FLYSAFE NG-ISS EVALUATION USING SEVERE WEATHER HIGH RESOLUTION SIMULATIONS

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Abstract: In the scope of the FLYSAFE project, specific tools aiming at improving flight safety are developed. In particular, efforts are directed towards elaboration of a Next Generation Integrated Surveillance System (NG-ISS) and implementation of atmospheric hazards nowcasts : the WIMSs (Weather Information Management Systems). We focus here on Météo-France activities within this project, and more particularly those related to the NG-ISS validation phase using simulated atmospheric conditions, and WIMS products generated from this meteorological simulation. The MAP-IOP2B precipitating event which occurred on the 20th of September, 1999 over Alps slopes is chosen as case study.

Keywords: *FLYSAFE, flight safety, weather hazards, NG-ISS, WIMS*

1. FLYSAFE OVERVIEW

Air traffic is expected to triple world-wide within the next 20 years. With the existing onboard and on-ground systems, this would lead to an increase of aircraft accidents in the same, or possibly even a higher proportion. Despite the fact that accidents are rare, this increase is perceived as unacceptable by society and new systems and solutions must be set up to maintain the accident rate at its current low level, or preferably reduce it. As safety of flight depends to a large extent on flight crew actions, it is essential that crew members are supplied with reliable information at all times : it is one of the FLYSAFE project objectives (`http://www.eu-flysafe.org/`, Integrated Project of the 6th framework of the European Commission). So, the most relevant skills across Europe are brought together to design, develop, implement, test and validate a complete NG-ISS which will allow the pilot to have a detailed, accurate, homogeneous and unambiguous presentation of the aircraft safety situation during all phases of flight. The NG-ISS is conceived to relay information on the areas identified as the main causes of accidents around the world: traffic collision, ground collision, and adverse weather conditions. Concerning this last item, specialised tools for generating nowcasts of atmospheric hazards are developed : the WIMSs. Four types of WIMSs feeding the NG-ISS were defined, each addressing one hazard: clear air turbulence (CAT), thunderstorms (CB), icing (ICE), and wake vortices. These products are generated by on-ground systems from observations and model forecasts, and are uplinked to the aircraft specific requirements by the Ground Weather Processors (GWP).

The next sections present some developments carried out by the French national meteorological center (Météo-France). The first one deals with specifications of ICE and CB WIMSs (the two others points of concern are the CAT WIMS and GWP, they are not made explicit here). The last part concerns tools used to evaluate the NG-ISS : a simulated weather scenario is presented.

2. INNOVATION ON ATMOSPHERIC HAZARD MANAGEMENT : THE WIMS

In order to improve the pilot weather hazards management during all the flight duration, including delicate stages of take-off and landing, WIMS are designed to address both the large scale/low spatial resolution for en route and the limited domain/fine spatial resolution for the Terminal Manoeuvring Area (TMA) of airports. They are implemented on three scales: the global, regional (European) and the TMA (a 200X200 km area centered on airports) scales. Hazards informations are delivered using object-based models specific to each area and to their severity attributes. Météo-France developments dedicated to WIMSs concern three types of them, each on particular scales : ICE WIMS on TMA scale, CB WIMS on TMA plus regional scales, and CAT WIMS on regional scale.

2.1 ICE WIMS on TMA scale

Météo-France has developed a system for the identification of icing areas, named SIGMA (System of Icing Geographic identification in Meteorology for Aviation) (Le Bot, 2004). This is the ICE WIMS precursor system from which a baseline version at TMA scale has been developed. This baseline system is based on the fusion of three sources of data: ***(i)*** an icing risk index calculated from Météo-France's numerical weather prediction model Aladin (resolution of 0.1˚, $\sim$12km); ***(ii)*** the Meteosat-8 infra-red brightness temperatures (4km resolution); ***(iii)*** the 2D reflectivity from the French operational centimetric radar network (1km resolution).

