25 years NDACC observation at Tsukuba: Temporal variations of some trace species

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Instrument

Location: Tsukuba
(36.05ºN, 140.1ºE, 31m A.S.L.)

Instruments:

Bruker 120M (1998-2006)
120HR (2001-2010)
125HR (2010-)

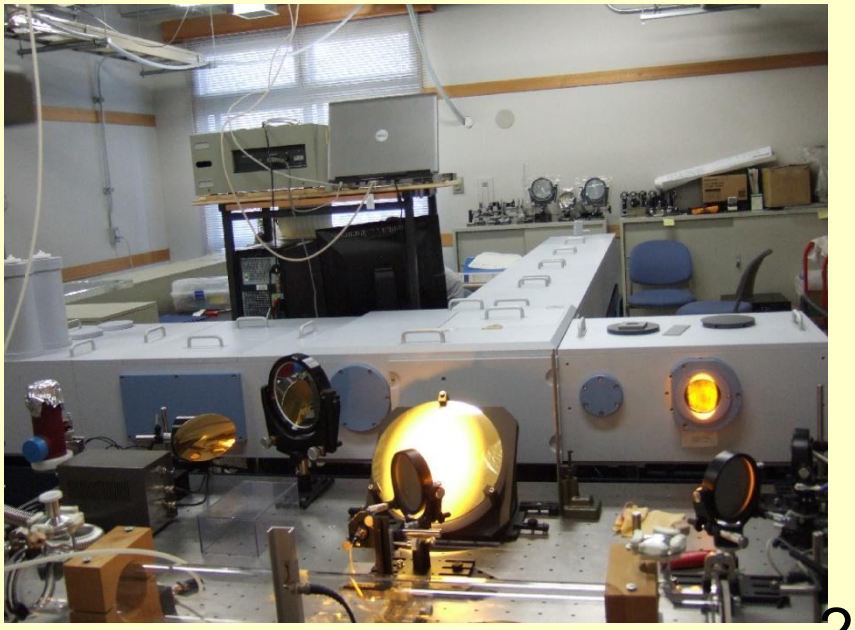
Resolution: 0.0035 cm^{-1}





120M in Container





120HR (left) and 125HR (right) in NIES building

Upload data to NDACC site

15 species are regularly analyzed and uploaded to NDACC public data web site

Analyzed with SFIT4 v1.0.21 (IRWG2023)

O_3, HNO_3, $ClONO_2$, NH_3 2001, 2014 - 2025

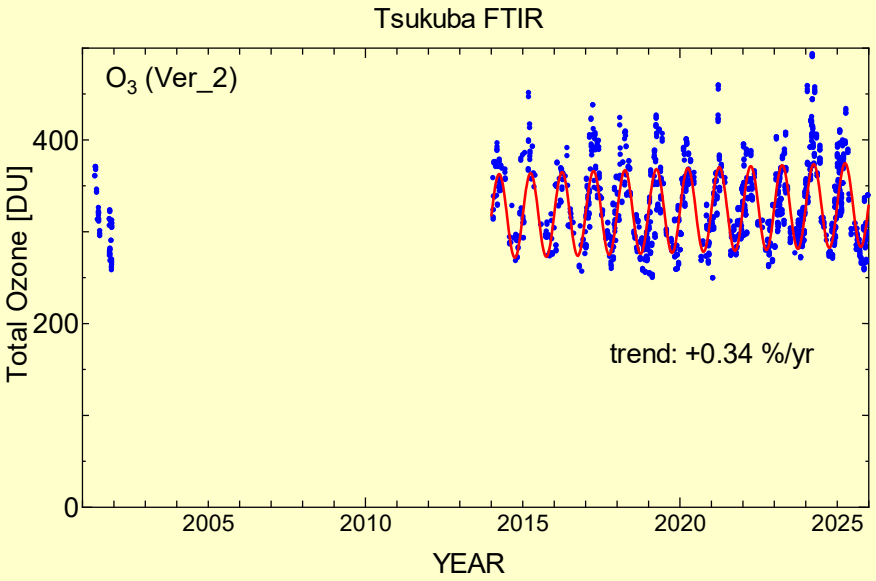
HCl, HF, C_2H_6, CO, N_2O, CH_4, HCN, HCHO, OCS 2001 - 2025

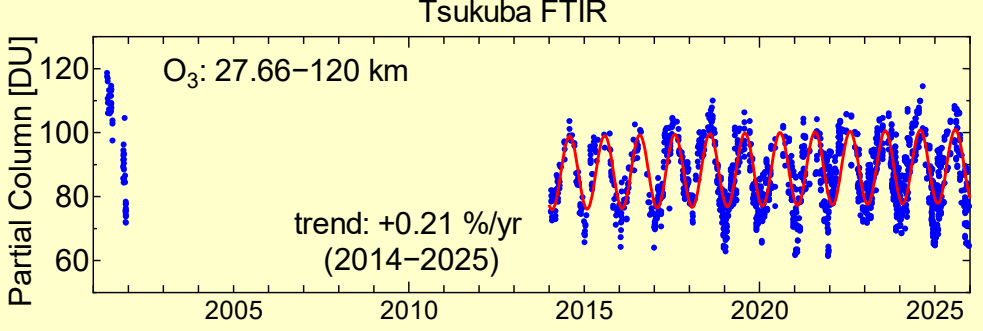
on going C_2H_2, NO_2

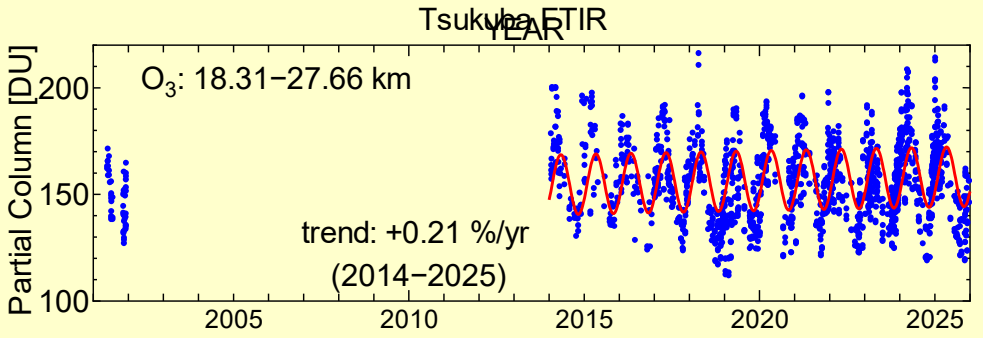
*For MCT channel (Fil.#6), we don't have measurements between 2002 and 2013.

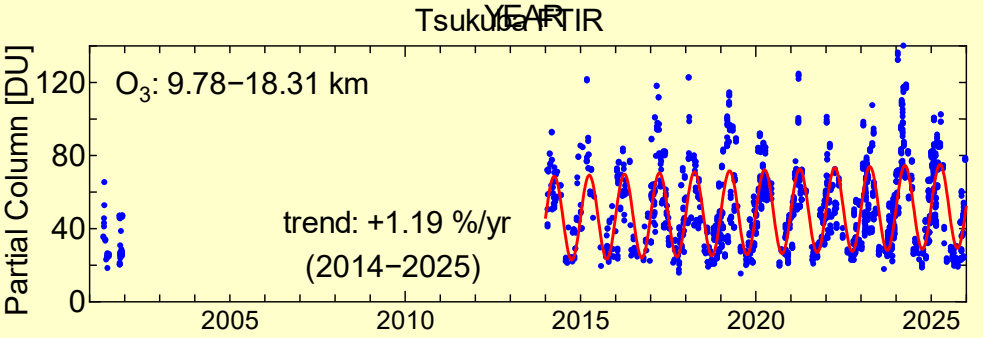
* For Fil.#4 & 5, we don't have measurements between 2004 and 2009.

