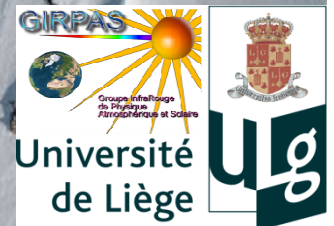


# Historical Jungfraujoch grating spectra: database extended back to 1977

*Ph. Demoulin, G. Roland, W. Bader, B. Lejeune,  
P. Duchatelet, E. Mahieu, C. Servais and R. Zander*



NDACC symposium, St-Paul, La Réunion, 7-10 Nov. 2011





**Jungfrauoch  
(3580 m)**

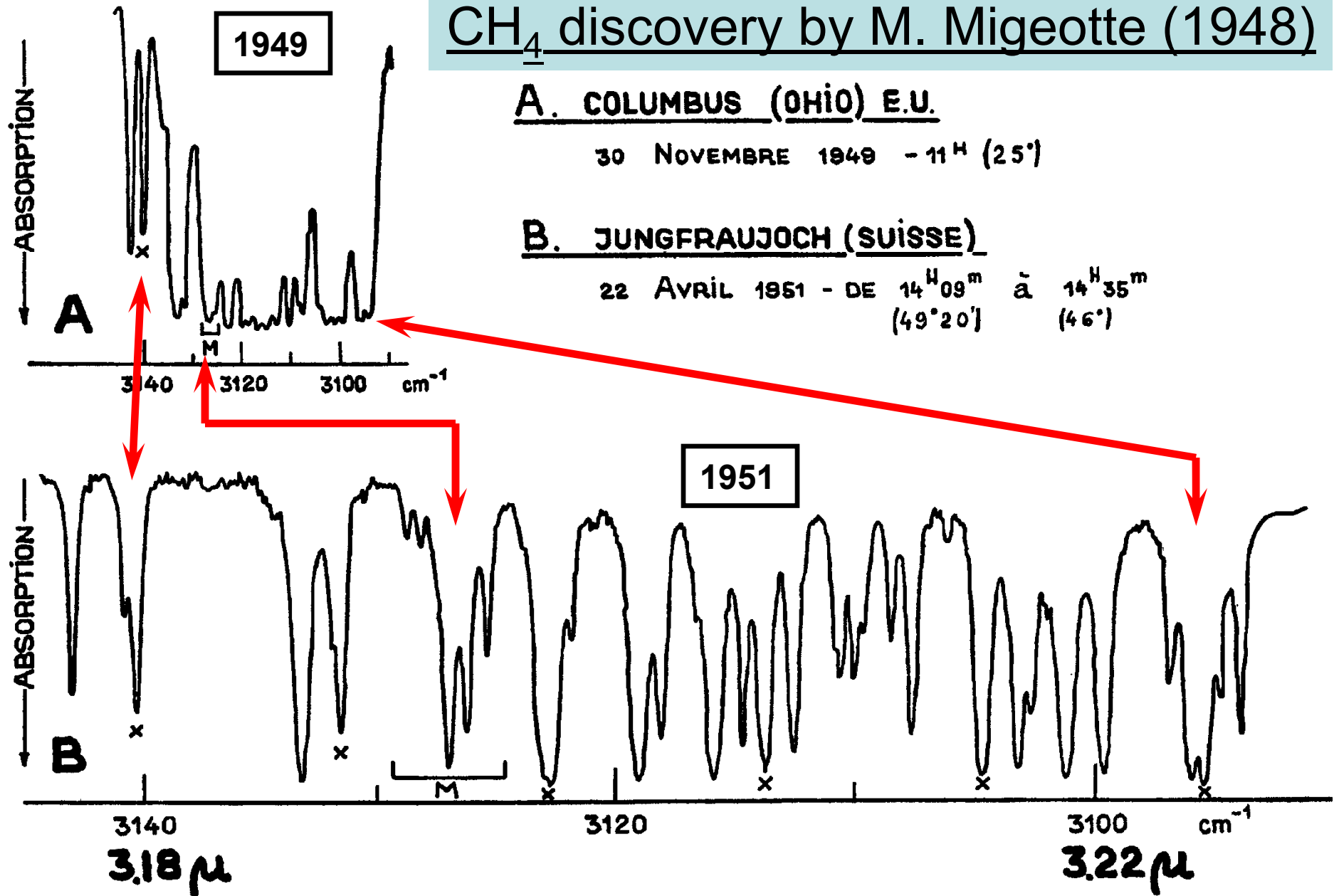
# CH<sub>4</sub> discovery by M. Migeotte (1948)

## A. COLUMBUS (OHIO) E.U.

30 NOVEMBRE 1949 - 11<sup>H</sup> (25')

## B. JUNGFRAUJOCH (SUISSE)

22 AVRIL 1951 - DE 14<sup>H</sup>09<sup>m</sup> à 14<sup>H</sup>35<sup>m</sup>  
(49°20') (46')



M. Migeotte also discovered CO in the Earth's atmosphere (1949)

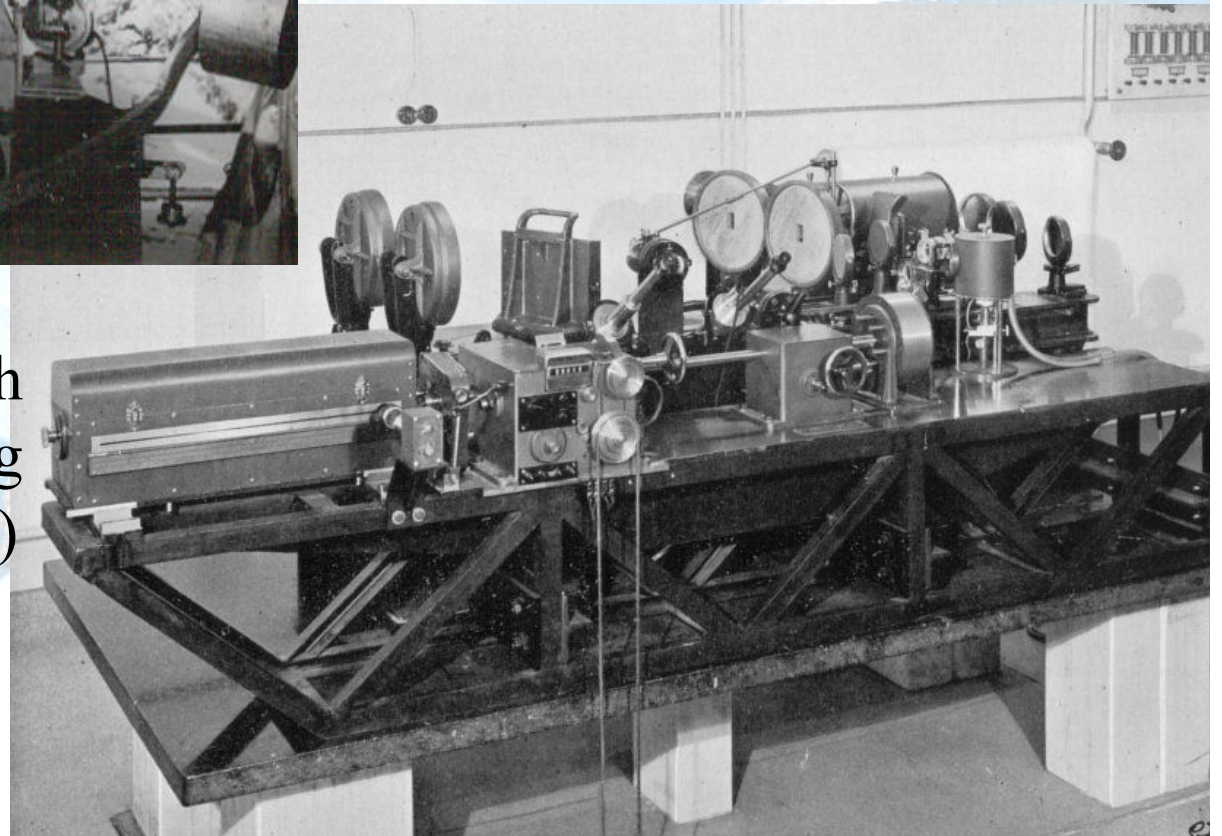
# 1950-1951

Since 1950, solar absorption spectra have been recorded at the Jungfrauoch, with various instruments operated by the University of Liège



One-meter focal length infrared Pfund-type grating spectrometer (M. Migeotte)

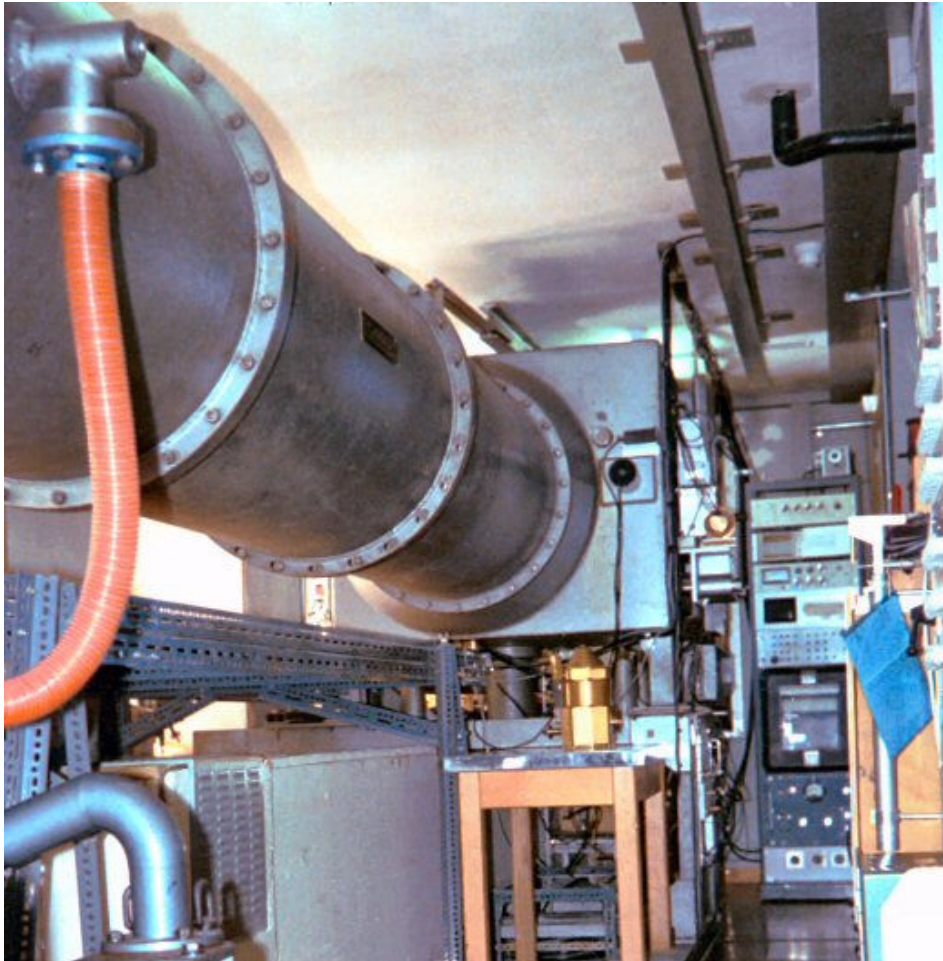
- solar atlas  
(2.8 - 23.7  $\mu\text{m}$ )



“ It will be very interesting to systematically record telluric bands due to CH<sub>4</sub>, N<sub>2</sub>O and CO in view to study or detect intensity variations with time”.

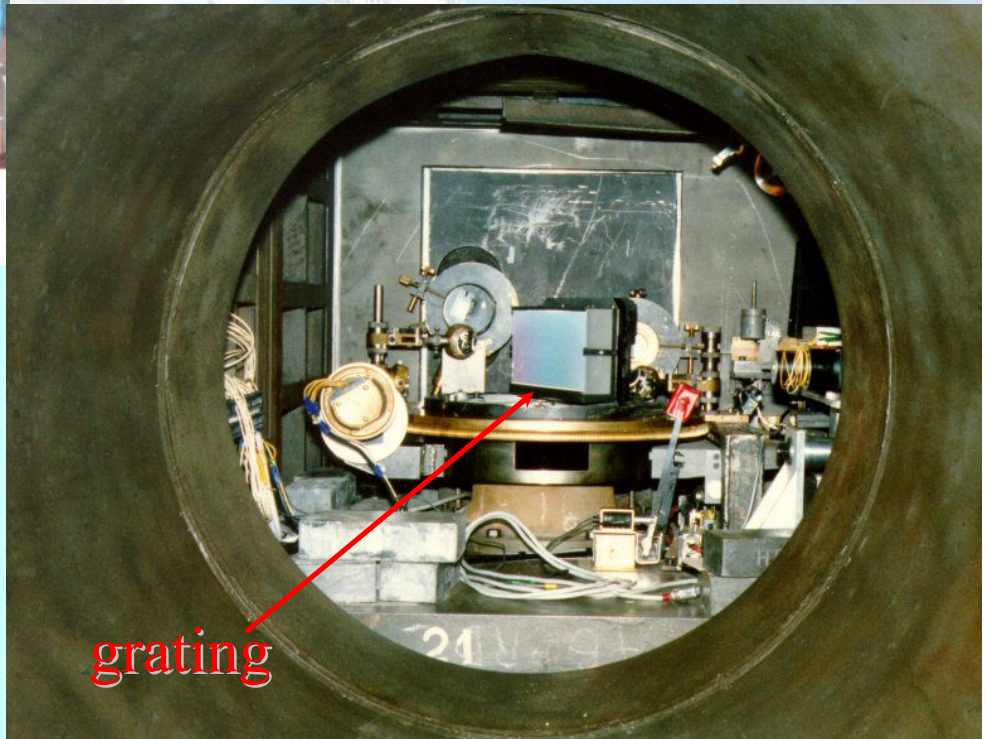
Marcel Migeotte, 1951

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



# 1958-1989

7.2-m focal length Ebert-Fastie  
IR, visible and UV grating  
spectrometer (L. Delbouille, G.  
Roland)



## Grating spectra

- 1958-1967 : a few hundreds of paper recordings
- 1968-1989 : ~ 8000 spectra, digitally recorded



- **1963 Delbouille, Roland**  
**The Solar Spectrum from  $\lambda$  7498 to  $\lambda$  12016 Å**
  - **1970 Swensson, Benedict, Delbouille, Roland**  
**Table of Measures and Identifications.**
  
- **1973-1988 Delbouille , Neven, Roland**  
**Photometric Atlas of the Solar Spectrum from**  
**3000 to 10,000 Å.**

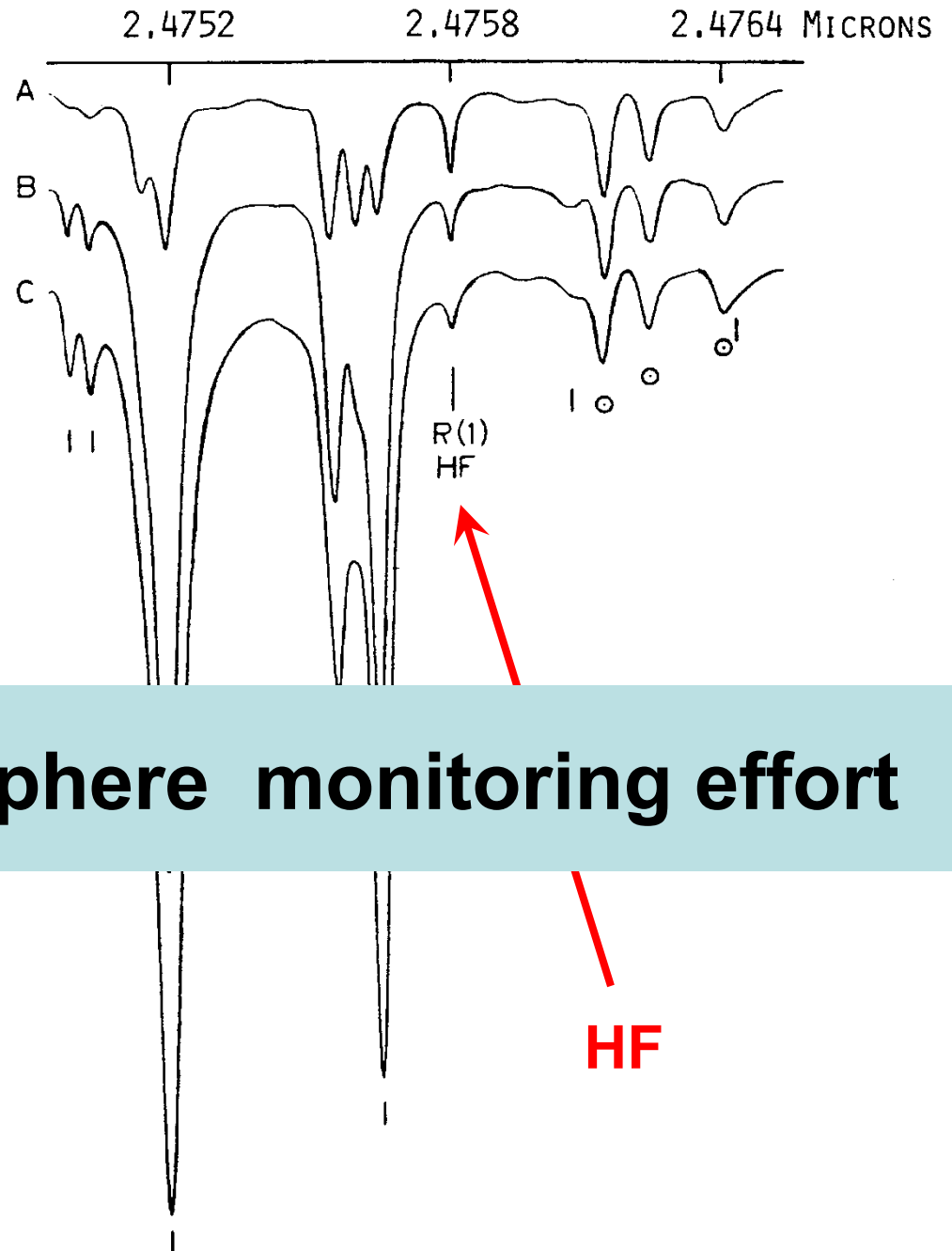
# Discovery of fluorhydric acid (HF)

- in 1974, by R. Zander, above 20 km, during a stratospheric balloon flight over Texas
- no natural source of F  
⇒ convincing proof that CFC, released in the atmosphere

