Investigating the climate change response of the NH wintertime storm tracks

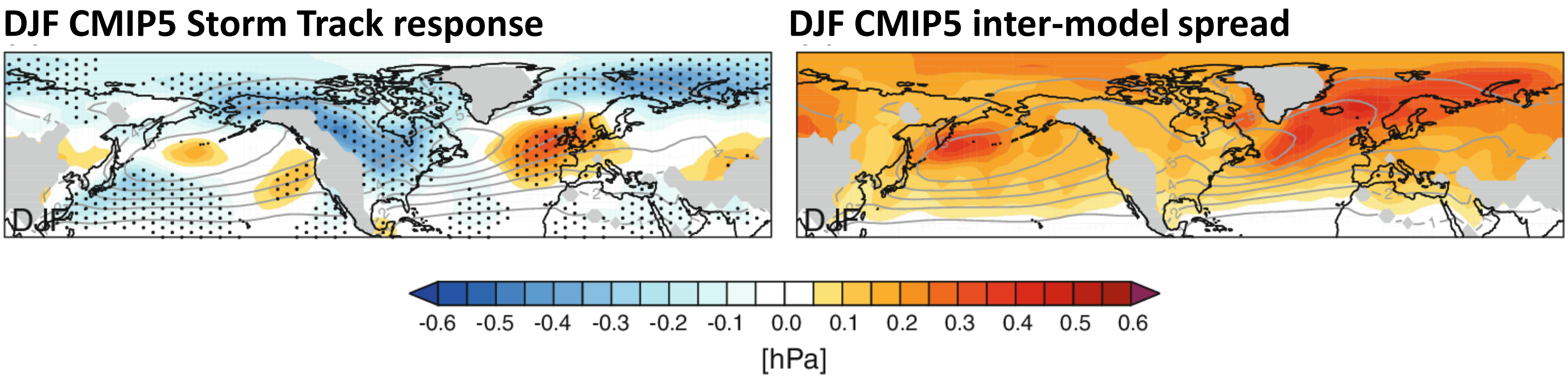
Len Shaffrey
National Centre for Atmospheric Science
University of Reading

Thanks to Ben Harvey, Tim Woollings, Giuseppe Zappa, Kevin Hodges

CMIP5 storm track projections

National Centre for Atmospheric Science
NATURAL ENVIRONMENT RESEARCH COUNCIL

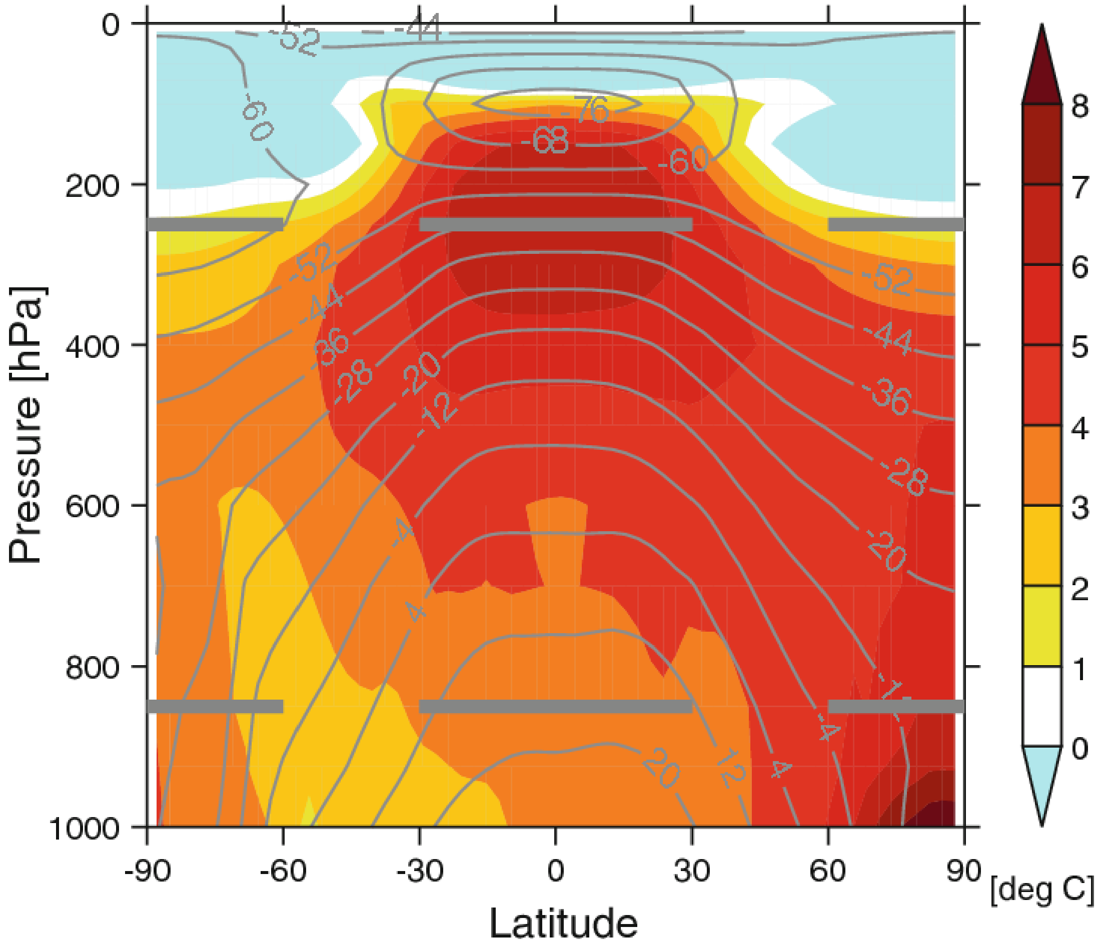
1. What governs the mean response?
2. Why is the inter-model spread so large?



