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Higher Tropical SSTs Strengthen the Tropical Upwelling via Deep Convection

(00115)

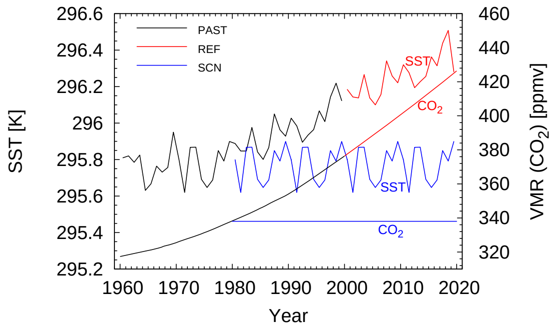
Summary

Recent observations show a distinct cooling of the tropical lower stratosphere, and chemistry-climate models (CCMs) suggest a spatial coincidence of the cooling with a stronger upward advection of ozone-poor tropospheric air. This advection increase appears to result from a currently unexplained strengthening of the planetary-wave driven mean meridional transport, arguably relating to increases in greenhouse gas concentrations from anthropogenic activity.

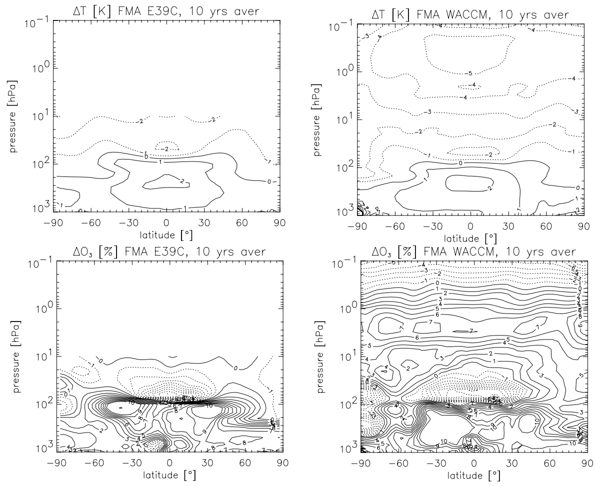
The present study explores the strengthening by comparing realisations of two different scenarios with the CCM E39C. Both share the same boundary conditions including concentrations of ozone-depleting substances, but differ in their climate forcing via sea surface temperatures (SSTs) and well-mixed greenhouse gas concentrations.

In the summer hemisphere tropics, higher SSTs for the warmer scenario amplify deep convection and hence the convective excitation of internal planetary waves. These waves travel upward through the tropical easterly winds while dissipating, but still carry enough of the signal into the lower stratosphere to intensify the mean meridional transport. The transport change in turn strengthens the input rate into the tropical lower stratosphere of ozone-poor tropospheric air, ultimately weakening lower-stratospheric ozone concentrations via higher tropical SSTs.

Boundary conditions for E39C simulations

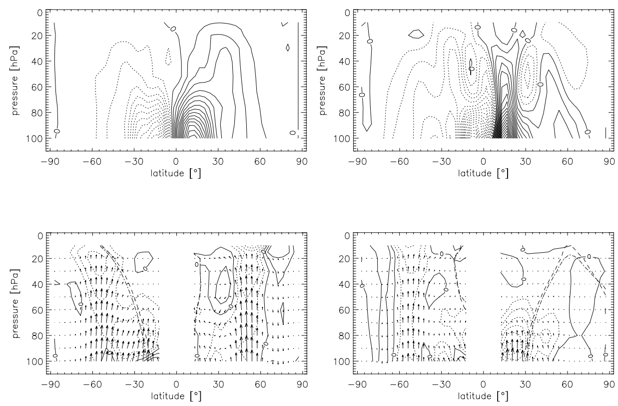


Temperature and Ozone Differences



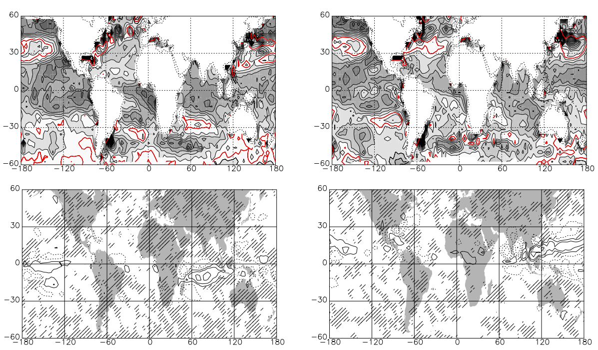
Temperature (top) and ozone (bottom) anomalies (REF-SCN) in E39C (left) and WACCM (right).

Meridional Circulation and EP-Fluxes



Top: Ensemble mean anomalous (REF-SCN) TEM streamfunction. The anomalous mass transport is parallel to isolines, clockwise around a streamfunction maximum, counter-clockwise around a minimum, and its strength proportional to the density of the iso-lines. Bottom: Anomalous quasi-stationary EP diagnostics. Left: Dec/Jan; Right: Jul/Aug.

Changes of SSTs and convective precipitation



Top: SST differences in the REF and SCN simulations (mean value for last 20 years). Areas framed in red mark negative changes. Bottom: Rate of ensemble mean anomalous (REF-SCN) surface convective precipitation. Hatching marks regions where not all of the six individual anomalies have the same sign. Left: Dec/Jan; Right: Jul/Aug.

Conclusion

The present CCM study demonstrates for the first time that higher tropical SSTs in a warmer climate can change the tropical lower stratospheric BD circulation in the summer hemisphere via the deep-convective generation of upward propagating quasi-stationary eddies. The upper lid of E39C, centred at 10 hPa, is unlikely to interfere since the tropical eddy dissipation enhancement mostly occurs at levels lower than 50 hPa.

The mechanism is relevant during the period June to September in the Northern Hemisphere, and during December to March in the Southern Hemisphere. As a consequence, it modulates the tropical lower stratospheric BD circulation during eight months of the year, lowering tropical lower stratospheric ozone concentrations and temperatures for the warmer climate.

It is worth emphasizing that the mechanism investigated neither affects regions poleward of the summer hemisphere subtropics, nor affects the winter hemisphere. However, enhanced tropical deep convection may not only amplify the local generation of upward propagating quasi-stationary internal eddies, but also strengthen the generation of poleward propagating external eddies (e.g. Garcia and Salby, 1987). The latter eddies could be able to enter the winter-hemispheric extra-tropical stratosphere and intensify the BD circulation there.

Ref.: Deckert, Rudolf and Martin Dameris, *Geophys. Res. Lett.*, **35**, L10813, doi: 10.1029/2008GL033719, 2008.

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