⇒ **start of our atmosphere monitoring effort**

are photo-dissociated by solar UV and release F and Cl atoms ⇒ ozone destruction

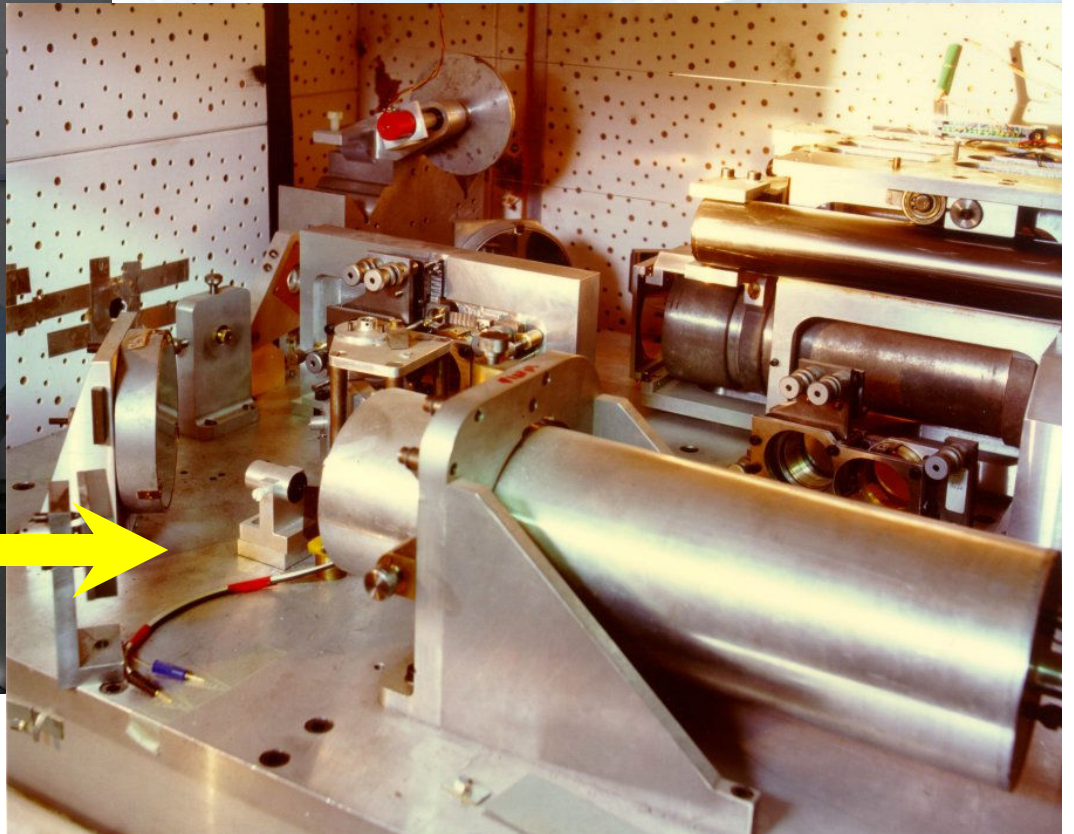
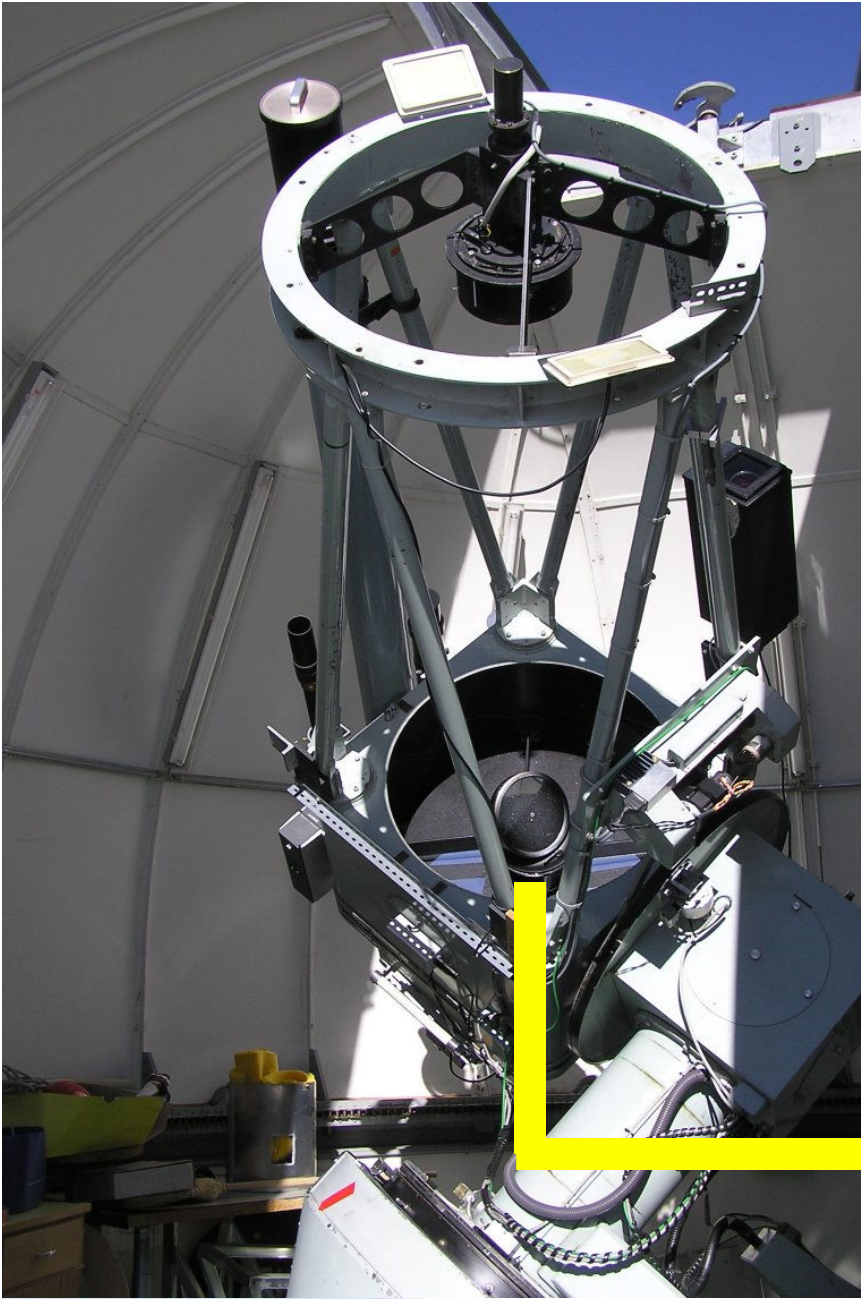
- in 1976, detection with the Jungfraujoch spectrometer

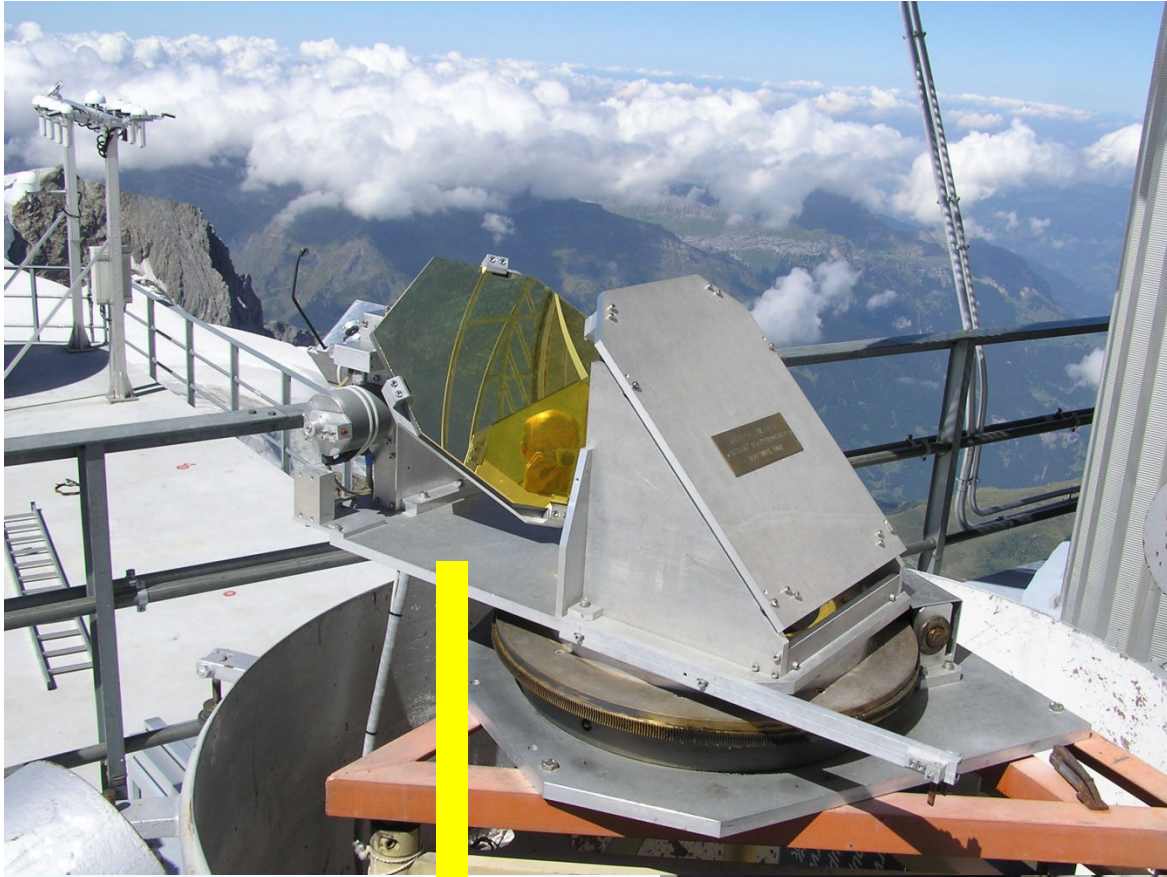




# Fast scanning FTS (since 1984)

- home-made FTS (Ph. Demoulin)
  - good angular resolution
  - more than 11000 mid-IR spectra





# Bruker FTS (since 1990)

- commercial Bruker IFS-120HR
- more than 37000 mid-infrared solar spectra



Spectrometer		Date	Domain	Wavenumber (cm <sup>-1</sup> )	Wavelength (μm)	# spectra
1 m grating	Migeotte atlas	1950 - 1951	MIR & FIR	421 - 3565	2.8 – 23.7	
7.2 m grating	single-pass	1958 - 1963	NIR			
	Delbouille atlas	1959 - 1960		8320 - 13330	0.75 – 1.2	
	double-pass	1963 - 1989	UV to MIR	2380 - 33390	0.3 – 4.2	
	Delbouille atlas	1966 - 1976		9995 - 33390	0.3 – 1.0	
	atmosph. interest	<b>1976 - 1989</b>	MIR	<b>2400 - 4200</b>	<b>2.4 – 4.2</b>	<b>~ 10 000</b>
home-made FTS	stepping	1974 - 1976	NIR	3950 - 8620	1.2 – 2.5	
	continuous	<b>1984 - now</b>	MIR	<b>700 - 5600</b>	<b>1.8 – 14.3</b>	<b>10 418</b>
Bruker IFS-120 HR FTS	atmosphere (NDACC)	<b>1990 - now</b>	MIR	<b>700 - 4300</b>	<b>2.3 – 14.3</b>	<b>37 650</b>
	Farmer atlas	March 2003	FIR	250 - 630	16 – 40	

Atmospheric spectra from 1950 to now  
⇒ unique in the world database !

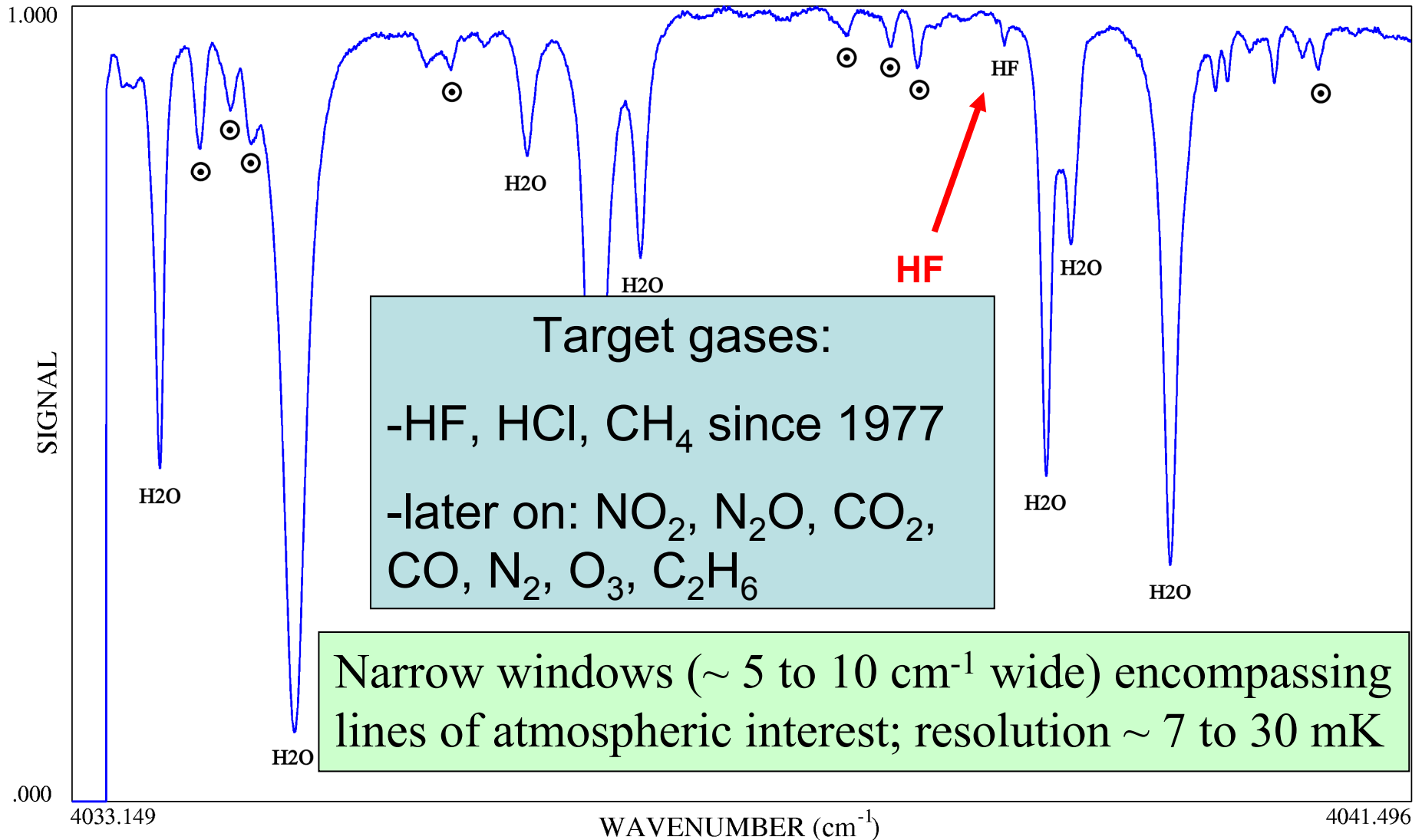
# Example of grating spectrum (1976)

JUNGFRAUJOCH

G:\H2O\STVTESTHFV77A07AA.DAT

DSP 22 AUG 2008 11:41:35

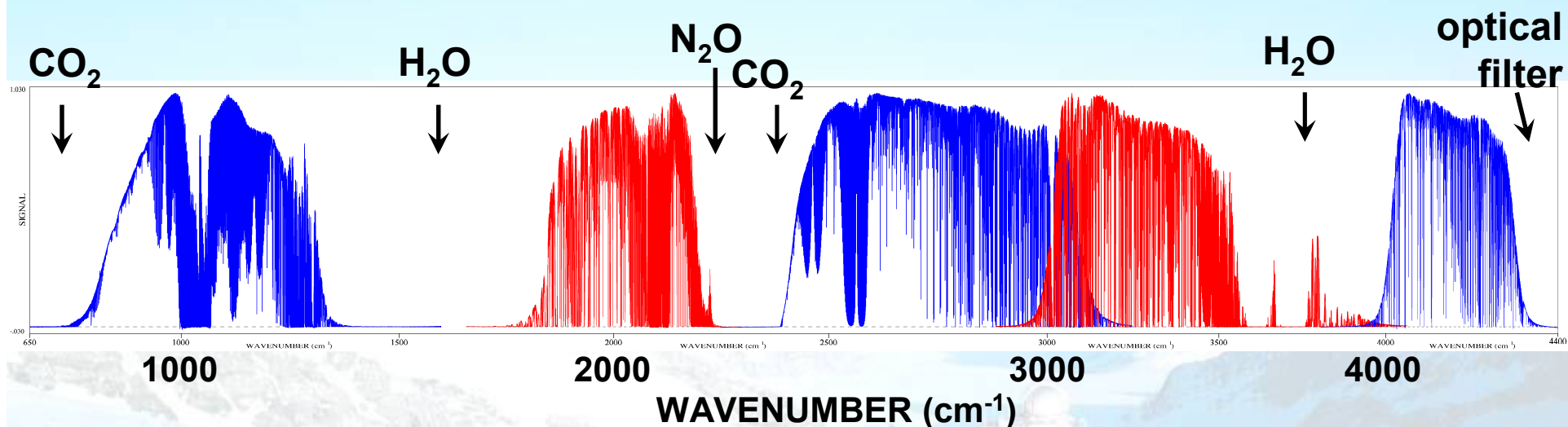
d77a07aa.dat 07 OCT 1976 10:32:30 Z = 57.38°



Target gases:  
-HF, HCl, CH<sub>4</sub> since 1977  
-later on: NO<sub>2</sub>, N<sub>2</sub>O, CO<sub>2</sub>,  
CO, N<sub>2</sub>, O<sub>3</sub>, C<sub>2</sub>H<sub>6</sub>

Narrow windows (~ 5 to 10 cm<sup>-1</sup> wide) encompassing lines of atmospheric interest; resolution ~ 7 to 30 mK

