More Frequent and Stronger Blocking Events with the Presence of Latent Heating for a Fixed Jet Speed in a Two-Layer QG model

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Background and Motivation

How the blocking will change in the future is uncertain as there are many processes involved (Woolings et al. 2018). Previous work show blocking can be affected by upstream latent heating (Steinfeld and Pfahl 2019, Neal et al. 2022). We aim to understand the role of future change of moisture on the blockings using a very simple model.

Key Question

How do the frequency and strength of blocking change with moisture in a very simple dynamical model?

Idealized Two-Layer QG model with moisture is used

(Lutsko and Hell 2021)

- Moisture's impact is controlled from $\boldsymbol{L}$.

$$\frac{\partial q_k}{\partial t} + J(\psi_k, q_k) = -\frac{1}{\tau_d}(-1)^k(\psi_1 - \psi_2 - \psi_R) + (-1)^k \boldsymbol{L}P - F_r$$

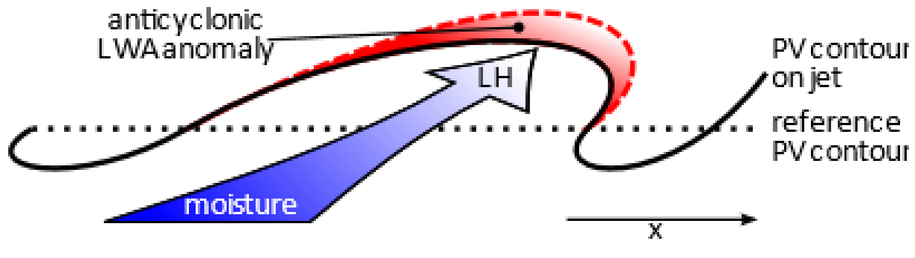
- Overall dynamics is controlled from U_o.

$$-\frac{\partial \psi_R}{\partial y} = U_o \mathrm{sech}(\frac{y}{\sigma})$$

- Moisture is controlled in the lower layer.

$$\frac{\partial m}{\partial t} + J(\psi_2, m) = E - P + \nabla \cdot \mathrm{u}_2$$

- All terms are nondimensionalized.
- We examine the parameter space of $\boldsymbol{L}$ and U_o. **The results are interpolated onto space of simulated $\overline{U}$ and $\boldsymbol{L}$.**



Blockings are identified and understood using the Local Wave Activity (LWA) framework

(Huang and Nakamura 2016)

- Local Wave Activity (A)

$$A = -\int_0^{\eta(x,y,k,t)} q_e(x, y+y', k, t)\, dy', \qquad q_e = q - Q_{REF}$$

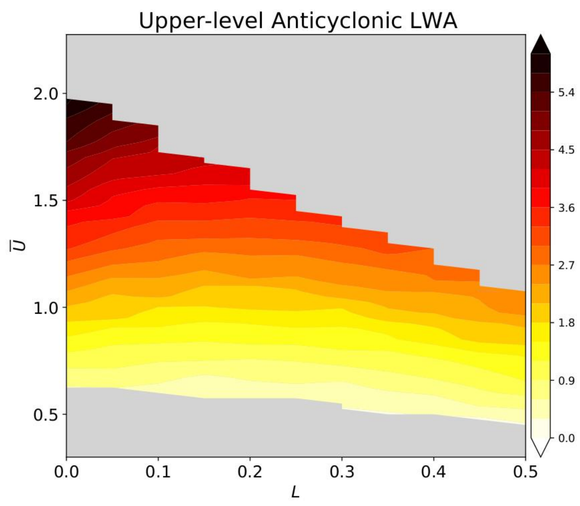
- LWA has cyclonic and anticyclonic components.
- LWA is controlled by dynamic and diabatic effects.

