A study of the breeze circulation during summer and fall 2008 in Calabria, Italy

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\textbf{A B S T R A C T}

We present a study of the characteristics and importance of breezes at a coastal site in the Central Mediterranean Basin. The site is located on the west coast of the Peninsular Calabria Region at the southern tip of Italy. This study adds new data on breeze circulations over a unique experimental coastal site characterized by the sea–land contrast in a flat area which is also influenced by the complex orography of the region.

The first part of the study compares data from a surface meteorological station and meteorological analysis at 850 hPa to show the importance of breeze circulation at the site.

Results show that breezes dominate the local circulation and play a major role in the local climate. Moreover, the characteristics of the breeze exhibit significant differences between summer and fall.

The second part of the paper examines the thermal and large-scale forcings that play an important role in the breeze circulation. A sharp difference in thermal forcing was observed between July–August and September. The diurnal breeze acts in phase with the large-scale flow and is particularly intense in summer. The modulation of the nocturnal breeze by the large-scale flow is also apparent.

The third part of the paper focuses on two selected case studies one for summer and the other for fall and explains differences in the breeze circulation. Finally, the behaviours of summer and fall breezes are presented and discussed.

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\textbf{1. Introduction}

The sea breeze blows inland across the coast on fine weather days. It is caused by the horizontal temperature contrast between the sea (cool) and the land (warm) during daytime. The temperature difference produces a pressure gradient between the sea and the land that forces the sea breeze. The opposite circulation occurs at night, when the horizontal temperature gradient between the land (cool) and the sea (warm) causes the land breeze to flow. The observed sea breeze intensity, which can reach 10 ms\textsuperscript{-1}, varies depending on several factors including thermal forcing, large-scale winds, atmospheric stability, cloud cover, land use, etc. The land breeze is a shallower and weaker phenomenon because the planetary boundary layer (PBL) over the land is stably stratified at night. Defant (1951) and Pielke (1981) present an excellent qualitative description of sea and land breeze development, in the absence of large-scale wind.

In a region with irregular terrain, local wind patterns can develop because of the differential heating between the ground surface and the free atmosphere at the same elevation some distance away. A larger diurnal temperature variation usually occurs at the ground, so that, during the day, elevated terrain becomes a heat source, while at night it is a heat sink. As a consequence of the temperature gradient generated, an
upslope flow (anabatic wind) develops on fair weather days. At night, downslope (katabatic) winds develop.

Because of the specificity of the breeze circulation at a particular site, many papers and books can be found in the literature on the sea breeze and local winds, some of them reported in Simpson (1994) and Pielke (2002).

This study investigates local circulation at a site on the Calabria Peninsula (Fig. 1). Calabria extends between 38° and 40° N latitude and between 15°30’ and 17°15’ E longitude. The region is bounded by the Tyrrhenian Sea (west) and by the Ionian Sea (east and south). The Apennines run north–south along the peninsula and are characterized by five main topographical features reaching elevations of 1500 to 2000 m: Pollino, Catena Costiera, Sila, Serre, and Aspromonte. The average width of the region is about 50 km in the east–west direction and 300 km in the north–south direction. There are three main plains by the sea (Sibari, Gioa Tauro, Lamezia).

The physical characteristics of the peninsula, i.e., the presence of elevated peaks in a symmetric position between the Tyrrhenian and the Ionian Sea, present a rather unique condition for breeze development. Sea breezes and land breezes act in phase with upslope and downslope winds to generate stronger and more persistent breeze flows. Federico et al. (2000, 2003), using a theoretical and modelling approach, studied the relative role of the sea–land and mountain–valley contrasts in the local thermal convergence pattern over an idealized mountainous peninsula. They showed that the presence of mountains strongly enhances the wind intensity and, for an idealized peninsula with the aspect of Calabria (i.e., east–west width and mountain elevation), the energetic contribution of the mountain–valley contrast is larger than that of the sea–land contrast. Therefore, the local circulation is caused by the presence of the sea but also by the presence of elevated peaks. Because we cannot distinguish the different breeze components (sea/land/mountain/valley), hereafter we will call them diurnal (onshore) and nocturnal (offshore) components of the breeze.

