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THE QUIBERON 2006 EXPERIMENT: DESCRIPTION AND FIRST RESULTS ON THE SEA-BREEZE LOCAL BEHAVIOR

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1. INTRODUCTION

In order to investigate the sea-breeze behavior in complex topographical configurations, a campaign of meteorological measurements was carried out during three weeks (June 13-29, 2006) over the Quiberon bay (Southern Brittany, France), where the ENVSN (Ecole Nationale de Voile et des Sports Nautiques) is located. ENVSN is one of the french training and regatta centers for nautical sports.
This work is part of an ECN - ENVSN cooperative research program entitled “Characterization of the sailing performance”, which is supported by the Ministère de la Santé, de la Jeunesse et des Sports and the French Sailing Federation (FFV).

Figure 1: Geographic situation

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The meteorological part of this research program aims to better understand and predict the local wind regimes at small-scale in Quiberon bay . The final objective is to bring to the sailors and to their coaches some means to refine their analysis of the wind in this sailing area. However the aims of this first campaign are essentially technical and scientific.
Firstly, the technical aim is to prove the feasibility of such an experiment for further larger campaigns with eventually more permanent instrumentation. We have to confirm that this site and its infrastructure are adapted to the deployment and the exploitations of the instrumentation.
Secondly, the scientific aim was to constitute a database that will be used, in a near future, to validate high resolution simulations performed with atmospheric models. If validation is satisfying, then numerical simulations could be performed in conditions different from those encountered during the campaign, in order to better assess the very complex breeze systems of this rather closed and shallow bay.
This paper starts with the description of the instrumentation and procedures. Then, the observations of land-breeze and sea-breeze are described. Finally two sea-breeze situations, typical of the particular regimes observed in the Quiberon bay, are analyzed (June 23 and 28).

2. EXPERIMENTAL SET-UP

2.1 Geographic situation

The Quiberon bay is located on the southern coast of the French Brittany. It is laying on a circle 12 km in diameter, the centre of which is located at 47.31N and 3.03W.
The particularity of this bay is the peninsula of Quiberon that is bounding it on the west and partly on the south; the sandy isthmus is very narrow and low while the southern Quiberon is a quasi-island, followed by a line of shallows and low islands up to Houat and Hoëdic, forming a natural border of the bay in the south. Slightly further south, a more elevated island (Belle-Ile) also influences the wind and water flow. The eastern part of the bay is more open and may also be influenced by the outlet of Gulf of Morbihan.

2.2 Measurement sites and instrumentation

The list of instruments with their localization is given in Table 1. Five sites located on the ground close to the shore line around the bay were instrumented (Fig. 1). For wind measurement, a 28m mast was erected on the isthmus of Penthièvre (PEN), an other smaller one on a tiny island near the south foreland of the peninsula (INZ) and a third one on the north coast (STP). An anemometer was set 1 km inland on the military semaphore of Quiberon (SEM). In addition, four instrumented light catamarans (KTA) were positioned every day onto the bay according to the expected wind regime, to further document the wind flow on the bay between the inland sites. During this feasibility experiment only the western half of the bay has been documented.

The measurements include wind velocity and direction, air temperature, surface temperature, relative humidity, global and infrared radiations (ENV) and atmospheric pressure. The sodar was located at ENV.
The measurements were stored 24 hours a day except for catamarans and sodar which were operated during daytime only. The measurement period lasted from June 17 to June 28. Figure 2 shows the 15 minutes averaged wind direction and velocity time series during the whole campaign, where the red rectangles identify the analyzed periods.

