Mitigating the impact of weather hazards on aviation

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Safety, economy and ecology in aviation

- 13% of aircraft losses between 1995 and 2004 primarily by weather (Boeing 2005)
- 33% of all accidents/incidents due to adverse weather (NTSB 2004-2007)
  - Thunderstorms are top-ranked by pilots as hazards affecting flight safety (FLYSAFE, 2006)
- Weather is largest single contributor to delays (FLYSAFE D2.1-1, 2006)
- Weather is responsible for 40-50% of delays at European airports (EUROCONTROL 2007)

- Aviation contributes to pollution and climate change
Growth of the Air Transport System

Based on ICAO data
Europe’s Vision for Aviation:
Challenges & Goals of Flightpath 2050

Flights arrive within 1 minute of the planned arrival time regardless of weather conditions.

Weather and other hazards from the environment are precisely evaluated and risks are properly mitigated.
Safe, efficient, and sustainable aviation

• How can air traffic be managed and guided to avoid **adverse weather**, **disruptive events** and minimize **environmental impact**?

• **Adverse weather:** deep convection / thunderstorm, turbulence, wind shear, in-flight icing, winter weather, wake vortex => multi-hazards

• **Disruptive events:** volcanic ash clouds, dust clouds

• **Environmental sensitivity:** climate, noise, pollution
The multi-hazards for aviation

- noise
- winter weather
- reduced visibility
- thunderstorm
- turbulence
- volcanic ash clouds
- wake vortex
- high climate impact
- in-flight icing
- thunderstorm
- wake vortex
Safe, efficient, and sustainable aviation
Proposal: „5D MET Advisory“

• Provision, distribution and integration of complex information on different hazards or sensitive areas in a standardised form with interfaces to different users (ATC, ATM, AOC, crews in flight, APOC) (WXXM / SWIM)

• Presentation of the (weather) hazard as a (weather) object
5D MET Advisory

- **Working principle:** Monitoring, seamless and continuous prediction, and fusion of data
- Considering different temporal and spatial scales
- Combining output of different approaches, algorithms, and measurements
- Modelling the region of the hazard or the environmentally sensitive zone as objects according to the users' requirements
- Coding acc. to WXXM for SWIM / 4d-WxCube in SESAR/NextGen
Goal

Help to increase safety and efficiency for air traffic during adverse weather situations

Provide consistent, easy to understand, unambiguous warnings and forecasts tailored to the needs of:

• ... Airports and air traffic control: would help to regulate the air traffic in time and to reduce delays (costs!) and holdings
• ... Pilots: would increase flight safety, as the pilots have a better overview of the weather situation (situational awareness)

• System-wide information sharing (joint situational awareness)
• Collaborative decision making (joint conflict solutions)
Timely and dedicated information on hazardous weather is still poor today – especially in the cockpit.
Cb-TRAM: _Cumulonimbus Tracking and Monitoring_

Rad-TRAM: _Radar Tracking and Monitoring_
Cb-TRAM - where can it be applied?
Global coverage in the (near) future: Cb-global
Use cases

Cb-TRAM: objects for aircraft en-route, encountering thunderstorms
Rad-TRAM: objects for airports / air traffic control when thunderstorms approach

Bottom: Rad-TRAM
weather radar data analysis
→take-off and landing

Top: Cb-TRAM
satellite data analysis
→en-route
Thunderstorm warnings

- near-real time, on time
- update every 5/15 minutes
- forecast up to 60 minutes
- precise in space and time
- easy to interpret
- simultaneous for all: pilots, AOC, ATC, ATM, airports

Use cases
Cb-TRAM: objects for aircraft en-route, encountering thunderstorms
Rad-TRAM: objects for airports / air traffic control when thunderstorms approach
5D MET Advisory

- **Output** is provided simultaneously and can easily be interpreted and further processed and displayed at the user’s site.
test of innovative met-tools in the cockpit: in-flight uplink of Cb-TRAM
first successful data link tests cooperation DLR - DLH

Lufthansa GADCom project (Ground Air Data Link Communication):

Real time link of Rad-TRAM and Cb-TRAM data in 5 EFBs (Electronic Flight Bags) of Lufthansa Cityline aircraft via mobile network on the ground and later in 5 EFBs of Lufthansa aircraft via FlyNet during cruise-flight.
The Test Flight: Rio de Janeiro to Frankfurt, February 2013

"According to the charts: Business as usual at the ITCZ"
The Test Flight: Rio de Janeiro to Frankfurt, February 2013

“But once we got there, the weather radar showed large red cells, embedded in amber”

“Initially without the help of Cb-TRAM, the crew decided to deviate 90 degrees to the right”
“Then, we uplinked the latest Cb-TRAMs to the eRM ... 

... planned the safest route with the eRM ... 

... and flew it tactically by looking at the weather radar”
The result
“If we would have uplinked the Cb-TRAM a few minutes earlier ....

... we would have seen the gap on the PUGSU DIKEB route

... or the gap on the ORARO-TASIL route ...

