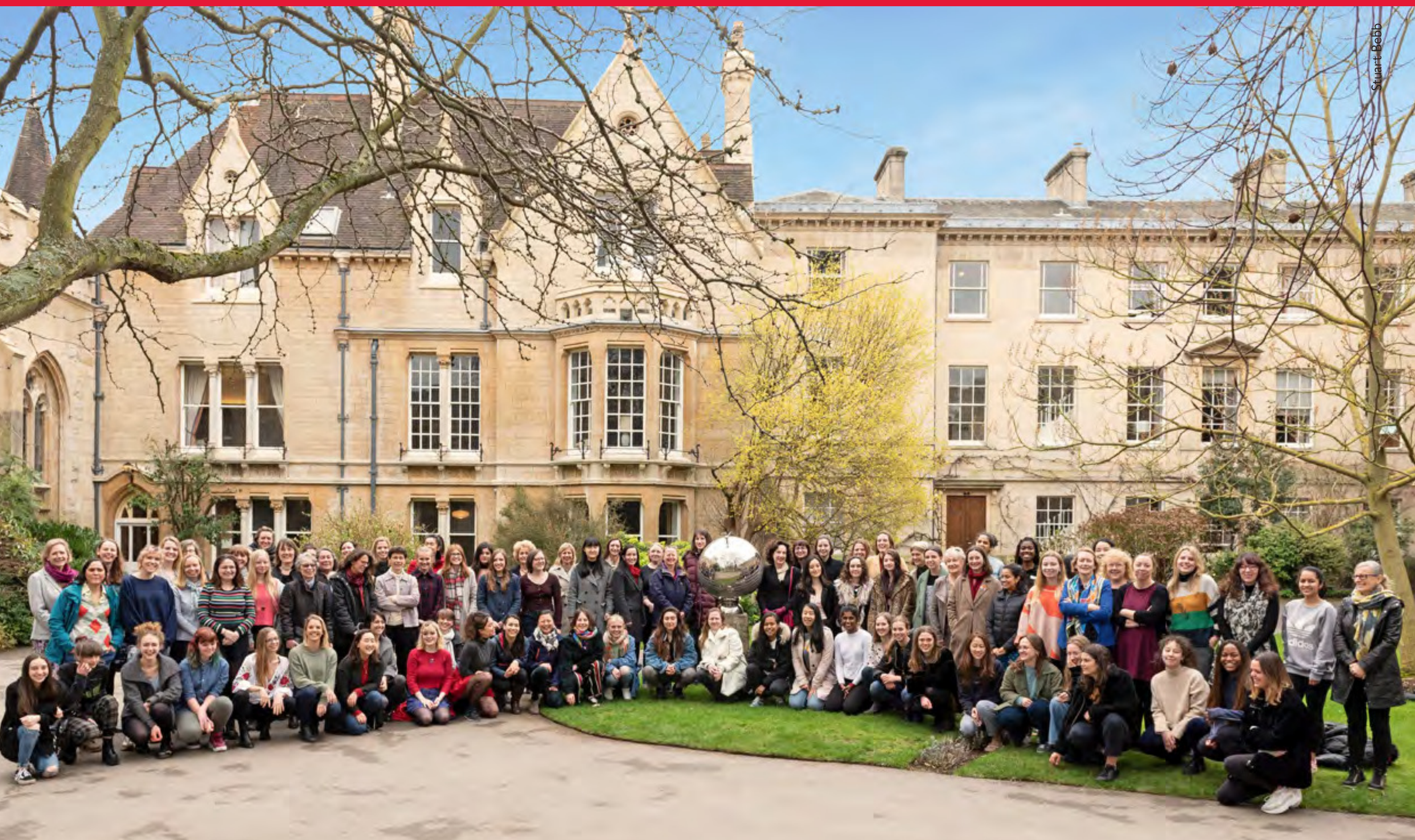
BALLIOL COLLEGE
UNIVERSITY OF OXFORD

FLOREAT DOMUS

NEWS AND FEATURES FROM THE BALLIOL COMMUNITY | JUNE 2019


Stuart Bebb

BALLIOL WOMEN: 40 YEARS ON

Celebrating the anniversary of the admission of women students in 1979

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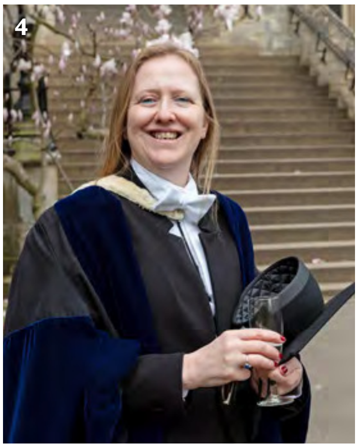

