The Canadian ozonesonde network

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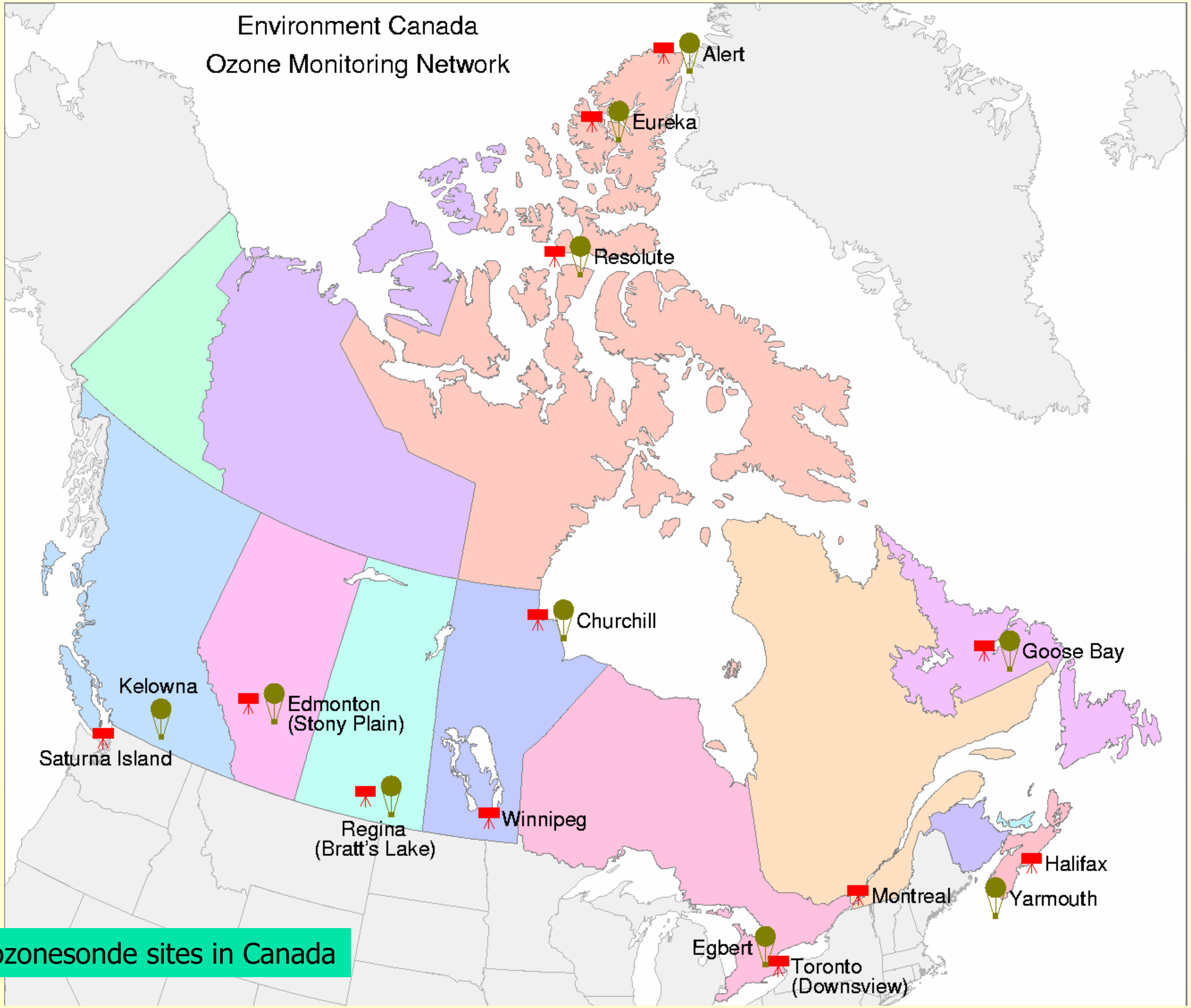
www: http://exp-studies.tor.ec.gc.ca/



Brewer and ozonesonde sites in Canada

Station	Location	Altitude (m)	Start of sonde record
Edmonton	53.6°N, 114.1°W	766	Brewer-Mast (1970); ECC (1979)
Goose Bay	53.3°N, 60.3°W	44	Brewer-Mast (1969); ECC (1980)
Churchill	58.8°N, 94.1°W	35	Brewer-Mast (1973); ECC (1979)
Resolute	74.7°N, 95.0°W	64	Brewer-Mast (1966); ECC (1979)
Eureka	80.1°N, 86.4°W	10	ECC (1992)
Alert	82.5°N, 62.3°W	62	ECC (1987)
Kelowna	49.9 °N, 119.4°W	456	ECC (2003)
Bratt's Lake	50.2 °N, 104.7°W	580	ECC (2003)
Egbert	44.2 °N, 79.8°W	251	ECC (2003)
Yarmouth	43.9 °N, 66.1°W	9	ECC (2003)

- *Weekly releases (generally Wednesdays)*
- *Also special campaigns (MATCH, TOPSE, IONS, BORTAS)*
- *Regular ozone soundings at Resolute since January, 1966*

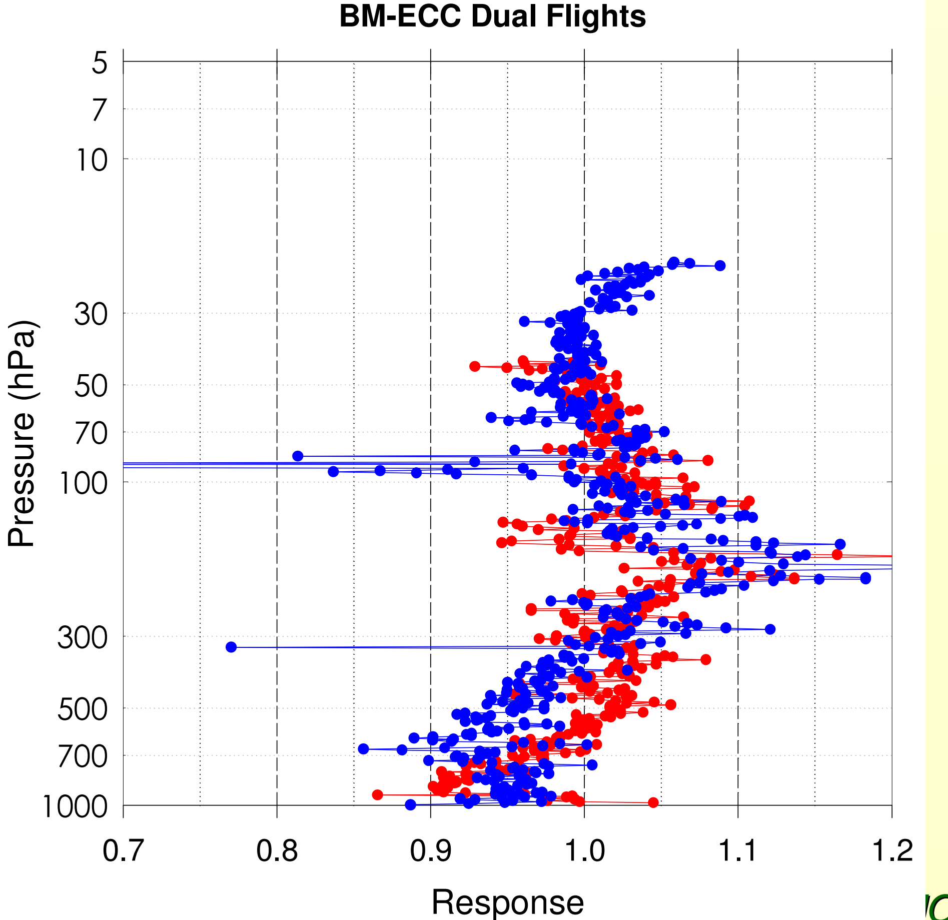
Major International Intercomparisons

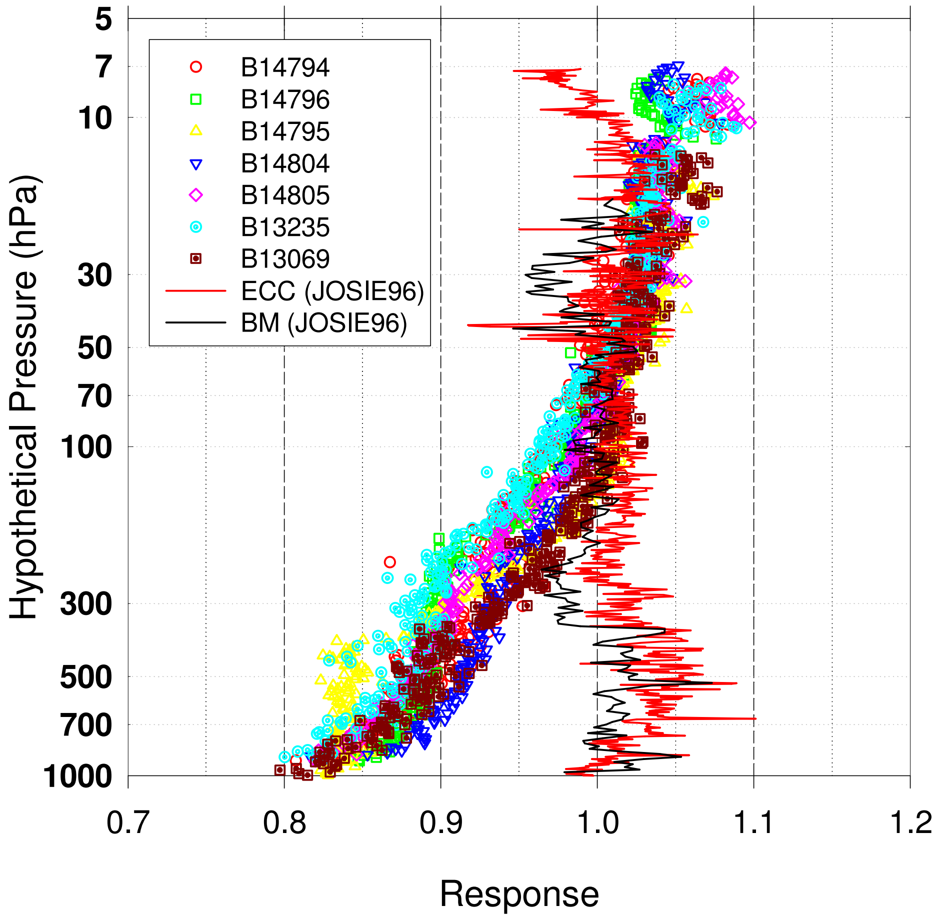
- Hohenpeissenberg, Germany, 1970 (WMO-I).
- Hohenpeissenberg, Germany, 1981 (WMO-II).
- Palestine, Texas, USA, 1986 (BOIC).
- Vanscoy, Saskatchewan, 1991 (WMO-III).
- Julich , Germany, 1996 (JOSIE96).
- Julich , Germany, 2000 (JOSIE2000).
- Wyoming, 2004 (BESOS)

Canadian Brewer-Mast Data

- 1966-1979
- Not as reliable as ECC data
- Need to be corrected (normalized) to total ozone measurement (average value used in Arctic winter)
- Fairly good in stratosphere
- Low bias in troposphere needs to be better characterized

Response of BM sondes prepared according to standard procedures in the 1970's in Canada (*Mueller* [1976]). Also: average response of BM sondes prepared via *Claude et al.*, [1987] and for Canadian ECC sondes, to the standard mid-latitude profile in JOSIE96.





Dual Flights: Built "ozone cabinet"; attempt to reproduce sonde preparation procedures used in Canada in 1970s.

Data is questionable --problems with sticky pump on new sondes?

Canadian ECC Data

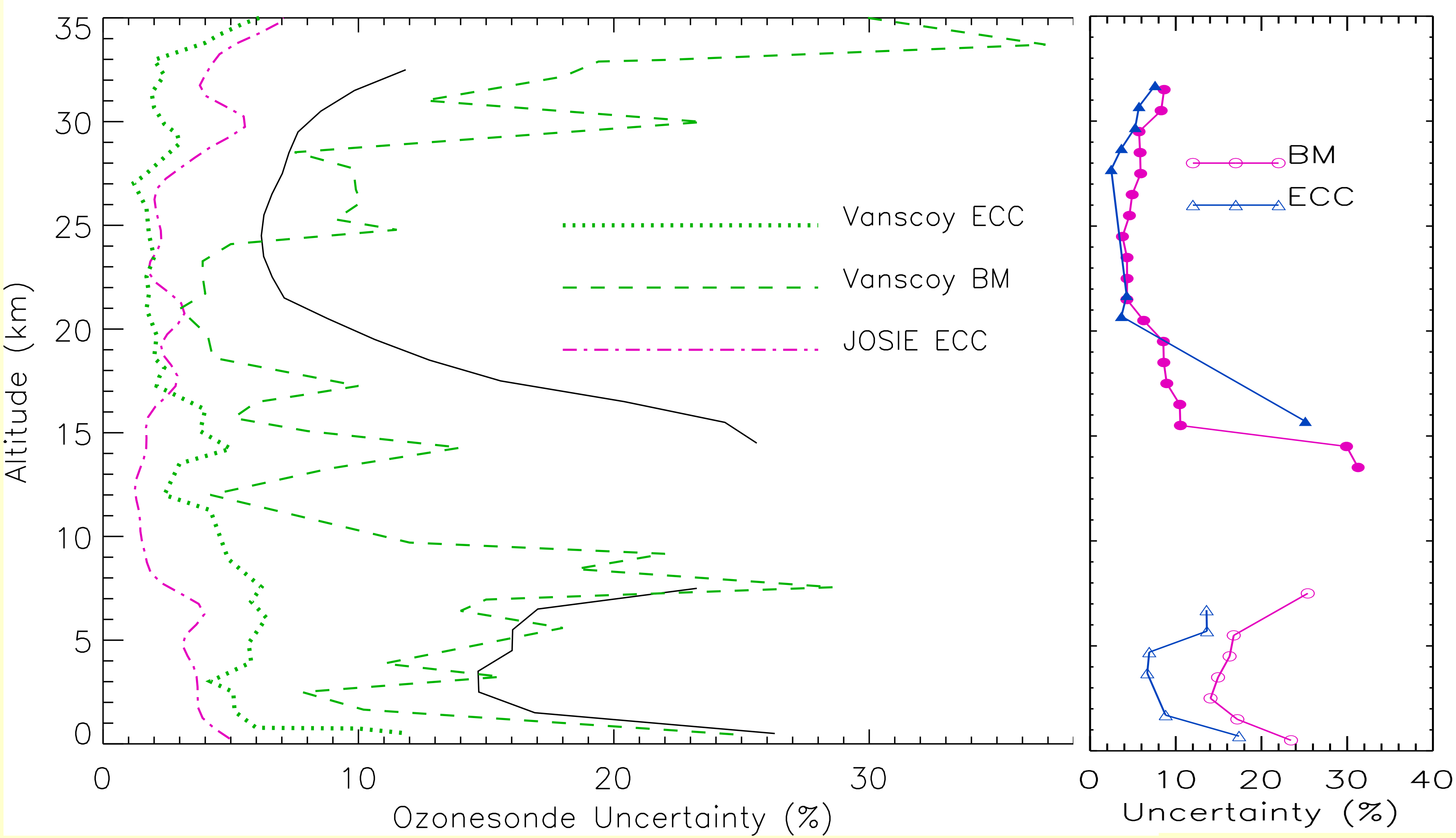
- 1979-80 to present
- Good results in international intercomparisons
- Quality control during processing by network manager (J. Davies)
- Canadian practice is to correct to total ozone measurement where available (reduces scatter)
- Probably better not to "correct". Sonde trends then independent of Brewer trends. Can still use correction factor as QC check.

