Intelligent Modeling the Impact of Unpredictable Adverse Weather on ATM Performance

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Motivation, Objectives & Methodology

Adverse weather conditions, e.g. thunderstorms or icing, are responsible for

- about 50% of all delays
- > 10% of all accidents and incidents

Main objective of any future adverse weather solution for aviation is the reduction of delays and the increase of safety.

→ Understanding the interaction of the two complex systems ***air traffic*** and ***adverse weather.***

→ Investigation, exploration and development of an adverse weather ATM solution model: DIVMET

Similar tools in US developed at MIT-Lincoln Lab [1] and at NCAR, Boulder [2]. Necessity of these developments results from increased weather related delays.

Note: Lack of equivalent tools to support ATM in adverse weather conditions in Europe.

Development of the DIVMET algorithm

- Simulates the CDM between pilot and ATC
- Proposes a realistic route through a field of adverse weather

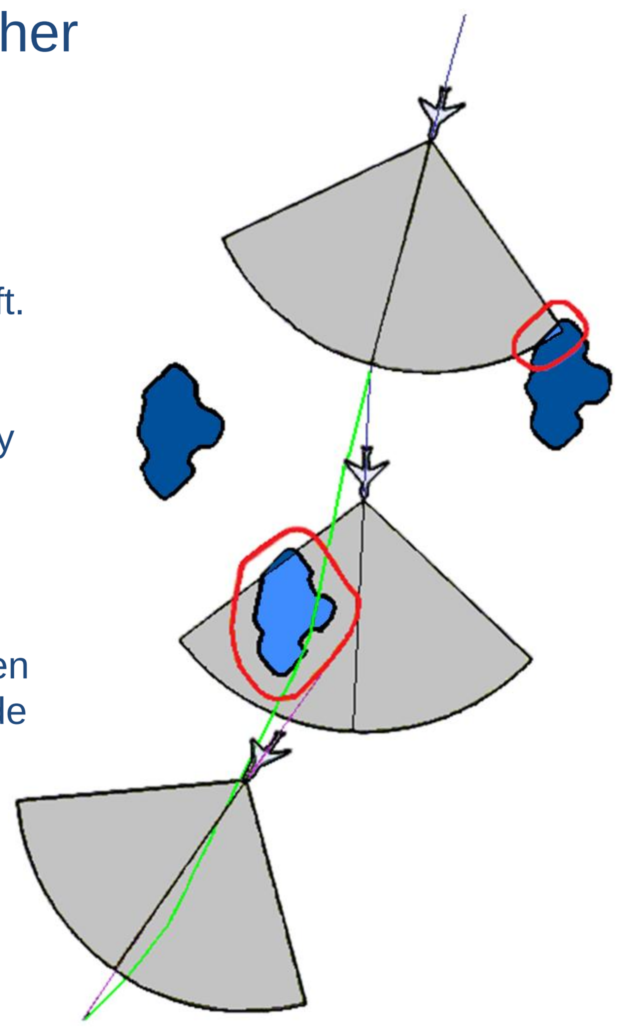

Fig. 1: Concept of the algorithm DIVMET. The green line shows the given route of an aircraft. The grey sectors represent the aircraft's radar field of view. If any weather object (blue) is recognized in this field of view and the aircraft will hit it or its safety margin (red) on the given route, a decision is made and a rerouting via an heading change will happen in the model.

Needs

- Transformation of adverse weather into, for aircraft impenetrable, weather objects
- Account for motion, decay and generation of weather objects with time

References

[1] NAWPC, *National Aviation Weather Program Strategic Plan. Prepared by the Joint Action Group for Aviation Weather, for the National Aviation Weather Program Council.* OFCM Document FCM-P32-1997

[2] Bernstein, B. C., *Integrated Icing Diagnostic Algorithm* (WEB address: http://www.rap.ucar.edu/largedrop/integrated)

Research topics & Validation results

Research topics

- Modeling realistic routes and weather related diversions. Do they match observed ones?
- Effect of increased en route adverse weather information
- Worst case weather scenarios
- Best ATM strategies to account for the stochastic nature of the problem
- Optimum routing strategies in unpredictable adverse weather
- Vulnerability of air traffic
- Provide guidance for controllers and pilots to find a safe and efficient route through a field of thunderstorms ahead

Validation is planned to be performed by demonstrations together with pilots and controllers:

Weather and flight data in the TMA of the Hong Kong International Airport are available for comparison with the simulation results.

