Determination and analysis of the time series of CFC-11 from Lauder and Jungfraujoch

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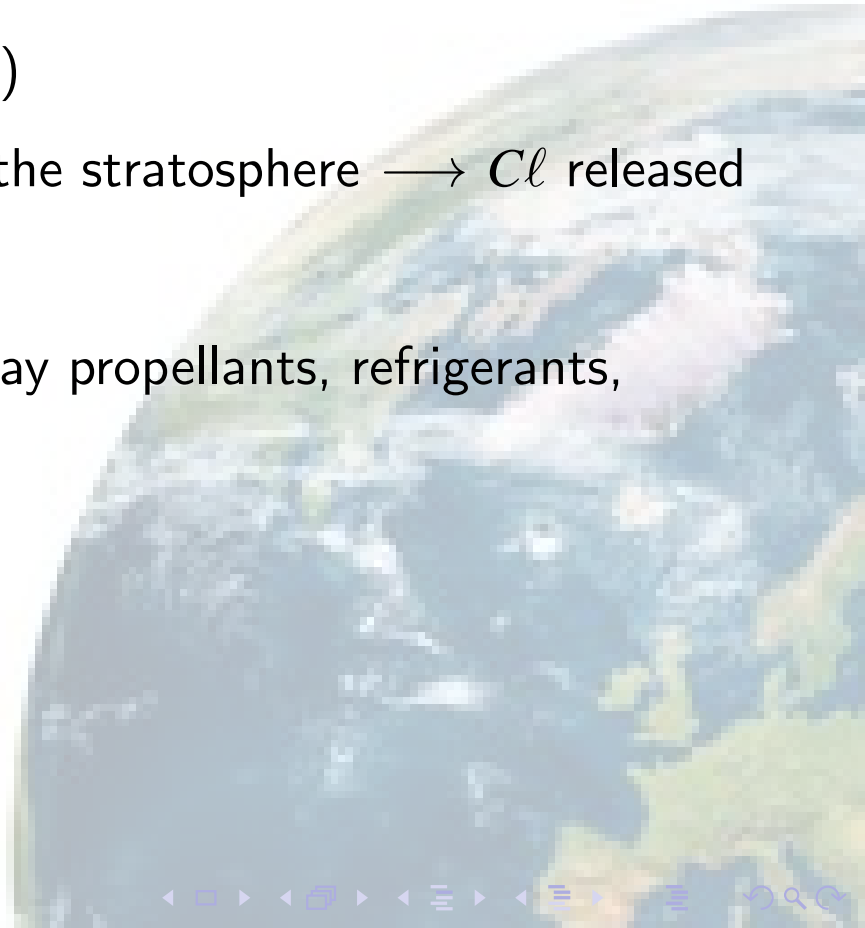
2021 NDACC IRWG Virtual Meeting

Introduction

Chlorofluorocarbons (CFC)

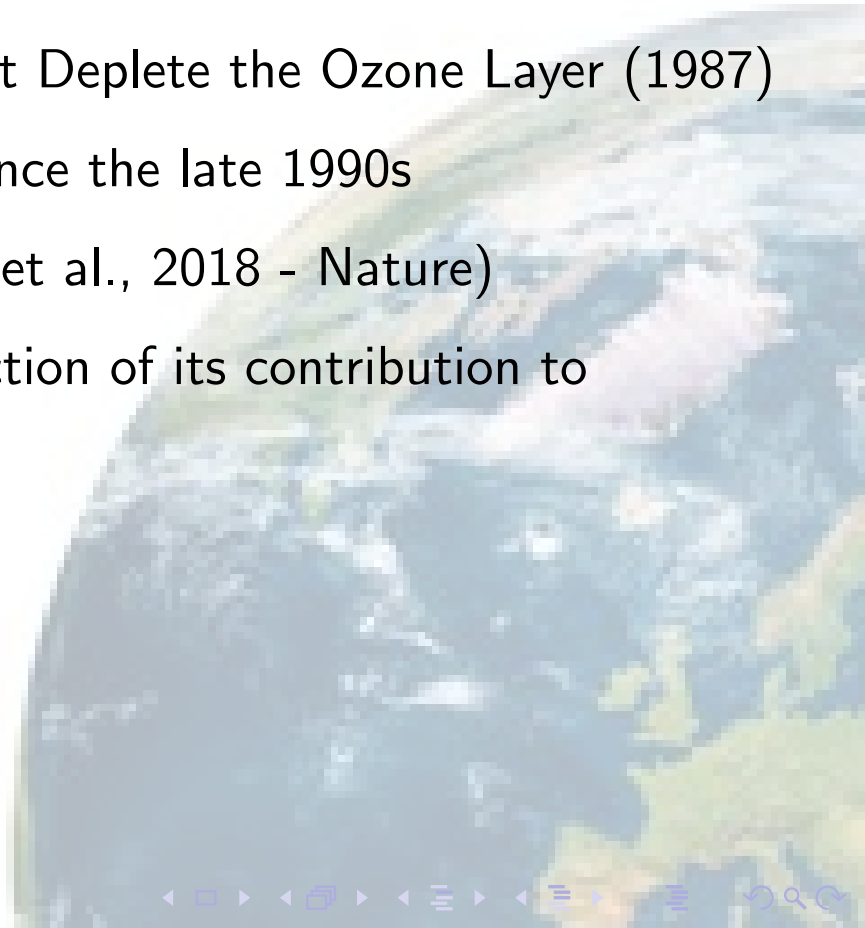
- CFC-11 ($CC\ell_3F$) & CFC-12 ($CC\ell_2F_2$)
- Photodissociated by UV radiation in the stratosphere $\longrightarrow$ $C\ell$ released
- Destruction of the stratospheric O_3
- Anthropogenic origin $\longrightarrow$ Aerosol spray propellants, refrigerants, inflating agents, and solvents



Introduction

Montreal Protocol

- Montreal Protocol on Substances that Deplete the Ozone Layer (1987)
- CFC-11 concentration has declined since the late 1990s
- Slowing decline after 2012 (Montzka et al., 2018 - Nature)
- Delay in ozone recovery and on reduction of its contribution to radiative forcing



