AROBASE

AROME-BAsed Coupled SystEm
Towards a regional kilometre-scale multi-coupled modelling and forecasting system

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and the AROBASE team

Assemble a fine-scale modelling system including atmosphere physics & chemistry + ocean (sea-ice, biogeochemistry) + waves + land surfaces (soil, vegetation, towns, snow, lakes, hydrology)

ATMOSPHERE
physics + chemistry

LAND SURFACES:
- soil, vegetation
- towns
- lakes, hydrology
- snow

WAVES

OCEAN
- free ocean
- sea-ice
- *biogeochemistry*
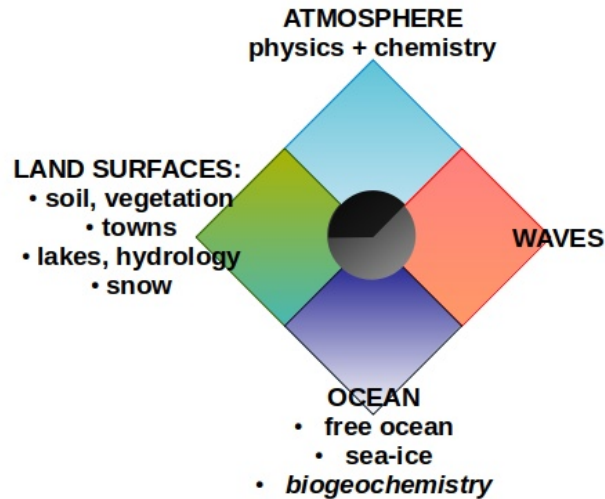
Prepare couplings for the new generation of the regional climate system model CNRM-RCSM

→ *based on AROME to reach the kilometre scale*

A system for NWP

→ *AROBASE must be inserted in the same environment as Météo-France NWP systems*

A research and collaborative numerical tools to better understand and represent the exchange processes at km-scale

with possibility to deploy on various regions depending on interests

1. Motivations & outlines of AROBASE

The AROBASE transversal project:

Pool of expertises and collaborations to build the multi-coupled modelling and forecasting platform around AROME at kilometric scale for research and operational uses

4 development criteria:

modularity (possibility of interchanging models)
transportability (deployment over different domains)
internal **expertise(s)**; strengthened through collaborations
continuum of coupled modelling between different applications

3 scientific and technical workpackages:

Assembling a research tool
What coupling(s) for **numerical forecasting**?
Synergy with **observations**

2. Assemble the AROBASE numerical tool

AROBASE assemble Earth System components to represent key processes and interactions @km-scale:

- atmosphere (physics + chemistry): **AROME** [+ chemistry/aerosols library from ACCALMIE],
- land surfaces: **SURFEX** (ISBA: soil/vegetation, TEB: town, Flake/Mlake: lakes, snow) + hydrology **CTRIP** [+ chem exchanges from ACCALMIE],
- ocean (blue, white, green): **NEMO** (+SI^3 +PISCES)
- waves: **MFWAM**
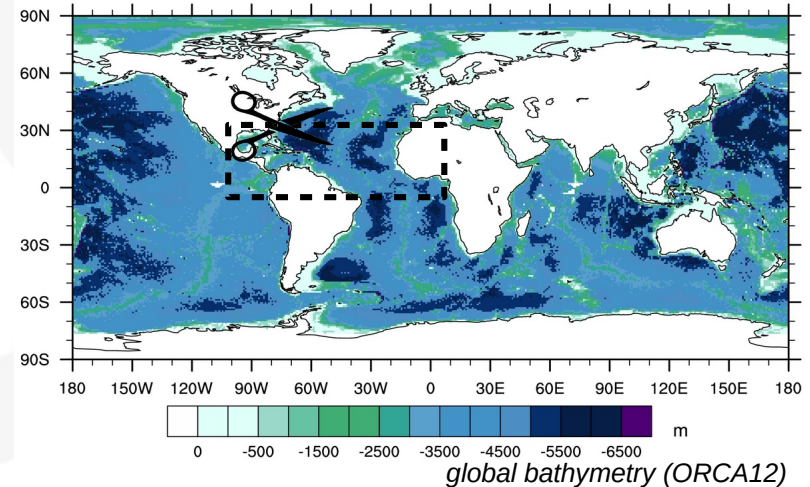
global bathymetry (ORCA12)

