OCEAN-ATMOSPHERE INTERACTIONS AND COUPLING ASSOCIATED WITH TORRENTIAL RAINFALL EVENTS

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Abstract: The mountainous areas surrounding the Mediterranean basin are prone to torrential rainfall in autumn. The Mediterranean Sea is an important source of heat and moisture for these extreme events. The study here presents results about the Mediterranean Sea surface influence on the atmospheric convection and on the low-level jet that characterize these events, obtained by using various sea surface fluxes parameterizations for high-resolution forecasts (2-3 km) on three heavy rainfall events. Some results about the sensitivity of the oceanic mixed layer to the sea surface fluxes formulation obtained by forcing a 1D oceanic model with an heavy precipitating case environment, are also presented here.

Keywords: *air-sea fluxes, ocean-atmosphere interactions, Mediterranean torrential rainfall events*

1. INTRODUCTION

Heavy rainfall events that often occur over the Mediterranean mountainous areas in autumn are characterized by large amounts of precipitation (>100-200 mm) in a short time (24h). These extreme events are favoured by a slow-evolving synoptic situation and by the Mediterranean basin near-coastal topography. They are generally induced by quasi-stationary mesoscale convective systems (MCS) or frontal disturbances that stay over the same area for several hours to a few days. Sometimes, the two types of precipitating systems may combine.

The Mediterranean Sea is an important source of heat and moisture for these systems. Moreover, the strong low-level winds that prevail during these events constitute a strong forcing on the oceanic mixed layer through momentum exchanges. The Meso-NH research model (Lafore et al., 1998) running with two nested grids and coupled to its surface scheme SURFEX, is used here as a numerical laboratory to study energy exchanges at the air-sea interface and their impacts on the torrential rainfall events forecast. This study concerns three heavy rainfall events that occurred over Southern France: *i)* Two MCS cases: over Aude, 12-13 November 1999 (Ducrocq et al., 2003) and over Gard, 8-9 September 2002 (Delrieu et al., 2005), and *ii)* a case of a stationary frontal system with embedded convection over Hérault, 3 December 2003 (Lebeaupin et al., 2006).

Lebeaupin et al. (2006) have examined the sensitivity of these events to the Sea Surface Temperature (SST) for high-resolution and short range forecasts. Various SST fields were tested : an optimal interpolation of in-situ data and a high-resolution SST field based on AVHRR satellite data; other tests were done by increasing or decreasing the analysed SST over the sea basin. The averaged value of SST overall the basin is found modulating the convection intensity and the precipitation amounts, and in some extent the stationarity of the precipitating systems. The SST effect relies however on how the air-sea fluxes are parameterized in the model. This is examined here for the same heavy rainfall events using various air-sea surface fluxes parameterizations.

2. THE AIR-SEA FLUXES PARAMETERIZATIONS

In order to evaluate the sensitivity to the sea surface turbulent fluxes parameterization, we introduced in the Meso-NH surface scheme (*i.e.* SURFEX) two parameterizations based on bulk iterative algorithms:

– Firstly, the UNIfied Turbulent Fluxes Parameterization (UNITFP - Belamari, 2005) developed within the MERSEA project framework. It includes a multi-campain calibration of the exchange coefficients obtained by compilation of the ALBATROS experimental database (Weill et al., 2003) including the turbulent air-sea fluxes measurements during five experiments over the Atlantic Ocean or the Mediterranean Sea (CATCH, FETCH, SEMAPHORE, EQUALANT99, and POMME);

– Secondly, the algorithm developed from the beginning of the TOGA COARE experiment (Weller et al., 2004). We introduced in the surface scheme its last version described in Fairall et al. (2003) slightly modified in order to not take into account the cool-skin or warm layer corrections. We called it here after COARE 3.0.

