# Recent investigations in Meso-NH and AROME models

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| Méso-NH (Lafore et al., 1998) | AROME Applications of Research to Operations at MesoscalE |
|---|---|
| **Research** model, onset of development in 1990's | **Operational** in 2008 |
| **From 100km to 10m resolution (grid-nesting)** | **2.5km** |
| No data assimilation | 3D-VAR data assimilation |
| NH **Anelastic** | Full **compressible** |
| Eulerian - Explicit | **ALADIN-NH** dynamics : SL-SI |
| From **simple** to **sophisticated** physics | A single physics from **Méso-NH** |
| 1D or 3D turbulence | 1D turbulence |
| 1-moment or 2-moment microphysics | ICE3 microphysics (Pinty et al.) |
| ECMWF radiation | ECMWF radiation |
| Kain-Fritsch-Bechtold convection | Kain-Fritsch-Bechtold shallow convection |
| Externalized surface SURFEX | Externalized surface SURFEX |
| In-line gaseous-aqueous chemistry and aerosols | Same chemistry but not operational |

# Complementarity AROME/Méso-NH

-AROME physics identical to a subset of Meso-NH

- Meso-NH is computationnally more expensive and doesn't have its own data assimilation

-Physics contribution from the research community through Meso-NH : Meso-NH has a better environment for in-depth research : LES comparisons, grid-nesting, diagnostics and budgets

- During the current evaluation phase of AROME, Meso-NH is useful to investigate specific real test cases

- Objective scores of AROME are usefull for the Meso-NH physics

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# PLAN

1. **Meso-NH dynamics** : a recent improvement of the advection schemes

2. **AROME** : Design of the pre-operational suite ; Some « good AROME forecasts »

3. **AROME dynamics** : an identified problem with the horizontal diffusion causing « fireworks »

4. **Meso-NH/AROME physics** : a recent improvement with EDKF shallow convection scheme

5. Conclusion

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# Previous numerical set-up of MesoNH

- momentum (U, V, W) and meteorological and scalar variables :
  - Standard centered and flux-corrected **$2^{nd}$ order scheme** and MPDATA (Smolarkiewicz, 1984)
- **Leap-Frog** time marching

• **Need** to upgrade the numerical setup of Meso-NH:

– increase **stability** and **efficiency** ($\Delta t$)

– have more **accurate** scheme for scalar advection

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# New numerical set-up of MesoNH *(T.Maric)*

- momentum (U, V, W) and meteorological variables
  - **CEN4TH** – centered 4$^{th}$ order
- meteorological variables (Θ, TKE, Rx, SV)
  - **PPM_00** – unlimited PPM
  - **PPM_01** – monotonic PPM (Colella and Woodward, 1984), classic limiter
  - **PPM_02** – monotonic PPM (Skamarock, 2005) : possible extension to remove time step restriction
- PPM algorithm requires **forward in time** integration, not leap-frog
- Extension of advection operator to 3D done with time-split scheme as described in Skamarock (2006), altering order at each time step (Strang, 1968)
- Mixing of leap-frog and forward-in-time (FIT) time marching – not optimal

# 2D test case – trapped waves *(T.Maric)* : 2nd order advection

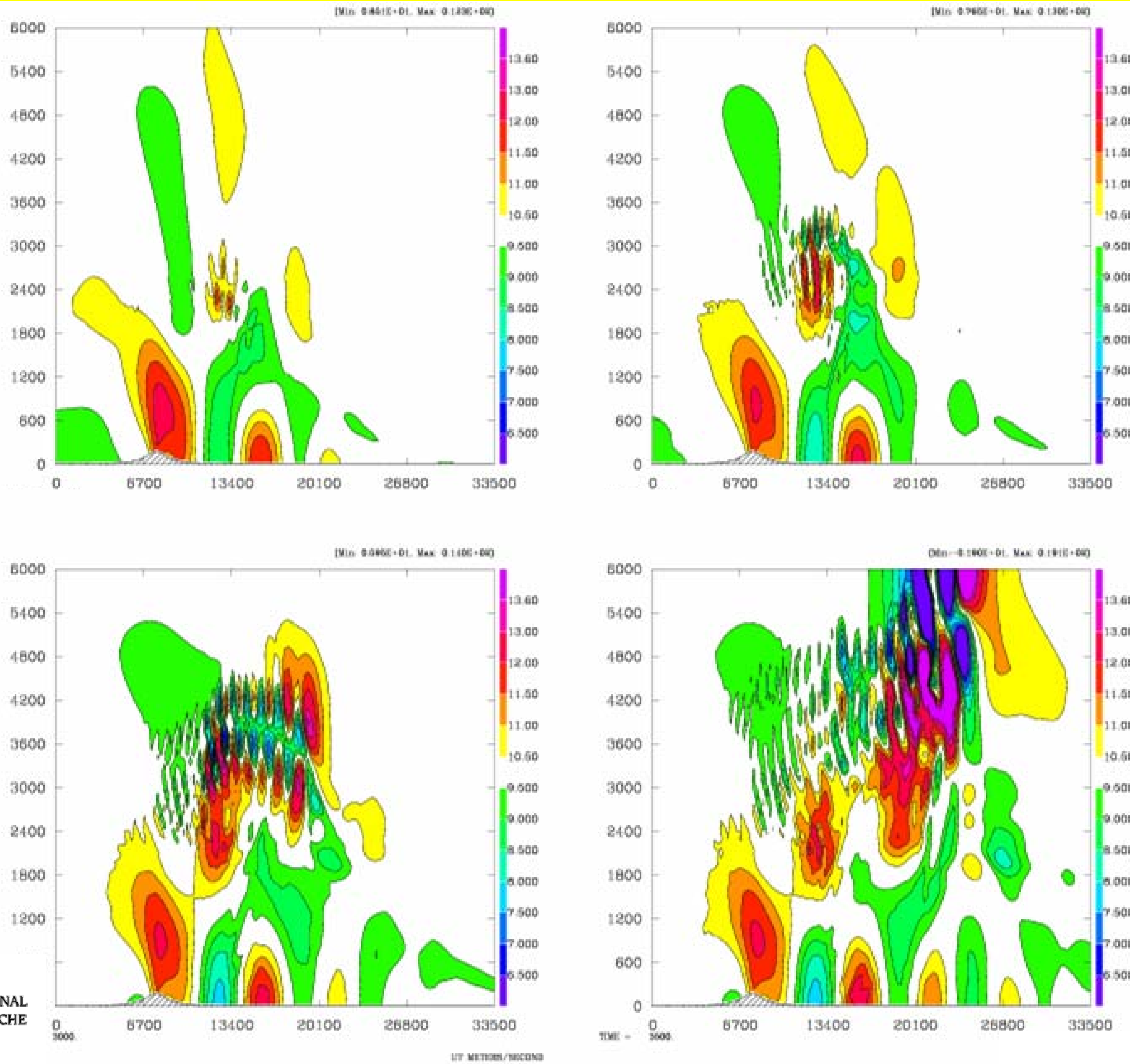
**U m/s**

**2000 s**

**2500 s**

**3000 s**

**3500 s**

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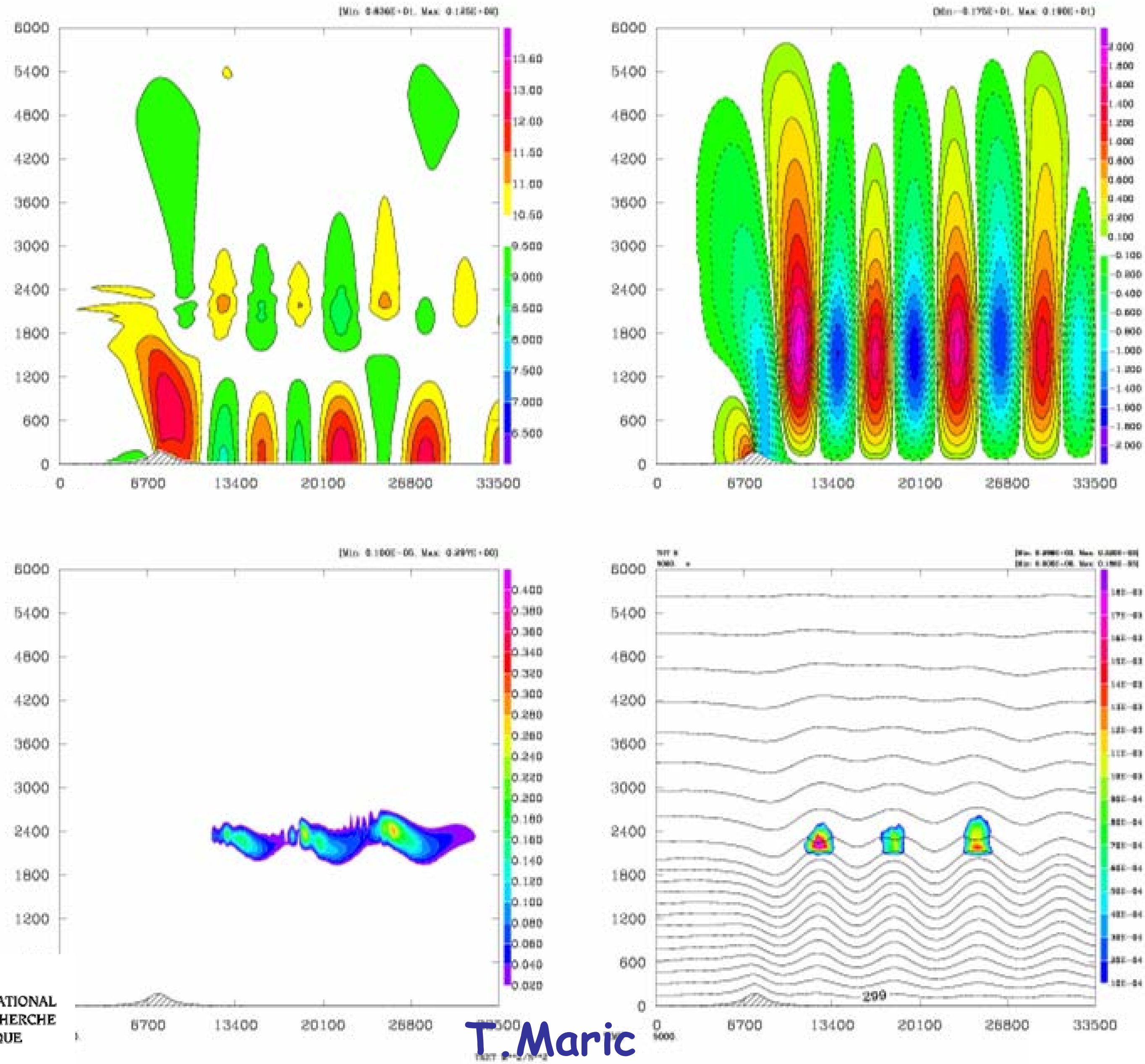
# 4th order advection for U,V,W ; 2nd order advection for meteorological variables

