Improvement of thunderstorm hazard information for pilots through a ground based weather information and management system: The CB WIMS approach in FLYSAFE

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Outline of talk

- Thunderstorms are a safety issue for a/c
- FLYSAFE project
- FLYSAFE WIMS - Weather Information and Management systems
- WIMS realization
- WIMS evaluation in FLYSAFE flight test
- Conclusions
Thunderstorms are a safety issue for more than one reason:

- wind shear & turbulence
- lightning stroke
- hail

Boeing 737, Geneva 15 Aug. 2003
Weather diversions Memphis 23 August 2003
The FLYSAFE Project

- Project full title: *Airborne Integrated Systems for Safety Improvement, Flight Hazard Protection and All Weather Operations*

- Integrated Project of the 6th Framework Programme of the European Commission
  - Coordinator: THALES, Toulouse
  - 36 Partners from 14 countries
  - 53 million €
  - EC contribution: 29 million €

- Started on February 1st, 2005
- Ended: 30 June 2009

Today!!
FLYSAFE objectives 1/2

- FLYSAFE is the first decisive big step towards the ACARE’s “VISION 2020”

- FLYSAFE allowed to design, develop, implement, test and validate a complete Next Generation Integrated Surveillance System (NG ISS)

- FLYSAFE addressed the three types of threats:
  - traffic collision
  - ground collision
  - adverse weather conditions
FLYSAFE objectives 2/2

- FLYSAFE developed new systems and functions
  - improved situation awareness
  - advanced warning
  - alert prioritisation
  - enhance current human-machine interfaces

- FLYSAFE developed ground-based Weather Information Management Systems (WIMS)
  - retrievable for all aircraft
  - provide timely, dedicated, improved weather hazard information
Weather Information Management Systems (WIMS):

- Provide more accurate FORECAST of specific atmospheric hazards
- Are up-linked to the cockpit
- Potential to link/provide them to the Air Traffic Management (ATM) and Airline Operational Centres (AOC)
- Information is tailored to the specific situation, flight state and flight plan of the aircraft

Weather Corridor Concept
FLYSAFE WIMS (2/2)

- 4 WIMS, addressing
  - Wake vortices
  - Clear Air Turbulence
  - In-flight Icing
  - Thunderstorms (CB’s)

- Other Information on hazards currently available will also be uplinked to the cockpit (e.g. volcanic ash)
CB WIMS realization

Target Weather Object "Cb"

**Cb top volumes:**
- convective turbulence, lightning

**Cb bottom volumes:**
- hail, icing, lightning, heavy rain, wind shear, turbulence
CB WIMS realization

Object attributes:

- Area covered, as a polygon
- Layer (top or bottom)
- Upper boundary
- Lower boundary
- Moving direction
- Moving speed
- Gravity centre location
- Severity level (moderate, severe)
- Trend on area
- Trend on vertical development
- Hail occurrence flag
- Confidence level
CB WIMS realization

CB WIMS bottom volumes for TMA
Paris provided by Meteo-France

Using 3 D radar data from 5 ground radars.
Provides max reflectivity on columns
and cell top height
- 1km x 5 minutes space/time resolution
- CONO software used

Objects at 2 severity levels, based on
33 and 41 dBZ: matches yellow and red
on WXR (provided calibration and gain
are nominal)
Hail occurrence based on dual-polarization
radar return
CB WIMS realization

CB WIMS top volumes provided by DLR

Based on **Cb-TRAM** software using four data channels from METEOSAT 8 (MSG):

- high resolution visible (HRV)
- infra-red 10.8 μm
- infra-red 12.0 μm
- infra-red 6.2 μm (water vapour, WV)

- Also uses ECMWF forecast data to estimate clout top height

- HRV texture is related to turbulence
- LINET Lightning data drives severity diagnostic
CB WIMS realization

1500TU LINET.20060704.asc
CDG TMA dist=5km

CB WIMS lightning volumes provided by ONERA

Distinction of single strokes and active cells
CB WIMS evaluation

Cb objects in TMA Paris perspective view

Cyan: bottom objects type moderate
Red: bottom objects type severe
White: top objects type moderate
CB WIMS evaluation

