Some comments on “Transient anticyclonic eddies and Their relationship to Atmospheric blocking persistence“ by Suiters et al.

More recently, I have read a manuscript “Transient anticyclonic eddies and their relationship to atmospheric blocking persistence”. I found that this manuscript is interesting, but this study is a phenomenological one, which cannot identify the causal relationship between transient anticyclonic eddies and blocking persistence. Because this study is in my research domain and the relation between blocking and transient synoptic eddies has been examined in my group before many years, below I give some comments on this manuscript to help the authors understand how transient eddies reinforce and maintain blocking and how intensified blocking deforms transient eddies.

Comments:

(1) In the daily geopotential height field of a blocking flow, the synoptic-scale anticyclonic (cyclonic) eddies are often seen to be intensified and shifted northward (southward) during the blocking growth and maintenance episodes (Berggren et al. 1949). Such an eddy deformation is also referred to as eddy straining or cyclonic wave breaking (CWB). Thus, many investigators inferred that eddy straining or CWB leads to blocking onset. Based on this, they also concluded that persistent eddy straining or persistent CWB leads to persistent blocking. In fact, the relationship between transient eddies and blocking is a chicken-egg problem. Thus, one cannot examine the causal relationship between the blocking persistence and transient anticyclonic eddies only using the identification method. However, this issue can be solved by a nonlinear theoretical model that considers a blocking as a nonlinear initial value issue of the blocking interacting with synoptic-scale eddies. The relationship between blocking and transient synoptic-scale eddies and what determines the persistence of atmospheric blocking has been widely examined in a nonlinear multi-scale interaction (NMI) model and has been clearly clarified (Luo

et al. 2005, 2014, 2019).

(2) The mutual relationship between the blocking and synoptic-scale eddies has been examined in Luo (2005). It is found that the blocking and synoptic-scale eddies are dependent each other. Because of the feedback of the intensified blocking on the preexisting synoptic-scale eddies prior to entering the blocking region, the preexisting synoptic-scale eddies may slow down and undergo a north-south straining, which are dominated by deformed eddies with meridional tripoles.

(3) Atmospheric blocking persistence has been first investigated by Yeh (1949), who found that atmospheric blocking tends to be long-lived in high latitudes. Luo et al. (2019) found from the NMI model that when the north-south gradient (PVy) of background potential vorticity is smaller, atmospheric blocking tends to be more persistent. Note that PVy is a modified β。 When the background westerly wind or meridional temperature gradient is weaker or the latitude is higher, PVy is smaller. In this case, the blocking system has weaker energy dispersion and stronger nonlinearity so that the blocking can be more persistent. Thus, the persistence of atmospheric blocking is mainly determined by the background condition (i.e., the magnitude of PVy), rather than synoptic-scale eddies, even though synoptic-scale eddies have different phase speeds under different background conditions. As also noted by Luo et al (2019), the eddy forcing induced by preexisting synoptic-scale eddies prior to entering the initial blocking is more persistent as PVy is smaller. In this case, atmospheric blocking can be more persistent due to persistent eddy forcing by preexisting synoptic eddies prior to entering the initial blocking.

(4) The interaction between transient eddies and blocking satisfies the symbiotic relation noted by Cai and Mak (1990). The onset and intensification of atmospheric blocking not only depends on the spatial structure of preexisting synoptic-scale eddies prior to entering the initial blocking, but also the deformation of preexisting synoptic-scale eddies depends on the intensification of atmospheric blocking. Thus, the blocking and synoptic-scale eddies are coupled together and dependent each other. For an given initial blocking, the initial blocking can be amplified into a