t = 5000 s

U

W



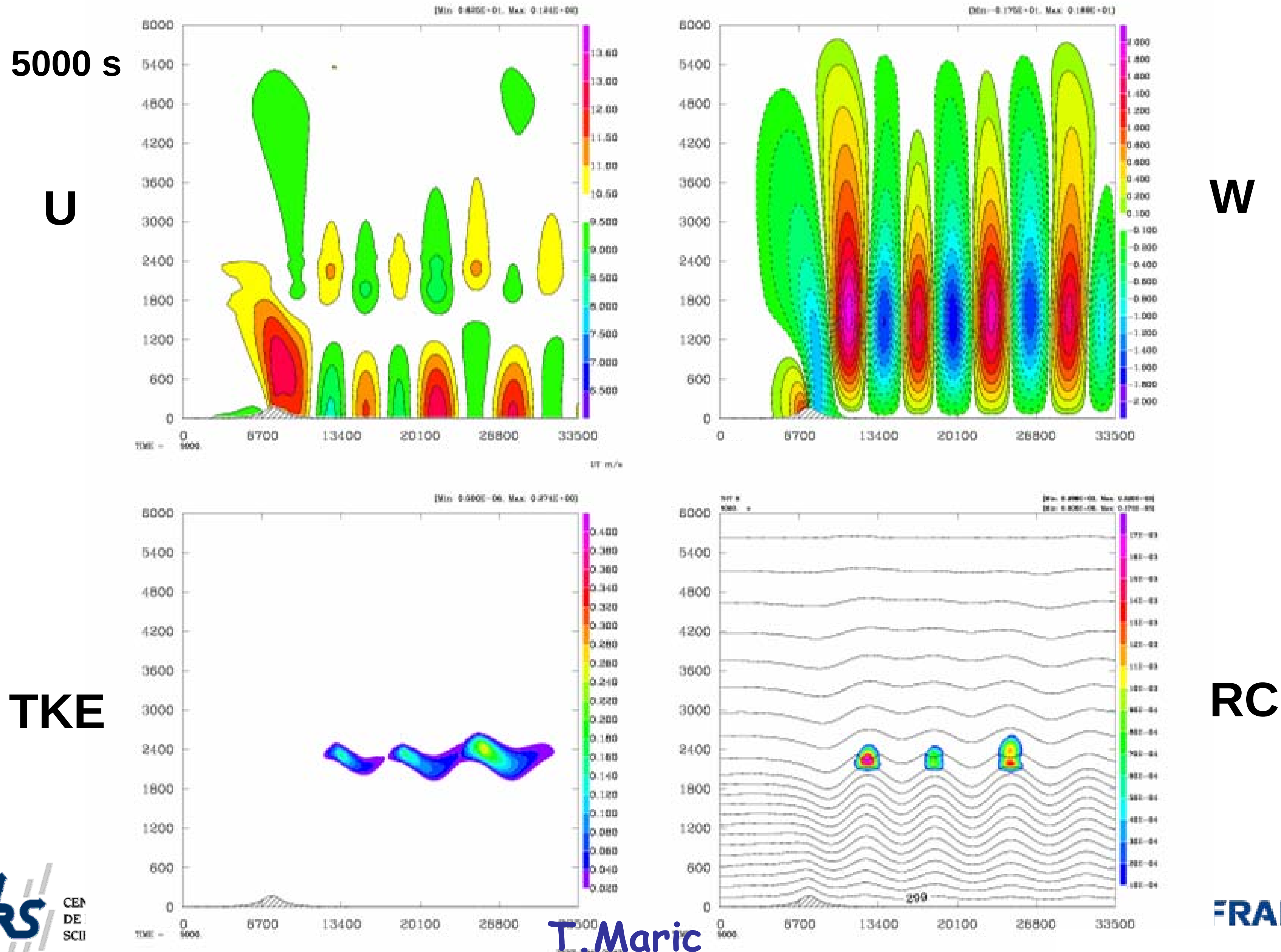

TKE

RC

T.Maric

# 4th order advection for U,V,W ; PPM_00 for meteorological variables

t = 5000 s




T.Maric

# New numerical set-up of MesoNH *(T.Maric)*

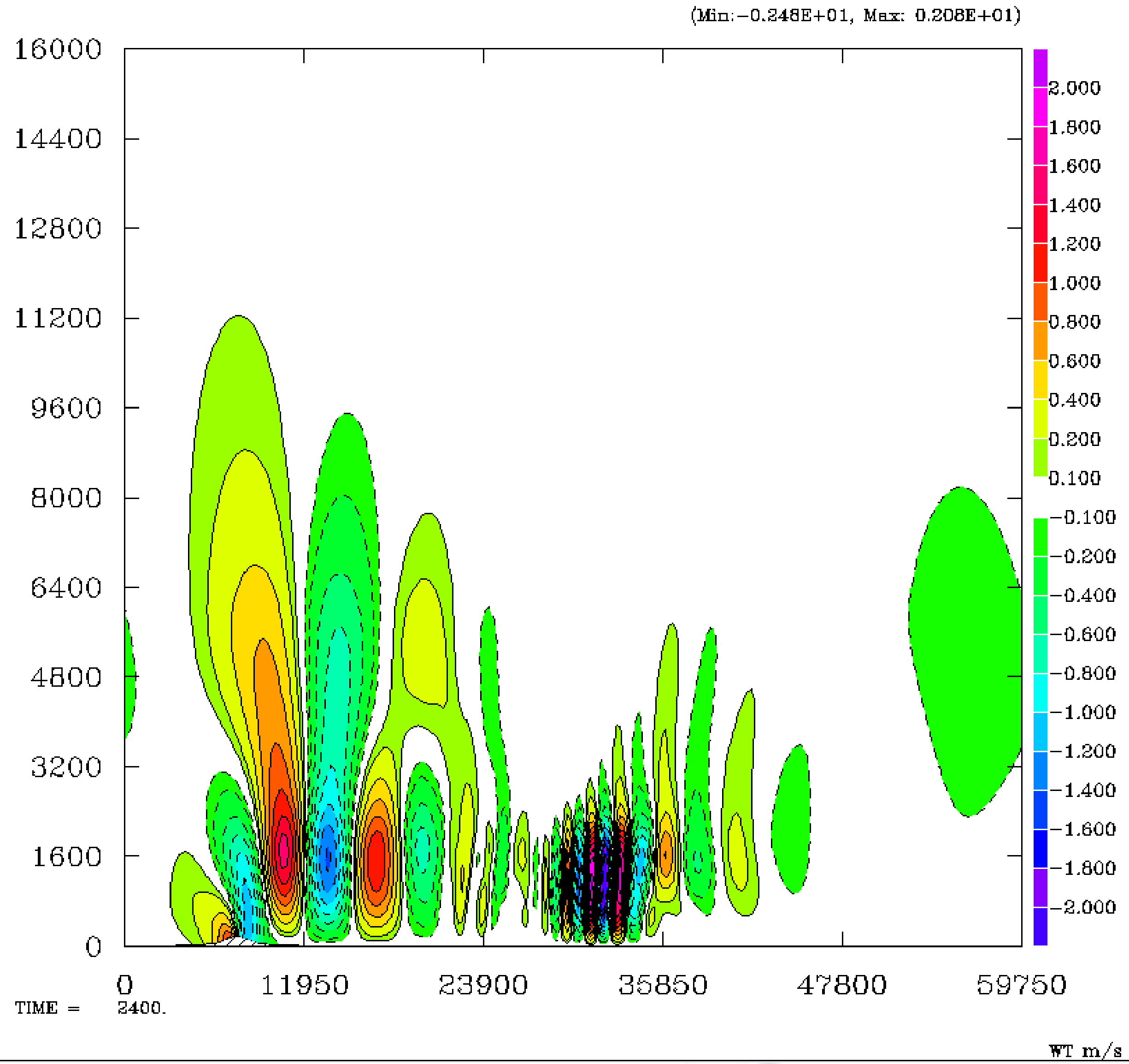
- **Accuracy improved** as PPM schemes and CEN4TH are at least an order of magnitude more accurate than previous ones
- **Stability improved**:

**PPM:** $$MAX(C_x = \frac{U\Delta t}{\Delta x}, C_y = \frac{U\Delta t}{\Delta y}, C_z = \frac{U\Delta t}{\Delta z}) \leq 1$$

**CEN4TH:** $$\begin{cases} |C_x| + |C_y| + |C_z| \leq 1 \\ \Delta t(\frac{3}{2}\frac{|V|}{\Delta x, y} + \frac{|w|}{\Delta z} + N) \leq \frac{1}{\sqrt{2}} \end{cases}$$

- **BUT** Stability still limited by the momentum advection
- Extension of PPM to momentum (all variables) non-trivial:
  - main difficulty is to estimate wind vectors used for advection

# 2D test case - trapped waves : PPM for all variables



# Future work for Meso-NH – momentum advection

- Change time marching to **FIT** and then to **Runge-Kutta** (3rd order)
  - more accurate and stable, even with CEN4TH
  - WENO 5th or 3rd order schemes can easily be implemented for momentum, keeping PPM for scalar variables

→ complete overhaul of the model : Investigate which problems might occur when changing time-marching in the model

