Perdigão: Instrument descriptions and deployment locations: Cornell University

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Status October 11, 2016

Contents

1 Objectives

1. Fluxes, wind (incl. gusts) and turbulence profiles through the heights relevant to wind energy ** *Related: Evaluate 'gust shape' formulation (in standards) and spatial scales and gust-pressure-seismic response functions*
2. Quantification of the characteristics of wake behavior, including the meandering component of wind-turbine wake expansion, its differentiation from diffusive expansion
    - Develop a long-term data set for characterization of wakes (catalogue)
    - Quantify freestream profiles
    - Use scans to define wake metrics at different distances from turbine
    - Cf wake models
3. Optimization and algorithm development for Lidar deployments and data processing
    - Reduce 'empty scans' & limit range gates (via measured particle size distributions)
    - Streamline/optimize data processing for wake characterization

Key aspect of 2 & 3: Integration with DTU Windscanner.

2 Instrumentation: Extended Measurement Period: Jan-June 2017

2.1 Instrumentation overview

Table 1a: Overview of lidars

Lidars	#	Operating details	Measurement range (R)/ accuracy (A)	Variables/range (D) and heights (z)	Weight & dimensions	Power requirements & logging
Continuous wave vertically-pointing Doppler lidars (ZephIR 300)	1	Operating wavelength =1.575 µm 50 Hz, 1 s average Scanning cone angle 30°	R<1-70 ms^{-1} A<0.1 ms^{-1} (ws)	Wind speed (ws), direction (wd), turbulence intensity (TI), vertical wind speed (w). Vertical D=10-200 m (10 z)	55 kg, approx. 1 m by 1 m by 1 m	69 W in regular operation, (up to 150 W if internal fans are used)
Pulse scanning Doppler lidar (Galion)	1	Operating wavelength =1.55µm Range gate 30 m	R=0-70 ms^{-1} A<±0.1 ms^{-1}	Arc scans and VAD scans ws, wd, Vertical D=80-1000 m Horizontal D=80-4000 m	85 kg, 84x66x66cm (nominal height does not include met mast)	150 W if fans not in use, up to 350 W
Direct detection (SpiDAR) (coherence)	1	Operating wavelength =1.55 µm Scanning cone angle 10°	R=0-70 ms^{-1} A=±2% (ws)	ws, wd, Vertical D=30-200 m (10 z)	75 kg, Triangle (three legs). Maximum 1640 mm each side, height 1305 mm. Minimum 964mm x 1139mm x 1182mm	35 W (up to 150 W if heated). Can be 24 DC, internal conversion to 220 V or 110 V, currently 110 V, should be ok checked with Pentalum.

Table 1b: Other instrumentation (see Table 2 for exact met masts).

Other	#	Operating details	Measurement range (R)/ Accuracy (A)/ Resolution (Re)	Power	Logging
Gill WindMaster Pro 3-D sonics	5	3-Axis sonic anemometer (measures; u, v, w, T) up to 32 Hz	R:0-65 ms^{-1} A<1.5% Re: 0.01 ms^{-1}	Via DTU	Deploy all on DTU 60m mast at riSW_06
Setra 278	4	Microbarometer (measures pressure)	R: 850-1400 hPa A~1 hPa Re: 0.01 hPa	12V DC	Via NCAR depending on precise MM. Output of 0-5V, at 10 Hz
Sercel L-28-3D High Frequency Seismometers	3	High Frequency Seismometers: Measures three-channel seismic signals		12V DC (<2 W)	Record at 100 Hz (internal logging). NCAR to supply 12 V DC power.

2.2 Lidars: ZephIRs

- Vertically pointing Doppler lidar (ZephIR 300 series, serial # Z423, Z448).
- Data logging: internally (processed and raw data, 10 minute averaging 90Kb / day, 1 second data 3MB / day, On board storage 36 months – not with raw data).
- Remote access:
    - Data could be accessed via wireless if the network is sufficient at the ZephIR locations (Data transfer is possible)
    - Internal modem is the other option. This would only permit status updates, possibly mean quantities
    - Need SIM card – CU have requested 5 3G SIM cards in total from Ted Russell, 09/29/2016
    - Both ZephIRs have unique IP addresses
- Access to raw data requested from Natural Power. NDA in preparation. ***Status:*** Awaiting Natural Power software/firmware update and access given to raw data (RB following up, hope this can be done 10/13/16, testing to follow).
- Deployment locations:
    1. ZephIR in the valley near Galion at Orange Grove (UTM coordinates (in zone WGS 29) 608304.1E, 4396730.6N, used to derived Latitude and Longitude of 39°42'48.9"N 7°44'11.3"W). Purpose: VAD scans cf. Galion. Also evaluate whether the vertical wind speeds can be derived from individual readings of wind speed at particular angles. Have secured access to raw data to test this approach.

