RÉPUBLIQUE FRANÇAISE
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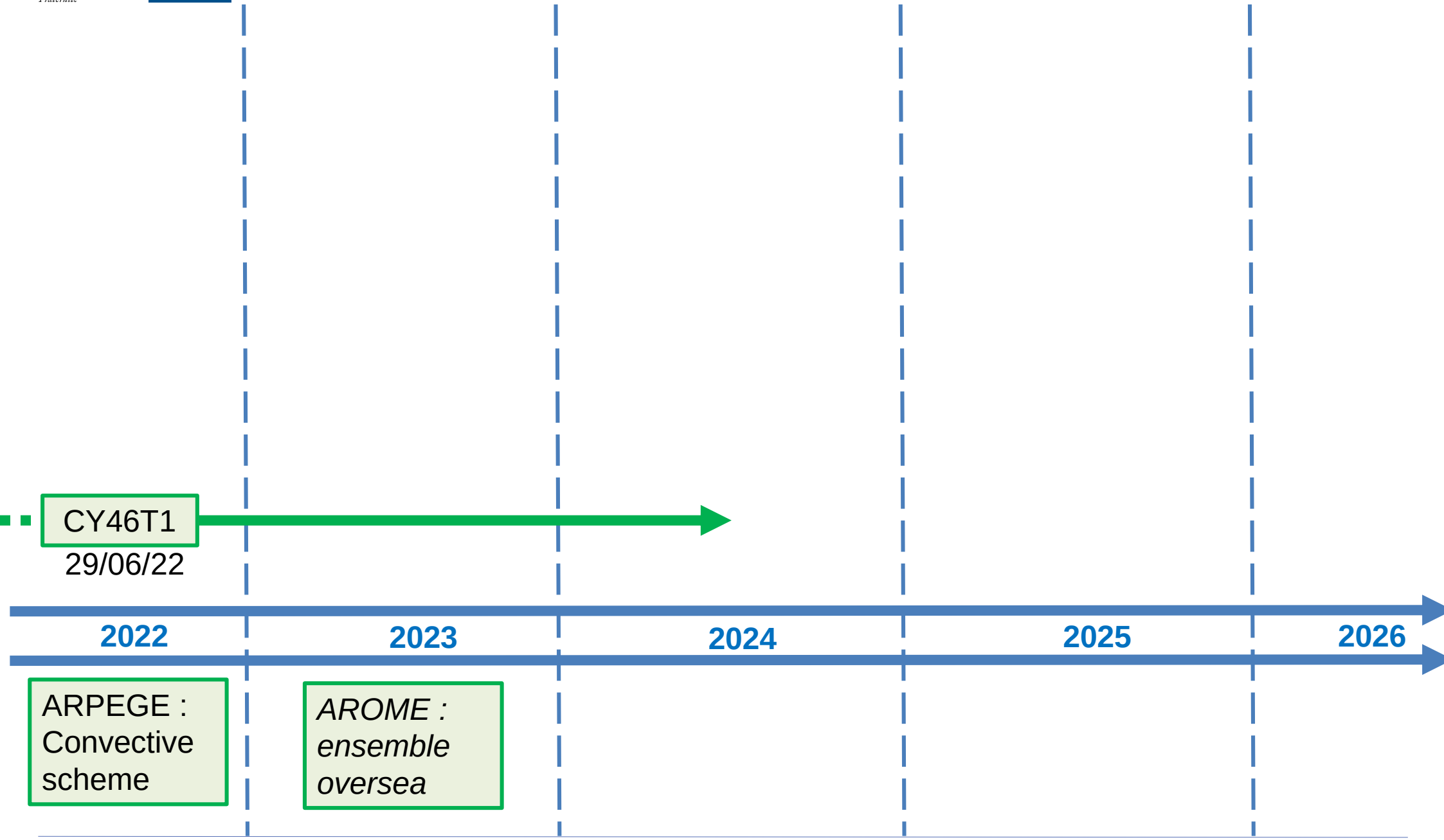
METEO FRANCE

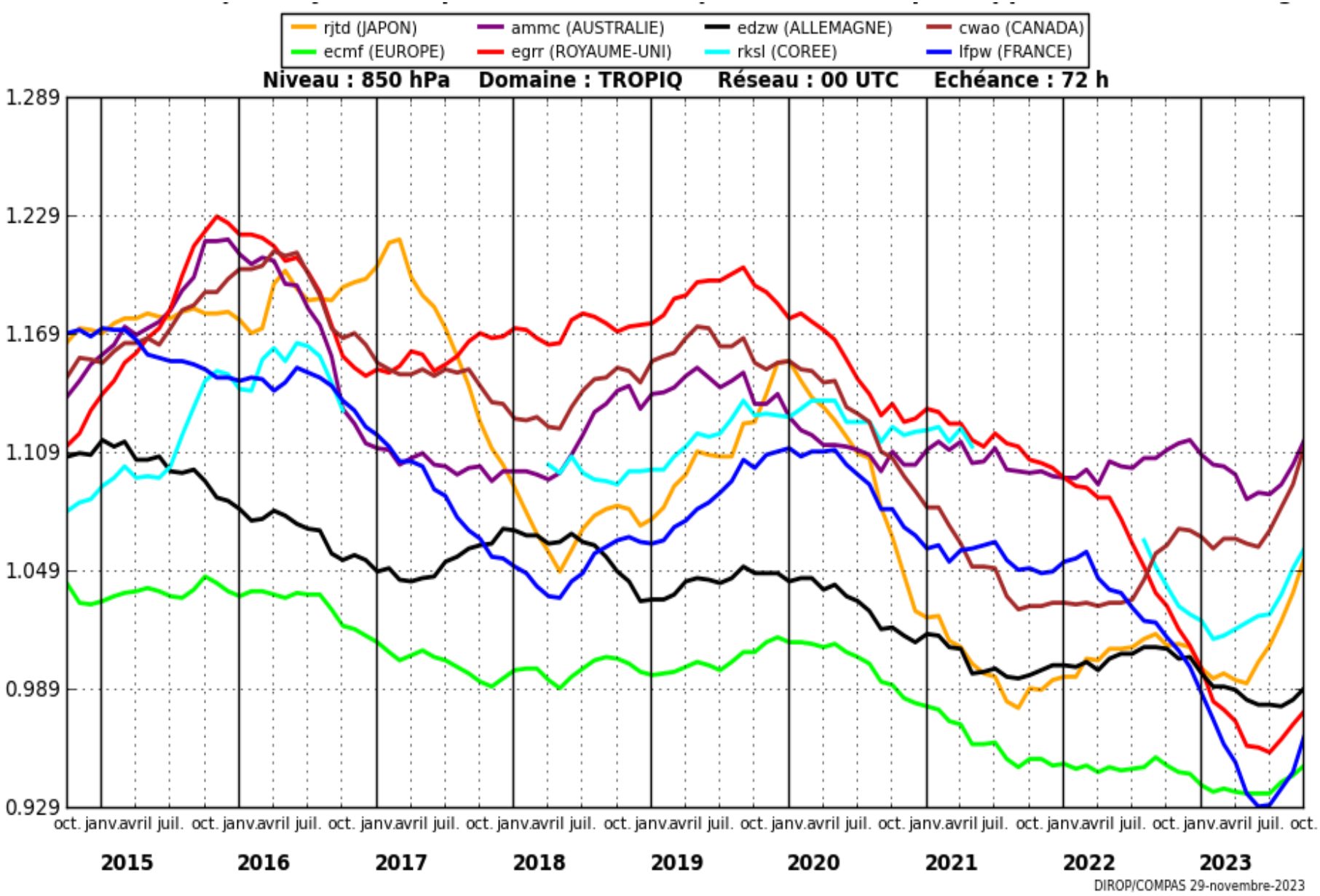
Progress and plans of E-suites at Météo-France

ACCORD General Assembly, 04/12/2023

Overview of next NWP suites



• ARPEGE: T850hPa RMSE against RS in the Tropics (20° S-20° N) at 72h lead time



A new NWP instance: AROME-Overseas EPS

Généralities

5 domains, same as deterministic ones

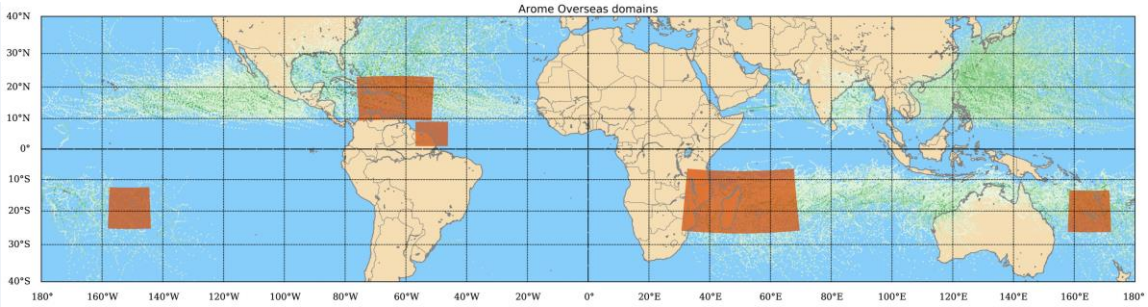
15+1 members at 2.5 km, simple precision, hydrostatic

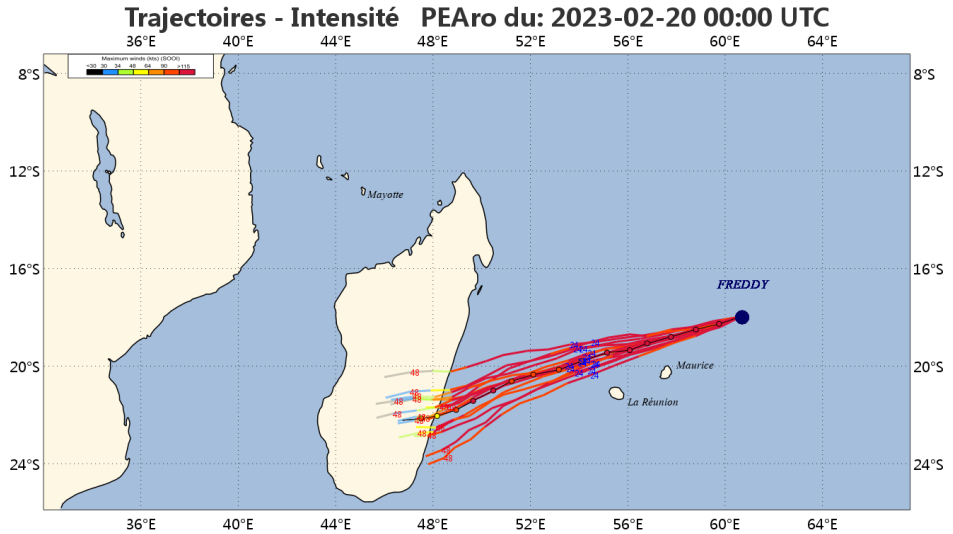
Initial conditions (unperturbed) : same as deterministic (IFS)

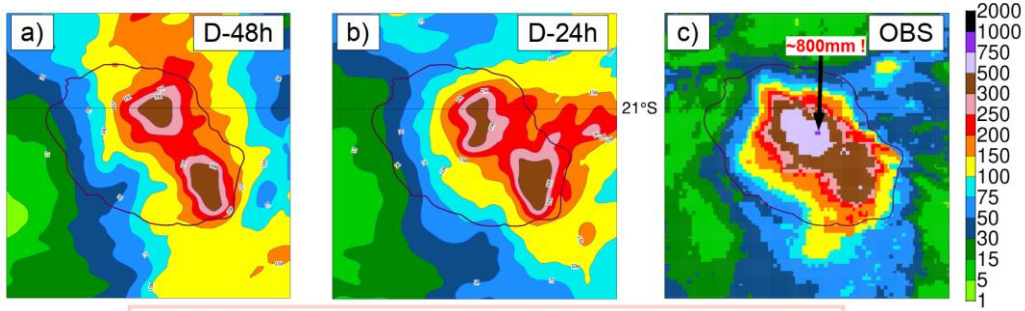
Boundary conditions + initial perturbations : ARPEGE-EPS

