What Science Have We Learned from Our Combined Airborne and Ground-based Measurements of HATS Gases?

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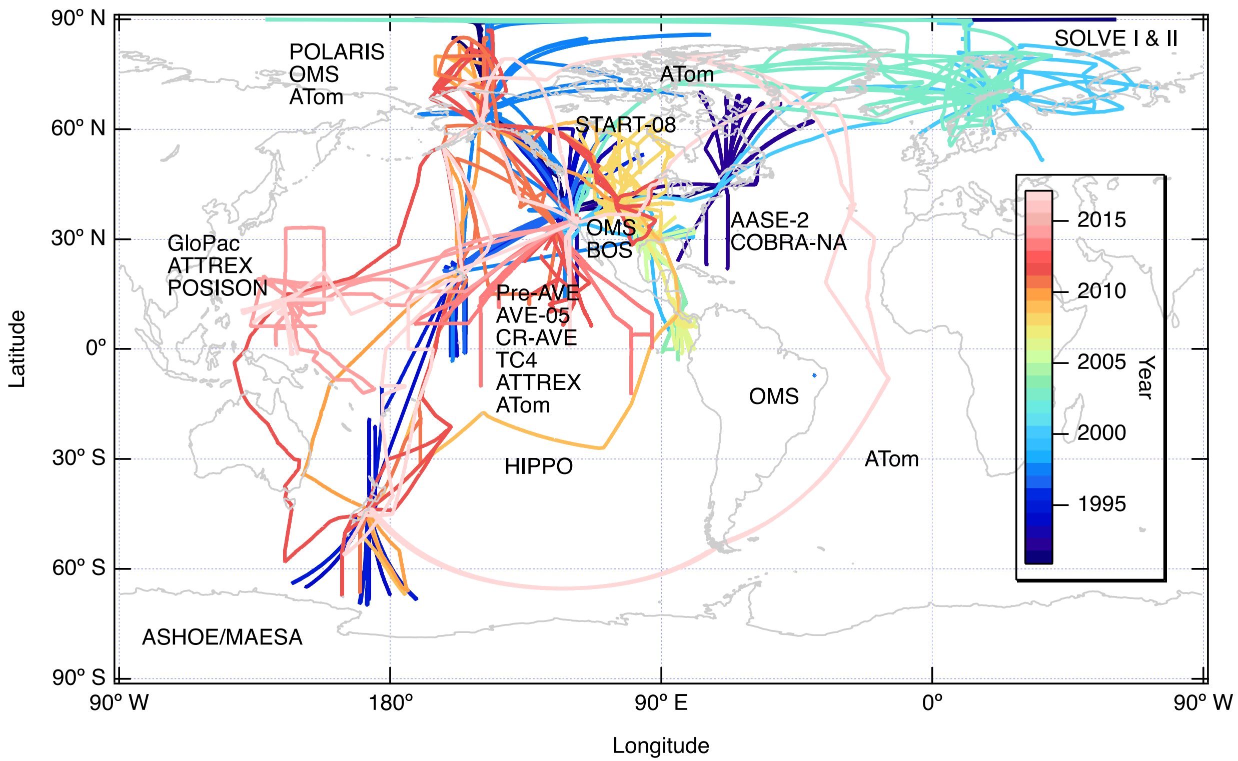
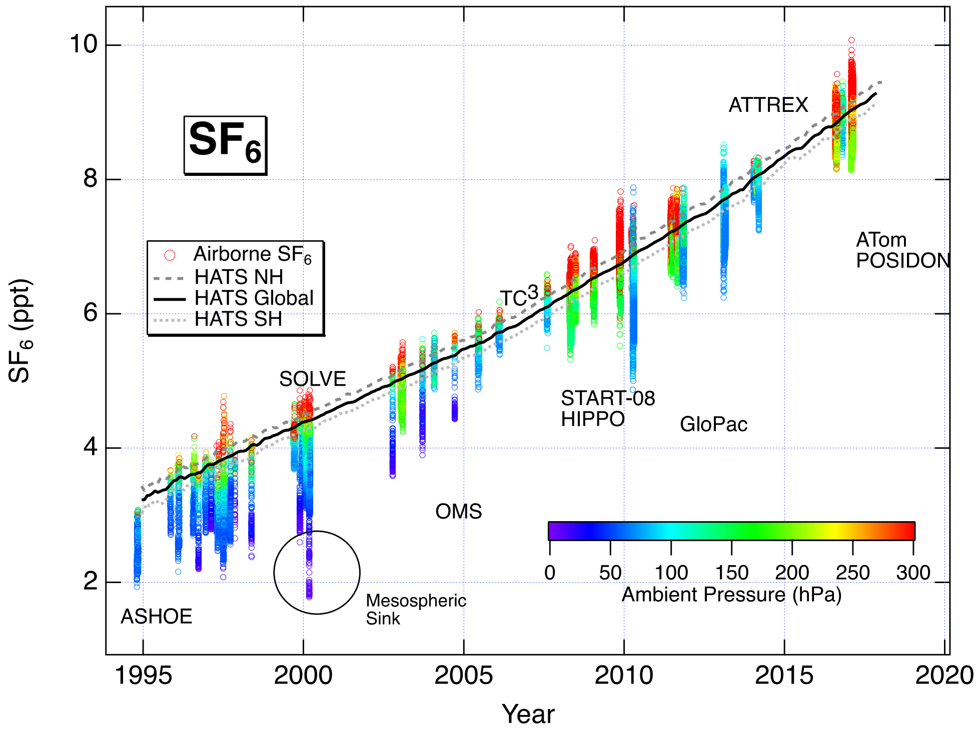
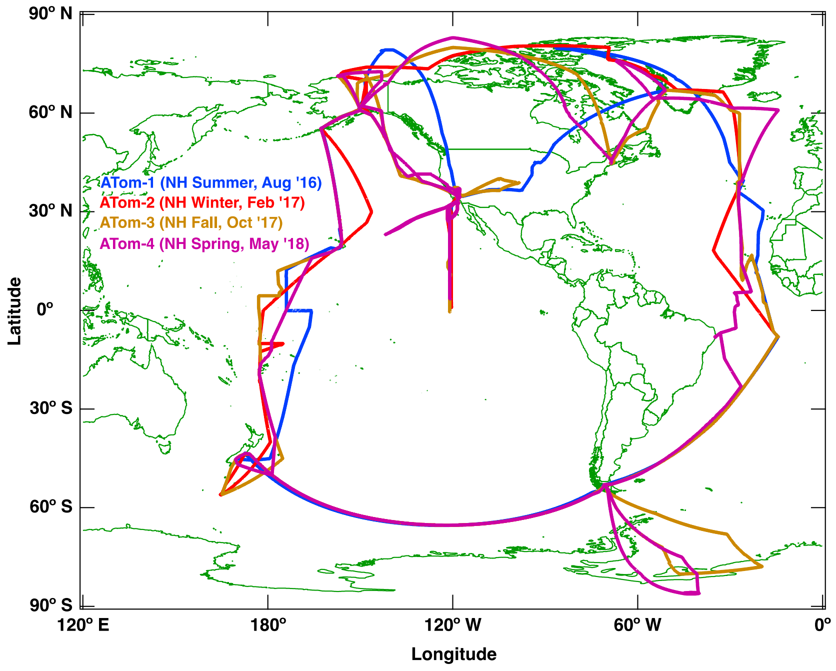
Airborne Missions and Measurements & SF_6