Left) DJF CMIP5 multi-model mean storm track response (RCP4.5 2080-2100 minus HIST 1985-2005) measured by standard deviation of the 2-6 bandpass filtered mean sea level pressure. Right) DJF CMIP5 inter-model standard deviation of storm track responses

Harvey et al. (2012), *GRL*

DJF zonal mean temperature

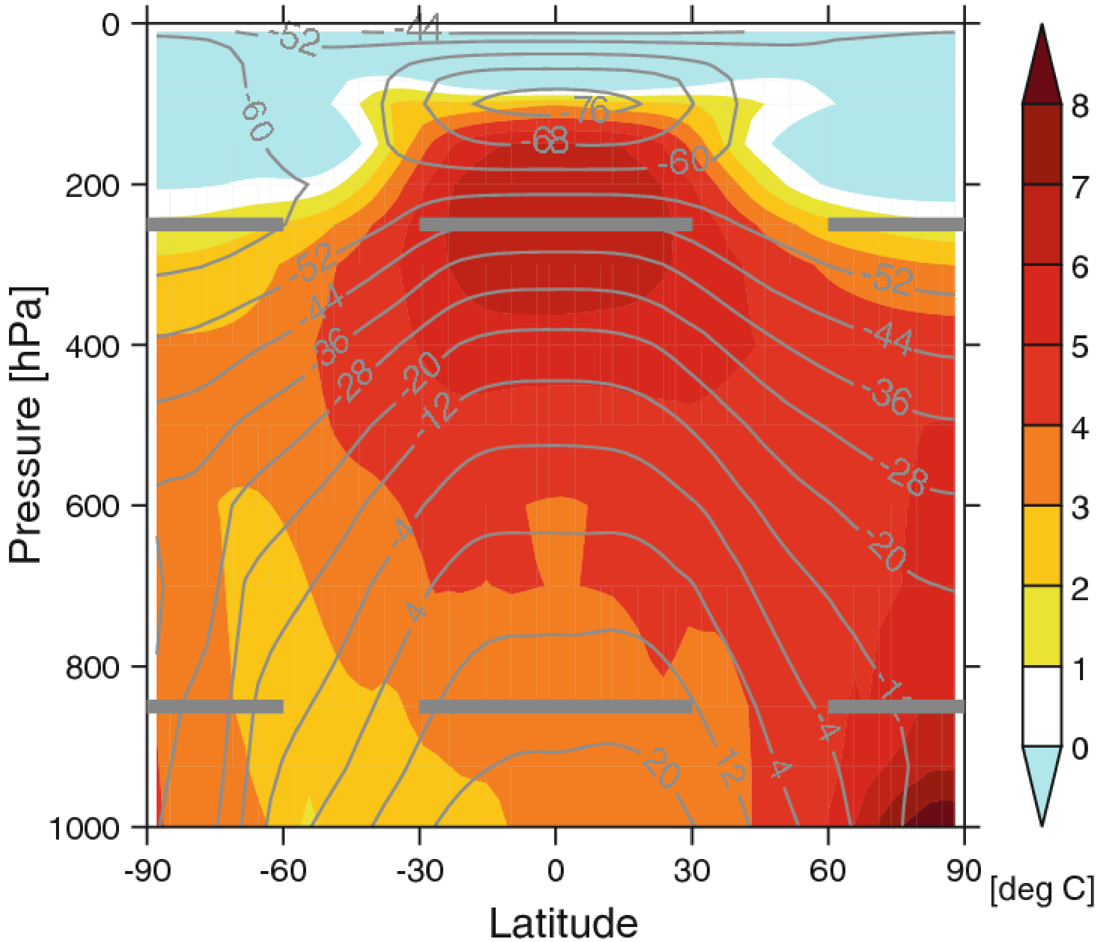


