

Wind Modelled Data for Offshore Projects






Vortex Solutions and Experiences

February 16th, 2022

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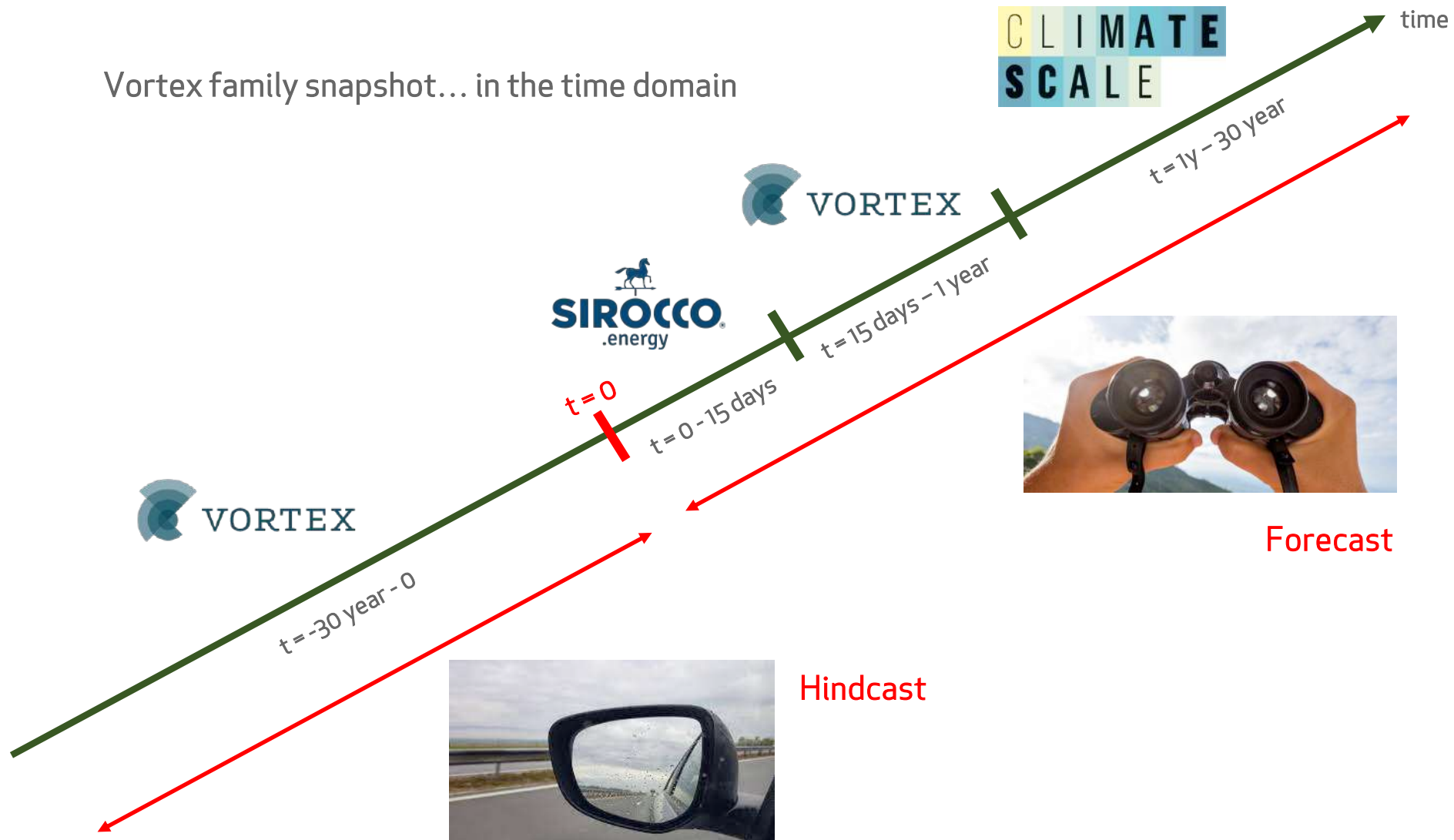
Vortex Fdc Inc.
Industrious Austin
98 San Jacinto Blvd., 4th floor
Austin, TX 78701

For those that may not know much about Vortex...

- Established in 2005 in Barcelona by atmospheric physicists, university researchers (DTU-Risø, University of Oxford), computer experts and former wind engineers with more than 20 years experience in wind resource assessment (Nordex & Ecotècnia - Alstom - GE) 
- Private company, independent of investment funds 
- Modeled wind data global supplier 
- ~~— Consultants (AEP calculations, Site Assessment, Turbine class, Due Dilligence...) ~~
- ~~— Software supplier (licenses, updates, trainings...) ~~

