Sigma: Diagnosis and Nowcasting of In-flight Icing - Improving Aircrew Awareness Through Flysafe

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Outline

- Context of icing diagnostics
- SIGMA Icing Diagnostic System
  - Algorithm
  - Validation and verifications
- Icing diagnostics within FLYSAFE
- New algorithm
- Wrap-up

Context

- **In-flight icing induces**
  - **Hazards** for aircraft safety
  - Significant impacts on accidents and delays
  - **A tool to detect icing areas is needed**
- **SIGMA**
  - Icing diagnostic tool
  - Developed for forecasters
- **SIGMA Current developments**
  - Use of data from new meteorological instruments
  - Adaptation for direct use by aircrew (in the scope of the FLYSAFE project)

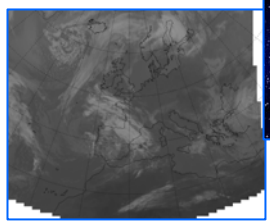
SIGMA Icing Diagnostic System : DATA FUSION

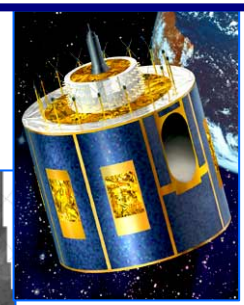
Satellite

Meteosat-8

IR channel

15min / 4km





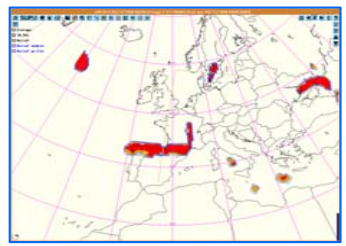
Cloud Top Temperature

Numerical model forecast

Meteo-France

NWP model Arpege

3h / 25km



Icing Index

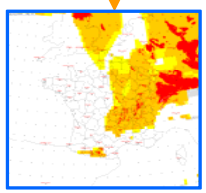
Radar

2D composite

15min / 1km

Radar Reflectivity

Decision Tree

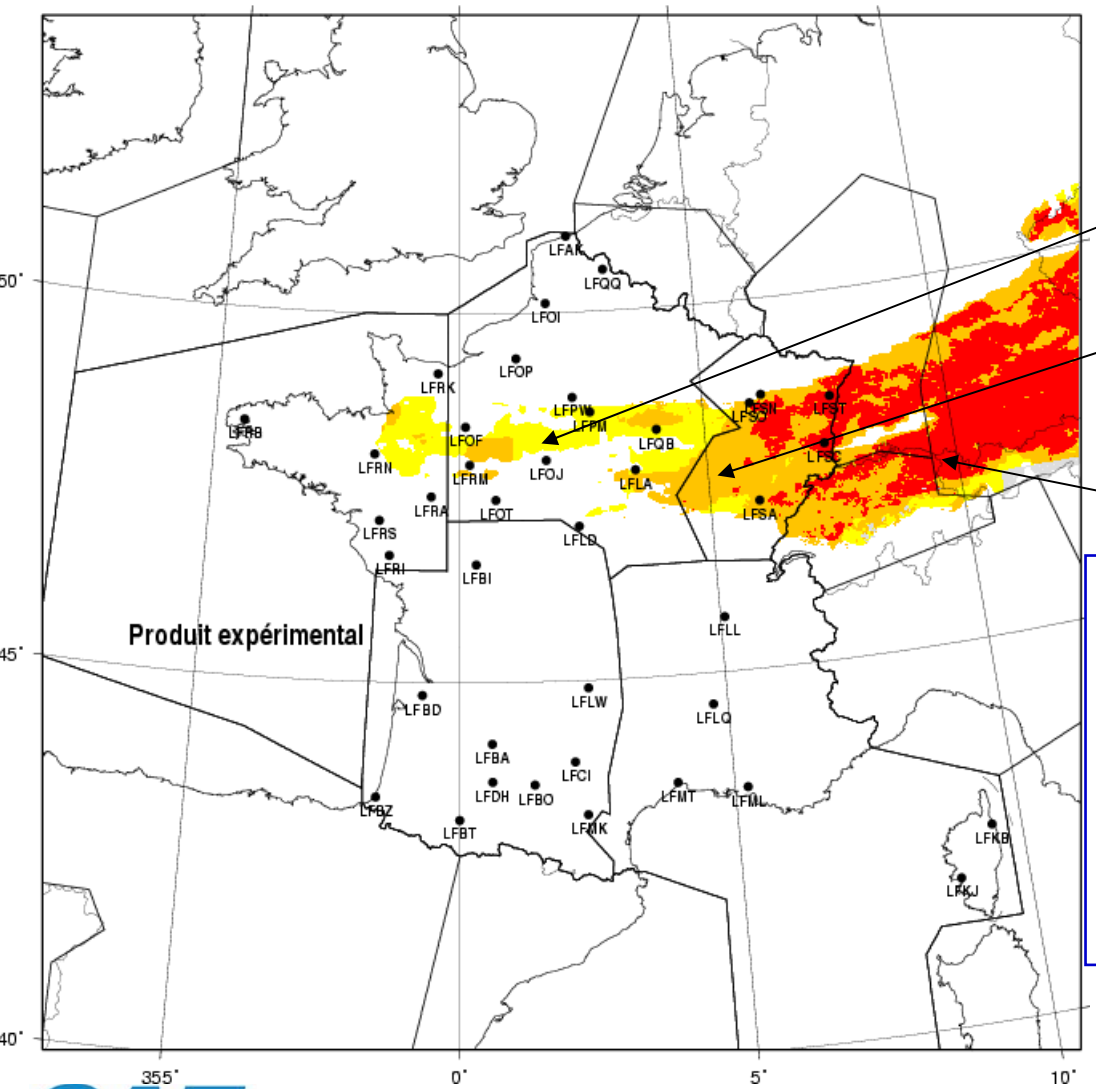


Icing risk

Optional Vertical Motion threshold

SIGMA Output

SIGMA 3D 3C FL140/600 hPa 09 11 2006 10h00Z



Icing risk

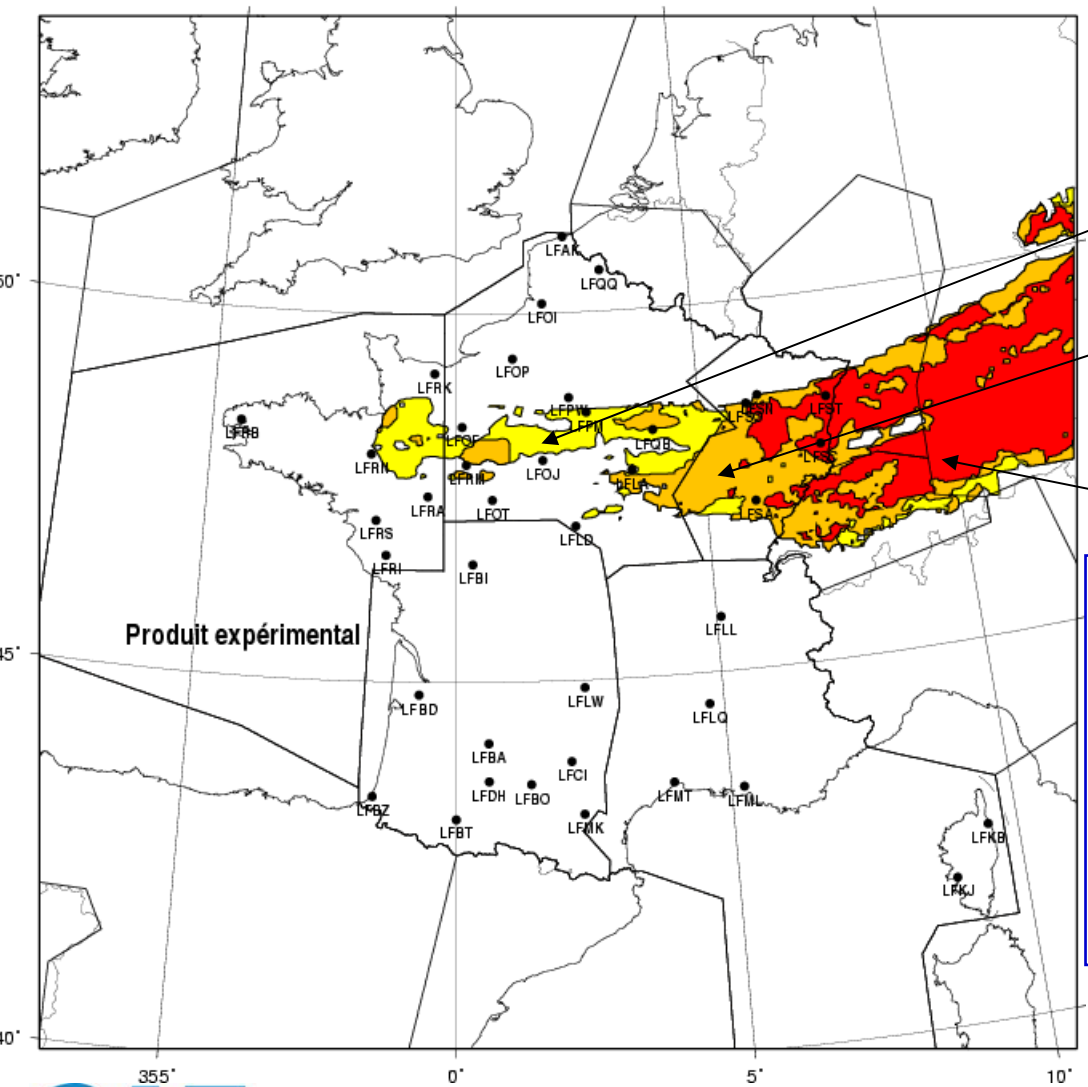
Light (light icing)

Moderate (moderate to heavy icing)

High (severe icing)

- 3D output ⇨ also maximum in the vertical
- Covers France and neighbouring countries
- 1 km horizontal resolution
- Output refreshed each 15 minutes

SIGMA Output: 2D Objects



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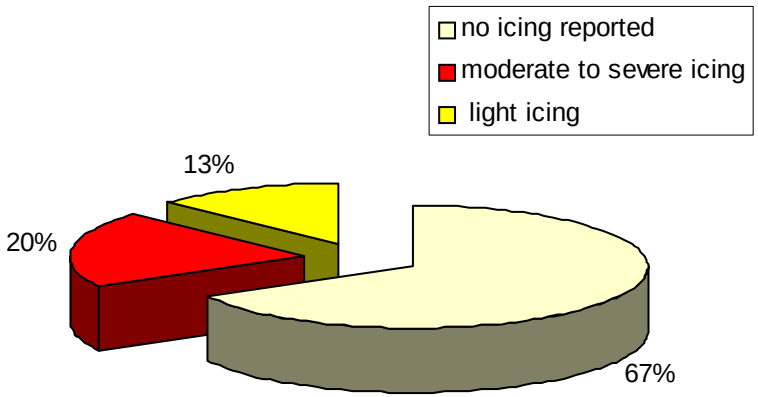
Validation – 1

