NDACC Workshop on Water Vapor:

Comparison Microwave with Satellites

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Overview

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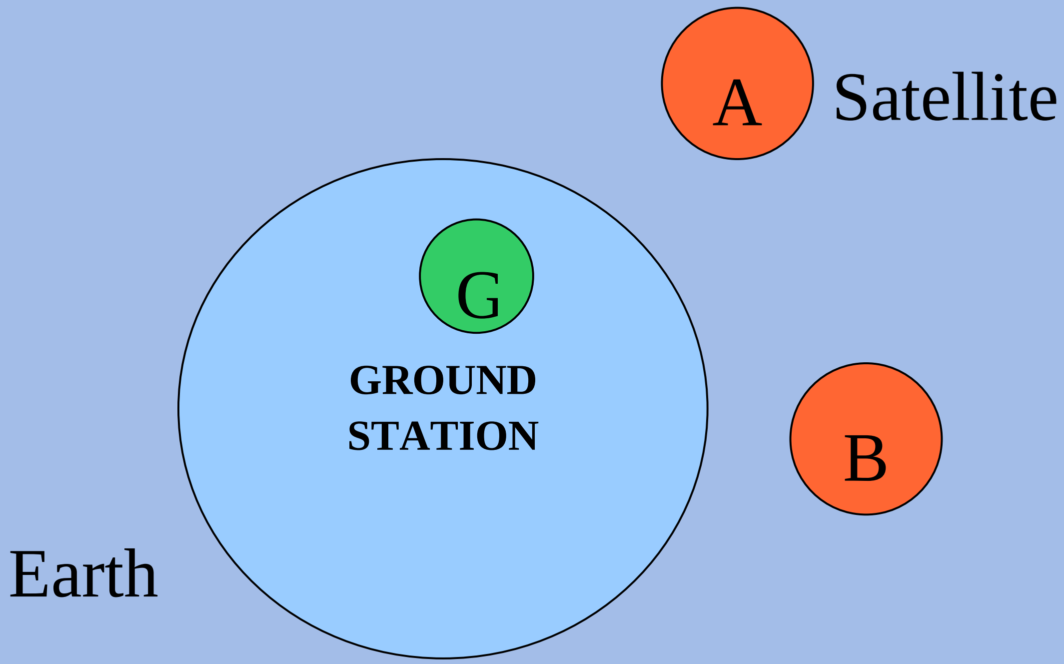
1. Fundamental considerations on cross-validation
2. Cross-validation of satellites by a ground station
3. Cross-validation of two ground stations by Aura/MLS
4. A statistical study of ozone differences between Aura/MLS and SOMORA
5. Geographic ozone maps from ground- and spacebased measurements

Fundamental considerations:

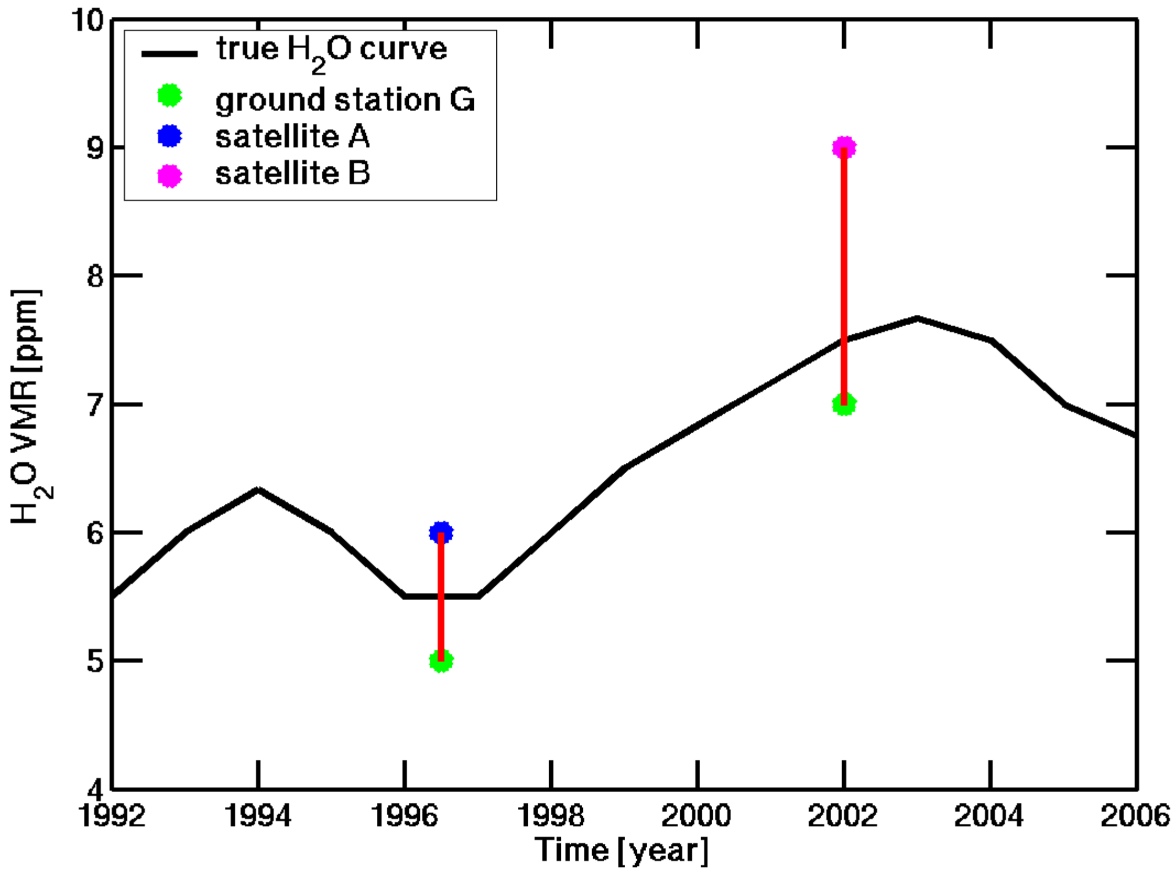
- Validation of satellite data sets requires spatial and temporal coincidence of the measurements
- Orbit planes and operation time intervals of satellites are usually quite different
- Life time of satellites is short compared to ground stations
- Modification/optimization of satellite experiments in orbit is often not possible

→ long-term ground station data are needed for calibration and validation of satellite experiments!

