UNCERTAINTIES IN RECENT SATELLITE OZONE PROFILE TREND ASSESSMENTS (SI2N, WMO 2014) : A NETWORK-BASED ASSESSMENT OF FOURTEEN CONTRIBUTING LIMB AND OCCULTATION DATA RECORDS

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ABSTRACT

Numerous vertical ozone profile data records collected over the past decades from space-based platforms have the potential to allow the ozone and climate communities to tackle a variety of research questions. A prime topic is the study and documentation of long-term changes in the vertical distribution of atmospheric ozone, as targeted by the recent SPARC/IO3C/IGACO-O3/NDACC Initiative (SI2N) and WMO's ozone assessment. Such studies typically require data records with documented mutual consistency in terms of bias and long-term stability. We performed a comprehensive assessment of fourteen limb/occultation ozone profile data records, using NDACC/GAW/SHADOZ ozonesonde and NDACC lidar network data as reference standards.

1. INTRODUCTION

We limit ourselves to a summary of the main results of our assessment of fourteen limb/occultation satellite ozone profile records. For exhaustive details we refer the interested reader to Hubert et al. (2015).

2. METHODOLOGY

All satellite data records were co-located with ground-based ozone profile observations at 72 ozonesonde stations (NDACC, GAW/WOUDC and SHADOZ) and 13 stratospheric lidar stations (NDACC). The ground-based networks hereby act as independent transfer

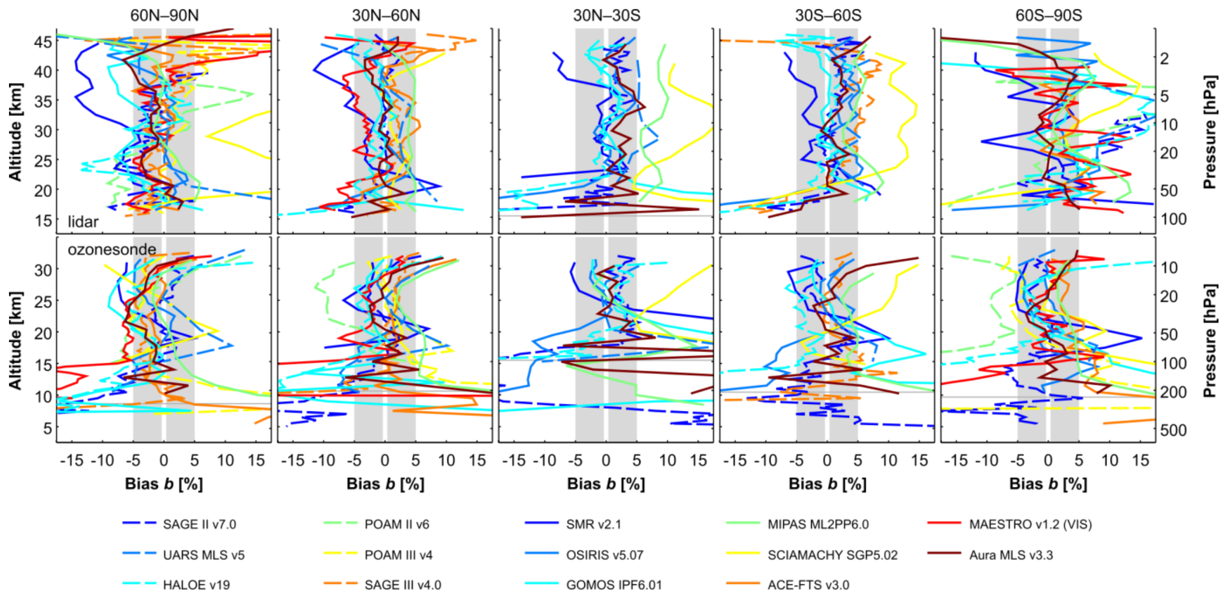

Figure 1. Vertical structure of median relative bias of satellite ozone profile data relative to ground-based observations by the lidar (top) and ozonesonde networks (bottom), in five latitude bands. The satellite bias is generally less than about 5% in the middle and upper stratosphere (grey band). Figure from Hubert et al. (2015).