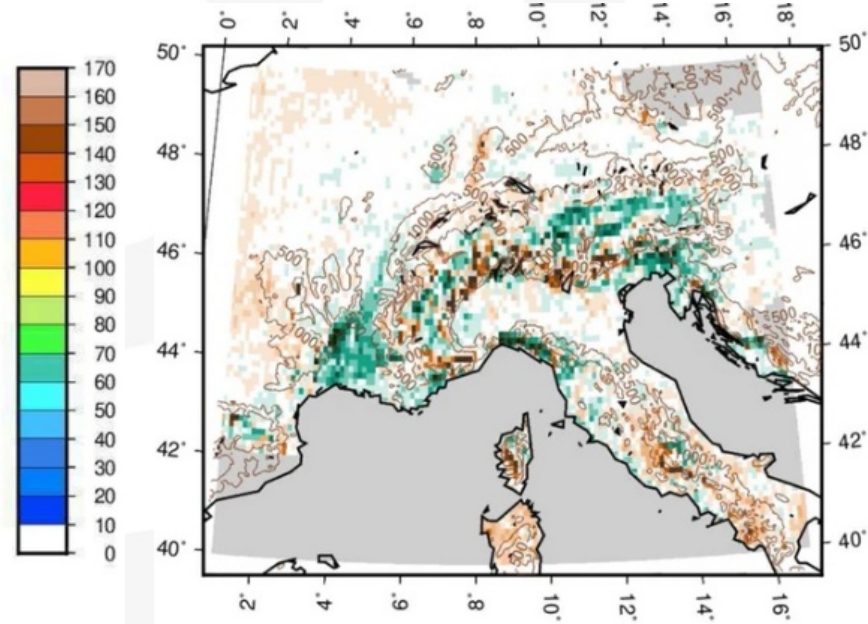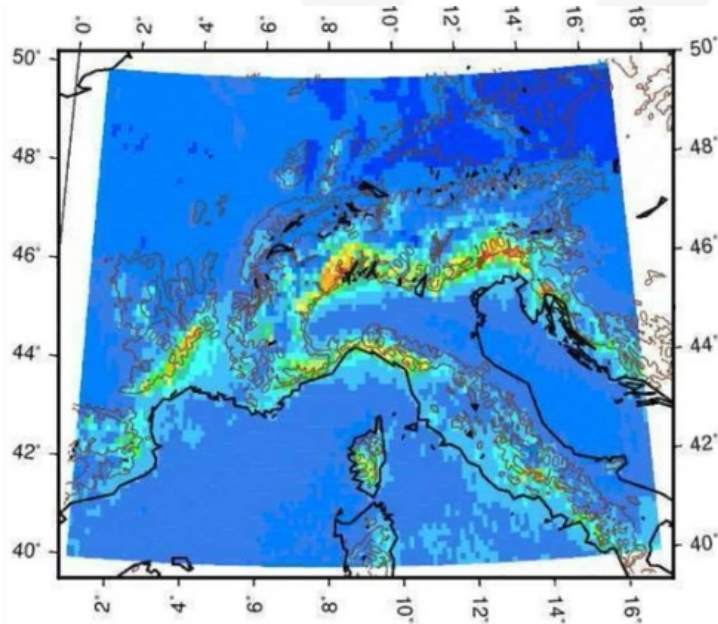# 2. Assemble the AROBASE numerical tool

AROME:

Model for kilometric-scale Numerical Weather Prediction at Météo-France

Used as Convection-Permitting Regional Climate Model (CP-RCM)

90th percentile of daily precipitation in CNRM-AROME (2.5 km) and comparison to ALADIN-Climate (12 km)
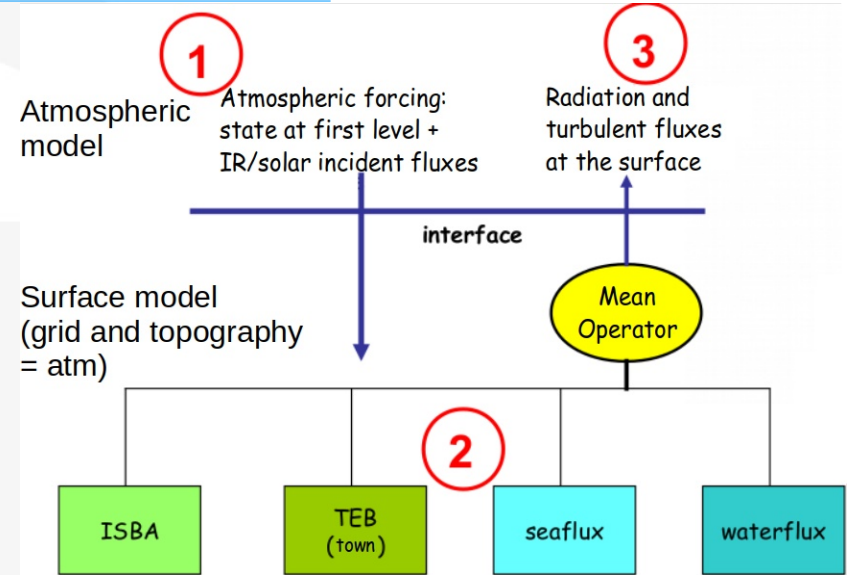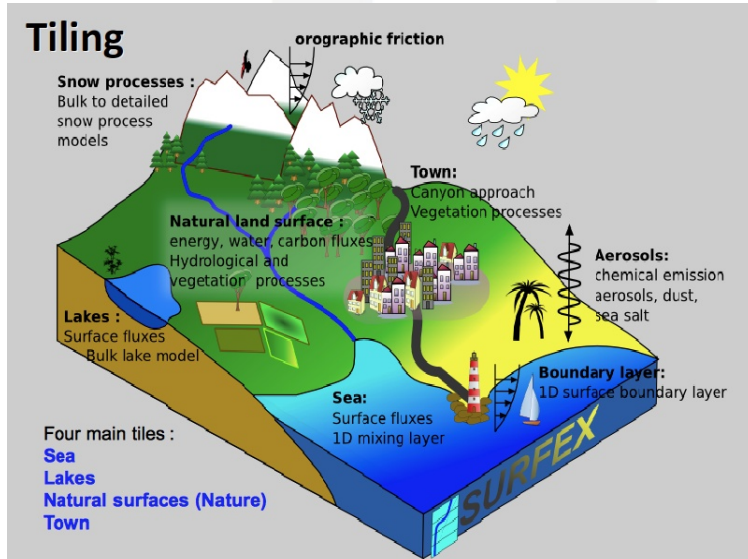
Caillaud et al. 2021

AROME:
Model for kilometric-scale Numerical Weather Prediction at Météo-France
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Coupled to **SURFEX**

