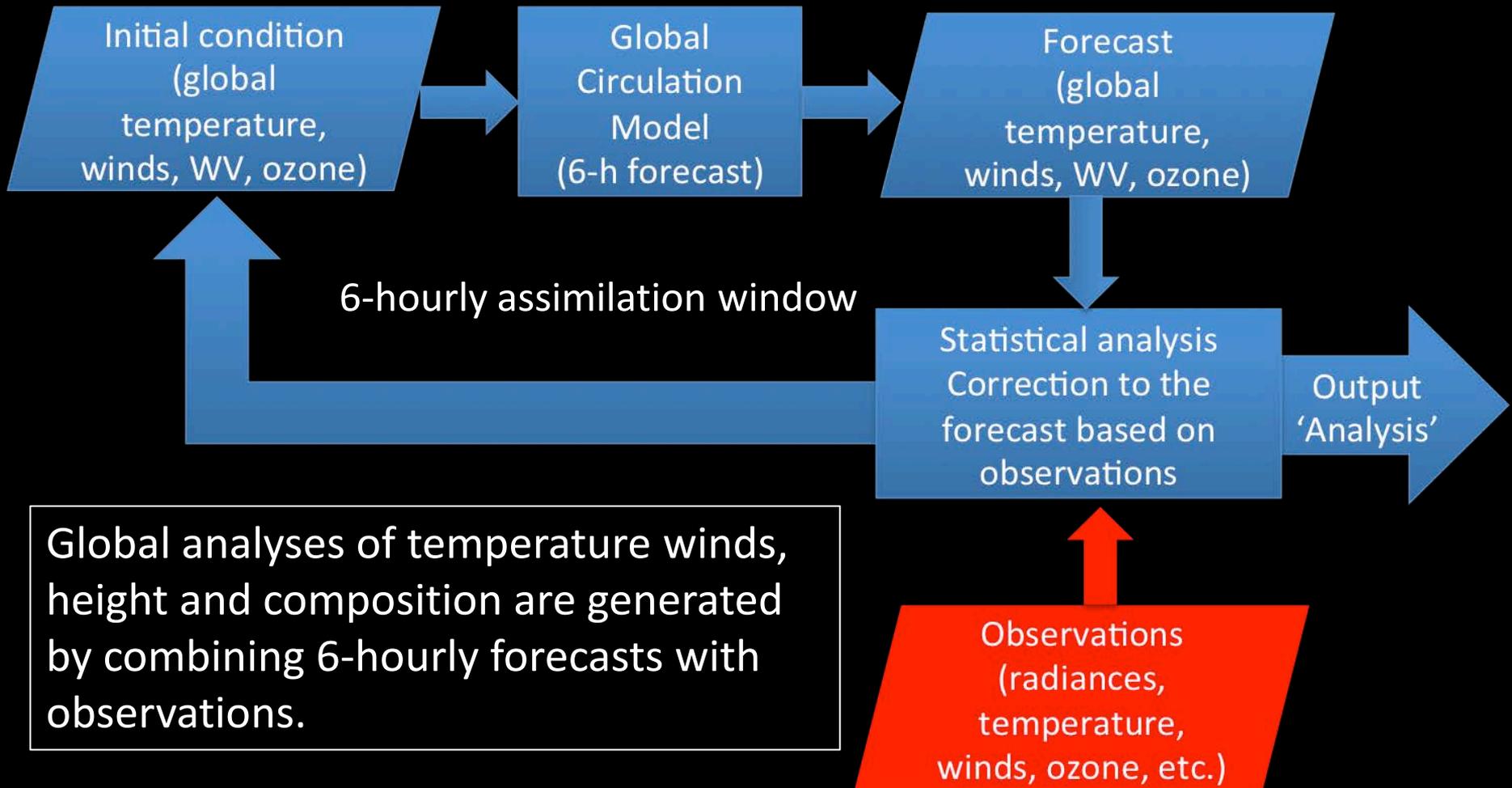
K. Wargan, S. Pawson, N. Livesey and N. Kramarova

Outline

Recent developments and results with limb ozone data assimilation

- MLS assimilation: MERRA-2
- OMPS-LP assimilation, early results: representation of vertical and horizontal structures

GEOS-5 Data Assimilation System (a very simplified picture)



Assimilated limb ozone data

Microwave Limb Sounder

- Ozone profiles retrieved from measured microwave emissions – day and night coverage.
- 261 hPa – mesosphere
- Vertical resolution: 2.5-6 km
- Longitudinal separation: 10°-20°
- On the EOS Aura satellite, 2004 – present
- Version 4.2
- **Used in GMAO's operational analyses**

Ozone Mapping and Profiler Suite - Limb Profiler

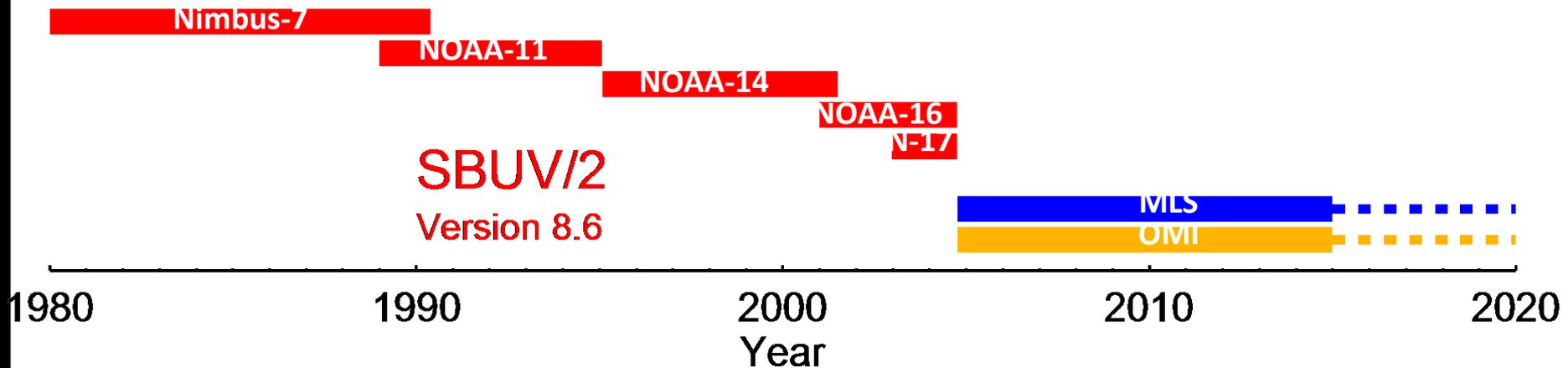
- Ozone profiles from backscattered UV (above 32 km) and visible radiation – daylight only
- 240 hPa – mesosphere
- Vertical resolution: ~1.8 km
- Three slits with 4.25° separation provide more cross-track coverage
- On Suomi-NPP, 2011 – present
- Version 2.x

Very different principles of measurement!