- **Verifications against :**
  - Pilot reports from French Air Force Army
  - Observed Radiosoundings analysed by forecasters
  - Routine Pilot Reports (PIREPS) over USA
  - Flight tests from AIRS2 campaign in Canada

- **Difficulties to make a real-time verification of icing conditions**
  - No automated observation system
  - No PIREPS database over Europe
  - TAMDARs ?

Validation – 2

- **Icing do occur over France (PIREPS)**
  - 1/3 of observed cases are reporting icing conditions
  - 60% of these cases are moderate to severe

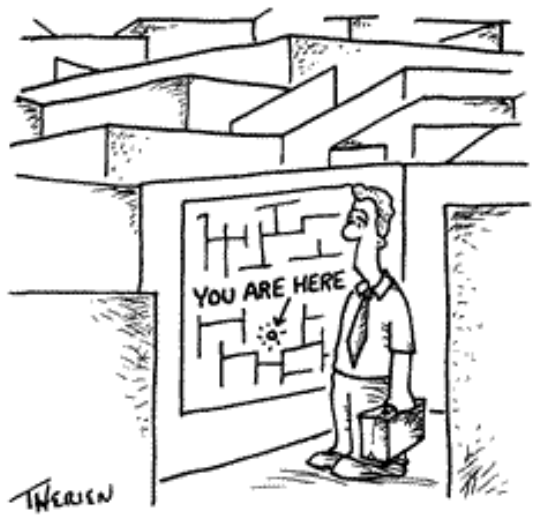


- **Data fusion improves the Numerical Model Icing Index**
  - Icing Index was overestimating icing risks
  - Difficult to use solely satellite images

First Conclusions…

- Data fusion is an appropriate methodology to improve the identification of icing areas

- SIGMA is effectively used by the forecasters as an aid in the decision-making process
- **But…**
  improvements can be done



FLYSAFE: an Integrated Project

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

- Integrated Project of the Sixth Framework Programme of the European Commission, budget of 53 M€, 29 M€ EC funded

- Aimed at designing a **Next Generation Integrated Surveillance System** (**NG ISS**):
  - A generation further than the emerging integrated safety systems

- Started on 1 February 2005
- Duration: 4 years
- 36 Partners / 14 countries

FLYSAFE: addressing Threats

- **FLYSAFE** will address these three types of threats:
  - Adverse Weather Conditions

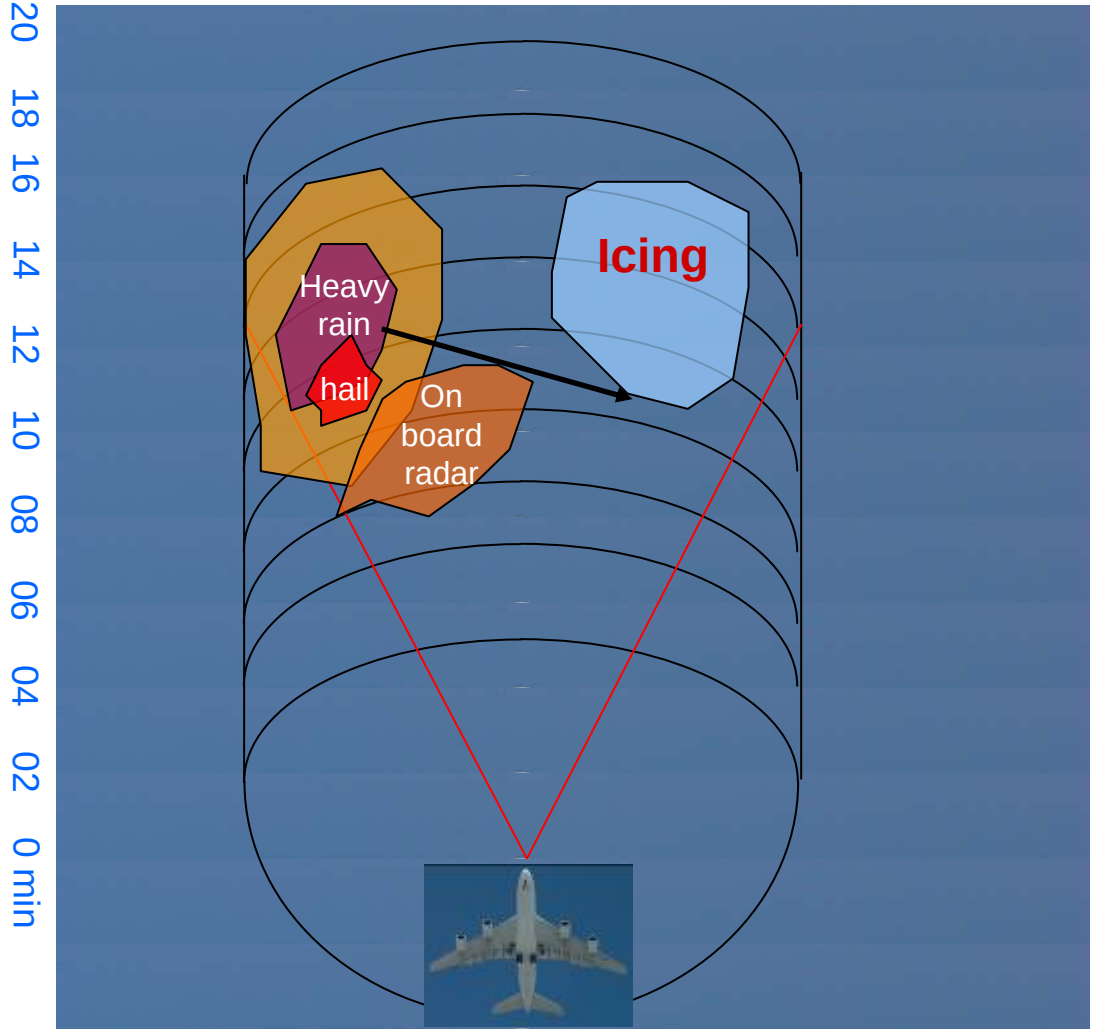
  - Traffic collision
  - Ground collision

