Towards ocean-atmosphere-wave coupled forecasts with AROME-NEMO-WW3: development, first results and future work

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Chronological view of OAW coupling developments

OASIS interface in SURFEX v8

WASP + waves (→SFX v9)

2015 *2016* *2017* *2018* *2019* *2020* *2021*

- Ocean coupling over W Med Sea
- AROME-NEMO WMED (2.5 km)
- HyMeX case studies: IOP13, IOP16, SOP2

Rainaud et al. (2017,qjrms), Lebeaupin Brossier et al. (2017, jgro)

- Wave coupling over NW Med Sea
- AROME-WW3 (1.3 km)
- HPE in 2016

- OA coupling for Indian Ocean (LACy)
- AROME-NEMO
- Tropical cyclones

Ocean model design and OA coupling for AROME-France

- OAW coupling over NW Med Sea
- AROME-NEMO-WW3 (1.3 km)
- HPE in 2016

- Runoff forcing on ocean
- NEMO NWMED72 (1.3 km)
- HyMeX case studies: SOP1

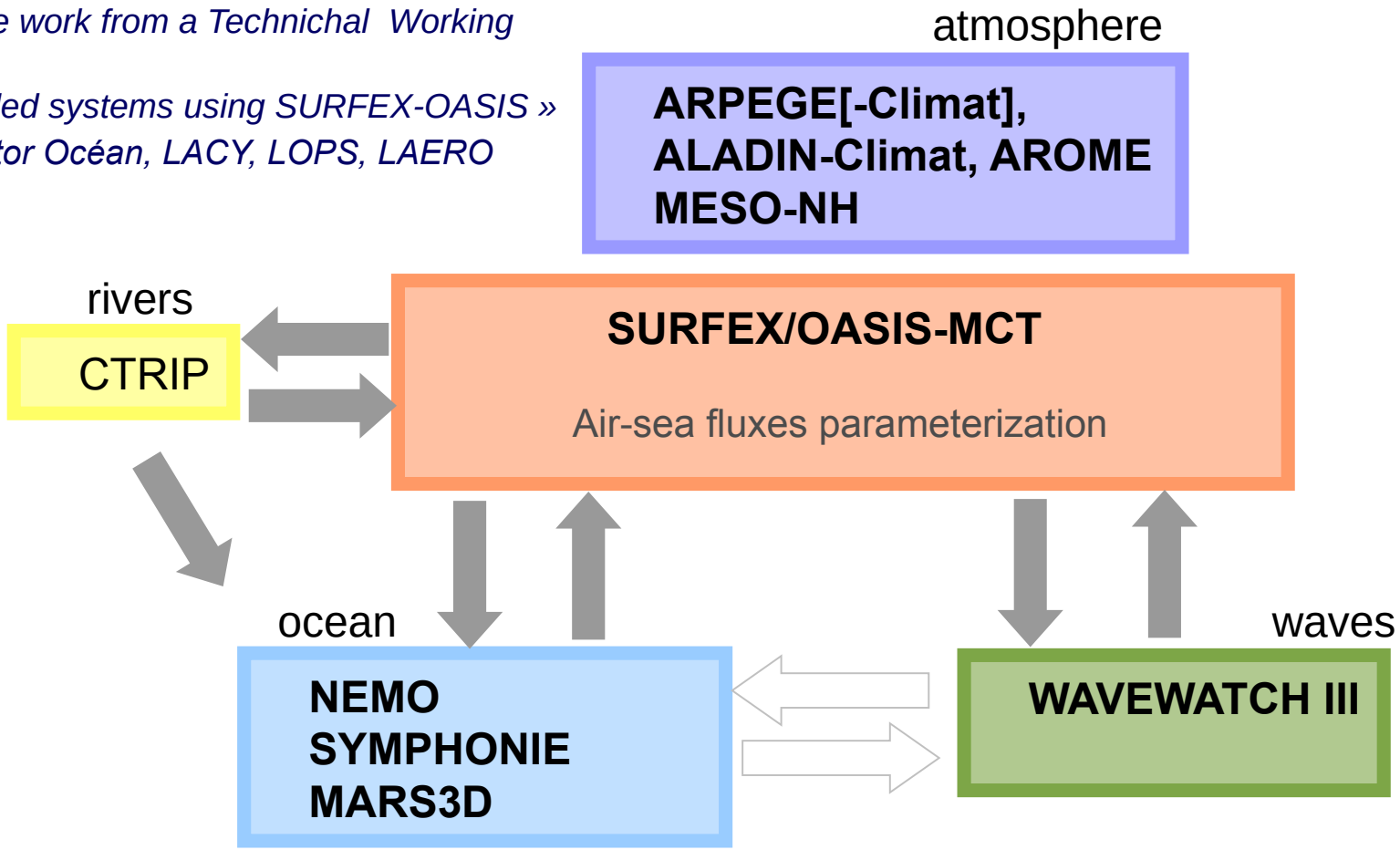
Sauvage et al. (2019,om)

- OA coupling over Central Med Sea
- MESONH-NEMO
- Qendresa medicane

- OA coupling for eIBI (Mercator Ocean)
- AROME-NEMO (2.5 km)
- 7-day range HR ocean forecasts

The SURFEX-OASIS coupling interface

A collaborative work from a Technichal Working Group
« O-A-W coupled systems using SURFEX-OASIS »
CNRM, Mercator Océan, LACY, LOPS, LAERO



Voldoire et al. 2017 (10.5194/gmd-10-4207-2017)