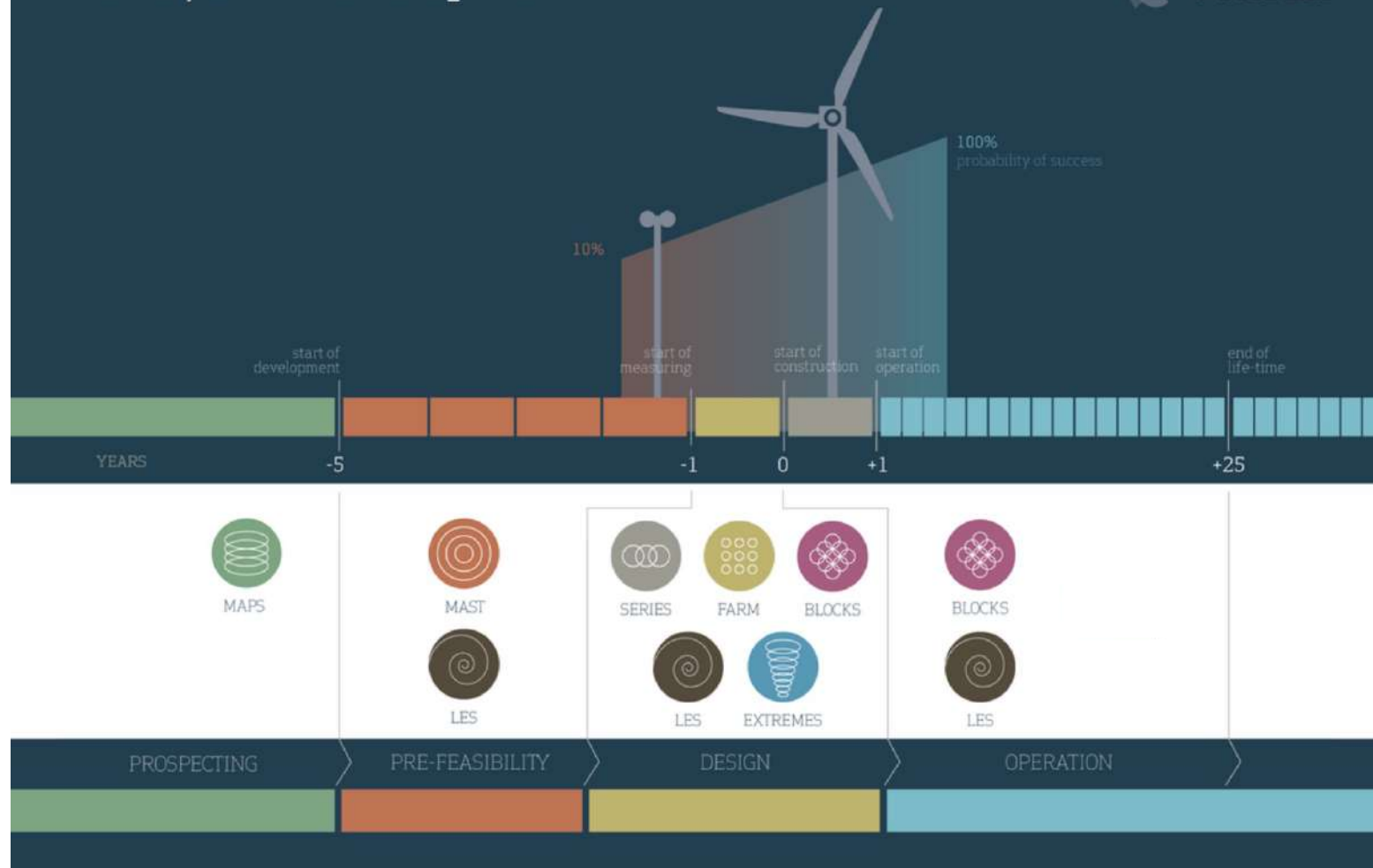
For those that may not know much about Vortex...

Vortex family snapshot... in the time domain



For those that may not know much about Vortex...

Wind farm development



For those that may not know much about Vortex...

The screenshot displays the Vortex web application interface. The top navigation bar includes the Vortex logo, a search bar, and user account options. The main content area shows a map of Africa with a color-coded overlay representing wind or solar data. A sign-up modal is overlaid on the map, titled "Get your free account". The modal text reads: "and gain access to wind and solar data at any coordinate worldwide." and "Check the accuracy yourself by getting an unlimited number of free 6-month time series at sites of your interest." The sign-up form includes fields for "Complete Name", "Email address", "Confirm E-mail", "New password", and "Repeat password". Below the form are two checkboxes: "I agree to Vortex's terms and conditions, privacy policy, and cookies policy.*" and "I want to receive emails from Vortex with products, documents, events, and webinars updates." At the bottom of the modal, there is a link "Already have an account? Log in" and a "Sign Up" button.

Get your free account

and gain access to wind and solar data at any coordinate worldwide.

Check the accuracy yourself by getting an unlimited number of free 6-month time series at sites of your interest.

Complete Name

Email address

Confirm E-mail

New password

Repeat password

☐ I agree to Vortex's [terms and conditions](#), [privacy policy](#), and [cookies policy](#).*

☐ I want to receive emails from Vortex with products, documents, events, and webinars updates.

