Nonlinear time series analysis of atmospheric gravity waves

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Internal gravity waves in the Earths atmosphere are a very interesting and complex research subject in modern atmospheric physics. These gravity waves couple different atmospheric regions both in vertical as well as in the horizontal directions by means of momentum and energy transport. They can propagate upwards, and also in the opposite direction, from the troposphere to the stratosphere, mesosphere and thermosphere where they eventually break. They transfer energy, momentum and chemical species between the different atmospheric layers and therefore play an important role on atmospheric winds, temperatures, chemistry and especially turbulence. A better understanding of the excitation and propagation of these waves would contribute to climate models.
Nonlinear network based analysis of multidimensional meteorological time series has led to new insights in climatology [Ref1, Donges]. We apply techniques from nonlinear time series analysis to nonlinear data sets of simulated multidimensional time series of wind velocities and other atmospheric parameters and combine them with complex networks analysis. The simulations are adapted to measurements of the GW-LCYCLE coordinated field program [Ref2, Rapp]. Specifically, we analyze the vertical component of the wind speed in 137 horizontal layers of the atmosphere ranging from the ground level up to an altitude of approximately 40 km. A comparison of Pearson correlation and the mutual information reveals linear and nonlinear dependencies between certain altitude levels. In order to identify continuing signals traversing different height levels over time we test the approach of varying time lags between the time series of different layers. A maximization of the correlation measures, whether linear or nonlinear, could enable the identification of such signatures. These signatures might resemble the signatures of atmospheric gravity waves. A family of networks is constructed from the time series correlation analysis. The network analysis allows to compare different network topologies. Our findings give new insights into the processes of momentum and energy transfer into higher layers of the atmosphere.

[l] J.F. Donges et al, EPL **87**, 48007 (2009).
[2] M. Rapp, 40th COSPAR Scientif (2014).