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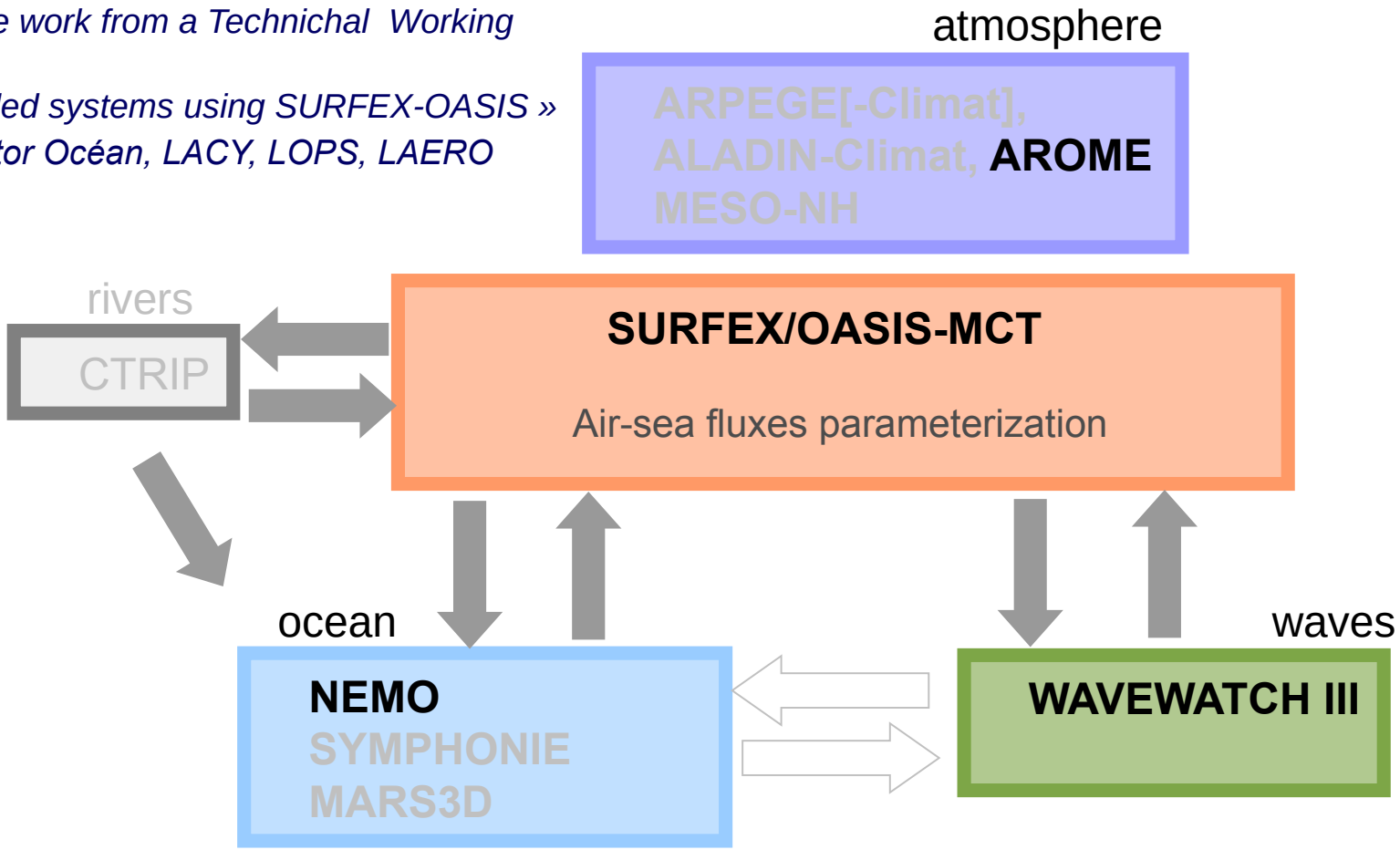


Voldoire et al. 2017 (10.5194/gmd-10-4207-2017)

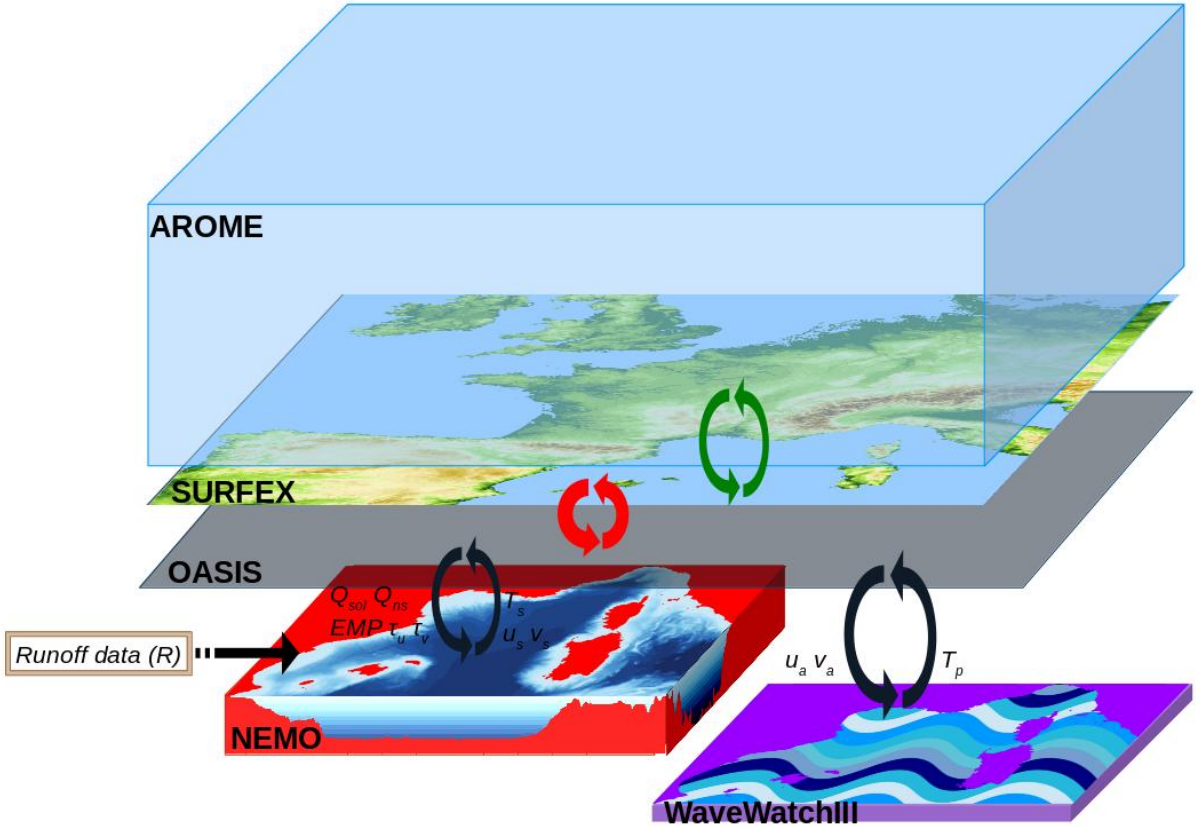
AROME-France / NEMO-NWMED72 / WW3

AROME-FR:
- cy41t1 with SURFEX v7.3 (+new sea surface fluxes param: WASP)
- no assimilation (dynamical adaptation)
- Δx,y = 1.3 km [1440 x 1536]
- 90 vertical levels
- IC: AROME analysis
- LC: ARPEGE forecast

NEMO: NWMED72
- v3.6_STABLE
- no assimilation
- Δx,y ~ 1/72° [~1.2km] over NW Med Sea
- 50 vertical z-levels
- IC/LC : PSY4 global daily analysis (1/12°) or 7day- spin-up

WW3:
- same horizontal domain as NEMO (1/72°)
- IC: WW3 experiment
- LC: 8 wave spectra from MARC

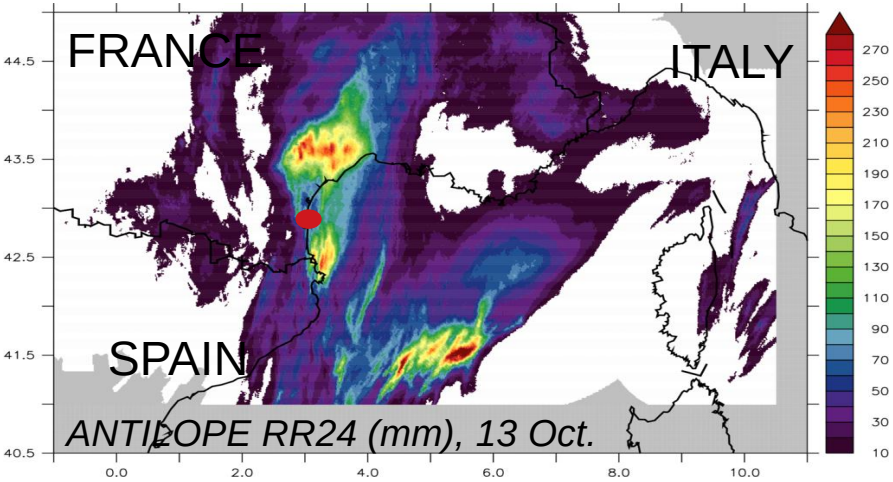
OASIS coupler:
- fields exchanged every 1 hr
- bilinear interpolations
- no O-W coupling

