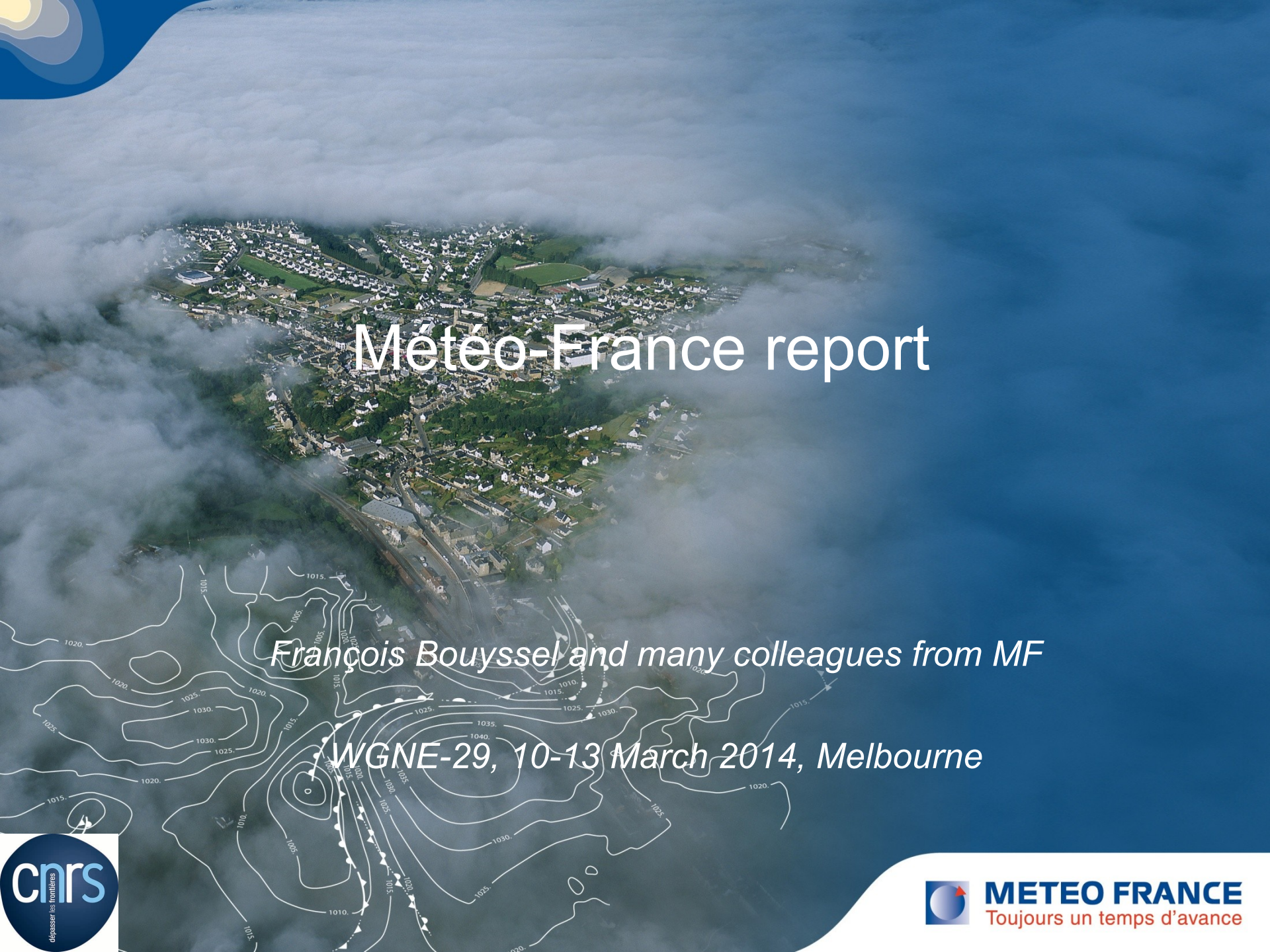


Météo-France report

François Bouyssel and many colleagues from MF

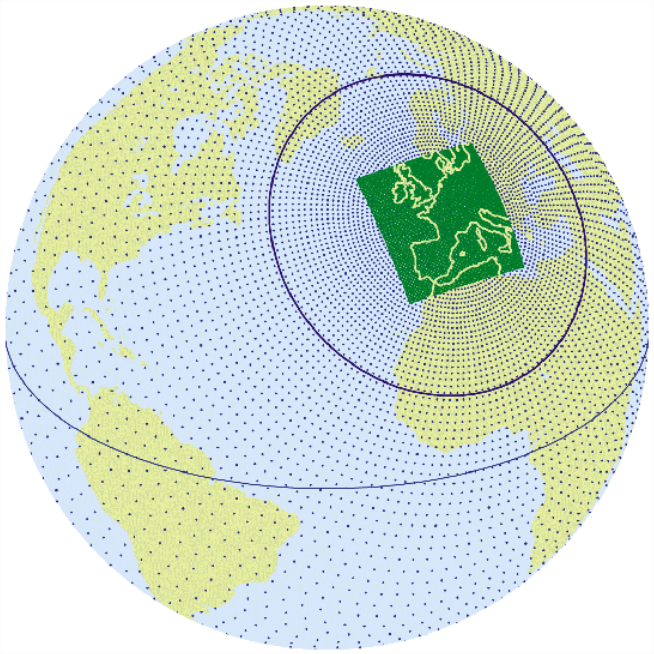
WGNE-29, 10-13 March 2014, Melbourne

cnrs
dépasser les frontières

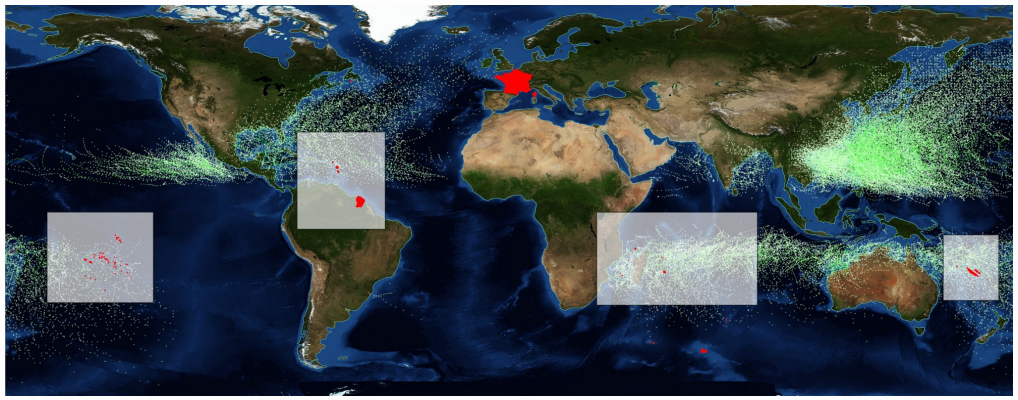
METEO FRANCE
Toujours un temps d'avance

Operational NWP systems and recent changes

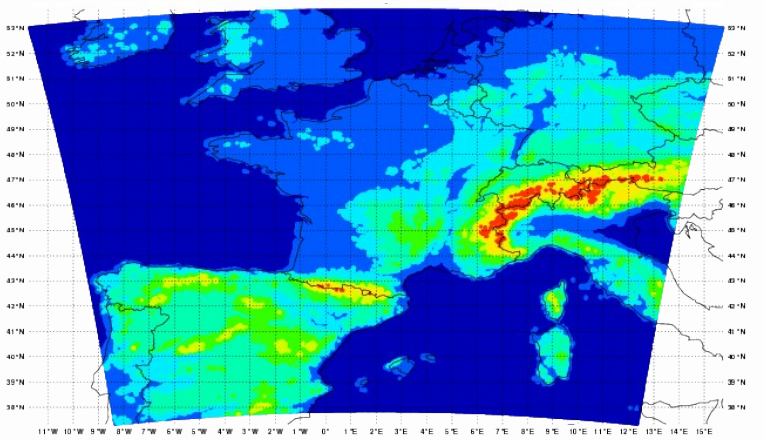
NWP deterministic systems with assimilation



Global ARPEGE : T798c2.4L70
~4-days forecasts every 6 hours
dx~10km over France, ~60km over antipodes,
dt~9mn, 70 vertical levels
4DVar incremental Data Assimilation
Low resolutions : T107c1L70 (~180km)
and T323c1L70 (~60km)



LAM ALADIN Overseas : ~3-days forecasts, dx~8km,
70 vertical levels, dt=450s - *3DVar Data Assimilation*

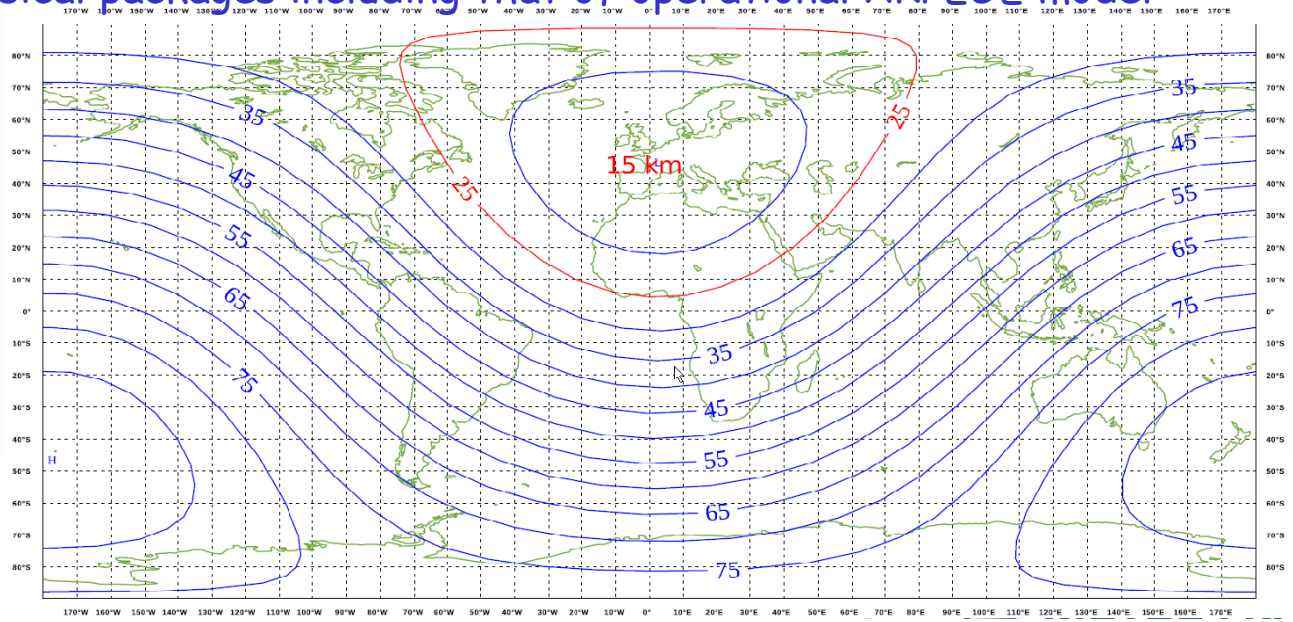


LAM Cloud Resolving Model AROME
30 h forecasts every 6h
dx=2.5km, 60 vertical levels, dt=1mn
3DVar Data Assimilation (RUC3h)

4DVar EDA (AEARP) and global EPS (PEARP)

AEARP: Oper since July 2008 : 6 perturbed global members, T399 L70 with 4D-Var Arpege (explicit obs perturbations, implicit background perturbations through perturbed DA cycling).
Flow-dependent background error variances for obs. quality control and for minimizations
Model error contributions by on-line inflation of perturbations in 2012

PEARP: 35 members including the control member
Running at : 06UTC (72h range) and 18UTC (108h range)
Forecasts resolution : T538C2.4L65 (~15km over France, 90km on antipodes)
Using the 6 background states and the mean from AEARP since 2009 (Berre & Desroziers)
Singular vectors computed over 7 areas (rescaled by σ_b): resolution Tl95, norm: TE or KE
Using 10 physical packages including that of operational ARPEGE model



CY38T1 E-suite: ARPEGE

Observations:

- satellite data from new instruments : Suomi-NPP/ATMS + CriS radiances, Oceansat-2/OSCAT winds, METOP-B instruments (IASI, AMSU-A, MHS, GRAS, ASCAT)

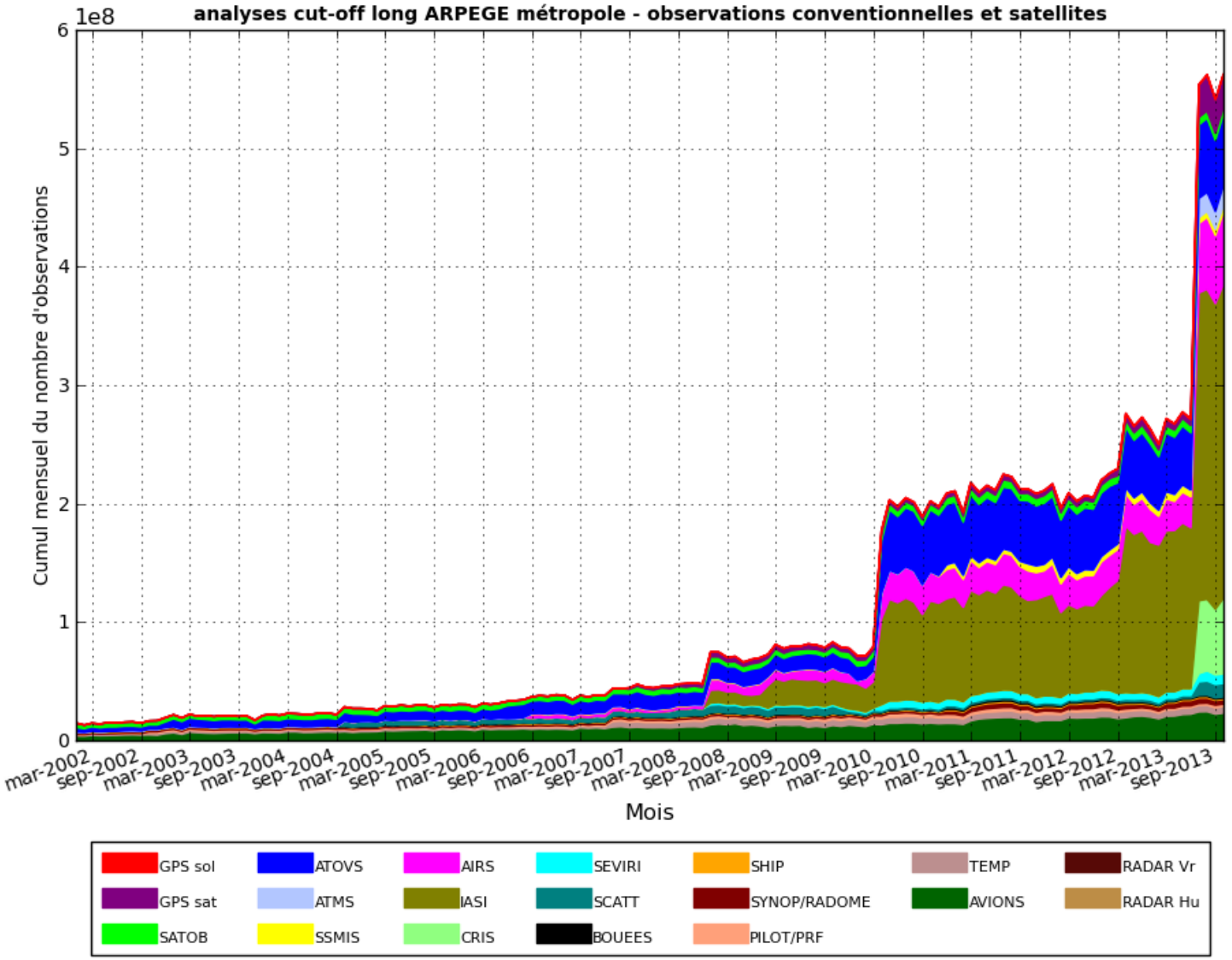
-increased usage of existing instruments : METOP-A (GRAS, IASI WV channels, MHS), Aqua/AIRS (over land+additional upper tropospheric channels), GNSS-RO (reduced vertical thinning), SSMI/S sounding channels, CSR from GOES-13 and GOES-14

4DVar: Wavelet approach for a flow dependent B matrix from an ensemble data assimilation ensemble

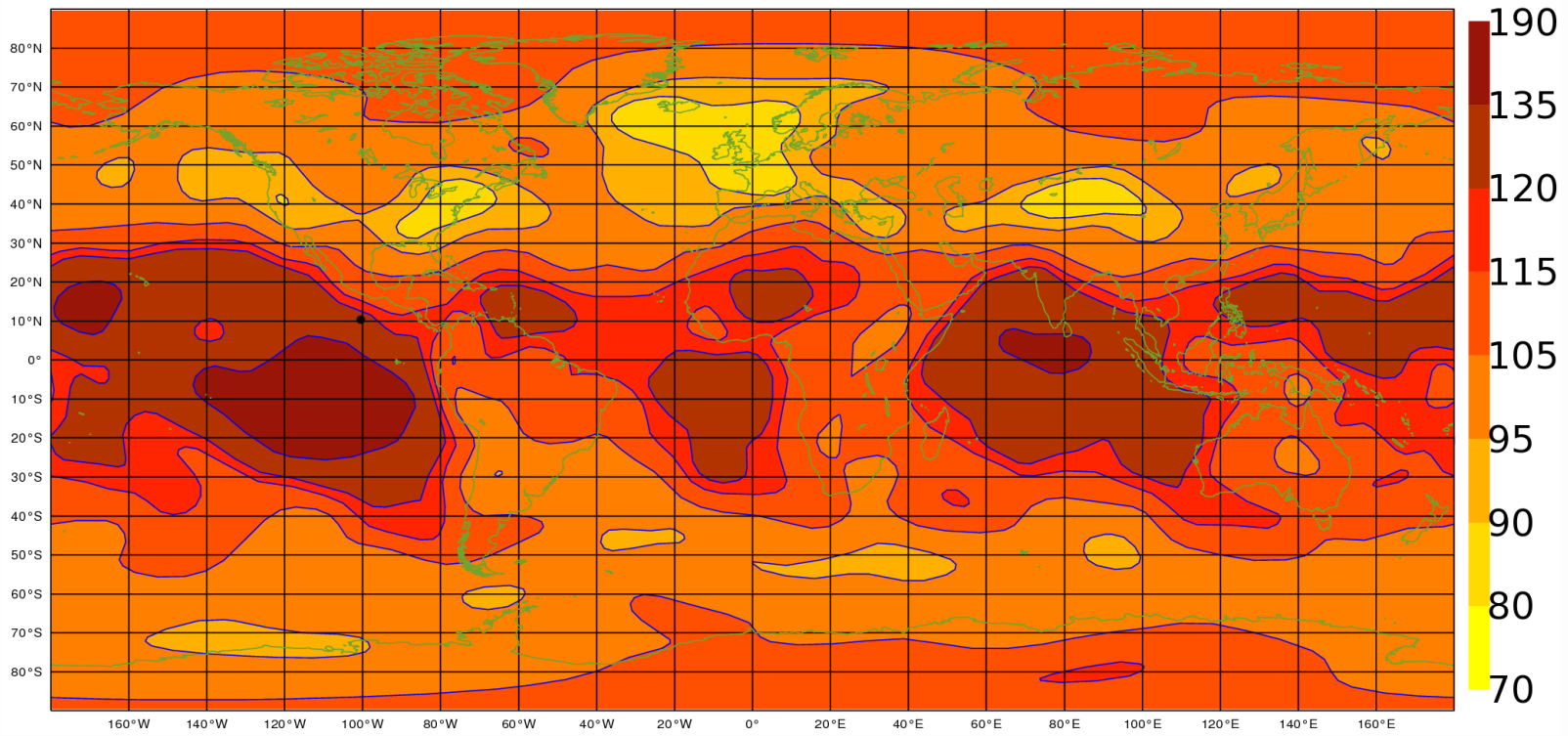
Physics: changes to the shallow convection scheme, improved description of surface properties over ice caps (thermal inertia, albedo, roughness length)

