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The Effects of Cold Weather on Wind Data Quality

An empirical study on how data produced from met mast and SODAR is affected by cold weather

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Introduction

Wind measurements are performed in order to estimate production levels in wind power projects. Properly performed wind measurements decrease risk in investment decisions.

Wind measurement equipment is affected by cold climate. This can result in long periods of unreliable data that increases risk in bankable data and uncertainty in production estimations.

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Summary (1/3)

- A total of 107 sites all over Sweden have contributed data to the study

- The data covers 2010 and 2011

- Data from both SODAR and met masts have been analyzed

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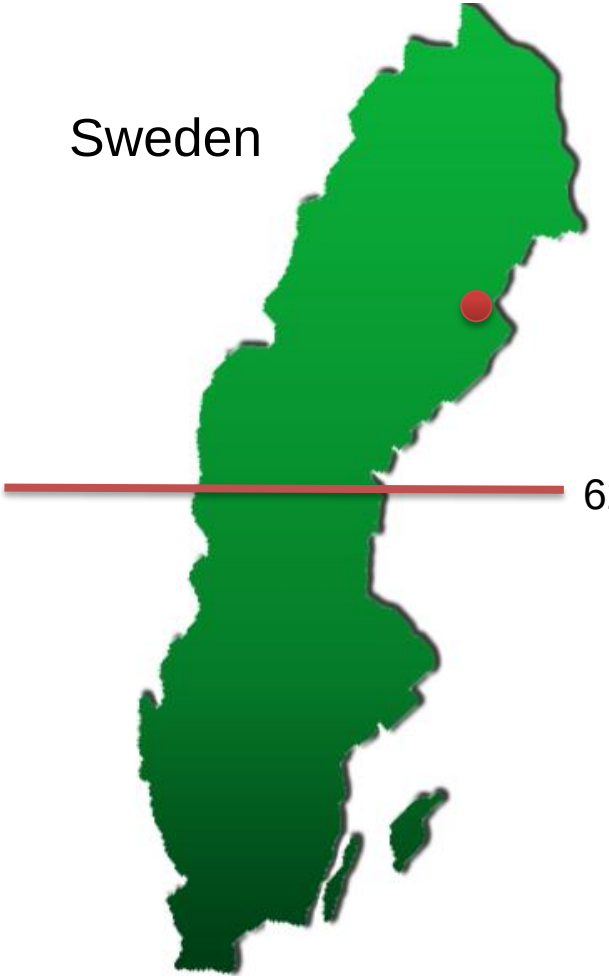
Summary (2/3)



- Northern Sweden
  - Total 37 sites

- Southern Sweden
  - Total 70 sites

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Summary (3/3)

- Met masts
  - Total 19 sites

- SODARs
  - Total 88 sites

Images are unrelated to the actual data.

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Purpose

- Bring awareness concerning problems in cold climate wind measurements

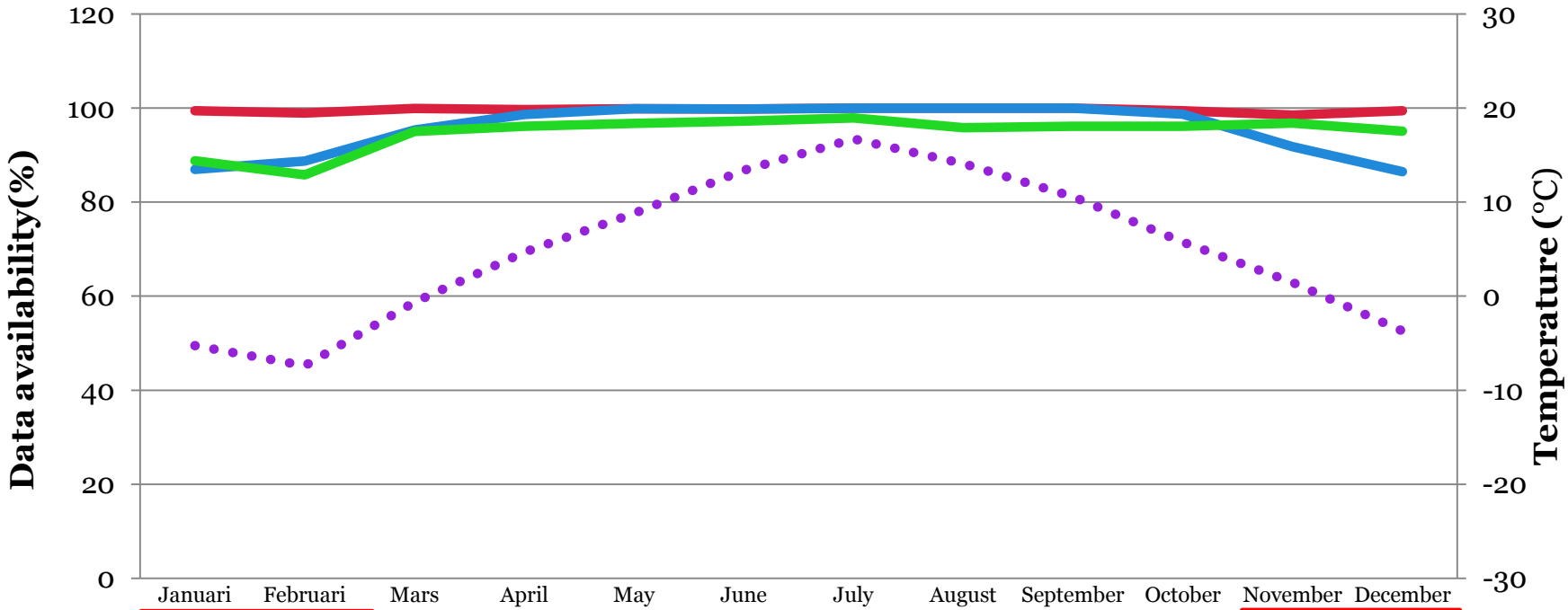
- Demonstrate cold climate problems that can occur during a wind measurement

- Discuss SODAR and met mast specific problems

- Discuss if and how cold climate problems can be minimized or prevented

- Discuss if and how data affected by cold climate should be post processed to increase reliability and accuracy

Data from all sites 2010-2012



	Januari	Februari	Mars	April	May	June	July	August	September	October	November	December
Met mast DA	99,45	98,95	99,94	99,7	99,85	99,81	100	99,99	99,99	99,45	98,49	99,44
Met mast DA icing	86,95	88,73	95,31	98,61	99,85	99,81	100	99,99	99,99	98,68	91,77	86,49
SODAR DA	88,77	85,78	95	96,1	96,75	97,24	97,92	95,8	96,11	96,11	96,82	95,06
Temperature	-5,25	-7,41	-0,64	4,67	8,79	13,4	16,72	14,09	10,58	5,74	1,47	-3,71

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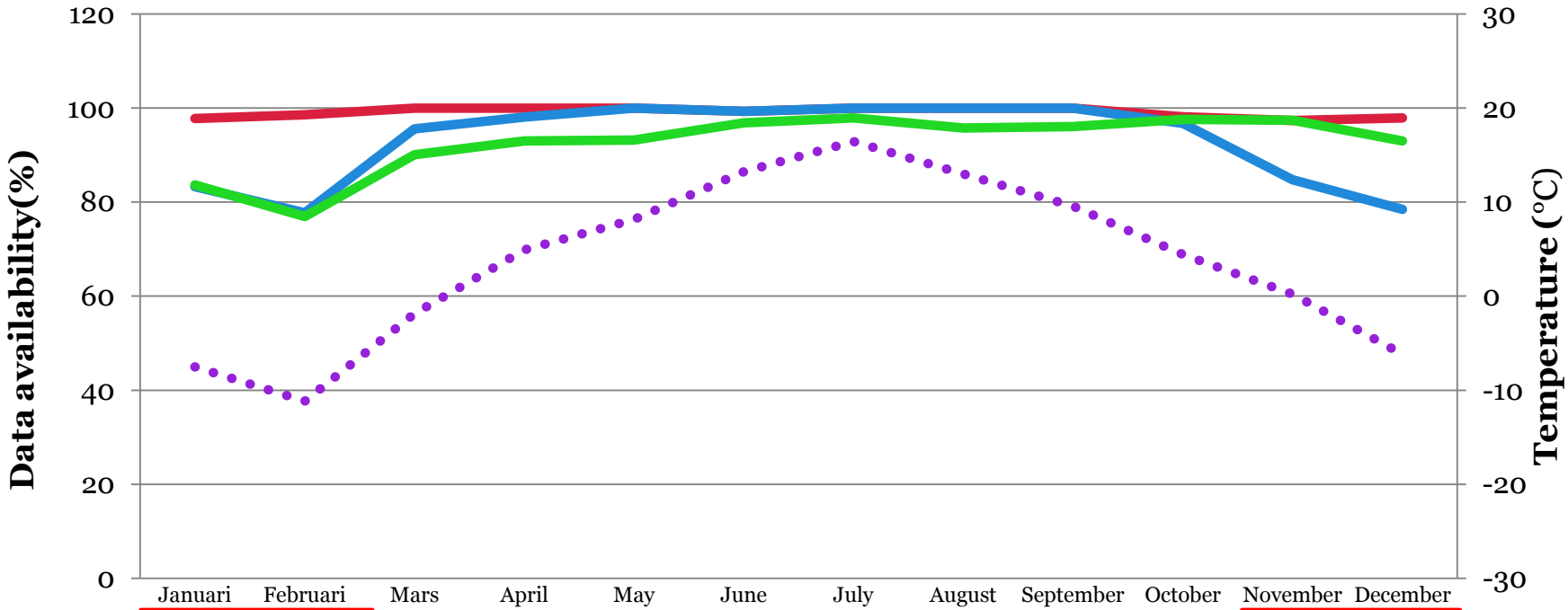
Data from northern sites 2010-2012



	Januari	Februari	Mars	April	May	June	July	August	September	October	November	December
Met mast DA	97,76	98,57	100	100	100	99,3	99,99	99,98	99,99	98,13	97,32	97,89
Met mast DA icing	83,29	77,75	95,55	98,08	100	99,3	99,99	99,98	99,99	96,73	84,78	78,43
SODAR DA	83,63	76,95	90,07	93,01	93,21	96,87	97,88	95,77	96,08	97,62	97,42	92,99
Temperature	-7,53	-11,16	-1,88	4,91	8,15	13,24	16,43	12,98	9,57	4,42	0,21	-6,19

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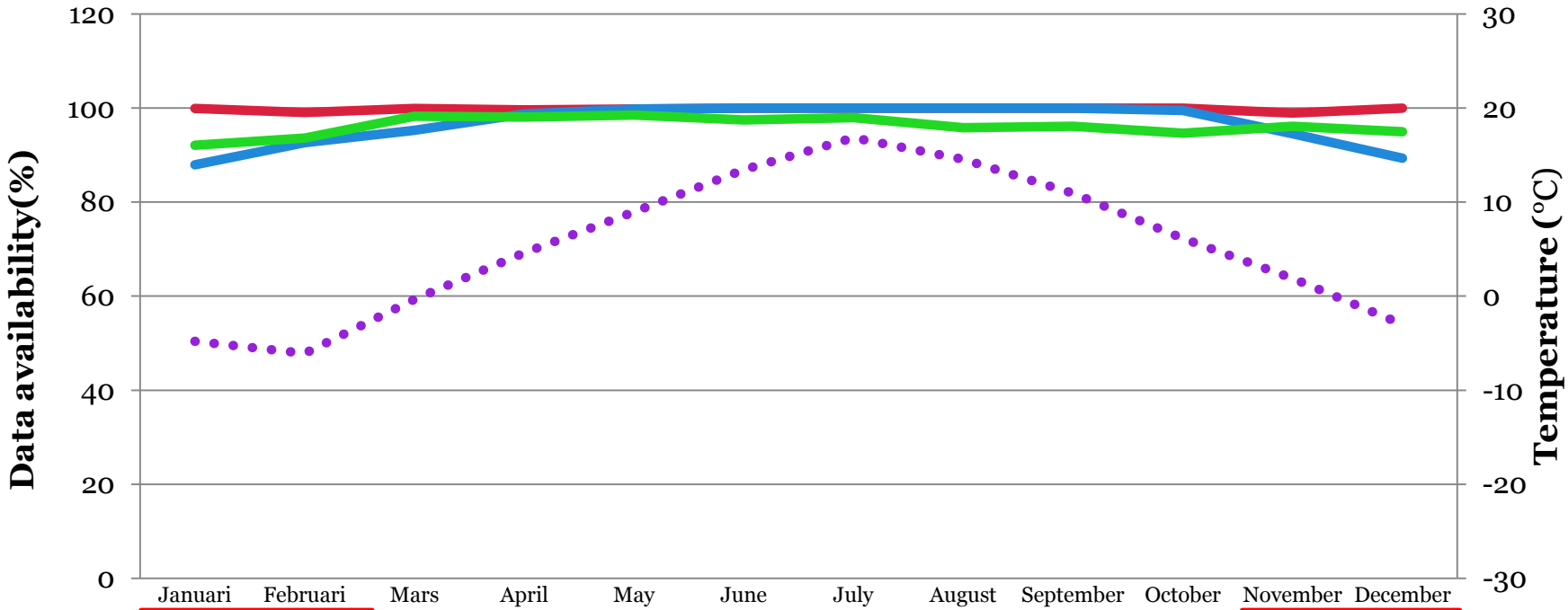
Data from southern sites 2010-2012



	Januari	Februari	Mars	April	May	June	July	August	September	October	November	December
Met mast DA	99,9	99,09	99,93	99,63	99,81	100	100	100	99,99	100	98,96	100
Met mast DA icing	87,93	92,64	95,25	98,74	99,81	100	100	100	99,99	99,48	94,56	89,37
SODAR DA	92,1	93,63	98,29	98,11	98,52	97,45	97,94	95,81	96,14	94,68	96,15	94,94
Temperature	-4,79	-6,07	-0,35	4,61	8,94	13,46	16,83	14,54	10,93	6,13	1,89	-3

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Summary of results: Data availability

Data source	Sites	Cold months (Nov – Feb)	Warm months	Warm-Cold (difference)
Met mast DA	North	97.89	99.84	1.79
Met mast DA icing	North	81.06	99.03	**17.64**
SODAR DA	North	87.75	96.38	**7.32**
Met mast DA	South	99.49	99.92	0.43
Met mast DA icing	South	91.13	99.16	**8.03**
SODAR DA	South	94.21	99.92	**2.91**
Met mast DA	All	99.08	96.38	0.76
Met mast DA icing	All	88.49	99.03	**10.55**
SODAR DA	All	91.61	99.84	**4.77**

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Summary of results

• 100% data availability is defined as 100% available wind speed data at 100m (inhomogeneous data set)

• “Met mast data availability icing” is the data availability with invalid/iced met mast data removed

  • A simple icing filter: “Any time interval of at least 4h during which the value of average wind speed changes less than 0.25 and the average temperature is less than 2° C”

  • Using several icing filters in combination will detect even more data as affected by icing

• SODAR data is intrinsically filtered using a quality filter within the SODAR (invalid data values are marked or discarded)

- If icing is considered, data availability is lower during cold months (November - February)
- If icing is considered, data availability for the northern sites is less than that of the southern sites
- SODAR has slightly higher data availability during cold months
- Ignoring cold climate effects will **negatively affect wind measurement equipment ➔ negatively affect measurement data ➔ Increases risk in bankable data ➔ Less reliable investment decisions**

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SODAR cold climate problems

- SODAR - Sound Detection And Ranging.
  - Uses sound waves to measure wind.
  - Operating range approximately 20 – 200m
  - Less reliable at low and high heights

- SODAR cold climate problems
  - Sound waves are affected by snow, sleet and rain (both ongoing and accumulated)

  - Snow and ice may introduce problems in antennas if it accumulates in the antenna compartment (disrupts sound waves)

  - Solar panels less efficient during winter time (less sunlight), more dependent on other generators (diesel). Generators are themselves prone to cold climate effects

  - Power supply errors caused by heating failure (SODAR operating temperatures approximately -30 °C to +50 °C)

  - Affected by general cold climate problems (wear and tear, engines and moving parts are less reliable if temperatures are freezing)

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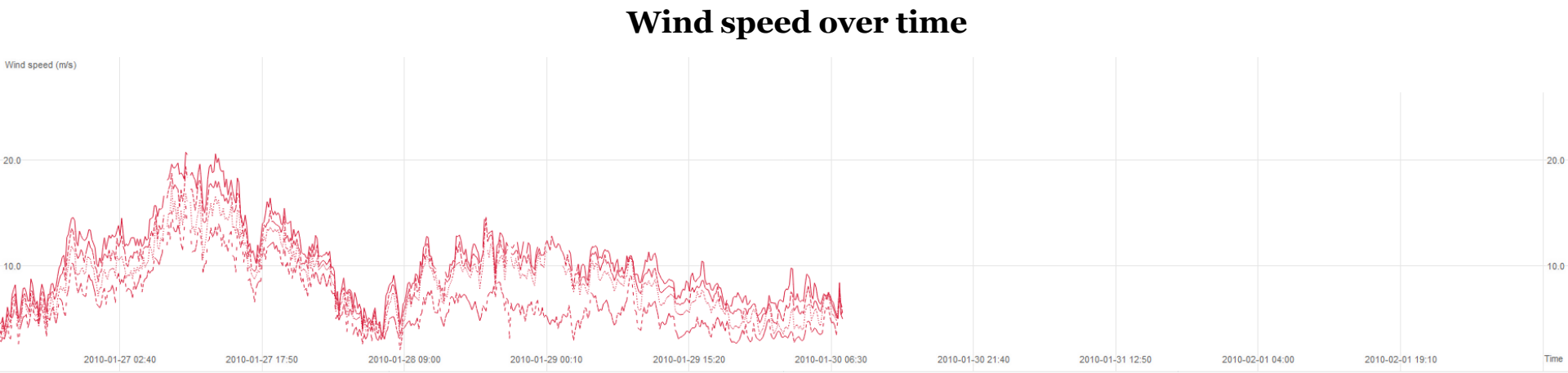
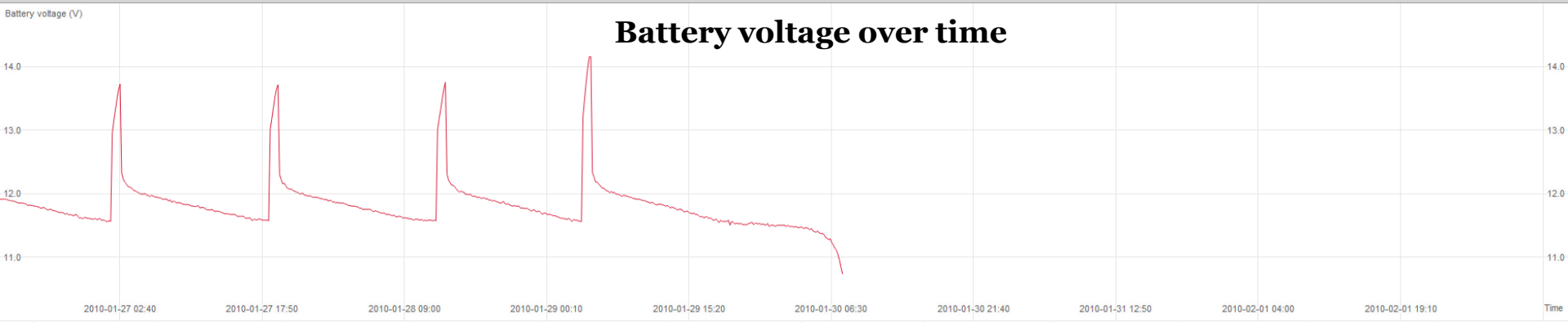
SODAR case study – Battery voltage





- Case: Battery discharged in 24 hours. More power required during cold time periods.
- Generator not starting due to low temperature (less than -20° C)

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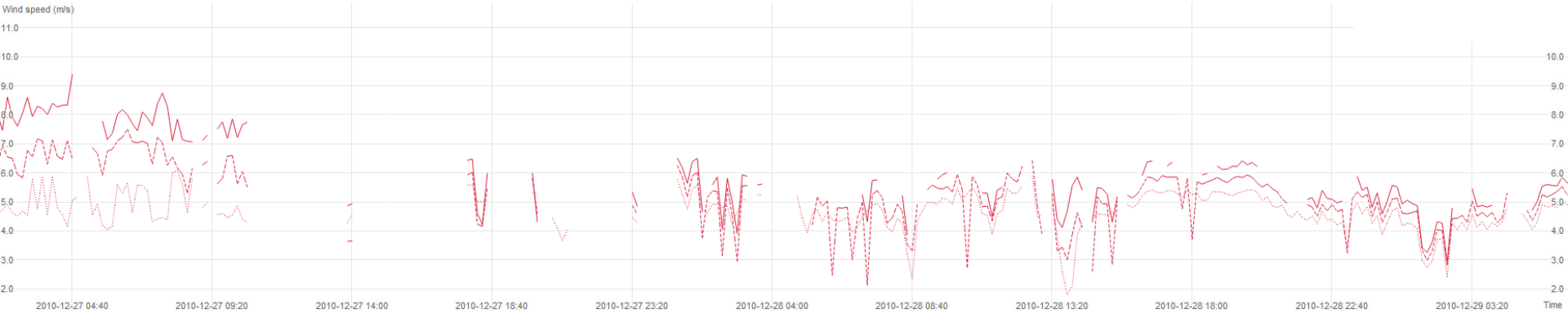
SODAR case study – Snow/ice

Wind speed from 3 heights over time



- 3 days of affected data
- Snow and ice affect data availability (gaps in the graph)
- More than 50% of the data is invalid or missing
- Data availability decreases when the measurement height increases (e.g. less data available for higher heights)

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Met mast cold climate problems

- Met mats are constructed in different ways and have different sensors
- Some configurations can be more error prone than others
- Met mast cold climate problems
    - Sensors are affected by snow, ice, sleet and rain (both ongoing and accumulated)
    - Snow and ice may introduce problems in the sensors, they can freeze stuck or slow down
    - Equipment and heated sensors require more energy in cold climate
    - General wear and tear increases during winter time

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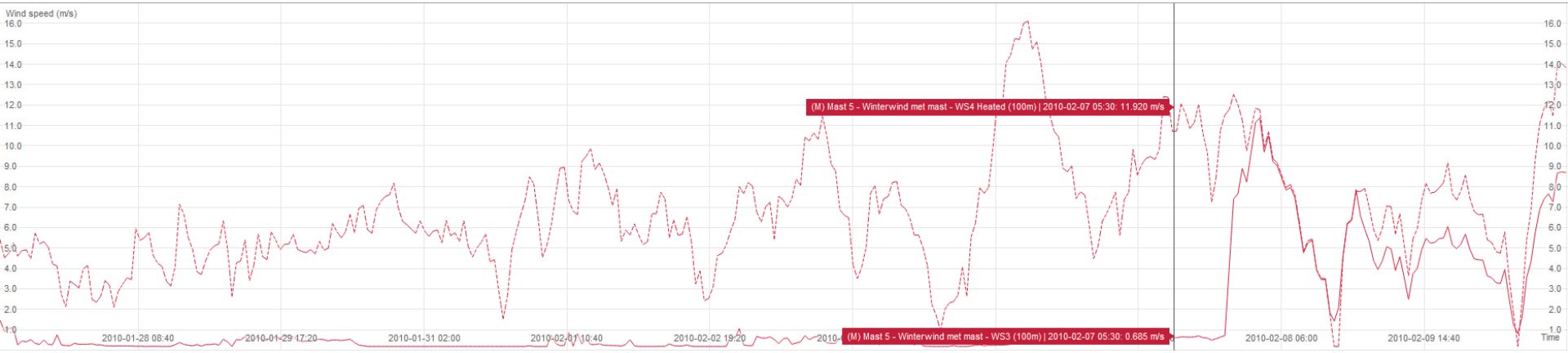
Met mast case study – Frozen sensor

Wind speed over time



- More than one week of affected data
- Non-heated anemometer frozen (flat line at the bottom)
- Heated anemometer is still working properly

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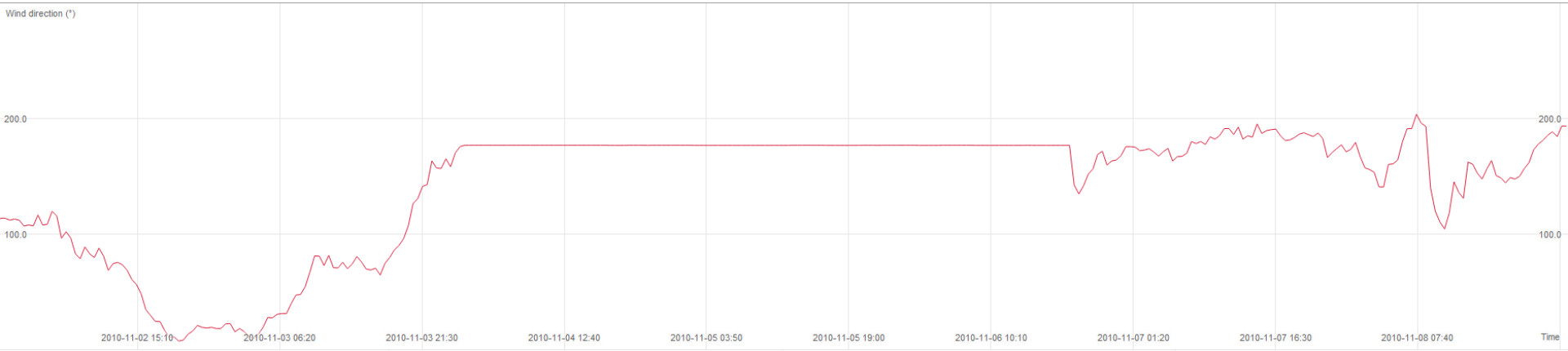
Met mast case study – Wind vane icing

Wind direction over time



- 3 days of affected data
- Wind vane completely frozen (flat line)
- Exactly the same wind direction is reported for a long period of time

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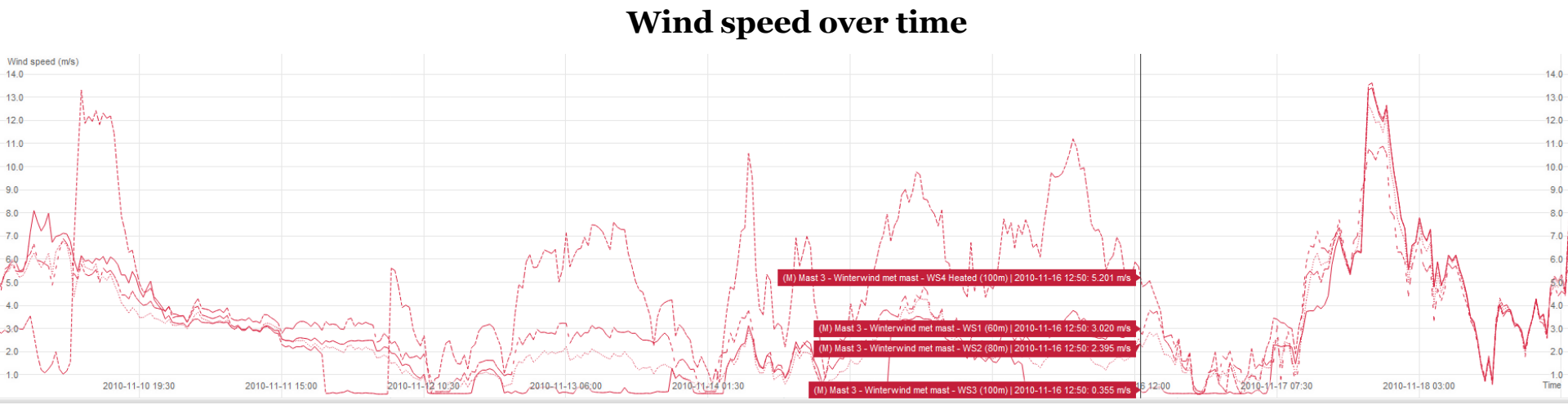
Met mast case study – Iced sensors



- More than one week of affected data
- Anemometers are frozen or slowed down due to snow/ice
- Problematic case, hard to determine which data is valid / correct (if any)

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Key Takeaways (1/2)

It might not be feasible to fully prevent all cold climate effects on measurement data. However, measures can be taken to prevent major loss of data if and when such effects occur.

- Utilize an external heating system (diesel generator). This will reduce wear and tear and help to keep equipment within operating temperatures.

- Closely maintain equipment and monitor measurement data, more so during cold climate periods

- Use proper monitoring software to monitor equipment and data. It can alert you of problems before they occur or get out of hand.

- If possible, try to have a contact person with physical access to the equipment who does regular checkups. Increase the number of checkups during cold climate periods .

- Use both a met mast and a SODAR / LIDAR in combination to decrease risk of loosing data. They are affected differently by cold climate. If one stops working, the other might still function well.

- For met masts, use both heated and unheated sensors and use several different types of anemometers (cup, aerovane, sonic).

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Key Takeaways (2/2)

Measurement data affected by cold climate should be post processed or the results based on calculations from such data will be inaccurate.

• No concensus about ”the best method”. It depends on the data source, the purpose of the measurement, the target audience and the availabile options for this specific measurement.

• Two common methods for post processing data

1. Discard data - If only data from a short period of time is affected, simply discard the affected data and adjust future calculations

2. Gap fill data - Replace affected data with valid data from one or several other data sources (data transformation might be necessary depending on the situation)

    • Data from another sensor on the same or close height
    • Data from another SODAR or met mast close by
    • Data from metrological and statistical models

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Sponsors

- Several organizations have contributed data to this study.
- They wish to remain anonymous.
- Without their help this study would not have been possible.
- Thank you! (You know who you are)

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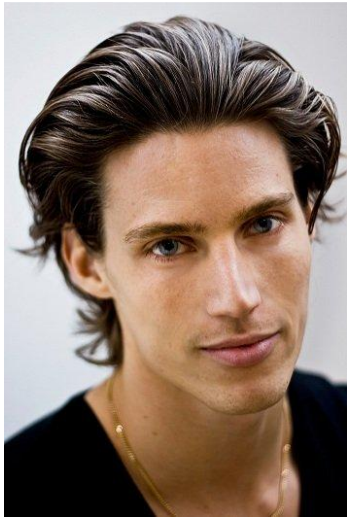

Thank you for listening!

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Do you have any questions about the study? Please come and see us in the Greenbyte monter after the presentation and we will gladly answer them!

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