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Polar vortex dynamics observed by means of stratospheric and mesospheric CO ground-based measurements carried out at Thule (76.5 N, 68.8 W), Greenland

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Outline

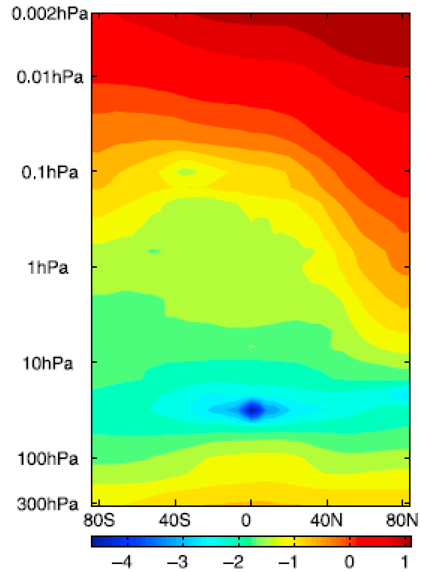
- Brief description of the observing technique and sample results
- Comparison with satellite observations
- Results from 4 winter measurement campaigns
- Estimate of air masses subsidence rates inside the polar vortex

Motivation

CO is a useful tracer in the polar winter middle atmosphere due to:

1) long photochemical lifetime (≈ time scale for many dynamical processes)

2) latitudinal and vertical gradient



MLS CO zonal mean (in log ppmv) for the NH winter (from "Aura Microwave Limb Sounder Observations of the Polar Middle Atmosphere: Dynamics and Transport of CO and H2O" Lee et al., 2011)

useful tool for studying:

1) Subsidence of mesospheric air inside the polar vortex with significant effects on ozone chemistry

2) Cross-vortex fast dynamical processes driven by planetary wave

Observing technique

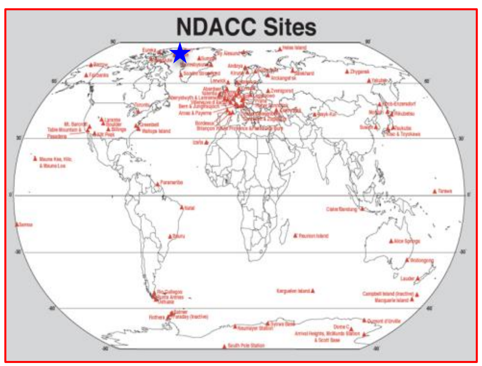
Ground-based millimeter-wave Spectrometer (GBMS) designed and built at the Stony Brook University [de Zafra, 1995]

- Rotational emission spectra of stratospheric and mesospheric trace gases (O_3, HNO_3, CO and N_2O) between 230 and 280 GHz (tunable).

- Deconvolution technique (to retrieve mixing ratio vertical profiles from the emission spectra): Optimal Estimation Method [Rodgers, 2000].

Observing site

Thule Air Base, Greenland (76.5° N 68.8° W)



NDACC (Network for the Detection of Atmospheric Composition Change) Arctic station

CO observations

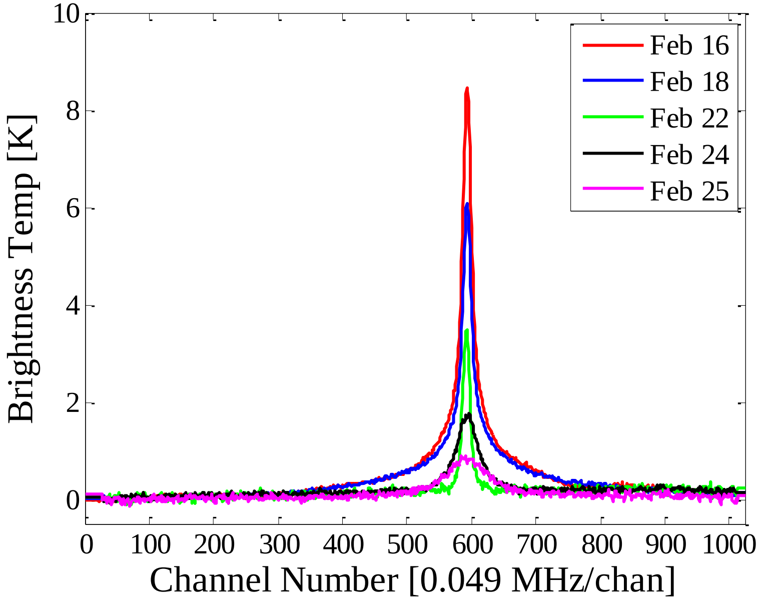
- Bandwidth: 50 MHz
- Maximum resolution: 65 kHz
- Integration time: 15-60 min