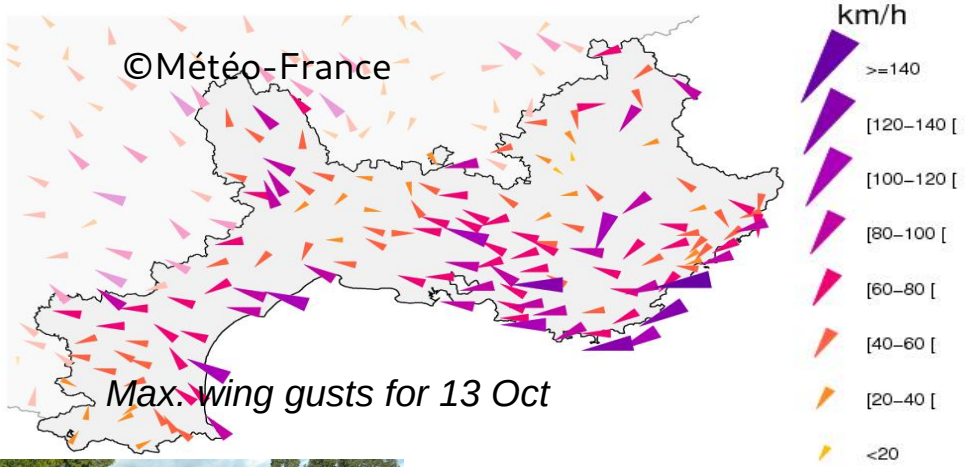


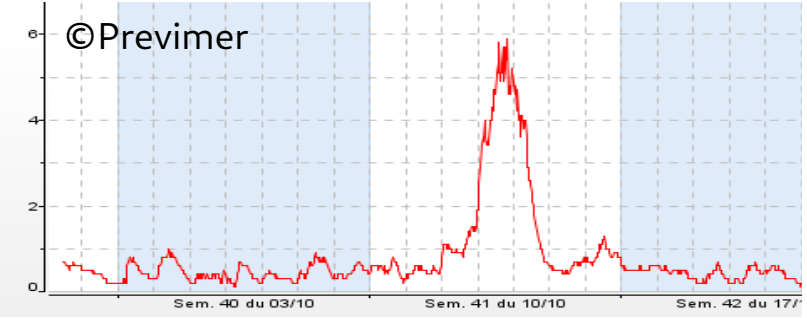
Sauvage et al. 2020 (10.5194/acp-20-1675-2020) and 2021 (10.5194/acp-2021-239)

AROME-France / NEMO-NWMED72 / WW3

Heavy precipitation Hérault: 12-14 Oct 2016







Wave significant height at Leucate (m)

Heavy precipitation over Hérault: **300 mm in 24h**

Strong easterly winds with gusts above **100 km/h**

High sea state with significant height **up to 6 m**

AROME-France / NEMO-NWMED72 / WW3

Heavy precipitation Hérault: 12-14 Oct 2016

Numerical experiments:

	models	SST outside NWM	SST over NWM	current (over NWM)	Tp (over NWM) in WASP
AY	AROME	PSY4 global daily analysis		null	f(Ua)
AYSSTatl	AROME	AROME analysis	PSY4 global daily analysis	null	f(Ua)
AWF	AROME	PSY4 global daily analysis		null	WW3 run outputs
AWC	AROME-WW3	PSY4 global daily analysis		null	**coupled**
AOW	AROME-WW3-NEMO	AROME analysis	**coupled** *initially: NEMO spin-up for 12 Oct., then AOW D-1 +24h forecast*		**coupled**

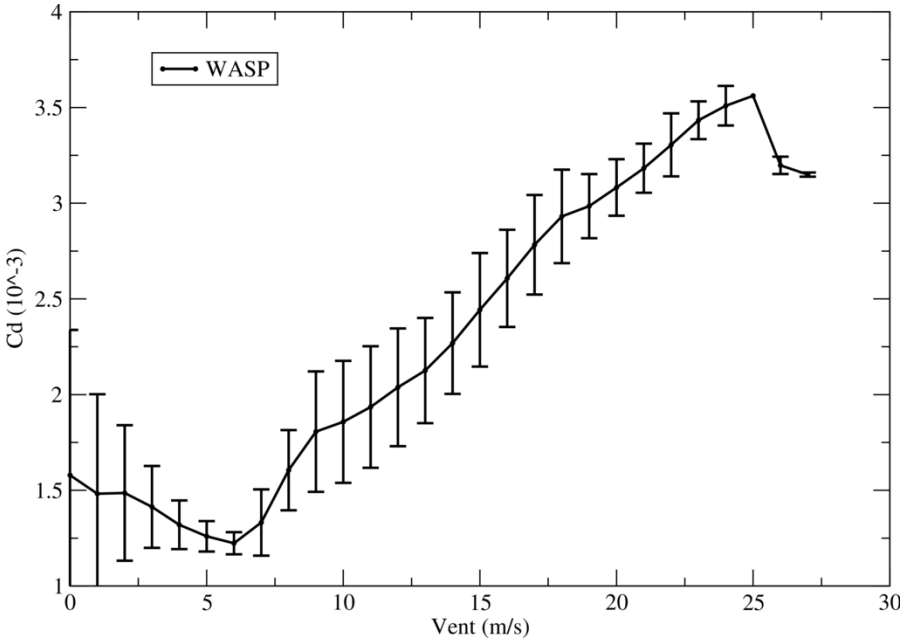
AROME-France / NEMO-NWMED72 / WW3

WASP:

$$C_d = f(z_0) \qquad C_H = f(z_0, z_{0h})$$

(Idem for C_E)

z_0 and z_{0h} : roughness lengths (drag and thermal)



