A GIS-based tool for the estimation of impacts of volcanic ash dispersal on European air traffic

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AFTER 2010...

ICAO International Volcanic Ash Task Force (IVATF)
1st IUGG-WMO Workshop (Bonadonna et al., 2011)
... and many more

NOW:

2nd IUGG-WMO Workshop (Geneva)
Sesar Innovation Days 2013 (Stockholm)

OPEN ISSUES (thresholds, graphical output, uncertainty, communication)
RESEARCH INTO OPERATION
Monitoring
@Volcano observatories and many others...
Satellite
Ground-based
Opportunistic

Management
@Eurocontrol, many others...
Training (VOLCEX)
Tools (EVITA)
SRA (Safety Risk Assessment)

Modeling
@VAACS and many others...
Different models and strategies
Monitoring
@Volcano observatories and many others...
Satellite
Ground-based
Opportunistic

Modeling

Management
@Eurocontrol, many others...
Training (VOLCEX)
Tools (EVITA)
SRA (Safety Risk Assessment)

Different models and strategies
@ VAACS and many others...
WHERE, WHEN, HOW?

Results of ash dispersal modeling

Air traffic data

Expected impacts

Automated GIS-based overlap
ASH DISPERSAL MODELLING

**INPUTS**: Meteorological (wind speed and direction, humidity, temperature, etc.)

Volcanological (column height, duration, grain size, etc.)

*Calculate ash concentration on a 4-D domain*

**OUTPUTS**: Binary files (grib, Netcdf, HDF5) (usually contain a header)

Metadata, but no standard/harmonized output
How does a Netcdf look like?
POST-PROCESSING
Automated post-processing and production of hourly maps

15 April 2010 - 22.00 UTC

- Eyjafjallajokull
- Ash concentration at FL150

Ash concentration threshold:
- a) zero tolerance (2*10^-5 mg/m3)
- b) 0.2 mg/m3
CASE-STUDY: Eyjafjallajökull 2010

Numerical simulations performed at BSC (Folch et al. 2011)

Ash concentration maps for selected Flight Levels (FLs)

Critical ash concentration: zero tolerance, 0.2 and 2 mg/m$^3$
ASH DISPERSAL MODELLING RESULTS

Modeling results - 14.00 UTC

- Eyjafjallajökull volcano

Ash concentration airborne:
- Green: > 0
- Yellow: > 0.2 mg/m³
- Red: > 0.4 mg/m³

0 1000 2000 km

FL100

15 April

16 April

FL200

FL300
AIR TRAFFIC DATA

European airports and Intra-European routes
Use of last filed flight plan (Source: Eurocontrol DDR m1so6 database)

ASSUMPTION: Data for 14/04 can be used to analyze 15-16/04
METHODOLOGY

ASH CLOUD

AIR TRAFFIC DATA

GIS-BASED OVERLAP AT FL TIME STEP = 1 HOUR

EXPECTED IMPACTS
**Assumptions:**

Airport disrupted only if overlapped by ash at FL050
Flight disrupted only if intersect ash cloud at FLs
Not accounting take-off/landing disruptions
All filed flights plans are operating
1- **Extract flights** (SQL query) at FL interval and time-step

2- **Overlap** ash cloud and selected flights

3- **Extract way-points and segments** scheduled at time-step

4- **Calculate** length of disrupted segments and exposed time
EXAMPLE - Airports

For each time step (1 hour) and ash concentration threshold identify expected disruptions at airports (FL050)

15 April - 21.00 UTC
- Eyjafjallajokull volcano
- Ash cloud (0 tolerance) at FL050
- Airports impacted

0 km 1000 km 2000 km
EXAMPLE - Routes

Identify routes expected to be disrupted

For each time step, FL, ash concentration threshold

a) Ash cloud extent at given FL and concentration threshold
b) All flight plans that intersect ash cloud at FL interval
c) Flight plans in b) coherent with time interval (1 hour)
d) All waypoints that intersect ash cloud
e) Select waypoints in d) in time interval (1 hour)