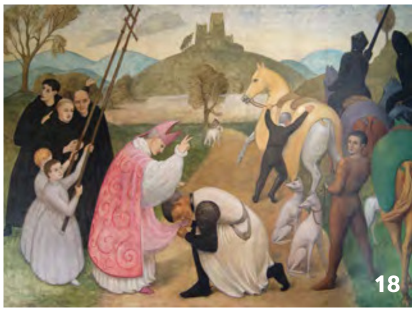

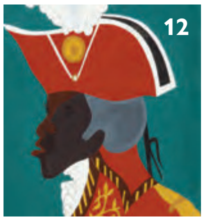

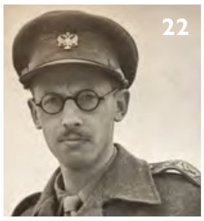

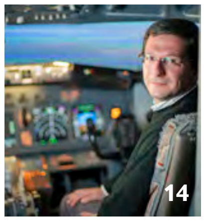

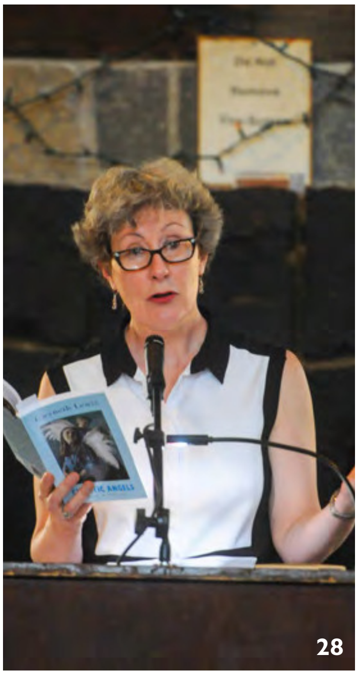

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Front cover image: To celebrate International Women's Day and 40 years of women at Balliol – that is, 40 years since the admission of women students in 1979 – current Balliol women (any Fellow, Lecturer, student or member of staff who was free was invited to attend) gathered for a photograph at the sundial. Bearing the words 'For all women at Balliol: past present and future', the sundial was installed to mark the 30th anniversary. Photograph by Stuart Bebb.

Making flights smoother, safer, and cleaner

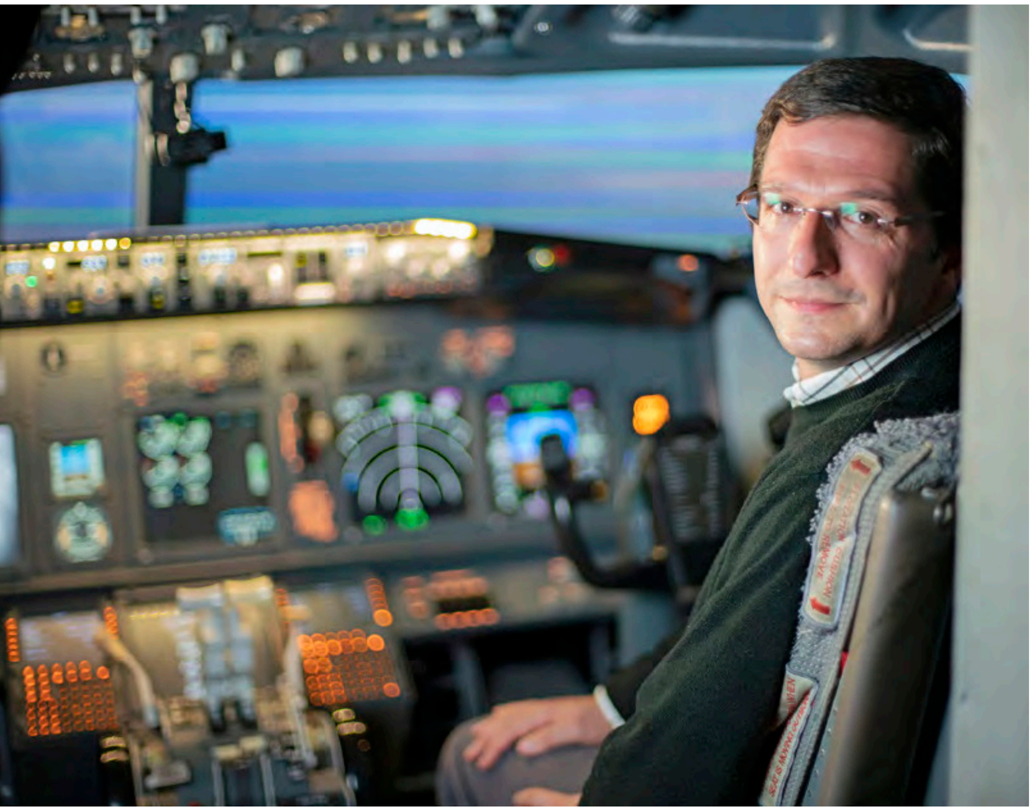
Professor Paul Williams (1999) tells the story of how his award-winning turbulence-forecasting algorithm is improving air travel

