climate change initiative

LONG-LIVED GREENHOUSE GAS PRODUCTS PERFORMANCES

Age of air from ACE-FTS measurements of sulphur hexafluoride

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Motivation: The Brewer-Dobson circulation (BDC)

Climate models predict that the BDC will speed up due to increasing radiative forcing caused by greenhouse gases.

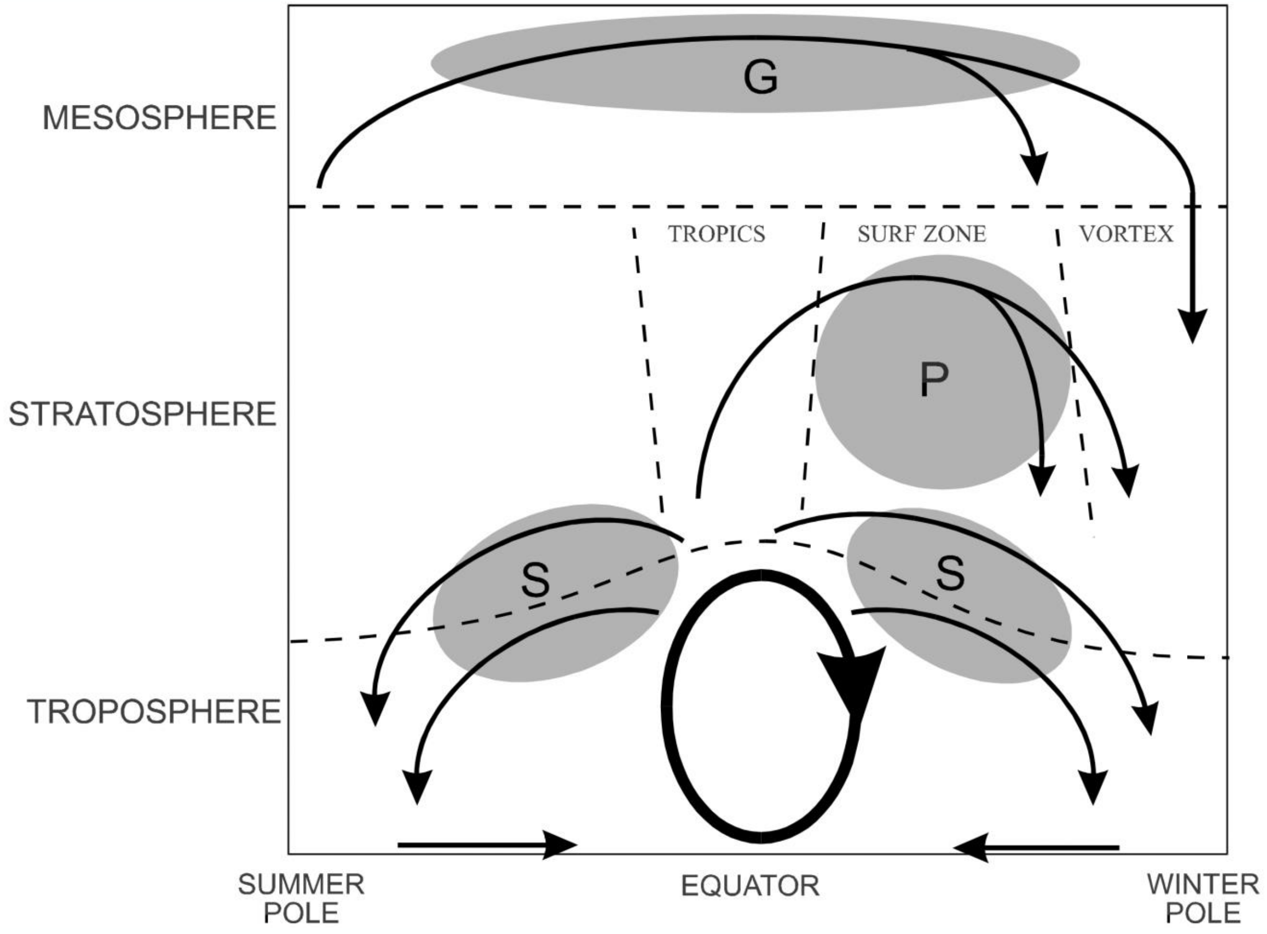
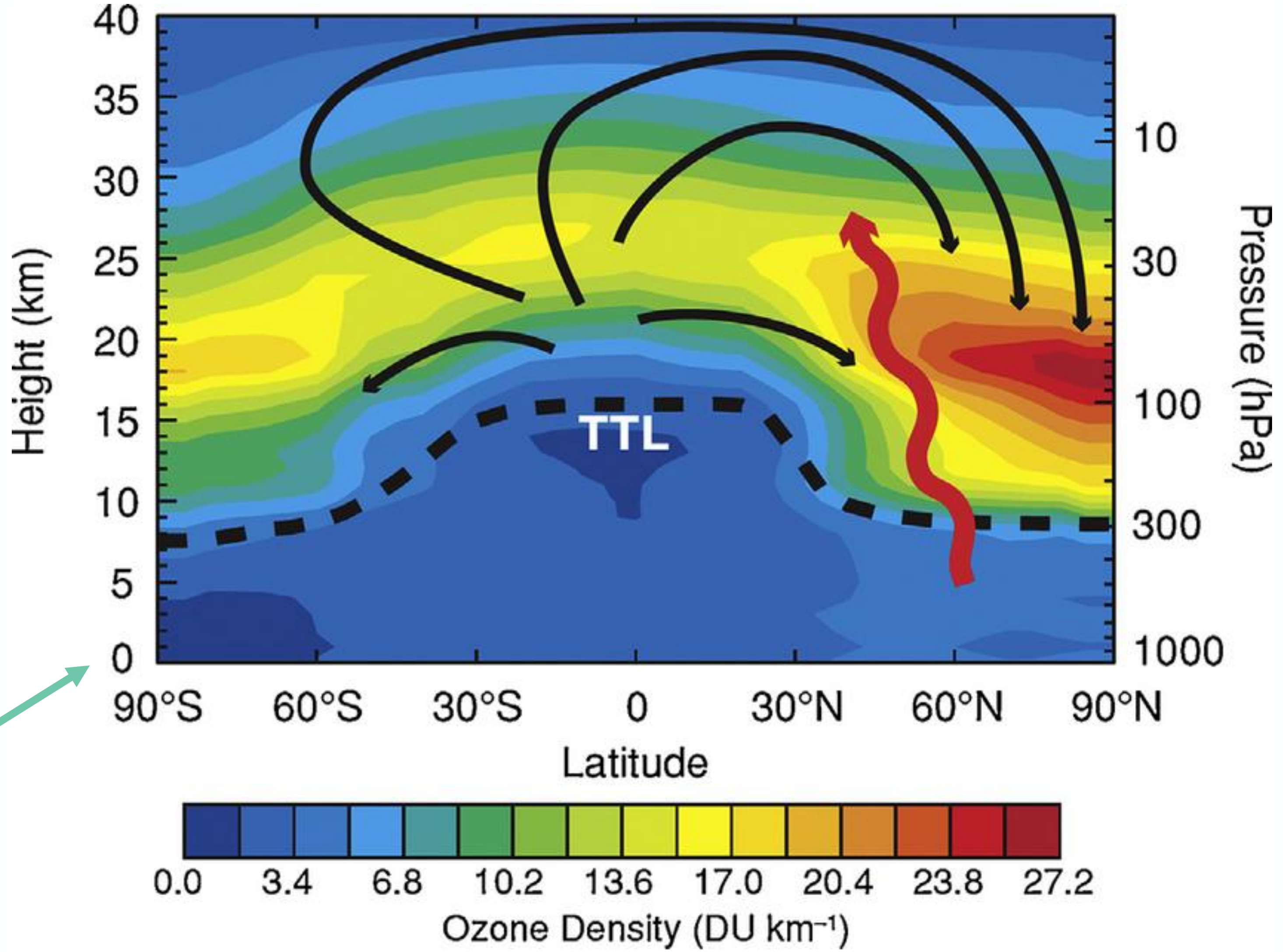