- **Threats information tailored ➡ Aircrew and Air Traffic Controllers informed in time**
- **Shall ideally result in timely flight path corrections**
  - **Avoiding last minute safety nets**

FLYSAFE: Meteorological aspects

- Severe hazards are not presently forecasted accurately enough
- **Main meteorological hazards** to be addressed in **FLYSAFE**
  - Clear air turbulence
  - Wake vortices
  - Thunderstorms
  - **In-flight icing**
  - Routine weather products such as
    - Volcanic ash
    - Significant weather
    - Poor visibility
    - Tropical cyclones

FLYSAFE: Aircrew Awareness



Picture credits to **A. Tafferner, DLR**

Example of two different hazards

Information in NG ISS:

- **fusion with on-board weather data,**
- **prioritisation**

FLYSAFE: In-flight Icing Hazard

- **ICE Weather Information Management System** (ICE WIMS) will provide **intensity of icing hazardous areas**

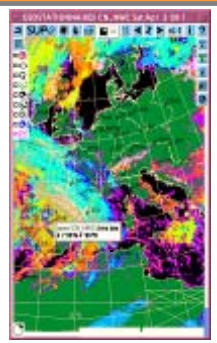
- **Three scales** for different uses and needs

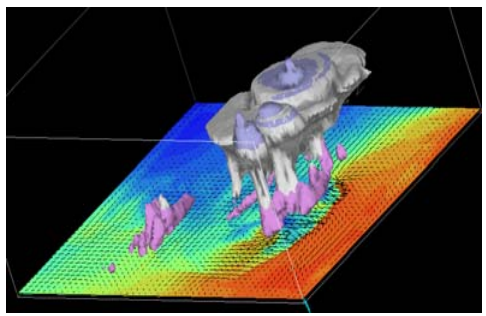
Scale	System	Horizontal resolution	Refresh rate
Global	**UK Met Office** ***Unified Model***	**40 km**	**6h**
Continental (Europe)	**Hannover University** ***ADWICE***	**7 km**	**1h**
Local (TMA)	**Météo-France** ***SIGMA***	**1 km**	**15 min.**

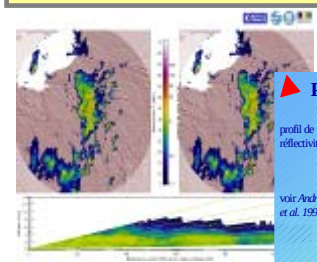
Evolution… to the New Algorithm

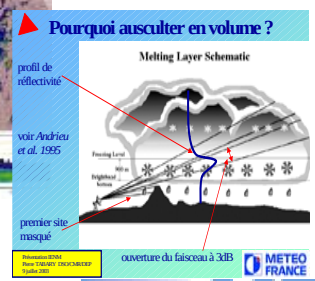
In-flight ICING

Satellite	***Numerical model***	***Ground Weather Radar***	**OLD**
Meteosat-7 ***Cloud-Top IR Temperature*** *6 km resolution*	**ARPEGE Model** ***French Icing Index*** *25 km resolution*	**2D composite** ***Precipitation occurrence*** *1 km resolution*	
Meteosat-8 & 9 ***Icing Cloud Product*** ***Cloud Top Pressure*** ***Cloud Types*** *4 km resolution*	**AROME Model** ***High resolution*** ***Cloud identification*** ***Microphysics*** *2.5 km resolution*	**3D composite** ***Precipitation occurrence*** ***Microphysics (polar.)*** ***Melting layer altitude*** *1 km resolution*	**NEW**





