Physics in ARPEGE/ALADIN-MF/AROME

- **Development of common physics for NWP & Climate for ARPEGE and ALADIN-MF, having several parameterisations in common with AROME**

Valéry Masson

- **Contributors: F. Bouyssel, G. Hello, Y. Seity, Y. Bouteloup, E. Bazile, S. Malardel, C. Lac, P. Tulet, M. Mokhtari, C. Kocha and many others**

Physics in ARPEGE/ALADIN-MF/AROME

- **Development of common physics for NWP & Climate for ARPEGE and ALADIN-MF, having several parameterisations in common with AROME**

		AROME
2006/06:	Microphysics : « Lopez »	« ICE3 »
	Radiation IFS « RRTM / FM »	=
2008/06 :	Subgrid orographic effects, Catry et al	Supposed resolved
2008/12 :	Turbulence « CBR »	=
	Shallow convection « KFB »	EDKF
	Top PBL entrainment « GBM »	x
2009 :	Externalized surface scheme « SURFEX »	=
	Test of Deep convection based on 3MT	Supposed resolved
	Test of EDKF	=

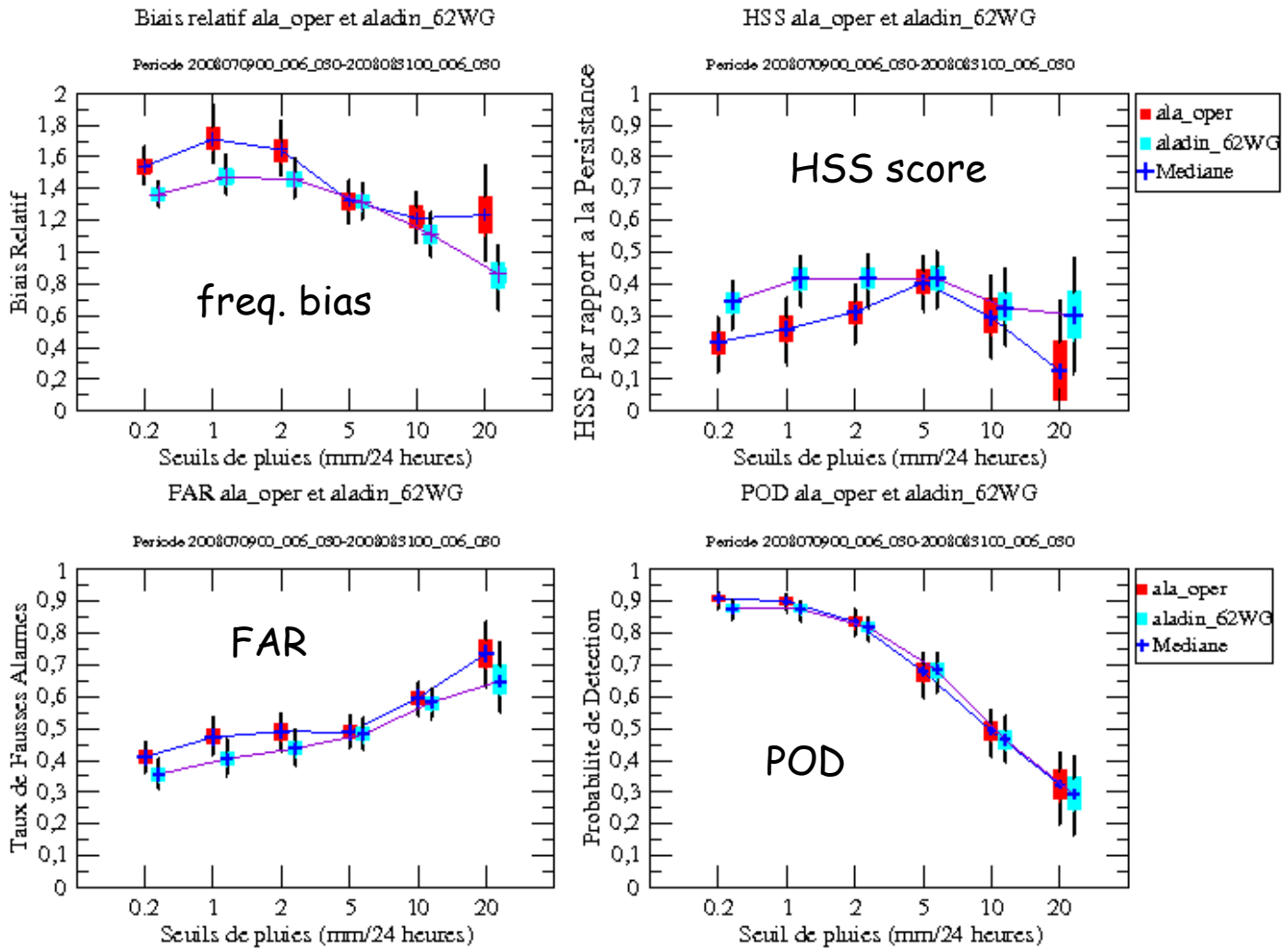
Parallel suite in ARPEGE / ALADIN-MF

- **“CBR” turbulence (Cuxart, Bougeault, Redelsperger, 2000)**
- **“BL89” mixing length (Bougeault and Lacarrere, 1989)**
- **“KFB” moist shallow convection (Bechtold et al., 2001)**
- **Production term of TKE and modification of mixing length from “KFB” scheme**
- **Top PBL entrainment (Grenier, Bretherton)**
- **“ECUME” parameterisation for oceanic fluxes (iterative algorithm)**
- **Use of 6 spectral bands (previously 2) in shortwave radiation (Fouquart and Morcrette)**
- **Use of ECMWF ozone climatology (Fortuin and Langematz, 1995)**
- **Tuning of the diagnostic parameterisation for deep convective clouds**
- **Modification of horizontal diffusion (suppression of divergence damping)**

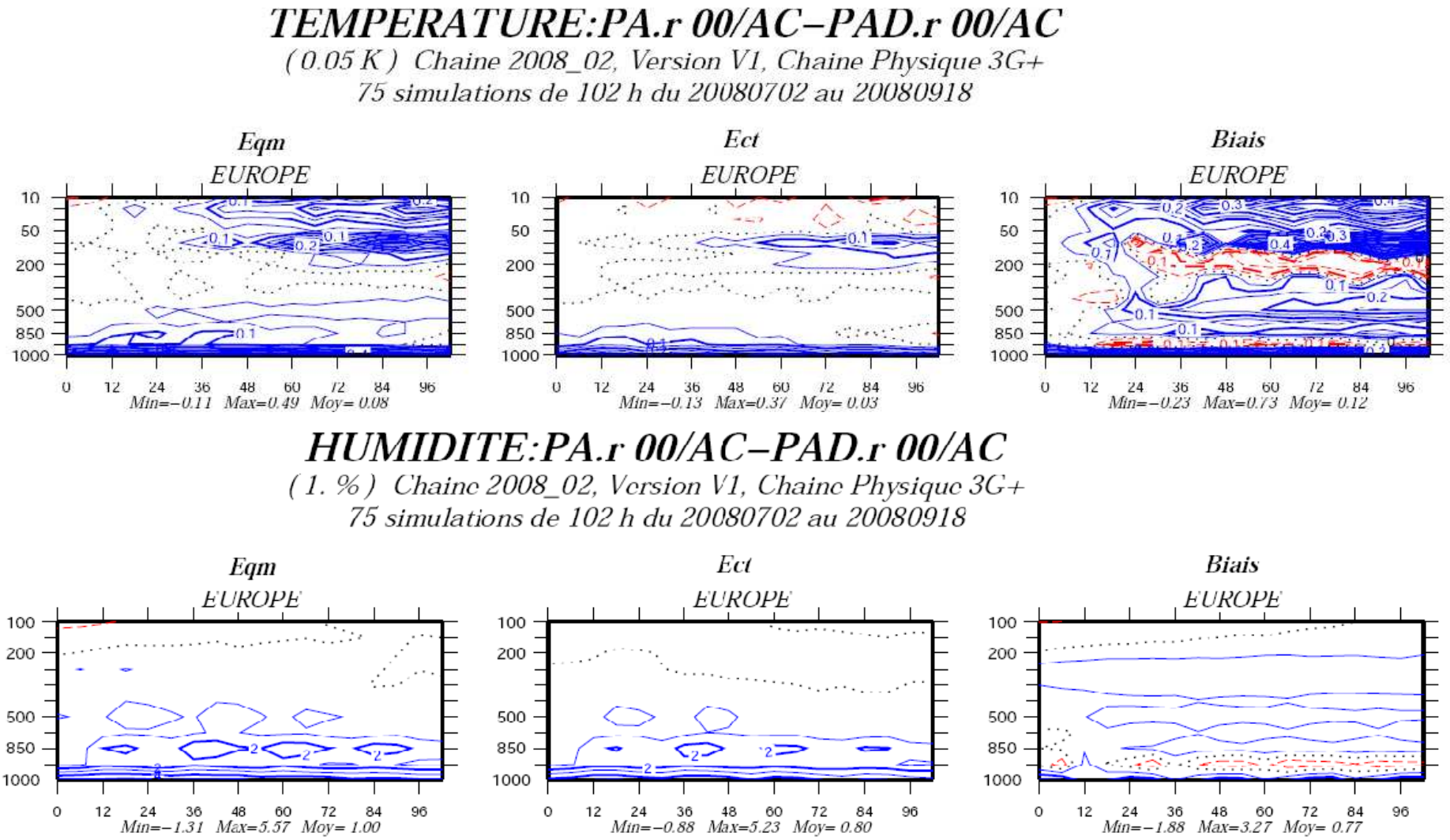
An MF NWP improvement: the summer 2008 ARP/ALD physics

ALDMF oper = Red ALDMF-new=blue

Scores of 24-h precipitation over 1 month



Not only precipitation: T/Hu score improvement thanks to the new CBR+KFB in ARPEGE/ALADIN-MF...