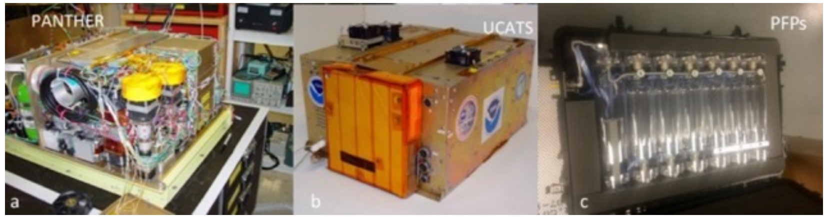




- Missions started in 1991 for regional polar O_3 loss research studies, covered Pacific ocean, moved to CFC replacements and shorter lived trace gases with PANTHER, UAS Altair and Global Hawk, and global GHG & chemistry studies.
- SF_6 added in 1994, identified SF_6 mesospheric sink (3200 yr to 850 yr lifetime). Started atmospheric transport studies.

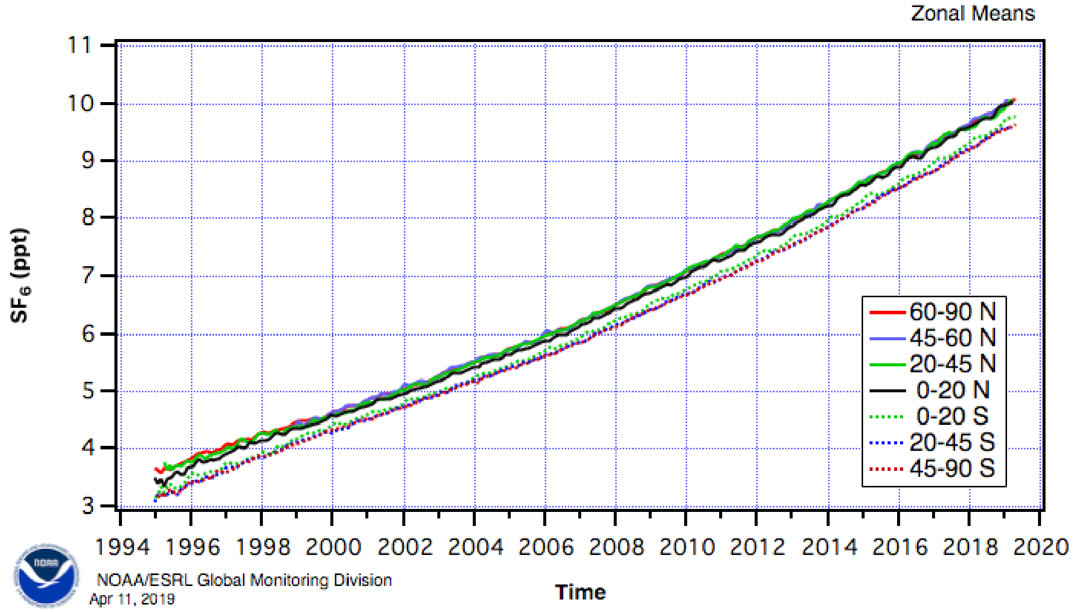
An Example from Tropospheric Seasonal Survery: Measurement of SF_6 on ATmospheric Tomography Mission (Atom)

