2C.6 THE IMPACT OF CLIMATE CHANGE ON NORTHWEST ATLANTIC HURRICANES AND WINTER STORMS

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1. Introduction

Understanding North Atlantic storm climate is the key in ongoing studies and simulations of ocean surface waves and currents. Following two differing methodologies presented in studies by Knutson and Tuleya (2004), and Nguyen and Walsh (2001), we explore possible climate change scenarios on North Atlantic storms. These include winter storms as well as midlatitude hurricanes.

Two approaches are adopted. Summer-autumn extratropical cyclone simulations are performed with the Canadian mesoscale compressible community (MC2) model, driven by control and high-CO2 climate estimates from the global coupled atmosphere-ocean climate model, (the Canadian Climate Centre CGCM2 model), using an ensemble approach. For winter storms, simulations were performed with the Canadian Regional Climate Model (CRCM), again driven by control and high-CO2 climate estimates from CGCM2.

The control condition, representing present climate, consists of years 1975 to 1994. The high-CO2 climate change conditions were obtained from years 2040-2059 of a transient +1% yr-1 CO2 increase experiment with CGCM2, following IPCC IS92a, which gives a nearly doubling of CO2 concentrations by 2050, compared to the 1980s.

2. MC2 model results

Two experiments were conducted using MC2. In the first experiment, an ensemble of storm simulations were performed in each of the two scenarios (present and future climate), using an embedded initialization bogus vortex with a central SLP (sea level pressure) that was normally distributed with a mean of 985 hPa and a fixed initial location at (72.5°W, 35°N). Within each ensemble (present and future climate), results suggest that storm development shows little variation in peak intensity or storm track trajectory, despite large variations in initial bogus intensity. The high CO_2 climate results in slightly higher mean peak storm intensity than that of the control climate, and mean storm tracks that are 100-200 km closer to the North American coastline (Fig. 1).

In the second experiment, storm simulations were completed in each of the two scenarios (present and future climate) with the same initialization bogus vortex intensity (980 hPa), but distributed uniformly in space over a sub-region of the integration domain. Large differences in storm intensity, storm development and track strongly depend on the large-scale climate environment. Results from the high CO_2 scenario can be rather different from those of the control climate. However, averaged environment scenario fields are not the only factor. The impact of averaged environmental scenario fields on storm intensity and track is dependent on the location of the storm initialization within these averaged scenario fields. In comparing the effects of the high CO_2 and control scenarios with the four sub-regions in Fig. 2, the storms that are initially located south of 35°N and west of 65°W exhibit the largest differences in intensity and track under two climate scenarios. These storms develop greater peak intensities and follow storm tracks that experience the largest shift towards the North American coast under high CO_2 conditions, compared to other storms.

3. Regional Climate Model Results

In this approach, outputs from the CGCM2 simulations for the control years, 1975-1994, and the climate change years, 2040-2059, are used to drive CRCM, thus achieving a downscaling in climate data. Objective criteria are used to select all the resulting features that resemble storms from the two datasets, representing present and future climate. Following Nguyen and Walsh (2001) the criteria consist of: 1) A local minimum of sea level

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pressure (SLP) less than 1010 hPa within 240 km. 2) The center has at least one closed isobar on a 4 hPa increment. 3) The lifetime of cyclones is at least 24h. 4) The trajectories are determined by a simple nearest-neighbour search within 1100km in the preceding SLP field without assuming a preferred propagation direction.

Baroclinic instability is an important mechanism for the development of extratropical cyclones. To identify the changes in baroclinicity, the maximum Eady growth rate is calculated, which is an accurate estimate of baroclinicity and defined as $\sigma = 0.31(f/N)|\partial V/\partial Z|$ where f is the Coriolis parameter, N is the static stability, Z is the vertical height and V is horizontal wind vector. The maximum Eady growth rate was estimated from monthly wind, temperature and geopotential height for 250-500hPa layer and 700-850hPa layer. Figs. 3a - 3b show the maximum Eady growth rate in the lower troposphere, estimated from NCEP reanalyses and CRCM simulation suggesting that CRCM well reproduces the baroclinicity of lower troposphere. For example, both NCEP reanalyses and CRCM simulation show a distinct maximum along the east coast of North America. Fig. 3c shows the changes of baroclinicity. Under the enhanced greenhouse warming conditions, there is a significant decrease in the baroclinicity along the east coast of North America, which is consistent with the maximum change in temperature gradient (not shown). Since the activity of extratropical cyclones is more sensitive to the lower troposphere, it is reasonable to expect that there is a significant decrease of extratropical cyclones along the east coast of North America.