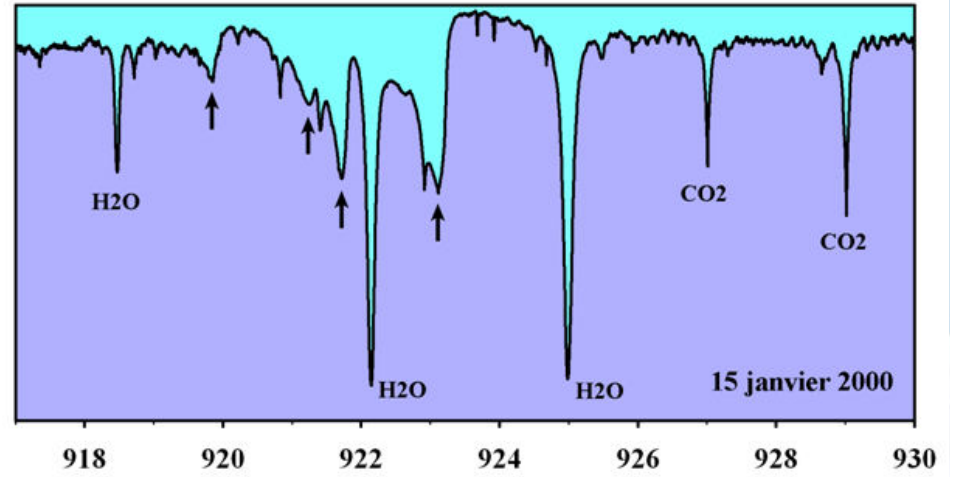
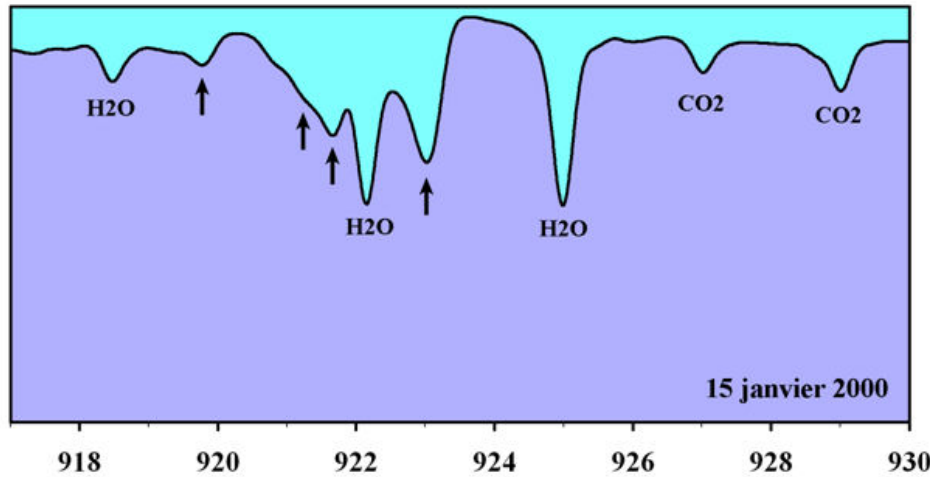
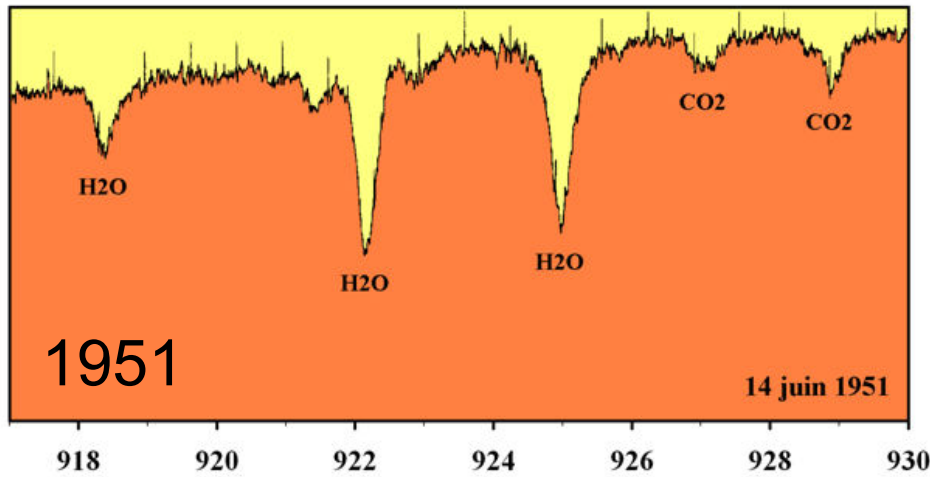
# FTIR spectra: 5 optical filters



Abundances of 28 gases currently derived from this spectral domain:

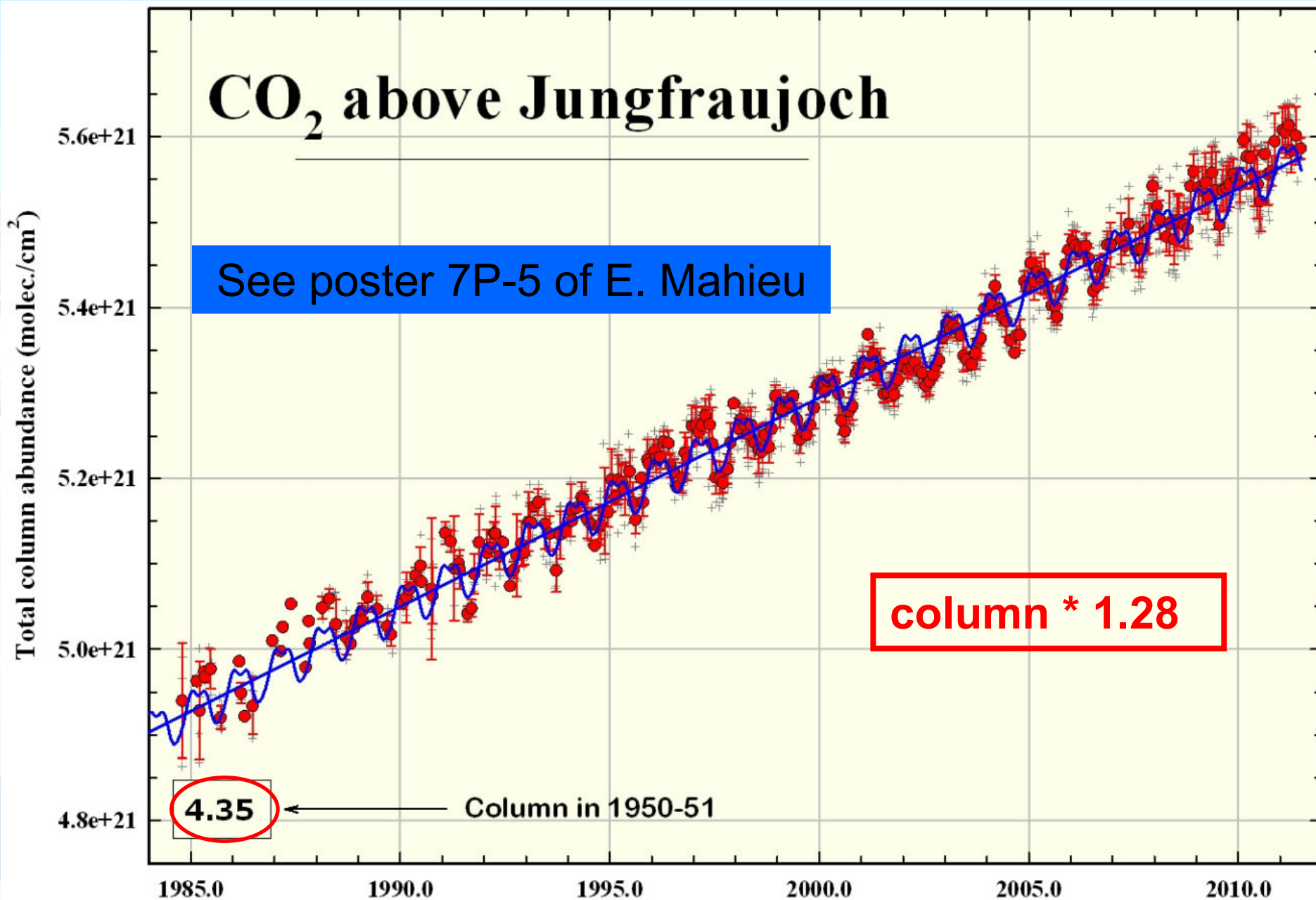
O <sub>3</sub> layer-related	HCl, ClONO <sub>2</sub> , HNO <sub>3</sub> , NO, NO <sub>2</sub> , HF, COF <sub>2</sub> , O <sub>3</sub>
O <sub>3</sub> layer- & climate- related	CCl <sub>2</sub> F <sub>2</sub> , CHClF <sub>2</sub> , CCl <sub>3</sub> F, CCl <sub>4</sub> , CF <sub>4</sub>
Climate-related	N <sub>2</sub> O, CH <sub>4</sub> , <sup>13</sup> CH <sub>4</sub> , CO <sub>2</sub> , SF <sub>6</sub> , H <sub>2</sub> O, HDO
Others (troposphere...)	CO, C <sub>2</sub> H <sub>2</sub> , C <sub>2</sub> H <sub>6</sub> , OCS, HCN, H <sub>2</sub> CO, H <sub>2</sub> CO <sub>2</sub> , N <sub>2</sub>

# CFC-12 from 1951 to 2000

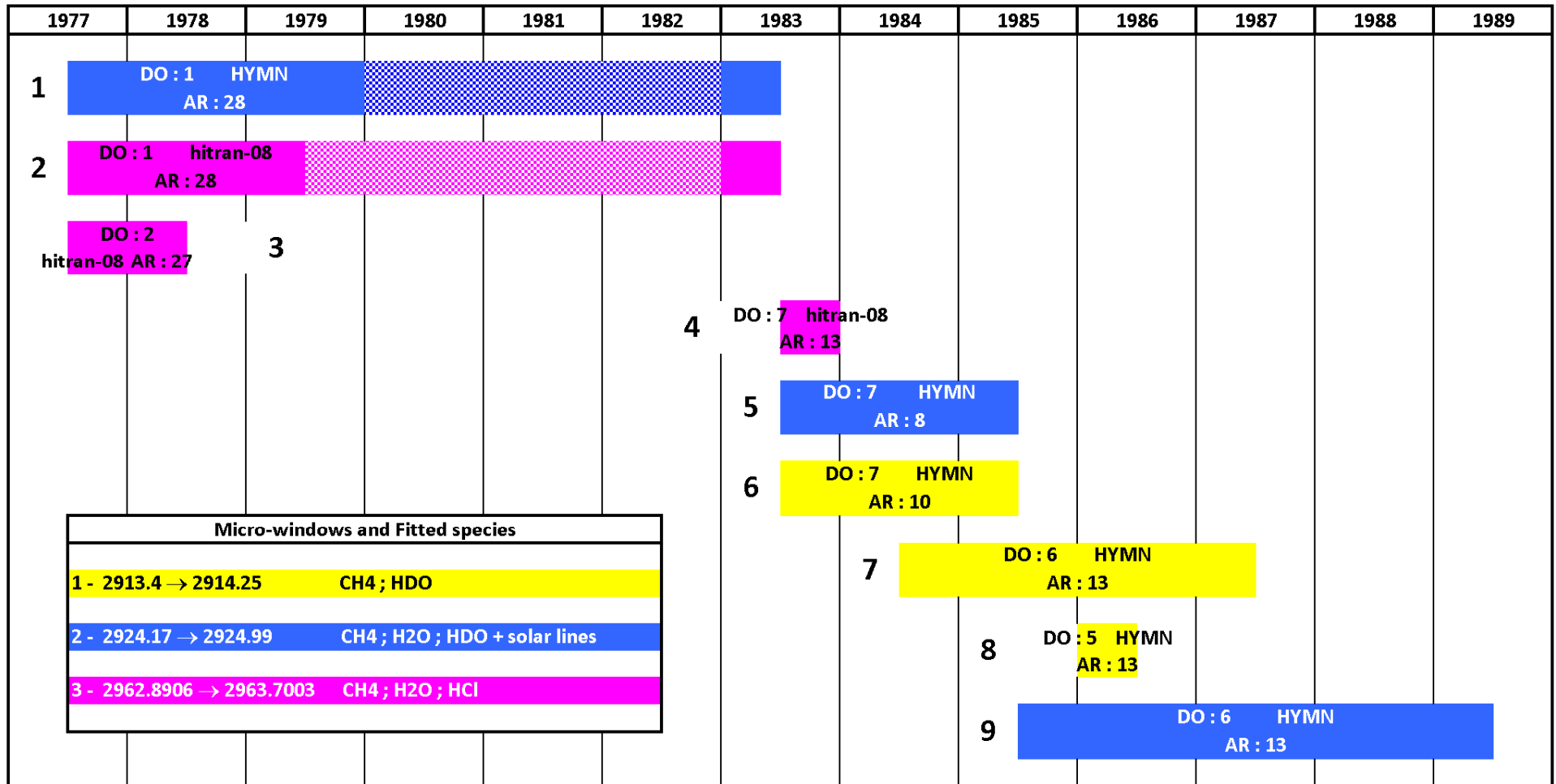


# CO<sub>2</sub> above Jungfraujoch

See poster 7P-5 of E. Mahieu



# CH<sub>4</sub> spectra availability



DO = diffraction order AR = assumed resolution (mK)

- intercalibration of spectral domains: spectra recorded the same day, or with DPGS and FTS

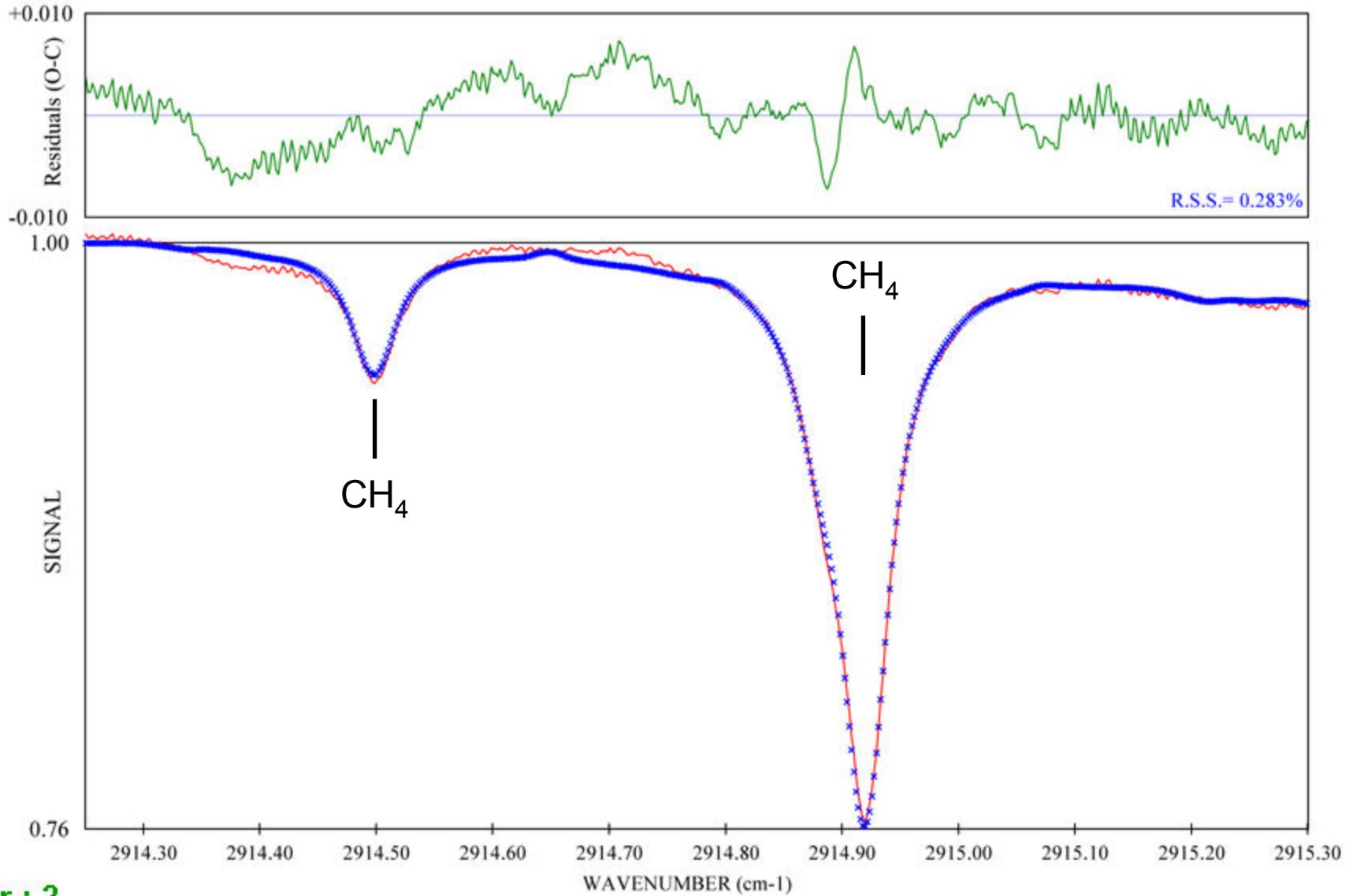


# CH<sub>4</sub> grating spectrum

JJB-G86314AN.DAT 14 MAR 1986 12.848

Res: 13.000 mK Dia: 0.0 mm App.Z.Ang: 48.874 Deg S/N: 0

Retrieved Gases : CH<sub>4</sub> NO<sub>2</sub>  
Vert Col (mol/cm<sup>2</sup>) : 2.127E+19 -2.435E+15



