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QUADRENNIAL OZONE SYMPOSIUM

[E283] Homogenisation of the Observatoire de Haute Provence ECC ozonesonde data record: comparison with lidar and satellite observation

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Introduction

At Observatoire de Haute Provence (OHP), stratospheric and free tropospheric ozone monitoring is carried out since the mid-1980s with ozonesonde and lidar observations. Improvement and homogenization of the OHP ozone ECC observations have been achieved from 1991 to 2021 using the recent ozonesonde data quality assessment (O3S-DQA) recommendations. We present here comparisons of ECC observations with lidar, surface UV photometer and satellite observations.

1) Lidar observations are carried out at the same location with two different DIAL instruments: a 289/316 nm DIAL for tropospheric measurements (2.5-14 km ASL) since 1991 and a 308/355 nm DIAL for stratospheric measurements (10-50 km ASL) since 1985.

2) Surface ozone hourly measurements are carried out since December 1997 at OHP using standard UV absorption method

3) Satellite observations are reported since 2005 using MLS stratospheric profiles (50 hPa - 5 hPa), or GOME, OMI and OMPS total ozone columns.

ECC homogenisation method

The ozone partial pressure P_{O3} measured by the EEC is related to the electrochemical current I, the background current I_0 measured in the lab with an ozone removal filter, the internal temperature of the air sample T_{ecc} , the capture efficiency of the O3 in the liquid phase α, the stoichiometry S of the O_3 to I_2 conversion and the ECC pump flow rate t_{pump}

$$P_{O3} = 4.308\,10^{-4} \cdot (I - I_0) \cdot T_{ecc} \cdot t_{pump} / (S \cdot \alpha)$$

A major change in the sounding procedure occurred in 1997 when the Science Pump Corporation (SPC) ozonesonde was replaced by an EnSCi ozonesonde while using the same KI concentration (1%) in the cathode cell. The following corrections have been made:

- Change of α with pressure before 1995 when 2.5 cm3 of KI solution was used
- Scaling of P_{O3} measured by ENSCI ozonesonde after 1997 to SPC ozonesonde observations (before 1997)
- Use an average I_0 value if I_0 > 0.1μA and increase the uncertainty on I_0
- Remove the dependency of the background current with the air pressure since the O_2 concentration is not playing a significant role in the residual current when ozone is removed
- Correction of measured T_{ecc} to account for changes in the position of the thermistor to assess the true air sample temperature
- Correction of the pump flow rate to account for humidification effect when using the bubble flowmeter under different laboratory conditions
- Use two different pump flow rate efficiency correction tables at pressure below 100 hPa for ENSCI and SPC ozonesondes

Methodology for homogenisation assessment

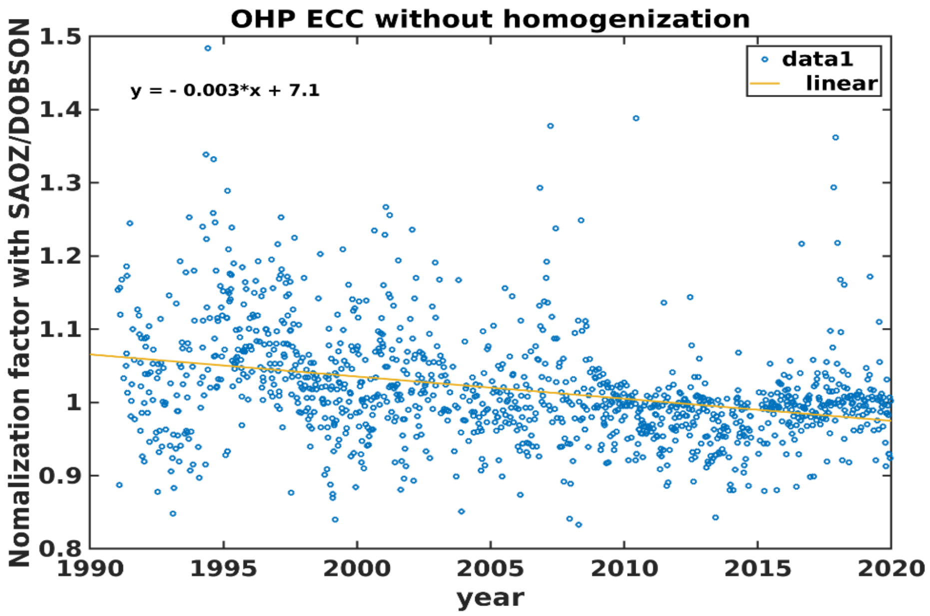
The methodology for the assessment of the homogenisation work is based on:

