High-Resolution Gridded Air-Sea Surface Fluxes over the Mediterranean Basin by a Synthesis Approach

BY

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SUMMARY

As a part of the Mediterranean Forecasting System: Toward Environmental Predictions (MFSTEP) Project, this work provides a set of daily air-sea surface fluxes over the Mediterranean basin for January 2003. Fluxes are available on a regular 20 km wide grid. This data set has been produced by a synthesis approach, i.e. by selecting the best available products among different sources.

Radiative air-sea surface fluxes (short-wave and long wave radiation) are derived from satellite estimates produced operationally by the Centre de Météorologie Spatiale (CMS) in Lannion (Bretagne, France). Validation of these products in different seasons and over different oceanic basins has proved their high quality at the meso-scale (Weill *et al*., 2003; Caniaux *et al*., 2004).

Turbulent heat (latent and sensible) and momentum fluxes were produced from the European Center for Medium Range Forecast (ECMWF) observables (temperature, humidity, sea surface pressure and wind) and from satellite and in-situ sea surface temperature analyses. A state-of-art parameterisation is used to compute the turbulent fluxes. This parameterisation has been derived from a specific in-situ experiment (Dupuis *et al*., 2003), which took place in the Mediteranean Basin in 1998 (the FETCH Experiment, Hauser *et al*., 2003). The high quality of the heat fluxes obtained is assured by their high spatial and temporal resolution.

Publications in the open literature (Arpe, 1991; Hagemann, 2002) have analysed the spin-up effect in precipitation/evaporation produced by NWP models - i.e. the initial increase or decrease of model outputs with forecast length - by examining global averages as a function of the forecast lead time. Results indicate that the main changes affect precipitation during the first 12 h of the forecasts. Thus, two short-range forecasts of precipitation were processed: 00-24h and 12-36h forecasts from the ECMWF data. Results indicate that precipitation taken during the 12-36h time interval is generally smaller than that at 00-24h.

Keywords: air-sea surface heat fluxes, MFSTEP, ocean operational forecasting system

Contents

1. Introduction

This work is part of the MFSTEP (Mediterranean Forecasting System: Toward Environmental Predictions) Subtask 10320 (Sensitivity experiments to heat and momentum flux parameterisation). The objective of this work is to provide a set of gridded air-sea surface fluxes over the Mediterranean Basin with the best spatial and temporal coverage and resolution for January 2003. This dataset is destined to force a Limited Area Model (LAM) to investigate the contribution of air-sea surface fluxes in the formation and evolution of oceanic features in response to different weather regimes[1].

In order to reach this objective two sources of basic flux variables were combined. Atmospheric parameters were given by the ECMWF (European Center for Medium Range Forecast) operational analyses: temperature, humidity, sea surface pressure and wind. Precipitation were also from the ECMWF. Radiative air-sea surface fluxes (short-wave and long-wave radiations) were derived from satellite measurements produced operationally by the Centre de Météorologie Spatiale (CMS) of Lannion (Bretagne, France).

Sea surface turbulent heat (latent and sensible) and momentum fluxes were estimated with a state-of-art bulk algorithm (Dupuis *et al*., 2003) developed from the field experiment FETCH (Hauser *et al*., 2003), which contributes to the high-quality of this new flux dataset.

2. Basic Variables

2.1. ECMWF Products

The Integrated Forecasting System (IFS) is developed jointly by ECMWF and Météo-France. During the period considered in this study, the operational model changed to a new cycle (CY25R4) on the 14th January, 2003. The description of changes in data assimilation and forecasting system can be found on the Website quoted below[2].

The analysis and forecast were recovered from the MARS archive on a regular 0.4° grid mesh, which corresponds to the finest resolution available.

[1] ***WP10-Atmospheric Forcing and Air-Sea Interaction Studies***
Task 10300 Study of air-sea interactions physical parameterisations on the atmospheric processes
Subtask 10320: Sensitivity experiments to heat and momentum flux parameterisation
[2] http://www.ecmwf.int/products/data/operational_system/evolution/evolution_2003.html

3.1.1. Atmospheric Parameters

Four-daily analyses were used to acquire appropriate input data. Analyses were archived every six hours. These are the operational analyses produced by the newer variational analysis (4D-Var). The 4D-Var technique uses the atmospheric model resolution T159L60 of the IFS, where T159 is a spherical-harmonic representation for basic dynamical fields and L60 represents the 60 hybrid levels on the vertical. Table 1 lists atmospheric parameters obtained from MARS archive with the GRIB codes.

