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


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• Missions started in 1991 for regional polar O₃ 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.
• SF₆ added in 1994, identified SF₆ mesospheric sink (3200 yr to 850 yr lifetime). Started atmospheric transport studies.
An Example from Tropospheric Seasonal Survey: 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 $\sim$7700 obs./circuit.
- PFP typically had 1-2 twelve flask packages per flight. $\sim$220 obs./circuit.
Using SF$_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

IH Exchange $\sim$1.2 yr

Older air: Stratosphere

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$_2$O-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$_2$O & 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$_2$O 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.

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