The SURFEX model
   Masson et al. 2013
and its use in AROME NWP
   Seity et al. 2011

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AROME:
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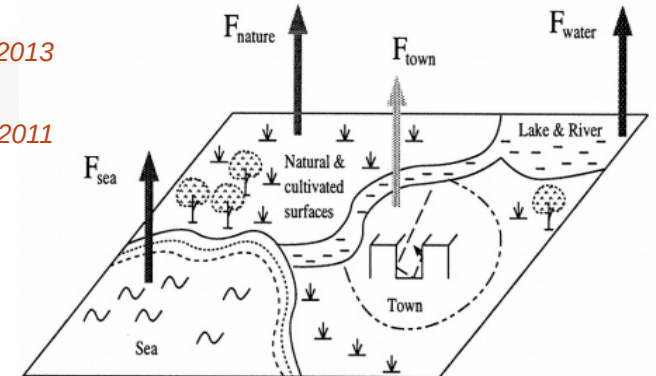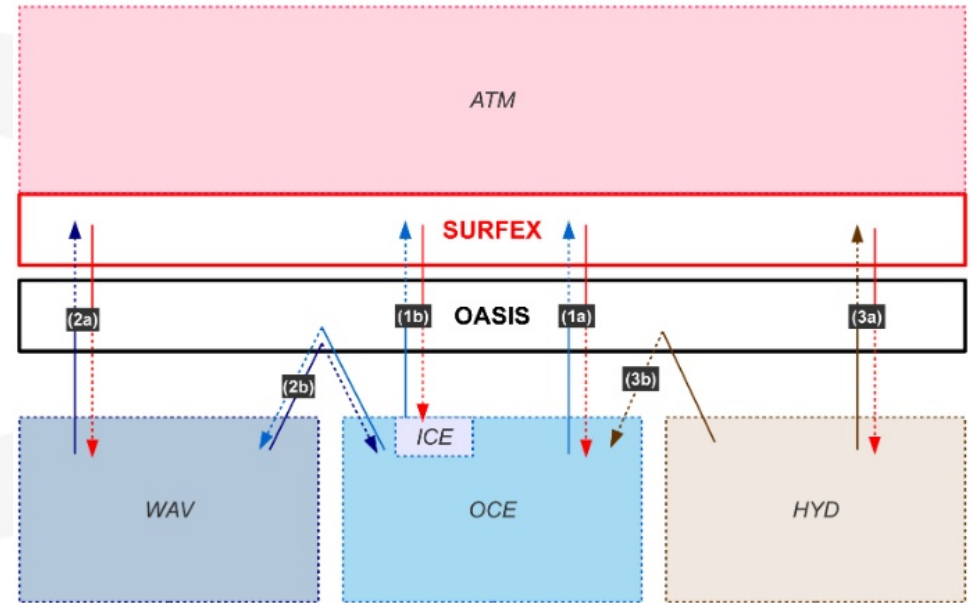
Coupled to **SURFEX**
with an interface with the *OASIS* coupler available

The SURFEX-OASIS coupling interface
(collab. CNRM-LOPS-LAERO-LACY-CECI/CERFACS)
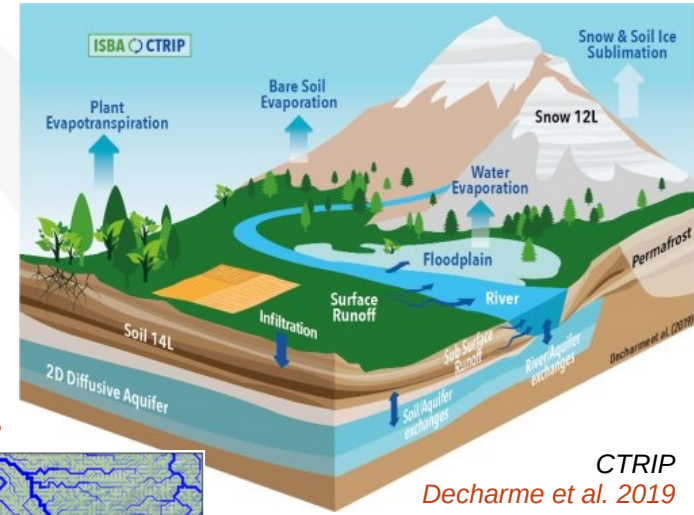*Voldoire et al. 2017*