    2. ZephIR to be deployed west of WT (west of the valley). Latitude and Longitude of 39°42'22.36"N, 7°45'15.46"W. Purpose: Examine if wake terrain following under east winds & provide 'upstream' profile under west winds. Also evaluate whether the vertical wind speeds can be derived from individual readings of wind speed at particular angles. Have secured access to raw data to test this approach.

2.3 Lidars: Sgurr Galion

- Scanning Doppler lidar (serial # 42)
- Data logging: internally (processed and raw data). The HD of our Galion is 160GB (Some of the 160GB is used for the operation system and software. The remainder should be sufficient for 2 years of scan files storage).
- Remote access:
    - Data access will be by 3G compliant modem (no internal wireless) so SIM card will be needed.
    - Has fixed IP.
    - Need SIM card – CU have requested 5 3G SIM cards in total from Ted Russell, 09/29/2016
- Location (note: ***Question:*** Sufficient power at both locations?)
    - For EOP (and likely IOP). At the field northeast of the 'Orange Grove' UTM coordinates (in zone WGS 29) 608304.1E, 4396730.6N, used to derived Latitude and Longitude of 39°42'48.9"N 7°44'11.3"W). Scanning essentially 'up to the WT' (looking approx. WEST)

Location (close to the Orange Grove).

Line-of-sight to WT from this location.

    - Back-up At base of WT (near where the Windscanner was deployed in summer 2015). Approximate Latitude and Longitude; 39°42'27.50"N 7°44'41.38"W. Scanning essentially OUT from the WT (i.e. approximately due EAST)

Figure showing view from approx.. location below WT for Galion – looking approx. due east.

2.4 Lidars: SpiDAR

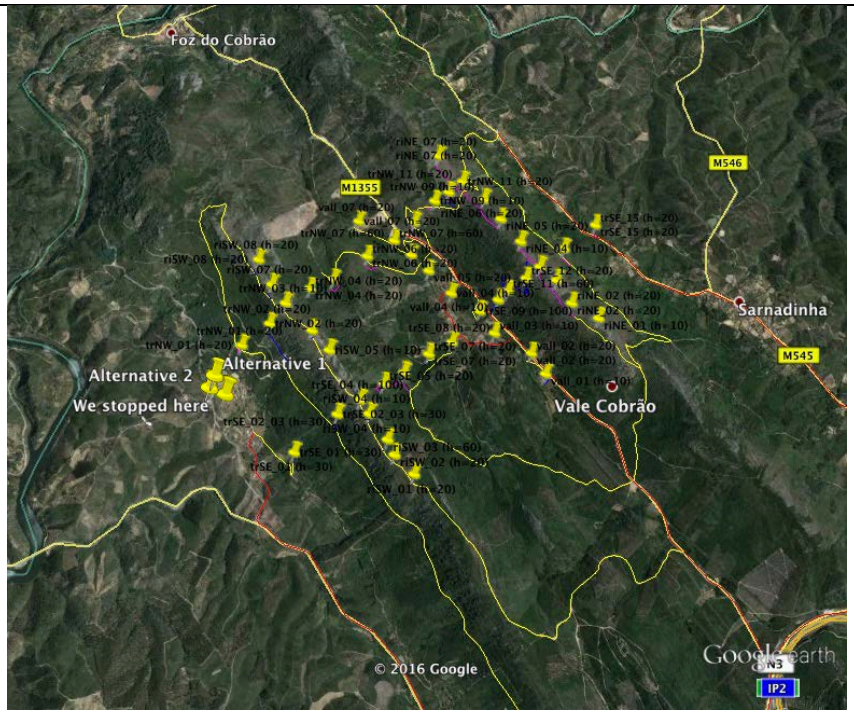
- Vertically pointing, direct detection lidar (serial # ??)
- Data logging: internal. Data storage reported as up to 3 years.
- Remote access:
    - It has internal modem. Modem should be ok with SIM card, could be on NCAR wifi.
    - Need SIM card – CU have requested 5 3G SIM cards in total from Ted Russell, 09/29/2016
    - Has fixed IP
- Location:
    - Next to the 100-m mast on the WT ridge (located just south of the WT, this is denoted as trSE_04 and has a location of 39°42'21.30"N, 7°44'37.30"W in the file NEWA_20160420.kmz on the google drive in directory 'Start here'). ***Status:*** Awaiting news on whether DTU will control and instrument this met mast. ***Question:*** If DTU has that mast we are assuming there is sufficient power for the SpiDAR (and a plug in). This should work as it is relatively low power and there is mains power along the ridge.

