Inter-comparison of MAX-DOAS measurements of tropospheric HONO slant column densities and vertical profiles during the CINDI-2 Campaign

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26.02.2019

Overview:

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- Inter-comparison results of tropospheric HONO ΔSCDs
- Inter-comparison results of tropospheric HONO vertical profiles
- Sensitivity studies of HONO profile retrievals based on synthetic ΔSCDs
- Conclusion

Comparison schemes and participants for HONO ΔSCDs

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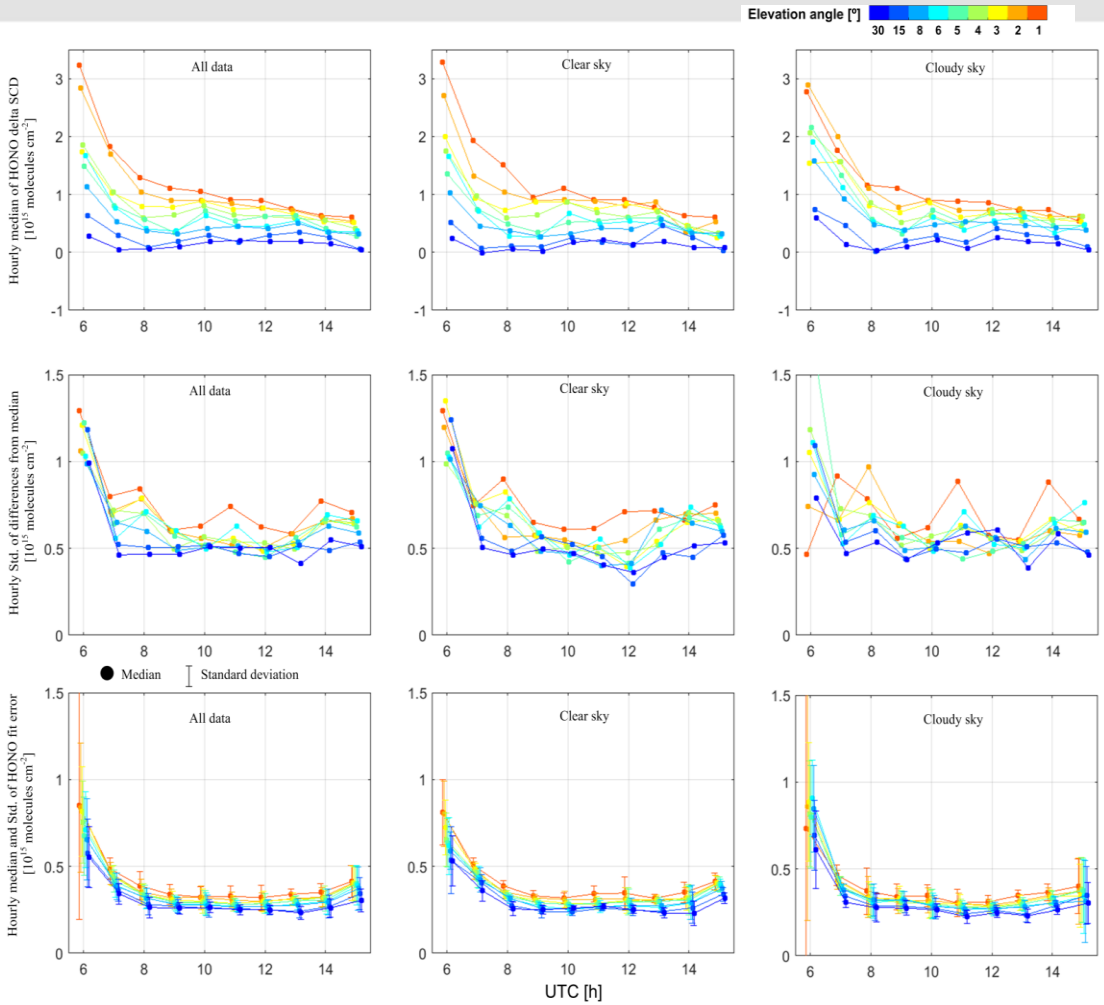
Comparisons of HONO ΔSCDs retrieved with the "daily noon FRS" and the "sequential FRS":

13 Participants for "**daily noon FRS**": BIRA, Boulder, MPIC, AIOFM, NIWA(1) (instrument #29), NIWA (2) (#30), DLR (1) (#13), DLR (2) (#14), USTC (1) (#13), USTC (2) (#14), CMA, BSU, AMOIAP.