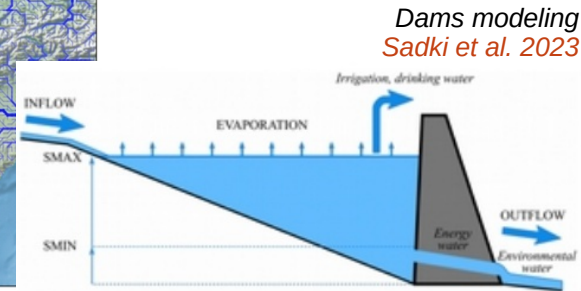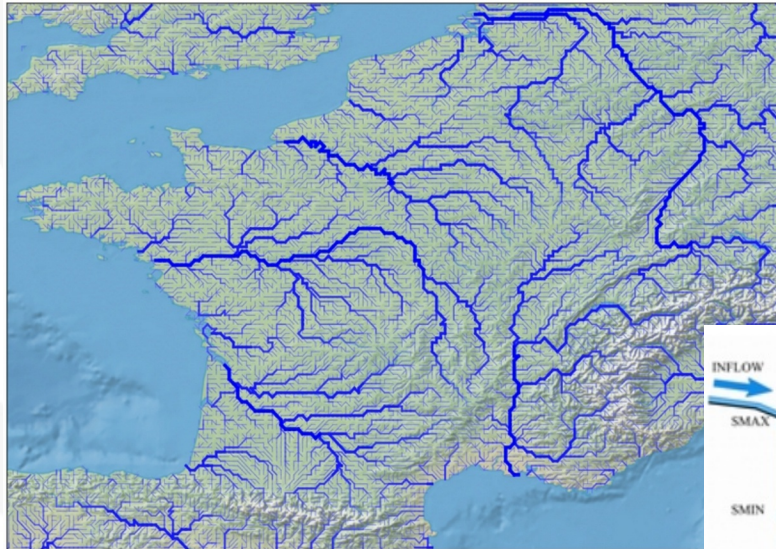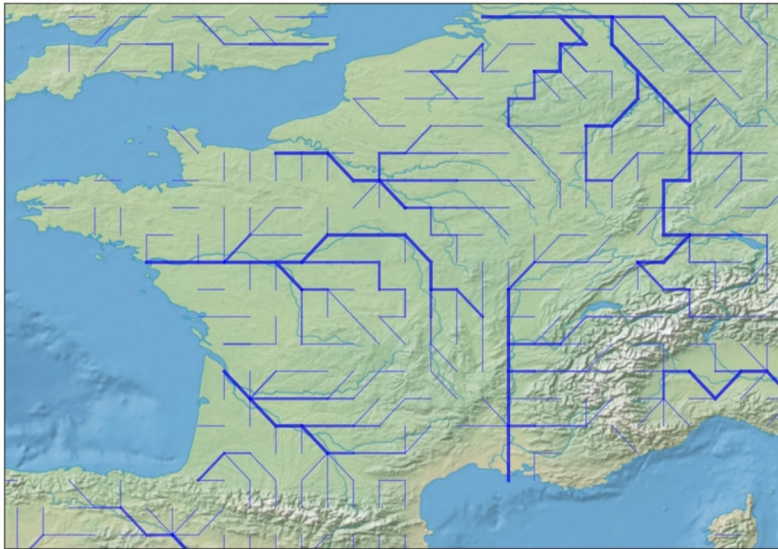# 2. Assemble the AROBASE numerical tool

CTRIP:
for the simulation of rivers routing
coupled to ISBA through the SURFEX/OASIS interface
and NEMO through OASIS
Available with a new global resolution of 1/12°, to test in
regional + addition of anthropic effects (irrigation/dams)

CTRIP
Decharme et al. 2019

CTRIP-D12
Munier and Decharme 2022

Dams modeling
Sadki et al. 2023

2. Assemble the AROBASE numerical tool

NEMO:

Model of operational oceanography in Europe;
Widely used in the research community (processes and climate);
Includes an interface with the OASIS coupler for exchanges with atmosphere, rivers and waves;
Several regional configurations deployed and coupled
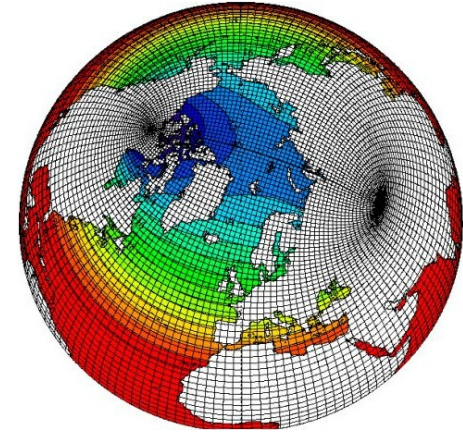
NEMO ORCA025 (1/4°) grid

NEMOMED12

NEMO IO (1/12°)

WMED36

FRA36
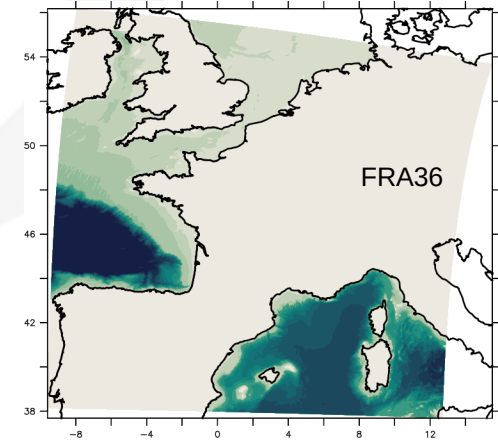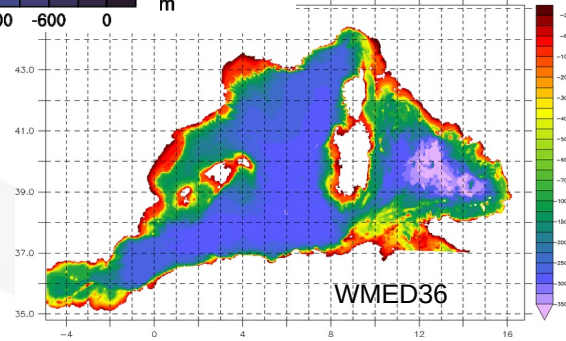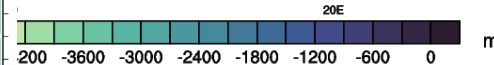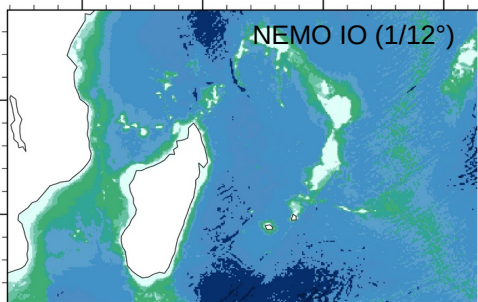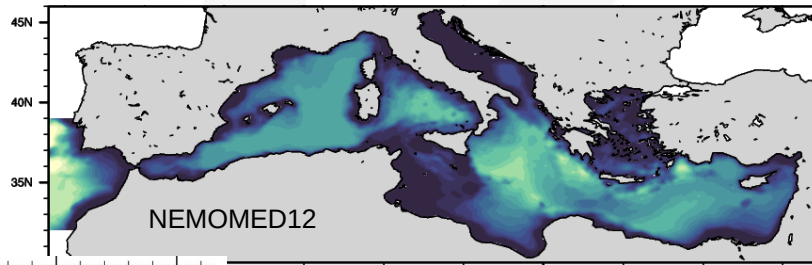
2. Assemble the AROBASE numerical tool

