



Monitoring the atmospheric composition at Jungfraujoch since the Fifties: an epic!

Why/When/How? A bit of history...

- **1945**: M. Migeotte thesis on high-resolution spectroscopy
- **End of the 1940s**: detection of CH₄, N₂O, CO (Columbus, Ohio) => need an unpolluted site to confirm their ubiquity
- **1950**: First measurements at Jungfraujoch, extended in 1951 => atlas (2.8 – 23.7 μm) + line identifications (1958)
- **1958-1974**: “focus” on the sun and successive improvement of the instrumentation (prism/grating/double-pass)
- **1974**: Molina & Rowland hypothesis (CFC ↓O₃) receives a large echo in the scientific community

Some more milestones...

- The same year (1974): Zander detects HF in the upper stratosphere in IR spectra recorded from Palestine (TX) with the Liège gondola ⇒ the team resumes its atmospheric observational program (HCl, HF, N₂O, CH₄...) in **1976-1977**
- 1984: beginning of routine operation for the homemade FTS
- 1990: installation of a Bruker 120HR FTS, after dismantling the grating spectrometer
- 2008: implem. of remote operation of instrum. (↑ statistics)
- Today: the program continues to extend our database, unique worldwide (40+ years!!)

1950: the first measurements!



M. Migeotte on the Sphinx terrasse

Pioneering observations of atmospheric methane

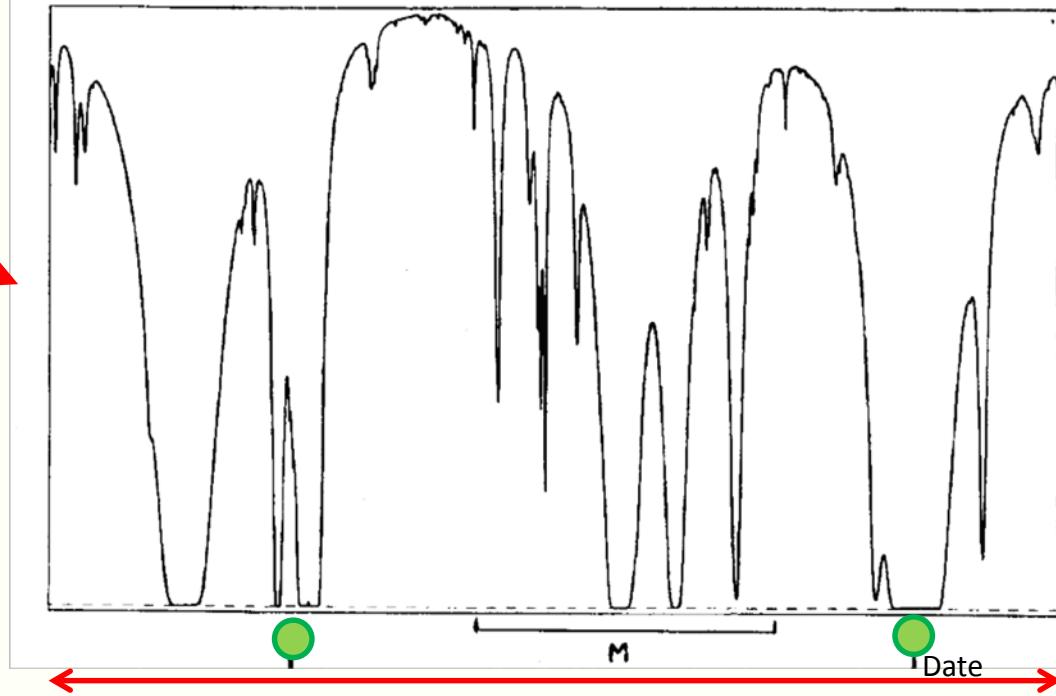
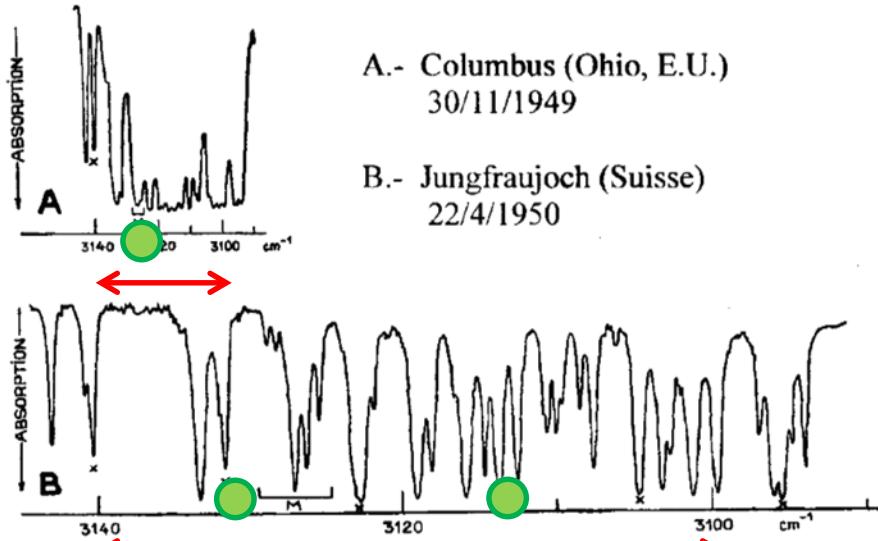
Milestones • Site • FTIR • Long-term • Key results

Columbus – grating

Jungfraujoch – grating

Jungfraujoch – FTIR

● CH_4 lines



Pr. Migeotte's vision...

“ It will be very interesting to systematically record telluric bands due to CH₄, N₂O and CO in view to study or detect intensity variations with time”.

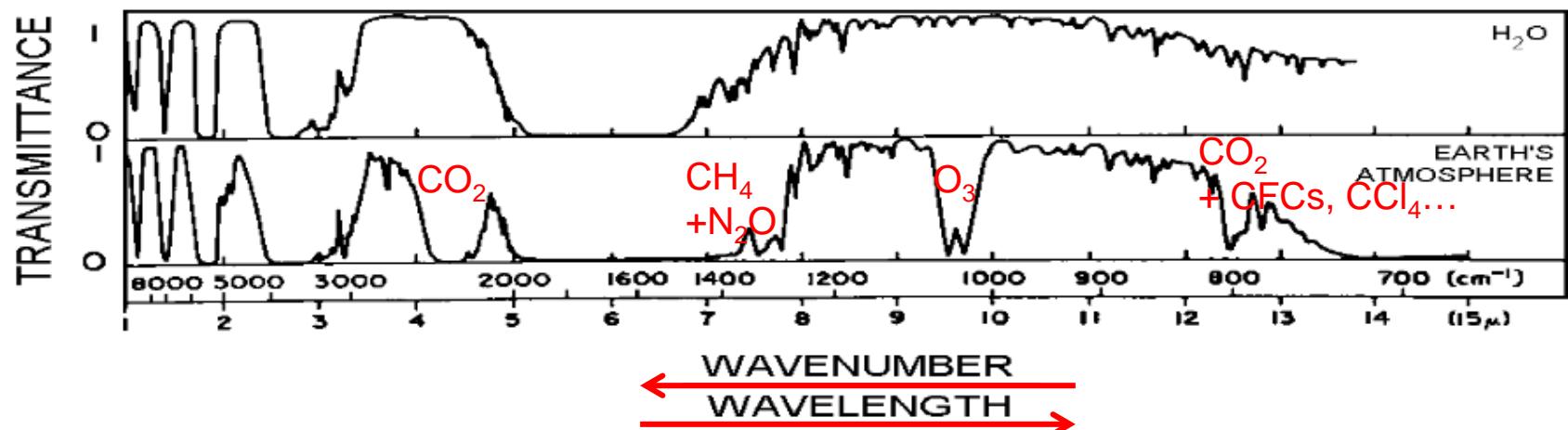
Marcel Migeotte, 1951

In: “Zwanzig Jahre Hochalpine Forschungsstation Jungfraujoch”
Editor : A. von Muralt
Verlag Stämpfli & Cie, Bern, 1951

... is now - and more than ever - our mission!