Cross-validation of satellites by means of a ground station:



Difference of systematic errors of satellites A and B:



e_A - e_B = difference of lengths of the red lines

Double difference operator O for not coincident profiles X of satellites A and B:

$$O(X_A(t1),X_B(t2)) := [X_A(t1) - X_G(t1)] - [X_B(t2) - X_G(t2)]$$

$X_A(t)$: vertical profile of species X observed by satellite A over ground station G at time t

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What will be the result of *double differencing*?

$$O(X_A(t1),X_B(t2)) := [X_A(t1) - X_G(t1)] - [X_B(t2) - X_G(t2)]$$

$$= [(X_{true}(t1) + e_A) - (X_{true}(t1) + e_G)] - [(X_{true}(t2) + e_B) - (X_{true}(t2) + e_G)]$$

$$= [e_A - e_G] - [e_B - e_G]$$

$$= \boxed{e_A - e_B}$$

Result is the difference of the systematic errors e_A and e_B of satellite A and B (if systematic error e_G of the ground station is constant).

Ozone VMR from SOMORA microwave radiometer in Payerne (MeteoSwiss):

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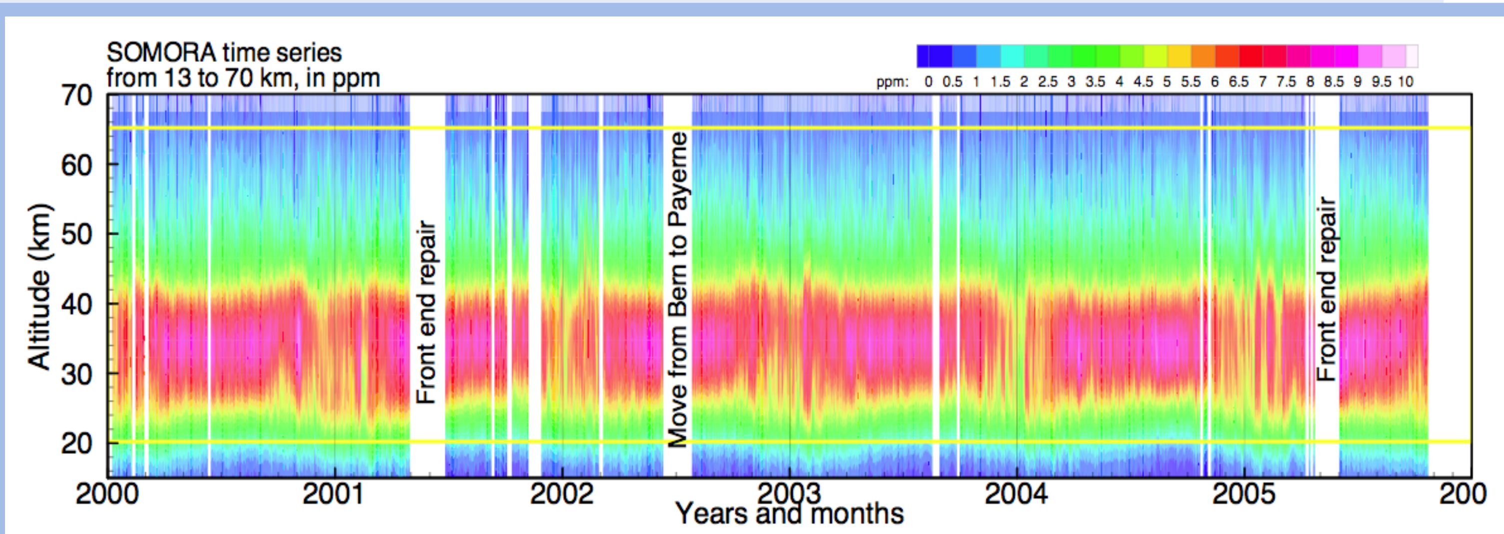
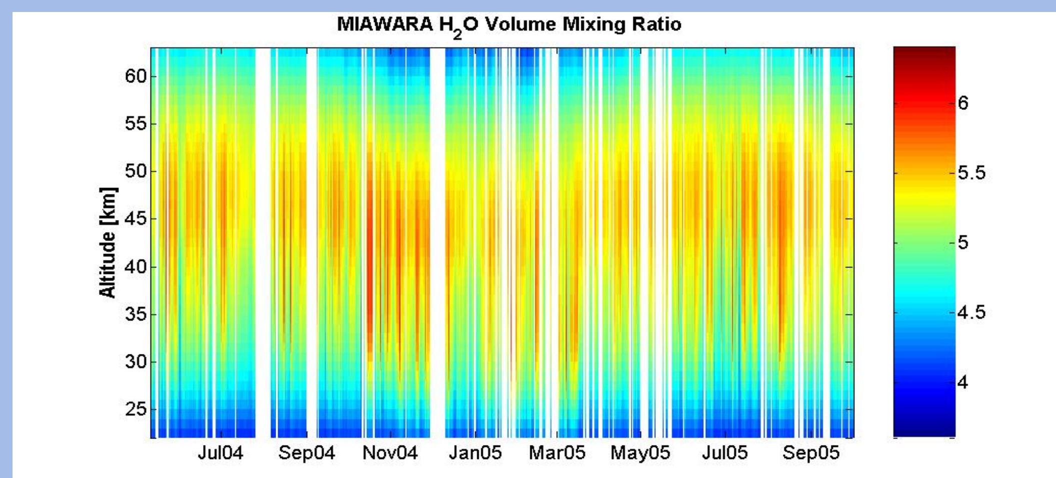


Water Vapor VMR from MIAWARA microwave radiometer in Bern:



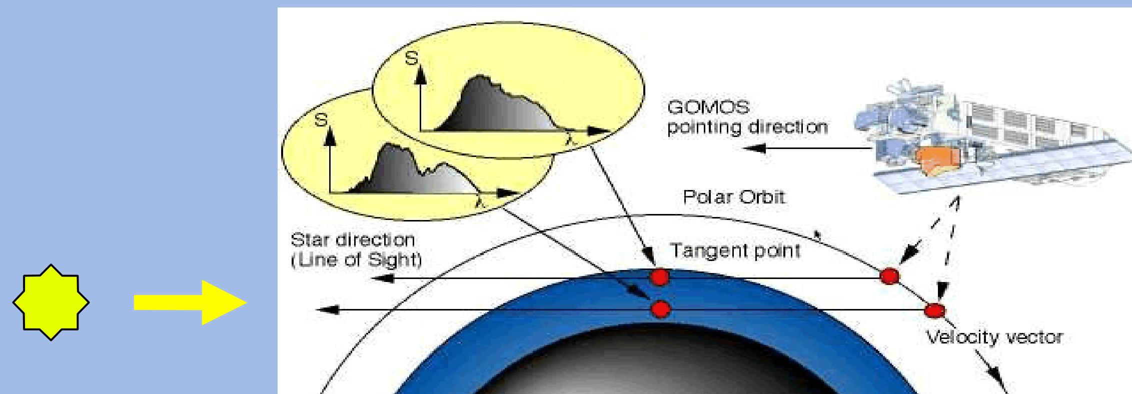
Selected satellite limb sounders:

Solar occultation (absorption of solar radiation by the Earth's atmosphere)

- **ACE/FTS** (infrared)

- **SAGE II and III** (UV/visible)

- **UARS/HALOE** (infrared)



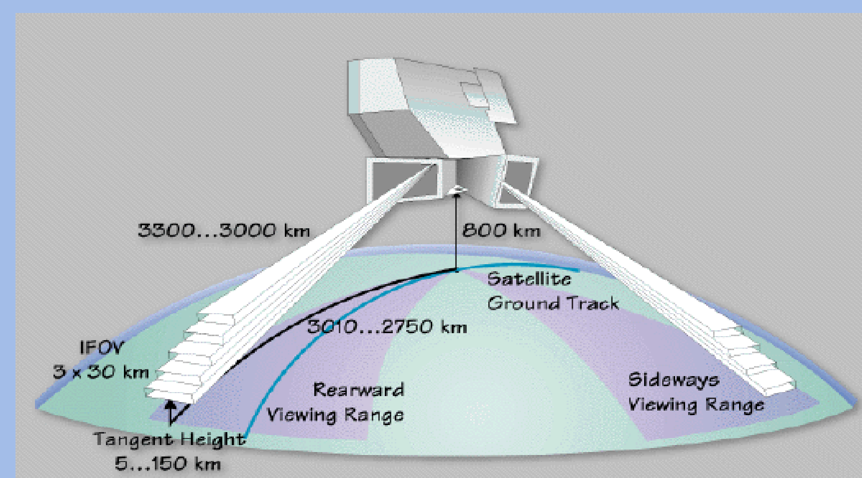
Star occultation (absorption of star radiation by the Earth's atmosphere)

-**ENVISAT/GOMOS** (UV/visible)

Atmospheric emission limb sounders:

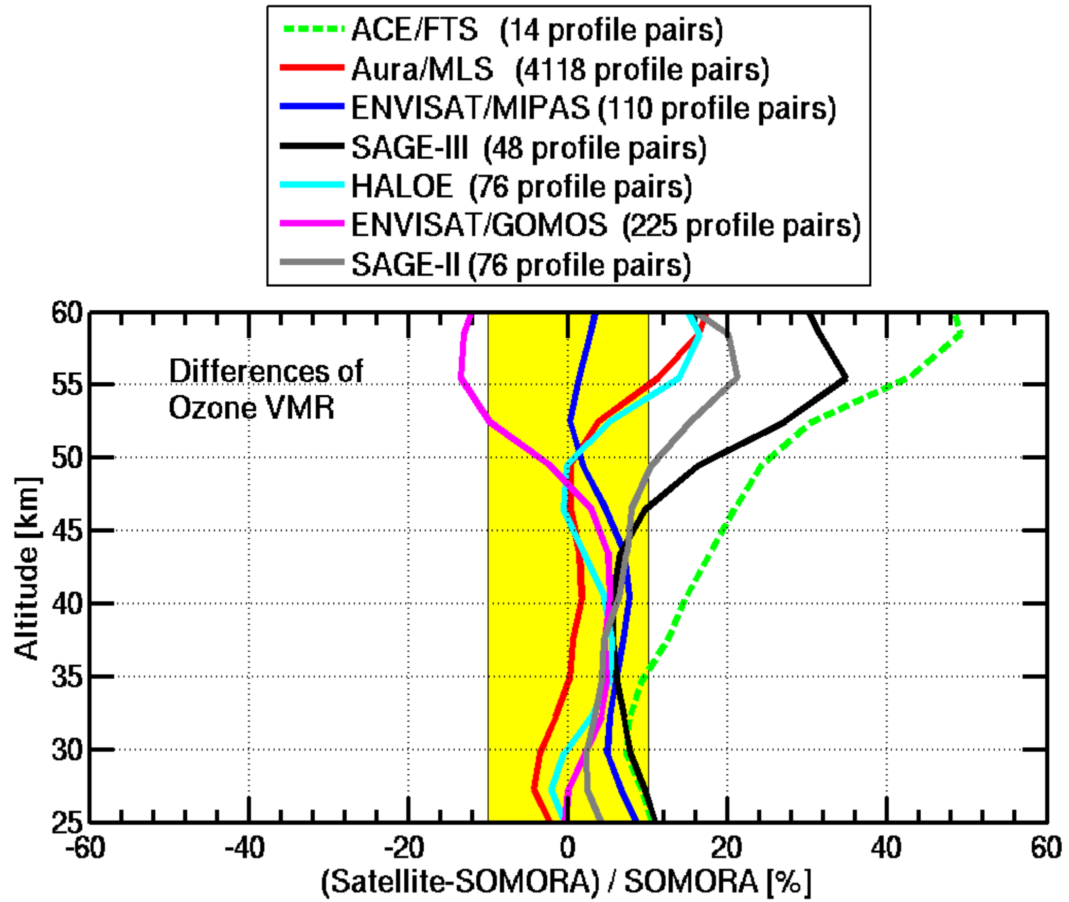
- **Aura/MLS** (microwave limb sounder)

- **ENVISAT/MIPAS** (infrared interferometer)



Cross-validation of satellite measurements by the SOMORA radiometer:

- Averaging kernel smoothing has been applied
- horizontal distance < 800 km from SOMORA in Payerne
- time difference < 1h between ground and satellite data
- data time intervals of the satellites are quite different



→ good agreement of all instruments at altitudes < 45 km

Double differencing of MIPAS and MLS:

