Will climate change increase transatlantic aviation turbulence?

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Introduction

Atmospheric turbulence causes most weather-related aircraft incidents (Sharman et al. 2006). Commercial aircraft encounter moderate-or-greater turbulence tens of thousands of times each year world-wide, injuring probably hundreds of passengers (occasionally fatally), costing airlines tens of millions of dollars, and causing structural damage to planes. Clear-air turbulence is especially difficult to avoid, because it cannot be seen by pilots or detected on-board radar.

Clear-air turbulence is linked to atmospheric jet streams, which are projected to be strengthened by anthropogenic climate change (Lorenz & DeWeaver 2007). However, the response of clear-air turbulence to projected climate change has not previously been studied.

Here we enquire whether the incidence of clear-air turbulence might change in response to anthropogenic climate change.

Methodology

We use simulations from the GFDL-CM2.1 coupled atmosphere–ocean model. We use 20 years of daily-mean data from two model integrations: pre-industrial and doubled-CO_2.

We focus on the months of December, January and February, which are when Northern Hemispheric clear-air turbulence is most intense. We calculate clear-air turbulence diagnostics from the daily-mean temperature and wind fields at the 200 hPa pressure level, which is within the permitted cruise altitudes.

We focus our analysis on the North Atlantic flight corridor between Europe and North America, which is the airspace within 30-75°N and 10-60°W. This flight corridor is one of the world's busiest, containing approximately 300 eastbound and 300 westbound flights per day (Irvine et al. 2013).

