Report on ALADIN, ALARO and AROME

F. Bouttier, Y. Seity, S. Malardel, G. Hello, C. Fischer
(CNRM/MF) and some Aladin scientists (T. Kovacic, L. Kullman,
A. Bogatchev, D. Banciu, M. Jurasek, the Aladin-NH and 3DVar specialists

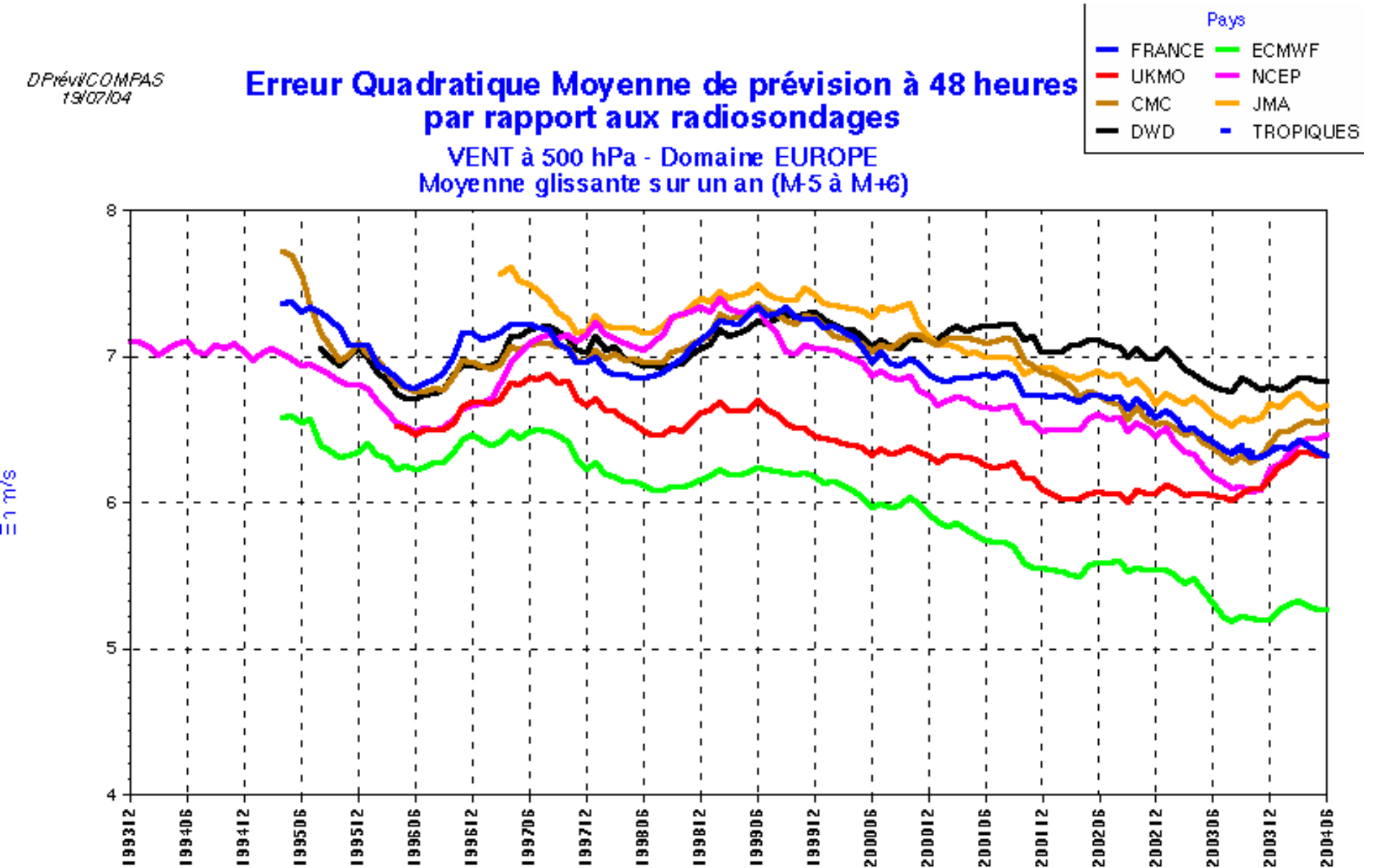
- Strategy
- Report on Arpège/Aladin
- Report on the Alaro-10km prototype
- Report on the Arome-2.5km model
- Conclusion: how to prepare for Arome ?

NWP software strategy

- Most software shared with **ECMWF model and 4D-Var.**
- **ARPEGE** original physics, data processing, stretched grid = **designed for short-range NWP.**
- **ALADIN** = adaptation of ARPEGE to LAM geometry, **cooperation on software and science. ALADIN will keep running and improving until at least 2010.**
- **ALARO** = **different physics** from ARPEGE/ALADIN, but cheaper than AROME.
- **AROME** = adaptation of ALADIN to resolutions better than 3km, with completely **different physics, currently shared with the mesoscale research community.**
- **AROME will be available for use by ALADIN partners in winter 2005 (operational at Météo-France in 2008)**
- (Hirlam cooperation: more workforce to improve the AROME system)

ARPEGE model performance

500hPa wind 2-day forecast scores over Europe for past 10 years



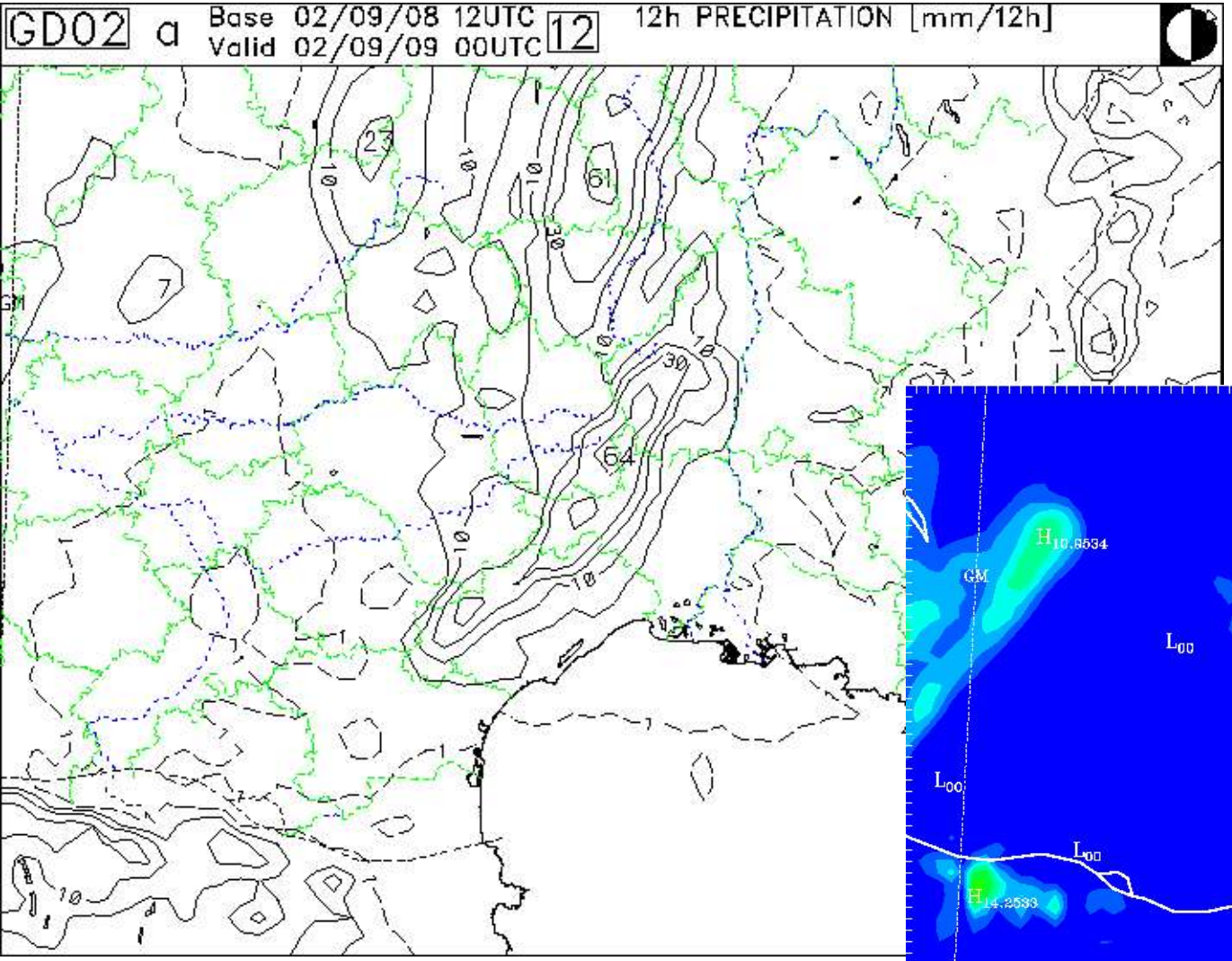
Status and plans for Arpege/Aladin

- Good recent improvements of ARPEGE/ALADIN performance thanks to reduced stretching, improved physics, better assimilation with much more satellite data
- More improvements expected in 2005/2006 (**new physics** from ARPEGE-climate, even more **satellite data, radar** later) e.g. on cloudiness & surface fluxes
- Strong effort on **ALADIN assimilation** (operational end 2004) – very good short-range performance (e.g. Precipitation)
- with moderate increase in model and telecom costs

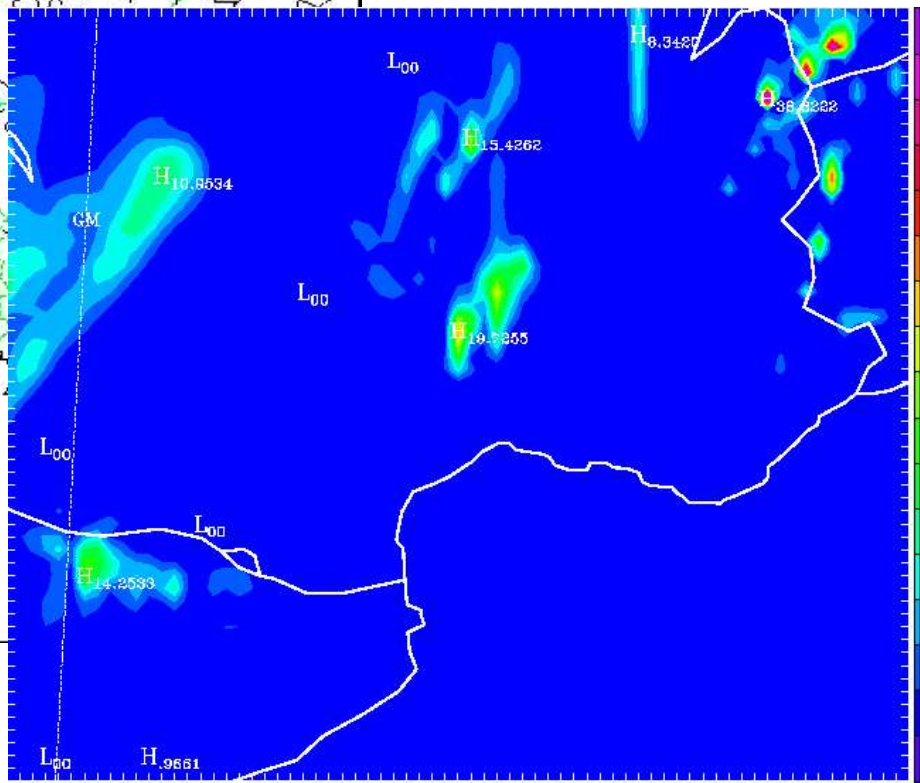
The ALARO feasibility study

- **Idea:** can the AROME software be useful at 10-km resolution ?
- Requires extra components in the model (**subgrid** physics, adaptation to **long timesteps**)
- Feasibility study done by G. Hello + visit from T. Kovacic
- **The good news:** the prototype started working very quickly (Spring 2004, investment of 4 man.months)
- **The bad news:** first results (on a few test cases) are not good.