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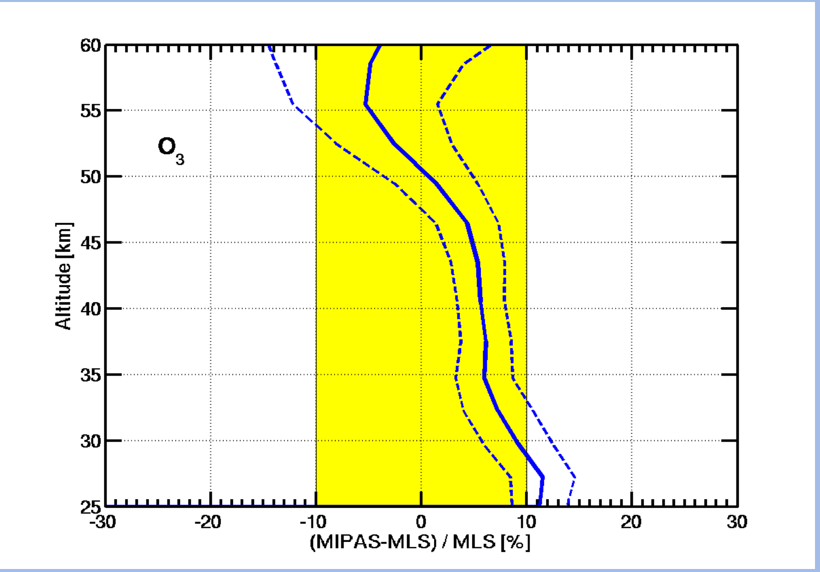
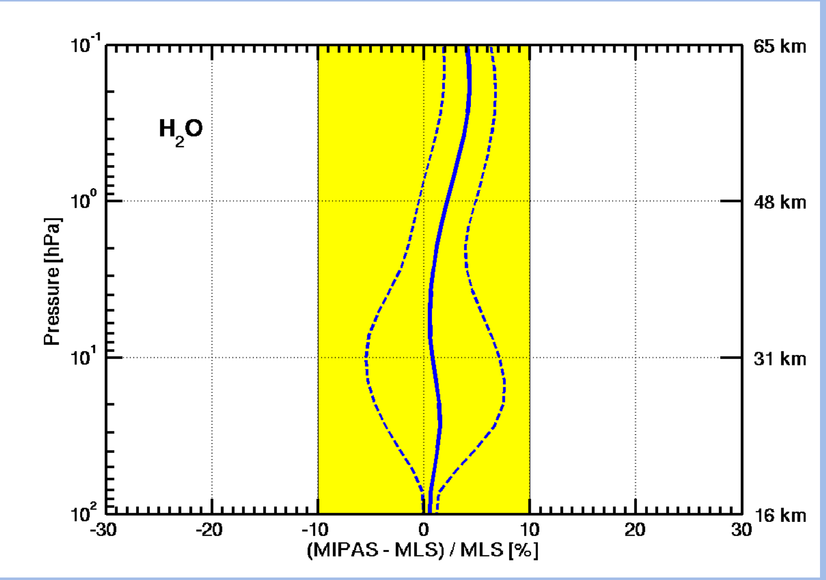
The available MIPAS data set stops in March 2004 while the MLS data set starts in August 2004. Double differencing with respect to SOMORA and MIAWARA gives:



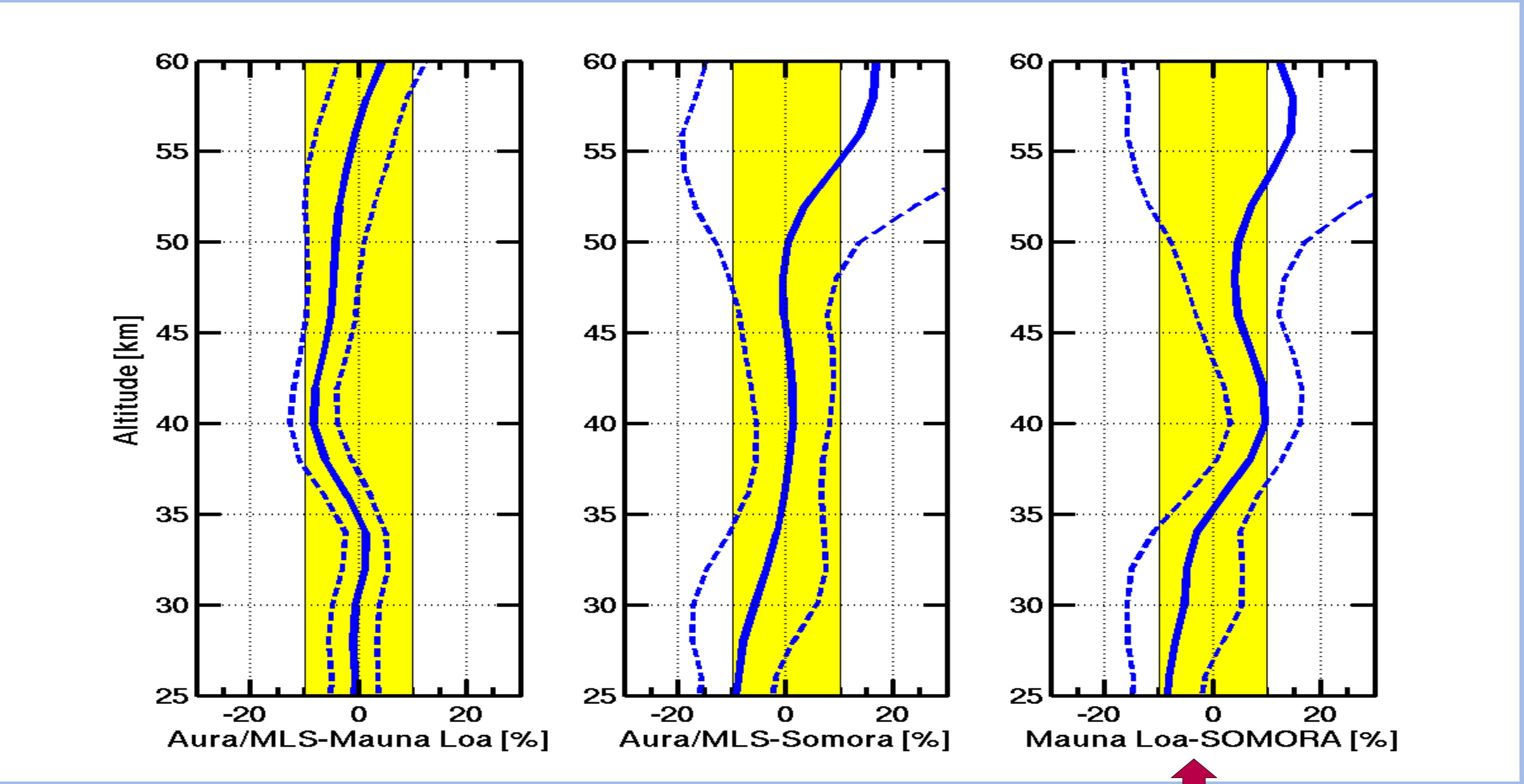


[(MIPAS -SOMORA) - (MLS-SOMORA)] / MLS

[(MIPAS -MIAWARA) - (MLS-MIAWARA)] / MLS

The agreement of the H_2O measurements of MIPAS and MLS is excellent (within 4%).

