50 years of balloon borne ozone profile measurements at Uccle, Belgium

D. Poyraz, R. Van Malderen, H. De Backer, D. De Muer , A. Delcloo,
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Royal Meteorological Institute of Belgium

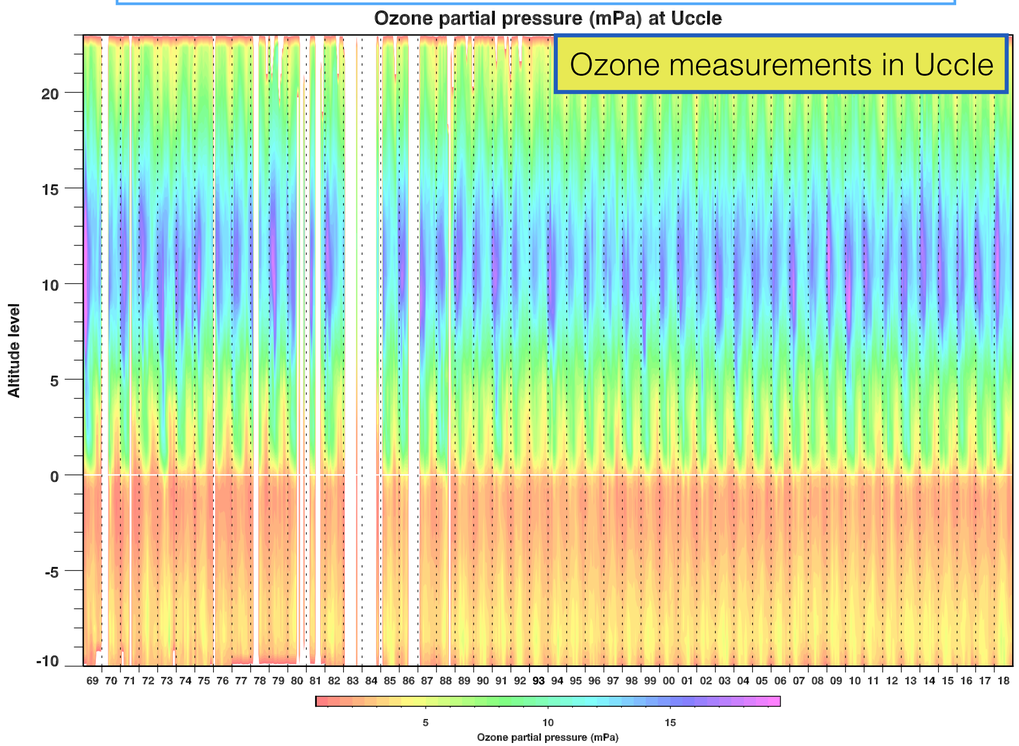
Importance

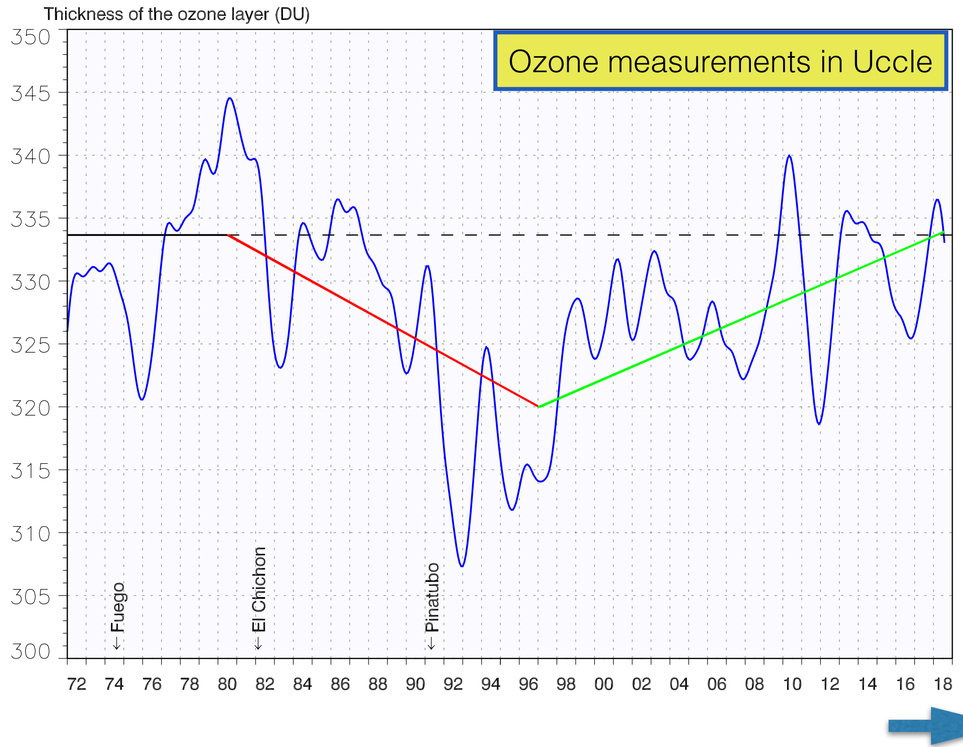
- Since 1969, ozonesondes are launched with weather balloons 3 times a week at Uccle, Belgium ($50°\ 48'\ \mathrm{N}, 4°\ 21'\ \mathrm{E}$)
- This is the third longest time series of Europe
- Total ozone column measurements with Dobson/Brewers since 1971

Ozone studies

The long term ozone datasets are important for:

