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# Application of *Research* to *Operations* at *Mesoscale*



Arome-team

Speaker Gwenaëlle Hello (Météo-France)

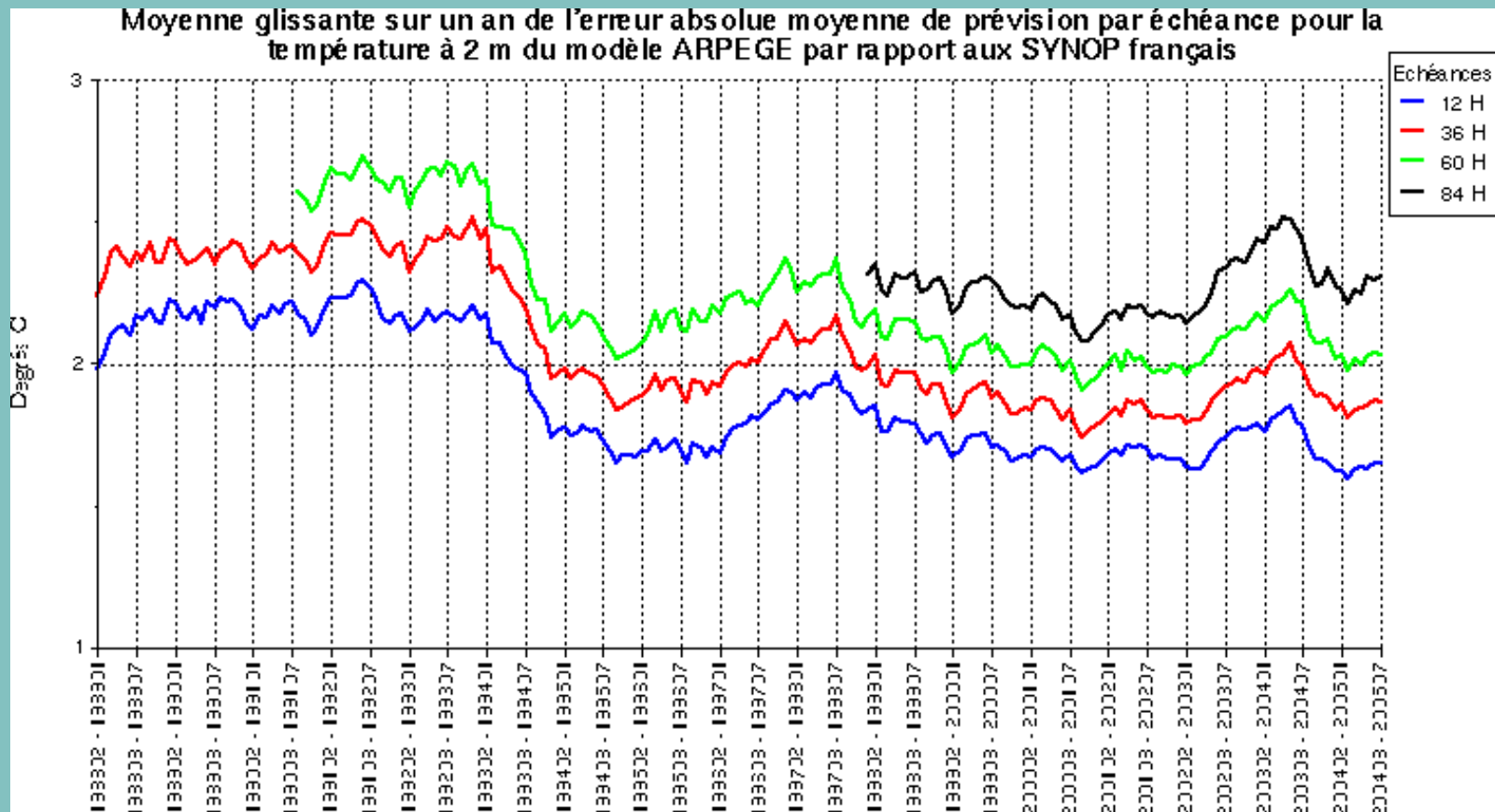


# CONTENTS

1. The context
2. Overview of the project history until now
3. Current status
4. Overview of the training course

# The internal context

## *Meteorological improvements*



# The external context

*more weather-sensitive populations & infrastructures*

## L'A7 et l'A8 coupées, l'A9 sous un mètre d'eau et des routes impraticables

► "On a rarement connu une telle situation dans la région. L'état des routes nationales et départementales est tel, que nous ne pouvons pas faire dé-

La seule alternative en attendant une amélioration étant de réduire au maximum le flux pour parvenir à libérer l'auto-route. Sur la radio Trafic FM



puis dimanche soir 22 heures), jusqu'à Salon - avec déviation vers l'A54 - et l'A9 coupée entre Orange et Nîmes-Ouest vers Montpellier.

Noyée sous un mètre d'eau à hauteur de Nîmes, l'A9 a fait vivre des heures terribles aux automobilistes, bloqués sur 16 km de bouchons dans

leur de Bonnic-Avignon, 80 (Nîmes-Ardèche), 106 (Alès-Nîmes), 110 (Alès-Montpellier), et 580 (Avignon-Bagnols). Il en était de même pour de nombreuses routes départementales des Bouches-du-Rhône dans le secteur de Tarascon, Saint-Rémy de Provence et Châteaurenard. Dans la soirée, les axes autoroutiers ont été progressivement

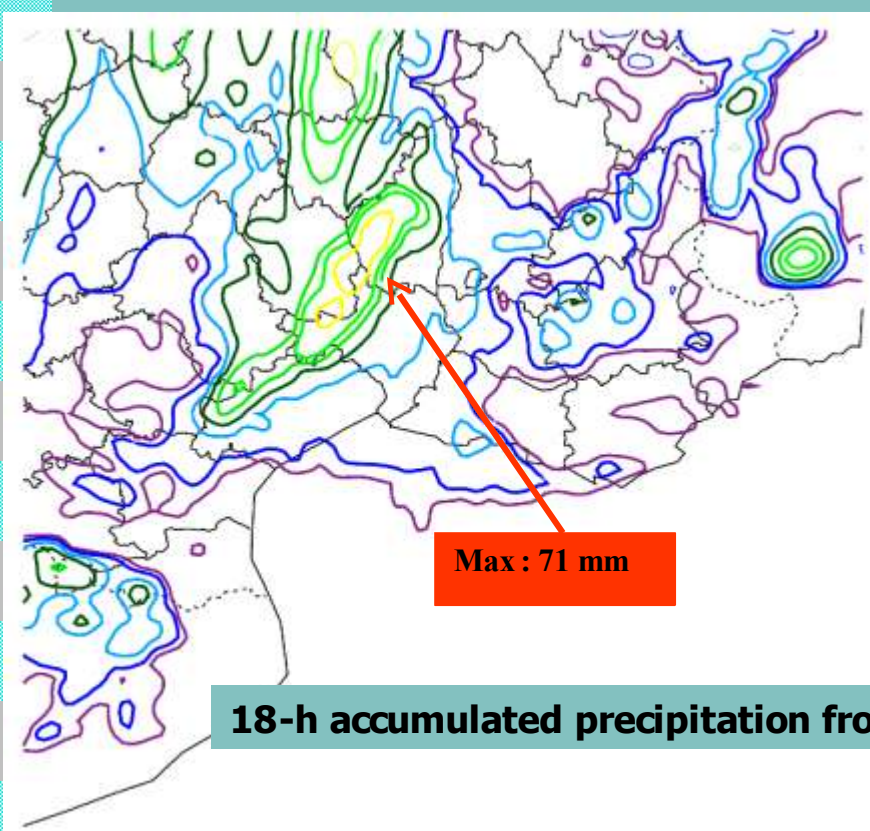
# ■ The demands on NWP products

- Continuous improvements on the accuracy of the forecasts imply different users requirements
  - More accuracy on the NWP products (for extreme events → civil security)
  - More diversity of the external applications (chemistry, hydrology, air pollution, ...)

# The scientific context

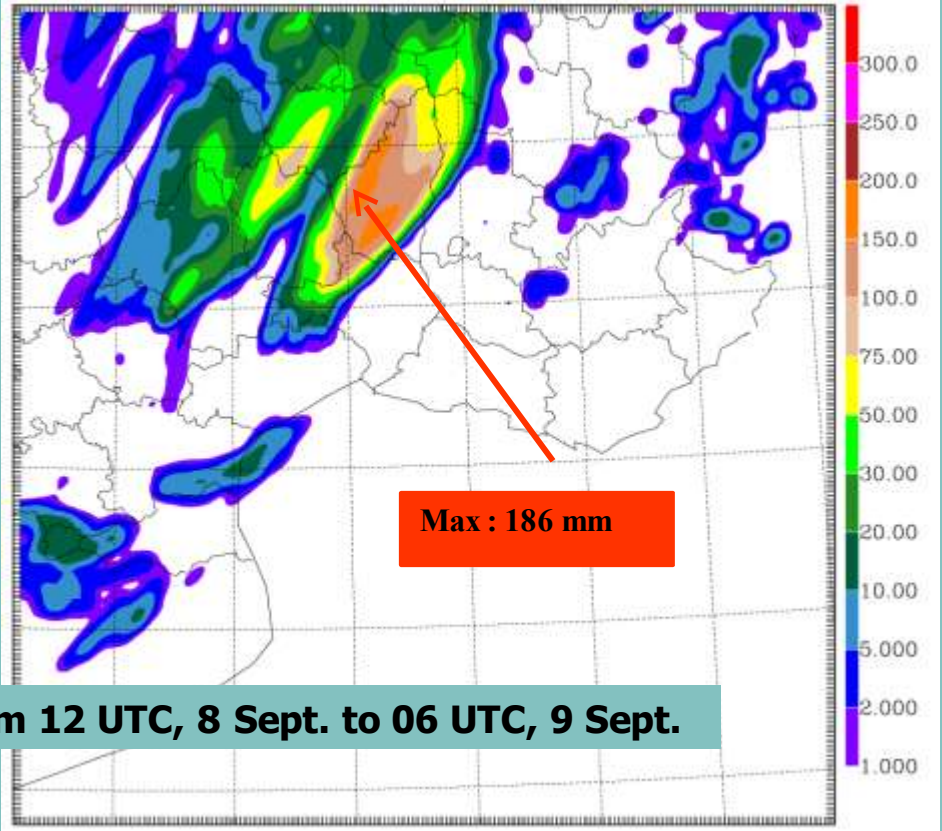
- To meet such kind of demands → new generation of NWP models are needed:
  - Working at horizontal scales where convection is explicit « Cloud Resolving Model »
  - Where there is still expensive physical parametrisations such as « microphysics »
  - Where data assimilation is of a new kind speaking in terms of data and algorithms (moisture, balance not simple ...)
  - Where the gap between radar-satellite based nowcastings products & NWP ranges – scales could be filled.