ASSIMILATION OF MLS OZONE: MERRA-2

Modern Era Retrospective Analysis for Research and Applications - 2

Ozone Data Sources in MERRA-2



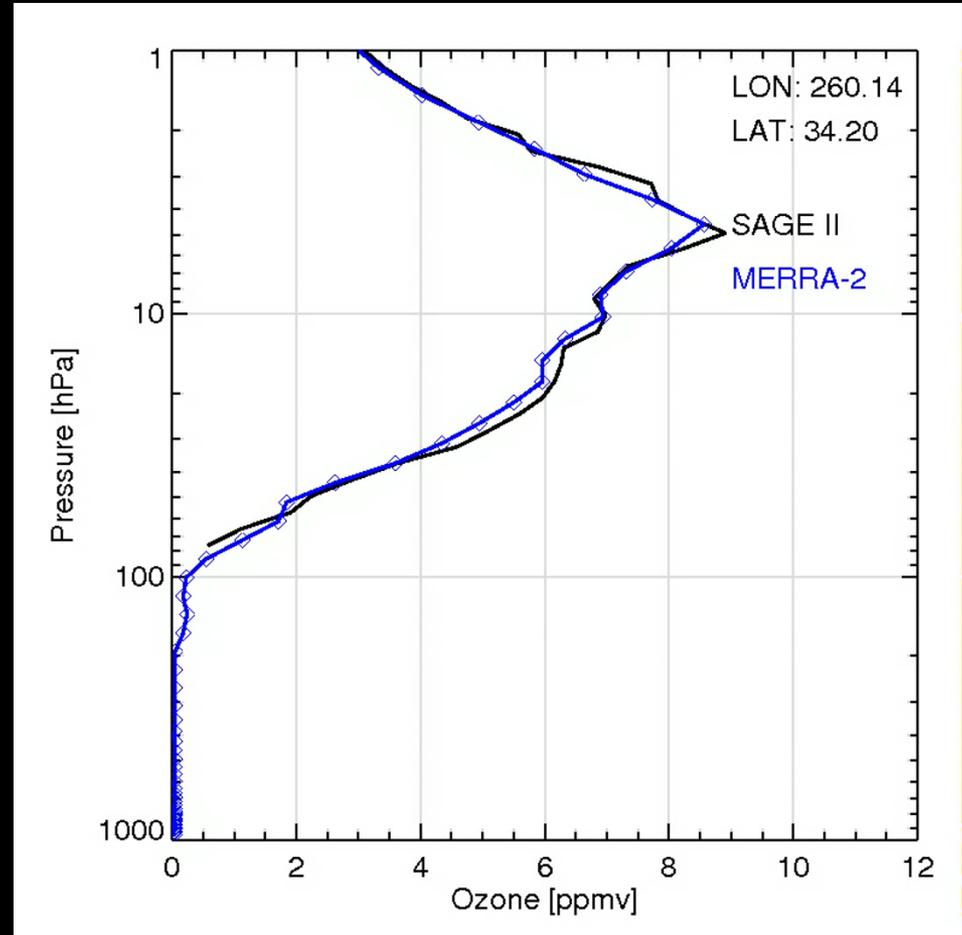
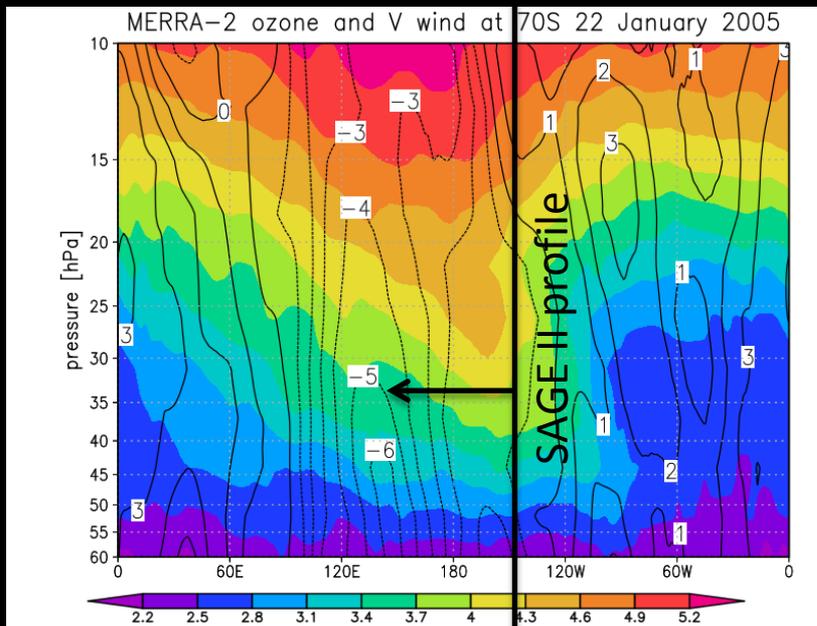
- New GMAO reanalysis, 1980 – present
- 3-hourly global fields at $0.625^{\circ} \times 0.5^{\circ}$ horizontal resolution, 72 levels, surface to 0.01 hPa
- Stratospheric ozone constrained by MLS data, Oct. 2004-present

The record of limb ozone observations is limited. We need to develop a better way to assimilate nadir data! Averaging kernels, correct error specification,...

