

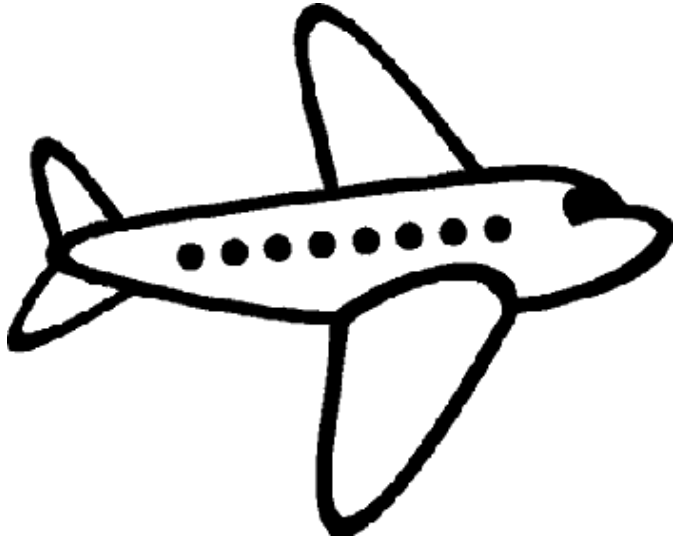
Aviation and the Need for Climate Adaptation



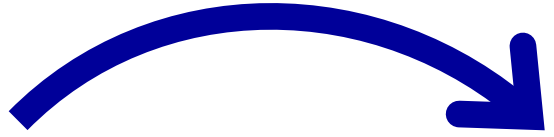
Dr Paul D. Williams, University of Reading, UK

A two-way interaction

AVIATION



CLIMATE



Proceedings of the 2017 WMO Aeronautical Meteorology Scientific Conference

A changing climate scenario may render some of today's aerodrome, airspace and airframe design and operation standards inadequate in the years or decades to come. Using past climatological records alone as an indicator of future climate at an airport, say, may be insufficient given the (current) rate at which the world's climate is changing (warming).



WORLD
METEOROLOGICAL
ORGANIZATION

RECOMMENDATION 3

In the context of **climate change and variability on aviation and associated science requirements**, the conference *recommended* that:

- The potential impacts of climate change and variability on aviation operations on the ground and in the air, downscaled to the local level, must be well researched and communicated;
- The mitigation of extreme weather events and the adaptation to a changing climate demands a multidisciplinary effort involving both the physical and the

airframe design and operation standards inadequate in the years or decades to come. Using past climatological records alone as an indicator of future climate at an airport, say, may be insufficient given the (current) rate at which the world's climate is changing (warming).

STATEMENT

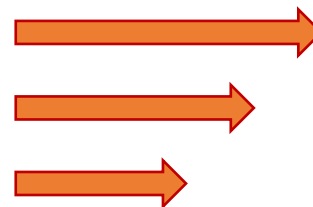
The conference *stated* that:

- There is a tremendous amount of ongoing cross-disciplinary research in the field of aeronautical meteorology (MET). This collaborative scientific excellence should be leveraged to enable the future global air traffic management (ATM) system;
- The role of MET as a key enabler to aviation's vision for a globally interoperable, harmonized ATM system of the future that is safer, more efficient and more environmentally responsible will only be realized through the accelerated transition of scientific research and technological advancement into operations based on aviation users' needs, new and improved community partnerships, trust, transparency and openness; and
- As the potential impacts of climate change and variability on aviation operations become better understood, the research community should continue to advance relevant science and communicate in a style that is well understood by the user.

Climate change impacts on aviation



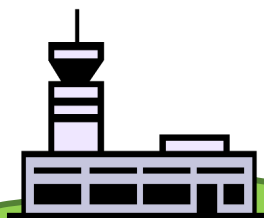
Shifting wind patterns
modify optimal flight
routes and fuel
consumption



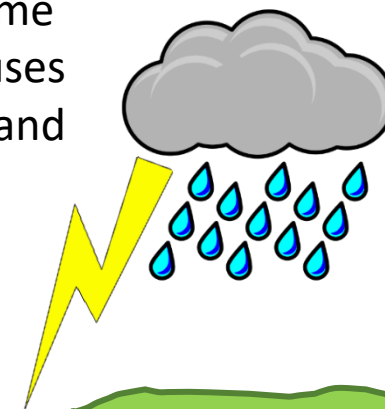
Stronger jet-stream
wind shears increase
clear-air turbulence

Rising sea levels and
storm surges threaten
coastal airports

Warmer air
imposes take-off
weight restrictions



More extreme
weather causes
disruptions and
delays



Puempel & Williams (2016)
ICAO Environmental Report

Global sea level rise

1900

The sea-level rise resulting from 2°C global warming would place 100 airports below sea level
(Yesudian & Dawson 2021)

Rising sea levels:
13 of the USA's largest
airports have at least one
runway within reach of a
moderate-to-high storm surge

5.4 feet
San Francisco
International

5.6 feet
Oakland International

8.3 feet
Philadelphia International

11.3 feet
John F. Kennedy International

6.7 feet
LaGuardia

8.6 feet
Newark Liberty International

10.3 feet
Ronald Reagan Washington National

-1.7 feet
Louis Armstrong International

5.2 feet
Ft. Lauderdale International

10.6 feet
Tampa International

7.4 feet
Miami International

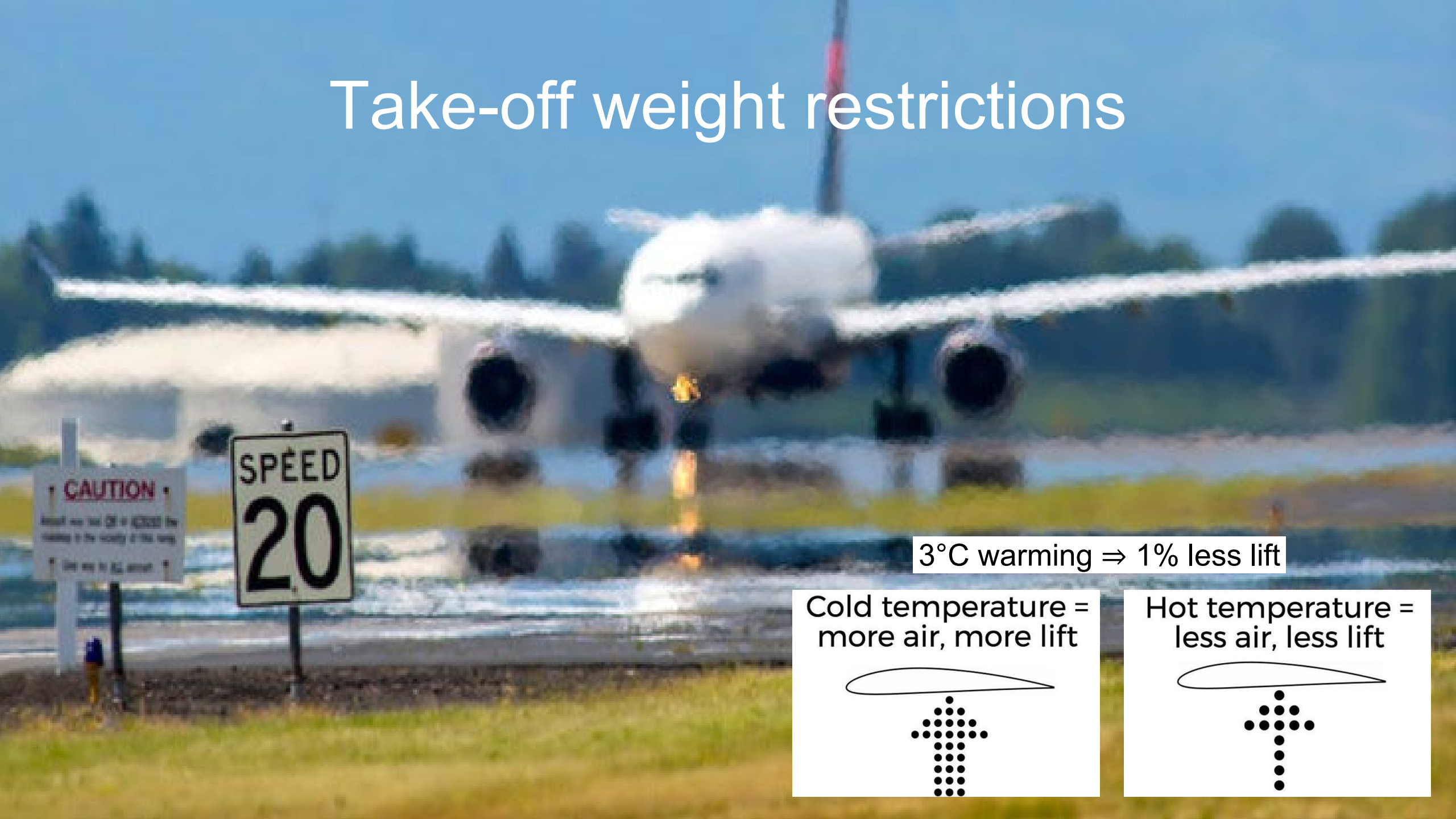
6.8 feet
Isla Grande
San Juan, Puerto Rico

