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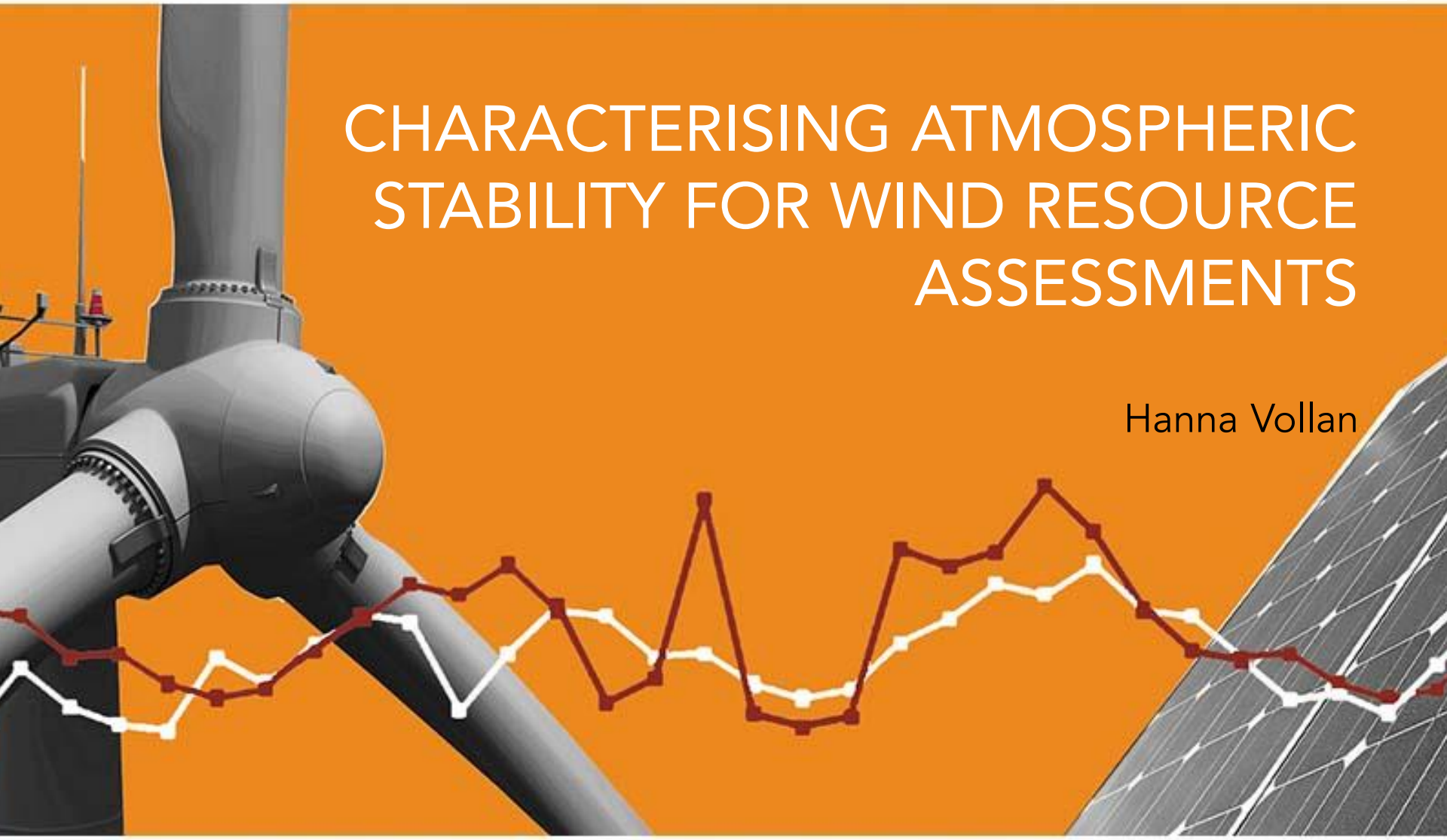
K2 MANAGEMENT