standards, giving access to the troposphere and stratosphere at a pseudo-global scale. Besides the preprocessing step, whose details varies by satellite instrument (satellite & ground data screening, vertical smoothing of ground-based data to satellite resolution and conversion of sonde/lidar profile representation to that of satellite), the analysis set-up and data flow are identical for all fourteen records. Doing so allows us to compare the outcome of all 14 comparison analyses and assess the mutual consistency of the limb/occultation observation system.

The analysis is based on the study of relative differences $\Delta x_{ij}(l) = 100 \times \frac{x_{ij,sat}(l) - x_{ij,gnd}(l)}{x_{ij,gnd}(l)}$, for co-located pair i, ground station j and vertical grid level l. We applied robust statistical techniques to estimate the *long-term stability* (slope of linear regression to Δx time series, also referred to as *decadal drift*), the *overall bias* (median of Δx distribution) and the *short-term variability* (spread of Δx distribution, also referred to as *comparison spread*), and (where feasible) their dependence on e.g. altitude, latitude and season. The uncertainty estimate for decadal drift plays a central role in our analysis as it defines the significance of our results. We refer to Hubert et al. (2015) for further details.

3. RESULTS

Hubert et al. (2015) start off by a detailed presentation of the structure of decadal drift, overall bias and comparison spread results of each instrument individually, in the native profile representation of the satellite record. It is followed by a discussion of the impact of the auxiliary pressure/temperature data provided along with the ozone record on the data quality parameters in non-native representations. All of these results serve as input to an assessment of the consistency of the limb/occultation ozone profile records. In this proceedings, we restrict ourselves to the latter, more synthetic discussion.

Fig. 1 shows the overall bias of satellite data in five latitude bands. It is generally less than ±5% between 20-40 km (~2-50 hPa), and increases gently towards the stratopause (±10%) and quite rapidly towards the tropopause (±15% and more). The comparison spread (Fig. 2) exhibits a similar vertical dependence, generally ranging between 5-12% over 20-40 km, and increasing towards the stratopause (15-20%) and tropopause (40% and more). However, the comparison error budget contains terms associated to the ground-based record, and to differences in co-location mismatch and smoothing induced by natural variability (e.g. in the UTLS) as well. So, especially the precision of the satellite records will be better than suggested by the observed spread in the comparisons. A couple of instruments do not fit in previous general conclusions. Some satellite records (POAM II, SCIAMACHY) exhibit biases of 10% and more, or have intricate bias substructure in altitude, latitude and even season (SCIAMACHY, OSIRIS, Aura MLS, SMR, MIPAS). Some records (SCIAMACHY, SMR) have a more elevated single-profile profile noise of 15-30%, in addition to peculiar substructure.

