Large-scale temperature gradients and the extratropical storm tracks

Ben Harvey, Len Shaffrey, Tim Woollings
NCAS Climate/University of Reading

CWC/SRM Annual meeting, Oxford, 14th May 2013

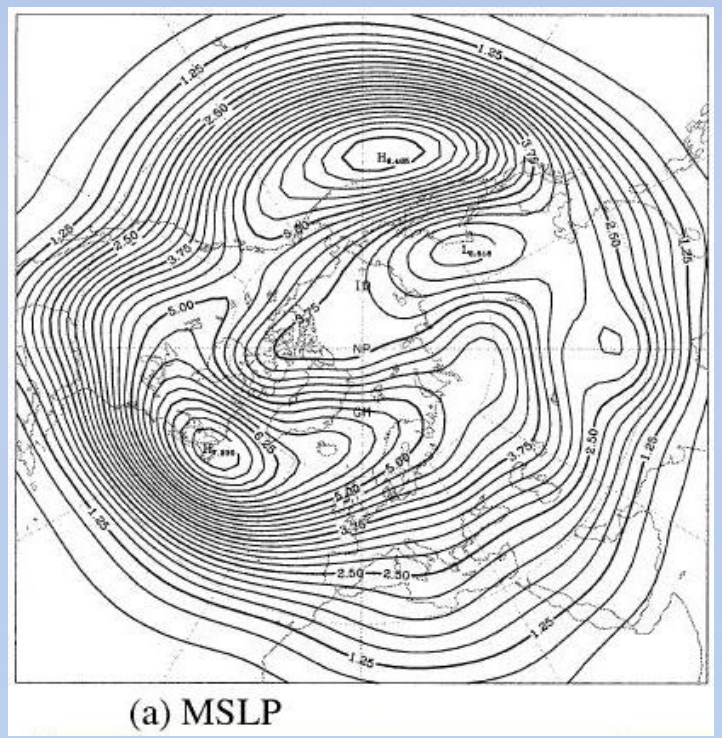
NATURAL ENVIRONMENT RESEARCH COUNCIL

Storm risk mitigation

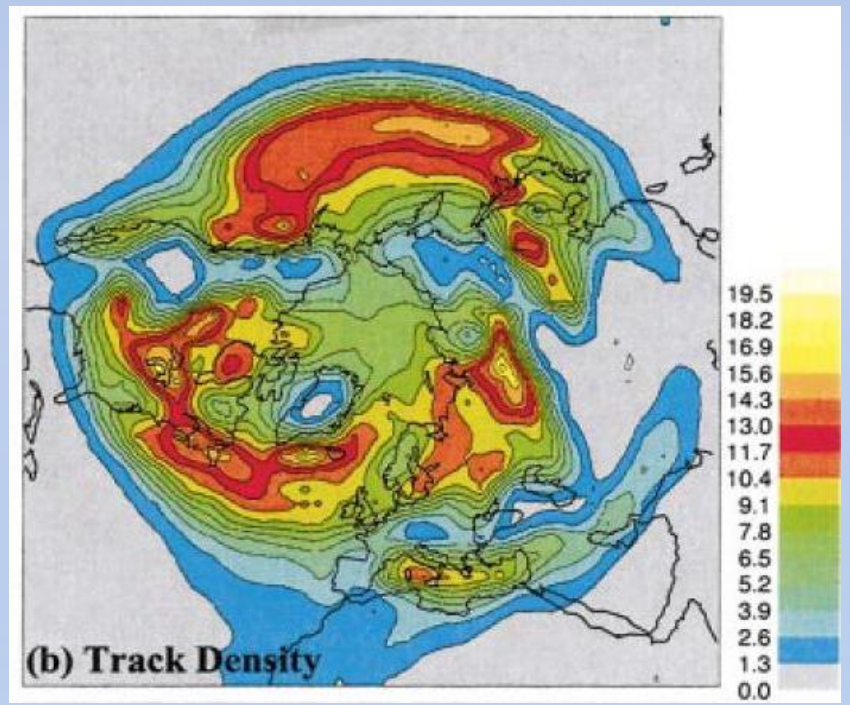
Lots of storm track diagnostics – which to use?

- Depends on purpose and data availability
- 'Eulerian' or 'feature tracking'?

2-6 day MSLP standard deviation

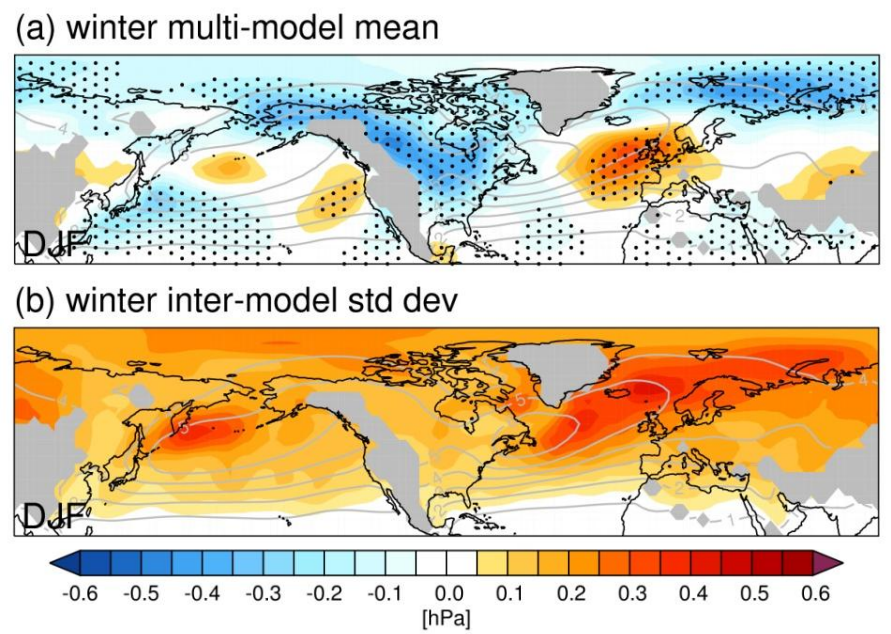


Feature tracking using 850 hPa vorticity



Hoskins and Hodges (2002)