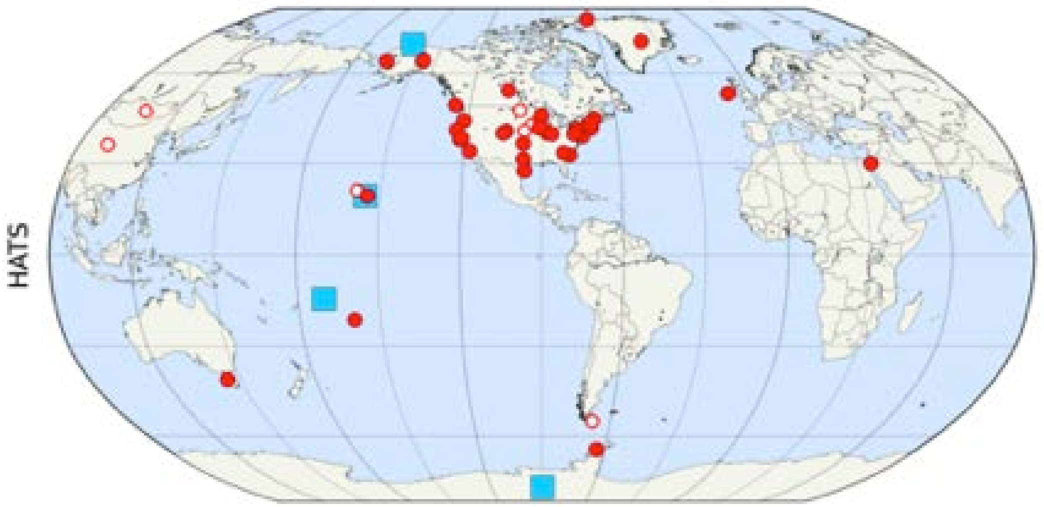




- **ATom had 11-13 flights per circuit (ATom 1-4), 4-9 vertical profiles per flight.**
- Three airborne GMD instruments (**PANTHER, UCATS, and PFPs**) used GC-ECD and the WMO CCL standard scale on all circuits.
- **PANTHER and UCATS** measured SF_6 once every 70 seconds and not in sync. Twice the data! Total **~7700 obs./circuit.**
- **PFP** typically had 1-2 twelve flask packages per flight. **~220 obs./circuit.**