Verification of MERRA-2 ozone profiles against Stratospheric Aerosol and Gas Experiment II (SAGE II)

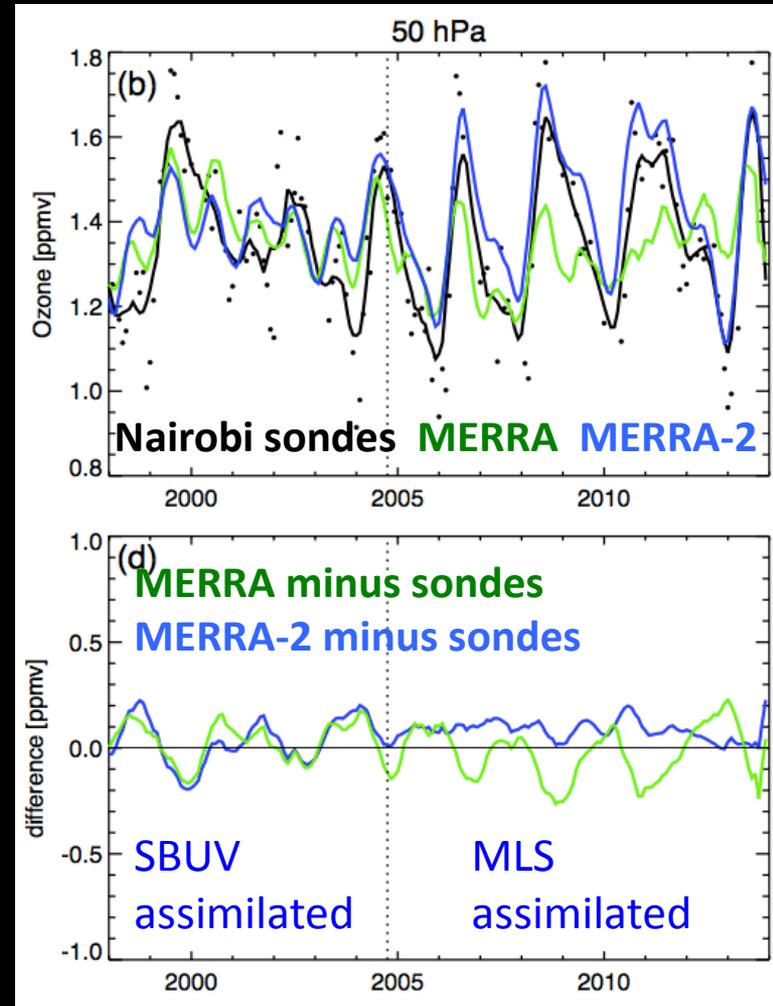
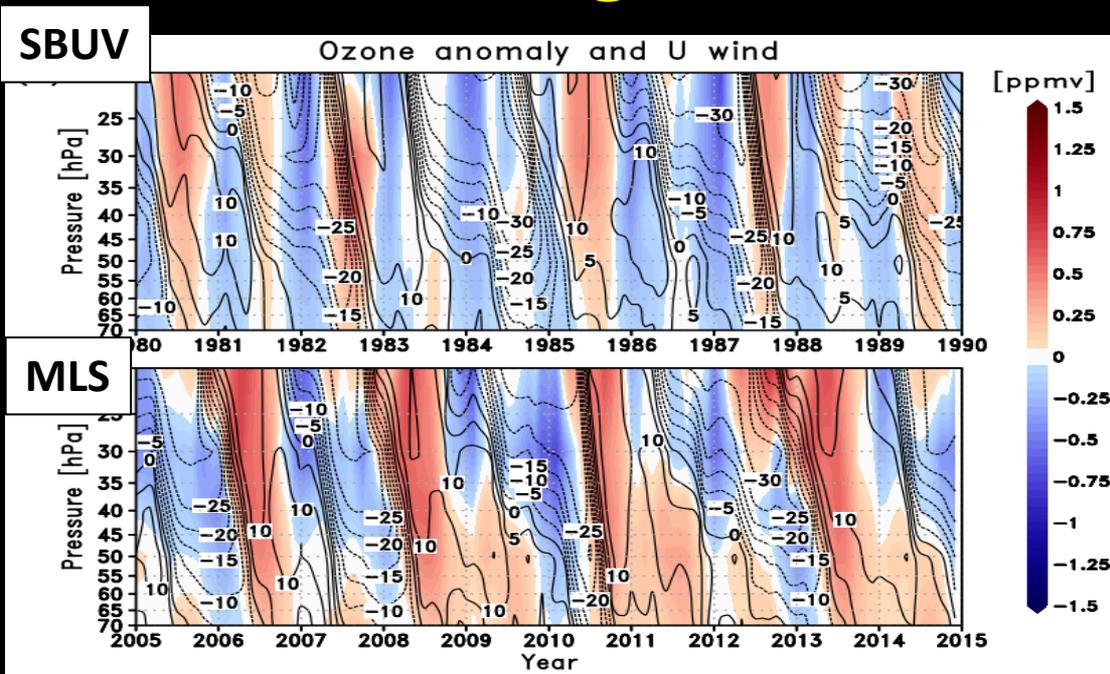
Collocated MERRA-2 and consecutive SAGE II ozone profiles for several days in January 2005.

MERRA-2 assimilates MLS but NOT SAGE II



Profile variability is very well represented in MERRA-2

QBO signature in MERRA-2 ozone



Coy et al., 2016

When MLS is assimilated in MERRA-2 the QBO signal in ozone shows more realistic phase propagation

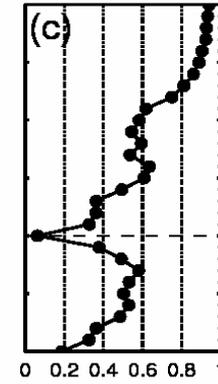
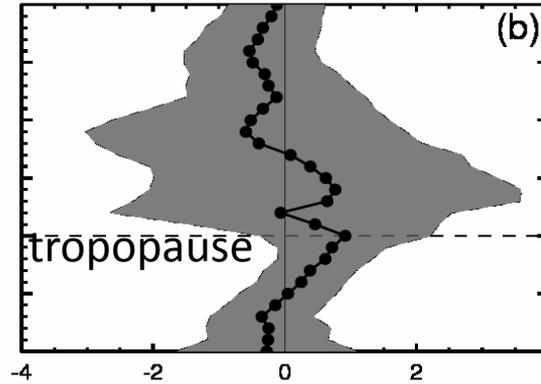
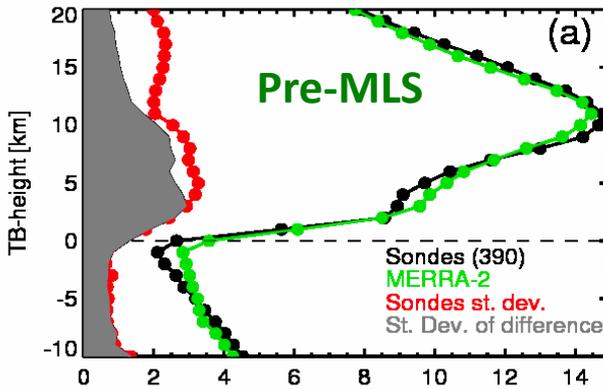
- Consistent with the zonal wind
- In agreement with ozonesondes

