EGU22-2796
https://doi.org/10.5194/egusphere-egu22-2796
EGU General Assembly 2022

Present climate characterization and future changes in Clear-Air Turbulence (CAT) over the northern hemisphere

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Airplanes spend about 1% of cruise time in Moderate-Or-Greater (MOG) CAT (Sharman et al. 2006), which is defined as any turbulence occurring in the atmosphere away from a visible convective activity and which is particularly difficult to detect. MOG CAT events can injure passengers, cause structural damage to planes, and induce considerable economic loss. A major source of CAT is the Kelvin–Helmholtz instability (KHI), which is often induced by vertical wind shear associated with the jet stream and upper-level fronts. Recent studies have shown that under climate change, jet streams could be strengthened, and CAT frequency and intensity could significantly increase (Williams 2017). Assessing future CAT changes is a relatively new research topic and there are a lot of open questions. In particular, there is a need to understand the CAT trends in the present climate in atmospheric reanalysis and climate models and the mechanisms at play. The second step is to investigate the CAT sensitivity to global warming and the associated uncertainties.

In this study, we characterize present and future climate CAT trends in the Northern Hemisphere. For this purpose, we rely on a set of CAT indices computed with five different reanalysis datasets (among whom ERA5) and experiments performed by two CMIP6 climate models (CNRM-CM6-1 and IPSL-CM6A-LR).

In present climate, the analysis of the CAT indices over the last four decades shows that CAT is more frequent over the North Atlantic, the Pacific Northwest, the Himalayas and the Rocky Mountains. We find that the spatial distribution of CAT over the North Atlantic is strongly related to the variability of large-scale circulation patterns. In particular, the occurrence of CAT is clearly associated with the positive phase of the North Atlantic Oscillation (NAO+) and the Atlantic Ridge weather regimes. A significant positive trend of CAT frequency is found using reanalysis in different regions of the northern hemisphere. However, the signal-to-noise ratio estimated from the climate models is still very weak in the present climate except over Northeast Asia.

We find that positive trends of CAT frequency are enhanced in response to global warming for the ssp8.5 worst-case scenario over the midlatitudes at the level 200hPa. This is coherent with previous studies. However, results also suggest that CAT future changes highly depend on altitude level and the region considered. For example, over the North Atlantic, CAT frequency significantly increases at the 200hPa (about 11 km) and 300hPa (about 9 km) levels, while it decreases at the 250hPa (about 10 km) level. This highlights the importance of study future changes in the vertical

structure of the atmosphere.

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