MFWAM:
Model for marine forecast at Météo-France with a significant and specific place in the forecast chain;
An internal code expertise with regular exchanges with ECMWF for the code evolutions;
Possibility to reach the kilometric resolution for regional domains as proposed for AROBASE [MF]WAM already used as an impact model to investigate the CC effect on waves
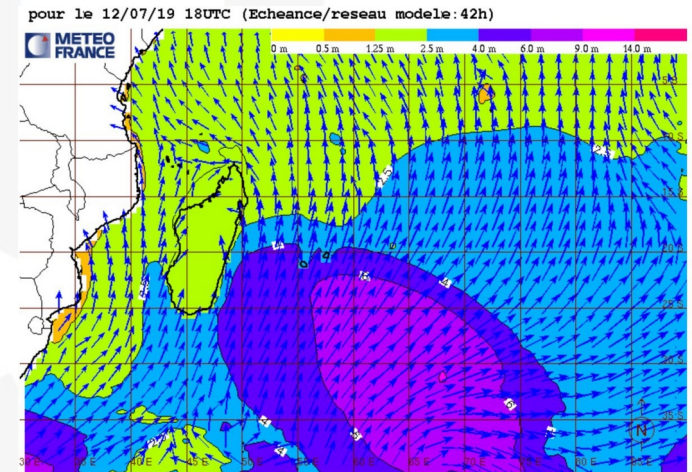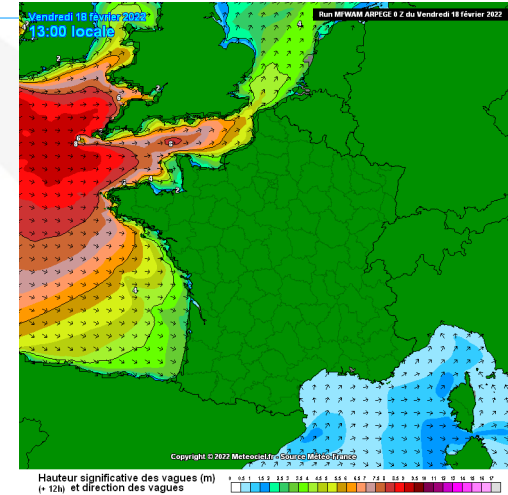
Regional MFWAM forecasts for metropolitan France and for South-West Indian Ocean

MFWAM *Challenges for waves coupling:*

- *Insertion of OASIS interface in MFWAM*
- *Building of a km-scale configuration and grids management*
- *Development and tests of wave-aware sea surface turbulent flux parametrizations*
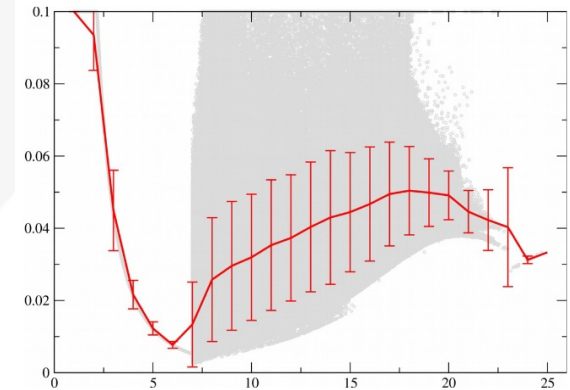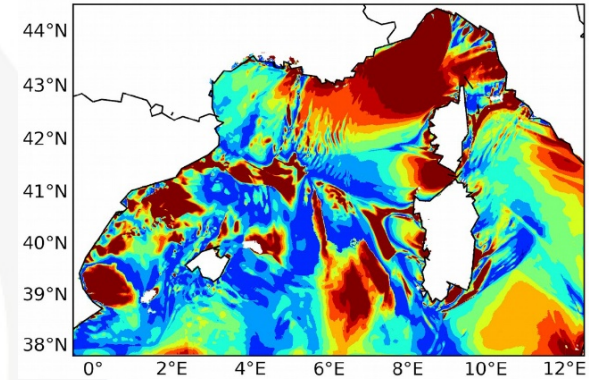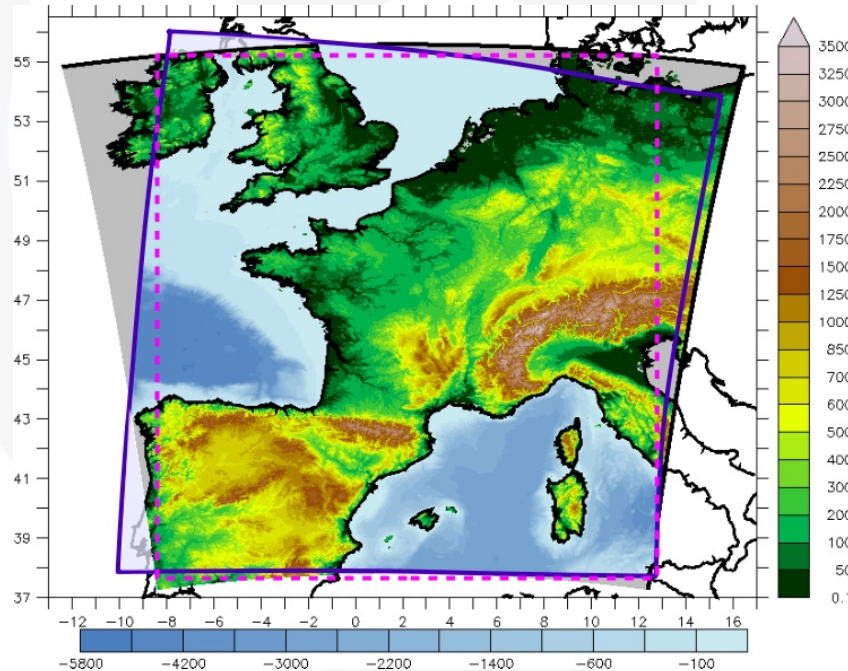
14 oct 2016 00UTC: Charnock parameter map and as a function of 10m-wind speed (AROME forecast, WASP, initial start : 13 oct 2016 00UTC) – Sauvage et al. 2020