- Trend analysis
- Validation of satellite ozone retrivials
- Process studies





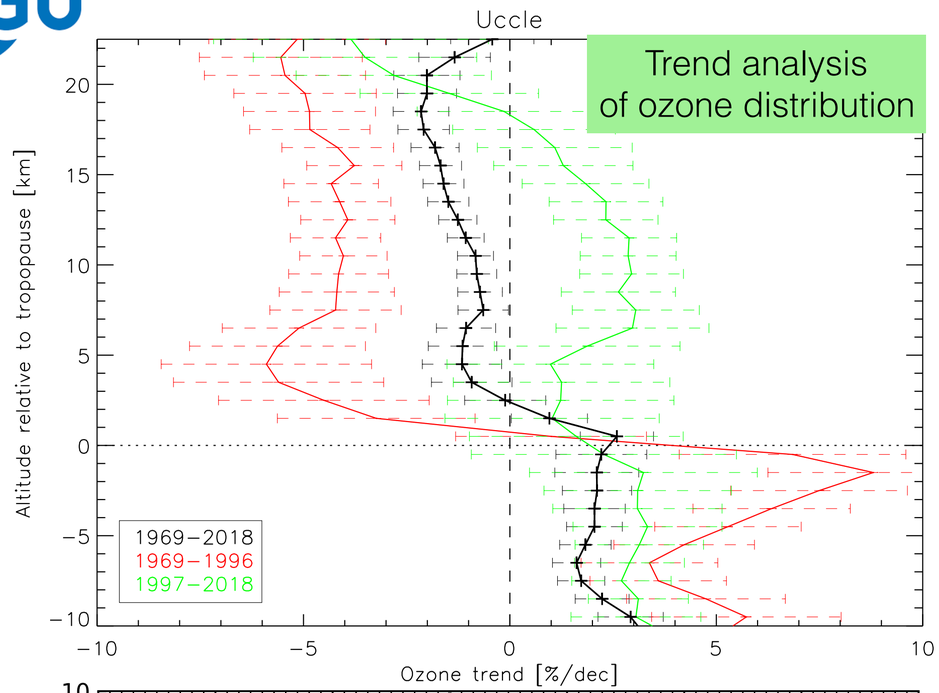
Photography encouraged

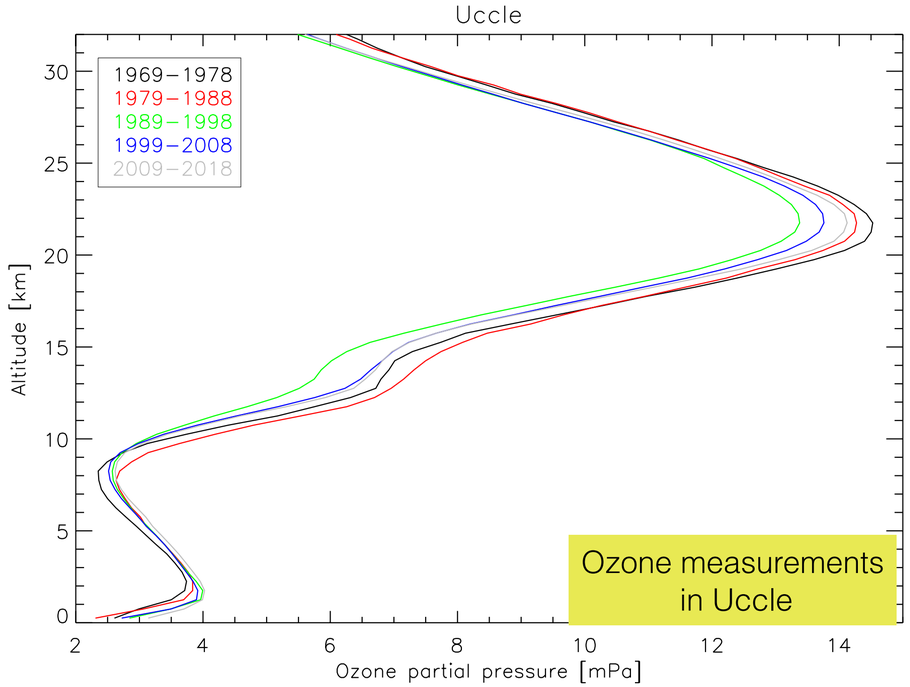
2-minute madness

50 years of balloon borne ozone profile measurements at Uccle, Belgium

2-minute madness

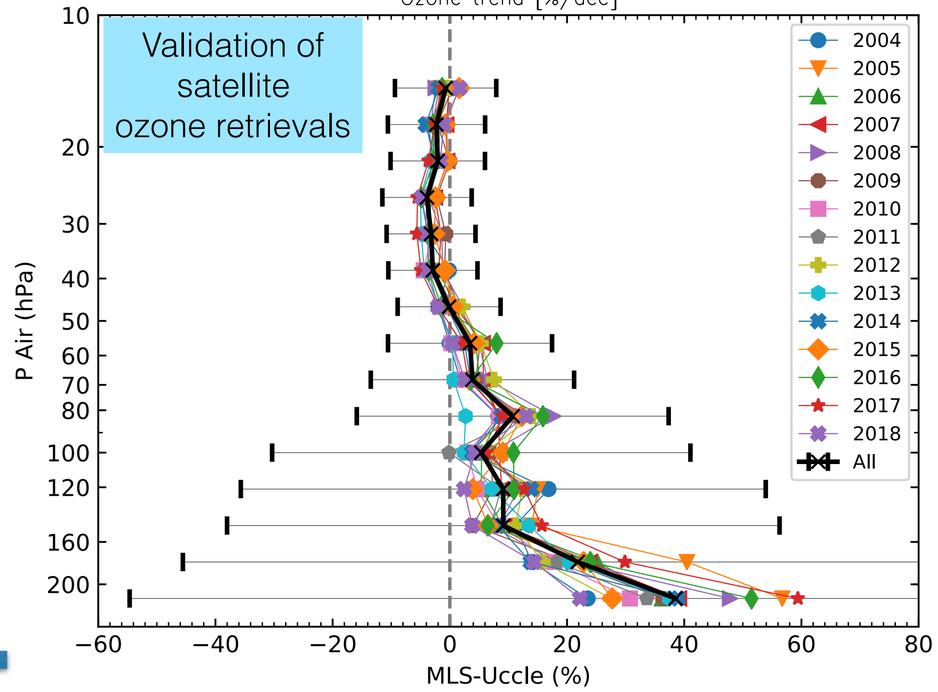
Trend analysis of ozone distribution



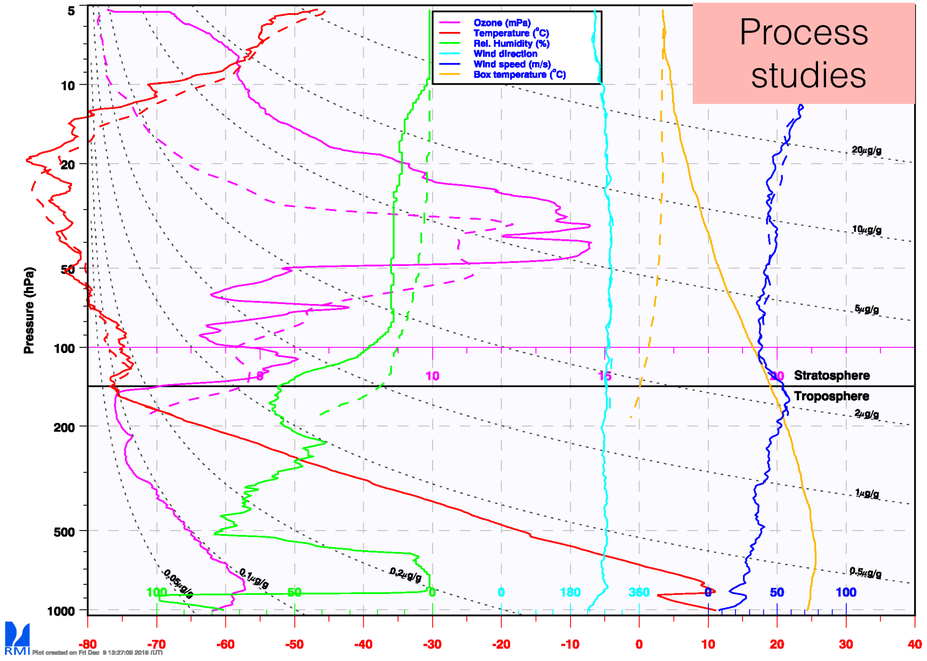


Ozone measurements in Uccle

Validation of satellite ozone retrievals



Process studies



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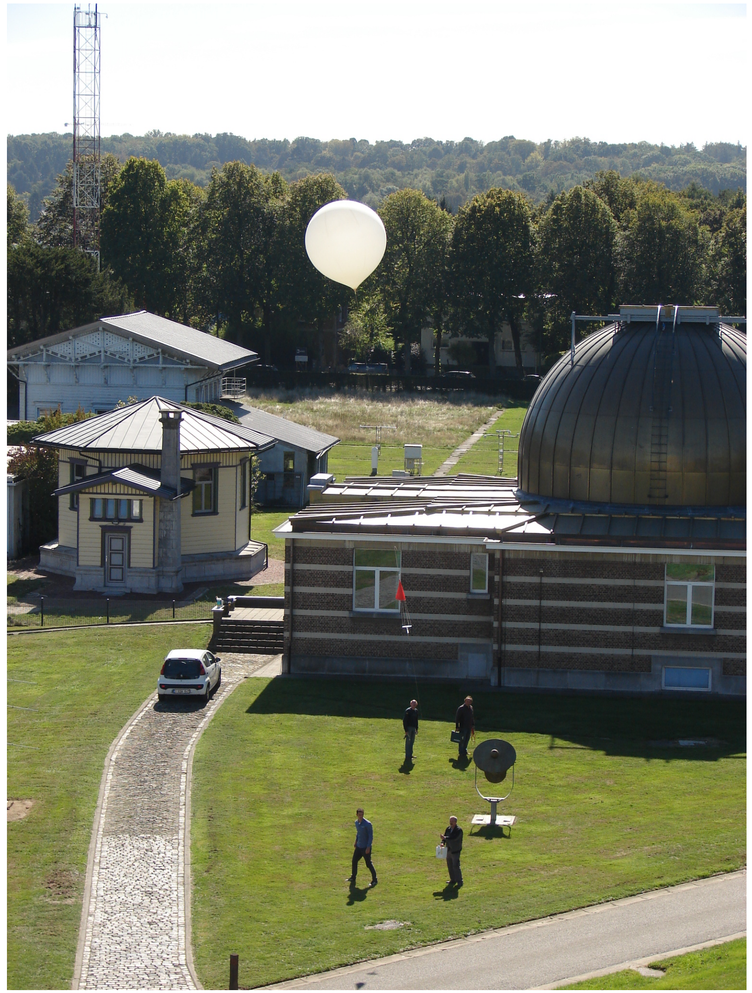
1) Ozone measurements in Uccle

2) Trend analysis of ozone distribution

3) Validation of satellite ozone retrievals

4) Process studies

5) Conclusions



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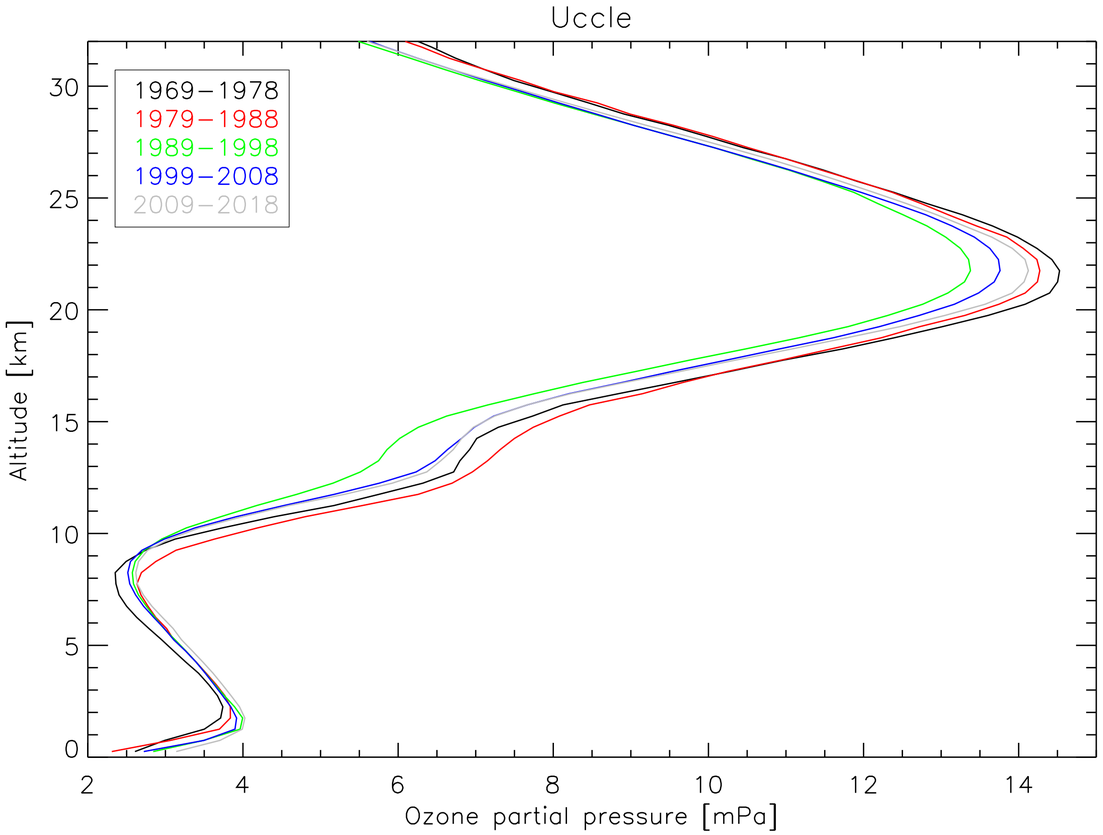
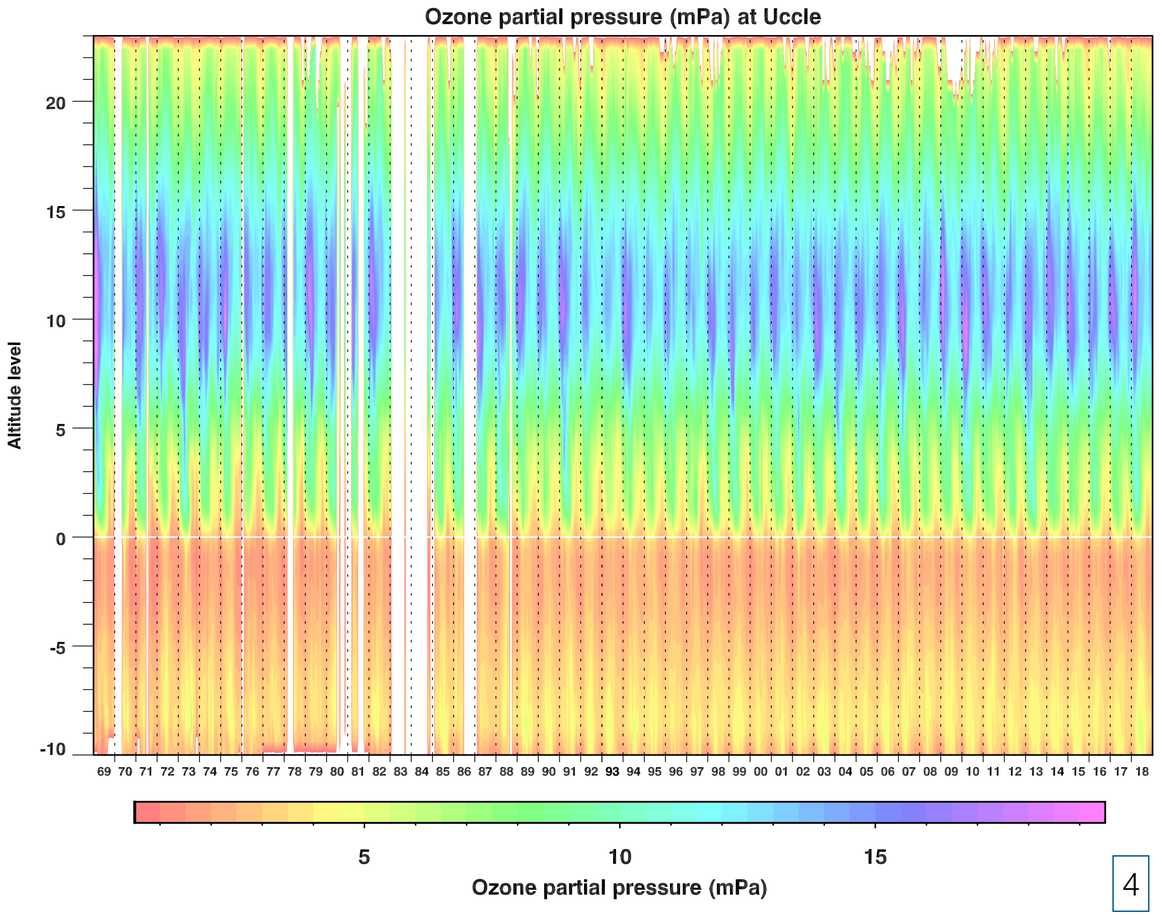
Zoom

1) Ozone measurements in Uccle

- Vertical ozone profiles obtained with ozonesondes, three times a week, since January 1969
- Only some major periods of gaps (1983, 1984, 1986) due to decreased sources
- Change from Brewer-Mast to ENSCI ECC-Z on 1 April 1997

  ➡ well documented based on dual soundings



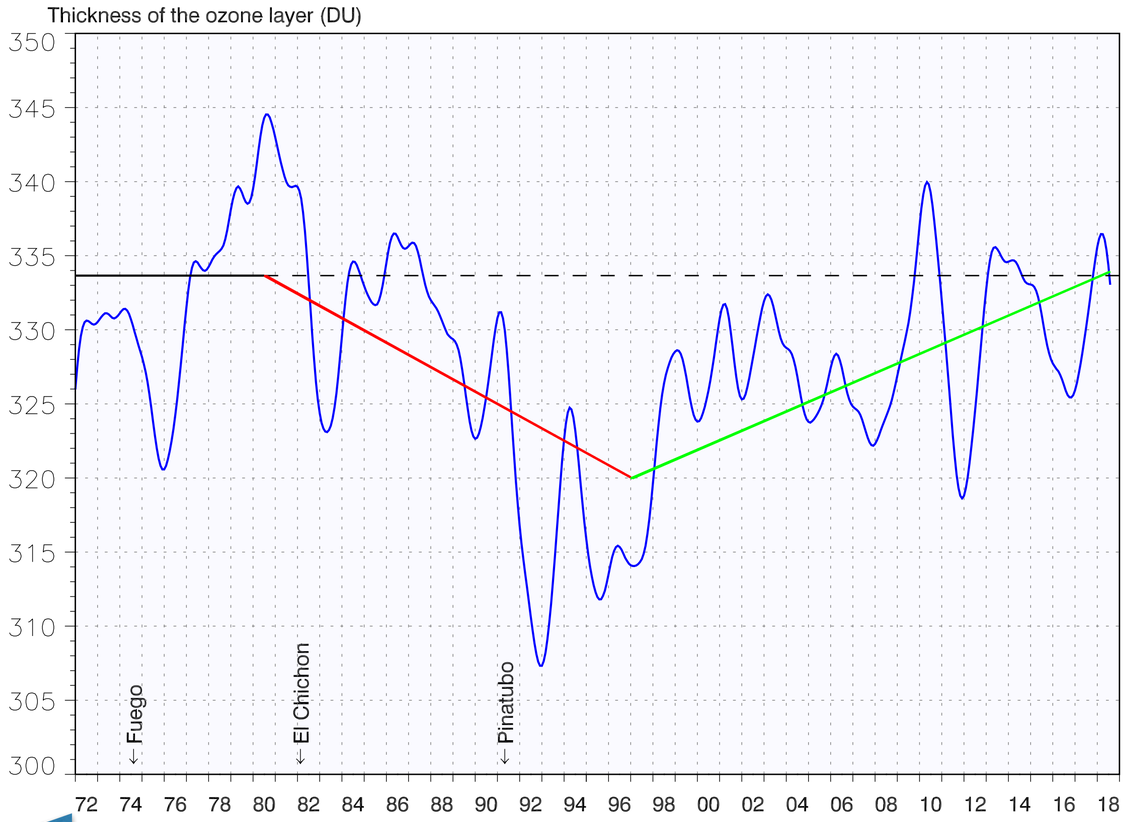


Photography encouraged

1) Ozone measurements in Uccle

Total ozone column measurements with either a Dobson or Brewer spectrophotometer since mid 1971.
The total ozone column above Uccle:

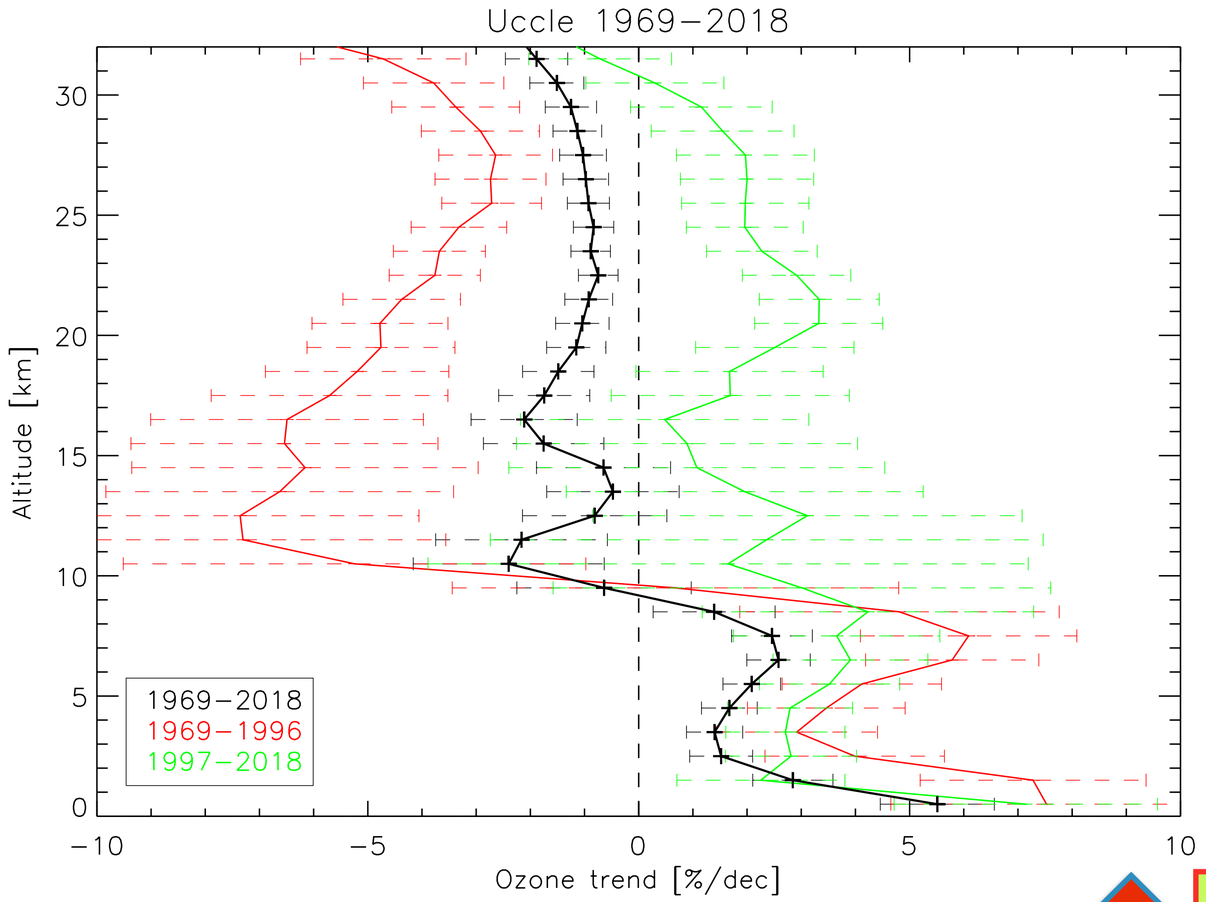
- decreased slightly from 1971 until 1991,
- reached its minimum in the years 1992–1993 (especially in the winter), enhanced by the volcanic eruption of Pinatubo in June 1991,
- starts to increase again from the second half of the 1990s as a result of the protocol of Montreal.



2) Trend Analysis of Ozone distribution

The vertical ozone trends can be obtained by using the ozonesonde data

- Negative trends until mid of 90s'
- Increasing after mid of 90's, Montreal protocol
- Overall a negative trend is seen, 1969-2018



- **Ozone trends**
- Temperature trends
- Comparison with De Bilt(NL)
- Surface ozone trends O_3,CO, NO, NO_2
- ozone trend with respect to the tropopause

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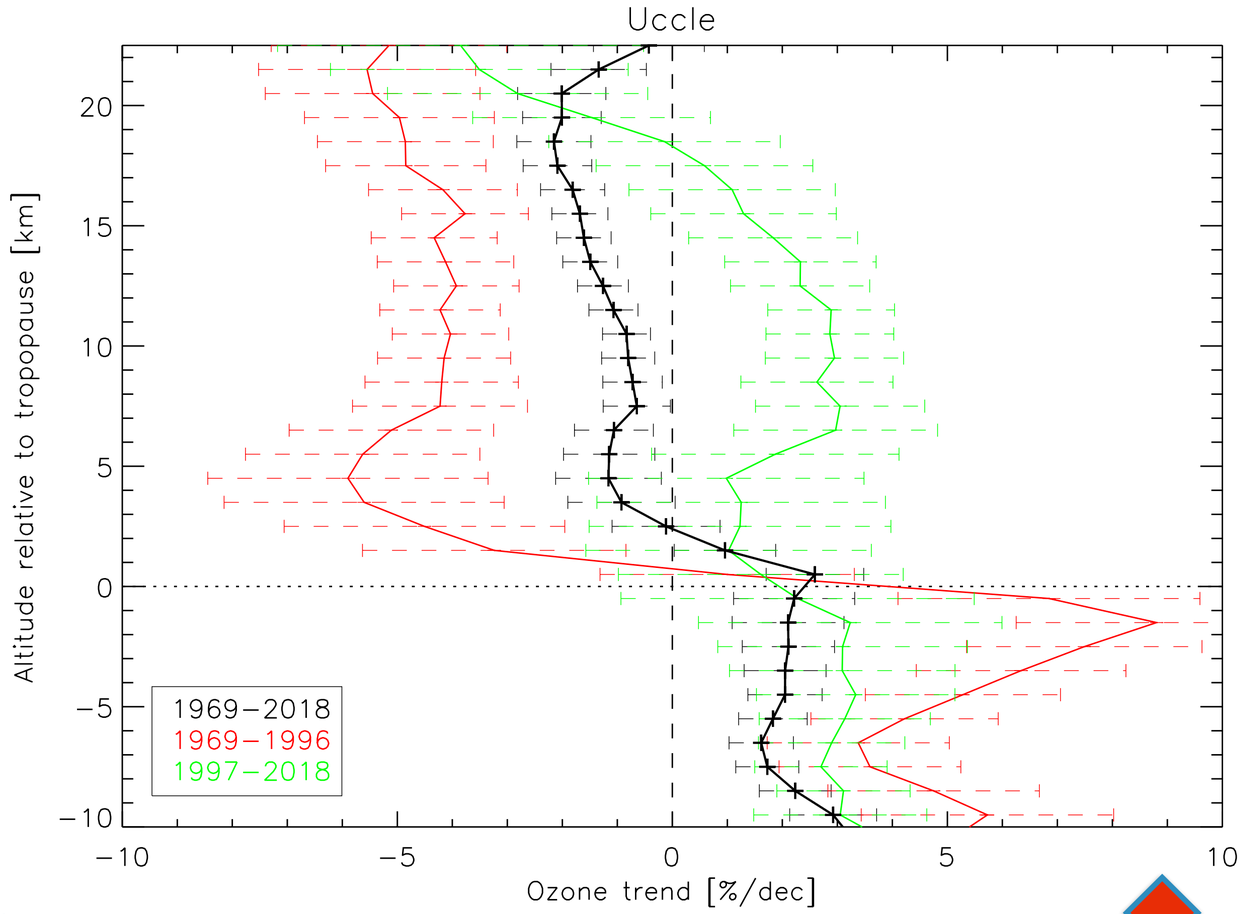

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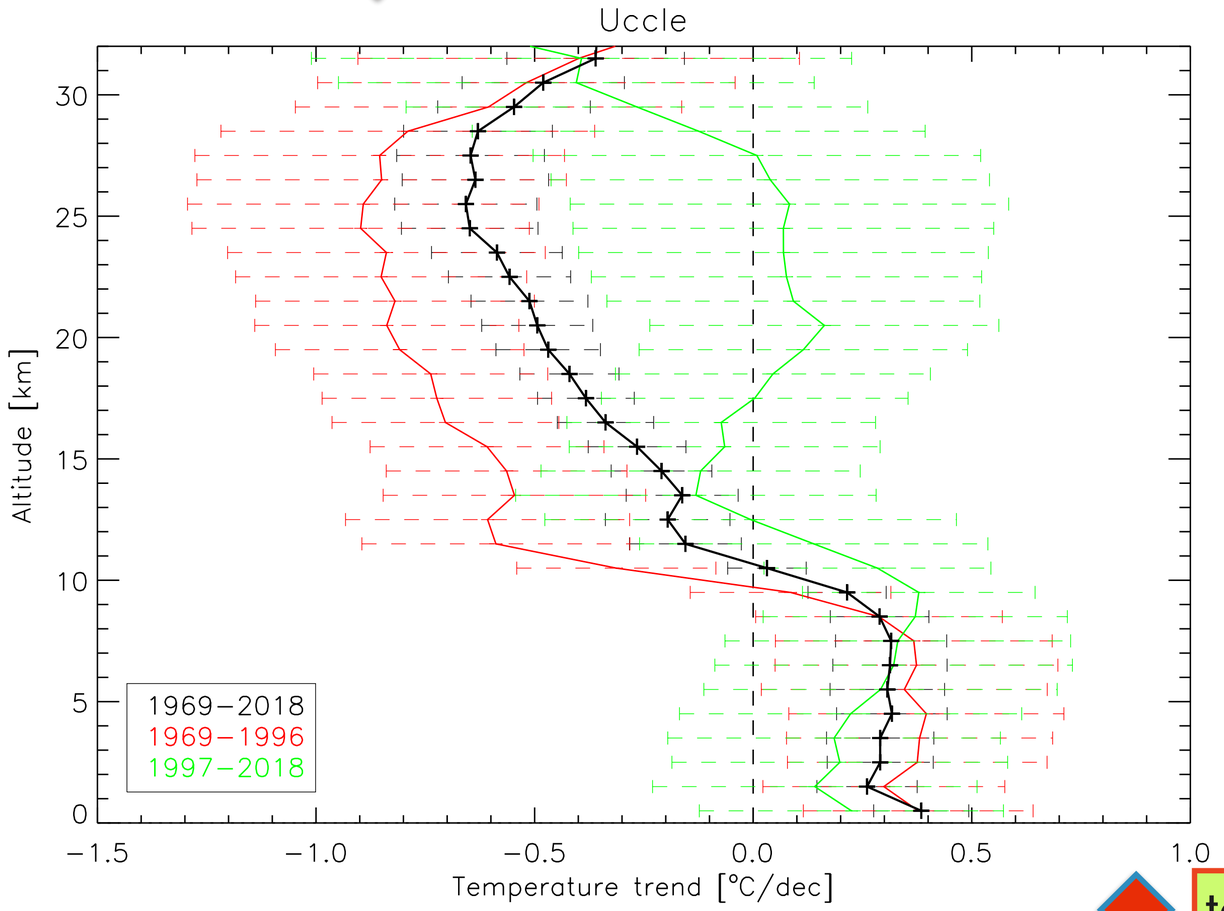
ozone trend with respect to the surface

2) Trend Analysis of Ozone distribution

- The temperature decreased as ozone trends had been negative until end of the 20th century
- Temperature has been increasing as ozone increases, since 1997,while climate models and average satellite observations do not show an indication of positive trends

➡ documented in



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temperature trend with respect to the tropopause

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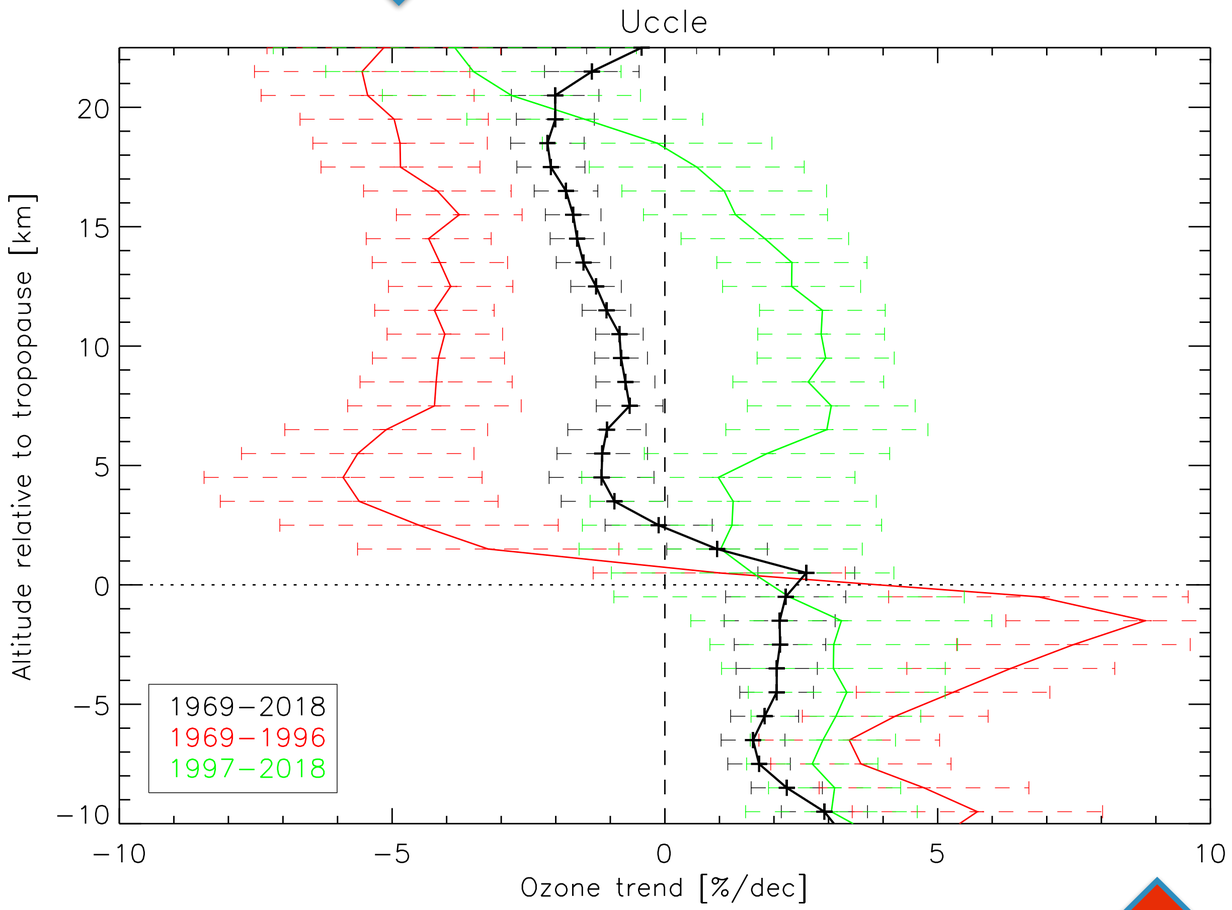

