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-CO2.

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 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-CO2 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 315 x 10^3 s^-2 and 419 x 10^3 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-CO2 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-CO2 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.

Conclusions

• Most clear-air turbulence diagnostics show a 10-40% increase in the median, and a 90-170% increase in the occurrence of moderate-or-greater turbulence, when CO2 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 tropopause-stratosphere exchange.

Further information


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