Impact of oceanic fine scales during the intense convection event of winter 2012-2013 in the North-Western Mediterranean sea

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Introduction

During winter, strong atmospheric fluxes in the North-Western Mediterranean sea area strongly affect the vertical stratification. When the stratification is completely destroyed, deep convection occurs, which leads to strong exchanges between the surface and the bottom.

Here, we use diagnostics of submesoscale activity to study the sensitivity of deep convection modelling to the horizontal resolution.

Methods

Numerical framework

Different CROCO model (https://www.croco-ocean.org/) configurations of the North-Western Mediterranean sea are set up at different horizontal resolutions: 400 m, 1200 m and 3600 m (Figure 1). Model simulations are run from 1 August 2012 to 1 May 2013, covering the intense deep convection event of winter 2012-2013.

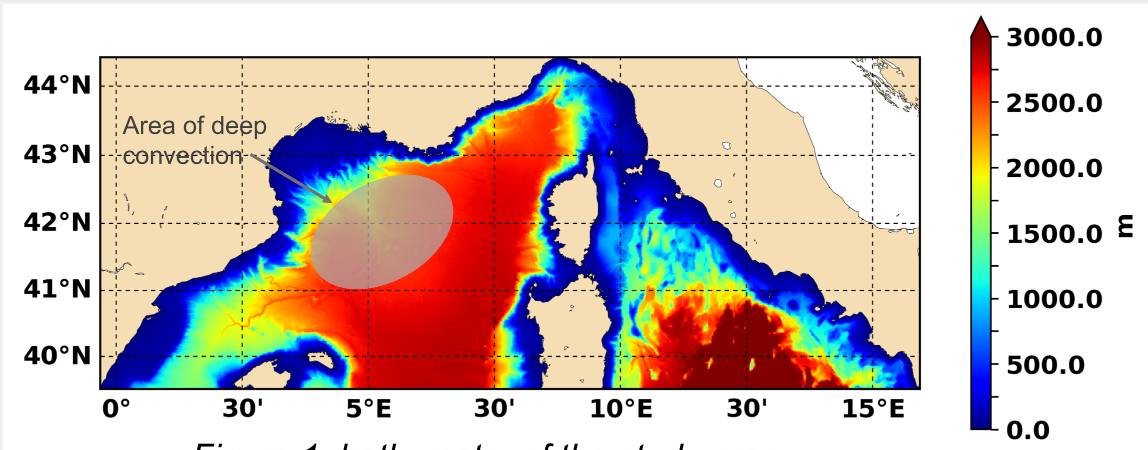

Figure 1: bathymetry of the study area

Scale separation

A spatio-temporal filter is used to separate the different dynamical components. For any variable v, $v = \bar{v} + v' + v''$, where $\bar{v}$, v' and v'' are respectively the mean, mesoscale and submesoscale components (*Capet et al.*, 2008). The time filter consists in a time-average over 4 days and the spatial filter removes scales greater than 10 kms (twice the Rossby radius of deformation - *Couvelard et al.*, 2015).

Results (1): vertical velocity

At high horizontal resolution (400m configuration), deep convection events are easily identified with an increase of the vertical velocity (Figure 2). Several events are visible at the beginning and the end of February and at the middle of March.

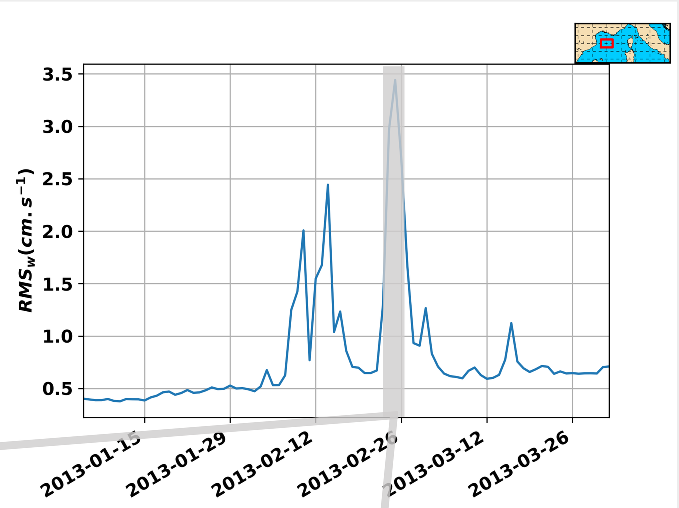

Figure 2: Vertical velocity root mean square in the area of deep convection

Snapshot of vertical velocity (Figure 3) shows organized structures with strong downwellings along thin plumes.