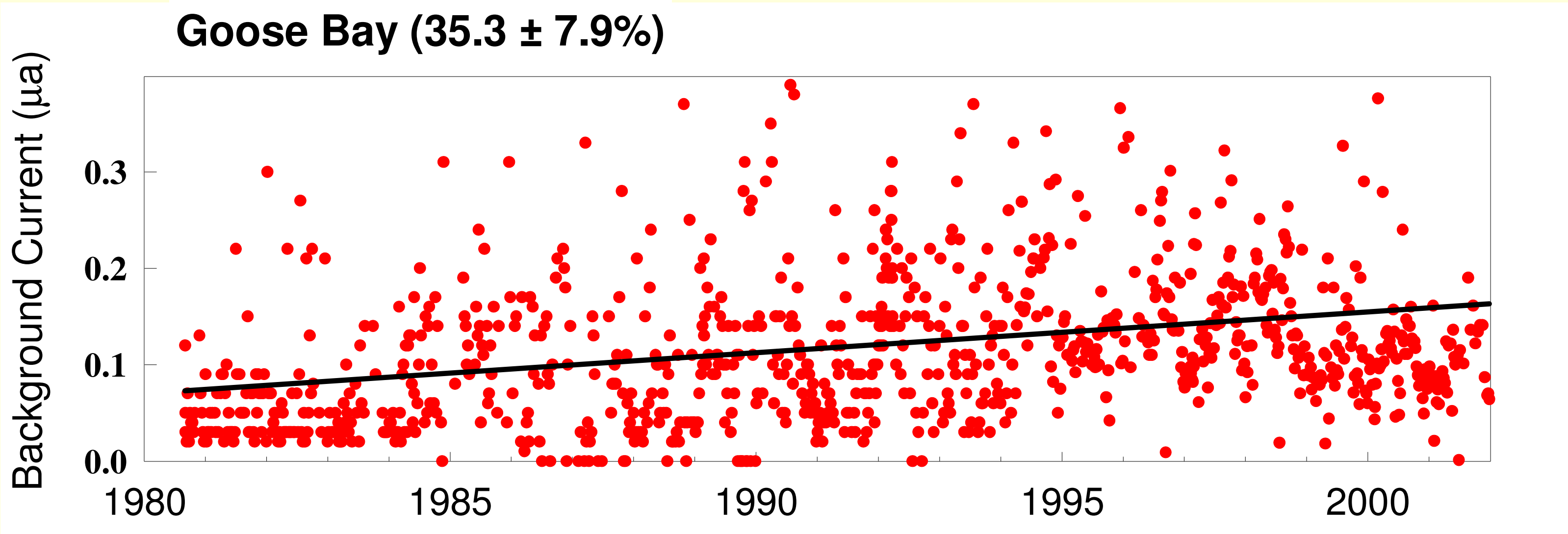
ECC Data – accuracy & precision

Measurement via the KI reaction is (in principle) absolute: i.e., get 2 electrons for each ozone molecule; however:

- losses of ozone in the pump & to the walls of the sensor chamber
- iodine evaporation, also adsorption to the platinum cathode
- efficiency of the pump is reduced at low pressures, and a correction (measured or estimated) must be applied for this.
- slow side reactions with the phosphate buffer can cause the stoichiometry of the KI reaction to be greater than 1
- background current?
- Interference from other gases in polluted areas: SO_2, NO_2
- Best practice: precision of better than ±(3-5)% and an accuracy of about ±(5-10)% up to 30 km altitude [*Smit et al.,* 2007].

Liu, G., et al. (2009), Ozone correlation lengths and measurement uncertainties from analysis of historical ozonesonde data in North America and Europe, *J. Geophys. Res.*, 114, D04112, doi:10.1029/2008JD010576.





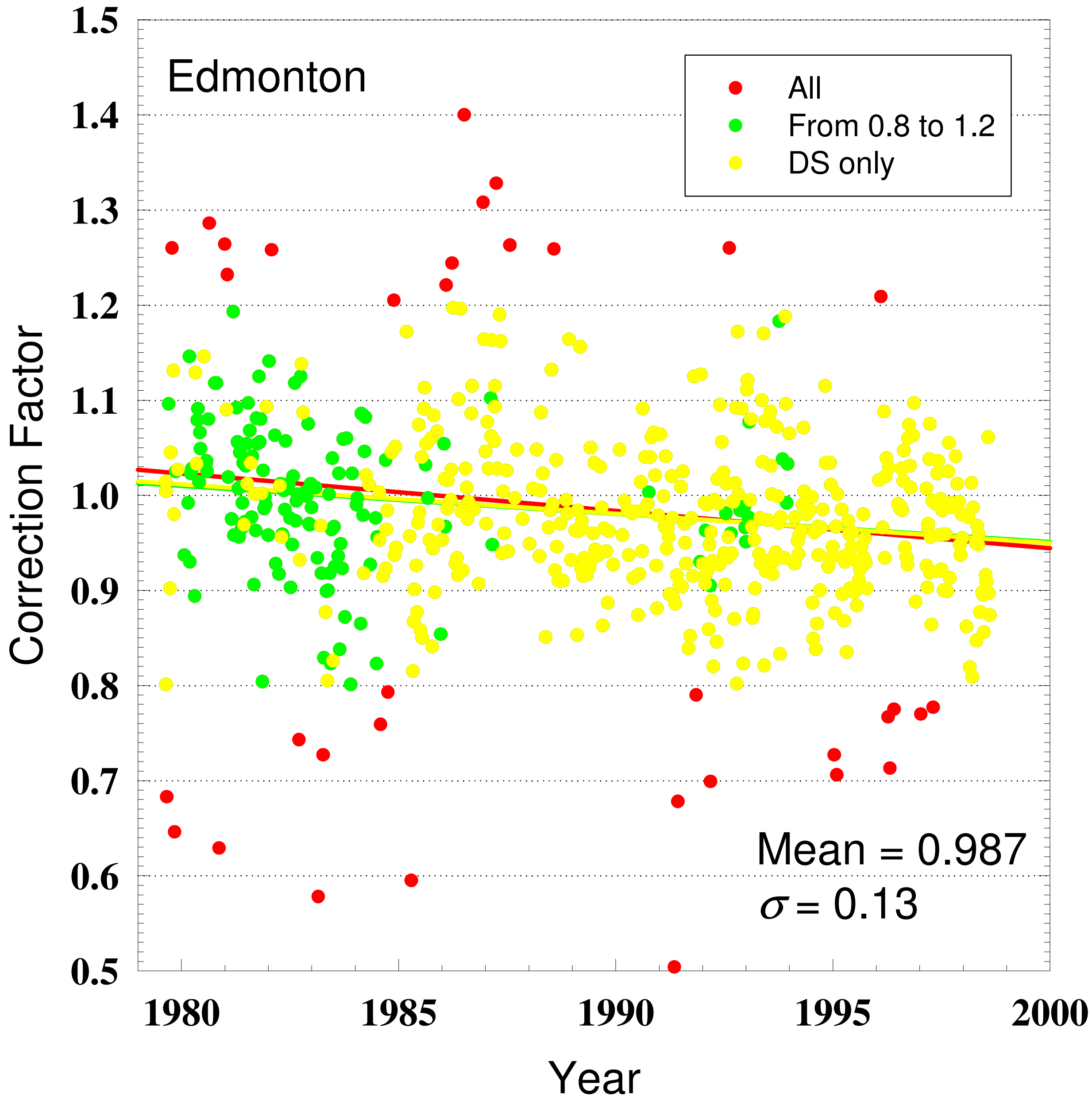
Other issues (in Canada and elsewhere):

- Background current trends: can affect values in upper troposphere if correction is not appropriate.
- Some evidence that *Komhyr* [1986] pump correction is too small, but compensating for 2nd time constant. Would lead to overestimate of upper part of profile, when ozone is high.

Canadian data:

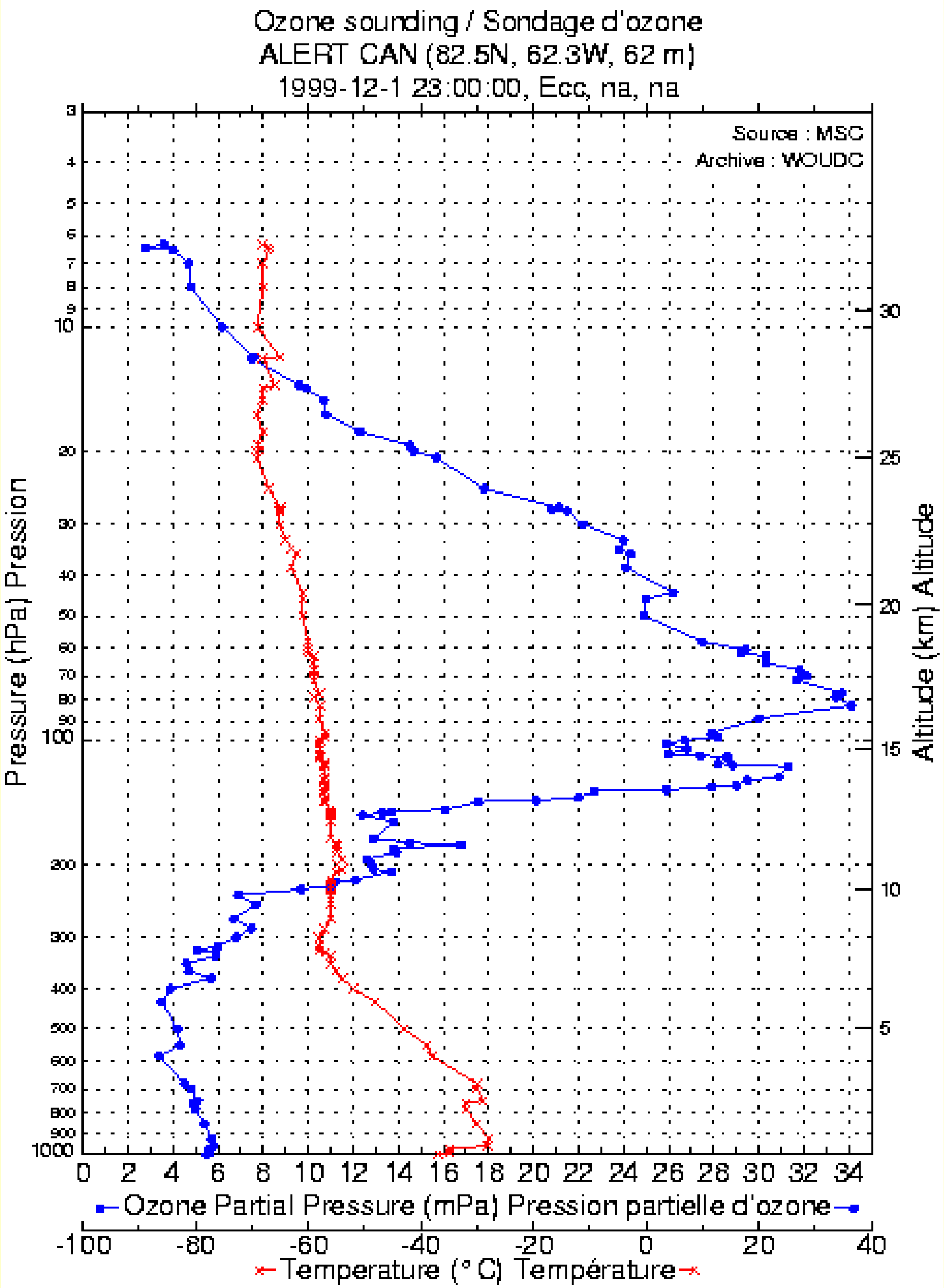
Correction factors: used to normalize profiles to Brewer measurement (where available). Useful as a check on data quality. Puzzling trend at Edmonton. Brewer record has been revised. Some correction factors are therefore wrong. Need to revisit this.

Comparing WOUDC total ozone record to total ozone values in sonde files: at several sites WOUDC total O_3 appears to have been revised, but not sonde record.



Some puzzling issues…

- Occasional very large correction factors (as high as 2.5)?
- Also low values (as low as 0.6)?
- Other QC: outliers, spikes …



Some things we can’t fix: need to characterize:

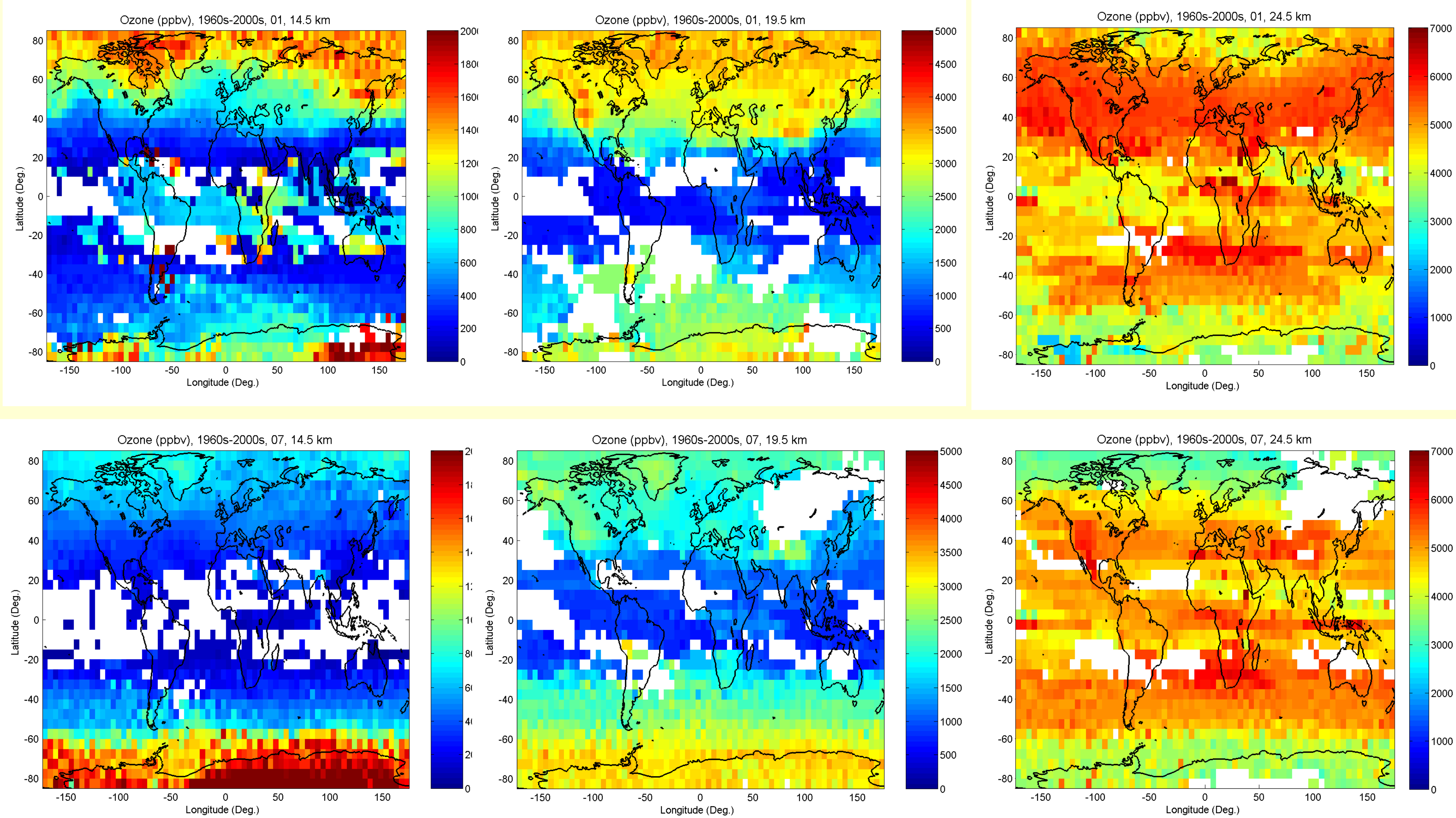
Changes in the ECC ozonesonde and associated radiosonde

Year	Change	Possible Effect
1979	ECC 4A introduced	~15% increase in tropospheric response
1984	ECC 4A introduced	redesigned pump; maximum change <1%, at 50-20 hPa.
1993	ECC 5A introduced	New pump correction; maximum change ~1%, at 100 hPa.
1993	Vaisala RS-80, RSA-11 introduced	may introduce altitude shift in profile above 25 hPa (25km).
1996	ECC 6A	No systematic differences below about 20-25 km [*Smit et al*., 2000].
1997	ENSCI 1Z	High bias with 1% KI solution [*Smit et al*., 2007].
2006	Vaisala RS-92 introduced	None known.
2009	Switch to WMO SOP’s recommended by JOSIE	Need to characterize!

