The role and performance of ground-based networks in tracking the evolution of the ozone layer

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Outline

1. First ozone measurements
2. History Prior to International Geophysical Year (1957)
3. Global Atmospheric Watch network
4. Measurements Post Montreal Protocol
5. Key results of NDACC-network
6. Ozone measurements in Antarctica
7. Conclusions

1. First ozone measurements

Dobson and Harrison, 1926

Table II.—Provisional Ozone Values—continued.

Times of observation are given to the nearest hour.

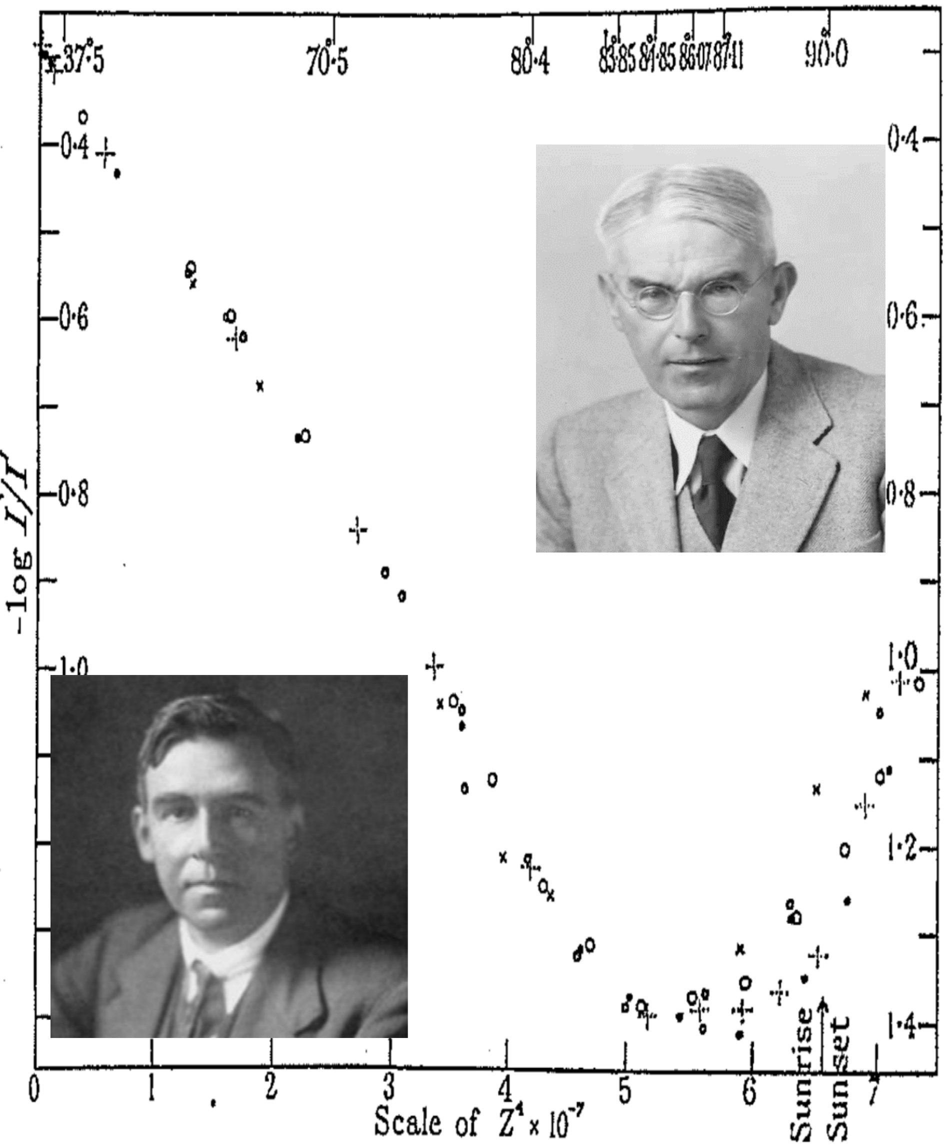
August, 1926.	Oxford.		Lerwick.		Arosa.		Lindenberg.	
	O_3	G.M.T.	O_3	G.M.T.	O_3	G.M.T.	O_3	G.M.T.
1	267	9, 16	253	10, 11, 17	260	7, 8, 14	266	10
2	268	9, 11	—	—	254	8, 9	280?	7, 14
3	286	9, 11	—	—	259	7, 16	277	7, 16
4	268	8, 16	260	15, 17	—	—	269	8, 14
5	282	8	—	—	268	11	—	—
6	282	16	—	—	280	14, 16	286?	8, 15
7	277 287	8, 13 16	279	11, 17	—	—	272	8, 15
8	264 255	8 16	278 291	9 17	—	—	—	—
9	247 267	13 17	—	—	256	7, 16	—	—
10	295	17	—	—	250	7, 15	—	—
11	294 280	9 15, 16	—	—	260	11, 13	—	—
12	251	9, 13, 16	287	13, 16	245	13, 14	288?	9
13	—	—	252	9, 10	243	8, 10	266?	10
14	258	8, 12, 17	—	—	244	8, 11, 15	—	—
15	243	12	255	15	243	8, 11, 13	253	9, 15
16	243	16, 17	245	10	242	8, 11	—	—
17	260	9, 12, 16	—	—	238	7	251	7, 13
18	244 259	8, 14 17	—	—	238	7, 11	263	12

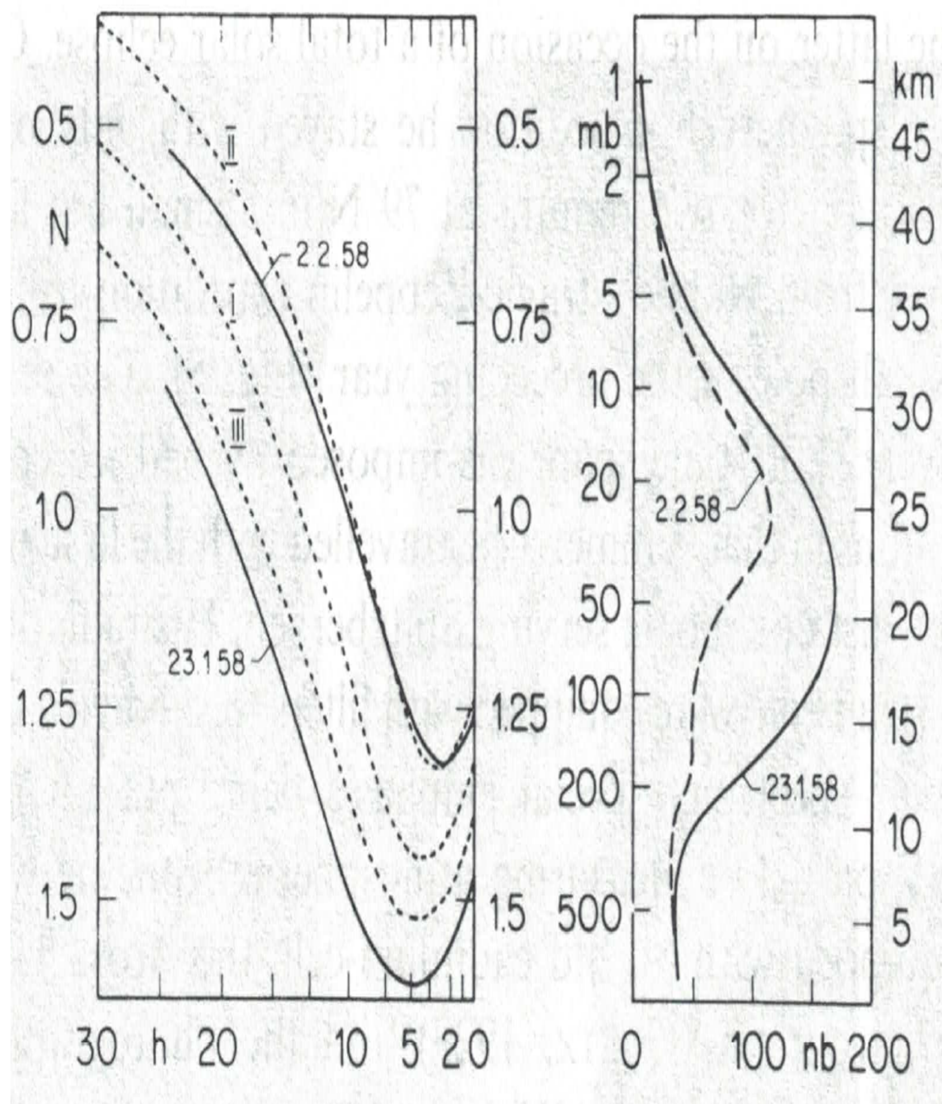
2. History of GAW Prior to IGY
spectrophotometers designed by Dobson (Arosa)

Féry spectrophotometer,
photographic detection
(July 7, 1926 – middle of 1950)
Dobson spectrophotometer,
photoelectric detection (D7)
(July 7, 1939-Aug. 1949)
Dobson spectrophotometer,
photomultiplier (D15)
Aug. 27, 1949-Aug. 3, 1992
D101 (June 1967-pres.); D62
(Aug. 1992-pres.)