Storm track responses in CMIP5



Data from 24 models
One run per model

Scenario:
RCP8.5 – HISTORICAL

Storm track measure:
2-6 day MSLP std dev

<u>Possible causes of the spread</u>

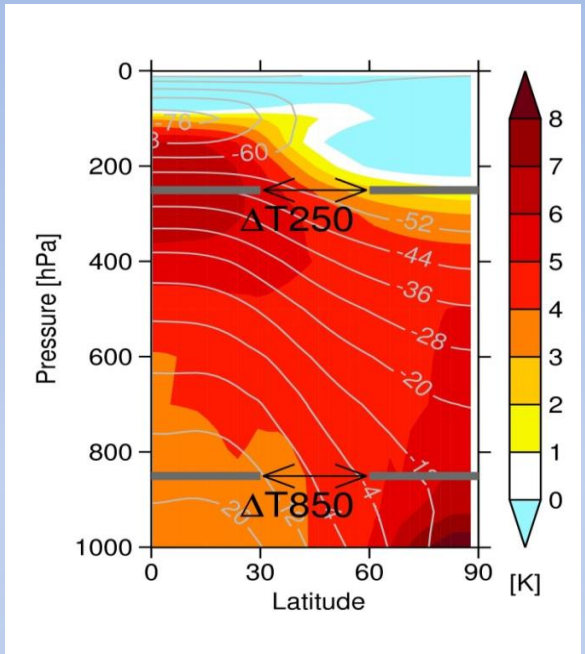
Natural variability

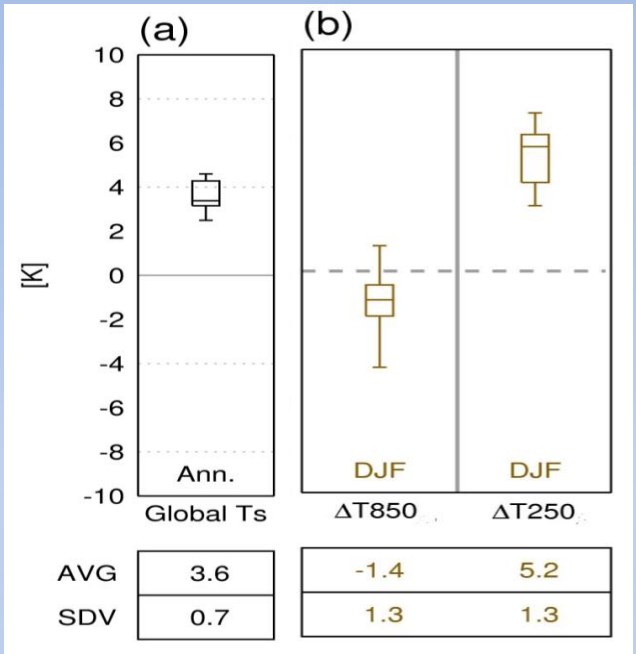
Baroclinicity (horizontal T gradients vs static stability)