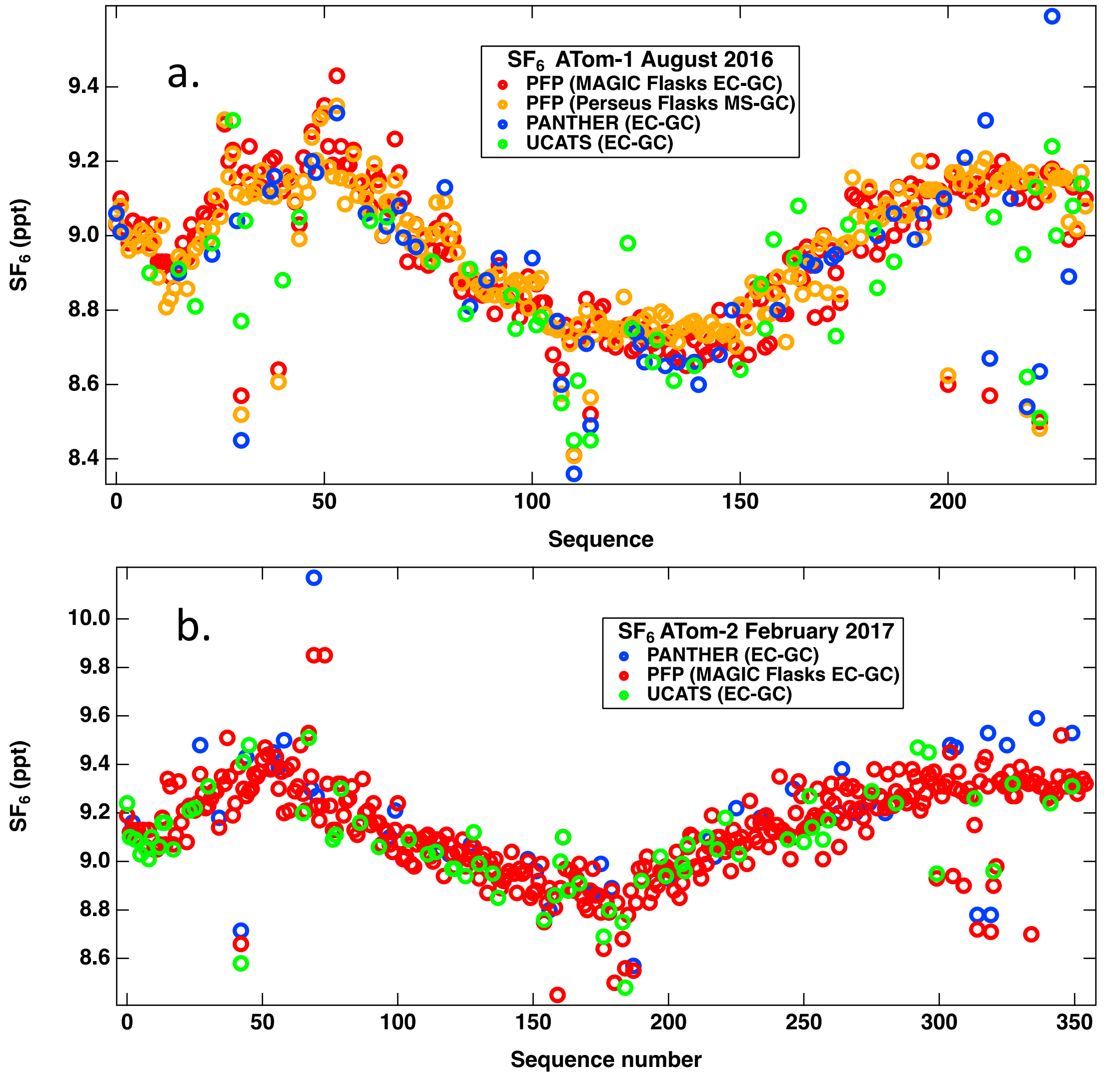
Using SF_6 as a Tropospheric Clock





- NOAA GMD ground based network measured SF_6 since 1995 from 3.5 to >10 ppt globally.
- Growth rate over the past 5 years was 0.32 ppt yr^{-1}. Strong N-S gradient. Has lifetime of 850 yr. Great atmospheric clock!
- Used in the electric power distribution, large growth in usage in East Asia.
- Emitted mainly from 30 to 60° N.
- Used to show stratospheric delay of peak EESC of 3 years in midlatitudes and 5 years in polar regions for stratospheric ozone depletion.
- First proposed by D. Waugh as a tropospheric age of the air mass from polluted NH regions. Extremely useful for long term greenhouse and ozone depleting gases.

Comparisons of multiple NOAA instruments for SF_6

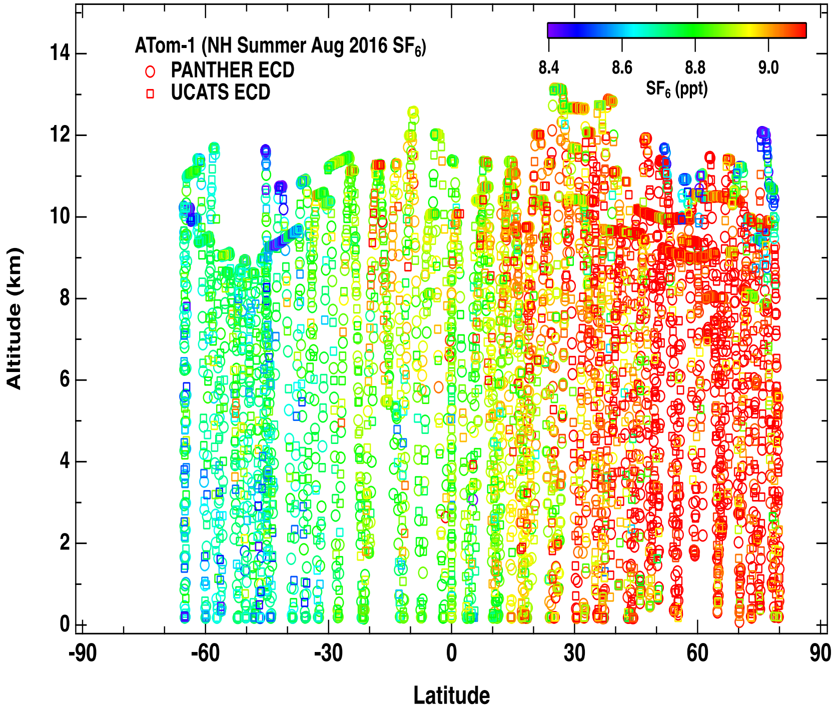


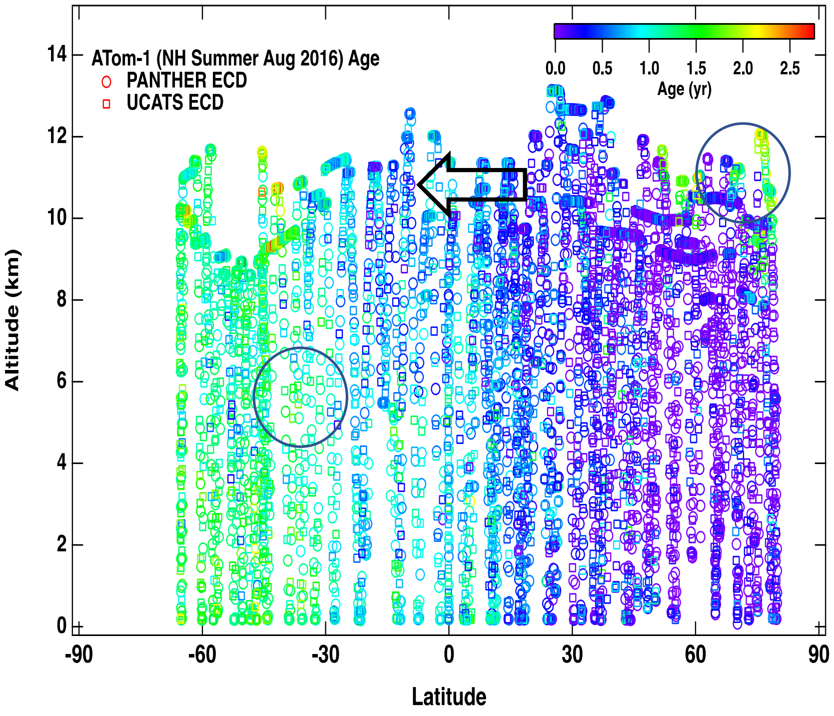
- Two separate instruments, MAGIC EC-GC & Perseus MS-GC, in our Boulder lab measured the same PFPs for SF_6 for ATom-1 (**a**) to within ±0.05 ppt (±2 mon).
- Perseus MS-GC was dropped after ATom-2, because of work load issues at NOAA.
- Two airborne GCs measured within ±0.08 ppt (±3 mon) for both circuits but includes atmospheric variability and instrumental precision (**b**).
- Results give us encouragement for combining sets, but differences do exist between circuits.
- Created large data combining the two airborne GCs (UCATS & PANTHER).