Iter : 2

# CH<sub>4</sub> grating spectrum

JUNGFRAUJOCH

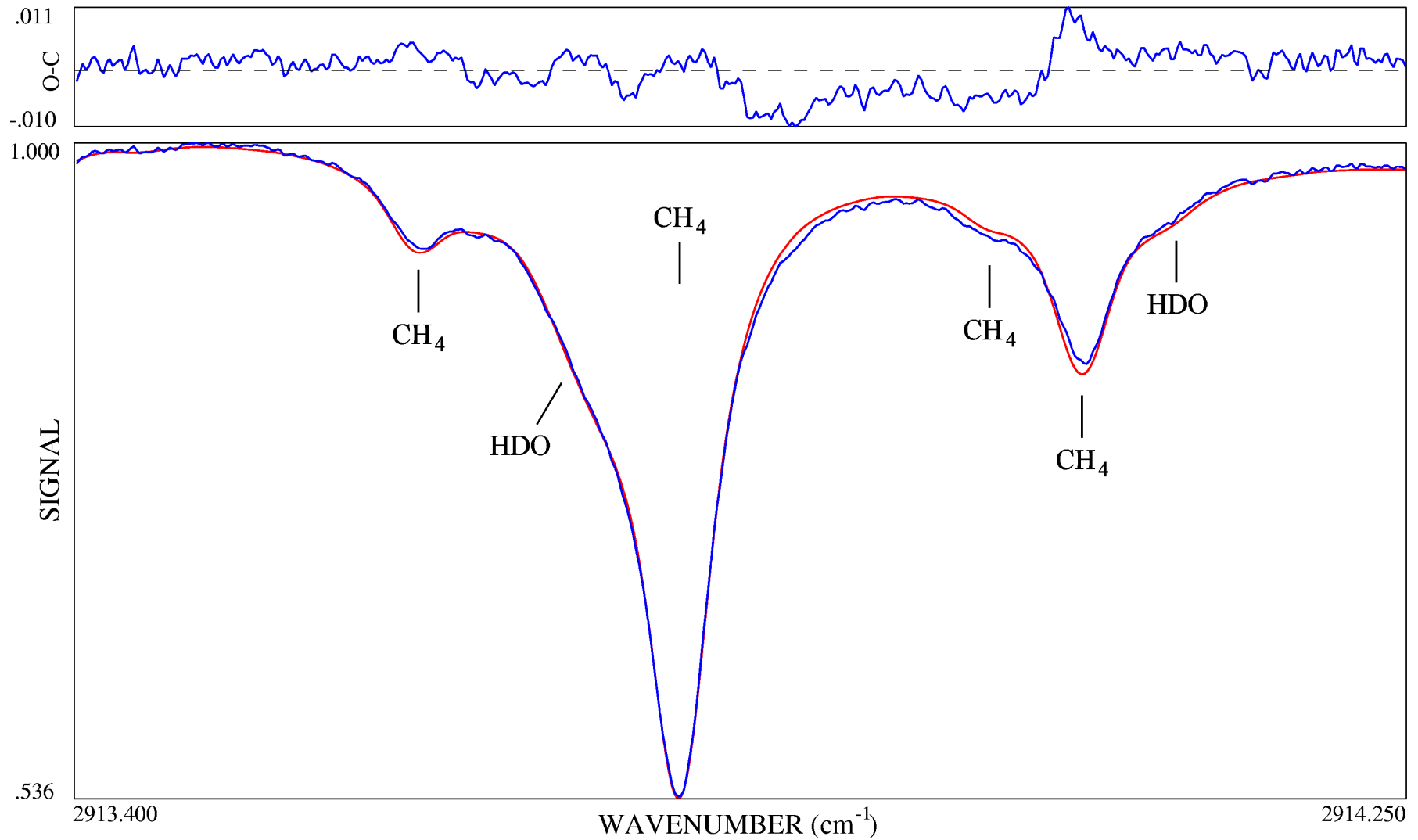
P85910AN.MOY

GRATING

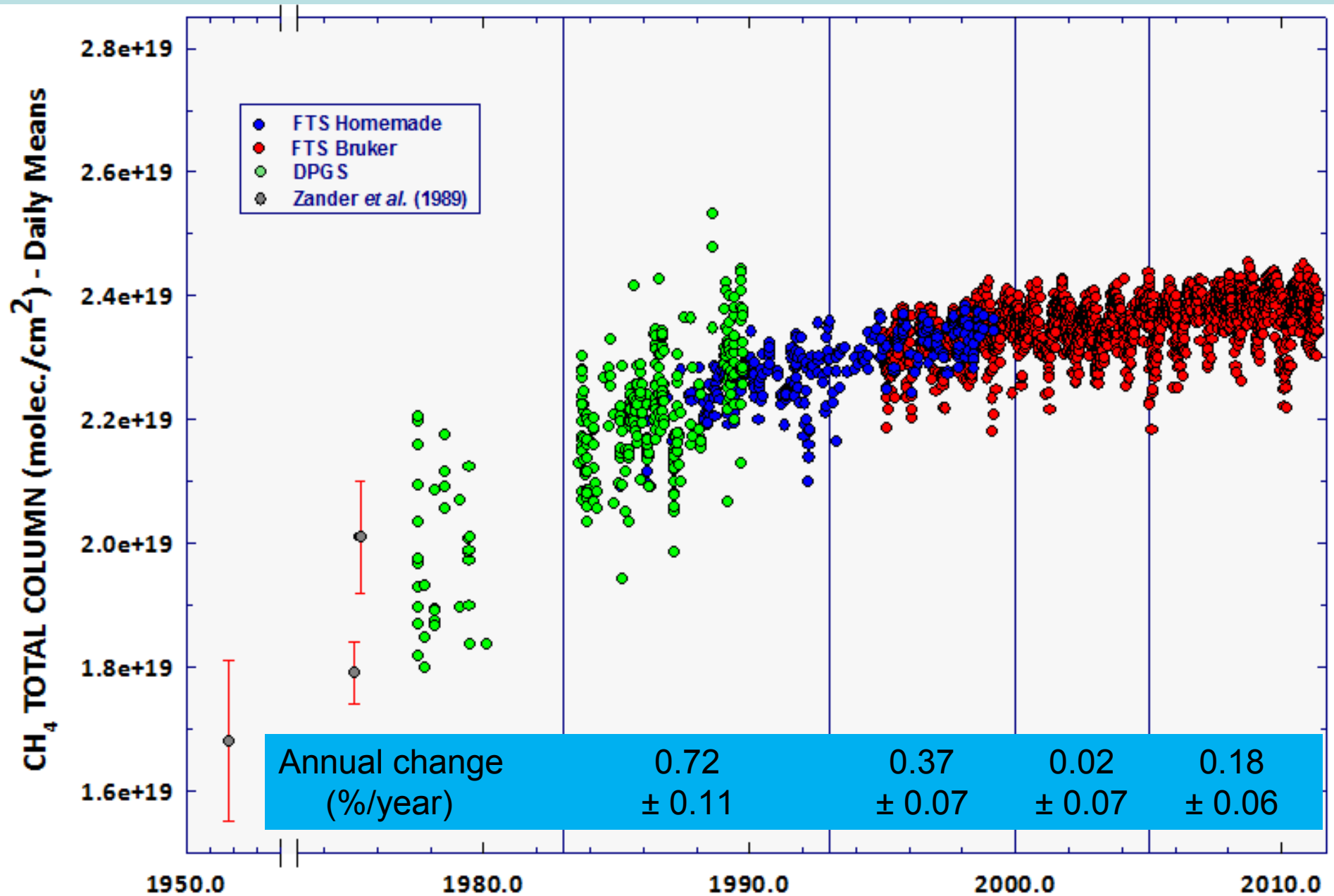
DSP 29 MAR 2011 15:38:32

StDev = .3736 %

w 1/1 Z = 71.85°



# CH<sub>4</sub> above Jungfraujoch



# Harmonized long-term time series of CH<sub>4</sub> above Jungfraujoch

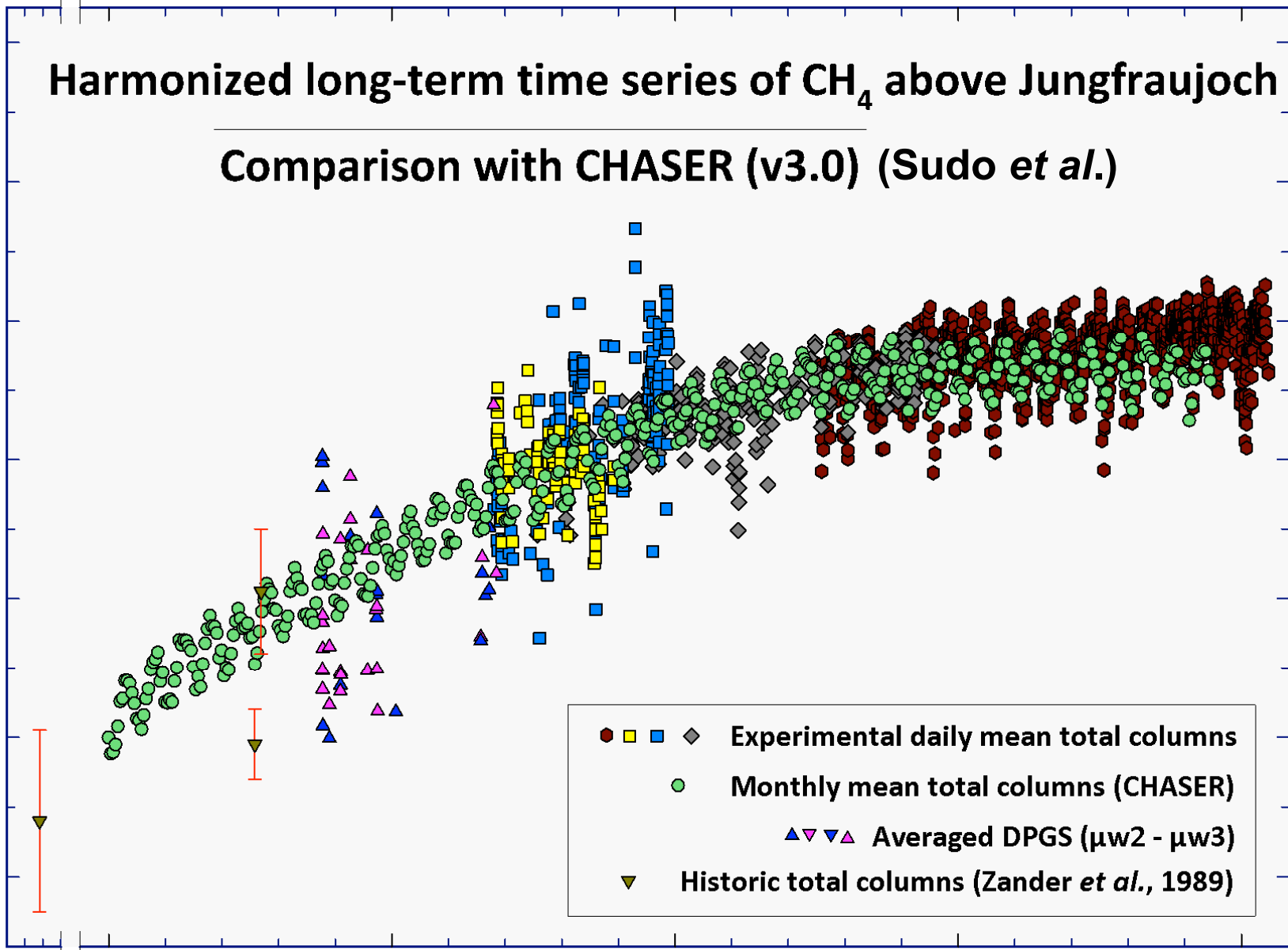
## Comparison with CHASER (v3.0) (Sudo *et al.*)

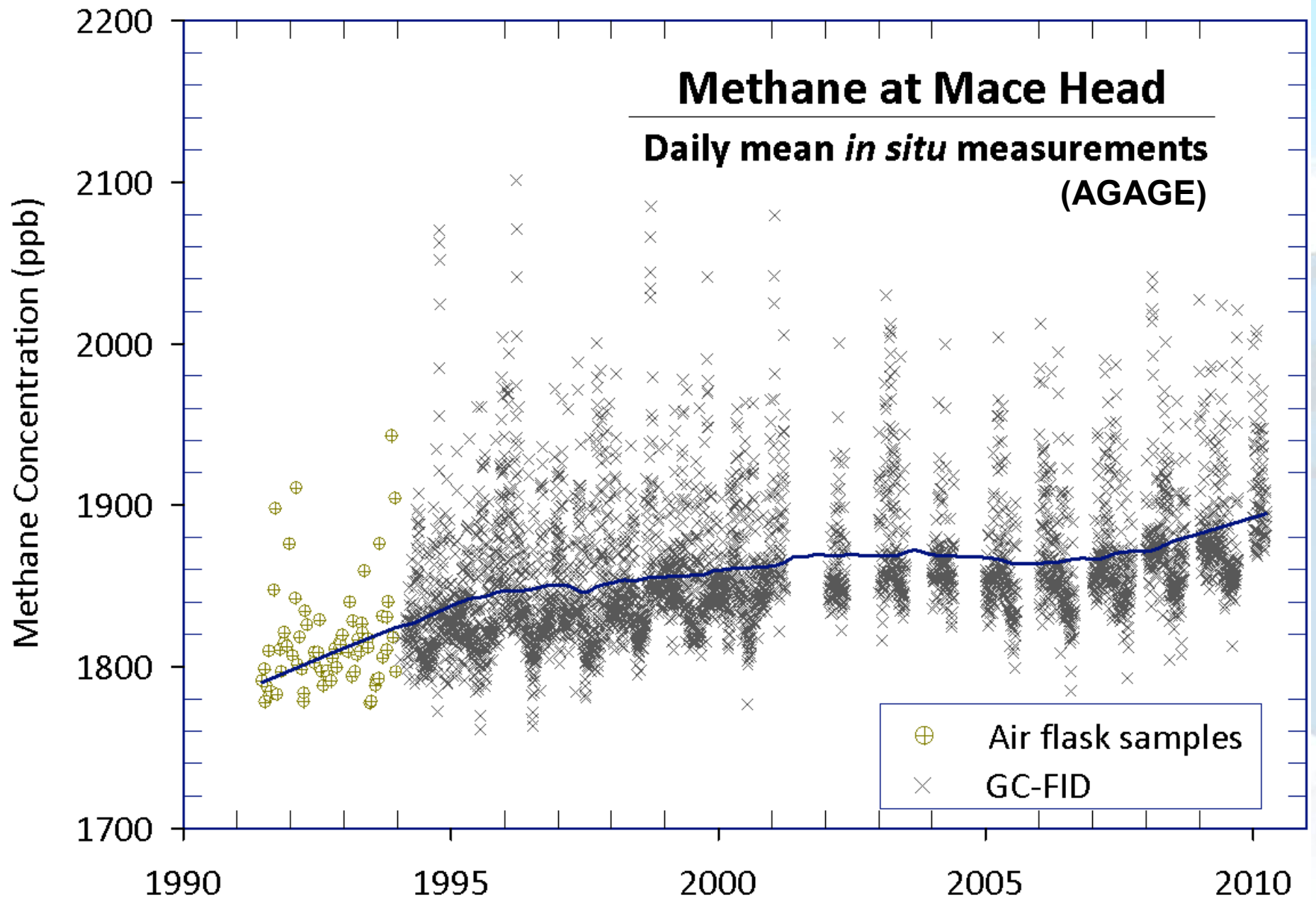
TOTAL COLUMN (molec./cm<sup>2</sup>)

2.8e+19  
2.6e+19  
2.4e+19  
2.2e+19  
2.0e+19  
1.8e+19  
1.6e+19

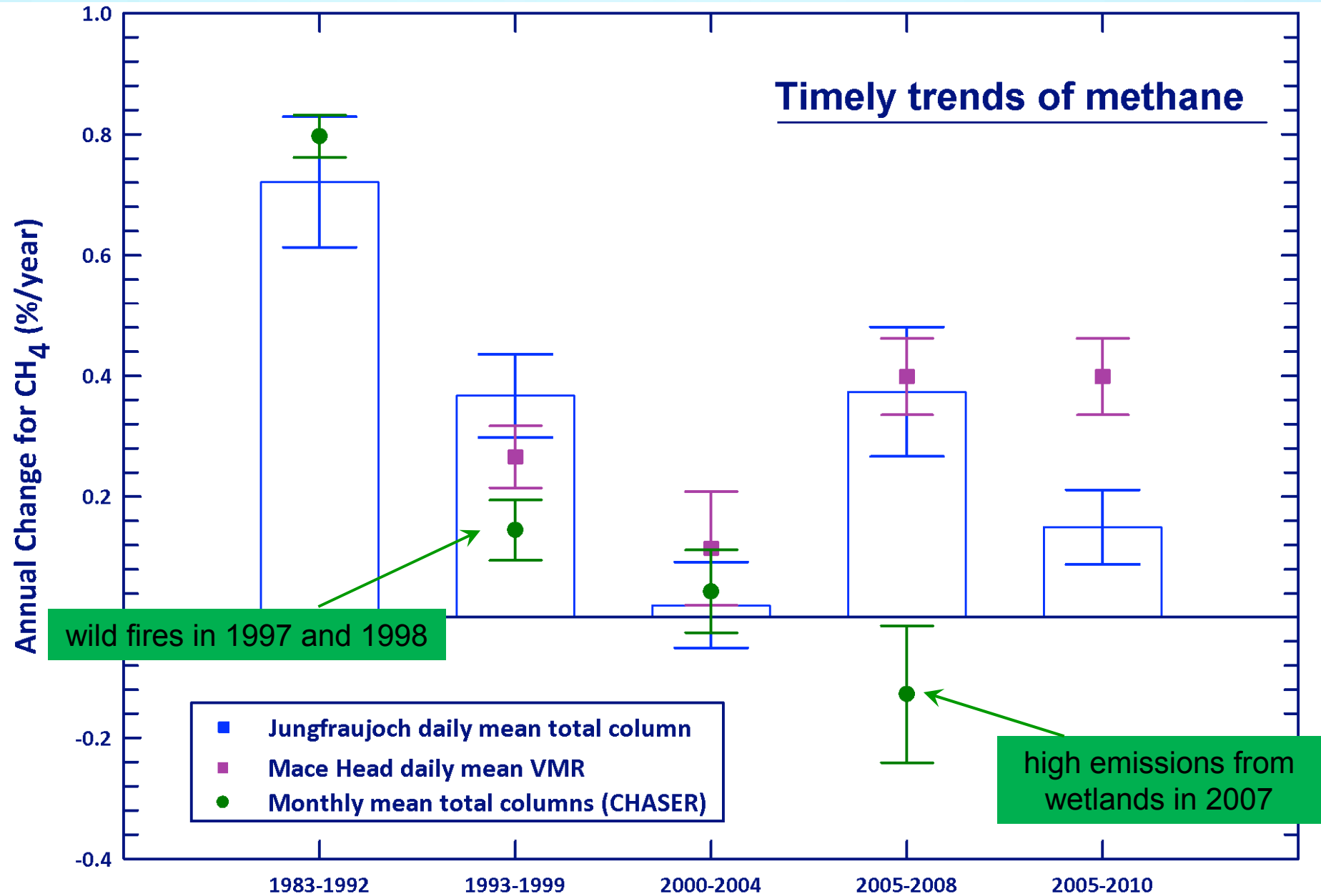
1950.0 1970.0 1980.0 1990.0 2000.0 2010.0

- ■ ◆ Experimental daily mean total columns
- Monthly mean total columns (CHASER)
- ▲ ▼ ▲ Averaged DPGS ( $\mu w2 - \mu w3$ )
- ▼ Historic total columns (Zander *et al.*, 1989)