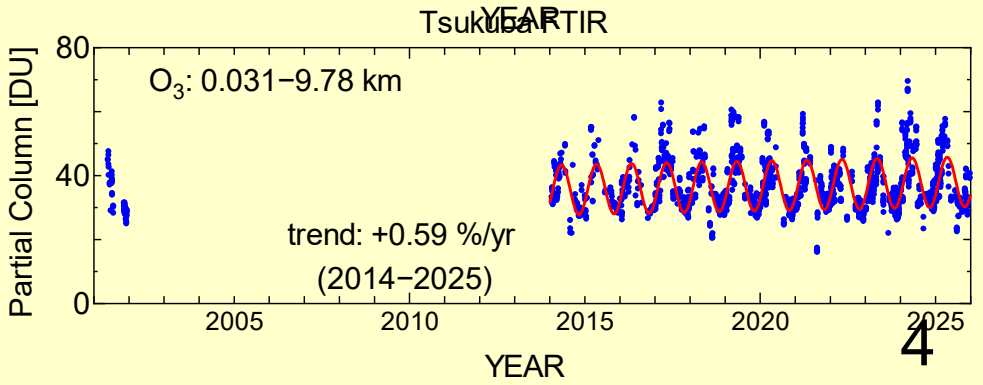
Results: O_3









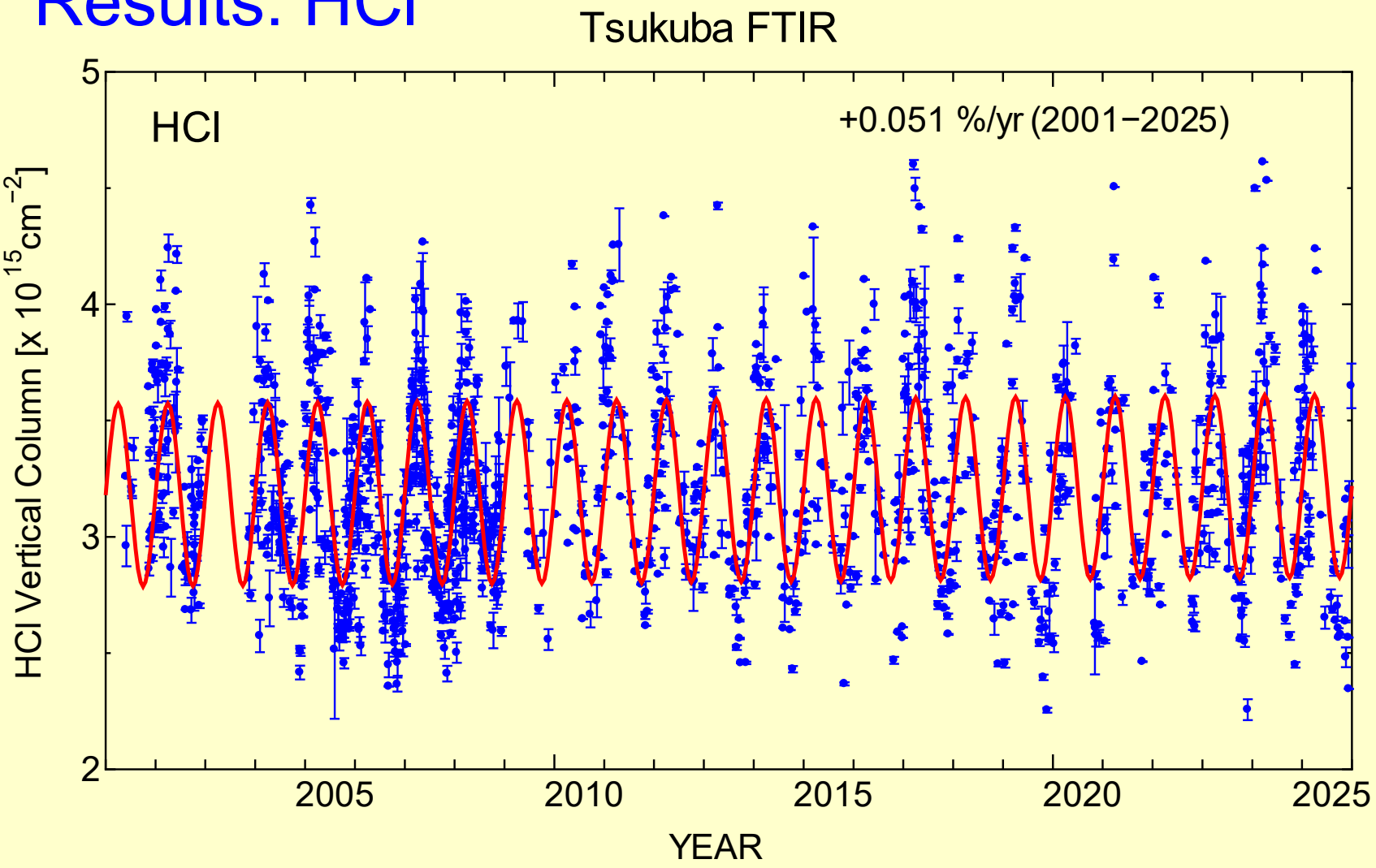


Trends (2014-2025) shows increase in total and all partial columns.

The results are used for TOAR-II assessment. Some papers were published in ACP. (Van Malderen et al. [2025]

Mirallie et al., accepted to ACP)

Results: HCl

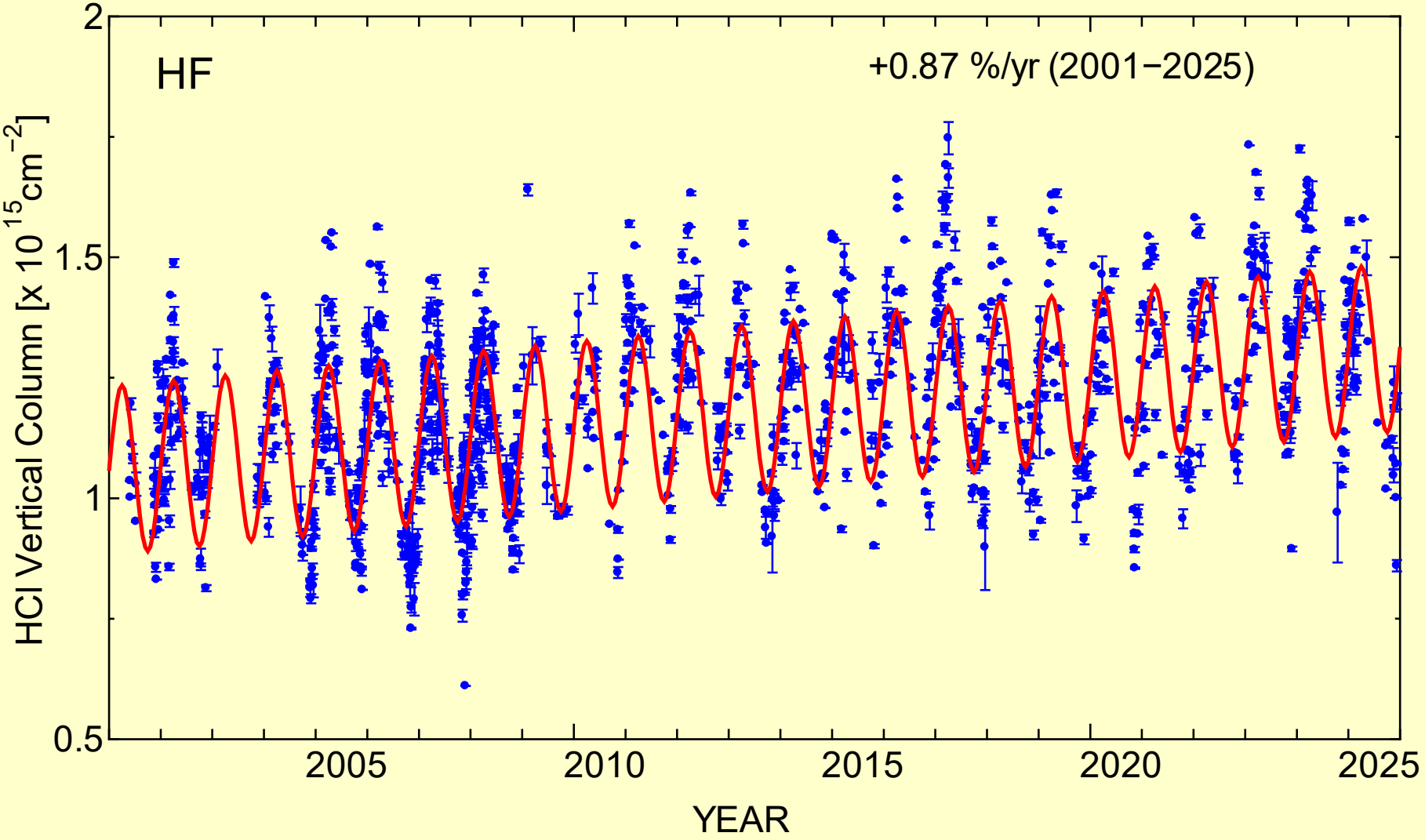


HCl isn't decreasing in total despite the stratospheric chlorine reduction.

Increasing and decreasing are seen.

Results: HF

Tsukuba FTIR



HF is still increasing (F is included in HCFCs and HFCs).
Increasing and decreasing due to the change of the meridional circulation are seen.

Stratospheric Chlorine should be decreasing …

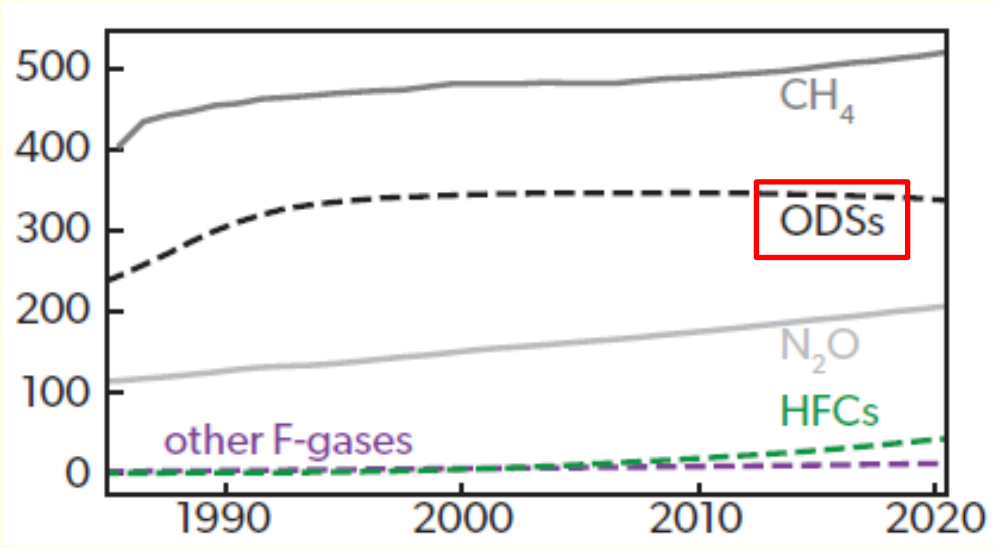


Fig. 1-5

ODSs isn't decreasing (but it includes Bromine).

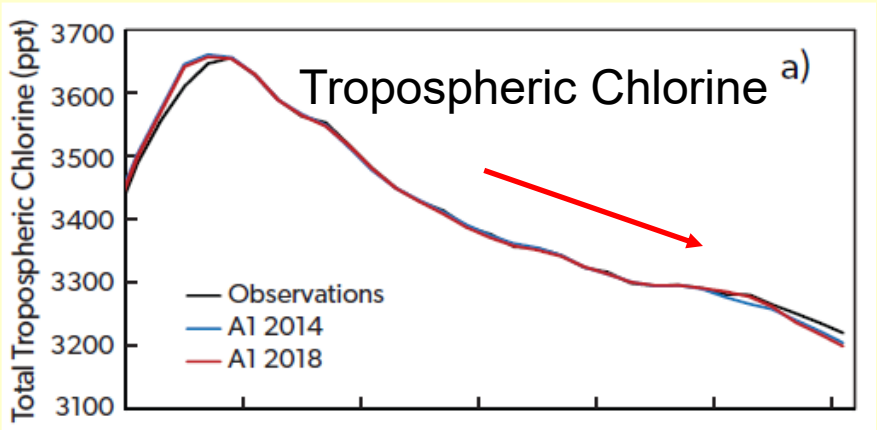


Fig. 1-11 (a)

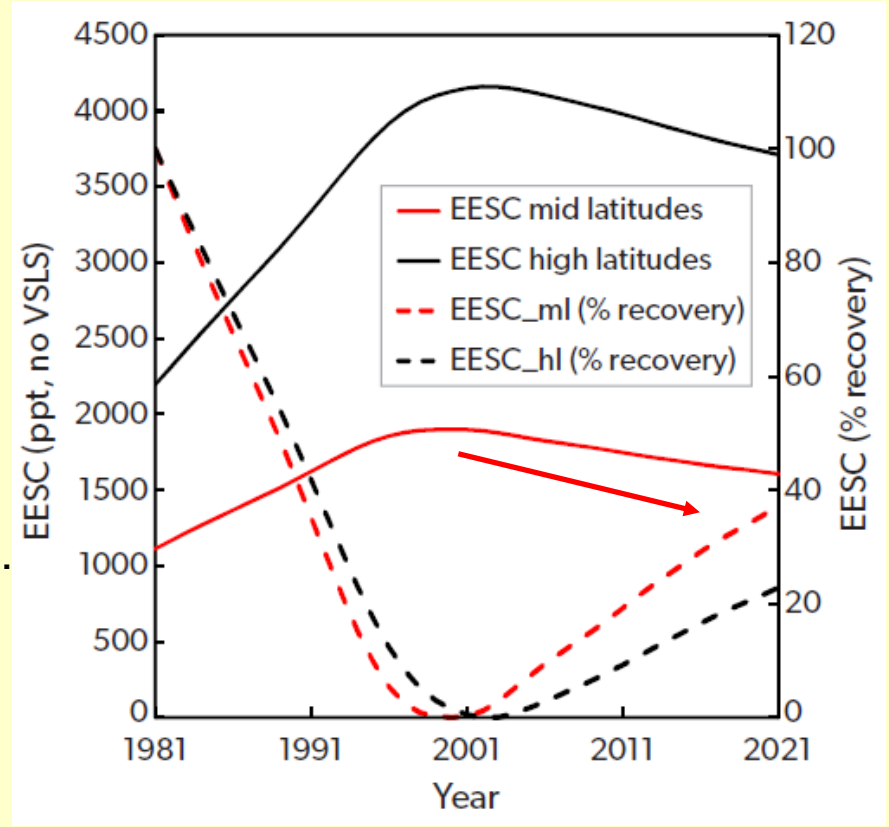


Fig. 1-16

Tropospheric Chlorine and EESC are decreasing.

