Research and operation updates at Météo-France

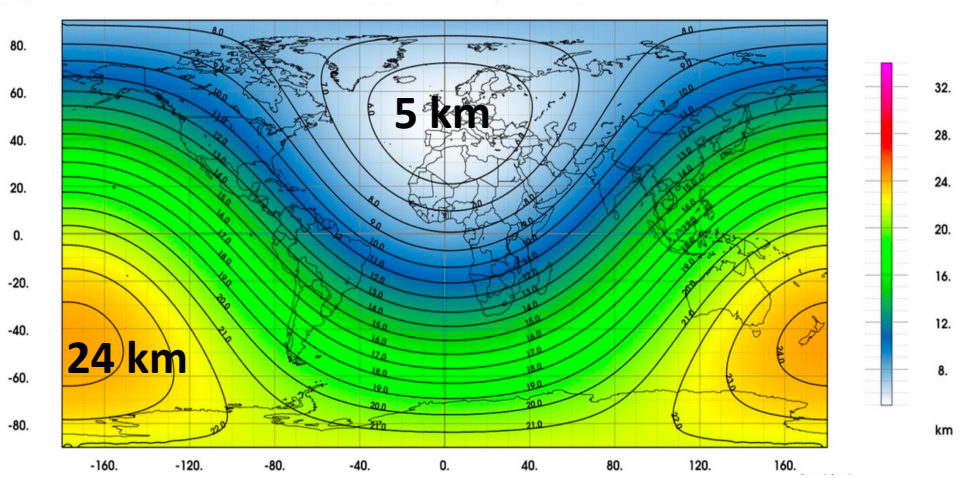
Romain Roehrig

with contributions from many CNRM colleagues

40th annual meeting of the WGNE, 3-7 November 2025, Beijing, China

Current e-suite (48t1 since October 2024) – Global system

Systems	48t1 (October 2024)	48t1 main updates vs. previous e-suite
ARPEGE (deterministic)	Tl1798c2.2 L105 (5km on W Europe) 4DVar (6h cycle): Tl224c1L105 & Tl499c1L105 4x per day up to 114h	Deep convection scheme updates (mixed closure, pr detrainment) **EcRad** with McICA solver New interpolations in the stratosphere SST product update (from Mercator)
ARPEGE-EDA	Tl499c1 L105 ; 50 members 4D-Var (6h cycle): Tl224c1 L105 Background covariances: 12-h avg / 6-h update	**Hybrid 4DVar** with 3D anisotropic covariances Direct assim. of **all-sky microwave radiances** Assim. of new **GNSS-RO** data Technical updates of assimilation schemes (OOPS)
ARPEGE-EPS	Tl1798c2.2 L90 (5km on W Europe) ; 34+1 members ; 4x102h 35 EDA members and singular vectors Perturbed parameters, 2 convection schemes	Removal of some singular vectors over NH/SH domains

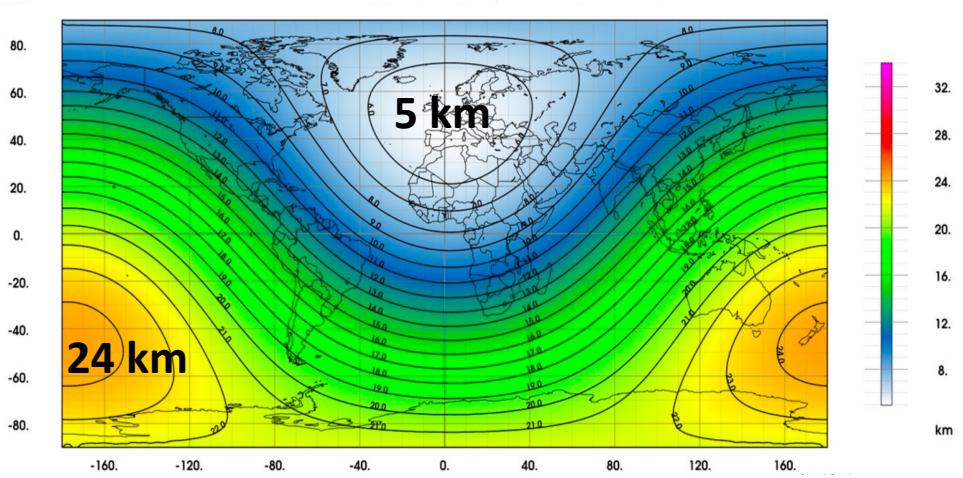


Tl1798c2.2: from 5 km over Western Europe
to 24 km over the southern Pacific

Courtesy F. Bouyssel et al.

Upcoming e-suite (49t1 in operation late 2026) – Global system

Systems	48t1 (October 2024)	49t1 main updates (late 2026)
ARPEGE (deterministic)	Tl1798c2.2 L105 (5km on W Europe) 4DVar (6h cycle): Tl224c1L105 & Tl499c1L105 4x per day up to 114h	**Oceanic mixed layer** (relaxed towards Mercator analysis)
ARPEGE-EDA	Tl499c1 L105 ; 50 members 4D-Var (6h cycle): Tl224c1 L105 Background covariances: 12-h avg / 6-h update	Quality check revision of AMVs Revised spatial thinning of satellite observations New obs: Mode-S EMADDC data, CrIS, GOES-18/ABIn HY-2D/HSCAT, OceanSat-3/OSCAT IMS snow cover product in surface analysis.
ARPEGE-EPS	Tl1798c2.2 L90 (5km on W Europe) ; 34+1 members ; 4x102h 35 EDA members and singular vectors Perturbed parameters, 2 convection schemes	Perturbations of the surface initial state Full removal of singular vectors



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Courtesy F. Bouyssel et al.

