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Ground-based network assessment of the long-term stability and mutual consistency of limb/occultation ozone profile decadal data records

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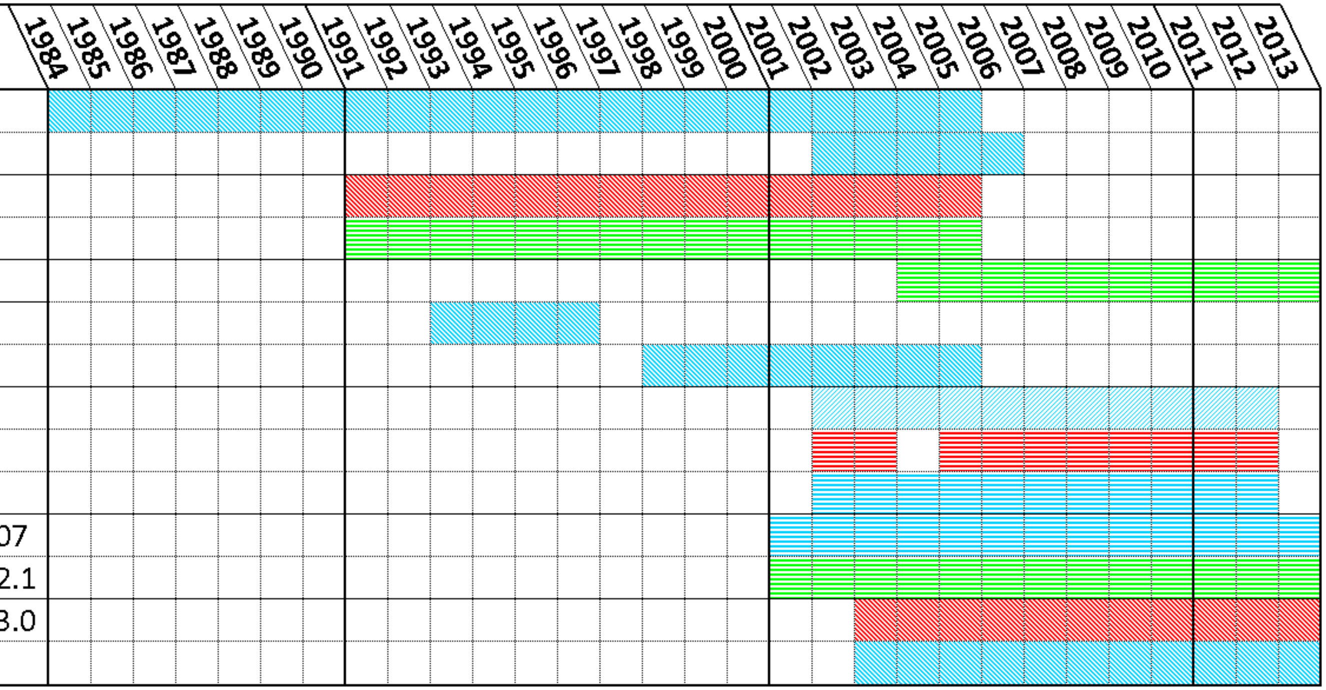
Many satellite ozone profile records exist,
but none provide conclusive evidence of a (positive) trend since mid 1990s

MISSION	SOUNDER	VERSION
ERBS	SAGE II	LaRC v7.0
Meteor-3M	SAGE III	LaRC v4.0
UARS	HALOE	LaRC v19
	MLS	JPL v5
EOS Aura	MLS	JPL v3.3
SPOT 3	POAM II	NRL v6
SPOT 4	POAM III	NRL v4
Envisat	GOMOS	IPF 6.01
	MIPAS	ML2PP 6.0
	SCIAMACHY	SGP 5.02
Odin	OSIRIS	U Sask v5.07
	SMR	U Chalm v2.1
SCISAT-1	ACE-FTS	U Water v3.0
	MAESTRO	v1.2 VIS



