Ground truthing long-term ozone trends from satellites

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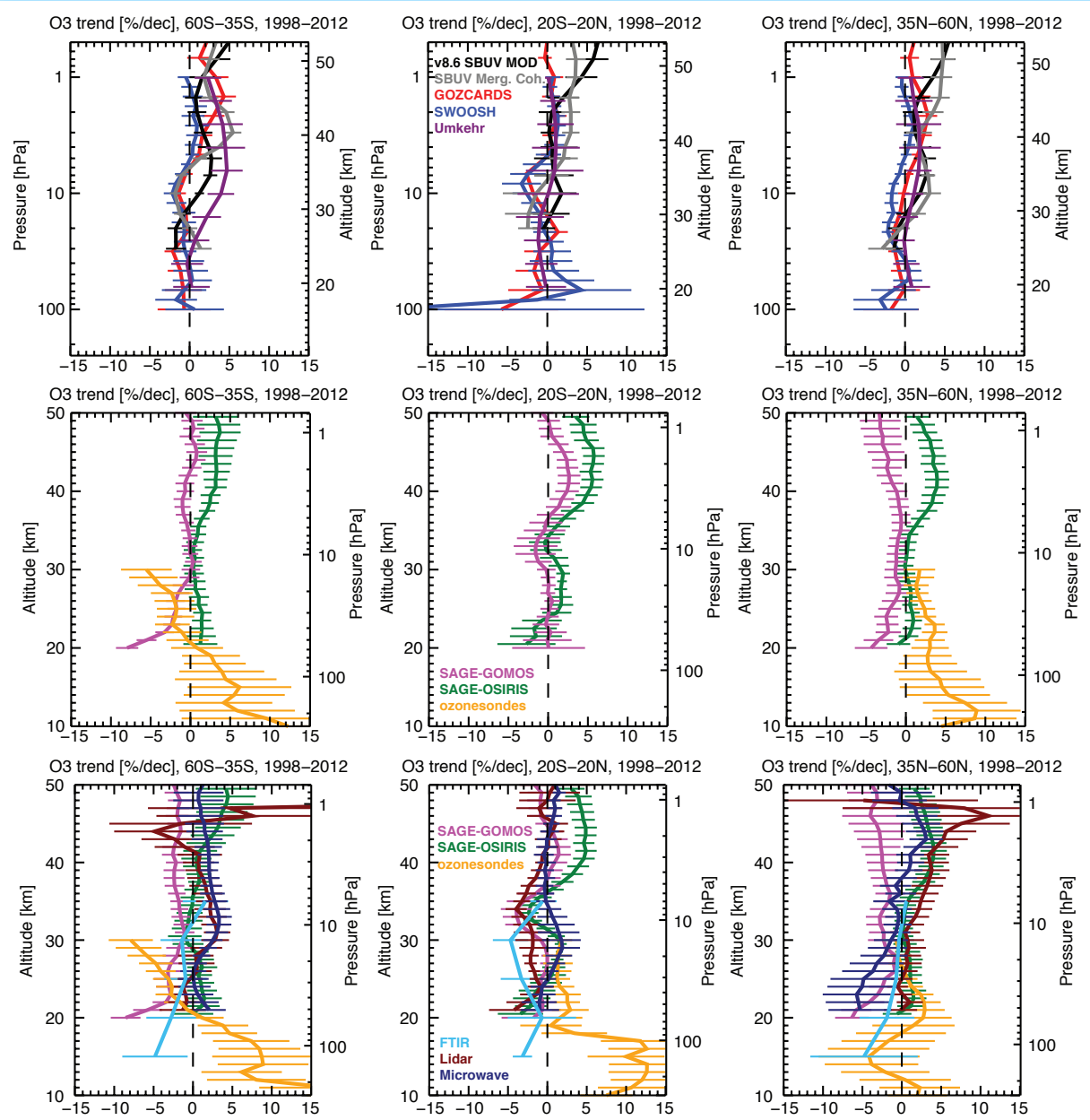
Motivation

- Requirements that are imposed on ground-based data to evaluate long-term trends
- What did we learn from the SI2N Initiative?
- Specific problems? Missing information? Gaps?
- Facilitation of trend analysis with well defined uncertainties
- Implications for the future (data selection, information needed, etc.)