SBUV has large vertical smoothing errors
[Kramarova et al., 2013]

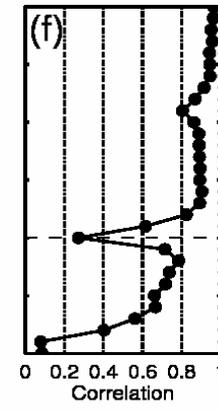
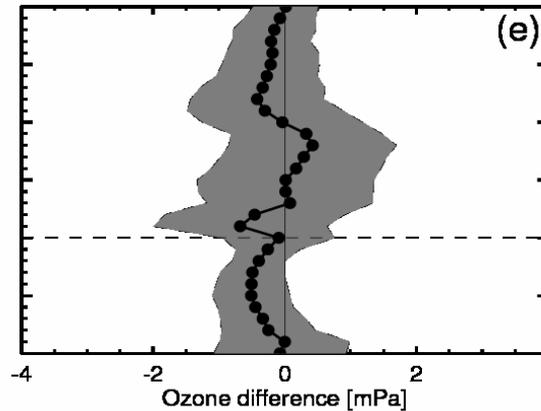
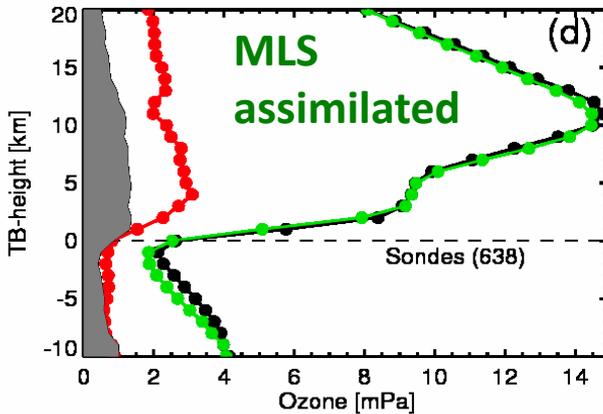
The right lesson to draw: We have to do a better job assimilating SBUV ozone : use averaging kernels and better error specifications

Ozonesondes: upper troposphere – lower stratosphere, Europe, March-May

2003



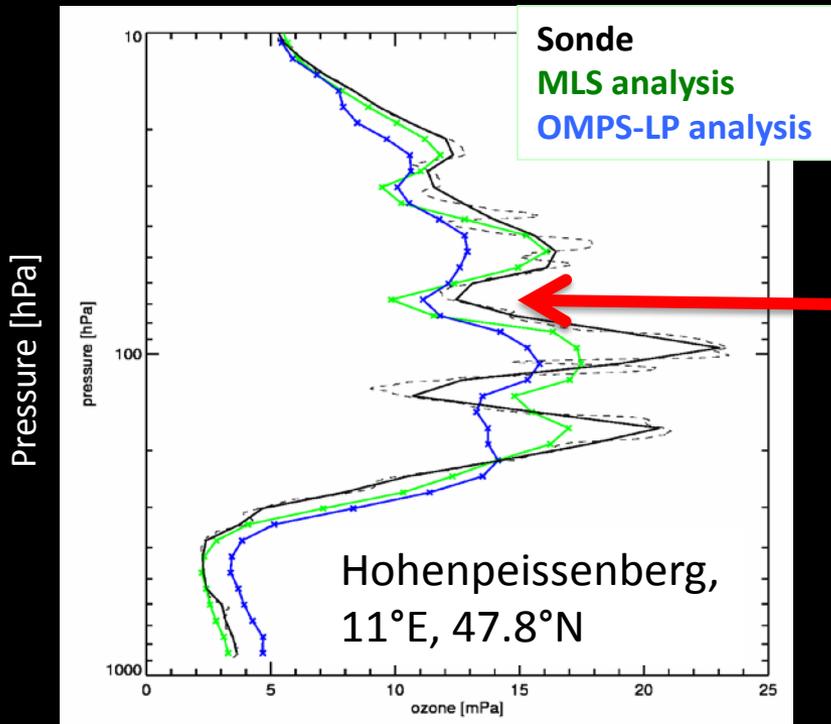
2005



- Good agreement of MERRA-2 with ozonesondes in the UTLS
- In the MLS assimilation period:
 - Smaller difference standard deviations
 - Higher correlations in the LS
 - Sharper gradient across the tropopause