Figure: Plumb, *J. Meteor. Soc. Japan*, 2002.

Motivation: The Brewer-Dobson circulation (BDC)

Climate models predict that the BDC will speed up due to increasing radiative forcing caused by greenhouse gases.

This will in turn modify the distributions of atmospheric gases.



BDC (black arrows) effect on ozone during northern winter. The red arrow represents planetary waves. TTL=tropical transition layer

Figure: IPCC/TEAP, 2005.

What is age of air?

We define age of air as the time that has elapsed since an air parcel left the troposphere.

Air near the tips of the arrows is older, while air near the tails is younger.

A decrease in age of air over time would indicate that the BDC is speeding up.

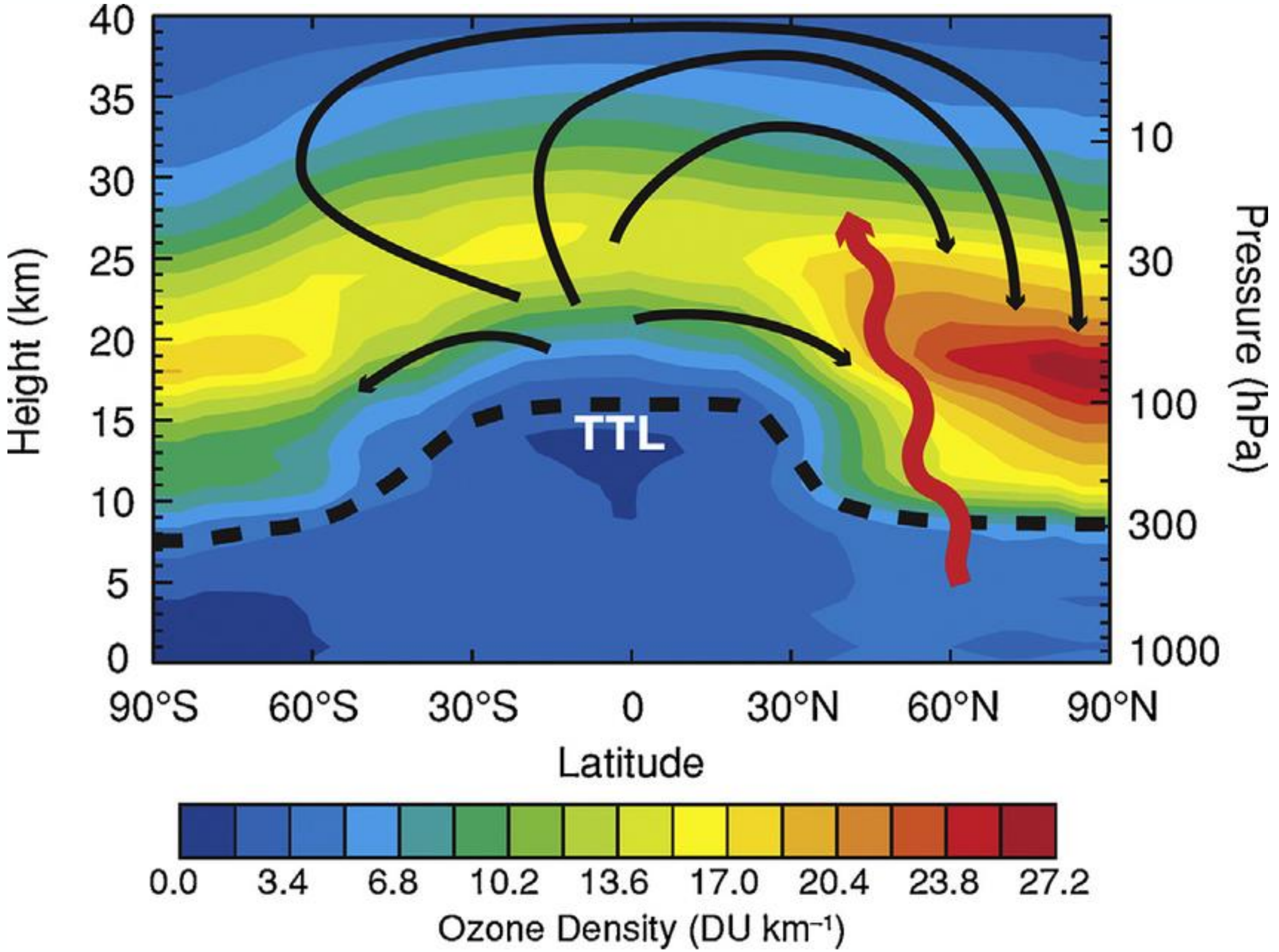
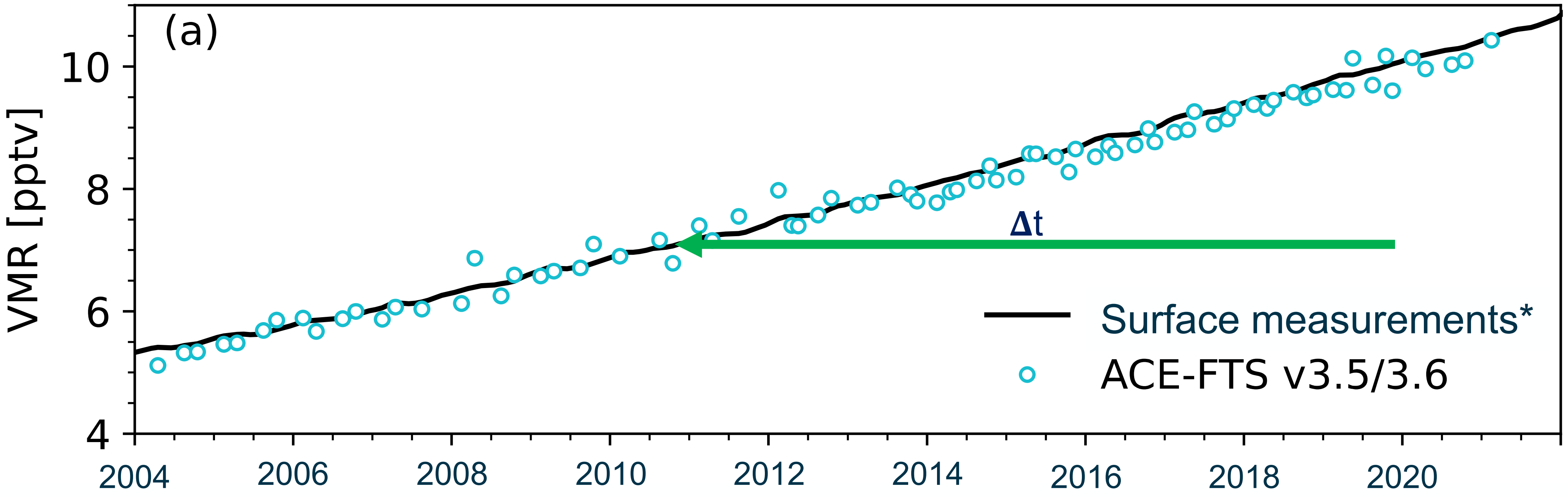