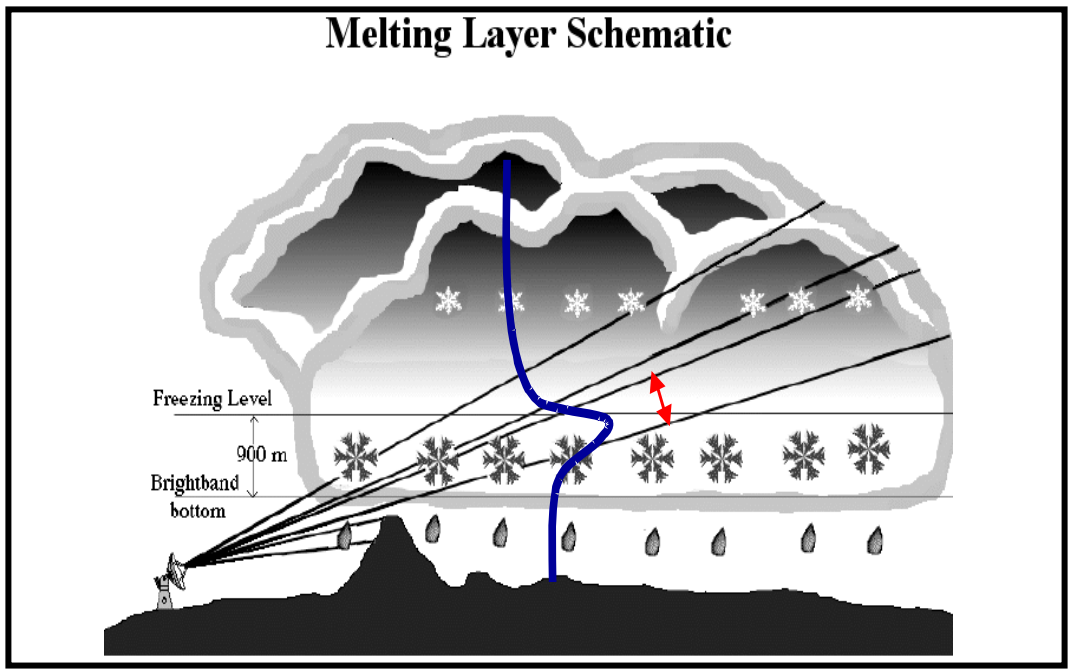




Evolution… to the New Algorithm

Ground Based Weather Radar

- Melting Layer Identification
  - 0°C altitude
  - Melting Layer Identified : Mixed Layer
  - No Melting Layer : convection, supercooled rain



Evolution… to the New Algorithm

Ground Based Weather Radar

- Precipitation occurrence : increases icing potential risk
  - Precipitation scavenging dominates the aerosol removal processes: ~80% of total aerosol removal

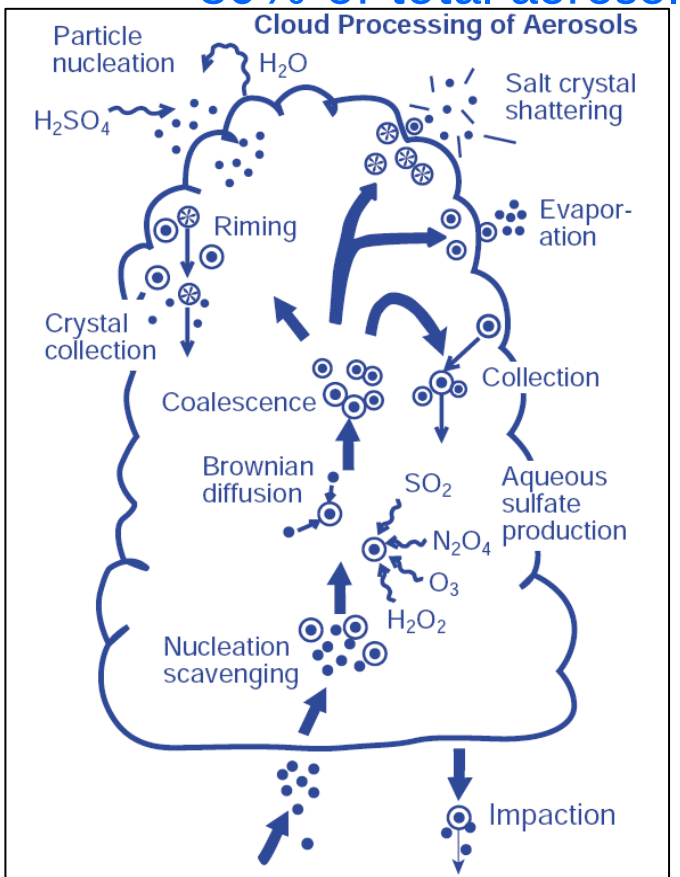


Figure 1. A schematic diagram of the in- or near-cloud processes that can alter the aerosol size distribution.

