Sector Occupancy Analysis with the Adverse Weather Diversion Model DIVMET

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Motivation for model development

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

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

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 the US developed at MIT-Lincoln Lab [1], at NCAR, Boulder [2] and by NASA [3]. 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 collaborative decision making between pilot and ATC
- Proposes a short and safe route through a field of storms

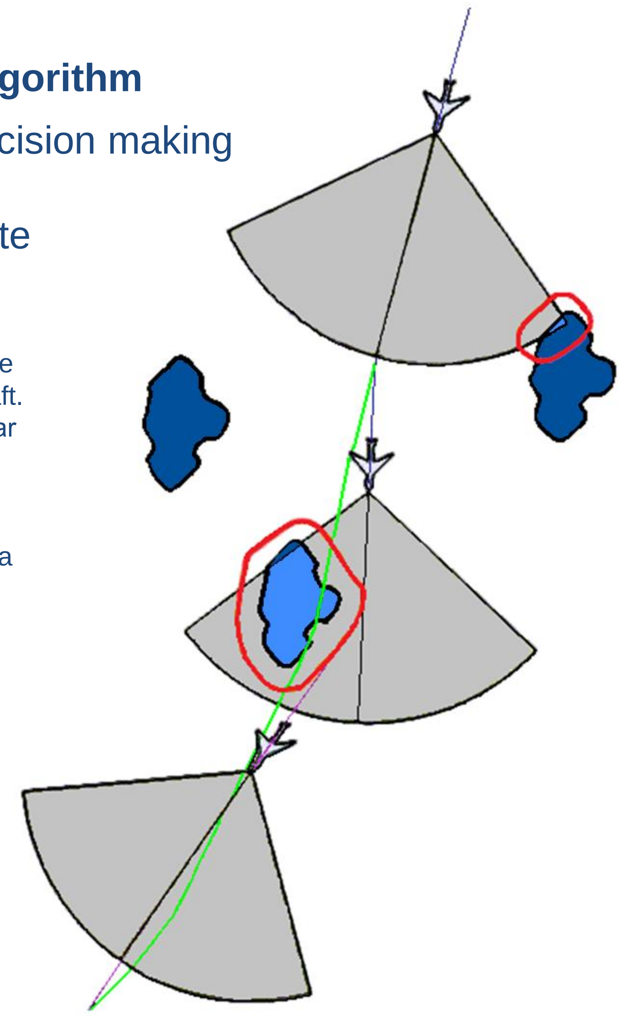

Fig. 1: Concept of the algorithm DIVMET. The green line shows the given route of an aircraft. The grey sectors represent the aircraft's radar field of view. If any weather object (blue) is recognized in this field of view and the aircraft will hit it or its safety margin/convex hull (red) on the given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

Adverse weather object, e.g. storm
Seen part of the weather object
Convex hull
Original, planned route
Deviation route
Flown route
Conical radar field of view

Needs

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

References & Additional information

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

[3] D. McNally, K. Shet, C. Gong, J. Love, C. H. Lee, S. Sahlman, and J.-H. Cheng, 2012, *Dynamic Weather Routes: A Weather Avoidance System for Near-Term Trajectory-Based Operations (WEB address: http://www.aviationsystemsdivision.arc.nasa.gov/publications/2012/ ICAS2012_McNally.pdf)*

Additional information
T. Hauf, L. Sakiew, and M. Sauer, Adverse weather diversion model DIVMET, Submitted to Journal of Aerospace Operations