Figure: IPCC/TEAP, 2005.

Calculation of age of air: Basic idea

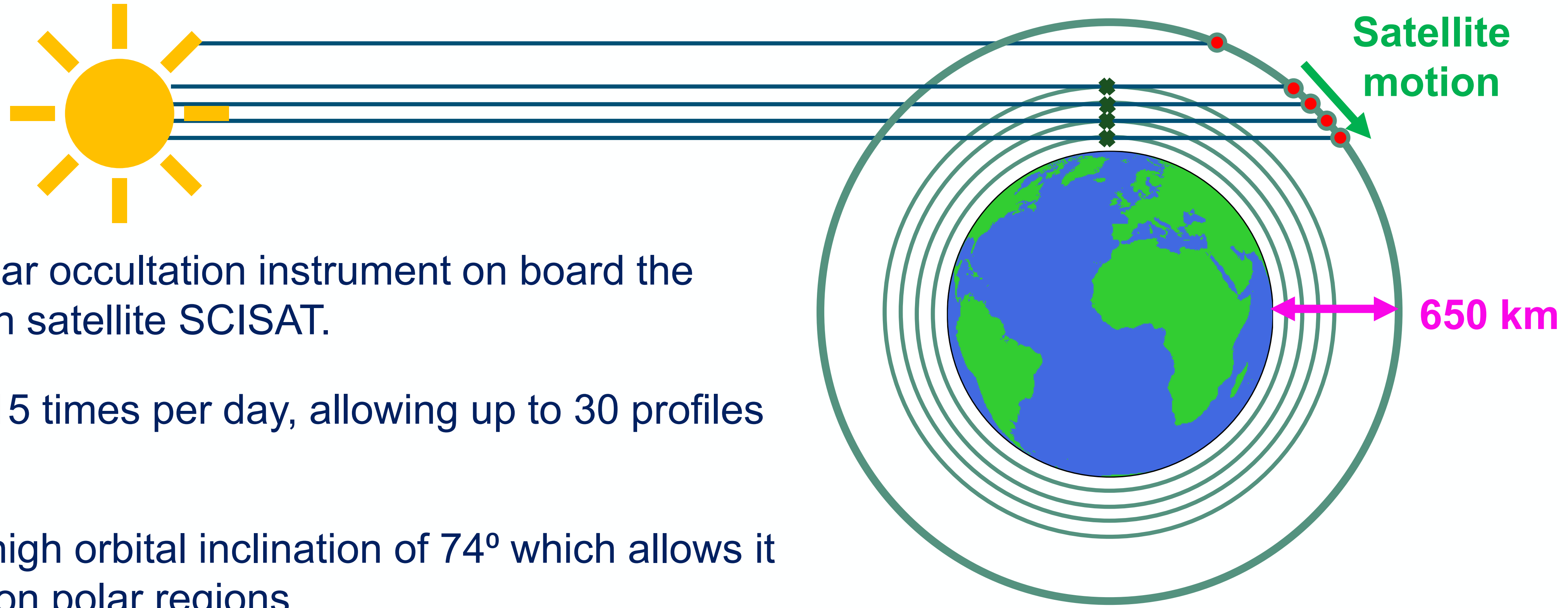
Tropospheric SF_6 is increasing with time and has no seasonal cycle, making it a useful clock.



Say we have a stratospheric SF_6 measurement ● of 7pptv in 2020.This corresponds to the tropospheric VMR in 2011, so **Δt**=~9 years.

*NOAA Marine Boundary Layer reference (https://gml.noaa.gov/ccgg/mbl/data.php)

The **A**tmospheric **C**hemistry **E**xperiment **F**ourier **T**ransform **S**pectrometer



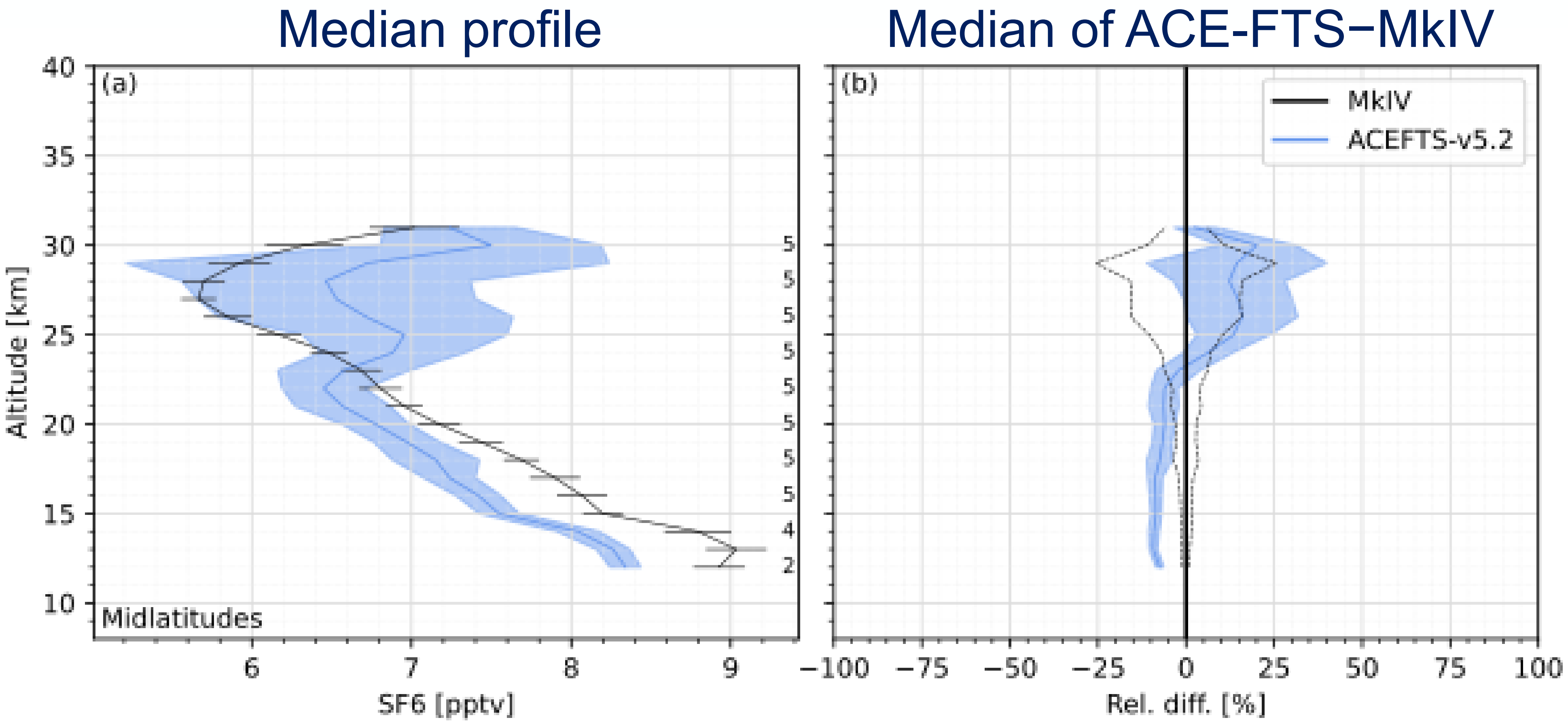
It is a solar occultation instrument on board the Canadian satellite SCISAT.