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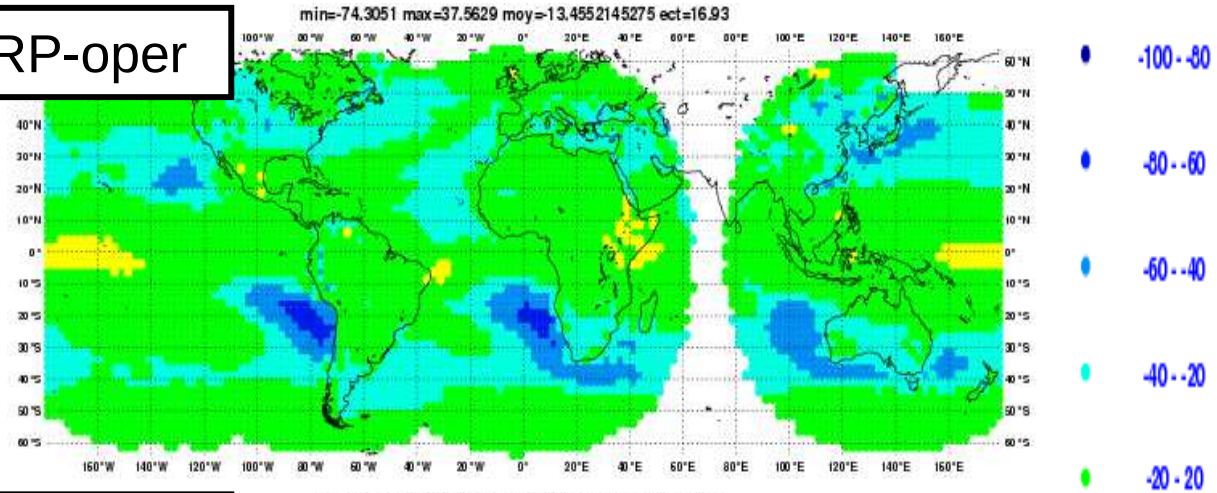
→ Better and more coherent lateral conditions for AROME

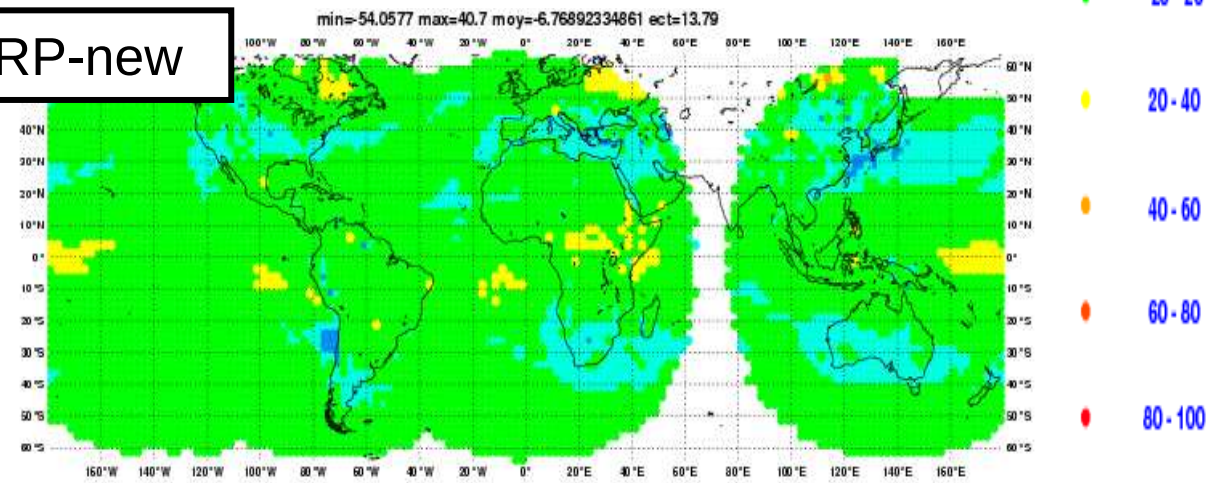
... and the very important global cloud climate is improved, too.

Mean error for total cloudiness (compared with ISCCP satellite climatology (for DJF))

ARP-oper



ARP-new



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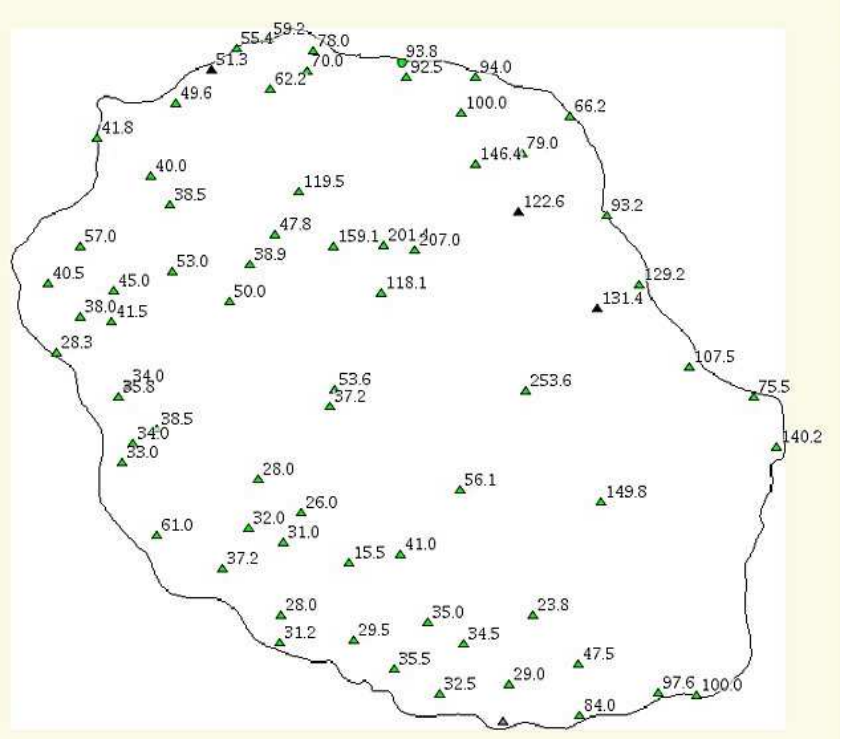
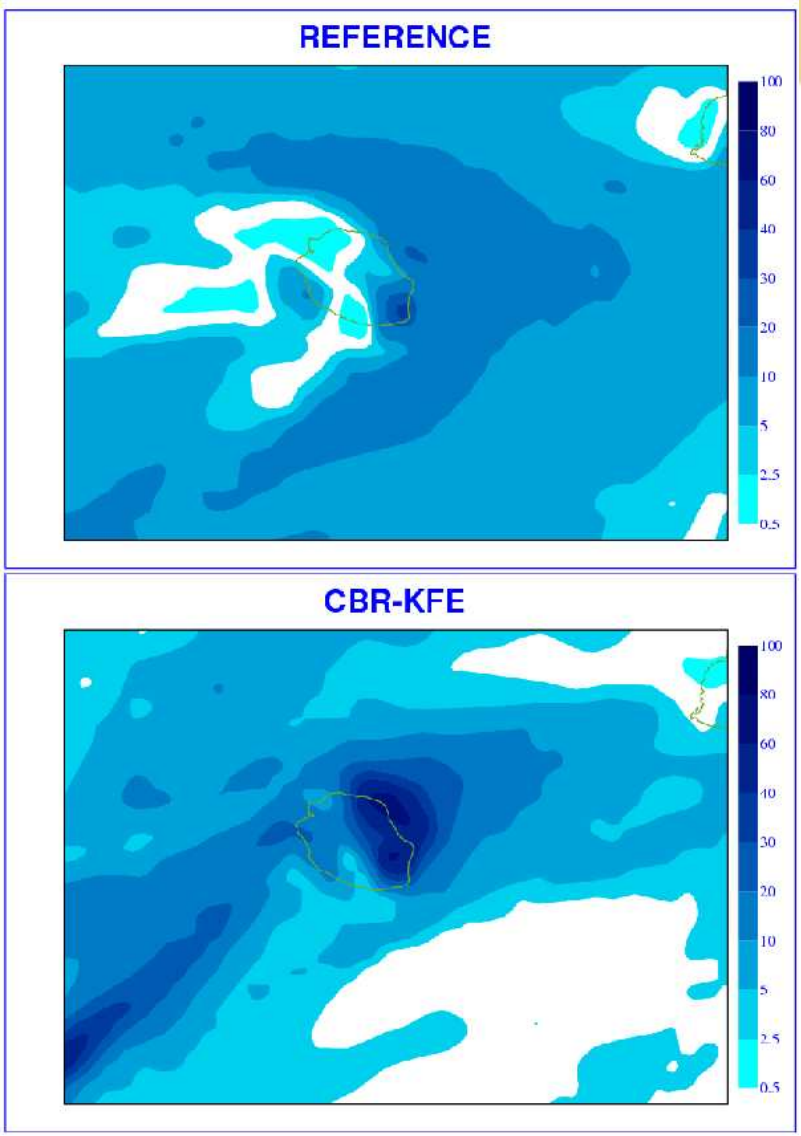
Improvement of precipitation in ALADIN-Réunion (7 June 2008)





