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Sensitivity of the North Atlantic storm track to regional drivers of change

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In the **zonal mean**, the **extra-tropical storm tracks** are expected to shift **poleward** and **upward** in response to anthropogenic greenhouse-gas forcing[1], consistent with **enhanced tropical convection** widening the **Hadley cell**.

Model simulations suggest, however, that the **North Atlantic storm track** will respond **differently**. Instead of a poleward shift, a **strengthening** and an **eastward extension** towards Europe is predicted (Figure 1a), albeit with a **large inter-model spread** (Figure 1b).

As part of the UK's NERC-funded **TEMPEST** project we are investigating the **mechanisms** behind this North Atlantic storm track response pattern, and also the **sources** of the large inter-model spread.

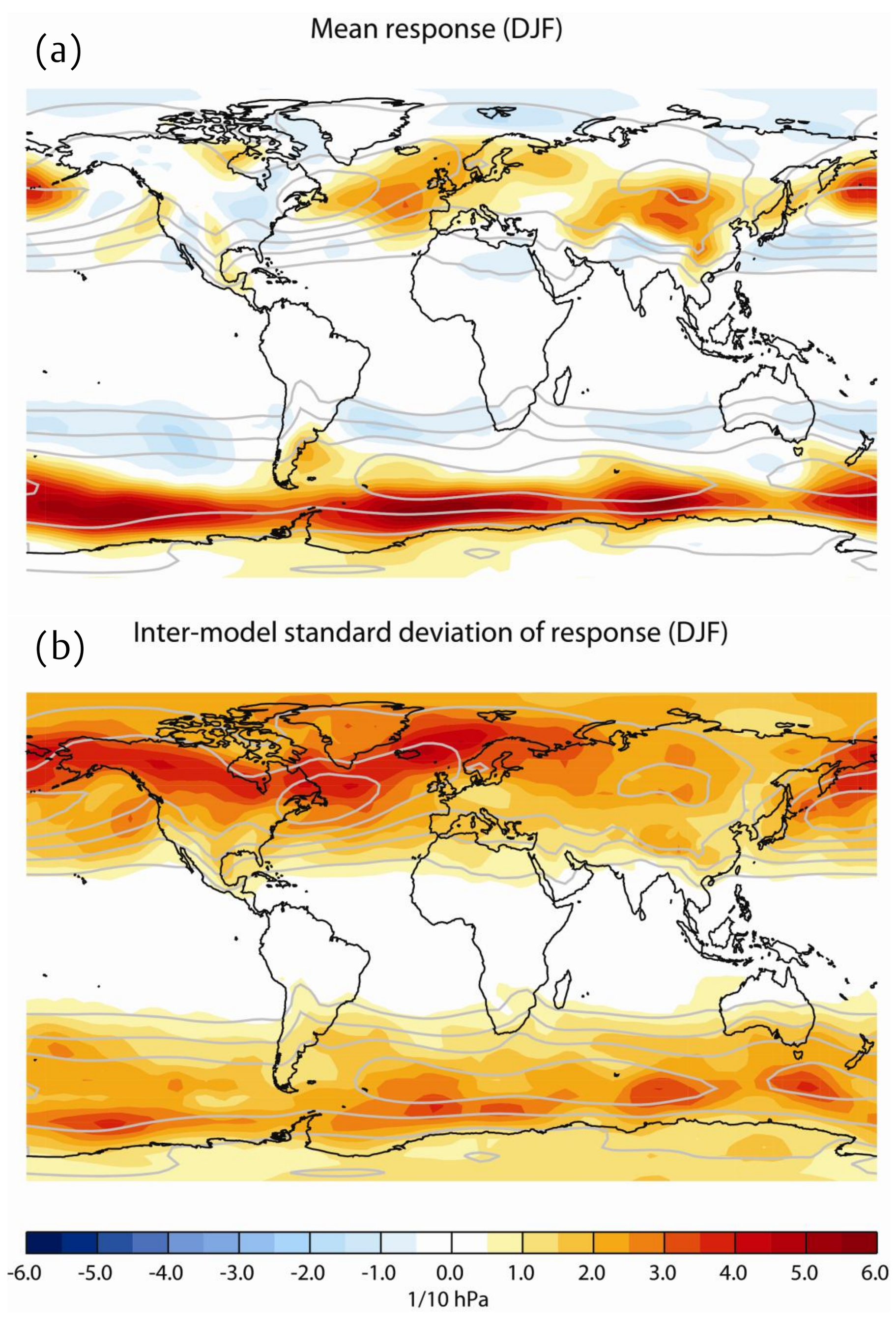

Figure 1: MSLP DJF storm tracks from the CMIP3 multi-model dataset.

