Météo-France report

François Bouyssel

WGNE-30, 23-26 March 2015, College Park, Maryland

CNRS
dépasser les frontières

METEO FRANCE
Toujours un temps d'avance

HPC

Operational suite on new computer since January 2014
Upgrade planned for mid-2016

<u>Research</u>
522 Tflops peak performance
56 racks bullx DLC
1008 nodes
Fat Tree InfiniBand FDR
Lustre 2 Po, 69 GB/s
Disks storage 209 TB

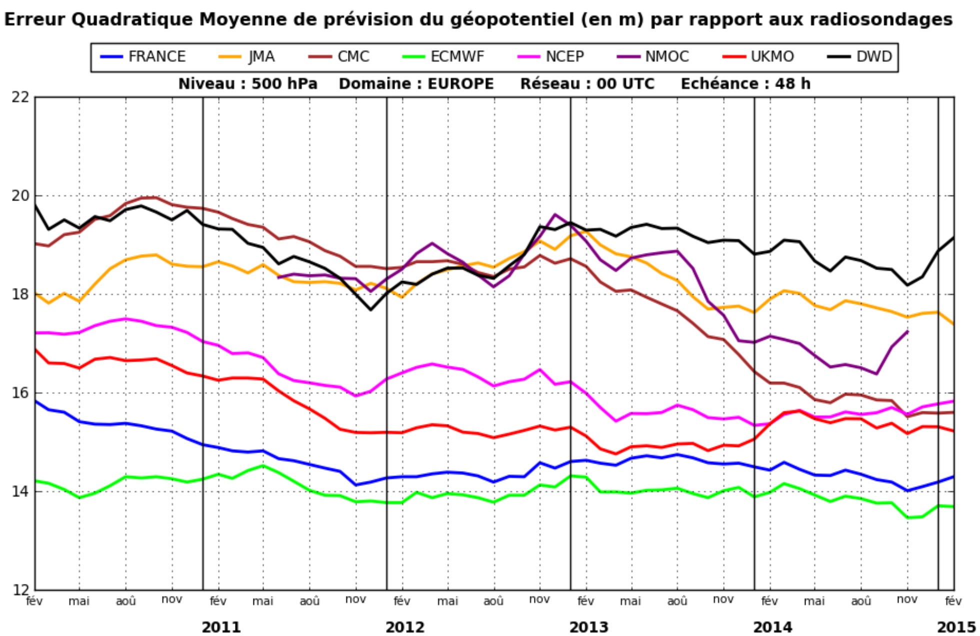
<u>Operations</u>
513 TFlops peak performance
55 racks bullx DLC
990 nodes
Fat Tree InfiniBand FDR
Lustre 1,53 Po, 46 GB/s
Disks storage 135 TB

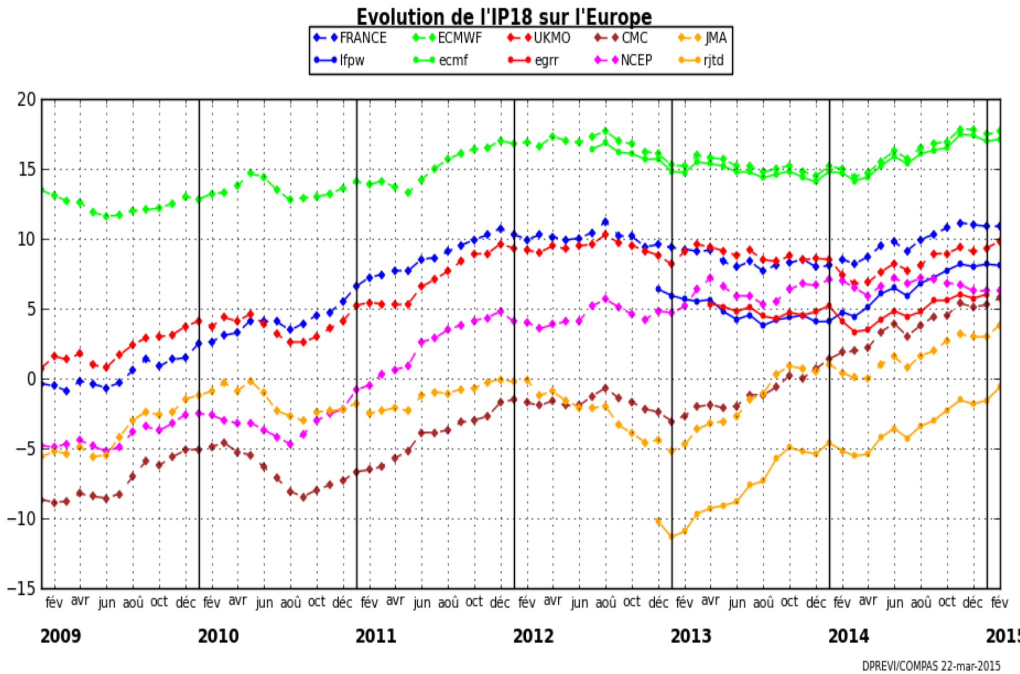
Evolution of NWP index

Up to now, NWP Index based on global deterministic model Arpege 48h forecast RMS Z500 against radiosoundings over Europe

Be replaced by 2 scores:

- global model Arpege: Index based on RMS against radiosoundings of Z500, T850, V250 parameters at 48h and 72h forecast over Europe
- convective scale model Arome: Index based on BSS against surface observations for RR6 (3 thresholds) and FX6 (1 threshold) at 6, 12, 18, 24h forecast over France

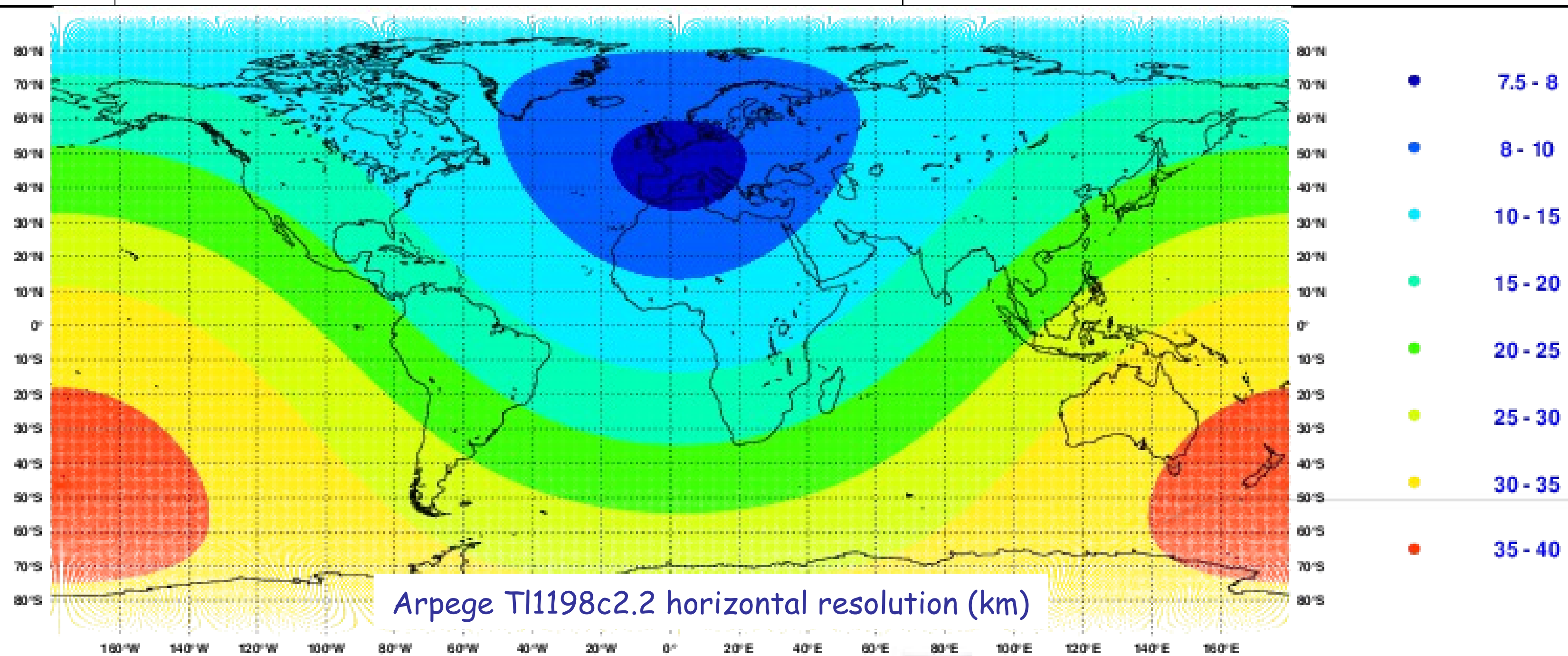




Operational NWP systems and recent changes

Global NWP forecasting systems

	Oper	E-suite CY40_op2 (to be operational in April 2015)
ARPEGE *Deterministic*	Tl798c2.4 L70 (10km on W Europe) 4DVar (6h cycle): Tl107c1L70 & Tl323c1L70 5 forecasts per day up to 102h	**Tl1198c2.2 L105 (7.5km on W Europe)** 4DVar (6h cycle): **Tl149c1L105** & **Tl399c1L105** 5 forecasts per day up to 102h
ARPEGE *Ensemble Data Assimilation (AEARP)*	Tl399c1 L70 ; 6 members 4D-Var (6h cycle): Tl107c1 L70 Background covariances averaged on 6 days and updated every 24h	**Tl479c1 L105 ; 25 members** 4D-Var (6h cycle): **Tl149c1 L105** Background covariances **averaged on 1.5 days** and **updated every 6h**
ARPEGE *Ensemble Prediction System (PEARP)*	Tl538c2.4 L65 (15km on W Europe) 35 members ; twice a day up to 108h Using 6 EDA members and singular vectors	**Tl798c2.4 L90 (10km on W Europe)** 35 members ; twice a day up to 108h Using **17 EDA members** and singular vectors **New set of 10 physical packages**



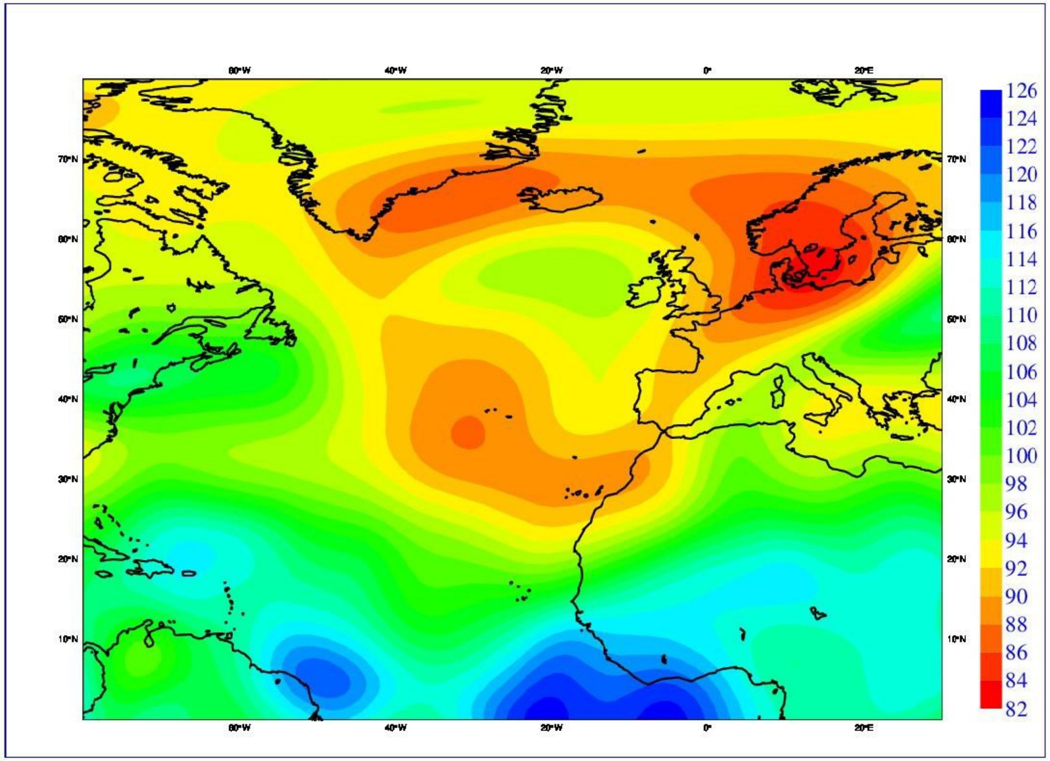
Arpege Tl1198c2.2 horizontal resolution (km)

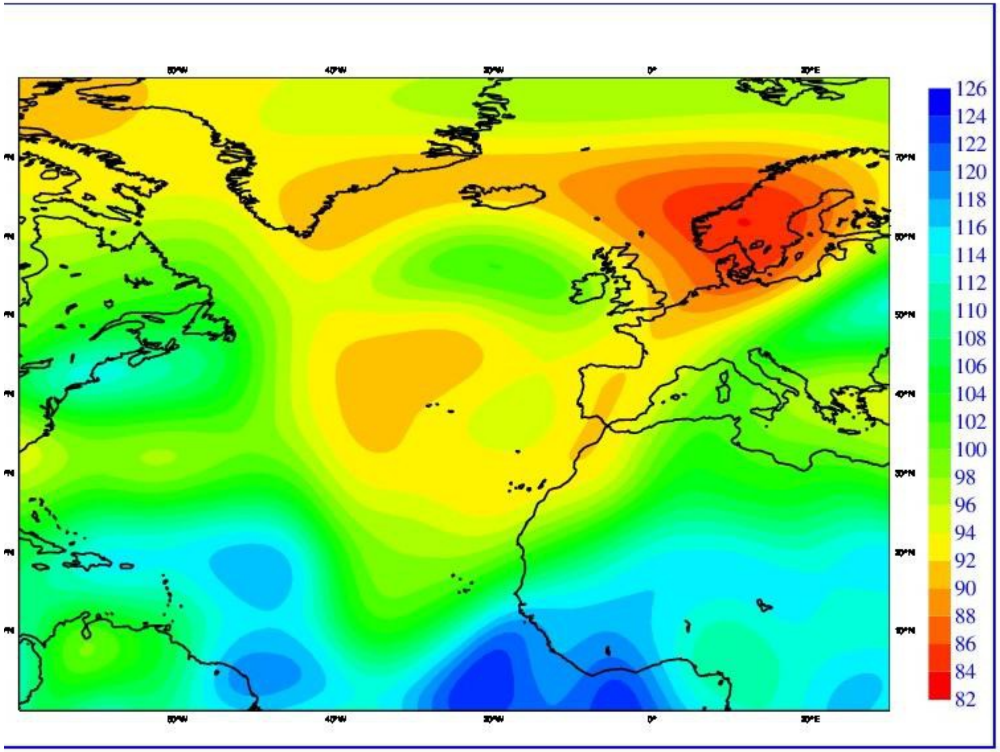
Other modifications in e-suite "CY40_op2" for global system Arpege

- Calibartion in EDA and background error variances filtering
- 30' time-slots in Arpege 4D-Var (instead of 1h)
- Increase of radiances density (factor 2) as input data in screening
- 6 SSMI/S sounding channels of DMSP-F17 and F18
- Use of edge swath ATMS data
- Assimilation of 6 sounding channels of SAPHIR on Megha-Tropiques
- GPS-RO (vertical extension, reduced sigmaO, new satellites)
- New CrIS tropospheric channels (+22 over sea, +8 over land)
- EARS ASCAT Metop-B
- Clear Sky Radiances of Meteosat-7 and Mtsat-2
- New white liste of GPS ground observation (adaptation to new orography)
- Radiosoundings in Bufr format
- "Jc_dfi" revision (on surface pressure and divergence only)
- Radiation computations every hour (instead of 3h)