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temperature trend with respect to the surface

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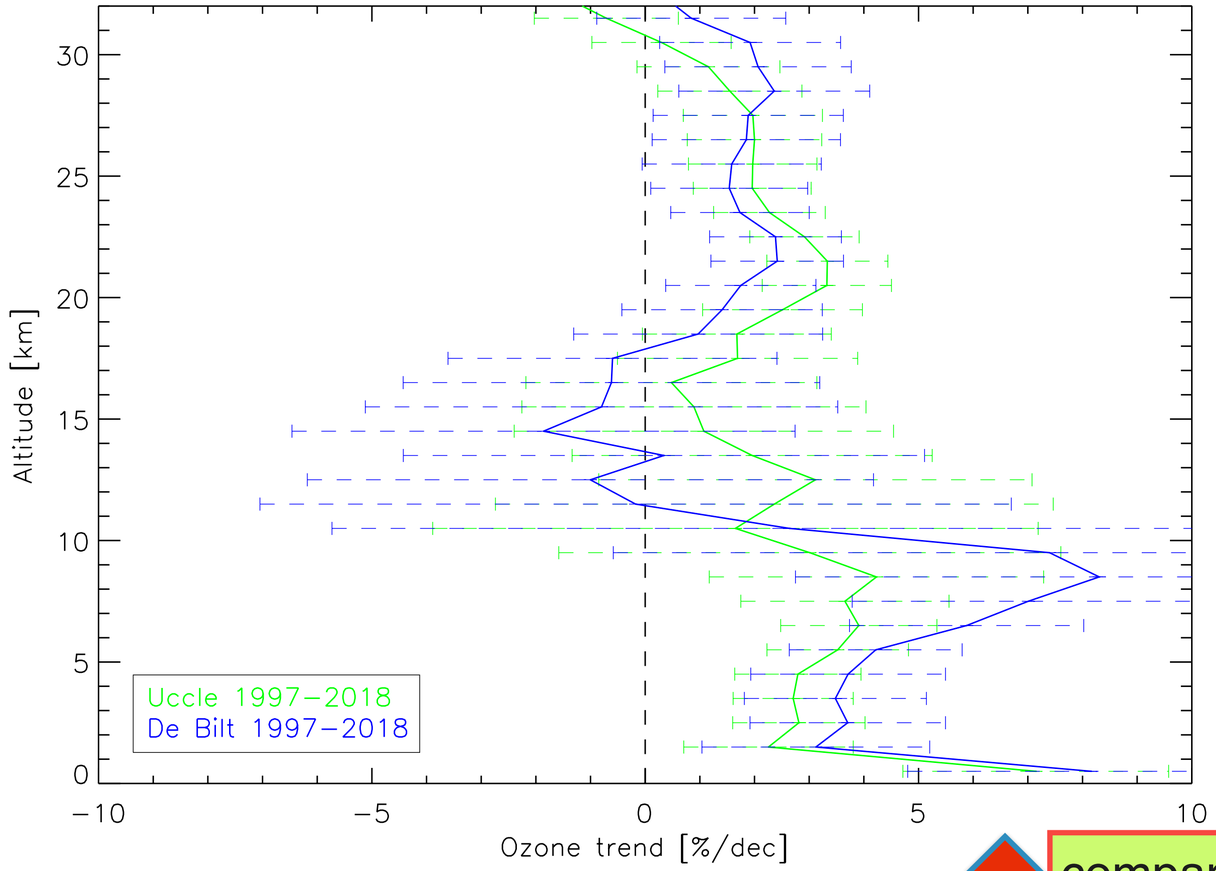
The vertical ozone trends using the ozonesonde data from:

- Uccle, $50°\ 48'\ \mathrm{N}, 4°\ 21'\ \mathrm{E}$
- De Bilt, $52°\ 10'\ \mathrm{N}, 5°\ 18'\ \mathrm{E}$

➡ Uccle and De Bilt are very close in altitude and longitude, therefore no difference is expected in the ozone trend at the troposphere

✳ For a detailed study



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comparison with De Bilt with respect to the tropopause

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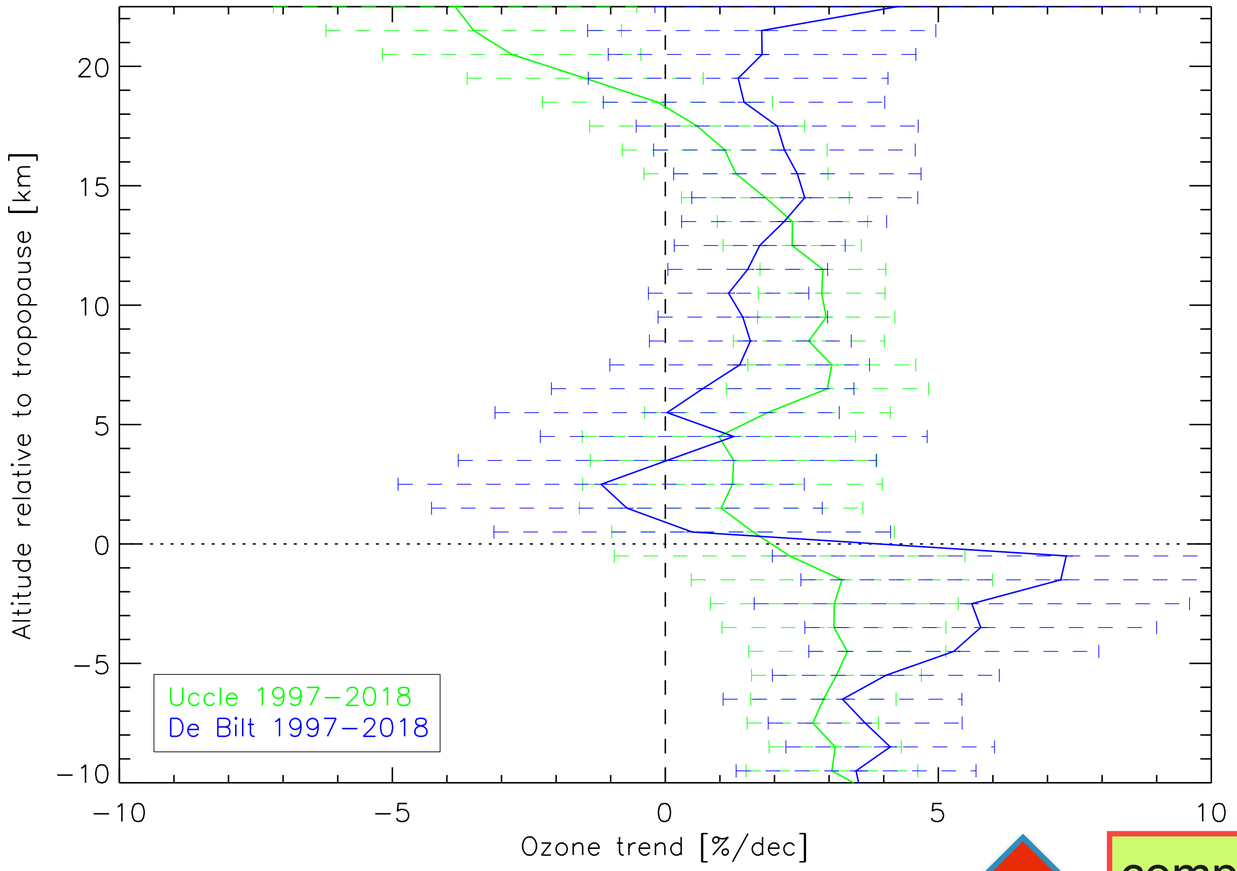

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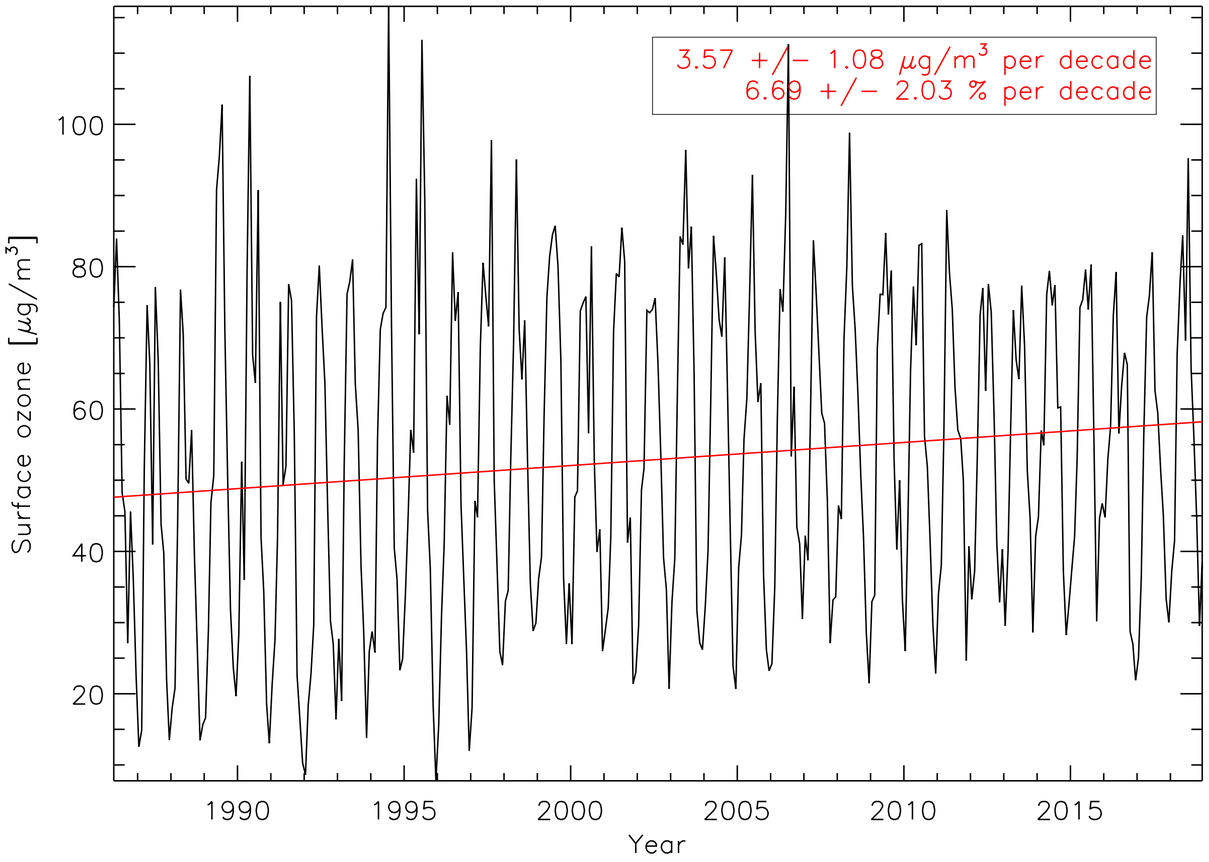
2) Trend Analysis of Ozone distribution

The observed small but significant increase of surface ozone in Brussels might be due to , among other effects, the reduced NO_X titration effect caused by the slow decreasing surface emissions of NO_2 and NO in a highly polluted urban environment.