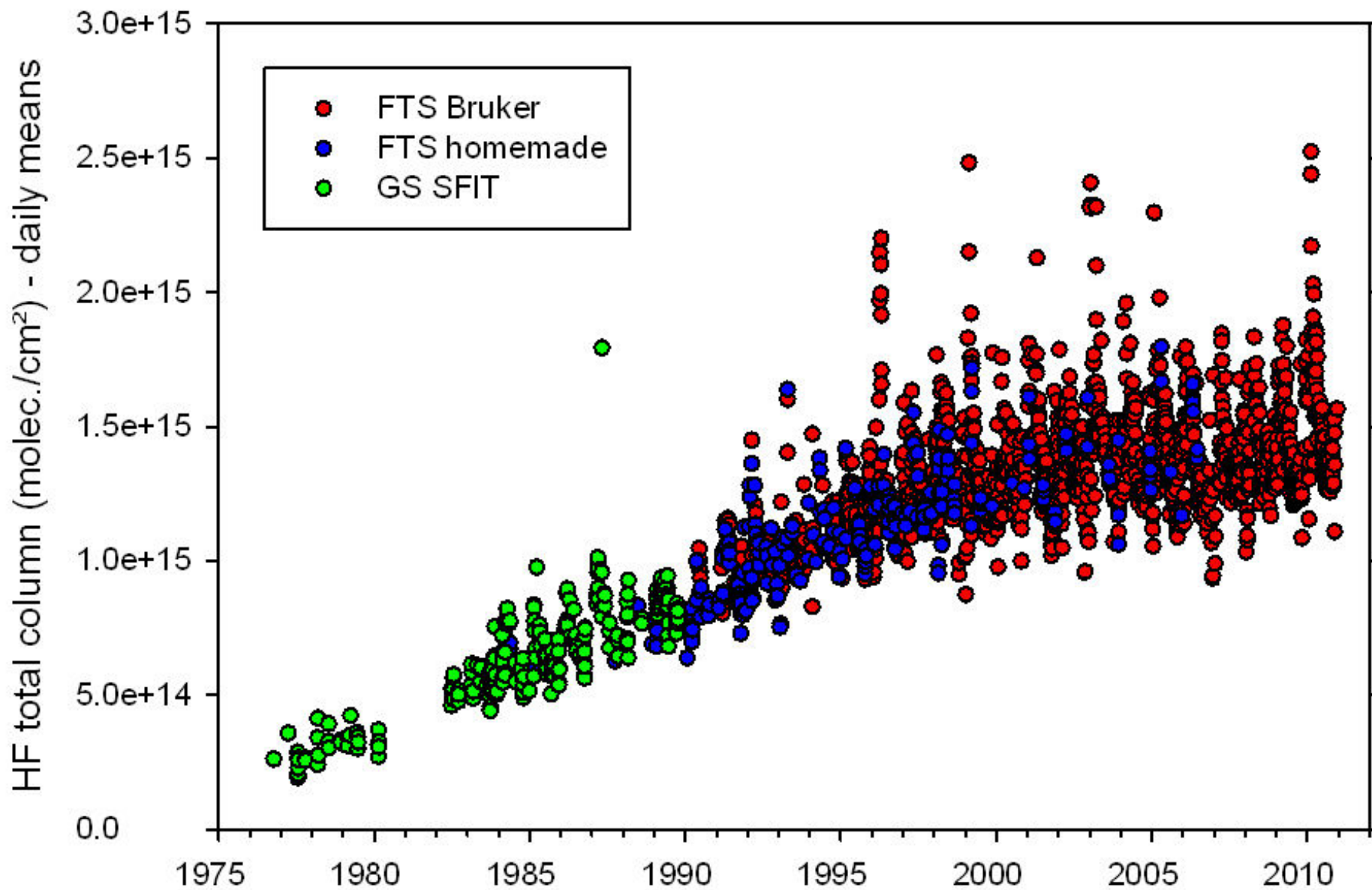




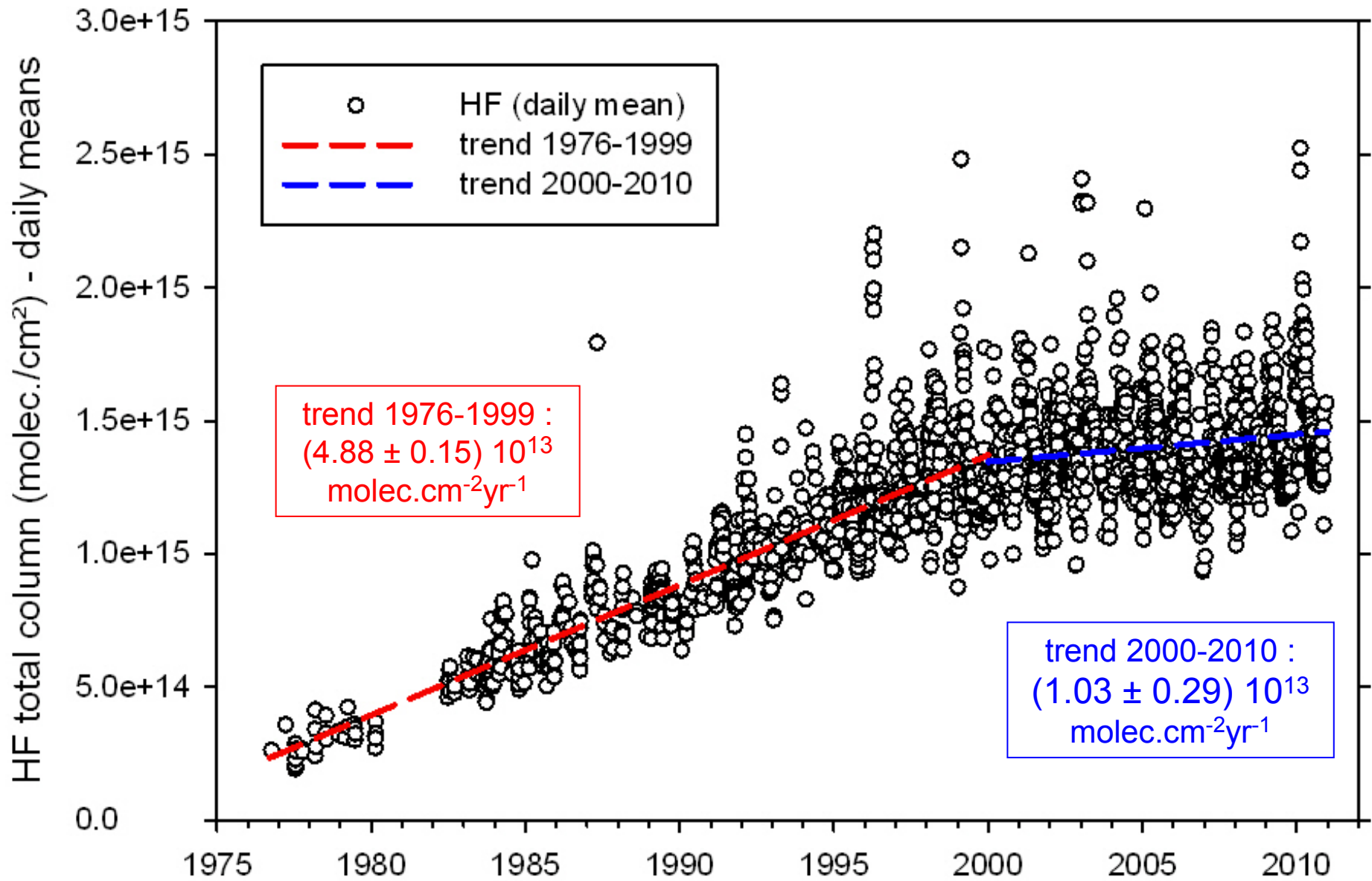
# CH<sub>4</sub> – trends comparison



# HF above Jungfrauoch

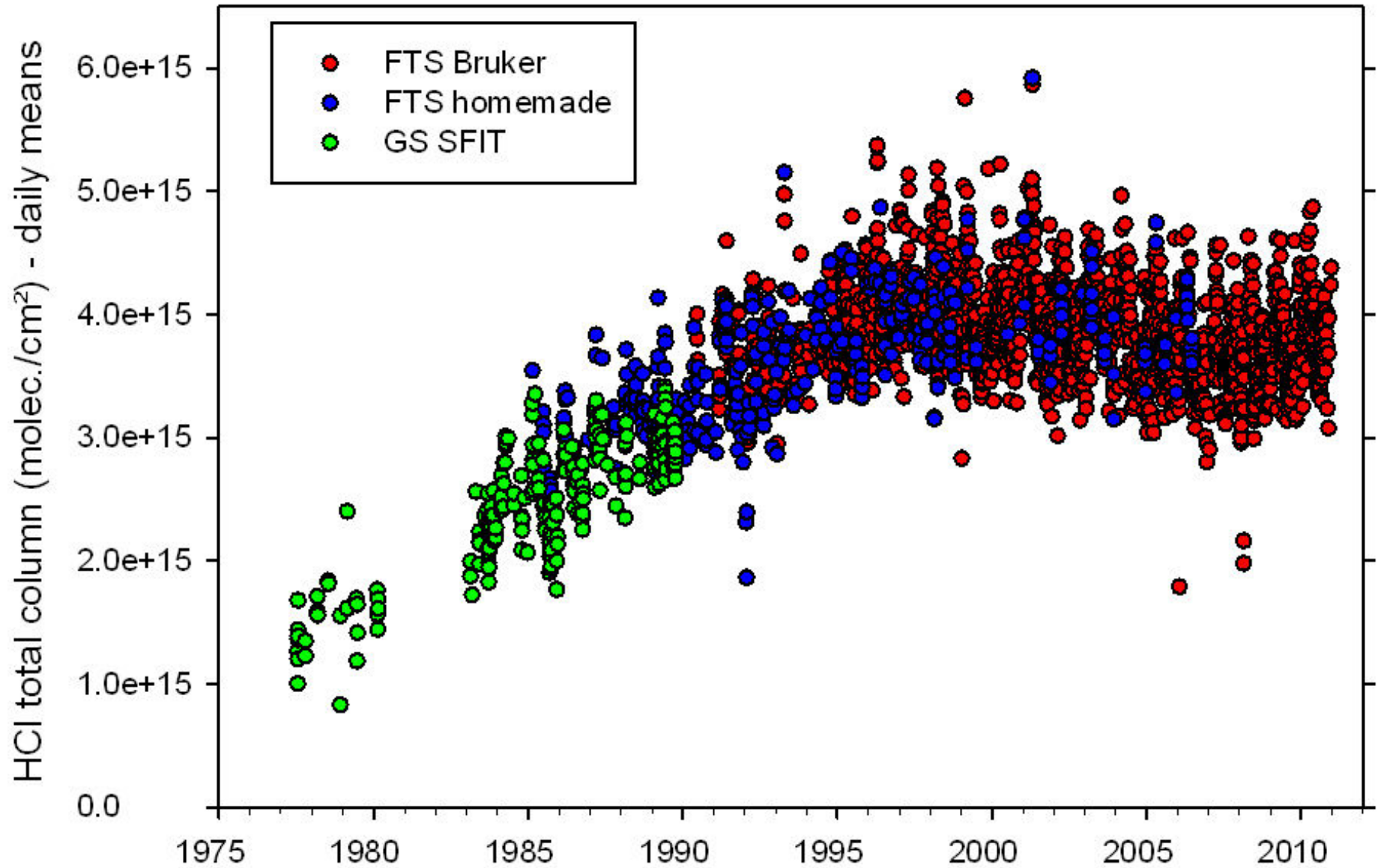


# HF trends

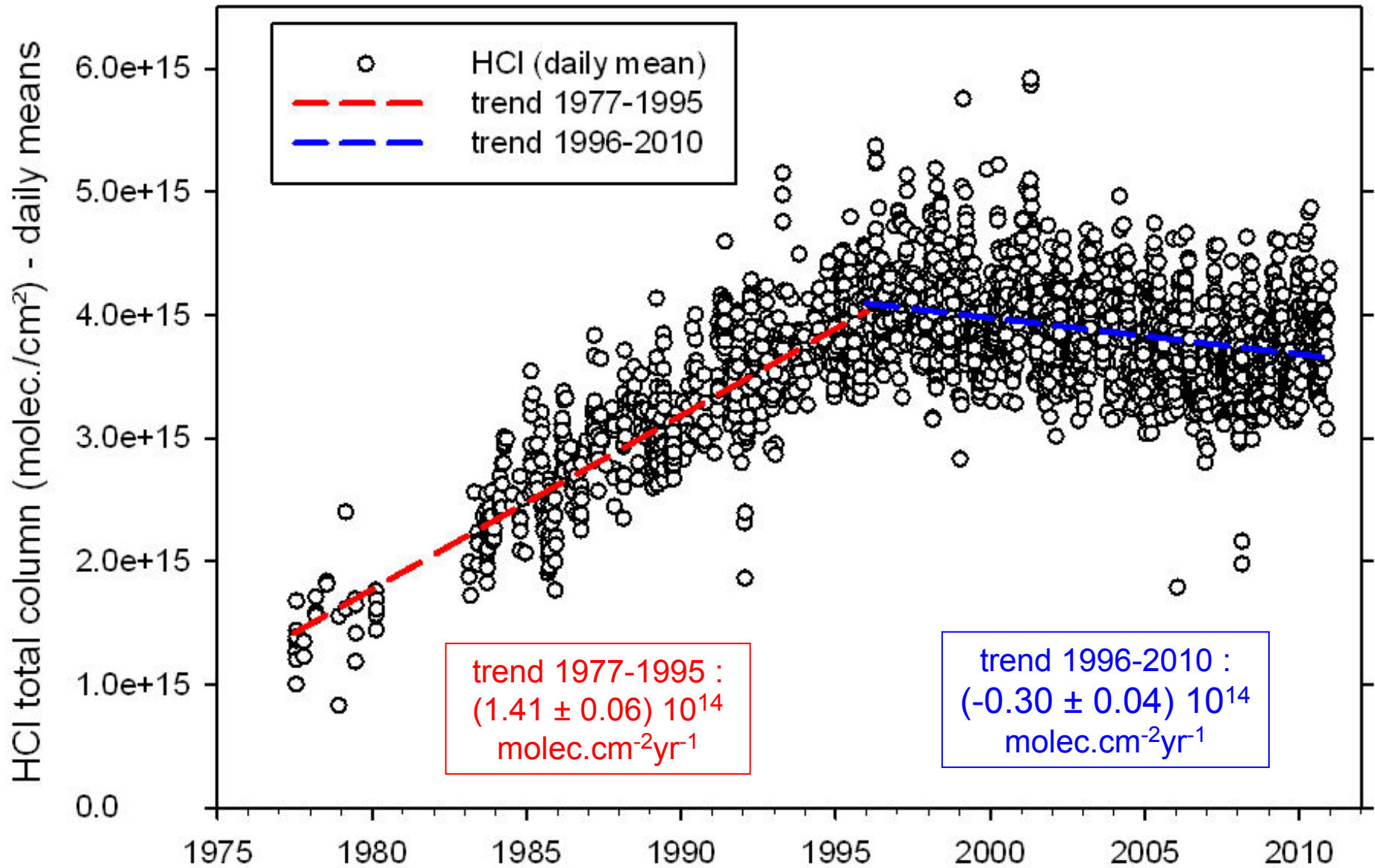




# HCl above Jungfrauoch



# HCl trends

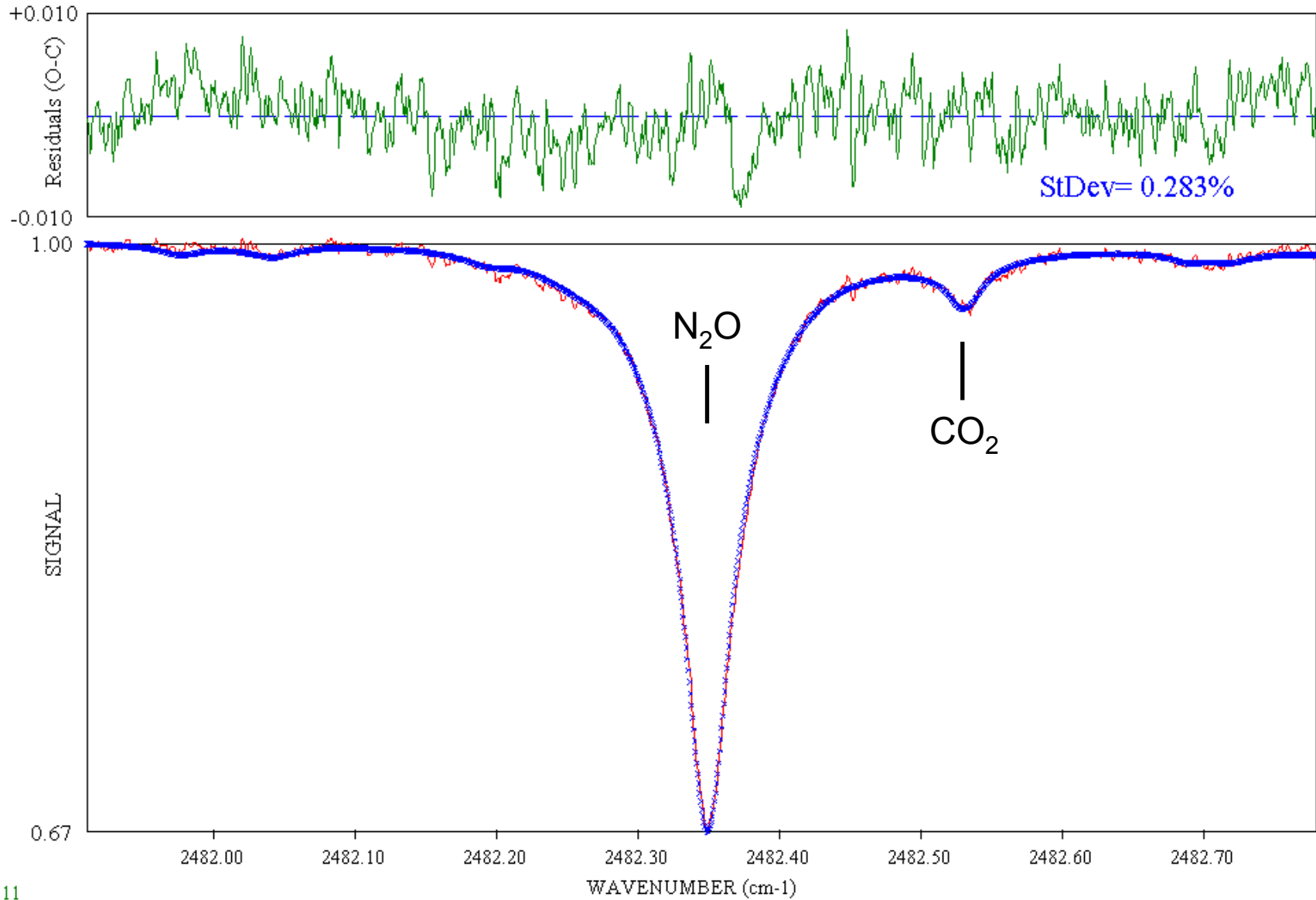


# N<sub>2</sub>O grating spectrum

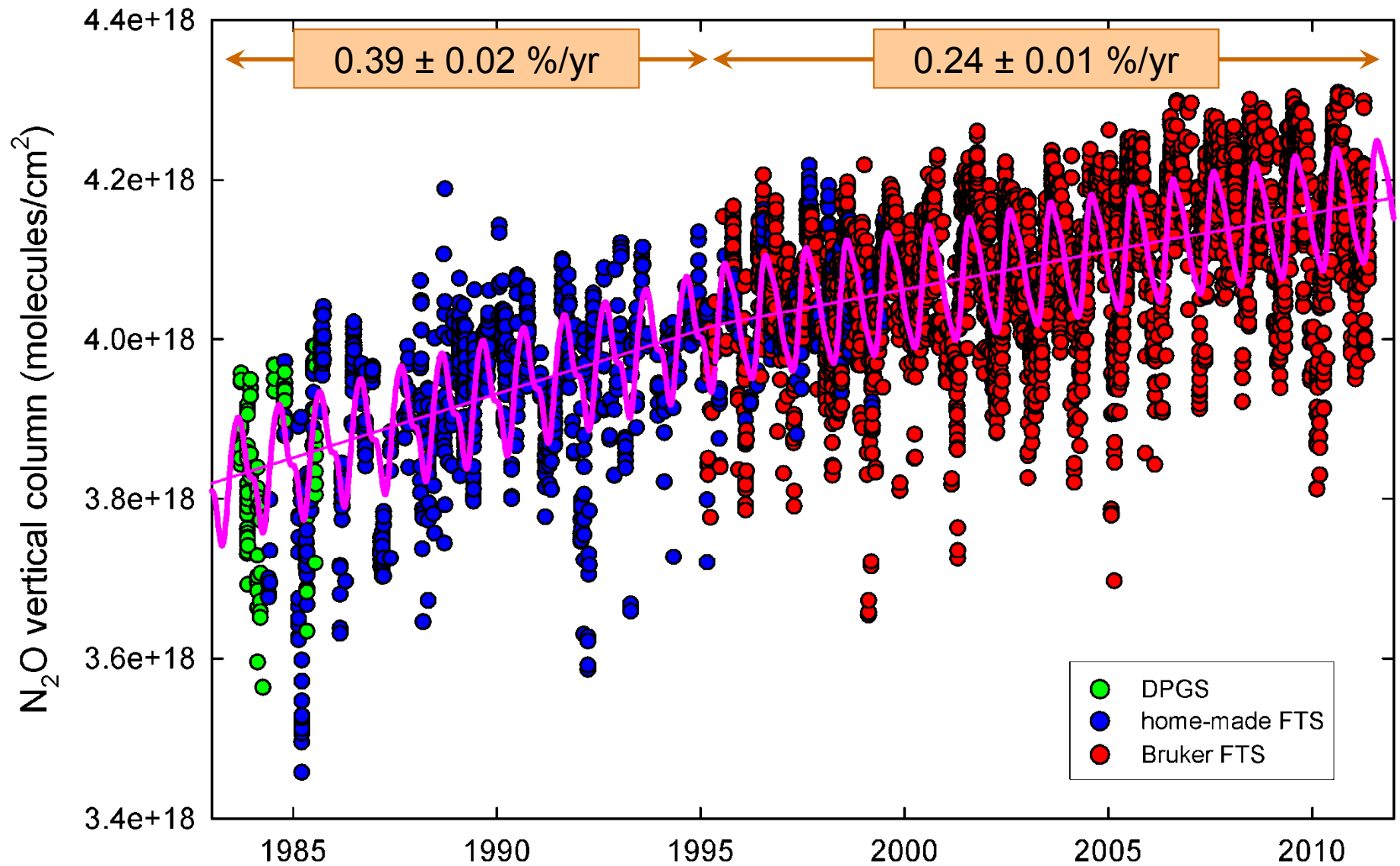
JJG-G84215AN.DAT 15 FEB 1984 12.377