New physics improve significantly precipitation forecasts over « la Réunion » (presently not enough precipitation over the island)

(G. Faure, CRC)

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First operational version of Arome at Météo-France (1)

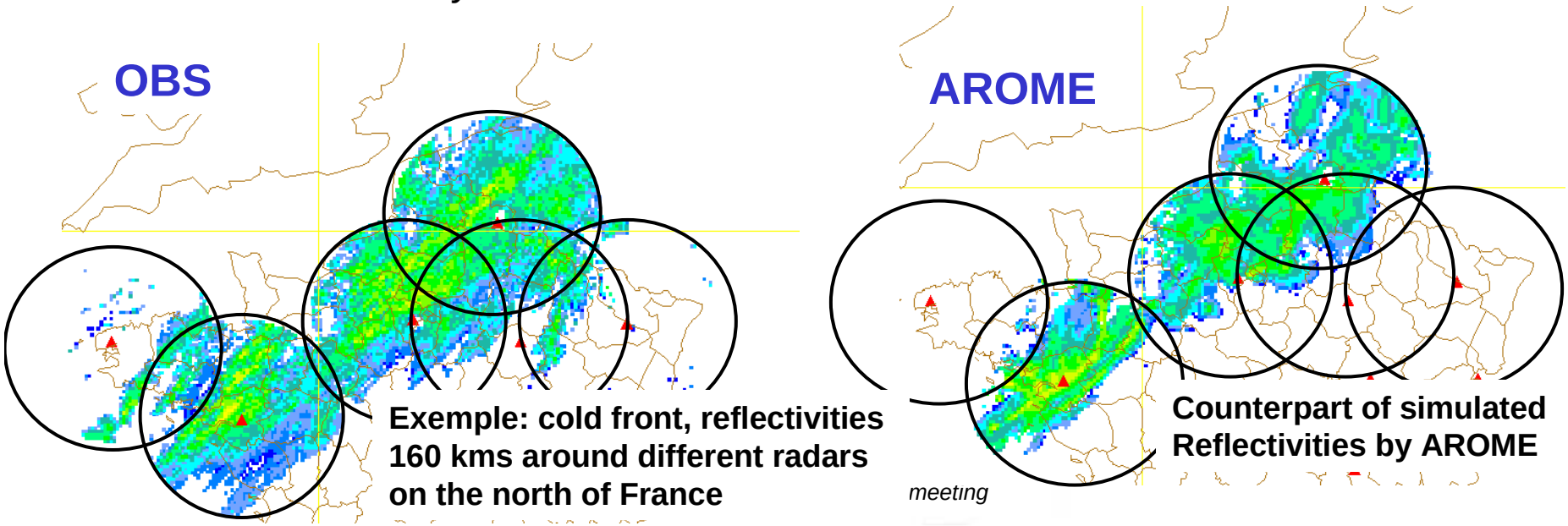
- The pre-operational suite is now running in its final form. This one contains :
  - Dynamical core :
    - The dynamical core of Arome is the one of Aladin-NH *(Bubnova et al. 1995*). It uses also a SISL2TL with a 1 minute time step.
    - The coupling to the large scale is done every hour with the operational Aladin-France

First operational version of Arome at Météo-France (2)

- The pre-operational suite is now running in its final form. This one contains :
  - Assimilation part :
    - 3D variational assimilation every 3 hours *(Fischer et al. 2006*). The background error statistics is calculated using an ensemble-based method *(Berre et al. 2006).*
    - Same assimilated observations as in ALADIN-France : conventional observations, 2m temperature and humidity, IR radiances from ATOVS and SEVIRI instruments, winds from AMV and scatterometers, ground based GPS.

      \+ wind for doppler radars.

Towards reflectivity assimilation : illustration of radar simulator in the model



Exemple: cold front, reflectivities 160 kms around different radars on the north of France

Counterpart of simulated Reflectivities by AROME

First operational version of Arome at Météo-France (3)

- The pre-operational suite is now running in its final form. This one contains :

  - Atmospheric physical package :
    - Pronostic microphysics (ICE3) with 5 water species *(Pinty and Jabouille, 1998)*
    - 1D Tubulence scheme with pronostic turbulent kinetic energy *(Cuxart and al. 2000)*
    - Radiation : so called rrtm scheme in long wave *(Mlawer and al. 1997)* and Fouquart Mocrette with 6 channels in short wave. The frequency of the radiation call is every 15 time steps
    - Shallow convection : EDKF scheme (EDMF type, Pergaud et al 2009)

  - Surface physical package :
    - Surfex witch includes the modelisation of nature (*Isba scheme Noilhan and Planton 1998*), sea (Ecume fluxes), town (TEB scheme :*Masson 2000*) and lakes. Surfex have been recently been improved with the development of a turbulent scheme inside the canopy (Masson and Seity 2009)

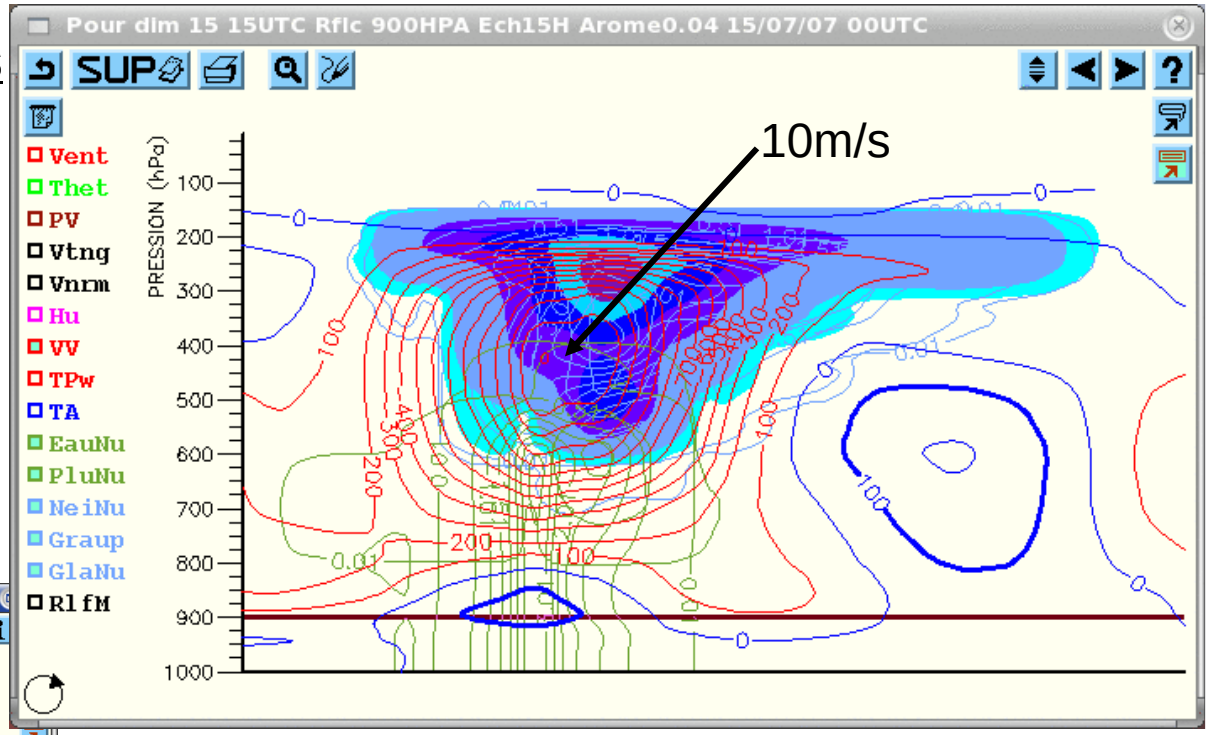
First operational version of Arome at Météo-France (4)