Sounding strategy: limb, stellar occultation, Sun/Moon occultation

Spectral range: UV/VIS/NIR, IR, MW

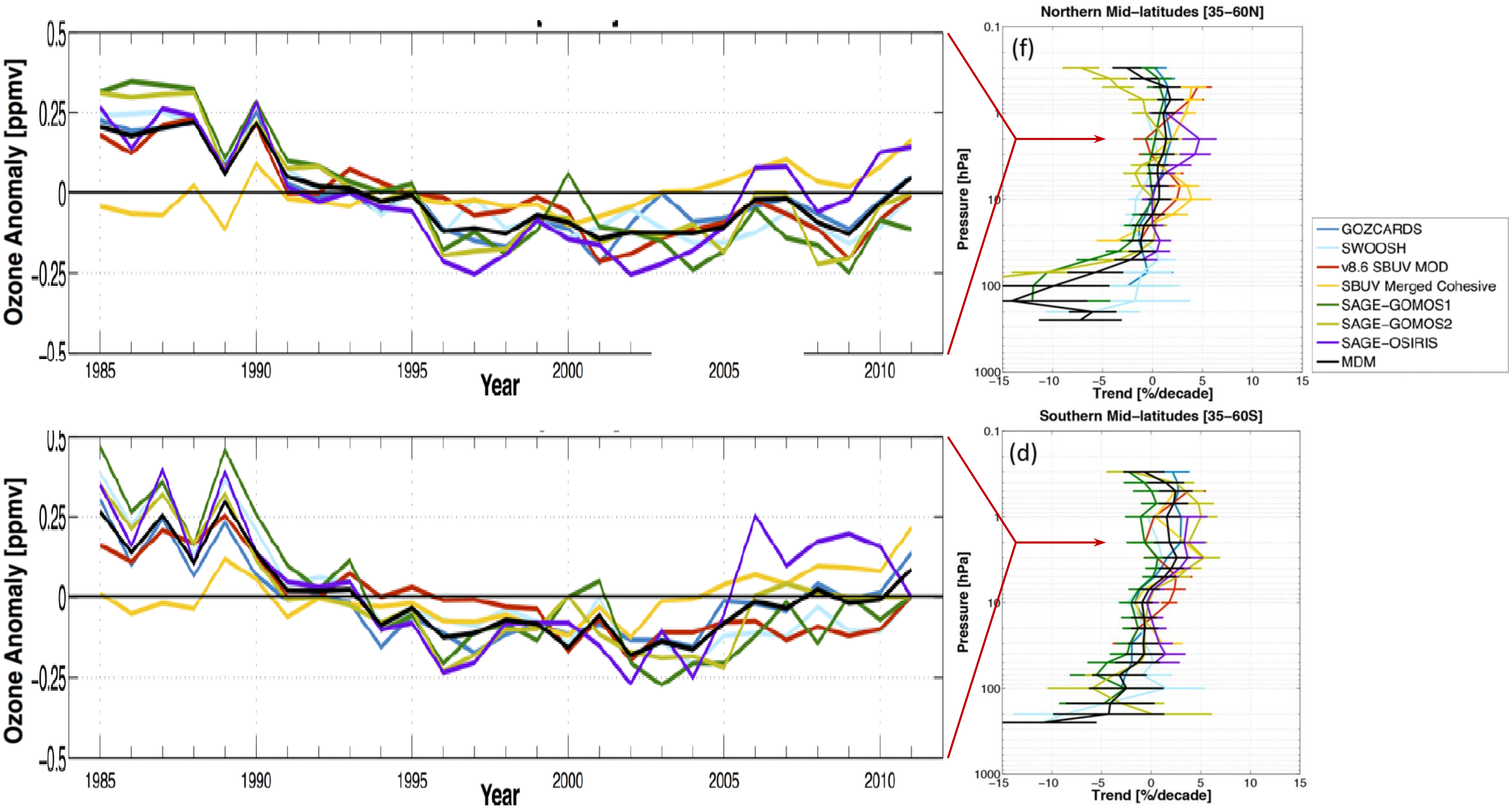
Current international activities (SI2N, WMO, CCI, GOZCARDS, …)
focus on merging different satellite records.

Conclusions from inter-comparison of merged ozone profile records

BIRA•IASB 1964•2014

Tummon *et al*, ACPD (2014)…

"For the data sets based on SAGE-II […] the choice of instrument records to be merged was found to have a greater impact than the choice of merging technique."



Analysis methodology

Three design principles

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I. Compare fourteen limb/occultation satellite records to co-located ground-based observations

- NDACC/WOUDC/SHADOZ ozonesonde: ground up to ~33 km
- NDACC stratospheric ozone lidar: tropopause up to ~47 km

II. Minimize number of manipulations of satellite record

e.g. by using satellite profile grid & representation for the comparison

III. Harmonized analysis framework using robust statistical techniques

apart from some unavoidable differences in preprocessing, all analysis steps and code is identical

→ observed inconsistencies between records are hence unlikely of methodological nature

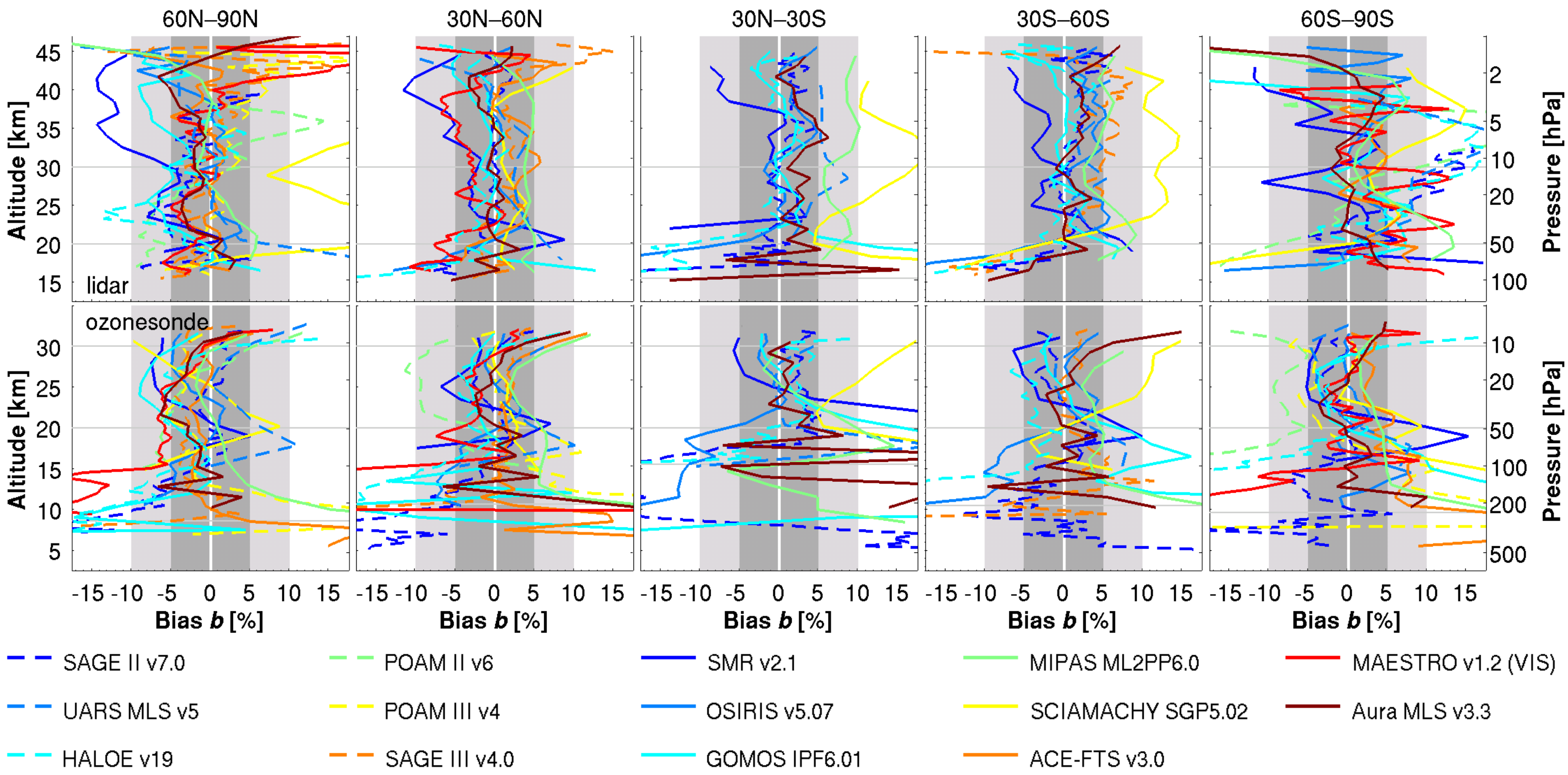
Study vertical (and meridian) structure of