# Modelling at mesoscales



18-h accumulated precipitation from 12 UTC, 8 Sept. to 06 UTC, 9 Sept.

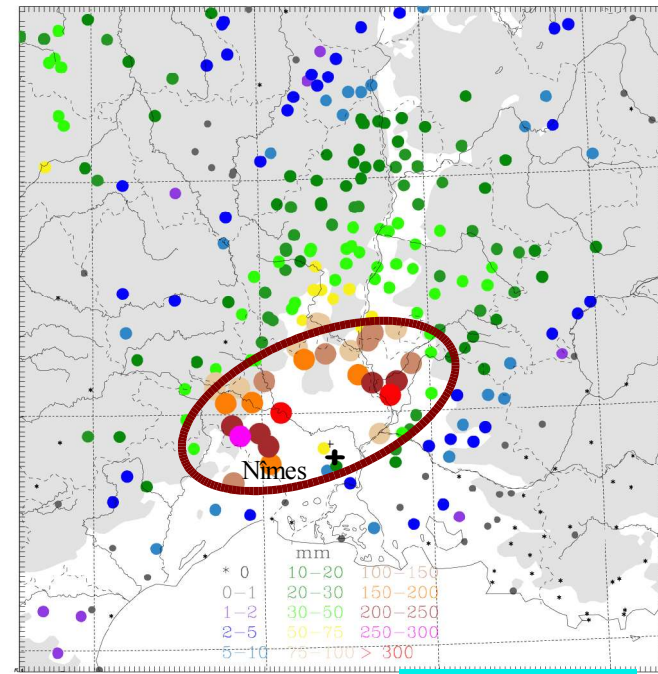
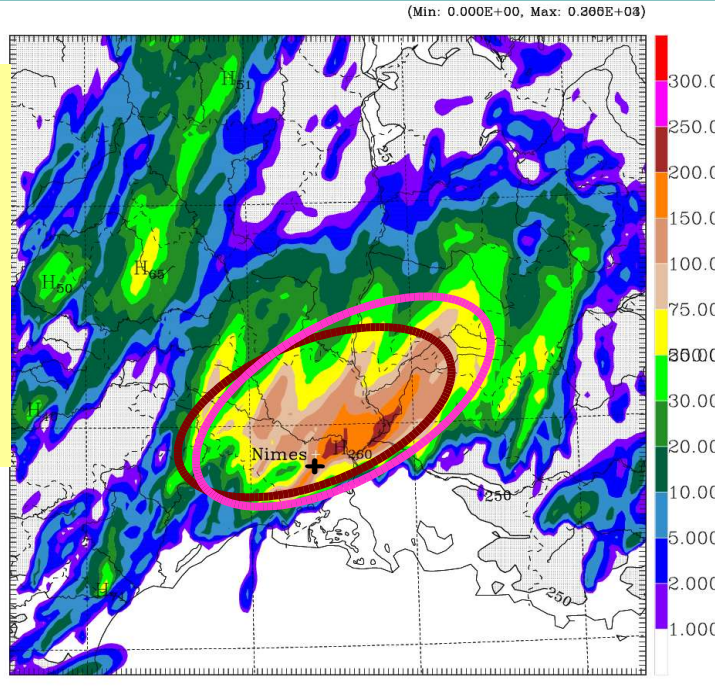
Aladin-France 10 km resolution explicit & parametrized precipitation



Méso-NH 2,5 km explicit precipitation averaged over the Aladin-France grid-mesh

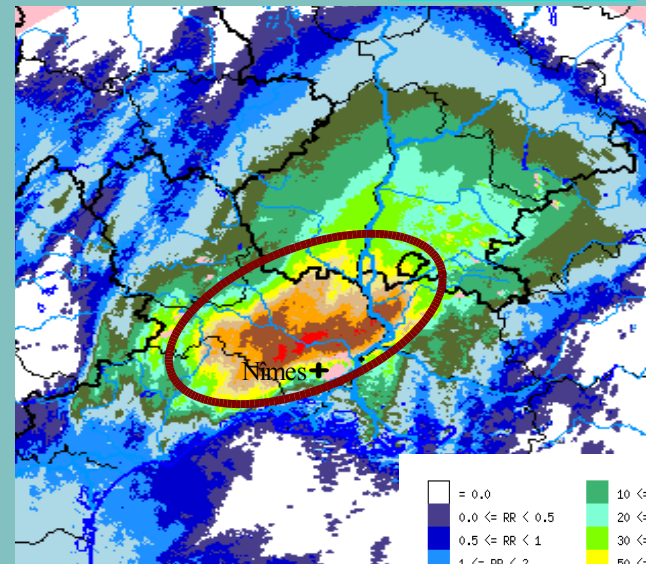
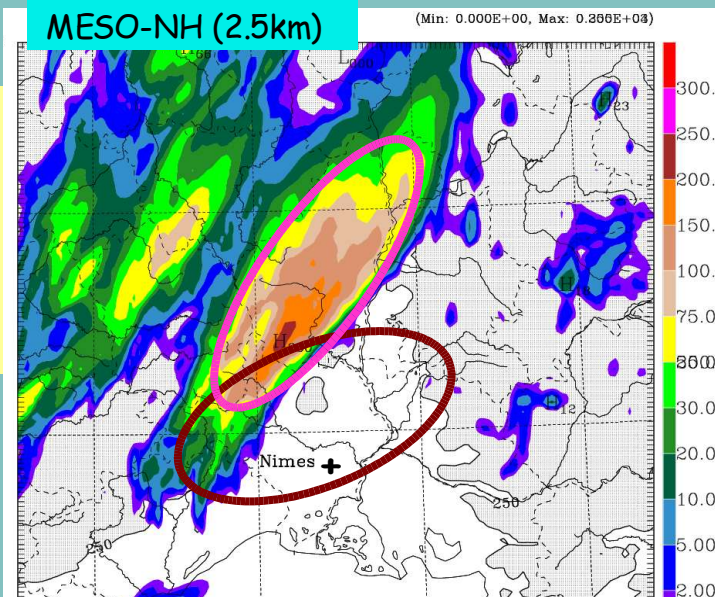
# TESTING OF MESOSCALE ANALYSIS IMPACT (V. DUCROCQ, DEC 2004)

Initial conditions : mesoscale analysis (surface obs, radar, satellite) for 12UTC, 8th Sept. 2002



Raingauges

Initial conditions : large scale ARPEGE analysis for 12UTC, 8th Sept. 2002



Observations

Ducrocq et al, 2003

Nîmes radar

12-h accumulated rainfall from 12 UTC, 8 Sept to 0 UTC, 9 Sept 2002





# The technical context

- Mesoscale data more or less available (radar, MSG, GPS, METOP, ...) → 3/5 km  
15 mn, water cycle
- Mesoscale ingredients (dynamical core & physical packages) exist in the research community
- Expensive computing cost : Grid point X 3 (« science cost ») resolution X  $\approx 20$

# ■ The international context

- Competing projects in US (WRF), Germany (LM), UK, ...
- Improvement of global resolution models (with appropriate physics also)
- A strong habit to work together in a « network spirit » on LAM developemnt in Aladin & Hirlam.

# History of Arome

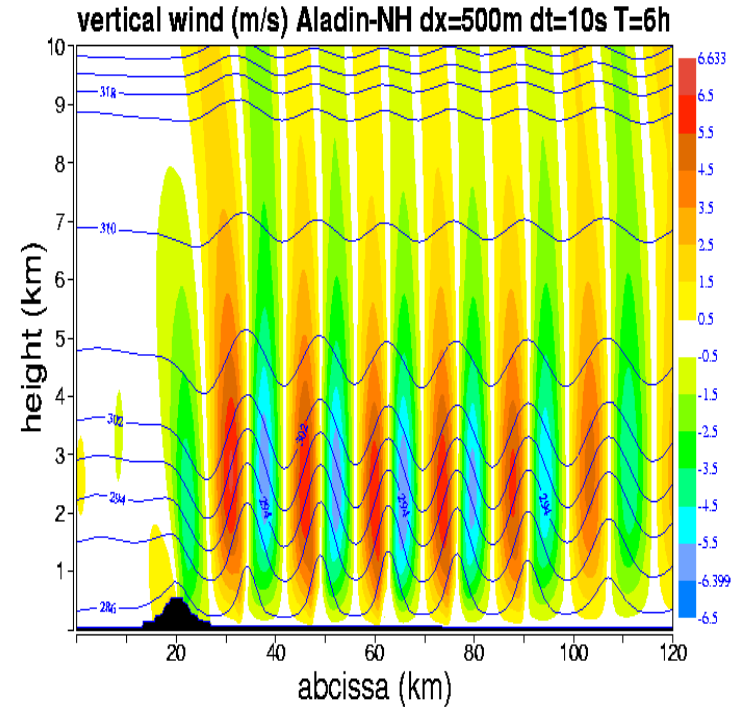
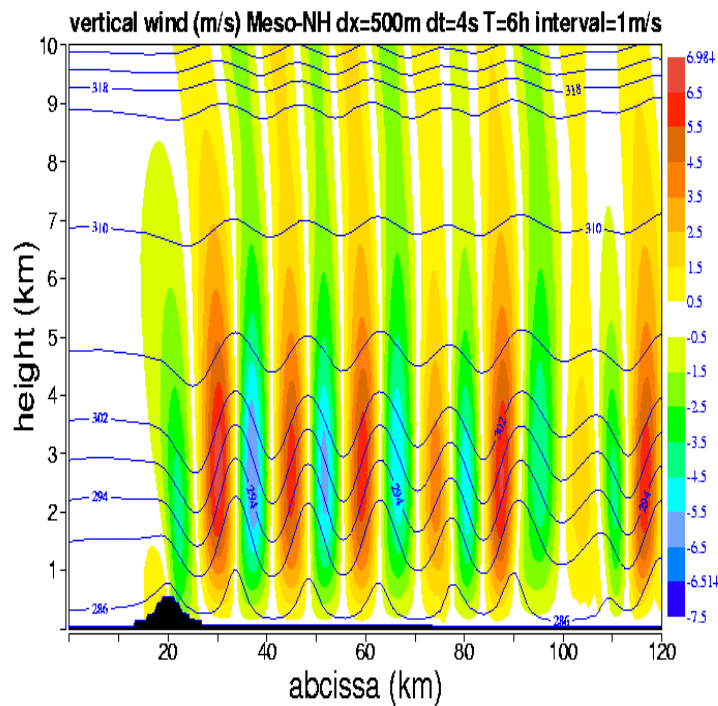
- Phase 0: 2000-2001, the « meso project »
  - Intense brainstorming organized in thematic sub-projects providing guidelines to choose the ingredients for the system
    - Da
    - Dynamics
    - Chemistry
    - Coupling
    - Physics
    - Surface
    - Software aspects
    - ...

