Transatlantic flight times and climate change

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Introduction

Aviation contributes to climate change (Stuber et al. 2006, Lee et al. 2009). However, it is becoming increasingly clear that the interaction is two-way, and that climate change has important consequences for aviation, such as increased clear-air turbulence (Williams & Joshi 2013).

The average along-track winds between New York (JFK) and London (LHR) at 200 hPa in winter may increase by 14.8 % from 21.4 to 24.6 m s^{-1} when the CO_2 is doubled, as shown in Figure 1. This increase is composed of changes to both the jet stream (Lorenz & DeWeaver 2007) and the stationary planetary wave (Simpson et al. 2016). What are the implications for transatlantic flight times?

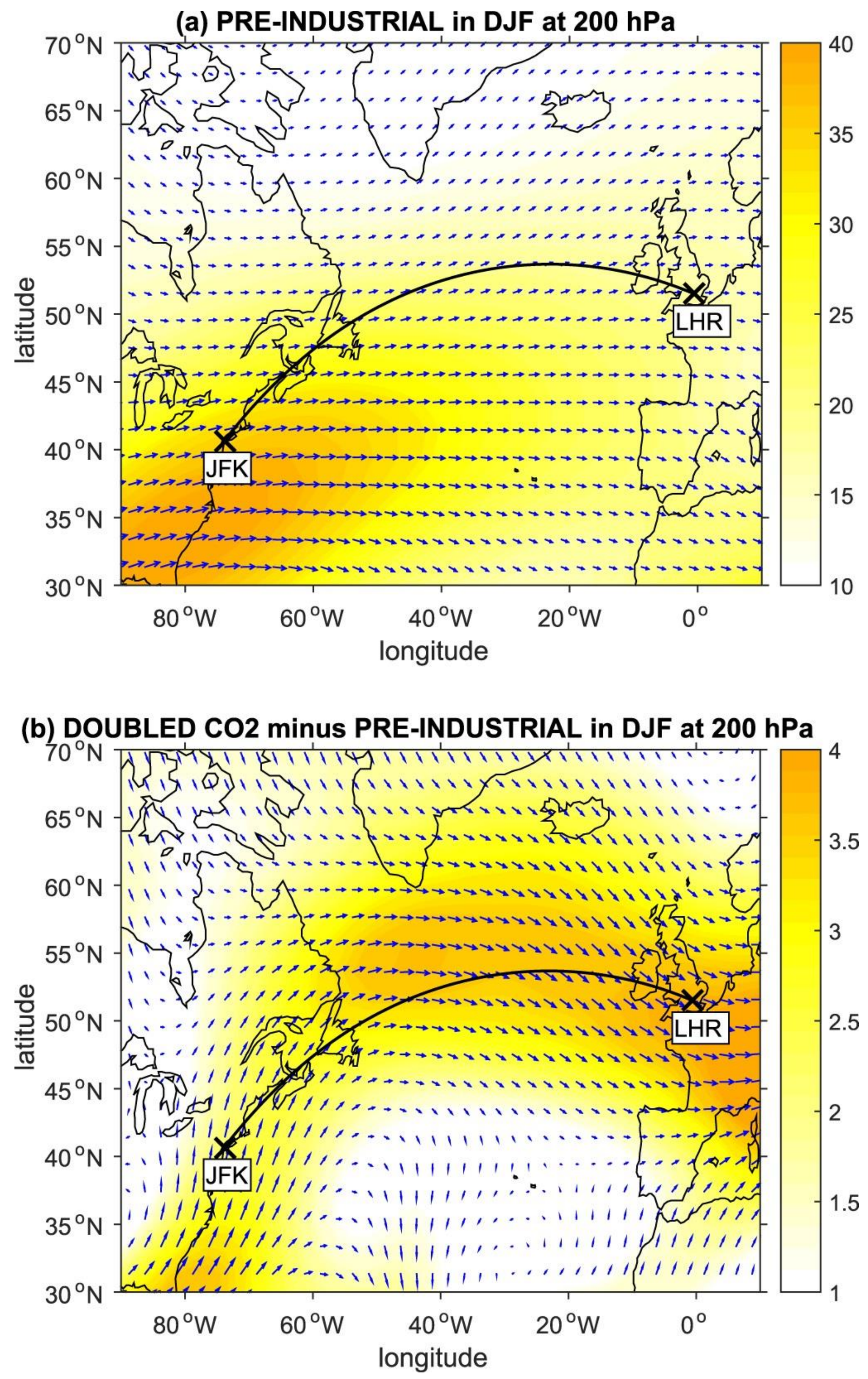

Figure 1. Changing winter winds in the north Atlantic sector. Blue vectors (one per grid point) indicate the horizontal wind field in the atmosphere at the 200 hPa level, averaged over 20 winters (from 1 December to 28 February) in the GFDL CM2.1 climate model. Panel (a) shows a pre-industrial control simulation and panel (b) shows the equilibrated anomaly in a doubled-CO_2 simulation. Coloured shading indicates the magnitude of the wind vectors in m s^{-1}. The black line indicates the great circle route between New York and London.

Methodology

The route between two airports that minimises the distance travelled is the great circle. However, it is more economical to minimise the journey time, so aircraft routinely deviate away from the great circle in a carefully optimised manner, to exploit tailwinds or avoid headwinds.

Here we feed synthetic atmospheric wind fields generated from climate model simulations into a routing algorithm of the type used operationally by flight planners. The algorithm calculates the minimum-time flight path through a given horizontal wind field (Zermelo 1930). We feed the algorithm with 20 years of daily-mean wind fields at 200 hPa from two integrations of the GFDL CM2.1 climate model: pre-industrial and doubled-CO_2. Sample output is shown in Figure 2.