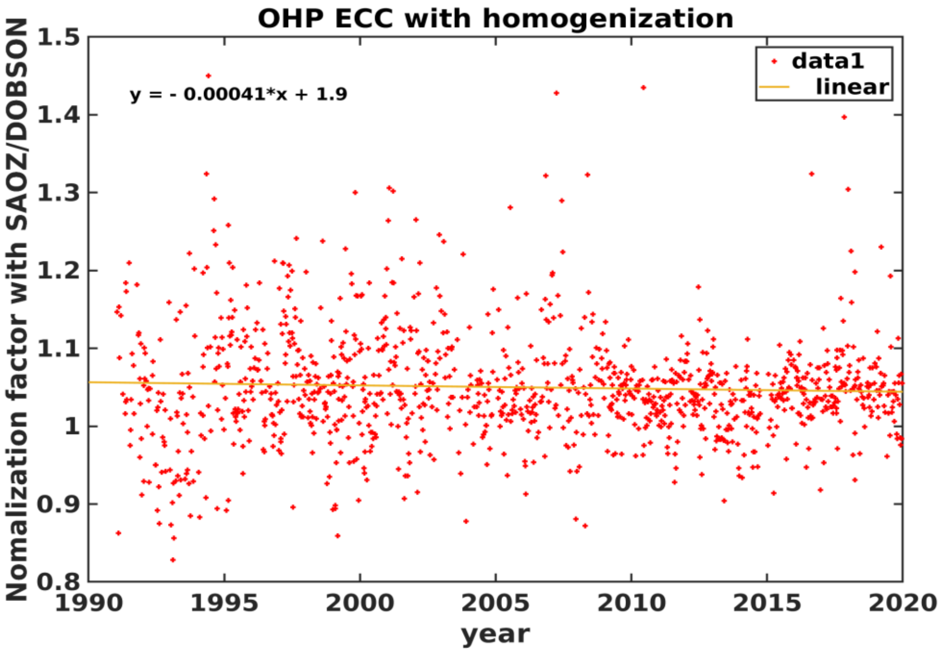
- ozone differences with or without the homogenisation correction using 40 nighttime ECC vertical profiles available at the lidar measurement times (10 soundings during the 2017/2018 LAVANDE intercomparison campaign, 15 soundings in 1995/2005, 15 soundings in 2017/2021).
- ozone differences with or without the homogenisation correction using ECC and MLS satellite stratospheric profile time series between 2005 and 2021 or using total ozone column from ECC and satellite observation. ECC total column is calculated integrating the profile up to 10 hPa and adding the McPeters and Labow (2012) climatology above 10 hPa.
- comparison of 30-year trends of ozone concentrations vertically averaged in several 2 km bins using ECC with or without the homogenisation correction and DIAL lidars
- comparison of 22-year trends of ozone concentrations using ECC measurements vertically averaged in the PBL between 0.6-1.6 km with or without the homogenisation and the surface OHP ozone daily mean

Impact on SAOZ/Dobson correction factor

The correction factor i.e. the ratio between the Dobson/SAOZ total O_3 column and the ECC profile integrated total O_3 column, is improved with the homogenization:

- removal of the negative trend due to changes in the sonde type and preparation in uncorrected values (blue dots) when the ECC are homogenised (red dots)
- the small overall remaining negative bias (5%) can be related to (i) the accuracy of the estimate of the residual ozone column above the balloon burst (the residual is of the order 10-20% of the total column) (ii) an underestimate of the ECC in the stratosphere above 50 hPa probably related to an uncertainty to evaporation/boiling or freezing of the solutions