Diabatic processes

Equator-to-pole temperature differences

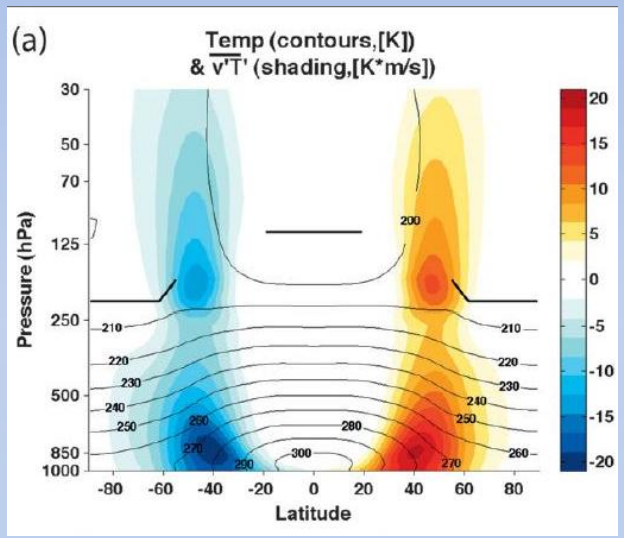
North Atlantic: 10W-60W

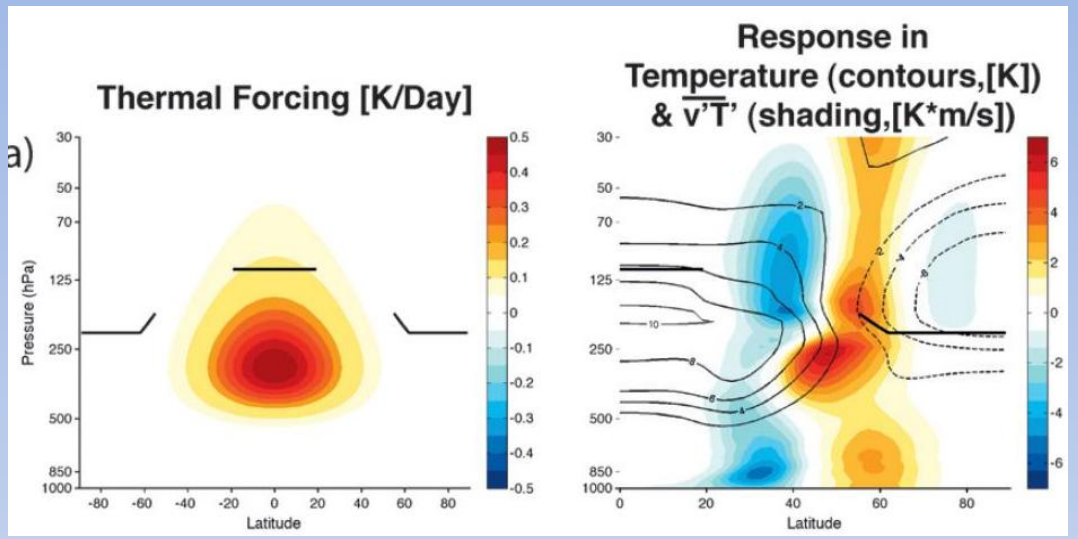


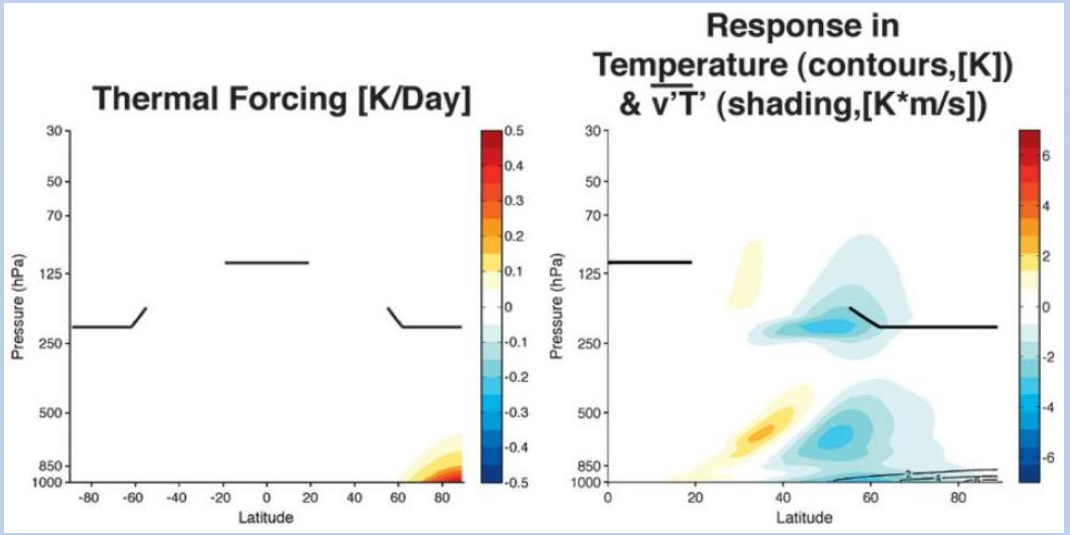


	Winter		
	Global Ts	Tropical Ts (ATL)	Polar Ts (ATL)
$\Delta T850_{\mathrm{ATL}}$	-0.13	0.10	**-0.81**
$\Delta T250_{\mathrm{ATL}}$	**0.66**	**0.83**	0.04

Idealised GCM study: Butler et al (2010)

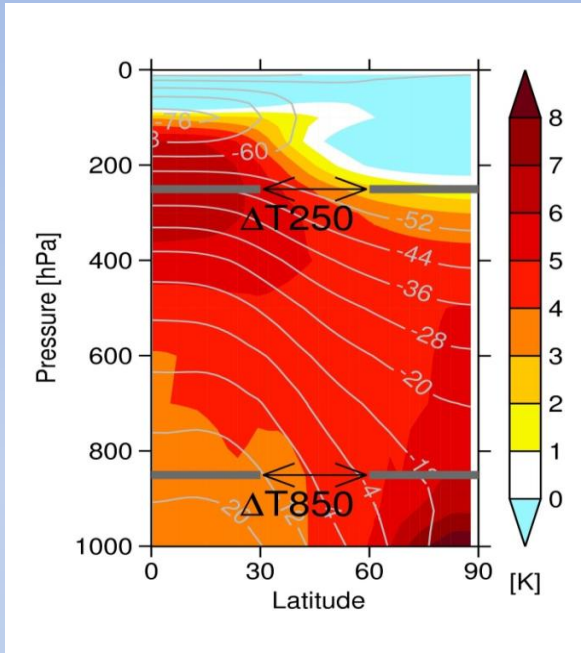


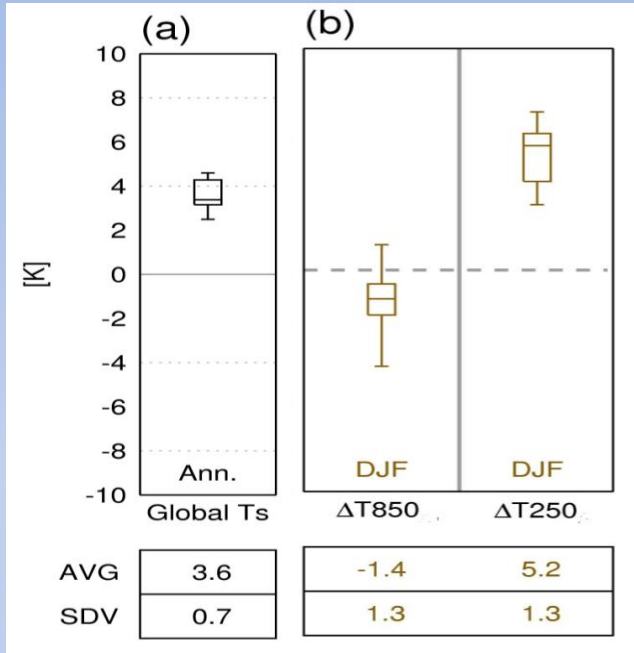




Equator-to-pole temperature differences

North Atlantic: 10W-60W



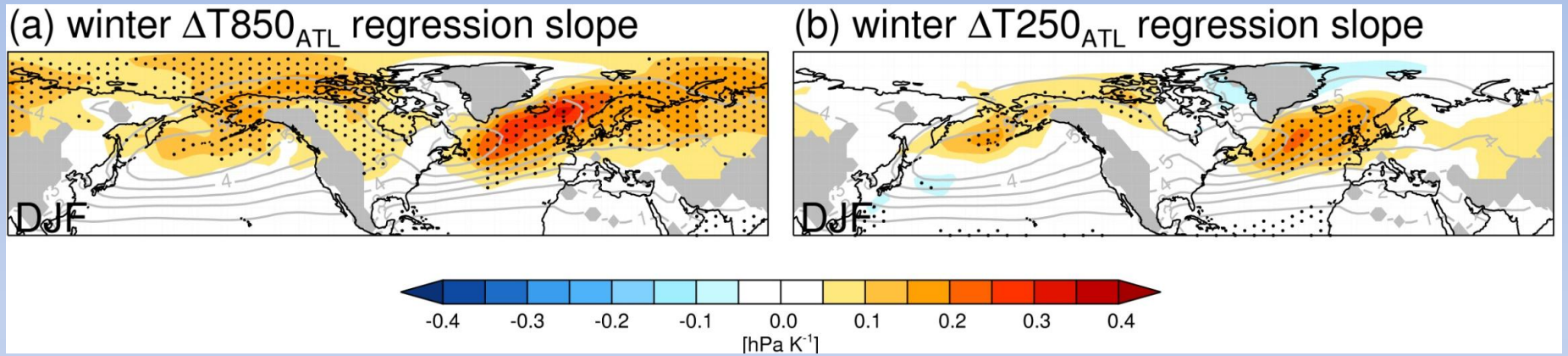


Perform a simple linear regression across the ensemble:

$$ST_{\mathrm{resp},i} = \alpha + \beta \Delta T_{\mathrm{resp},i} + \epsilon_i$$