$$\Delta x_i(z,t) = 100 \times \frac{x_{SAT,i}(z,t) - x_{GND,i}(z,t)}{x_{GND,i}(z,t)}$$

{ Bias
Short-term variability
Long-term stability
Consistency profile representations }

Bias relative to NDACC/WOUDC ozonesondes and lidars

Multi-mission consistency

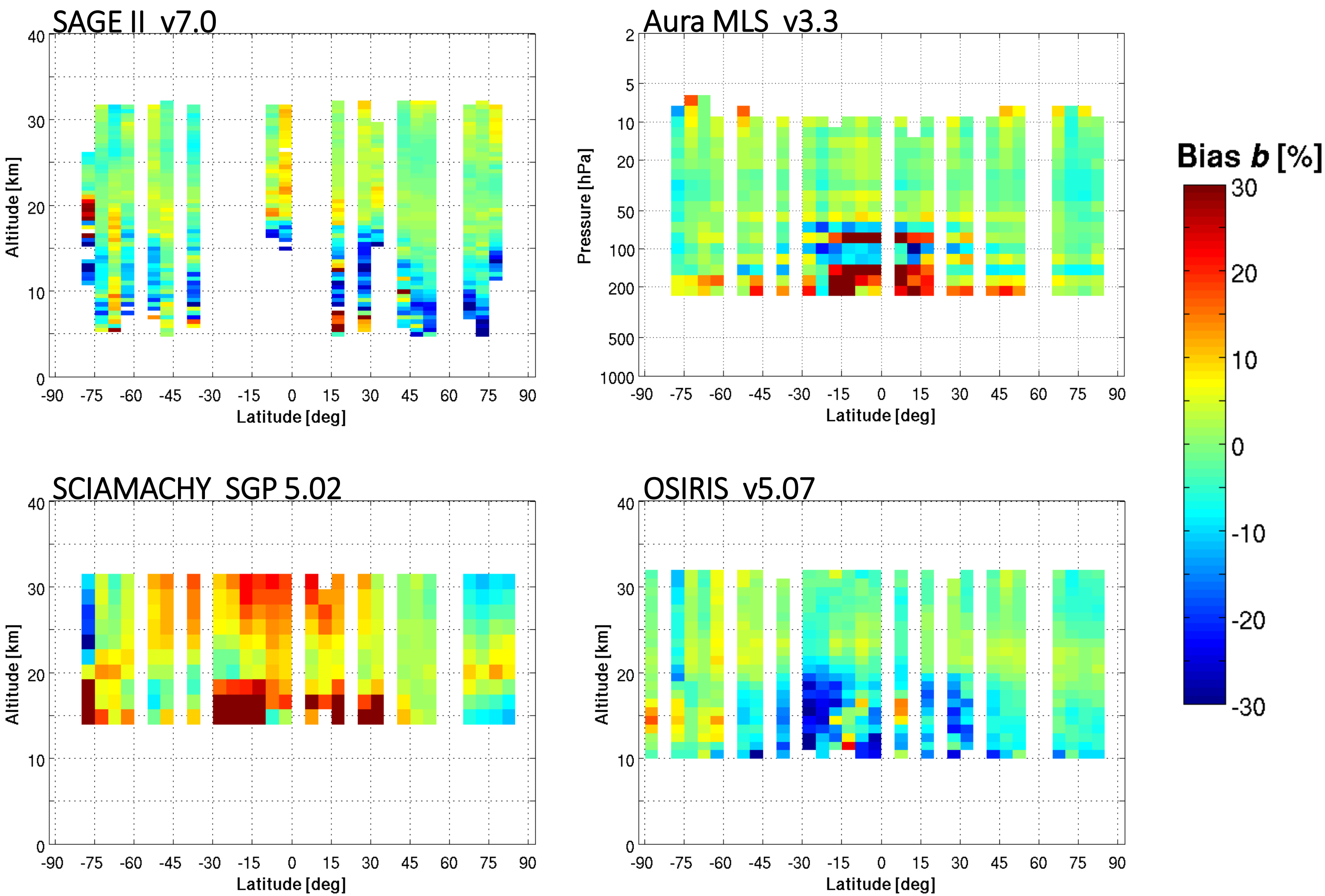


Median bias generally less than ±5%, but…

- Arctic middle stratosphere: satellite ozone mostly low biased
- Tropical middle/upper stratosphere: satellite ozone mostly high biased
- More elevated in Antarctic ozone hole conditions

