Aviation meteorology in a changing climate

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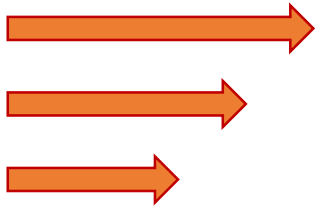
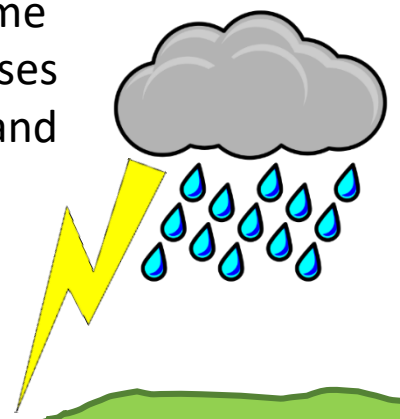
Climate change impacts on aviation

Shifting wind patterns modify optimal flight routes and fuel consumption



Stronger jet-stream wind shears increase clear-air turbulence

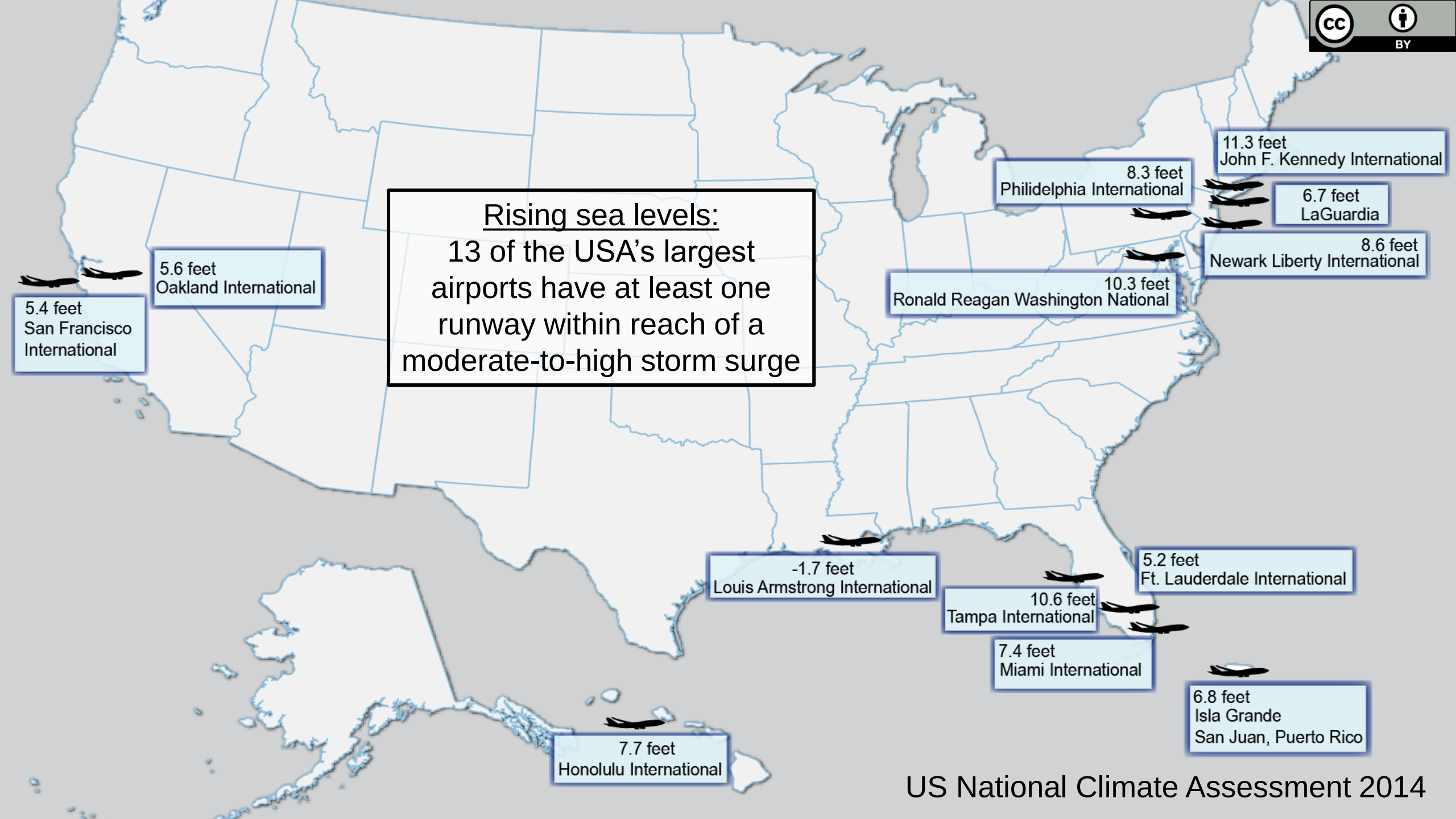
More extreme weather causes disruptions and delays