There are two maximum cyclone count centers: one over the Great Lakes and Hudson Bay region, and the other extends along the east coast of North America which exhibits a southwest-northeast orientation. The latter family of storms is considered in Fig. 4. These patterns are very similar to other studies (Carnell and Senior, 1998) which suggests that our automated identification and tracking scheme can detect and track most of the extra-tropical cyclones over northeast America and the western Atlantic region. CRCM reproduces the centers and geographic locations of cyclone counts reasonably well, compared to CMC analyses (not shown). The agreement between observed and simulated cyclone numbers is reasonably good, but CRCM somewhat overestimates the number of weak cyclone (with central pressure > 975hPa) and underestimates the deep cyclones (with central pressure below 975hPa). Fig. 4 shows mean storm tracks comparing present and future climate scenarios, suggesting a northwest displacement of the mean storm track. Results are not inconsistent with trends seen in Figs. 1-2. Our presentation will show that in essentially all categories, under the climate change scenario, there are fewer storms than in the current climate. This can also be found in the time series of storm counts. In particular, results suggest that in a the future climate scenario, there are fewer deep storms than in the current climate.

4. Conclusions

Understanding North Atlantic storm climate is the key in ongoing studies and simulations of ocean surface waves and currents. Compared with the current climate, the storm tracks in the climate change scenario move nearer the coastal area of North Atlantic, become less tightly distributed in space. A very slight increase in storm intensity is suggested in simulations of summer-autumn extra-tropical hurricanes, but not in winter storms, and composite storm structure does show change. In summer-autumn storm simulations, the net impact of the climate change scenario is to cause a slight tendency for increase in number of severe storms (~5%).

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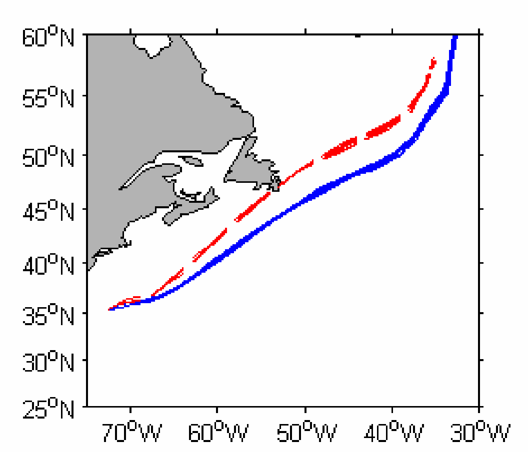


Figure 1. First experiment. Storm tracks from ensemble studies using MC2, for storms simulated in the present ——, and high CO_2 scenario — —.