New version of EDA 4D-Var (AEARP) (with increased ensemble size)

Correlation length-scales estimated for wind near 300 hPa on 15/11/2013 (06UTC)

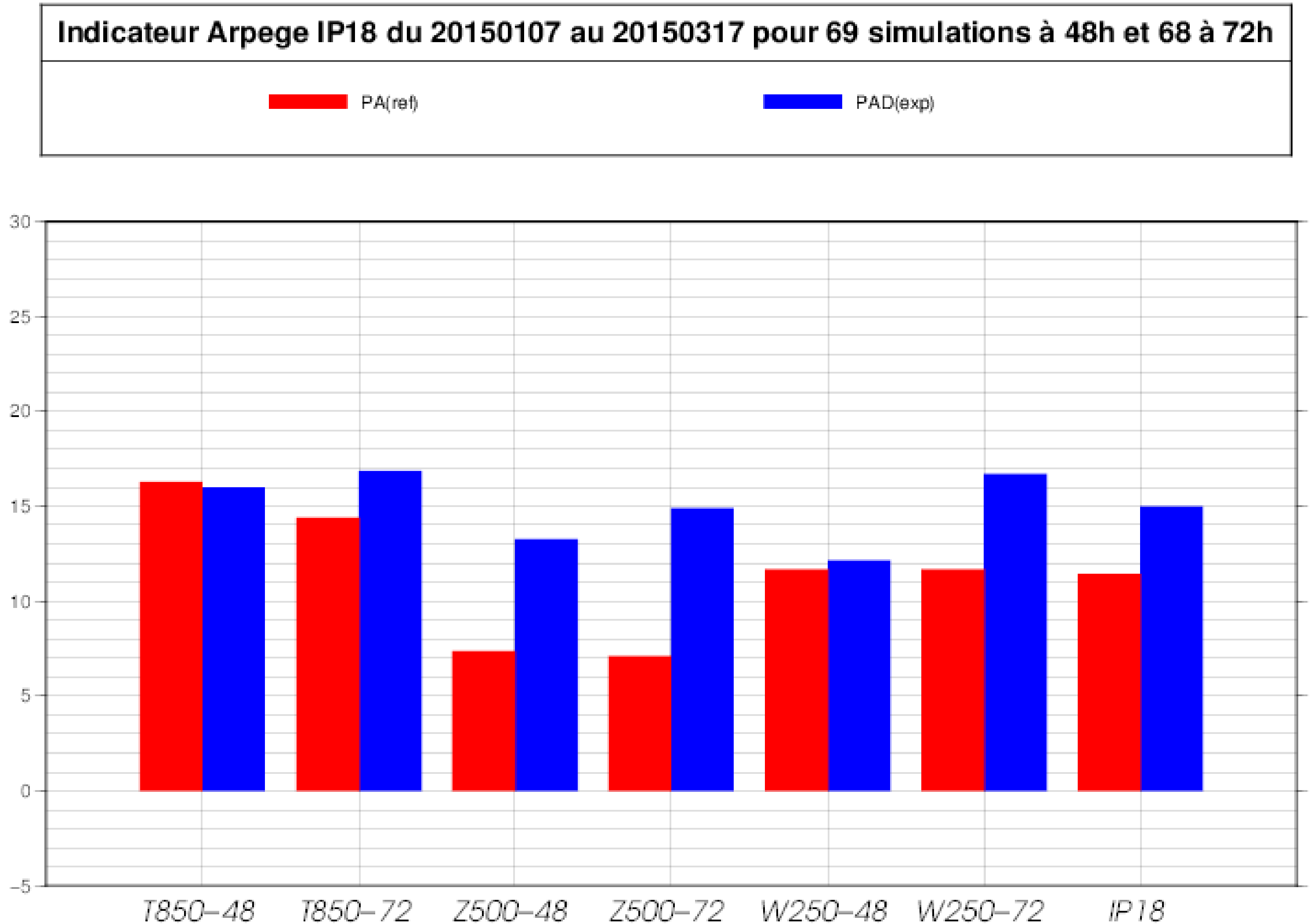




6 members :
correlations averaged
over 24 cycles (6 days)

24 members :
correlations averaged
over 6 cycles (1 day ½)

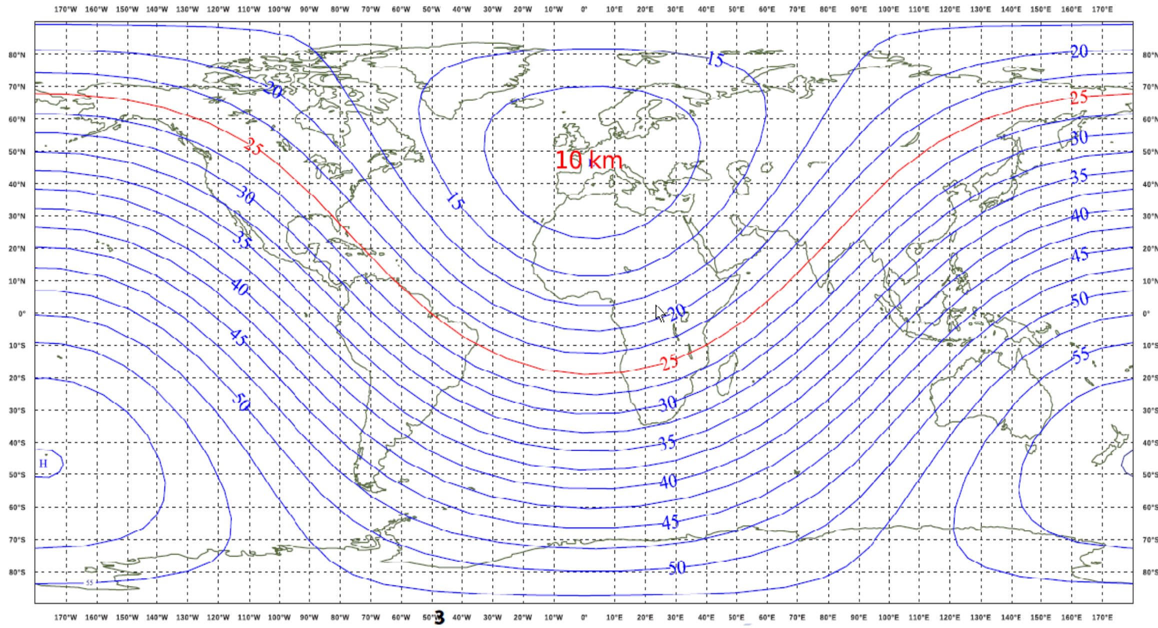
E-suite “CY40_op2”: Arpege Index



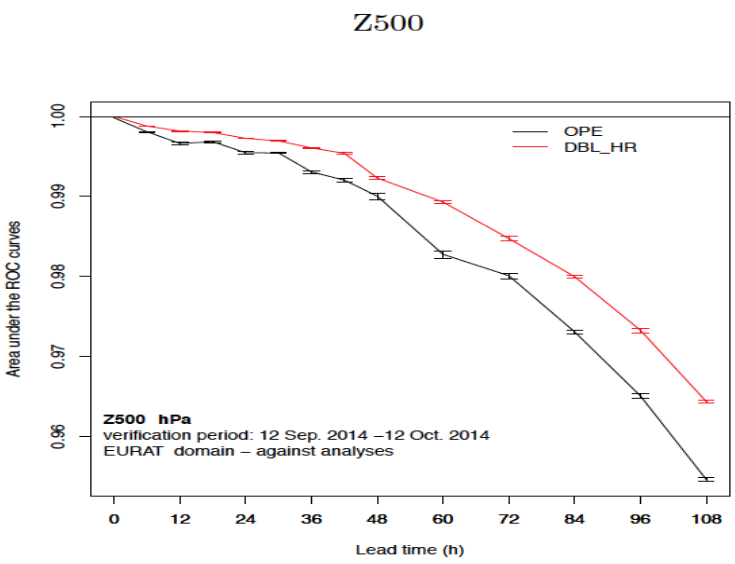
Arpege Index based on 6 normalized EQM of T850, Z500, V250 at 48 and 72h lead time against radiosoundings over a domain covering Europe

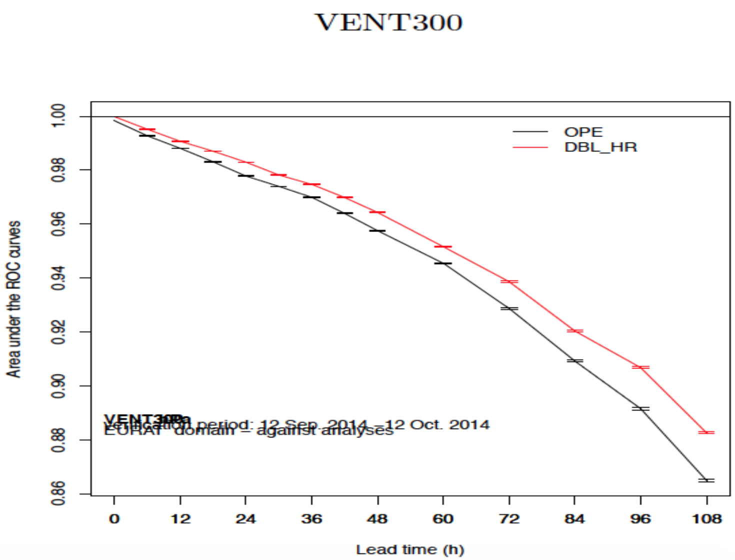
Global Arpege EPS (PEARP)

35 members including the control member
Forecasts resolution : T798C2.4L90 (T538c2.4L70)
Using 17 background states and the mean from EDA
Singular vectors computed over 7 areas: resol Tl95
New set of 10 physical packages



Improvement of statistical resolution of the ensemble

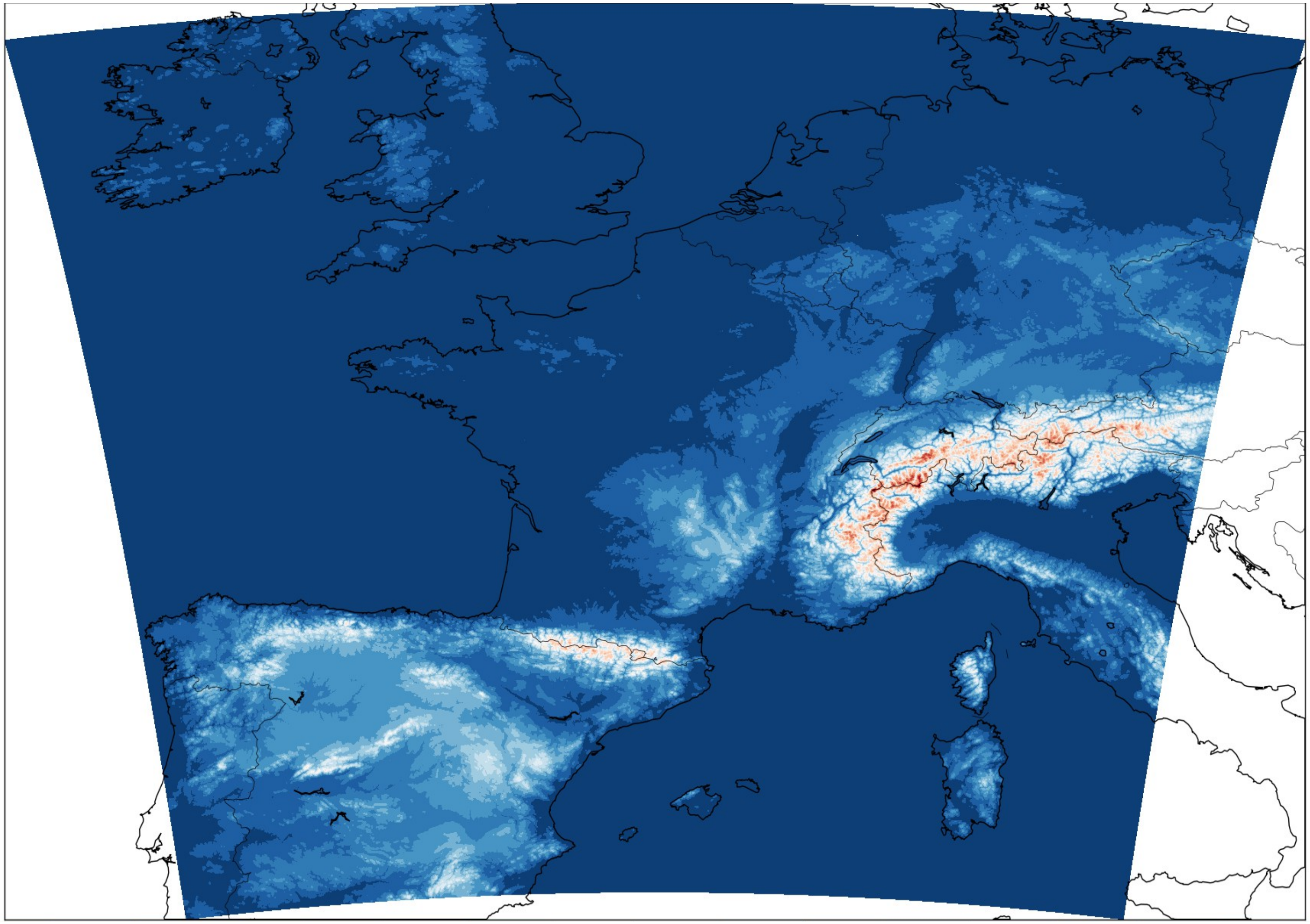




ROC area function of lead time

Convective scale system Arome (CY40_op2)

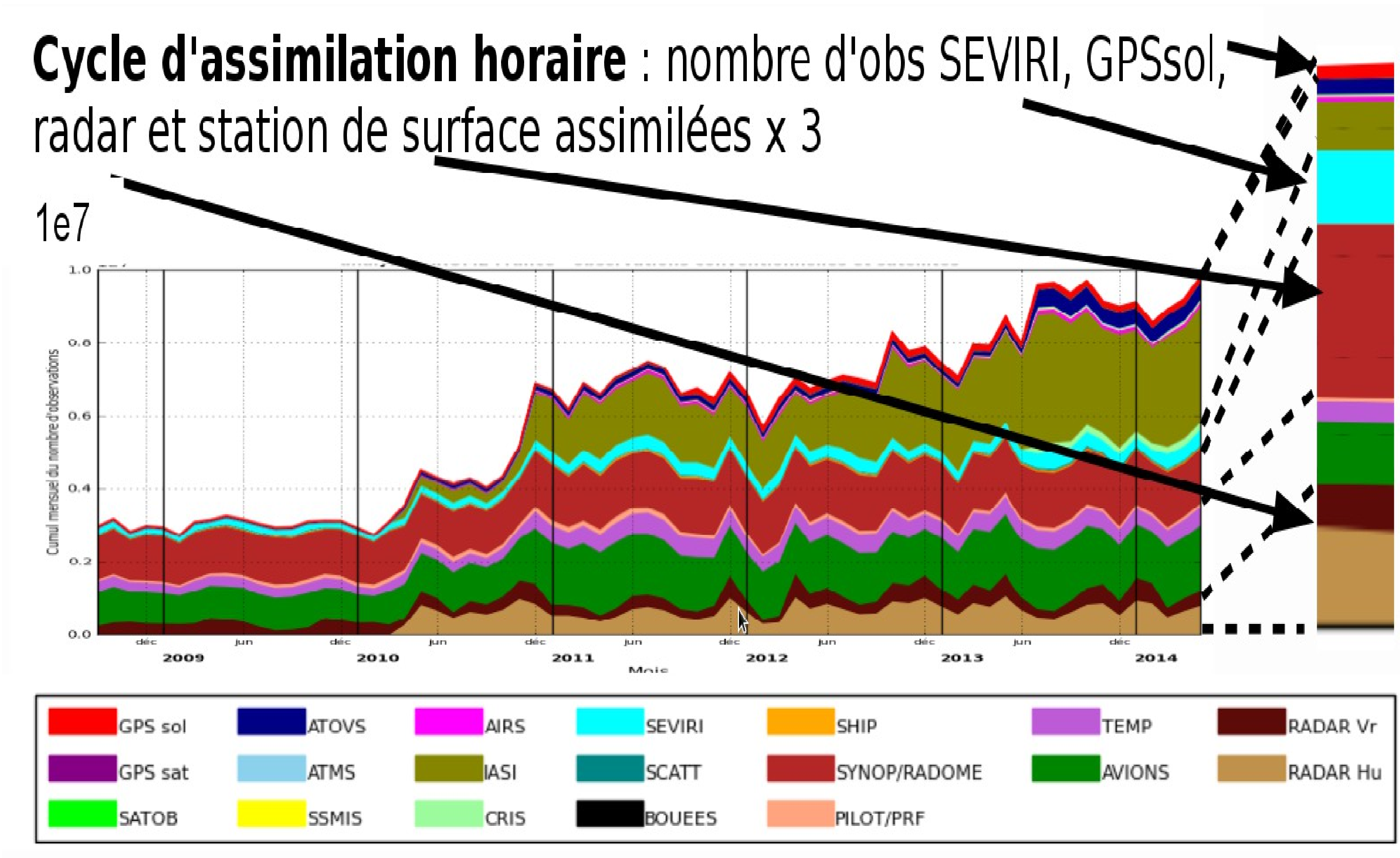
	Oper	E-suite
AROME *Deterministic*	2.5km L60 (750 x 720 pts) 3DVar (3h cycle) 5 forecasts per day up to 36h	**1.3km L90 (1536 x 1440 pts)** 3DVar (**1h cycle**) 5 forecasts per day **up to 42h**