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3. AROME dynamics : an identified problem with the horizontal diffusion causing « fireworks »
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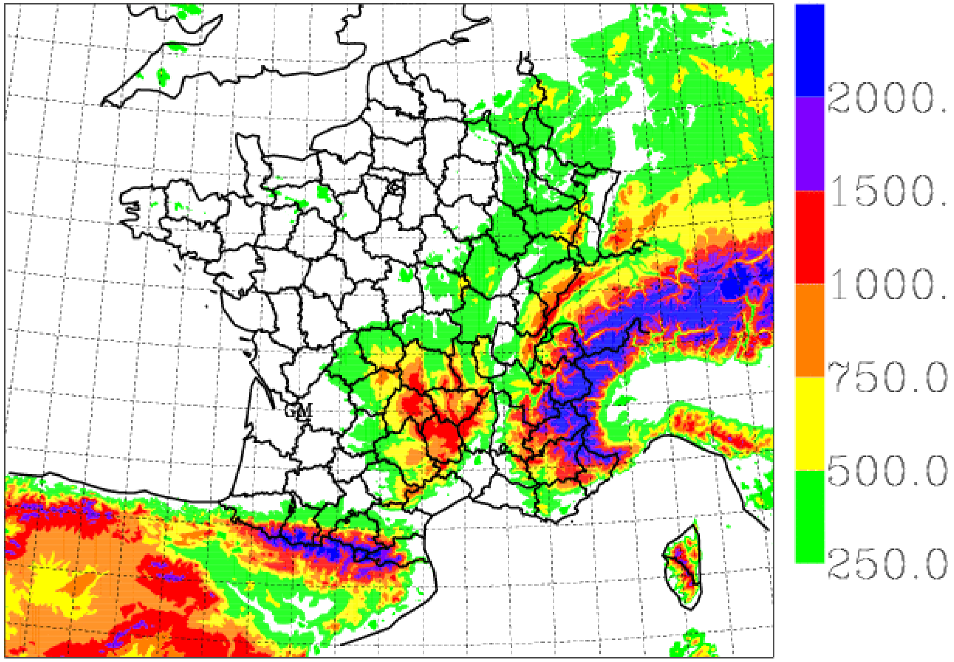
# AROME

- **<u>September 2007</u>** : Configuration of AROME with data assimilation (30 h forecasts at 0, 6, 12 and 18 TU)

- **<u>October 2008</u>** : AROME would be declared operational at Meteo-France

**Model domain (600x512)**

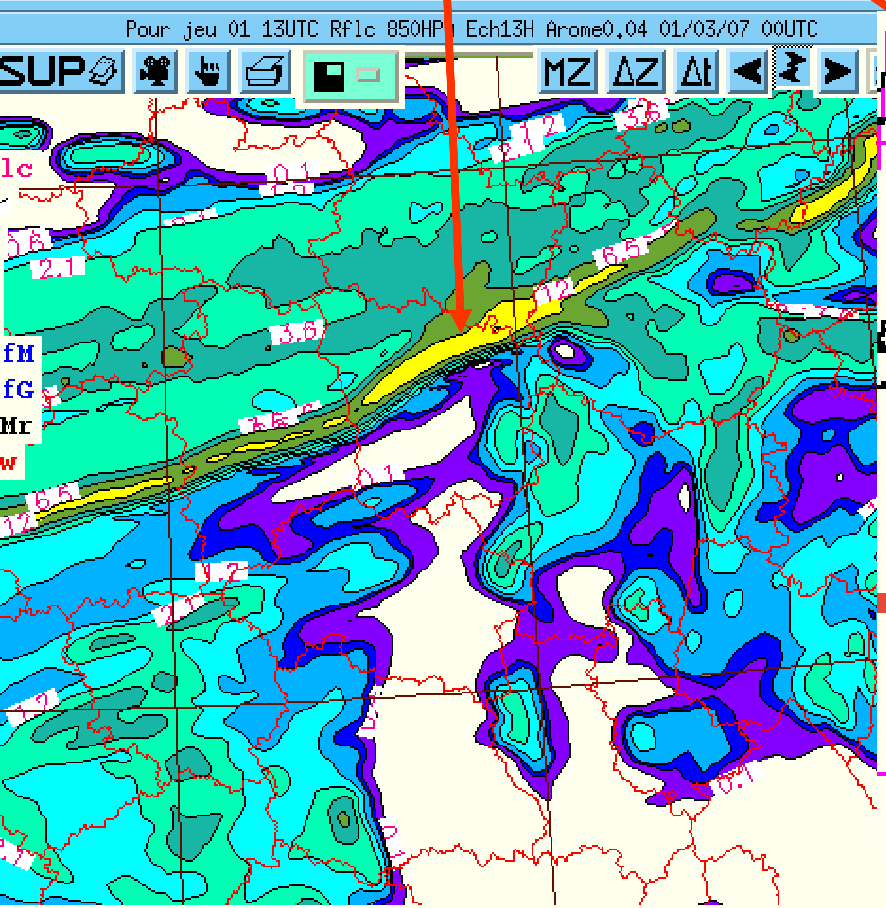


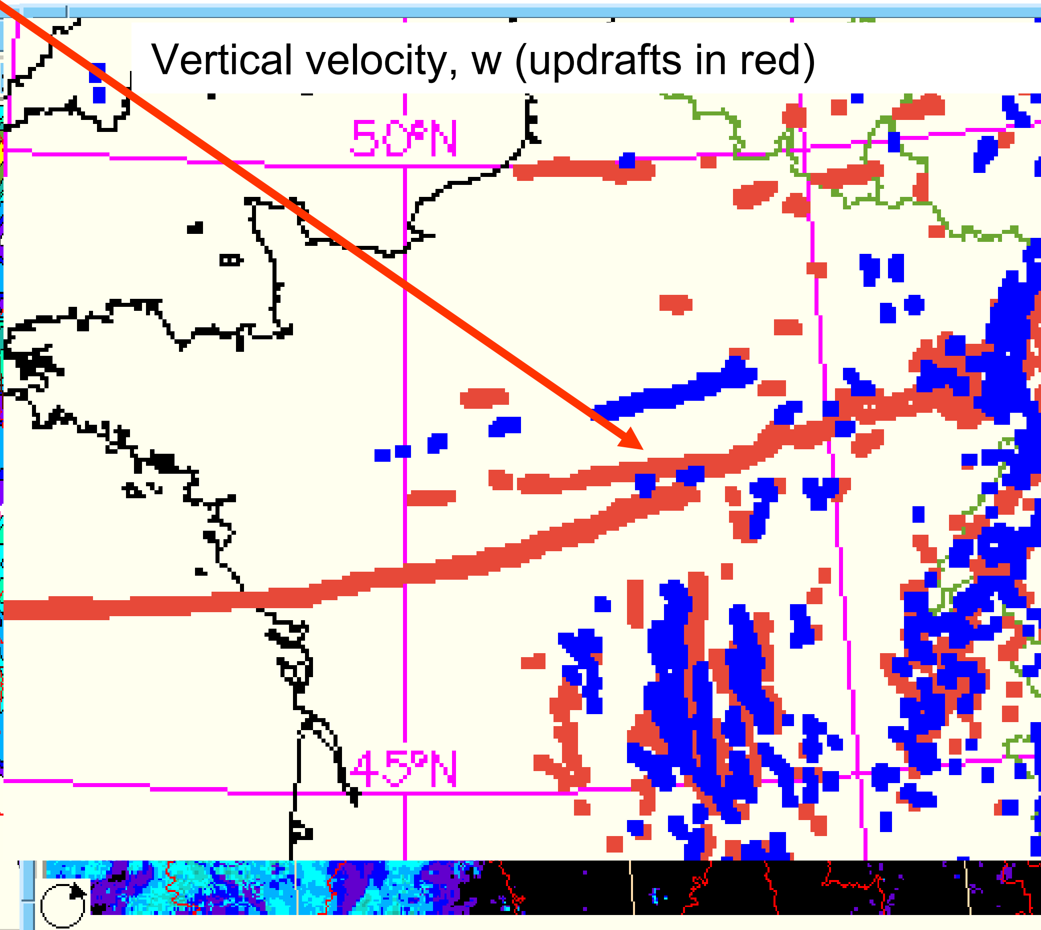

**Vertical levels = 40, Time step=60s**

Time computing for 24h = 1800s on 64 processors

# Frontal precipitation bands (1)

A thin cold front precipitating band.

