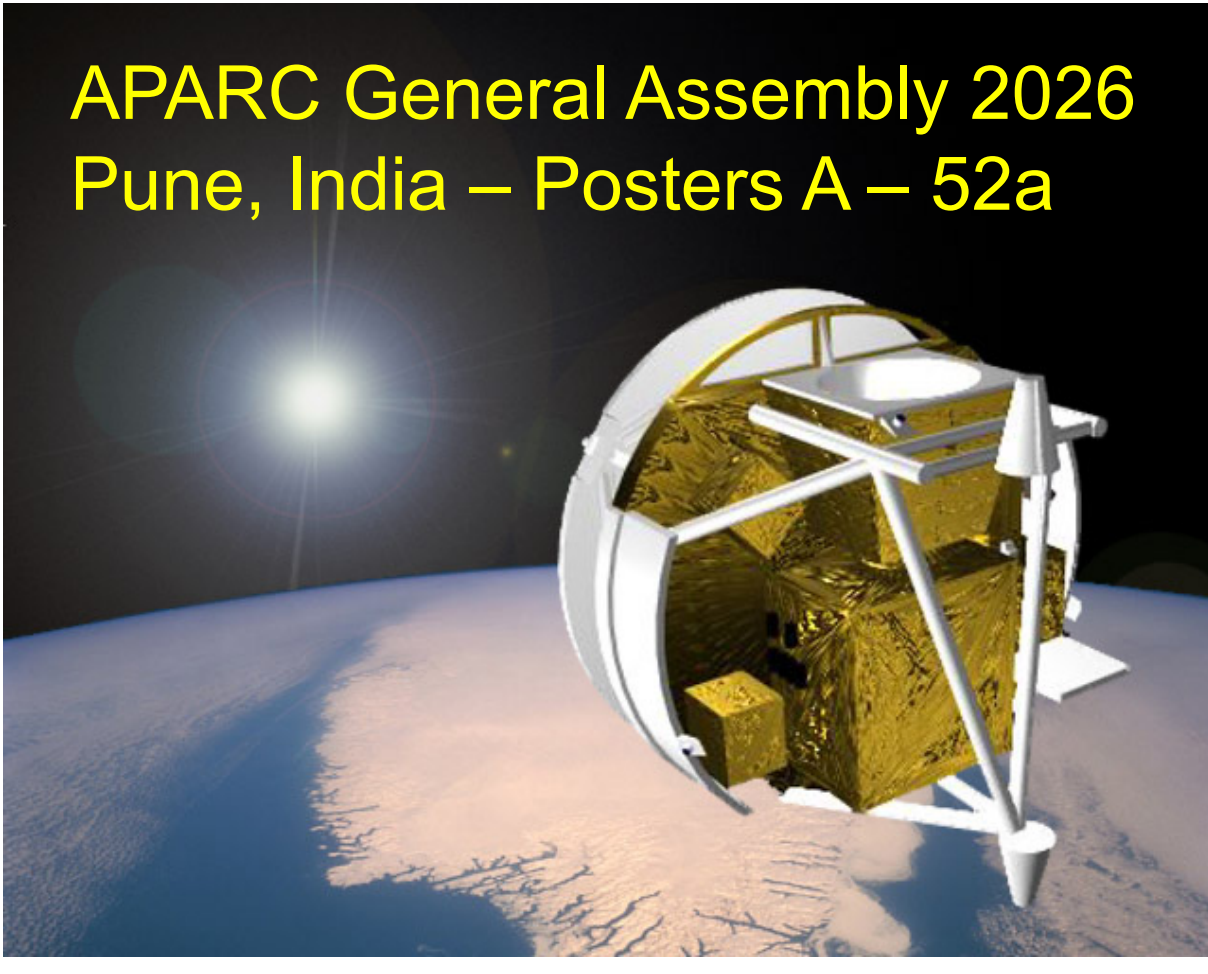




The Atmospheric Chemistry Experiment: More than two decades of Validation and Science Results

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Introduction to the Atmospheric Chemistry Experiment (ACE) Mission

- Using solar occultation, ACE provides up to 15 sunrise and 15 sunset measurements per day

Orbit: 74° inclined circular orbit at 650 km

Time series: Late February 2004 to present

ACE-FTS (Fourier Transform Spectrometer):

- Mid-infrared FTIR spectrometer – 2-13 microns at 0.02 cm⁻¹ spectral resolution and two filtered imagers (Visible and NIR)