Motivation & Objectives of the study

Squall line situation over Austria

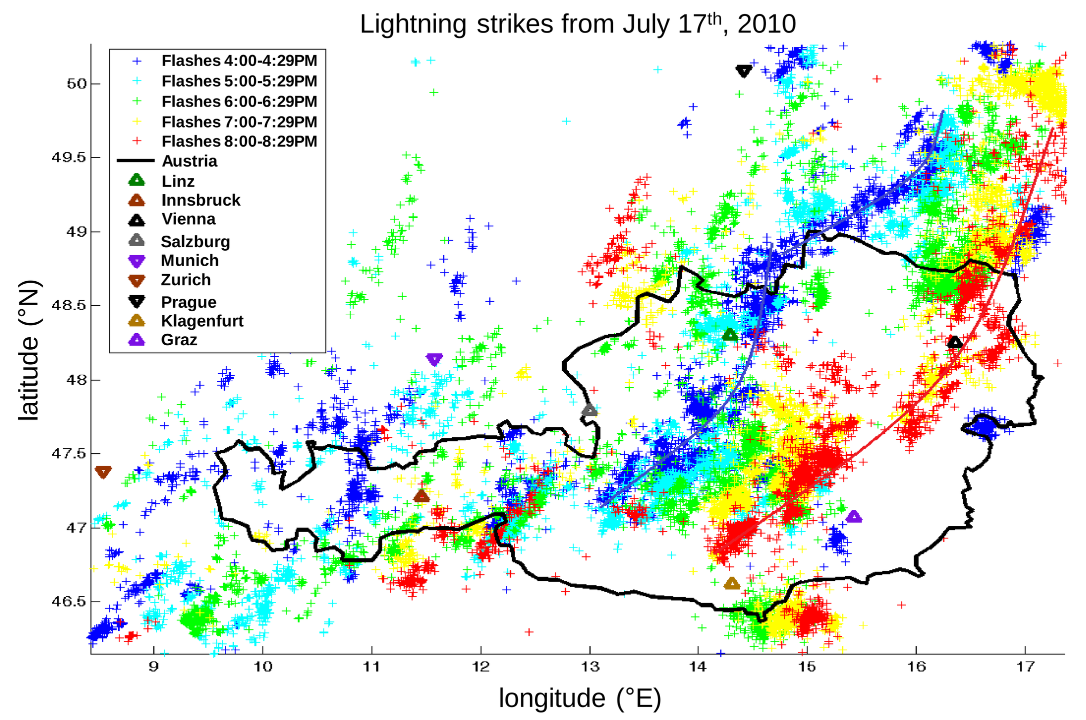

Fig. 2: Lightning data over Austria from ALDIS (received from Austro Control).

Fig. 3: Europe (Source: http://de.wikipedia.org/wiki/Österreich).

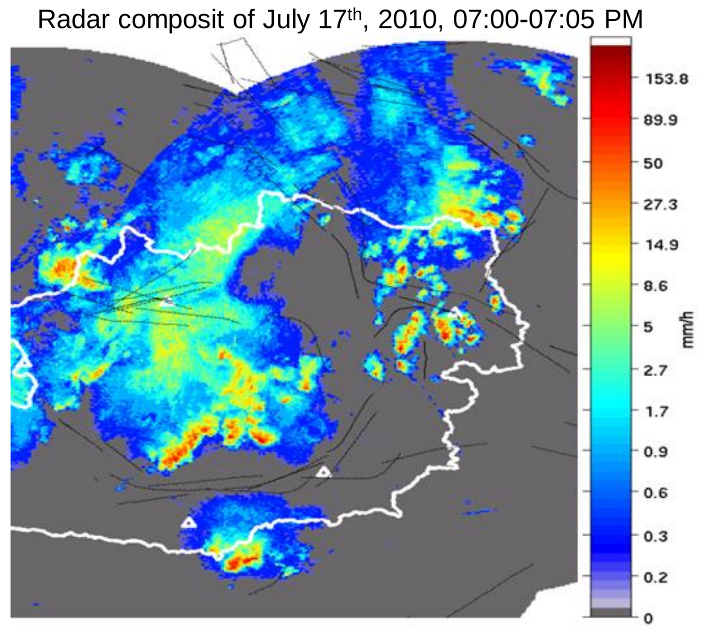

Fig. 4: Radar composit over Austria and parts of Czech Republic with overlayed flight tracks of July 17th, 2010 between 07:00 and 07:05 PM (Source: Austro Control).