ALARO test case: Gard convective floods

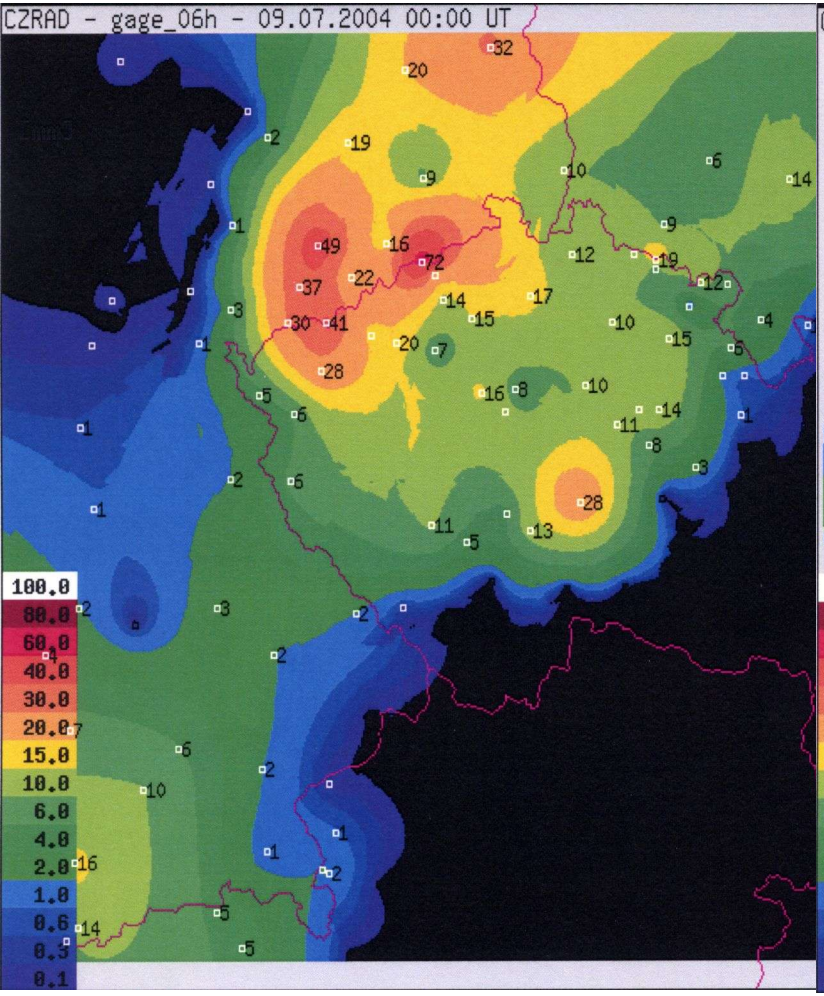


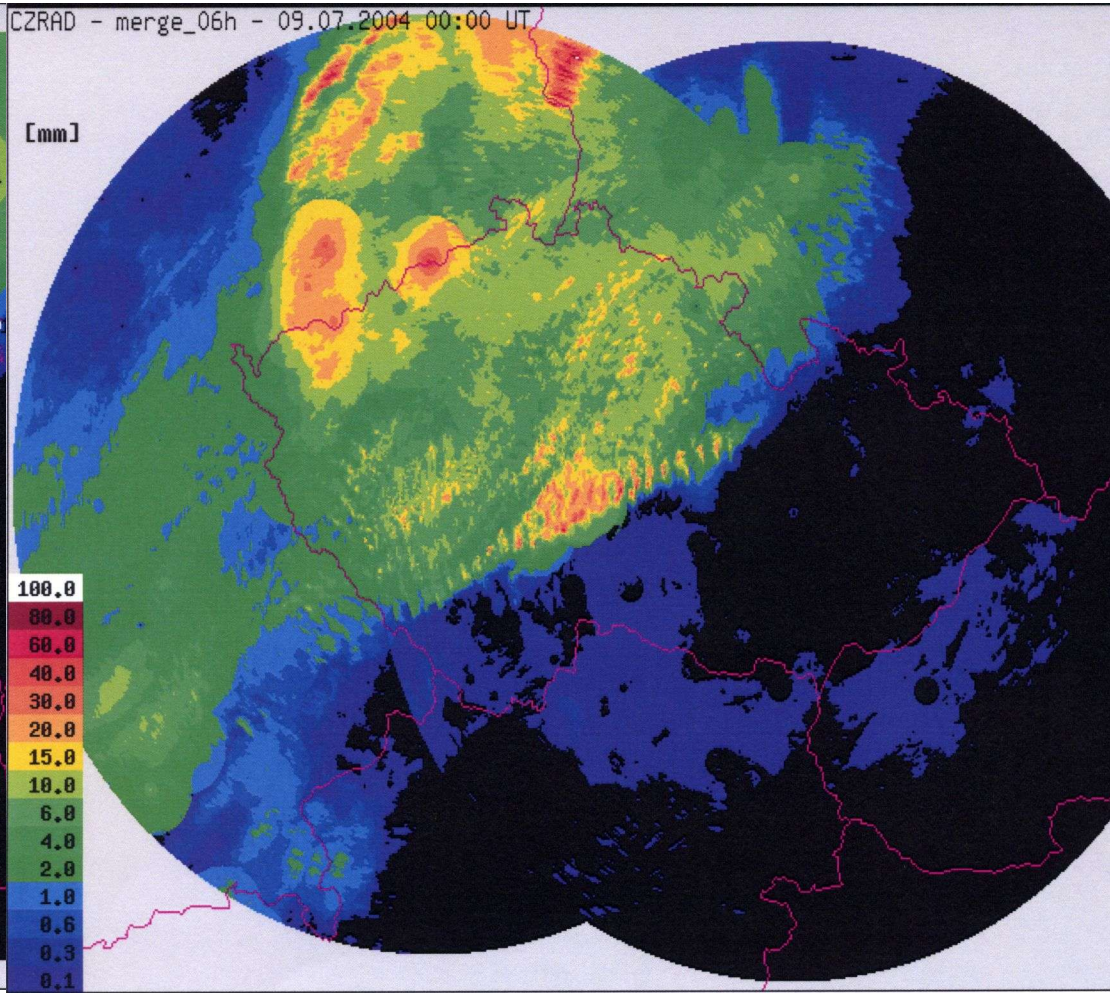
Aladin oper



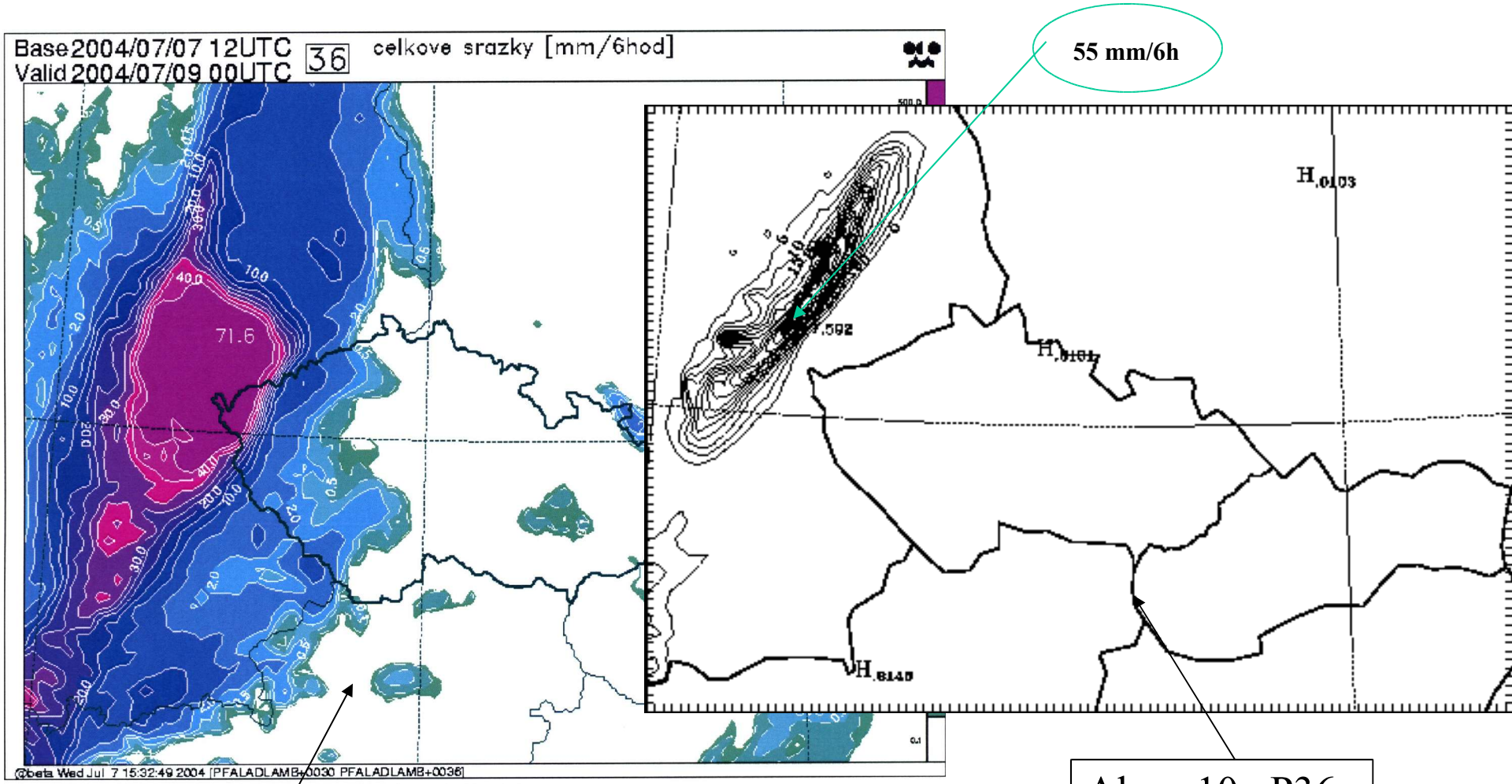
Alaro

ALARO test case 2: strongly precipitating cold front - observations





CZ cold front : forecasts

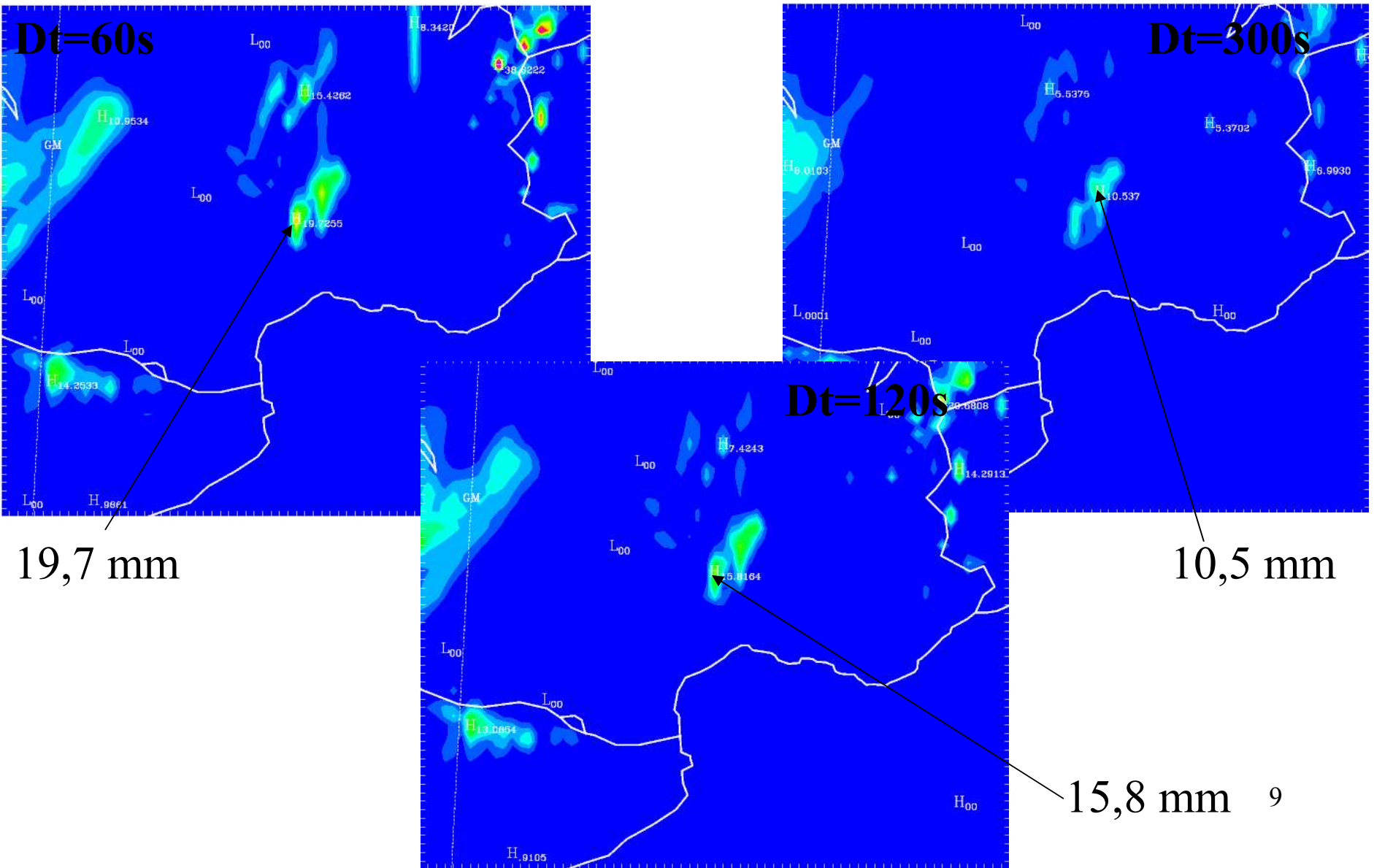


Aladin EC-P36-

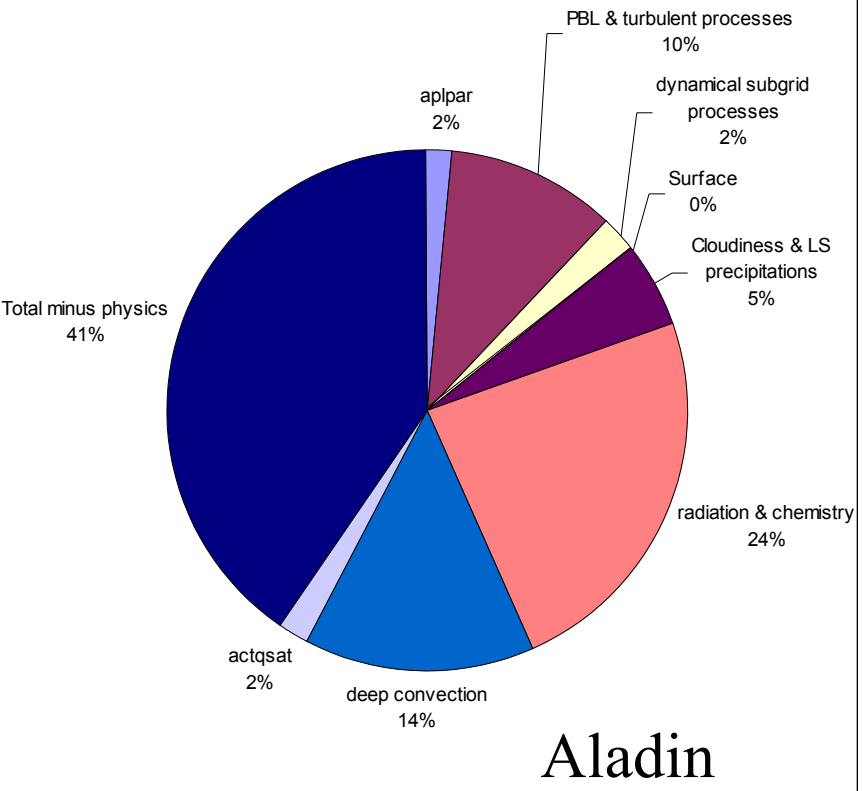
Alaro-10 –P36-

Precipitations 0812→0900

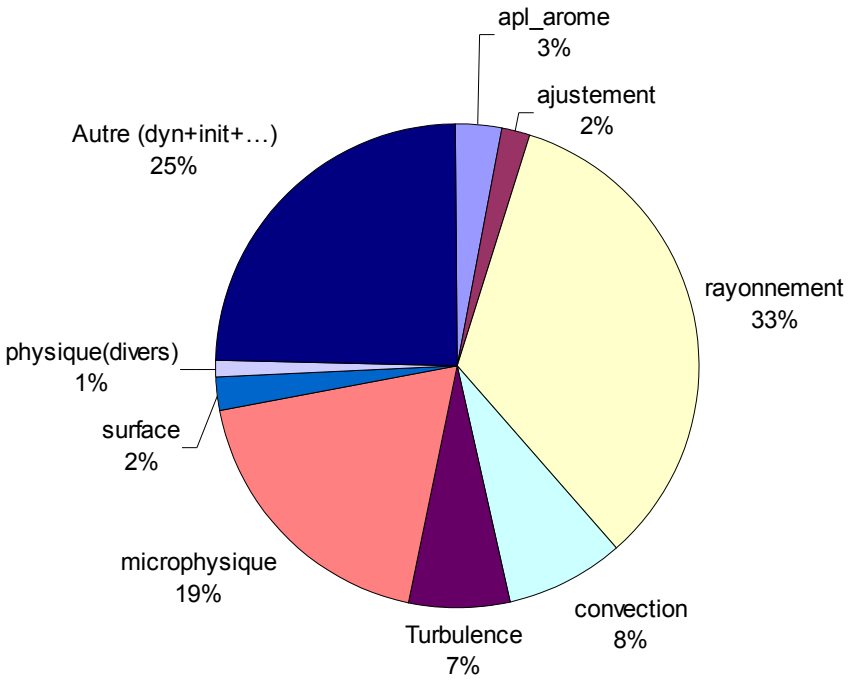
Sensitivity of ALARO to increasing timestep



ALARO is about 3 times more expensive per timestep than ALADIN, mainly because of the physics.



