The tropospheric response to the zonal asymmetric momentum torques: implications for the downward response to wave reflection and SSW events

האוניברסיטה העברית בירושלים
THE HEBREW UNIVERSITY OF JERUSALEM

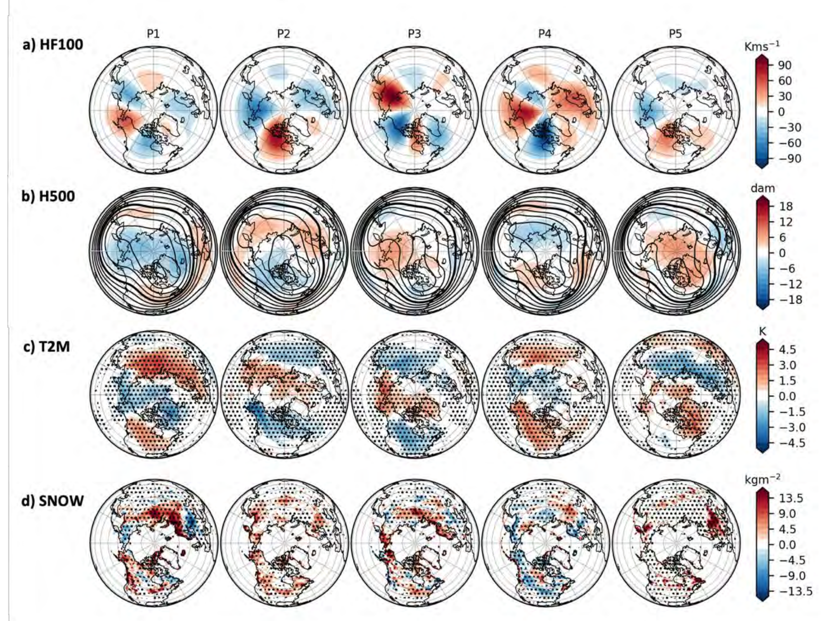
Wuhan Ning, Chaim I. Garfinkel, Ian White, and Judah Cohen

Correspondence: wuhan.ning@mail.huji.ac.il chaim.garfinkel@mail.huji.ac.il

1. Introduction

1. Does the surface impact of polar vortex anomalies depend on the zonal structure of the vortex? Specifically, does the direction in which a polar vortex is displaced matter for its impact?
2. We use the model of an idealized moist atmosphere (MiMA) to study the downward response to reflection and SSW events by applying asymmetric momentum torques to the zonal momentum budget.

2. Research Background/Motivation



Agel, et.al. 2024 (submitted)

- P1 denotes strong vortex states while P2-P5 denotes moderate and weak vortex states.
- P2and P3 can result in the cooling in North America and Europe.
- Our goal is to isolate the role of the the vortex anomaly for the surface impact from any precursor wave pattern)

3. MiMA experiments

- The applied momentum torque to model's zonal momentum budget:

$$\boldsymbol{F(\lambda,\varphi,p,t) = \Lambda(\lambda)\Phi(\varphi)H(p)\tau(t)}$$

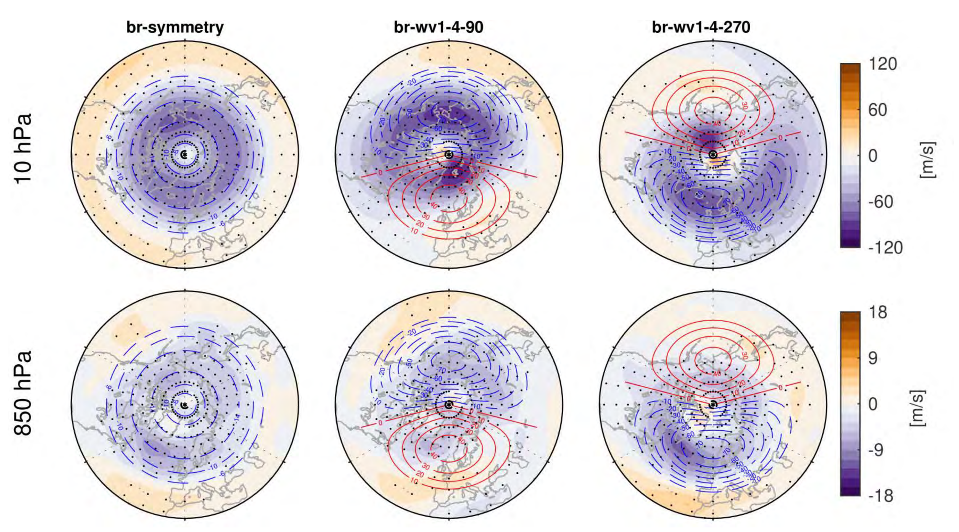
$$\Lambda(\lambda) = 1 + M_{FAS} * sin(k * (\lambda - \lambda_0))$$

$$\Phi(\varphi) = M_{FS} sin(\pi \frac{\varphi - \varphi_L}{\varphi_H - \varphi_L})$$

$$H(p) = \begin{cases} \frac{P - P_b}{P_t - P_b}, & if\ P_b < P < P_t, \\ 1, & if\ P \leq P_t \\ 0, & if\ P \geq P_b \end{cases}$$