Perturbation of surface + ocean layers

2 runs a day

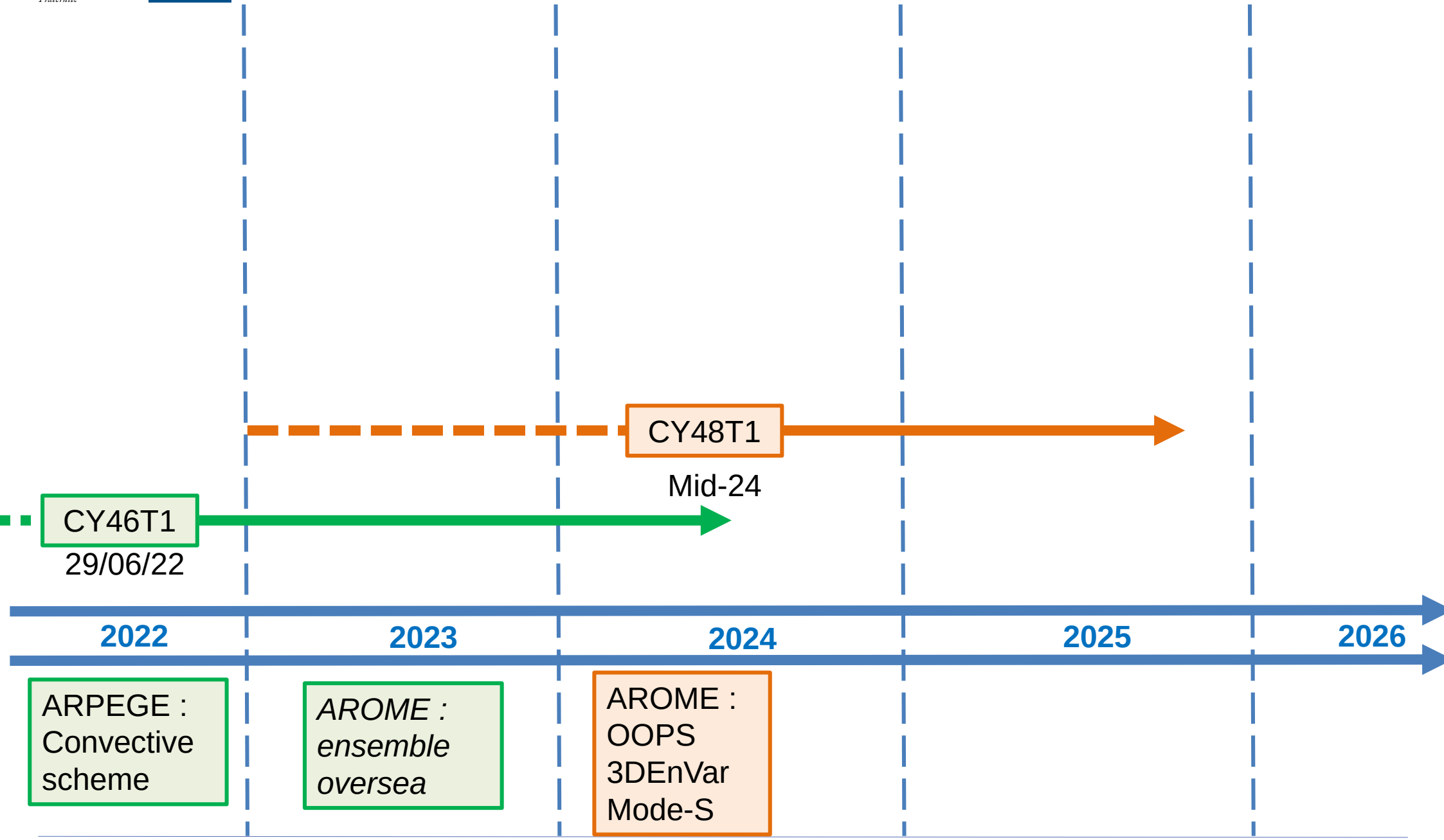






*24h- accumulated surface precipitation of the upper 10th percentile from Arome-OM EPS valid for the 03/04 at 18:00 UTC : **a)** starting at 18:00 UTC on 31/03 and **b)** starting at 18:00 UTC on 01/04, respectively. Panel **c)** shows the corresponding estimation from radar observations.*

Overview of next NWP suites



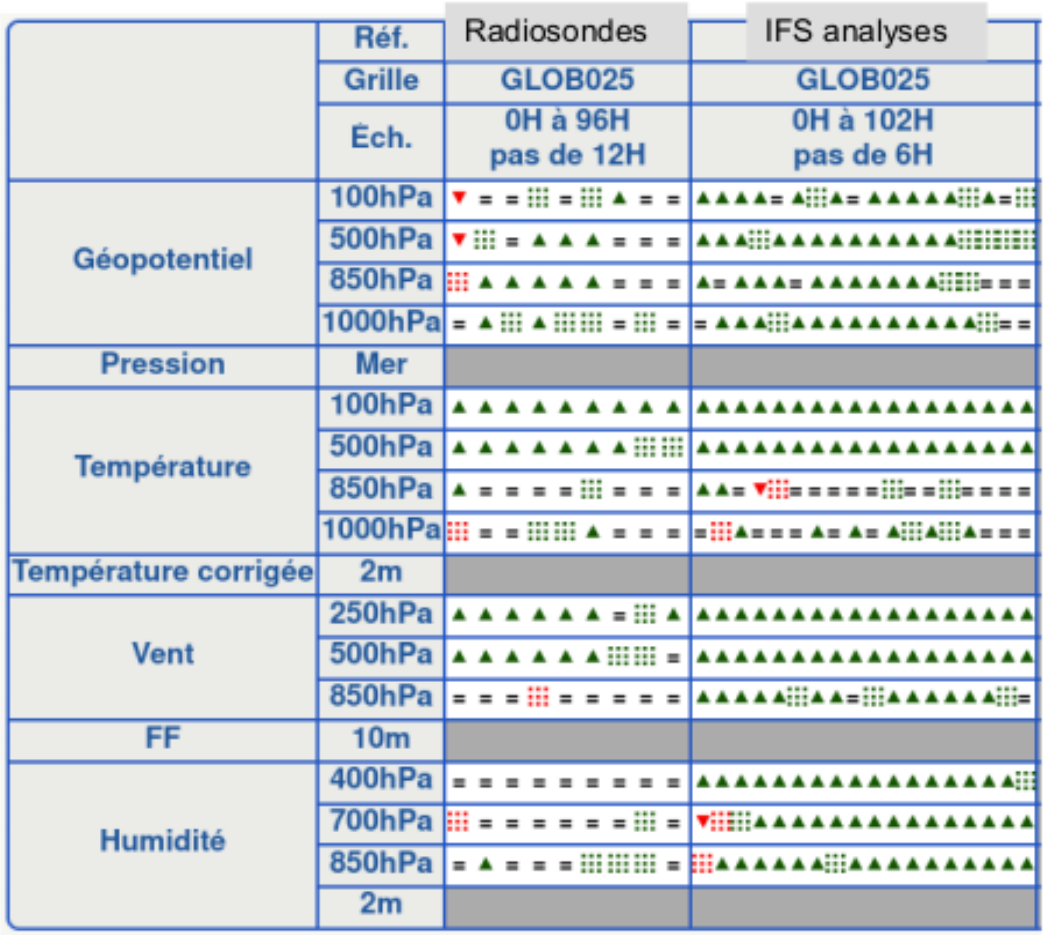
48t1 ARPEGE e-suite

- Implement of assimilation schemes (ARPEGE, EDA) under **OOPS** (Object-oriented layer)
- **Hybrid 4DVAR** : 3D anisotropic covariances from ARPEGE-EDA
- ARPEGE-EDA : addition of a control unperturbed member
- **Direct assimilation of microwave radiances in « all-sky » conditions**
- Assimilation of **GNSS-RO data from SPIRE, GRACE-C, Sentinel-6**
- Variational debiasing of aircraft data
- **Update of the « Tiedtke Bechtold » deep convection scheme**
- WENO interpolations in the stratosphere (T and q)
- **Radiation : EcRad with McIca solver**
- Include the effect of solar eclipses on radiation
- SST from Mercator (PSY4 1/12° product, now moving to GLO12)
- ARPEGE-EPS : Removal of some singular vectors (over NH and SH domains)

48t1 ARPEGE e-suite – Scores

Score cards

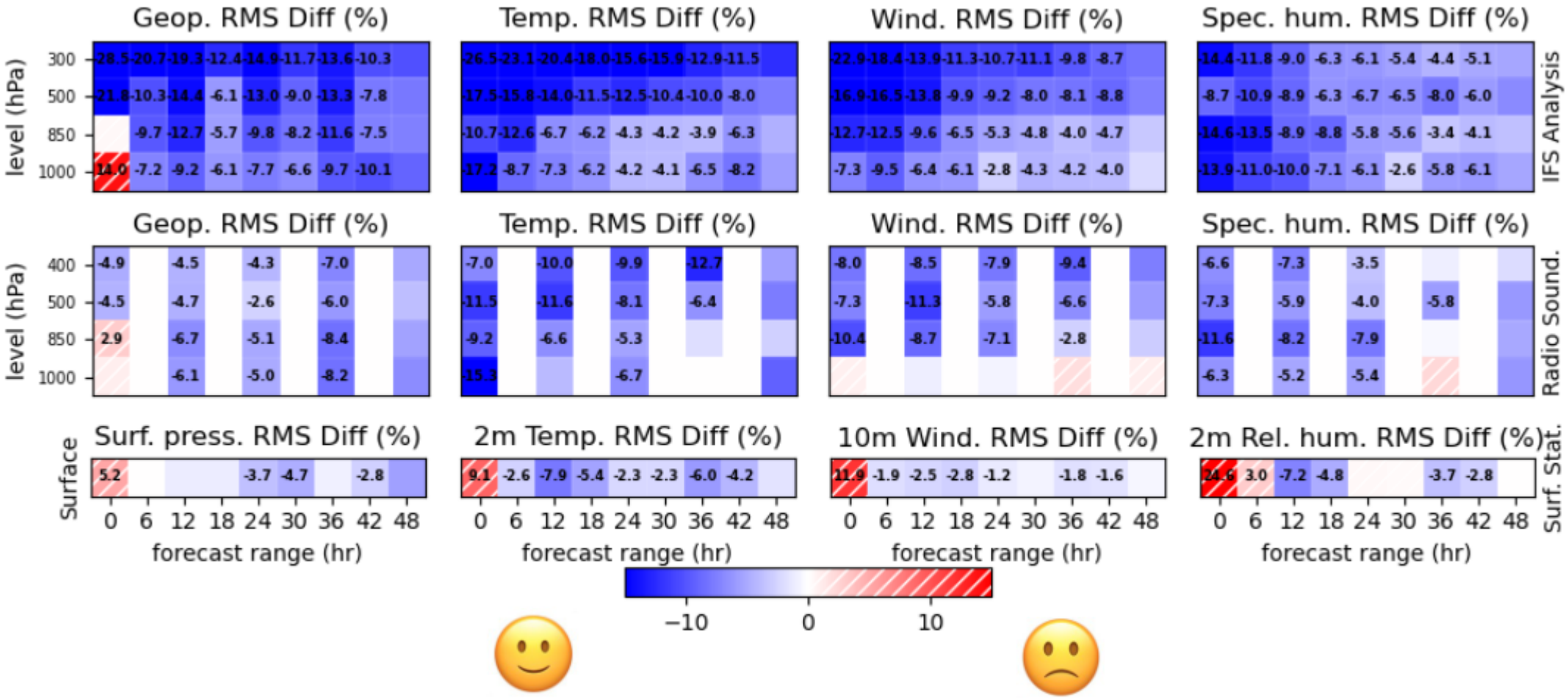
- 48t1 experiment against 46t1 o-suite
- 05/08/2022 → 15/01/2023,
- domain Europe,
- Verification against radiosondes and IFS analyses :



