Airborne and Emissions Studies of Non-CO2 Climate Gases

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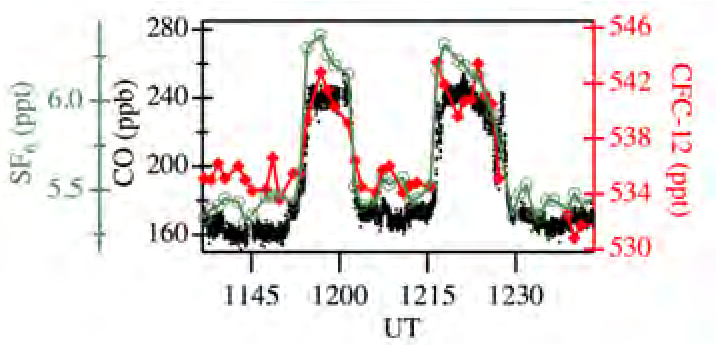
1. How large are the emissions of non-CO2 climate gases in different regions?

- Audits of larger-scale emission estimates (and banks)
- Identify sources and co-emissions
- Reveal seasonal and inter-annual differences in emissions

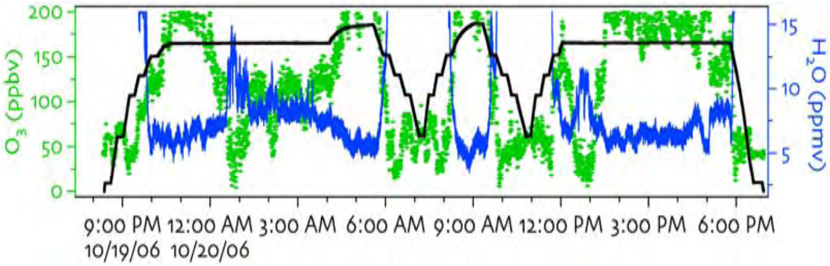
Emissions studies using aircraft and trains as measurement platforms



2. How are the distributions of non-CO2 climate gases influenced by dynamical processes in the upper atmosphere?

- Convective systems impact the tropical tropopause layer
- Stratosphere to troposphere exchange

High-altitude aircraft for in situ tracer measurements that identify and quantify dynamical processes (Ex-UTLS, TTL)



Trans-Siberian Observations Into the Chemistry of the Atmosphere (TROICA)

- NOAA ESRL and CU CIRES
- Institute of Atm. Physics, Russia
- Max Planck Institute, Germany

Hurst et al. (2004)

Motivations:

- In situ measurements of non-CO2 climate gases in a very under-sampled region of the world
- Inaugural large-scale study of the distributions of climate gases in Russia
- Develop collaboration between ESRL and Russian scientists

Post-Expedition Question *(based on WMO [2003])*

Are disproportionately large Russian emissions of CFC-11, CFC-113, CBrClF2 and CCl4 the reason their inventory-based global emission estimates are 30-60% less than their burden-based global emission estimates?