Site	Instrument	Number	Height (above ground level)	Acquisition rate
PEN	26 m high mast	1		
	3D Sonic Anemometer (Metek USA-1)	2	28 m, 16 m	20 Hz
	2D propeller-vane anemometer (Young 05103)	1	11 m	2 Hz
	Temperature / humidity sensors	3	26 m, 16 m, 2 m	2 Hz
	Thermocouples (surface temperature)	6	0	2 Hz
	Thermocouples (air temperature)	7	0, 2, 11, 16, 21, 26, 28 m	2 Hz
STP	10 m high mast	1		
	3D Sonic Anemometer (Metek USA-1)	1	10 m	10 Hz
	2D Sonic anemometer (LCJ Capteur CV3F)	1	6 m	2 Hz
	Temperature / humidity sensors	1	2 m	2 Hz
	Barometer	1	2 m	2 Hz
	Pyranometer	1	0 m	2 Hz
INZ	8 m high mast	1		
	3D Sonic Anemometer (Metek USA-1)	1	8 m	10 Hz
	Temperature / humidity sensors	2	2 m, 6 m	2 Hz
ENV	Temperature / humidity sensors	1	2 m	2 Hz
	Barometer	1	2 m	1 Hz
	Pyranometer	1	0 m	2 Hz
	Pyrgeometer	1	0 m	2 Hz
	Sodar	1	40-420 m	1/15 min
SEM	2D Sonic anemometer (LCJ Capteur CV3F)	1	50m	1 Hz
KTA	2D Sonic anemometer (LCJ Capteur CV3F)	4	5 m above sea level	0.05 Hz
	Water temperature	2	- 0.5 m	

Table 1 : Specifications of the instrumentation

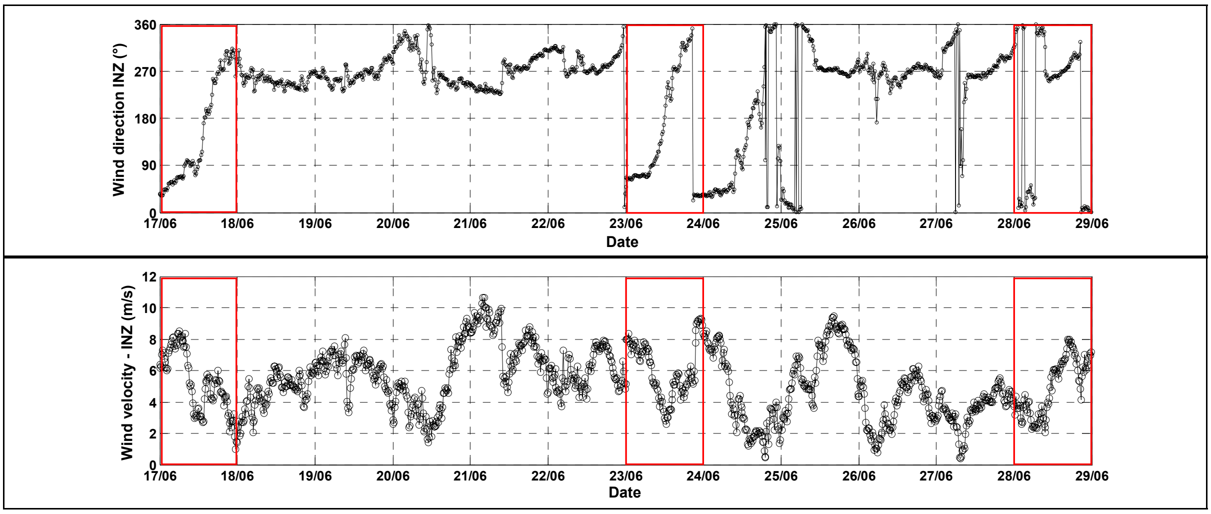

Figure 2 : Wind direction and velocity during the measurement period at INZ (June 17-28, 2006)

3. DATA ANALYSIS

The initial analysis of this database focuses on the 3 days when large-scale sea-breeze events occurred. Two typical situations of sea-breeze are observed: on June 17 and 23, the wind is from the north-east in the morning and veers clockwise during the whole day. On June 28, the situation is different since the wind is from the north on the morning: it veers from north to west-southwest anti-clockwise, and finally returns to northerly at the end of the day. Here we present the results from June 23 and 28 measurements.

3.1 Land breeze analysis

The observation of the June 23 meteorological data obtained at different places in the country (inland, at the coast, or in the islands) shows that during the previous night (June 22-23) there was no wind inland while a land-breeze developed on both southern and northern Brittany coastlines. On the contrary, during the following night, there was a homogeneous north-easterly synoptic flow over the country (Fig. 3).