Results

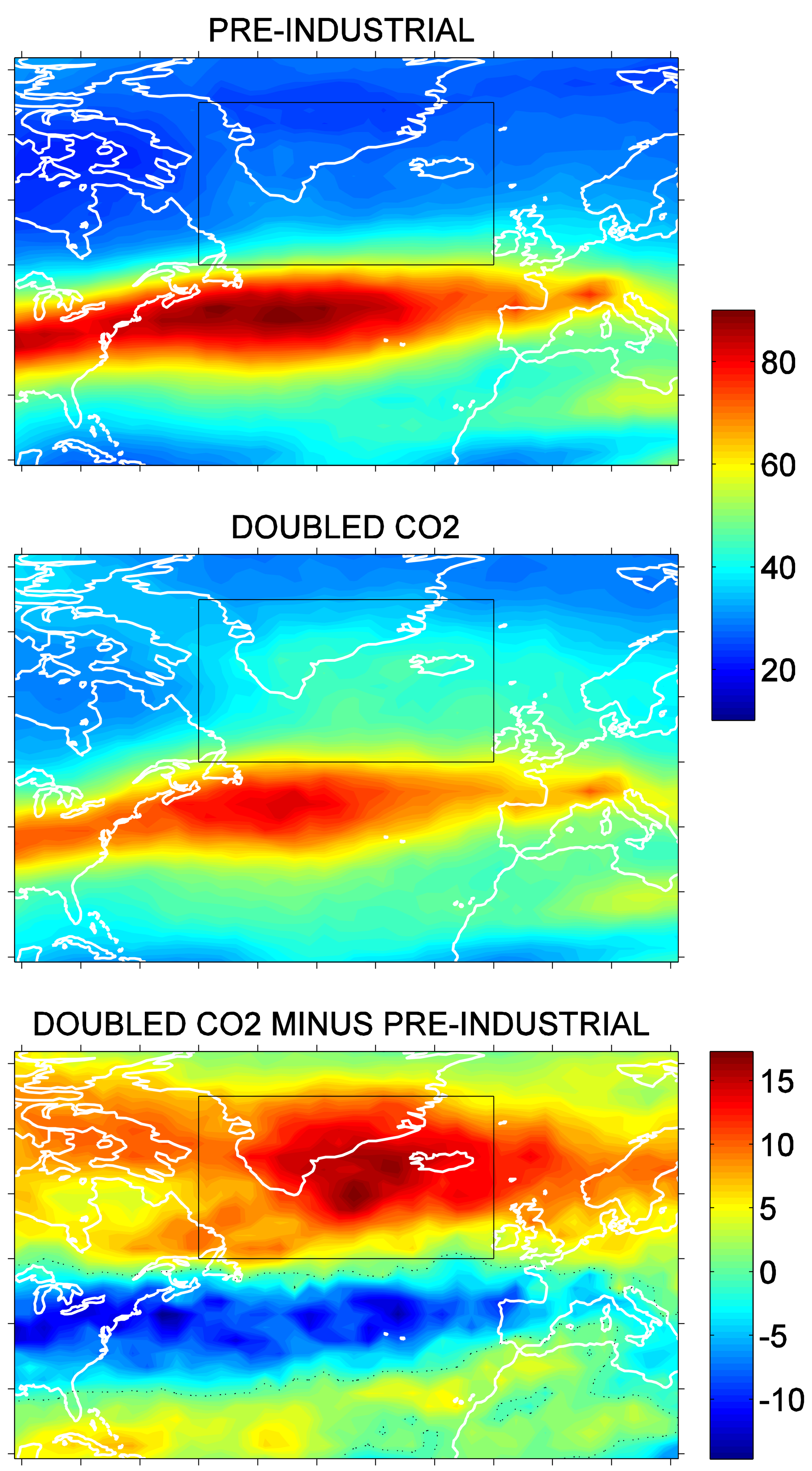

Figure 1. Spatial patterns of North Atlantic flight-level winter clear-air turbulence in a changing climate. The quantity shown is the median of variant 1 of Ellrod's turbulence index (10^{-9} s^{-2}), computed from 20 years of daily-mean data in December, January and February at 200 hPa. The top two panels are from pre-industrial and doubled-CO_2 integrations, and the bottom panel is the difference. The black dotted line in bottom panel is the zero contour. The rectangles outline the analysis box used in Figure 2. The maps span 20-80°N and 90°W-20°E.

Figure 1 shows maps of the median of Ellrod's index, which is one of the most widely used clear-air turbulence diagnostics. Higher values indicate more turbulence. In the doubled-CO2 simulation, the turbulence strengthens north of 50°N, consistent with the poleward migration of the jet stream in this model.

Figure 2 shows probability distributions of Ellrod's index. Compared to the pre-industrial histogram, the doubled-CO_2 histogram is wider and less peaked, with probability density spread out to higher values. The longer tail indicates a shift towards stronger turbulence. The medians of the two distributions are 31.5×10^{-9} s^{-2} and 41.9×10^{-9} s^{-2}, an increase of 32.8%.

We next repeat the above calculations for 20 other clear-air turbulence diagnostics. Each one shows an increased median in the doubled-CO_2 integration, mostly in the range 10-40%. We also examine the right-hand tails, by taking the 99th percentile of the pre-industrial histogram to correspond to the threshold for moderate turbulence. Nearly all the diagnostics show an increase in the frequency of occurrence of moderate-or-greater turbulence in the doubled-CO_2 integration, mostly in the range 40-170%.

Figure 3 shows a synthesis map indicating the level of agreement between the changes in the 21 diagnostics. Most or all of the British Isles, Norway, Sweden, and Iceland lie within airspace at which 21 out of 21 diagnostics show an increase.

