

Chemical and dynamical effects of a Stratospheric Aerosol Injection

Andrin Jörmann (andrin.joerimann@pmoewrc.ch), Timofei Sukhodolov, Simone Tilmes, David Plummer, Shingo Watanabe, Hideharu Akiyoshi, Gabriel Chiodo, Daniele Visioni, Sandro Vattioni, Eugene Rozanov, Ewa Bednarz, Béatrice Josse, Yousuke Yamashita, Thomas Peter



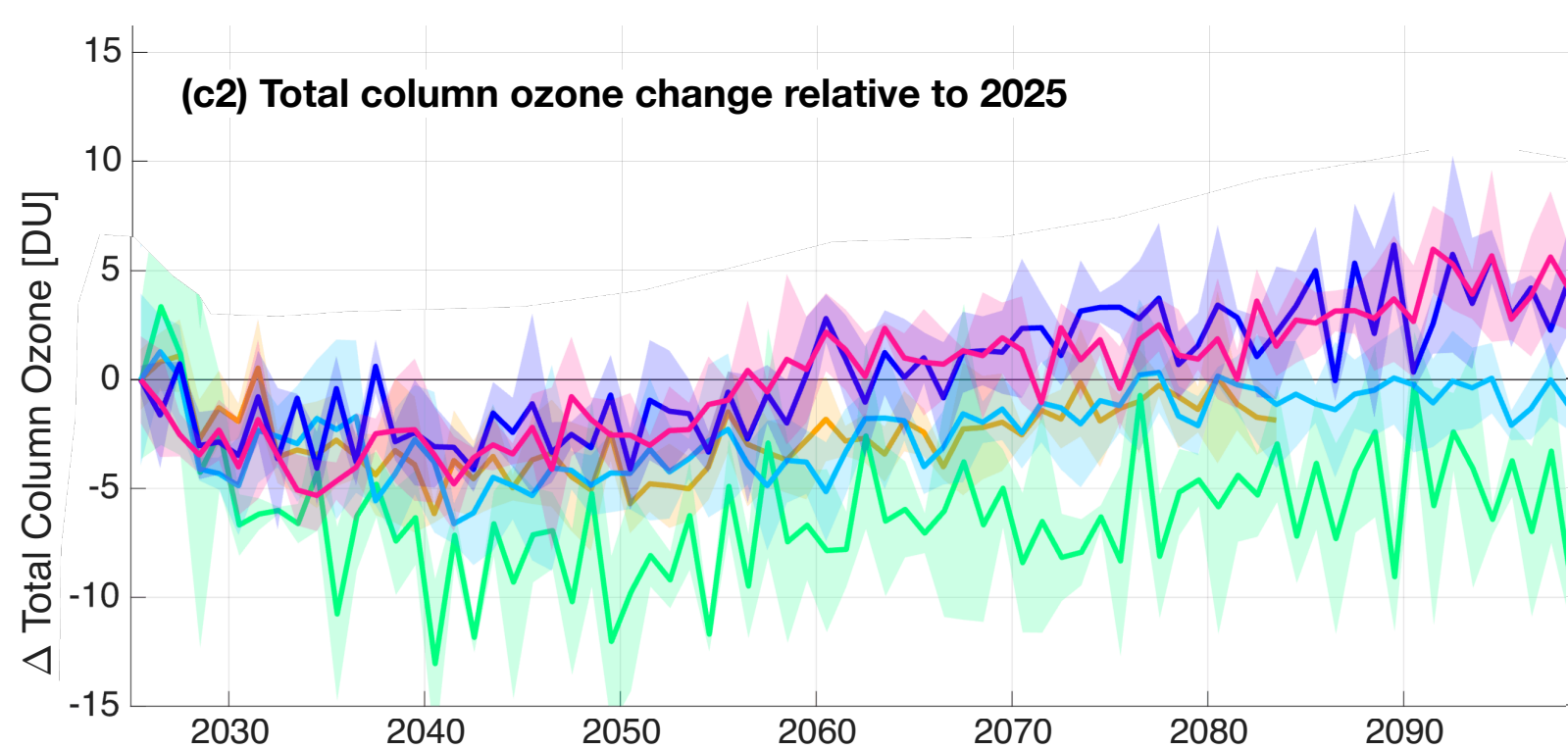
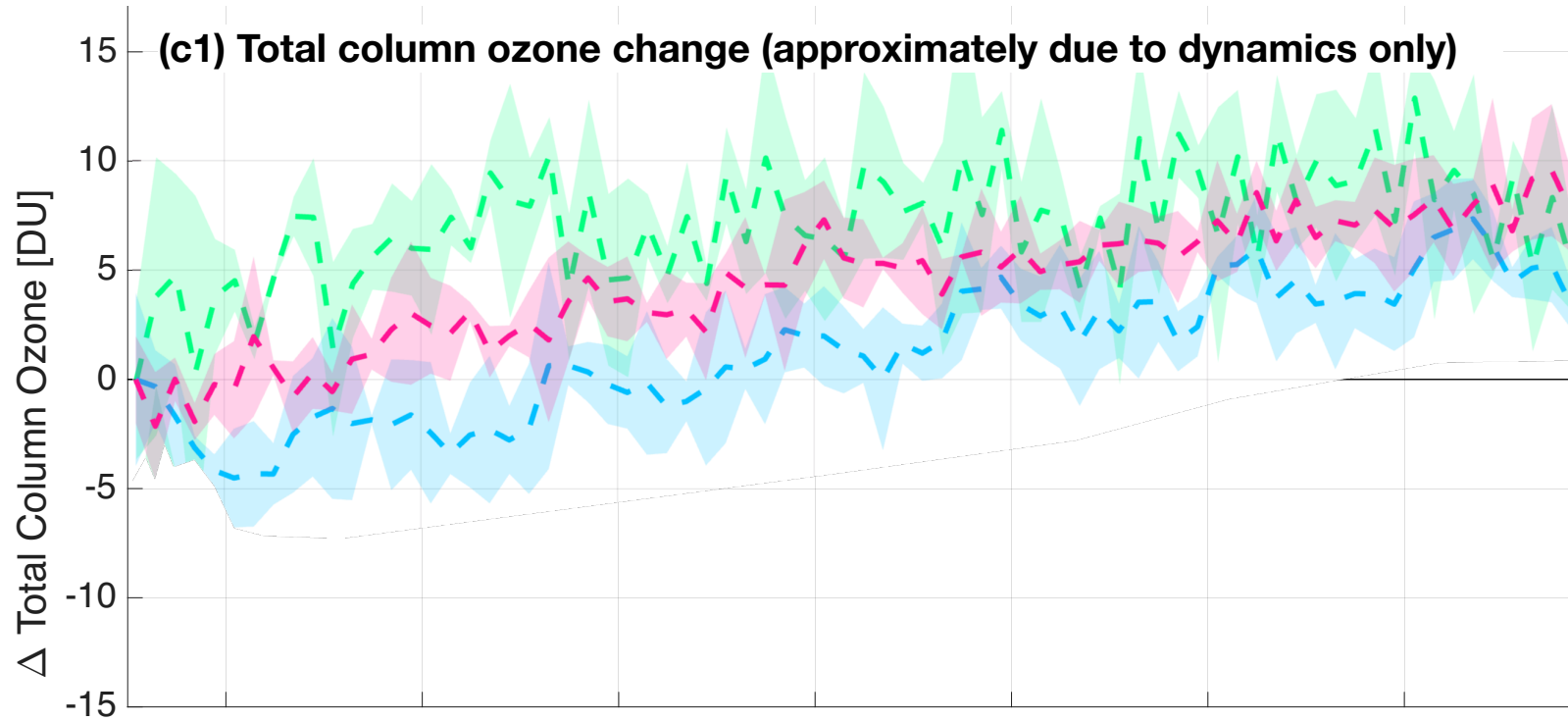
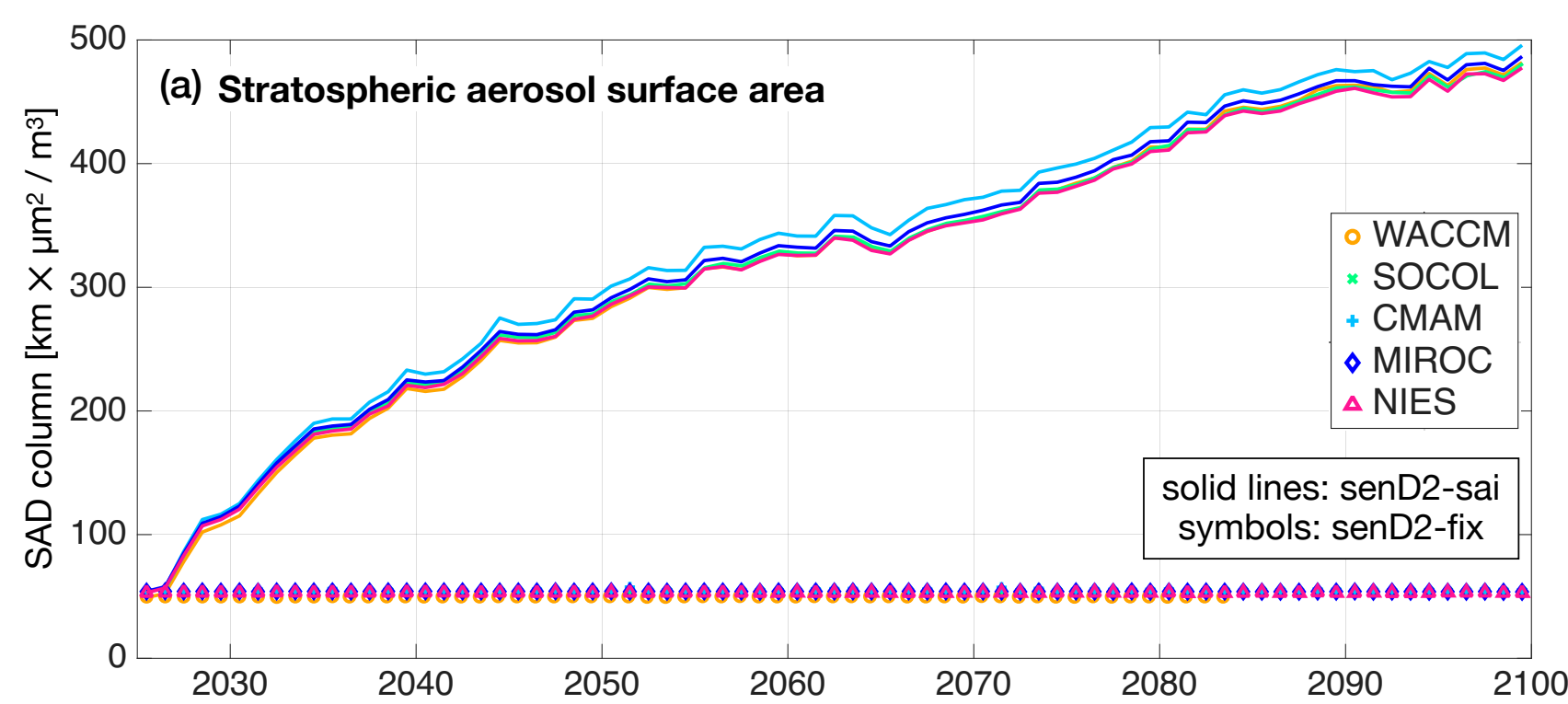
ACP article