# History of Arome

- Phase 1: 2001 → CIPN02 (December 2002)
  - Change of naming: meso → Arome
  - Tests & validation in order to make the key decisions
  - Special staff appointed
  - Developpement of tools to ease the research in an Arome-oriented way (hybrid assimilation, « arotools », ...)

# History of Arome- intercomparison of dynamics

*Bouttier, Stein and Bénard 2002*



C: Aladin-NH & Méso-NH of same quality but Aladin-NH is more efficient (allow longer time-steps)

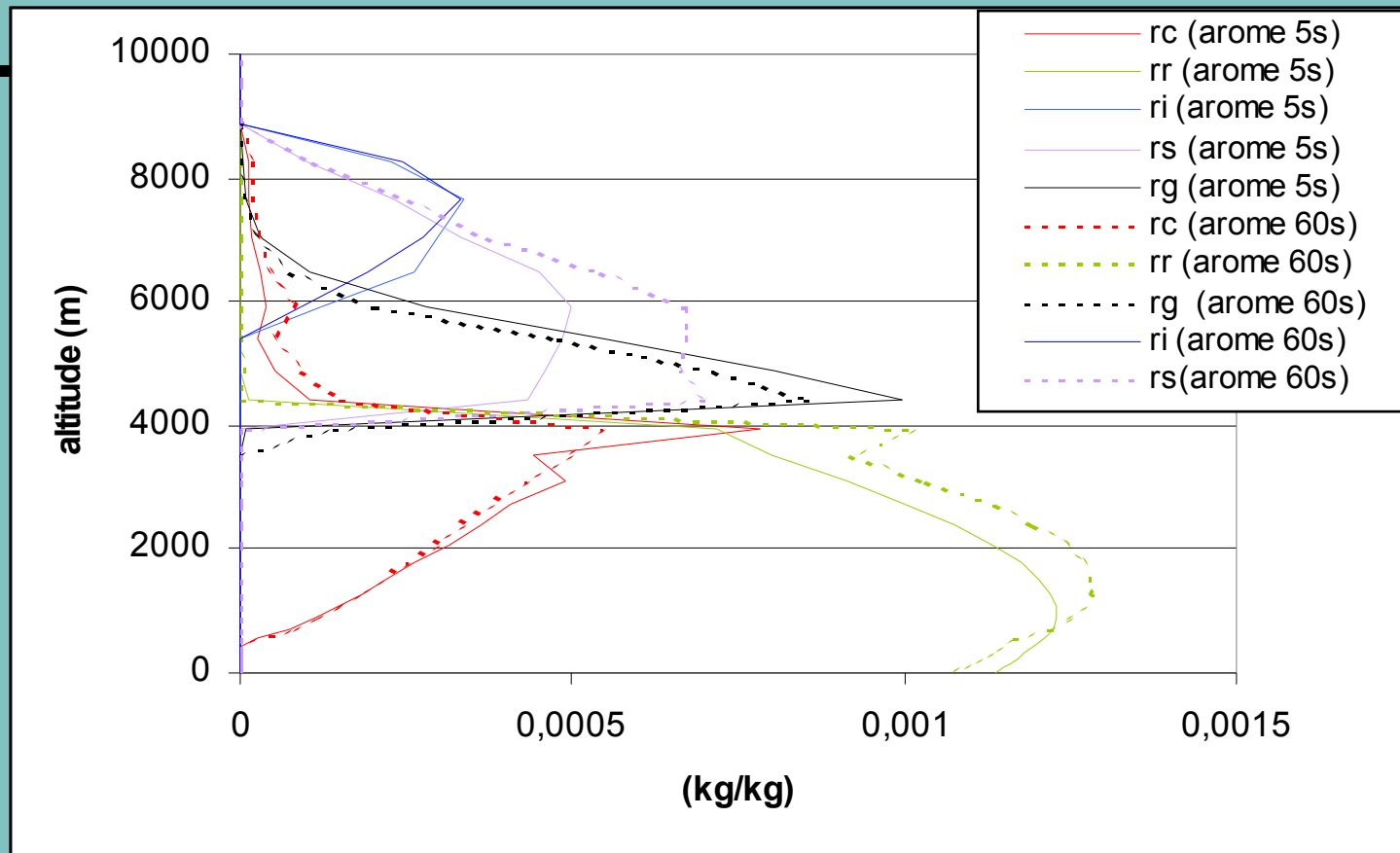
# History of Arome

- The key decision of december 2002
    - Choose Aladin-NH as Arome's dynamical core for Arome, consequences:
      - IFS/Arp/Ald is used as software basis for Arome
      - Ald 3DVar is used as basis for Arome's analysis
      - Import Méso-NH suitable physics
- *Prototyping could start*

# History of Arome

- Phase 2: 2003-2005
  - The Arome prototype
  - Enlargement to international issues, Aladin-2 and Alaro
  - « Arome-0 », i.e. the Aladin-France 3dvar is operational considered as a very first step to the arrival of Arome in operations