13 Participants for "**sequential FRS**": BIRA, Boulder, MPIC, AIOFM, NIWA(1), NIWA (2), DLR (1), DLR (2), USTC (1), USTC (2), CMA, CSIC, LMU.

Inter-comparison results of tropospheric HONO ΔSCDs: Statistic inter-comparisons



Main findings:

Median HONO ΔSCDs: peak value at 6 UTC and steep decrease afterwards; large spread along elevation angles (EA)

Std of data from median values:

a. Peak values (~1.2×10^{15} molecules cm^{-2}) at 6 UTC; usually ~0.6×10^{15} molecules cm^{-2}.

b. relative difference of 40-100% at 1° and 200%-400% at 30° EA

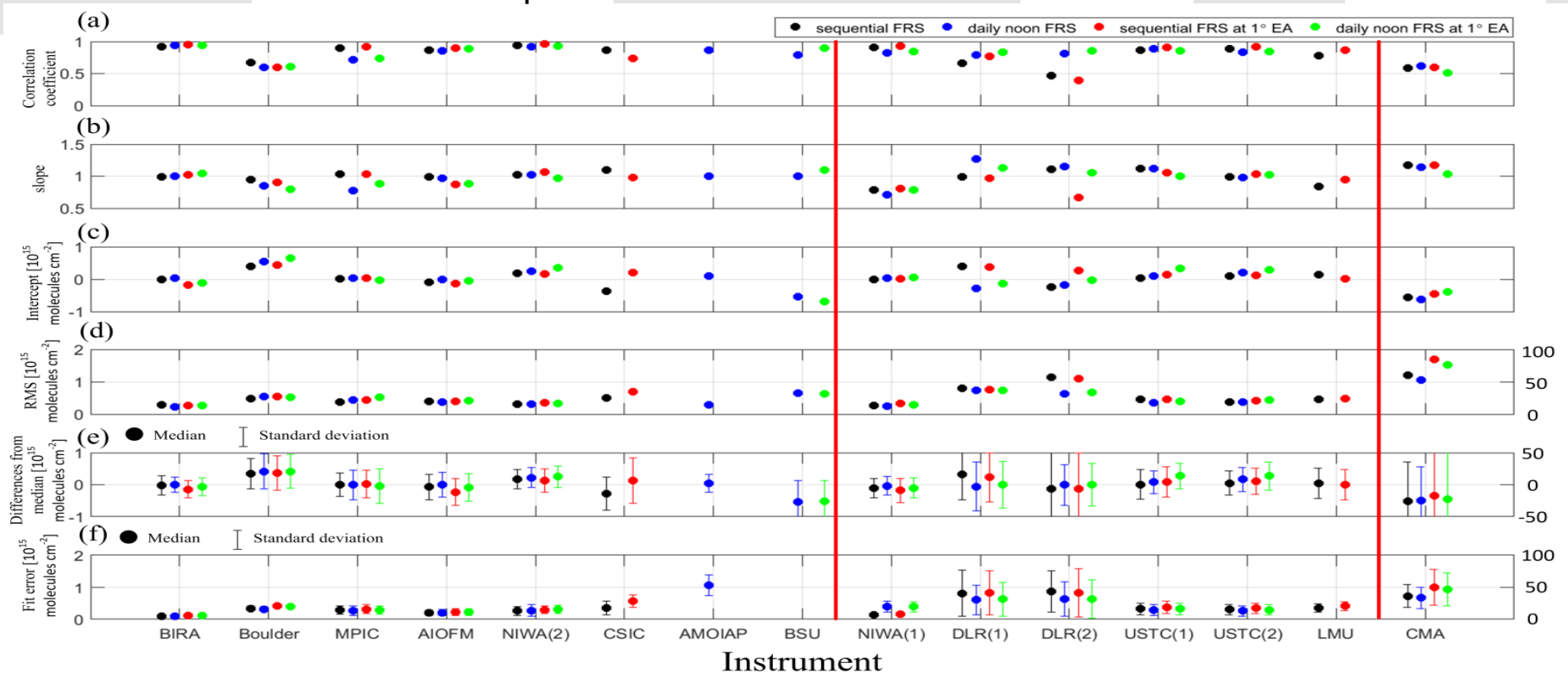
Fit errors: generally smaller than standard deviations by 40% to 100%, but similar diurnal variations.