Aladin



Alaro

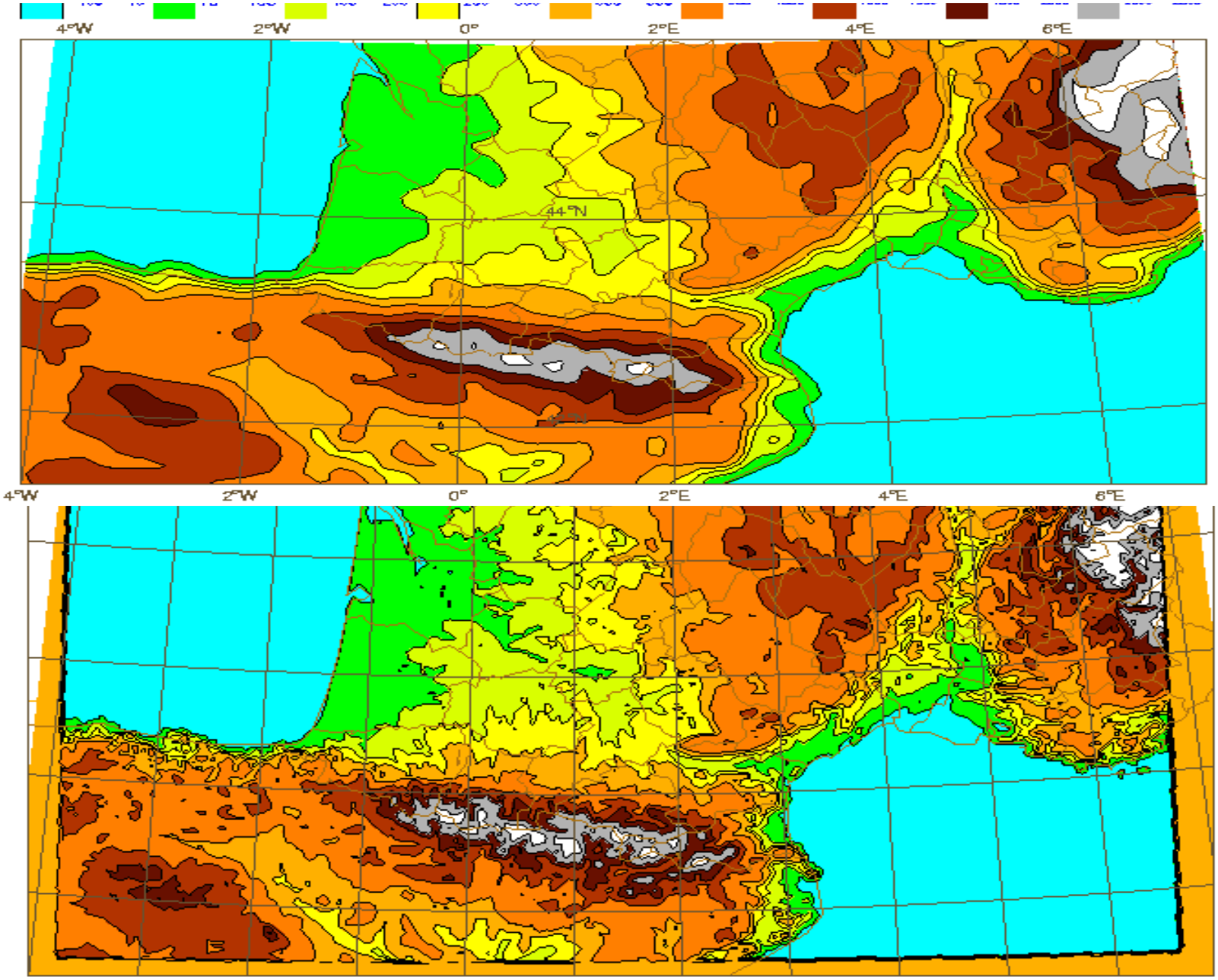
Conclusions on ALARO

- ALARO is **more sophisticated** than ALADIN (clouds, turbulence, surface), 3x more expensive and not yet better
- very few experiments have run and the reasons for the poor ALARO performance are **not yet understood**.
- Extra work there would probably make ALARO **better and cheaper.**
- BUT there is a lack of interest in this model. 0.3 man.year/year of manpower cannot be enough to make a competitive model of ALARO. **More involvement would be needed to make it work well.**

The AROME project

- **Non-hydrostatic, convection-resolving** model, concept similar to MM5, WRF, LM: resolution better than 3km improves a lot the forecast quality
- Main mission: improve forecasts of short-range heavy convection, QPF and low-level weather forecasts, operational in 2007
- Claim of originality : **very efficient numerics** and **advanced data assimilation**
- **New 3D fields:** NH dynamics, 5 cloud water species, turbulent kinetic energy, chemicals/aerosols and **new physics**
- Coupled with **model of soil/snow/town/biosphere/ocean**
- 30 times more expensive than ALADIN, but affordable.
- Assimilation similar to ALADIN-3DVar, with **much more mesoscale data** (low-level, satellite, radar) and optimization for fine resolution

Higher horizontal resolution (from 10 to 2km)



Arome team

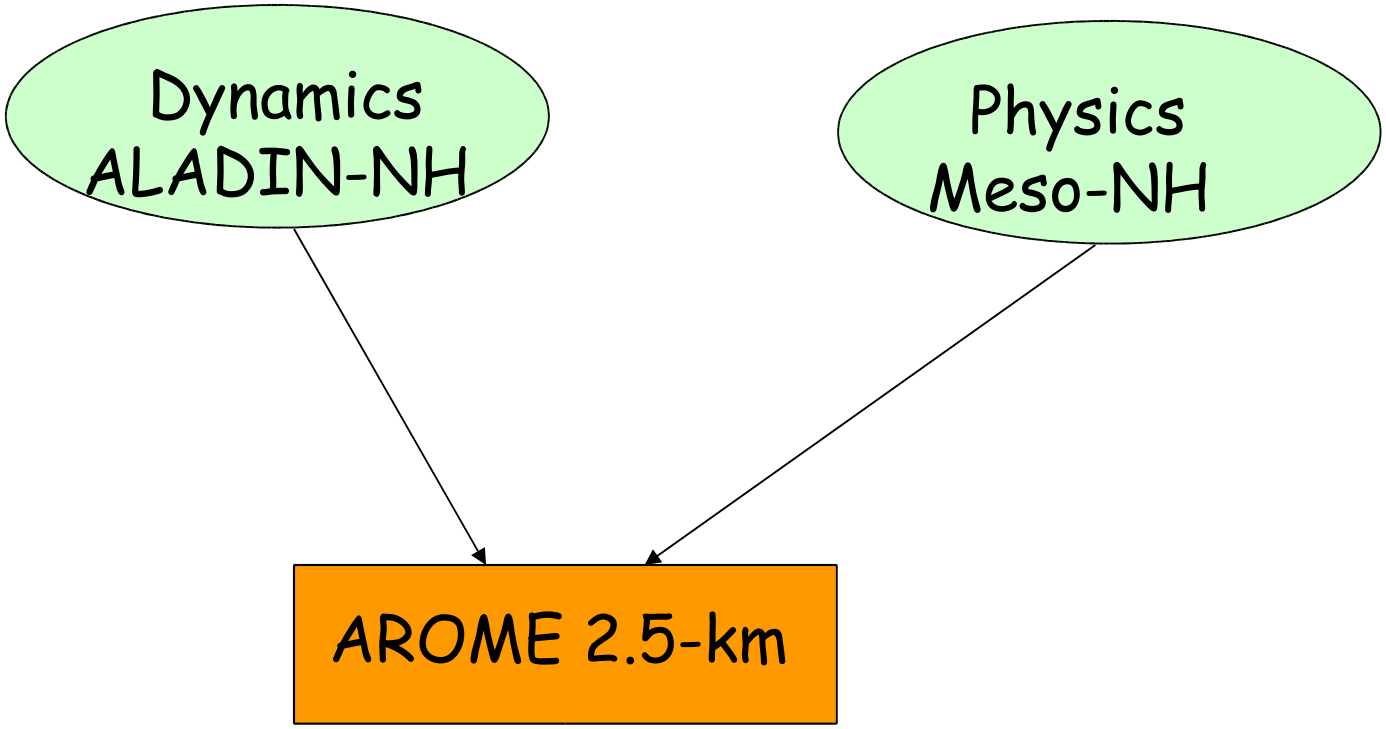
- **François Bouttier** : management and communication
- **Gwenaelle Hello :** model science and link with ALARO
- **Sylvie Malardel:** Meso-NH physics
- **Yann Seity:** model, software management
- **Frédéric Duret/Geneviève Jaubert:** experimentation, support to external users
- **Eric Wattrelot:** radar data assimilation
- **Ludovic Auger:** nowcasting-oriented data assimilation
- Good support from Aladin partners on ALADIN-NH dynamics and 3DVar assimilation...
- ...but still very little on AROME validation and physics (less than 0.5 man.year in 2004, mostly on training)

AROME has specific problems that require help from ALADIN scientists !

Arome status and plans

- The prototype exists since April 2004, source code and MesoNH documentation are available to ALADIN partners
- **Visitors can run Arome** in Toulouse since May 2004
- Several convective case studies have run with excellent results
- Good sensitivity to data assimilation has been verified
- Model installed on ECMWF computers in Oct 2004
- First **AROME export version will be sent in Feb 2005**
- Sept 2005: AROME will be in the joint cycle, preoperational studies start in Météo-France.

Arome model (1/9)



AROME numerics (2/9)

- Spectral LAM with linear collocation grid and rectangular truncation i.e. no spectral aliasing
- Semi-Lagrangian advection
- Dynamics derived from Laprise's system: terrain-following mass vertical coordinate, compressible non-hydrostatic equations
- (very !) careful discretisation, 2nd-order accurate, preserving energy and angular momentum
- NH dyn variables: vertical divergence, NH mass departure
- SI timestep, iteration of nonlinear terms, spectral solver
- A major ALADIN research effort since 1994

AROME physics (3/9)

Shared with the Méso-NH community

=

Microphysics (tendencies+adjustment)

+

Turbulent mixing

+

Radiation

+

Surface (coupled model)

Not yet implemented features

- Large-scale coupling of hydrometeors (=w=0), TKE (=constant)
- Orthogonal projection w.r.t slopes (surface, turbulence, radiation)
- Monotonous SL advection (but adjustment of negative microphysics values is implemented)
- Diffusion of microphysics and TKE fields
- Not yet validated for shallow convection and stratiform clouds (will be done in 2005)

AROME physics (4/9)

Microphysics : ICE3 : 6 species of water = vapour, cloud liquid, rain, cloud ice, graupel, snow

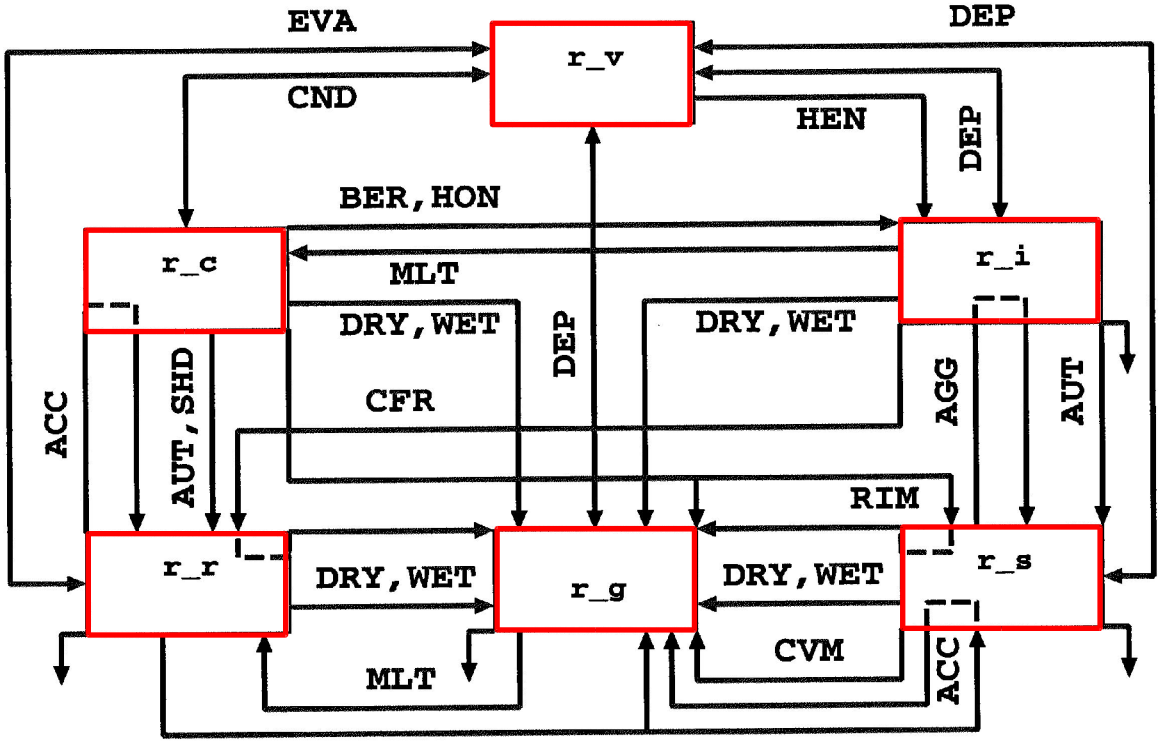


Diagram of the microphysical processes for mixed phase cloud in the present scheme

AROME physics (5/9)

Turbulence :

=1D version of the MesoNH scheme :

- ➢ Prognostic TKE
- ➢ Bougeault-Lacarrère mixing length closure
- ❖ Current work on improving:
  - 3rd order moments (counter gradient)
  - mixing length inside clouds
  - Lateral mixing on cloud sides

- (go to 3D turbulence when we reach 1km resolution)

AROME physics (6/9)

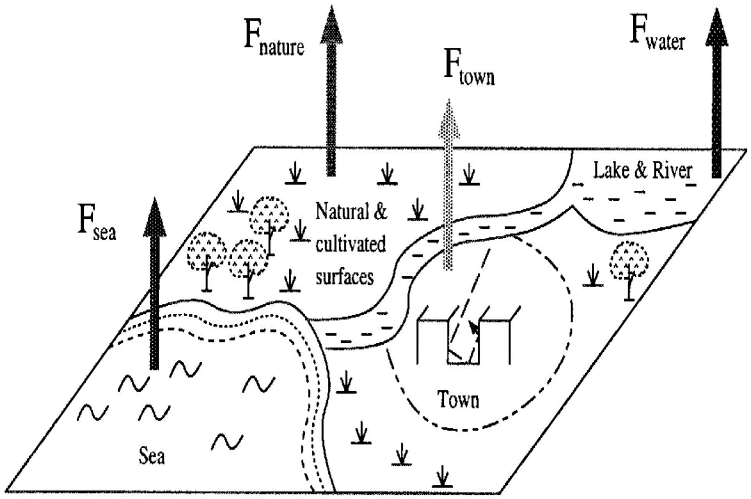
Radiation : from ECMWF (SW = Fouquart-Morcrette, LW = RRTM)

6 visible spectral bands, over 140 IR bands, ozone and aerosols

Surface : external software (towns, vegetation, sea, lakes, snow) with pluggable slow- and fast-hydrology, prognostic marine mixed layer

AROME physics (7/9)

Surface : town :TEB (Masson, 2000)
vegetation : ISBA (Noilhan and Planton, 1989)
sea/lakes : Charnock closure and constant SST so far.