Switch to operations on July 2, 2013

Evolution des cumuls mensuels de nombre d'observations utilisées par type d'observation



Wavelets in Arpège Bg Err Cov Matrix: horizontal lengthscales for wind at 500 hPa



Horizontal length scale (in km), for wind at 500 hPa:

mean on 4 days : 6 members x 4 networks x 4 days = 96 realizations

(Old operational horizontal length scales = 100 km uniform)

(Varella et al, 2012)

CY38T1 E-suite: LAMs

Aladin-Overseas:

✓ Same additional observations as in ARPEGE

✓ New clim data for sand & clay (HWSD) and for orography (GMTED2010)

Arome-France:

✓ Same additional observations as in ARPEGE

✓ Denser thinning of AMSU-A (80km) and SSMI/S (139km);

✓ Doppler winds from one X-band radar are assimilated (Mont-Maurel, Var);

✓more SEVIRI radiances over land, using climatological maps of surface emissivity and retrieval of Ts (Karbou et al. Method based on solving the RT equation at the surface for one surface-sensitive SEVIRI channel)

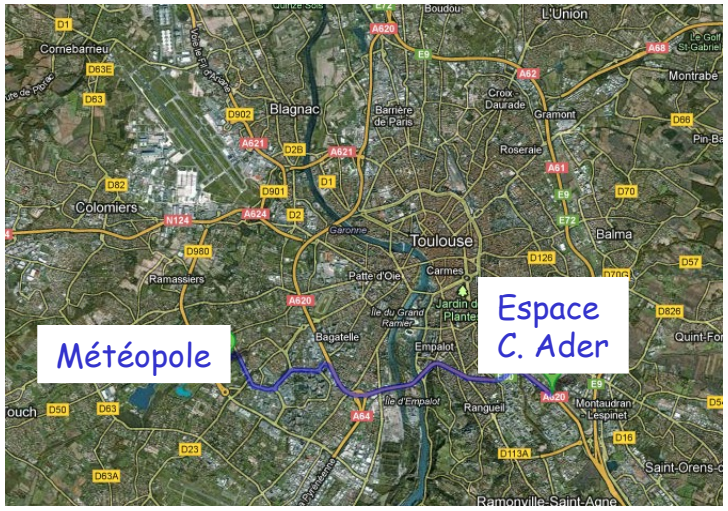
Switch to operations on July 2, 2013

New HPC at MF

Migration from NEC SX9 to BULL (bullx DLC)
Operational suite on new computer since 14th January 2014
Two clusters (second cluster currently in verification phase)

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

Operations
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



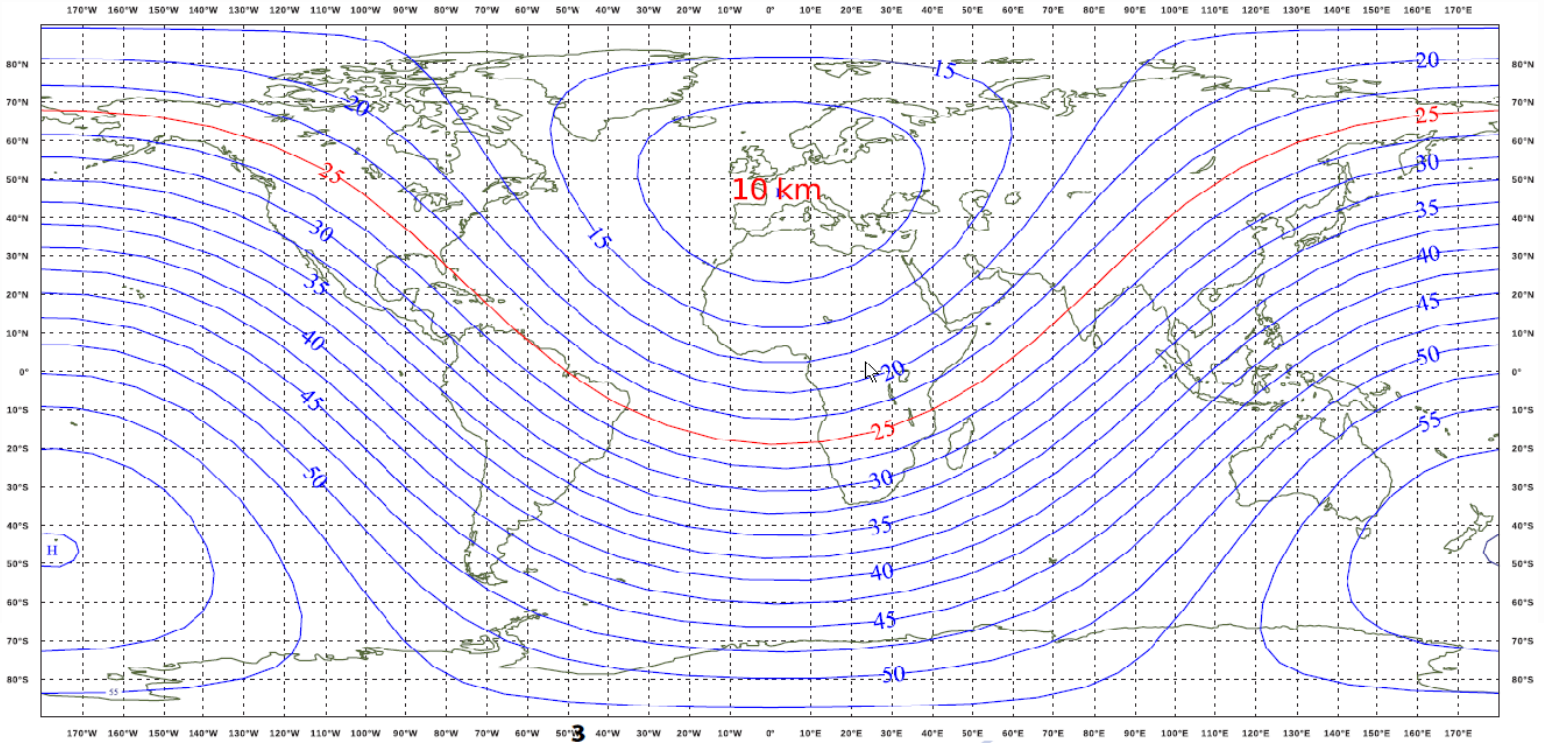
Preparation of resolution upgrades for global and local models

Future versions of 4DVar EDA (AEARP) and global EPS (PEARP)

AEARP: ~25 perturbed global members, ~T479 L105 with 4D-Var Arpege

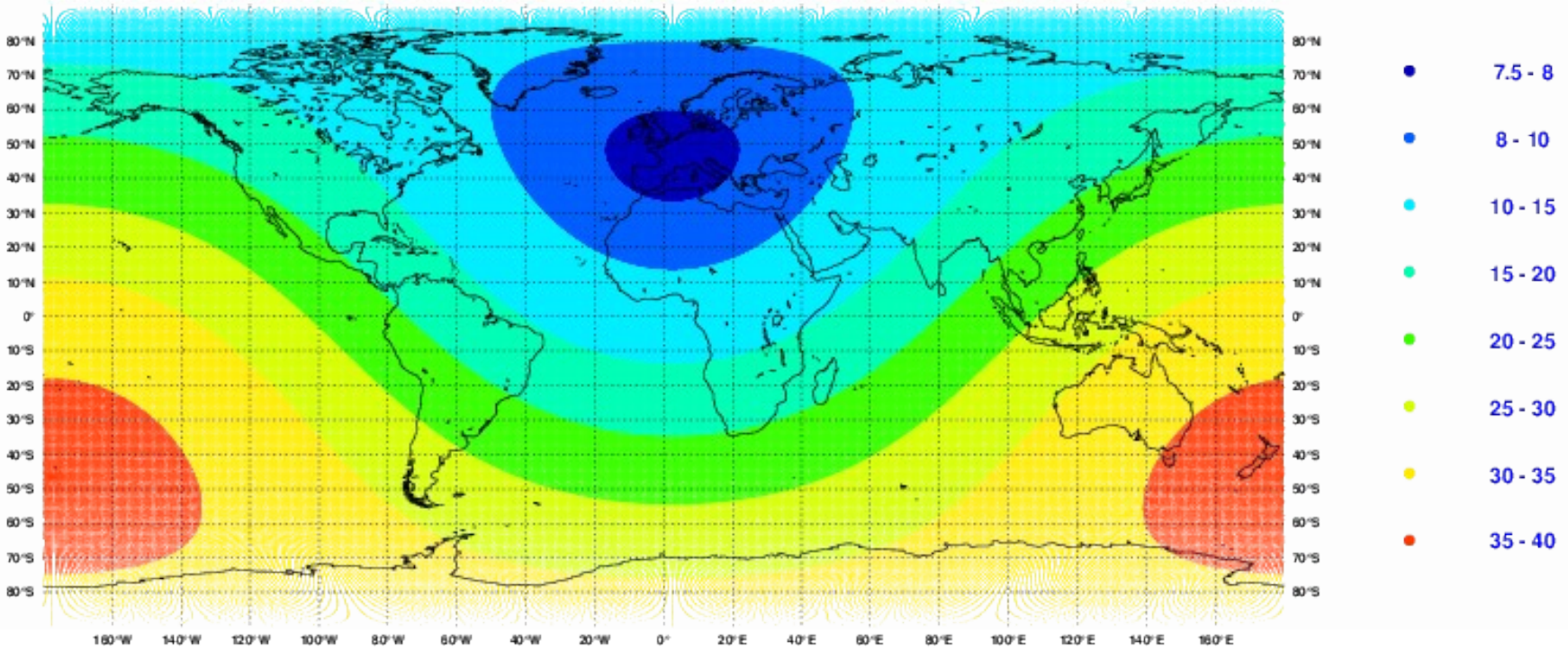
Background error covariance averaged on 1.5 days.

PEARP: ~35 members including the control member
Forecasts resolution : ~T798C2.4L72 (~10km over France, 60km over antipodes)
Using the ~25 background states and the mean from AEARP (Berre & Desroziers)
Singular vectors computed over 7 areas (rescaled by σ_b): resolution Tl95, norm: TE or KE
Using a new set of 10 physical packages including that of operational ARPEGE model



Arpege HR: new resolutions

New horizontal resolution Tl1198 with stretching factor 2.2
(~7.5km over France, ~36km over antipodes)
From 70 to 105 vertical levels. Highest model level unchanged (0.1hPa).
Lowest model level changed from 17m to 10m.



Arome's thermal scheme in Arpege

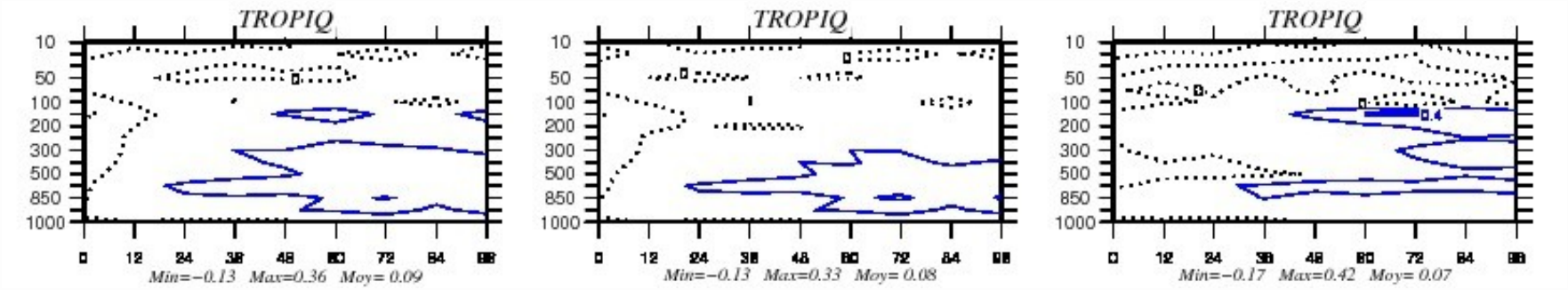
Motivations of evaluating "Pergaud et al, 2009" scheme in Arpege :

Improve representation of thermals (dry thermals, closure, momentum mixing)

Extend validation of the scheme on the globe

Convergence of PBL schemes with Arome (seamless prediction)

Improvement of wind in the tropical area



New convection scheme PCMT

Developed for Arpege NWP and Climat

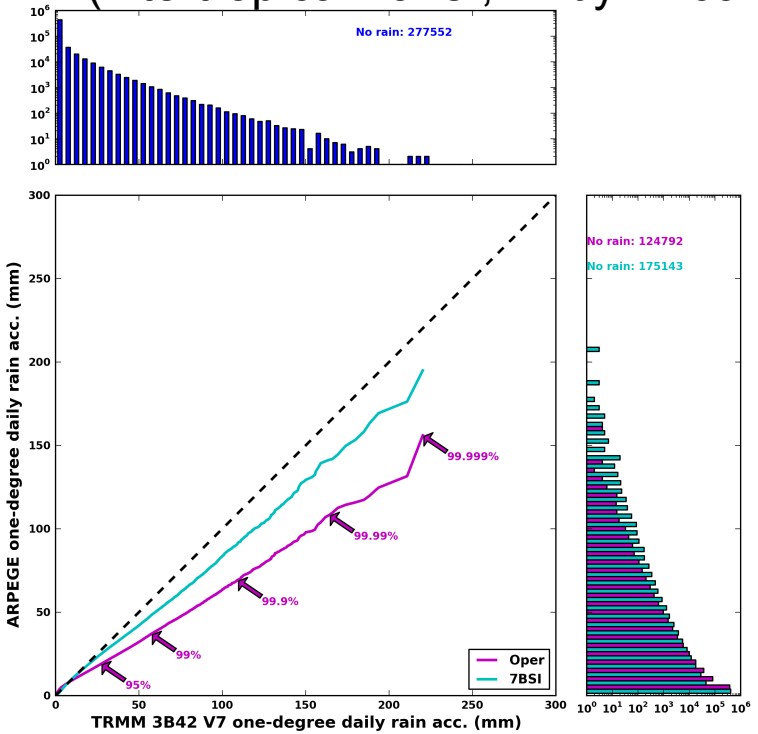
Based on (Piriou 2007) and (Guérémy 2011)

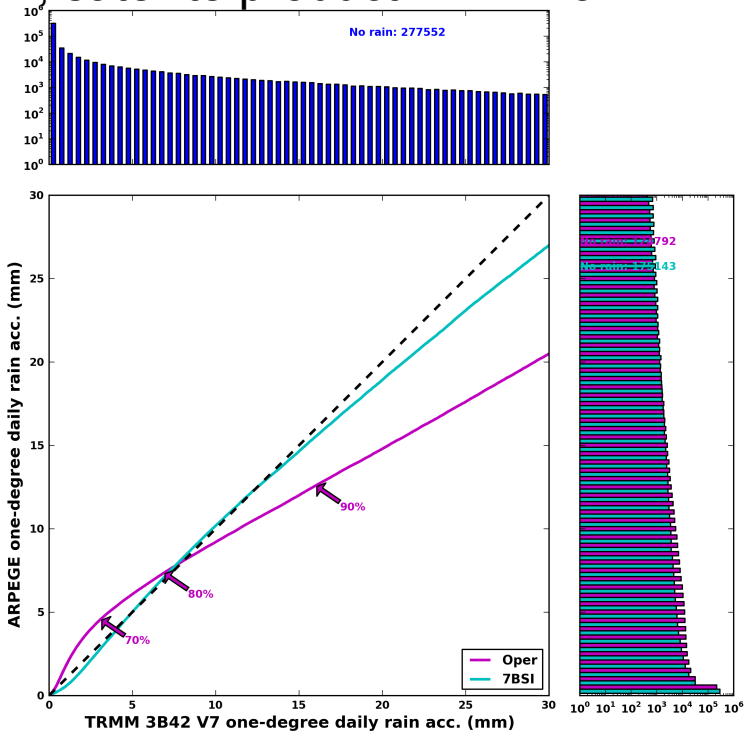
Prognostic equations for convective condensates (ql, qi, qr, qs), vertical velocity (w)

Same microphysics used for resolved and convective precipitations

Updraft mesh fraction, entrainment/detrainment function of saturation deficit

Forecast versus observed 24h accumulated precipitation distributions comparison (intertropical zone ; 1° by 1° comparison ; satellite product TRMM 3B42 V7)





AROME system: new resolutions

Small extension northwards of the geographical domain

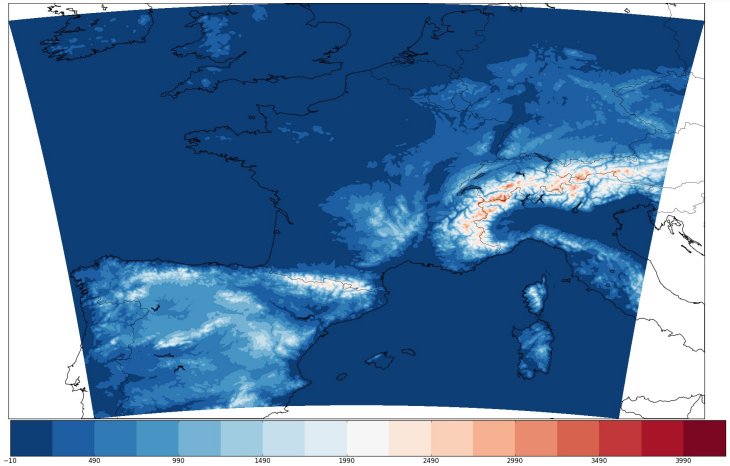
New horizontal resolution: from 2.5km to 1.3km