Cloud effects: slightly larger std of differences and fit errors

Note that: only coincident results of 2D and 1D system (first 15 min of each hour) are included ; sky conditions are derived from the MPIC MAX-DOAS measurements using the MPIC sky cloud classification scheme.

Comparison results for individual data sets

in-house developed | EnviMes | Mini DOAS



Following: RMS (linear regression) -> Random discrepancies; median differences, slopes, and intercepts-> systematic differences of all data, large values, low values.

Main findings: Mostly **systematic discrepancies** $< \pm 0.3 \times 10^{15}$ molec. cm^{-2} (typically **15%** of a large ΔSCDs of 2×10^{15} molec. cm^{-2}), **random discrepancies around** $< \pm 0.6 \times 10^{15}$ molec. cm^{-2} (typically **30%**); large discrepancies of CMA (mini MAX-DOAS); substantially larger biases of both "DLR" than both "USTC", but from the same spectra, indicating **effects of implementation of DOAS fits by individual analysts**; generally **negligible effects of using two different FRS**; similar results between for 1° and all EA; Similar RMS with DOAS fit error indicating **contribution of instrumental noise to random discrepancies**.

Comparison schemes and participants for HONO profiles

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Task title	Task activity	participants
T1a	Retrieve profiles from the **HONO ΔSCDs retrieved from individual instruments** with the **"sequential FRS"**.	MPIC (PriAM) , BIRA (BePro), CMA, AIOFM (PriAM) ,USTC (1) (HePro), USTC (2) LMU (3M)
T1b	Retrieve profiles from the **HONO ΔSCDs retrieved from individual instruments** with the **"daily noon FRS"**.	MPIC, BIRA, CMA, AIOFM, USTC (1) ,USTC (2)
T2a	Retrieve profiles from **the common HONO ΔSCDs** using **common aerosol profiles**	MPIC, BIRA, BIRA MMF, AUTH, USTC
T2b	Retrieve profiles from **the common HONO ΔSCDs** using **retrieved aerosol profiles from the common O_4 delta SCDs**	MPIC, BIRA, BIRA MMF (MMF), AUTH (HePro), USTC (HePro), MPIC(MAPA)

Overview of VCD and near-surface VMRs in Task T2b (common HONO and O_4 SCD)

