

Site Description

Zugspitze (ZUG): 47°N, 11°E, 2962 m asl,
at the northern rim of the Alps
Neighbouring mountain **Wank (WNK)**, 1780 m asl

Type of site / Surrounding:

Zugspitze High-altitude summit
Wank Medium-altitude mountain top



Instrumentation:

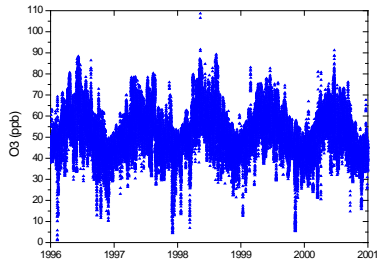
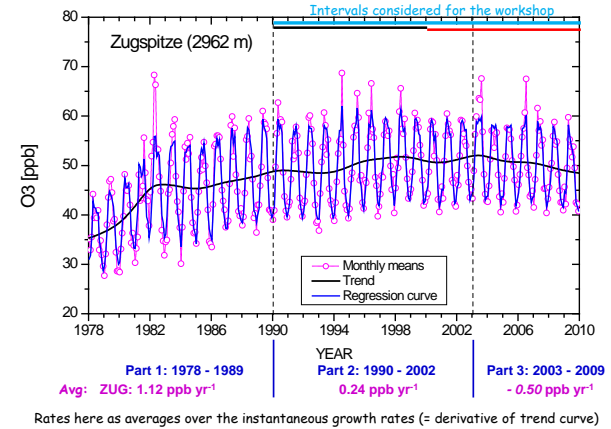
Chemiluminescence technique 1978–1999,
UV absorption ~1996 till present. Two or three
instruments operated in parallel. Air intake on
the roof deck of the station.
Calibration tied to the WMO/GAW scale.

Data sets for surface ozone:

1978 – 2009, data coverage typically > 90 %
Years of general tendency change: 1989 & 2002
→ The time series can be regarded as
being composed of 3 parts.

Time Series Overview

O₃ monthly means (1978 – 2009), regression curve and long-term trend component

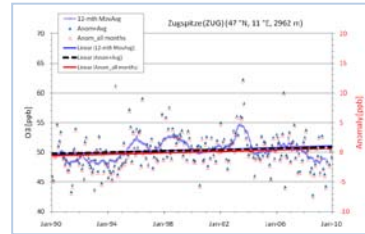


Overview on the O₃ data structure at Zugspitze (half-hourly mean values, 1996 - 2000).

By short-term variations a range of about 110 ppb is covered.

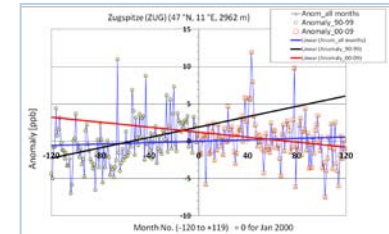
Trend Estimates

Zugspitze: Anomalies and Moving Averages (1990 - 2009)

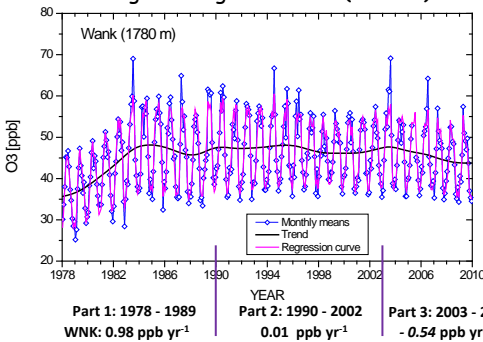


Comparison of anomalies (relative and absolute) with 12-month moving averages → Agreement of the regression lines

O₃ Changes 1990 - 2009, 1990 - 1999, 2000 - 2009



Neighbouring Site Wank (1780 m)



-0.16 (-0.23 -0.09)
46.5 (46.1 - 47.0)
7.5 %

Anomaly Results: 1990 - 2009, 1990 - 1999, 2000 - 2009

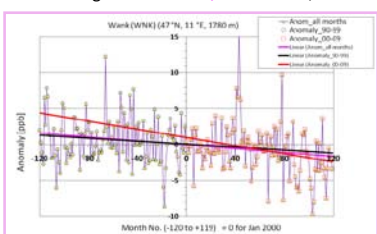
ppb / yr (95%-conf. interval)
Intercept Jan 2000 (C.I.)
r² [%]

0.06 (-0.01 - 0.12)
50.3 (49.9 - 50.7)
1.3 %

0.42 (0.24 - 0.59)
52.2 (51.2 - 53.2)
15.5 %

-0.20 (-0.38 -0.02)
51.5 (50.5 - 52.5)
4.0 %

Wank: Changes 1990 - 2009, 1990 - 1999, 2000 - 2009



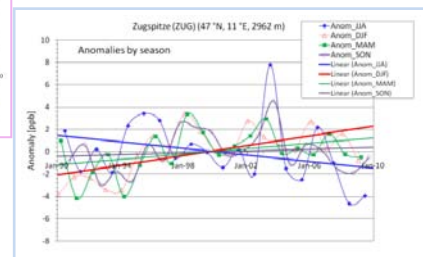
-0.13 (-0.32 - 0.07)
46.6 (45.5 - 47.8)
1.3 %

-0.34 (-0.55 -0.13)
47.5 (46.3 - 48.8)
7.9 %



Seasonal trends (WNK)
DJF: -0.05 ppb/yr
JJA: -0.40 ppb/yr

Seasonal Trends 1990 - 2009



Seasonal trends (ZUG)

DJF: Max. rate (increase) 0.22 ppb/yr
JJA: Min. rate (decrease) -0.15 ppb/yr
(for details see Table)

Wank: Seasonal trends (1990 - 2009)

display O₃ decrease for all seasons,
strongest for JJA (summer) :
- 0.40 ppb/yr (-0.71 - -0.09), cf. figure.