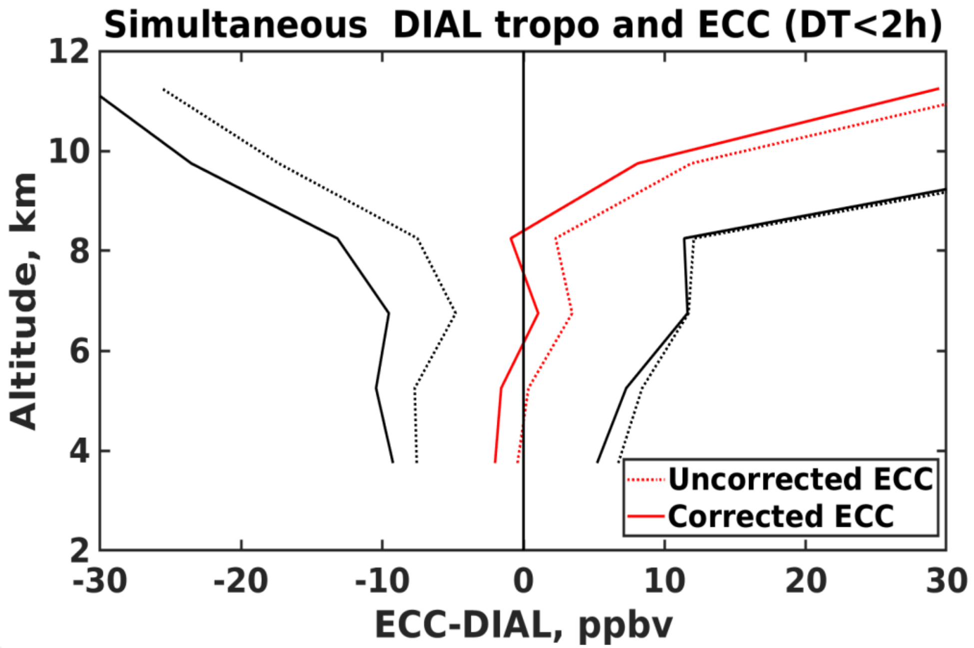


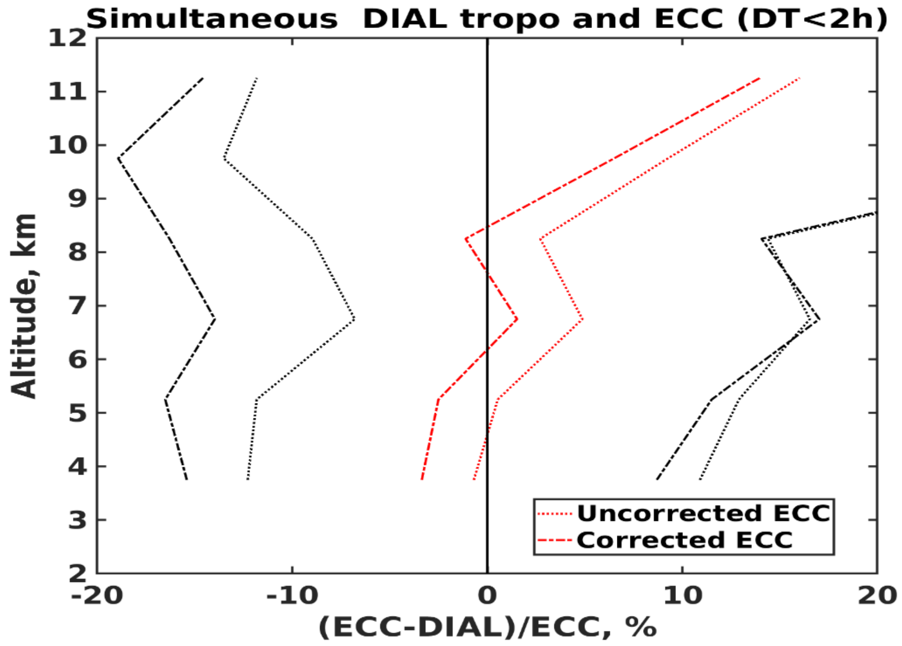
Comparison between 40 nighttime ECC and tropospheric DIAL when the measurement time difference is less than 2 hours

ECC-DIAL differences are calculated for 6 vertical slices of 1.5 km between 3 and 12 km. The mean (red) and the standard deviation (black) of the differences are reported.

The 3-ppbv mixing ratio bias between ECC and Tropo DIAL in the mid-troposphere (5-10 km) where the DIAL accuracy is maximum, is removed when using homogenisation