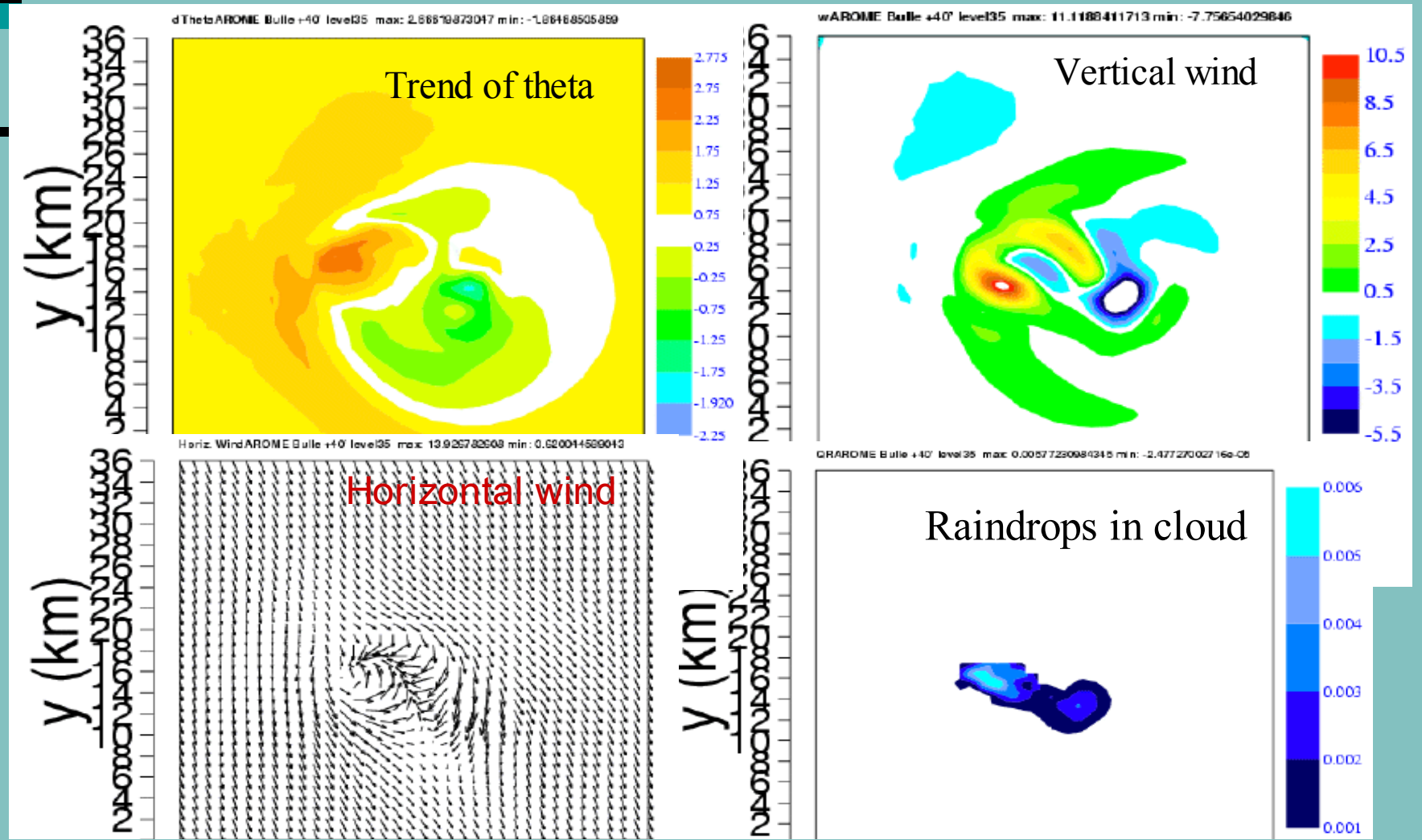
# 1D-tests Méso-NH microphysics



C: no loss of accuracy until  $dt=1$  mn, need to call physics at  $t-dt$



# 3D-academic with Radiation + microphysics +



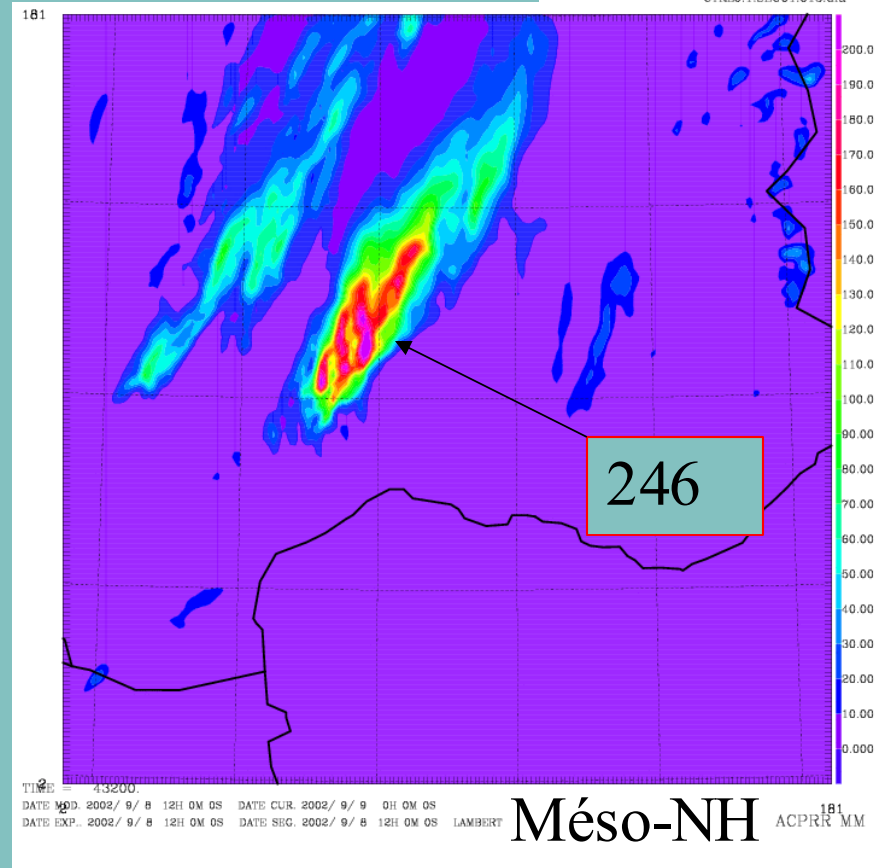
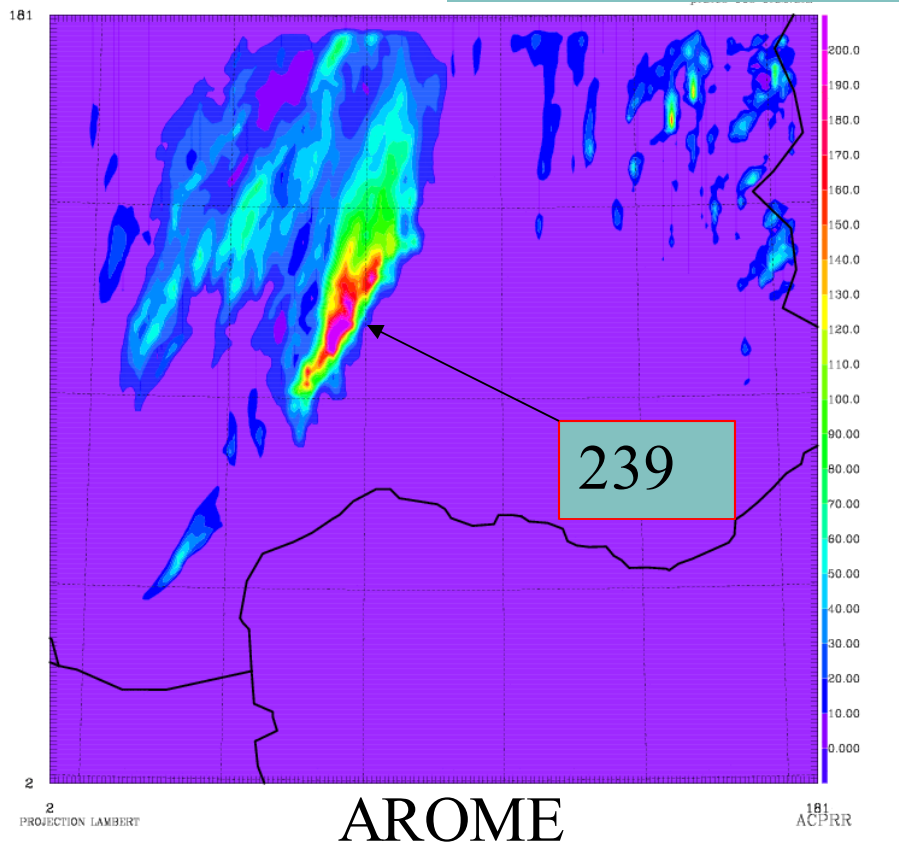
Test-run: fully 3D case with physics, an academic convective cloud at 1-km resolution (compares well with MésoNH, with 4x longer timestep)

# 3D-real case (+ surface scheme) comparison of Méso-NH and Arome

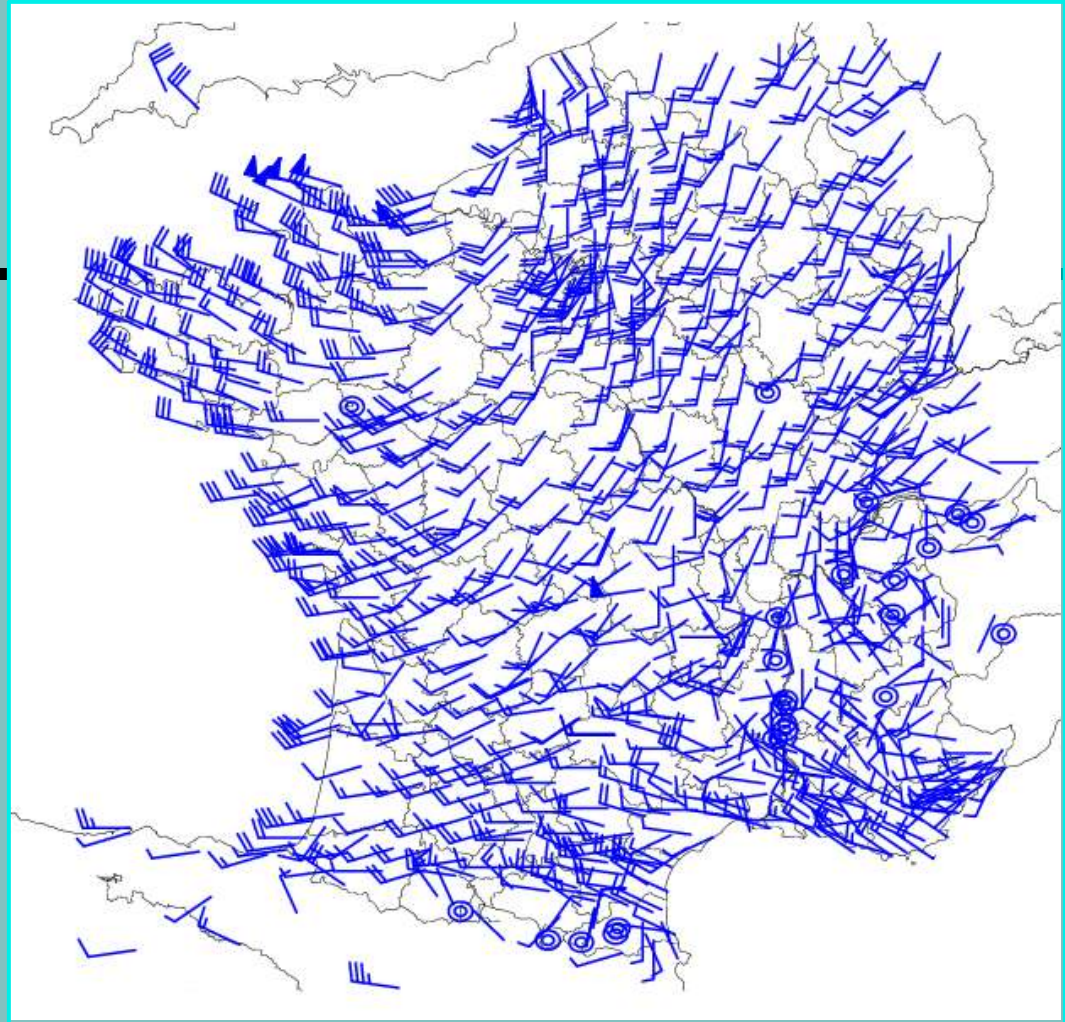
12 hours accumulated rain from 080902  
12UTC (« Gard case »)