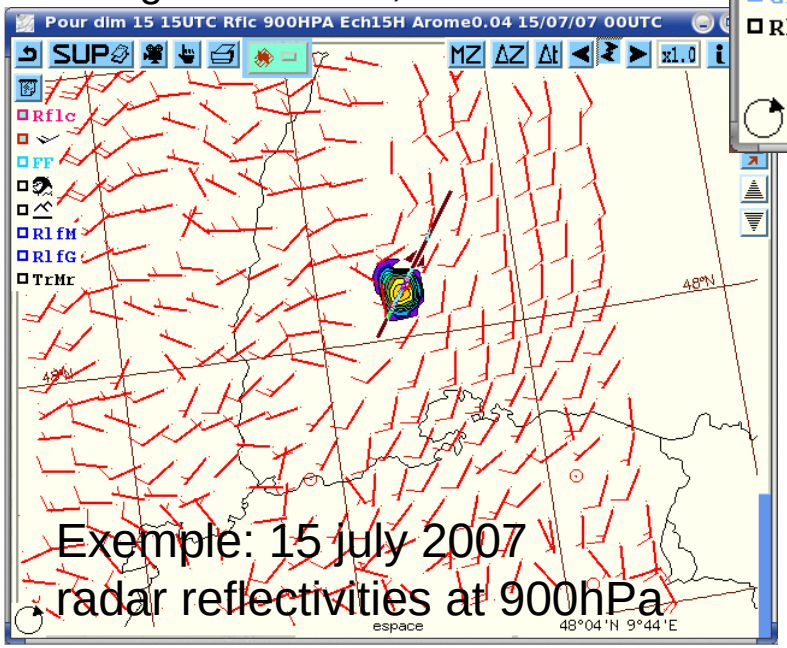
<u>special formation of forecasters</u> needed to these new physics:

« How to look at AROME ? »

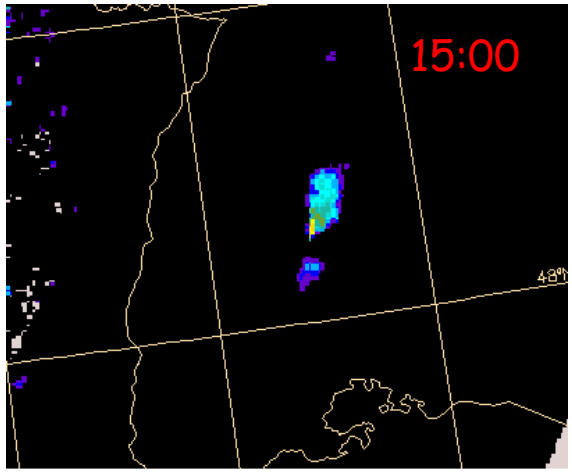
→ New physical fields to look at (hydrometeors)

→ New meteorological structures in the model:
e.g. convection, breeze fronts





Exemple: 15 july 2007
, radar reflectivities at 900hPa



The latest developments

- The horizontal numerical diffusion has been revisited :
  - Same coefficient applied to divergent and rotational part of the wind. Diminution of the diffusion on all variables

- A new scheme for the canopy has been implemented inside the surface module of the model (→ see surface session)

- A new scheme for the shallow convection has been implemented (EDKF)
  - Based on the EDMF scheme (Soares et al 2004, collaboration with HIRLAM)

$$\overline{w'\phi'} \cong -K\frac{\partial\overline{\phi}}{\partial z} + M(\phi_{\mathrm{up}} - \overline{\phi}),$$

Non local transport:
- Convection scheme
- Thermals in the BL

EDKF scheme

- **Eq for w**

$$w\frac{\partial w}{\partial z} = aB - b\frac{E}{M}w^2$$

a= 1 b=1

- **Eq for conservative variables (+ optional: wind)**

$$\frac{\partial \varphi_u}{\partial z} = -\frac{E}{M}(\varphi_u - \overline{\varphi})$$

$\varphi_u \in (\theta_l , r_t)$

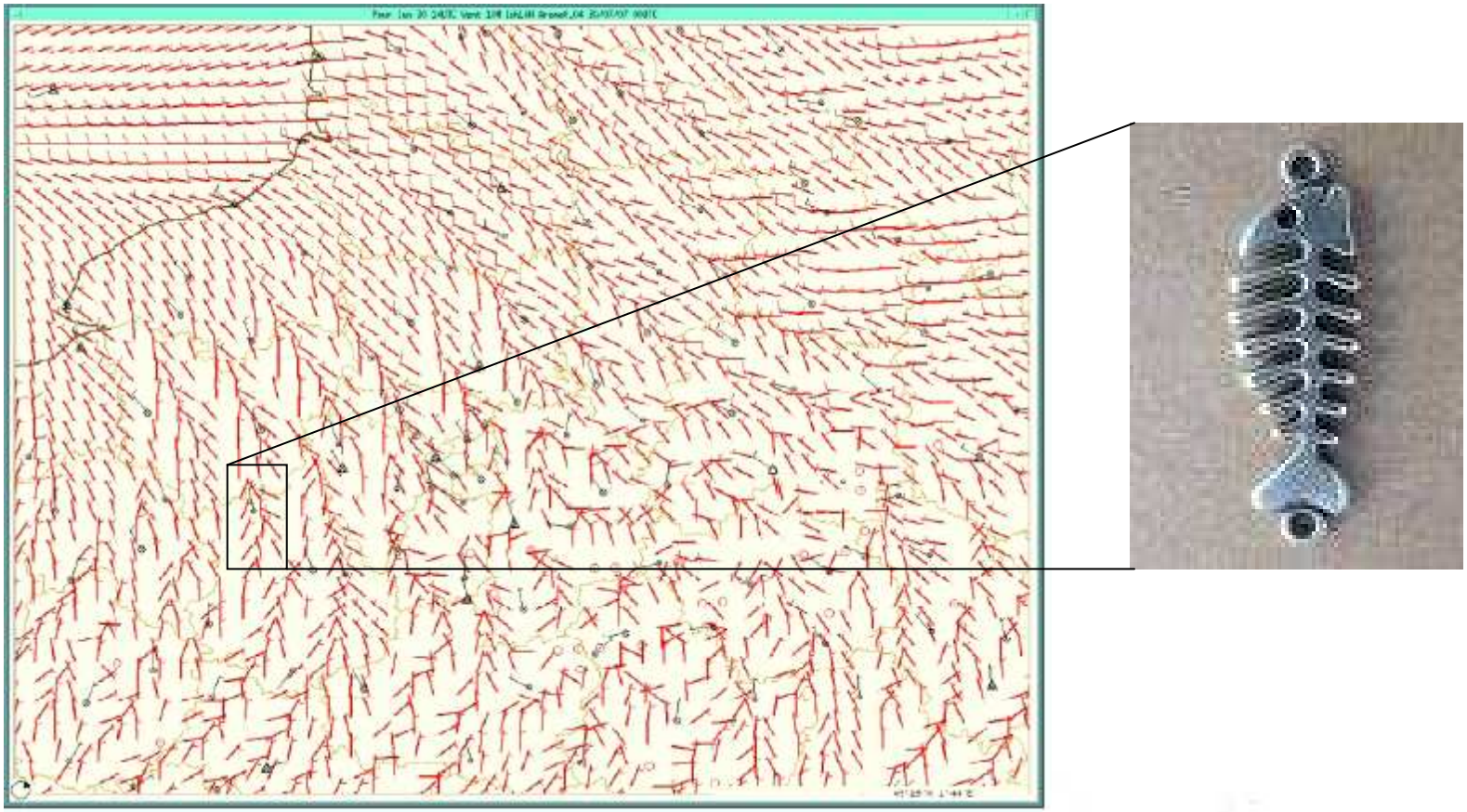
- **Eq for the Mass flux**

$$\frac{\partial M}{\partial z} = E - D \qquad M = \rho\sigma w$$

- **w equation is used to stop the updraft**
- **Using both equations for w and MF enable us to diagnose σ the fractional updraft area, and hence the cloud cover**
- **Entrainment & Detrainment:**
  - **In the boundary layer, E,and D depend on buoyancy and vertical speed of the updraft**
  - **In clouds, E and D comes from Kain & Fritsch buoyancy sorting**
- **Tested for: dry BL, shallow convection, Sc** (EDKF effect weakens naturally)

Impact of the activation of EDKF on the "herringbone" problem

- "herringbones": strong organisation of low-level winds and shallow cumulus in weakly convective boundary layers over land
  - a spurious organisation of PBL eddies as 'streets' on the model grid