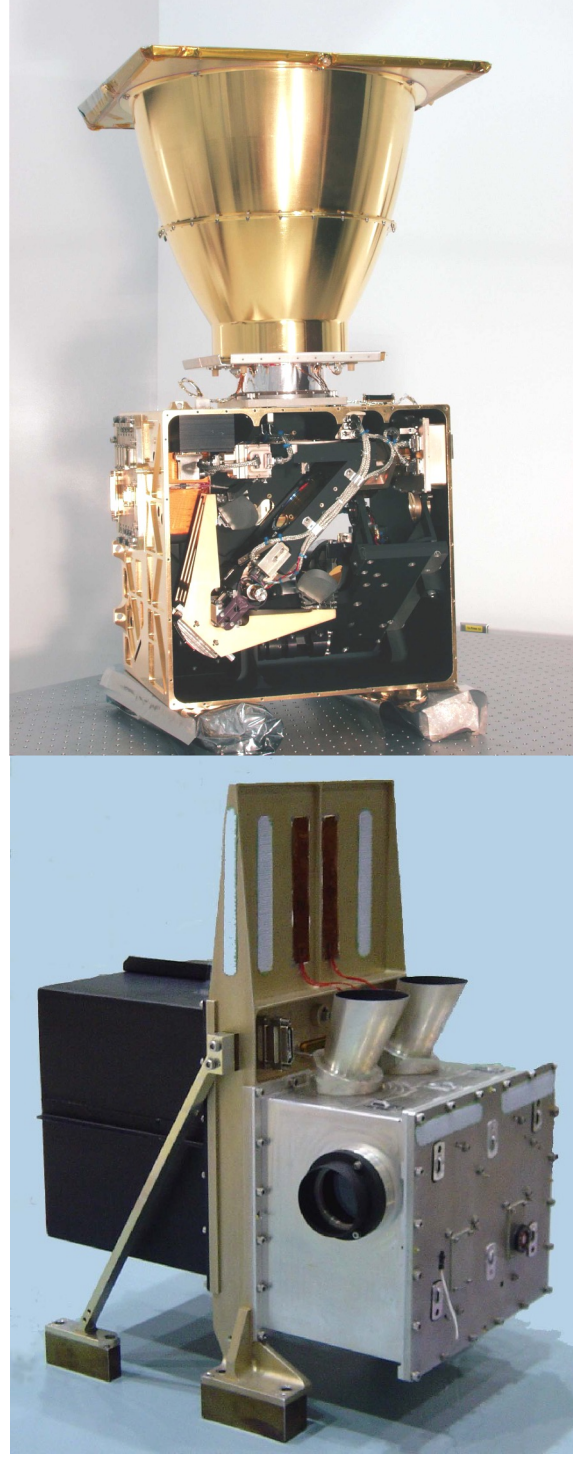
- Bernath et al., GRL, 32, L15S01 (2005)

ACE-MAESTRO (Measurement of Aerosol Extinction in the Stratosphere and Troposphere Retrieved by Occultation):

- Dual UV/Visible/NIR spectrometer – designed for 285 to 1030 nm, with ~1-2 nm resolution

- McElroy et al., Appl. Opt., 46, 4341 (2007)

<https://database.scisat.ca/level2> (reg. required)



ACE Misson Data Products

ACE-FTS profiles (newest 5.3, previous v4.1/4.2):

- Minor update from v5.2 to 5.3 in January 2025
- Boone et al., JQSRT, 310, 108749 (2023)
- Tracers: H₂O, O₃, N₂O, NO, NO₂, HNO₃, N₂O₅, H₂O₂, HO₂NO₂, N₂, SO₂
- Halogen-containing gases: HCl, HF, ClONO₂, ClO, CFC-11, CFC-12, CFC-113, COF₂, COCl₂, COFCl, CF₄, SF₆, CH₃Cl, CCl₄, HCFC-22, HCFC-141b, HCFC-142b, HFC134a, HFC-23, HOCl, HFC-32
- Carbon-containing gases: CO, CH₄, CH₃OH, H₂CO, HCOOH, C₂H₂, C₂H₄, C₂H₆, OCS, HCN, acetone, CH₃CN, peroxyacetyl nitrate (PAN), CO₂ (5-18 km and >60 km), pressure / temperature retrieved from CO₂ lines
- Isotopologues: Minor species of H₂O, CO₂, O₃, N₂O, CO, CH₄, OCS, NO₂, HNO₃

MAESTRO profiles (current version 4.5):

