

# Measurements at the PICO-NARE station: The ICARTT period and prior summers

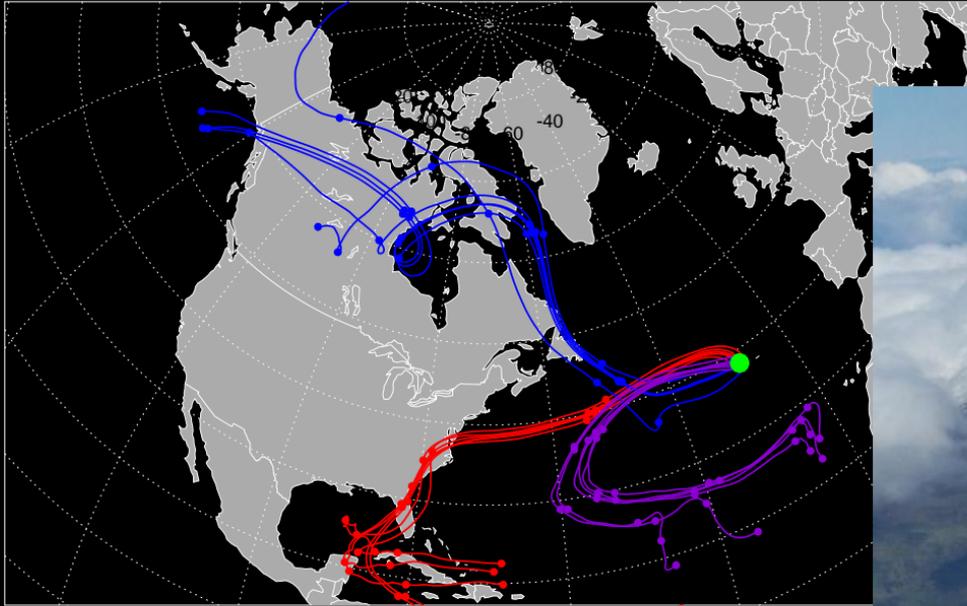


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W. McMillan

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# PICO-NARE station location: The Azores Islands



Summit altitude: 2225 m, or 7200 feet.

## The station on the summit caldera



and a bit closer



## and a bit closer



Note U.K. ITOP Bae-146 flyby in background.

# Instruments inside



NMHC

CO

Ozone

B.C.



NO

# Primary Objectives

- Assess  $O_3$  export and production resulting from U.S. emissions exported to the lower free troposphere (over the first  $\sim 4$ – $5$  days downwind).
- Quantify impacts of boreal biomass burning on midlatitude background  $O_3$ , CO and nitrogen oxides.
- Provide a multiyear context for the ICARTT study period.

# Summary of presentation topics

- What was measured when.
- U.S. export example.
- Boreal fire example.
- Interannual variability.
- Summer 2004 overview: U.S. and biomass burning impacts.
- Summary results for CO and O<sub>3</sub>, and NMHCs.

# Measurements

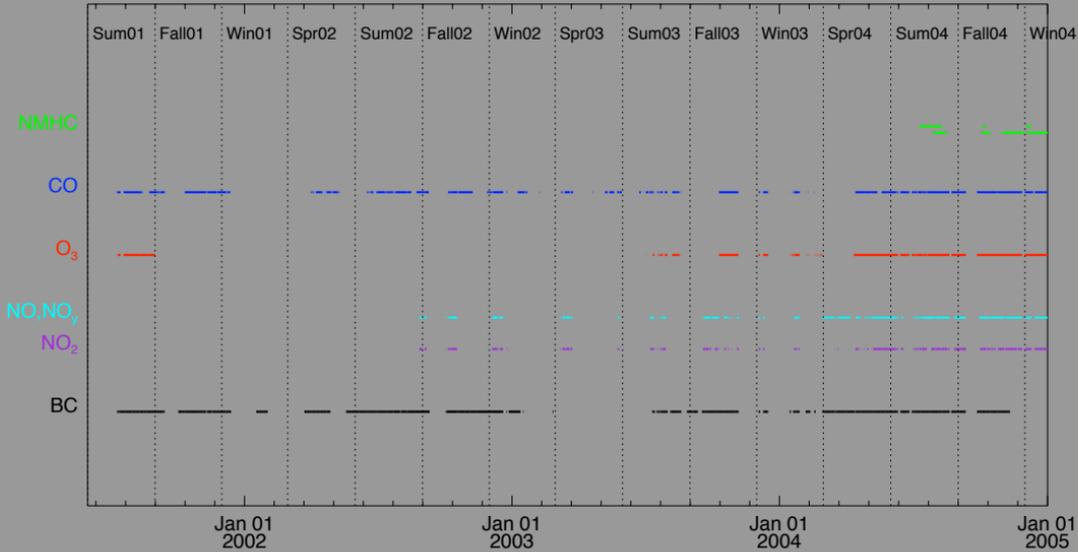
CO, O <sub>3</sub> , meteorological variables	July 2001–present
Black carbon (aethalometer)	July 2001–present
NO, NO <sub>2</sub> , NO <sub>y</sub>	August 2002–present
Non-methane hydrocarbons	July 2004–present

## Additional measurements, summer 2004

Multiple met stations along mountainside to characterize upslope flow occurrence.

