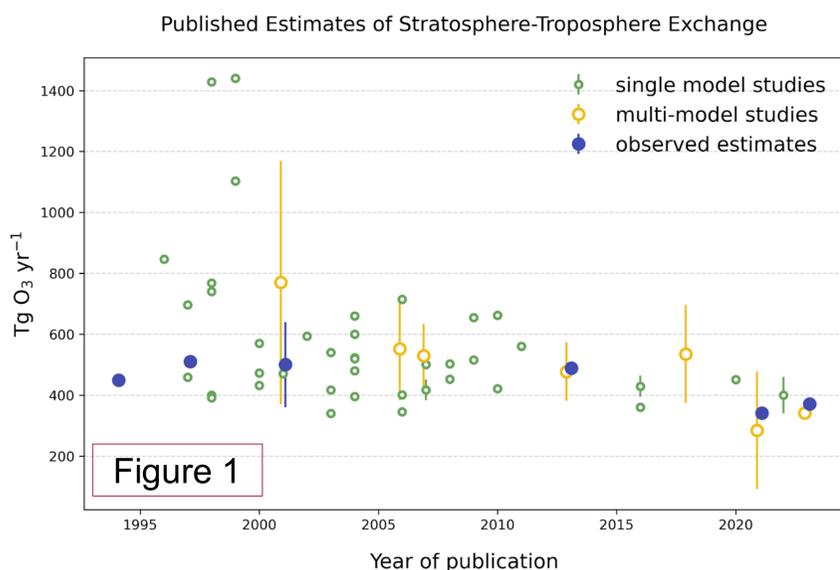


Tropospheric Ozone in CMIP: Progress and Challenges in Quantifying the Role of Stratosphere–Troposphere Exchange in CMIP7

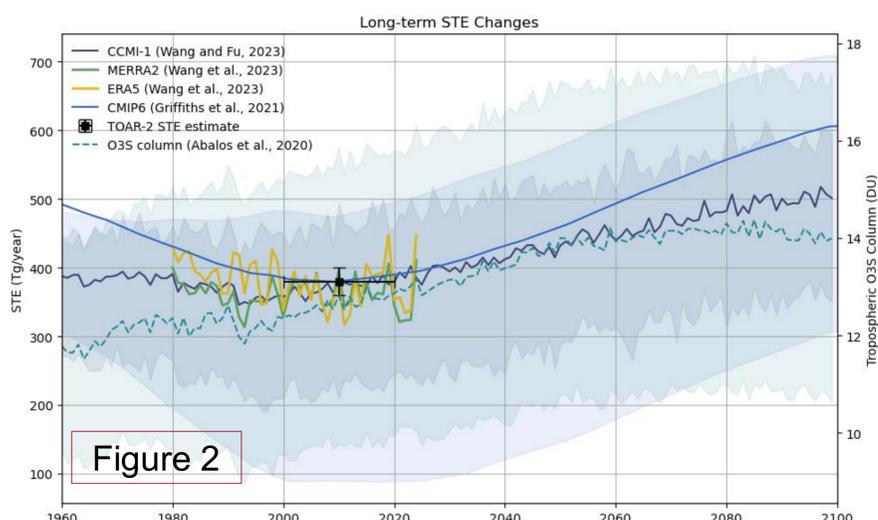
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TOAR-II Assessment of Strat-Trop Exchange

- STE represents the two-way transport of air masses across the tropopause, significantly influencing the tropospheric ozone budget, regional air quality, and climate forcing.
- As part of TOAR-II, we assessed the impact of past and future changes on STE on tropospheric ozone, as well as current estimates of STE flux into the troposphere.
- **Figure 1:** The present-day global net STE of ozone is assessed to be 380 Tg O₃ yr⁻¹. Currently, STE accounts for approximately 6% to 9% of the total tropospheric ozone source



- **Figure 2:** During the late 20th century, STE declined by approximately 2.7% per decade, with a model spread ranging from approximately 1% to -9% decade⁻¹. This was primarily driven by ozone-depleting substances (ODS) reducing STE ozone concentrations in the lower stratosphere.
- Conversely, chemistry-climate models consistently project that STE will increase by 4.7% per decade over the 21st century with a model spread of 3.7–8.9% decade⁻¹.
- This future acceleration is driven by the recovery of the stratospheric ozone layer combined with a greenhouse-gas-induced strengthening of the Brewer-Dobson circulation.



Lessons learned since CMIP6

- No single, generally useful tropopause definition exists – stability-based, dynamical-based, composition-based all relevant and ‘should be chosen based on the research objective.’ [Keeble et al., 2026].
- By design, the CMIP diagnostics **O3PROD**, **O3LOSS** and **O3DRY** do not close the Ox budget. Using the residual method to infer STE introduces uncertainty in calculated STE.
- The **O3S diagnostic**, O3STE, can be useful – increases in O₃S at high latitudes in future scenarios are attributed to enhanced STE and stratospheric ozone recovery [Zanis et al., 2022], faster circulation [Abalos, 2020].
- But care is required in the interpretation [Prather and Zhu, 2024].
- ssp370-pdSST ‘climate penalty’ experiments critical to diagnose the circulation response to GHG forcing [Zanis et al., 2022] that drives increased STE.

Outlook for CMIP7

- **CMIP7 introduces a total ozone tendency, dO3CHEM and tropdo3chm**, to improve budget calculations of STE via explicit calculation of net chemical tendencies.
- **Tropopause pressure** remains based on WMO definition. Composition-based tropopause definitions removed some source of inter-model diversity [Griffiths et al., 2021]. Tropopause definition can affect inferred and diagnosed STE.
- Tagged tracers can provide useful complements to budget studies. Perturbation experiments provide transport and chemistry sensitivities.
- Additional scenarios with AerChemMIP diagnostics will be available but greater participation from chemistry-climate models is required to expand the model database of future air quality / climate interactions.

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