SI2N - Overview

- SI2N: SPARC/IO3C/IGACO- O3/NDACC (SI2N) initiative
- Aim of updating knowledge of changes in the vertical distribution of ozone
- Ground-based and satellite measurements of ozone profiles were revisited and improved *(Hassler et al., AMT, 2014)*
- Standardized comparison of single-instrument satellite data records to ozonesonde and O3 lidar networks *(Hubert et al., AMTD, 2015)*
- Standardized comparison of combined data sets (built on more than one measurement system) *(Tummon et al., ACP, 2015)*
- Standardized trend analysis of all individual measurement systems *(Harris et al., ACP, 2015)*
- Attempt of quantifying the uncertainties on trends with combining different trend estimates *(Harris et al., ACP, 2015)*

Lessons learned from SI2N



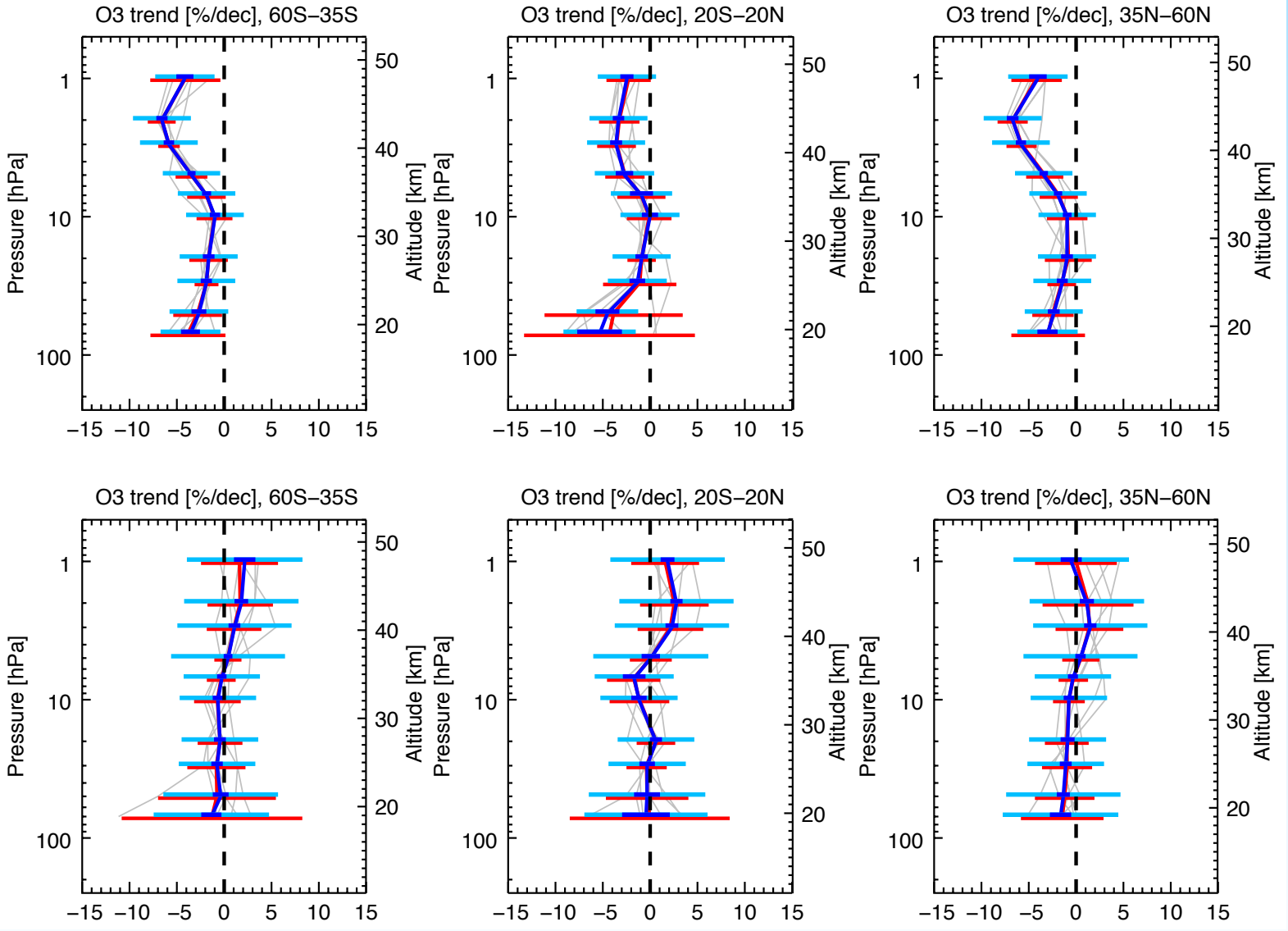
- Ozone trends in [%/dec] for the period 1998-2012, for three different latitude bands
- Same methodology, same data pre-processing, same time period, same uncertainty treatment for all data sets
- Many different trend results for individual measurement systems
- All measuring the same atmosphere, but the results are very different!

