National Aeronautics and Space Administration

Mid-IR Solar Occultation Spectrometry from Balloons

Trace Gas Measurements from the MkIV Balloon-borne FTS

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Introduction

The JPL MkIV interferometer is a Fourier Transform Spectrometer that measures the composition of the Earth's atmosphere by solar occultation spectrometry. The MkIV has completed 21 balloon flights since 1989, each measuring profiles of 30+ trace gases simultaneously, with high accuracy and vertical resolution.

In this presentation, we show results from 18 years of MkIV measurements. Although these measurements are very sparse, we show that, by careful use of tracers (e.g. N_2O), dynamical variations can be largely eliminated allowing useful trend information to be discerned. Results are shown for HCl, HF, CFCs, HCN, CH_4 and H_2O at various N_2O isopleths in the stratosphere and upper troposphere.

We also use MkIV data for non-coincident validation of the Atmospheric Chemistry Experiment (ACE), a spaceborne occultation FTS very similar to MkIV.

The MkIV Balloon Interferometer

The JPL MkIV Interferometer is a Fourier Transform Infra-Red (FTIR) Spectrometer, designed and built at the Jet Propulsion Laboratory, to remotely sense the composition of the Earth's atmosphere by the technique of solar absorption spectrometry. Its design was based on that of the ATMOS instrument.

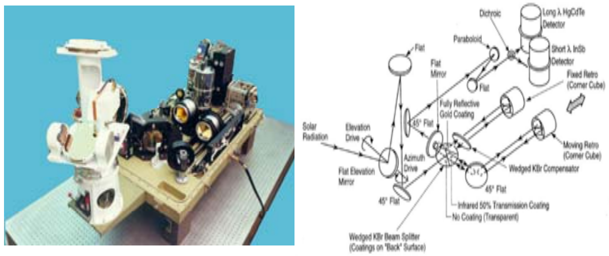

Figure 1. The JPL MkIV Interferometer: Photograph and Optics Diagram

The MkIV Balloon Flights

The JPL MkIV interferometer has performed 21 balloon flights since 1989. Flights are 6-30 hours duration depending on float winds and provide one or two occultation events covering altitudes from the PBL or cloud tops to the balloon (35-40 km) at 2-3 km vertical resolution.

The majority of the MkIV balloon flights have been from Ft Sumner, New Mexico (~35N), but there have also been 6 flights from Esrange, Sweden and Fairbanks, Alaska (~65N), in 1997, 1999, 2000, 2002, 2003

Figure 2. MkIV balloon launch from Ft. Sumner, New Mexico, on Sep 20, 2005.

References:

Toon, G.C., The JPL MkIV Interferometer, *Opt. Photonics News, 2,* 19-21, 1991.

MkIV Website: http://mark4sun.jpl.nasa.gov

G. L. Manney et al. Solar occultation satellite data and derived meteorological products: Sampling issues and comparisons with Aura Microwave Limb Sounder, JGR, 112, D24S50, doi:10.1029/2007JD008709, 2007

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Trend Studies

The 18 year baseline of the MkIV measurements make them valuable for trend studies. The major drawback is their sparsity (only 21 flights in 18 years). With dynamically induced variations larger than the trends for many gases, the representativeness of the MkIV measurements becomes an issue. We therefore used a tracer, N_2O, to minimize the impact of dynamically-induced variations that otherwise would hinder trend estimation.

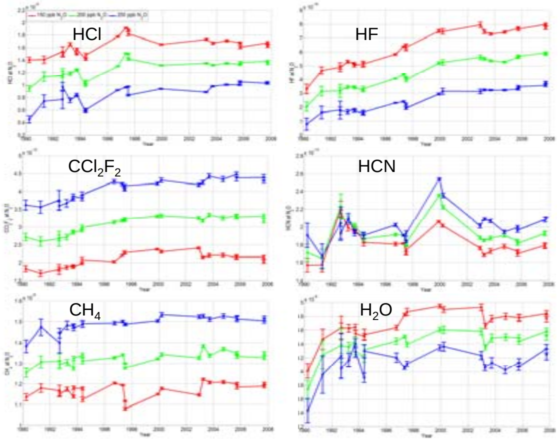

Figure 3. Trends at N_2O levels: 150 ppb (~27km), 200 ppb (~24km), 250 ppb (~21km)

Figure 3 shows stratospheric trends of some of the trace gases measured by the MkIV spectrometer over the period 1989 to 2007. The volume mixing ratios are presented here have been interpolated to specific N_2O levels (150, 200, & 250 ppb). N_2O is a good tracer of the movement of air parcels thanks to its long life-time.