Observations

- Nearly completely blocked air space over Czech Republic
- Highly blocked air space over Austria
- Unexpected shift of air traffic from Czech Republic to Austria
- Maximum workload for Austrian controllers due to increased airspace sector occupancy

Key questions

→ Is it possible to predict the arising sector and work load using weather forecast and/or nowcast models?

→ Can the shift of trajectories be simulated?

→ Is, especially, DIVMET suitable for sector load shift analyses?

Benefits

- Ability to schedule resources (personnel, airspace sector distribution)
- Provision of deviation routes
- Avoidance of sector closing and holding patterns because of the overall traffic situation and sector occupancy

Setup for feasibility analysis & Basic results

Basic numerical experiment

- 1°x1° grid sectors
- Intended homogenous coverage of airspace by trajectories
- Approximated by 63 direct routes connecting 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
- Setting of route points (RP) every 15 s at a flight velocity of 280 m/s

→ Number of route points per sector, the sector route coverage density, is assumed as a measure for sector load

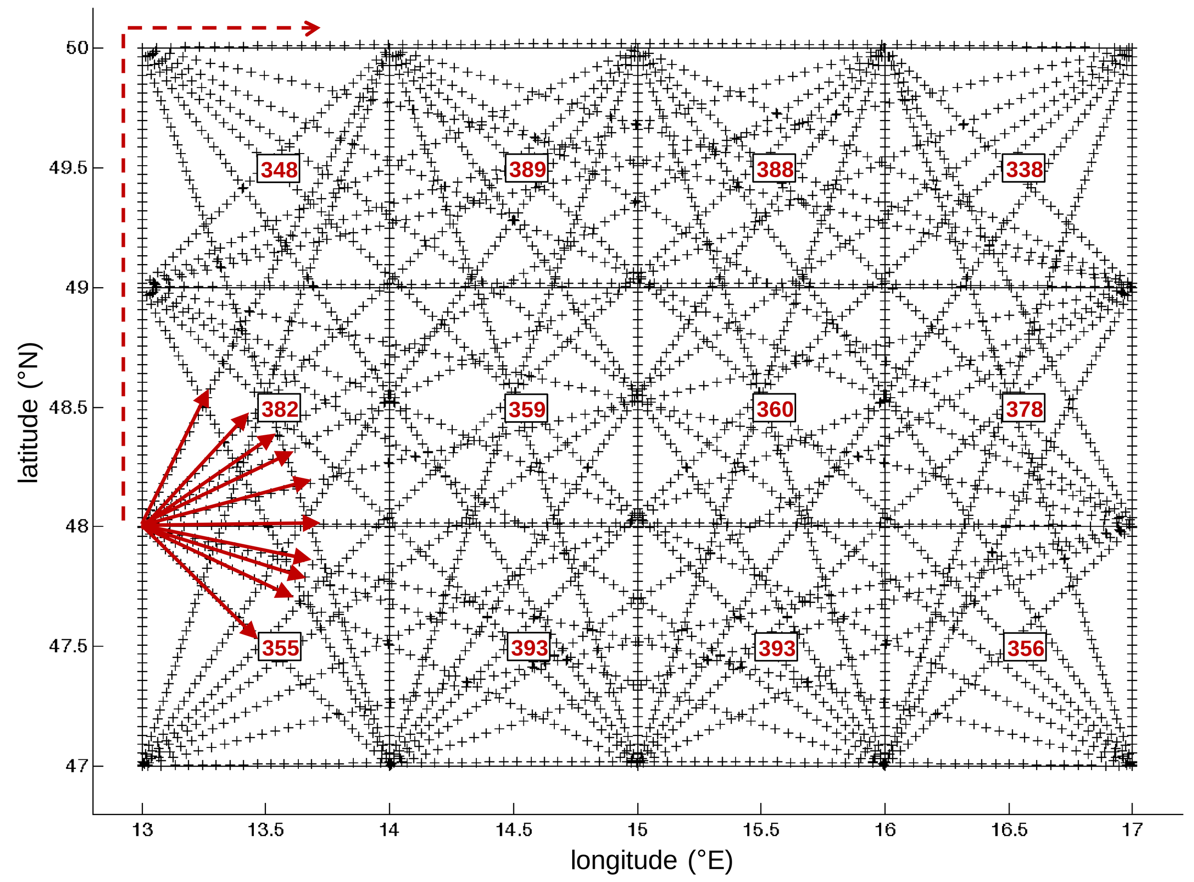

Fig. 5: Generation of flight trajectories (total number of RP: 4439).

→ Implementation of stationary weather objects

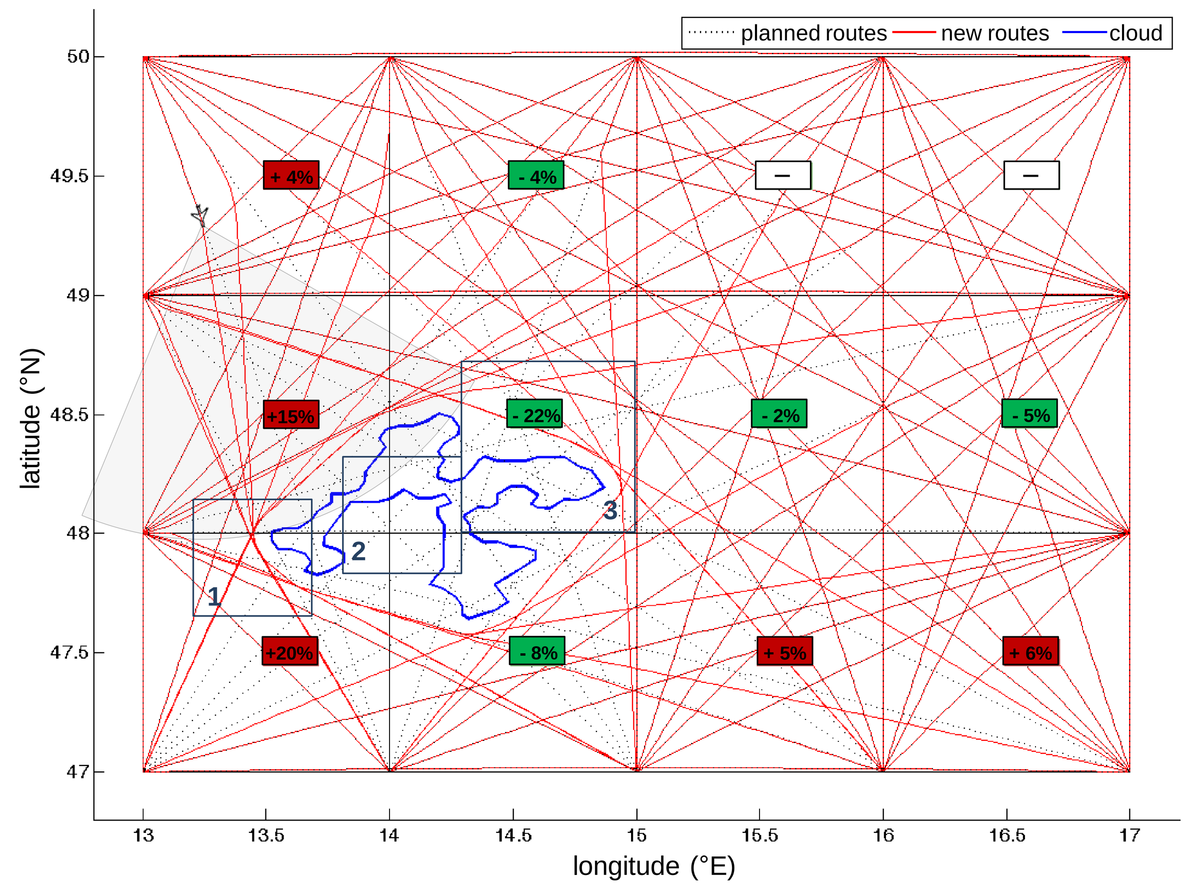

Fig. 6: Relative change of the number of route points (total number of RP: 4471).