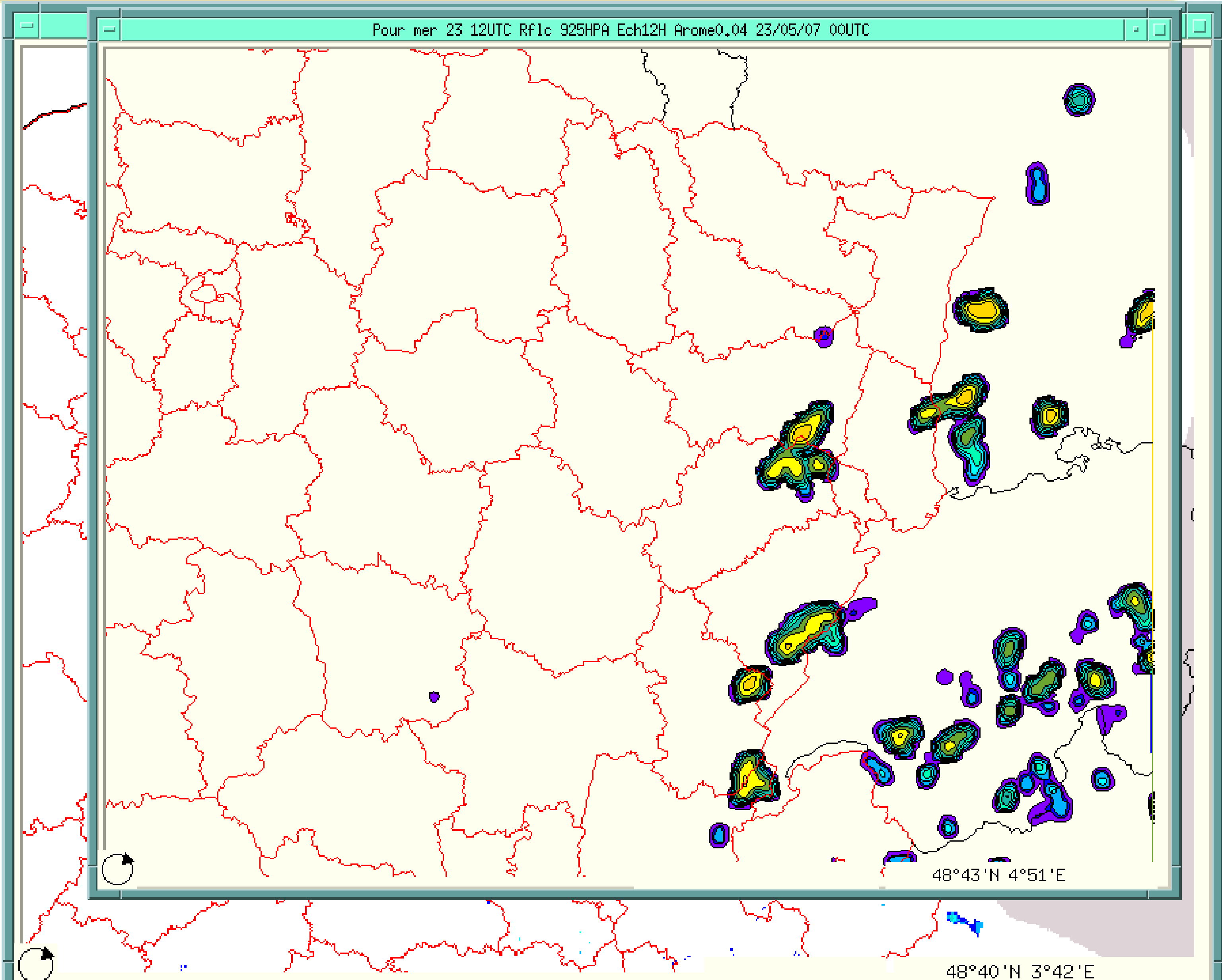



**Simulated radar reflectivity (FC+13h ) vs radar picture, 1 March 2007 ; 13 UTC**

# Diurnal convection *(2)*

**Obs radar**

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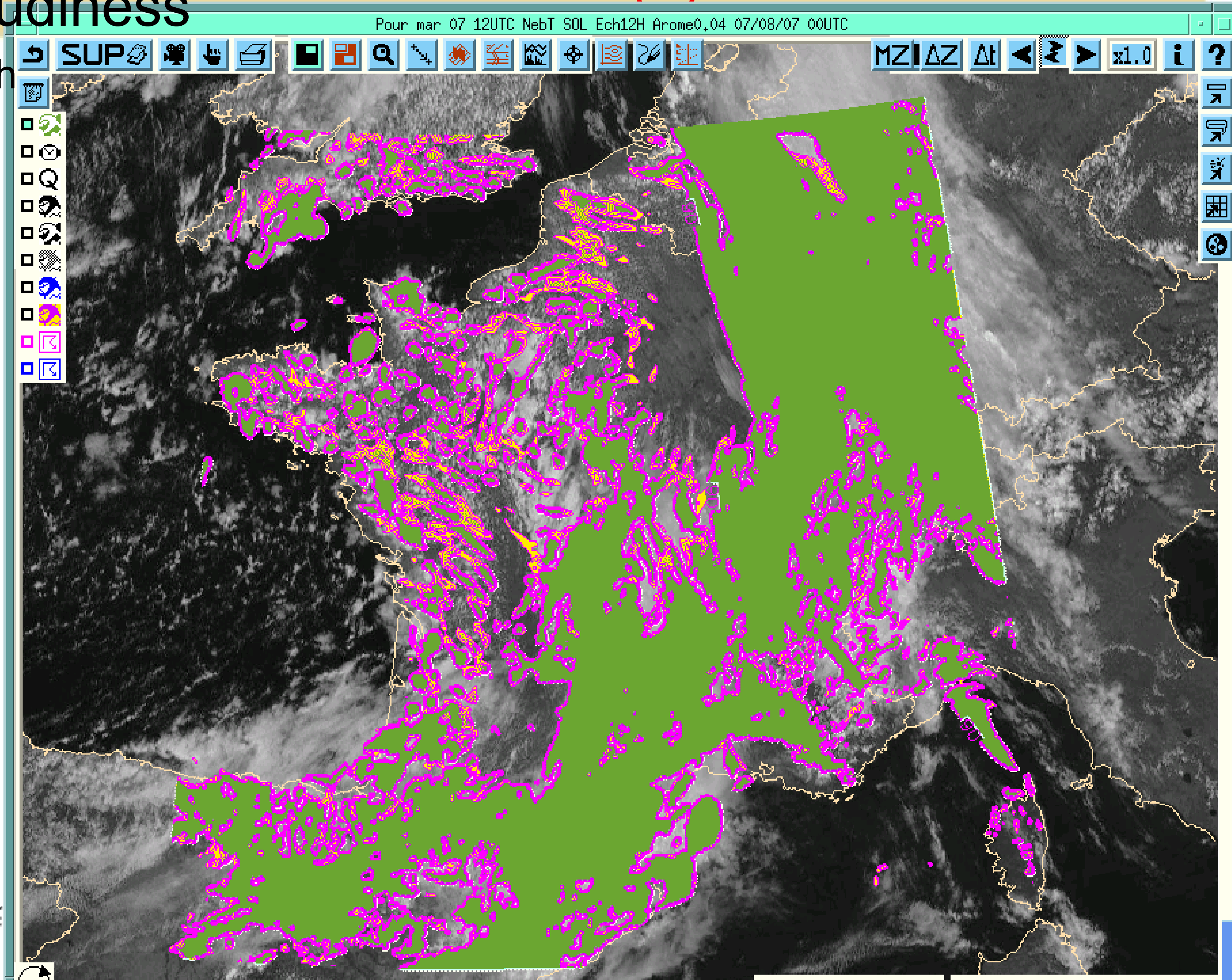
# Cloudiness (3)

## Total cloudiness

AROME 12 h

vs Sat Vis

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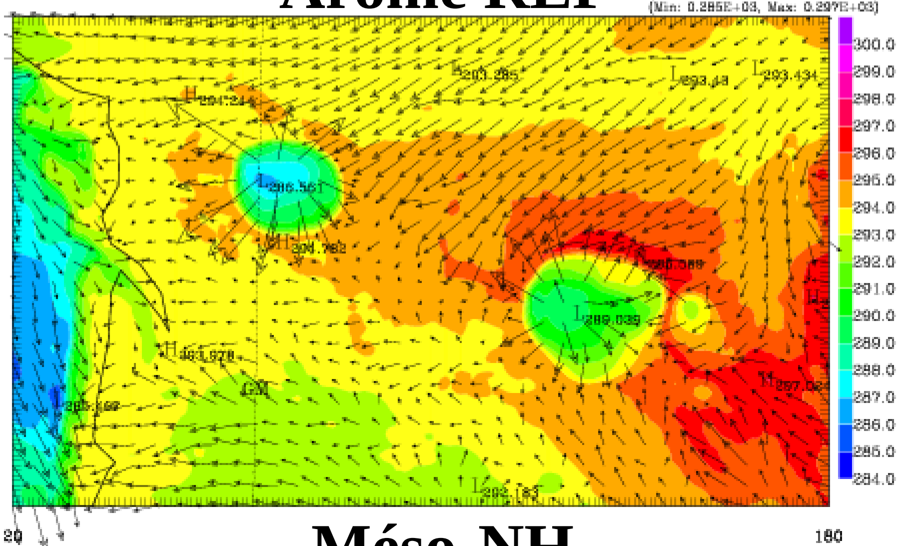
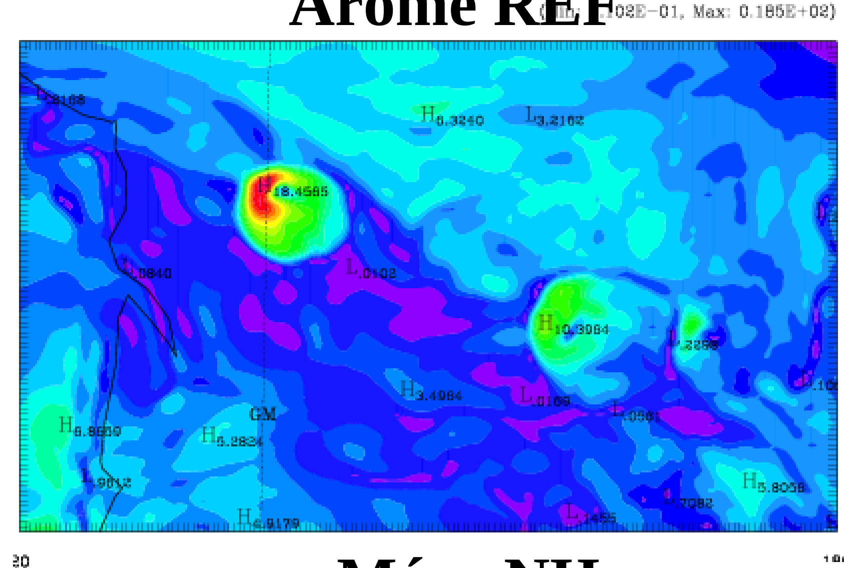
# AROME : "Fireworks" (11-04-2007)