It orbits 15 times per day, allowing up to 30 profiles per day.

It has a high orbital inclination of 74º which allows it to focus on polar regions.

Dataset: v3.5/3.6 **(Feb 2004-Feb 2021),** has over 30 molecules and isotopologues (including SF_6).

Why did we use SF_6 v3.5/3.6?



From LOLIPOP validation: The mean ACE-FTS v5.2 profile stops decreasing above 22 km.

Why did we use SF_6 v3.5/3.6?

Comparisons with coincident profiles from MIPAS V5R show the same issue.

<u>Coincidence criteria</u>
-within 12 h and 1000 km
-same side of the vortex edge

The v3.5/3.6 mean profiles decrease with altitude above 22 km, as expected.

Error bars represent the standard error of the mean.

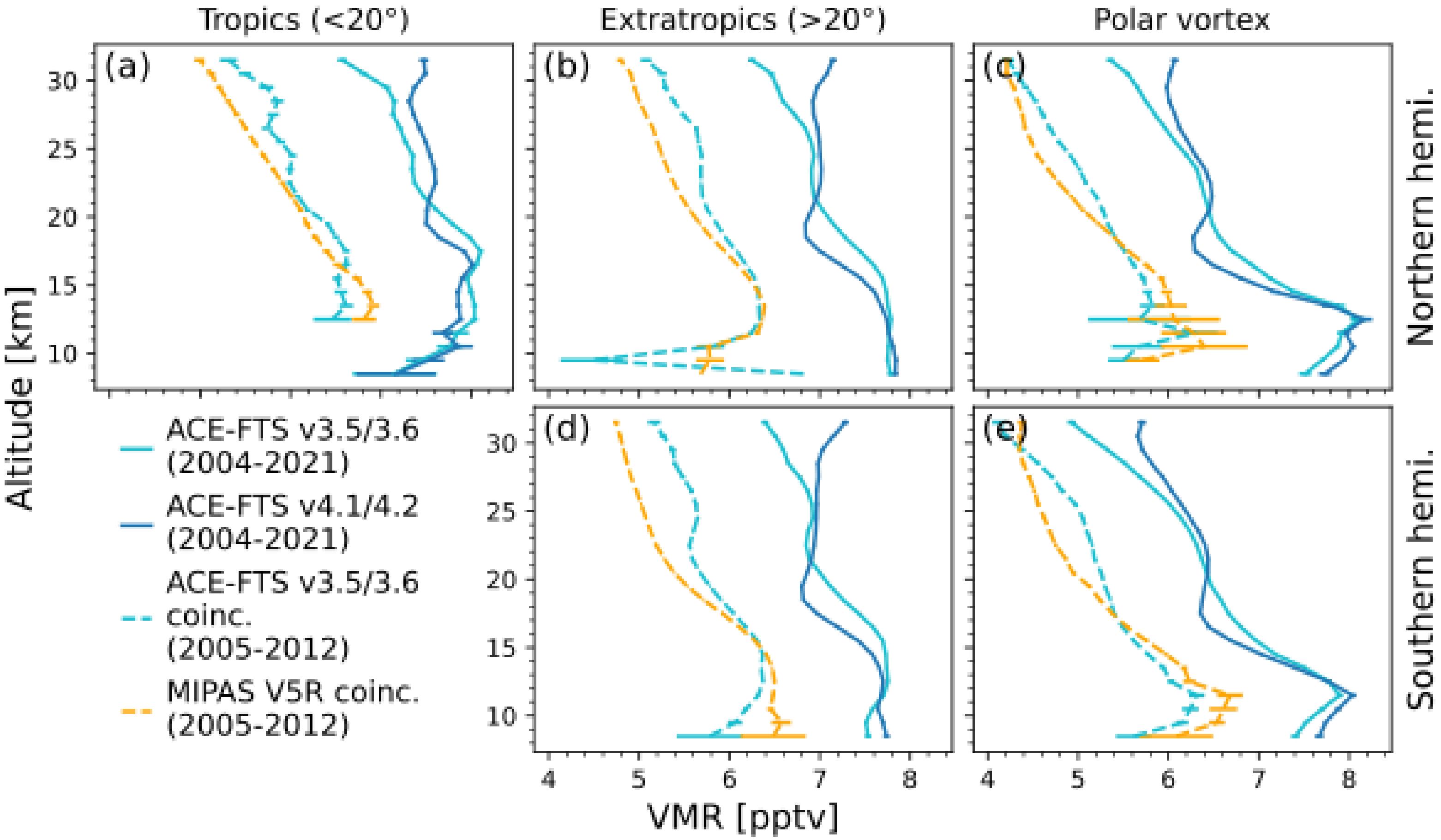


Figure: Saunders et al., *ACP*, 2025.

Further validation of v3.5/3.6

Comparisons with three BONBON balloon flights.

<u>Coincidence criteria</u>
-within 90 days
-within 5º latitude

The v3.5/3.6 mean profiles agree with the balloon measurements.

Error bars represent one standard deviation.