CHARACTERISING ATMOSPHERIC STABILITY FOR WIND RESOURCE ASSESSMENTS

Hanna Vollan

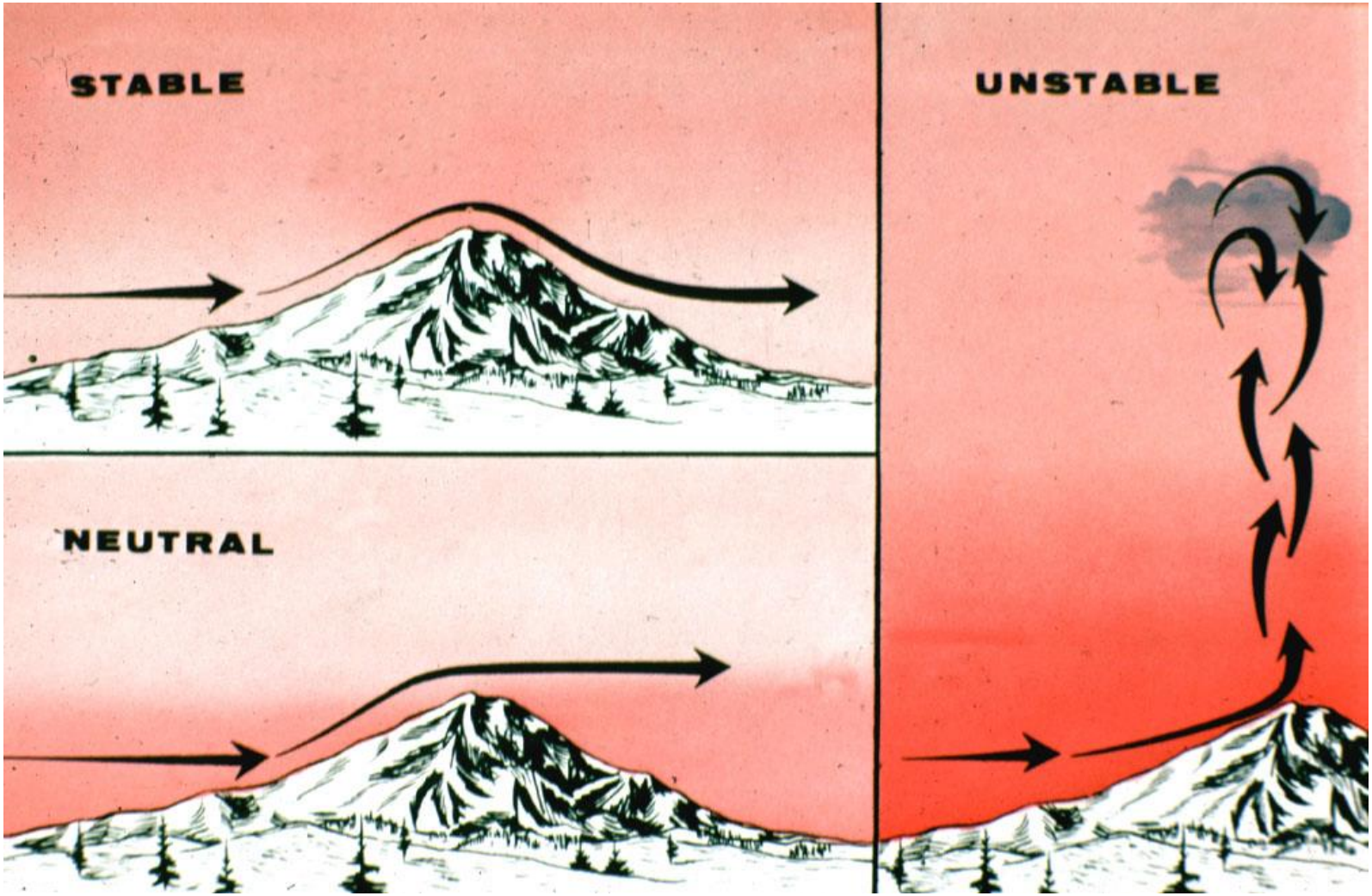


Defensible analysis. Informed investment.

OVERVIEW OF PRESENTATION

- Quick overview of atmospheric stability theory
- Assessing current characterisation approaches
- Propose an alternative approach
  - Stability indicator
  - Reanalysis data

ATMOSPHERIC STABILITY



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ATMOSPHERIC STABILITY

Stability level	Definition
Unstable	Turbulence is caused by solar ground heating, warming the air close to the ground and causing it to rise. Cooler air from the surrounding area is drawn in to replace the rising air. Vertical mixing is prevalent.
Neutral	Turbulence mainly caused by orography, producing swirling eddies. Mixing occurs both horizontally and vertically.
Stable	Flow is increasingly laminar and there is low turbulence. Stability suppresses eddies even when the wind is displaced by terrain.

RELEVANCE IN WIND RESOURCE ASSESSMENTS

- Stability affects
  - Shear
  - Wind flow across the site
  - Turbulence
  - By extension; wind turbine performance and wake losses
- Cold climates
  - Large seasonal and diurnal stability variations

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CURRENT CHARACTERISATION APPROACH

- Using shear and turbulence from site measurements
  - Easily derived from anemometer measurements ✓
  - Stability variations affect shear and turbulence ✓
  - The parameters are also affected by local terrain and ground cover ✗
  - Data coverage e.g. instrument icing ✗
  - Does not take temperature gradient into account ✗

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CHARACTERISING STABILITY

- Richardson number is a measure of dynamic stability

$$Ri = \frac{g}{\overline{\theta_v}} \frac{\Delta\theta_v / \Delta z}{\left(\Delta U / \Delta z\right)^2} \rightarrow \begin{cases} > 0 & Stable \\ = 0 & Neutral \\ < 0 & Unstable \end{cases}$$

θ_v is potential virtual temperature
g is acceleration due to gravity
U is windspeed
z is height