Charnock's relationship

$$z_0 = \frac{\alpha_{ch} \cdot u_*}{g} + \frac{\beta \cdot \nu}{u_*}$$

Charnock's coefficient

$$\alpha_{ch} = A\chi^{-B}$$

Wave age

$$\chi = \frac{C_p}{U_a} \qquad C_p = g.\frac{T_p}{2\pi}$$

Peak period

$\chi < 0,8$	$0,8 < \chi < 1,2$	$\chi > 1,2$
young sea	developed sea	swell

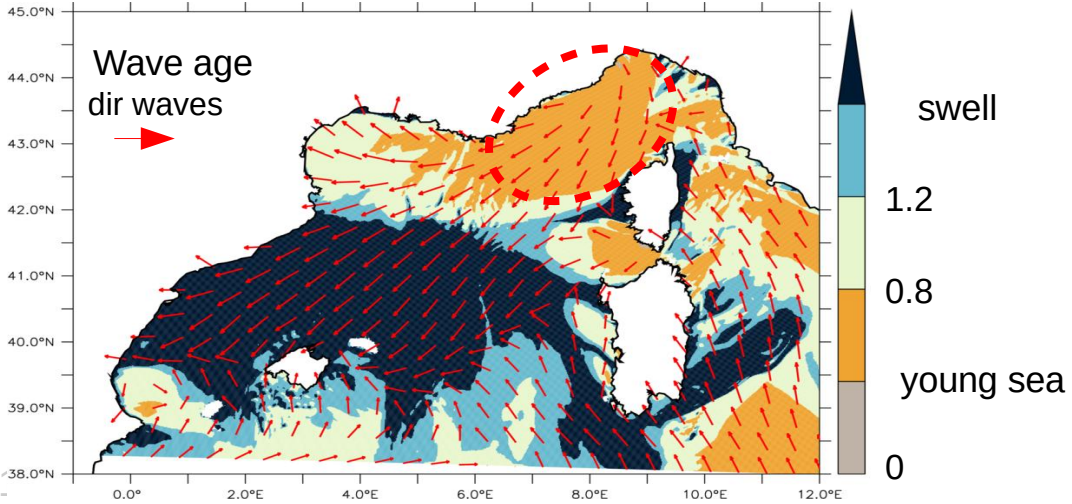
wind sea

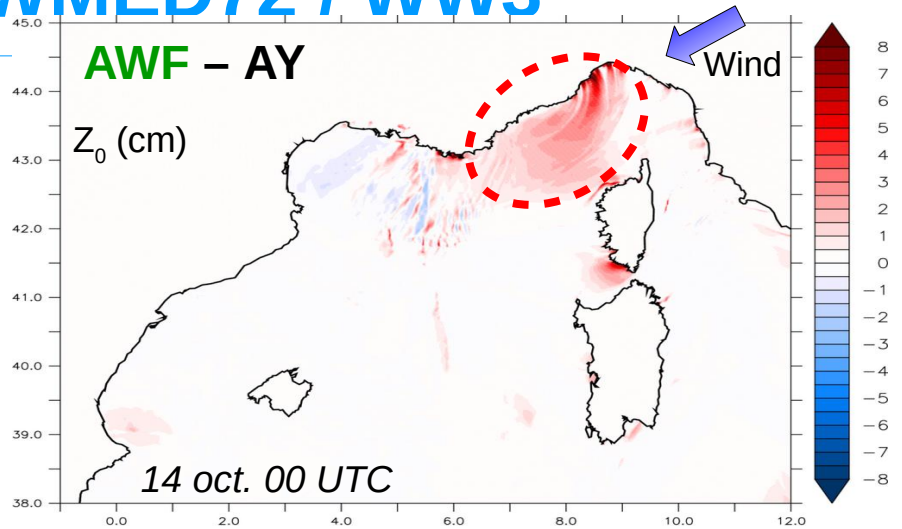
AROME-France / NEMO-NWMED72 / WW3

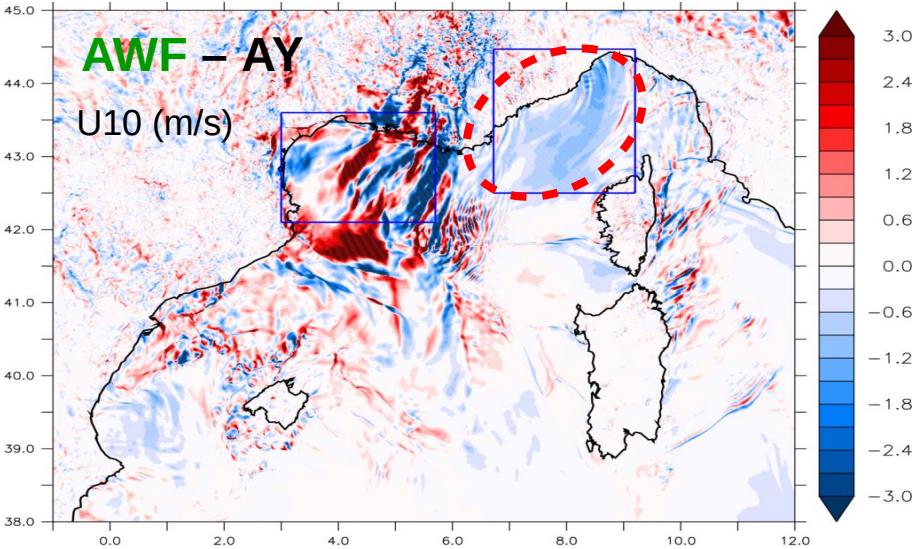
Wave coupling : impacts the low-level dynamics

AWF vs AY

- U10 decreases by 7% on average

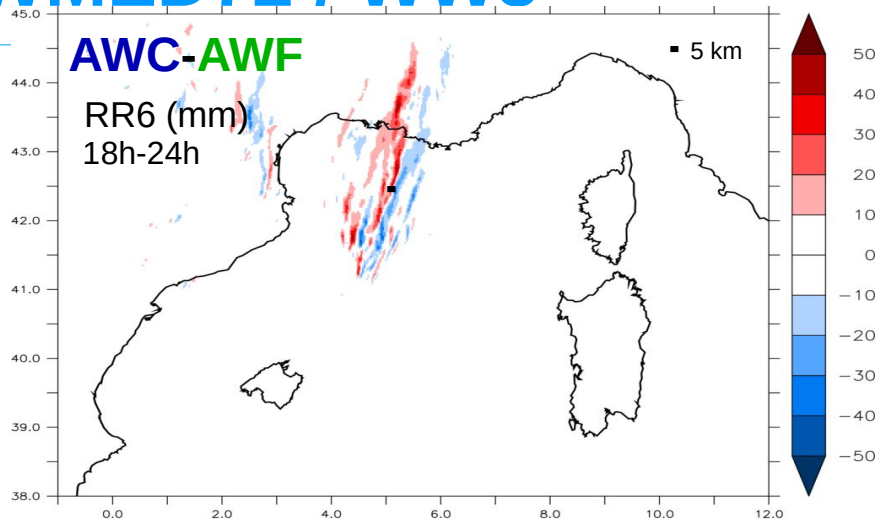


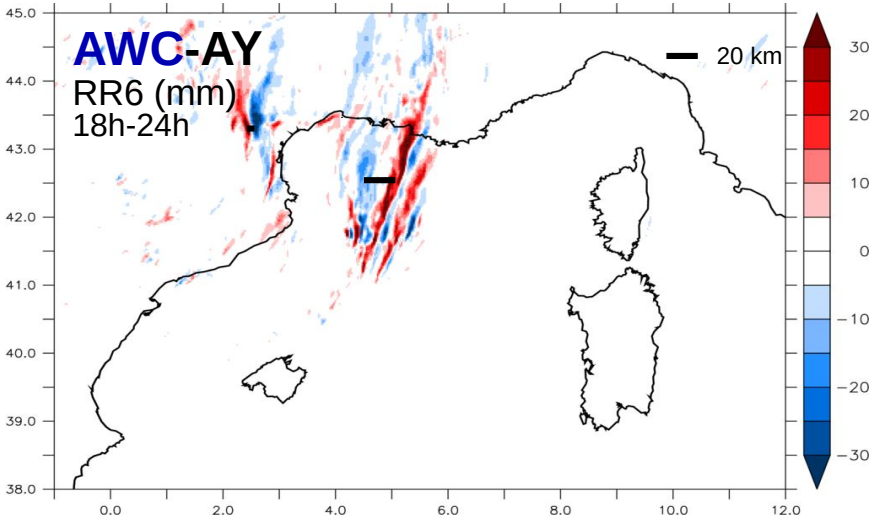




AROME-France / NEMO-NWMED72 / WW3

Wave coupling : impacts on rainfall forecast





- **small changes in intensity**
  24h amounts (13/10-14/10):
  Hérault:
  - 56.8 mm (max 271 mm)
  - 58 mm (max 278 mm)
  - 58.8 mm (max 273mm)