Zonal mean climate change temperature responses from the CMIP5 climate models

Warming in the:

1. Upper Tropics
2. Lower Polar troposphere

DJF zonal mean temperature



Zonal mean climate change temperature responses from the CMIP5 climate models

Warming in the:

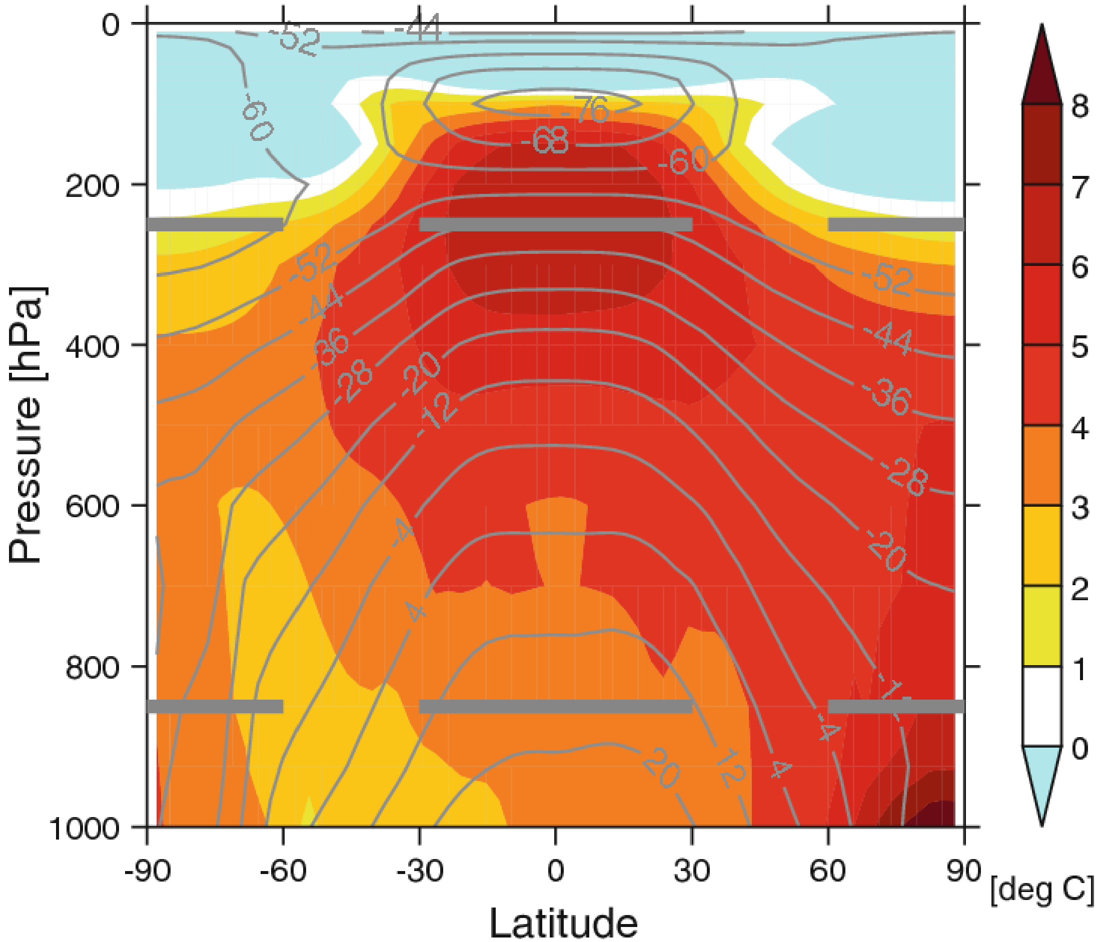
1. Upper Tropics
2. Lower Polar troposphere