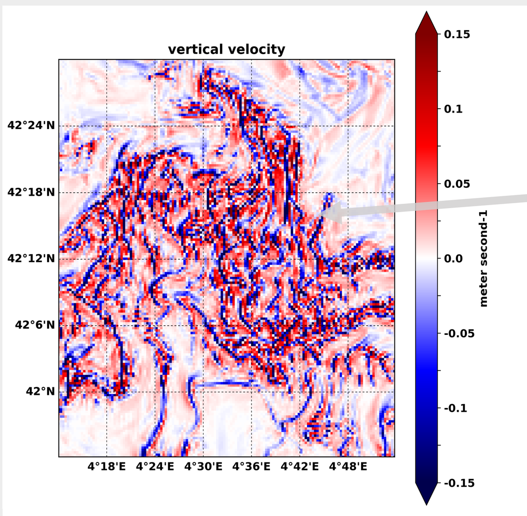

Figure 3: Snapshot of vertical velocity at 600m depth

Vertical velocity distribution for February 25 (Figure 4) reveals a strong asymmetry, exhibited by a negative skewness, with stronger downwellings compared to upwellings. Skewness values vary depending on the resolution: -1.2 and -0.5 for the 1200m and 3600m configurations, respectively.

Maximum velocities are in the range [20; 30] cm.s^{-1}. These results are comparable with observations of *Margirier et al.* (2016), where vertical velocities are evaluated from buoy and glider data.

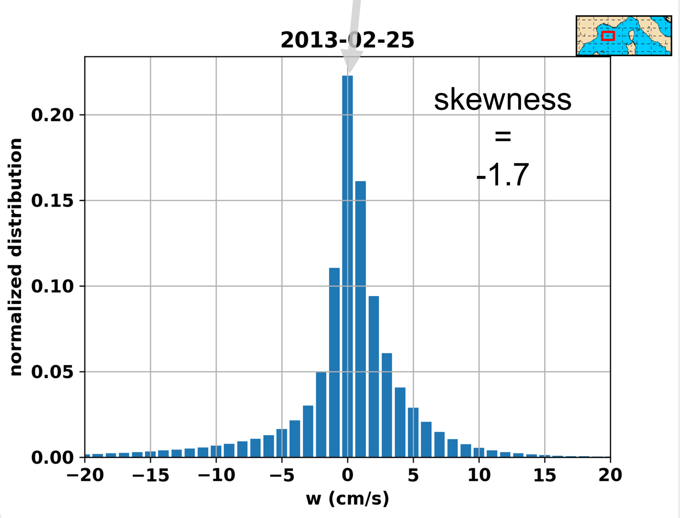

Figure 4: Vertical velocity distribution where convection occurs (400m configuration)

Mean mesoscale and submesoscale vertical buoyancy fluxes (respectively $w'b'$ and $w''b''$) are shown in Figure 5. They are mainly positive (restratification flux). Submesoscale fluxes are more intense, with an order of magnitude between mesoscale and submesoscale contributions. At submesoscale, deep convection is « restratification ».