The Mediterranean climate is another important factor that favours breeze development in Calabria. Calabria’s geographical position is at the centre of the Mediterranean, where calm synoptic conditions often prevail (Trigo et al., 1999, 2002; Bolle, 2003), especially in summer and fall (Colacino, 1990; Piervitali et al., 1999). The favourable conditions for breeze development in the Mediterranean have been discussed and reported in several papers, including Neumann (1951) and Doran (1979) for Israel; Lalas et al. (1982) and Kallos et al. (1993) for Greece; Caccia et al. (2004) for France; and Ferretti et al. (2003) and Mastrantonio et al. (2008) for Italy.

While previous studies over Calabria focused on the energetic and mesoscale simulation of the breezes, this paper focuses on experimental data collected at Lamezia Terme (Fig. 1).

Fig. 1. Calabria Region in the Central Mediterranean. Left: topography (m, grey shading) with topographical features described in the text. The black dot shows the location of the experimental field.
The study does not follow a planned measurement campaign but uses measurements from different sources that either operated for a while or are permanently installed at the site. The experimental site is located 8 m above sea level and 500 m from the coastline. The mountains around the plain are about 10 km from the experimental site. Table 1 shows the operational time for each instrument and Appendix A introduces the instruments and data.

The aim of the study is to show the change in the characteristics of the breeze circulation between Summer and Fall 2008. For this purpose we show the characteristics and the vertical structure of the breeze circulation for selected case studies and we show statistics for July–August and September 2008, limiting the analysis to this period because of the availability of SODAR (Sonic Detection and Ranging) data.

2. Results

2.1. Breeze circulation for July–August and September 2008

This section shows the importance of breezes to the local climate. Fig. 2(a) shows that the surface station wind rose for July–August 2008. Winds come mainly from the W–SW direction (from 220° to 280°), which account for 65% of occurrences. A relative maximum (14%) is found in the E–NE direction (from 40° to 100°). Wind speed is low, with more than 90% of occurrences having speeds less than 5 m s⁻¹.

Fig. 2(b) shows that the wind rose at 850 hPa for the same period as Fig. 2(a) derived from the ECMWF (European Centre for Medium-Range Weather Forecasts) operational analysis at 850 hPa (Uppala et al., 2005). These data, available at 6-h intervals, are representative of the large-scale circulations above the PBL. About 60% of the winds come from the NW sector. Apart from the obvious higher wind speed at 850 hPa, the comparison between Fig. 2(a) and (b) reveals the importance of local circulations because: a) the directions in Fig. 2(a) are well focused (W–SW and E–NE) while at 850 hPa they are more diffuse; b) the E–NE winds are more frequent at the surface than at 850 hPa (1% and 48%, respectively); and c) the W–SW winds are much more frequent at the surface than at 850 hPa (10% and 62%, respectively).

Fig. 2(c) and (d) shows the same distributions of Fig. 2(a) and (b) for September 2008. Local circulations are apparent. More precisely: a) winds come mainly from the W–SW (33%) and E–NE (48%) directions at the surface while at 850 hPa they are more diffuse; and b) the E–NE winds are much more frequent than at 850 hPa (1% and 48%, respectively). The comparison between Fig. 2(a) and (c) shows an important change in the circulation at the surface: in summer winds come mainly onshore (65%) while in September their most frequent direction is offshore (48%).

The breeze plays a major role in the local circulation. Fig. 3(a) shows the distributions of wind direction and intensity as a function of the time of day in July–August. Winds blow from W–SW in the mid-morning and afternoon. At the night winds blow from two main directions: E–NE and W–SW. Their frequency of occurrence is similar. The nocturnal breeze circulation accounts for the E–NE component. The large-scale flow accounts for the W–SW component. This component will be discussed in Sections 2.2 and 2.4. The diurnal breeze develops between 8 and 23 h local standard time (LST).

