High resolution solar infrared Fourier transform spectrometry: application to the study and long-term monitoring of the Earth's atmosphere

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1. Project description

The Liège team has a long tradition in the monitoring of the Earth's atmosphere. Indeed, the first observations and investigations were carried out by Pr Marcel Migeotte and collaborators in the late 1940s, using a grating infrared spectrometer. This instrument was then installed at the Jungfraujoch station and infrared spectra were systematically recorded in 1950-1951 such as to cover the 2.8 to 23.7 micrometer (μm) spectral range (Migeotte et al., 1956). The next period was dedicated to the study of the sun and to the production of photometric solar atlases, using a 7 m grating spectrometer, in single then double pass mode. In the mid-1970s, the team resumed its atmospheric monitoring activities which are still ongoing nowadays. Since the mid-1980s, Fourier Transform InfraRed (FTIR) instruments are used, allowing to record very high resolution and signal-to-noise wide-band solar infrared spectra. This sustained effort has led to an unrivalled collection of infrared spectra which is unique worldwide in terms of length, measurement density and quality. At the end of 2019, we reached 36 years of continuous FTIR measurements at the Jungfraujoch station!

The main objectives of the team are essentially twofold: (i) maintain the instrumentation operational while also improving its performance, (ii) analyse the spectra in order to produce high-level geophysical parameters and valorise them.

In 2019, observations have been performed on site or recorded through a proprietary remote-control internet interface. Altogether, about 1200 high resolution infrared solar spectra have been collected on 72 days over the first eleven months of the year (the statistics for December are not yet available at the time of writing). A failure of the instrumentation (sun-tracker protection control) prevented the recording of spectra in August.

The analysis of our spectra allows us to determine the abundance of an increasing number of key constituents of the Earth atmosphere (currently more than 30, see Table 1), playing a role in ozone depletion, climate change, or affecting air quality. Numerous target species are therefore relevant to the Montreal Protocol on substances that deplete stratospheric ozone (e.g. CFCs, HCFCs, HCl) and/or to the Paris Agreement (COP21) to mitigate climate change (e.g. CO_2, CH_4, N_2O).

Table 1. List of atmospheric species (>30) currently retrieved from the Jungfraujoch observational database.

Greenhouse gases; support to the Paris Agreement	H_2O, CO_2, CH_4, N_2O, CF_4, SF_6
Ozone-related; support to the Montreal Protocol	O_3, NO, NO_2, HNO_3, $ClONO_2$, HCl, HF, COF_2, CFC-11, CFC-12, HCFC-22, HCFC-142b, CCl_4, CH_3Cl
Air quality; support to the EU-Copernicus programme	CO, CH_3OH, C_2H_6, C_2H_2, C_2H_4, HCN, HCHO, HCOOH, NH_3, PAN
Other	OCS, N_2, various isotopologues[1]

[1)] an isotopologue is a molecular twin that differs from the reference molecule in the isotopic composition; for example, $^{13}C^{16}O$ and $^{12}C^{18}O$ are the isotopologues of the most abundant $^{12}C^{16}O$.

2. Update of the long-lived halocarbon time series

As obvious from Table 1, several halogenated source and reservoir species are systematically retrieved from the Jungfraujoch FTIR spectra. The corresponding time series are regularly included in the Scientific Assessment of Ozone Depletion reports, supporting the evaluation of the success of the Montreal Protocol. This was again the case in the last edition of that report (WMO2018, see Figures 1-2, 1-13, 1-20 and Table 1-2 in its chapter 1).

Figure 1 provides the updated time series of the most abundant (hydro)chlorofluorocarbons ((H)CFCs). The HCFC-22 time series has