Already have an account? [Log in](#)

Sign Up

1. VORTEX offshore experience

2. WRF model

3. VORTEX solutions for offshore projects:

- Standard
- Customized

Top offshore wind countries in 2021

Installed offshore wind power capacity in megawatts

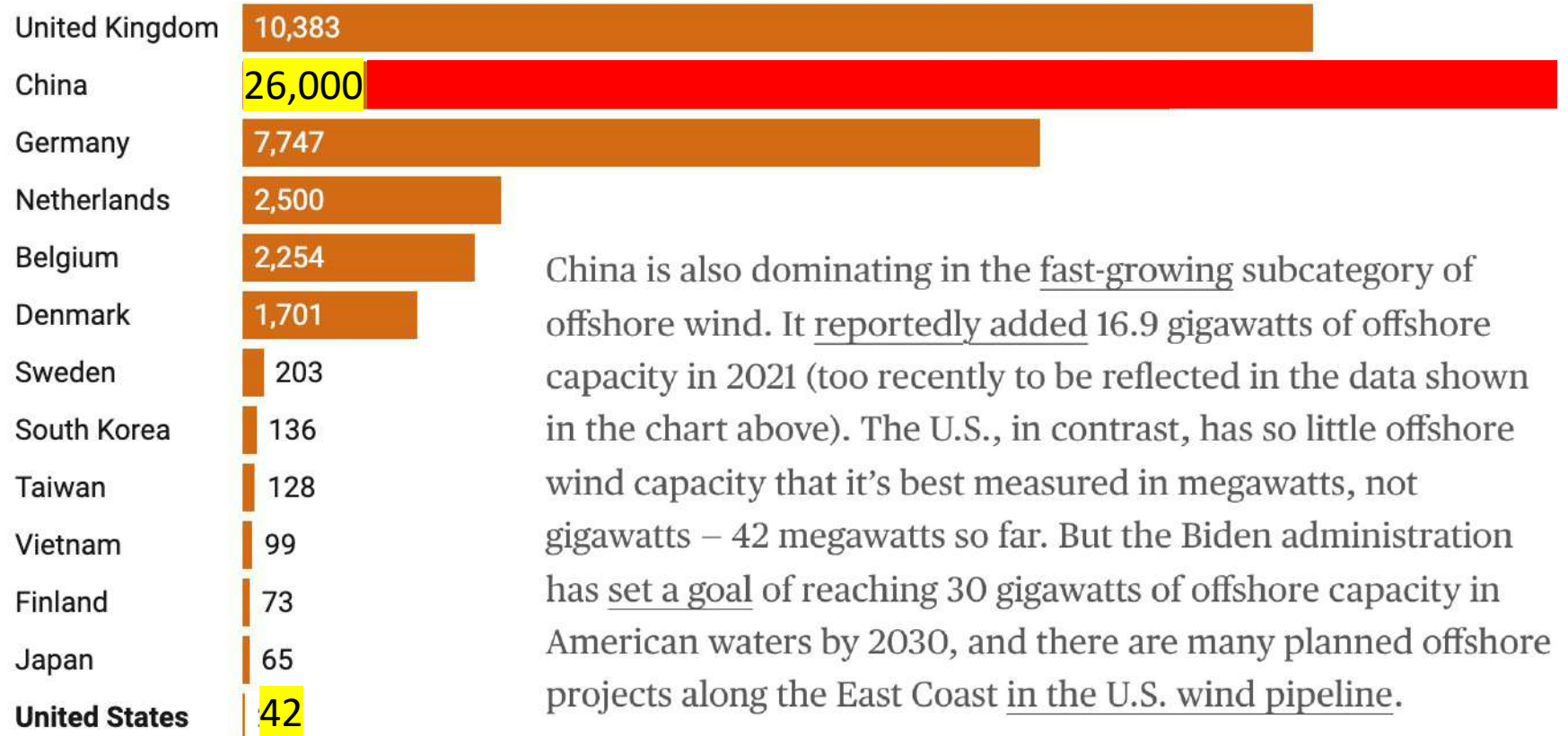
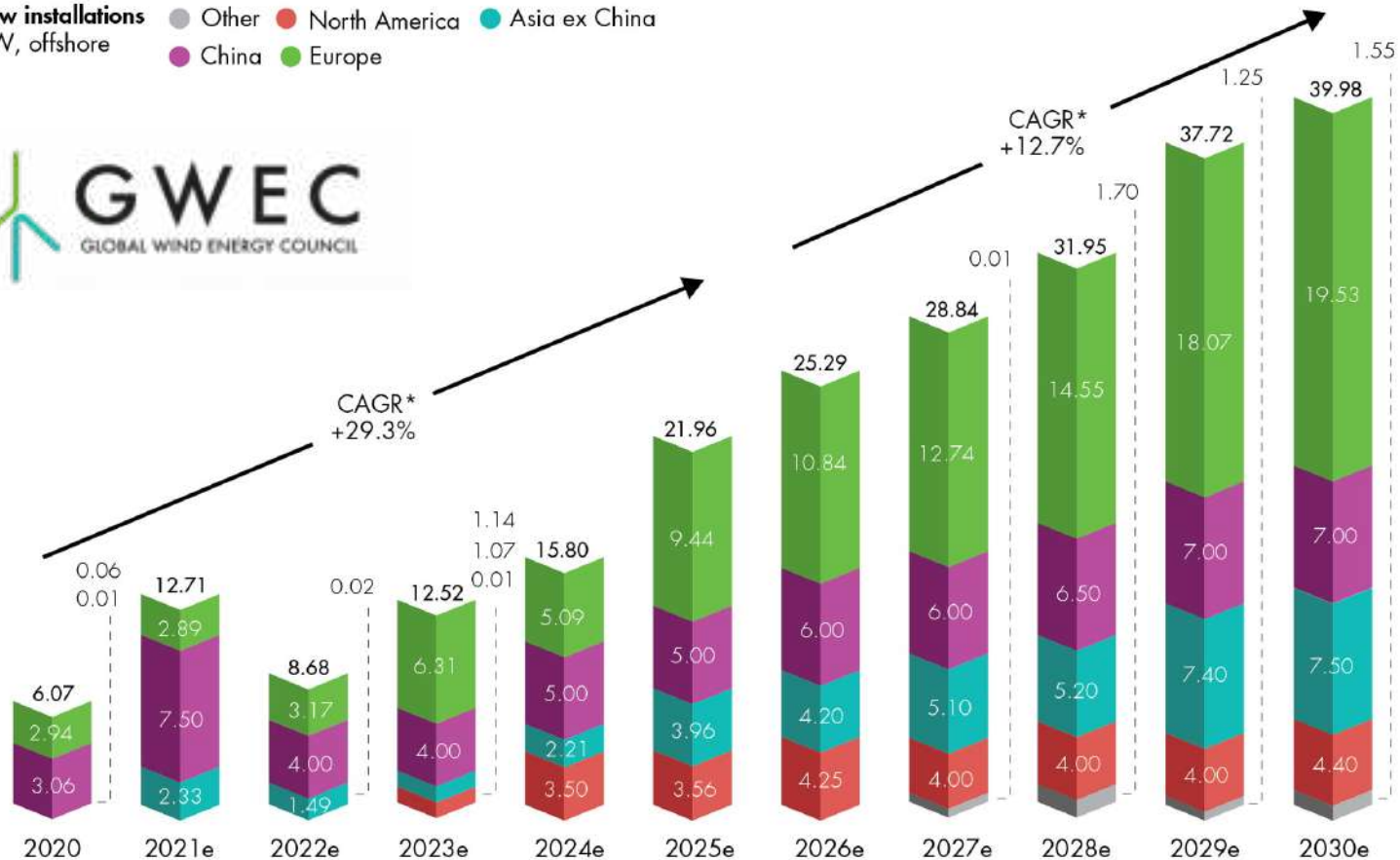