48t1 AROME e-suite

- Implementation of assimilation schemes (3DEnVar, AROME-EDA 3DVAR, AROME-NWC) under **OOPS**
- 3D Ensemble variational scheme « **3DEnVar** », replacing 3DVAR
- Use of Incremental Analysis Update
- AROME-EDA (used for 3DEnVar): **50 members**, longer forecast term
- Direct assimilation of microwave radiances in « all-sky » conditions
- Assimilation of GNSS-RO data from SPIRE, GRACE-C, Sentinel-6
- Assimilation of wind and temperature data derived from **Mode-S**
- Assimilation of wind scatterometer HY-2B and HY-2C
- AROME-NWC : assimilation of MeteoSat/RapidScan radiances
- SST from Mercator (PSY4 1/12° product, now moving to GLO12)
- Radiation : **EcRad** with McIca solver
- Include the effect of solar eclipses on radiation

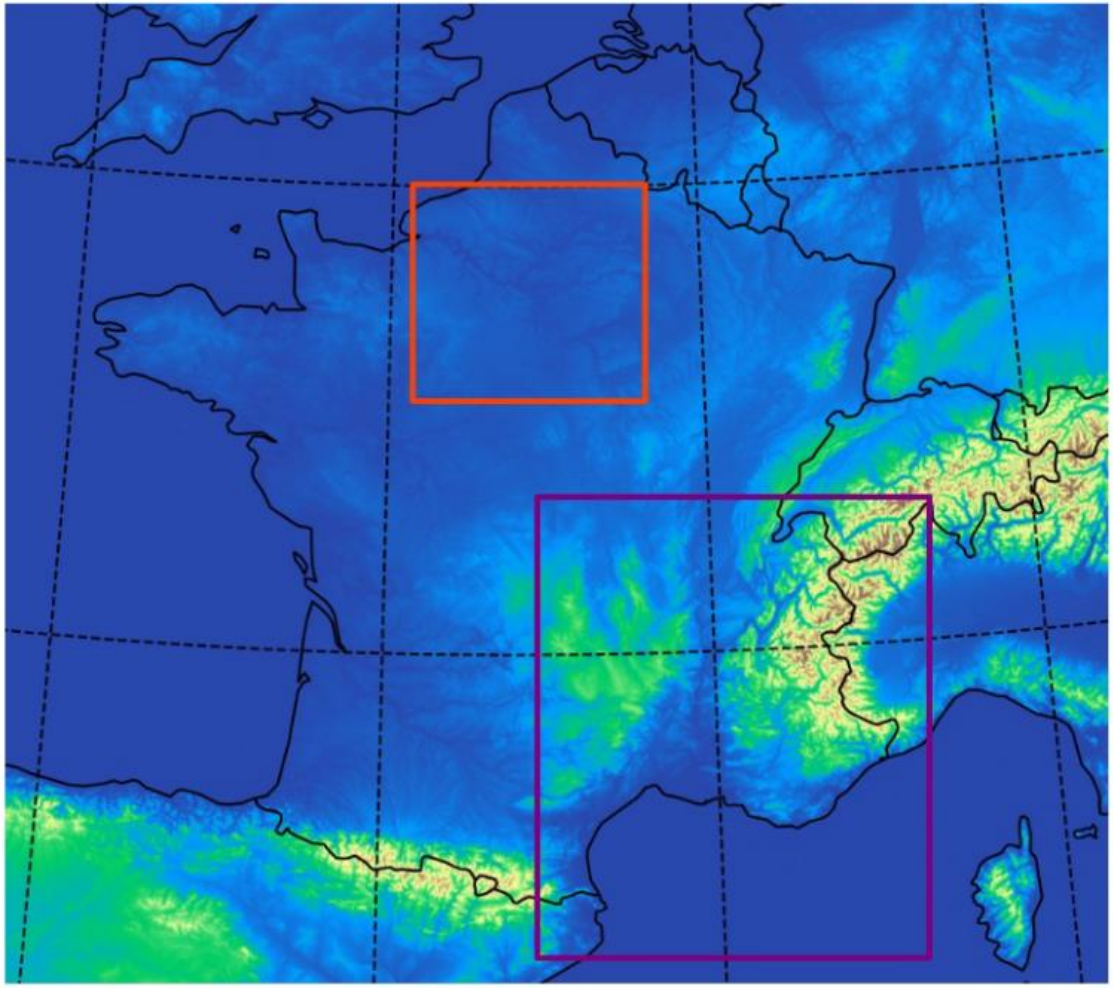
48t1 AROME e-suite – Scores



% of reduction of RMSE
for different parameters over 3 months (30/07/2022-01/11/2022)
(ref = IFS analysis, radiosondes, surface stations)

New NWP systems under development : Arome-500m

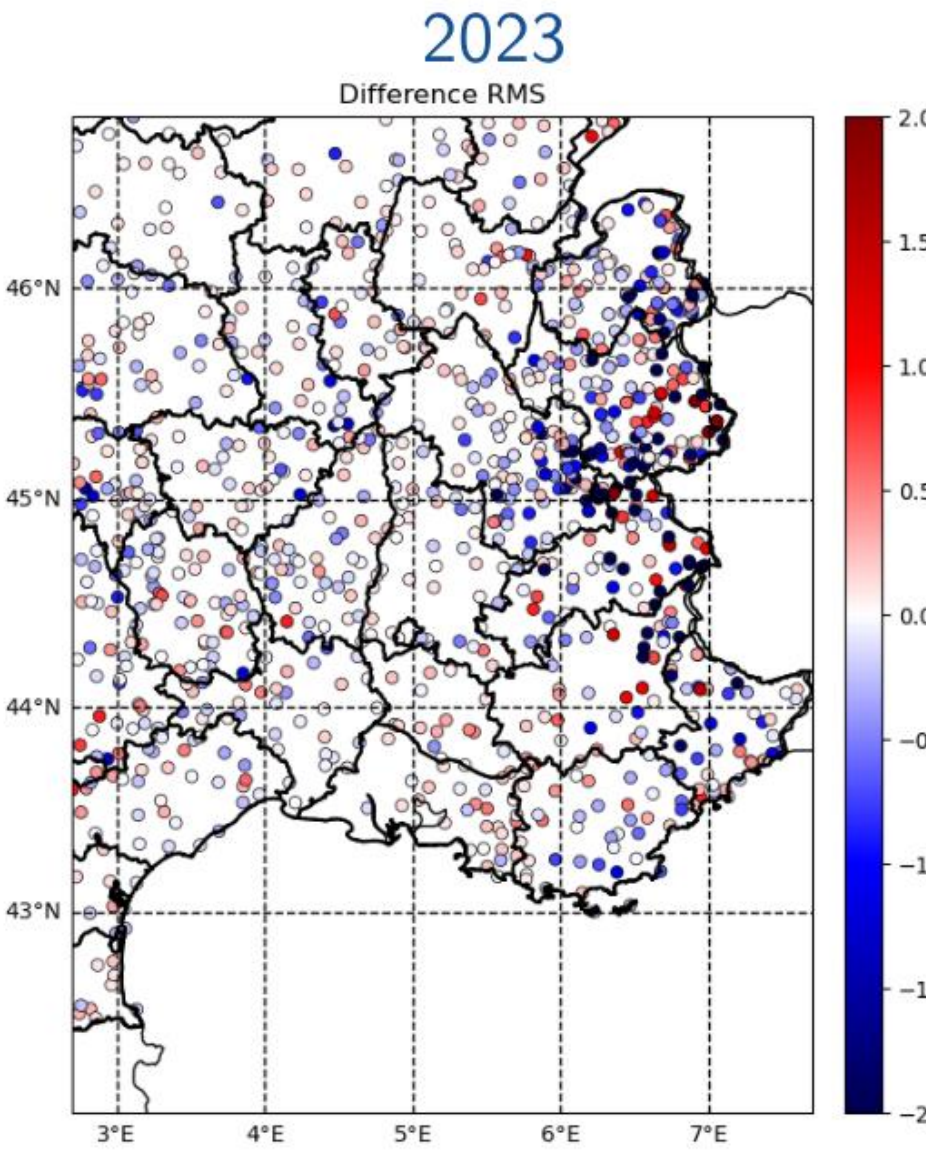
	Paris 250km x 250km	MeditAlpes 480km x 576km
Short range forecast	1P36 (00 UTC) Hourly outputs	1P24 (00 UTC) Hourly outputs
Nowcasting	24P6 Outputs 1/4h	12P6 Outputs 1/4h



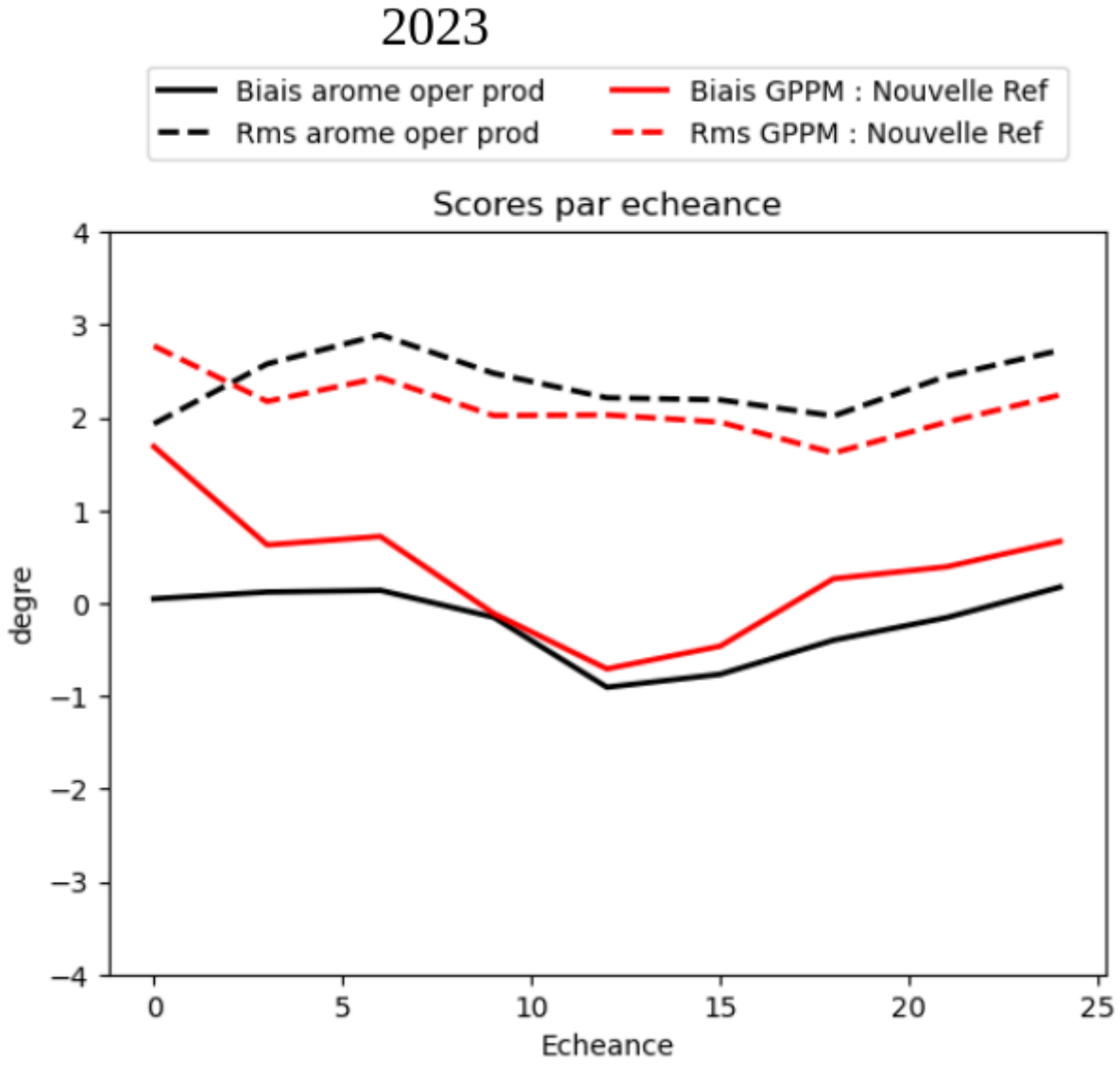
- CY48T1
- Dynamical adaptation of AROME-FR and AROME-PI
- Single precision
- Some spécificities compared with AROME-FR à 1.3km :