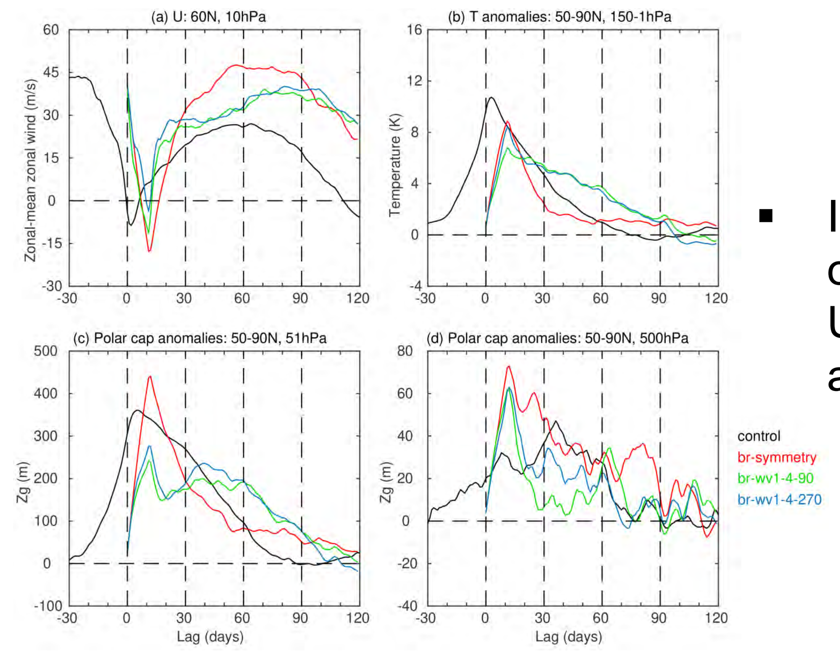
$$\tau(t) = \begin{cases} 1, & if\ 0 < t - t_0 \leq N_d \\ 0, & otherwise \end{cases}$$

4. Wave forcing & Zonal wind



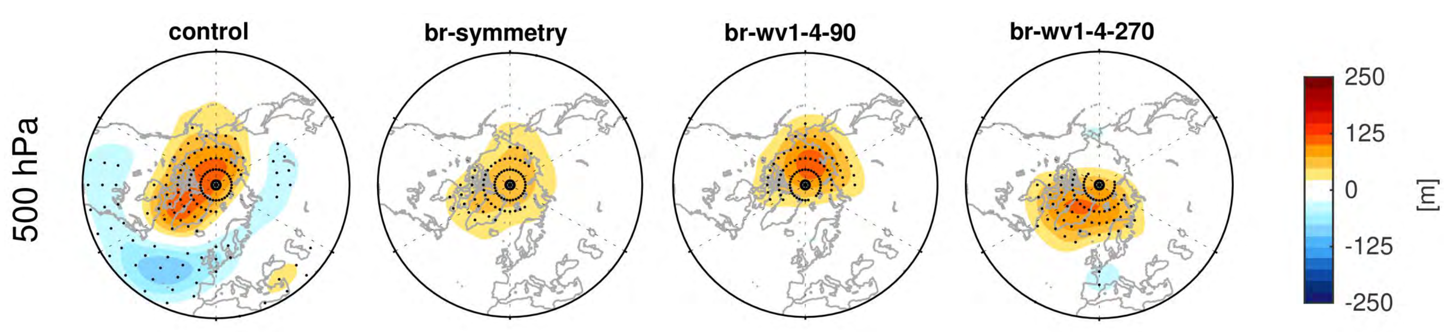
- The forcing allows us to alternately decelerates westerlies to easterlies in the zonal mean, or just in the western or eastern hemispheres. Surface impact is qualitatively different.