The remaining differences (-5% below 4 km and +10% above 10 km) are related to known lidar errors due to uncomplete laser/telescope overlap below 4 km and poor lidar signal to noise ratio or very large ozone gradient in the UTLS above 10 km.





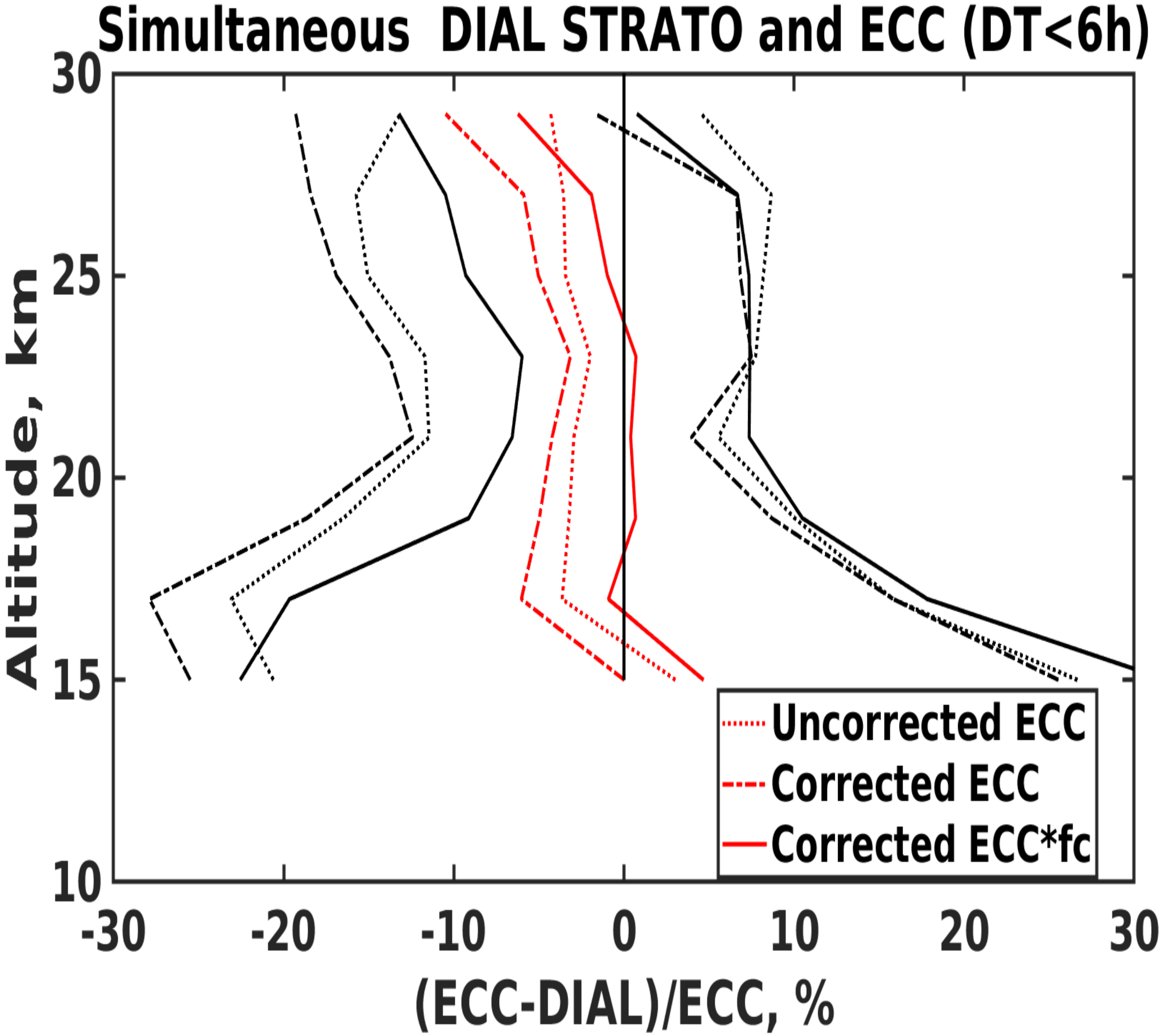
Comparison between 40 nighttime ECC and stratospheric DIAL when the measurement time difference is less than 6 hours