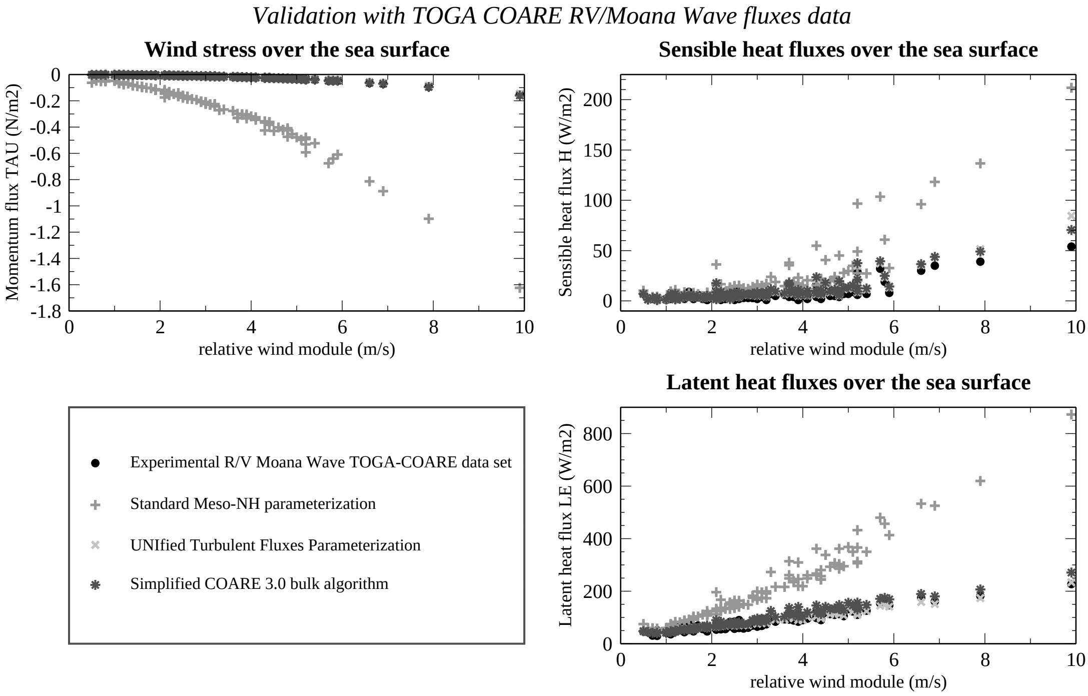

Figure 1: Momentum and heat fluxes over sea observed and computed off-line from the TOGA COARE experimental atmospheric data (T_a, T_s, q_a, q_{sat} and $\vec{v_a}$) according to the UNITFP, COARE 3.0 and standard parameterizations.

These two parameterizations are compared to the standard fluxes formulation of the Meso-NH surface scheme following Louis (1979).

The TOGA COARE experiment data set has been used to validate the new parameterizations. When the air-sea fluxes parameterizations are forced by the TOGA COARE atmospheric data, the simulated momentum and heat fluxes are closer to the observed fluxes for the UNITFP and COARE 3.0 parameterizations (Figure 1). The UNITFP and COARE 3.0 parameterizations provide very close values of fluxes. For strong wind regime ($\geq$10 m/s), the standard parameterization of Meso-NH strongly over-estimates the momentum fluxes and the latent heat flux.

3. IMPACT ON THE HEAVY PRECIPITATION FORECAST

Then, we examined the sensitivity to the sea surface turbulent fluxes parameterization for the same heavy precipitation events as Lebeaupin et al. (2006). Reference simulations ***stdhh*** uses in every case the standard parameterization of Meso-NH. Simulations ***unihh*** and ***coahh*** used the UNITFP and the COARE 3.0 parameterization respectively (Table 1).