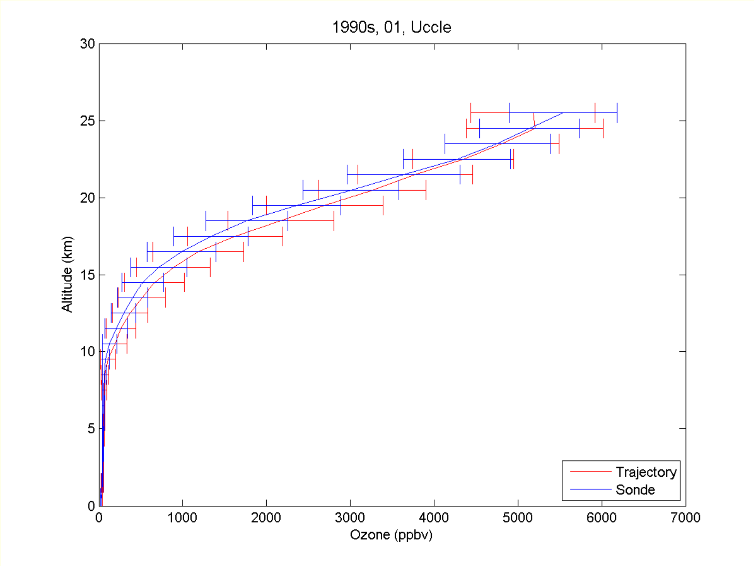
A Stratospheric Ozone Climatology from the Trajectory Mapping of Global Ozonesonde Data

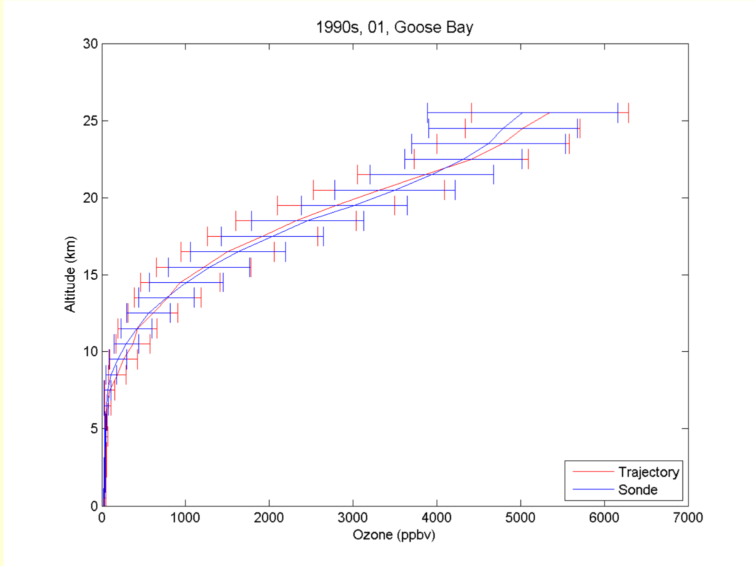
- Ozonesonde data, 116 stations, 44 years (1965-2008)
- use forward and back-trajectory calculations for each sounding to map ozone measurements to a number of other locations, and so to fill in the spatial domain.
- HYSPLIT (Hybrid Single Particle Lagrangian Integrated Trajectory Model), NOAA, Air Resources Laboratory, version 4.8 (http://ready.arl.noaa.gov/HYSPLIT.php)
- NCEP reanalysis data
- Global mapping: 5°×5° horizontal, 1 km vertical resolution

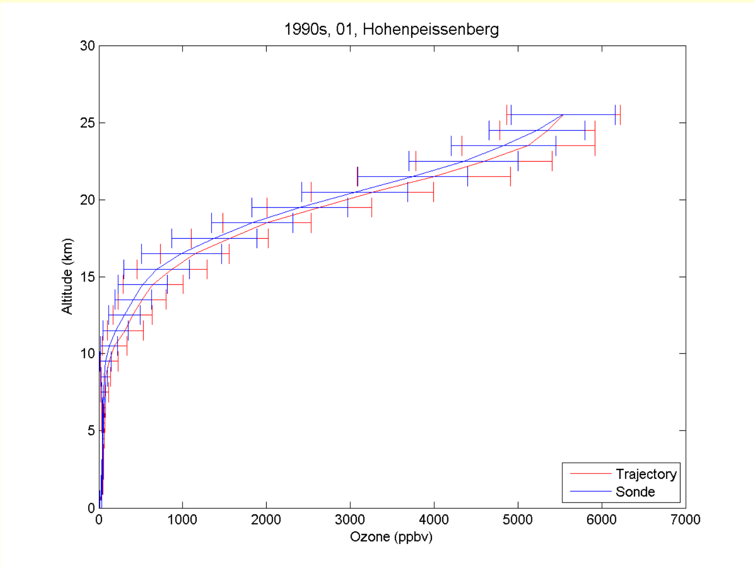
Long-term Mean (1966-2008)