7.7 feet
Honolulu International

LaGuardia Airport after Hurricane Sandy (2012)

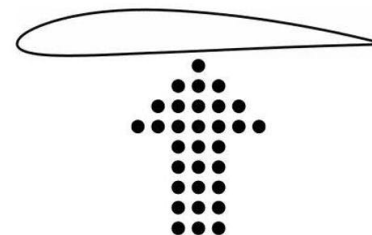
The flood height return period for Sandy-like flooding of NYC was 500 years pre-industrially, is 25 years today, and will be 5 years by 2050 (Garner et al. 2017)

Take-off weight restrictions

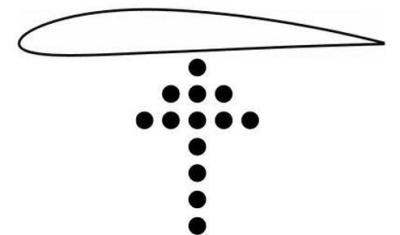


3°C warming $\Rightarrow$ 1% less lift

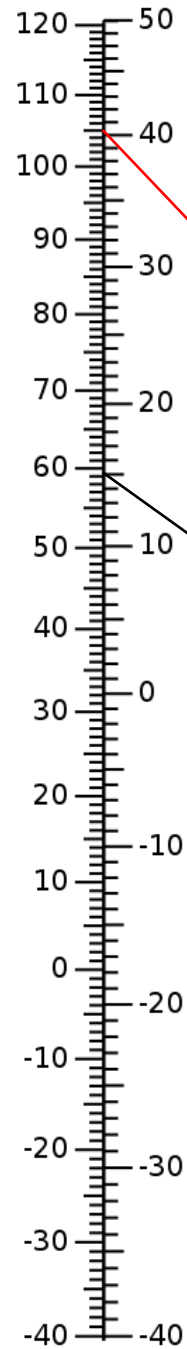
Cold temperature =
more air, more lift



Hot temperature =
less air, less lift

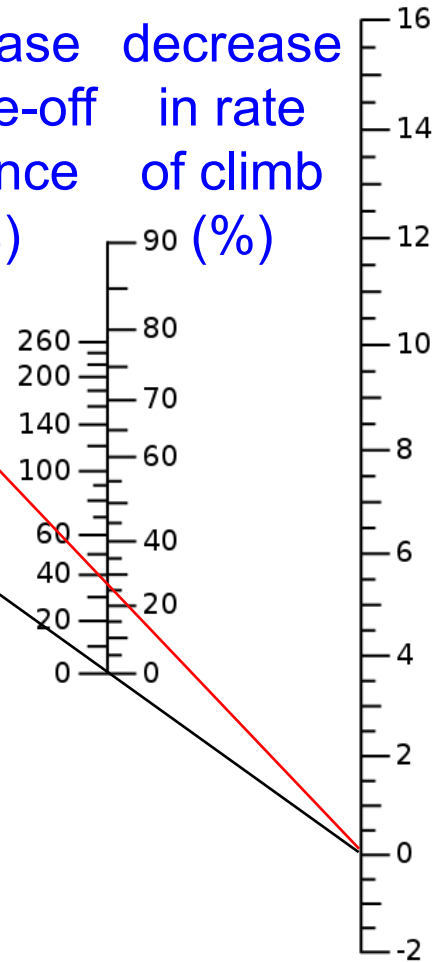


airport
temperature
(°F or °C)



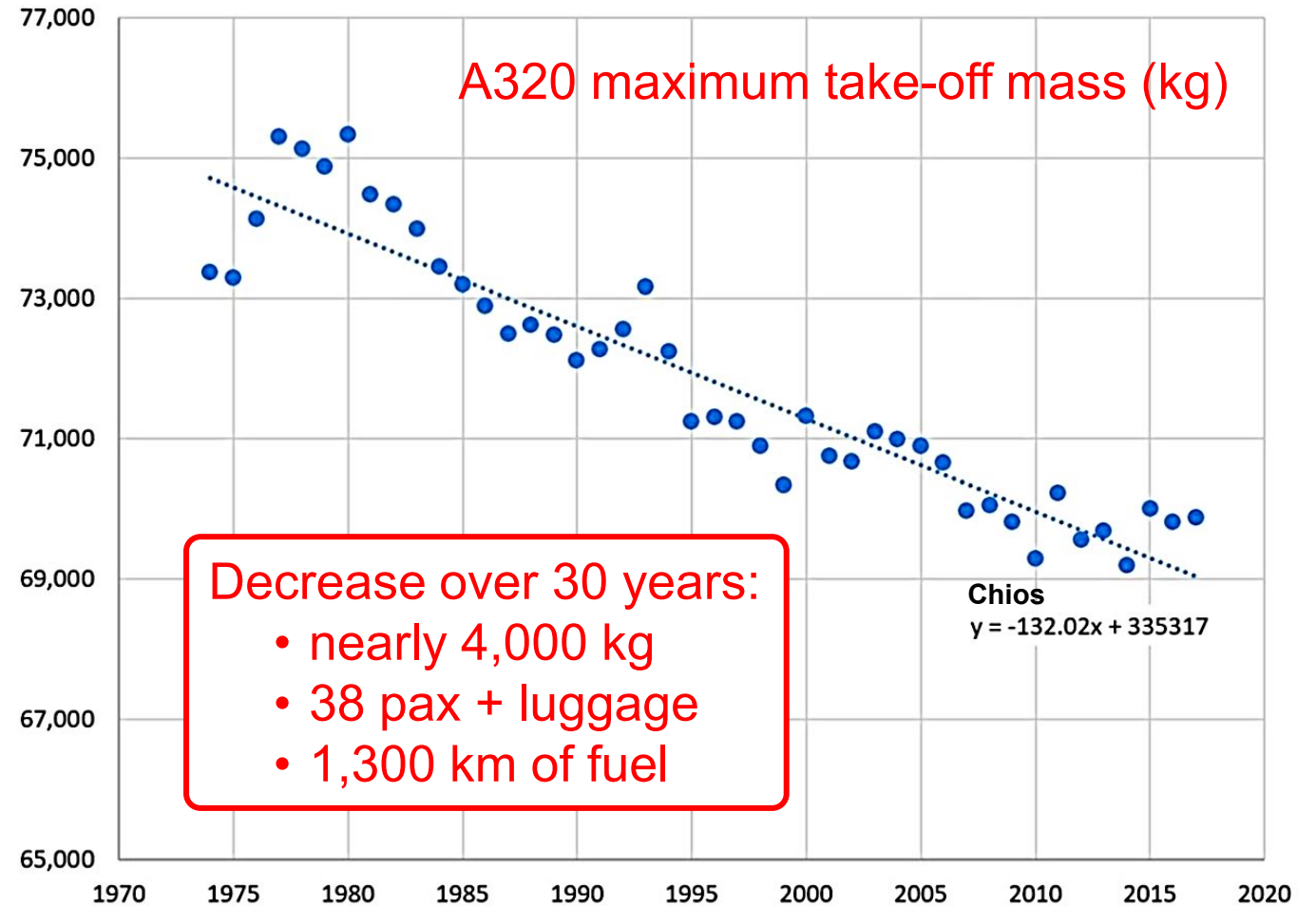
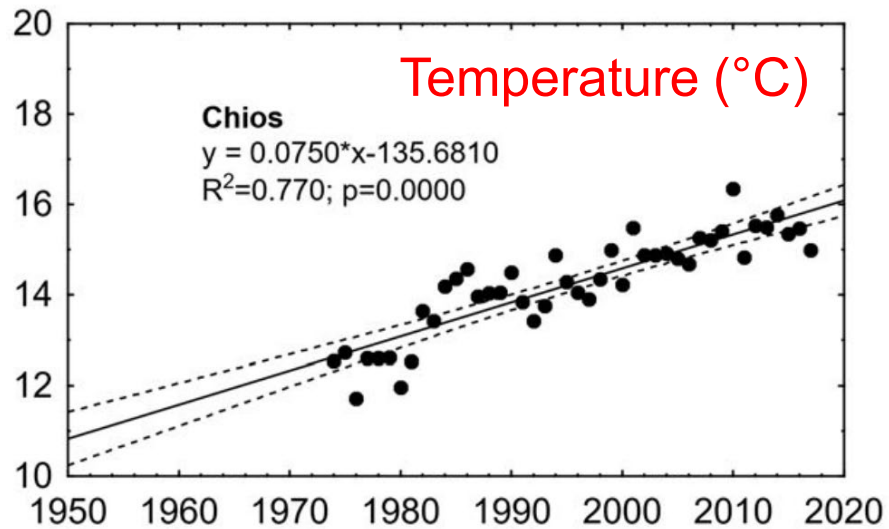
increase
in take-off
distance
(%)