Introduction

ACE data

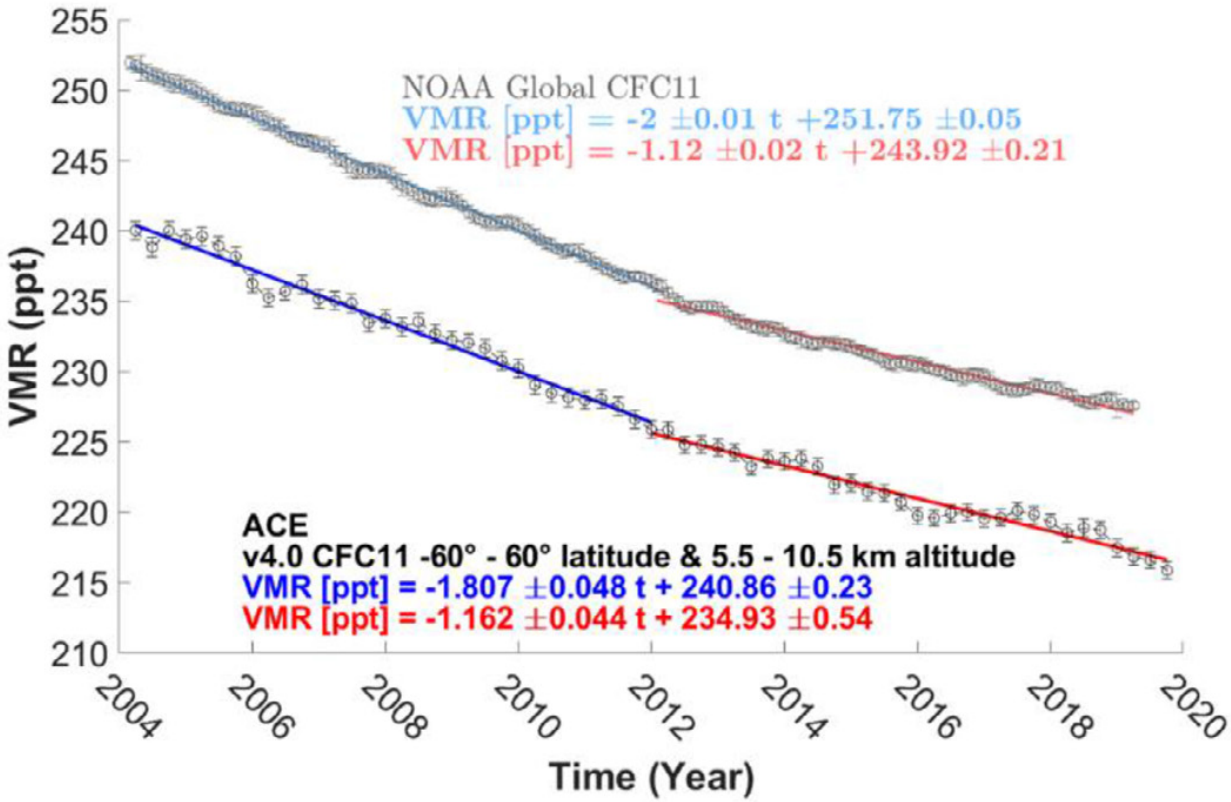
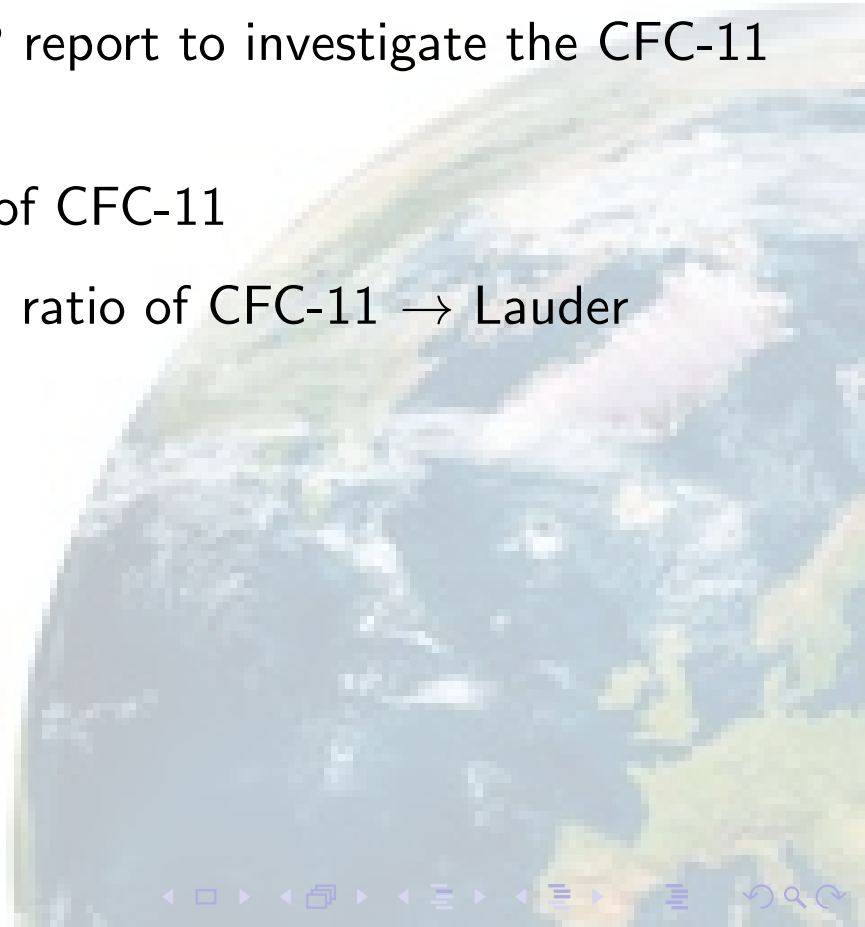


Figure: Trends for ACE-FTS and from Montzka et al., 2018. Source: Bernath et al., 2020. Slowdown in the decrease of CFC-11 atmospheric concentrations.

Introduction

This study

- Requested contribution for the UNEP report to investigate the CFC-11 trend and evolution
- Update the Jungfraujoch time series of CFC-11
- Evaluate the interhemispheric column ratio of CFC-11 $\rightarrow$ Lauder station (SH)
- Comparison with model data



Jungfraujoch station (Swiss Alps)

Latitude: 46.55°N
Longitude: 7.98°E
Elevation: 3580m a.m.s.l.

FTIR spectrometers

- 1984 – 2008: Homemade instrument
- 1994 – present: Commercial Bruker IFS-120HR improved by the team

Latitude: 45.04°S
Longitude: 169.68°W
Elevation: 370m a.m.s.l.

FTIR spectrometers

- Oct 2001 – May 2018: Bruker 120HR
- Nov 2017 – present: Bruker 125HR

Lauder station (New Zealand)

IR Spectra

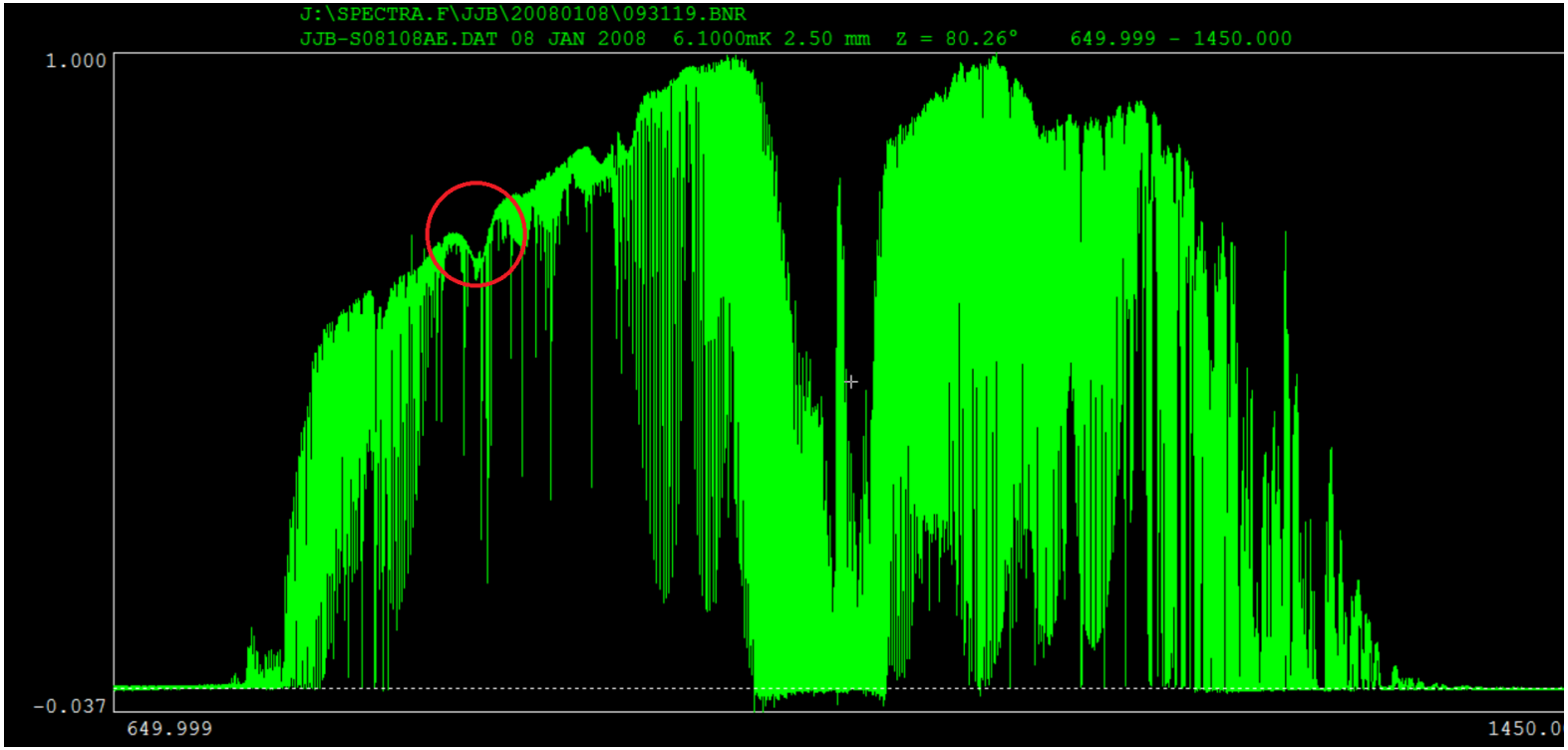


Figure: Spectrum recorded by the Bruker FTIR instrument at Jungfraujoch station on 8th January 2008. Red circle: spectral window for CFC-11.