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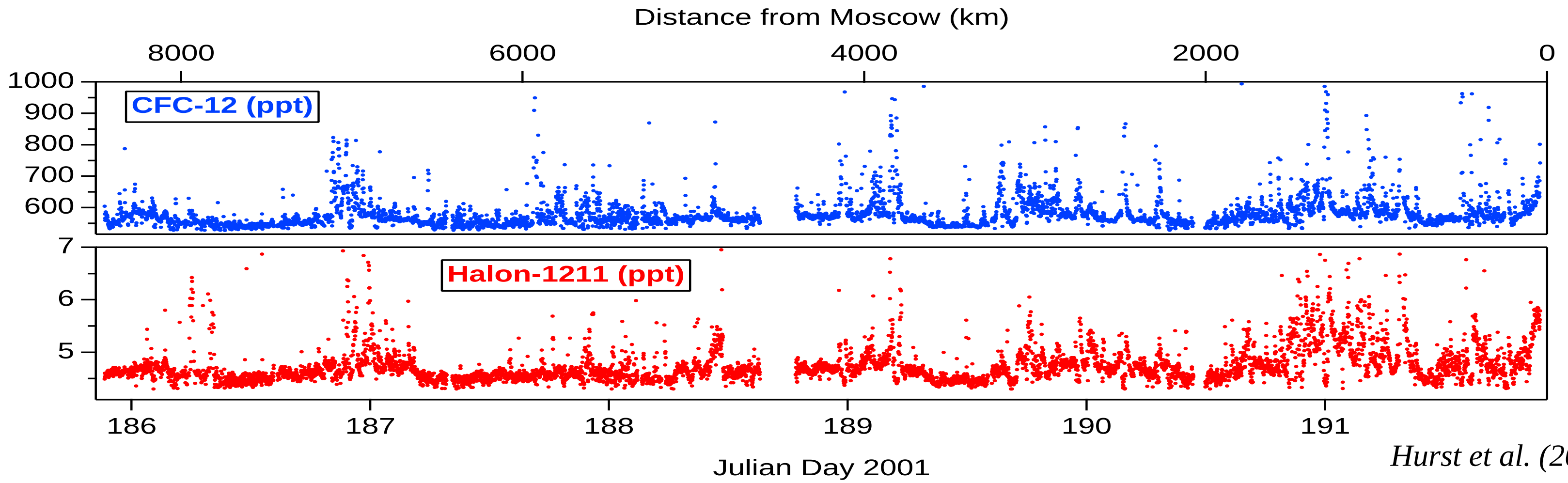
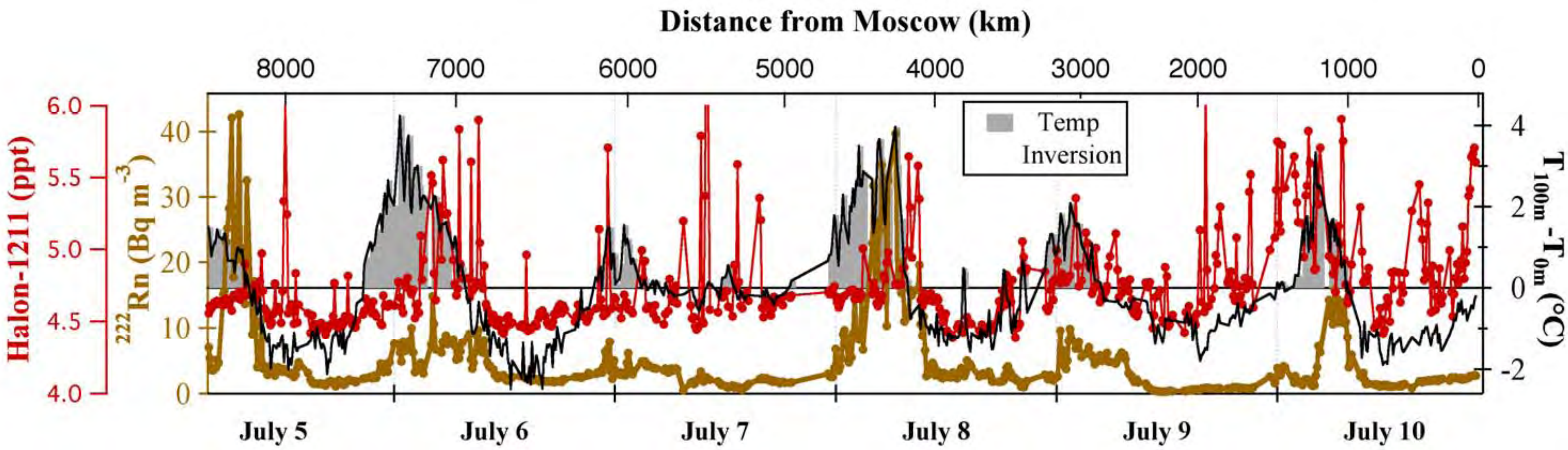


Hurst et al. (2004)