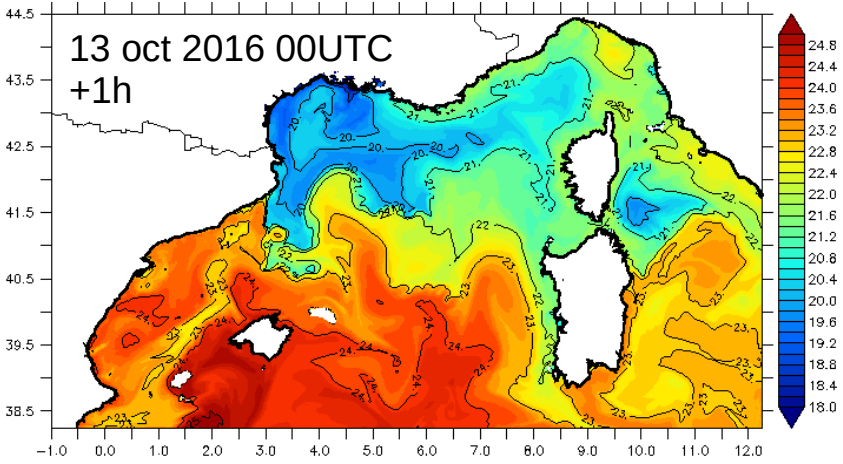
  Offshore:
  - 43.5 mm (max 188 mm)
  - 43.4 mm (max 187 mm)
  - 42.2 mm (max 214mm)

- **Impacts on localisation**

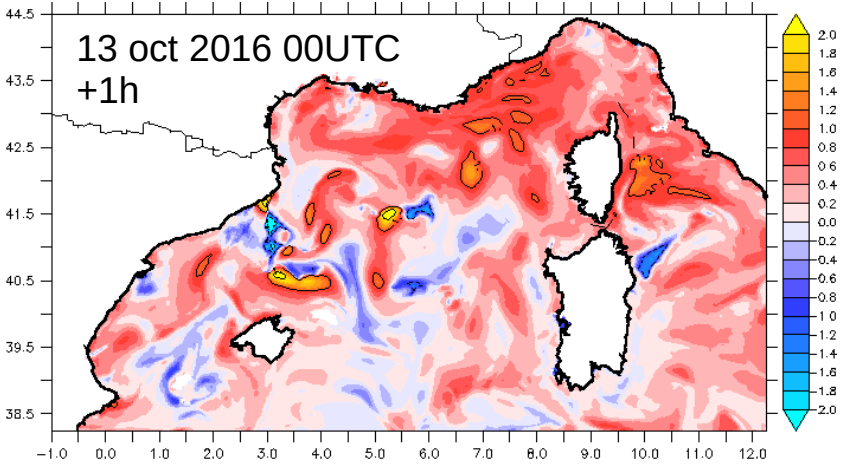
AROME-France / NEMO-NWMED72 / WW3

Ocean coupling : SST change induced by initialisation

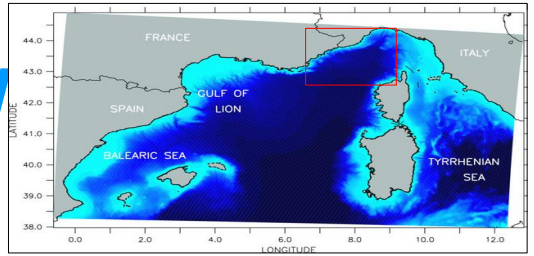
AOW exp



AOW exp differences with AWC (=PSY4)



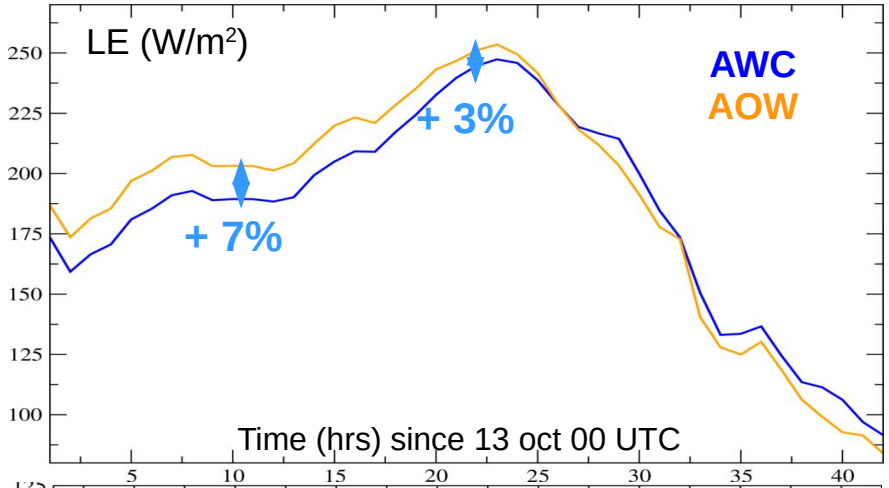
AROME-France / NEMO-NWMED72 / W

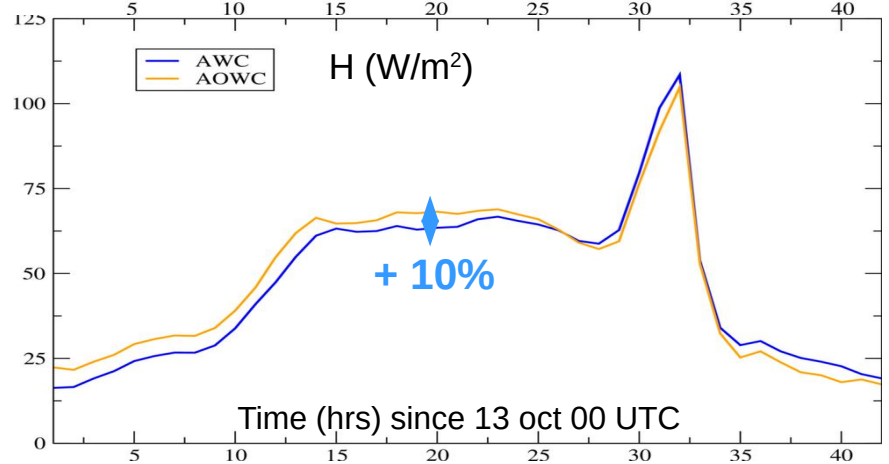


Ocean coupling : heat flux modifications

AOW vs AWC

- **Increase in heat fluxes**
  → due to initial SST
- **smoothing effect**
  → due to surface cooling reproduce by ocean coupling





