Airborne Integrated Systems for Safety Improvement,
Flight Hazard Protection and All Weather Operations

FLYSAFE
Final Forum

Weather Information Management Systems (WIMS) and Onboard Applications II

Aircraft Wake Vortices and Thunderstorms

25-26 March 2009, NLR, Amsterdam

Summary

- Objectives
- Aircraft Wake Vortices
  - Wake Vortex (WV) WIMS
  - On board wake prediction and alert system
- Thunderstorm (Cb) WIMS

Objectives

- Develop, validate and test ground-based weather information management systems (WIMS) for wake vortices (WV) and thunderstorms (Cb)
- Provide aircraft with weather safety related information
- Prove that WIMS will increase safety / assess how WIMS contribute to safety
- Demonstrate the functionality and applicability of an airborne Wake Encounter Prevention System as part of the Next-Generation Integrated Surveillance System

Aircraft Wake Vortices

- **Safe and efficient air transport requires adequate aircraft separation**
  - **ICAO wake turbulence separation minima for take-off, cruise, and approach**
  - **Wake vortex separations are one limiting factor to air transport growth**

- **Very few accidents to commercial transport aircraft but ...**
  - **... severe encounters occur during all phases of flight**
  - **... number of events could increase with growing traffic**

- **Complementary mitigation strategies**
  - **Benign vortex aerodynamic design**
  - **Improved ATM concepts** (e.g. time-based separation, re-categorisation)
    - **Ground-based wake prediction & monitoring systems**
  - **On-board wake information and encounter alleviation systems**
    - **On-board wake detection, prediction & alert systems**
    - **Automated flight control**

Wake Vortex WIMS

- **Mode for en-route traffic**
  - **Operational weather forecast models predict the parameters which control the movement and dissipation of upper level wake vortices:**
    - **wind vector (all three components),**
    - **density (temperature)**
    - **vertical wind shear**
    - **turbulent kinetic energy**
- **Mode for traffic in the Terminal Manoeuvring Area (TMA)**

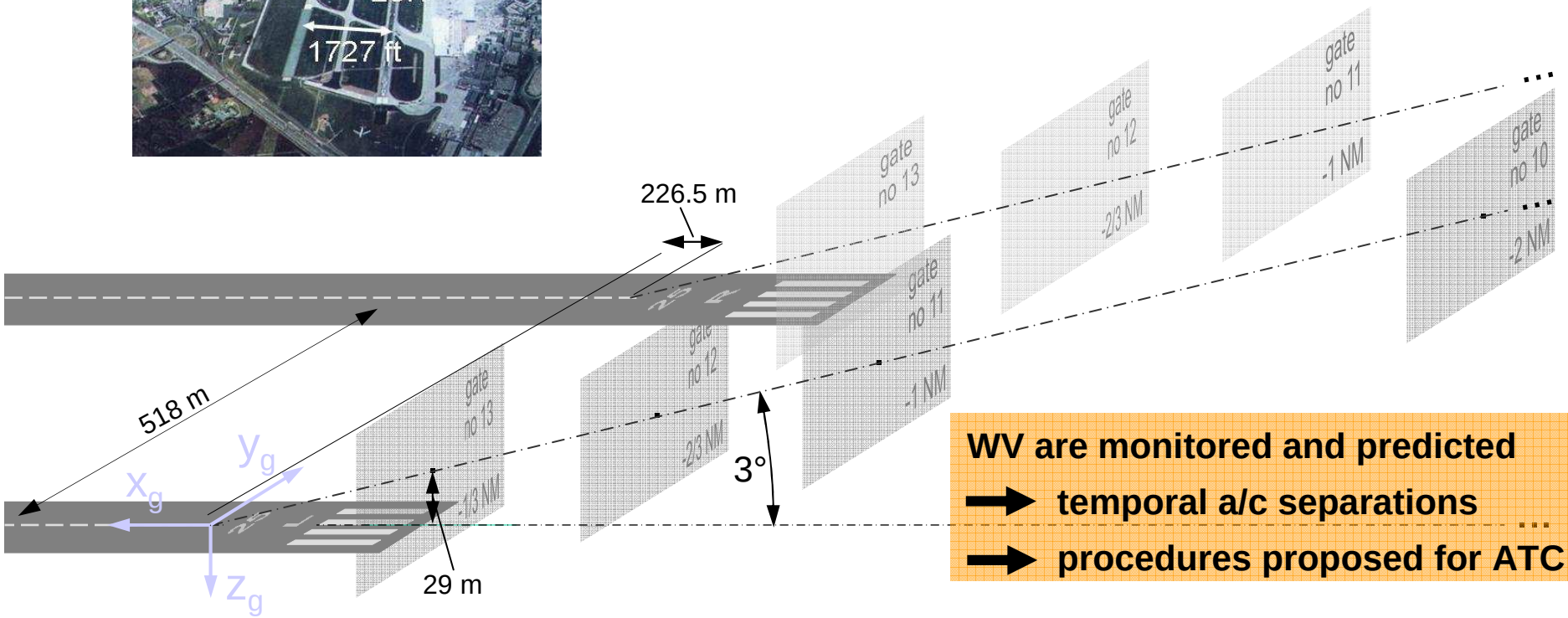
Wake Vortex WIMS - TMA Mode (TMA)