decrease
in rate
of climb
(%)



airport
pressure altitude
(1000 feet)

Take-off weight restrictions



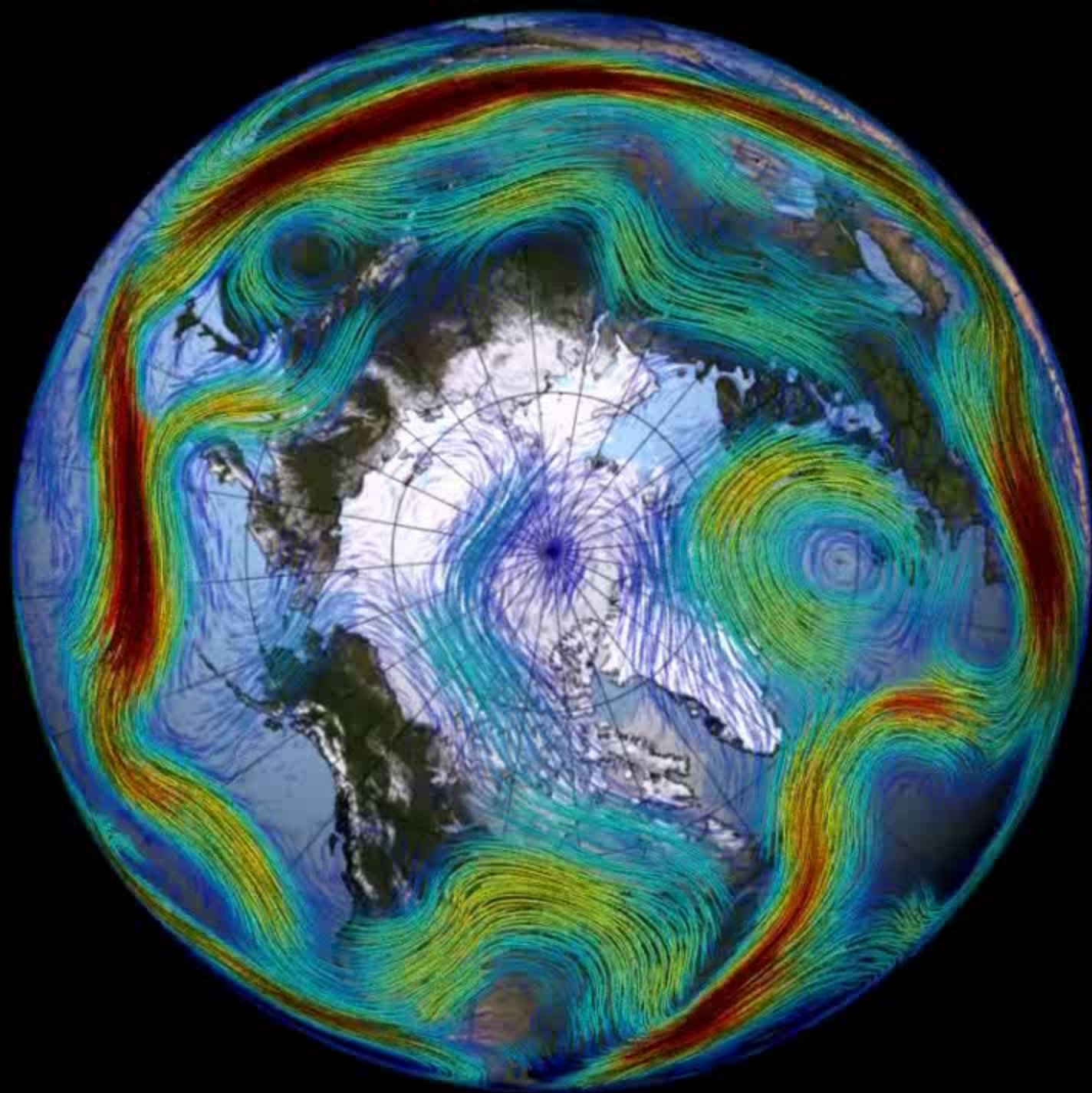
Memphis International Airport, 21 October 2019



More extreme weather: lightning

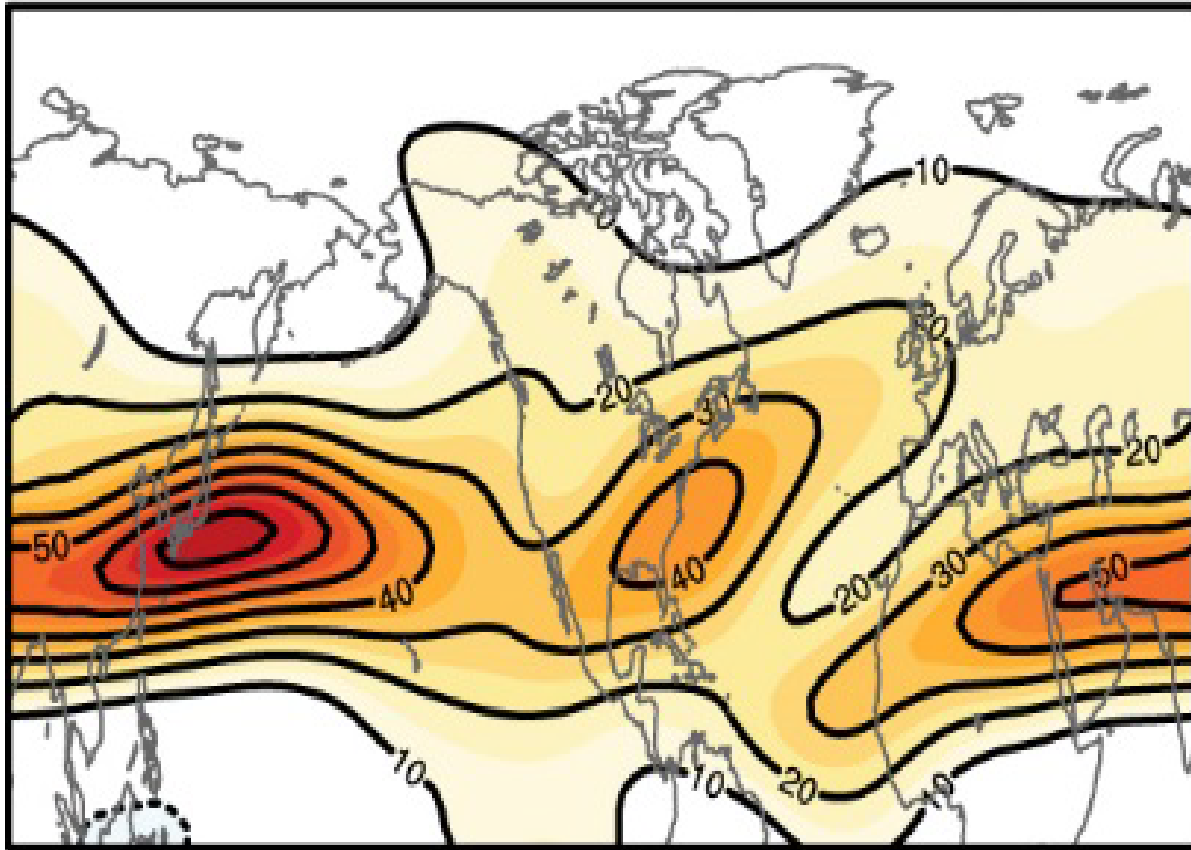
- The annual number of lightning strikes in the USA is predicted to increase by 12% for each 1°C of global warming (Romps et al. 2014)
- This figure equates to an increase of about 50% over this century
- Possible adaptation measure: negatively charging the airframe (Pavan et al. 2019)