IGY (1957): **Methodology**
Dobson instruments (2 wavelength pair observation)
Archive: Data sent to secretary of IO3C

Ozone profile information Umkehr or «Götz» effect (Götz et al., 1934): discovered in Spitsbergen, 1929, measurements 1931/32 in collaboration with Dobson





3. GAW network: anthropogenic ozone depletion

– ***Chlorofluorocarbons:*** 1974: **ClO_x**: Molina and Rowland (CFCs); Stolarski and Cicerone

long debate: **DuPont**, advertisement in New York Times, 1975: **"Should reputable evidence show that some fluorocarbons cause health hazard through depletion of the ozone layer, we are prepared to stop production of the offending compounds"**

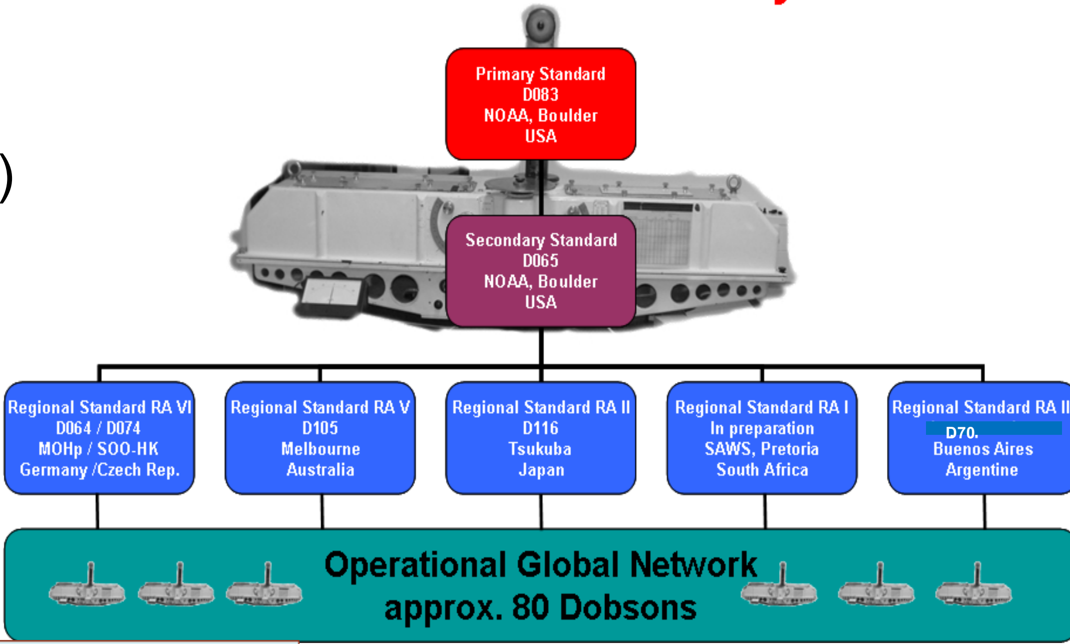
In 1978**, Sweden and the USA banned the use of CFCs in aerosol spray cans**

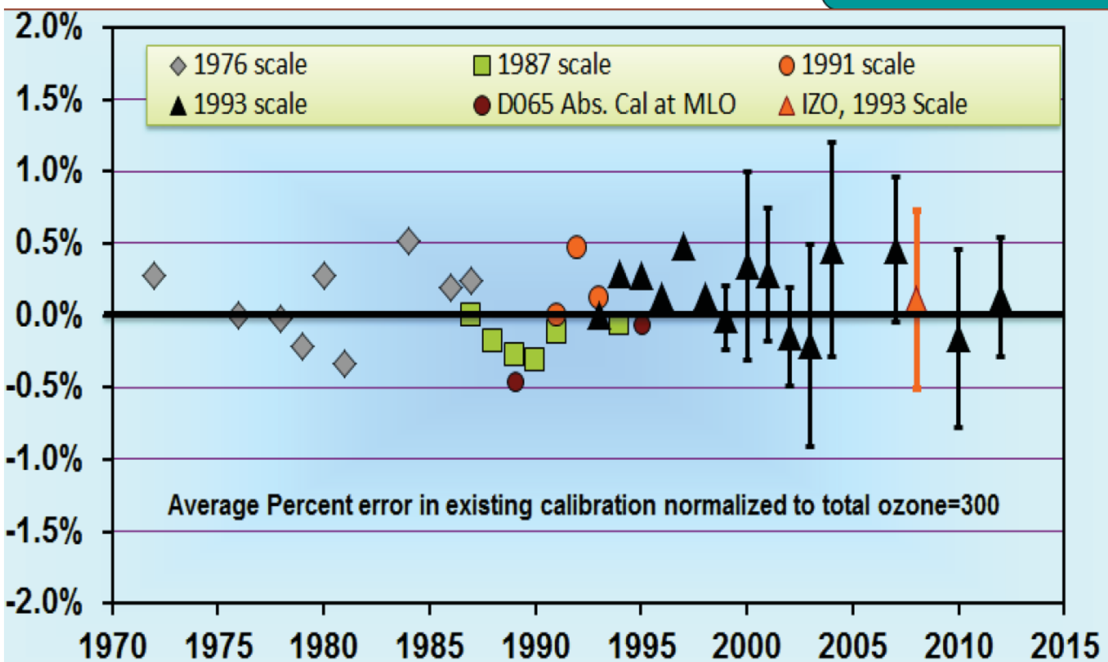
Monitoring under WMO (Global Ozone Observing system (GO3S), Global Atmosphere Watch (GAW)

World primary
Dobson instrument
(Dobson # 83, NOAA, Boulder)

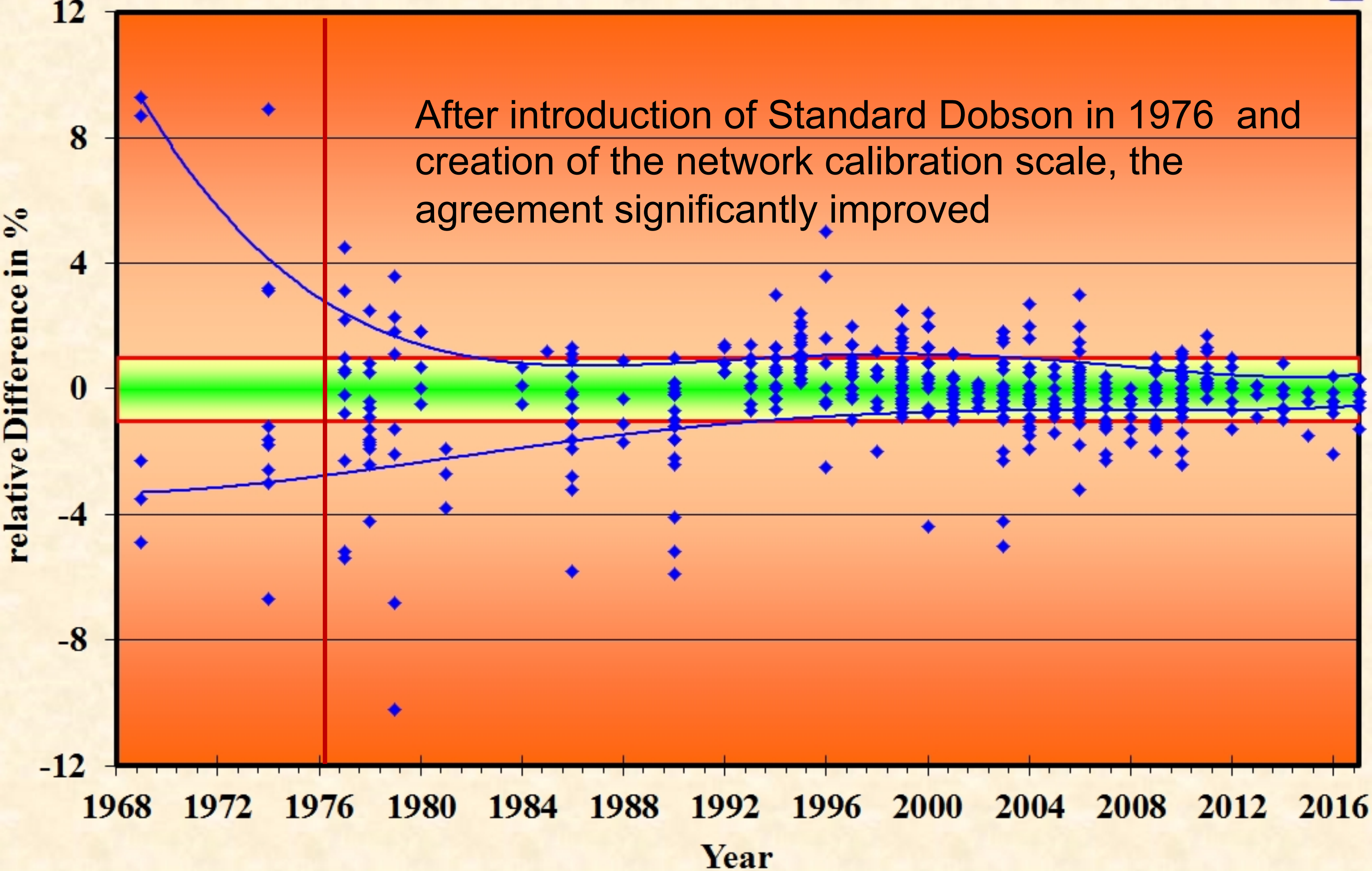
Walter Komhyr
Ruman Bojkov
GAW O3 SAG
Many Dobson
observers

Global Dobson Calibration System



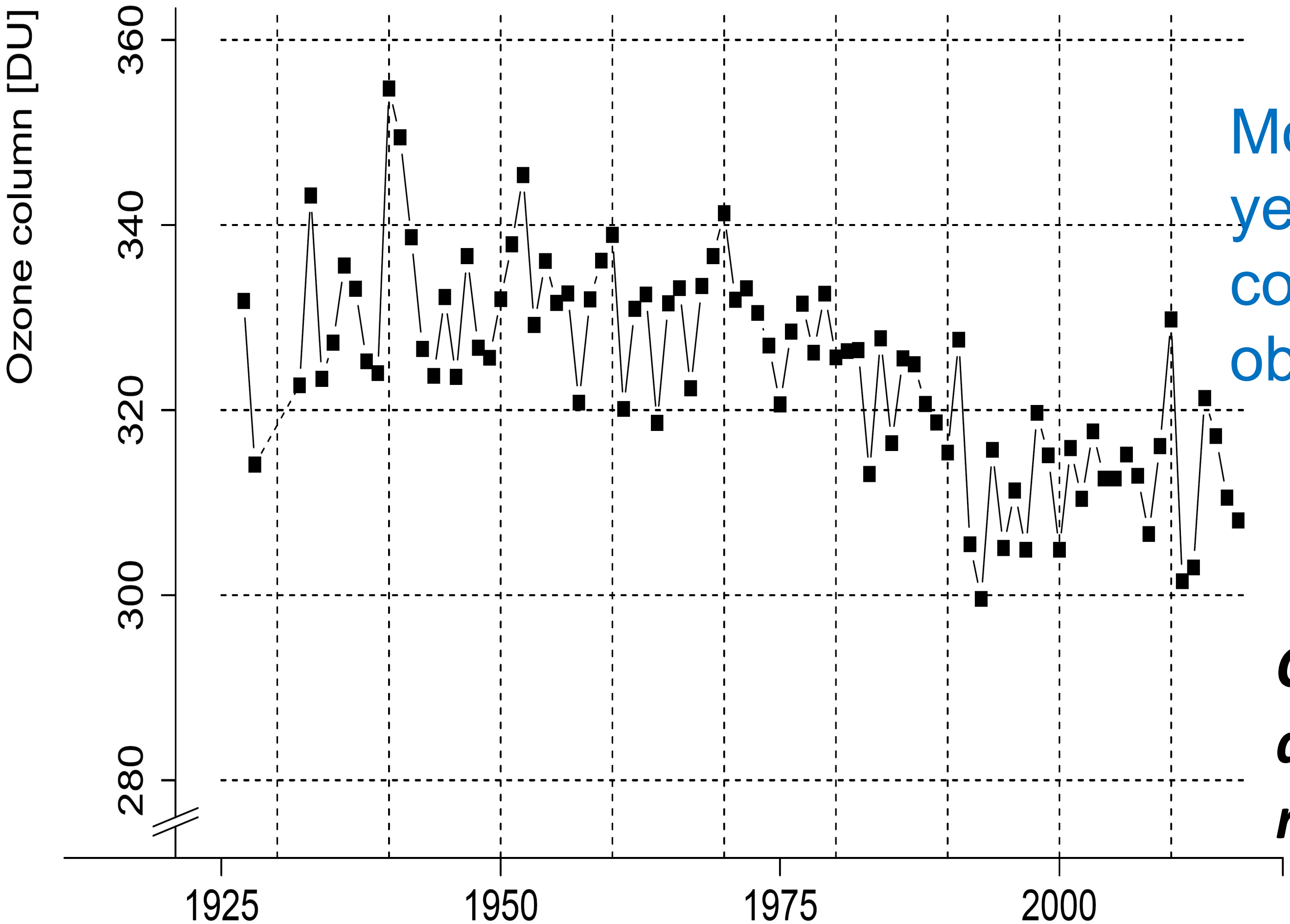


Initial Cal.-Diff. of field Dobsons (479) to Ref. Dobson in %



Longest worldwide total ozone record

Arosa (Switzerland)



More than 80 years of continuous ozone observations!