120 vertical levels, Dt=30s, LBC 15min, 2 itérations of PC scheme, SRTM-30m, TEB with gardens, Soilgrid (300 m), Ecoclimap-SG (250m), Open Street Map (OSM), etc.

T2m RMSE for February 2023
« AROME 500m » vs « AROME oper »

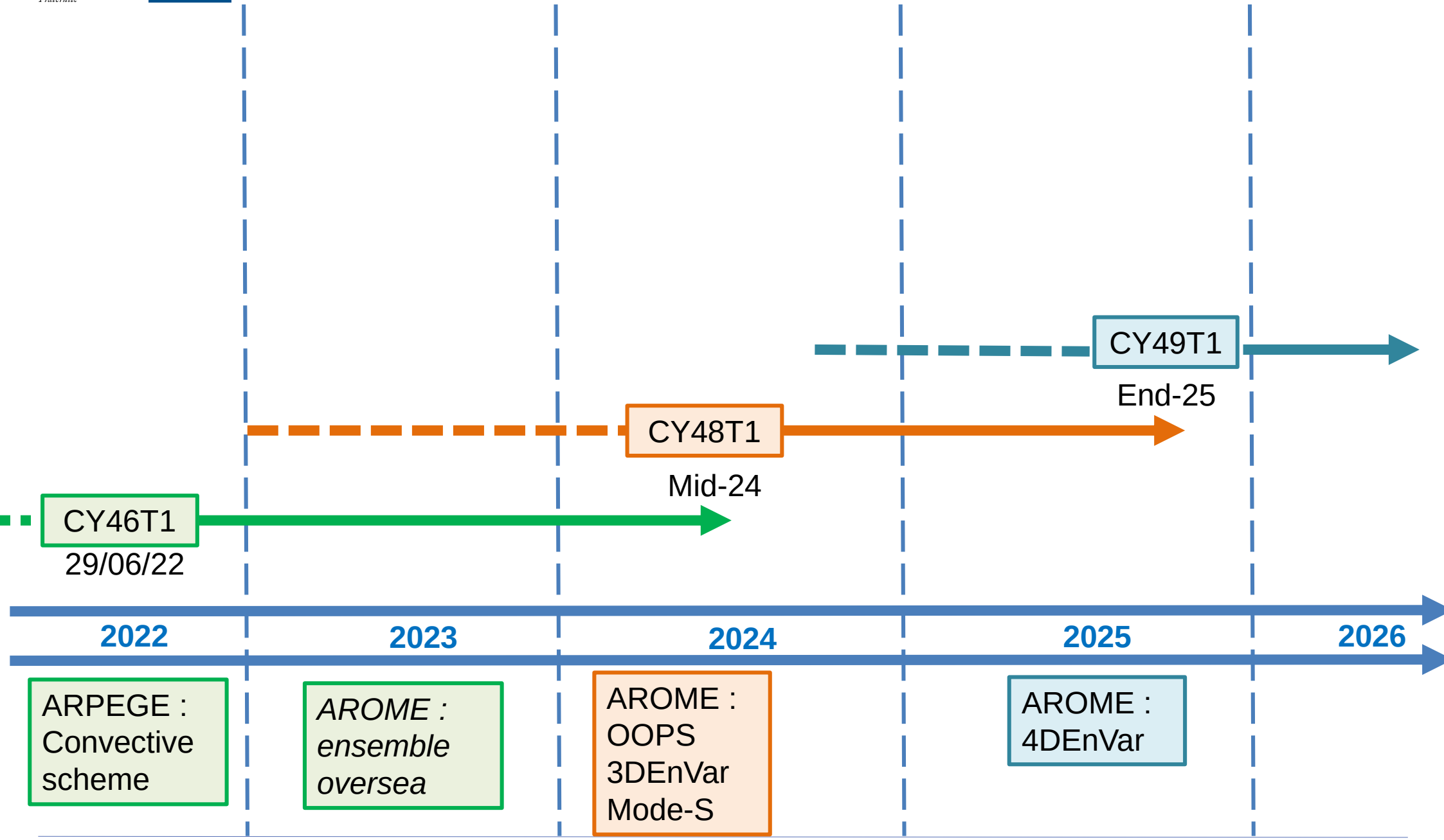


T2m RMSE at 24h lead time from r0



NB : The degradation at 0h lead time is due to interpolation from 1300mL90 to 500mL120

Overview of next NWP suites



Next e-suite content based on CY49T1

- Single precision in ARPEGE and ARPEGE-EPS forecast

- **AROME 4DEnVar**

- **Include hydrometeors in the AROME control variable (in order to enable direct assimilation of radar reflectivity, assimilation of MTG-I/LI)**

- Improved ARPEGE covariances though random perturbed parameters (RPP) in ARPEGE-EDA

- Model perturbations in AROME-EPS

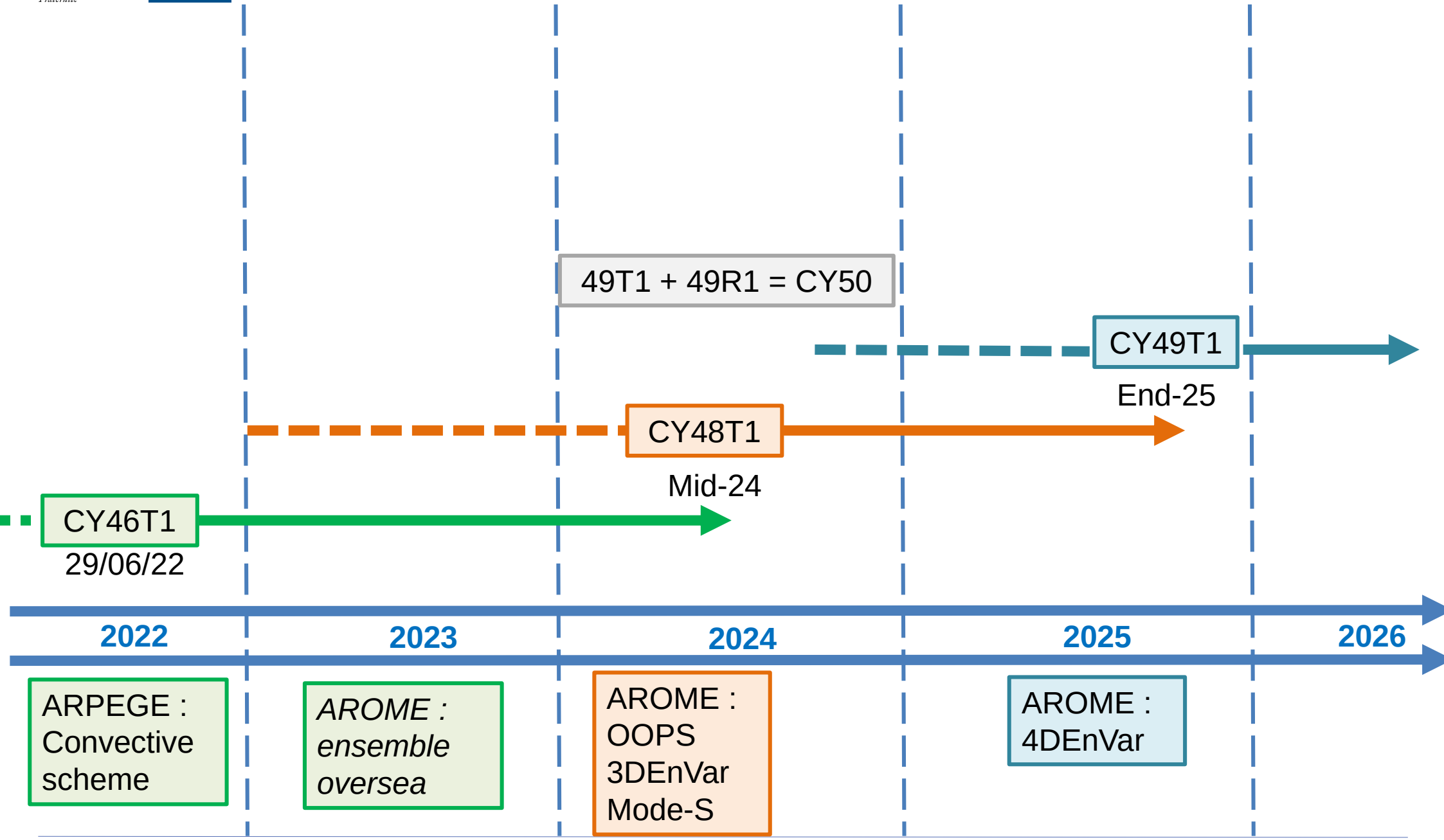
- Assimilation of Mode-S in ARPEGE

- Include Ocean mixed layer coupling in ARPEGE and AROME-FR

- Other technical and scientific evolutions to be confirmed

Preparation from end of 2023 - Beginning of e-suite end of 2024 – In operation end of 2025