Using an idealised dry GCM, Butler et al. (2010) found that:

Upper Tropics heating = Intensified (and poleward shifted) storm track

Lower Polar heating = Weakened (and equatorward shifted) storm track

DJF zonal mean temperature



Zonal mean climate change temperature responses from the CMIP5 climate models

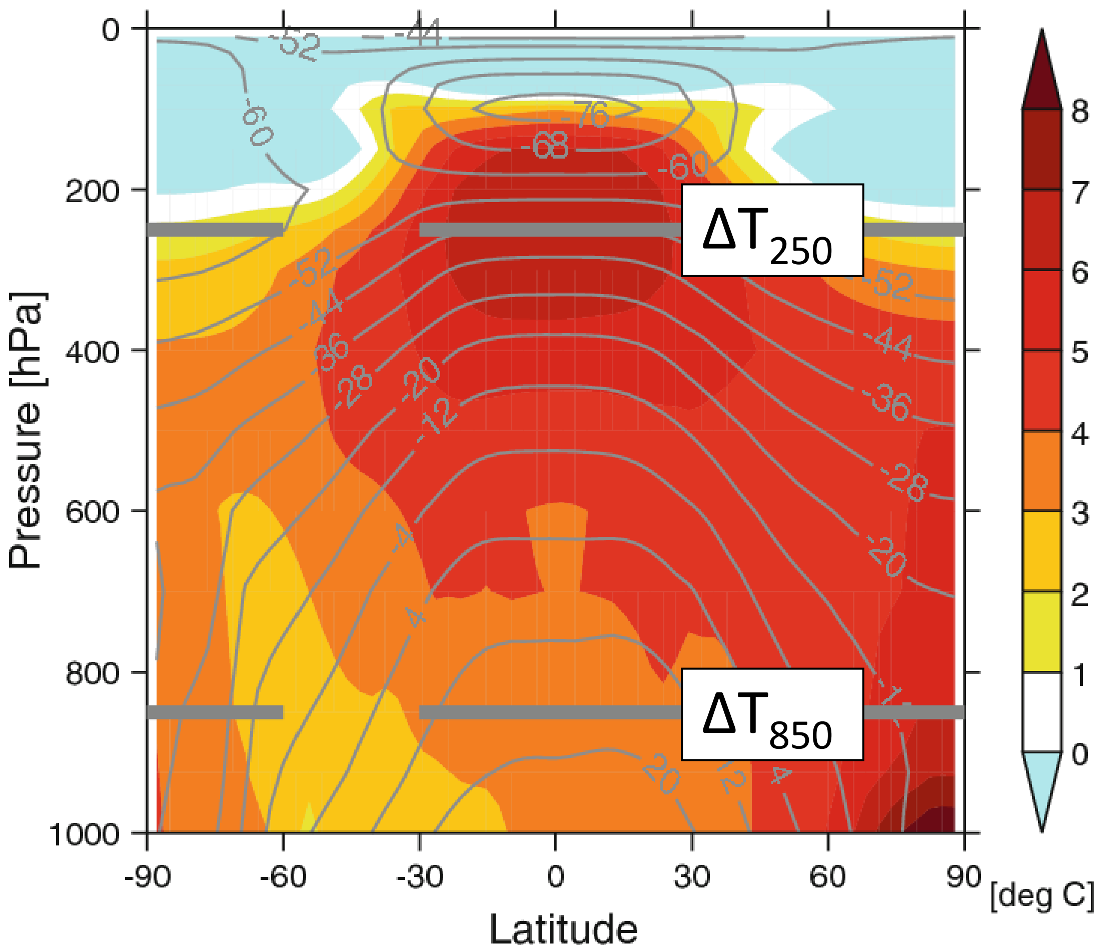
Warming in the:

1. Upper Tropics
2. Lower Polar troposphere

Investigate this:

1. In the CMIP5 climate model ensemble (Harvey et al. 2013)
2. By performing climate model sensitivity experiments (Harvey et al. 2015)

DJF zonal mean temperature



Zonal mean climate change temperature responses from the CMIP5 climate models

Warming in the:

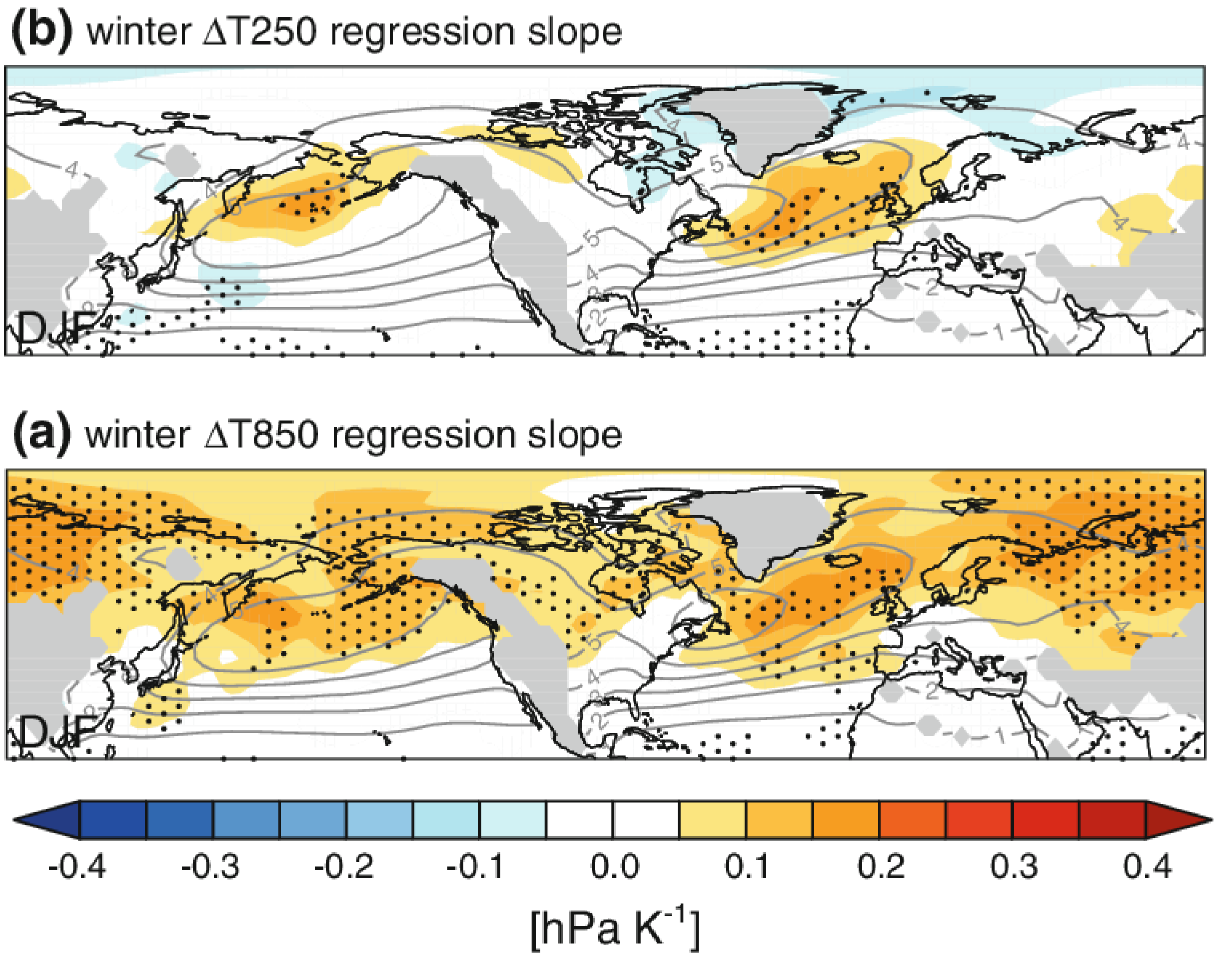
1. Upper Tropics
2. Lower Polar troposphere

Investigate this:

1. In the CMIP5 climate model ensemble (Harvey et al. 2013)
2. By performing climate model sensitivity experiments (Harvey et al. 2015)