New e-suite (49t1) – Global system

Score card (Normalized RMSE differences) 49t1 vs 48t1
Lead time up to 96h / 6 months (01/12/2024 to 10/06/2025)

max: 10%

Temperature

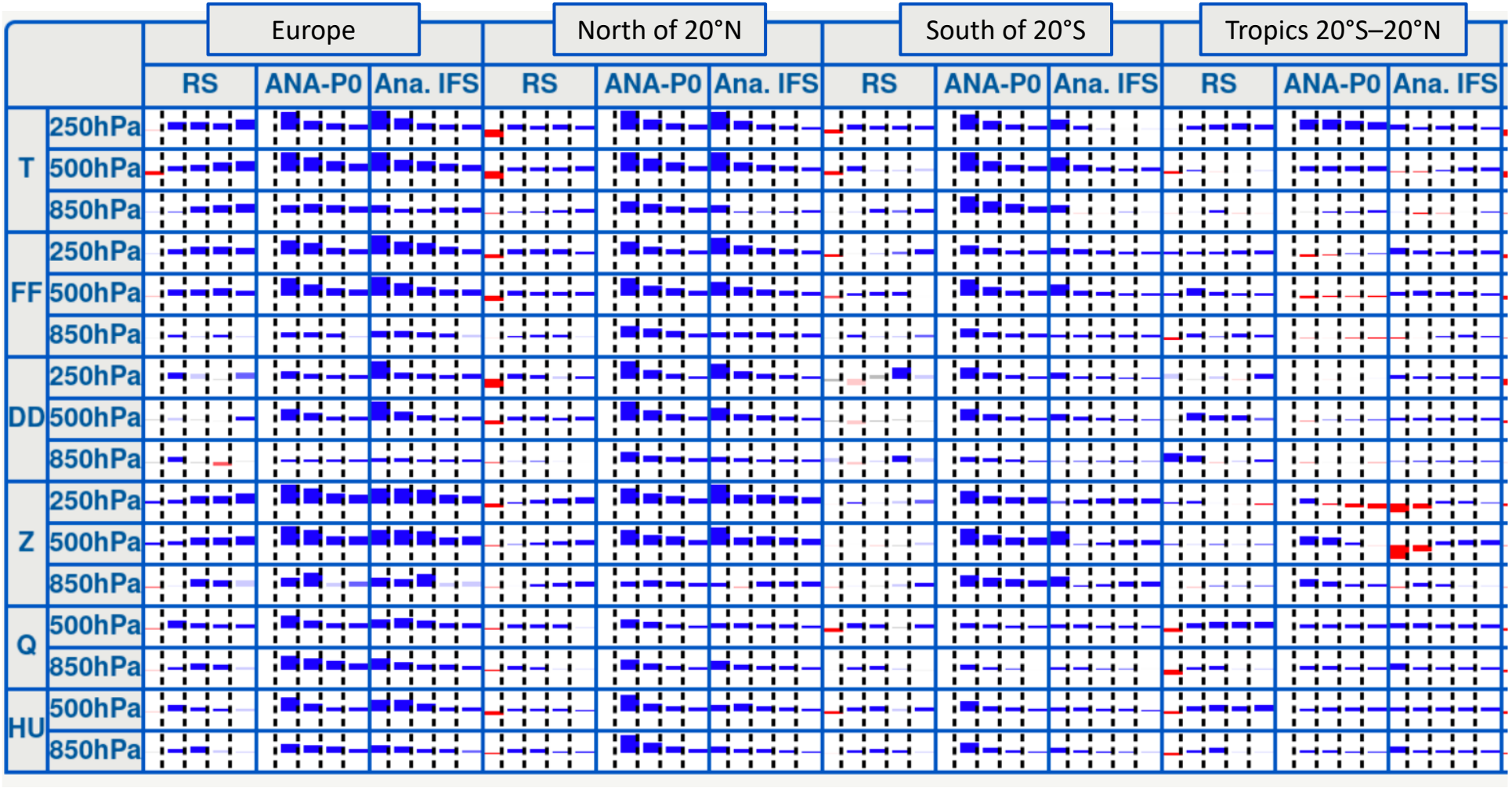
Wind speed

Wind direction

Geopotential

Moisture

RH

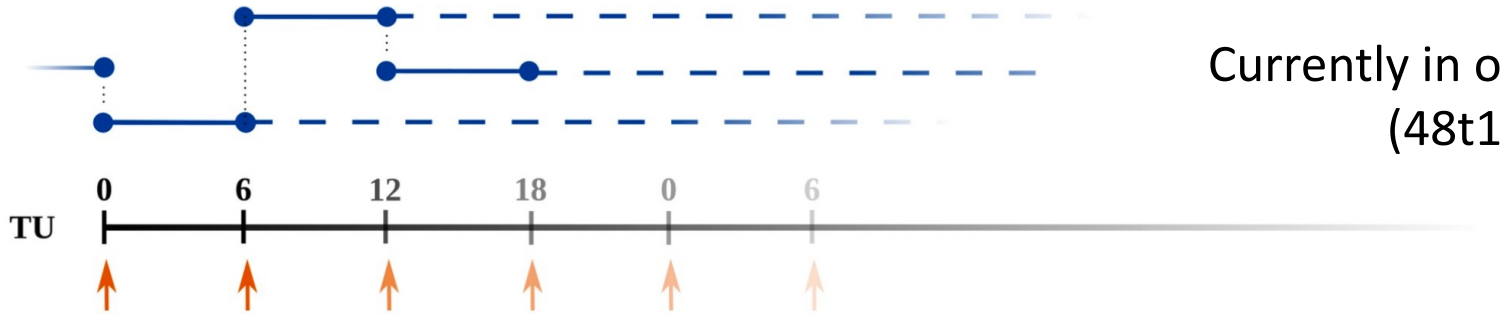


Courtesy F. Bouyssel et al.

Introduction of an ocean mixed-layer parameterization

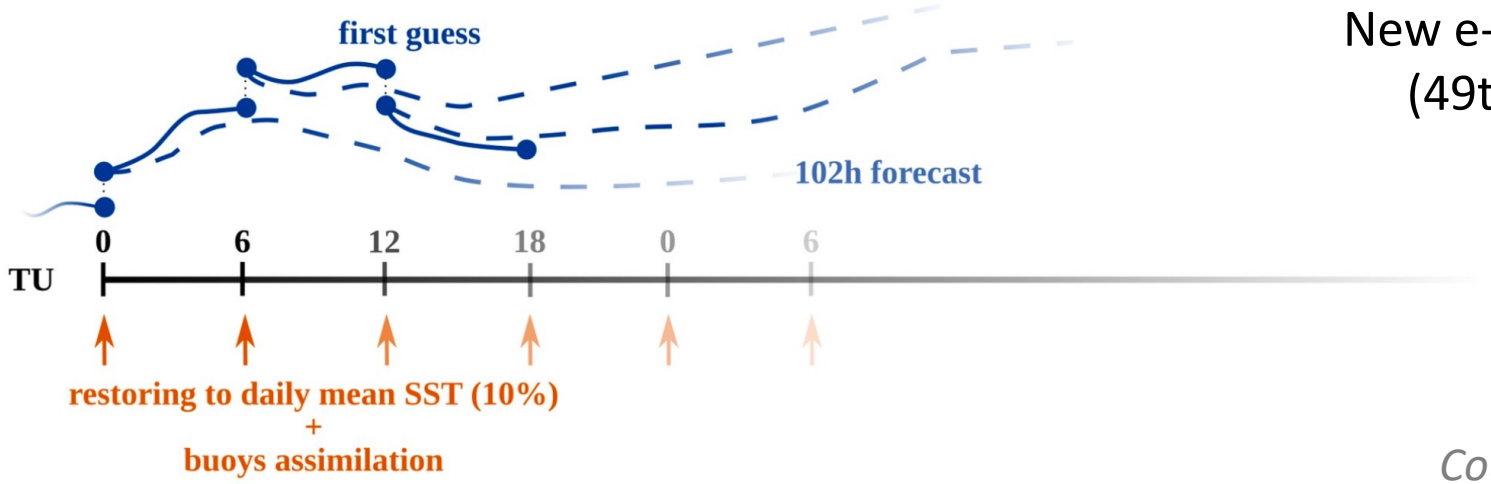
- 1D scheme from Gaspard et al. (1990) with further developments for diapycnal mixing (see Masson et al. 2013)
- Prognostic equations for TKE, temperature, salinity and momentum.
- Mixing length from Bougeault and Lacarrère (1989)
- Restoring to daily mean SST, assimilation of buoy data