Cb objects in TMA Paris perspective view

Red: bottom objects type severe
Yellow: lightning objects
CB WIMS evaluation

Cb WIMS regional Products overlaid on Meteosat HRV image 4 July 2006 15 UTC
The FLYSAFE Project
Flight Test Evaluations

- Weather Aspects only

- SAFIRE (ATR - 42) for new weather sensors

- NLR Metro Swearingen II for Weather data fusion of WXR data and WIMS uplinked data
Flight Test System Architecture

Simplified view of the data flow between the airborne and ground segments used in FLYSAFE’s Flight Trials.
The FLYSAFE Project
Weather Aspects Validation

- Validation of the complete chain of weather information processing

- FLIGHT TESTS & results are used to validate:
  - aircraft atmospheric data
  - WIMS and routine data
  - uplink and downlink of weather data
  - fusion of onboard sensor data (WXR) with weather hazard data (WIMS) from the ground

- FLIGHT SIMULATIONS of WIMS-CB & WIMS-ICE
  - Weather data fusion of WXR and WIMS
  - Cockpit HMI
  - Operational aspects
  - Impact on Safety
Flights performed during summer 2008

- Two TMA flights: no icing / few CBs

- 9 European flights:
  - Isolated CBs
  - Embedded CBs
  - Icing light, moderate and severe

- 6 most successful flights
CB WIMS added value in CB crowded cases
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- Reason for WXR blindness: its wavelength, ~3cm, is prone to attenuation of the signal by heavy rain
- Reason for ground radar good depiction:
  - wavelength 5 or 10 cm
  - Multiple line of sight by multiple radars
- Reason for good satellite depiction: it sees from above (which sometimes is an issue)
CB WIMS is ground clutter free
CB WIMS wider coverage during turns

19 August 2008 1319 - 1321 UTC

Only CB top contours shown here, in yellow (except first and last snapshots)

Quick and strong turn typical of TMA tracks

Top objects are 10 minutes forecasts
Conclusions on CB WIMS value

This case shows that the CB WIMS objects:
- are much more clutter-free than the on-board radar data
- match very well the close range part of the on-board radar depiction
- provide additional valuable information on the occurrence of convective activity beyond close cells (which is confirmed by later on-board radar images)
- and also provide information over a wider sector (including behind the aircraft), which could be much valuable in case the aircraft had to turn sharp (which is likely in take-off and landing situations)

They do provide added value except at shortest ranges, where WXR is un-replaceable

Timeliness of CB WIMS data is instrumental in quickly evolving cases
- even for regional scale, a refresh period of 5 min should be envisaged,
- this would be fine w.r.t CBs lifetime and ranges at which CB WIMS is most useful
Pilots' opinion on use of CB WIMS

- Potential operational value of WIMS Cb data was recognized
- Among Wims-CB objects, severity 1 bottom objects and top objects can be seen as places outside which there is definitely no hazard
- Accuracy and details of the WXR data should be preserved in the fusion when relevant (i.e. at shortest ranges)

- WIMS-CB trend activity should be available to the pilot
- Lightning activity information should be included in Wims CB objects, where available to the ground segment
- More details from ground radar than 2 severity levels could be useful
Perspectives

- Representation of thunderstorms by relatively simple bottom and top volumes seems to render realistic coherent hazard areas for air traffic.
- Timeliness issues have to be kept in mind in the design of the ground segment, particularly for use at the tactical horizon, so especially in the TMA.
  - Satellite and ground radar network perspectives are quite in line with the requirements
- The real potential of the CB WIMS concept for aircraft safety lies in two more aspects:
  - The level of observation coverage and fusion that can be reached by a ground segment is significantly higher than what can be achieved on-board. This includes the fusion of lightning data, satellite rapid scan data in multiple spectral bands, advanced, polarimetric, C- and S-band meteorological radar data and atmospheric state analyses
  - The upcoming capacity of the operational Weather Services in numerical prediction of thunderstorms for the next hour will definitely improve the quality of thunderstorm nowcasts at the time horizon of the FLYSAFE project Target Platform, namely 2015.