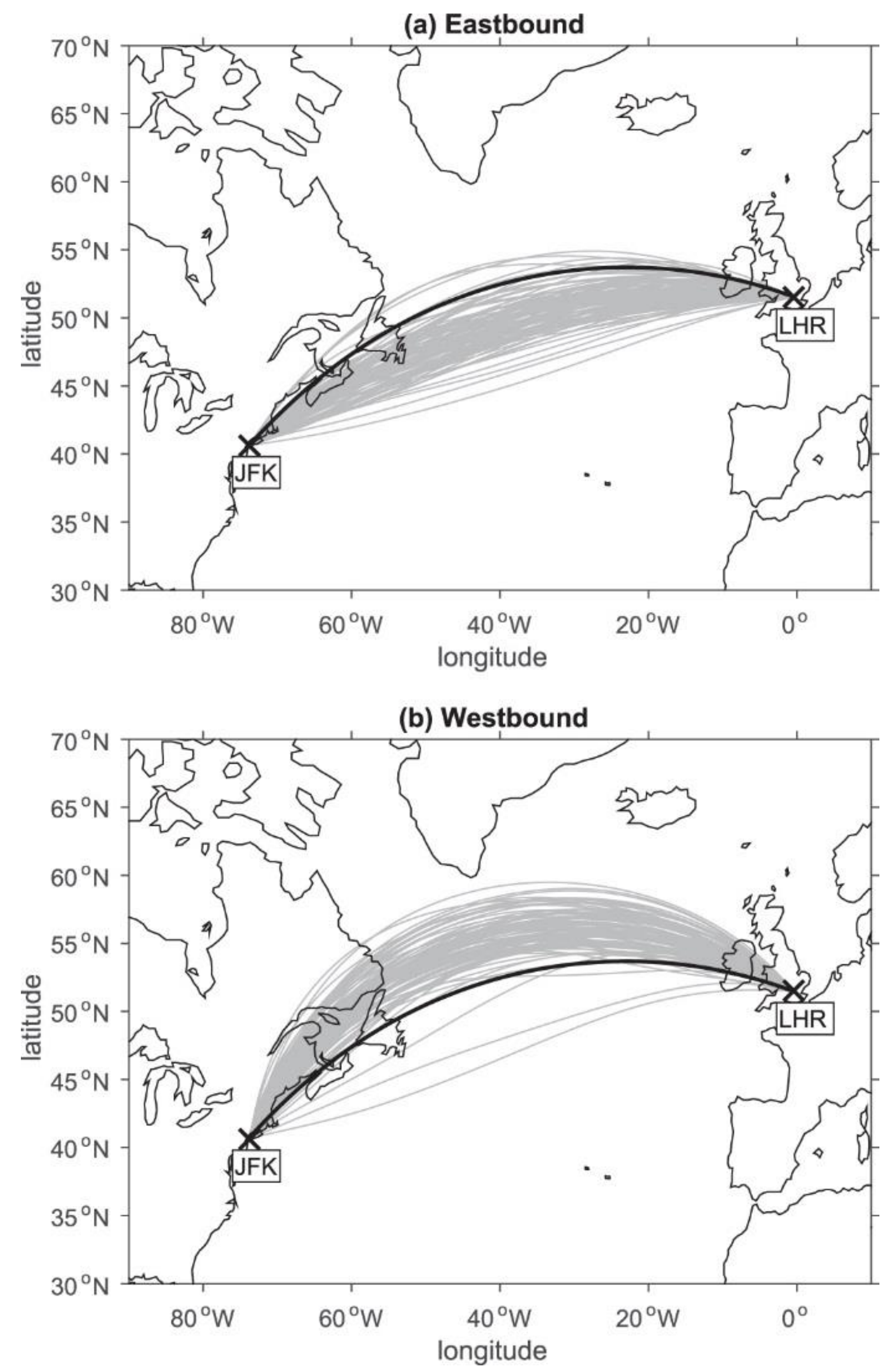

Figure 2. Minimum-time routes between JFK and LHR. The 90 grey lines in each panel indicate the daily (a) eastbound and (b) westbound minimum-time routes at the 200 hPa level. The routes are calculated using a pre-industrial control simulation from the GFDL CM2.1 climate model over one winter (from 1 December to 28 February). The black lines indicate the great circle route.

Results

The journey-time statistics for the minimum-time routes in winter are summarised as histograms in Figure 3. The effect of doubling CO_2 is to shift the eastbound distribution to shorter journey times and the westbound distribution to longer journey times. The mean eastbound journey time shortens by 4 min 00 s and the mean westbound journey time lengthens by 5 min 18 s.

For reasons that may be explained using a conceptual model (Williams 2016), the eastbound shortening and westbound lengthening are unequal and do not cancel out. Consequently, the mean round-trip journey time lengthens by 1 min 18 s.