typical blocking if preexisting synoptic-scale eddies (ψ_1') prior to entering the initial blocking satisfy $\frac{\partial q}{\partial t} \simeq -\nabla \cdot (\mathbf{v}_1' q_1')_P$ (Luo et al. 2014), where q is the PV anomaly of the initial blocking, $\mathbf{v}_1'$=(-$\partial \psi_1'/\partial y$, $\partial \psi_1'/\partial x$) and q_1'=$\nabla^2 \psi_1'$. In other words, when the eddy forcing $-\nabla \cdot (\mathbf{v}_1' q_1')_P$ has the same spatial structure as the PV anomaly q of the initial blocking, a typical blocking can form from this initial blocking under the eddy forcing. When the initial blocking is intensified (Fig. 4a of Luo et al. 2014), the feedback of intensified blocking can cause the deformation of preexisting synoptic-scale eddies. In this case, deformed eddies (ψ_2') are produced. The daily synoptic-scale eddy field during the blocking episode can be represented by $\psi' = \psi_1' + \psi_2'$. Because ψ_2' includes the amplitude of the intensified blocking, the synoptic-scale eddies in the daily synoptic-scale eddy field ($\psi' = \psi_1' + \psi_2'$) are inevitably intensified, split into two branches and slowed down with the growth of blocking (Fig. 4b of Luo et al. 2014). This case corresponds to eddy straining. In the daily total field (the sum of mean flow, blocking part and $\psi' = \psi_1' + \psi_2'$) of the blocking flow, anticyclonic (cyclonic) eddies are intensified and shifted northward with the blocking growth (Fig. A2), which corresponds to CWB (Fig. 4c of Luo et al. 2014). When the blocking is more persistent (Luo et al. 2019), more transient anticyclonic eddies are seen due to the persistent feedback of blocking because there is a symbiotic relationship between the blocking and anticyclonic eddies (Fig. 4c of Luo et al. 2014). This does not imply that persistent blocking is produced by more anticyclonic eddies.

(5) The authors concluded that blocks can be maintained through repeated absorption of anticyclonic eddies. In fact, blocking events do not always occur, but synoptic-scale anticyclonic eddies can often be seen. Why some anticyclonic eddies can be absorbed into the blocking, but others cannot. The authors should answer under what condition the anticyclonic eddies can be absorbed into the blocking to

maintain it. This problem is easily explained in terms of $\frac{\partial q}{\partial t} \simeq -\nabla \cdot (\mathbf{v}_1' q_1')_P$ because only some of synoptic-scale eddies can meet this condition. When the preexisting synoptic-scale eddies (ψ_1') drive the onset and intensification of blocking (q), the feedback of blocking can cause the deformation of preexisting synoptic-scale eddies to result in the repeated absorption of anticyclonic (cyclonic) eddies by the blocking (Fig. A2 or Fig. 4c of Luo et al. 2014). When the blocking has longer lifetime, there are inevitably more anticyclonic (cyclonic) eddies within the blocking regions. Thus, persistent blocking can often occur together with more anticyclonic (cyclonic) eddies. But, this cannot lead us to conclude that more anticyclonic (cyclonic) eddies lead to persistent blocking.

I suggest that the authors should read the following references to improve the understanding of how the blocking and synoptic-scale eddies interact and what leads to the persistence of atmospheric blocking.

References:

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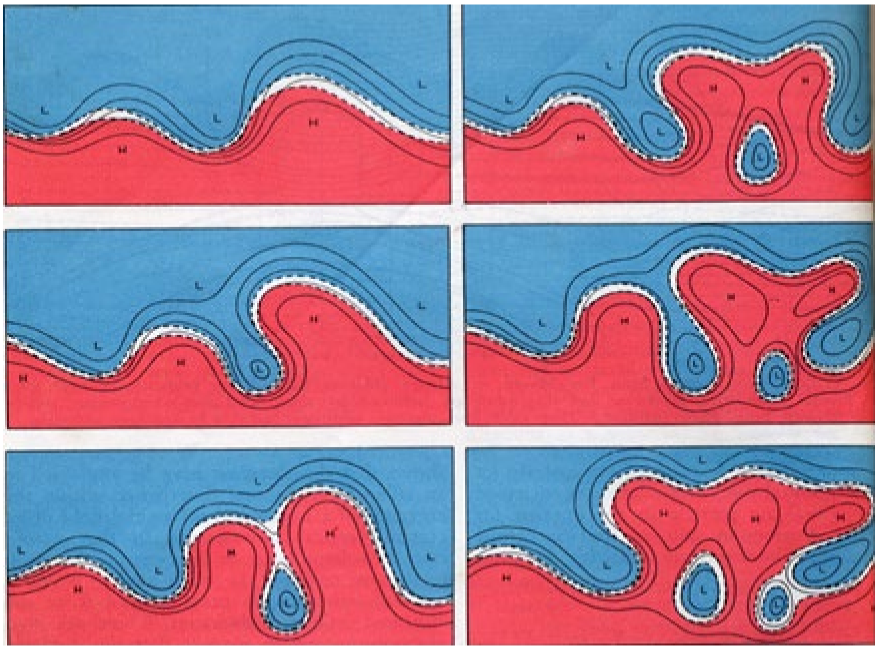
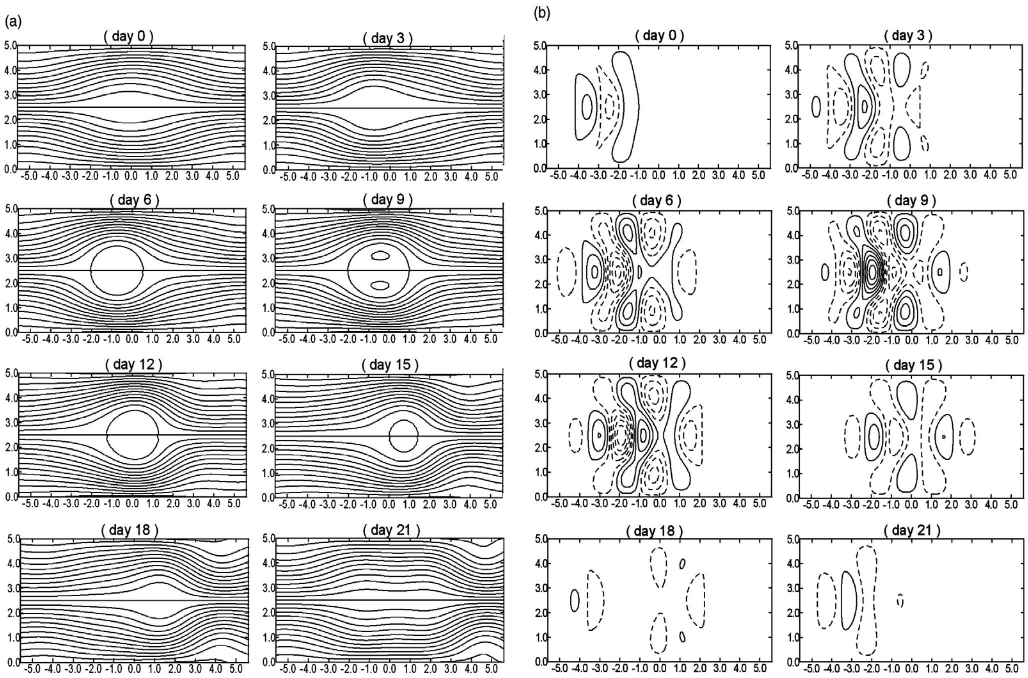


Figure A1. Idealized sketches of the development of unstable waves at the 500 mb level, in association with the development of a blocking anticyclone in high latitudes. Cold air is in blue color and warm air in red. Solid lines are stream lines and broken lines the frontal boundaries (Taken from Berggren et al. 1949).



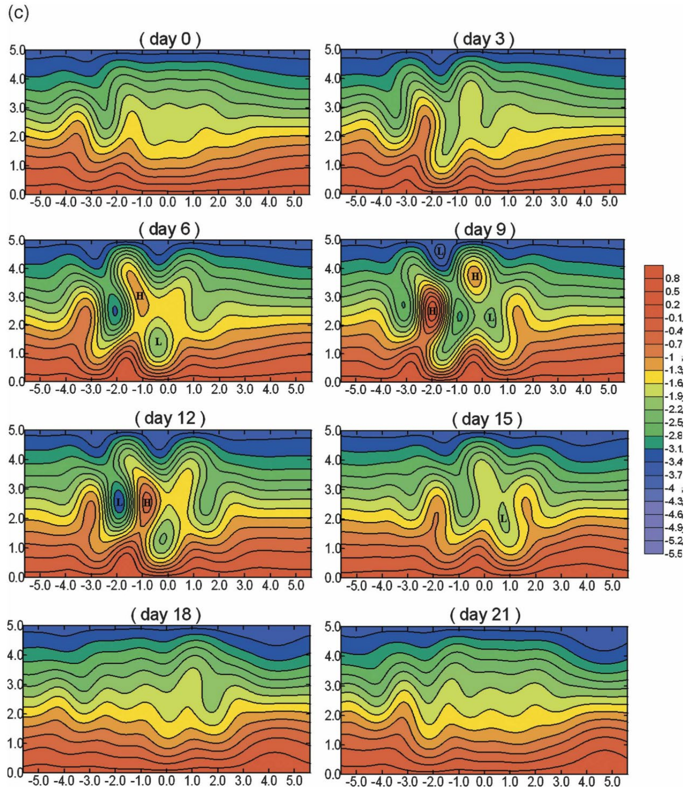


Figure A2. Life process of blocking interacting with synoptic-scale eddies obtained from the NMI model (Fig. 3 of Luo 2005).