Investigating the Link Between Sudden Stratospheric Warming and Tropospheric Blocking in the Northern Hemisphere

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Introduction

- Mid-tropospheric blocking (anticyclone persistence/stationarity) occurs approximately 4-8 times per winter.
- Polar stratospheric vortex is the defining feature of the wintertime stratosphere, but breaks down approximately 8 times per decade, called sudden stratospheric warmings (SSWs) and are frequently associated with mid-tropospheric blocking events (Martius et al., 2009).
- Thus blocking occurs more frequently without an SSW, though SSWs are almost invariably preceded by a blocking event, suggested also by the results of Baldwin and Holton (1988).

Methods and Data

- NCEP/NCAR Reanalysis, interpolated to 17 pressure levels. Horizontal resolution of 2.5°x 2.5°.
- Modified Pelly and Hoskins (2003) blocking index for isobaric Ertel's potential vorticity (EPV) as in equation 1

$$B(t,\phi_0,\lambda_0) = \left(\int_{\lambda_{-1}}^{\lambda_{+1}}\int_{\phi_{-1}}^{\phi_0} Q d\phi d\lambda\right)/A_{-1} - \left(\int_{\lambda_{-1}}^{\lambda_{+1}}\int_{\phi_0}^{\phi_{+1}} Q d\phi d\lambda\right)/A_{+1} \quad (1)$$

  where Q is EPV, ϕ is lattitude, λ is longitude, A_{-1} and A_{+1} are the areas over which each average is taken (equatorward and poleward respectively).
- Blocks are identified when blocking index $B > 0$ for at least: 15°latitude, 10°longitude for 3 days
- Blocks are then sorted by their location into 3 geographic sectors [0°W (Atlantic/Europe), 60°W (Greenland) and 120°W (Pacific/Asia)], then into temporal groups, "PRE" for blocks preceded by an SSW event, "POST" for blocks followed by an SSW event, and "NSW" for blocks where no SSW occurs within 10 days of onset or breakdown. (The SSW group combines "PRE" and "POST")