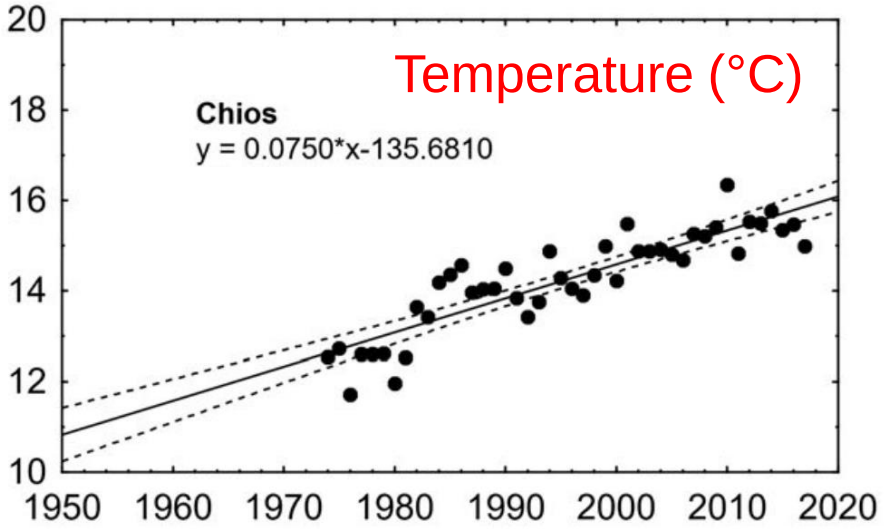
Warmer air imposes take-off weight restrictions

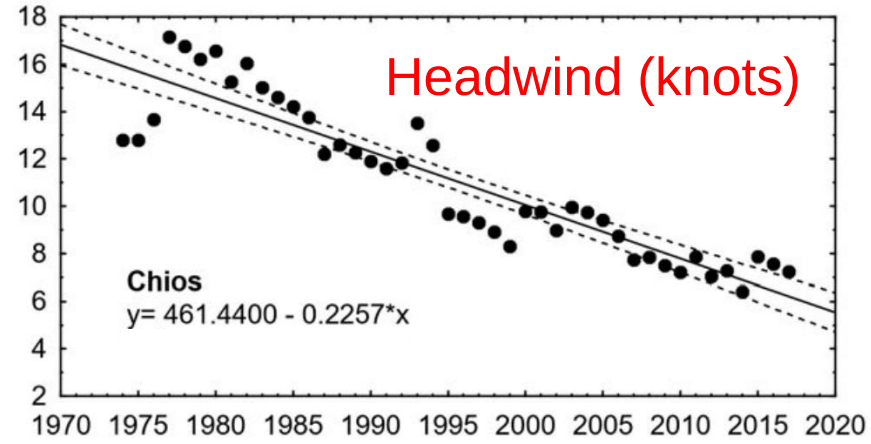
Rising sea levels and storm surges threaten coastal airports