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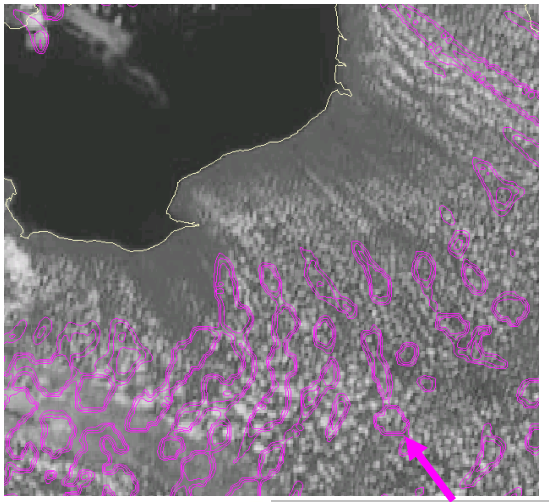
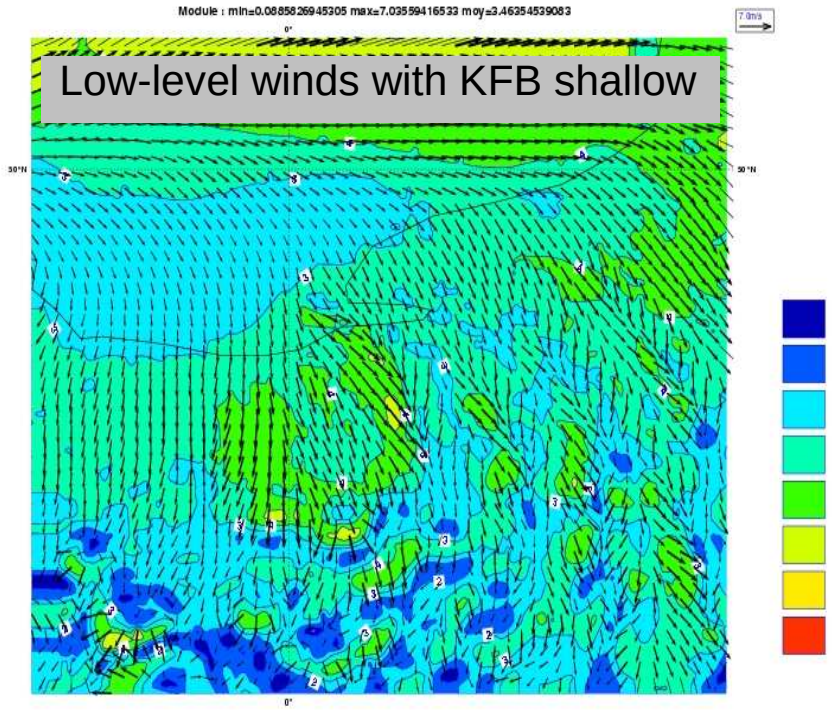
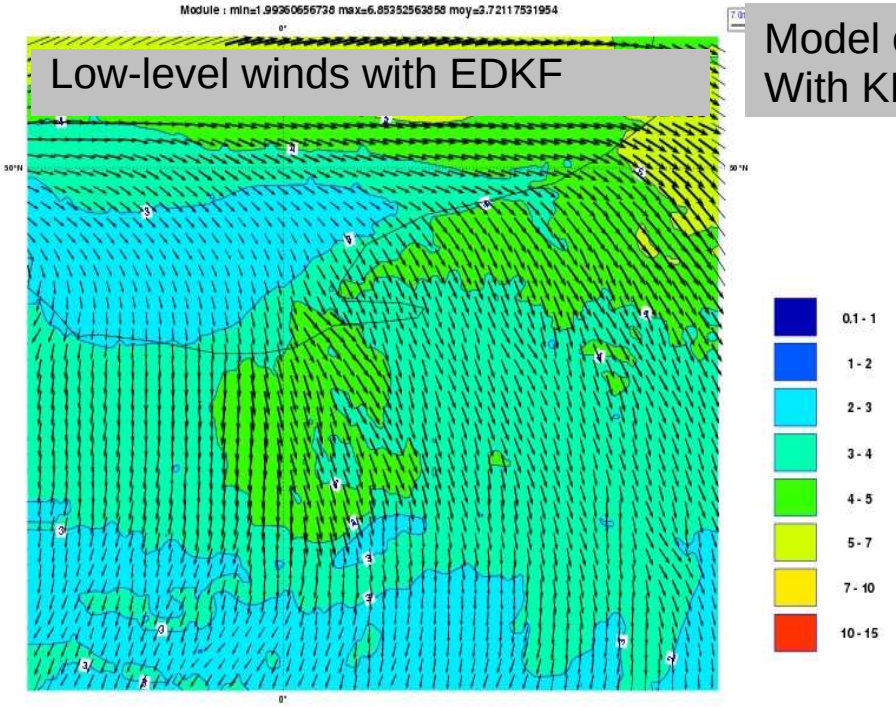
→ A better representation of the countergradient zone in the upper boundary Layer

→ Additionally (but not the major effect) : due to wind Mass Flux mixing



Model clouds With KFB





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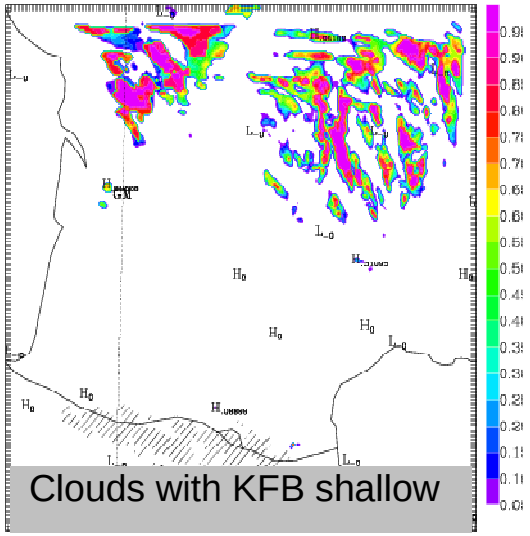
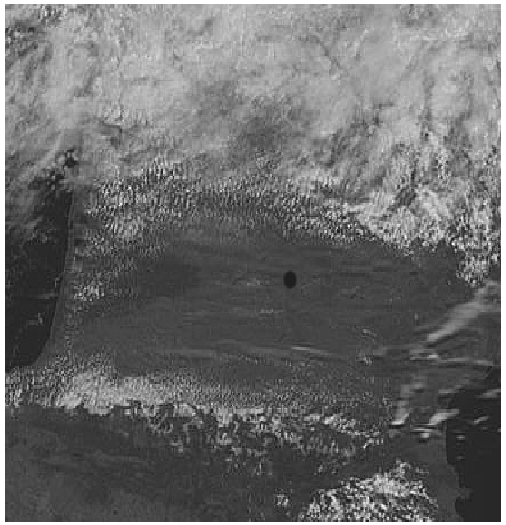
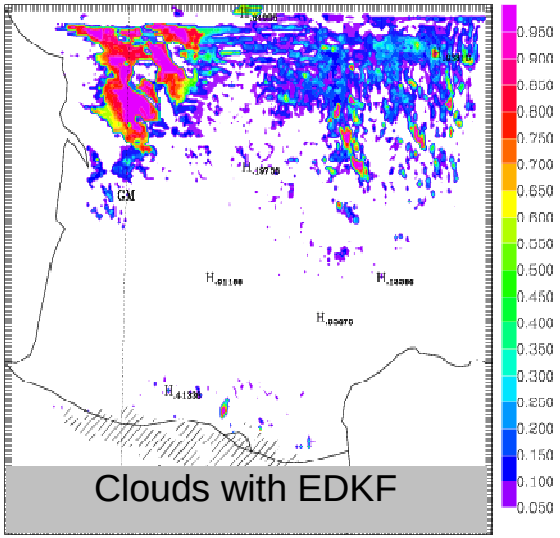
  - And clouds ?


Clouds with KFB shallow

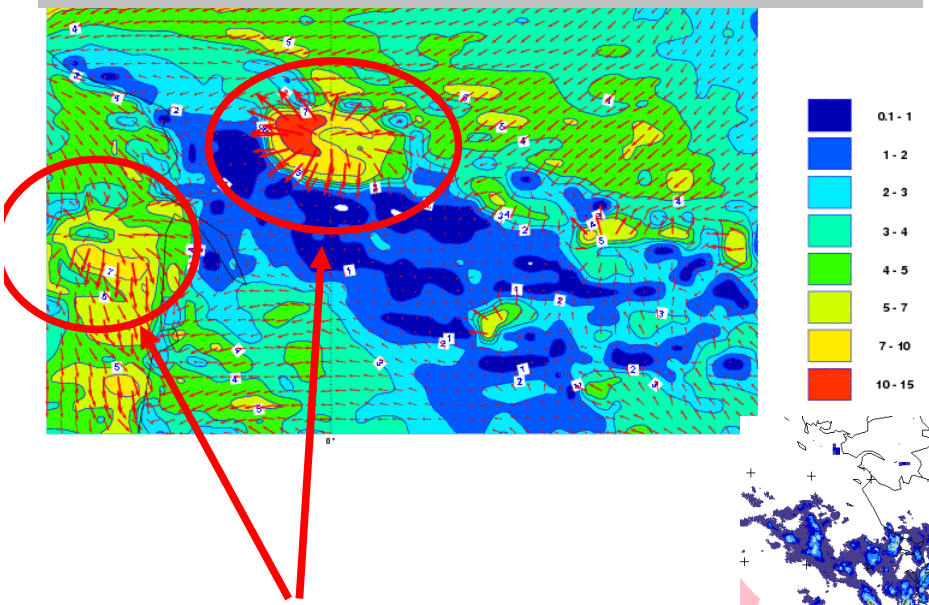



Clouds with EDKF

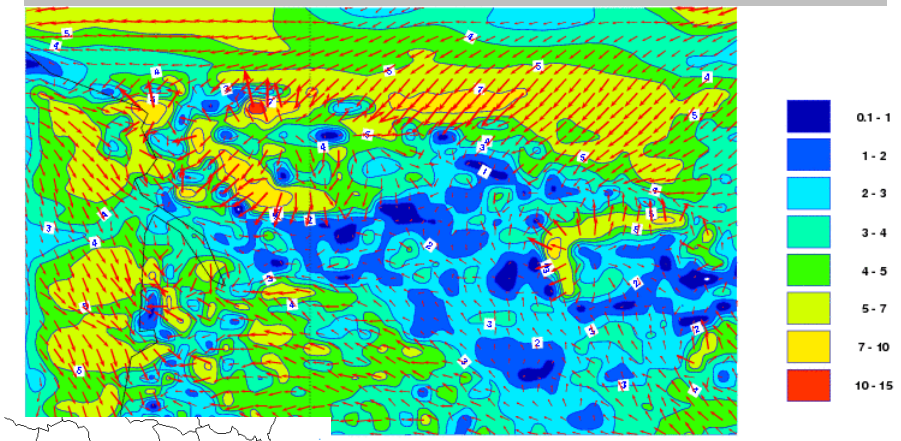
Impact of the tuning of the diffusion on the "fireworks" problem