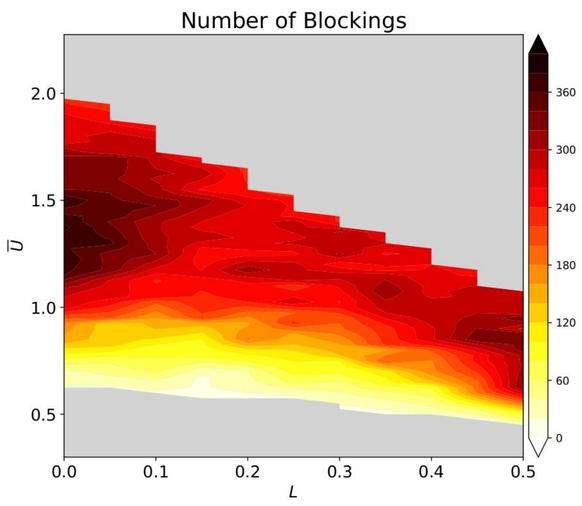
$$\frac{\partial A}{\partial t} = -\nabla \cdot F_{adv} - v_e q_e + \int_0^{\eta(x,y,k,t)} LP\, dy' + Dry\ Res$$

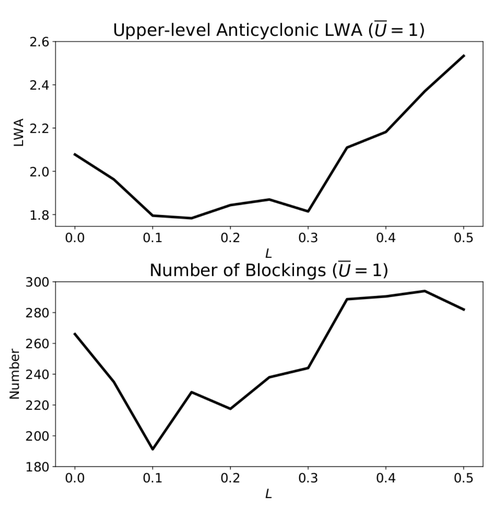
Blockings are identified in the following steps:

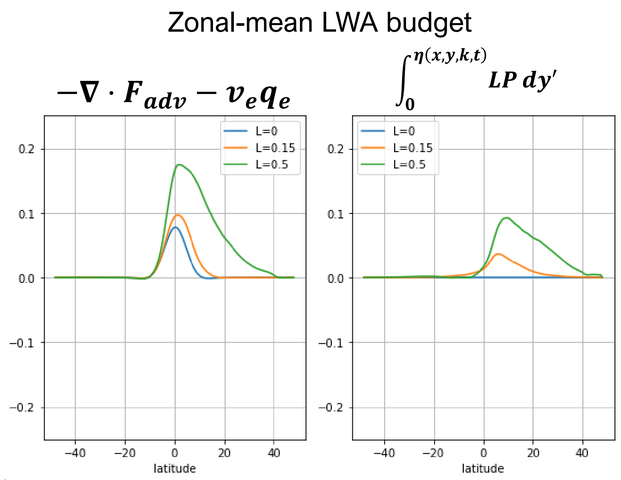
I. **[Intensity]** Using clustering algorithm, connected grid points with LWA at least 6 times the $\overline{U}$ is identified in the x, y, t space.
II. **[Persistence]** The identified systems should last longer than 7 model time steps (this is roughly similar to 3 Earth days).
III. **[Stationary]** The identified systems should propagate slower than 0.1 (this is roughly similar to 40 km day^{-1}).