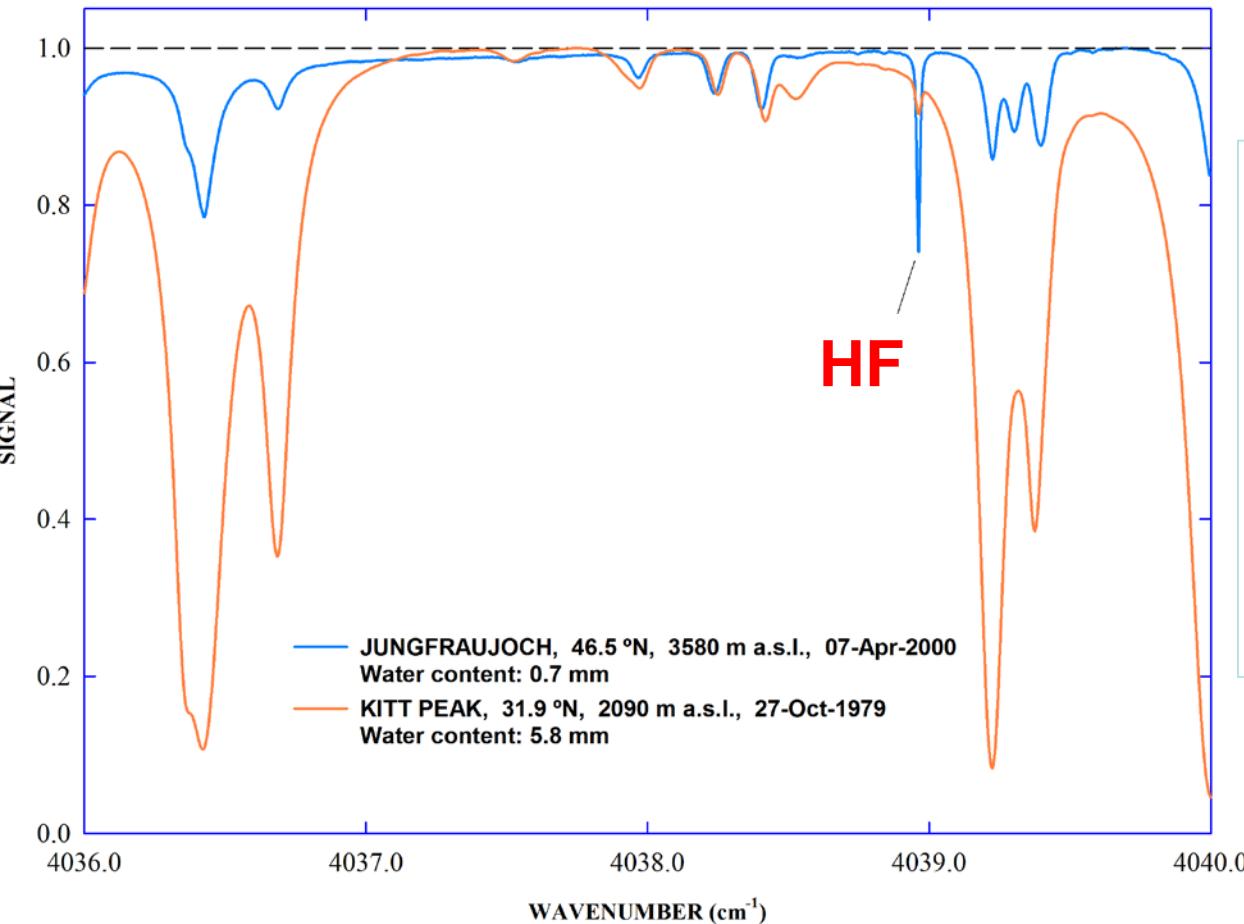
The Jungfraujoch site: why?

Water vapour absorptions between 1 and 14 μ m



The infrared absorption spectrum of water vapor (top) and of the entire atmosphere (bottom) (Stephens 1994).

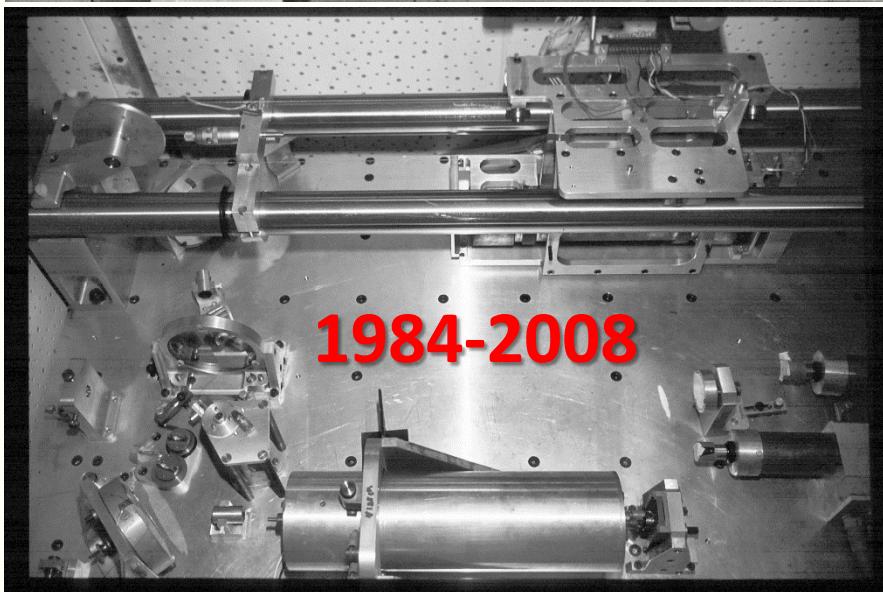
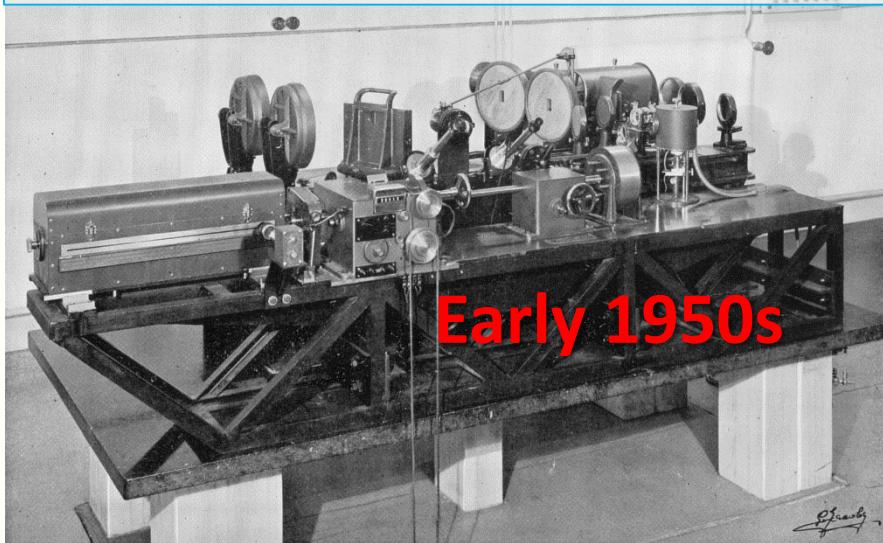
Infrared spectra at 2 high-altitude sites



- Kitt Peak : site close to the Arizona desert, 2 km d'altitude
- The spectra were recorded under dry conditions at both sites

≥ 2/3 of the water vapour column found below 3.6 km !!,
half of it below 1.5 km.