New vertical resolution: from 60 to 90 vertical levels :

Highest model level fixed at 10hPa

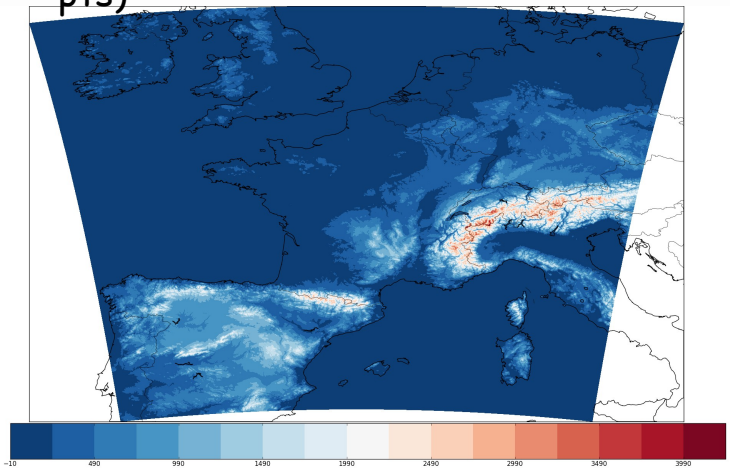
Lwest model level fixed at 5m

AROME 2.5km (750x720 pts)



GTOP030 database at 1 km

AROME 1.3km (1536x1440 pts)



GMTED2010 database at 250m

AROME 1.3km: objective scores

Scores computed on summer 2012 and winter 2012-2013 (Y.Seity, LAuger)

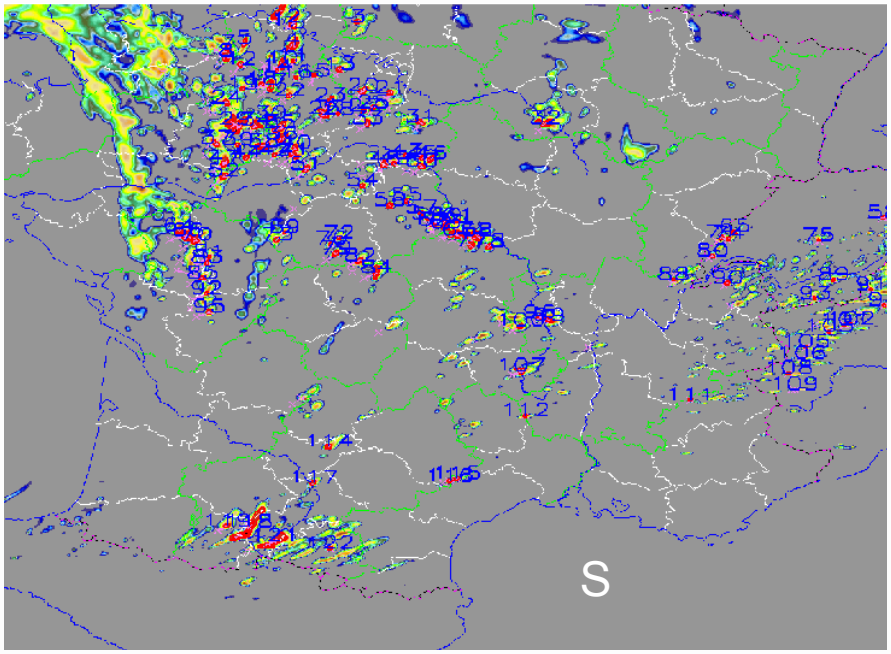
	Scores (Bias, RMS)			Brier skill scores (Amodei and Stein, 2008)			
Parameters	T2m	H2m	V10m	RR24	RR6	Gust1h	TB
Vertical resolution	-	-	+	=	-	=	=
Horizontal resolution	-	-	+	+	+	+	+
Both	-	-	+	+	+	+	+

⇒ More benefits of increasing horizontal resolution than vertical one

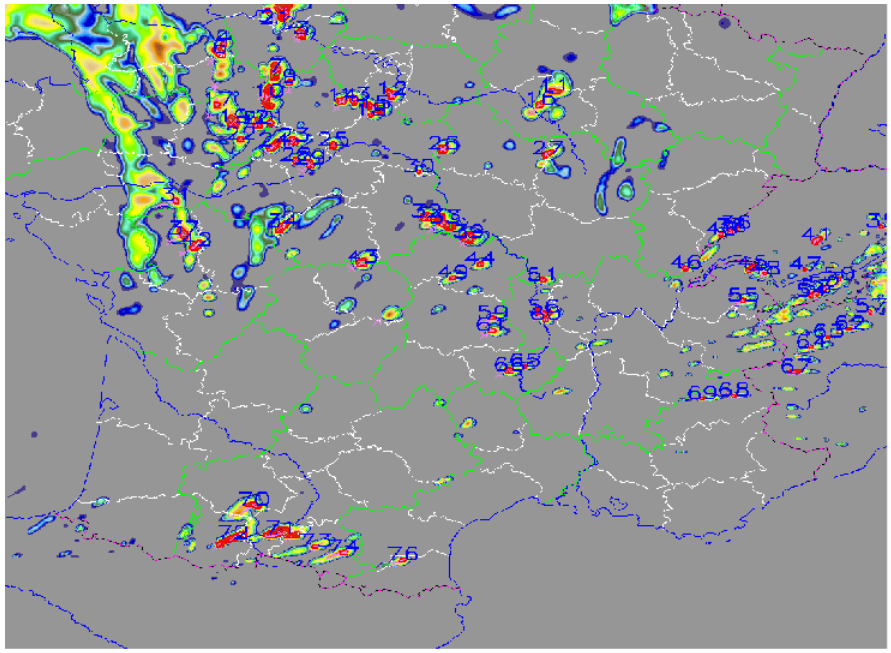
Automatic detection of convective cells

NWC SAF "RDT" software (Morel et al., 2002) to detect convective cells based on simulated reflectivity. Threshold used at 41 dBz.

Simulated radar reflectivity at 1500m on 21 June 2012 at 12TU



1.3km : 122 convective cells > 41dBZ

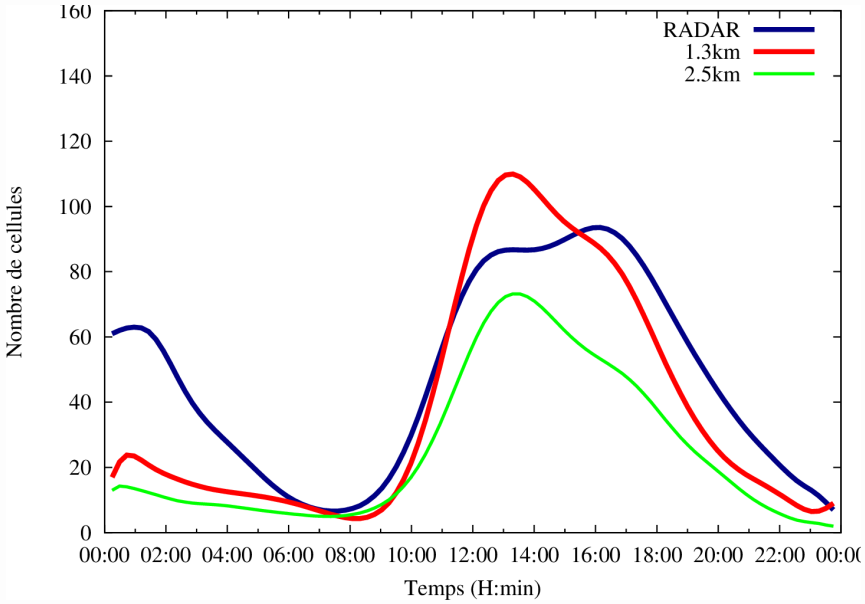


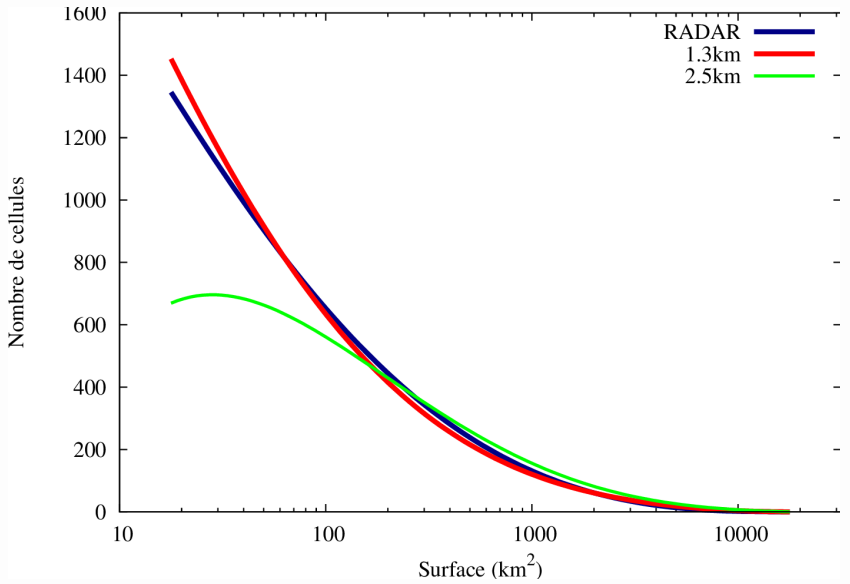
2.5km : 76 convective cells > 41dBZ

(J. Léger, D. Ricard, Y. Seity)

Automatic detection of convective cells

21 June 2012 : 41dBz





1.3 km: nb of small convective cells increased and nb of big cells decreased

1.3 km: closer to observed radar reflectivity

Strong impact of semi-lagrangian horizontal diffusion (not shown)

Small impact of spectral diffusion and time-step (not shown)

(J. Léger, D. Ricard, Y. Seity)

Plans in assimilation

Next e-suite:

RTTOV 10 (internal interpolation)

Thinning at higher resolution for satellite obs and radars

Revisit tuning of observation and backgroung error covariances

VarBC for GPS.

New channels (SSMI/S, CrIS)

Assimilation SAPHIR sounder channels on MEGHA-TROPIQUES

Surface and radiosoundings (high resolution) in BUFR format

Activation of Ts inversion over land for IASI and use of cloud detection

Radar data V2 « double polarisation » from CMR (Arome only)

Assimilation des vents du radar en bande X du Mt Colombis (Arome only)

Longer term: 4D EnVar for Arpege and Arome

Preparation of new applications: Arome EPS, Arome for nowcasting

AROME Ensemble Prediction System

AROME EPS is under development (operational in 2015)

AROME-France members running every 6 hours to ~40-h range

~10 members at 2.5km resolution (vs 1.3km for deterministic AROME-France beginning 2015)

Perturbations:

- initial upper-air: rescaled & centered perturbations from global PEARP ensemble (with 8km local resolution)
- initial surface: correlated random perturbations of SST, soil moisture/humidity, snow, physiographies
- lateral boundary conditions: 10 members selected from the 35-member PEARP ensemble (by clustering)
- model error: SPPT (stochastic perturbation of physics tendencies), similar to ECMWF EPS

Current research:

- calibration, verification of radar reflectivities, validation in context of hydrology & air traffic management
- study of forecast error correlations & coupling with EDA

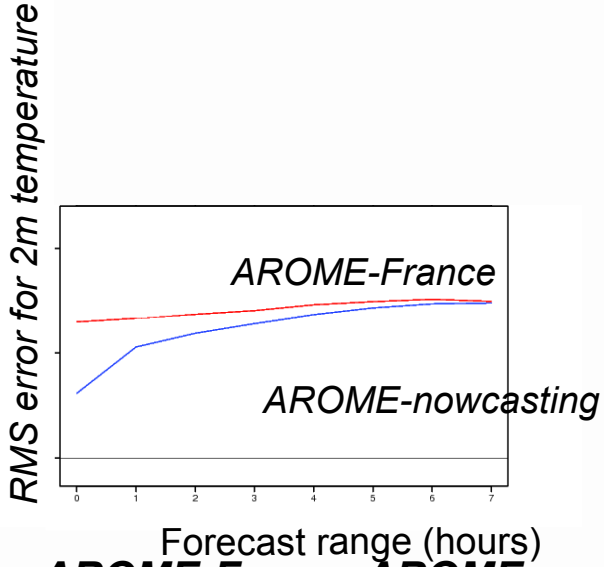
AROME-Nowcasting

AROME-Nowcasting under development (operational in 2015)

AROME 1.3km : 6h forecast every hour based on 3DVar analysis with 15min cut-off

Boundary conditions are re-computed every hour from our AROME-France model.

No cycling so far and no specific surface data assimilation.



Comparaison AROME-France AROME-nowcasting for 2m temperature

The scores are better for most of the parameters.

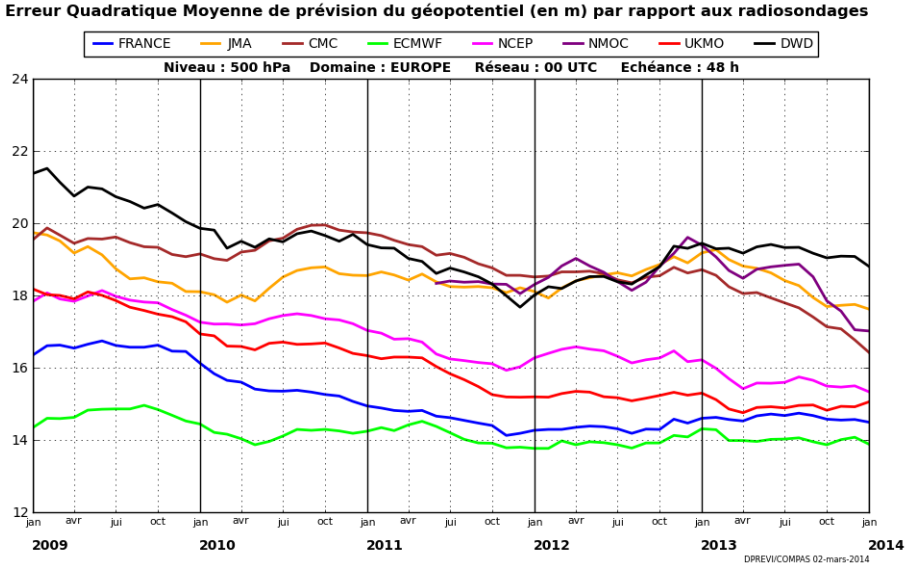
After 3 hours the improvement is weak

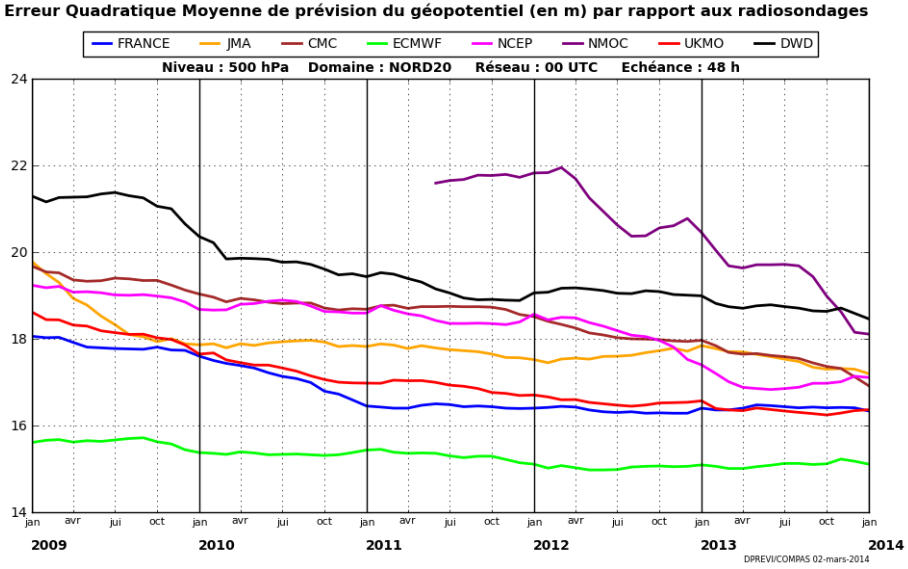
Appendices

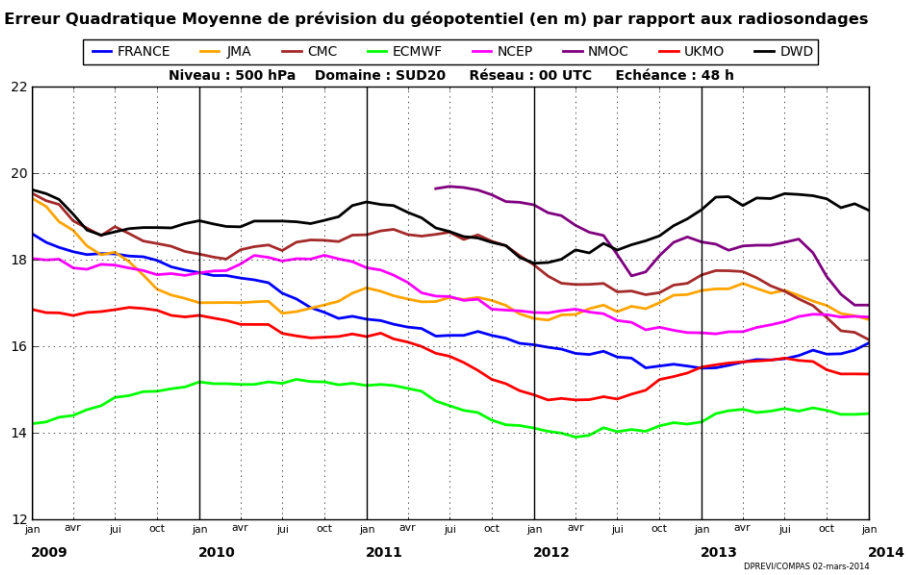
Physical parameterizations

	ARPEGE/ALADIN NWP	AROME NWP
Turbulence	Cuxart et al. (2000) {tke}	
Mixing length	Bougeault-Lacarrère (1989)	
Shallow convection	KFB (Bechtold, 2001)	PMMC09 (Pergaud et al., 2009)
Clouds (PDF)	Smith (1990)	Bougeault (1982)
Microphysics	Lopez (2002) Bouteloup et al (2005) {ql,qi,qr,qs}	ICE3 (Pinty and Jabouille, 1998) {ql,qi,qr,qs,qg}
Deep convection	Bougeault (85) / Gerard (99)	
GWD	Catry-Geleyn (2008)	
Radiation	RRTM for LW (Mlawer et al. 1997) and Morcrette et al. 2001 for SW (6b)	
Surface	ISBA 2L, ECUME	SURFEX (ISBA 3L, TEB, ECUME)