Contours show the 1960-2000 multi-model mean storm track (hPa) and the shading shows (a) the multi-model mean 2060-2100 response, and (b) the inter-model spread in the responses.

Here the storm track is defined as the **standard deviation of the 2-6 day filtered mean sea level pressure field**.

Data for this analysis was available for 15 of the 23 CMIP3 models.

Possible drivers of change

Table 1 lists some **physical processes** which are likely to be important factors in setting the **intensity** and **location** of the North Atlantic storm track. They are split into **"global drivers"**, meaning those that act on all storm tracks, and **"regional drivers"**, meaning those that are particular to the North Atlantic region.

Global drivers	Regional drivers	
Upper level pole-eq. T contrast	Atlantic SSTs	AMOC?
Low level pole-eq. T contrast	Arctic sea ice extent	
Local moisture content	Land-sea contrast	
	Tropically-forced stationary waves	

Table 1. Possible drivers of change for the North Atlantic storm track.

Here we focus on the **regional drivers of change**, in particular the impacts of the **Atlantic sea surface temperatures (SSTs)** and the **Arctic sea ice extent**. We have designed a series of **atmospheric GCM** experiments to investigate quantitatively the effects of these drivers on the North Atlantic storm track.

There are **two** main questions we would like to answer

1. How much of the **mean response** of Figure 1(a) is reproduced using the CMIP3 multi-model mean SST and sea ice fields to force an atmosphere model
2. How much of the **spread** of Figure 1(b) is reproduced using forcing fields that represent the spread in the CMIP3 SST and sea ice response fields?

Experimental design

We have run four 20-year experiments using the atmosphere component of the **UK Met Office's Unified Model** (HadGAM1) as illustrated in Figure 2. Each experiment is forced by different SST and sea ice fields.

These represent multi-model mean conditions for the late 20th and 21st centuries (**CONTROL** and **A1B**), and also the inter-model spread in the 21st century predictions (**A1B+** and **A1B-**).

The **spread in the SST responses** is characterised using the **leading EOF of the inter-model response patterns**. That is, the pattern which explains the most of the spread between the 22 individual models. An example is shown in Figure 3.

The **spread in the Arctic ice responses** is characterised by measuring the ice edge retreat exhibited by each model. The position of the ice edge is then retreated at each longitude by the **median value** for the A1B experiment, and by an **upper and lower percentile** for the A1B- and A1B+ experiments respectively.