Sea Surface Temperature



Currently in operation
(48t1)

Sea Surface Temperature



New e-suite
(49t1)

Courtesy A. Napoly and C. Labadie

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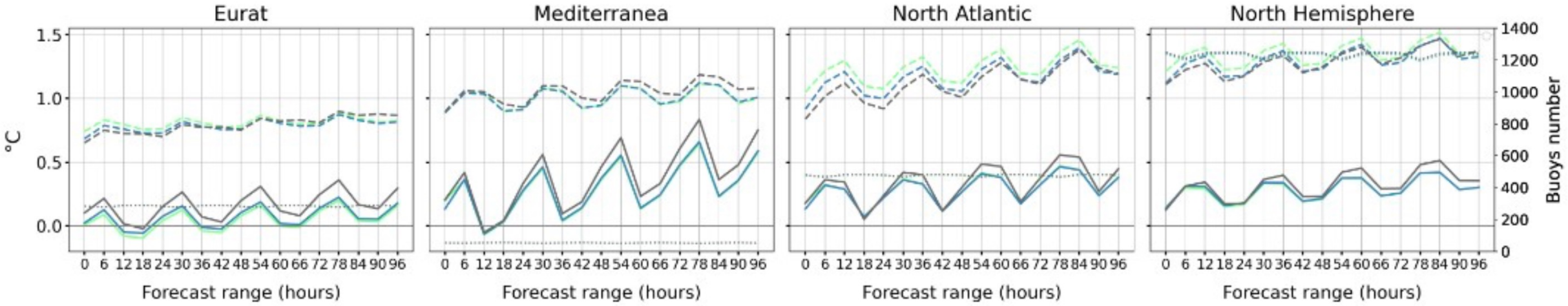
SST Bias and RMSE as a function of forecast lead time – September 2022



Reference
OML only
OML + buoys assimilation

——— Bias
- - - - - RMSE
..... Number of buoys

Courtesy A. Napoly and C. Labadie

Deep convection in upcoming e-suite?

Introducing convective organisation in the IFS Tiedtke-Bechtold scheme

- Proxy for convective organization M_o :

$$\frac{dM_o}{dt} = c_1\, Evap + c_2\, \overline{w} - \frac{M_o}{\tau}$$

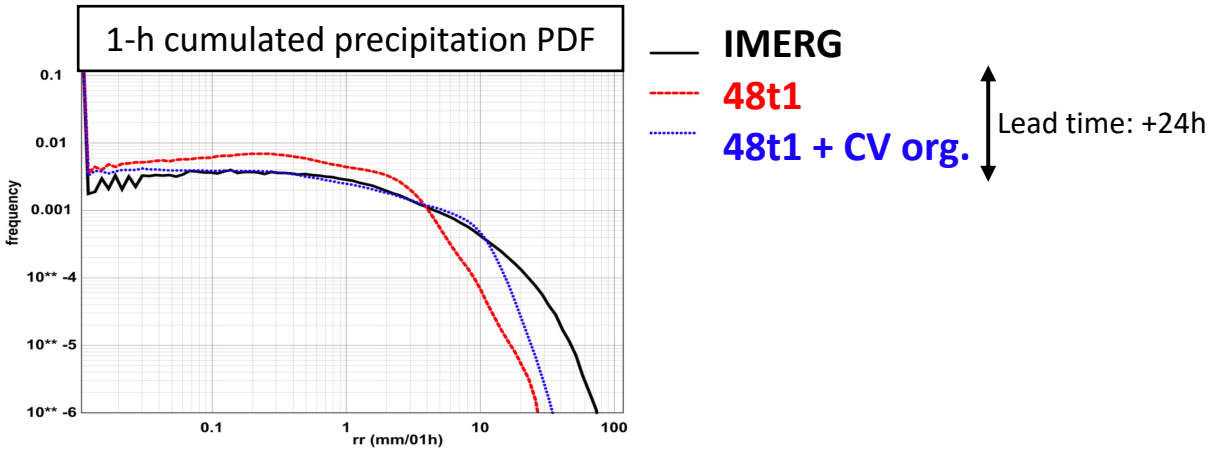
- *Evap* is the evaporation of convective precipitation :

$$Evap = -\frac{\partial RR}{\partial p}$$

- M_o is 3D and advected by the semi-lagrangian advection scheme.
- Entrainment

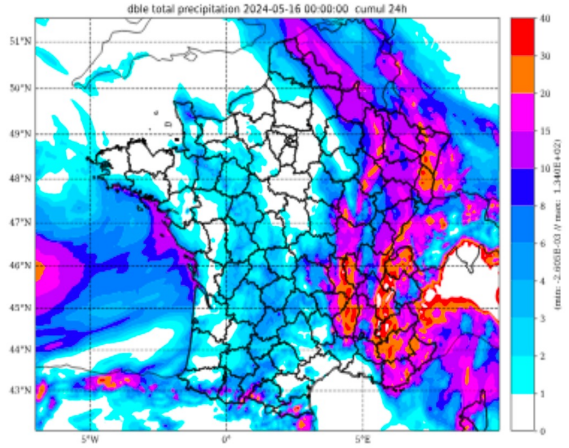
$$E_{up} = \epsilon_{up}\, f_\epsilon\, \frac{M_{up}}{\overline{\rho}}\, (1.3 - RH)\, f_{scale}\, g(M_o)$$

- CAPE consumption time : $\tau = \frac{H}{\overline{w}_{up}}$ is replaced by $\tau = h(M_o)$.

