Cross-equatorial Rossby wave propagation in JJA climatological flow

Yanjie Li¹, Jianping Li², Sen Zhao³, Feifei Jin³, Jin Feng⁴

1. Institute of Atmospheric Physics, Chinese Academy of Sciences;
2. GCCES, Beijing Normal University;
3. University of Hawaii, Honolulu, USA
4. Institute of Urban Meteorology, CMA, Beijing

06/19/2018, Boulder
Development of the Rossby wave propagation theory

**Basic model:**

- **Mid-latitude β-plane**
  - (Rossby 1939, 1945; Yeh 1949)
  - 
  \[
  \left( \frac{\partial}{\partial t} + \mathbf{u} \cdot \nabla \right) \nabla^2 \psi + \beta \frac{\partial \psi}{\partial x} = 0
  \]

- **Spherical coordinate**
  - 
  \[
  \left( \frac{\partial}{\partial t} + \frac{u}{\cos \phi} \frac{\partial}{\partial x} + \frac{v}{\cos \phi} \frac{\partial}{\partial y} \right) \left( \frac{\nabla^2 \psi}{\cos^2 \phi} \right) + \frac{2\Omega}{a} \frac{\partial \psi}{\partial x} = 0
  \]

**Dimension:**

- Yeh 1949

**Basic state:**

- **Rest Atmos**
  - (Yeh 1949)

- **Lat-Varying**
  - (Hoskins and Karoly 1981)

- **Lon- and Lat-varying**
  - (Webster and Holton 1982; Hoskins and Ambrizzi 1993)

Cited from [http://class.atmos.ucla.edu/aos102/rossby.html](http://class.atmos.ucla.edu/aos102/rossby.html)
Cross-eq propagation in DJF through the tropical westerly window

(Tropical westerly duct)

(Li et al., 2015, follow HA93)
Including V provides possibility of crossing easterly

Stationary waves could cross the tropical easterly with zonal mean meridional wind V included in the basic state (Schneider and Watterson 1984, Miu et al. 1990). However, few studies has considered this issue in JJA climatological flow, which is accompanied by strong monsoonal cross-eq flow.

Stationary wavenumber HA93

\[ K_{SS}^2 = \frac{\bar{q}_y}{\bar{u}_M} \]

Stationary wavenumber with-V

\[ K_S^2 = K_{SS}^2 \frac{1 + \tan \alpha \cdot \tan \eta}{1 + \tan \alpha \cdot \tan \gamma} \]

\[ \tan \alpha = \frac{l}{k}, \tan \eta = \left. \frac{dy}{dx} \right|_{\bar{q}}, \tan \gamma = \left. \frac{dy}{dx} \right|_{\bar{\psi}} \]

(Hoskins and Ambrizzi 1993)

(tan \alpha \to 0 \leftrightarrow L_x \ll L_y \]

or

\[ \tan \eta \approx \tan \gamma \]

(tan \alpha \neq 0 \leftrightarrow L_x > L_y \]

or

\[ \tan \eta \neq \tan \gamma \]

(Li et al., 2015)
With $V$, stationary waves can exist in tropical easterly

Setting of the ideal basic flows

At critical latitude $U=0$,

Tilt of constant phase line $\tan \alpha = \frac{1}{C} \frac{\bar{q}_y 1}{k^2 \bar{v}}$

Meridional group velocity $v_g \propto \bar{v}$

Meridional wavenumber solutions in ideal basic flows; With-$V$: red; Without-$V$ (same as HK81): gray

(Li et al., 2015)
Preferred tilting and direction for waves across easterly

Specific tilt structure

\[
\tan \alpha = \frac{1}{C} \frac{\bar{q}_y}{k^2 \bar{v}}
\]

Barotropic Model results

Propagation direction along with the meridional background flow

\[
\nu_g \propto \bar{v}
\]
Cross-EQ propagation under JJA climatological flow

Steered by the strong cross-eq flow

Preferred spot: Asian-Australian Summer monsoon region

Barotropic model results to NH and SH forcing.

Wave ray trajectories results starting from NH and SH tropics.

(Li et al., 2015)
Summary

- Stationary waves could propagate across the tropical easterly under the JJA flow;
- Preferred tilting structure and direction determined by $V$;
- Preferred spot: Asian-Australian Monsoon region;
- Cross-EQ stationary wave propagation could contribute to the interhemispheric teleconnection related to the Asian monsoon (Sakaguchi et al. 2016; Zhao et al., under review).
- Wave ray tracing method based on the theory in HN flow provides a useful tool to identify the role of the wave propagation in the teleconnection.
On-going works

• How will the cross-eq Rossby wave propagation change under the climate change?

• Rossby wave behaviors in high-latitude, and its role in Arctic warming effect on mid-latitude extreme events.

• Samples of the basic state in CESM simulations.
Thanks for your attention
lyj@mail.iap.ac.cn

Related publication:

- Zhao Sen, Jianping Li, Yanjie Li. 2015: Dynamics of an interhemispheric teleconnection across the critical latitude through a southerly duct during boreal winter, J. Climate, 28, 7437-7456, doi:10.1175/JCLI-D-14-00425.1.
Applied to the SH connection with NH convective forcing

IPCO: the second dominant mode of convection over the Indo-Pacific region during JJA;
Connected with EASM closely;
Connected with Brazil and Australia rainfall significantly.

(Zhao et al., 2018, CD, under review)
Applied to the upscale effects on the SH jet of MPAS-CAM4 variable-resolution simulations

Refinement in Asia can enhance wave sources and upper southerly flow.

Stationary wave related to the ASM precipitation could propagate to the SH middle latitude, which is an important pathway for this upscale effect.

Sakaguchi et al. 2016