Scores ARPEGE

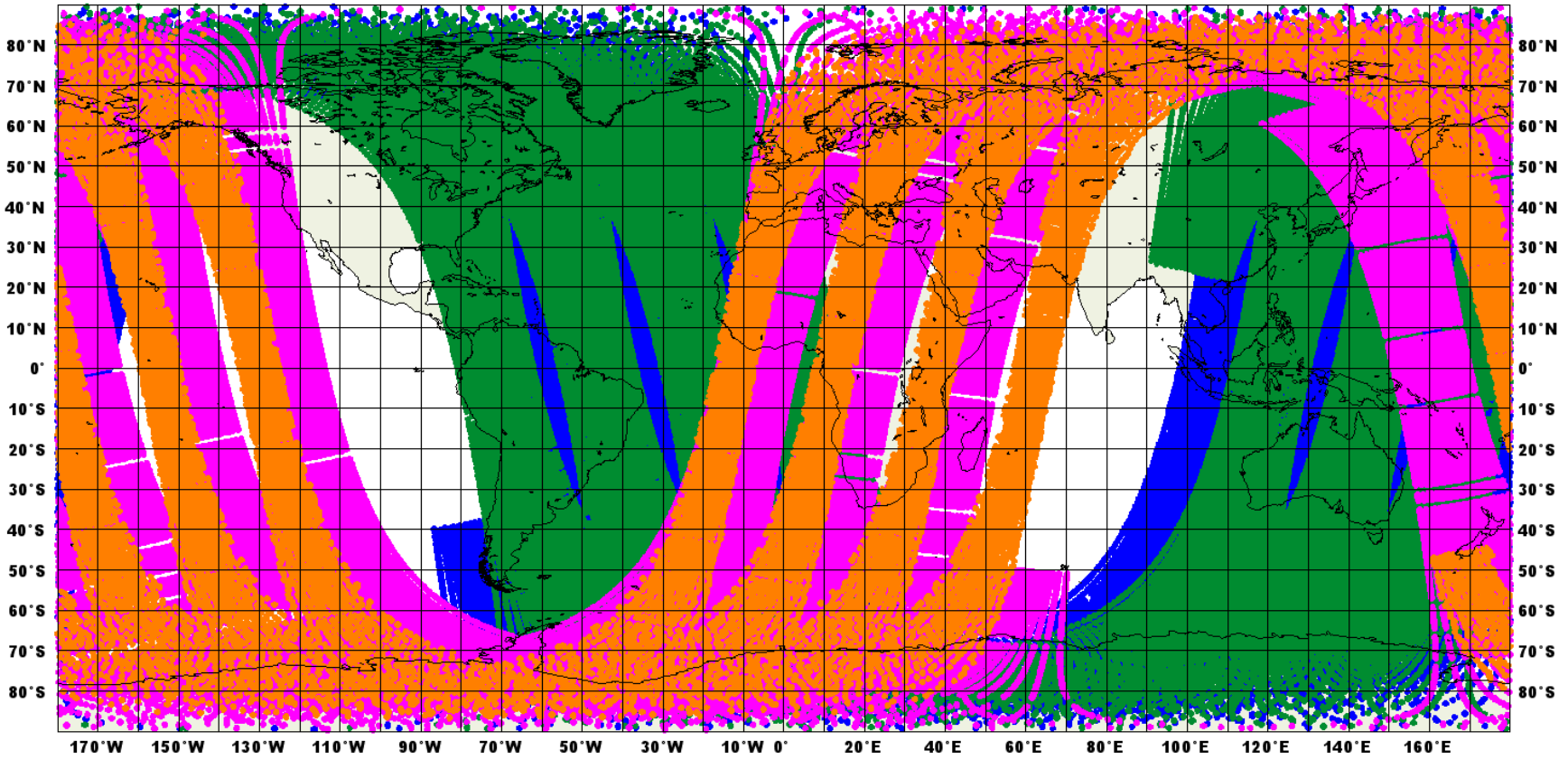






Coverage of IR hyper-spectral sounders

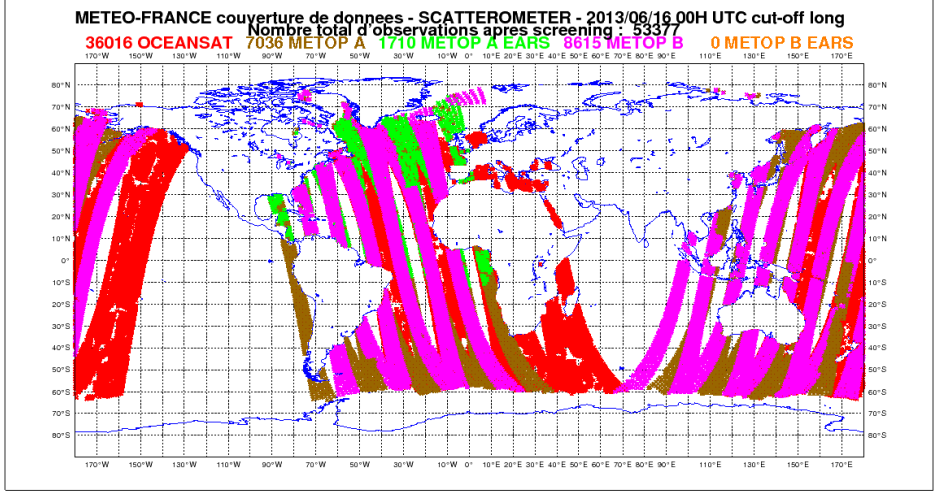
MetOp-A/IASI (green), MetOp-B/IASI (blue), AIRS (orange), CrIS (pink)



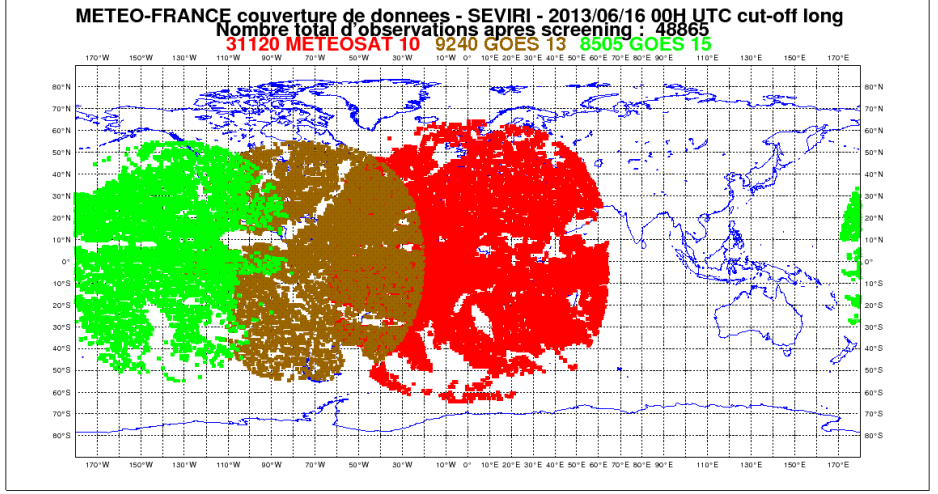
11/02/2013 r0 (long cut-off)

New channels assimilated for IASI and AIRS
and new instruments : CRIS + IASI B

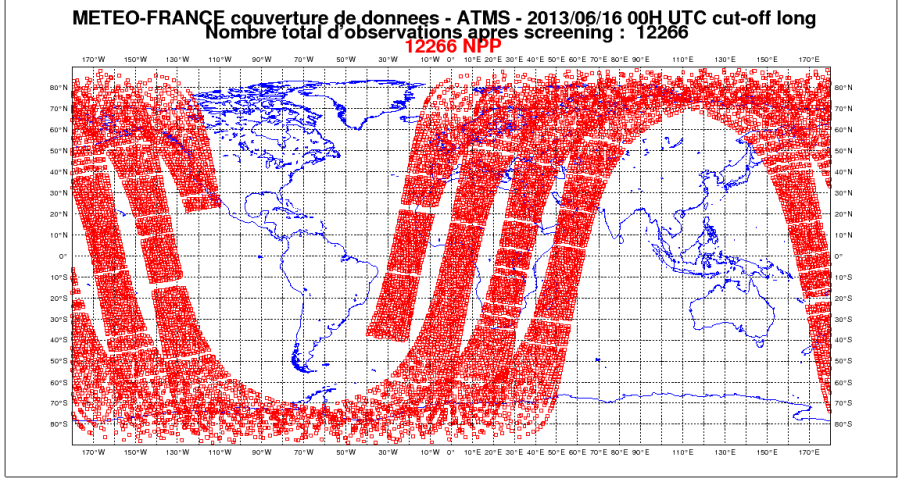
diffusiomètres



Radiances geostationaires



ATMS ≈ AMSUA + MHS



+ de GPS sat

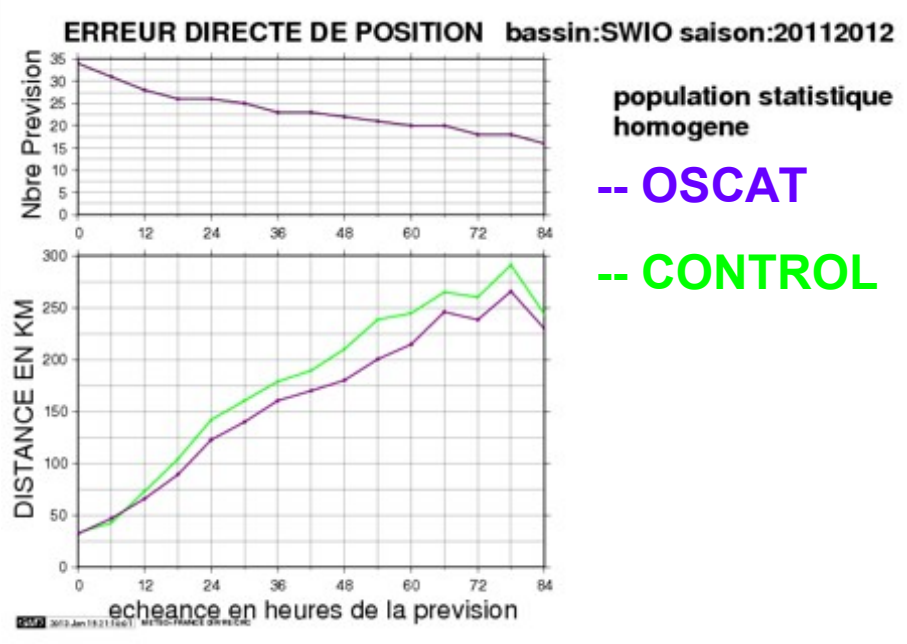
+ de GPS sol

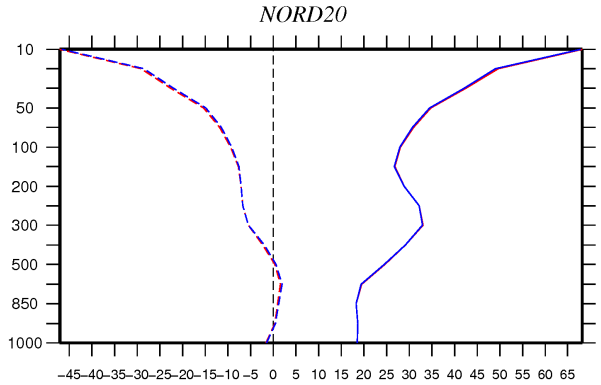
METOP B: AMSU A + MHS

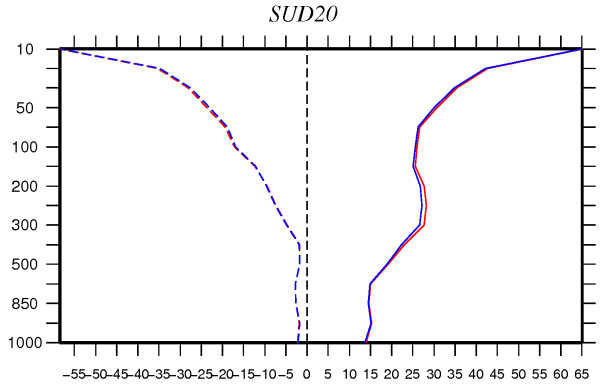
Réglage des écarts-types d'erreurs d'observations dans Arpège, Aladin et Arome pour rééquilibrer la minimisation.

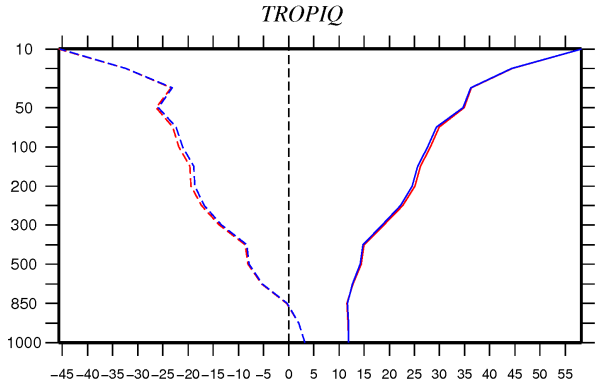
Impact of OSCAT winds on forecast scores

Trajectory of tropical cyclones in ALADIN Réunion









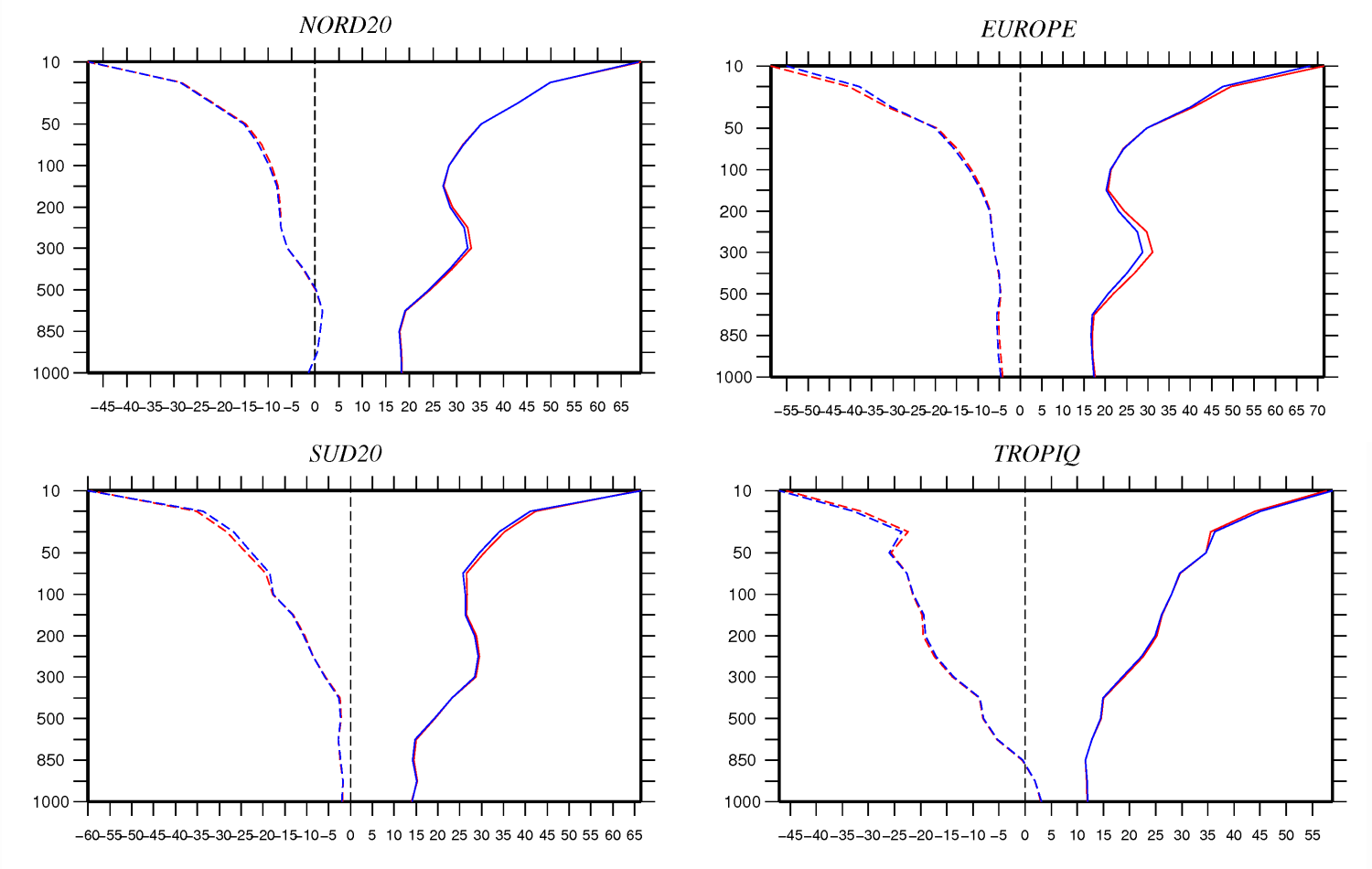
-- OSCAT / -- CONTROL

Geopotential at 72h in ARPEGE

Ref = TEMP

24 cases

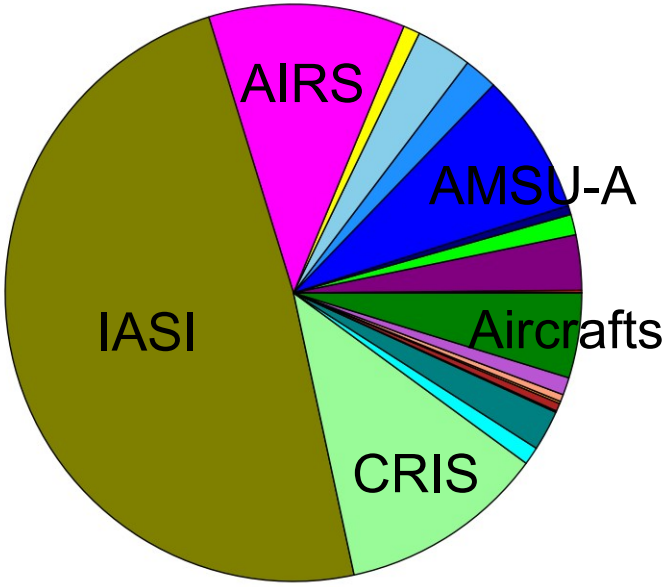
Impact of CrIS on forecast scores



Geopotential FC+72h against TEMP – 19 days
(28/11/2012 -> 20/12/2012)