CMIP5 Temperature differences

ΔT_{850} = $T\_TROPICS_{850}$ minus T_POLAR_{850}

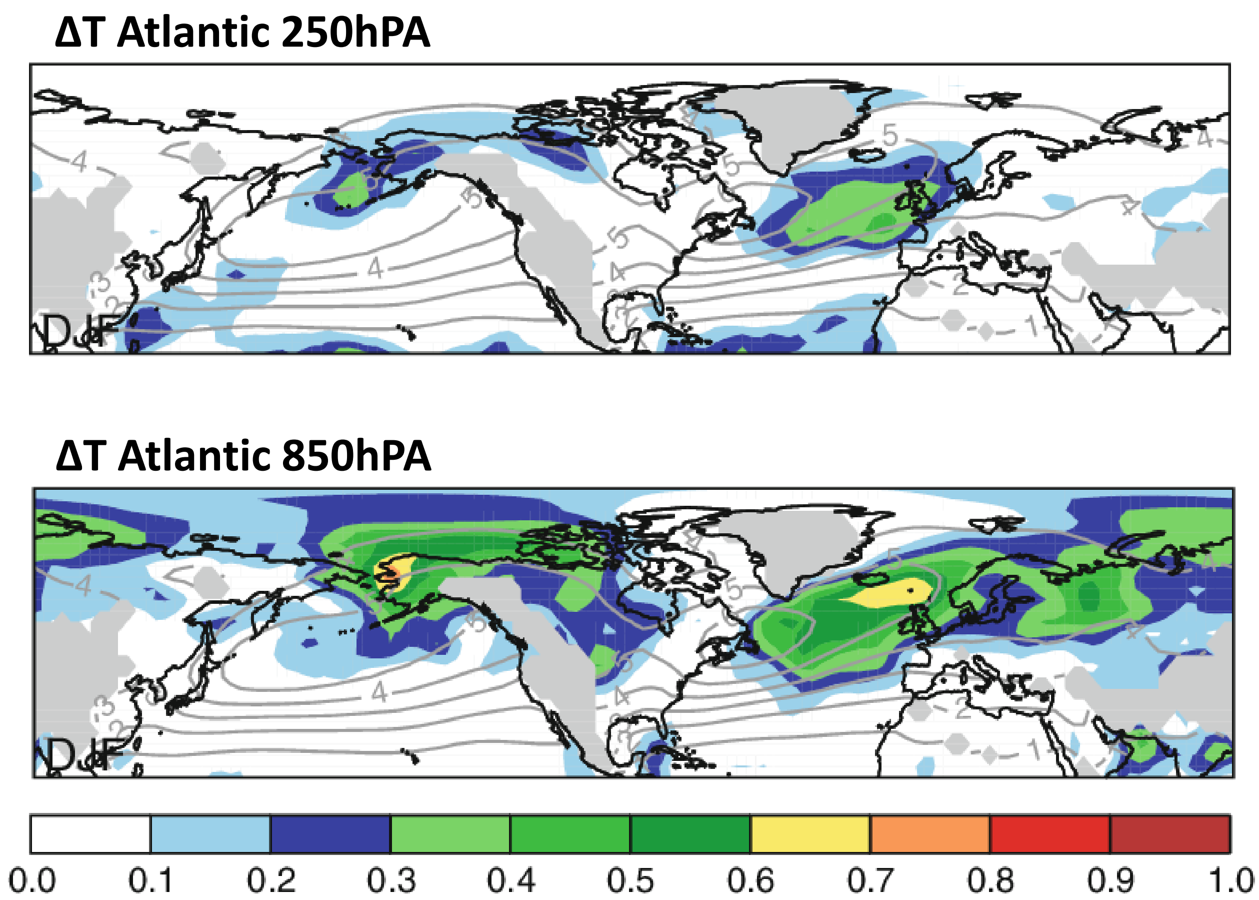


Regression coefficients for DJF CMIP5 storm track responses against lower) the 850hPa temperature differences and upper) the 250hPa temperature differences.

Both ΔT_{250} and ΔT_{850} appear to be important for the mean response of the NH DJF storm tracks

Harvey et al. (2013), *Clim. Dyn.*

CMIP5 Temperature differences



Fraction of the inter-model spread in the DJF CMIP5 storm track responses explained by lower) linear regression with equator-to-pole 850hPa Atlantic temperature differences and upper) with the 250hPa Atlantic temperature differences.

