

**Assessment of
Odin-OSIRIS ozone
measurements from
2001 to the present**

C. Adams et al.

**Assessment of Odin-OSIRIS ozone
measurements from 2001 to the present
using MLS, GOMOS, and ozone sondes**

**C. Adams¹, A. E. Bourassa¹, V. Sofieva², L. Froidevaux³, C. A. McLinden^{1,4},
D. Hubert⁵, J. -C. Lambert⁵, C. E. Sioris¹, and D. A. Degenstein¹**

¹Institute for Space and Atmospheric Studies, University of Saskatchewan, Saskatoon, Saskatchewan, Canada

²Finnish Meteorological Institute, Helsinki, Finland

³Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California, USA

⁴Environment Canada, Downsview, Ontario, Canada

⁵Belgian Institute for Space Aeronomy, Brussels, Belgium

Received: 1 March 2013 – Accepted: 29 March 2013 – Published: 17 April 2013

Correspondence to: C. Adams (cristen.adams@usask.ca)

Published by Copernicus Publications on behalf of the European Geosciences Union.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures

⏪

⏩

◀

▶

Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Abstract

The Optical Spectrograph and InfraRed Imaging System (OSIRIS) was launched aboard the Odin satellite in 2001 and is continuing to take limb-scattered sunlight measurements of the atmosphere. This work aims to characterize and assess the stability of the OSIRIS 11 yr v5.0x ozone data set. Three validation data sets were used: the v2.2 Microwave Limb Sounder (MLS) and v6 Global Ozone Monitoring of Occultation on Stars (GOMOS) satellite data records, and ozone sonde measurements. Global mean percent differences between coincident OSIRIS and validation measurements are within 5% of zero at all altitude layers above 18.5 km for MLS, above 21.5 km for GOMOS, and above 17.5 km for ozone sondes. Below 17.5 km, OSIRIS measurements agree with ozone sondes within 5% and are well-correlated ($R > 0.75$) with them. For low OSIRIS optics temperatures ($< 16^\circ\text{C}$), OSIRIS ozone measurements are biased low by up to 6% compared with the validation data sets for 25.5–40.5 km. Biases between OSIRIS ascending and descending node measurements were investigated and were found to be related to aerosol retrievals below 27.5 km. Above 30 km, agreement between OSIRIS and the validation data sets was related to the OSIRIS retrieved albedo, which measures apparent upwelling, with a high bias for in OSIRIS data with large albedos. In order to assess the long-term stability of OSIRIS measurements, global average drifts relative to the validation data sets were calculated and were found to be $< 3\%$ per decade for comparisons against MLS for 19.5–36.5 km, GOMOS for 18.5–54.5 km, and ozone sondes for 12.5–22.5 km, and within error of 3% per decade at most altitudes. Above 36.5 km, the relative drift for OSIRIS versus MLS ranged from ~ 0 –6%, depending on the data set used to convert MLS data to the OSIRIS altitude versus number density grid. Overall, this work demonstrates that the OSIRIS 11 yr ozone data set from 2001 to the present is suitable for trend studies.

Assessment of Odin-OSIRIS ozone measurements from 2001 to the present

C. Adams et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures



Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



1 Introduction

In order to assess trends in stratospheric ozone, consistency within long-term data records is essential. Small drifts in a time series, caused by, e.g. instrument degradation or changes to a satellite orbit, can have a large effect on trend calculations. The SI²N (SPARC – Stratospheric Processes and their Role in Climate, IO₃C – International Ozone Commission, IGACO-O3 – Integrated Global Atmospheric Chemistry Observations, NDACC – Network for the Detection of Atmospheric Composition Change) initiative aims to compile short-term satellite, long-term satellite, and ground-based ozone measurements in a consistent manner in order to assess current and past changes in the vertical distribution of ozone (SI²N, 2012). The European Space Agency Ozone Climate Change Initiative (Ozone_cci), which is a major contributor to SI²N, aims to create a merged ozone data set from satellite measurements meeting the quality requirements of climate change research. Trends in stratospheric ozone since the 1980s vary across latitude and altitude, but range from ~0–8 % per decade according to satellite data records (e.g. WMO, 2010). Therefore, for trend studies, the Ozone_cci requires that instruments be stable within 3 % per decade (Ozone_cci, 2011).

The Optical Spectrograph and InfraRed Imaging System (OSIRIS) has been taking limb-scattered measurements of the atmosphere from 2001 to the present, yielding an 11 yr ozone number density data set. While excellent agreement was found between OSIRIS and the Stratospheric Aerosol and Gas Experiment II (SAGE II) for 2001–2005 (Adams et al., 2013), the long-term stability of the OSIRIS ozone data set has not yet been demonstrated. Furthermore, small biases were identified between OSIRIS and SAGE II, but they could not be fully characterized due to the small number of coincident measurements.

This work aims to fully characterize the OSIRIS ozone measurements using Microwave Limb Sounder (MLS) and Global Ozone Monitoring of Occultation on Stars (GOMOS) satellite, and ozone sonde data sets, all of which span at least eight years of the OSIRIS measurement period. The GOMOS data set was selected for validation

Assessment of Odin-OSIRIS ozone measurements from 2001 to the present

C. Adams et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures



Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Assessment of Odin-OSIRIS ozone measurements from 2001 to the present

C. Adams et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures

⏪

⏩

◀

▶

Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



because of its high precision and good vertical resolution (Tamminen et al., 2010), while the MLS data set has excellent spatiotemporal coverage (Waters et al., 2006) and ozone sondes have very high vertical resolution. Detailed comparisons between these instruments can be used for future projects, such as the merging of ozone data sets, including both OSIRIS and GOMOS, in the SPIN, Ozone_cci, and SI²N collaborations.

This paper is organized as follows. In Sect. 2, the OSIRIS instrument and ozone retrievals are presented and the small changes that have occurred during the 11 yr mission are described. The three validation data sets are presented in Sect. 3, and the validation methodology is given in Sect. 4. In Sect. 5, the OSIRIS data set is characterized, with a focus on long-term consistency and the investigation of small biases within the data set. Finally, a summary of results is given in Sect. 6.

2 The OSIRIS ozone data set from 2001 to the present

The Canadian-made OSIRIS instrument, aboard the Swedish satellite Odin, was launched into a Sun-synchronous orbit on 20 February 2001 (Murtagh et al., 2002; Llewellyn et al., 2004). Odin has a polar orbit with a 96 min period with a northward equatorial crossing at ~ 18:00 LT (ascending node) and a southward equatorial crossing at ~ 06:00 LT (descending node). Ozone measurements are only taken in the summer hemisphere, with coverage in both hemispheres in the spring and fall. The optical spectrograph measures limb scattered sunlight at 280–810 nm, with a ~ 1 nm spectral resolution. A review of the first decade of OSIRIS measurements is given by McLinden et al. (2012).

The OSIRIS SaskMART v5.0x ozone data is retrieved using the Multiplicative Algebraic Reconstruction Technique (MART) retrieval algorithm (Roth et al., 2007; Degenstein et al., 2009), which uses radiative transfer from the SASKTRAN model (Bourassa et al., 2008b). Ozone number density profiles are retrieved from the cloud tops to 60 km (down to a minimum of 10 km in the absence of clouds) using a combination of ozone

Assessment of Odin-OSIRIS ozone measurements from 2001 to the present

C. Adams et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures



Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



absorption information in the UV and visible parts of the spectrum. Aerosol and NO₂ are also retrieved with ozone to reduce biases (Bourassa et al., 2007, 2008a, 2011). SaskMART v5.0x ozone has an estimated precision of 3–4 % in the middle stratosphere and a vertical resolution of ~ 2 km (Bourassa et al., 2012). OSIRIS ozone data were filtered for outliers according to the techniques described by Adams et al. (2013).

From 2001 to the present, few changes have been observed in OSIRIS measurements. The absolute calibration of the OSIRIS spectra, which is used in the albedo calculations for the ozone retrievals, has shown very little variation over the course of the Odin mission. The dark current has increased over time but remains at insignificant levels for stratospheric ozone retrievals. Furthermore, the configuration of the Odin satellite is small and simple, which ultimately favours stability, as there are not many moving parts or operational modes.

The time series of OSIRIS optics temperatures (the temperature associated with the OSIRIS instrument and often used as a diagnostic) and latitudinal coverage of descending and ascending node measurements are shown in Fig. 1. Low optics temperatures are observed when the Earth comes between Odin and the Sun for part of the orbit annually in May–July. These low temperatures are associated with a low bias of 5–12 % in OSIRIS measurements when compared with SAGE II (Adams et al., 2013). This may be caused by misalignment between OSIRIS and the star tracker due to thermal deformation, leading to pointing errors (McLinden et al., 2007). Furthermore, the quality of ozone retrievals may be affected by defocusing, reduced spectral resolution, and wavelength shifts at low temperatures (Llewellyn et al., 2004). The optics temperature, both during and outside of this period of eclipse, decreases at a rate of ~ 0.5 °Cyr⁻¹ from 2001–2012. Furthermore, due to the precession of the local time of the equatorial crossing, the coverage of descending versus ascending node measurements has changed over the 11 yr mission. Since biases have been observed between descending and ascending node ozone profiles (Adams et al., 2013), this could cause systematic changes in the OSIRIS ozone data set over time. Therefore the long-term

validation of OSIRIS ozone verifies whether changes to the optics temperature and equatorial crossing time have introduced significant drifts within the time series.