Trans-Siberian Observations Into the Chemistry of the Atmosphere (TROICA)

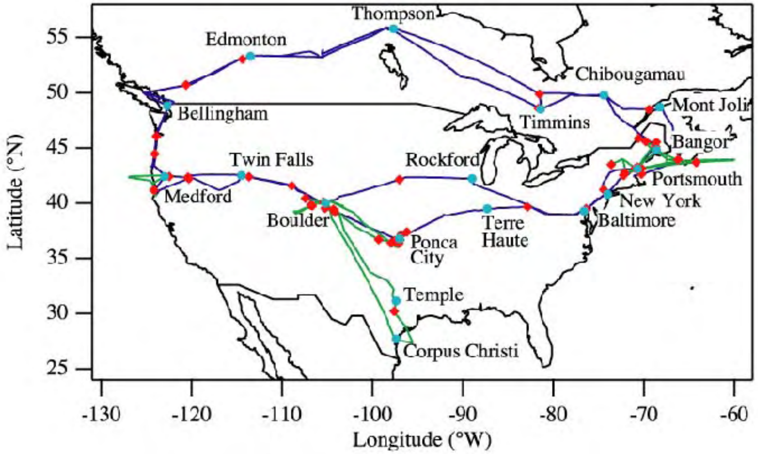


2001 Emissions (Gg)		
	Russia *Hurst et al. (2004)*	Global *WMO (2007)*
CFC-11	1.2	82
CFC-113	0.8	12
$CBrClF_2$	1.1	8.7
CCl_4	0.6	65

<u>Conclusion</u>

Russian emissions of these halocarbons could **not** account for the 30-60% shortfalls in their inventory-based global emission estimates

2003 COBRA-North America



- NOAA ESRL and CU CIRES
- Harvard University
- University of North Dakota
- NCAR

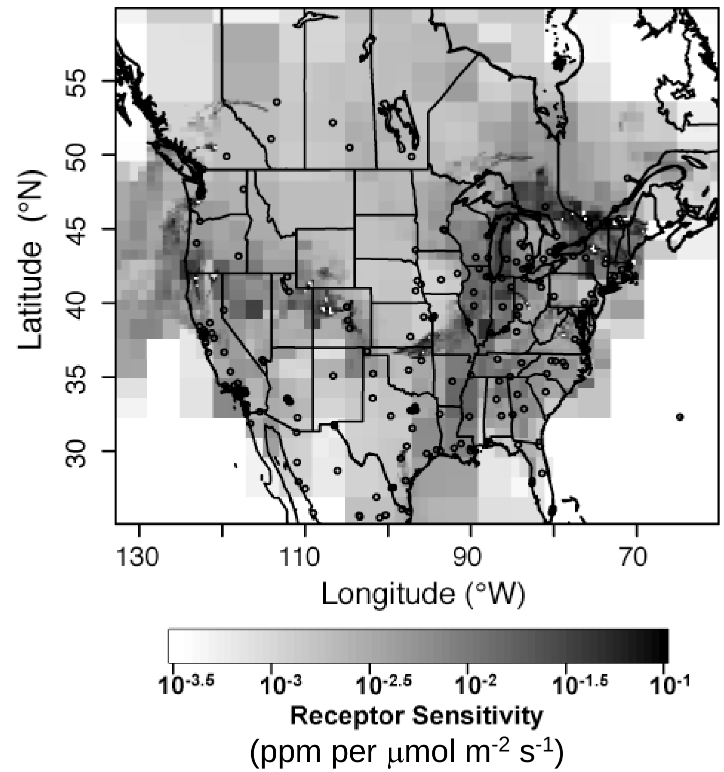
Hurst et al. (2006)

Motivation:

- In situ measurements of non-CO2 climate gases over a large extent of the USA & Canada
- Quality of emission estimates increased by high-quality USA emission inventories for CO

Questions:

- Are there regional differences in the emissions of climate gases?
- Are N. American emissions of halocarbons still significant on the global scale?
- Is the global CFC-12 bank truly exhausted?



