Rapid upper ocean responses to intense meteorological events in mesoscale ocean-atmosphere regional modelling

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1. Experimental design
   atmospheric and ocean models
   sensitivity experiments

2. Validation
   Evaluation of the atmospheric reference forcing
   Validation of the spin-up run in the ocean model

3. Impacts of the high space and time resolutions
   Comparison of the various atmospheric forcing
   Sensitivity of the Mediterranean circulation

4. Rapid upper ocean responses under intense meteorological events

5. Conclusions and perspectives
Regional atmospheric model

The WRF configuration:
- code version 3.0 [Skamarock, 2008] non-hydrostatic
- Regional domain: 240x130 grid-points – $\Delta x=20\text{km} - \Delta t=60\text{s}$
- 28 vertical levels
- Initial and boundary conditions from NCEP reanalysis (2°x2°)
- Zoom domain: 105x105 grid-points – $\Delta x=6.7\text{km} - \Delta t=20\text{s}$
- 28 vertical levels
- Initial and boundary conditions from the regional domain simulation
- SST field updated every 6hrs from reanalyses

- microphysics: WSM3
- convection: Kain-Fritsch
- turbulence: YSU-PBL
- IR radiation: RRTM [Mlawer et al., 1997]
- solar radiation: Dudhia [1989]
- turbulent fluxes: «MM5 similarity» [Monin and Obhukov, 1954]
1. Experimental design

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Ocean model:

The MED12 model configuration:
- NEMO code v2_3 [Madec 2008]
- ORCA12 grid, i.e. Δx=6 to 8 km-resolution from North to South
- 50 vertical levels
- Δt=12mn
- Initial state (T,S): Levitus [2005]

Exchanges with the Atlantic Ocean via a bufferzone
Black Sea inputs modelled as a runoff.
A climatology for the main rivers catchments is taken for runoffs
Free surface parameterization: The evaporated volume in the Mediterranean zone is reported in the bufferzone as an Atlantic Water surface input.

See also poster MWB10
Air/Sea experiments in the forcing mode

MED12 simulations in perpetual mode using the WRF atmospheric forcing.

1. Spin-up run (8 years) with the reference forcing (20km, daily).

2. Sensitivity experiments (4 years):
   - The control experiment (CTL) used the reference forcing (20km, daily).
   - In ZOOMGOL: high spatial resolution (6.7km) over the GoL area
   - In 3HFREQ: high temporal resolution (3 hrs)
   - In HIGHRES: high spatial resolution over the GoL area (6.7km) and high temporal resolution (3hrs)
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**QUESTIONS:**

Considering the Mediterranean basin's particularities, what are the required spatial and temporal resolutions of the atmospheric model for coupled regional climate modelling?

Quality of the sea surface fluxes from the non-hydrostatic high-resolution WRF model? Impacts of a finer spatial resolution over the North-Western Mediterranean basin? Benefit of a higher temporal resolution?

Sensitivity of the NEMO-MED12 ocean model to the space-time resolution of the forcing? Effects on the thermohaline circulation? Impacts on the ocean response at mesoscale under intense weather events?
2. Validation

Evaluation of the reference forcing

Heat and freshwater annual budgets in the reference atmospheric forcing (20km, daily)

Scores against the GSSTF2 [Chou et al., 2003] and HOAPS3 [Andersson et al., 2007] air-sea fluxes products over the Mediterranean region.

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<td>rms</td>
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</table>
2. Validation

General circulation during the spin-up: SSH

Mean SSH (m) + mean current at 47m

Mean Dynamic Topography from altimetry and in-situ measurements and derived geostrophic currents [Rio et al., 2007]
2. Validation

General circulation during the spin-up: MLD

RMS calculated using differences between daily and monthly mean values → interannual and seasonal cycles filtered

Short-range variations are located along boundary currents and in convective areas

Monthly mean Mixed Layer Depth (m) for the last year of the spinup

Good representation of the seasonal MLD compared to D'Ortenzio et al., 2005
2. Validation

General circulation during the spin-up: SST, SSS

Thermal and salt contents in the first 300 meters during the spin-up

After 4 year, no drift in the first 300 meters in S and T

RMS calculated using differences between daily and monthly mean values
→ interannual and seasonal cycles filtered

Short-range variations:
SST: along boundary current
SSS: mainly near rivers
3. Impacts of the high resolutions

Comparison of the various atmospheric forcings

- Probability density functions for the precipitation rate in the various forcings
- Differences in the annual wind stress module between ZOOMGOL and CTL

Example of the different forcing components between 12 November and 12 December 1998 at 4.9°E-42°N.

High resolution atmospheric forcing ➤ significant impacts on the intense forcing
3. Impacts of the high resolutions

**IMPACTS ON THE MED CIRCULATION OF DIFFERENT SPACE/TIME RESOLUTION FORCINGS**

**CTL**

**ZOOMGOL-CTL**

**3HFREQ-CTL**

**HIGHRES-CTL**

Additional variability in ZOOMGOL, 3HFREQ and HIGHRES

*Modifications by 5 to 10% of the variability, until +50% locally*
The diurnal cycle in the 3-hourly forcing tends to limit the ocean deep convection. Some convective chimneys persist a few days later with the high space resolution forcing.
4. Rapid upper ocean responses

Extreme meteorological events detection with thresholds:

HWE: daily averaged 10m-wind >18m/s
HPE: daily accumulated precipitation >80mm

Heavy windy episodes mainly located in the North-Western part of the Mediterranean;

Heavy precipitation events more scattered over the basin and more frequent in summer and autumn

Probability density functions for the precipitation rate and the 10m-wind speed in the reference forcing.
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UPWELLING UNDER HIGH WIND

Daily SST(°C) [year12] in NWE

Good correspondence with the upwelling zones reported in Millot, 1979
4. **Rapid upper ocean responses**

**UPWELLING UNDER HIGH WIND**

Daily SST(°C) + surface currents (cm/s) [year12] in NWE

- **CTL**
- **HIGHRES**

Strong variations in the surface current, finer Rhône river plume with the high space-time resolution.
4. Rapid upper ocean responses

**FRESHENING UNDER STRONG RAIN**

**Daily freshwater flux (kg/m²/s)** + **salinity modifications [year12]**

Same amount of water exchanged between **CTL** and **3HFREQ** but short range and intense precipitation peaks leads to a more significant freshening
5. Conclusions and perspectives

The sensitivity experiments show that:

(I) the WRF model is able to produce **accurate sea surface fluxes**
    - good estimation of the heat and water annual budgets
    - representation of extreme meteorological events.

(II) the MED12 model **well represents the Mediterranean circulation patterns**
    - cyclonic main circulation and main mesoscale gyres and coastal currents
    - accurate seasonal cycle of the ocean mixed layer depth

(III) the Mediterranean thermohaline and surface circulations are **significantly sensitive to the space-time resolutions** of the atmospheric forcing
    - strong modifications of the ocean variability at mesoscale

(IV) **High space-time resolutions are crucial** to well represent **the local ocean response under intense meteorological events**
    - 3-hourly forcing crucial to represent the diurnal cycle and the intense forcing peaks
    - High space resolution allows a finer representation of the wind jets and of the mesoscale precipitating systems

**Next step:** **Coupling WRF-(oasis)-MED12**

Perform 20-year runs (ERA-Interim period) in the forced and coupled modes

This OA coupling is part of the future MORCE-Med regional earth system