[WMO, Scientific Assessment of Ozone depletion: 2022, GAW Report No.278, 2022]

Stratospheric Fluorine maybe still increasing

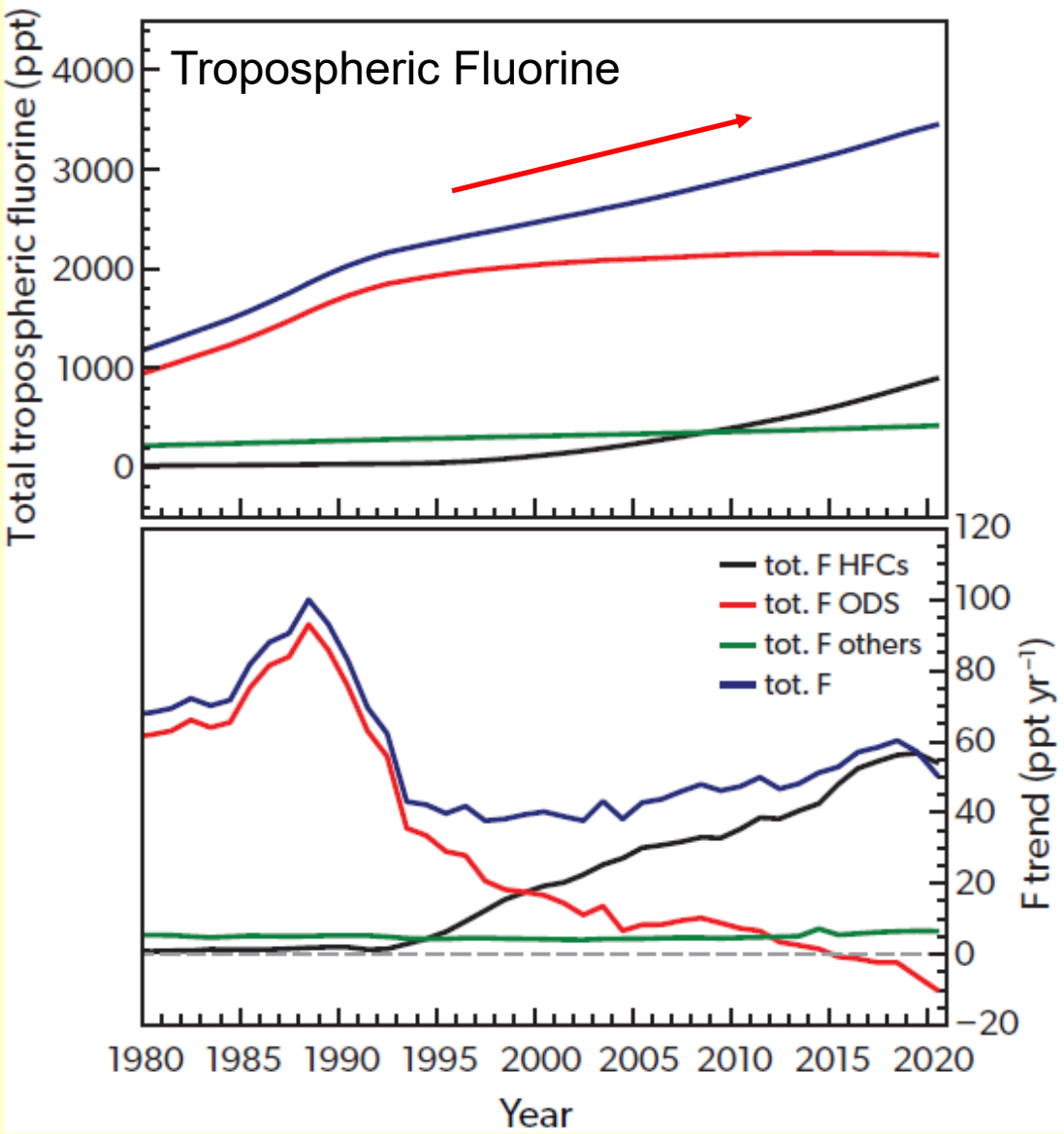
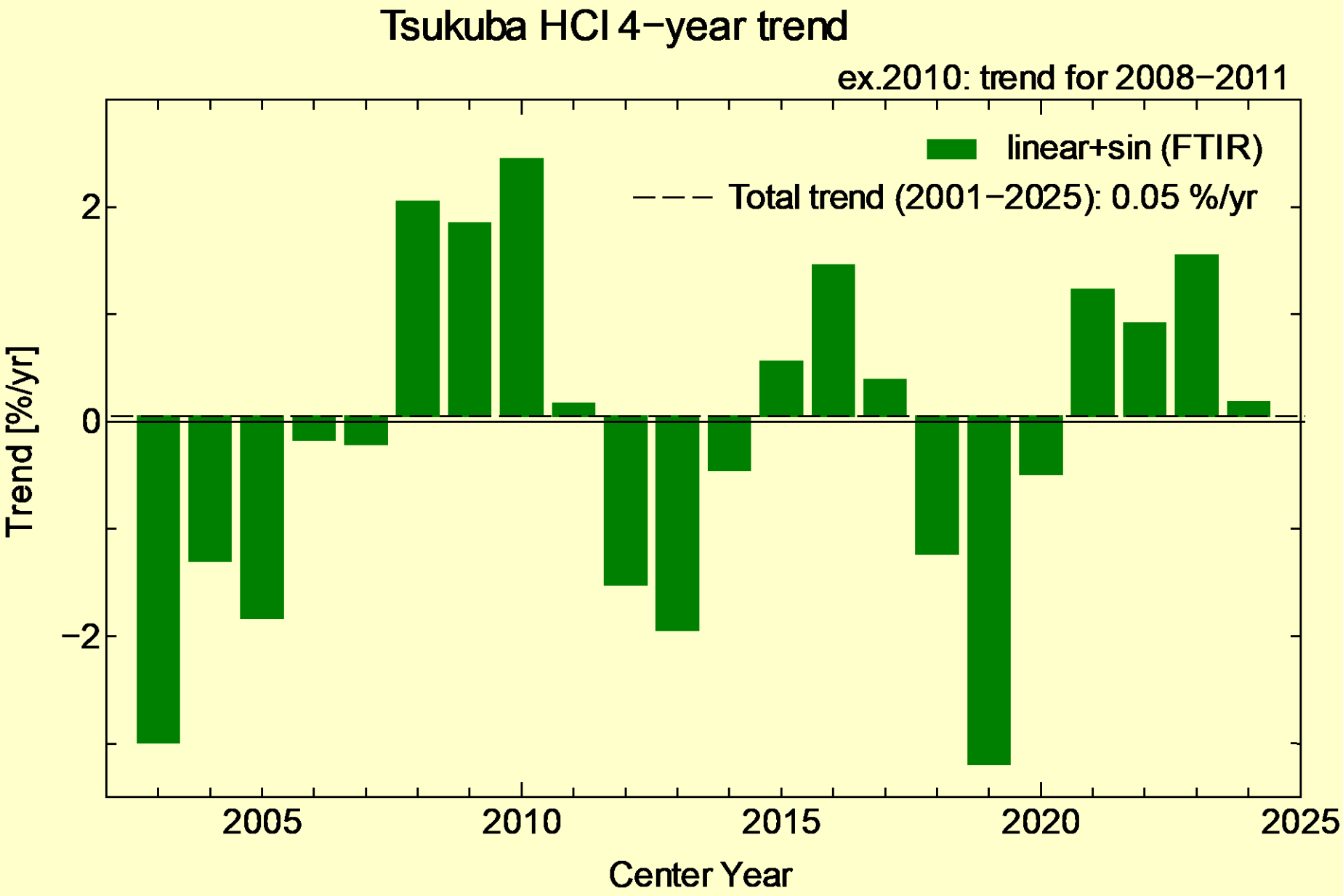
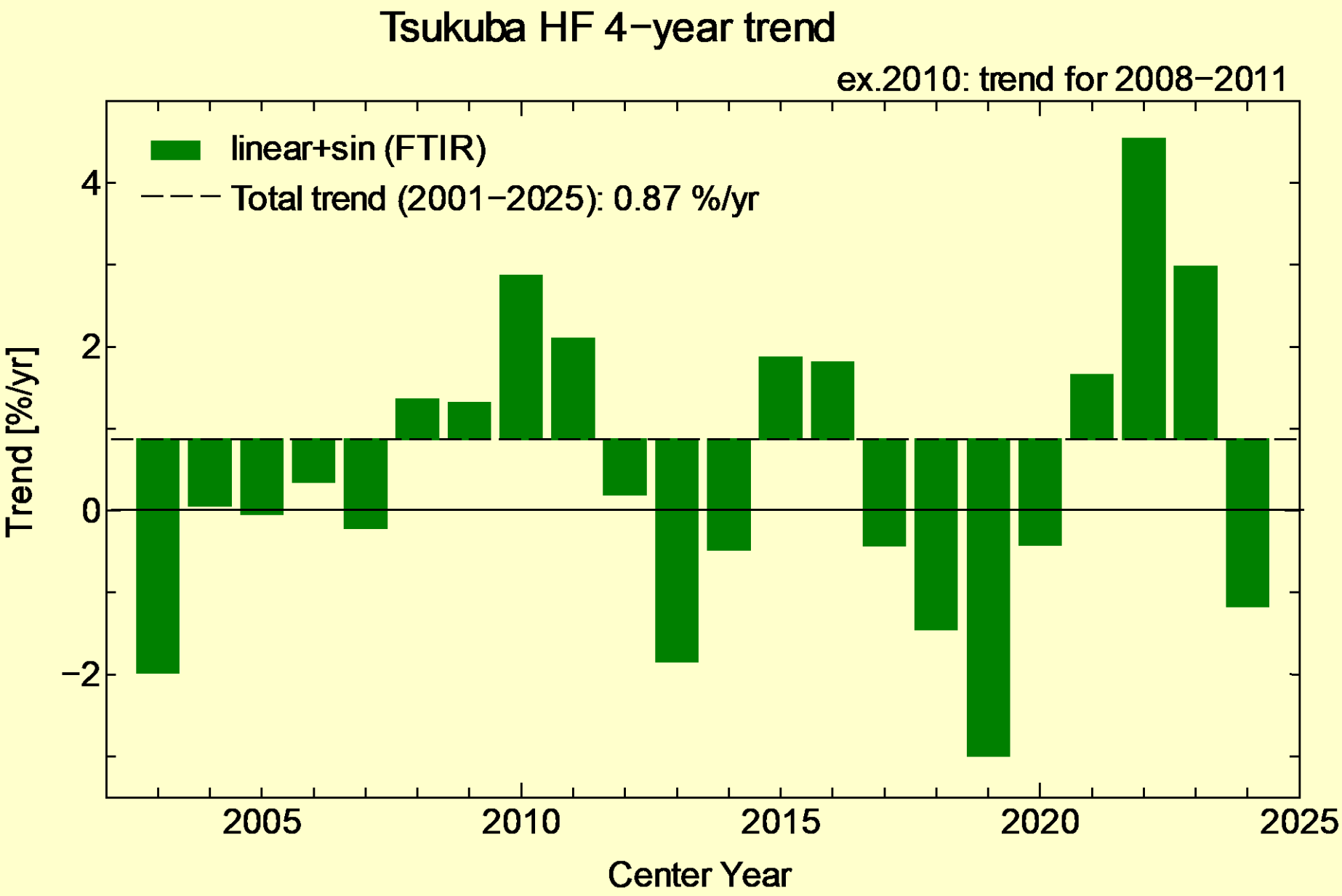