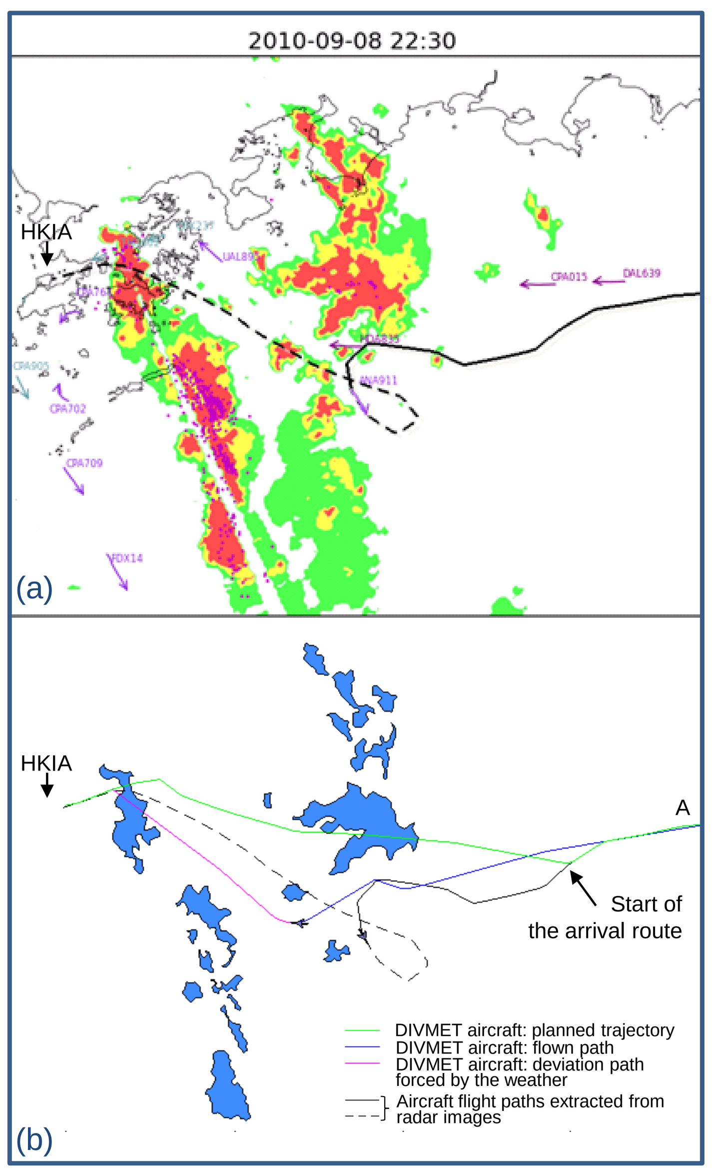

Fig. 2: (a) Observed air traffic and radar data in the terminal area of Hong Kong International Airport (red circle) in the evening of September 8th, 2010. Convective cells moved southwest-ward across the airport. Those conditions forced the approaching aircraft to circumnavigate around the clouds. (b) Same situation modeled with DIVMET. Actual route of flight ANA911 and a planned route along way points starting from point A.

First opinion of a controller:

- No measure needed to describe the quality of any simulation
  → Simulation results are realistic if direction of deviation equals the actual one
- Holding patterns are due to traffic situation (mainly not because of weather)
  → should not be simulated

Applications

Shift of airspace sector load

Theoretical setup for feasibility analysis:

- 1°x1° grid sectors
- Stationary weather objects
- 63 direct routes connect all outer grid points except those on the same border
- Flights only in one direction; no interaction and no conflicts considered
- Main flow from the east and north
- Number of route points per sector is assumed as a measure for sector load