IR Spectra

(830.0 - 859.3 cm^{-1} spectral window)

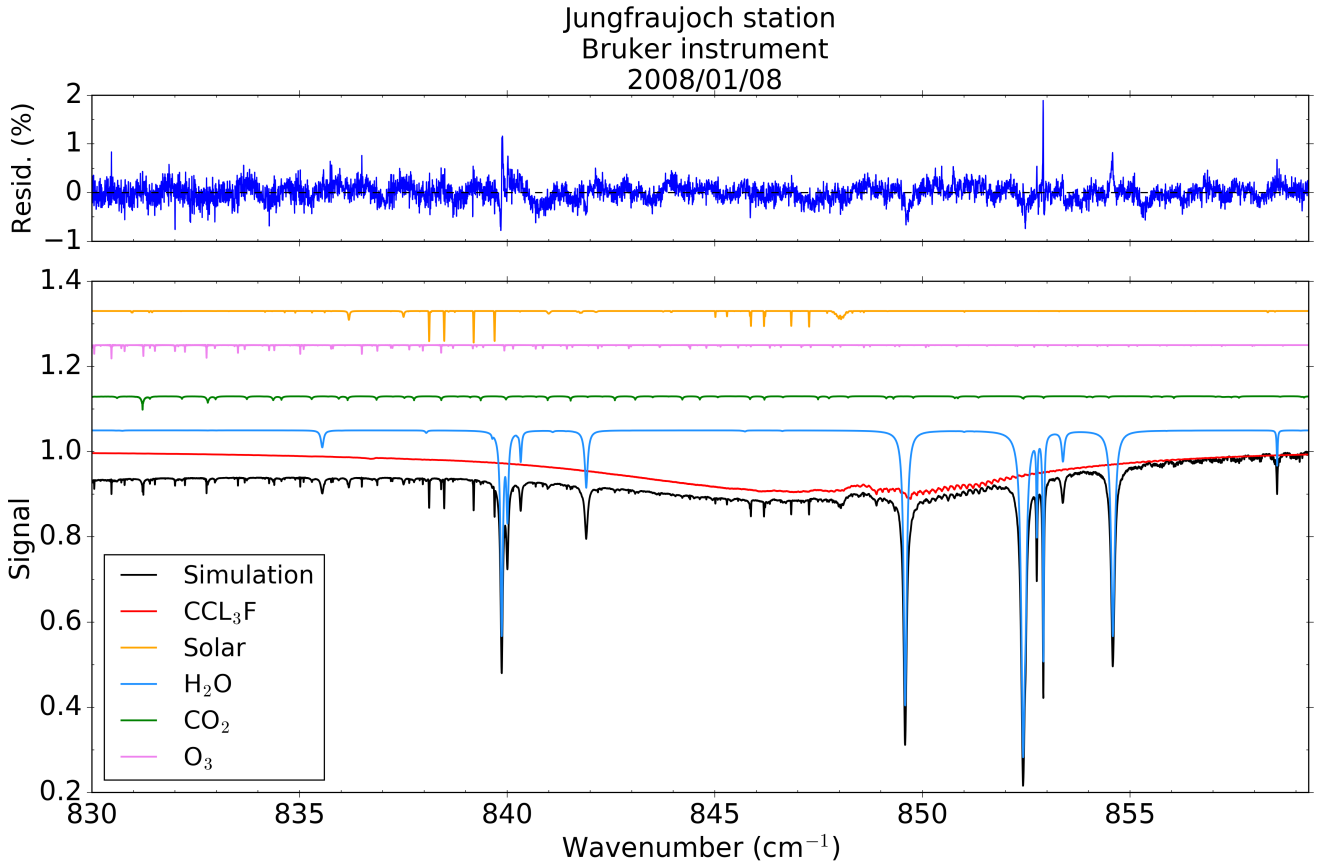


Figure: Up: Residuals from the fits to the spectrum. Bottom: Simulations of the 830.0 - 859.3 cm^{-1} spectral window from the spectrum recorded by the Bruker (8th January 2008) FTIR instrument at Jungfraujoch station.

Averaging Kernels and Eigenvectors

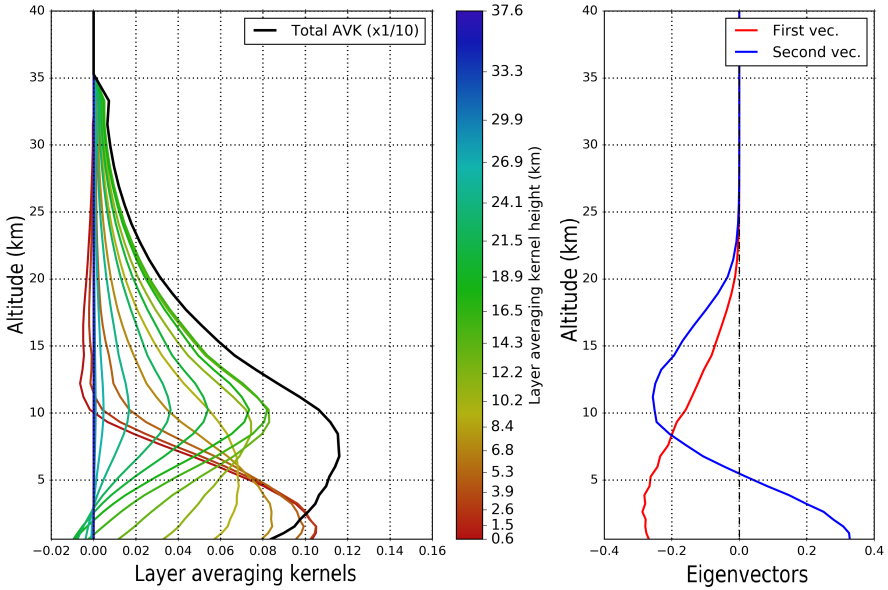


Figure: Lauder Station (SH)