2003 COBRA-North America

2003 Emissions	USA+CAN *Hurst et al. (2006)*	Global *WMO (2003)*
CFC-11	8 ± 3	71
CFC-12	16 ± 4	92
CFC-113	2 ± 1	4
CH_3CCl_3	4 ± 1	39
$CBrClF_2$	0.5 ± 0.2	7
CCl_4	-0.1 ± 0.7	64

Unrealistic!

	ΔBank (2015) +	ΔEmissions (2002-2015)	
CFC-11	1026 Gg +	109 Gg	= **1135 Gg**
CFC-12	280 Gg +	275 Gg	= **555 Gg**

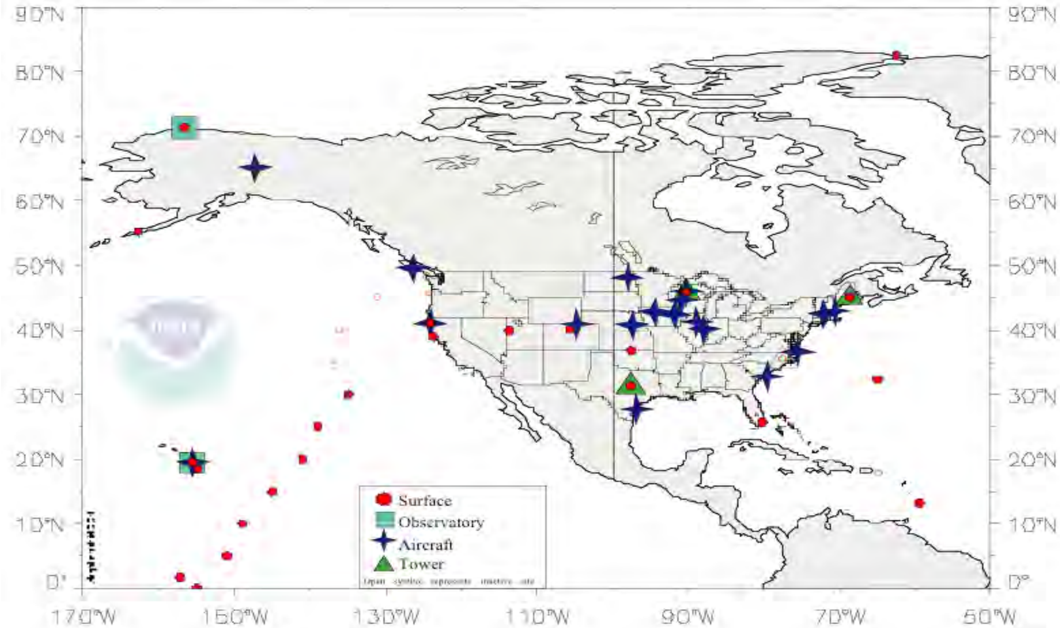
Impacts of Increased Emissions Projections

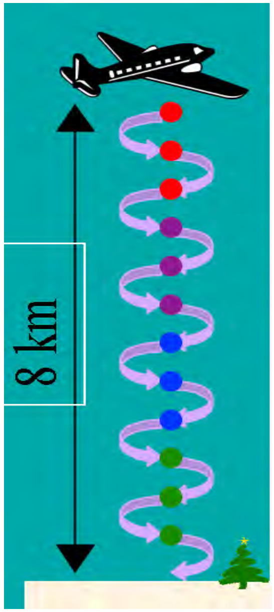
ΔEESC: +165 ppt (6-7 yr delay in O_3 recovery)