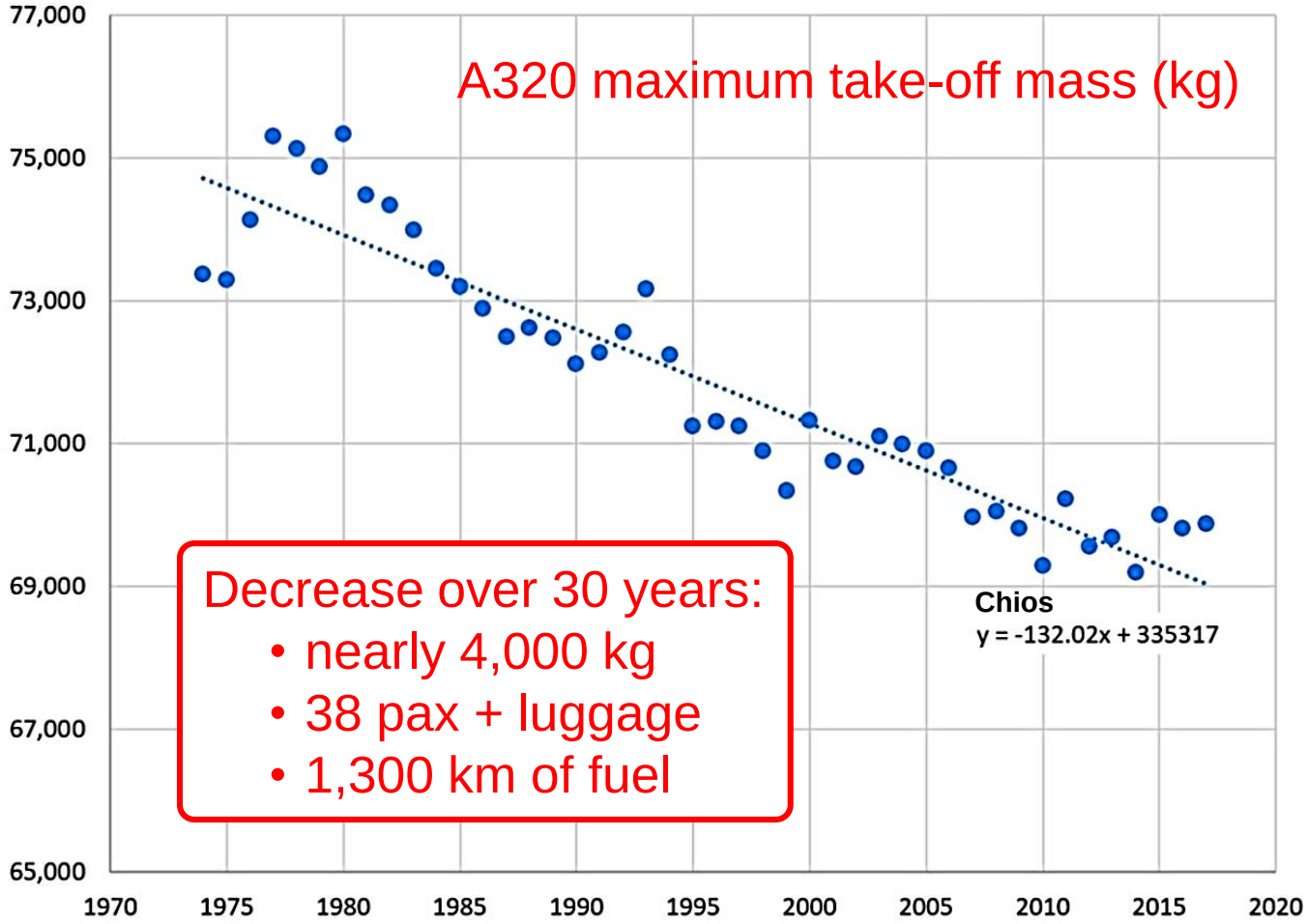
Puempel & Williams (2016)
ICAO Environmental Report


Rising sea levels:
13 of the USA's largest airports have at least one runway within reach of a moderate-to-high storm surge
11.3 feet
John F. Kennedy International
8.3 feet
Philidelphia International
6.7 feet
LaGuardia
8.6 feet
Newark Liberty International
10.3 feet
Ronald Reagan Washington National
5.6 feet
Oakland International
5.4 feet
San Francisco International
-1.7 feet
Louis Armstrong International
5.2 feet
Ft. Lauderdale International
10.6 feet
Tampa International
7.4 feet
Miami International
6.8 feet
Isla Grande
San Juan, Puerto Rico
7.7 feet
Honolulu International
US National Climate Assessment 2014

