High-Resolution Gridded Air-Sea Surface Forcing over the Mediterranean Basin

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 forcing over the Mediterranean basin for January 2003 on a regular 20 km wide mesh grid. The data set has been produced by a synthetic approach, i.e. by selecting the best available products among different sources.

Turbulent heat (latent and sensible) and momentum fluxes were produced from the European Centre for Medium Range Forecast (ECMWF) atmospheric parameters (temperature, humidity, sea surface pressure and wind) and from post-processing satellite and in-situ sea surface temperature. Its high-quality is assured by its high spatial and temporal resolutions and in particular, by the use of a state-of-art turbulent flux parameterisation (Dupuis et al., 2003) derived from a specific in-situ experiment (the FETCH experiment, Hauser et al., 2003).

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

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 main changes affect precipitations during the first 12 h forecasts. Thus, two short-range forecasts of precipitations and evaporation were processed: 00-24 and 12-36 h forecasts. Results indicate that precipitations taken during the 12-36 h time interval are generally smaller than those at 00-24 h.

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

Contents

1. Introduction

This work is a 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 air-sea surface forcing on a regular grid over the Mediterranean basin with the best spatio-temporal resolution for January 2003. These dataset are destined to force a Limited Area Model (LAM) to investigate the contribution of air-sea surface fluxes in the formation and evolution of 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 Centre for Medium Range Forecast) analyses: temperature, humidity, sea surface pressure and wind. Precipitation and evaporation were also recovered from the ECMWF. Radiative air-sea surface fluxes (short-wave and long wave radiations) were derived from satellite measurement 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 using a state-of-art bulk flux algorithm (Dupuis et al., 2003) which contribute to the high-quality of the dataset.

2. Basic Variables

2.1. ECMWF Products

The Integrated Forecasting System (IFS) is developed jointly by ECMWF and Météo-France. The operational model changed to a new cycle (CY25R4) in January, 14 2003. Description of changes in data assimilation and forecasting system can be found on the Web site quoted above[2].

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

2.1.1. Atmospheric Parameters

Four-daily analyses were used to acquire appropriate input data. Analyses were achieved every six hours by applying the newer variational analysis (4D-Var). The 4D-Var technique use 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. This choice limits errors due to several changes in spatial and temporal resolutions. Table 1 list atmospheric parameters obtained from MARS archive with the GRIB codes.

[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

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 40 km horizontal grid spacing ECMWF analysed fields were interpolated on a 20 km horizontal regular grid. Differences between the original and the interpolated two meters temperature are shown in Figure 1. Differences are not significant that proves the consistency of the interpolation procedure. Note that there is no variability in the homogenous structures initially apprehended and that only changes of values are less abrupt.

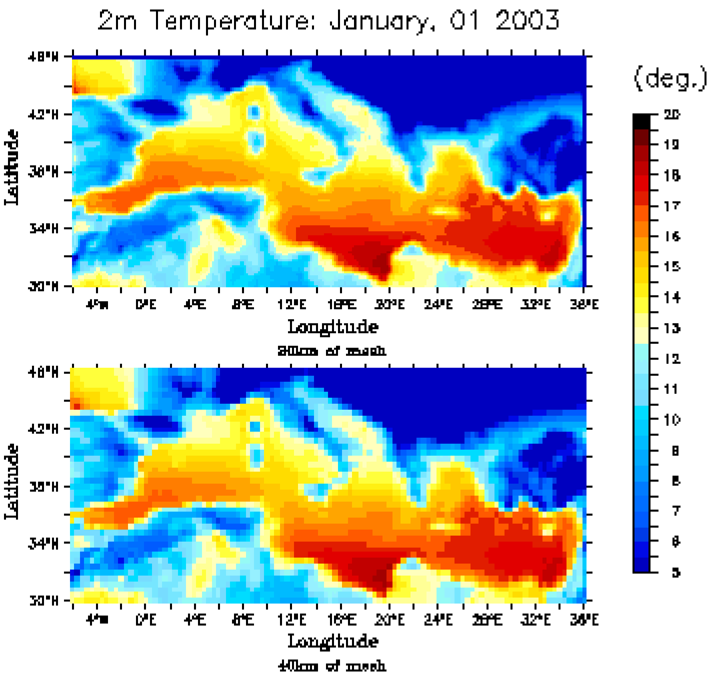

Figure 1. Two meters temperature after (top) and before (bottom) optimum interpolation, respectively for 20 km and 40 km grid mesh.