AROME-France / NEMO-NWMED72 / WW3

- **Eastward displacement of heavy rainfall**

- **Intensification**

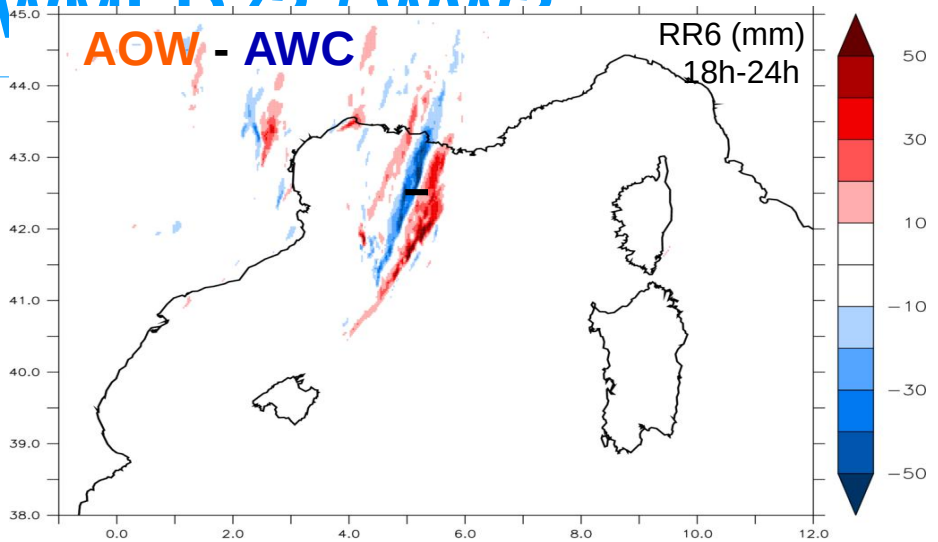
24h amounts (13/10-14/10):

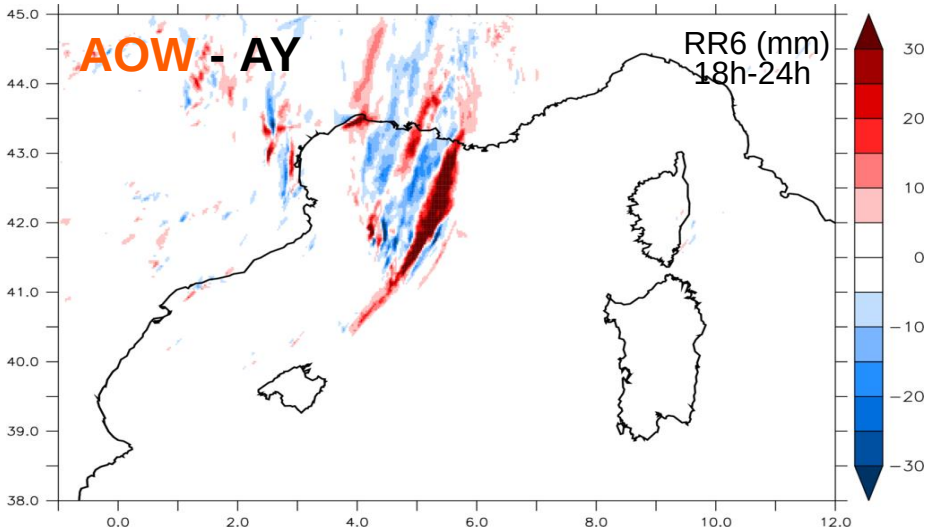
Hérault:

58.4 mm (max 264mm)
56.8 mm (max 271mm)
58.8 mm (max 273mm)

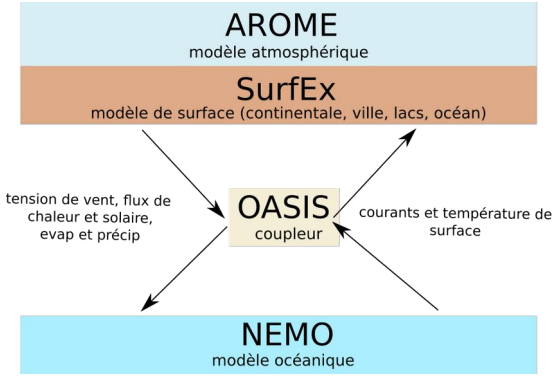
Offshore:

45.1 mm (max 228mm)
43.5 mm (max 118mm)
42.1 mm (max 214mm)





AROME-NEMO eIBI

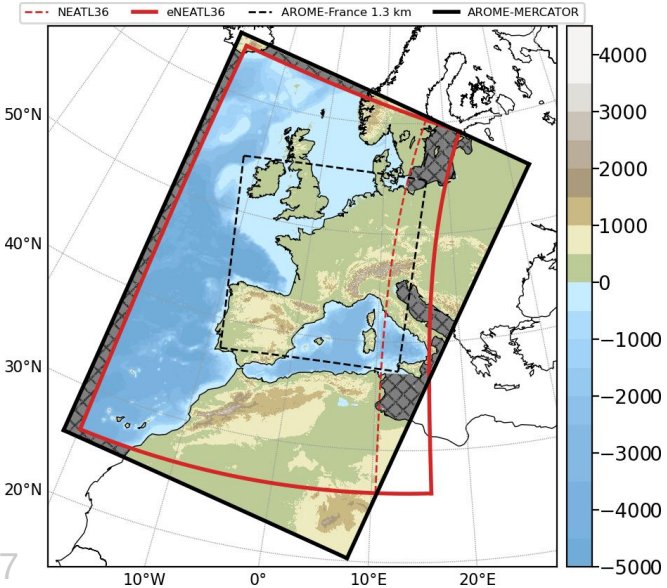


Development of an ocean-atmosphere coupled configuration at high-resolution (1/36°) for ocean forecasts on North-Eastern Atlantic Ocean and Western Mediterranean Sea (= IBI36 zone extended eastwards)

MERCATOR's objectives :

- **Improve** the ocean **high-resolution forecasts** (higher resolution of the atmospheric forcing and consistency with the ocean dynamics)
- Be able to provide high-resolution forecasts for the whole Western Med Sea, notably **fully covering Corsica's coasts** (eastwards extension of IBI36) and **improve** the representation of the **Northern Current** (originating from the Ligurian Sea)
- **Improve the initialisation** of coupled models using the **AROME / NEMO systems** (consistency with large scale models used at lateral boundaries)
- Start preparing **assimilation** methods for **operational coupled models**

Simulation domains



AROME: new domain

- cy43t2 (SFX v8_0), same atmos. physics as oper AROME-France
- sea surface fluxes parameterization (COARE 3.0)
- No assimilation (dynamical adaptation)
- Δx,y = 2.5 km [1285 x 1789]
- 90 vertical levels
- IC/LC: ARPEGE or IFS