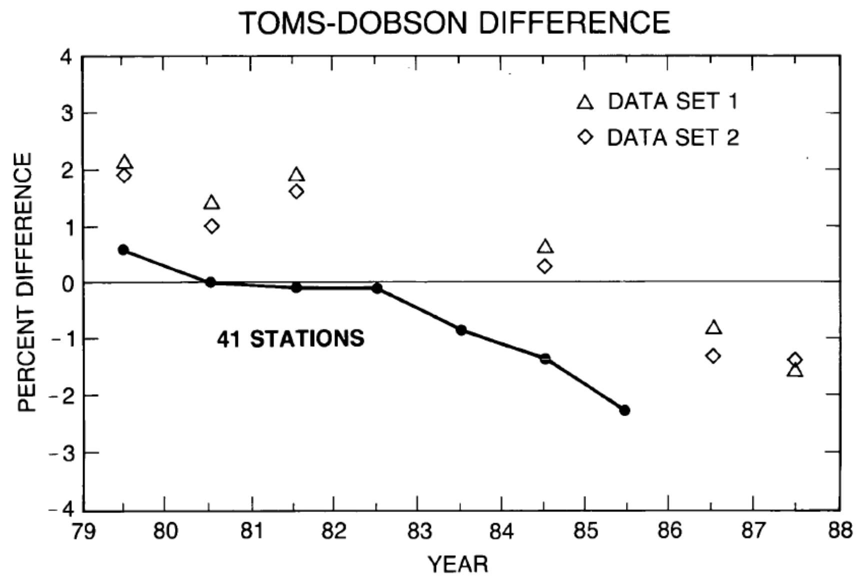
Contributes to GAW and NDACC networks

Report of the International Ozone Trends Panel (IOTP) 1988.

First analyses of total ozone trends from TOMS observations indicated a large ozone decrease since 1979

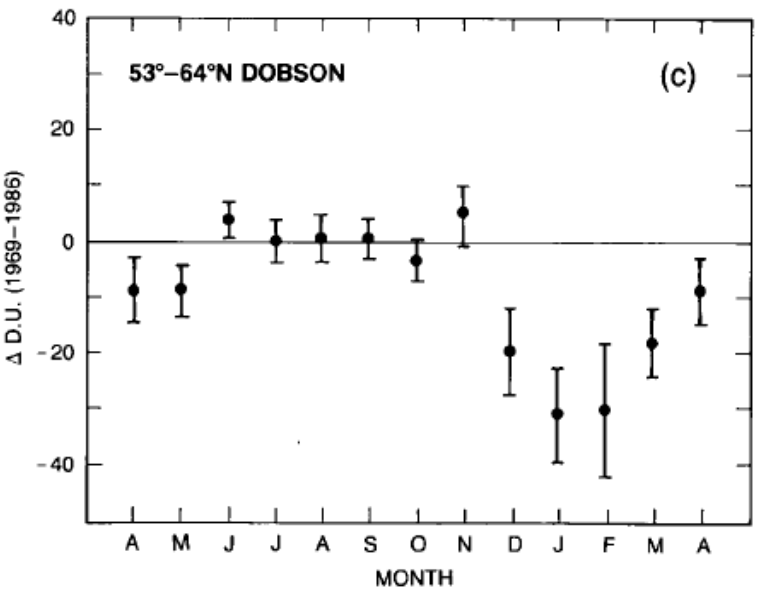
IOTP: check the various total ozone records (ground-based and satellite):

1. Calibration problems found in some individual station total ozone records.



2. Detection of a drift of TOMS observation record with respect to the whole Dobson network, attributed to the degradation of the diffuser plate

IOTP: First trend analysis of satellite and ground-based total ozone records



Trend model

$$oz(i,j) = S(i,j) + X(i,j) + T(i,j) + N(i,j).$$

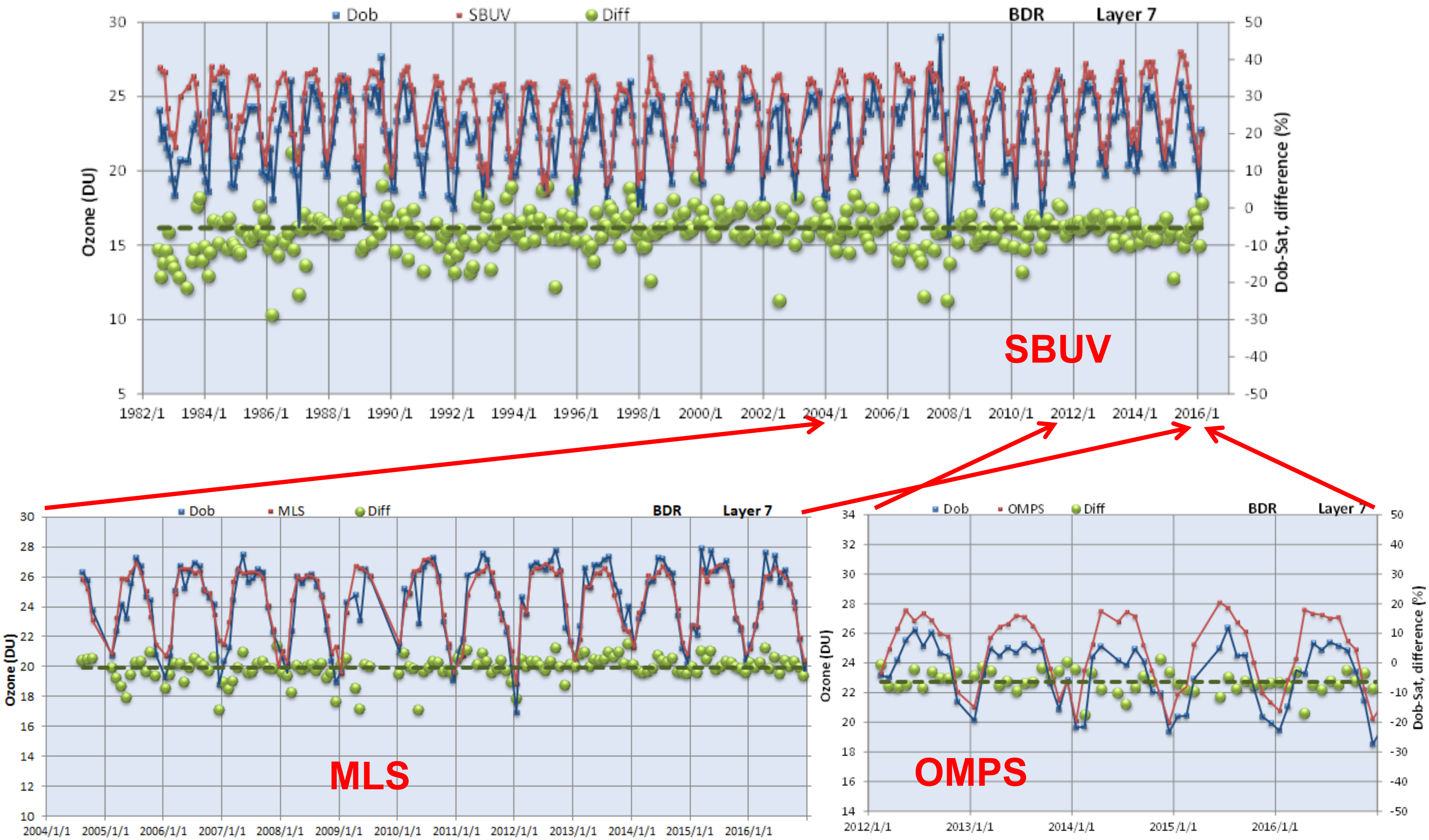
seasonal interannual trend residual

First evidence of ozone depletion in winter in the Northern Hemisphere:

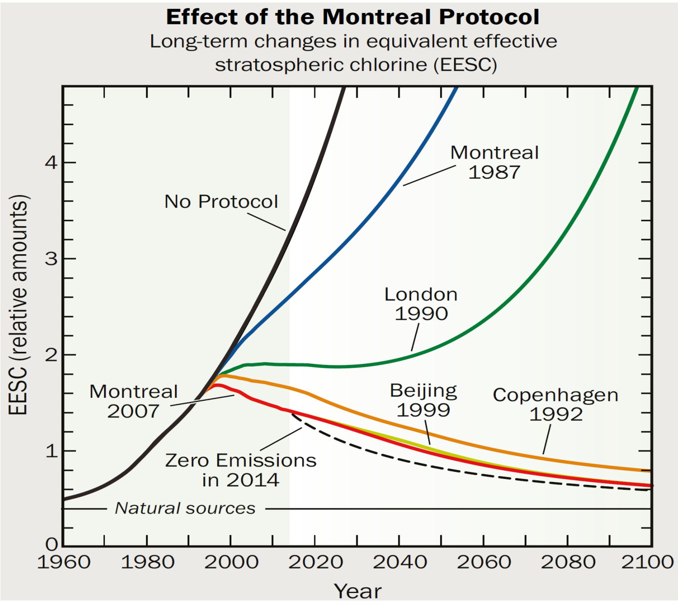
- Statistically significant losses have occurred in the late winter and early spring in the Northern Hemisphere. For example, in the latitude band from 53–64°N, a loss of 6.2 percent is measured for December, January, February, and March from 1969–1986 when the data from 1965–1986 are considered.