INTRO

Within the latest phase of the Chemistry-Climate Model Initiative (CCMI-2022), an experiment was designed to examine the effects of a **climate intervention** scenario. This includes three sets of simulations:

- senD2-fix: reference with 2025 aerosol
- senD2-sai: SAI aerosol offsets climate change
- senD2-chem: only chemical effects of SAI

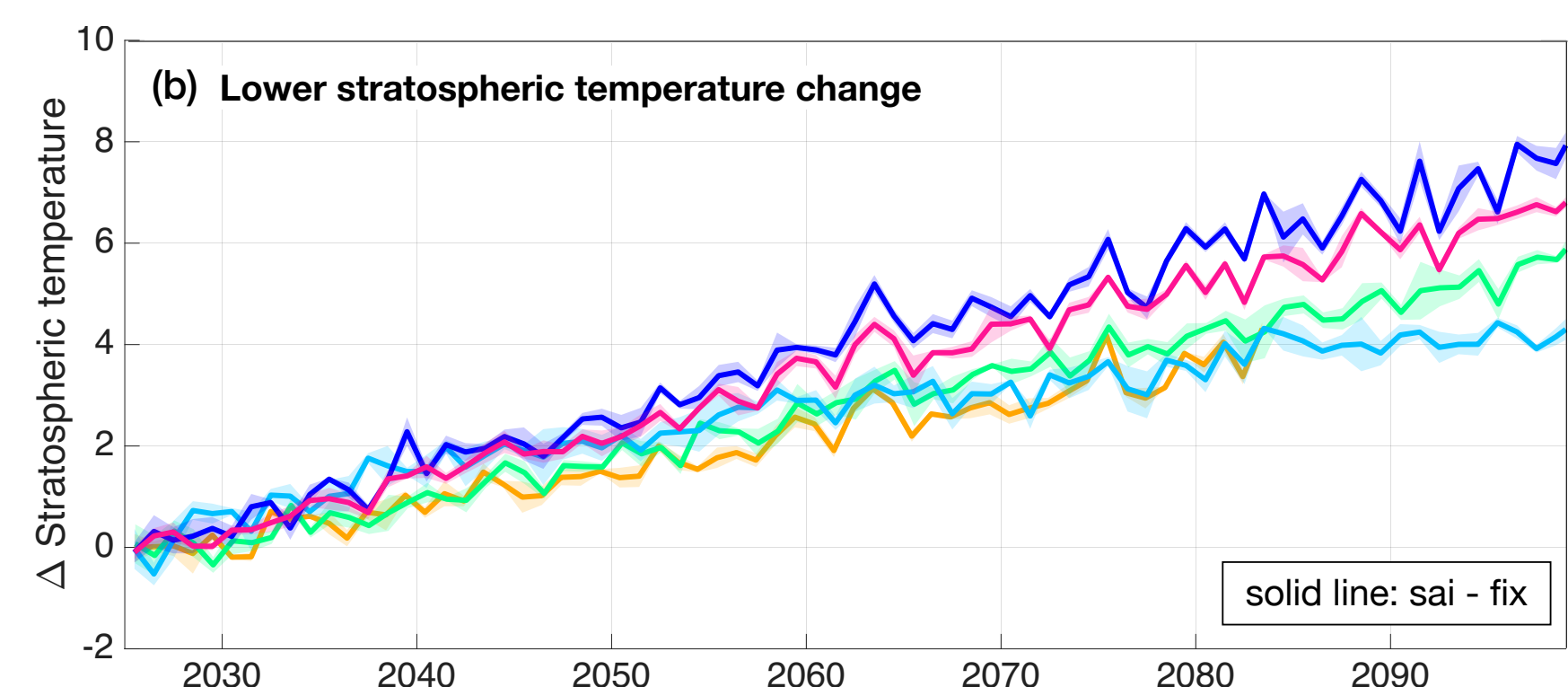
Using respective anomalies, the **full**, **chemical-only**, or **"dynamical"** effects (full-chemical) can be examined.



The transient stratospheric aerosol is derived from a separate simulation that kept the global mean surface temperature constant at 2025 levels by injecting SO₂ with a feedback controller.