HORIZONTAL SECTION NINP= 2 NISUP=181 N

2 NJSUP=0180E+00 07/07/01 14H01M47  
CINP=0246E+00 CINC=0138E+00



Hourly surface network:  
Not really useful for  
global DA but for LAM



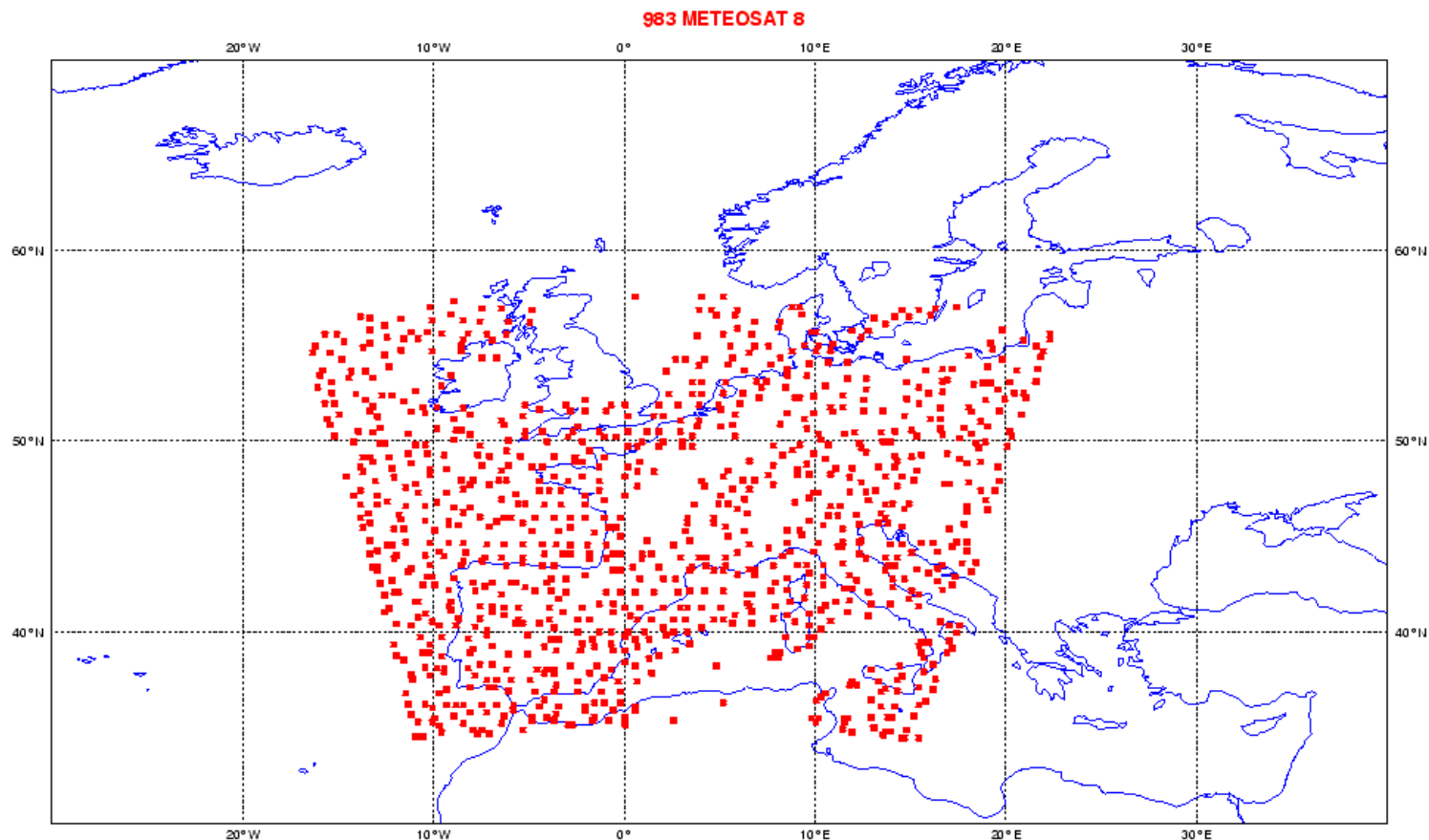
Observations BDM  
(SYNOP+SYNOR+RADOMEH)