Cross-validation of the Payerne and Mauna Loa microwave radiometers by means of Aura/MLS:



(Mauna Loa – Aura) – (SOMORA – Aura) [%]

Mauna Loa data are from A. Parrish and I. Boyd for Oct-Dec 2005 and available via NASA's Aura Validation Data Center (B. Bojkov)

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A statistical comparison of Aura/MLS and SOMORA ozone profiles:

- the high data rate of Aura/MLS (1 profile /25 sec) provides around 2000-3000 coincident profile pairs per year and for one ground station at mid-latitudes

- a detailed statistical study of the dependencies of the ozone differences is feasible

Gaussian distribution of ozone differences:

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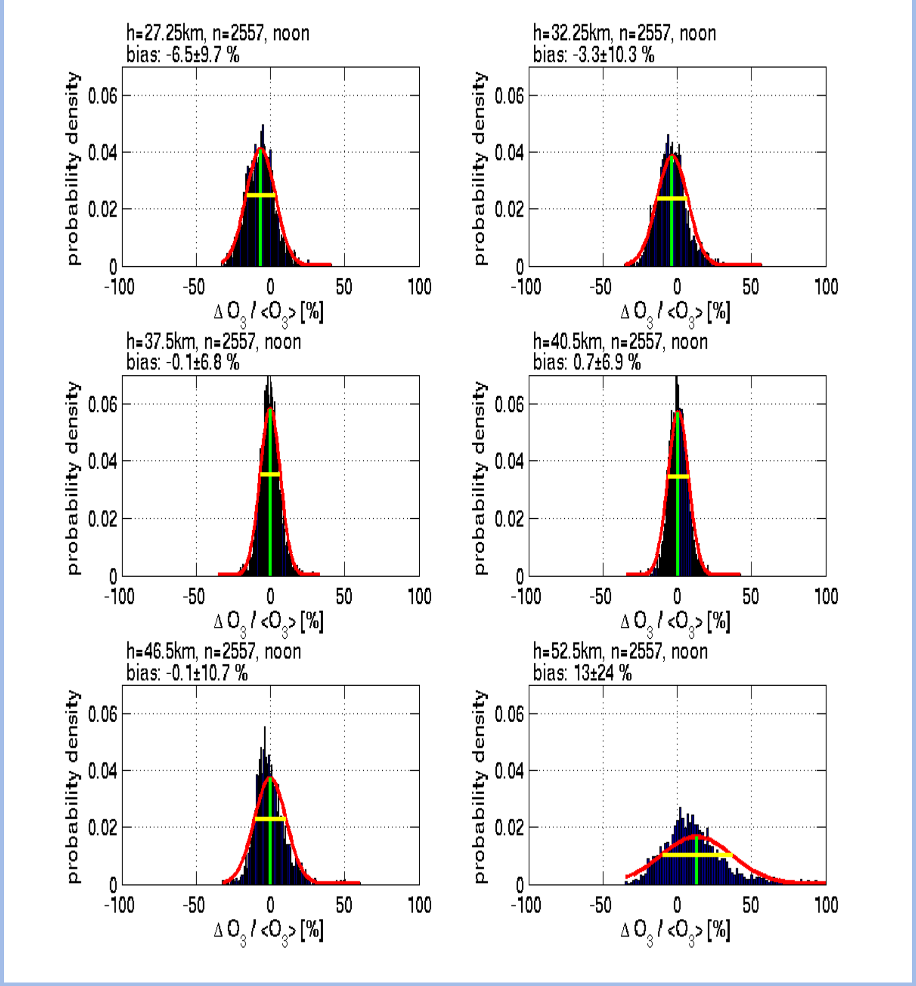
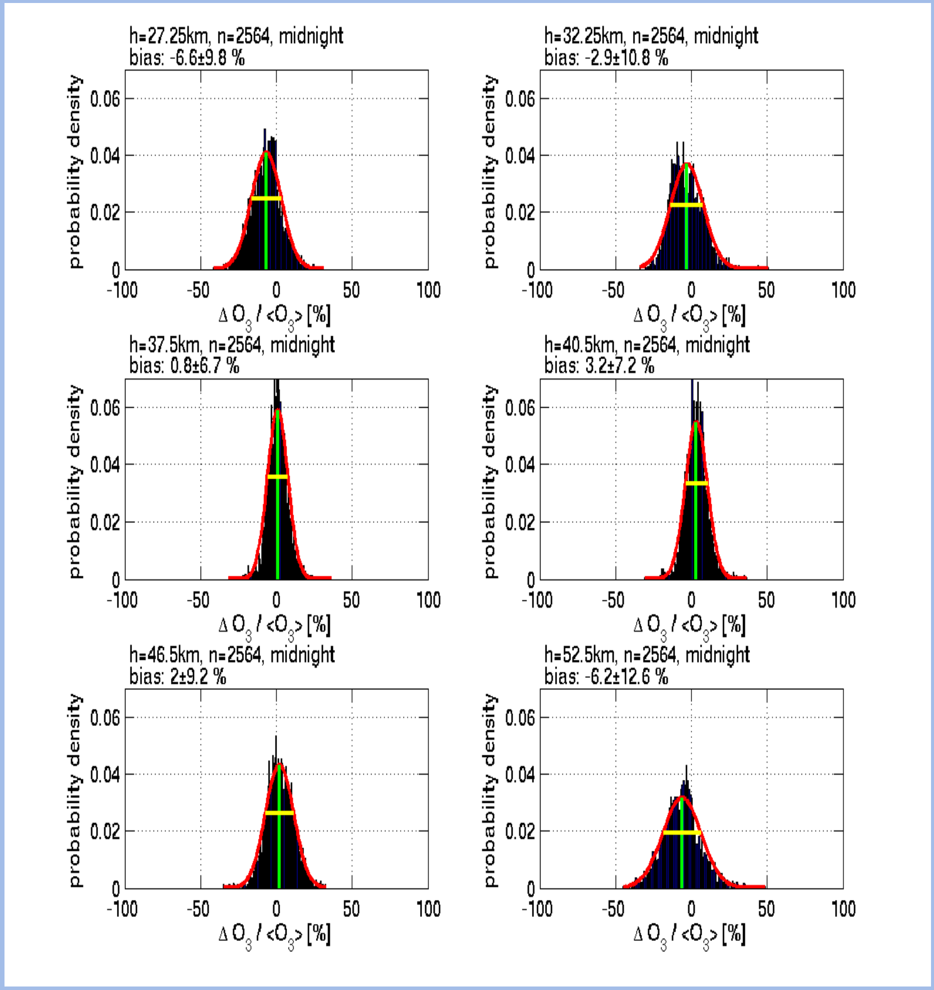
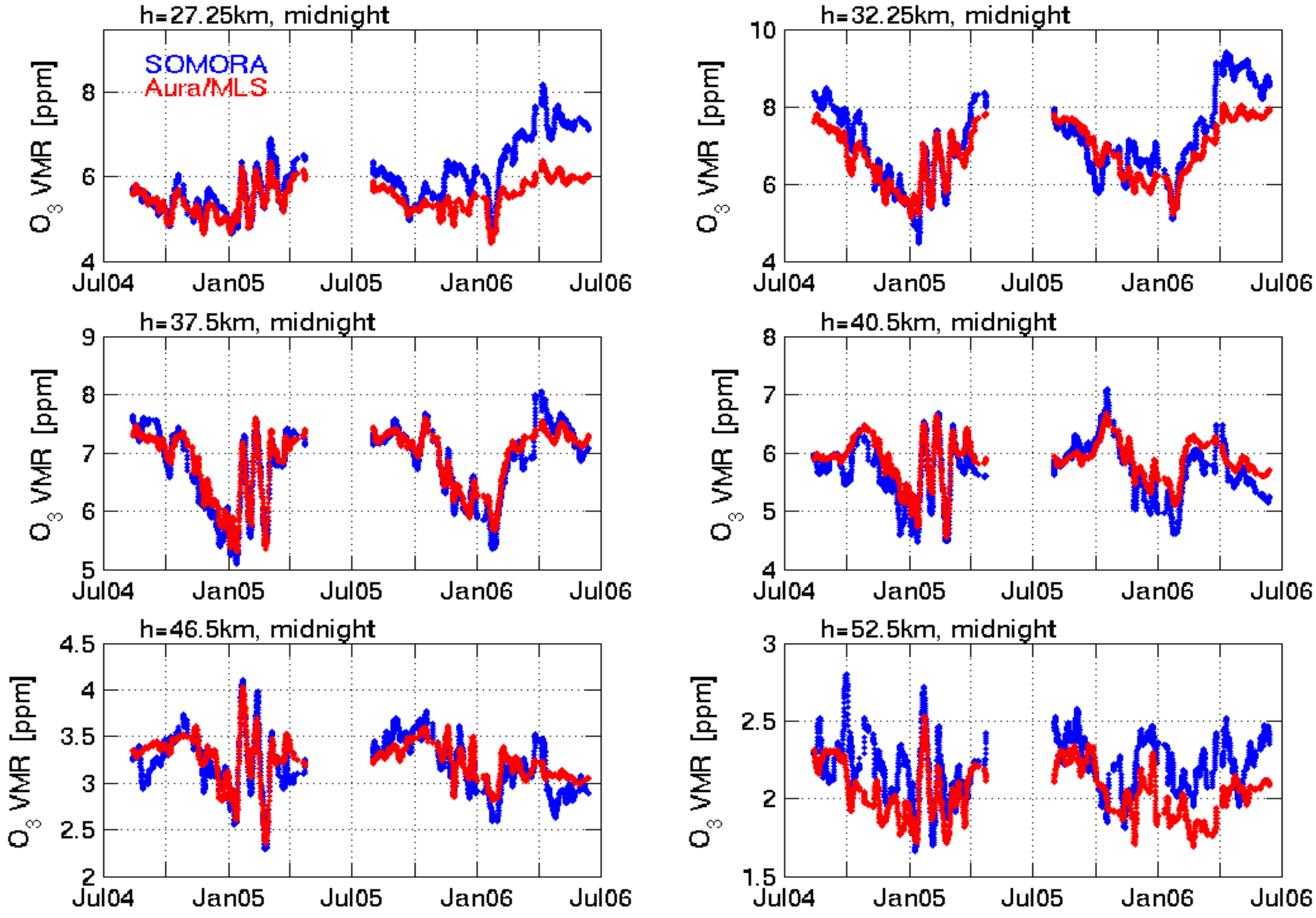