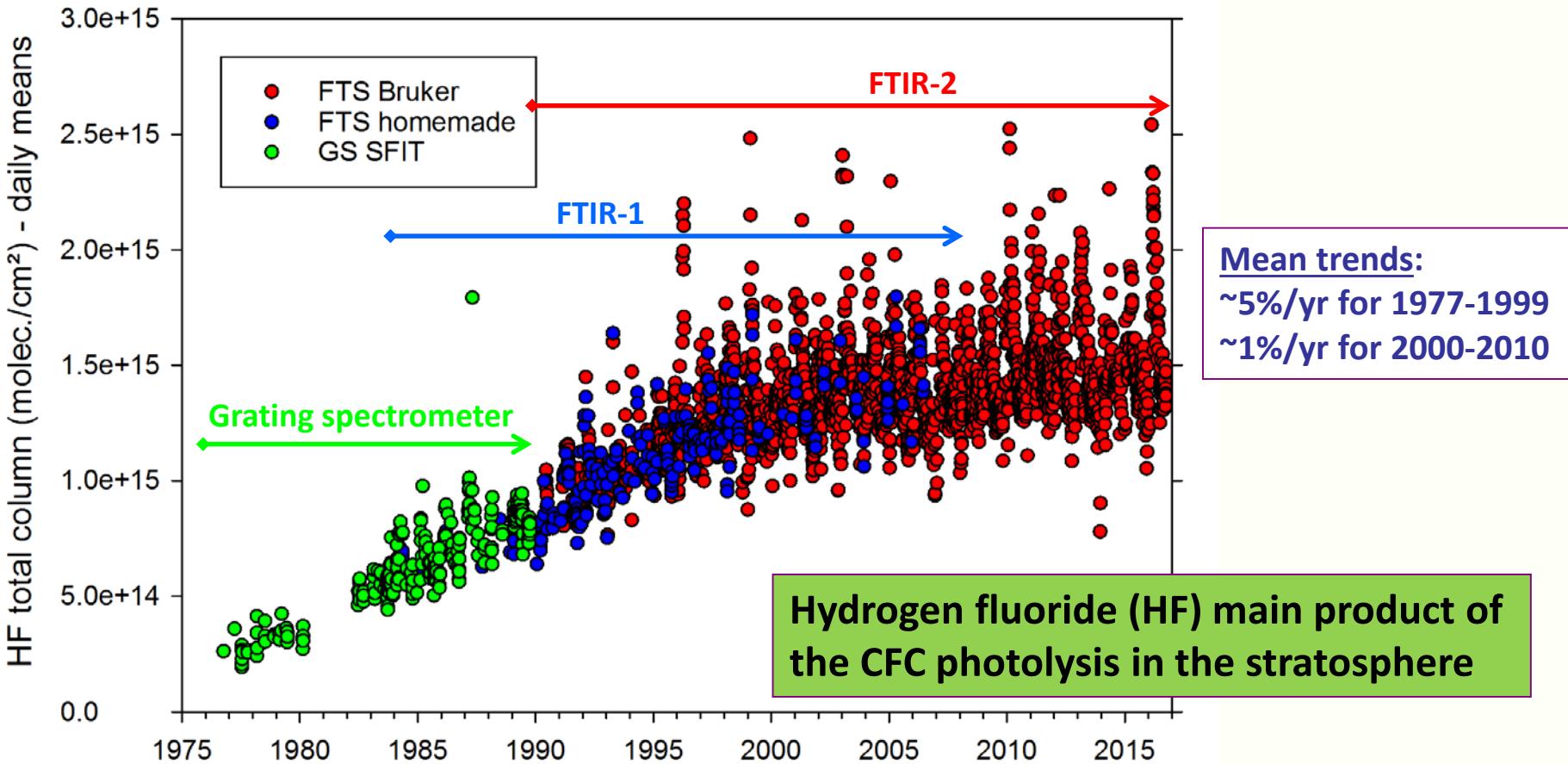
Team's instrumentation at Jungfraujoch over time...



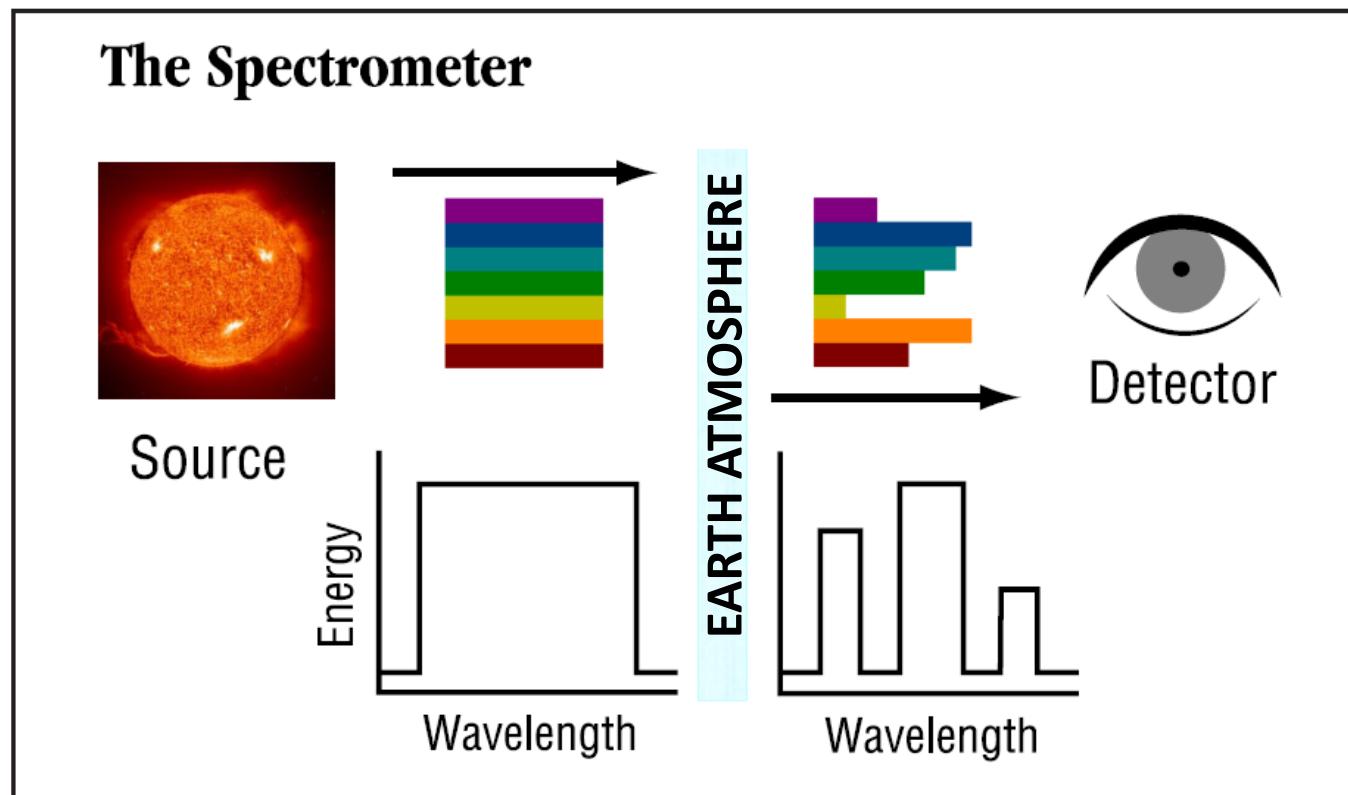
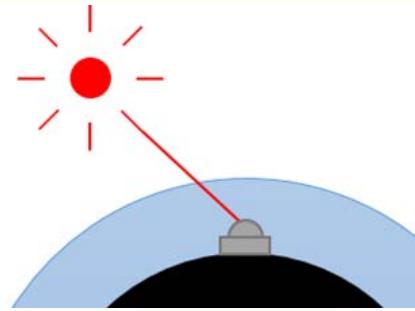
Overlaps help ensuring... consistency!