Chart: Canary Media • Source: [IRENA, Renewable Capacity Statistics 2021](#) • [Embed](#) • [Download image](#)

1 – Vortex offshore track record

New installations
GW, offshore

- Other
- North America
- Asia ex China
- China
- Europe



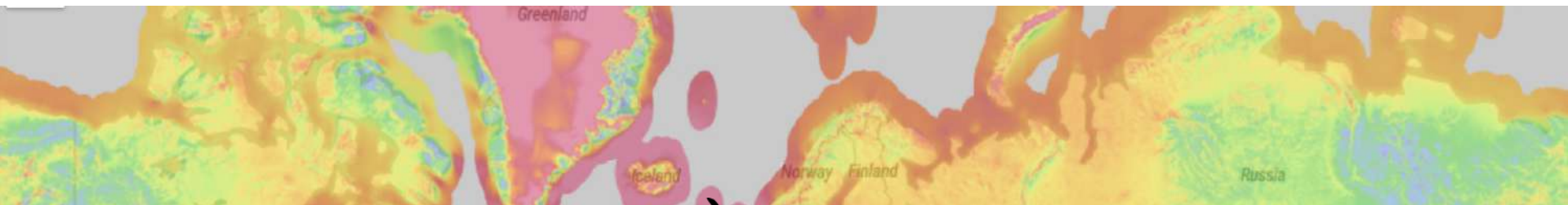
*CAGR = Compound Annual Growth Rate
Source: GWEC Market Intelligence, July 2021

1 – Vortex offshore experience

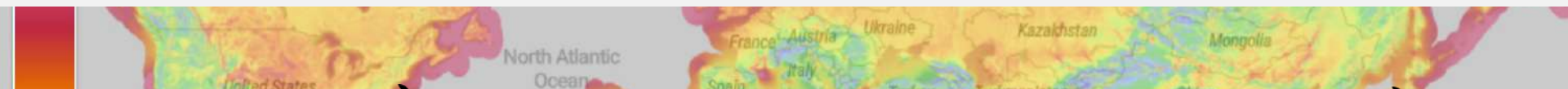
Vortex modeled data supplied for all offshore sites around the world