Each kind of data can confirm or invalidate the information deduced from the others. The algorithm is based on the theory of warm cloud-tops (Pobanz et al., 1994). The IR satellite imagery is first used to identify the cloudy areas. Icing risk depends on temperature cloud top. The 0˚C and -18˚C range presents the highest risk of severe icing due to super-cooled water presence. The additional information provided by the icing index is then taken into account. It defines the areas where both the humidity and temperature conditions favour the formation of icing, at each model vertical level. Finally, the radar information is used to identify the presence of precipitation or, in the cases of weak radar echoes, the possibility that droplets are in suspension. The algorithm produces 3D grid point data, which shows cloudy areas having humidity and temperature conditions favourable to icing in four different severity levels. These data are then converted to 2D objects (per vertical level). The algorithm is run every 15' with a horizontal resolution of about 1km side centered on a given TMA. An advanced version of the ICE WIMS/TMA is currently being developed.

2.2 CB WIMS on regional and TMA scales

The CB WIMS implementations at the various scales deliver to the GWP a representation of observed and nowcast CB-related hazards through hazard objects: ***(i)*** for the upper part of the CBs (**CB top volume**, developped by the DLR), the turbulence and lightning; ***(ii)*** for the lower part of the CBs (**CB bottom volume**), the hail, heavy rain, convective shear/turbulence, and lightning.

Regional scale mode Description is made on the basis of NWP outputs, satellite, radar, and lightning data. Satellite and NWP data are used to identify hazards for the CB top volume (using lightning data as an auxiliary source), and radar and lightning data for the CB bottom volume. Regions of risk are extracted and tracked over time for monitoring their move and evolution. The minimum size of detected hazard objects is 10km in diameter. The WIMS provide forecasts at a one hour time horizon, with a 15' time step, and refreshed every 15'. Météo-France uses its CONO system (Hering et al., 2005) for the CB bottom volumes diagnostic.

TMA scale mode Description is made on the basis of meso-beta scale wind field analysis (MUSCAT (Bousquet and Chong, 1998) and MANDOP (Tabary and Scialom, 2001) methods), satellite, radar and lightning data. It details storm top, occurrence of hail, shear and turbulence. Multiple polarization radar data allow to address the hail diagnostic. The meso-beta wind field analysis will be used for the CB leading edge identification. As in the regional mode, CB top volumes are identified by using satellite data (visible, IR and water vapour channels). Lightning data are used to estimate the threat in the CB top volume. The TMA mode provides forecasts at a one hour time horizon with a 5' time step for the first half hour, and 15' thereafter.

3. NG-ISS EVALUATION TOOLS: SIMULATED MAP IOP2B PRECIPITATION EVENT

In order to evaluate the NG-ISS with regards to both the flight atmospheric conditions and outputs of the baseline CB and ICE WIMSs, high resolution simulations were performed with the mesoscale non-hydrostatic model Méso-NH (Lafore et al., 1998). Meso-NH diagnostic package produces quantities similar to, or derived from observations used as CB and ICE WIMS inputs (reflectivity, brightness temperature, wind components,...). Simulated scenarios are heavy precipitating events which occurred in the vicinity of airports. The first one takes place over Paris, on the 23rd of June, 2005. The second, presented here, concerns Innsbruck airport. It occurred on the 20th of September, 1999 during IOP2B of the Mesoscale Alpine Program (MAP, Bougeault et al. (2001)). Figure 1 shows how the different synthetic outputs integrate into the full flight simulator (FFS, NLR). Simulated meteorological parameters (blue box) are used *(i)* to produce synthetic CB and ICE WIMS on the TMA scale mode (green box) which are sent to the FFS (red box) via the Local Weather Processor (part of the GWP managing local TMA scale products); and *(ii)* to feed the Airborne Doppler Weather Radar (ADWR) database. With this two inputs and within FFS, flight crew has access to consistent on-board weather radar data and hazards nowcasts.