N. Harris PhD Thesis, 1989 (results published in IOTP, 1988)

Long-term Umkehr measurements



4. Post Montreal Protocol measurements



Science driven protocol:

Regular (4 year) reports on the state of the ozone layer and substitutes production

Set up of long term measurement networks for the surveillance of the ozone layer:

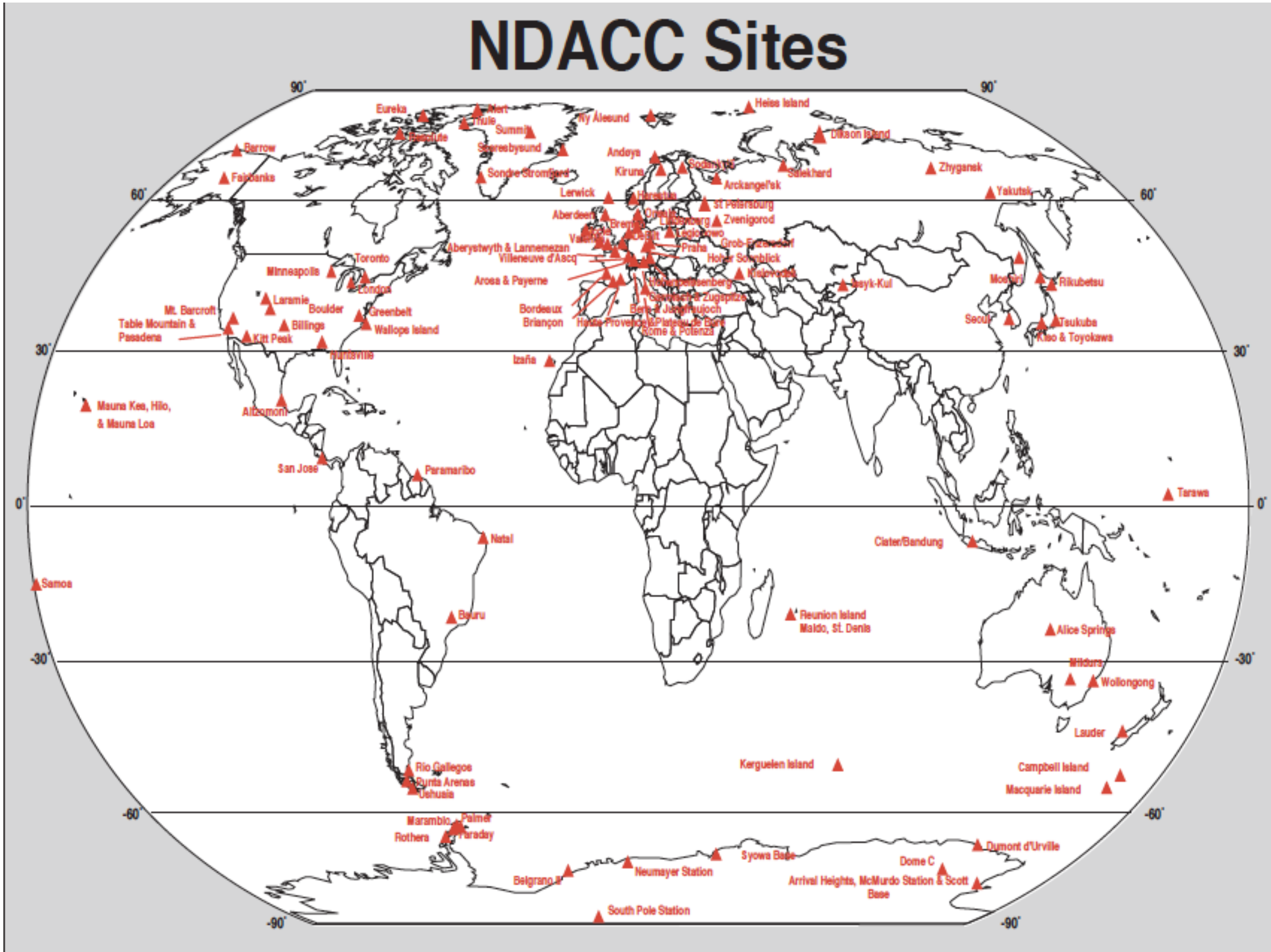
- **Network for the Detection of Stratospheric Changes**

Kurylo, Proc. SPIE 1491, Remote Sensing of Atmospheric Chemistry, 1991

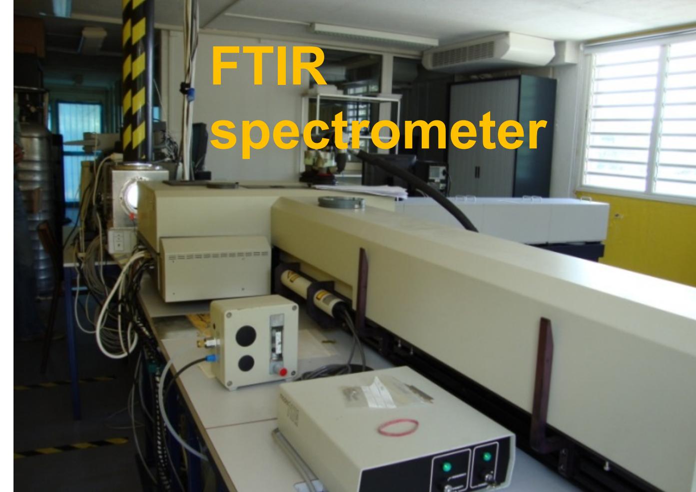
In 2005, NDSC changed its name to NDACC (Network for Detection of Atmospheric Composition Changes) reflecting is extended scope

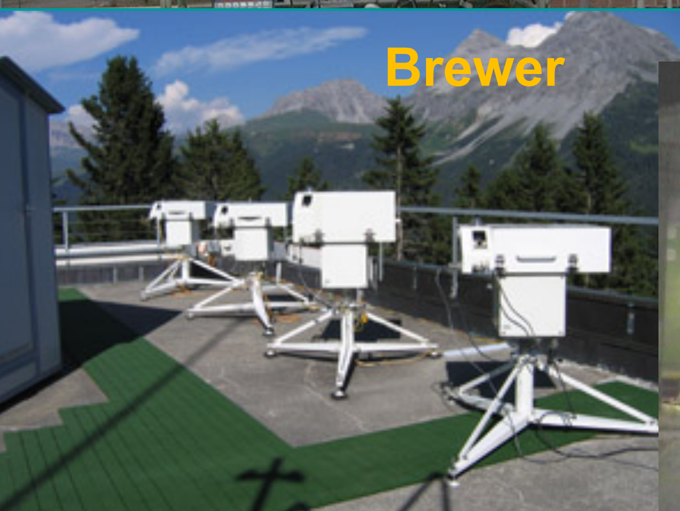
- **Consolidation of the WMO GAW GO3S**

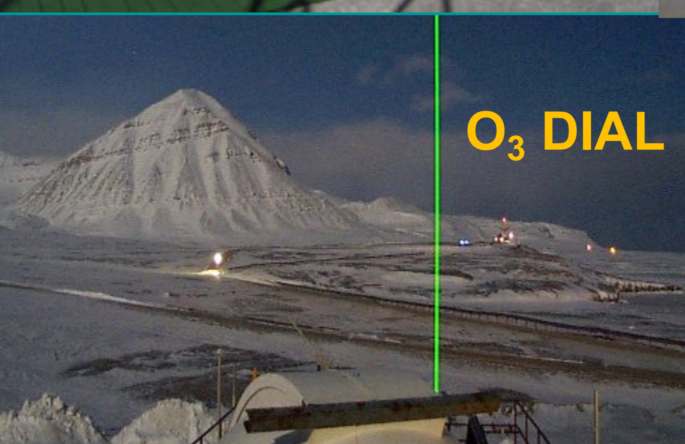
5. NDACC network since 1991



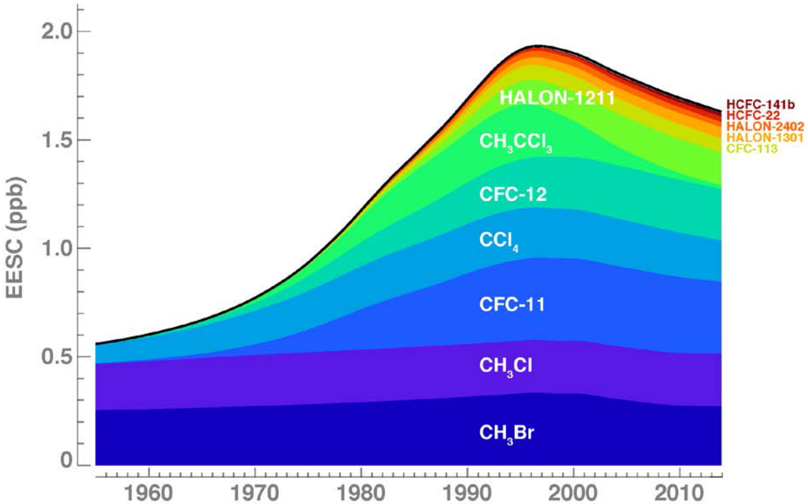
NDACC Instruments (O3)