Take-off weight restrictions





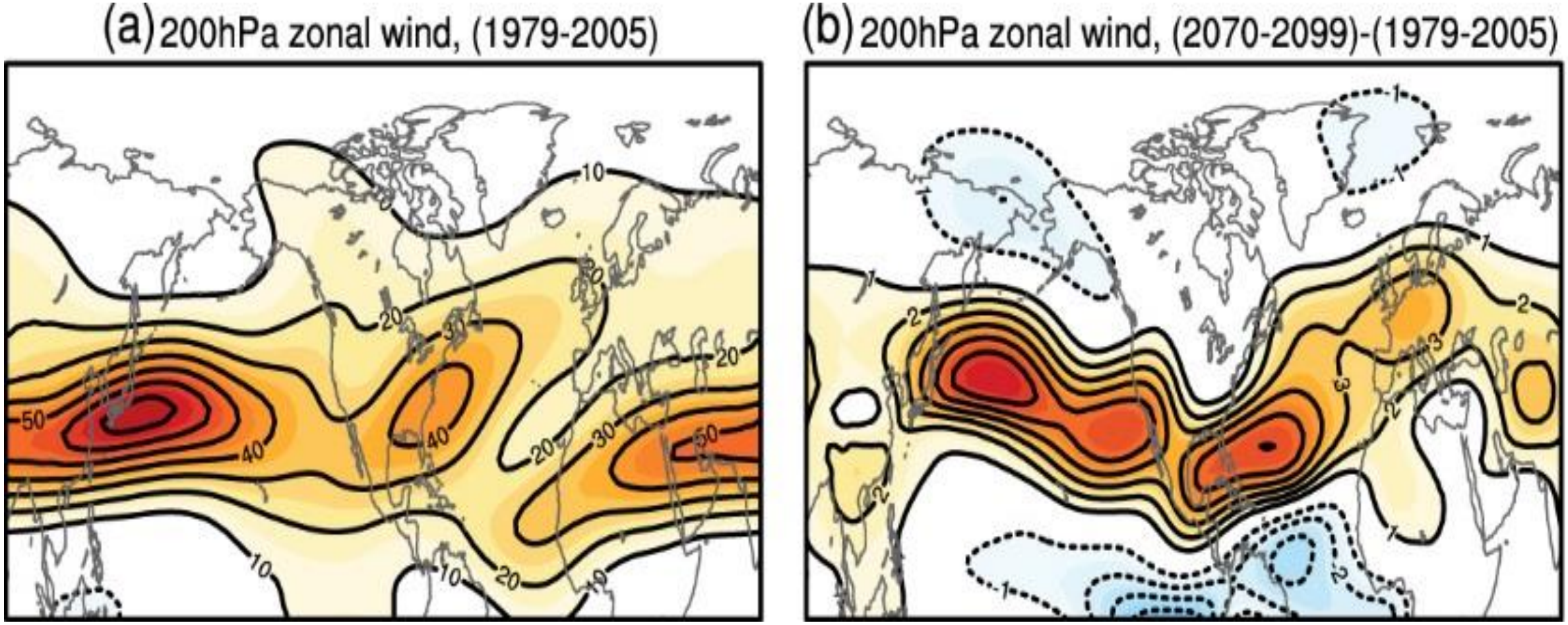


Gratton, Padhra, Rapsomanikis & Williams (2020)

More extreme weather: lightning

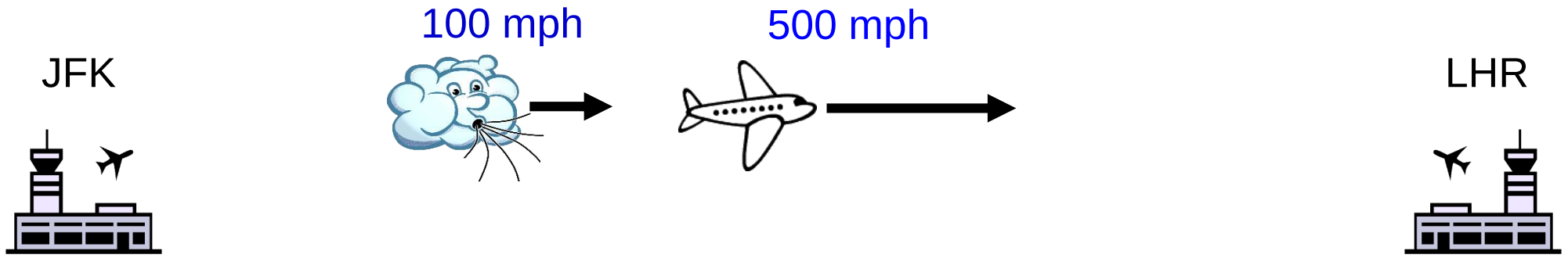
- The annual number of lightning strikes in the USA is predicted to increase by 11.9% per °C of global warming (Romps et al. 2014)
- This figure equates to an increase of about 50% over this century

Impacts of climate change on the jet stream



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

How do winds affect flight times?