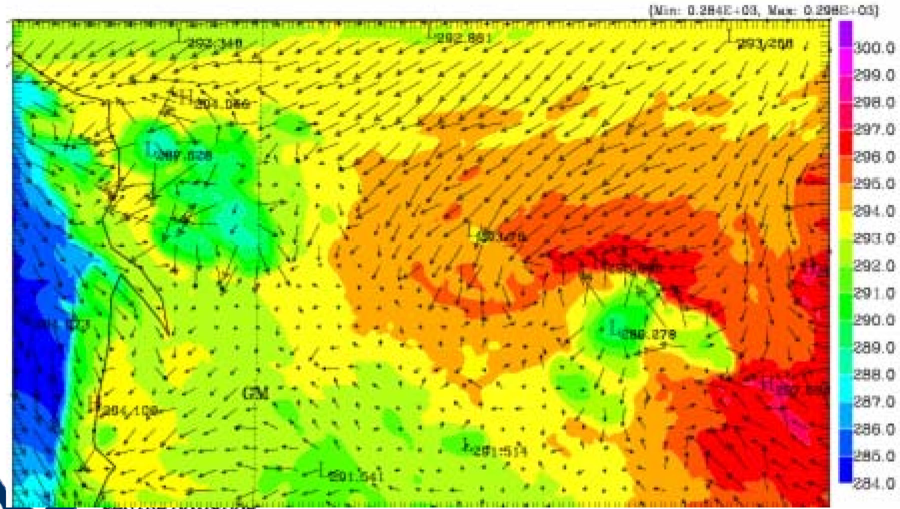
**Arome REF**



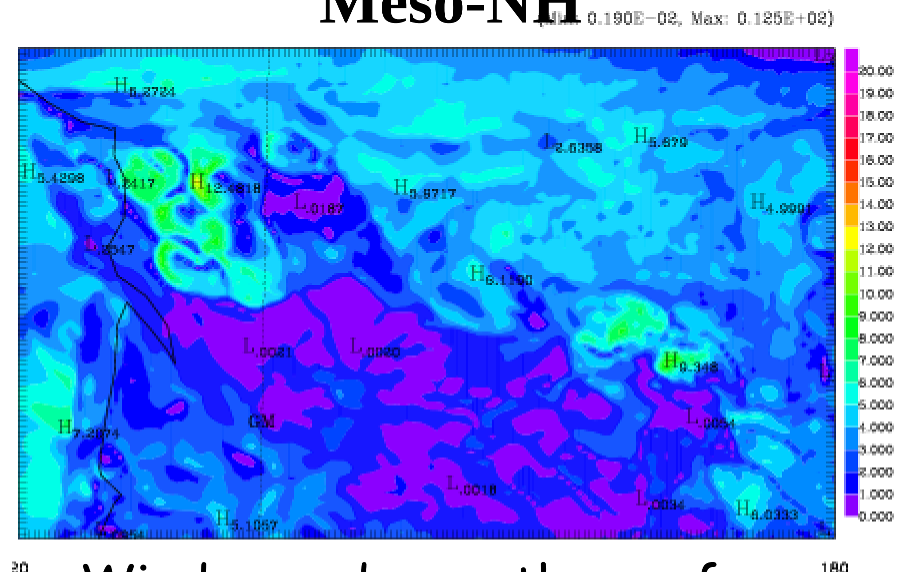
**Arome REF**



**Méso-NH**



**Méso-NH**



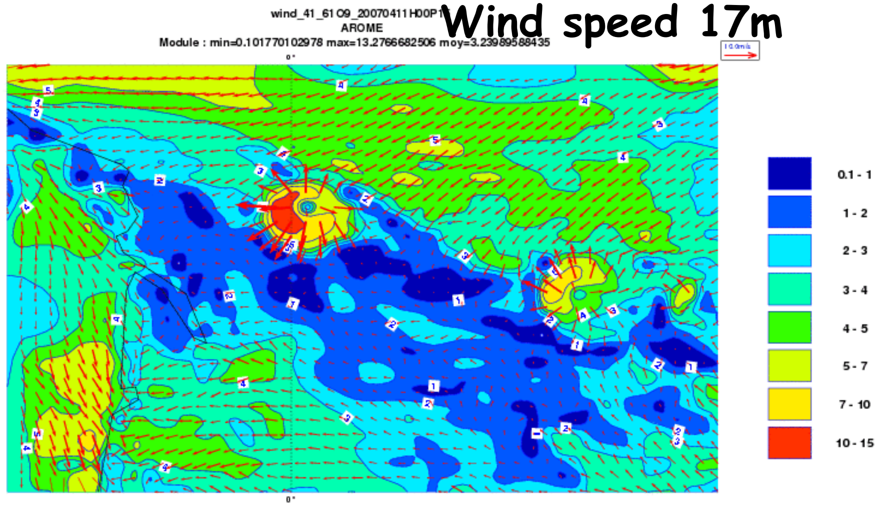


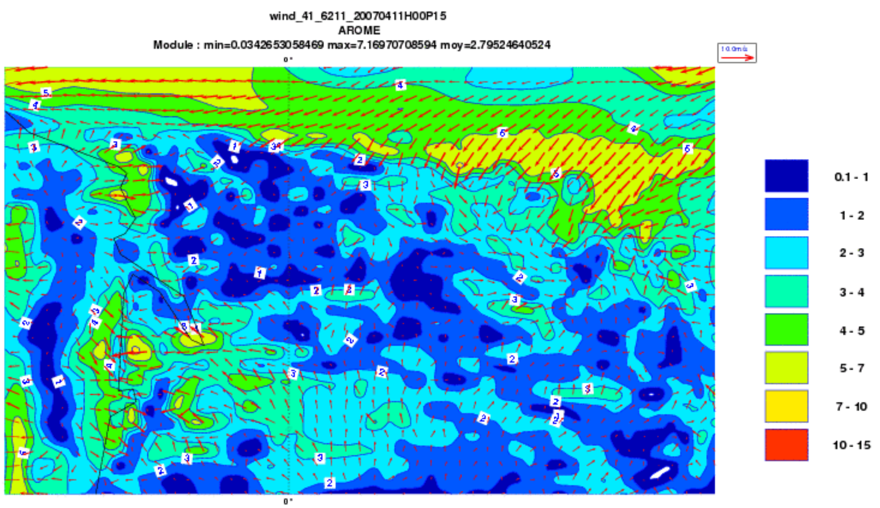
Temperature near the surface

Wind speed near the surface

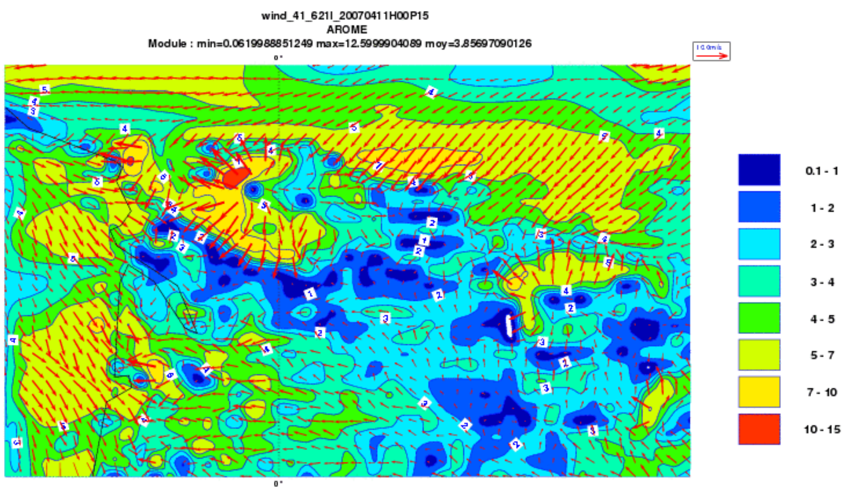
# AROME : "Fireworks" (11-04-2007)

Wind speed 17m



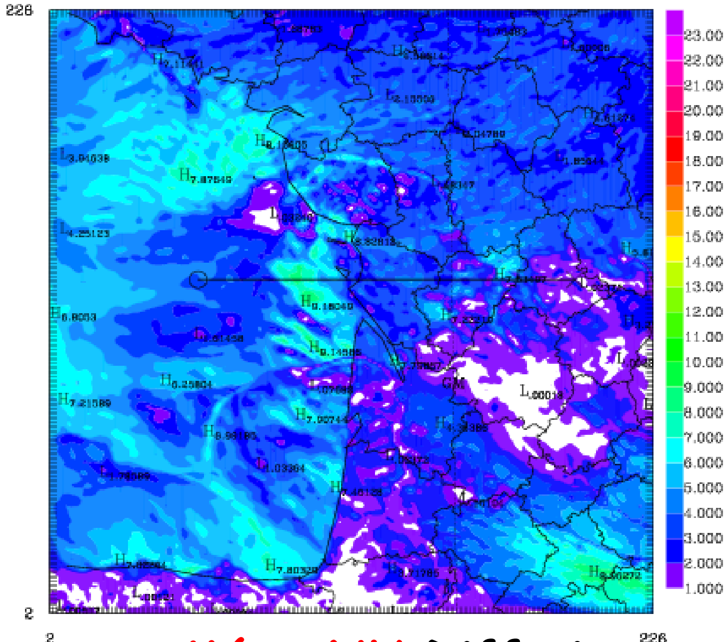



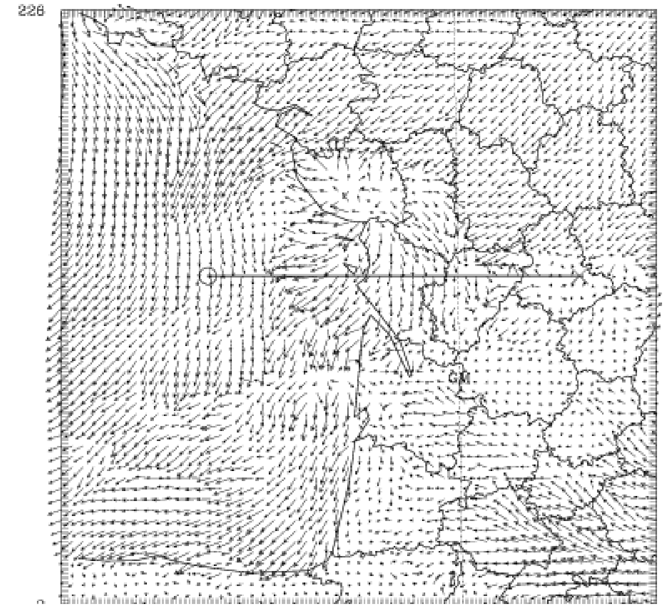

Reduced horizontal diffusion on horizontal divergence




Reduced horizontal diffusion on vertical divergence

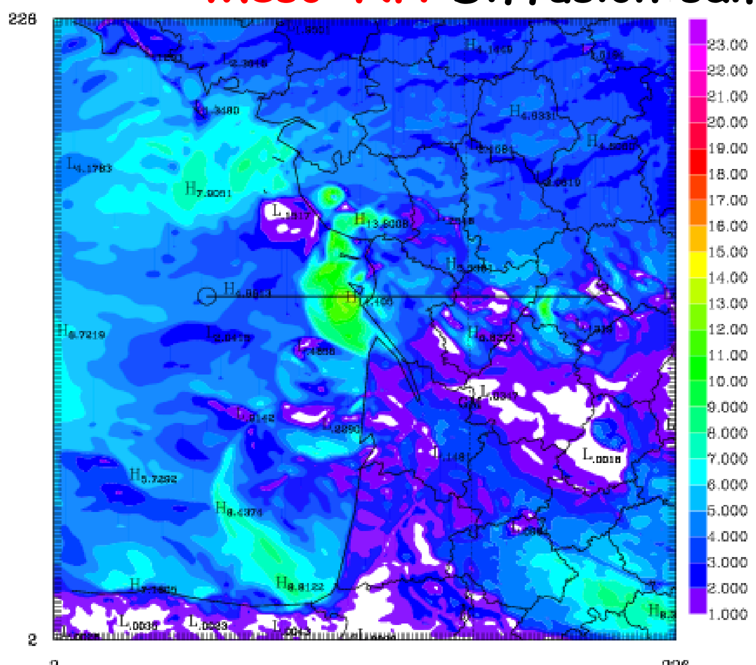
## Méso-NH Diffusion 4 times weaker than AROME