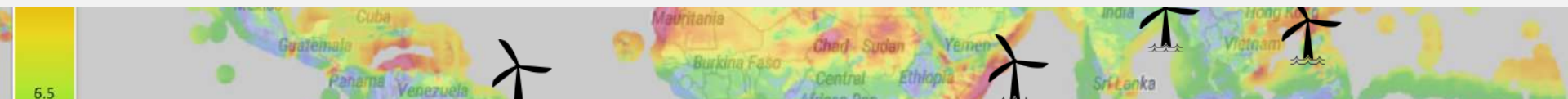
1 – Vortex offshore experience



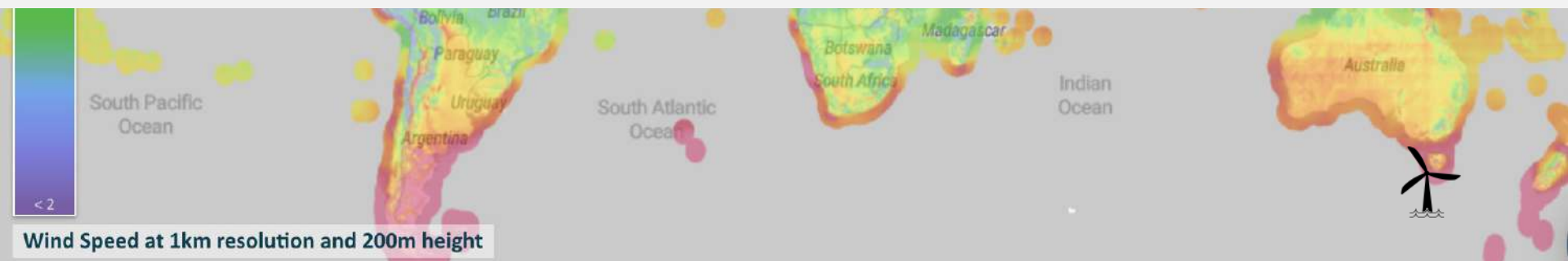
Less measurements



Different environment



Waves

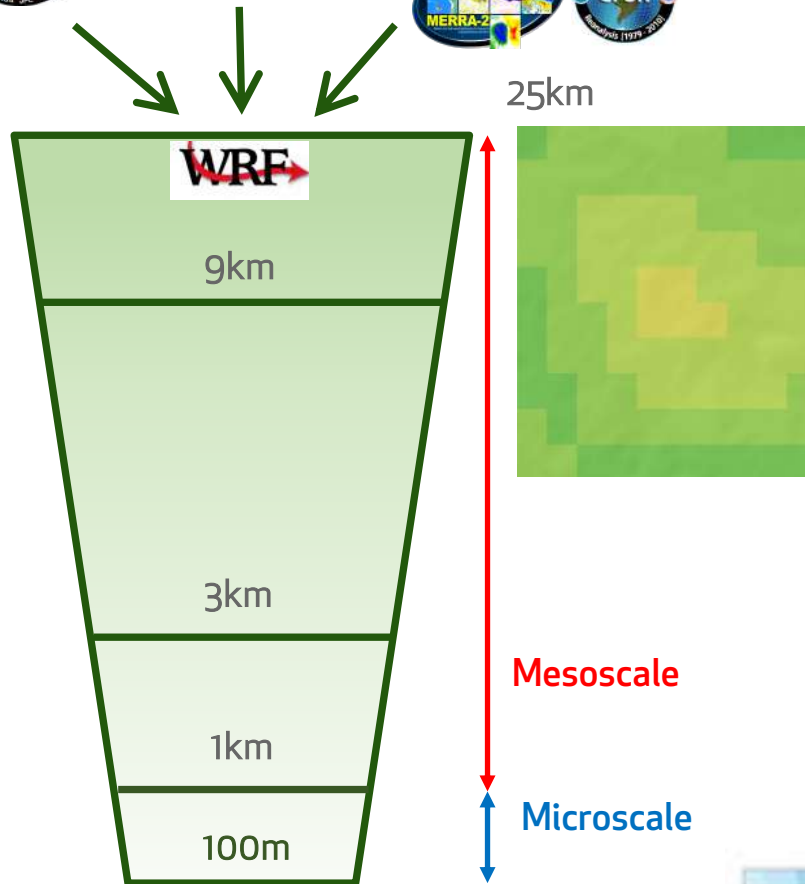


2 – WRF model

Topography

Land cover

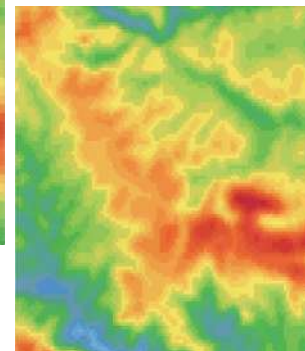
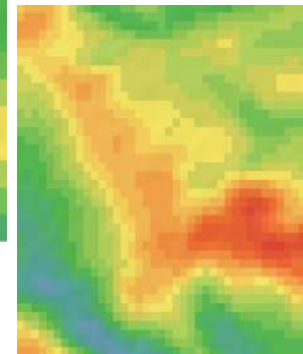
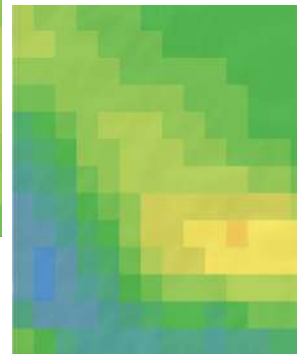
Reanalysis



25km

Recreation of atmospheric conditions (numerical modeling, Navier&Stokes,...) and downscaling with nested domains to end up to higher horizontal resolution

- Online interface ('one click away' approach)
- On demand
- No data precomputed (latest reanalysis data used)



2 – WRF model : a picture is WRF a thousand words...