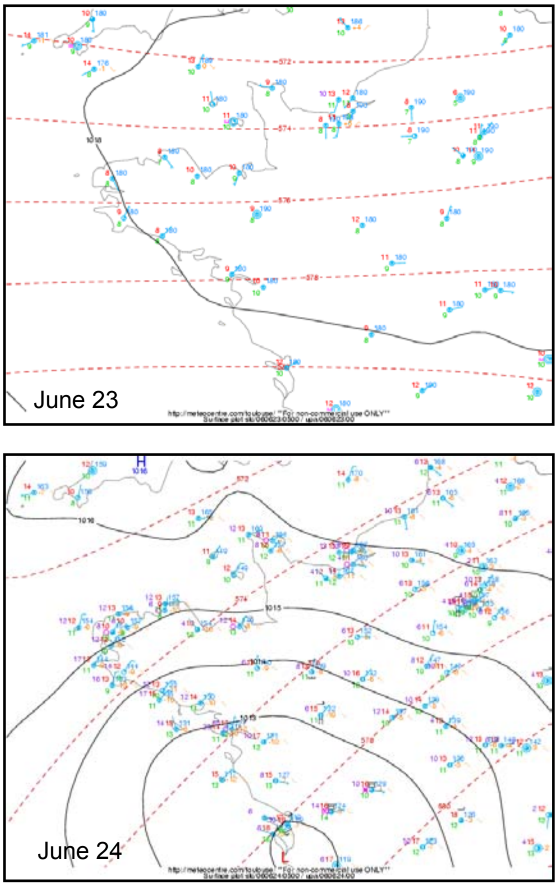

Figure 3 : Meteorological charts at 0500 UTC

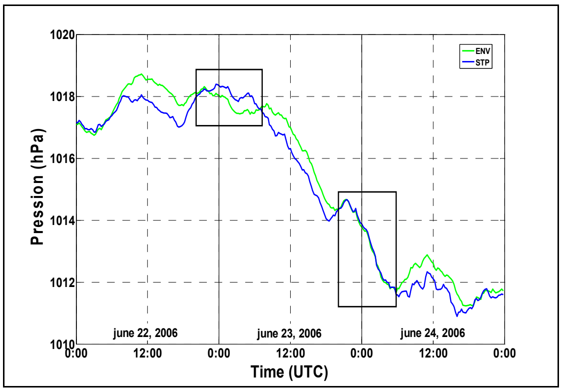

Figure 4 : Pressure evolution at STP and ENV

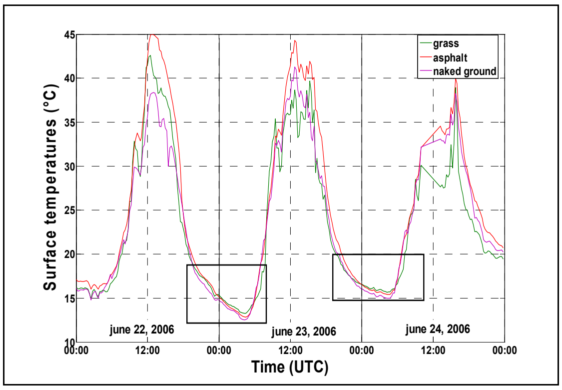

Figure 5 : Evolution of surface temperatures measured with the thermocouples at PEN

Figure 4 presents the measures of atmospheric pressure at the two opposite sites ENV and STP from June 22 - 24 where the rectangular boxes identify these two nights, exhibiting a pressure difference during the first night and no difference during the second night. We think that this Figure demonstrates that the measure of atmospheric pressure difference between these two sites is a significant signal of the land breeze through the Quiberon Bay.
This observation is confirmed by surface temperatures (Fig. 5) showing a much larger temperature drop during the first night than during the second one, indicating a larger temperature difference between the sea and the land accompanying the onset of the land breeze.

3.2 The sea-breeze on June 23

In this section, the analysis focuses on the day of June 23, 2006. The observed meteorological conditions are a weak synoptic pressure gradient, with a low pressure (1013 hPa) over the British Islands, and a front crossing the country in the middle of the day. Excepting along the front, the synoptic wind is staying pretty steady all the day long, about 1-3 m/s, with an averaged direction from north-east.