More than 40 years of continuous measurements, with three instruments!

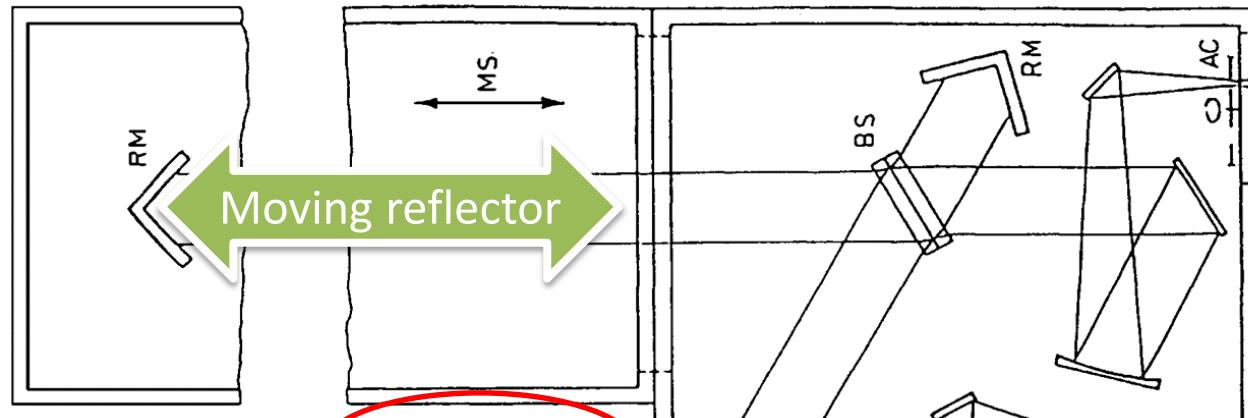
Milestones • Site • FTIR • Long-term • Key results



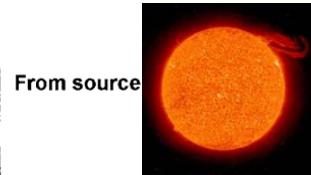
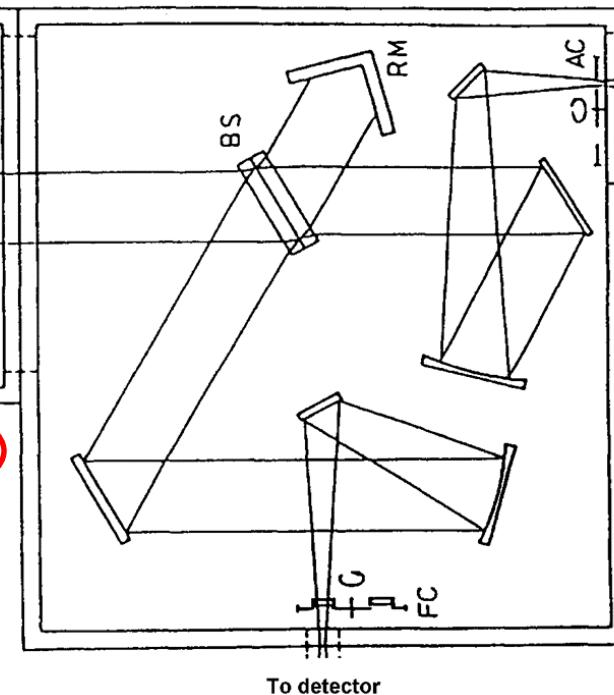
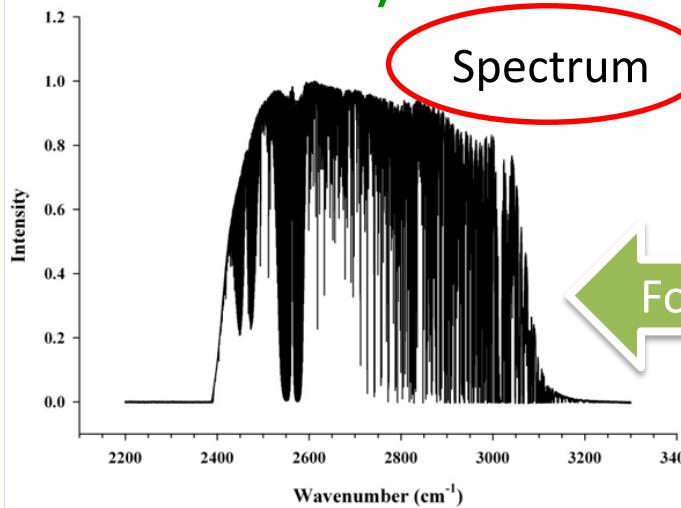
Remote-sensing of the atmospheric composition: the basic principle



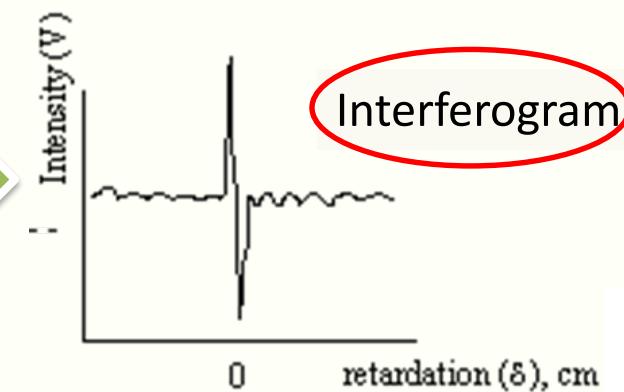
Remote-sensing of the atmospheric composition: the basic principle



