The Daily SST Variations within the South Eastern Mediterranean Sea

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Abstract

Studying the behaviour of the sea surface temperature (SST) is important in the examination of many oceanographic activities. The variations in the SST are mainly controlled by atmospheric conditions. However, other physical parameters are also impacting on these variations, *e.g.* solar radiation, relative humidity, water depth, groundwater inflow and wind speed.

Using a one year (04/02/99-04/02/00) data set, the present paper aims at describing the general behaviour of the daily SST variations within the south-eastern Mediterranean Sea region, off the Egyptian Mediterranean coast. The relationships between both the air temperature and wind speed, and the SST were built using regression techniques.

The general pattern of the daily SST anomaly, produced in this research, reflects stability and homogeneity in the thermal distribution within the area of study. The seasonal presentation of the SST data reveals normal thermal variation behaviour, *e.g.* maxima in summer and minima in winter.

There is a strong correlation between daily SST and air temperature variations, exceeding 0.91. The slightly differences between the produced mathematical constants may be attributed to both the change in the record periods and in the values of the recorded measurements. The inverse relationship between daily SST and wind speed variations is proved, with a correlation not exceeding -0.2.

The observed odd behaviour of daily SST at location SST04, in the present study, is attributed to the shallowness of this station (7.8m depth) and also to the close position to the shore. Hence, seawater-seabed interaction and the shore processes may have their effects on the recorded SST. Moreover, SST04 is influenced by the dynamical process of the water exchange between Lake Manzalah and the Mediterranean Sea.

The variations in the daily SST in the study area are more related to variations in air temperature rather than in wind speed.

Introduction

The sea surface is considered the lower boundary of the atmosphere, which impacts on both weather and climate through the variations in the sea surface temperature (SST). The upper ocean layer is known to be of special importance for certain practical applications such as remote sensing, climate modelling and determining the global carbon cycle (Sdoviev and Lukas, 2006). Accordingly, variations in the SST on diurnal, monthly, seasonal and inter-annual scales greatly impact on our understanding of the air-sea interaction process and on the examination of many important oceanographic activities, *e.g.* climate monitoring, climate prediction and research. The variability of SST, on different scales, is widely studied worldwide (*e.g.* Krishna *et al.*, 1972; Kawamura *et al.*, 2008; Shenoi *et al.*, 2009; Maiyza *et al.*, 2010; Skliris *et al.*, 2011; Abudaya, 2013). Previous investigations have shown that the diurnal, seasonal, inter-annual and long-term natural climate fluctuations in mid-latitude regions are particularly sensitive to the SST distribution (Kawamura *et al.*, 2008). Long time-scale events and their variations, *e.g.* the Madden–Julian Oscillation (MJO) and El Niño Southern Oscillation (ENSO), are affected by the variations in the SST (Shinoda, 2005; Solomon and Jin, 2005).

Generally speaking, SST has been categorised into five main groups (See Fig. 1 in Donlon *et al.*, 2007). In actuality, SST_{int} cannot be known even with current technology (Donlon *et al.*, 2007) and SST_{skin} is usually utilized as a substitute for SST_{int} on the assumption that SST_{skin} is close enough to the true SST_{int} (Kawai and Wada, 2007).

The SST variations are mainly controlled by variations in the air-sea heat flux as well as in the vertical mixing and the horizontal advection of heat (Skliris *et al.*, 2011). Other physical parameters, which also impact on the SST variations include solar radiation, relative humidity, water depth, groundwater inflow, artificial heat inputs, and thermal conductivity of the sediments and wind speed (Pilgrim *et al.*, 1998). The SST variations in the Mediterranean Sea have been previously studied, *e.g.* Poulos *et al.*, 1997; Cacho *et al.*, 2001; Barale *et al.*, 2004; Troupin *et al.*, 2009. The relationship between SST and atmospheric variables is very important for the formation of the Mediterranean intermediate and deep waters (Maiyza, 1986; Maiyza *et al.*, 1995). The

3D interpretation of the hydrographic parameters of the southeastern Mediterranean off the Egyptian coast reveals horizontal and vertical movements of various water masses (three in winter and five in summer) (Said and Eid, 1994a). In winter, the upper 400 m layer is characterized by temperature between 15 and 17 °C and a salinity maximum of 38.9-39.2, while, in summer, the warming effect increases the temperature of the surface water (the upper 30-50 m) up to 28 °C and a strong thermocline is developed. The temperature and the salinity of the subsurface layer (50-100 m) range between 17.0 and 22.0 °C and between 38.6 and 38.8 respectively and is identify as the Atlantic Water Mass (AWM) (Sharaf El-Din and El-Gindy, 1987).