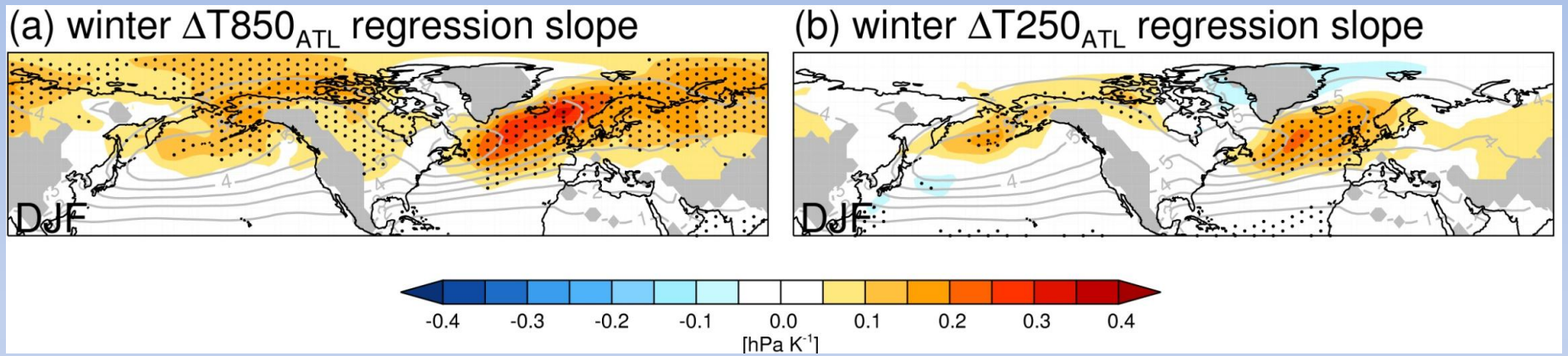
Results

Regression slopes (shading) and significance of correlation (stippling, p=0.05)

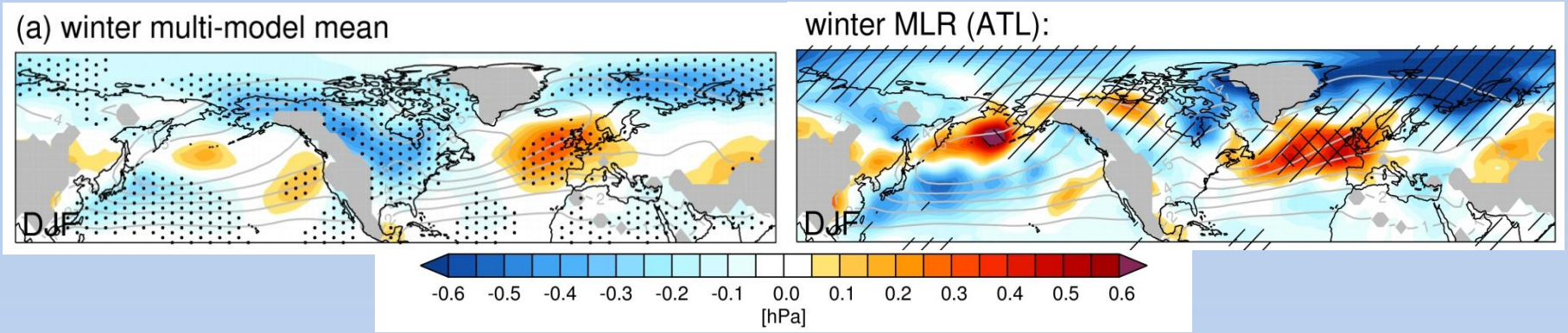


Results

Regression slopes (shading) and significance of correlation (stippling, p=0.05)

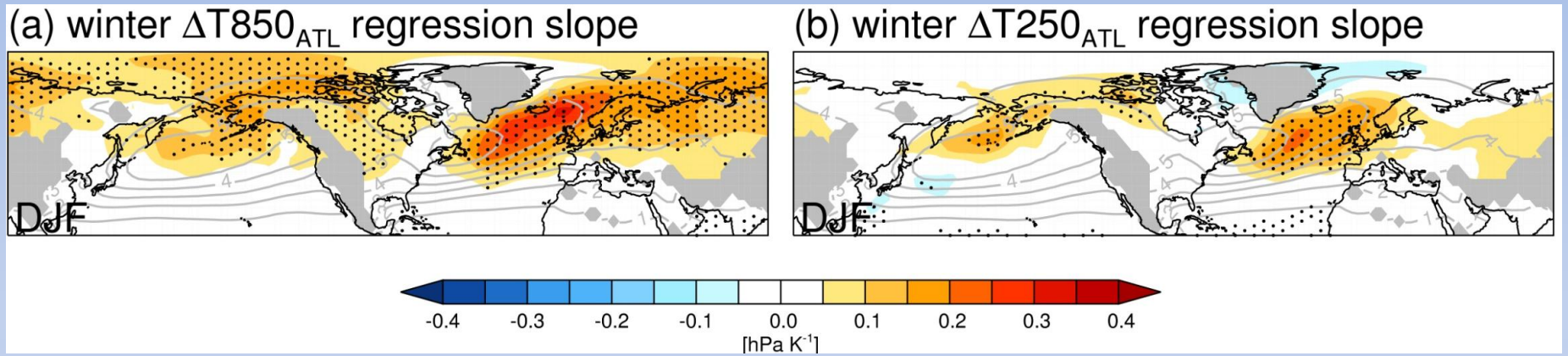


Comparison to mean storm track response:

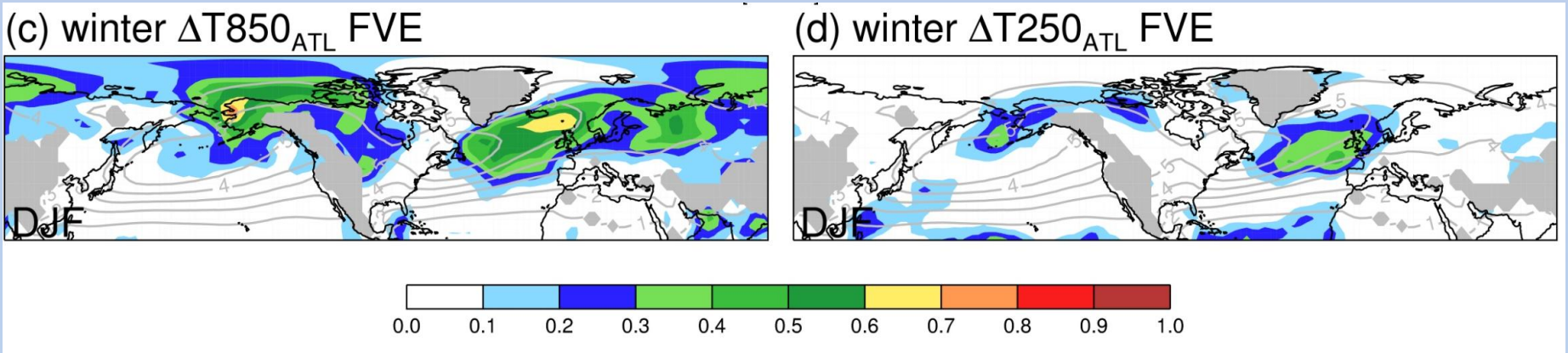


Results

Regression slopes (shading) and significance of correlation (stippling, p=0.05)



Fraction of inter-model variance 'explained':



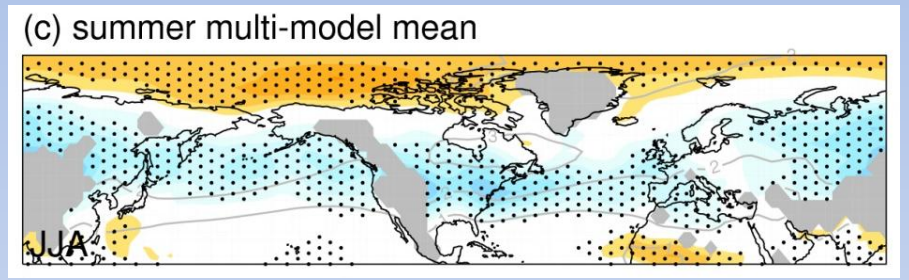
Summary - North Atlantic

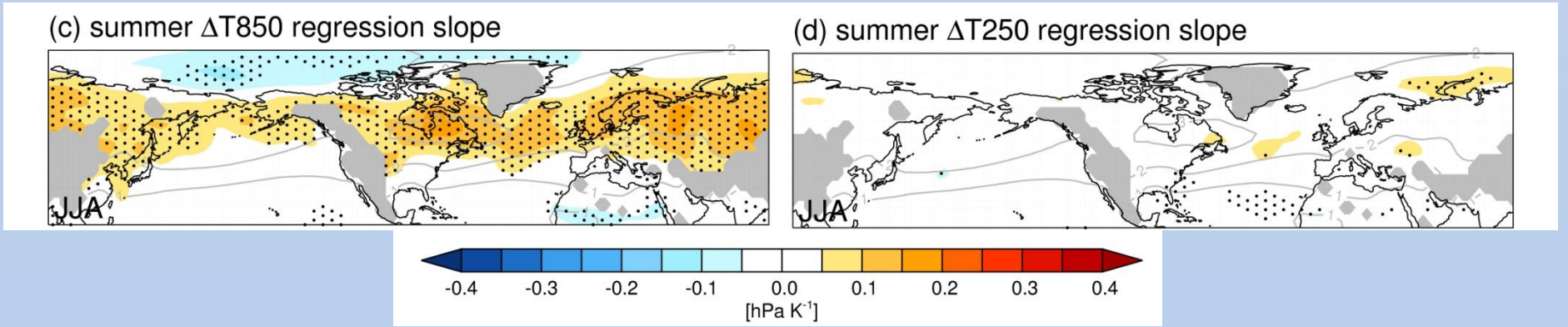
- There are **large regions with significant correlation** for both the ΔT850 and ΔT250 temperature differences.
- The **regression slopes** in these regions are mostly **positive**, suggesting the storm track responses are **driven by the responses of the baroclinicity.**
- The **impact of ΔT850** on the multi-model mean storm track response is **negative** across most of the hemisphere, whereas the **impact of ΔT250** is **positive** but confined to the ocean basins.
- Together, the two linear regression maps qualitatively **capture the spatial pattern of the multi-model mean response**.
- The FVE by ΔT850 is over **50%** in the North Atlantic and Norwegian Sea and by ΔT250 is over **30%** in the North Atlantic but small elsewhere.
- Suggests that there is potential to **reduce the spread** in the storm track responses by **constraining the relative strengths** of the warming in the tropics and polar regions.