ECC-DIAL differences are calculated for 8 vertical slices of 2 km between 14 and 30 km. The mean (red) and the standard deviation (black) of the differences are reported. The ECC with homogenisation is also reported after multiplication by the correction factor (solid line).

Contrary to comparison in the troposphere the -5% negative bias in the stratosphere between ECC and DIAL is not improved by the homogenisation

The -5% bias also explains the mean correction factor of 1.05. The lidar/ECC bias vanishes when multiplying the ECC by the correction factor.

Above 28 km the homogenisation increases the negative bias implying that the uncertainty to evaporation/boiling or freezing of the solutions must be studied more carefully



Homogenisation of the OHP ECC ozonesonde

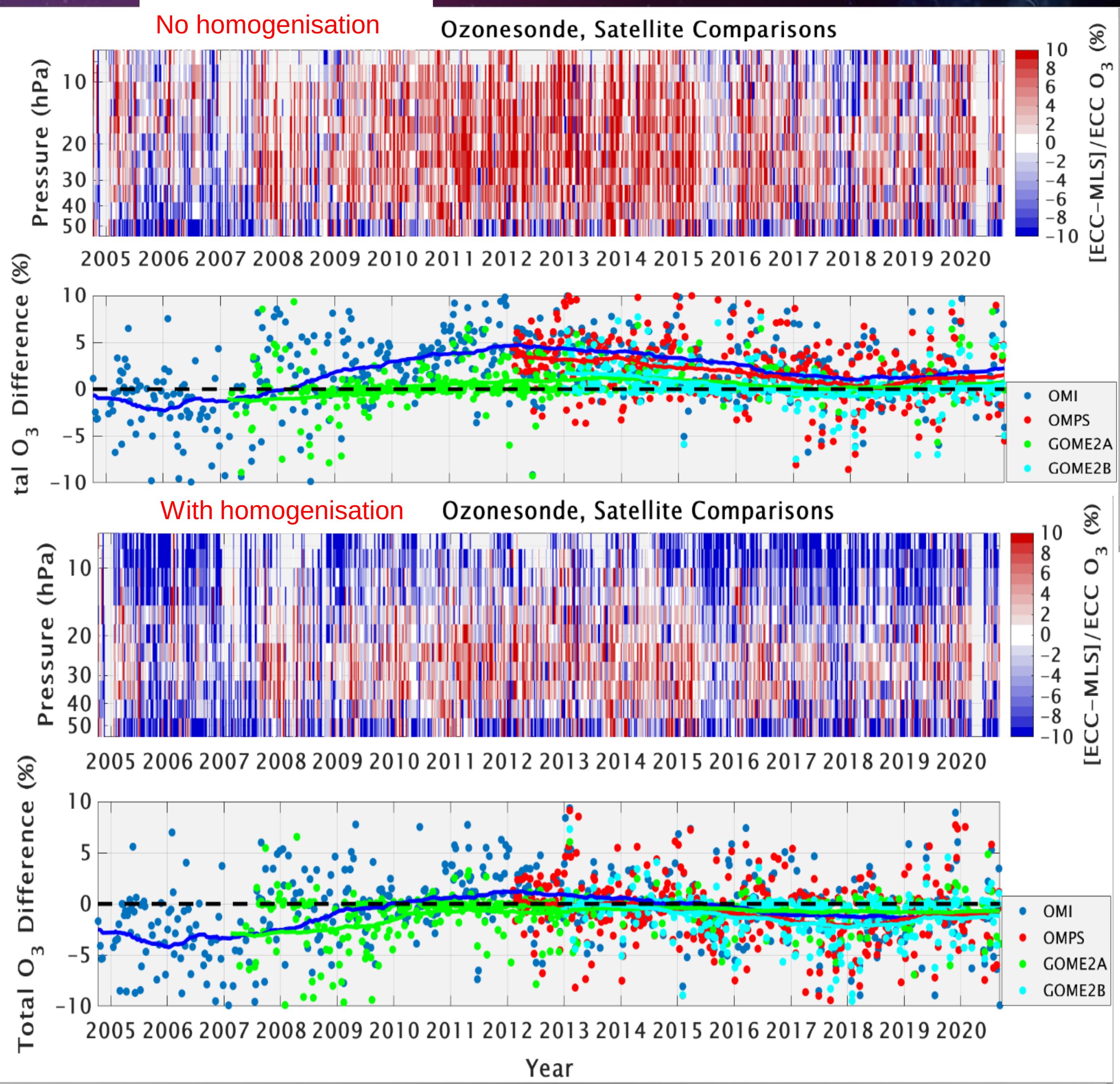
Comparison between ECC and satellite measurements in the stratosphere

ECC differences differences are calculated as a function of altitude for MLS between 50 hPa and 10 hPa. The bottom plots are for the total ozone column comparisons for several satellite data sets. No correction factor multiplication is applied.