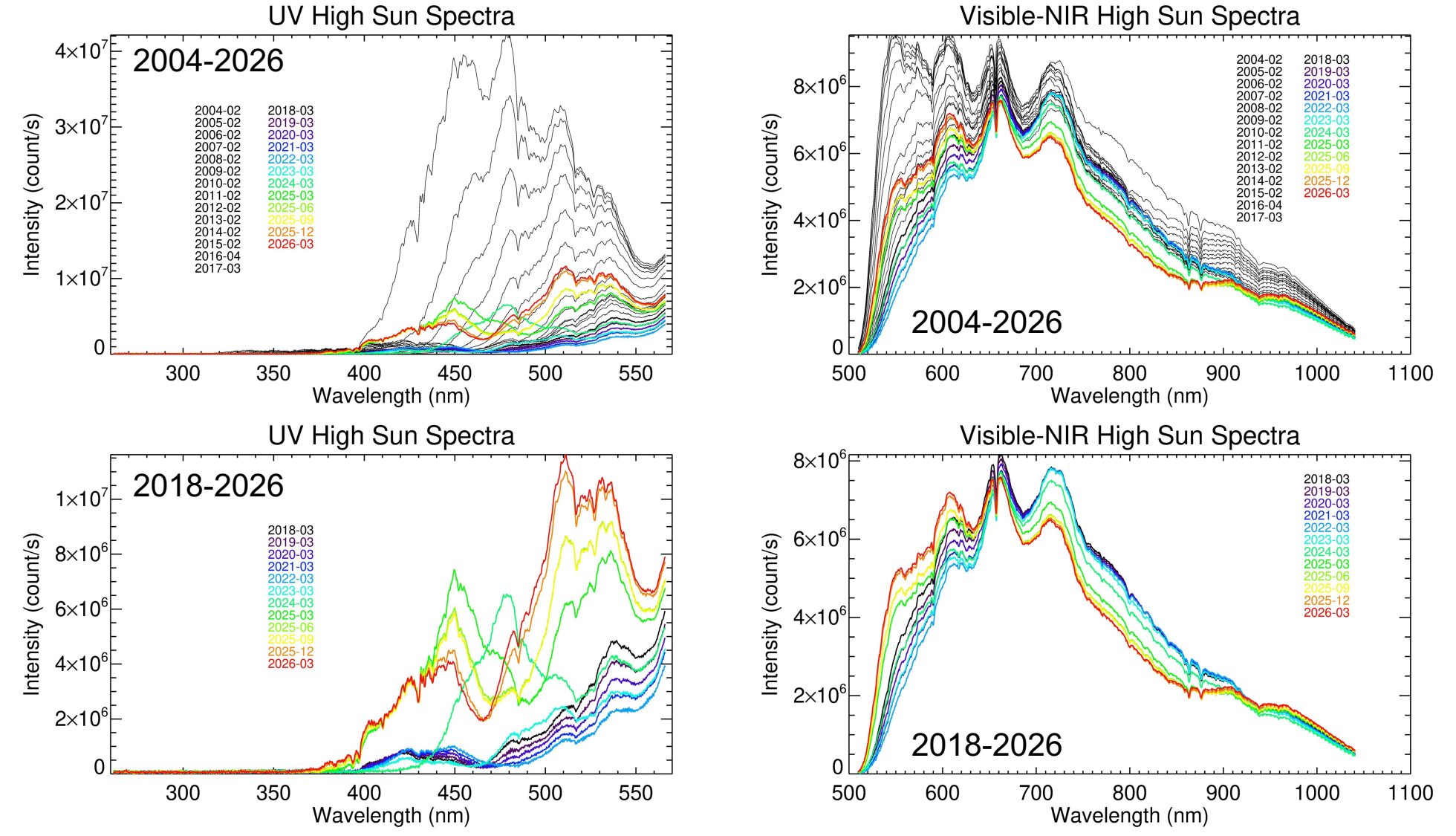
- O₃, NO₂, optical depth, and water vapor (v31) – aerosol extinction to come

IMAGERS profiles (current version v5.3):

- Atmospheric & aerosol extinction at 0.5 and 1.02 μm

ACE-MAESTRO Instrument Performance

- UV channel degradation started at beginning of mission with more recent stabilization and increase!



- Consistent change in sensitivity seen in overlap between spectrometers
- Likely caused by common element, as degradation also seen in ACE-Imagers

For details see: J. Zou et al., AMT, 19, 1991–2008 (2026).

ACE-FTS Temperature Drift Estimate

Using coincident profiles within Δ6h, Δ500km for drift estimate (K per decade)

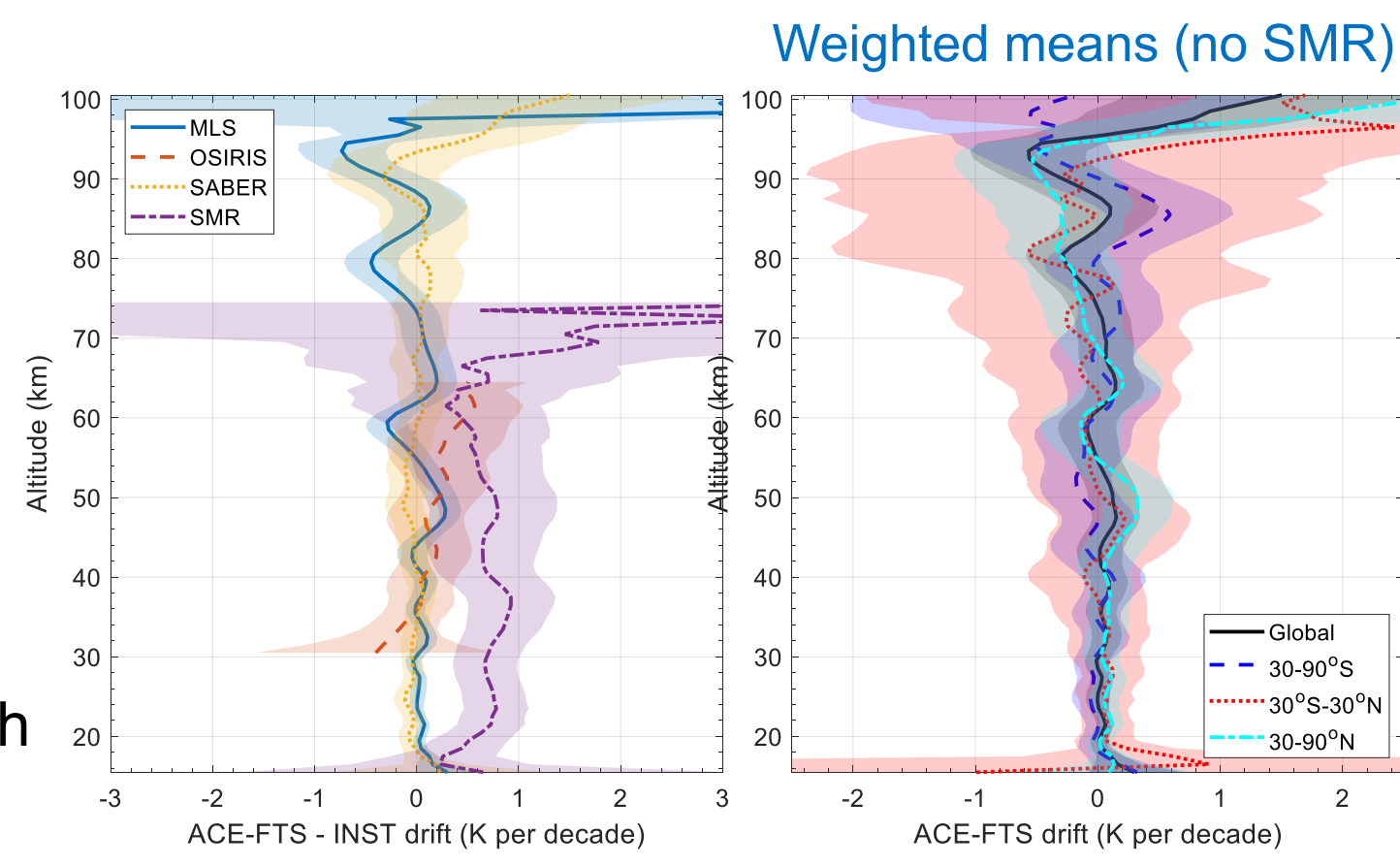
- Overall, no significant drifts found in weighted means, except near 92 km

