Future changes in Northern Hemisphere extra-tropical cyclones

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1. Introduction

Aims
To assess future changes in storms in experiments carried out with HadGEM1
To compare results to those of earlier Hadley Centre models
To assess the uncertainty of the changes in storms

Model
HadGEM1 coupled ocean-atmosphere model (see Martin et al. 2006; Ringer et al. 2006; Johns et al. 2006)
Atmosphere: horizontal resolution of N96 (1.25° latitude x 1.875° longitude, 150km), L38
Ocean: zonal resolution of 1°, meridional resolution of 1° longitude between poles and 30° latitude, from which it increases smoothly to 1/3° at the equator

Experiments
CTRL: 120y mean (1931-2050) from pre-industrial control (forcing fixed at 1860)
2xCO2: 120y mean from fixed 2xCO_2 experiment, continued from year 70 of experiment with CO_2 increasing at 1% pa
HA: 30y mean (1961-1990) from experiment with historical forcing
A1B: 30y mean (2070-2099) from IPCC SRES A1B experiment
A1Bstab: 90y mean (2109-2199) from A1B stabilisation experiment (forcing fixed at 1 Dec 2099 of A1B)

Cyclone location and tracking
Cyclones are located and tracked in 6-hourly mean sea-level pressure (MSLP) data using TRACK (Hodges 1994)

2. Cyclone track density in the CTRL experiment

The location and magnitude of the cyclone tracks in CTRL (b) compare fairly well with those in ERA40 (a) and are an improvement of those in previous models. Some large differences remain (c) and these are often larger than the climate change signal and so add to the uncertainty of the future changes.

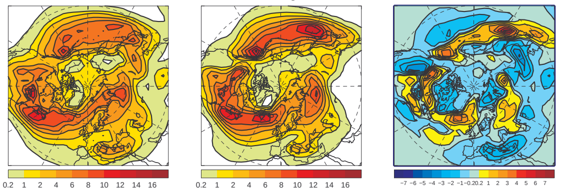

Figure 1: *Winter (DJF) track density in (a) ERA40, (b) 120y of HadGEM1 CTRL and (c) difference from ERA40. Units are tracks per month per 10^6 km²*

3. Natural variability of cyclones in HadGEM1 CTRL experiment

The CTRL simulation can be used to test if the future changes are outside natural variability. **Figure 2** shows examples of the variability in the location and magnitude of the cyclones. There is some variability of the North Pacific and North Atlantic cyclone tracks in HadGEM1. The track density is less variable over Western Europe than in the main track regions.

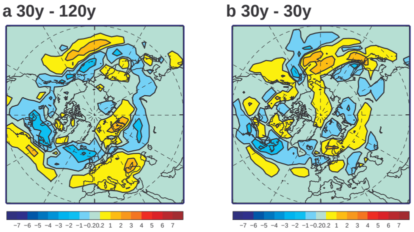

Figure 2: *Winter (DJF) track density for CTRL (a) 30y mean (2051-2080) minus 120y mean (1931-2050) and (b) 30y (2021-2050) minus 30y (1931-1960). Units are tracks per month per 10^6 km²*

4. Future changes in cyclones in HadGEM1 A1B experiment

The global mean warming is 3.6K in A1B and 4.4K in A1Bstab. The cyclone activity is reduced in most regions in both A1B (a) and A1bstab (b) compared to CTRL, with the largest reduction in activity occurring in the North Pacific. From the results in Box 3 this reduction appears to be significant. There are more cyclones at high latitudes where sea ice has melted. There is little change in the frequency of cyclones over the UK and Western Europe.

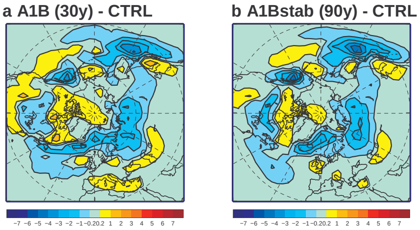

Figure 3: *Winter (DJF) track density for (a) A1B (2070-2099) minus CTRL and (b) A1Bstab (2110-2199) minus CTRL. Units are tracks per month per 10^6 km²*

5. Comparison of HadGEM1 and HadAM3P

Here we compare the changes in storms in HadGEM1 to those in the earlier HadAM3P model. The global mean warming is 3.2K in (a) and 3.3K in (b). The main difference in the response is around the UK where the increase in storminess seen in HadAM3P (a) does not occur in HadGEM1 (b).