17 décembre 2004, 12h UTC

# METEO-FRANCE couverture de donnees - SEVIRI Lannion

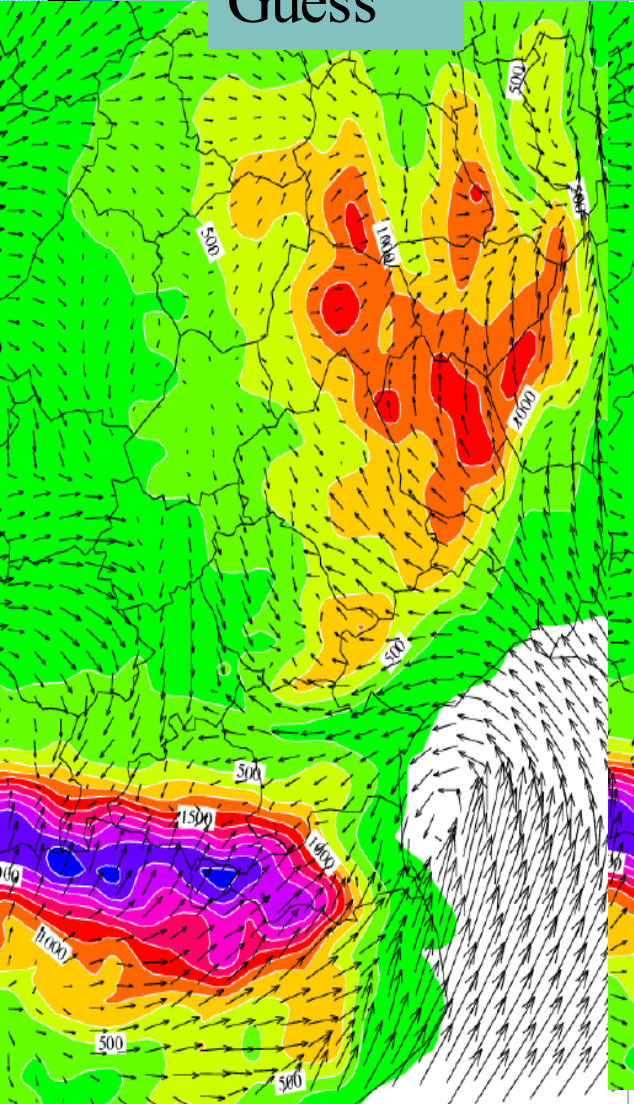
2005/09/12 00H UTC cut-off long

Nombre total d'observations apres screening : 983

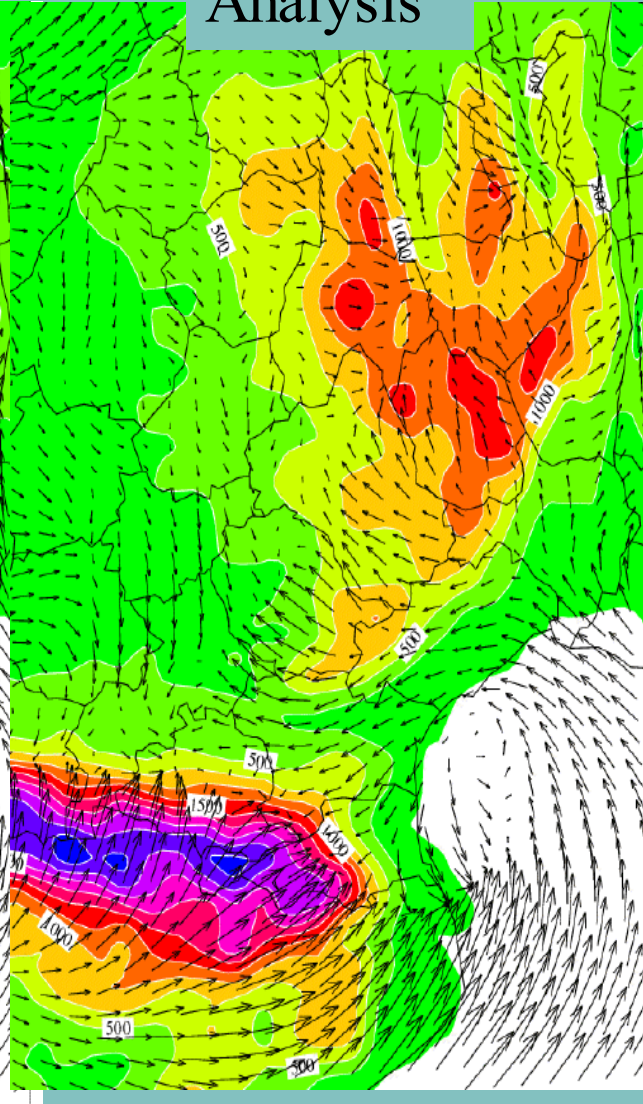


# Ex. of 10m wind in ALADIN-10km

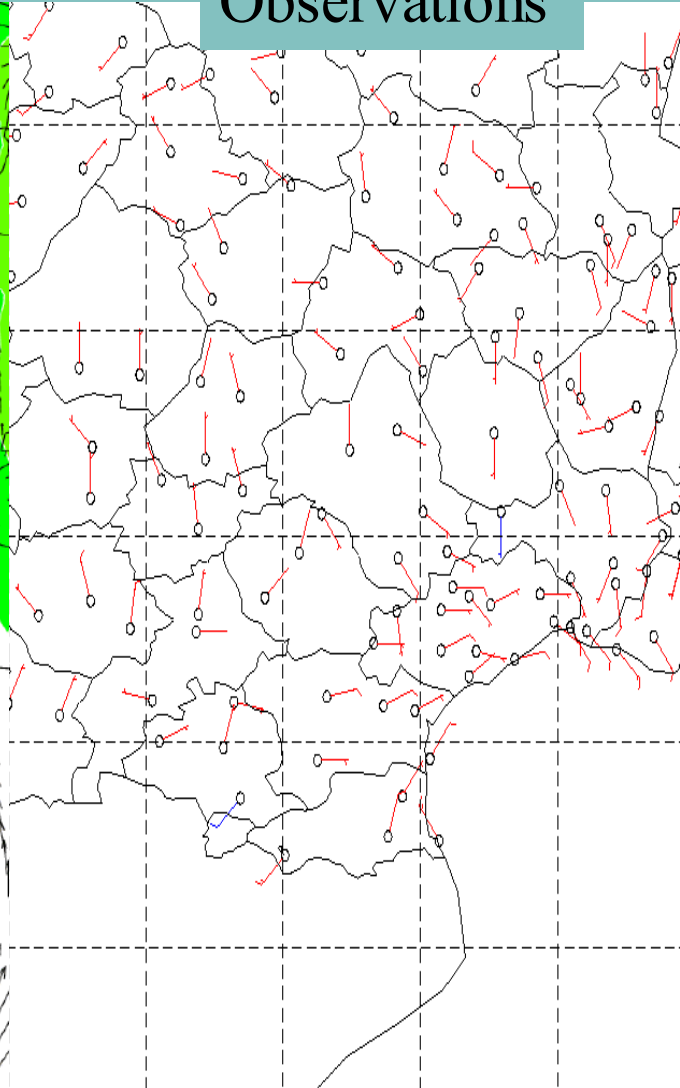
Guess



Analysis



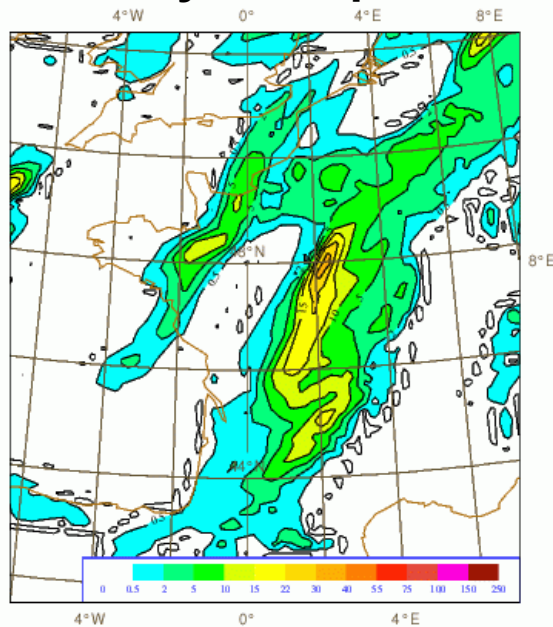
Observations



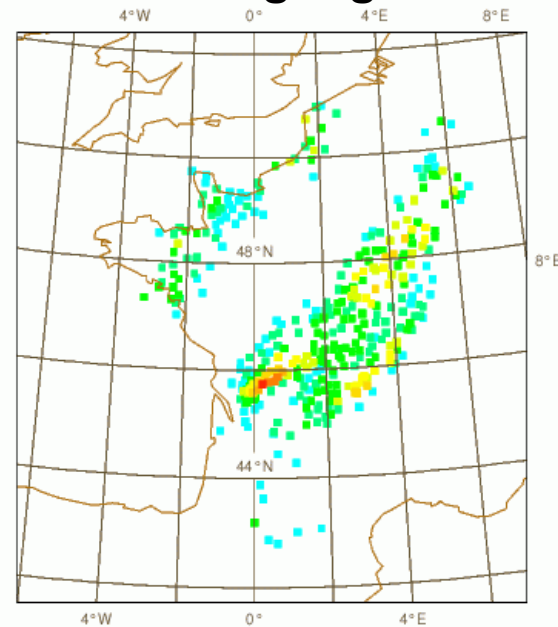
# Impact study : Precipitation forecast

2004/07/18 12UTC  
RR P12 – P6

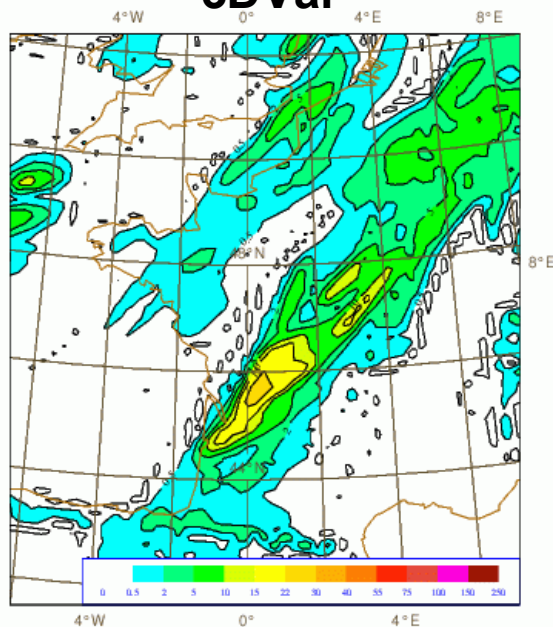
### Dyn. Adapt.



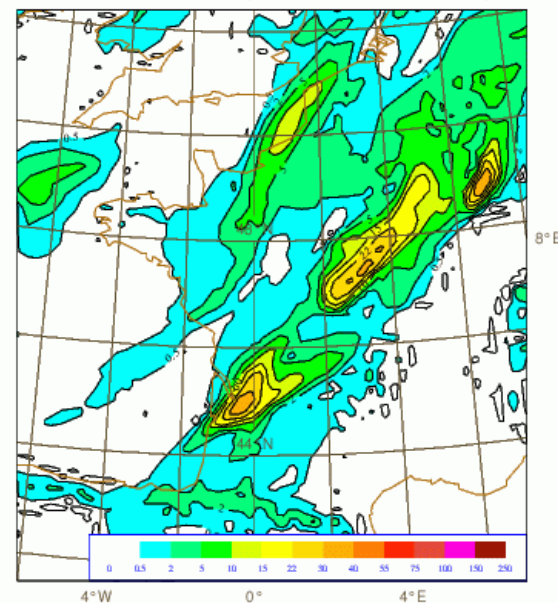
### Raingauges



### 3DVar



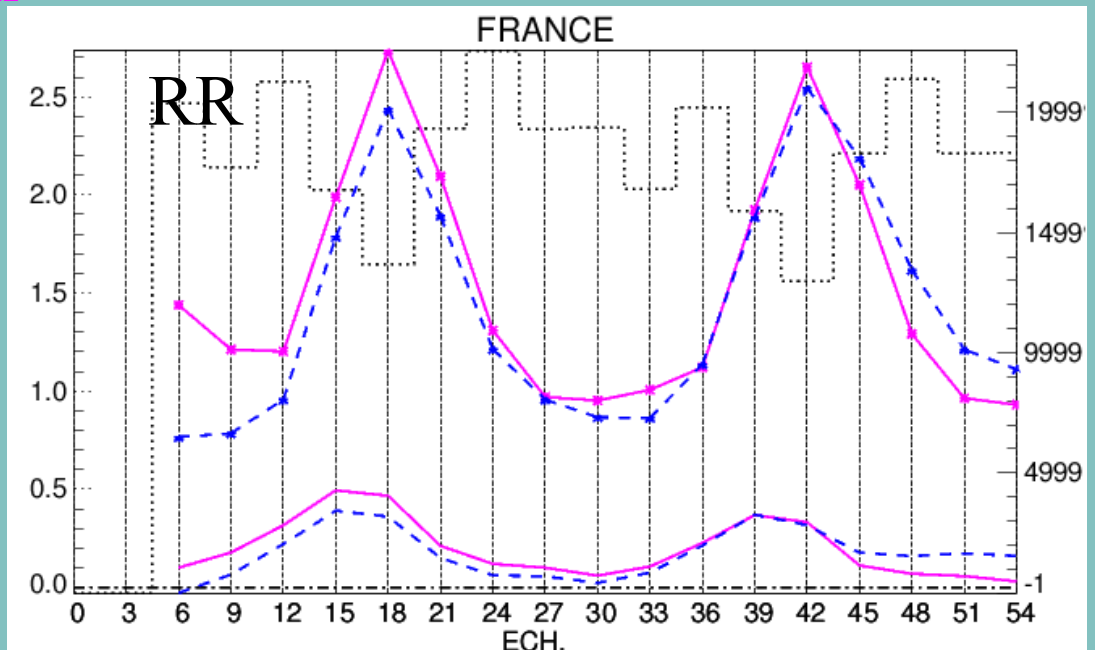
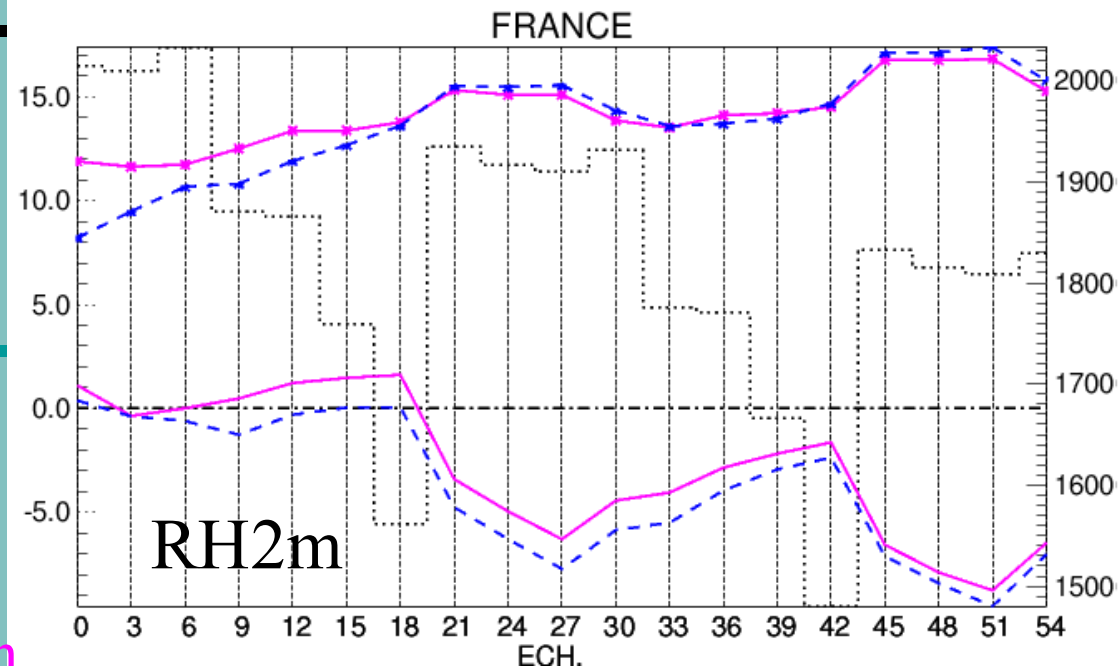
### 3DVar with SEVIRI



# 3D-VAR scores

bleu: Aladin 3DVar  
violet: dynamical adaptation

top: RMS  
bottom: biais



# Specificities of a mesoscale assimilation

- Requires very good analysis of moisture and low-level atmosphere
- AROME assimilation is a high-resolution version of ALADIN 3DVar-FGAT algorithm including all ARPEGE/ALADIN assimilation features
- Much higher resolution of model and observations, at high frequency
- Use radar and satellites to initialize prognostic cloud variables (1D-Var retrievals of clouds)
- Situation-dependent  $J_b$  structure functions : transformed humidity variable in  $J_b$ , flow-dependent covariances



# ■ Test of a 2,5 km assimilation

- The Hybrid tool:
  - MNH model is used for the forecast & Aladin 3DVAR to compute the increments
  - An enhanced Jb is derived from the one of Aladin with
    - Finer horizontal length-scale (30 km)
    - Possibly more variance in the low levels

# 3D-Var corrections of wind and humidity from 110 SYNOP reports in a 150x150km domain

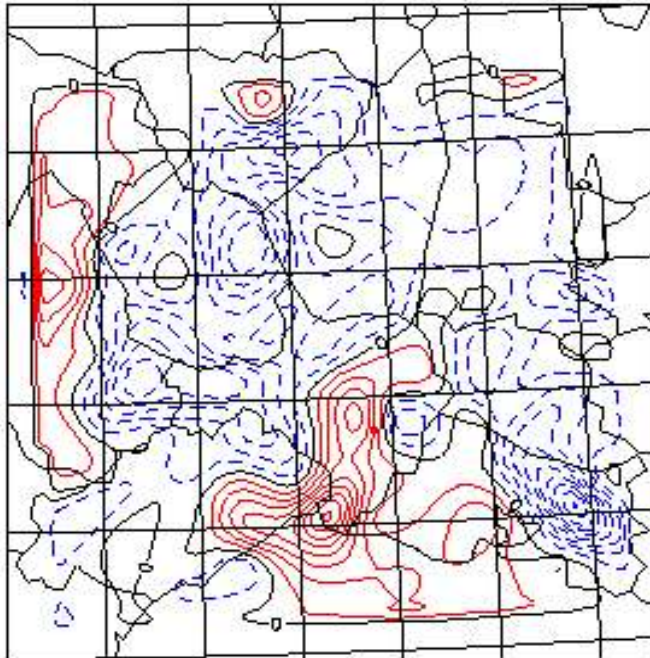
humidity

wind

lv33 Q\* 2002-09-08 12h exp:POS2

—— .0001 (.0004)