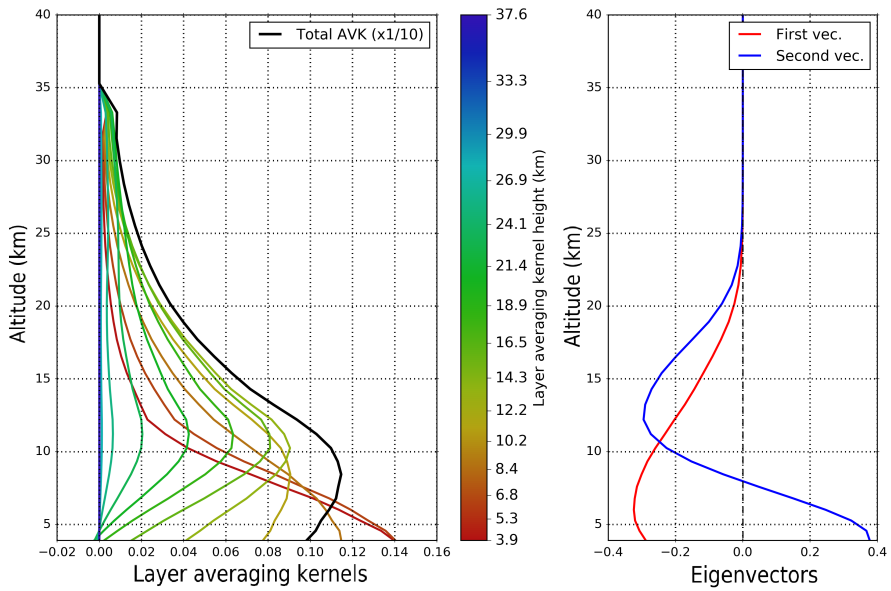
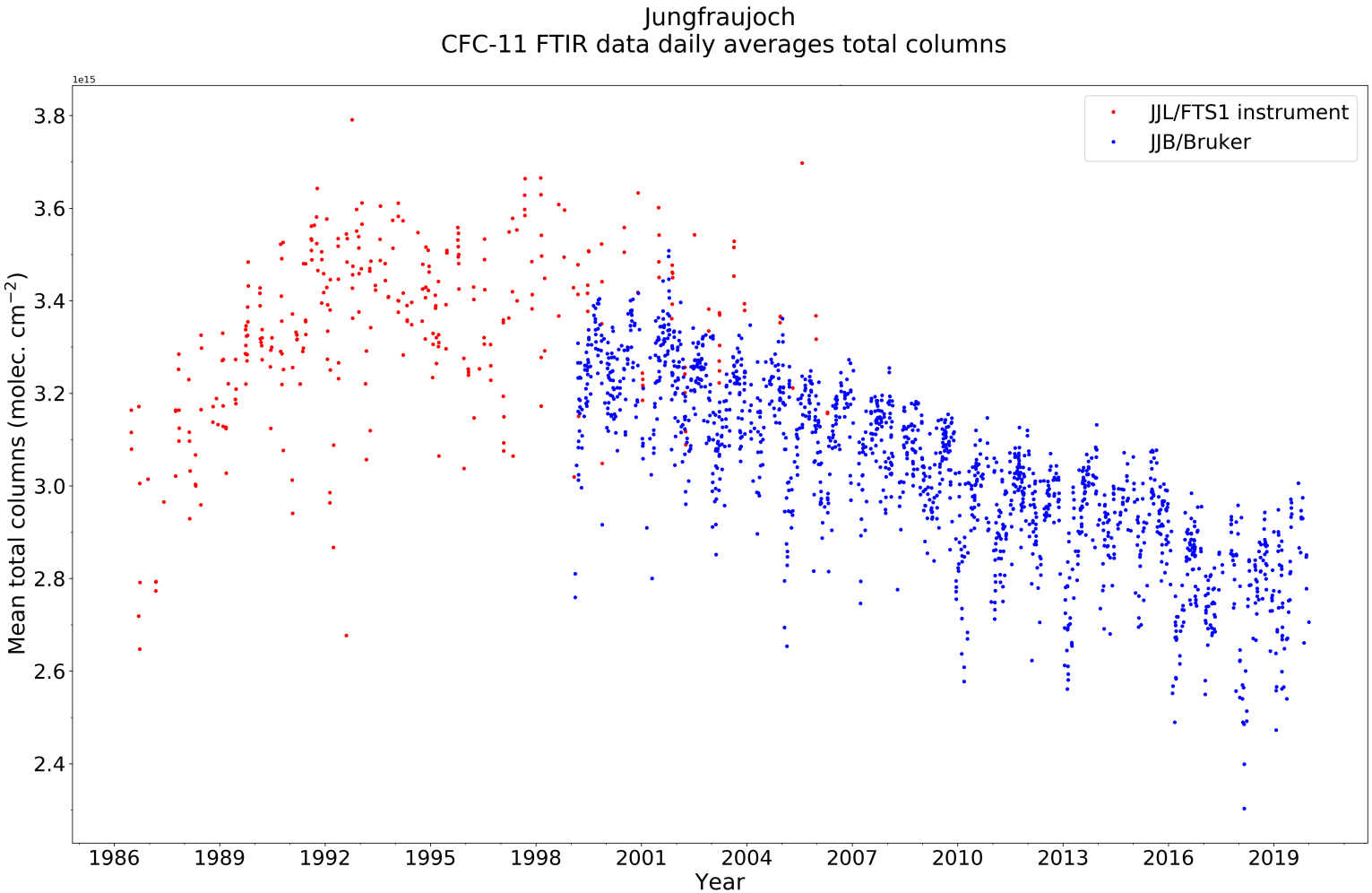


Figure: Jungfraujoch Station (NH)

Station	DOFS	1st eigval	2nd eigval	1st eigvec FWHM	2nd eigvec intersec
Lauder	1.57	1.00	0.56	12km	5km
Jungfraujoch	1.36	0.99	0.35	14km	8km