3 Validation data sets

The MLS and GOMOS satellite data sets and balloonborne ozone sonde measurements were selected for the long-term validation of OSIRIS. The latitudinal and temporal coverage of these validation data sets are shown in Fig. 1. All three data sets span much of the OSIRIS time series, and sample a large range of latitudes. The three validation data sets complement one another. MLS yields excellent spatiotemporal coverage at 2.5–3 km vertical resolution, while GOMOS provides higher vertical resolution of ~2 km and single-profile precision. GOMOS measures in the same wavelength region (UV-visible) as OSIRIS, but uses stellar occultations instead of scattered sunlight, while MLS measures in a different spectral region than OSIRIS. Ozone sonde data offer very high vertical resolution of 150 m in the troposphere and lower stratosphere. Since all three validation data sets use independent measurement techniques, the reliability of the conclusions about the OSIRIS data quality is improved. The validation instruments and ozone retrievals are described below.

The Earth Observing System MLS (Waters et al., 2006) is on board the Aura satellite, which was launched by NASA on 15 July 2004 and has been operational, taking measurements of ozone and other trace gases from 13 August 2004 to the present. MLS measures thermal radiance emissions from the limb at spectral regions centred near 118, 190, 240 and 640 GHz, and 2.5 THz with heterodyne radiometers. Aura is in a Sun-synchronous orbit at a 705 km altitude with 98° inclination, a 98.8 min period, and an ascending equatorial crossing time of ~13:45 LT. This results in near-global coverage from 82° S to 82° N with 3500 limb scans daily. The MLS v2.2 ozone product (Froidevaux et al., 2008), which is retrieved in the 240 GHz spectral region, was used for this study. In the stratosphere, profiles are retrieved on a pressure grid, with a resolution of 6 levels per decade or ~2.5–3 km. Uncertainties in MLS v2.2 ozone are

Assessment of Odin-OSIRIS ozone measurements from 2001 to the present

C. Adams et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures

⏪

⏩

◀

▶

Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



Assessment of Odin-OSIRIS ozone measurements from 2001 to the present

C. Adams et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures

⏪

⏩

◀

▶

Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



MLS and smoothed OSIRIS pressure versus VMR profiles were converted back to an altitude versus number density grid using the ECMWF analysis data, and interpolated to the OSIRIS retrieval altitude grid. The impact of the data set used to convert MLS pressure versus VMR to altitude versus number density is discussed in Sect. 5.3. Note that a simple triangular filter smoothing technique was also tested and yielded similar results to the least squares fitting and averaging kernel smoothing technique used in this paper.

For comparisons with GOMOS and ozone sondes a broader set of coincidence criteria of ± 1000 km, ± 24 h, and $\pm 1^\circ$ latitude were employed because the measurement frequency of these data sets is lower than for MLS. In comparisons between OSIRIS and SAGE II, these coincidence criteria yielded similar overall results to the narrow coincidence criteria, with slightly weaker correlation due to mismatching of air masses (Adams et al., 2013). For GOMOS and OSIRIS coincidences, smoothing was not applied because they have similar vertical resolution. Ozone sonde data were smoothed to the resolution of OSIRIS using a triangular filter, with a half-width of 2 km. Note that a Gaussian filter was also tested and yielded very similar results.

In order to assess overall agreement between data sets, the mean percent difference PD between the OSIRIS (M^{OS}) and validation (M^{val}) ozone number density measurements is defined as

$$\text{PD}(z) = 100\% \times \frac{1}{N(z)} \sum_{i=1}^N \frac{(M_i^{\text{OS}}(z) - M_i^{\text{val}}(z))}{M_i^{\text{val}}(z)}, \quad (1)$$

where N is the number of coincident measurements. The standard deviation (σ) and the standard error (σ/\sqrt{N}) in the percent differences and correlation coefficients between coincident measurements were also calculated. Furthermore, drifts between data sets were calculated using linear regressions over time series of percent differences, as described in Sect. 5.3.

5 Results

5.1 Overall agreement

Comparison statistics for all OSIRIS coincidences with MLS, GOMOS, and ozone sondes are shown in Fig. 2. For comparisons with MLS there are > 200 000 coincidences, and for comparisons with GOMOS and ozone sondes there are > 10 000 coincidences. At most altitudes, the standard deviations from both instruments are much larger than the reported measurement errors (not shown) and are similar to one another, indicating that OSIRIS and the validation data sets have sampled similar large-scale seasonal and latitudinal structures in the ozone field. The variability in the ozone profiles for comparisons with GOMOS is small because most coincidences are at low latitudes.

Mean percent differences between OSIRIS and the validation data sets are within 5 % of zero at all altitude layers above 18.5 km for MLS, above 21.5 km for GOMOS, and at all altitudes for ozone sondes. For 14.5–16.5 km, OSIRIS is biased low compared with MLS by 10–11 %. Below 18.5 km, the variability in the GOMOS data is much larger than OSIRIS, suggesting that comparisons at these altitudes are unreliable. Above 20.5 km, OSIRIS agrees with MLS within 2 %, except for positive biases of ~ 2–4 % for 22.5–24.5 km and 39.5–45.5 km. A positive bias for 22.5–24.5 km is also observed in comparisons with ozone sondes and was noted in comparisons with SAGE II (Adams et al., 2013). Possible reasons for this bias are explored further in Sect. 5.2.2. OSIRIS agrees with GOMOS within 2 % for 22.5–53.5 km. The small positive bias for 22.5–24.5 km is not observed in these comparisons because there are few coincidences between OSIRIS and GOMOS at high latitudes, where this bias is the largest.

Correlation coefficients indicate that OSIRIS ozone data are well correlated with coincident MLS, GOMOS, and ozone sonde data sets. For comparisons with MLS, $R > 0.8$ is observed for 11.5–44.5 km, with R values exceeding 0.9 at many altitude levels. For comparisons with ozone sondes, $R > 0.8$ above 10.5 km. Correlation between OSIRIS and GOMOS is slightly weaker, due in part to the smaller variability in the ozone profiles for the OSIRIS and GOMOS coincidences, which are primarily sampled at lower

Assessment of Odin-OSIRIS ozone measurements from 2001 to the present

C. Adams et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures



Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



Assessment of Odin-OSIRIS ozone measurements from 2001 to the present

C. Adams et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures

⏪

⏩

◀

▶

Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

ozone sondes. Large positive percent differences are observed below ~ 20 km at southern hemisphere high latitudes for comparisons with MLS, and are associated with large standard deviations. These values do not improve when only southern hemisphere summer months are considered, suggesting that this is not due to polar stratospheric clouds.

Figure 4 shows comparison results for OSIRIS versus ozone sondes, when data are re-gridded in altitude relative to the World Meteorological Organization (WMO) thermal tropopause, calculated from ECMWF analysis data. Note that the lower limit of OSIRIS retrievals is 10 km, so air masses below the tropopause are primarily measured at low latitudes. At the tropopause, OSIRIS data are biased low by $-10 \pm 1\%$, where the given error is the standard error. Furthermore, $R > 0.8$ from the tropopause to 4 km above the tropopause, indicating weaker correlation between OSIRIS and the ozone sondes in this region. The reduced agreement at the tropopause may be caused by mismatching of air masses due to the broad coincidence criteria and/or by imperfect smoothing of the ozone sondes to the vertical resolution of OSIRIS. For tropospheric air, 2–5 km beneath the tropopause, strong correlation $R > 0.9$ is observed between OSIRIS and ozone sondes, suggesting that OSIRIS is capturing tropospheric variations, despite mean percent differences of up to 15%.

5.2 Investigation of OSIRIS biases

In order to fully understand the OSIRIS measurements, the agreement between OSIRIS and the validation data sets was characterized for various OSIRIS retrieval parameters including optics temperature, aerosol extinction, albedo, solar zenith angle, and measurement node. Several systematic biases were identified and are discussed in the sub-sections below.

5.2.1 OSIRIS optics temperature

Figure 5 shows mean percent differences between OSIRIS and the validation data sets binned according to the OSIRIS optics temperature. For optics temperatures $< 16^{\circ}\text{C}$ OSIRIS ozone data are biased low for 25.5–40.5 km by up to 6 %, while for optics temperatures $> 16^{\circ}\text{C}$ positive biases of $\sim 1\text{--}3\%$ are observed. This is qualitatively consistent with SAGE II comparisons, in which a larger low bias of 5–12 % was observed for OSIRIS optics temperatures $< 16^{\circ}\text{C}$, but no positive bias was noted larger optics temperatures (Adams et al., 2013).

The latitudinal dependence of this bias at 32.5 km is shown in Fig. 6 for comparisons with MLS. The low bias for low optics temperatures shows little dependence on the measurement latitude. Note that this could not be confirmed with ozone sondes or GOMOS because there were fewer coincidences available. This supports the explanation that a low bias in ozone measurements is caused by altitude pointing errors and/or lower spectral resolution under low optics temperature (see Sect. 2), both of which would affect retrievals at all latitudes. Improvements to the retrieval software to account for spectral resolution and pointing errors are currently being tested and will be implemented for future versions of the OSIRIS ozone data set.

5.2.2 OSIRIS ascending versus descending measurement nodes

Mean percent differences between OSIRIS and the validation data sets, divided into ascending and descending node measurements are shown in Fig. 7. In the tropical troposphere, descending node measurements are biased low against MLS and ozone sondes, with a larger low bias in the Southern Hemisphere. Contrarily, the ascending node measurements in the tropical troposphere are biased high in the Southern Hemisphere and biased low in the Northern Hemisphere. The positive bias in OSIRIS measurements at 22.5–24.5 km is largest in the Southern Hemisphere for descending node measurements and in the Northern Hemisphere for ascending node measurements. For 25.5–40.5 km agreement is within 5 % at most latitudes for both ascending

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures

◀

▶

◀

▶

Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



and descending nodes. This is qualitatively consistent with comparisons against SAGE II (Adams et al., 2013).