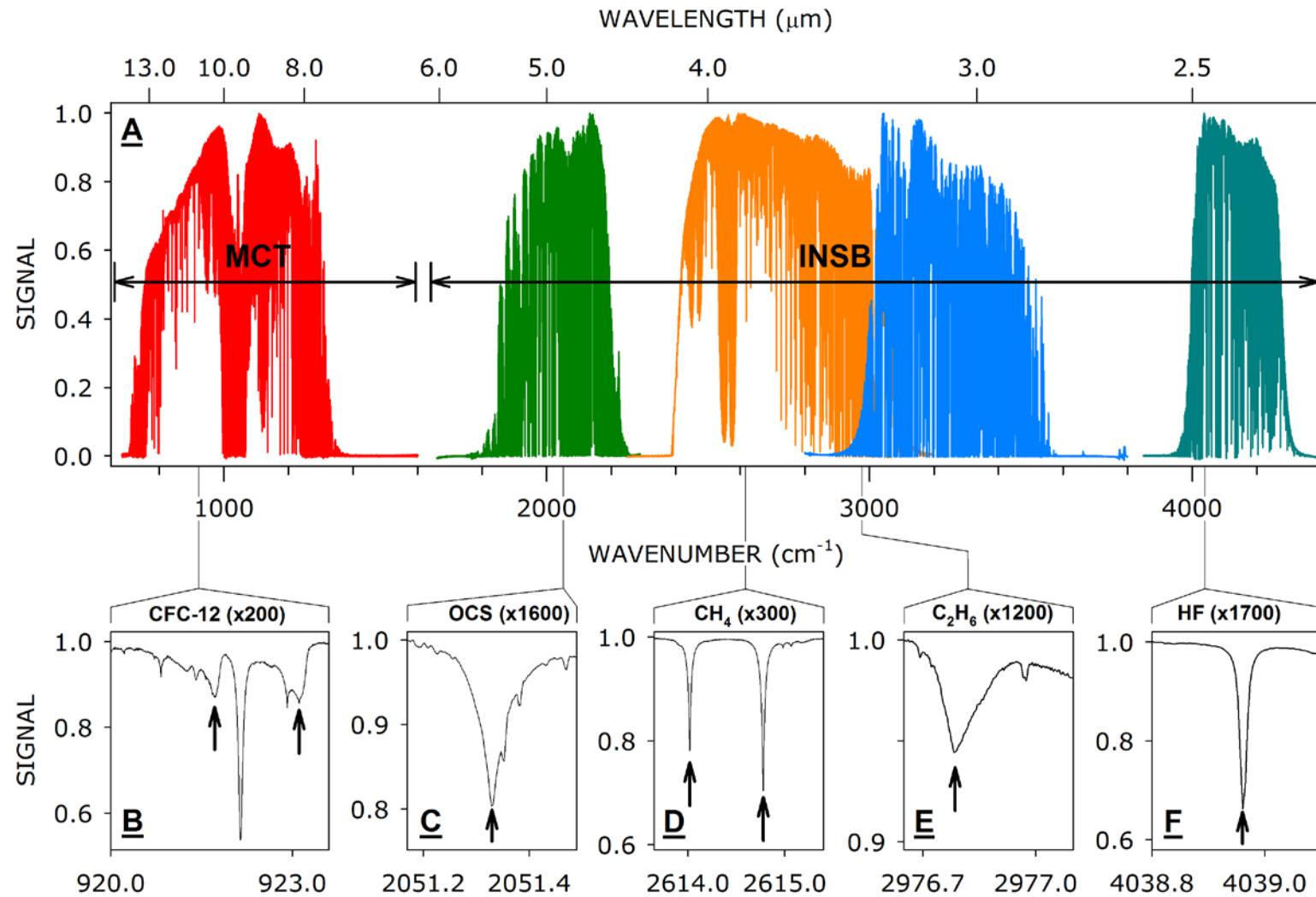
⇒ broadband
high-resolution spectra
(more than 60000!!)



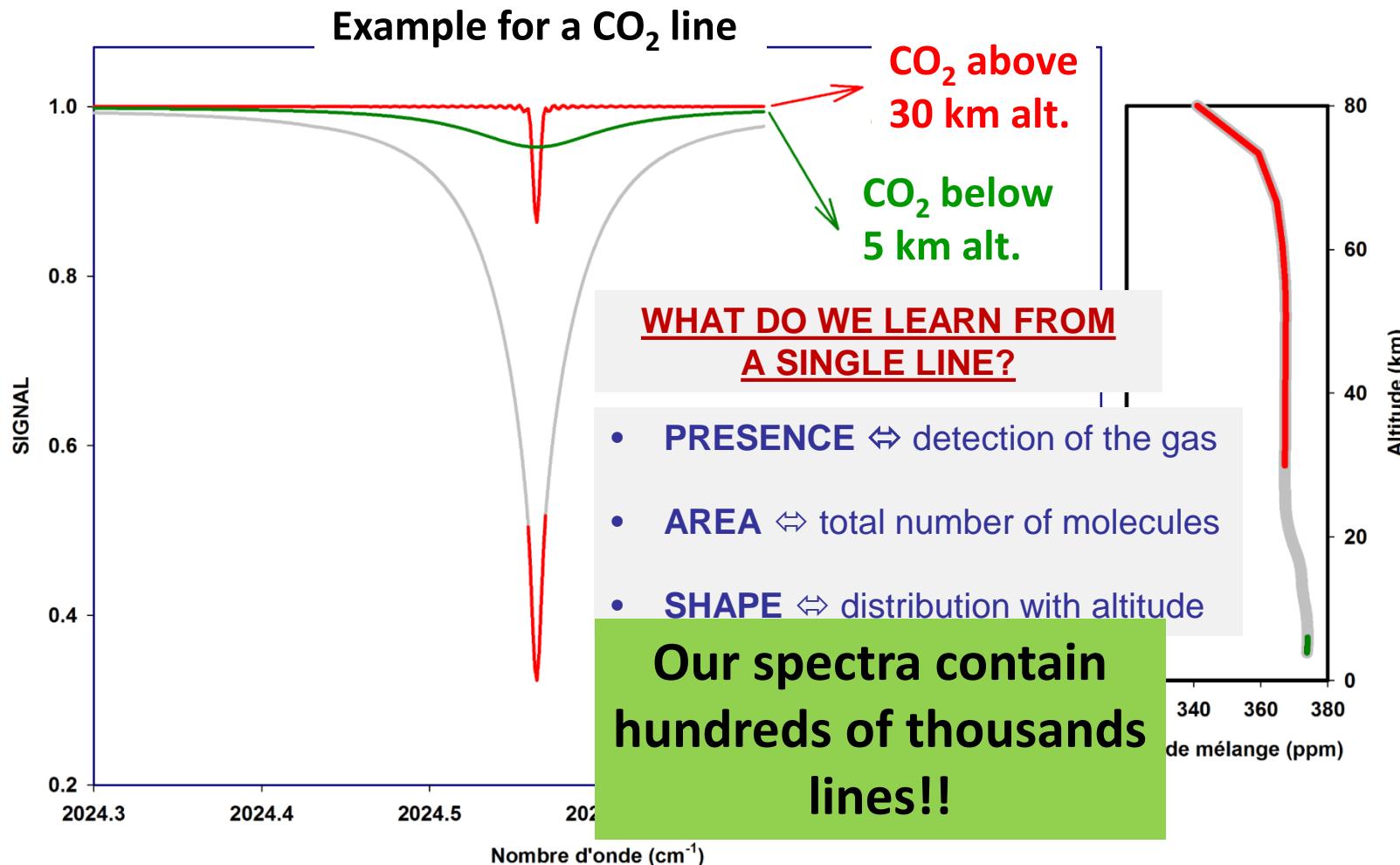
Clear-sky
mandatory!



Bruker FTIR setup: two detectors and 5 optical filters



What do we learn from a single line?



Current list of FTIR target gases at Jungfraujoch (30+, still expanding!)