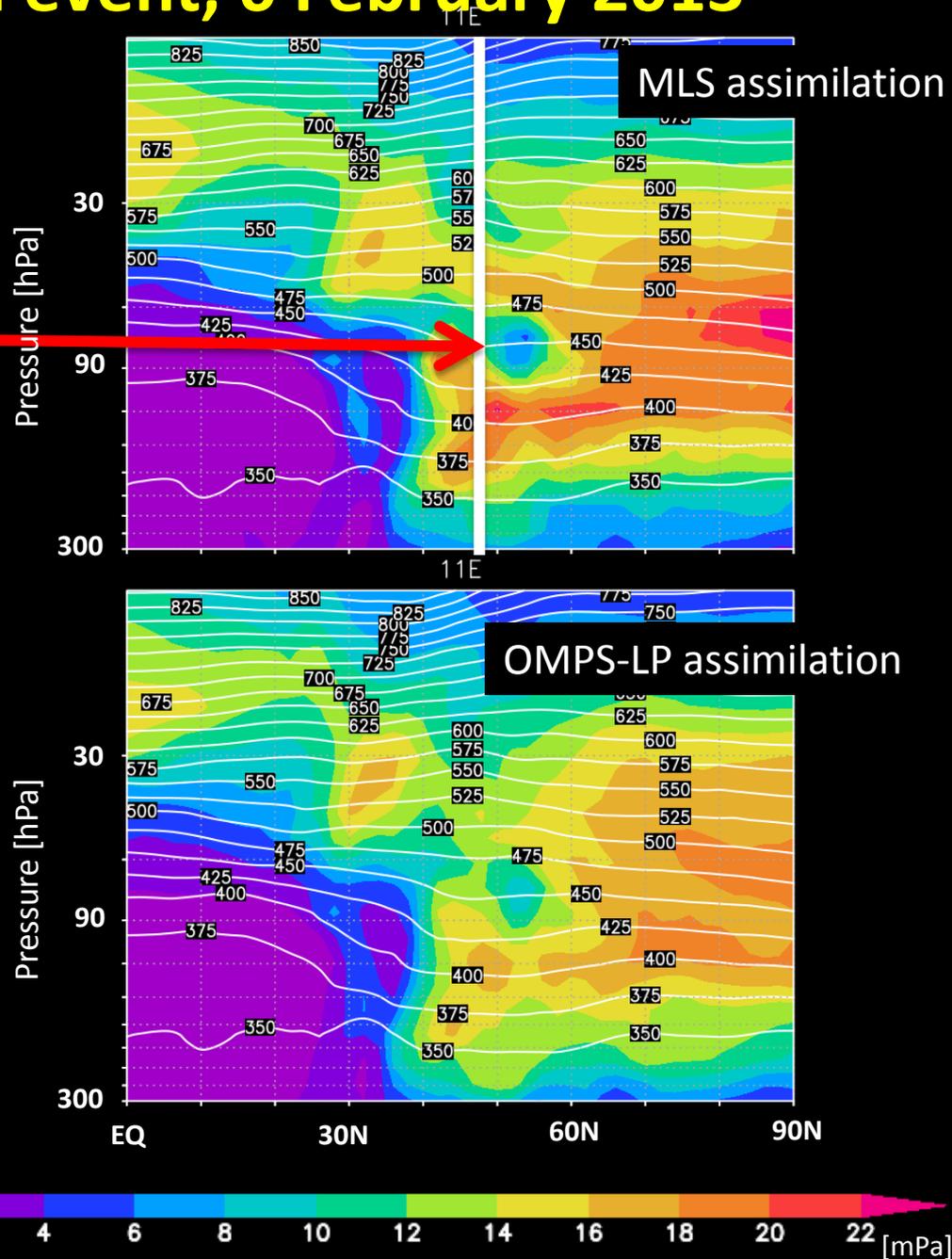
**PRELIMINARY RESULTS WITH OMPS-LP:
VERTICAL STRUCTURES**

A low ozone lamina event, 6 February 2013

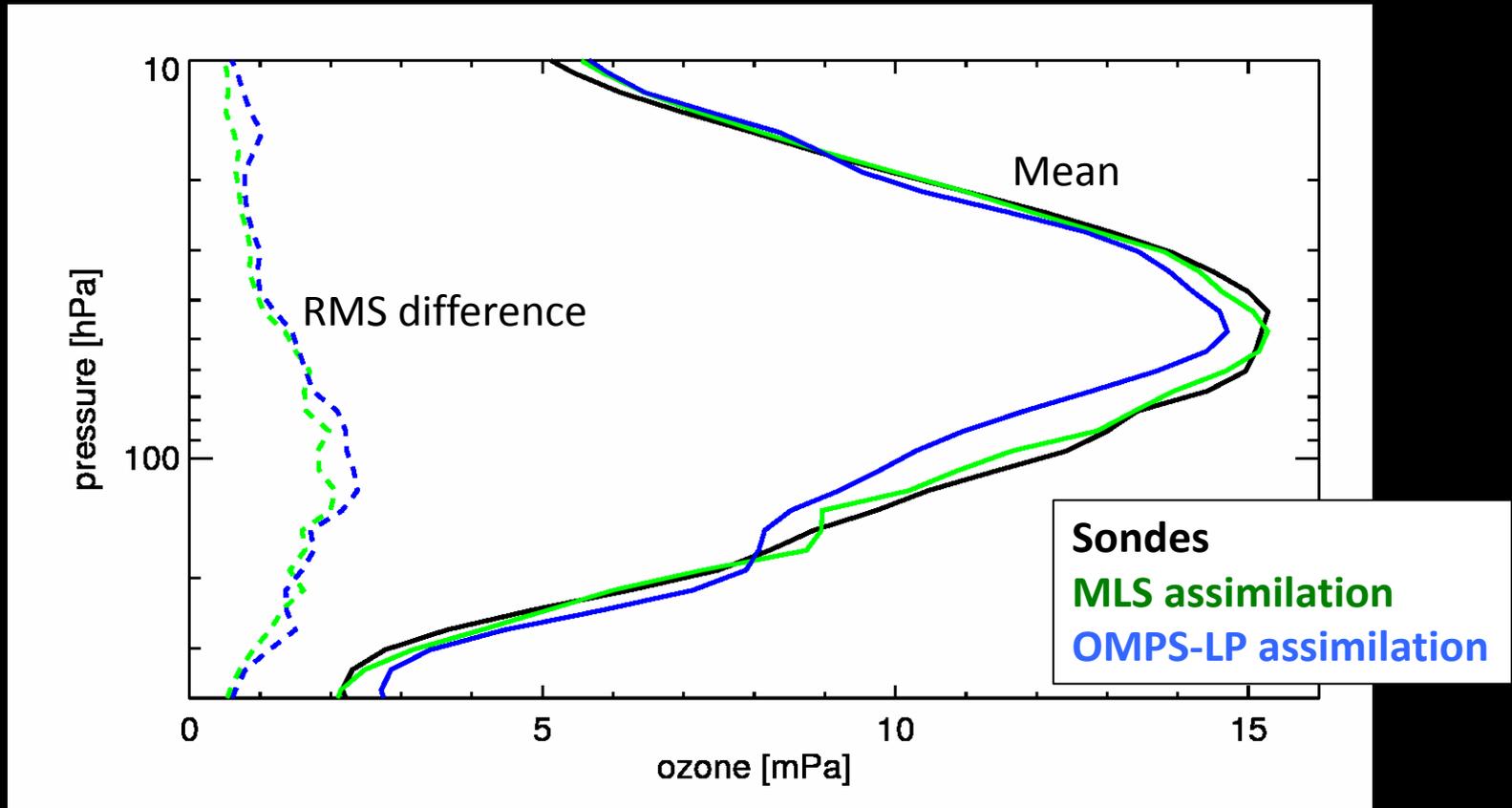


- A complex profile structure over Hohenpeissenberg is reproduced (to some degree) by both analyses
- A low ozone lamina at ~70 hPa is seen in both experiments