2.5 Non-lidar instruments

Table 2: Other instrumentation – locations and logging.

Mast designation	Mast height (m)	Responsible	Latitude	Longitude	Gill sonic anemometer	Setra-278 barometer @ 2-m	Sercel L-28-3D seismometers
riSW_06	60	DTU	39°42'35.45"N	7°44'50.19"W	10, 20, 30, 40, 60		
riSW_05	10	NCAR	39°42'31.38"N	7°44'45.52"W		1	1
trSE_04	100	DTU	39°42'21.30"N	7°44'37.30"W			
riSW_04	10	NCAR	39°42'18.52"N	7°44'34.92"W		1	1
riSW_03	60	DTU	39°42'13.40"N	7°44'30.10"W		1	
riSW_02	20	NCAR	39°42'10.43"N	7°44'28.30"W		1	1

Map from google drive NEWA_20160420.kmz showing the mast locations



2.5.1 Gill Windmaster Pro sonic anemometers.

- 5 to be deployed on DTU mast.

Serial #'s etc of sonics to be sent to Perdigao			
Description	**Label**	**Make and Model**	**Serial Number**
Gill Sonic 2	SCP EAS 202	Gill 1561-PK-020	122205
Gill Sonic 3	SCP EAS 203	Gill 1561-PK-020	131109
Gill Sonic 5	SCP EAS 207	Gill 1561-PK-020/W	161401
Gill Sonic 7	SCP EAS 209	Gill 1561-PK-020(W)	162505
Gill Sonic 8	SCP EAS 2010	Gill 1561-PK-020(W)	162504

The case dimensions are: 35" long, 10.5" wide, 13.5: high

The weight of the case with a sonic, and a vertical mount (but no PCI box) inside is 26 pounds.

2.5.2 Setra barometers

See above for locations (Table 2).

- NCAR dealing with power and logging for all 4 barometers
- Barometers were sent to NCAR for the first shipment 08/03/2016. Receipt acknowledged 08/04/2016.

Steve Oncley
NCAR/EOL
3090 Center Green Drive,
Boulder, CO 80301
ph: 303-497-8757
oncley@ucar.edu

2.5.3 Sercel seismometers

- See above for locations (Table 2).
- NCAR will provide 12 V DC power. NCAR can terminate the power cable with NCAR connector if Cornell supply the cable (SP sent emails to Steve to requesting info. on cable connector: 09/22/2016 and 10/9/2016). Data will be logged internally only.
- On loan from PASSCAL. https://www.passcal.nmt.edu/content/instrumentation/sensors/high-frequency-sensors/l-28-hf-sensor

3 Intensive Period: 1 May to 15 June

3.1 Instrument overview

Table 3. Instrumentation, power and other logistics

Type	#	Operating details	Measurement range (R)/ accuracy (A)	Power	Size/weight
TSI Nanoscan SMPS	1	Scanning Mobility Particle Sizer: Aerosol particle number size distributions (1 min)	10 to 420 nm, 13 channels of resolution. Time resolution: 1 minute	100 to 240 VAC, 50/60 Hz; AC Adaptor (<100 W)	45 cm x 23 cm x 39 cm 9 Kg *Challenge: Operating range only to T=30 degC*
TSI APS3321	1	Aerodynamic particle sizer: particle number size distributions	500 nm to 20 µm, 52 channels: Time resolution: 1 second	100 to 240 VAC, 50/60 Hz, 100 W	18 cm x 30 cm x 38 cm 10 Kg Operating range up to T=40 deg C

Computers:

- Dedicated computer will run PSD instrumentation and log data.

3.2 Particle sizing instruments

TSI APS3321 and Nanoscan SMPS: To be deployed near base of WT (location: 39°42'27.30"N, 7°44'41.87"W) (will be deployed in an instrument enclosure with fan to assist cooling, along with a dedicated laptop computer for control and logging. Computer will not be linked to wifi).

- Request for Jose Carlos team: It would be good to have the enclosure sit on the transformer roof – is that OK? Follow-up sent to J-C 11 July 2016:
    - Cornell response: The box will have dimensions of 1 m x 1m (footprint) and < 1m tall. If we can install on the roof– how can we secure it to the roof so it does not blow off?? Maybe a ratchet strap? But then I am not sure where to secure it? The issue is they cannot really sit on the ground since too much dust will get pulled into the instrument.
- Request for Jose Carlos team: Nanoscan SMPS requires Reagent grade (99.5% or better); isopropyl alcohol.
- 'Agreement' from J-C and information sent 11 July 2016:
    - Contact: hugomonteiro@enzymatic.pt hugomonteiro@enzymatic.pt I will be buying the ISOPROPYL ALCOHOL (also known as Isopropanol, reagent grade 99.5% or better). 2.5 L should be enough at least to start – and your price is lower than in the USA! I will give you here our Administrative Assistant's name (Crystal) and email (clb9@cornell.edu) since she will likely actually be the one sending you billing information etc. Please note the institution is Cornell University (not University of Cornell).
    - Crystal- I will need this alcohol for one of the instruments I will operate in Portugal during a field experiment in May and June 2017. We need to buy it locally – i.e. In Portugal and so we will need for you/Shari to make our Portuguese supplier a vendor in the system — UNLESS of course we can use

the fact that Fisher Chemical in the USA already is a vendor to Cornell??? We will not need this until May 2017!

4 Dates for Cornell U participants at Perdigao

- Tentative installation for extensive period 17-28 January 2017
- Maintenance visit 1-9 April 2017
- Intensive period 8 May - 18 June
- NB the teardown is listed as June 15.

5 To do list for Cornell U

List of tasks Sep 28 2016

	Instrument	Task	Per-son	Dead-line	Date completed
EOP	Setra barometers	To be sent to NCAR	SP		YES
	Sonic	Carnet	SP		
	Sonic	Shipped to Perdigao	SP		
	Seismometers	To be sent directly from PASSCAL to Perdigao	SP		
	ZephIR	Test communication	RB		
	Galion	Test communication (modem)	RB		
	Spidar	Test communication	RB		
	ZephIR	Carnet	RB		
	Galion	Carnet	RB		
	Spidar	Carnet	RB		
	ZephIR/Galion/ SpiDAR	Computer +software	RB		
	ZephIR/Galion/ Spidar	Shipping	RB		
		Travel & accommodation Jan	RB		
		Travel & accommodation Mar	RB		
		Equipment insurance	RB		
IOP	Particle instruments	Need enclosure	SP		
	Particle instruments	Computer	SP		
		Travel & accommodation IOP	RB		
		Equipment insurance	RB		

6 Appendices

6.1 Copies of materials uploaded to google drive documents

in document on google drive:
https://docs.google.com/spreadsheets/d/1JhKZkA8OweKVj3dc5WQtJqTHy5aMtnIRiEOTAMCg2tQ/edit#gid=129783456
'Lidars_WindTurbine(Cornell)' tab.

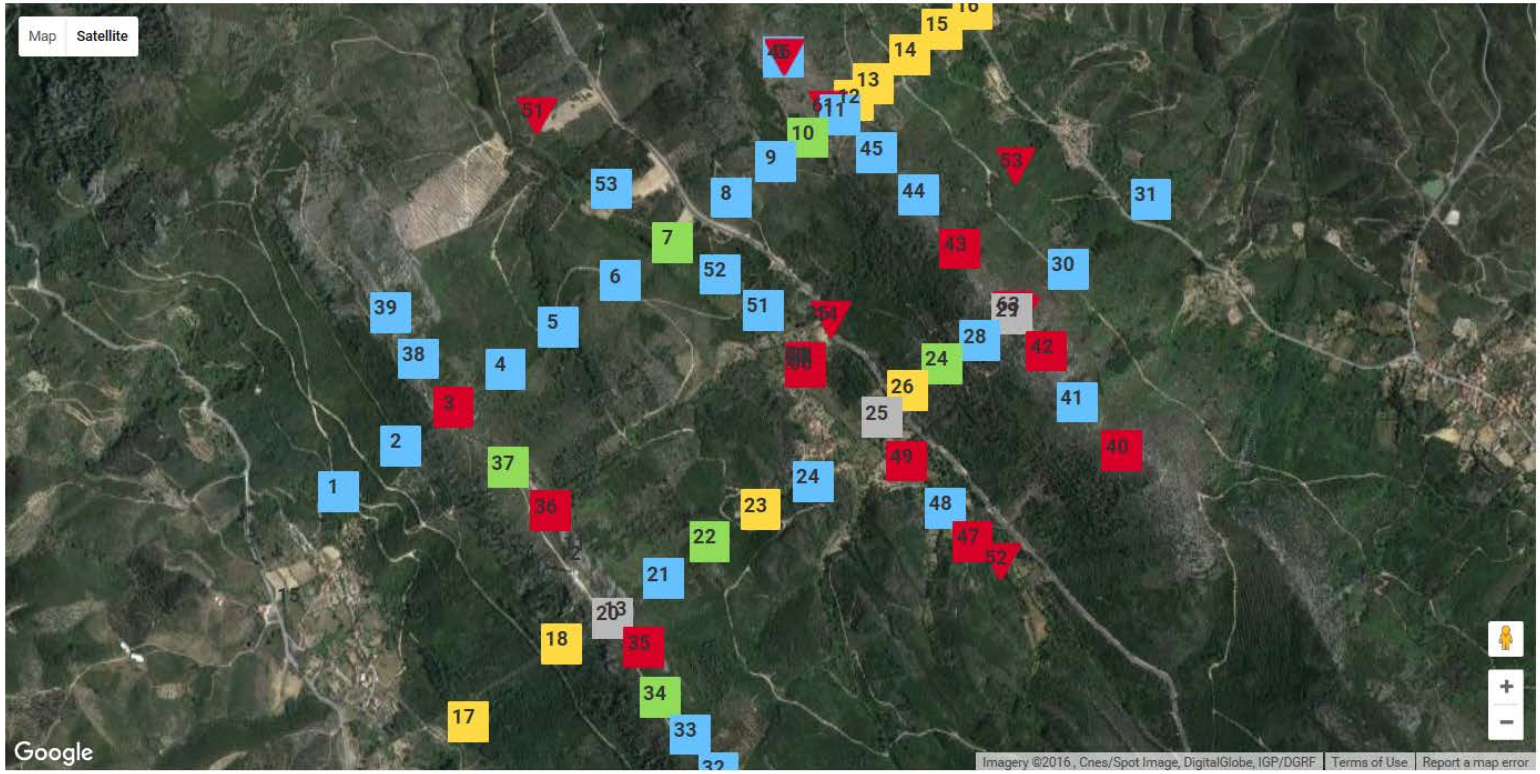
Cornell lidars	Brand / model	Power [W]	Frequency	Location			Observation Period	Installation Period	Observations	Qty.	Total power [W]	REFERENCE
			MHz	Lat	Long	Height Above Gound/ Altitude			# in parantheses indicate inst. # of WindSP map ** note locations wrong on that map!			
GALLION	SGURR GALION	350.00	No	39°42'48.9"N	7°44'11.3"W	1 m	EOP	~17 Jan 2017	Near orange grove scanning towards wind turbine (14 on WindSP map)	1	350.00	http://www.sgurrenergy.com/wp-content/uploads/2015/09/galion-brochure-b2.pdf
Zephir	Zephir	150.00	No	39°42'48.9"N	7°44'11.3"W	1 m	EOP	~17 Jan 2017	Near Galion near orange grove (12)	1	300.00	http://www.zephirlidar.com/wp-content/uploads/2015/03/ZephIR-Lidar-2015-brochure.pdf
Zephir	Zephir	150.00	No	39°42'22.36"N	7°45'15.46"W	1 m	EOP	~17 Jan 2017	West of WT.	1	300.00	http://www.zephirlidar.com/wp-content/uploads/2015/03/ZephIR-Lidar-2015-brochure.pdf
Spidar	Pentalum	150.00	No	39°42'21.30"N	7°44'37.30"W	1 m	EOP	~17 Jan 2017	Located near 100 m met tower on the ridge (given as -7°44′37.47″E, 39°42′21.15″N) on WindSP (spiDAR is 13 on WindSP)	1	150.00	http://pentalum.com/spidar.aspx
TOTAL										4	1,100.00	

in document on google drive: https://docs.google.com/spreadsheets/d/1JhKZkA8OweKVj3dc5WQtJqTHy5aMtnIRiEOTAMCg2tQ/edit#gid=129783456.
On Cornell Equipment tab

	Brand / model	Power [W]	Frequency	Location			Observation Period	Installation Period	Observations	Qty.	Total power [W]	REFERENCE
			MHz	Lat	Long	Height Above Ground/Altitude						
Cornell TSI Nanoscan	TSI SMPS 3910	100.00	No	39°42'21.30"N	7°44'37.30"W	1 m	IOP	May 8 2017	Location near wind turbine/spidar	1	100.00	http://www.tsi.com/NanoScan_SMPS_Nanoparticle_Sizer_3910/
Cornell TSI APS	APS3321	100.00	No	39°42'21.30"N	7°44'37.30"W	1 m	IOP	May 8 2017	Location near wind turbine/ spidar	1	100.00	http://www.tsi.com/Aerodynamic-Particle-Sizer-Spectrometer-3321/
Cornell Laptop and cooling enclosure to control TSI instruments		100.00	No	39°42'21.30"N	7°44'37.30"W	1 m	IOP	May 8 2017	Location near wind turbine/ spidar	1	100.00	
Cornell Setra 1	278 Microbarometer	5.00	No	39°42'31.06"N	7°44'45.05"W	2 m on riSW_05	EOP	During NCAR Deployment	12 V DC NCAR DC network. At met masts on riSW transect (riSW_05)	1	5.00	http://www.setra.com/products/pressure/model-278-barometric-pressure-transducer
Cornell Setra 2	278 Microbarometer	5.00	No	39°42'18.35"N	7°44'33.79"W	2 m on riSW_04	EOP	During NCAR Deployment	12 V DC NCAR DC network. At met masts on riSW transect (riSW_04)	1	5.00	http://www.setra.com/products/pressure/model-278-barometric-pressure-transducer
Cornell Setra 3	278 Microbarometer	5.00	No	39°42'13.69"N	7°44'31.68"W	2 m on riSW_03	EOP	During NCAR Deployment	12 V DC NCAR DC network. At met masts on riSW transect (riSW_03)	1	5.00	http://www.setra.com/products/pressure/model-278-barometric-pressure-transducer
Cornell Setra 4	278 Microbarometer	5.00	No	39°42'10.25"N	7°44'27.96"W	2 m on riSW_02	EOP	During NCAR Deployment	12 V DC NCAR DC network. At met masts on riSW transect (riSW_02)	1	5.00	http://www.setra.com/products/pressure/model-278-barometric-pressure-transducer
Cornell Sercel	L-28-3D Seismometer	5.00	No	39°42'31.06"N	7°44'45.05"W	At ground at riSW_05	EOP	Jan 18 2017	12 V DC probably on NCAR DC network. At met masts on riSW transect (riSW_05, riSW_04, riSW_02)	1	5.00	On loan from PASSCAL

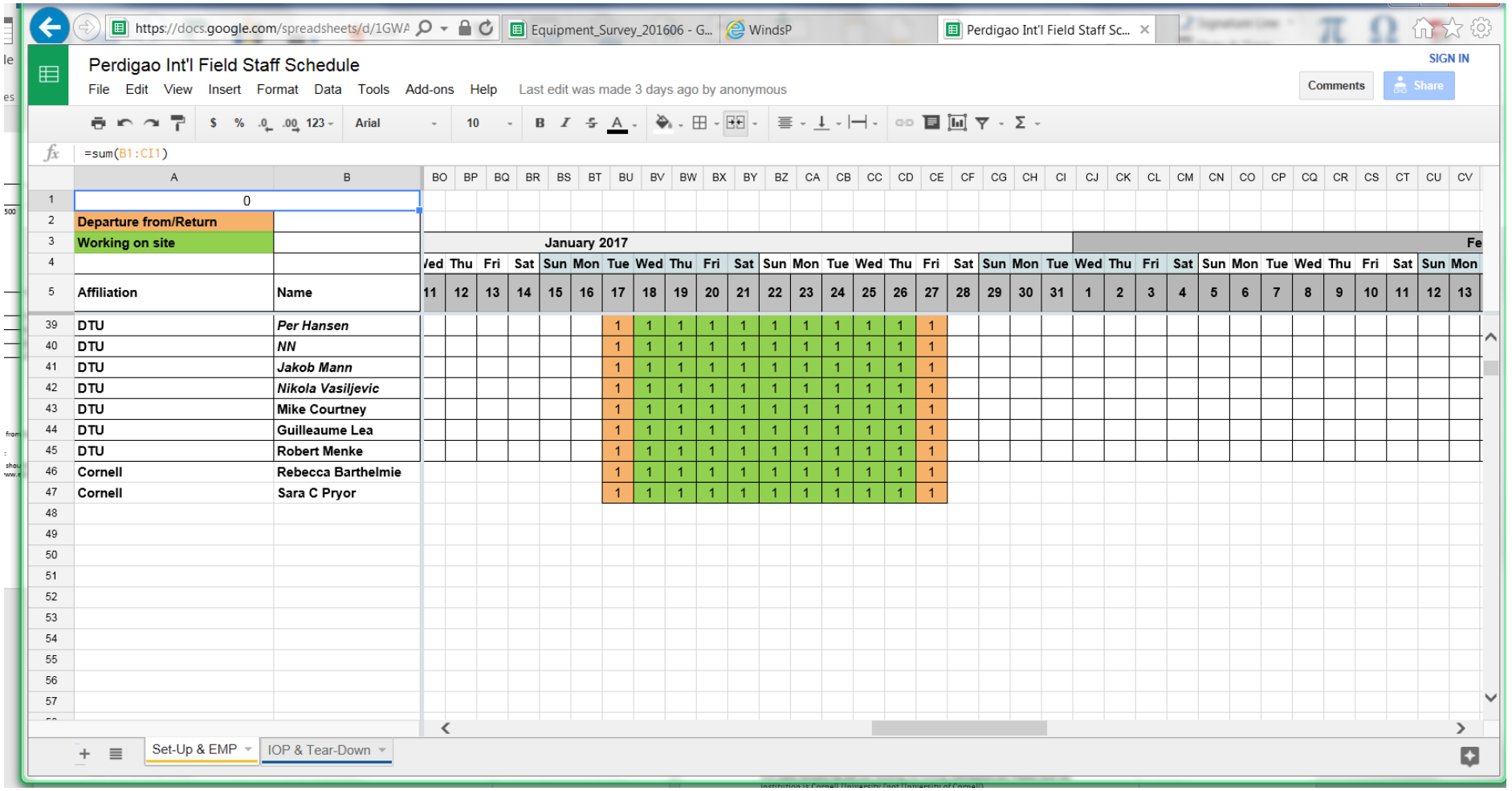
Cornell Sercel	L-28-3D Seismometer	5.00	No	39°42′18.35″N	7°44′33.79″W	At ground at riSW_04	EOP	Jan 18 2017	12 V DC probably on NCAR DC network. At met masts on riSW transect (riSW_05, riSW_04, riSW_02)	1	5.00	On loan from PASSCAL
Cornell Sercel	L-28-3D Seismometer	5.00	No	39°42′10.25″N	7°44′27.96″W	At ground at riSW_02	EOP	Jan 18 2017	12 V DC probably on NCAR DC network. At met masts on riSW transect (riSW_05, riSW_04, riSW_02)	1	5.00	On loan from PASSCAL
5 Gill sonics being deployed by DTU on riSW_06	Gill WindMaster Pro		No	39°42′35.45″N	7°44′50.19″W	10,20,30,40 60m	EOP	By DTU on Nov/Dec 2016		6		

