Introducing EXC³ITE: Exploring stratospheric composition, chemistry and circulation with innovative techniques

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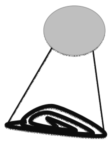
WHY?

- Significant stratospheric chemistry and circulation changes and feedbacks are to be expected from both ozone losses and global warming.
- Models predict an increase in the strength of the stratospheric mean meridional circulation[1] (the Brewer-Dobson circulation, BDC), although substantial uncertainties still surround our understanding of changes in this region.
- Changes to the BDC would have an impact on chemical processes in the stratosphere, notably altering the removal of ozone depleting substances (ODSs).
- Previous studies have been limited:
  - Sampling is expensive → patchy temporal and seasonal coverage.
  - Satellites often lack precision and vertical resolution; require validation; and can only quantify a few species.

WP1: BETTER STRATOSPHERIC OBSERVATIONS THROUGH NEW AIRCORE TECHNOLOGY

Aircores[2]: Long (up to 100 m), thin stainless steel tubes, closed at one end. The tube evacuates during ascent as it equilibrates to low ambient pressure and fills on descent–collecting a vertical profile of the atmosphere.



Launched via small balloon (payload < 3 kg) Aircores can ascend to >30 km.

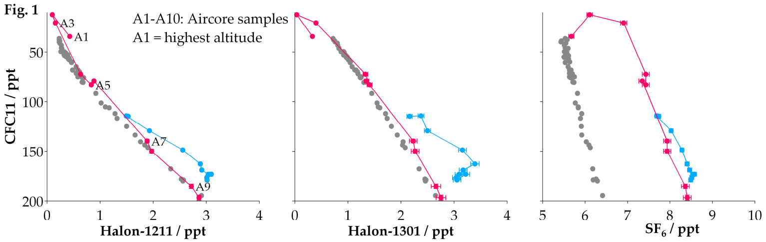
Flights: At least 45 flights over 9 campaigns:
- test campaign,
- 8 campaigns over 2 years, sampling each season twice.

Sampling will hopefully include joint campaigns with partners measuring key greenhouse gases such as N_2O, CO_2 and CH_4.

Analysis: State of the art analysis via UEA's highly sensitive (detection limits of 0.01-0.1 ppt in 10 ml of air) gas chromatography mass spectrometry system which has the capability of measuring > 30 atmospherically important species.

PRELIMINARY RESULTS

Several Aircore deployments have already been made (by [b, c, d]) and the samples analysed at UEA. Fig. 1 shows a subset of results for deployments in March (●) and (●) April 2016 compared to measurements from [3] (●). The March Aircore sampled closer to the UTLS, whilst the April profile shows measurements extending deep into the stratosphere.



Precisions (calculated from replicate analyses of a standard across a day, error bars on Fig. 1) as low as 0.56% (SF_6, March) were achieved, and will hopefully be improved upon with the development of an automated sample pre-concentration system in the coming months.

EXTRA BENEFITS

1. Observations of ODSs not controlled by the Montreal Protocol but currently increasing in the atmosphere, e.g. short-lived chlorocarbons.
2. Observations of HFCs and PFCs – strong greenhouse gases with high global warming potentials for which we have a poor understanding of their stratospheric distributions.
3. Crucial calibrations and validations of satellite instruments.

WP2: USING IMPROVED AGE OF AIR SPECTRA TO DIAGNOSE CIRCULATION CHANGES

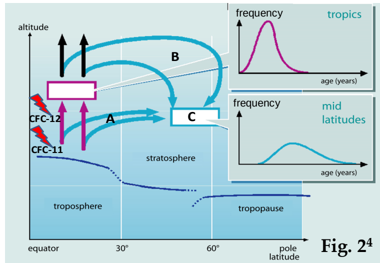


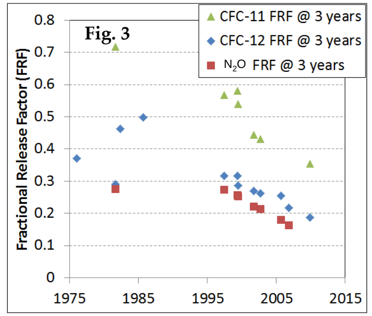
Fig. 2[4]

The age of any stratospheric air sample can be described by a probability distribution function (Fig. 1) with the mean age of air representing the average transport time in the stratosphere. **Altering stratospheric dynamics may alter transport times and therefore observed mean ages are also likely to change.**

We will conduct high precision analysis of > 300 samples historical (1975-2012) stratospheric samples for > 50 compounds.

We will use up to 18 long-lived halocarbon tracers to refine our understanding of age spectra and to help diagnose stratospheric circulation changes.

WP3: USING FRACTIONAL RELEASE FACTORS (FRFS) TO DIAGNOSE STRATOSPHERIC CHEMISTRY CHANGES



FRFs tell us the degree of decomposition of a halocarbon at a particular point and time. The relationship between mean age and FRF should be constant…unless transport pathways or stratospheric chemistry processes change.

Preliminary work at UEA is already showing changes in the relationship between FRFs and mean air over time - **by over 40 % between 1997 and 2009 alone** - evidence for substantial past stratospheric changes (Fig. 3).

WP4: MODEL COMPARISONS AND ASSESSMENT OF FUTURE IMPACTS

(1) Combining age spectra and FRFs from WP2&3 to update ozone depletion potentials for key gases.

(2) Comparing these values with those derived from recent chemistry-climate model runs.

Quantification of the differences between (1) and (2) to help improve future model analyses.

REFERENCES

[1] Austin & Li (2006) doi:10.1029/2006GL026867; [2] Karion et al. (2010) doi:10.1175/2010JTECHA1448; [3] Laube et al. (2013) doi:10.5194/acp-13-2779-2013; [4] adapted from Schmidt et al. (2001) Forschung Frankfurt, 11-19

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