Simulations using bulk iterative parameterizations produce very different sea surface turbulent fluxes values compared to references especially for latent heat flux and momentum flux in strong to intense wind regime. Changing the parameterization has therefore a significant impact on the atmospheric dynamics in the region of high-winds. The strong latent heat flux decrease results in less water vapor available for the convection and

Table 1: Numerical experiments to test sensitivity to the sea surface fluxes parameterization.

		using **standard** parameterization	using **UNITFP** parameterization	using **COARE 3.0** parameterization
AUDE CASE	duration: 18h; initial time: 12UTC 11/12/1999	std12	uni12	coa2
GARD CASE	duration: 24h; initial time: 12UTC 09/8/2002	std12	uni12	coa12
HERAULT CASE	duration: 24h; initial time: 00UTC 12/3/2003	std00	uni00	coa00

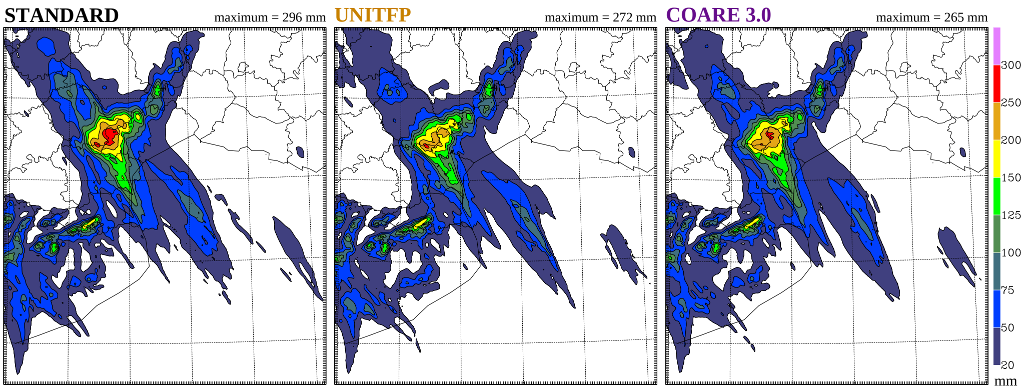

Figure 2: Sensitivity to the fluxes parameterization: Simulated surface rainfall totals (mm) after 18h for the Aude case.

consequently the simulated quantities of precipitation are less important. The largest differences are therefore found for the torrential rainfall event with the strongest low-level jet, *i.e.* the Aude case, where the low-level wind exceeded 30 m/s. The evaporation is in that case strongly decreased. In uni12 and coa12 compared to std12, latent heat flux is decreased by nearly 200W/m^2 within the low-level jet area, and the maximum value of rainfall amounts after 18h simulated is decreased by about 10% (Figure 2). For situations with weaker wind regime over sea (<10 m/s) as for the Gard case, changing the air-sea parameterization has almost no impact on the rainfall amount.

Even tough using the iterative parameterizations does not improve the short-range high-resolution atmospheric convection forecast, the strong differences of momentum fluxes over sea surface could be very important for the oceanic dynamics in case of air-sea coupling forecasts.

4. IMPACT ON THE OCEANIC MIXED LAYER

To evaluate the impacts of an air-sea parameterization change on the oceanic mixed layer dynamics and thermodynamics in Mediterranean heavy rainfall situations, we experienced off-line oceanic simulations with the 1D model from Gaspar et al. (1990) in turbulent kinetic energy equations. Some seawater columns in the Gulf of Lions modelled by Gaspar et al. (1990) are forced during 24h with air-sea turbulent fluxes corresponding to the Hérault case. Fluxes are computed off-line by the Meso-NH surface scheme (*i.e.* SURFEX) according to the parameterization chosen using oceanic data from the Mercator forecast (Bahurel et al., 2004) for 00UTC, 3 December 2003 and atmospheric data from a Meso-NH forecast for midday. Radiative fluxes evolve diurnally between 0830UTC and 1730UTC.