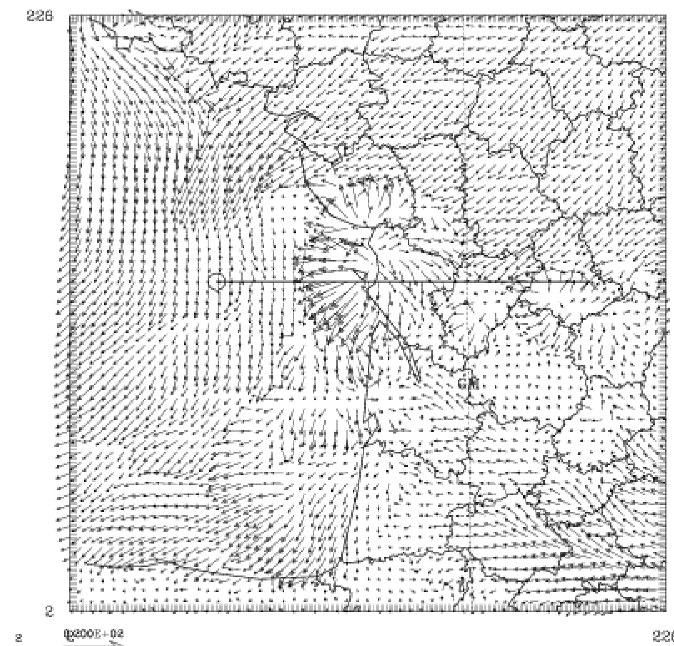


**17H30**

## Méso-NH Diffusion same intensity as AROME



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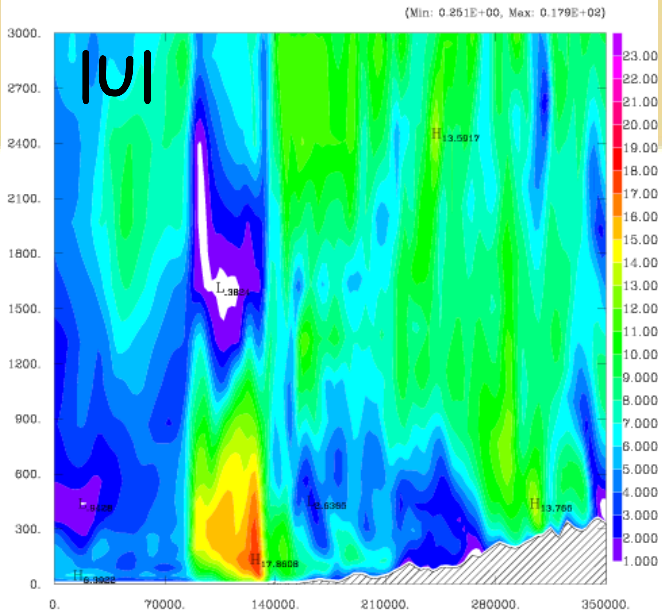
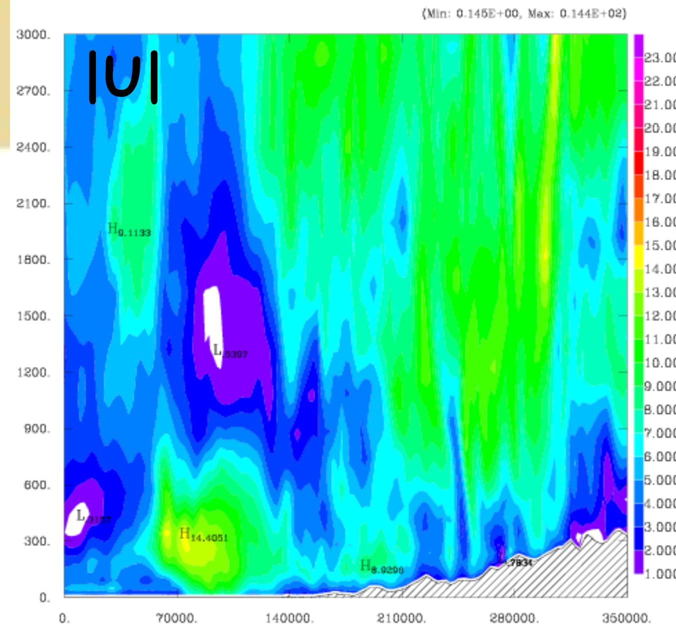
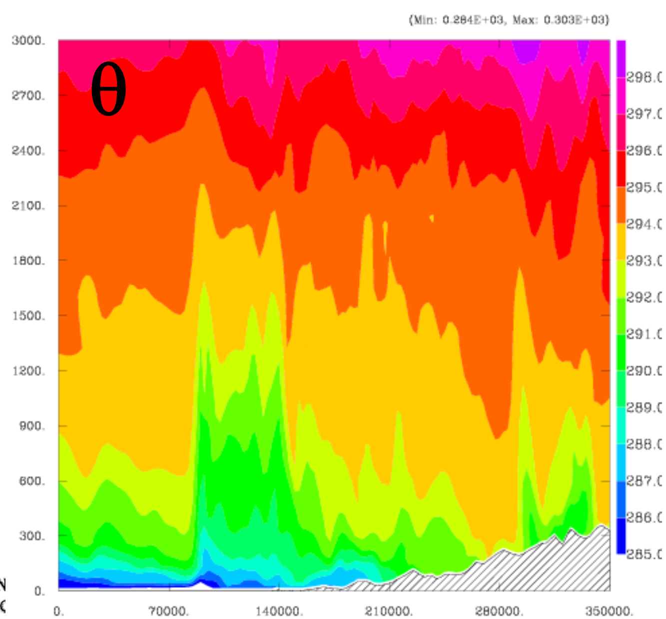
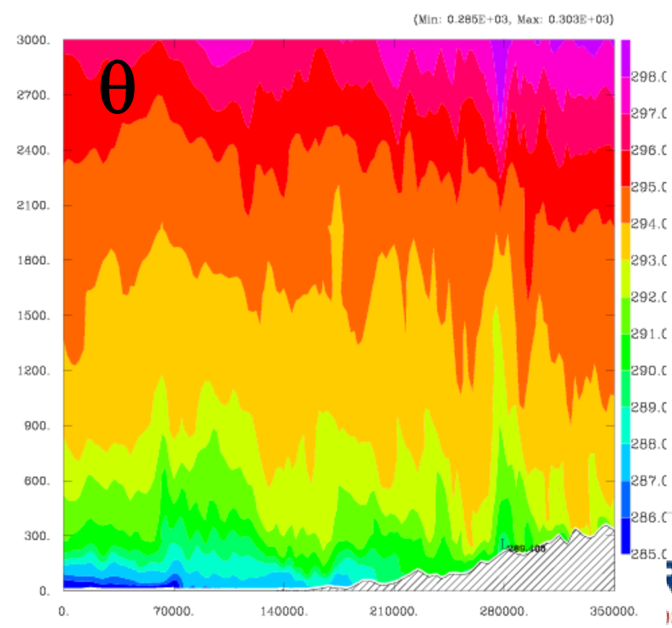



Meso-NH : High diffusion (~AROME)

Lower diffusion



# A major problem with AROME : the « fireworks »

- « Fire works » are related to horizontal diffusion.

- Damping by horizontal diffusion **affects the longer waves** and inhibits the production of eddy kinetic energy due to the downdrafts and the induced cooling.

- But the impacts of the new diffusion tunings are huge and the best tuning is not straightforward

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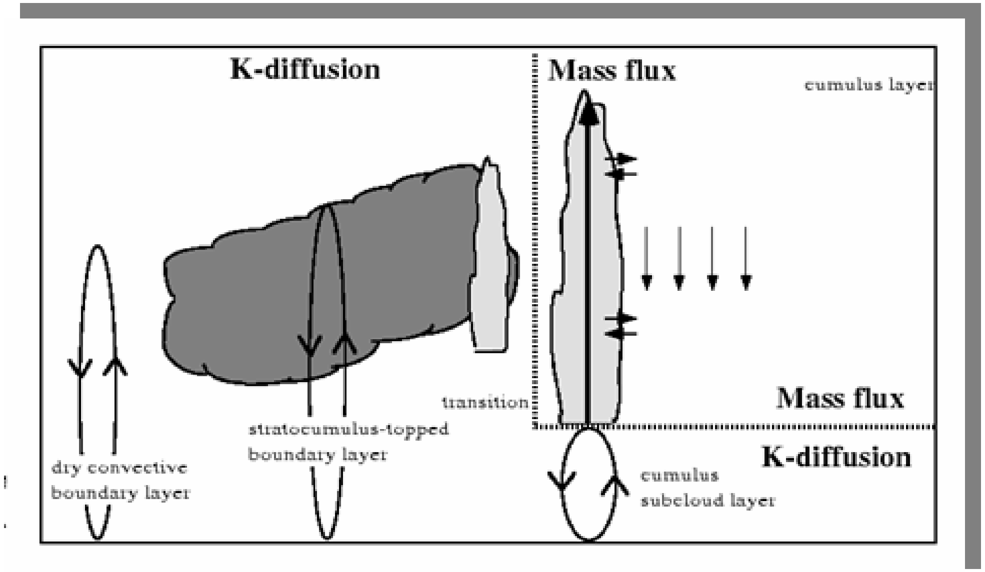
# EDKF : for dry and cloudy boundary layers

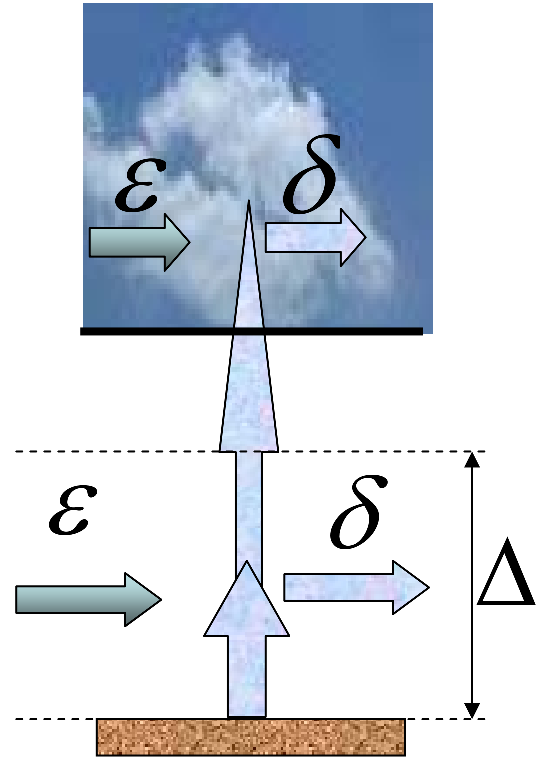
*Pergaud, J., S.Malardel, V.Masson*

General principle of Eddy-Diffusivity-Mass-Flux (Soares et al., 2004)

$$\overline{w'\phi'} \cong -K \frac{\partial \overline{\phi}}{\partial z} \qquad \overline{w'\phi'} \cong M_u(\phi_u - \overline{\phi})$$



