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## **Starry Sky Quality Survey in Pic du Midi RICE/IDSR area (Core and Buffer zone)**

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# **Starry Sky Quality Survey in Pic du Midi RICE/IDSR area (Core and Buffer zone)**

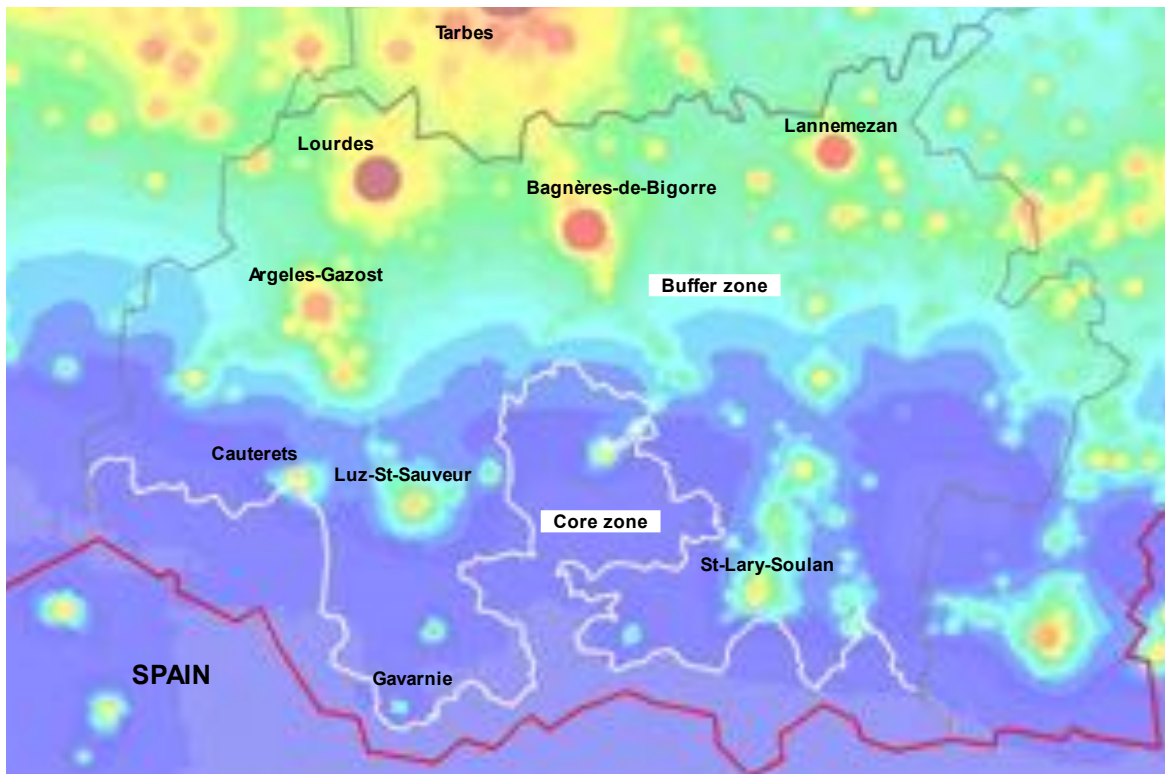
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UMR CNRS-UPPA 5319**

**Septembre 2013**

## E2. Starry Sky Quality Survey in Pic du Midi RICE/IDSR area (Core and Buffer zone)

### E2.1. The level of light pollution in Pic du Midi RICE/IDSR area

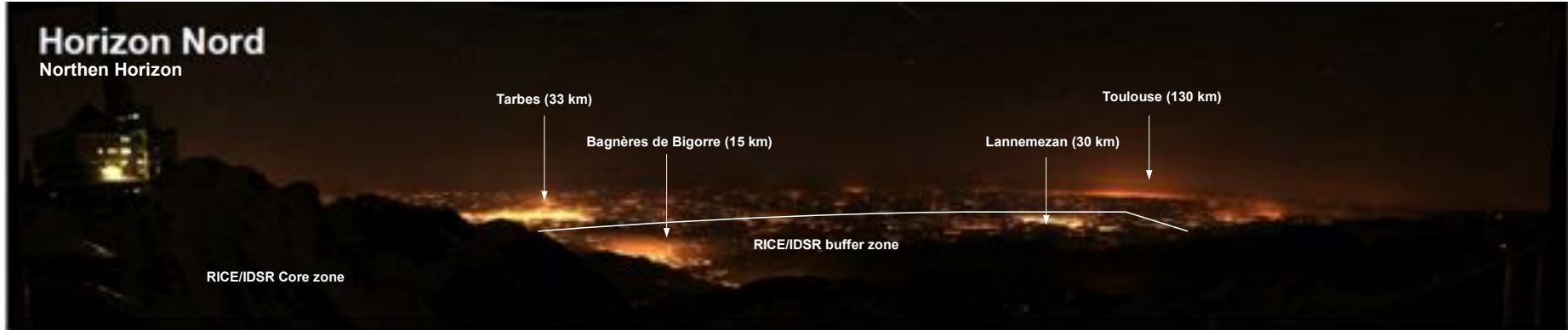
The level of light pollution in Pic du Midi RICE/IDSR area was estimated using the software Thotpro. This software was developed by Michel BONAVIDACOLA and Nicolas BESSOLAZ from the team Licorness. This map and the pictures below show that Pic du Midi RICE/IDSR provide an exceptional starry sky resource relative to the communities and cities that surround it. The most polluted skies are found in the north in the urban areas. In the south, due to the shadowing effect of mountains, the starry sky quality is very good.



Color Scale :	Light Pollution Index	Starry sky quality	SQM Devices : Level on Bortle scale SQM-L	Magnitude Loss
	$q > 10$	Very Bad	$9 > 7.5$	$0 > 1.8$
	$10 > q > 8$	Bad	$8.5 > 8 > 7.5$	$1.8 > 0 > 1.8$
	$8 > q > 6$	Passable	$7.5 > 8 > 6.5$	$1.75 > 0 > 1.8$
	$6.5 > q > 6$	Average	$6.5 > 8 > 5.5$	$1.85 > 0 > 1.75$
	$6 > q > 5.5$	Correct	$6.5 > 8 > 4.5$	$0.75 > 0 > 1.35$
	$5.5 > q > 5$	Good	$5.5 > 8 > 4.5$	$0.45 > 0 > 0.75$
	$0.25 > q > 0.55$	Very Good	$5.5 > 8 > 3.5$	$0.5 > 0 > 0.45$
	$0.35 > q > 0.50$	Excellent	$5.0 > 8 > 3.0$	$0.5 > 0 > 0.5$
	$q > 0.35$	Reference	$8 > 3$	$0 > 0.1$

The level of light pollution in Pic du Midi RICE/IDSR area

- XX -



## E2.2. Starry sky quality data collection methods

Most of sky brightness measurements were obtained using the Unihedron Corporation Sky Quality Meter with lens (SQM-L). We also used in test : SQM-DL (datalogger) and SQM-LU (SQM-L with USB port) for mobile application (see below).

Most recently we also used SENTINEL station. Designed by the French corporation Shelyak instruments, SENTINEL is an astronomical weather station (for further details see part « Requirement D »).

All the devices used for sky brightness measurements in Pic du Midi IDSR area are described in the table below.

## E2.3. SQM Measurements protocol

All SQM-L were calibrated with a blackbox in accordance with the method described for the NixNox project (<http://eprints.ucm.es/12262/1/Zamorano.pdf>)

Thus, knowing the differences of measurements between each devices, the values collected from the night sky brightness could be transformed into a common frame of reference for all the RICE/IDSR area. All SQM-L data presented in this application have been corrected with the results of the calibration.



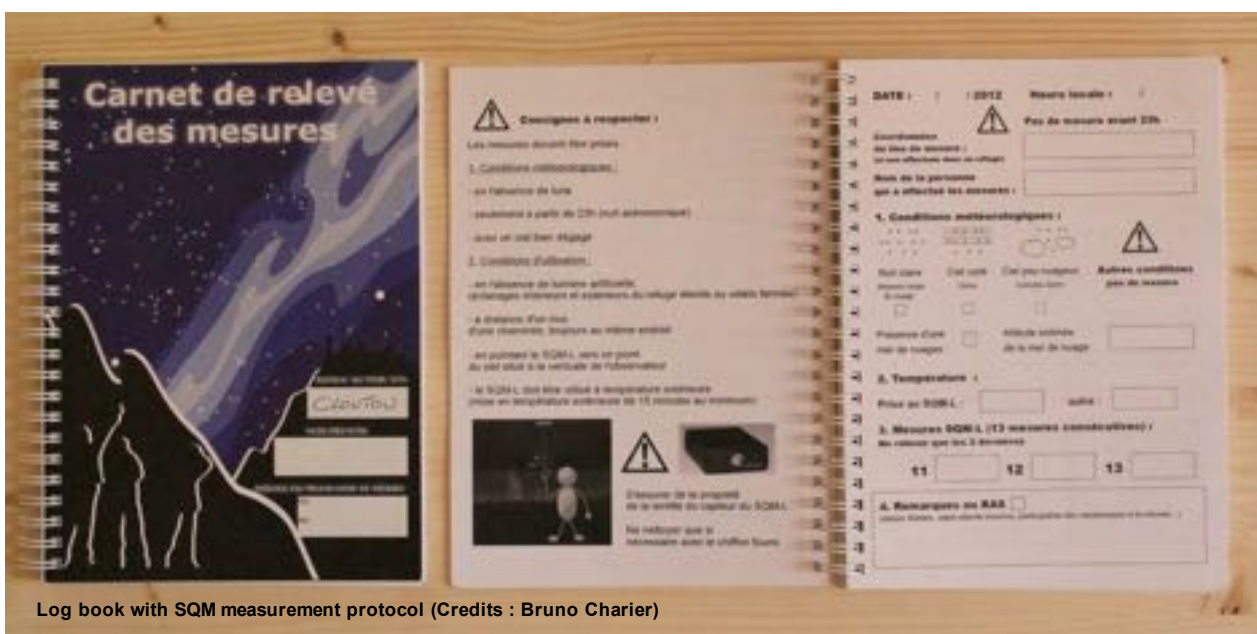
Each SQM have a name and is inventoried by serial number and assigned to a particular site (see photo). Every summer the same SQM-L will be returned in the same sites for night sky survey campaign.



The measurements were made in accordance with the IDA and “Globe at Night” protocols. All measurements were made when the sky was free of clouds and moonlight. All data collection commenced at astronomical twilight (when the sun is 18 degrees below the horizon).


The SQM-L were allowed to reach ambient temperature before any measurements were taken. All measurements were made away from obstructions (buildings, trees, walls) and in darkness.

In core zone a grid of locations was made. We were able to get coverage of the entire RICE/IDSR area (see map E2.4.)



Log book with SQM measurement protocol (Credits : Bruno Charier)

**Table E2.2 : Pic du Midi RICE/ IDSR Dark Sky Survey : Equipment**

Equipment	Quantity	Use	Location
Unihedron Sky Quality Meter  SQM-L	28	Portable measurement	IDSR Core and Buffer Zones Pyrénées National Park
Unihedron Sky Quality Meter  SQM-LU	3	mobile measurement system coupled with a GPS via a notebook	Roads in IDSR Core and Buffer zones
Unihedron Sky Quality Meter  SQM-L DataLogger	3	autonomous measurement system with battery (up to 30 days standby)	Remote sites in IDSR Core and Buffer zones
Shelyak Instrument  Sentinel	1	autonomous measurement system with : - measures sky brightness - meteorological dataset - FTP link to automatically transfer graphs on web site	Hautacam Amateur Observatory (in test) Néouvielle National Nature Reserve (1)
Alcor-system  All Sky Camera	1	FRIPON Project : Fireball Recovery and Inter Planetary Observation Network (2)	Pic du Midi Observatory (3)
CANON DSLR 	1 : EOS 5D Mark III 2 : EOS 60D  Lens : 1 : SIGMA Circular Fish-Eye 4.5 mm f 2.8 1 : SAMYANG Fish-Eye 8 mm f 3.5		IDSR Core and Buffer Zones

(1) Other sites will be equipped in the future

(2) For more details about this project : <http://www.imcce.fr/fripon/>

(3) Live image : <http://www.picdumidi.com/web/fr/12-webcam.php> (webcam nocturne)

#### **E2.4. « Gardien des étoiles » : sky quality participatory measurement project**

The sky quality participatory measurement project called « Gardien des étoiles » (stars guard) was launched in summer 2012 with the partnership of mountain refuge guards and Pyrénées park national rangers.

After a short training, each participant has received a bag with :

- a SQM-L,
- a log book,
- a map of the summer sky. This map was offer by the french astronomical review « Astronomie Magazine ».
- communication tools (stickers, posters)

(see below)

The campaign was a success. It allowed us to collect a lot of SQM readings and to promote and publicize the project.



#### **E2.5. Starry Sky Quality measurements in and near Pic du Midi RICE/IDSR Core zone :**

In all over, more than 600 readings were taken in assessing the quality of starry sky in Pic du Midi RICE/IDSR area. The readings taken in core zone are compliant with the eligibility criteria. In the core zone all readings (max value) are higher than 21 mag/arcsec<sup>2</sup>. For the entire core zone the mean value is 21.31 mag/arcsec<sup>2</sup>.

The darkest readings (22,04) in core zone was recorded in Néouvielle National Nature Reserve (Refuge du Bastan - site number 12). An other one (22,27) was recorded in the buffer zone at the boundary of the core zone (Auberge du Maillet - site number 22). This second site is accessible by car. In Pyrénées National Park, the readings reach 21,92 (site number 19) or 21,84 (site number 4).

Pic du Midi RICE/IDSR core zone would appears to have starry skies levels comparable to others areas recognized by the IDA in a similar geographical context (Mont-Mégantic, Exmoor, Brecon Beacons). However a full array of visible sky phenomena can be viewed in Pic du Midi RICE/IDSR area (see below part E2.7).



**Table E2.5.1. Pic du Midi RICE/IDSR Starry Sky Survey**

Site n° (1)	Location (2)	Altitude (m)	RICE/IDSR Zone (3)	Measurement devices	SQM Measurement (mag/arcsec <sup>2</sup> )			
					Number of readings	Min. value	Max. value	Mean value
1	Pic du Midi	2,877m	C -Observatory	SQM-L	33	20,92	21,52	21,26
2	Refuge de Campana de Cloutou	2,225m	C - RNN	SQM-L	57	20,13	21,54	21,21
3	Refuge d'Estom	1,804m	C	SQM-L	24	20,68	21,49	21,16
4	Refuge d'Illhéou	1,988m	C	SQM-L	18	20,72	21,84	21,32
5	Refuge de l'Oule	1,820m	C	SQM-L	24	20,72	21,3	21,1
6	Refuge de la Glère	2,184m	C - RNN	SQM-L	30	20,66	21,5	21,15
7	Refuge de La Soula	1,690m	C	SQM-L	21	20,65	21,55	21,17
8	Refuge de Larribet	2,065m	C- PNP	SQM-L	51	21,37	21,72	21,55
9	Refuge des Espuguettes	2,027m	C- PNP	SQM-L	36	20,31	21,43	21,16
10	Refuge des Oulettes de Gaube	2,150m	C- PNP	SQM-L	24	21,24	21,41	21,32
11	Refuge des Sarradets	2,587m	C- PNP	SQM-L	12	21,41	21,72	21,54
12	Refuge du Bastan	2,250m	C- PNP	SQM-L	30	21,28	22,04	21,46
13	Refuge du Clot	1,522m	C- PNP	SQM-L	30	20,59	21,56	21,18
14	Refuge Wallon-Marcadau	1,865m	C- PNP	SQM-L	30	20,96	21,6	21,23
15	Refuge de Barroude	2,377m	C- PNP	SQM-L	15	21,43	21,78	21,56
16	Refuge d'Orédon	1,870m	C-RNR	SQM-L	33	19,63	21,43	20,98
17	Cirque de Gavarnie	1,400m	C-PNP	SQM-L	15	21,4	21,6	21,5
18	Barrage de Cap de Long	2,161m	C	SQM-L	3	21,2	21,34	21,28
19	Hourquette de Monicot	2,460m	C-RNN	SQM-L	12	21,35	21,92	21,68
20	Lac Aubert	2,150m	C-RNN	SQM-L	9	21,39	21,71	21,51
21	Lac Aumar	2,203m	C-RNN	SQM-L	3	21,27	21,27	21,27
22	Auberge du Maillet	1,837m	B	SQM-L	81	20,74	22,27	21,55
23	Pouey Laou	2,200m	C-RNN	SQM-L	3	21,1	21,18	21,14
24	Aulon	1,357 m	C-RNR	SQM-L	15	21,31	21,52	21,44
25	Refuge de La Fruitière	1,371m	B	SQM-L	6	20,91	21,65	21,28
26	Grange d'Holle	1,495m	B	SQM-L	21	19,73	21,77	21,17
27	Col du Tourmalet	2,115m	C	SQM-L	28	21,26	21,31	21,27

(1) (2) see Map E2.5.1

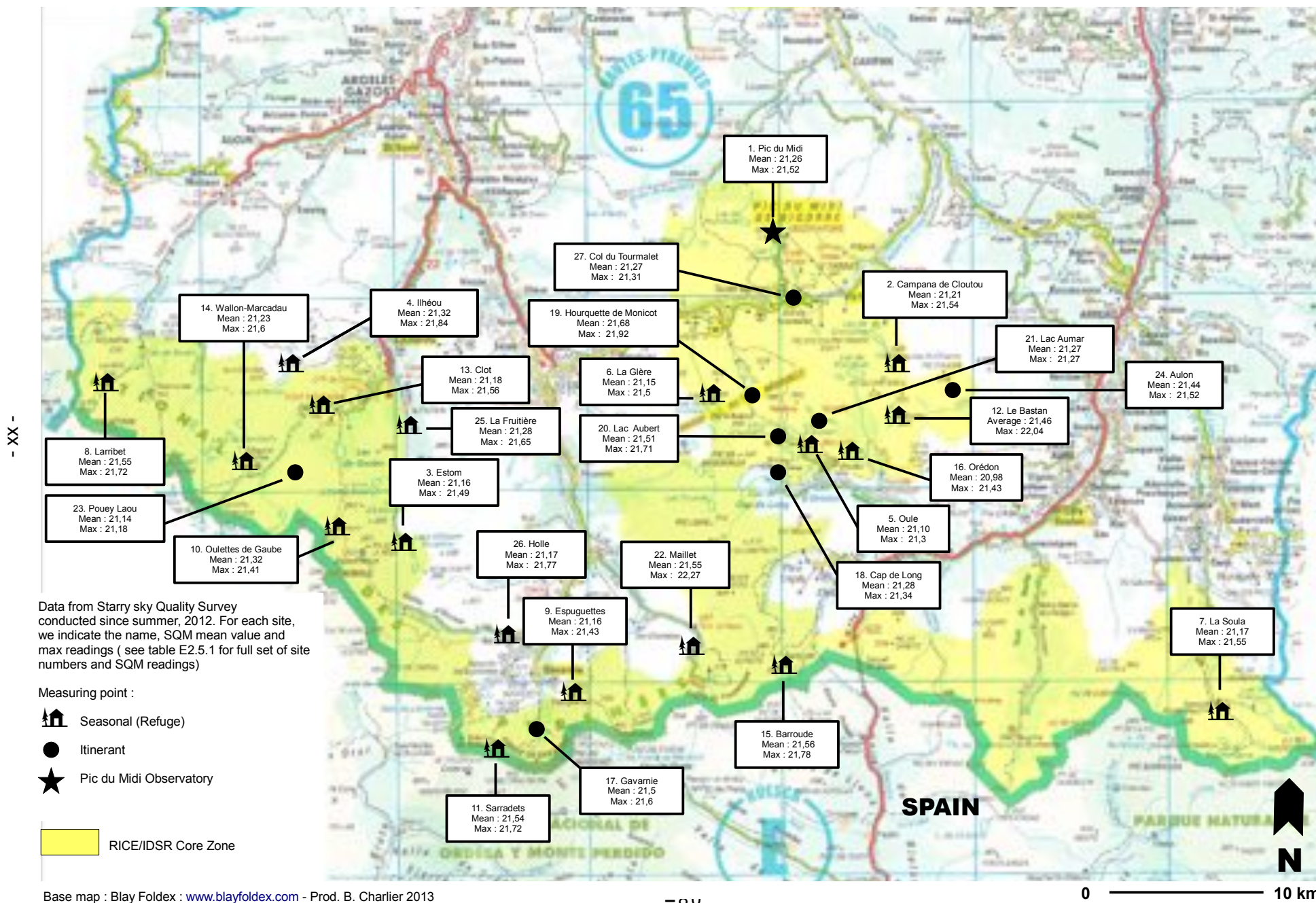
(3) Zone key :

- C = RICE/IDSR core zone
- C-RNN = RICE/IDSR Core zone and Néouvielle National Nature Reserve
- C-PNP = RICE/IDSR Core zone and Pyrénées National Park
- C-RNR = RICE/IDSR Core zone and Aulon Regional Nature Reserve
- B = Buffer zone

**Table E2.5.2. Pic du Midi RICE/IDSR Starry Sky Survey in different parts of Core zone**

Location :	SQM Measurement (mag/arcsec <sup>2</sup> )		
	Min. value	Max. value	Mean value
Pic du Midi Observatory	20,92	21,52	21,26
Pyrénées national Park	20,31	22,04	21,39
Néouvielle National Nature Reserve	20,13	21,92	21,33
Aulon Regional Nature Reserve	21,31	21,52	21,44
RICE/IDSR Core zone	19,63	22,27	21,31

**Map E2.5. SQM-L readings in and near Pic du Midi RICE/IDSR core zone**



Data from Starry sky Quality Survey conducted since summer, 2012. For each site, we indicate the name, SQM mean value and max readings ( see table E2.5.1 for full set of site numbers and SQM readings)

Measuring point :

- Seasonal (Refuge)
- Itinerant
- Pic du Midi Observatory

RICE/IDSR Core Zone

Figure E2.4 : "Gardien des étoiles" bag content :

SQM-L :



Each SQM-L is :

- labelled with his serial number and a name
- supplied with a bag for camera

Notebook :



**Consignes à respecter !**  
Les mesures doivent être prises :

- Conditions météorologiques :**
  - en l'absence de lune
  - seulement à partir de 23h (nuit astronomique)
  - sans nuage ou peu de nuage
- Conditions d'observation :**
  - en l'absence de lumières artificielles (éclairage intérieur et extérieur du refuge étoilé ou autres tentes)
  - à distance d'au moins 100m des habitations, des routes, des champs, des zones éclairées
  - en portant le SQM-L vers un point du ciel visible à la verticale de l'observateur
  - le SQM-L doit être laissé à température ambiante (moins en température extérieure de 15 minutes au minimum)

**Attention de la propriété de la notice du SQM-L**  
Ne l'utiliser que si autorisé par le club de Bigorre

DATE : / / 2012 Heure locale : / /

**Pos de mesure avant E2B**

Coordonnées du pos de mesure :   
 01 ou 02 (à remplir dans le tableau)

Nom de la personne qui a effectué les mesures :

**1. Conditions météorologiques :**

Nuit claire :  Nuageux :  Autre condition pas de mesure :

Autres conditions pas de mesure :

Présence d'une tour de nuage :  Altitude estimée de la tour de nuage :

**2. Température :**  
 Prise au SQM-L :  autre :

**3. Mesures SQM-L (13 mesures consécutives) :**  
 Ne relever que des 3 secondes

11  12  13

**4. Remarques sur E2B**

Consumables :



Eraser, pencil, microfiber optical cleaning cloth for SQM Lens, battery

Communication tools :



▲ Waterproff Signage panel with IDA logo



▲ Summer sky poster



◀ Pic du Midi RICE/IDSR project poster with IDA logo



« Gardien des étoiles » : some participants (Credits : Nicolas Bourgeois, Bruno Charlier)



« Gardien des étoiles » : photographic summary (Credits : Nicolas Bourgeois, Bruno Charlier)



▲ « Gardien des étoiles » carrying bag



▲ Deliveries of some remote sites were made after several hours of walking



▲ Demonstration of How to Use a SQM-L



▲ Presentation of Pic du Midi RICE/IDSR project



Pic du Midi RICE/IDSR poster ▲



Communication tools ▲►

Waterproof signage panel ►



## E2.6. SQM Measurements in test (SQM-DL, SQM-LU)

We are testing SQM-LU (Lens and USB port) and SQM-DL (Data Logger). The SQM-LU is testing with a mobil station connected to a GPS. We use Road Runner software to process data. The software was developed by Daniel Rosa Infantes from a Spanish amateur astronomers association : Sociedad Malagueña de Astronomía.

Road Runner is a portable, lightweight, inexpensive and quick system, which allows measurement of light pollution from any location and immediate viewing of the data captured by the system.

Finished the measurement, the software generates two types of files : CSV File and KML File for Google Earth. The data can be viewed directly on a map. With this mobil system, the data

For each measuring point, SQM readings are completed by several information : serial number of the device, date and hour, temperature, vehicle speed...

This mobile system must be improved to fix few minor bugs. But, it's already very interesting because numerous data can be obtained in a single night.



Example of SQM readings in Buffer Zone with Road Runner System (1 reading per minute)

**Requirement D** : A measurement program must be maintained either by the park or by another public or private organization (university, research center, IDA chapter, astronomy club, etc.) to follow the evolution of light pollution in the IDA DSR core and assert that the night sky quality does not degrade. Installation of at least one permanently mounted, approved, night sky brightness monitor (NSBM) and participation in the IDA Global Sky Monitor website is recommended (IDA, DSR Designation Guidelines, May, 2013)

## D1. Measurement program : equipment and protocols

### D1.1. About SQM

In the part of application related to eligibility criteria « E », we have already presented the measuring equipment being used (SQM-L, SQM-LU, SQM-DL and SENTINEL). We will keep using this equipment by diversifying its use. For example, in winter, we will develop an awareness program in schools. The involvement of children in night sky brightness monitoring program can be promoted as part of an innovative process of learning and experiencing.

We will propose the same procedure in holidays centers. This could be integrated into scientific tourism products in link with RICE/IDSR awareness program.

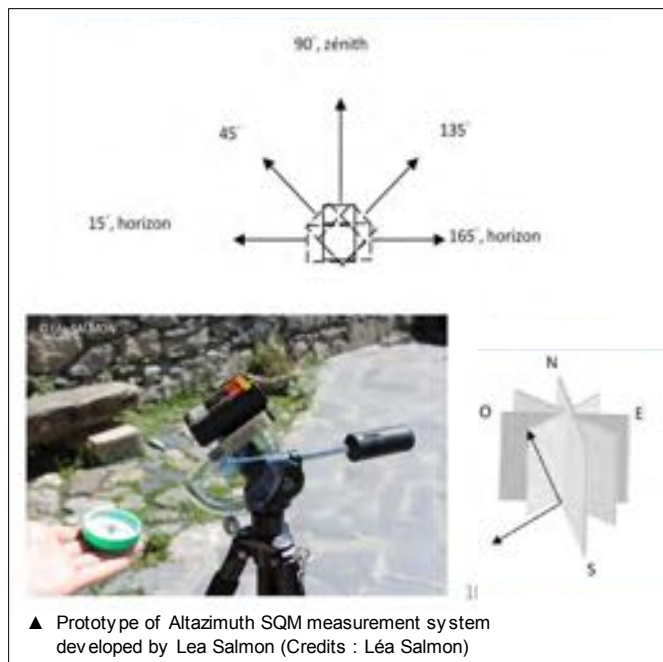
### D1.2. New measurement protocol

In partnership with Martin Aubé (Cepeg of Sherbrooke) - our scientific referent on light pollution monitoring issues - we start to change the measurement protocol to reflect IDA new requirements published in April, 2013 (Definition of the community standard for skyglow observations Version 1.0.).

We tested a measurement protocol in several direction and azimuthal angles : Northern, Eastern, Southern and Western direction and for each elevation : 15°horizon, 45°, 90°zenith ▼



▲ Nicolas Bourgeois testing the new SQM-L measurement protocol (June 2013) – Credit : Nicolas Bourgeois



▲ Prototype of Altazimuth SQM measurement system developed by Lea Salmon (Credits : Léa Salmon)

## D2. Scientifical partnerships

### D2.1. Scientifical partnerships with universities and research laboratories

The establishment of partnerships with Universities and research laboratories - and fostering them - has been a priority since the launch of the RICE/IDSR project in 2009. The strategy adopted is to position the Pic du Midi RICE/IDSR project as a R&D project.

The overall partner for the project is Pau and Pays de l'Adour University and « Société, Environnement, Territoire » (SET) research laboratory. SET is a research laboratory in social science and humanities associated with the French National Research Center (UMR CNRS 5603). For more details, please see : <http://set.univ-pau.fr/live/>

The second largest scientific partner is « Observatoire Midi-Pyrénées » and the Research Institute in Astrophysics and Planetology (IRAP). IRAP is also a Mixed Research Unity (UMR 5277) of the Paul Sabatier University (Toulouse), and of the CNRS (for more details, please see : <http://www.irap.omp.eu>)

Firstly, the project has been successfully completed in a timely manner (2009-2013) only through this partnership.

This partnership framework has been also useful in mobilising funding from various sources including : French Association for Research and Technology, fund for innovation and research from General Council of Hautes-Pyrénées.

In the future, the permanently night sky brightness monitoring will be managed by the RICE operational team with the support of universities.

#### D2.2. Partnership with Mont-Mégantic RICE/IDSR

Since 2012, we maintain close links with our Québécois partners and friends. In particular, this links are used to develop light pollution monitoring tools and protocols.

Nicolas Bourgeois and Bruno Charlier with Martin Aubé posing next the SAND-3A spectrometer installed on the roof of the Astrolab Center (Mont Mégantic National Park) ►



### D3. Installation of permanently night sky brightness monitoring system (NSBM)

#### D3.1. SQM monitoring



(Credits : Henri Aurignac)

In the sites located in the RICE/IDSR Core zone, the SQM monitoring of night sky quality will be continued with the help of Pyrénées National Park rangers and mountain refuges guards.

It is very important for us to continue this program. This program provides us essential data and it is also an excellent awareness tool.

### D3.2. Sky brightness monitoring in Pic du Midi RICE/IDSR area : SENTINEL Network

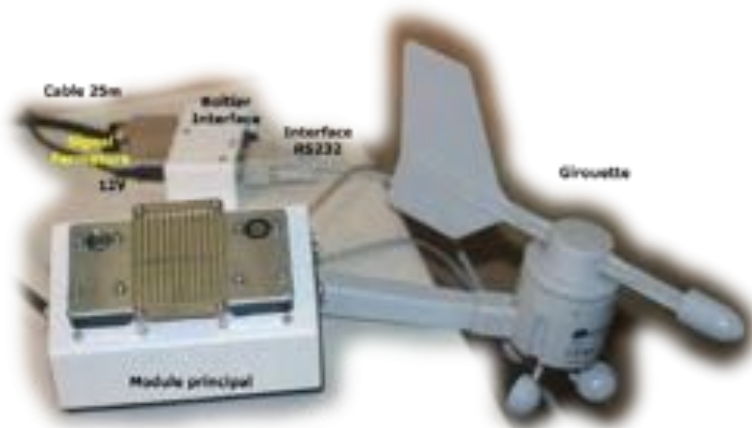
Designed by the French corporation Shelyak instruments, SENTINEL is an astronomical weather station that detects rain or snow and measures the cloud cover, the strength and direction of wind, the temperature, the moisture level and the brightness of the sky. Depending on the frequency of datalogging, SENTINEL can records those data in its internal memory during several months. Compared with SQM, SENTINEL ensures a very fine monitoring of the quality of the night sky and its variations depending on the meteorological data (especially moisture level and temperature but also cloud cover).

SENTINEL stations can be associated with all-sky cameras. The data from SENTINEL and all-sky camera can be viewed live online. This kind of installation will be tested soon at the Pic du Midi observatory. The first monitoring station (SENTINEL) was installed in test in April 2013 in Hautacam ski resorts. Other SENTINEL stations will be installed to build a network of 8 units. These units will be connected to the website of Pic du Midi RICE/IDSR to view data remotely.

The goal is to have a « zero » state of night sky quality very quickly and to assess changes of light pollution level over several years.



(Credits : Henri Aurnagac, Bruno Charlier)



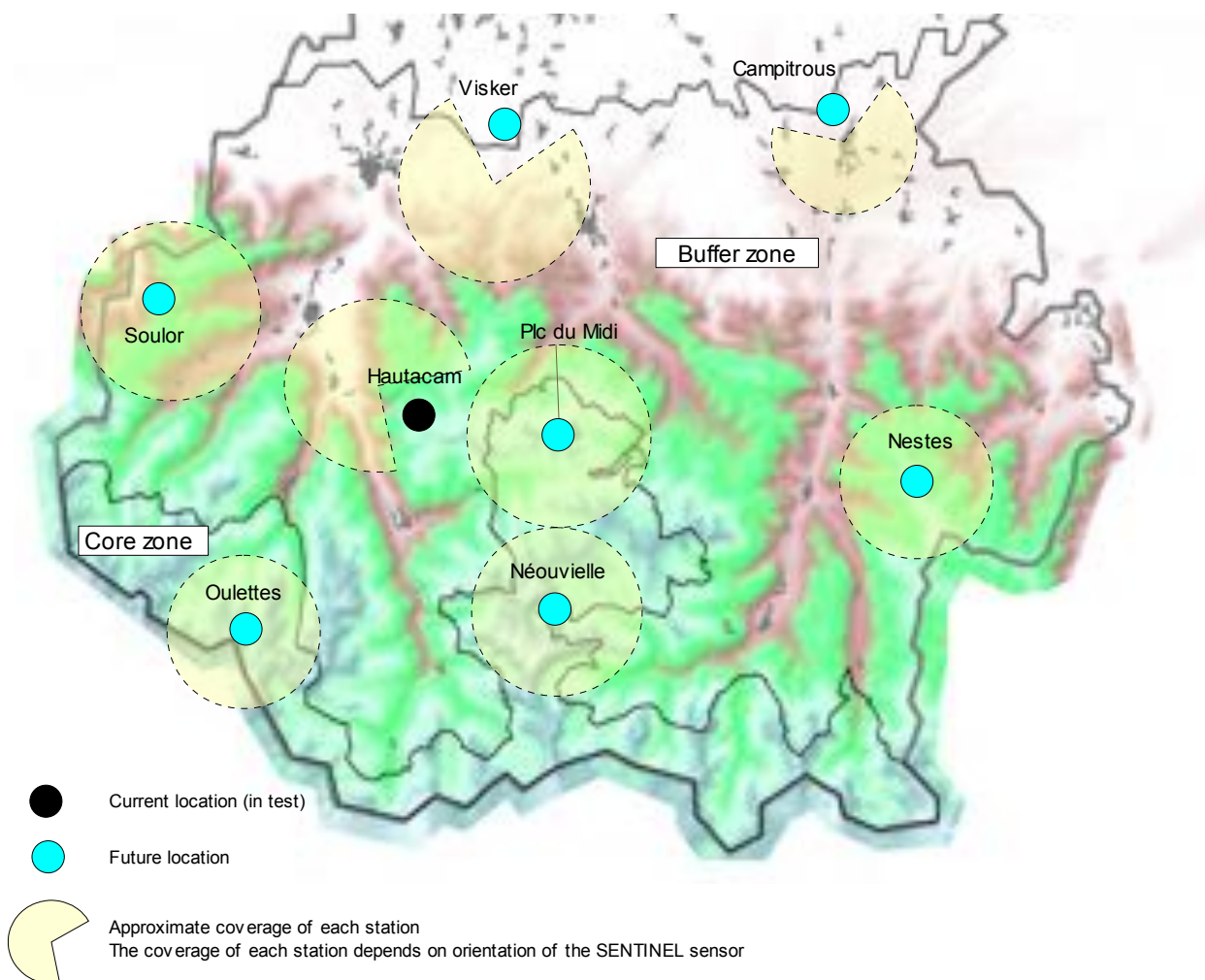
SENTINEL External module :

- measures cloud coverage with an internal cloud sensor (IR temp. sensor)
- detects rain or snow
- measures wind strength and direction
- measures ambient temperature
- measures humidity level
- measures sky brightness

(Credits : Shelyak Instrument)

**Map D3.2. The future deployment of SENTINEL Network**

Site :	Owner and Manager of SENTINEL station :	Partner :	Scheduled installation year
Hautacam	Pau and Pays de l'Adour University – SET laboratory	Régie du Pic du Midi Syndicat Mixte du Hautacam Astro-Club du Hautacam	2013 (in test)
Oulettes	Pau and Pays de l'Adour University – SET laboratory	Régie du Pic du Midi Pyrénées National Park	2014
Néouvielle	Pau and Pays de l'Adour University – SET laboratory	Electricité de France (EDF) National Power Company	2014
Pic du Midi	IMCCE – Paris Observatory	FRIPON network	2014
Campitrous	undetermined	Observatoire Midi-Pyrénées Pyrénées National Park	2014
Visker	undetermined	Astro-Club DINASTRO Pyrénées National Park	2015
Soulor	undetermined	undetermined	2015-2016
Nestes	undetermined	undetermined	2015-2016
<b>Total cost for 8 units : 11,200 euros / 16,875 USD</b>			



## Link between SENTINEL and All-Sky Camera

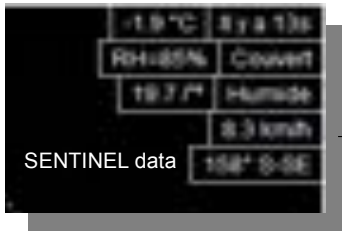


Caméra All-Sky  
Alcor System

SENTINEL and All-Sky Camera may be linked so that both data and pictures may be viewed together in live on the future Pic du Midi RICE/IDSR web site.



Interface



SENTINEL data