Current usage of observations in ARPEGE

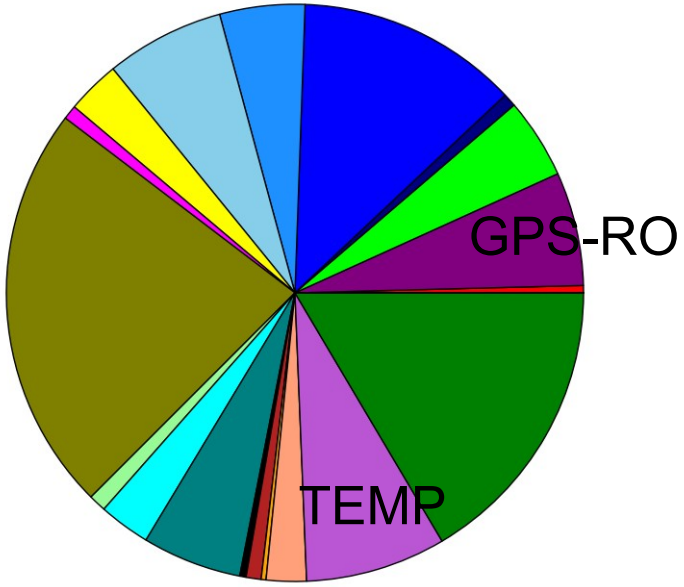
Proportions des nombres d'observations utilisées par type d'obs
analyses cut-off long - ARPEGE metropole oper
observations conventionnelles et satellites
cumul du nombre d'observations utilisées sur la période 2013122700 - 2013122718 : 17618260



GPS ground	0.15%	AIRS	11.00%	SHIP	0.13%		
GPS sat	3.09%	IASI	48.63%	PILOT/PRF	0.40%		
SATOB	1.15%	CRIS	11.57%	TEMP	0.98%		
ATOVS HIRS	0.51%	SEVIRI	1.00%	AIRCRAFTS	4.76%		
ATOVS AMSU-A	7.91%	SCATT	2.26%	RADAR Vr	0.00%		
ATOVS AMSU-B	1.88%	BUOY	0.08%	RADAR Hur	0.00%		
ATMS	3.12%	SYNOP/SYNOR/RADOME	0.44%	BOGUS	0.00%		
SSMIS	0.94%						

Number of obs

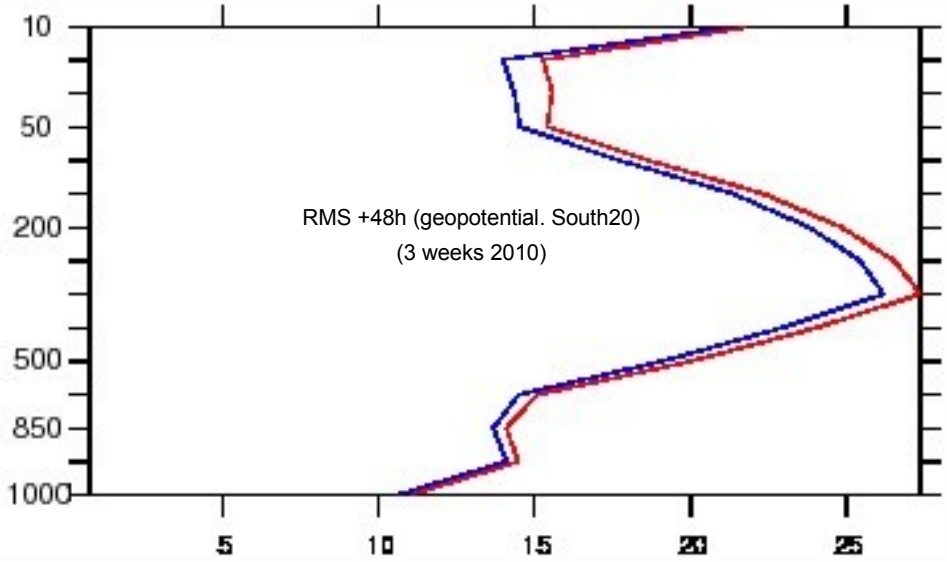
Part des DFS par type d'obs
analyses cut-off long - ARPEGE metropole oper
observations conventionnelles et satellites
cumul du DFS sur la période 2013122700 - 2013122718 : 233933

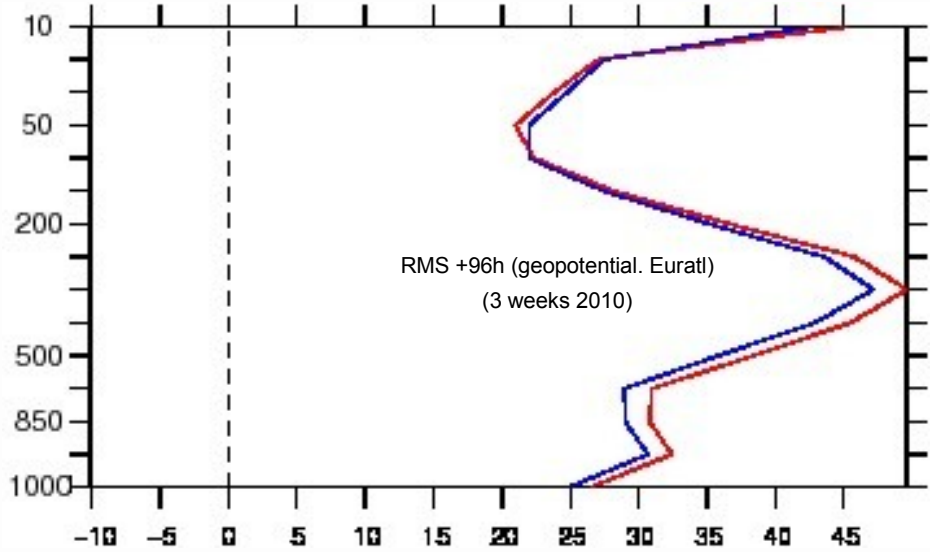


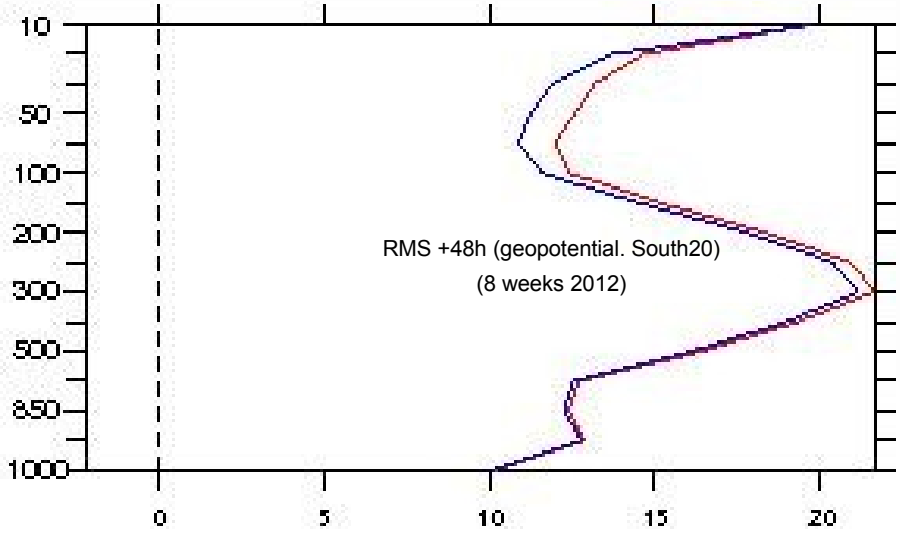
GPS ground	0.41%	AIRS	0.79%	SHIP	0.27%		
GPS sat	6.37%	IASI	22.86%	PILOT/PRF	2.24%		
SATOB	4.50%	CRIS	0.98%	TEMP	7.87%		
ATOVS HIRS	0.74%	SEVIRI	2.88%	AIRCRAFTS	16.48%		
ATOVS AMSU-A	12.43%	SCATT	5.57%	RADAR Vr	0.00%		
ATOVS AMSU-B	4.77%	BUOY	0.36%	RADAR Hur	0.00%		
ATMS	6.65%	SYNOP/SYNOR/RADOME	0.84%	BOGUS	0.00%		
SSMIS	3.00%						

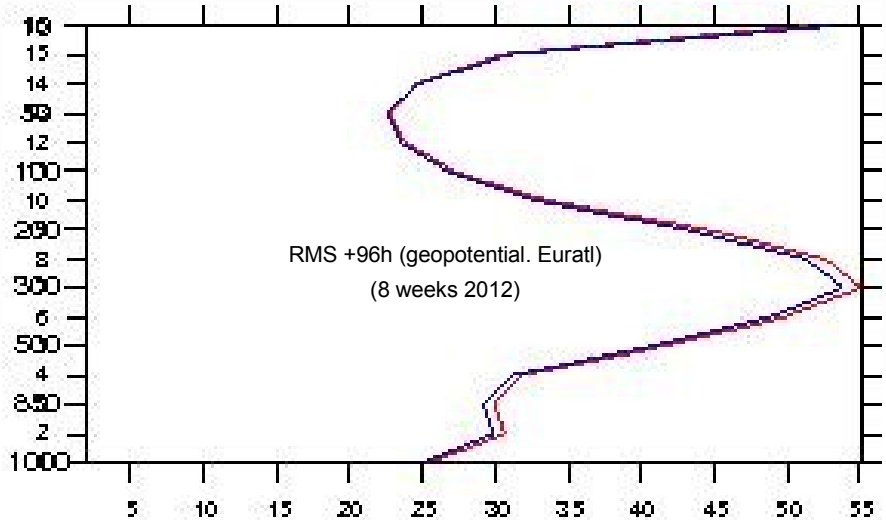
Fractional DFS

Impact of correlations wavelets (versus oper spectral, winter 2010 and 2012)

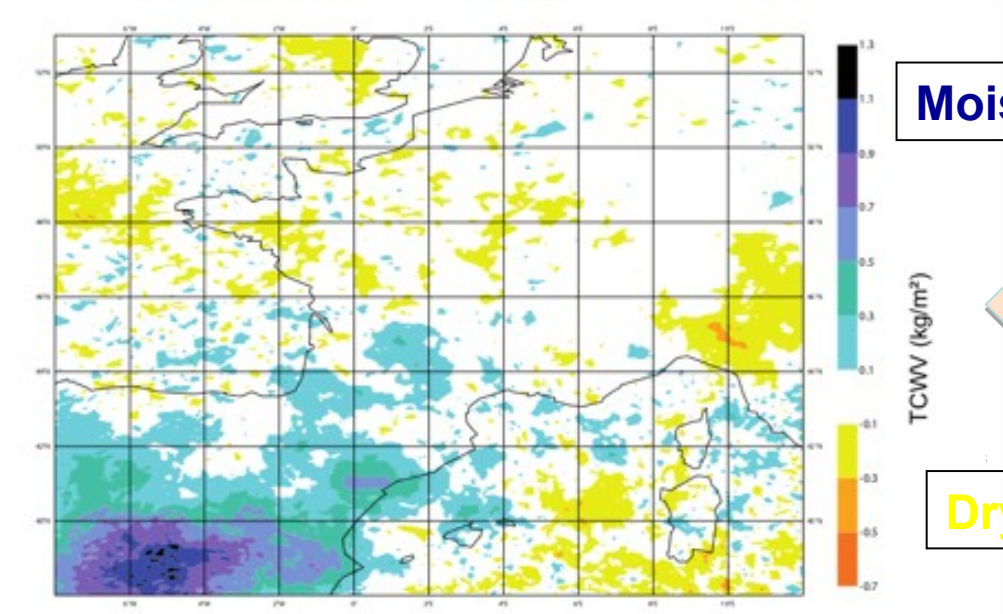




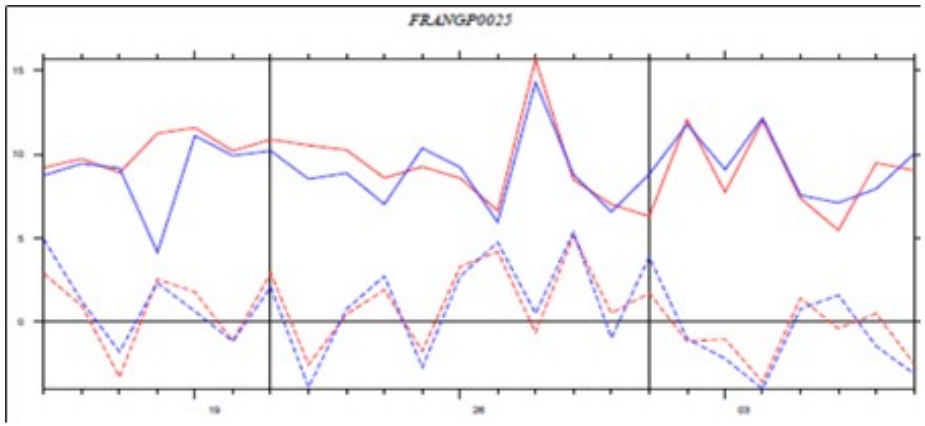




Additional SEVIRI channels over land



TCWV analysis differences
35 days
(Dec 2009 –Jan 2010)

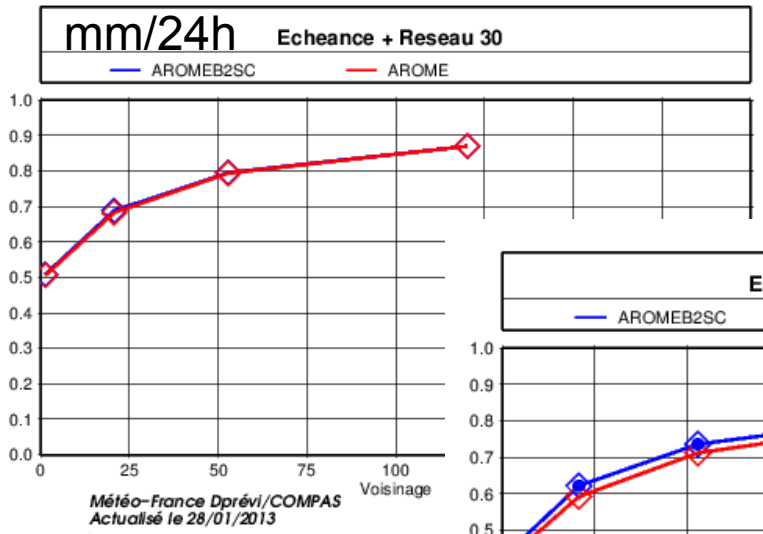


RH 1000hPa
FC+12 errors
(15/06/2011-> 08/07/2011)

-- SEVIRI -- CONTROL

Impact of IASI WV channels on AROME precipitation forecasts

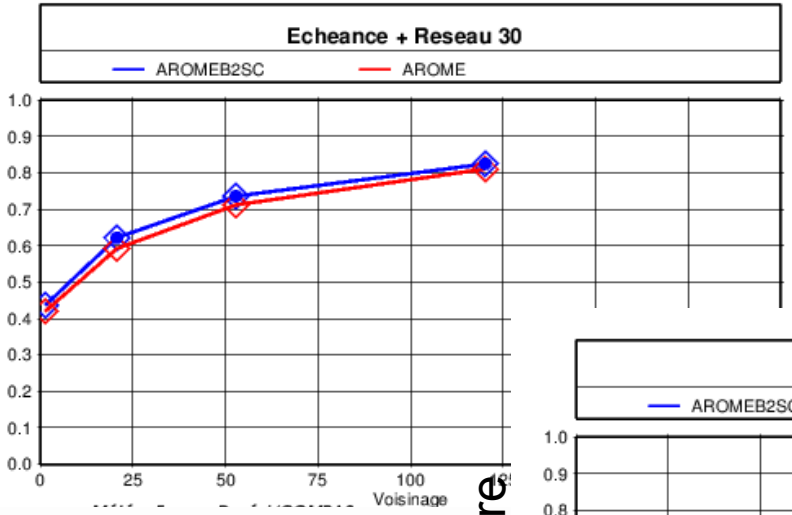
Threshold 5 mm/24h



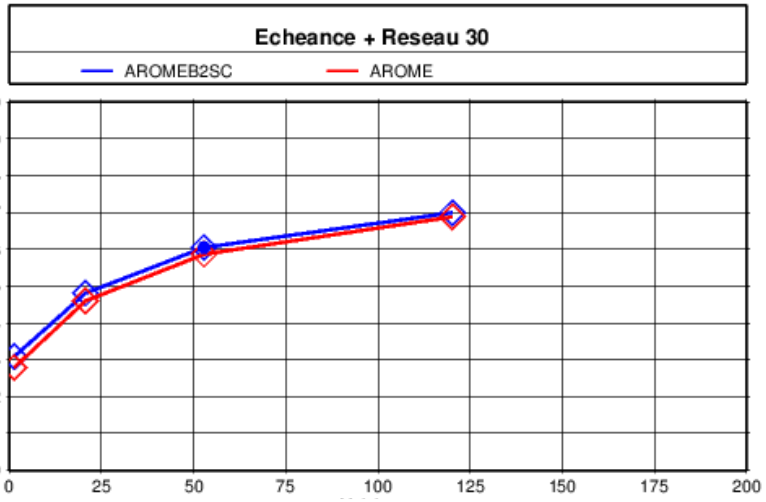
AROME WV

CONTROL

Threshold 10 mm/24h

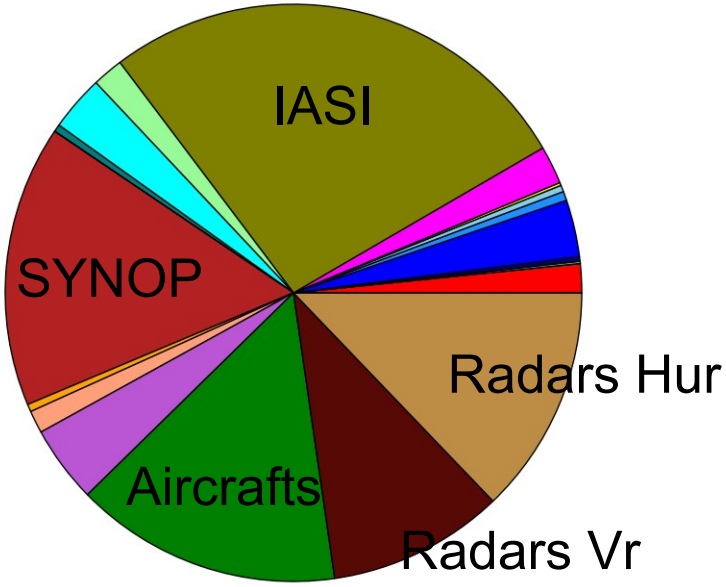


Threshold 20 mm/24h



Current usage of observations in AROME

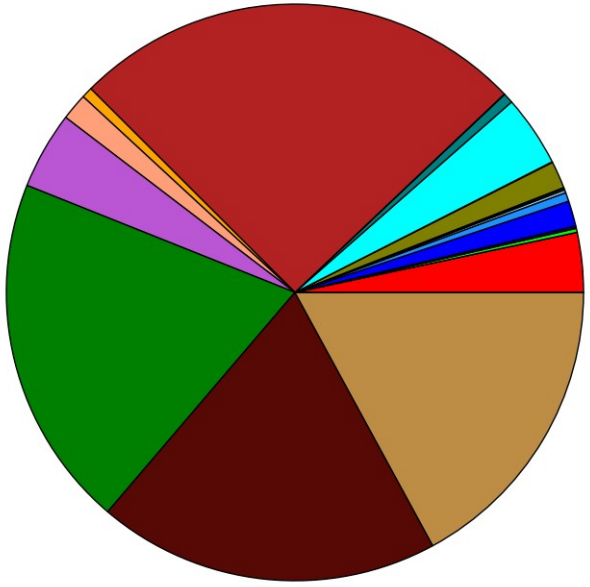
Proportions des nombres d'observations utilisées par type d'obs
analyses cut-off AROME - AROME France oper
observations conventionnelles et satellites
cumul du nombre d'observations utilisées sur la période 2014012600 - 2014012621 : 309393