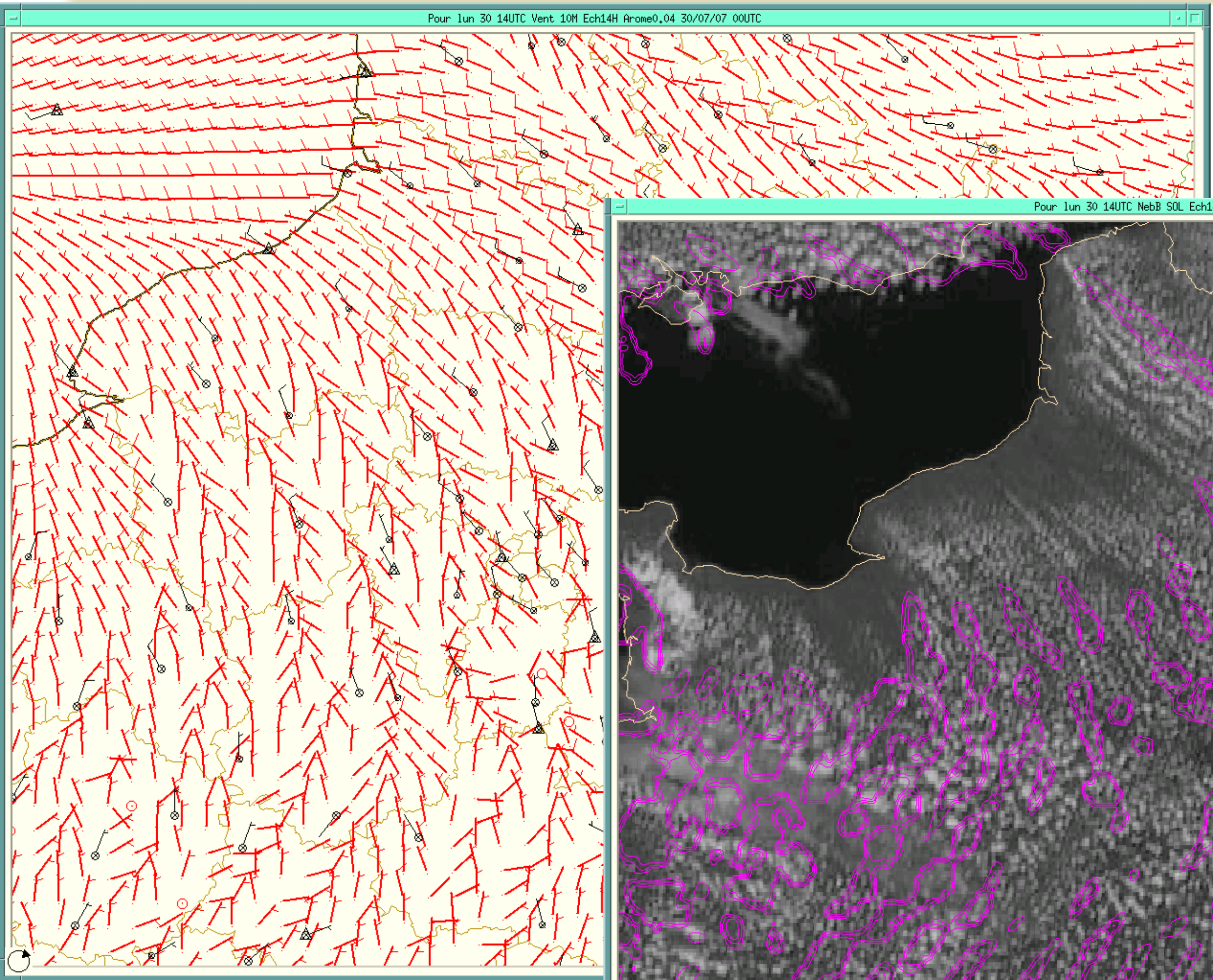

An idealized updraft starting from the ground :




- Also applied to momentum
- The updraft used to determine the subgrid cloud

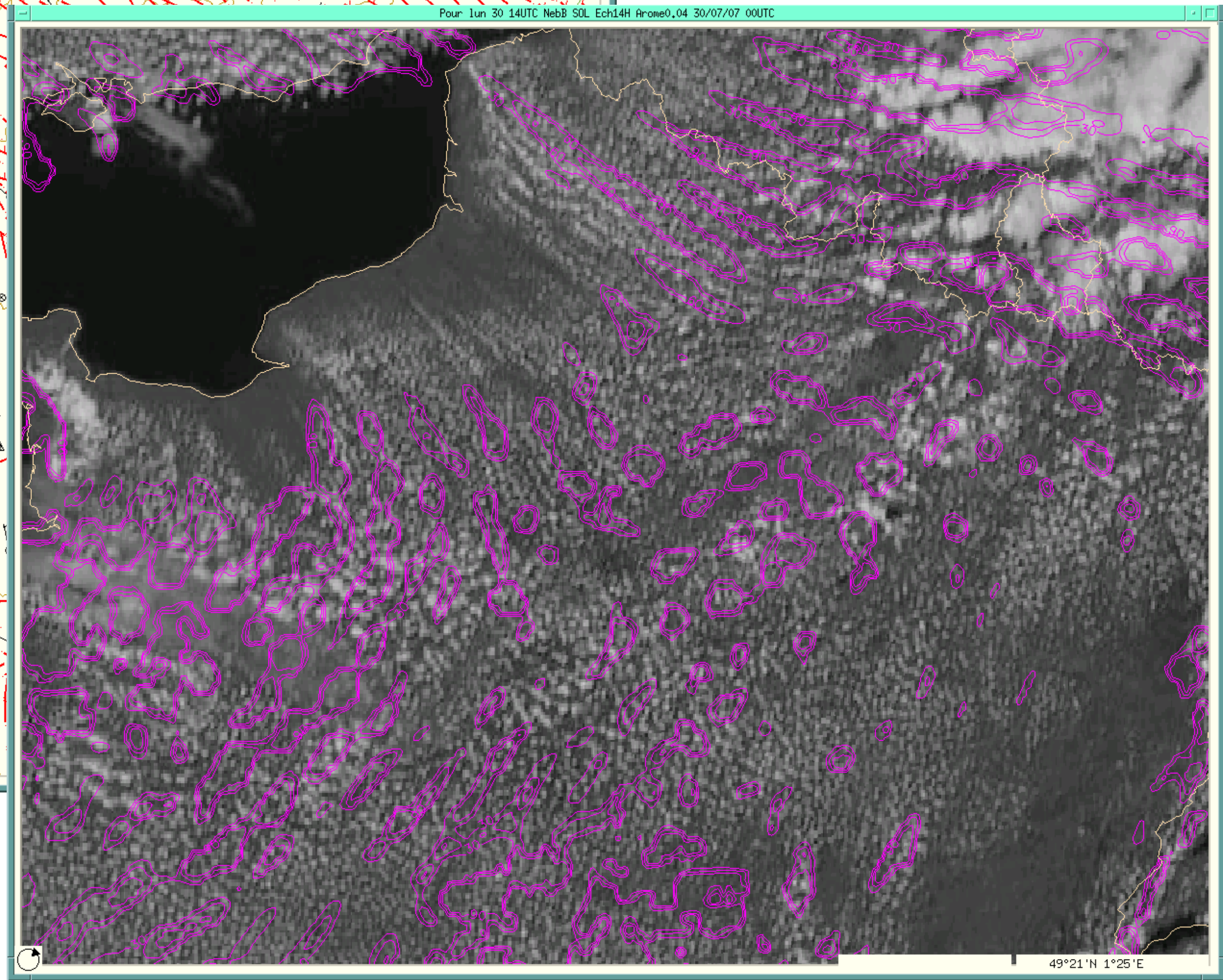
# Problème of « herringbone » pattern ( 30/07/07)