High moisture limit: more frequent blockings with increasing moisture

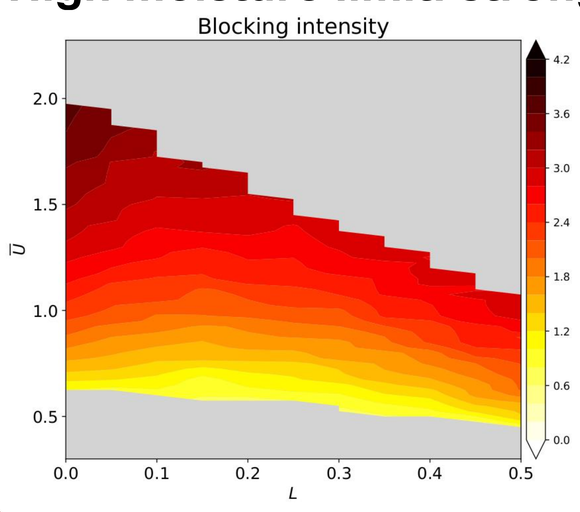


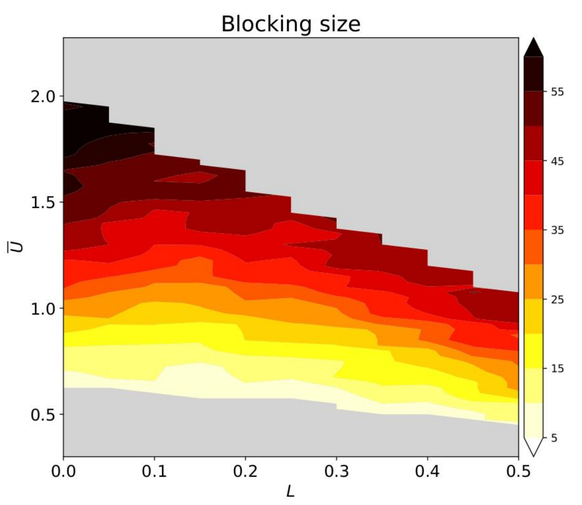


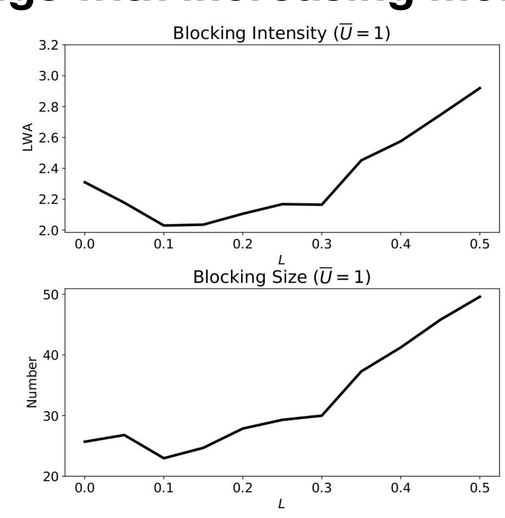


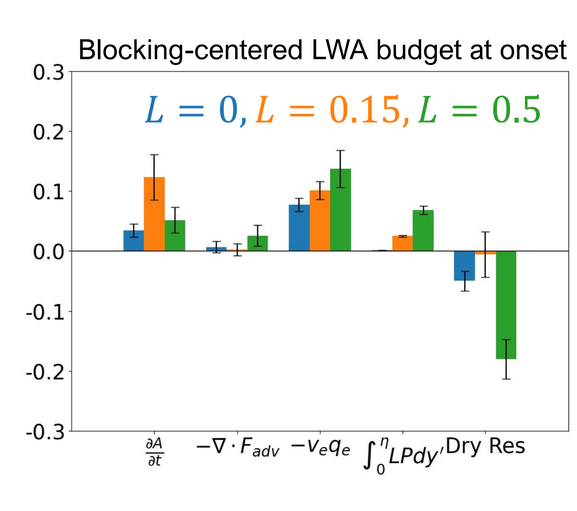


High moisture limit: stronger and more intense blockings with increasing moisture

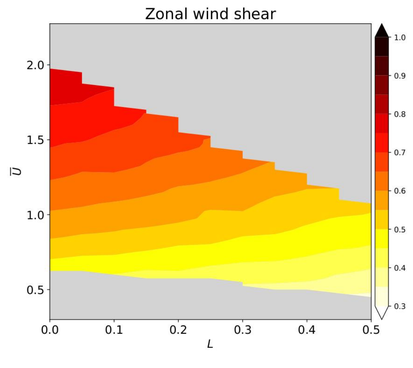


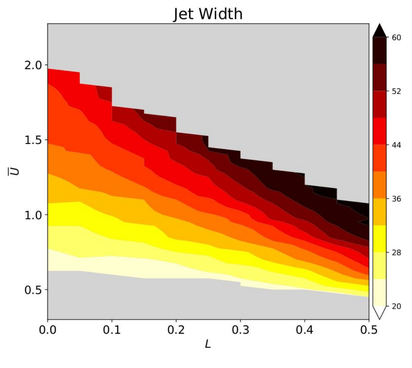






Low moisture limit: changes in the jet structure are important





- Decreasing shear with moisture provides less favorable condition for eddy forcing.
- Increasing jet width suggests broader regions are favorable for eddy forcing.
- Linear instability analysis shows non-monotonic behavior in growth rates of high-frequency waves.

Take-Away Messages

- Large increase in latent heating increases the number of blocks and their intensity.
- Consistent with the PV and LWA framework, more LWA is produced through latent heating. Moreover, increased latent heating is connected to increased eddy forcing.
- The blocking number and intensity change for small increase in latent heating is more complicated.