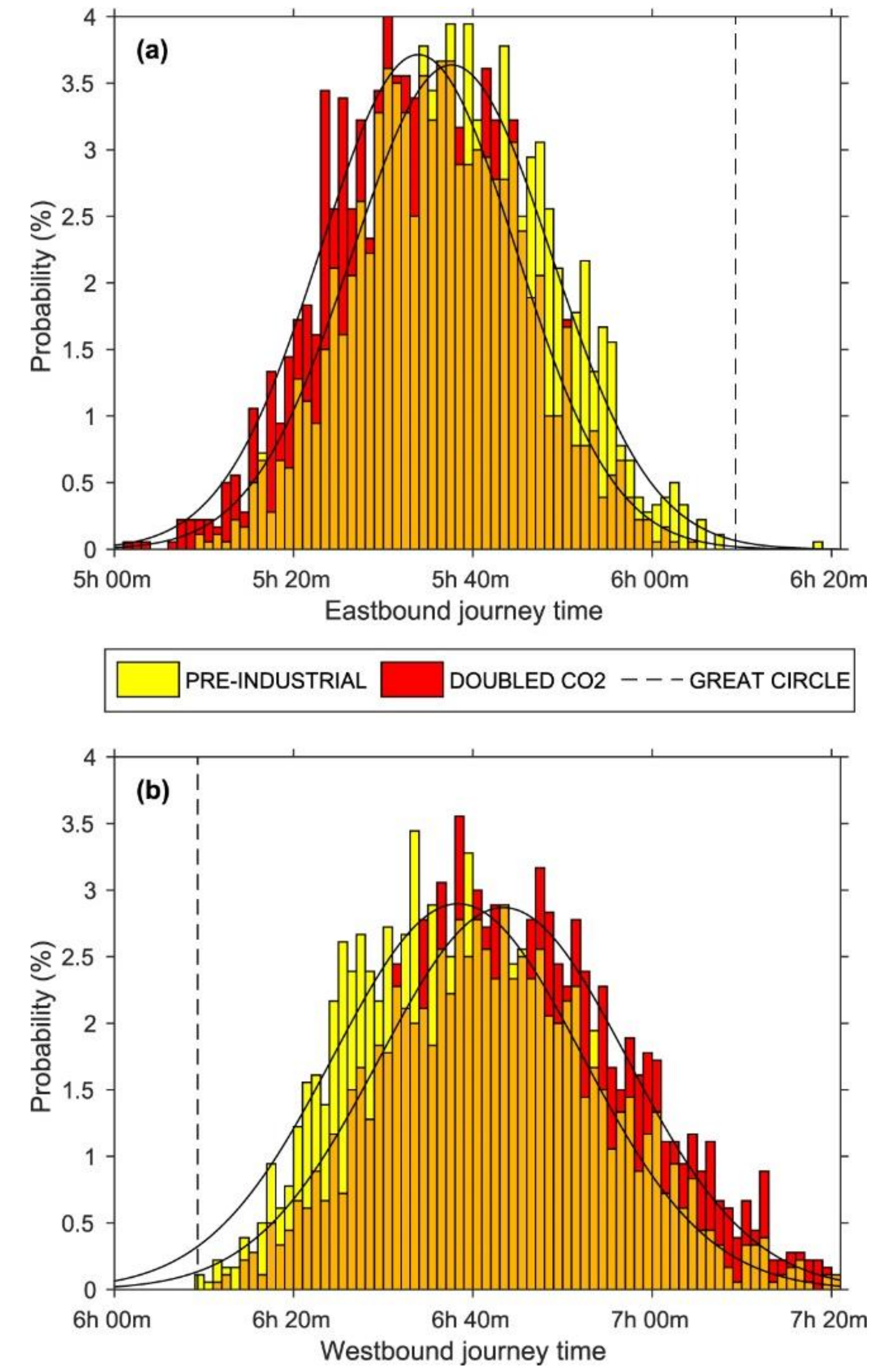

Figure 3. Histograms of journey times between JFK and LHR. The histograms indicate the probability distributions of the durations of the daily (a) eastbound and (b) westbound minimum-time routes at the 200 hPa level. The bin width used for calculating the probabilities is 1 min. The routes are calculated using a pre-industrial control simulation and a doubled-CO_2 simulation from the GFDL CM2.1 climate model over 20 winters (from 1 December to 28 February). The solid black lines are fitted normal distributions. The broken black lines indicate the duration of the great circle route in still air.

By examining the tails of the distributions, we calculate that the probability of eastbound crossings taking under 5 h 20 min more than doubles from 3.5 % to 8.1 %. Similarly, the probability of westbound crossings taking over 7 h 00 min nearly doubles from 8.6 % to 15.3 %.

Have these changes already begun? A formal attribution will be left for future work, but it is noteworthy that the winds on the JFK–LHR route on 8–12 January 2015 were extremely strong. An eastbound crossing took only 5 h 16 min, which is the current non-Concorde record. Westbound crossings took so long that two flights had to make unscheduled refuelling stops in Maine.

Conclusions

- Very fast eastbound transatlantic crossings will occur with increasing frequency in the coming decades.
- Delayed arrivals into North America will also become increasingly common.
- Similar results to those shown here (for winter at 200 hPa) are obtained in the other seasons and at other pressure levels.
- Even assuming no future growth in aviation, extrapolation of our results to all transatlantic traffic suggests that aircraft will collectively be airborne for an extra 2,000 h each year, burning an extra 7.2 million gallons of jet fuel at a cost of US$ 22 million, and emitting an extra 70 million kg CO_2 into the atmosphere, which is equivalent to the annual emissions of 7,100 average British homes.
- Our results provide further evidence of the two-way interaction between aviation and climate change.

Further information

- PD Williams (2016) Transatlantic flight times and climate change. *Environmental Research Letters*, **11**(2), 024008. DOI: 10.1088/1748-9326/11/2/024008.

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