GPS ground	1.62%	AIRS	2.13%	SHIP	0.42%		
GPS sat	0.00%	IASI	26.92%	PILOT/PRF	1.27%		
SATOB	0.13%	CRIS	1.73%	TEMP	4.31%		
ATOVS HIRS	0.26%	SEVIRI	3.11%	AIRCRAFTS	14.96%		
ATOVS AMSU-A	3.19%	SCATT	0.41%	RADAR Vr	9.89%		
ATOVS AMSU-B	0.51%	BUOY	0.02%	RADAR Hur	12.83%		
ATMS	0.37%	SYNOP/SYNOR/RADOME	15.77%	BOGUS	0.00%		
SSMIS	0.16%						

Number of obs

Part des DFS par type d'obs
analyses cut-off AROME - AROME France oper
observations conventionnelles et satellites
cumul du DFS sur la période 2014012600 - 2014012621 : 109693



GPS ground	3.35%	AIRS	0.05%	SHIP	0.61%		
GPS sat	0.00%	IASI	1.52%	PILOT/PRF	1.50%		
SATOB	0.22%	CRIS	0.04%	TEMP	4.33%		
ATOVS HIRS	0.14%	SEVIRI	4.00%	AIRCRAFTS	19.82%		
ATOVS AMSU-A	1.42%	SCATT	0.57%	RADAR Vr	19.16%		
ATOVS AMSU-B	0.50%	BUOY	0.02%	RADAR Hur	17.07%		
ATMS	0.17%	SYNOP/SYNOR/RADOME	25.43%	BOGUS	0.00%		
SSMIS	0.09%						

Fractional DFS

Mocage (chemistry-transport model)

A 3D multi-scale chemistry-transport model, with a data-assimilation scheme;

Stratospheric chemistry: REPROBUS; Tropospheric chemistry: RACM;

Aerosols : 5 primary species (desert dust, sea salt, black carbon, anthropogenic, birch pollen), 6 bins (except for pollen)

Forcing meteorological model: Arpege, Arome or IFS;

Applications:

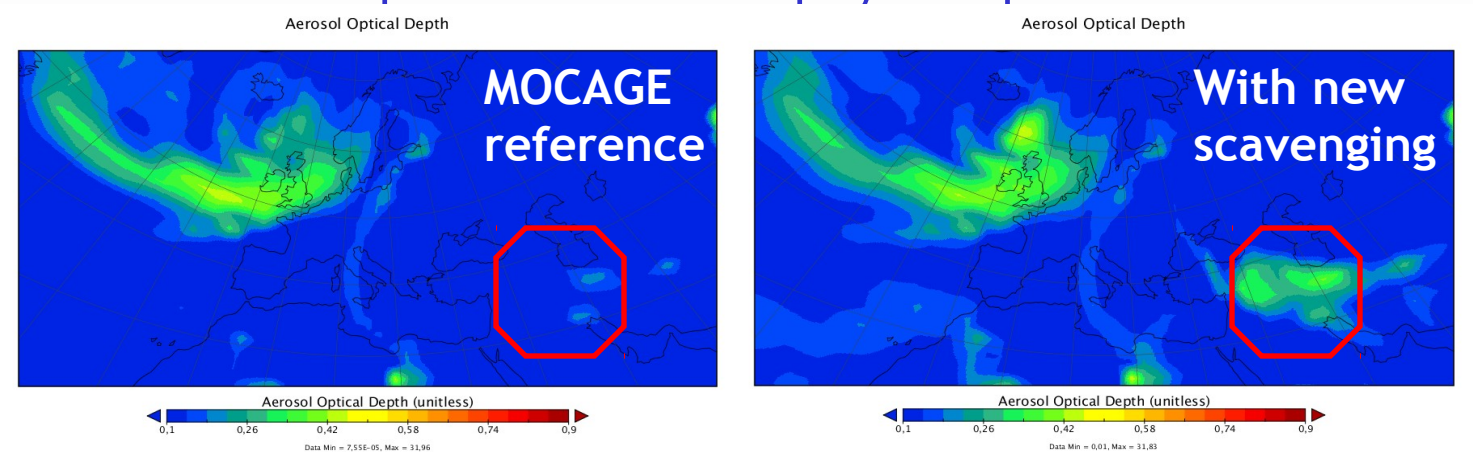
- air-quality prediction at global and regional scales (MACC-II project),
- dispersion of pollutants (volcanic ashes, industrial and radioactive emissions),
- UV indices, ozone hole evolution,
- impact of climate change on air quality.

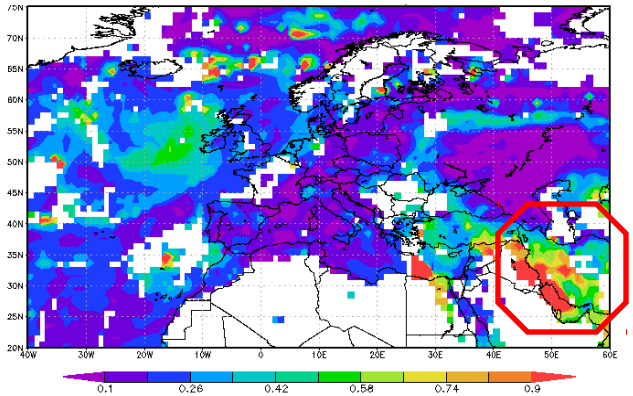
Mocage: Present developments

Chemistry:

- including a new cycle for sulfur, with aqueous chemistry;
- interfacing the Mocage chemistry sheme inside the C-IFS model (IFS model with on-line chemistry, developed in the MACC-II project): a collaboration between ECMWF and Météo-France ;

Aerosols: improvement of the physical parametrizations





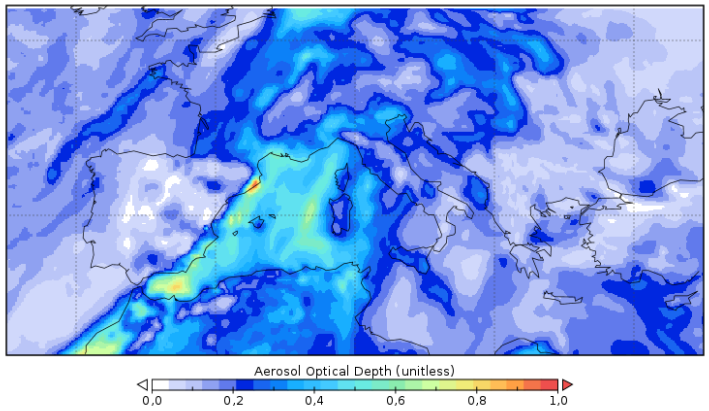
Courtesy of B. Sic
Sic et al, GMDD, 2014

Mocage: Present developments

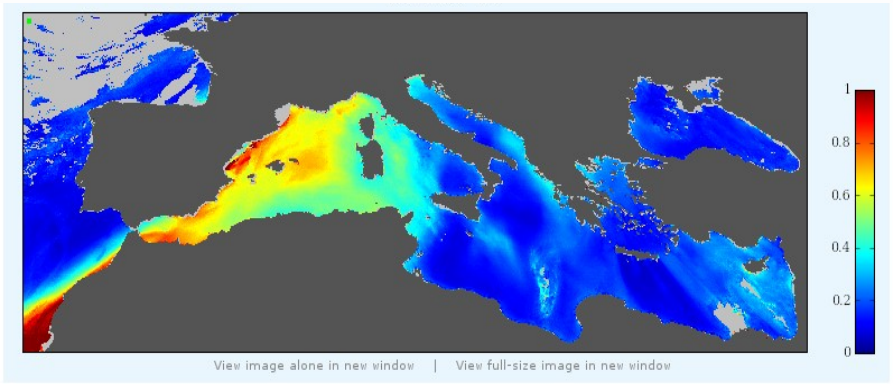
Aerosol :

Development of the assimilation of aerosol optical depth (AOD) and aerosol lidar profiles

Mocage analysis after MODIS AOD assimilation



Independent AOD from SEVIRI



Courtesy of B. Sic, L. El Amraoui

Development of secondary aerosols in 2014 (ISORROPIA scheme for inorganic aerosols)

ENSO contribution to the recent global warming hiatus

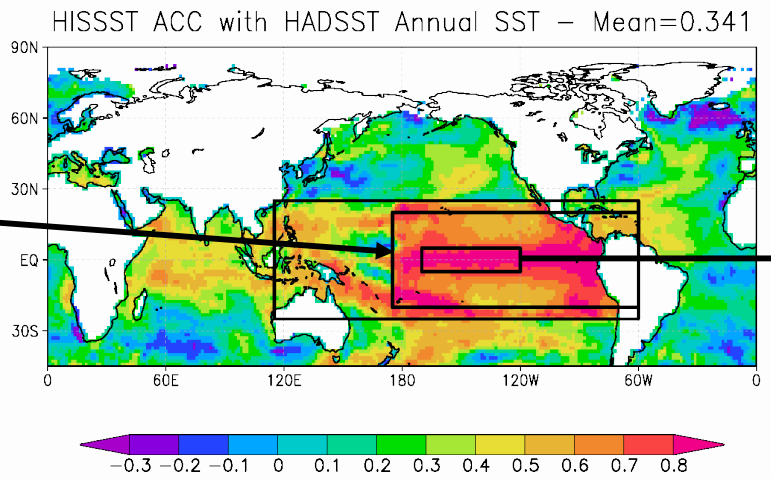
Experiment design

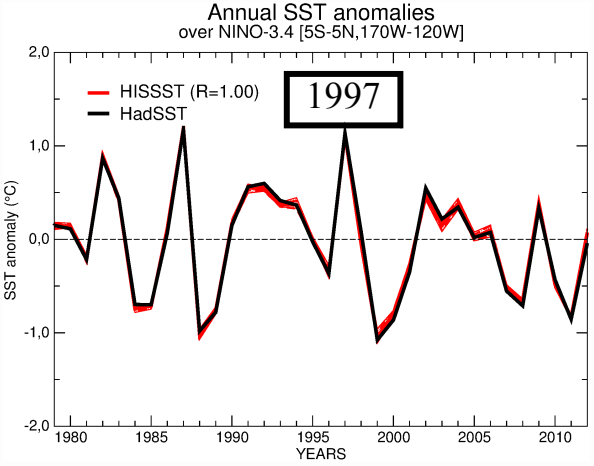
- ✓ 1979-2012 integrations
- ✓ ARPEGE V5.2 AGCM / NEMO V3.2 OGCM (Gelato sea-ice)
- ✓ TI127 (1.4°) L31 / 1°L42
- ✓ 5 members (initial states from historical CMIP5 simulations)
- ✓ **HISCTL**: CMIP5 simulations (ALL forcings)
- ✓ **HISSST**: HISCTL + SST anomaly nudging in central and eastern tropical Pacific (as in Kosaka and Xie 2013)
- ✓ **HISTAU**: HISCTL + prescribed wind stress in the tropical Pacific (not exactly as in England et al. 2014)
- ✓ All anomalies relative to the 1979-2008 climatology

- ✓ Question not addressed here and still a matter of debate:
  Should we expect more la Niña events in a warmer climate?

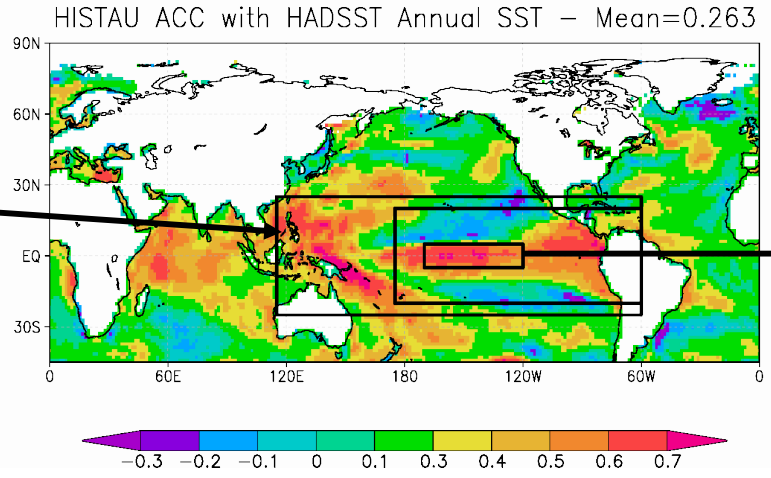
Correlation with observed annual mean SST

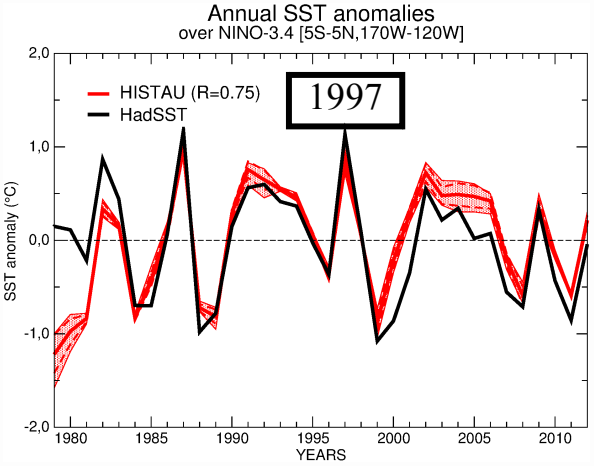
Domain with SST nudging in **HISSST**





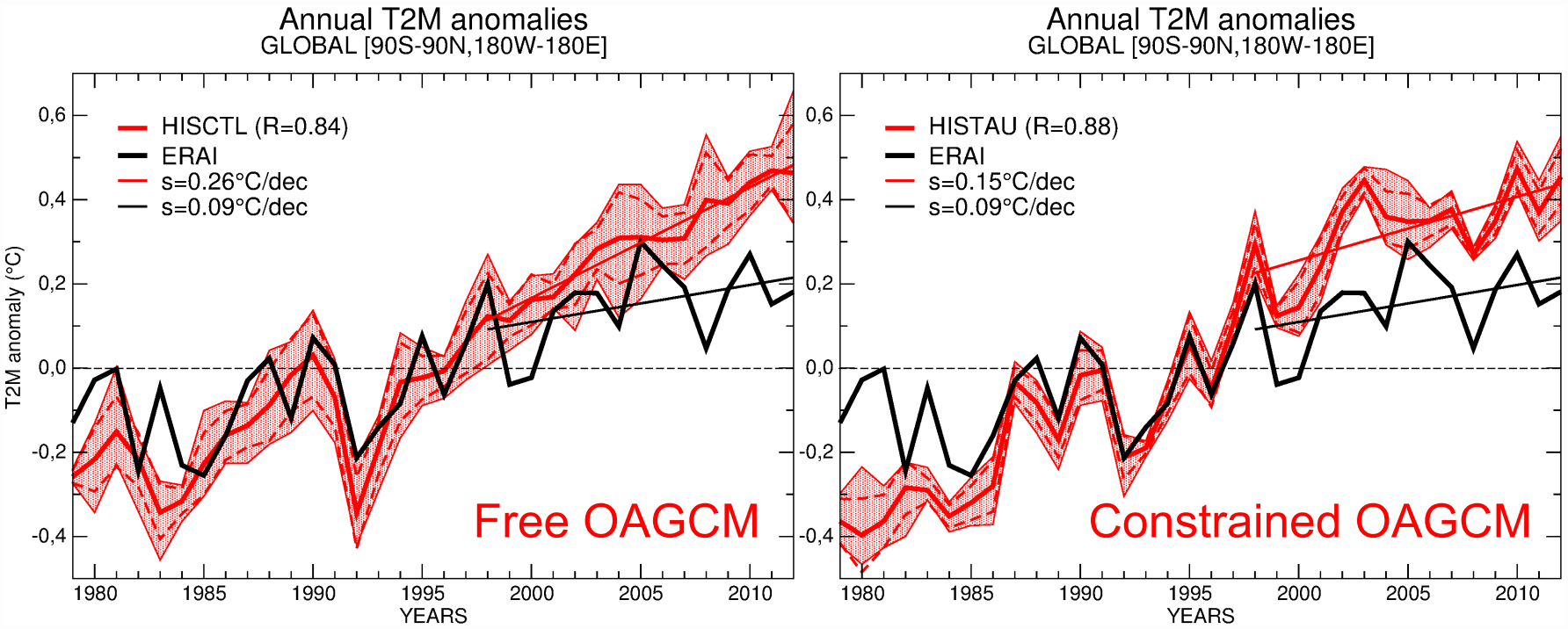
Domain with prescribed wind stress in **HISTAU**





(Douville and Voldoire, in preparation)