Overview of next NWP suites



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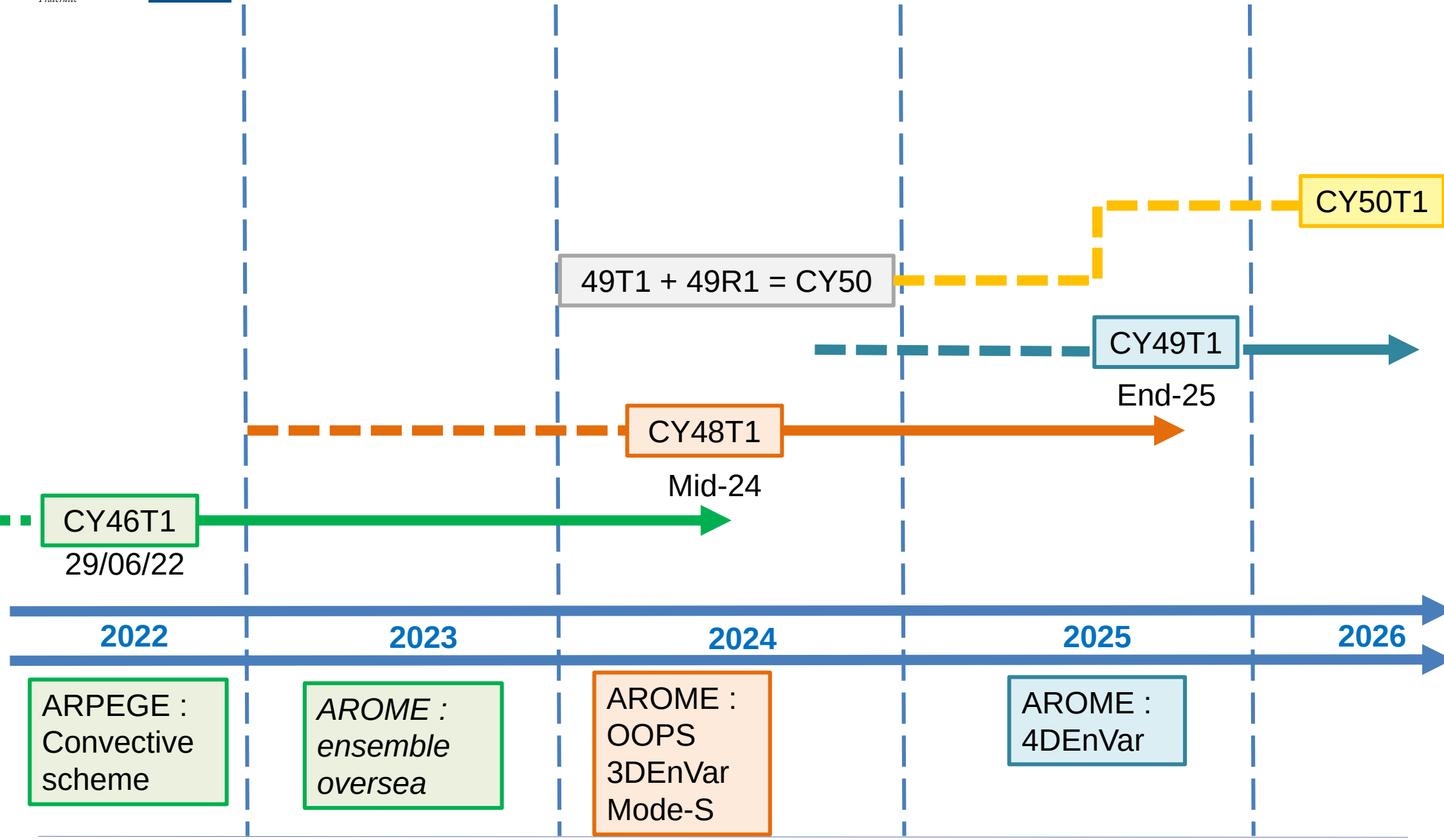

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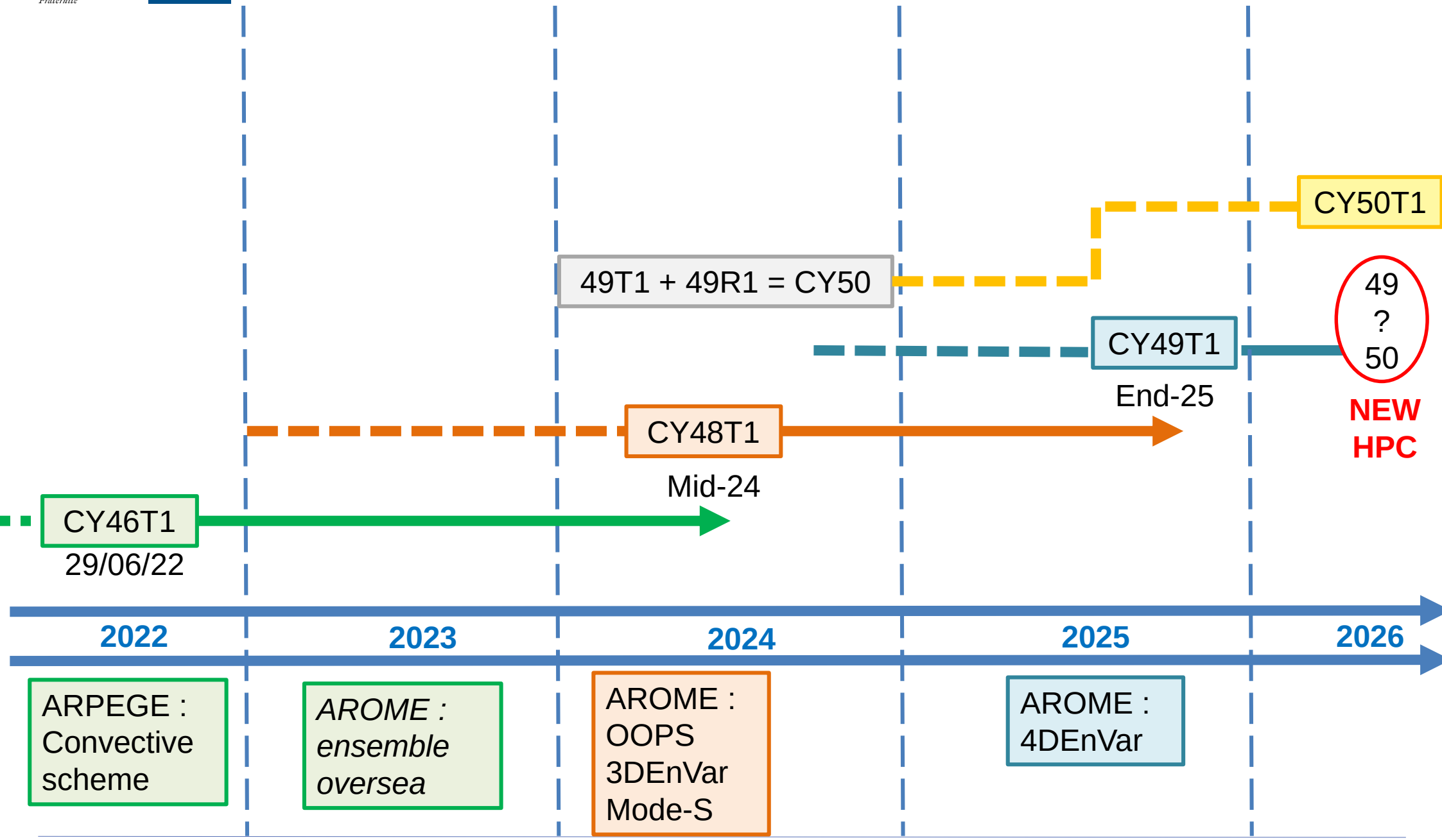
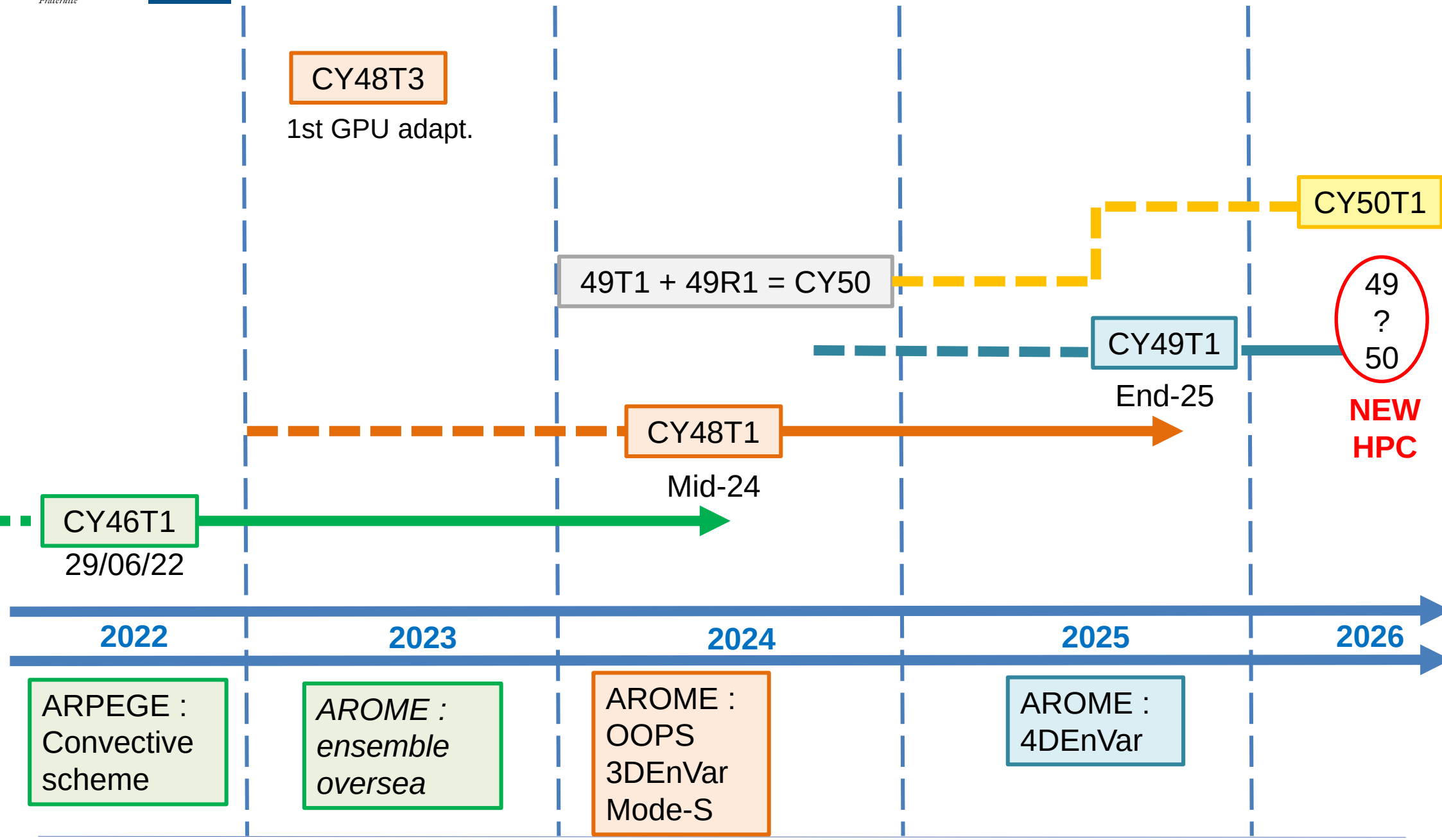