Map from WindSP (the Cornell equipment is in the wrong places since we have decided to relocate ZephIRs)



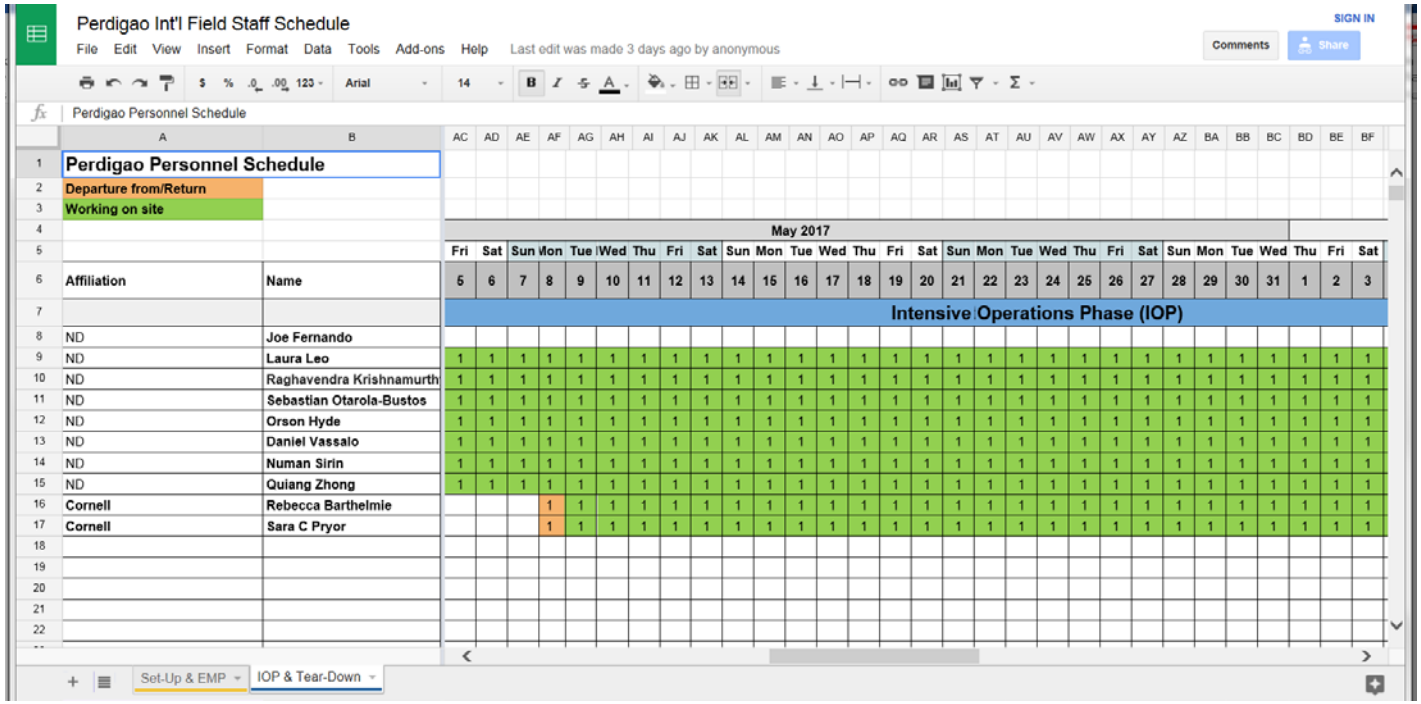
Personnel schedule EMP

https://docs.google.com/spreadsheets/d/1GWAWBRE0rNIQQCQooxHFrmfs2Z8XZr8SdlEV1eYDxkE/edit?pli=1#gid=402948804



Personnel schedule IOP

https://docs.google.com/spreadsheets/d/1GWAWBRE0rNIQQCQooxHFrmfs2Z8XZr8SdlEV1eYDxkE/edit?pli=1#gid=402948804



Perdigao Int'l Field Staff Schedule

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Perdigao Personnel Schedule

	A	B	AC	AD	AE	AF	AG	AH	AI	AJ	AK	AL	AM	AN	AO	AP	AQ	AR	AS	AT	AU	AV	AW	AX	AY	AZ	BA	BB	BC	BD	BE	BF
1	Perdigao Personnel Schedule																															
2	Departure from/Return																															
3	Working on site																															
4			May 2017																													
5			Fri	Sat	Sun	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Mon	Tue	Wed	Thu	Fri	Sat
6	Affiliation	Name	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	1	2	3
7			Intensive Operations Phase (IOP)																													
8	ND	Joe Fernando																														
9	ND	Laura Leo	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
10	ND	Raghavendra Krishnamurth	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
11	ND	Sebastian Otarola-Bustos	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
12	ND	Orson Hyde	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
13	ND	Daniel Vassalo	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
14	ND	Numan Sirin	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
15	ND	Quiang Zhong	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
16	Cornell	Rebecca Barthelmie				1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
17	Cornell	Sara C Pryor				1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
18																																
19																																
20																																
21																																
22																																

Set-Up & EMP | IOP & Tear-Down

6.2 LIST OF TASKS from other groups.

- UCAR Perdigao data questionnaire sent 26 Sep 2016
- Joe's science report.
- Book accommodation (Jose Carlos).
- Update the instrument locations at http://winds.fe.up.pt/windsp (this is the password protected site that has all of the instrument locations on a map, but they appear to be wrong?)

This table needs to be corrected to the locations on the google doc site. The ZephIR locations are incorrect.

56 (Maximet (Cornell))	**WGS84:** -7°44′14.65″E, 39°42′45.28″N **ETRS89:** 33,932.10E, 4,995.62N	Towers-002
11 (ZephIR447 - East (Cornell))	**WGS84: -7°44′41.48″E, 39°42′27.67″N** **ETRS89: 33,295.39E, 4,449.68N**	Profiling LIDAR
12 (ZephIR423 - West (Cornell))	**WGS84: -7°44′42.11″E, 39°42′26.65″N** **ETRS89: 33,280.48E, 4,418.19N**	Profiling LIDAR
13 (SpiDAR (Cornell))	**WGS84: -7°44′36.49″E, 39°42′21.60″N** **ETRS89: 33,415.02E, 4,262.99N**	Profiling LIDAR
14 (Galion (Cornell))	**WGS84: -7°44′11.01″E, 39°42′48.88″N** **ETRS89: 34,018.31E, 5,106.92N**	Scanning LIDAR
15 (Tethersonde (Cornell))	**WGS84: -7°45′16.06″E, 39°42′22.83″N** **ETRS89: 32,472.37E, 4,296.93N**	Tethersonde