The same morphology in both analyses



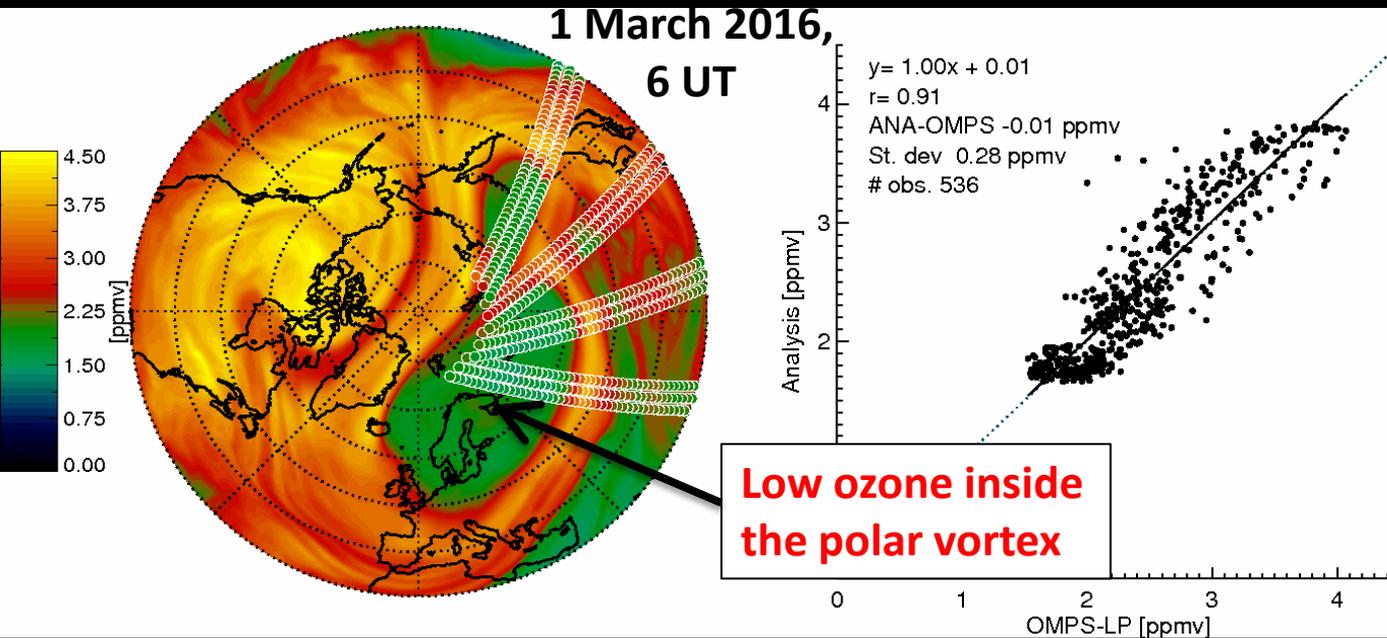
Comparison with ozonesondes 45°N-90°N in DJF 2012/2013



- Some systematic differences: The MLS analysis is slightly closer to the sondes
- The RMS differences are close: both analyses reproduce the variability about equally

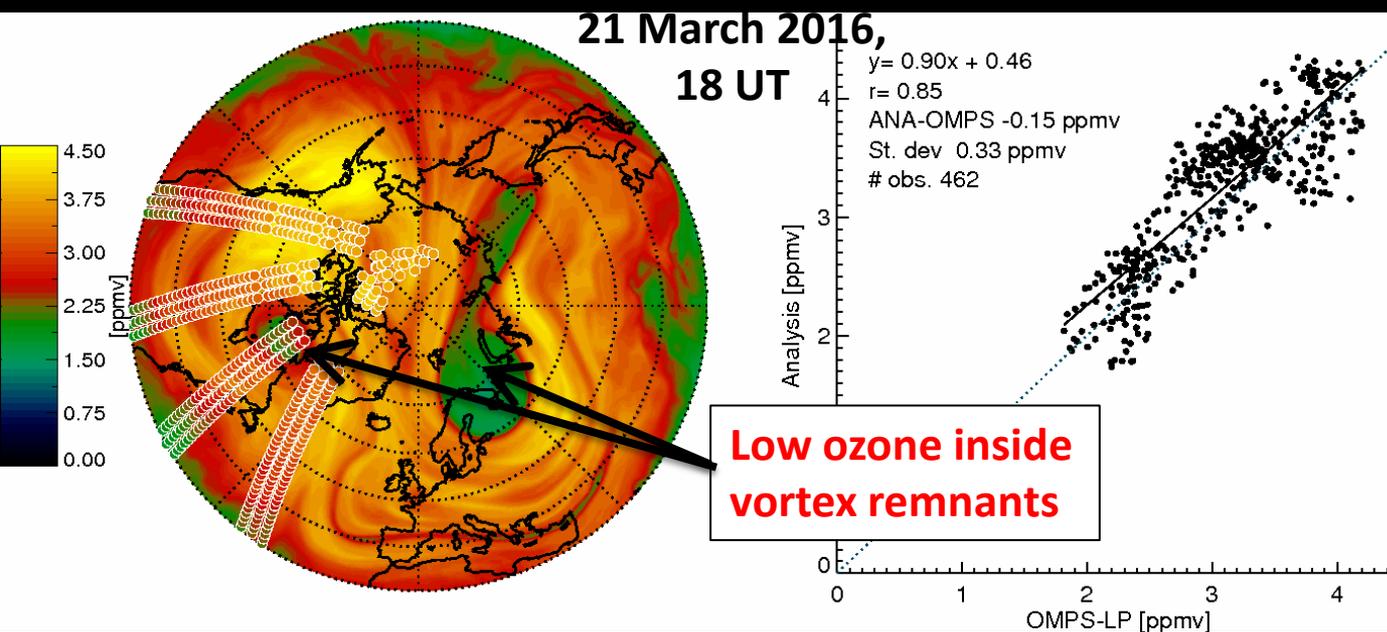
**PRELIMINARY RESULTS WITH OMPS-LP:
HORIZONTAL STRUCTURES**