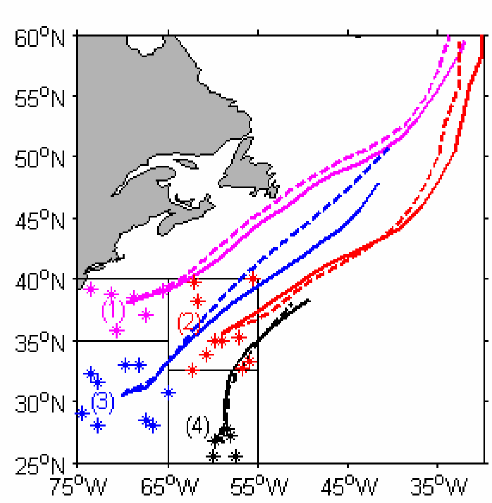
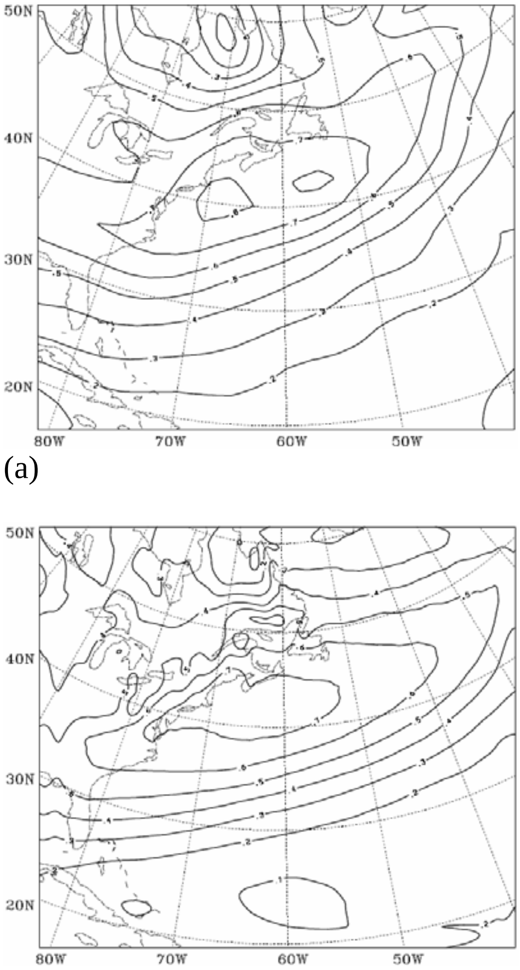


Figure 2. As in Fig.1, storm tracks for 2nd experiment storms in 4 geographic groups: mean storm tracks, control (solid) and high CO_2 (dashed).



(a)

(b)

Figure 3. Winter (DJF) averaged maximum Eady growth rate for the 700hPa to 850hPa. (a) NCEP reanalyses, (b) simulated by CRCM for current climate.

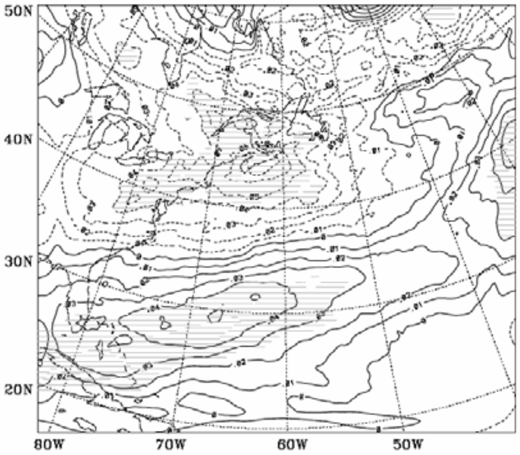


Figure 3c. Continued from Figs. 3a-3b. Future climate minus current climate. Isoline spacing is 0.1 day^{-1} in (a) and (b) and 0.01 day^{-1} in (c). Light hatching in (c) indicates 5% significance level with student's t-test.

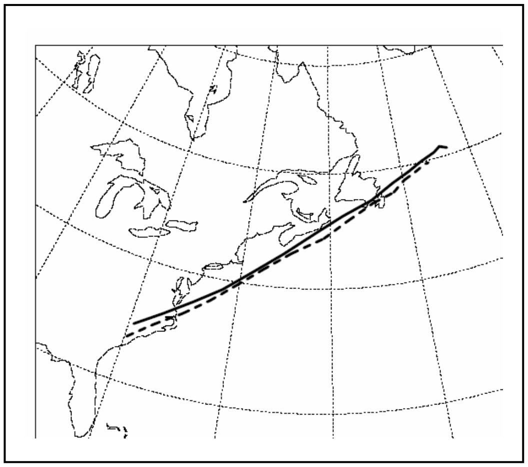


Figure 4. As in Fig. 1, using CRCM to simulate mean winter storm tracks, showing control (dashed) and future climate scenario (solid).