Frankfurt Airport

Wake Vortex WIMS - TMA Mode (TMA)

Frankfurt Airport

13 Gates
along nominal ILS Flight Path
(Δx = 1/3 NM - 1 NM)

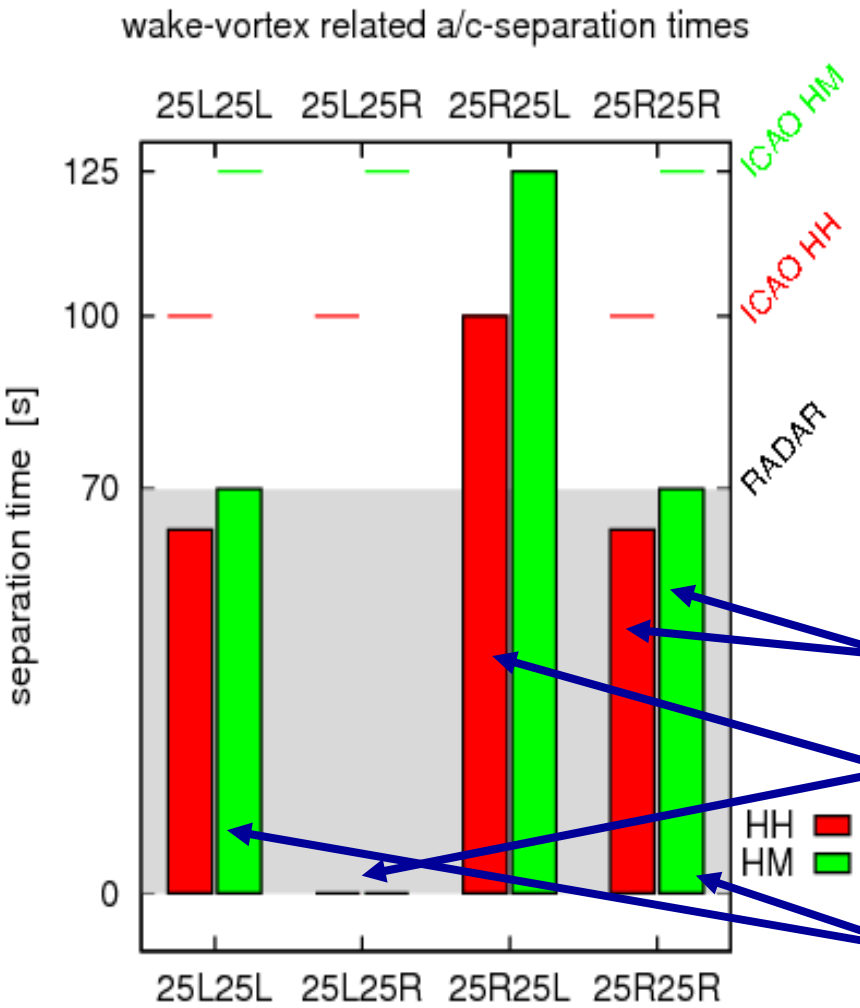


WV are monitored and predicted

- **temporal a/c separations**
- **procedures proposed for ATC**

display for parallel runways

full information and procedures, example: 2007-Jan-25 15:10 UTC



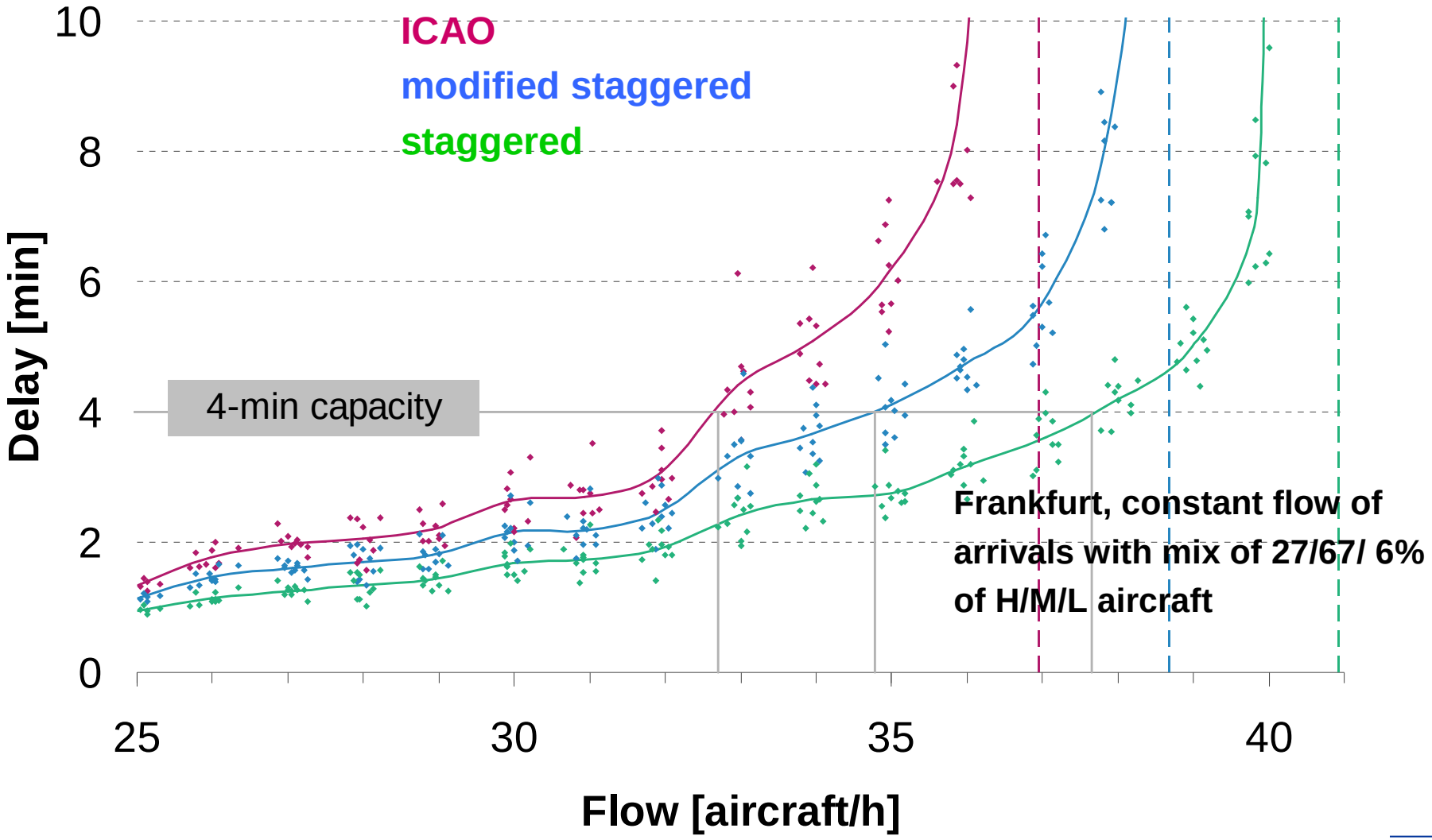
separate consideration of HH and HM

staggered separation reductions

in-trail separation reductions

Integration in the Air Traffic Control environment

Reducing delays or increasing capacity ?



WV WIMS - TMA mode : Conclusions for Frankfurt Airport Recommendations

- **WV WIMS - TMA mode - demonstrated its functionality at Frankfurt airport in winter 2006/2007**