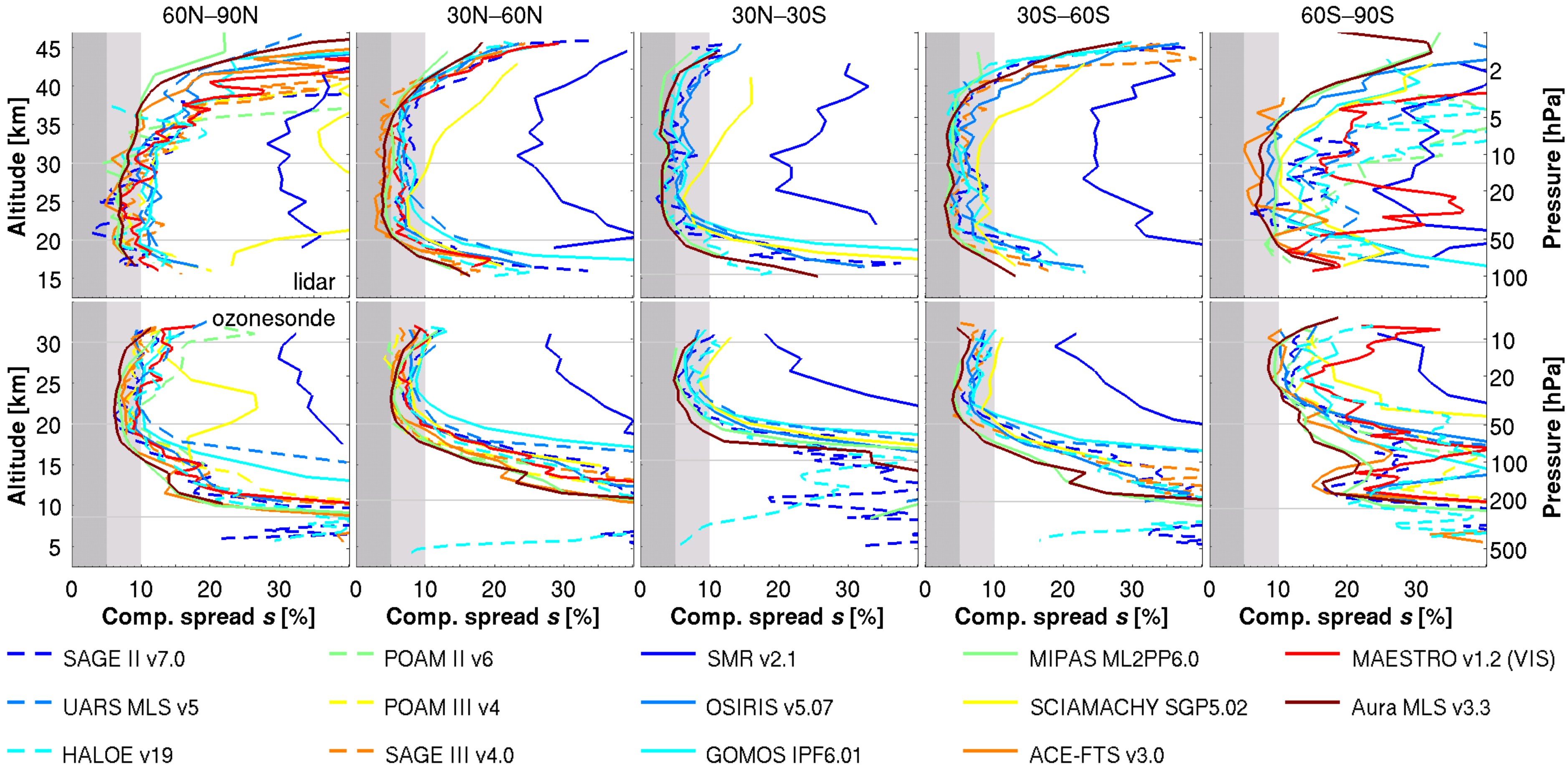
Bias relative to NDACC/WOUDC ozonesondes