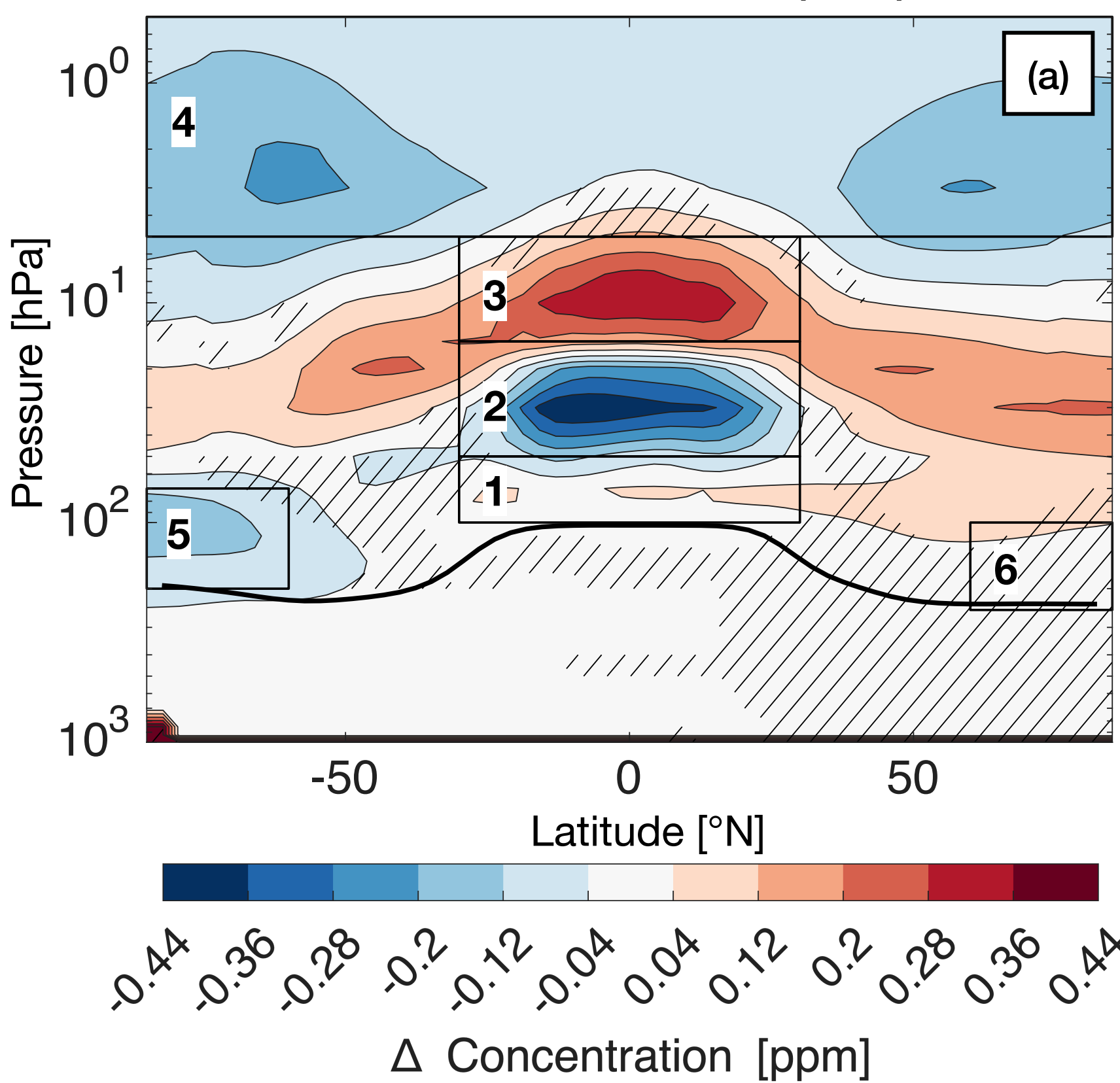
From that aerosol distribution, the radiative (extinction coefficient, single-scattering albedo, asymmetry factor) and chemical (surface area density) properties were prescribed in each participating model.

The sulfuric aerosol (a) heats the stratosphere (b) and impacts total column ozone (c).