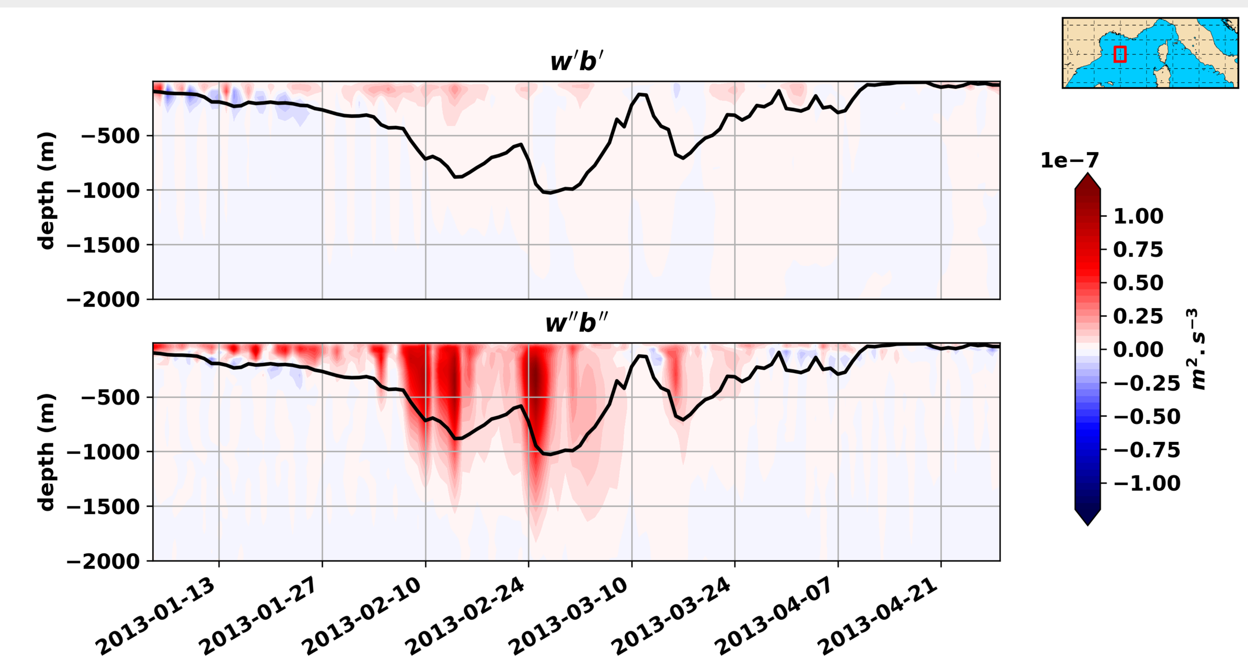

Figure 5: Depth-time section of the (top) mesoscale and (bottom) spatially-averaged vertical buoyancy fluxes in the area of deep convection (400m configuration). The black line is the mean mixed layer depth.

Results (2): sensitivity to the horizontal resolution

Following *Waldman et al.* (2016), time evolution of the dense water volume is computed for the three configurations (Figure 6). Dense water volume formation are computed and reveals strong differences beween configurations:

- 400 m: 0.298 e^{13} m^3
- 1200 m: 0.716 e^{13} m^3
- 3600 m: 2.07 e^{13} m^3
- *Waldman et al.* (2016): 4.5 $\pm$ 1.1 e^{13} m^3

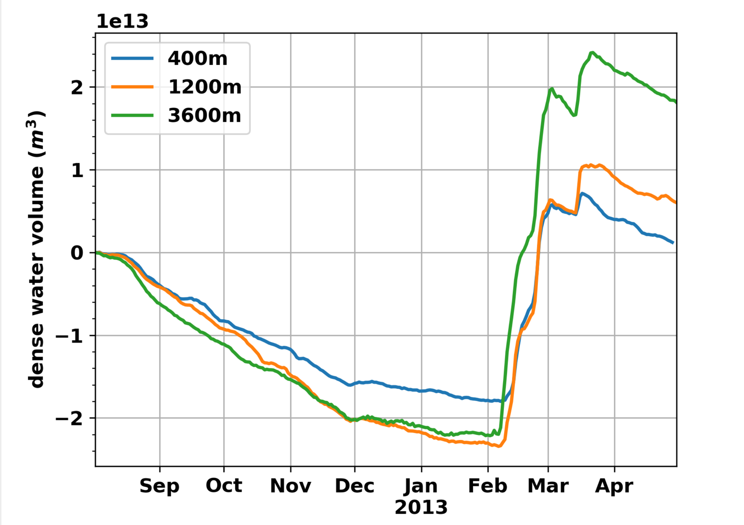

Figure 6: Time series of the dense water volume for the three different configurations (density greater than 1029.11 kg.m^{-3}).

To explain the differences between the three configurations, vertical fluxes of buoyancy due to vertical velocity or to vertical mixing are computed (Figure 7). The intensity of the fluxes due to vertical velocity increases when the resolution is finer, as shown by previous studies (*Capet et al.*, 2008; *Couvelard et al.*, 2015). Vertical mixing term reaches stronger values near the surface. Depending on the resolution, vertical fluxes are balanced differently between vertical advection and vertical mixing.