The long-term time series (1948-2008) distribution of SST anomaly (SSTA) in front of the northern Egyptian waters reflects cyclic behaviour (Maiyza *et al.*, 2010). The periods of these cycles fluctuated between 8 and 15 years and are nearly associated with the 11-year cycle of sun-spots activities. Abudaya (2013) used dataset of seven years (1998-2004) of Advanced Very High Resolution Radiometer-Sea Surface Temperature (AVHRR-SST) to study the seasonal variability in SST in the Levantine Basin. He concluded that the seasonal and monthly SST distributions are strongly correlated with the dynamical structure of the basin upper thermocline circulation.

In the present paper, daily SST variations have been investigated using diurnal records with 10-minutes temporal resolution. The paper aims at describing the general behaviour of the mean SST daily variation within the south-eastern Mediterranean Sea region, taking the Egyptian coast as an exemplar case study. Moreover, the relationships between both the air temperature and wind, and the SST were built using regression techniques.

Data and Methods of Analysis

The data set in the present work consists of the SST records for one year period extending from 04th February 1999 to 04th February 2000. During this period, seven recording stations (SST01 to SST07) and one meteorological station (Met.01) took place within the south-eastern Mediterranean Sea region, off the Egyptian coast (Fig. 2). The locations of deployment and the total depth of each station are shown in Table 1.

Every deployed ADCP was used to record, for every 10 minutes interval, current speed and direction, and water column temperature. As there is no universal definition of the SST layer in meters because the mixing regime below the air-sea interface depends on meteorological, radiation and surface wave condition (Sdoviev and Lukas, 2006), the upper pin layer at each measuring point, which does not exceed 26 m, was taken as a SST layer in the present study.

For every location, the SST layer was determined. The daily mean SST was calculated from the recorded data. The deviation from the mean for the whole data set is used to calculate the daily SST anomaly (DSSTA) over the period of investigation and this is graphically represented for every station in the present work. Daily mean air temperature and wind speed data for the same period (04/02/99 – 04/02/00) are taken from the meteorological station (Met.01), and are used to investigate the relationships between the daily variations in these metrological parameters and the sea surface temperature.

Table 1: Locations of deployment and water depth at the investigated area

Station	Location		Water Depth (m)
	Lat.(N)	Long.(E)	
SST01	31° 40.04'	031° 11.98'	21
SST02	31° 37.96'	031° 56.98'	22
SST03	31° 34.90'	032° 15.93'	29
SST04	31° 22.98'	032° 07.00'	08
SST05	31° 34.90'	032° 30.01'	26
SST06	31° 36.98'	030° 35.03'	21
SST07	31° 43.00'	032° 24.50'	45
Met.01	31° 43.00'	032° 24.50'	45

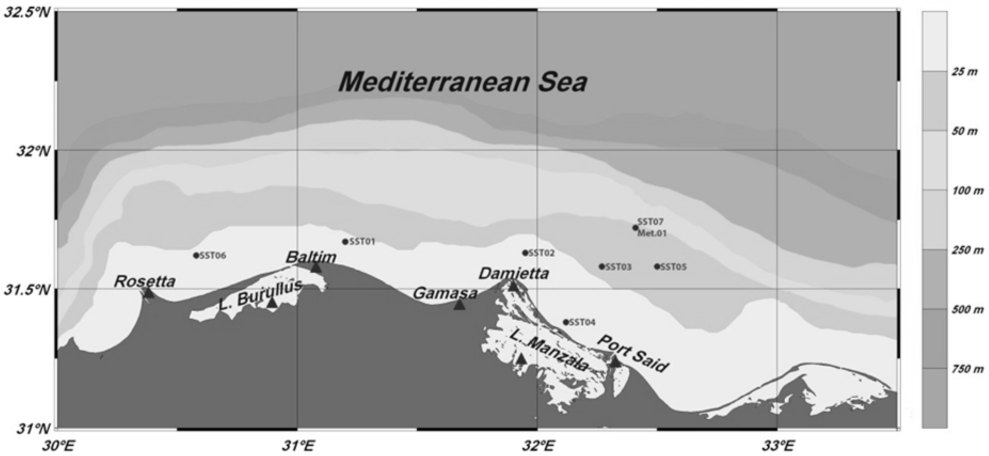

Fig. 2: Locations of recording stations for the present work

The SST-air temperature relationship can be mathematically represented by a linear equation taking the following form (Pilgrim *et al.*, 1998; Smith, 1981):