- No significant drifts found between ACE and SABER

- Oscillations in the ACE vs. MLS drift profile leading to areas of significant drift

- Drift values larger in ACE-OSIRIS results, but so are uncertainties

- Significant positive drift with respect to SMR in the stratosphere

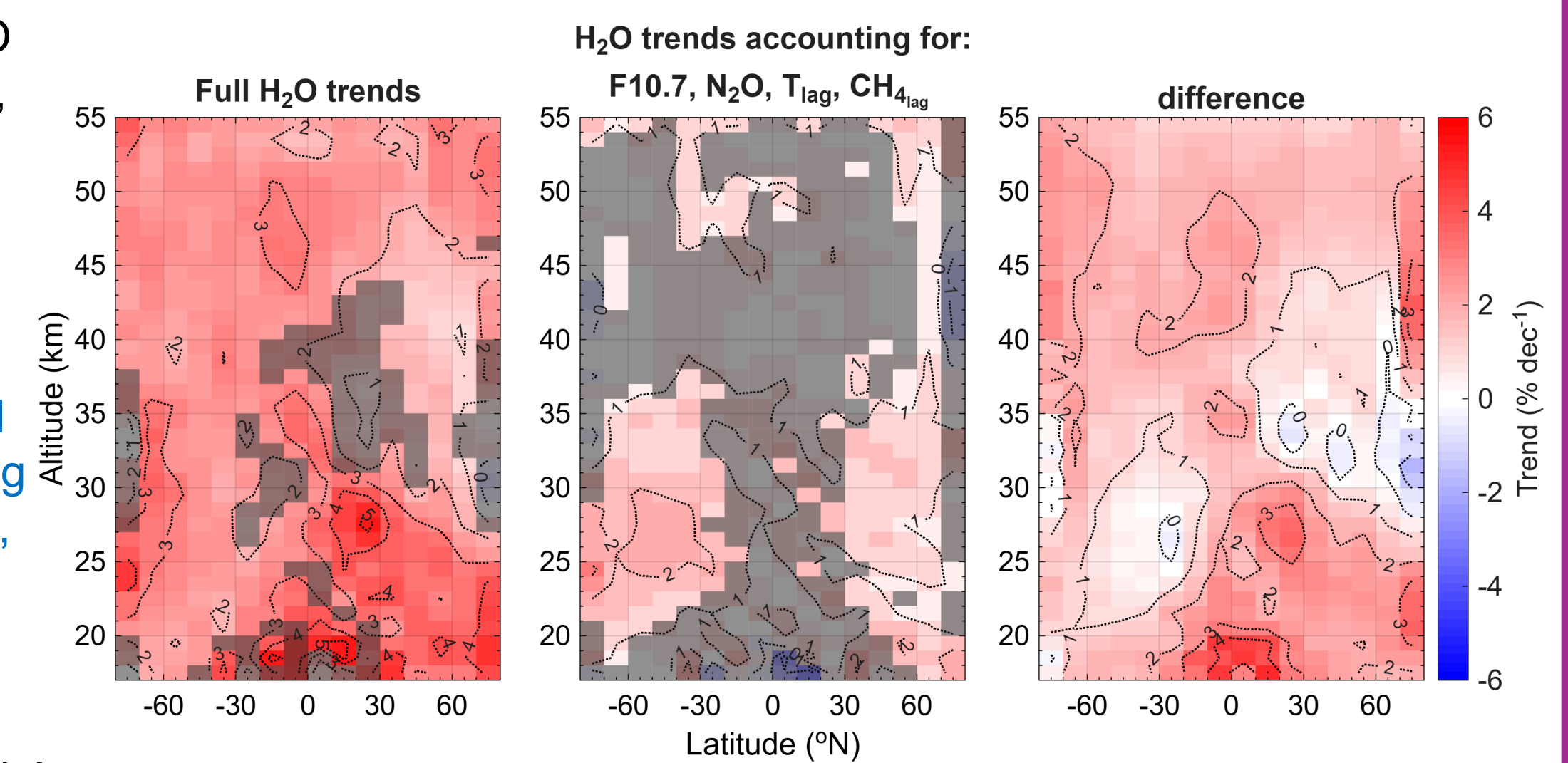


P. E. Sheese, in preparation.

Quantifying Sources of Stratospheric H₂O Trends

ACE-FTS measurements from 2004 to 2022 show an increase in water vapour of 1 %–5 % per decade throughout nearly all of the stratosphere, using multiple linear regression and comparing to a “full” trend that only fit annual and semi-annual cycles

- BDC changes accounted for using ACE-FTS N₂O time series with surface trend removed (for QBO, ENSO, tropopause pressure)
- Both CH₄ and tropopause temperatures were “lagged” to account for transport in stratosphere