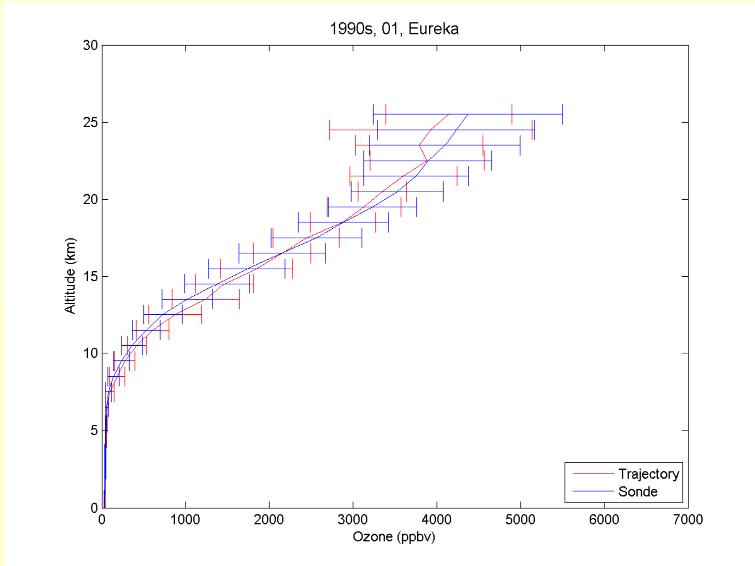


Validation: 1990s, January

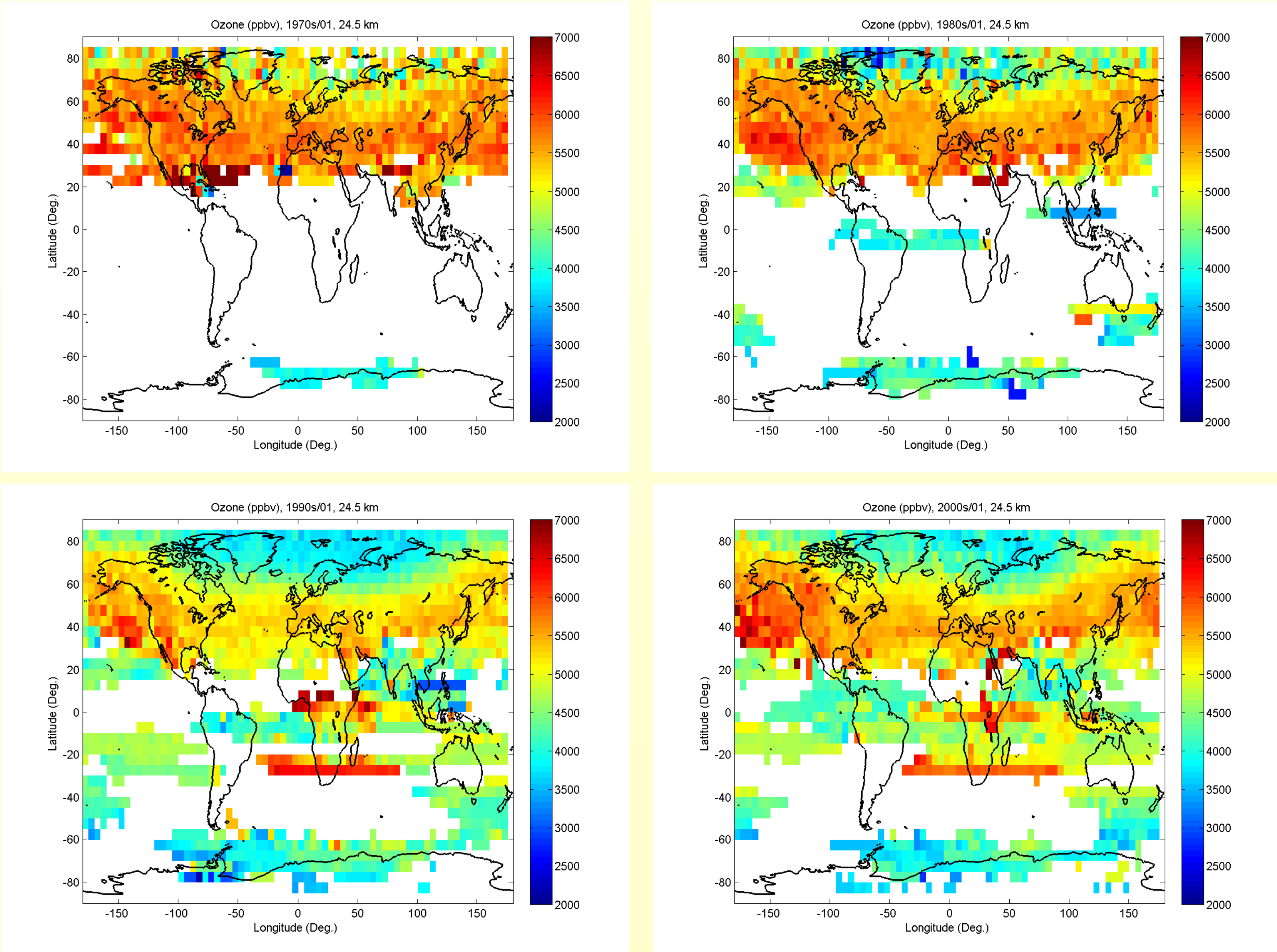




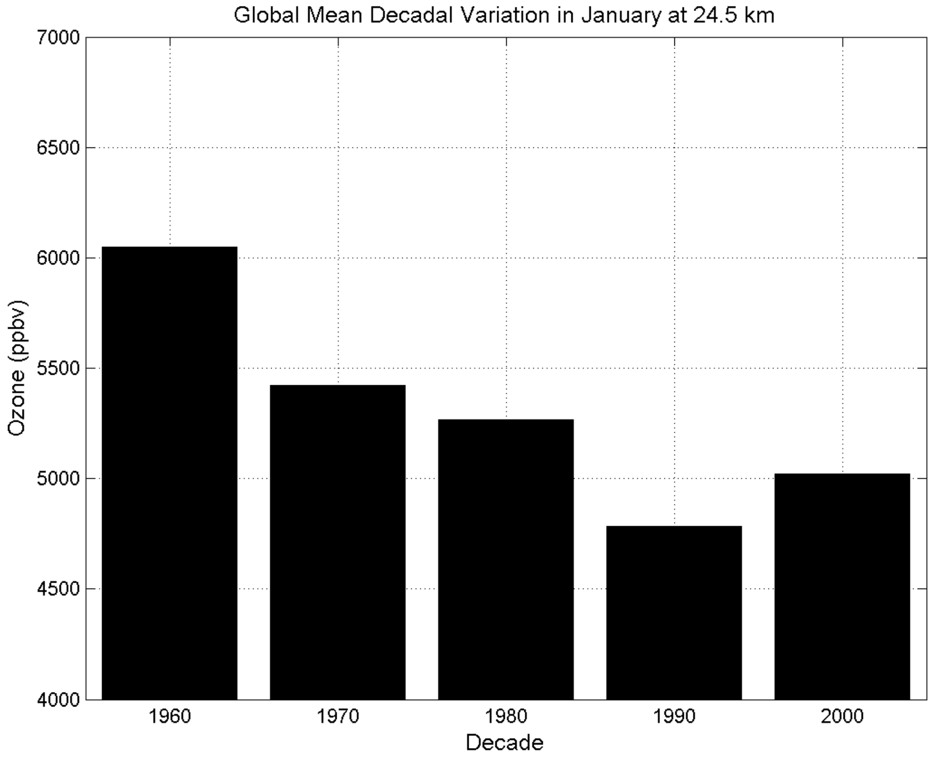


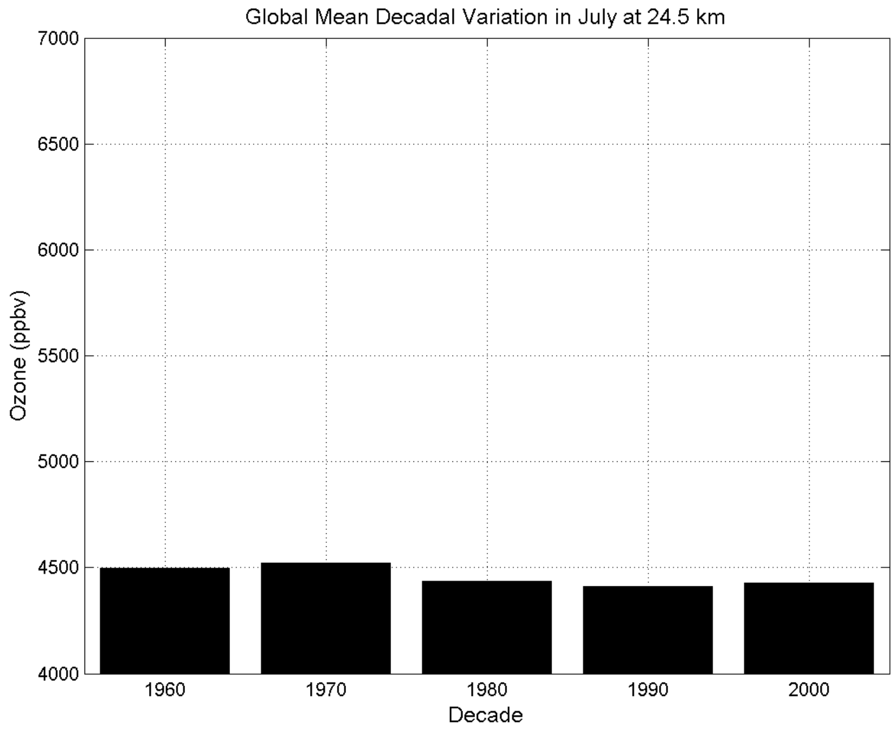


Decadal Variation

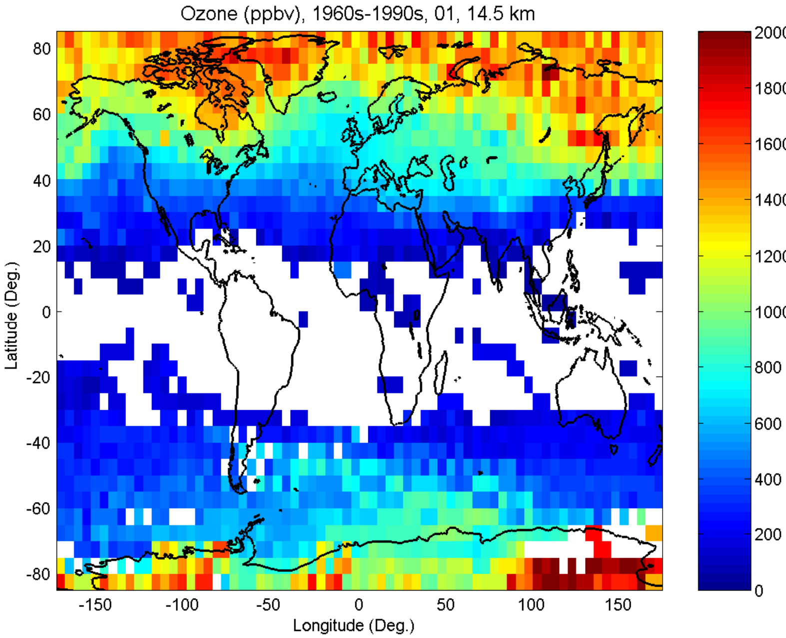


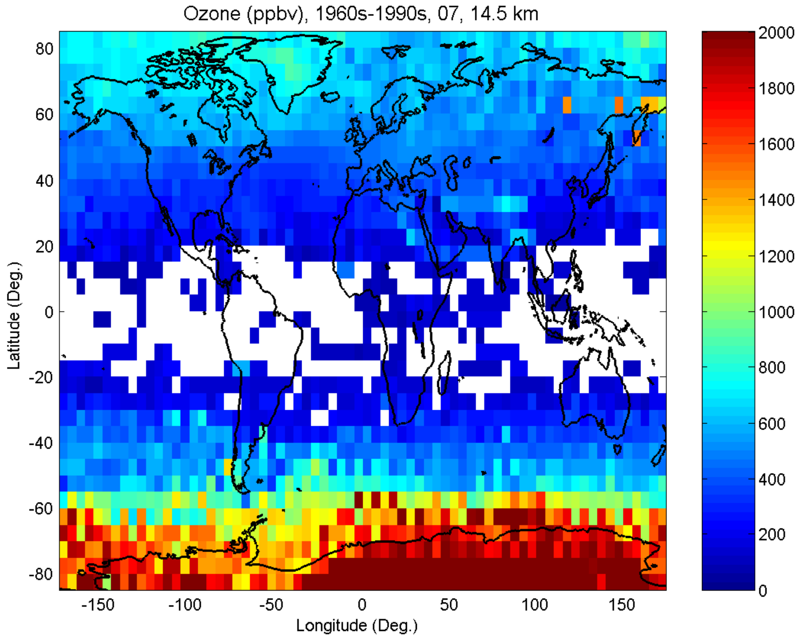
Decadal Variation

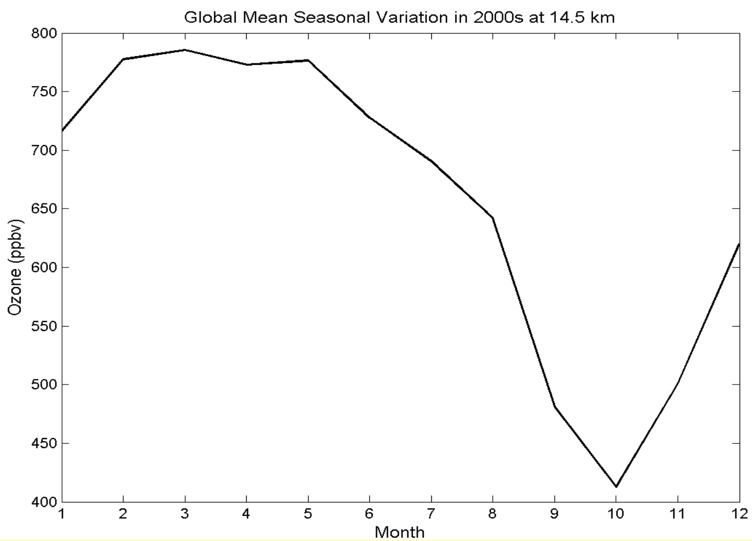


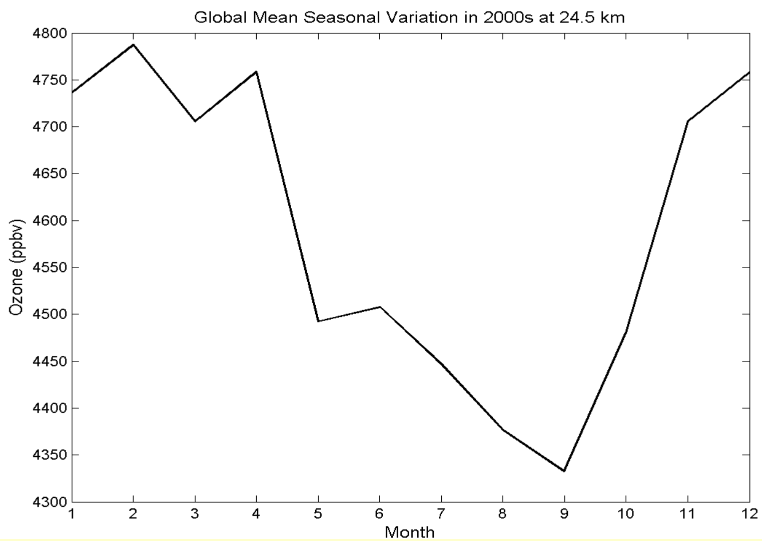


Seasonal variation









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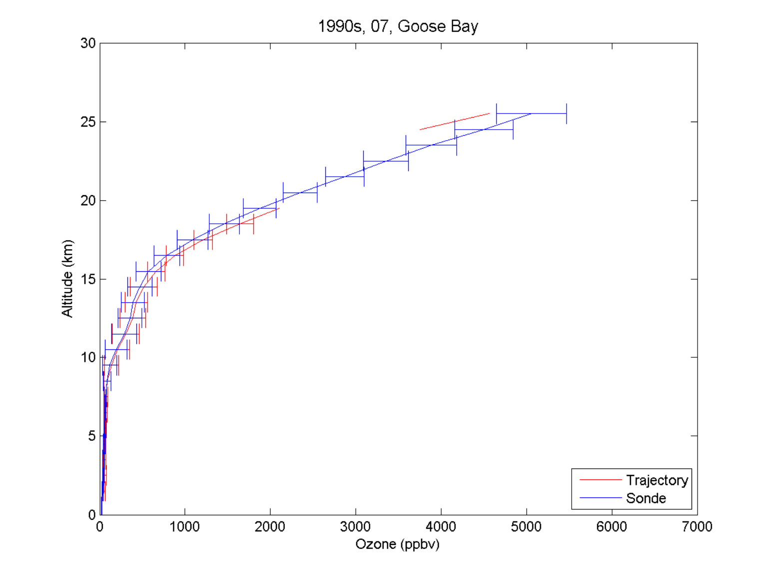
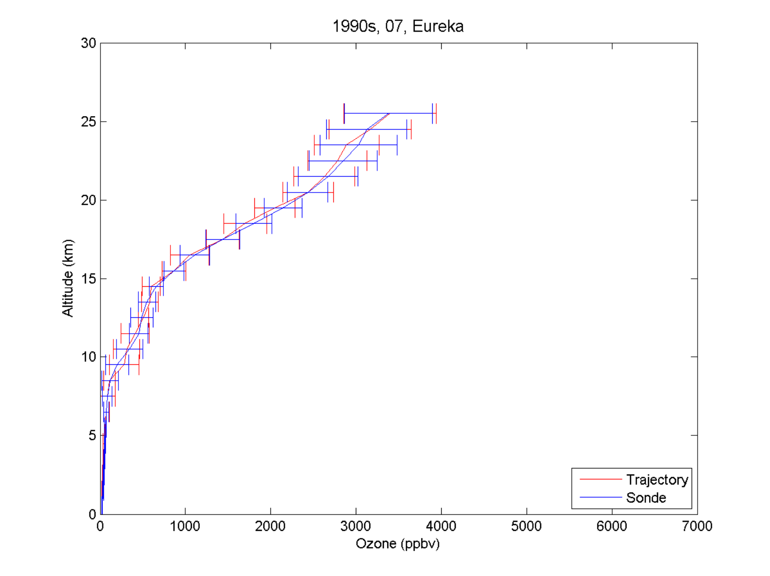
Credits

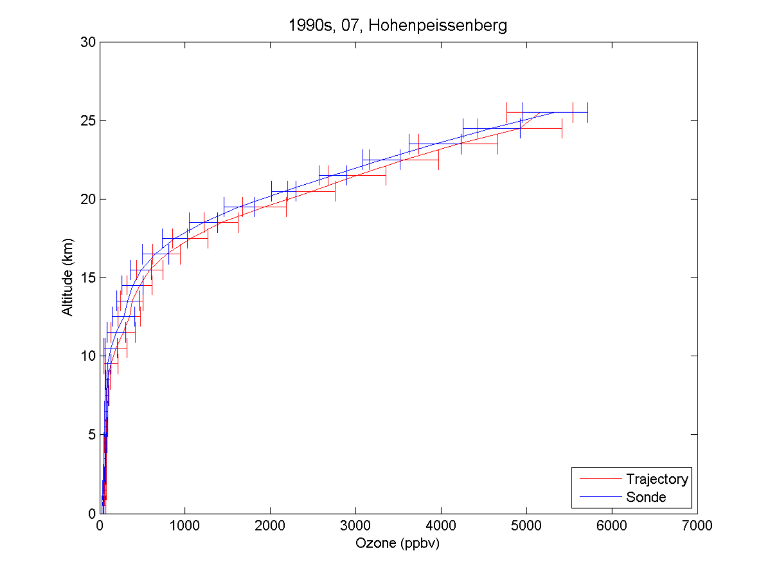
- J. Liu, J. Davies, I. Beres, G. Liu, V. Fioletov
- B. McArthur, R. Mittermeier
- I.A. Asbridge, J.J. Bellefleur, F. Karpenik
- Most especially the many observers over many years whose careful work obtained the ozonesonde measurements.

