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Impact of the representation of the freshwater river input in the Western Mediterranean Sea

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ABSTRACT

The Western Mediterranean Sea is often affected by heavy precipitation which frequently generates floods or even flash floods. These events generally produce brief but major freshwater inputs in the ocean. In order to evaluate the sensitivity to the representation of river freshwater input, three different runoff forcing dataset are used to drive the NEMO ocean model: a monthly climatology, an observational dataset with a daily or a hourly frequency. The sensitivity is investigated over the first Special Observation Period (SOP1) of the HyMeX program that took place in autumn 2012, in two configurations of NEMO: the first is WMED36 over the Western Mediterranean Sea at 1/36°-resolution and the second is a new configuration covering the North-Western Mediterranean Sea with a 1/72°-resolution named NWMED72. With NWMED72, the impact of the representation of the river freshwater flux, i.e. moving from a surface flux to a vertical distribution of the flux, is also evaluated. The results show that the ocean stratification is significantly modified locally in simulations where runoff observations are used compared to those using the climatology. The sea surface salinity is modified as well as the mixed layer which is thinner as bounded by a well marked halocline. The sea surface temperature is also impacted by the change in runoff frequency. Moreover, the current intensity in river plume during flood is increased. Vertical profiles of salinity and temperature and thus the mixed layer depth are changed when the runoff forcing is distributed over a depth. Those changes are limited and very local but the realism of the river runoff input is improved.

1. Introduction

The Mediterranean Sea is a semi-enclosed sea where all of the water exchanges are concentrated in the Strait of Gibraltar with the Atlantic Ocean and in the Bosphorus Strait with the Black Sea. Well-known as an evaporation basin, the loss of water in the atmosphere is compensated by an inflow of Atlantic water (AW) (Bormans et al., 1986; Mariotti et al., 2002), which circulates cyclonically at basin scale (see Millot and Taupier-Letage (2005) for a review). In the Western Basin it forms the eastward Algerian Current (AC, Fig. 1) and the southwestward Northern Current (NC, Fig. 1). The latter flows along slope from the Ligurian Sea to the Balearic Sea. The northern limit of the reservoir of AW is materialized by the North Balearic Front (NBF, Fig. 1). The associated eastward recirculation along the northern side of the NBF and the NC form a cyclonic gyre, interacting with atmosphere, continental surface and bathymetry (Fig. 1). During wintertime, the dry and cold regional winds (northerly Mistral and northwesterly Tramontane) can induce deep water formation in the Gulf of Lion, both by cascading and open-sea convection (Marshall and Schott, 1999; Houpert et al., 2016; Testor et al., 2018). During the stratified period, these winds induce upwelling cells in the Gulf of Lion (e.g. Millot (1990)) and frequent shallow anticyclonic eddies along its western coast (Rubio et al., 2009; Hu et al., 2011).

The Mediterranean Sea is also a region frequently affected by heavy precipitation events (HPEs). Such events are characterized by large amounts of accumulated rainfall in short time, typically more than 100 mm in 24h, associated with mesoscale convective systems (MCSs) (Ducrocq et al., 2016). Falling over small river catchments that are