Other regions

A similar analysis has been performed for both summer and winter of all the extratropical storm track regions.

e.g. NH summer

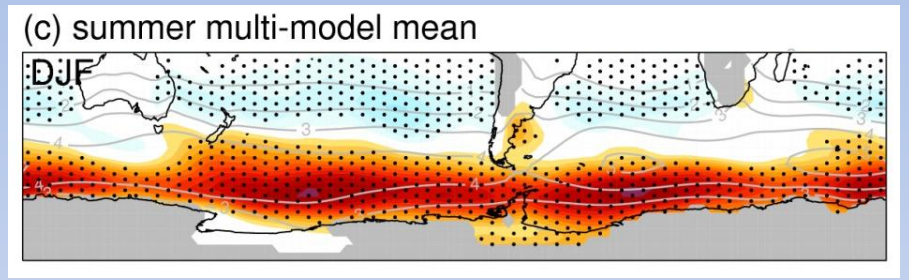


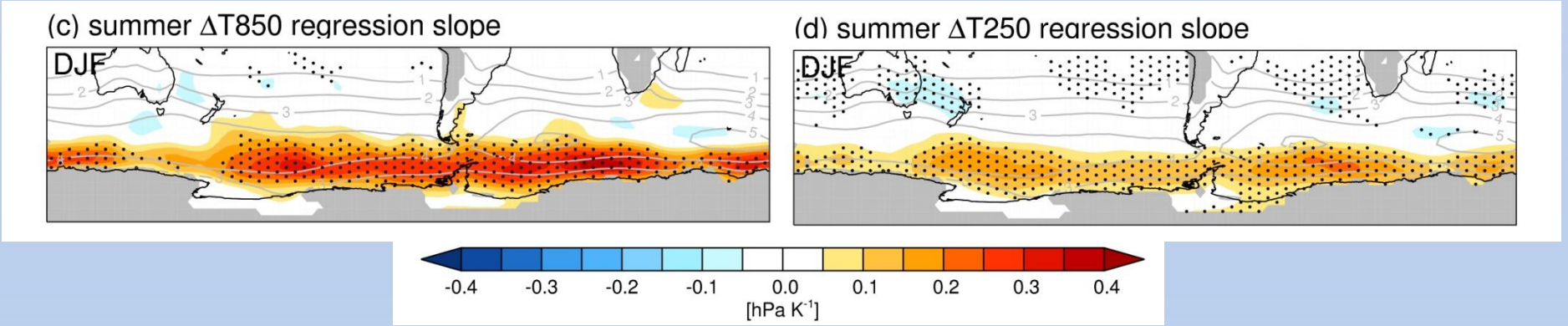


Other regions

A similar analysis has been performed for both summer and winter of all the extratropical storm track regions.

e.g. SH summer





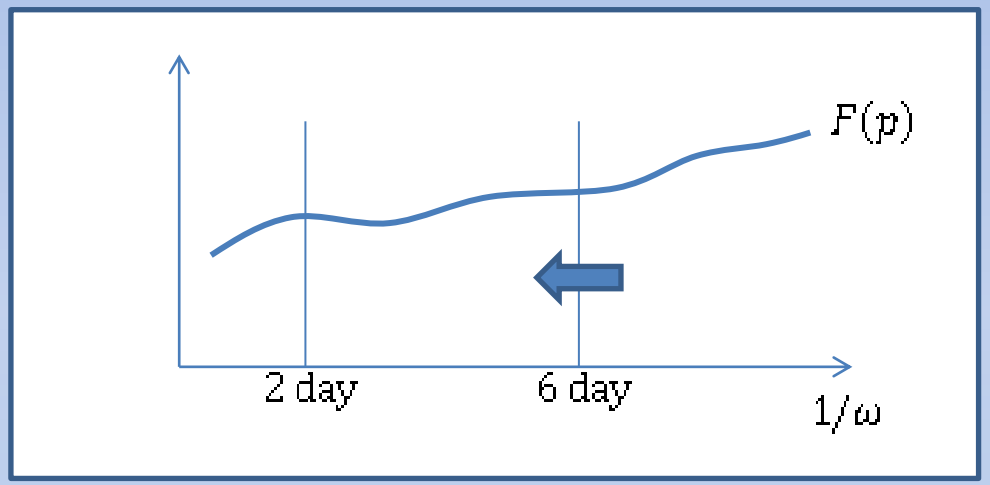
Summary - continued

- The **North Atlantic winter is unique** in that **both the ΔT850 and ΔT250 regressions are needed to capture the pattern of the mean response**. This more complex behaviour may go some way towards explaining the particularly large inter-model spread in the North Atlantic region.
- One limitation of this study is that the **causality of the correlations cannot be determined**. It is not clear whether the storm tracks respond directly to the **equator-to-pole temperature difference**, or instead to more **local baroclinicity changes** (e.g. SST, sea-ice or land-sea contrast changes) which may themselves be correlated with the equator-to-pole temperature difference.

Thank you for listening

What about Doppler effects?

A problem for bandpass filtered storm track measures

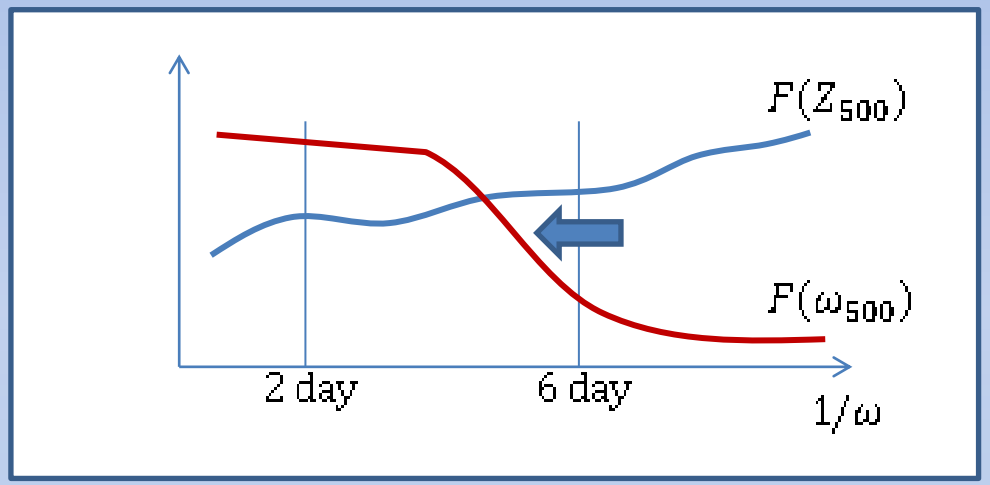


e.g. Burkhardt & James (2006)

- Investigate NAO/storm track relationship
- Use an 'extended EOF analysis' to correct for Doppler shifting

What about Doppler effects?