  - Stable prediction characteristics - no forecast breakdowns
  - Potential ("weather-wise") use of new ConOps in 75% of the time
  - Potential capacity gain > 3 % (real traffic flow and traffic mix)
  - The predictions were correct: no warnings from the LIDAR
    - from a-posteriori analysis of ≈1100 heavy a/c approaches
  - The controllers confirmed the benefit of such a system and agreed with the proposed procedures and display layout


Foto: NOAA and FAA

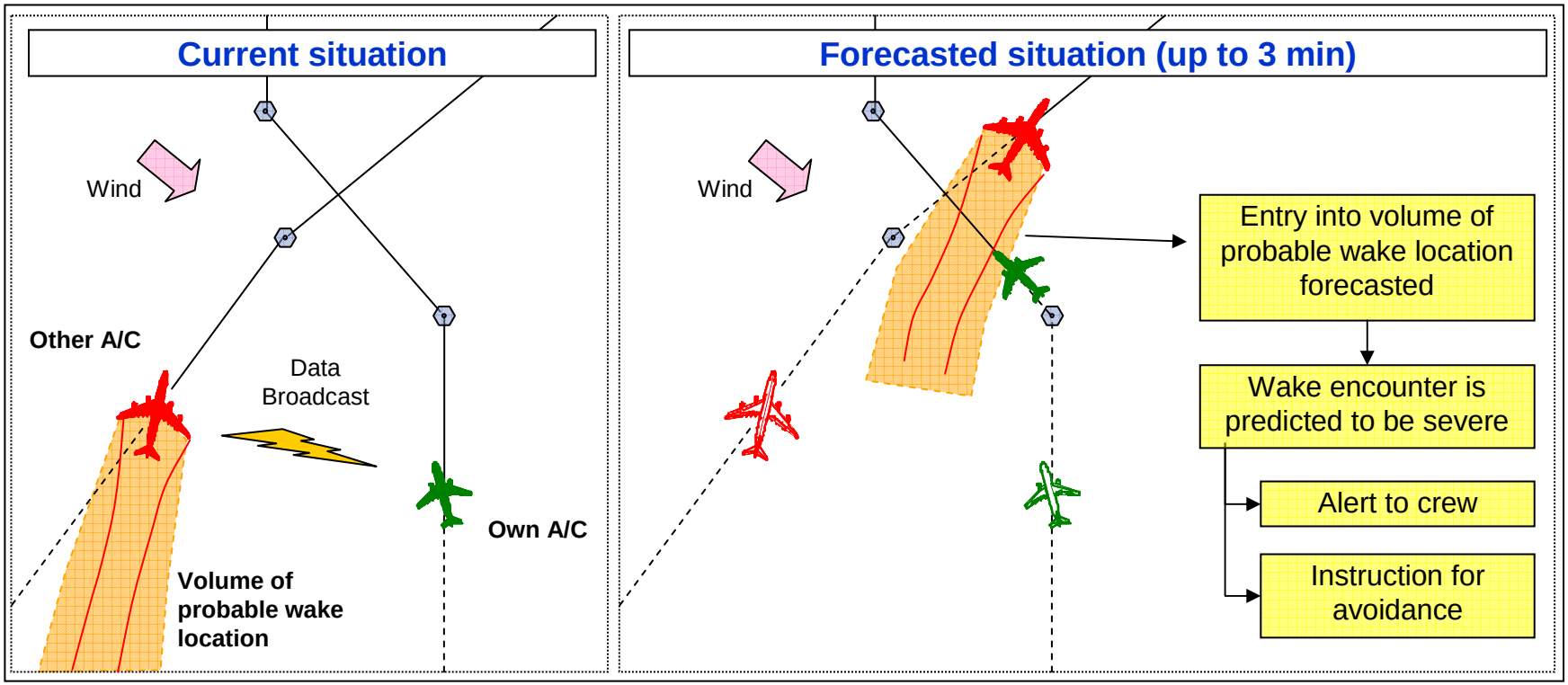
- **Future Work** (within CREDOS, *Weather & Flying*, and *SESAR*)
  - extension to runways 07 and departures; risk analysis
  - consideration of wake-vortex curvature effects
  - automatic real-time wake vortex monitoring

