GROUND-BASED OBSERVATIONS FROM A HIGH ALTITUDE SITE BY THE JPL MKIV INTERFEROMETER

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Abstract

Since October 1998, the JPL MkIV interferometer has made routine observations from Mt. Barcroft (37.584°N; 118.235°W; 3801 m) in the White Mountains of California. This site is sunny, dry, and far from sources of pollution. These characteristics make it ideal for atmospheric monitoring by FTIR solar absorption spectrometers, and more than compensate for its inaccessibility and the need to remotely control the instrument. In this work, we compare the quality of the column abundances retrieved from this site, with those obtained earlier using the same instrument from lower altitude, e.g. Table Mountain (2258 m) or Pasadena (360 m). We show that the data acquired from Mt. Barcroft are of higher quality and exhibit better consistency (i.e. precision). This is mainly thanks to the reduction in the absorption from gases that interfere with the stratospheric measurements. For example, the Mt. Barcroft H_2O column is typically 3 times less than Table Mountain and 9 times less than Pasadena. In addition, temperature-sensitive interfering absorptions by H_2O, CO_2, and CH_4 are reduced by the colder temperatures. Also, the lower atmospheric pressure (650 hPa) results in narrower absorption features for the interferences, further limiting their effect. Finally, Mt. Barcroft is above most of the boundary-layer tropospheric pollution (e.g. CO, NO_x, C_2H_2), and far from Los Angeles and San Francisco: this further reduces the spectral interferences and variations thereof.

Introduction

The MkIV is an FTIR spectrometer designed and built at JPL in 1984 for remote sensing the composition of the Earth's atmosphere by solar absorption spectrometry. Optically, MkIV is very similar to the JPL ATMOS instrument, which flew four times on the Space Shuttle. Both use double-passed configurations with a KBr beamsplitter and compensator, in order to cover the mid-infrared. The main advantage of the MkIV is that it uses two detectors in parallel, a HgCdTe photoconductor for the long wavelengths and an InSb photodiode for the short wavelengths, allowing the entire 650 to 5650 cm^{-1} region to be measured simultaneously. At a 10 kHz sampling rate, each 116 cm OPD interferogram takes 3 minutes to acquire.

Although the MkIV instrument was designed primarily for balloon flights, it has also made measurements from the NASA DC–8 aircraft and has performed hundreds of days of ground-based observations. The latter were made in support of the Network for Detection of Stratospheric Change (NDSC), a collaborative, international effort to monitor the changing composition of the stratosphere by a variety of measurement techniques, including FTIR spectrometry. Indeed, the MkIV instrument has made ground-based measurements for several years from JPL (Pasadena, California). However, the low altitude (360 m) and warmth of this site made it unsuitable for measuring gases whose spectral signatures are blended with lines of H_2O (e.g. NO_2 at 1600 cm^{-1}, HNO_3 at 896 cm^{-1}) or with temperature-dependent lines of CO_2 (e.g. $ClNO_3$ at 780 cm^{-1}). Moreover, JPL adjoins a large pollution source (Los Angeles) for many of the gases that we are trying to monitor (e.g. O_3, NO_2, hydrocarbons, chloro-fluoro-carbons), which confuses the interpretation of the results.

We therefore decided that the MkIV ground-based observations would be of greater scientific value if they were made from a site that was at a higher altitude and less polluted than JPL. Since the MkIV instrument had been designed from the outset to be flown on balloons, when it is controlled remotely and powered by batteries, this made it feasible to take ground-based observations from a very remote site with little infrastructure.

The site finally chosen was the Barcroft facility of the White Mountain Research Station, operated by the University of California at San Diego. The White Mountains are far from possible sources of gas pollution: they lie 380 km due north of Los Angeles and 350 km east of San Francisco. The Barcroft facility is located at 37.584°N and 118.235°W, near the Ancient Bristlecone Pine forest. With an altitude of 3801 m, this is basically the highest point in the Western USA to which a large vehicle, such as the 36-foot trailer that houses the MkIV instrument and associated equipment, can be hauled. The temperature average is -10°C in the winter and $+5$°C in the summer, with an annual precipitation of 450 mm. The Barcroft facility is unstaffed and without ground power in the winter and spring (November through June). However, it is a very sunny site, providing the opportunity for solar power generation. There is no hard-wired phone lines, but the facility is well served by cellular phone.

The MkIV instrument was adapted for remote operation at the Barcroft site, where the harsh winter conditions make access difficult. Some of the main technical challenges were: (i) operation from solar panels and batteries, (ii) cooling the detectors with LN_2 on request, (iii) instrument control and monitoring over a cellular phone, and (iv) data storage, processing and analysis. Spectra and vertical columns measured from Barcroft are compared with those measured from JPL and Table Mountain, to highlight the advantages of the higher altitude site.

This figure shows a comparison of MkIV spectra measured from Barcroft (2001), Table Mountain (1996), and JPL (1996) at similar solar zenith angles (indicated on the right-hand side of the figure). It is clear that the contribution of H_2O to the absorption in the vicinity of the HF line is greatly reduced in the Barcroft spectrum.

Vertical column abundances of H_2O, retrieved from spectra taken at JPL, Ft. Sumner, NM (FTS), Daggett, CA (DAG), Table Mountain Facility (TMF), and Mt. Barcroft (MTB), plotted as a function of the day of the year.

Vertical column abundances of HF, retrieved from spectra taken at JPL, Ft. Sumner, NM (FTS), Daggett, CA (DAG), Table Mountain Facility (TMF), and Mt. Barcroft (MTB), plotted as a function of time.