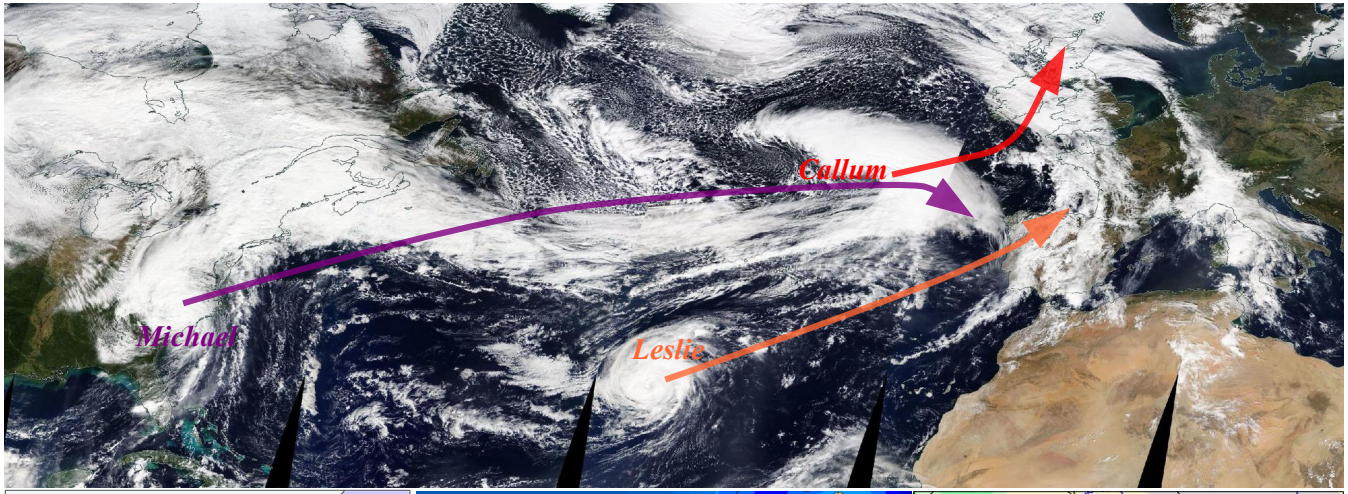
OASIS coupler:

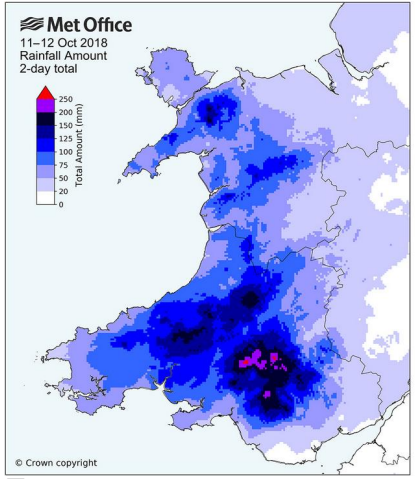
- fields exchanged every 10 min

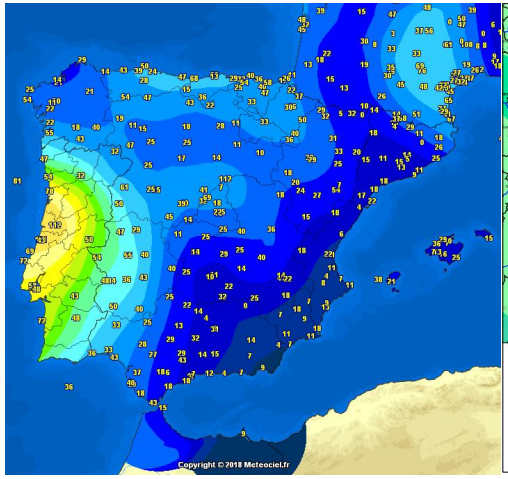
NEMO: eNEATL36

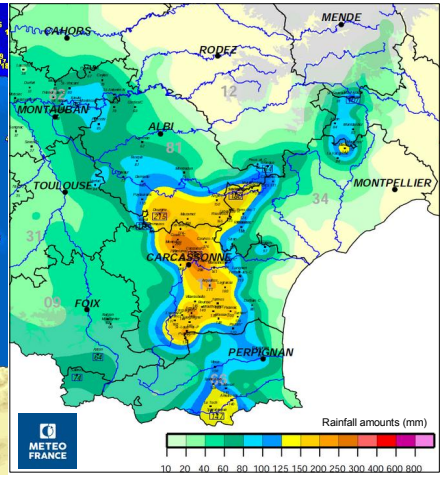
- V3.6, same physics as NEMO-NEATL36 (IBI36 oper)
- No assimilation
- Δx,y ~ 1/36° [1294 x 1894]
- 50 vertical z-levels
- IC/LC : mix between PSY4 and IBI36

AROME-NEMO eIBI









12-18 Oct 2018

→ successive severe events over the area with potential high OA interactions

- **Callum storm :**

Strong wind and rainfall over Wales

- **Leslie tropical cyclone :**

Strong wind over Portugal

- **Leslie & Michael cyclone remnants**
- **Aude heavy precipitation and flash-flood**

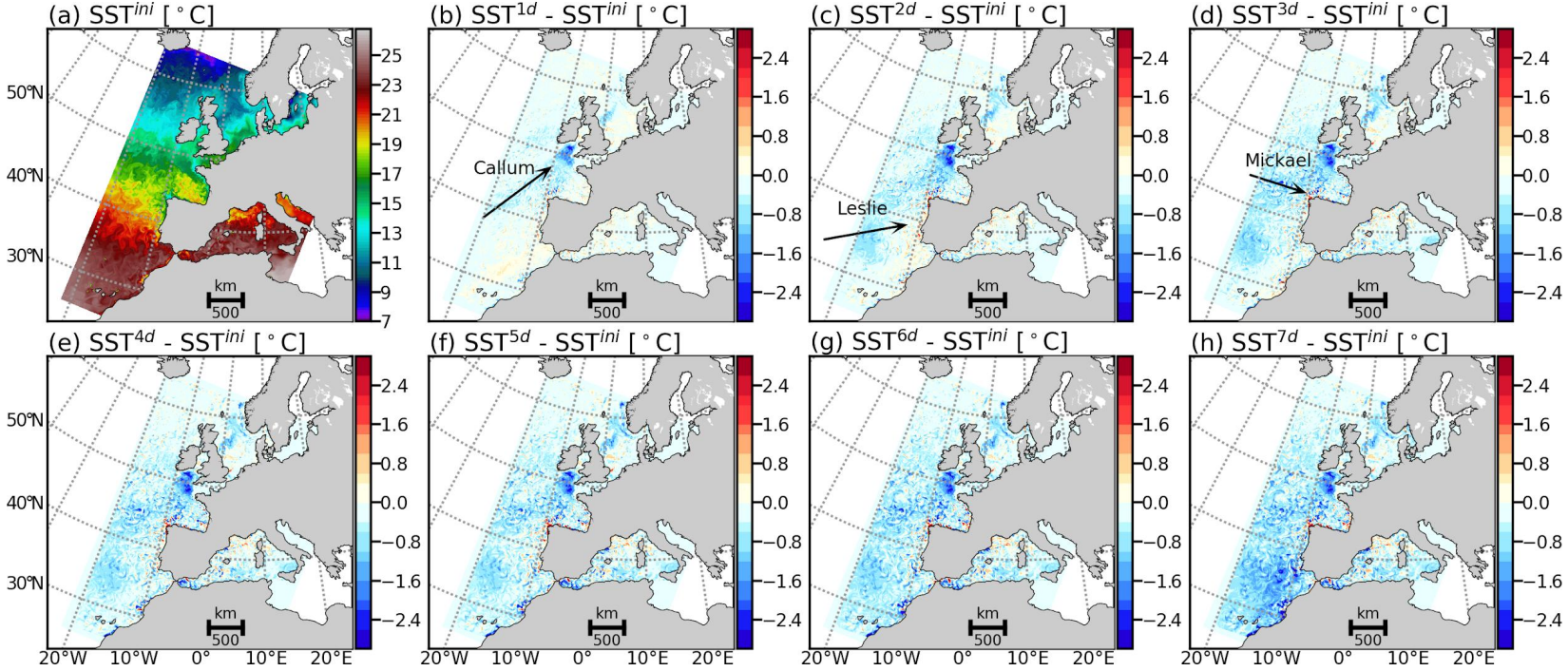
295.5 mm in 12 hours in Trèbes

Kendon et al. 2019 (10.1002/joc.6213)
Caumont et al. 2021 (10.5194/nhess-21-1135-2021)