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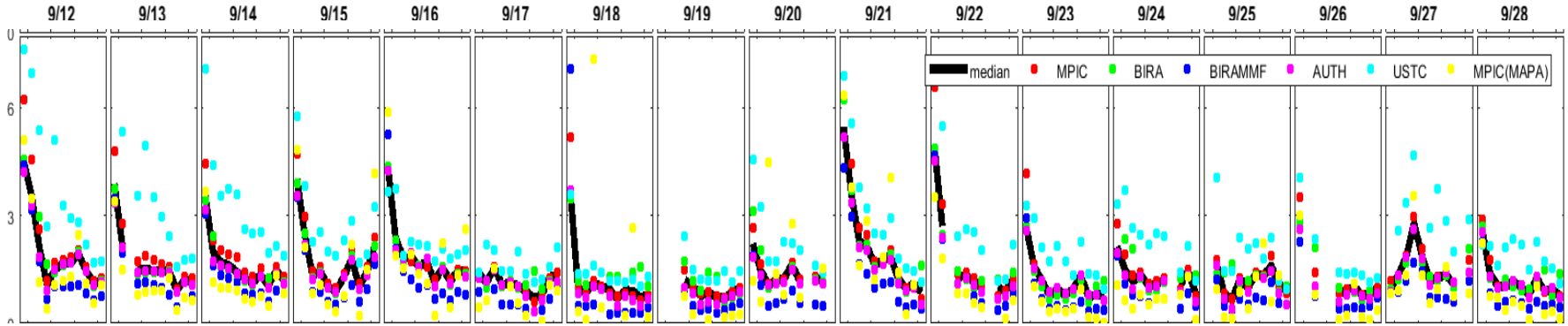
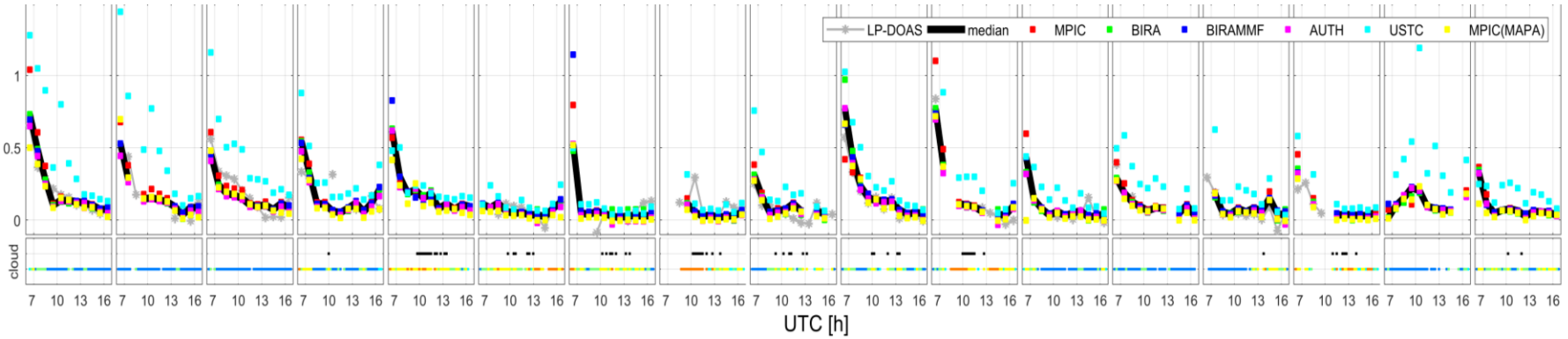
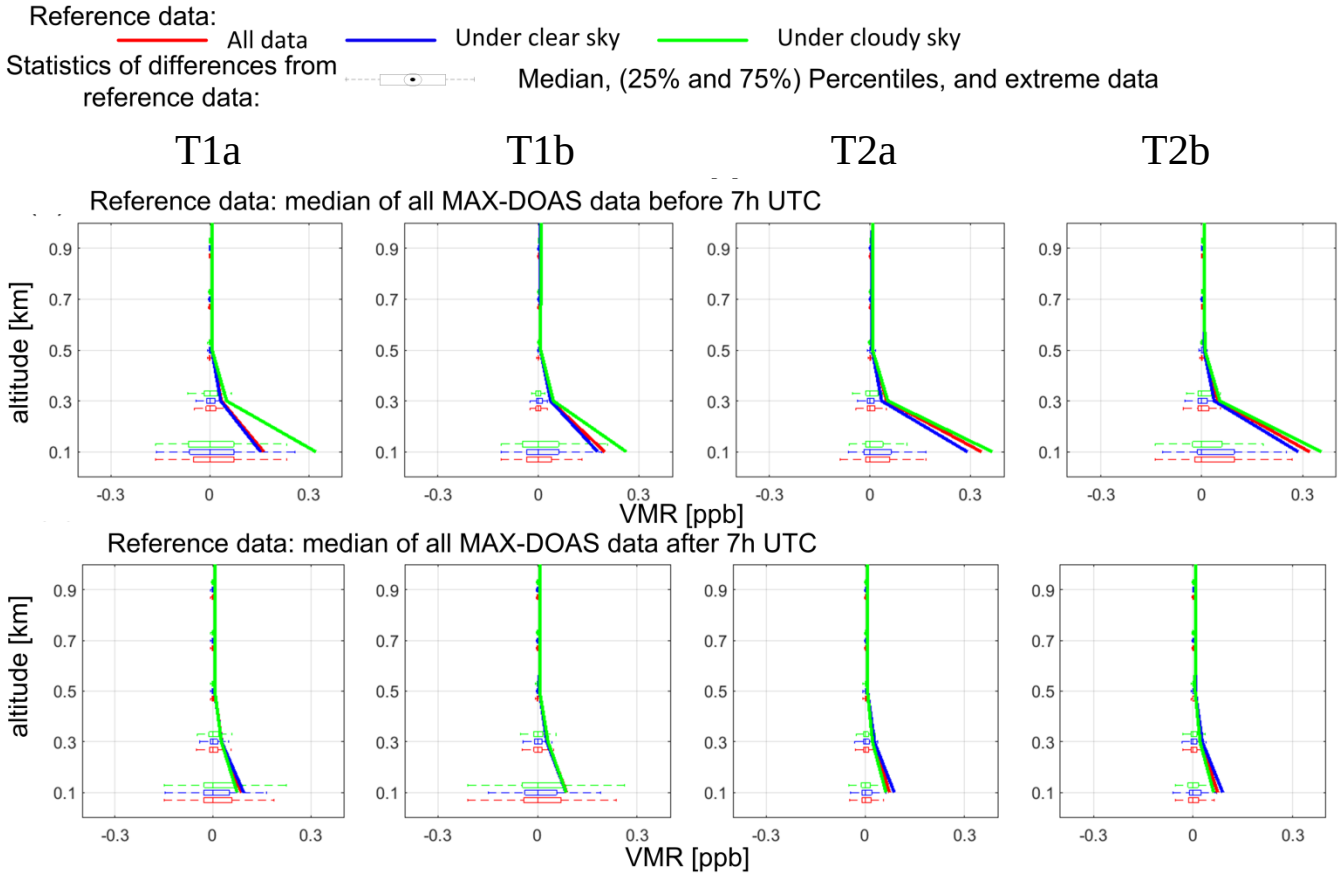
HONO VCDs



