Probabilistic weather avoidance routes for medium-term storm avoidance ('PSA-Met')

Executive summary

Weather can significantly affect aircraft operations. In particular, thunderstorms and the additional associated phenomena (i.e. hail, severe icing, and severe turbulence) present serious hazards to aviation. Furthermore, the apparent motion of the individual storm cells comprising the storm field is not deterministic but has a stochastic component in it.

The major risk mitigation measure for thunderstorm hazards is thunderstorm avoidance. However, the avoidance deviations increase the flight time and, therefore, the fuel consumption, thus negatively impacting the flight efficiency and the environment. Additionally, the flight crew workload increases significantly, and so does the workload of air traffic controllers. This increase in the controllers' workload translates into a reduction of the airspace capacity, eventually leading to further delays and inefficiencies.

The problem addressed by PSA-Met is the impact of weather-related hazardous events (thunderstorms) and its mitigation measures (storm avoidance) on flight efficiency and air traffic control. Particularly, PSA-Met is framed in the context of 'TBO-Met' (SESAR funded project, H2020-SESAR-2015-1, Grant Agreement 699294), and is fully aligned with the challenge *Efficient provision and use of meteorological information in ATM* of the Engage Knowledge Transfer Network (thematic challenge 3), as described next.

In TBO-Met, a probabilistic approach to en-route sector demand prediction at tactical level subject to thunderstorm activity was presented. The developed methodology requires the use of a storm-avoidance tool; in particular DIVMET (property of MeteoSolutions GmbH) was used, a deterministic algorithm. Since this methodology follows an ensemble-based approach, in TBO-Met an ensemble of deviation trajectories for each flight was obtained, using the deterministic DIVMET algorithm several times. Note that DIVMET did not provide a unique avoidance route that took into account the uncertainty information about the storm cells available.

Hence, the goal of PSA-Met is to develop a probabilistic version of DIVMET (named DIVMET-P), capable of generating probabilistic weather avoidance routes. The required input for DIVMET-P is a probabilistic nowcast, providing information about the uncertainty of the convective cells, and a risk level, which is an adjustable parameter intended to define the avoidance strategy. By properly choosing the risk level, one can obtain safer and more predictable, intermediate solutions between underreacting and overreacting to the weather hazard information. The output is a unique avoidance route that takes into account the uncertainty of the convective cells, obtained for the given risk level.

To achieve the desired goal of PSA-Met, a methodology has been implemented, which consists of three steps: 1) concept development, 2) software development, and 3) concept assessment (via simulation).

This project has contributed to the development of tools that integrate the uncertainty of meteorological disruptive events. The improvement of the state of the art is clear: following today's practice, the deviations and delay caused by a storm are not anticipated in the reference trajectory (which is not modified to face the storm) but they are tactically generated. Conversely, following the PSA-Met concept, i.e., replacing the reference trajectory with a probabilistic avoidance trajectory, some of the inevitable weather-related deviations and delays are anticipated, leading to smaller subsequent tactical deviations and delays at the cost of a slight increase in the executed time of arrival. Equivalently, the predictability, the safety and the workload of pilots and air traffic controllers are improved, at the cost of a small loss of flight efficiency.

From the point of view of air traffic controllers and pilots, the benefit of the concept developed in this project is the possibility of being informed, some time before facing the thunderstorm, about the best/safer avoidance strategy. This improves situational awareness and contributes to better-informed decision-making.

From the point of view of air traffic flow management, there is great interest in the probabilistic analysis of demand and capacity of en-route sectors when affected by adverse weather. With the development of a probabilistic storm-avoidance concept, we take a step forward towards enhancing the predictability of each individual flight and, thus, the predictability of the demand.

This new weather avoidance concept would allow air traffic controllers to be involved with a more active role in the storm avoidance process, because it would provide them with more resources to better organise the traffic. To assist them in this new role, the University of Seville has devised a decision-support tool called MTSA: Medium-Term Storm Avoidance, for which a probabilistic storm avoidance tool, such as DIVMET-P, will be the key enabler. MTSA tool will help controllers to determine an appropriate avoidance route for each flight predicted to run into storm cells; however, it is intended to complement, not replace, the current practice in which pilots evade storms using the on-board weather radar. With the MTSA tool, the workload of tactical and planning tasks is expected to become more evenly balanced, enhancing sector team efficiency and providing a safer and better service to airspace users, and to reduce the trajectory uncertainty associated to storm avoidance.

As part of the project, a preliminary description of the MTSA tool concept has been developed, and, additionally, there has been an external assessment, namely, a consultation to stakeholders (pilots and air traffic controllers) about this tool concept, which has received a very positive feedback. This early involvement of target users (airlines and air navigation service providers) has led to a better identification of the required capabilities of the MTSA tool, its potential contexts of use, and the related operational concepts and their possible implications.

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