AROME-NEMO eIBI

Experiments:

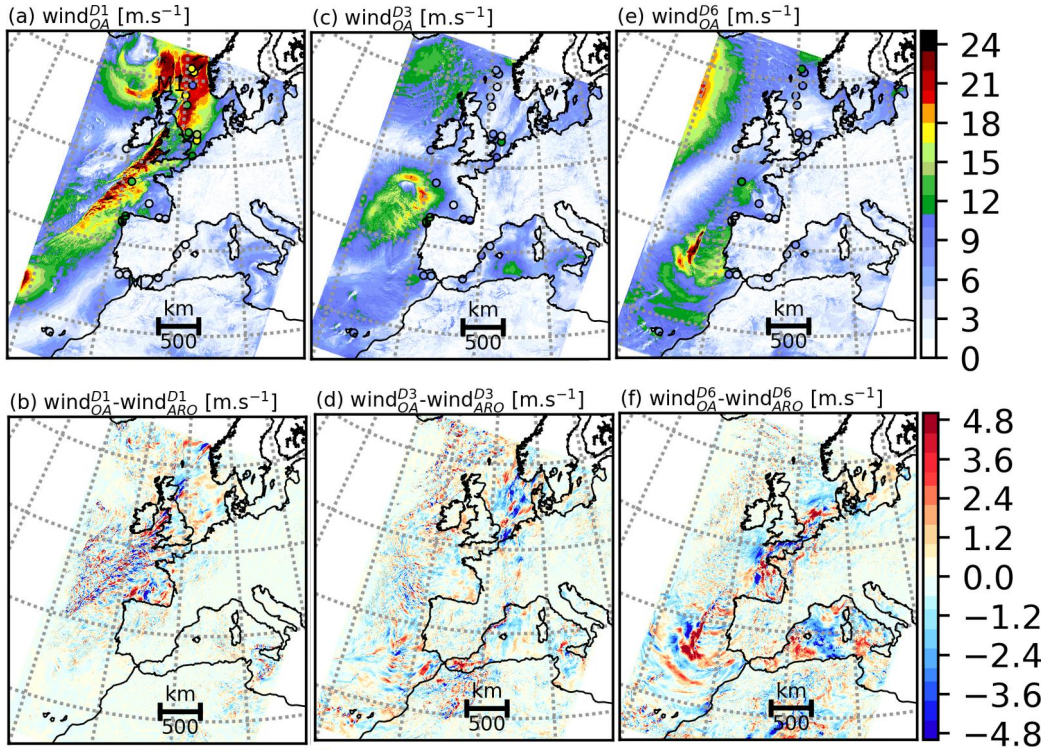
- *OA coupled experiment:* ***OA***
- *Atmosphere-only exp persistent SST coming from OAREF at t=0:* ***ARO***
- *Ocean-only experiment with IFS atmospheric forcing:* ***OCE-ifs***
- *Ocean-only experiment with 'ARO' atmospheric forcing:* ***OCE-aro***

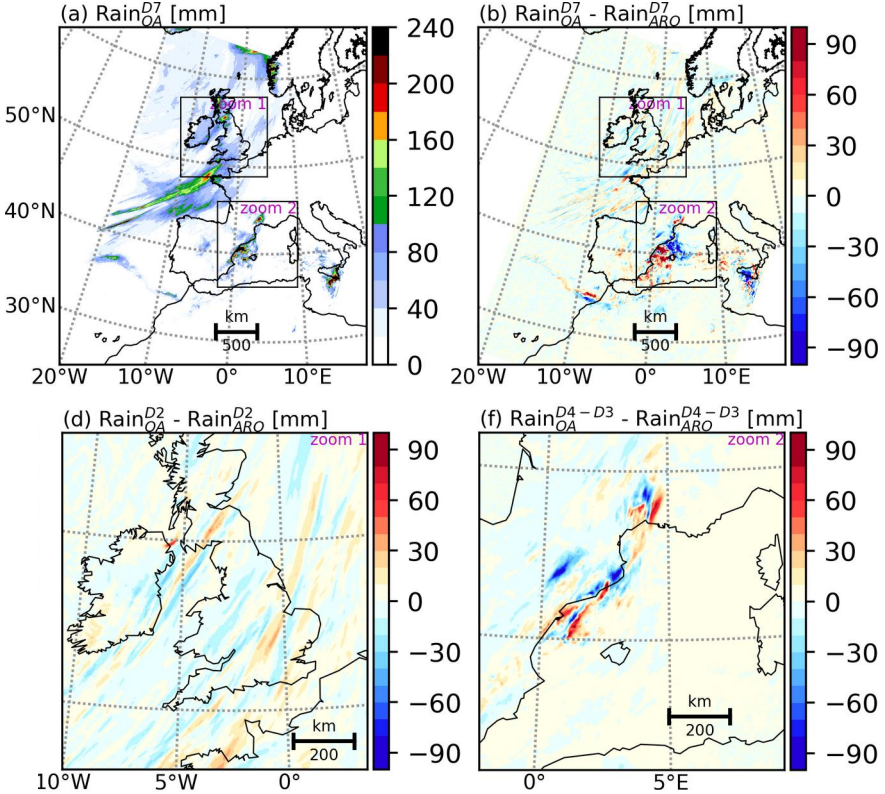


SST evolution in OA (and comparison with ARO)

AROME-NEMO eIBI

Summary of the results on the weather forecast side: OA-ARO





Conclusion

Improved interface for OAW coupling in SURFEX/AROME:

→ interface with OASIS since v8_0 for OA (and OAW in the future v9)

→ available since cy38, insertion in the official release planned for cy48 (work by S. Malardel)

→ sea surface flux computation taking sea state into account (WASP, also COARE) in forced or coupled modes

Impact on weather forecast:

→evolving sea surface conditions with fine-scale structures: more realistic

→ocean coupling (and initialisation) have main impacts on heat and moisture fluxes and indirectly on low-level circulation

→wave coupling strongly impacts the low-level wind

→both couplings induce modifications of the weather forecast

but only few case studies…

Perspectives

Ocean initialisation and uncertainties propagation

→ build a NEMO configuration suitable for coupling with AROME-France (domain, common physics with Mercator regional system) and evaluate various initial conditions (daily mean 1/12°, 1/36°, instantaneous fields) and impacts in ocean-only experiments

(Master internship 2021)

→ investigate the propagation of ocean perturbations (initial fields or boundary conditions) in the atmospheric forecast (and vice-versa) with the coupled system

(PhD thesis 2021-2024)

Towards a regional "Earth"/coupled system for NWP

→ have and maintain an OA coupled model close to the operational NWP system,
serving as a basis for the insertion of other components (in particular wave coupling to be pursued in collaboration, aerosols, hydrology, etc.),
ready to be used for coupled assimilation tests if needed,
fully usable for research applications, and in preparation for future AROME-based RCSM

(CNRM « pre-project »)

Thank you for your attention!

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