2.2. The role of SST and large-scale flow from 1 July to 30 September 2008

Breezes depend on several physical factors, including thermal forcing, synoptic-scale flow, atmospheric stability, soil and vegetation characteristics, etc. Among these, the thermal forcing and synoptic-scale flow are particularly important and are studied in this section.

Fig. 4 shows the daily difference between the sea surface temperature (SST) of the St. Eufemia Gulf (Fig. 1; Appendix A explains how it is computed) and surface temperature recorded at the experimental site between 11 and 16 LST (diurnal difference) and between 00 and 06 LST (nocturnal difference). The diurnal difference is negative (i.e., the land is warmer than the sea) for July and August but it is positive for several days in September. The temperature difference averages are −3, −4, and −1 °C for July, August, and September, respectively.

The nocturnal difference between the SST and surface temperature is always positive with the exception of a few days in summer. The average temperature difference is 2 °C in July and August and 6 °C in September.

From Fig. 4 it is apparent that the thermal forcing of the diurnal breeze is larger in July and August while the thermal forcing of the nocturnal breeze is larger in September. While this result is expected, we highlight the substantial change in the thermal forcing between July–August and September.
This feature is consistent with the change in the breeze regime between summer and fall recorded at the site. To quantify the impact of large-scale flow and channelling through the Marcellinara gap on local circulation, we use the 850 hPa wind distribution derived from the ECMWF analysis. To avoid the influence of topography, we analyze two grid points: 15.5° E, 39° N and 17° E, 38.5° N. The first point is over the Tyrrhenian Sea west of Lamezia Terme; the second is over the Ionian Sea, near the eastern entrance to the Marcellinara Gap. The first grid point is used to evaluate the frequency of winds with directions between 210° and 330° (NNW–SSW, hereafter westerlies) and the second is used for winds with directions between 30° and 160° (NNE–SSE, hereafter easterlies).

Table 2 shows the occurrence of westerlies and easterlies for wind speeds greater and less than 8 ms\(^{-1}\). This threshold was chosen because it has a major effect on the breeze circulation pattern for the largest thermal forcing involved in Lamezia Terme breezes (Lyons, 1972). Large-scale flow usually acts in phase with the diurnal breeze in all three months because westerlies are far more frequent than easterlies. At the same time, it acts against the nocturnal breeze. Weak westerlies (<8 ms\(^{-1}\)) are more frequent in September compared to summer while intense westerlies (>8 ms\(^{-1}\)) are more frequent in July. Weak easterlies are more frequent in summer and negligible in September, no intense easterlies were found for the period considered.

Considering the above results for thermal and large-scale forcing it follows that:

a) the large-scale flow cannot account for the high percentage of easterlies recorded in September 2008, which are due to the nocturnal breeze; and
b) for July–August 2008, because the thermal forcing of the nocturnal breeze is weak, westerlies often suppress the nocturnal breeze development (about 50% of the time).

These issues are further investigated in Section 2.4.

2.3. Two selected case studies for summer and fall

The “circulation of the day” was classified from 1 July to 30 September by a semi-objective method. The method is objective because measurements must satisfy precise requirements. Nevertheless, these requirements are defined after a subjective analysis of all the days. Days were divided into two classes: complete and incomplete breeze circulation (Table 3). Complete breeze circulation days must satisfy the following requirements: a) surface wind measurements show both the diurnal (onshore) and nocturnal (offshore) breeze components; b) winds at the first (35 m) and second (45 m) SODAR level show both the diurnal and nocturnal breeze components; c) the nocturnal breeze component blows for at least two consecutive hours at the surface and at first and
second SODAR levels; and d) no precipitation is recorded. Incomplete breeze circulation days are those not satisfying the requirements a–d.

We show measurements for two selected days with complete breeze circulation, one for summer and the other for fall.