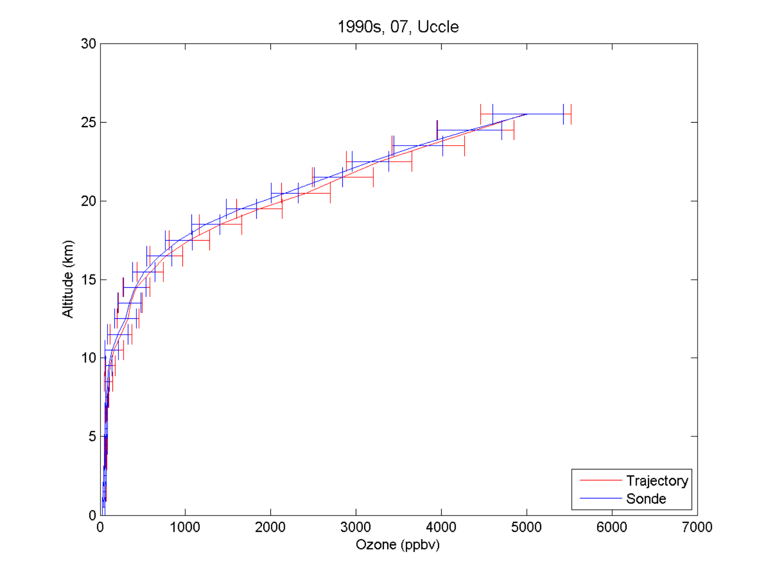
Extras

Validation: 1990s, July

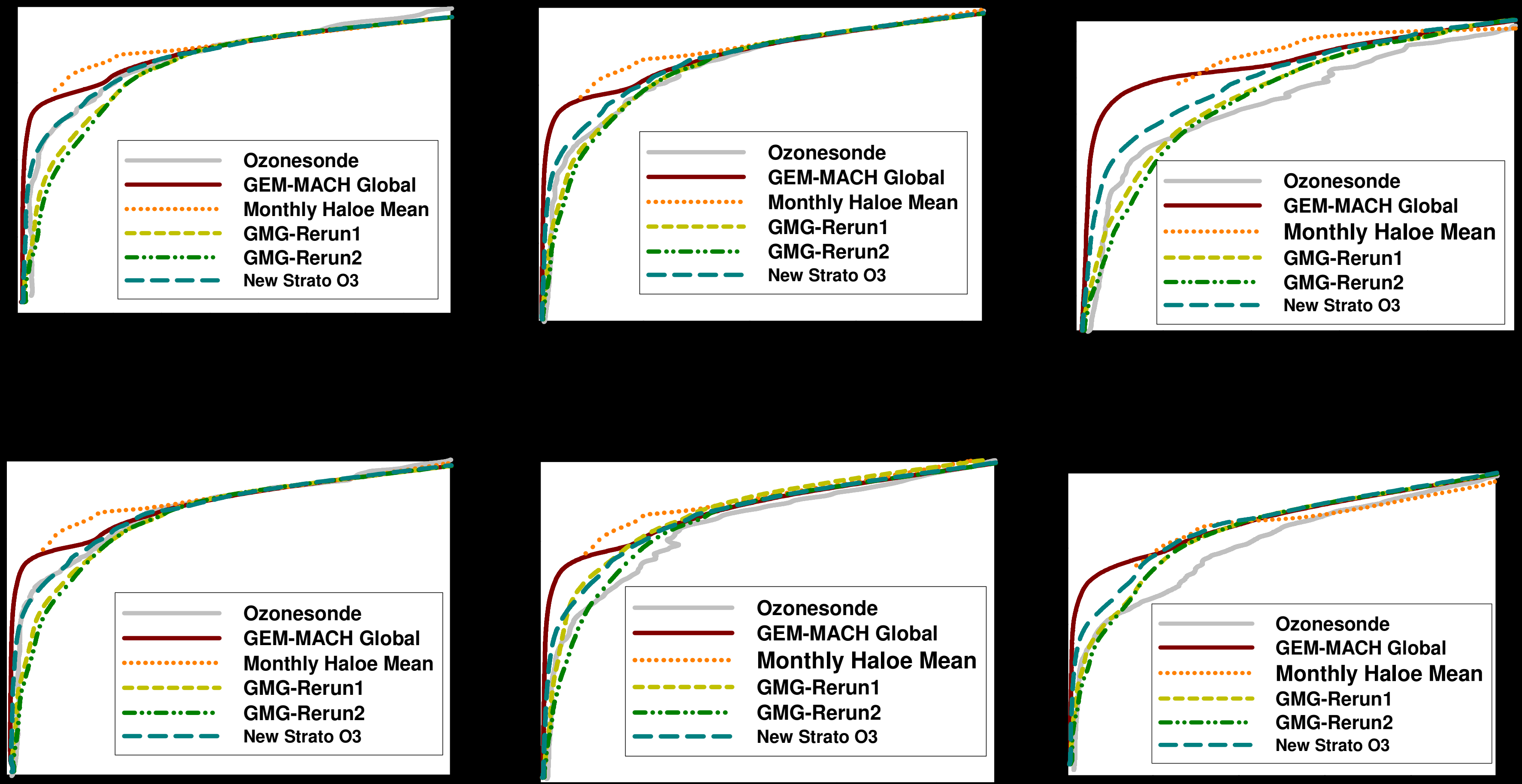


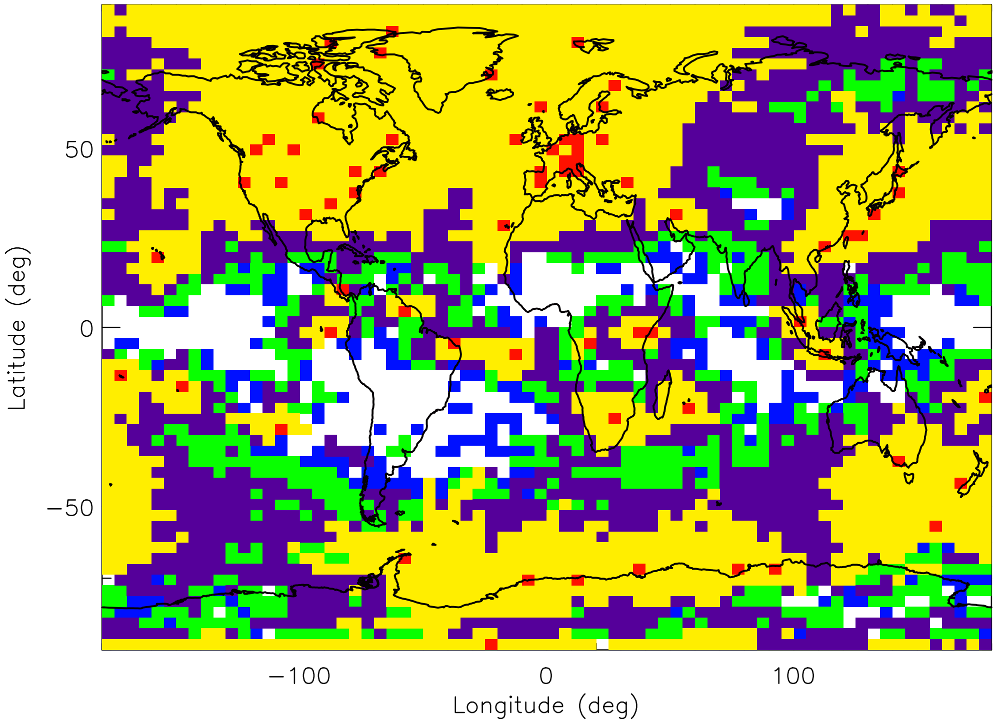






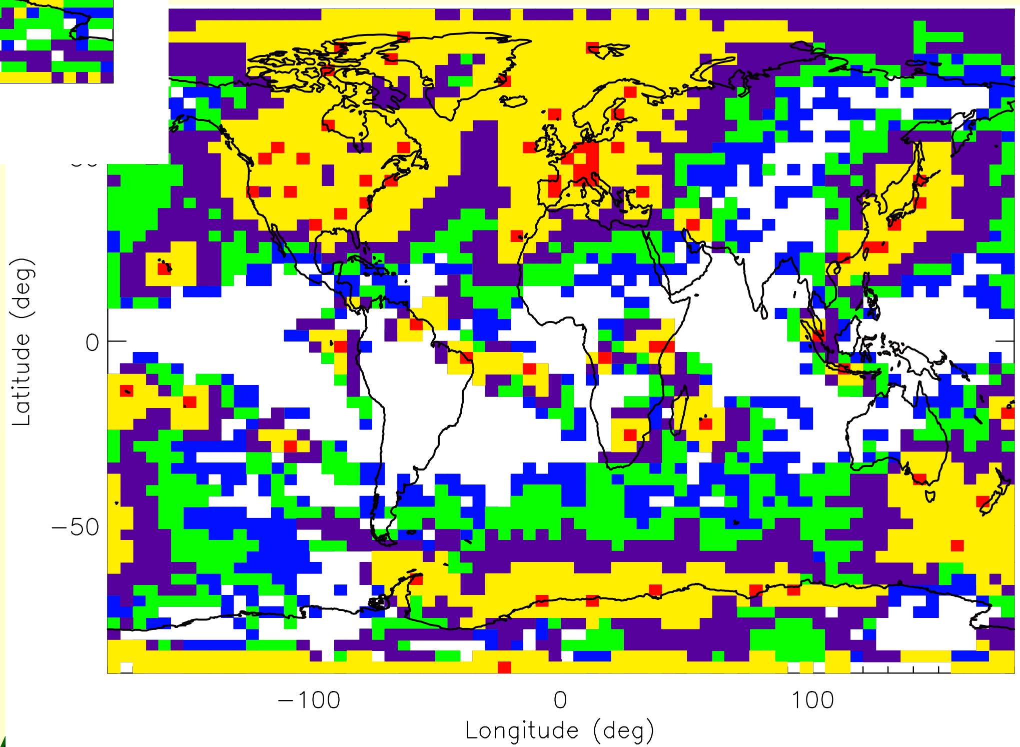
Applications: *a priori* in Models

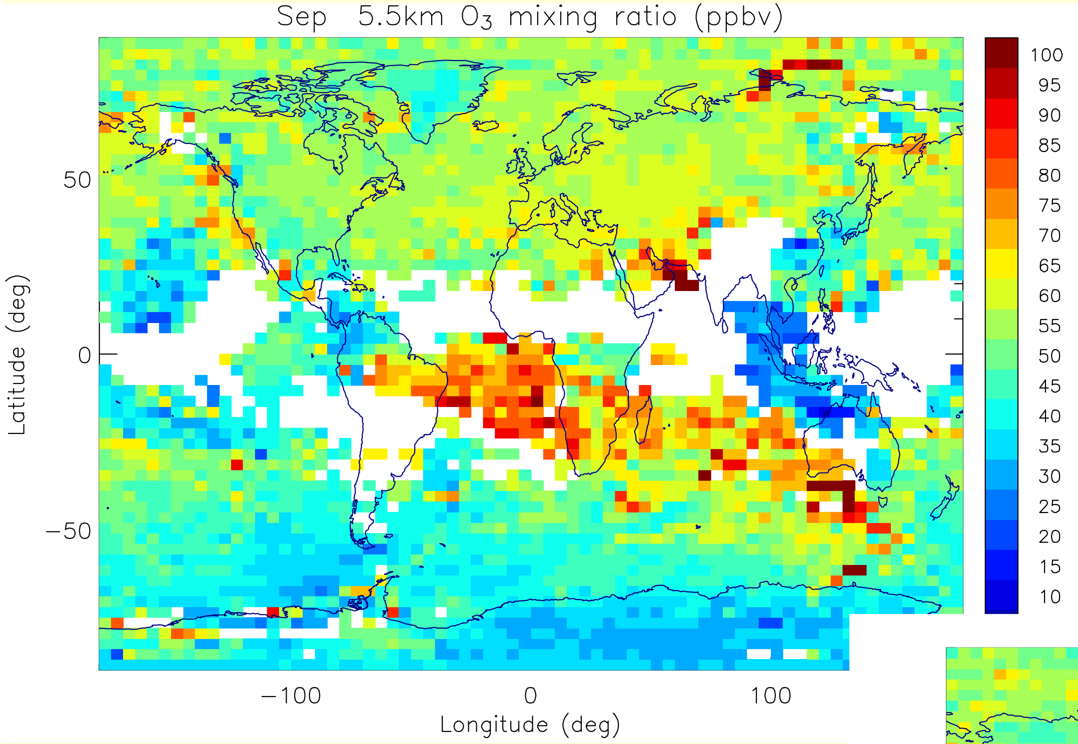




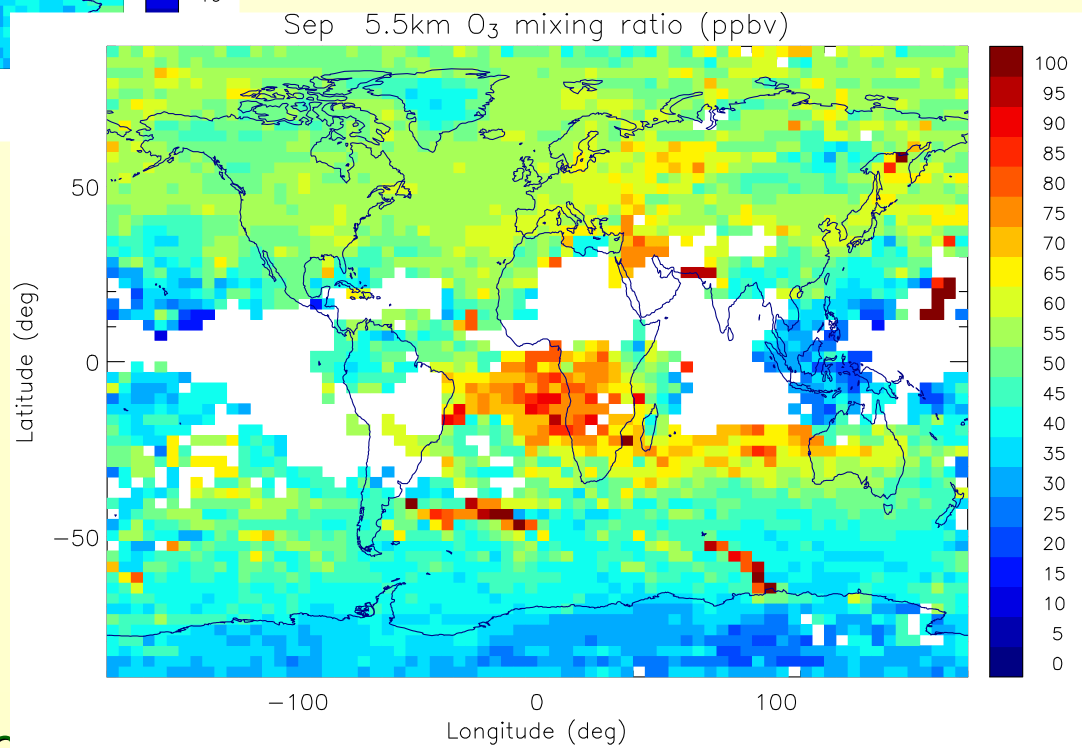
WOUDC Ozonesondes; data from 1980-present (> 45,000 profiles)

Coverage for 1 (yellow), 2 (purple), 3 (green), and 4 day (blue) trajectory mapping in April. The red squares denote the actual measurements at the ozonesonde stations.
Above: 5.5 km above sea level.
Right: 0.5 km above surface.

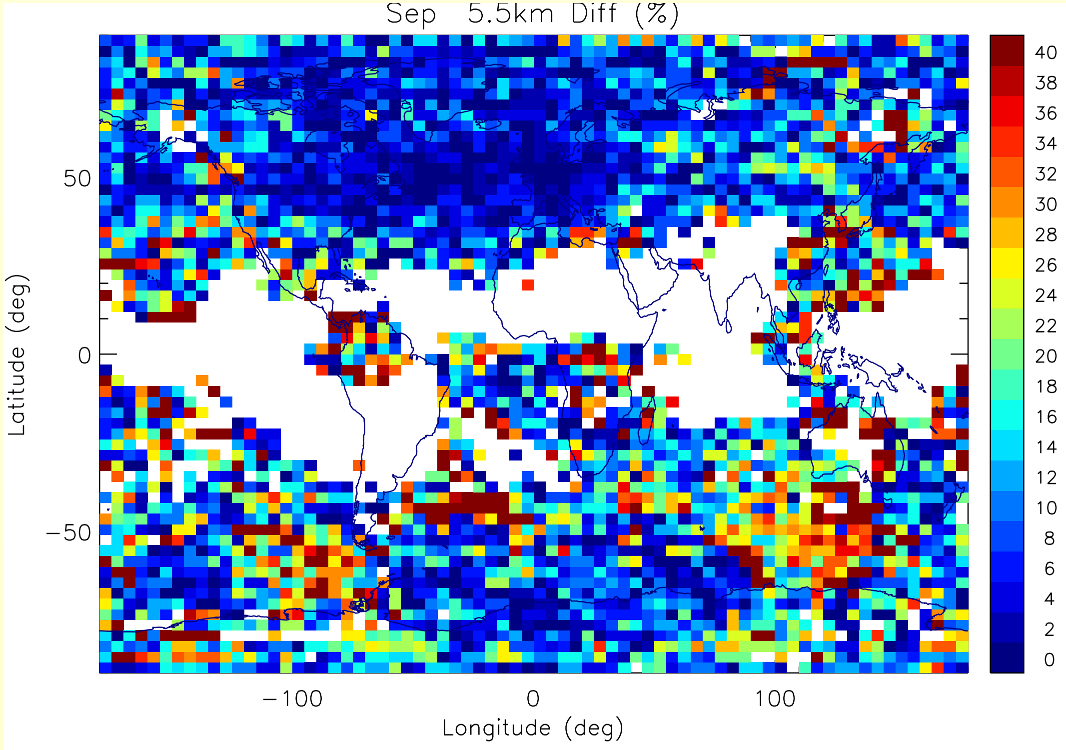




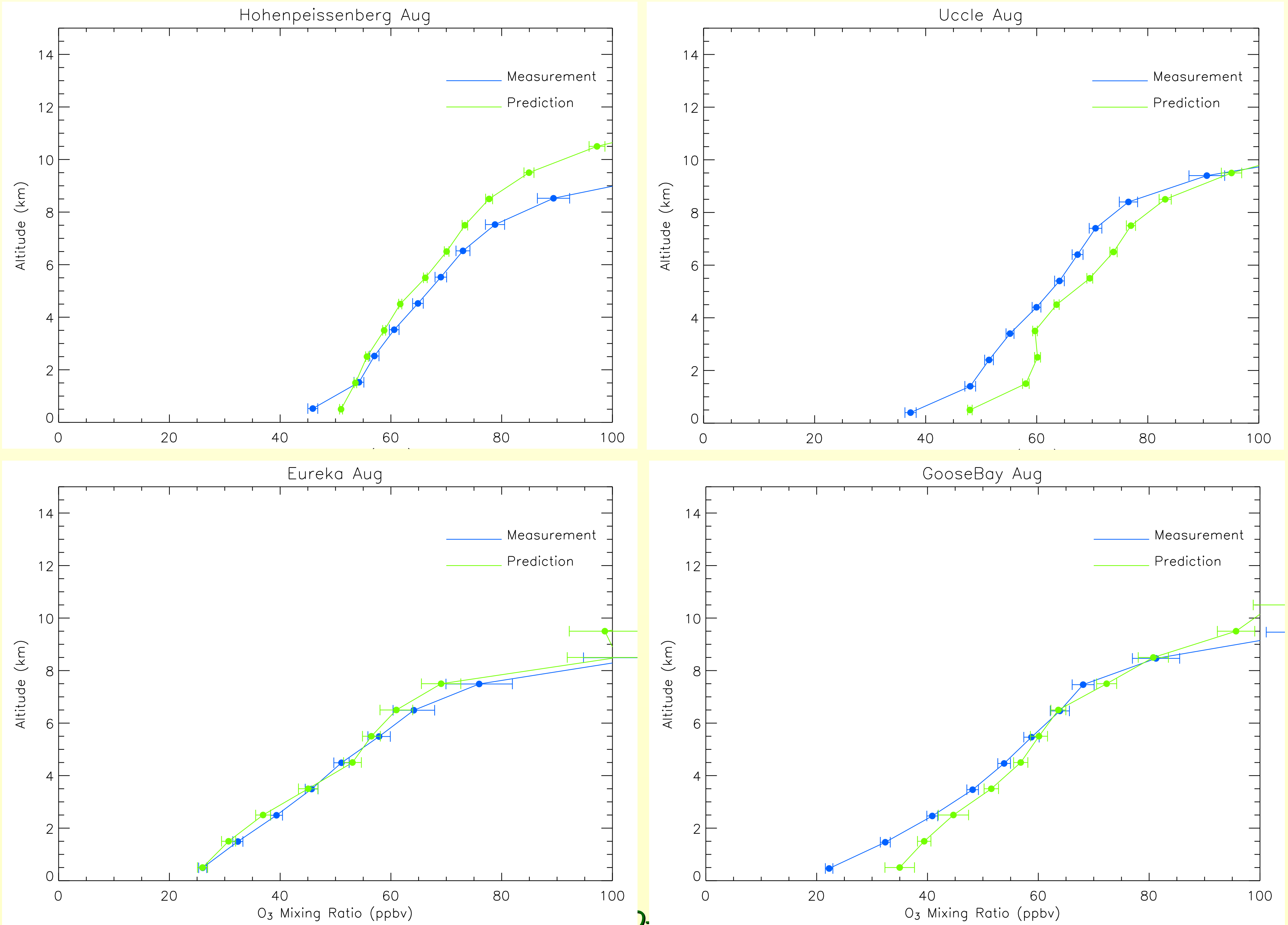
Comparison of ozone maps using only forward (left) and only backward (below) trajectories