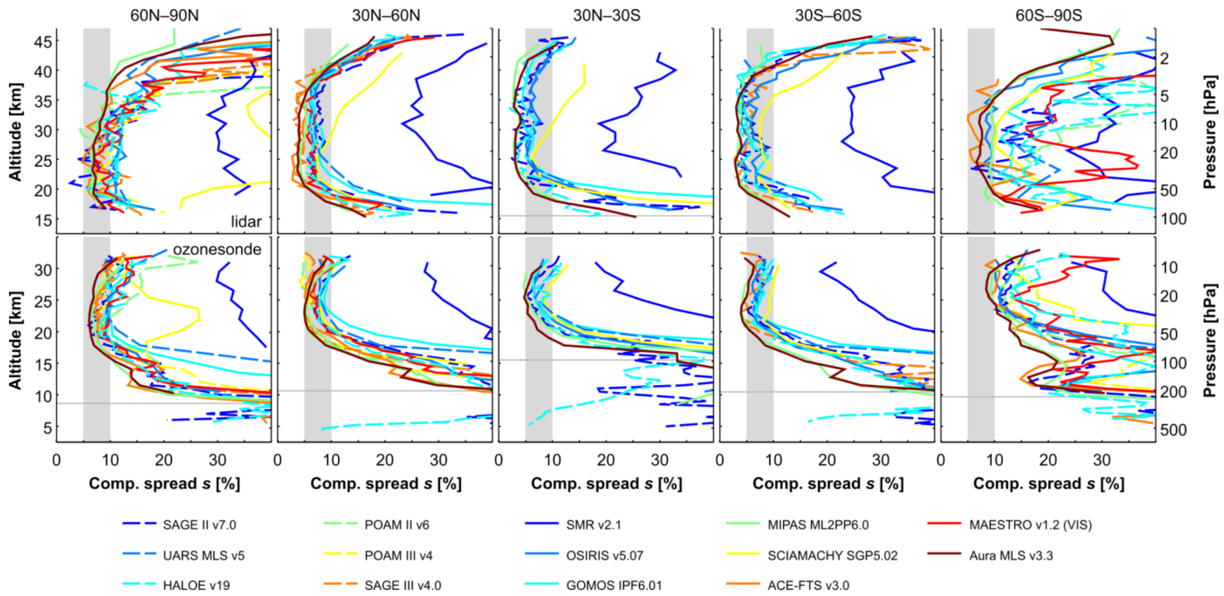

Figure 2. Similar as Fig. 1, but for the spread observed in the comparisons. These typically range between 5-12% in the middle and upper stratosphere, and represent an upper limit to the single-profile precision of the satellite records. Figure from Hubert et al. (2015).

The decadal drift (Fig. 3) typically remains less than about ±5% per decade in the middle and upper stratosphere. A few records (SAGE II, Aura MLS and MIPAS) are stable within ±3% per decade. Others exhibit a significant decadal drift of ~5% per decade or more in part of the atmosphere. E.g. OSIRIS and SCIAMACHY in the upper stratosphere and HALOE in the middle stratosphere. The GOMOS (lower stratosphere) and SMR (upper stratosphere) results are close to the significance threshold, and we therefore suggest to use the latter two records with care until a more conclusive analysis has been performed.

Finally, we noted that auxiliary pressure/temperature data are mostly of sufficient quality to avoid artefacts when considering ozone data quality in non-native profile representations. The observed changes in bias and comparison spread are less than 1%, decadal stability remains within 1% per decade. For a few instruments the impact is larger, up to 3-5% in terms of bias and 3% per decade and more for stability. However, these issues are not related to the satellite ozone retrieval itself, and can easily be avoided by using other sources of auxiliary data. Conversions using MERRA and ERA-Interim reanalysis fields, for instance, appear consistent with those done with ozonesonde data.

4. DISCUSSION

We conclude by reflecting on the implication of our assessment for (a) the verification of user requirements, (b) the construction of merged data records, and (c) the interpretation of different ozone profile trend assessments.

The good overall consistency between the ozonesonde- and lidar-derived comparison results shows the adequacy of these ground-based networks for comprehensive satellite validation analyses. The sonde and lidar networks allow to verify user requirements on accuracy down to 5-10% in the middle and upper stratosphere, which can also be resolved by latitude and season. Decadal drifts can generally be detected down to ~2-3% per decade in the middle stratosphere and ~3-4% per decade in the upper and lower stratosphere. While the capabilities are sufficient to verify the GCOS targets (GCOS, 2011) on accuracy, that is not the case for long-term stability. Further progress is therefore needed, and may come e.g. from an improved ozonesonde data set currently being prepared by the Ozonesonde Data Quality Assessment initiative (O3S-DQA) (Smit et al., 2012). In the UTLS, improvements may be expected with detailed studies of the comparison error budget using model data.