CHARACTERISING STABILITY

- Deriving Richardson number from mast data;
  - Measured onsite ✓
  - Availability of instrumentation ✗
  - Calibration ✗
  - In cold climates; icing affecting data coverage ✗

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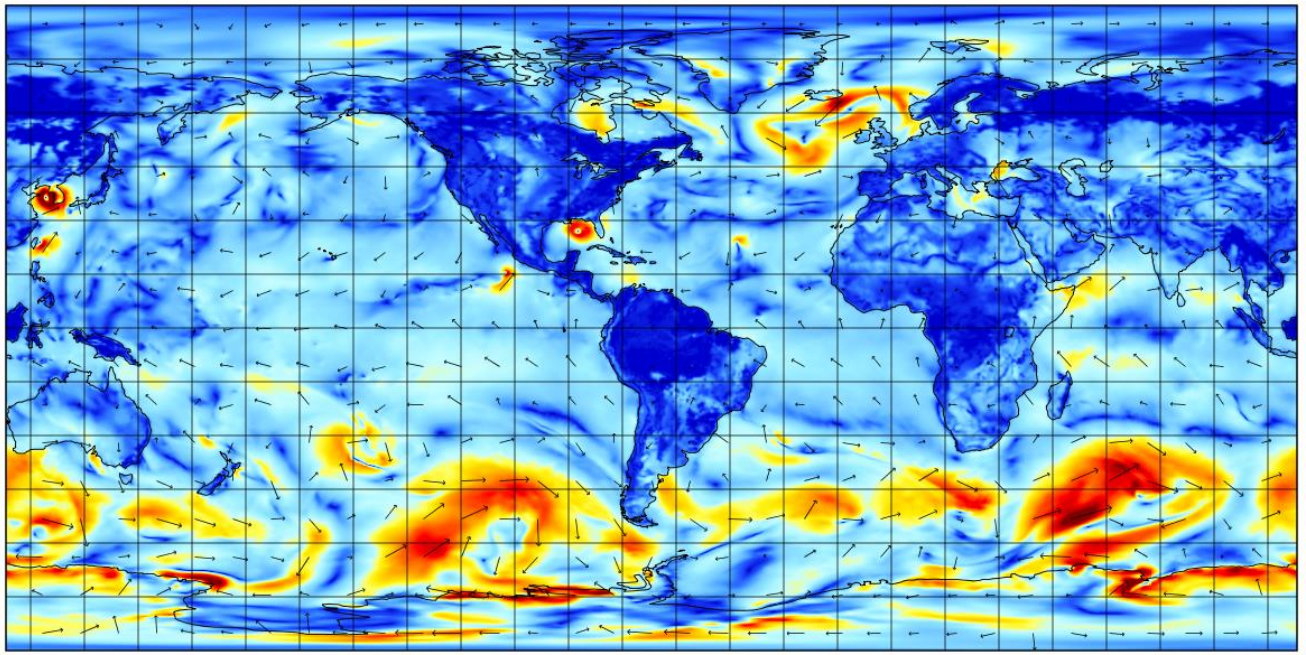
CHARACTERISING STABILITY

- Proposed method – use reanalysis data



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CHARACTERISING STABILITY

- Comparison of stability indicators derived from mast data and MERRA2
- Using data from:
  - 10 sites in 7 countries
  - Tall masts with high quality measurements
  - Onshore and offshore
- Producing 12x24 matrices

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COMPARISON WITH MAST DATA – SWEDISH SITE