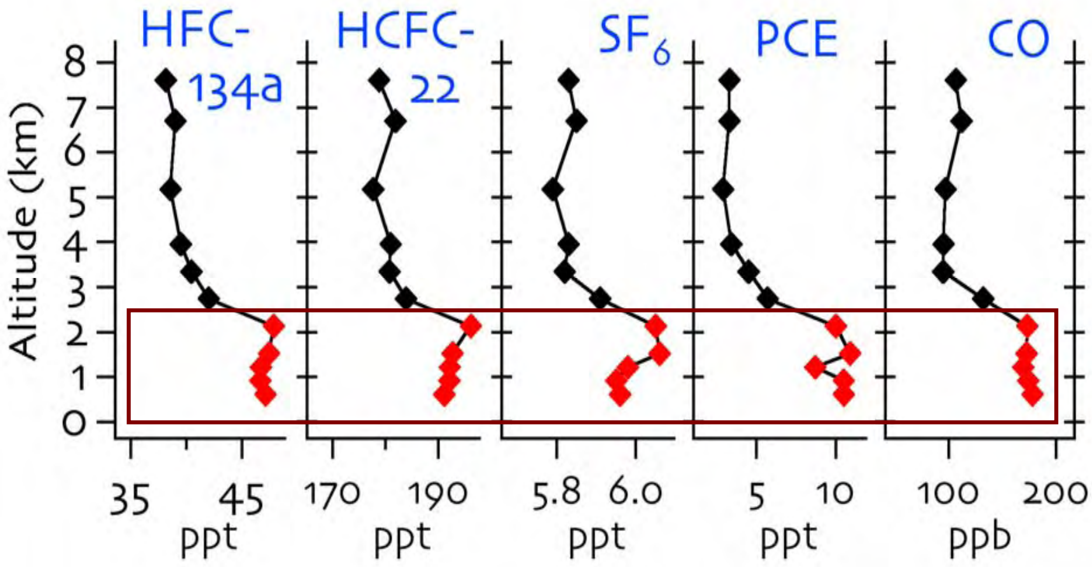
ΔRadiative Forcing: +0.02 W m^{-2} (*eq* CO_2 +1.3 ppm)

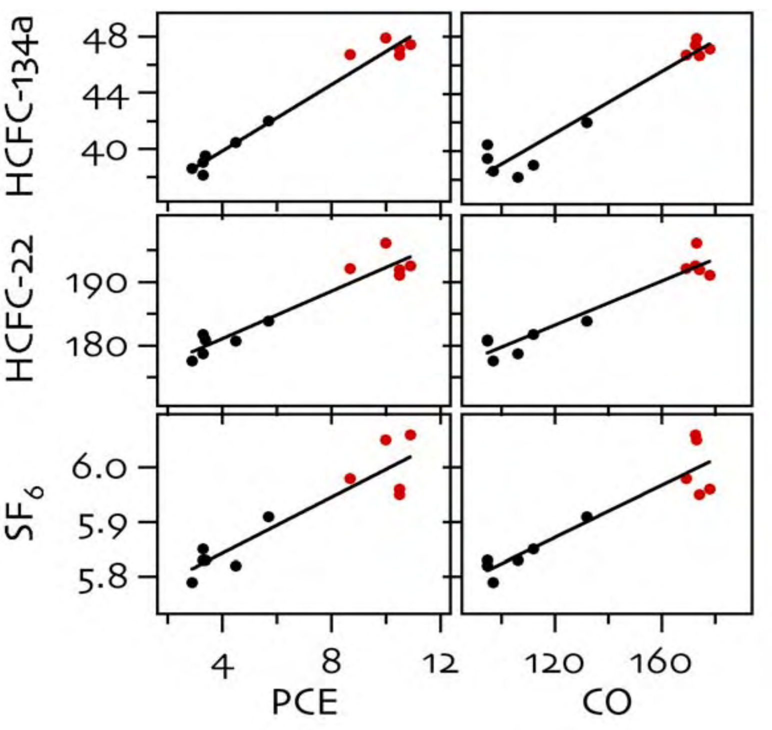
Regional-scale emissions studies like COBRA-NA and TROICA provide critical "spot" checks of global estimates of emissions and banks.

