Sudden Stratospheric Warmings as Noise-Induced Transitions

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NCAS-Climate researchers, as part of an international collaboration with Colorado State University, have proposed a new mechanism for triggering rapid flow transitions in the stratosphere. The winter stratospheric circulation in both hemispheres is dominated by a strong cyclonic vortex over the pole. However, planetary waves frequently perturb the vortex. For sufficiently strong planetary waves, disturbances can grow enough to destroy the vortex as a well-organized entity. These abrupt transitions – which are poorly captured by state-of-the-art general circulation models – are usually associated with a rapid reduction of the mean circumpolar wind and a rapid warming of the polar stratosphere, and are called Sudden Stratospheric Warmings (SSWs). Conventionally, SSWs are considered to be caused by an interaction between planetary waves and the mean flow. Random small-scale variability due to breaking gravity waves, although well known to be ubiquitous in the winter stratosphere, has not traditionally been considered strong enough to cause SSWs. Inspired by recent laboratory evidence that gravity-wave noise can trigger rapid transitions between different large-scale flow patterns, the collaborators used a simple atmospheric model to investigate whether small-scale gravity-wave variability can trigger SSWs. The researchers concluded that, surprisingly, even weak gravity-wave noise can be sufficient to cause a SSW that would otherwise not have occurred. The results suggest a new and alternative mechanism for SSW initiation. The results also suggest that the poor capturing of SSWs by state-of-the-art general circulation models could be improved by adding weak noise to represent the unresolved gravity waves.

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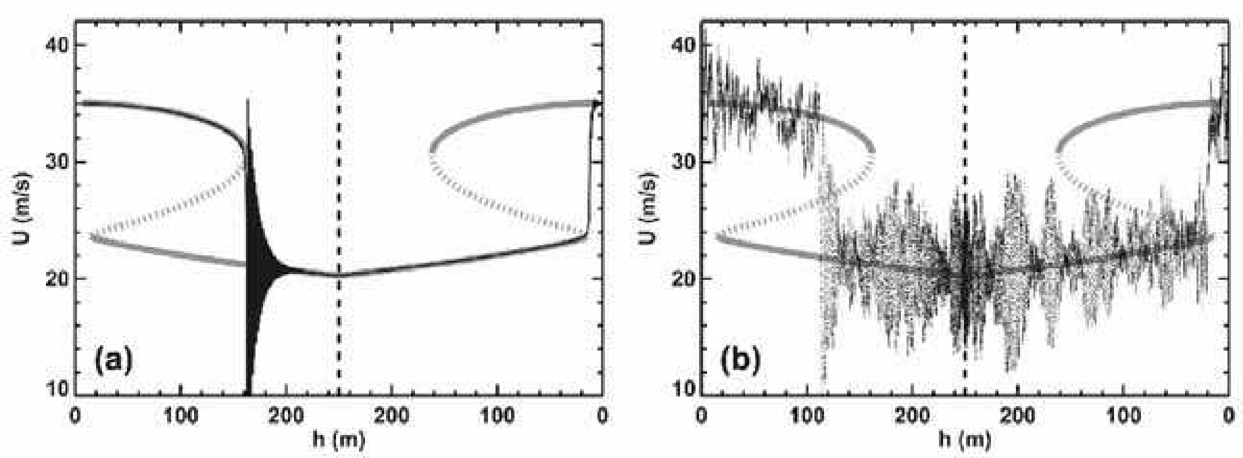

Simulations of a Sudden Stratospheric Warming (SSW) in the absence (left) and presence (right) of gravity wave noise. The mean circumpolar wind, U, is plotted as a function of the planetary wave amplitude, h, which in this simulation slowly increases from zero to 250 metres (marked by vertical dashed lines) and then slowly decreases back to zero. Solid grey lines mark the equilibrium solutions, with the high-wind branch representing the undisturbed vortex and the low-wind branch representing the SSW state. Notice that the SSW occurs much earlier when gravity wave noise is included in the model, at planetary wave amplitudes that would not otherwise have triggered a SSW.