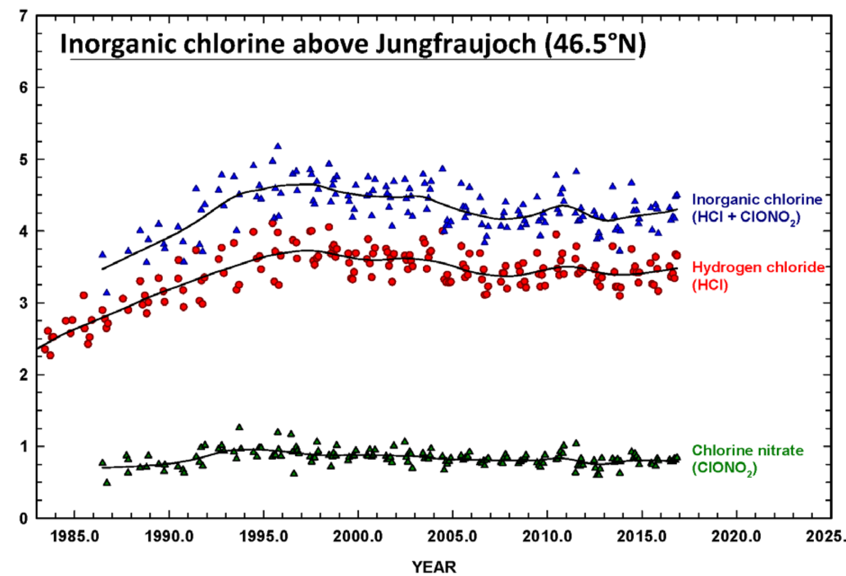


Ozone Depleting Substances tracking implementation of Montreal protocol

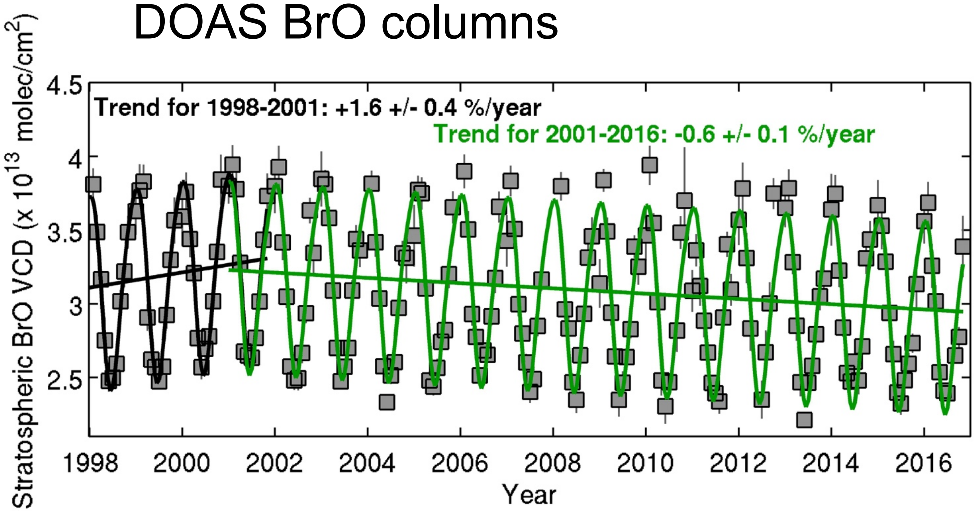


NDACC and cooperating NOAA and AGAGE networks

FTIR Inorganic Chlorine columns

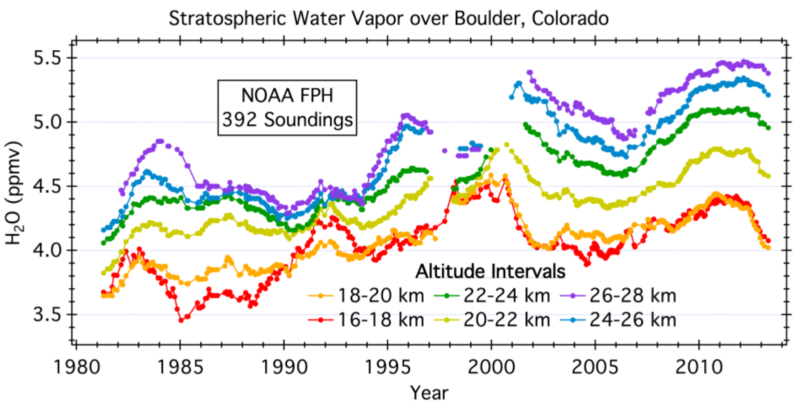


DOAS BrO columns

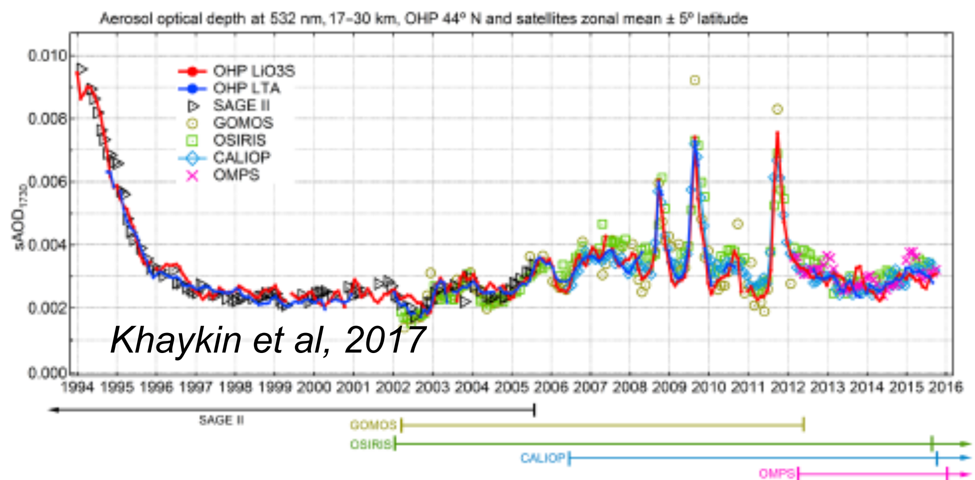


Tracking changes in ozone-related species

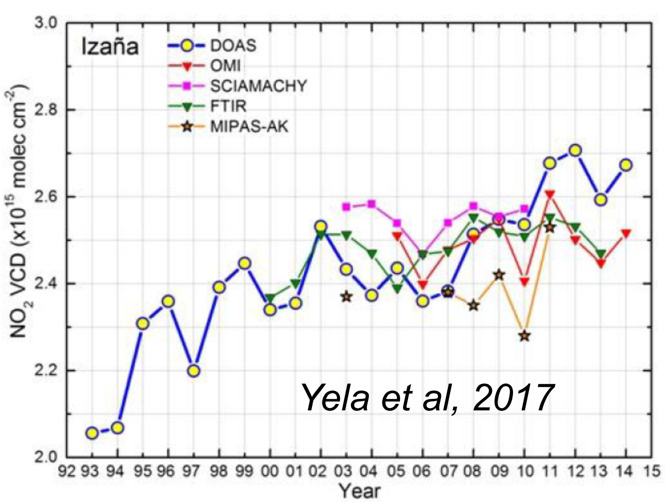
Water vapour: Balloon-borne NOAA Frost Point Hygrometer, Boulder, Colorado



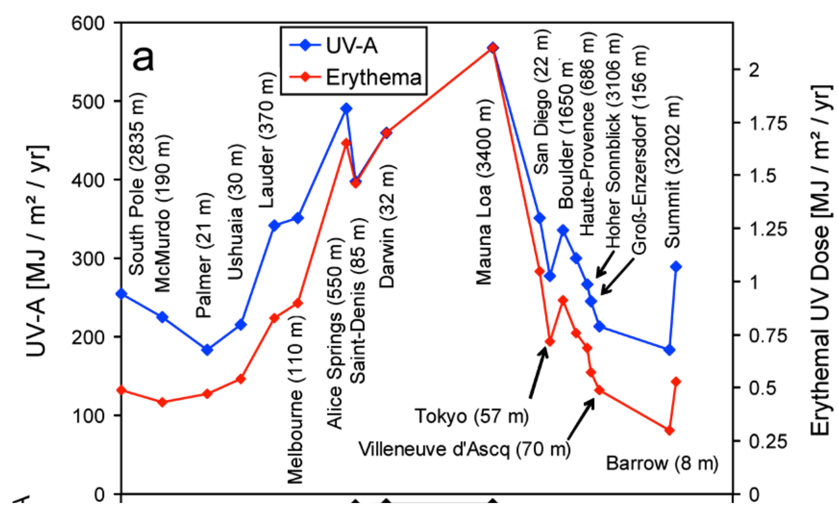
Background stratospheric aerosols Lidar measurements OHP, France