Fig. 5 shows the evolution of the meteorological parameters measured by the surface station on 11 July. The measurements show a bell-shaped global radiation. No precipitation was recorded. Surface temperature followed the radiative forcing with values between 21 and 29 °C, while relative humidity ranged from about 65% (evening and night) to 80% (mid-morning and afternoon).

Wind speed and direction followed the typical diurnal evolution of breeze circulation days at the site. Wind speed was less than 1 ms$^{-1}$ during the evening and night, while it increased to 4.0 ms$^{-1}$ in the afternoon. Nocturnal winds were from E–NE (i.e., offshore) but, between 08 and 09 LST, they shifted to W–SW (i.e., onshore), causing the onset of the diurnal breeze (note also the sharp gradient in temperature associated with this shift).

Fig. 6 shows the SODAR measurements of the zonal component. This component is perpendicular to the along-coastline direction and it is the best component for observing the breeze development. For this instrument, time is given in UTC (LST = UTC + 2 h). Below 100 m, the nocturnal offshore
breeze development is apparent between 00 and 06 UTC (02-08 LST). Absolute values were less than 3 ms$^{-1}$ and the nocturnal breeze was weak at all levels. At 08 LST the diurnal onshore breeze started and reached, in the afternoon, values greater than 9 ms$^{-1}$ between 50 m and 100 m, denoting a much more intense circulation compared to the nocturnal breeze. After 21 UTC (23 LST), the nocturnal offshore breeze started again.

A complete breeze circulation developed on 18 September (surface measurements are not shown for brevity). Fig. 7 shows the zonal wind component measured by the SODAR for that day. Diurnal and nocturnal components of the breeze are evident. The nocturnal breeze was higher than 300 m between 01 and 03 UTC and was above the maximum vertical range of the instrument.

Comparing Figs. 6 and 7 it can be seen that the nocturnal breeze was more intense, higher, and lasted longer on 18 September compared to 11 July. This result is confirmed by the wind profiler measurements for the two days (Fig. 8). On 18 September, the nocturnal breeze height reached 600 m (04 UTC). This high value is not attained in a flat sea–land situation and highlights the role of the mountains around the Lamezia Terme Plain. Mountain–valley winds merge with the land breeze and produce a more intense, higher, and longer-lasting nocturnal breeze. On 11 July, the nocturnal breeze did not reach 150 m in agreement with SODAR measurements (Fig. 6). The comparison between Fig. 8(a) and (b) clearly shows the different nocturnal breeze development between the two days.

The 11 July and 18 September are typical breeze cases in their corresponding seasons. More in detail, 11 July shows the following typical characteristics of summer breezes: a) the nocturnal breeze is weak (<3 ms$^{-1}$); b) the diurnal breeze is longer-lasting than the nocturnal breeze; and c) the height of the nocturnal breeze is less than 150 m.

The 18 September is a typical case of breeze circulation in fall because: a) the diurnal and nocturnal breeze intensities are comparable; b) the diurnal and nocturnal breezes blow for about 12 h each; and c) the nocturnal breeze is usually higher than 200 m.

### 2.4. Patterns for summer and fall breezes

The semi-objective analysis of all days from 1 July to 31 August shows that the nocturnal breeze did not develop on 55% of the days (Table 3). Incomplete breeze days in summer have a positive zonal velocity at the surface. For these days, SODAR measurements usually show a positive zonal component throughout the day and at all levels even if a weak (<1 ms$^{-1}$), shallow (<75 m), and short (<2 h) nocturnal flow is occasionally measured.