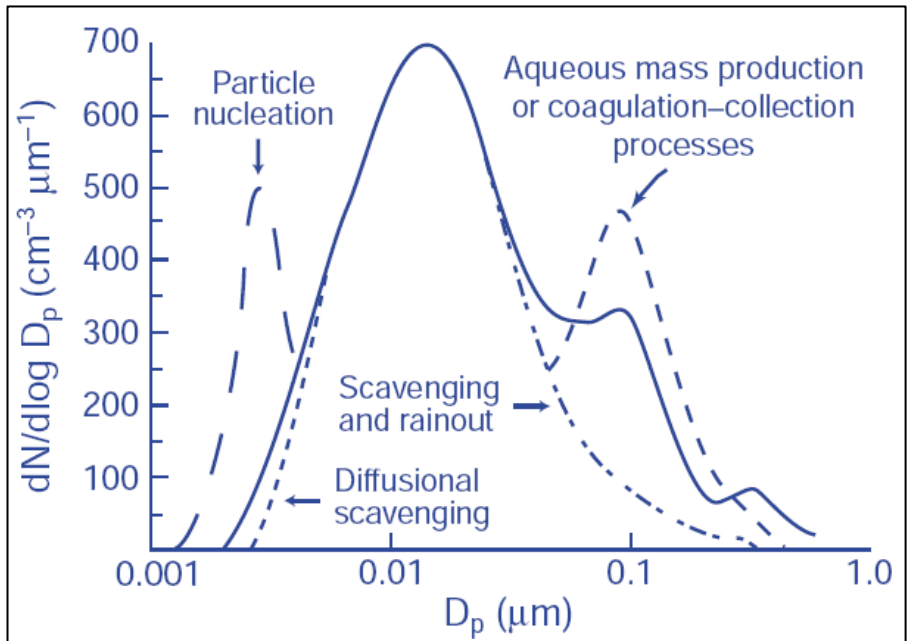


Figure 2. A qualitative schematic illustrating the impact of the various processes discussed in the text on the aerosol size distribution. The magnitude of the individual effects will be scenario dependent and could be either substantially larger or smaller than those shown here.

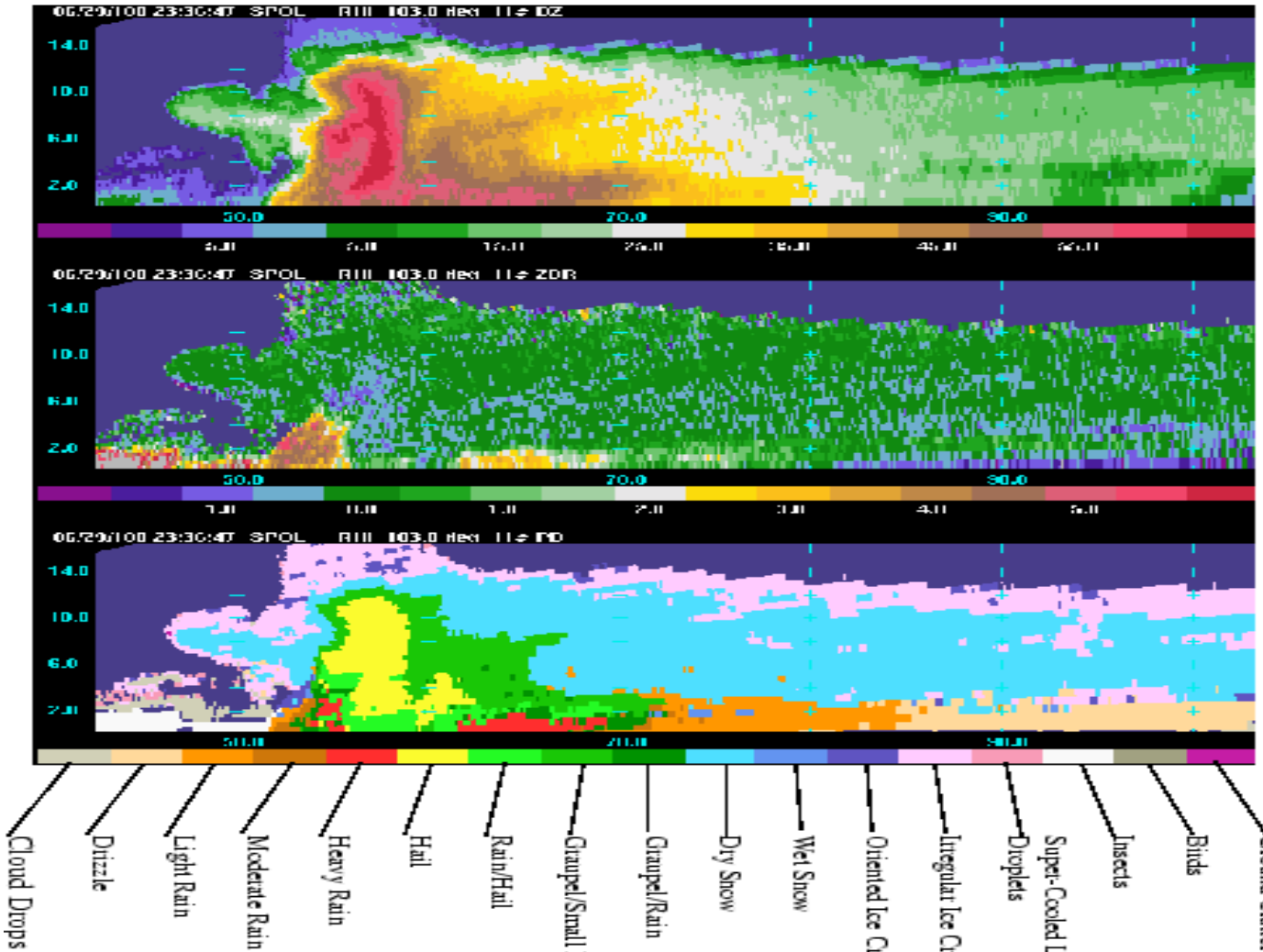
Source: Hegg, D. A. (U. Wash.)
The impact of clouds on aerosol populations