Below ~ 30 km, some of the information in OSIRIS ozone retrievals is gained from the Chappuis band (544, 602, and 679 nm) (Degenstein et al., 2009). At these wavelengths, limb-scattered sunlight is sensitive to aerosols. At 600 nm, the peak sensitivity is at ~ 23 km (Fig. 1 of Bourassa et al., 2007). In order to investigate the connection between retrieved aerosol and ozone, OSIRIS descending and ascending node measurements were matched using coincidence criteria of ± 24 h, ± 1000 km, and $\pm 1^\circ$ latitude. The mean relative differences ozone from these collocated measurements are given in latitude-altitude bins by Adams et al. (Fig. 8, 2013) and are consistent with Fig. 7. Therefore the observed latitudinal structure in comparisons between ascending and descending nodes and the validation data sets is not caused by the different seasonal coverage of the ascending and descending nodes.

Figure 8 shows the mean percent difference between coincident OSIRIS aerosol extinctions in the descending minus ascending nodes at various latitudes. Note that this is the aerosol used in the ozone retrievals, not the OSIRIS level 2 aerosol extinction product, which is screened prior to distribution. Latitudinal and hemispheric biases in the aerosol are observed and are qualitatively similar to the ascending versus descending node ozone biases.

Mean percent differences in ascending minus descending node ozone were binned by latitude and the difference in retrieved aerosol extinction at 22.5 km, as shown in Fig. 9. For latitudes north of 30° N, and south of 30° S, the measurement node with the larger aerosol extinction observes more ozone. The magnitude of this bias increases toward higher latitudes. Mean percent differences for OSIRIS minus MLS at 22.5 km, binned by latitude and the OSIRIS aerosol extinction are also shown. At high latitudes, OSIRIS measures more ozone than MLS when OSIRIS aerosol extinctions are large. While this aerosol-dependent bias is the clearest at 22.5 km, near the peak sensitivity of limb-scattered measurements to aerosol, some systematic dependence on aerosol

Assessment of Odin-OSIRIS ozone measurements from 2001 to the present

C. Adams et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures

⏪

⏩

◀

▶

Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

extinction was observed for $\sim 12.5\text{--}27.5$ km (not shown). This may explain the high bias in OSIRIS measurements at 22.5 km.

Aerosol can be used as a dynamical tracer (e.g. Harvey et al., 1999) and is therefore expected to be related to ozone for natural reasons. For example, aerosol extinctions and ozone amounts are both expected to be low within the polar vortex. In order to test whether the retrieved ozone at 22.5 km is related to aerosol for this reason, the analysis was repeated with a variety of filters described below. In order to test for mismatched air-masses, the coincidence criteria were narrowed to ± 1 h and ± 500 km. Furthermore a stratospheric temperature criterion of ± 1 K was applied. The analysis was also repeated for individual seasons, to determine whether, e.g. the presence of the polar vortex affected results. In all cases, results were consistent with Fig. 9, suggesting that biases observed between ascending and descending node ozone are related to similar biases in the retrieved aerosol extinction. Improvements to the aerosol retrieval software are currently being tested and may lead to the reduction of biases in ozone between OSIRIS ascending and descending node measurements in future versions of the data product.

5.2.3 Albedo

Above ~ 30 km, agreement between OSIRIS and the validation data sets was found to be related to the OSIRIS albedo, which measures apparent upwelling and is obtained by fitting the absolute value of the 740 nm modelled limb radiance at 40 km by adjusting the albedo with a forward model (Bourassa et al., 2007). The strongest bias was observed at ~ 42.5 km, and is shown in Fig. 10 for comparisons with MLS and GOMOS. At all latitudes, OSIRIS ozone measurements are larger for higher albedo. At these altitudes, UV wavelengths are used in the ozone retrievals, so very little limb-scattered sunlight would originate from the lower altitudes, suggesting that this bias is not caused by errors in the radiative transfer due to poor estimates of albedo. Therefore, this may reflect the relationship between albedo and another OSIRIS measurement parameter. In order to check for this, Fig. 10 was reproduced and found to be consistent

Assessment of Odin-OSIRIS ozone measurements from 2001 to the present

C. Adams et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures

⏪

⏩

◀

▶

Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



Assessment of Odin-OSIRIS ozone measurements from 2001 to the present

C. Adams et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures

◀

▶

◀

▶

Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



under a variety of additional conditions, including various narrow ranges of OSIRIS optics temperature, solar zenith angle, solar scattering angle, and measurement season. This observed bias may also point to a feature in the spectra in this altitude range, since albedo is retrieved using radiances at 40 km. The reason for the relationship between ozone and albedo at these altitudes remains under investigation.

5.3 Drift analysis

In order to assess the long-term consistency of OSIRIS ozone data, time series of percent differences between OSIRIS and the correlative data sets were analyzed. Hubert et al. (2013) tested techniques for evaluating drifts between satellite instruments and ozone sonde and lidar networks. They calculated drifts for various temporal averaging settings (e.g. no averaging, daily, monthly), regression techniques, and regression models (e.g. the inclusion of a seasonal term). The methods used in the present study were based on the preferred settings of Hubert et al. (2013), and are described below. Linear regressions of daily-averaged mean percent differences versus time were performed using a bi-square weighted robust fitting technique (e.g. Holland and Welsch, 1977). The robust fitting technique is preferred to classical least squares fits as it is less sensitive to outliers. The 2σ fitting error of the drift was approximately corrected for autocorrelation of the noise (Weatherhead et al., 1998), using the formula

$$\sigma' = \sigma \sqrt{\frac{1 + \varphi}{1 - \varphi}}, \quad (2)$$

where φ is the autocorrelation within the percent difference time series for a lag of one measurement, σ is the fitting error, and σ' is the autocorrelation-corrected error. This yields a more conservative estimate of σ . Error estimates were also calculated using the bootstrapping technique (Efron, 1979) over the fitting residuals, and were found to be very similar to the standard fitting error. For comparisons with MLS and GOMOS, the drift was calculated within 10° latitude bins. For ozone sondes, calculations were

Assessment of Odin-OSIRIS ozone measurements from 2001 to the present

C. Adams et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures

⏪

⏩

◀

▶

Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

performed at individual ozone sonde stations to avoid artificial drifts if, e.g. a station started or stopped taking measurements part way through the time series. Drifts were only considered for latitude bins or ozone sondes stations with at least eight years of correlative measurements, with at least 10 measurements per year.

Figure 11 shows drift analysis results in 10° latitude bins for OSIRIS minus MLS and OSIRIS minus GOMOS. Drifts with magnitudes $< 3\%$ per decade are required for trend studies (Ozone_cci, 2011). Above 20.5 km, drifts meet this requirement and errors are $< 2\%$ at most latitudes and altitudes for comparisons with MLS and GOMOS, suggesting good stability in the OSIRIS measurements. Some latitudinal structure is observed in the drifts, with positive drifts exceeding 3% in the tropics at some altitudes in both the MLS and GOMOS comparisons. Furthermore, at low latitudes near the tropopause, drifts of up to 10% per decade are observed, with errors of $\sim 5\text{--}10\%$ per decade. These larger drifts are mostly positive, but the latitudinal structure of the sign of the drifts is not exactly consistent between the MLS and GOMOS data sets. This suggests that perhaps the apparent drifts at lower altitudes are affected by sampling of highly variable percent differences.

The mean of the drifts within the latitude bins and ozone sonde stations are shown in Fig. 12, with the associated standard error. Absolute values of global drifts relative are $< 3\%$ per decade above 18.5 km relative to MLS and above 19.5 km relative to GOMOS. For comparisons against MLS, drifts are within the standard error of $\pm 3\%$ per decade at all altitudes. Drifts compared with ozone sondes are within 3% per decade for 13.5–22.5 km, with a positive drift of $3\text{--}5\%$ per decade for 23.5–29.5 km. At all altitudes, drifts relative to ozone sondes are within error of 3% per decade.

When assessing the time series of percent differences between two instruments, inconsistencies in parameters used to enable the comparisons may bias the result. In particular, erroneous trends in temperature may manifest as trends in ozone, as temperature affects neutral density and layer thickness. This has been observed for temperatures from the National Center for Environmental Prediction (NCEP) reanalysis (e.g. McLinden and Fioletov, 2011). For comparisons with GOMOS, this is not an issue,

different units is problematic, especially in the upper stratosphere where reanalyses often produce unreliable temperature trends (Gaffen et al., 2000).

To summarize, the OSIRIS data set meets the Ozone_cci criterion for stability relative to MLS and GOMOS for 19.5–36.5 km and is within error of the criterion at all altitudes relative to ozone sondes. Above 36.5 km, drifts between OSIRIS and GOMOS meet the standards, but drifts relative to MLS vary from 0–6 % per decade, depending on the conversion of MLS profiles to the OSIRIS grid. Therefore, this work demonstrates that gradual changes in the local time of the OSIRIS ascending node and optics temperature (Fig. 1) have not caused significant drifts in the OSIRIS ozone data set, with the most robust results for 19.5–36.5 km.