On-board wake prediction & alert

- **Top-level objectives**
  - Prevent severe wake encounters during all phases of flight
  - Create additional tactical safety layer
  - Alert crew with time for educated decision making
  - Provide crew with instructions for safe avoidance and improved situational information
- **Objective within FLYSAFE**
  - Demonstrate the functionality and applicability of an airborne Wake Encounter Prevention System as part of the Next-Generation Integrated Surveillance System
- **Sub-level objectives**
  - Specify target system
  - Specify, develop and evaluate relevant sub-systems on AIRBUS research flight simulator

On-board wake prediction & alert

- **On-board sensor for wake detection (LIDAR or RADAR technology)**
- **On-board prediction of wake location and characteristics (WEPS)**
  - Data input from own A/C, other A/C (e.g. through ADS-B) and WIMS
  - Models to predict 3D wake evolution up to cruise altitude
  - 4D conflict detection (i.e. forecasts of impending conflicts)



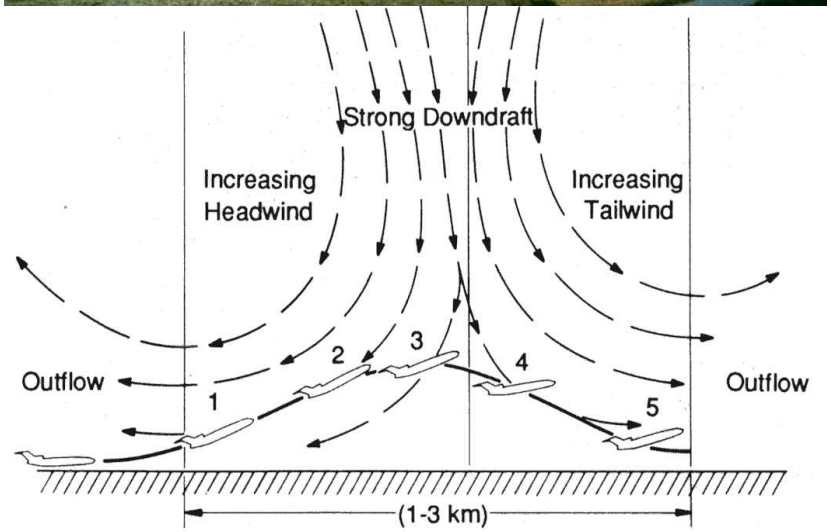
On-board wake prediction & alert

- Airborne Wake Encounter Prevention System up to cruise altitude is feasible, even when based on wake prediction alone (including piloted tests on AIRBUS THOR flight simulator)
- Advanced alerting allows avoidance of severe wake encounters with benign avoidance manoeuvres
- Accurate wake prediction requires aircraft (weight, wingspan, speed) and wind data (direction, speed) - e.g. from future ADS-B
- Suggestion for future research items
  - Validation of the wake predictors up to cruise altitude and for various aircraft and conditions
  - Development of estimation & fusion filters for meteorological data
  - Further development of prototype including coupling of wake detection and prediction

Thunderstorm (Cb) WIMS

Cb's pose a threat to aviation:

- wind shear & turbulence
- lightning stroke
- hail
- icing
- heavy rain
- visibility



