How will climate change affect flight routes and turbulence?

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NATURAL ENVIRONMENT RESEARCH COUNCIL

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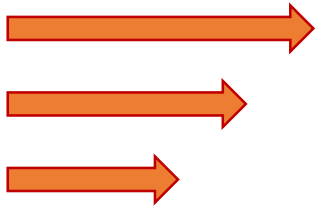
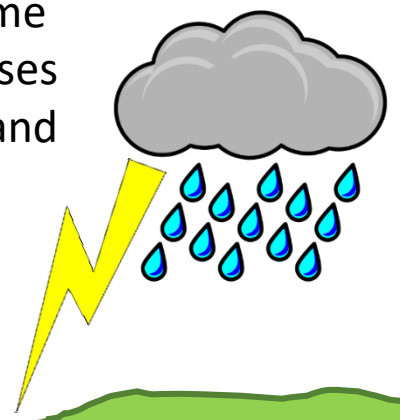
Climate change impacts on aviation

Shifting wind patterns modify optimal flight routes and fuel consumption



Stronger jet-stream wind shears increase clear-air turbulence

More extreme weather causes disruptions and delays

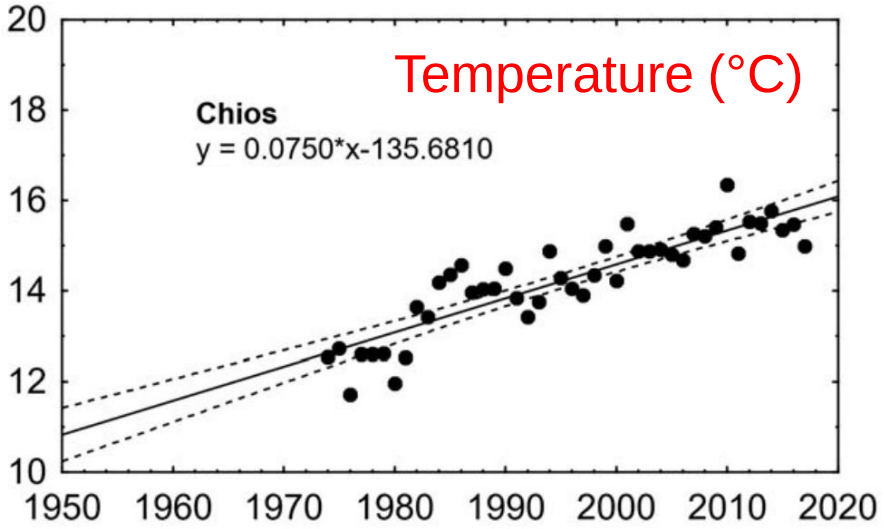


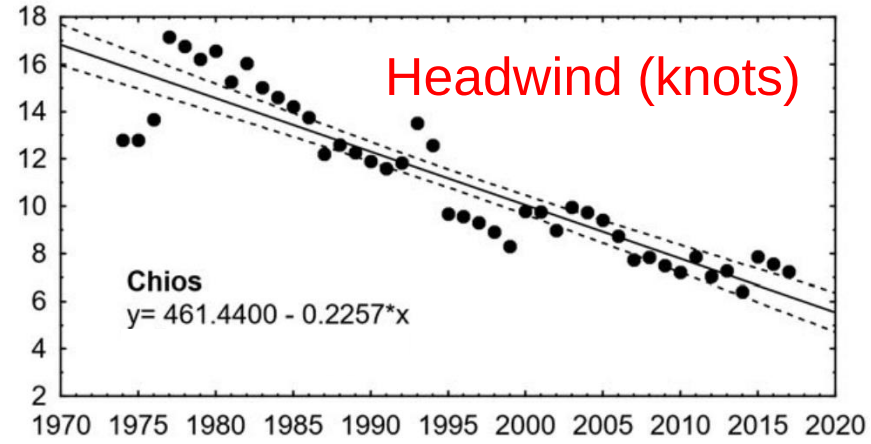
Warmer air imposes take-off weight restrictions