Hour	Month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	0.7	0.6	0.5	1.0	1.3	1.5	1.7	1.2	1.4	0.9	1.0	0.8
1	0.7	0.8	0.7	1.0	1.3	1.5	1.6	1.2	1.3	1.1	1.1	0.7
2	0.9	0.9	0.8	0.9	1.0	1.5	1.7	1.4	1.1	1.1	1.0	0.7
3	1.0	0.7	0.8	1.0	1.0	1.3	1.7	1.4	1.2	0.9	1.0	0.7
4	0.9	0.5	0.7	1.2	0.8	0.4	1.5	1.4	1.2	1.0	1.1	1.0
5	0.8	0.7	0.5	0.9	0.5	-0.4	0.5	1.0	1.1	0.9	0.9	1.3
6	0.8	0.6	0.7	0.3	-0.5	-1.6	-0.7	0.8	1.0	1.0	1.0	1.3
7	0.7	0.6	0.4	-0.4	-1.2	-2.2	-2.3	-0.6	0.5	0.9	0.8	1.3
8	0.9	0.7	0.3	-1.2	-1.5	-2.6	-2.9	-1.8	-0.3	0.7	0.7	1.2
9	0.8	0.5	-0.3	-1.9	-1.8	-2.7	-3.3	-2.6	-0.9	0.2	0.7	1.4
10	0.7	0.5	-1.1	-2.2	-1.8	-2.5	-3.0	-2.8	-1.8	-0.3	0.5	1.5
11	0.5	0.0	-1.5	-2.3	-2.0	-2.5	-3.1	-2.7	-2.0	-0.7	0.5	1.3
12	0.5	-0.2	-1.4	-2.7	-2.0	-2.4	-2.7	-2.6	-1.9	-1.0	0.5	0.7
13	0.5	-0.2	-1.2	-2.4	-1.8	-2.1	-2.8	-2.4	-1.6	-1.0	0.6	0.7
14	0.6	0.0	-0.9	-1.9	-1.6	-2.0	-2.6	-2.1	-1.4	-0.6	0.5	1.0
15	0.6	0.5	-0.3	-2.0	-1.7	-2.1	-2.4	-1.8	-0.8	0.2	0.7	1.0
16	0.8	0.7	0.1	-1.6	-1.5	-1.5	-1.8	-1.3	-0.2	1.0	0.8	1.1
17	0.5	0.9	0.4	-0.5	-1.0	-1.3	-1.1	-0.1	0.8	1.1	0.9	1.0
18	0.8	0.7	0.4	0.5	-0.3	-0.6	-0.3	0.6	1.3	1.0	0.9	1.0
19	0.8	0.7	0.6	1.1	0.6	0.1	0.6	1.1	1.2	1.0	0.8	1.2
20	1.0	0.7	0.6	1.1	1.2	0.9	1.4	1.3	1.1	1.0	0.7	1.1
21	0.8	0.7	0.8	0.9	1.5	1.3	1.7	1.3	1.2	1.0	0.7	0.9
22	0.7	0.7	0.6	1.1	1.4	1.4	1.7	1.3	1.3	1.0	0.7	0.7
23	0.8	0.5	0.5	1.1	1.4	1.6	1.8	1.3	1.3	1.1	0.6	0.7

Mast Richardson number

Hour	Month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	0.5	0.4	0.4	0.9	0.7	0.9	0.8	0.6	0.6	0.3	0.4	0.4
1	0.5	0.3	0.5	0.6	0.7	0.7	0.9	0.7	0.6	0.2	0.3	0.4
2	0.4	0.4	0.4	0.5	0.8	0.7	1.2	0.7	0.6	0.2	0.3	0.4
3	0.5	0.4	0.7	0.6	0.7	0.4	0.7	0.8	0.4	0.3	0.4	0.4
4	0.4	0.6	0.5	0.6	0.2	-0.1	0.0	0.5	0.5	0.3	0.4	0.4
5	0.4	0.9	0.3	0.3	-0.2	-0.5	-0.4	-0.1	0.4	0.2	0.4	0.5
6	0.4	0.4	0.3	0.0	-0.4	-0.5	-0.5	-0.6	0.1	0.2	0.5	0.6
7	0.5	0.5	0.3	-0.2	-0.4	-0.5	-0.6	-0.7	-0.3	0.1	0.6	0.5
8	0.5	0.3	0.1	-0.4	-0.5	-0.6	-0.6	-0.7	-0.4	0.0	0.6	0.3
9	0.5	0.1	-0.1	-0.2	-0.4	-0.7	-0.7	-0.8	-0.4	-0.1	0.4	0.3
10	0.3	0.0	-0.1	-0.2	-0.4	-0.8	-0.7	-0.7	-0.4	-0.2	0.2	0.4
11	0.2	0.0	-0.1	-0.2	-0.4	-0.7	-0.8	-0.6	-0.4	-0.2	0.1	0.4
12	0.3	0.0	-0.1	-0.2	-0.4	-0.7	-0.6	-0.5	-0.3	-0.2	0.0	0.3
13	0.5	0.0	-0.1	-0.2	-0.4	-0.6	-0.5	-0.4	-0.3	-0.1	0.1	0.3
14	0.5	0.1	0.0	-0.1	-0.4	-0.5	-0.3	-0.3	-0.2	0.0	0.3	0.4
15	0.5	0.2	0.0	0.0	-0.3	-0.4	-0.3	-0.2	-0.1	0.2	0.4	0.4
16	0.6	0.2	0.2	0.0	-0.1	-0.2	-0.3	-0.2	0.1	0.4	0.4	0.3
17	0.4	0.2	0.4	0.2	0.0	-0.2	-0.3	-0.1	0.7	0.4	0.5	0.4
18	0.5	0.3	0.5	0.4	0.3	0.0	0.0	0.4	0.8	0.5	0.6	0.5
19	0.5	0.3	0.6	0.8	0.6	0.2	0.3	0.6	0.7	0.6	0.5	0.5
20	0.5	0.3	0.5	0.9	0.7	0.6	0.8	0.7	0.6	0.6	0.4	0.6
21	0.6	0.3	0.8	1.0	0.6	0.9	0.7	0.6	0.5	0.4	0.4	0.4
22	0.6	0.3	0.5	0.9	0.7	1.1	0.6	0.6	0.4	0.4	0.4	0.4
23	0.5	0.3	0.4	0.9	0.7	1.2	0.7	0.6	0.5	0.3	0.5	0.4