To highlight the impact of the large-scale flow on breeze circulation, July and August days were divided into two

<table>
<thead>
<tr>
<th>Month</th>
<th>% (210&lt;dir&lt;330; speed&lt;8 ms$^{-1}$)</th>
<th>% (210&lt;dir&lt;330; speed&gt;8 ms$^{-1}$)</th>
<th>% (30&lt;dir&lt;160; speed&lt;8 ms$^{-1}$)</th>
<th>% (30&lt;dir&lt;160; speed&gt;8 ms$^{-1}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>July</td>
<td>37</td>
<td>21</td>
<td>8</td>
<td>0</td>
</tr>
<tr>
<td>August</td>
<td>37</td>
<td>5</td>
<td>12</td>
<td>0</td>
</tr>
<tr>
<td>September</td>
<td>59</td>
<td>15</td>
<td>&lt;1</td>
<td>0</td>
</tr>
</tbody>
</table>
Table 3
Breeze circulation from 1 July to 30 September 2008. First column: missing days; second column: days with incomplete breeze circulation; third column: days with complete breeze circulation. Cloudy or rainy days shown in bold. Format: YYMMDD. Subtotals from 1 July to 31 August and from 1 to 30 September are also reported.

<table>
<thead>
<tr>
<th>Missing days</th>
<th>Incomplete breeze circulation</th>
<th>Complete breeze circulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>080801; 080805; 080912; 080913; 080914; 080913;</td>
<td>080701; 080703; 080705; 080706; 080709; 080710;</td>
<td>080702; 080704; 080707; 080708</td>
</tr>
<tr>
<td>Subtotal 32</td>
<td>27</td>
<td></td>
</tr>
<tr>
<td>080909; 080907; 080908; 080909; 080923; 080924; 080925; 080926; 080927; 080929;</td>
<td>080903; 080904; 080905; 080906; 080910; 080911; 080916; 080917; 080918; 080919; 080920; 080921; 080922; 080928; 080930</td>
<td></td>
</tr>
<tr>
<td>Subtotal 10</td>
<td>16</td>
<td></td>
</tr>
</tbody>
</table>

6 days 42 days 43 days

groups: days with complete and days with incomplete breeze circulation. The average of SODAR measurements was computed for each group.

Fig. 9 shows the result for the wind speed. Lower wind speeds were recorded for the nights of complete breeze days compared to incomplete breeze days (<3 m s⁻¹ below 200 m and >4 m s⁻¹ below 200 m, respectively). In the afternoon, stronger winds were measured (7–8 m s⁻¹) for both groups because of the diurnal breeze development. Nevertheless, the winds in the afternoons of incomplete breeze days were more intense because the large-scale flow is usually from the west and merges with the diurnal breeze, enhancing the overall wind speed.

These results definitively show the impact of the large-scale flow on breeze development in July and August 2008 and clarify the origin of the positive zonal component recorded at night for about half of the days in summer (Fig. 3(a)).

The second feature discussed in this section is the change between the July–August and September breeze regimes. In Section 2.2 we showed that there is a substantial increase in the thermal forcing of the nocturnal breeze in September. Moreover, westerlies are weaker in September and usually do not overcome the nocturnal thermal contrast (Table 2). So, in contrast to summer, a well-developed nocturnal breeze is expected.

Useful statistics can be obtained by comparing the periods 1 July to 31 August and 1 to 30 September. We consider two groups of days: days with complete breeze circulation from 1 July to 31 August and from 1 to 30 September (Table 3). We computed the average of SODAR measurements over all days belonging to each group. Fig. 10 shows the result for the zonal wind component.

In summer (Fig. 10(a)), the nocturnal weak breeze (≈2 m s⁻¹) developed between 00 and 06 UTC (02-08 LST). The nocturnal breeze was, on average, 100 m in height. During the day, a rather intense breeze circulation developed (≈9 m s⁻¹). The diurnal breeze lasts longer than the nocturnal breeze.

In September (Fig. 10(b)), the nocturnal breeze circulation exhibits major differences compared to summer because: a) it was more intense (≈4 m s⁻¹); b) it was higher in elevation (250–300 m compared to 100–150 m); and c) the diurnal and nocturnal breezes blow for about 12 h each.