- Ozone trends
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  - **O_3**
  - CO
  - NO
  - NO_2

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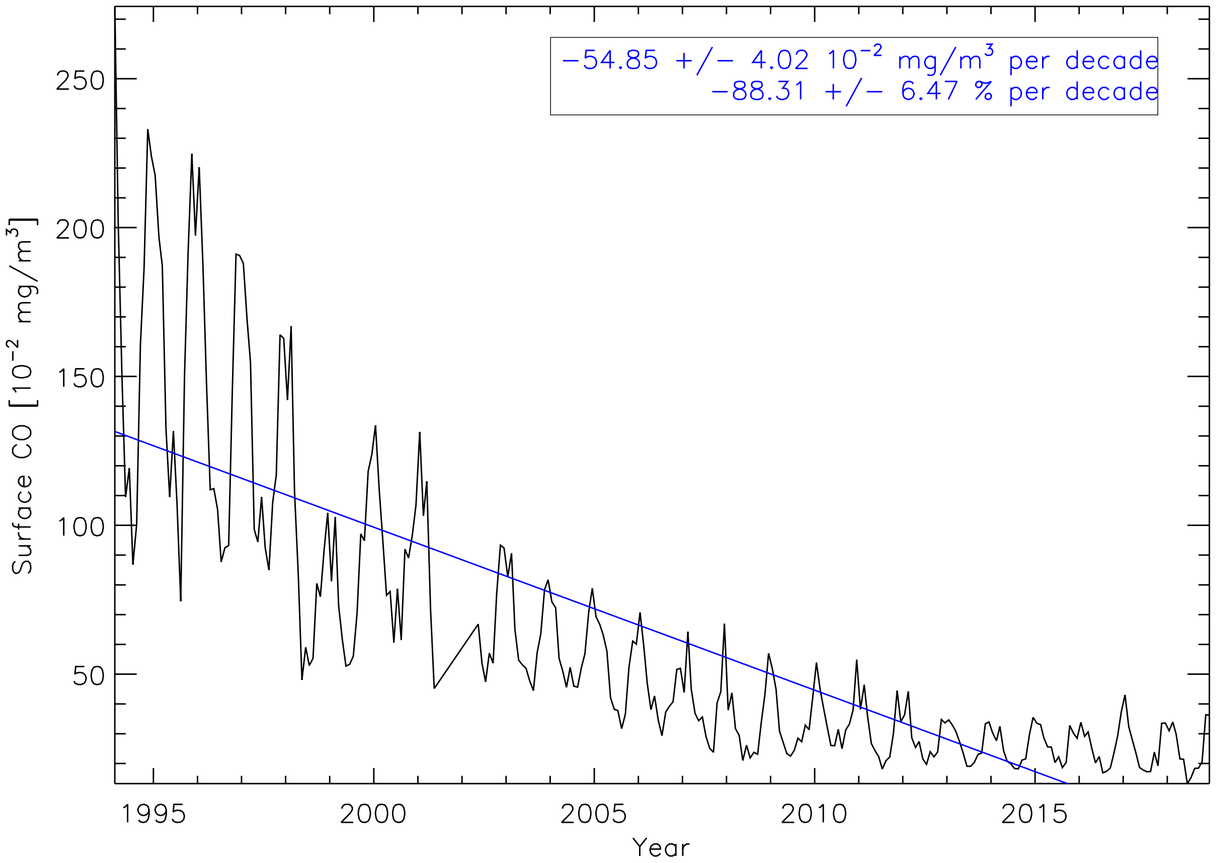

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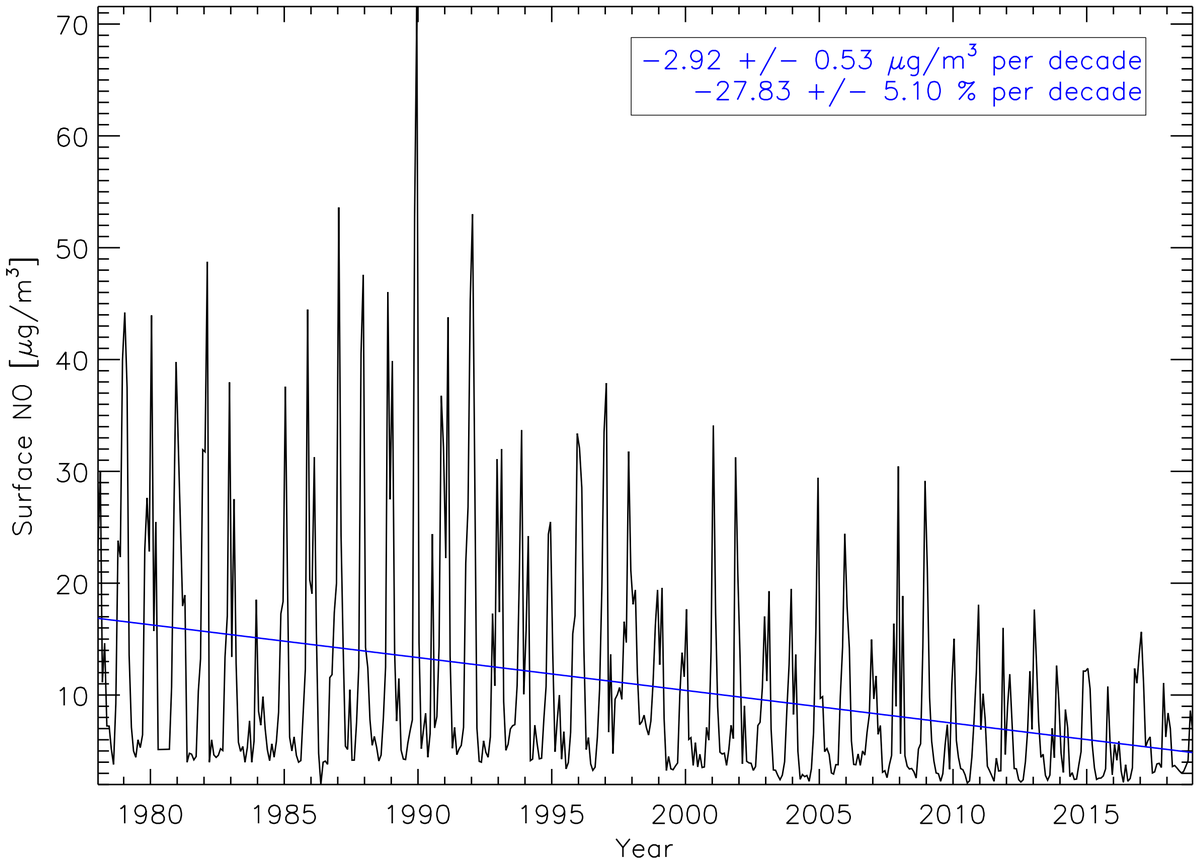

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O_3 CO **NO** NO_2

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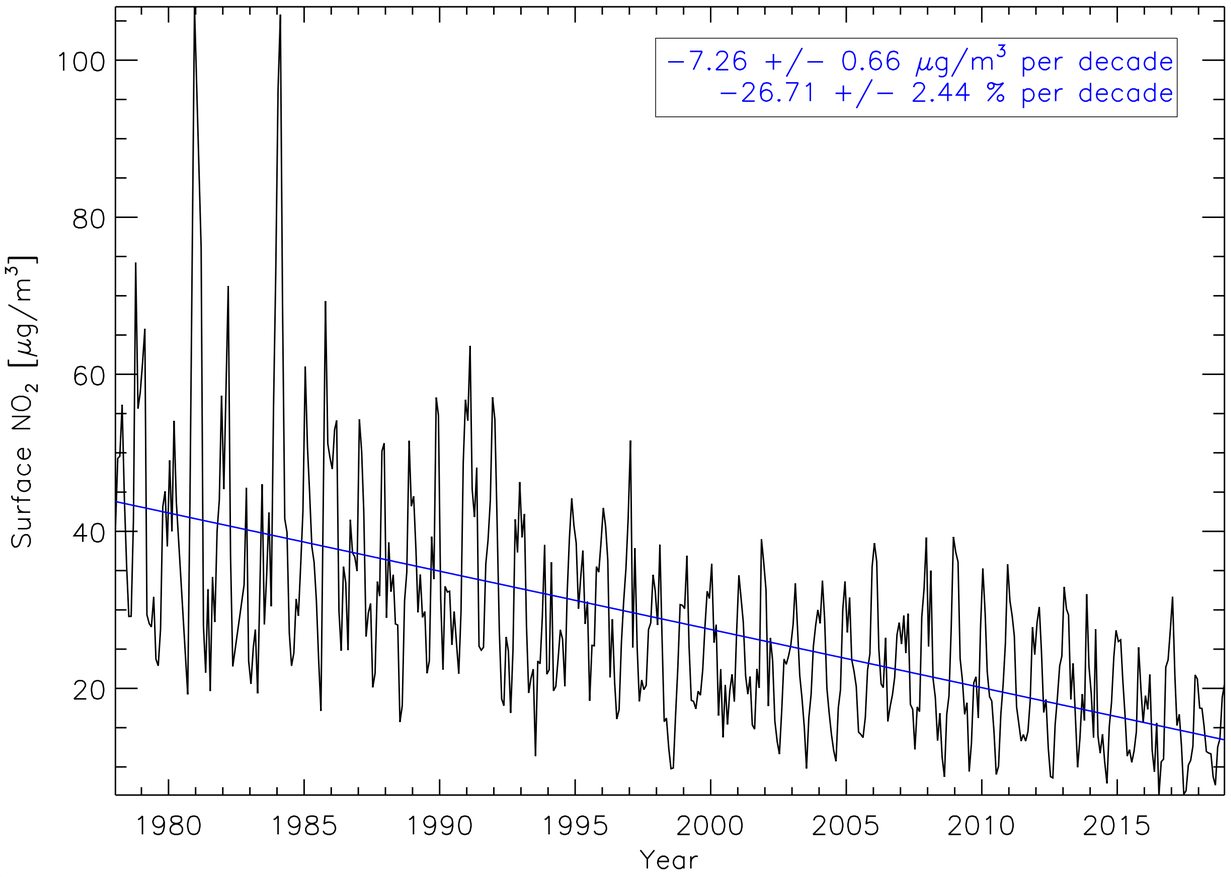

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O_3 CO NO **NO_2**

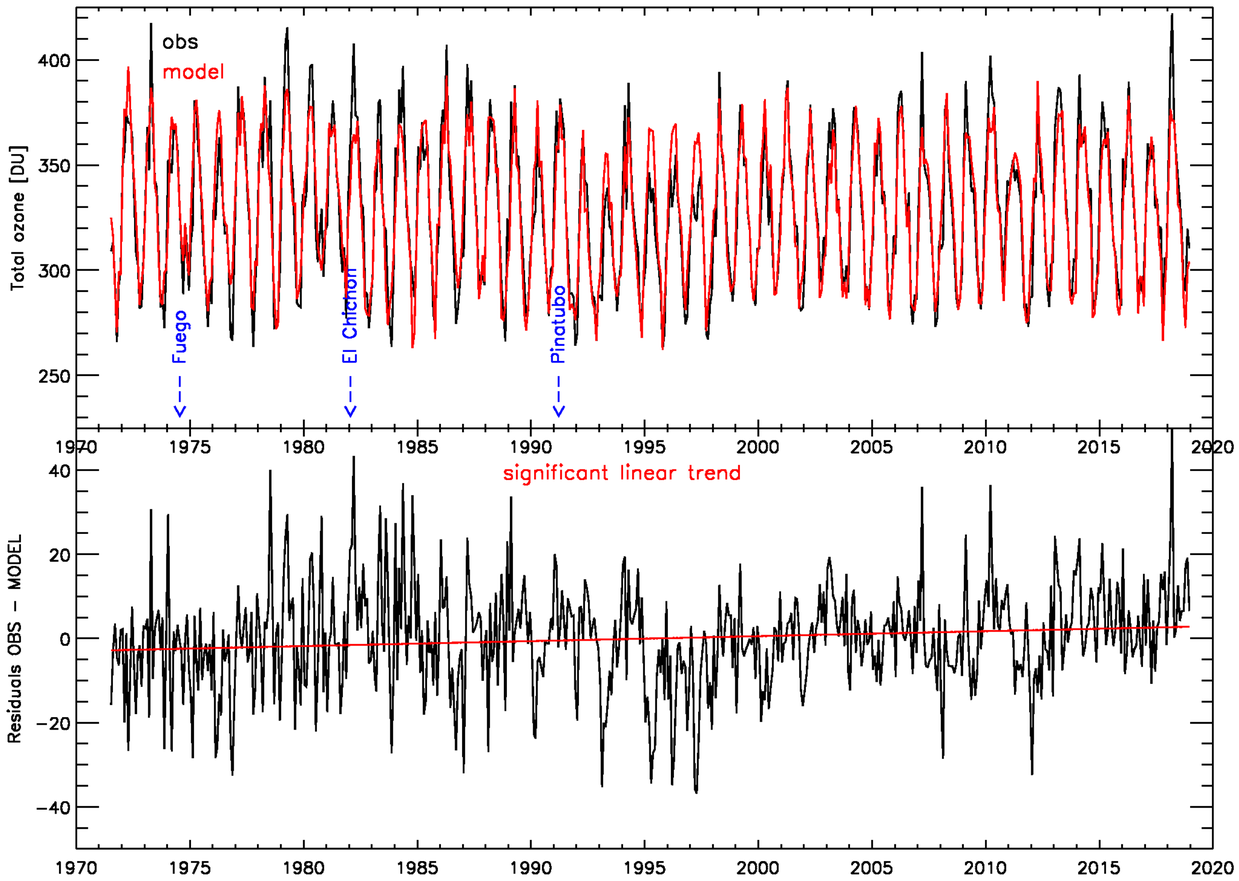
2) Trend Analysis of Ozone distribution

Multiple regression analysis of total ozone column measurements

$$Y(t) = A_0 + A_1 t + \sum_{i=2}^{n} A_{seas,i} X_{seas,i}(t) + \sum_{j=0}^{m} B_j X_j(t) + \epsilon(t)$$

with $X_j(t)$ piecewise linear, solar flux, T@ surface, T@100 hPa, T@500 hPa, tropopause pressure , EESC,ENSO, SOI, NOI, aerosols, QBO, AO, AAO, NAO, EA, EAWR, SCA, POL