23:13:37:43:173

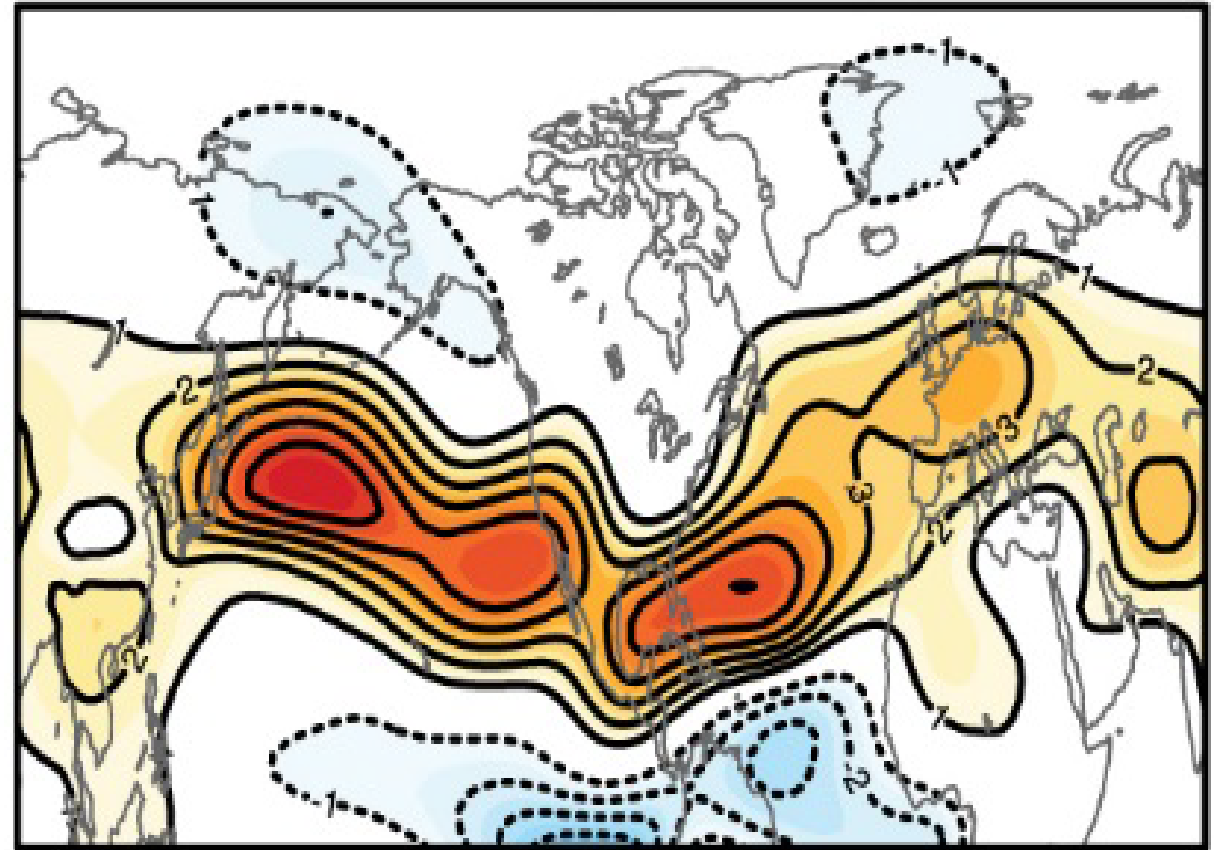


Impacts of climate change on the jet stream

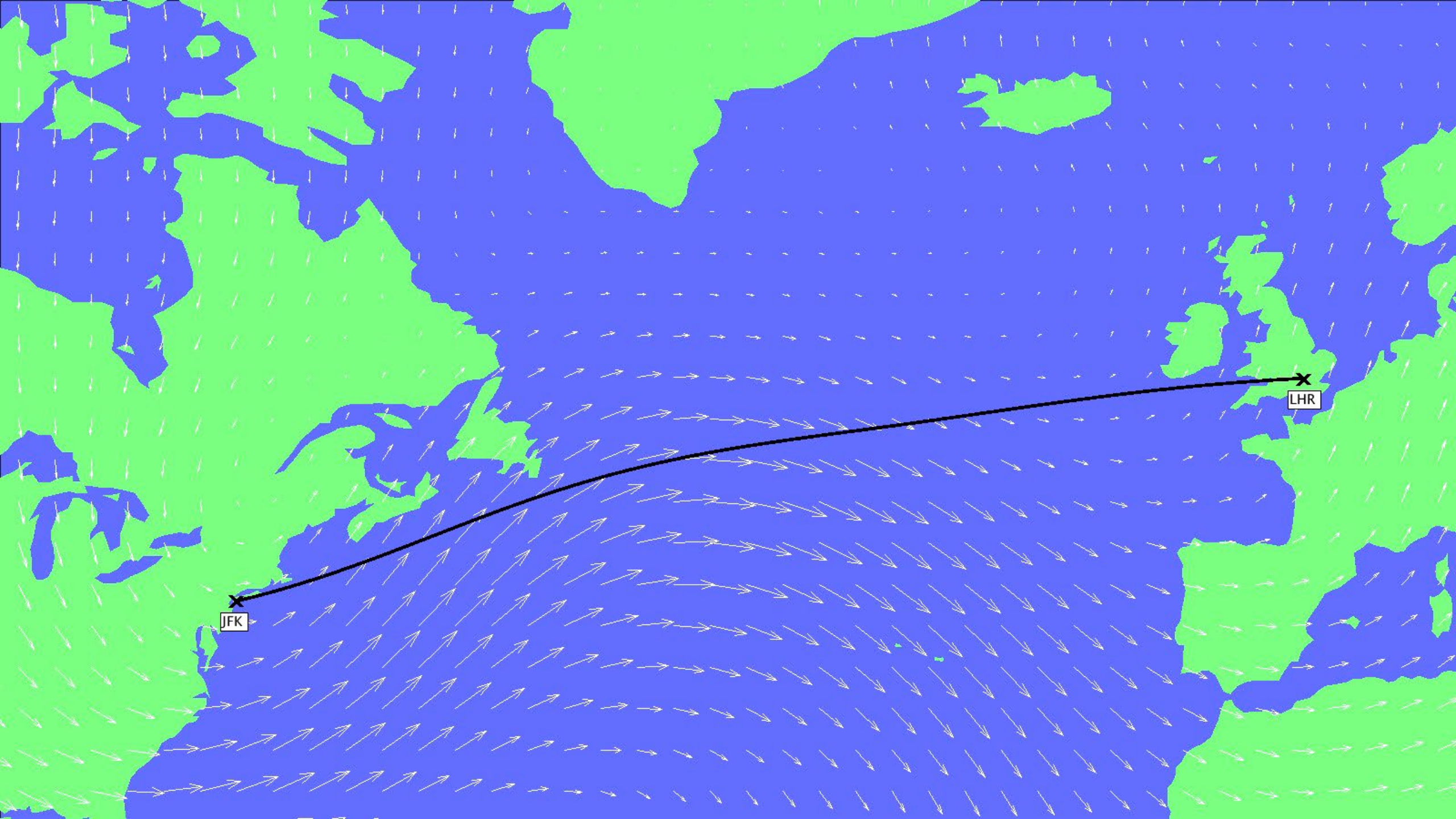
(a) 200hPa zonal wind, (1979-2005)