(Harris et al., ACP, 2015)

Lessons learned from SI2N

1979/84 – 1997

1998 – 2012



(Uncertainty estimates based on methodology introduced in the SPARC CFC lifetime report: *Appendix 2 of Chapter 6 in Ko et al., 2013*)

(Harris et al., ACP, 2015)

Lessons learned from SI2N

- How to treat the uncertainties of the individual trend estimates?
- Simple approach (averaging, simple error propagation) underestimates the real uncertainties
- How to incorporate drifts of satellite measurements in the uncertainty estimates?
- Uncertainties still clearly above the goal of ~5%/dec for measurement systems, supposedly mainly caused by instrument drift

Lessons learned from SI2N

So, what now?

Implications for the future

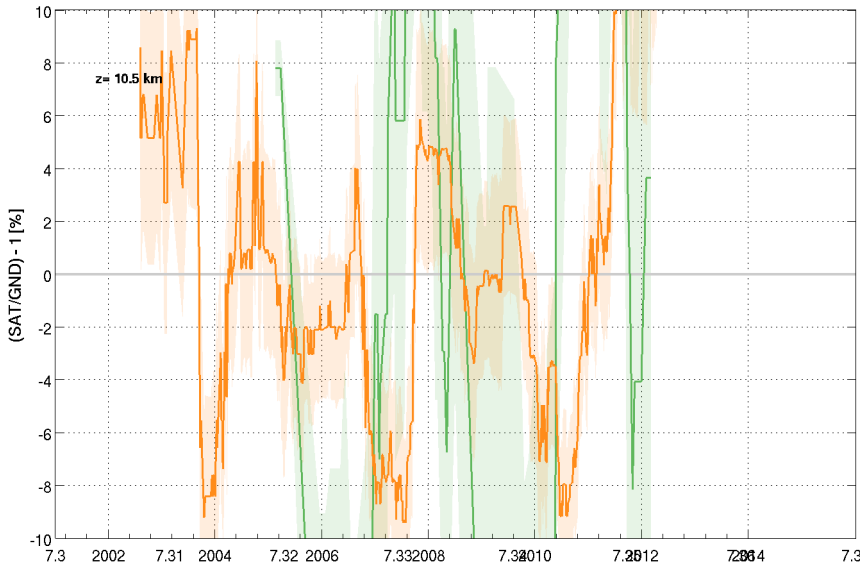
1. High-quality ground-based instruments are critical for high-quality, well understood satellite measurements