# Data coverage, 2001–2004

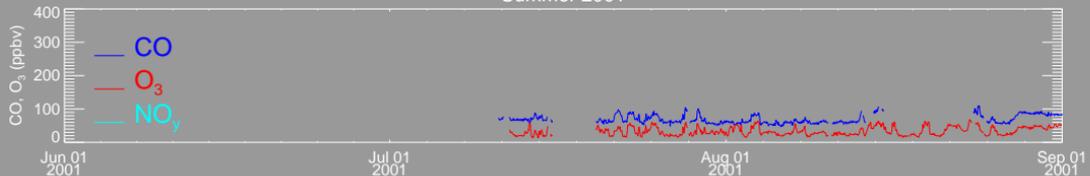
PICO-NARE Data Coverage



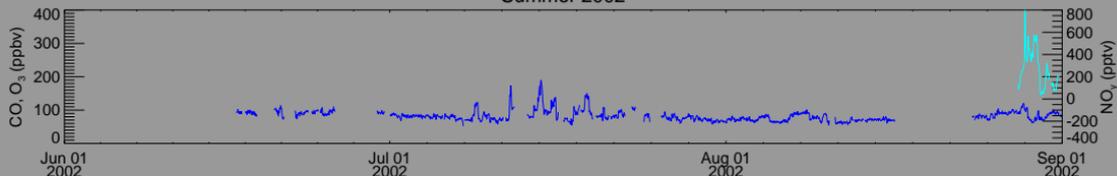
Wed Mar 9 22:49:54 2005

# Data coverage, Summers 2001–2004

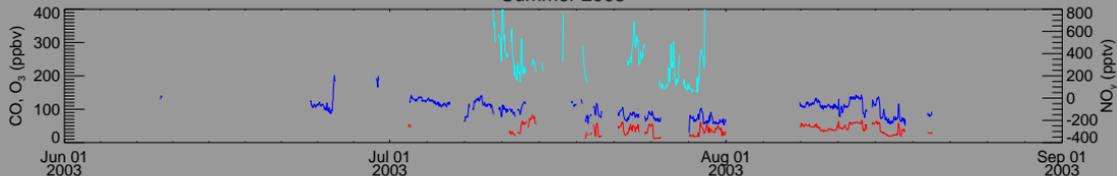
Summer 2001



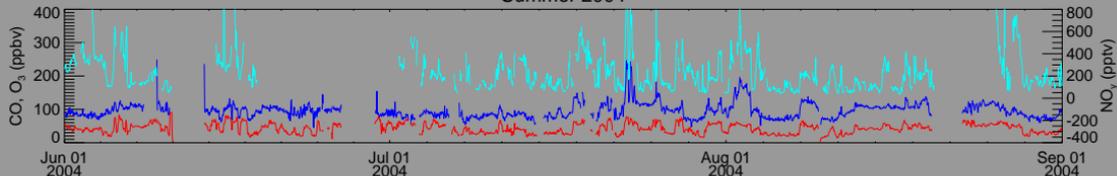
Summer 2002



Summer 2003

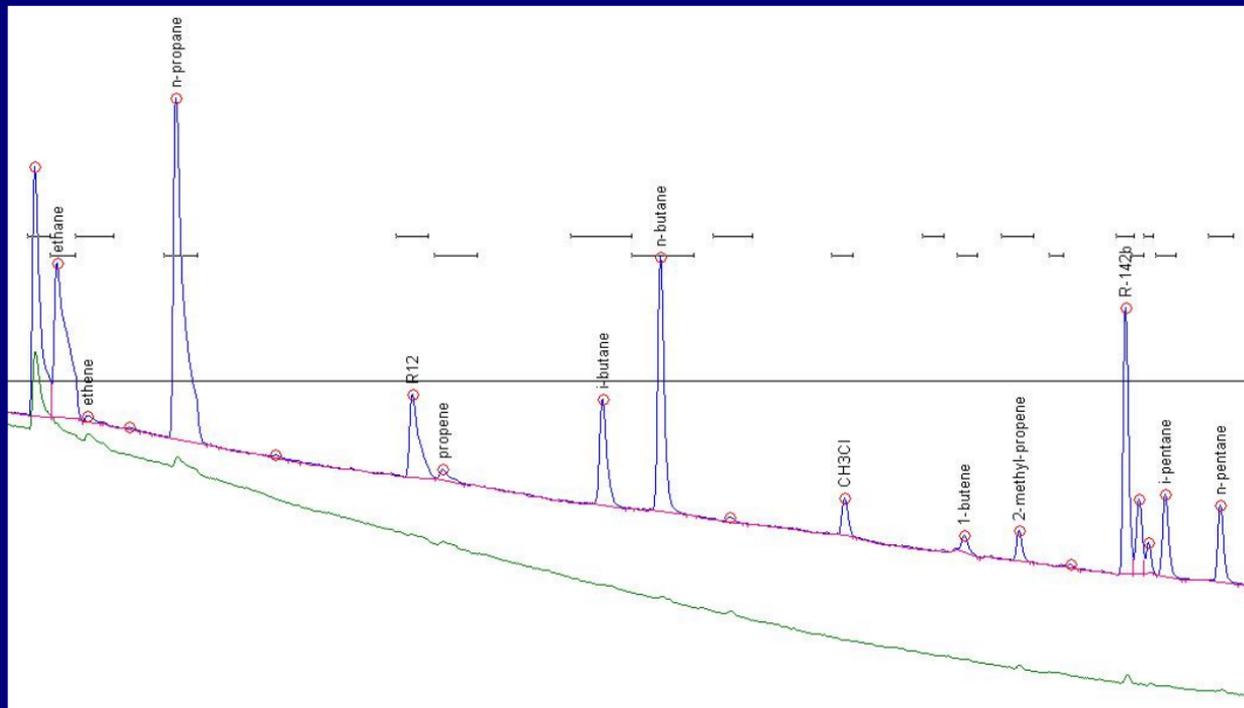


Summer 2004

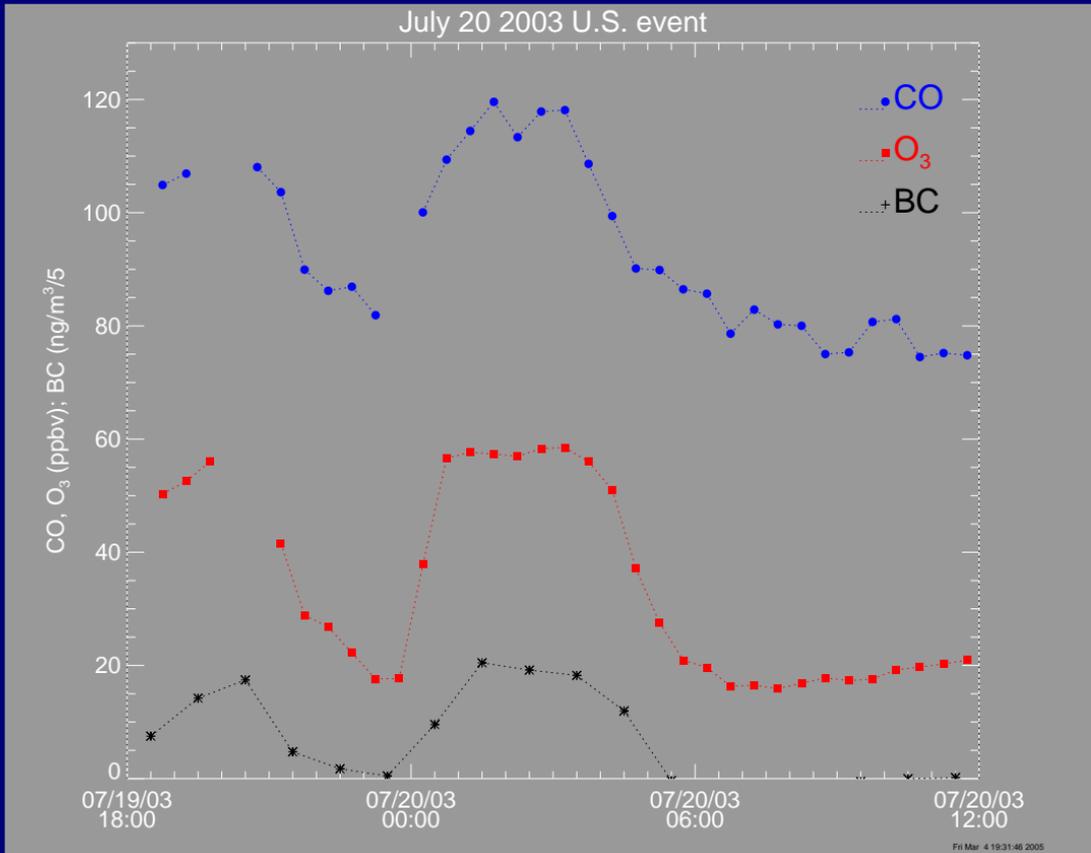


FH Mar 4 21:26:51 2005

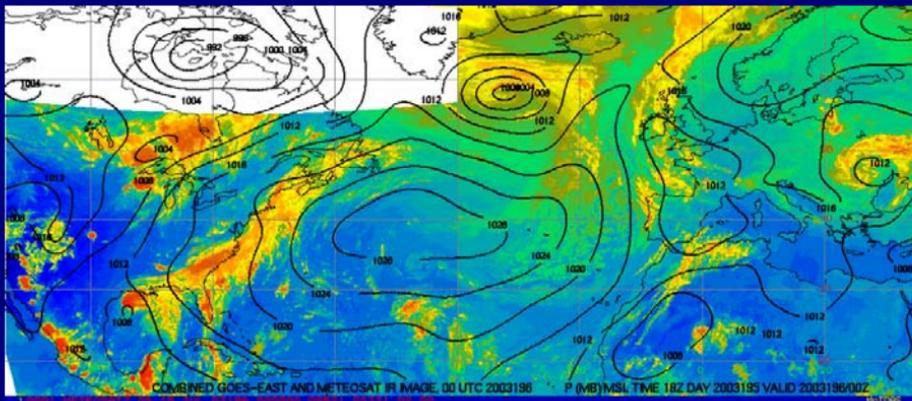
# NMHC measurements: example chromatogram



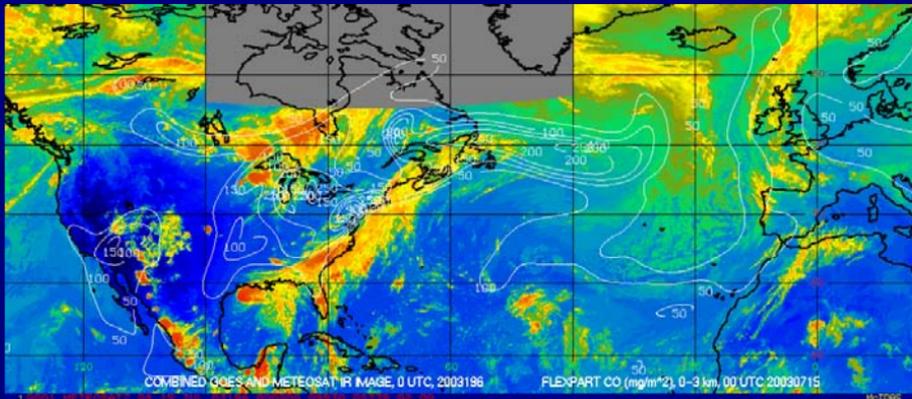
# Example U.S. export event (July 20, 2003)