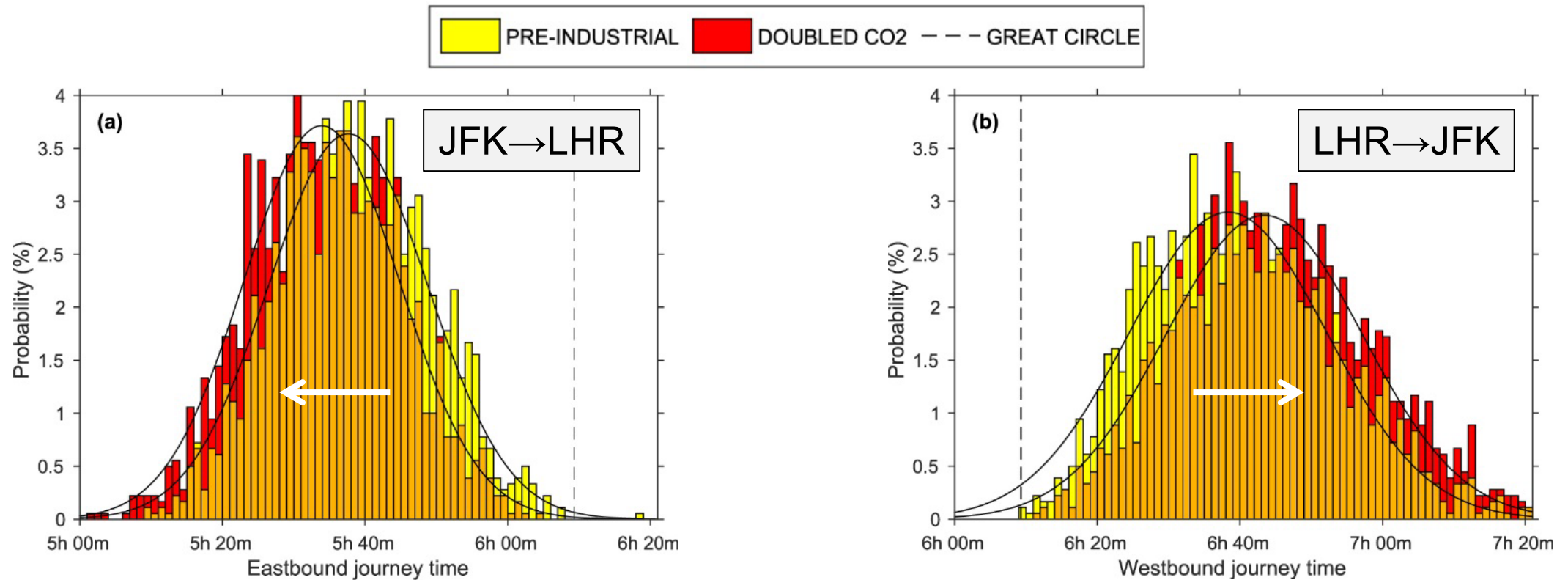
(b) 200hPa zonal wind, (2070-2099)-(1979-2005)



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

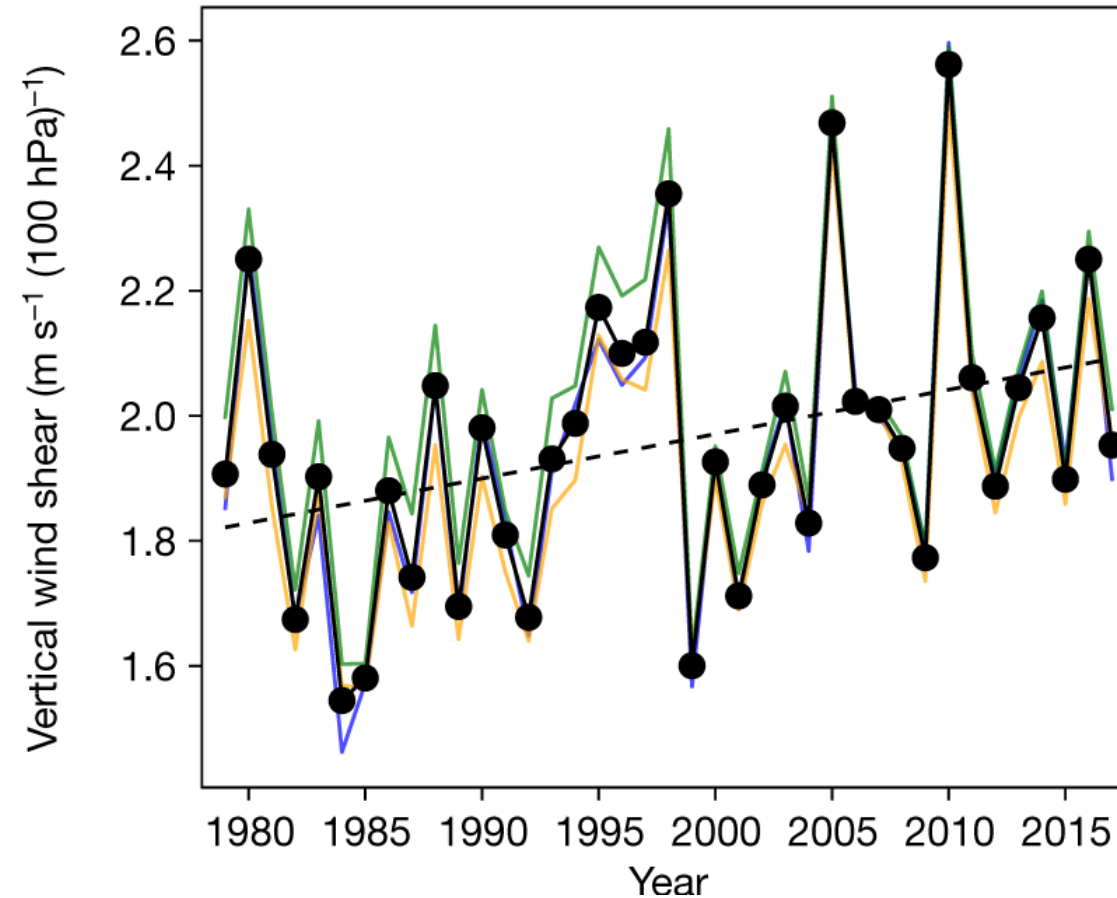
Turbulence

5,500 aircraft encounter severe turbulence ($>1.0g$) each year in the USA, causing:

- 100s of serious injuries
- structural damage to planes
- flight diversions and delays
- costs of \$150m–\$500m