Full effects

senD2-sai - senD2-fix ("full")



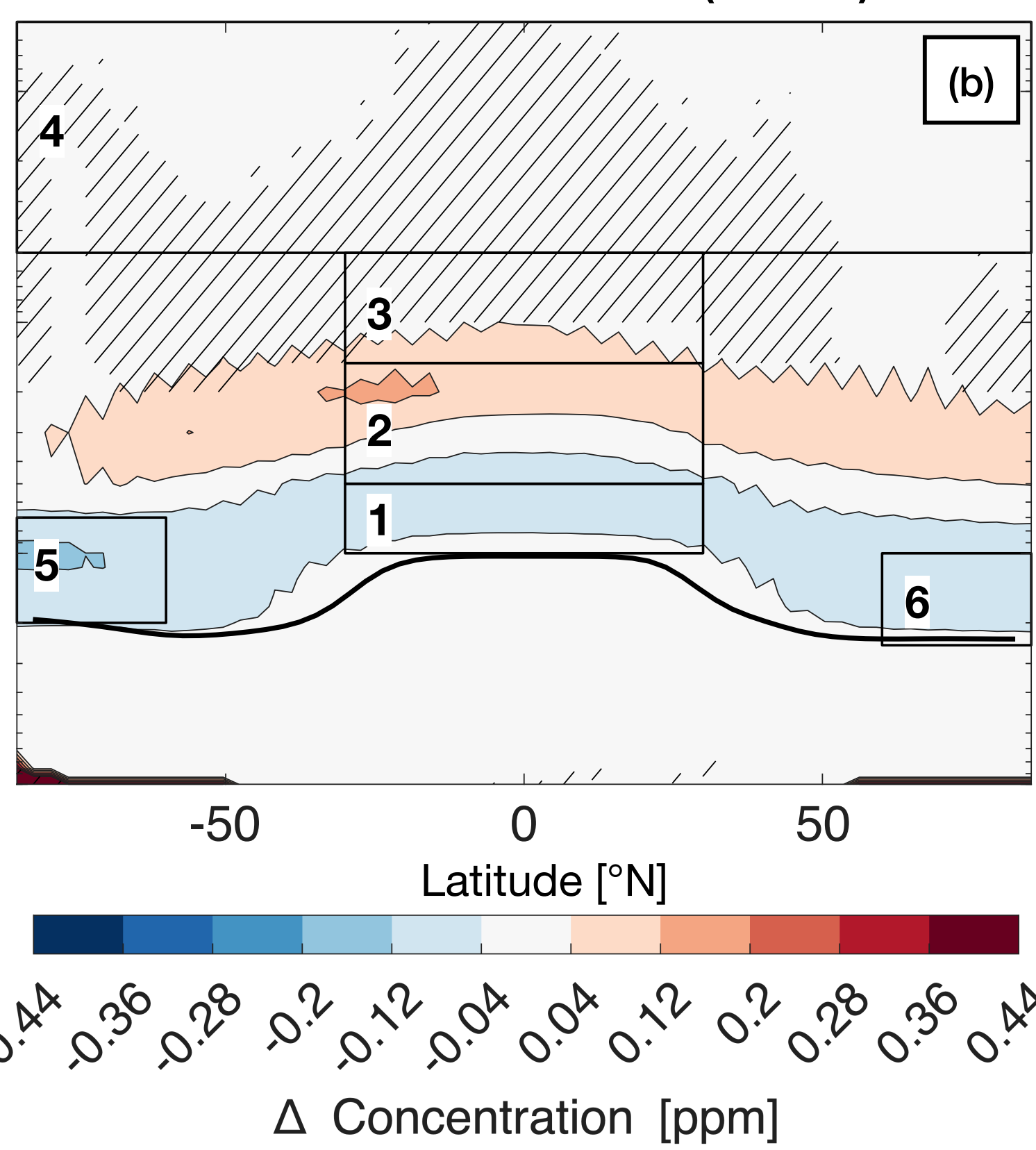
1 The lowermost tropical stratosphere lies below the main heating region and experiences an increase in mean age of air (not shown) due to a slowed BDC shallow branch. This would lead to positive ozone anomalies, but they are almost entirely cancelled by some ozone loss due to chlorine activation ("chemical" and "dyn" compete)

2 Dynamics dominate; absorptive heating strengthens the BDC deep branch and comparatively ozone-poor air is drawn into this region.