Select flight plans in c) and e): will pass through ash cloud in the time interval
# IMPACT ASSESSMENT - Routes

**Qualitative impact rating**

based on percentage of flight disrupted

Comparative (not absolute) measure of impacts

<table>
<thead>
<tr>
<th>Length disrupted x (%)</th>
<th>Impact</th>
<th>Impact rating</th>
<th>Strategy</th>
</tr>
</thead>
<tbody>
<tr>
<td>X &lt; 10%</td>
<td>Low</td>
<td>1</td>
<td>Small deviation</td>
</tr>
<tr>
<td>10% &lt; x &lt; 80%</td>
<td>Medium</td>
<td>2</td>
<td>Change FL</td>
</tr>
<tr>
<td>X &gt; 80%</td>
<td>High</td>
<td>3</td>
<td>Not flying</td>
</tr>
</tbody>
</table>
### RESULTS – Hourly tables

**Impacted flights**

**Expected disruption (length, duration, %)**

<table>
<thead>
<tr>
<th>Flight ID</th>
<th>Time tot (min)</th>
<th>Length tot (km)</th>
<th>Length dis (km)</th>
<th>Time dis (min)</th>
<th>Length dis (%)</th>
<th>Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>135199866</td>
<td>36</td>
<td>251</td>
<td>17</td>
<td>2</td>
<td>7</td>
<td>1</td>
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<tr>
<td>135195266</td>
<td>268</td>
<td>974</td>
<td>1724</td>
<td>47</td>
<td>18</td>
<td>2</td>
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<tr>
<td>135199526</td>
<td>40</td>
<td>425</td>
<td>280</td>
<td>26</td>
<td>66</td>
<td>2</td>
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<tr>
<td>135200495</td>
<td>32.83</td>
<td>247</td>
<td>221</td>
<td>29</td>
<td>89</td>
<td>3</td>
</tr>
</tbody>
</table>

(excerpt of impacted routes for 15 April 2010 - FL150 – 14.00 to 15.00 UTC)
RESULTS - Time series

Impacted flights for each hour at considered FLs

FL150

FL200

FL250
RESULTS – Graphical output

Digital maps (GIS) of disrupted airports and flights
Visualization of impacted flights
Impact assessment rating

Advantage: supports further spatial analysis
RESULTS - Google Earth video (screenshot)

**Advantage:** user friendly, easy to share
MAIN FINDINGS

Substantial **impacts** at lower FLs, but low at upper FLs

**Possible rerouting** especially in case of low columns

Most affected FLs: 100 ÷ 250

**BUT**

Most congested FLs: 300 ÷ 400
DISCUSSION:

Comparison with 2010 shows a reduction of impacted flights

**BUT:**

Strong assumptions in methodology (all filed files plans are operating, not considering disruptions due to airport closure)

In 2010, precautionary closure of great part of Central European airspace

Secondary disruptions (fleet and crew allocation, ...)

Differences in the expected impacts from those in 2010 (better characterization of input parameters, improved modeling strategies)

*A direct comparison with 2010 is therefore biased!*
FURTHER WORK AND PERSPECTIVES:

<table>
<thead>
<tr>
<th>LIMITATIONS</th>
<th>ADVANTAGES</th>
<th>IMPROVEMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strong assumptions</td>
<td>Link modelling and management</td>
<td>Economic aspect</td>
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<tr>
<td>Not operational</td>
<td>Synthesis</td>
<td>Become operational</td>
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<tr>
<td>Uncertainties</td>
<td>Hourly analysis</td>
<td>Include probabilistic forecast</td>
</tr>
<tr>
<td></td>
<td>Model-independent</td>
<td>Include satellite retrievals</td>
</tr>
</tbody>
</table>

Lot of work to be done!!!

Account for closed airports
Spatial and temporal uncertainties
Stakeholders feedback – SURVEY to be performed
CONCLUSIONS

Improved **post-processing** of ash dispersal modeling results

**Automated impact assessment at higher temporal resolution**

**Simplified** but **multidisciplinary** approach improves air traffic management during volcanic eruptions

Importance of **team-working** and diversity
Thank you :)