Aircraft-Based Flask Sampling over North America









NASA - NOAA ESRL
Collaborative Airborne Projects

ER-2
(ACATS)
1989-2000

Balloon
(LACE)
1996-2004

WB-57
(LACE, PANTHER)
1999 -

Motivation

Accurate model representations of transport and chemistry are prerequisite to meaningful projections of climate change and stratospheric ozone depletion

Our Objective

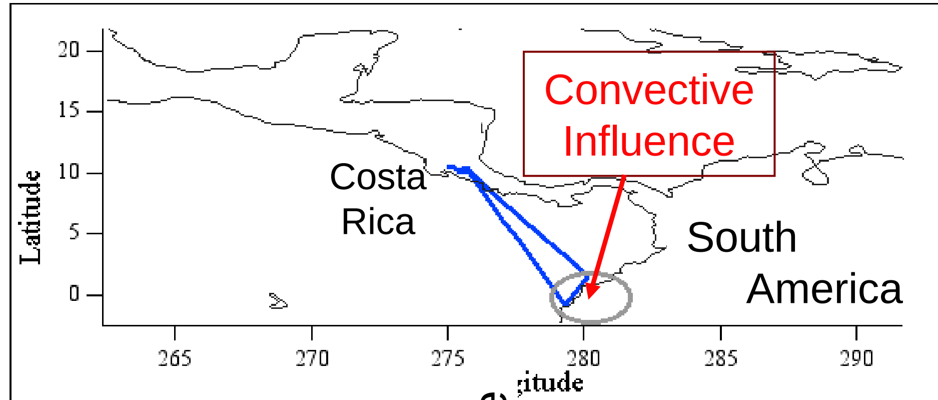
Make high-quality tracer measurements to identify and quantify important chemical and dynamical processes in the upper atmosphere

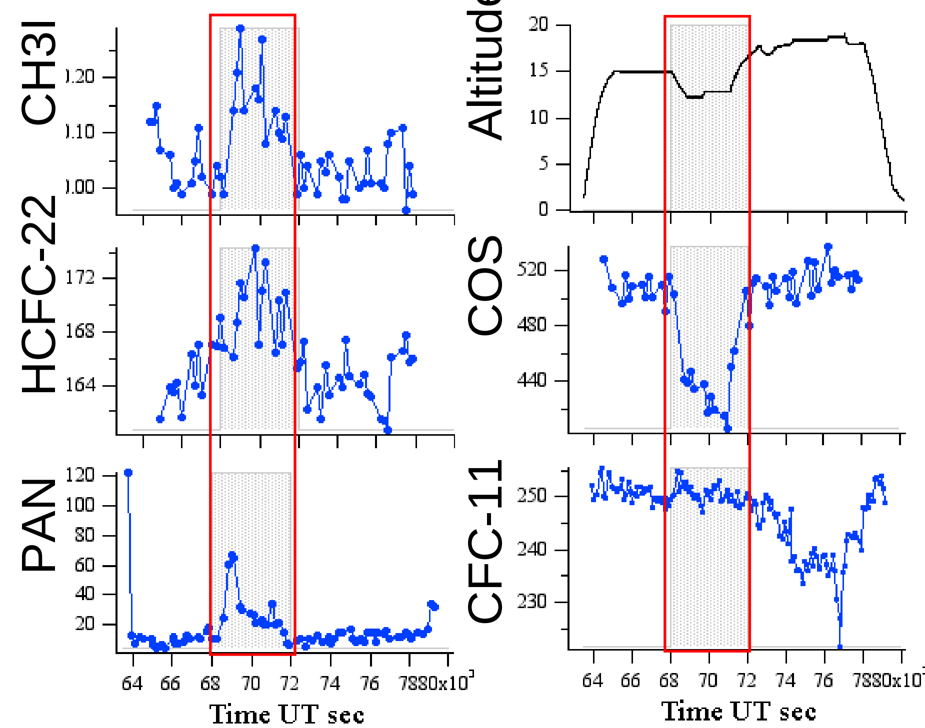
Accomplishments

- Stratospheric lifetimes of climate gases
- Stratospheric mean ages (SF6)
- Entrainment/detrainment rates (tropical pipe)
- Transport into the lowermost stratosphere
- Descent and mixing in N. polar vortex

Recent Work January 2006
CR-AVE: Investigation of the TTL

PANTHER measurements





Unmanned Aircraft Systems (UAS)

2005 UAS Flight Demonstration Project
2006 NASA/USDA-Forest Service Fire Mission

- Tropopause anomalies can bring O3-rich stratospheric air into the troposphere
- Important source of tropospheric O3
- How will this source be altered by a changing climate?