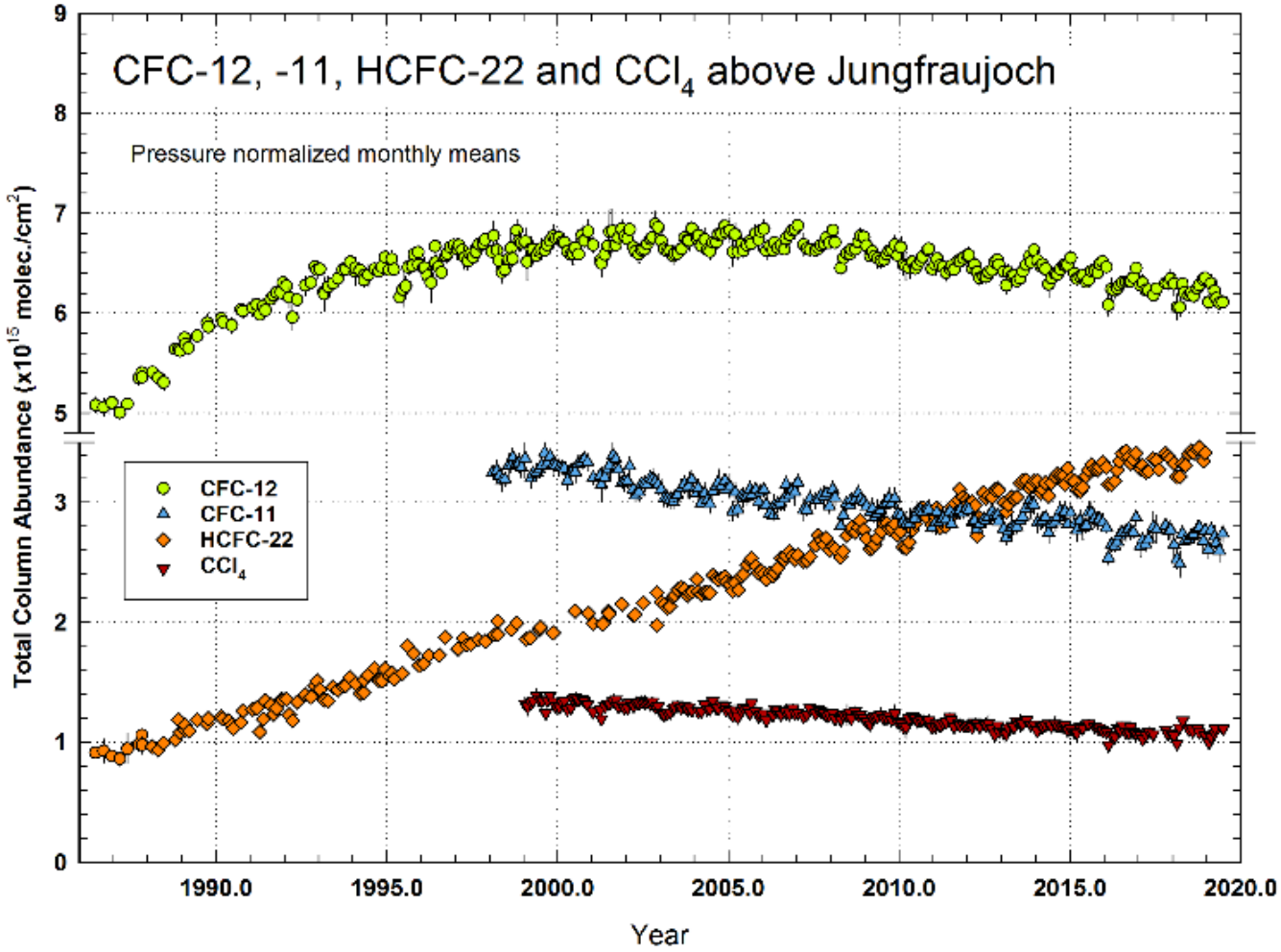

Figure 1. Monthly mean total vertical column abundances (in molecules per square centimeter) of CFC-12 (CCl_2F_2), CFC-11 (CCl_3F), CCl_4 and HCFC-22 ($CHClF_2$) as derived from the long-term monitoring program conducted by ULiège at the Jungfraujoch station. The CFC-11 and CFC-12 time series have been consistently updated from Zander et al. (2008), the CCl_4 time series from Rinsland et al. (2012). The HCFC-22 data set is described in Prignon et al (2019).

been recently updated and improved (Prignon et al., 2019) while the three other data sets have been extended until mid-2019. Current trends have been evaluated considering all available daily means for the 2013-2019 time period, and accounting for the auto-correlation present in the data sets following Santer et al. (1999). When compared with the rates of change reported in Table 1-2 of WMO2018 (using data from 2010-2016), we don't see significant differences for the CFC-11, CFC-12 and CCl_4 trends. For HCFC-22, the absolute yearly increase (E13 molec.cm^{-2}.yr^{-1}) drops from 7.58 over 2010-2016 to 5.65 over 2013-2019, i.e., lower by 25%. This corresponds to relative rates of increase of 2.54(20) and 1.77(12) %.yr^{-1}, when using the year 2013 and 2016 as reference, respectively.

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ftp://ftp.cpc.ncep.noaa.gov/ndacc/RD/jungfrau/hdf/ftir/

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Refereed journal articles and their internet access

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