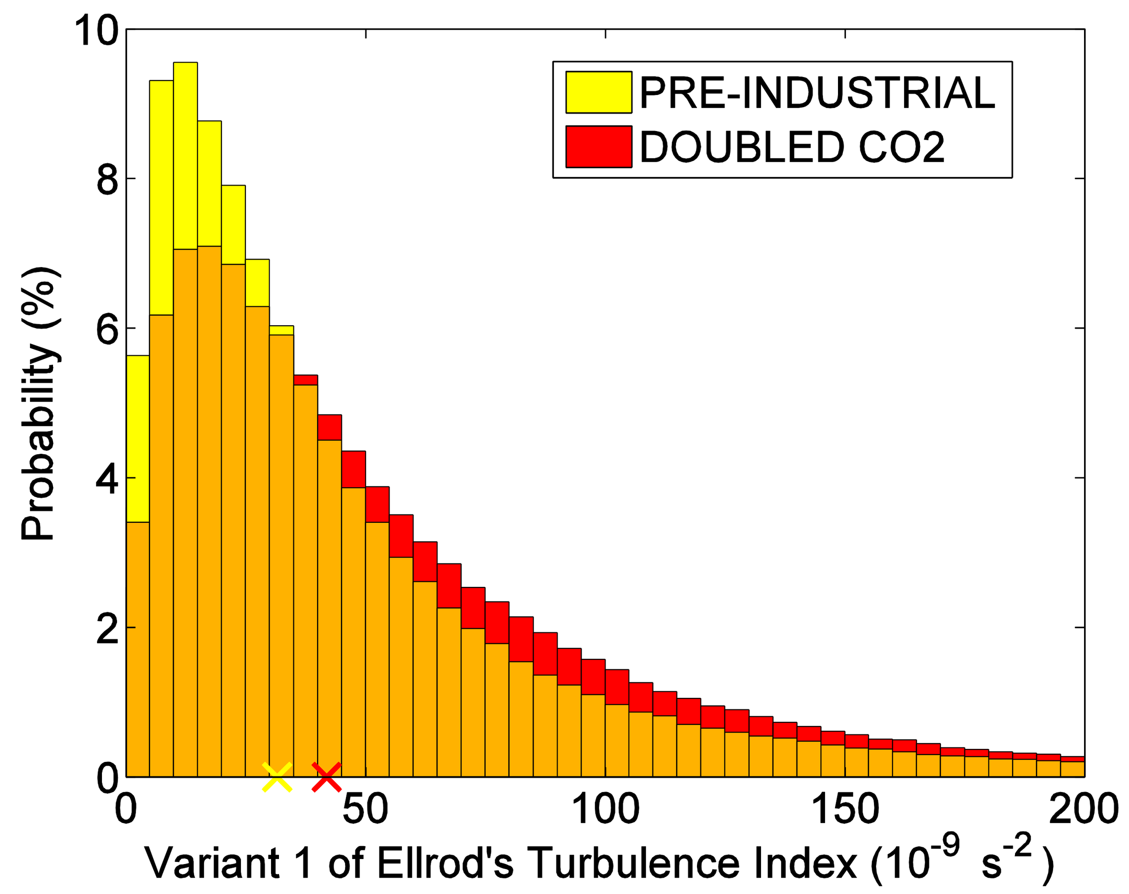

Figure 2. Probability distributions of northern North Atlantic flight-level winter clear-air turbulence in a changing climate. The probabilities of lying within consecutive bins of width 5×10^{-9} s^{-2} are computed from 20 years of daily-mean data in December, January and February, at 200 hPa and within 50-75°N and 10-60°W. The overlap between the two histograms is shaded orange. The crosses on the turbulence axis indicate the medians.

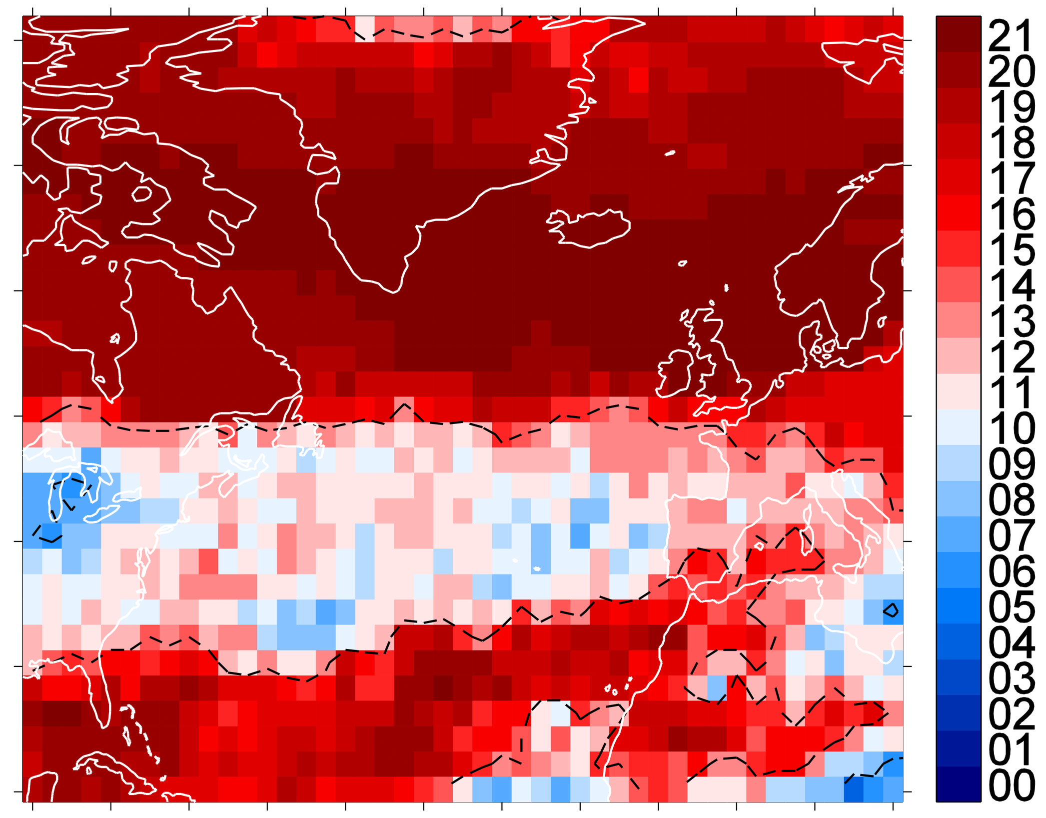

Figure 3. Will North Atlantic flight-level winter clear-air turbulence increase or decrease in a warmer climate? The quantity shown is the number of the 21 clear-air turbulence diagnostics to show an increase in the median, in the doubled-CO_2 integration relative to the pre-industrial integration. The medians are computed from 20 years of daily-mean data in December, January and February at 200 hPa. Red shading indicates that the majority of the diagnostics show an increase, and blue shading indicates that the majority show a decrease. The black dashed lines are 90% confidence limits. The map spans 20-80°N and 90°W-20°E.

Conclusions

- Most clear-air turbulence diagnostics show a 10-40% increase in the median, and a 40-170% increase in the occurrence of moderate-or-greater turbulence, when CO_2 is doubled.
- We conclude that climate change will lead to bumpier transatlantic flights by the middle of this century.
- Flight paths may need to become more convoluted to avoid patches of turbulence that are stronger and more frequent, in which case journey times will lengthen and fuel consumption and emissions will increase.
- Any increase in clear-air turbulence could have important implications for the large-scale atmospheric circulation, because clear-air turbulence contributes significantly to troposphere–stratosphere exchange.

Further information

- PD Williams & MM Joshi (2013) Intensification of winter transatlantic aviation turbulence in response to climate change. *Nature Climate Change*, doi: 10.1038/nclimate1866.

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