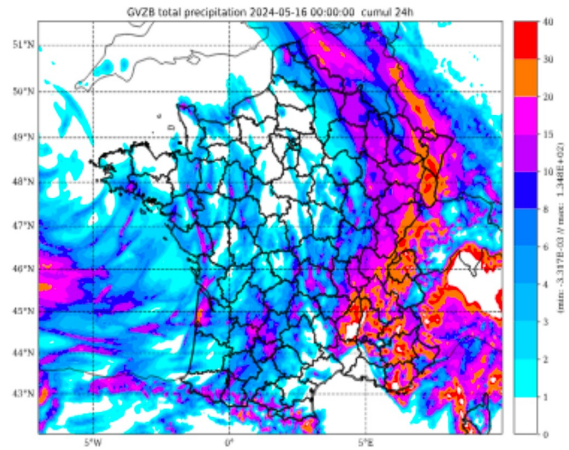


Init: 14 May 2024 / Lead time: +48h
24-h cumulated precipitation

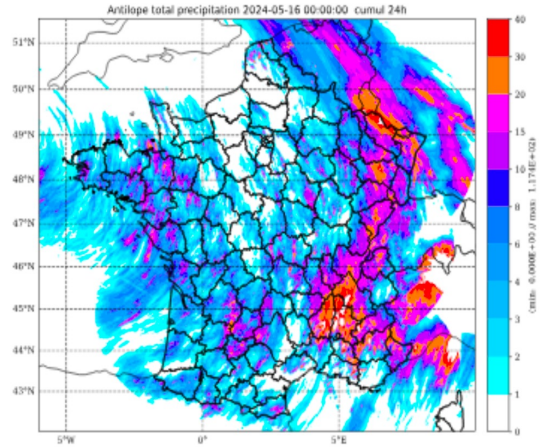
48t1



48t1 + CV org.



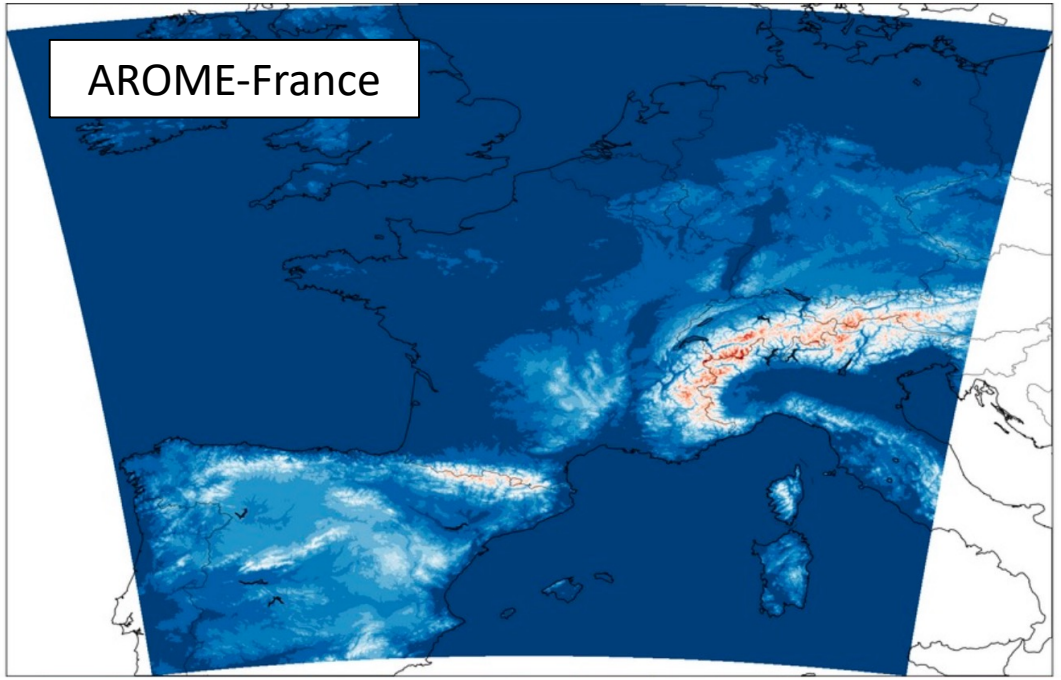
ANTILOPE (Radar)

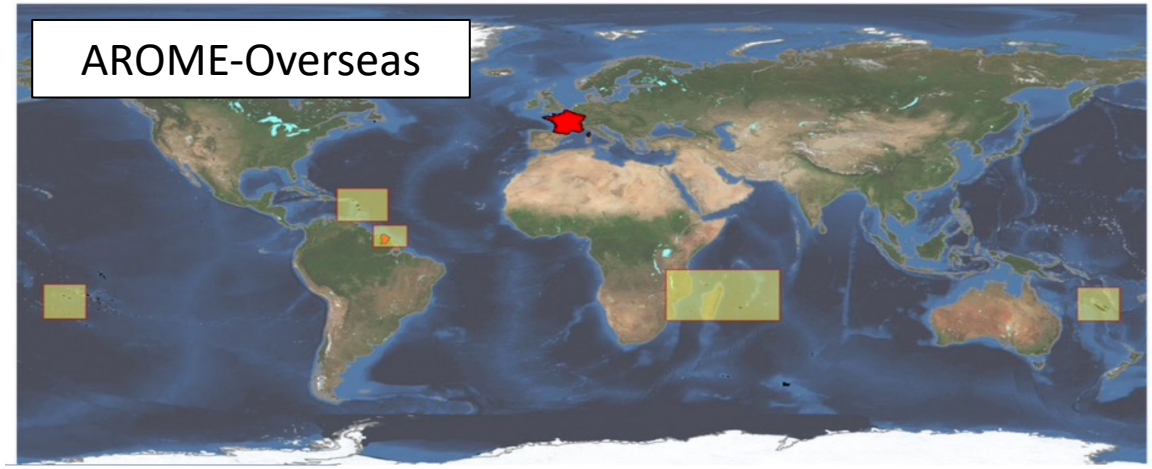


Courtesy J.-M. Piriou et al.