Atmospheric turbulence is the leading cause of injuries to air travellers and flight attendants. Rough air costs the global aviation sector around 1 billion dollars annually, and climate change is causing it to strengthen. For all these reasons, improving turbulence forecasting is essential to the comfort and safety of air travel passengers.

While studying at Balliol for my DPhil in the Department of Physics, I worked on a physical theory for the generation of gravity waves in the atmosphere. Realising that these waves can produce clear-air turbulence, which is hazardous to aviation because it is invisible and currently undetectable, I set out to develop the theory into a practical turbulence-forecasting algorithm. I achieved this by collaborating with John Knox (University of Georgia, USA) and Don McCann (McCann Aviation Weather Research, Inc., USA). Our forecasting method works by analysing the atmosphere and using a set of equations to identify the regions where the winds are becoming unbalanced and unstable, which leads to the production of turbulence.

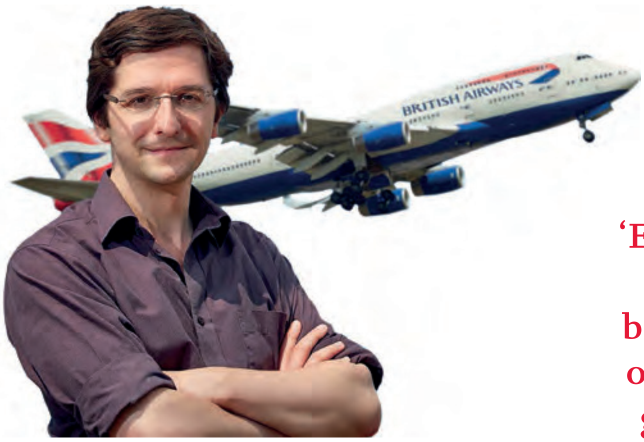
> **‘Climate change is expected to make turbulence much worse in future’**

After I left Balliol to take up my academic post at the University of Reading, we conducted some initial tests on the accuracy of our forecasting algorithm, with promising results. At that time, the US Federal Government’s goals for aviation turbulence forecasting were not being achieved, either by automated systems or by experienced human forecasters, but our algorithm came tantalisingly close. We published our results, concluding that ‘major improvements in clear-air turbulence forecasting could result if the methods presented herein become operational’.



Rough air has long plagued the global aviation sector. Tens of thousands of aircraft annually encounter turbulence strong enough to throw unsecured objects and people around inside the cabin. On scheduled commercial flights involving large airliners, official statistics indicate that several hundred passengers and flight attendants are injured every year, but we know that the real injury rate is probably in the thousands. A typical airline loses 7,000 working days annually because of flight attendants being injured by turbulence and unable to work. On smaller planes, turbulence causes around 40 fatalities each year in the USA alone.