MLS assimilation & OMPS-LP data : horizontal structures



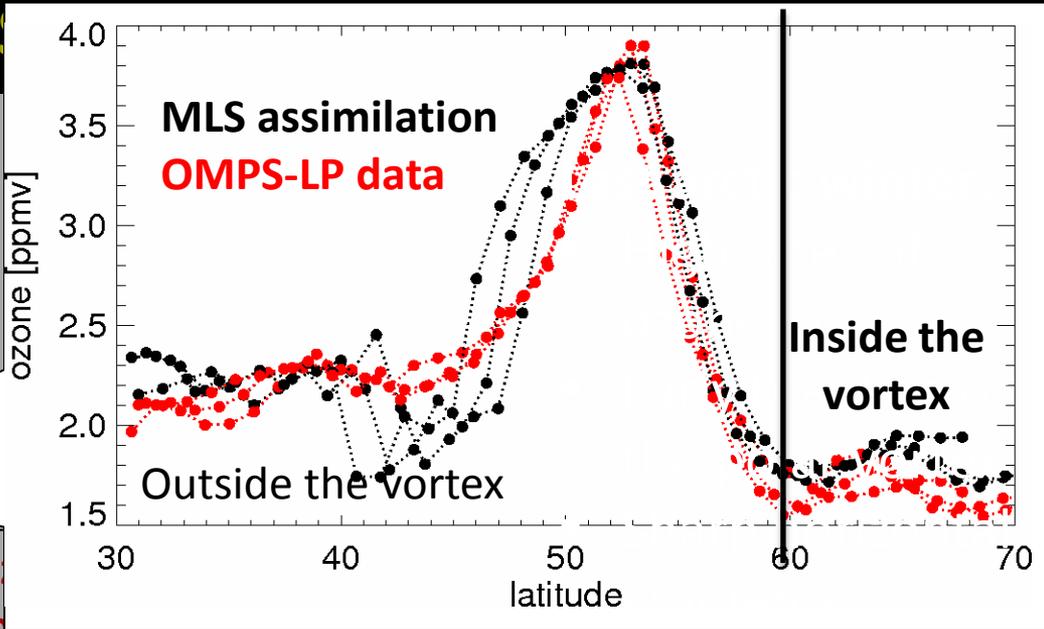
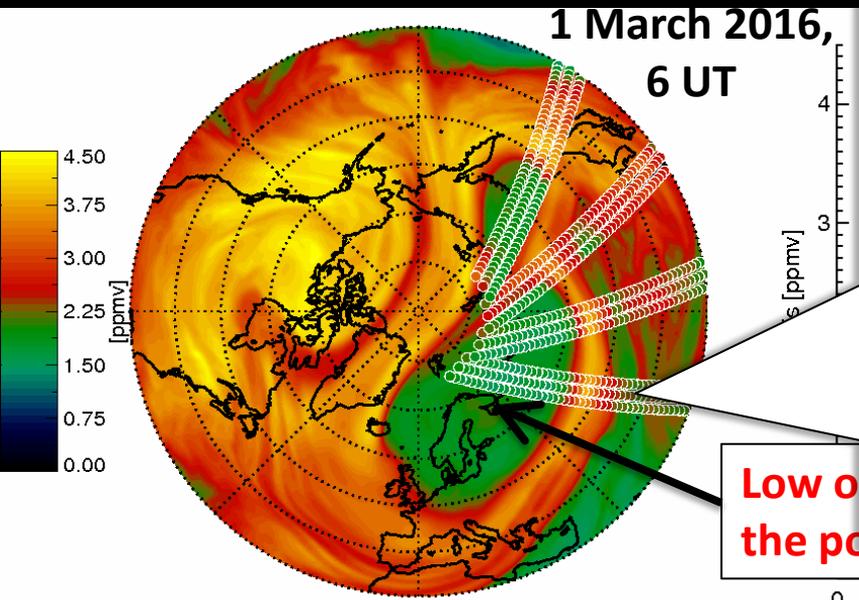
2015/2016 Arctic winter:

- High rates of ozone loss
- Early breakup of the polar vortex
- Sharp horizontal gradients

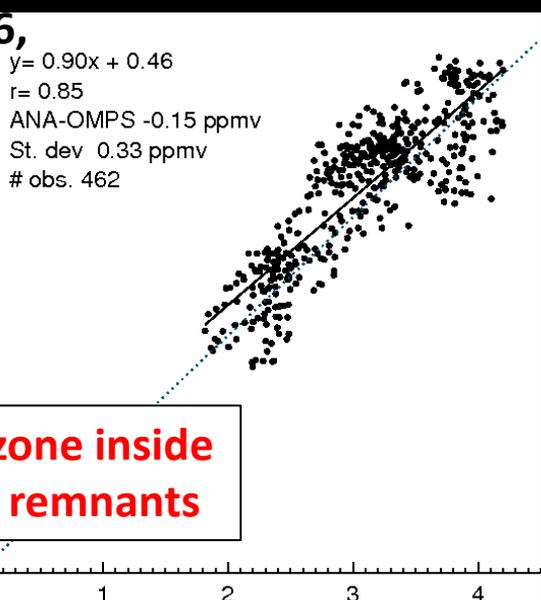
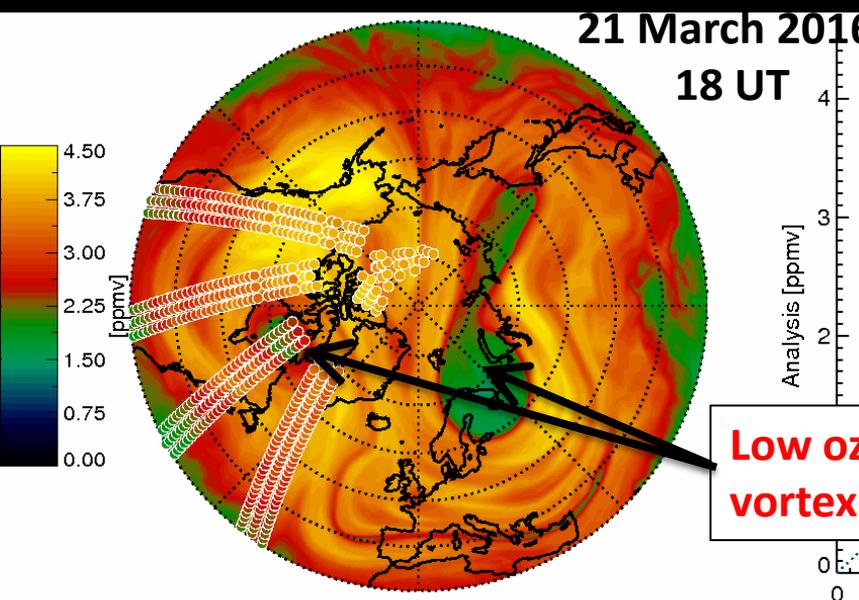
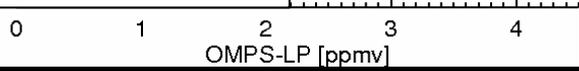


