

wood.

Power Curve Tests in Cold Climates on Complex Terrain

Experience, Challenges and Solutions

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28th March 2023



Power Curve Tests in Cold Climates on Complex Terrain

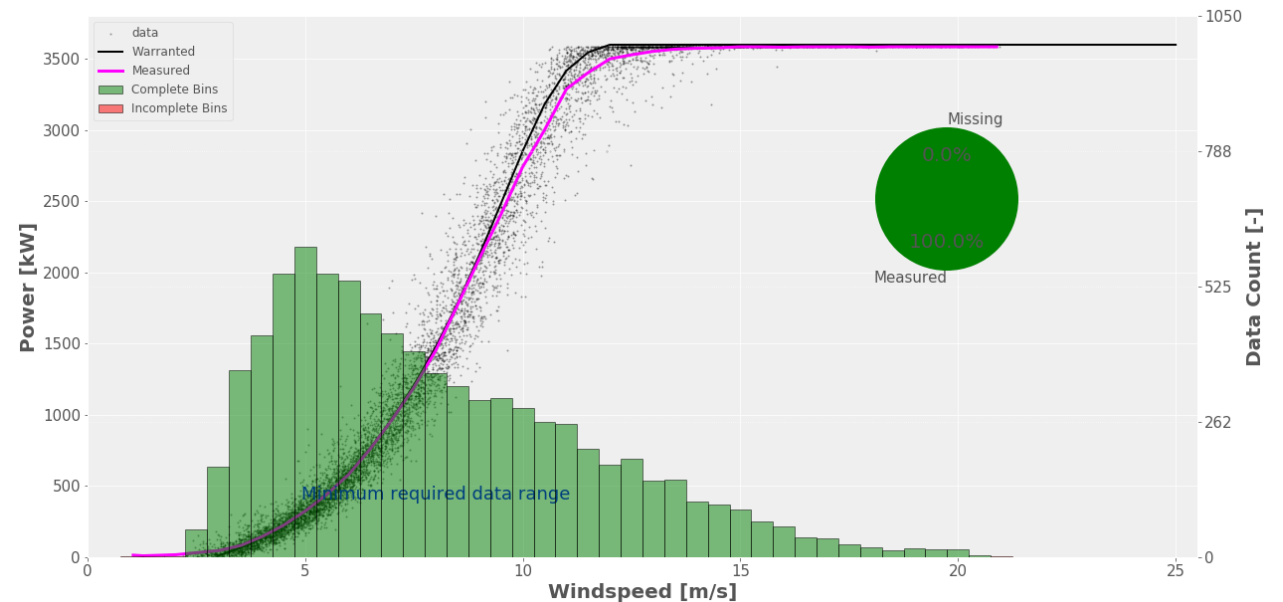
- What is PPT – purpose and outcomes
- PPT – stages of process and fit into wind farm construction schedule
- Challenges and solutions:
 - Filters on meteorological parameters
 - Construction-based activities
 - Cold climate site-work
 - Instrument icing
- Summary of solutions – road map to success!



Power Performance Testing

PPT – A Strictly Controlled Power Curve Measurement

- Independent measurement of WTG power performance.
- IEC Standard: Measure the wind, measure the power, report the performance.
- Application: Compare the performance to what is expected.



Power Performance Testing

PPT – Purpose

- Investor requirement?
- Perceived underperformance:
 - Warranty AEP comparison?
 - Understand WTG power performance?
- Internationally recognised industry-standard method;
the only irrefutable way to define how well WTGs are performing.



Power Performance Testing

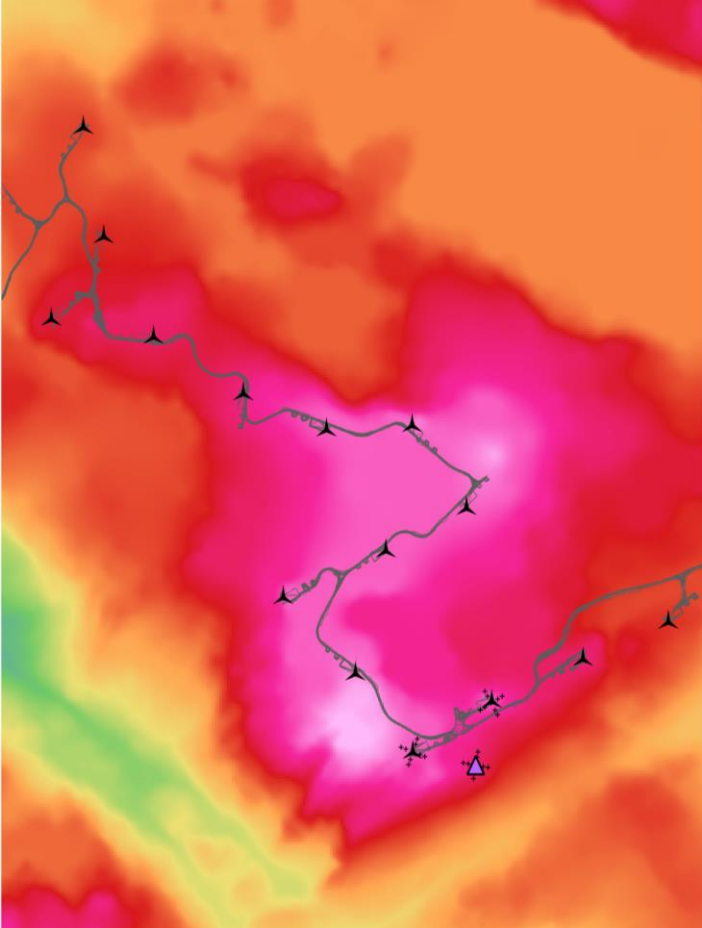
PPT – Outcome

- Ostensible (unusual but possible):
warranty claims.
- More likely:
highlight any opportunities
to optimise performance.
- Definitive baseline of performance.



PPT overview - stages

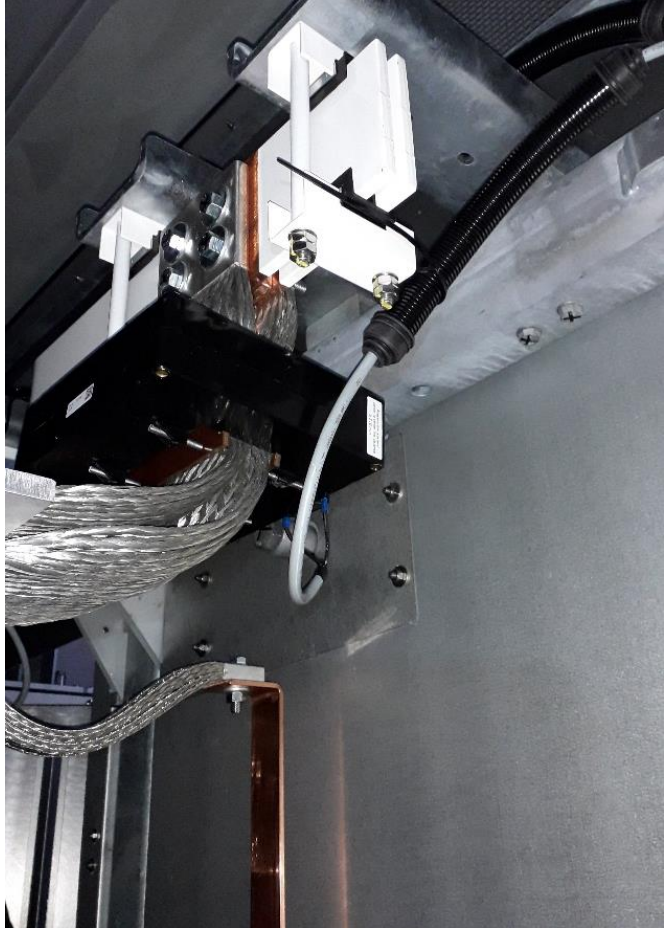
Complexity Assessment



Site Calibration

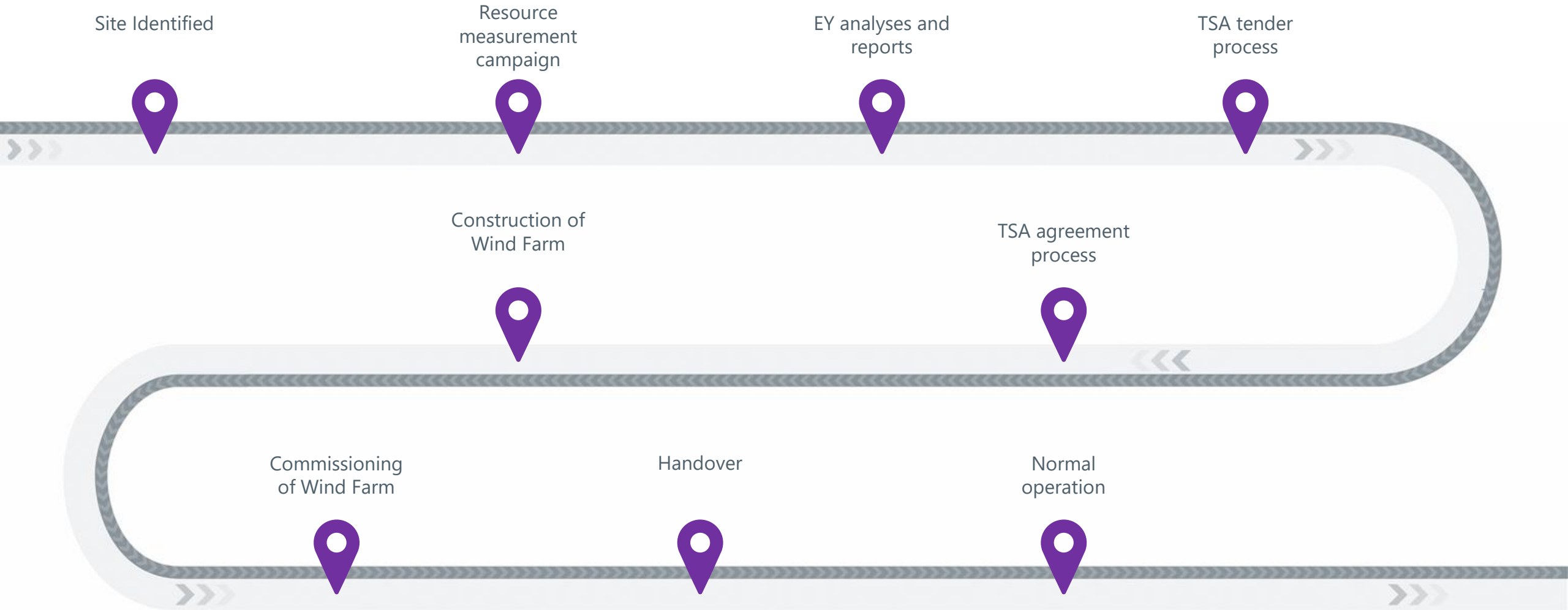


Power Measurement



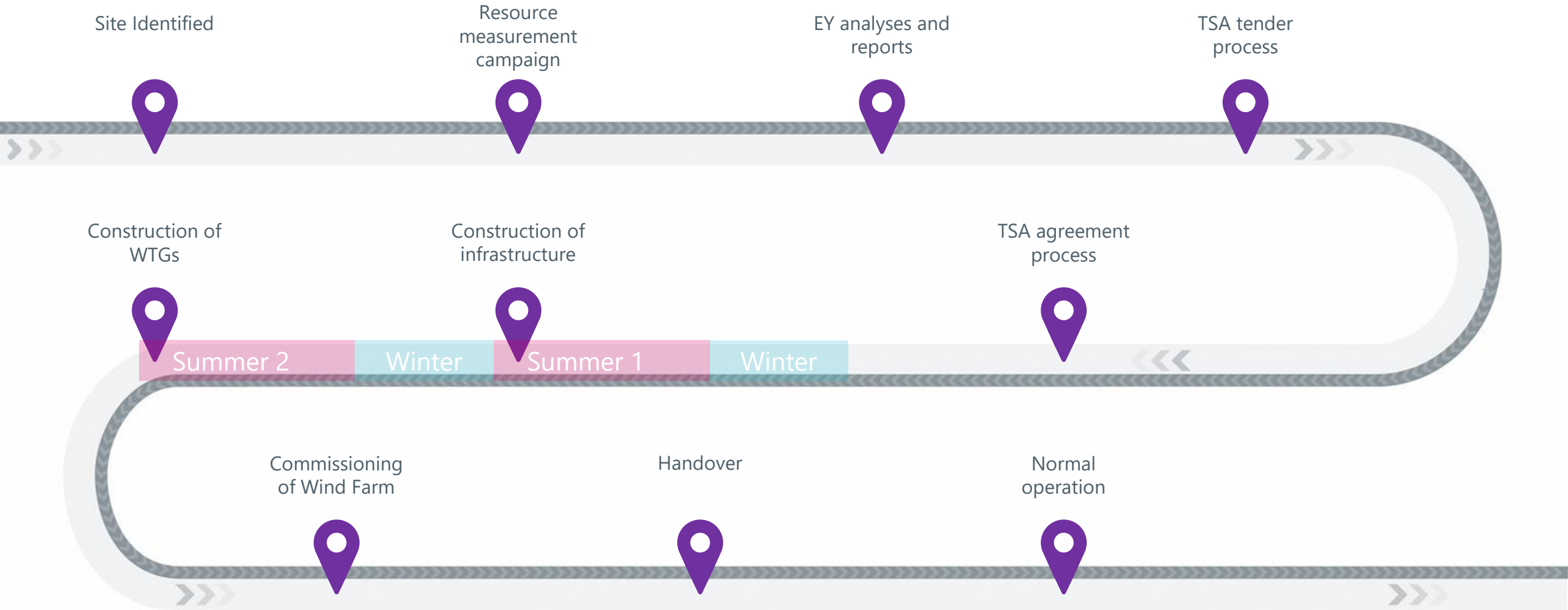
Relevant Wind Farm Development Stages

Mild Climate



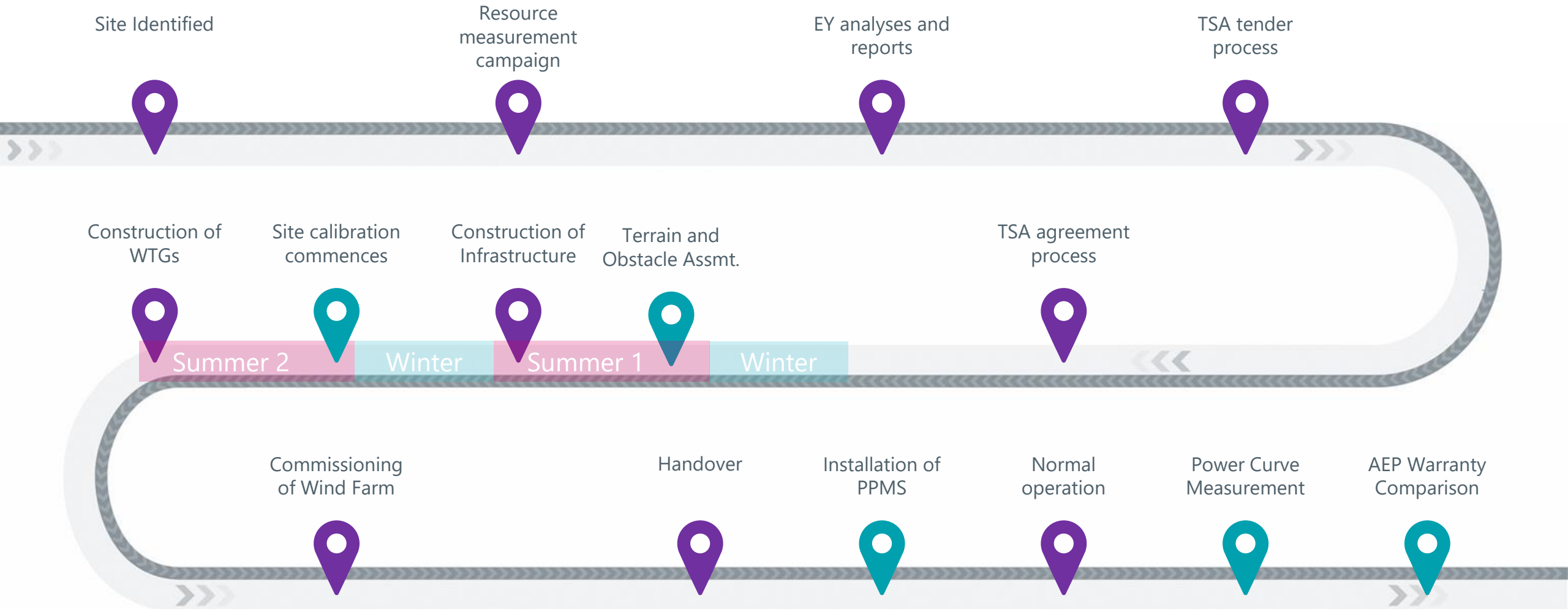
Relevant Wind Farm Development Stages

Cold Climate



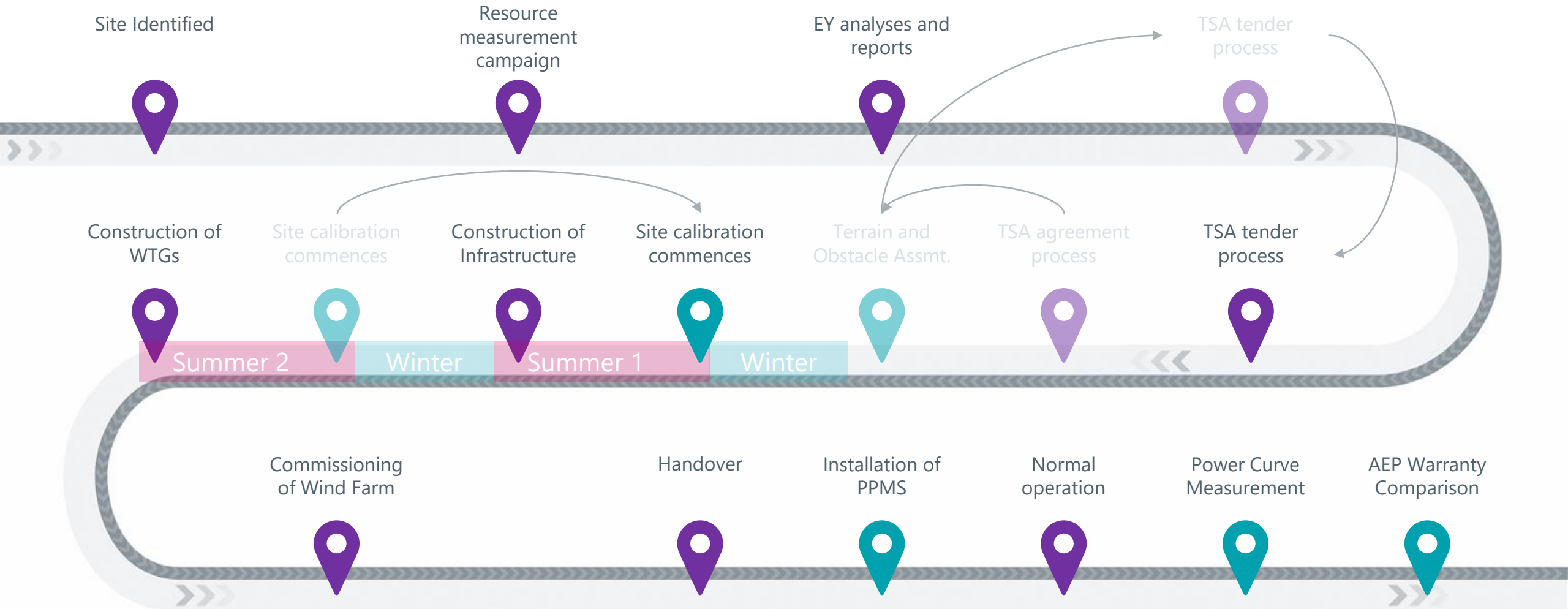
PPT in Relevant Wind Farm Development Stages

The Usual Approach Does Not Work for Cold Complex Sites



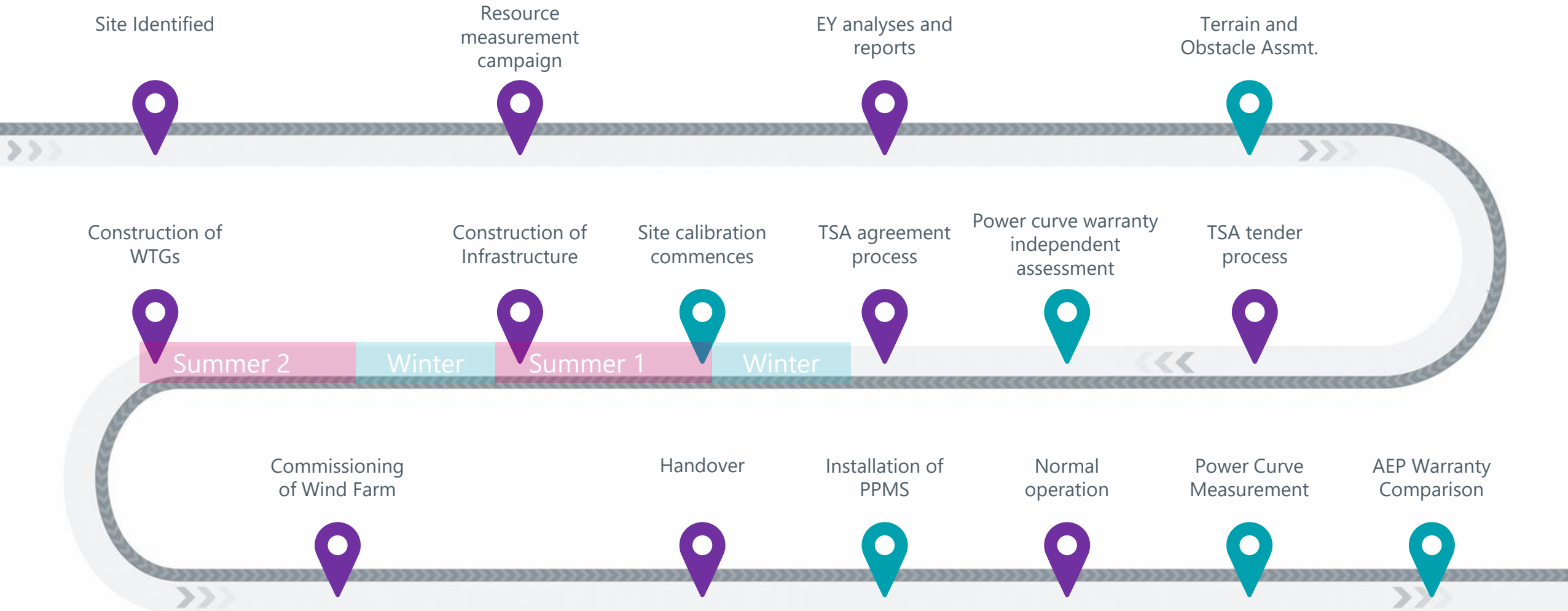
PPT in Relevant Wind Farm Development Stages

Practicable Solution for Cold and Complex Sites



PPT in Relevant Wind Farm Development Stages

Practicable Solution for Cold and Complex Sites



PPT in Cold Climates

Working with Construction Schedule



Challenges	Solutions
Road/WTG construction order fixed	Select test WTGs to accommodate
Roads incomplete	Erect masts with helicopters
Through-access needed and guy lines crossing roads	Masts micrositied to allow passage underneath
Blasting needed	Prioritise test locations first
Access to hardstand required	Microsite mast and guys
Short daylight hours	Ground team ready to go at short notice; dedicated, experienced staff
Unsafe weather for climbing	Project management monitoring weather

Key Points

Start mast erection in spring of first construction period

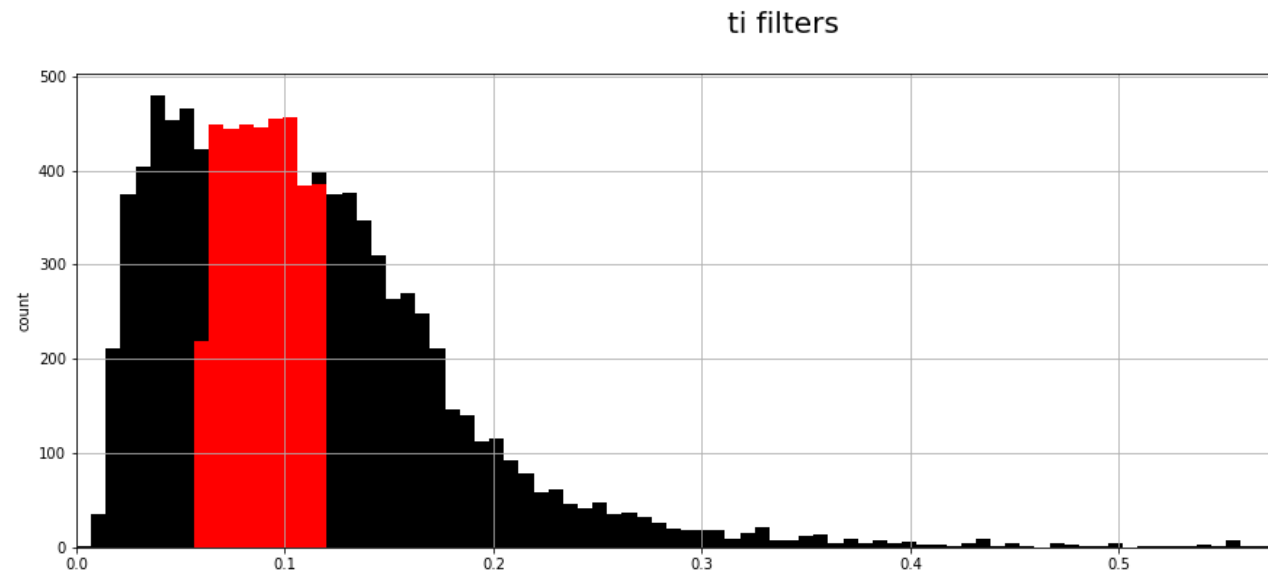
Share information openly and early to maximise ease of process

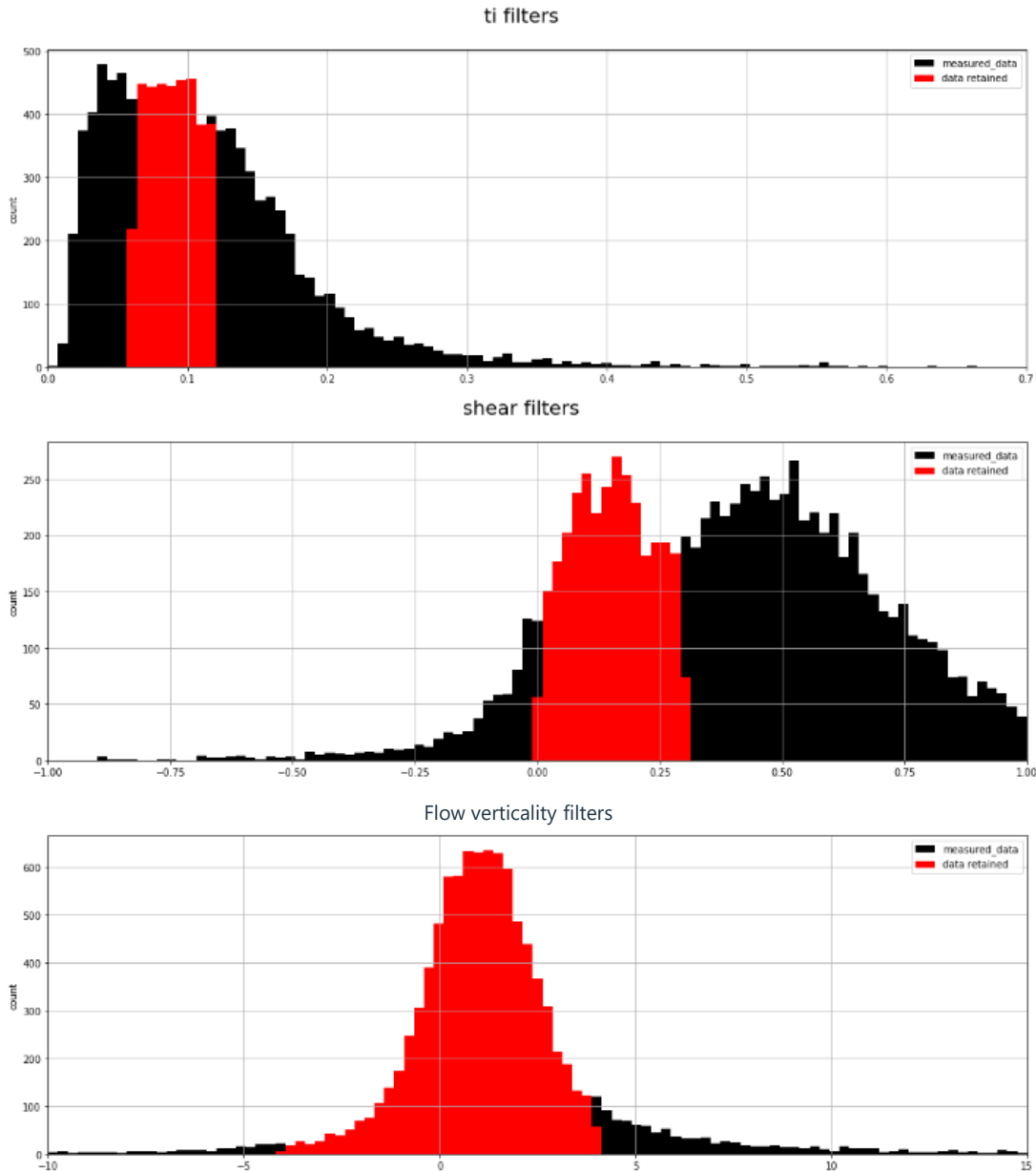
Meteorological Parameters and PPT

Parameter Ranges and Terrain Complexity

- Meteorological parameters:
 - Turbulence intensity
 - Wind shear
 - Flow verticality
 - Veer
 - Precipitation

- *Filters are applied in most warranted power curves.*





Meteorological Parameters and PPT

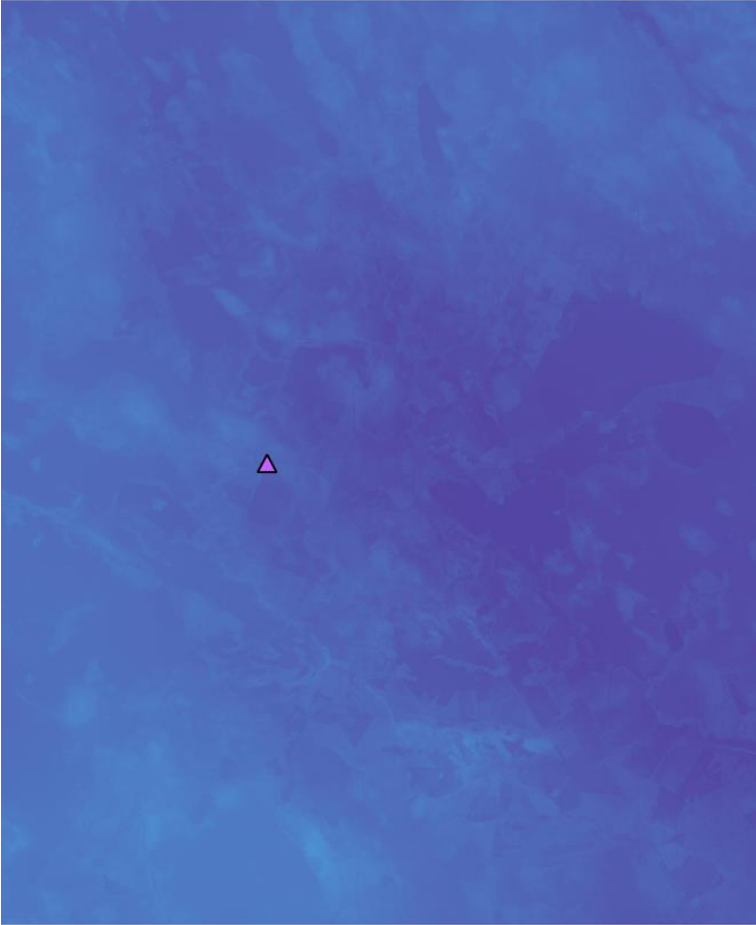
Parameter Ranges and Terrain Complexity

- Complex forestry or terrain means higher ranges/values of meteorological parameters.
- Unoptimised filters:
 - Limit representativeness of PPT.
 - Lengthen measurement periods.

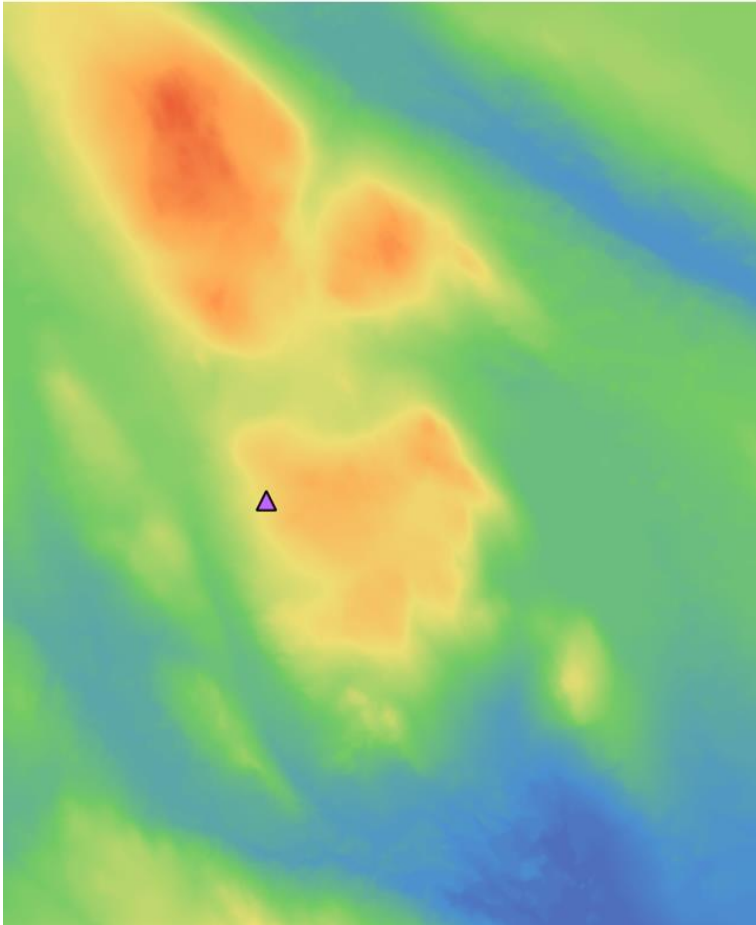
In cold climates this can make site calibration difficult to complete.

Meteorological Parameters and PPT

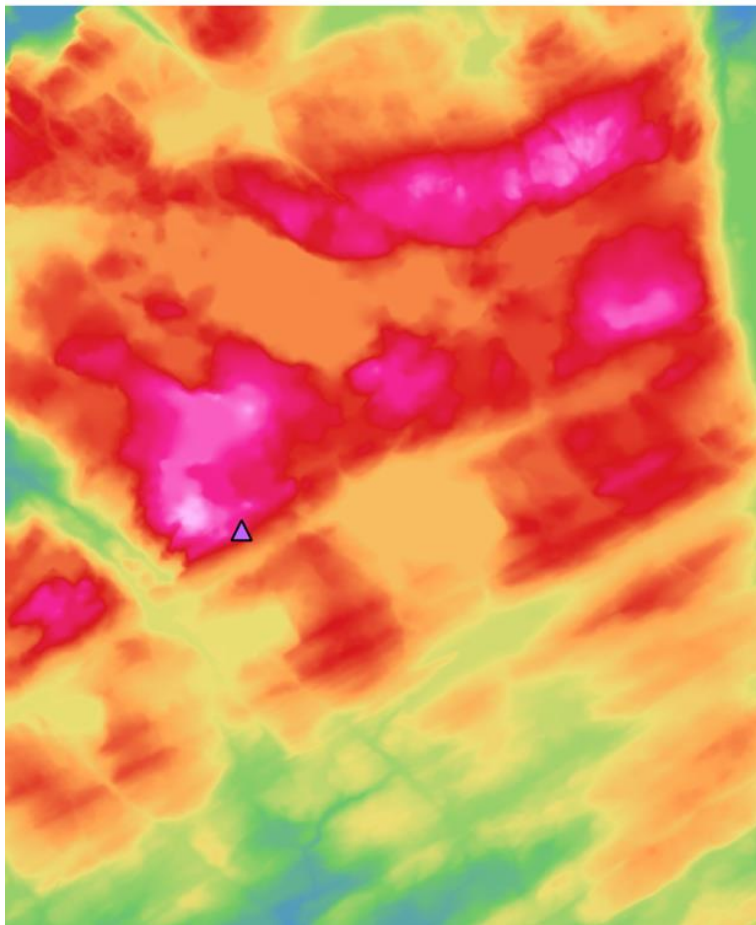
Flat site with complex forestry



Complex site

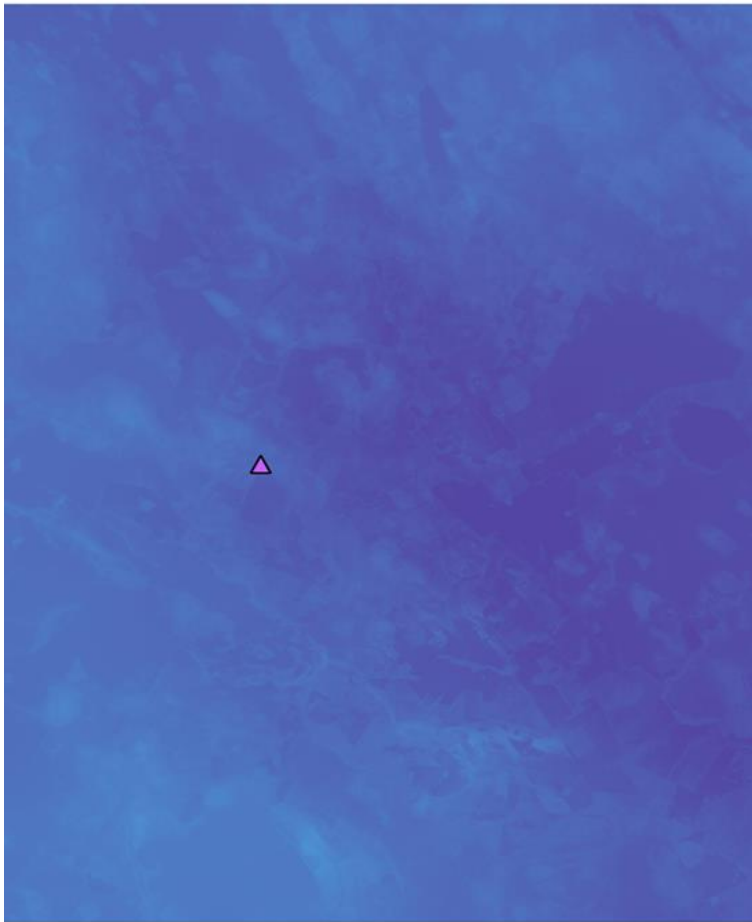


Highly complex site



Meteorological Parameters and PPT

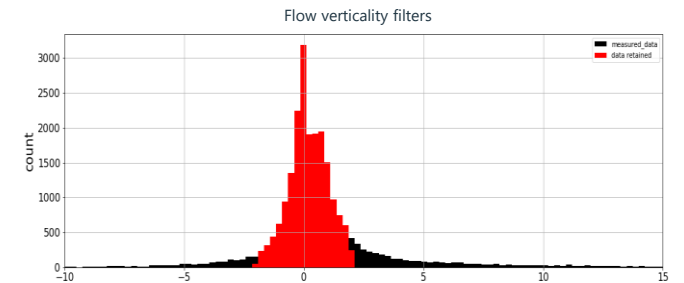
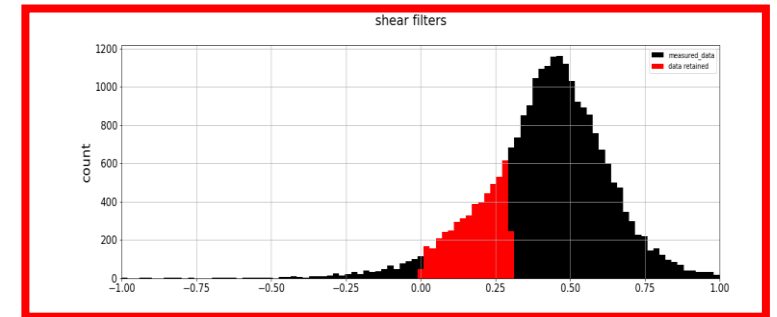
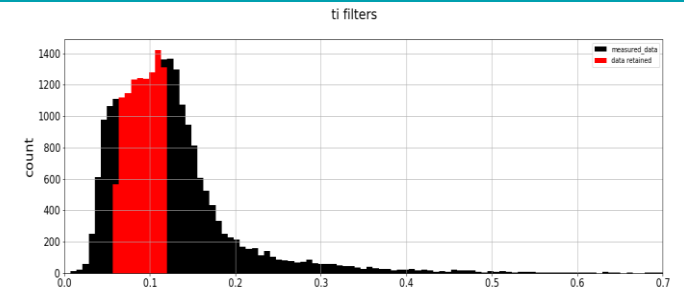
Site map (non-dimensionalised)



Filters are applied in most warranted power curves

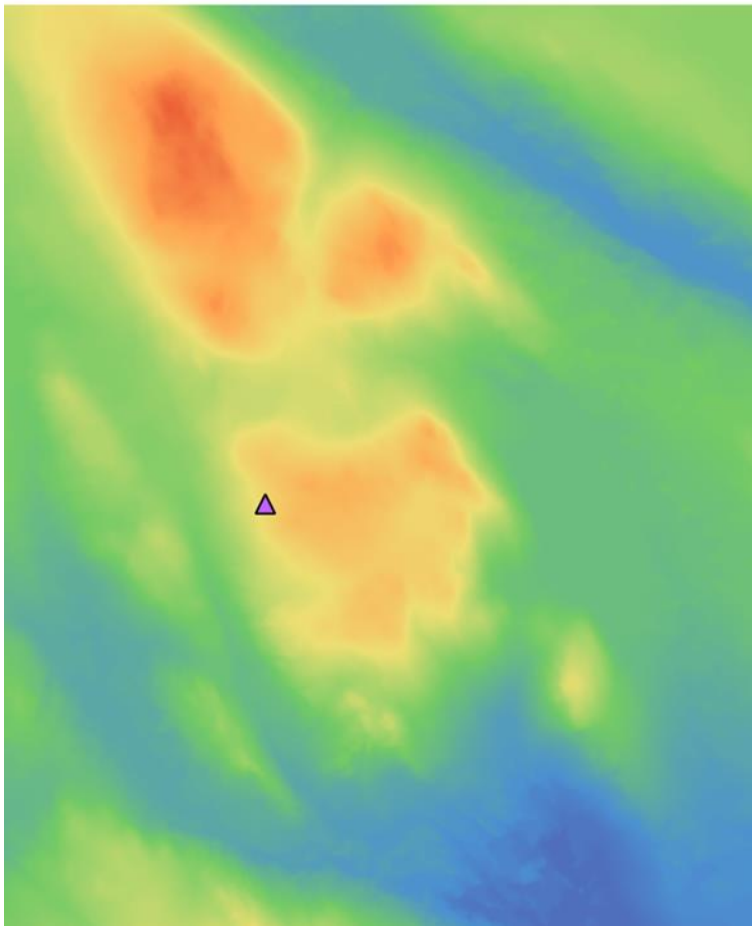
*In flat sites, un-optimised **wind shear** filter can limit data retention*

Distribution and retention of data



Meteorological Parameters and PPT

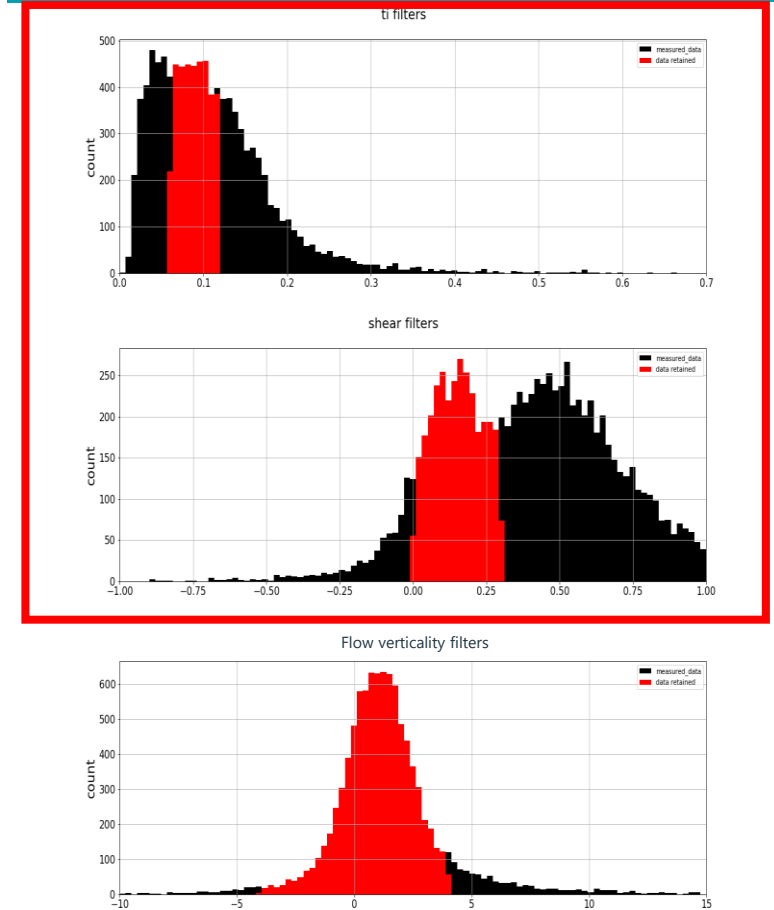
Site map (non-dimensionalised)



Filters are applied in most warranted power curves

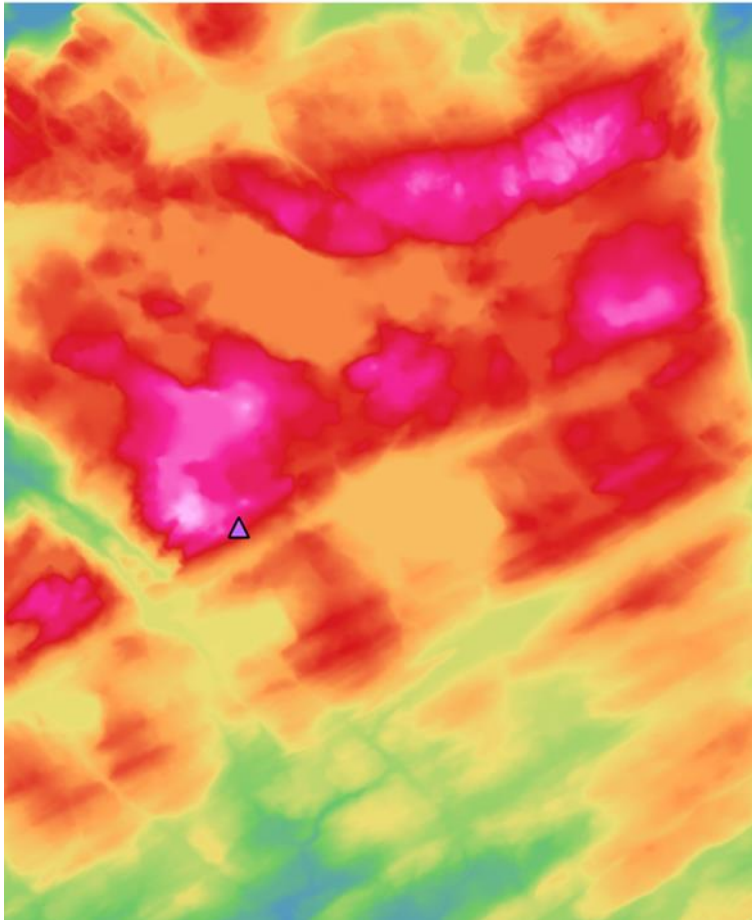
*In moderately complex sites, un-optimised **wind shear** and **TI** filters can limit data retention*

Distribution and retention of data



Meteorological Parameters and PPT

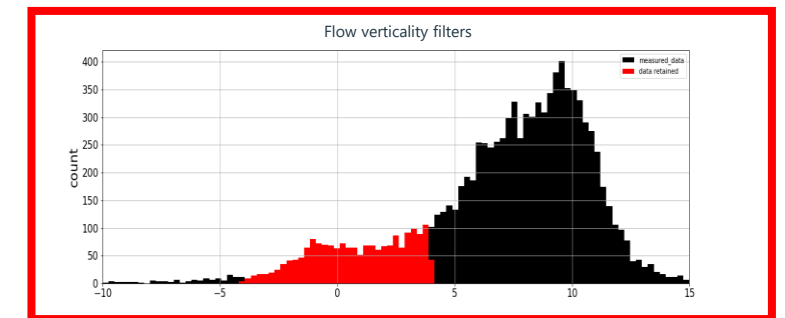
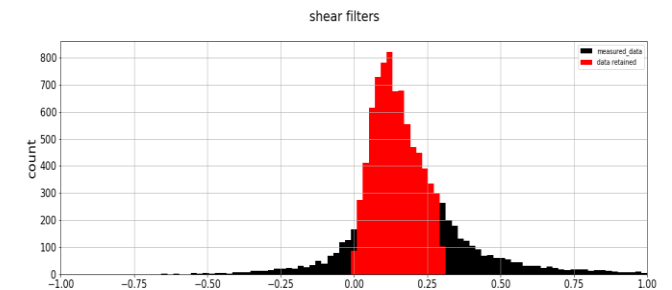
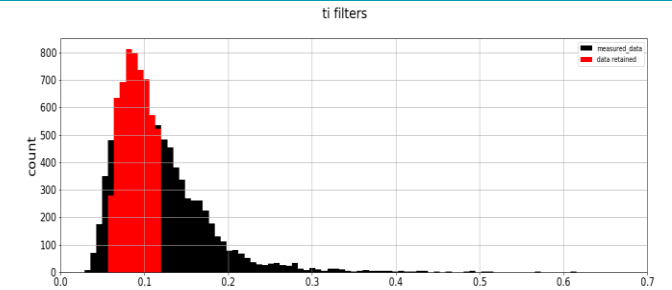
Site map (non-dimensionalised)



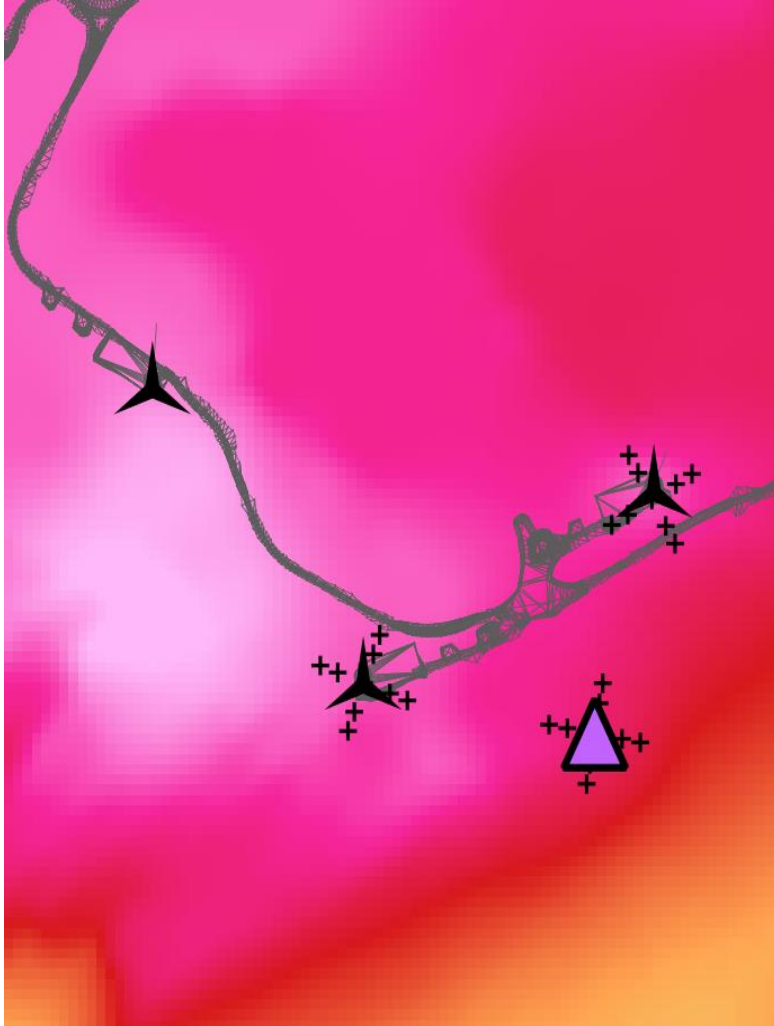
Filters are applied in most warranted power curves

*In very complex sites, un-optimised **TI** and, particularly, **flow verticality** filters can limit data retention*

Distribution and retention of data



Meteorological Parameters - PPT in Cold Climates



In cold climates, un-optimised filters can make site calibration difficult to complete

Solution(s):

- ***Allocate plenty of time for SC by working within and around first construction schedule***
- ***Agree site specific environmental filtering conditions ahead of time***



PPT in Cold Climates

Data Collection in Cold Weather

- Instrumentation icing
 - Limits capture of data in cold weather.
 - Limits representativeness of PPT.
- Heating all instrumentation expensive – at site calibration all but unfeasible.
- Our experience-derived solution:
 - Heated ultrasonic anemometer as secondary instrument.

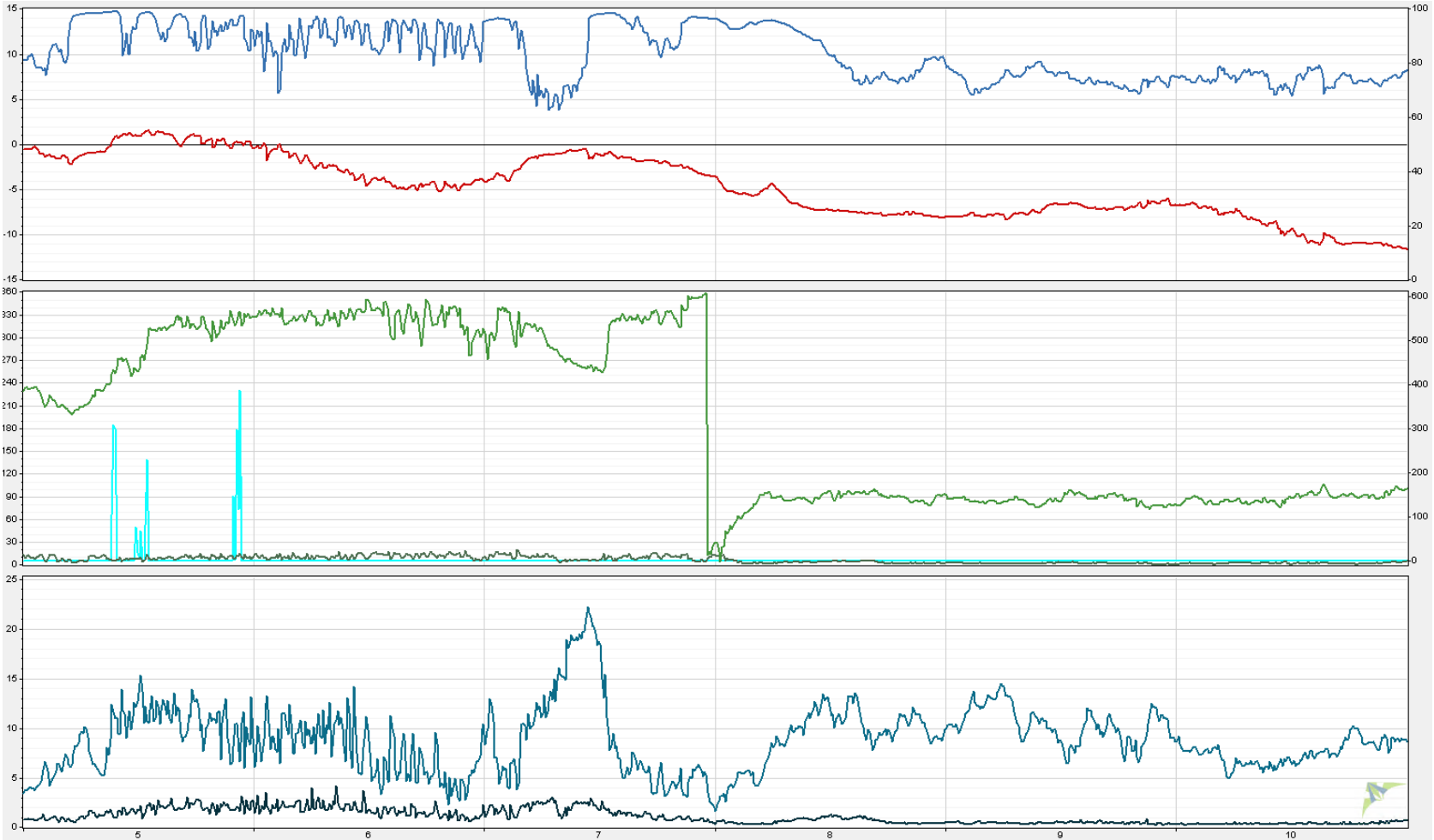
Heated USA as secondary instrument
maximises data retention



PPT in Cold Climates

Data Collection in Cold Weather

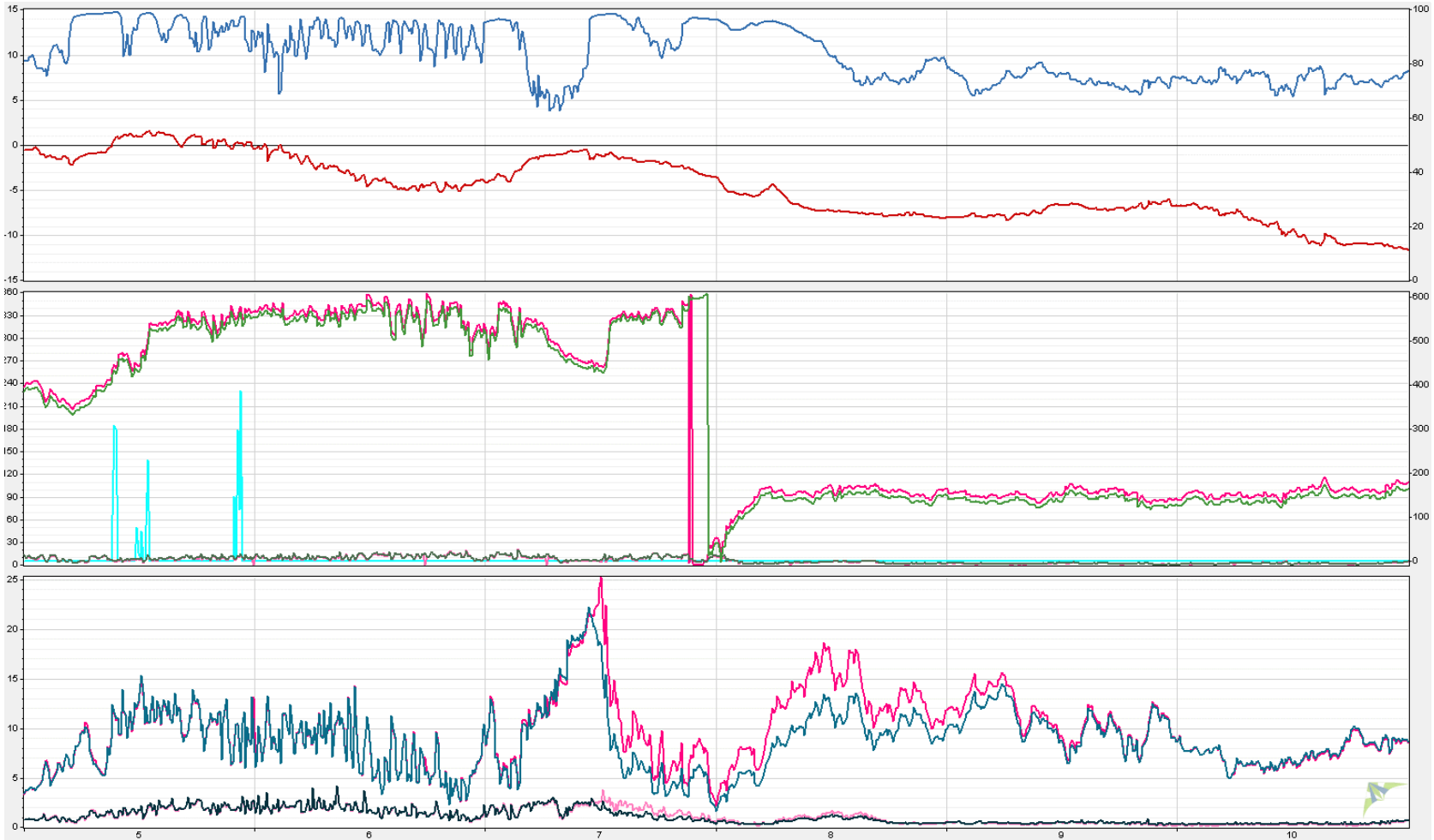
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PPT in Cold Climates

Data Collection in Cold Weather

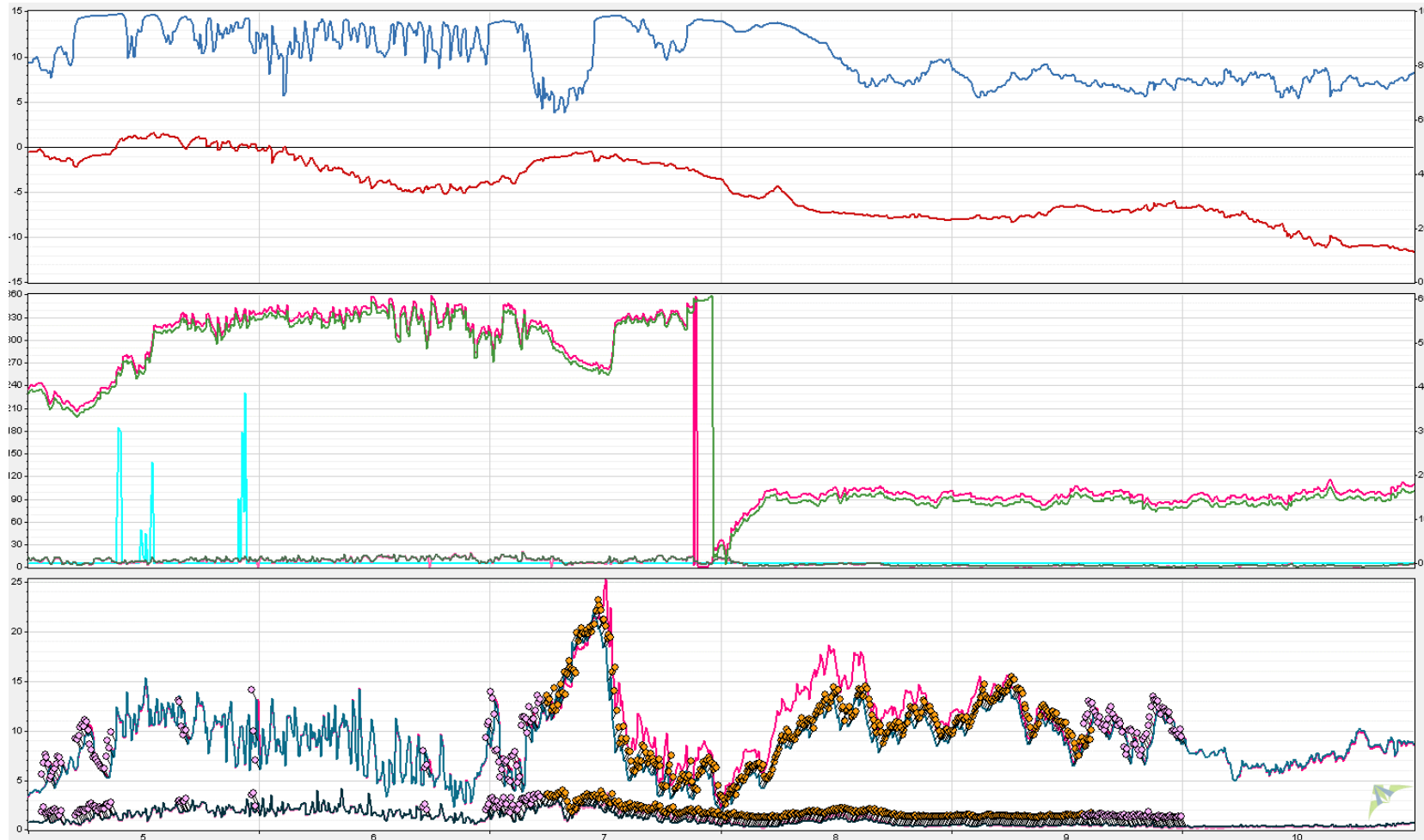
Heated USA as secondary instrument maximises data retention



PPT in Cold Climates

Data Collection in Cold Weather

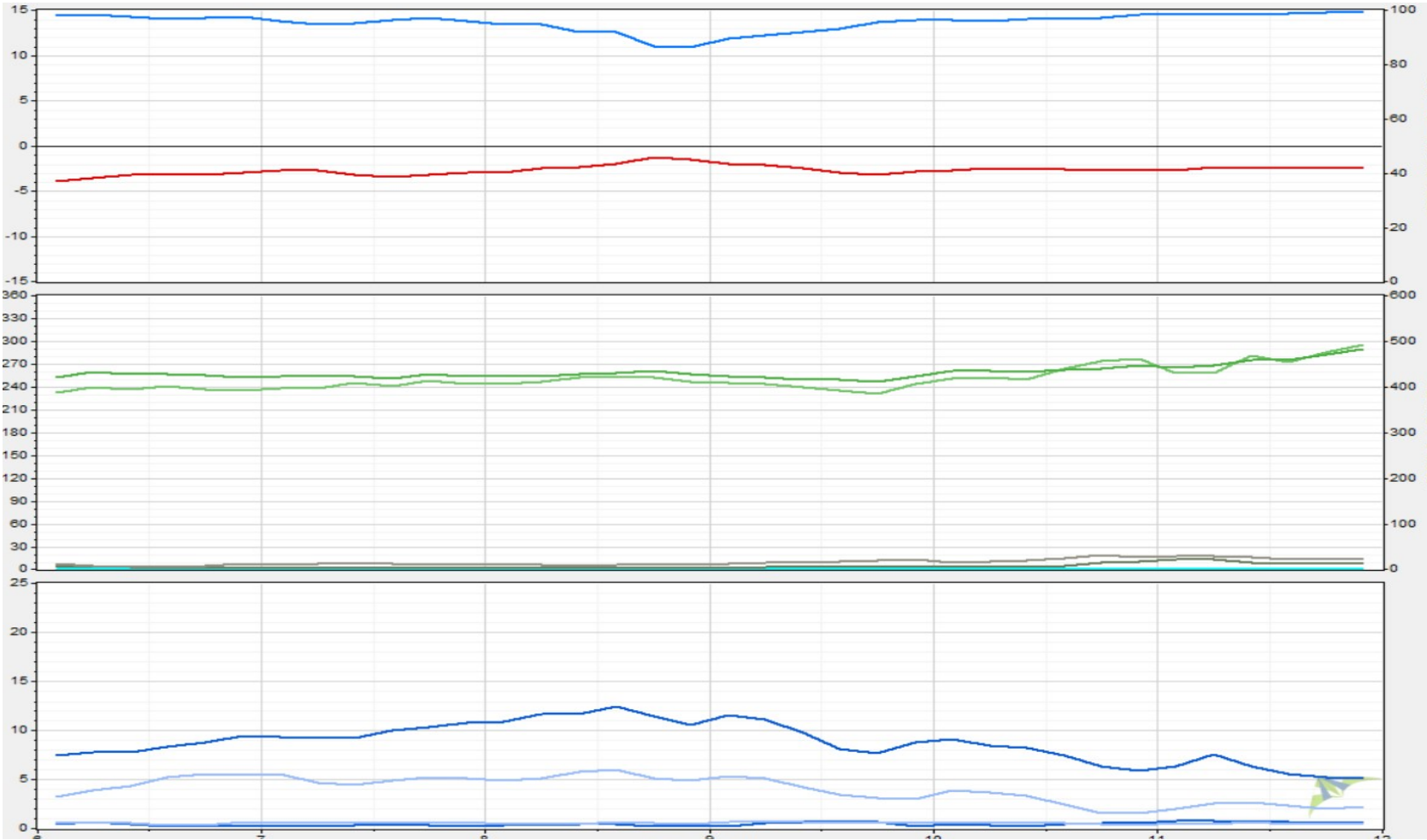
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PPT in Cold Climates

Data Collection in Cold Weather

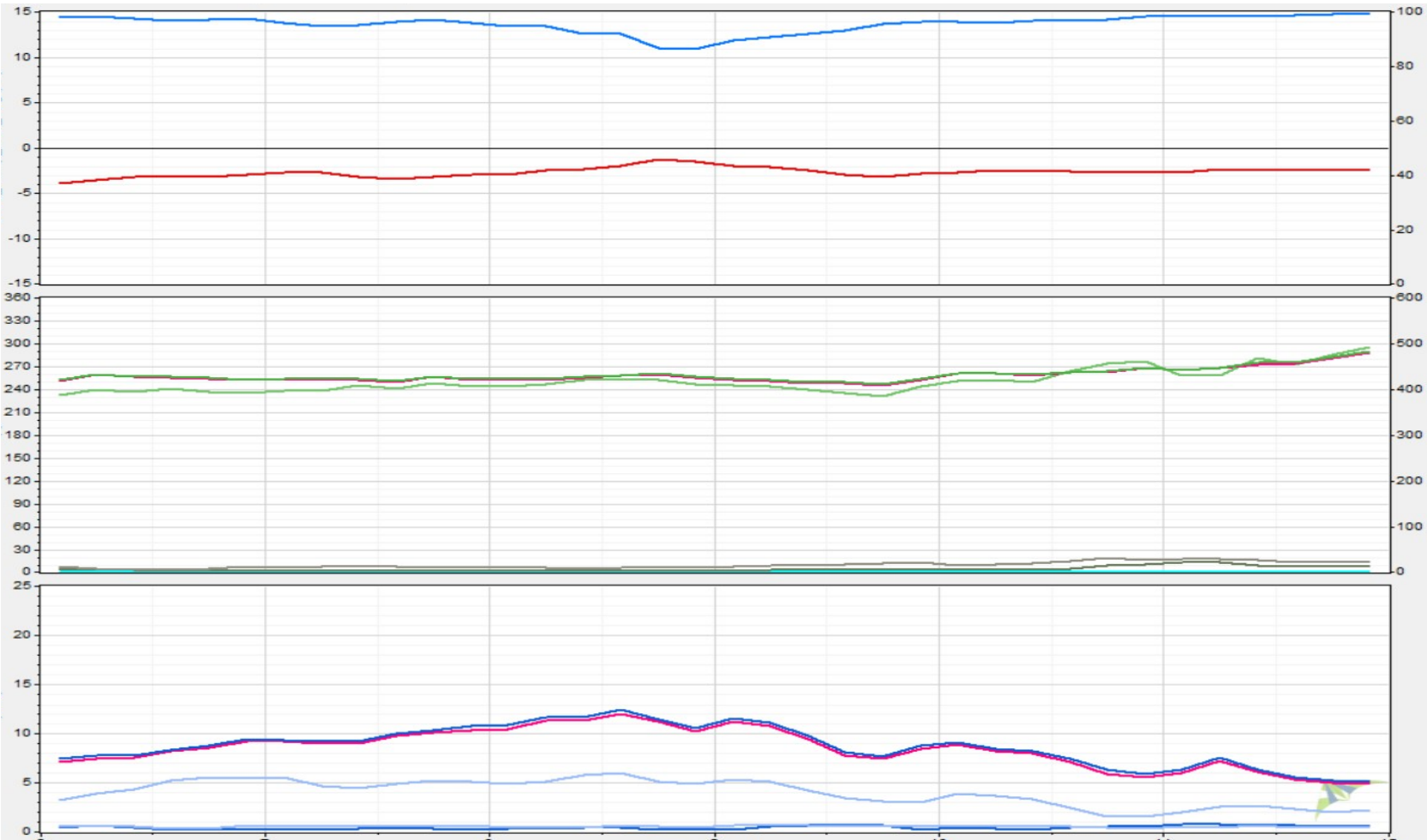
Heated NML instrument: Can it help maximise data retention at all mast levels?



PPT in Cold Climates

Data Collection in Cold Weather

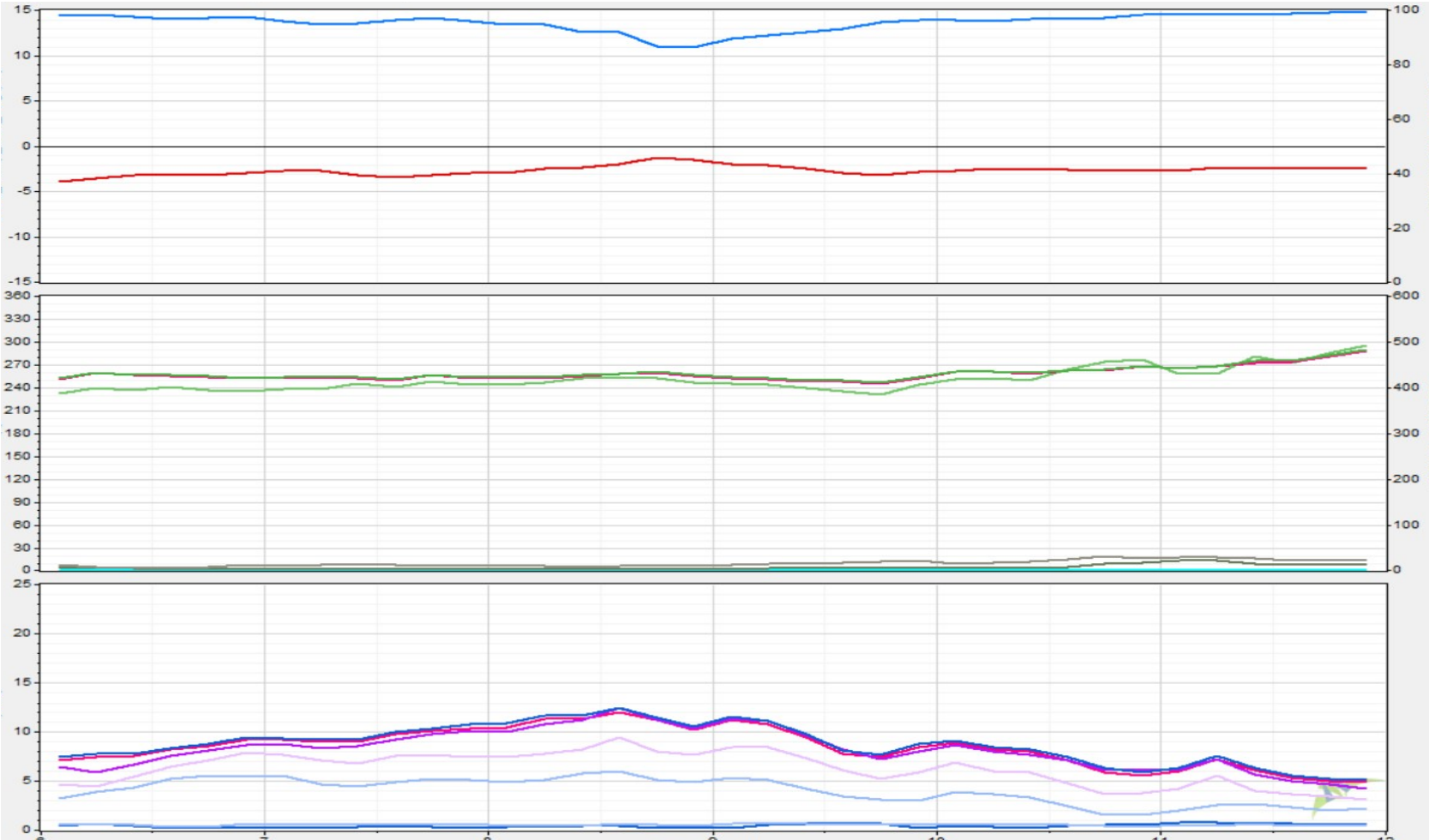
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PPT in Cold Climates