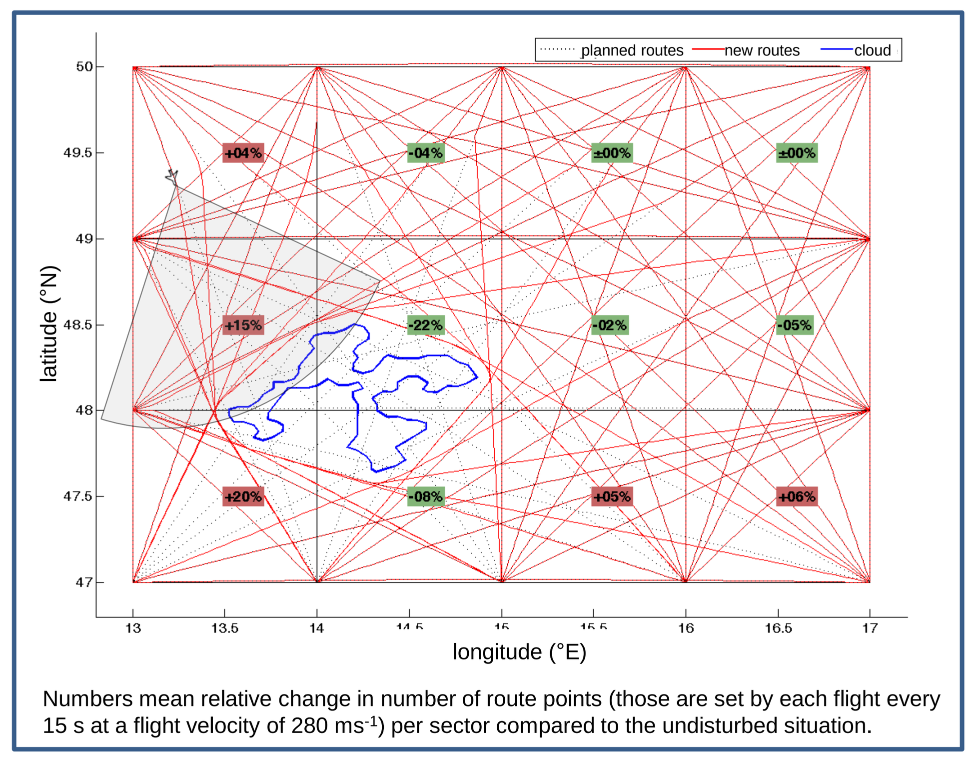

Fig. 3: Shift in sector load due to a weather object. The field of view is limited (angle = 80°, range = 80 NM) as can be seen by means of a successive adjustment of the deviation routes (esp. in the northwestern part of the area).

→ Transfer to real conditions over Austria

Safety and efficiency analysis

- Developing and moving field of simulated circular showers
- One single generic route
- Varying safety margins

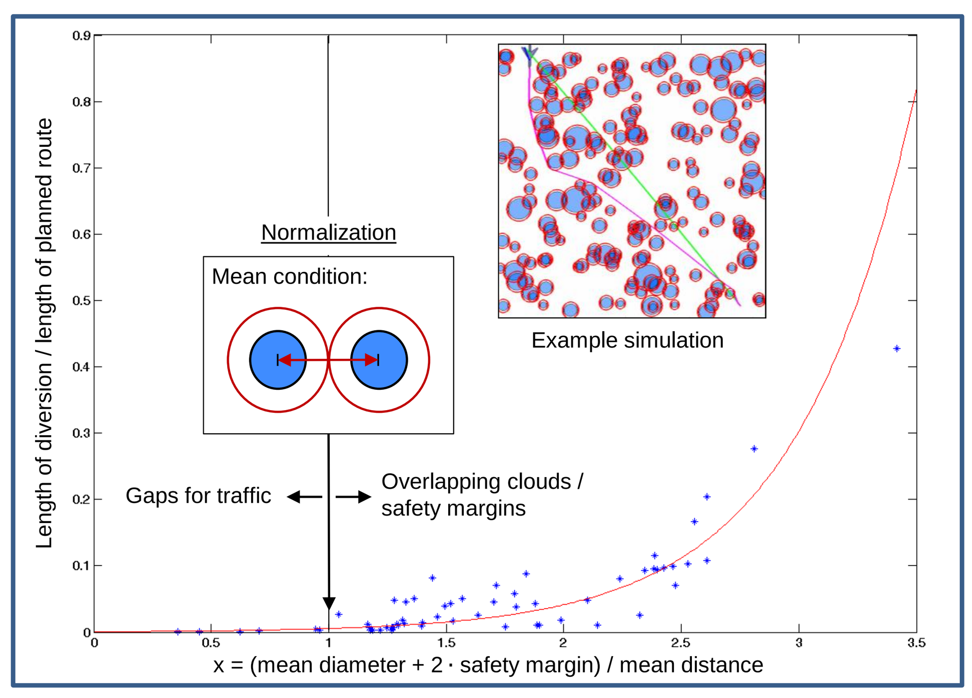

Fig. 4: Higher density of showers leads to clustering which causes longer diversions. As long as there are gaps between showers or at least safety margins (x < 1) it is a linear distribution, afterwards it becomes exponential.

→ Repetition of the analysis with more routes and other shower fields to verify these results

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