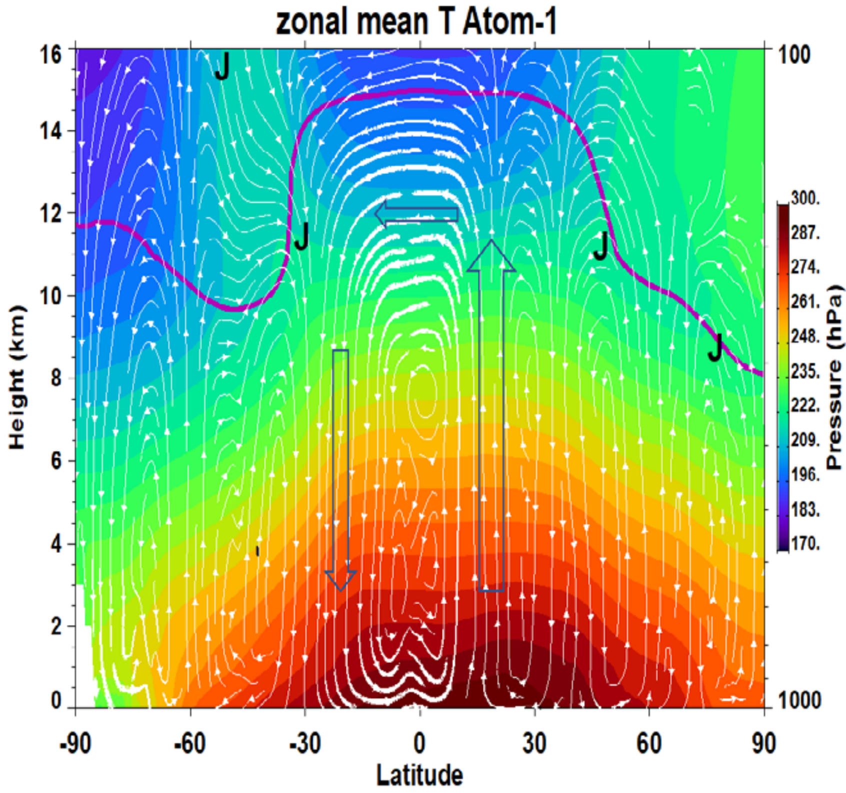
NH Summer (Aug. 2016): SF_6, age, met fields