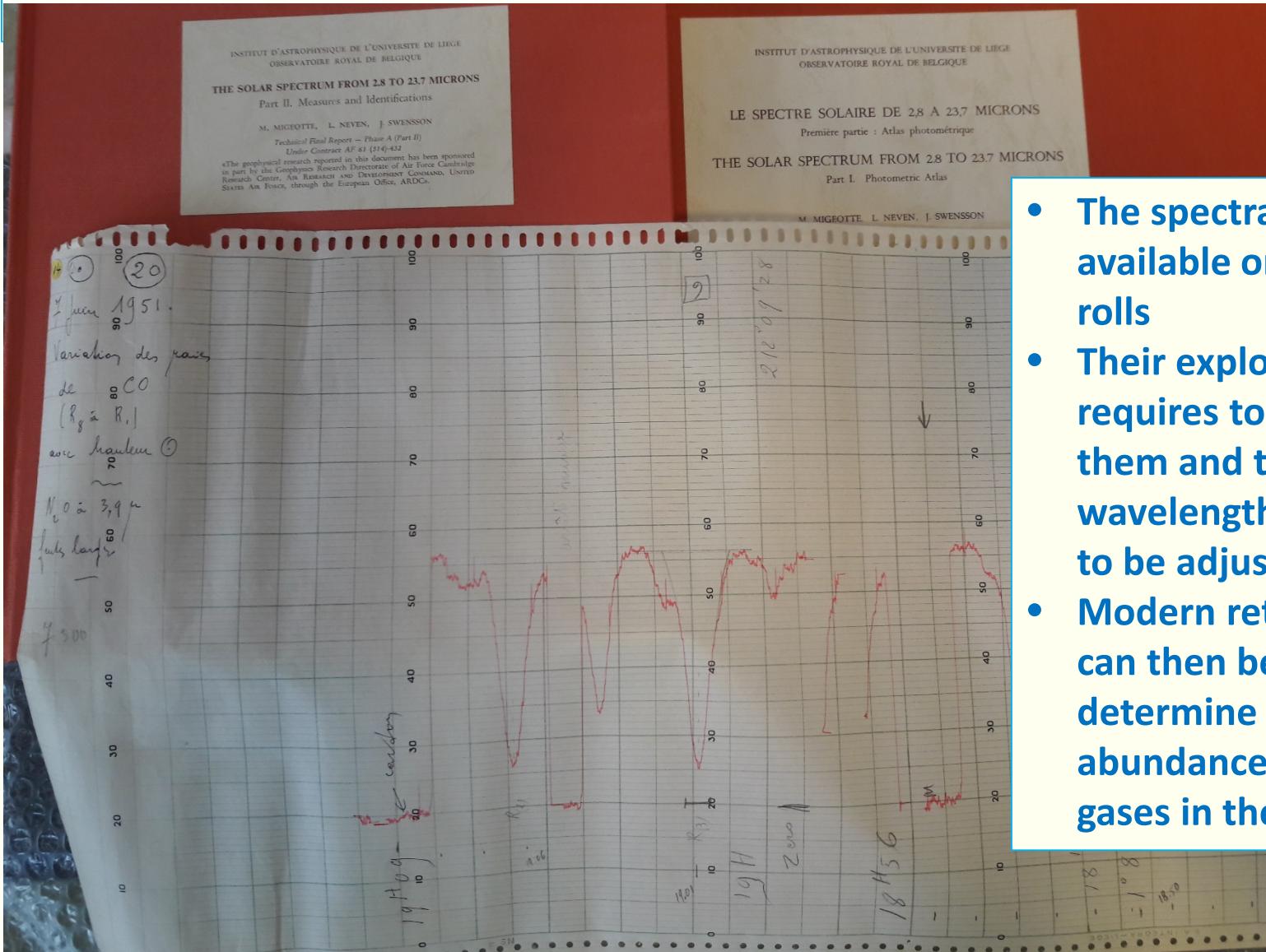
Currently, more than 35 gases are routinely retrieved from our spectra

Major greenhouse gases	H_2O , CO_2 , CH_4 , N_2O , CF_4 , SF_6	Support to the Kyoto Protocol and the Paris Agreement (COP21)
Related to stratospheric ozone depletion	O_3 , NO , NO_2 , HNO_3 , ClONO_2 , HCl , HF , COF_2 , CFC-11, CFC-12, HCFC-22, HCFC-142b, CCl_4	Support to the Montreal Protocol on substances that deplete ozone
Air quality, biomass burning, oil production and transport	CO , CH_3OH , C_2H_6 , C_2H_2 , C_2H_4 , HCN , HCHO , HCOOH , PAN, NH_3	Support, e.g., to CAMS: 
Other	OCS, N_2 , numerous isotopologues (HDO , CH_3D , $^{13}\text{CH}_4$, ^{13}CO ...)	Various applications; e.g., source apportionment/attribution



Our FTIR monitoring activities are conducted within the framework of the NDACC network, which includes an “infrared” component: achievements at Jungfraujoch stimulated other teams to set up a FTIR experiment

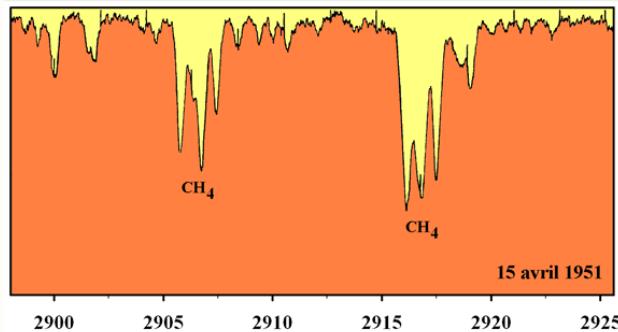
Use of early observations



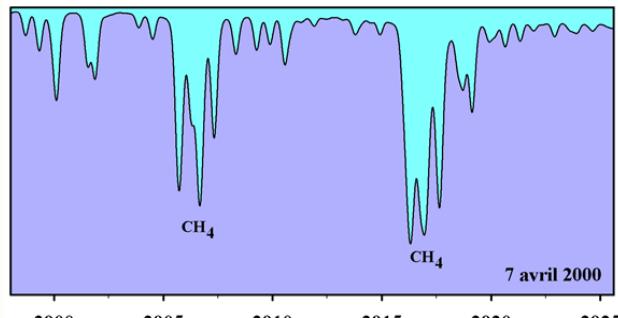
- The spectra are available on paper-rolls
- Their exploitation requires to digitize them and the wavelength scale has to be adjusted
- Modern retrieval tools can then be used to determine the abundance of target gases in the 1950s