Alternative Statistical Approaches

	Anomalies as ref.	Lin. regr. on monthly means	Lin. regr. on 12-month moving avg.	Lin. regr. on trend curve	Average rates derived from trend curve
Rates in ppb/yr					
1990 - 2009	ZUG	0.06	0.04	0.07	0.06
	WNK	-0.16	-0.18	-0.16	-0.19
1990 - 1999	ZUG	0.42	0.36	0.40	0.39
	WNK	-0.13	-0.21	-0.15	-0.14
2000 - 2009	ZUG	-0.20	-0.26	-0.18	-0.24
	WNK	-0.34	-0.42	-0.33	-0.34

Summary and Discussion

Surface ozone has been recorded at the Alpine sites Zugspitze (ZUG) and Wank (WNK) since 1978.

The time series display 3 different regimes: 1978 – 1989, 1990 – 2002, and 2003 – 2009 with different trend behaviour.

→ Previous separate studies have shown:

(i) Differences in the seasonal dependence of growth rates between the 1st and 2nd part.

(ii) Part of the trend behaviour seems to reflect the development of precursor emissions. With CO-based clean-air data filtering (1990 – 2002), growth rates are above the all-data value.

(iii) Indications of an increasing influence of upper tropospheric air masses on ozone at Zugspitze.

The present coordinated study (periods 1990 - 2009, 1990 - 1999 and 2000 - 2009) partially merges the trend observations.

Zugspitze:

Significant positive O₃ growth rates for 1990 – 1999 (all data & DJF(winter)) and 1990 – 2009 (DJF only).
Significant negative rate for 2000 – 2009 (all data).

Wank:

Significant negative rates for 1990 – 2009 as well as 1990 – 1999 and 2000 – 2009 (all data & JJA (summer)).

Other rates are statistically not significant at the 95% level (cf. Table for ZUG results).

Overall picture →

Strongest O₃ decrease for the summer season.

O₃ reference mixing ratios for January 2000 as calculated from linear regression:
50.3 ppb (ZUG) and 46.5 ppb (WNK)

Table of Statistical Results

Site: ZUG Annual trends	Statist. param. of Lin. Regr., Intercept (absol.) for Jan 2000	From monthly mean (available data)	Neighbouring site: Wank (WNK)
1990 - 2009	Slope [ppb/yr] Intercept [ppb] r ²	0.06 (-0.01 - 0.12) 50.3 (49.9 - 50.7) 1.3 %	-0.16 (-0.23 -0.09) 46.5 (46.1 - 47.0) 7.5 %
1990 - 1999	Slope [ppb/yr] Intercept [ppb] r ²	0.42 (0.24 - 0.59) 52.2 (51.2 - 53.2) 15.5 %	-0.13 (-0.32 -0.07) 46.6 (45.5 - 47.8) 1.3 %
2000 - 2009	Slope [ppb/yr] Intercept [ppb] r ²	-0.20 (-0.38 -0.02) 51.5 (50.5 - 52.5) 4.0 %	-0.34 (-0.55 -0.13) 47.5 (46.3 - 48.8) 7.9 %
Seasonal trends (ZUG)	DJF Winter	MAM Spring	JJA Summer
1990 - 2009	0.22 (0.08 - 0.36) 43.8 (43.0 - 44.6) 37.0 %	0.12 (-0.03 - 0.27) 55.4 (54.5 - 56.2) 13.7 %	-0.15 (-0.37 - 0.08) 57.0 (55.7 - 58.4) 9.5 %
1990 - 1999	0.75 (0.42 - 1.07) 46.9 (44.9 - 48.9) 28.2 %	0.43 (-0.13 - 0.99) 57.1 (53.7 - 60.5) 28.2 %	0.07 (-0.43 - 0.56) 58.1 (55.2 - 61.0) 1.3 %
2000 - 2009	-0.02 (-0.34 - 0.30) 44.6 (42.9 - 46.4) 0.3 %	-0.09 (-0.38 - 0.20) 56.3 (54.7 - 57.9) 6.2 %	-0.42 (-1.31 - 0.47) 58.4 (53.3 - 63.5) 12.7 %
			SON Autumn
1990 - 2009			0.04 (-0.11 - 0.19) 45.2 (44.3 - 46.1) 1.6 %
1990 - 1999			0.41 (0.00 - 0.83) 47.1 (44.8 - 49.4) 40.0 %
2000 - 2009			-0.25 (-0.70 - 0.20) 46.7 % 17.2 %