Current e-suite (48t1) – AROME-based regional systems

	Systems	48t1 (October 2024)
AROME-France	AROME-France (deterministic)	1.3km L90 / **3DEnVar** (1h cycle) 8x per day, up to 51h
	AROME-France Nowcasting	1.3km L90 / 3DVar (no cycling – 10' cut-off) 24x per day, up to 6h
	AROME-IFS	1.3km L90 Init/LBC: IFS + AROME-Fr (sfc) 4x per day, up to 51h
	AROME-EDA	3.25km L90 / 25 members 3DVar (3h cycle)
	AROME-EPS	1.3km L90 / **24**+1 members Initial perturbations: AROME-EDA LBC: ARPEGE-EPS 4x per day up to 51h
AROME-Overseas	AROME-Overseas (5 domains)	1.3km L90 Init/LBC: IFS + ARPEGE (sfc) 4x per day, up to 51h
	AROME-EPS Overseas (5 domains)	2.5km L90 / 15 members Init. as AROME-Overseas LBC from ARPEGE-EPS 2x per day, up to 51h
	Various 'on-demand' AROME configuration	2.5km L90 / Several domains ARPEGE dyn. adaptation





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49t1 main updates (in operation late 2026)

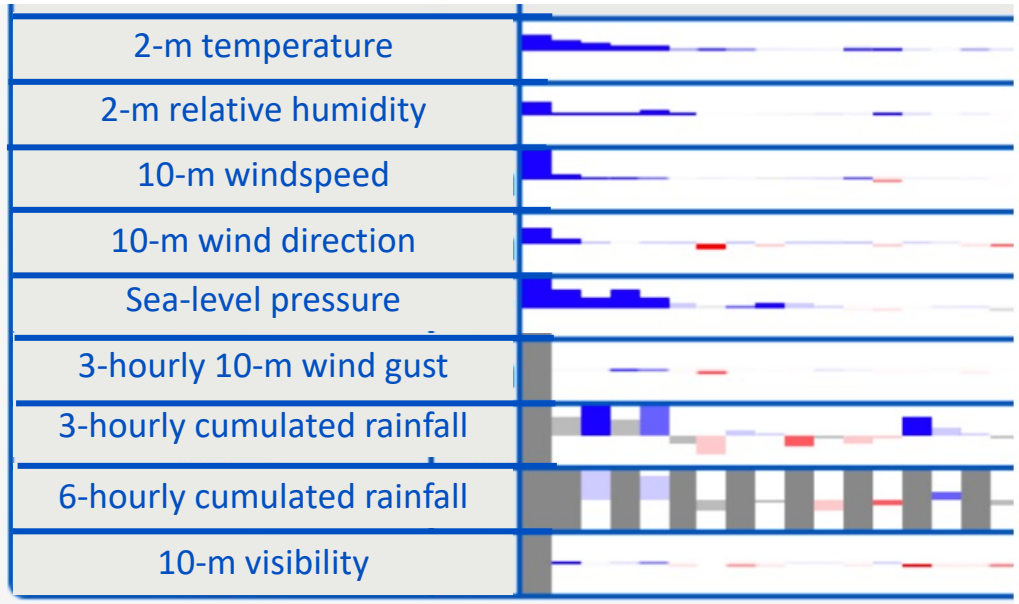
- Physics
  - Parameterization of **hydrometeor deposition** to improve fog forecasting
- Assimilation
  - **4DEnVar** with scale-dependent localization
  - Use of **hydrometeors as control variables** to improve assimilation of Radar reflectivities
  - **AROME-EDA: 3DEnVar / 50 members**
- Ensemble prediction
  - **AROME-EPS: Random Perturbed Parameter (RPP)** for model error representation

Courtesy F. Bouyssel et al.

New e-suite (49t1) – AROME-France

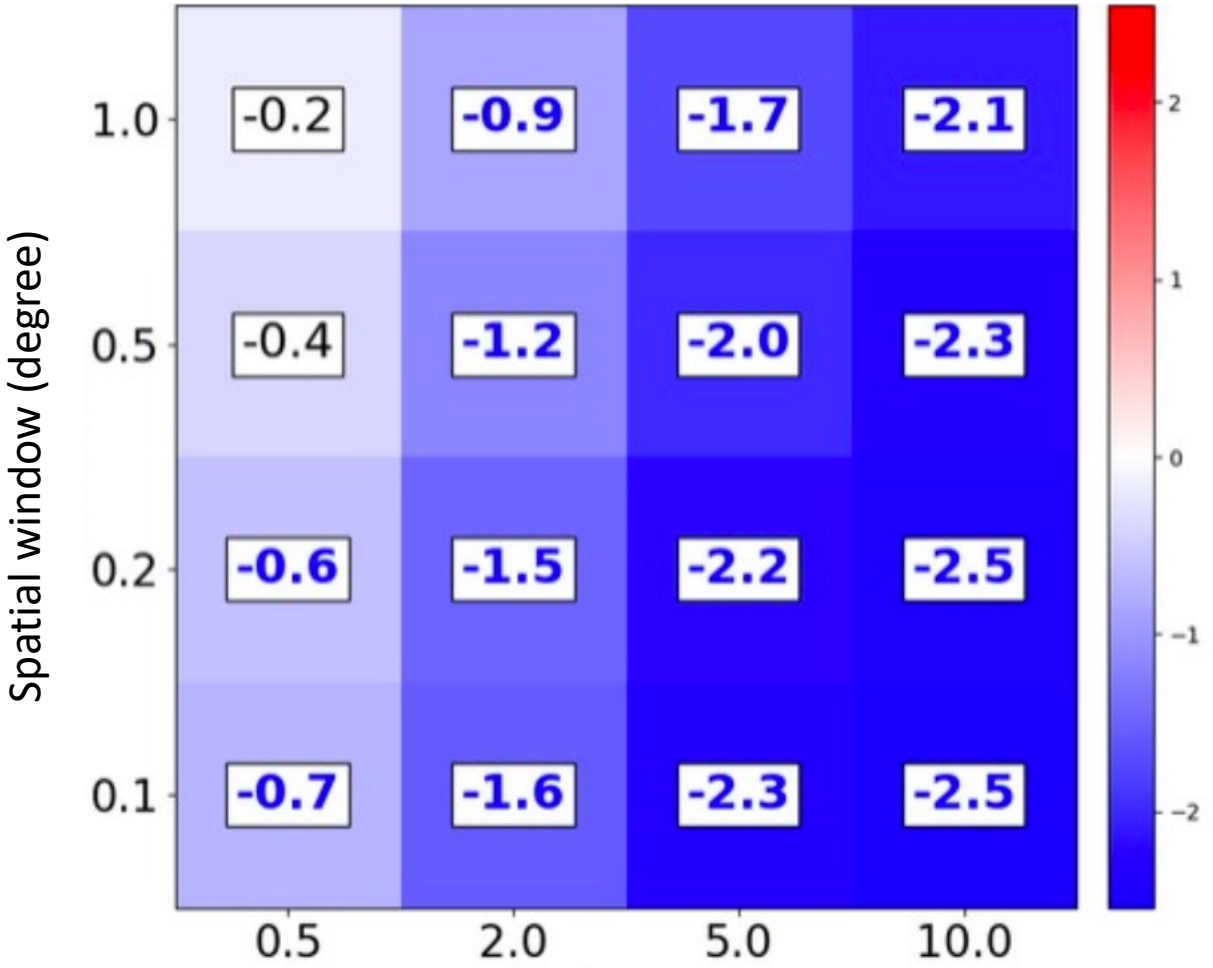
Normalized RMSE difference between 49t1 and 48t1
France domain / Autumn 2024

max: 10%



Lead-time up to 48h

Normalized Fractional Skill Score (FSS) difference between 49t1 and 48t1 – 1-day lead time



Courtesy F. Bouyssel et al.