NO2 total column increase Izaña, Spain; DOAS measurements



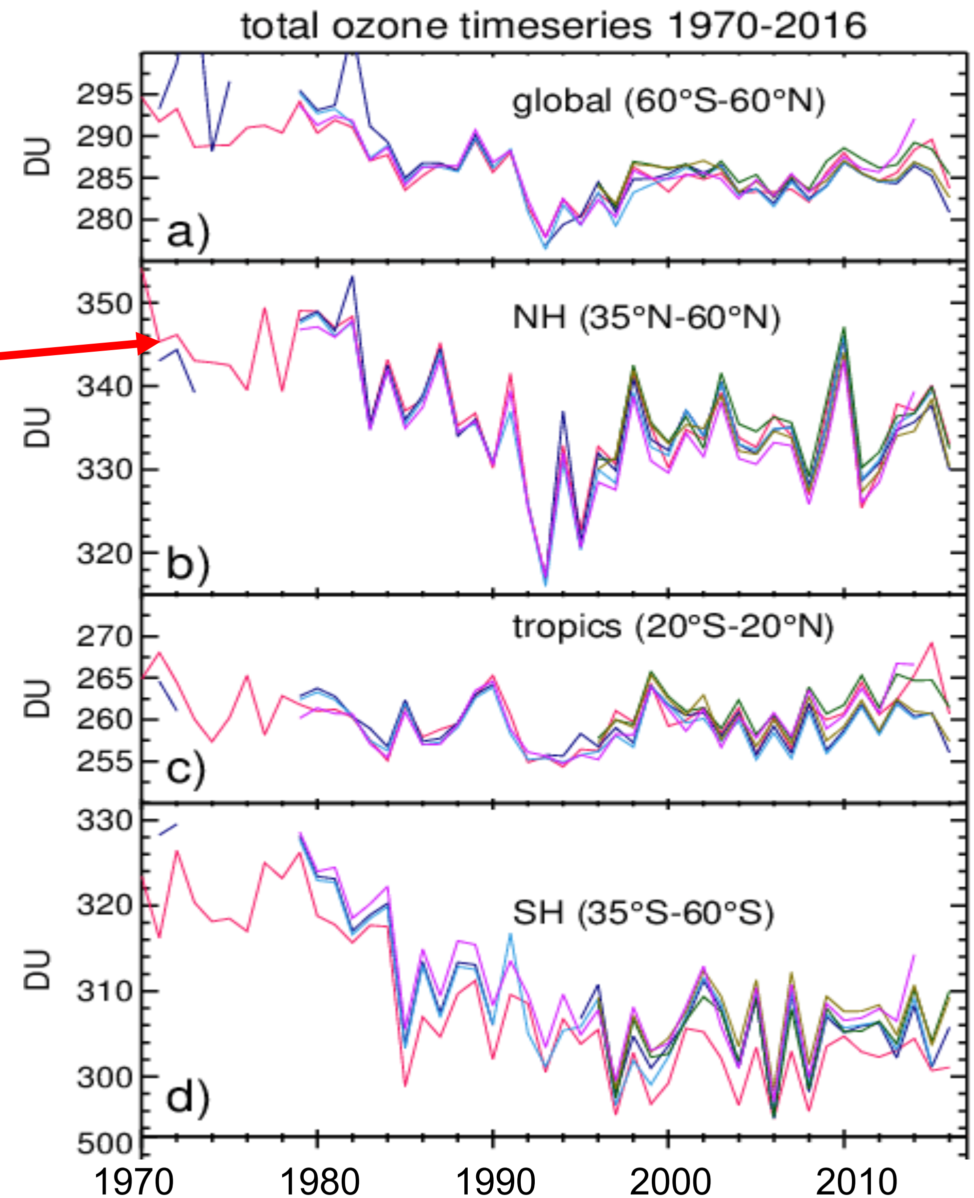
Spectral UV measurements



Tracking total ozone changes

WOUDC
Ground-based
Total ozone data

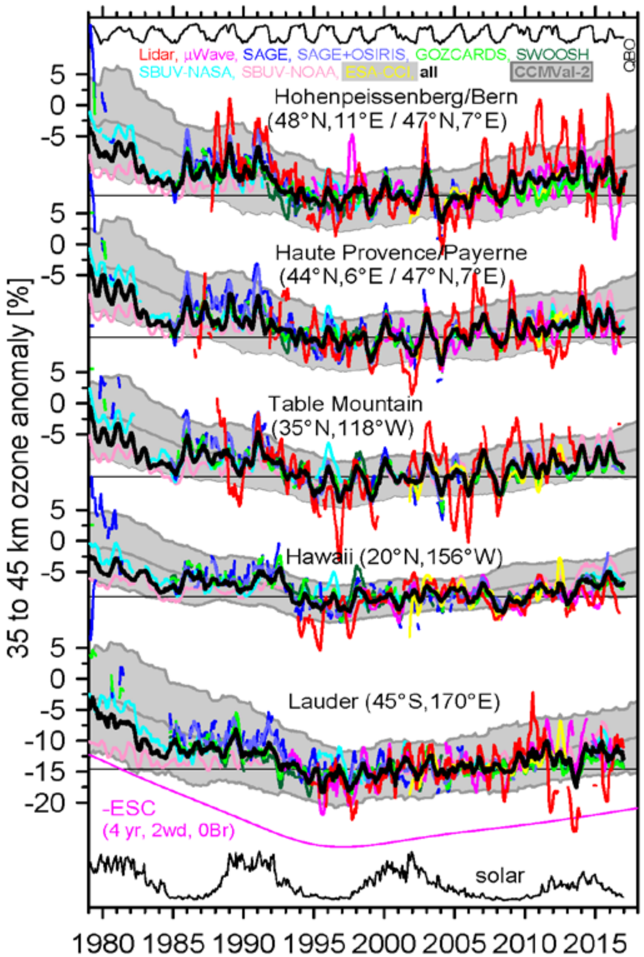
Fioletov et al. 2002



From Weber, BAMS, 2016

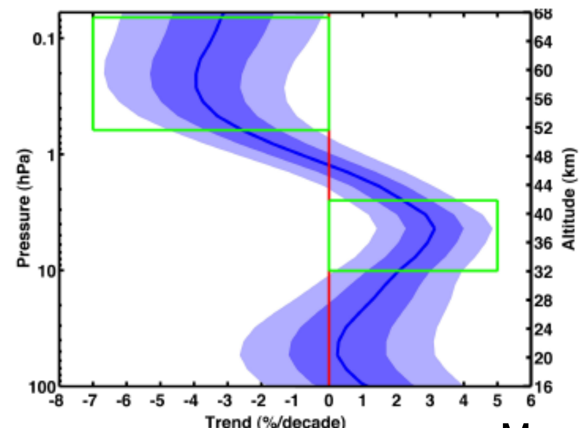
Tracking ozone profile changes

Lidar long-term ozone records
2 hPa (42 km)



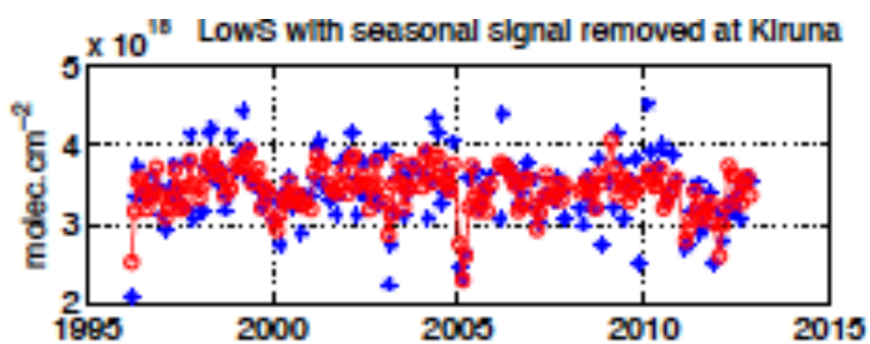
Steinbrecht et al, 2017

Microwave measurements in Bern
1997 - 2015



Moreira, 2016

FTIR Partial ozone column (low stratosphere)

