Predictability of blocking and zonal flow regimes in a reduced-order land-atmosphere coupled model

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Abstract

- Low-frequency variability (LFV) encompasses atmospheric and climate processes on time scales from a few weeks to decades like atmospheric blocking, cold spell and heat waves.
- Better understanding of LFV, could contribute to improved long term forecasts.
- Here we investigate predictability of atmosphere blocking on the basis of local Lyapunov exponents using low order idealized land atmospheric coupled model.

I. Introduction

Atmospheric blocking is a long lasting stationary high pressure region which disrupts the usual eastward progression of the pressure systems (Kautz et al. 2021). Simulating and investigating the dynamics of the atmospheric blocking is essential in this scenario.

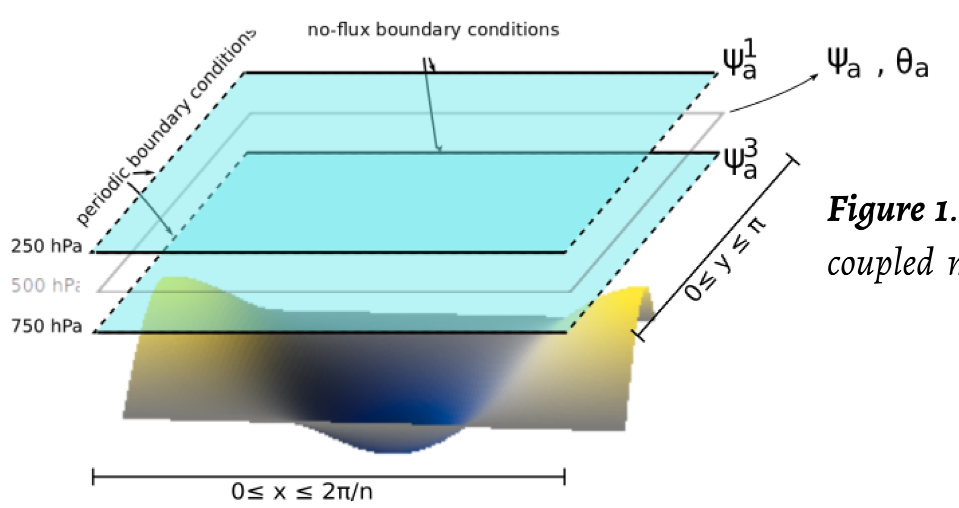

Figure 1. *Schematic representation of QGS land atmospheric-coupled model (left)*

Qgs is a Python implementation of an atmospheric model for mid latitudes (Demaeyer et al. 2020). It models the dynamics of a 2-layer quasi-geostrophic (QG) channel atmosphere on a beta-plane, coupled to a simple land component helps us to study dry atmospheric dynamics (Li et al.2017). The dynamics thus obtained allow one to identify typical features of the atmospheric circulation, such as blocked and zonal circulation regimes, with less computational cost.

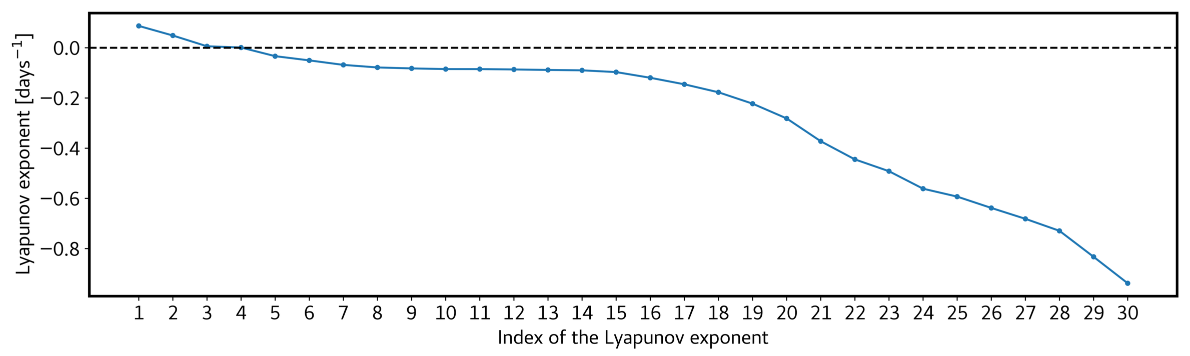

Figure 2. *Lyapunov Spectra of the QGS land atmospheric model for the 30-mode model version that is used for the study*

- The system under investigation has 3 positive, 1 zero and 26 negative Lyapunov exponents.
- Similarly to the ocean-atmospheric coupled model (Vannitsem, 2017), the spectrum contains a set of Lyapunov exponents forming a plateau close to 0.
- The amplitude of the Lyapunov exponents around this plateau is however quite substantial as compared to the coupled ocean-atmosphere model.
- This plateau is expected to be associated with the presence of the land whose typical time scales of variability are slower than the atmosphere.