2.1.2. 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 main changes affect precipitations during the first 12 h forecasts.

Thus, two short-range forecasts of precipitations and evaporation were processed: 00-24 and 12-36 h 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

Precipitations taken during the 12-36 h time interval are generally smaller than those at 00-24 h (Figures 2 and 3) but the time evolution of daily evaporation remains similar between 00-24 and 12-36 h forecast. Consequently, the 12-36 h cumulative precipitation must be retained to be out the precipitation spin-up period but for the evaporation the choice of the cumulative period is not relevant.

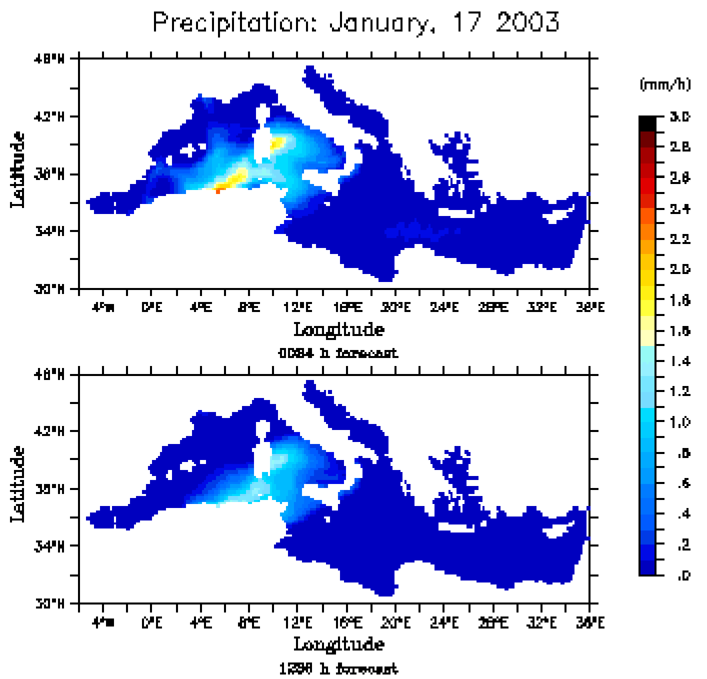

Figure 2. Total precipitation for 00-24 (top) and 12-36 h (bottom) forecast.

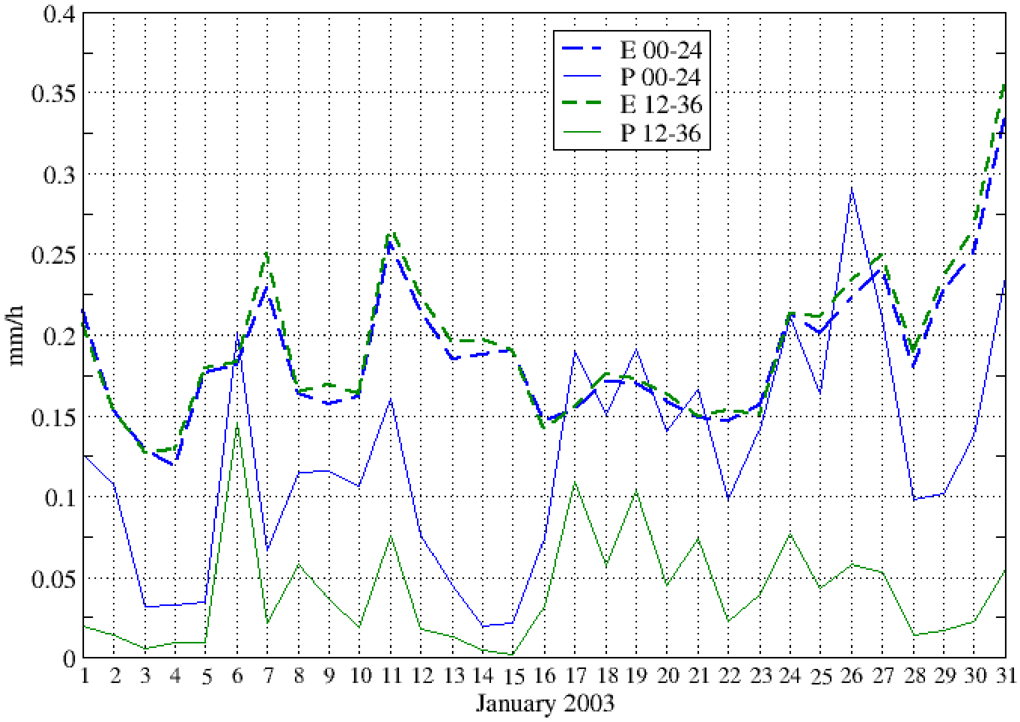

Figure 3. Time evolution of daily total precipitation and evaporation for 00-24 and 12-36 h forecast.