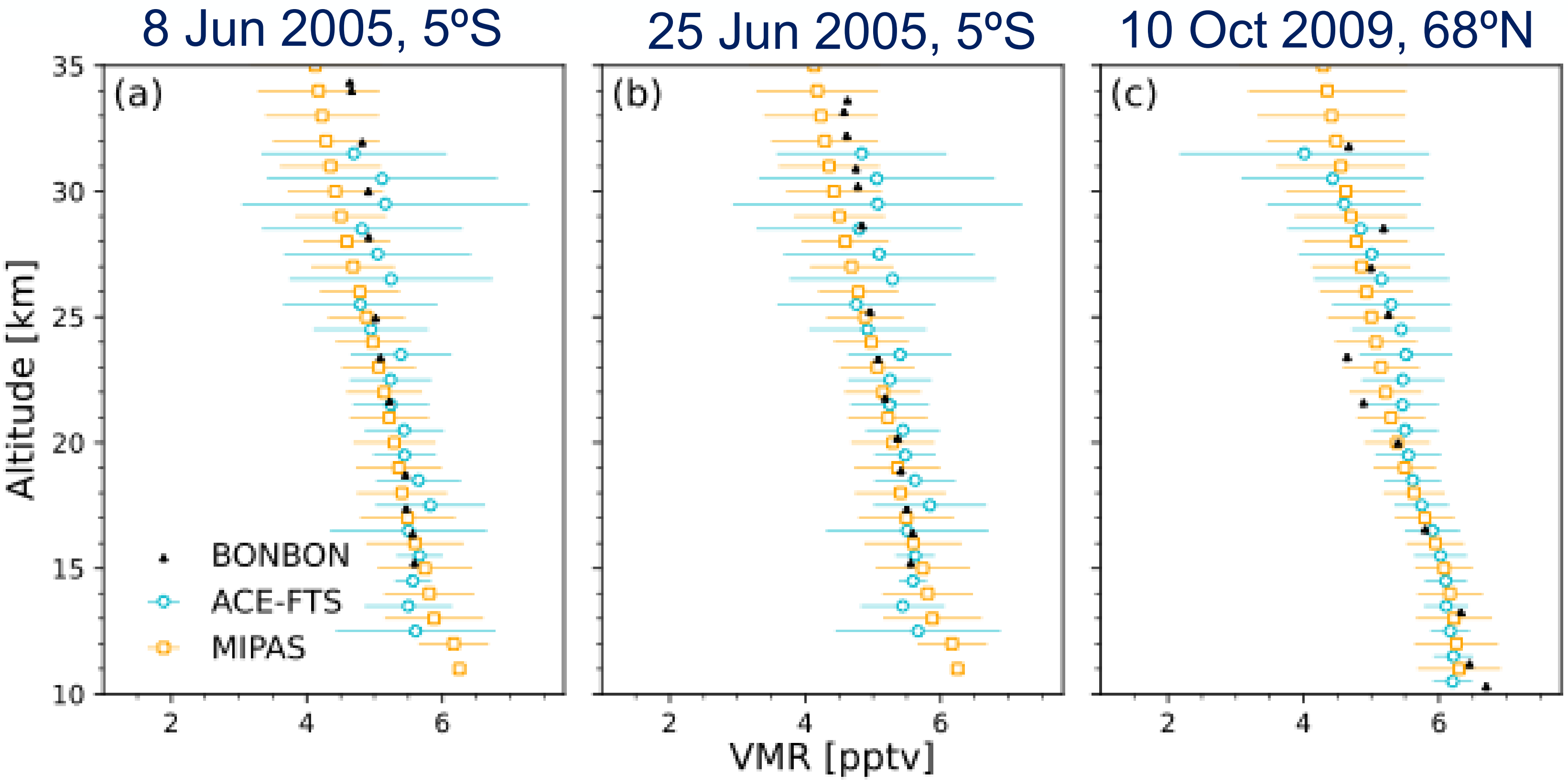


Figure: Saunders et al., *ACP*, 2025.

ACE-FTS age of air climatology

1 month, 10º latitude, 3 km altitude bins

Age increases with distance from the tropical tropopause.

Air in the upper stratosphere appears older than in reality due to a mesospheric SF_6 sink.

A correction scheme developed by H. Garny (Garny et al., *ACP*, 2024) was used to account for this.

Multi-year mean zonal mean AoA

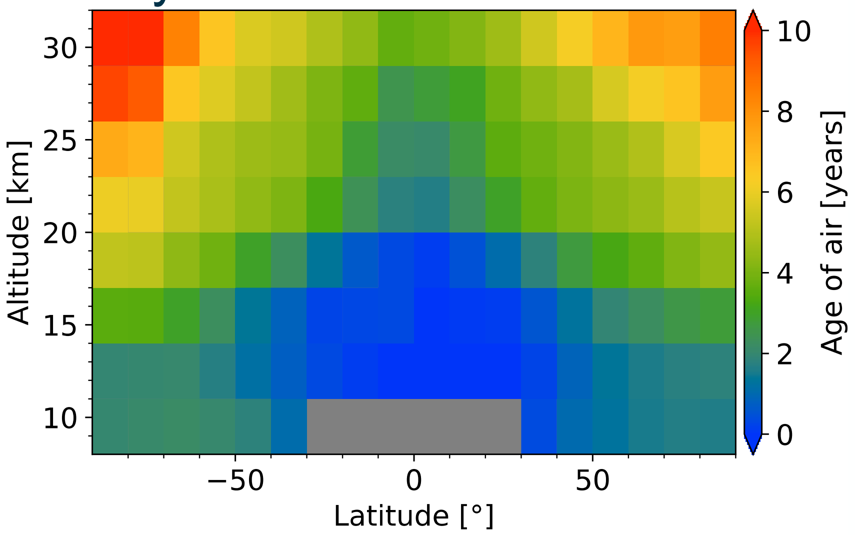


Figure: Saunders et al., *ACP*, 2025.

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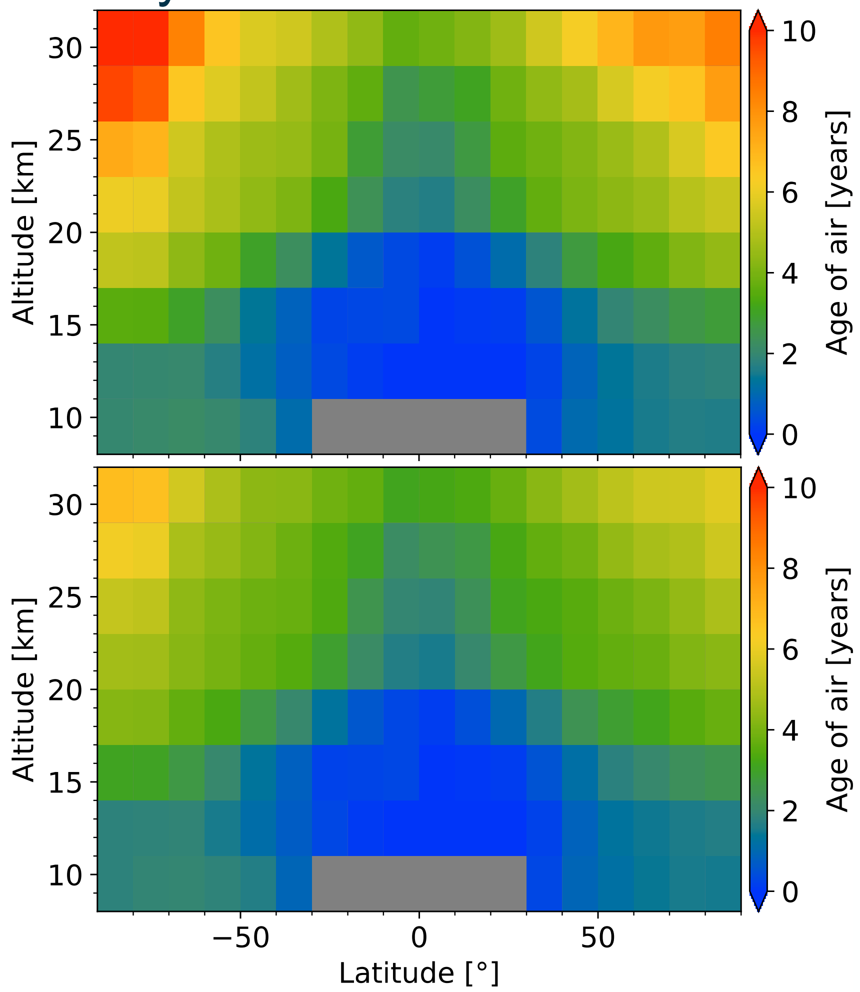


Sink-corrected

Figure: Saunders et al., *ACP*, 2025.