The homogenisation significantly reduces the positive differences (+10%) between ECC and MLS observations during the 2009 and 2015 period. The same conclusion, can be drawn from the total ozone comparisons.

For the overall 2005-2020 period, the slight 5% negative bias for the homogenised data set is also seen in the comparison with satellite observations

Again above 15 hPa homogenisation increases the negative biases of the ECC measurements.



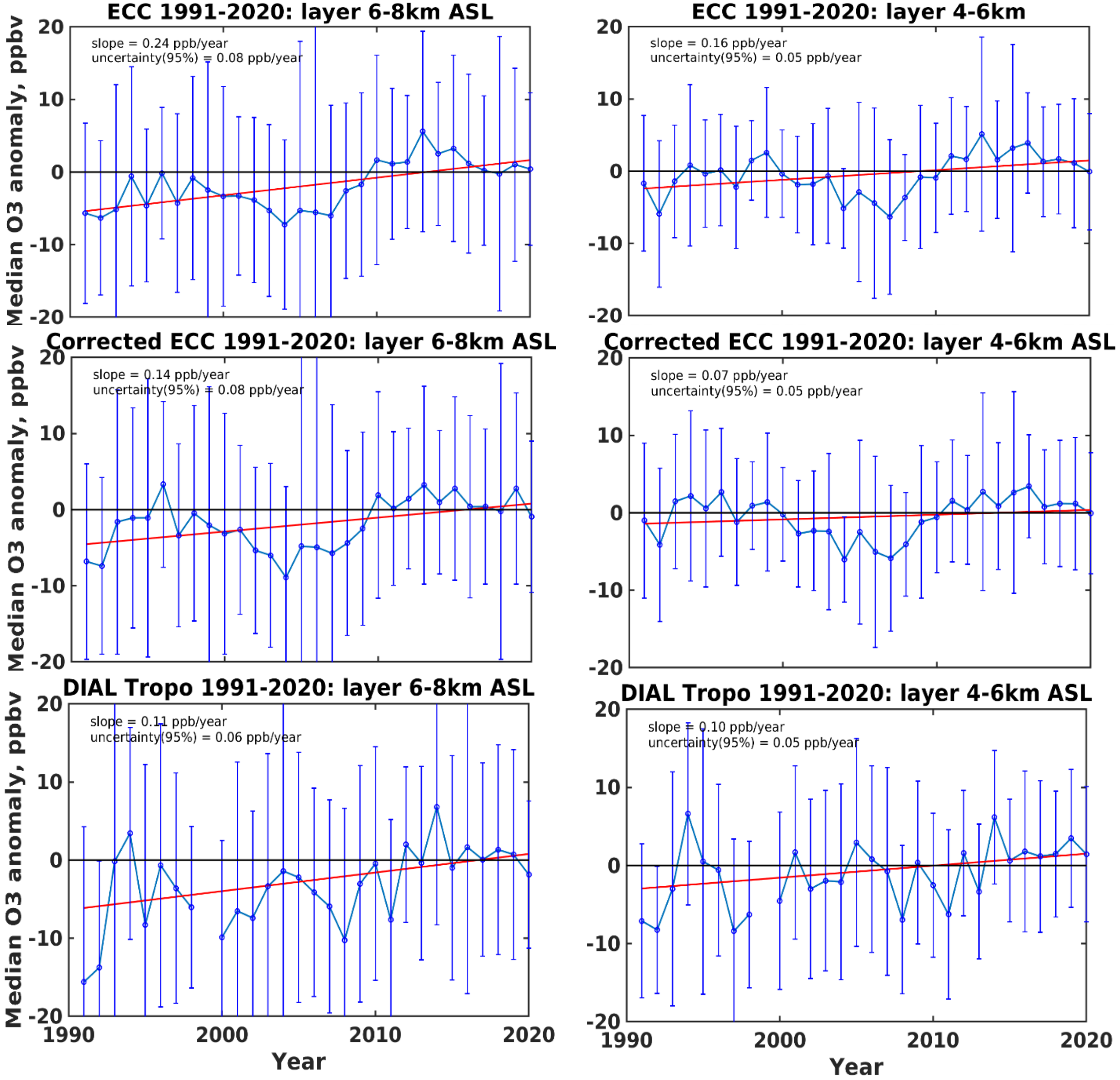
Comparison of trends in the troposphere

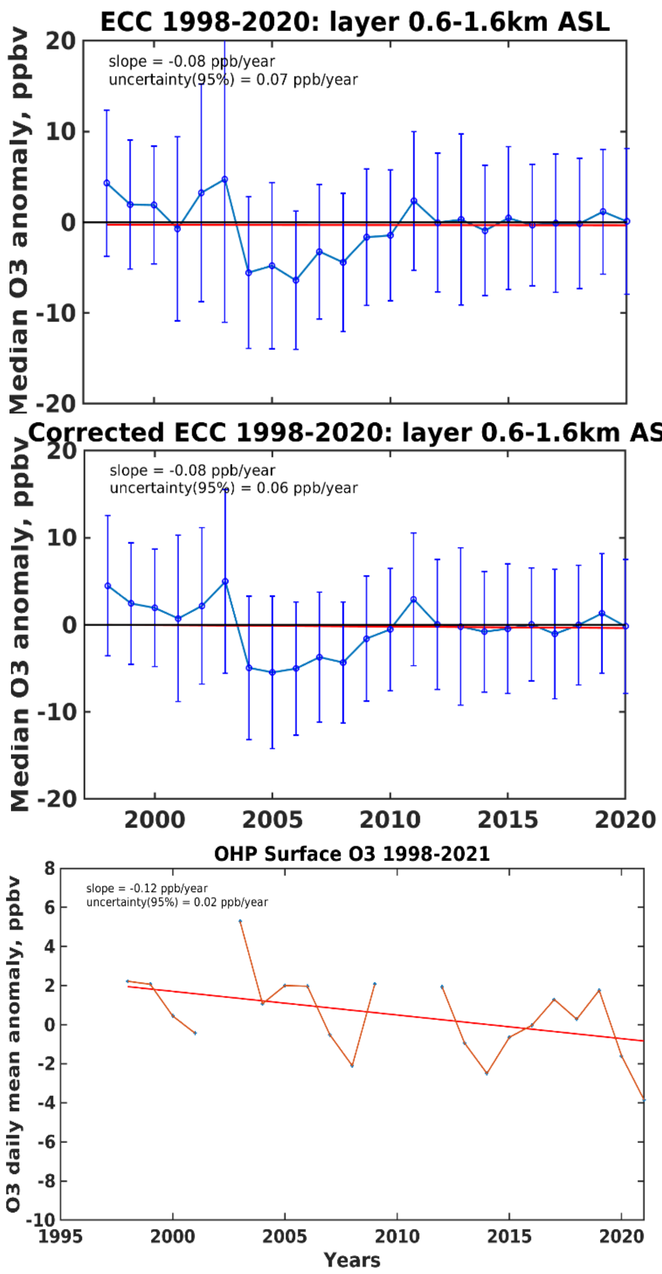
The ozone mixing ratio anomaly is the 2-km layer mean where the seasonal variation is removed. The range of annual O_3 anomalies is similar for ECC and tropo DIAL: -5 ppbv in the 90's and slightly positive in the period 2010-2020. Years with too little observations are removed for the trend calculation (lidar in 1999, surface data in 2002-2003 and 2010-2011)

The ECC trends are closer to those observed by the tropo DIAL when the ECC is homogenised.

No significant change for the surface measurements where observations started in 1998.

Notice the sign change of the trend from slightly negative (-0.8 ± 0.6 ppbv/decade) in the lowermost troposphere to slightly positive (+1 ± 0.6 ppbv/decade) in the mid troposphere.