AROME



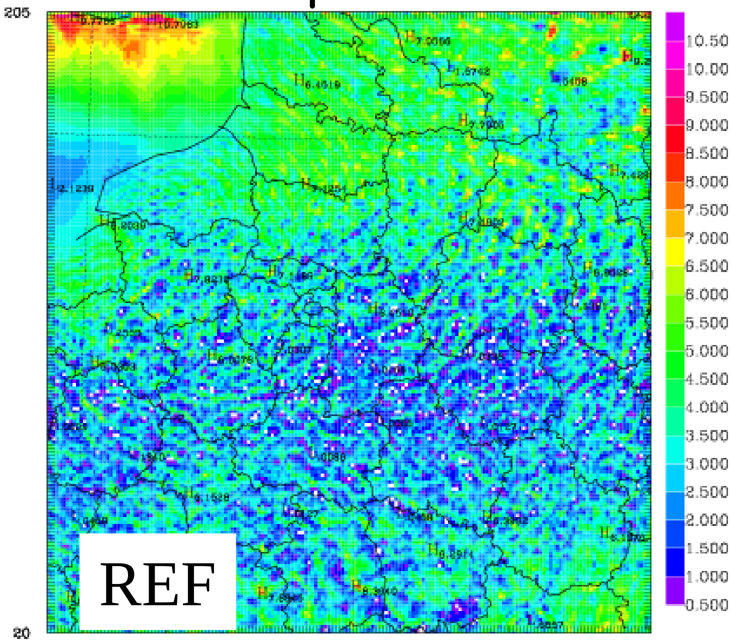

Wind near the surface

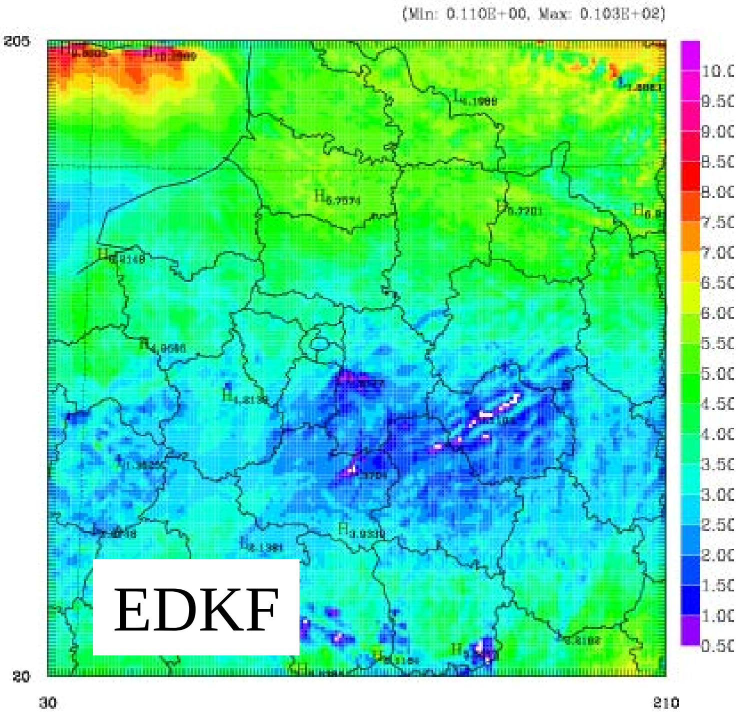
Nebul



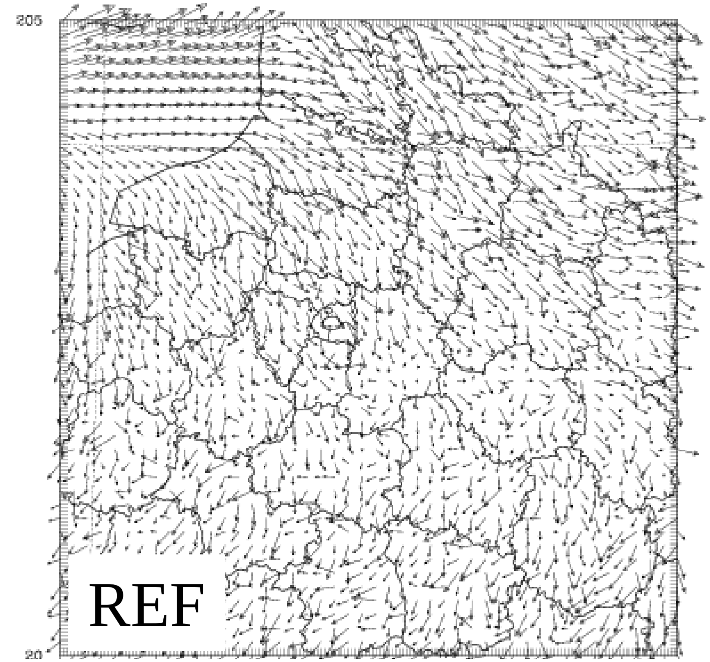
Méso-NH

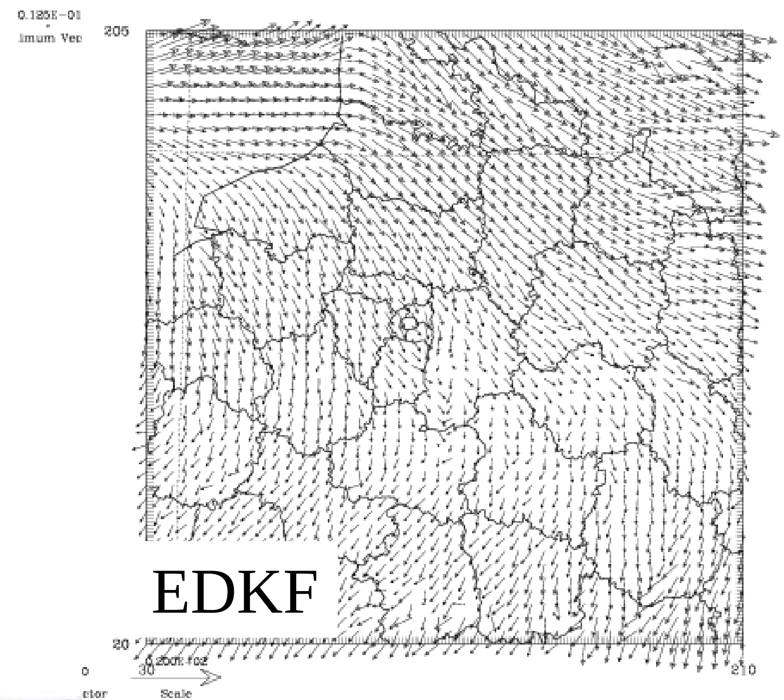
## Wind speed at 17m



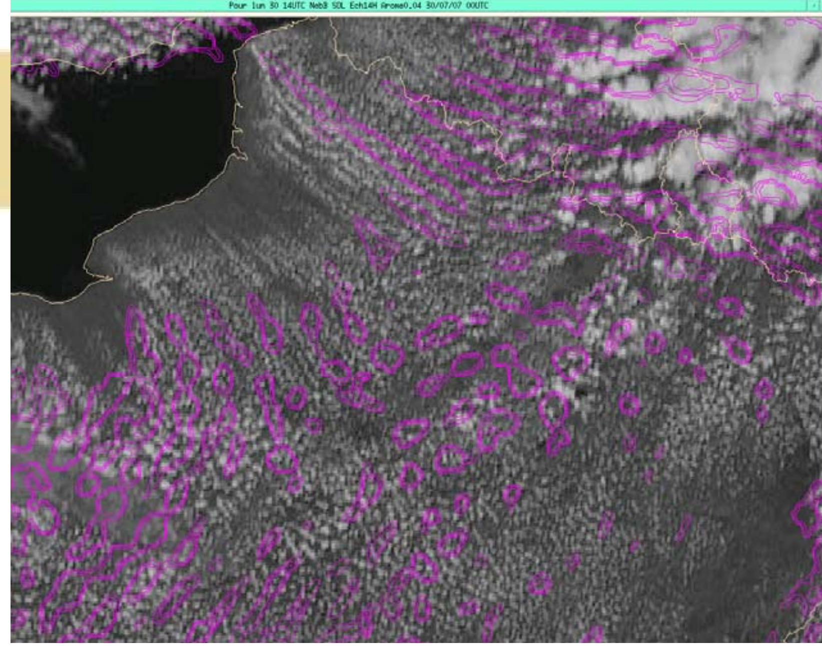



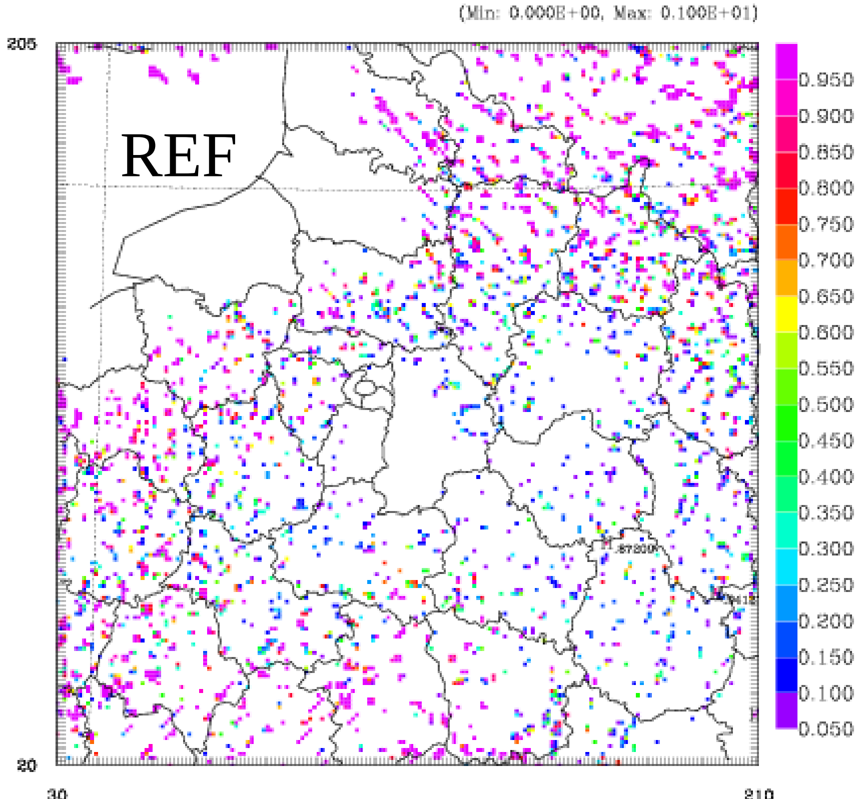

## Wind direction at 17m

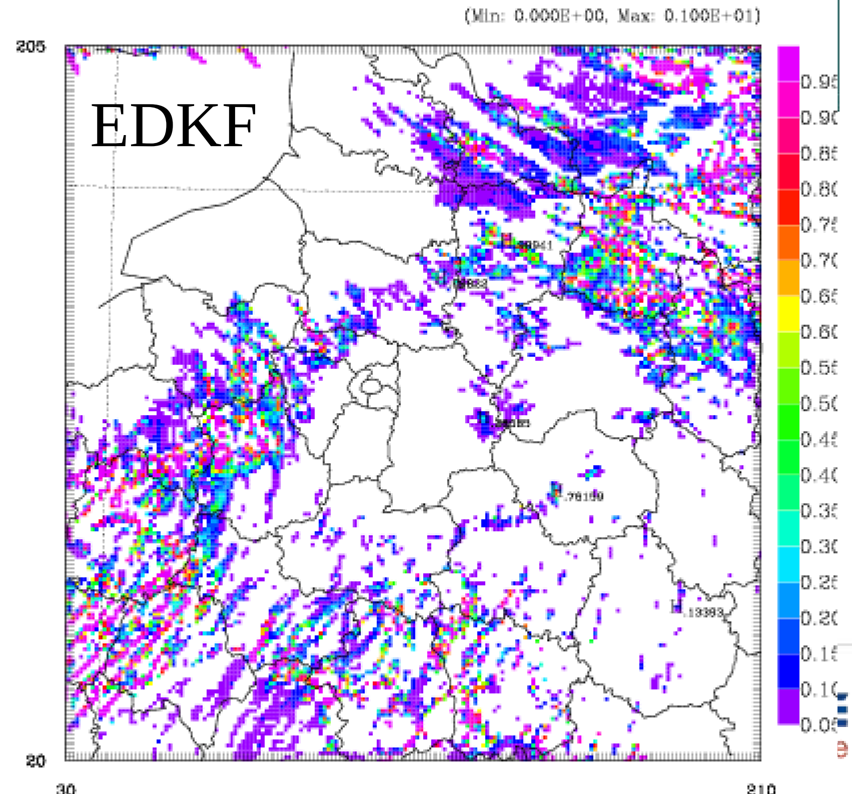


Méso-NH 30/07/07
Cloud fraction at 1500m





# CONCLUSION

➢ Interactivity between Méso-NH and AROME.

➢ For Meso-NH the improvement of the stability and the efficiency remains a necessity. The evolution of the temporal scheme is the next step towards higher order schemes for momentum.

➢ AROME : Finalisation of the 1st operational version in 2008.

- The prototype shows promising meso-scale features.

- Serious problems are clearly identified :« fireworks », « herringbone » due to insufficient mixing in the PBL, overestimation of precipitation for moderate convection, lack of clouds on the sea …

- … and also ways of improvement : horizontal diffusion, EDKF …

➢ Objectives scores (with AROME) and real case studies (with Meso-NH) are complementary to progress.

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