The diurnal breeze developed between 08 UTC (10 LST) and 18 UTC (20 LST) but, because the thermal forcing was lower, its intensity was roughly 2 m s⁻¹ weaker than in summer.

3. Conclusions

In this paper, we studied the breeze circulation characteristics at Lamezia Terme on the west coast of the Calabria Peninsula. For this purpose, we used data from different instruments: a surface meteorological station, a SODAR, a wind profiler, ECMWF meteorological analysis, and satellite-derived SST (from the O&S SAF). The sea–land contrast affects the local circulation because the experimental site is 500 m from the coastline. The local circulation is also influenced by the Apennines around the plain.

By comparing wind roses at the station and computed at 850 hPa from ECMWF analysis for July–August and September 2008, we show that local circulation is important for the site. The wind distribution as a function of time of day clearly reveals the role of the breeze in the local circulation.

Breezes are modulated by the season and a significant change occurs between summer and fall (at least for 2008): in summer the breezes come from W–SW, while in fall they are more frequent from E–NE.

To better investigate this change we first analyzed the two main physical forcings involved, i.e., the thermal contrast of diurnal and nocturnal breezes and the large-scale flow, and then focused, using case studies and statistics, on the breeze structure and characteristics.

The thermal forcing of the diurnal breeze is larger in July and August than in September, while the reverse is found for the nocturnal forcing. Although this result was expected, we found a sharp thermal forcing increase/decrease between the two periods, which is consistent with the significant change in the breeze circulation.

The large-scale flow analysis shows that westerlies are by far more frequent than easterlies. The synoptic-scale winds act in phase with the diurnal breeze and against the nocturnal breeze. Westerlies in September are more frequent than in July and August and are weak.
Finally, the analysis of the breeze structure and characteristics for the period 1 July to 30 September 2008 can be summarized in the following two points:

a) In July and August, the nocturnal breeze was strongly suppressed by the large-scale flow. Complete breeze days, i.e., those with both diurnal and nocturnal breeze development, occurred on about half of the days. The nocturnal breeze was suppressed by the large-scale flow on the remaining days. On these days, the diurnal breeze developed more intensely because it acted in phase with the large-scale wind. On average, the nocturnal breeze front height was 100 m and breezes did not develop in the evening.

b) In September, the nocturnal breeze was much more developed than in July and August because the thermal...
forcing was greater and large-scale westerlies were usually weak. On average, the nocturnal breeze had a height of 200 to 250 m and was present in the evening as well. The diurnal breeze was less intense compared to July and August because the thermal forcing was lower.

The study of breeze circulation in Calabria is important for understanding the local climate. The frequency of shower occurrence in certain locations due to the local winds is well known (Colacino et al., 1997; Pielke, 2001; Estoque, 1962; Yoshikado, 1981) and affects the local climate. De Leo et al. (2008), using a case studies approach, showed that the breeze circulation increases summer precipitation over the main peaks of Calabria. However, their results are still preliminary and based on case studies.

Apart from understanding the local climate, this research is important for agriculture, wind energy exploitation, aviation operation and safety, air pollution, tourism, and services and research is in progress to better analyze the characteristics, structure, and behaviour of the breezes at this site.

Finally, the paper presents a diagnostic study which may have a predictive value as well. For the period considered in this paper we found that the average of the nocturnal temperature (00-06 LST) at Lamezia Terme is about 2 °C lower on days when the nocturnal breeze develops. The results of this paper can be used to refine the temperature forecast considering the occurrence/non occurrence of the nocturnal breeze at the site.

Acknowledgments

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Appendix A

This appendix briefly introduces instruments and data used in this work.