<u>Without winds:</u>

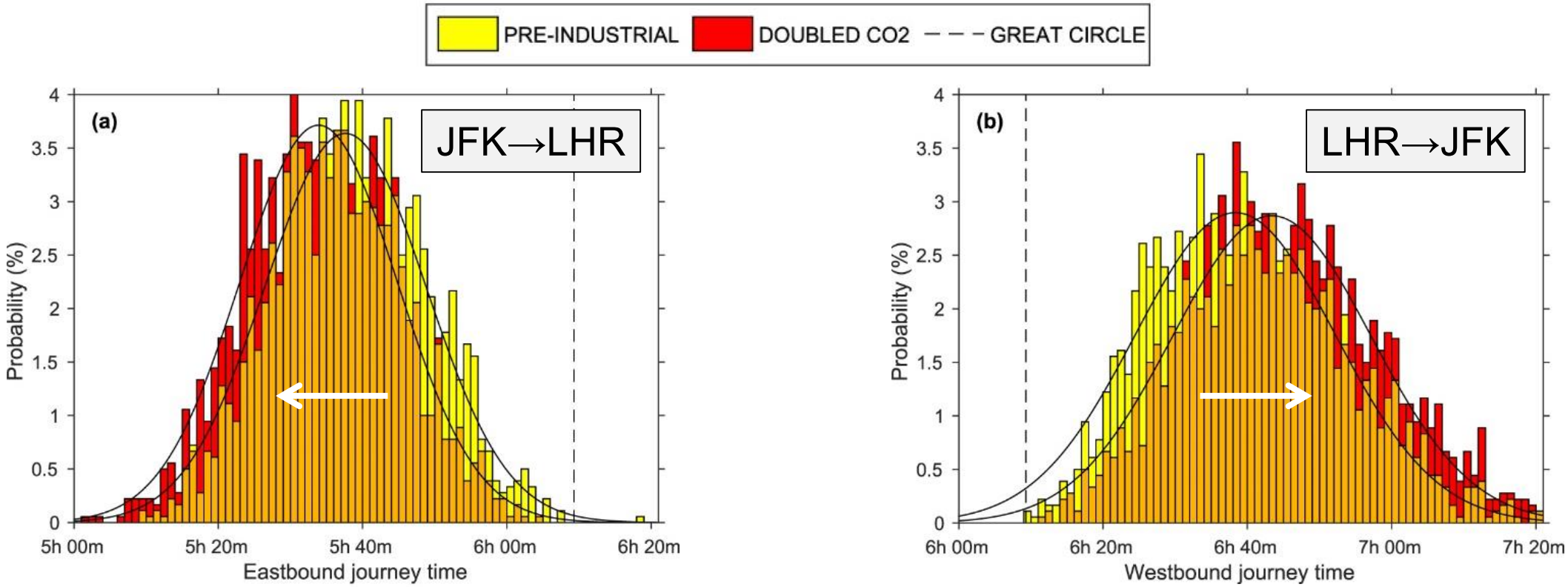
- Eastbound groundspeed: 500 mph
- Westbound groundspeed: 500 mph
- Roundtrip average groundspeed: 500 mph

<u>With winds:</u>

- Eastbound groundspeed: 600 mph
- Westbound groundspeed: 400 mph
- Roundtrip average groundspeed: 480 mph (!)

Williams (2016)

How do 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)

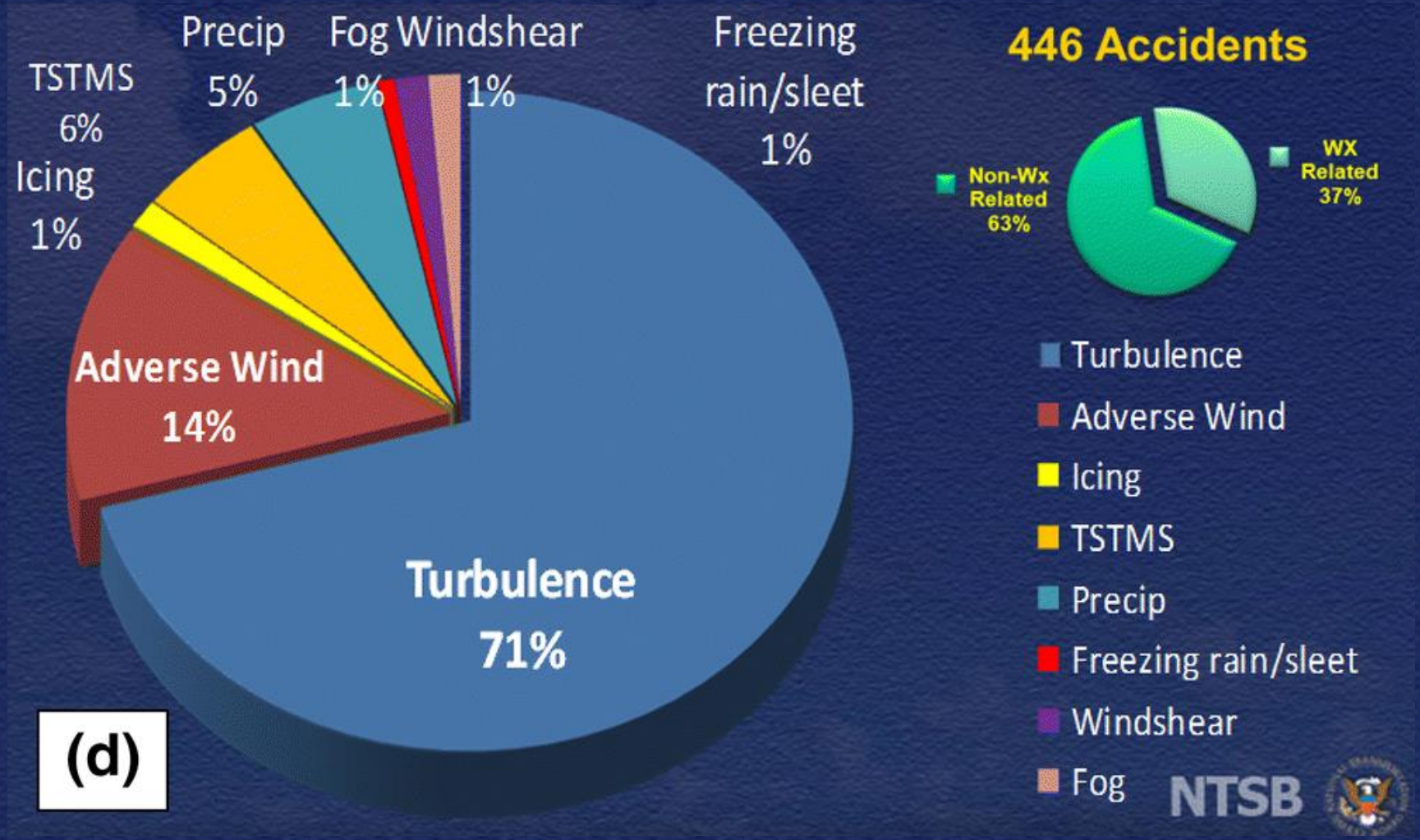
Impacts of climate change on the jet stream