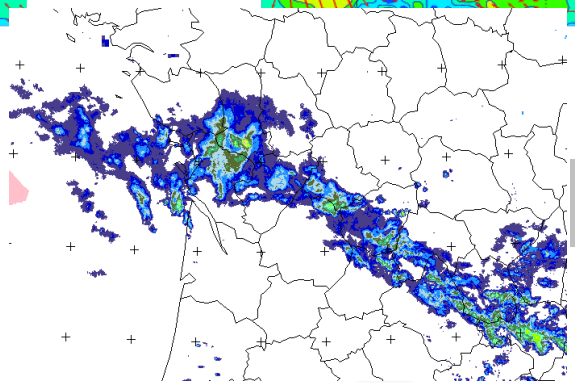
- "fireworks": overactive thunderstorms with strong cooling and divergent wind underneath, sometimes organised as violent squall lines:
  - very detrimental to all AROME evaluations until end 2007
  - mostly solved by a recalibration (reduction) of horizontal diffusion (MF, Oct 07)

Arome low-level wind under a thunderstorm, using summer 2007 setup



with new diffusion tuning

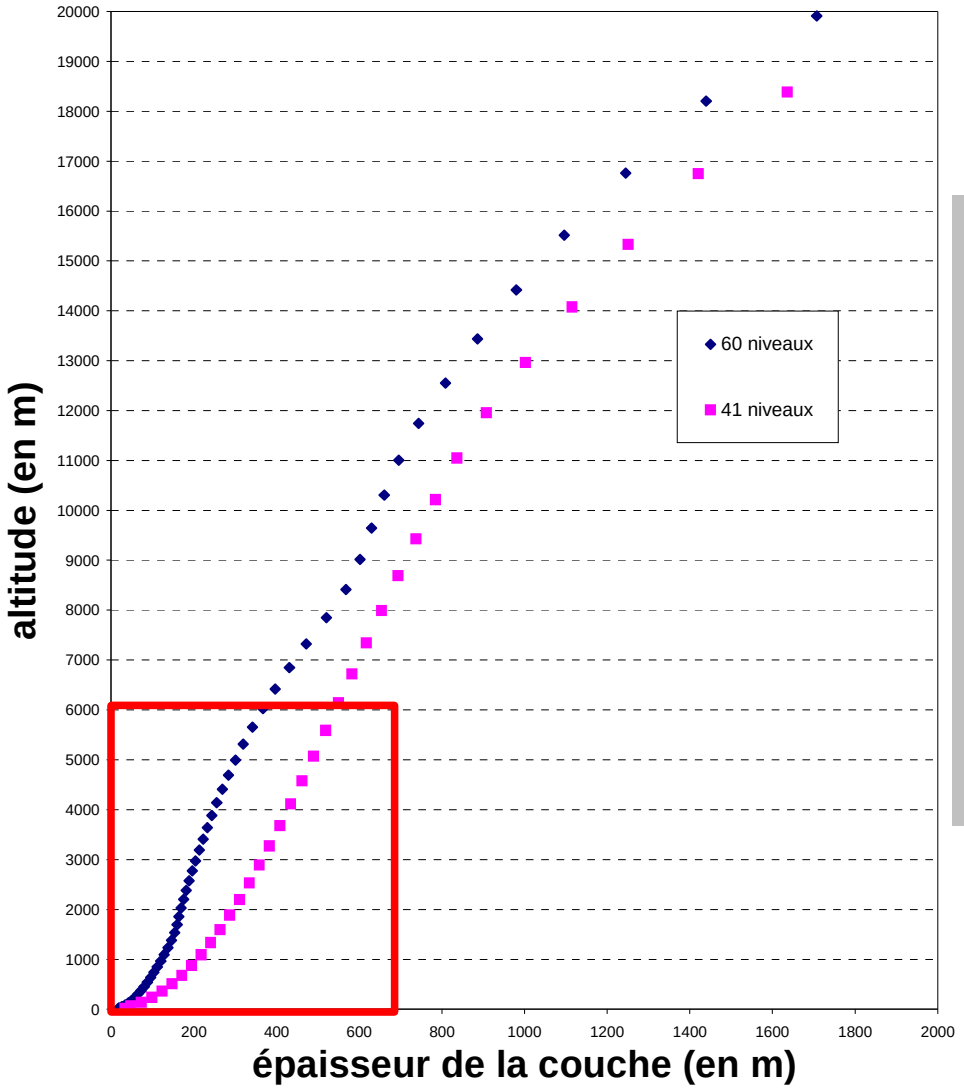




observed radar precip

The increase of vertical resolution (1)

- **for 2009, double the vertical resolution in the lower troposphere :**



Moving from L41 to L60:

- costs 37% extra CPU
- 1st level at 8m (vs 17m)
- 21 levels below 2000m (vs 12)

Supposed to improve forecasts of fog and low clouds

Chemistry in AROME : NWP and/or research tool

- The following chemistry parameterizations are implemented (but not yet in the operationnal version!

CPU time AROME=1

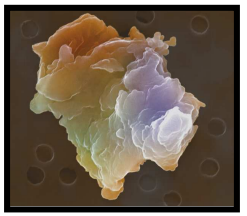
- <u>Desertic Dust</u> (Grini et al 2007, collaboration with M. Mokhtari, ALADIN Algeria):
  → **may be soon of interest for NWP**
  (Algeria, Morocco, Tunisia)
  - Allows direct effect of aerosols on radiation
  - Modifies CAPE and convection occurence

1.10

- <u>Gazeous chemistry</u> (Tulet et al 2003):
  - Relacs scheme (37 chemical species)
  - Allows better O3 field impact on radiation
  - Inline chemistry allows better coupling with fine scale flows

5.

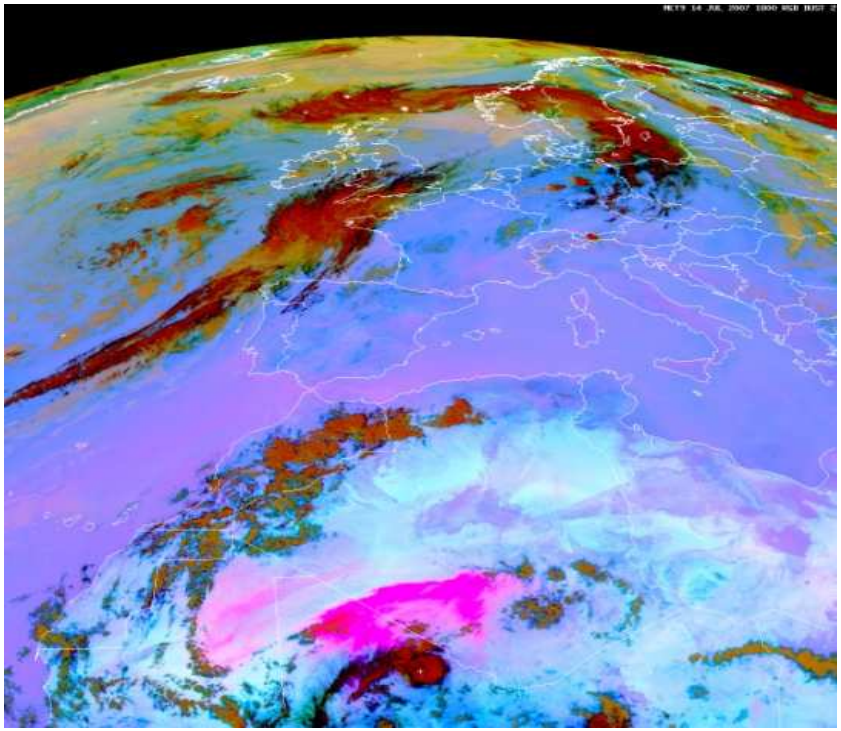
- <u>Aerosol chemistry</u> (Tulet et al 2007):
  - ORILAM scheme (189 chemical species)
  - Cloud activation → better Sc, fog, Ci clouds
  - Needs of course to be simplified/parameterized to be of use in NWP in foreseen future



10.