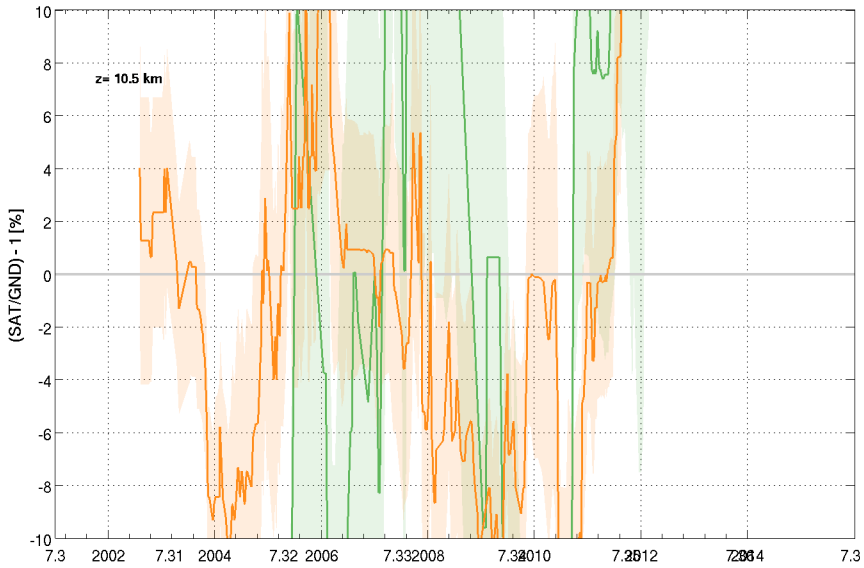
- Ground-based measurements can be regularly calibrated
- Stability of measurements is relatively well understood
- Uncertainties can be quantified and described
- Need to consider impact of # and location of instruments
- Ensure ground-based measurements remain independent from satellite records

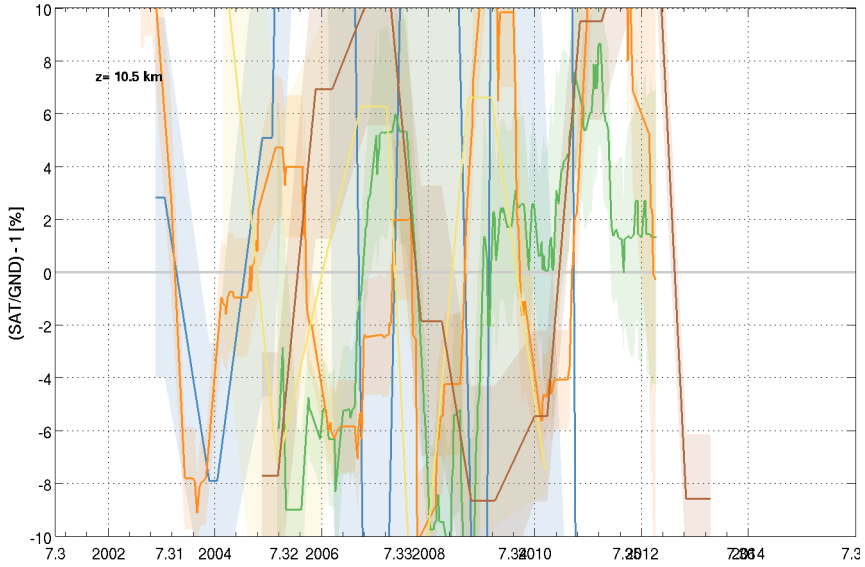
Why?