Real (wind measurements)

Modeled (Vortex solutions)

WRF

- * Topography
- * Land cover
- * Reanalysis

Vortex
people



THE WEATHER RESEARCH & FORECASTING MODEL



1. VORTEX offshore experience

2. WRF model

3. VORTEX solutions for offshore projects:

- Standard
- Customized

- All our products start from scratch, so no data precomputed.
- Latest reanalysis datasets used

3 - Vortex solutions for offshore projects – STANDARD

SERIES



- Computed with WRF
- 3km horizontal resolution
- Hourly data
- Heights between 50m and 300m
- Wind speed & wind direction
- Others (Temperature, Density, Pressure...)
- 10y, 20y, 30y and 38y
- ERA5, CFSR and Merra2 reanalysis datasets
- Can be calibrated with on-site measurements
- Free monthly updates

vortex.serie.421873.10y 100m UTC-05.0 ERA5 (4).txt

Lat=34.07862 Lon=-99.06342 Hub-Height=100 Timezone=-05.0 ASL-Height(avg. 3km-grid)=372
(file requested on 2021-08-06 19:59:29)
VORTEX (www.vortex.es) - Computed at 3km resolution based on ERA5 data (designed for correlation purposes)

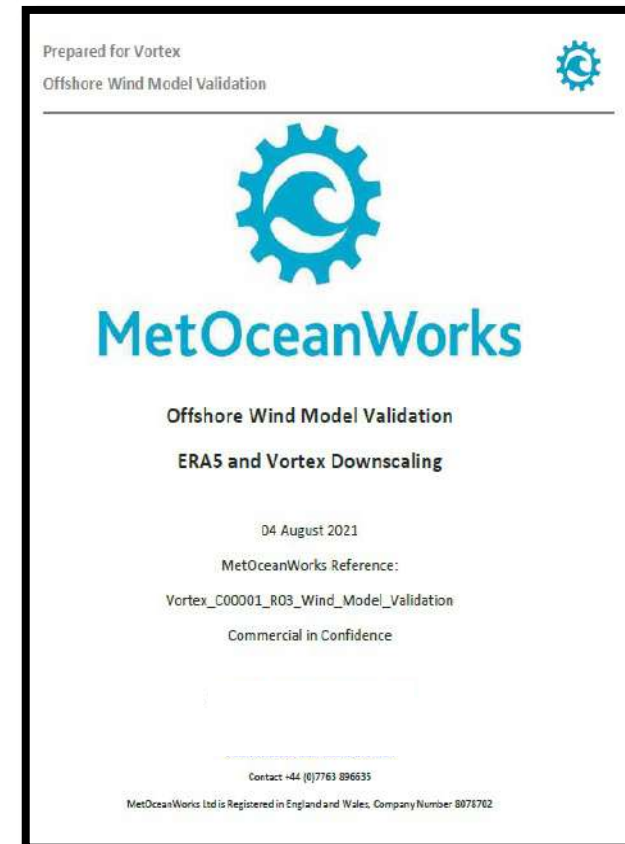
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20101231	1900	5.9	254	7.8	1.19	956.2	0.61	19.7	0.0744
20101231	2000	5.0	248	7.6	1.19	957.1	0.88	17.8	0.1442
20101231	2100	4.1	243	7.4	1.19	957.7	1.13	18.2	0.1797
20101231	2200	3.5	231	7.1	1.19	957.9	2.01	18.5	0.1370
20101231	2300	3.0	239	6.6	1.19	958.3	14.35	20.3	0.3448
20110101	0000	7.0	5	2.5	1.21	960.2	0.42	34.3	0.0027
20110101	0100	8.7	8	0.3	1.23	961.3	0.15	43.6	0.0002
20110101	0200	10.5	13	-1.6	1.23	962.1	0.03	49.4	-0.0002
20110101	0300	10.2	14	-2.9	1.24	963.1	0.03	50.5	-0.0005
20110101	0400	9.1	13	-3.8	1.25	963.9	0.05	50.3	-0.0007
20110101	0500	8.2	7	-4.4	1.25	965.5	0.06	50.2	-0.0009
20110101	0600	7.8	1	-5.5	1.26	966.8	-0.01	50.3	-0.0018
20110101	0700	7.2	354	-6.7	1.27	967.2	-0.10	51.1	-0.0031
20110101	0800	6.3	351	-7.2	1.27	968.6	0.01	51.9	-0.0041
20110101	0900	5.8	347	-7.3	1.27	969.4	0.10	52.7	-0.0047
20110101	1000	5.4	341	-7.1	1.27	970.1	-0.50	53.4	-0.0152
20110101	1100	4.5	340	-6.2	1.27	970.7	-2.96	50.1	-0.0303
20110101	1200	3.6	338	-5.0	1.26	970.6	-13.13	48.7	-0.0516
20110101	1300	2.6	334	-3.5	1.25	970.2	-16.09	49.1	-0.0787
20110101	1400	1.9	331	-2.3	1.25	969.1	-29.10	46.8	-0.1002
20110101	1500	1.3	356	-1.2	1.24	968.2	-28.44	43.1	-0.0954
20110101	1600	0.8	36	-0.5	1.24	967.6	-100.57	41.2	-0.1005
20110101	1700	0.7	131	-0.1	1.24	967.8	-24.68	42.2	-0.0958
20110101	1800	1.0	168	-0.0	1.24	968.3	-2.37	43.1	-0.0725
20110101	1900	0.8	132	0.4	1.23	968.2	1.74	35.2	0.1809
20110101	2000	1.8	127	0.3	1.23	968.5	2.28	36.8	0.1534
20110101	2100	2.3	116	0.2	1.24	969.1	39.30	37.5	0.1909
20110101	2200	3.2	120	-0.0	1.24	969.3	9.83	39.5	0.1169
20110101	2300	3.9	133	-0.0	1.24	970.0	35.01	40.2	0.1088
20110102	0000	4.2	139	-0.1	1.24	970.3	831.58	35.5	0.0911
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20110102	0200	5.1	147	-1.4	1.25	971.0	6.29	34.8	0.1075
20110102	0300	4.0	163	-2.4	1.25	971.3	0.72	42.5	0.1577
20110102	0400	3.9	177	-2.8	1.25	971.3	0.37	43.9	0.1460