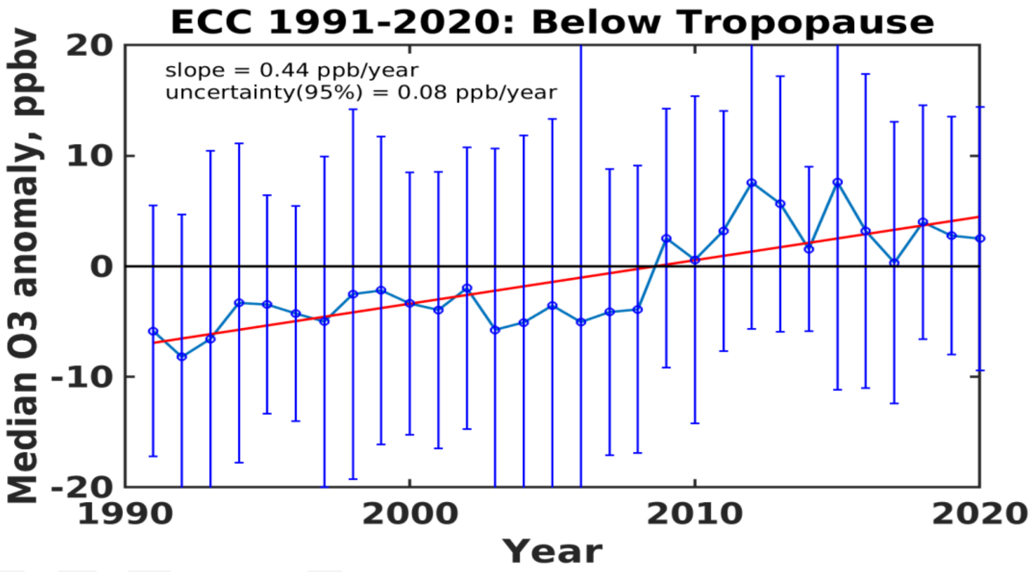


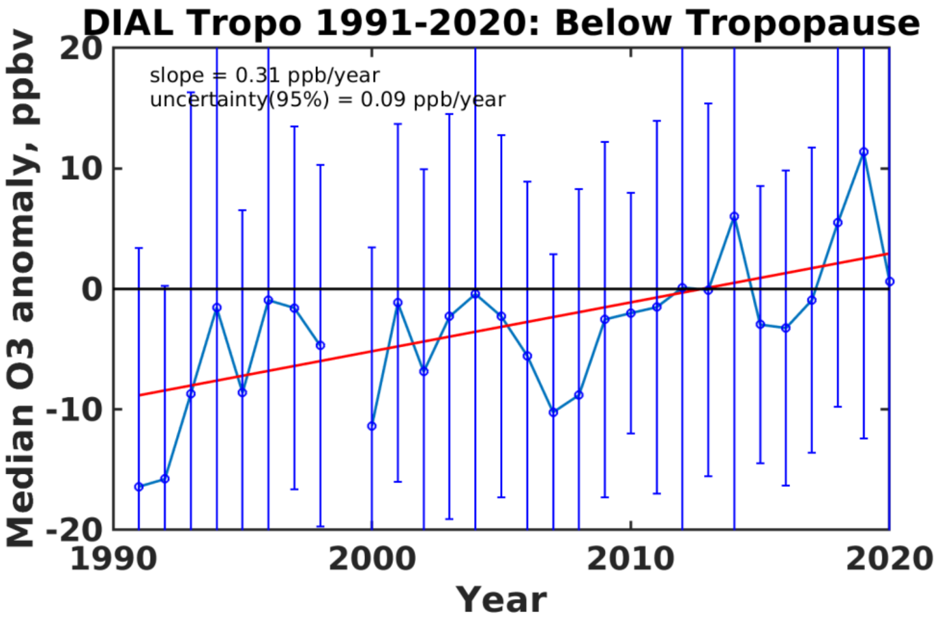
Comparison of trends in the Upper Troposphere/Lower Stratosphere (UTLS)

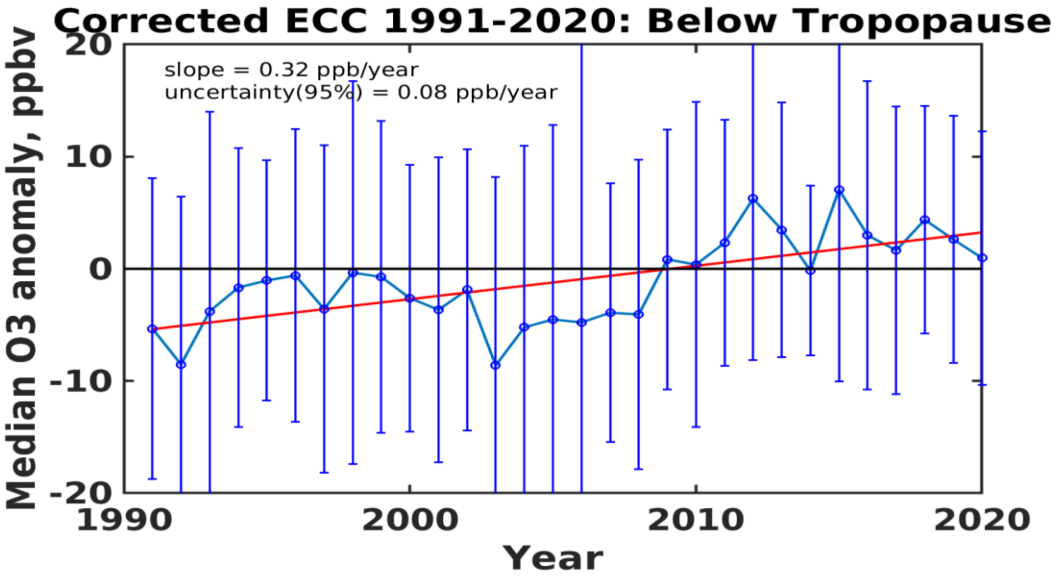
The mean of the ozone mixing ratio anomalies are calculated in the 2-km layer below the dynamical tropopause taken at 2 PVu. Seasonal variations of mixing ratio in this layer is removed. The range of annual O_3 anomalies is similar for ECC and tropo DIAL: -10 ppbv in the 90's and +5 ppbv in the period 2010-2020.

The agreement between lidar and ECC trend is again better for the homogenised ECC data set.

The positive trend is significant (+3 ± 0.8 ppbv/decade) in this layer.