HCL and CCl_2F_2 stopped increasing around the year 2000. HF is still increasing, but at a much reduced rate since 2000. H_2O increased during the 1990's, peaking around 2000. The variations in HCN are driven by biomass burning.

Summary and Future Work

The MkIV balloon measurements are a valuable indicator of atmospheric change, provided that limitations associated with the representativeness of these sparse observations can be overcome by use of tracers. We next plan to correct for the slight increase in tropospheric N_2O over the measurement period, and for seasonal and latitudinal variations in the tracer/N_2O relationship.

The MkIV measurements are also valuable for satellite validation purposes. A technique for non-coincident validation of ACE using Equivalent Latitude (EqL) and Potential Temperature (Theta) is shown to be very successful for N_2O and CH_4 and will be extended to other gases.

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William Daffer (JPL) for performing the MkIV EqL calculations.

Non-Coincident Validation of ACE

The Atmospheric Chemistry Experiment (ACE), on board SCISAT, is a solar occultation FTS very similar to MkIV. ACE acquires up to 30 occultations per day (~10,000 per year). The ACE profiles are becoming much more widely used for validation (e.g. Aura).

The MkIV is the perfect instrument for ACE validation since it measures the same gases in the same spectral regions using the same technique. MkIV also has a long heritage of satellite validation going back to the UARS era.

To date, the MkIV balloon profiles have not been used much for ACE validation. This is because all the MkIV flights performed since ACE launched (2003) have been from Ft. Sumner, New Mexico (35N), in late September, which unfortunately falls in a hole in the ACE coverage (right). The nearest ACE measurements are 2-3 weeks later than those of MkIV and therefore fail any sort of a co-incidence criterion.

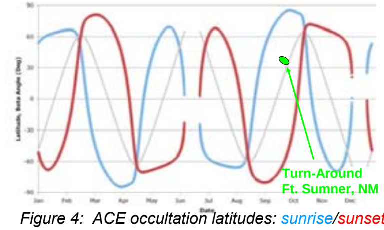

Figure 4: ACE occultation latitudes: sunrise/sunset

Comparing MkIV profiles (colored squares) with a zonal mean of the ACE results (black dashes) acquired within 5° of latitude and 6 weeks of the MkIV, gives poor agreement. But the ACE data, color-coded by their Equivalent Latitude (EqL), match well MkIV observations of the same color/EqL. [EqL was calculated for ACE and MkIV data using the procedures described in Manney et al., 2007].

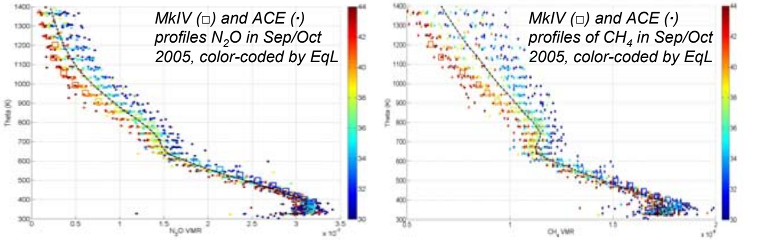

Figure 5. N_2O (left) and CH_4 (right) profiles from ACE and MkIV color-coded by EqL

A method of non-coincident validation was therefore employed. A surface is fitted to the Version 2.2 ACE vmrs in EqL-Theta space. We then perform 2-D interpolation onto this surface at the EqL-Theta values of the MkIV measurements. The resulting interpolated ACE profiles are compared with MkIV (below). The agreement in much improved over simply comparing with the ACE zonal mean.

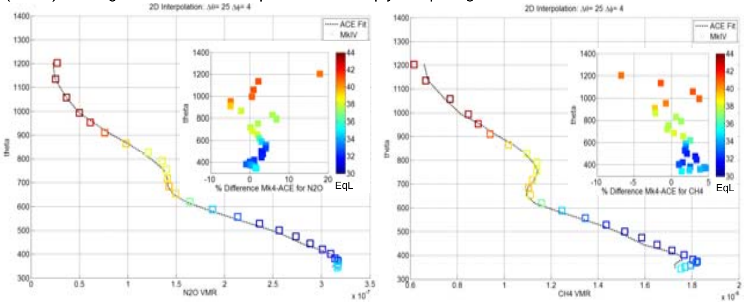

Figure 6. N_2O (left) and CH_4 (right) profiles from MkIV and ACE (2-D interpolated). Inset shows differences.