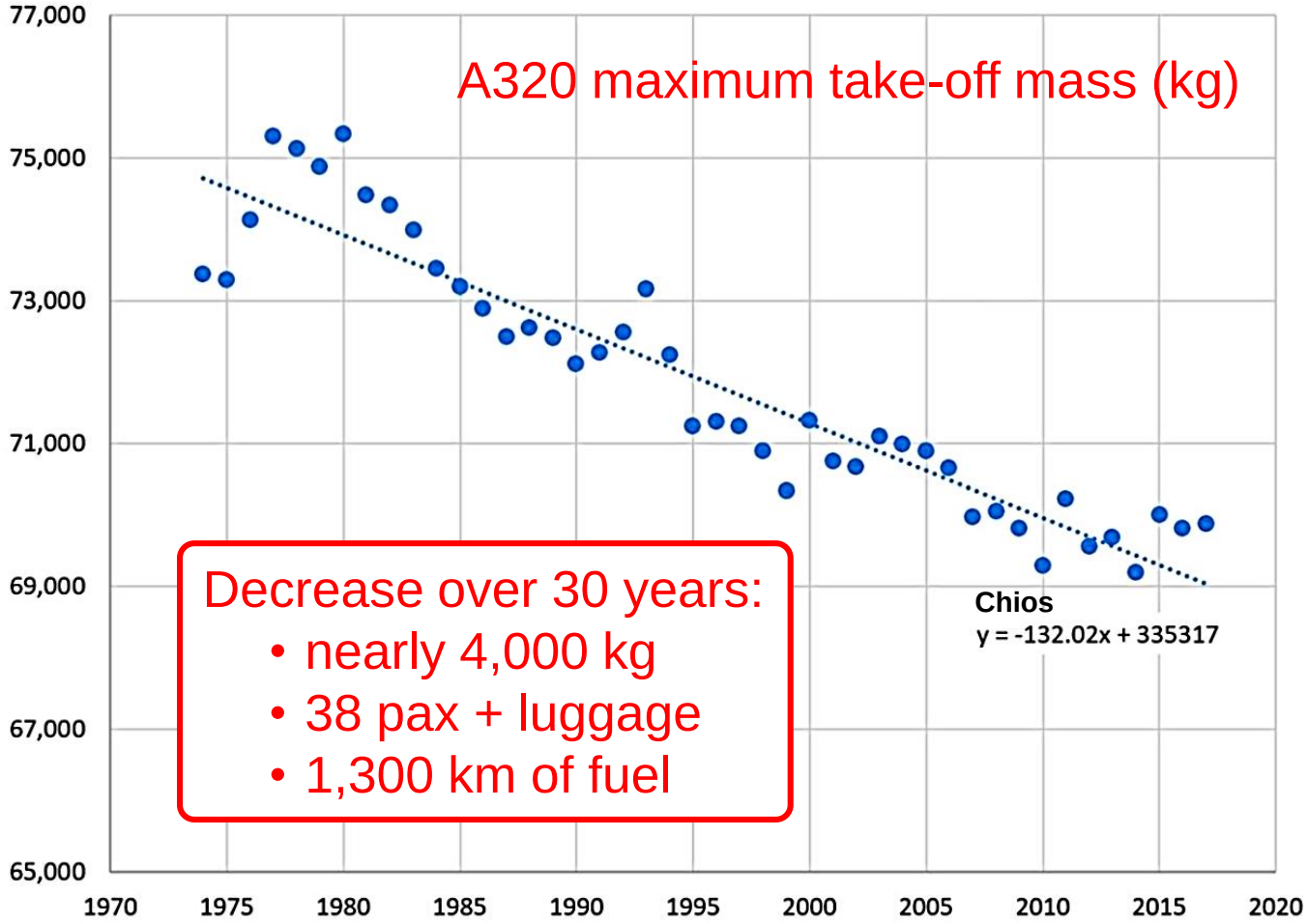
Rising sea levels and storm surges threaten coastal airports