Global annual mean T2M anomalies

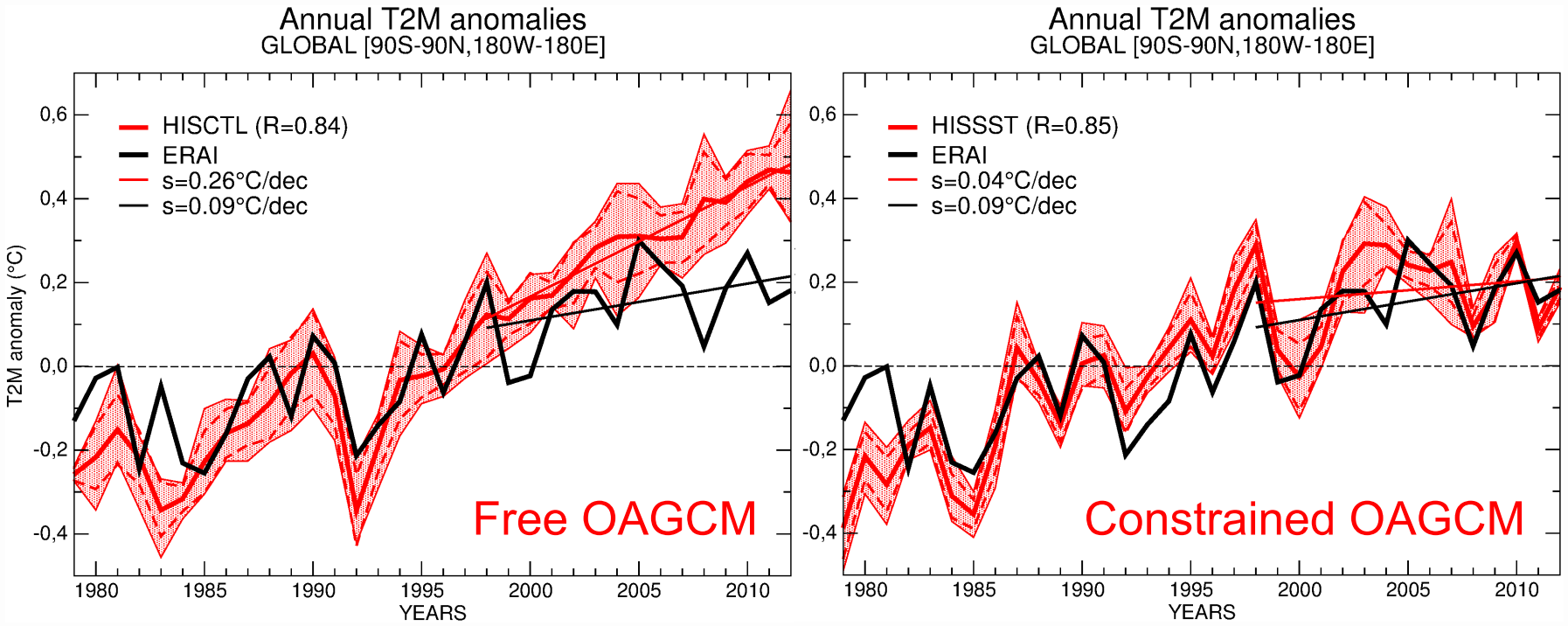


- **HISSST** results in line with Kosaka and Xie (2013) despite a lower (more realistic) ENSO influence on global mean temperature in CNRM-CM5: ENSO multi-decadal variability (mostly internal and not predictable by state-of-the-art OAGCMs) is sufficient to explain the recent global warming hiatus;

- **HISTAU** results in line England et al. (2014) despite a reduced domain with prescribed wind stress; global warming hiatus less pronounced than in HISSST due to a too narrow ENSO signal in Pacific SST (+ cold start).

(Douville and Voldoire, in preparation)

Global annual mean T2M anomalies



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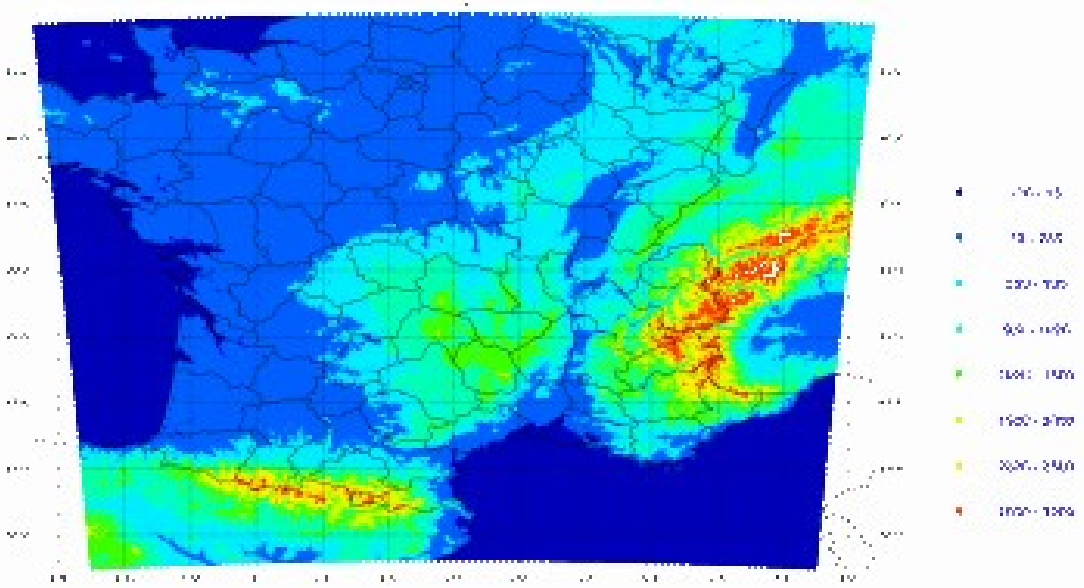
(Douville and Voldoire, in preparation)

Prototype AROME 1.3km

Evaluation on smaller domain (720x720 points)



- Daily forecast r0 +30h since 1st June 2012
  Dynamical adaptation AROME oper 2.5km
- Predictor-corrector scheme (one iteration)
- Time-step=45s

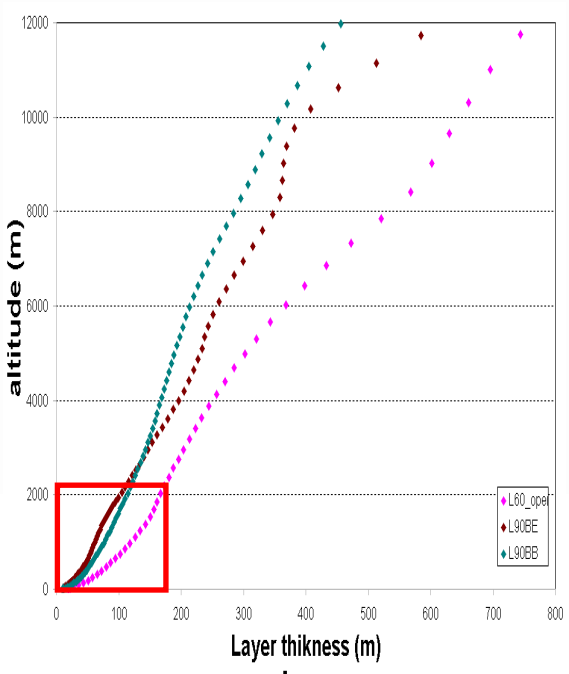
AROME 1.3km: vertical resolution

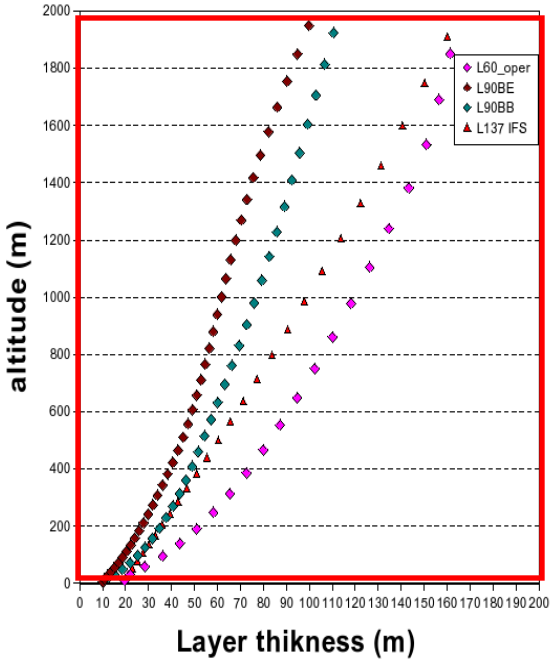
Several sets of 90 and 120 vertical levels tested: impact on forecasts (convection, precipitations, clouds, surface parameters), stability, etc.

-> Highest model level fixed at 10hPa

-> Benefits of very fine resolution near surface for modelling radiative fog, but constraint on time-step : lowest model level fixed at 5m

-> No additional benefit from L120 compared with L90

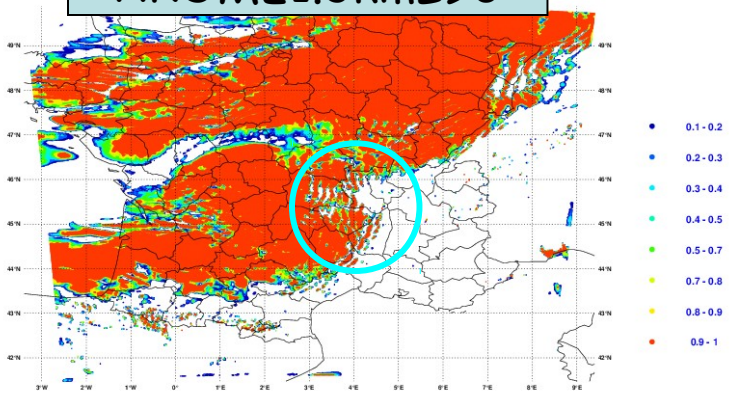




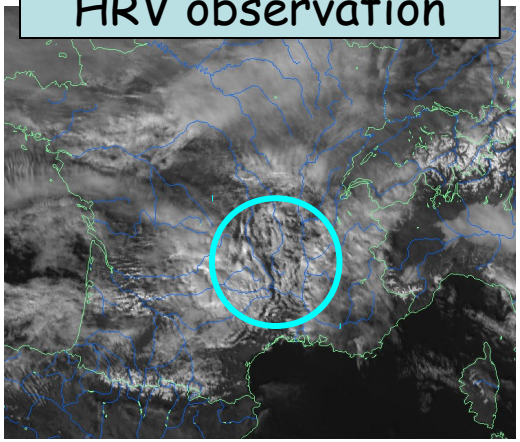
31-01-2013 (+14h)

Low level cloudiness AROME

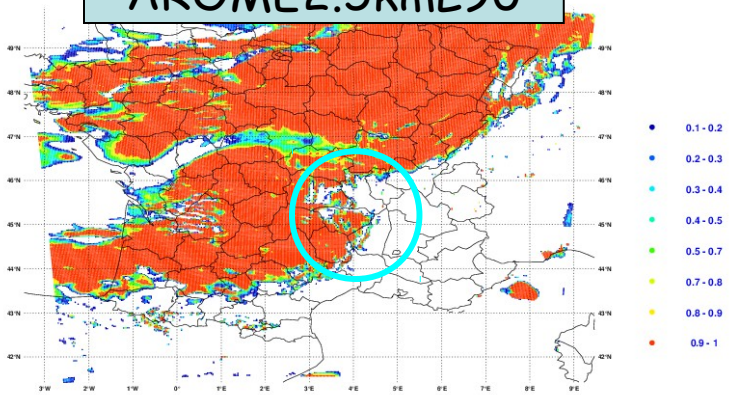
AROME1.3kmL90



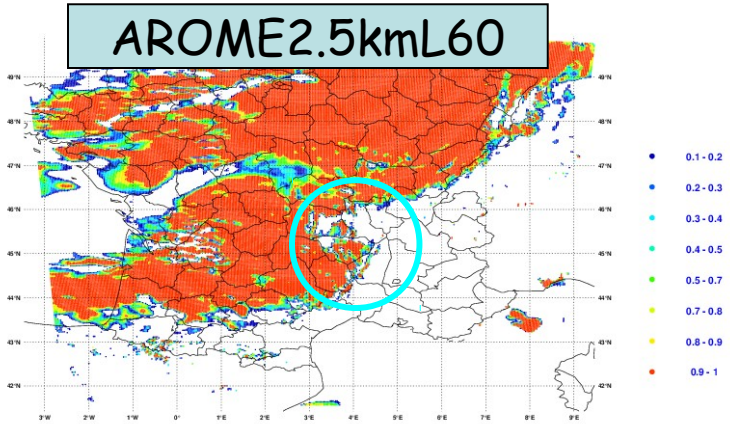
HRV observation



AROME2.5kmL90

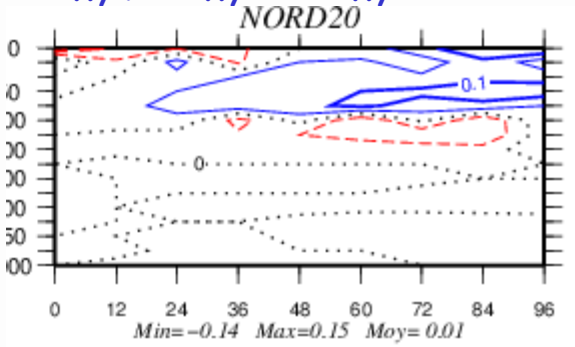


AROME2.5kmL60



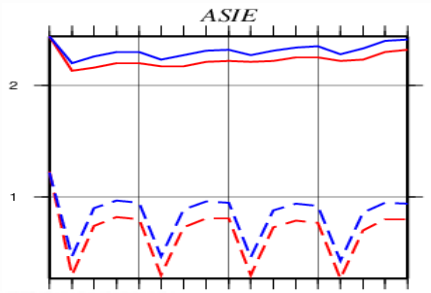
Arpege HR: scores

Evaluation in dynamical adaptation (no assimilation) with operational physics : upper-air (PHI, T, V, HU, Pmer) and surface (T2m, H2m, V10m, RR24, Cloud) scores

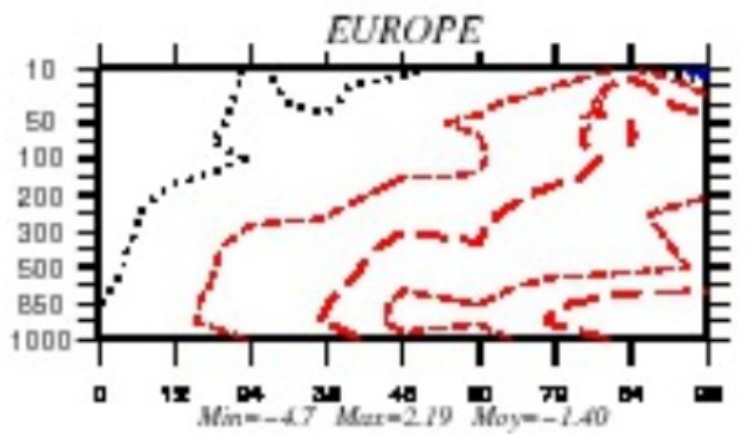


Impact of vertical resolution: neutral except on
- Temperature in the stratosphere and H2m (+)
- V10m (module) (-)

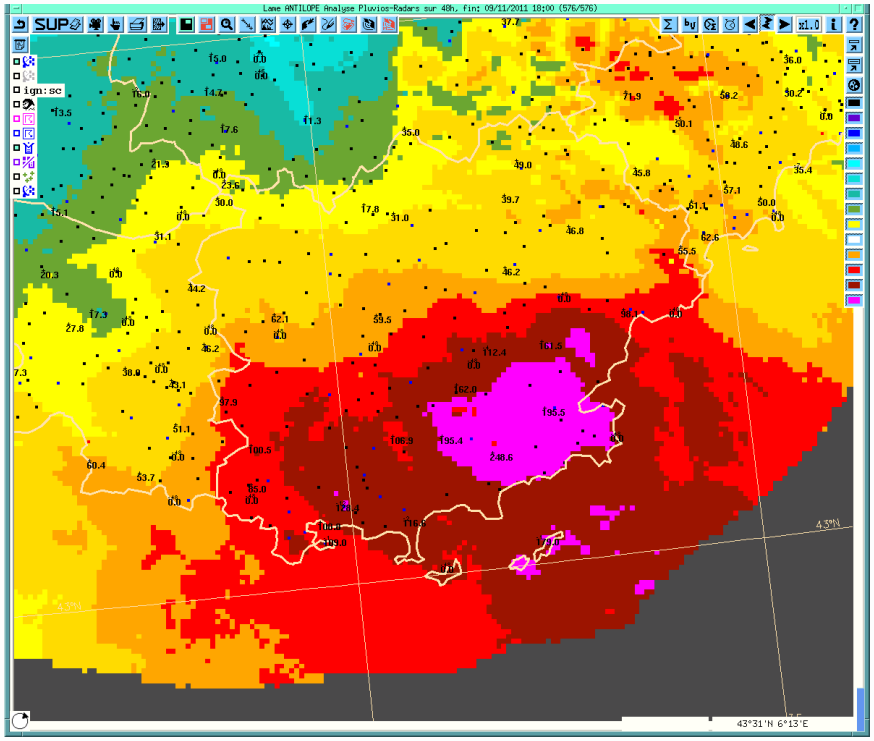
Impact of horizontal resolution: neutral except on
- Geopotentiel in the troposphere (+)
- Wind in the troposphere, V10m (direction, module), Pmer (-)

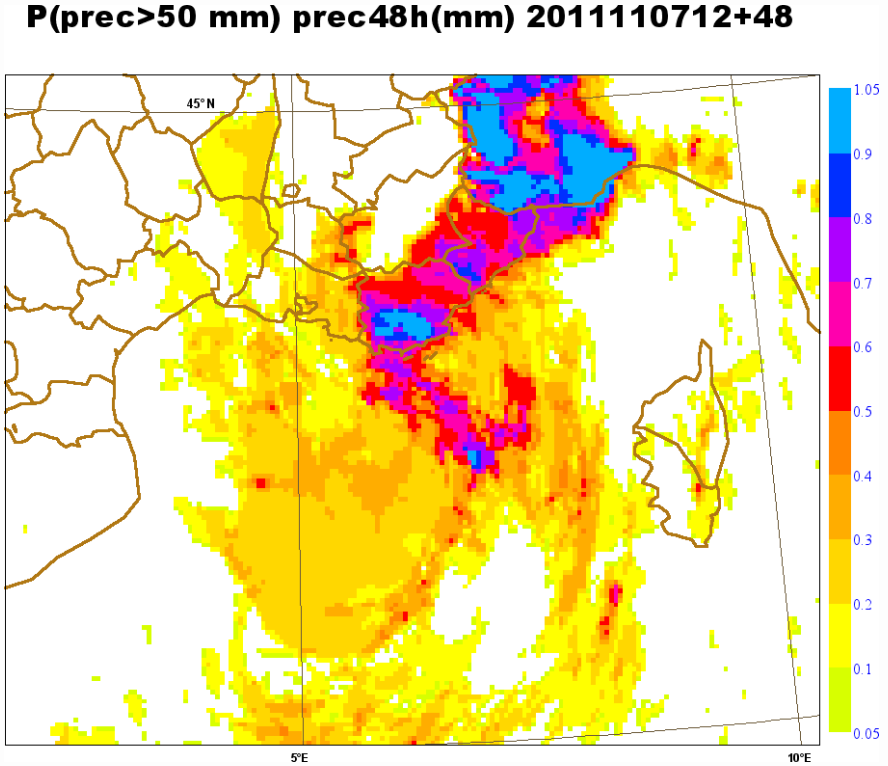


Impact on geopotentiel scores against RS over Europe when removing envelope orography over a winter period →



AROME Ensemble Prediction System





Left, (raingauge+radar) analysis of precipitation accumulated over 48h during Medicane Rolf.
The pink area delineates precipitation larger than 100m.