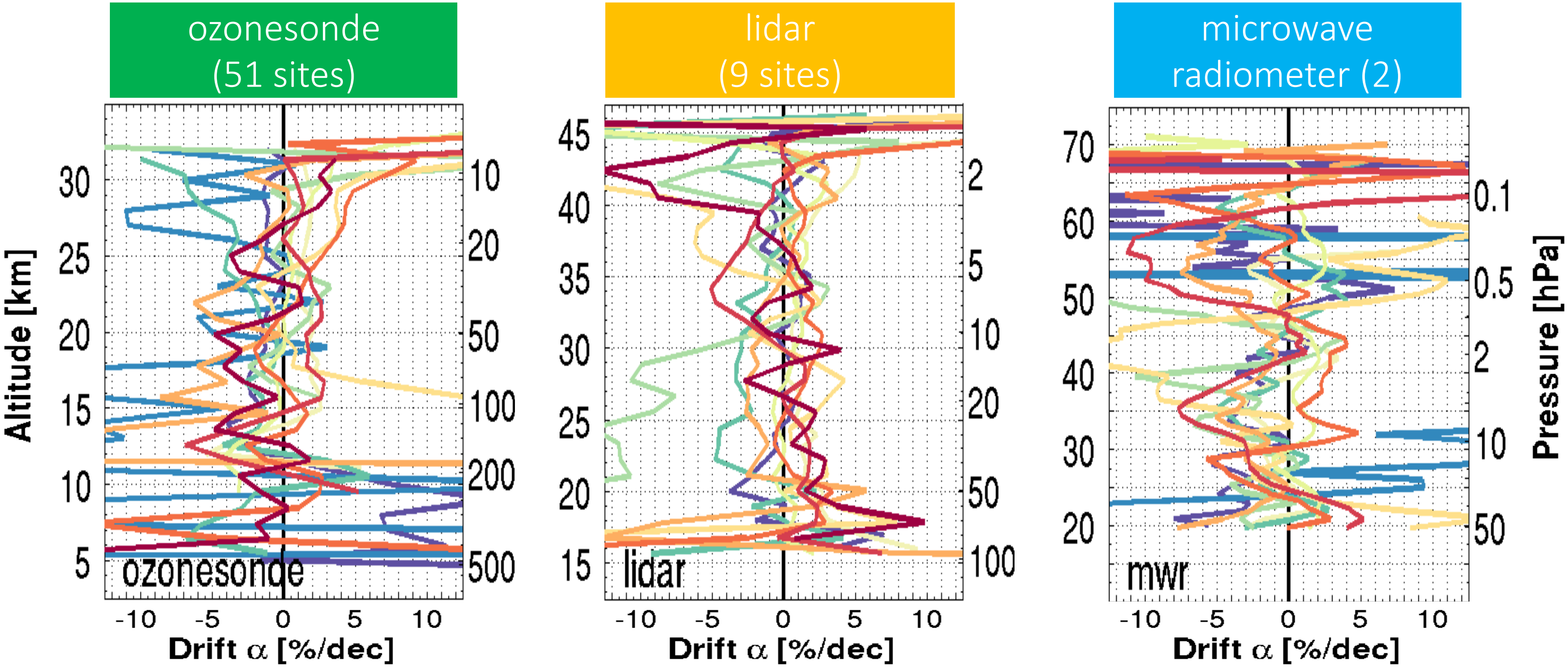


8 FTIR stations

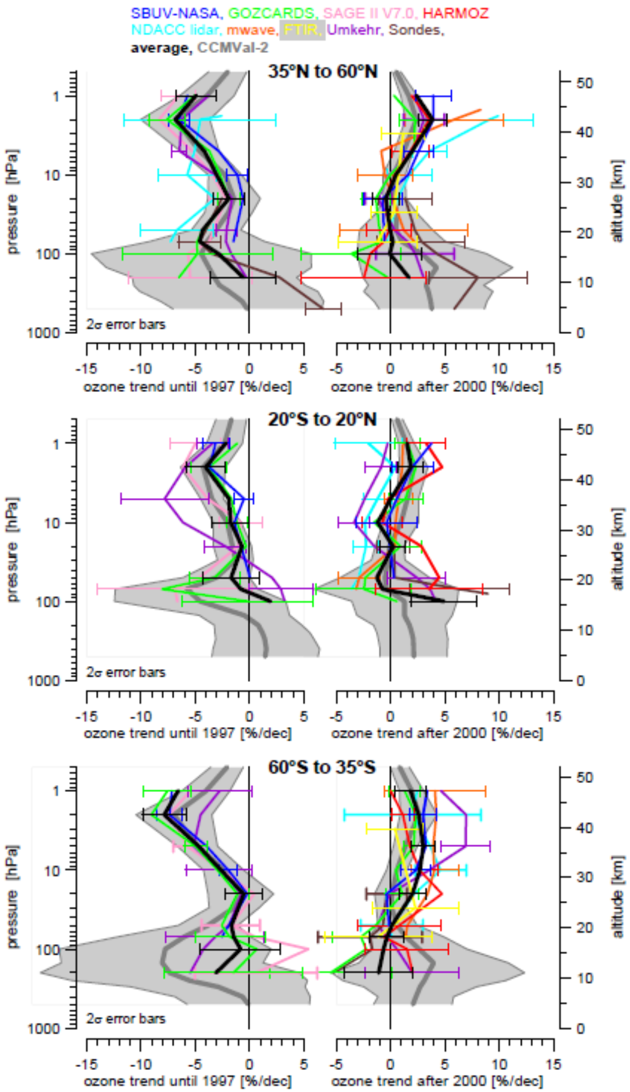
Vigouroux, 2015

Evaluating satellite stability

Limb sounders – SAGE II, SAGE III, HALOE, UARS MLS, Aura MLS, OSIRIS, SMR, GOMOS, MIPAS, SCIAMACHY, ACE-FTS

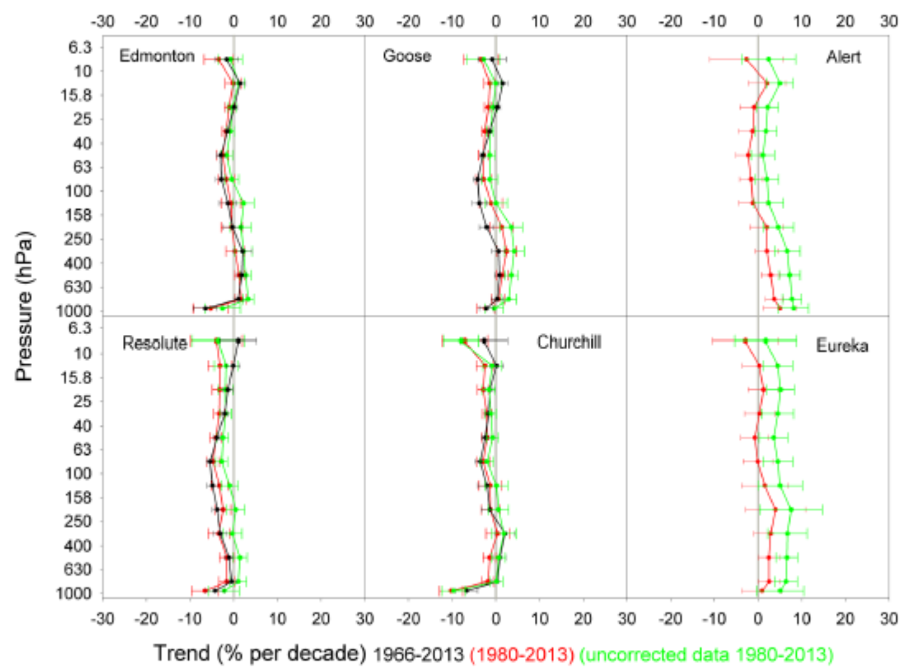


Ozone profile trends
Looking for ozone recovery

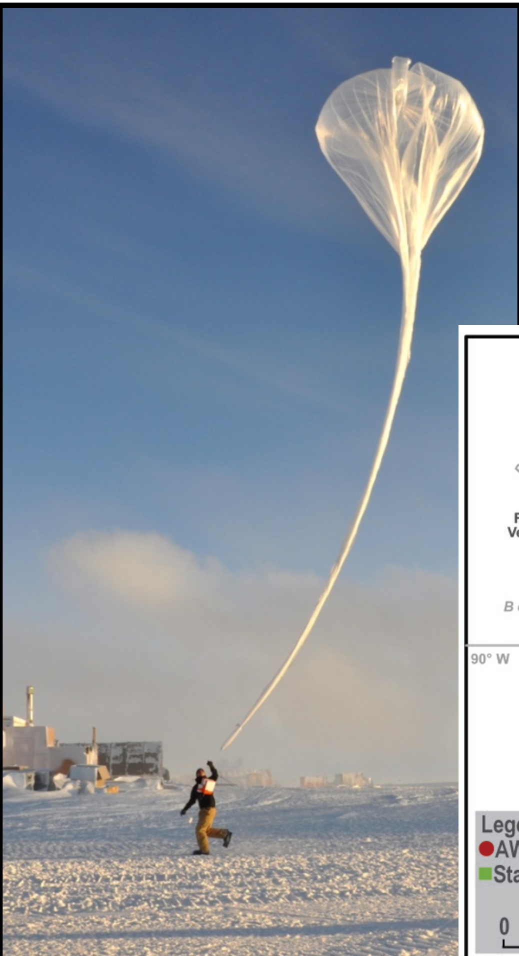


WMO 2014 ozone assessment

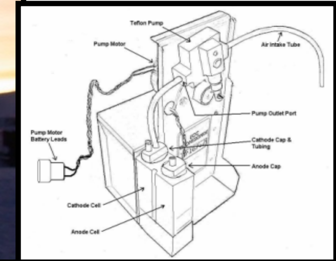
Homogenization of ozone sondes changes in ozone trends

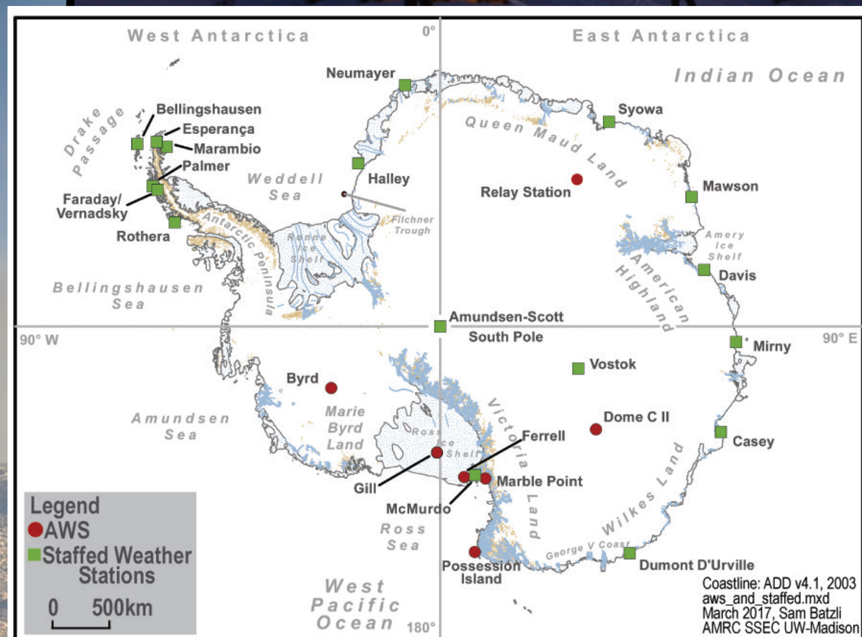


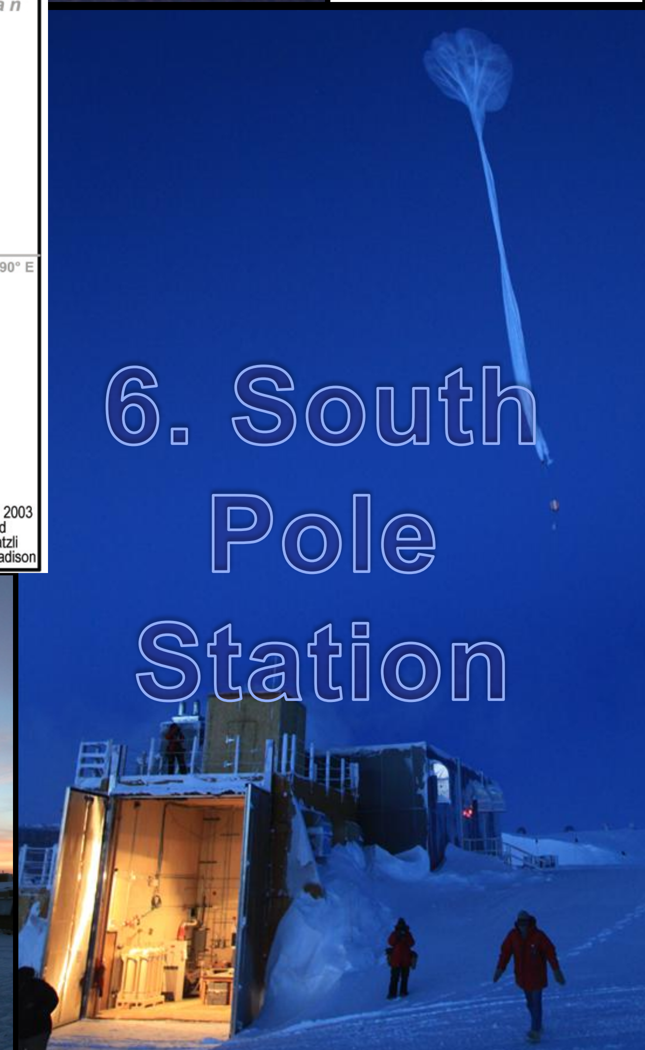
6. South Pole Station



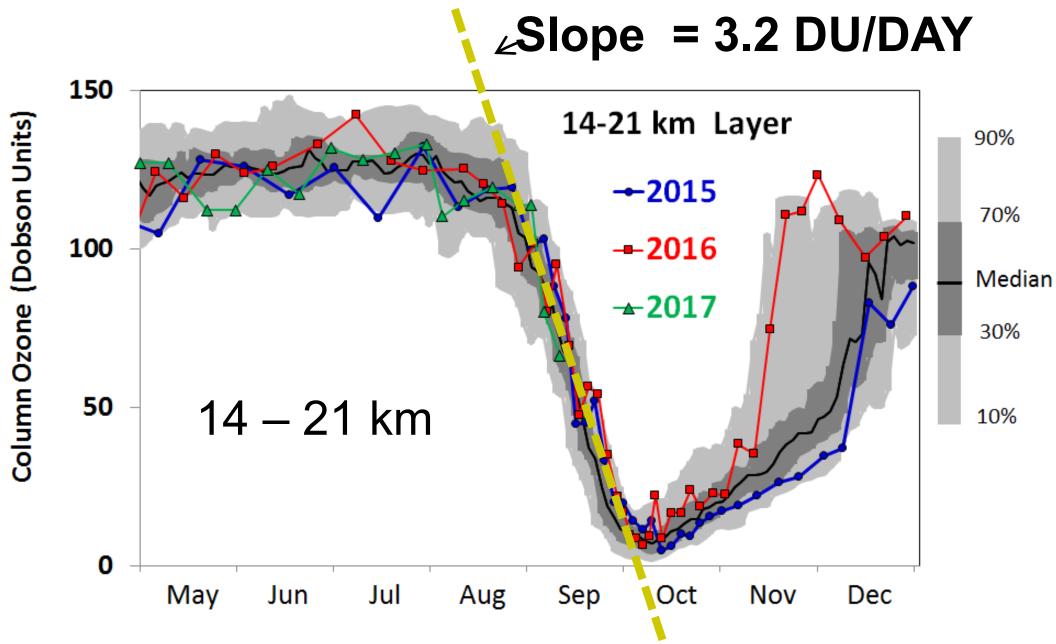
Electrochemical **C**oncentration **C**ell ozonesonde