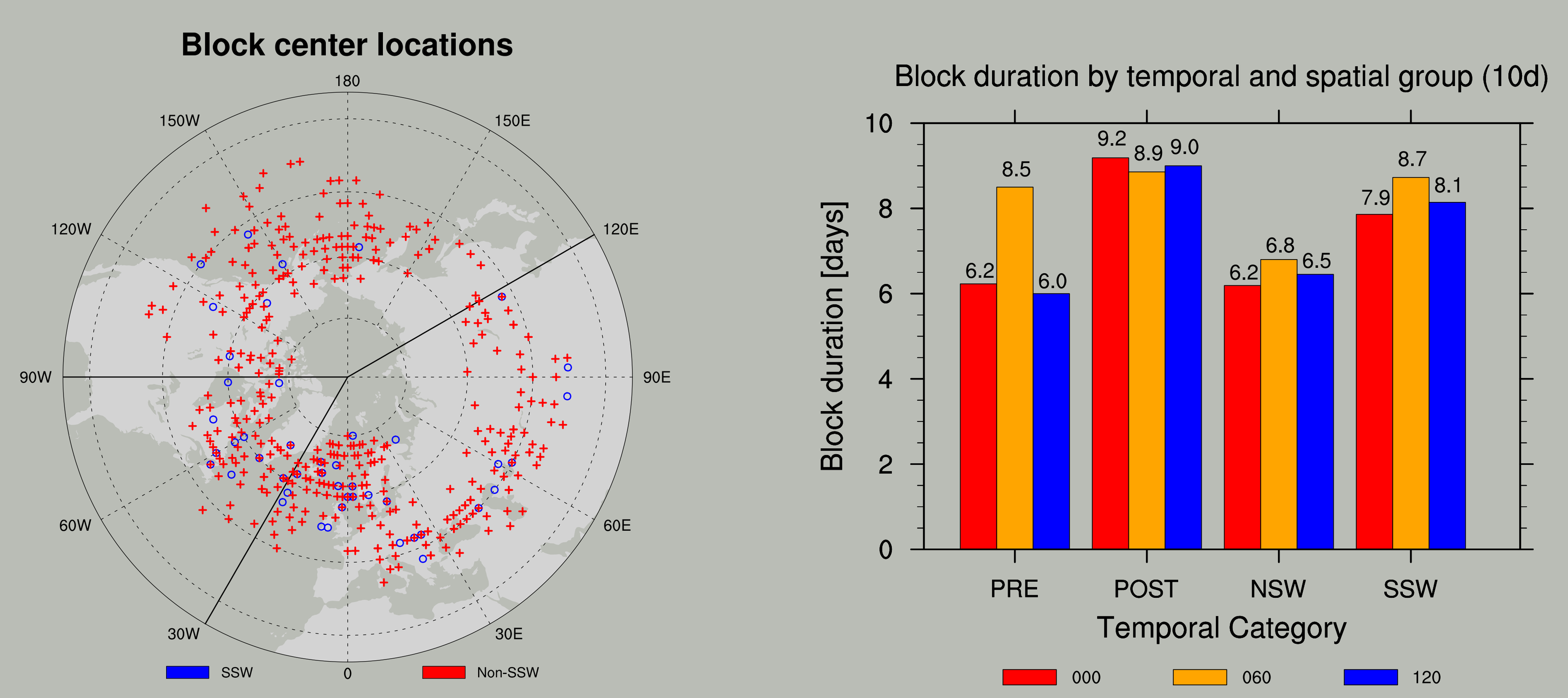

Figure 1: (Left) Locations of blocking events from 1949-2010. SSW Associated blocks plotted in blue, Non-SSW assocated blocks in red. (Right) Average duration of blocking events from 1949-2010, sorted by sector and temporal group.

Block Statistics

Table 1 shows that in the 0°W sector, SSW-associated blocks are significantly longer in duration than non-SSW proximal blocking events. It also suggests the same in the 60°W and 120°W, but the results are not statistically significant.

1-(P-value): Block duration

Cat./Sector	0	60	120
SSW-NSW	0.902	0.717	0.787

Table 1: Table of 1-(P-value) of duration of blocking events by sector from Student's t-Test.

Heat Flux

Meridional heat flux (HF) is defined as $HF = \overline{v'T'}$, where the overline indicates zonal average, and the prime departure from it. In this research, the average is taken zonally, then between 45°N -75°N on 200 hPa as in Sjoberg and Birner (2012). The average is then taken over the 10 days previous to each indicated day. V-wind and temperature are split into climatological (subscript C) and anomaly from climatology (subscript A) components as in Nishii et al. (2011).