3 Dynamically-facilitated N₂O₅ hydrolysis dominates here. In "chem" this positive anomaly lies a bit lower and is weaker, because less water is available.

Chemical effects

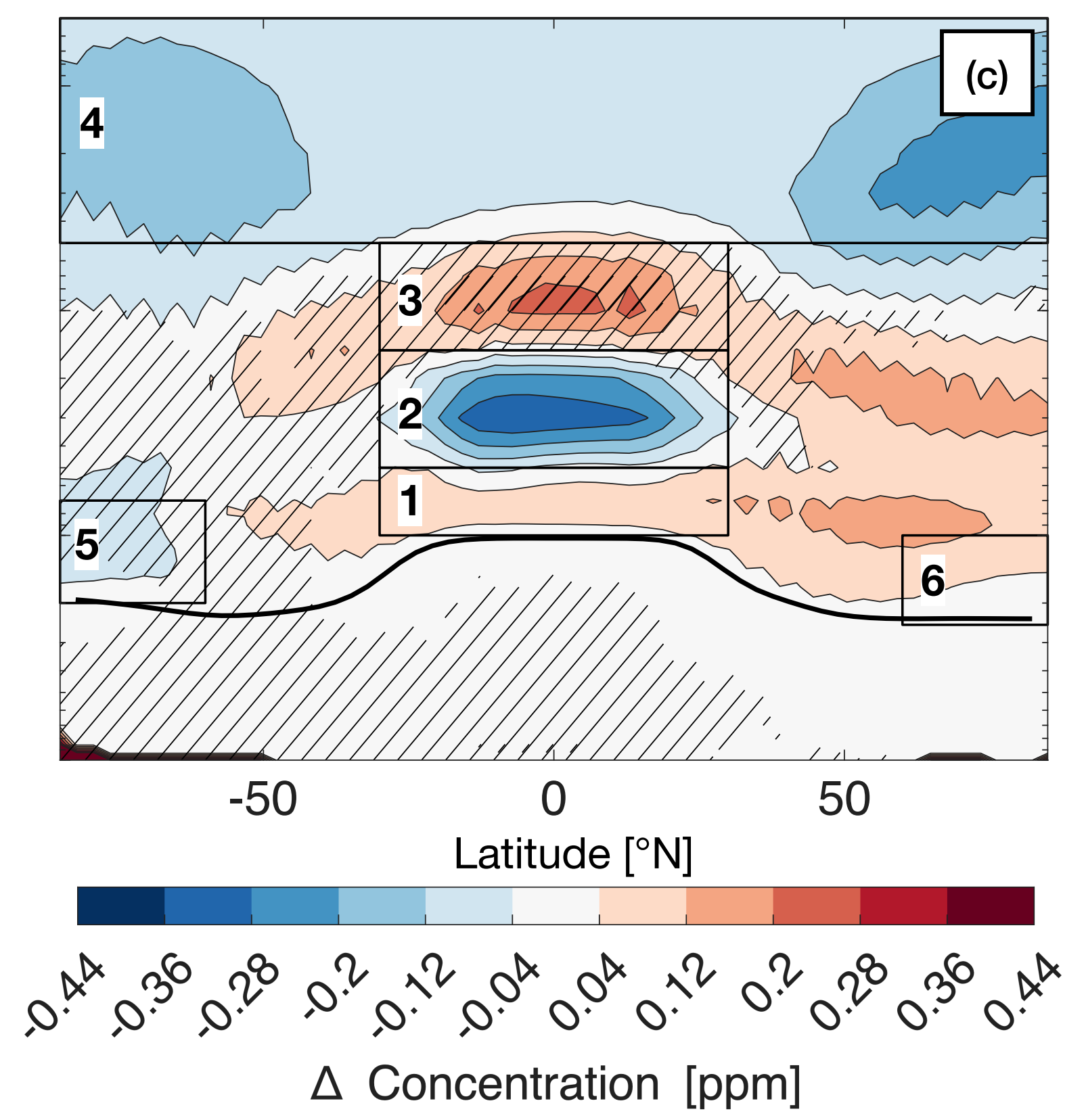
senD2-chem - senD2-fix ("chem")



4 The upper stratosphere only sees a change in chemical composition with circulation changes. In "full", the increased transport of NO_x and HO_x (and their source gases) to above 5 hPa leads to ozone destruction. In "chem" the only effect that could be observed would be changes to photolysis from UV scattering above aerosols, but this is minor.