Puempel & Williams (2016)
ICAO Environmental Report

Take-off weight restrictions

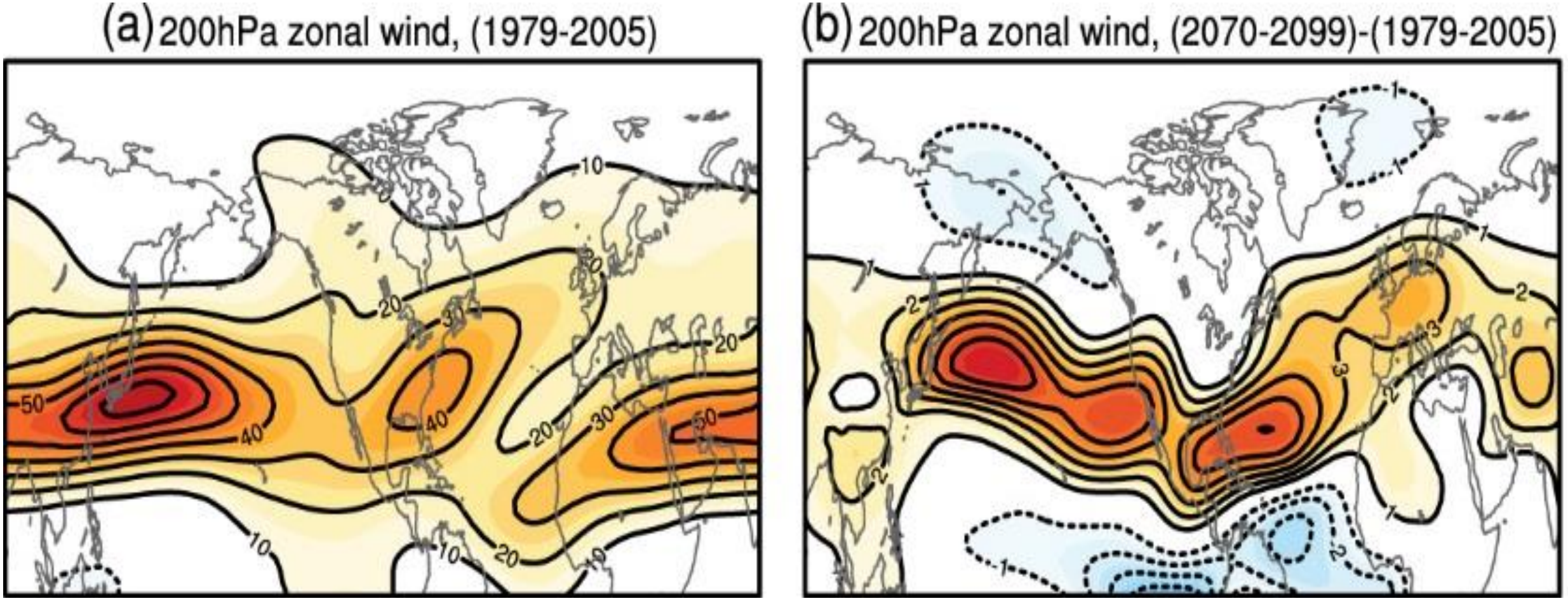




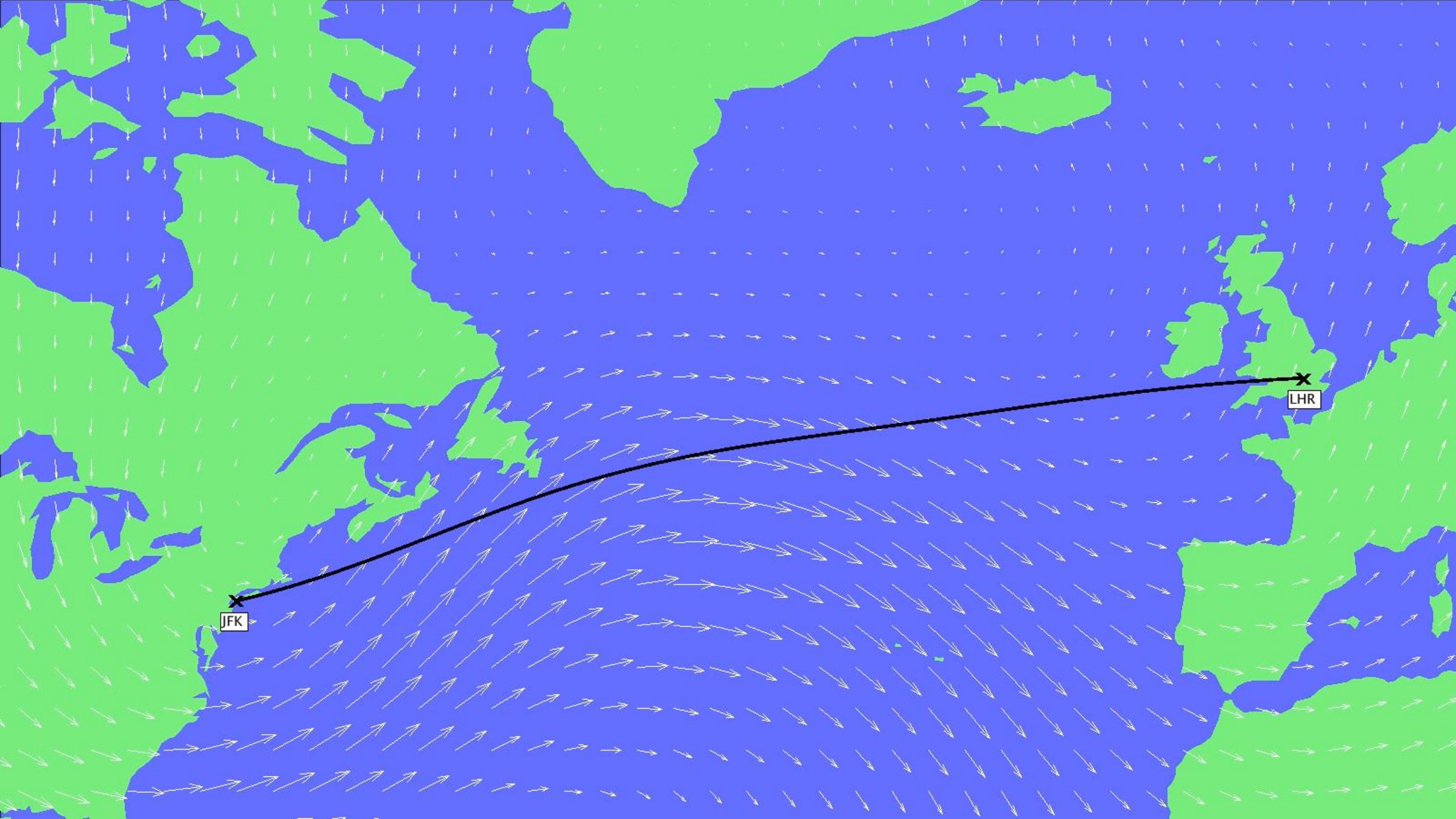


Gratton, Padhra, Rapsomanikis & Williams (2020)