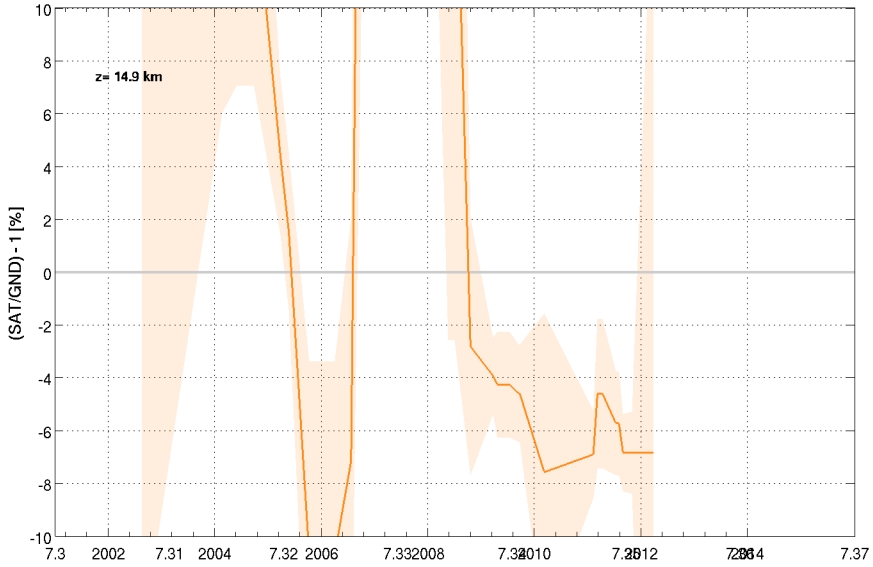
- Satellite instruments drift and degrade over time
- These changes need to be quantified to be accounted for when looking for long-term changes in constituents
- With current uncertainties on ground-based measurements it is possible to verify relatively small uncertainties for combined data sets (e.g. ~3-5%/decade)