$$T_w(t) = A + B \times T_a(t) \quad (1)$$

Where $T_w(t)$ and $T_a(t)$ are the SST and air temperatures (°C) at time t, respectively, and A and B are constants. This mathematical relationship, for each location in the present work, was generated.

Lastly, the relationship between the wind speed and the SST for the area of investigation was mathematically derived using the linear regression technique. The statistica10® software was applied for the statistics calculations in the present work.

Results

The mean daily SST distribution

The daily mean SST at the seven locations in the present study is shown in Fig. 3. The observed gaps in the figure refer to the missed data during the recording time period. Over the period of investigation, four stations had full data sets of 366 days; these are SST01, SST05, SST06 and SST07. Station SST02 had 55 missing days, while SST03 and SST04 had one and 56 missing days, respectively. The average mean daily

SST for the whole recording stations varied between 22.42 °C at SST01 and SST03, and 22.62 °C at SST02 and SST04. SST04 recorded both the lowest (14.67 °C) and the highest (30.33 °C) mean daily SST over the period of investigation among the seven points of recording.

The daily SST anomaly:

The deviation from the daily mean is computed in order to express the daily sea surface temperature anomaly (DSSTA), using the following Equation:

$$\Delta SST = SST - SST_D \quad (2)$$

where,
ΔSST is the DSSTA (°C),
SST is the mean daily SST (°C) and
SSTD is the daily mean SST (°C)

ΔSST (Fig. 4) varied between -2.41°C and 2.52 °C at SST01, between -1.98 °C and 1.90 °C at SST02 and between -2.07 °C and 1.94 °C at SST03. At SST05, ΔSST varied between -1.80 °C and 1.59 °C. Both SST06 and SST07 had a maximum ΔSST of 1.63 °C, while the former had a minimum ΔSST of -2.38 °C and the later had a minimum ΔSST of -2.45 °C. Again, SST04 records the lowest and highest ΔSST among the different locations with a minimum ΔSST of -2.79 °C and a maximum ΔSST of 2.17 °C.

The air temperature-SST relationship

The mathematical relationship between the air temperature (AT) and the daily mean SST is produced for each location in the present study. SST03, SST05, SST06 and SST07 almost have the same AT-SST relationship, with minor variations in the resultant constants (Eq. 1). At SST01 and SST02, the AT-SST relationship is also controlled by almost the same mathematical constants. The SST04 location appears odd in its mathematical formula (Fig. 5). This might refer to the location of this station, being the closest to the shore and being in the vicinity of Lake Manzalah, hence it is affected by the water exchange process, with all its impact, between the Lake and the Mediterranean Sea through the lake's outlet. Each graphical presentation, for the seven locations, shows the histogram of the recorded data frequency for both air temperature and SST. Moreover, the correlation factor (r) has been produced using the Statistica10® software for each location.

Wind speed – SST relationships

The linear relationship between the wind speed and the daily mean SST at each recording location is produced. The entire set of locations almost shows the same mathematical relationship, with only minor variations in the regression constants (Fig. 6). The inverse correlation between variations in wind speed and daily SST is clearly shown in the scatter plots. The correlation factor, which does not exceed -0.2, reflects the normal behaviour between the two parameters. When the wind speed was 0.1 m/s (the lowest daily mean in the present study), the daily mean SST was 20-21 °C. When the wind speed reached its maximum (15.5 m/s), the mean daily SST dropped to 17.2-18.1 °C.

