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PERSPECTIVE

Climate change predicted to lengthen transatlantic travel times

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Abstract

Among the many consequences of rising atmospheric greenhouse gas concentrations, is a change to the medium through which planes fly. An emerging area of research is the impact that these changes may have on the airline industry, with studies addressing aspects ranging from the impact of rising temperatures on aeroplane weight restrictions (Coffel and Horton 2015 *Wea. Climate Soc.* **7** 94–102) to the impact of changing wind shears on the occurrence of clear air turbulence (Williams and Joshi 2014 *Nat. Clim. Change* **3** 644–8). Now, a recent study by Paul Williams (2016 *Environ. Res. Lett.* **11** 024008), assesses the impact that changing winds may have on the duration of transatlantic flights.

Most people who have taken a round trip flight across the Atlantic are aware that it typically takes longer to travel from east to west than from west to east. This is a consequence of the prevailing westerly winds or jet streams that circle the planet in the mid-latitudes (e.g., figure 1(a)). As the planet warms under rising greenhouse gas concentrations, these winds are expected to change. This has consequences, not only for regional climate and weather in the mid-latitudes, but also, as pointed out by Williams [1], for transatlantic travel times.

The possible impact of changing atmospheric circulation on flight duration was previously assessed in a study last year by Karnauskas *et al* [2] who examined flight durations between Hawaii and the continental US. By comparing interannual variability in the westerly winds with flight duration records, they found, as one might expect, stronger westerly winds favour shorter eastbound journeys and longer westbound journeys. The impacts on the westbound and eastbound legs do not completely cancel, however, leaving a net residual amounting to an overall lengthening of round trip journeys under increased westerly winds. The reason behind this residual remained illusive, although it was key to the overall conclusion that predicted future increases in westerly winds in the East Pacific will lengthen round trip flight durations in that region.

Williams now explains this curious residual through simple arguments, making it clear that, for a flight on a direct great circle path, the residual is a simple consequence of the fact that flight duration is inversely proportional to the sum of the air speed of the plane and the tail wind speed. strengthened westerly winds in the mid-latitude upper troposphere, as is commonly simulated to occur under climate change (e.g. [3] and figure 1(b)), should then be expected to lengthen round trip transatlantic travel times. As a simple example, take the approximate distance between London and New York as 5500 km, present day westerly wind speeds of 20 m s^{-1} and a future increase in westerly wind speed of 3 m s^{-1}. Assuming the flight time is simply the distance divided by the plane speed plus the tail wind speed, one finds that under the increased westerly wind speed of 3 m s^{-1}, the eastbound journey is shortened by approximately 3 min 53 s, whereas the westbound journey is lengthened by 5 min 16 s. The overall round trip is, therefore, lengthened by 1 min 23 s.

But how does one go about quantifying the magnitude of this effect or the impact it will have? The reality is not as simple as in the above example. The planning of flight routes is complex with the optimal route deviating from the direct great circle path according to day to day variability in the wind field. To consider how flight durations will change in the future, one must not only consider how the winds are expected to change, but also how the optimal flight paths, as determined by flight planners, may change.

To address this issue, Williams applies a flight planning algorithm, used by the airline industry, to examine the optimal routes and flight durations for journeys between London and New York. Wind fields generated from a global climate model under a

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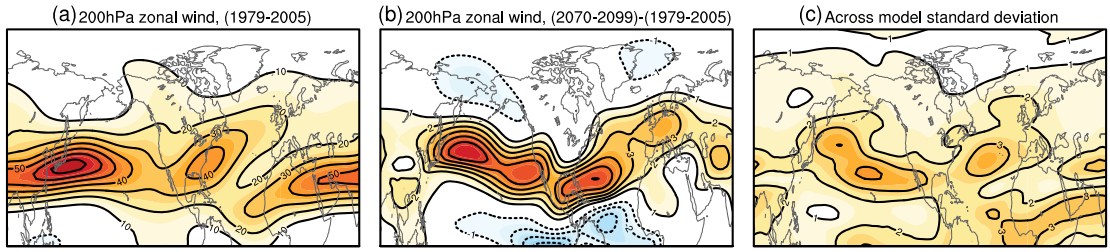

Figure 1. Upper tropospheric (200hPa) zonal winds, averaged over December, January and February, as simulated by 35 models participating in the Coupled Model Intercomparison Project, Phase 5. This makes use of all available ensemble members for each model. (a) The multi-model mean climatology averaged from 1979–2005 of historical simulations. (b) The multi-model mean difference between 2070–2099 under the RCP8.5 forcing scenario and the historical (1979–2005) period. (c) gives an indication of the uncertainty in the future projections in (b) by showing the, across model, standard deviation in the Future-Past difference. Contour intervals are: (a) 10 m s^{-1}, (b) 1 m s^{-1} and (c) 1 m s^{-1}.

doubling of pre-industrial atmospheric CO_2 are fed in to this algorithm day by day for 20 years to accumulate statistics of the optimal flight paths and journey times under doubled CO_2 wind conditions. These are then compared with similar calculations performed using wind output from a control simulation at pre-industrial CO_2 levels. Results indicate that round trip journey times will increase throughout the year, with minimum increases during summer of 33 seconds, maximum increases during autumn of 1 min 51 s and an annual average increase of 1 min 6 s. In addition, the probability of eastbound journeys taking under 5 hours 20 minutes is found to increase from 3.5% to 8.1% while the probability of a westbound crossing taking over 7 hours increases from 8.6% to 15.3%.

These changes are small and are unlikely to be noticed by even the most frequent of flyers, but the impact that they could have on fuel consumption and the air industry are not negligible. Considering all transatlantic flights, William's estimates that this would amount to an extra 2000 flight hours per year, burning 7.2 million extra US gallons of jet fuel at a cost of $22 million US dollars to the airline industry and resulting in an additional 70 million kg of CO_2 emitted into the atmosphere. To put these numbers in perspective, US airlines spent a total of $16.6 billion US dollars on jet fuel for scheduled international flights in 2014[1] and the global airline industry is currently responsible for around 705 billion kg CO_2 emissions annually[2]. So these are relatively small, but non-negligible changes.

The numbers predicted by Williams are not without their uncertainties. A strengthening of the westerly winds in the upper troposphere is expected as a consequence of the fact that, increasing CO_2 concentrations, warm the upper troposphere (and preferrentially so in the tropics) and cool the stratosphere [4]. This leads to a strengthening of the equator-to-pole temperature gradient in the upper troposphere and an associated increase in the westerly winds. However, there is considerable spread among models, as to the exact magnitude and spatial structure of these wind changes, as indicated by figure 1 (c) (see also [3]). The calculations performed by Williams are very computationally intensive and so wind fields from only one such model were used. This uncertain future of the wind field, therefore, leads to uncertainty in the exact values that this calculation produces. Nevertheless, this is one of the first studies that has made a comprehensive attempt to assess the impact that future circulation change may have, through the use of flight planning algorithms. It will no doubt spur future research in this area as well as research into other aspects such as the impact that changes in atmospheric variability or extremes may have on flight delays etc. Such research will improve our overall estimates of the impact that changes to our atmosphere may have on the aviation industry.

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