Total column O_3



- proxies used: mean ozone, tropopause p, EAWR, SOI, aerosols, T@100hPa, AO, EESC
- explained variability: 86.6%
- $R^2 = 0.931$

- Total column O_3
- Stratospheric O_3 column
- Tropospheric O_3 column

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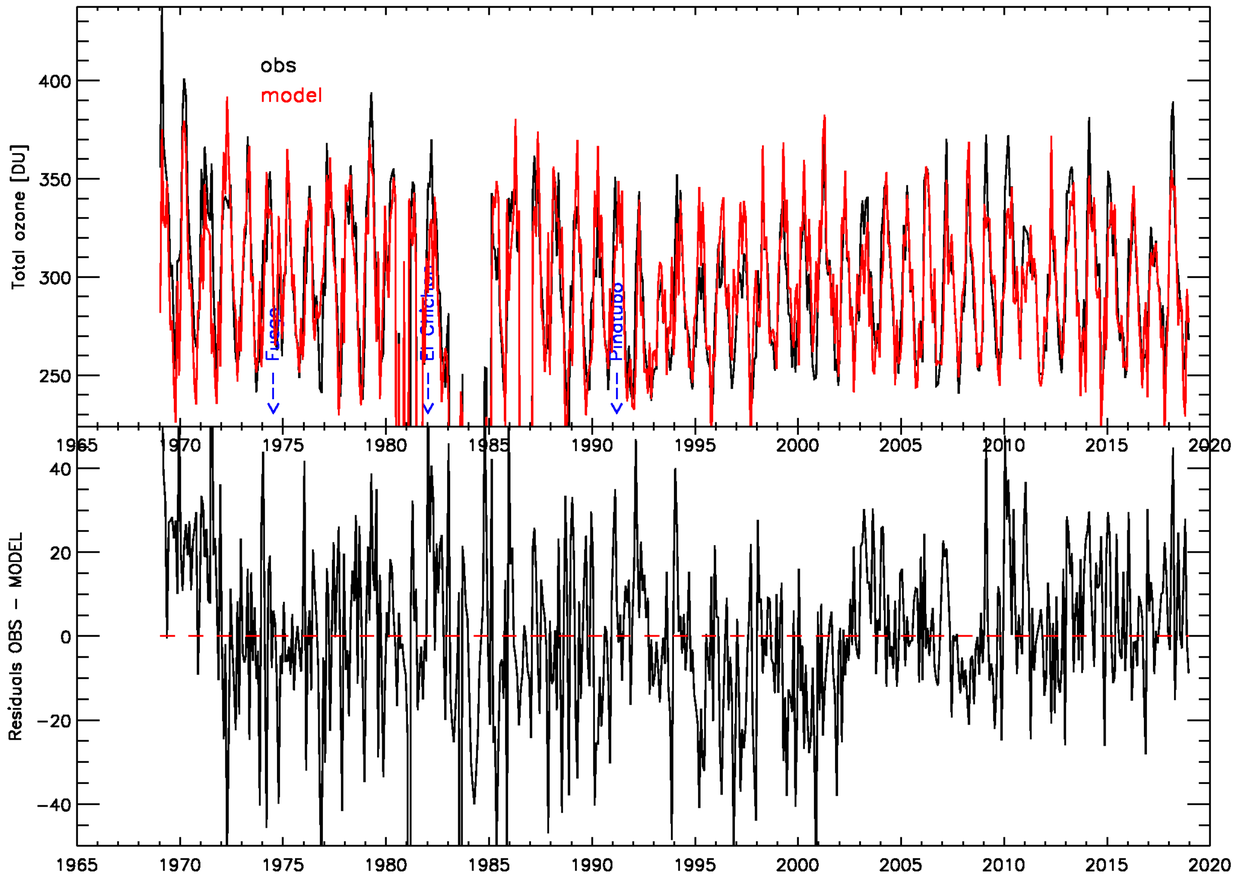
Stratospheric O_3 column



- proxies used: tropopause p mean ozone, aerosols, AO, linear trend, EA
- explained variability: 89.2%
- $R^2 = 0.944$

- Total column O_3
- Stratospheric O_3 column
- Tropospheric O_3 column

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Multiple regression analysis of total ozone column measurements

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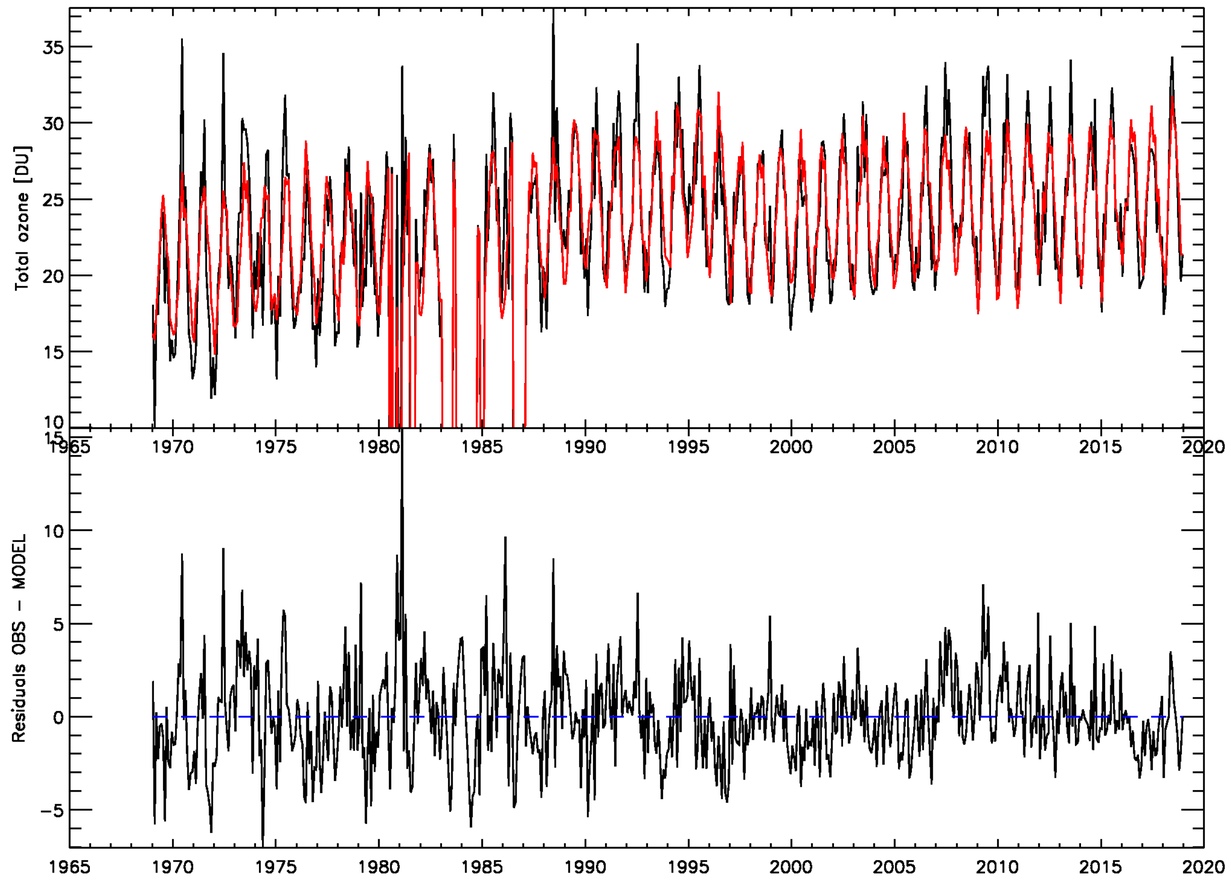
Tropospheric O_3 column



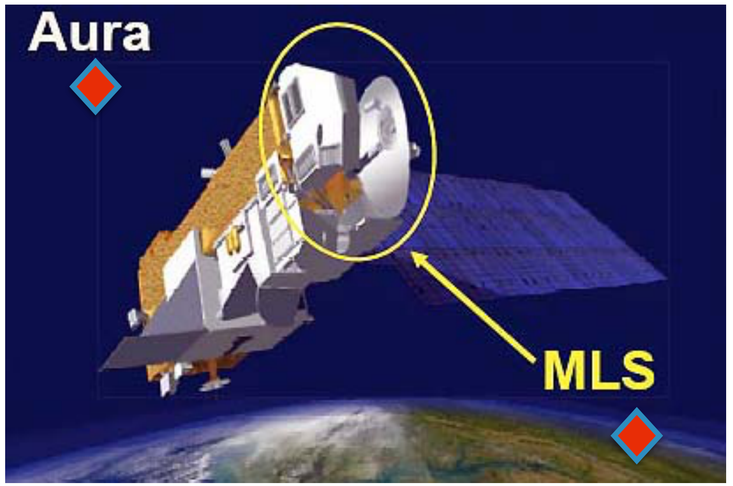
- proxies used: AO, T@100hPa, mean ozone, linear, piecewise linear, aerosols, (T@surface, NO)
- explained variability: 86.9%
- R^2 = 0.932

- Total column O_3
- Stratospheric O_3 column
- Tropospheric O_3 column

3) Validation of satellite ozone retrievals

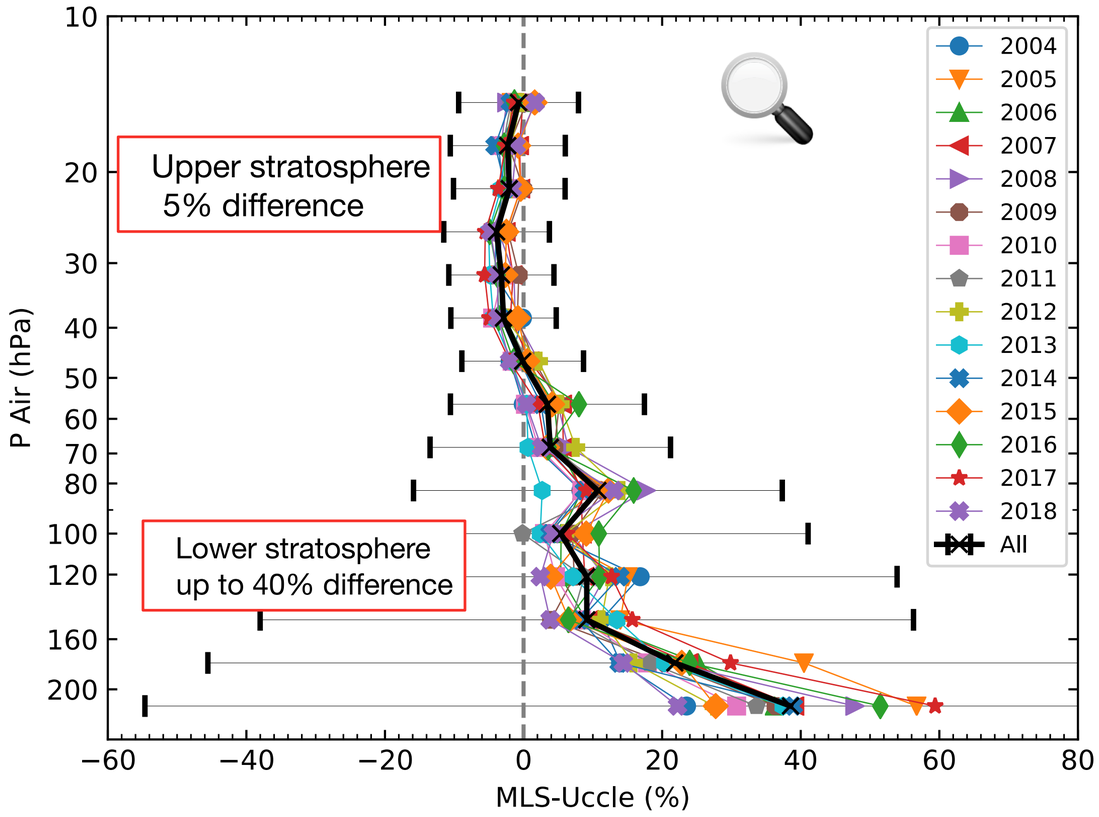
i) Validation of Aura Microwave Limb Sounder (MLS) Ozone by ozonesonde measurements in Uccle:

- The MLS is one of four instruments on the Earth Observing System (EOS) Aura satellite which was launched on 15 July 2004 and placed into a near-polar orbit at 705 km altitude
- The Aura mission objectives are to study the Earth's ozone, air quality, and climate