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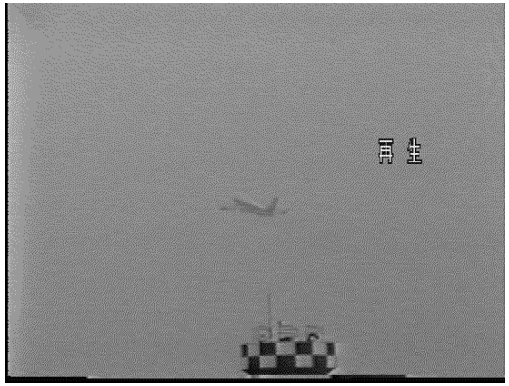
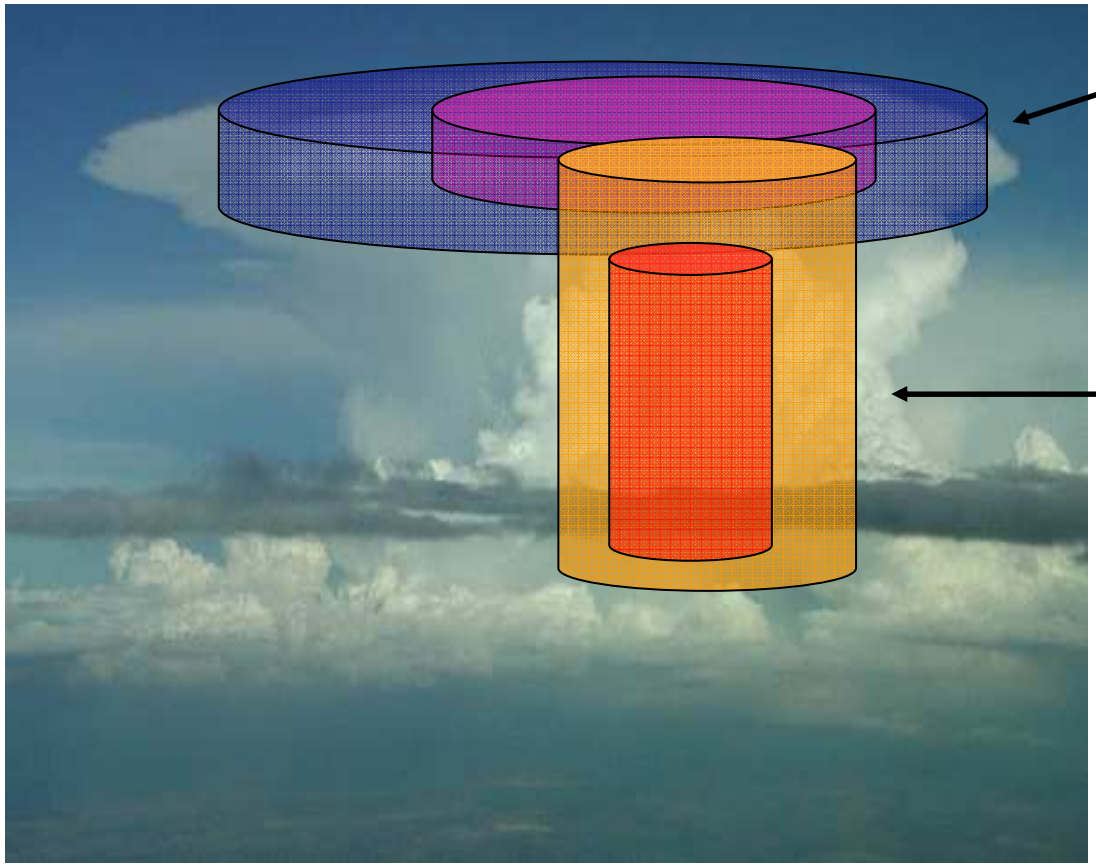


Thunderstorm (Cb) WIMS

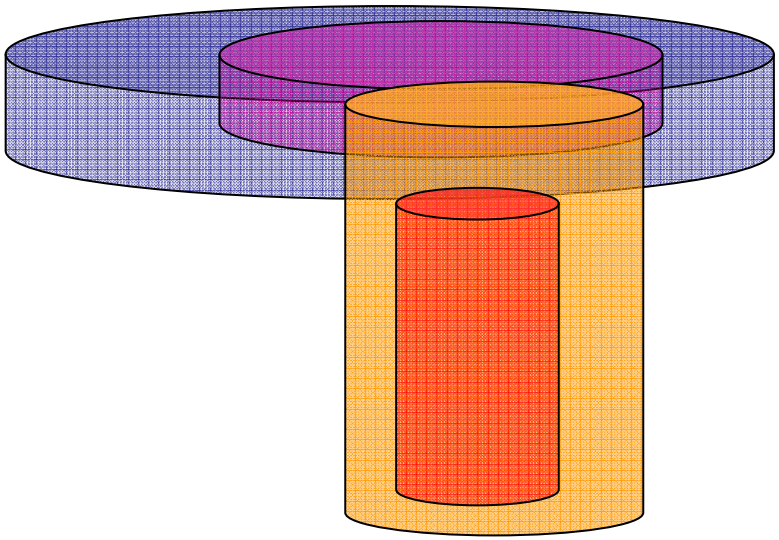
Target Weather Object "Cb"