Table 1. ECMWF meteorological products.

ECMWF Operational Archives			
Parameter	Analysis		
	MARS Abbreviation	GRIB Code	Units
Surface Pressure	SP	134	Pa
10 metre U wind component	10U	165	$m.s^{-1}$
10 metre V wind component	10V	166	$m.s^{-1}$
Two metre temperature	2T	167	°K
Two metre dew point	2D	168	°K
Land Sea Mask	LSM	172	-

The ECMWF analysis fields, initially on a 40 km grid, were interpolated onto a 20 km horizontal regular grid. The original and the interpolated two meter high temperature fields are displayed on Figure 1. The patterns of the main SST structures are not affected by the interpolation procedure and local differences between the two fields are not significant; this proves the consistency of the interpolation procedure.

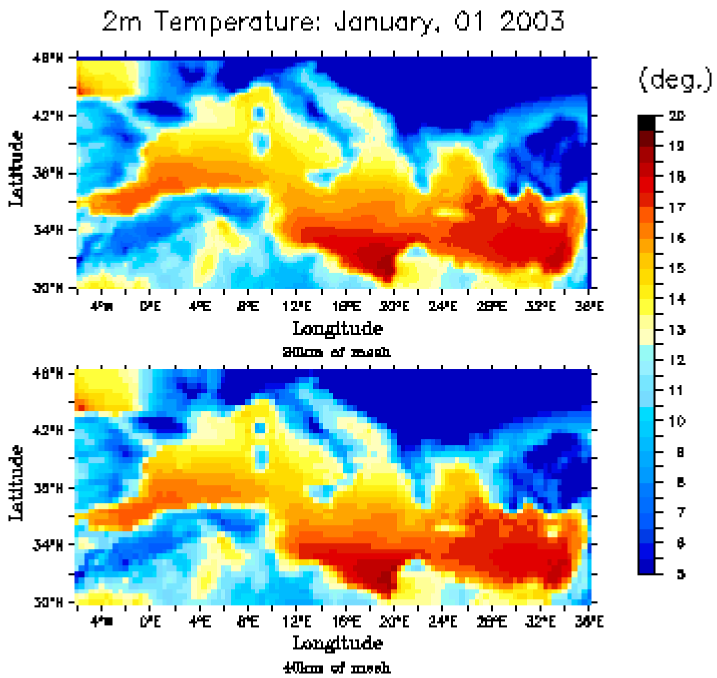

Figure 1. Two meter high temperature fields after (top) and before (bottom) optimum interpolation, respectively for 20 km and 40 km grid mesh.

3.1.2. Precipitation and Evaporation

Publications in the open literature (Arpe, 1991; Hagemann, 2002) have analysed the spin-up effect in precipitation/evaporation produced by NWP models - i.e. the initial increase or decrease of model outputs with forecast length. Results indicate that strong changes affect precipitation during the first 12 hr of the forecast.

Thus, two short-range forecasts of precipitation were processed: 00-24hr and 12-36hr forecasts. Total precipitation was obtained by summing large scale and convective precipitation (Table 2).

Table 2. ECMWF products.

ECMWF Operational Archives			
Parameter	Forecast		
	MARS Abbreviation	GRIB Code	Units
Large Scale Precipitation	LSP	142	M
Convective Precipitation	CP	143	M
Evaporation	E	182	M

Precipitation during the 12-36hr time interval are generally smaller than those at 00-24hr (Figures 2 and 3) but the time evolution of daily evaporation remains similar between 00-24hr and 12-36hr forecasts. Consequently, the 12-36hr cumulative precipitation is considered to be out of the precipitation spin-up period. Note that for evaporation this choice is not relevant (Figure 3).