Comparison with other datasets: Overview

Triangles are in situ aircraft measurements taken from 1992-1997.

MIPAS measurements are V5R_221 and V5R_222 taken from 2005-2012.

AoA from MIPAS was recalculated for this study.

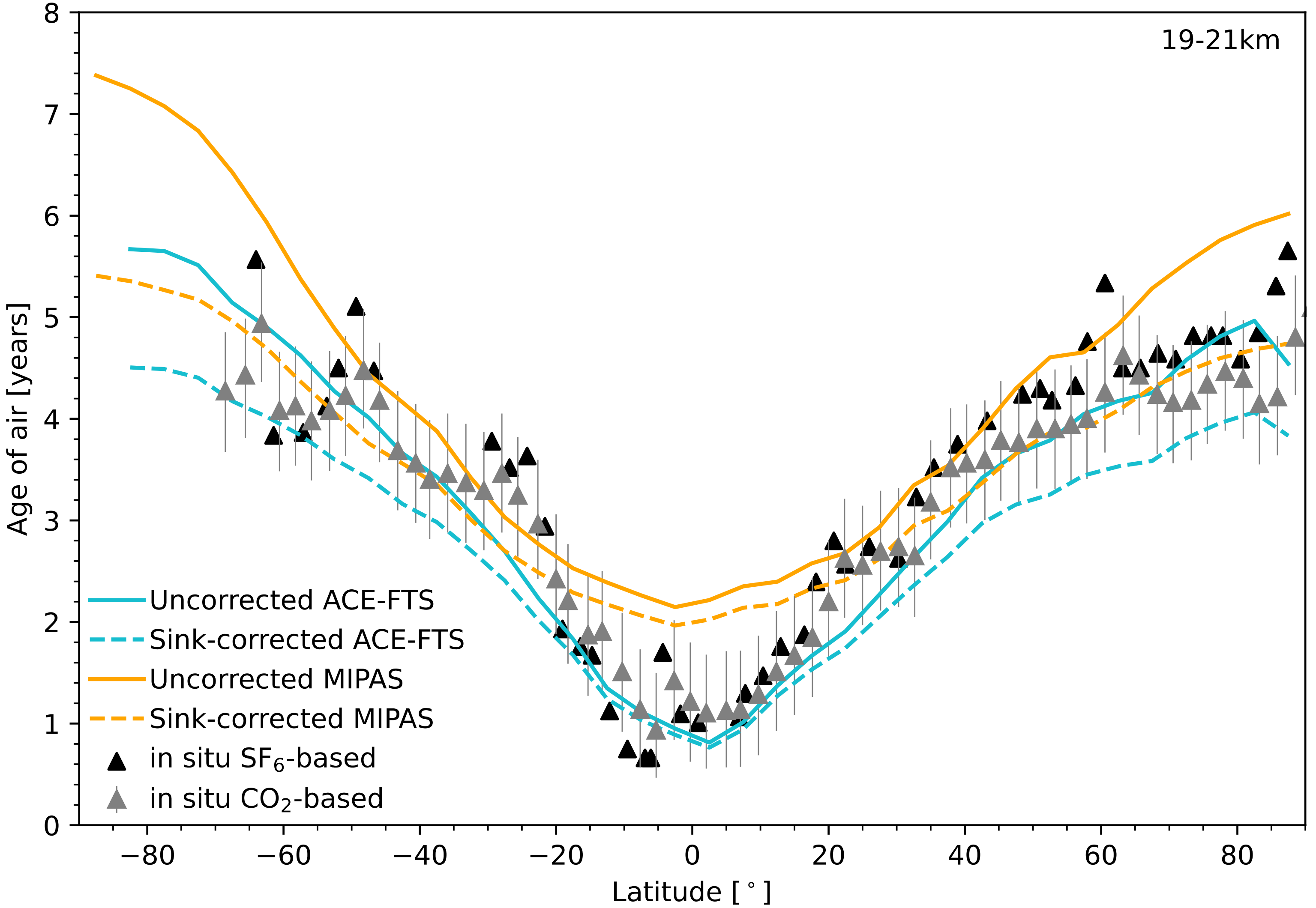


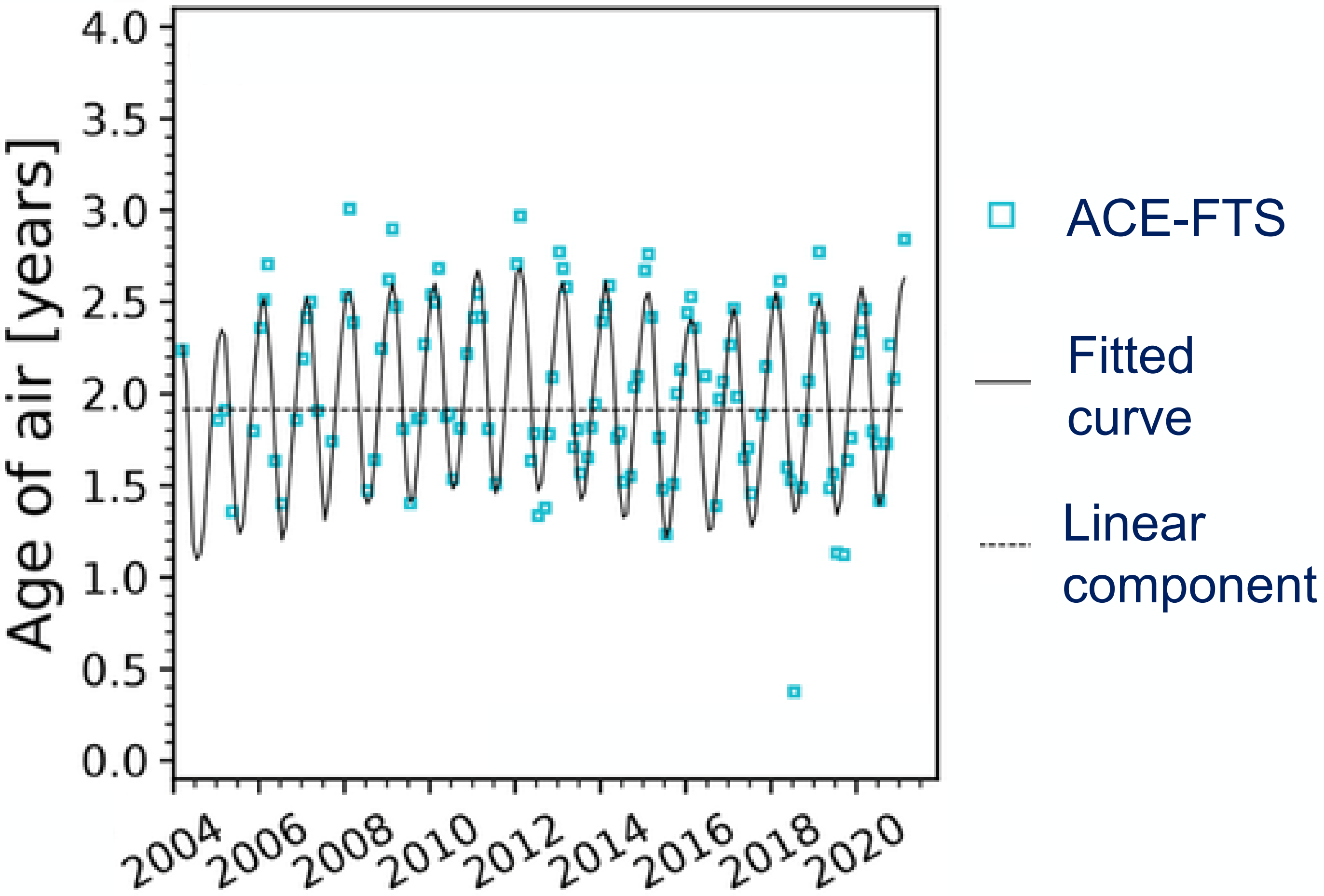
Figure: Saunders et al., *ACP*, 2025.