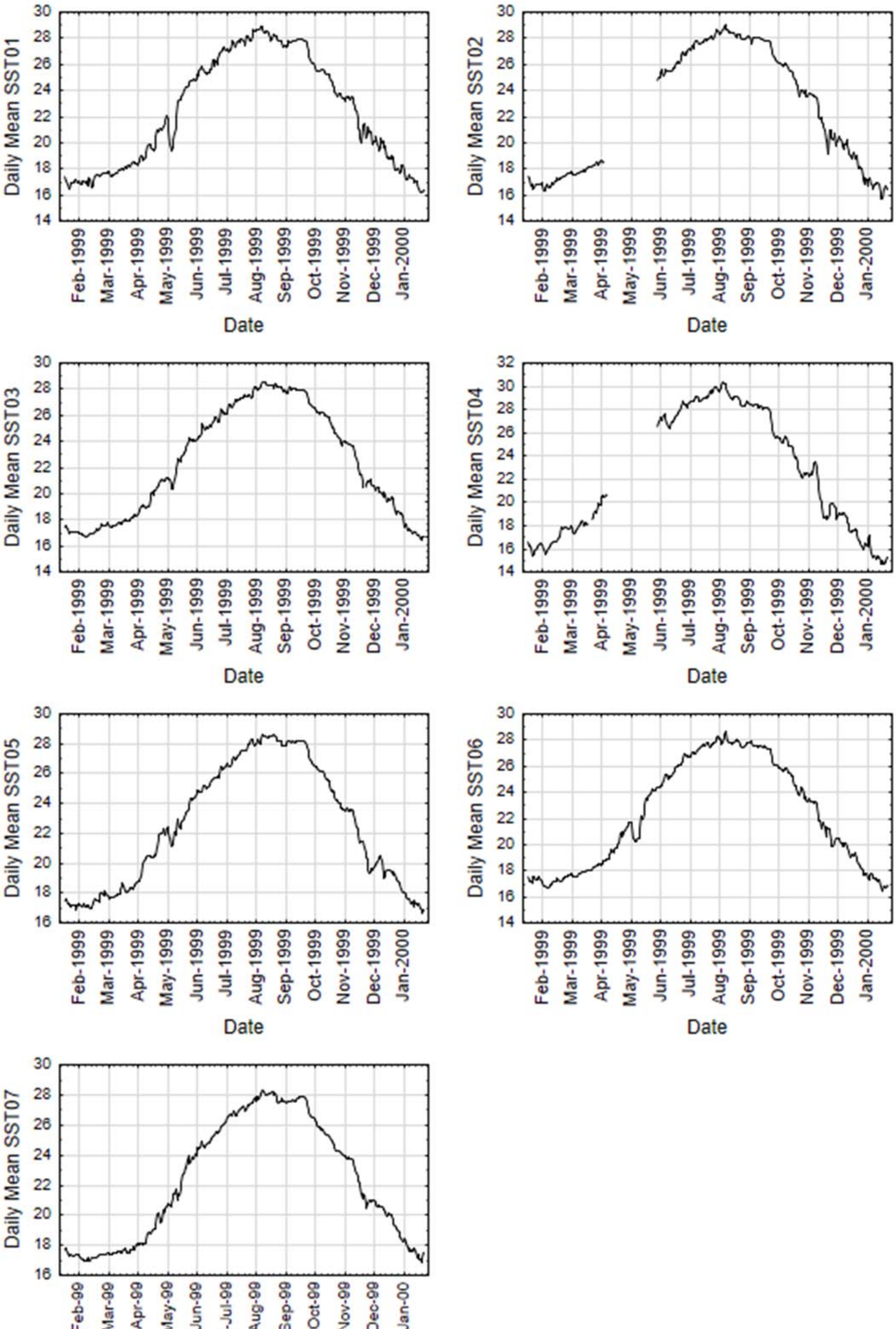

Fig. 3: The Daily Mean SST at the seven locations of recording (04.02.99-04.02.00)