UAS advantage

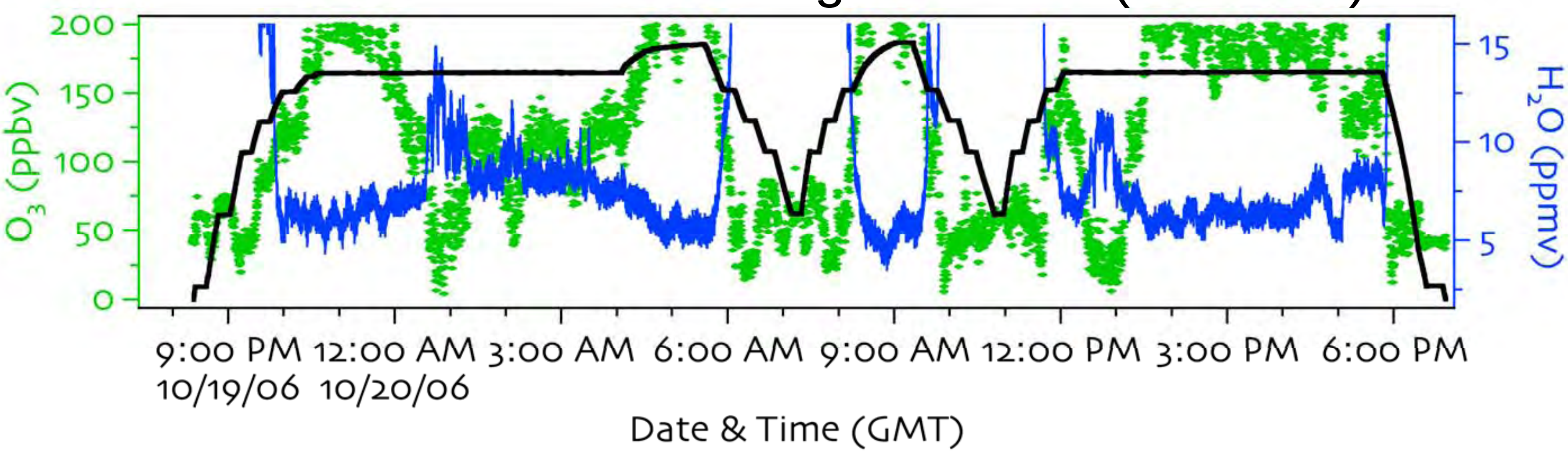
Endurance (>24 hours)

- Can target, re-target flight objectives *w/ feedback from earlier measurements!*

Motivation and Question:

- Determine UAS suitability for NOAA's needs
- Demonstrate reliability and safety
- What advantages are gained using UAS ?

UCATS Data: Altair Flight 061019 (23 hours)



Summary

Mobile-platform emission studies of non-CO2 climate gases

- Emissions "missing" from inventory-based global estimates (select halocarbons): <u>not in Russia</u>
- North American CFC-12 emissions in 2003 dismiss the reported exhaustion of global CFC-12 bank
- Ongoing monitoring of North American emissions of climate gases with routine vertical profiles

High altitude airborne measurements of non-CO2 climate gases

- Have advanced our knowledge of many chemical and dynamical processes
- Most recent investigations:
  - Influence of convective activity on TTL composition
  - Stratosphere-troposphere exchanges (tropospheric ozone)
- Demonstrated the utility of UAS in studies of the mid-latitude UTLS
  - Shows promise for monitoring of changes in UTLS processes like STE