3 - Vortex solutions for offshore projects – STANDARD

SERIES

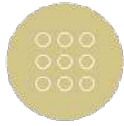


- External validation 13 offshore sites
 - Comparing raw ERA5 vs Vortex SERIES
-
- High heights (100m – 140m)
 - Vortex Series bias is closer to 0 than raw ERA5 in 11 of 13 sites
 - Vortex RMS is lower than raw ERA5 in 11 of 13 sites
 - Low heights (20m – 50m)
 - Similar results to high heights range. Vortex Series statistics shows even better performance than raw ERA5
 - High wind speeds (15m/s – 20m/s)
 - Raw ERA5 underpredicts \cong 5m/s
 - Vortex Series underpredicts \cong 1.5 – 2 m/s



Available at <https://vortexfdc.com/knowledge/meteoceanworks-offshore-validation/>

FARM



- Computed with WRF
- 100m horizontal resolution
- All heights from 50m to 300m
- Standard (500km²), Large (2,000km²)
- Can be calibrated with multi met masts (Remodeling)
- WRG/WRB files in 12 or 16 sectors
- Reports for different turbines layouts
- Layers: Wind speed, TI (15m/s), Mean TI, Temperature
- Long-term representative (20 years)

Time dependent information? X

3 - Vortex solutions for offshore projects – STANDARD

BLOCKS

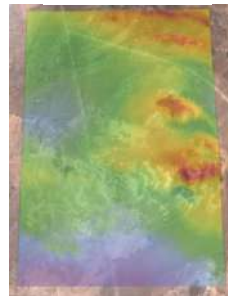


- Computed with WRF
- 100m horizontal resolution
- All heights from 50m to 300m
- Standard (500km²), Large (2,000km²)
- Can be calibrated with multi met masts (Remodeling)
- WRG/WRB files in 12 or 16 sectors... or 24... or 36
- Reports for different turbines layouts
- Layers: Wind speed, TI (15m/s), Mean TI, Temperature, Density, Pressure, Richardson Num. & Inv. MO-Length
- Long-term representative (20 years)