2.2. Radiative forcing

Radiative air-sea surface exchanges include budget of short (incident solar radiation and radiation reflected by the sea surface) and long wave (infrared radiation emitted by the atmosphere and radiation from the sea surface) radiation from satellite measurement. Validation of these products in different seasons and over different oceanic basins has already proved their very high quality to retrieve 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) comes from METEOSAT observation.

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 includes a monthly validation of solar radiation with pyranometric measurements of the METEO-FRANCE network .

DLI is also hourly over a regular grid with 10 km of mesh. More information can be founded on-line at http://www.meteorologie.eu.org/safo.

2.2.2. Sea Surface Temperature

Sea Surface Temperature (SST) are 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).

Dimensions of the extracted field (900 X 2100 points) allow high spatial resolution over regular grid (≅2.5 km). However, spatial resolution of atmospheric parameters necessary to process turbulent heat is not also high (=40 km, §3.1). Thus, we retained a resolution of 20 km.

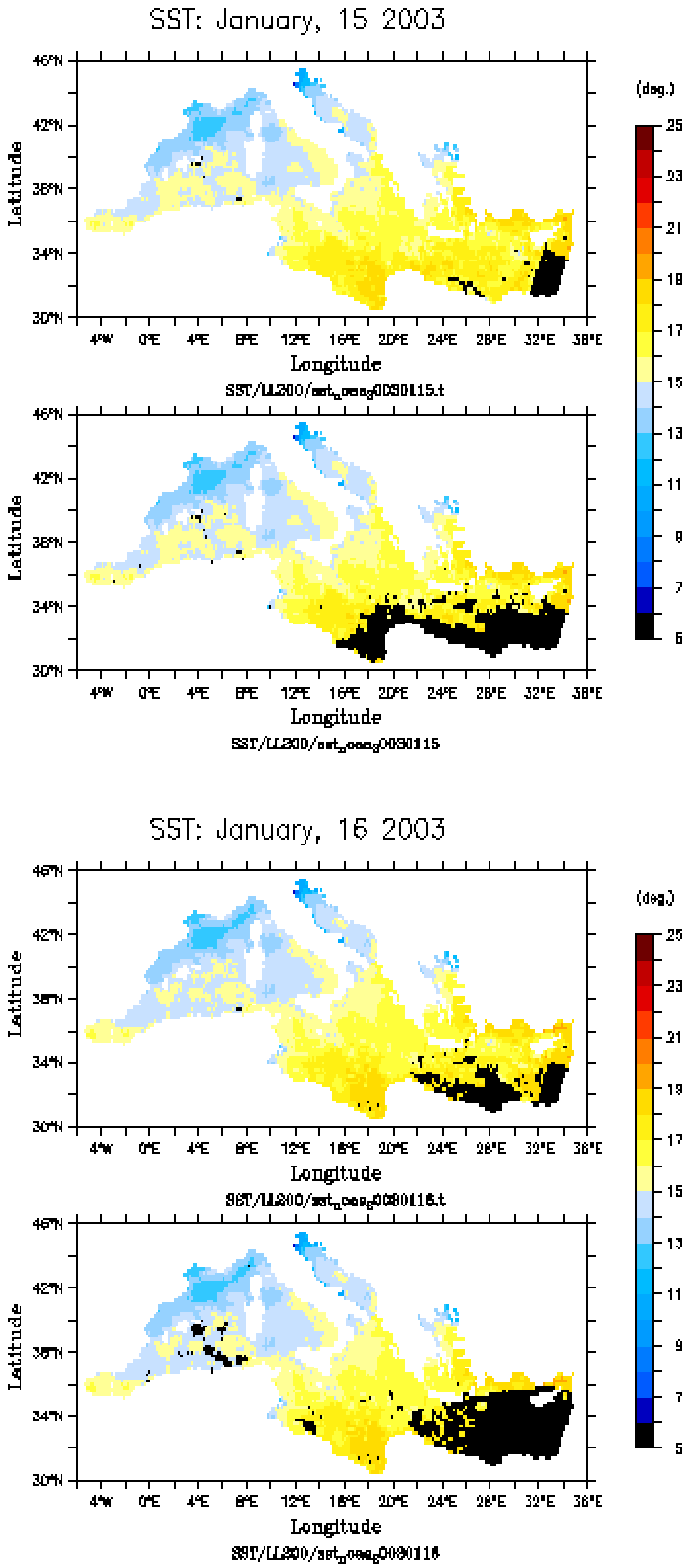

Figure 4. Daily Sea Surface Temperature (SST) after (top) and before (bottom) temporal collocation for January, 15 and 16 respectively, from top to bottom.

