LARGE DEVIATIONS OF PLANETARY JETS

Freddy Bouchet[1], Brad Marston[2], Cesare Nardini[1] & Tomás Tangarife[1]
[1] *École Normale Supérieure de Lyon and CNRS, France*
[2] *Physics Department, Brown University, USA*

Rare or extreme events are of great interest in climate and other systems. Few studies address these statistics from a dynamical perspective. Classical statistical approaches, for instance closures or stochastic averaging usually describe typical states or low order statistics only [1, 4]. Large deviation theory is a very interesting alternative to these classical methods. It can in principle describe both typical fluctuations and extreme fluctuations [5]. This allows us to discuss the long time evolution of the jet. One goal is to predict the dynamics that may lead to change of regimes and change of attractors in atmospheric jet dynamics.

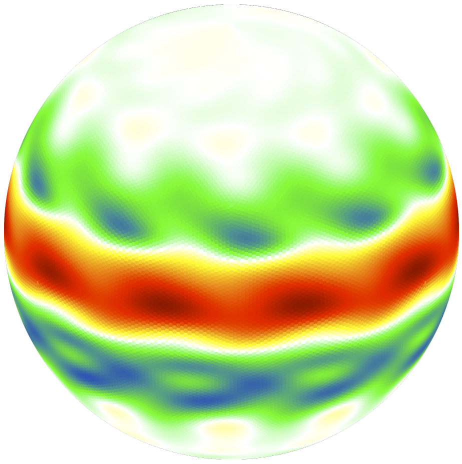

Figure 1. Zonal (east-west) velocity field in a direct numerical simulation of the quasi-linear barotropic equation, with stochastic forcing, on a rotating sphere [2].

We consider the dynamics of atmospheric jets in a quasi-geostrophic framework and compute the large deviation rate function of the zonally averaged Reynolds stress, the most interesting quantity for the dynamics of the jets. In the limit of a time scale separation between the large scales and the eddies, we expect a quasi-linear approximation to descibe accurately the mean flow statistics [1], figure 1. Then, we derive an explicit equation for the large deviation rate function within this quasi-linear dynamics. These theoretical results are compared with empirical measures of the rate function [3], obtained from direct numerical simulations of both the quasi-linear and the full non-linear equations of motion.

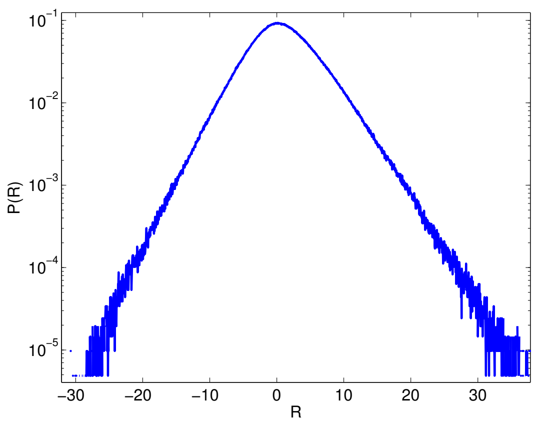

Figure 2. Probability distribution function of the zonally averaged Reynolds stress divergence R at a given latitude. This distribution is sampled from a direct numerical simulation of the barotropic equation.

We also investigate the probability distribution function of the zonally averaged Reynolds stress, see figure 2. The typical state is predicted by statistical closures of the dynamics, and we are also able to explain the exponential tails of the distribution.

References

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