MERRA-2 Richardson number

Hour	Month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	0.33	0.37	0.35	0.33	0.34	0.31	0.32	0.34	0.32	0.34	0.33	0.34
1	0.35	0.35	0.34	0.34	0.33	0.31	0.34	0.34	0.34	0.33	0.32	0.33
2	0.35	0.35	0.32	0.34	0.34	0.31	0.34	0.34	0.35	0.32	0.33	0.33
3	0.37	0.34	0.31	0.35	0.35	0.30	0.33	0.33	0.34	0.34	0.32	0.34
4	0.36	0.34	0.33	0.34	0.34	0.32	0.32	0.32	0.33	0.34	0.33	0.34
5	0.37	0.33	0.34	0.34	0.30	0.24	0.27	0.32	0.31	0.34	0.33	0.35
6	0.36	0.36	0.33	0.31	0.25	0.18	0.18	0.28	0.32	0.35	0.33	0.35
7	0.37	0.37	0.33	0.23	0.19	0.15	0.14	0.20	0.30	0.36	0.32	0.34
8	0.38	0.36	0.28	0.16	0.17	0.14	0.11	0.14	0.25	0.33	0.32	0.33
9	0.40	0.36	0.21	0.14	0.17	0.13	0.11	0.11	0.19	0.30	0.32	0.34
10	0.39	0.31	0.17	0.14	0.16	0.14	0.12	0.11	0.15	0.25	0.31	0.34
11	0.40	0.29	0.14	0.14	0.16	0.14	0.12	0.11	0.14	0.22	0.30	0.34
12	0.39	0.26	0.14	0.14	0.16	0.14	0.13	0.13	0.15	0.20	0.31	0.33
13	0.40	0.25	0.14	0.15	0.16	0.13	0.13	0.13	0.15	0.19	0.29	0.34
14	0.39	0.25	0.15	0.16	0.16	0.14	0.13	0.13	0.16	0.22	0.30	0.36
15	0.39	0.26	0.17	0.16	0.16	0.15	0.14	0.15	0.16	0.25	0.31	0.35
16	0.39	0.30	0.19	0.17	0.16	0.15	0.15	0.16	0.20	0.29	0.31	0.35
17	0.38	0.31	0.23	0.20	0.18	0.17	0.16	0.20	0.25	0.31	0.31	0.37
18	0.36	0.35	0.27	0.24	0.21	0.19	0.20	0.24	0.27	0.31	0.31	0.37
19	0.36	0.35	0.29	0.27	0.25	0.22	0.24	0.28	0.29	0.32	0.32	0.34
20	0.33	0.34	0.29	0.29	0.28	0.26	0.27	0.28	0.31	0.33	0.33	0.33
21	0.34	0.32	0.30	0.30	0.29	0.28	0.29	0.29	0.33	0.33	0.33	0.34
22	0.34	0.34	0.33	0.29	0.31	0.29	0.29	0.32	0.34	0.33	0.33	0.32
23	0.35	0.37	0.34	0.31	0.32	0.30	0.31	0.33	0.32	0.33	0.34	0.34

Mast shear exponent

Hour	Month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	7.3	8.1	8.1	7.9	7.0	7.1	6.9	7.4	7.6	8.1	8.3	8.0
1	7.4	7.7	8.1	7.9	6.9	7.3	6.8	7.4	7.4	8.2	8.4	8.1
2	7.7	8.0	8.3	8.0	7.1	7.4	7.1	7.2	7.8	8.1	8.3	8.0
3	7.4	7.5	8.5	7.9	7.2	8.1	7.3	7.4	7.9	7.7	8.3	8.1
4	7.6	8.0	8.3	8.0	7.9	9.6	8.0	7.4	8.0	7.9	8.4	7.9
5	8.0	7.8	8.1	9.1	9.8	11.6	10.0	8.3	8.0	8.0	8.7	7.6
6	8.3	7.5	8.3	10.3	11.8	12.6	12.1	10.1	8.6	8.0	8.6	7.9
7	7.8	7.6	8.9	11.9	13.0	13.3	13.0	12.1	10.2	8.3	8.9	7.8
8	7.6	7.6	10.8	13.0	13.9	14.1	13.8	13.0	11.9	9.3	8.6	7.9
9	7.2	8.9	11.9	13.5	14.5	14.9	14.9	14.4	12.9	10.8	8.9	8.0
10	7.6	10.0	12.8	13.9	15.3	15.4	15.1	14.6	13.8	11.8	9.8	8.4
11	7.5	10.4	13.3	14.3	15.9	16.0	15.7	15.4	14.2	12.3	10.3	8.6
12	7.6	11.2	13.2	14.2	15.8	15.9	15.7	15.3	14.0	12.4	10.4	8.9
13	7.4	11.5	13.1	14.1	15.6	15.6	15.3	15.0	14.0	12.5	9.9	8.5
14	7.4	10.9	13.2	14.2	15.7	15.9	15.5	14.7	13.7	11.7	9.1	8.3
15	7.2	10.2	13.0	13.7	14.9	15.3	15.2	14.1	13.2	10.7	8.9	8.1
16	6.8	9.4	12.2	12.8	14.5	14.4	14.9	12.9	12.0	8.8	8.8	8.3
17	7.0	8.6	10.4	12.3	13.5	13.8	13.3	12.0	9.7	8.3	8.9	8.1
18	6.9	8.4	8.7	10.7	12.2	12.7	12.2	10.3	8.1	8.4	9.0	8.5
19	7.0	8.7	8.3	9.0	10.2	11.4	10.4	8.5	8.0	8.2	8.9	8.3
20	7.1	8.4	8.6	8.2	8.1	9.7	8.4	6.9	7.9	8.4	9.2	8.2
21	7.3	8.3	8.4	8.0	7.2	8.2	7.2	6.8	8.0	8.0	8.9	8.0
22	7.4	8.2	8.2	8.0	6.7	7.5	6.8	7.0	7.7	7.7	8.9	8.1
23	7.1	8.5	8.2	8.0	6.8	7.2	6.7	7.0	7.8	7.9	8.8	8.4