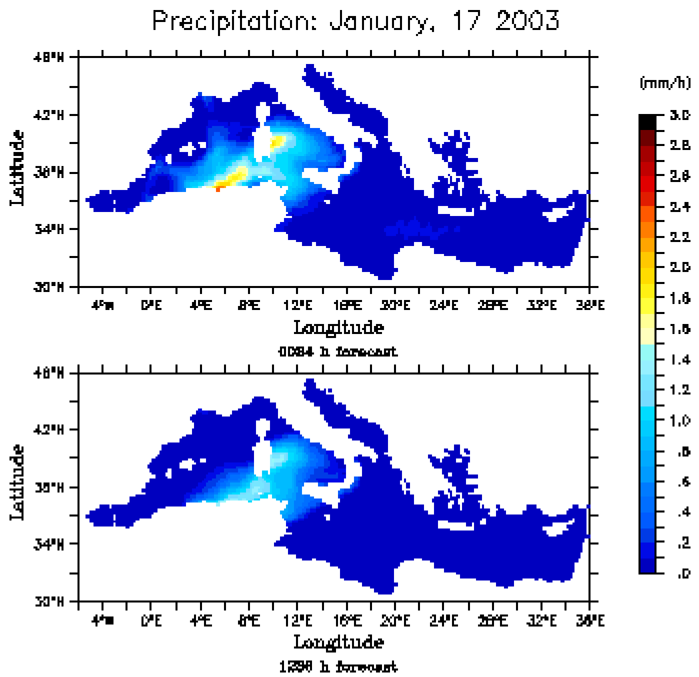

Figure 2. Total precipitation for 00-24h (top) and 12-36h (bottom) forecasts.

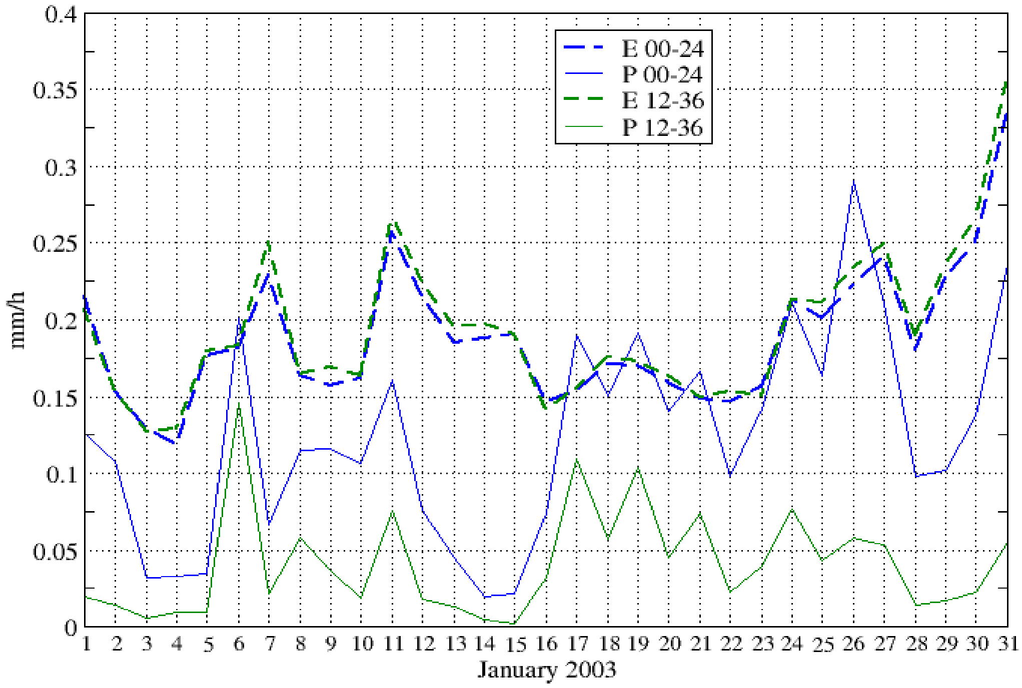

Figure 3. Time evolution of daily total precipitation and evaporation from 00-24h and 12-36h forecasts.