What’s about code adaptation

Overview of next NWP suites



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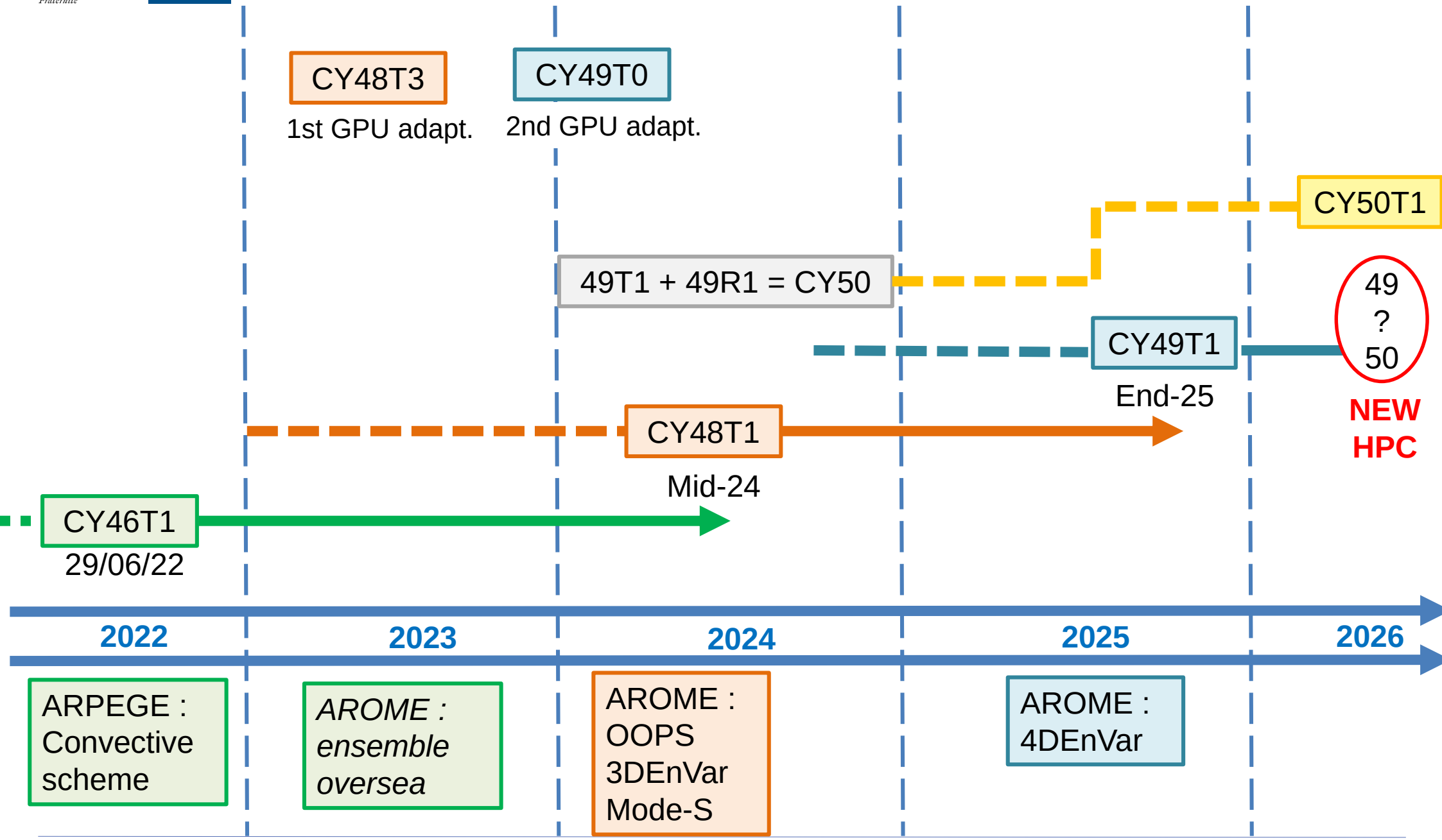

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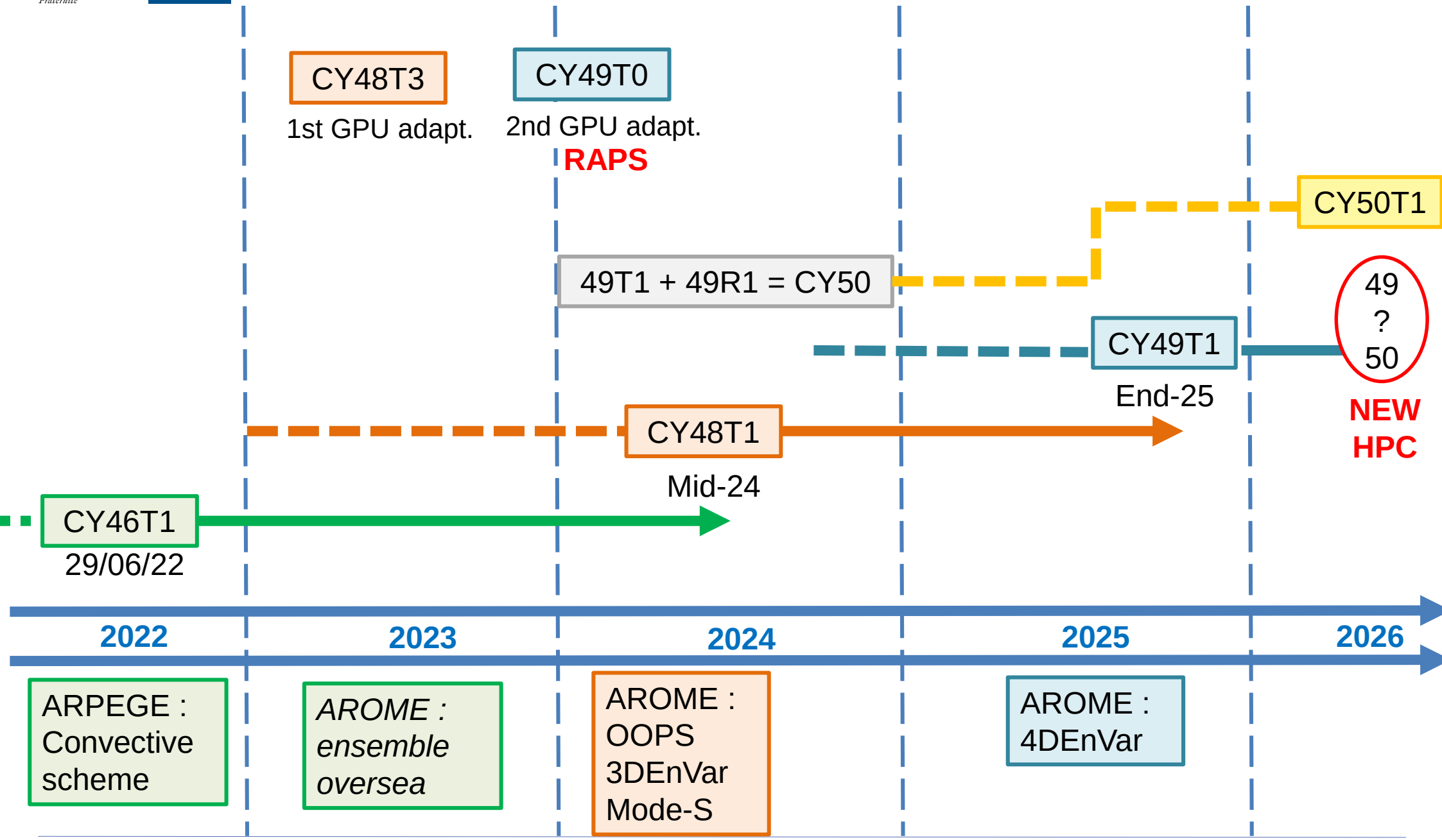

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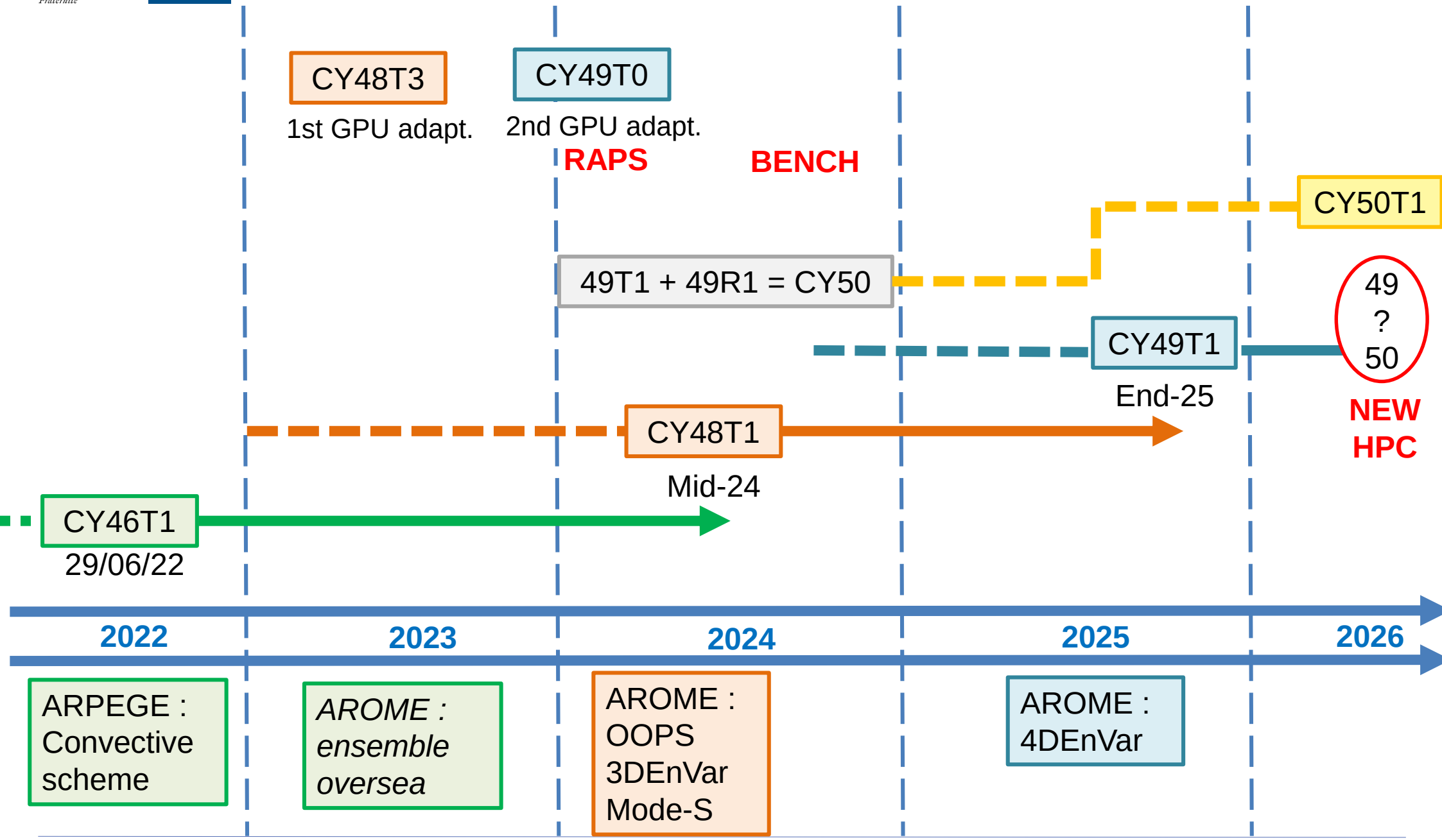