Fig. 1-17

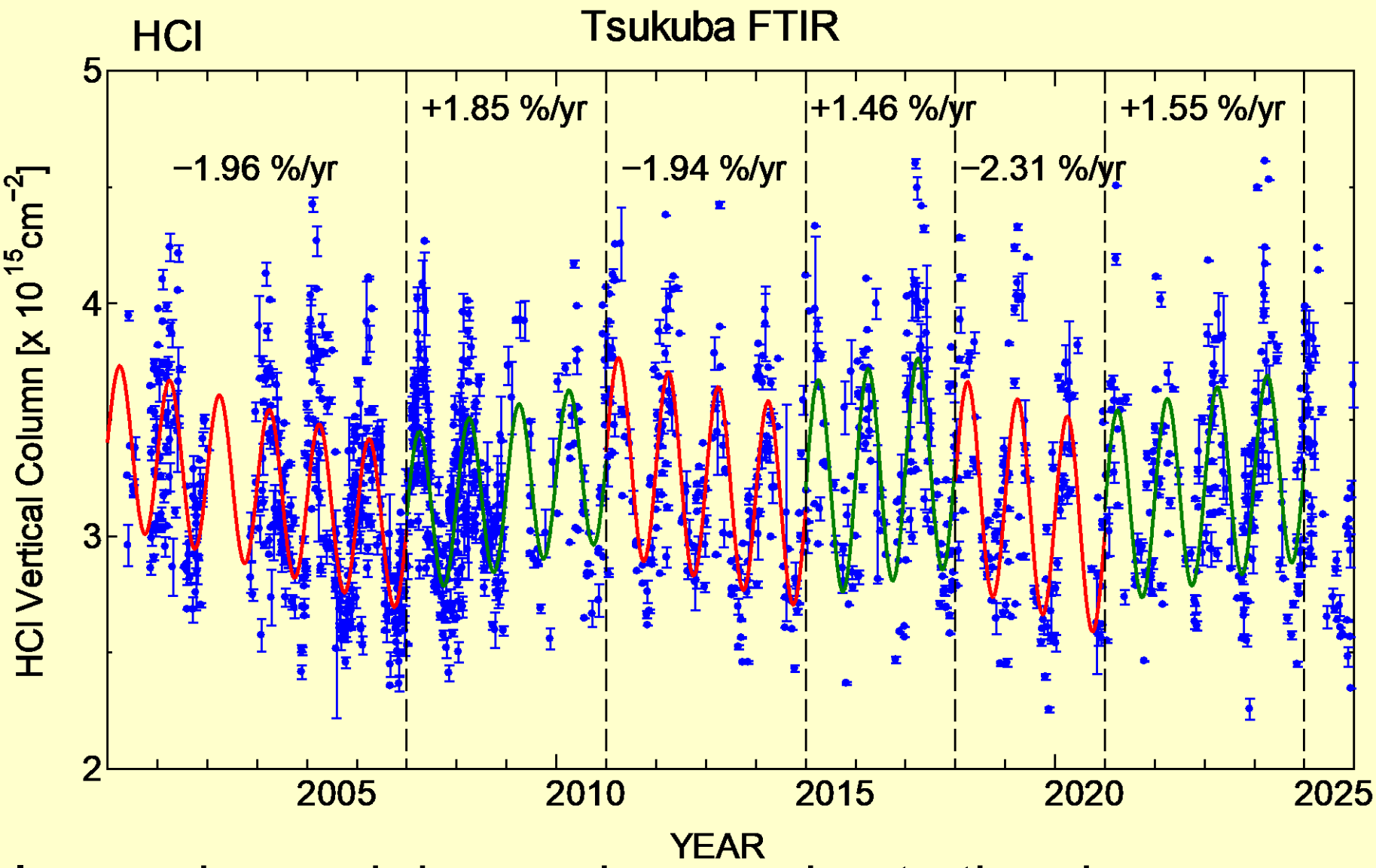
[WMO, Scientific Assessment of Ozone depletion: 2022, GAW Report No.278, 2022]



Trend reversal occurred every several years

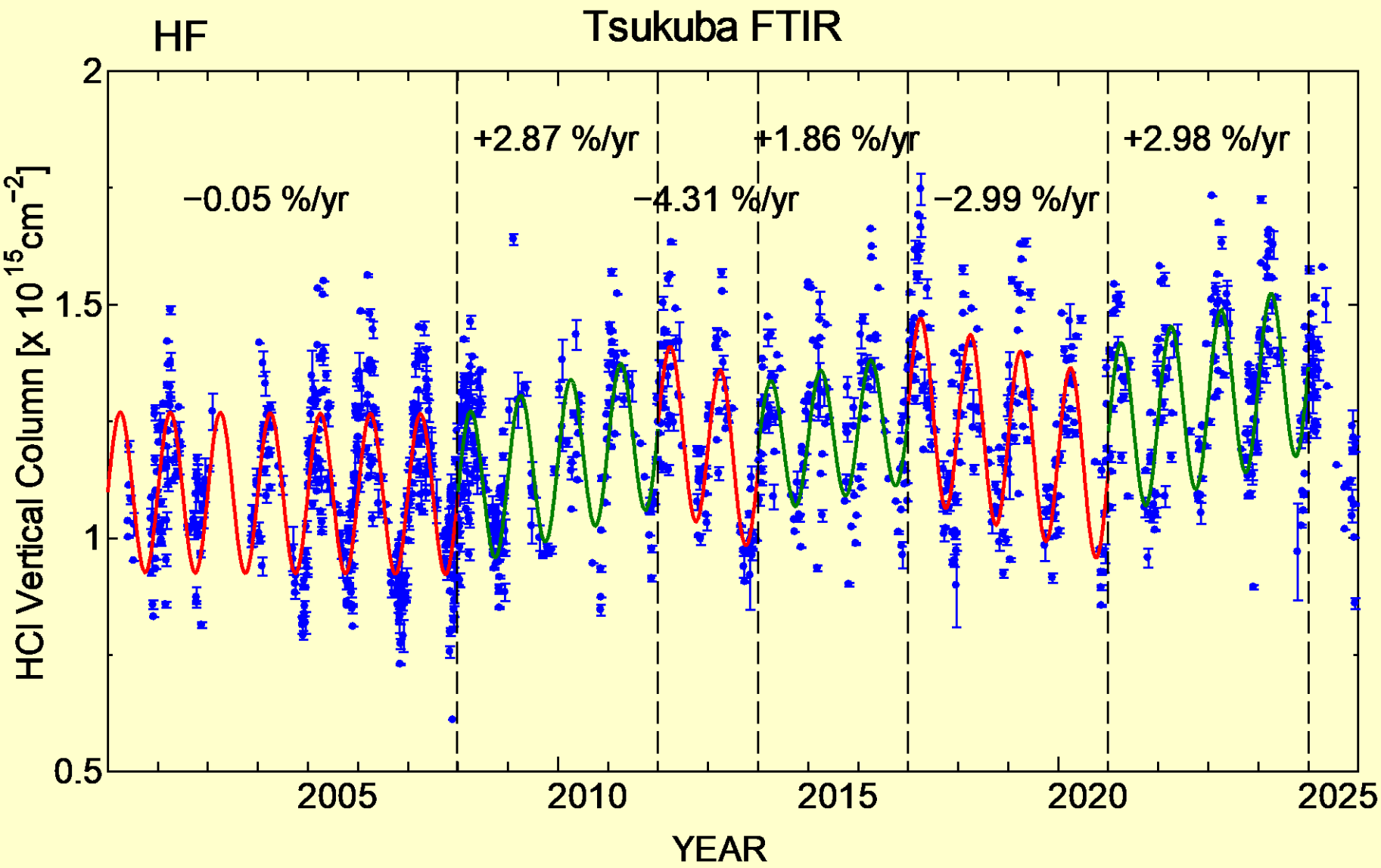


Timings of the trend reversals are nearly the same as those of the HCl



Increasing and decreasing are due to the change of the meridional circulation.

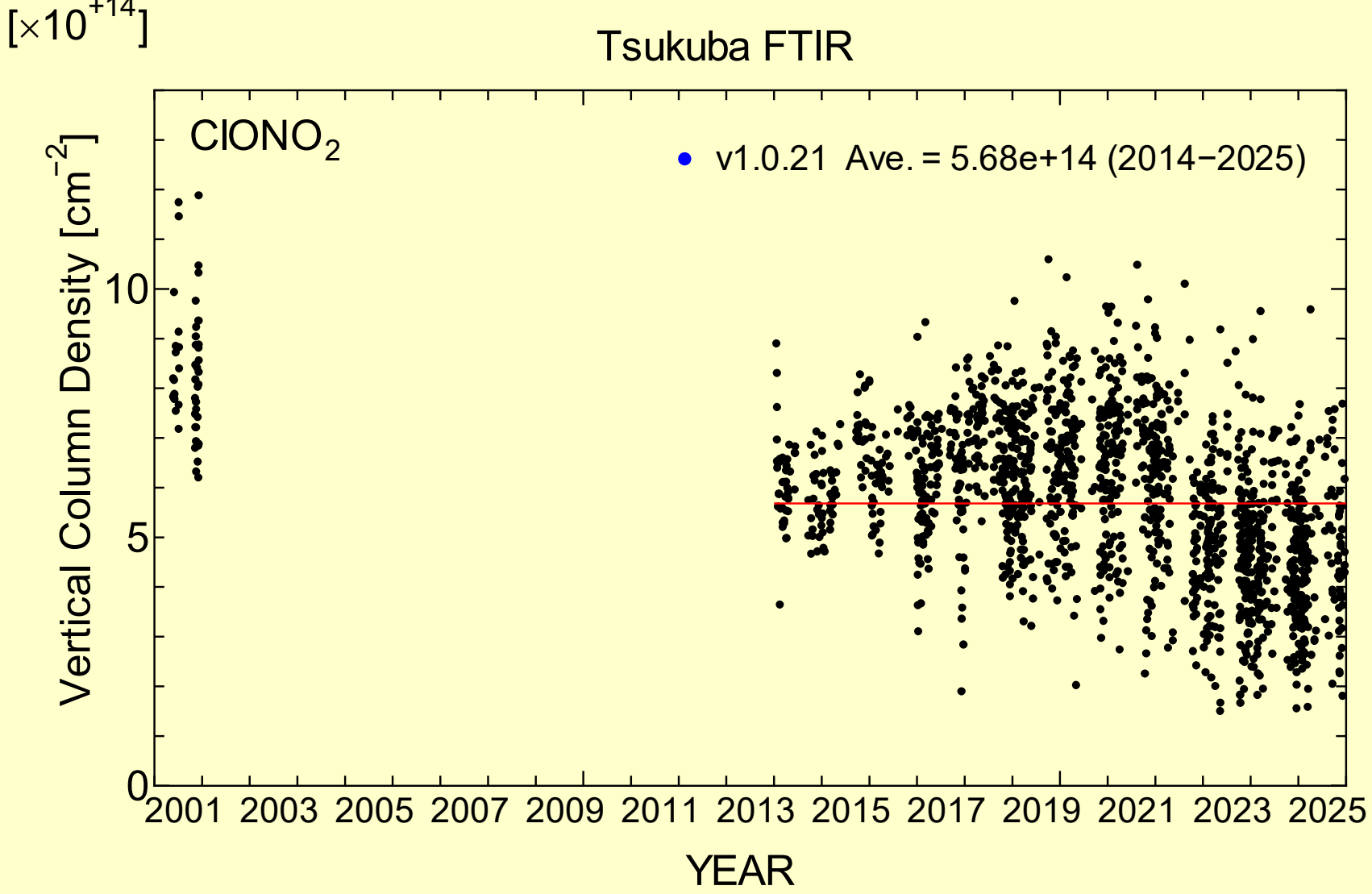
(See Mahieu et al., Nature [2014])



Increasing and decreasing are due to the change of the meridional circulation.