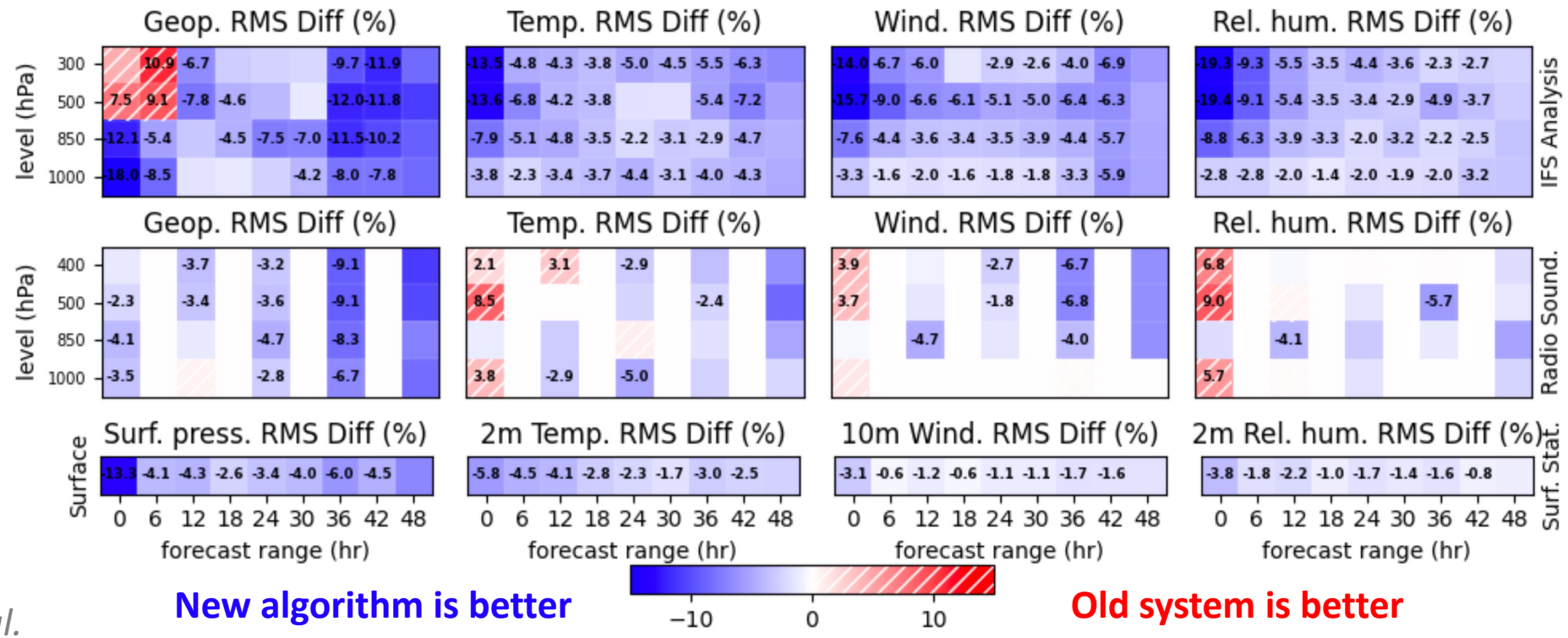
AROME – From 3DEnVar to 4DEnVar with new control variables

Assimilation algorithm evolution

- Since 2024, a 3DEnVar scheme replaces the historical 3DVar scheme : the background error covariances became flow-dependent (computed from the EDA system – Brousseau et al. 2025)

- In the new suite
  - Use **hydrometeors as control variables** to directly assimilate radar reflectivities (instead of converting them into a pseudo-observation of RH)
  - **4DEnVar**: 15-min observations (radar, ground GNSS, SEVIRI, surface stations), 1-hour window

Normalized RMSE difference
France domain



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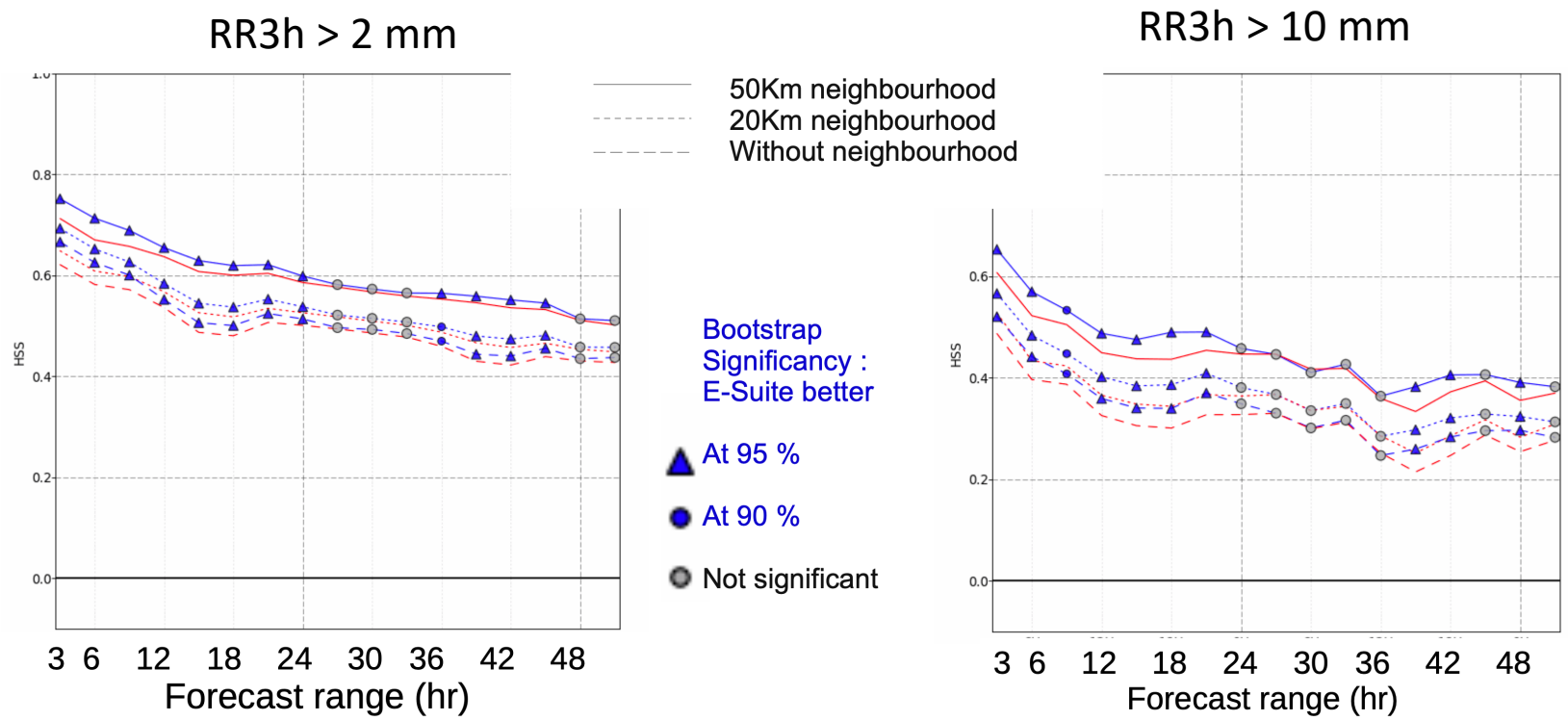
Heidke Skill Score (HSS)
3-hourly cumulated rainfall
France domain
09-2024 to 09-2025