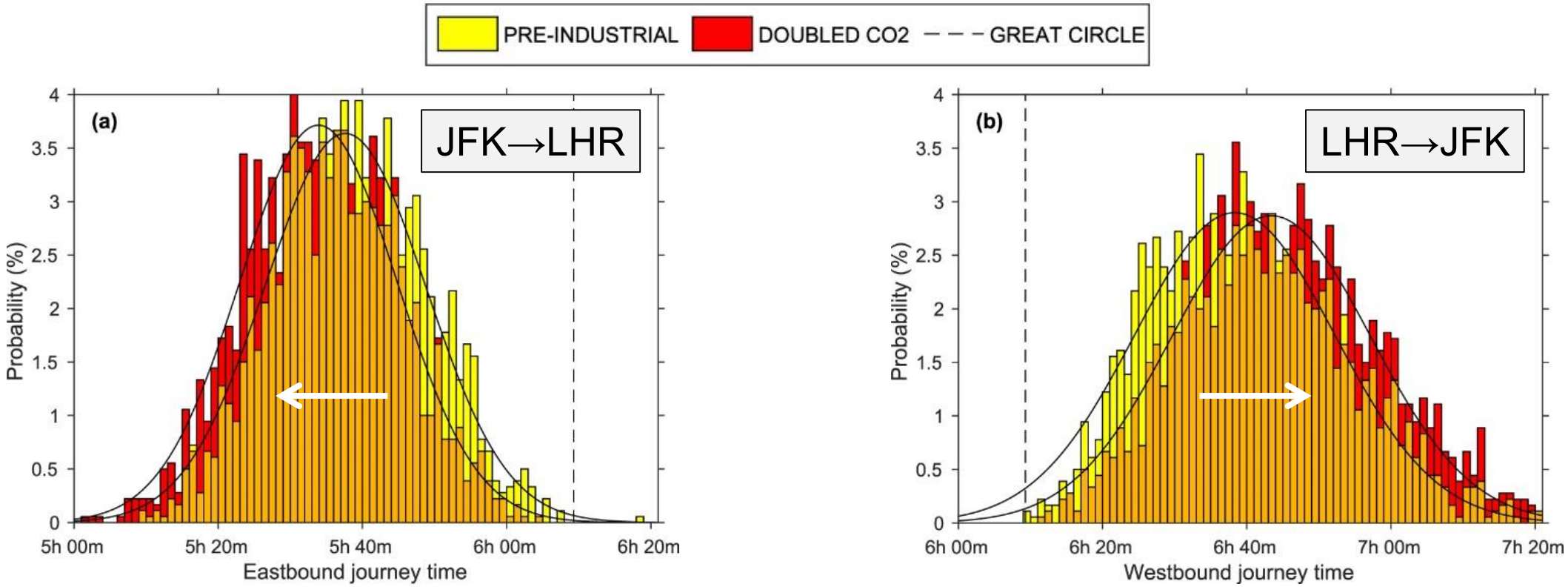
Impacts of climate change on wind speeds



The zonal wind speed (m s^{-1}) in DJF increases in CMIP5 / RCP8.5 (Simpson 2016)


JFK
LHR

How do stronger winds affect flight times?



Likelihood of taking under 5 h 20 min more than doubles from 3.5% to 8.1%

Likelihood of taking over 7 h 00 min nearly doubles from 8.6% to 15.3%

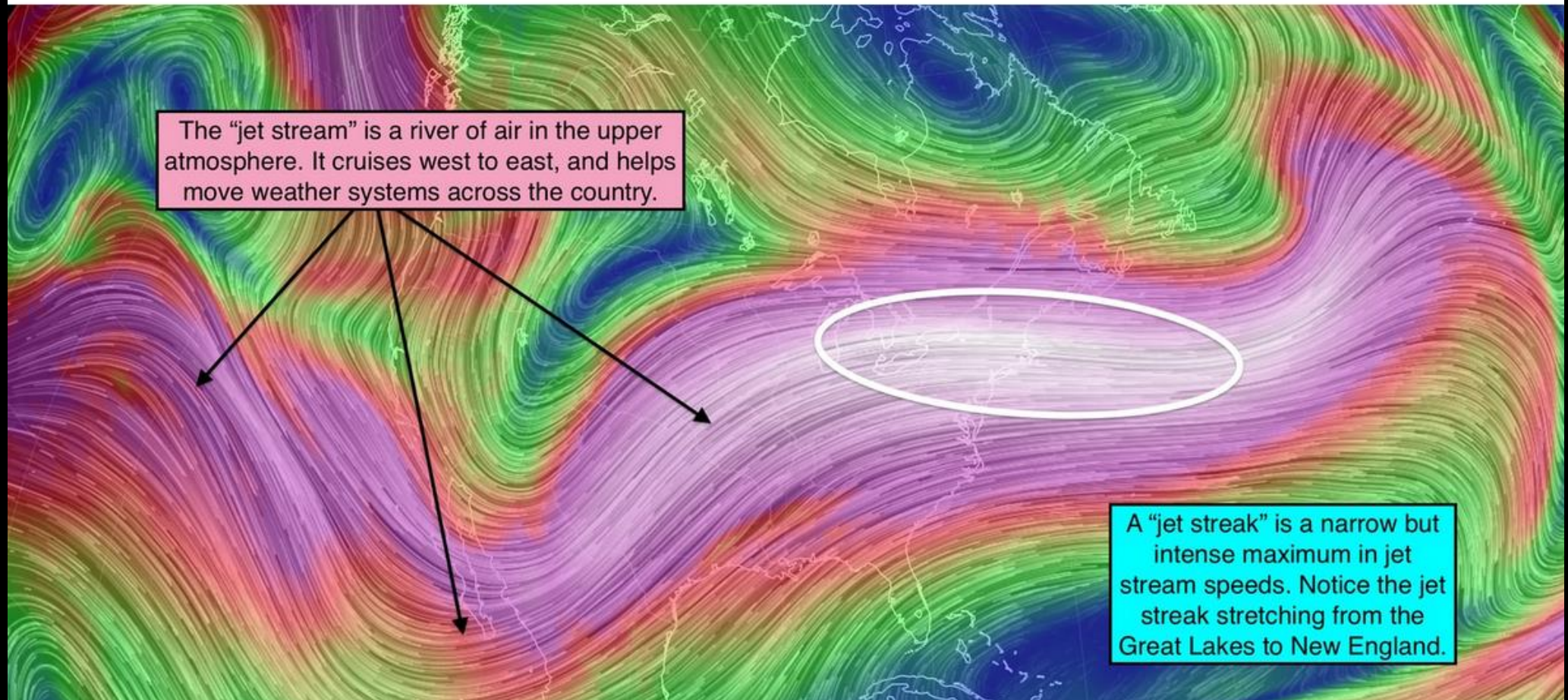
Williams (2016)