Clear structure in space and time



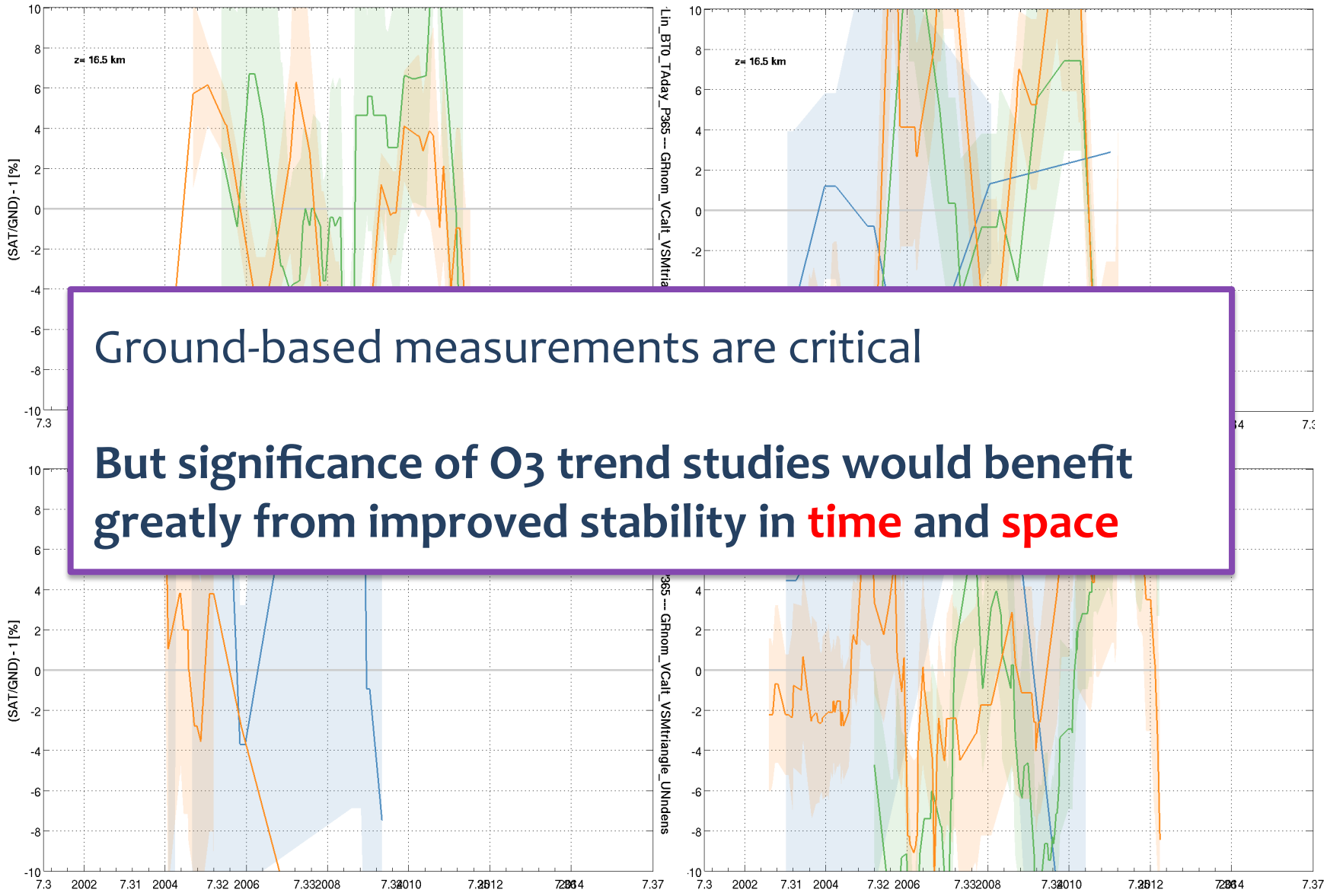






Debiased comparison timeseries at 4 sonde stations for 6 satellite instruments

Clear structure in space and time

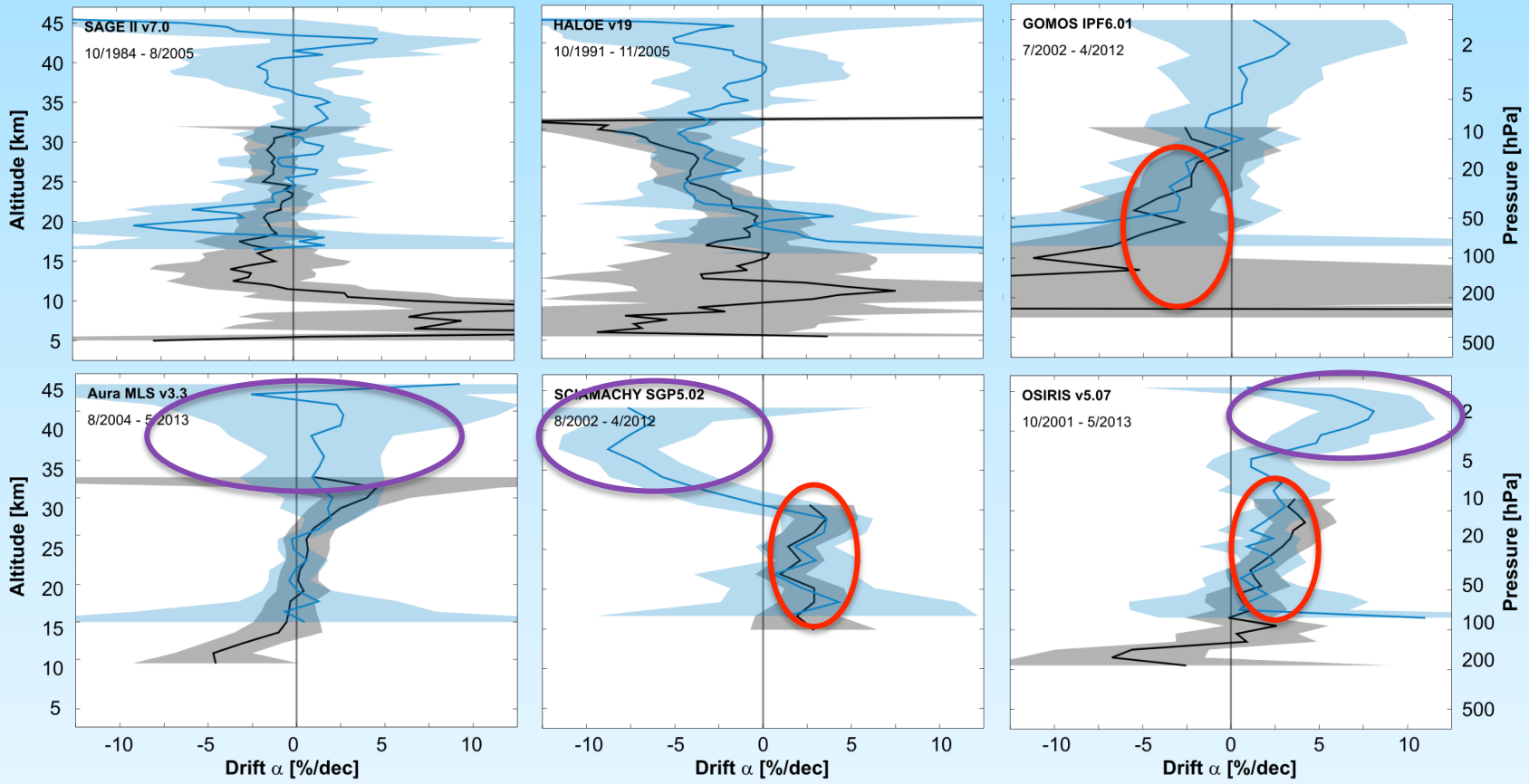


Ground-based measurements are critical

But significance of O3 trend studies would benefit greatly from improved stability in time and space

Debiased comparison timeseries at 4 lidar stations for 6 satellite instruments

Improve ground network homogeneity



(Hubert et al., AMTD, 2015)

- Current drift 2σ detection threshold is about 2-4% / decade
- These thresholds would be up to 2x smaller for many recent satellite records, if ground observations were perfectly homogeneous from one station to another

From O3 drift estimate perspective…

… the following things would be desirable (prioritized):

1. Continuation of observations at stations with long-term records, especially the lidar stations
2. Improved homogeneity across the ground networks, e.g. O3S-DQA for ozonesonde, GRUAN , …
3. Maintain / start observations in tropics and Southern mid-latitudes, progress towards latitude-dependent satellite drift estimates
4. Improved stability at individual stations, especially in the upper stratosphere
5. Document any changes that may impact timeseries, and share those with the users (!)
6. …

Implications for the future

2. Be selective!

- Selective about each individual data point that is used
- Selective about which satellite instruments are combined
- Selective about which ground-based stations are used for ground truthing
- In all these, the validation and intercomparison of multiple records in a standardized way is truly vital

Why?

- For trends, it's all about reducing uncertainties