OMPS-LP picks up horizontal structures and gradients across the vortex edge

MLS assimilation & OMP



Low ozone inside the polar vortex



Low ozone inside vortex remnants

OMPS-LP picks up horizontal structures and gradients across the vortex edge

Summary

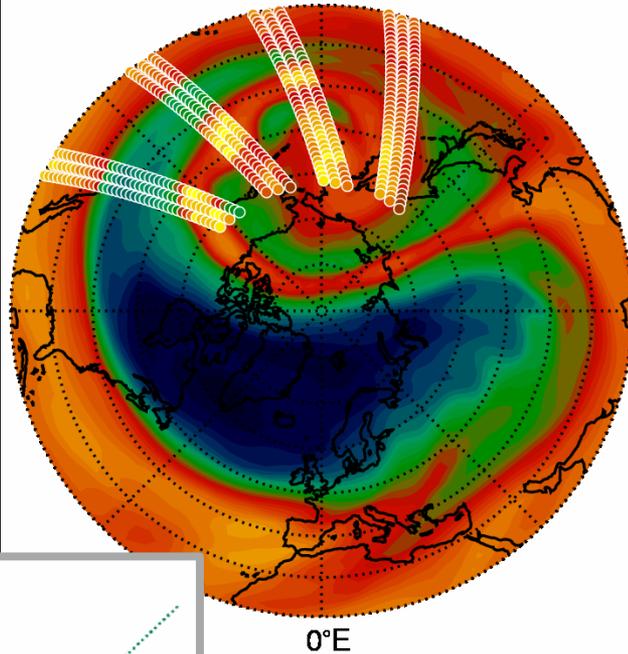
- MERRA-2 uses MLS ozone data from late 2004 onward
 - Good representation of stratospheric profiles
 - Realistic ozone response to QBO
 - Faithful representation of the lower stratosphere O₃
- Early results with OMPS-LP
 - Vertical structures and variability comparable to MLS assimilation
 - Capability to resolve horizontal O₃ gradients
 - Some systematic offsets relative to MLS assimilation
- Potential future directions
 - Assimilation of aerosols from OMPS-LP
 - Assimilation of OMPS-LP radiances
 - Better ways to assimilate nadir ozone data

backup

MLS & OMPS-LP assimilation reproduce a transport event

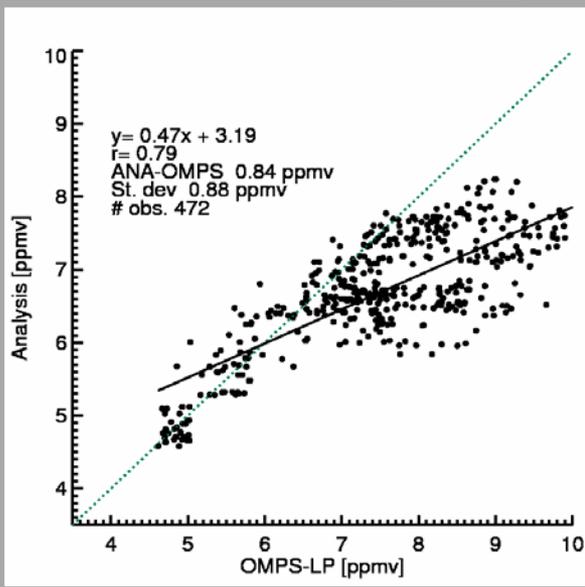
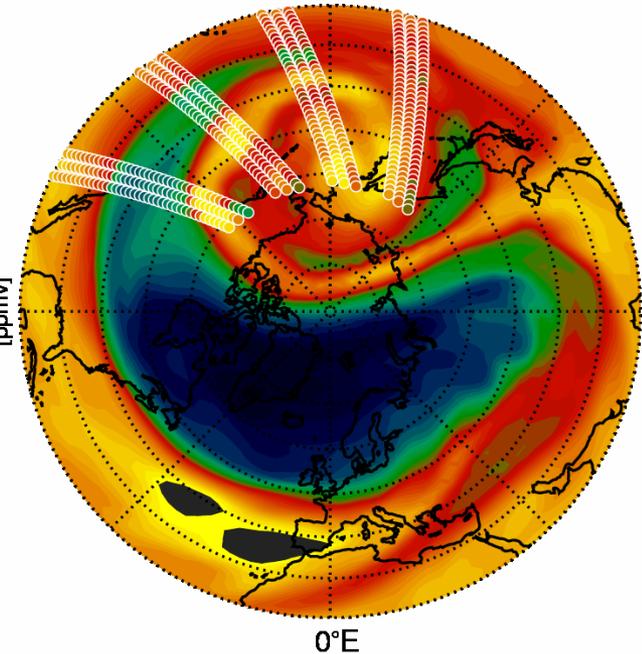
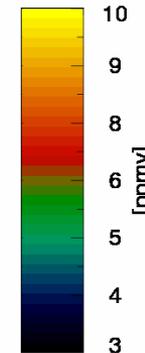
Ozone-rich tropical air wrapped around the Aleutian anticyclone

MLS analysis and OMPS-LP ozone at 10 hPa
6 Dec. 2012 0Z



OMPS-LP analysis and OMPS-LP ozone at 10 hPa
6 Dec. 2012 0Z

10 hPa



- OMPS-LP observations at 10 hPa are biased high with respect to MLS analysis but show the same filamentary structures
- Assimilated OMPS-LP produces the same ozone field morphology