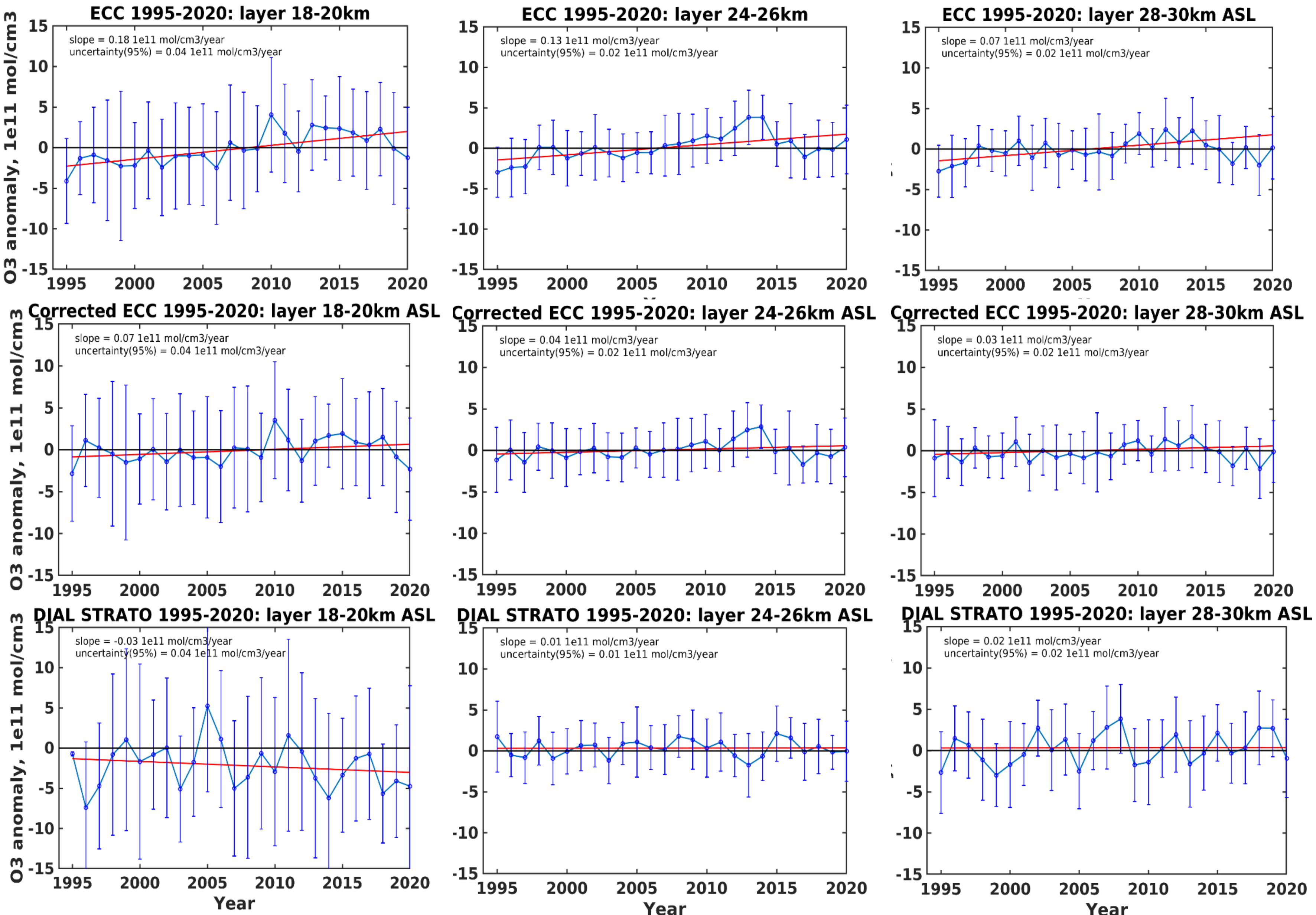
Homogenisation of the OHP ECC ozonesonde

Comparison of trends in the stratosphere

The 2-km layer mean ozone concentration anomalies are given from 18 km to 30 km. No multiplication by the correction factor is applied since the seasonal variation of the O3 concentration is removed. The range of annual O_3 anomalies are similar for ECC and strato DIAL above 24 km but lower for strato DIAL(-3 10^{11} mol.cm^3) than ECC (> -10^{11} mol.cm^3) after 2007 in the 18-20 km layer.

The ECC trends (7±4 10^{10} mol.cm^3/decade at 19 km and 3±2 10^{10} mol.cm^3/decade at 29 km) are closer to the small values observed by the strato DIAL (-3±4 10^{10} mol.cm^3/decade at 19 km and 2±2 10^{10} mol.cm^3/decade at 29 km) when the ECC is homogenised.

Notice that the trends becomes not significant for the 1995-2020 time period in the selected altitude layers when the ECC concentrations are homogenised.



Conclusions

Assessment of the OHP ECC homogenisation benefit has been carried out using comparisons with ground based instruments located at the same station (lidar, surface measurements) and collocated satellite observations. Results are:

- The 3-4 ppb positive bias of the ECC in the troposphere due to the ENSCI 1% KI is corrected with the homogenisation with better agreement between tropo DIAL and ECC in the mid-troposphere

- A very important result is that ECC trends of the seasonally adjusted ozone concentrations is significantly improved both in the troposphere and the stratosphere when the ECC concentrations are homogenised

- The negative trend of the correction factor calculated using the OHP SAOZ total column disappears thanks to the homogenisation of the ECC. There is however a remaining -5% negative bias which is likely related to an underestimate of the ECC concentrations in the stratosphere above 50 hPa as shown by comparison with the OHP strato DIAL (no bias between ECC and lidar when the ECC is multiplied by the correction factor).

- The assessment of the homogenisation based on direct comparisons of concentrations in the stratosphere between 18 km and 28 km is still difficult as comparisons with first strato DIAL in 1995-2005 and 2017-2020 and second with satellite observations from 2005 to 2020 do not give the same results. Both comparisons however suggest that homogenisation increases the negative bias of the ECC above 28 km