Vertical and meridian structure is important



Spread of comparisons to NDACC/WOUDC ozonesondes and lidars

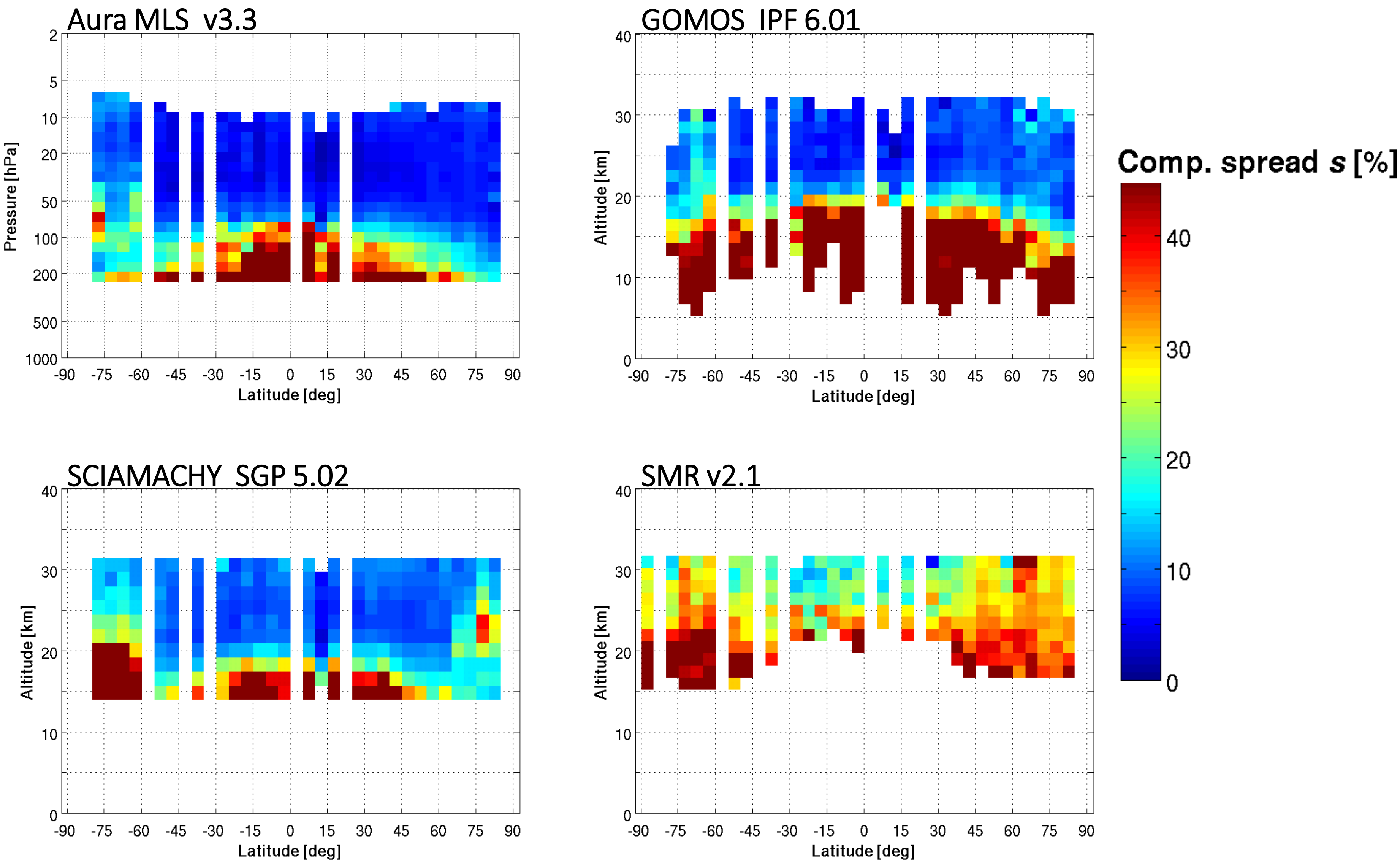
Multi-mission consistency



Comparison spread has less structure than bias

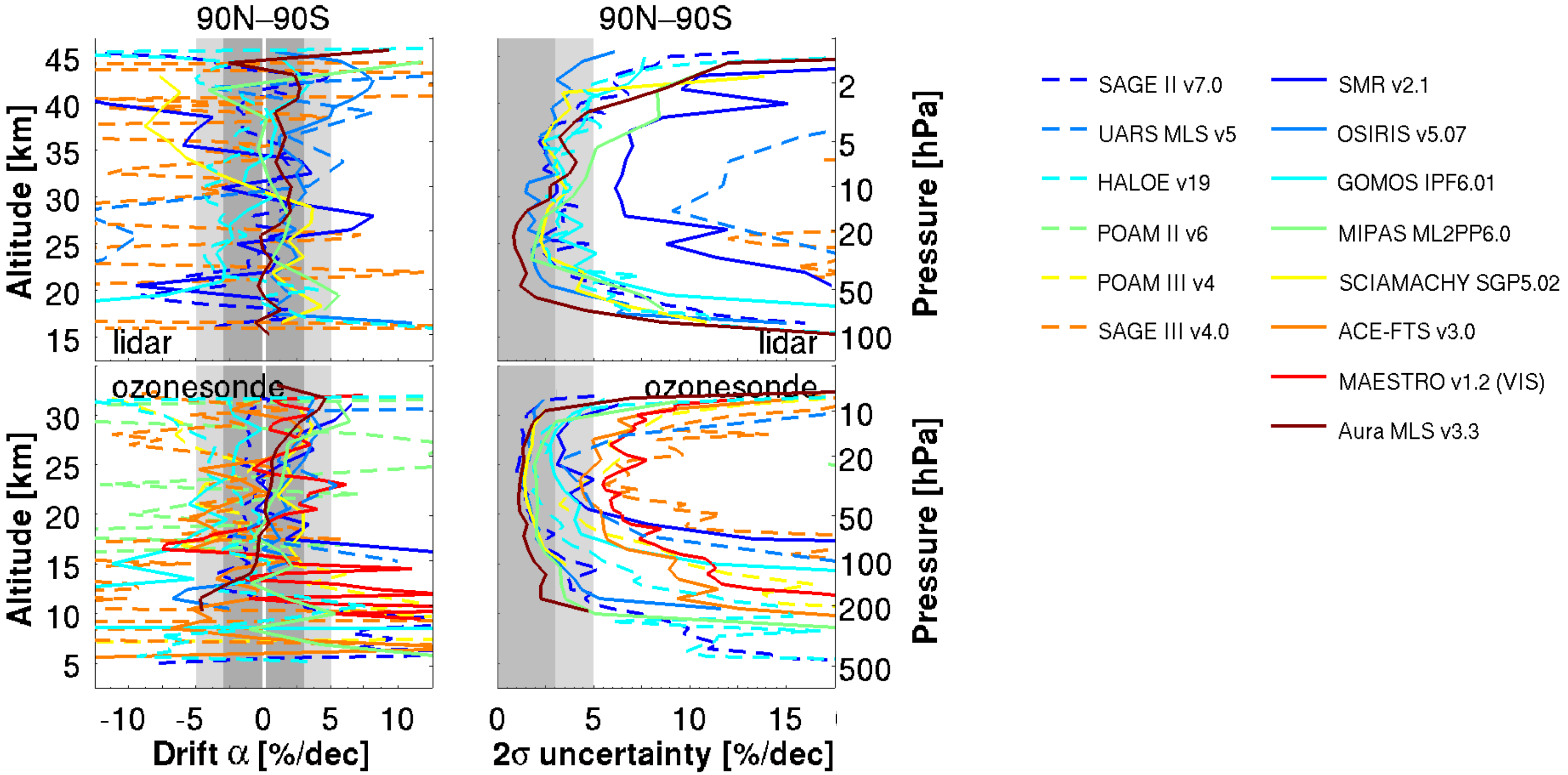
- Vertical dependence: generally 5-10 % in middle/upper stratosphere, increasing towards lower strato.
- Meridian dependence: spread increases towards higher latitudes
- Some satellite records are much more noisy

