

**Field Programs in the North Atlantic:
WATOX and AEROCE**

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Photooxidants, Particles, and Haze across the Arctic and North Atlantic: Transport,
Observations, and Models

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How much pollution (O₃, N, S, C) is advected from N America to the N Atlantic?

Nonlinear function of: Multiphase photochemistry
 Surface winds
 Vertical mixing
 Free trop winds.

Winter - cold fronts frequent and powerful, convection weak & less frequent over continent, chemistry slow.

Spring - colds fronts weakening (retreating), convection growing, chemistry accelerating, tropopause folding.

Summer - blocking Bermuda High, convection strong & deep, chemistry fast.

Fall - cold fronts strengthening, convection weakening, chemistry slowing.

WATOX: 1986 Winter intensive.

AEROCE: 1988-1998 Spring intensives.

WATOX

(Hard copy images attached)

Few experiments have looked at long-range transport during the cold months. In winter 1986, the NOAA P3 and Kingair were flown off the East Coast of the US to measure pollution concentrations in the MBL and lower FT. Behind cold fronts, large quantities of reactive nitrogen, sulfur, VOC's and aerosols were measured. Most of the pollution was found in the MBL, with smaller amounts in the lower FT, apparently lifted by modest convection associated with the fronts. Between 10 and 30% of the N and 25-35% of the S emitted over the eastern US was advected to the NAO. The fate of these pollutants is uncertain – are they deposited to the ocean? Do multiphase processes play a role? Or does convection over the Gulf Stream lift pollutants to the free troposphere where long-range transport can occur?

- **WATOX References**

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AEROCE 1996

(Soft copy postscript images available)

The objective of the AEROCE study was to determine the transport of pollutants from N America to the North Atlantic Ocean and to determine the impact of continental emissions on tropospheric ozone, especially episodes in Bermuda. Long-term monitoring at surface sites in Bermuda, Barbados, and Ireland tracked O₃, CO, and aerosols. During intensive experiments an expanded set of measurements at the Bermuda surface site and with the Wyoming Kingair were acquired.

As an example, the flight of April 28, 1996 showed substantial NO_y, CO, VOC's, aerosols in layers in the free troposphere between the East Coast and Bermuda. Ozone layers were also observed, and some of them could be attributed to pollution while others originated in the UT/LS region. The mechanism was shown to be linked cyclones and associated cold fronts. Subsidence behind one cold front encounters convective clouds ahead of the next cold front. Thus polluted continental boundary layer air is found in close proximity to layers of air from the UT/LS containing high mixing ratios of O₃.

A summary of all 18 flights shows gives mean profiles of T, Td, O₃, CO, NO, NO_y, and b_{sp}. These profiles can be separated by meteorological conditions and into events when the ozone in the free troposphere is of stratospheric or photochemical origin. Events of stratospheric ozone showed high O₃ but low CO and dew points in the upper trop. In the lower trop, ozone was still correlated with CO and NO_y indicating a photochemical origin. Stratospheric intrusions were observed behind essentially every cold front investigated.

Possible long range transport of pollutants resulting from frontal and convective lifting could be seen in increased concentrations of pollutants in the free trop in the profiles acquired ahead of fronts.

Results were simulated with the NASA/GSFC Data Assimilation Model (Allen et al., 1996) and often the details of the distribution of CO were well reproduced. Convection is critical however – on one occasion the model produced the correct location and timing of the clouds, but overestimated the depth and grossly underestimated the concentration of CO in the lower free troposphere.

Conclusion: The linked nature of cyclones over N America may well lead to the vertical mixing necessary for pollutant emissions in the US to impact air quality over Europe.

AEROCE References

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Hypotheses

1. Advection transports large quantities of pollutants (O_3 , aerosols, and their precursors) from N America to the NAO in winter, but multiphase chemistry in the MBL removes it quickly.
2. Advection transports large quantities of pollutants (O_3 , aerosols, and their precursors) from N America to the NAO in winter, where convection over the Gulf Stream lifts it to the free troposphere and sends it to Europe.
3. Linked cold fronts over N. America lift pollutants into the mid troposphere, fold in ozone from the stratosphere and send them to Europe.
4. Deep spring/summer convection over N America lifts pollutants from fossil fuel combustion and forest fires, mixes in NO_x from lightning, and sends it on to Europe.