... and could have avoided a 300 NM deviation”
Disruptive Events: Volcano ash clouds
ICAO’s zero-tolerance rule:
- 75% of mid-European airspace closed
- over 100,000 flights cancelled
- 313 European airports closed

Eyjafjallajökull eruption: severe disruption of the air traffic system 16 – 21 April 2010
Current Avoidance Guidance is based on “Visible volcanic ash” (ICAO, 2012)

**Primary** source for navigation: forecast areas of volcanic ash clouds by Volcanic Ash Advisory Centres, VAAC

**Secondary** source: any information on “visible volcanic ash”, assuming concentrations of 100-1000 µg/m³

However, visibility depends on:
- Particle size spectrum
- Wavelength dependent aerosol refractive index
- Particle shapes
- Relative positions of light source, cloud and observer
VADUGS
Volcanic Ash Detection Utilizing Geostationary Satellites

Aim:

• to distinguish areas “no cloud”, “cloud”, “no info”
• to provide this information as secondary source

Methodology

• based on SEVIRI on Meteosat 2nd Generation
• high temporal and spatial resolution
• 7 channels located in the thermal infrared (day/night)
• trained on a neuronal network by radiative transfer calculations with several ash definitions (Eyjafjalla, Andesite, Andesite mix, Rhyolite mix, mineral dust, etc.)
• combined with cirrus retrieval COCS
• detection, retrieval of ash concentration and altitude in one step
• global coverage foreseen
VADUGS + COCS on 17th May 2010

- High ice clouds partly covering the ash cloud

Cirrus clouds
Aviation in the southern hemisphere is affected by volcanoes quite often.

The Puyehue volcano, dormant for decades, erupted in south-central Chile on Saturday June 4, 2011

A total of 41,000 passengers have been stranded by 283 cancelled Qantas, Jeststar, Tiger and Virgin Australia flights.

www.perthnow.com
VADUGS + COCS on June 2011

Puyehue eruption (Chile)

Typical scenario, where cirrus clouds cover VA in many cases
From MET to ATM: What are the impacts of adverse weather to aviation?

Who are the stakeholders in aviation?

- Airlines (operation centres, flight crew, …)
- Air navigation safety providers (air traffic control, air traffic management)
- Airports (operation centres, ground handling, …, side-business)
- …
- Flying citizen (punctuality, service, comfort)
- Non-flying citizen (comfort, noise, pollution)

These stakeholders have very different, conflicting interests!
Summary

Meteorology:
- Need for system-wide information sharing among all aviation stakeholders
- ... necessary for their collaborative decision making processes
- Derive simple, unambiguous and standardised products
- Combine different hazards when and where appropriate: seamless

Aviation:
- Develop impact scenarios for various stakeholders
- Derive business cases to tailor MET info to the user’s needs

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Options for an airline

1) Fly direct and hope for the best
   a) If succeed, 729 miles, direct
   b) If deviate, 342+320+442 = 1104 miles (151%)

Courtesy: Dave Pace, FAA
Options (cont)

2) Plan a strategic reroute around the weather

a) If the weather appears, $519 + 442 = 961$ miles (132 % of the direct route)

b) If the weather does not appear, still 132%
## Cost of decisions and outcomes

<table>
<thead>
<tr>
<th></th>
<th>Weather Yes</th>
<th>Weather No</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Strategic Reroute</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>961 miles (132%)</td>
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</tr>
<tr>
<td>No</td>
<td>1104 miles (152%)</td>
<td>729 miles (100%)</td>
</tr>
</tbody>
</table>

Courtesy: Dave Pace, FAA
Cost of decisions

- If this route is flown on 100 typical days maybe 30 times there will be weather, and 70 times there will not be weather.
- Making the same decision every day will result in the following costs:

<table>
<thead>
<tr>
<th>After 100 similar flight days</th>
<th>Weather Yes</th>
<th>Weather No</th>
<th>Forecast (30% probability)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strategic Reroute Yes</td>
<td>961 miles (132%)</td>
<td>961 miles (132%)</td>
<td>30<em>961+70</em>9 61 = 96100 miles flown</td>
</tr>
<tr>
<td>Strategic Reroute No</td>
<td>1104 miles (152%)</td>
<td>729 miles (100%)</td>
<td>30<em>1104+70</em>729 = 84150 miles</td>
</tr>
</tbody>
</table>

• Conclusion: with a 30% probability of weather, do not reroute.

Courtesy: Dave Pace, FAA
## Cost of decisions, other forecasts

- What happens for forecasts with 50%, 60%, or 70% probability?

<table>
<thead>
<tr>
<th>After 100 flight days</th>
<th>Weather Yes</th>
<th>Weather No</th>
<th>50%</th>
<th>60%</th>
<th>70%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strategic Reroute Yes</td>
<td>961 miles (132%)</td>
<td>961 miles (132%)</td>
<td>50<em>961 + 50</em>961 = 96100 miles</td>
<td>60<em>961 + 40</em>961 = 96100 miles</td>
<td>70<em>961 + 30</em>961 = 96100 miles</td>
</tr>
<tr>
<td>Strategic Reroute No</td>
<td>1104 miles (152%)</td>
<td>729 miles (100%)</td>
<td>50<em>1104 + 50</em>729 = 91650 miles</td>
<td>60<em>1104 + 40</em>729 = 95400 miles</td>
<td>70<em>1104 + 30</em>729 = 99150 miles</td>
</tr>
</tbody>
</table>

- Conclusion: with a 50% or 60% probability, do not reroute
- If the probability is larger than 61.9%, reroute to reduce long-term cost

Courtesy: Dave Pace, FAA