Turbulence project

Alberto Blanco
Bun-Liong Saw
Christine Le Bot
Summary

- What is turbulence
- Observed data from instruments in the airplane: IT and DEVG
  - IT, a turbulence index, categorized
  - DEVG, vertical gust index, continuous values
- Forecasted data from ALADIN model:
  - 2 indices calculated: Ellrod 1 and Ellrod2
- Contingency table for each indices
- Importance of the domain of verification
What is turbulence?

- Sudden updraft or downdraft
- Generated by rising air
- Usually associated with Cb-clouds
- Fronts (embedded Cb)
- Convective cells (Cb-clouds)
- Mountain lee waves
- Low pressure area updraft (Cb-clouds)
- Usually appears with some other weather phenomena eg. rain in CB-cloud shows in onboard radar or lenticular ("almond") clouds of lee waves can be visually observed
- → can be detected
What is Clear Air Turbulence, CAT

- Downdraft and updraft very violent (+100m/s\(^2\) to -40m/s\(^2\))
- Effects on the plane:
  - Damages on the structure of the plane
    - 1966 BOAC 707 crashed to Mt Fuji, lee wave
    - obs 70kts on top of Mt Fuji
  - Passengers and crew could be injured
- In clear air = INVISIBLE
Observed data: turbulence indices from AMDAR

- AMDAR (Aircraft Meteorological Data Relay) data is composed by messages automatically emitted during the flight by some commercial aircraft (T, p, WS and WD)

- DATA:
  - Position, temperature, wind, pressure
  - Sent most of the time during take off and landing, less information during the flight
  - IT, Turbulent intensity, depending on the type of plane (larger plane -> more inertia -> IT smaller value)
  - DEVG Derived Vertical Gust, NOT depending on the plane
  - Measurements from wind speed and angular heading changes

<table>
<thead>
<tr>
<th>DEVG Value</th>
<th>Intensity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than 2m/s</td>
<td>no</td>
</tr>
<tr>
<td>from 2 to 4.5 m/s</td>
<td>Light</td>
</tr>
<tr>
<td>from 4.5 to 9 m/s</td>
<td>High</td>
</tr>
<tr>
<td>Higher than 9m/s</td>
<td>Intense</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>IT Value</th>
<th>Intensity</th>
</tr>
</thead>
<tbody>
<tr>
<td>IT &lt; 0.15g</td>
<td>no</td>
</tr>
<tr>
<td>0.15g ≤ IT&lt; 0.5g</td>
<td>Light</td>
</tr>
<tr>
<td>0.5g ≤ IT &lt; 1g</td>
<td>Moderate</td>
</tr>
<tr>
<td>IT &gt; 1g</td>
<td>Severe</td>
</tr>
</tbody>
</table>
DATA SET:
- During 40 days (20/11/2005-31/12/2005)
- Several airlines
- 50000 messages

Preparation of the data set
- Convective situations are omitted by using lightning impacts (in a circle of radius 50km around the data and in a time interval of \( \frac{1}{2} \) hour)

The observation sample sizes are NOT the same, some values are missing (no measurement), but the same order of magnitude: DEVG 22000 and IT 41000
Observed data

Low number of turbulence events
Observed data repartition

- Classification of severity depending on the altitude

- Decrease of severity with decreasing altitude

- Maximum for heavy turbulence at 6000-8000m
- BUT
- Large variation

- ~41000 observations
- ~22000 observations
Correlation between turbulence from DEVG and IT

Boxplot with whiskers (sample dependent variation limits, not 5% and 95%)
NO turb during night 00-04 hours, few at 05 and 22-23
Developed at 07, quite consistent during the day
Convective driven?
Hourly obs of IT, Turbulence Intensity