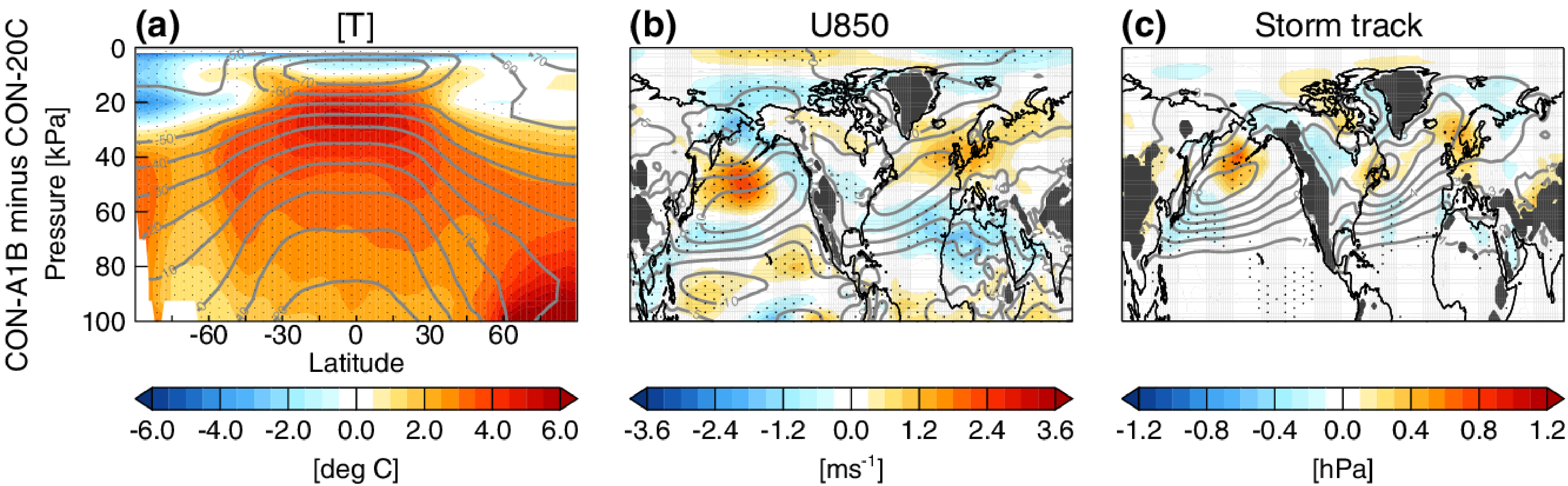
The inter-model spread in CMIP5 North Atlantic storm track responses is more associated with Atlantic ΔT_{850}

Harvey et al. (2013), *Clim. Dyn.*

HadGAM1 sensitivity experiments

Perform sensitivity experiments with the N96 L38 HadGAM1 atmosphere model with forcings derived from the CMIP3 ensemble:

1. **Present day experiment** with multi-model mean CMIP3 SST and constructed sea ice
2. **Climate change experiment** (A1B scenario) with multi-model mean CMIP3 SST and constructed sea ice



Harvey et al. (2015), *Clim. Dyn.*

HadGAM1 sensitivity experiments

National Centre for Atmospheric Science
NATURAL ENVIRONMENT RESEARCH COUNCIL

Perform sensitivity experiments with the N96 L38 HadGAM1 atmosphere model with forcing from CMIP3 ensemble:

1. **Present day experiment** with multi-model mean CMIP3 SST and constructed sea ice
2. **Climate change experiment** (A1B scenario) with multi-model mean CMIP3 SST and constructed sea ice

Two sets of sensitivity experiments intended to simulate the CMIP3 inter-model spread (plus and minus one standard deviation) :

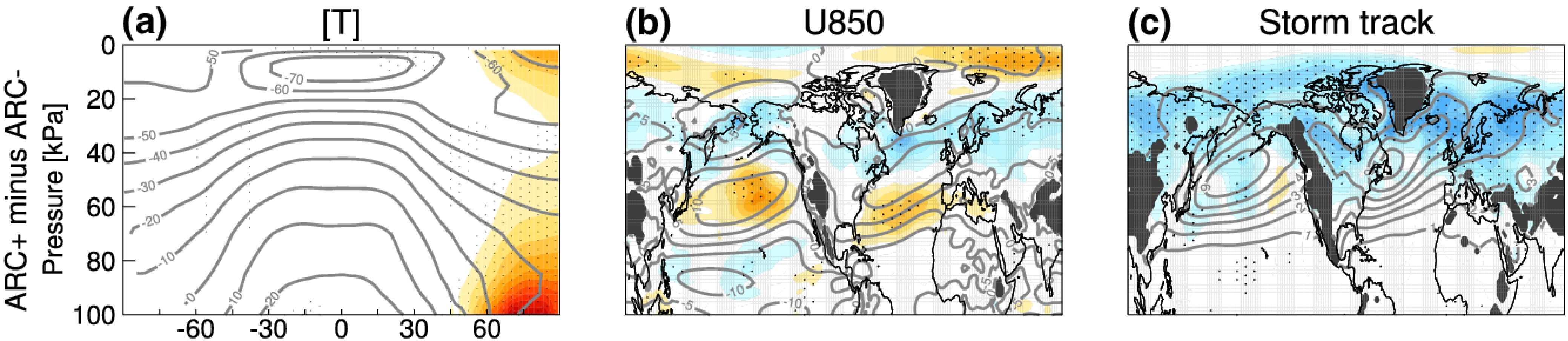
3. **Large Arctic Warming** and **Small Arctic Warming** by applying Arctic sea ice perturbations and high-latitude SST perturbations
4. **Large Tropical Warming** and **Small Tropical Warming** by applying globally uniform SST perturbations