2.2. Radiative forcing

Radiative air-sea surface fluxes include the net shortwave (incident solar radiation and radiation reflected by the sea surface) and the net longwave (infrared radiation emitted by the atmosphere and the sea surface) radiation. These fluxes were derived from satellite measurements. The validation of these products has been carried out during dedicated experiments at sea, in different seasons and over different oceanic basins; this has proved the very high quality of the fluxes at the meso-scale (Weill *et al*., 2003; Caniaux *et al*., 2004).

2.2.1. METEOSAT products

Solar Radiation and Downward Long-wave Irradiance (DLI) come from METEOSAT retrievals. Solar radiation is hourly and issued from AJONC products (visible channel). It has 2560 x 1144 pixels over the Europe with a resolution of 4 x 4 Km. Since 1999, AJONC products include monthly validations of solar radiation with pyranometric measurements of the METEO-FRANCE network . DLI is also hourly on a regular 10 km grid. More information can be found on-line at http://www.meteorologie.eu.org/safo.

2.2.2. Sea Surface Temperature

Sea Surface Temperature (SST) is available four-daily from NOAA-16/17 AVHRR (Advanced Very High Resolution Radiometer) (hours of ref.. 02:00 and 12:00 UTC for NOAA16, 10:00 and 20:00 for NOAA17) over a stereographic grid framing the field of interest (30N/46N 6W/37E). The dimensions of the extracted field (900 X 2100 points) allow a high spatial resolution over a regular grid of 2.5 km. However, the spatial resolution of the atmospheric parameters necessary to process the turbulent heat is not as high (=40 km, §3.1). Thus, a resolution of 20 km was considered.