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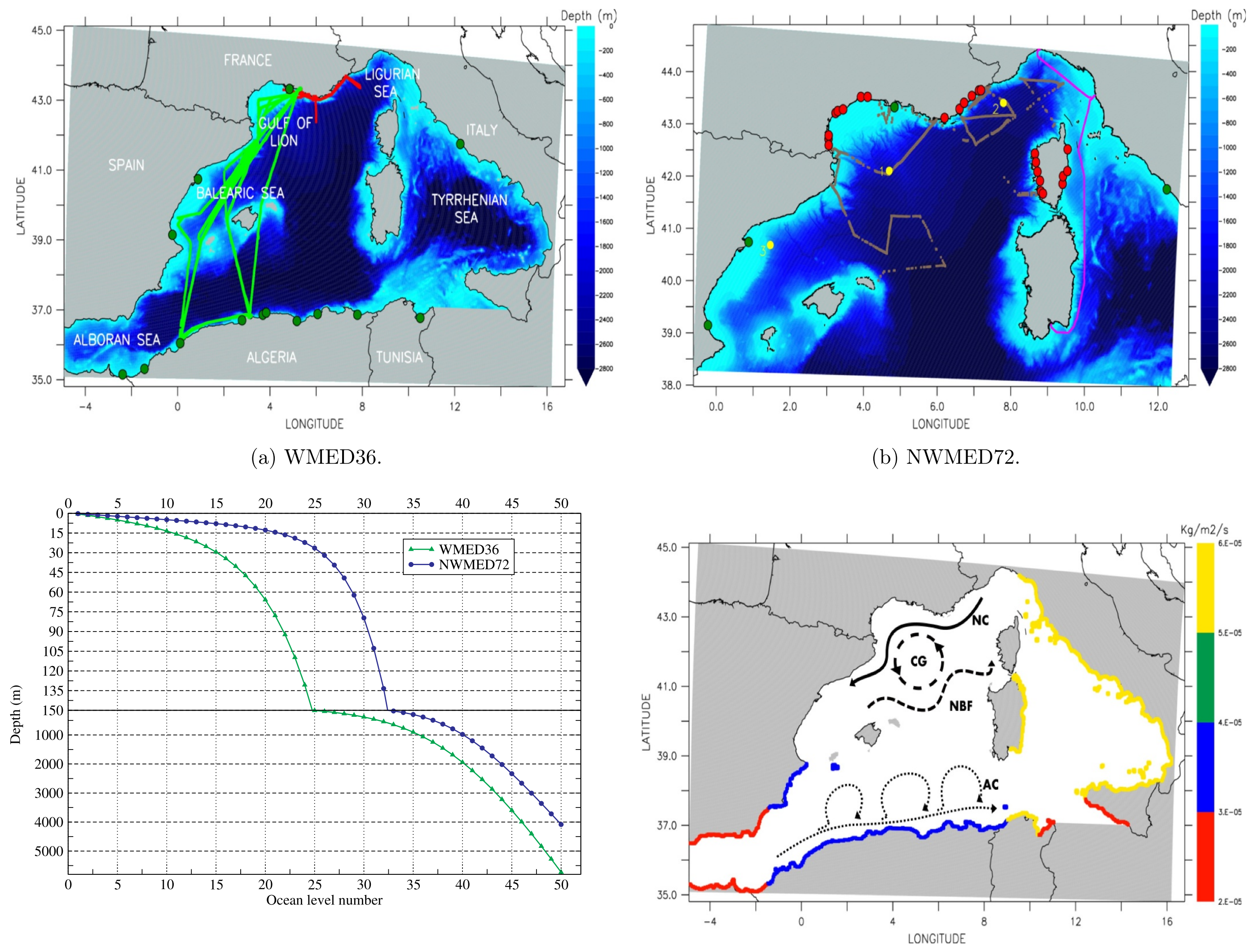

(c) Vertical grids. (d) Coastal runoff in W36_DD and W36_HH.

Fig. 1. Domains of the two ocean model configurations [bathymetry in meters]: (a) WMED36, (b) NWMED72 and (c) their vertical grids. (d) Coastal runoff (in kg/m^2/s) from climatology kept for W36_DD and W36_HH simulations. In (a,b): Green circles represent the main rivers in the climatology; Red circles represent rivers added with runoff observations; Coloured lines represent ship/TSG tracks: Marfret – Niolon in green, Téthys II in brown, Europe in red and Barcelona Express in purple; and yellow circles represent the moored buoys: 1 is GL, 2 is Az and 3 is Ta. In (d): NC is for Northern Current, NBF is for North Balearic Front, CG is for Cyclonic Gyre and AC is for Algerian Current. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

characteristic of the Mediterranean region (Tarolli et al., 2012; Merheb et al., 2016), these large and sudden precipitation amounts often lead to devastating flash floods and flooding events, causing damages and sometimes casualties (Buzzi et al., 1998; Romero et al., 1998; Krichak et al., 2004; Delrieu et al., 2005; Efstathiou et al., 2014; Ivančan-Picek et al., 2014)

HPEs and the associated flooding can produce large amount of freshwater input into ocean. Therefore, river freshwater runoff plays an important role on coastal regions. Freshwater flows from the river mouths to the ocean as a plume and previous studies have shown impact on the local circulation (e.g. Brando et al. (2015)). In most of the cases, water from the plume tends to flow along the coast with the land on the right in the northern hemisphere due to the influence of the Earth's rotation (Simpson, 1997). This low salinity buoyant freshwater alters stratification in the vicinity of the river mouth. Thus, a variability of the sea surface salinity (SSS) and the sea surface temperature (SST) is observed. Sometimes, it can be advected downstream and have an impact off-shore (Brando et al., 2015; Tseng et al., 2016; Fournier et al., 2016).

This study investigates the impact of a better representation of river runoffs in a high-resolution ocean model, with a focus in the Western Mediterranean area. Indeed, several case studies such as Schiller and Kourafalou (2010) and Herzfeld (2015) have shown that the way the river runoff is modeled impacts the river plume area and the mixing processes in coastal regions. More particularly a vertical distribution of the runoff flow can reduce low salinity surface bias (Tseng et al., 2016). The morphology of the plumes is sensitive to wind events and river discharges (Otero et al., 2008). More especially, in our area of interest, one of the largest rivers is the Rhône River, flowing in the Gulf of Lion with an average flow around 1 700 m^3/s. Its plume can extend far away (about 40 km) from the coast (Estournel et al., 1997) and presents a high variability depending on the meteorological conditions and outflow forcing (Broche et al., 1998; Estournel et al., 2001).

This study investigates how river plumes are represented and how a high temporal frequency flow can affect them, especially during floods. Moreover, we focus on how the heat and salt contents are impacted, along with the stratification, in the vicinity of river mouths. To evaluate the sensitivity to the representation of river runoff, the NEMO ocean