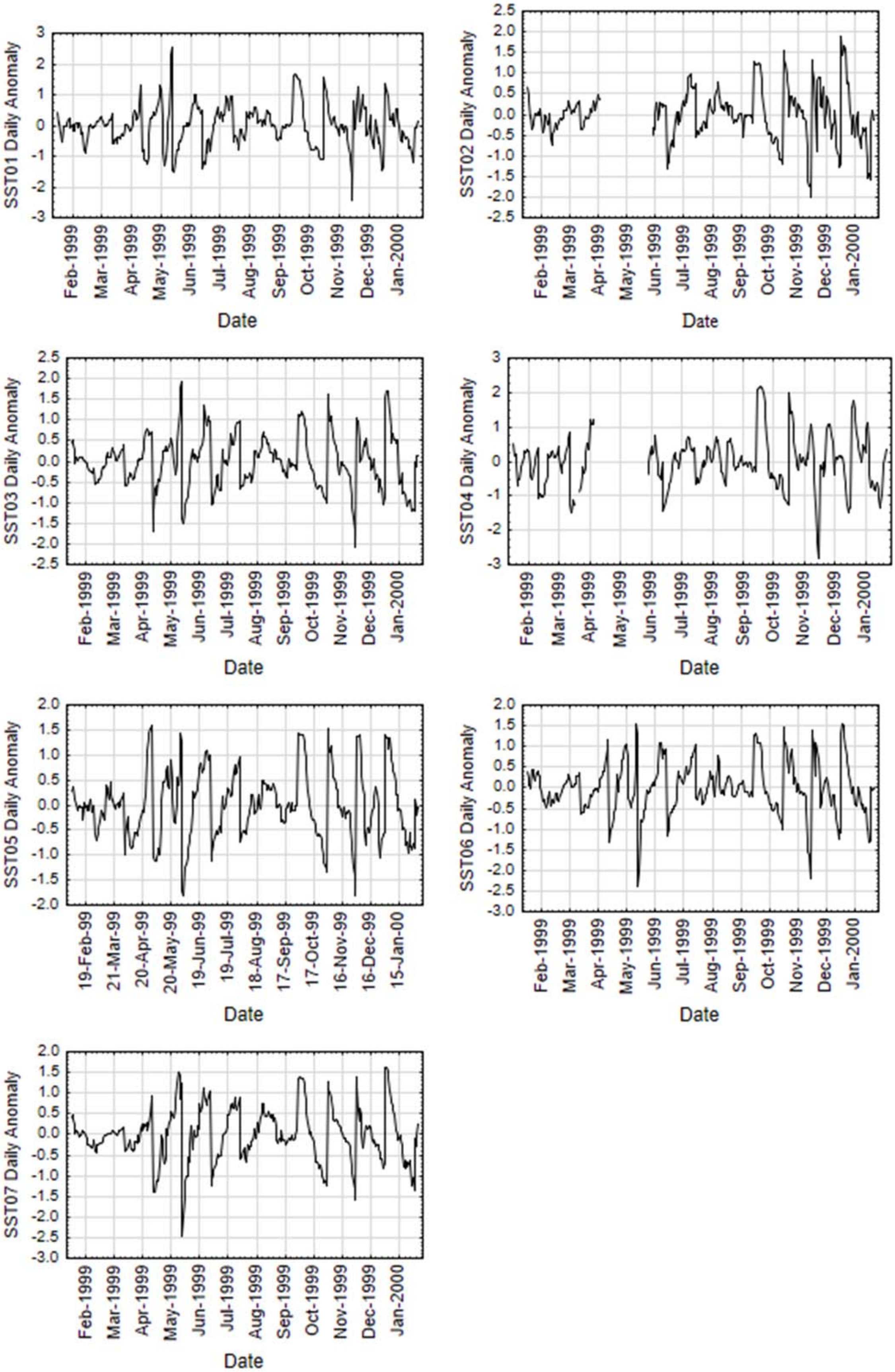

Fig. 4: Daily SST anomaly at the different locations over the period of investigation