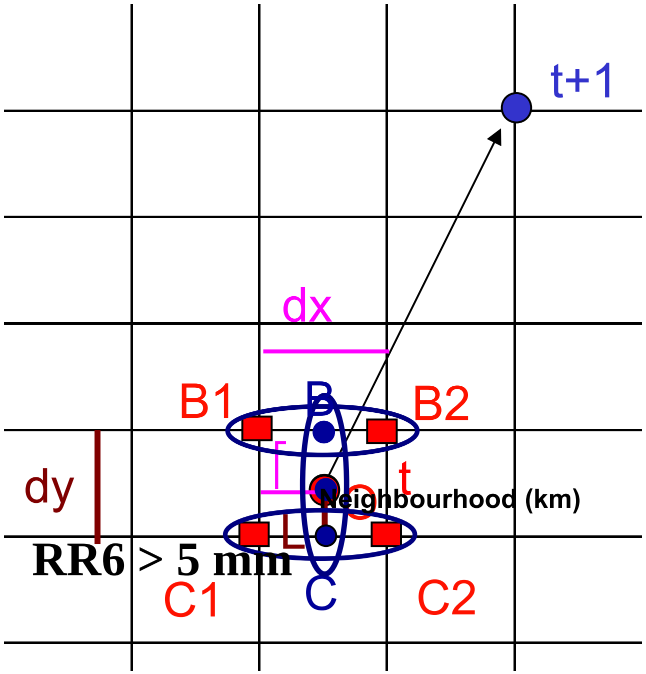
Other modifications in e-suite "CY40_op2" for convective scale system Arome

- 1h assimilation cycle (instead of 3h) : more observations assimilated such as radar, ground GPS, SYNOP, SEVIRI, etc.
- Incremental Analysis Update (IAU) used to keep 0, 3, 6, 9h, etc. production time bases
- Predictor-corrector temporal scheme with one iteration
- Modified semi-lagrangian advection scheme "COMAD"
- Numerical diffusion tunings (spectral and grid-point)
- New orographic database (GMTED 2010 at 250m resolution)
- Changes in the physics (autoconversion, orographic surface drag, ...)
- Radio-soundings BUFR
- New diagnostics
- New post-processing lat/lon domain (containing whole computing domain)

1h assimilation cycle (Nb obs assimilated)



Modified Semi-Lagrangian scheme

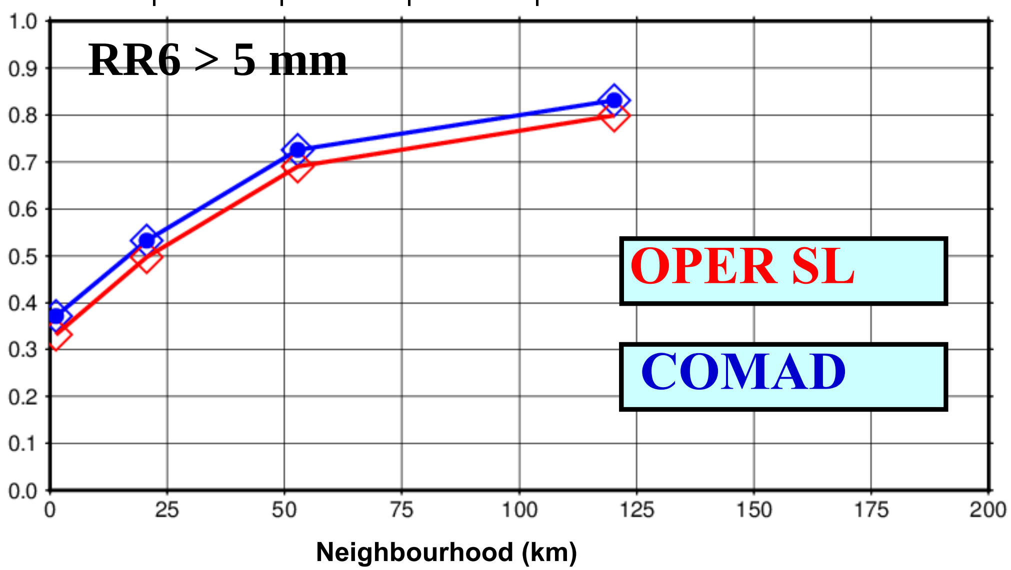


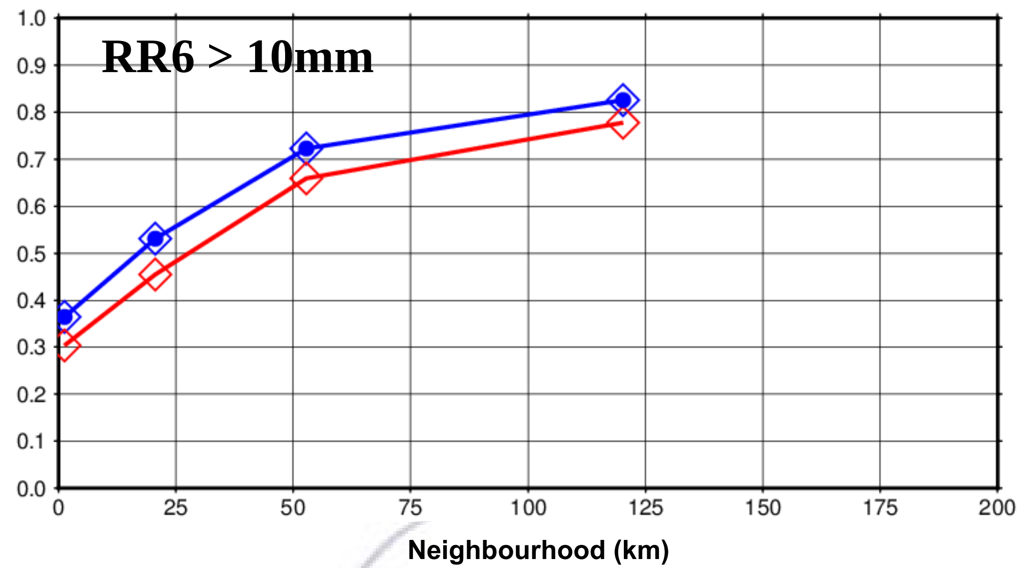
COMAD scheme (Malardel and Ricard, 2015, QJ)

* Computation of the trajectories: no modification

* Computation of the value of variables at the origin point → modification of the SL interpolation weights to take into account deformation

Brier Skill Scores for 6-h precipitation (12UTC-18UTC)
15 July – 15 September 2013 – AROME 2.5 km



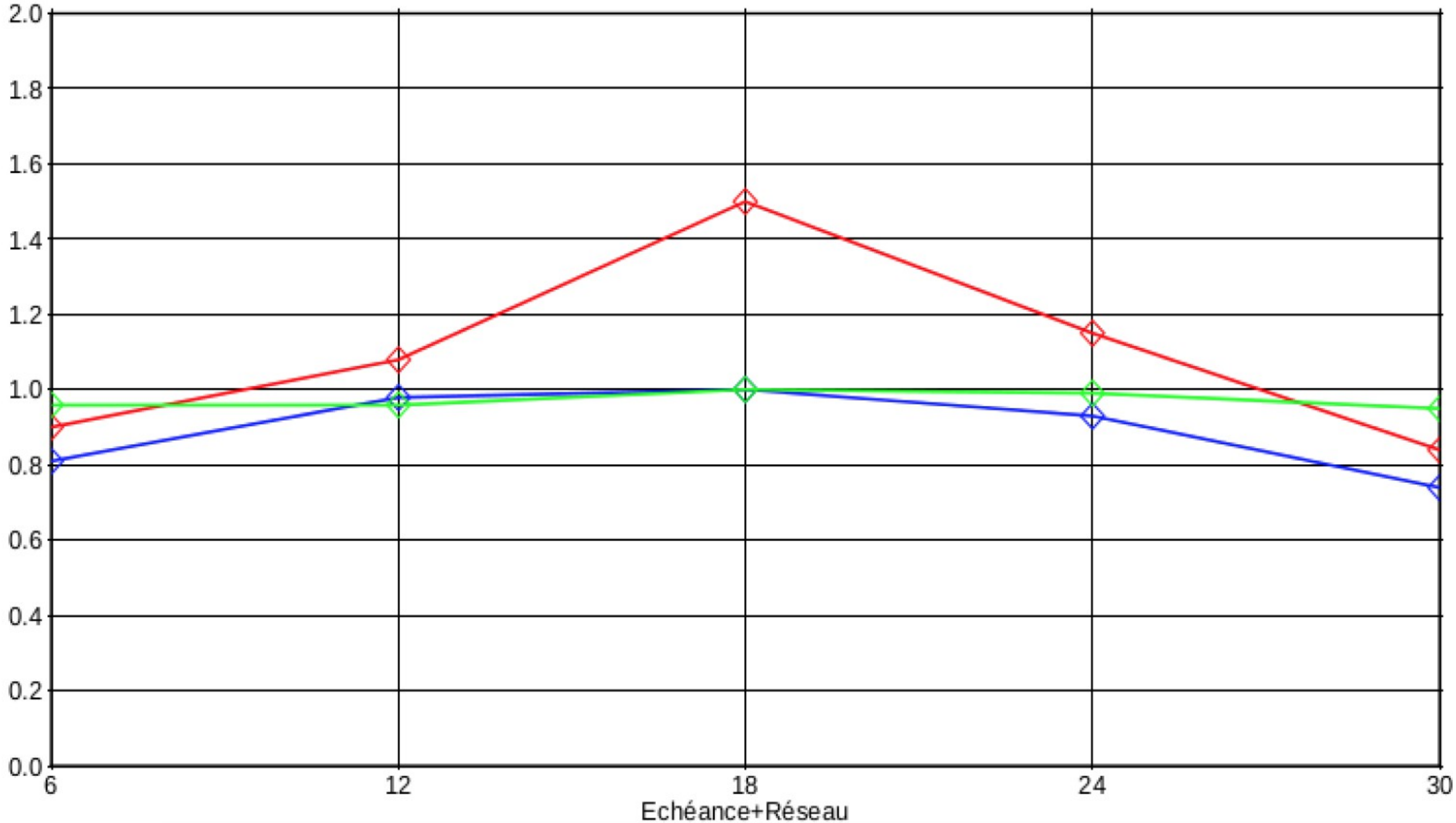


Better scores for all thresholds and all neighbourhoods. Less intense convective cells

AROME e-suite (precipitation score)

Precipitation Frequency Bias for the threshold 10mm/6h function lead time on summer and autumn 2014

OPER E-SUITE PERSISTENCE

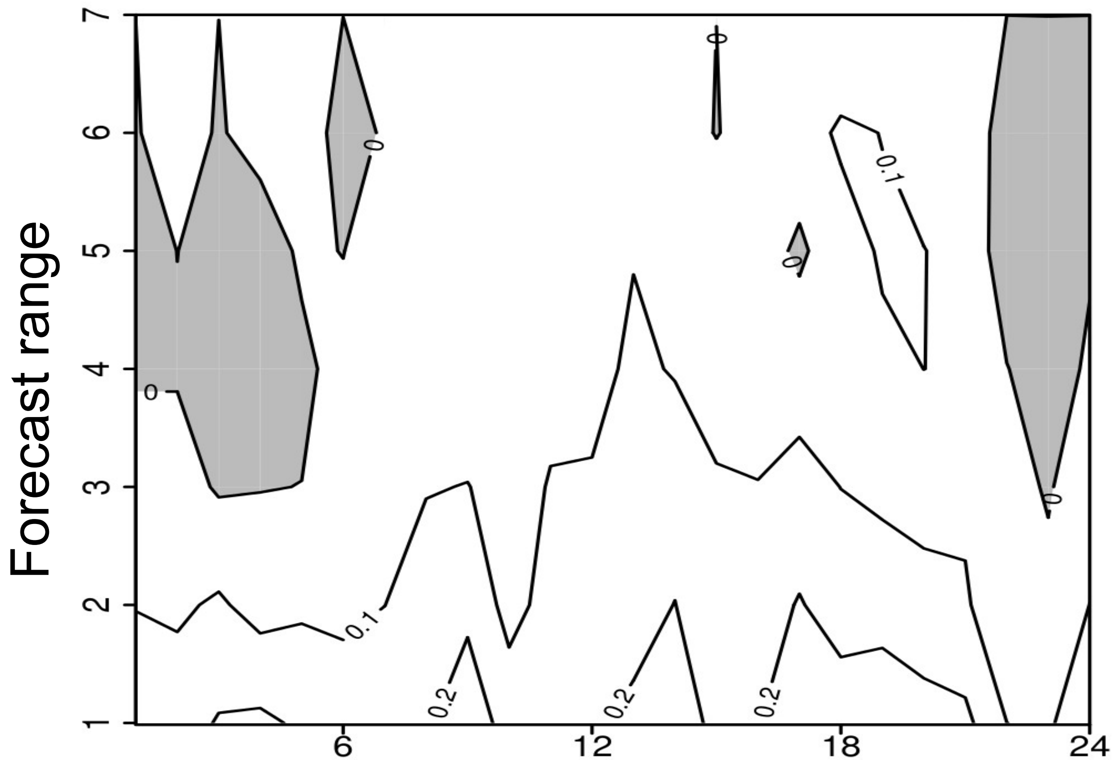


Preparation of new systems

AROME-Nowcasting

AROME-Nowcasting system will be running in pre-operational mode from mid 2015
AROME 1.3km : 6h forecast every hour based on 3DVar analysis with 10min cut-off
Boundary conditions are given every hour by AROME-France model. No cycling.