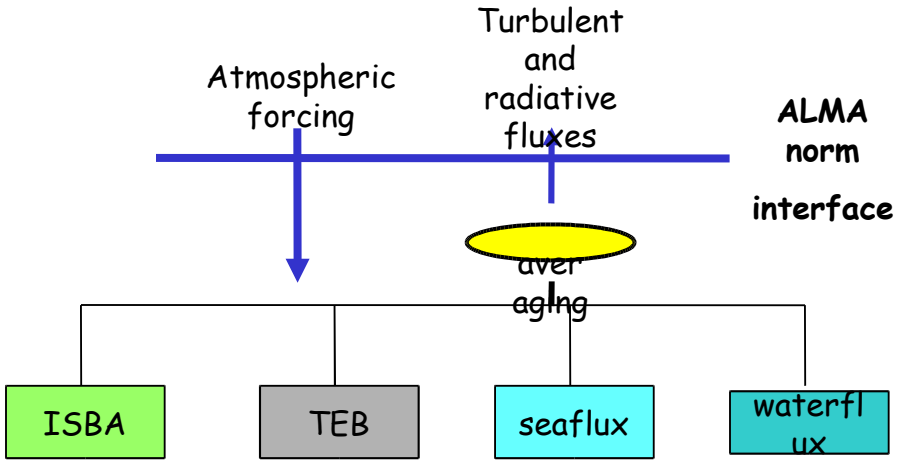


Figure 15.1: Partitioning of the MESO-NH grid box, and corresponding turbulent fluxes. F stands either for M (momentum flux), H (sensible heat flux), LE (latent heat flux), $S^{\uparrow}$ (the reflected solar radiation) or $L^{\uparrow}$ (the upward longwave radiation).

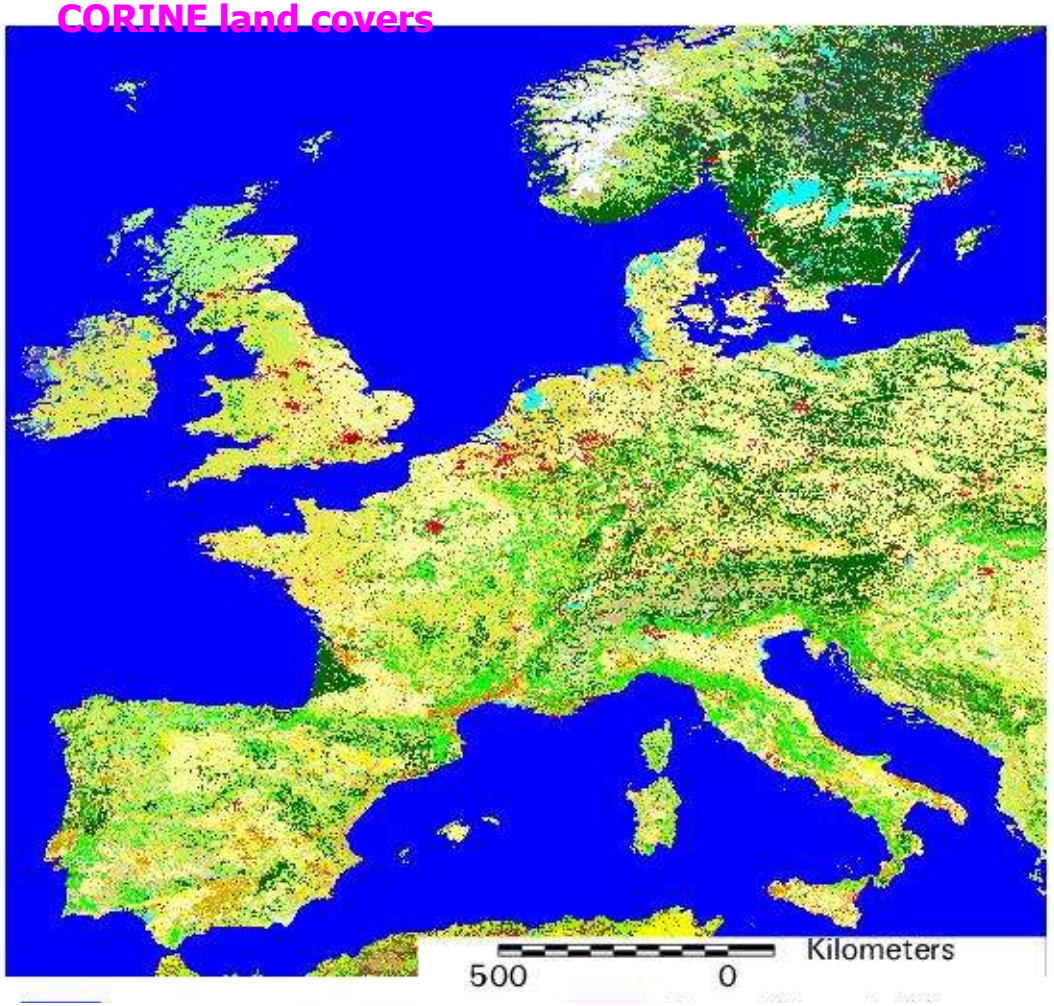
AROME physics (8/9

Surface physiography (TEB, ISBA) from Ecoclimap classification (Masson, 2003)

242 cover types

+

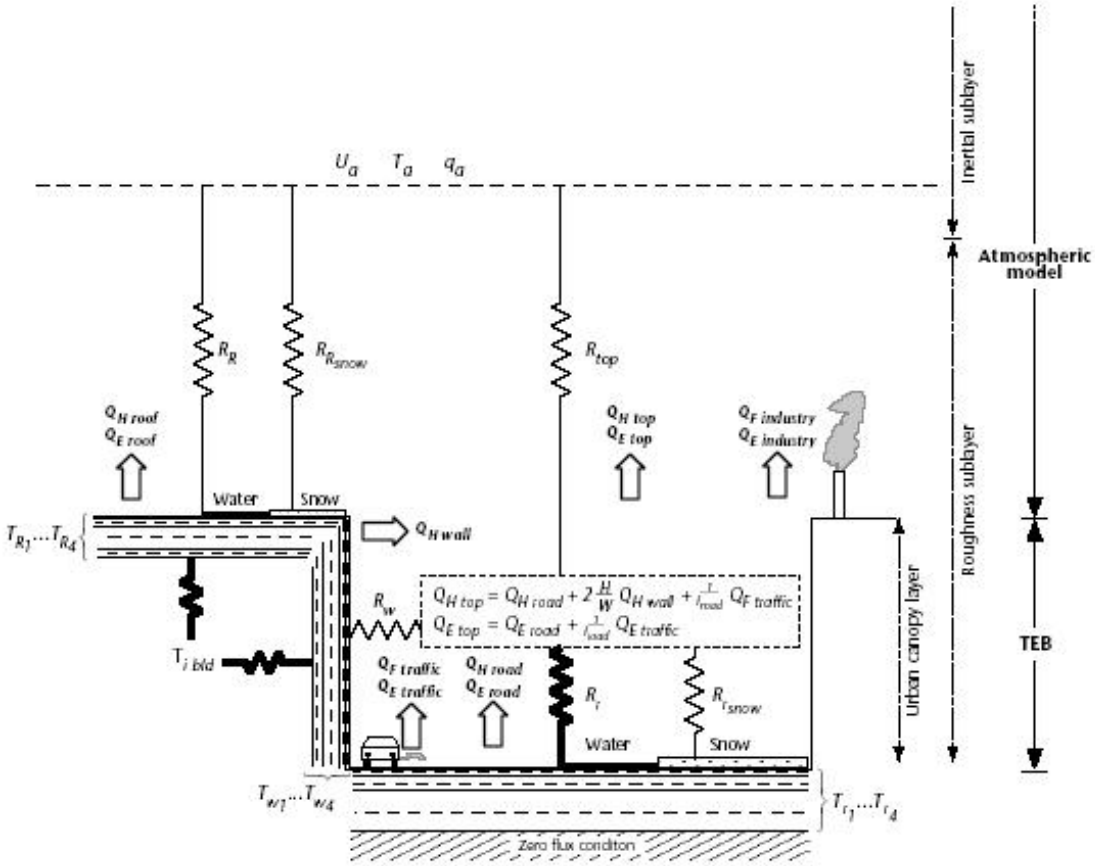
1km-resolution cover fractions



AROME physics (9/9)

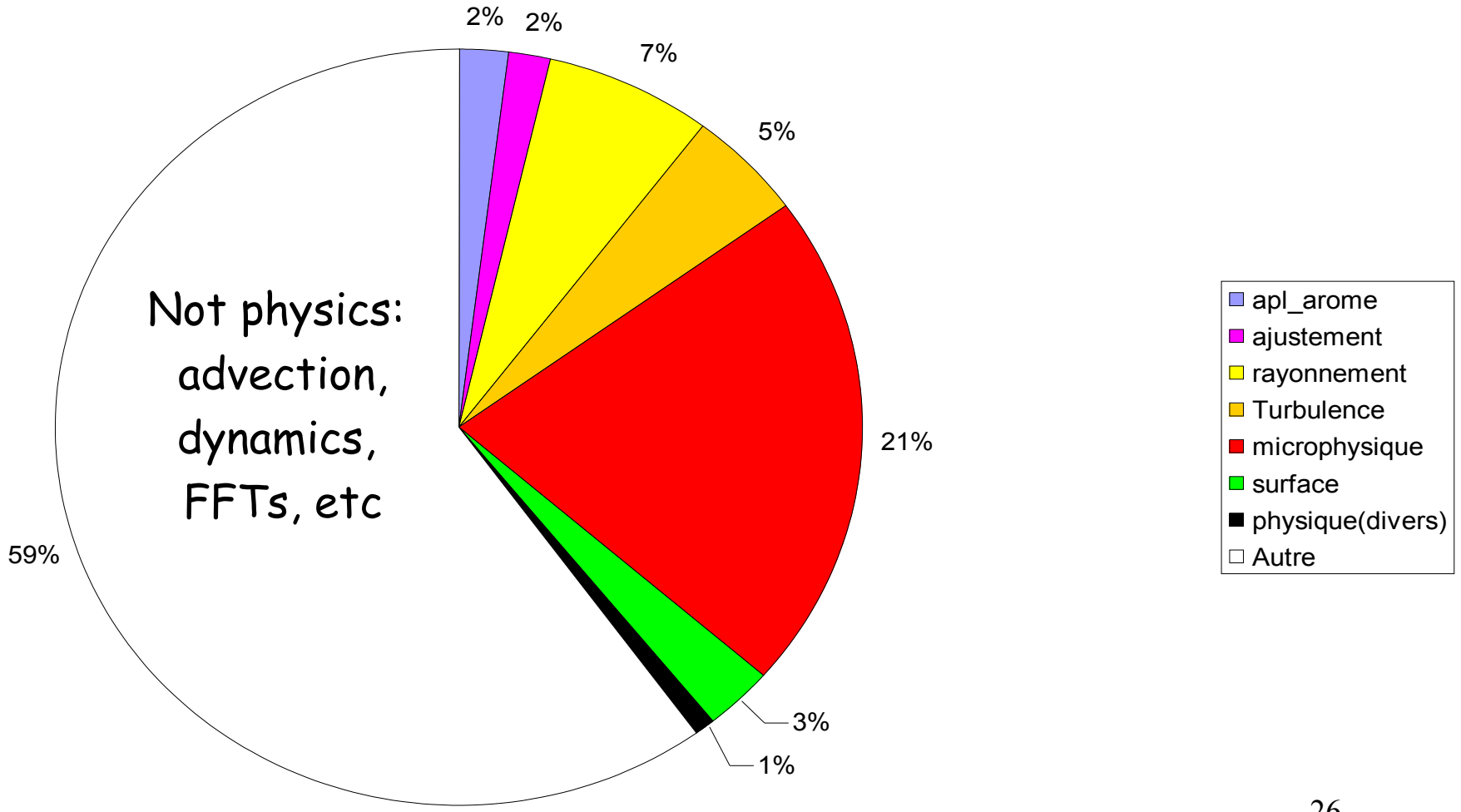
Town Energy Balance (TEB)

- Based on urban canyon concept
- Radiation trapping
- Heat storage in surfaces (walls, roads, roofs)
- Urban hydrology
- Antropogenic fluxes