A problem for bandpass filtered storm track measures



e.g. Chang (2009)

- Also investigate NAO/storm track relationship
- Use multiple storm track measures to understand problem

What about Doppler effects?

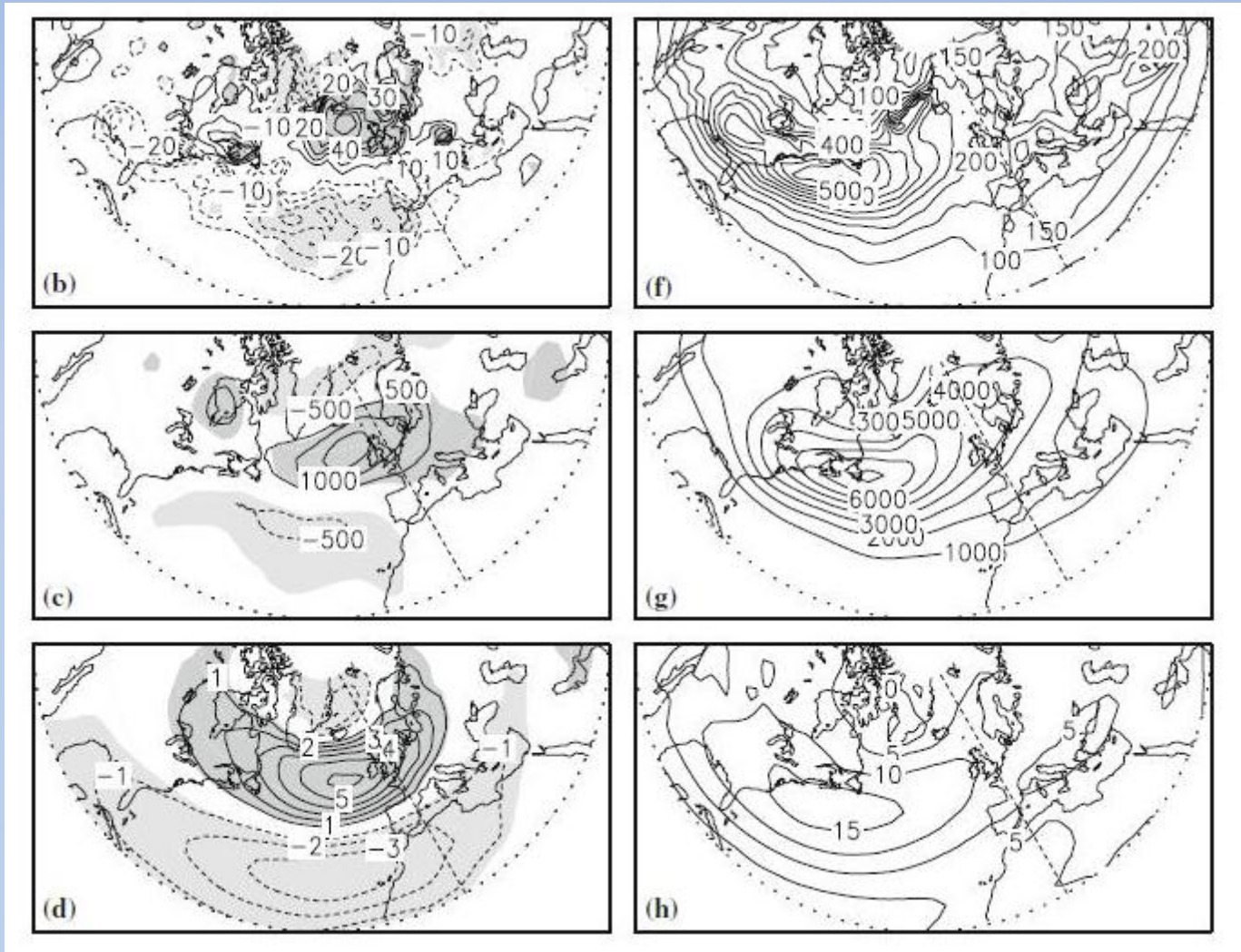
NAO regression

DJF mean

2 to 6 day ω_{500}

2 to 6 day Z_{500}

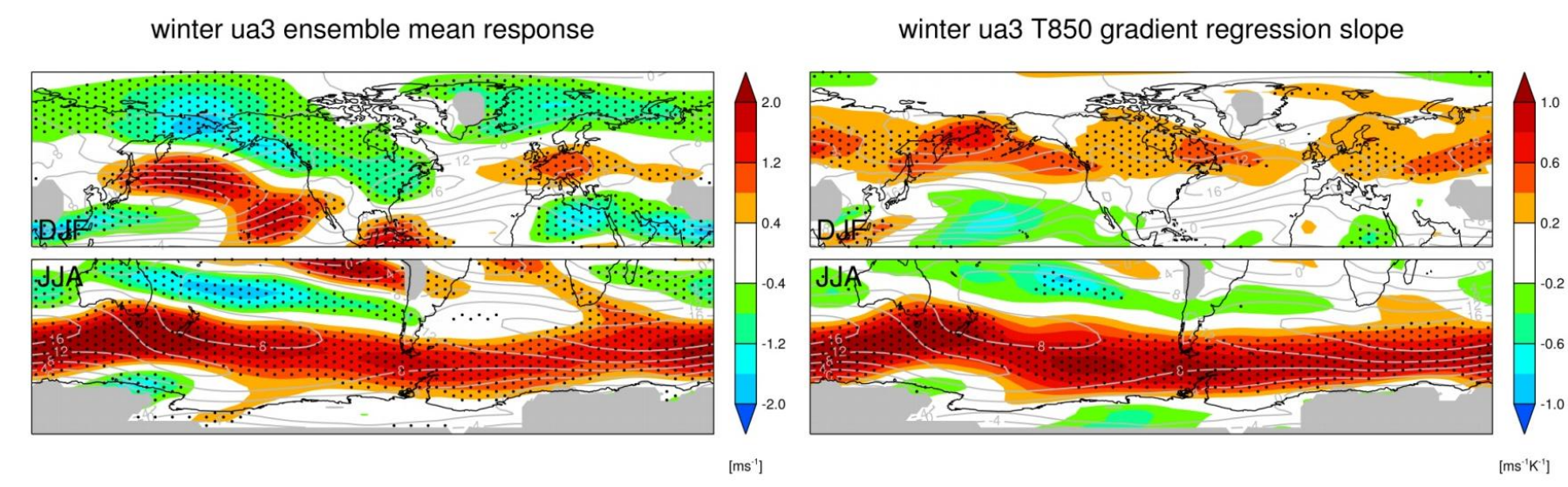
mean U_{700}



Chang (2009)

What about Doppler effects?