Mast turbulence intensity

prevailing - has joined

K2 MANAGEMENT

COMPARISON WITH MAST DATA – EGYPTIAN SITE

Hour	Month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	2.1	1.8	1.1	1.3	0.9	0.5	0.3	0.3	0.3	0.7	1.5	1.7
1	2.1	1.7	1.0	1.3	0.9	0.5	0.3	0.3	0.3	0.7	1.5	1.7
2	2.0	1.8	1.0	1.4	0.8	0.4	0.3	0.3	0.3	0.6	1.5	1.8
3	2.0	1.8	1.0	1.3	0.8	0.5	0.4	0.5	0.4	0.7	1.6	1.8
4	2.1	1.8	1.0	1.4	1.0	0.6	0.5	0.6	0.5	0.8	1.5	1.7
5	2.2	1.8	1.1	1.4	1.0	0.6	0.6	0.7	0.5	0.8	1.6	1.7
6	2.2	1.9	1.1	1.0	0.1	-0.4	-0.2	0.2	0.3	0.6	1.6	1.8
7	2.0	1.4	-0.2	-1.6	-3.3	-3.6	-3.4	-2.7	-1.8	-0.4	1.0	1.5
8	0.4	-1.1	-3.8	-4.2	-4.5	-4.6	-4.7	-4.6	-3.9	-3.4	-1.5	0.1
9	-3.2	-3.9	-4.6	-4.6	-4.6	-4.7	-4.8	-4.8	-4.3	-4.3	-4.1	-3.1
10	-4.1	-4.3	-4.6	-4.7	-4.8	-4.7	-4.7	-4.8	-4.3	-4.5	-4.5	-4.2
11	-4.2	-4.4	-4.6	-4.7	-4.8	-4.6	-4.7	-4.7	-4.3	-4.4	-4.5	-4.4
12	-4.2	-4.4	-4.7	-4.7	-4.7	-4.7	-4.6	-4.7	-4.2	-4.5	-4.4	-4.3
13	-4.0	-4.5	-4.7	-4.4	-4.7	-4.6	-4.7	-4.7	-4.4	-4.5	-4.4	-4.4
14	-4.1	-4.3	-4.6	-4.5	-4.8	-4.7	-4.7	-4.8	-4.5	-4.3	-4.5	-4.1
15	-3.8	-4.3	-4.6	-4.5	-4.8	-4.7	-4.7	-4.7	-4.6	-4.3	-4.0	-3.5
16	-2.3	-3.8	-4.4	-4.3	-4.7	-4.7	-4.7	-4.6	-4.3	-3.6	-1.9	-1.0
17	0.8	-0.8	-2.6	-3.2	-3.9	-4.1	-4.3	-4.0	-2.5	-0.5	0.8	1.2
18	1.4	1.1	0.7	0.3	-0.5	-1.4	-1.8	-0.6	0.3	0.6	1.2	1.5
19	2.0	1.3	1.0	1.1	0.9	0.4	0.5	0.5	0.6	0.8	1.6	1.8
20	2.1	1.7	1.2	1.3	1.0	0.5	0.7	0.7	0.8	1.1	1.6	1.8
21	2.1	1.8	1.2	1.4	1.0	0.5	0.6	0.8	0.7	1.0	1.6	1.8
22	2.1	1.7	1.2	1.4	1.0	0.5	0.6	0.5	0.5	1.0	1.6	1.7
23	2.2	1.8	1.2	1.3	1.0	0.4	0.4	0.3	0.3	0.8	1.6	1.7