Spread of comparisons to NDACC/WOUDC ozonesondes
Vertical and meridian structure is important



Decadal drift relative to NDACC/WOUDC ozonesondes and lidars

Multi-mission consistency



Long-term stability is typically better than ±5% per decade

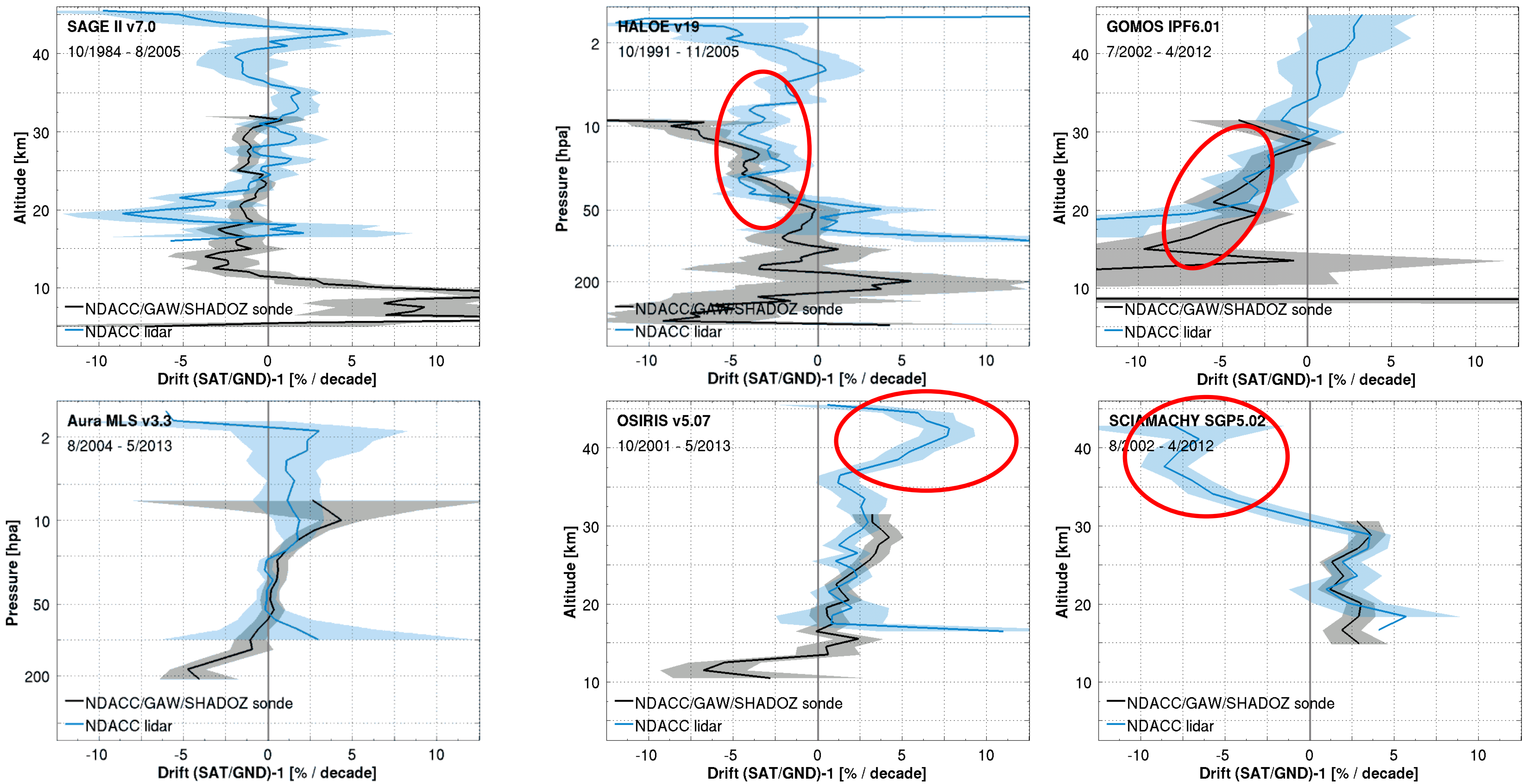
- Some satellite records drift significantly
- 2σ uncertainty is larger than 5% per decade for half of the records

Decadal drift relative to NDACC/WOUDC ozonesondes and lidars

Some records drift significantly

“Stable”