The Washington Post
Democracy Dies in Darkness

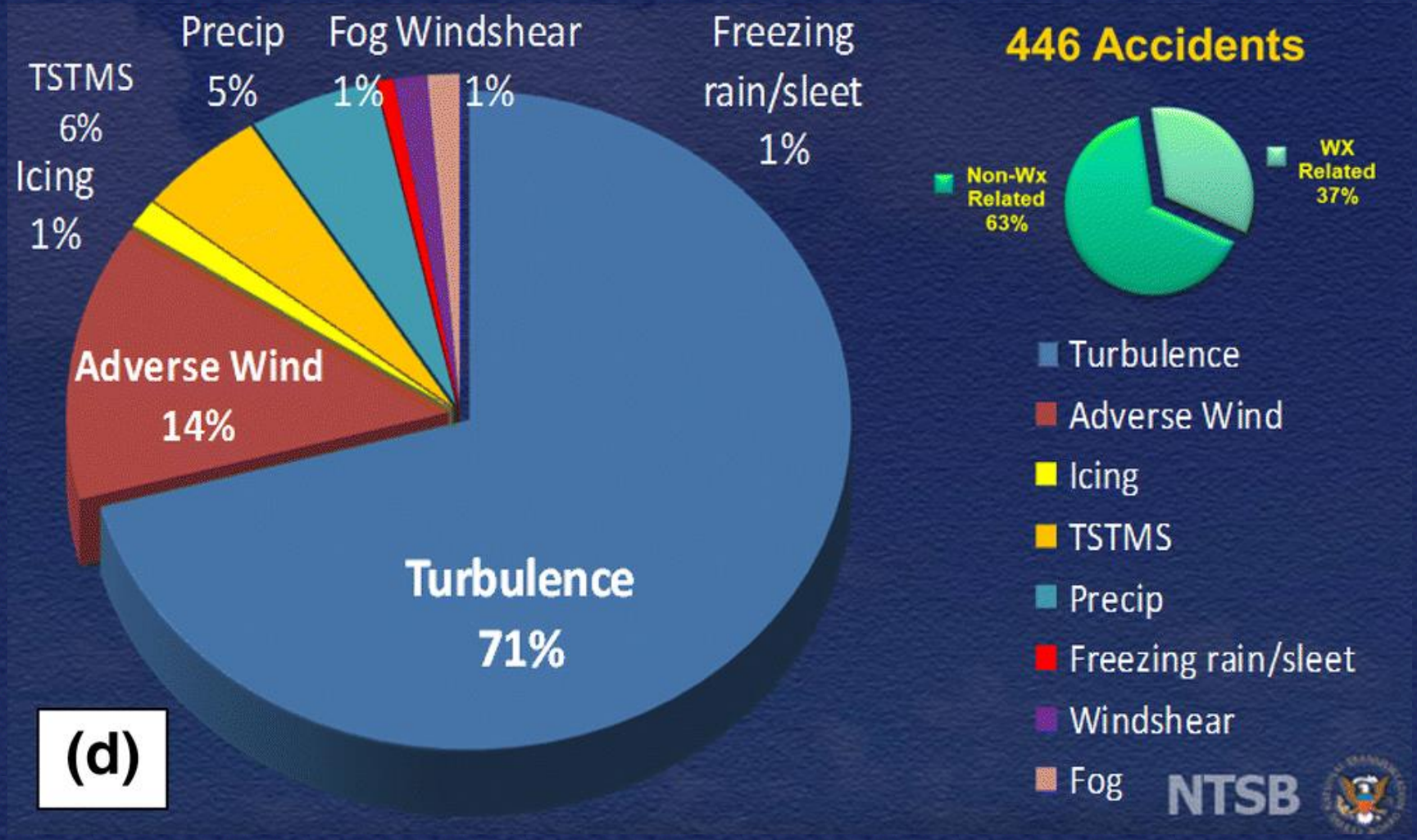
Capital Weather Gang

Flight reaches 801 mph as a furious jet stream packs record-breaking speeds

19 February 2019



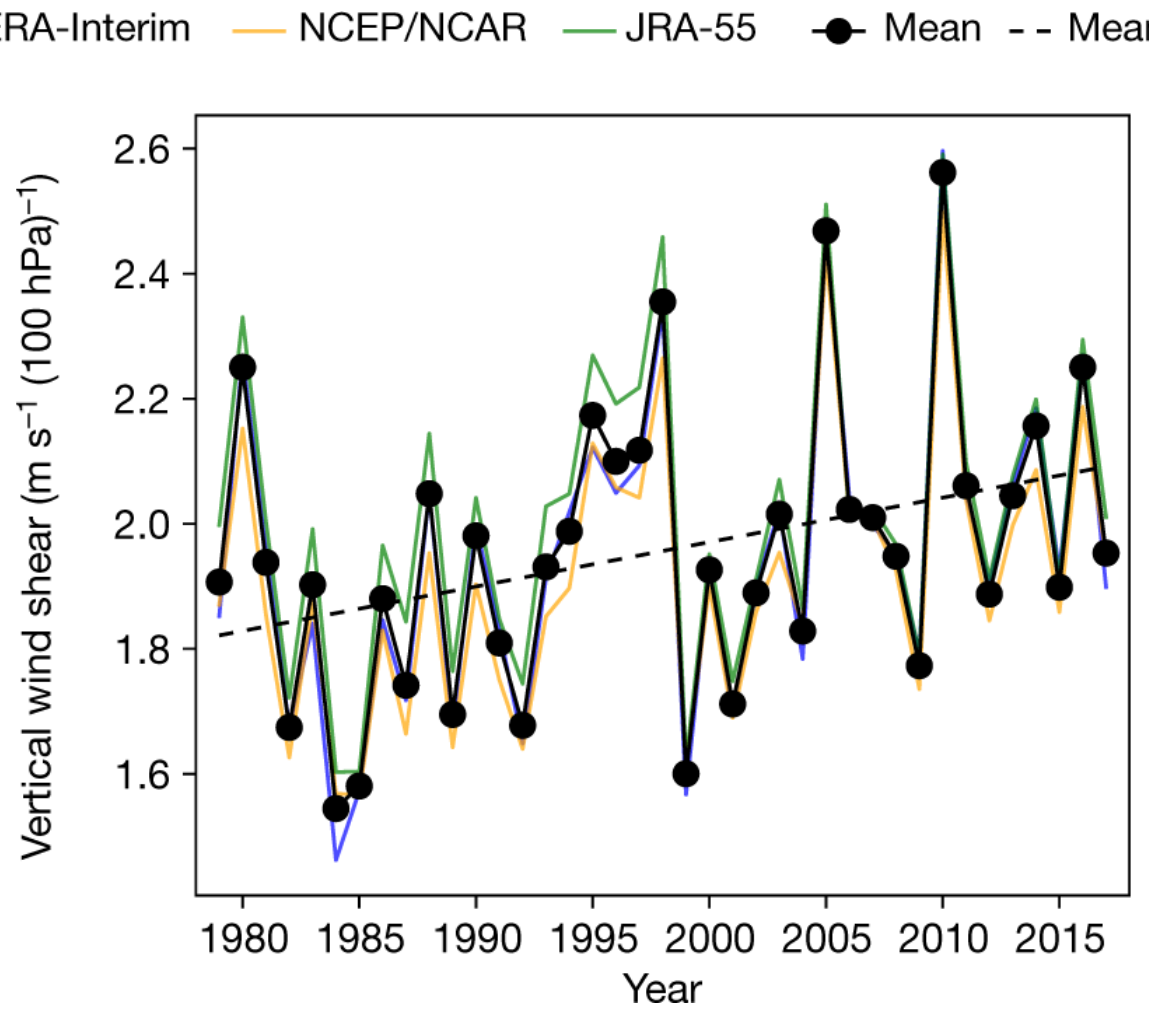
Turbulence



Gultepe, Sharman, Williams et al. (2019)

Impacts of climate change on wind shear

Annual-mean wind shear in North Atlantic at 250 hPa (~35,000 feet)