3.1 MAP-IOP2B

MAP-IOP2B lasted 2 days (19 and 20 September). It is one of the most intense rainfall episodes during the MAP Special Observing Period. The synoptic situation is a typical one of a southerly flow and associated convection over Alpine orography. Detailed description of this IOP can be found in Asencio et al., (2003). Meso-NH was used in a 2-way nested configuration with three domains of 10, 2.5 and 1 km resolution, respectively. The highest resolution domain is represented on Fig.2, it covers an area of about 200X200 km. Innsbruck is located to the north, in the east-west oriented Inn valley. The domain includes high summits and large valleys (Fig.2.a). On the 20^{th}, precipitating bands ahead of a cold front crossed the Alps from west to east. Intensity maxima are simulated between 1330 and 16UTC on the Fig.2 domain. They are located on the southern alpine slopes, where a southerly flow is incident (Fig.2.b). Innsbruck is away of the precipitating core, but an air approach towards the airport can turn out to be delicate.

Meso-NH simulations were generated over the highest resolution domain between 1330 and 16UTC, with a time step of 5'. For the FFS, 3D wind and reflectivity fields feed the ADWR database. ICE WIMSs take several 3D fields as inputs : temperature, specific humidity, IR brightness temperature, reflectivity and water mixing ratio. The next section presents synthetic CB WIMS process, and results for the IOP2B case.

3.2 Simulated CB WIMS products on TMA scale

For the simulation of CB WIMS products, the Meso-NH advanced diagnostic package provided synthetic 2D fields: ***(i)*** Zmax : maximum reflectivity for each vertical column, ***(ii)*** Ztop : highest altitude where the 18 dBZ reflectivity level is encountered, and ***(iii)*** VIL : Vertically Integrated Liquid water content. In the present stage of CB WIMS development, the main parameter used is Zmax, while Ztop will contribute to describe the hazard objects vertical extension, and VIL is considered as an alternate basic parameter for defining their horizontal extension. Simulated winds will be used for further characterizing the hazards associated to shears, but only in precipitating regions (as the operational radars do not include clear air observations). The reflectivity levels used for defining hazard objects horizontal extent are based on Rhoda et al. (2002), and Vincent (1999) results. These studies show that 40 dBZ reflectivity levels represent a major threat for aircrafts. It is generally largely avoided during the en-route flight phase, while constraints linked to the approach phase may drive the pilots to penetrate 40 dBZ areas. Reflectivity levels of 30 dBZ are avoided when few constraints apply to the flight path. Operation procedures currently in use for a number of aircrafts do not explicitly address reflectivity levels displayed by the on-board radars. The current practice is to use a colour-coding scheme showing levels above 30 dBZ in yellow and above 40 dBZ in red. This is why the preliminary design of Cb WIMS uses reflectivity levels around 30 and 40 dBZ for defining hazard objects. The main challenge for an automated object tracking is to deal with the evolving nature of the reflectivity field in order to diagnose reliable move speeds; for the nowcast phase, it is also instrumental that the diagnosed objects are predictable enough. Figure 3 shows an example of the CONO tracking system output for the MAP-IOP2B case, for the 40dBz reflectivity level (red isoline). It shows how different the moves are for different objects, depending on the processes involved : cells move channelled by the main valley (A), pure orographic forcing (B) or combination of free move and orographic forcing (C). Work is underway to assess the quality of the extrapolation based on such move diagnostics.

4. NEXT STEPS

In the next months, the first NG-ISS evaluation will be performed from Innsbruck and Paris Méso-NH simulated environments, with synthetic-generated CB and ICE WIMSs. If the evaluation goal is firstly to draw technical conclusions, and to determine works to carry out, pilots judgment will also be of great value to improve the NG-ISS attributes.