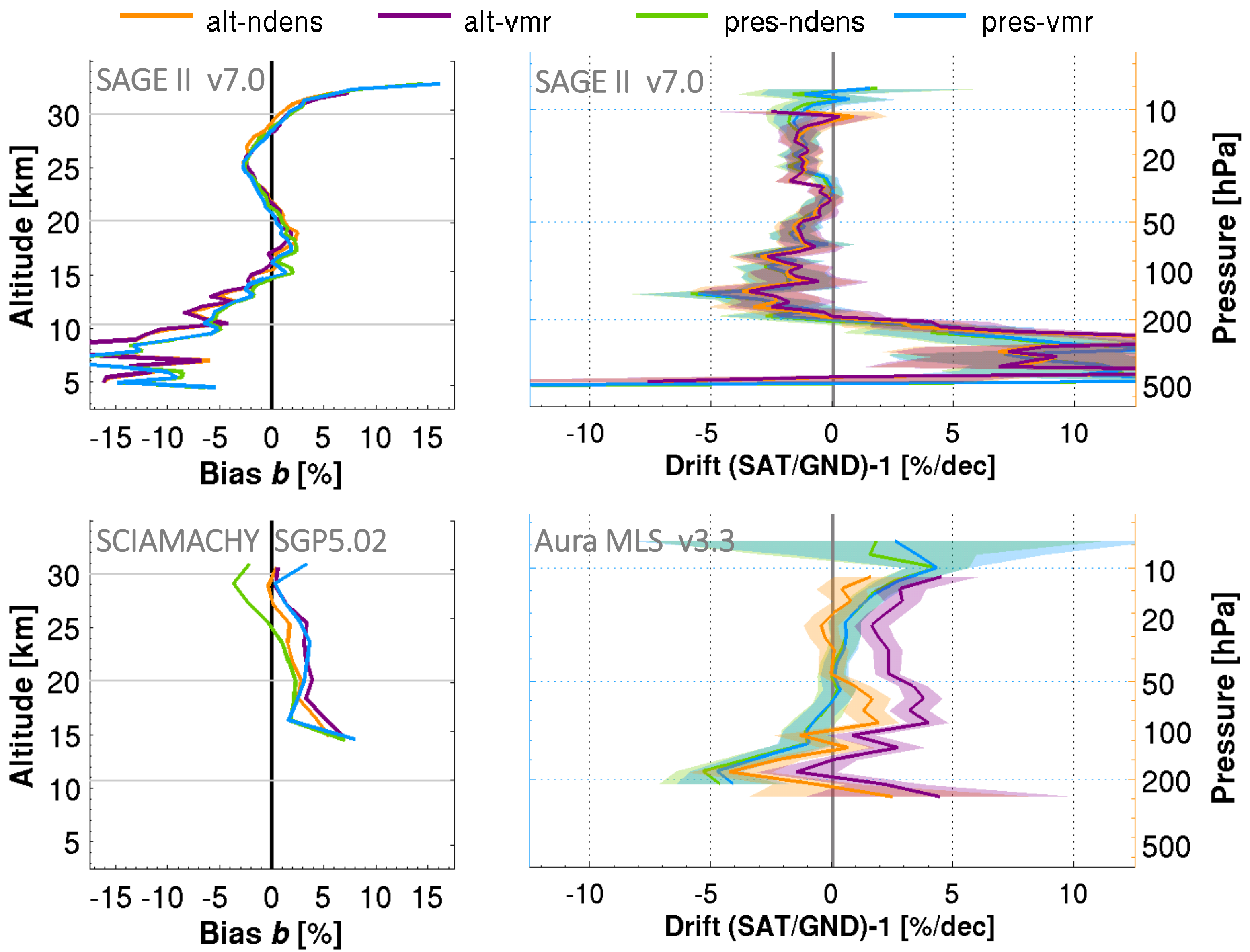
“Unstable at some altitudes”



Shaded area represents ±1 sigma uncertainty

Impact of coordinate conversions

Changes seen only for a few records



Conclusions
Comparison studies are essential for merging and trend analyses

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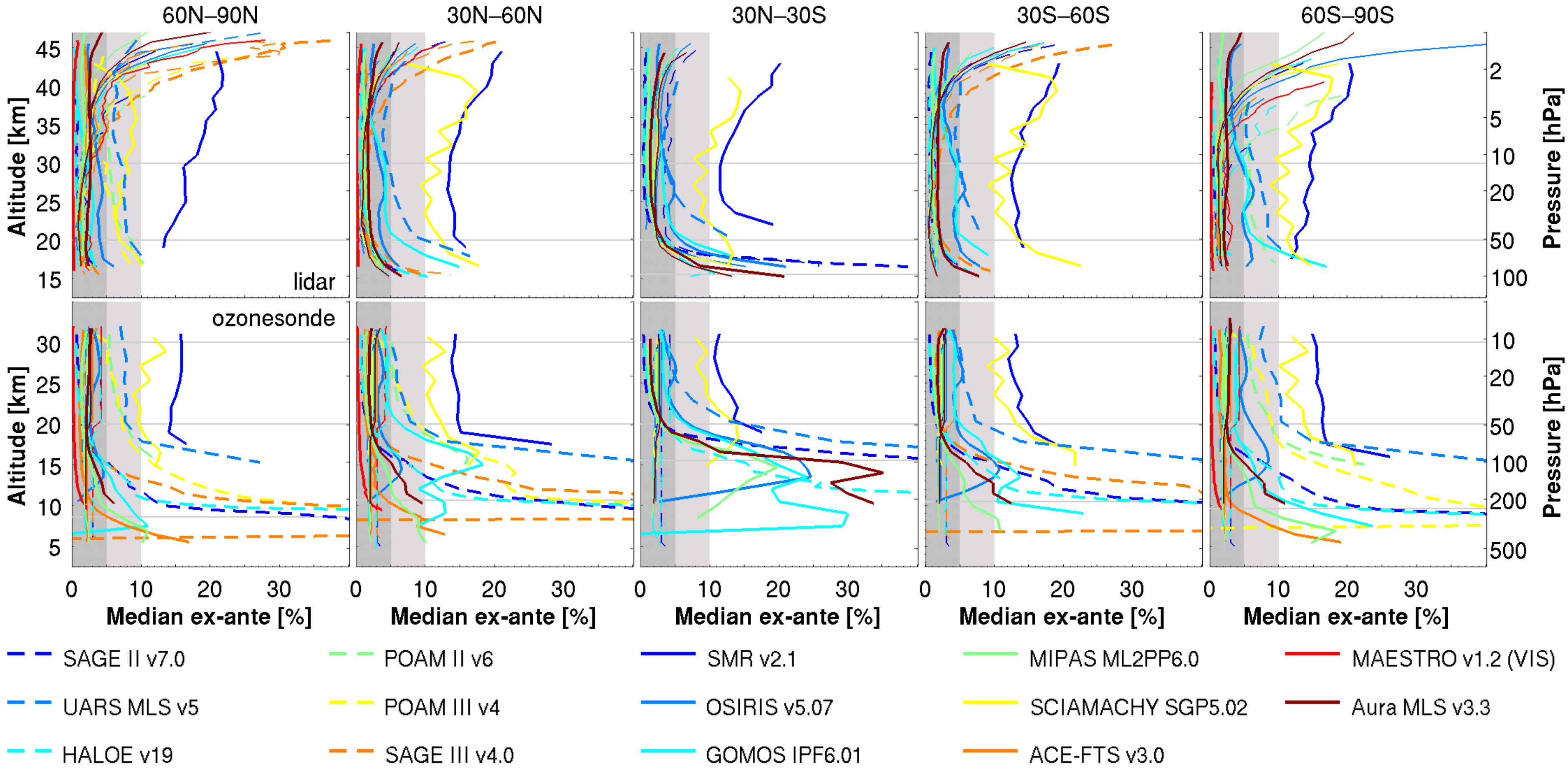
From a systematic comparison of satellite ozone profile records to ozonesonde and lidar observations, we conclude that