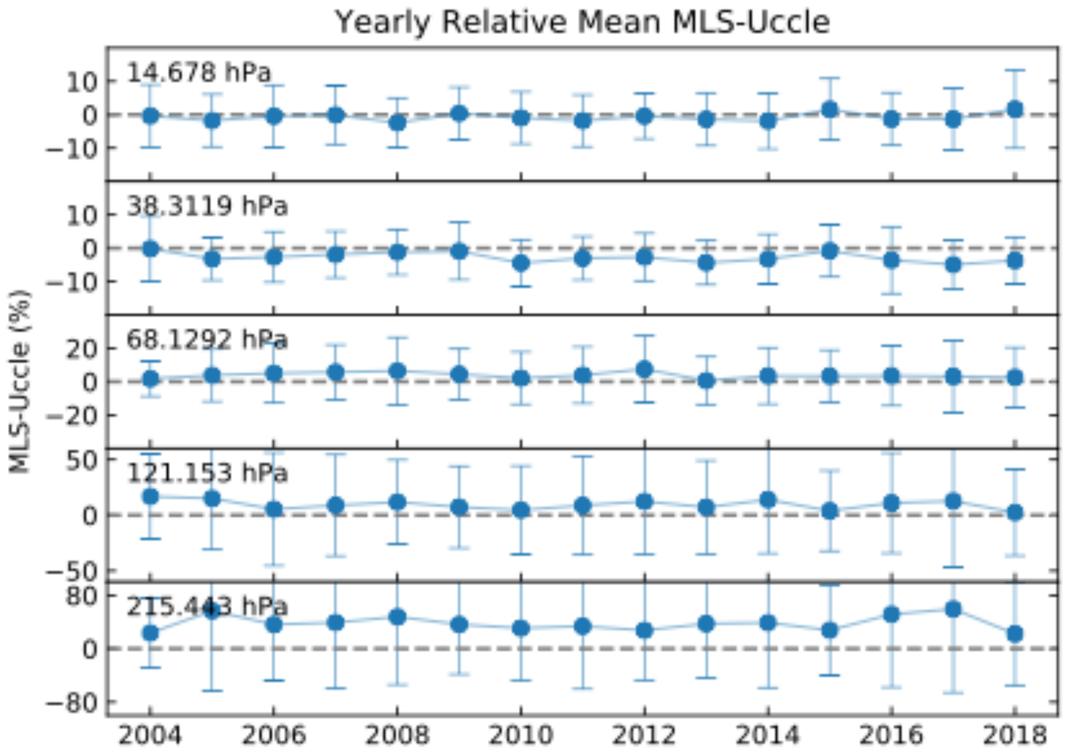
Data and method

- ✦ MLS ozone data v2.2 considering ozone at pressures of 215 hPa or less
- ✦ Ozonesonde data is tuned to the resolution of the MLS data using linear least squares regression
- ✦ ~3000 profiles to compare MLS and ozonesonde data between 2004 and 2018



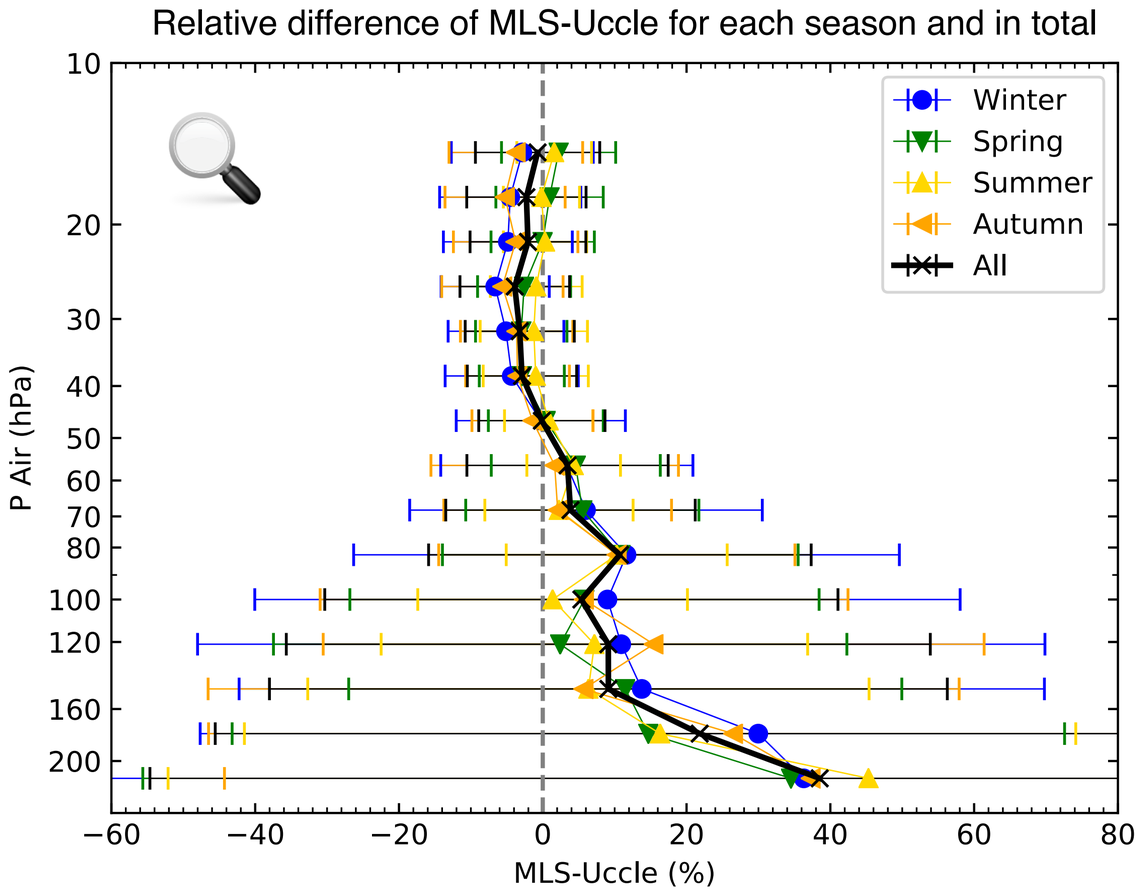
➡ Relative difference of MLS-Uccle. The black lines correspond to the combined 1σ error of the all years.

3) Validation of satellite ozone retrievals



- Yearly relative means of the difference of MLS and Uccle for different pressure levels .
- No drift in the biases, while the variation of the MLS-Uccle is higher for higher pressure values.
- The error bars show the 1σ error.

- Total and seasonal relative means of the difference of MLS and Uccle for different pressure levels.
- No seasonal dependence is seen
- The lines correspond to the 1σ error of each seasons and the total combined.

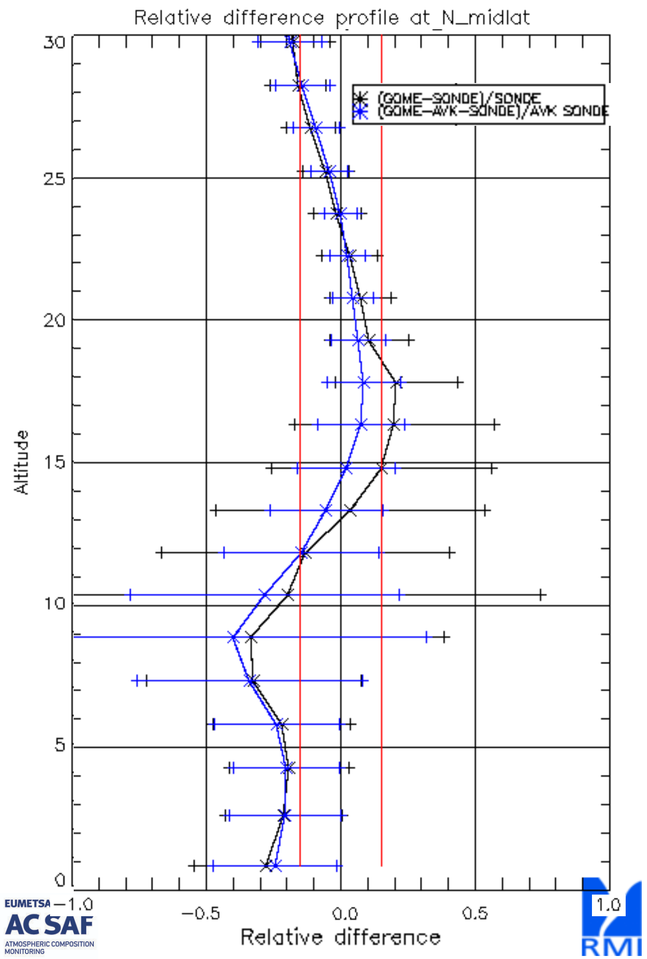


3) Validation of satellite ozone retrievals

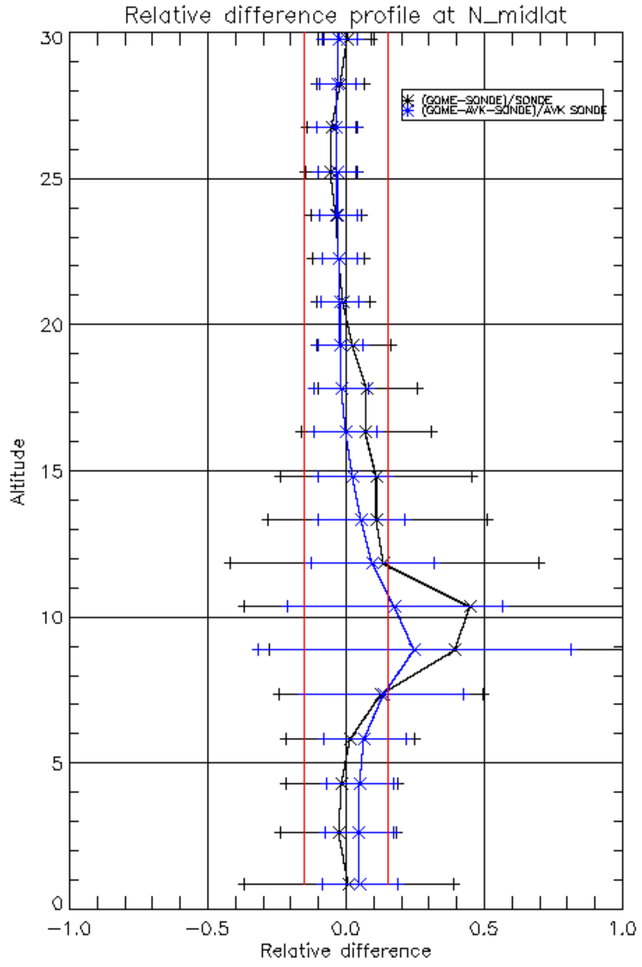
Importance of ozonesondes in operational validation work @ Atmospheric Composition Satellite Application Facility (AC SAF), EUMETSAT

- AC SAF, EUMETSAT
- GOME-2
- MetOp

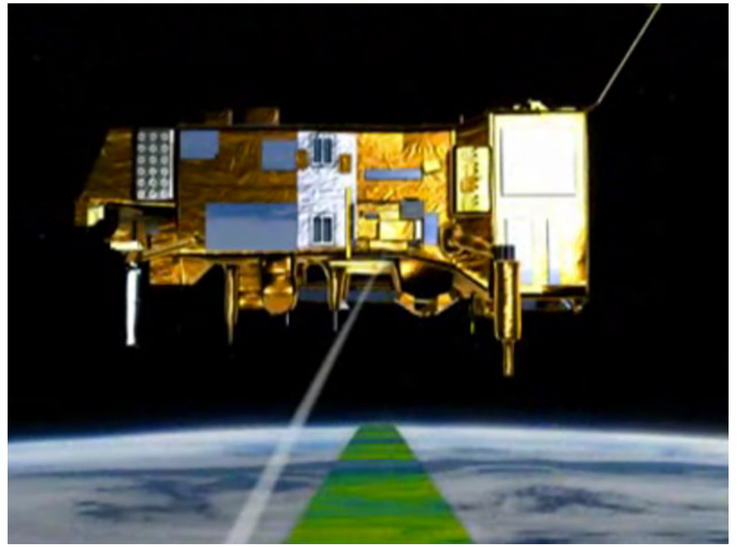
GOME-2A operational results
201801 - 201812



GOME-2A reprocessed time series
2007-2014



- The Global Ozone Monitoring Experiment-2 (GOME-2) is one of the new-generation European instruments carried on MetOp.
- It is used to get a detailed picture of the total atmospheric content of ozone and the vertical ozone profile in the atmosphere.