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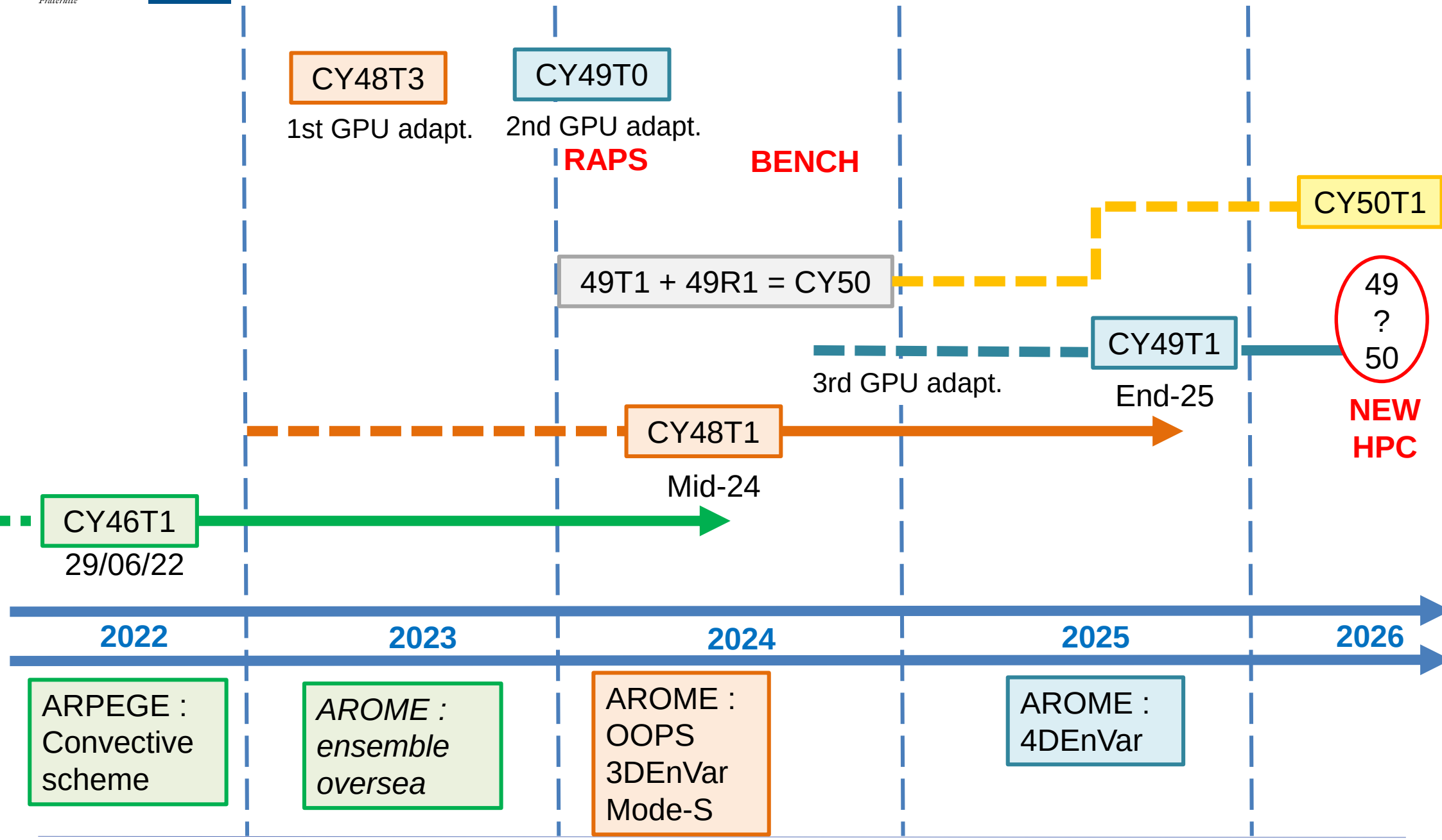

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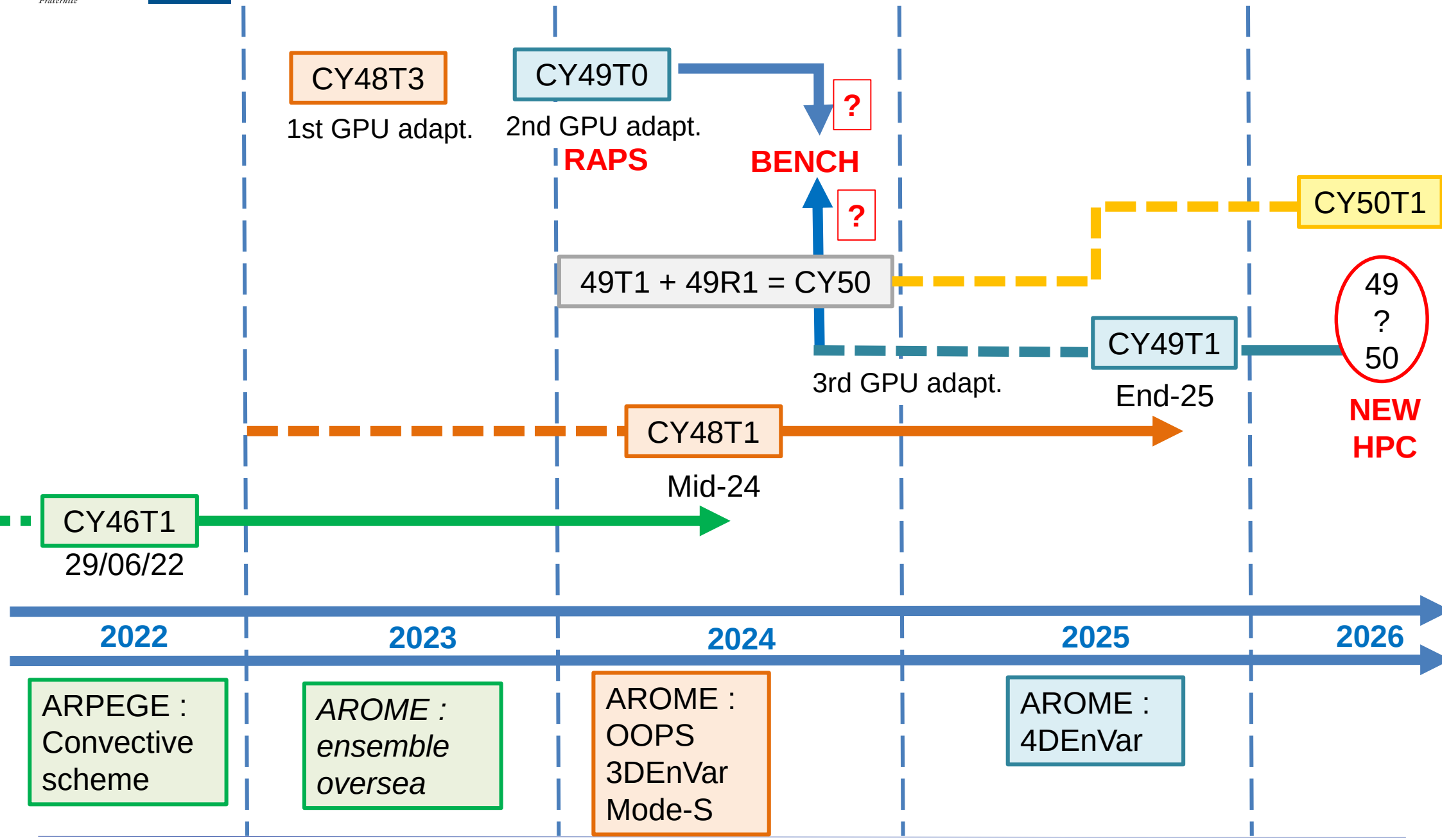


ARPEGE forecast GPU adaptation progress

Component	Method	Status (NVIDIA only)
ARPEGE physics	Field API + transform	Good enough EcRad work in progress at ECMWF
SURFEX	Keep on CPU	
1D dynamics	Field API + transform	Good enough
Semi-Lagrangian calculations	Field API + transform	Refactored, port beginning of 2024
Semi-Lagrangian communications	Refactor + manual	
Semi-Implicit calculations	Refactor + transform	Preliminary study, refactoring
Semi-Implicit communications	Refactor + manual	Refactored
Spectral transforms	Use ectrans	Done by ECMWF, integrating

Done	Not feasible	In progress	Not started

AROME forecast GPU adaptation progress

Most of the work done on ARPEGE for GPU code adaptation done is useful for the LAM GPU code adaptation (sometimes identical code):

- Refactoring the whole grid-point computations below “cpg.F90 »
- Improving the flexibility of the code with respect to the granularity of the parallelism
- Refactoring the Semi-Lagrangian scheme
- Developing an improved version on “Field_API” library
- Defining new coding norms for GPU

PHYEX

- All the AROME physics has been refactored and an external library PHYEX has been developed for Arome and Harmonie-Arome physics.
- The demonstrator is complete and will be introduced into CY49T1.

AROME forecast GPU adaptation progress

On-going work on refactoring the AROME and HARMONIE-AROME physics interface “APL_AROME” by ACCORD colleagues from Norway and Netherlands. Some of the refactoring will be provided in an official code cycle (CY49T1).

The spectral transform code for the limited area was ported to an AMD-GPU processor (LUMI machine) by colleagues at the IRM in Belgium.

But several other parts of the code need to be analyzed and if necessary prototyped and refactored: semi-implicit, NH, LBC coupling, I/O, SPP, post-processing, DDH, etc.

=> Need for people with knowledge of the code for code analysis and code refactoring

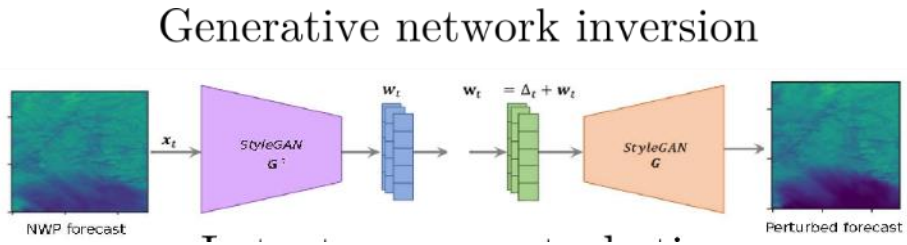
Vector adaptation progress

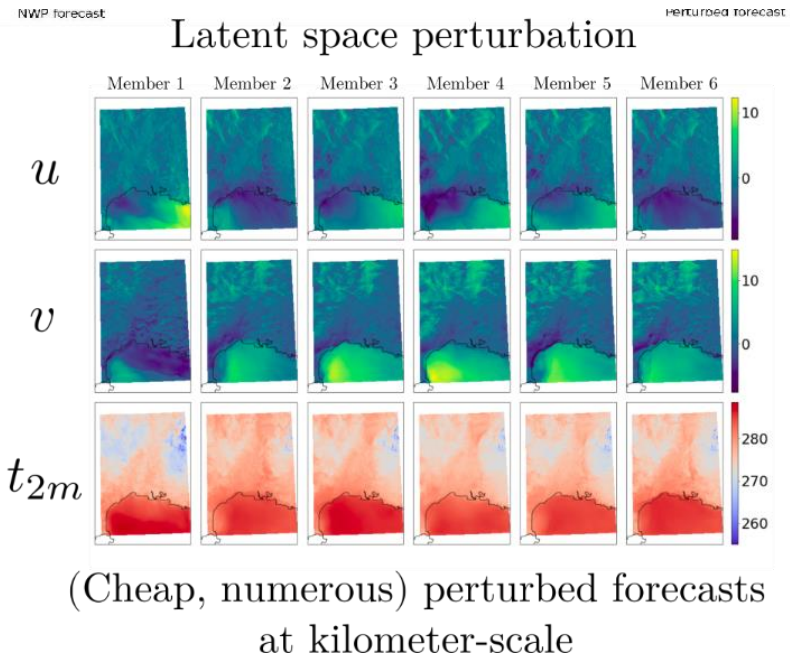
Adaptation on NEC SX-AURORA
(thanks to our Czech partner for access to their hpc)

- To maintain the CPU/GPU/vector versatility
- CY49T0 does not support Open-MP on Aurora but à pre-version of CY49T1 does
- So CY49T1 sounds promising
- Simple precision under-performing (compared to x86 CPU)

Plans for 2024 regarding Artificial Intelligence for NWP

Ensemble augmentation





(Cheap, numerous) perturbed forecasts at kilometer-scale

ML based emulator

- Daily real time Pangu-weather forecast with ARPEGE initial conditions
- Develop & evaluate an AROME emulator (from AROME analysis)
- Downscaling at hectometric scales