At its worst, turbulence can cause structural damage to aircraft. For example, a plane flying over Colorado on 9 December 1992 encountered extreme turbulence, which tore off



‘Every day, pilots, flight dispatchers, and air-traffic controllers are benefiting from advance knowledge of the locations of turbulence, with greater accuracy than ever before’

about 6 metres of its left wing and one of its four engines.

For all these reasons, turbulence is the underlying cause of many people’s fear of flying. This fear reportedly affects up to 40 per cent of the population, and it is classified as a specific phobia in the Diagnostic and Statistical Manual of Mental Disorders. For sufferers of aviophobia, even light turbulence can be extremely distressing, but most non-sufferers also find it generally unpleasant and uncomfortable to be randomly buffeted up and down.

Turbulence also has consequences for the environment, by causing excessive fuel consumption and CO_2 emissions. Up to two-thirds of flights deviate from the most fuel-efficient altitude because of turbulence. This wastes fuel – up to 160 million gallons annually in the USA; it also contributes to climate change, through 1.5 million tonnes of unnecessary CO_2 emissions annually. At a time when we are all concerned about aviation’s carbon footprint, reducing turbulence encounters represents some seriously low-hanging fruit to help make flying greener.

Furthermore, climate change is expected to make turbulence much worse in future. In particular, our published projections indicate that there will be several hundred per cent more turbulence globally by 2050–2080. These findings, which have been cited by the Intergovernmental Panel on Climate Change (IPCC) and the United Nations Climate Change Newsroom, underline the increasingly urgent need to develop better aviation turbulence-forecasting techniques.

The operational challenges associated with turbulence are compounded by the projected future growth of the aviation sector. Historically, global air traffic (measured in passenger–kilometres) has experienced an average long-term growth rate of 5 per cent per year, which corresponds to a doubling period of about 14 years. According to Boeing’s market outlook, this trend is expected to continue for at least the next 20 years. Accurate turbulence forecasts are needed to ensure the efficient use of airspace in our increasingly crowded skies. All other things being equal, future passenger growth coupled with climate change will lead to more turbulence encounters.

It is therefore excellent news for air travellers and the aviation sector alike that our improved turbulence-forecasting algorithm is now being used operationally by the Aviation Weather Center (AWC) in the National Weather Service (NWS), which is the US equivalent of the Met Office. The United States was a natural place to test and roll out the algorithm, because it has arguably the most extensive air transportation network in the world. It comprises 5.3 million square miles of domestic airspace and 20,000 airports. There are 5,000 aircraft airborne at any given time, controlled by 14,000 air-traffic controllers. On an average day in the US, 2.6 million people fly on a scheduled passenger service.

The turbulence forecasts are freely available via an official US government website (www.aviationweather.gov/turbulence/gtg). The forecasts cover all 48 contiguous US states, plus much of Canada and Mexico and parts of the Pacific and Atlantic Oceans. They forecast turbulence up to 18 hours ahead, updated hourly. Our algorithm is the latest in a basket of diagnostics that are optimally combined to produce the final published forecast.

Every day since 20 October 2015, turbulence forecasts made with our algorithm have been used in flight planning by commercial and private pilots, flight dispatchers, and air-traffic controllers. They are benefiting from advance knowledge of the locations of turbulence, with greater accuracy than ever before, allowing flight routes through smooth air to be planned. Pilots and air-traffic controllers are benefiting from a reduced workload, because unexpected turbulence results in burdensome re-routing requests. Airlines are benefiting from fewer unplanned diversions around turbulence, reduced fuel costs and emissions associated with those diversions, fewer delayed arrivals, fewer flight attendants unable to work due to turbulence-related injuries, and a reduced maintenance schedule for their aircraft. To date, our algorithm has improved the comfort and safety of air travel on up to 2.5 billion passenger journeys.

Our algorithm has won several awards recently, but the real prize is the knowledge that it is making a difference to people’s lives every day. In the time it has taken you to read this article, thousands of passengers have taken to the skies and are benefiting from our research, and nothing can beat that feeling. It is the perfect and somewhat unexpected culmination of a DPhil research project that began in earnest at Balliol 20 years ago.

Paul Williams is Professor of Atmospheric Science in the Department of Meterology at the University of Reading.