Older air: Stratosphere

IH Exchange ~1.2 yr





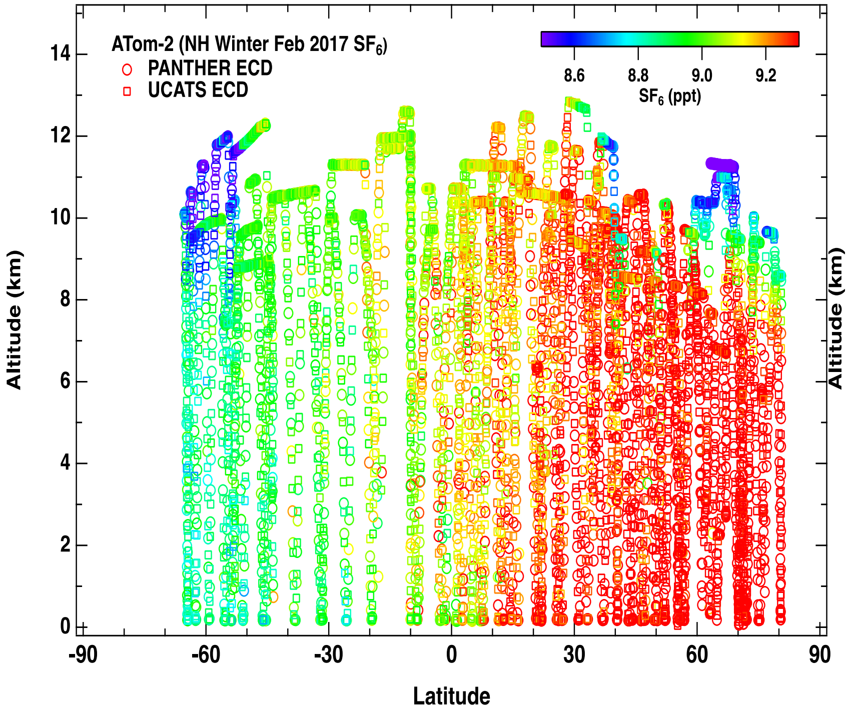


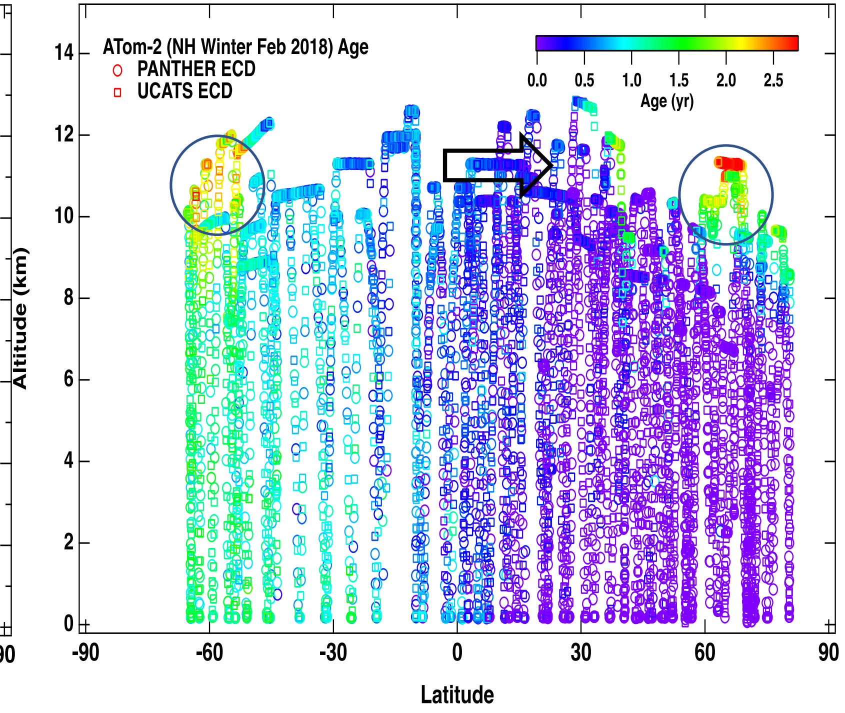
Over the top exchange

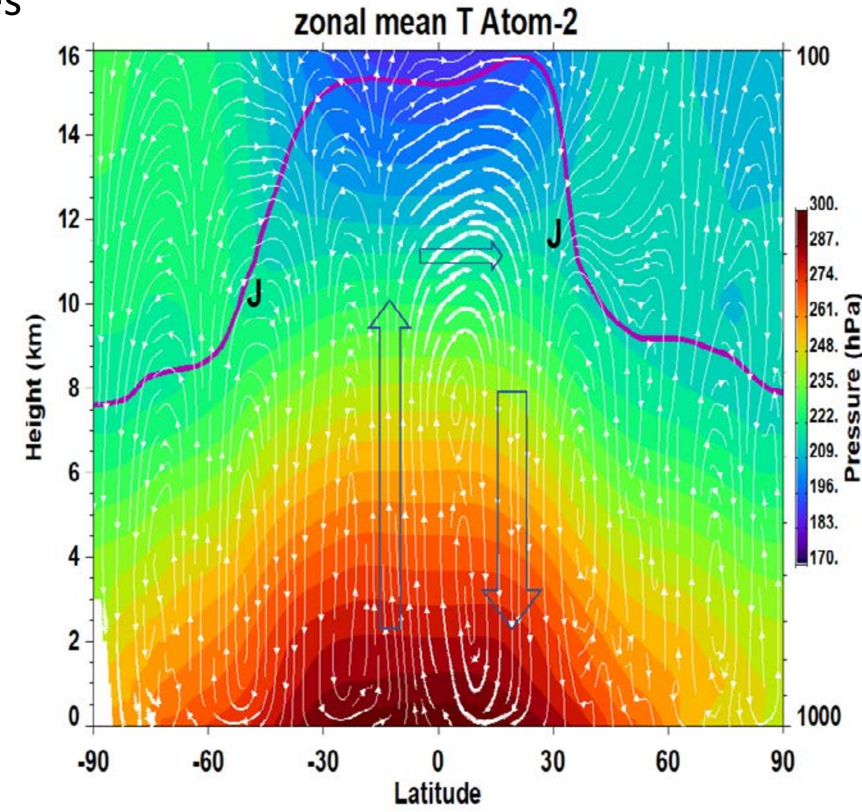
ATom-1

NH Winter (Feb. 2017): SF_6, age, met fields