- Solar cycle influence was less than +0.5% dec⁻¹
- Most significant contribution is increasing tropical tropopause temperatures (+1-4% dec⁻¹ depending on region), followed BDC changes (+1-2% dec⁻¹), and then increasing CH₄ oxidation (+1-2% dec⁻¹)
- Explains all but ~1 %–2 % dec⁻¹ trend in NH and SH mid-latitude mid-stratosphere (middle panel)
- On-going record is needed to unravel these trends!



For more see: Sheese et al., ACP, 25, 5199–5213 (2025).

Assessing N₂O and SF₆: ESA LOLIPOP CCI+

LONG-Lived greenhouse gas PrODucts Performances (LOLIPOP) project

- CCI+ activity to survey and assess currently available satellite measurements of “other” long-lived greenhouse gases (aside from CO₂ and CH₄)

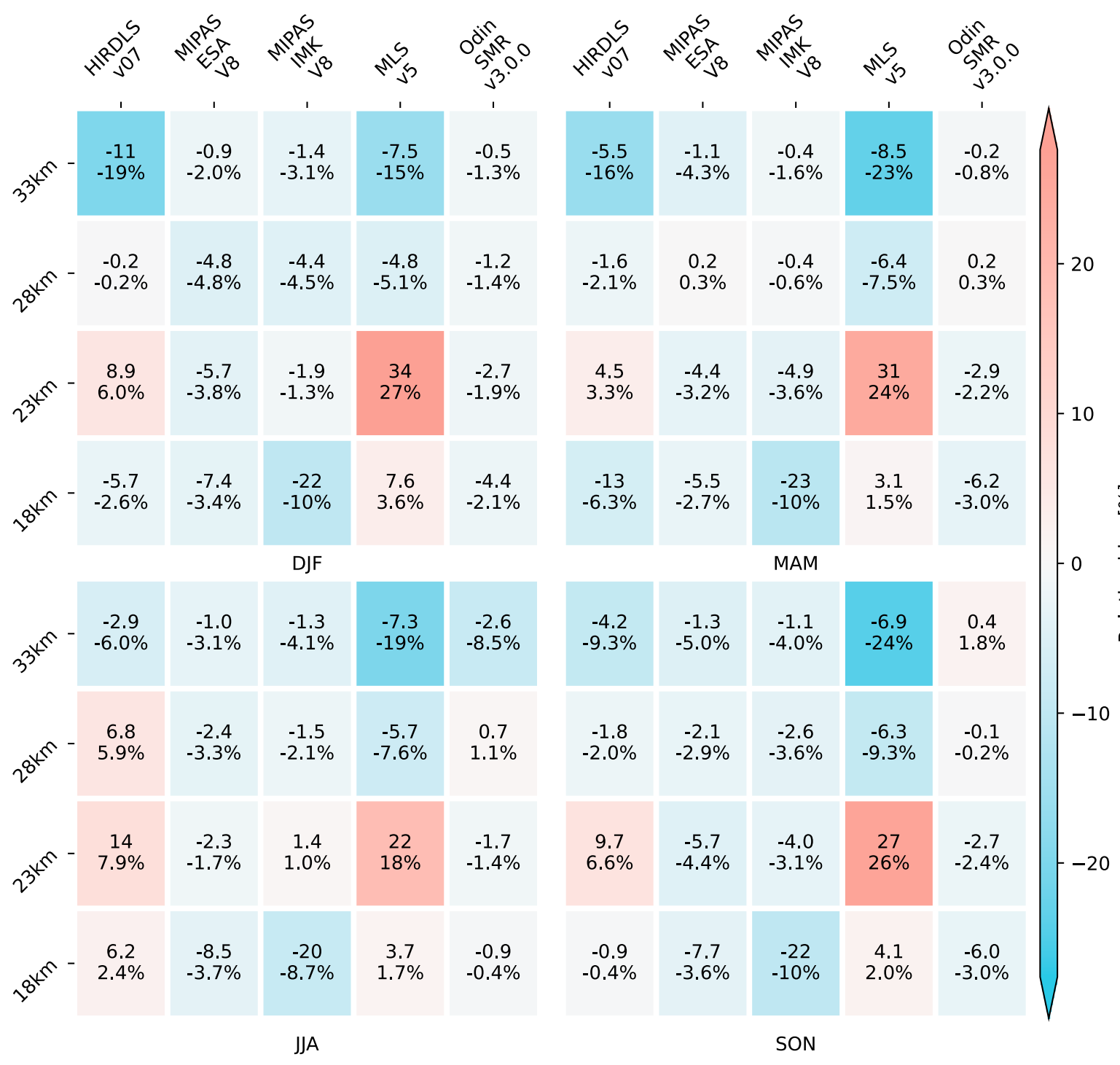
- Limb datasets: ACE-FTS, MIPAS (both IMK & ESA), HIRDLS, Aura-MLS, and SMR for N₂O, CFC-11, CFC-12, SF₆, HCFC-22, CCl₄, CF₄