Regional grid for the metropolitan France area : AROME-FR (conformal projection with E zone without SURFEX)
MFWAM-FR@1km (pseudo-regular lon/lat grid, transformed in 1D and reduced)
NEMO-FRA36 (ORCA grid)

3. Which coupling(s) for km-scale NWP?

AROBASE is designed as a **numerical prediction** system, and thus must be inserted in the production tools, the dedicated analyse methods and uses, **in line with AROME**.

Benefits of gradual complexity induced by couplings will be examined specifically for numerical prediction taking into account the operational constraints:

- **Evaluation of coupling benefits** on forecasts: skill scores & case studies; several kind of forecasts; advantages for the production chain / sequence

- **Estimate of costs**: numerical costs; running time : constraints on models and coupling methods, costs of pre-/post-treatment, transfers to (new) users, costs of maintenance

Current NWP syst: atmosphere « alone or almost»

@ -NWP

« full » @

A

L   W

O

3. Which coupling(s) for km-scale NWP?

Illustration of issues related to ocean coupling insertion in ensemble forecast:

What are the role of SST perturbations on ensemble forecast @km?
How to perturb the ocean model efficiently for short-range NWP?
How perturbations propagate with coupling?

Atmospheric initial conditions

Extraction of perturbations from the ensemble assimilation scheme of AROME (AEARO)

Raynaud et al. 2016

Lateral conditions

Clustering: Selection of 16 members in the ARPEGE EPS (PEARP)

Bouttier and Raynaud 2018

Surface

surface initial perturbations *including random SST perturbations*

Bouttier et al. 2016

Model errors

Stochastic perturbations (SPPT)

Bouttier et al. 2012

16 perturbed forecast runs

+1 CTRL = deterministic run

AROME EPS

AROME

SURFEX

OASIS

Q_{sol} Q_{ns}
EMP T, T
P_{atm}

U, V

Runoff data (R)

NEMO

AROME-NEMO coupled system over Metropolitan France

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AROME EPS

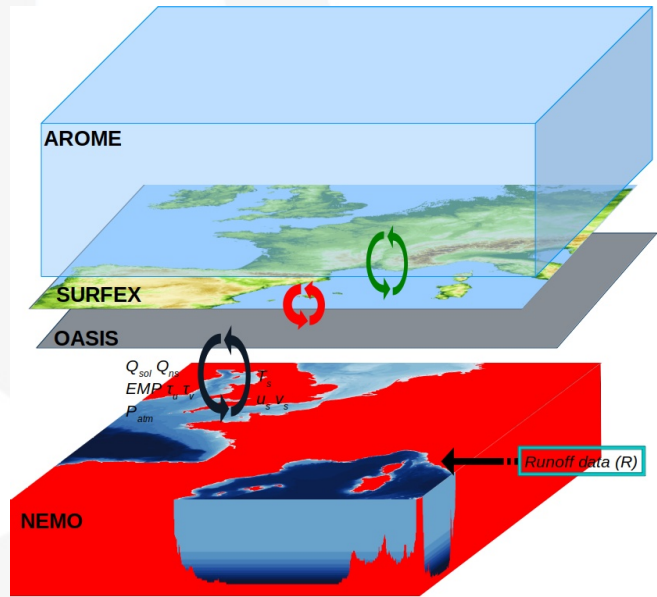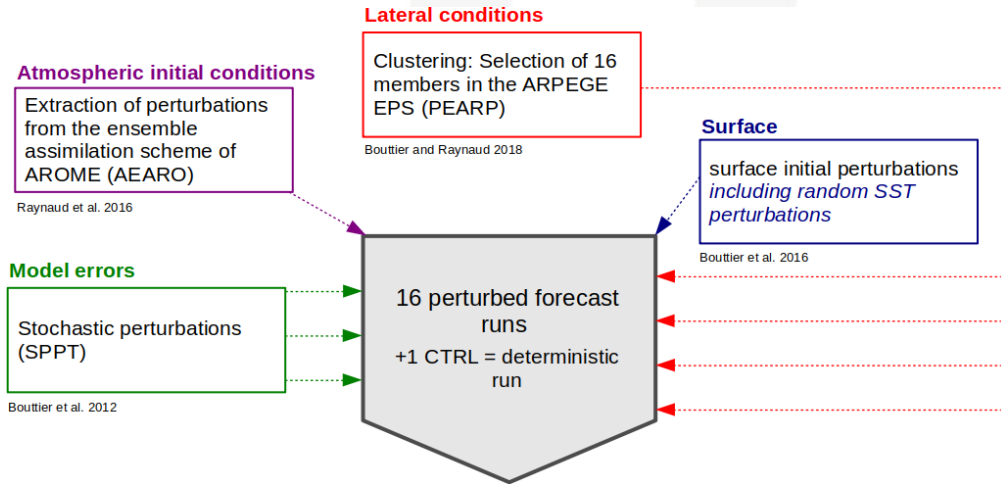AROME-NEMO coupled system over Metropolitan France