Res: 8.600 mK Dia: 0.0 mm App.Z.Ang: 59.560 Deg S/N: 0

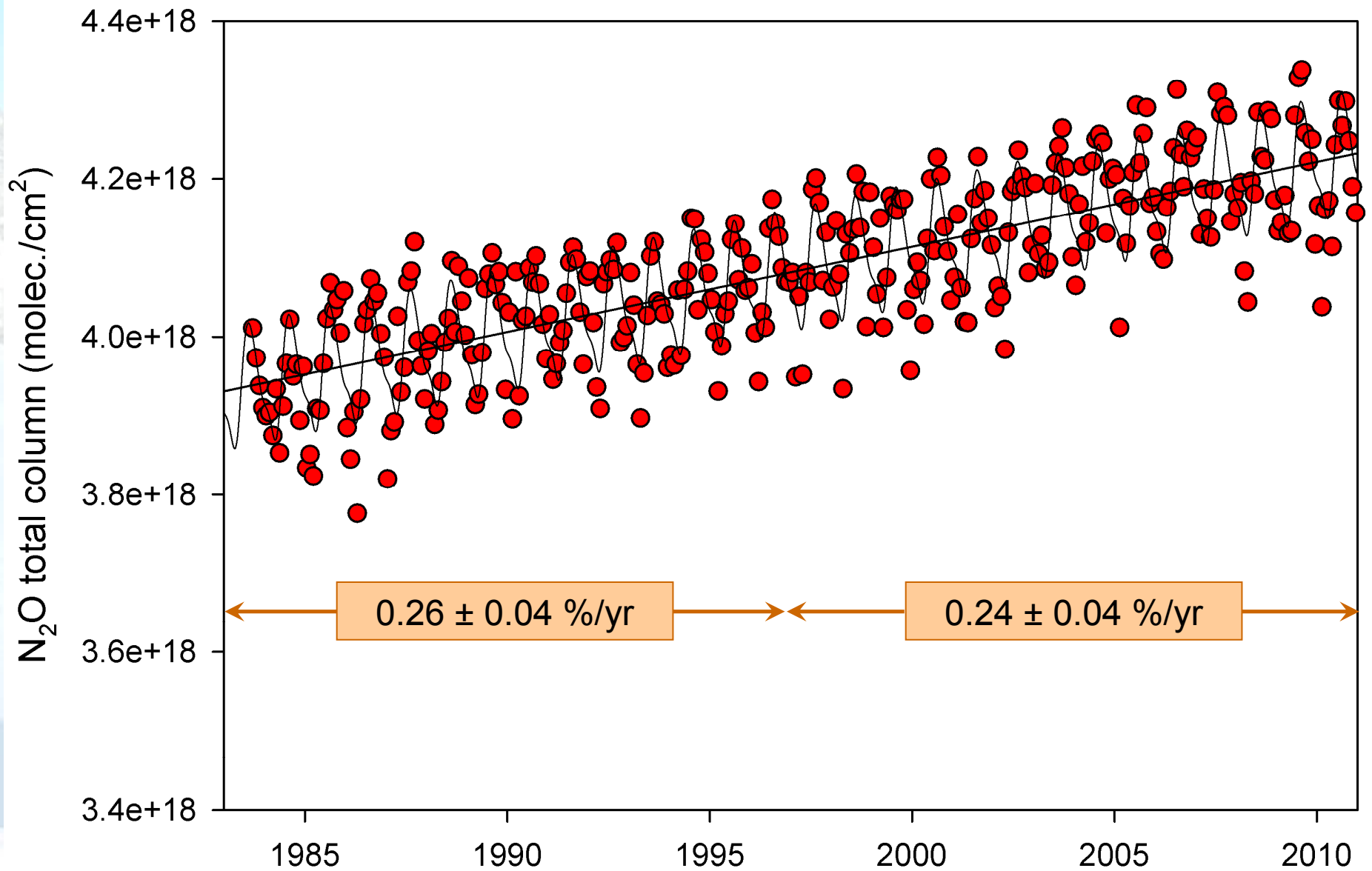
Retrieved Gases : N<sub>2</sub>O CO<sub>2</sub> H<sub>2</sub>O CH<sub>4</sub>  
Vert Col (mol/cm<sup>2</sup>) : 3.786E+18 4.978E+21 2.020E+21 9.429E+18



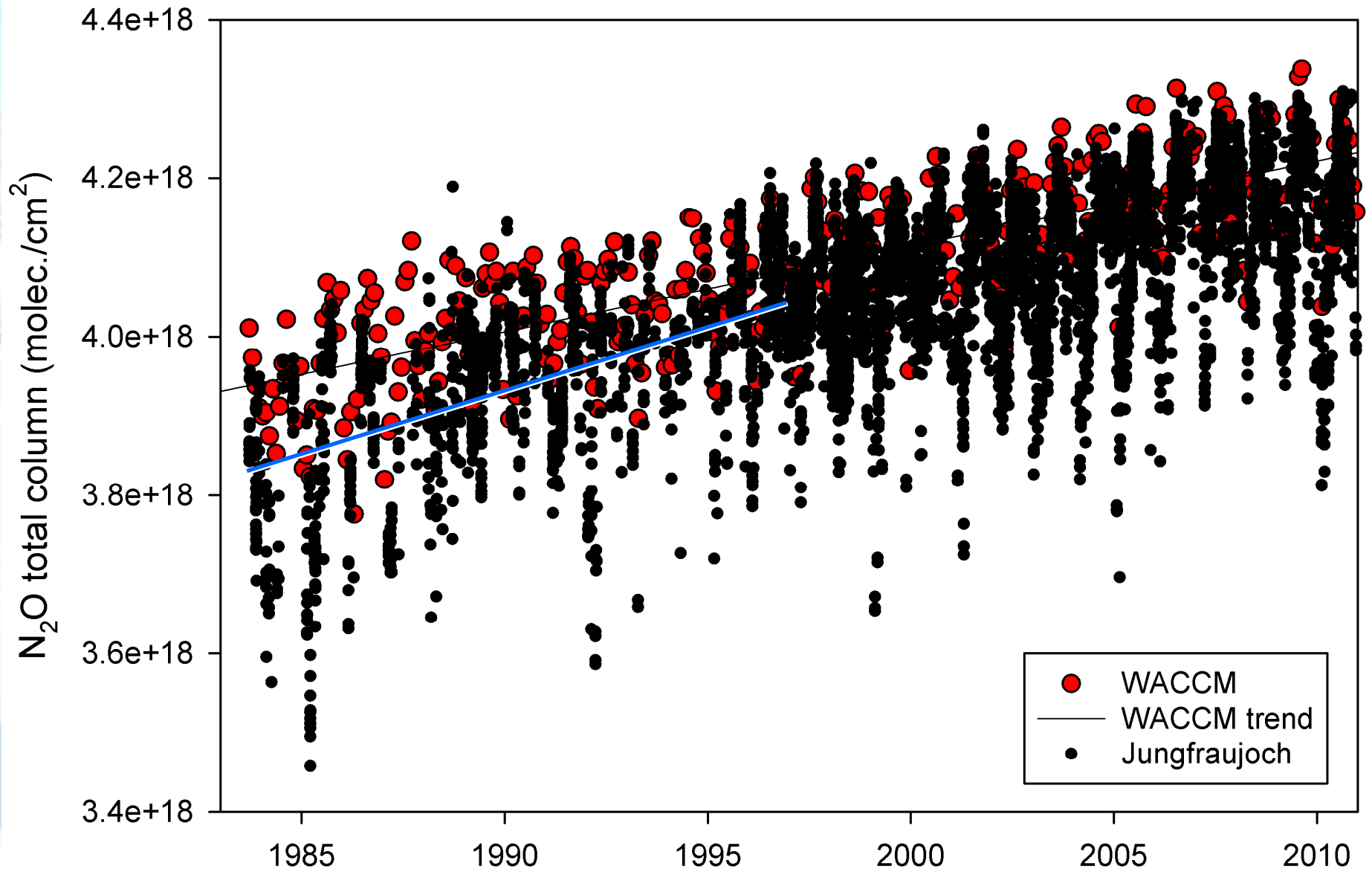
# N<sub>2</sub>O above Jungfraujoch



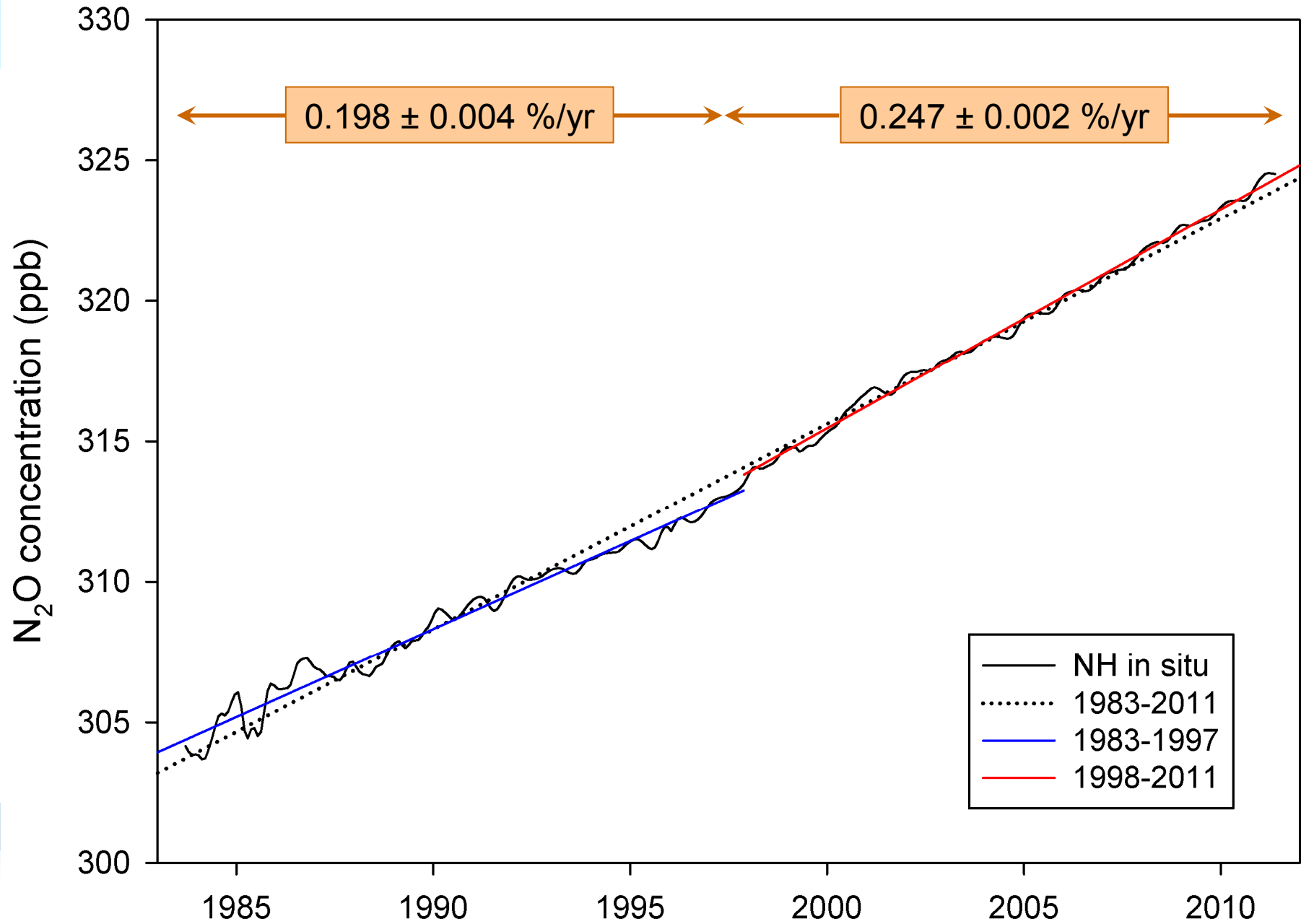
# N<sub>2</sub>O total columns (WCAMM 5)



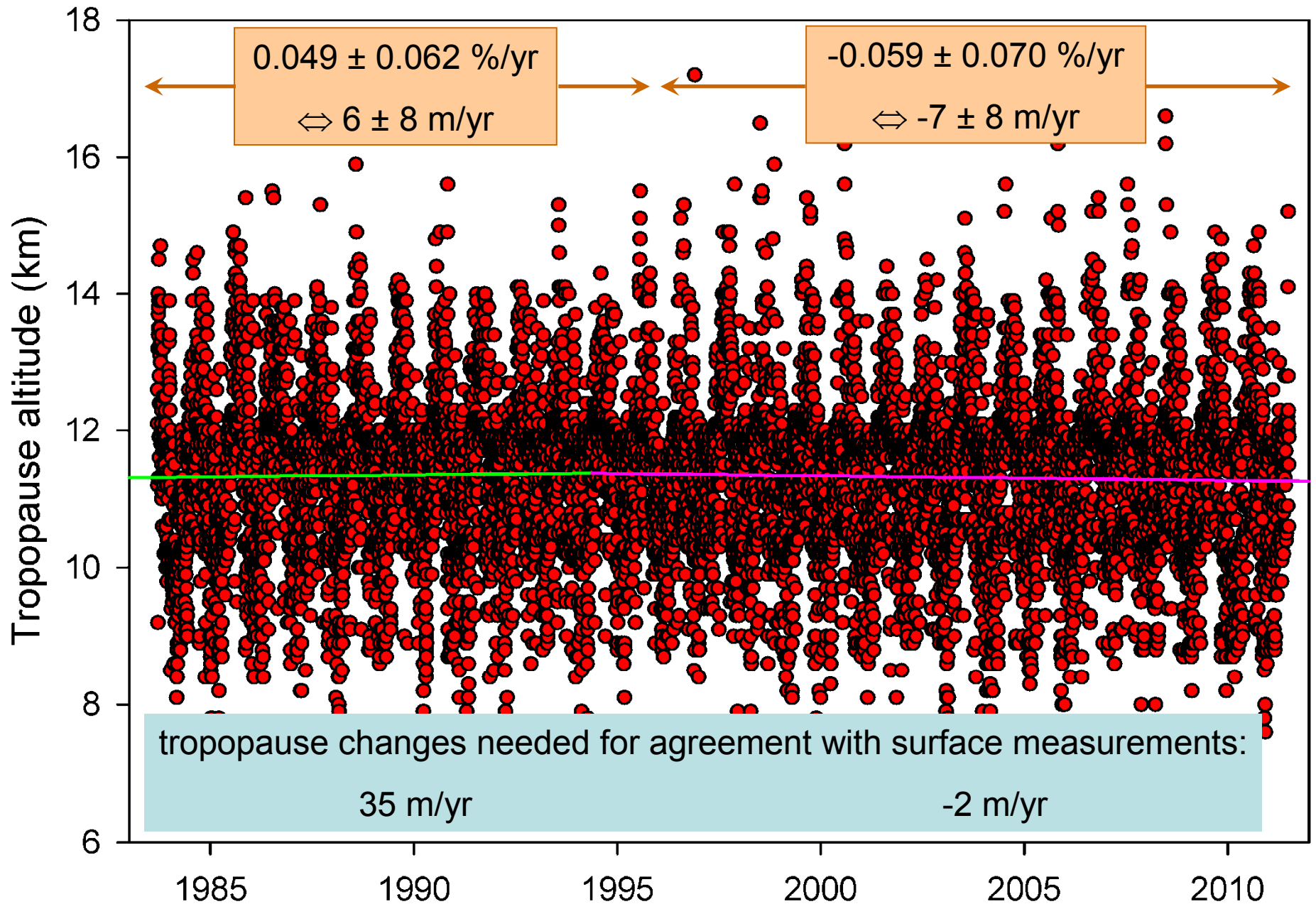
# N<sub>2</sub>O (WCAMM 5 and FTIR)