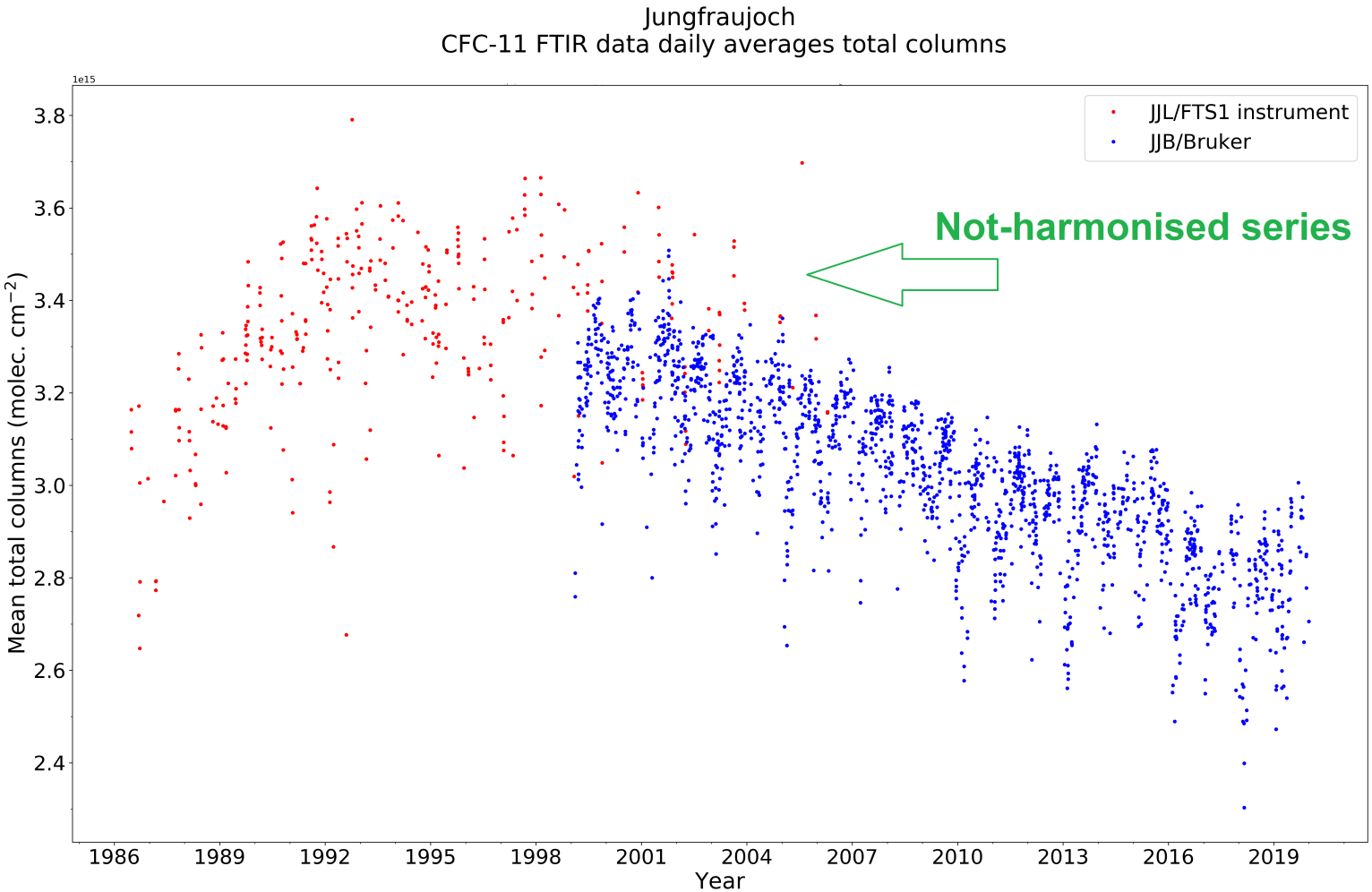
Instruments harmonisation

Jungfraujoch not-harmonised time series



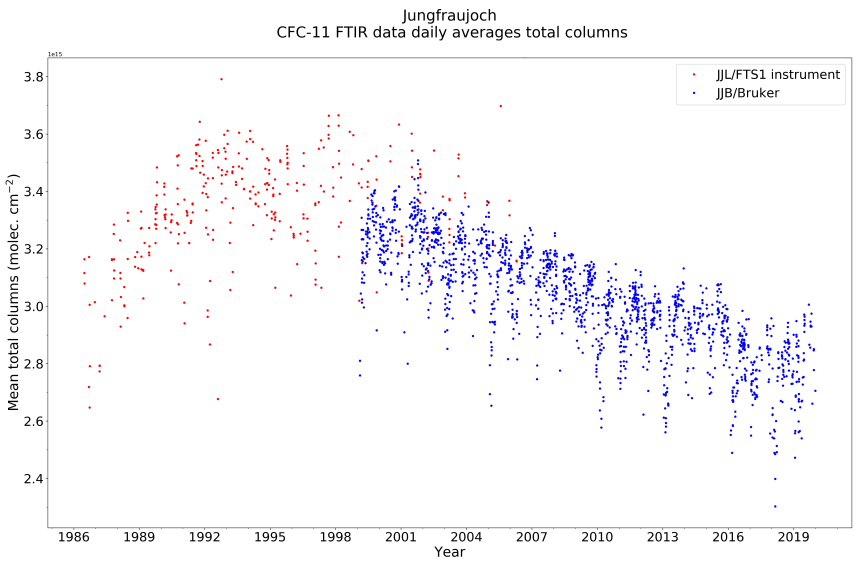
Instruments harmonisation

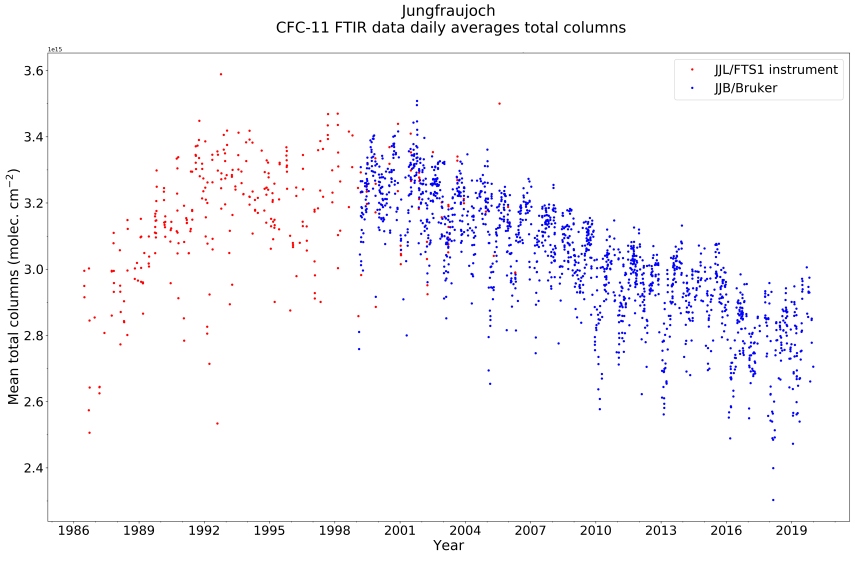
Jungfraujoch not-harmonised time series



Instruments harmonisation

Jungfraujoch not-harmonised time series

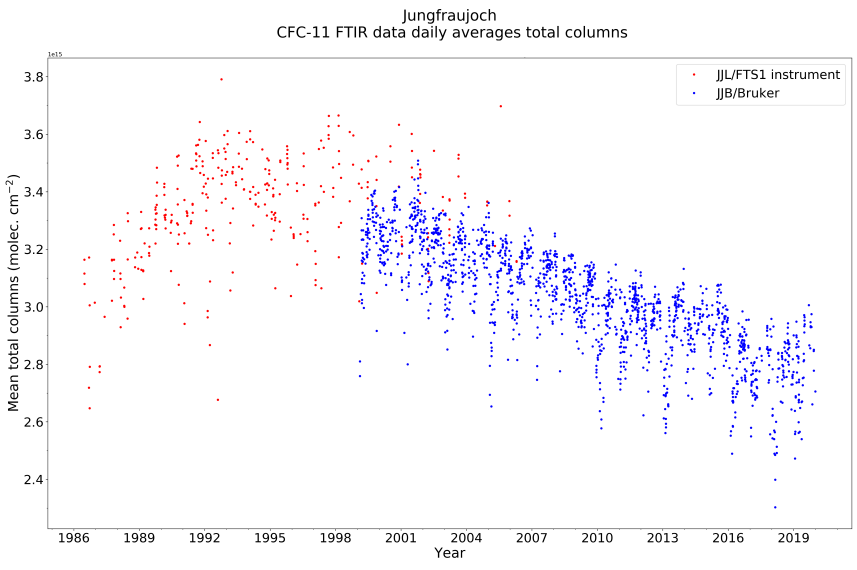


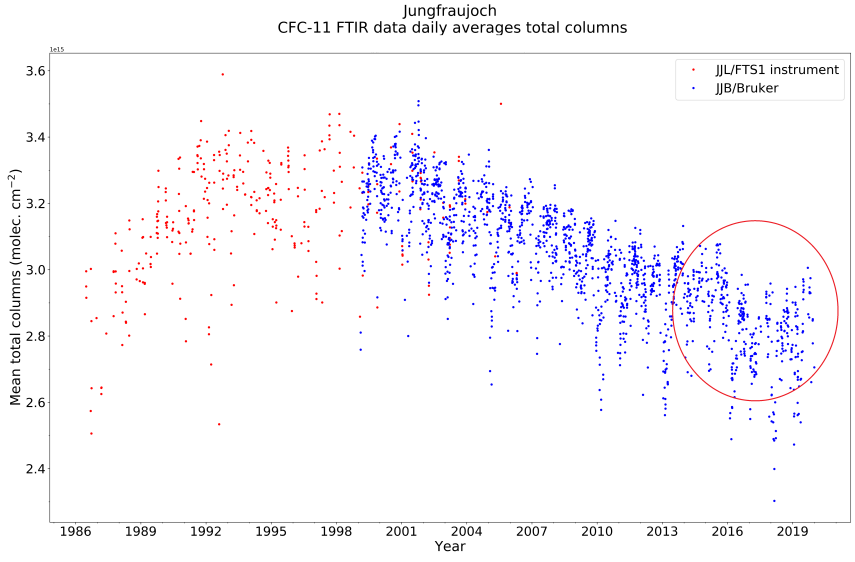


- Dataset of the Bruker (JJB) multiplied by 0.9692 from 12/02/1999 and 09/10/2001
- Dataset of the homemade instrument (JJL) multiplied by 0.9467