Methane

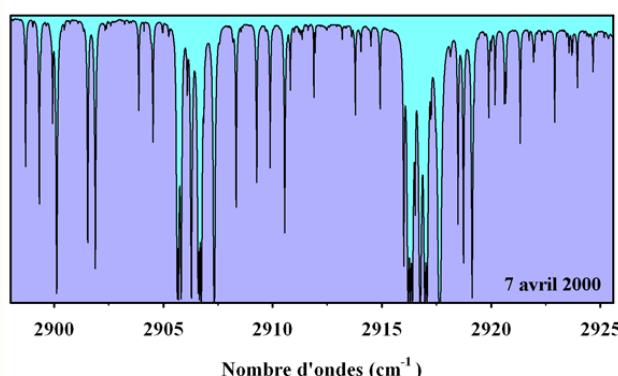
Comparison with present observations



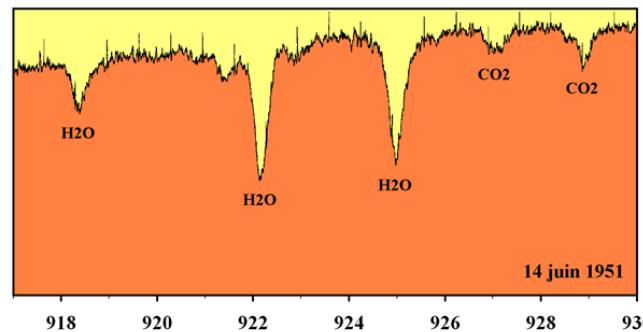
1951



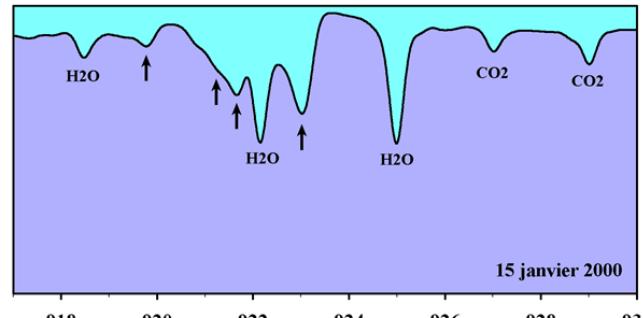
**2000
LR**



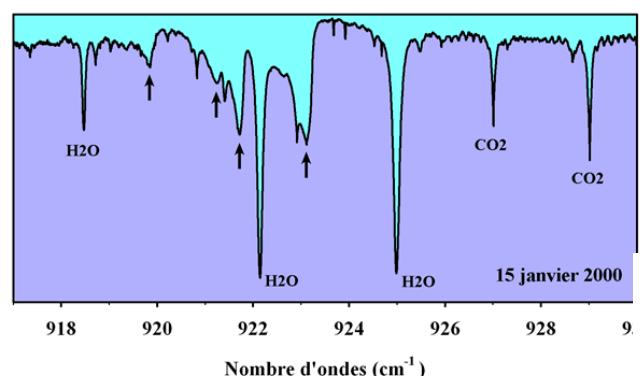
**2000
HR**



14 juin 1951



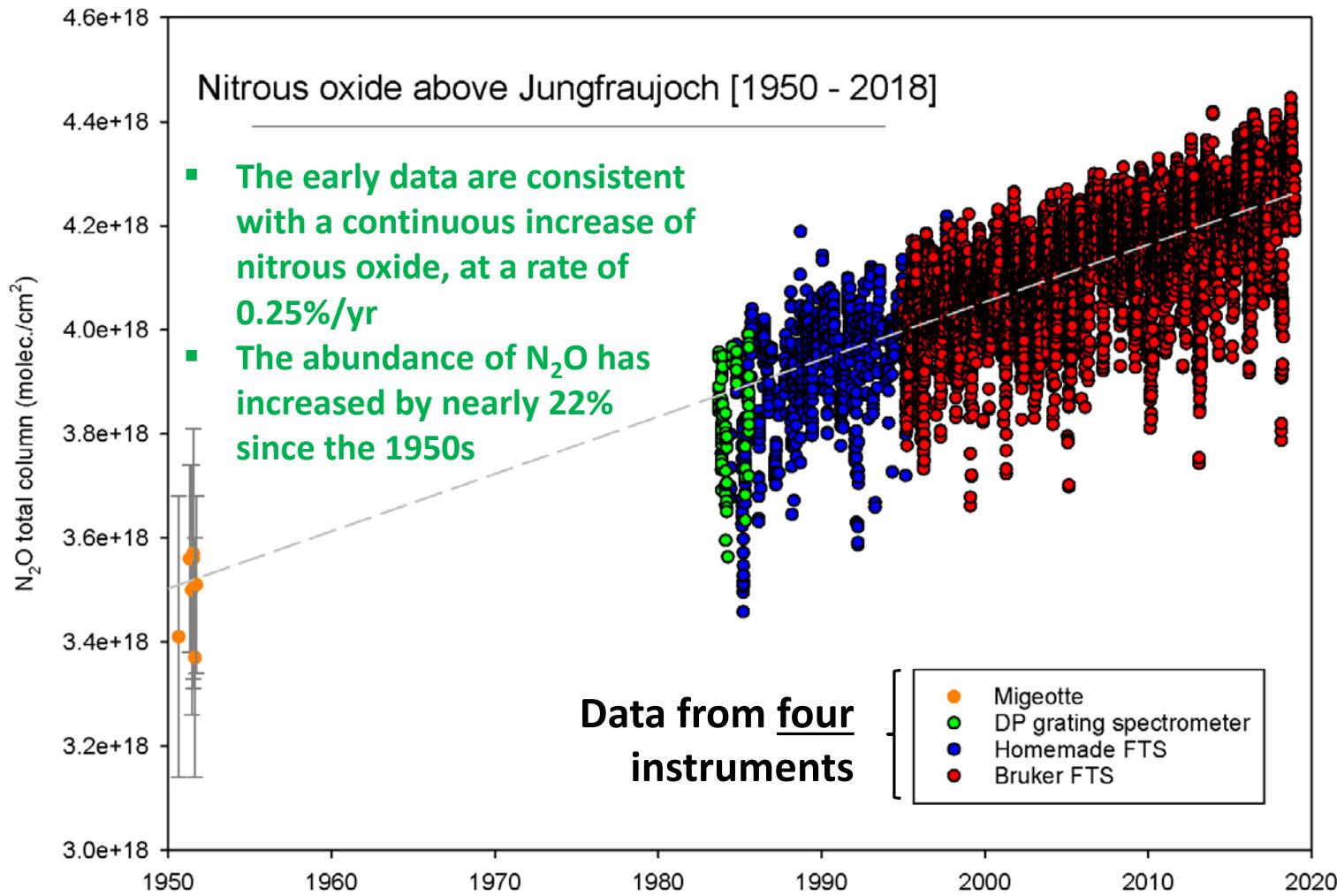
15 janvier 2000



15 janvier 2000

C
F
C -
1
2

Use of early observations: N₂O



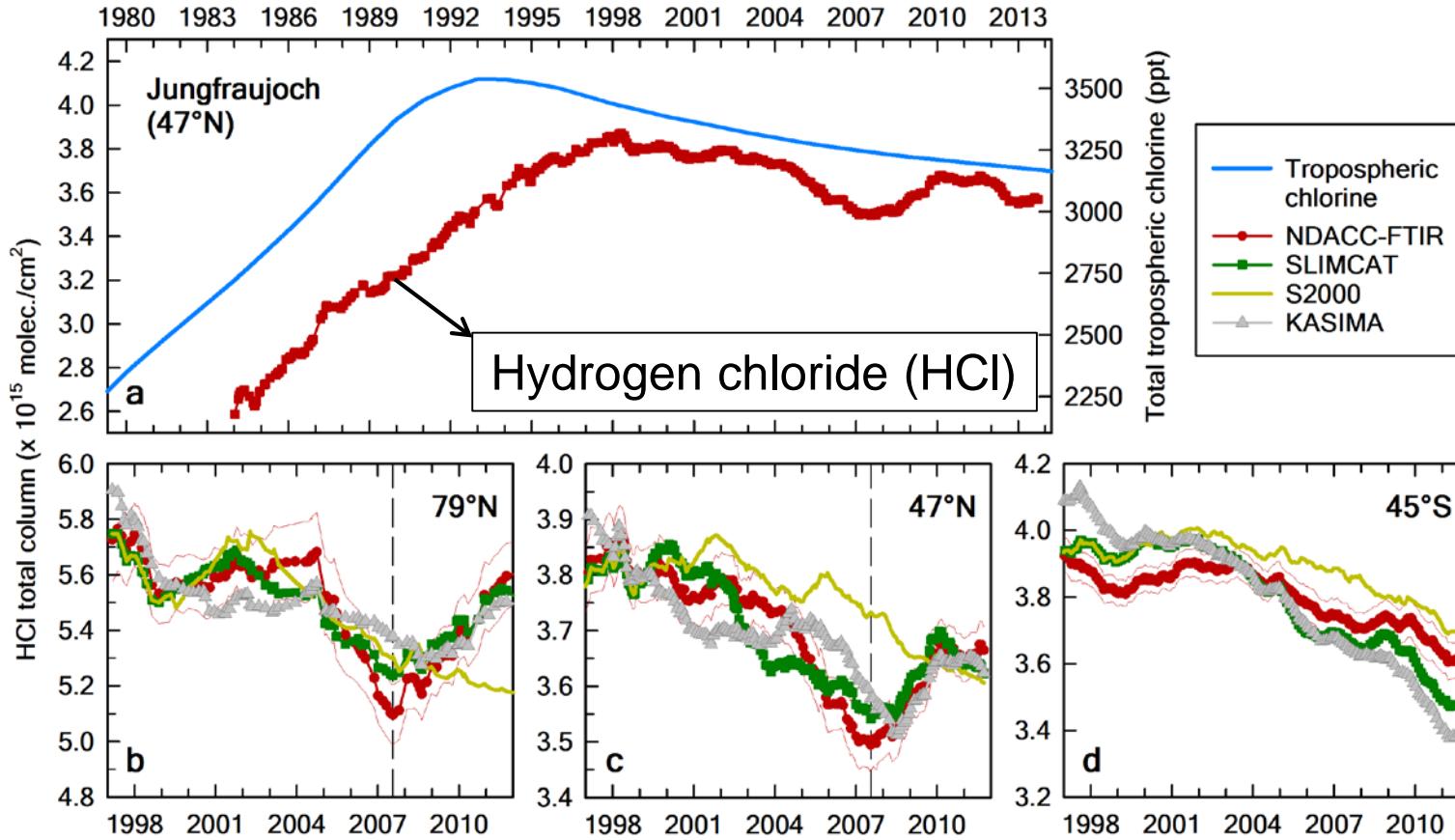


RECENT KEY RESULTS: THE HCL TREND ANOMALY

Why do we monitor HCl?

- Main product of the photolysis of the CFCs and other Cl-bearing source gas in the stratosphere
- Relevant indicator to verify the success of the Montreal Protocol on substances that deplete stratospheric ozone
