Statistical Analysis of Aviation Turbulence in the Middle–Upper Troposphere over Japan

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Introduction

Aircrafts often encounters turbulence (aviation turbulence), which potentially causes injuries. Predicting turbulence is critically important for safety of aviation aircrafts. However, it is still difficult to accurately predict the turbulence. One of the major reasons for the difficulty would be that general features of turbulence are not fully understood.

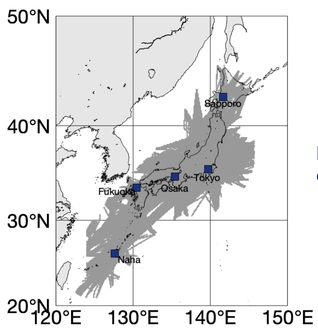
- Wolff and Sharman (2008) analyzed pilot reports (PIREPs) from 1994 to 2005 to examine the statistics of upper-level aviation turbulence over United States and revealed that many cases in western regions are caused mountain waves while cases in south are associated with convective clouds. The number of cases associated with mountain waves is smallest in summer, whereas those with convective clouds are smallest in winter.
- Lane et al. (2009) also investigated the turbulence statistics over Greenland based on the PIREPs, which showed that a low--level cyclones play a role in producing turbulence.
- Kim and Chun (2011) conducted a statistical analysis of aviation turbulence over south Korea using PIREPs from 2003 to 2008 except for 2005. They showed that the number of cases is largest in spring and the total number increases from 2003 to 2008. Whereas the number of cases is dominant along major flight routes, there are local peaks in the spatial number distribution.

Since there are number of international and domestic flights over Japan, it is expected that significant number of airplanes encounter turbulence. However, the statistics of turbulence over Japan has never examined.

GOAL:
Reveal the statistics of turbulence occurred around Japan

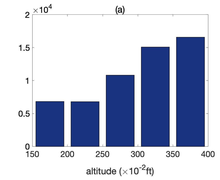
Data

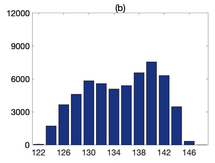
1. Turbulence (horizontal location, level, and category) : PIREP from 2006 to 2018.
2. Flight info. (horizontal location and level): CARATS open data by Ministry of Land, Infrastructure, Transport and Tourism (MLIT), Japan in May 2015

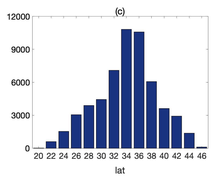


Category of turbulence intensity:
LGTM: light minus
LGT: light
LGTP: light plus
MOD: moderate
MODP: moderate plus
SEV: severe

Fig. 1: Horizontal locations of the CARATS flight data in May 2012.







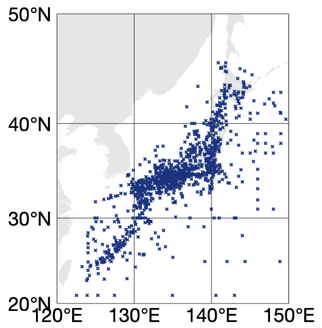
The number of reported latitude is large as the latitude is high. There is a peak at the bin of 140-deg longitude. Another peak is observed at the 130-deg longitude bin at which the major airport, Fukuoka, is located and number of aircrafts heading to or coming from Naha airport pass through the longitude. There is a clear peak around the latitude from 34 to 36 and the number of aircrafts decreases from the latitude. In this latitude range, several major airports such as Tokyo, Osaka, and Fukuoka are located.

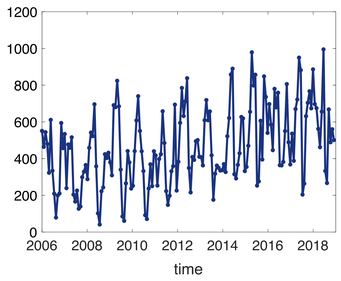
Fig. 2: Histogram of (a) altitude, (b) longitude, and (c) latitude of aircraft over Japan in May 2015, which is obtained from CARATS open data.

Results: Statistics of aviation turbulence

The locations of turbulence in PIREP are widely distributed over Japan. Particularly, the number of cases is concentrated along the popular flight routes between Tokyo and big cities: Osaka, Fukuoka, and Sapporo. In addition, there are a number of cases around Okinawa, which is located in the south west of main island and one of the most popular destinations for vacation in Japan.

Fig. 3: Spatial distribution of turbulence around Japan reported in PIREP from 2006 to 2018.





A periodic annual variation is clearly observed: the number of cases is in general large in winter and small in summer. It is also observed that the total number of cases of turbulence increases with time especially after 2014.

Fig. 4: Spatial distribution of turbulence around Japan reported in PIREP from 2006 to 2018.

The largest number of cases is reported as light plus or greater among the eight intensity categories, but the number is greatly different (Fig. 5a). The number of reported cases of turbulence around Japan was largest in spring season, particularly from March to May, and smallest in summer, July and August (Fig. 5c). This is consistent with previous studies for United States (Wolff and Sharman 2008) and for South Korea (Kim et al. 2011). Turbulence is mostly reported mainly from 9 to 21 local time, which approximately corresponds to the period of active flight operation for domestic flights (Fig. 5b). The largest number is observed from 9 to 13 local time.