Three kinds of effects:

1. Crowding effect along the convex hull of a weather object
2. Blocked airspace by adverse weather with no routes
3. Compensating effects when considering a larger area

Further results

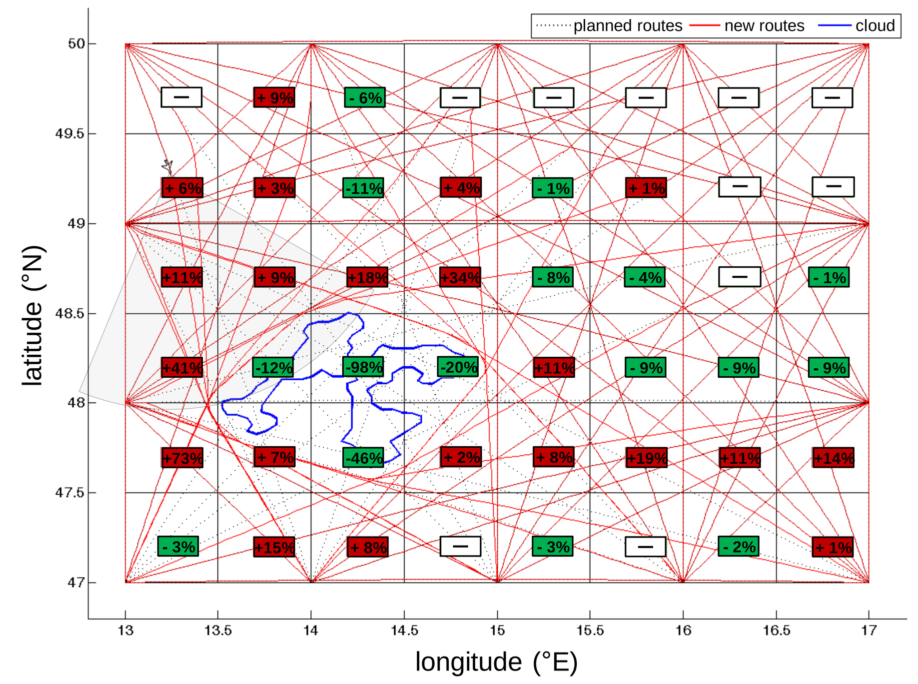

Fig. 7: Higher spatial resolution (0.5° x 0.5°) and sector load change.