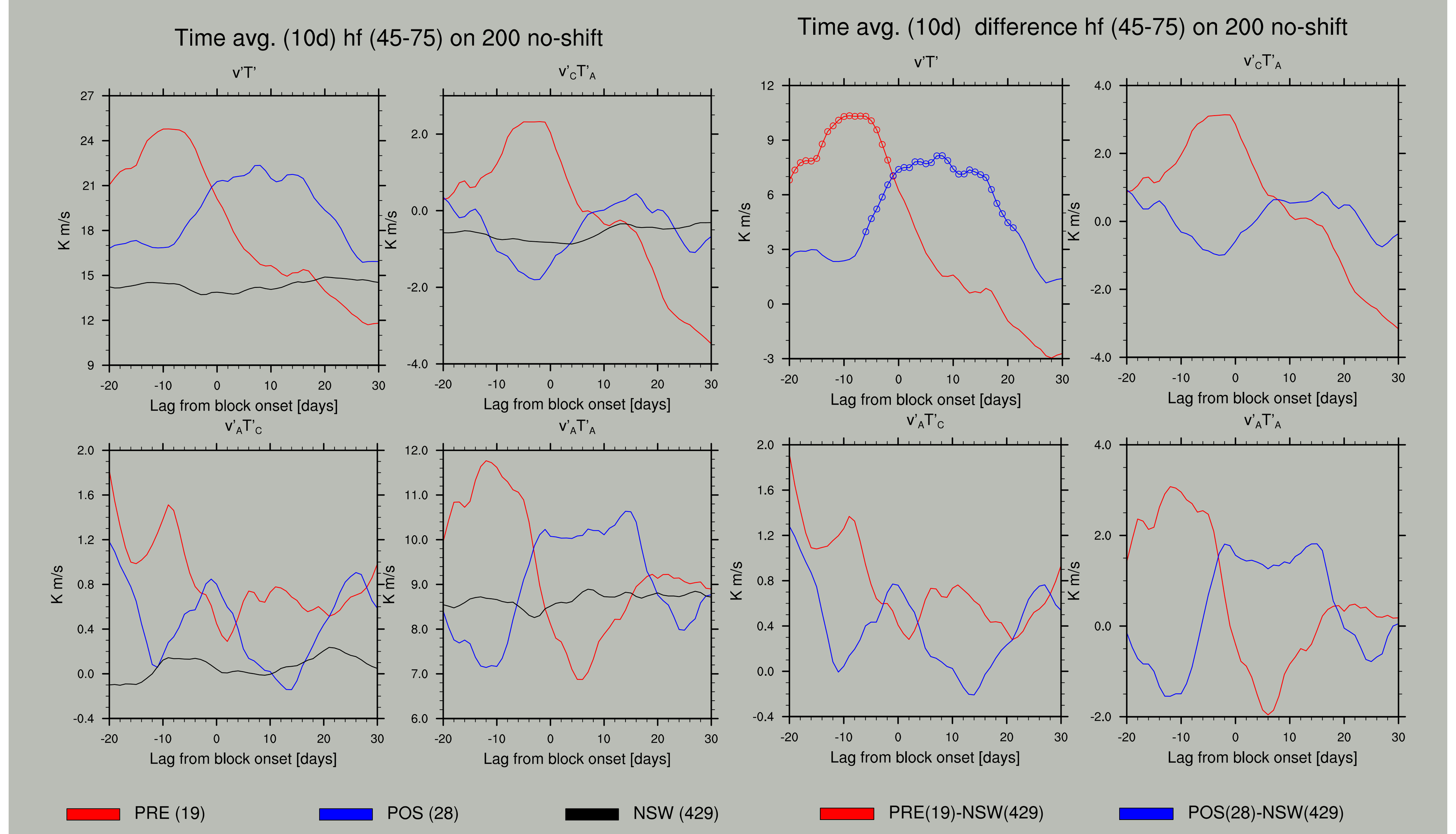

Figure 2: (Left) 10 day averaged heat flux for all sectors. (Right) Differences between groups. Circles indicate statistically significant to $\alpha = 0.1$.