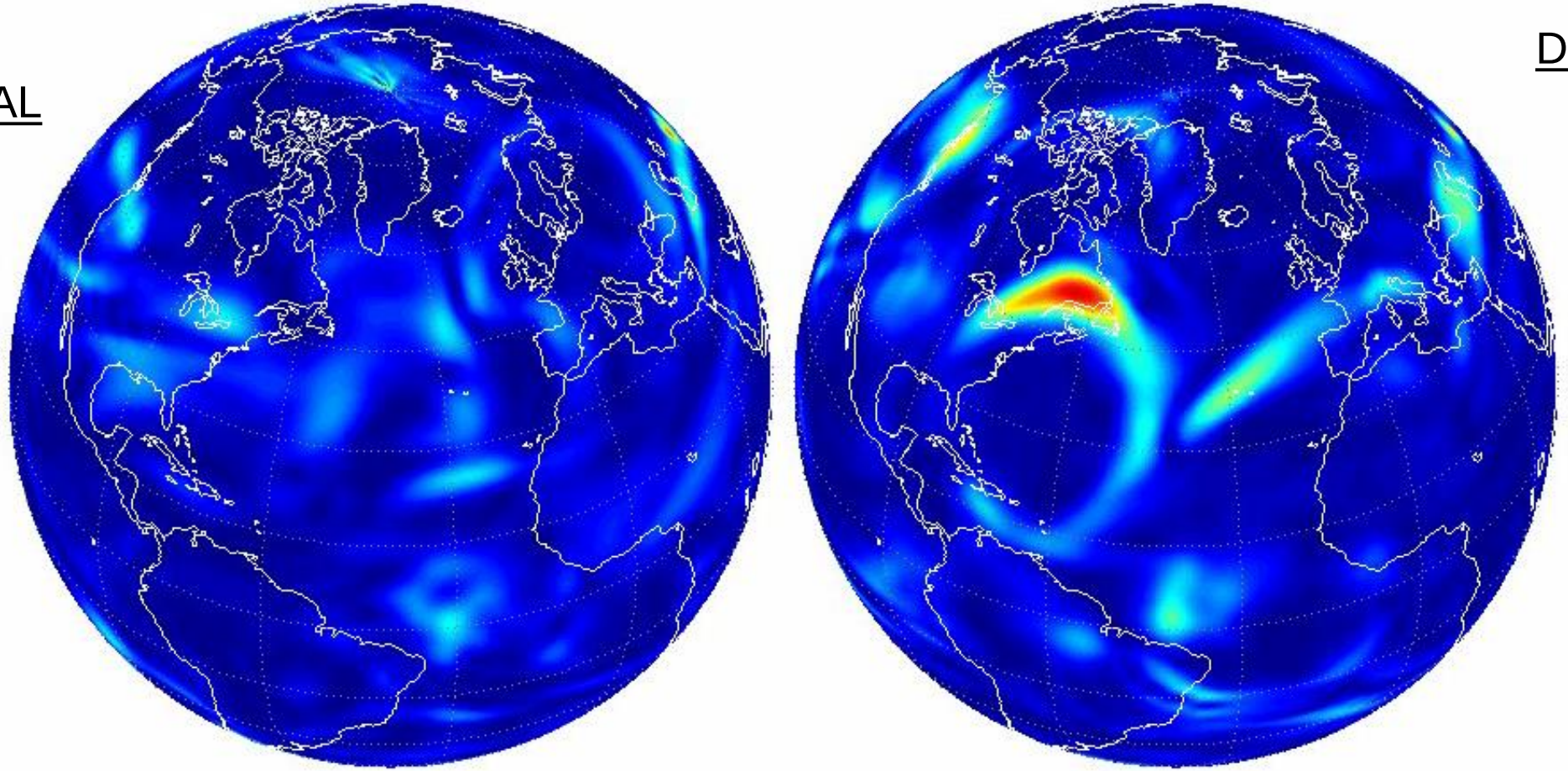


15% increase over 40 years ⇒ more CAT

Lee, Williams, and Frame (2019)

Clear-air turbulence

PRE-INDUSTRIAL

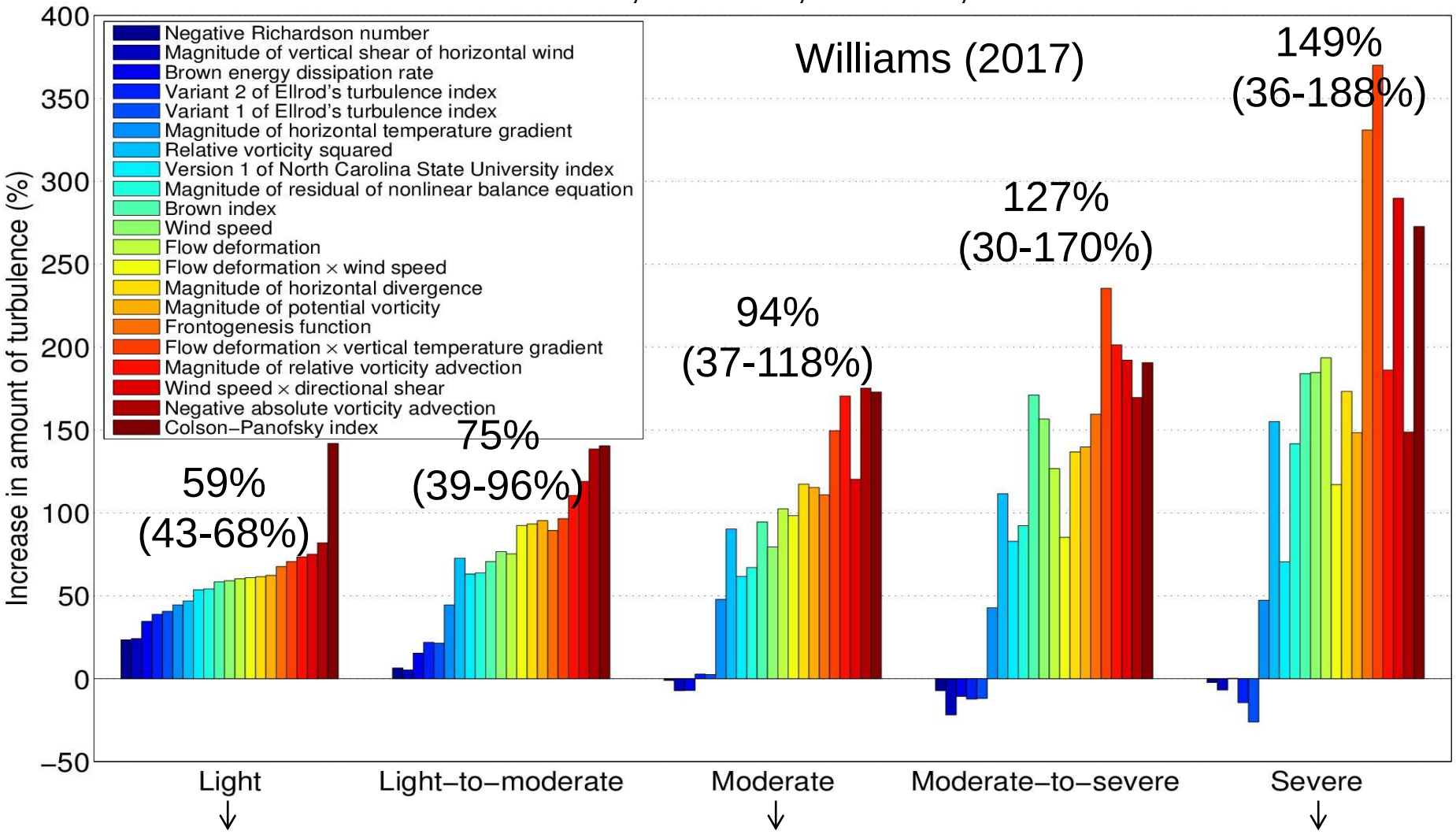


DOUBLED CO2

$$\mathrm{TI1} = \sqrt{\left(\frac{\partial u}{\partial z}\right)^2 + \left(\frac{\partial v}{\partial z}\right)^2} \times \sqrt{\left(\frac{\partial u}{\partial x} - \frac{\partial v}{\partial y}\right)^2 + \left(\frac{\partial v}{\partial x} + \frac{\partial u}{\partial y}\right)^2}$$