The combination of individual satellite records may introduce artefacts when the merging algorithm does not remove all biases or drifts between the records. In addition, differences in single-profile noise may be a limiting factor as well. Our assessment shows that bias correction schemes should at least have an altitude and latitude component and, occasionally, also a seasonal dimension. If the merging is performed at too small spatio-temporal scales single-profile noise may hamper the estimation of robust bias estimates. Also, the detection of decadal drift for some instruments shows

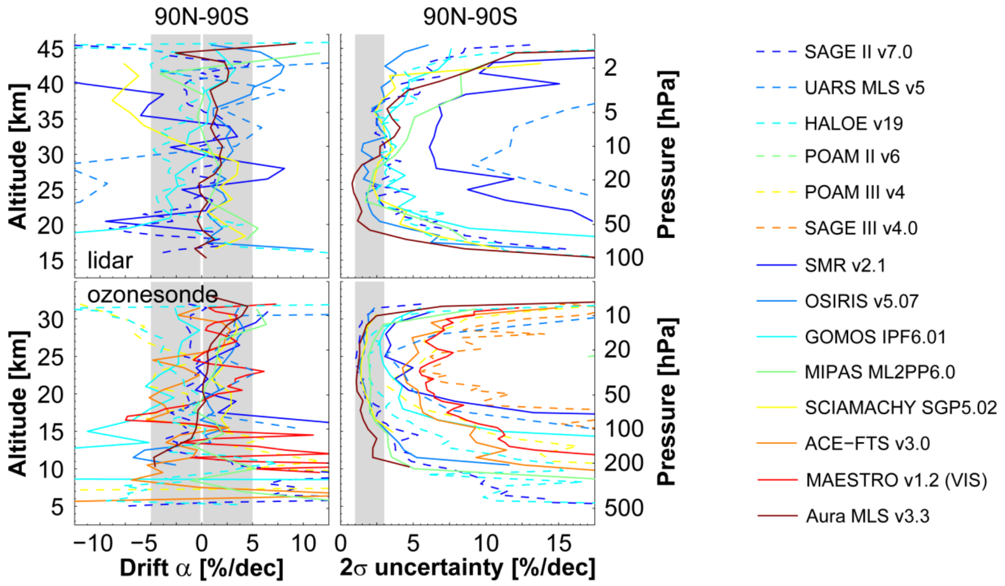

Figure 3. Left: Vertical structure of decadal drift of satellite ozone profile data relative to ground-based observations by the lidar (top) and ozonesonde networks (bottom). Most satellite records are stable within about ±5% per decade in the middle and upper stratosphere (grey band). Right: 2σ uncertainty on the network-averaged drift estimates. The GCOS user requirements for long-term stability can be verified for only a few satellite records (grey band). Figure from Hubert et al. (2015).

the need for a long-term temporal component in the merging schemes, although we agree that it is too challenging to obtain reliable drift corrections in most cases. Instead, we encourage the data merging teams to estimate the impact of drift on the combined data set a-posteriori. We also recommend the use of a single source, of high-quality, auxiliary data for any necessary conversion to the profile representation of the "anchor record", as we noted a non-negligible impact on ozone characteristics of a few satellite records.

Various ozone profile trend assessments were published recently, using a variety of merged data records. For an overview and discussion, see e.g. WMO (2014) and Harris et al. (2015) and references therein. Some of these studies reveal differences in decadal trends in parts of the atmosphere that are not explained by the quoted uncertainties. Interestingly, these trend differences seem to agree quite well with our decadal drift estimates. For instance, SCIAMACHY trends at 35km are more negative than those of Aura MLS and OSIRIS, consistent with our claim of a negative drift in the SCIAMACHY data at these altitudes. Similarly, we reinterpret the more positive OSIRIS trends in the upper stratosphere as due to instrumental drift. Also the quite negative GOMOS trends in the lower stratosphere can be explained by negative drift. These observations build additional confidence that our decadal drift estimates can be employed as 1σ systematic uncertainties for trend analyses.

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