Deliverable Dc-2.3

"Measurement campaign in Alaiz - Overview"

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Abstract: This deliverable presents an overview of measurement campaign in complex terrain performed within SafeWind Work package 2, Task 2.3.

AUTHORS[1], REVIEWERS				
MAIN AUTHOR/EDITOR:	Paula Gómez			
AFFILIATION:	CENER			
ADDRESS:	Pol. Rocaforte, Parcelas G2-H1. 31400 Sangüesa, Spain			
TEL.:	+34 948 87 17 45			
EMAIL:	pgomez@cener.com			
FURTHER AUTHORS:	Mike Courtney			
PEER REVIEWERS:	Gabriel Alzueta (CENER)			
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PL: *Project leader* **WPL:** *Work package leader* **TL:** *Task leader*

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Contents

1. Introduction

The purpose of this report is to present an overview of the measurement campaign in complex terrain carried out in SafeWind Task 2.3. The aim of this document is to provide a description of the test site, the instrumentation involved, and a summary of the recorded dataset. A detailed analysis of the campaign results will be presented in a subsequent version of the deliverable, DC2.3-assessment.

The data obtained from this measurement campaign is also used in Safewind tasks 2.4, 2.5 and 2.6.

2. Test site description

The measurement campaign takes place in CENER’s Alaiz station for wind turbine testing. It is located in northern Spain, approximately 30km south of Pamplona, in Echagüe municipal district.

It consists of six wind turbine stands (A1 to A6) and five reference meteorological masts of height 118m (MP0 to MP5). Mast and test stands are distributed in the East-West direction along a mountain ridge, as shown in Figure 1. Each wind turbine position is calibrated [1] at four different heights (118m, 102m, 90m and 78m), to allow for the testing of wind turbines of different hub heights.

The site is roughly 1100m a.s.l. (Figure 2) and is of class IA according to [2], with an average wind speed above 8 m/s. Prevailing wind direction is North.

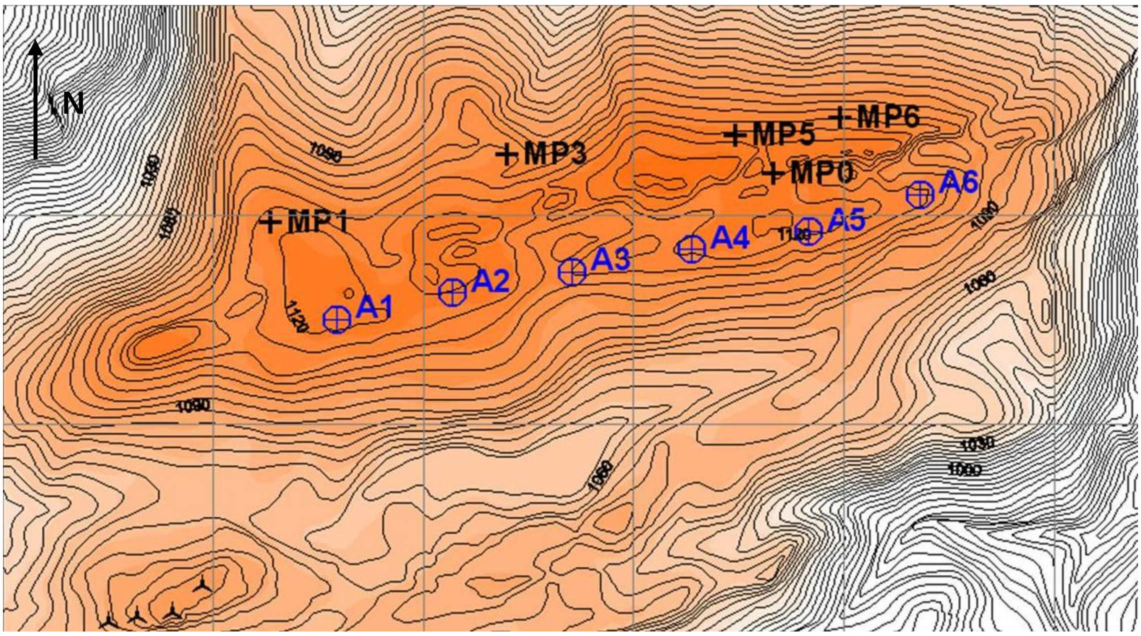

Figure 1 – Layout of wind turbine stands and meteorological mast positions in Alaiz test station.

The location of the test station is a mountainous area, with large terrain variations, and a steep slope looking into the north direction, followed by a plateau. The vegetation present at the site

consists of bushes and trees not higher than 10m. The surrounding terrains are dedicated to cattle grazing (Figure 3).

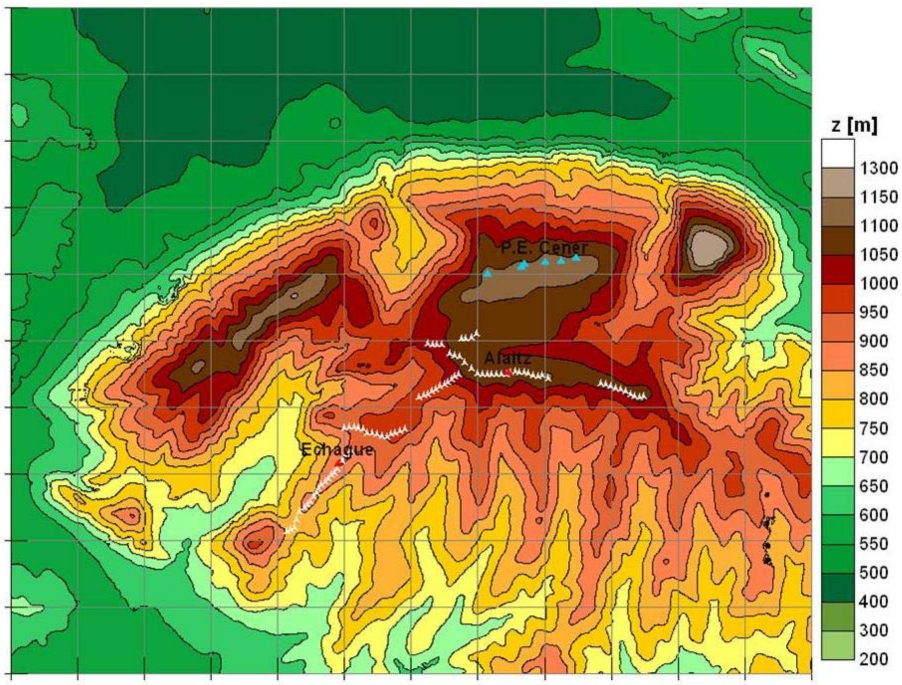

Figure 2 – 12Km x 10Km elevation map of Alaiz Mountain. CENER’s test station positions are indicated as blue triangles. Wind turbines from neighbouring wind farms are indicate in white.

Figure 3 – General view of the test station location, as seen from North.

3. Campaign overview

Measurement campaign is divided in different stages:

- First Phase (or “Phase 0” in some work package documentation): one lidar is installed in the vicinity of one meteorological mast, to perform lidar to mast comparisons, and a lidar to mast site calibration.

- Second Phase (or “Phase 1” in some work package documentation): two lidars are installed close to a reference mast, and one sodar is installed at a certain distance (aprox. 200m apart) in the cross-wind direction. This campaign aims at comparisons between different remote sensing instruments.
    - For a short period of time (roughly one month), one lidar is moved close to the sodar for the purpose of inter-comparison and check assumption of 2D northerly flow

A third phase was originally planed, in which the remote sensing equipment was to be re-allocated along the test station, for the purpose to further investigate spatial correlation of extreme events. This was finally not carried out in order to be able to expand the duration of the previous phases and obtain better datasets.

Any other significant modifications to the campaign plan are detailed in section 5.

4. Instrumentation

4.1 Meteorological mast

Although there are several meteorological masts in the test station, the mast used in the SafeWind campaign as the reference to which remote sensing data is compared is MP5 (Figure 1). It is a 118m high lattice mast, which has cup anemometers, wind vanes and propeller anemometers at different levels. The mast is equipped with additional meteorological sensors such as pressure and temperature, as detailed in Table 1.

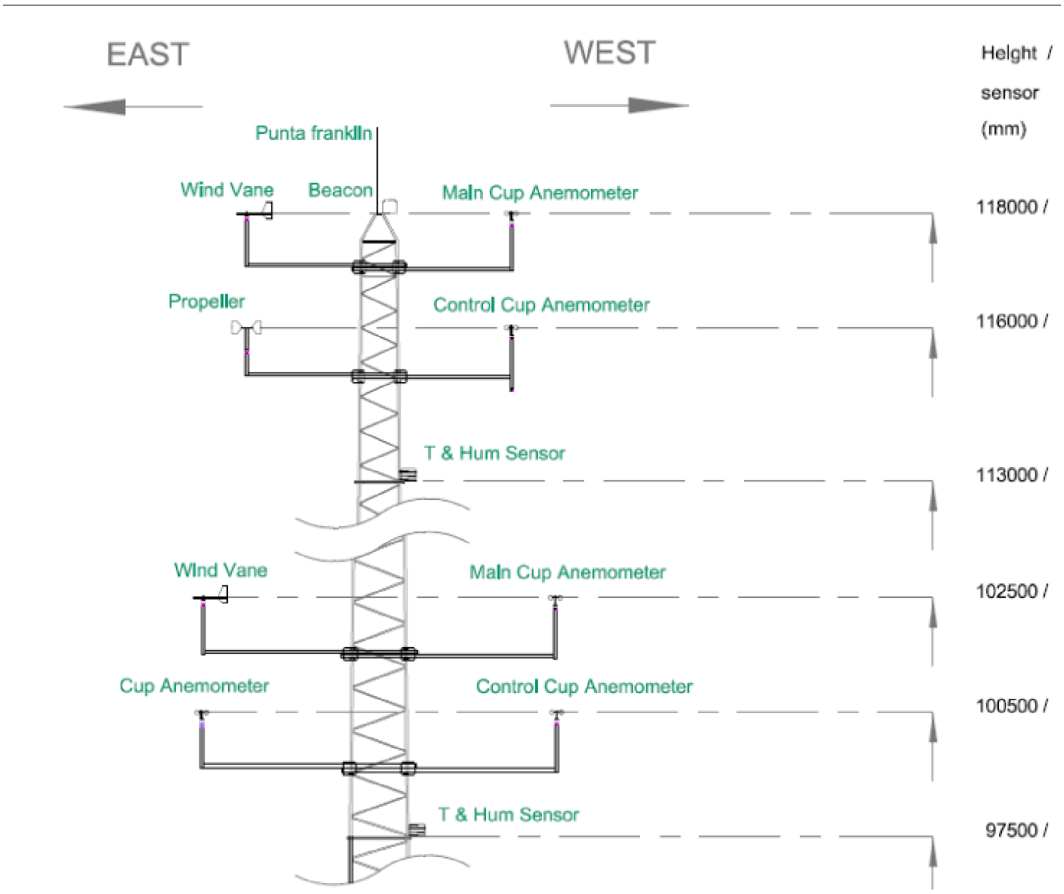

Figure 4 – Detail of top instrumentation levels of meteorological mast MP5.

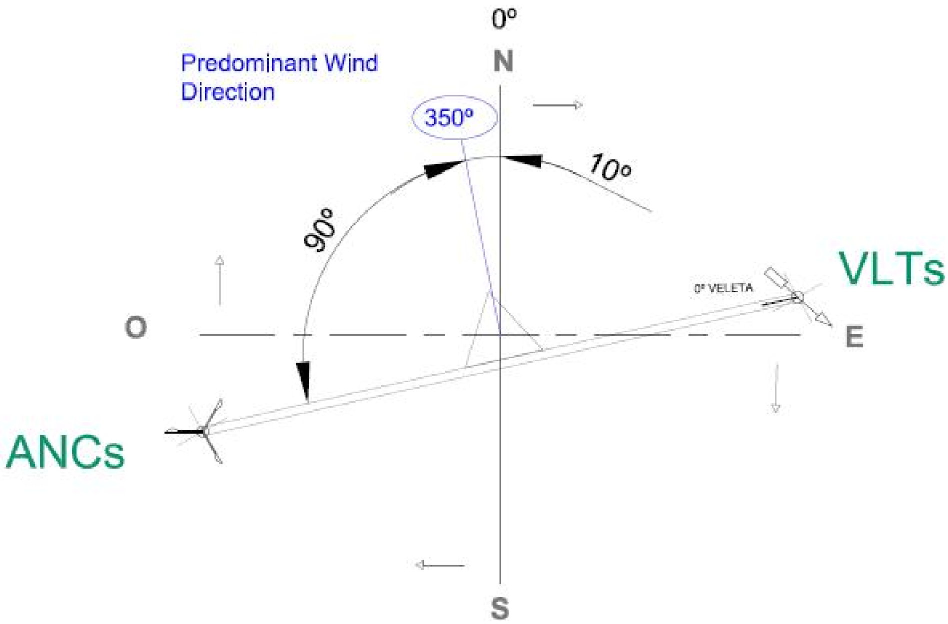

Figure 5 – Scheme plan view of the meteorological mast.

4.1.1 Sensors

Cup anemometers, vanes, and propeller anemometers are mounted on booms of length increasing with mast width, in order to alleviate flow distortion caused by the mast. Boom orientations are either 260º or 80º with respect to North (perpendicular to the prevailing wind direction), as can be seen in Figure 5. Sensor heights and boom orientations are detailed in Table 1 and Table 2.

Cup anemometers indicated as “control” anemometers in Table 1 are not used in the analysis performed in other SafeWind tasks, and are only for the purpose of quality check of the main cup anemometers. During the time span of the campaign (November 2009 to June 2011) the mast instrumentation suffered some modifications, in order to accommodate for different purposes. For this reason, some sensors were only installed on the mast at one part of the campaign, as indicated in next table.

Sensor	Height a.g.l. (m)	Boom orientation (º)	Present in 1st Phase	Present in 2nd Phase
Cup anemometer (main)	118	260	Yes	Yes
Cup anemometer (control)	116	260	Yes	Yes
Wind Vane	118	80	Yes	Yes
Propeller	116	80	Yes	Yes
Humidity & Temperature sensor	113	--	Yes	Yes
Cup anemometer (main)	102	260	Yes	Yes
Cup anemometer (control)	100	260	Yes	Yes
Wind Vane	102	80	Yes	Yes
Propeller	100	80	Yes	No
Cup anemometer	100	80	No	Yes
Humidity & Temperature sensor	98	--	Yes	Yes
Cup anemometer (main)	90	260	Yes	Yes
Cup anemometer (control)	88	260	Yes	Yes
Wind Vane	90	80	Yes	Yes
Propeller	88	80	Yes	No
Cup anemometer	88	80	No	Yes
Humidity & Temperature sensor	81	--	Yes	Yes
Cup anemometer (main)	78	260	Yes	Yes
Cup anemometer (control)	76	260	Yes	Yes
Wind Vane	78	80	Yes	Yes
Propeller	76	80	Yes	Yes
Cup anemometer	40	260	Yes	Yes
Humidity & Temperature sensor	38	--	No	Yes
Rain sensor	5	--	Yes	Yes
Humidity & Temperature sensor	2	--	No	Yes
Pressure sensor	1.5	--	Yes	Yes

Table 1 - Meteorological mast instrumentation

All sensors of the same type are from the same manufacturer and of the same model. Sensor models are specified in Table 2.

Type of Sensor	Model
Cup anemometer	Vector A100LK-PC3
Wind Vane	Thies-Compact
Propeller	Young 27106T
Humidity & Temperature sensor	Ammonit P6312
Pressure sensor	Vaisala PTB110
Rain sensor	Lambrecht 15152

Table 2 – Meteorological mast sensor models

The pressure sensors, temperature and humidity sensors, and the propellers have been calibrated by laboratories accredited by UNE-EN ISO/IEC 17025 standard [3]. Additionally, cup anemometers have been calibrated by a laboratory accredited by Measnet [4].

4.1.2 Free sectors

In order to ensure that the measurements of meteorological mast sensors are not influenced by wakes from neighbouring wind turbines or other obstacles, an assessment of obstacles is carried out according to [1]. During this campaign there aren’t wind turbines installed in the A1 to A6 stands. The outcome of the obstacle assessment is that there are not significant obstacles influencing MP5 in the sector [0º, 360º). However, it is recommended that only sectors of ±20º or ±40º centred around 350º and 170º (Figure 5) are used in the data analysis, in order to reduce flow distortion effects caused by the meteorological mast.

4.2 Remote sensing equipment

The different measurement principles and technologies of lidars and sodars are described in detail in the report Dp-2.1 “Ground Based Remote Sensing – An overview of existing technologies". For this reason, this document will only provide (sections 4.2.1 to 4.2.3) a brief description of the equipment together with the specific settings used in the campaign in Alaiz.

The three remote sensing devices used in this campaign are also used at some (ZephIR, SFAS) or all periods (WindCube) of the flat terrain measurements in Høvsøre (SafeWind report Dc2.2).

4.2.1 SFAS Sodar

Scintec SFAS is a compact sodar that allows the user to select different operation parameters (such as number of frequencies, length of pulses, averaging time, etc). The following configuration is used during this campaign:

Parameter	Value
Number of frequencies	10
Range of frequencies	2500 to 4900 Hz
Number of beams	9
Period of integration	10 min
Pulse duration	5 to 15 m
Height range of measurement	10 to 150 m
Output vertical resolution	5 m
Antenna azimuth angle	44º

Table 3 – Sodar settings during measurement campaign in Alaiz.

The pulse duration corresponds to a measurement every 5 m for the highest frequencies and 15 m for the lowest frequencies. The output data are provided with a vertical resolution of 5 m. Measurements below 30m are usually discarded due to low data quality.

Figure 6 – Scintec SFAS

4.2.2 ZephIR lidar

The ZephIR is a continuous wave lidar with a variable focus. It is configured to measure sequentially at heights 40m, 78m, 90m, 102m and 118m above ground level. Additional focus heights are sensed (as a factory setting): 38m and 800m, which are used only by the ZephIR internal cloud correction software to process wind data in order to compensate for cloud effects and detect fog. Scan settings are modified from the factory default three-second scan per height to one-second scan per height.

During the measurement campaign, special care is taken to keep the lidar updated with the latest firmware version and manufacturer’s software, in order to achieve the best data quality possible. For this reason, a major change in the ZephIR firmware version was performed on 11/02/2011, which introduced an additional focus height for the purpose of improving the fog detection process.

Figure 7 – ZephIR lidar deployed at Alaiz Test Station

4.2.3 WindCube lidar

The WindCube is a pulsed lidar with a fixed focus, which is able to provide wind profile data approximately each six seconds. It allows for the possibility of obtaining wind measurements at up to ten different heights ranging between 40m and 300m. In this campaign it is configured to measure at 40m, 78m, 90m, 102m, 118m, to match relevant mast instrumentation, and additional heights of 130m, 200m, 250m and 300m.

The lidar comprises its usual factory configuration (30º prism to deflect the laser beam), and no major modifications in the system settings or components were performed during the campaign.

Figure 8 – WindCube lidar

5. Campaign phases

5.1 First phase

The first part of the SafeWind campaign was carried out between November 2009 and June 2010. The original start-up date (proposed in the Description of Work) was postponed due to the delay in the beginning of construction works of the test station.

This campaign was carried out simultaneously to the first stage of site calibrations (eastern wind turbine positions: A6, A5 and A4, Figure 1) in Alaiz test station. Hence, the start up of the SafeWind campaign was determined by the end of the works to install the meteorological masts and start-up of sensors and acquisition systems.

During this period, six meteorological masts were present at the test station: MP6, MP5 and MP0 (reference masts) and MC6, MC5 and MC4 (temporary masts in wind turbine positions), see Figure 9. Their instrumentation is very similar to the description in 4.1.

Only one remote sensing instrument is used at this stage: CENER’s ZephIR, which is installed approximately 20m west of mast MP5. This phase has two objectives:

- Main goal is to provide a preliminary assessment of the lidar behaviour in this complex terrain environment, before performing the principal part of the campaign where the

three remote sensing instruments are used. To this aim, an analysis comparing lidar and MP5 measurements has been performed.

- Second goal is to involve a remote sensing instrument in the site calibration to investigate the possible benefits with respect to the standard methodology.

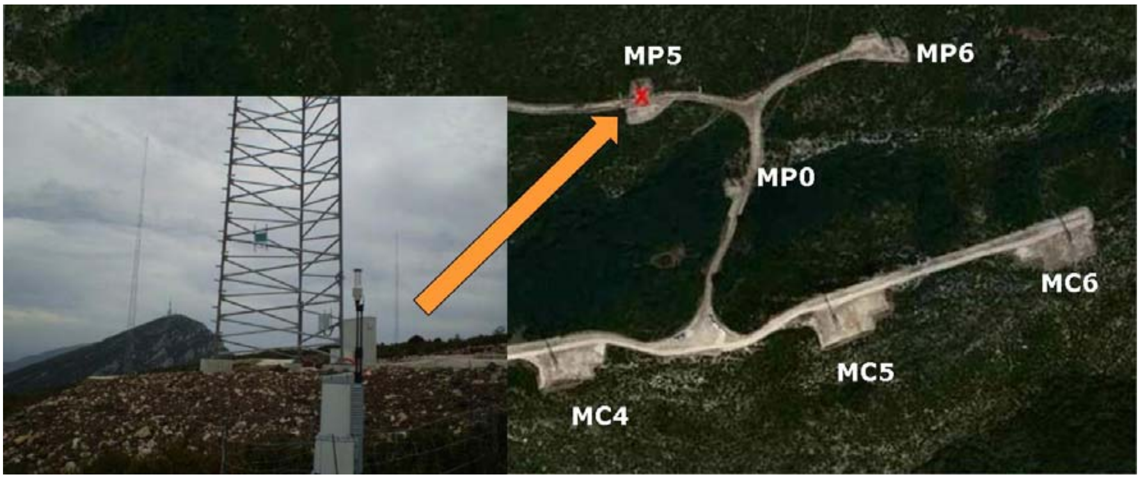

Figure 9 – Aerial view of the test station (December 2009) and positions of the meteorological masts installed at the site during this phase. View of ZephIR deployed near MP5.

Originally, this phase was planned to last three months, but the span had to be increased. On one hand, very severe winter weather caused low lidar and mast data availability: long periods of time with temperatures below 0ºC and frequent occurrences of snow or ice originated either damaged or frozen mast instruments. Lidar, although not affected by icing, experienced some electrical failures in very low temperatures, and additionally, the frequent presence of fog at measurement heights or at ground level reduced significantly its data availability. On the other hand the completion of the site calibration was delayed; both due to the mentioned low data availability during winter, and the wind direction distribution (only northern winds are useful for this aim).

5.2 Second phase

The second part of the SafeWind campaign was carried out between October 2010 and June 2011.

When this phase of the campaign started, the second stage of site calibrations (western wind turbine positions of the test station: A1, A2 and A3, Figure 1) was still in progress. Six meteorological masts were present at the test station: MP1, MP3 and MP5 (reference masts) and MC1, MC2 and MC3 (temporary masts in wind turbine positions), see Figure 10. Their instrumentation is very similar to the description in 4.1.

The three remote sensing instruments were installed as shown in next figures:

- ZephIR and WindCube were installed 20m west of meteorological mast MP5
- The sodar was installed 220m west of MP5. This position was selected taking into account that the sodar must be separated from the mast to avoid fixed echoes. Although it would be preferable that it were closer to the mast to minimize the wind flow change between sodar and mast, this is not possible due to the terrain conditions (irregularities and vegetation).

This deployment was maintained during all the campaign except for the period 08/03/2011 to 12/04/2011, during which the Windcube lidar was moved to the sodar position, for inter-comparison purposes.

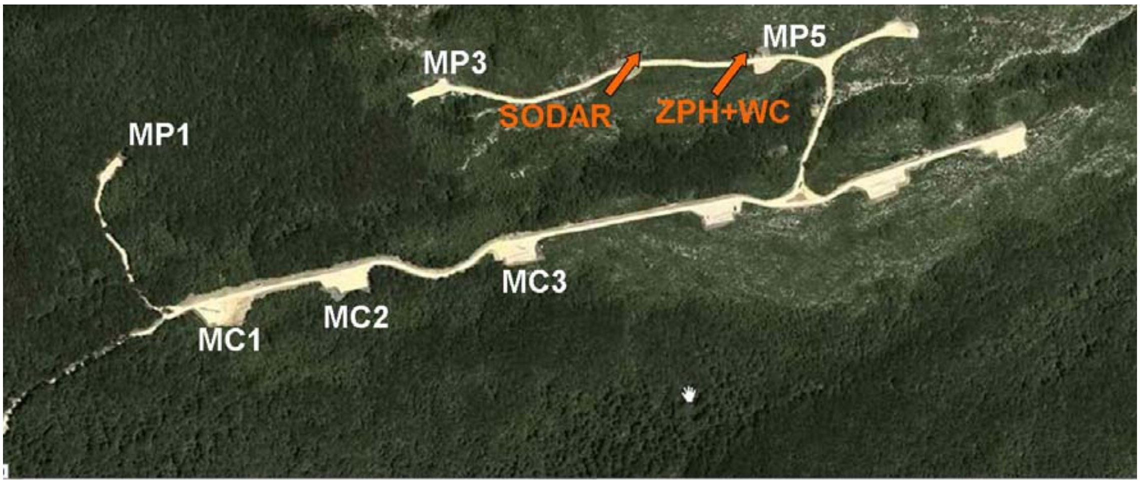

Figure 10 – Aerial view of the test station during the second phase of the campaign. Positions of sodar, ZephIR ("ZPH") and WindCube ("WC") and meteorological masts.

Figure 11 – Deployment of lidars in Alaiz and reference meteorological mast MP5.

Figure 12 – Sodar and reference meteorological mast MP5

6. Database summary

Remote sensing data is available in the SafeWind database, corresponding to the following periods:

Period	Start date	End date
1st Phase	20/11/2009	02/06/2010
2nd Phase	15/10/2010	27/06/2011

Table 4

Detailed statistics on data availability will be provided in report Dc-2.3 "Assessment".

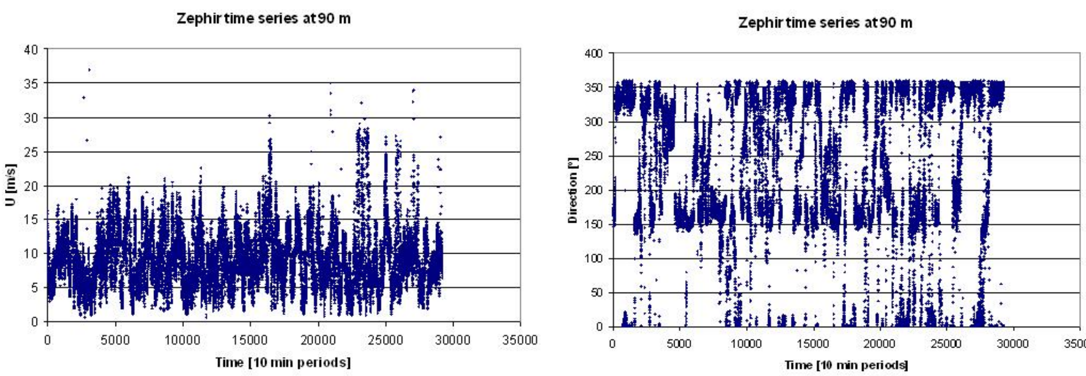

Figure 13 – Time series of ZephIR data corresponding to first phase: wind speed (left) and wind direction (right).

7. Conclusions

A total of 15 months of remote sensing data have been collected at the Alaiz site. These data are available in the Wp2 database. This forms the complex terrain dataset for use in the analysis of tasks 2.4, 2.5 and 2.6. A complementary data set for flat terrain was obtained Task 2.2 [5].

8. References

[1] IEC 61400-12-1: Power performance measurements of electricity producing wind turbines. Edition 2005.

[2] IEC 61400-1: Wind Turbine Generator Systems. Part 1: Safety requirements. Second edition 1999-02.

[3] UNE-EN ISO/IEC 17025:2000 “Requisitos generales relativos a la competencia de los laboratorios de ensayo y calibración”.

[4] MEASNET “Cup Anemometer Calibration Procedure Version 2”. October 2009.

[5] Dc-2.2 Overview “Results of the measurement campaign in flat terrain – An overview of the collected data”, SafeWind deliverable, 2011.