Turbulence is frequently observed around the 30000-ft altitude and the number frequency decreases in higher and lower altitudes (Fig. 3d). But the number is relatively large below 28000 ft.

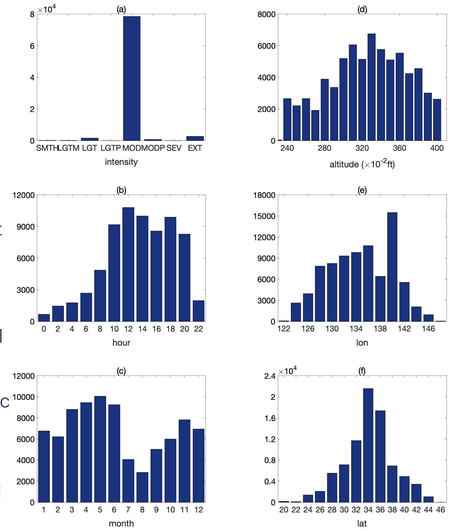


Fig. 5: Histogram of (a) turbulence category, (b) hour, (c) month, (d) altitude, (e) latitude, and (f) longitude for all the detected cases of turbulence over Japan from 2006 to 2018.

The frequency of longitude at which turbulence is reported appears to be Gaussian distribution with a peak around 135, except for the range from 139 to 141 deg (Fig. 5e). Osaka is located around the 135 longitude and is between Tokyo and Fukuoka, which is one of the busiest flight paths. This would make the number of cases large. There are many flights around the 140 longitude between Tokyo and Sapporo, which is also one of the busiest flight paths. This would be the major cause of the large number of cases of turbulence. The frequency for latitude of reported turbulence is also nearly the Gaussian distribution with a peak at the range from 33 to 35 deg which involves several major cities in Japan such as Tokyo, Osaka, and Fukuoka (cf. Fig. 1) and hence many flights are operated constantly.

Results: Statistics of aviation turbulence

The number frequencies of quantities associated with reported turbulence are normalized by the CARATS data. Thus, larger values indicate higher probability of occurrence of turbulence.
The highest probability is in the range between 30000 and 35000 ft, followed by that from 20000 to 30000 ft.
Regarding of longitude, the turbulence is most likely occurred in the range from 139 to 141 deg, followed by that from 133 to 137 deg.
The highest probability is observed in the range from 33 to 35 deg of latitude and the probability decreases with latitudes.
The spatial distribution of normalized number of turbulence by the CARATS data displays that the probablitiy is high around Tokyo and Osaka in low altitudes, especially below 25000 ft. In high altitudes, high probability regions are not concentrated, but observed separatedly.

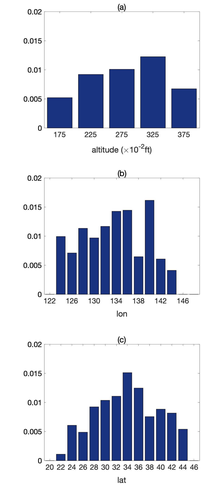


Fig. 6: Same as Fig. 5d-f, but for those normalized by the CARATS data.

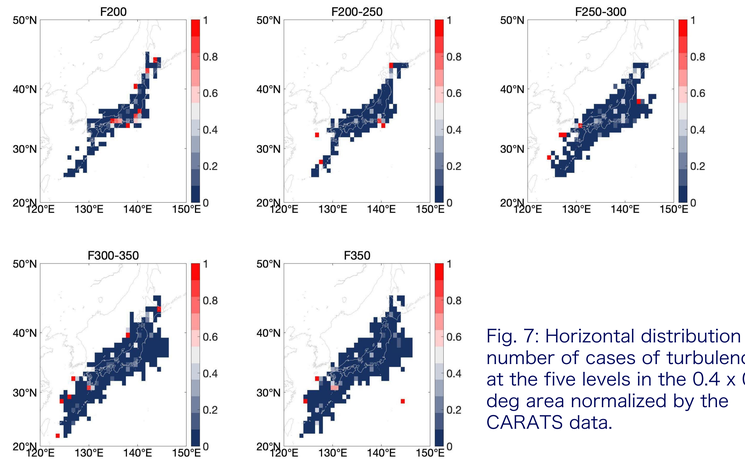


Fig. 7: Horizontal distribution of number of cases of turbulence at the five levels in the 0.4 x 0.4 deg area normalized by the CARATS data.

Conclusion

We conducted a statistical analysis of aviation turbulence over Japan by analyzing the PIREP data from 2006 to 2018. The number of cases of turbulence is dominant along the major flight routes in Japan, especially concentrated around Tokyo. The number of cases varies seasonally: the largest number is observed from January to June, whereas the number is smallest in summer. We will investigate turbulence cases associated with clouds and those without clouds by using satellites.

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