Analysis of historical grating spectra: Jungfraujoch atmospheric database extended back to 1977

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Historical solar spectra recorded at the Jungfraujoch station (Swiss Alps, 46.55°N, 7.98°E, 3580 m a.s.l.) with a high-resolution grating spectrometer have been re-analyzed to derive total columns of a series of atmospheric gases. This instrument, built and operated by the University of Liège (Belgium), was used in the Sixties and Seventies to record two solar spectrum atlases extending from the near-ultraviolet to the near-infrared (from ~300 to ~1200 nm) [1][2]. From 1977 to 1989, it was also regularly used to record narrow spectral intervals in the mid-infrared, encompassing absorption lines of gases of atmospheric interest, e.g. CH_4, HF, HCl, H_2O, N_2O, NO_2, C_2H_6, O_3 and CO [6]. More than 10 thousand spectra were recorded during this period.

Despite their small spectral extent (typically 5 to 10 cm^{-1}), these grating observations may contain interesting lines belonging to gases different from the target gas, particularly numerous CH_4 and H_2O lines, which can then be used to increase the number of retrieved columns. Special care must however be taken to ensure that the different lines used to retrieve the columns of a given gas provide consistent results. Fortunately, from 1984 to 1989, the grating spectrometer was often operated simultaneously with a co-located home-made Fourier Transform infrared (FTIR) spectrometer, providing a convenient way to intercompare columns retrieved from different spectral ranges or derived from the same line but with 2 different instruments.

In the 1970s – 1980s, the plotted grating spectra were analyzed by manually measuring the equivalent width of the target gas lines with a high-precision Coradi planimeter [5]. They were never analyzed with fitting programs, which did not exist at that time. In this contribution, we report about the effort undertaken at University of Liège to cautiously and consistently re-analyze and valorize these early observations, with modern tools.

The first steps to their re-analysis were to read them from old magnetic tapes, to take into account their zero offsets (measured before and after each recording), to carefully calibrate their wavenumber scale, to verify their associated airmass (approximate airmass routine was used at that time) and to save them in the format needed by the FTIR retrieval programs.

It is important to note that the non-linearity introduced when switching from the wavelength scale – original scale for a grating spectrum – to the wavenumber scale results in a negligible error, because of the small size of the recorded domains: for a micro-window of about 5 cm^{-1}, relative total column error is not larger than 0.10 % for unsaturated lines.

Total columns have been derived with the retrieval algorithm SFIT-2 v3.91, which uses the optimal estimation method [4] to fit a synthetic spectrum to the observation. The

pressure and temperature profiles adopted in the retrievals were provided by the National Centers for Environmental Prediction (NCEP, http://www.ncep.noaa.gov).
As the SFIT-2 software has been specifically developed for FTIR instruments with a sinc function as instrumental profile, we had to apply a strong Norton-Beer apodization [3] to the synthetic spectra to simulate at best the observed line shapes.

The total columns derived from grating spectra have been combined with the FTIR columns derived at the Jungfraujoch since the mid-1980s, in order to derive the temporal evolution of various target gases for the period 1977-2011. For water vapor, we hope to derive columns for a still longer period, thanks to systematic measurements of a water vapor line at 694.37 nm, initiated in 1974 to check the dryness of the atmosphere when recording solar atlases.

References

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