# Situation 5 days prior over the east coast

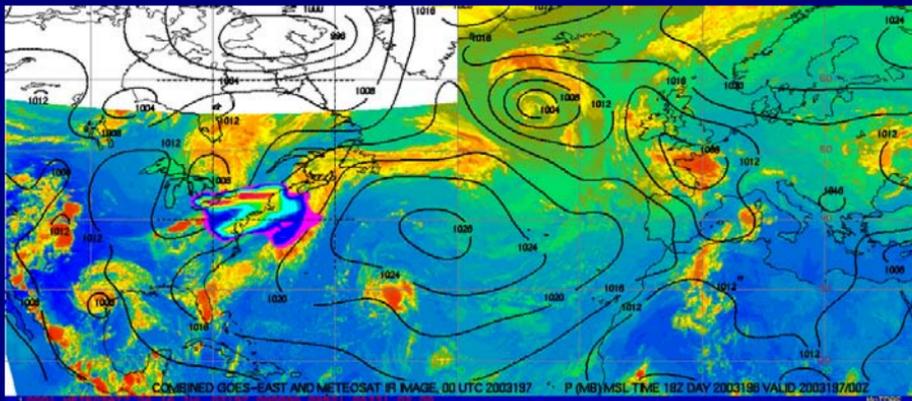


07/15/2003 00 UTC

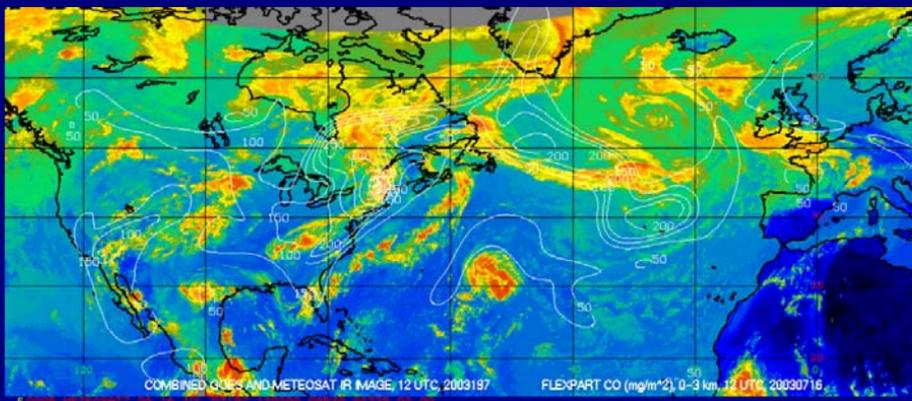


07/15/2003 00 UTC

# Situation 4 days prior

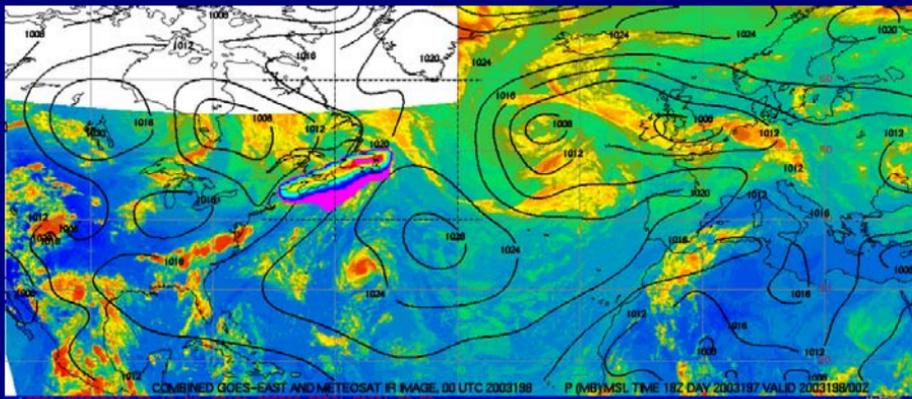


07/16/2003 00 UTC



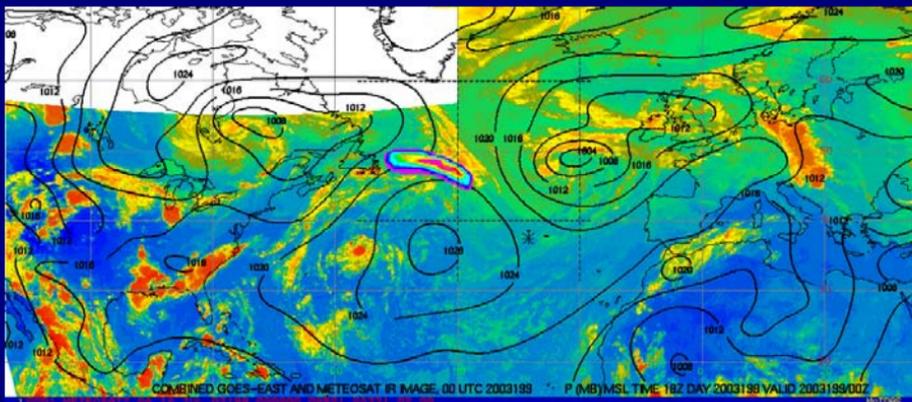
07/16/2003 12 UTC

# Situation 3 days prior

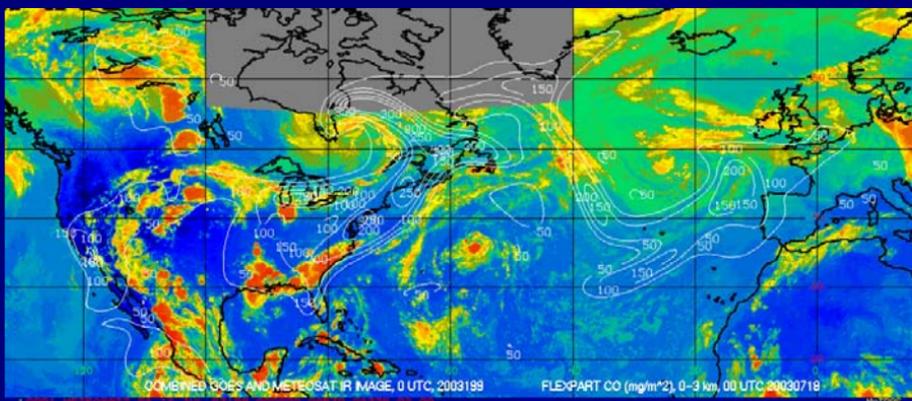


07/17/2003 00 UTC

# Situation 2 days prior

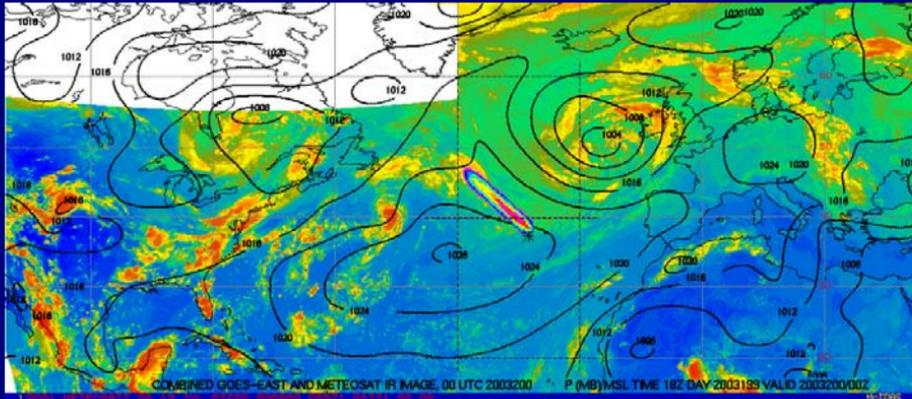


07/18/2003 00 UTC