Cb top volumes:
convective turbulence, lightning

Cb bottom volumes:
hail, icing, lightning, heavy rain, wind shear, turbulence

Thunderstorm (Cb) WIMS

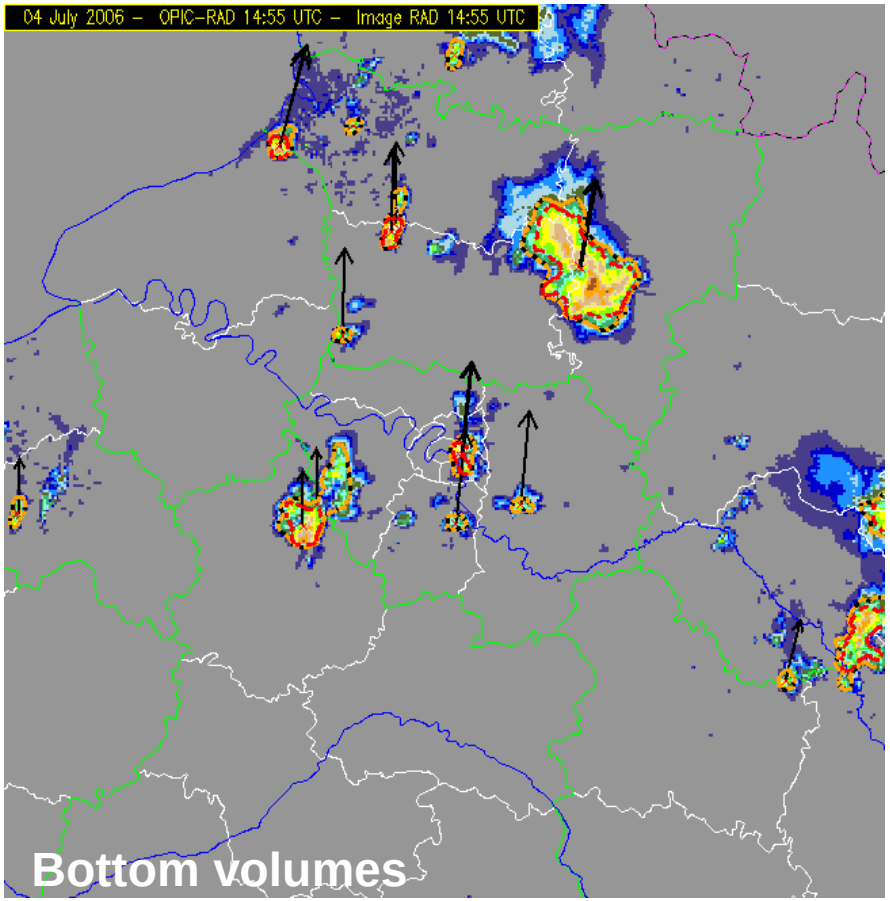


Object attributes (coded in XML):

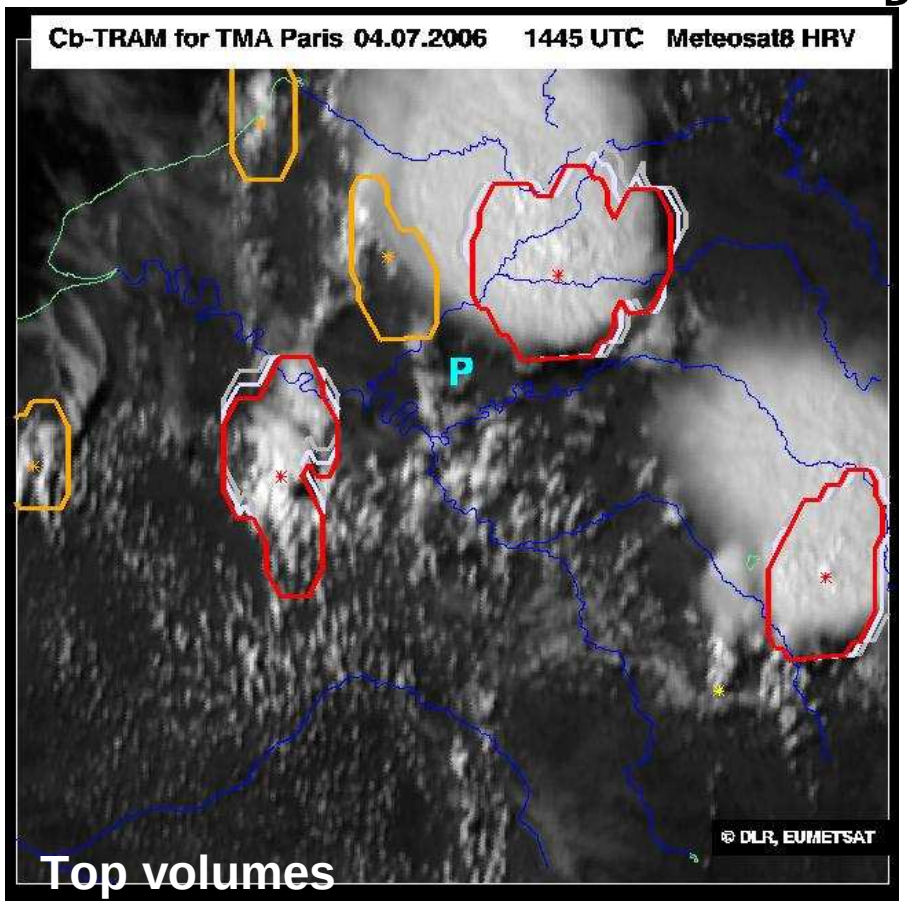
- Area covered, as a polygon
- Layer (top or bottom)
- Upper boundary
- Lower boundary
- Moving direction
- Moving speed
- Gravity centre location
- Severity level (moderate, severe)
- Trend on area
- Trend on vertical development
- Hail occurrence flag
- Confidence level