Mast Richardson number

Hour	Month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	0.3	0.4	0.3	0.4	0.3	0.2	0.1	0.2	0.1	0.2	0.3	0.3
1	0.3	0.4	0.3	0.3	0.3	0.1	0.1	0.2	0.1	0.2	0.3	0.3
2	0.3	0.4	0.3	0.3	0.3	0.1	0.1	0.2	0.1	0.2	0.3	0.3
3	0.3	0.3	0.3	0.3	0.3	0.1	0.1	0.1	0.1	0.3	0.3	0.3
4	0.3	0.3	0.3	0.3	0.3	0.1	0.1	0.1	0.1	0.3	0.3	0.2
5	0.3	0.3	0.3	0.3	0.2	0.1	0.1	0.1	0.1	0.3	0.3	0.2
6	0.3	0.3	0.2	0.1	-0.1	-0.1	-0.1	-0.1	0.0	0.2	0.3	0.3
7	0.1	0.0	-0.3	-0.4	-0.5	-0.3	-0.4	-0.3	-0.3	-0.3	0.0	0.1
8	-0.4	-0.6	-0.6	-0.6	-0.6	-0.5	-0.5	-0.4	-0.4	-0.8	-0.6	-0.3
9	-0.7	-0.8	-0.7	-0.8	-0.6	-0.5	-0.7	-0.5	-0.6	-1.2	-1.0	-0.7
10	-0.8	-0.9	-0.8	-0.8	-0.7	-0.6	-0.8	-0.6	-0.7	-1.3	-1.2	-0.8
11	-0.9	-0.9	-0.8	-0.9	-0.7	-0.5	-0.7	-0.6	-0.8	-1.3	-1.3	-0.9
12	-0.9	-0.8	-0.8	-0.9	-0.7	-0.5	-0.7	-0.5	-0.8	-1.3	-1.3	-1.0
13	-0.8	-0.7	-0.7	-0.8	-0.6	-0.4	-0.6	-0.5	-0.7	-1.2	-1.1	-0.9
14	-0.7	-0.6	-0.6	-0.6	-0.4	-0.4	-0.5	-0.4	-0.6	-1.0	-0.8	-0.7
15	-0.5	-0.4	-0.4	-0.4	-0.3	-0.3	-0.4	-0.3	-0.4	-0.6	-0.5	-0.4
16	-0.1	-0.1	-0.1	-0.2	-0.1	-0.1	-0.2	-0.2	-0.2	-0.2	0.0	0.0
17	0.2	0.2	0.2	0.1	0.0	0.0	-0.1	0.0	0.0	0.2	0.3	0.3
18	0.2	0.3	0.3	0.4	0.2	0.1	0.1	0.1	0.1	0.2	0.3	0.2
19	0.2	0.3	0.3	0.4	0.3	0.1	0.1	0.1	0.1	0.2	0.3	0.2
20	0.2	0.3	0.3	0.4	0.3	0.1	0.2	0.1	0.1	0.2	0.3	0.2
21	0.3	0.3	0.3	0.4	0.3	0.1	0.2	0.1	0.1	0.2	0.3	0.3
22	0.3	0.3	0.3	0.4	0.3	0.2	0.2	0.1	0.1	0.2	0.3	0.3
23	0.3	0.3	0.3	0.3	0.3	0.2	0.2	0.1	0.1	0.2	0.3	0.3

MERRA-2 Richardson number

Hour	Month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	0.11	0.13	0.16	0.15	0.17	0.16	0.17	0.18	0.18	0.18	0.14	0.13
1	0.12	0.16	0.15	0.15	0.16	0.16	0.16	0.17	0.17	0.17	0.14	0.13
2	0.13	0.14	0.15	0.14	0.16	0.16	0.16	0.18	0.17	0.16	0.15	0.13
3	0.13	0.14	0.17	0.16	0.16	0.16	0.16	0.15	0.16	0.17	0.15	0.12
4	0.12	0.12	0.15	0.16	0.16	0.16	0.15	0.15	0.16	0.16	0.16	0.13
5	0.11	0.15	0.15	0.16	0.15	0.16	0.15	0.16	0.17	0.16	0.16	0.14
6	0.10	0.15	0.16	0.15	0.11	0.11	0.12	0.14	0.16	0.16	0.15	0.13
7	0.11	0.16	0.12	0.08	0.04	0.04	0.05	0.06	0.08	0.13	0.16	0.14
8	0.12	0.11	0.04	0.04	0.03	0.03	0.03	0.03	0.04	0.05	0.08	0.12
9	0.06	0.04	0.03	0.04	0.04	0.03	0.03	0.04	0.04	0.05	0.04	0.05
10	0.05	0.03	0.04	0.04	0.03	0.04	0.04	0.04	0.05	0.05	0.04	0.04
11	0.04	0.04	0.04	0.04	0.03	0.04	0.04	0.04	0.05	0.05	0.04	0.04
12	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.05	0.05	0.04	0.04
13	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.05	0.04	0.04
14	0.04	0.04	0.04	0.04	0.03	0.04	0.04	0.04	0.04	0.05	0.04	0.04
15	0.04	0.04	0.03	0.04	0.03	0.04	0.04	0.03	0.03	0.04	0.04	0.04
16	0.05	0.04	0.03	0.04	0.03	0.03	0.03	0.03	0.04	0.04	0.06	0.07
17	0.12	0.07	0.05	0.04	0.04	0.03	0.03	0.03	0.05	0.10	0.17	0.16
18	0.19	0.15	0.14	0.12	0.09	0.07	0.06	0.09	0.15	0.20	0.19	0.17
19	0.14	0.16	0.18	0.18	0.16	0.16	0.17	0.19	0.19	0.19	0.16	0.14
20	0.12	0.12	0.16	0.17	0.16	0.18	0.18	0.18	0.18	0.17	0.15	0.13
21	0.12	0.11	0.15	0.16	0.15	0.17	0.16	0.18	0.18	0.17	0.14	0.12
22	0.12	0.13	0.15	0.16	0.16	0.17	0.16	0.18	0.19	0.17	0.14	0.13
23	0.12	0.13	0.16	0.16	0.16	0.17	0.16	0.18	0.19	0.18	0.14	0.13