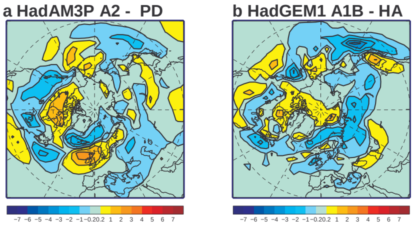

Figure 4: *Winter (DJF) track density for (a) HadAM3P ensemble mean of A2 (2071-2100) minus PD (1961-1990) and (b) HadGEM1 A1B (2070-2099) minus HA (1961-1990). HadAM3P is an N96 atmosphere only model, based on HadAM3 but with a higher horizontal resolution and some physics changes to improve the simulation of MSLP in the North Atlantic. The experiments are run as time-slices for the PD and A2 periods. A 3-member ensemble was run for each period. Units are tracks per month per 10^6 km²*

6. Future changes in Southern Hemisphere cyclones as simulated by HadGEM1

There are some large differences between the cyclone tracks in CTRL and ERA40 (a). In the future simulations both A1B (b) and A1bstab (c) indicate a poleward shift of the Southern Hemisphere tracks, giving an increase in cyclones around Antarctica.

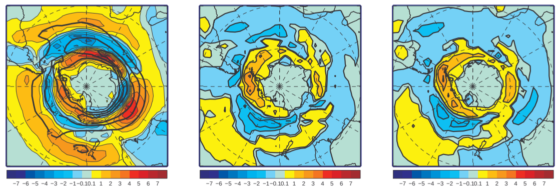

Figure 5: *Winter (JJA) track density for (a) CTRL minus ERA40 and CTRL (bold contours), (b) A1B (2070-2099) minus CTRL and (c) A1Bstab (2110-2199) minus CTRL. Units are tracks per month per 10^6 km²*

7. Changes in frequency of cyclones

	Experiment	Period	Mean number of storms per winter	Change in mean number of storms per winter	Change on number of deep storms (P<970 hPa)	ΔT (K) annual mean global mean
HadGEM1 Northern Hemisphere (North of 30° north)	Ctrl	120y	154.8		(40 in Ctrl)	
	2xCO_2 - Ctrl	120y	148.2	**-6.6**	-0.7	2.3
	A1B - Ctrl	2070-2099	146.2	**-8.7**	**-2.5**	3.6
	A1Bstab - Ctrl	2110-2199	144.1	**-10.7**	**-2.7**	4.4
	A1B – HA (1961-1990)	2070-2099		**-8.4**	-2.5	3.3
HadAM3P Northern Hemisphere	HadAM3P PD	3 x 30y 1960-1990	157.1		(32 in PD)	
	HadAM3P A2	3 x 30y 2070-2100	151.9	**-5.1**	**2.4**	3.2
HadGEM1 Southern Hemisphere (South of 30° south)	Ctrl	120y	165.2			
	2xCO_2	120y	161.2	**-3.9**	1.0	2.3
	A1B	2070-2099	157.4	**-7.8**	1.8	3.6
	A1Bstab	2110-2199	157.7	**-8.3**	1.1	4.4
	A1B – HA (1961-1990)	2070-2099		**-9.5**	1.0	3.3

Fewer storms
Fewer deep
More deep

The mean number of cyclone tracks per winter (DJF) is calculated for the Northern and Southern Hemisphere for all cyclone tracks and for those with a central MSLP less than 970 hPa. Changes in bold are significant using a t-test.

8. Conclusions

The changes to intensity of storms and regional frequency changes due to CO_2 increases remain uncertain. The degree of natural variability of regional storm characteristics is large.

HadGEM1 has fewer Northern and Southern Hemisphere storms in winter in the future. The magnitude of the change in the number of storms increases as the temperature rises. Other Hadley Centre models also have fewer Northern Hemisphere winter storms. Unlike previous Hadley Centre models there is no shift to deeper storms in the Northern Hemisphere. There is some evidence of a shift to deeper storms in the Southern Hemisphere.

There are some local increases in storminess in both hemispheres. The location of the North Hemisphere increases varies with model and simulation. In the HadGEM1 A1B simulation the Southern Hemisphere tracks shift polewards.

There is no increase in storminess over the UK in HadGEM1, unlike in HadAM3P. The projections of increased storminess during this century around the UK by HadAM3P are therefore not robust.

References
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