- It might not help the overall uncertainties by just combining more individual instruments
- With better selection of what will be combined the uncertainties can be reduced

Implications for the future

3. Increase information content of data

- New methods, e.g. combined retrievals for different ground-based measurement systems
- Not enough anymore to just add measurements to the suite of available data, make sure they are consistent with those collected earlier on, and those at other (nearby) stations
- Focus on different vertical resolution, region of sparse data sampling, time of sparse data sampling, etc.
- Document any changes (when & what) that can impact the timeseries

Why?

- Again: It's all about reducing uncertainties
- But also about refining our current uncertainty estimates, e.g. establish potential latitude-dependences of drift

"The need to ensure that both the quality and relative stability of the satellite instruments are known requires a complementary capability for independent assessment, most likely from the ground-based instruments in the NDACC and WMO-GAW observing networks. For example, lidars have been shown to have the technical capability to provide this assessment between 20 and 40 km (Nair et al., 2012). Ozonesondes have the capability of providing measurements of suitably high quality at lower altitudes, while Umkehr, microwave, and FTIR have the potential for high-quality measurements at higher altitudes. The ground-based networks have been designed and developed with this capability in mind. It is very important to ensure that they continue to possess the same capability in a period when ozone will be affected by declining levels of halogen compounds, increasing N_2O and CH_4, as well as dynamical changes from climate change."

(Harris et al., ACP, 2015)