II. Methodology

- Identified blocking regimes in the system by selecting appropriate parameters
- Characterized and classified blocking and zonal regimes using Gaussian mixture clustering
- Calculated the local Lyapunov exponents for the entire trajectory of the attractor to investigate predictability of the system and of the different regimes

III. Results and Discussion

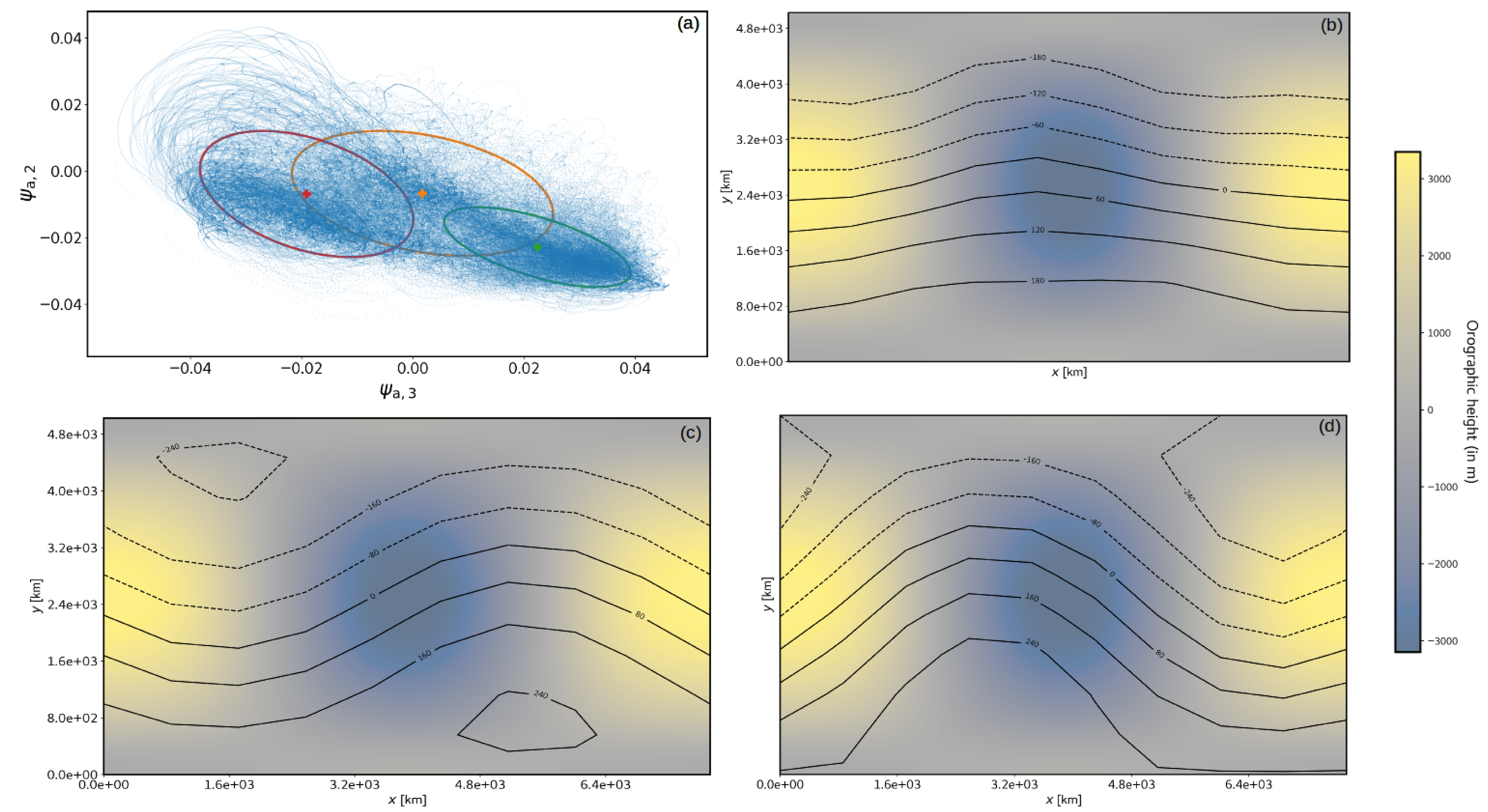

Figure 3. *Gaussian mixture clusters are represented with green, orange and red centres. Cluster with centre orange represent zonal regime which can be identified by the geopotential height of 500 hPa in panel (a). Other two clusters are blocking regimes attributed in panel (c) and (d).*

- Above panel indicates the existence of 3 major regimes, a zonal flow and 2 blocking patterns.
- Blocking high of event - 1 is formed just after the highest point of the applied topography where as in event - 2, it is formed before the heighest point.