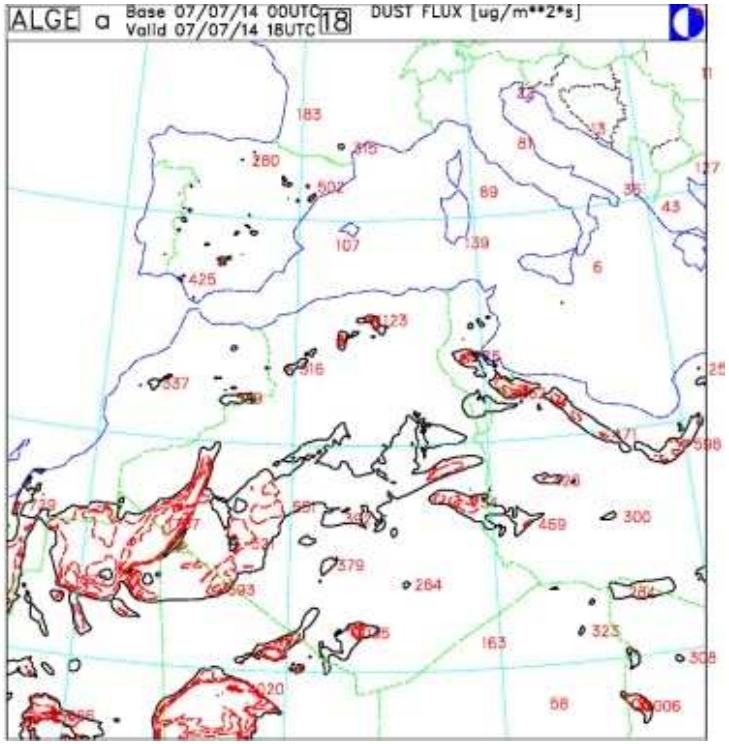
Dust (1)

- Improvement of the dust emission of SURFEX by Mohamed Mokhtari in ALADIN-Algeria



EUMETSAT image (pink = dust)

14 juillet 2007, 18h



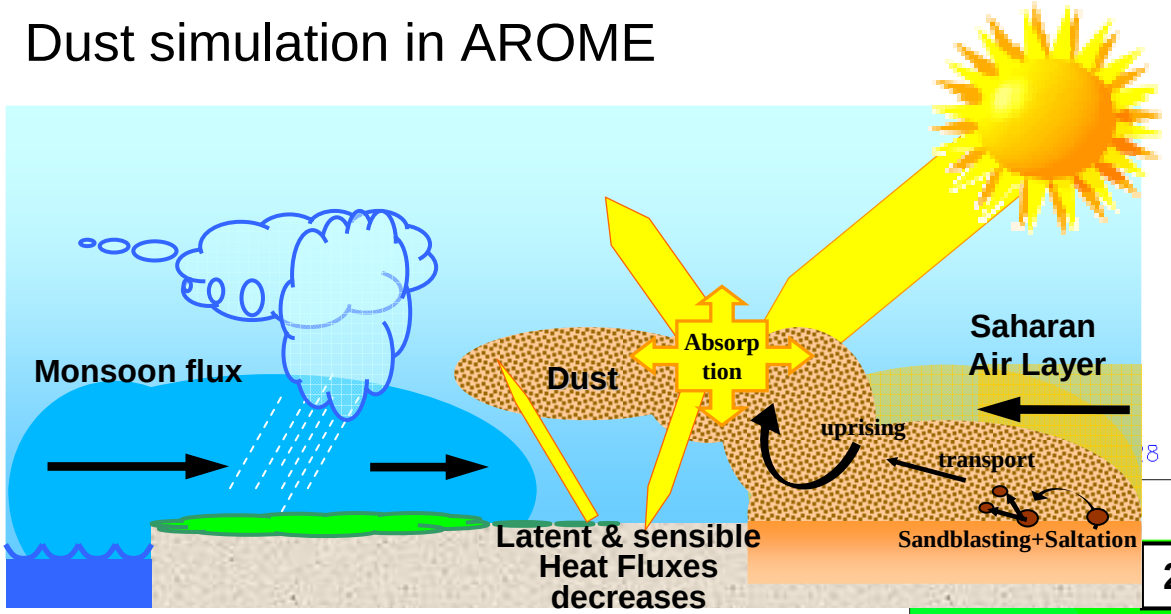
Dust emission by SURFEX coupled to ALADIN-Algeria

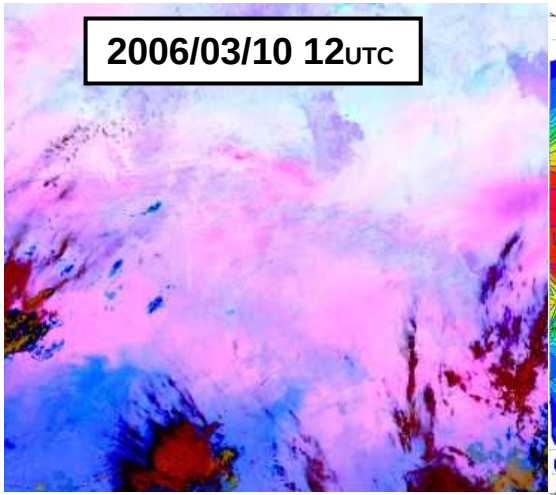
14 juillet 2007, 18h

Source: M. Mokhtari

Dust (2)

- Dust simulation in AROME





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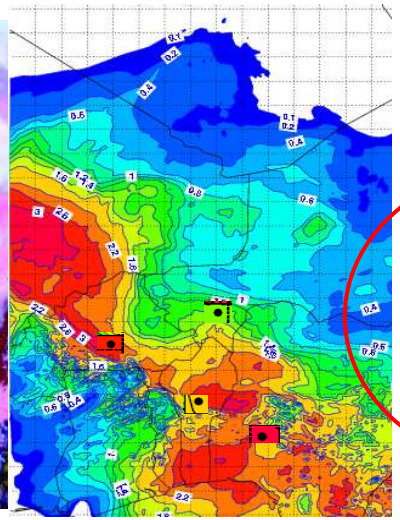
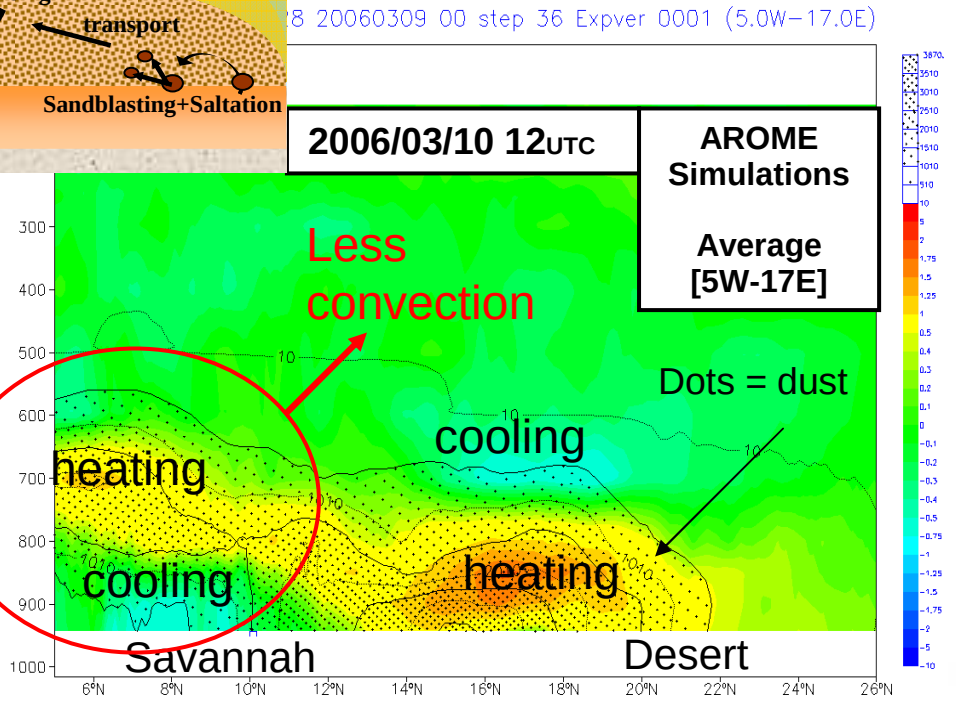