Mast shear exponent

Hour	Month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	8.0	7.0	6.0	8.0	7.0	6.0	6.0	6.0	6.0	6.0	6.0	8.0
1	8.0	8.0	6.0	7.0	7.0	6.0	6.0	6.0	6.0	5.0	6.0	8.0
2	7.0	9.0	6.0	8.0	7.0	6.0	6.0	6.0	6.0	6.0	6.0	7.0
3	7.0	8.0	6.0	6.0	7.0	6.0	6.0	6.0	5.0	6.0	6.0	7.0
4	7.0	8.0	6.0	7.0	8.0	5.0	6.0	5.0	5.0	6.0	6.0	6.0
5	7.0	9.0	6.0	6.0	8.0	6.0	6.0	5.0	5.0	6.0	7.0	7.0
6	6.0	8.0	6.0	8.0	8.0	8.0	7.0	6.0	6.0	5.0	7.0	8.0
7	7.0	8.0	8.0	9.0	8.0	7.0	7.0	7.0	7.0	7.0	7.0	10.0
8	8.0	10.0	9.0	10.0	10.0	8.0	8.0	8.0	7.0	8.0	9.0	10.0
9	10.0	12.0	11.0	13.0	12.0	10.0	10.0	10.0	9.0	9.0	10.0	11.0
10	12.0	14.0	13.0	15.0	13.0	11.0	12.0	11.0	11.0	11.0	12.0	12.0
11	15.0	16.0	14.0	15.0	14.0	11.0	12.0	12.0	12.0	13.0	14.0	14.0
12	17.0	16.0	14.0	16.0	13.0	11.0	12.0	12.0	12.0	13.0	14.0	15.0
13	17.0	14.0	13.0	16.0	12.0	11.0	12.0	11.0	11.0	12.0	13.0	14.0
14	15.0	13.0	12.0	15.0	11.0	11.0	11.0	10.0	10.0	10.0	11.0	12.0
15	12.0	11.0	11.0	13.0	10.0	10.0	10.0	9.0	9.0	9.0	10.0	10.0
16	9.0	10.0	10.0	10.0	9.0	8.0	9.0	8.0	7.0	7.0	8.0	8.0
17	8.0	9.0	8.0	9.0	9.0	7.0	7.0	7.0	7.0	7.0	7.0	9.0
18	8.0	8.0	8.0	8.0	9.0	8.0	7.0	7.0	7.0	6.0	7.0	8.0
19	7.0	8.0	7.0	10.0	8.0	7.0	7.0	7.0	6.0	6.0	6.0	7.0
20	6.0	7.0	7.0	9.0	7.0	7.0	7.0	7.0	6.0	6.0	6.0	8.0
21	7.0	8.0	6.0	8.0	7.0	7.0	7.0	6.0	6.0	5.0	6.0	8.0
22	7.0	7.0	7.0	7.0	7.0	6.0	7.0	7.0	6.0	6.0	6.0	7.0
23	7.0	7.0	6.0	7.0	7.0	7.0	7.0	6.0	6.0	6.0	5.0	8.0

Mast turbulence intensity

prevailing - has joined

K2 MANAGEMENT

CONCLUSIONS

- Benefits of Richardson number from reanalysis data
  - Comprehensive characterisation of stability ✓
  - Consistent ✓
  - No data coverage issues ✓
  - Applicable offshore and onshore ✓
    - Care required for coastal sites ✗

prevailing
- has joined

K2 MANAGEMENT

REDUCING UNCERTAINTIES

- Cross-correlations
- Shear extrapolation
- Wind flow modelling
- Performance losses
- Wake modelling
- Classify and compare sites

prevailing
- has joined
K2 MANAGEMENT

THANK YOU

- Hanna Vollan, Hanna.Vollan@prevailinganalysis.com
- K2 Management office locations:

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