5. U & T & Polar cap



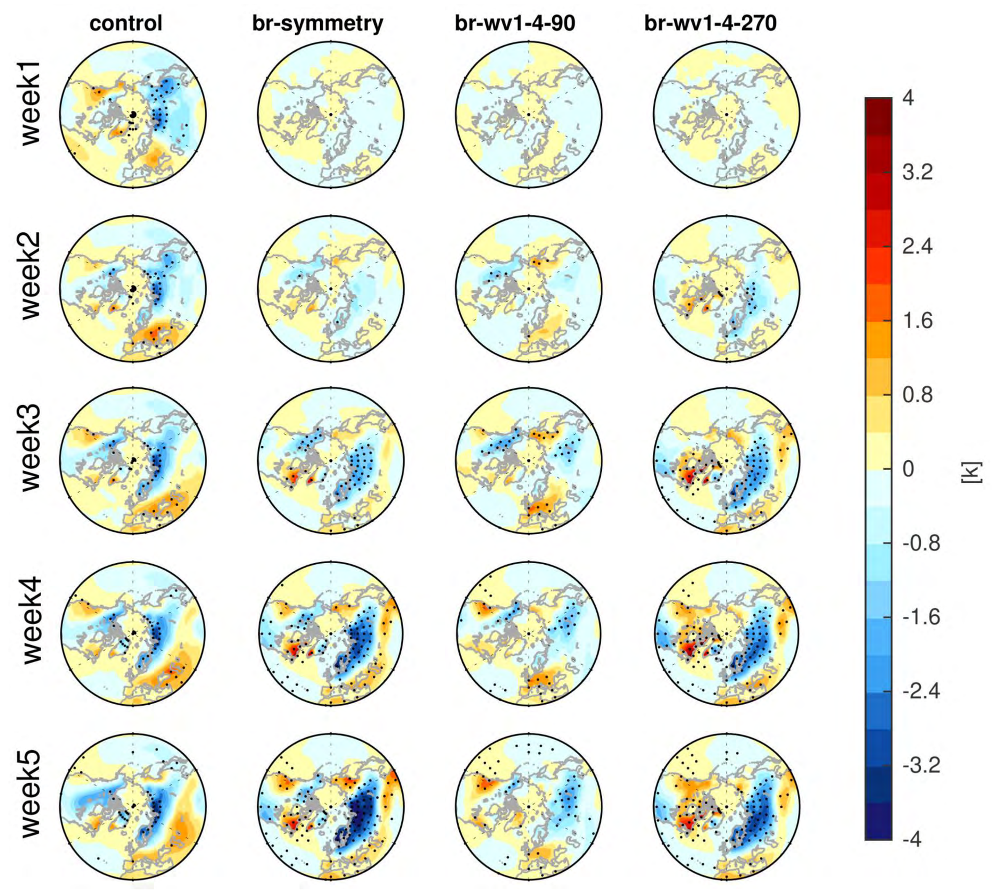
- In all cases the zonal mean structure of the SSW events are similar: U1060 easterlies, warmer polar cap, and higher geopotential height.