Age of air trend

<u>Midlatitude lower stratosphere</u>
40-50, 50-60, 60-70ºN and S
14-17km and 17-20km

The fit includes proxies for the QBO, ENSO, and the solar cycle.

The trend was insignificant in 8/12 regions, and negative in the others.



The negative trends suggest that the shallow branch of the BDC is accelerating.

Figure: adapted from Saunders et al., *ACP*, 2025.

Age of air trend: Contributions of each proxy

60-70ºN, 14-17km

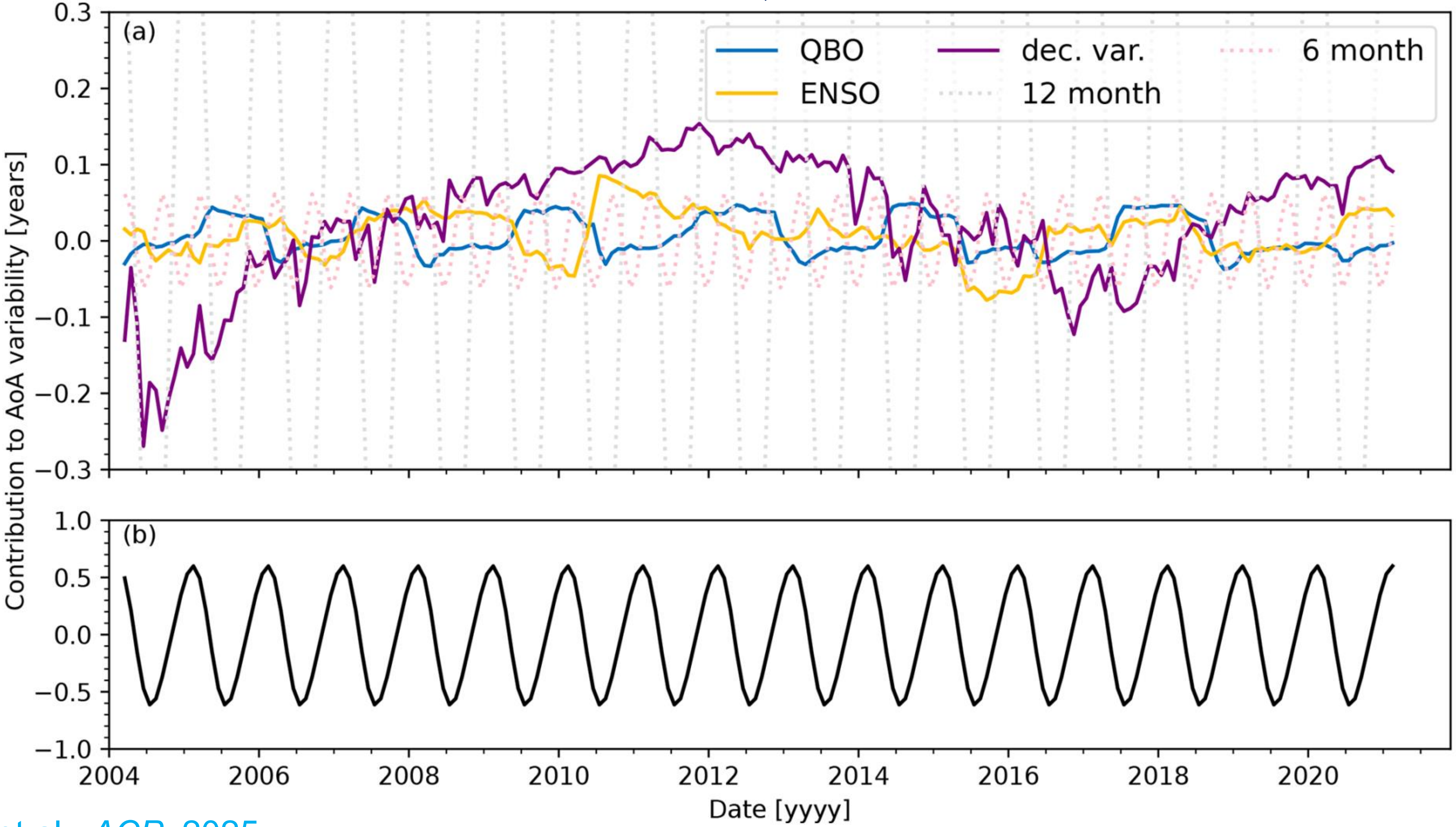


Figure: Saunders et al., *ACP*, 2025.

Age of air trends: Summary

The ACE-FTS 2004-2021 trends are negative, but only significant where outlined.