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	model(s)	Atm pert	Surf perturbations [SST]	Ocean perturbations
OPER	AROME	Yes	Yes [random perturbations added to AROME SST analysis]	
IP-A	AROME	Yes	Yes for land *but* AROME SST analysis for all members	
IP-A NEMOSST	AROME	Yes	Yes for land *but* NEMO-FRA36 surface state for all members	
IP-A NEMOCPL	**AROME-NEMO**	Yes	Yes for land prognostic SST in NEMO, *but* initially the same for all members	No (except due to coupling)
IP-AO NEMOCPL	**AROME-NEMO**	Yes	Yes prognostic SST in NEMO	**Yes** for initial state

3. Which coupling(s) for km-scale NWP?

Examples of SST perturbations
applied operationally in AROME-EPS
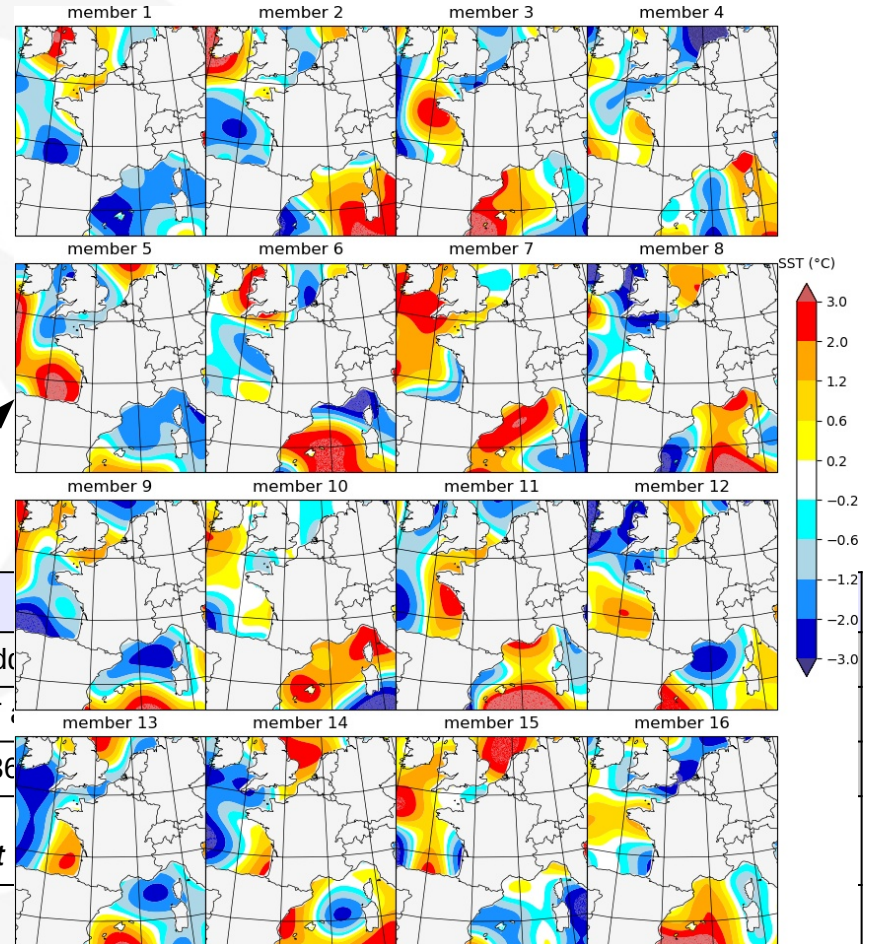
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IP-A	AROME	Yes	Yes for land *but* AROME SST a...
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3. Which coupling(s) for km-scale NWP?