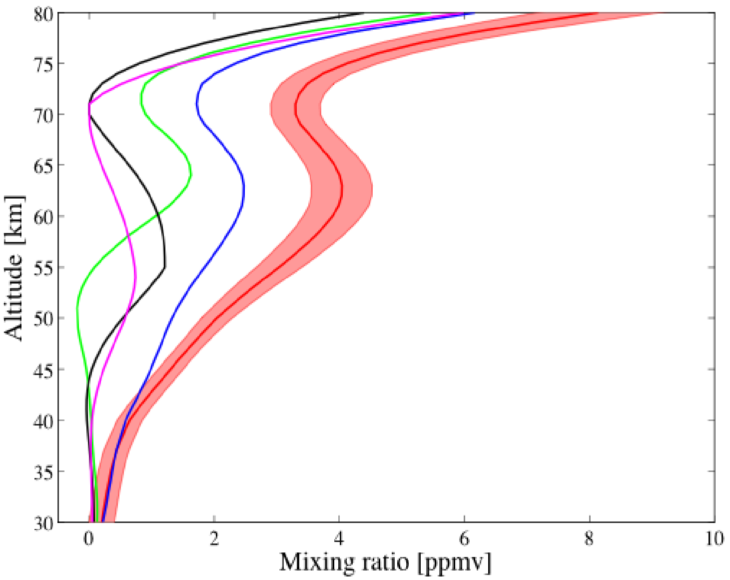
Long-term observation plan of the polar middle atmosphere for tracking long term trends and for bridging between global satellite-based measurements.

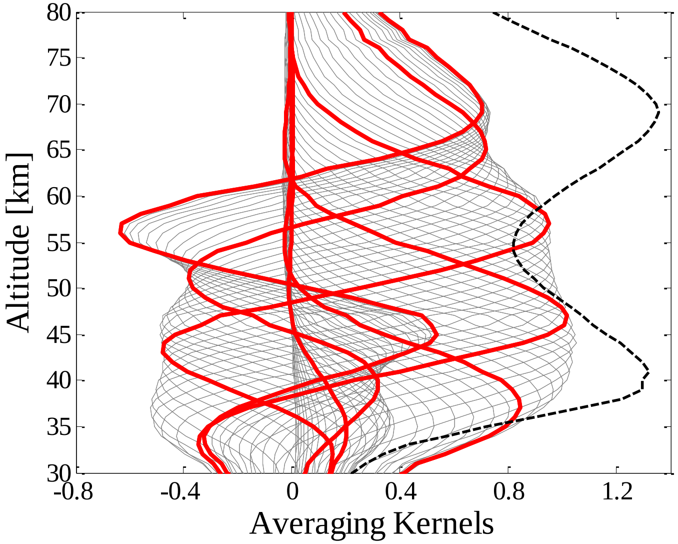
Four winter campaigns:

January-March 2009-2010-2011-2012

Sample CO spectra observed by GBMS







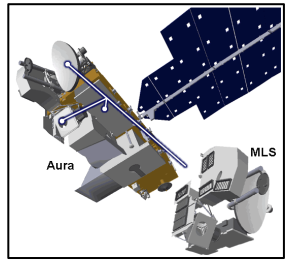
Altitude sensitivity range: 35-80 km

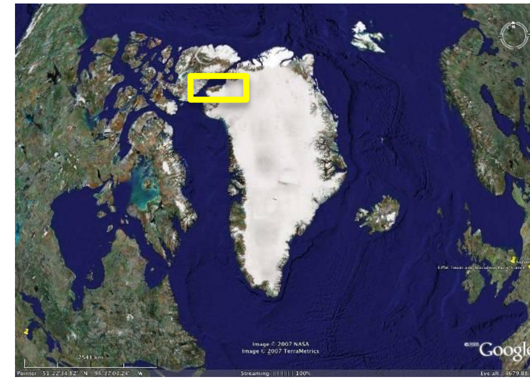
Theoretical vertical resolution: 11-14 km

Satellite comparison

EOS Aura MLS

- Near-polar orbit
- Useful Range: 215-0.0046 hPa
- Vertical resolution (mesosphere): 6-7 km