Evolution… to the New Algorithm

Ground Based Weather Radar

Polarimetric Information

Precipitation Typing, Microphysics



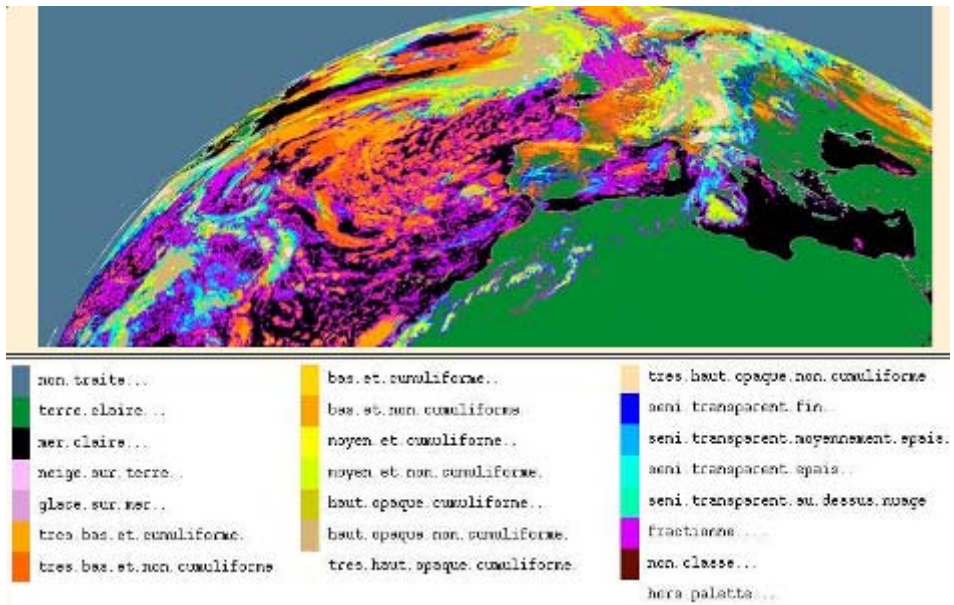
Evolution… to the New Algorithm

Advanced multi-channels Meteosat geostationary satellite products

- Cloud Types
  - Convective areas
  - Non-cloudy areas
  - No icing risk clouds
- Icing Clouds (NCAR algorithm)
  - High probability of icing
- Cloud Top Pressure & Temperature
  - Identify top of cloud layer
  - Eliminate too warm clouds

➢ 4 to 9 satellite channels

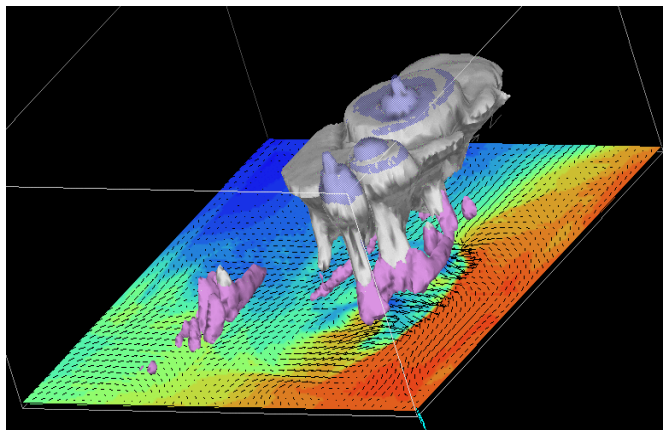
➢ Various Numerical model forecast fields



Evolution… to the New Algorithm

New high-resolution numerical weather prediction models

- AROME Meteo-France new high-resolution model
  - Operational in 2008
  - 2.5 km horizontal resolution over France
  - Forecast output : 1h time step
  - Explicit cloud microphysics
    - Prognosis of hydrometeors