Noon **Midnight**

Time series of ozone vmr of Aura/MLS and SOMORA:



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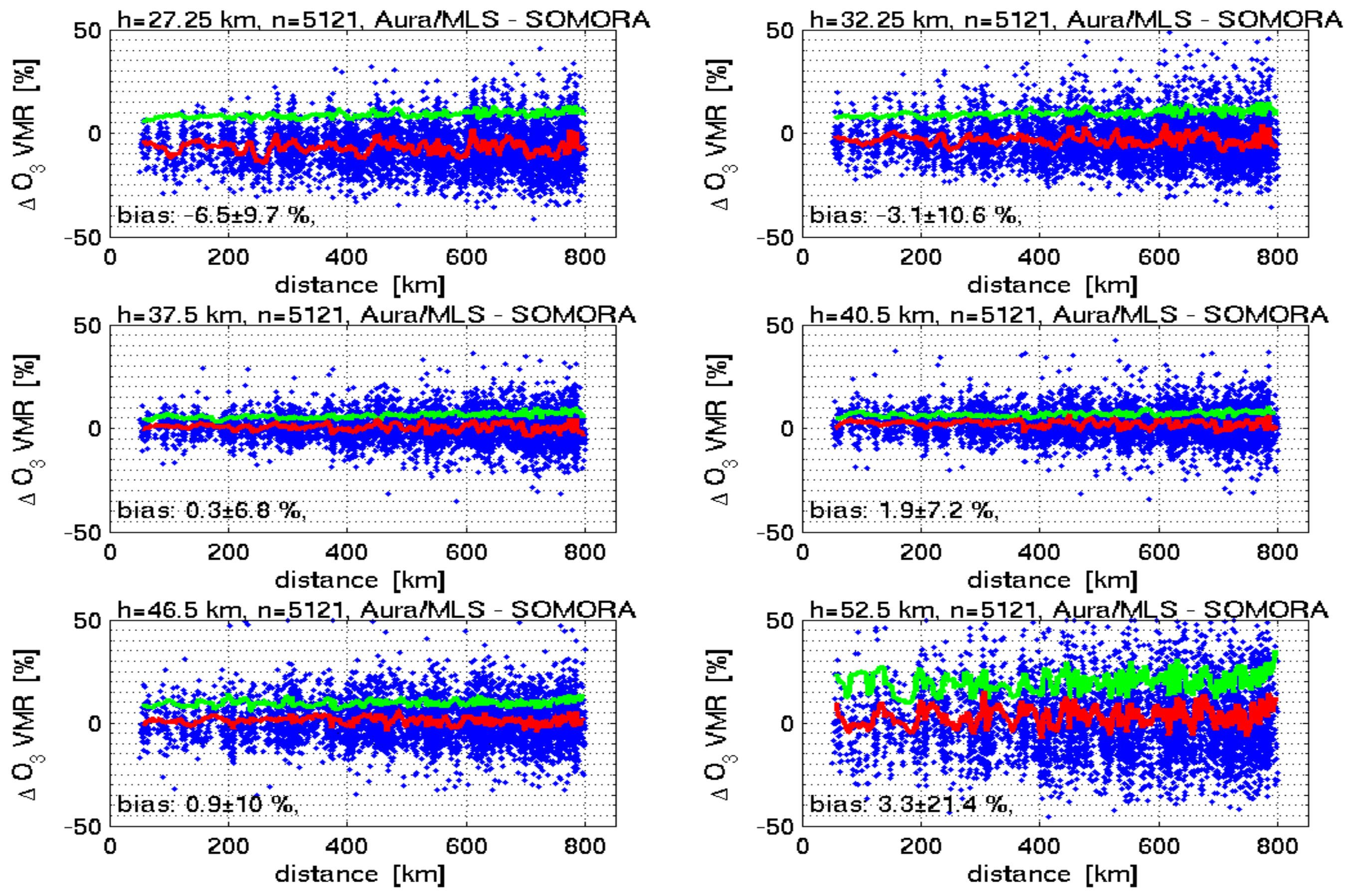
Dependence of ozone differences on horizontal distance:



Green line: standard deviation, red line: mean bias

Local maps of ozone differences around Payerne (+):

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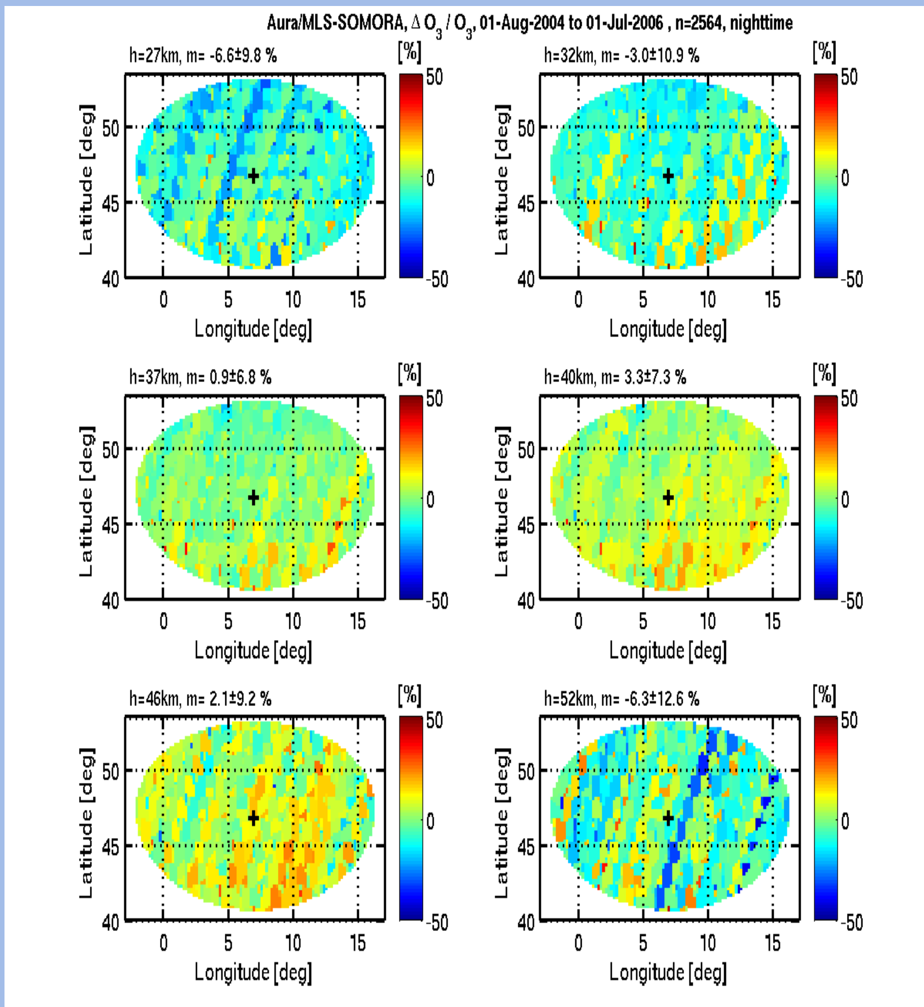
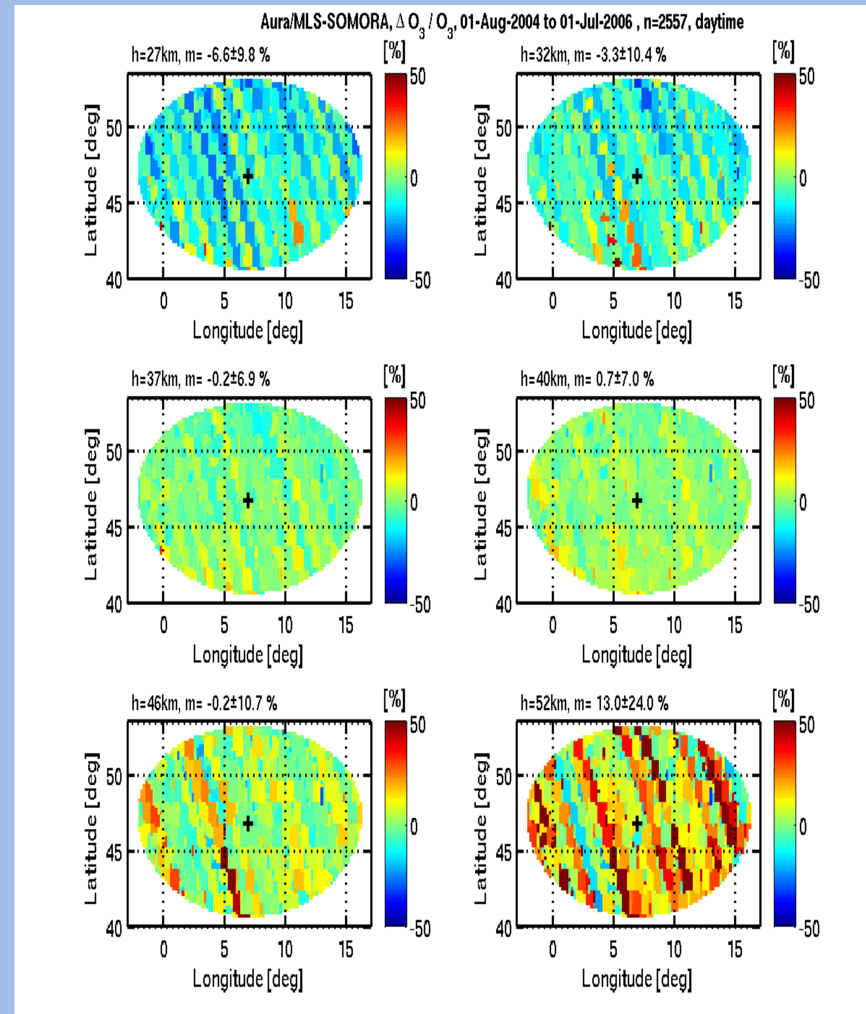
Midnight