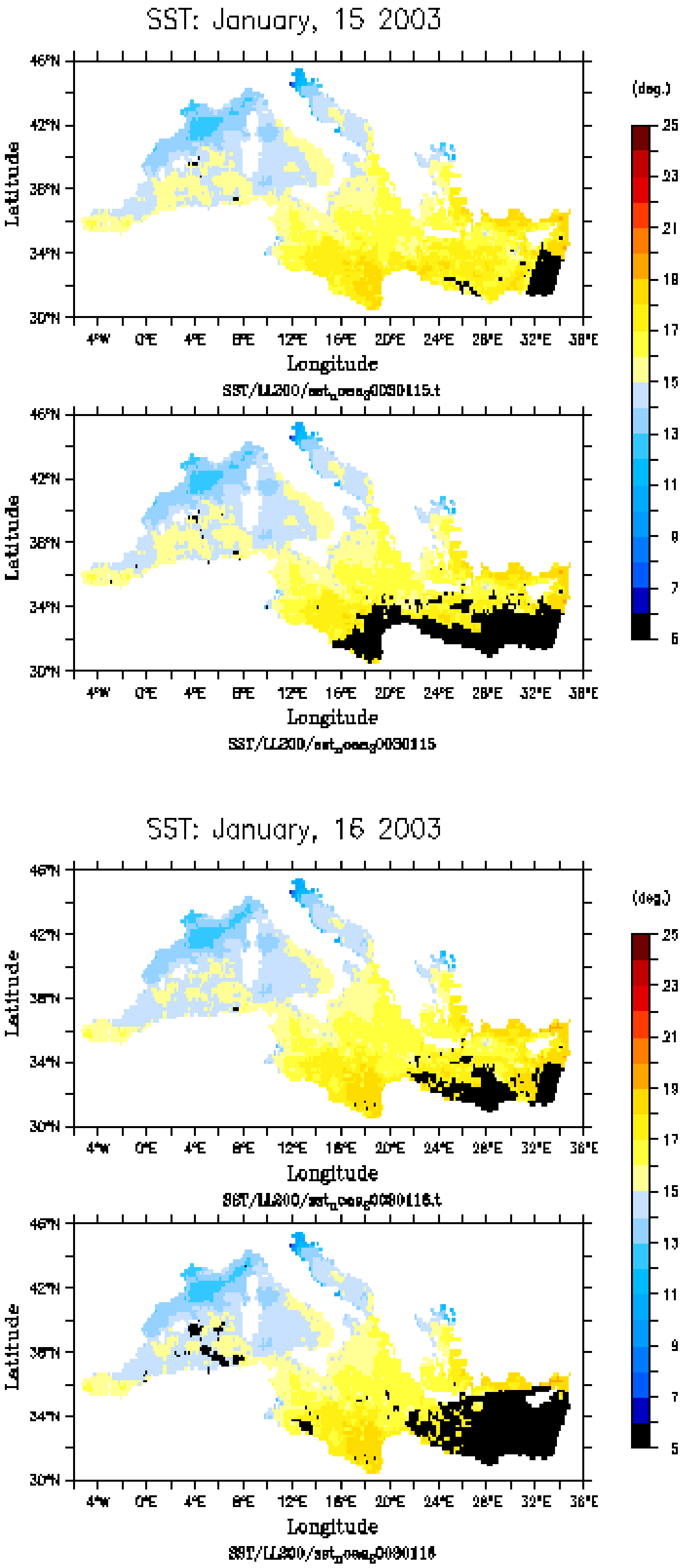

Figure 4. Daily Sea Surface Temperature (SST) after (top) and before (bottom) temporal interpolation for January, 15 and 16 respectively, from top to bottom.

In case of lacking SST data, due to the presence of clouds, a specific procedure has been applied including: (i) a temporal average for each four daily measurements (ii) daily means (iii) a temporal interpolation for daily averages (iv) a linear interpolation.

In the first stage, the temporal interpolation is made for each one of the four daily measurements. A period of three days has been adopted for the temporal interpolation, the processed day staying in the middle of the period: the priority of collocation is given to the day before the processed day. This method ensures the spatial continuity of the measurements and preserves the diurnal cycle. If SST are still lacking after this phase, daily averages were made from the morning and night values. In the third stage, temporal interpolation is made following the same procedure as described above. Figure 4 displays two examples of fields after and before interpolation. We can verify the spatial continuity of the SST but some regions in the eastern Mediterranean Sea are still lacking. Thus as last solution, an interpolation was made from the surrounding points. This concerns mainly the eastern Mediterranean Sea (Figure 5).

3. Turbulent flux

Momentum and turbulent heat fluxes were computed with a state-of-art algorithm (Dupuis *et al*., 2003) derived from the FETCH experiment which was held in the Mediterranean sea (Hauser et al., 2003). These parameterisations were obtained by the inertial-dissipation method and take into account flow distortion effects. A full description of the parameterizations obtained and the methodology applied to derive heat and momentum fluxes can be found in Weill *et al*. (2003). In this paper, the sources of errors come from both random and systematic uncertainties in the basic observations and the coefficients of the bulk formulae are discussed.

4. Net Air-sea surface flux

The Net Ocean Surface Flux (NOSF) is given by the sum of radiative and turbulent fluxes as follows :

Q_{sw} and Q_{lw} are respectively the net short-wave (including an albedo of 0.055) and the net long-wave radiations, the sum of the upward and downward components (including a reflectance of 0.045 for the downward long-wave). Q_S and Q_L are respectively the sensible and latent heat flux prescribed from bulk formulae.