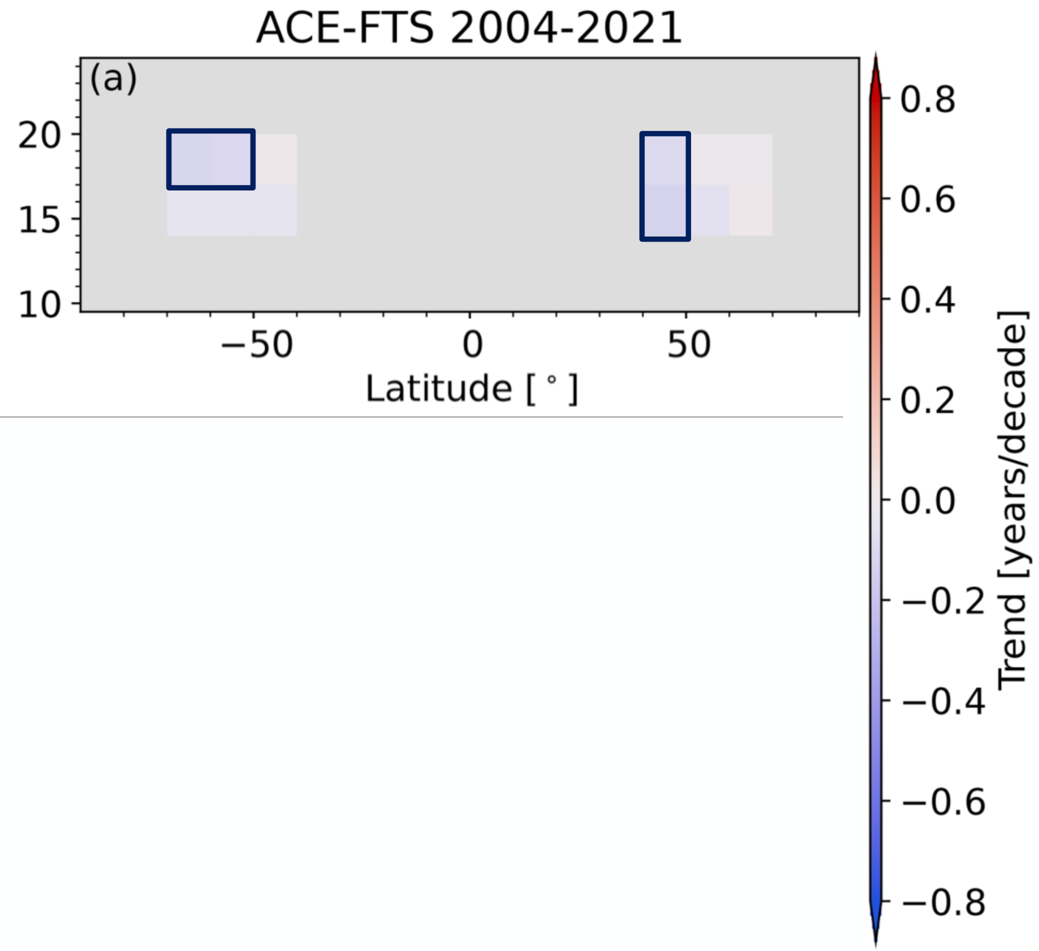


Figure: Saunders et al., *ACP*, 2025.

Age of air trends: Summary

The ACE-FTS 2004-2021 trends are negative, but only significant where outlined.

The trends were recalculated for ACE-FTS during the MIPAS reduced resolution period (2005-2012).

These were compared with trends from MIPAS (newly calculated for this study).

ACE-FTS and MIPAS trends are within 2 standard deviations of each other.

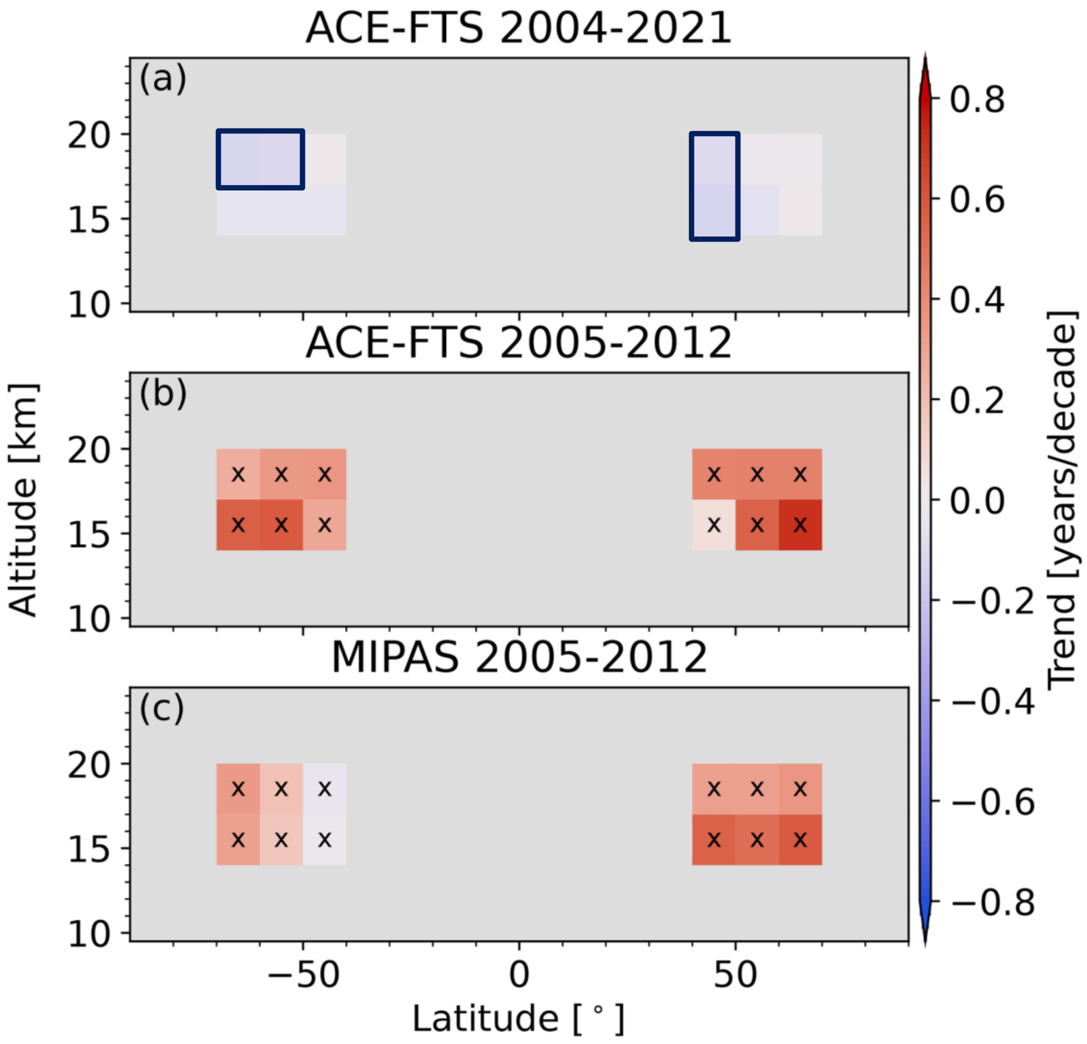


Figure: Saunders et al., *ACP*, 2025.

Summary

ACE-FTS v3.5/3.6 has the highest quality global SF_6 product available at this time.

We have a global 17-year age of air dataset based on SF_6 measurements from ACE-FTS.

The age of air trends inferred from this dataset suggest that the shallow branch of the BDC could be accelerating.

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