07/19/2003 00 UTC

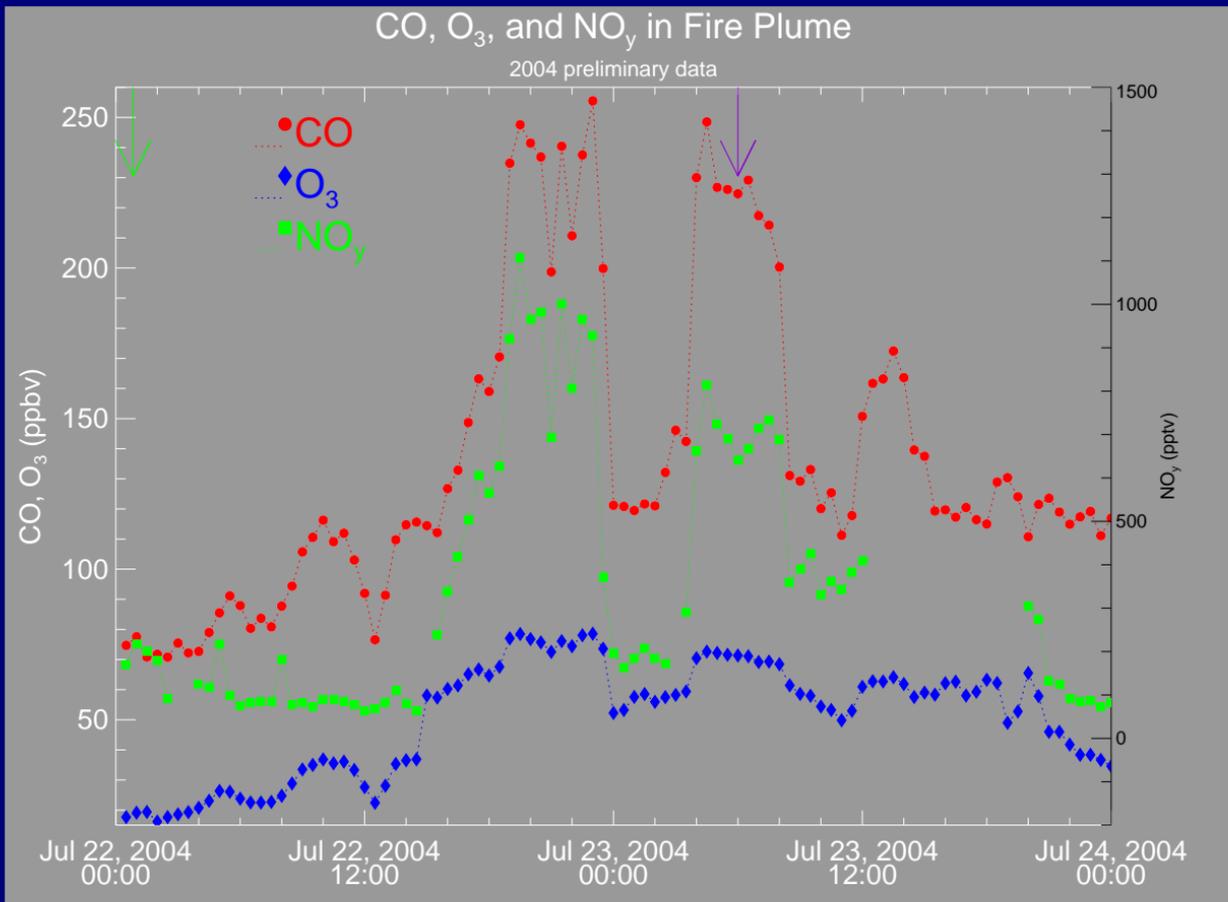
# Situation 1 day prior



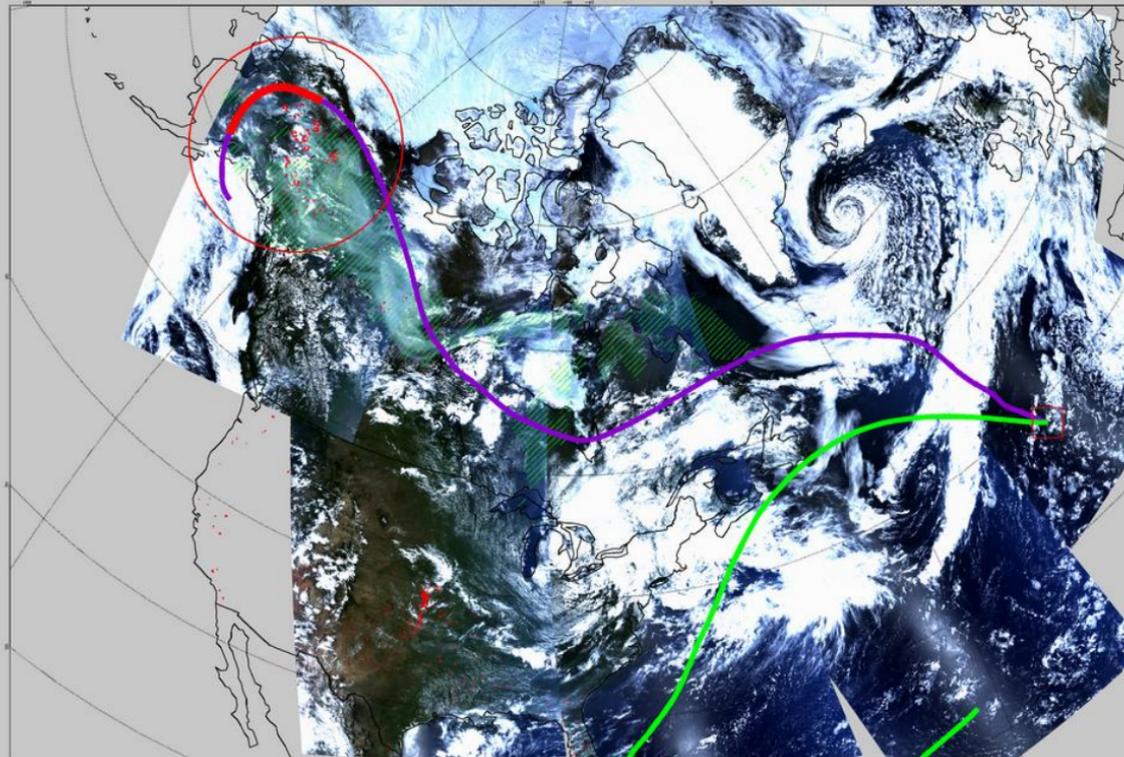
07/19 /2003 00 UTC

For more details, see Owen, R.C.; Cooper, O.R.; Stohl, A.; Honrath, R.E., Mechanisms of North American export and transport to the central North Atlantic lower free troposphere during the summers of 2003 and 2004, poster EGU05-A-05598, General Assembly of the European Geosciences Union, 28 April 2005; manuscript in preparation.