# N.H. N<sub>2</sub>O concentration (NOAA/ESRL)



# Altitude of the tropopause above the Jungfrauoch

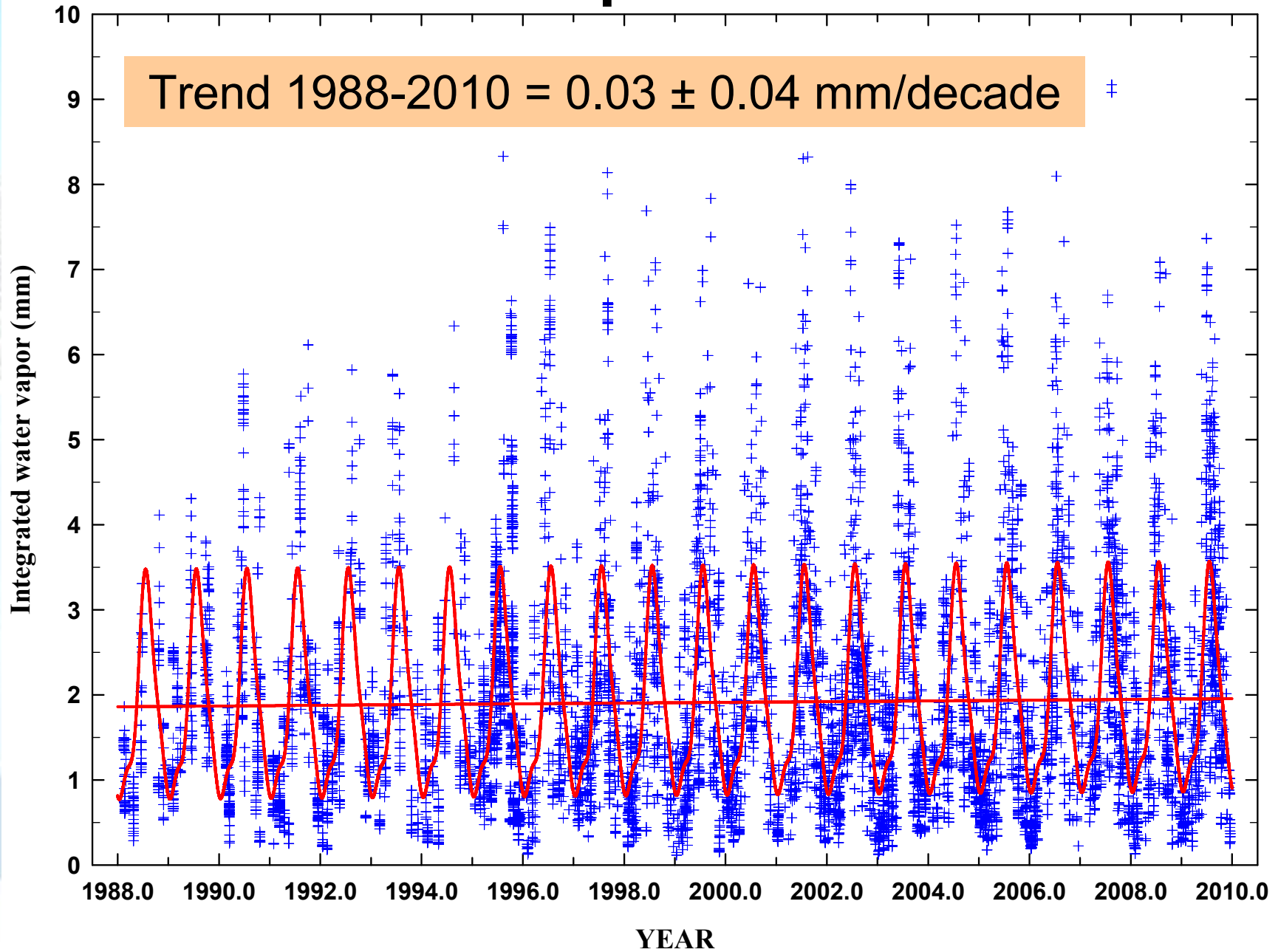




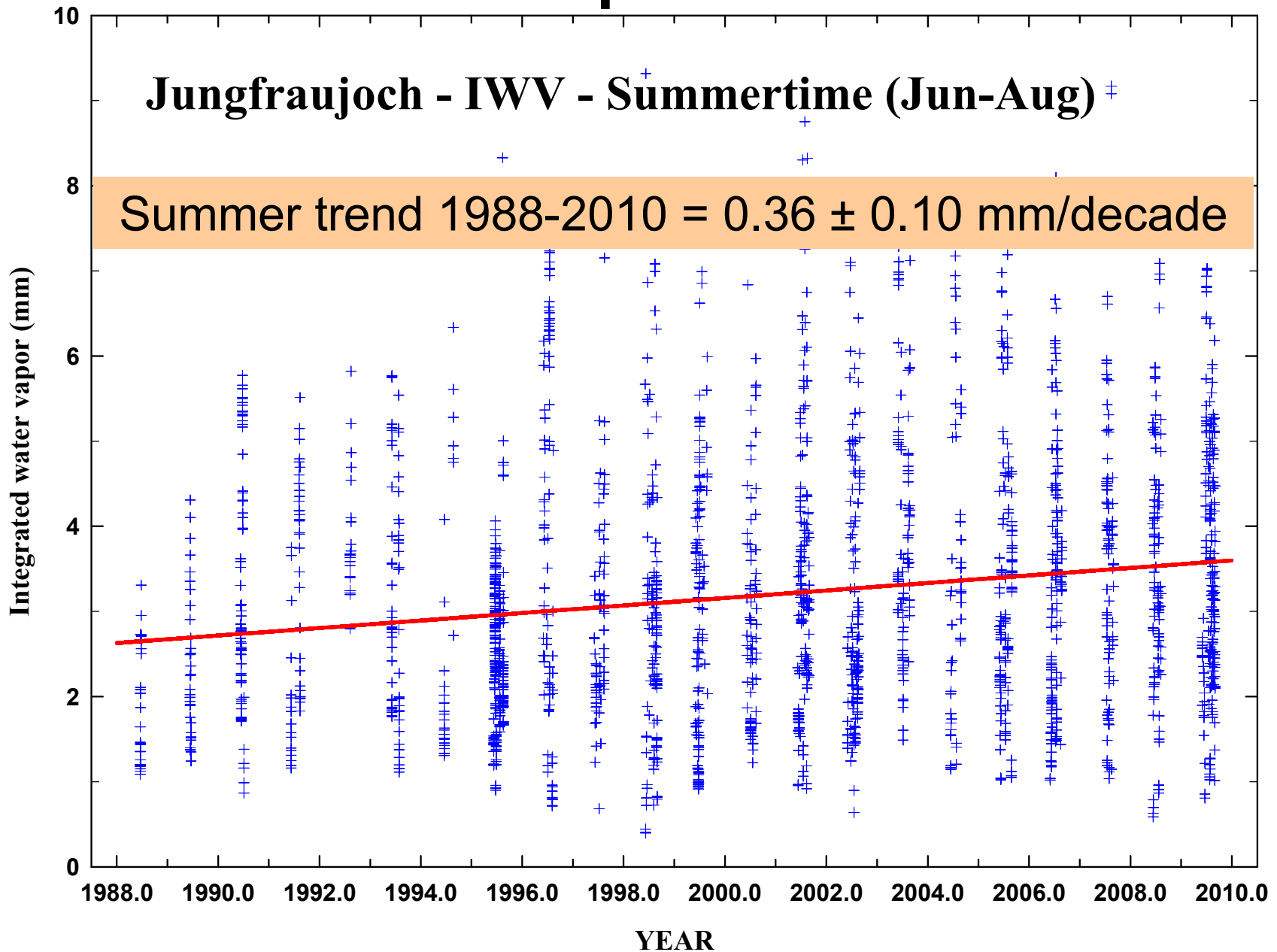
## N<sub>2</sub>O trends summary (%/year)

	<b>Jungfrau joch</b>	<b>N.H. surface NOAA/ESRL</b>	<b>WACCM 5</b>	<b>tropopause</b>
1983-2011	0.283 ± 0.007	0.231 ± 0.002	0.262 ± 0.016	-0.023 ± 0.024
1983-1997	0.393 ± 0.021	0.198 ± 0.004	0.259 ± 0.038	0.049 ± 0.062
1998-2011	0.236 ± 0.014	0.247 ± 0.002	0.238 ± 0.044	-0.059 ± 0.070

# Water vapor from FTS

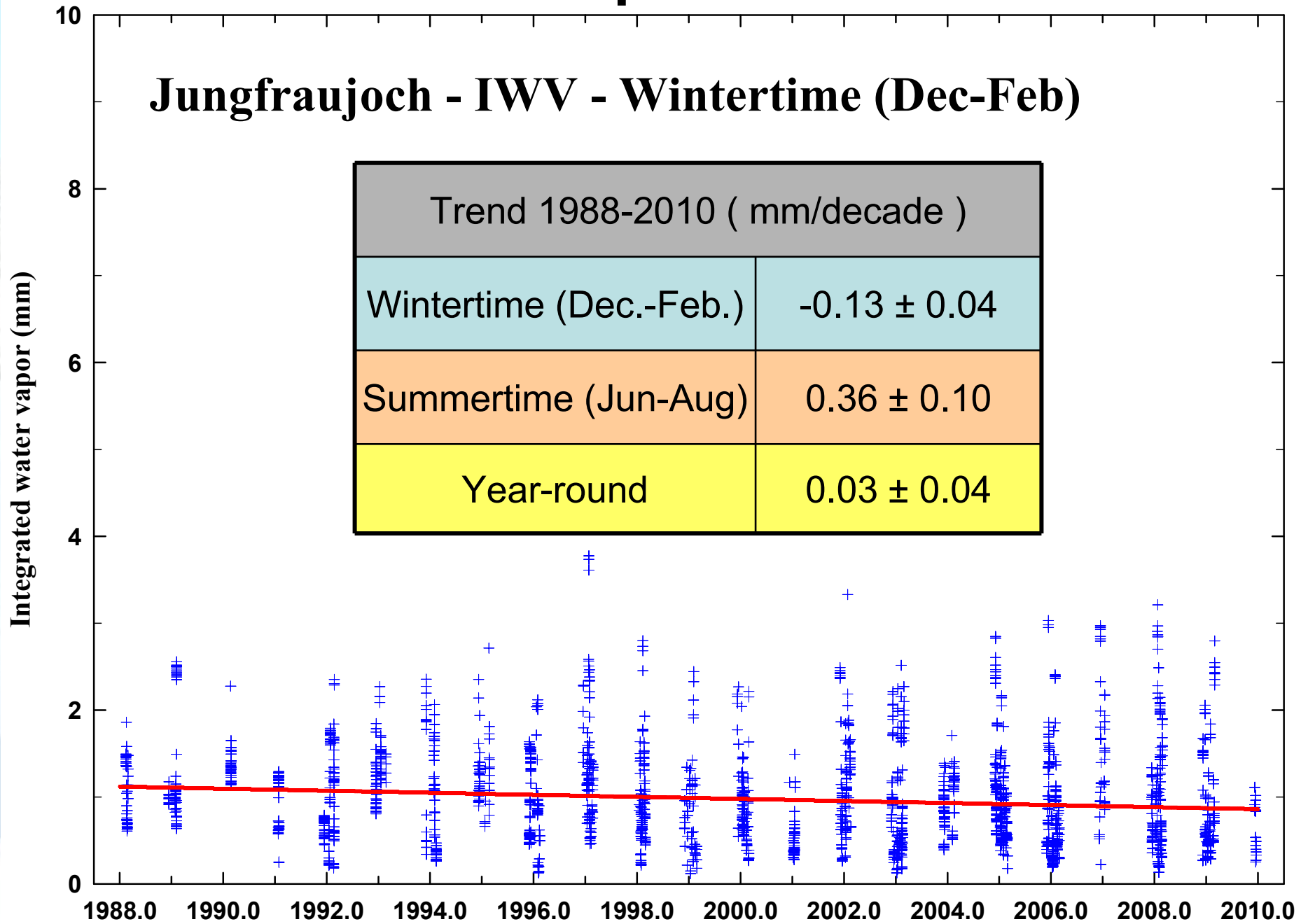


# Water vapor from FTS



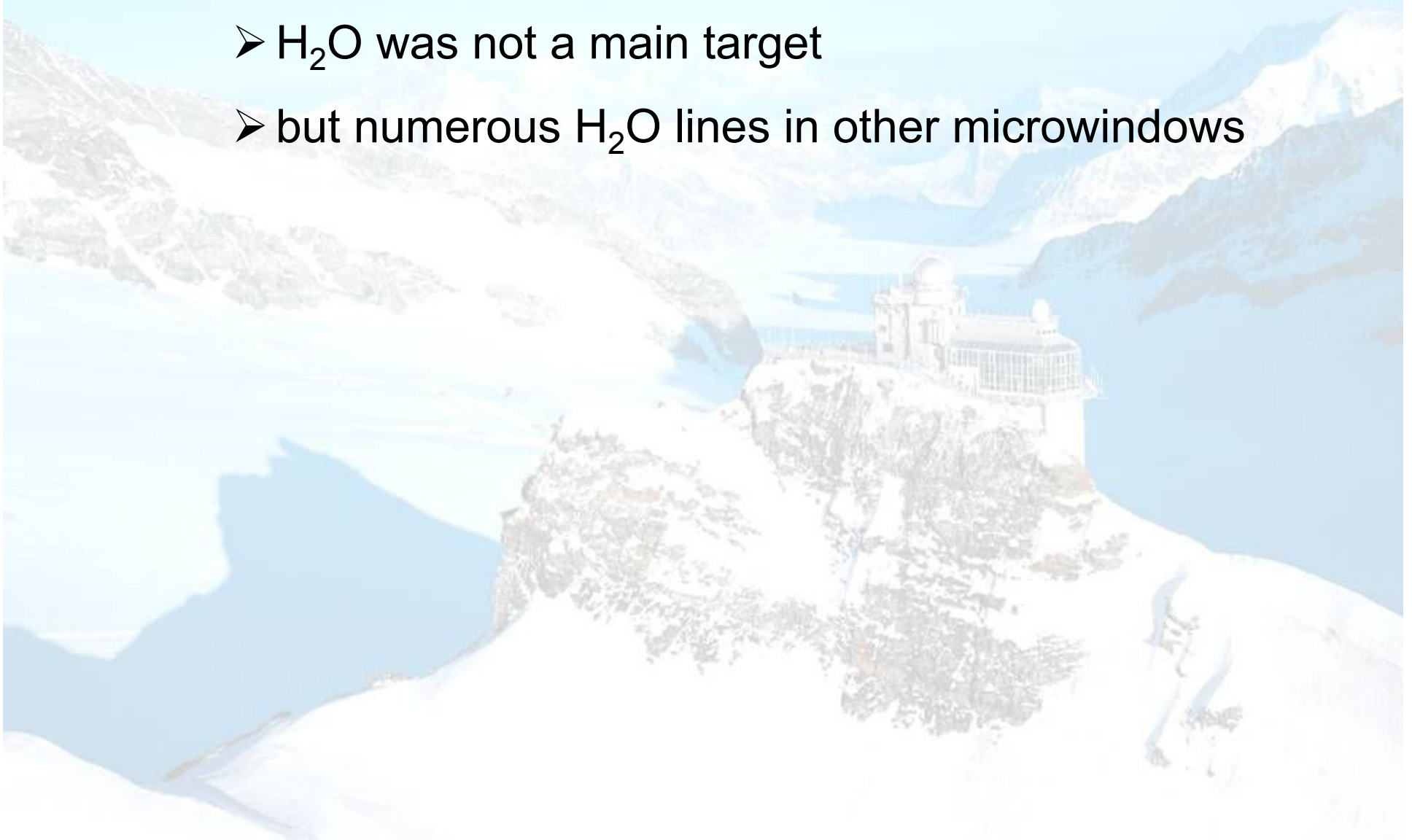
# Water vapor from FTS

## Jungfrauoch - IWV - Wintertime (Dec-Feb)



# Water vapor from grating spectrometer

- $\text{H}_2\text{O}$  was not a main target
- but numerous  $\text{H}_2\text{O}$  lines in other microwindows