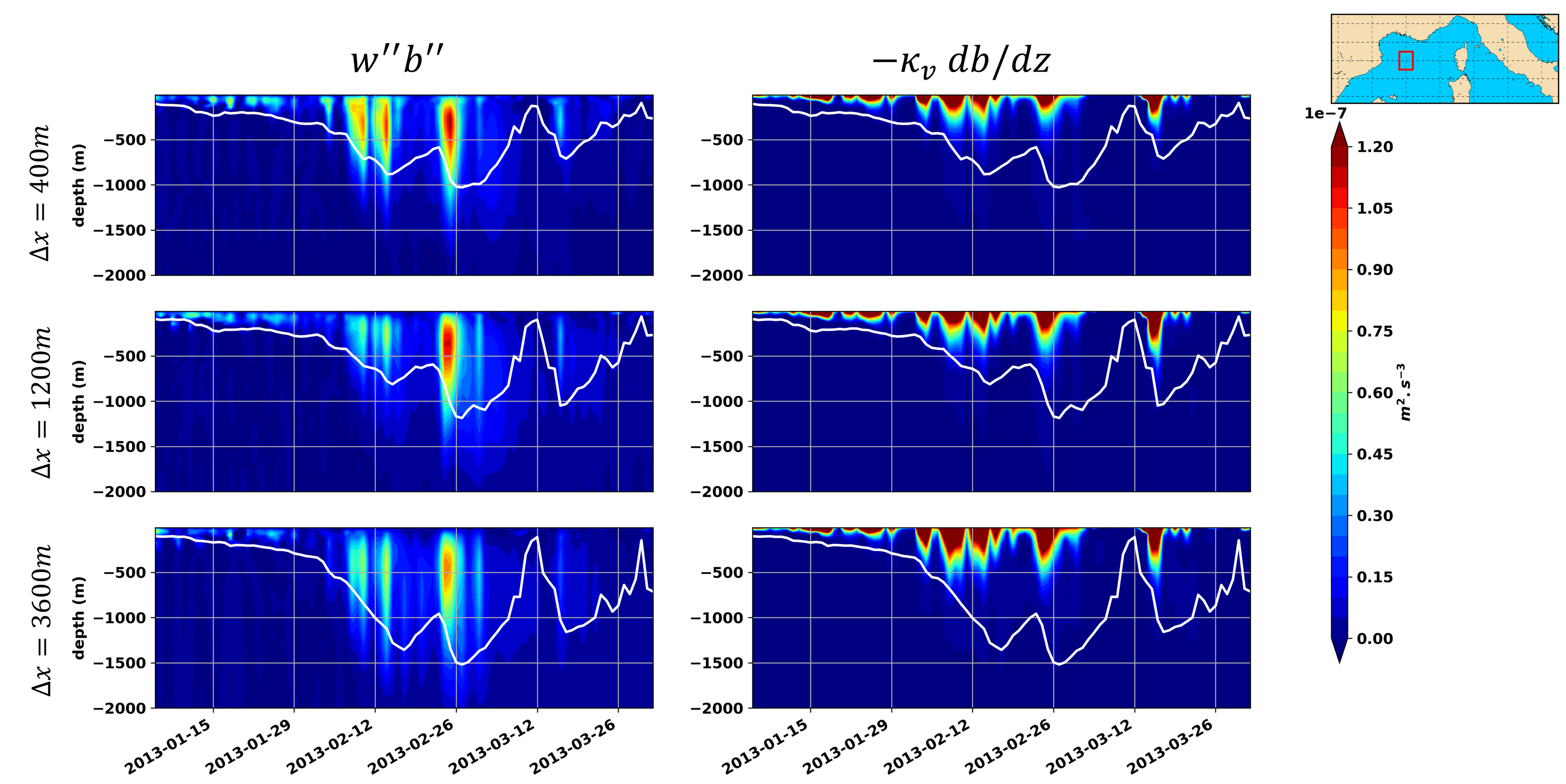

Figure 7: Depth-time section of the spatially-averaged (left) submesoscale vertical buoyancy flux and (right) vertical mixing flux for the three horizontal resolutions. The white line is the mean mixed layer depth.

Conclusions

- Vertical velocities are intense during deep convection events (up to 20 cm/s) as observed and compared to computed velocities under the hydrostatic assumption at various résolutions. Vertical velocity distributions are consistent with the statistics obtained from the observations.
- The horizontal resolution has a large impact on the numerical representation of deep convection and especially for the various vertical components of the buoyancy fluxes (advective at meso and submesoscale and diffusive). The balance between advective and diffusive flux is also deeply shifted.
- The key role of small scales on restratification has been known for more than a decade (e.g. *Boccaletti et al,* 2007) and pointed out in realistic simulations since *Capet et al* (2008). In the western Mediterranean Sea the vertical advection acts as a restratification agent during deep convection. These fluxes are stronger at high resolution and the formation of deep water is significantly reduced, raising fundamental questions about the turbulent closure adaptation with increasing resolution.

References

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