1. the satellite data sets are mutually very consistent between 20-45 km
   – bias remains typically within ± 5%, but typical vertical-meridian fingerprint exists
   – comparison spread typically below 5-10%, for some records up to 30%
   – long-term stability within ± 5% per decade, some records drift significantly
2. at lower altitudes comparison noise complicates the analysis
   – biases are more elevated due to low ozone values
   – it is very challenging to estimate drift
3. in some cases auxiliary data introduces artificial biases or trends
   e.g. for SCIAMACHY, UARS-MLS and Aura-MLS

Also, some recent published ozone trend results can partially be ascribed to instrument drift.

→ These comparison studies are essential for any merging activity or trend analysis.

Median ex-ante random uncertainty



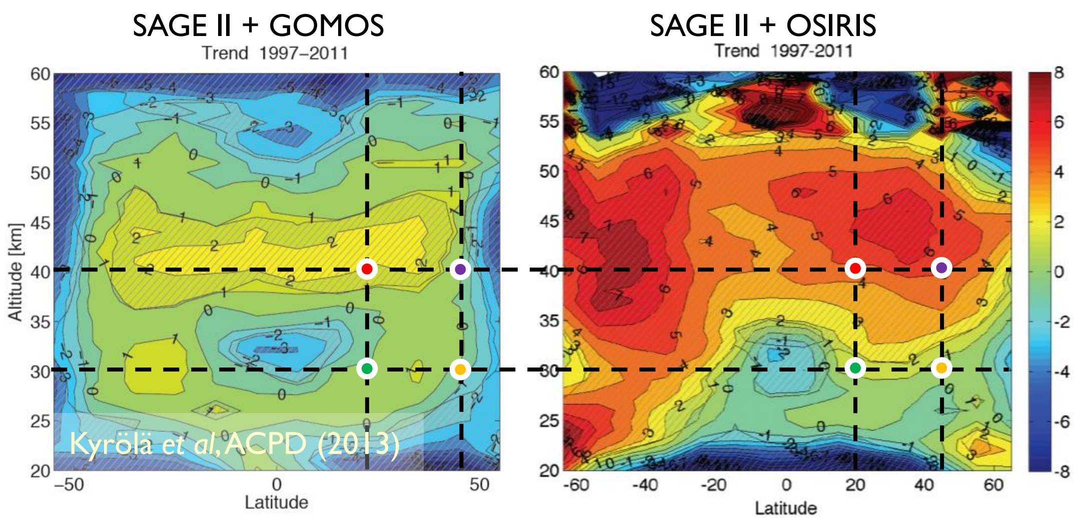
The provided random uncertainties of satellite and ground-based instruments generally do not explain the observed spread in the comparisons, not even when taking very large margins for the random uncertainties introduced by sampling and smoothing.

Relevance for merging & trend studies
SAGE-II merged with GOMOS or OSIRIS

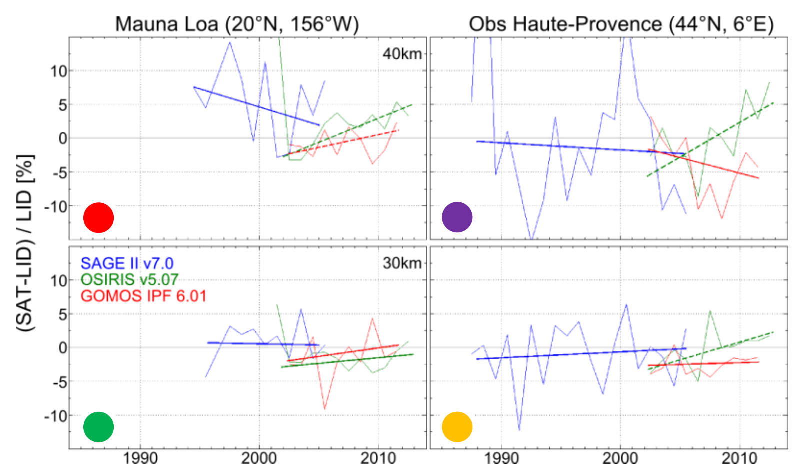
1. The upper stratospheric trend results from two different merged records differ by 3% per decade
   SAGE-II was extended with GOMOS, and also with OSIRIS data

2. Interestingly, the trend differences have similar characteristics as the differences of the drift results relative to lidar
   OSIRIS exhibits a larger, significant positive drift above 40 km, while that is not the case at 30 km

Ozone trend



Ozone drift



3. Again, this suggests a non-negligible contribution of instrument drift to trend estimates