Difference of BSS for 1h rainfall accumulation
between AROME and AROME-Nowcasting forecasts



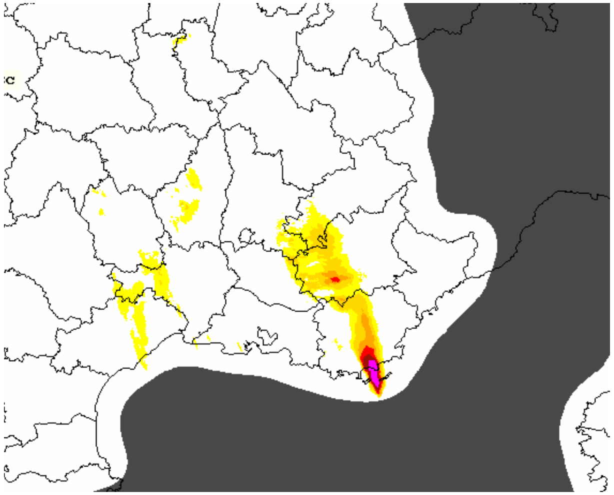
Analysis time of AROME-Nowcasting forecasts

AROME Ensemble Prediction System

- 12 members at 2.5km resolution (vs 1.3km for deterministic AROME-France)
- 42-hour range production starts at 09 and 21UTC
- **lateral boundary:** selected from the 35-member global EPS (PEARP at 8km)
- **initial upper-air:** rescaled & centered perturbations from PEARP
- **initial surface:** correlated random perturbations of SST, soil moisture/humidity, snow, physiographies
- **model error:** SPPT (stochastic perturbation of physics tendencies)

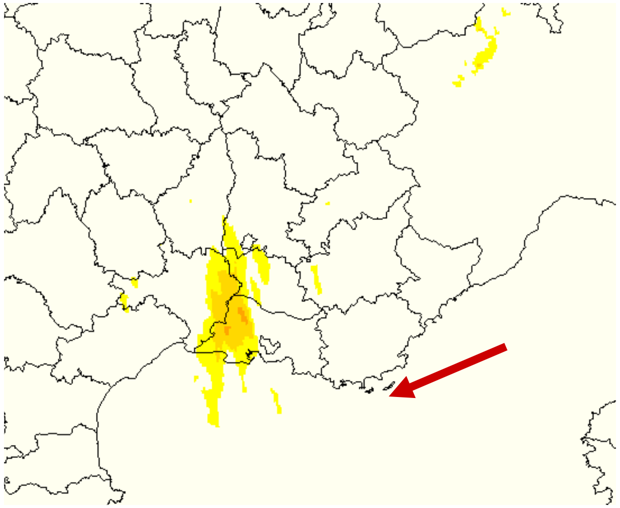
Precipitation case study 19 January 2014 at 12UTC over Var

RADAR



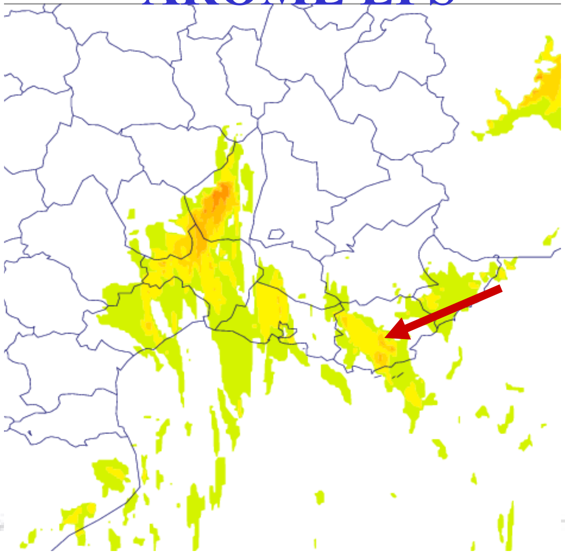
Observed 6h cumulated precipitation threshold at 20mm

AROME



AROME 24h forecast
-> Pbs of localization and intensity !

AROME EPS

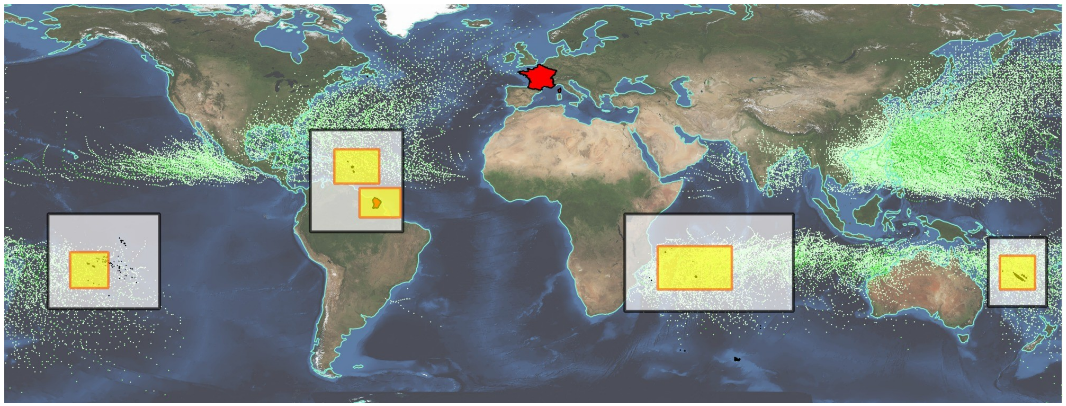


PE AROME 24h forecast
Proba (cumul 6h > 20mm)
-> better localization

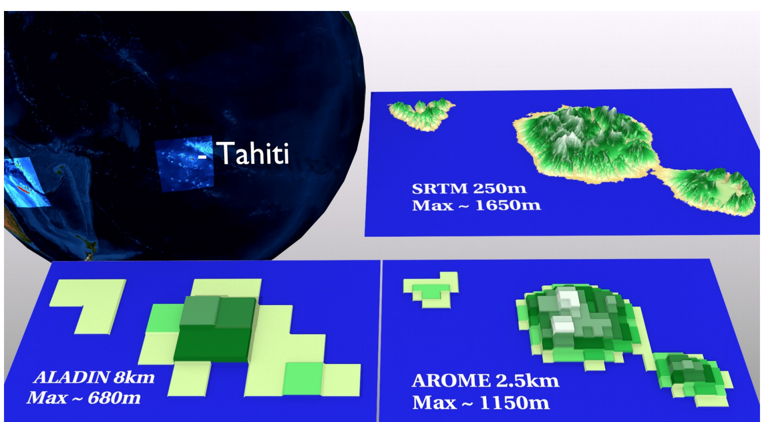
AROME-Overseas

Domains spread all along the tropical belt

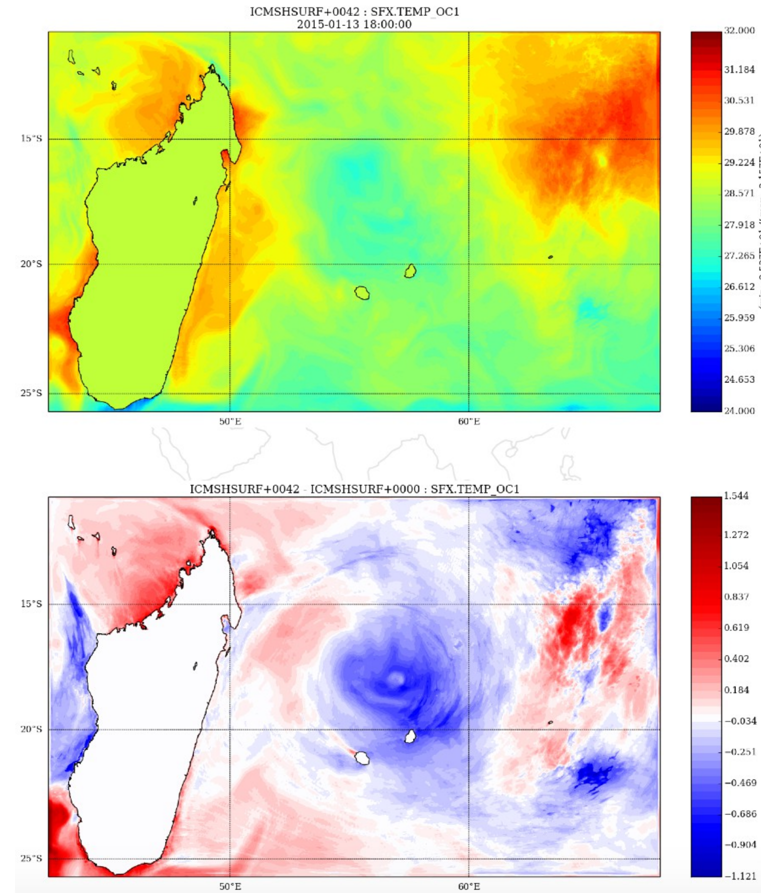
2.5km resolution (instead of 8km) with 1D ocean mixing layer scheme



Future AROME overseas domains (in yellow) and current operational ALADIN domains (in white)



Tahiti orography
(in ALADIN and in AROME)



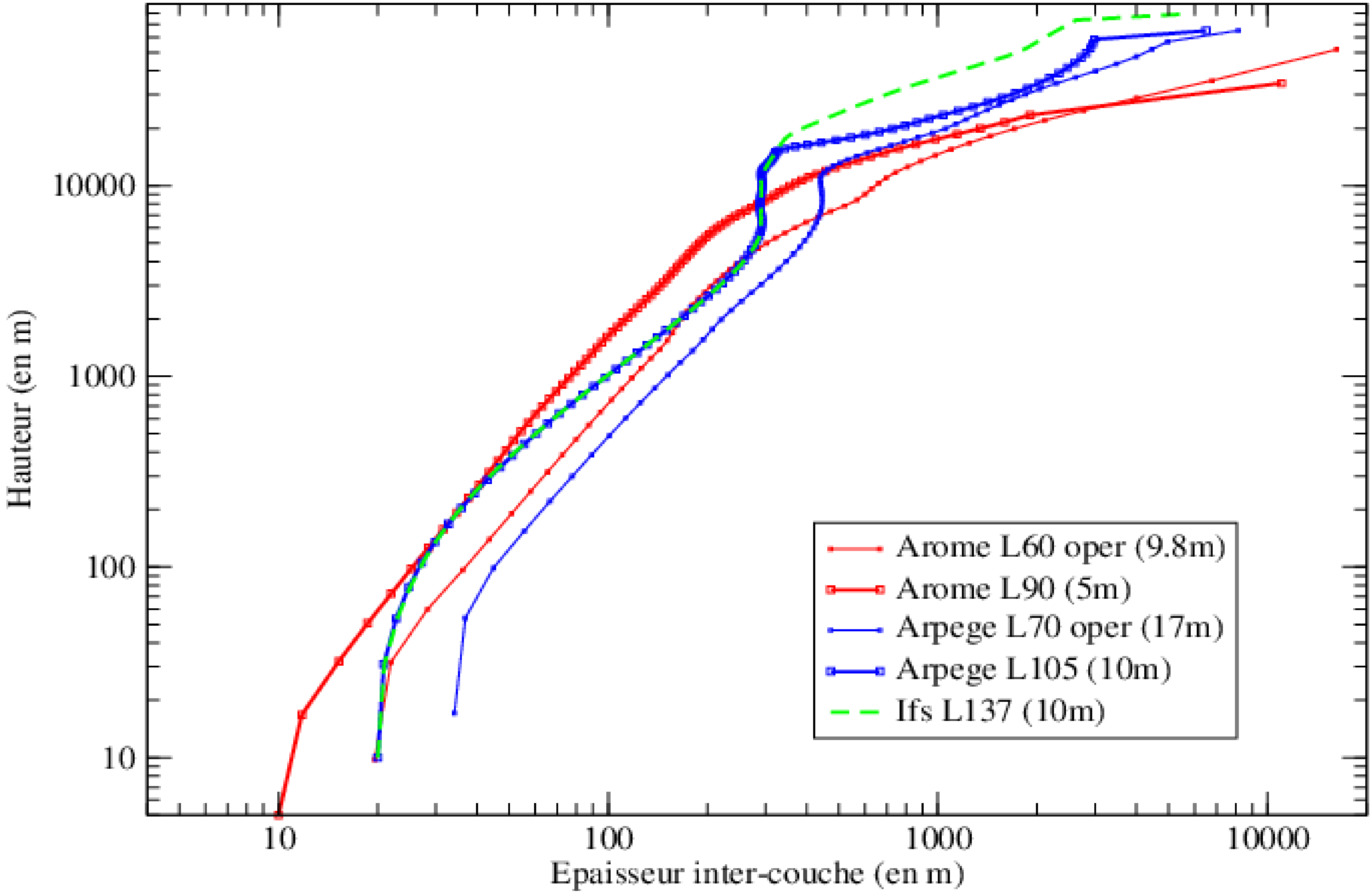
SST and SST difference after 42h forecast with Arome including 1D ocean mixing layer scheme for 13/01/2015 (Bansi cyclone)

Seasonal prediction system 5 for EUROSIP

- To be released in September 2015 (COPERNICUS proof of concept)
- Doubling horizontal resolution (and time step) : t127 → t255
- Tripling the vertical resolution : 31levels → 91levels
- Adding sea-ice (GELATO model)
- Improvements in the surface (SURFEX model) and stratosphere (Ozone, gravity waves)
- Stochastic perturbations to the dynamics equations
- New ocean analyses/reanalyses by Mercator-Ocean (NEMO 1°)
- Computation cost x24

Appendices

New vertical resolutions



AROME Ensemble Prediction System

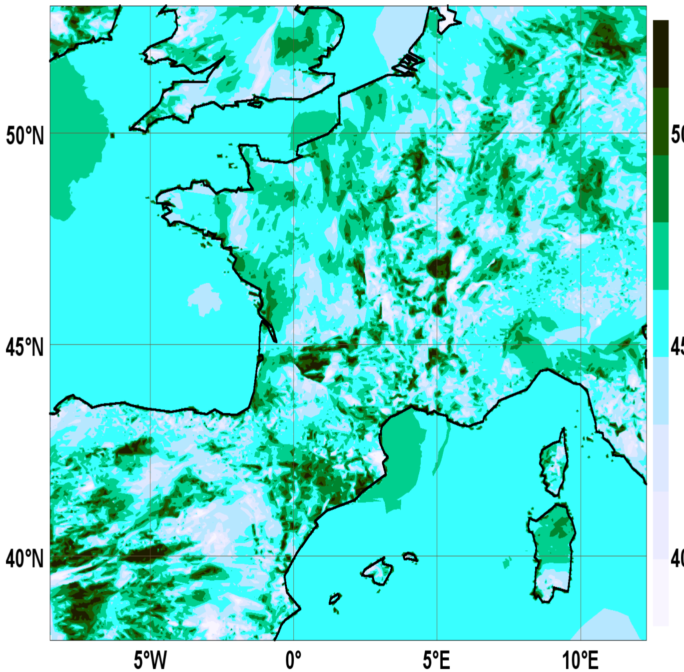
AROME-France-EPS in preoperational mode :

- 12 members at 2.5km resolution (vs 1.3km for deterministic AROME-France)
- 42-hour range production starts at 09 and 21UTC
- Perturbations:
    - **lateral boundary conditions:** selected from the 35-member global PEARP ensemble (using clustering) (PEARP has 8 km resolution)
    - **initial upper-air:** rescaled & centered perturbations from PEARP
    - **initial surface:** correlated random perturbations of SST, soil moisture/humidity, snow, physiographies
    - **model error:** SPPT (stochastic perturbation of physics tendencies)
- Current research:
    - coupling between initial, lateral and surface perturbations
    - better ICs (using EDA or B-based random noise)
    - dispersion-preserving clustering of LBCs
    - post-processing :
        - precipitation calibration, neighbourhood methods and economic value
        - coupling to flood prediction models & aircraft trajectory planning

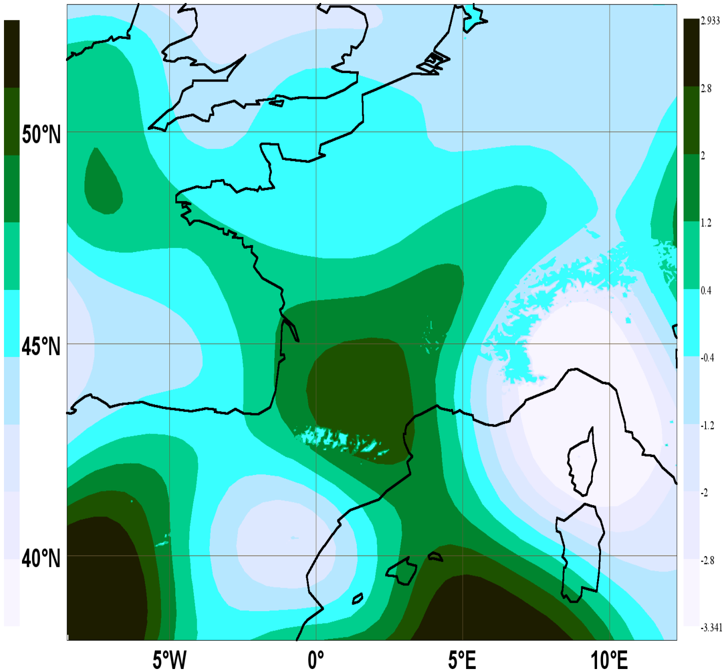
Interaction between EDA and surface perturbations

Ensemble perturbations from the AROME EDA (ensemble data assimilation) are improved when simple random noise is used at the surface, instead.
i.e. a better surface perturbation scheme should be developed in EDA.