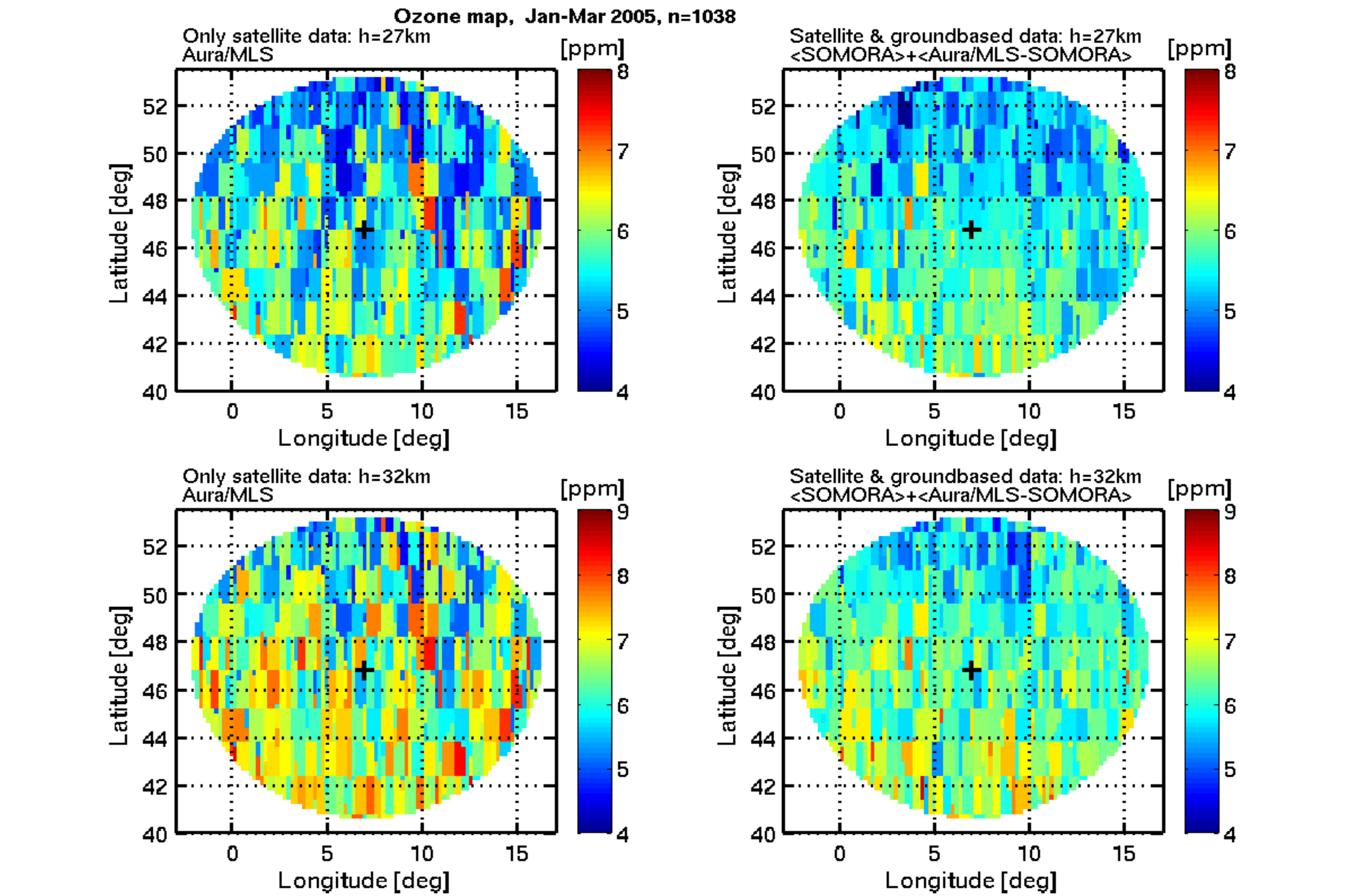


Noon



Synergy of ground- and spacebased measurements:

Reduction of temporal noise in Aura's ozone maps by use of the SOMORA ground station in Payerne:



Conclusions:

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- Ground- and space-based data are complementary
- Satellite data can be used for cross-validation of NDACC ground stations (e.g., Mauna Loa and Payerne). AVDC and Nilu CalVal data center provide all relevant informations in hdf-files (averaging kernels, a priori, ...)
- Ground station data can be used for cross-validation of not coincident satellite data (e.g., ENVISAT/MIPAS and Aura/MLS)
- Long term stability is most important for the ground station (constant bias is removed by double differencing)
- Statistical analysis of about 5000 profile pairs Aura-SOMORA gave information on spatial coincidence condition and probability density function
- Temporal noise in satellite ozone maps is reduced by means of ground station data