Documentation : http://www.aero.obs-mip.fr/~mesonh/

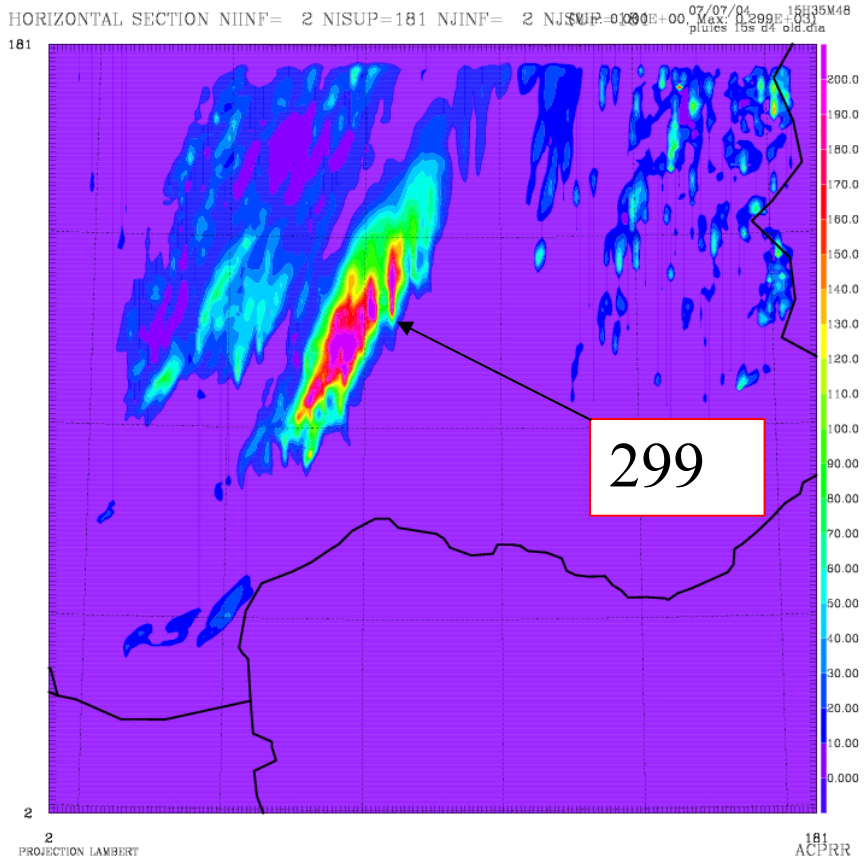
Breakdown of Arome model CPU cost



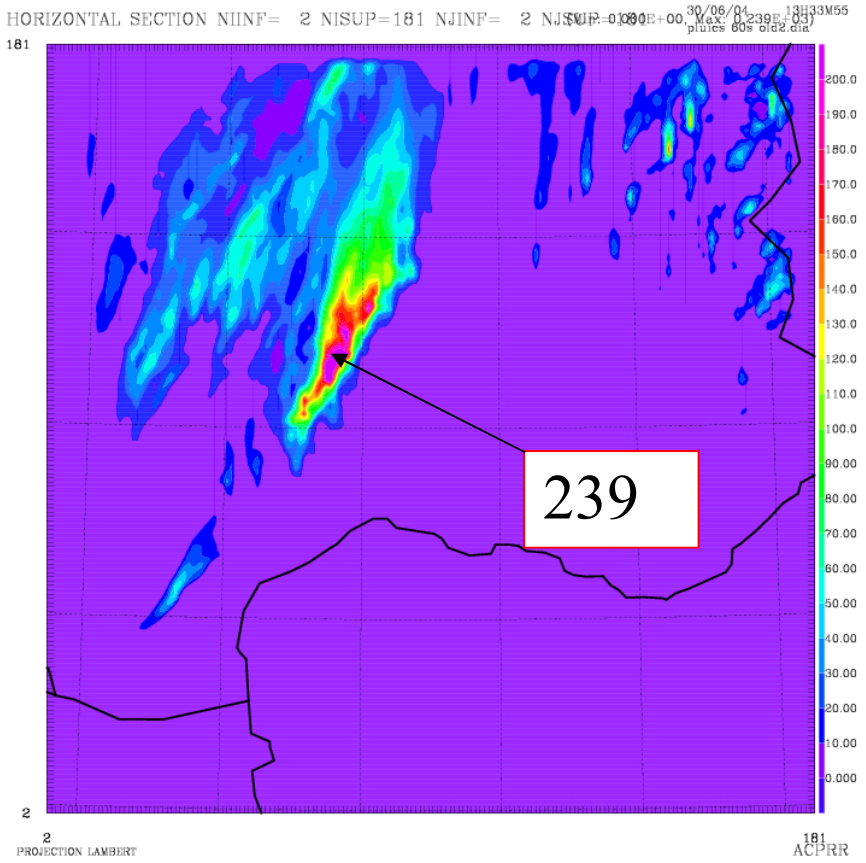
AROME real case: Gard floods

12-h cumulated rainfall, AROME model with dx=2.5km

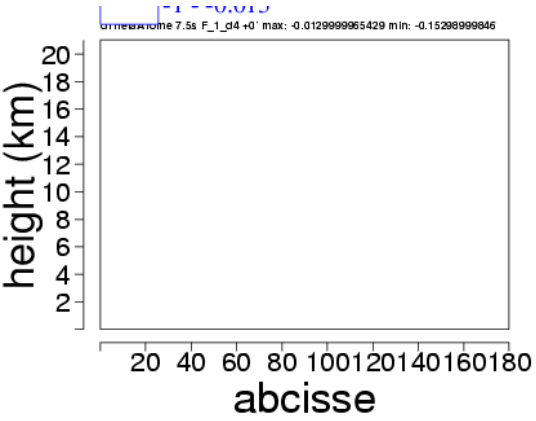
dt=15s

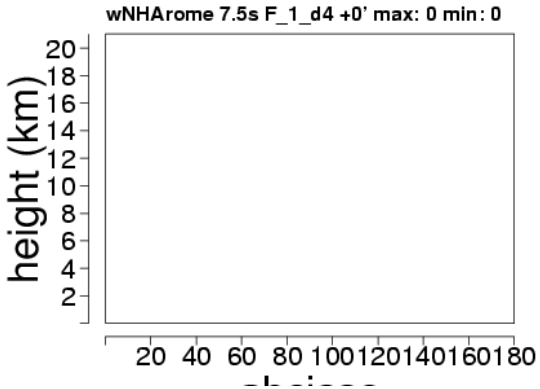


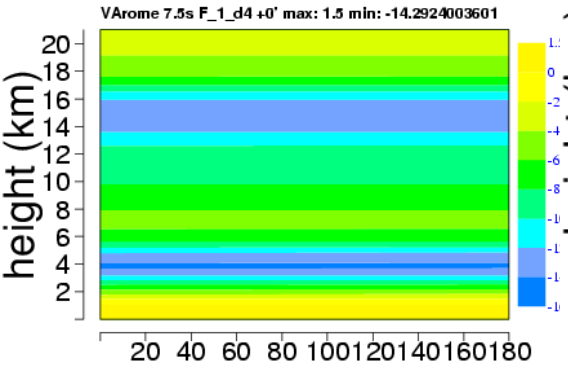
dt=60s

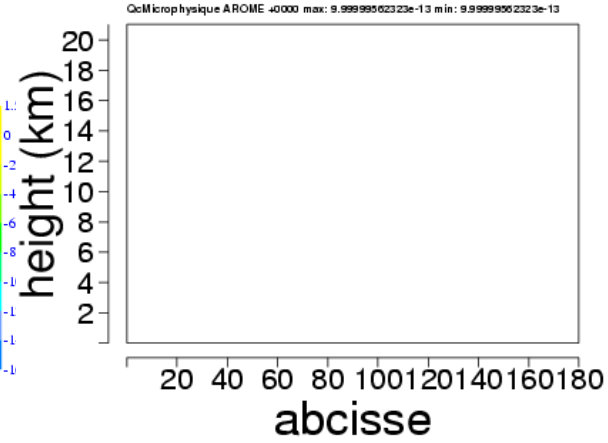


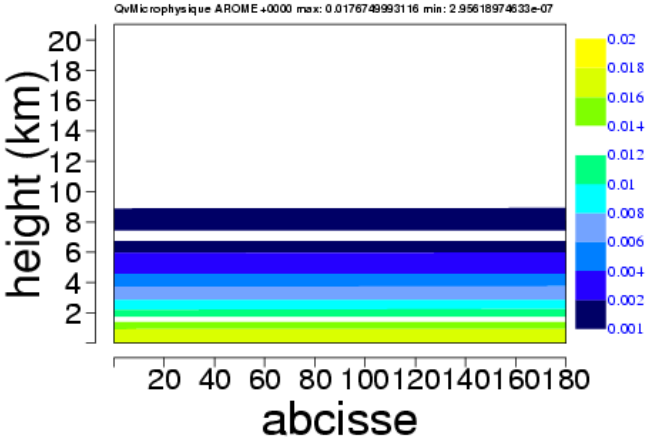
AROME case: Tropical squall line : vertical cross-section

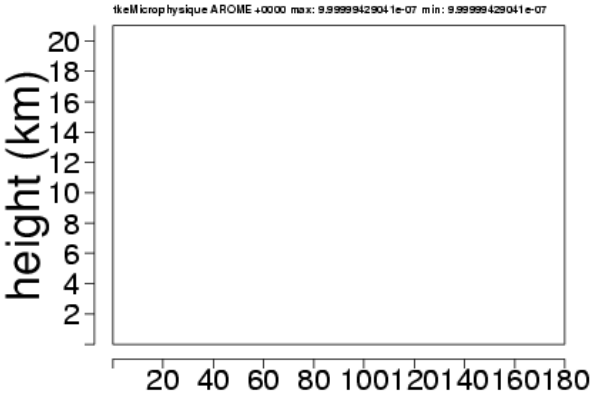


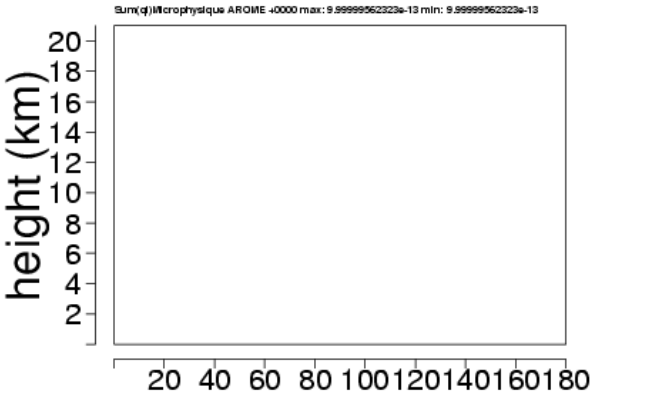








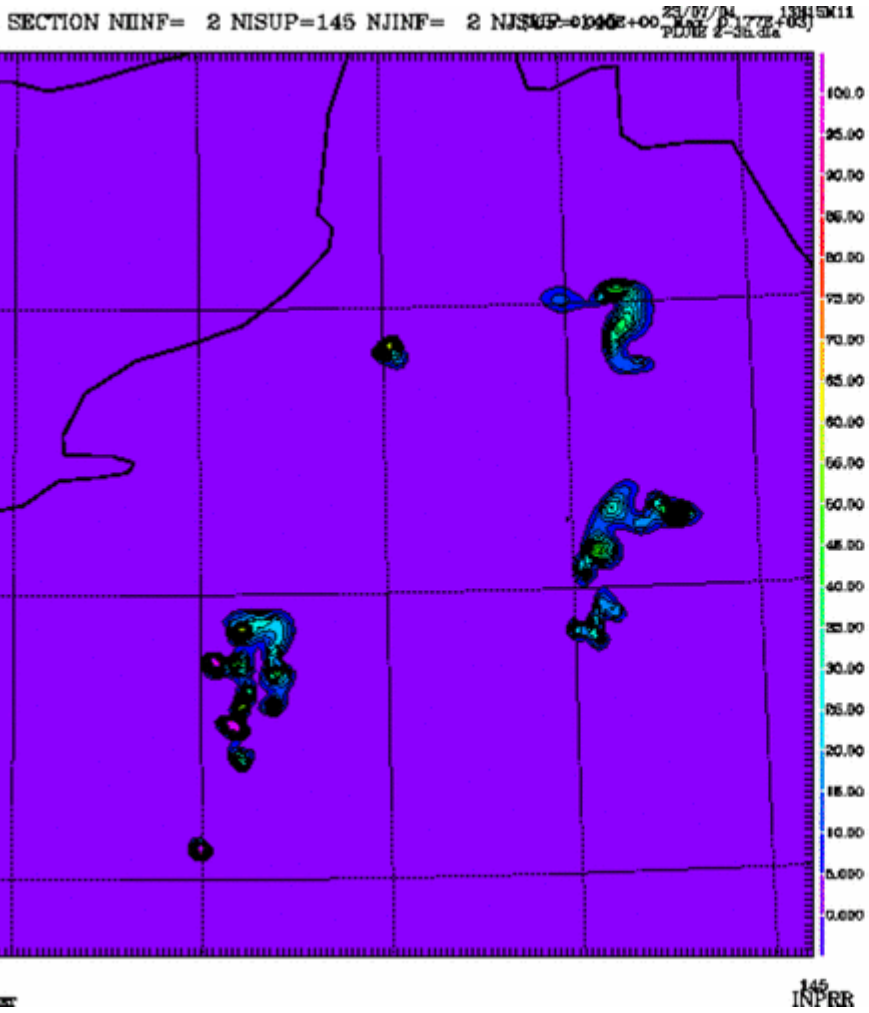


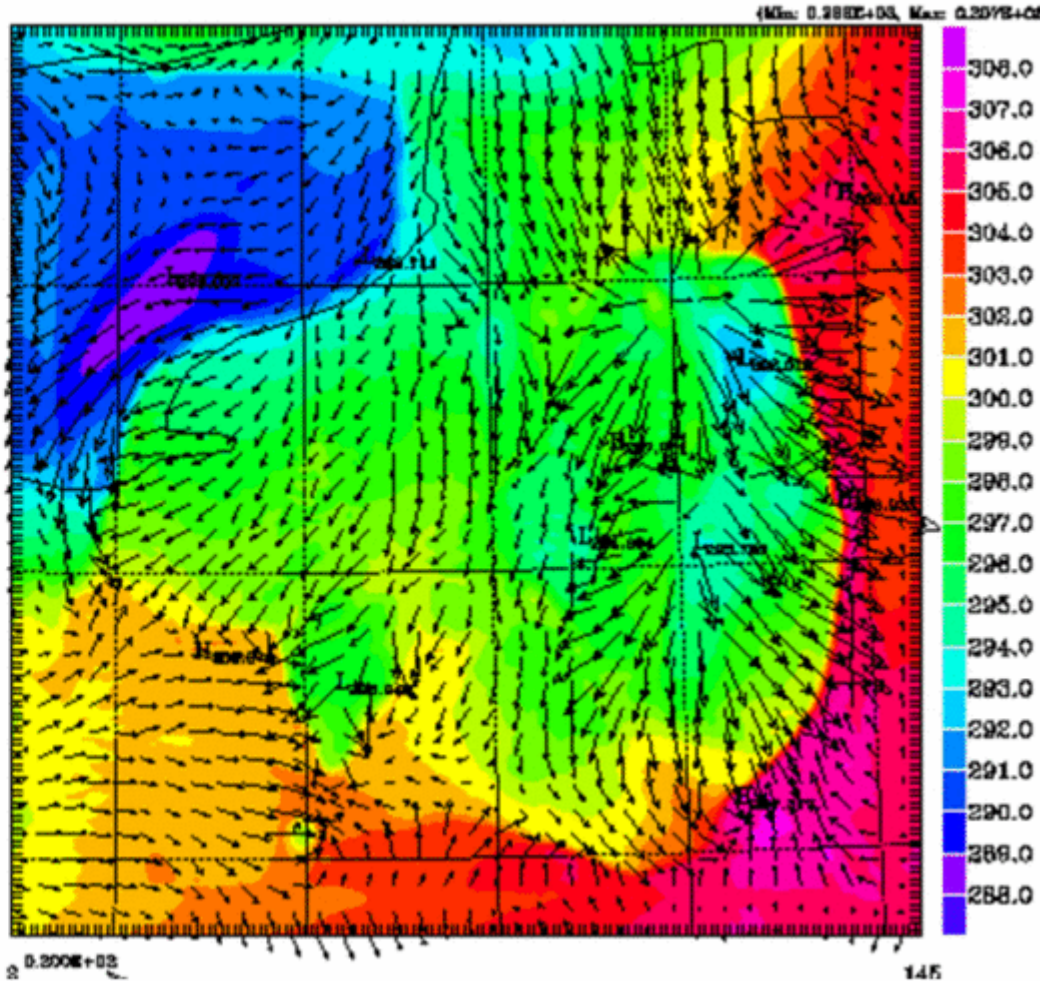


Thunderstorms over Paris simulated by Arome, 2.5km resolution, started from mesoscale analysis