Processing data for cloudy regions concerns four phases: (i) temporal collocation for the four-daily measurements (ii) daily means (iii) temporal collocation for daily means (iv) interpolation after buoy collocation.

In the first, temporal collocation is made for each of the four-daily measurement. Three days is the period retained for the temporal collocation with the processed day in the middle: the priority of collocation is given to the day before the processed day. This method ensures spatial continuity of the measurement and preserves the SST sensitivity to the diurnal cycle.

After this phase, several and extended cloudy regions persist and daily means was made over two selected times (on the morning and night).

In the third, temporal collocation is made following the same principle described below. Figure 4 shows two examples of fields after and before collocation. We can verify the spatial continuity of the SST and that the eastern Mediterranean Sea is always under clouds.

Thus as last solution, an interpolation was made. Buoys observations were collocated when there was no satellite measurement. Unfortunately, buoys measurement were often over sunny regions. After buoys collocation, the eastern part the Mediterranean sea remained without observations (Figure 5). This case is frequent and must be taken into account.

3. Turbulent flux

Momentum and turbulent heat fluxes were estimated by bulk algorithm using a state-of-art turbulent flux parameterization (Dupuis et al., 2003) from the FETCH experiment which was held in Mediterranean sea (Eymard et al., 2003). Parameterizations were obtained by inertial-dissipation method and taken into account flow distortion effects. Full description of parameterizations obtained from several experiments and methods used to derive heat and momentum fluxes can be found in Weill et al. (2003). In this paper, sources of errors come from both random and systematic uncertainties in the basic observations and in the coefficients in the bulk formulae are discussed.

We stress that only the module of momentum fluxes was calculated by bulk formulae. Momentum fluxes components are provided by ECMWF analyses and interpolated onto the ocean model grid mesh.

4. Net Air-sea surface flux

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

$$Q_{Net} = Q_{sw} - Q_{lw} - Q_S - Q_L$$

Q_{sw} and Q_{lw} are respectively the short-wave and the long-wave radiations. Q_{lw} is the sum of the upward and downward components. Q_S and Q_L are respectively the sensible and latent heat flux prescribed from bulk formulae.

