Relationship between Northern Hemisphere stationary planetary wave activity and East Asian winter monsoon

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BACKGROUND

Previous researches on the East Asian winter monsoon (EAWM)
- Mainly focused on the external forcing such as SST, Tibetan Plateau, and soil moisture.
- Less attention was paid to the internal dynamical process.

The physical nature of stationary planetary waves (SPW) and the EAWM
- SPW are forced in the troposphere by the topography and diabatic heating arising from the distribution of land and sea.
- Land-sea thermal contrast is fundamental to monsoon circulations.
- Hence, it is reasonable to conduct an investigation into the relationship between the SPW activity and the EAWM.

The variations of upper atmosphere and its association with SPW and EAWM
- In boreal winter, the stratospheric and tropospheric circulations are dynamically coupled through the interaction of mean flow with upward propagating SPW.
- The stratospheric polar vortex may modify the structure of tropospheric SPW by the influence on the vertically propagating waves.
- The equatorial quasi-biennial oscillation (QBO) is one of the strongest influences on extratropical stratosphere.
- QBO signal is transmitted to extratropical latitudes not only in the upper atmosphere but also to the surface.

PURPOSE OF THIS STUDY

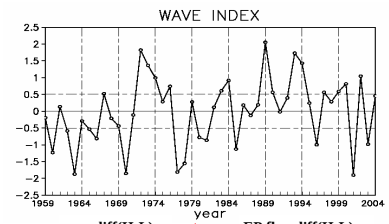
1. Investigate the relationship between the SPW activity and the EAWM, and associated mechanism.
2. Investigate the forcing from upper atmosphere on the EA climate: the possibility of QBO modulation on the relationship between the SPW activity and the EAWM.

DATA AND METHODS

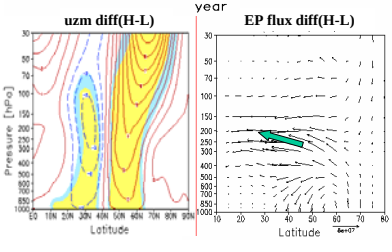
Data:
- Monthly mean NCEP/NCAR reanalysis.
- Observed surface air temperature (SAT) from 160 China stations.

Methods:
- Eliassen-Palm flux (EP flux) and its divergence.
- Composite and correlation analyses.

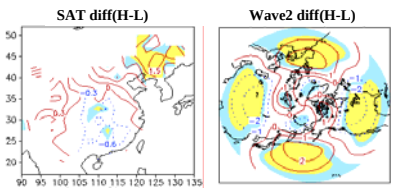
RESULTS



By examining the teleconnectivity in the EP flux divergence field in the latitude pressure domain, Chen et al. (2002) defined a SPW index to describe the SPW activity mainly in the troposphere.



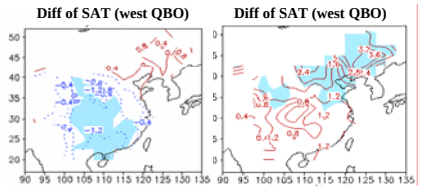
High SPW index corresponds to an enhanced equatorward propagation of SPW activity, and a dipole in zonal mean zonal wind field, which resembles the NAM signal.



More disturbances are found in mid latitudes in high SPW phase. The change in wave number 2 decreases the pressure gradient over East Asia, and leads to a warming over Northeast China and cooling over South China.

Distribution of the winters in the high or low SPW indices for the westerly and easterly phases of the QBO.

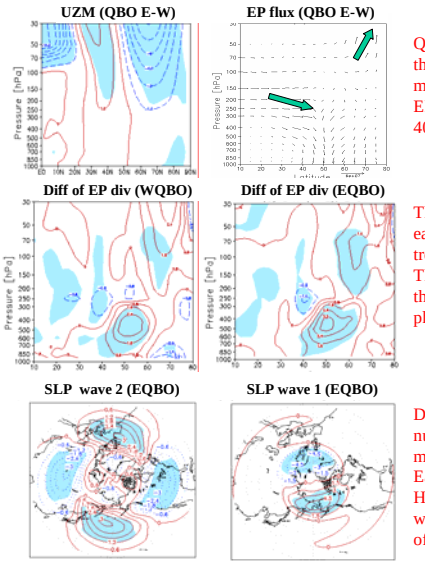
	QBO Westerly	QBO Easterly
High SPW index (13)	1967, 1972, 1974, 1976, 1983, 1989, 2000 (7)	1973, 1990, 1994, 1997, 1999, 2002 (6)
Low SPW index (14)	1960, 1962, 1965, 1970, 1981, 1996, 2003 (7)	1963, 1966, 1967, 1978, 1980, 1985, 2001 (7)



The high and low SPW index years are further grouped according to the phase of QBO.

It is found that the SPW activity- East Asian winter climate relationship is different during different phases of QBO.

Only during the east phase of QBO, the high SPW index – Northeast Asian warming relationship is significant. While during the west phase of QBO, the warming over Northeast China is not statistically significant.



QBO can exert significant influence on the extratropical zonal wind, which in turn modulate the propagation of SPW. Hence, EP flux convergence is enhanced between 40N-50N during east phase of QBO.

The enhanced EP flux convergence during east phase of QBO leads to an enhanced tropospheric SPW teleconnectivity. Therefore, the variations associated with the SPW activity is intensified during east phase of QBO.

During the east phase of QBO, the wave number 2 and wave number 1 disturbances may both reduce the pressure gradient over East Asia, leading to significant warming. However, these disturbances are much weaker and insignificant during west phase of QBO.

CONCLUSIONS

1. There exist two regimes of wintertime planetary wave activity on interannual time-scales. One (high index) is the wave energy more propagated equatorward in the troposphere with a weaker upward propagation into the stratosphere, the other (low index) corresponds to the opposite situation.
2. High index winter of wave activity corresponds to a strong and cold polar vortex. In the meantime, the interaction between the planetary waves and the East Asian monsoon weakens the East Asian trough. And significant warming appears in the northeastern Asia.
3. The relationship between the wave activity and East Asian winter climate is strongly modulated by the QBO. Only when the QBO phase is easterly, the anomalies in East Asian climate associated with the wave activity become statistically significant.
4. The mechanism is suggested to result from the indirect influence of the QBO via the extratropical stratospheric circulation changes. In the easterly (westerly) QBO phase winters, the variations of wave activity tend to be enhanced (reduced), and as a result, the differences in the East Asian climate anomalies become larger (smaller) and robust (insignificant).

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