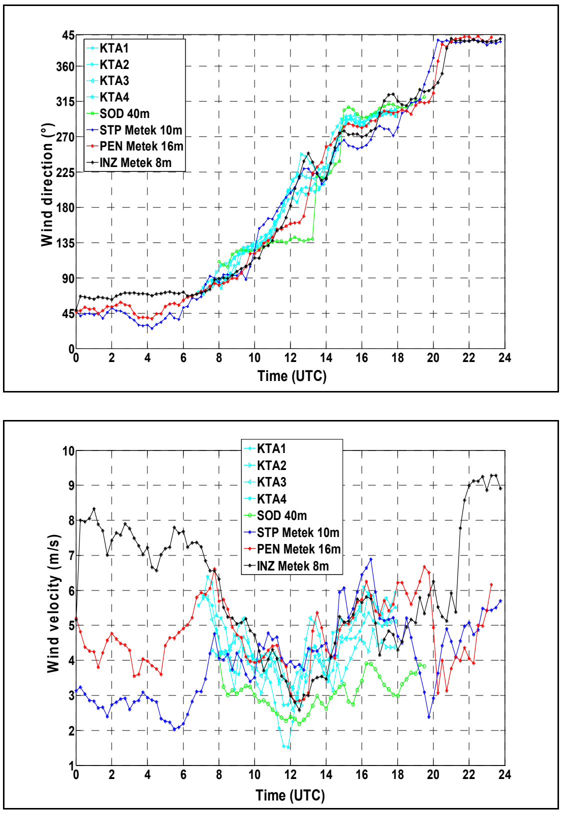

Figure 6 : Wind direction (top) and velocity (bottom) on June 23

Here, Figure 6 shows that from 0000 UTC to 0600 UTC a north-northeasterly flow is observed, due to the land-breeze (see §3.1). During this early morning the measured wind speed is quite stronger at INZ than at the other sites, with a small shift in direction, likely due to the difference in upwind surface roughness: with this wind direction at INZ the upwind surface is the bay water with a fetch of a dozen km, whereas the other two sites are downwind from land surfaces.

Between 0600 UTC and 0800 UTC we observe the critical point when the land surface temperature exceeds the sea temperature (Fig. 5); this is the same time when we observe the pressure crossover on Fig. 4.

At 0800 UTC the wind begins a right shift and a velocity decrease which are the clues of the transition between the land- and sea-breezes while the clock-wise rotation is determined by the synoptic flow.

After 1200 UTC we observe a general strengthening of wind speed. However, there are still important differences in the wind direction, due to the development of small-scale sea-breeze effects following local coast-line directions, until a larger-scale breeze overpasses these less energetic processes. The signature of a large-scale breeze front is identified on all sites data between 1200 UTC and 1330 UTC, and especially in the Sodar measurements over the ENV site at 1320 UTC (Fig. 7).

In the same time, around 1300 UTC, the remarkable backing (from 250° to 220°) may be explained by an included front observed over Brittany on Meteosat images and signaled by the sudden apparition of clouds (Fig. 8).

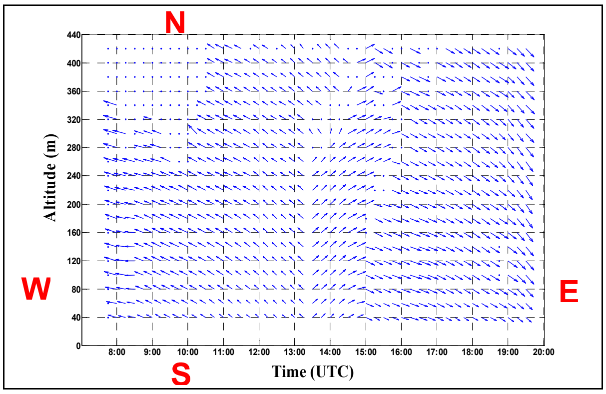

Figure 7 : Evolution of the horizontal wind from the Sodar measurements during June 23

Figure 8 : Apparition of clouds at 1300 UTC

At 1700 UTC, we notice at INZ a sudden and strong wind shift to the right, with plateaus just before and just after, and in the same time a temporary speed drop. These measurements show that the wind skirts round the peninsula by the west before 1700 UTC (wind direction < 300°), and by the North-West after 1730 UTC (dir > 300°). The speed drop is linked to the wind wake of the peninsula. Actually a similar behavior may be observed earlier in the afternoon (1300 UTC) in the Sodar measurements over ENV when the local wind direction shifts from 140° to 230° with a small speed drop.