=> **Objective :** 1st experimental version of regional ML model ready end of 2024

ML for Data Asimilation

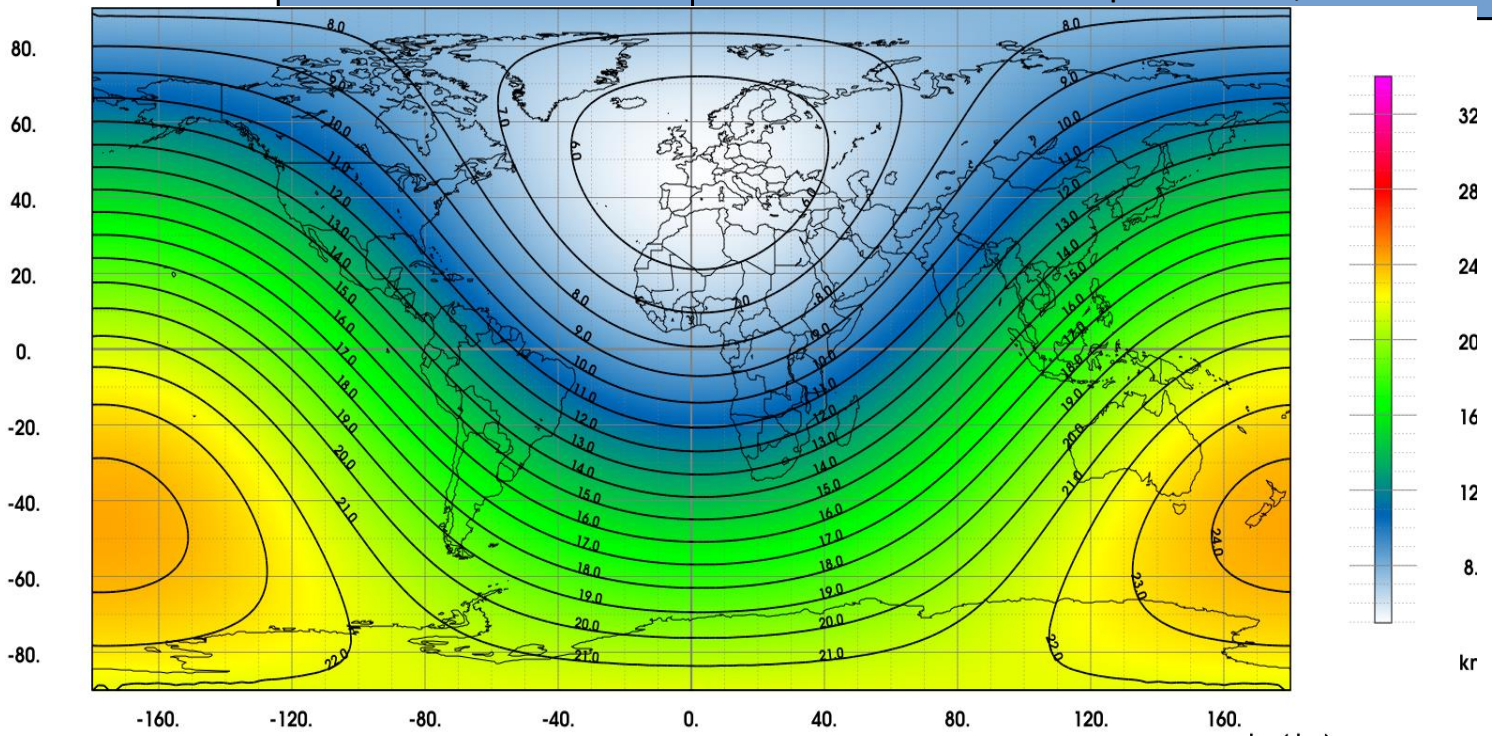
- Test ML-based adjoint models

THANKS

ANNEXES

Global operational NWP systems based on ARPEGE (since June 2022)

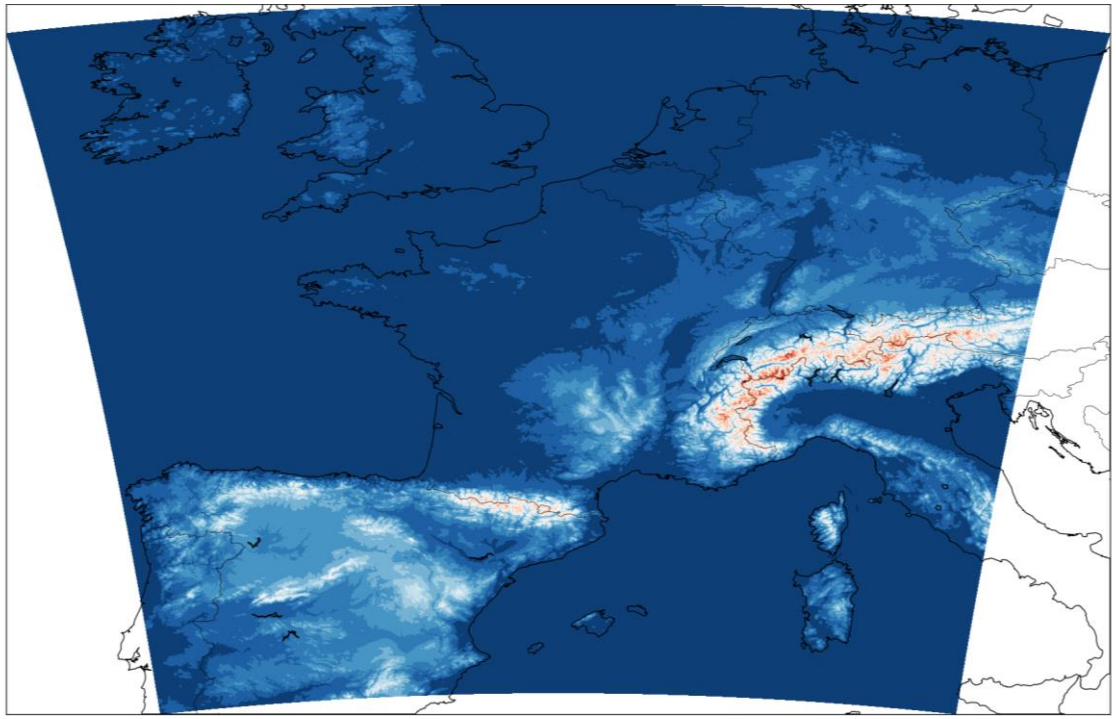
Systems	Characteristics
ARPEGE *Deterministic*	Tl1798c2.2 L105 (5km on W Europe) 4DVar (6h cycle): Tl224c1L105 & Tl499c1L105 5 forecasts per day up to 114h
ARPEGE-EDA (AEARP)	Tl499c1 L105 ; 50 members 4D-Var (6h cycle): Tl224c1 L105 Background covariances averaged on 12h and updated every 6h
ARPEGE-EPS (PEARP)	Tl1798c2.2 L90 (5km on W Europe) ; 34+1 members ; 4x102h 35 EDA members and singular vectors Perturbed parameters, 2 convection schemes

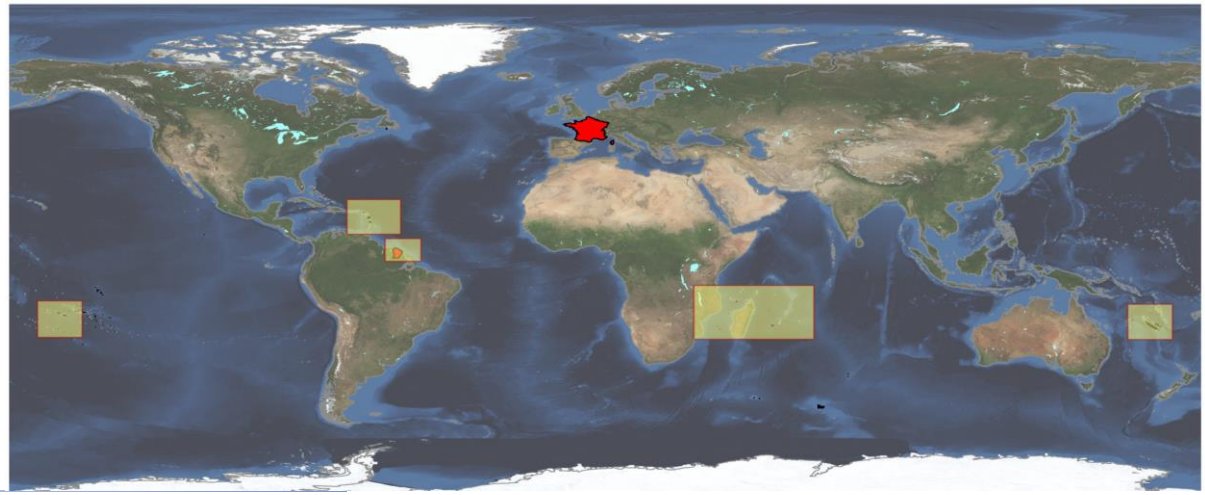


- Horizontal resolution ARPEGE/PEARP
  5km < Dx < 24km

Regional operational NWP systems based on AROME (since June 2022)

Systems	Characteristics
AROME-France *Deterministic*	1.3km L90 (from 5m to 10hPa) 3DVar (1h cycle) 8 forecasts per day up to 51h
AROME-France Nowcasting	1.3km L90 3DVar (no cycling – 10' cut-off) 24 forecasts per day up to 6h
AROME-IFS	1.3km L90– Dynamical adaptation of IFS (altitude) and Arome-Fr (surface) 4 forecasts per day up to 51h
AROME-EPS (PEARO)	1.3km L90 - 16+1 members • Four times per day up to 51h • Initial perturbations from AROME-EDA and boundary conditions from PEARP
AROME-EDA (AEARO)	3.25km L90 25 members 3DVar (3h cycle)
AROME Overseas (5 domains)	1.3km L90 – Dynamical adaptation of IFS (altitude) and Arpege (surface) 4 forecasts per day up to 51h
AROME-EPS Overseas (5 domains)	2.5km L90 – 15 members Same initial conditions AROME Overseas Lateral conditions from PEARP 2 forecasts per day up to 51h
AROME Commercial	2.5km L90 – several domains Dynamical adaptation Arpege





Evolution of code cycles

CY48T3

- GPU-readiness refactoring, round #1

CY49T0

- GPU-readiness refactoring, round #2

CY49T1

- GPU-readiness refactoring, round #3

- ACCORD developments and catch-ups (incl. SURFEX version common to all LAM)
- Catch-up with 48T1_op1 e-suite branch
- PHYEX (Meso-NH/Arome physics, pre-externalised)
- Various bugfixes (incl. porting on NEC)

Unique portal for contributions : https ://github.com/ACCORD-NWP/IAL
Declaration expected by the end of 2023
Meteorological validation ongoing

Evolution of code cycles

CY49T0 (declaration 24/04/2023)

- GPU-readiness refactoring, round #2

CY49T1

- GPU-readiness refactoring, round #3 (extern. field_api)
- ACCORD developments and catch-ups (incl. SURFEX version common to all LAM)
- Catch-up with 48T1_op1 e-suite branch
- PHYEX (Meso-NH/Arome physics, pre-externalised)
- Various bugfixes (incl. porting on NEC)

Unique portal for contributions : https ://github.com/ACCORD-NWP/IAL
Declaration expected by the end of 2023
Meteorological validation ongoing

CY50

Common release to serve as basis for subsequent CY50T1 and CY50R1
Start of merge : January 2024