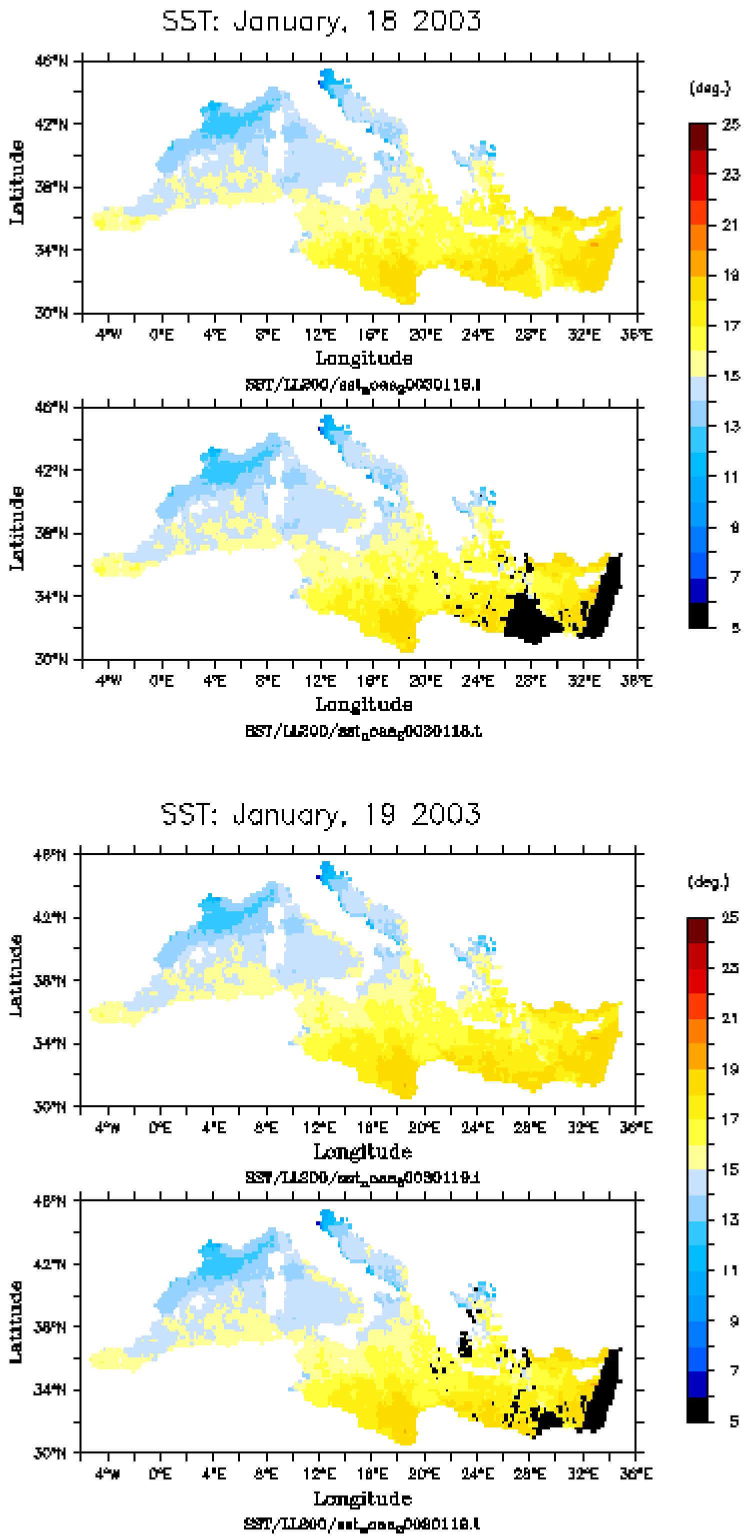

Figure 5. Daily Sea Surface Temperature (SST) after (top) and before (bottom) interpolation for 18 and 19 January, respectively, from top to bottom.

Thus, positive fluxes correspond to a gain for the ocean.

5. The high-resolution dataset

The content of the high-resolution dataset is listed in Table 3 in the same order as the output format. The daily air-sea surface heat fluxes averaged over the whole Mediterranean Basin are displayed on Figure 6. Negative fluxes mean cooling for the sea. The solar radiation is between 80 and 100 W/m2, and has low variability. Latent heat is the most negative flux component and its variability explains completely the variability of the net heat flux. As a whole, the net heat flux is negative at the domain scale for the month processed (January 2003), due to dominant latent heat loss.

Table 3. High-resolution dataset

	Forcing Products	Units
1.	Latitude	deg.
2.	Longitude	deg.
3.	Sensible Heat	W. m^{-2}
4.	Latent Heat	W. m^{-2}
5.	Net Thermal radiation	W. m^{-2}
6.	Solar Radiation	W. m^{-2}
7.	Net heat flux	W. m^{-2}
8.	Momentum	N. m^{-2}
9.	u-component of stress	N. m^{-2}
10.	v-component of stress	N. m^{-2}
11.	Evaporation from 00-24 h forecast	mm. h^{-1}
12.	Precipitation from 00-24 h forecast	mm. h^{-1}
13.	Evaporation from 12-36 h forecast	mm. h^{-1}
14.	Precipitation from 12-36 h forecast	mm. h^{-1}