# Example boreal fire event (July 23–23, 2004)

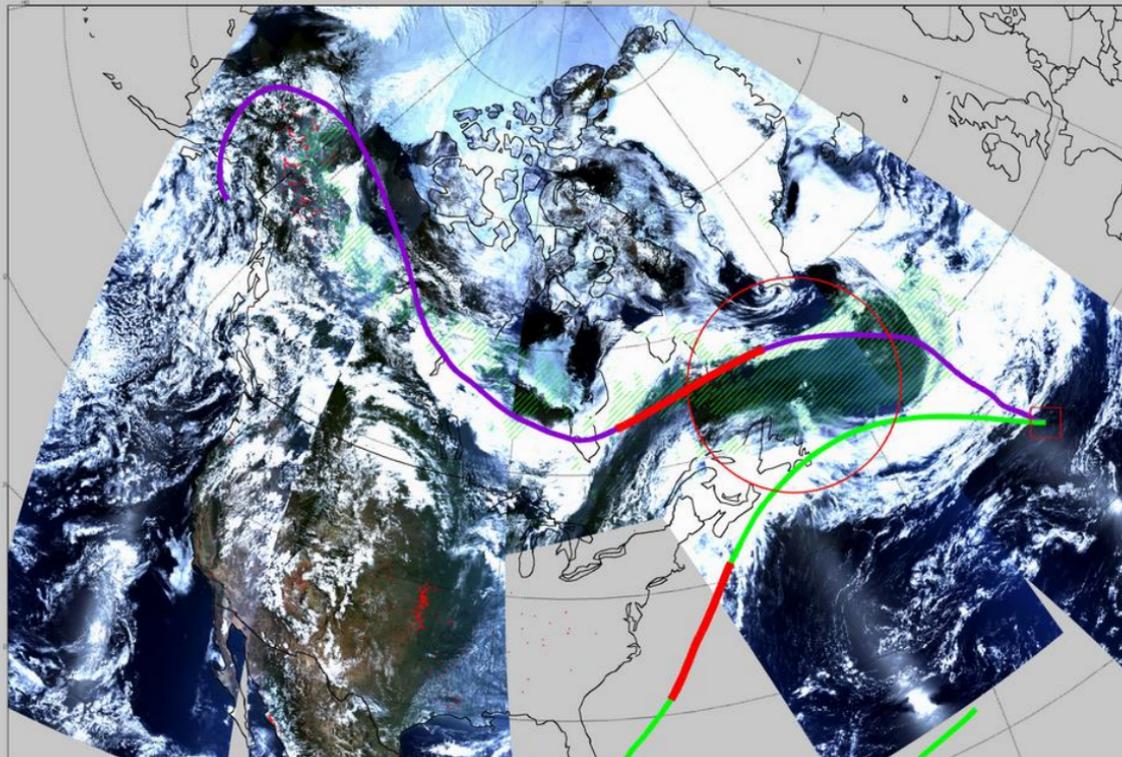


# MODIS/AIRS with air-flow trajectories to Pico: July 14



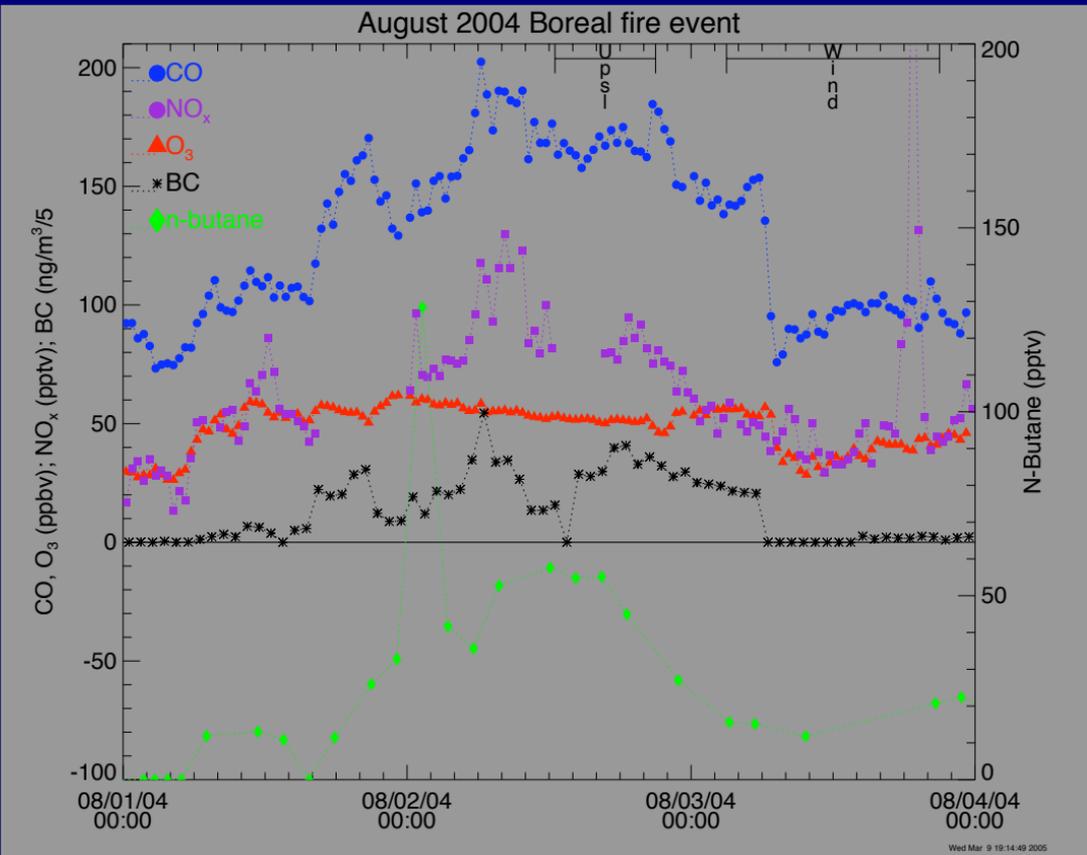
Jul 14, 2004 AIRS CO 95.%ile contour in green

# MODIS/AIRS with air-flow trajectories to Pico: July 19



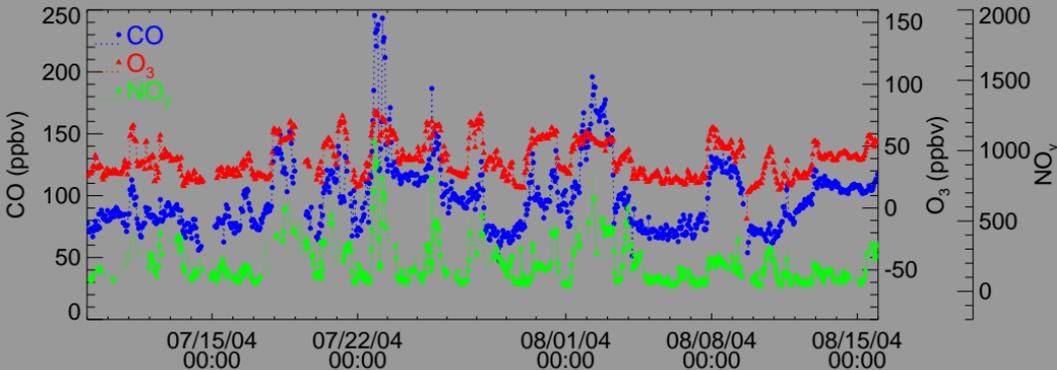
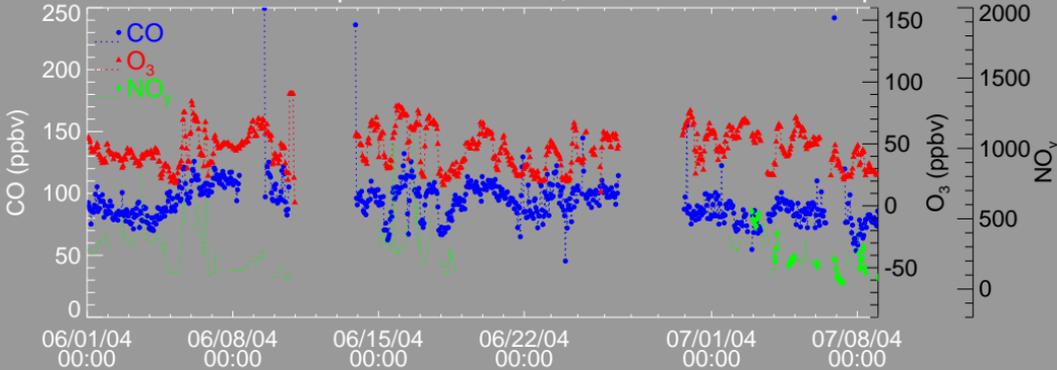
Jul 19, 2004 AIRS CO 95.%ile contour in green

# 2004 Fire (+US?) event, with n-butane and NO<sub>x</sub>



# Summer 2004: CO, O<sub>3</sub>, NO<sub>y</sub>

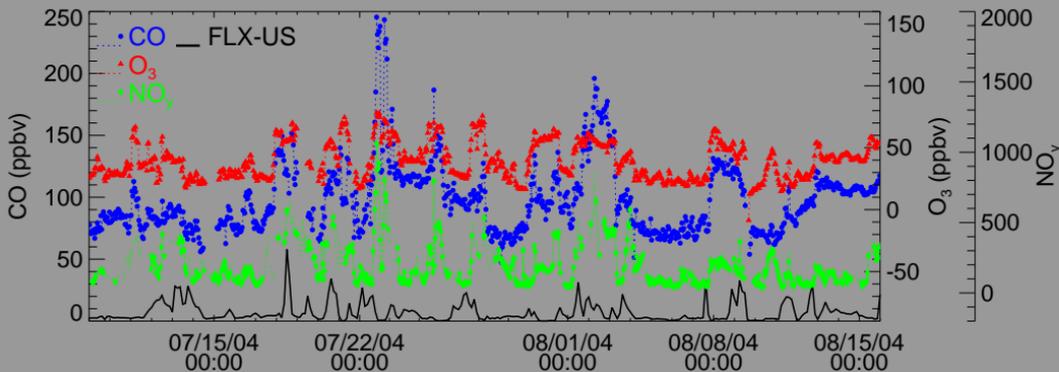
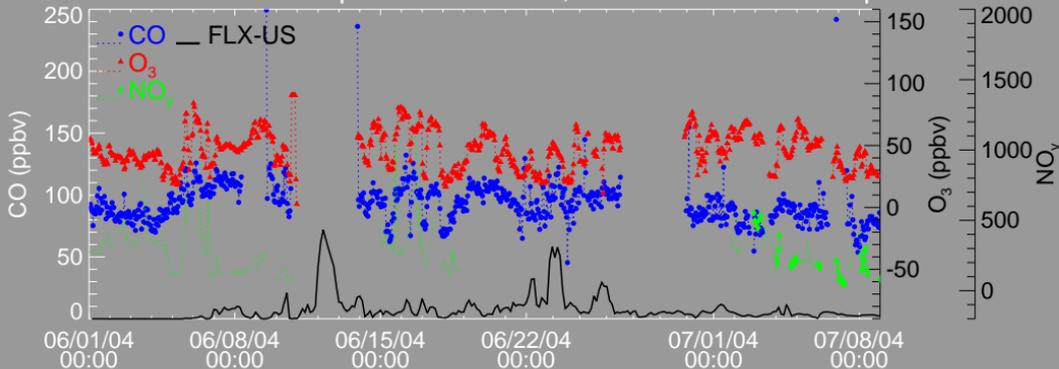
Summer 2004 ICARTT period: Pico Data; FLEXPART US/BB Impacts