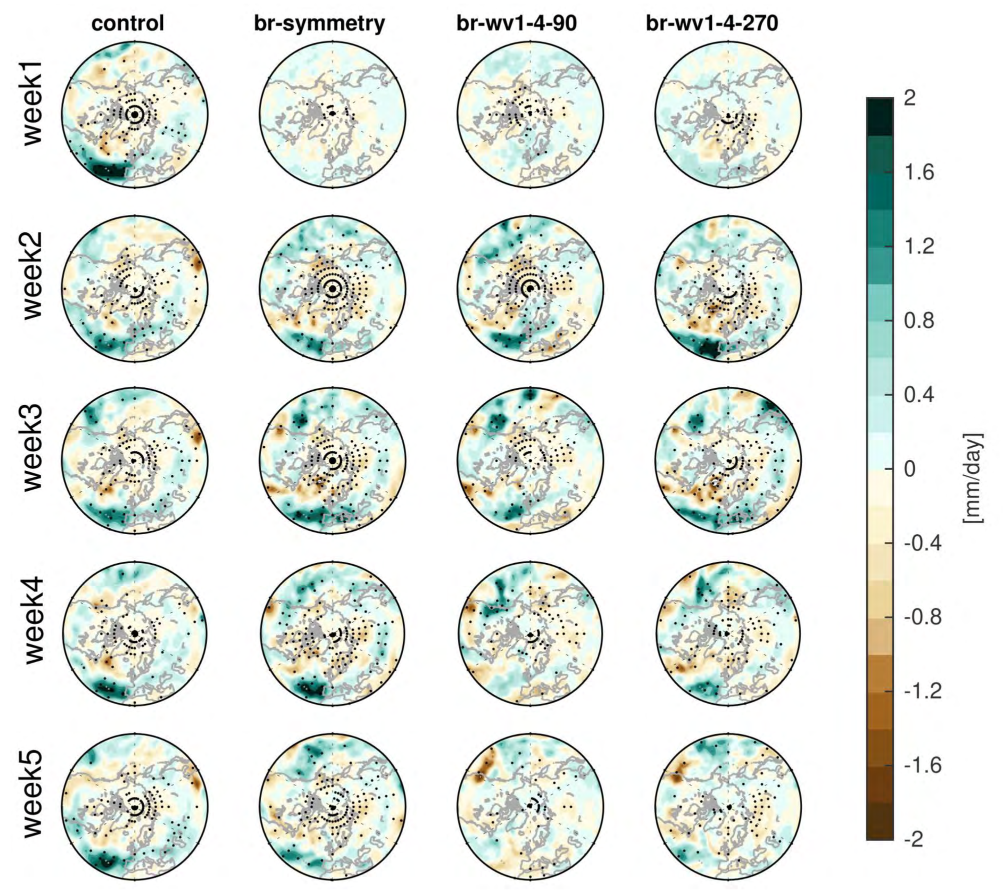
6. Zg, 500 hPa, week1



- The control and symmetric have similar response while *90* and *270* cases have the opposite phase response in the troposphere.