6 Conclusions

The 2002–present OSIRIS v5.0x ozone data set was characterized using MLS v2.2, GOMOS v6, and ozone sonde measurements. Biases in the OSIRIS data set were investigated in detail by binning mean percent differences according to various measurement parameters. For optics temperatures $< 16^{\circ}\text{C}$ OSIRIS ozone data are biased low for 25.5–40.5 km by up to 6 %, while for optics temperatures $> 16^{\circ}\text{C}$ positive biases of ~ 1 –3 % are observed. This is qualitatively consistent with previous comparisons against SAGE II v7.0 (Adams et al., 2013). This bias is apparent at all latitudes, supporting that it is caused by reduced resolution and/or pointing errors when the optics temperatures are low. Biases between ascending and descending node measurements were also observed and are consistent with comparisons against SAGE II (Adams et al., 2013). Below 30 km, these biases were found to be associated with biases in aerosol extinction, particularly near 22.5 km. This may therefore explain the 2–4 % positive bias in OSIRIS measurements at this altitude. Above 30 km, ozone biases varied systematically with albedo. The reasons for this are still under investigation. The information on OSIRIS biases gained through this study will be used in order to improve the retrieval algorithm for future versions of the OSIRIS ozone data set.

Assessment of Odin-OSIRIS ozone measurements from 2001 to the present

C. Adams et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures

◀

▶

◀

▶

Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



Assessment of Odin-OSIRIS ozone measurements from 2001 to the present

C. Adams et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures



Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



While biases were identified, good overall agreement between OSIRIS and the validation data sets was observed. Overall, OSIRIS agreed with all the three validation data sets to within 5% above 21.5 km. Furthermore, the absolute value of the global average drift between OSIRIS and the validation data sets was < 3% per decade for comparisons against MLS for 19.5–36.5 km, against GOMOS above 19.5 km, and against ozone sondes for 13.5–22.5 km, and within error of 3% per decade at most altitudes. For comparisons against MLS, the calculated drift was found to be dependent on the choice in data sets for conversion to the OSIRIS altitude versus neutral density grid, particularly above 35 km, where trends in ECWMF temperatures do not match the measured trends. Overall this work demonstrates that the 11 yr OSIRIS ozone data set has remained consistent with other ozone measurements throughout the Odin mission, and can therefore be used in merged ozone data products and trend studies.

Acknowledgements. Thank-you to Nick Lloyd, Chris Roth, and Landon Rieger for answering many questions about the OSIRIS data set. This work was supported by the Natural Sciences and Engineering Research Council (Canada) and the Canadian Space Agency. Odin is a Swedish-led satellite project funded jointly by Sweden (SNSB), Canada (CSA), France (CNES), and Finland (Tekes). The work at the Finnish Meteorological Institute was supported by the ESA Ozone_cci project and the Academy of Finland (project MIDAT). Work at the Jet Propulsion Laboratory, California Institute of Technology, was performed under contract with the National Aeronautics and Space Administration. The correlative data from balloon-based ozone sonde used in this publication were obtained from the World Ozone and Ultraviolet Data Center (WOUDC) archives (see <http://www.woudc.org>). We thank warmly several members of the NDACC community and ozone sonde working group for fruitful discussions.

References

Adams, C., Bourassa, A. E., Bathgate, A. F., McLinden, C. A., Lloyd, N. D., Roth, C. Z., Llewellyn, E. J., Zawodny, J. M., Flittner, D. E., Manney, G. L., Daffer, W. H., and Degenstein, D. A.: Characterization of Odin-OSIRIS ozone profiles with the SAGE II dataset, Atmos. Meas. Tech. Discuss., 6, 1033–1065, doi:10.5194/amtd-6-1033-2013, 2013.

**Assessment of
Odin-OSIRIS ozone
measurements from
2001 to the present**

C. Adams et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures

⏪

⏩

◀

▶

Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



- Bertaux, J. L., Kyrölä, E., Fussen, D., Hauchecorne, A., Dalaudier, F., Sofieva, V., Tamminen, J., Vanhellefont, F., Fanton d'Andon, O., Barrot, G., Mangin, A., Blanot, L., Lebrun, J. C., Pérot, K., Fehr, T., Saavedra, L., Leppelmeier, G. W., and Fraisse, R.: Global ozone monitoring by occultation of stars: an overview of GOMOS measurements on ENVISAT, *Atmos. Chem. Phys.*, 10, 12091–12148, doi:10.5194/acp-10-12091-2010, 2010.
- 5 Bourassa, A. E., Degenstein, D. A., Gattinger, R. L., and Llewellyn, E. J.: Stratospheric aerosol retrieval with optical spectrograph and infrared imaging system limb scatter measurements, *J. Geophys. Res.*, 112, 1–15, doi:10.1029/2006JD008079, 2007.
- Bourassa, A. E., Degenstein, D. A., and Llewellyn, E. J.: Retrieval of stratospheric aerosol size information from OSIRIS limb scattered sunlight spectra, *Atmos. Chem. Phys.*, 8, 6375–6380, doi:10.5194/acp-8-6375-2008, 2008a.
- 10 Bourassa, A. E., Degenstein, D. A., and Llewellyn, E. J.: SASKTRAN: a spherical geometry radiative transfer code for efficient estimation of limb scattered sunlight, *J. Quant. Spectrosc. Ra.*, 109, 52–73, doi:10.1016/j.jqsrt.2007.07.007, 2008b.
- 15 Bourassa, A. E., McLinden, C. A., Sioris, C. E., Brohede, S., Bathgate, A. F., Llewellyn, E. J., and Degenstein, D. A.: Fast NO₂ retrievals from Odin-OSIRIS limb scatter measurements, *Atmos. Meas. Tech.*, 4, 965–972, doi:10.5194/amt-4-965-2011, 2011.
- Bourassa, A. E., McLinden, C. A., Bathgate, A. F., Elash, B. J., and Degenstein, D. A.: Precision estimate for Odin-OSIRIS limb scatter retrievals, *J. Geophys. Res.*, 117, 1–9, doi:10.1029/2011JD016976, 2012.
- 20 Degenstein, D. A., Bourassa, A. E., Roth, C. Z., and Llewellyn, E. J.: Limb scatter ozone retrieval from 10 to 60 km using a multiplicative algebraic reconstruction technique, *Atmos. Chem. Phys.*, 9, 6521–6529, doi:10.5194/acp-9-6521-2009, 2009.
- Deshler, T., Mercer, J. L., Smit, H. G. J., Stubi, R., Levrat, G., Johnson, B. J., Oltmans, S. J., Kivi, R., Thompson, A. M., Witte, J., Davies, J., Schmidlin, F. J., Brothers, G., and Sasaki, T.: Atmospheric comparison of electrochemical cell ozone sondes from different manufacturers, and with different cathode solution strengths: the balloon experiment on standards for ozone sondes, *J. Geophys. Res.*, 113, 1–17, doi:10.1029/2007JD008975, 2008.
- 25 Efron, B.: Bootstrap methods: another look at the jackknife, *Ann. Stat.*, 7, 1–26, 1979.
- 30 Froidevaux, L., Jiang, Y. B., Lambert, A., Livesey, N. J., Read, W. G., Waters, J. W., Browell, E. V., Hair, J. W., Avery, M. A., McGee, T. J., Twigg, L. W., Sumnicht, G. K., Jucks, K. W., Margitan, J. J., Sen, B., Stachnik, R. A., Toon, G. C., Bernath, P. F., Boone, C. D., Walker, K. A., Filipiak, M. J., Harwood, R. S., Fuller, R. A., Manney, G. L., Schwartz, M. J.,

Assessment of Odin-OSIRIS ozone measurements from 2001 to the present

C. Adams et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures

◀

▶

◀

▶

Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



Daffer, W. H., Drouin, B. J., Cofield, R. E., Cuddy, D. T., Jarnot, R. F., Knosp, B. W., Perun, V. S., Snyder, W. V., Stek, P. C., Thurstans, R. P., and Wagner, P. A.: Validation of aura microwave limb Sounder stratospheric ozone measurements, *J. Geophys. Res.*, 113, 1–24, doi:10.1029/2007JD008771, 2008.

5 Gaffen, D. J., Sargent, M. A., Habermann, R. E., and Lazante, J. R.: Sensitivity of tropospheric and stratospheric temperature trends to radiosonde data quality, *J. Climate*, 13, 1776–1796, 2000.

GOMOS: GOMOS Level 2 Product Quality Readme File, ENVI-GSOP-EOGD-QD-12-0117, issue 1.0, 1–15 available at: http://earth.eo.esa.int/pcs/envisat/gomos/documentation/RMF_0117_GOM_NL_2P_Disclaimers.pdf, last access: 28 February 2013, 2012.

10 Harvey, V. L., Hitchman, M. H., Pierce, R. B., and Fairlie, T. D.: Tropical aerosol in the Aleutian High, *J. Geophys. Res.*, 104, 6281–6290, 1999.

Hassler, B., Bodeker, G. E., and Dameris, M.: Technical Note: A new global database of trace gases and aerosols from multiple sources of high vertical resolution measurements, *Atmos. Chem. Phys.*, 8, 5403–5421, doi:10.5194/acp-8-5403-2008, 2008.

Holland, P. W. and Welsch, R. E.: Robust regression using iteratively reweighted least-squares, *Commun. Stat. A-Theor.*, 6, 813–827, doi:10.1080/03610927708827533, 1977.

Hubert, D., Verhoelst, T., Keppens, A., Granville, J., Baray, J.-L., Cortesi, U., Degenstein, D. A., Froidevaux, L., Godin-Beekmann, S., Hoppel, K. W., Kyrola, E., Leblanc, T., Lichtenberg, G., McElroy, C. T., Nair, P., Nakane, H., Russell III, J. M., Stebel, K., Steinbrecht, W., Strawbridge, K. B., Stübi, R., Swart, D., Taha, G., Urban, J., van Gijsel, A., von der Gathen, P., Walker, K. A., Zawodny, J. M., and Lambert, J.-C.: Ground-based assessment of the bias and long-term stability of fourteen limb and occultation ozone profile data records, *Atmos. Meas. Tech.*, in preparation, 2013.