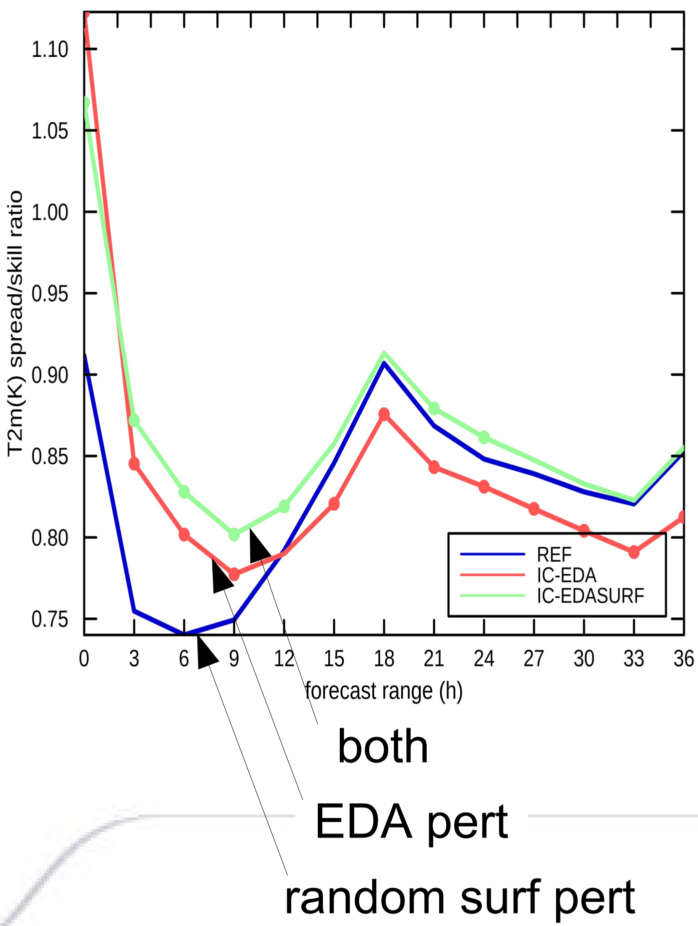
Ts perturbation (EDA)



Ts perturbation (random)



T2m spread/skill ratio
(higher is better)

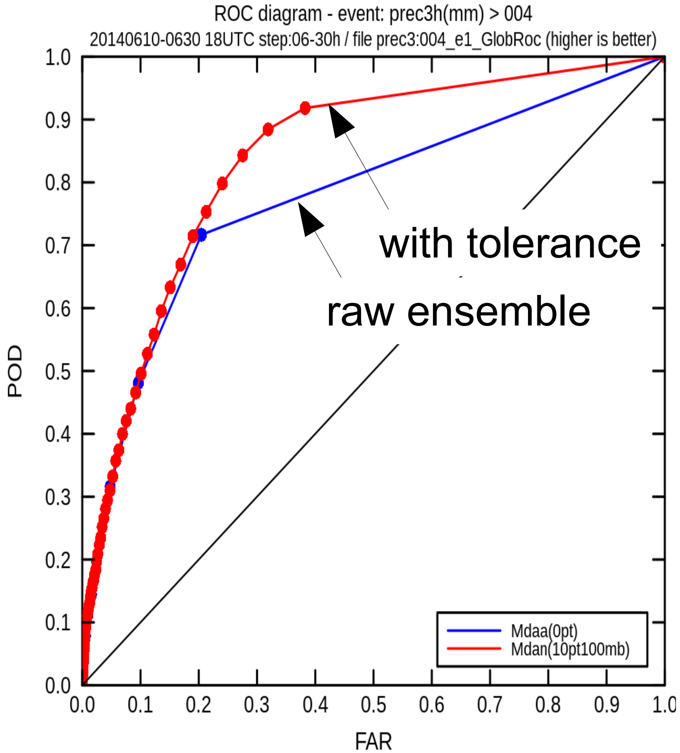


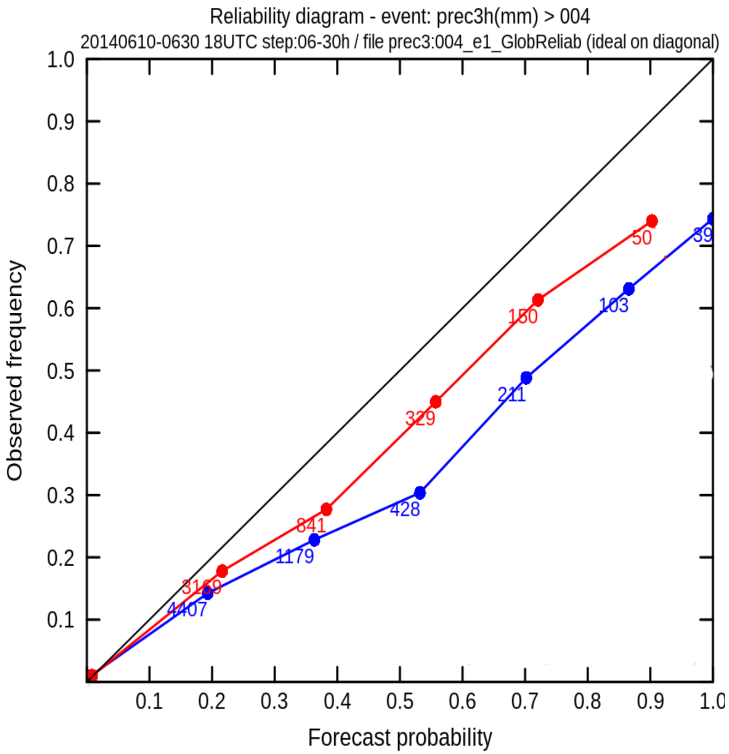
Neighbourhood methods for high precipitation forecasts

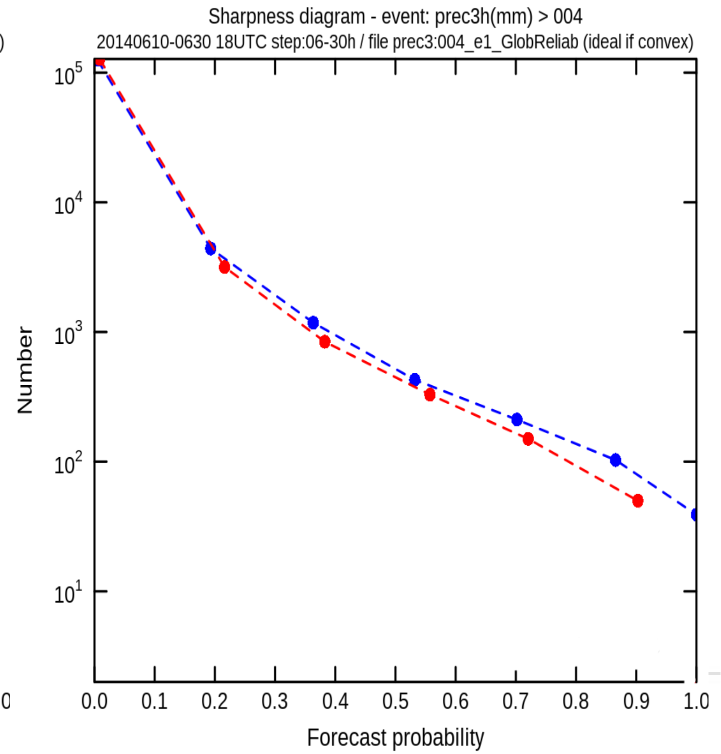
Ensemble scores improve when spatial tolerance is introduced in the forecast PDF computation :

- improved reliability & ROC metrics
- negligible loss of sharpness
- largest effect comes from improved membership

Performance is sensitive to details of the method used.







Contribution to S2S project

Coupled model CNRM-CM with ARPEGE/Surfex TL255L91r and NEMO/Gelato 1°

Dispersion mode : stochastic dynamics

	Hindcast	**Forecast**
Frequency	Monthly	Monthly
Ensemble size	15	51
Initial Conditions	Atm. : ERA-Interim Ocean : Mercator PSY2G2V3 reanalysis	Atm. : IFS Analyses Ocean : Mercator upscaled PSY2G2V3 an.
Length	1993-2014	
Status	In production	Start : Apr. 2015 (?)

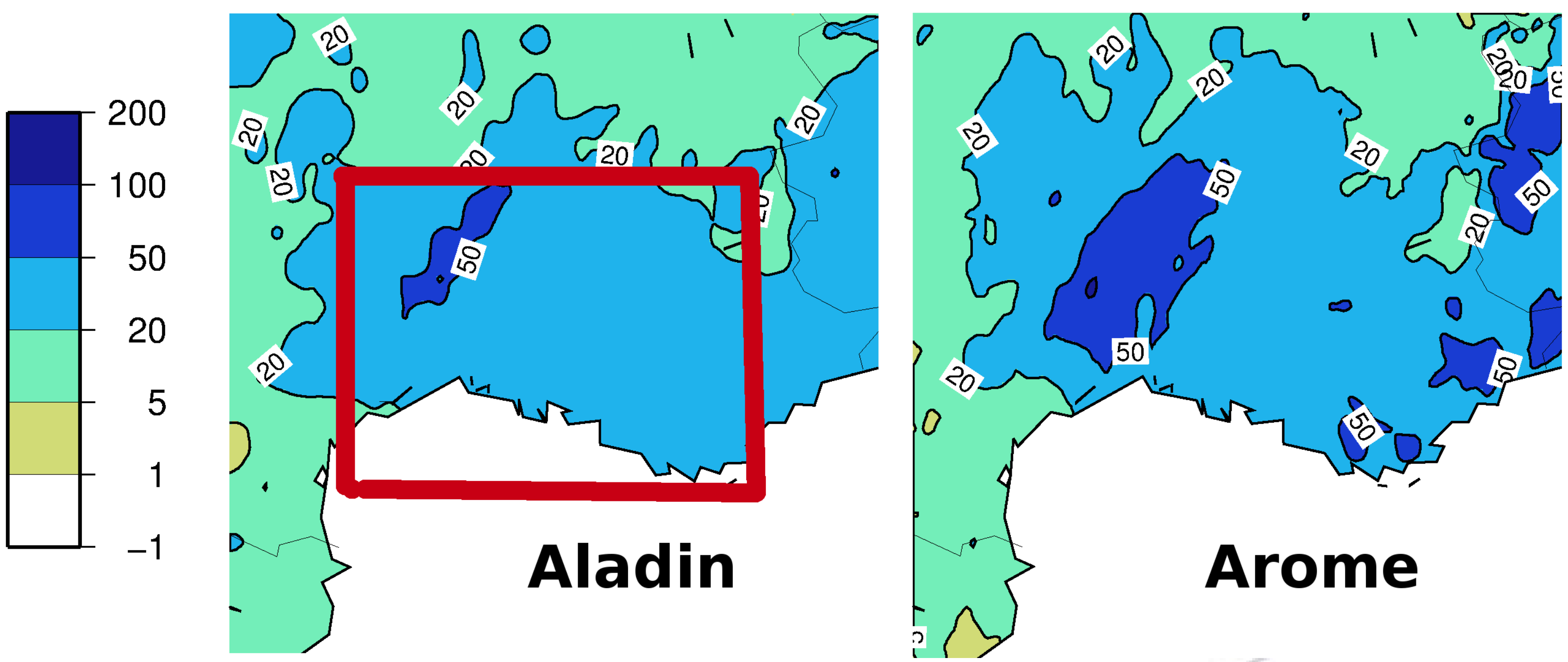
Outputs :

- Temporal resolution : Daily series (6h for precipitation)
- Leadtime: 61 days
- Spatial resolution : regular lat-lon 1.5 ° grid
- Format : grib2
- Retrieval : MARS archive

AROME for climate simulations

- Resolution 2.5 km on SE France
- Simulations for 20 summer-autumn seasons (1989-2008)
- ERA-interim drives ALADIN 12 km over France (22 years),which drives AROME
- Composite of the 10 days with most rainfall in 1994 (they are the same in ALADIN and in AROME)

Autumn 1994 : heavy rainfall rates (mm/day)

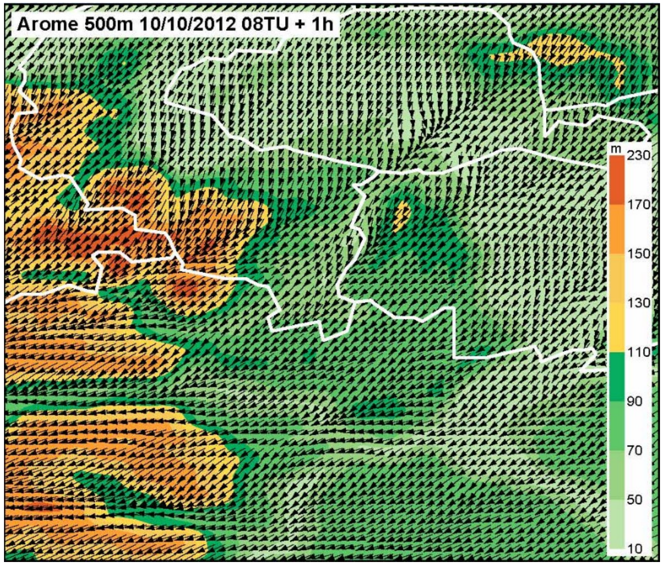


Red box used to select the 10 days with maximum rainfall

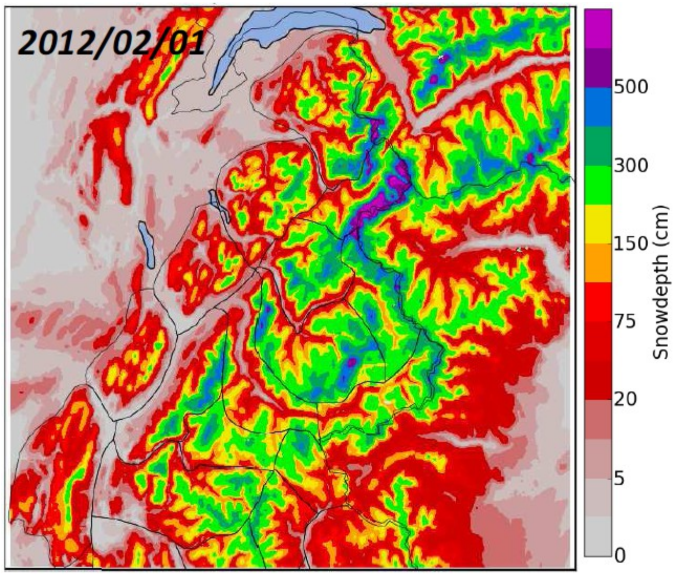
Simulations at very high resolution

Current operationnal resolution is 1.3 km on a large domain over europe (1536x1440)