Clear-air turbulence

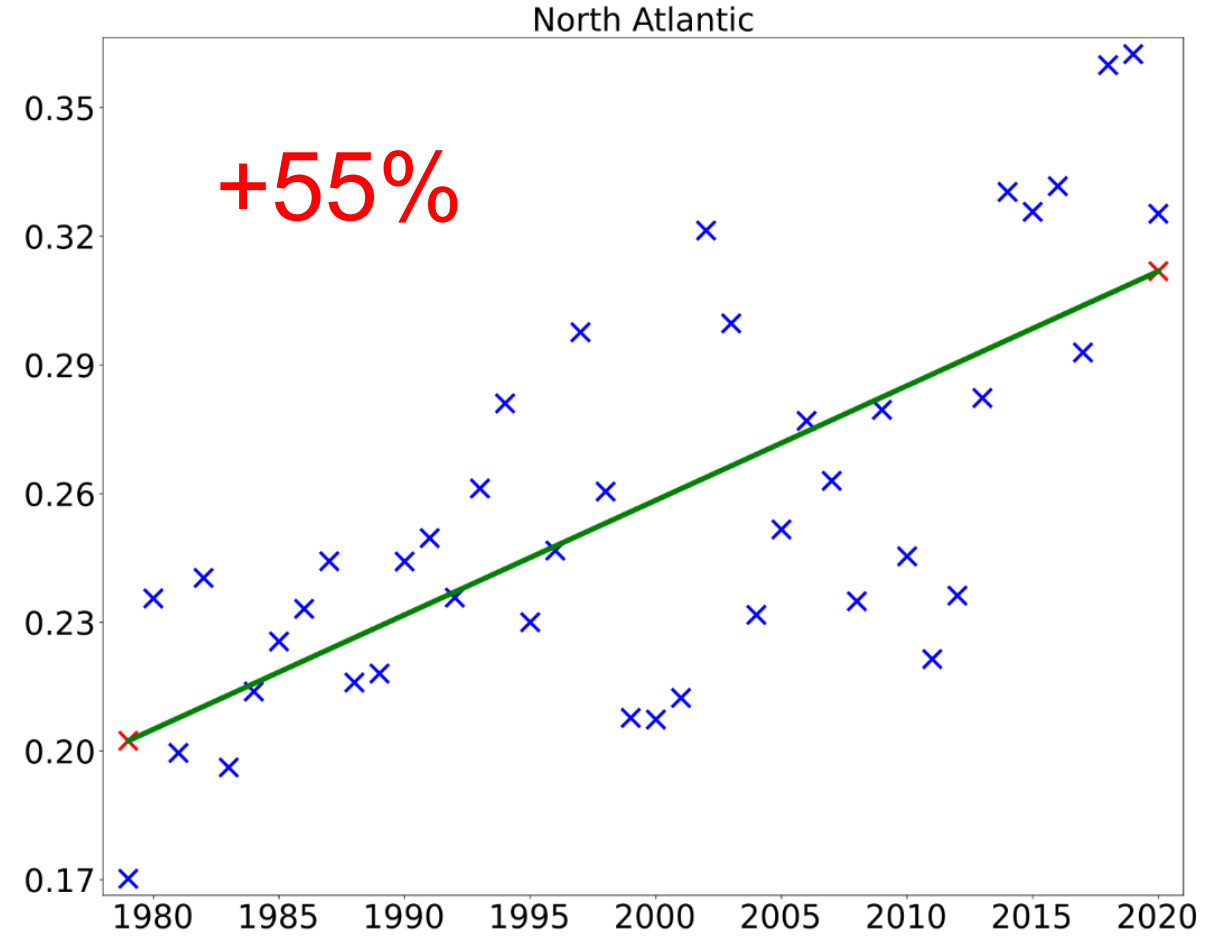
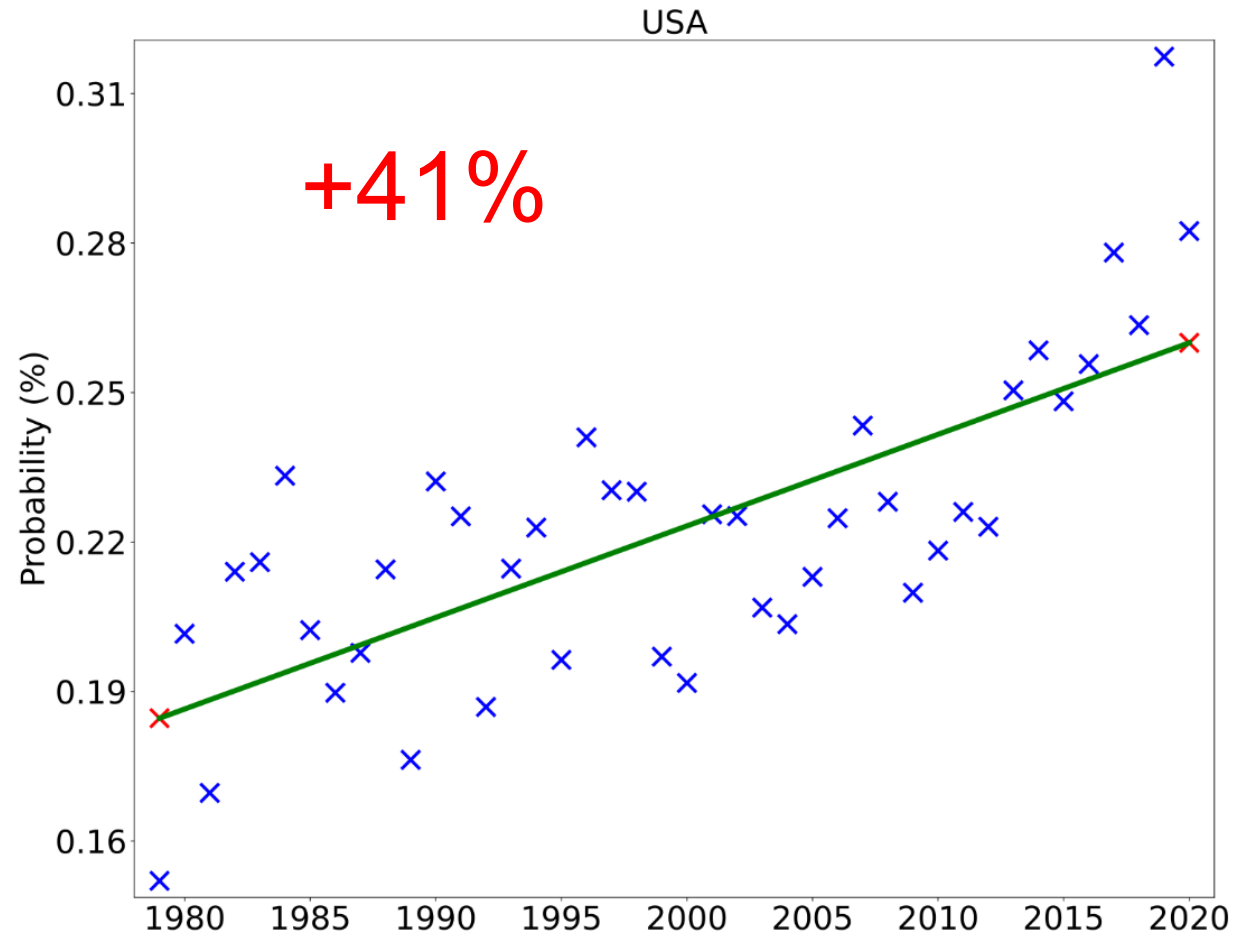
— ERA-Interim — NCEP/NCAR — JRA-55 ● Mean - - Mean trend