Right, forecast probabilities predicted by a 48h-run of the PEARO ensemble.
There also are high probabilities of exceeding 100mm (not shown) over the relevant area.

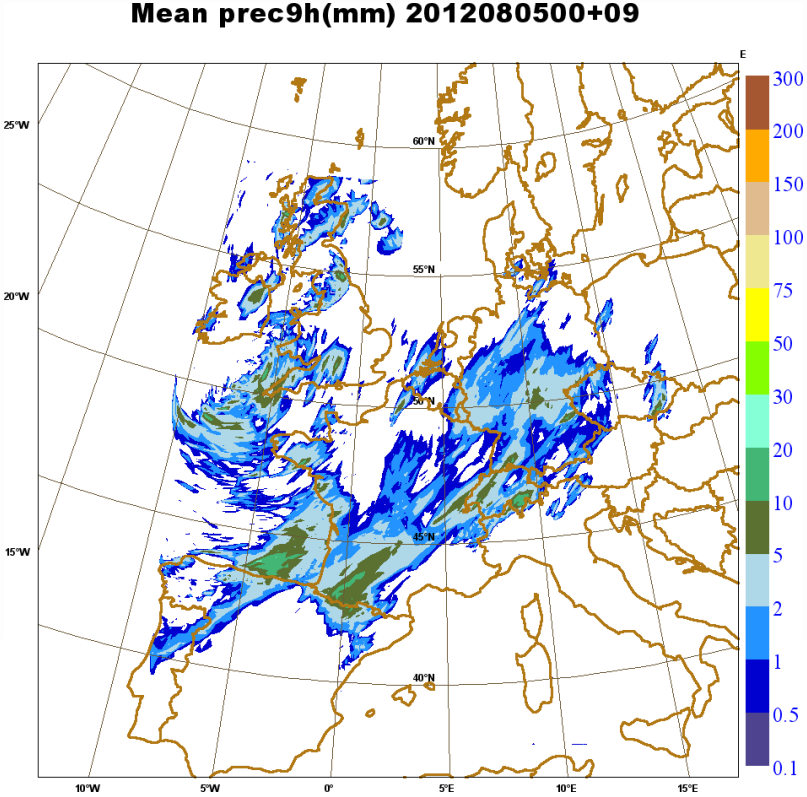
SESAR EU project: test multi-ensembles (for aviation)

Arome+UKV+COSMODE = 12+12+20 members = 44 members

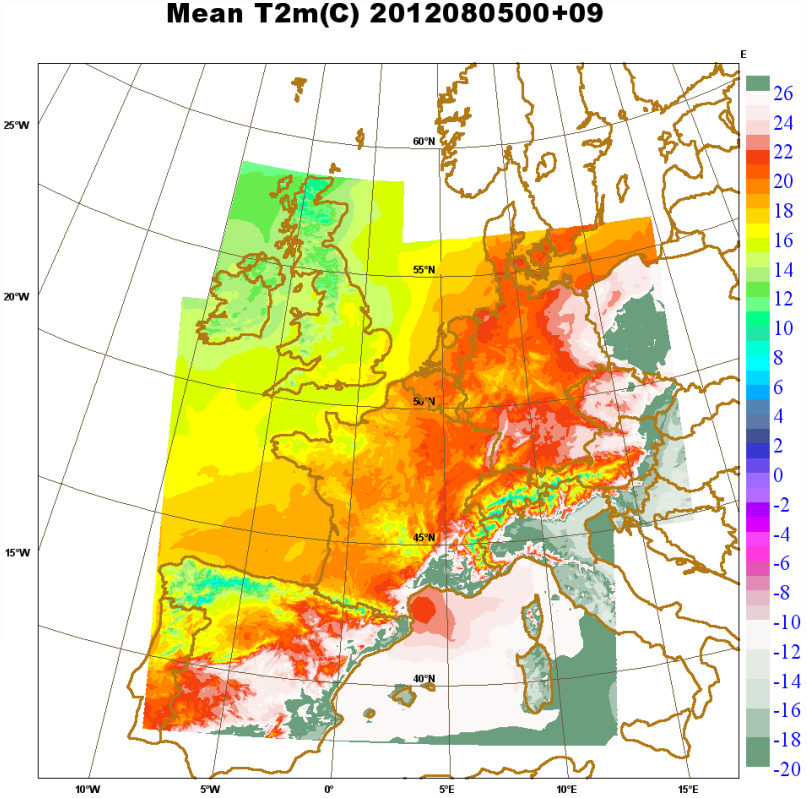
all members have equal weight (except for PDF smoothing near each model's domain edge) & similar resolution ~ 2.5km

Objective scores: multi-ensemble usually better than each ensemble in the overlap zones.

3-model PDF precip



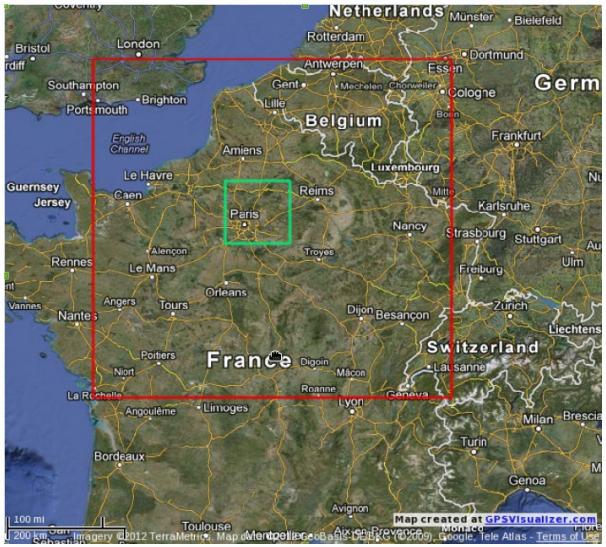
3-model PDF of T2m

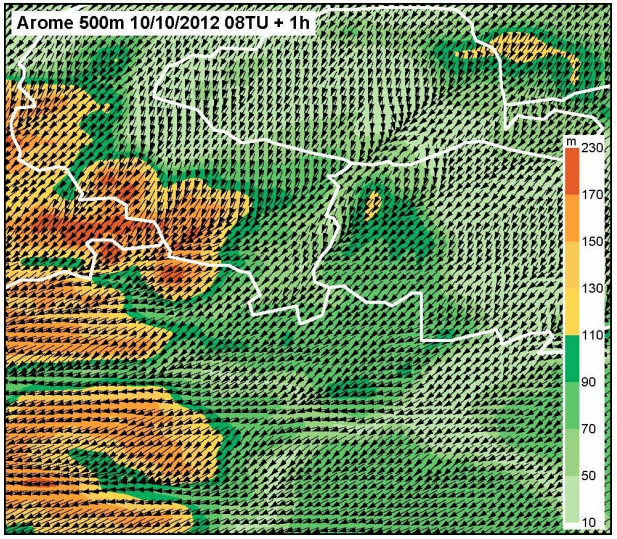


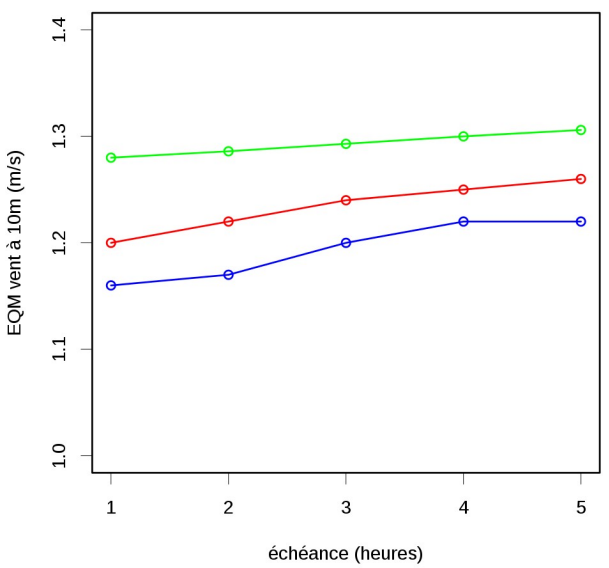
SESAR EU project: AROME-airport system

AROME hourly assimilation at 2.5km using AROME-France forecast as first guess (on red domain) : two additional wind profilers

AROME forecast at 500m performed on green domain to produce boundary conditions to a Wake-Vortex prediction model





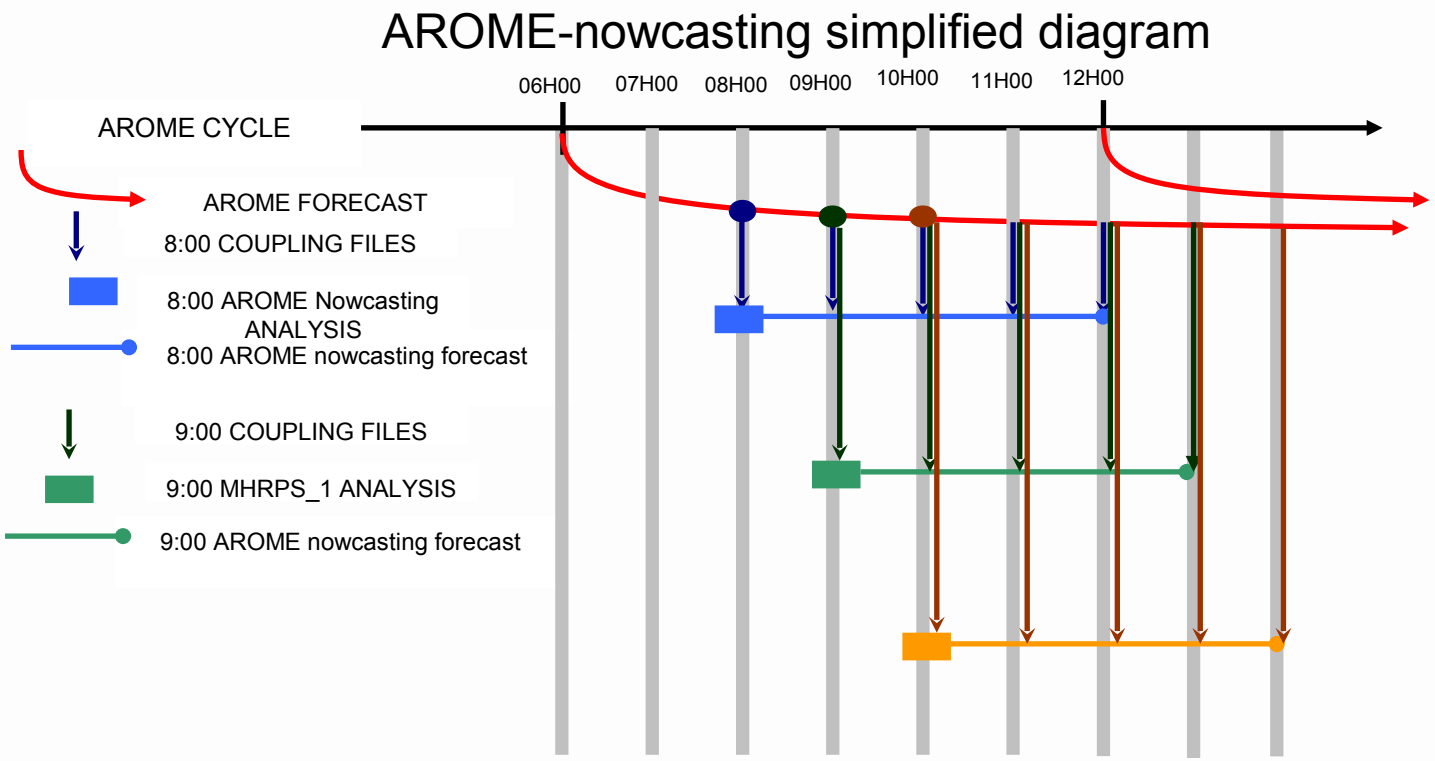


Zoom of an AROME-airport 500m forecast, vectors show wind direction and force, shaded areas is orography.

AROME-Nowcasting

AROME-Nowcasting under development (operational in 2015)

AROME 1.3km : 6h forecast every hour based on 3DVar analysis with 15min cut-off

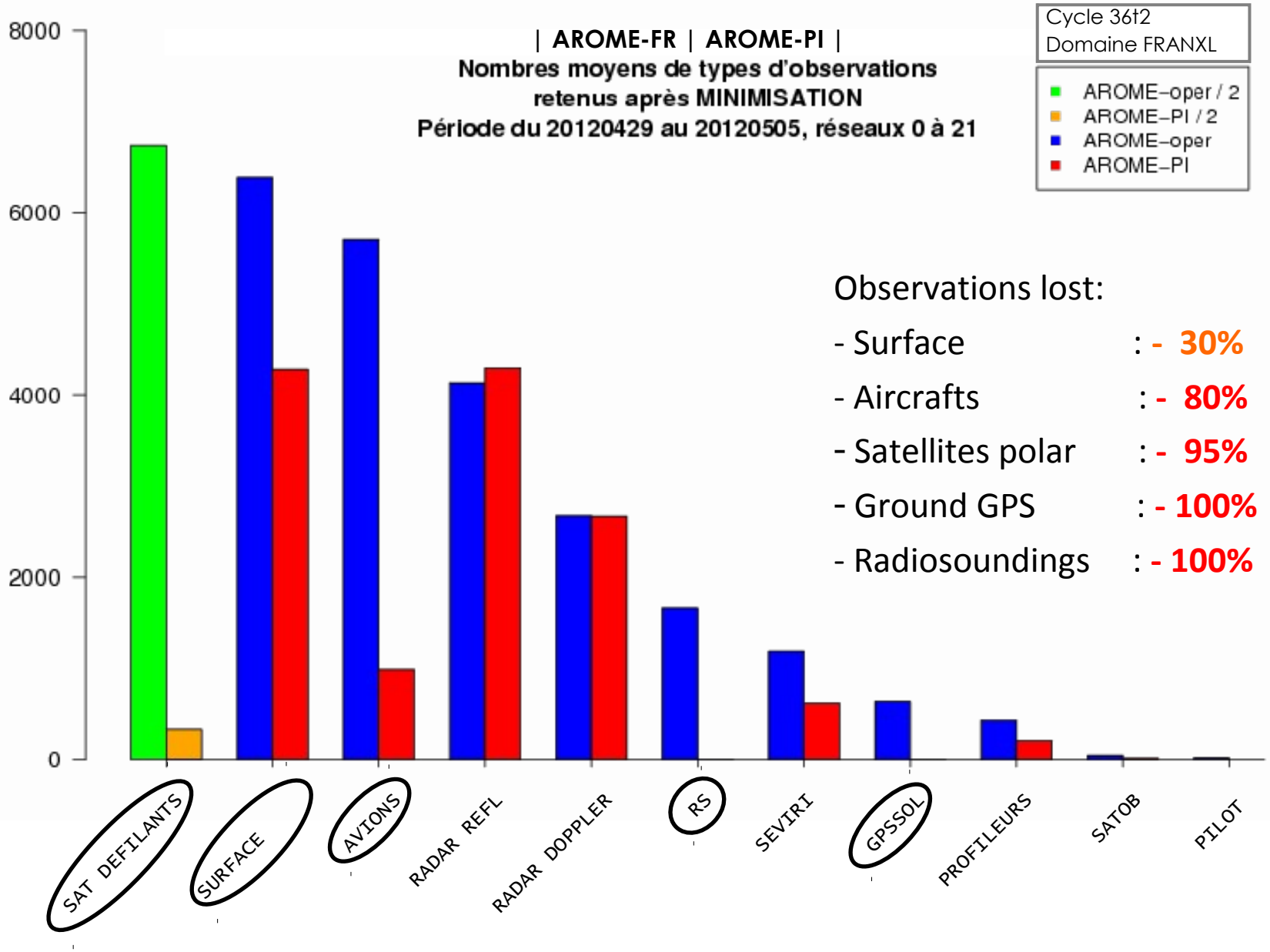


Boundary conditions are re-computed every hour from our AROME-France model.

No cycling so far.

No specific surface data assimilation, the initial conditions have to be taken from our AROME-France model once a day, and are cycled from previous forecast otherwise.

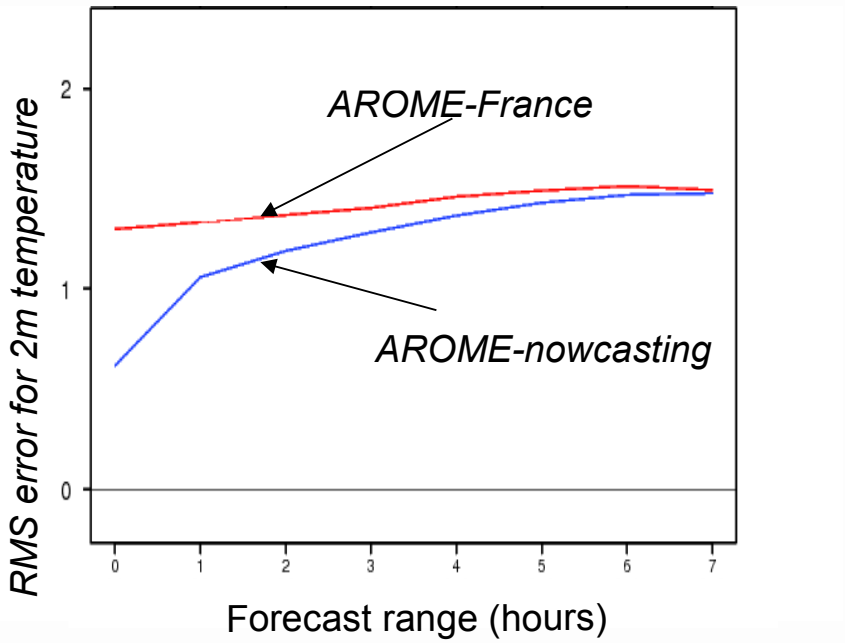
Observations : comparison AROME-FR / -PI



Observations lost:

- Surface : - 30%
- Aircrafts : - 80%
- Satellites polar : - 95%
- Ground GPS : - 100%
- Radiosoundings : - 100%

AROME-Nowcasting summary of the results



Comparaison AROME-France AROME-nowcasting for 2m temperature

The scores are better for most of the parameters.

After 3 hours the improvement is weak.