(See Mahieu et al., Nature [2014])

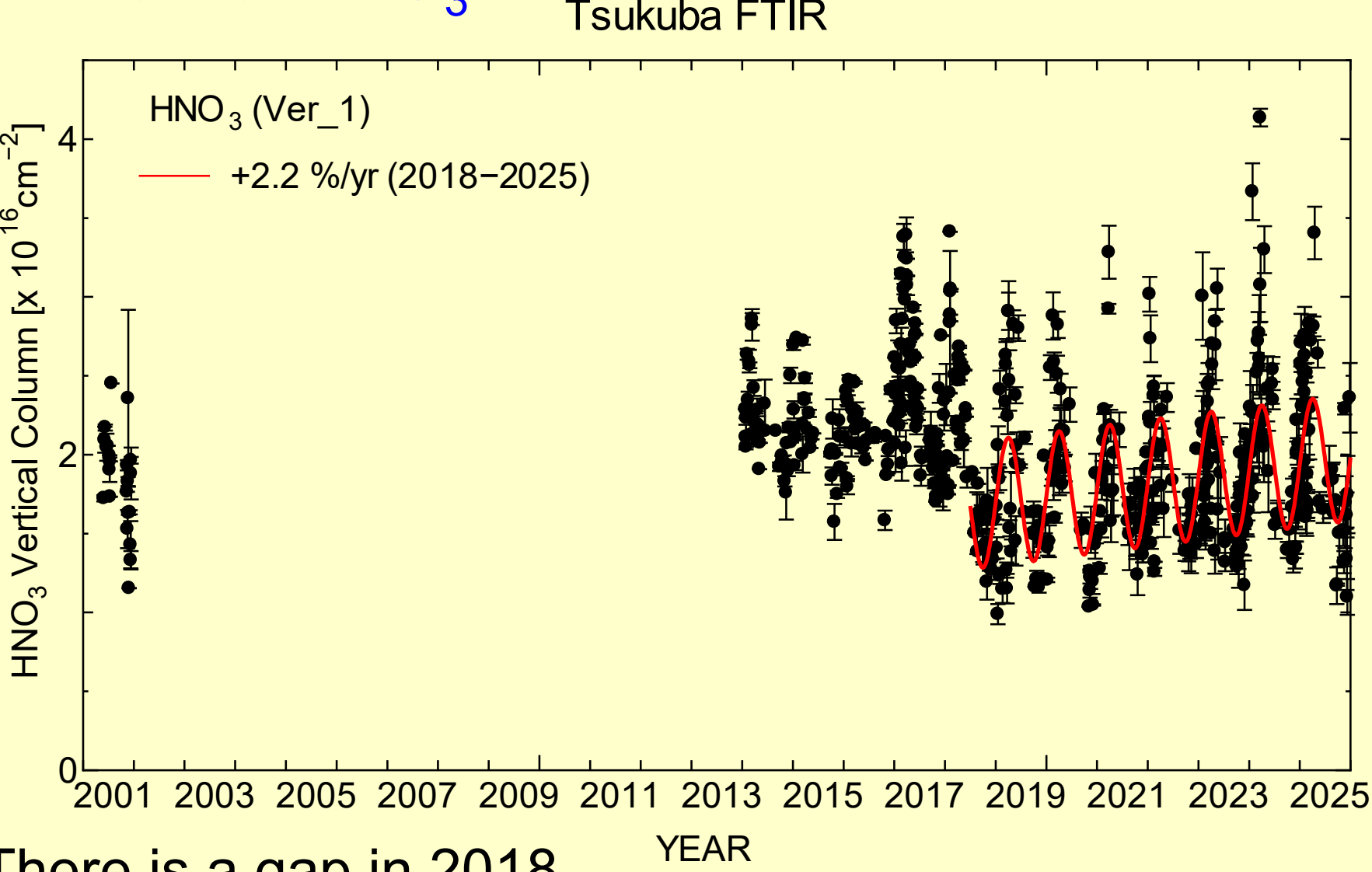
Results: $ClONO_2$



There is a gap in 2002.

Due to instrumental problem??

Results: HNO_3

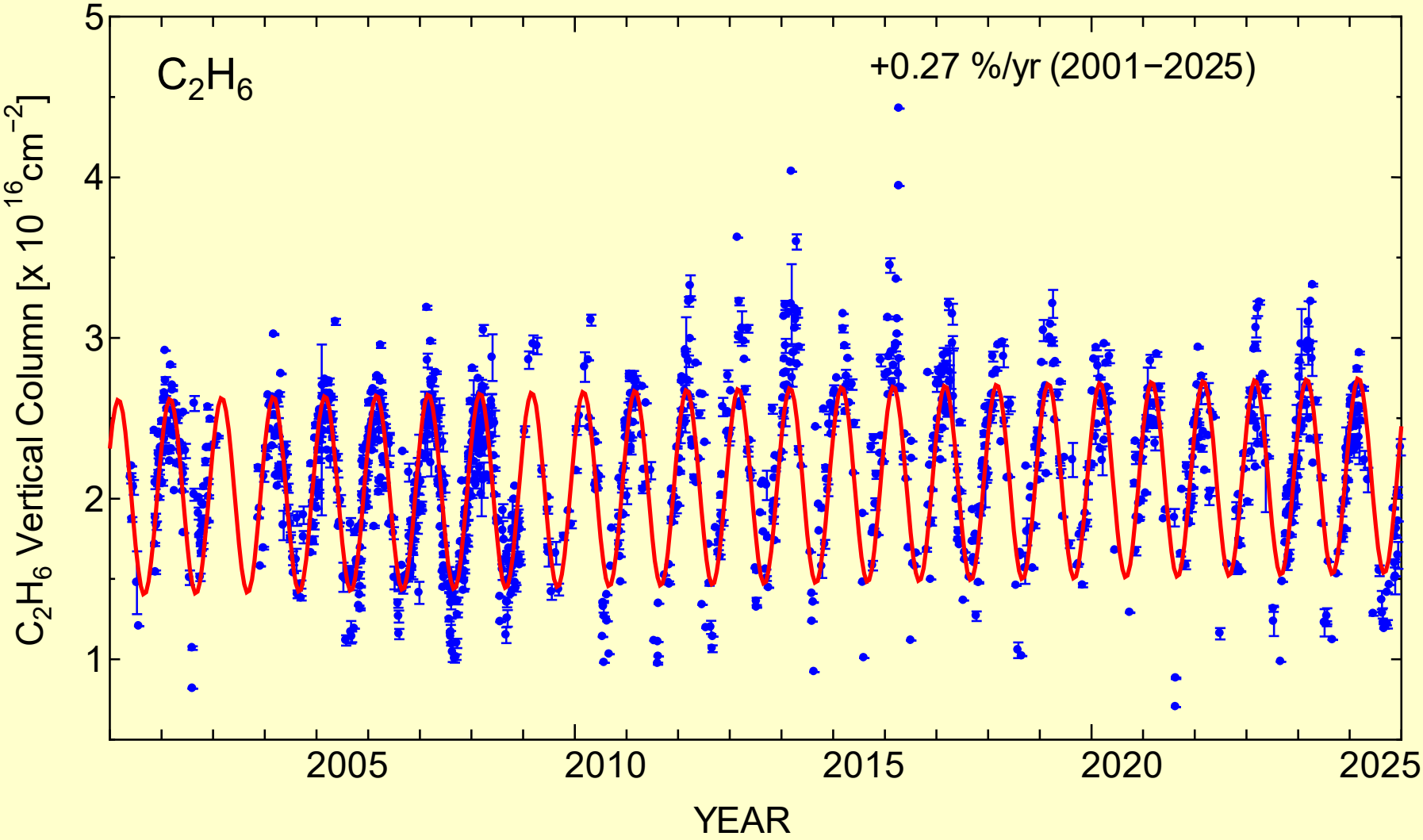


There is a gap in 2018.

It may be due to change of aperture setting (1.15 to 1.7).