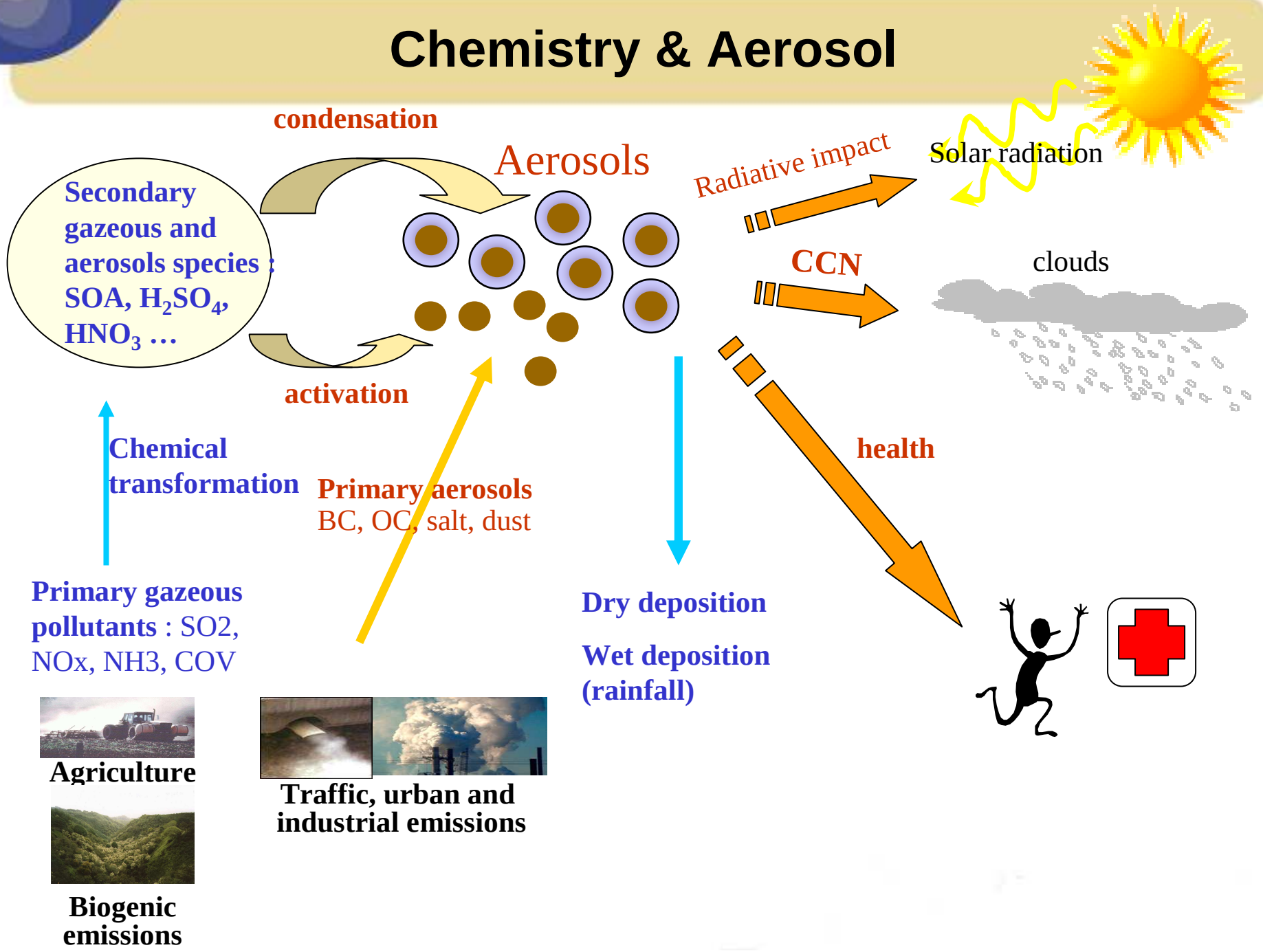
AROME



EWGLAM meeting

Source: C. Kocha

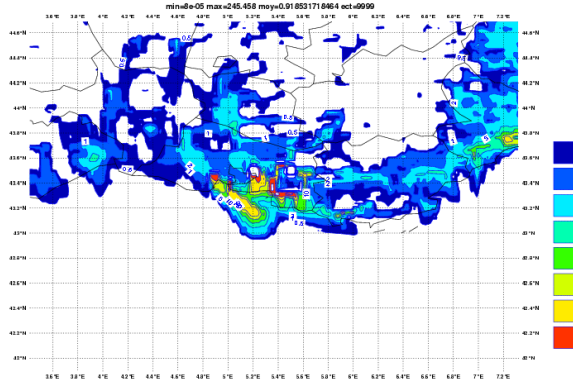
Chemistry & Aerosol



Chemistry & Aerosol

Exemple: AROME, 20th June 2008 on the South-East of France

Primary pollutants, at 6h



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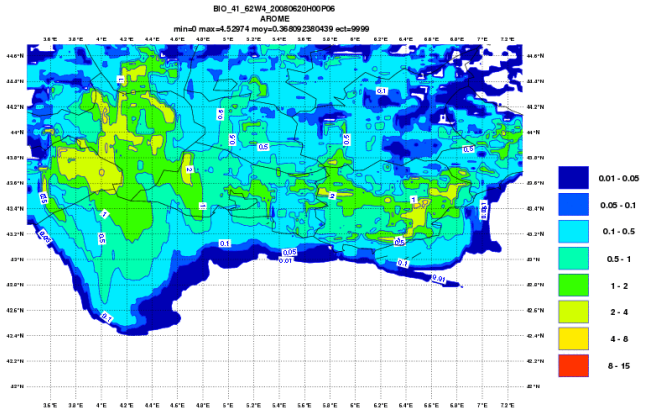
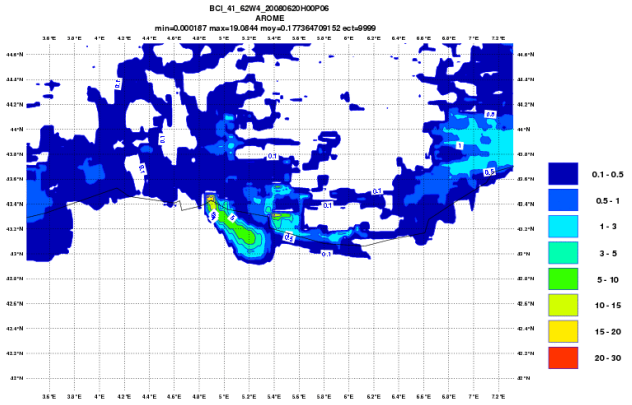
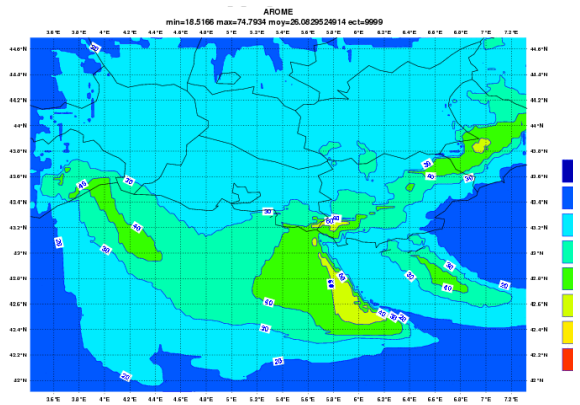


Biogenics

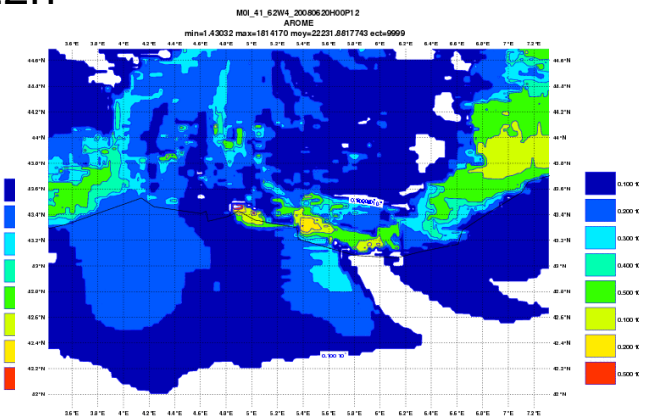


Black Carbon

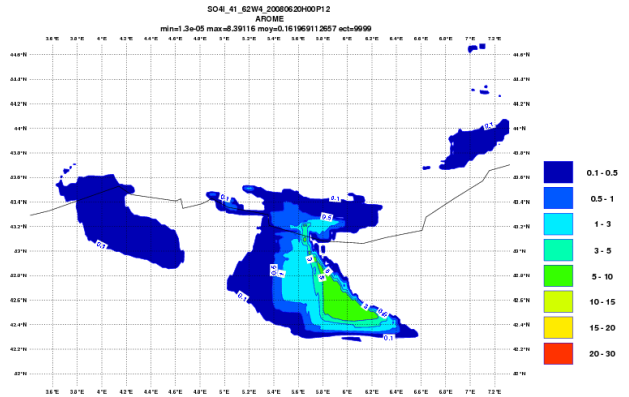
Secondary species, at 12h



O3



Aerosol number,
Ultra-fine mode



SO4 inside the aerosol

Validation strategy of physics at all scales

1D column model, Processes studies, intercomparisons

Tools: 1D ARPEGE/AROME model: MUSC, LES, CRM

Constraints: parameterizations must also be correct at the local scale (not only on average)

e.g. Clouds, transport processes in 1D intercomparison studies

Mesoscale NWP validation

Constraints: Physics must work on fine scale flows

Global NWP validation

Constraints: Physics must work everywhere, anytime

e.g. convection in the Tropics, Great Plains, over ocean…

Global climate validation

Constraints: Main equilibriums of the earth system must be conserved on the long run

Advantages:

High degree of validation of physical parameterizations

When needed, the LAM can be used with confidence everywhere

Common expertise & interactions of research teams on physical parameterizations

In the future

- Next year, in ARPEGE/ALADIN-MF:
  - SURFEX will be implemented
  - A deep convection scheme based on 3MT will be tested
  - EDKF will be tested
  - Implementation of desertic Dust (in collaboration with ALADIN-Algeria)

- The forthcoming versions of Arome are dealing mostly with the following aspects (from shorter terms to more longer terms) :
  - Increase of the vertical resolution of the model especially on the boundary layer
  - better assimilation algorithm using 3DVar FGAT, Jk coupling
  - Assimilation of the reflectivity data, cloudy radiances, .. in order to improve the initialisation of the clouds
  - Implementation of an assimilation of surface variables
  - Work on 3D turbulence
  - Improvement of the atmospheric physical package (test of 2-moments microphysics)