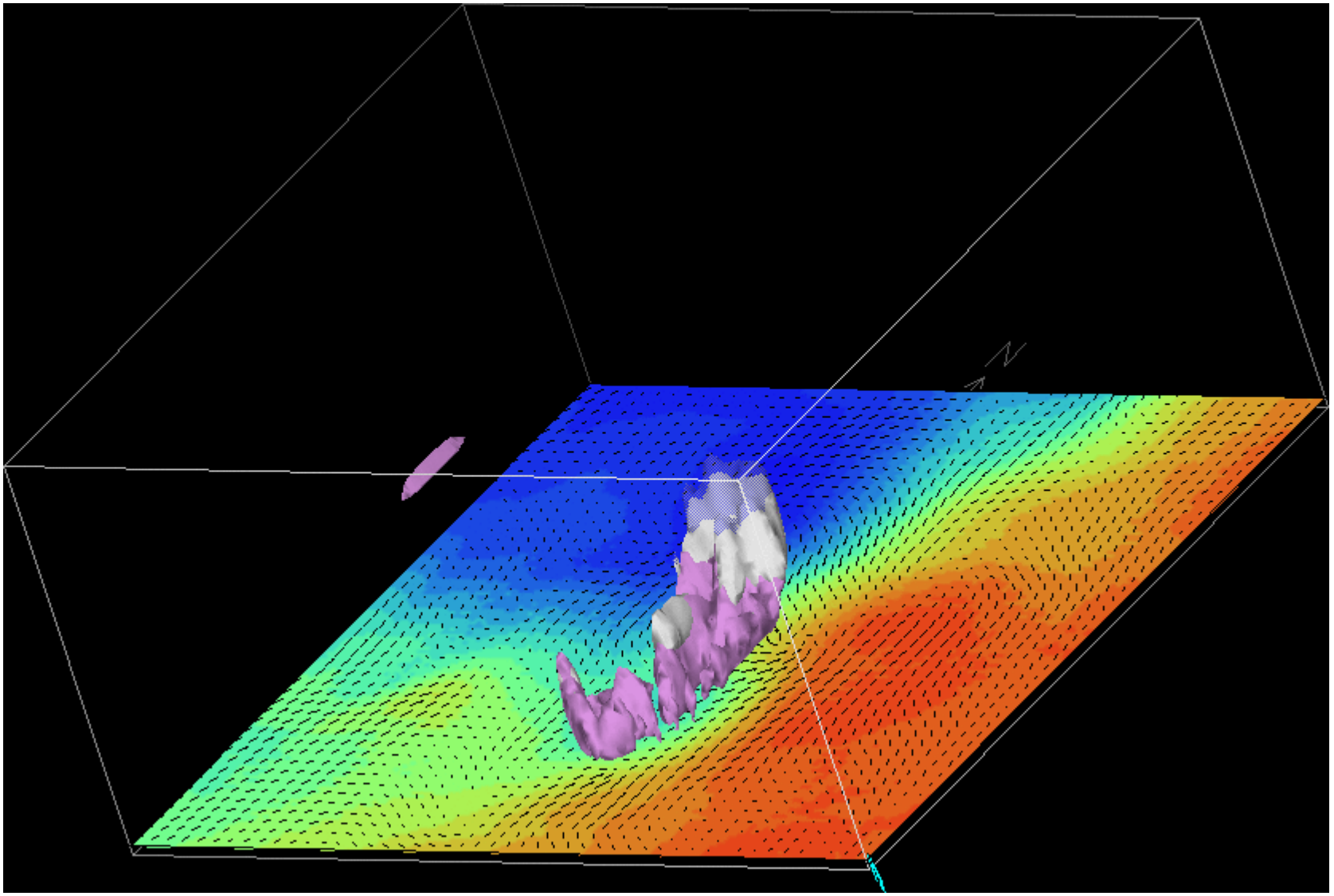
Rain rate

Low-level potential temperature and wind





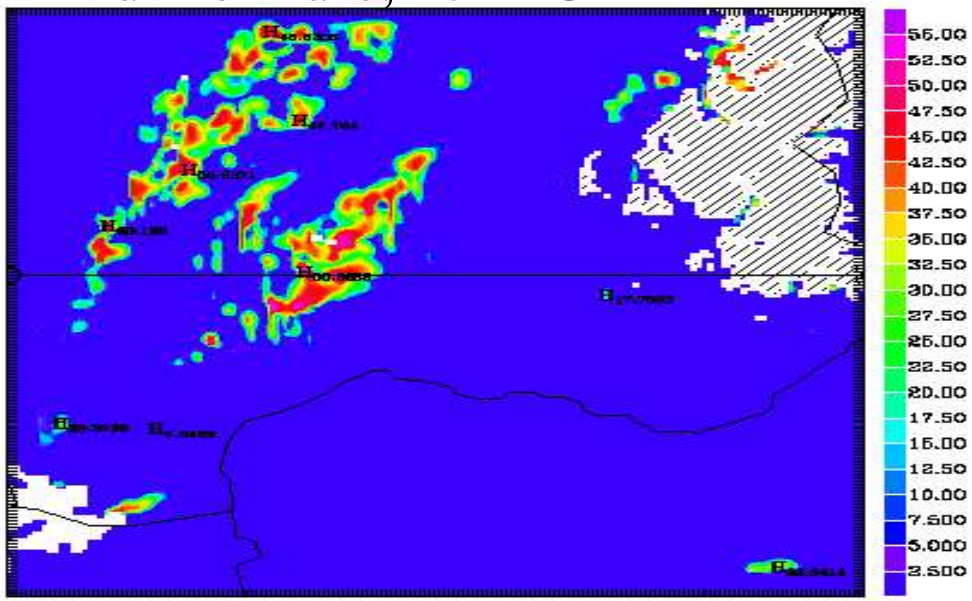
Three-dimensional view of the same thunderstorms



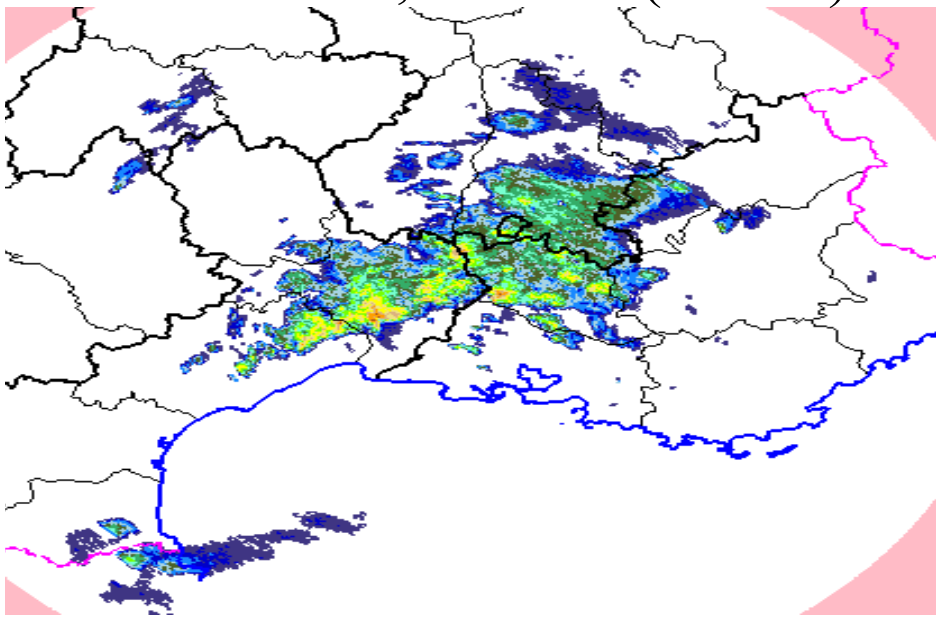
First Arome forecast, 2.5km resolution

Mediterranean floods, 8 Sept 2002

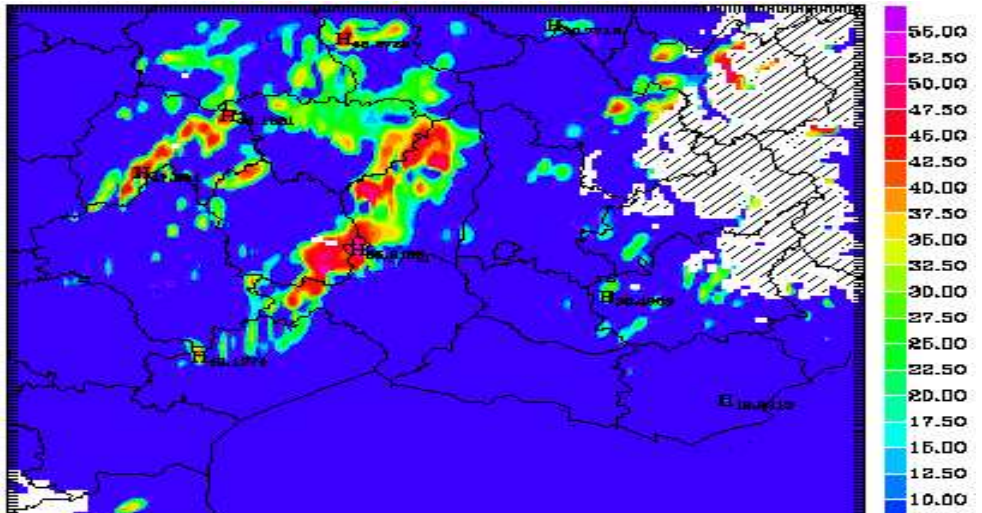
Radar simulé, 15hTU



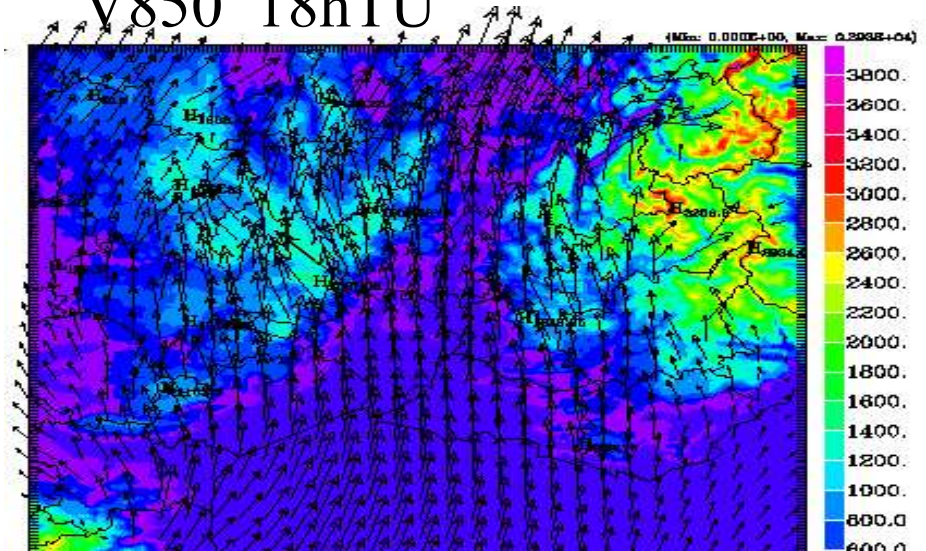
Radar observé, 15h TU (Nîmes)



Radar simulé, 18hTU

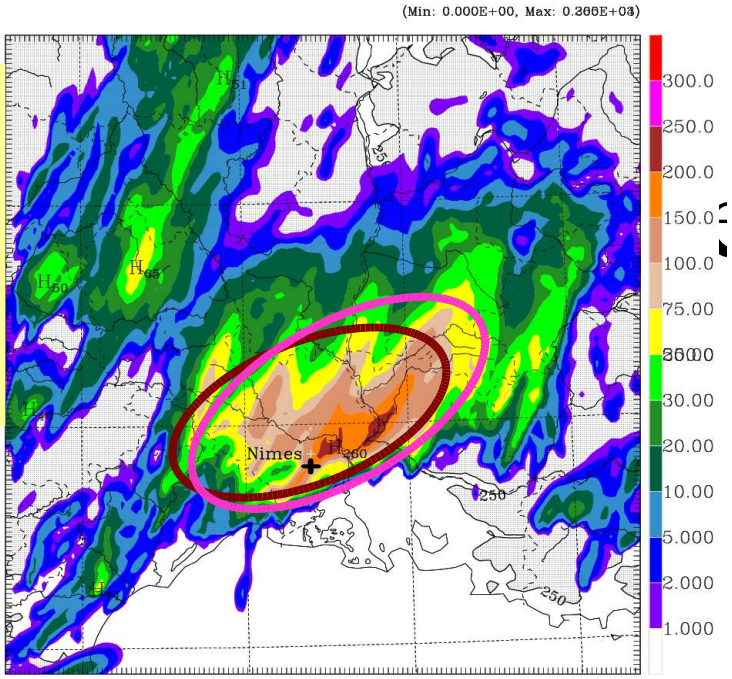


V850 18hTU

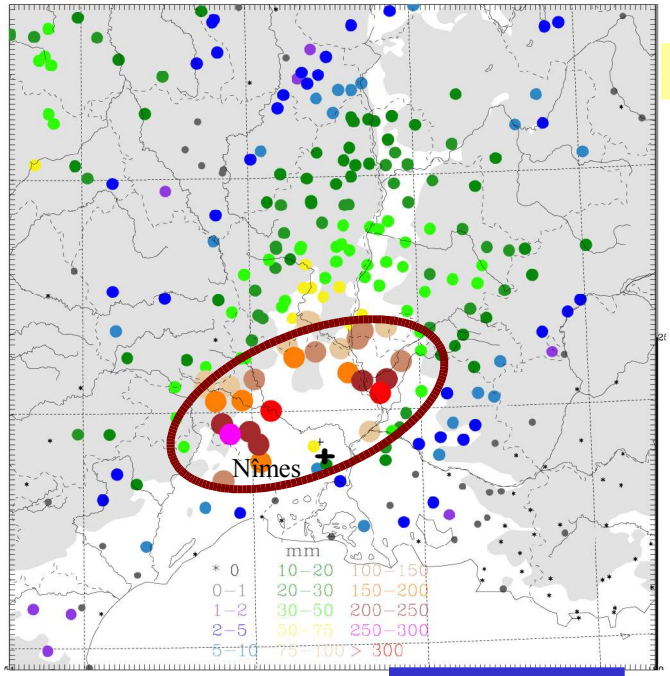


Accurate convection location requires mesoscale data assimilation

Prévision avec analyse à échelle fine (surface obs, radar, satellite) pour 12UTC, 8th Sept. 2002