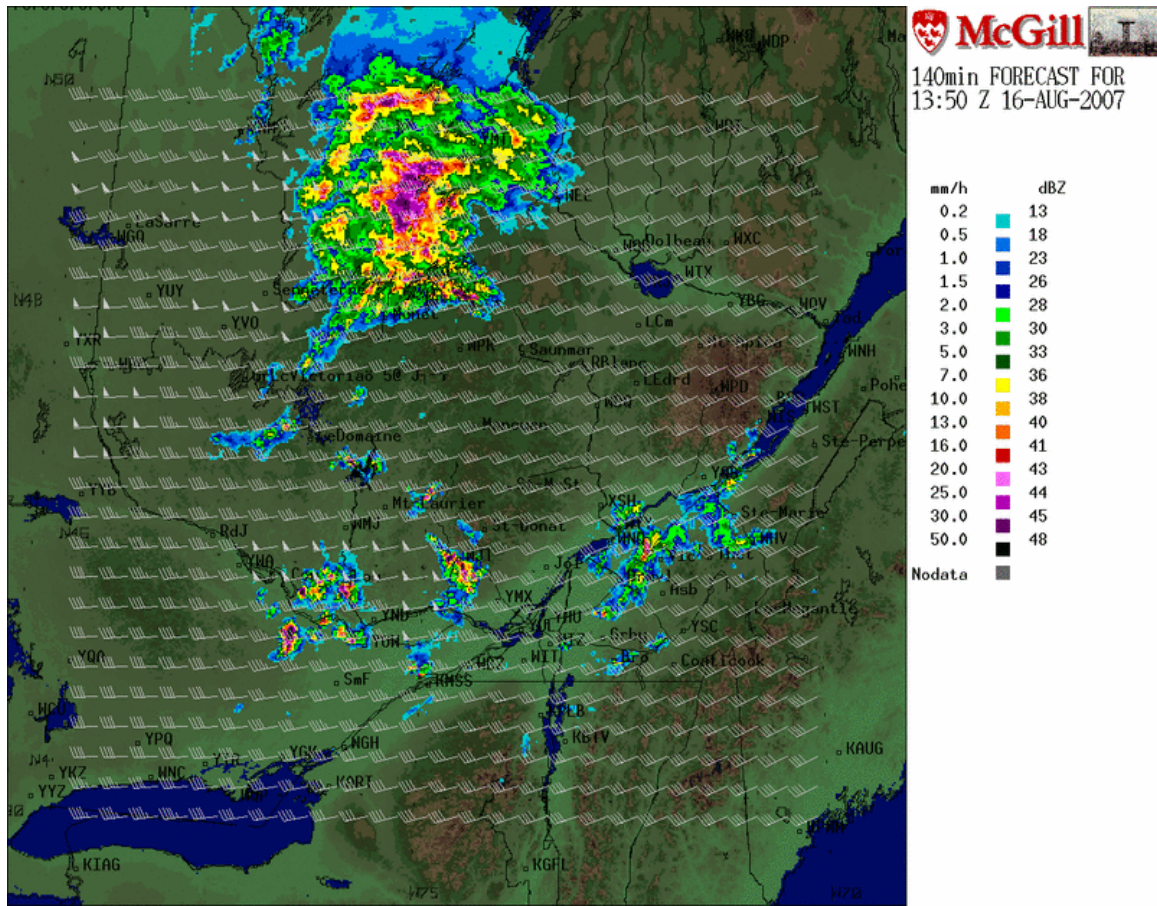
- Better spatial and temporal resolution matching with satellite and radar data
- Better representation of mesoscale features
- Radar and satellite data helps to correct for defaults in model convective assessment at mesoscale

Evolution… to the New Algorithm

- From Diagnosis to Forecasts ?
  - Example: Extrapolating Radar Echos example: MAPLE system (McGill Radar)

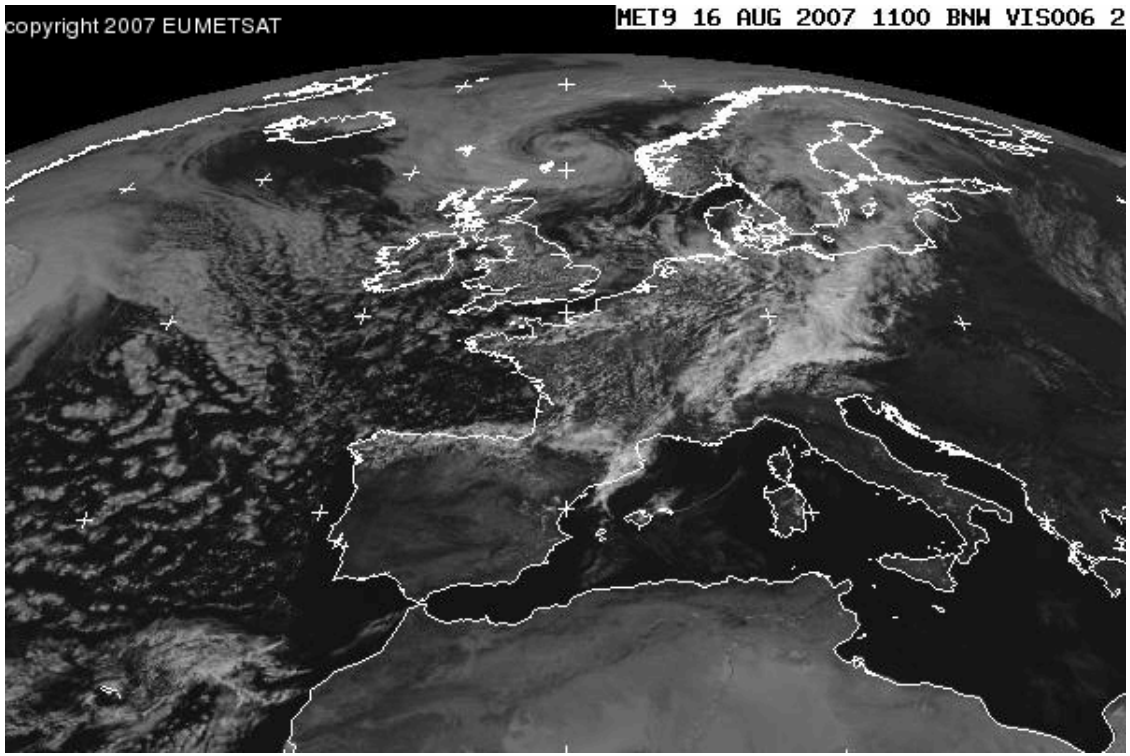
Variational Echo Tracking

Semi-Lagrangian Advection



Evolution… to the New Algorithm

- From Diagnosis to Forecasts ?
  - Extrapolating Satellite Images or Channels
    - Still very experimental
    - More research is needed…



Conclusions

- The methodology is giving **good results**
- Icing diagnostics: will be **sent directly to aircrew** and Air Traffic Controllers (FLYSAFE)
- **Improvements**: Better spatial and temporal resolutions of the products thanks to new technologies
- **More validation data** will be needed to assess correctly the new upcoming algorithm version

Questions ?