- Have these changes already begun?
  - The North Atlantic jet stream wind speeds reached 250 mph on 8-12 January 2015
  - An eastbound JFK→LHR crossing took only 5 h 16 min, which broke the non-Concorde flight time record
  - Westbound LHR→JFK crossings took so long that two flights had to make unscheduled refuelling stops in Maine

- Extrapolation of our results to all transatlantic traffic (600 crossings per day) suggests that aircraft will collectively be:
  - airborne for an extra 2,000 hours each year
  - burning an extra 7.2 million gallons of jet fuel at a cost of $22 million
  - emitting an extra 70 million kg of CO_2 into the atmosphere, equating to the average emissions of 7,100 British homes

Williams (2016)

Turbulence



Gultepe, Sharman, Williams et al. (2019)

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Air turbulence tests 'improved'

A more accurate way of predicting air turbulence for aeroplanes has been developed by researchers.

Dr Williams hopes the technique will be used by the aviation industry

Dr Paul Williams, from the University of Reading, was part of a global team of academics who have developed a new forecasting technique.

Dr Williams said clear-air turbulence can strike suddenly, causing damage to planes and injury to passengers.

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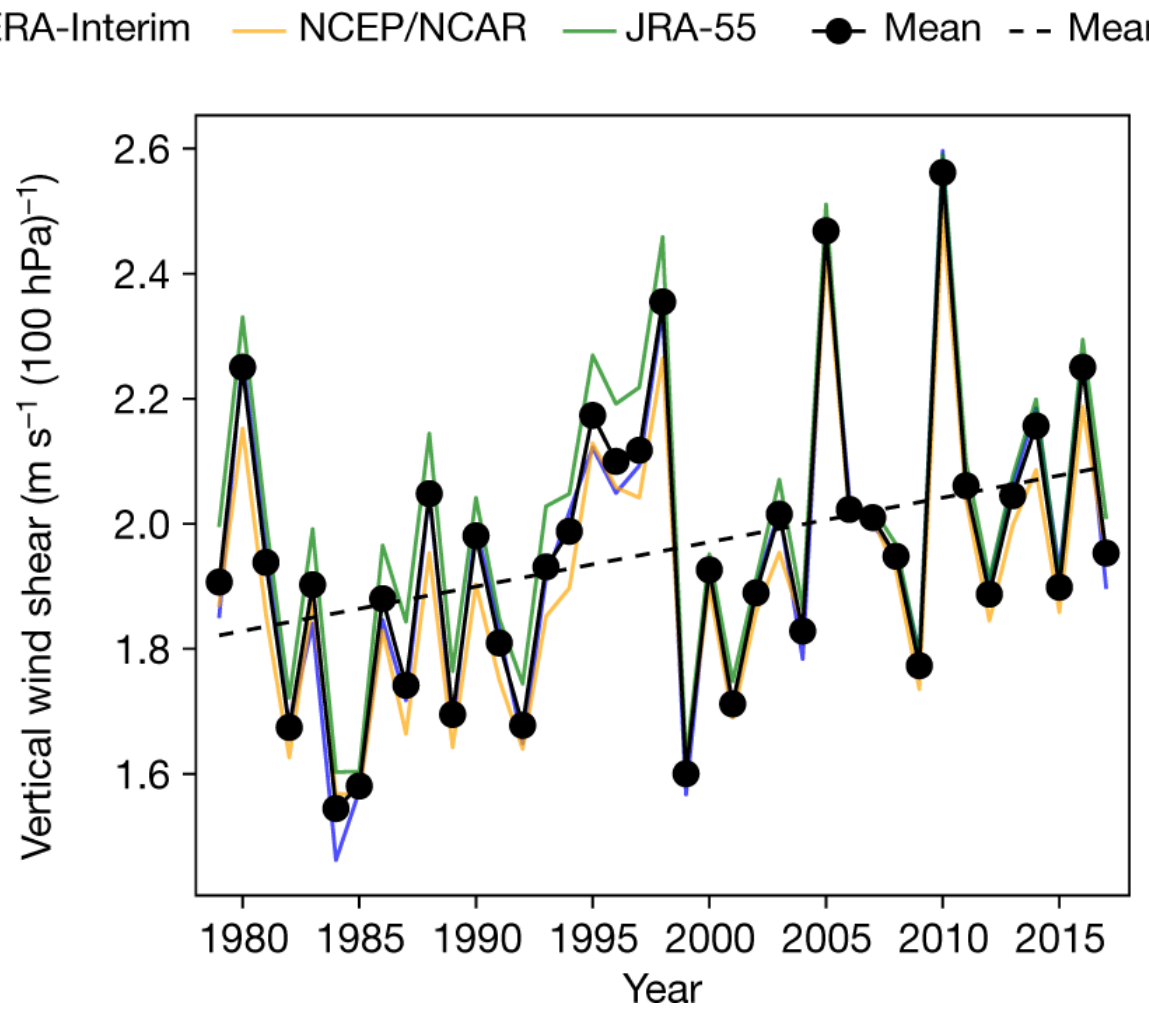
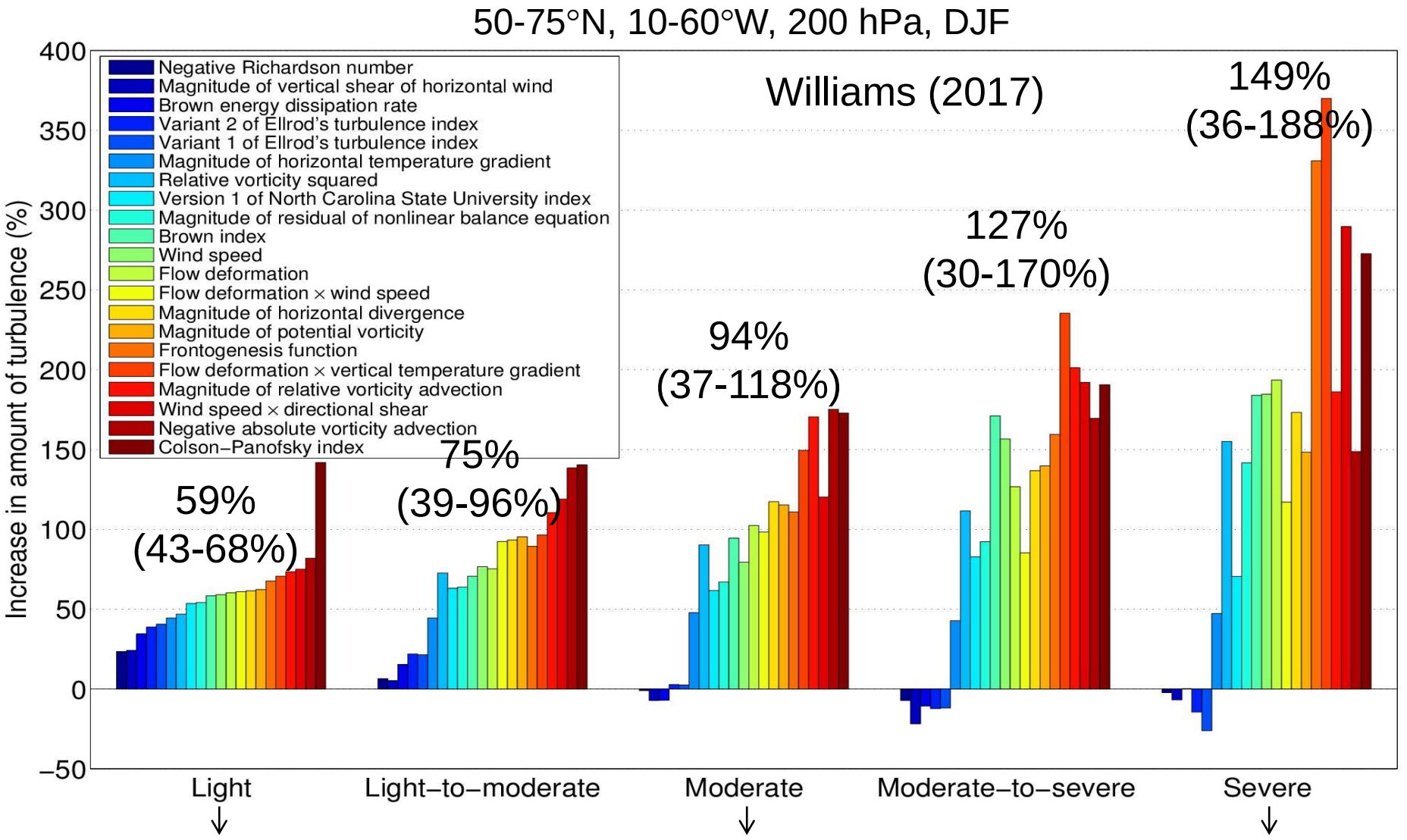
Clear-air turbulence