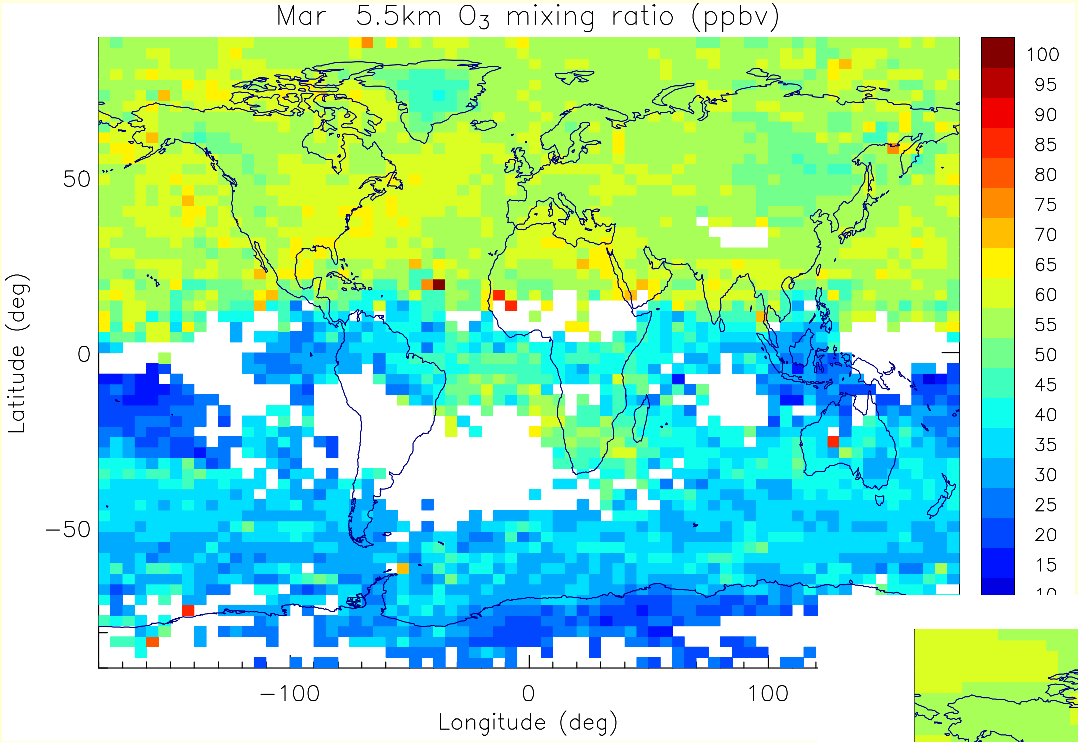


Difference between the two distributions in percent

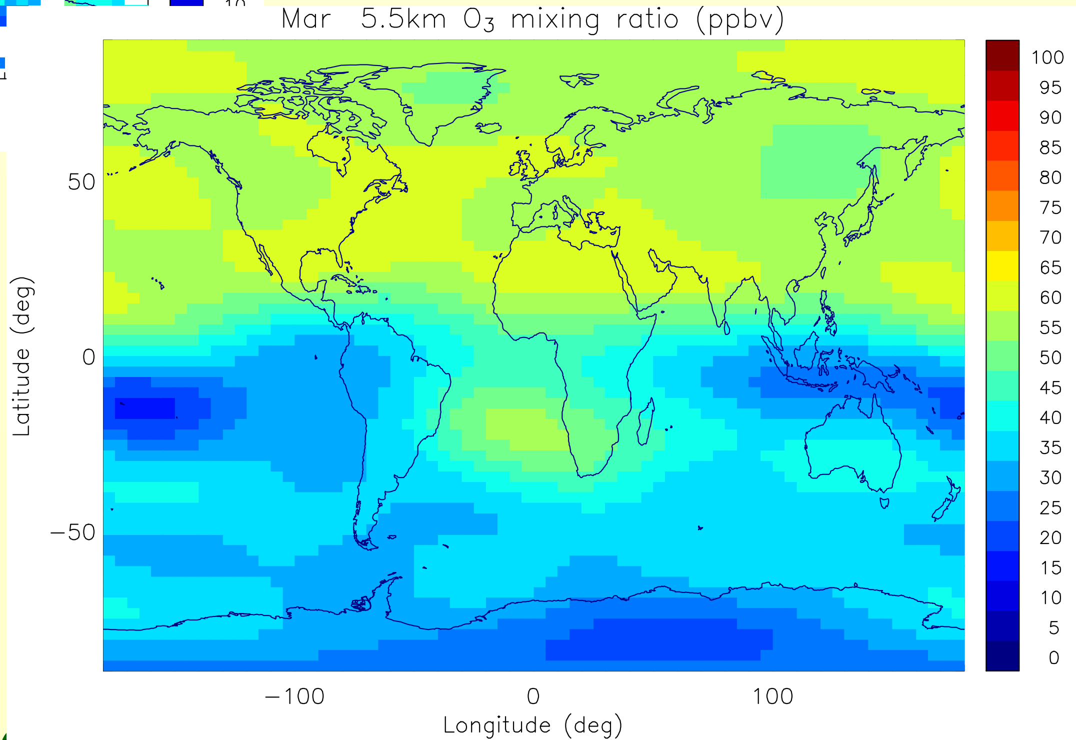


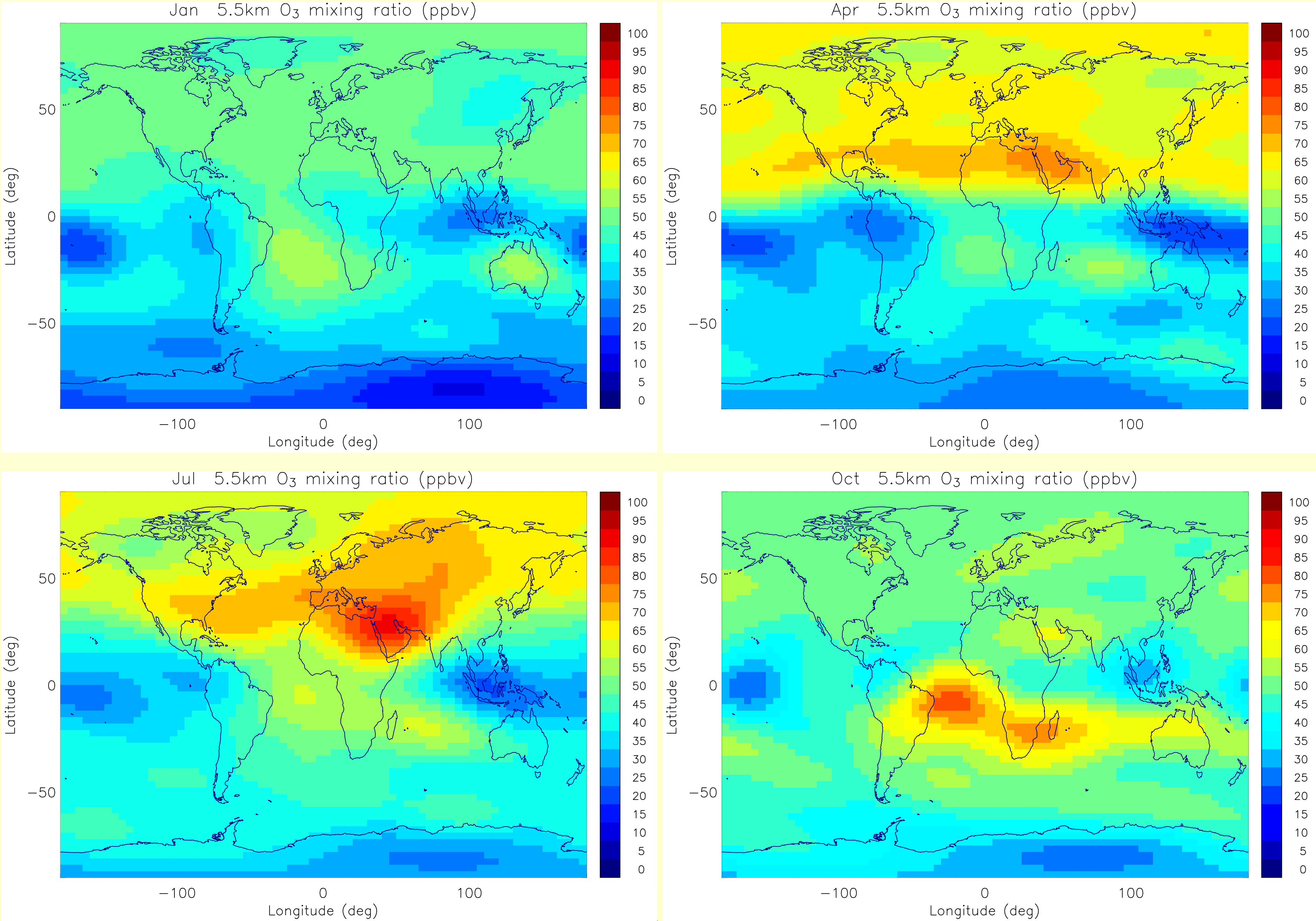
- Maximum differences ~ 40%
- No distinct pattern
- Some clustering in areas where trajectories are longest


Hohenpeissenberg Aug
Uccle Aug
Eureka Aug
GooseBay Aug
Measurement
Prediction
Altitude (km)
O3 Mixing Ratio (ppbv)
0
2
4
6
8
10
12
14
0
20
40
60
80
100



Average ozone field for March at 5-6 km altitude, from trajectory-mapped ozone soundings. The left-hand plot shows the individual (5x5º) pixel averages. The lower plot shows the smoothed field.





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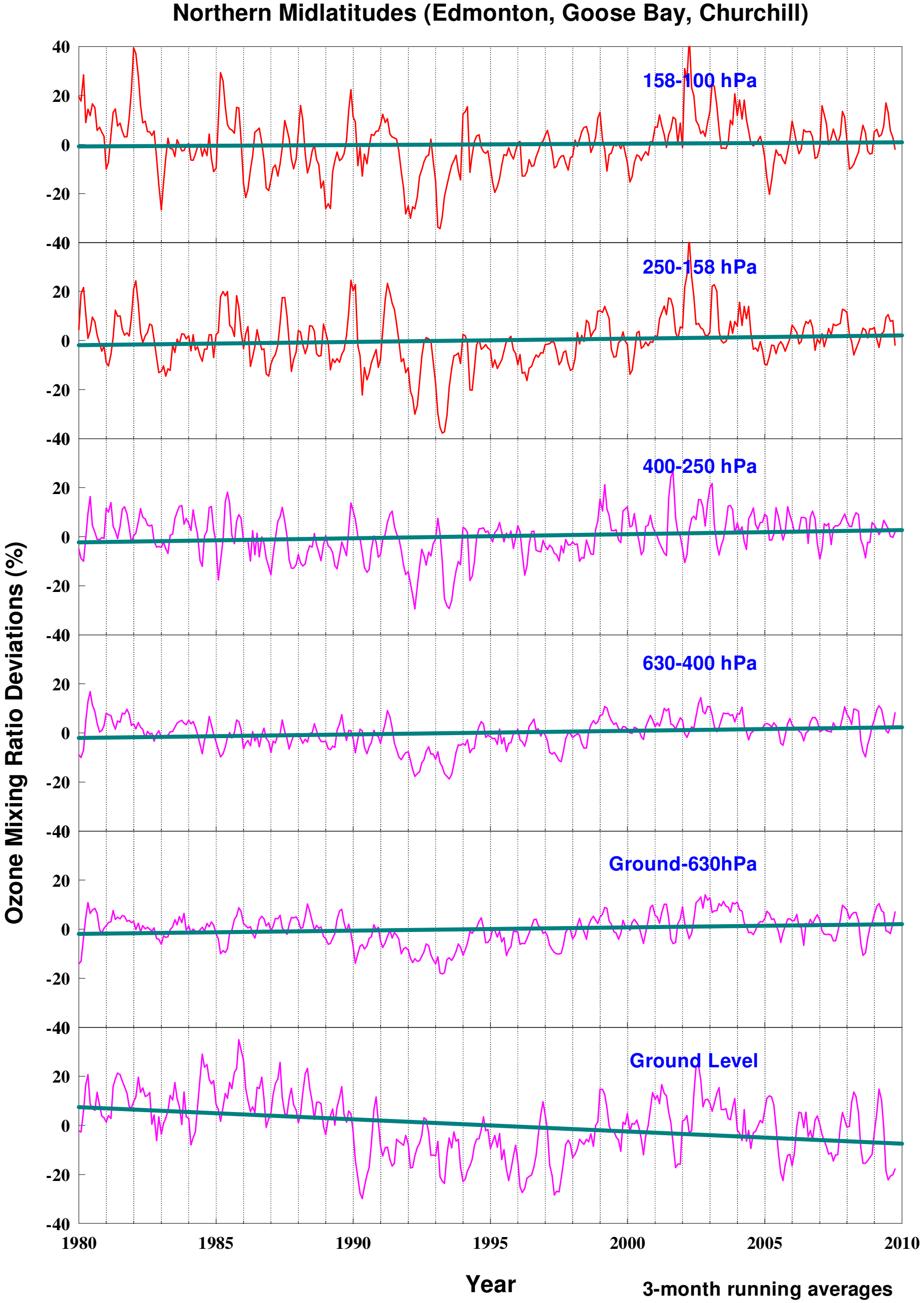
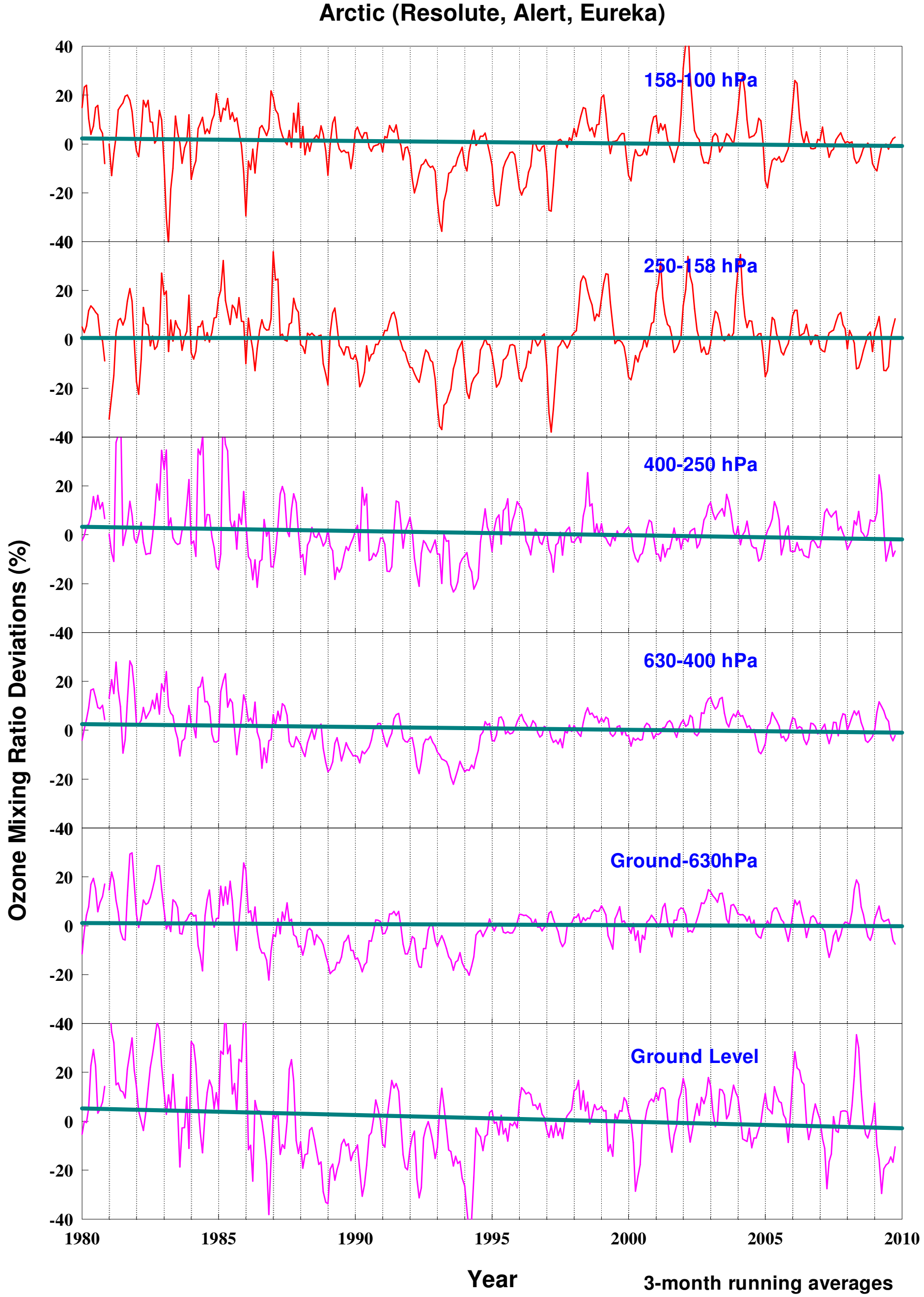

Northern Midlatitudes (Edmonton, Goose Bay, Churchill)
158-100 hPa
250-158 hPa
400-250 hPa
630-400 hPa
Ground-630hPa
Ground Level
Ozone Mixing Ratio Deviations (%)
Year
3-month running averages


Arctic (Resolute, Alert, Eureka)
158-100 hPa
250-158 hPa
400-250 hPa
630-400 hPa
Ground-630hPa
Ground Level
Ozone Mixing Ratio Deviations (%)
Year
3-month running averages

Special projects

- MATCH - direct evidence of chemical depletion of ozone
- MANTRA (‘98 ‘00 ‘02 ‘04)
- SOLVE, PAVE
- TOPSE, ALERT2000, INTEX-NA (IONS-04)
- INTEX-B (IONS-06), ARCTAS (ARC-IONS)
- CalNex, BORTAS

Other issues:

- To correct or not to correct …?
- If there is a big change in total ozone measured before & after the flight, should we quote a correction factor? Should we use the value for the flight day, or interpolate the values measured before & after the flight?
- Constant mixing ratio residual calculation – should do better: McPeters, R.D., G.J. Labow, and J.A. Logan (2007), Ozone climatological profiles for satellite retrieval algorithms, *J. Geophys. Res*, 112, D05308, doi:10.1029/2005JD006823.
- Put i_B and t_{100} from "blue books", in WOUDC files