Examples of SST initial perturbations obtained with 3D ocean daily-centered anomaly extraction
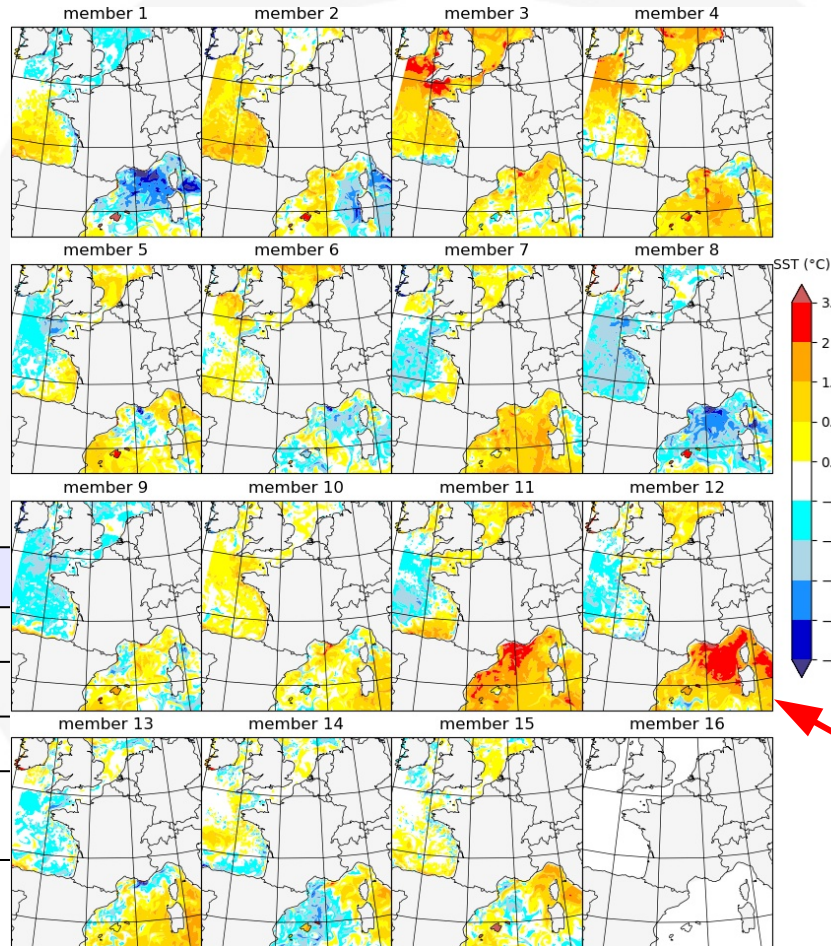
SST (°C)

	model(s)		Ocean perturbations
OPER	AROME	analysis]	
IP-A	AROME	mbers	
IP-A NEMOSST	AROME	ll members	
IP-A NEMOCPL	**AROME-NEMO**	or all members	No (except due to coupling)
IP-AO NEMOCPL	**AROME-NEMO**		**Yes** for initial state

3. Which coupling(s) for km-scale NWP?

Comparison of the 10m-temperature standard deviation over the total sea domain

contribution of the random (operational) SST perturbation

contribution of the initial ocean perturbations

	model(s)	Atm pert	Surf perturbations [SST]	Ocean perturbations
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4. Synergy with observations & validation

Re-use available **observations** (case studies, field campaigns) for model and/or parameterization validation in coupled mode

→ Inventory of documented cases of interest for AROBASE validation and physical process studies

+ user guide/catalogue of some reference databases for evaluation / validation

Provide AROBASE outputs for scientific exchanges and interact to **collect the needs** of downstream production/applications

→ Interactions with users, including forecasters

→ Running AROBASE on some case studies (define the number during the project) and period of interest

→ Provide AROBASE forecasts and test their use for downstream applications

4. Synergy with observations & validation

Difficulties in accessing observations for the validation of simulation results, amplified by the multi-compartment aspect of coupled modelling

→ Initiative to propose a catalogue/access guide

observation products from Météo-France vs. from other institutes

in-situ/satellite/teledetection/(re)analyses-gridded products

description/name/link

Observations et analyses externes à Météo-France

Observations in situ			Observations satellitaires			Observations télédétectées depuis le sol			Analyses des modèles de PN, réanalyses, produits grillés		
Description	**Nom**	**Accès**	**Description**	**Nom**	**Accès**	**Description**	**Nom**	**Accès**	**Description**	**Nom**	**Accès**
Mesures atmosphériques de campagnes	AERIS	Téléchargement	**NASA**	Worldview	Visualisation et téléchargement	**Radars italiens**		Visualisation Téléchargement	**CEPMMT** (*ECMWF*)	IFS, WAM	Visualisation
Mesures océanographiques de campagnes	ODATIS	Téléchargement	**EUMETSAT**	Eumetview (MSG/MTG, Metop A,B,C, Sentinel 3A,3B)	https://view.eumetsat.int/				**Réanalyses**	ERA5, CERRA, MERRA, UERRA	https://cds.climate.copernicus.eu/ ERA5 : une partie en téléchargement sur hendrix.meteo.fr, une partie sur Lustre CNRM, voir GMGEC - ERA5
Bouées ancrées, flotteurs argo, SVP drifters	CORIOLIS	https://www.coriolis.eu.org/Data-Products/Data-selection	**ESA MAXSS**	Vents de surface (vents forts) diffusiométrie, radiométrie, SAR, vagues	https://www.maxss.org/				**ESA Ocean Virtual Laboratory**		https://ovl.oceandatalab.com/

5. Summary

New research tool at km-scale for understanding and representation of exchange processes, with a shared coupling interface between CNRM's climate models, Météo-France's NWP systems and research models (MesoNH, SURFEX offline)

> ➢ Significance of the modularity criteria, that aims to ***facilitate collaborations*** with several modelling communities, and to ***ensure flexibility*** in order to answer and anticipate the various needs

A coupled system for numerical prediction (weather, air quality, sea state and upper-ocean) which imposes strong constraints (stability, performance, maintenance,…) but also opportunities to test new developments (physical parametrizations, new numerical methods) with dedicated analyse tools.

Deployment capacity on regions of interest (***transportability***), in particular for specific needs related to observation (field campaigns, new observing platforms,...)

New possibility to provide modelling products, ***more integrated*** and ***more consistent***, for the scientific community (ex : boundary conditions for very HR models), institutional product (wave/submersion vigilance, NWP downstream applications) and general public (with more integrated information on severe situations notably)

Thank you for your attention

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