- Profile-to-profile comparisons made for each gas and pair of instruments

- Global bias results for N₂O summarized for each dataset by altitude, season and comparison dataset

- Largest differences seen with MLS v5 across all seasons

ACE-FTS v5.2 N₂O Bias Summary

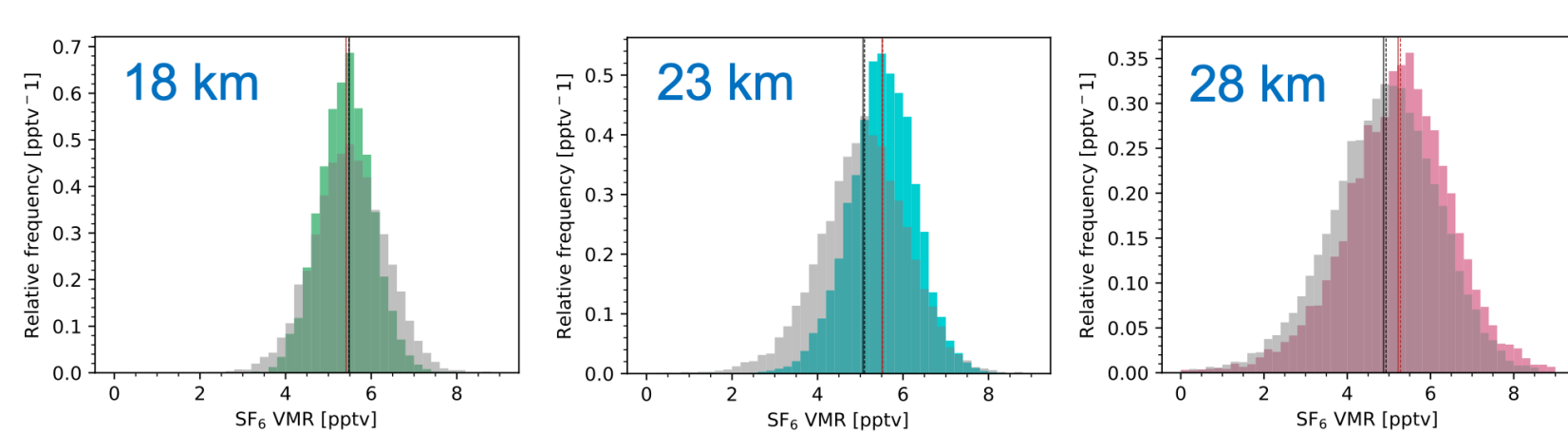


Distributions of global coincident measurements were also compared using probability density functions spanning selected altitudes

- ACE-FTS v5.2 shown in colours

- ACE-FTS SF₆ shows positive bias at higher altitudes in shift

ACE-FTS v5.2 and MIPAS IMK SF₆ Comparisons



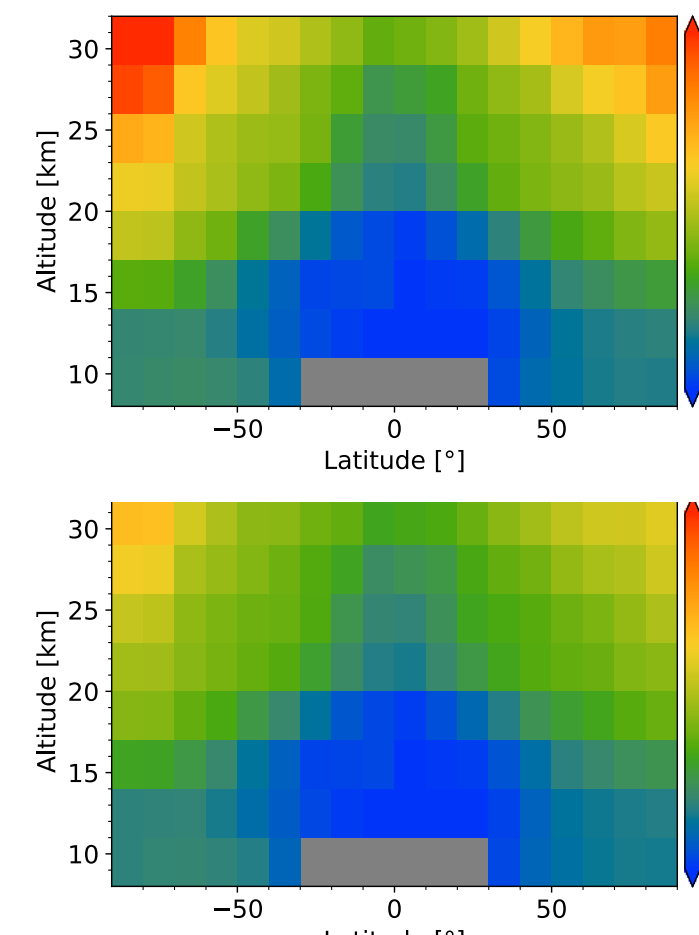
For LOLIPOP halogen comparisons, see: L. Saunders et al. poster 52b