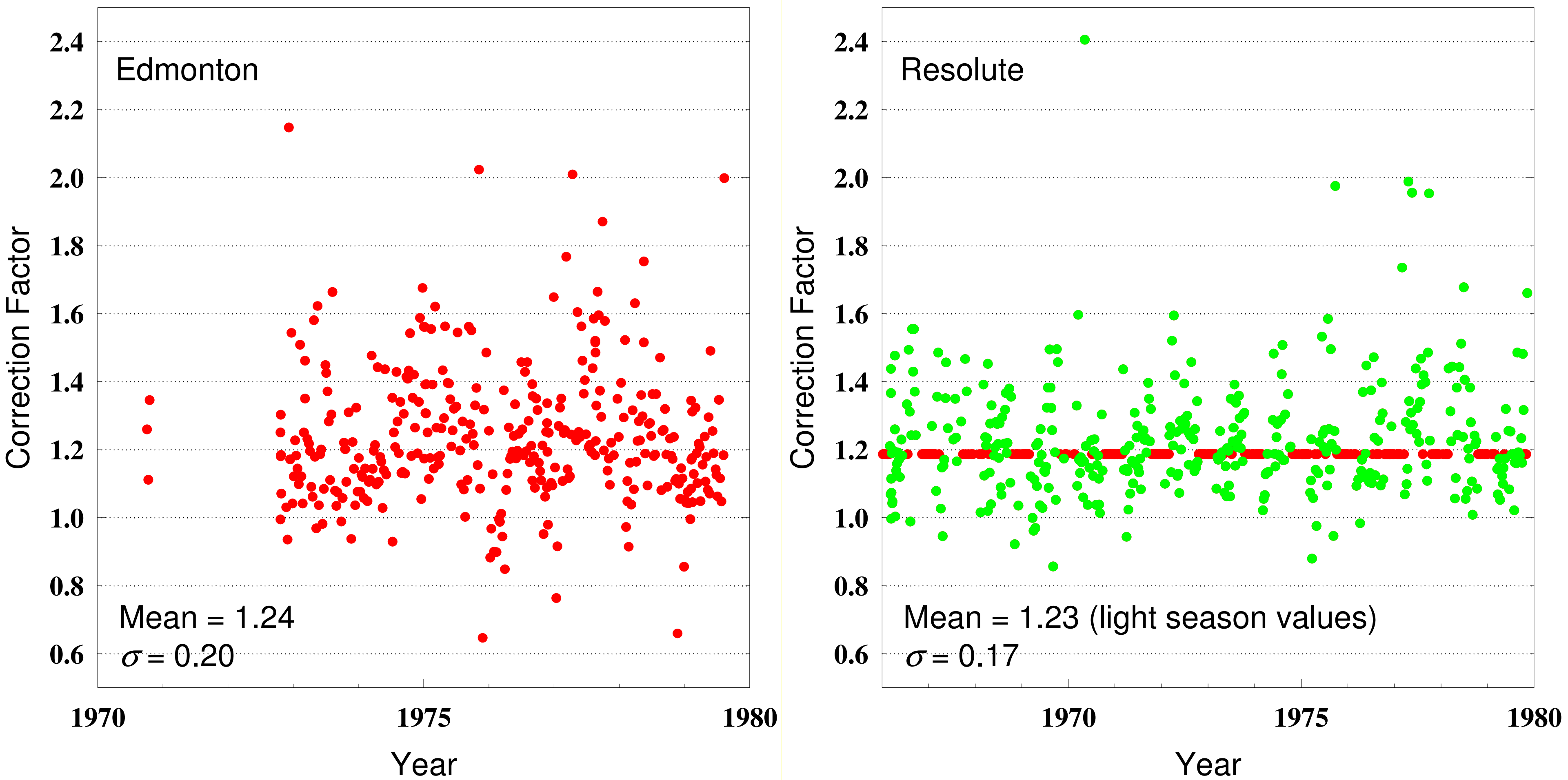
Trends

One can characterize the effects of correction, background current subtraction, changes of radiosonde, etc. on trends: the good news is that they don't affect things too much.

Tarasick, D.W., V.E. Fioletov, D.I. Wardle, J.B. Kerr, and J. Davies (2005), Changes in the vertical distribution of ozone over Canada from ozonesondes: 1980–2001, *J. Geophys. Res., 110*, D02304, doi:10.1029/2004JD004643.

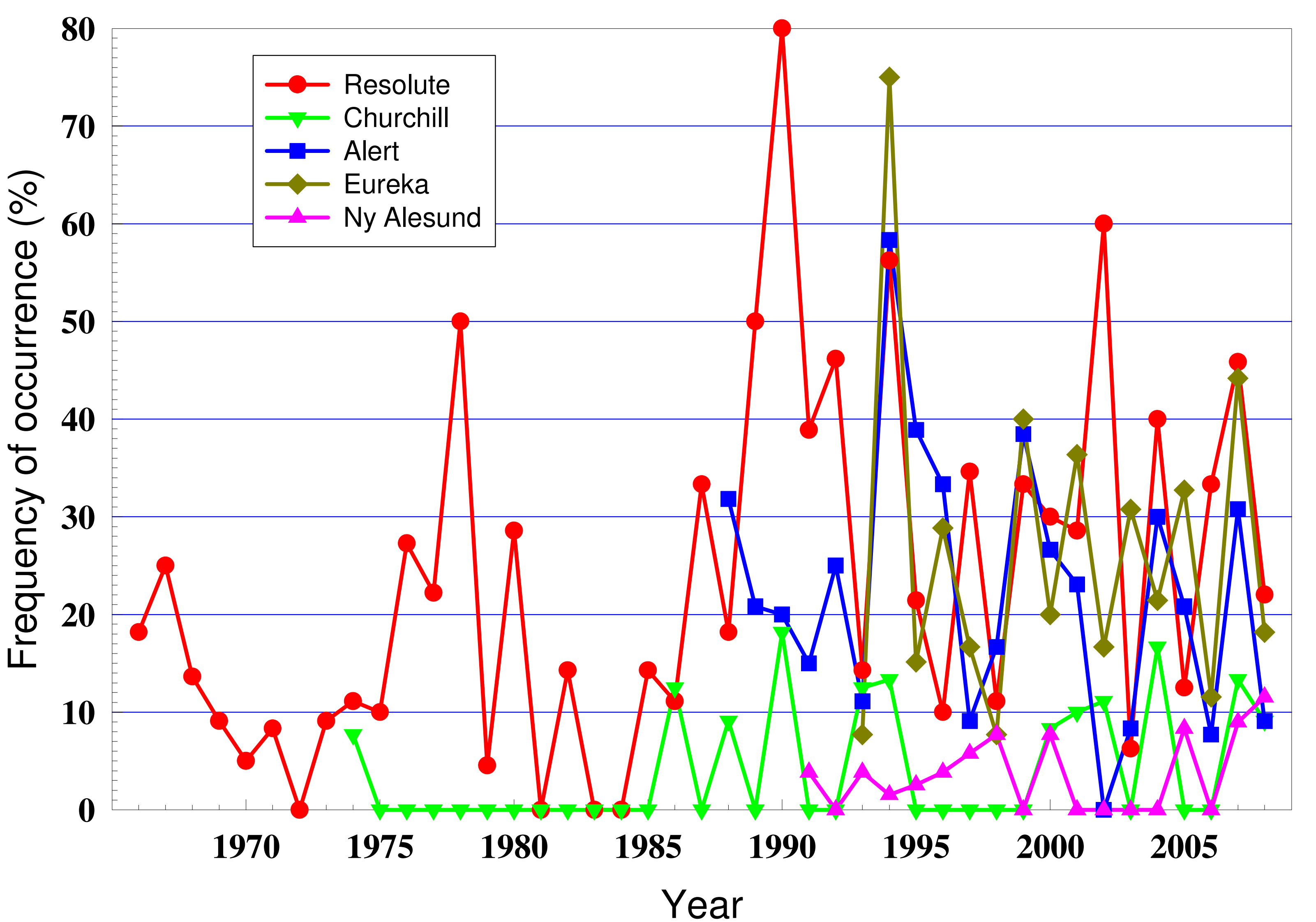
	Northern midlatitudes				Arctic			
	Ground	Gnd-630	630-400	400-250	Ground	Gnd-630	630-400	400-250
250-158 hPa	0.67	0.68	0.70	0.68	0.50	0.64	0.71	0.57
158-100 hPa	0.56	0.61	0.66	0.64	0.34	0.62	0.64	0.44
100- 63 hPa	0.43	0.57	0.70	0.65	0.18	0.51	0.55	0.35
63 - 40 hPa	0.44	0.67	0.75	0.68	0.02	0.23	0.28	0.12

Correlations between annual average ozone mixing ratio anomalies in the troposphere and in the lower stratosphere, for northern midlatitude and Arctic stations, 1980-2006. Statistically significant (95% confidence) correlations are indicated by shading. Stratosphere and troposphere are explicitly separated.



Brewer-Mast data need to be corrected to a total ozone measurement. Average correction factor used in Arctic winter, or if flight fails to reach 17mb. Can we do better?

Trends in frequency of depletions



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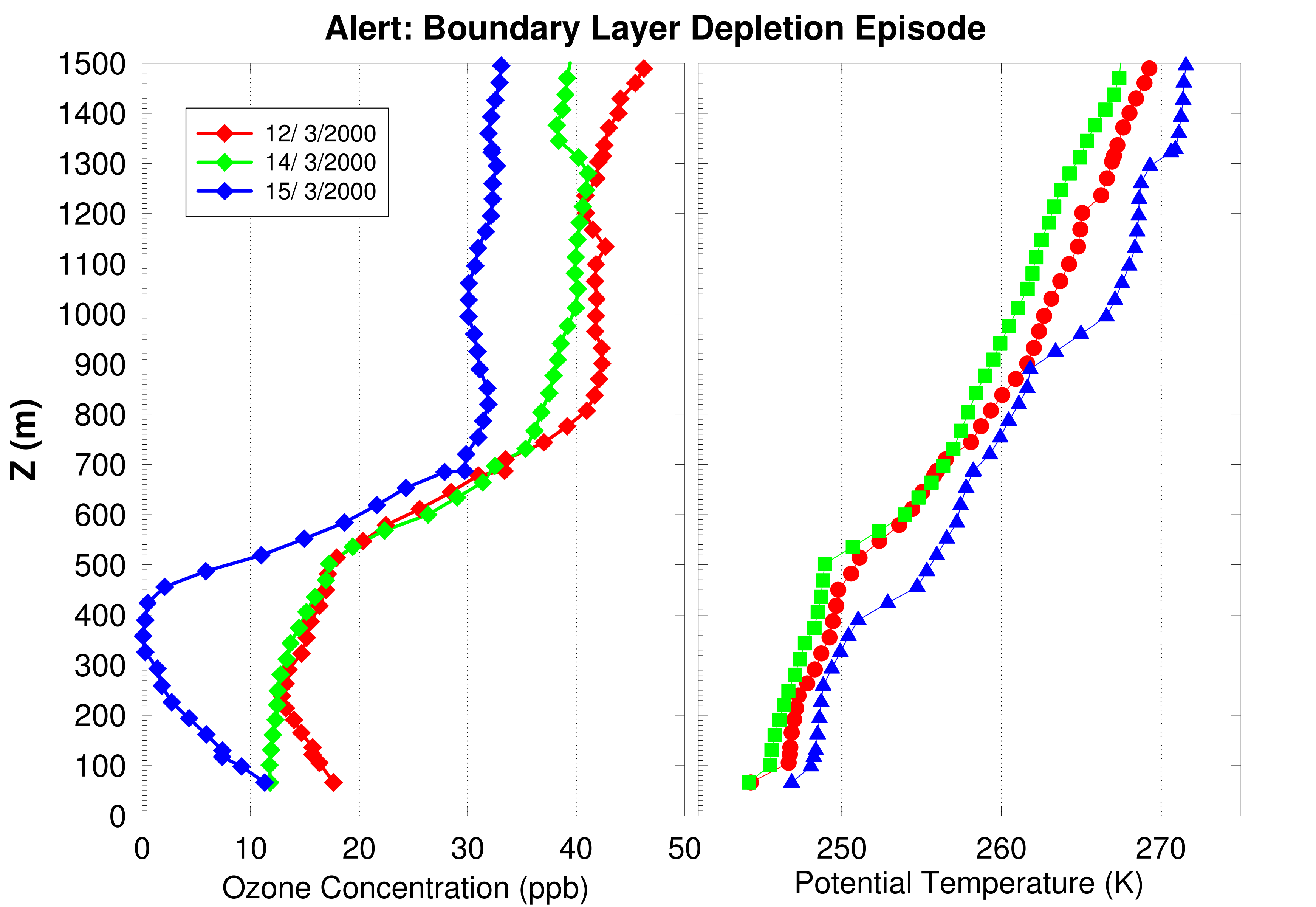
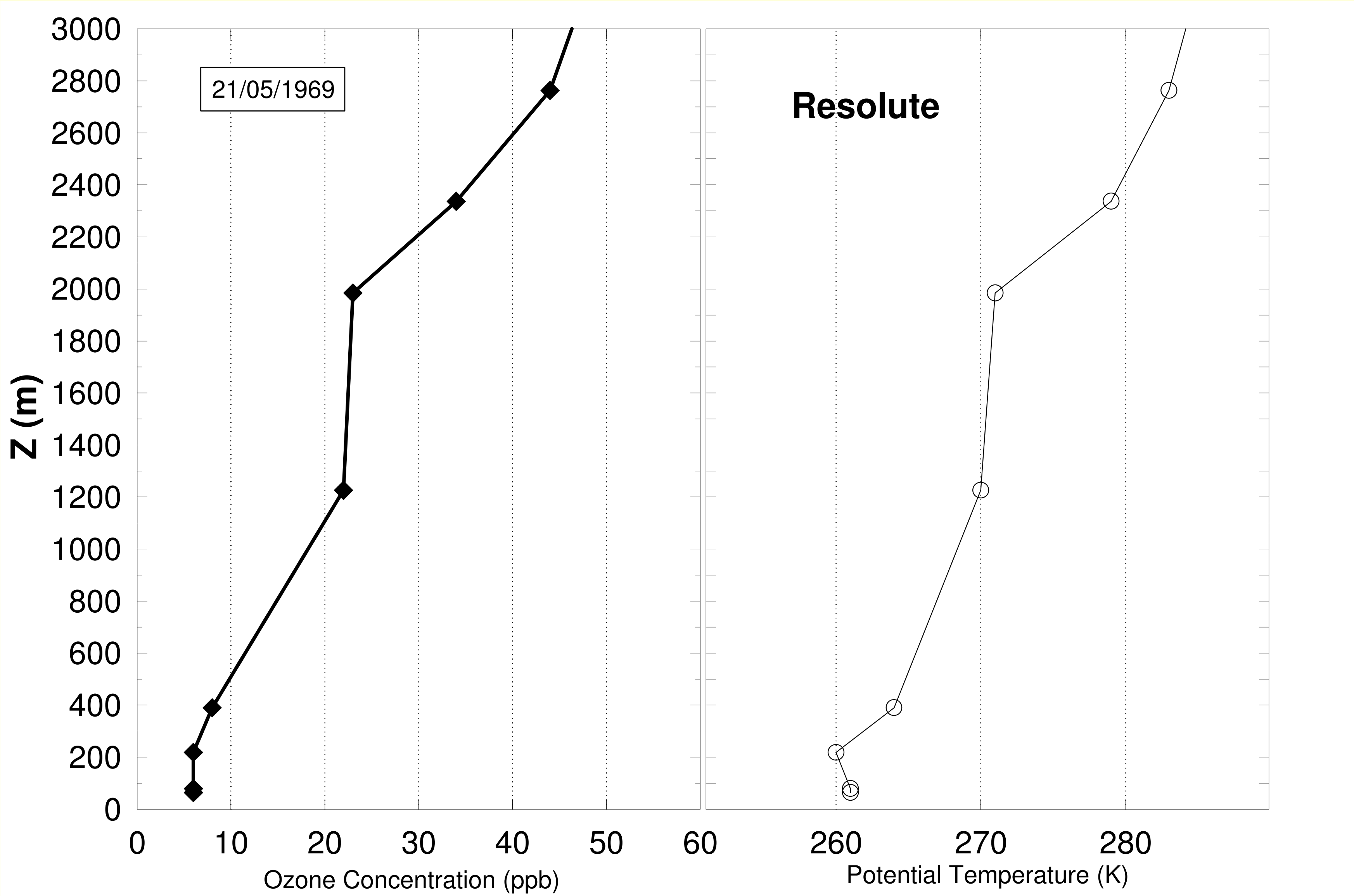
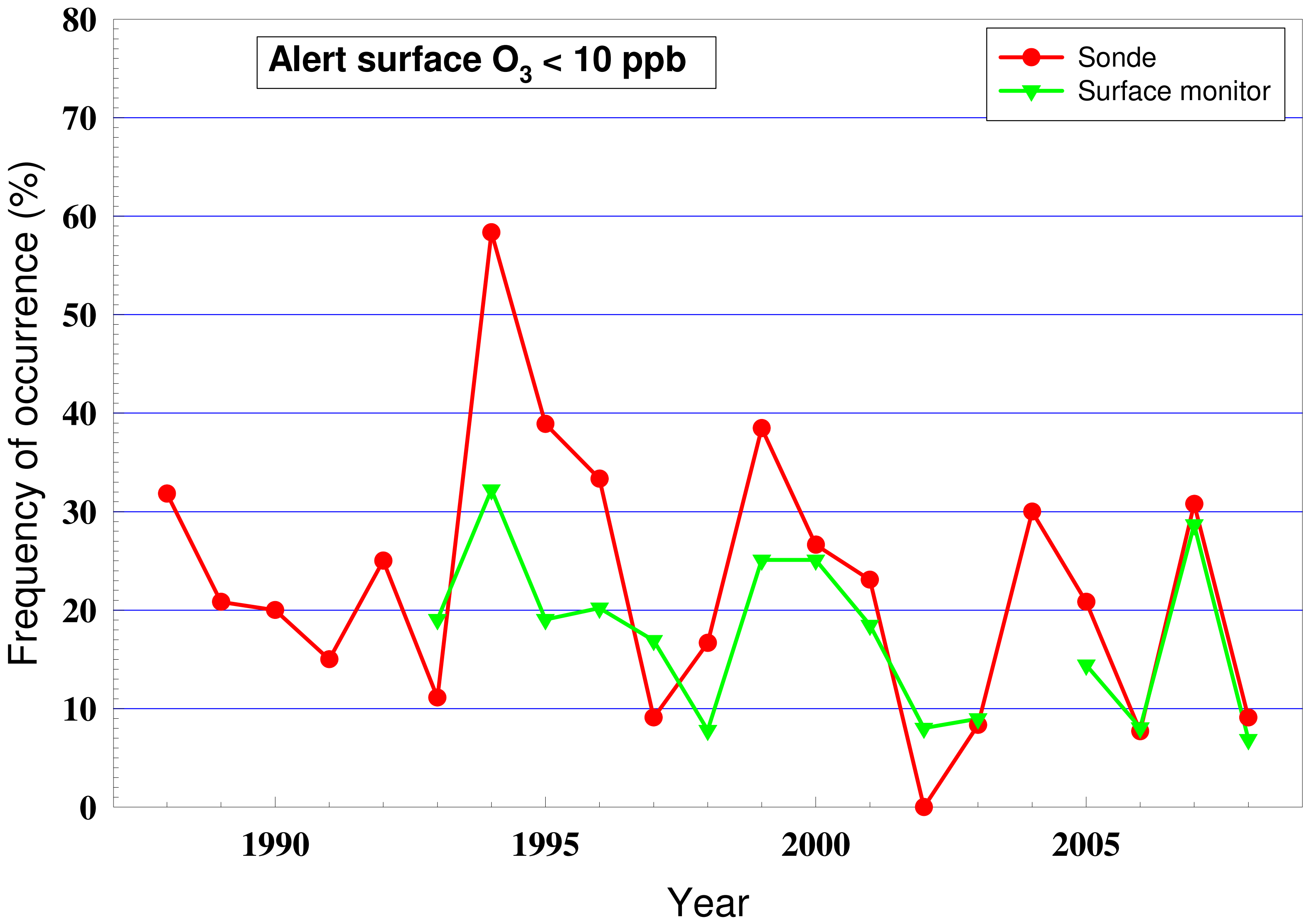