25 Jiang, Y. B., Froidevaux, L., Lambert, A., Livesey, N. J., Read, W. G., Waters, J. W., Bojkov, B., Leblanc, T., McDermid, I. S., Godin-Beekmann, S., Filipiak, M. J., Harwood, R. S., Fuller, R. A., Daffer, W. H., Drouin, B. J., Cofield, R. E., Cuddy, D. T., Jarnot, R. F., Knosp, B. W., Perun, V. S., Schwartz, M. J., Snyder, W. V., Stek, P. C., Thurstans, R. P., Wagner, P. A., Allaart, M., Andersen, S. B., Bodeker, G., Calpini, B., Claude, H., Coetzee, G., Davies, J., De Backer, H., Dier, H., Fujiwara, M., Johnson, B., Kelder, H., Leme, N. P., König-Langlo, G., Kyro, E., Laneve, G., Fook, L. S., Merrill, J., Morris, G., Newchurch, M., Oltmans, S., Parrondos, M. C., Posny, F., Schmidlin, F., Skrivankova, P., Stubi, R., Tarasick, D., Thompson, A., Thouret, V., Viatte, P., Vömel, H., Von Der Gathen, P., Yela, M., and

Assessment of Odin-OSIRIS ozone measurements from 2001 to the present

C. Adams et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures

◀

▶

◀

▶

Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Zablocki, G.: Validation of aura microwave limb sounder ozone by ozone sonde and lidar measurements, *J. Geophys. Res.*, 112, D24S34, doi:10.1029/2007JD008776, 2007.

Kyrölä, E., Tamminen, J., Leppelmeier, G. W., Sofieva, V., Hassinen, S., Bertaux, J. L., Hauchecorne, A., Dalaudier, F., Cot, C., Korabiev, O., Fanton d'Andon, O., Barrot, G., Mangin, A., Théodore, B., Guirlet, M., Etanchaud, F., Snoeij, P., Koopman, R., Saavedra, L., Fraisse, R., Fussen, D., and Vanhellemont, F.: GOMOS on Envisat: an overview, *Adv. Space Res.*, 33, 1020–1028, doi:10.1016/S0273-1177(03)00590-8, 2004.

Kyrölä, E., Tamminen, J., Sofieva, V., Bertaux, J. L., Hauchecorne, A., Dalaudier, F., Fussen, D., Vanhellemont, F., Fanton d'Andon, O., Barrot, G., Guirlet, M., Mangin, A., Blanot, L., Fehr, T., Saavedra de Miguel, L., and Fraisse, R.: Retrieval of atmospheric parameters from GOMOS data, *Atmos. Chem. Phys.*, 10, 11881–11903, doi:10.5194/acp-10-11881-2010, 2010.

Livesey, N. J., Read, W. G., Froidevaux, L., Lambert, A., Manney, G. L., Pumphrey, H. C., Santee, M. L., Schwartz, M. J., Wang, S., Cofield, R. E., Cuddy, D. T., Fuller, R. A., Jarnot, R. F., Jiang, J. H., Knosp, B. W., Stek, P. C., Wagner, P. A., and Wu, D. L.: EOS MLS Version 3.3 Level 2 data quality and description document, Jet Propulsion Laboratory, California Institute of Technology, Pasadena, available at: http://mls.jpl.nasa.gov/data/v3-3_data_quality_document.pdf, California, 2011.

Llewellyn, E. J., Lloyd, N. D., Degenstein, D. A., Gattinger, R. L., Petelina, S. V., Bourassa, A. E., Wiensz, J. T., Ivanov, E. V., Mcdade, I. C., Solheim, B. H., Mcconnell, J. C., Haley, C. S., Von Savigny, C., Sioris, C. E., Mclinden, C. A., Griffioen, E., Kaminski, J., Evans, W. F. J., Puckrin, E., Strong, K., Wehrle, V., Hum, R. H., Kendall, D. J. W., Matsushita, J., Murtagh, D. P., Brohede, S., Stegman, J., Witt, G., Barnes, G., Payne, W. F., Piché, L., Smith, K., Warsaw, G., Deslauniers, D., Marchand, P., Richardson, E. H., King, R. A., Wevers, I., McCreath, W., Kyrölä, E., Oikarinen, L., Leppelmeier, G. W., Auvinen, H., Mégie, G., Hauchecorne, A., Lefèvre, F., De La Nöe, J., Ricaud, P., Frisk, U., Sjöberg, F., Von Schéele, F., and Nordh, L.: The OSIRIS instrument on the Odin spacecraft, *Can. J. Phys.*, 82, 411–422, doi:10.1139/P04-005, 2004.

McLinden, C. A. and Fioletov, V.: Quantifying stratospheric ozone trends: complications due to stratospheric cooling, *J. Geophys. Res.*, 38, L03808, doi:10.1029/2010GL046012, 2011.

McLinden, C. A., Haley, C. S., and Sioris, C. E.: Diurnal effects in limb scatter observations, *J. Geophys. Res.*, 111, 1–10, doi:10.1029/2005JD006628, 2006.

McLinden, C. A., Fioletov, V. E., Haley, C. S., Lloyd, N., Roth, C., Degenstein, D., Bourassa, A., McElroy, C. T., and Llewellyn, E. J.: An evaluation of Odin/OSIRIS limb pointing and

Assessment of Odin-OSIRIS ozone measurements from 2001 to the present

C. Adams et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures

◀

▶

◀

▶

Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

stratospheric ozone through comparisons with ozone sondes, *Can. J. Phys.*, 85, 1125–1141, doi:10.1139/P07-112, 2007.

5 McLinden, C. A., Bourassa, A. E., Brohede, S., Cooper, M., Degenstein, D. A., Evans, W. J. F., Gattinger, R. L., Haley, C. S., Llewellyn, E. J., Lloyd, N. D., Loewen, P., Martin, R. V., McConnell, J. C., McDade, I. C., Murtagh, D., Rieger, L., Von Savigny, C., Sheese, P. E., Sioris, C. E., Solheim, B., and Strong, K.: OSIRIS: a decade of scattered light, *B. Am. Meteorol. Soc.*, 93, 1845–1863, doi:10.1175/BAMS-D-11-00135.1, 2012.

10 Murtagh, D., Frisk, U., Merino, F., Ridal, M., Jonsson, A., Stegman, J., Witt, G., Jiménez, C., Megie, G., Noë, J. De, Ricaud, P., Baron, P., Pardo, J. R., Llewellyn, E. J., Degenstein, D. A., Gattinger, R. L., Lloyd, N. D., Evans, W. F. J., McDade, I. C., Haley, C. S., Sioris, C., Savigny, V., Solheim, B. H., McConnell, J. C., Richardson, E. H., Leppelmeier, G. W., Auvinen, H., and Oikarinen, L.: Review: An overview of the Odin atmospheric mission, *Can. J. Phys.*, 80, 309–319, doi:10.1139/P01-157, 2002.

15 Nagatani, R. M. and Rosenfield, J. E.: Temperature, net heating and circulation, in: *The Atmospheric Effects of Stratospheric Aircraft: Report of the 1992 Models and Measurements Workshop*, MD 21076–1320 Springfield, VA 22161–2171, NASA Ref. Publ. 1291, edited by: Remsberg, E. E. and Prather, M. J., A1–A47, 1993.

20 Natarajan, M., Deaver, L. E., Thompson, E., and Magill, B.: Impact of twilight gradients on the retrieval of mesospheric ozone from HALOE, *J. Geophys. Res.*, 110, 1–11, doi:10.1029/2004JD005719, 2005.

Ozone_cci: Ozone_cci User Requirement Document, 2.1, 1–43, available at: http://www.esa-ozone-cci.org/?q=webfm_send/37, last access: 5 December 2012, 2011.

25 Randel, W. J., Shine, K. P., Austin, J., Barnett, J., Claud, C., Gillett, N. P., Keckhut, P., Lange-matz, U., Lin, R., Long, C., Mears, C., Miller, A., Nash, J., Seidel, D. J., Thompson, D. W. J., Wu, F., and Yoden, S.: An update of observed stratospheric temperature trends, *J. Geophys. Res.*, 114, D02107, doi:10.1029/2008JD010421, 2009.

Rodgers, C. D. and Connor, B. J.: Intercomparison of remote sounding instruments, *J. Geophys. Res.*, 108, 4116, doi:10.1029/2002JD002299, 2003.

30 Roth, C. Z., Degenstein, D. A., Bourassa, A. E., and Llewellyn, E. J.: The retrieval of vertical profiles of the ozone number density using Chappuis band absorption information and a multiplicative algebraic reconstruction technique, *Can. J. Phys.*, 85, 1225–1243, doi:10.1139/P07-130, 2007.

Assessment of Odin-OSIRIS ozone measurements from 2001 to the present

C. Adams et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures

◀

▶

◀

▶

Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Schwartz, M. J., Lambert, A., Manney, G. L., Read, W. G., Livesey, N. J., Froidevaux, L.,
Ao, C. O., Bernath, P. F., Boone, C. D., Cofield, R. E., Daffer, W. H., Drouin, B. J., Fet-
zer, E. J., Fuller, R. A., Jarnot, R. F., Jiang, J. H., Jiang, Y. B., Knosp, B. W., Krüger, K.,
Li, J.-L. F., Mlynczak, M. G., Pawson, S., Russell III, J. M., Santee, M. L., Snyder, W. V.,
5 Stek, P. C., Thurstans, R. P., Tompkins, A. M., Wagner, P. A., Walker, K. A., Waters, J. W.,
and Wu, D. L.: Validation of the aura microwave limb sounder temperature and geopotential
height measurements, *J. Geophys. Res.*, 113, D15S11, doi:10.1029/2007JD008783, 2008.