- We expect a decrease following the progressive (until 100%) ban of the main Cl-sources

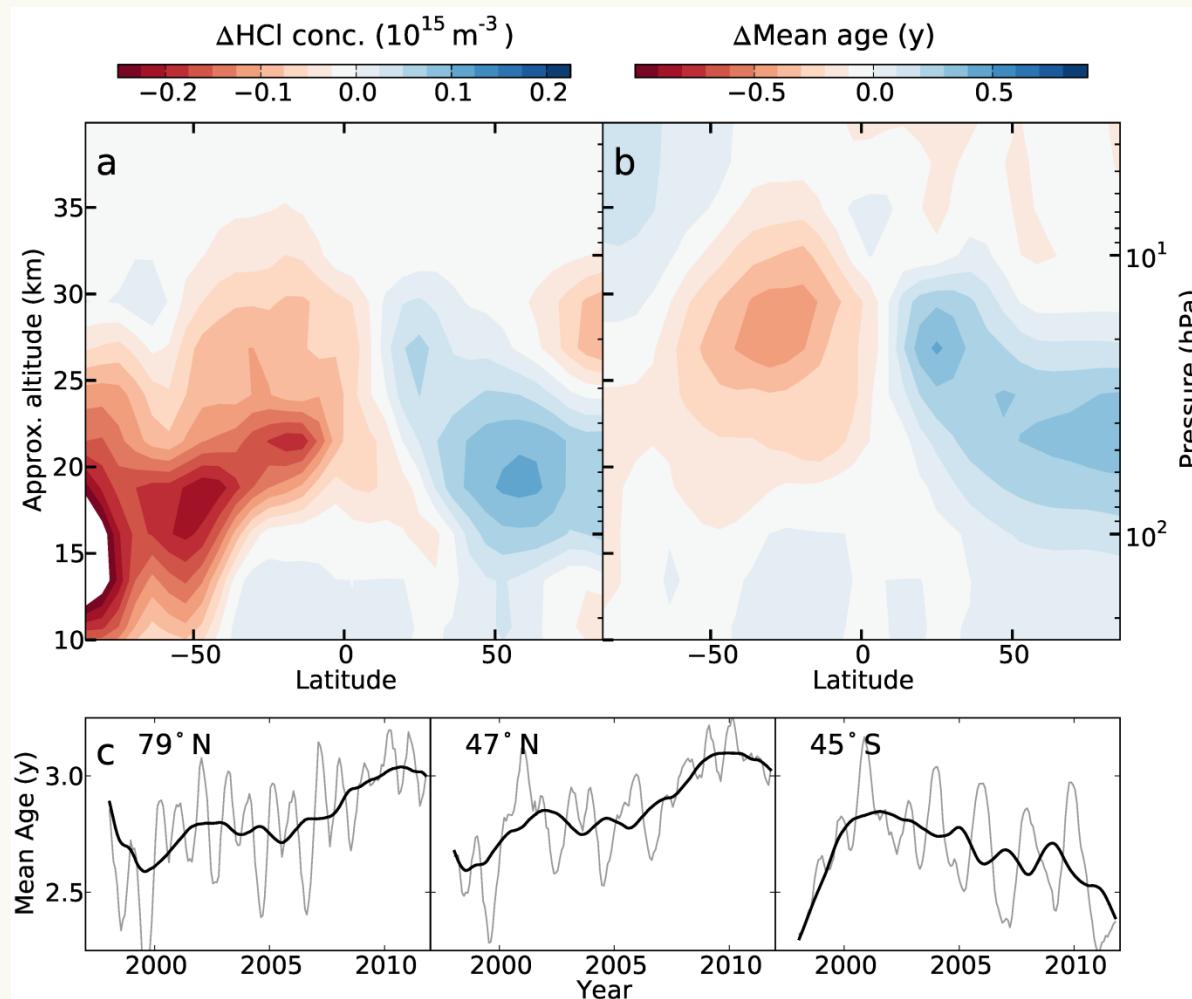
Atmospheric circulation and composition



The HCl trend anomaly is explained by a slowing down of the atmospheric circulation in the lower stratosphere of the Northern hemisphere

Updated from Fig. 1 in Mahieu et al., doi:10.1038/nature13857, 2014

Spatial distribution of the HCl and age-of-air changes between 2005 and 2010



From SLIMCAT model runs; Figure 4 in Mahieu et al., doi:10.1038/nature13857, 2014



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Ph. Demoulin



Dr Ch. Servais

Thank you for your attention!
Questions are welcome



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