15% increase
over 40 years
⇒ more CAT

Vertical wind shear
over North Atlantic
near FL350

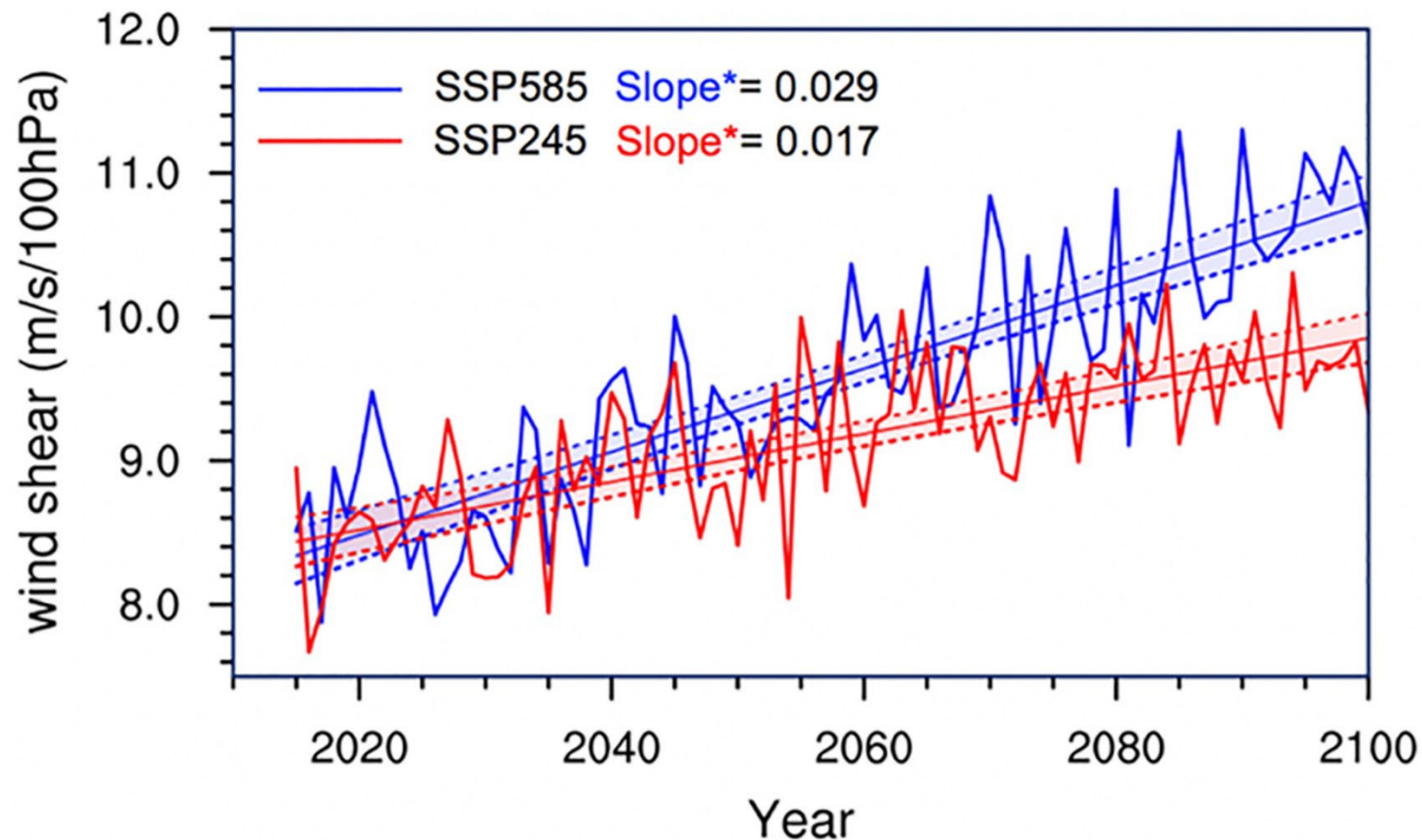
Clear-air turbulence



Prosser, Williams, Marlon & Harrison (2023)