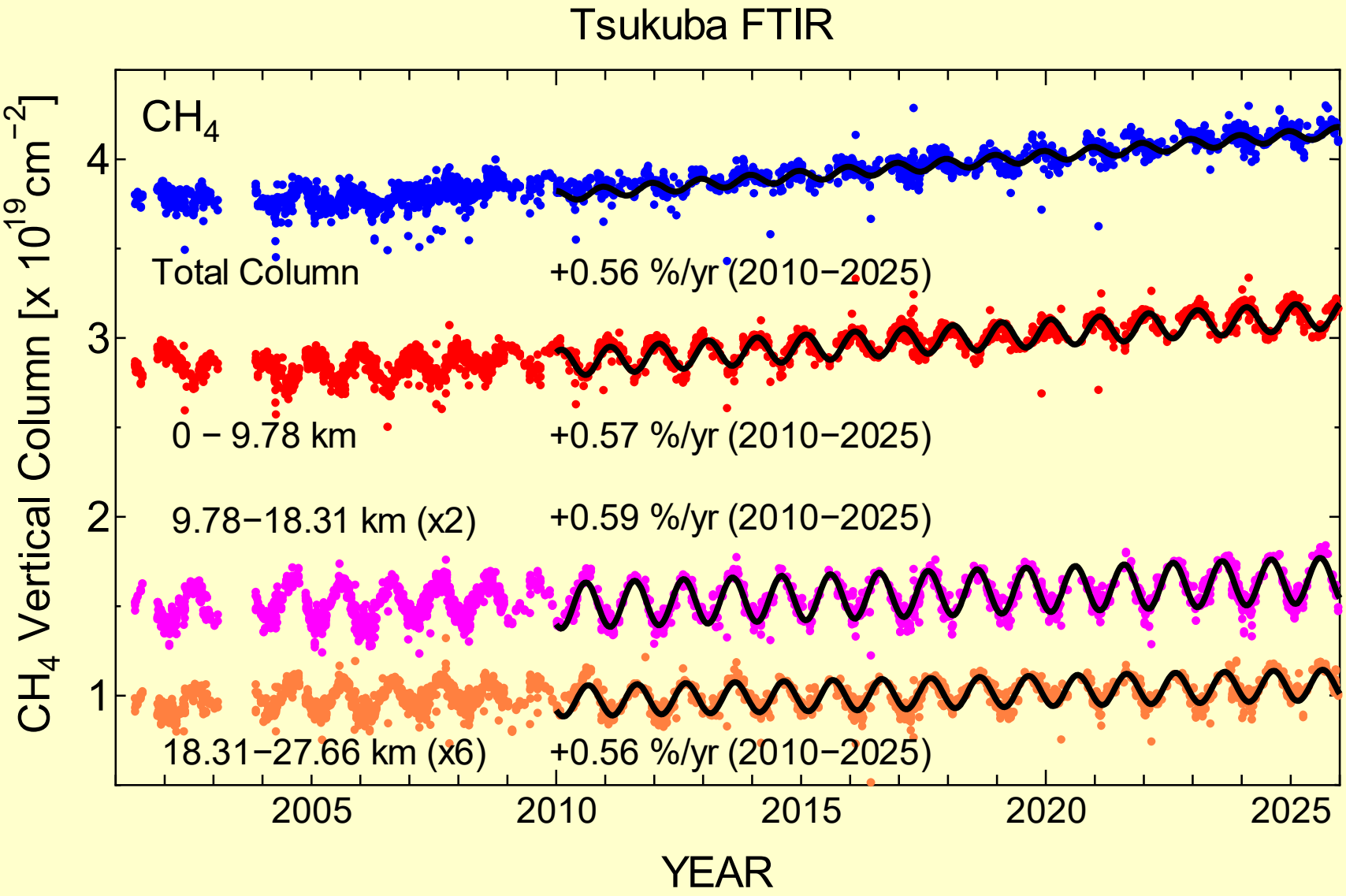
Increasing in recent years.

Results: C_2H_6



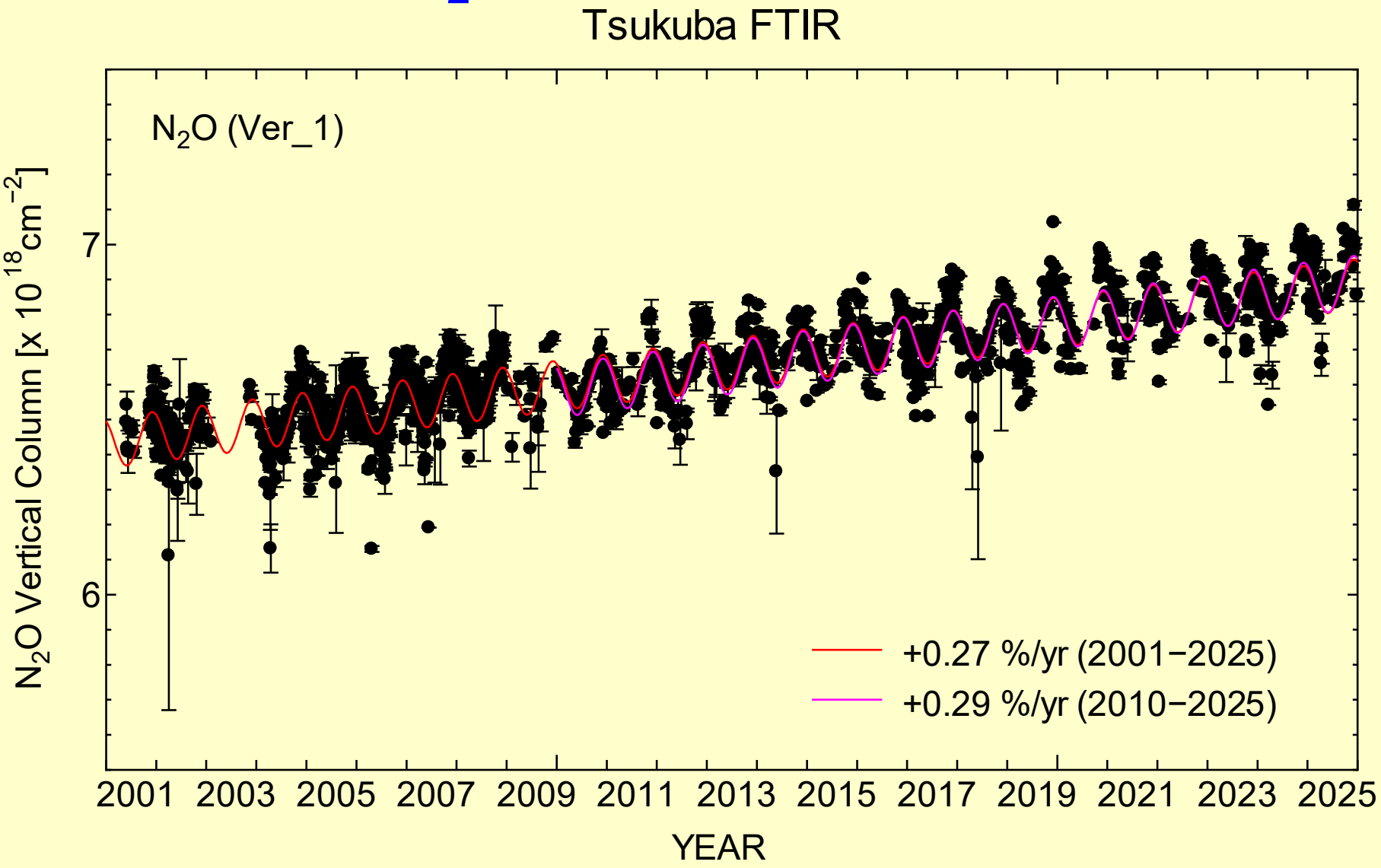
Increased around 2015 (Friedrich et al. [2026]).
It maybe due to shale oil production in USA.

Results: CH_4



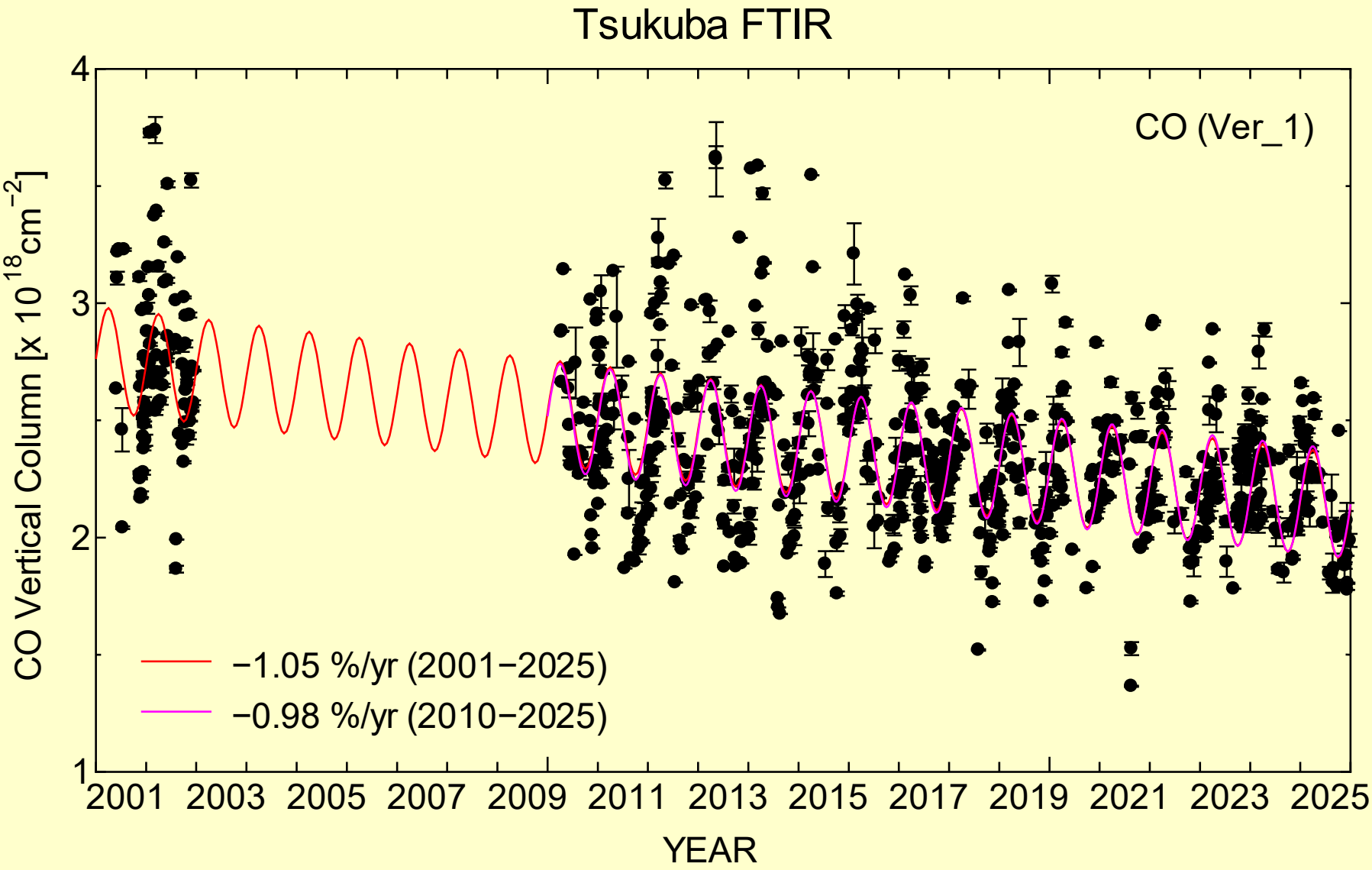
Increasing rate is consistent with surface measurements.