Regime		Predictability
Zonal	→	6.418 +/- 3.185 days
Blocking - 1	→	13.236 +/- 3.185 days
Blocking - 2	→	14.232 +/- 3.136 days

IV. Conclusions

- Confirmed the existence of different atmospheric regimes (mainly blocking and zonal) in QGS land atmospheric coupled model using clustering method
- Blocking regimes are more predictable as compared to the zonal regime
- Both blocking events are having different charecterisctics as well as predictability horizon

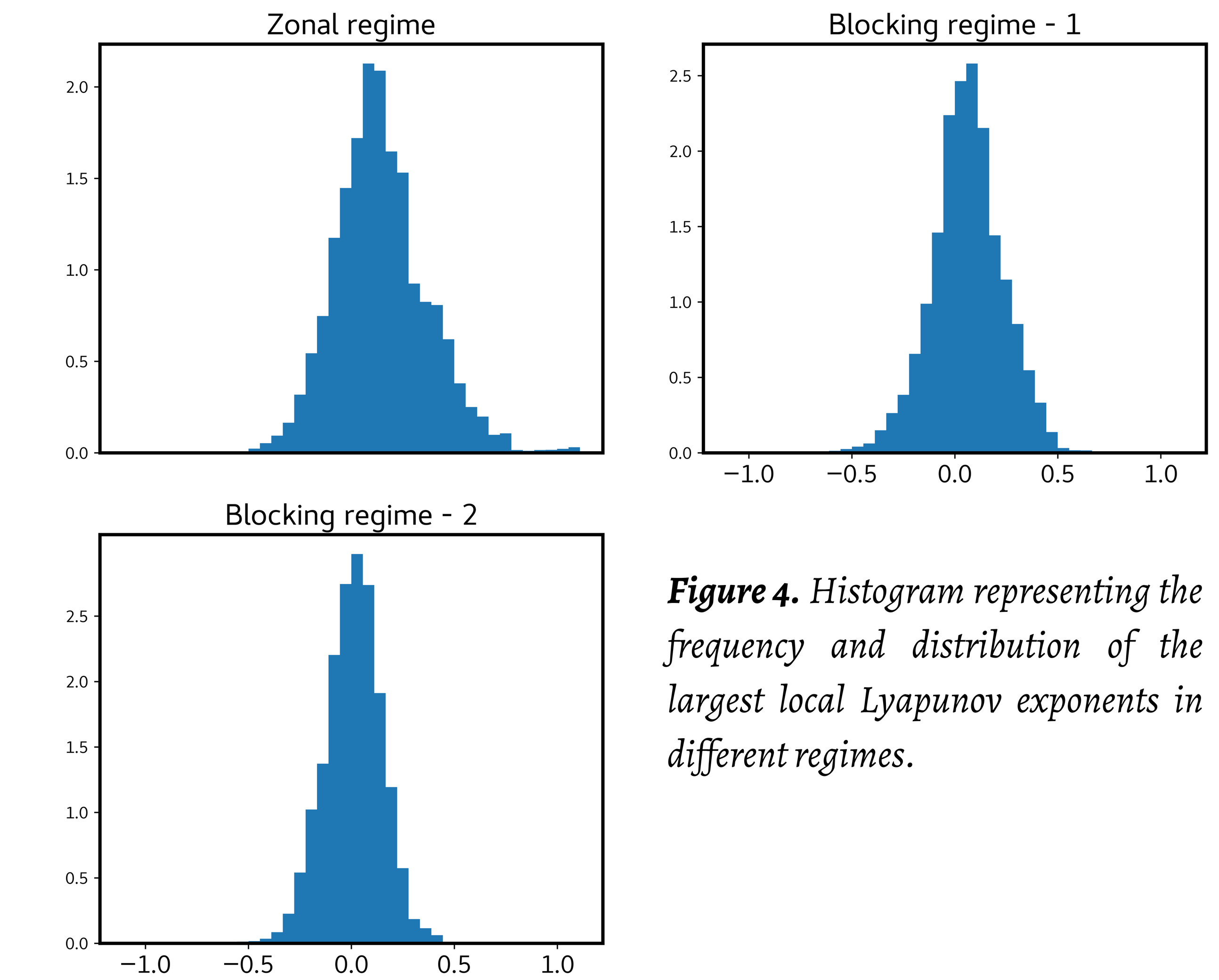

Figure 4. *Histogram representing the frequency and distribution of the largest local Lyapunov exponents in different regimes.*

- The frequency distribution of largest local Lyapunov exponents are staggered between -0.6 and 1.0 during the zonal regime
- Blocking events have much more concentrated frequency histogram and have lower value of largest Lyapunov exponent, hence their predictable horizon is larger compared to zonal regimes

V. References

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