Clear-air turbulence

Vertical wind shear
over Northern
Eurasia near FL350

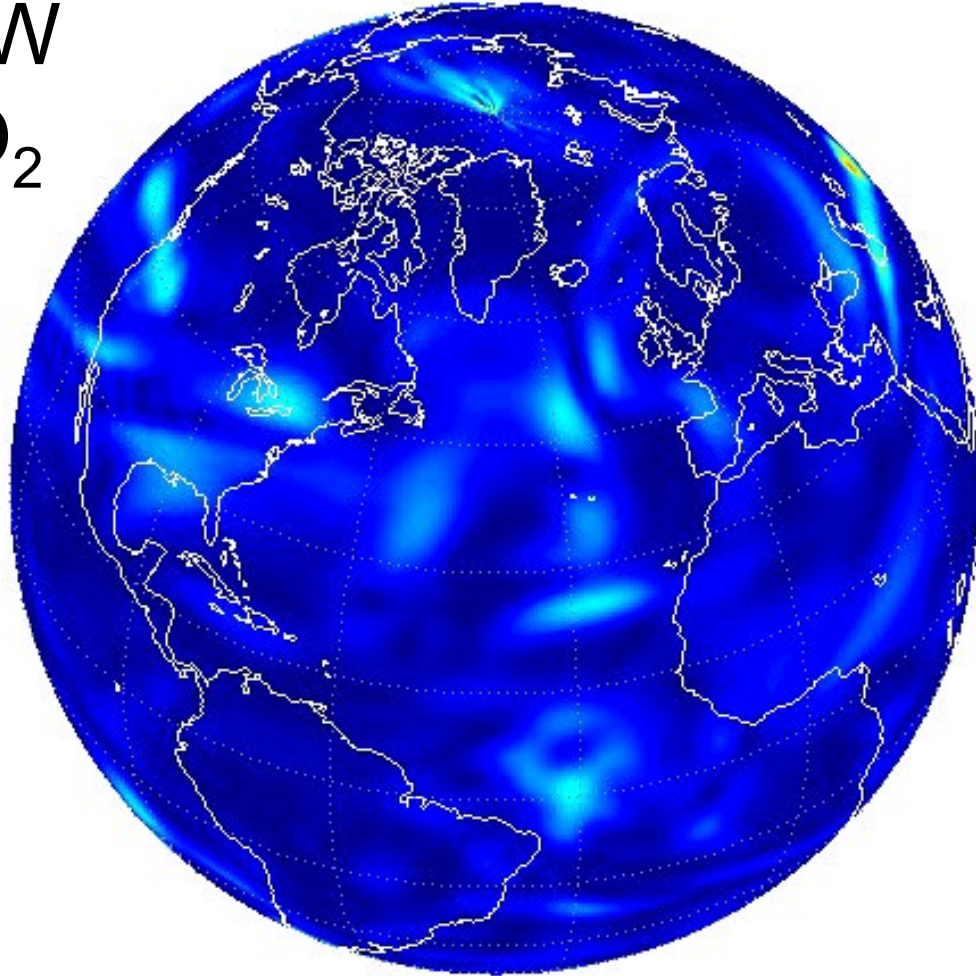


29% increase
over 85 years

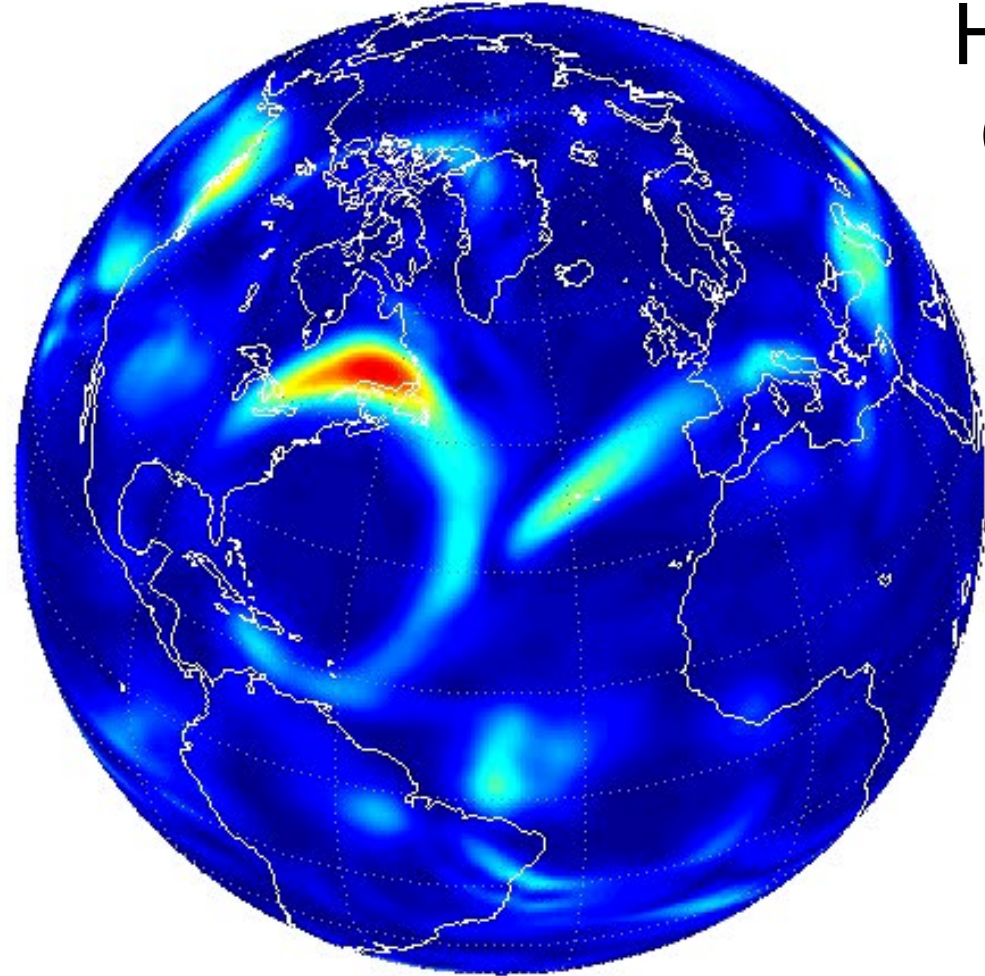
17% increase
over 85 years

Clear-air turbulence

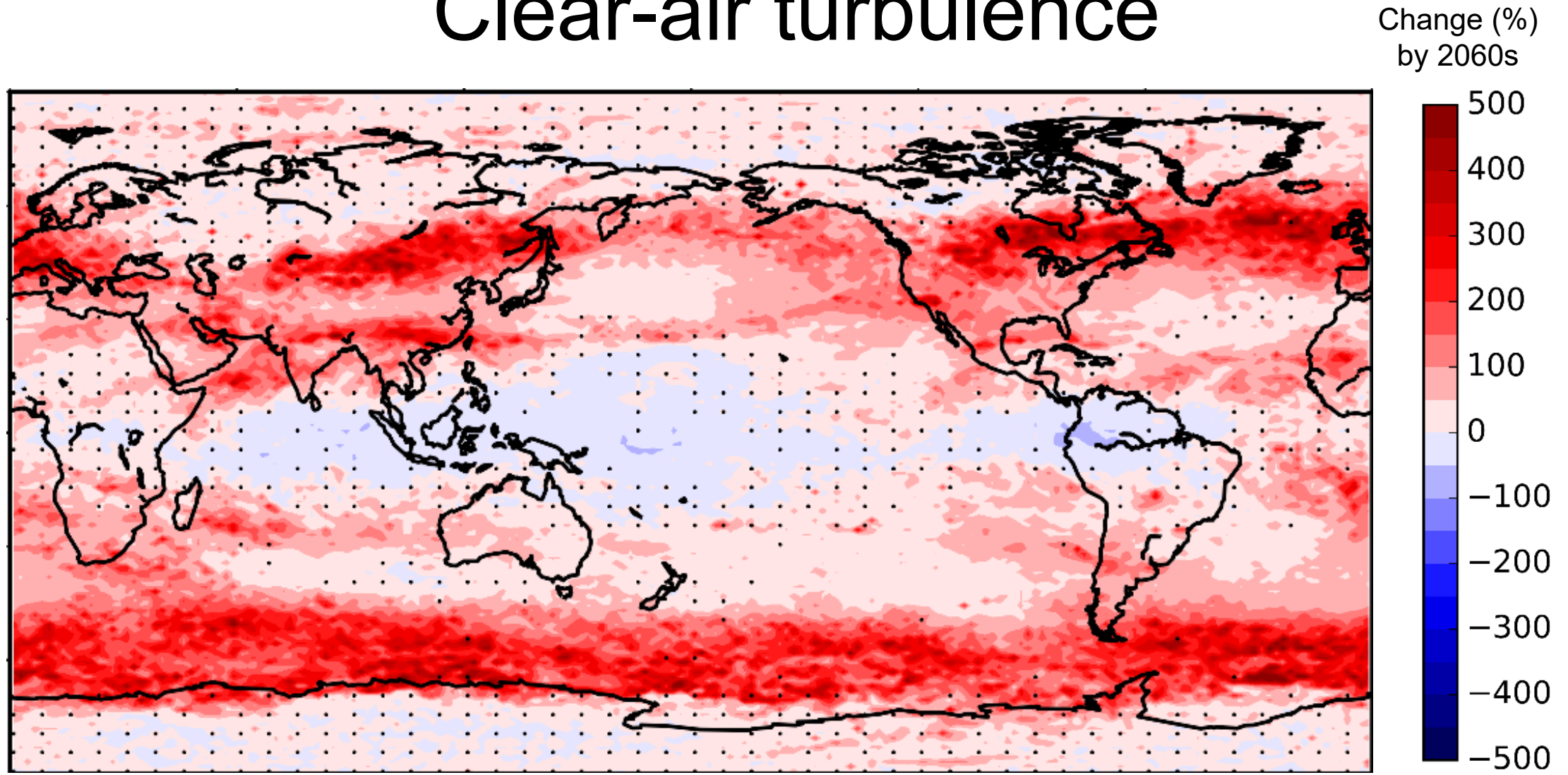
LOW
 CO_2



HIGH
 CO_2



Clear-air turbulence



Storer, Williams & Joshi (2017)



Turbulence takes instant noodles off Korean Air menu

■ ■ ■ BBC · 1d



The Korea Times

August. 3. 2024

“The climate crisis has recently spiked the turbulence's frequency. Compared to 2019, the frequency has more than doubled this year,” a Korean Air official said. “Some passengers have suffered serious burns.”

Outcomes of the 2020 Survey on the Impacts of Climate Change and Variability on Aviation

Standing Committee on Services for Aviation

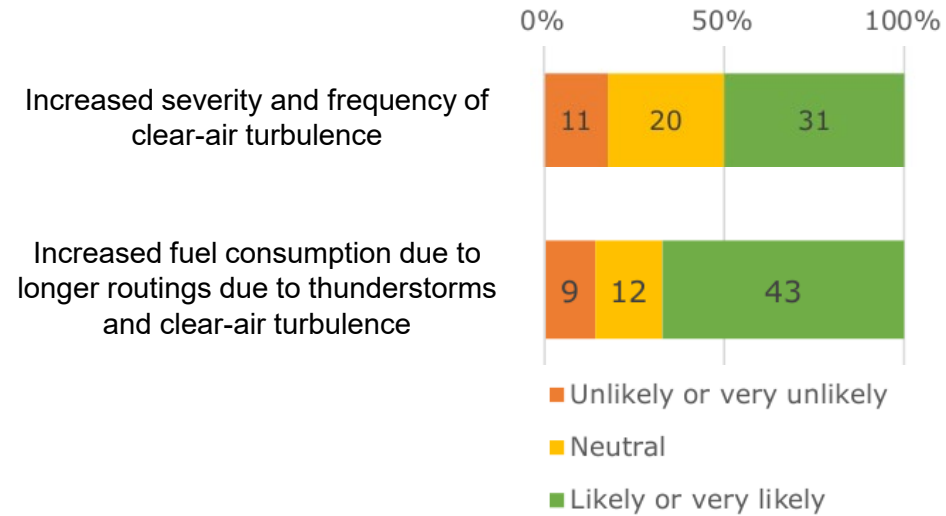
A subsidiary body of the WMO's Services Commission

Geneva

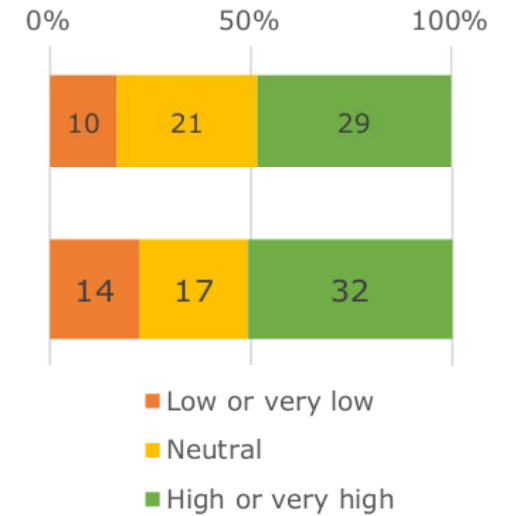
October 2020

Full report

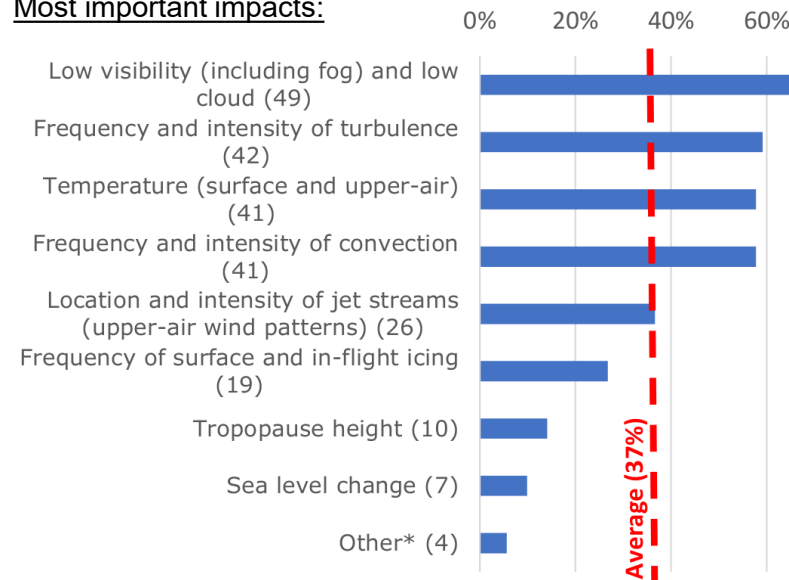
Likelihood of occurrence



Severity of impact



Most important impacts:



93% of respondents evaluated the overall impact of climate change on aviation to be moderate or greater

Summary

- Flooding from sea-level rise and storm surges threatens **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 but slow down westbound flights
- The jet stream today contains **15% more windshear and 55% more severe turbulence** than when satellites began observing it, with projections of **17–29% more windshear and 200–300% more severe turbulence** in the coming decades