Results: N_2O



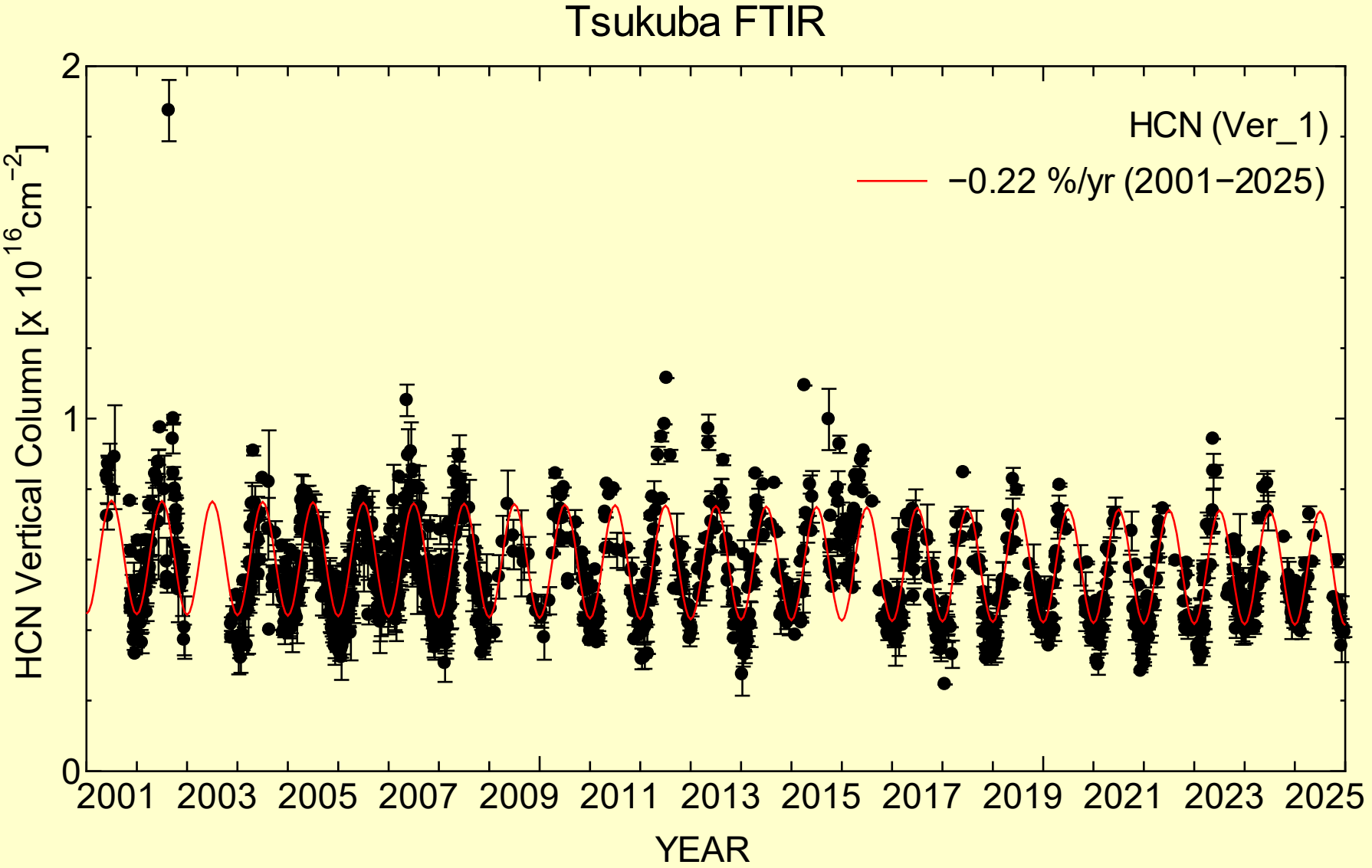
Increasing rate is consistent with surface measurements.

Results: CO



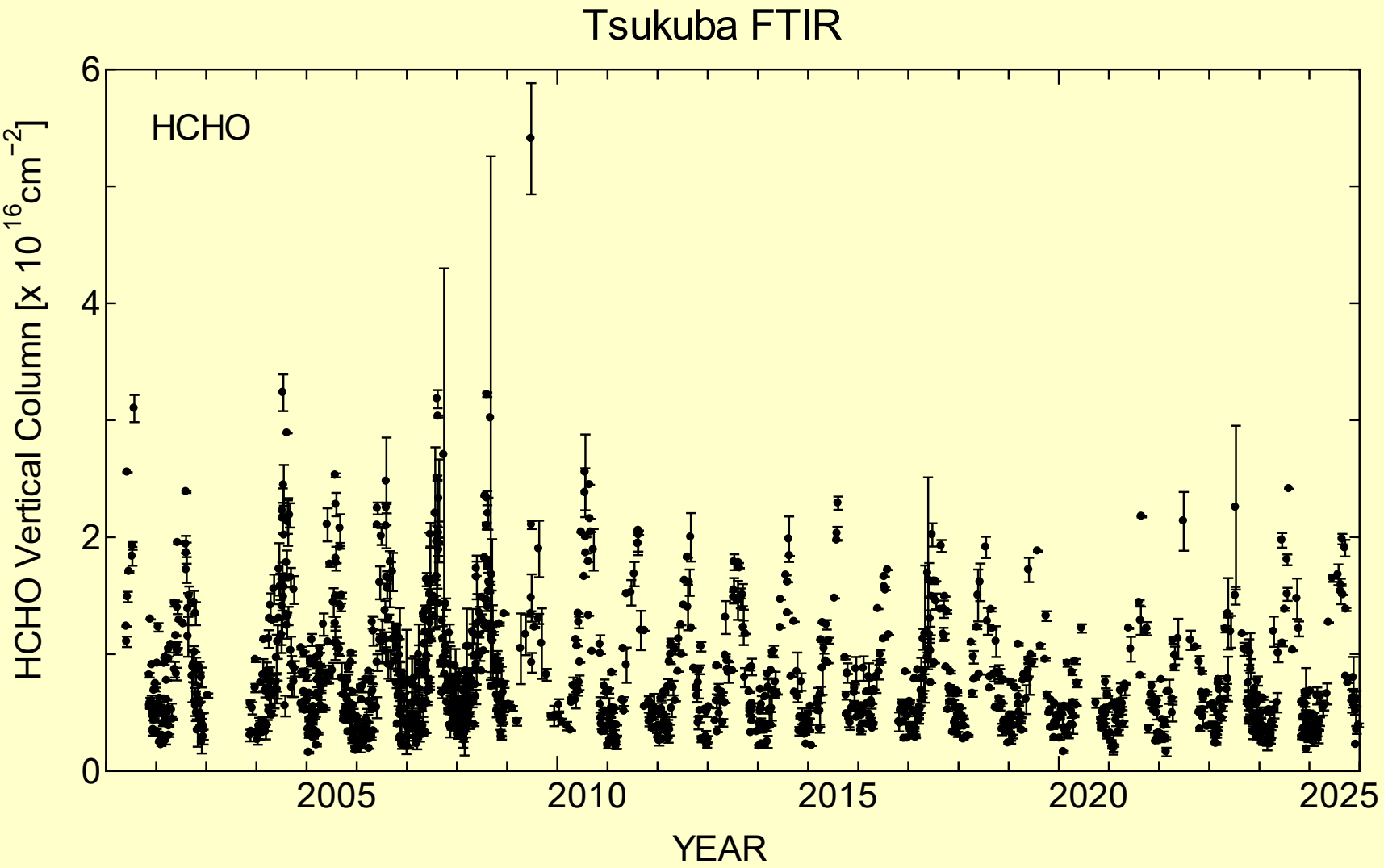
Decreasing rate is consistent with surface measurements.

Results: HCN



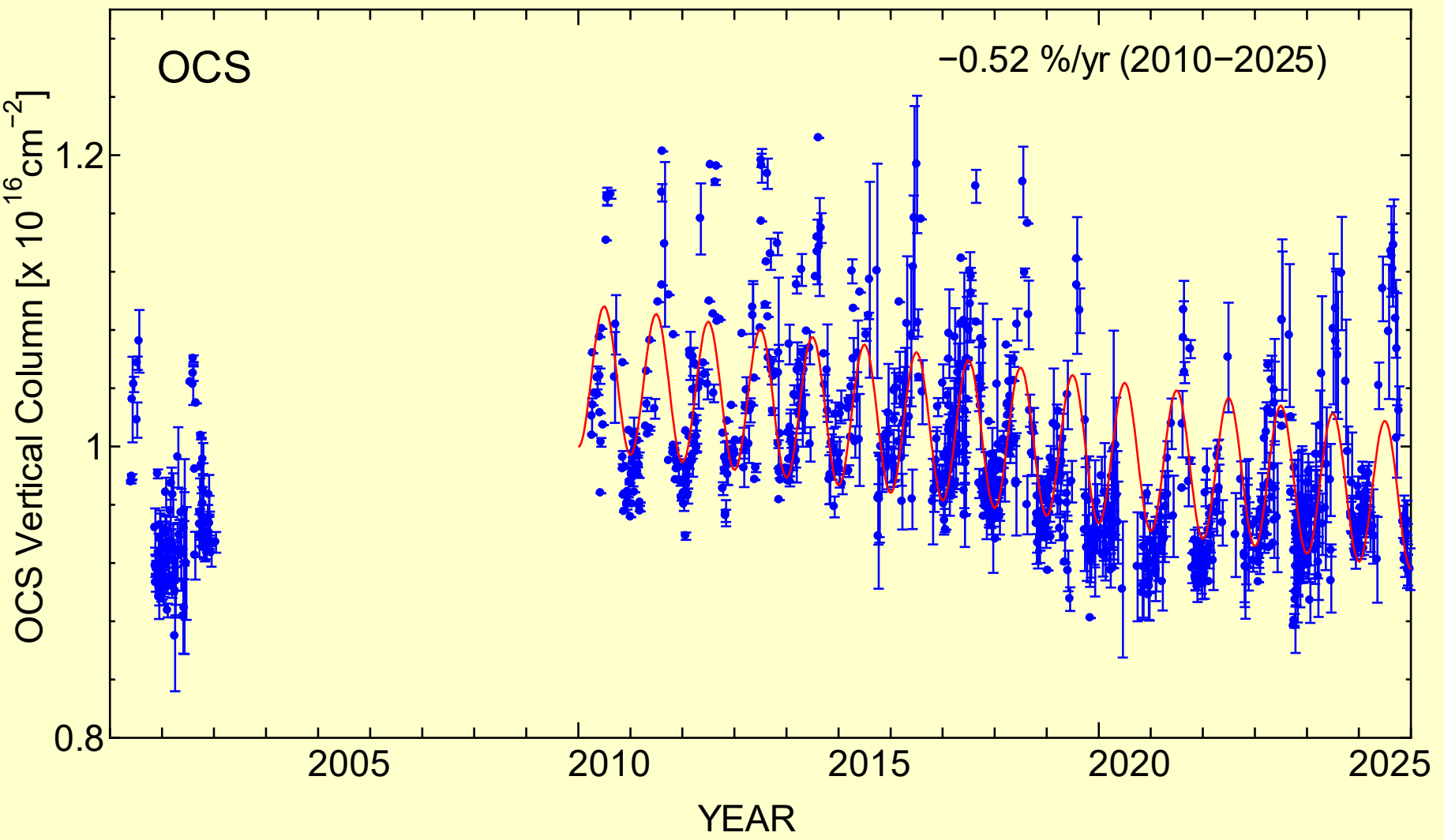
Sometimes observed high values.
Maybe due to forest fire.