- **Local** or TMA scale, where TMA stands for Terminal Manoeuvring Area of an airport, derived from systems developed at Météo France, DLR, ONERA
- **Continental** scale derived from systems developed at MF, DLR and ONERA
- **Global** scale provided by the UKMet-Office' global forecast model

Thunderstorm (Cb) WIMS
application to the TMA of Paris

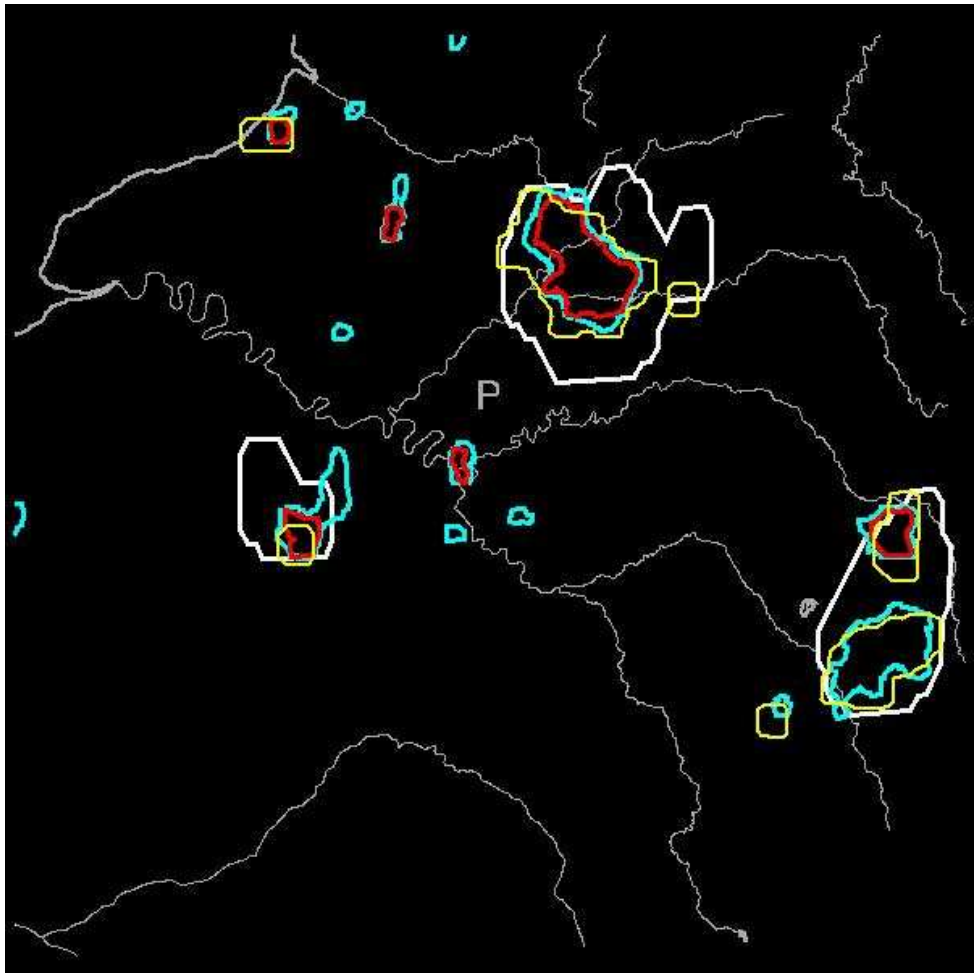


provided by Météo France's CONO using 3 D radar data; objects determined at severity levels 33 & 41 dBZ; arrows indicate moving direction and speed



provided by DLR's Cb-TRAM, using satellite data (METEOSAT visible, infrared and water vapour ch.); objects are analysed and nowcast for 5 and 10 min

Cb WIMS evaluation
in the TMA of Paris



Overlay of Cb top, bottom and lightning objects
(DLR, Météo France, ONERA)

Cyan: bottom objects type moderate
Red: bottom objects type severe
White: top objects type moderate
Yellow: lightning objects