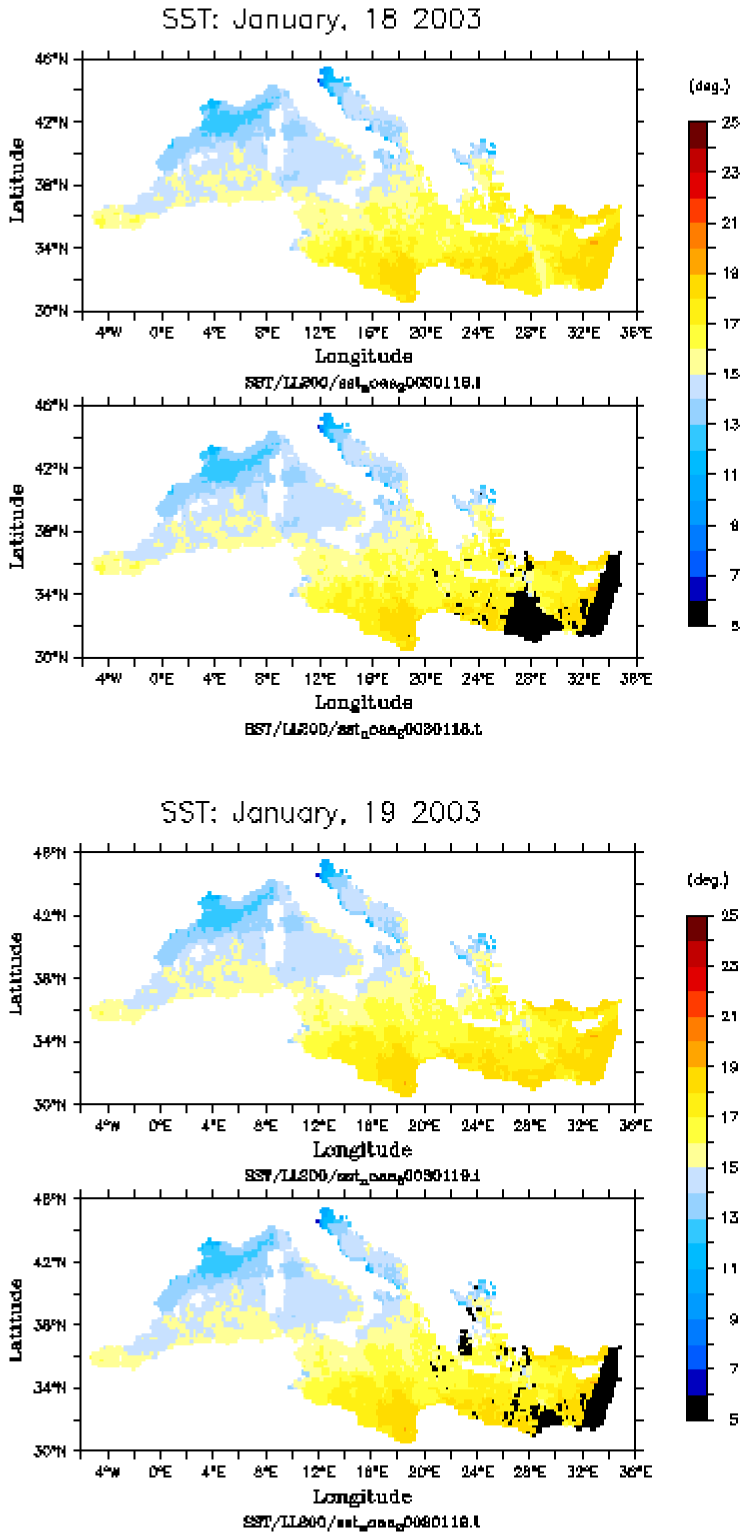

Figure 5. Daily Sea Surface Temperature (SST) after (top) and before (bottom) interpolation for 18 and 19 January, respectively, from top to bottom.

Thus, positive fluxes correspond to a gain for the ocean and radiative fluxes are the outgoing terms. The three outgoing terms have distributions strongly different on sea and on continents. This characteristic reduces strongly the surface of high-quality fluxes because on the coast fluxes are not reliable.

5. The high-resolution dataset

The high-resolution dataset are listed in Table 3 in the same order of outputs format. Variables stressed in italic come from the ECMWF. The processed daily air-sea surface heat flux terms are shown in Figure

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}

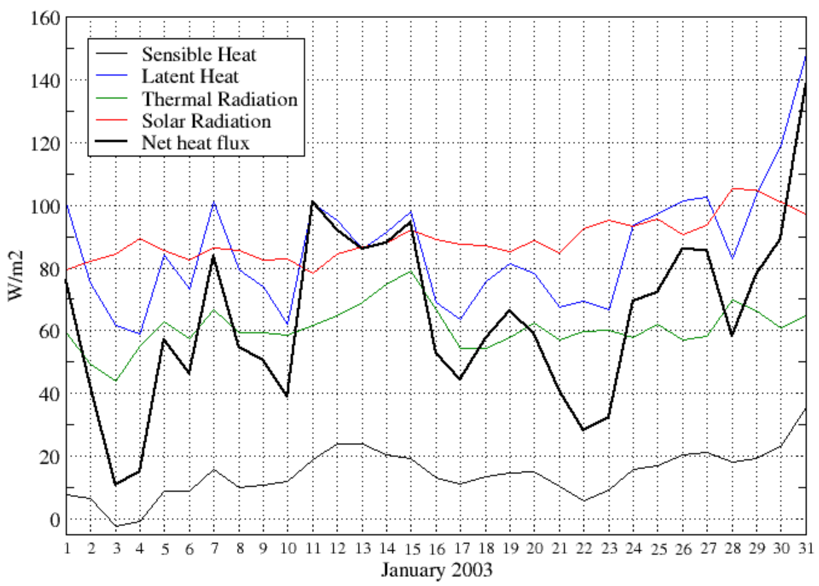

Figure 6. Daily air-sea surface heat fluxes averaged over the Mediterranean basin.

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