Results: HCHO



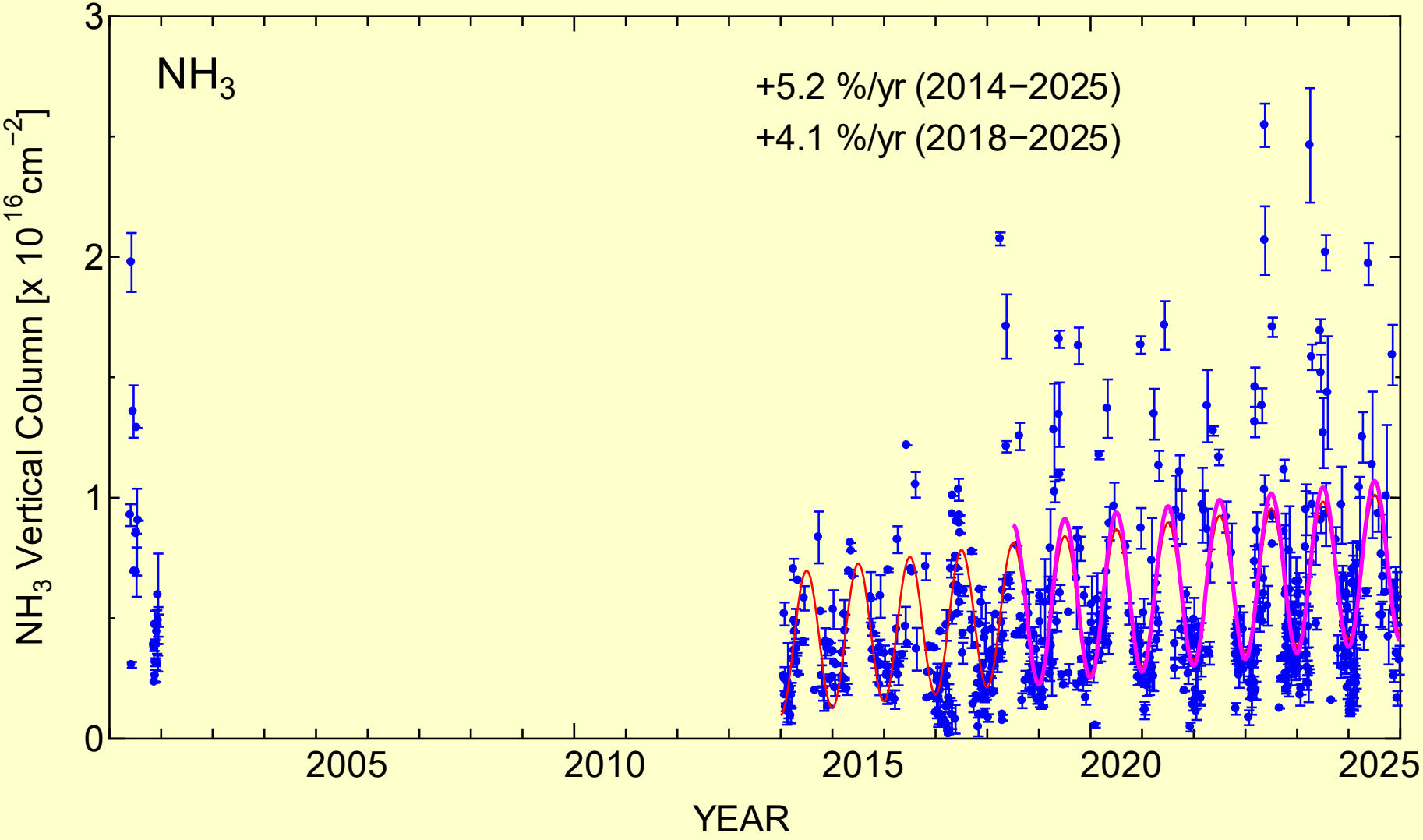
Sometimes observed high values.
Due to trans-boundary air pollution?

Results: OCS



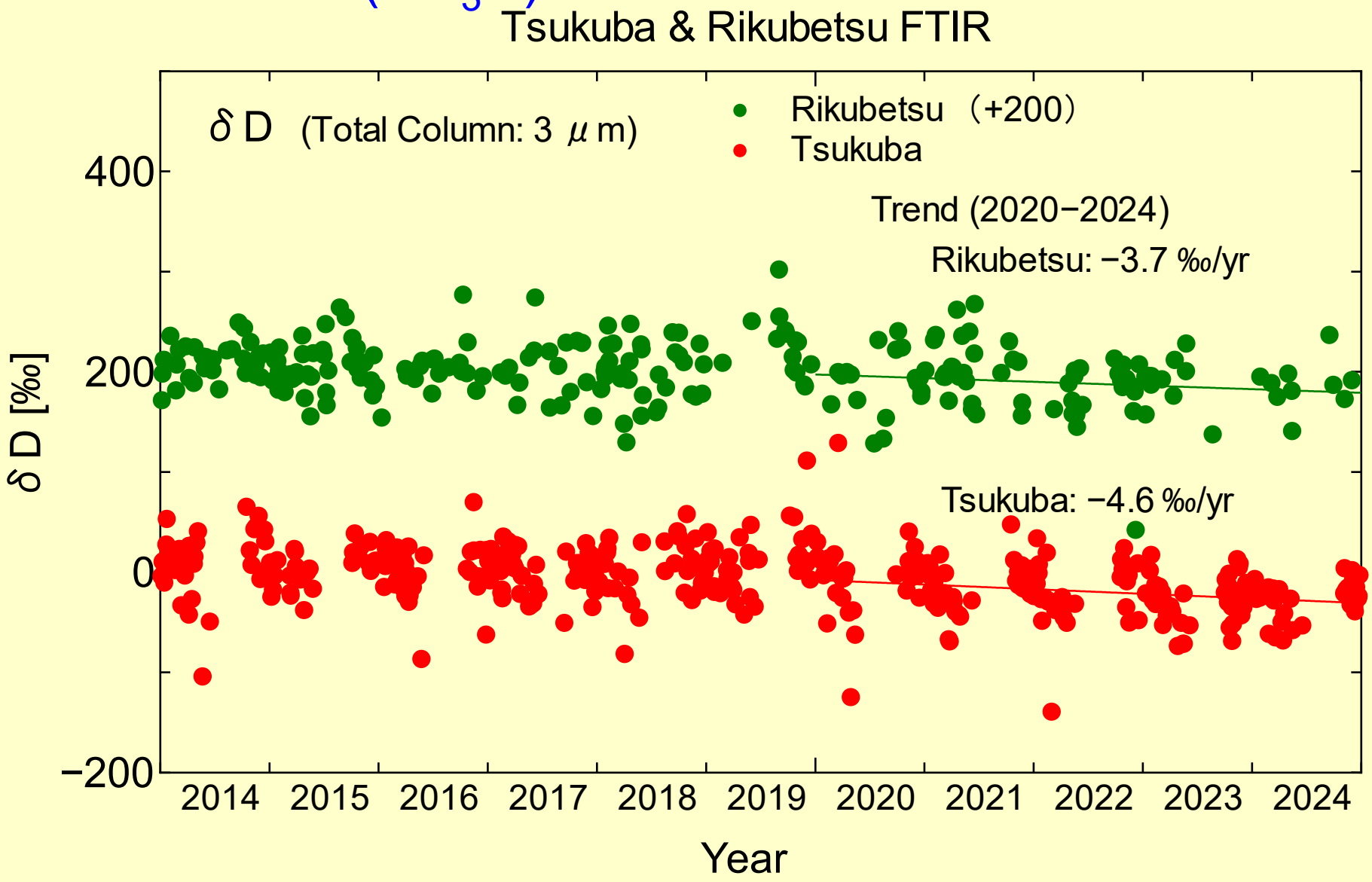
Increase before 2016. Decrease between 2016 and 2020.
Again increase after 2020.

Results: NH_3 Tsukuba FTIR



Increase after 2014. Number of event-driven spikes (due to pollution?) are increasing.

Results: δD (CH_3D)



Downward trend after 2020 are seen at both Tsukuba and Rikubetsu. Due to reaction with chlorine?

Contributed papers

Mirallie et al., Ozone stratospheric trends from regional Bayesian composite of ground-based partial columns, accepted to ACP

Friedrich et al., Identifying trend reversals in atmospheric ethane from a multi-site analysis, Climatic Change, 179, 66, 2026. https://doi.org/10.1007/s10584-026-04153-0

Voshtani et al., Quantifying CO emissions from boreal wildfires by assimilating TROPOMI and TCCON observations, Atmos. Chem. Phys., 25, 15527–15565, https://doi.org/10.5194/acp-25-15527-2025, 2025.

Van Malderen et al., Ground-based Tropospheric Ozone Measurements: Regional tropospheric ozone column trends from the TOAR-II/ HEGIFTOM homogenized datasets, Atmos. Chem. Phys., 25, 9905–9935, 2025. https://doi.org/10.5194/acp-25-9905-2025

Ayazpour et al. (2025). Aura ozone monitoring instrument (OMI) Collection 4 formaldehyde products. Earth and Space Science, 12, e2024EA003792. http://dx.doi.org/10.1029/2024EA003792

Zhou et al. (2024). Recent decreases in the growth rate of atmospheric HCFC-22 column derived from the ground-based FTIR harmonized retrievals at 16 NDACC sites. Geophysical Research Letters, 51, e2024GL112470. https://doi.org/10.1029/2024GL112470

Müller et al., Bias correction of OMI HCHO columns based on FTIR and aircraft measurements and impact on top-down emission estimates, Atmos. Chem. Phys., 24, 2207–2237, https://doi.org/10.5194/acp-24-2207-2024, 2024.

Ortega et al. 2023. Anomalies of O_3, CO, C_2H_2, H_2CO, and C_2H_6 detected with multiple ground-based Fourier-transform infrared spectrometers and assessed with model simulation in 2020: COVID-19 lockdowns versus natural variability. Elem Sci Anth, 11: 1. DOI: https://doi.org/10.1525/elementa.2023.00015

Kwon et al. (2023). Validation of OMPS Suomi NPP and OMPS NOAA-20 formaldehyde total columns with NDACC FTIR observations. Earth and Space Science, 10, e2022EA002778. https://doi.org/10.1029/2022EA002778.

Hannigan et al. (2022). Global atmospheric OCS trend analysis from 22 NDACC stations. Journal of Geophysical Research: Atmospheres, 127, e2021JD035764. https://doi.org/10.1029/2021JD035764

Takeda et al., First ground-based Fourier transform infrared (FTIR) spectrometer observations of HFC-23 at Rikubetsu, Japan, and Syowa Station, Antarctica, Atmos. Meas. Tech., 14, 5955–5976, https://doi.org/10.5194/amt-14-5955-2021, 2021.

Vigouroux et al., TROPOMI-Sentinel-5 Precursor formaldehyde validation using an extensive network of ground-based Fourier-transform infrared stations, Atmos. Meas. Tech., 13, 3751–3767, https://doi.org/10.5194/amt-13-3751-2020, 2020.

Nakajima et al., Chlorine partitioning near the polar vortex edge observed with ground-based FTIR and satellites at Syowa Station, Antarctica in 2007 and 2011, Atmos. Chem. Phys., 20, 1043–1074, https://doi.org/10.5194/acp-20-1043-2020, 2020.

Bader et al., The recent increase of atmospheric methane from 10 years of ground-based NDACC FTIR observations since 2005, Atmos. Chem. Phys., 17, 2255-2277, doi:10.5194/acp-17-2255-2017, 2017.
Mahieu et al., Recent Northern Hemisphere stratospheric HCl increase due to atmospheric circulation changes, Nature, Vol. 515, 104-107, doi:10.1038/nature13857, November, 2014.
Kohlhepp et al., Observed and simulated time evolution of HCl, $ClONO_2$, and HF total column abundances, Atmos. Chem. Phys., 12, 7, 3527-3557, doi:10.5194/acp-12-3527-2012, April, 2012.