Alert: Boundary Layer Depletion Episode
12/ 3/2000
14/ 3/2000
15/ 3/2000
Z (m)
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
0
10
20
30
40
50
Ozone Concentration (ppb)
250
260
270
Potential Temperature (K)

Depletion Event at Resolute 1969





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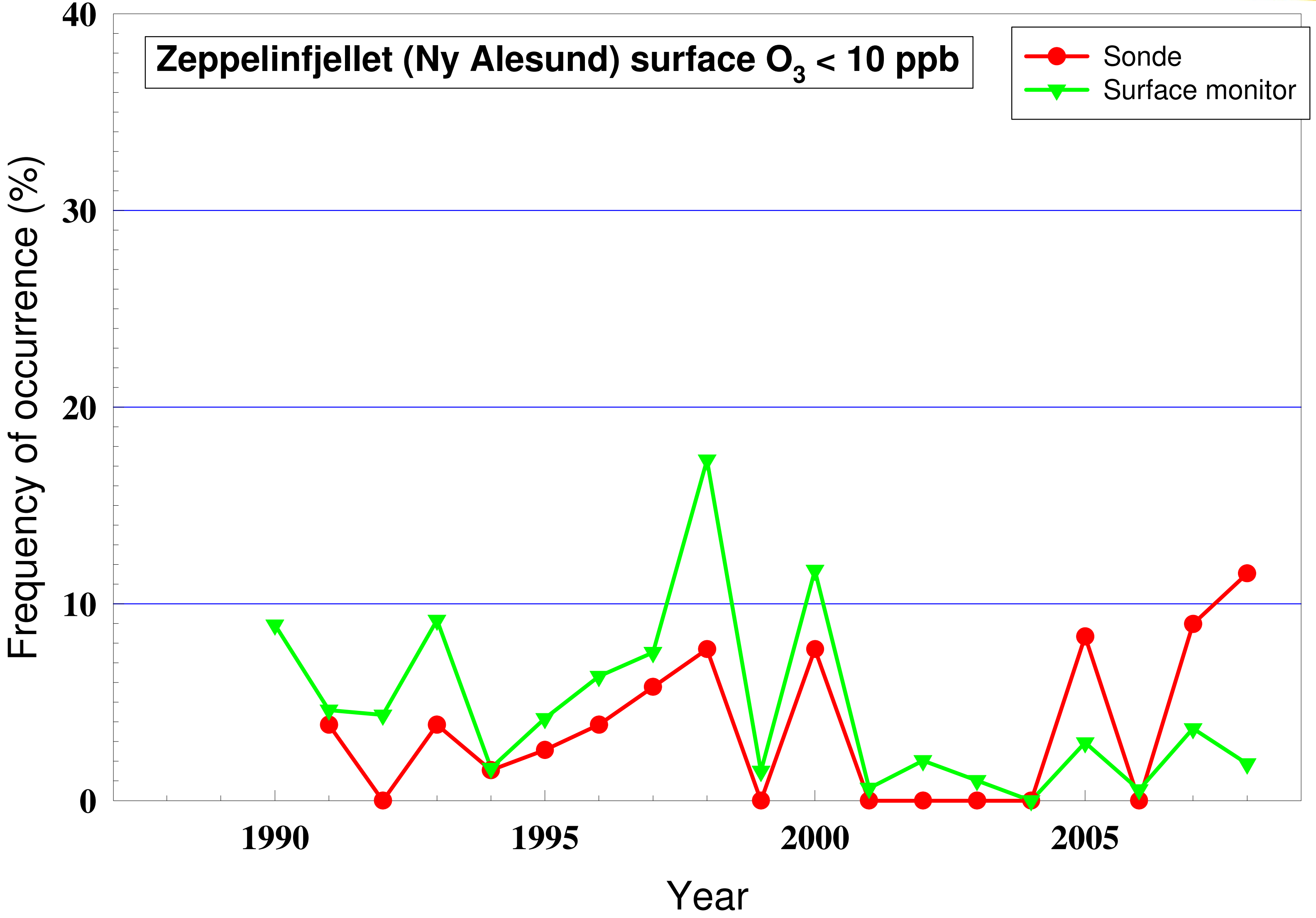
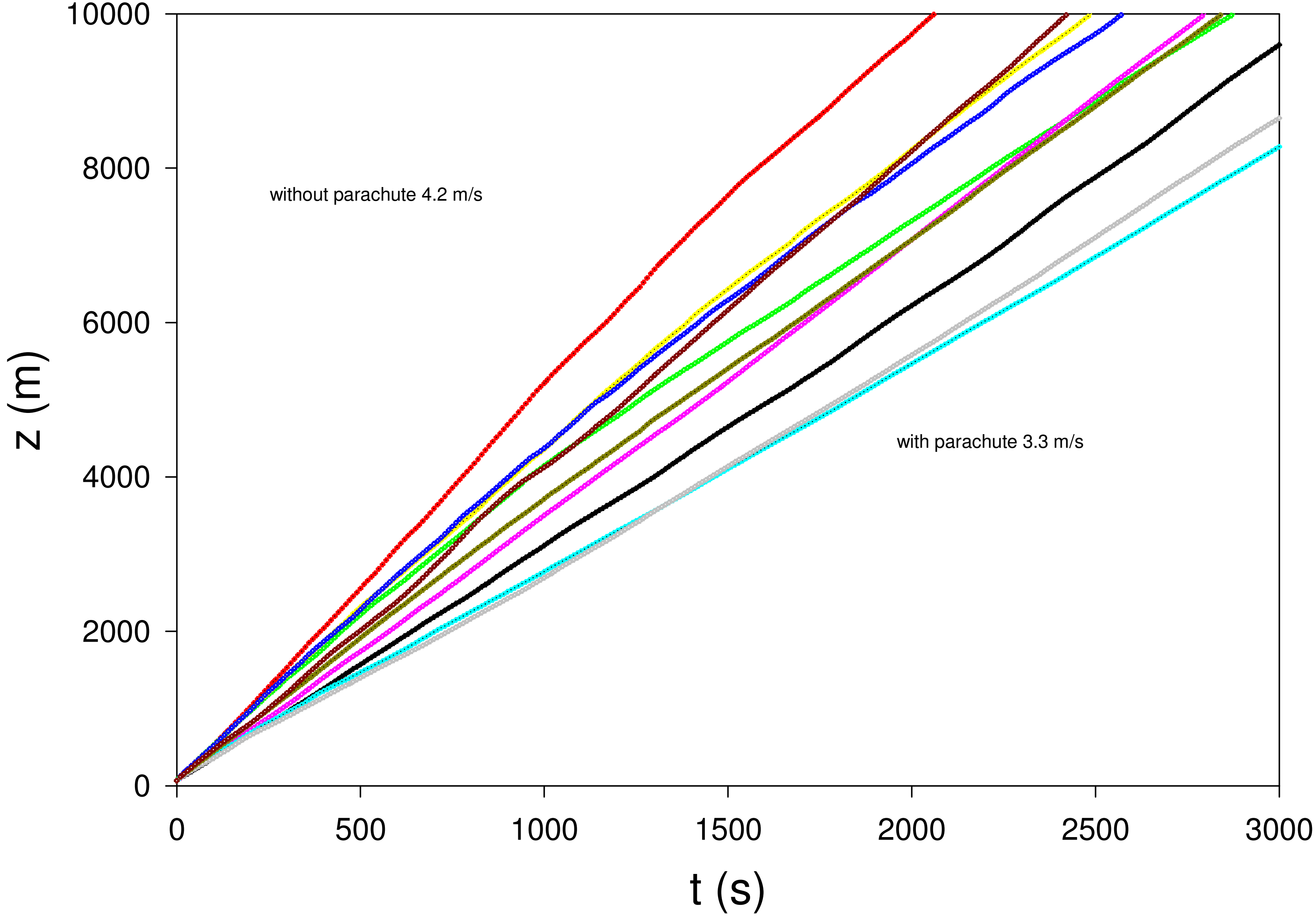
(Note change of vertical scale)



- The frequency of depletion events in the spring of 2008 was relatively low compared to historical norms.
- The long ozonesonde record at Resolute shows depletions since 1966, but with an increase in their frequency over the period 1966-2008 of 5.8 ± 4.3% per decade (95% confidence limits),
- That at Churchill shows much lower frequency overall, but an increase over the period 1974-2008 of 2.0 ± 1.9% per decade.
- Trends at Alert, Eureka & Ny Alesund are non-significant.
- Surface measurements indicate a shift toward increasing frequency earlier in the year.

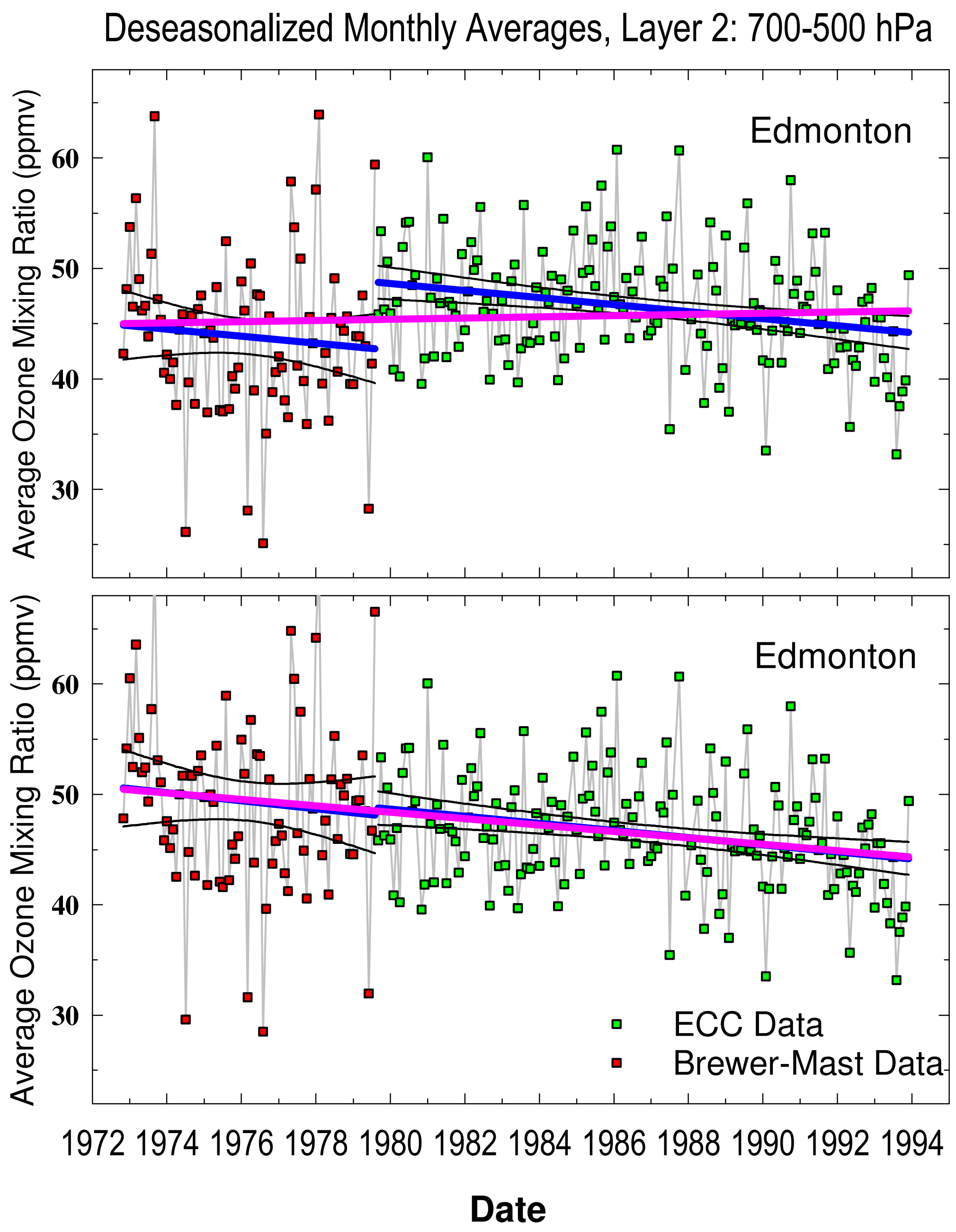
Sonde Ascent Rate



Upper panel: Trends in the middle troposphere at Edmonton from Brewer-Mast and ECC data. The thick purple line is the trend that is calculated by combining the two data sets.

Lower panel: with the corrections implied by the last figure.

(From Tarasick, D.W., J. Davies, K. Anlauf, M. Watt, W. Steinbrecht and H.J. Claude [2002] Laboratory investigations of the response of Brewer-Mast sondes to tropospheric ozone, *J. Geophys. Res.*, **107**(D16), 4308, doi:10.1029/2001JD001167.



Other issues:

- Why are there very large correction factors sometimes, especially in the Brewer-Mast record (as high as 4)? Also low values (as low as 0.6)?
- Do correction factors correlate with the type of total ozone measurement? With pump flow measurements?
- Put “blue book” ancilliary data in WOUDC files.
- Other QC: outliers, spikes …