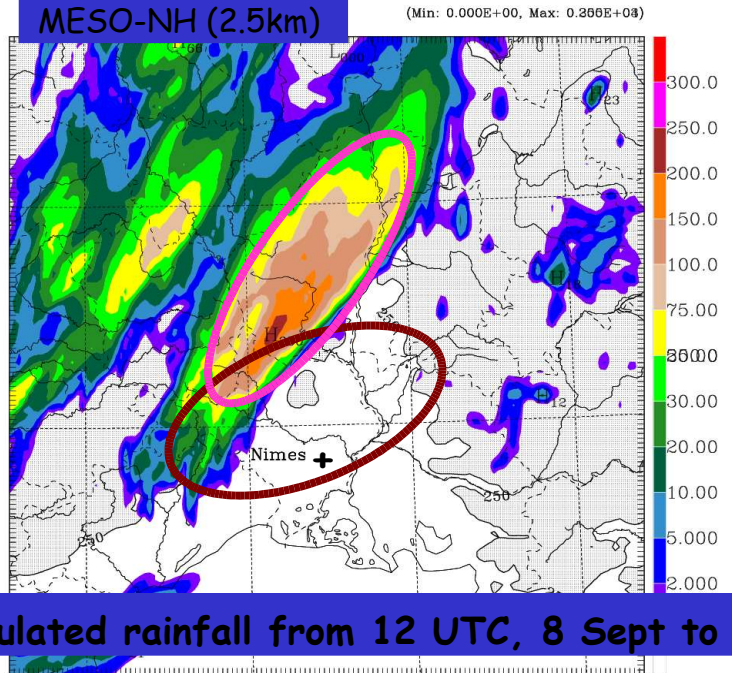
PLuviomètres



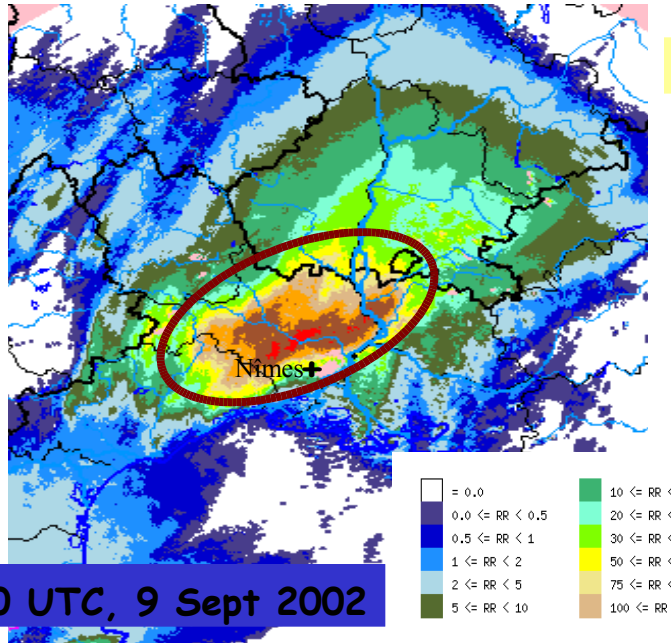
Observations

Ducrocq et al, 2003

MESO-NH (2.5km)



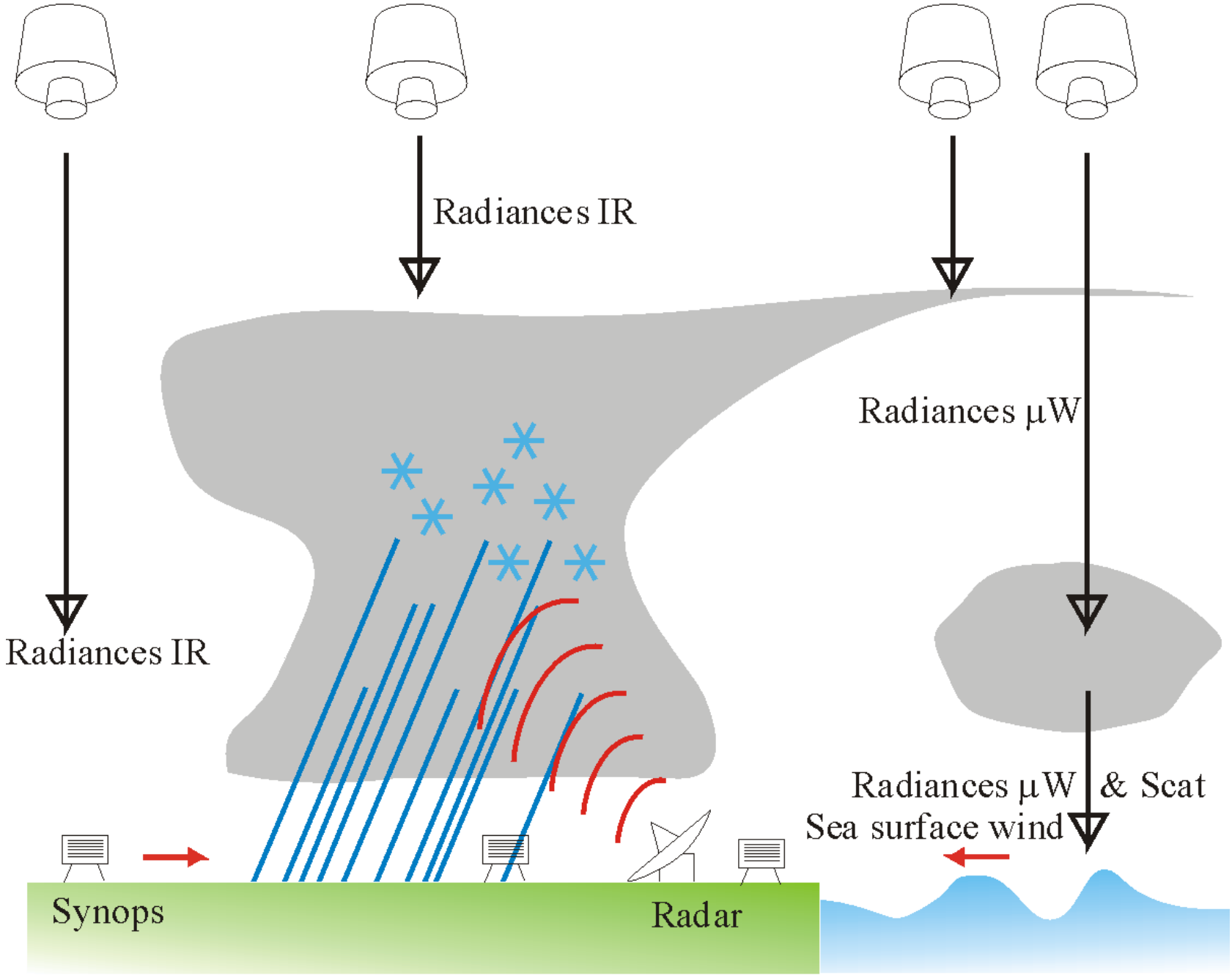
Prévision sans analyse spécifique



Nîmes radar

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

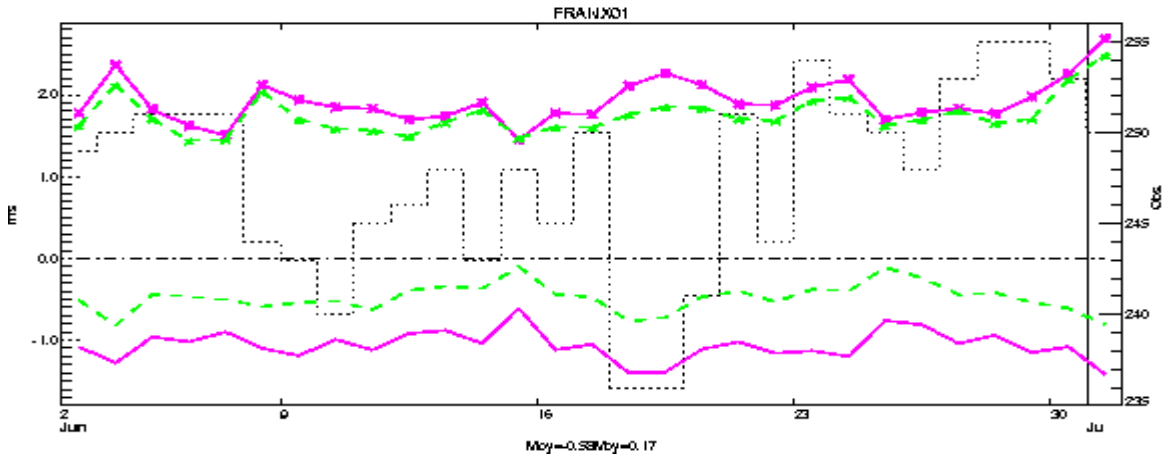
Required observations at convective scale



Usefulness of a regional analysis

Low-level wind model-observation error statistics over a few days: (rms and bias)

Pink : large-scale ARPEGE 4DVar analysis
Green : ALADIN 3D-Var analysis with same observations

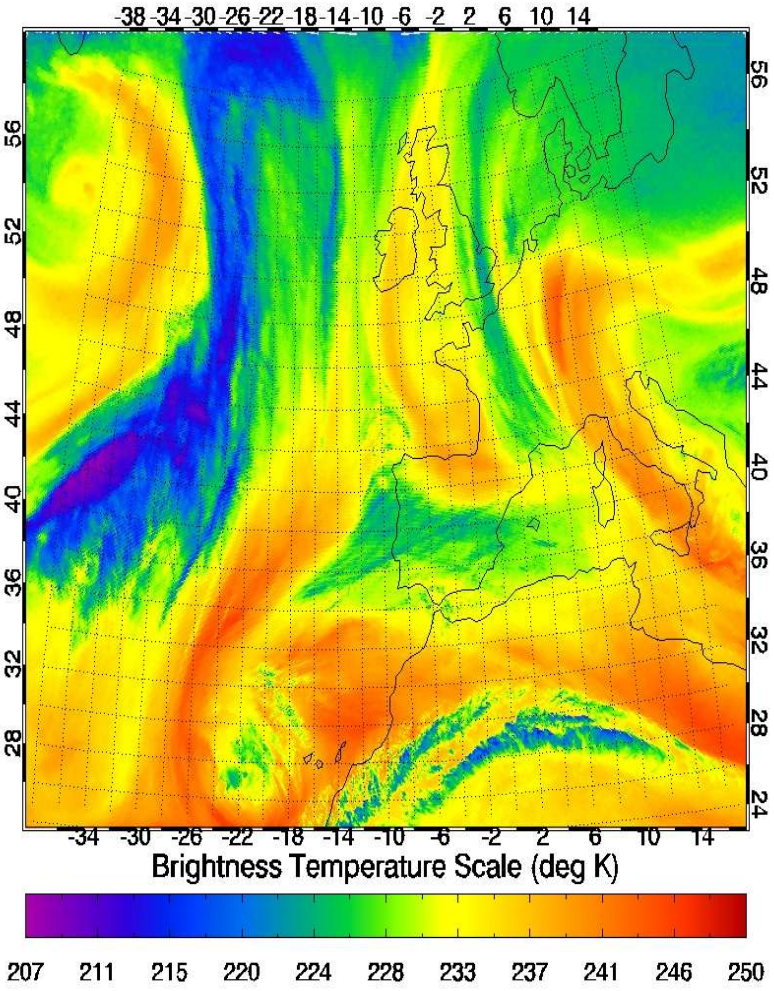


AROME analysis developments

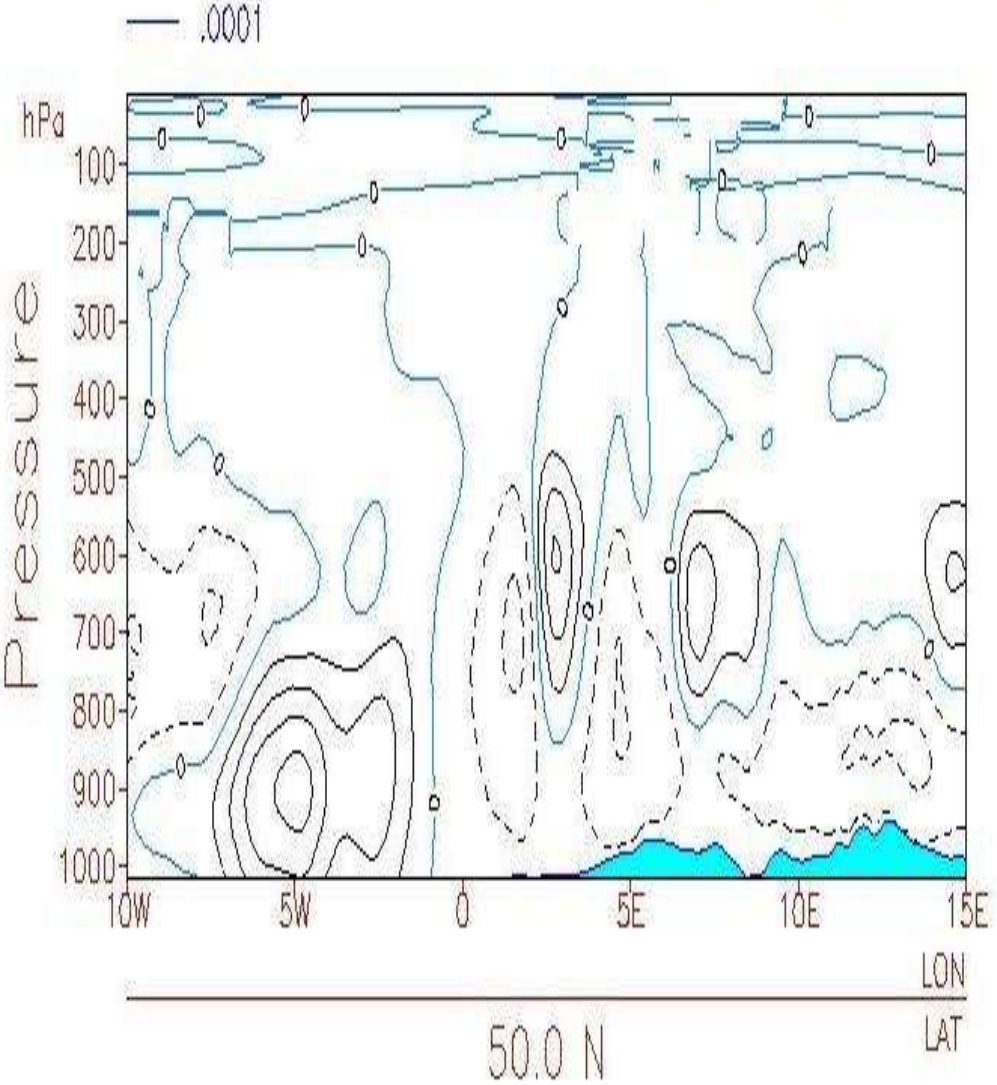
- Basic adaptation of ARPEGE features to ALADIN 3DVar is operational end 2004 (better than dynamical adaptation) + Meteosat radiances
- Most features already in ALADIN 3D-Var, but better in AROME
- High frequency observations (1min)
- Radar (reflectivity & Doppler wind) & satellites with cloud analysis
- Surface fields in control variable for low-level obs
- Large-scale variational coupling term
- Humidity and microphysical fields analysis
- Convective-scale **ensemble prediction**
- **4D-Var** work starts in 2005