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)

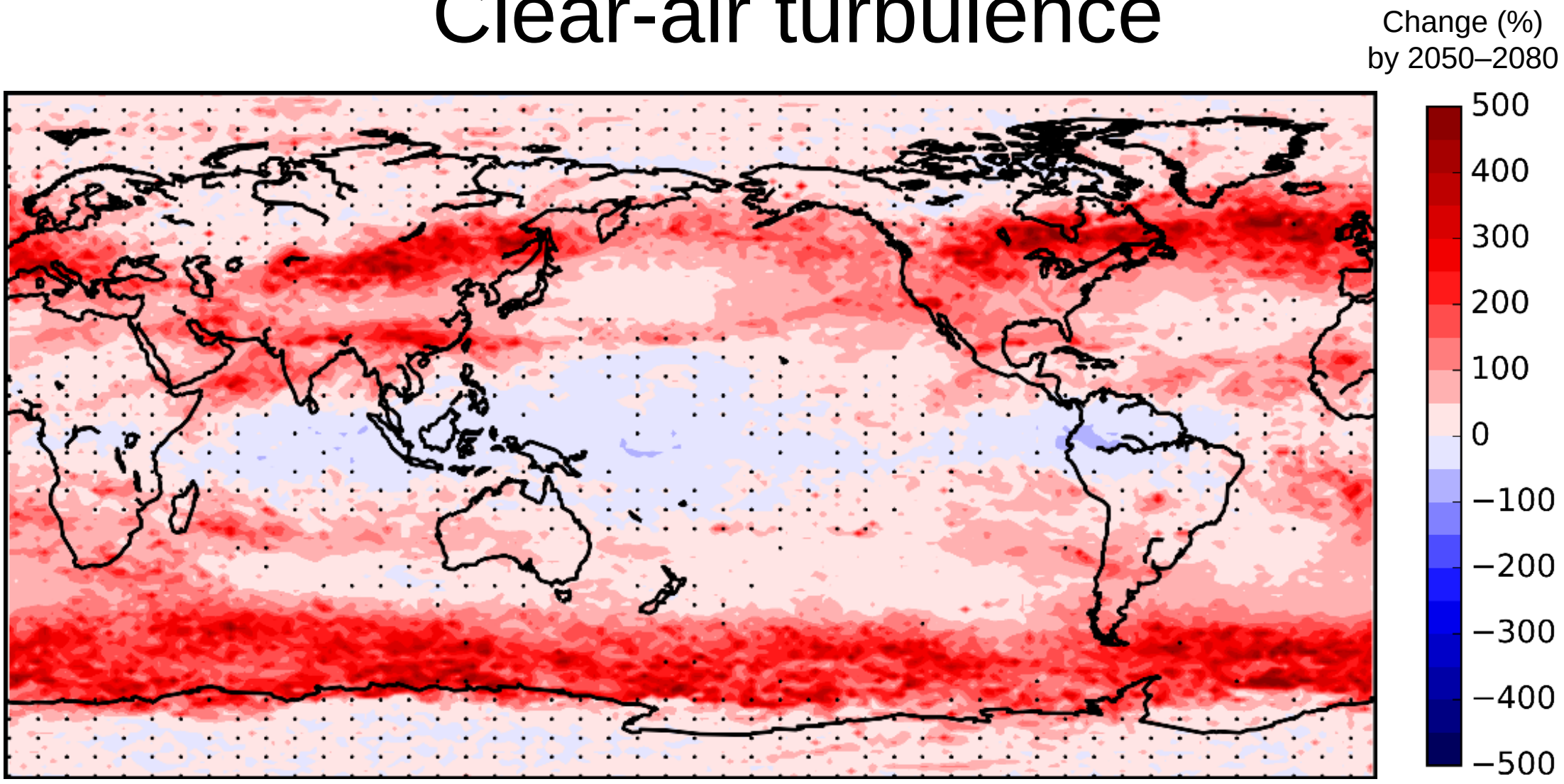


"Slight strain against seat belts; unsecured objects may be displaced slightly; food service may be conducted with little difficulty walking"

"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

- Sea-level rise and storm surges threaten runway capacity at many of the world's busiest airports
- Warmer air at ground level is decreasing air density and increasing the need for take-off weight restrictions
- The number of lightning strikes is predicted to increase by around 12% for each 1°C of global warming
- 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