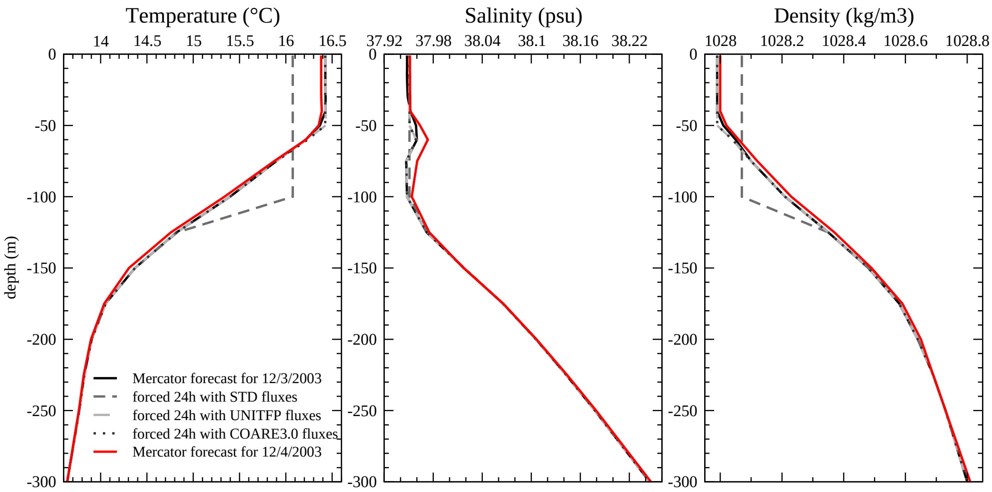

Figure 3: Oceanic profiles at 42.45N/5.80E: Initial from the Mercator forecast for 12/3/2003 in black and obtained after 24h-forcing the 1D model by SURFEX fluxes with various parameterizations (grey lines). Mercator profiles forecast for 12/4/2003 are in red.

Table 2: Bias and root mean squared errors from the Mercator forecast for 12/4/2003 after 24h-forcing 1D oceanic models for the mixed layer depth and for the temperature and salinity all along the seawater column.

	Temperature(°C)		Salinity (psu)		Mixed layer depth (m)	
	BIAS	RMS	BIAS	RMS	BIAS	RMS
standard	$0.5\ 10^{-2}$	$7.9\ 10^{-2}$	$0.4\ 10^{-2}$	$1.8\ 10^{-2}$	10.7	17.9
UNITFP	$2.2\ 10^{-2}$	$5.4\ 10^{-2}$	$-0.3\ 10^{-2}$	$1.9\ 10^{-2}$	-5.9	15.8
COARE 3.0	$2.1\ 10^{-2}$	$5.3\ 10^{-2}$	$-0.5\ 10^{-4}$	$1.8\ 10^{-2}$	-4.8	14.6

Results show that the sea surface fluxes parameterization choice influences significantly the oceanic modelling. Figure 3 shows that the standard air-sea fluxes parameterization gives strong values of stress and evaporation under high wind that deepen and cool strongly the oceanic mixed layer. Locally, the SST decrease reaches 0.3°C. Profiles obtained with the two iterative parameterizations are more realistic compared to the Mercator forecasts for 00UTC, 4 December 2003. Indeed, weaker turbulent fluxes are produced by UNITFP and COARE3.0. The oceanic mixed layer is weakly mixed and the SST is sometimes locally increased. The COARE 3.0 algorithm gives the smallest salinity and oceanic mixed layer depth bias and rms values for all seawater columns (Table 2). Note however that the two iterative parameterizations provide very close scores.

5. CONCLUSIONS AND PERSPECTIVES

Sensitivity to the sea surface turbulent fluxes parameterizations have been examined on three heavy rainfall events over the mountainous Mediterranean regions. Two iterative air-sea fluxes parameterizations (UNITFP and COARE 3.0), more accurate in strong wind regime, have been introduced in the surface scheme SURFEX common to Meso-NH and the future operational model AROME of Météo-France, and compared to the standard parametrization. Differences in rainfall forecasts when the sea surface parameterization is changed are visible in meteorological situations where a high-wind regime prevails over sea.

Results obtained by forcing off-line the 1D oceanic model from Gaspar et al. (1990) show the importance of a realistic sea surface fluxes parameterization for well simulated the oceanic mixed layer dynamics during heavy precipitation situations.

A full two-way coupling between Meso-NH sea and the Gaspar et al. (1990) 1D oceanic model is currently developed. It will allow us to study with more details the atmospheric forcing impact (wind and precipitation) on the oceanic mixed layer and the air-sea interactions during Mediterranean heavy rainfall events.

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