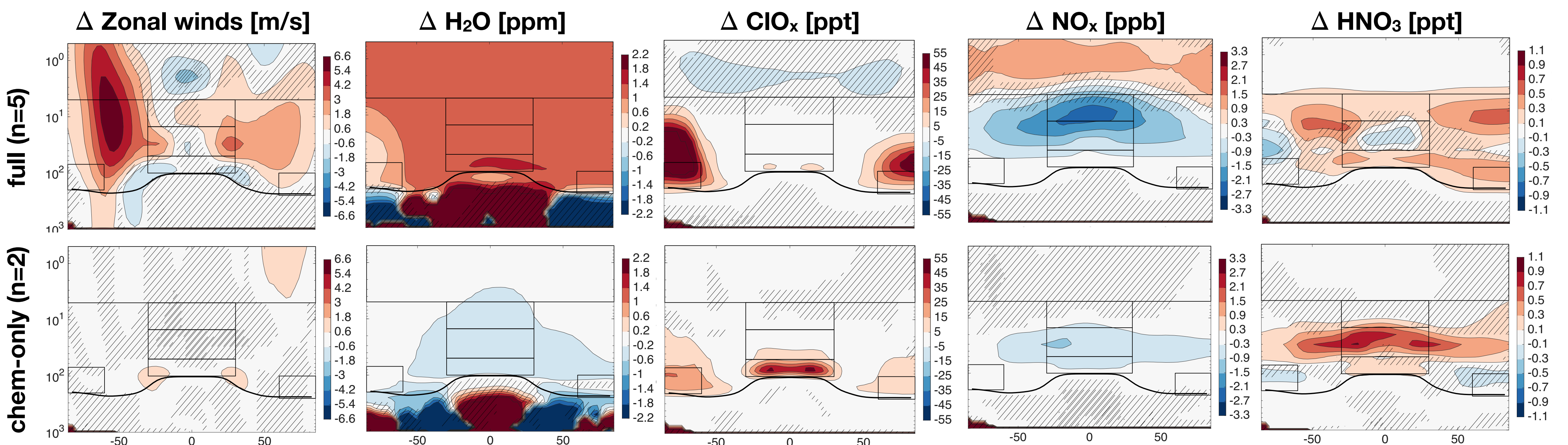
Dynamical effects

senD2-sai - senD2-chem ("dyn")



5 Ozone depletion by heterogeneous reactions on aerosol dominate this region. The "full" effect is still stronger than that from "chem", because the dynamical isolation leads to colder temperatures and thus better conditions for halogen activation.

6 This region is subject to strong inter-annual variability and inter-model differences. While the three "chem" models project negative ozone anomalies, the interplay between "chem" and "dyn" seems to produce model-dependent signals.



Strengthening of the polar vortex due to sulfuric **aerosol absorptive heating**. Also strong effect on **BDC**. Small changes in "chem" suggests minor effect for a hypothetical non-absorptive aerosol.

Strong anomalies due to warming of the TTL and BDC deep branch acceleration. Minor depletion via **N₂O₅ hydrolysis**. Similar signal in **CH₄** and **N₂O** (tracer-like to 0-th order).

Heterogeneous reactions on aerosol activate chlorine. In "full" this is most pronounced at the poles, but in "chem" the tropical effect dominates without aerosol heating and due to some model bias.

Dynamical contribution in the middle and upper stratosphere, but also significant chemical effect from **N₂O₅ hydrolysis** in lower levels. Responsible for positive O₃ anomalies.

Mostly chemical enhancement from **N₂O₅ hydrolysis**, but also visible are the strong South polar vortex and intense BDC deep branch, which draws relatively HNO₃-poor air up into region 2 in "full".