Surface HONO VMRs



Inter-comparison results of tropospheric HONO vertical profiles: Statistic inter-comparisons

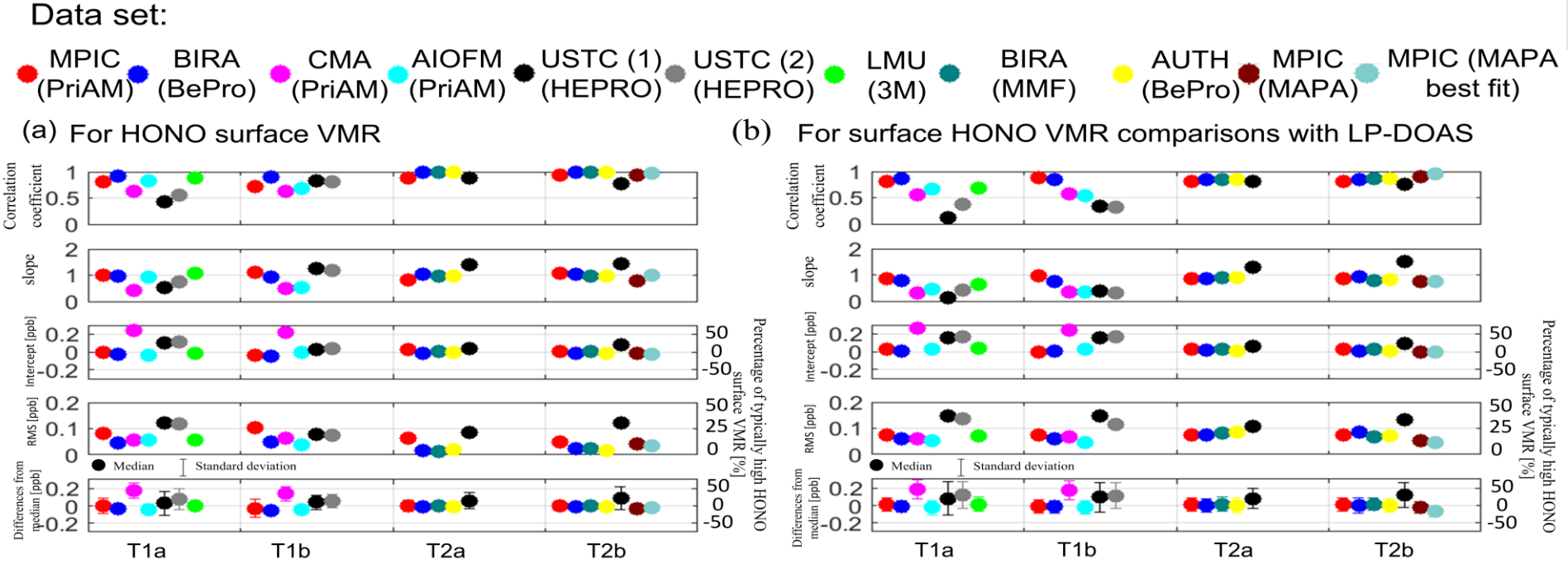


HONO accumulated near the surface.