- Similar to DEVG
Forecasted data (from MODEL):
2 turbulence indices

**MODEL**

**ELLROD 1**

**ELLROD 2**

**ALADIN**

*Resolution*

0,1°

*4 networks*

*6 levels:*

500, 400, 300, 250, 200, 150 hPa

Ellrod1 = $S_v \times DEF$

Ellrod2 = $S_v \times (DEF - CVG)$

Sh : cisaillement horizontal

Sv : cisaillement vertical

Dst: stretching deformation

Dsh: shearing deformation

DEF = $(D_{sh}^2 + D_{st}^2)^{1/2}$
Remarks

- Observation correspond to the nearest grid point
- A grid = 0.1° about 10 kms
- Pilots try to avoid the conditions
First results

<table>
<thead>
<tr>
<th>OBSERVATION</th>
<th>No EVENT/EVENT</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>DEVG</strong></td>
<td></td>
</tr>
<tr>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td>total</td>
<td>total</td>
</tr>
<tr>
<td>yes</td>
<td>5</td>
</tr>
<tr>
<td>no</td>
<td>117</td>
</tr>
<tr>
<td>total</td>
<td>122</td>
</tr>
</tbody>
</table>

**Turbulence INDEX**

| yes         | yes            |
| no          | no             |
| total       | total          |
| yes         | 69             |
| no          | 1264           |
| total       | 1333           |

**ELLROD1**

<table>
<thead>
<tr>
<th>yes</th>
<th>no</th>
<th>total</th>
</tr>
</thead>
<tbody>
<tr>
<td>yes</td>
<td>5</td>
<td>582</td>
</tr>
<tr>
<td>no</td>
<td>117</td>
<td>21672</td>
</tr>
<tr>
<td>total</td>
<td>122</td>
<td>22254</td>
</tr>
</tbody>
</table>

FAR=0.02   POD=0.04
Portion correct=0.97

**ELLROD2**

<table>
<thead>
<tr>
<th>yes</th>
<th>no</th>
<th>total</th>
</tr>
</thead>
<tbody>
<tr>
<td>yes</td>
<td>5</td>
<td>690</td>
</tr>
<tr>
<td>no</td>
<td>117</td>
<td>21564</td>
</tr>
<tr>
<td>total</td>
<td>122</td>
<td>22254</td>
</tr>
</tbody>
</table>

FAR=0.02   POD=0.04
Portion correct=0.97

<table>
<thead>
<tr>
<th>yes</th>
<th>no</th>
<th>total</th>
</tr>
</thead>
<tbody>
<tr>
<td>yes</td>
<td>70</td>
<td>1096</td>
</tr>
<tr>
<td>no</td>
<td>1263</td>
<td>38170</td>
</tr>
<tr>
<td>total</td>
<td>1333</td>
<td>39266</td>
</tr>
</tbody>
</table>

FAR=0.03   POD=0.05
Portion correct=0.94
ROC Curves

Different levels for the numerical index

No event-event

No + light event – MOG event
Remarks

- Low number of turbulence event does not mean that turbulence does not exist, but that pilots try to avoid this areas.
- The forecasted data is the nearest grid point to the observation. Better to make an area verification, it could be best appropriate for the user.
Remarks

- Observation correspond to the nearest grid point
- A grid = 0.1° ~ 11 kms
- Pilots try to avoid the conditions
Size of the domain of comparism

66 kms

TURBULENCE AREA
Results - larger area

100pts
~ 50km around the plane

36pts
~ 30 kms around the plane

Increase the size of the verification domain improves the results
Conclusions

- POD~0.03 very low
- FAR~ 0.05 very low
- % correct = ~ 95% (show this number to Management)

- Rare observations: pilots avoid turbulence regions if they are known (eg. South pacific from New Zealand to USA)
- The scale of the turbulence phenomena has an effect on the verification:
  - Upper air JET = about 100-200 kilometers across
  - Mountain waves 50-100km
- Convection 10-50km (scale would fit the data and only some observed turbulence was in mountainous regions)
- Fine grid scale in model creates meso-scale phenomena in model, this fine scale creates a lot of non-events:
  - 95% correct, because most are non-events (no obs, no fcst)
- Increase the grid size, increase in POD
- Verification method has to be adapted to the scale and the user.
Questions ?