SI²N: SI²N Initiative, available at: http://igaco-o3.fmi.fi/VDO/working_groups.html (last access:
11 April 2013), 2013.

10 Smit, H. G. J., Straeter, W., Johnson, B. J., Oltmans, S. J., Davies, J., Tarasick, D. W.,
Hoegger, B., Stubi, R., Schmidlin, F. J., Northam, T., Thompson, A. M., Witte, J. C.,
Boyd, I., and Posny, F.: Assessment of the performance of ECC-ozone sondes under
quasi-flight conditions in the environmental simulation chamber: insights from the Juelich
Ozone Sonde Intercomparison Experiment (JOSIE), *J. Geophys. Res.*, 112, D19306,
15 doi:10.1029/2006JD007308, 2007.

Sofieva, V. F., Vira, J., Kyrölä, E., Tamminen, J., Kan, V., Dalaudier, F., Hauchecorne, A.,
Bertaux, J.-L., Fussen, D., Vanhellemont, F., Barrot, G., and Fanton d'Andon, O.: Retrievals
from GOMOS stellar occultation measurements using characterization of modeling errors,
Atmos. Meas. Tech., 3, 1019–1027, doi:10.5194/amt-3-1019-2010, 2010.

20 Tamminen, J., Kyrölä, E., Sofieva, V. F., Laine, M., Bertaux, J.-L., Hauchecorne, A.,
Dalaudier, F., Fussen, D., Vanhellemont, F., Fanton-d'Andon, O., Barrot, G., Mangin, A., Guir-
let, M., Blanot, L., Fehr, T., Saavedra de Miguel, L., and Fraise, R.: GOMOS data charac-
terisation and error estimation, *Atmos. Chem. Phys.*, 10, 9505–9519, doi:10.5194/acp-10-9505-
2010, 2010.

25 van Gijsel, J. A. E., Swart, D. P. J., Baray, J.-L., Bencherif, H., Claude, H., Fehr, T., Godin-
Beekmann, S., Hansen, G. H., Keckhut, P., Leblanc, T., McDermid, I. S., Meijer, Y. J.,
Nakane, H., Quel, E. J., Stebel, K., Steinbrecht, W., Strawbridge, K. B., Tatarov, B. I., and
Wolfram, E. A.: GOMOS ozone profile validation using ground-based and balloon sonde
measurements, *Atmos. Chem. Phys.*, 10, 10473–10488, doi:10.5194/acp-10-10473-2010,
30 2010.

Waters, J. W., Froidevaux, L., Harwood, R. S., Jarnot, R. F., Pickett, H. M., Read, W. G.,
Siegel, P. H., Cofield, R. E., Filipiak, M. J., Flower, D. A., Holden, J. R., Lau, G. K.,
Livesey, N. J., Manney, G. L., Pumphrey, H. C., Santee, M. L., Wu, D. L., Cuddy, D. T.,

Assessment of Odin-OSIRIS ozone measurements from 2001 to the present

C. Adams et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures

◀

▶

◀

▶

Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



Lay, R. R., Loo, M. S., Perun, V. S., Schwartz, M. J., Stek, P. C., Thurstans, R. P.,
Boyles, M. A., Chandra, K. M., Chavez, M. C., Chen, G., Chudasama, B. V., Dodge, R.,
Fuller, R. A., Girard, M. A., Jiang, J. H., Jiang, Y., Knosp, B. W., Labelle, R. C., Lam, J. C.,
Lee, K. A., Miller, D., Oswald, J. E., Patel, N. C., Pukala, D. M., Quintero, O., Scaff, D. M.,
5 Snyder, W. Van, Tope, M. C., Wagner, P. A., and Walch, M. J.: The Earth Observing System
Microwave Limb Sounder (EOS MLS) on the aura satellite, IEEE T. Geosci. Remote, 44,
1075–1092, 2006.

Weatherhead, E. C., Reinsel, G. C., Tiao, G. C., Meng, X., Choi, D., Cheang, W.-K., Keller, T.,
DeLuisi, J., Wuebbles, D. J., Kerr, J. B., Miller, A. J., Olthmans, S. J., and Frederick, J. E.:
10 Factors affecting the detection of trends: statistical considerations and applications to envi-
ronmental data range, J. Geophys. Res., 103, 17149–17161, 1998.

WMO: Scientific assessment of ozone depletion 2010, Rep. 52, Global ozone research moni-
toring project, Geneva, 2010.

WOUDC: World Ozone and Ultraviolet Radiation Data Centre, available at: <http://www.woudc.org/>
15 <http://www.woudc.org/> (12 July 2012), 2012.

Assessment of Odin-OSIRIS ozone measurements from 2001 to the present

C. Adams et al.

Table 1. Coincidence criteria and smoothing techniques.

	Time (\pm h)	Distance (\pm km)	Latitude (\pm $^{\circ}$)	Smoothing
OSIRIS-MLS	6*	500	1	OSIRIS smoothed to the resolution of MLS using least squares fitting technique followed by smoothing with averaging kernels
OSIRIS-GOMOS	24	1000	1	–
OSIRIS-Ozone sondes	24	1000	1	Ozone sondes smoothed to the resolution of OSIRIS using triangular filter

* For each OSIRIS measurement, only the MLS measurement closest in time was selected as a coincident pair.

[Title Page](#)
[Abstract](#)
[Introduction](#)
[Conclusions](#)
[References](#)
[Tables](#)
[Figures](#)
[Back](#)
[Close](#)
[Full Screen / Esc](#)
[Printer-friendly Version](#)
[Interactive Discussion](#)


Assessment of
Odin-OSIRIS ozone
measurements from
2001 to the present

C. Adams et al.

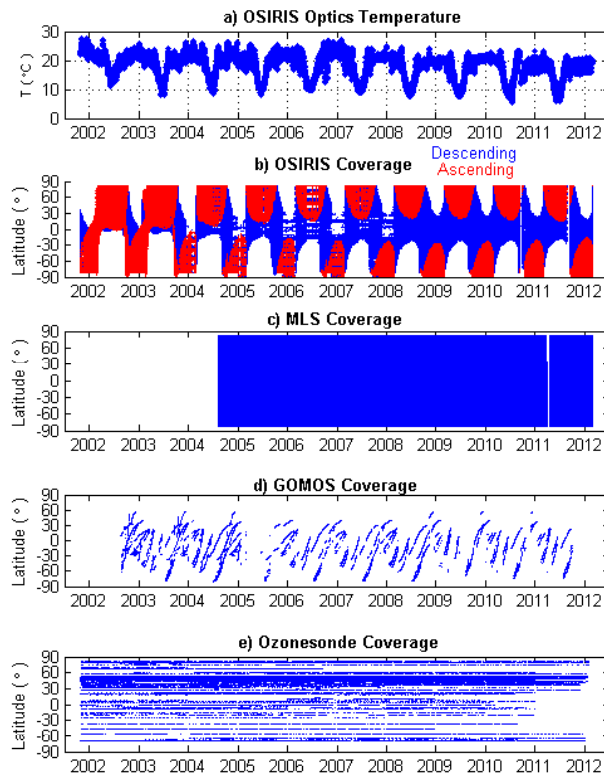


Fig. 1. Time series of (a) OSIRIS optics temperature and latitudes sampled by (b) OSIRIS, (c) MLS, (d) GOMOS, and (e) ozone sondes since the beginning of the OSIRIS ozone measurement record. OSIRIS descending node measurements are given in blue and ascending node measurements are given in red.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures

◀

▶

◀

▶

Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Assessment of Odin-OSIRIS ozone measurements from 2001 to the present

C. Adams et al.

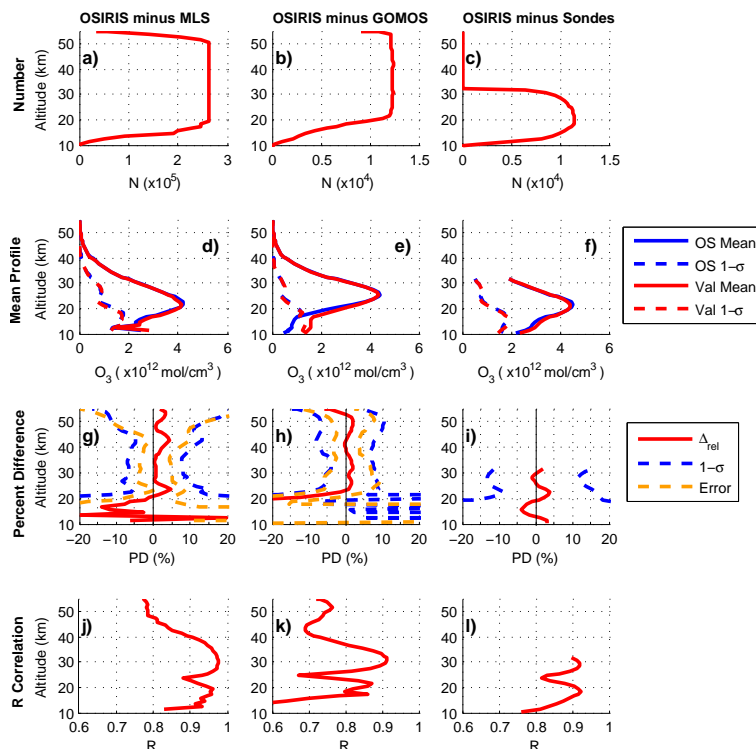


Fig. 2. Summary of global mean comparison results for (left) OSIRIS versus MLS, (middle) OSIRIS versus GOMOS, and (right) OSIRIS versus ozone-sondes over the full time-period of coincident measurements. (Top) Number of coincidences. (Middle-top) Mean (solid lines) and standard deviation (dashed lines) of coincident OSIRIS (blue) and validation data set (red) ozone profiles. (Middle bottom) Mean of percent differences (red), standard deviation (blue), and combined retrieval error added in quadrature (yellow) for OSIRIS validation data sets. (Right) R correlation coefficient for OSIRIS versus validation data sets.