MAPA not included

discrepancies are much larger in the lowest altitude range of 0 to 0.2 km than at high altitudes.

Individual comparison results of near-surface VMRs



Comparisons with the median values:

For Task 1, both systematic and random discrepancies are mostly in ~ $\pm$ 0.1 ppb (~ 20% of a typical large VMR).

For Task 2, both systematic and random discrepancies are mostly in ~ $\pm$ 0.02 ppb (typically ~ 5%).

-> Diff. of ΔSCDs dominate discrepancies of profile results;

For Task 2, extreme discrepancies of ~ 0.1 ppb (typically ~ 25%) (USTC). -> implementations of profile inversion algorithms by analysts could also cause comparable discrepancies with those caused by discrepancies of ΔSCDs.

Effects of FRS selections and aerosol retrievals on discrepancies of HONO profile results are not significant.

Comparisons with the LP-DOAS values:

Similar RMS (random discrepancies) and median differences (systematic discrepancies) with the comparisons with the median values. For Task 2, considerable overestimation is only found for the USTC data.

Sensitivity studies of HONO profile retrievals based on synthetic ΔSCDs

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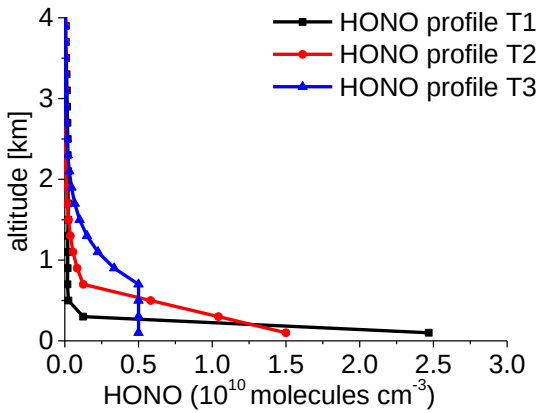
Synthetic HONO delta SCDs are generated by Bremen using the RTM SCIATRAN, version 3.6.0:

- geometries according to the real measurements on 14/09/2016
- in a pseudo-spherical atmosphere with pure Rayleigh scattering
- Three HONO profiles with a typical temperature and pressure profile during the campaign

