Geophysical Research Abstracts
Vol. 20, EGU2018-3222, 2018
EGU General Assembly 2018

A transition between a quasi-linear and nonlinear regime of the tropospheric jet stream

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The variability of the tropospheric jet stream on synoptic time scales arises from its interaction with the atmospheric waves. The variability properties of the jet stream change between different geographical locations, seasons and years, and are related to differences in the mean state of the jet. Using an idealized numerical model of the atmospheric circulation we reveal the dynamical mechanisms leading to a transition in the variability properties of the jet. With relatively low wave energy the system is in a quasi-linear regime, where the wave spectrum is dominated by a single synoptic-scale wave mode and the jet variability is weak. As the wave energy is increased the system transitions to a nonlinear regime where the wave spectrum is wide and the jet variability is strong. The jet variability in the nonlinear regime is characterized by rapid fluctuations of the jet latitude, similar to the observed annular modes. The state of the jet in the quasi-linear regime does not change much with time and is similar to the negative phase of the annular mode in the nonlinear regime, when the jet is displaced equatorwards. By analyzing the wave properties leading and lagging each phase of the annular mode, we find that the strong variability in the nonlinear regime arises from the interaction of the jet with planetary waves in high latitudes. These planetary waves gain energy mostly from nonlinear wave-wave interactions, but also from barotropic instability during the negative phase of the annular mode. The momentum flux from the planetary waves drives the positive phase of the annular mode.