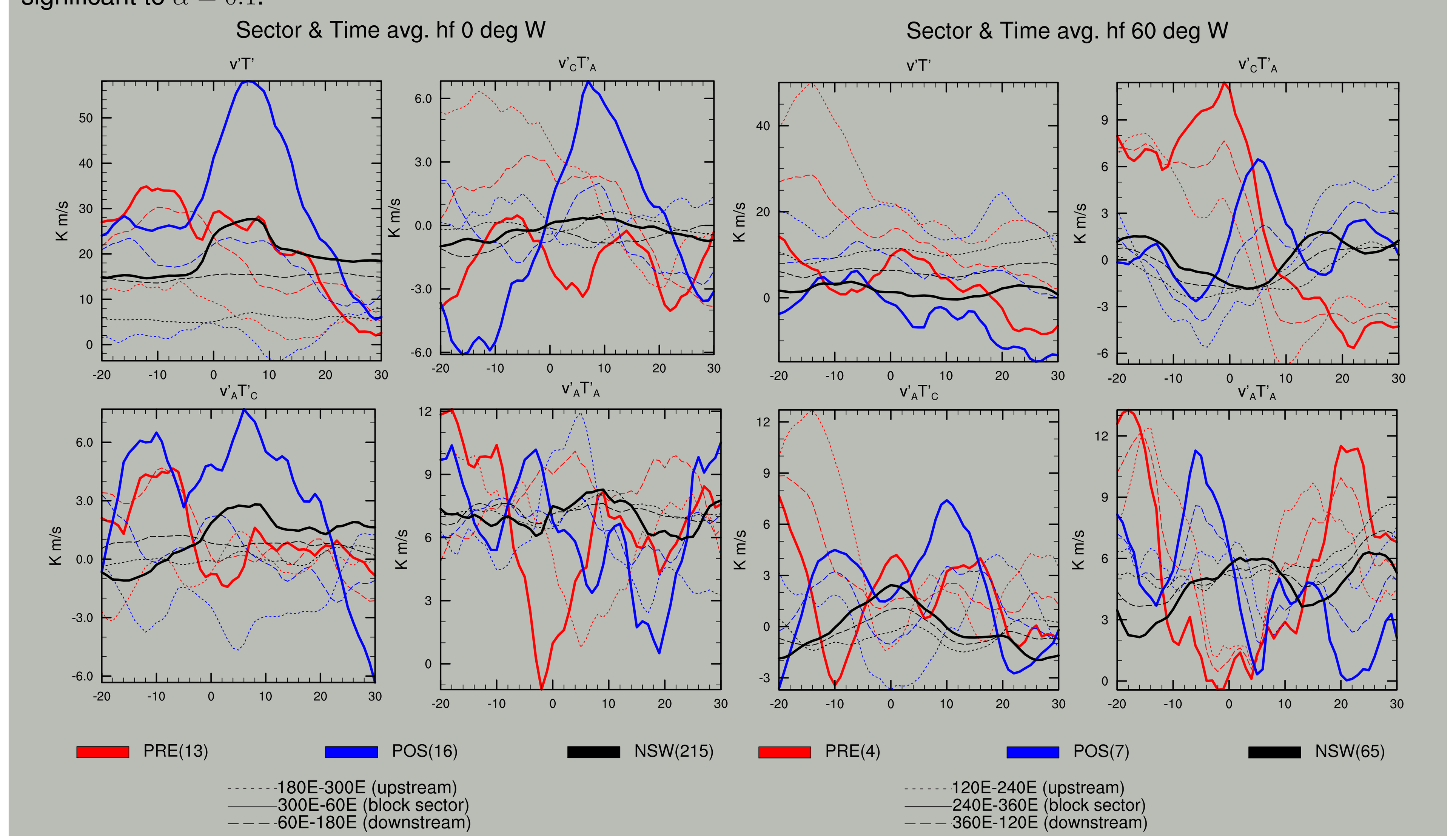

Figure 3: 10 day averaged heat flux for 0°W sector (60°W on right). Split into averages over upstream, block, and downstream sectors.

Wave Activity

The zonal mean zonal wind is related to the meridional heat flux by equation 2, where f_0 is the Coriolis parameter, R_d is the dry gas constant, $\overline{\sigma}$ is zonally averaged static stability and p is pressure.

$$\frac{\partial \overline{u}}{\partial t} \approx -\frac{\partial F_p}{\partial p} = -\frac{\partial}{\partial p}\left(\frac{f_0 R_d}{p\overline{\sigma}}\overline{v'T'}\right) \quad (2)$$