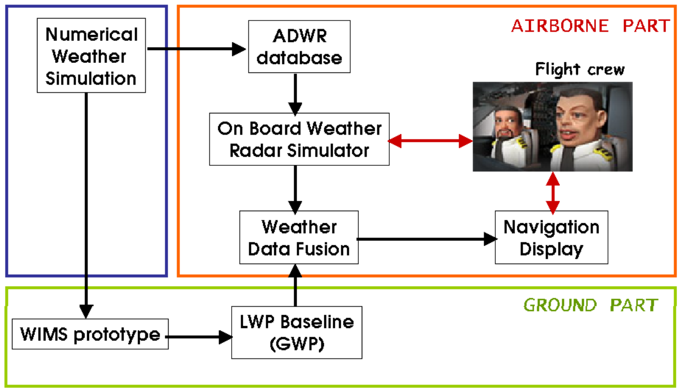

Figure 1: Weather simulation products integration in the Flight Simulator

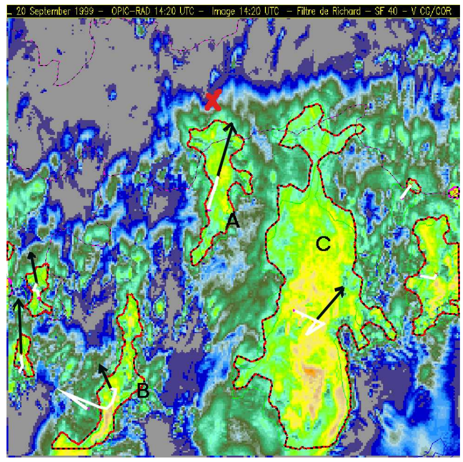

Figure 3: CONO results for 1420 UTC. 40 dbZ contour is in red. Black arrows indicate estimated speeds. Gravity center track is in white. Labels A B & C are referred to in the text. Red cross is for Innsbruck location.

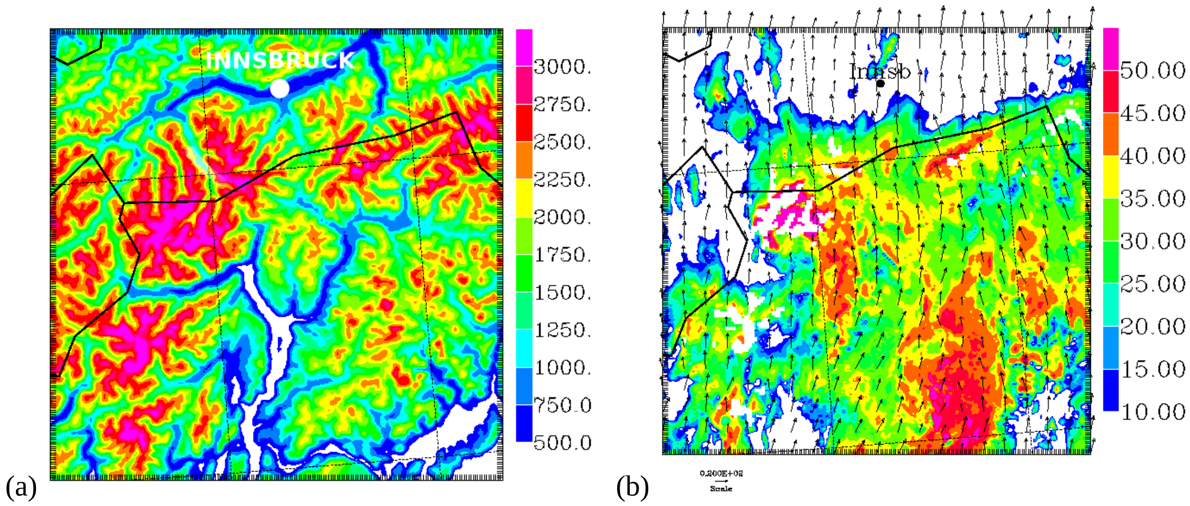

Figure 2: (a) Highest resolution domain topographic map (m); **(b)** reflectivity (dBZ) and horizontal wind (arrows) fields at 700 hPa on 20 September 1999 at 14UTC

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