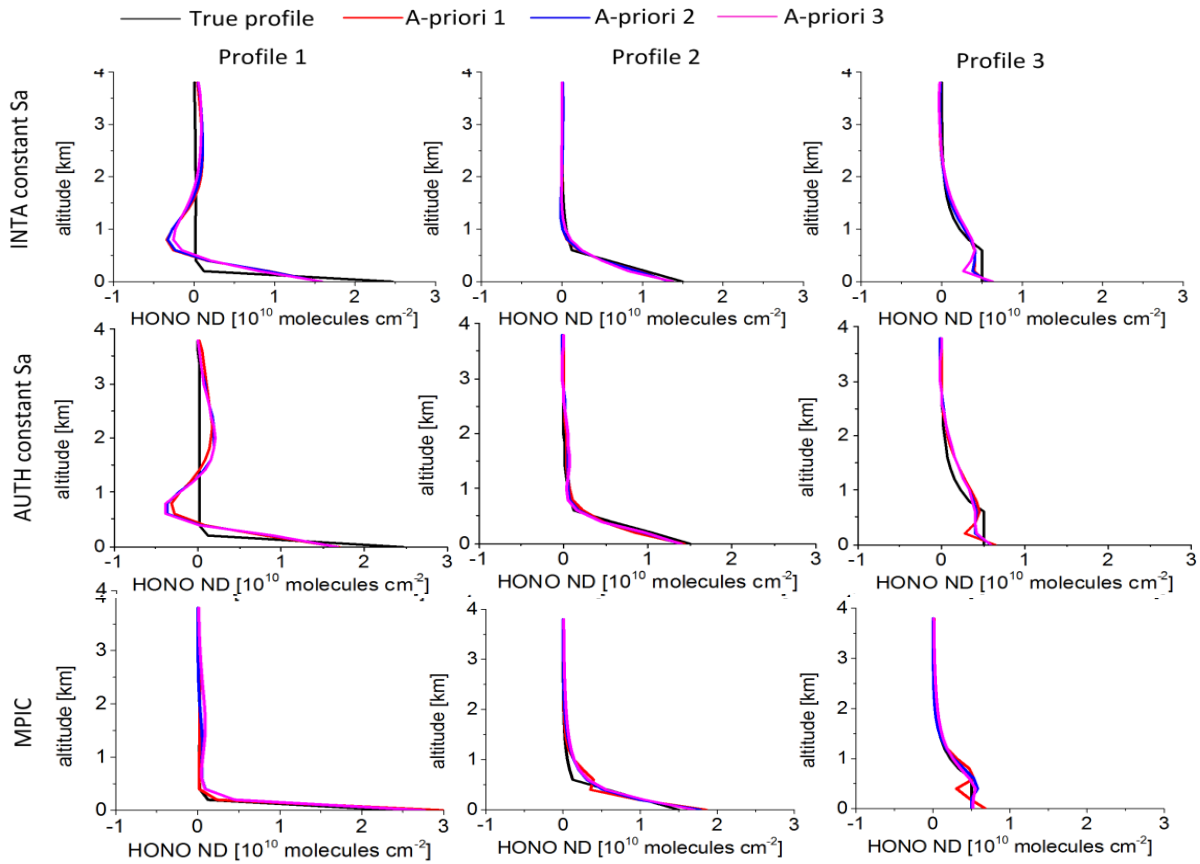


Participants: INTA and AUTH using the "BePro" algorithm; MPIC using "PriAM"

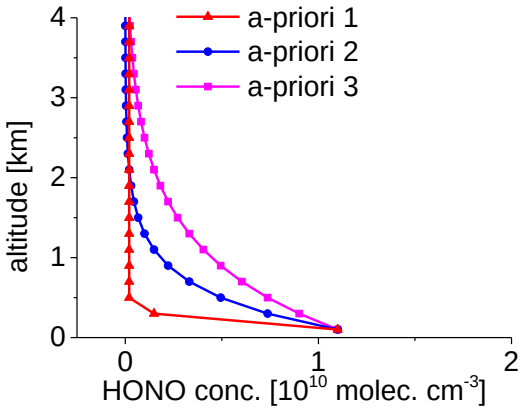
Differences of the two algorithms:
PriAM: nonlinear optimal estimation and logarithmic space
BePro: linear optimal estimation
logarithmic space causes different Sa in PriAM and BePro:

In BePro, diagonal elements of Sa at altitude z is square of 100% a-priori at z <-> In PriAM, diagonal elements at all altitudes are unity.

Sensitivity studies of HONO profile retrievals based on synthetic Δ SCDs



A priori profiles:



INTA and AUTH (BePro): results considerably deviate from real profiles due to a-priori constants

MPIC (PriAM): well consistent no matter which a-priori is used

"constant Sa" for BePro: Sa diagonal values are set as a constant value at all altitudes, which is square of 100% of the a-priori value in the lowest altitude grid.

If constant Sa used for BePro: much less dependent on a-priori profiles.

Conclusion:

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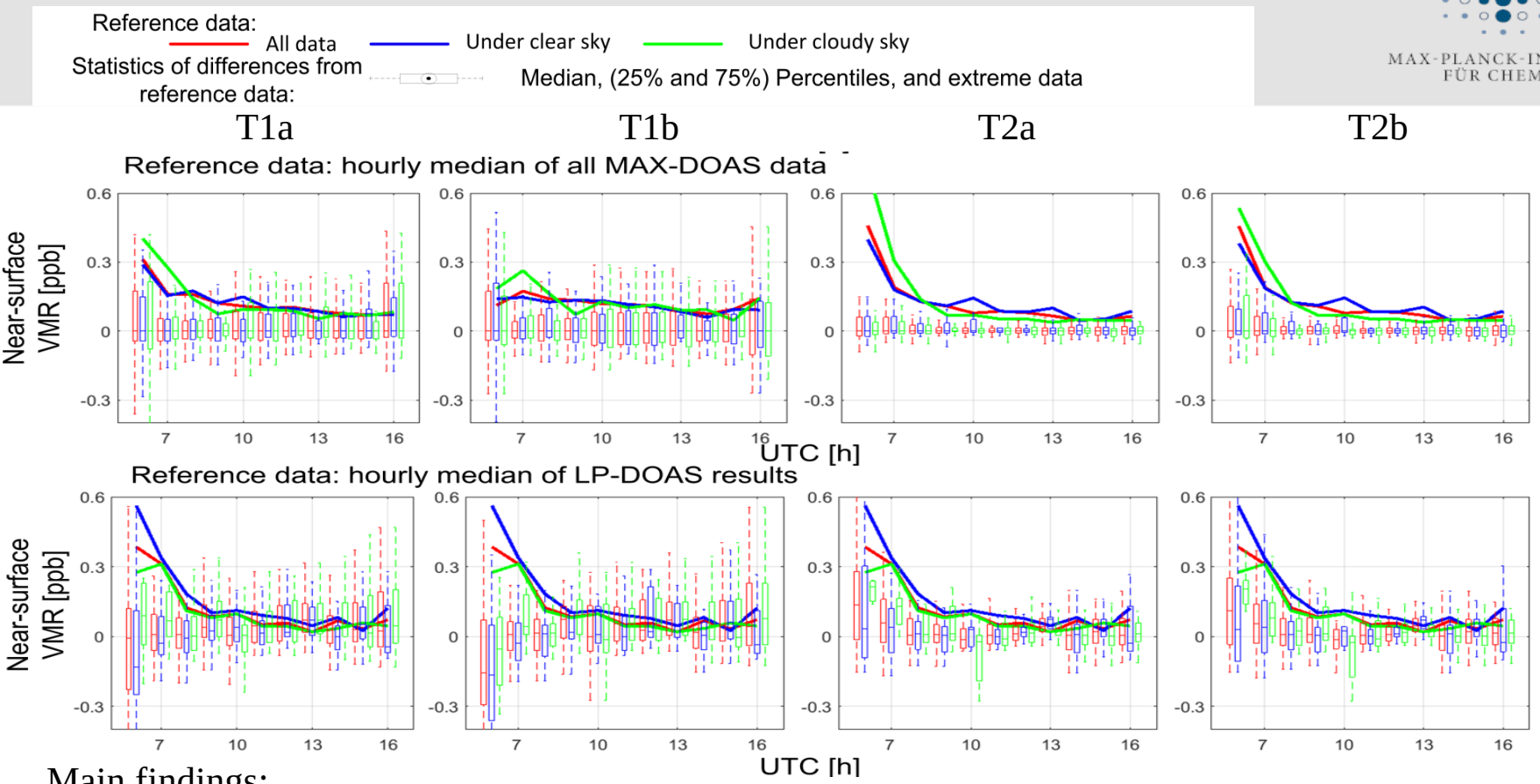
- HONO ΔSCDs: systematic and random discrepancies are typically in 15% and 30% of a large delta SCD of 2×10^{15} molec. cm^{-2}. HONO near-surface VMRs: systematic and random discrepancies are mostly in ~ 20% of a typical large VMR of 0.5 ppb. Profile retrievals normally contribute discrepancies of 5%, remaining discrepancies are mainly due to discrepancies of HONO ΔSCDs.
- Inappropriate implementations of DOAS fits and profile inversion algorithms can cause 2 times larger discrepancies.
- Effects of clouds and the FRS selections on discrepancies of HONO ΔSCDs and profile results are not critical.
- Synthetic analysis indicates: profile inversion algorithms developed based on the optimal estimation method with proper configurations (Sa) can well respond to different HONO profile shapes.
- The first version of the paper will be sent around in the next few weeks.

Statistic inter-comparisons of near-surface HONO VMRs



Main findings:

Differences of near-surface VMRs from the median values:

For T1a and T1b, VMR diff. mostly in -0.04 to 0.08 ppb; For T2a and T2b, VMR diff. mostly in ±0.02 ppb;

-> Diff. of ΔSCDs dominate discrepancies of profile results;

Comparisons with LP-DOAS:

A large percent of data are lower than LP-DOAS at 6 UTC by up to 0.3 ppb (~75%) in T1a and T1b.

Cloud effects on discrepancies are not significant.