Instruments harmonisation

Jungfraujoch not-harmonised time series



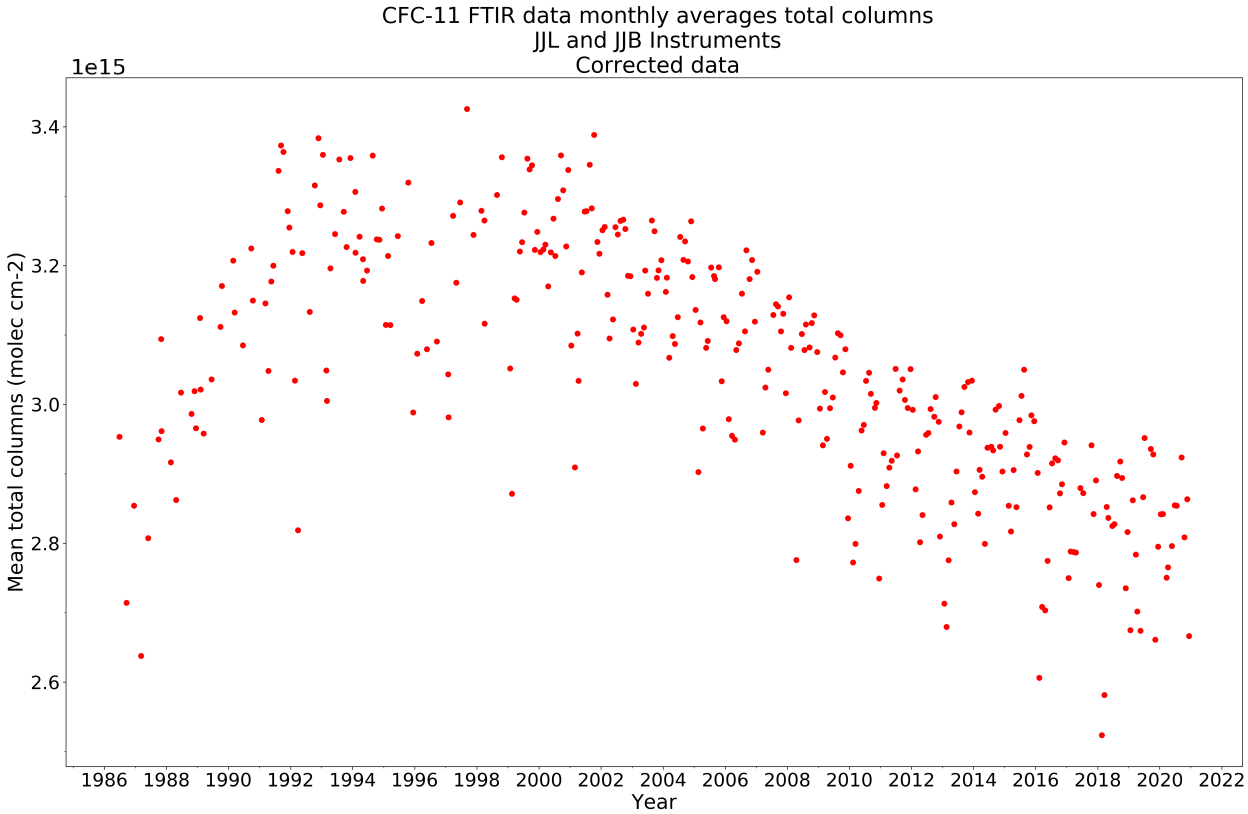


- Dataset of the Bruker (JJB) multiplied by 0.9692 from 12/02/1999 and 09/10/2001
- Dataset of the homemade instrument (JJL) multiplied by 0.9467

Problematic period $\approx$ 2016 - 2019

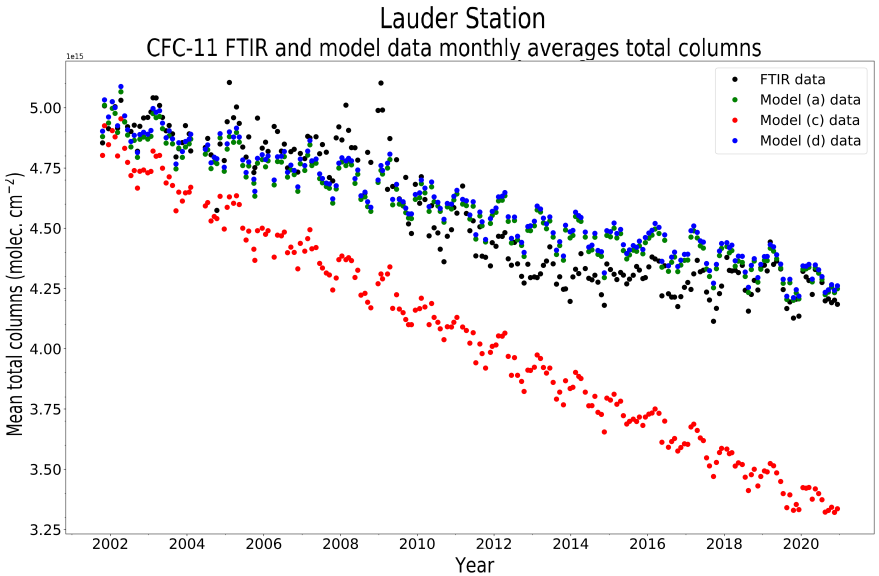
Jungfraujoch scaled data

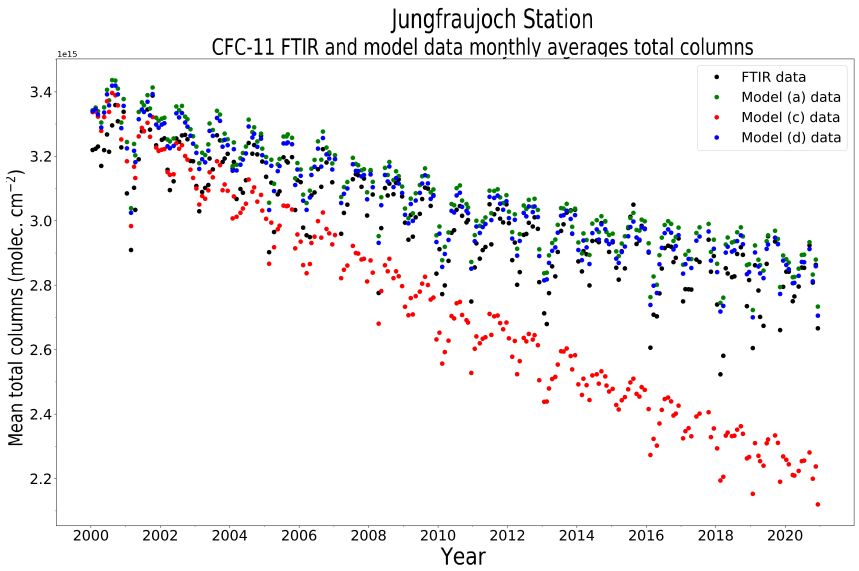
(16/10/2015 - 18/06/2019)



Change of one spectrometer mirror → Multiply this period data by 1.01812985 → Harmonised series from June 1986 to Dec 2020

Model and FTIR data comparison





Tracers:

(a) Best estimate of emissions and some realistic distribution

(c) Zero emissions since 2000 - Simple decay

(d) Same total emissions as (a) but equal emissions at all lat/lon

Model and FTIR data comparison

Lauder - Broken Trend

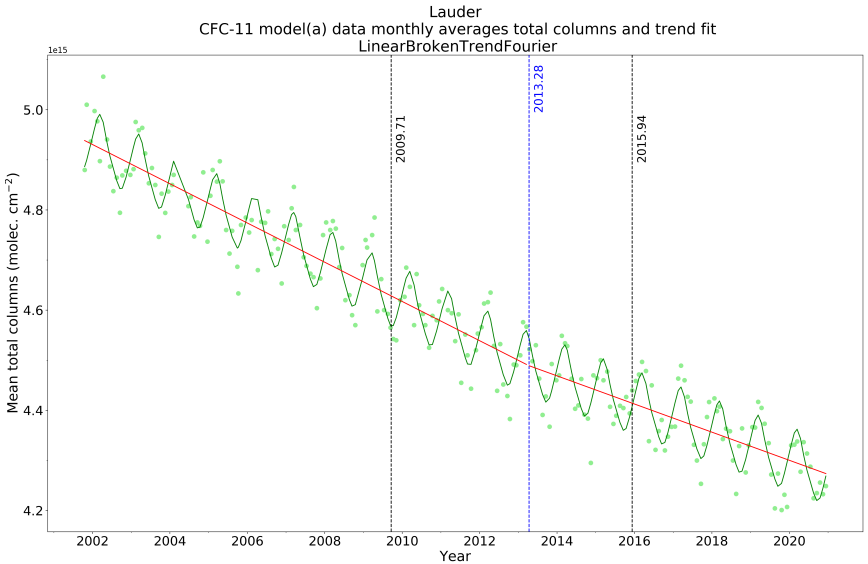


Figure: TOMCAT/SLIMCAT model data

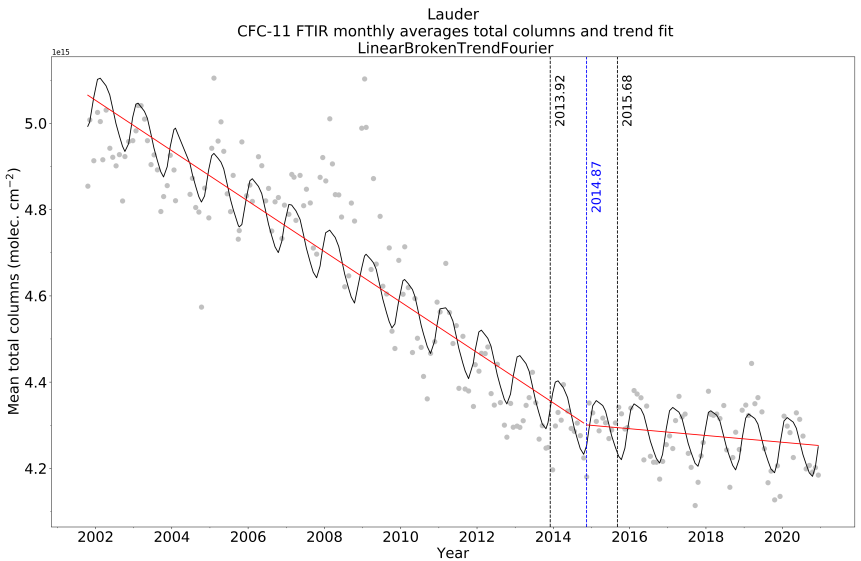


Figure: FTIR data

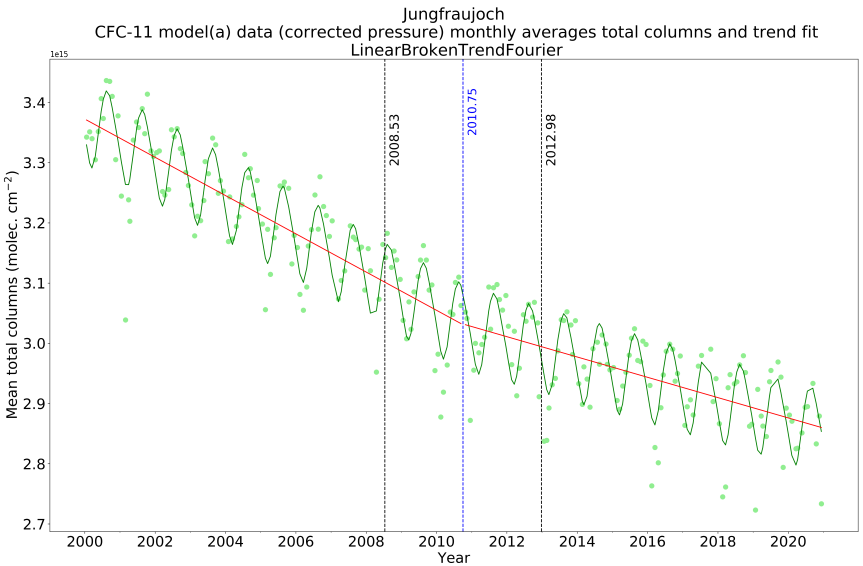
Data	Break	Slope1	Slope2	Trend change
Model	$2013.28^{+2.66}_{-3.57}$	$(-3.92 \pm 0.35)\,10^{13}$	$(-2.81 \pm 0.70)\,10^{13}$	$(1.11 \pm 0.64)\,10^{13}$
FTIR	$2014.87^{+0.81}_{-0.95}$	$(-5.85 \pm 0.32)\,10^{13}$	$(-0.78 \pm 1.17)\,10^{13}$	$(5.06 \pm 0.85)\,10^{13}$

Mean Model/FTIR ratio $= 1.01$

Ratio slope $= (3.40 \pm 0.50)\,10^{-3}$

Model and FTIR data comparison

Jungfraujoch - Broken Trend



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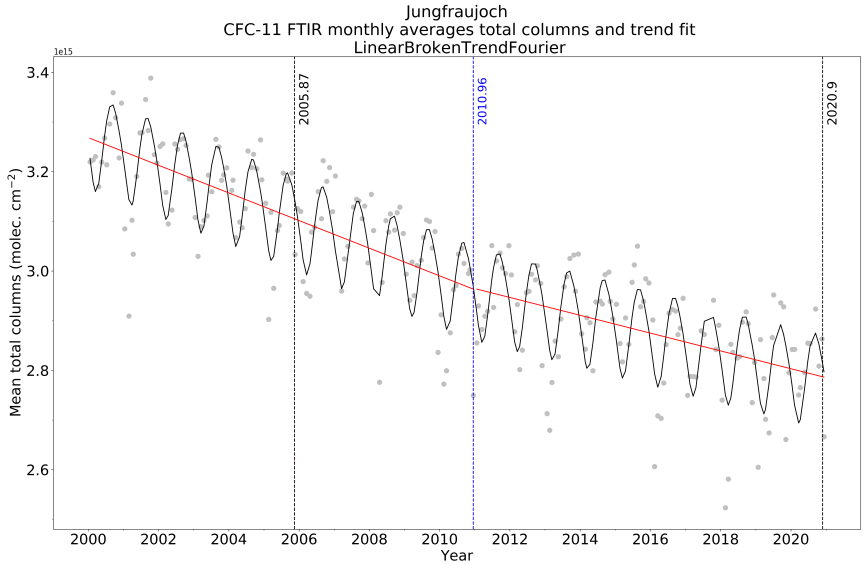


Figure: FTIR data

Data	Break	Slope1	Slope2	Trend change
Model	2010.75 ± 2.23	$(-3.18 \pm 0.31)\,10^{13}$	$(-1.69 \pm 0.70)\,10^{13}$	$(1.49 \pm 0.42)\,10^{13}$
FTIR	$2010.96^{+9.94}_{-5.09}$	$(-2.74 \pm 0.34)\,10^{13}$	$(-1.79 \pm 0.56)\,10^{13}$	$(0.99 \pm 334.99)\,10^{13}$