3°E 3.5°E 4°E 4.5°E 5°E 5.5°E 6°E 6°E

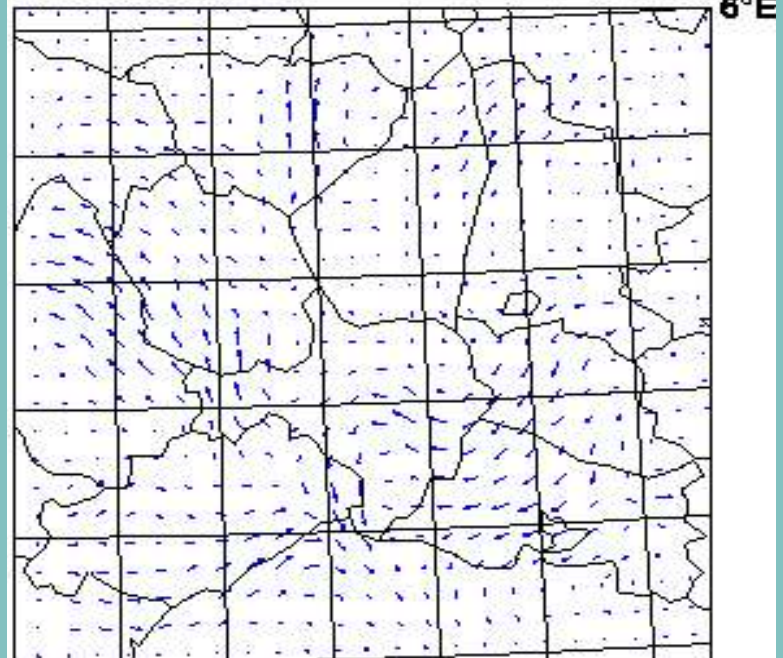


3°E 3.5°E 4°E 4.5°E 5°E 5.5°E

lv36 U/V\* 2002-09-08 12h exp:POS2

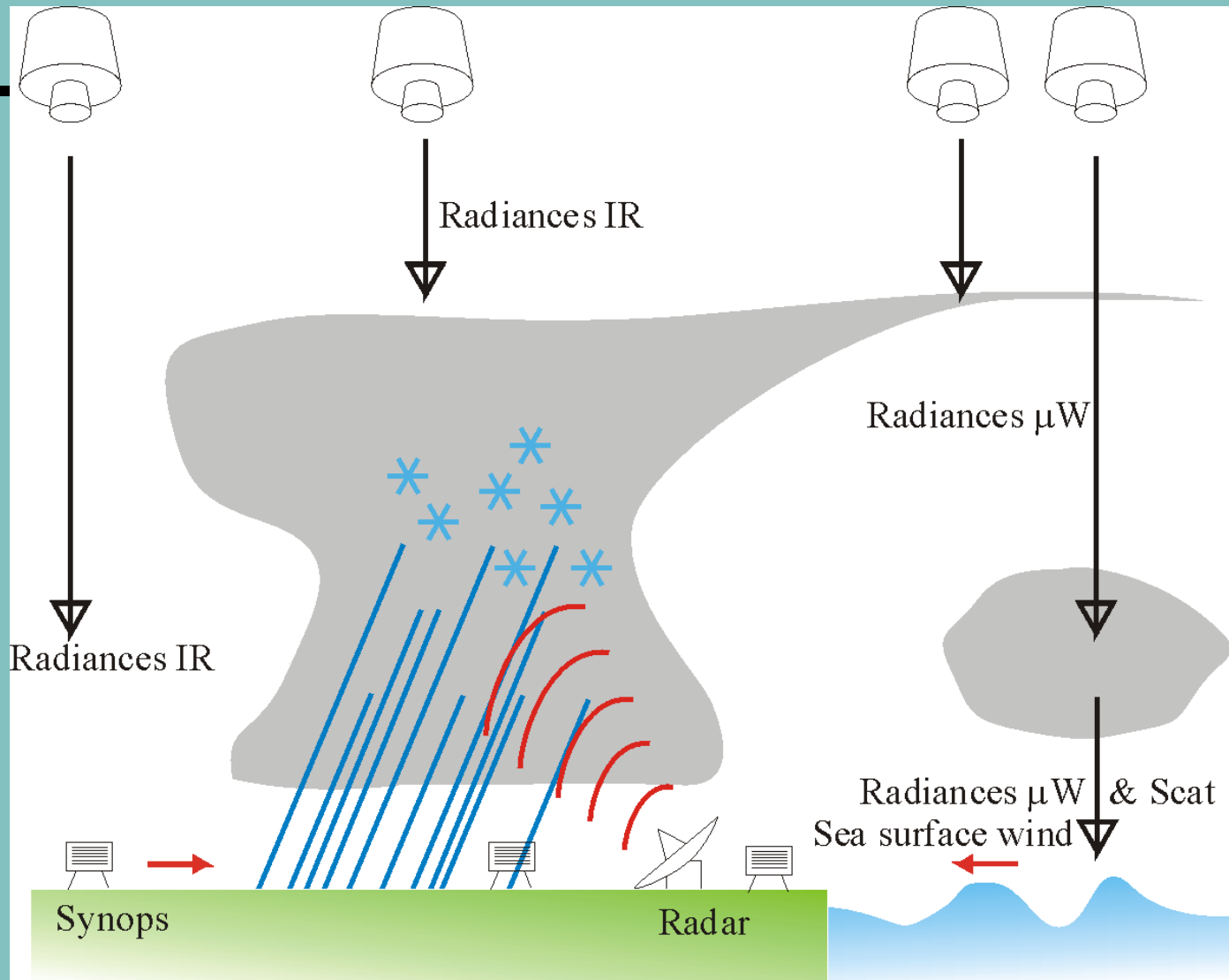
→ 20 m/s

3°E 3.5°E 4°E 4.5°E 5°E 5.5°E 6°E 6°E



3°E 3.5°E 4°E 4.5°E 5°E 5.5°E

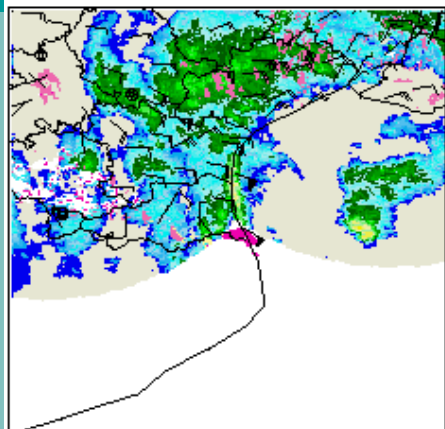
# Data for mesoscale assimilation



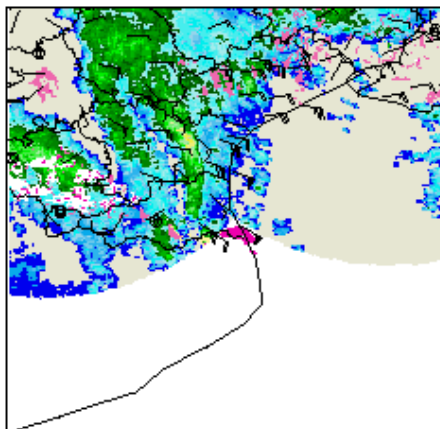
# Radar assimilation : observed and model-generated reflectivities

## OBSERVATIONS

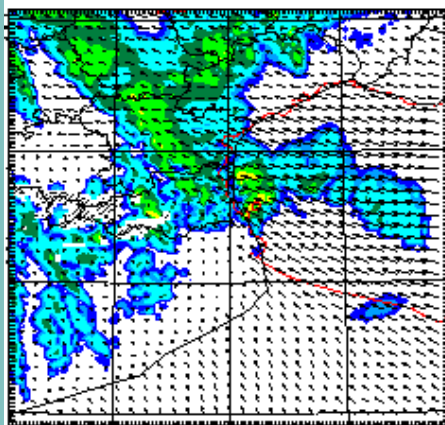
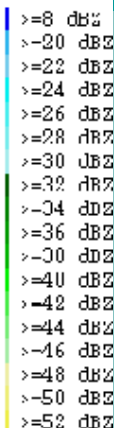
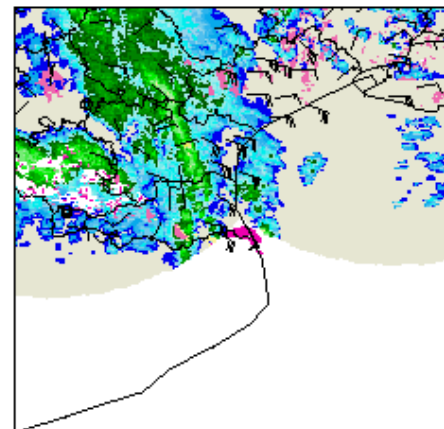
composite reflectivities at 15:45UTC  
10m-winds at 16:00UTC



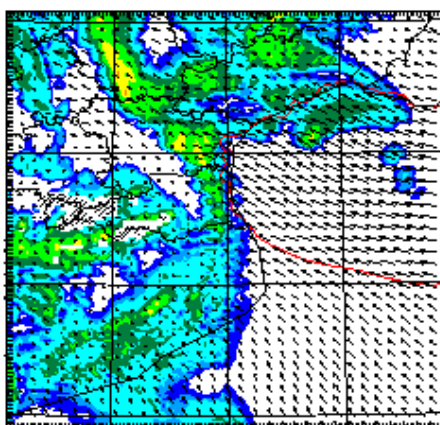
composite reflectivities at 18:45UTC  
10m-winds at 19:00UTC