We also regularly perform 500m simulation on small domain for research and development activities :



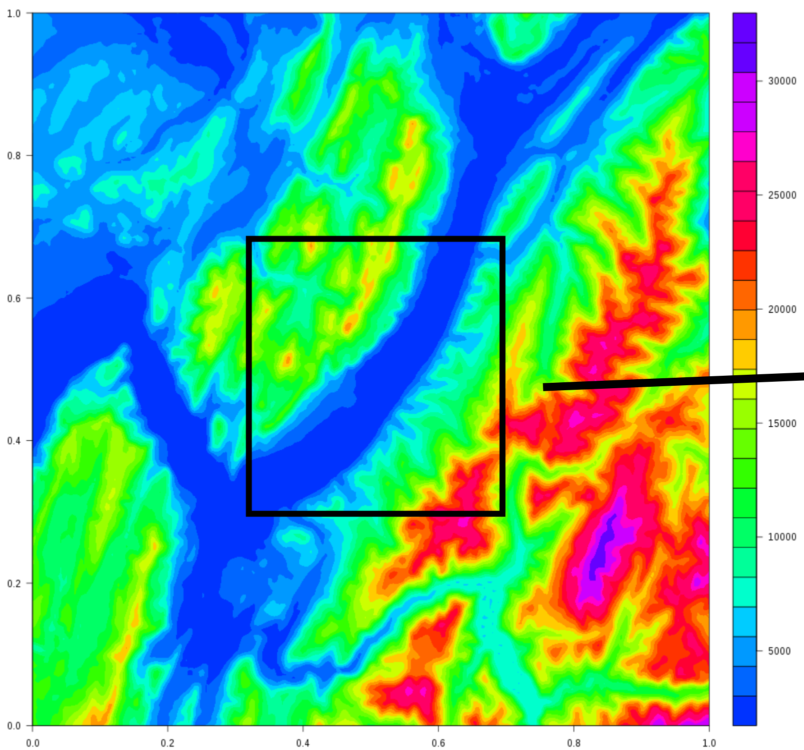
500m simulation in Paris area to provides wind and turbulence related parameters to a wake-vortex prediction model (here wind field over surface orography)



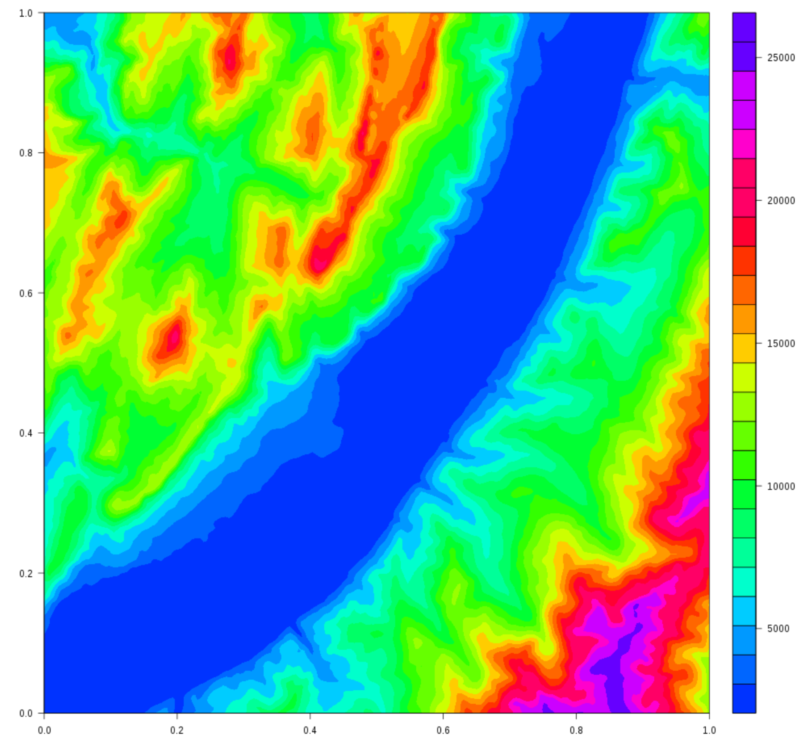
500m simulations over a whole winter period to force te snow model model CROCUS (here snowdepth at a particular time)

Simulations at very high resolution

- 500m resolution forecasts experiments help us prepare the future resolution of our forecast model



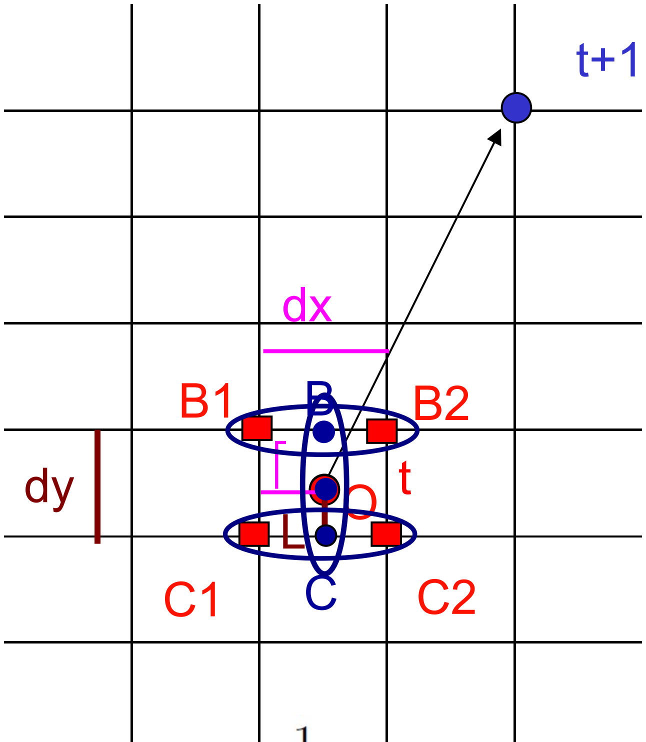
Chartreuse I domain, dx=250m, maximum slope is 61 °



Chartreuse II domain, dx=100m and dx=50m maximum slope is 67 ° and 76°

Modified Semi-Lagrangian scheme

COMAD scheme (Malardel and Ricard, 2015, QJ)



* Computation of the trajectories: no modification

* Computation of the value of variables at the origin point → modification of the SL interpolation weights

For example, with linear interpolations (2D and regular grid):

COMAD SL scheme:

2 linear zonal interpolations

$$V_B = w'_{x1} V_{B1} + w'_{x2} V_{B2} \qquad V_C = w'_{x1} V_{C1} + w'_{x2} V_{C2}$$

with $\begin{cases} w_{x2} = \dfrac{\lambda}{dx} \\ w_{x1} = 1 - \dfrac{\lambda}{dx} = 1 - w_{x2} \end{cases}$

- 1 meridian linear interpolation

$$V_O = w'_{y1} V_B + w'_{y2} V_C$$

with $\begin{cases} w_{y2} = \dfrac{L}{dy} \\ w_{y1} = 1 - \dfrac{L}{dy} = 1 - w_{y2} \end{cases}$

$$w'_{x1} = \alpha_x w_{x1} + \frac{1}{2}(1 - \alpha_x)$$

$$w'_{x2} = \alpha_x w_{x2} + \frac{1}{2}(1 - \alpha_x)$$

with $\alpha_x = 1 + \dfrac{\partial U}{\partial x} dt$ deformation factor along x-axis

$$w'_{y1} = \alpha_y w_{y1} + \frac{1}{2}(1 - \alpha_y)$$

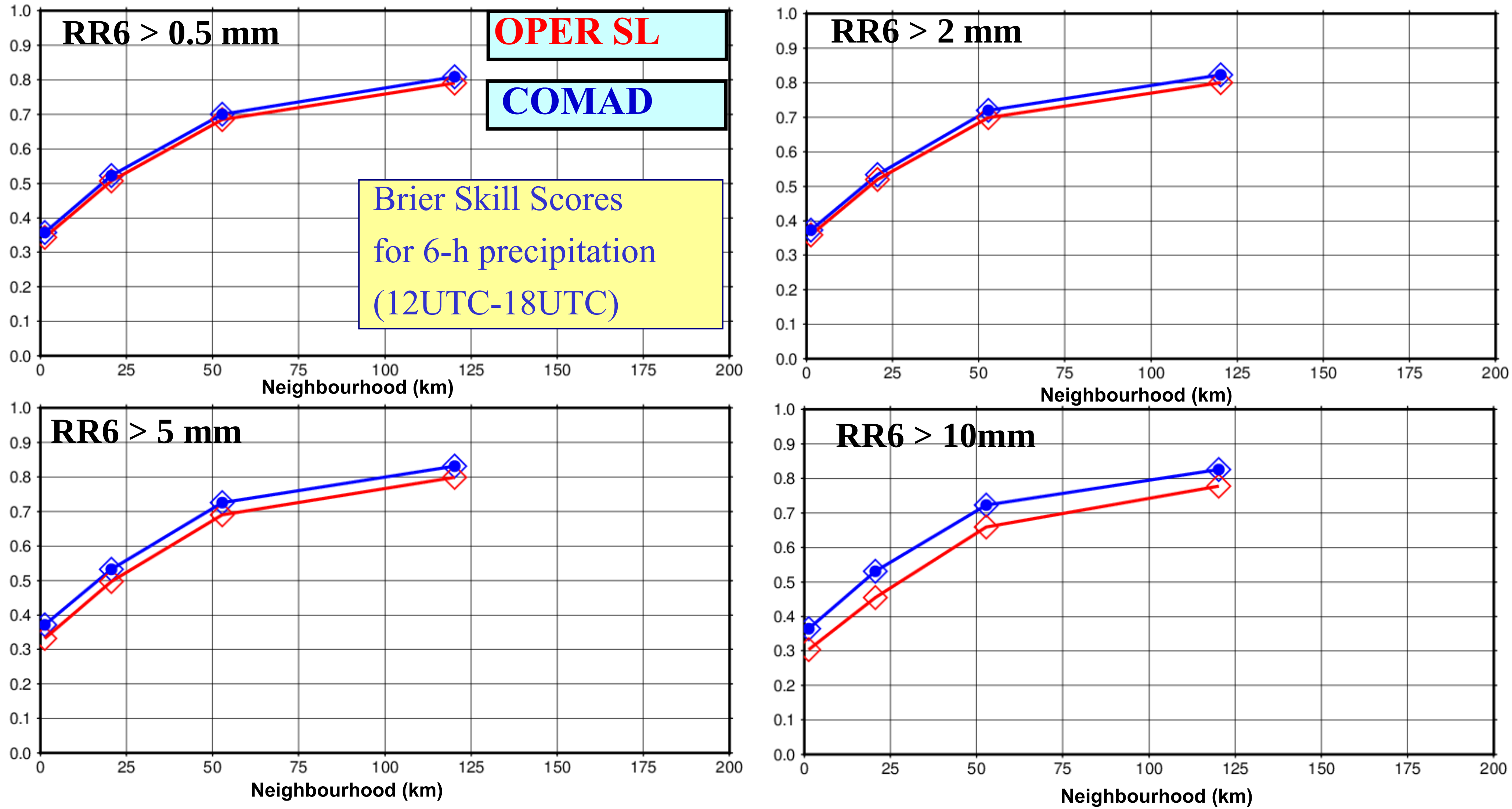
$$w'_{y2} = \alpha_y w_{y2} + \frac{1}{2}(1 - \alpha_y)$$

with $\alpha_y = 1 + \dfrac{\partial U}{\partial y} dt$ deformation factor along y-axis

→ modified linear weights can also be used after for computing cubic weights

Modified Semi-Lagrangian scheme

Fuzzy scores: 15 July - 15 September 2013 – AROME 2.5 km



Better scores for all thresholds and all neighbourhoods
Less intense convective cells
Improvement of QPF with less amount of precipitation

Spherical Geopotential Approximation

- Spherical Geopotential Approximation (SGA): neglects Earth's flattening, and most of centrifugal force. SGA errors acts uniformly at all heights
- Shallow-atmosphere Approximation (SA): neglects increased area of columns and decrease of g, with height. SA errors : zero near ground, same magnitude as SGA errors above 20 km
- SGA errors might therefore hinder NWP progresses earlier than SA errors
- Active work on physically consistent governing equations for Ellipsoidal Geopotential Approximation (EGA) by UK and French teams (UKMO, LMD, M-F) in 2012-2014
- First impact tests in Shallow-Water (SW) idealised cases show systematic / cumulative impact of error with forecast range.
- Positive impact of EGA still weakly-significant in SW real cases, but could become significant in a near future
- Investigations and tests must be pursued for a better estimation of impact, and decision about when EGA will become important, and necessary in NWP

Ongoing research for future dynamical kernels

1) Keeping current kernel (spectral SI/SL 2TL) as long as possible

- It is possible to perform precise derivative computations at poles on a reduced lat-lon grid provided you use an adapted base of functions.
- Semi-implicit could be solved by gridpoint solvers.

2) Towards future kernels

- Participation in a national research program on a global icosahedral model (HEAT project)
- Collaboration with ECMWF about new kernel/scalability projects (OOPS, PolyMitos)

The Passy-2015 field experiment : stable boundary layer and pollution in an Alpine valley

- LEGI, CNRM-GAME, LGGE, ARA, LTHE, NCAS
- Funding : LEFE/ADEME and METEO-FRANCE
- PI : LEGI and CNRM-GAME

- Initial objective:
  exploring atmospheric dynamics associated to pollution (stable conditions) in the Passy valley

- Research topics addressed by GMEI and CNRM
  - Temporal evolution of lower atmosphere
  - Local circulation and spatial heterogeneity
  - Stratified turbulence
  - Fog in a very polluted environment
  - Surface influence

- Tools :
  - Field experiment (nov 2014 – mar 2015)
    - 5 measurements sites
    - IOP : 6-14 and 17-20 February 2015
    - Leaded by CNRM-GAME/GMEI
  - Arome and Meso-NH (CNRM-GAME)
  - WRF (LEGI and ARA)

New convection scheme « PCMT »

