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Decay timescale of polar stratospheric temperature anomalies

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The dynamical coupling between the stratosphere and troposphere is of great interest for extended-range (seasonal) tropospheric forecasts. This potential for additional predictive skill is essentially based on the relatively long timescale of variability of the extratropical winter stratosphere compared to the troposphere. While stratospheric circulation anomalies are driven primarily by upward propagating planetary and gravity waves of tropospheric origin, radiative damping is the major process for their decay, both mechanisms setting the timescale of stratospheric variability. Here we focus on the decay timescale of stratospheric zonal mean temperature anomalies.

From the quasi-geostrophic potential vorticity equation it is clear that the decay timescale of a radiatively damped anomaly also depends on its relative spatial scale compared to the Rossby radius of deformation due to compensating ageostrophic circulations, with a longer decay timescale for smaller spatial scale, if frictional timescales are long compared to radiative timescales as it is the case for the stratosphere. The relevance of this scale dependent behaviour is investigated for stratospheric anomalies, using a dry primitive equation atmosphere model with Newtonian cooling, Rayleigh friction, and zonally symmetric forcing and boundary conditions.

First, in the zonally symmetric model the decay timescale of small amplitude, initially balanced stratospheric temperature anomalies from a state of rest is determined, separately for different meridional scales representative for typical stratospheric conditions. The smaller anomalies decay significantly slower and on a timescale that is 2-5 times longer than the radiative timescale. Second, in the zonally asymmetric model the thermal forcing of an idealised stratospheric polar vortex is switched on, and the transition timescale is again found to be significantly longer than the radiative timescale

for small meridional scales of the polar vortex forcing, though in this case the anomalies are large amplitude and non-linear wave-mean flow interactions play a role in the dynamics.

The numerical model results confirm that for realistic stratospheric configurations (meridional scale and Rossby radius) anomalies decay on a timescale significantly longer than the radiative timescale. Furthermore, the results have implications for stratosphere-troposphere modelling.