Could this be causing the storm track / temperature gradient relationship in the CMIP5 responses?

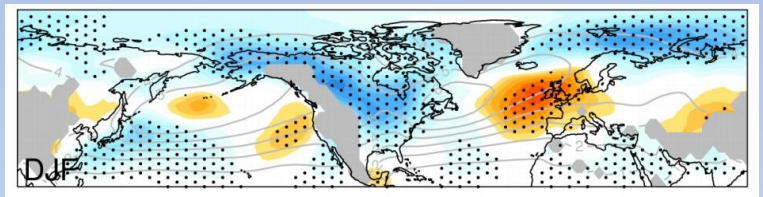


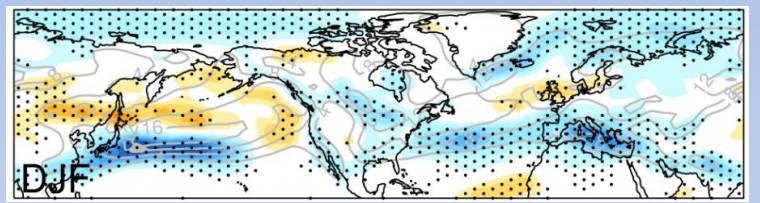
What about Doppler effects?

2-6 day MSLP standard deviation

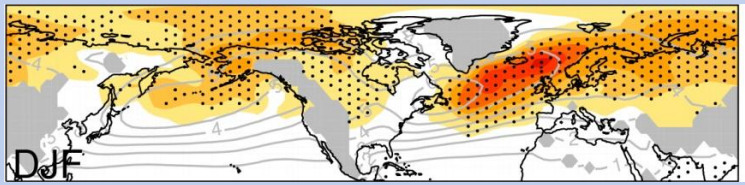
Feature tracking using 850 hPa vorticity

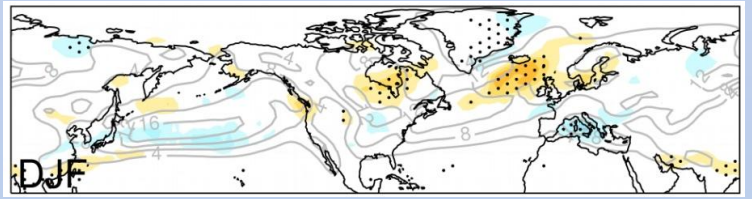
Ensemble mean response



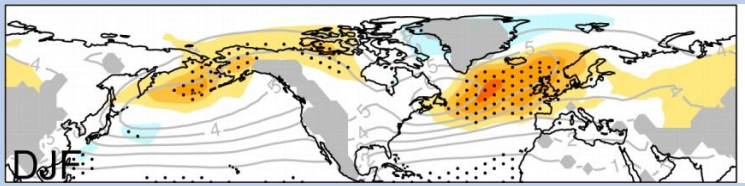


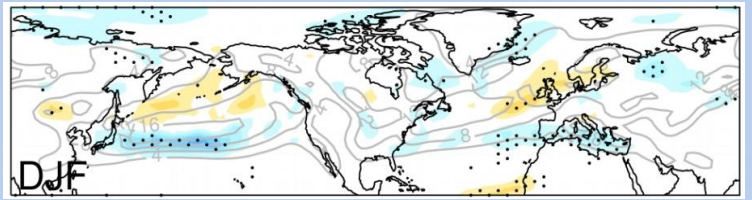
T850 regression





T250 regression



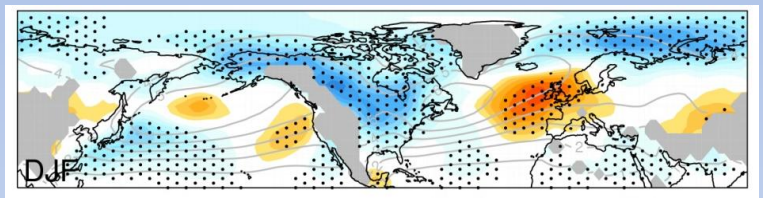


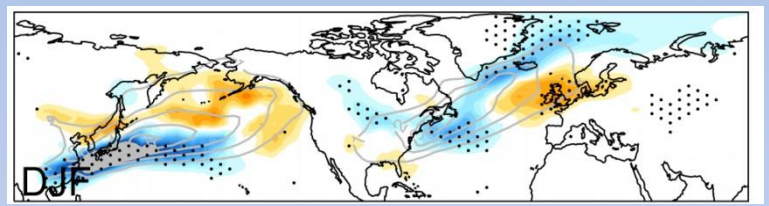
What about Doppler effects?

2-6 day MSLP standard deviation

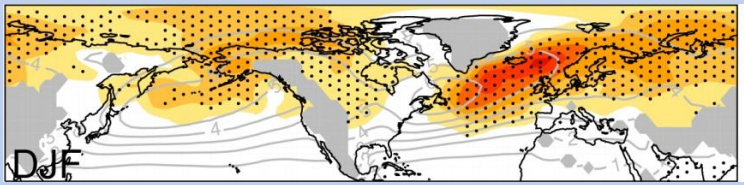
Feature tracking using 850 hPa vorticity

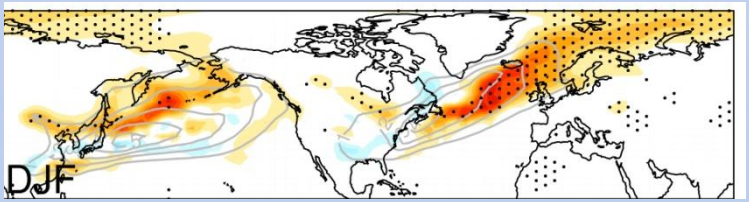
Ensemble mean response





T850 regression





T250 regression