Assessment of Odin-OSIRIS ozone measurements from 2001 to the present

C. Adams et al.

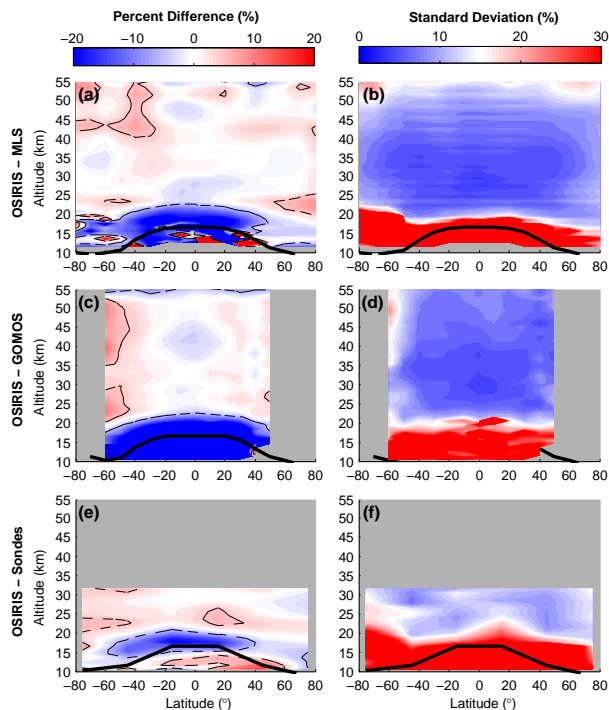


Fig. 3. Comparison results binned by latitude for (top) OSIRIS minus MLS, (middle) OSIRIS minus GOMOS, and (bottom) OSIRIS minus ozone sondes. (Left) Mean percent difference, with $\pm 5\%$ contour lines indicated with dashed lines. (Right) Standard deviation in mean percent difference. Comparison results were calculated in 10° latitude bins for comparisons with MLS and GOMOS and in 30° latitude bins for comparisons with ozone sondes. The thick black lines indicate the average World Meteorological Organization (WMO) thermal tropopause height of the coincident measurements, calculated from ECMWF analysis data. The grey shading indicates regions for which there are fewer than 10 coincidences.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures

◀

▶

◀

▶

Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Assessment of Odin-OSIRIS ozone measurements from 2001 to the present

C. Adams et al.

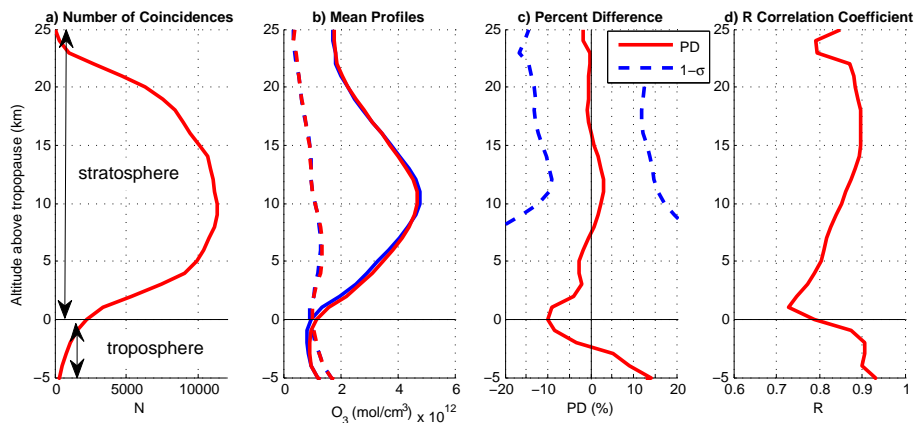


Fig. 4. As for the right column of Fig. 2, for OSIRIS and ozone sonde measurements re-gridded relative to the WMO thermal tropopause calculated with ECMWF analysis data. The black horizontal zero-line indicates the tropopause.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures

◀

▶

◀

▶

Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Assessment of Odin-OSIRIS ozone measurements from 2001 to the present

C. Adams et al.

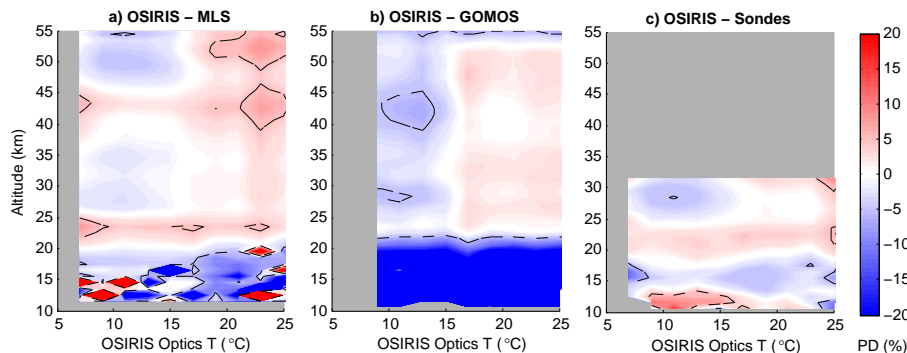


Fig. 5. Variation in percent differences for **(a)** OSIRIS minus MLS, **(b)** OSIRIS minus GOMOS and **(c)** OSIRIS minus ozon sondes at various OSIRIS optics temperatures. Contours of mean percent differences (color-scale) were calculated for 2°C OSIRIS optics temperature bins (x-axis) at various altitudes (y-axis). The black dashed lines indicate $\pm 5\%$ mean percent difference. The grey shading indicates bins for which there are fewer than 10 coincidences.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures

◀

▶

◀

▶

Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Assessment of Odin-OSIRIS ozone measurements from 2001 to the present

C. Adams et al.

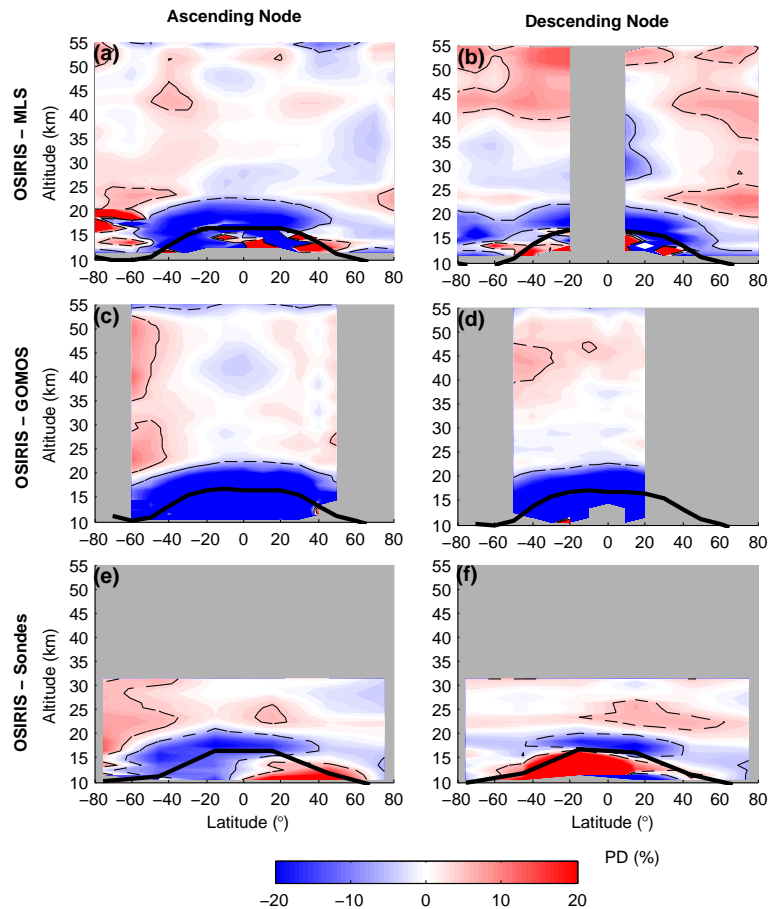


Fig. 7. As for left panels of Fig. 3, for mean percent differences for OSIRIS (left) descending node measurements and (right) OSIRIS ascending node measurements minus (top) MLS, (middle) GOMOS, and (bottom) ozone sondes.