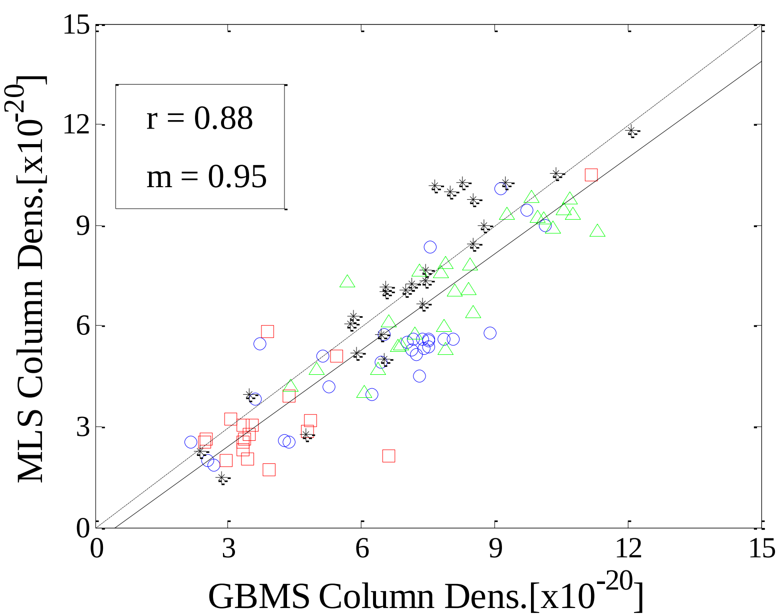




Coincidence criteria:

±8° longitude, ±1° latitude, ±12 h

Column Content 30-80 km

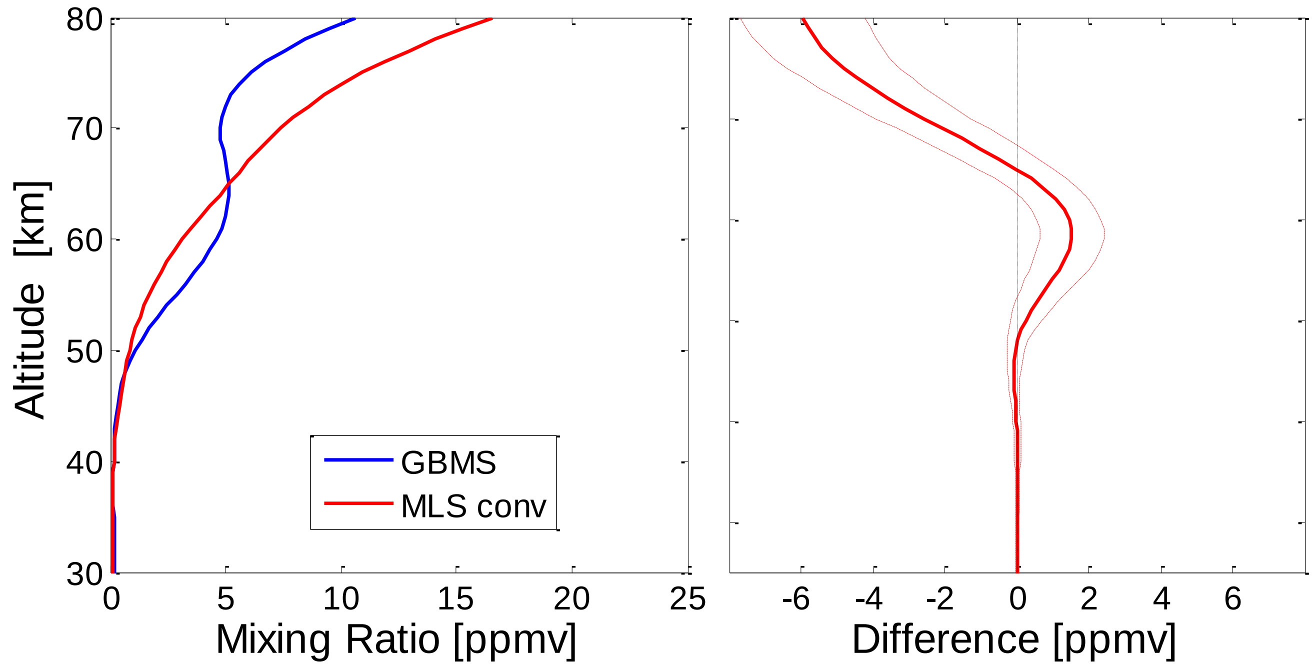


N_{TOT} = 102

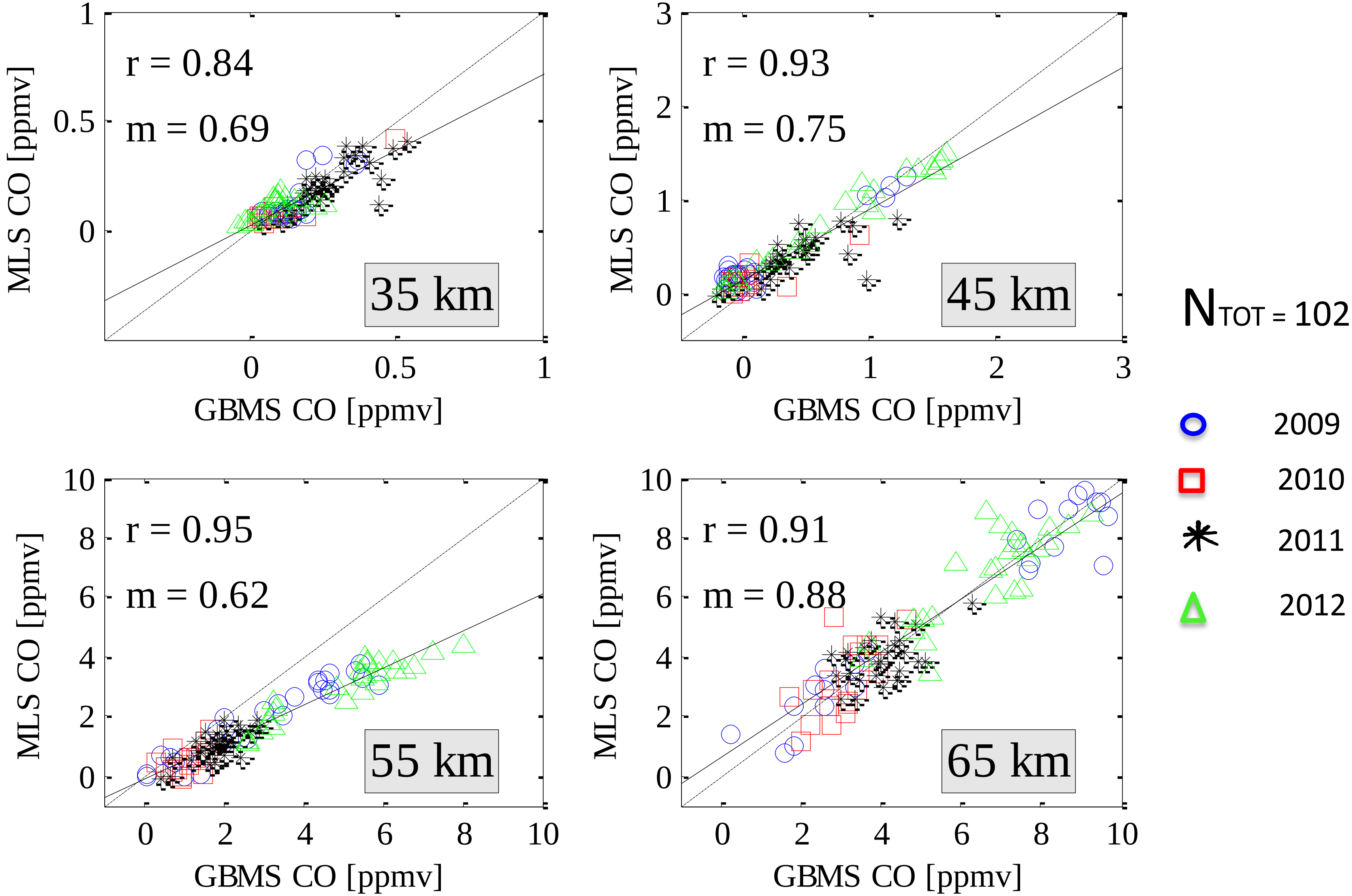
- ○ 2009
- □ 2010
- ✱ 2011
- △ 2012

Mean profiles

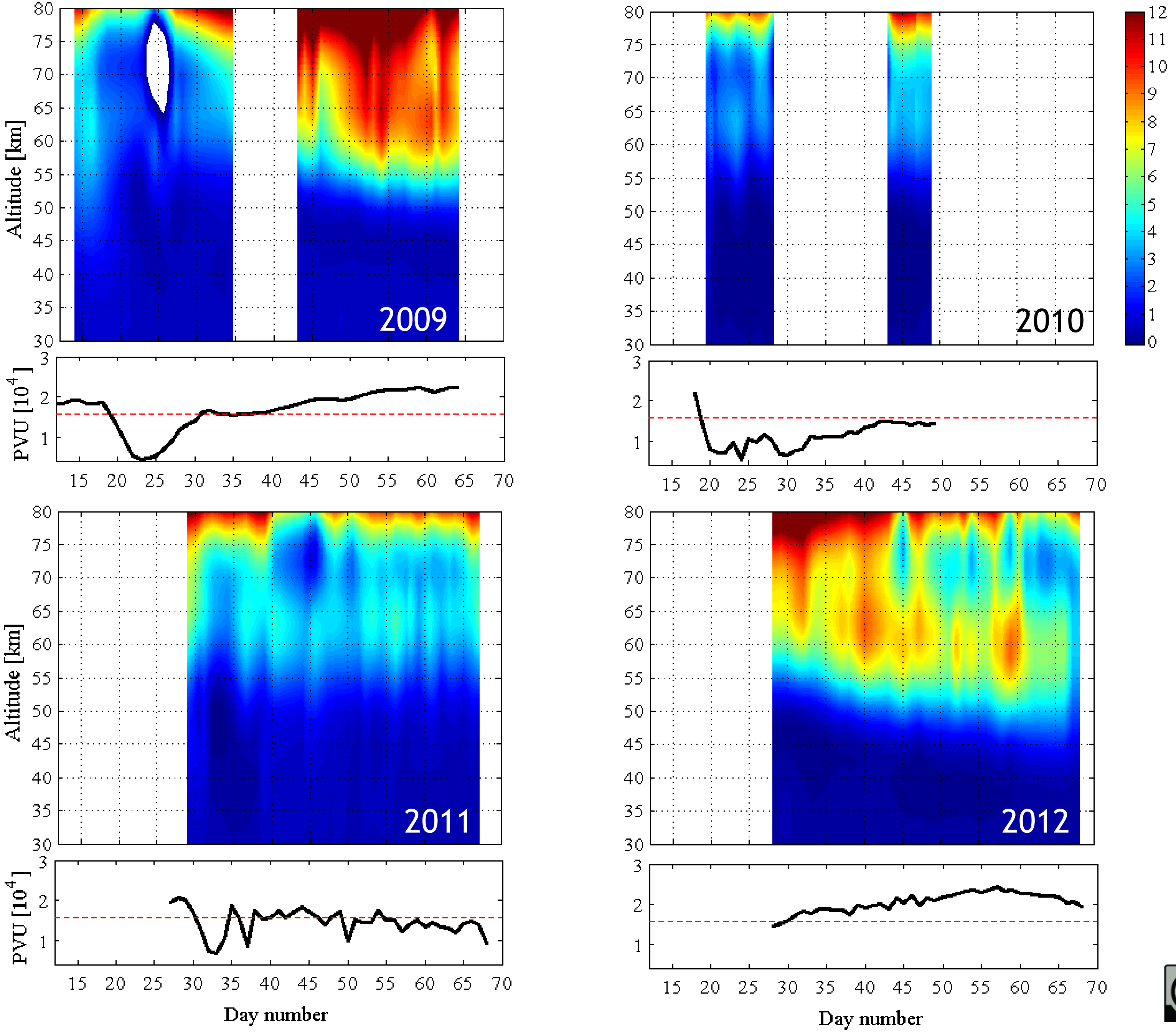
4 winters – 102 coincidences



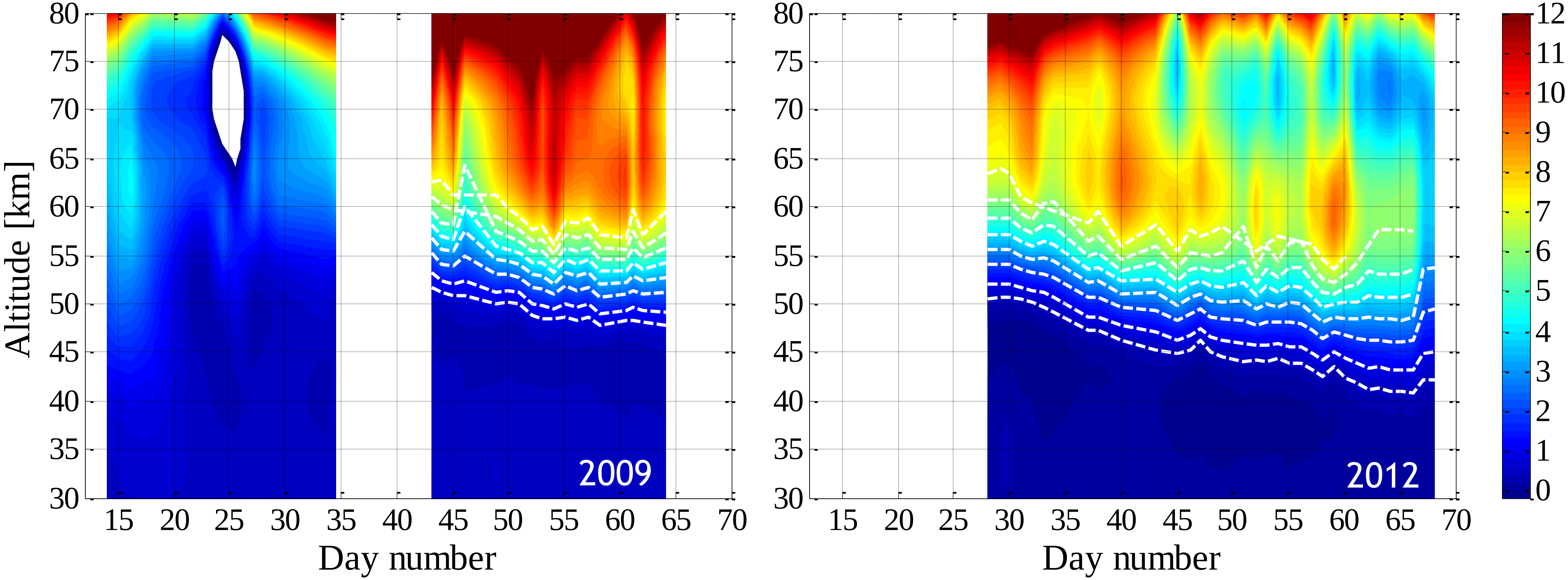
MLS profiles (higher resolution) have been "convolved" using the GBMS Averaging Kernels before the comparison


r = 0.84
m = 0.69
35 km
MLS CO [ppmv]
GBMS CO [ppmv]
r = 0.93
m = 0.75
45 km
MLS CO [ppmv]
GBMS CO [ppmv]
r = 0.95
m = 0.62
55 km
MLS CO [ppmv]
GBMS CO [ppmv]
r = 0.91
m = 0.88
65 km
MLS CO [ppmv]
GBMS CO [ppmv]
NTOT = 102
2009
2010
2011
2012

Timeseries of CO mixing ratio profiles



Estimate of subsidence rates inside the vortex



descent rate=0.17±0.04 km/day

descent rate=0.18±0.01 km/day