"PCMT": Prognostic Condensates Microphysics and Transport

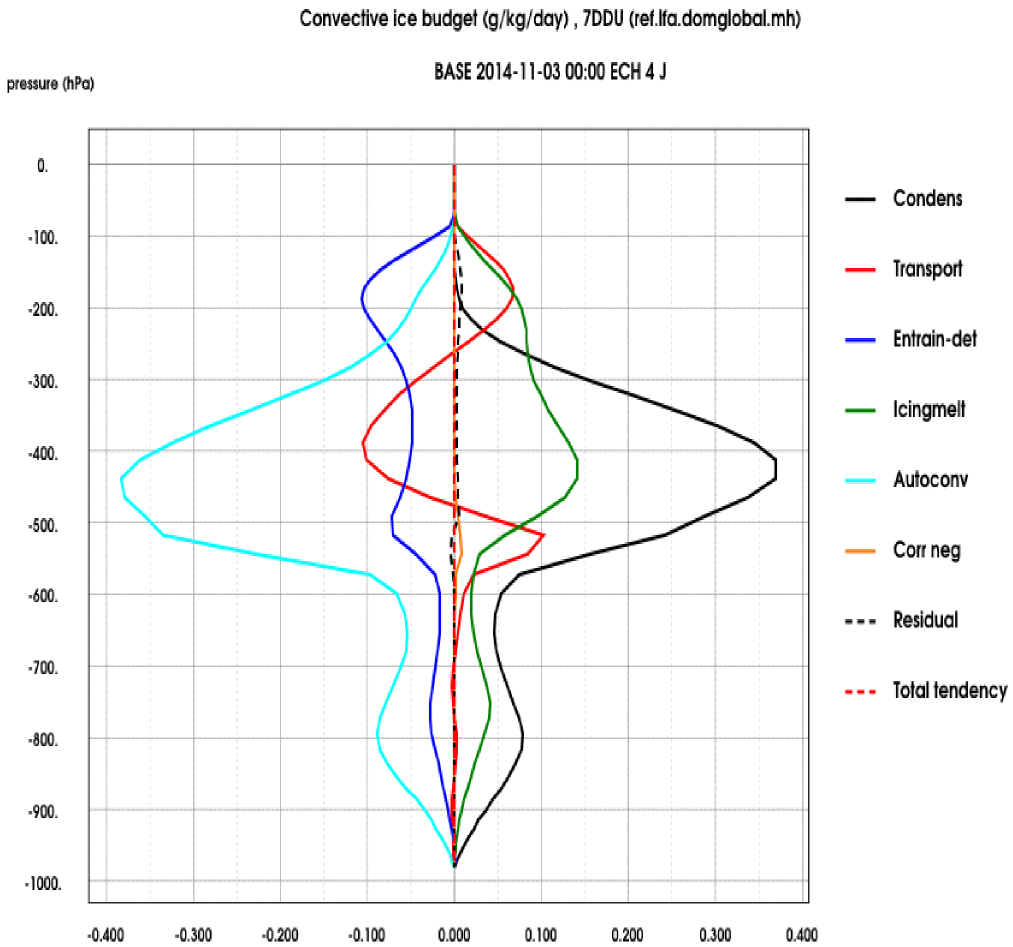
- 5 prognostic equations for convective hydrometeors (cloud droplets, ice crystals, rain, snow) and vertical velocity
- Grid-scale equations from the convection scheme separate microphysical processes and transport processes (Piriou et al., 2007)
- Same microphysics (Lopez, 2002) used for resolved and convective precipitations (called twice)
- Triggering condition, mass flux, entrainment based on buoyancy. CAPE relaxation time for closure (Gueremy, 2011)

Piriou J.-M., J.-L. Redelsperger, J.-F. Geleyn, J.-P. Lafore and F. Guichard, 2007: An approach for convective parameterization with memory, in separating microphysics and transport in grid-scale equations , J. Atmos. Sci., Volume 64, Issue 11, pp. 4127–4139

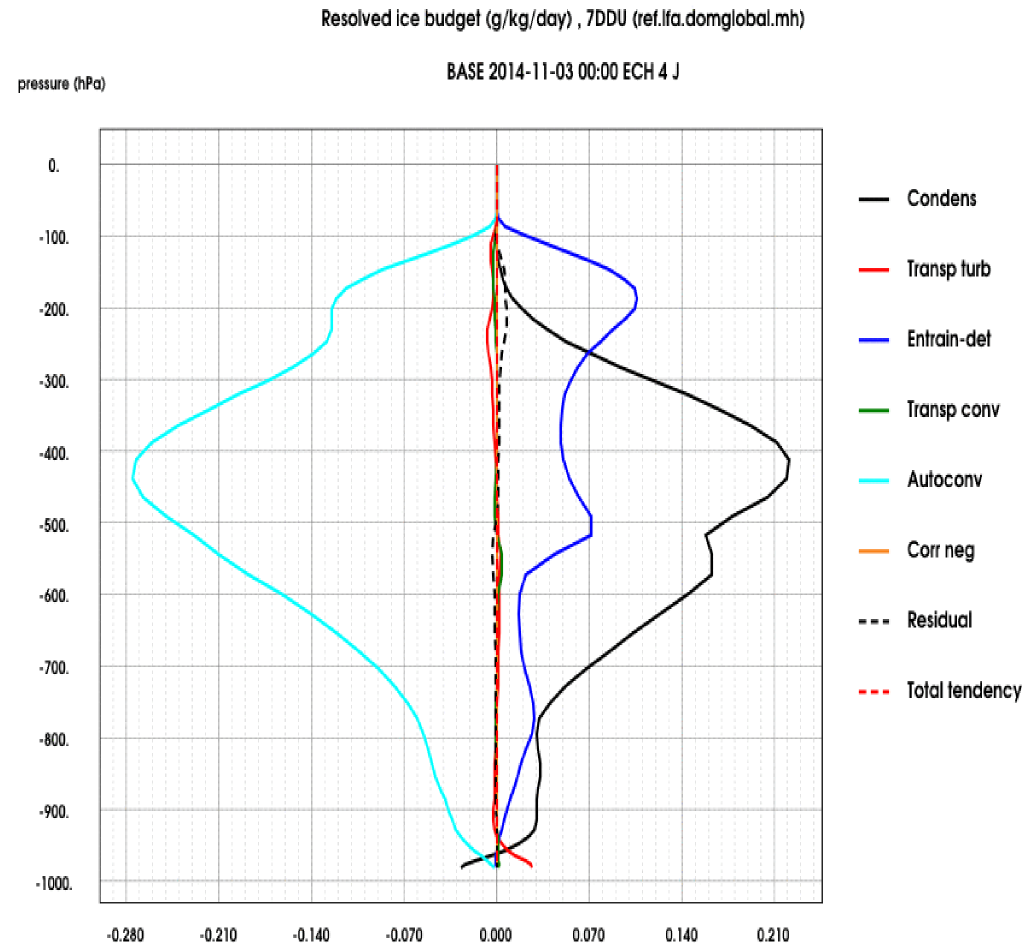
Gueremy, J. F., 2011: A continuous buoyancy based convection scheme: one- and three-dimensional validation. Tellus A, 63: 687–706.

« PCMT »: Global budgets for convective and environmental ice crystals

Convective ice CI



Environmental ice QI

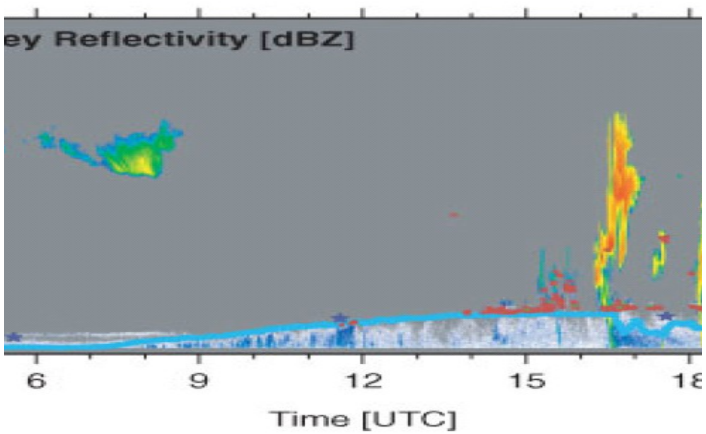


ARPEGE 4 days range prediction, horizontal mean budget

« PCMT » : 1D model evaluation

Evaluation of several 1D cases: ARM, BOMEX, EUROCS, LBA, AMMA, ...

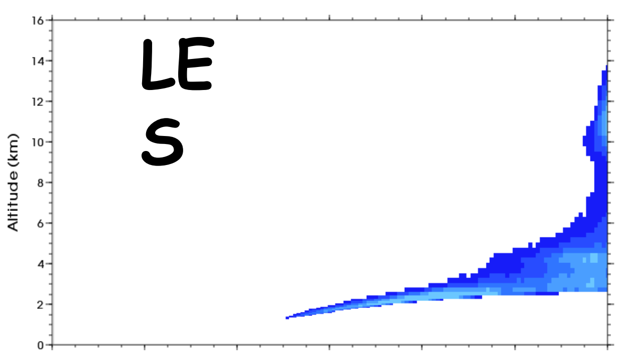
EMBRACE FP7 project : Diurnal cycle of convection over the Sahel derived from the AMMA campaign (10th of July 2006 over Niamey)

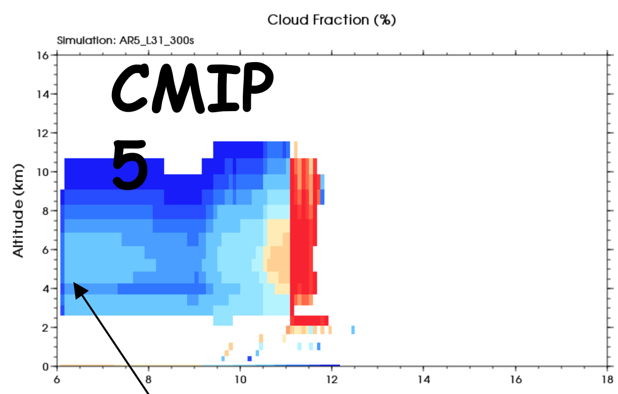


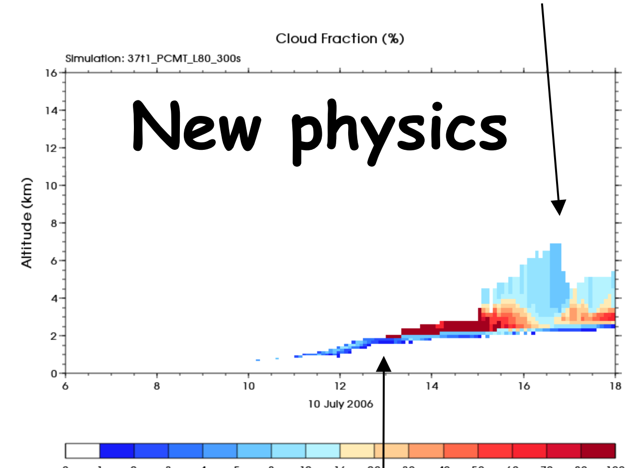
- Well documented case: Lothon et al. 2012
- Convection in a semi-arid environment
- Transition between shallow and deep convection
- Deep convection starts around 16h30

Deep convection underestimated

Cloud fraction







LES simulations
Couvreux et al. 2012

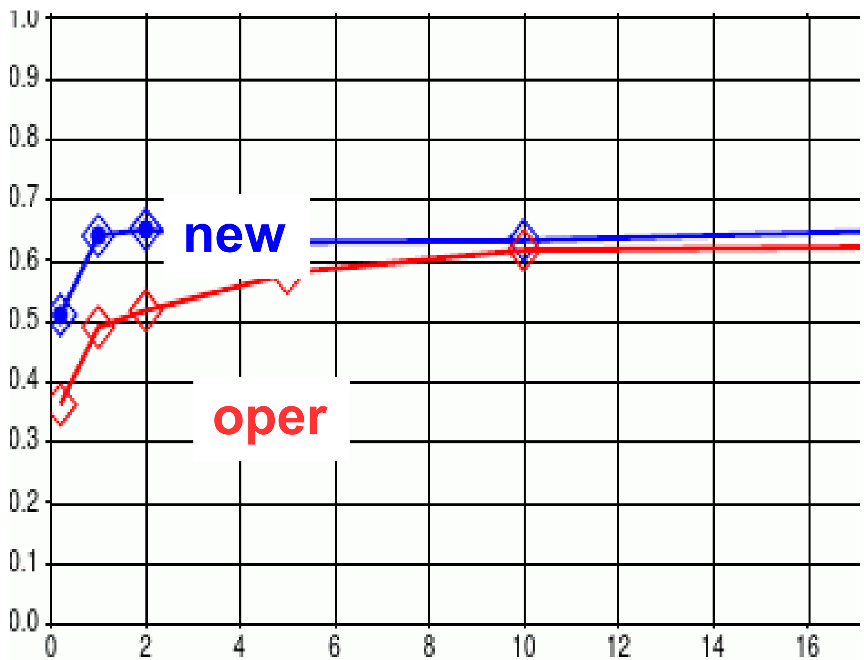
Triggering from the start of the simulation

Better representation of BL and shallow convection development

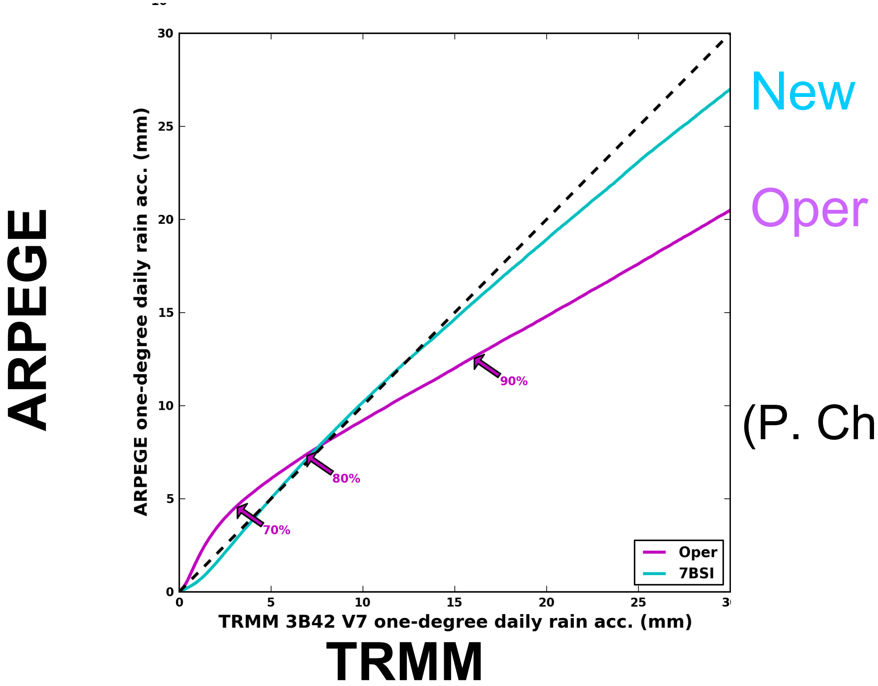
« PCMT »: NWP evaluation

Evaluation based on global forecasts starting from operational analysis and with full assimilation (4DVar and EDA)

24h Precipitation score against rain-gauges over France:
BSS score (50km tolerance)
July-August 2013



Forecast versus observed 24h precipitation distributions comparison
(intertropical zone ; 1° by 1° ;
TRMM 3B42 V7 ; July/August 2013)



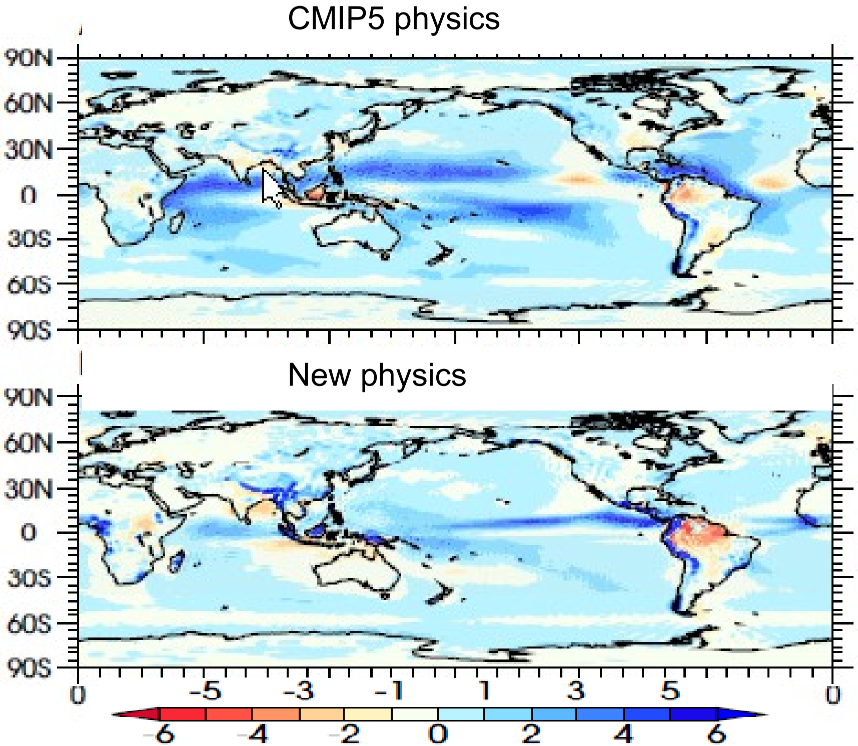
(P. Chambon)