- 0.5° x 0.5° grid sectors

Total number of RP: **4471 (+32)**

Compared to the undisturbed situation

Measure for the detour length

→ Smaller sectors show larger effects

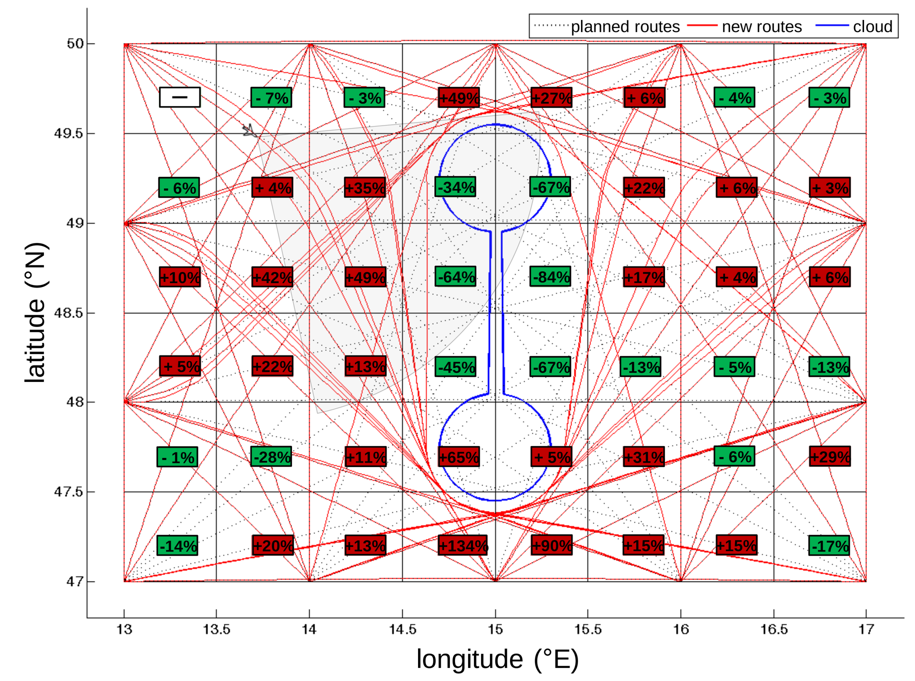

Fig. 8: Artificial north-south oriented weather object with a **limited** field of view (80 NM, 80°).

- Main flow from west and north
- Main deviation to the south due to limited knowledge

Total number of RP: **4701 (+262)**

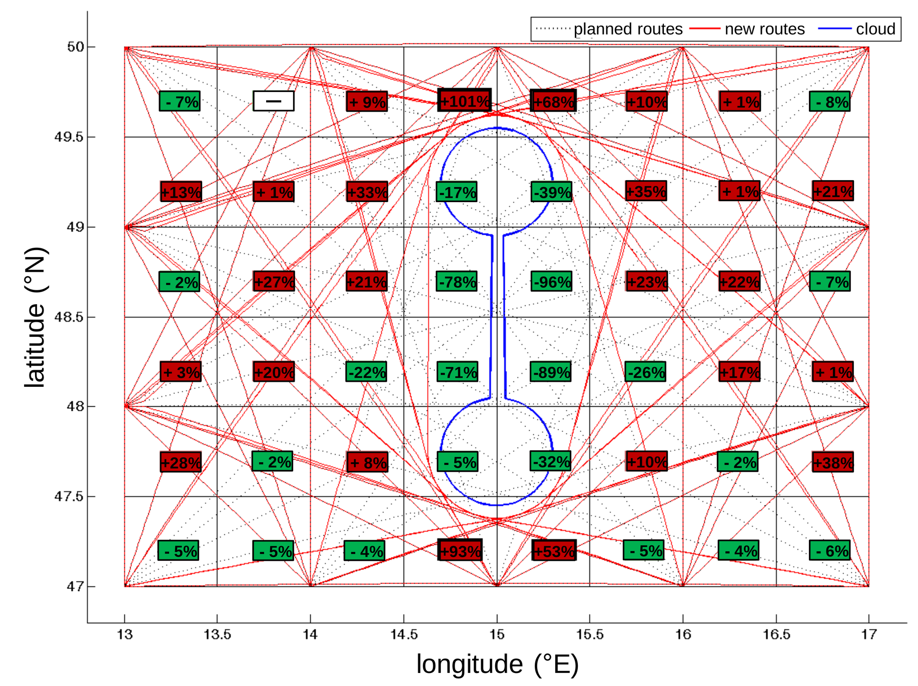

Fig. 9: Artificial north-south oriented weather object with an **unlimited** field of view.

- Unlimited knowledge
- Balanced deviation to the north and south
- Shorter detour

Total number of RP: **4564 (+125)**

Conclusions

- Simulation of sector load shift and anticipated effects is possible
- More efficient routes and more balanced load of available sectors in case of an increased radar field of view
- DIVMET is suitable for this application

→ Transfer to real conditions (airspace sectors, air traffic routes)

This poster can be found on
http://www.muk.uni-hannover.de/download/free/forschung/hauf/AMS_2013_Poster_Sauer.pdf

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