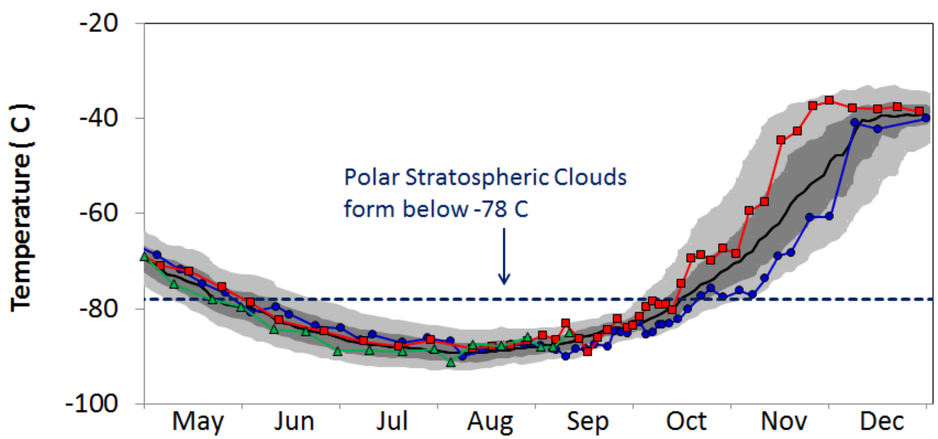


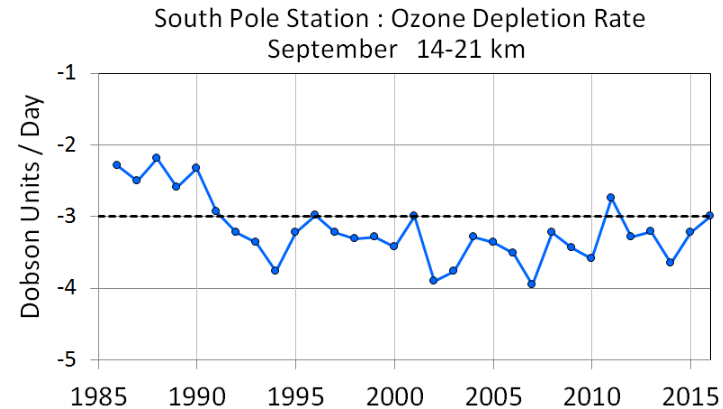


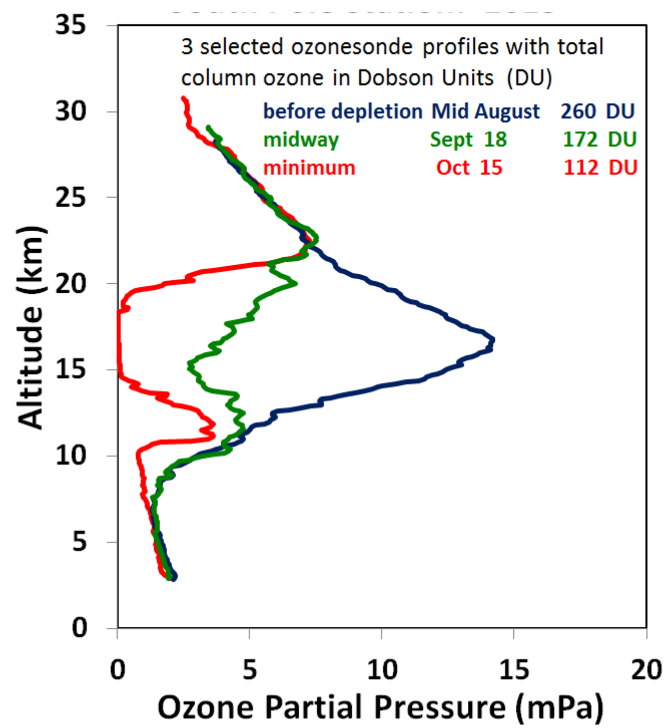


Polar ozone loss rate in September

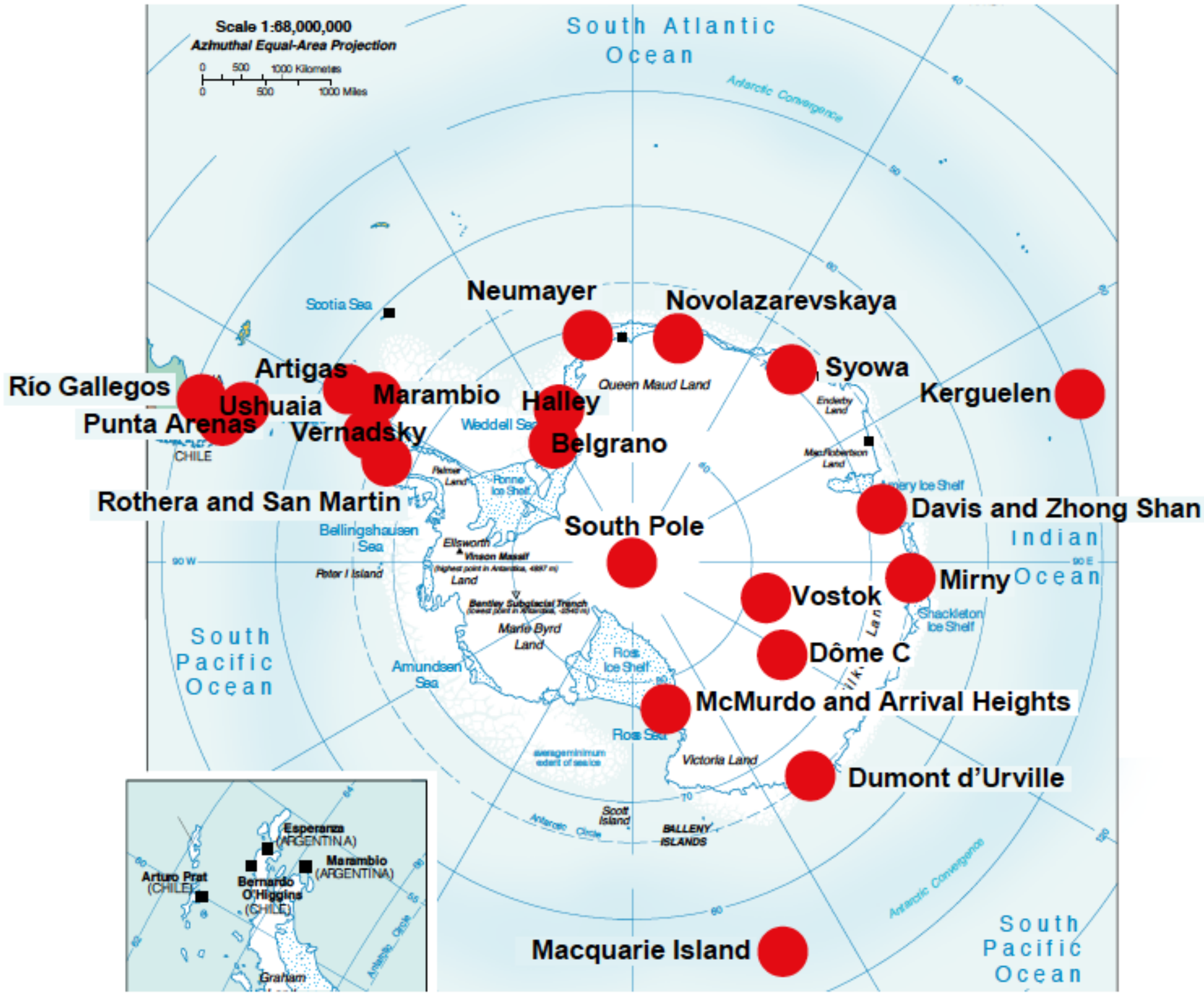








Other ozone measurement stations in Antarctica and SH high latitudes



6. Conclusions

- Ground based networks (GAW/NDACC) have been an important component in ozone research since early warnings on the ozone layer
- They played a crucial role in the documentation of anthropogenic ozone depletion and the validation of the long-term stability of (merged) satellite data
- Profile measurements will play an even more important role as satellite mission dedicated to atmospheric chemistry stop
- New developments:
  - Instrumentation: new spectrometers (e.g. Pandora), ozone sondes homogenization, standardization of retrieval algorithms, ...
  - Data analysis: the SPARC LOTUS activity : Long-term Ozone Trends and Uncertainties in the Stratosphere

However…

it is important to maintain the networks to continue assessing the evolution of the ozone layer

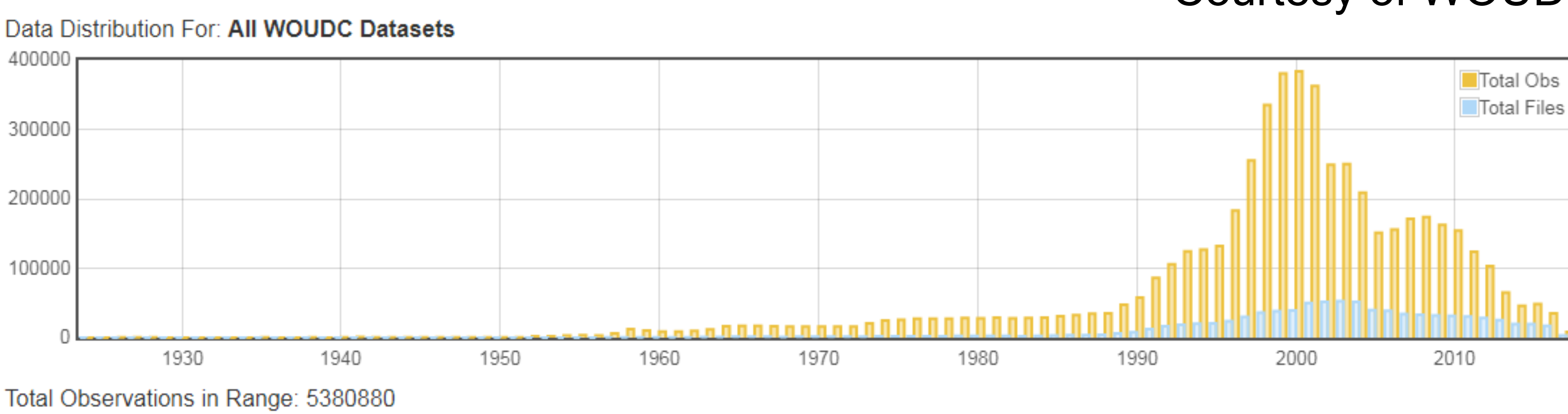
In the last years, threats to stop several measurement stations: e.g. Lauder (NZ), Macquarie Island (Australia), Lerwick (UK), Reading (UK), Paramaribo (lidar), …

Cinderella science

On-the-ground monitoring is unglamorous work, seldom rewarded by funding agencies or the science community. But we neglect it at our peril, warns **Euan Nisbet**.

Nisbet, Nature, 2007

Courtesy of WOUDC



Thank you!

Acknowledgments:

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Stations operators and all the individuals involved in the ground-based measurements