Williams & Joshi (2013)

50-75°N, 10-60°W, 200 hPa, DJF

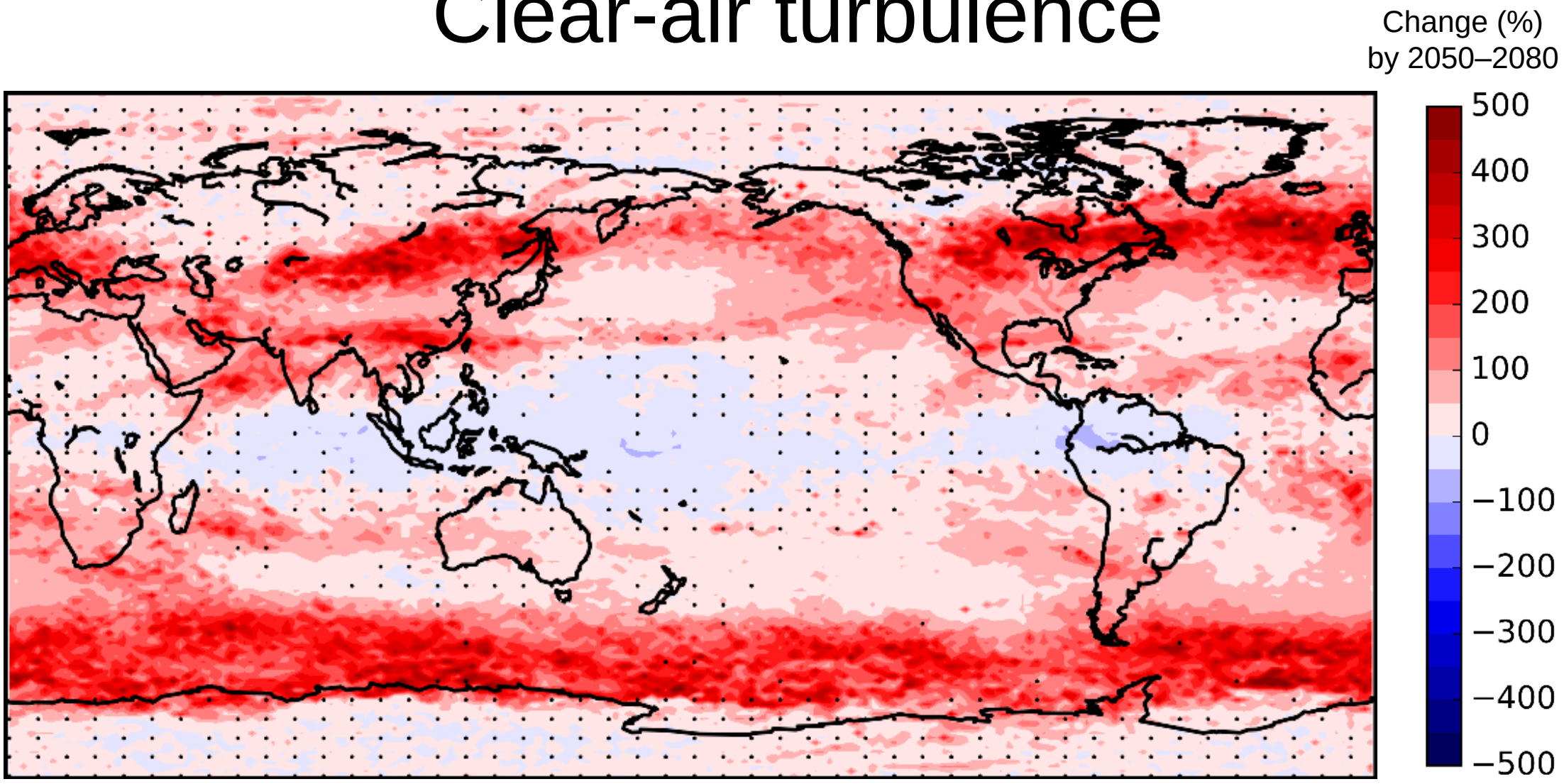


"Slight strain against seat belts; unsecured objects may be displaced slightly; food service may be conducted with little difficulty walking"

"Definite strain against seat belts; unsecured objects are dislodged; food service and walking are difficult"

"Occupants are forced violently against seat belts; unsecured objects are tossed about; food service and walking are impossible"

Clear-air turbulence



Storer, Williams & Joshi (2017)

Summary

- Warmer air at ground level is decreasing air density and increasing the need for take-off weight restrictions

- A stronger jet stream will speed up eastbound flights (a bit) but slow down westbound flights (a lot), lengthening roundtrip journeys and keeping transatlantic aircraft airborne for an extra 2,000 hours each year

- The jet stream is already 15% more sheared than when satellites began observing it, and this effect will double or treble the amount of severe clear-air turbulence in the coming decades

Questions?

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