Stratospheric age of air derived from ACE-FTS SF₆

Using SF₆ as a clock tracer, stratospheric age of air (AoA) has been calculated for ACE-FTS (v3.5/3.6) and MIPAS (V5R)

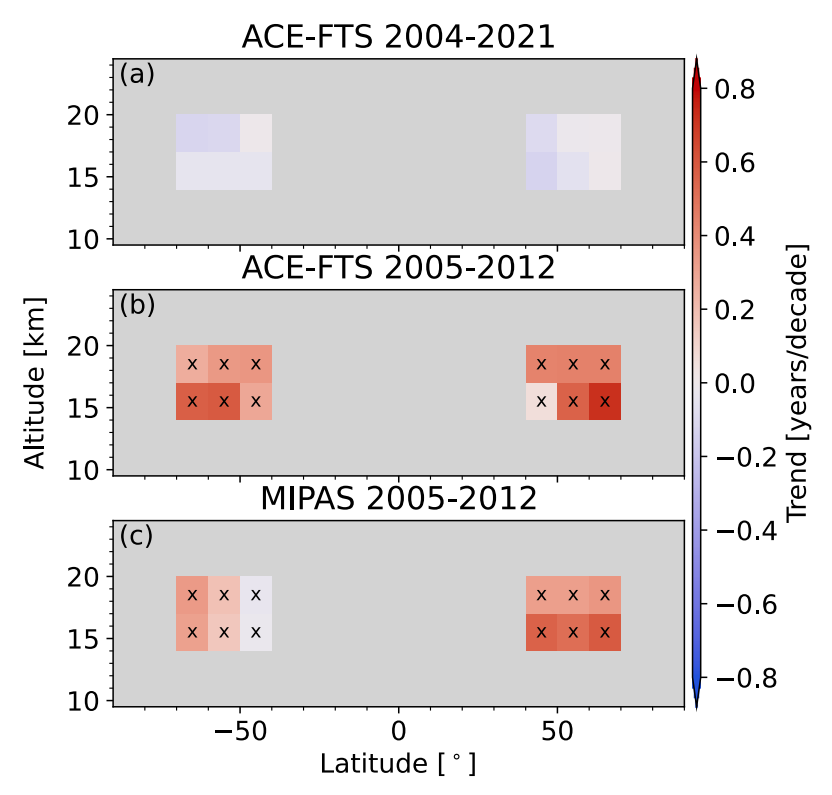
ACE-FTS Multi-year (2004–2021) mean zonal mean age of air

- Air in upper stratosphere appears older due to a mesospheric SF₆ sink (not included in upper panel)
- A correction scheme developed by H. Garny was implemented to account for this is applied (included in lower panel)



Zonal distribution of the linear trends in AoA

- Each sink-corrected time series was fitted with regression model
- Crosses indicate where the ACE-FTS 2005–2012 and MIPAS 2005–2012 trends are within 2-σ