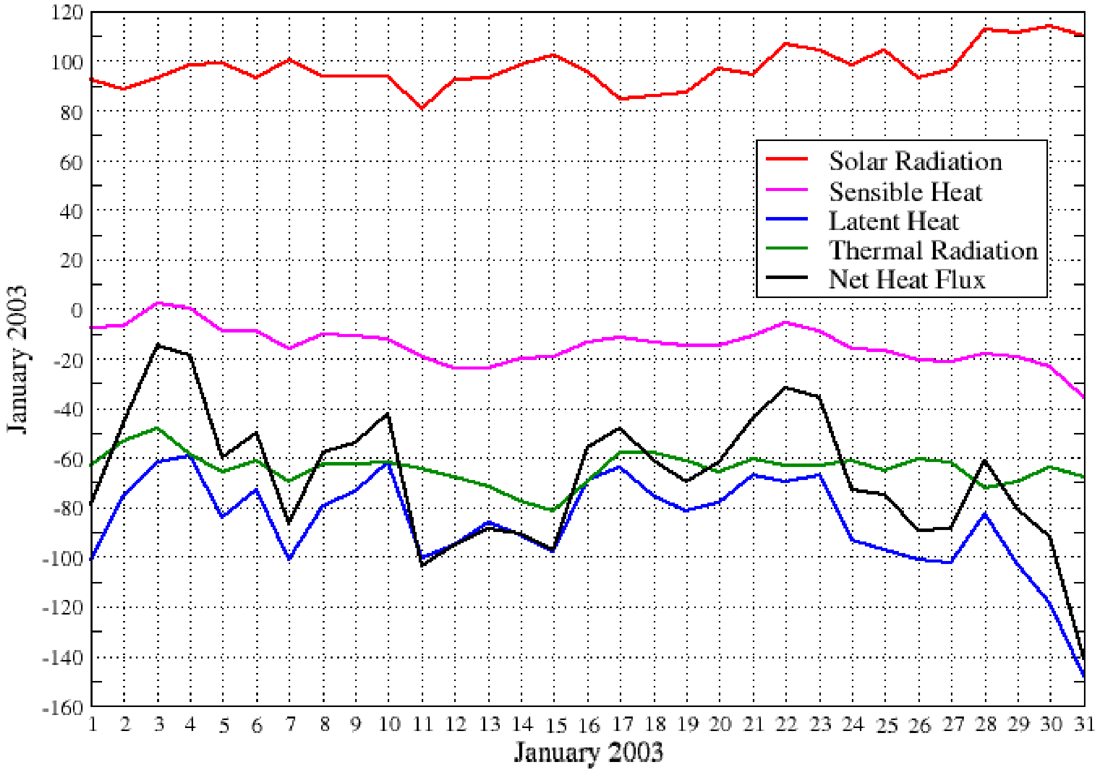

Figure 6. Daily air-sea surface heat fluxes averaged over the Mediterranean basin.

6. Conclusion

A set of daily air-sea surface fluxes has been produced over the whole Mediterranean basin for the month January 2003. The different flux components are available on a regular 20 km wide grid. This data set has been produced by a synthesis approach, i.e. by selecting the best available products among different sources. Radiative fluxes are specific satellite estimates. Turbulent heat fluxes were computed from the ECMWF NWP model outputs, from newly produced SST analyses and by using a state-of-art bulk algorithm developed specially on the Mediterranean Basin during the FETCH experiment.

For the whole Mediterranean Basin, the heat budget during the month processed (January 2003) is negative: -67.5 W/m2, meaning a cooling for the ocean. The different components of the budget indicate that the non solar heat flux is dominated by the latent heat (-85.8 W/m2) and then, by decreasing order, the net longwave (-64.2 W/m2) and the sensible heat (-14.5 W/m2). The net shortwave is of the same order of magnitude as the latent heat in absolute value (+97.0 W/m2).

The dataset is directly available by contacting S. Ramos-Buarque (silvana.buarque@meteo.fr)

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