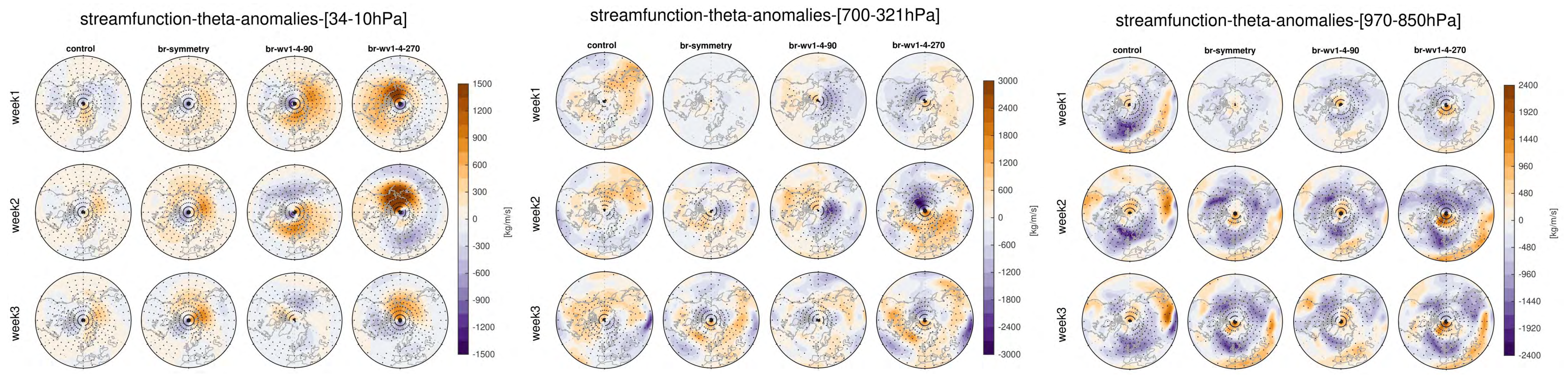
7. Surface Temperature & Precipitation





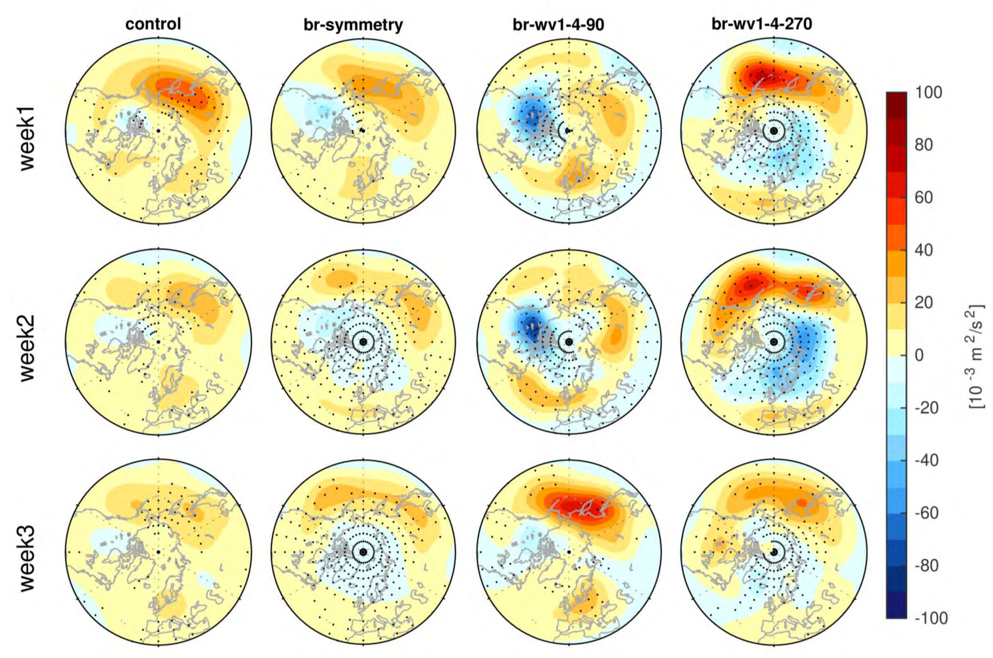
- Similar impacts in control and symmetric branch cases with cooling over north Eurasia and warmer Eastern Canada and subtropical Eurasia.
- The *90* case shows cooling over North America, while *270* case shows cooling over Eurasia.
- The rainfall dipole in Iberia/Scandanavia in control and symmetric is much weaker in *90* than in *270*. In *90* case, the impact on Western North America much more pronounced.

8. Streamfunction



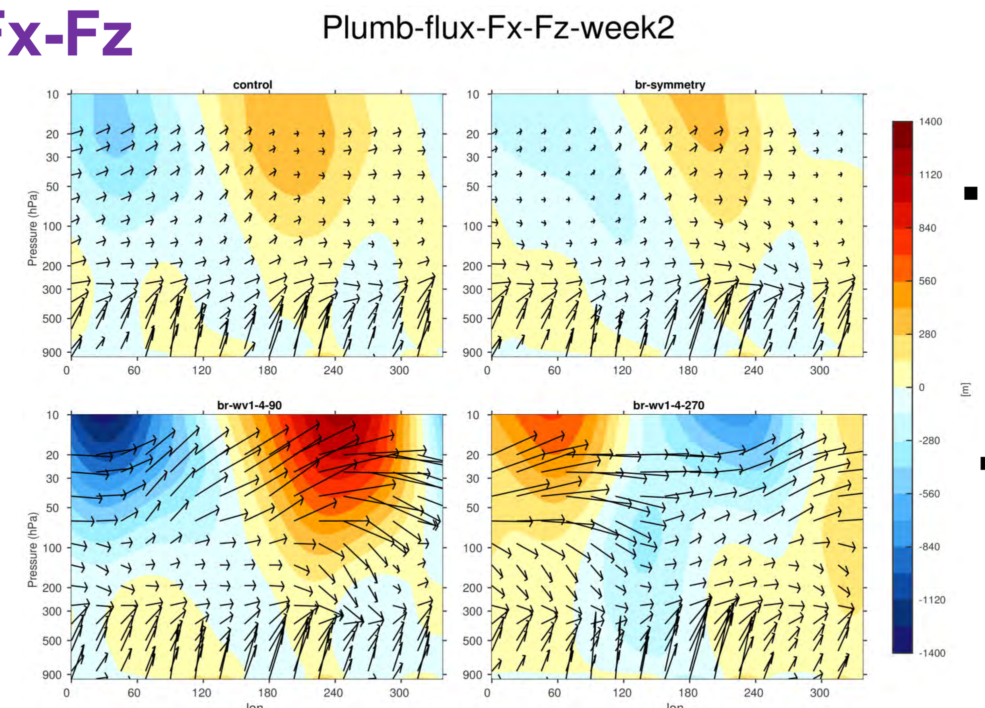
- The streamfunction zonal dipole in the stratosphere is balanced by an opposite signed dipole in the free-troposphere, though near the surface other factors play a role.

9. Fz, 93 hPa (raw field NOT anomalies)



- Negative Fz shows the downward propagation of quasi-stationary waves over north America for *90* and northern Eurasia for *270* case.

10. Fx-Fz



- The eddy of geopotential height tilts eastward with height is helpful for upward propagation while downward tilting indicates downward propagation.
- For *270* case, the waves are reflected over north Europe while other runs, especially *90*, reflected over North America.

11. Key Conclusions

1. The asymmetries of wave forcing result in an asymmetric response in stratosphere and lower troposphere.
2. The opposite phase of wave forcing have different impacts on the response of surface temperature and precipitation, which can be explained by the stream function of divergent part of meridional wind.
3. The waves are reflected over North America and North Europe, which is strongly affected by the phase of applied wave forcing.