Vertical column abundances of HF, retrieved from spectra taken at JPL, Ft. Sumner, NM (FTS), Daggett, CA (DAG), Table Mountain Facility (TMF), and Mt. Barcroft (MTB), plotted as a function of the day of the year.

Vertical column abundances of HCl, retrieved from spectra taken at JPL, Ft. Sumner, NM (FTS), Daggett, CA (DAG), Table Mountain Facility (TMF), and Mt. Barcroft (MTB), plotted as a function of time.

Vertical column abundances of HCl, retrieved from spectra taken at JPL, Ft. Sumner, NM (FTS), Daggett, CA (DAG), Table Mountain Facility (TMF), and Mt. Barcroft (MTB), plotted as a function of the day of the year.

Ratio HCl/HF, retrieved from spectra taken at JPL, Ft. Sumner, NM (FTS), Daggett, CA (DAG), Table Mountain Facility (TMF), and Mt. Barcroft (MTB), plotted as a function of time.

Ratio HCl/HF, retrieved from spectra taken at JPL, Ft. Sumner, NM (FTS), Daggett, CA (DAG), Table Mountain Facility (TMF), and Mt. Barcroft (MTB), plotted as a function of the day of the year.

This figure shows fits to MkIV spectra (diamonds) for the $ClNO_3$ region, as measured from JPL, Table Mtn., and Barcroft. The absorption due to H_2O is greatly reduced, and the interfering temperature-sensitive CO_2 feature is weaker.

Vertical column abundances of $ClNO_3$, retrieved from spectra taken at JPL, Ft. Sumner, NM (FTS), Daggett, CA (DAG), Table Mountain Facility (TMF), and Mt. Barcroft (MTB), plotted as a function of time.

Vertical column abundances of $ClNO_3$, retrieved from spectra taken at JPL, Ft. Sumner, NM (FTS), Daggett, CA (DAG), Table Mountain Facility (TMF), and Mt. Barcroft (MTB), plotted as a function of the day of the year.

Ratio $ClNO_3/HF$, retrieved from spectra taken at JPL, Ft. Sumner, NM (FTS), Daggett, CA (DAG), Table Mountain Facility (TMF), and Mt. Barcroft (MTB), plotted as a function of time.

Ratio $ClNO_3/HF$, retrieved from spectra taken at JPL, Ft. Sumner, NM (FTS), Daggett, CA (DAG), Table Mountain Facility (TMF), and Mt. Barcroft (MTB), plotted as a function of the day of the year.

This figure illustrates that, from Barcroft, it is possible to use the 1600 cm^{-1} region to measure column NO_2 (diamonds represent the measured spectrum; all other curves are computed spectra). These NO_2 lines are ten times stronger than those in the 2900 cm^{-1} region normally used for ground-based monitoring by FTIRs. From JPL, FTS, or TMF, this spectral window is blacked-out by H_2O absorption.

Vertical column abundances of NO_2, retrieved from spectra taken at JPL, Ft. Sumner, NM (FTS), Daggett, CA (DAG), Table Mountain Facility (TMF), and Mt. Barcroft (MTB), plotted as a function of time.

Vertical column abundances of NO_2, retrieved from spectra taken at JPL, Ft. Sumner, NM (FTS), Daggett, CA (DAG), Table Mountain Facility (TMF), and Mt. Barcroft (MTB), plotted as a function of the day of the year.

Vertical column abundances of HNO_3, retrieved from spectra taken at JPL, Ft. Sumner, NM (FTS), Daggett, CA (DAG), Table Mountain Facility (TMF), and Mt. Barcroft (MTB), plotted as a function of time.

Vertical column abundances of HNO_3, retrieved from spectra taken at JPL, Ft. Sumner, NM (FTS), Daggett, CA (DAG), Table Mountain Facility (TMF), and Mt. Barcroft (MTB), plotted as a function of the day of the year.

Vertical column abundances of CO, as a function of the day of the year. The large amounts of CO measured from JPL is a consequence of CO being a component of smog.

Conclusions

The MkIV FTIR was installed at the Barcroft facility from October 1998 to July 1999 and from October 2000 to present. So far, we have taken a total of 159 days observations. We have demonstrated the feasibility of obtaining high quality atmospheric spectra from a remote, unstaffed, high altitude site, without ground power or high speed communications. We intend to keep the MkIV instrument at Barcroft for the next nine months, as no balloon flights are planned for that period.

1. Due to its high altitude, the spectra measured from Barcroft (3801 m) are better for stratospheric monitoring than spectra from lower altitude sites:
    - The H_2O column is 3 times less than Table Mountain Facility (2258 m) and 9 times less than Jet Propulsion Laboratory (360 m).
    - Temperature-sensitive interfering absorptions by H_2O, CO_2, and CH_4 are reduced by the colder atmosphere.
    - Barcroft is above most of the boundary-layer tropospheric pollution (e.g. CO), and its remoteness from Los Angeles and San Francisco makes it even cleaner.
2. Barcroft column abundances show better consistency (i.e. precision) than measurements from JPL or TMF due to the reduction in spectral interferences and variations thereof.
3. Column abundances of stratospheric gases (e.g. O_3, HCl, HF, HNO_3) show high variability in the springtime due to airmasses of different origin, but in late summer the variability is much smaller.
4. Ratioing by HF reduces the springtime variability, allowing better estimation of the secular trends.