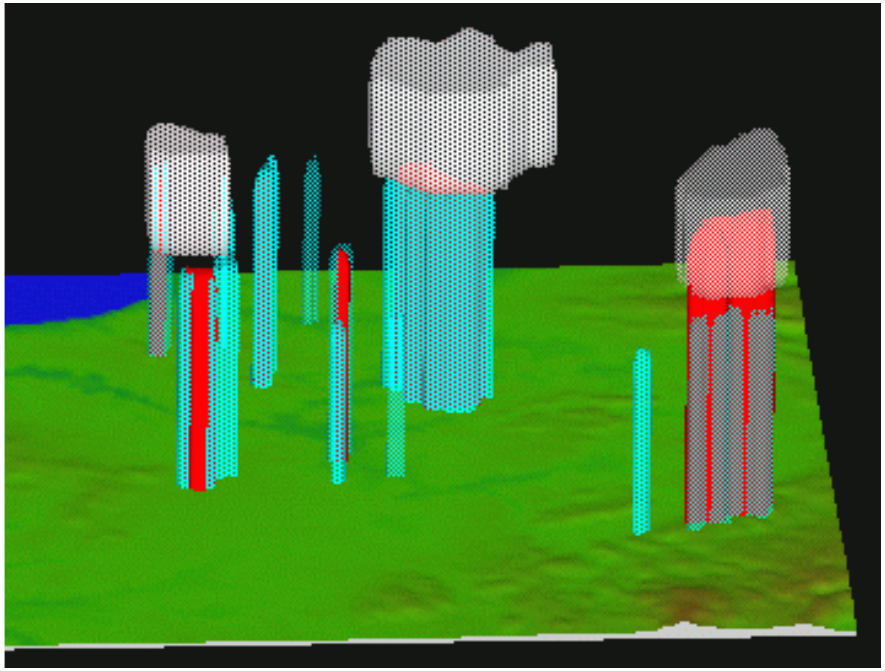
Follow also the Flight Test and Simulator presentations !

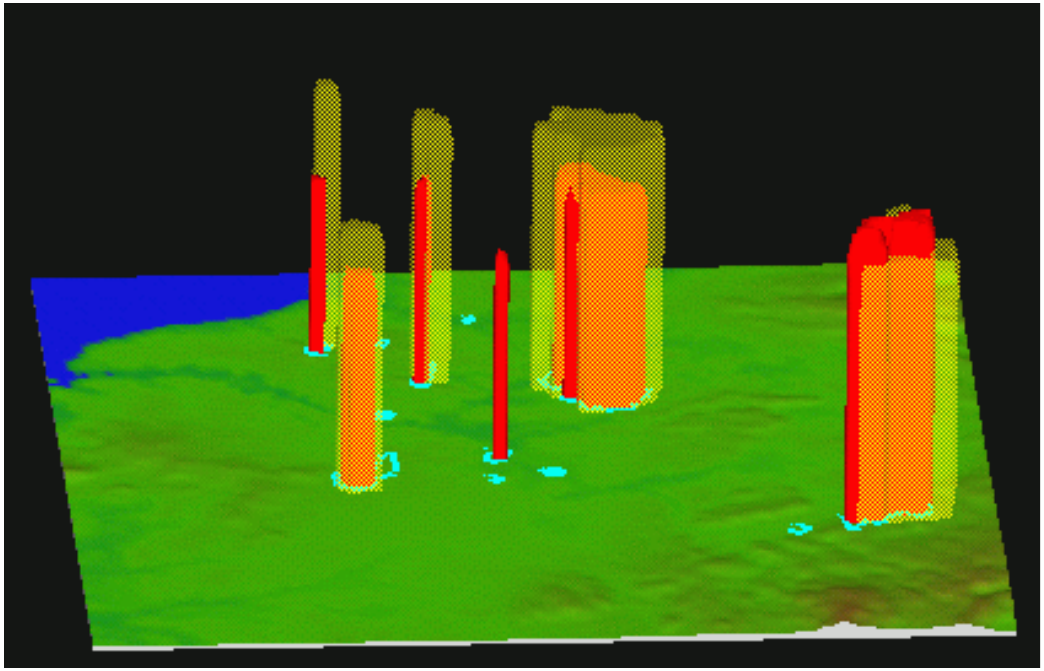
See this case animated in the demonstration room below !

See also a Cb approaching Munich Airport !

Cb WIMS evaluation
in the TMA of Paris

Cb objects in perspective view





Cyan: bottom objects type moderate
Red: bottom objects type severe
White: top objects type moderate

Red: bottom objects type severe
Yellow: lightning objects

Thunderstorm (Cb) WIMS Summary and Recommendations

- Thunderstorms can be represented by relatively simple bottom and top volumes in a meaningful way for aviation (pilots and controllers)

- There is a real potential of the Cb WIMS concept for safety in aviation since ...
  - it surveys a much larger area than a single radar on-board the aircraft
  - it fuses data from lightning, satellite (multiple channels), polarimetric C and S band radar and atmospheric analyses from ground with on-board information
  - and hence provides a "complete" picture

- Future inclusion of (advanced) operational numerical weather forecasts of thunderstorms will definitely improve the nowcast/forecast quality at the time horizon of the FLYSAFE project Target Platform (2015)