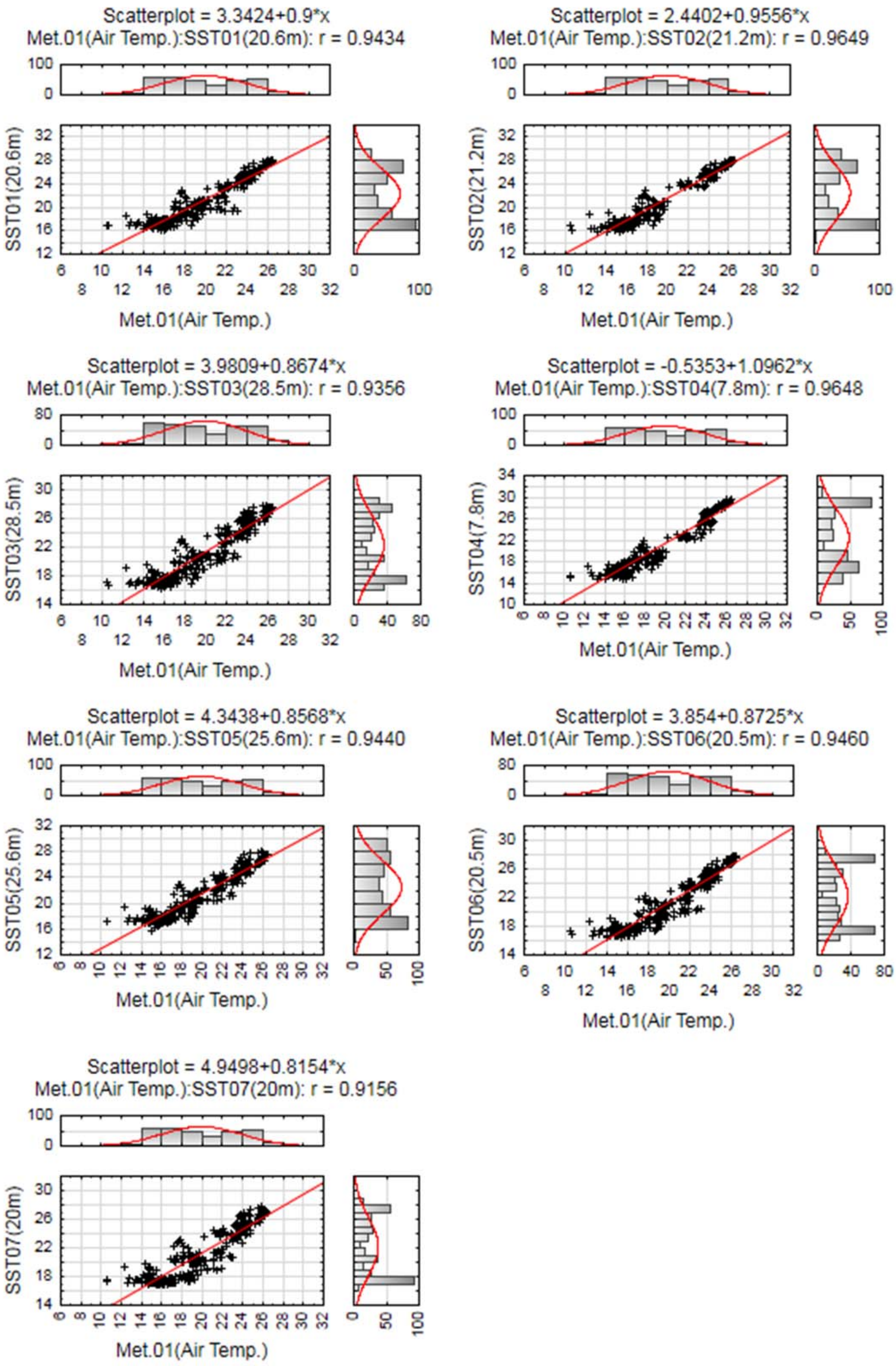

Fig. 5: The AT-SST relationships at the different locations in the present work

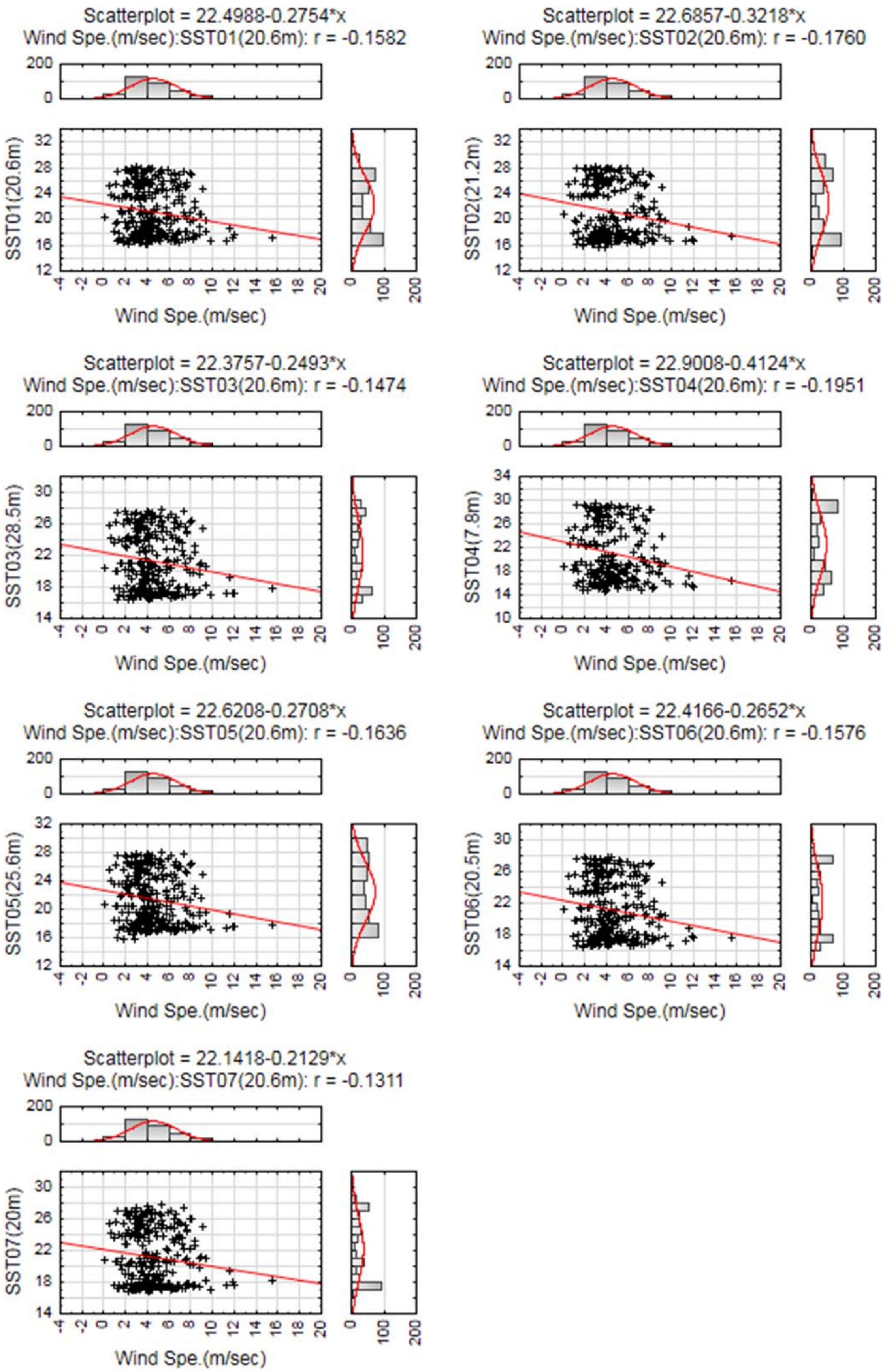

Fig. 6: The wind speed-SST relationships at the different locations in the present work

Conclusions

The present work investigates the variation of the daily mean sea surface temperature (SST) in the south-eastern Mediterranean Sea; taking the Egyptian Mediterranean Coast as exemplar case study. The area of investigation extends between latitudes 31° 22.98'-31° 43.00' N and longitudes 030° 35.03'-032° 30.01' E. The data set covers seven locations of SST records over one year period from 04th February 1999 to 04th February 2000. Also, meteorological parameters are taken from the meteorological station (31° 43.00'N, 032° 24.50'E), coincides in position with location number 7.

The general pattern of the daily SST anomaly is almost the same all over the area of investigation. Maxima and minima are simultaneously observed over the seven recording locations. This may be taken as an indicator of stability and homogeneity in the thermal distribution off the Egyptian Mediterranean coast. Location number 4 (SST04) had the maximum and minimum daily SST records and daily SST anomaly.

The mathematical relationships between daily SST variations and both air temperature and wind speed in the area of investigation, have been produced in the present study. There is a strong correlation between daily SST and air temperature variations, exceeding 0.91. The slightly differences between the mathematical constants may be attributed to both the change in the record periods, *e.g.* the return recorded data from the seven instruments, and in the values of the recorded measurements themselves. Again, SST04 appears odd in its mathematical formula. The inverse relationship between daily SST and wind speed is proved. The correlation does not exceed -0.2.

The authors attribute the observed odd behaviour of daily SST at SST04 in the present study to the position of this station being the shallowest location (7.8m depth) and also the closest to the shore. Hence, the shore processes and sea-seabed interaction may have effects on the recorded SST at this location. Moreover, SST04 is the only location affected by the water exchange process between Lake Manzalah and the Mediterranean Sea through Boughaz El-Gameel. This dynamical process may greatly impact on the variations of the daily SST at this location.

The variations in the daily SST in the study area are more related to and affected by variations in air temperature rather than in wind speed.

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