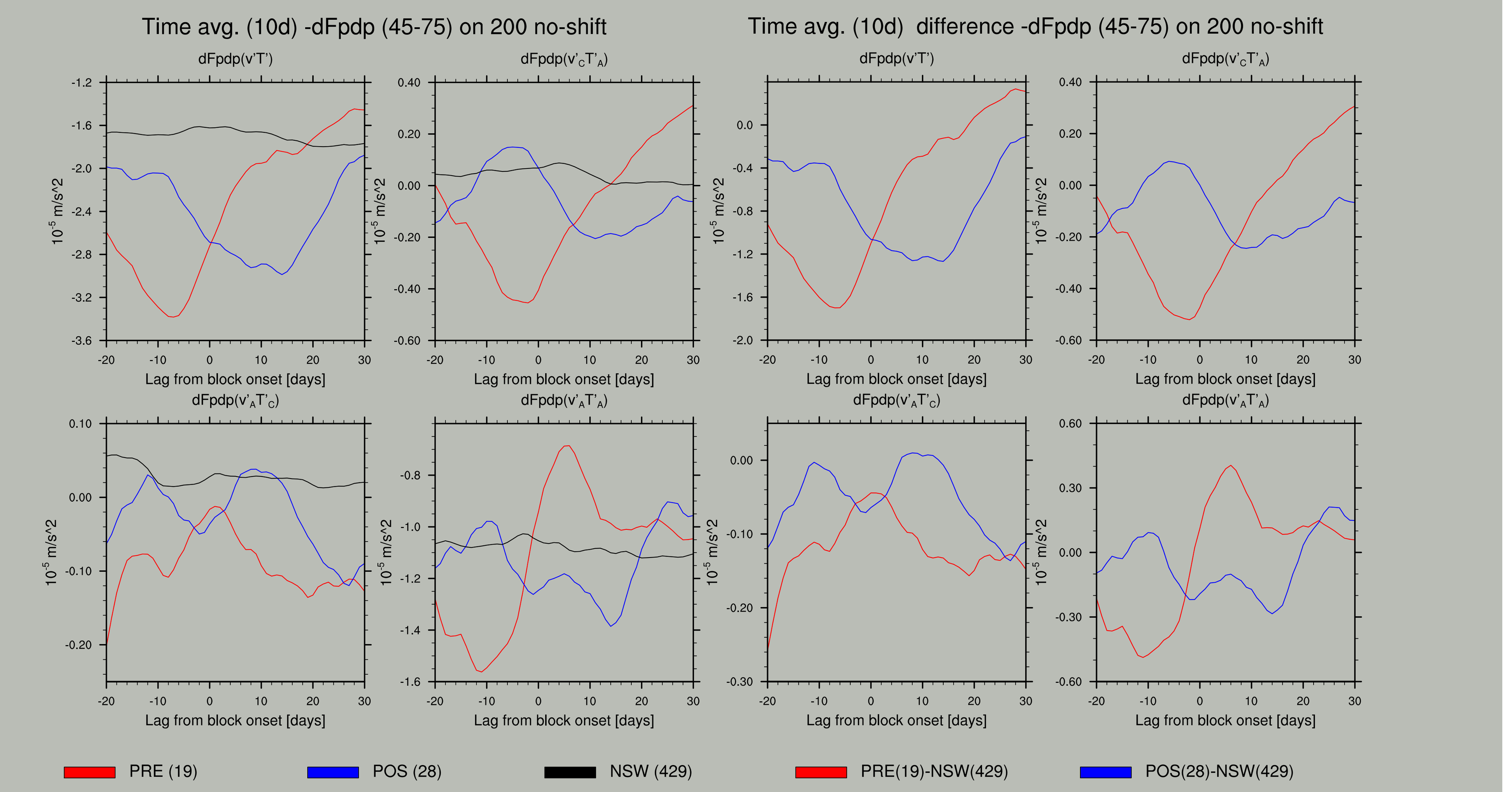

Figure 4: Ten day averaged vertical derivative of vertical component of EP-flux for all sectors ($-dF_p/dp$), (Left) Difference in ($-dF_p/dp$) between groups.

Conclusions

- Blocks associated with SSW events on average are longer in duration than those that are not to a statistically significant extent in the 0°W sector.
- Time averaged meridional heat flux is larger in magnitude in both categories of blocking events proximal to SSW events. This difference is statistically significant near the time of the SSW.
- When blocking occurs in the 0°W and 120°W sectors, the primary positive contribution to meridional heat flux comes from the sector where blocking is occurring.
- However, when blocking occurs in the 60°W sector, the primary contribution to meridional heat flux comes from upstream of the blocking sector with a secondary positive contribution from the downstream sector.
- Climatological meridional heat flux ($\overline{v'_C T'_C}$, not shown) appears to be a major factor in distinguishing blocking events associated or not associated with SSW events.
- This is a particularly interesting component when blocking occurs in the 60°W sector. Most of the contribution to positive meridional heat flux comes from outside the blocking sector from the climatological mean, whereas within the blocking sector, anomalous eddies contribute the most.
- A similar pattern is seen in the vertical wave activity divergence differences as in the meridional heat flux differences, though the result is not statistically significant.

References

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