Older air stratosphere in both hemispheres







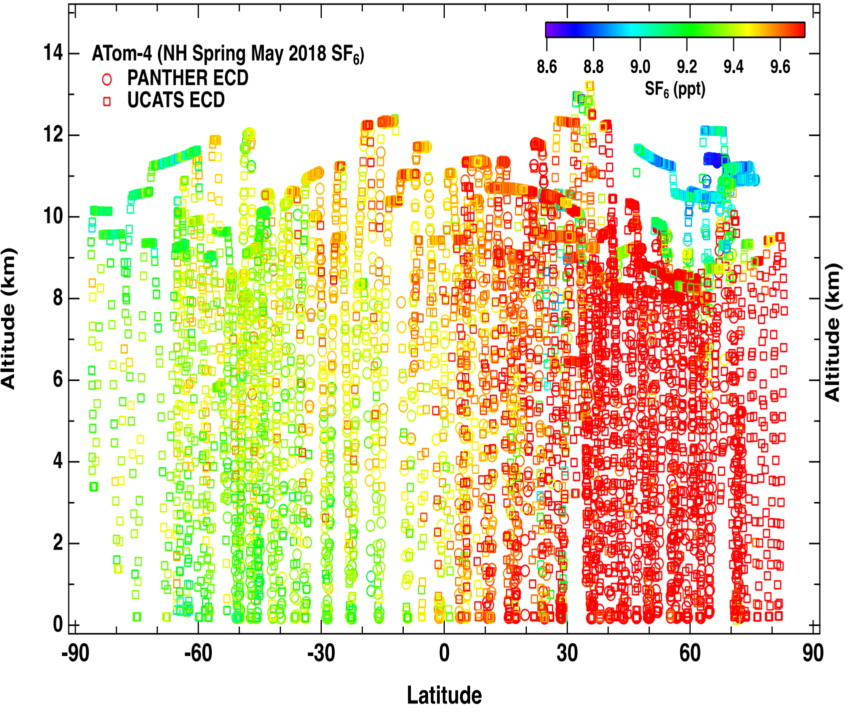
Young SH air moves to NH

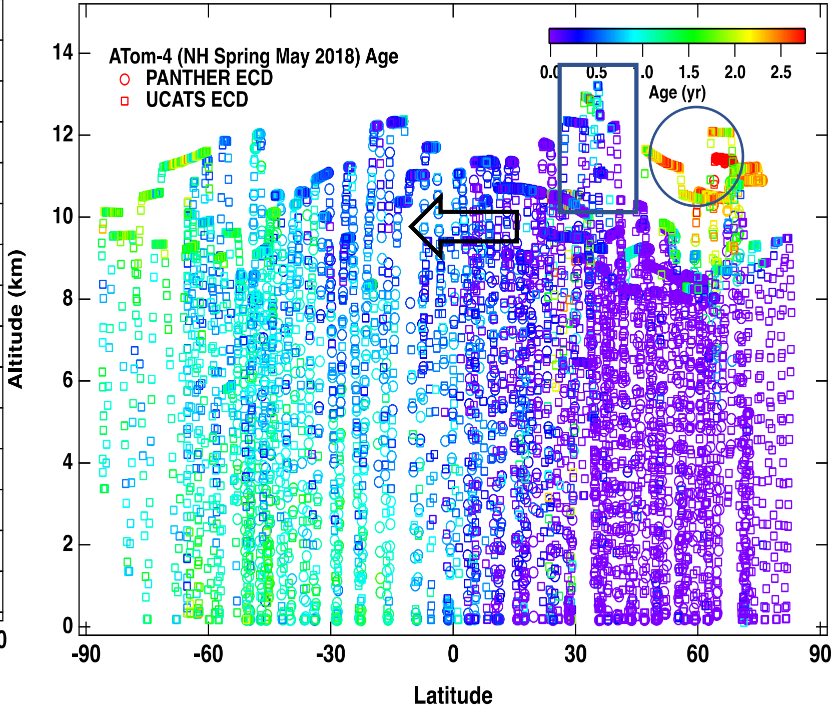
ATom-2

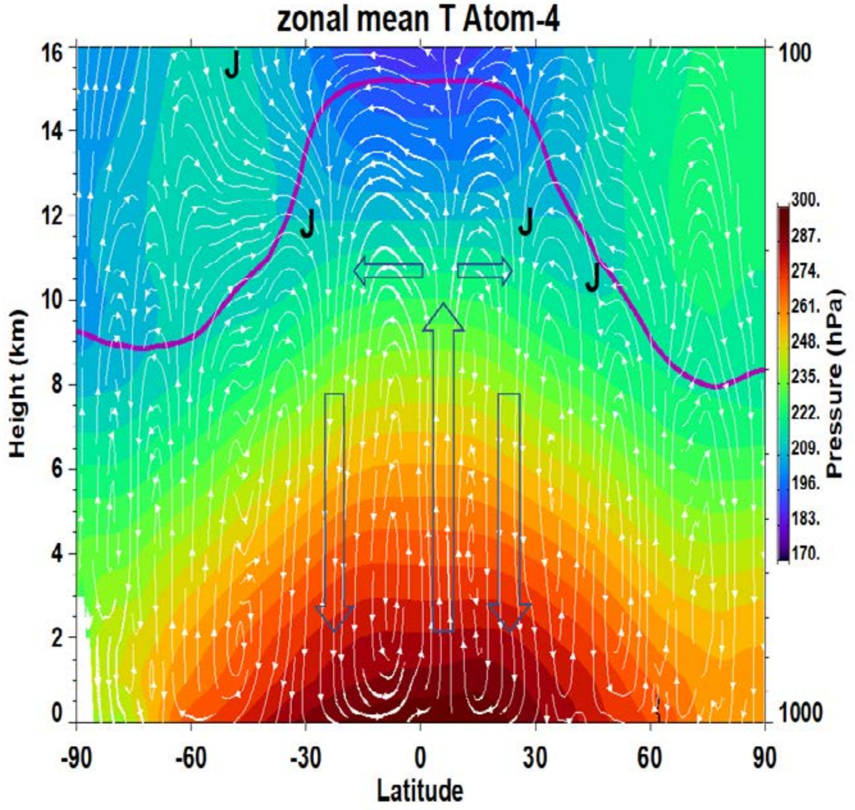
NH Spring (May 2018): SF_6, age, met fields