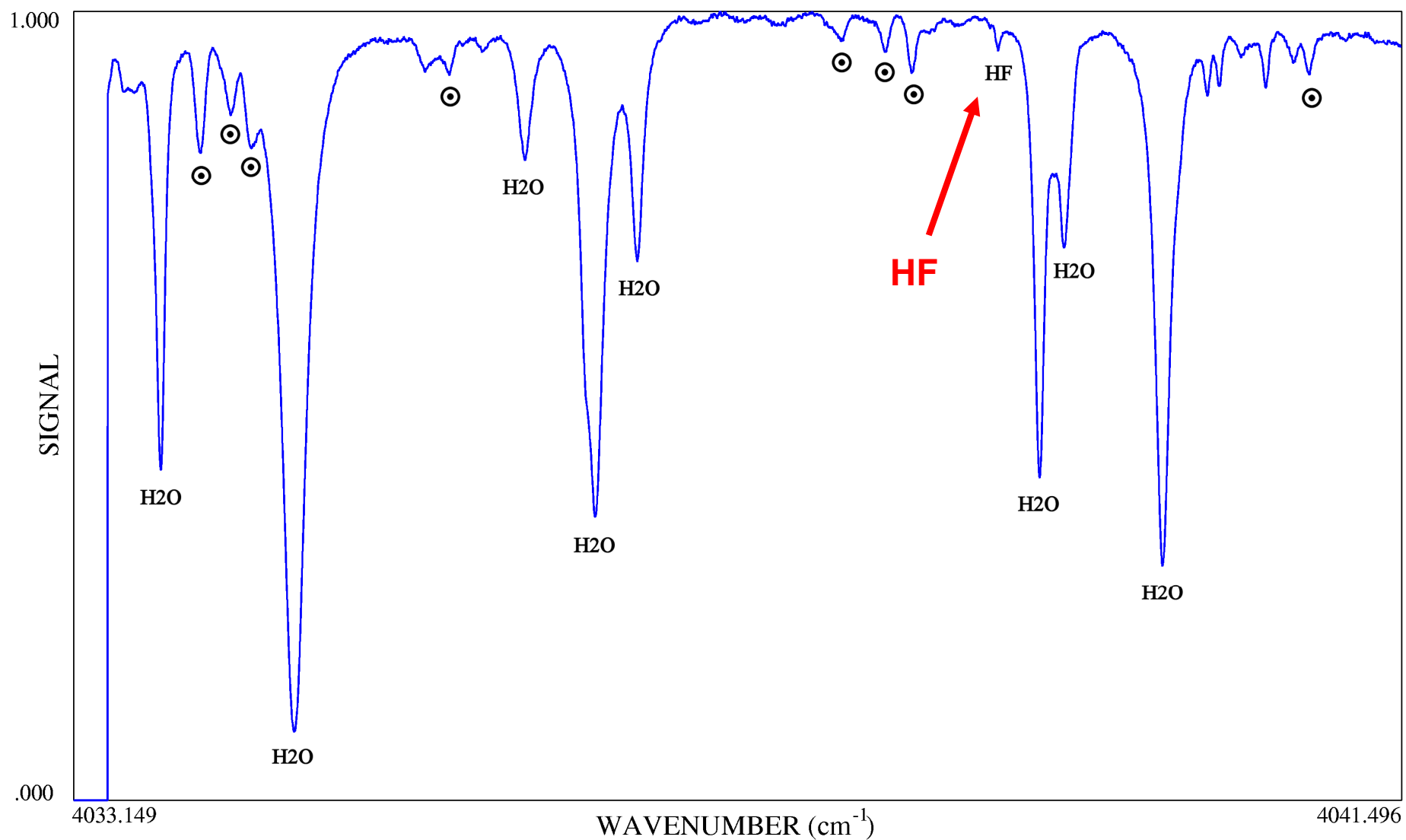
# H<sub>2</sub>O lines in HF spectrum

JUNGFRAUJOCH

G:\H2O\STVTESTHFV77A07AA.DAT

DSP 22 AUG 2008 11:41:35

d77a07aa.dat 07 OCT 1976 10:32:30 Z = 57.38°



# H<sub>2</sub>O lines in HCl spectrum

JUNGFRAUJOCH

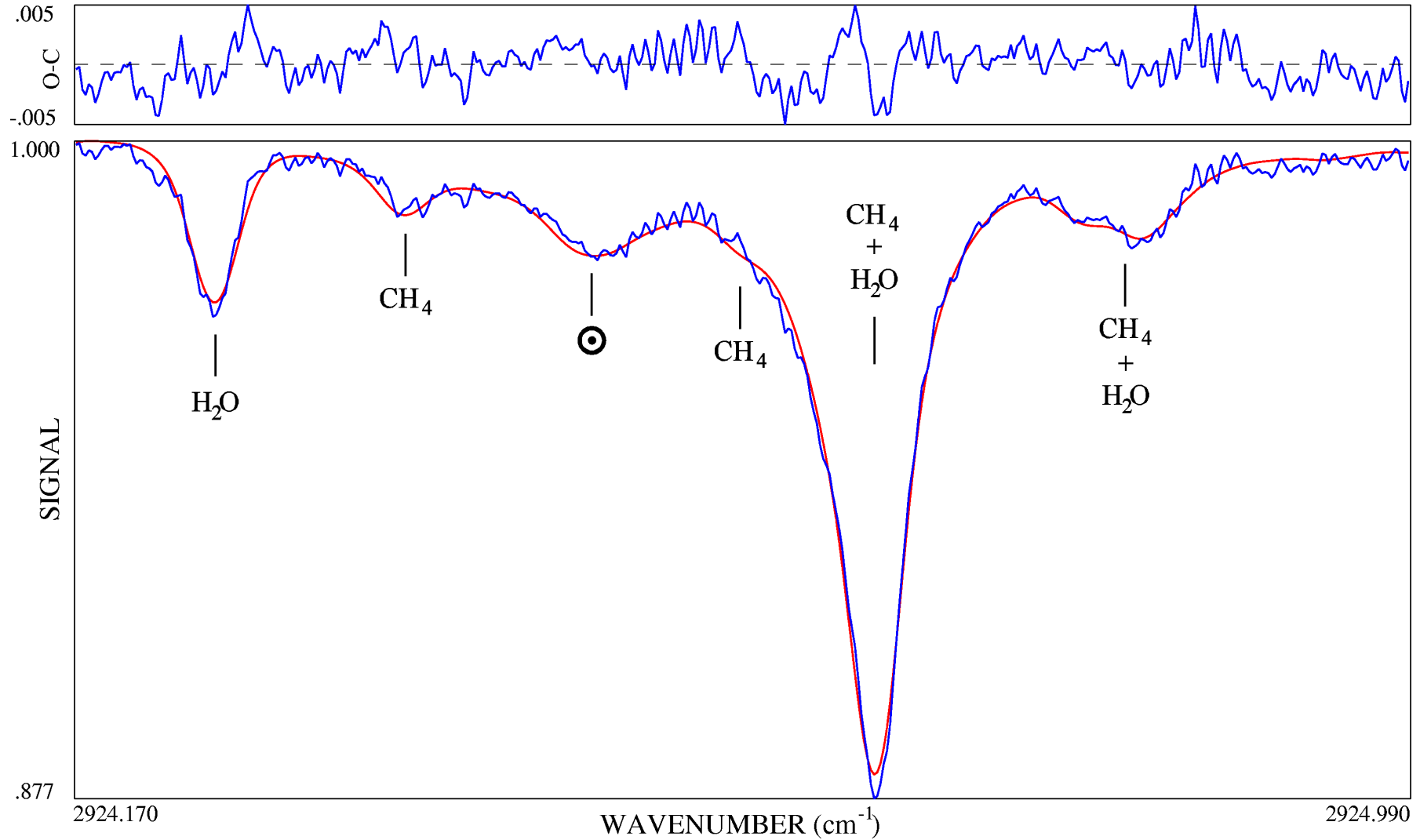
P85913AG.MOY

GRATING

DSP 29 MAR 2011 15:37:54

StDev = .1806 %

w 1/1 Z = 44.89°



# H<sub>2</sub>O line in near-IR

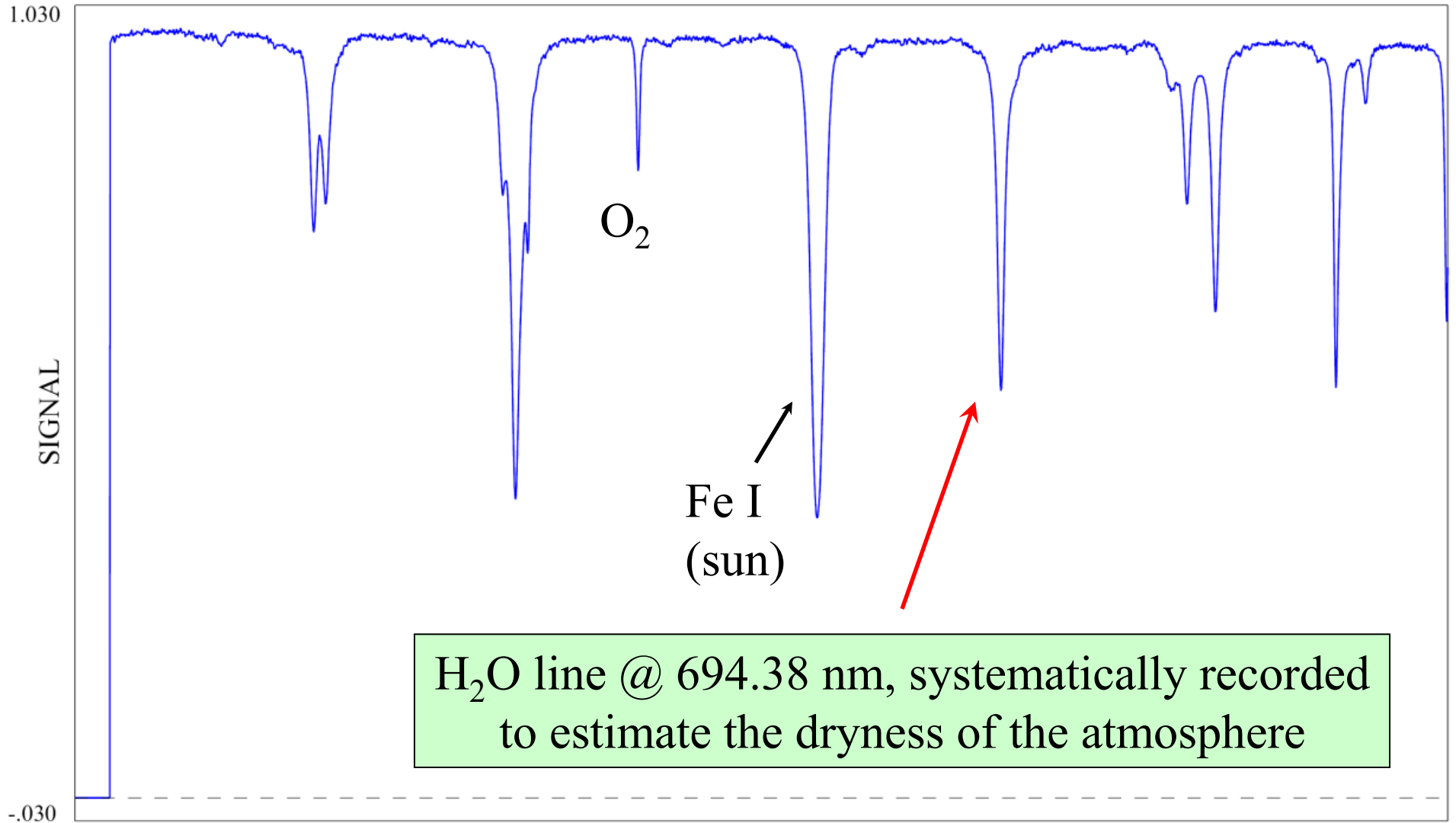
DSP 23 NOV 2008 12:21:22

JUNGFRAUJOCH

G74516AA.DAT

D74516AA.DAT

16 MAY 1974 07:34:00 Z = 64.27°





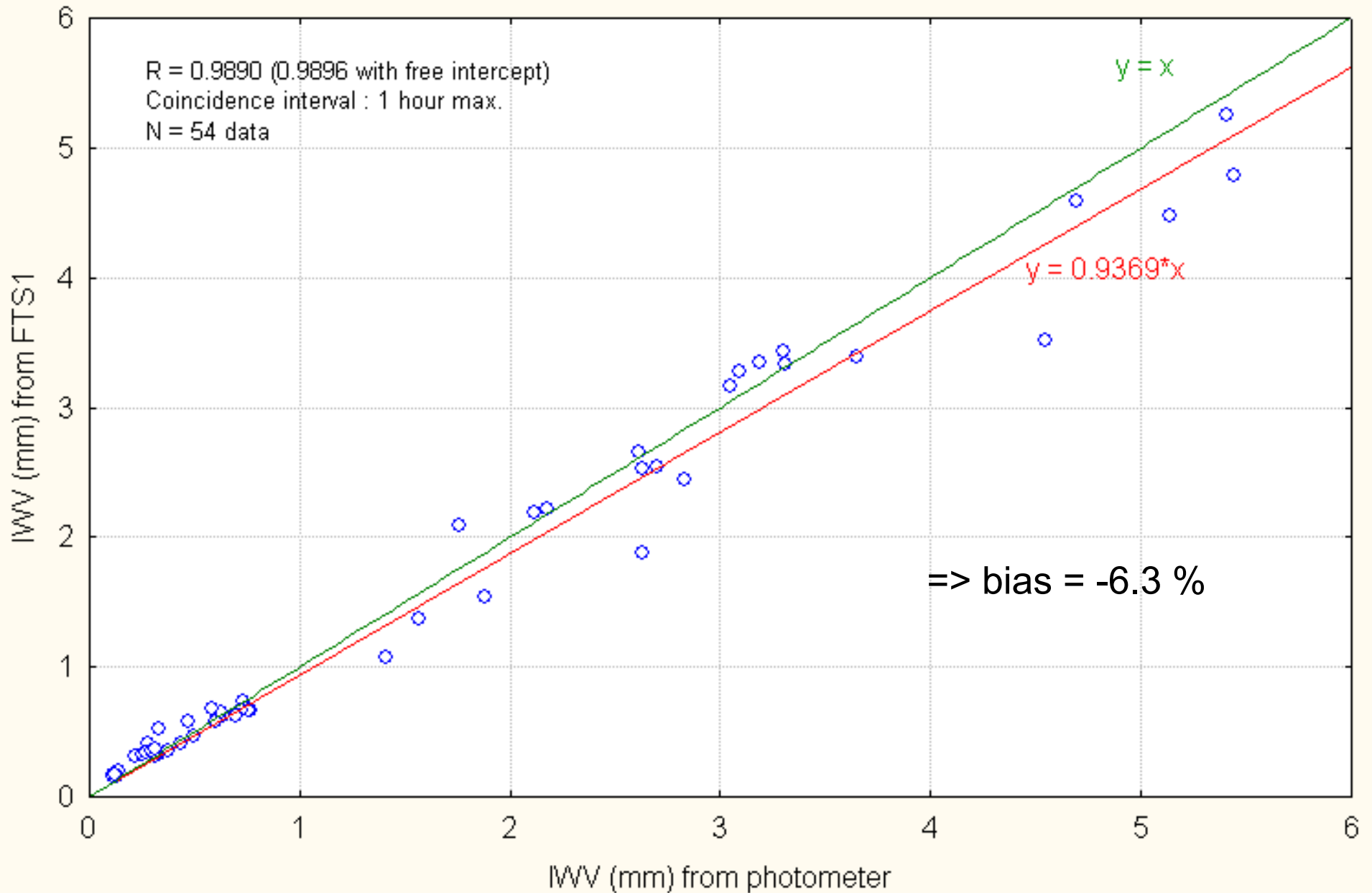
# Intercalibration of H<sub>2</sub>O lines

**To be carefully addressed**: lines in the different spectral ranges need to be intercalibrated with great care !  
(up to 50 % difference in H<sub>2</sub>O columns for the worse cases)

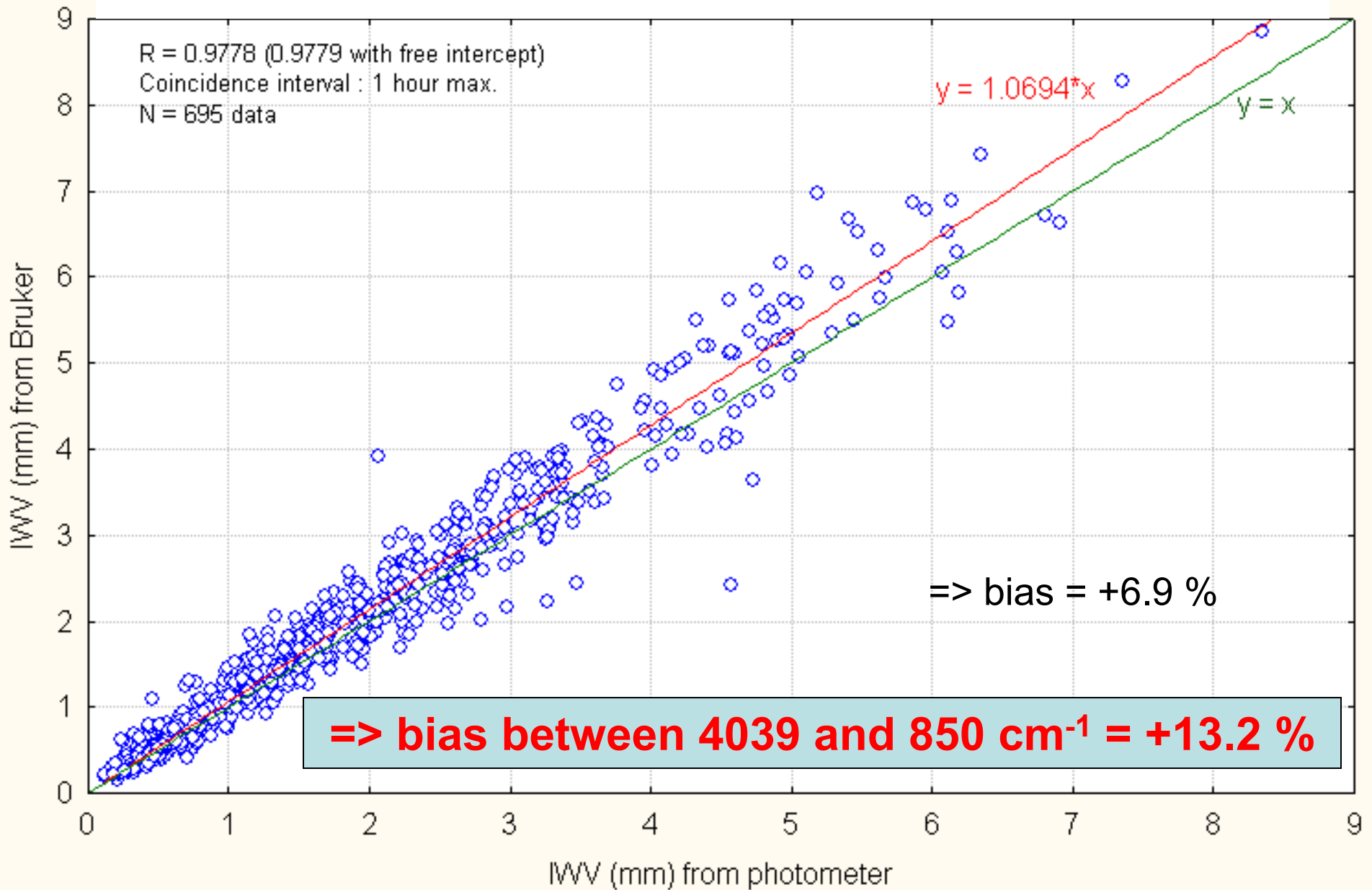
## Intercalibration possibilities

- spectra of different spectral domains, simultaneously recorded by 2 different instruments:
  - home-made and Bruker FTS (1990-2008)
  - home-made FTS & grating spectrometer (1984-1989)
- comparison with the MeteoSwiss IR photometer (domain A vs photometer, then domain B vs photometer)
- comparison with Swisstopo GPS

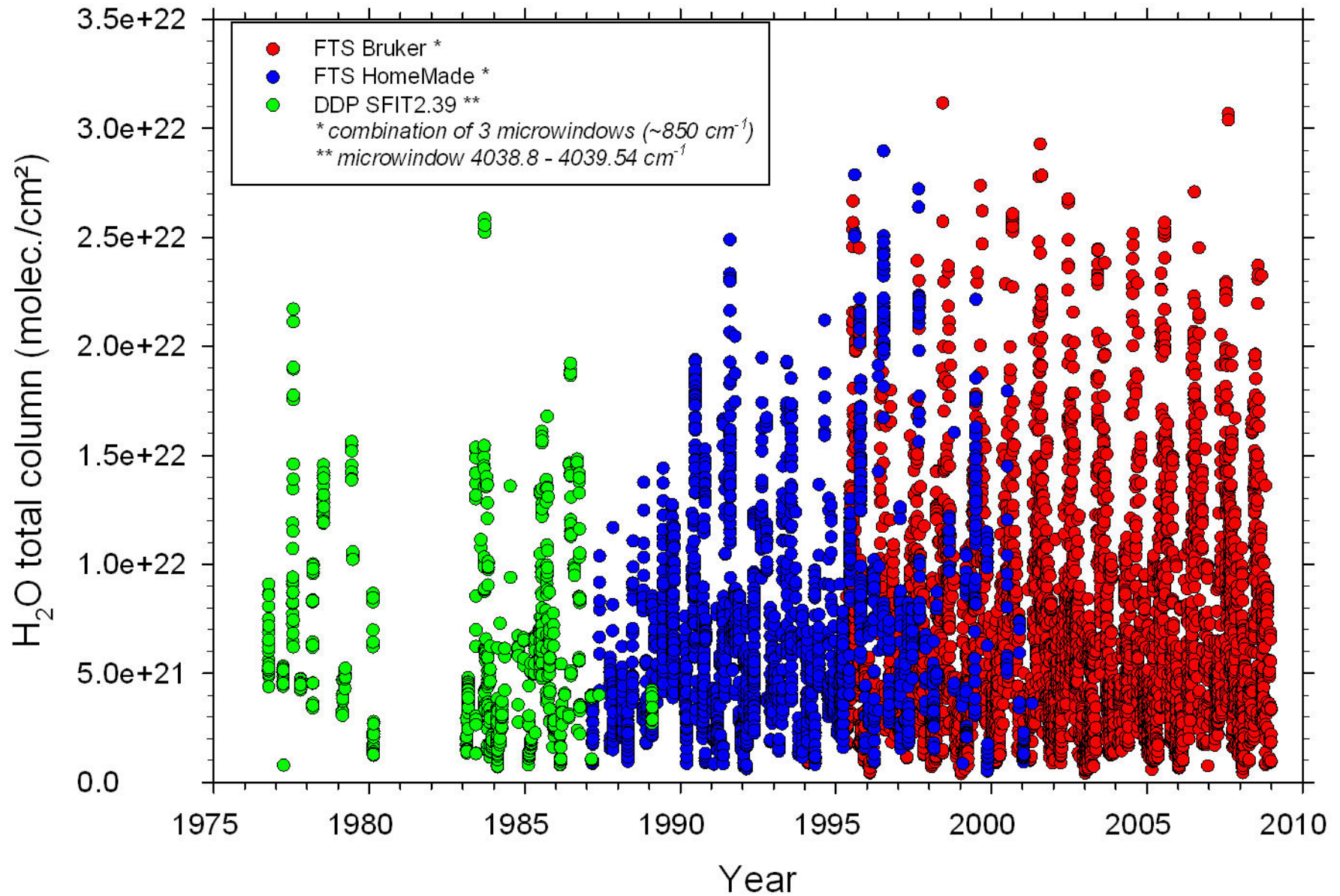
# H<sub>2</sub>O @ 4039 cm<sup>-1</sup> (FTS) and sun photometer



# H<sub>2</sub>O @ 850 cm<sup>-1</sup> (FTS) and sun photometer



# H<sub>2</sub>O from grating and FTS



# Future

- work still in progress
- H<sub>2</sub>O @ 694.4 nm
- search for interesting lines in solar atlases  
(recorded plate after plate, from 1959 to 1988)

Thank you for your attention.

