Ozone depletion and the European Arctic, some personal reflections

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After a decade of concern about possible O3 depletion by CFCs Farman et al (1985) reported their discovery of the Antarctic Ozone hole.

Much research, including a number of US-led field campaigns, established the basic facts in Antarctica.

What about the Arctic ?

1987-90 A German- French scientific initiative Ground-based stations and first balloon flights from Kiruna: CHEOPS I '87, CHEOPS II 1987/88, CHEOPS III 1989/90

1989 NASA AASE Airborne Artic Stratospheric Expedition: ER2 and DC8 from Stavanger, Norway





Research Questions, circa late 1980s

Is there loss in the Arctic similar to in the Antarctic?

What about the populated middle latitudes?

What about the future?





Some personal background



1980s models predict O₃ depletion, but fail to capture polar ozone depletion (Pyle,



...and recognize this as a chemistry/climate problem (Haigh and Pyle, 1982).



Some personal background

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Figure 58 Ozone changes for the three latitude bands 53–64°N, 40–52°N, and 30–39°N between 1970 and 1986. The statistical model used allowed for effects of the solar cycle and the quasi-biennial oscillation, and data from 1965–1986 were used. The ozone change in each month was assumed to have occurred in a linear fashion after 1969. The monthly ozone changes plotted are not trends; they are found by multiplying the calculated trend by the 17-year period over which the loss was assumed to have occurred. The vertical bars represent \pm 1 standard error in the estimate of the change. (a) 54–64°N, (b) 40–52°N, and (c) 30–39°N.

Statistical analysis of longterm data in 1990 showed wintertime loss at northern mid-latitudes. Could it be ozone loss in air processed in cold Arctic?

(Harris, PhD thesis, 1989.)



Figure 48. Difference between the means of each month for **E** the periods from 1931-1969 and 1970-1988 at Arosa.

INVOLVEMENT OF EUROPEAN COMMISSION IN OZONE RESEARCH

1987 Montreal Protocol

Immediate reaction of European Commission DG XII Heinrich OTT, head division Environment

1989 Creation of Ozone science panel, Chair G.Megie & European Ozone Research Coordinating Unit (EORCU) in Cambridge, R. A. Cox, J. Pyle, N. R.P. Harris

Oct 90 First European Workshop on Polar Stratospheric Ozone, Schliersee: Latest results on polar ozone. Plans for a European campaign

1990-91: European Arctic Stratospheric Ozone Experiment (EASOE) campaign prepared by Core Group (J.A.Pyle, N.R.P.Harris, J.C.Farman, F.Arnold, G.Braathen, R.A.Cox, P.Faucon, R.L.Jones, G.Megie, A.O'Neill, U.Platt, J-P.Pommereau, U.Schmidt and F.Stordal). Instrument development.





European Arctic Nov 91-Apr 92

> 300 scientists + Russian

ARCTIC CIRCL

- Ozone sondes
- Balloons
- Ground based
- Rocket
- Aircraft
- Weather ship
- Data Centre
- Coordination Unit
 - **Operational Headquarters**

16 Ground-Based sites Ozonesondes at 22 European sites (1057 launches)











Plus Laboratory Chemistry, Modelling, Central data-base at NILU



3 Research aircraft from Arena Arctica in Kiruna





NATURAL ENVIRONMENT RESEARCH COUNCIL



EASOE Strategy:

- Frequently repeated flights of core balloon instruments (CFCs, N₂O; H₂O; NO₂) to stablish 'climatology'
- Flights of complex payloads with more comprehensive constituent coverage (eg MIPAS)
- Regular sondes for O₃ & particles across European Arctic and mid-latitudes
- Ground-based network
- Aircraft
- Excellent met support (ECMWF, UK MetO)
- Strong chemical modelling element





43 stratospheric balloons operated by CNES from ESRANGE in Kiruna during EASOE



















National Centre for Atmospheric Science



















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AN OVERVIEW OF THE EASOE CAMPAIGN

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loss at lower latitudes



Repeated balloon obs confirmed the vortex was isolated, variable and could impact middle latitudes







(c)



Chlorine activated at low temperatures



•1994 and 1995 SESAME (Second Arctic and Middle latitudes European Campaign), extension of GB network, many balloon flights, 2 aircraft + Concorde

- •Ongoing: MATCH ozonesondes for O₃ loss
- •1996 Geophysica aircraft Rovaniemi Finland
- •1998 THESEO Third Arctic and Middle lats
 •2000 SOLVE-THESEO: US-Europe Arctic Ozone Campaign, G-B, 25 balloon flights, long duration balloon flights in polar vortex





Ozone loss occurred

REX ET AL.: 1991/1992 ARCTIC STRATOSPHERIC OZONE DEPLETION RATES







Ozone loss occurred – throughout the vortex



Arctic Ozone column reduction from SAOZ network since 1994





Loss derived from combination of observations and model. Courtesy Jean-Pierre Pommereau









Improved numerical models

Increasingly sophisticated 3D models forced by meteorological analyses could reproduce observed atmospheric structures...





.....including high resolution ER2 measurements of CIO





CONTOUR FROM 1.3 TO 8 BY .1



Ozone @ ~20km 7 March 2000 Large ozone loss inside polar vortexchlorine chemistry initiated by low temperatures





Ozone at ~20km







Middle latitude ozone change

% Ozone Column Anomaly 30°- 60° N



- Dynamical variability
- In situ loss
- Transport of
 loss from
 Arctic vortex





SUMMARY

Coordinated European action:

- Built a community of researchers
- Laid foundation for improved understanding & contribution to Montreal Protocol

The campaigns:

- Characterized the polar vortex
- improved understanding of fundamental processes (eg PSCs)
- determined O₃ loss by a number of techniques
- demonstrated links to middle latitude loss





















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Dedicated to the memory of Gerard Megie, Pierre Faucon and Joe Farman

and acknowledging the financial support of the European Commission (and, particularly, Heinz Ott, Jürgen Büsing and Georgios Amanatidis) and many European governments

CNES, ESRANGE

and, at EORCU, Helen Mullineux, Kate Wood and Rebecca Penkett











Ozone 'recovery'





The modelled response of O₃ to changing concentrations of ODS and

Braesicke, Morgenstern, Millar