Older air: Stratospheric

Stratospheric fold





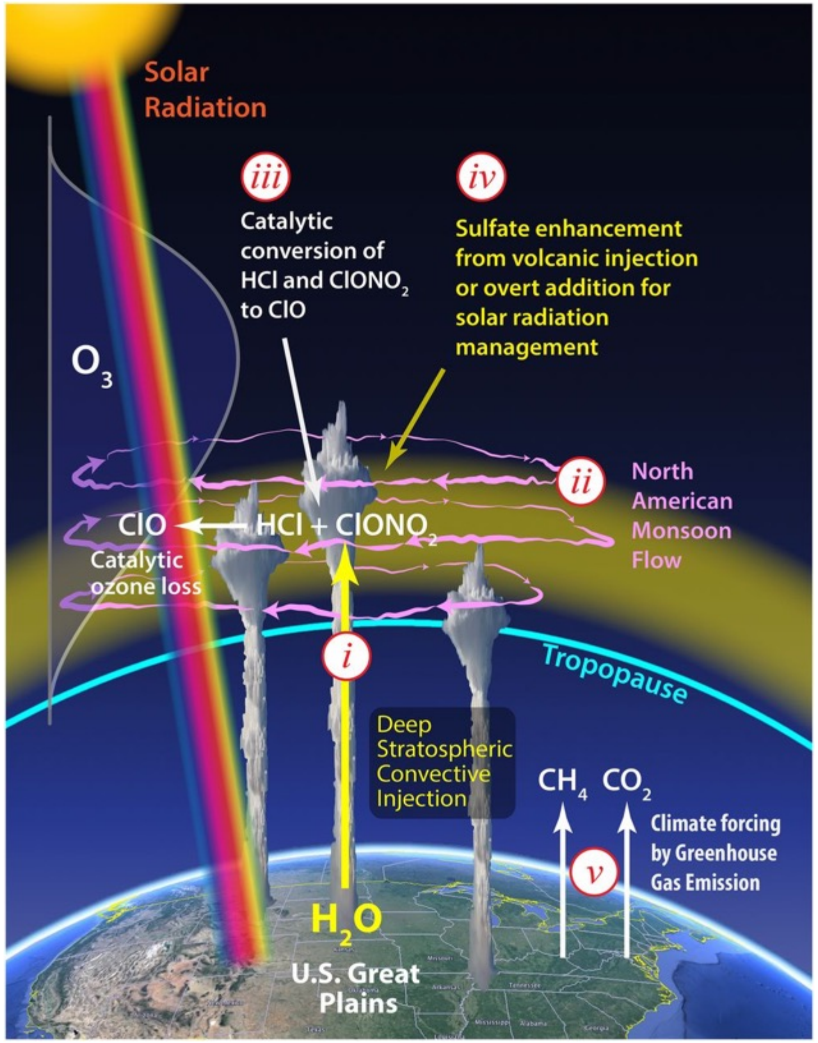


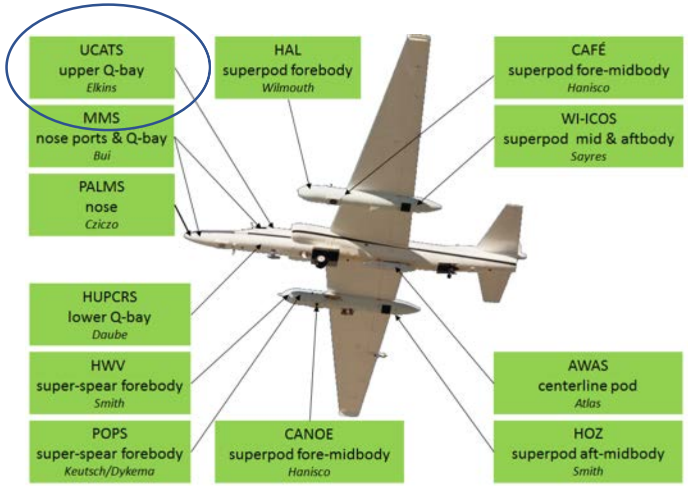
Over the top exchange

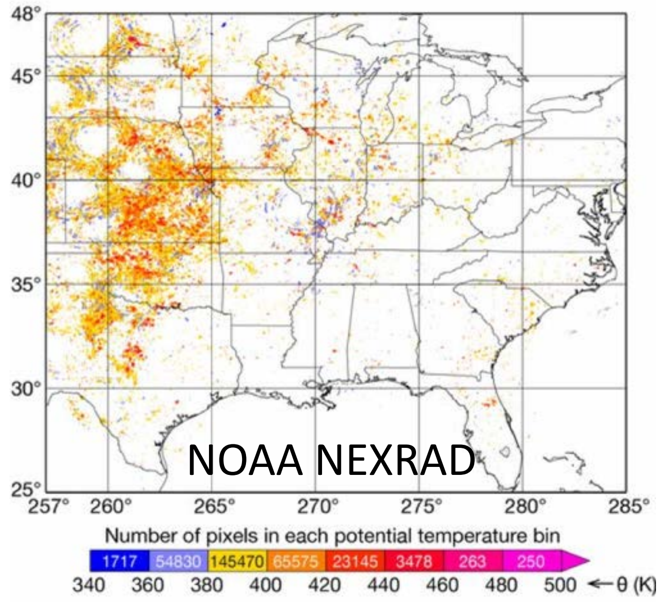
ATom-4

Dynamics & Chemistry in the Summertime Stratosphere (DCOTSS) (2019-2025)

- Deep convective injection of H_2O-rich air above tropopause with O_3 loss from catalytic loss halogens in sulfate from volcanos or geoengineering where NA monsoon contains chemistry for a week or more during a period of increasing climate forcing by GHGs.
- Over 19,000 storms between 2004 & 2013 above tropopause (390K).
- UCATS measures H_2O & O_3, and add a 3rd channel for CCl_4 and short lived halocarbons in the upper Q-bay of NASA ER-2. Provides N_2O vs O_3 for ozone loss calculations, and total inorganic bromine and chlorine estimates from UCATS 70 sec and flasks from WAS (E. Atlas, U Miami & E. Apel, NCAR)







Summary of Talk

- Our airborne program and ground based programs have been complementary, benefiting each other for science.
- SF_6 as a ”tropospheric clock” between source region and SH and stratosphere.
- SF_6 and age of polluted NH air show circulation in the tropics (Hadley cell) and stratospheric exchange in the polar regions.
- Future mission for ozone loss in NA monsoon preparing for sulfate additions by volcanos or geoengineering.


DC-8 Off Greenland and open waters

HATS network data available at ftp://ftp.cmdl.noaa.gov/hats
All Atom data are available publicly at the NASA ORNL DAAC https://daac.ornl.gov/ATOM/campaign/

Questions

- We acknowledge our sources of airborne research funding.

It takes a "community" for an airborne mission—NASA DC-8 ATom-4