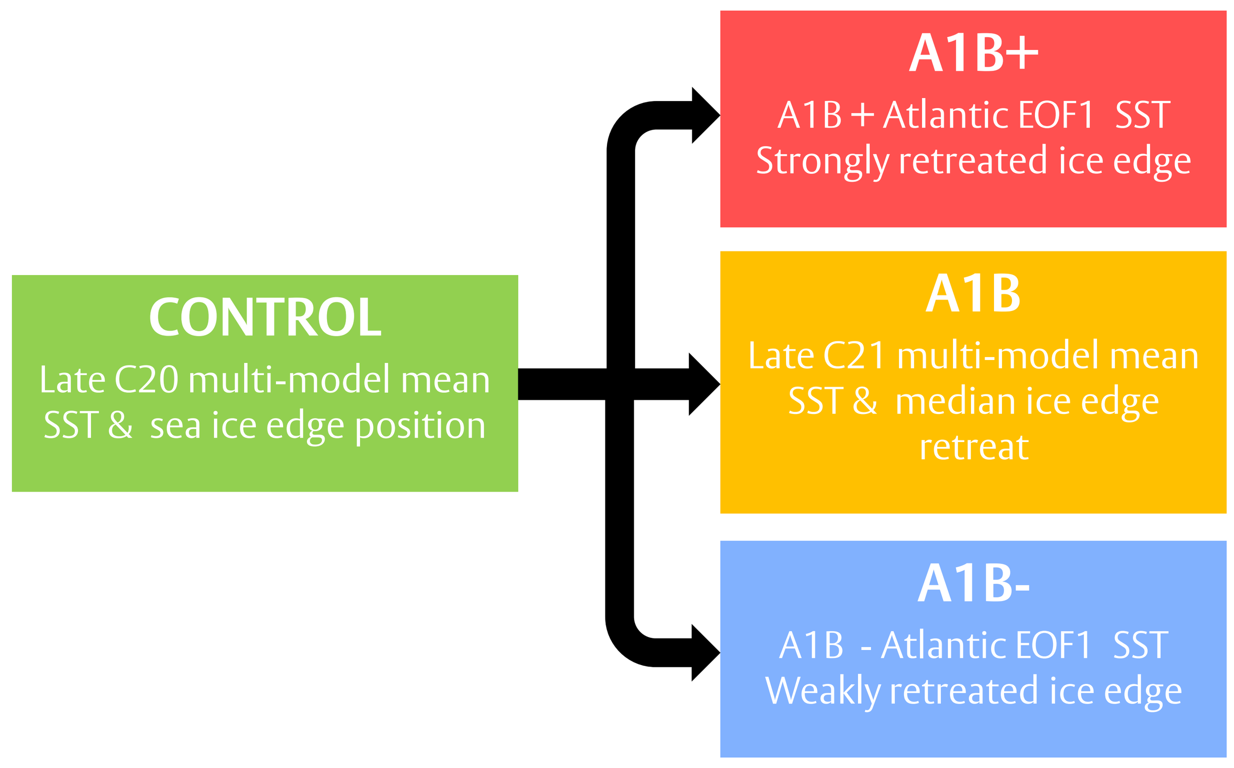

Figure 2. The experimental setup. In addition to the SST and sea ice differences, the CONTROL experiment uses late C20 gas concentrations whereas all three A1B experiments use late C21 gas concentrations from the A1B scenario.

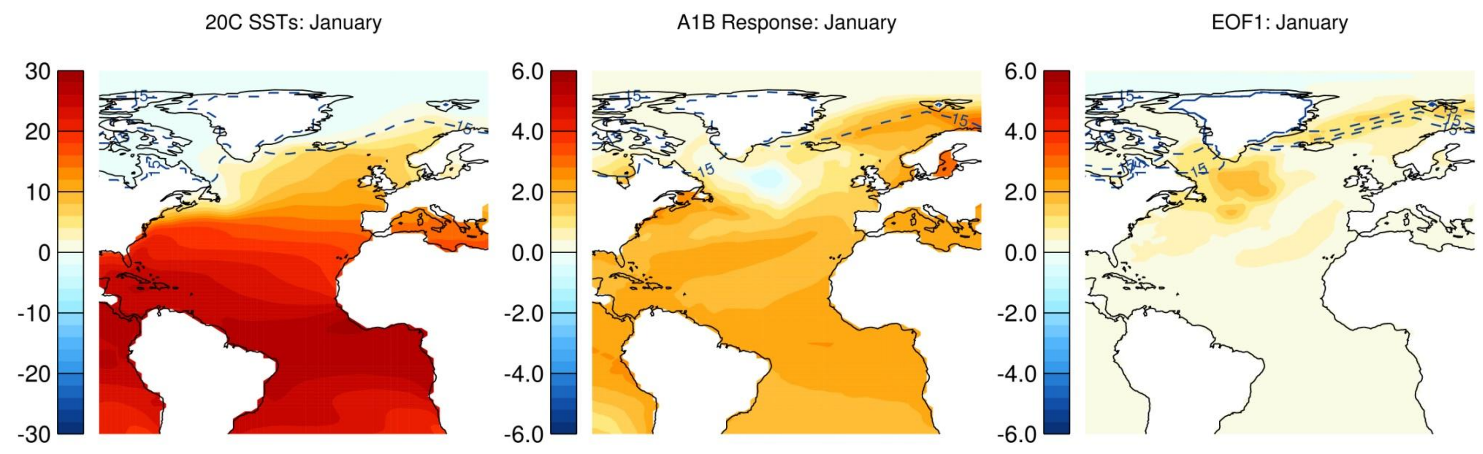

Figure 3. Atlantic SST distributions for January: (left) the 20c3m 1960-2000 multi-model mean, (centre) the A1B 2060-21000 multi-model mean response, and (right) the leading EOF of the inter-model response patterns. The dashed lines show the ice edge positions.

Preliminary Results

Figure 4 shows the **DJF storm track responses** for each of the A1B experiments.

The response to the **A1B SST and sea ice changes** (centre panel) shows some **geographical similarity** to the CMIP3 multi-model mean of Figure 1(a).

Both the **southern hemispheric and the Pacific storm tracks** shift poleward, whereas the **North Atlantic storm track** strengthens slightly and extends towards Europe.

The response to the **A1B+ and A1B- forcings** are shown relative to the A1B storm track in the upper and lower panels respectively. The responses are of **similar magnitude** to the inter-model standard deviation of Figure 1(b).

The responses are **not confined to the Atlantic sector**: there is a strong signal in the Pacific sector as well. The responses also appear to be **non-linear** in that they are not simply opposite in sign to each other.