Conclusions

• GBMS allows retrieval of CO vertical profile between ≈35-70 km with vertical resolution of 11-14 km

• Good agreement of GBMS and MLS column content between 30 and 80 km

• GBMS and MLS profiles are well correlated at altitudes between 35 and 65 km although GBMS values display a high bias (1.5 ppmv) around 60 km

• Estimated descent rates inside the polar vortex of about 0.18 km/day

References

de Zafra, R. L., and G. Muscari (2004), CO as an important high-altitude tracer of dynamics in the polar stratosphere and mesosphere, J. Geophys. Res., 109, D06105, doi:10.1029/2003JD004099.

de Zafra, R. L. (1995), The ground-based measurement of stratospheric gases using quantitative millimeter wave spectroscopy, in Diagnostic Tools in Atmospheric Physics, Proceedings of the international school of physics “Enrico Fermi”, 23-54, Società italiana di fisica, Bologna.

Fiorucci, I., Muscari, G., and de Zafra, R. L. (2011), Revising the retrieval technique of a long-term stratospheric HNO_3 data set: from a constrained matrix inversion to the optimal estimation algorithm, Ann. Geophys., 29, 1317-1330, doi:10.5194/angeo-29-1317-2011.

Rodgers, C. D. (2000), Inverse method for atmospheric sounding, Series on atmospheric, oceanic and Planetary Physics - vol.2, Taylor, F. W., World Scientific Publishing Co. Pte LTd, Singapore.

Lee, J.N., D.L. Wu, G.L. Manney, M.J. Schwartz, A. Lambert, N.J. Livesey, K.R. Minschwaner, H.C. Pumphrey, and W.G. Read (2011), Aura Microwave Limb Sounder Observations of the Polar Middle Atmosphere: Dynamics and Transport of CO and H2O, J. Geophys. Res. *116*, D05110, doi:10.1029/2010JD014608.