A.1. Surface station

A surface station has operated at the experimental site since June 2006, measuring the following parameters: temperature, pressure, global solar radiation, wind speed and direction (10 m above ground level), precipitation, relative humidity, and soil temperature at 10 cm depth (from 1 January 2008). Data are available every 15 min but for this paper we use hourly-accumulated values for precipitation and hourly averages for others parameters. The averaged wind vector is computed by the true vector average. In this scheme, the magnitude of the vector is represented by the wind speed observation and the direction observations are used for the orientation. The vectors are then broken down into their zonal ($u$) and meridional ($v$) components. All $u$ and $v$ components are then averaged separately. The resulting average speed and direction are calculated from the Pythagorean Theorem and Arctan ($u/v$), respectively. Velocities less than 0.5 ms$^{-1}$ (calm wind) have been discarded.

A.2. Doppler SODAR

A Doppler SODAR operated at the experimental site from 1 July to 30 September 2008. The SODAR transmits short acoustic pulses of a certain frequency into the atmosphere. A
small fraction of the acoustic energy is scattered back from density fluctuations in the atmosphere. Because these micro-turbulent fluctuations move with the mean wind flow, the frequency of the backscattered signal is shifted according to the wind component parallel to the propagation of the acoustic waves (Doppler shift). The SODAR used in this work emits short pulses at 1900 Hz, using a phased array with 24 loudspeakers. Measurements consist of vertical profiles of wind speed components (horizontal and vertical) and turbulence every 10 min with a vertical resolution of 10 m. The maximum vertical range is 300 m; however, the actual vertical range depends significantly on the ambient noise. The lowest range gate is 35 m. Data were not available for a few days (Table 3) due to instrument failure/maintenance.

A.3. Radar wind profiler

A radar wind profiler has operated at the experimental site since 1 June 2008. The radar sounds the lower troposphere, usually up to 3 km, and measures the horizontal and vertical wind components using one vertical and two oblique beams slanted at an off-zenith angle of 15.5°. The operating frequency is 1290 MHz (about 23 cm wavelength). Returned echoes are due to air masses refractive index fluctuation advected by the wind. Data consist of the three wind components (zonal, meridional and vertical) every 30 min. The vertical resolution is 100 m, the minimum range gate is 150 m, and the vertical range is 2 to 5 km depending on atmospheric conditions. Accuracy of the wind measurements is <1 ms⁻¹ for the
horizontal wind components, 0.5 ms\(^{-1}\) for the vertical component, and less than 10° for the direction.

A.4. Sea surface temperature (satellite observations)

Daily sea surface skin temperature (SST) was computed for the Tyrrhenian Sea facing the experimental site (St. Eufemia Gulf, Fig. 1) using data disseminated by the EUMETSAT Ocean & Sea Ice Satellite Application Facility (www.osi-saf.org). The original dataset consists of 12-hourly means centred at 00 and 12 h UTC from 1 July to 30 September 2008, with a horizontal resolution of about 10 km. A general overview of the dataset, the algorithms and processing scheme is given in O&SI SAF (2006). SST for the St. Eufemia Gulf is computed by spatially averaging the pixel values inside the area shown in Fig. 1. The area of Fig. 1 is representative of the sea area affecting the local circulation because the shape of Calabria limits the breeze extension to one Rossby radius (Abe and Yoshida, 1982; Dalu and Pielke, 1989), which is about 50 km for Calabria (Federico et al., 2000). Daily SST is the average of 00 UTC and 12 UTC values.

Data from O&SI SAF comes with a confidence flag corresponding to the quality of the calculated SST and information on the processing conditions. The pixels where the SST calculation was attempted are labelled on a five-level scale: 5 = “excellent,” 4 = “good,” 3 = “acceptable,” 2 = “bad,” and 1 = “erroneous”, depending on pixel distance from clouds, SST climatology, sun glint effect, etc. The “erroneous”

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**Fig. 9.** (a) SODAR wind speed average for July and August 2008 breeze days. Time in UTC (LST = UTC + 2 h). White area shows locations/hour with less than seven measurements; and (b) as in (a) but for incomplete breeze days.
confidence level may be attributed to a parameter missing due to a failure of the algorithm or present but with a very low level of confidence. For this study, we used only pixels with a confidence level greater than 3.

References