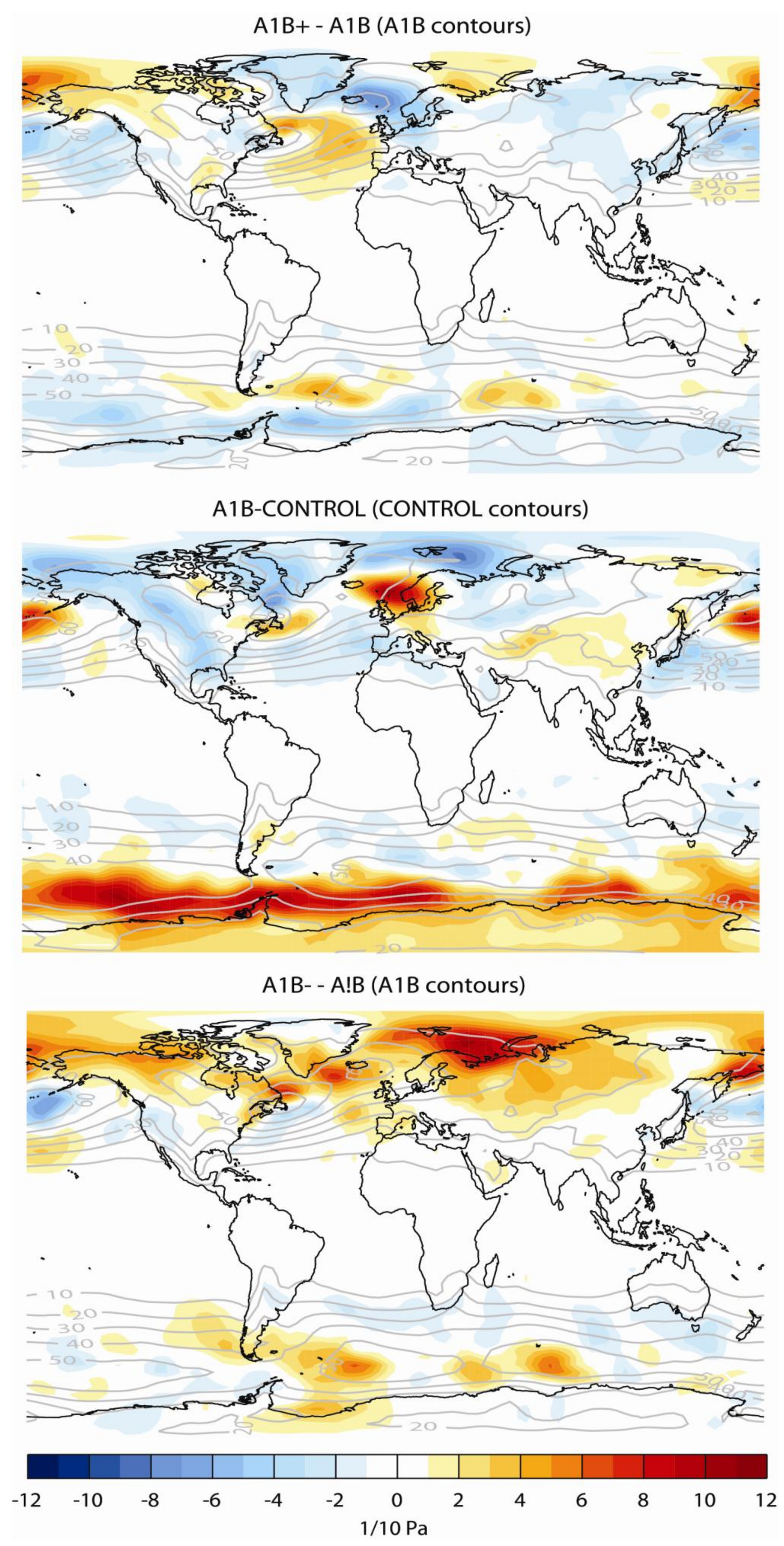

Figure 4. MSLP DJF storm track responses for the three A1B experiments.

The three panels show,: A1B+ relative to A1B (top), A1B relative to CONTROL (centre) and A1B- relative to A1B.

The storm track definition and the contour levels are as in Figure 1, but note that the colour scales are different.

Future Work

- Extend the analysis of these experiments to better understand the detailed **structure of the responses,** as well as the **relative importance** of the SST and sea ice changes.
- Relate these results to recent work[2] linking storm track responses to changes in the **Atlantic meridional overturning circulation** (AMOC). As Table 1 suggests, the AMOC strongly affects both the Atlantic SSTs and the Arctic sea ice extent.
- Design further experiments to examine the importance of the **other drivers of change** on the inter-model spread of storm track responses.

References

1. Yin, J. H. (2005), *Geophysical Research Letters*, **32, L18701**
2. Woollings, T. J., Gregory J. M., Reyers, M. and Pinto, J. G. (in prep)

Acknowledgements

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