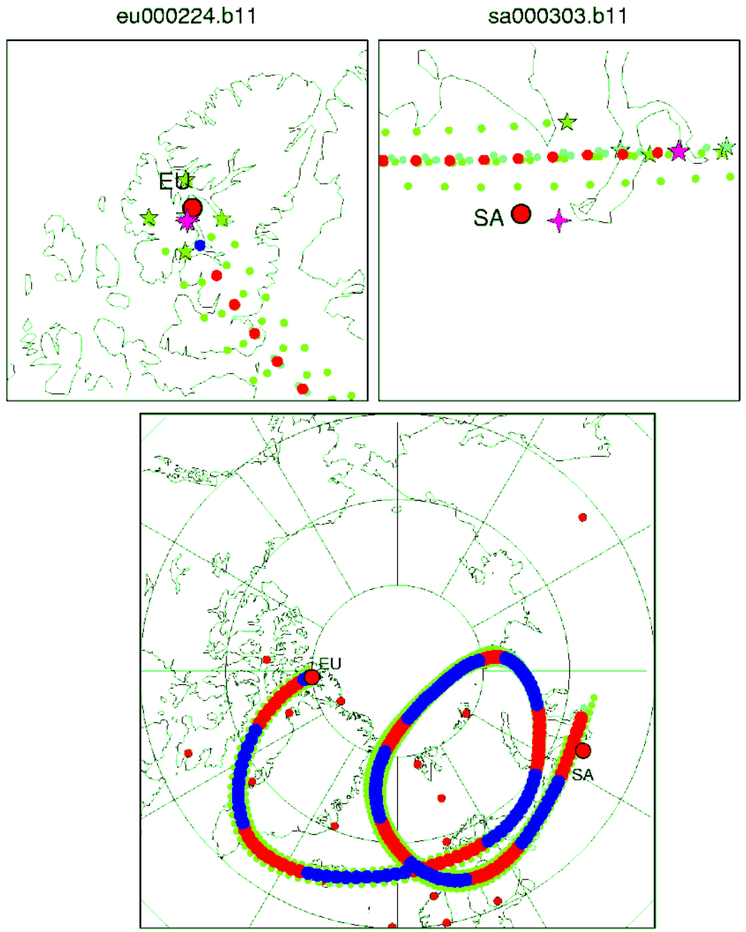
GOME-2 on MetOp Satellite

4) Process studies

Uccle participates in MATCH campaign

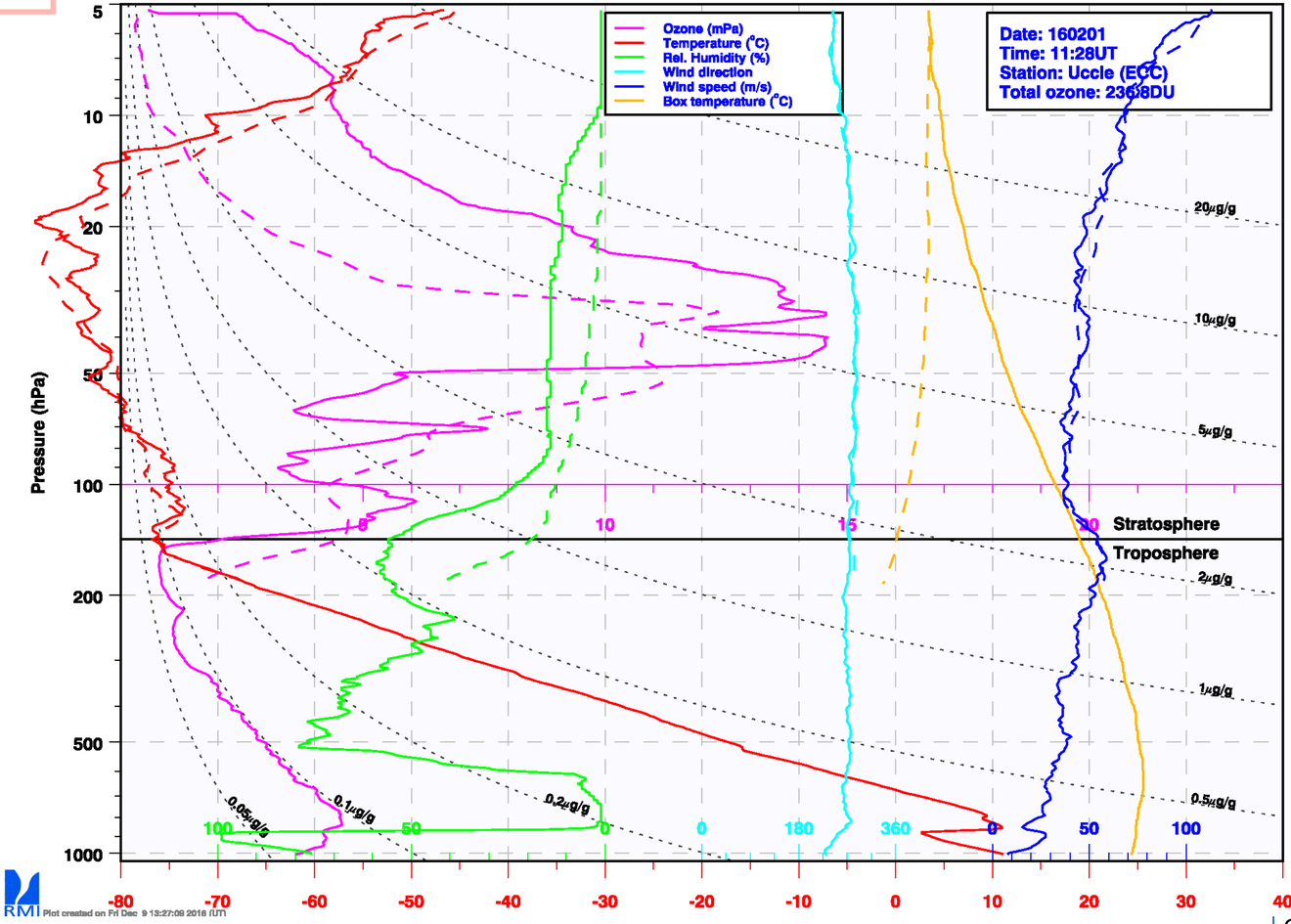
Principle of MATCH:

- measure identical air parcel twice by ozone soundings (trajectory)
- calculate ozone loss between measurements.



Uccle ozonesonde profile data at 1 Feb 2016:

- Uccle was located in polar vortex
- Stratospheric temperatures around -90°
- Very low ozone amounts



5) Conclusions

★ We highlighted the importance of a very long time series of ozonesonde measurements, with high frequency, in different aspects in ozone research.

Trend analysis:

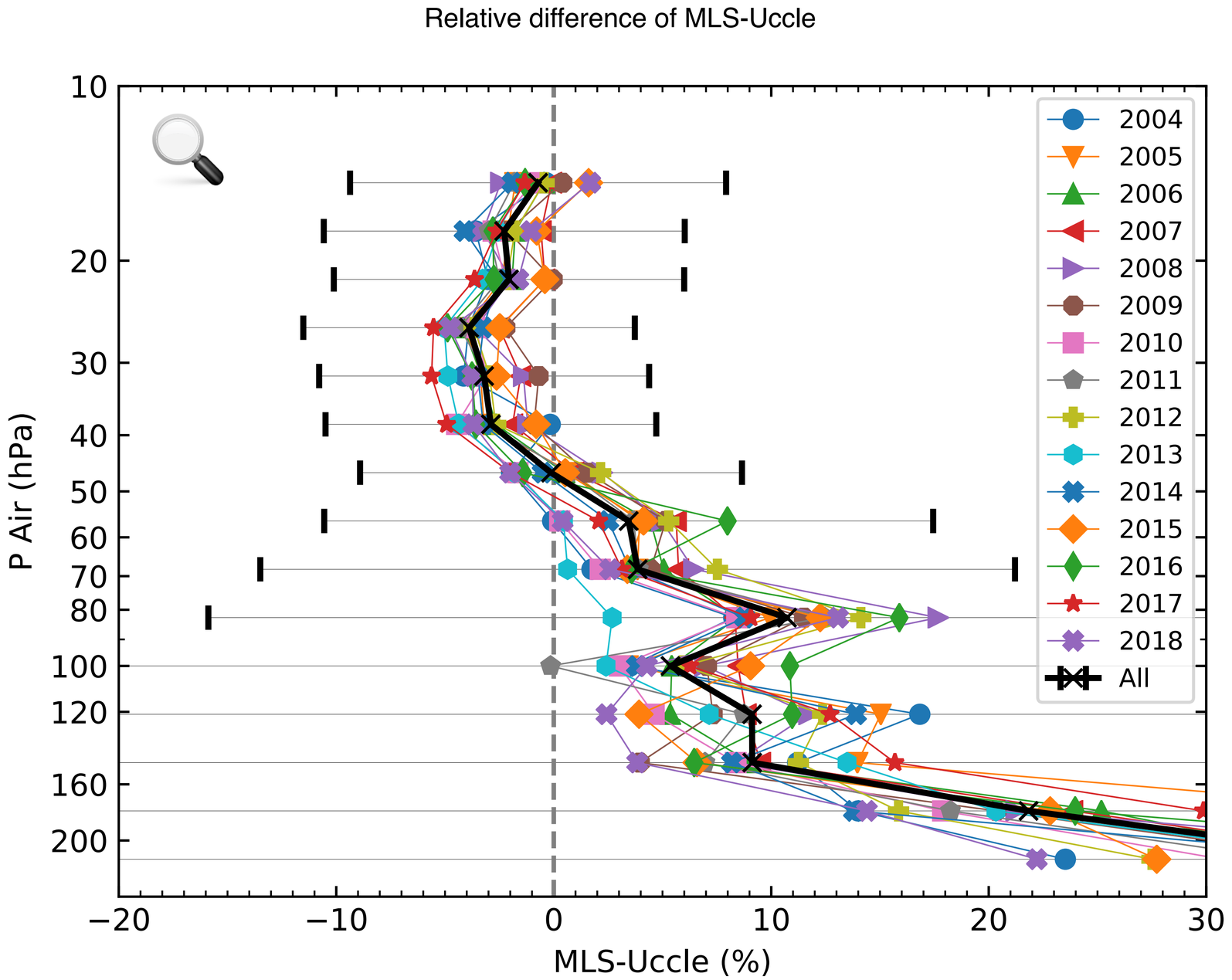
- Since 1969 and until end of 90's: stratospheric ozone declined at a rate of 5%
- At the ozone layer maximum heights, the ozone concentrations increase again above Uccle.
- Tt those altitudes, the temperatures tend to increase as well.
- The overall decrease in stratospheric ozone is 1.5% between 1969-2018
- Tropospheric ozone concentrations increased at around 2% since 1969, but there is a slowdown since 2000.
- These trends are consistent with the De Bilt ozonesonde and Uccle surface ozone trends.

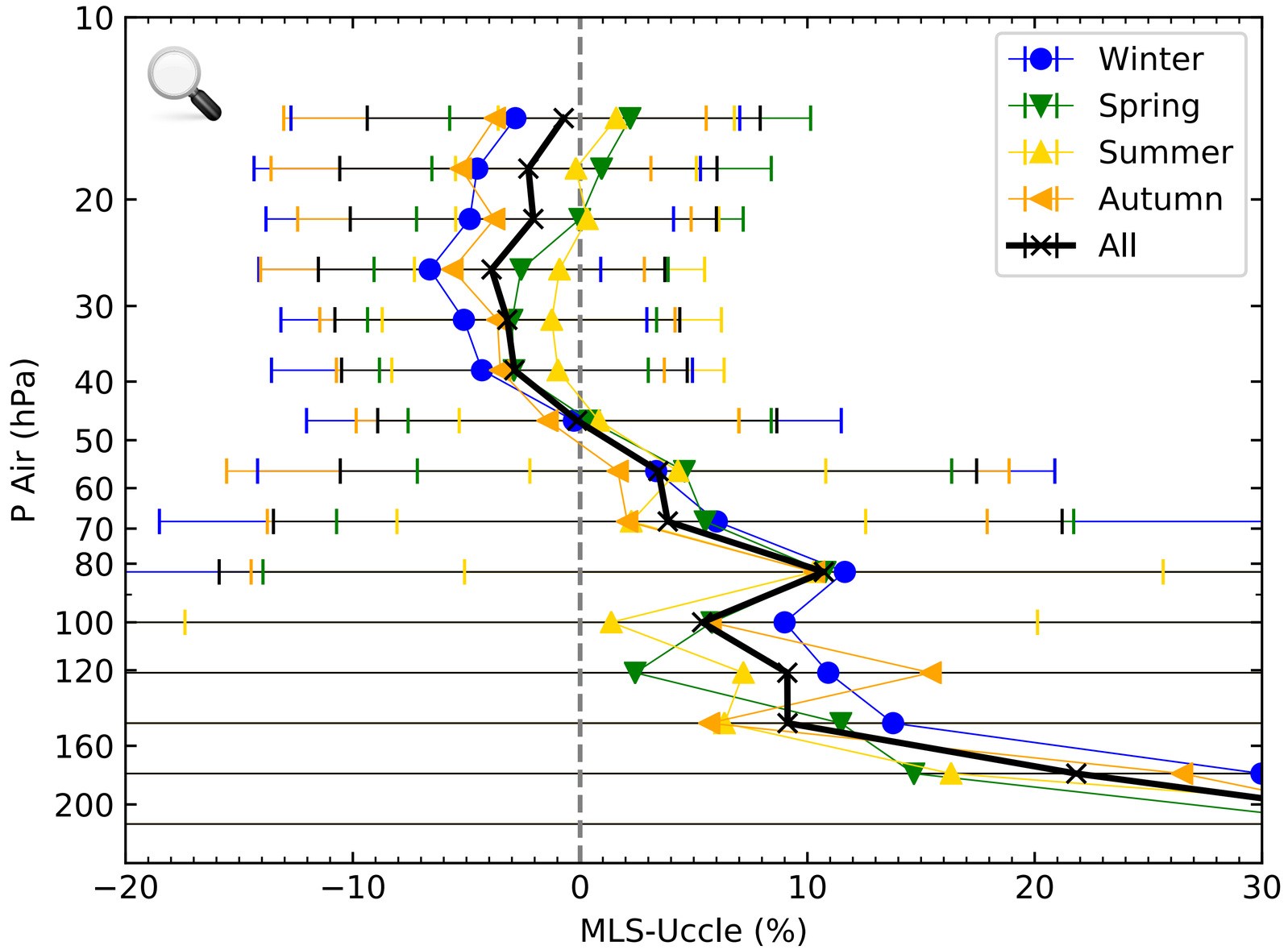
Satellite validation

- Our ozonesonde dataset is used as validation dataset for satellite ozone retrievals: we show that the agreement with GOME-2 and AURA-MLS is excellent and rather stable in time.

Process studies

- Uccle participates since the beginning in the MATCH campaign
- We will study the frequency of tropopause folds above Uccle.


Relative difference of MLS-Uccle
P Air (hPa)
10
20
30
40
50
60
70
80
100
120
160
200
−20
−10
0
10
20
30
MLS-Uccle (%)
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
All


Relative total and seasonal difference of MLS-Uccle
P Air (hPa)
10
20
30
40
50
60
70
80
100
120
160
200
−20
−10
0
10
20
30
MLS-Uccle (%)
Winter
Spring
Summer
Autumn
All