New algorithm

Old system

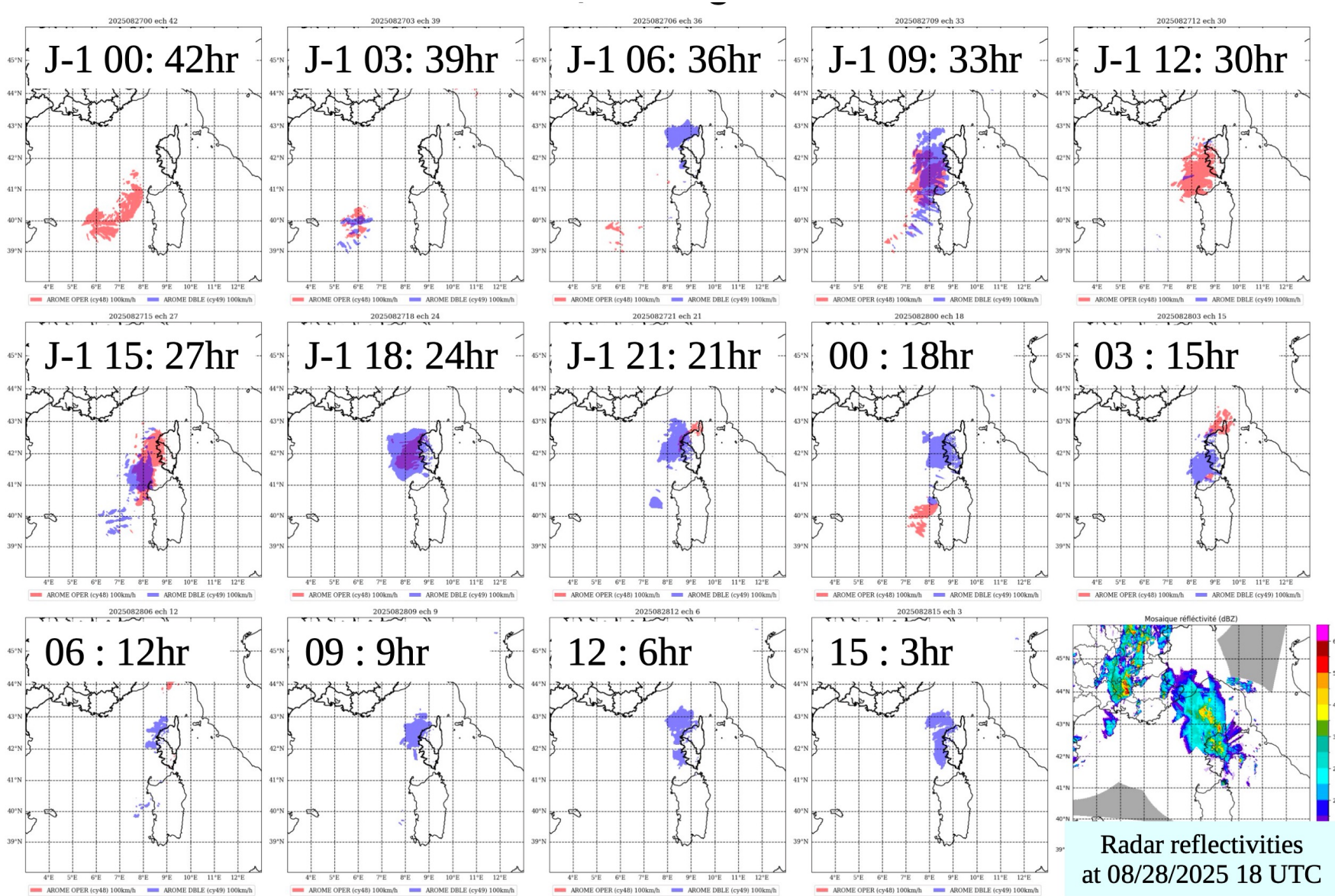


Courtesy P. Brousseau et al.

AROME – From 3DEnVar to 4DEnVar with new control variables

Corsica, 28 August 2025

Wind gust > 100 km/h
All forecast are valid at 18:00 UTC,
28 August 2025



Old system

New algorithm

Radar reflectivities
at 08/28/2025 18 UTC

Courtesy P. Brousseau et al.