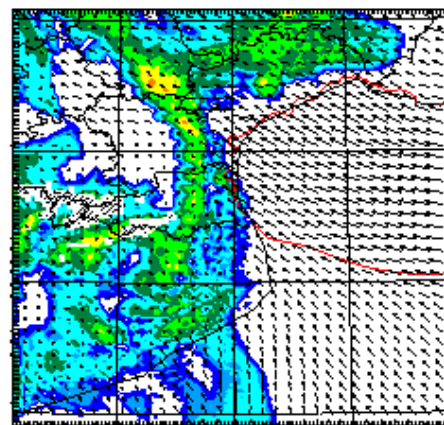
composite reflectivities at 20:15UTC  
10m-winds at 20:00UTC



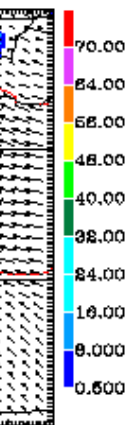
reflectivities at 2000m and  
10m-winds at 16:00UTC



reflectivities at 2000m and  
10m-winds at 19:00UTC



reflectivities at 2000m and  
10m-winds at 20:00UTC



— 30 kts

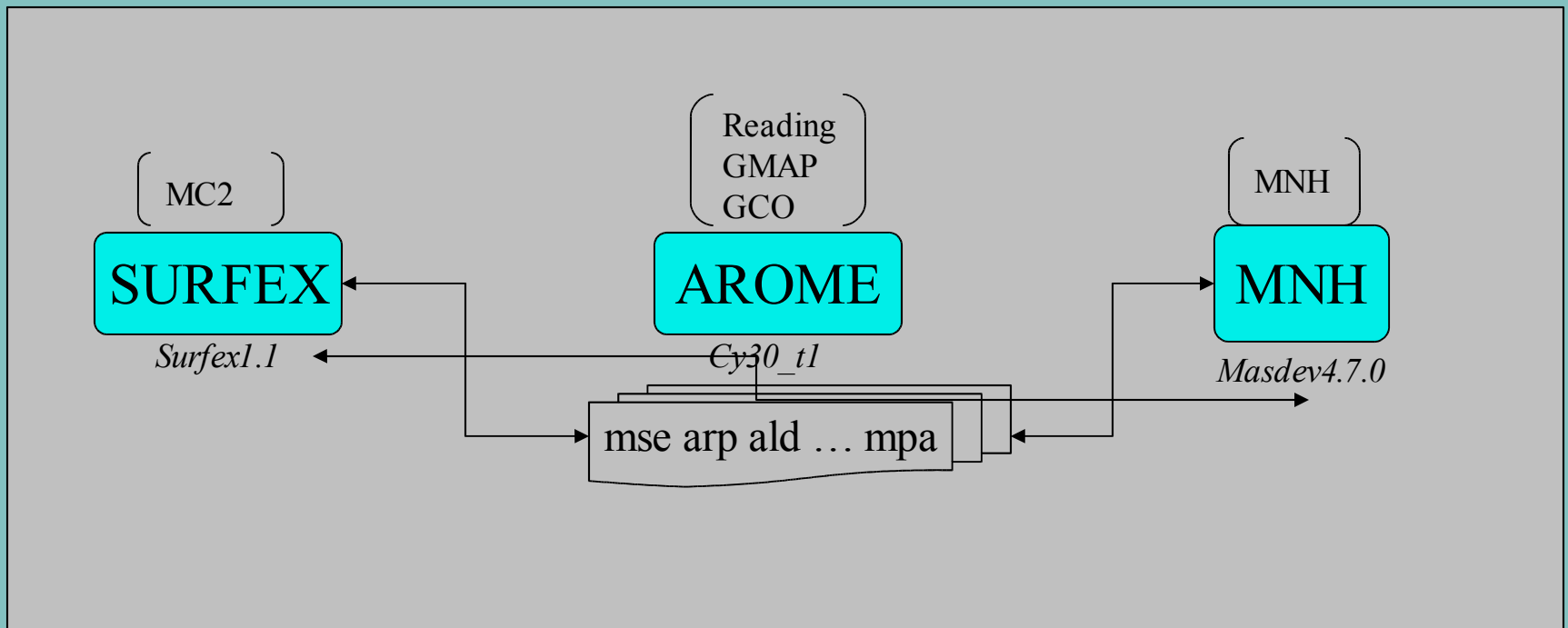
## MODEL

# Status of Arome

- Pre-op phase (→ 2008 for Météo-France)
  - Model: Intense phase of validation, development of diagnoses, participation to field campaign ?
  - Assimilation: towards a prototyping for 2,5 km assimilation
  - Including Arome in Olive to ease this pre-op phase

# Software management

- Arome in common IFS/arp/ald since cy29t1 (may 2005)
- // code evolution for Méso-NH physics (GMME/MNH & Externalized surface (GMME/MC2))

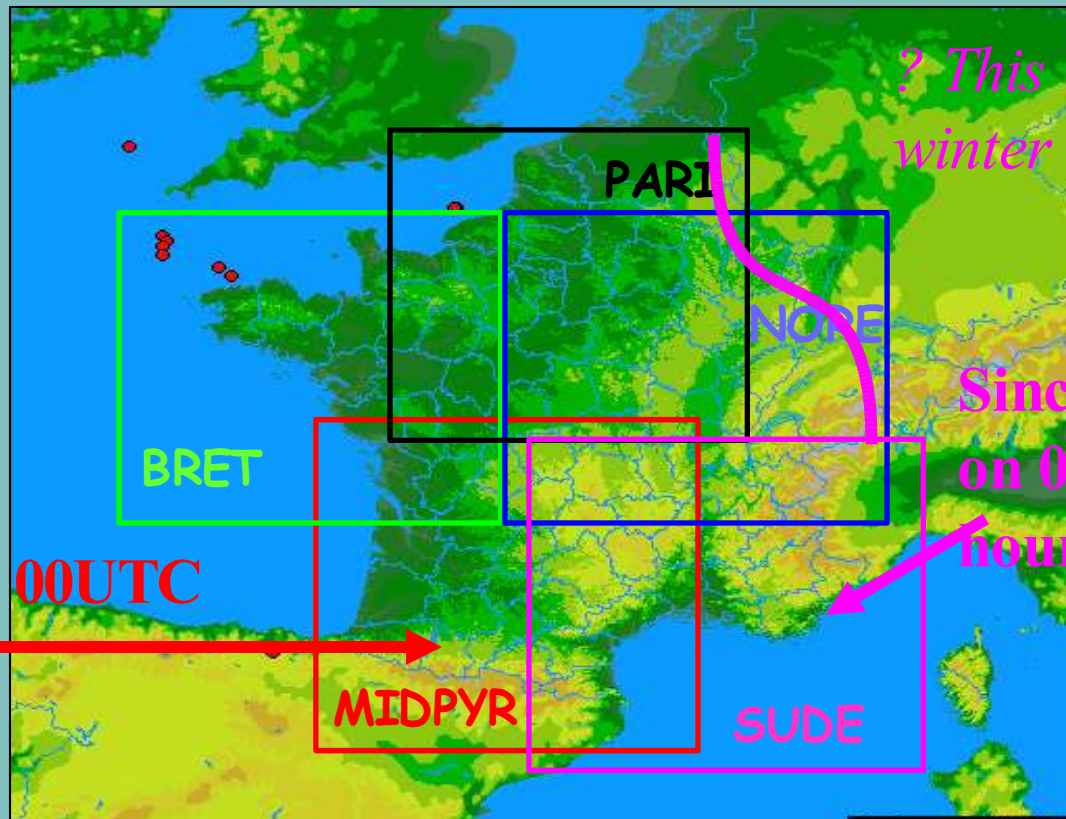


# Some figures on the cost of Arome (nowadays)

- On CPU:
  - The gridpoint cost: X 3 (wrt Aladin)
  - The time step: X 7 (wrt Aladin)
  - The resolution:  $\approx 20$  (4 X 4 X 1,5)
  - CPU repartition (60% dynamics, 40% physics)
- On memory:
  - Number of 3D variables: X3 (8 more)
  - Increasing number of surface variables (eq to one 3D variable more)
  - Model state: X12 to X24 & increasing volume for files (estimation of X3,5 the size of the files)

# Validation of Arome

## Routine runs (since june)



Since june on 00UTC  
+24 hours

? This  
winter

Since september  
on 00UTC + 24  
hours



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# ■ People involved in Arome

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- AROME specific staff
  - 8 people (5 devoted explicitly to assimilation aspects & 3 to model ones) at GMAP & GMME

# Arome collaborations

- In Météo-France (CNRM) 10% to 20% to CNRM ressources (including mesoscale research aspects & Aladin development) with a strong implication from GMME teams via surfex and Méso-NH physics
- In the international scientific community: strong implication and participation of Aladin people (NH, interfacing aspects, algorithms, ...) soon Hirlam
- In the french research community: strong implication via méso-nh physics (CNRS/LA), but also cooperations required by end-users (pollution modelling, oceanography, ...)

# The link between AROME- ALARO (1)

- The Aladin-2 project aimed to allow a convergence « à la carte » between Aladin and Arome. The partners will switch to Arome when they will want to.
- In the meantime Aladin will continue to improve in particular by a more prognostic physical package, this first step is called ALARO-0.

# The link between AROME- ALARO (2)

- In order to make this future convergence possible, the common part of the software has to evolve
- Thus a common effort is done on the interfacing aspects (physical-dynamical interface, surface issues,...)

# The use of Arome outside (Météo-France)

- Obviously the weak part of the project for the time being
  - Some historical reason for that (priority was given to build quickly a prototype)
- We try to improve
  - Preparation of files
  - Training
  - ....
- In the meantime we can offer user support and help to run on Météo-France computer and Ecmwf one.

# The ways towards operation at Météo-France

- 2 years & a half (that's not much)
- Many aspects:
  - Technical
  - Organizational
- Many questions (some related to the possibility of our next computer):
  - What will be affordable ?
  - What to do with Arome ? (for a forecaster point of view?)

# Overview of the training course

- Dynamics session: Monday & Tuesday, to cover theoretical & practical aspects
- Physics session: starting Tuesday & ending Thursday, a review of the méso-Nh parametrizations used in Arome
- A technical session: Thursday & Friday,

# Overview of the training course

- Moments for discussion (encouraged of course)
  - Now on general issues around Arome
  - Thursday afternoon on the know weaknesses related to the physics (animated by Christine Lac)
  - Friday morning on prospective aspects (animated by François Bouttier)