Mesoscale 3D-Var humidity analysis from geostationary radiances

MSG/Seviri *WV 6,2* μ Tb
on 12 Feb 2003, 1330

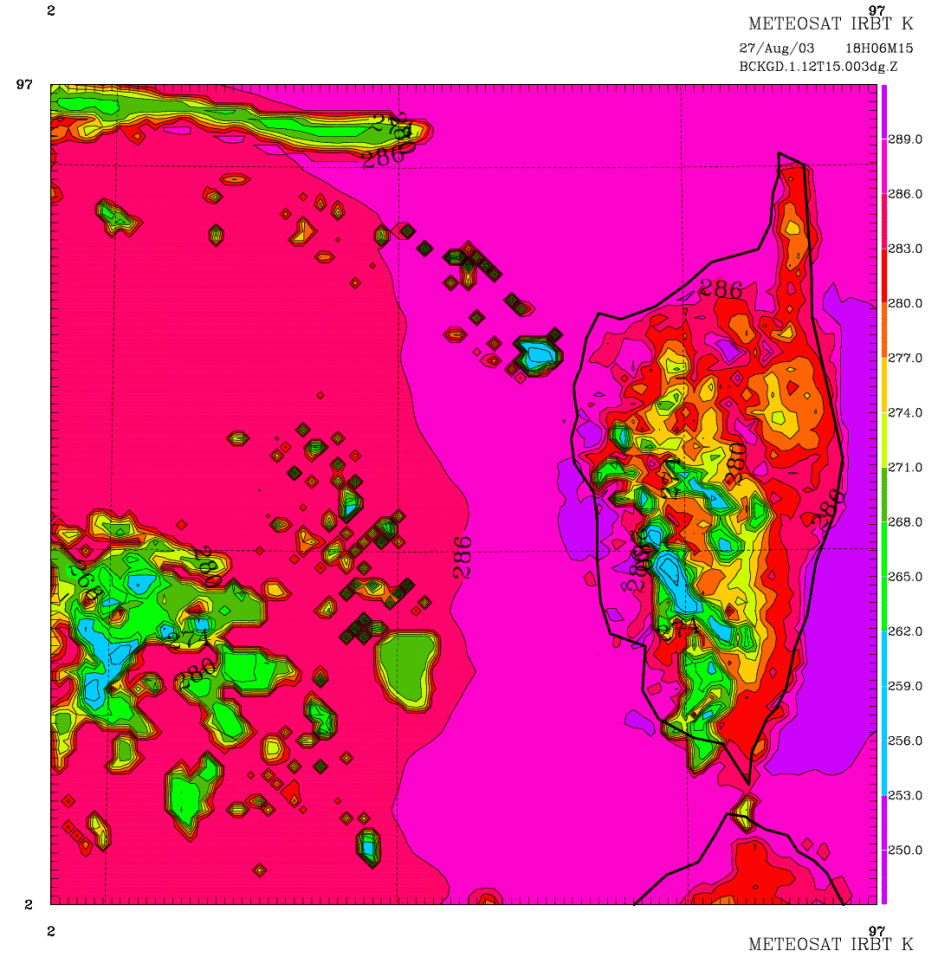


3DVar specific humidity increments

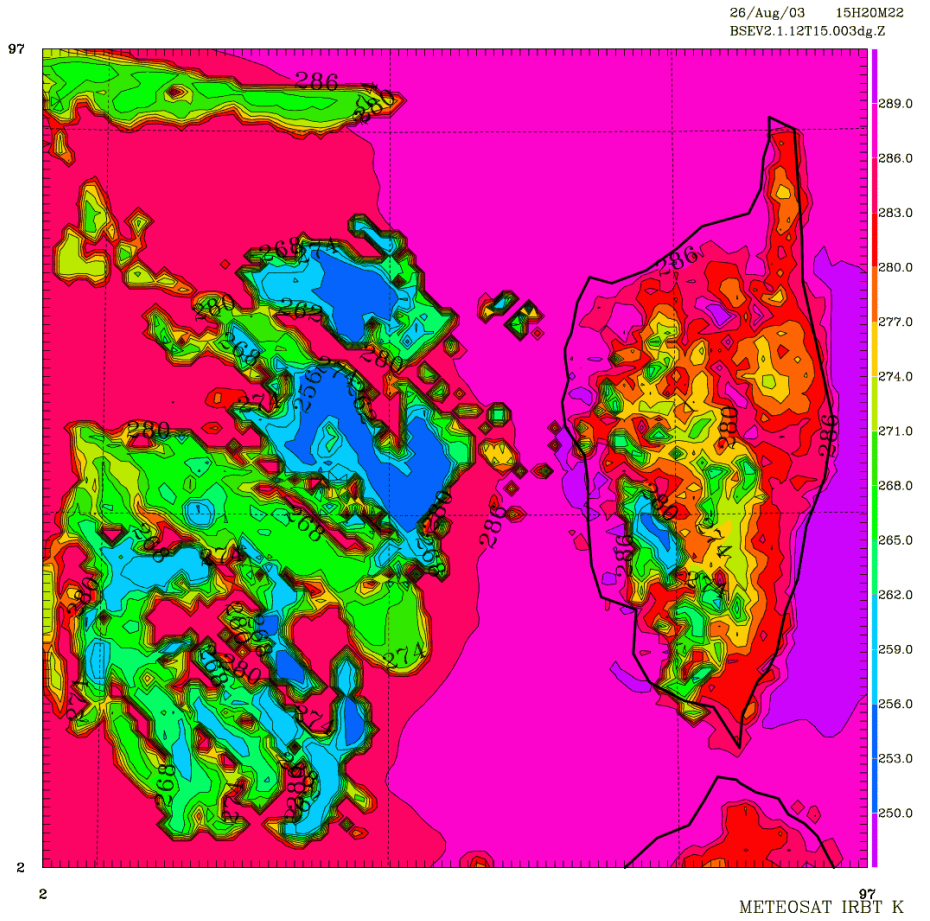


Impact of MSG radiance assimilation on 2.5km convection forecasts

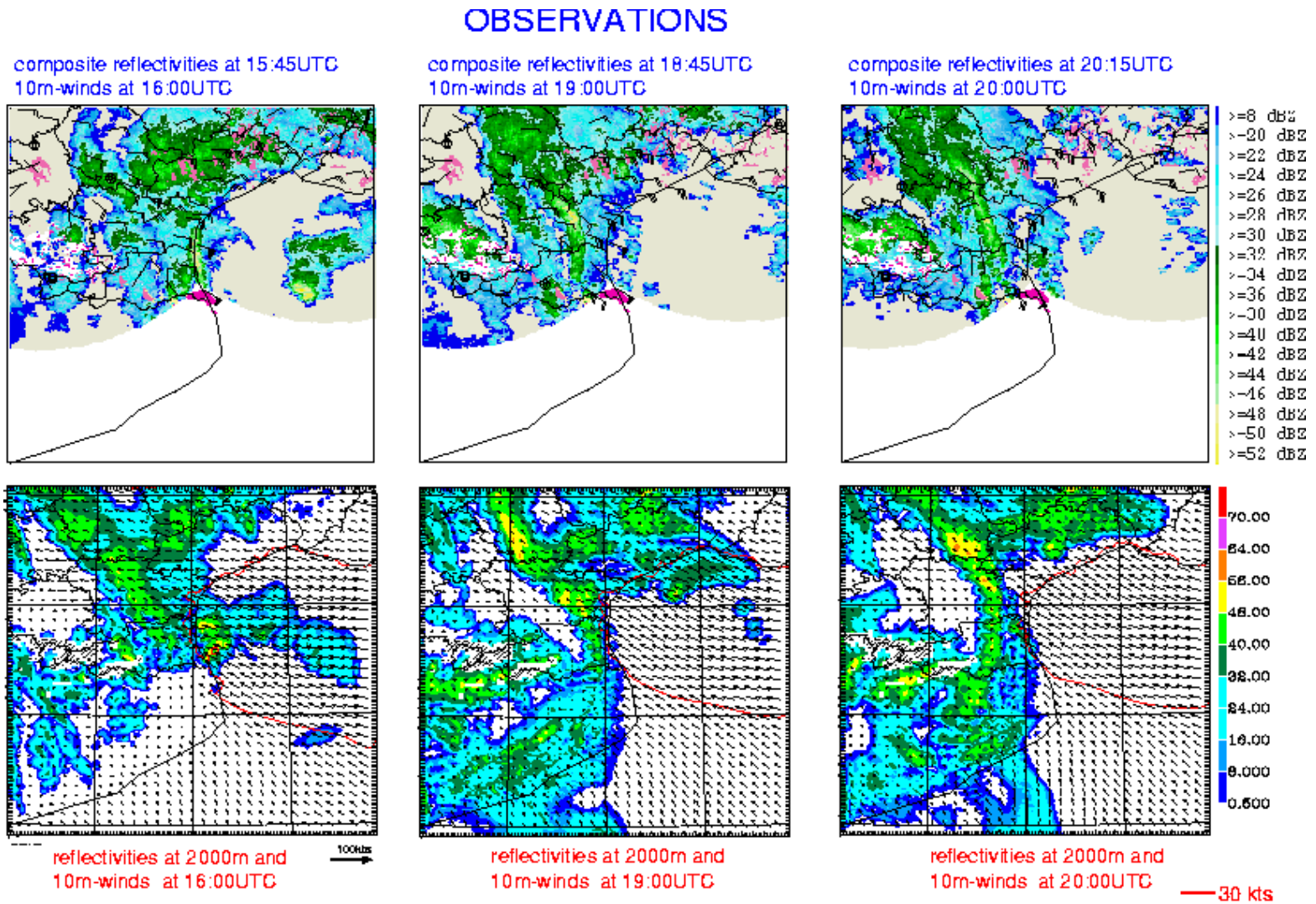
Forecast IR image, no analyis



with analysis



Preparation of radar assimilation : observed and model-generated reflectivities



Question 1: do we really need AROME now?

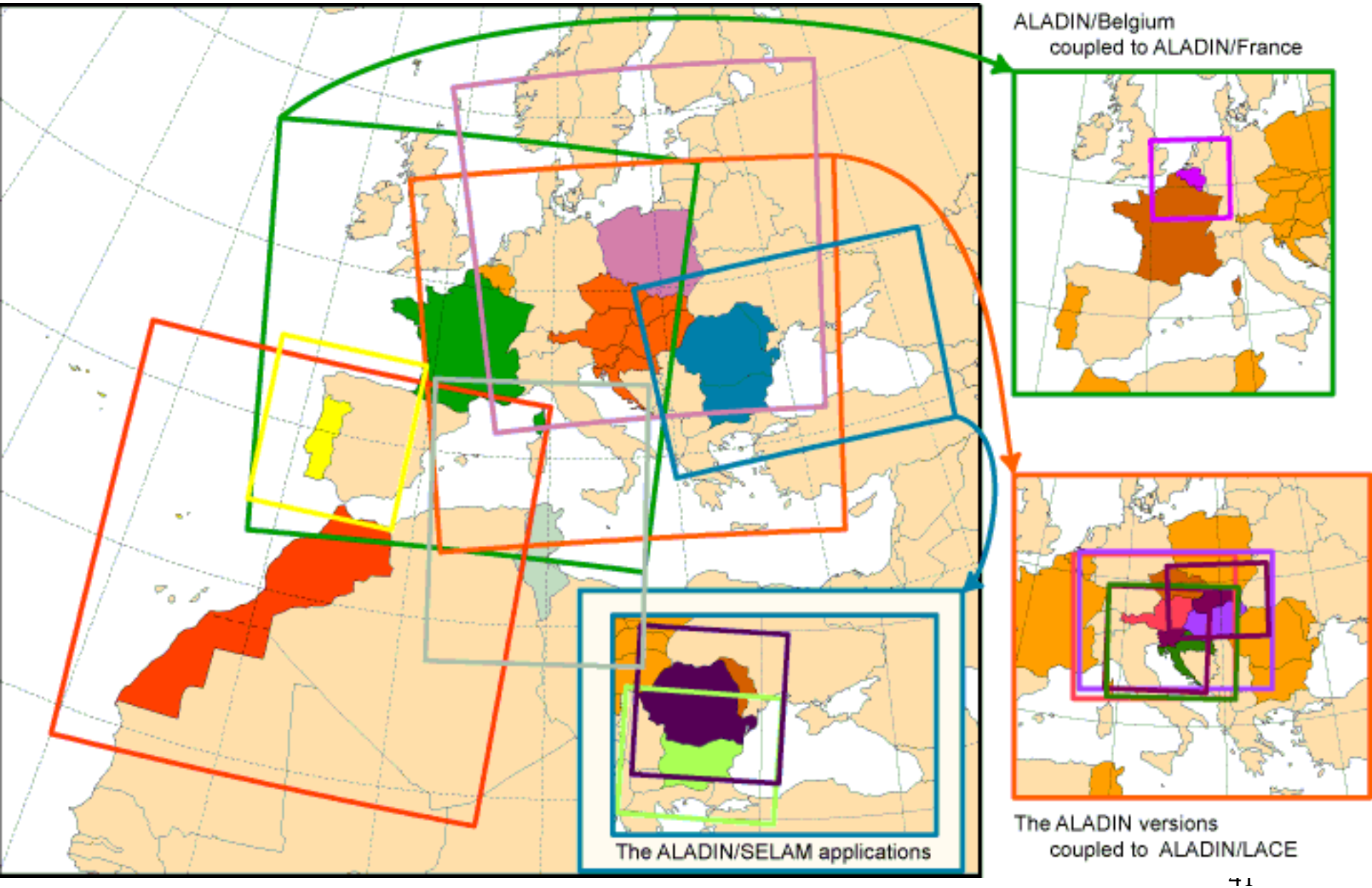
- YES ! **The competition is moving fast:**
  - Met Office mesoscale model is improving. Already used in Norway, soon in Spain.
  - German LMK model already runs daily at 2.7km.
  - American WRF model and 3DVar data assimilation is available, ready for use by private sector & universities
- urgent **customer interest** in fine-scale products, even on small domains or short ranges. e.g. Wind farms
- Lower resolution limited-area models will soon be made obsolescent by global models.

Question 2: is AROME too expensive ?

NO !

- Preoperational testing is not expensive and **must** be started a few years before real-time use
- The unoptimised gridpoint cost is 3 times Aladin, probably 2 times after optimization.
- The increase in grid size means a factor dx.dy.dt=4x4x7 i.e. Arome is about 300 times more expensive than 10-km Aladin *for the same operational setup*
- BUT only a fraction of it is needed if you reduce the domain and/or the forecast ranges.
- If convective-scale modelling is too expensive, why are other institutes doing it ?

ALADIN international cooperation, 14 operational domains



CONCLUSION

- ALADIN is still improving through ARPEGE work and will be maintained at Météo-France
- The future of ALARO shall be decided by the partners
- **AROME is available for use now, looks very promising but needs more effort for science and preoperational installation – time goes fast !**