In the late afternoon the wind is slightly veering to north-west due to Coriolis effects: as the land surface cools, the sea-breeze vanishes and it is replaced by the synoptic flow from the north-east (see §3.1).

3.3 The sea-breeze on June 28

On June 28, the synoptic wind is from the north (instead of the north-east on 23 June) which could explain why the wind shifts counterclockwise before sea-breeze establishment (Fig. 9). We notice that during this day the wind direction never turns more south than 270° (at the PEN reference site).
After 1400 UTC the large-scale breeze is established over all the measurements domain and the main wind flow is then coming from the 270-280° sector.

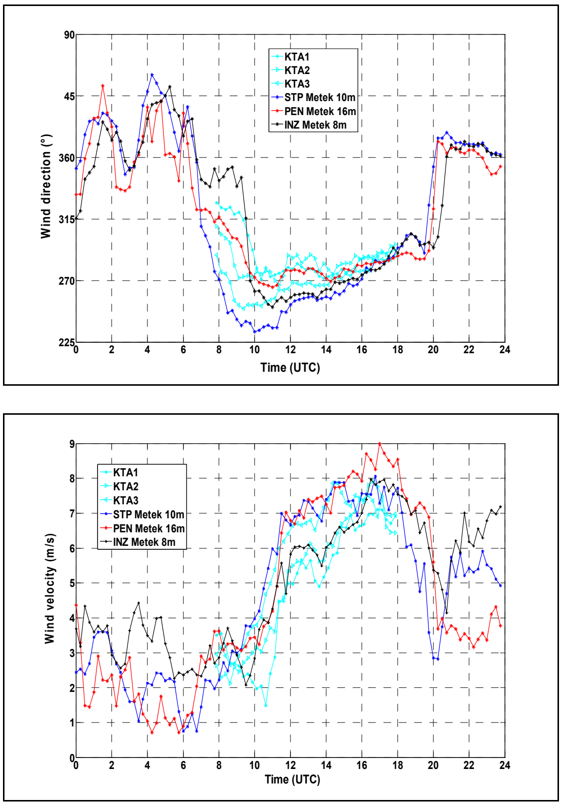

Figure 9 : Wind direction and velocity on June 28

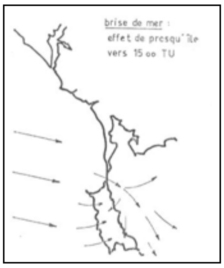

Figure 10 : Sketch of peninsula influence on the afternoon sea-breeze (after Kuhn et al., 1981)

During all the day we notice significant differences between the sites. The divergence of wind directions corresponds to an air flow fanning out downstream from the isthmus, as previously deduced by Kuhn et al. (1981) from statistical observations with that sea-breeze wind direction. Yet, the wind direction measurements at INZ show a more complex situation than Figure 10 : while in the morning the fanning out is observed over the whole domain, when the wind reaches the 270° sector between 0900 and 1000 UTC a rapid shift is observed at INZ, with a relative speed drop. They indicate that the southern part of the bay is then under the lee of the peninsula which generates a flow skirting around and slowing down that we observe during the whole afternoon.

4. CONCLUSION

This feasibility campaign demonstrates its usefulness for understanding the sea-breeze processes in complex situations where the influences of the local coast lines, synoptic wind, and surface temperature distribution may interfere. The acquired data base is sufficiently rich in signatures of very local effects to test/validate atmospheric models ability to drive numerical simulations at the very high spatial resolutions requested by sailing race strategy training.
The analysis of this campaign provides important information to prepare the next, larger, cooperative campaign in Quiberon bay. For example, the pressure and pressure difference seem to provide key signals for detecting the breeze onset, maybe its strength, and we will investigate further that point in the next campaign.
Also, the factors triggering the clockwise or anti-clockwise rotation of the breeze should be investigated further, maybe with numerical simulations.

Acknowledgements

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Reference

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