Climate model for CMIP7-Science

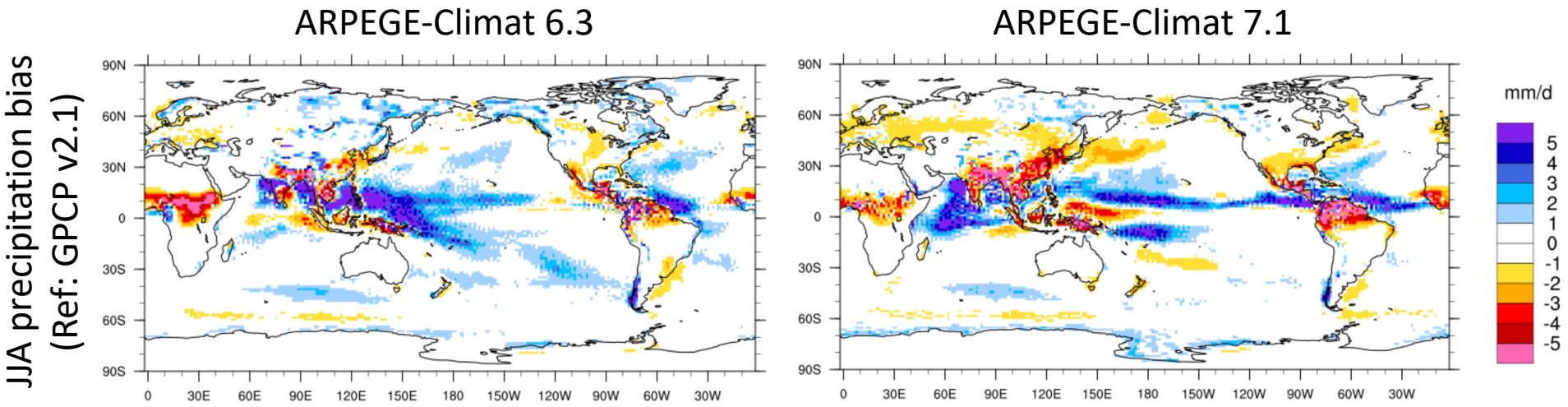
Strategy

➢ Continue adopting the approach of being as seamless as possible with the NWP global system (atmosphere)

CMIP6 : same turbulence, microphysics, different shallow and deep convection, older radiation scheme

So far

- Test of the NWP version in our climate workflow
- Large amount of work to port climate developments in cycle 49t1 (I/O, CMIP6 atmospheric and surface physics, chemistry and aerosols)



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- Large amount of work to port climate developments in cycle 49t1 (I/O, CMIP6 atmospheric and surface physics, chemistry and aerosols)
- Benefit on NWP past work on mixed precision (40% gain)
- Test of NEMO version 4 with the eddy-diffusivity mass-flux scheme of Giordani et al. (2020)

Ongoing

- Assembling of the new model components is starting
- Update of atmospheric physics (latest developments for low clouds, radiation)
- Using the ECMWF cubic truncation with octahedral reduced Gaussian grid (Malardel et al. 2016)
- Improved mass and energy conservation features
- Fine tuning, using semi-automatic tools
- Optimisation (I/O, conservation fixer)
- …

Developing a very low-resolution version of CNRM-CM6

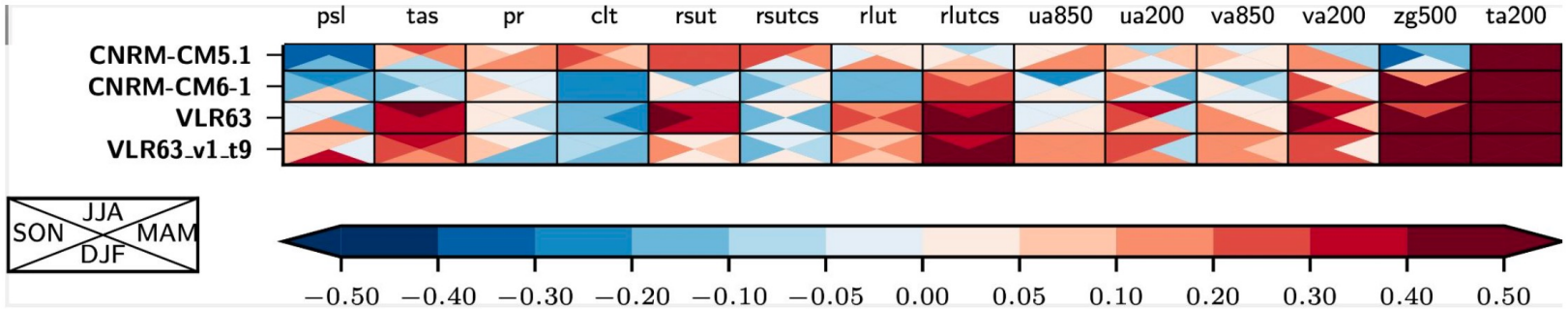
Objective

➢ Develop a low-cost version of CNRM-CM6 (> 100 SYPD) with the same complexity and of similar quality to be able to analyse and enhance calibration techniques, assess transition-to-equilibrium and associated acceleration techniques, and study modelling uncertainties (e.g., PPEs).

Approach

- Reduced horizontal and vertical resolution in all components
  - T127L91 / ORCA1L75 -> T63L60 / ORCA2L31
- Optimized river routing scheme (time step, coupling)
- Further optimisation in the atmospheric component (mass conservation, I/O, time step, radiation time step)
- Ocean-atmosphere coupling time step (1h -> 4h)
- Workflow optimisation

Gleckler's portrait plot (vs. CMIP5 model ensemble) – AMIP



Better than median model Worse than median model

A. Voldoire, R. Roehrig, R. Seguy

FRANCE 2030 PROGRAMME DE RECHERCHE CLIMAT

OptimESM
Optimal high resolution **Earth System Models** for exploring future climate change

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Ongoing

- Further calibration for the atmosphere, improved spin-up of land snow/ice (esp. ice sheets)
- AMOC issue -> testing a revised distribution of river runoff over the Arctic
- Long-term drift in the ocean being currently analysed.

A. Voldoire, R. Roehrig, R. Seguy

FRANCE 2030 PROGRAMME DE RECHERCHE CLIMAT

OptimESM
Optimal high resolution **Earth System Models** for exploring future climate change

Summary

- **Selective emphasis** on recent research activities at Météo-France

- The latest version of the MF NWP systems in operations since 14 October 2024
- **Update currently being tested, foreseen in operation late 2026**
- Will be the **latest e-suite on our current HPC**. New HPC to be implemented in 2027, still uncertain architecture.

- Other **MF NWP activities** include
  - Developments on **the low-cloud and microphysical parameterizations** (mixed phase, secondary ice production, from 1 to 2 moments)
  - Further assess the feasibility and added value of **very high resolutions** (km-scale global, hm-scale regional)
    >> cf. Sylvie Malardel's talk on Thursday afternoon
  - Continue developing a **regional system with more Earth system components** (AROBASE)
  - Preparing the model for GPU (and other accelerators): refactoring the code for source-to-source translation
    >> cf. Sarat's HPC/Exascale computing update
  - Increasing activities on **IA for NWP operations**, including online correction
    >> cf. Inna's bias correction review and Corentin Seznec's talk on Thursday afternoon

- Other **MF Climate activities** include preparing the CNRM contribution to the **AR7 Fast Track**
  - Same system as CMIP6, with a slight update for emission-driven capability
    >> ready to launch simulations (owing to the availability of forcings and data request)