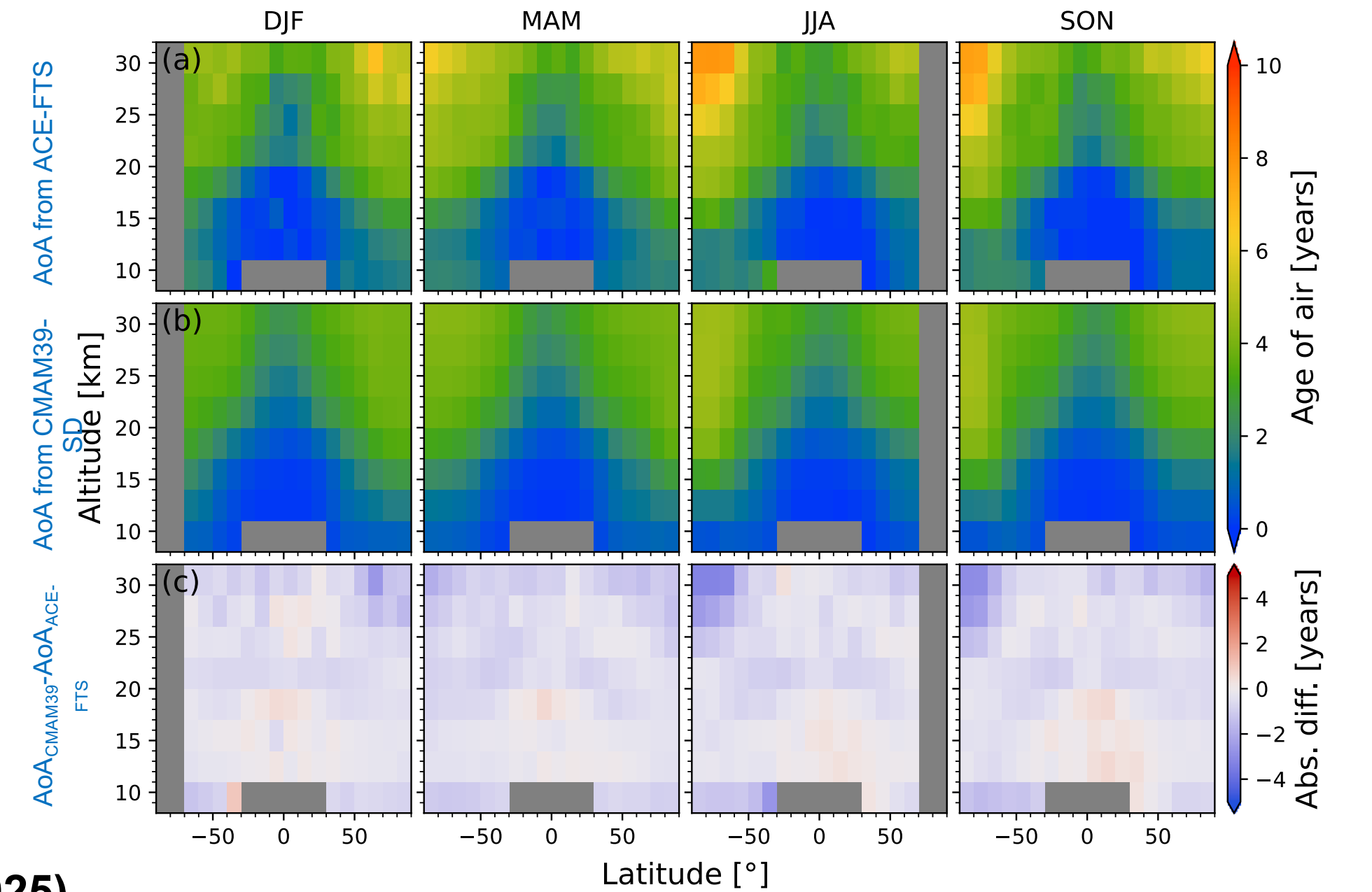


For more see: Saunders et al., ACP, 25, 4185–4209 (2025).

Comparison of Sampled CMAM39-SD with ACE-FTS

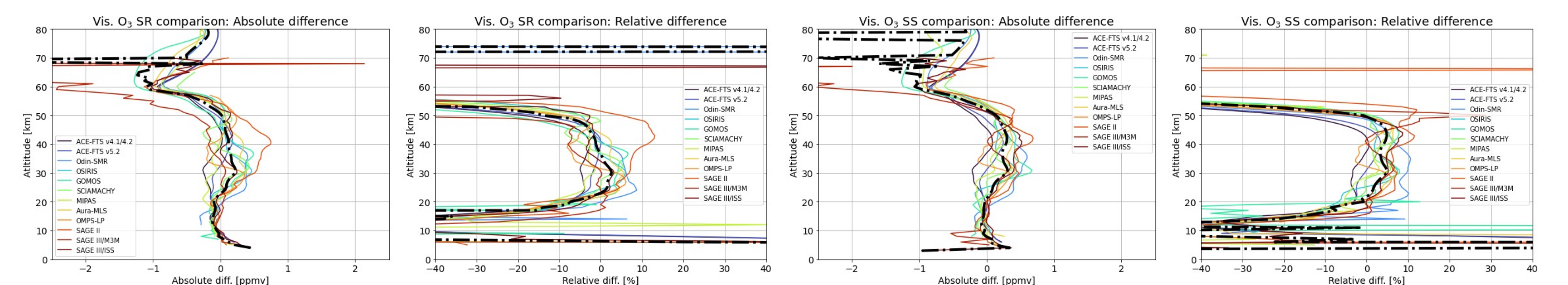
CMAM39-SD is the specified dynamics version of the Canadian Middle Atmosphere Model for 1980-2018

- Age of air in CMAM39-SD is from an idealized SF₆ tracer
- Model age output is sampled at locations and times of ACE-FTS measurements and then averaged for comparison
- CMAM modelled air is generally too young, especially at higher latitudes, compared to ACE-FTS SF₆ age of air



ACE-MAESTRO v4.5 Comparisons

- Comparisons shown for v4.5 MAESTRO Vis channel ozone versus suite of limb sounding satellite instruments
- Mean Vis differences between 20 and 50 km of +2.7% were found (range of +2.3 – +8.2%) and correlations (not shown) of greater than 0.70 from 15-40 km. Mean agreement for UV channel comparisons within +3.4% from 20 to 45 km (not shown).
- Coincident pairs found within 8 hours and 1000 km. Weighted mean of differences shown in thick black dash-dot line.



For more see: Jeffery et al., AMT, 18, 569–602 (2025)

Acknowledgements

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