Thu Mar 3 14:14:58 2005

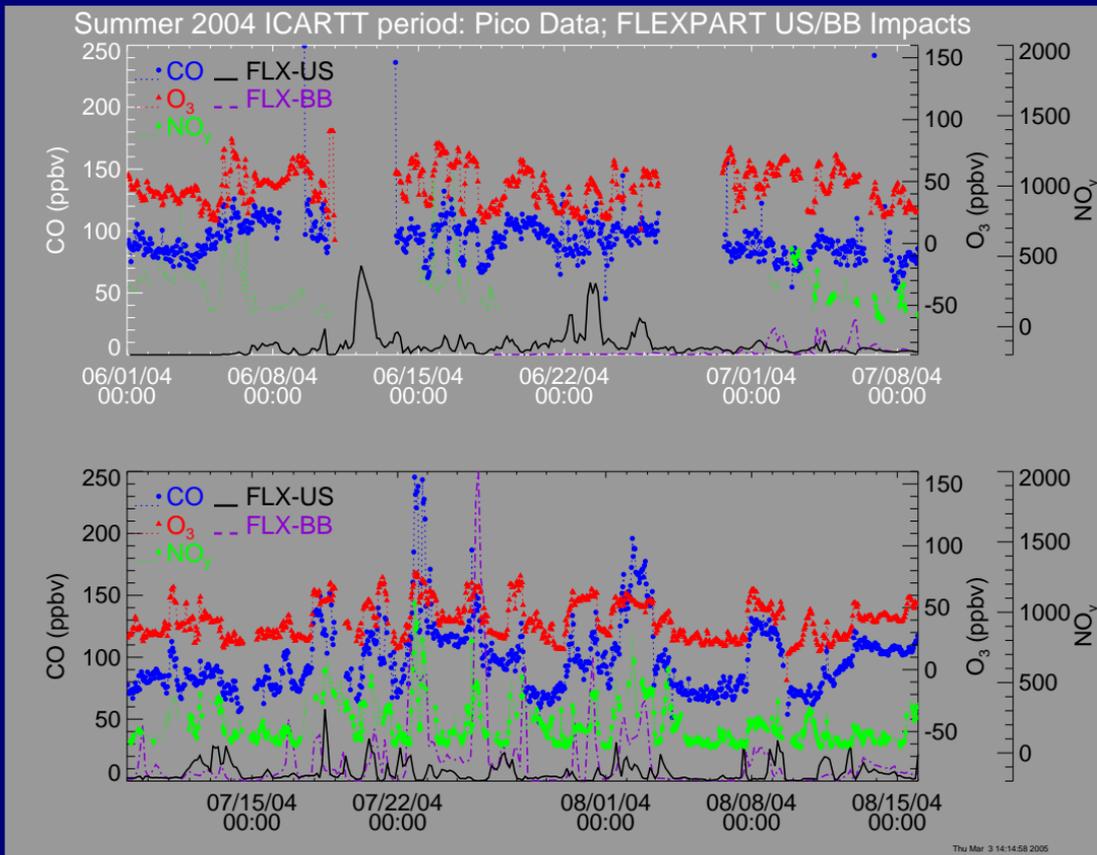
# Summer 2004: CO, O<sub>3</sub>, NO<sub>y</sub>, plus FLEXPART U.S. impact

Summer 2004 ICARTT period: Pico Data; FLEXPART US/BB Impacts



Thu Mar 3 14:14:58 2005

# Summer 2004: CO, O<sub>3</sub>, NO<sub>y</sub>, plus FLEXPART U.S. and Biomass-burning impact



# Causes of interannual variability

## Transport differences

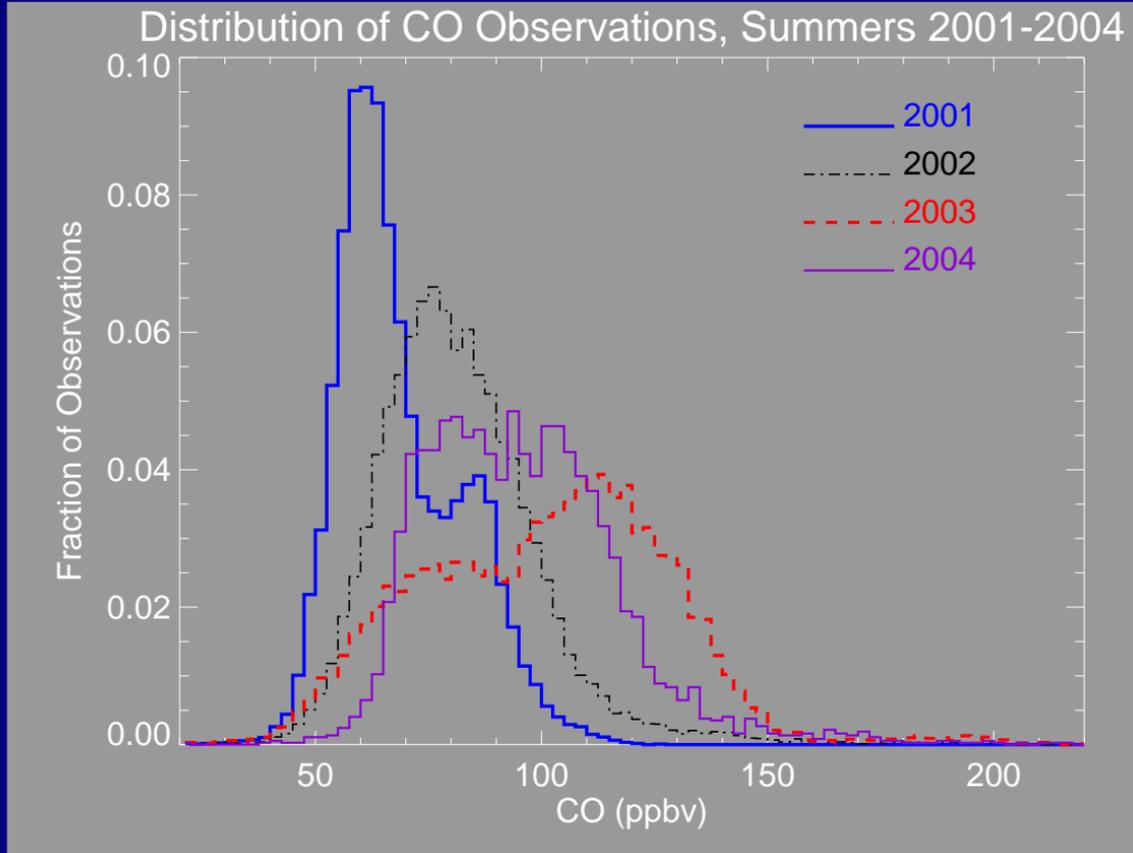
Based on backward trajectories,

	Percent of measurements in air potentially from		
	U.S.	Canada/Alaska	Clean marine
Summer 2001	25	30	29
Summer 2002	21	42	31
Summer 2003	46	60	15
Summer 2004	41	66	21

## Boreal fires

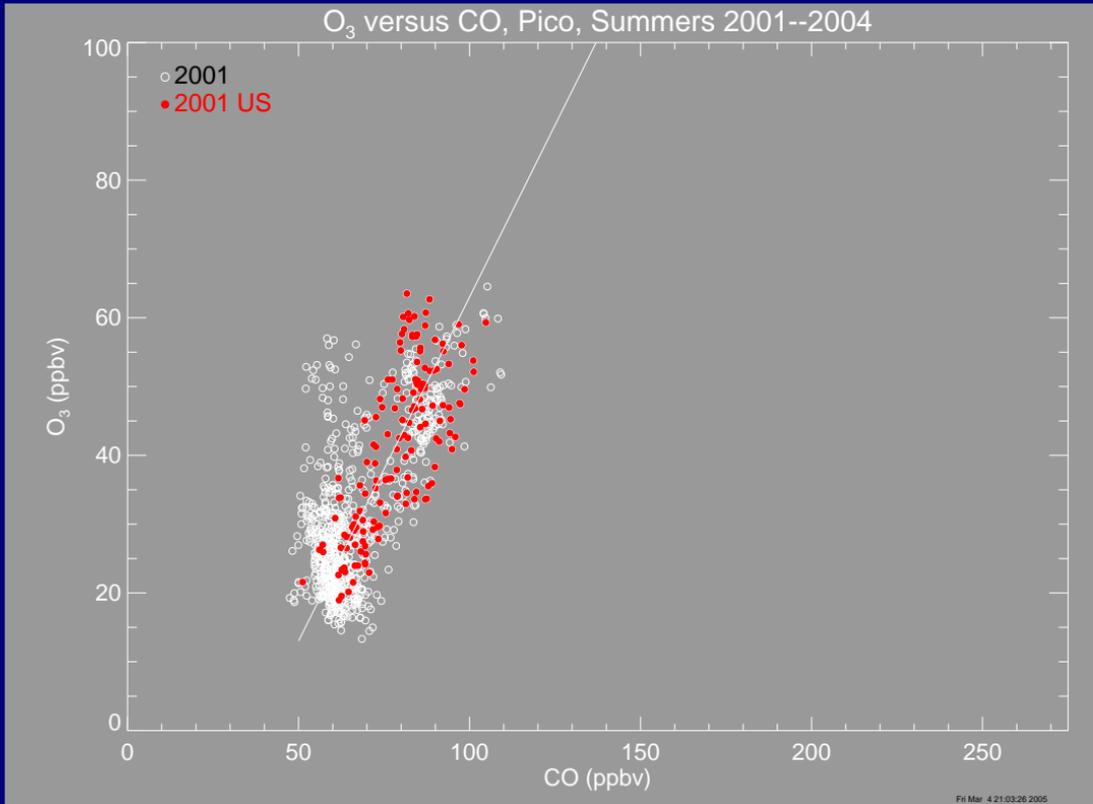
Summer 2001	Few fires
Summer 2002	eastern Canada fires (but no Pico O <sub>3</sub> )
Summer 2003	Major fires in Siberia
Summer 2004	Major fires in Alaska and western Canada