Mean Model/FTIR ratio $= 1.03$

Ratio slope $= (0.74 \pm 0.49)\,10^{-3}$

Interhemispheric ratio

LAU / JFJ

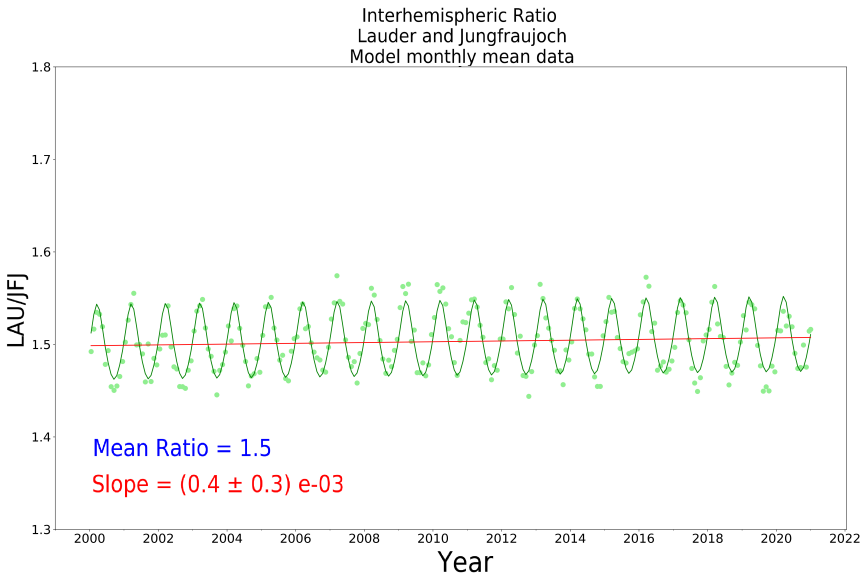


Figure: Model ratio

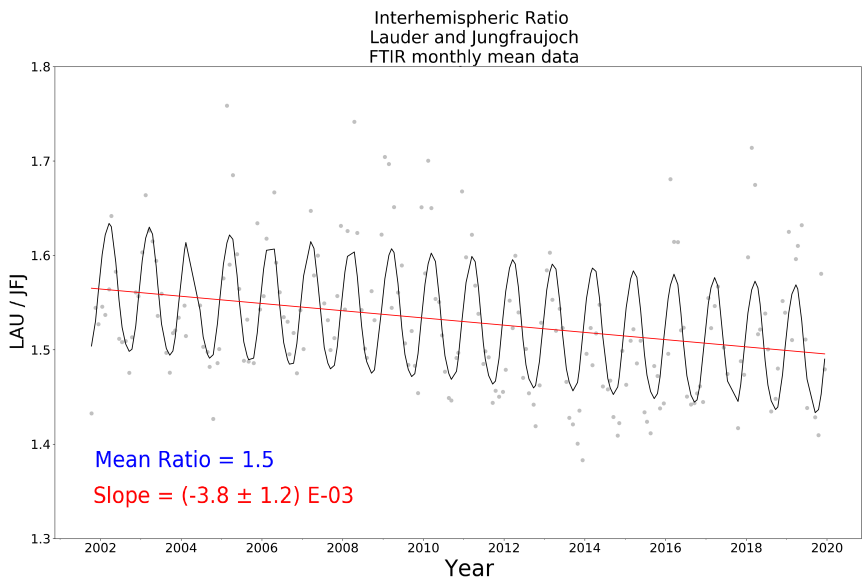
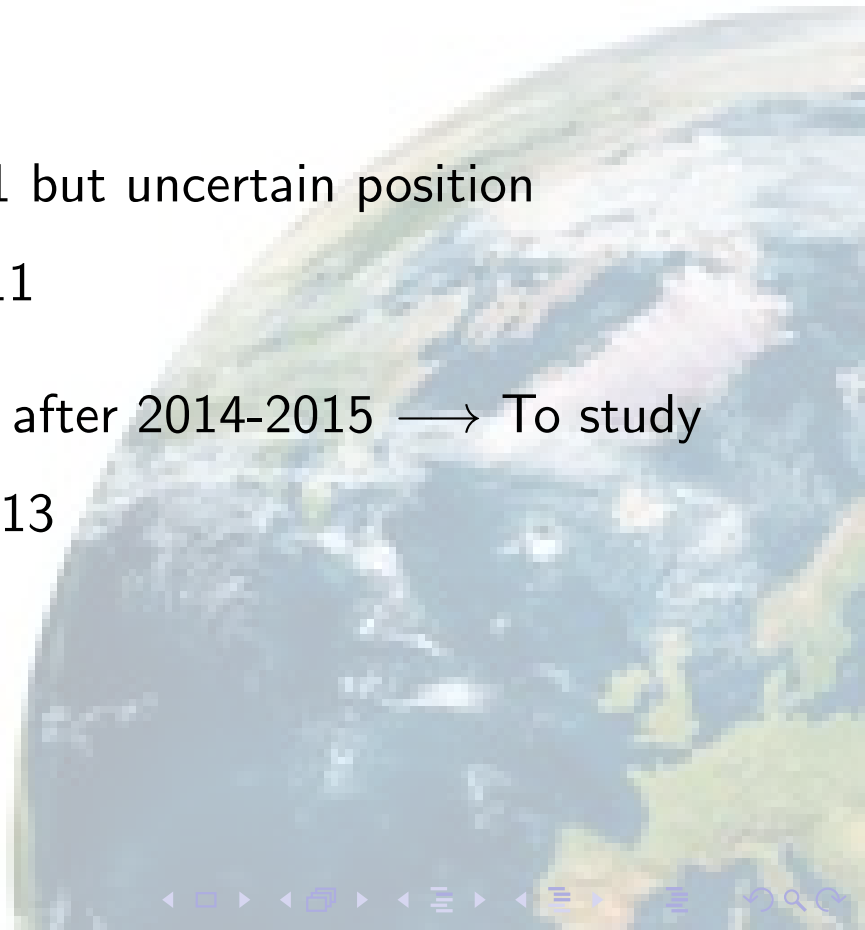


Figure: FTIR ratio

Conclusions

- Harmonised JFJ data set from June 1986 to December 2020 → NEW!
- Lauder CFC-11 time series → NEW!
- FTIR JFJ data: break point in ≈2011 but uncertain position
- Model JFJ data: break point in ≈2011
- FTIR LAU data: no-trend time series after 2014-2015 ⟶ To study
- Model LAU data: break point in ≈2013



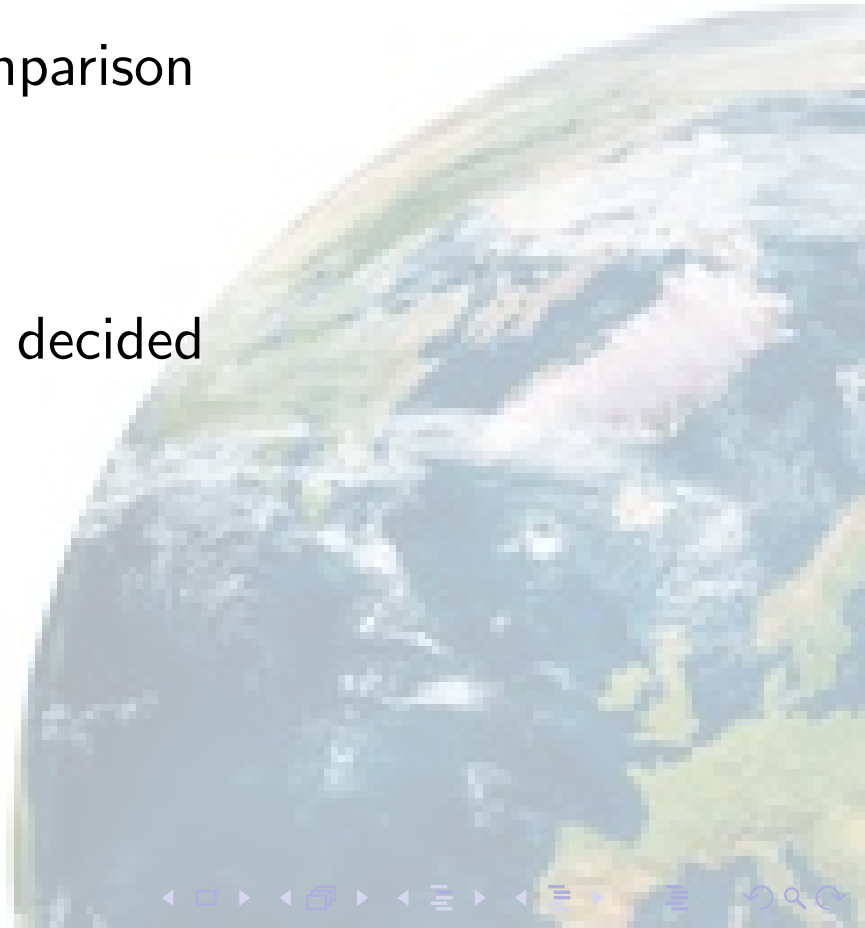
Conclusions

- Confirmation of new CFC-11 emissions
- Unreported emissions from eastern China (Rigby et. al, 2019 - Nature)

- Decrease in global CFC-11 emissions since 2018 (Montzka et al., 2021 & Park et al., 2021 - Nature)

Next steps

- Lauder CFC-12 time series for comparison
- Completion of the error analysis
- Completion of the CFC-11 paper
- Other target molecules $\longrightarrow$ To be decided



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Methodology

1. **Spectral window:** 830.0 - 859.3 cm^{-1}
2. **The SFIT4 inversion program**
   - A priori mean vertical profiles
   - Interfering species: H_2O, CO_2, HNO_3, $COCl_2$, OCS, O_3, $H_2{}^{18}O$
3. **Instruments harmonisation**
4. **Scale data from 16/10/2015 to 18/06/2019**
5. **Trends estimation** - Marina Friedrich (UMaastricht & Postdam Institute for Climate Impact Research)
6. **TOMCAT/SLIMCAT model** - Martyn Chipperfield (ULeeds)
   - 3D chemical transport model (CTM)
   - Abundance of chemical species in the tropo- and stratosphere
   - Winds and temperatures from ECMWF
   - Horizontal resolution: 2.8° × 2.8°