Use of GEOS-Chem for the interpretation of long-term FTIR measurements at the Jungfraujoch and other NDACC sites

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RECENT INCREASE OF ETHANE ABOVE NORTH AMERICA
(Bruno Franco et al.)

FIGURE 3 - Seasonal variation of ethane measured at the Jungfraujoch station (in blue) and modeled by GEOS-Chem (in red) for the days of observations over the mid-2005 - mid-2012 time period. We have taken into account the vertical resolution and specific sensitivity of the FTIR retrievals before comparison with the model data. Although the seasonal signal is well captured by the model, there is an overall underestimation of the ethane concentration by the model. The two data sets cannot be reconciled by accounting for the systematic errors affecting the observations. For more details, see Franco et al., Atmos. Meas. Tech., 6, 2495-2507, 2013

FIGURE 4 - Trends of ethane for Toronto, as deduced from long-term FTIR monitoring activities performed at Toronto airport and at GCAMNet. Consecutive trends are observed at other sites (e.g., Boulder, CO) and confirmed by ACE-FTS scalloping measurements above North America. The recent and massive growth in the exploitation of shale gas and oil of the Canadian part of the northern USA is a key factor for the significant C2H6 increase as of 2005 above North America, and more generally in the Northern Hemisphere. Efforts are made to update the emission inventories generated in GEOS-Chem and evaluate the magnitude of the fugitive emissions required to observe the observed increase and estimate the impact on air quality. For more details, see Franco et al., Atmos. Meas. Tech., 6, 2495-2507, 2013

CURRENT LIST OF AVAILABLE TARGET GASES (JUNGFRAUJOCR)

Numerous atmospheric species have exploitable spectral signatures in the infrared region routinely recorded by the NDACC-affiliated ground-based FTIR instruments (see map). First priority species include CH4, HNO3, HCl, HF, CO, NO, NH3, CH4, HCN, C2H6 and C2H4. Total and partial column time series of all these species are available in hdf and/or NASA-Ames format from the NDACC database (http://www.ndacc.org).

Altogether, more than 30 molecules are now routinely retrieved from the Jungfraujoch spectra:

-- major greenhouse gases: H2, CO2, CH4 and N2O
-- ozone (in the troposphere and stratosphere)
-- halogenated compounds: CF2Cl2 (CFC-11), CFCl3 (CFC-12), CHCl3 (HCFC-22), CH2ClF (HCFC-22a), CCl3F, CF2H, HCl, CINO2, HF and C2F2
-- nitrogen compounds: N2, NO, NO2, NH3, N2O5, CINO2, NH3, HNO2 and C2N2
-- organic compounds: CO, CH4, C2H6, C2H4, CH2=CH2, OH, CH3, HCN, formaldehyde, formic acid, etc.
-- many isotopologues of H2O, D2O, CO, O2...

CURRENTLY UNDER DEVELOPMENT: CH3, PAN, CH2Cl2

FIGURE 5 - Seasonal variation of formaldehyde as measured at the Jungfraujoch station (in green) and modeled by GEOS-Chem (in red) for the days of observations over the mid-2005 - mid-2012 time period. The model is able to capture the main features of the seasonal variation of formaldehyde, although the in-phase agreement is not very good. The inter-annual variability of formaldehyde is very uncertain. For more details, see Franco et al., Atmos. Meas. Tech., 6, 2495-2507, 2013

INVESTIGATING THE CAUSES FOR THE METHANE RISE AFTER 2005
(Whitney Bader et al.)

The attribution of the CH4 increase since 2005 to any source is difficult since the existing measurements datasets (FTIR, in situ, satellite...) are insufficient to characterize emissions by region and source process, emphasizing the need for source-tagged model simulations implementing reliable emission schemes. This study focuses on the analysis of the GEOS-Chem CH4 tagged simulation for 6 NDACC stations: Eureka, Toronto, Jungfraujoch, Tsukuba, Lauter and Arrival heights. It should provide information on processes causing the increase of atmospheric methane, provided that we determine consistent trends between the observations and the simulations at the various sites.

FIGURE 6 - A vertical bias between FTIR measurements and the GEOS-Chem simulation has been identified. It stands out that the annual changes of methane in the troposphere (3.38 - 11.7 {ppb}) computed from our measurements and GEOS-Chem (2005-2021) simulation are in agreement, contrary to the changes in the total and stratospheric (11.7 - 30.7 {ppb}) columns. Comparisons of the annual change of stratospheric CH4 from FTIR at Jungfraujoch with ACE-FTS measurements (correlations between 0.53 and 0.49, for instance) and GEOS-Chem simulations (correlation of 0.2) indicate that there is an overestimation of the annual change of methane between 11 and 20 km by the model.

FIGURE 7 - Daily mean total column time series of FTIR measurements (black) and the GEOS-Chem simulation (in red) are reproduced on the same frame. The vertical profiles of CH4 are in同行 (the troposphere and stratosphere)

FIGURE 8 - Seasonal variation of formaldehyde as measured at the Jungfraujoch station (in green) and modeled by GEOS-Chem (in red) for the days of observations over the mid-2005 - mid-2012 time period. The model is able to capture the main features of the seasonal variation of formaldehyde, although the in-phase agreement is not very good. The inter-annual variability of formaldehyde is very uncertain. For more details, see Franco et al., Atmos. Meas. Tech., 6, 2495-2507, 2013

NETWORK & SITE, INSTRUMENTATION, OBSERVATIONAL DATABASE AND TOOLS

-- Very high resolution (up to 0.003 cm{-1}) infrared solar spectra are recorded year-round, at the high-altitude International Scientific Station of the Jungfraujoch (Swiss Alps, 46.5°N, 8.0°E, 3580 m a.s.l). Clear-sky conditions are mandatory.

-- Fourier Transform InfraRed (FTIR) monitoring activities are conducted at that site within the framework of the Network for the Detection of Atmospheric Composition Change (NDACC, see http://www.ndacc.org). See Figure 1 for a map of the current official NDACC sites.

-- Our FTIR instruments are equipped with cooled HgCdTe and InSb detectors, allowing covering the 650 to 4500 cm^{-1} region of the electromagnetic spectrum. A set of optical filters (color-coded in Figure 2) are used to maximize the signal-to-noise ratio.

-- The retrievals are essentially performed with the SIFIT algorithm (v3.91), which is based on the semi-empirical implementation of the Optimal Estimation Method of Rodgers [JGR, 95, 1990], allowing in most cases to retrieve some information on the vertical distribution of the target species.

-- Multidetector FTIR time series are available from the Jungfraujoch (longest FTIR data sets worldwide), with earlier measurements in 1984.

THE PyChem PROJECT (Benoit Bovy, Emmanuel Mahieu)

PyChem is a high-level, user-friendly Python interface and development for the GEOS-Chem model. Several tools and notebooks (data visualization & treatment) are available, they can be downloaded from the following dedicated site:

https://github.com/bboyv/PyChem

FIGURE 1 – NDACC FTIR sites location.