"PCMT": Climat evaluation

Wide range of configurations (regional/global, nudging/forced/coupled) and diagnostics :

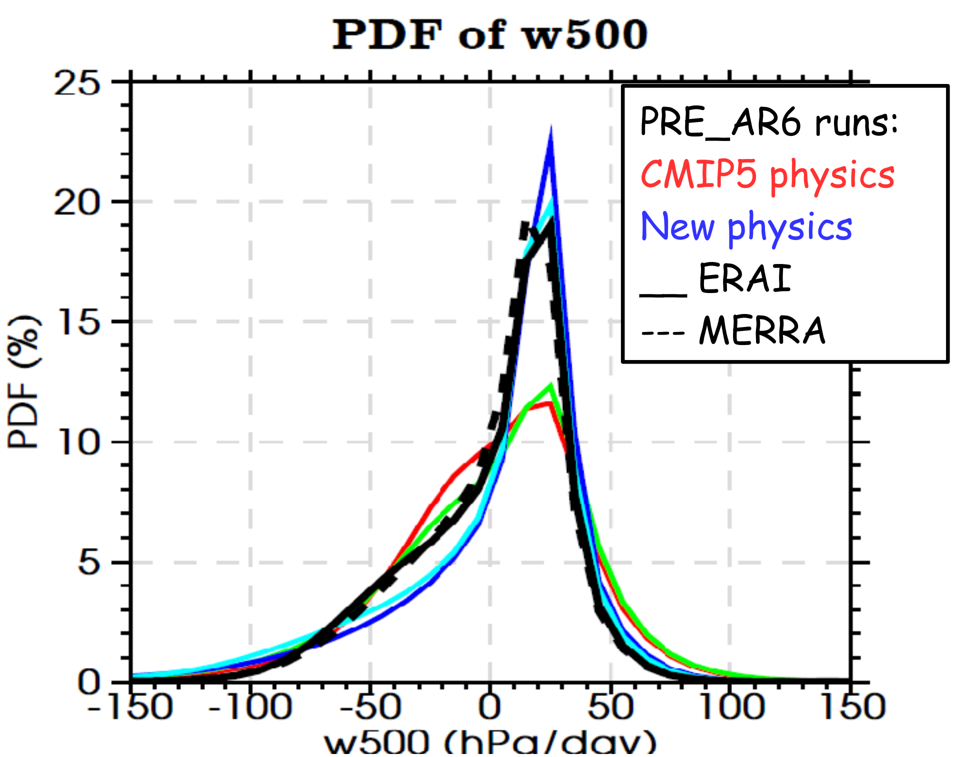
T127 AMIP simulations [1979-2012]

Annual precipitation biases vs GPCP



- Partially reduced double ITCZ
- Overestimation of convective RR (East Pacific,Himalaya, ...)
- Underestimation over Amazonia

Circulation over tropical oceans [30°S-30°N]



- Improvement of dynamical regimes
- Overestimation of strong ascendant regimes
- Underestimation of weak ascendant regimes

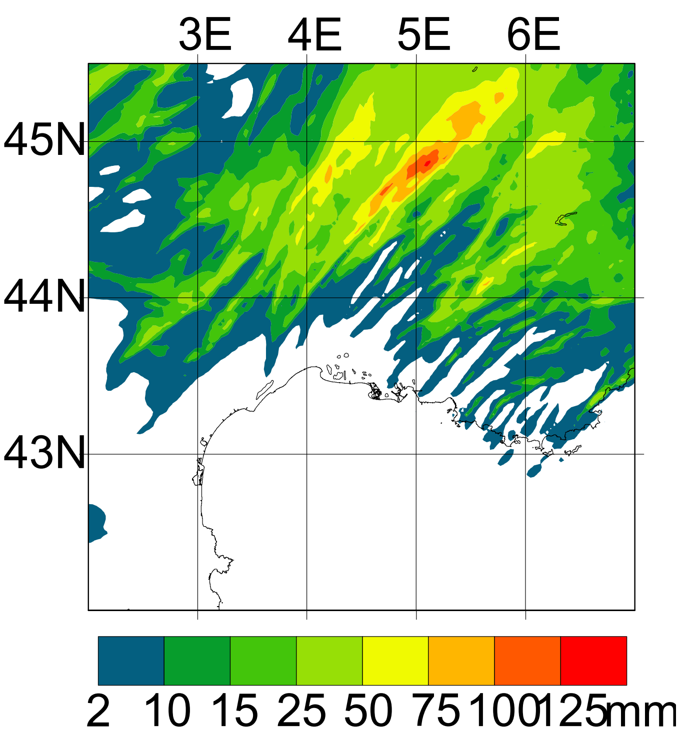
Microphysics developments

- Making microphysical tendencies independent from the time step

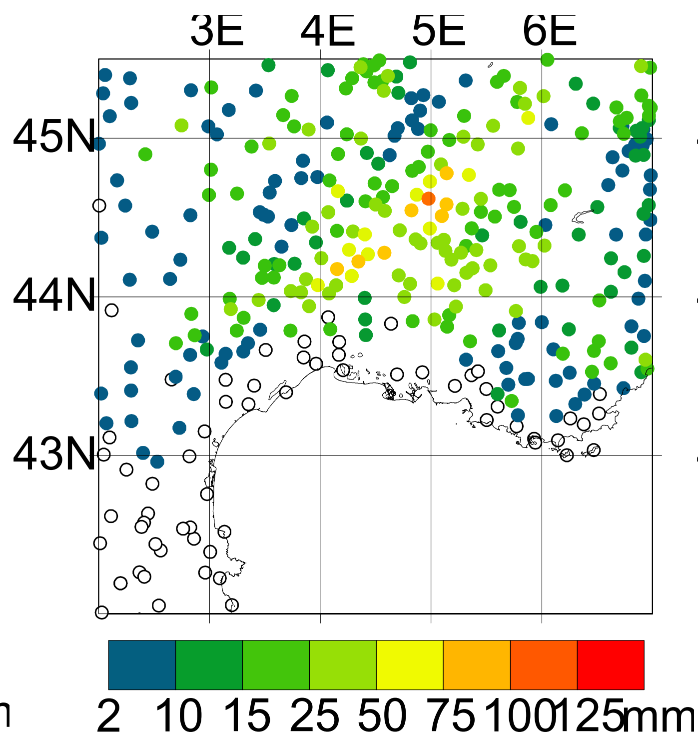
- LIMA: a 2-moment, mixed-phase microphysical scheme
  - Prognostic evolution of a realistic aerosol population
    - Multimodal (lognormal size distributions), 3D externally mixed aerosols
    - Distinction between several types of CCN / IFN / coated IFN
  - Explicit interactions between aerosols, clouds and precipitations
    - CCN activation extended from Cohard and Pinty 2000 -> cloud droplets
    - IFN nucleation following Phillips (2008,2013) -> ice crystals
    - Impaction scavenging of aerosols by rain
  - MACC (ECMWF) aerosol analyses provide initial and LB conditions

LIMA & MACC : a Hymex case study

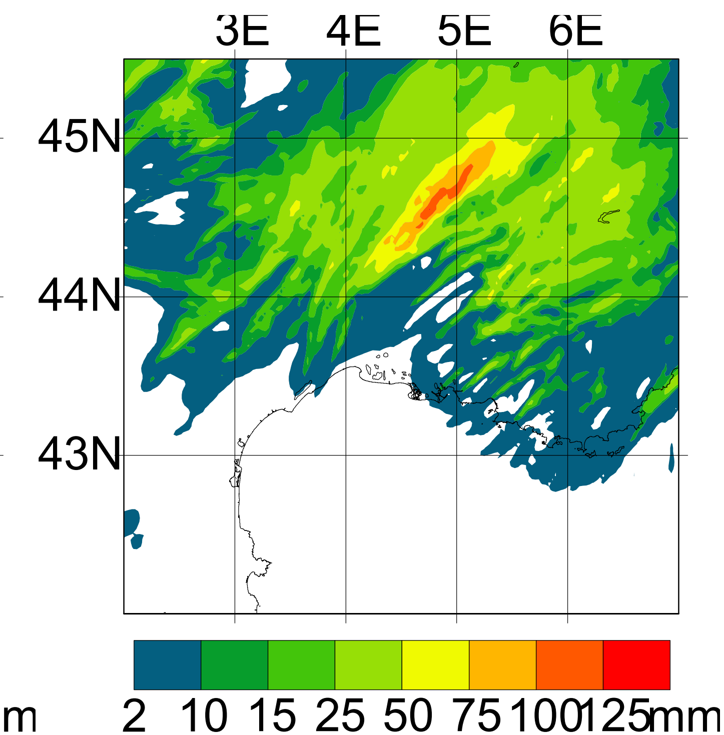
Southeastern France, 12-h accumulated precipitation (mm), 2012/09/24, 12 UTC



Default aerosol population



Raingauge observations



MACC aerosols

High density radar assimilation in the AROME model at 1.3 km of horizontal resolution

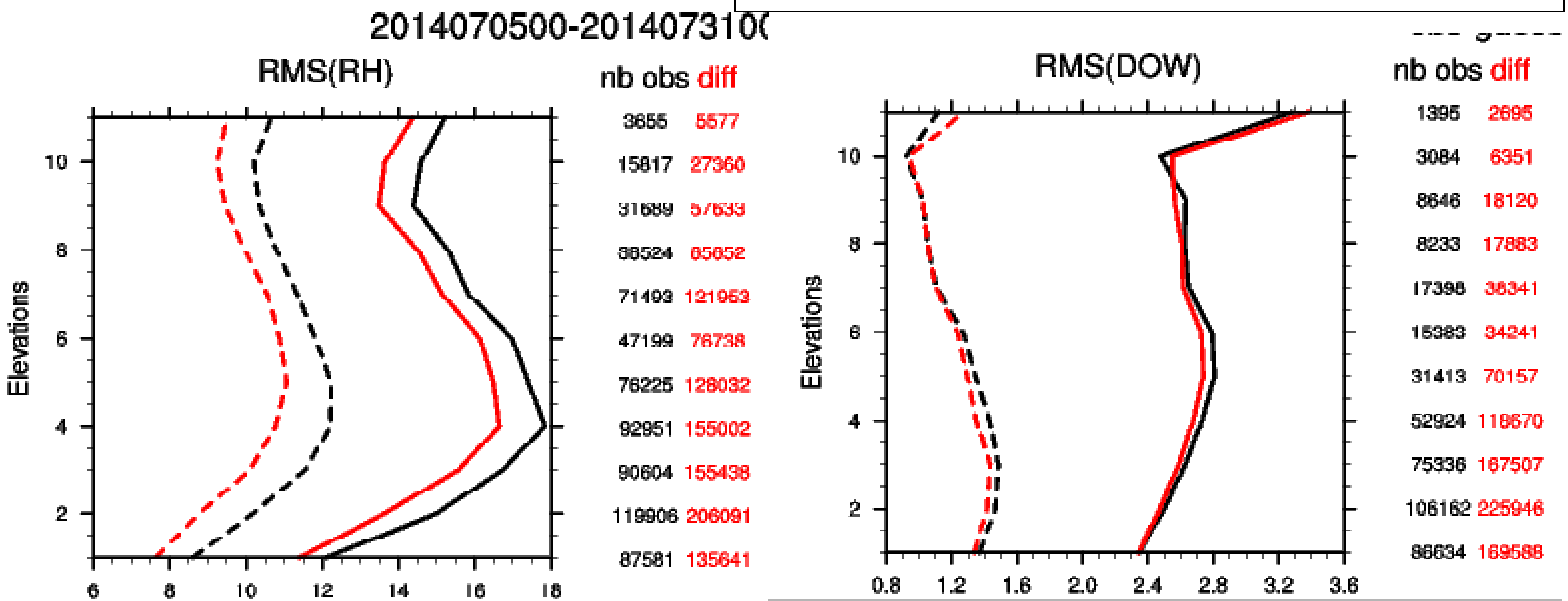
- - - obs-analysis Dble

___ obs-guess Dble

- - - obs-analysis « 8 km »

___ obs-guess « 8 km »

« 15 km » (black=double e-suite of AROME) against « 8 km » (red)

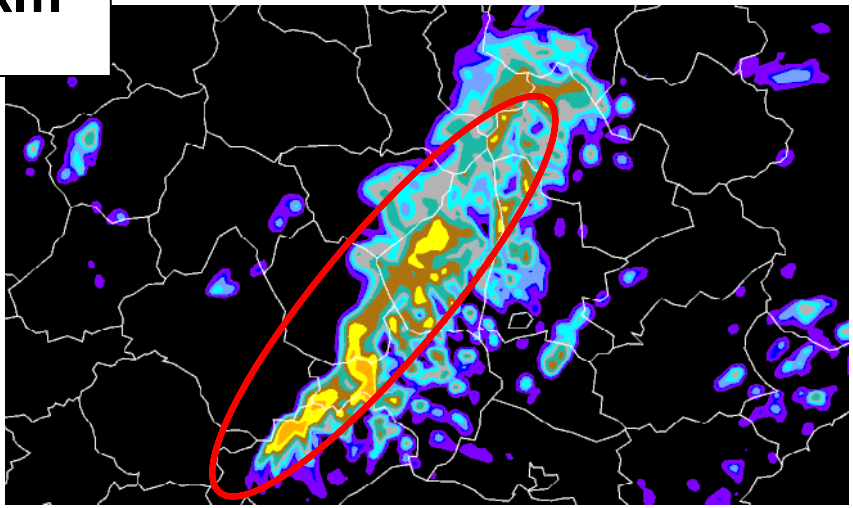


- Improvement of the fit of the analysis and also the 1-hour background to the radar observations (RMS calculated over 4 weeks in Summer 2014).
- More visible on the RMS of the relative humidity than the one of Radial Doppler winds

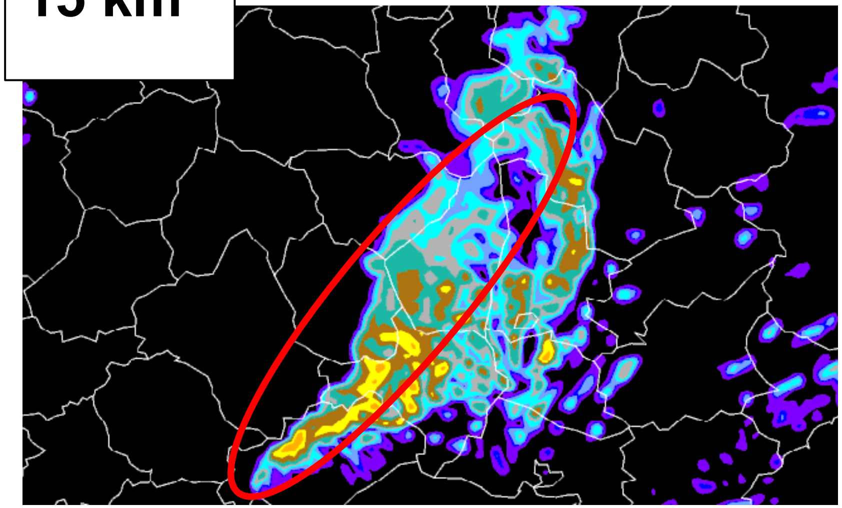
High density radar assimilation in the AROME model at 1.3km of horizontal resolution

Example of a « good case »: 9h - Arome forecast valid for the 2014/09/19 at 09 TU: reflectivity field at 700 hpa for both Arome model images (top)

8 km



15 km



Radar Composite