**Assessment of
Odin-OSIRIS ozone
measurements from
2001 to the present**

C. Adams et al.

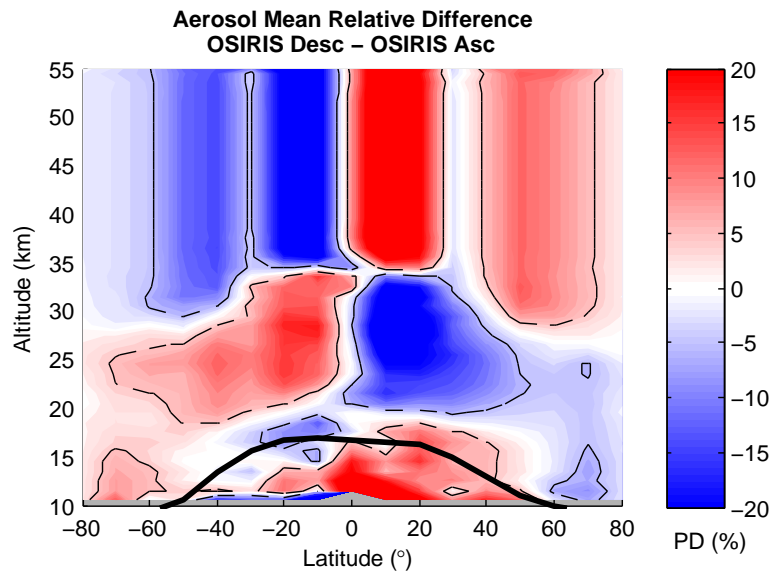


Fig. 8. As for left panels of Fig. 3, for coincident OSIRIS aerosol extinctions measured in the descending node minus aerosol extinction measured in the ascending node.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures

◀

▶

◀

▶

Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Assessment of Odin-OSIRIS ozone measurements from 2001 to the present

C. Adams et al.

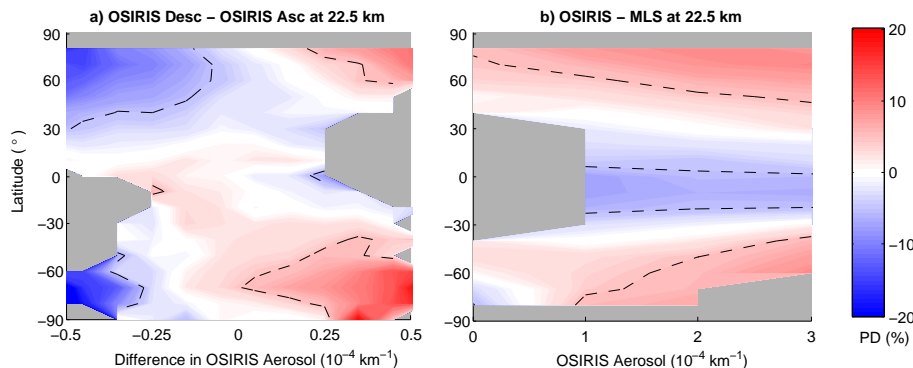


Fig. 9. (Left) Percent difference (color scale) in ozone for coincident OSIRIS descending node minus ascending node measurements binned by the difference in OSIRIS descending node minus ascending node aerosol extinction at 22.5 km (x-axis) and latitude (y-axis). (Right) Mean percent difference (color scale) in ozone for OSIRIS minus MLS binned according to the OSIRIS aerosol extinction at 22.5 km (x-axis) and latitude (y-axis). The dashed contour lines indicate mean percent differences of $\pm 5\%$. Comparison results were calculated in 10° latitude bins. The grey shading indicates bins for which there are fewer than 10 coincidences.

Assessment of Odin-OSIRIS ozone measurements from 2001 to the present

C. Adams et al.

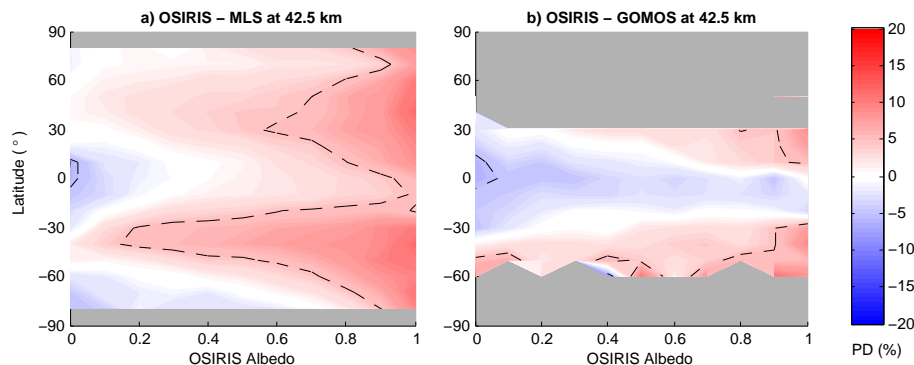


Fig. 10. Mean percent differences for (left) OSIRIS minus MLS and (right) OSIRIS minus GOMOS at 32.5 km in albedo (x-axis) and 10° latitude (y-axis) bins. The black dashed lines indicate $\pm 5\%$ mean percent difference. The grey shading indicates bins for which there are fewer than 10 coincidences.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures

◀

▶

◀

▶

Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



Assessment of Odin-OSIRIS ozone measurements from 2001 to the present

C. Adams et al.

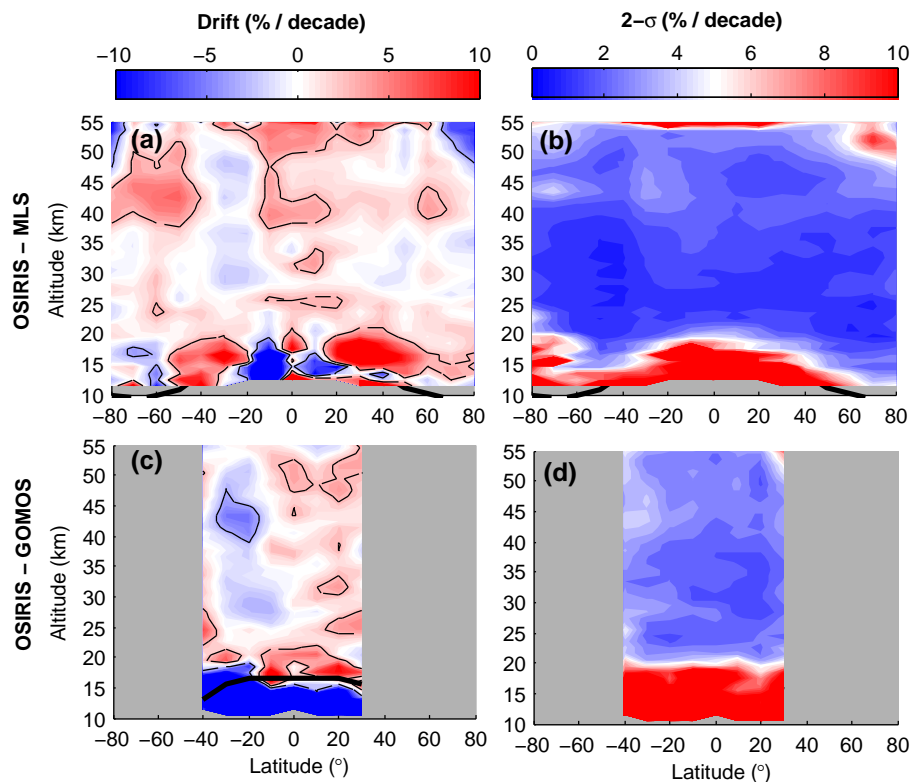


Fig. 11. Drift analysis results for (top) OSIRIS minus MLS and (bottom) OSIRIS minus GOMOS in 10° latitude bins. (Left) Drift in percent per decade, with drifts of $\pm 3\%$ indicated by the black dashed contour lines. (Right) 2σ error in drift estimate. The thick black lines indicate the average WMO thermal tropopause height of the coincident measurements, calculated from ECMWF analysis data. The grey shading indicates regions for which there are fewer than 10 coincidences.

Assessment of Odin-OSIRIS ozone measurements from 2001 to the present

C. Adams et al.

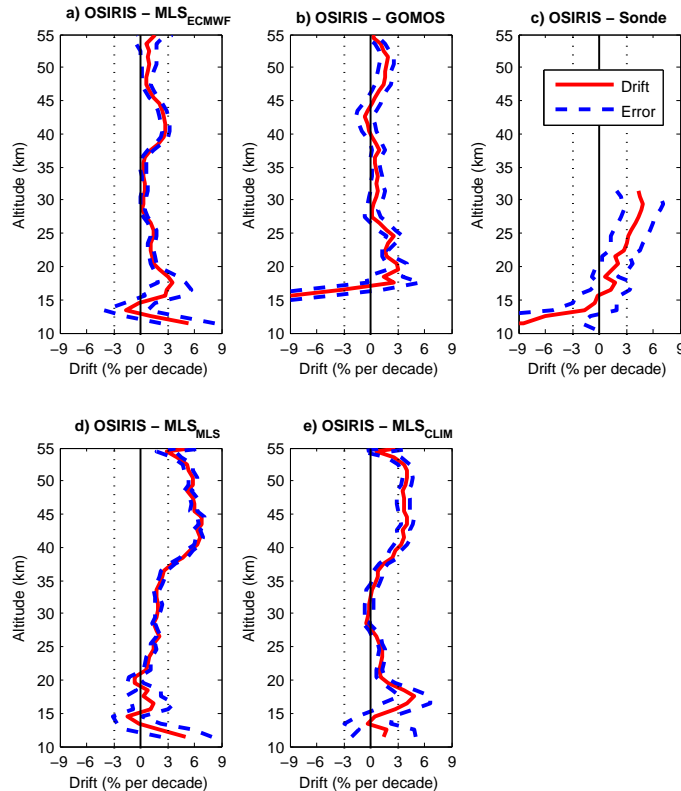


Fig. 12. Global average results from drift analysis for **(a)** OSIRIS minus MLS converted with ECMWF altitudes and temperatures, **(b)** OSIRIS minus GOMOS, **(c)** OSIRIS minus ozone sondes, **(d)** OSIRIS minus MLS converted using MLS-measured altitudes and temperatures, and **(e)** OSIRIS minus MLS converted using climatological altitudes and temperatures with measured temperature trends superimposed on the data set. The global average drift (solid red line) and the standard error (dashed blue line) across latitude bins and sonde-station are shown. The thin black dotted lines indicate $\pm 3\%$ per decade.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures

◀

▶

◀

▶

Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion