

Excluding context by means of fingerprint for wind turbine monitoring

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Kerman López de Calle Etxabel| Trondheim, 17th January 2019

Why monitor gearboxes?

- Longest downtimes
- High failure frequencies*
- High costs



Typical sensors for gearboxes



Our research

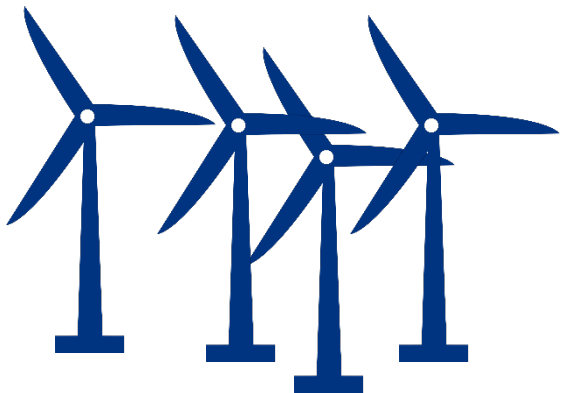
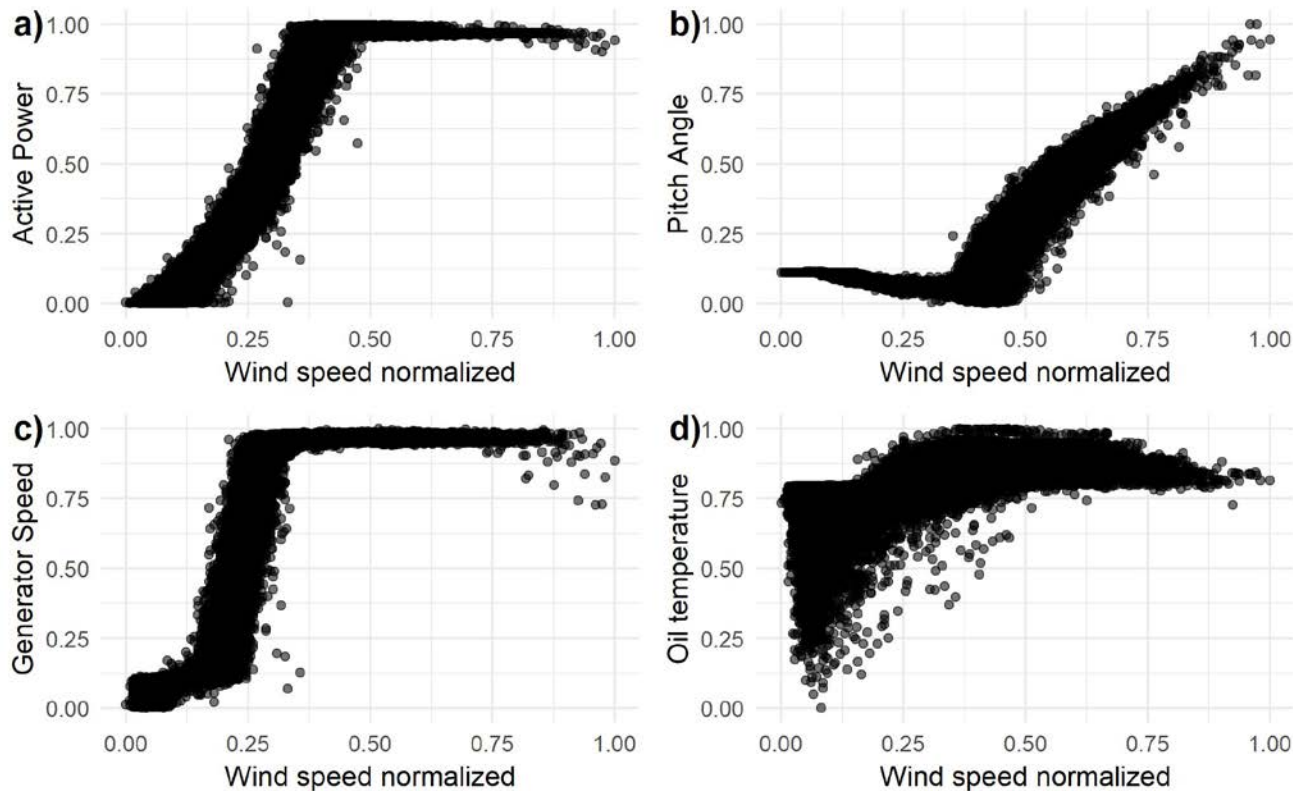


Table 1. Variables available in the dataset by data source.

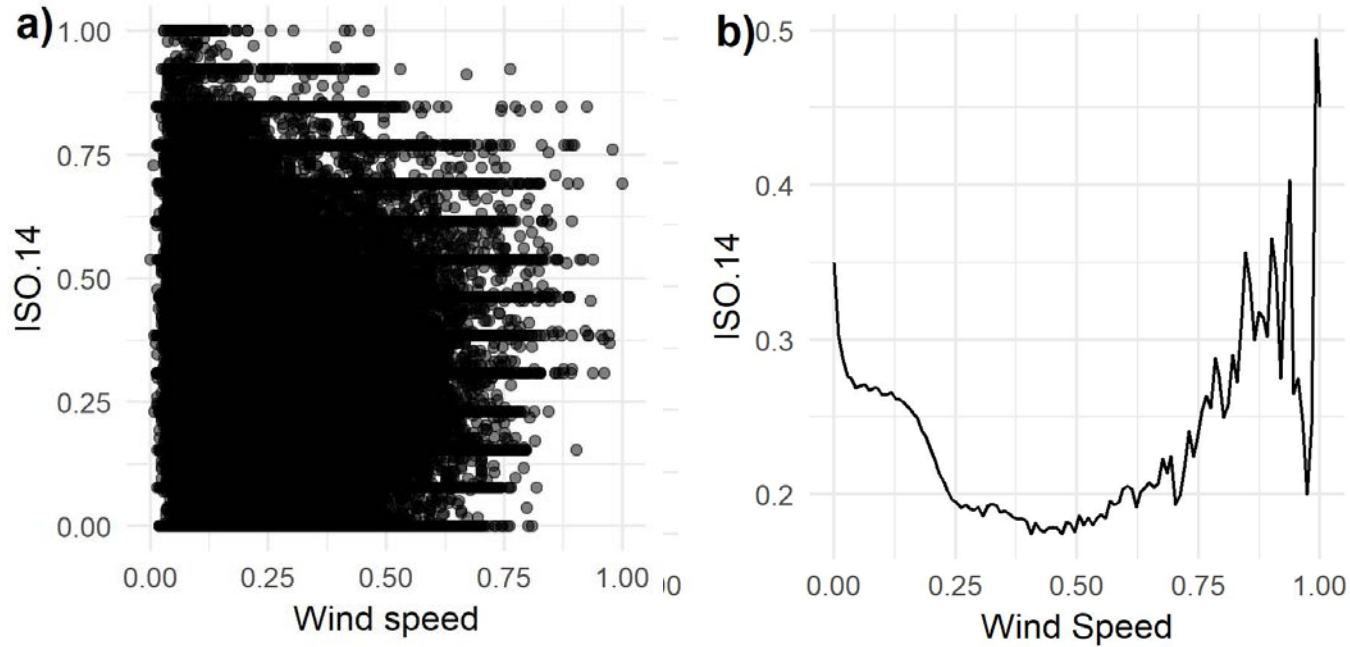
Source	Variable
SCADA	Pitch angle
	Gearbox Temperature
	Wind speed
	Generator speed
	Active power
Oil-debris sensor	ISO.4
	ISO.6
	ISO.14
	BUBBLES

June – January ~ 6 months
T = 1 minute

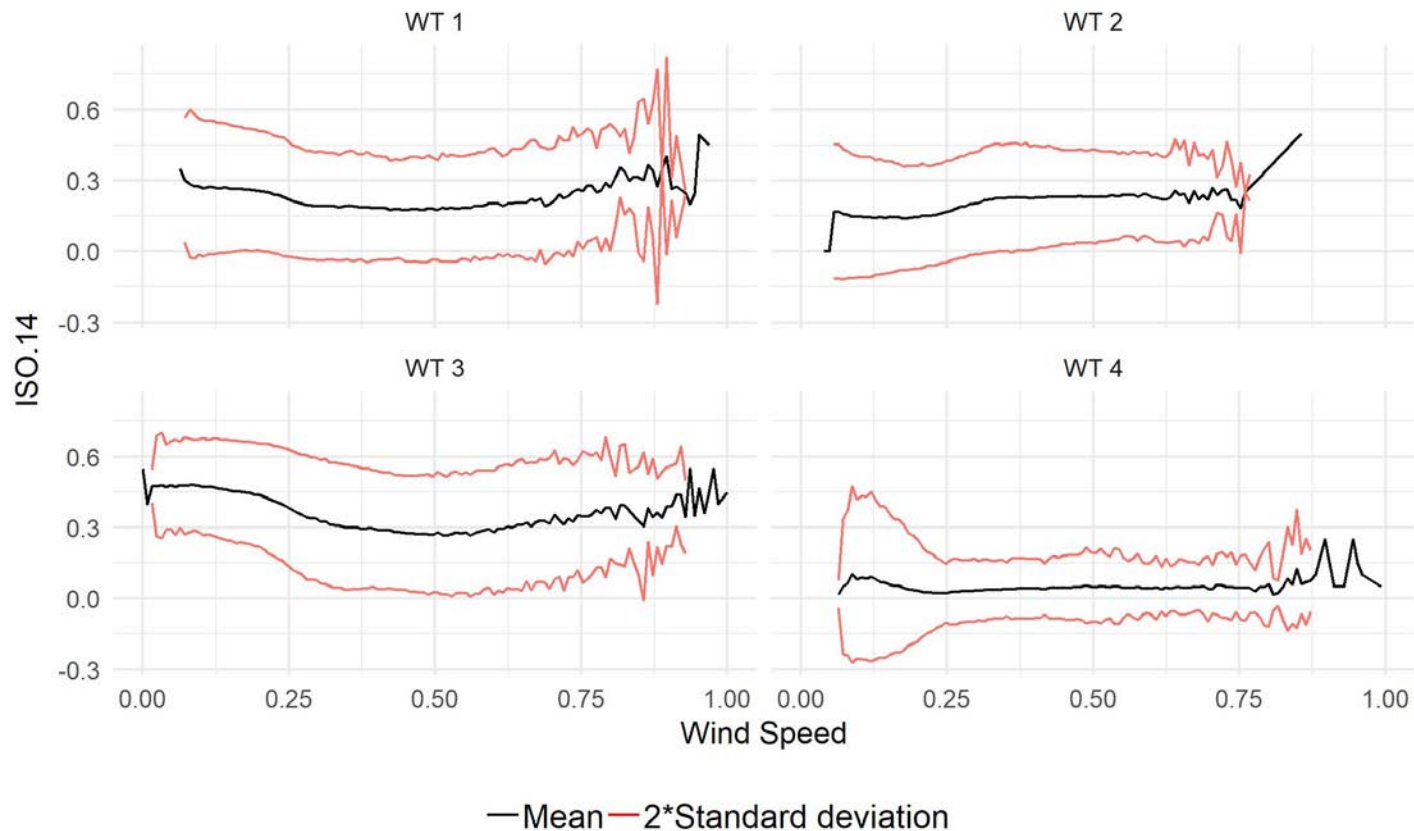
Complex operation context



Particles/wind speed relation during power production

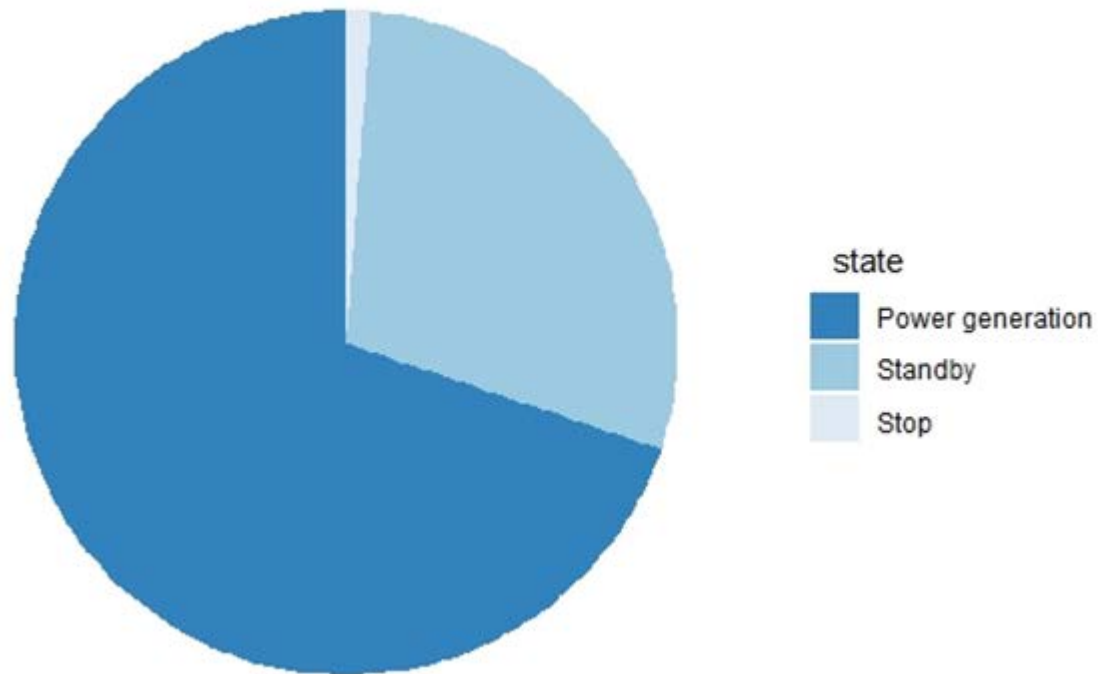


By turbine

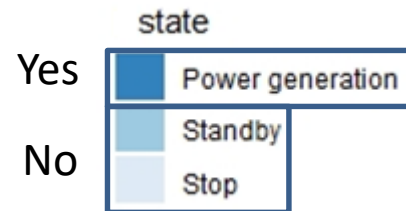
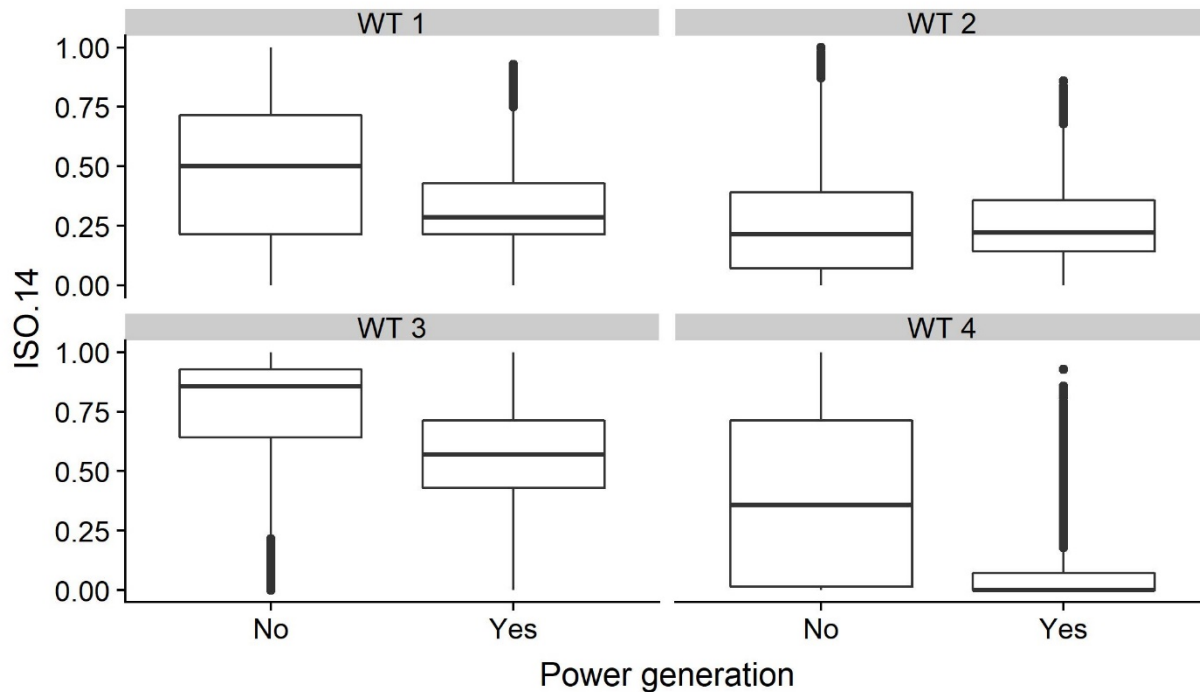


Complex operation context

Distribution of working states

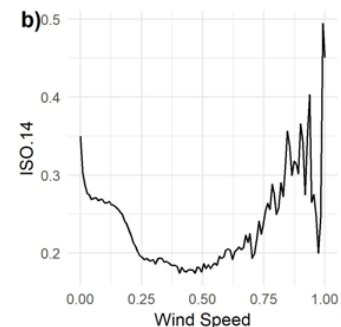
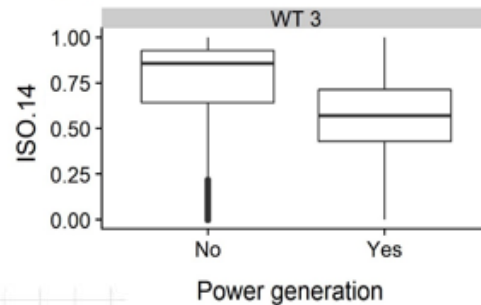


Particles w/ & w/o Power generation

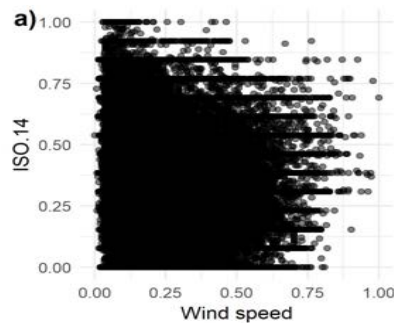


Influence of operation in particle creation

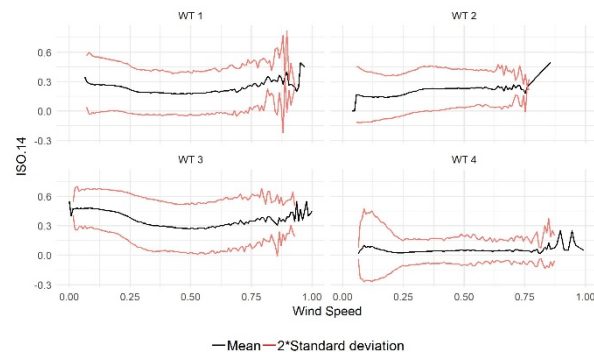
- Different particle creation rates



- No clear correlation



- Differences among WTs

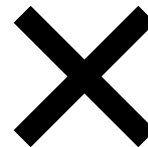


Context matters

Context



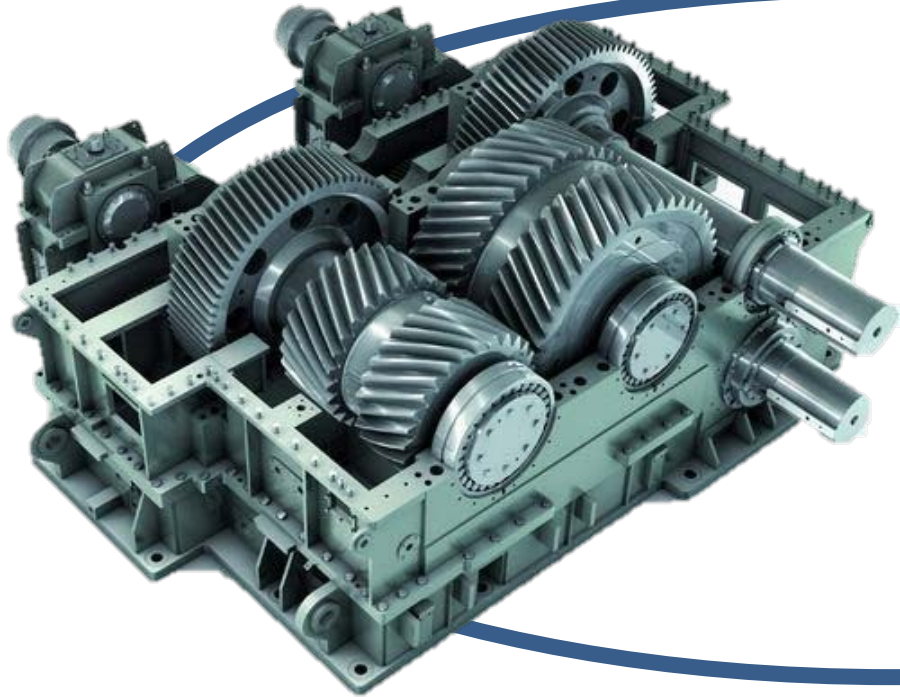
158 bpm



158 bpm



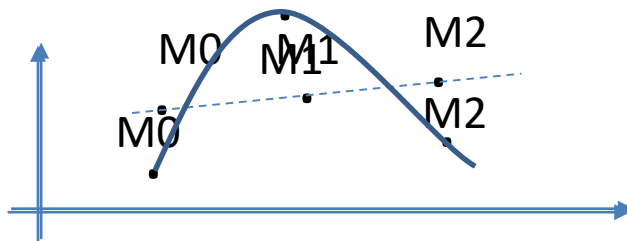
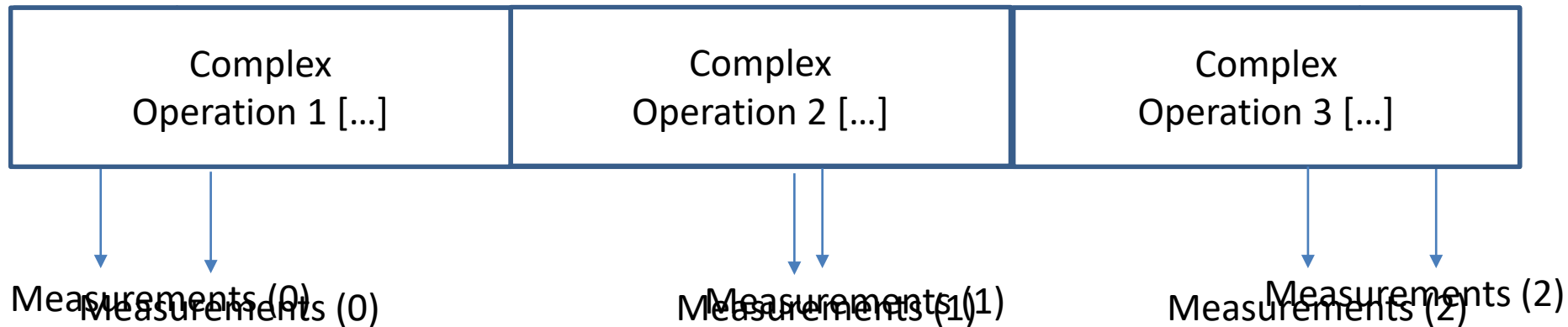
Complex operation



Context



Fingerprint



Fingerprint: Not applicable

- Impossible to force operation.

Instead:


- Find equally comparable contexts
 - Analyse frequency of occurrence
 - Analyse steadiness
 - Validate the results

Events

Groups of subsequent data points fulfilling specific criteria.

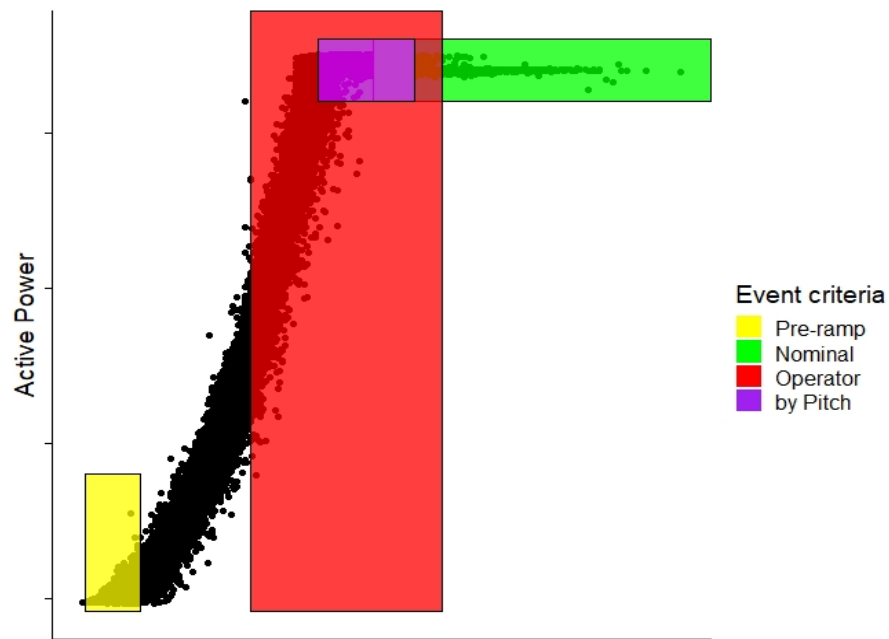


Follow a
chronological order



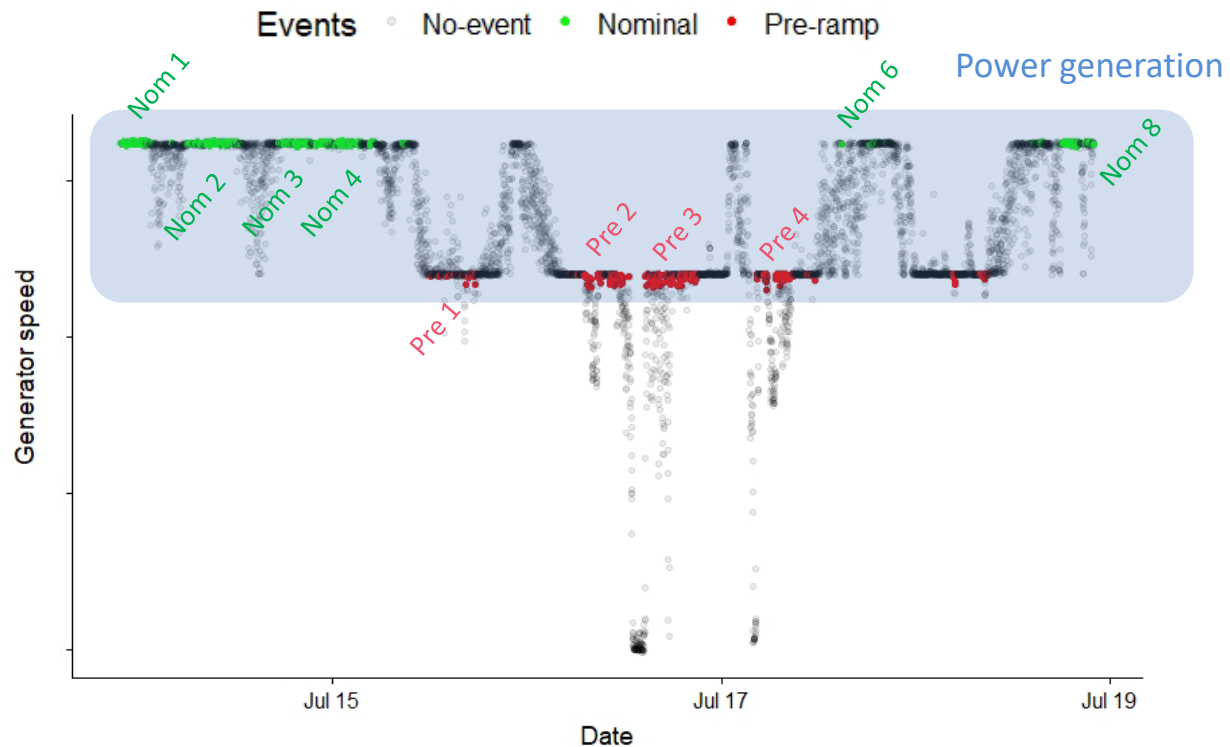
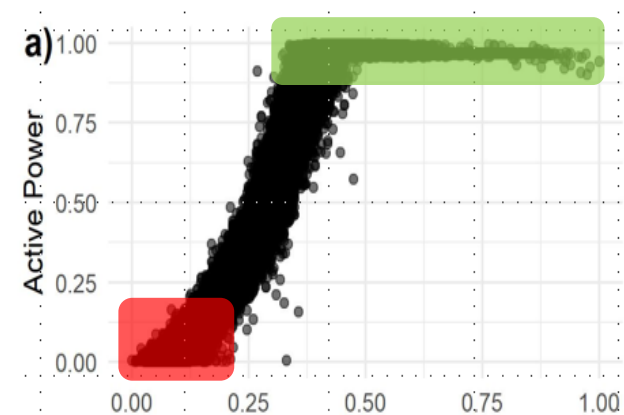
Enclosed under some
operation conditions

Event criteria



Event Criteria	Characteristic
Nominal	Stable power generation. Varying pitch
By pitch	Similar to nominal, but more restrictive and not including high windspeeds, delimited using pitch values.
Operator	Ranges from about the middle of the power curve to beginning of nominal.
Pre-ramp	Values taken before the generator speed ramp starts.

Events: Subsequent time instances



Frequency of occurrence

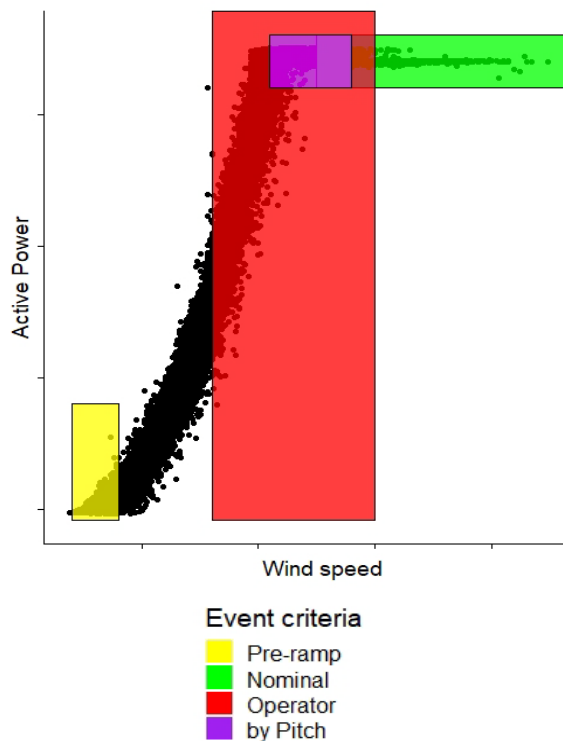
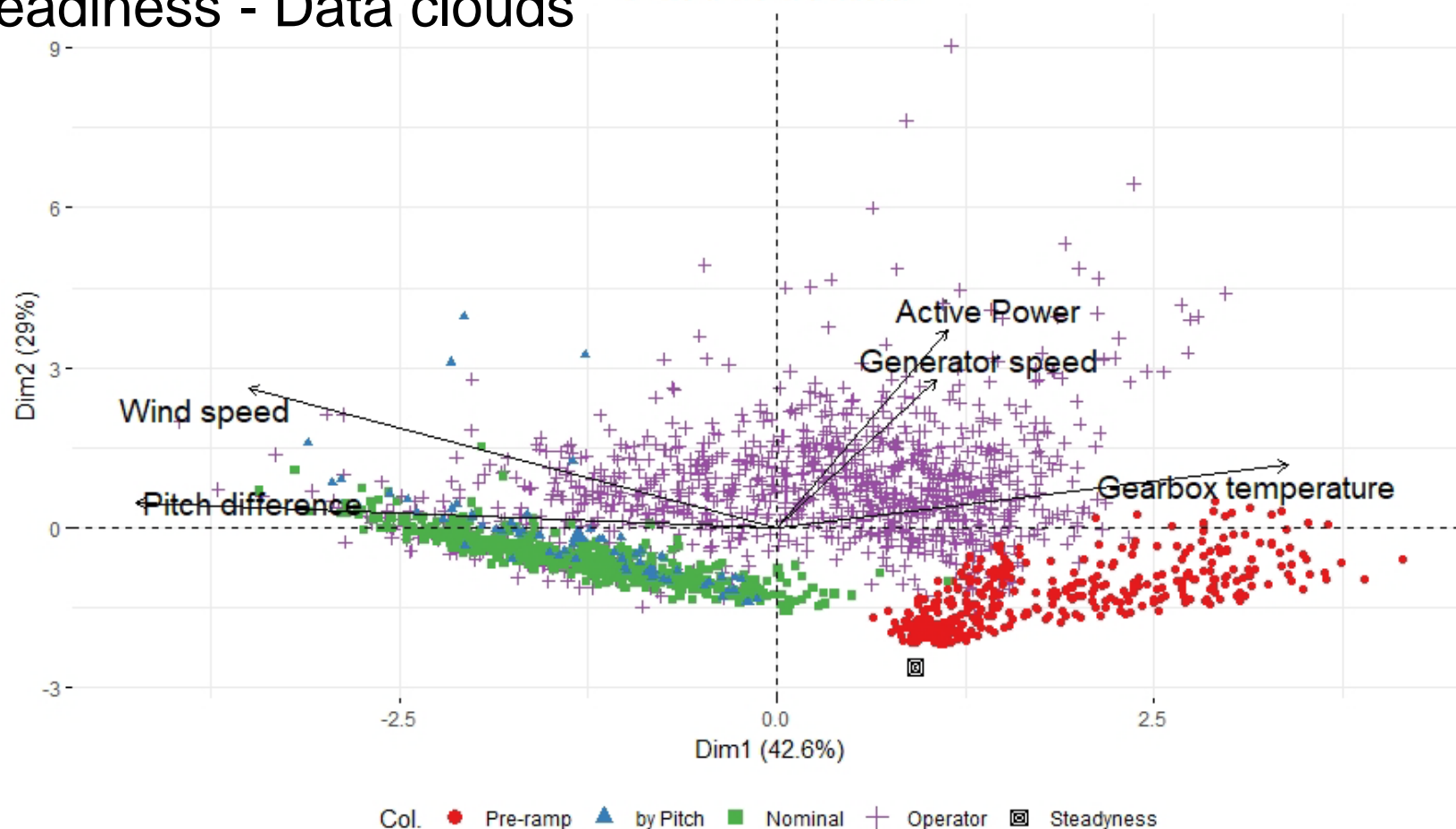


Table 3. Number of events and week rate by turbine and event criteria with different minimum length time filters.

Turbine	Event kind	>10	>10 week rate	>15	>15 week rate	>30	>30 week rate
WT 1	by Pitch	64	2	30	1	8	0
WT 1	Nominal	532	18	357	12	189	6
WT 1	Operator	1159	39	794	26	417	14
WT 1	Pre-ramp	367	12	155	5	25	1
WT 2	by Pitch	15	1	6	0	2	0
WT 2	Nominal	507	17	339	11	183	6
WT 2	Operator	1057	35	758	25	427	14
WT 2	Pre-ramp	325	11	140	5	29	1
WT 3	by Pitch	103	3	50	2	21	1
WT 3	Nominal	600	20	410	14	206	7
WT 3	Operator	1159	39	820	27	453	15
WT 3	Pre-ramp	403	13	174	6	19	1
WT 4	by Pitch	63	2	35	1	11	0
WT 4	Nominal	330	11	216	7	108	4
WT 4	Operator	830	28	577	19	315	11
WT 4	Pre-ramp	173	6	76	3	11	0

Steadiness - Data clouds

PCA of events

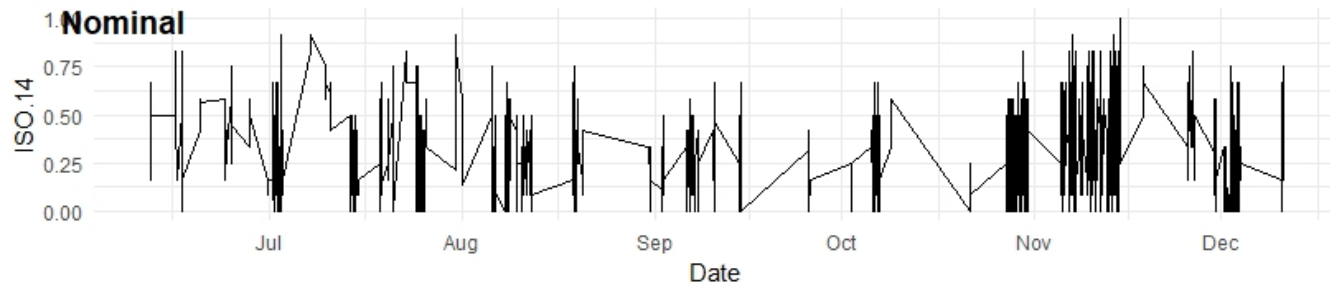
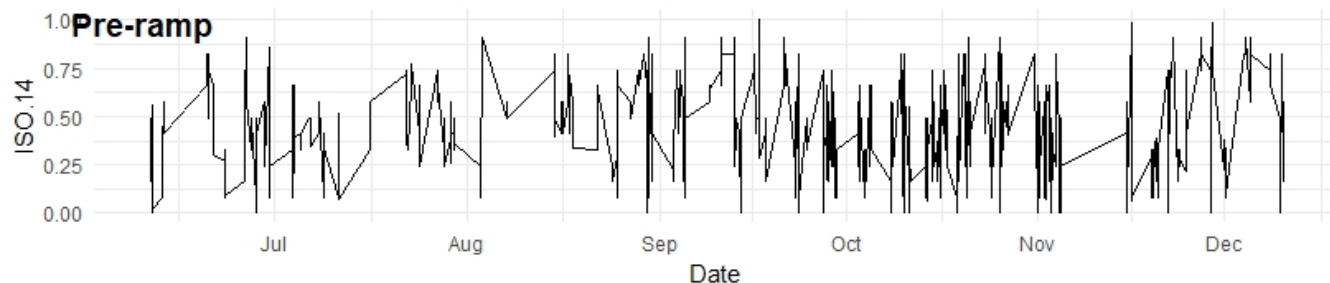
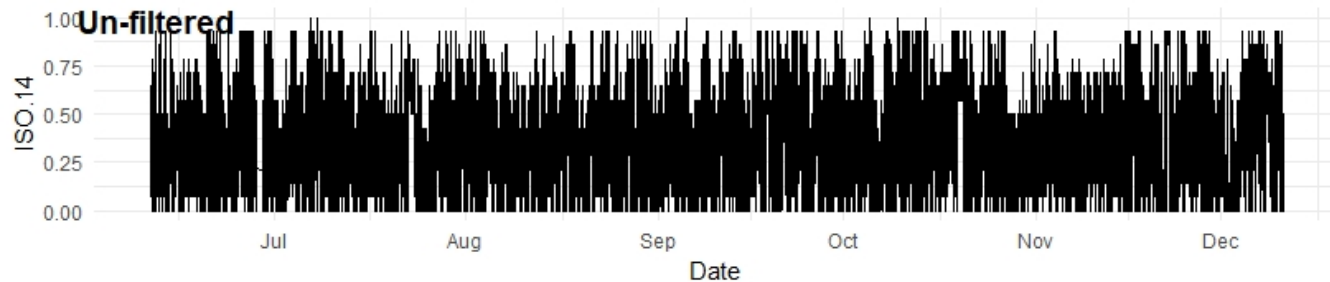


Distance to steadiness

Table 5. Euclidean distances from centroids to steadiness by turbine

WT	by Pitch	Nominal	Operator	Pre-ramp
WT 1	0.0549	0.0474	0.1191	0.0117
WT 2	0.0404	0.0352	0.1198	0.0136
WT 3	0.0563	0.0483	0.1107	0.0138
WT 4	0.0513	0.0535	0.1267	0.0116

Context extraction validation



Conclusions

- Measurements influenced by operation.
- Differences among WT behaviors
- Higher particle rates at low wind speeds
- Frequent event criteria
- Steady event criteria*
- Coincidences with oil debris sensor

Fuzzy relation.

Missing information?

Generator speed? Inertias?

Wide & Short t filter (Nominal/Operator)

Not in power-ramp (Pre-ramp<Nom.<byPit.)

Context is important

Future works

- Inside out
- Include past in events
- Try to model behaviour
- Suggestions?

Sugquestions?

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