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Sudden stratospheric warmings as noise-induced transitions

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Sudden stratospheric warmings (SSWs) are usually considered to be associated with planetary wave activity. Here it is asked whether small-scale variability, e.g. related to gravity waves, can lead to SSWs given a certain amount of planetary wave activity that is by itself not able to cause a SSW. A recently proposed highly truncated version of the Holten-Mass model of stratospheric wave-mean flow interaction (Ruzmaikin et al., 2003) is extended to include stochastic forcing. In deterministic setting, this low-order model exhibits multiple stable equilibria corresponding to the undisturbed vortex and SSW-state, respectively. Momentum forcing due to quasi-random gravity wave actitvity is introduced as an additive noise term in the zonal momentum equation. Two distinct approaches are pursued to study the stochastic system. First, initialized at the undisturbed state the system is numerically integrated many times in order to derive statistics of first passage times of the system undergoing a transition to the SSW-state. Second, the Fokker-Planck equation corresponding to the stochastic system is solved numerically in order to derive the stationary probability density function of the system. Both approaches show that even small to moderate strengths of the stochastic gravity wave forcing can be sufficient to cause a SSW for cases where the deterministic system would not have predicted a SSW.