Harvey et al. (2015), *Clim. Dyn.*

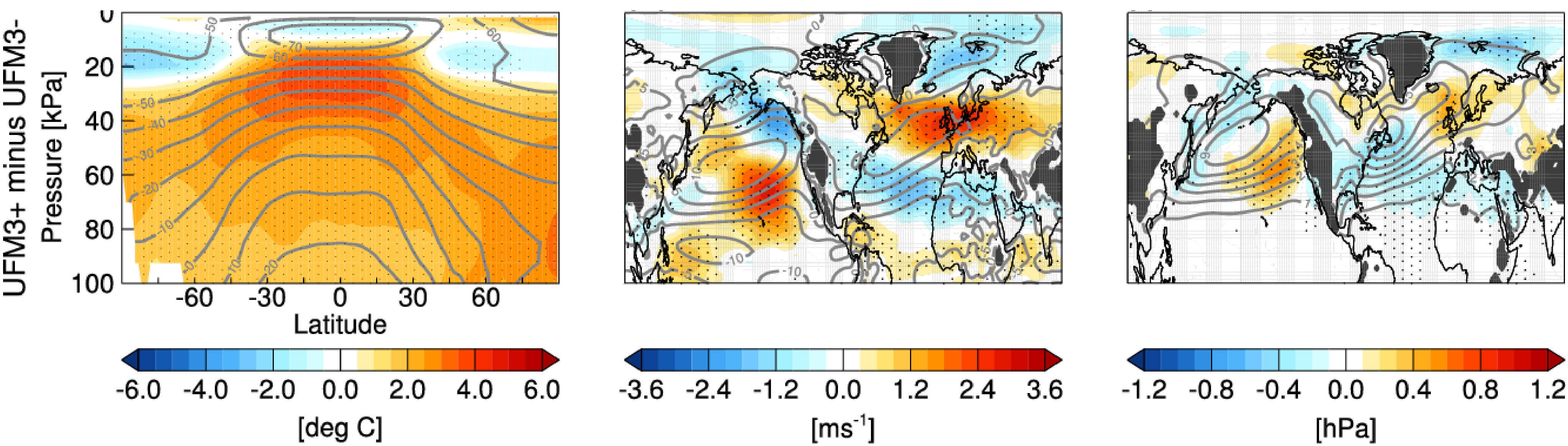
HadGAM1 sensitivity experiments

National Centre for Atmospheric Science
NATURAL ENVIRONMENT RESEARCH COUNCIL

Warm Arctic minus Cold Arctic



Warm Tropics minus Cold Tropics



Summary

National Centre for Atmospheric Science
NATURAL ENVIRONMENT RESEARCH COUNCIL

1. Analysis of the CMIP5 ensemble and sensitivity experiments with HadGEM1 suggest that
    - Upper Tropical Warming intensifies the NH DJF storms tracks
    - Lower Polar Warming weakens the NH DJF storm tracks
2. Both Upper Tropical and Lower Polar Warming are important for the mean response, but the Lower Polar Warming is more important for the large spread of projections in the North Atlantic (see also Son et al. 2015).

Caveats:

1. Have we chosen the correct processes to look at – e.g. role of SST changes in the North Atlantic (Woollings et al. 2012) or stratospheric responses (Manzini et al. 2014)?
2. The sensitivity experiments are with only one model – is robustness an issue? Are there better ways of performing the experiments?