# Interannual variability in CO



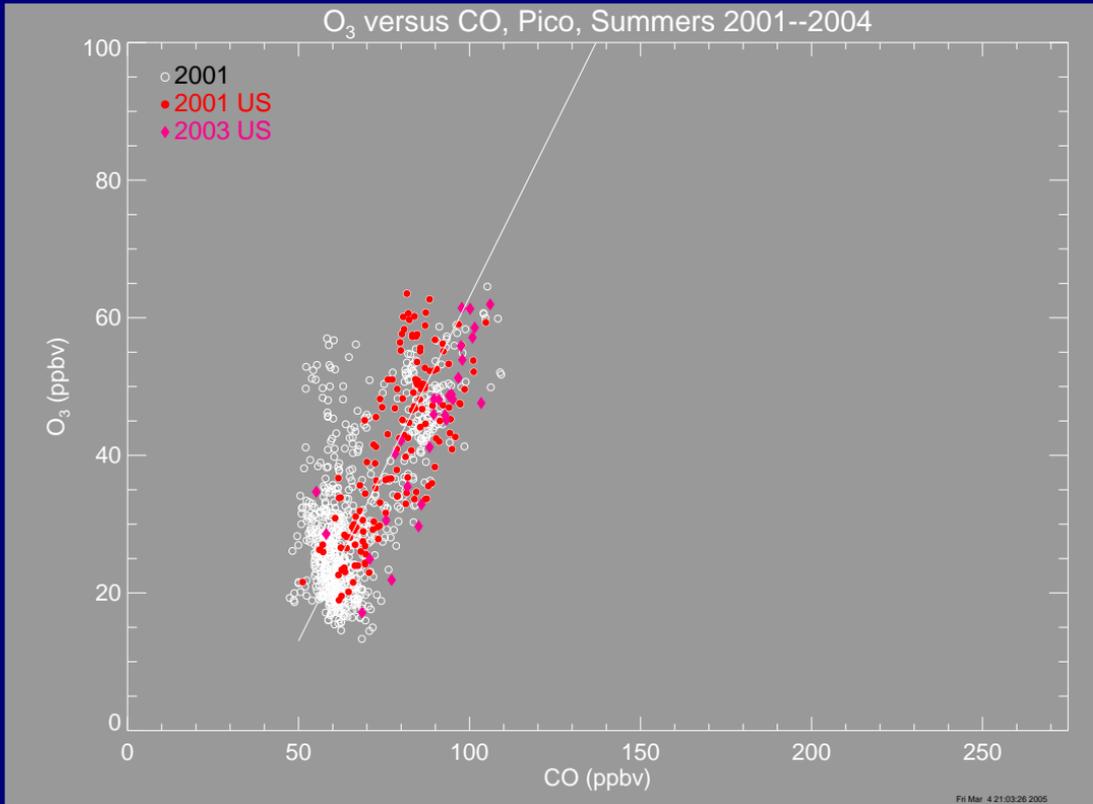
# CO-O<sub>3</sub> relationship

## 2001, U.S. events highlighted



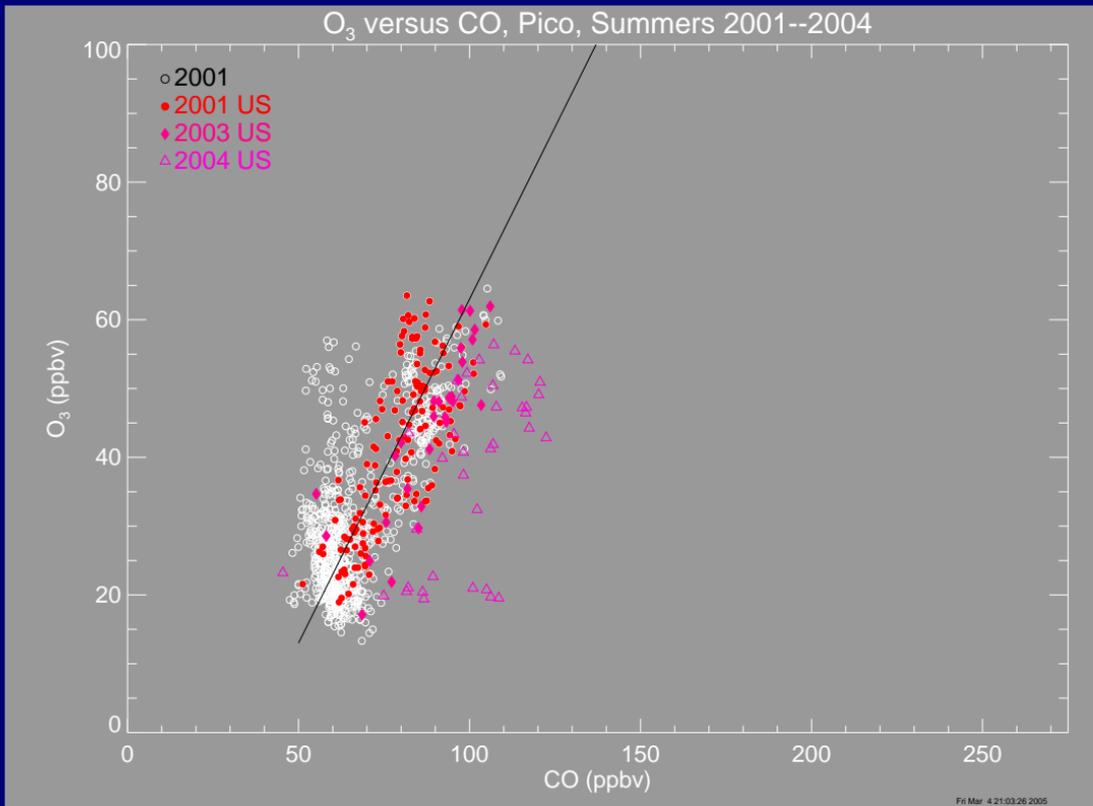
# CO-O<sub>3</sub> relationship

## 2001, plus 2003 U.S. events



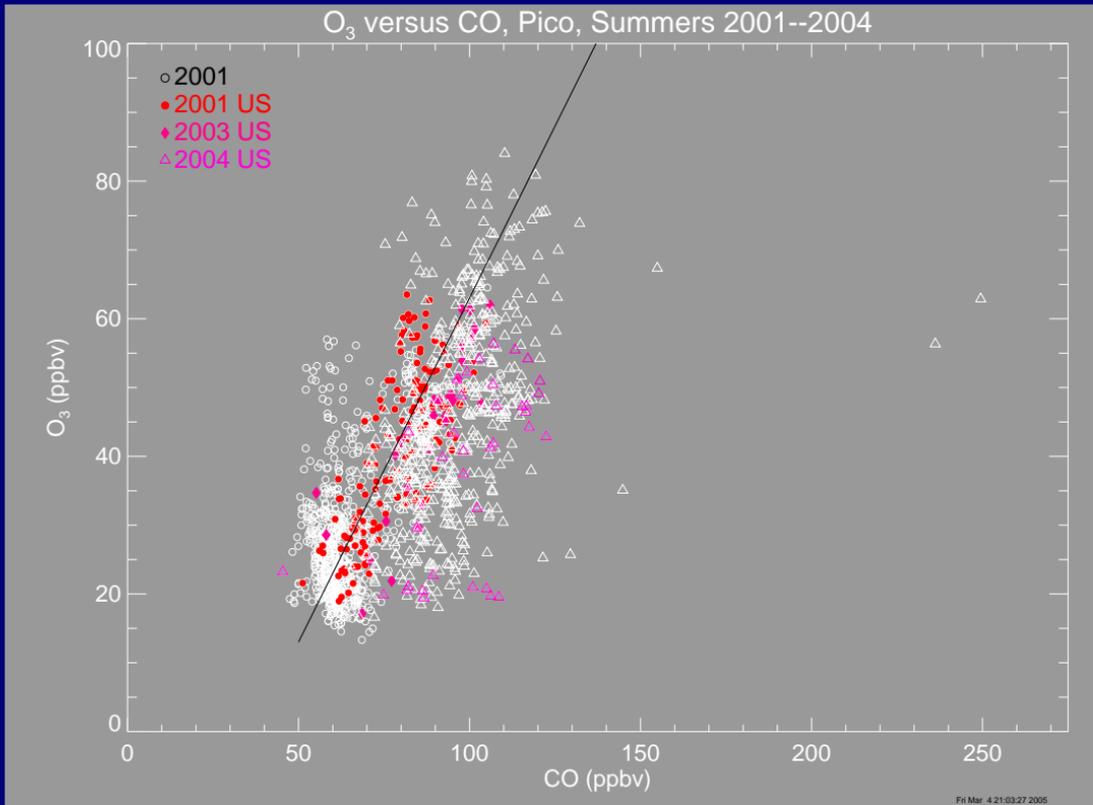
# CO-O<sub>3</sub> relationship

## 2001, plus 2003 and 2004 U.S. events



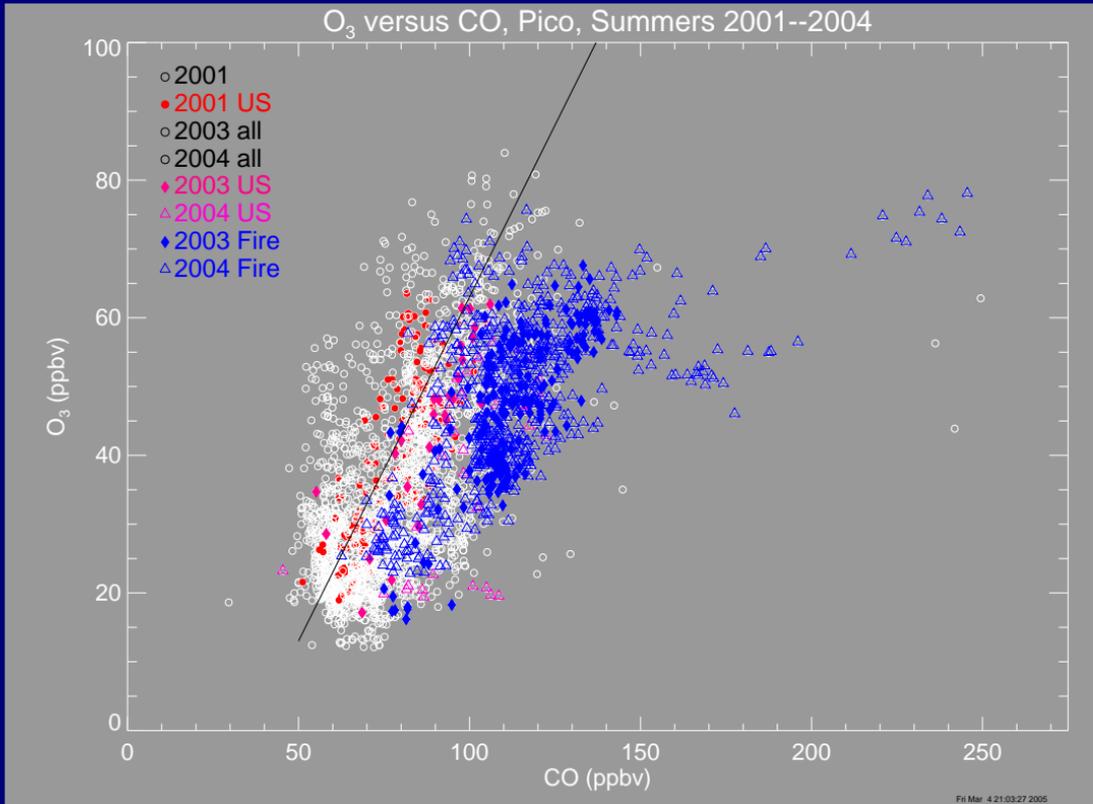
# CO-O<sub>3</sub> relationship

2001, plus 2003 and 2004 U.S. events, plus June 2004

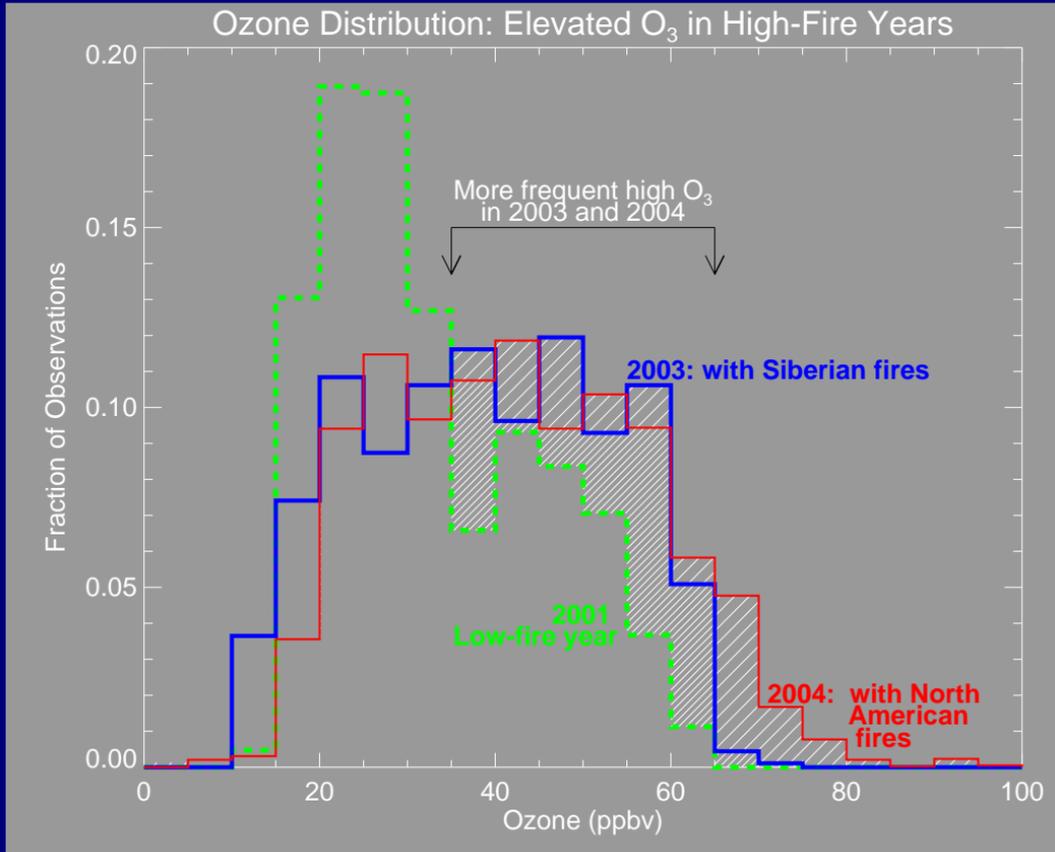


# CO-O<sub>3</sub> relationship

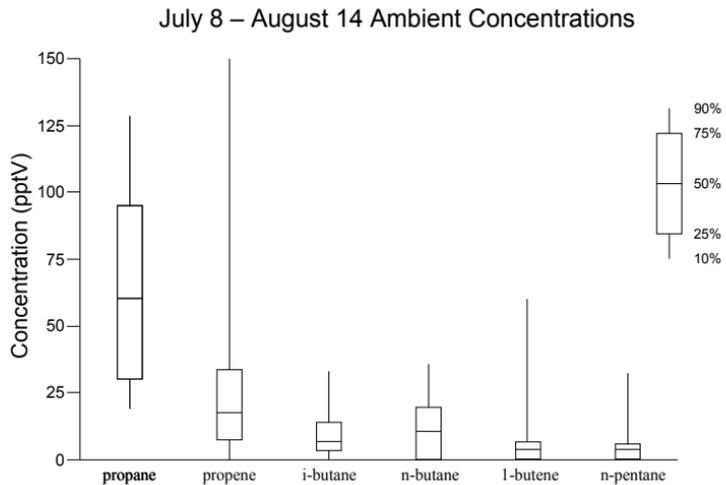
## 2001, 2003, 2004 including biomass-burning impacts



# Interannual variability in O<sub>3</sub>



# Summary statistics for some NMHCs



# Summary of key findings

- Clear enhancements (in CO, O<sub>3</sub>, nitrogen oxides, and black carbon) in U.S. outflow, but the large magnitude of O<sub>3</sub> enhancement not yet understood.
- Interannual variability in boreal forest fires has a large impact on CO, O<sub>3</sub>, and nitrogen oxides. During high-fire years:
  - Fire emissions are the main source of CO enhancements.
  - Fires have a similar or perhaps larger impact on O<sub>3</sub> enhancements than does U.S. outflow.
  - NO<sub>y</sub> and NO<sub>x</sub> are highly elevated, even in week-old fire plumes.

# Interests in collaborations

- For U.S. events (ICARTT period, past, and future): initial conditions over eastern U.S., relative to Pico.
- Modeling studies to evaluate U.S. outflow plumes.
- Comparisons of  $\text{NO}_y$  export in boundary layer (e.g., Chebogue Point) to lower FT  $\sim 5$  days later.