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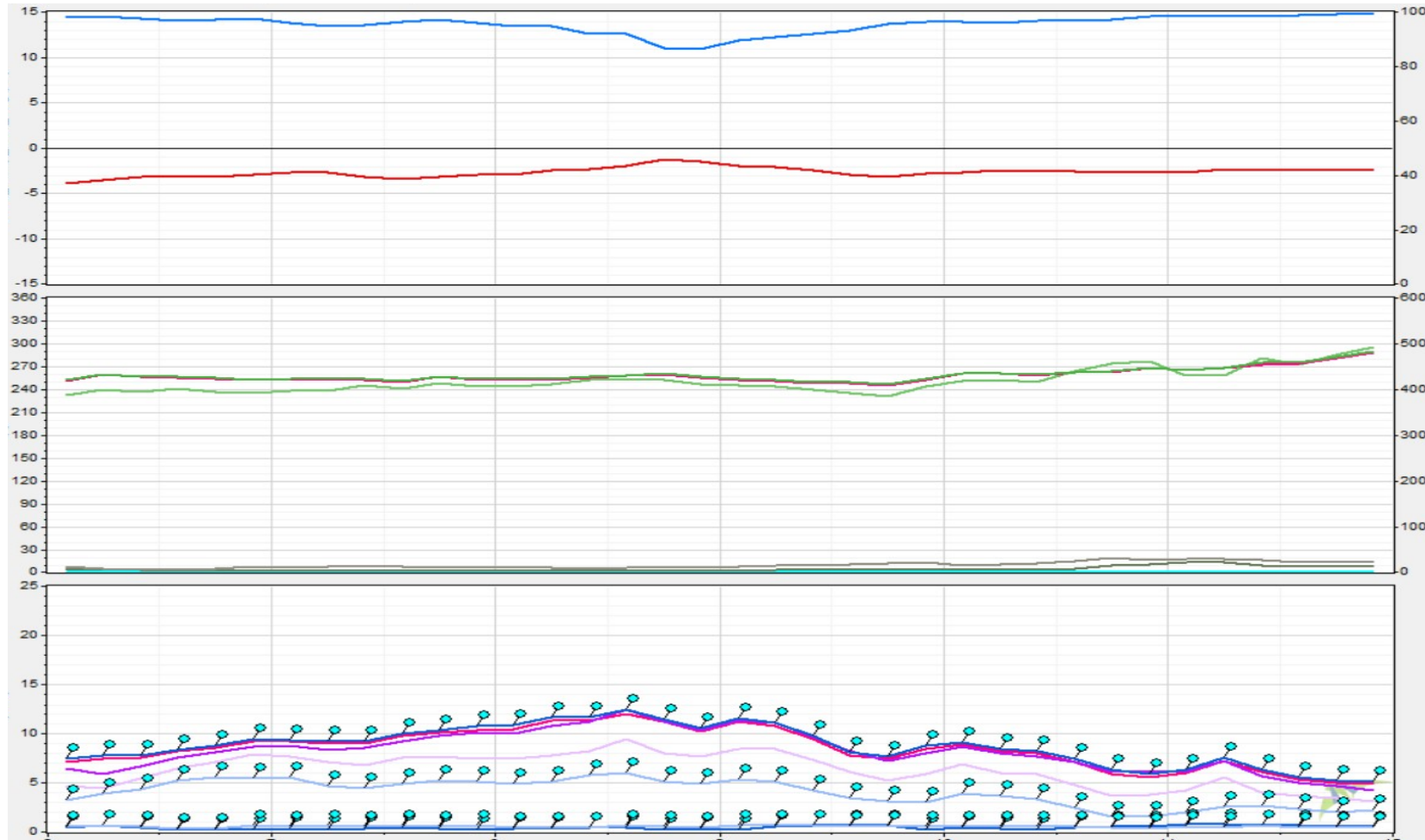
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PPT in Cold Climates

Data Collection in Cold Weather

Heated NML instrument: Can it help maximise data retention at all mast levels?



Summary

Key Solutions to the Challenges

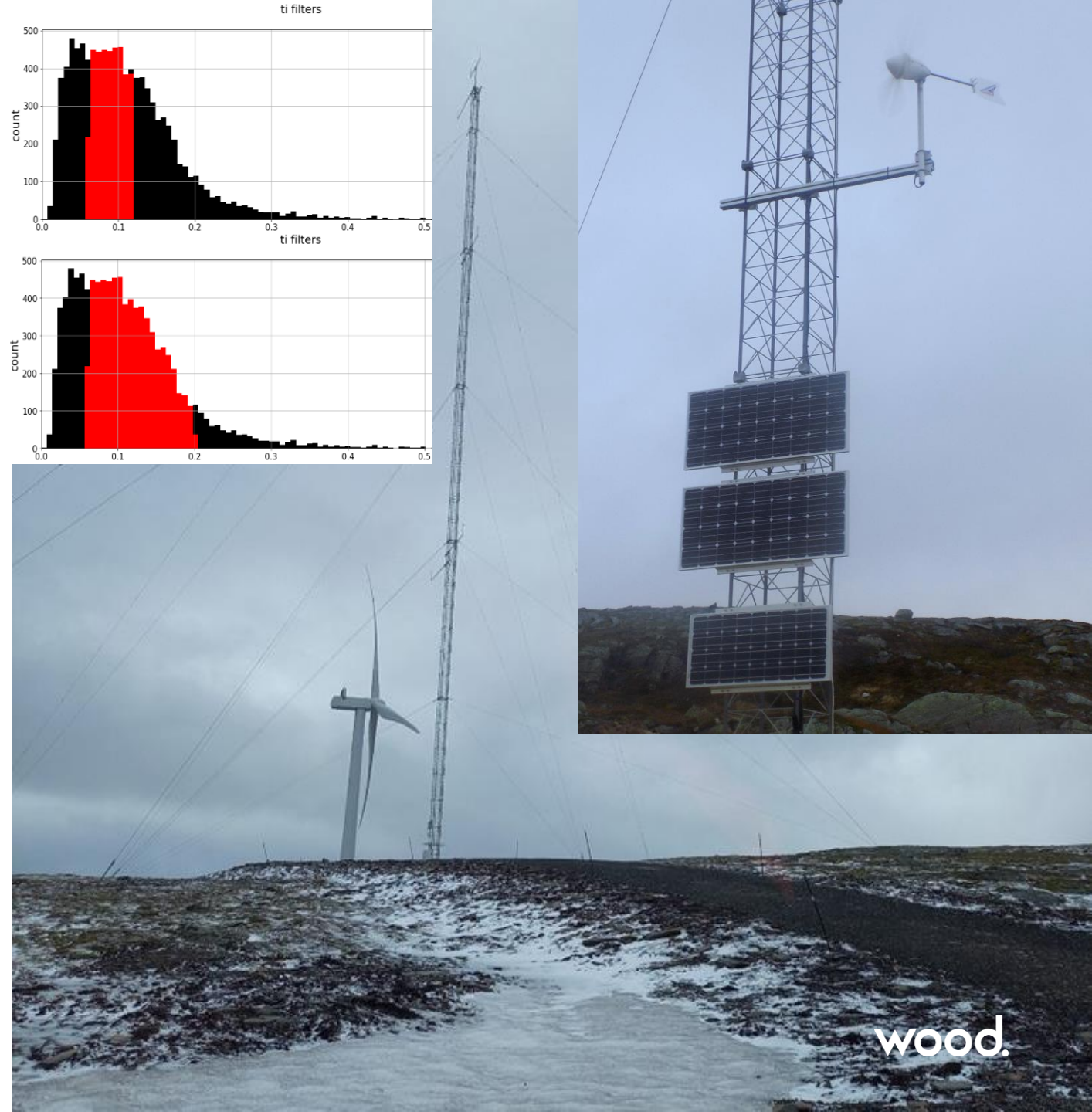
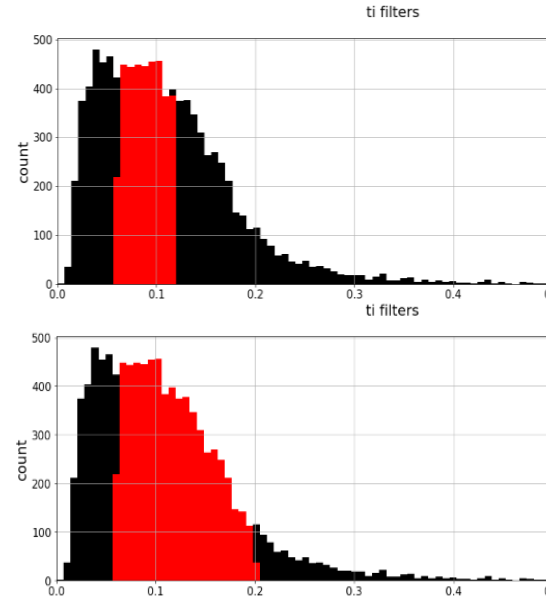
- Plan PPT into the construction schedule
 - Facilitate open communication between construction team and measurement experts
 - Arrange masts around roads and hardstands
 - Erect site calibration masts as early as possible



Summary

Key Solutions to the Challenges

- Measure meteorological parameters early in site development
 - Include a heated 3D USA to measure flow verticality!
- Fit PC filters to the site conditions
 - Communicate with WTG OEM and independent expert – cross-party agreements are possible and fruitful
- Power masts from multiple sources



Power Curve Tests in Cold Climates on Complex Terrain

Well-proven Process

- Checks warranted performance is met
- Identifies opportunities to optimize

Planning

- Engage early to:
 - Maximise benefits
 - Manage challenges

Experience

- Work collaboratively with open communication throughout process

End the first years of operation with a clear picture of wind farm power performance



Power Curve Tests in Cold Climates on Complex Terrain

With thanks to our Clients
for the use of Project data:

Suomen Hyotytuuli Oy

Statkraft

Austri

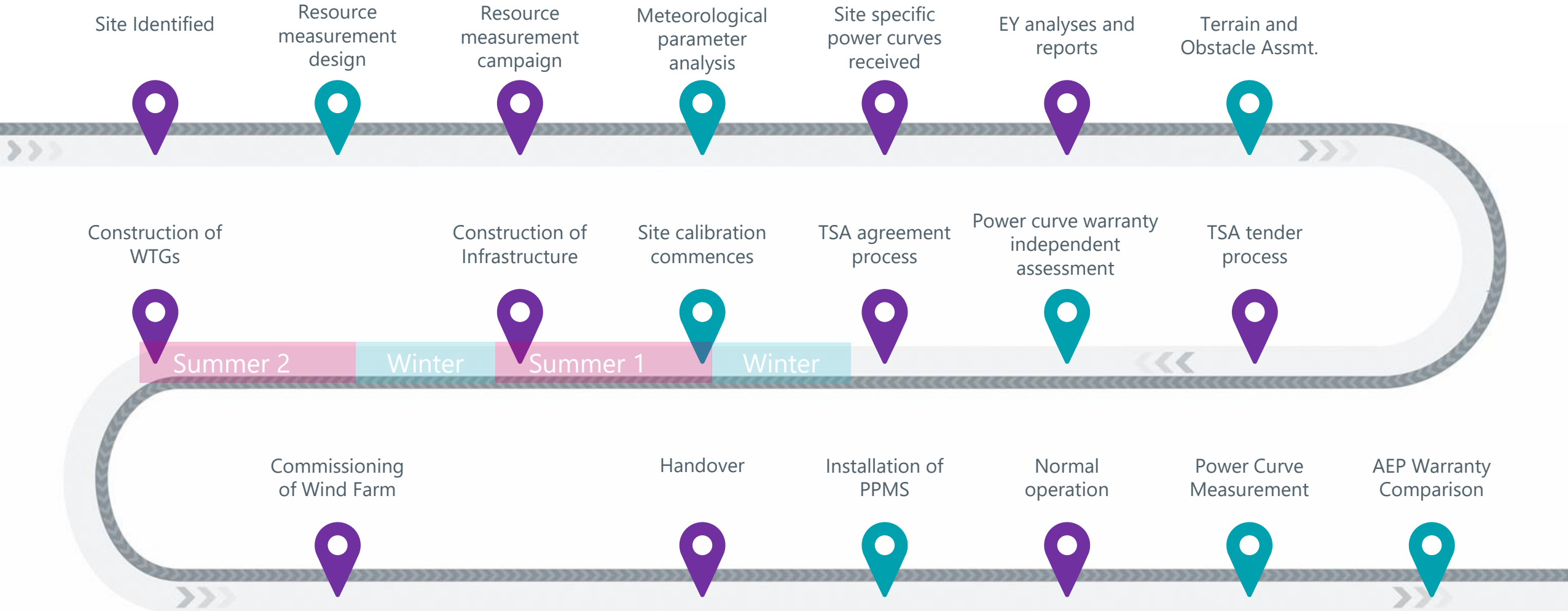
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PPT in Relevant Wind Farm Development Stages

Optimised Solution for Cold and Complex Sites



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PPT in Cold Climates

Working with Construction Schedule



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