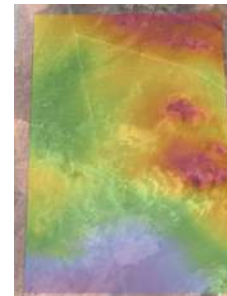
Time dependent information ? ✓

30-min time SERIES at each grid point

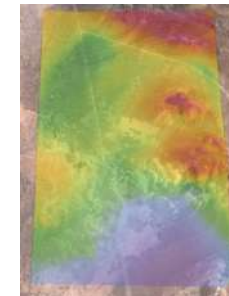
WRG
Day



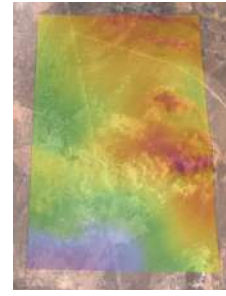
WRG
Night



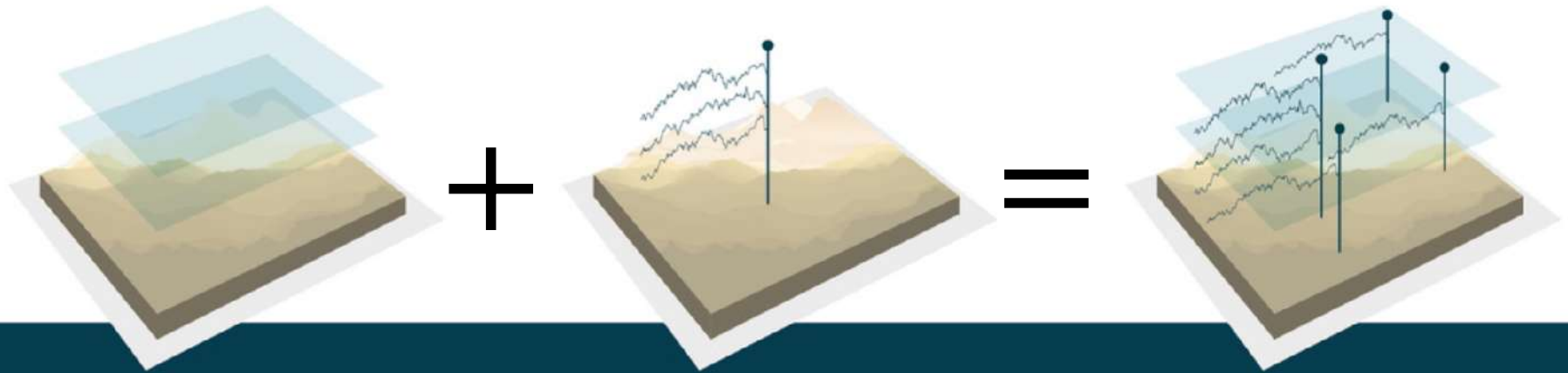
WRG
Winter



WRG
Summer



$$\text{FARM}_{(x,y,z)} + \text{SERIES}_{(t)} = \text{BLOCKS}_{(x,y,z,t)}$$



FARM

+



SERIES

=



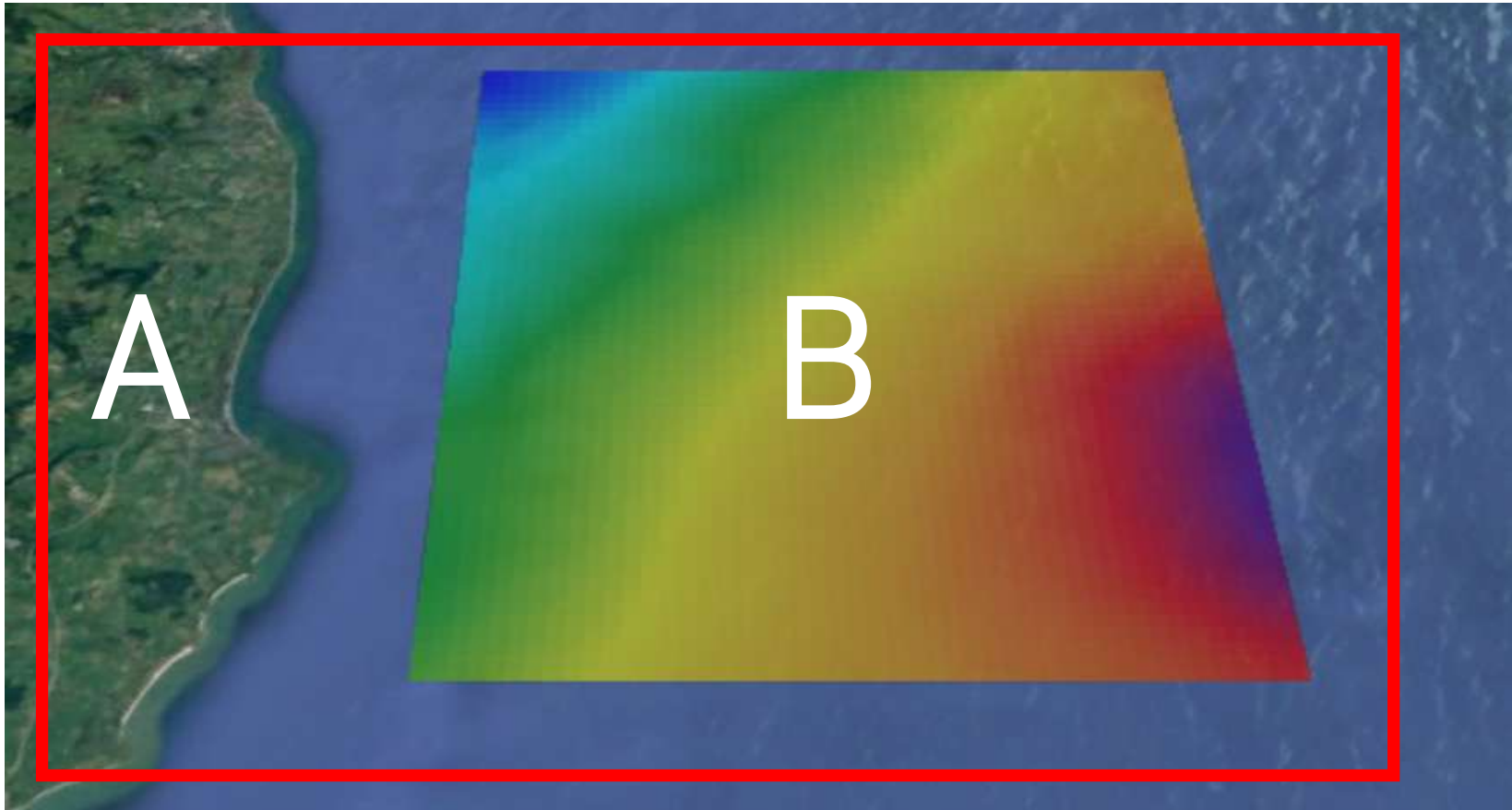
BLOCKS

3 - Vortex solutions for offshore projects – STANDARD



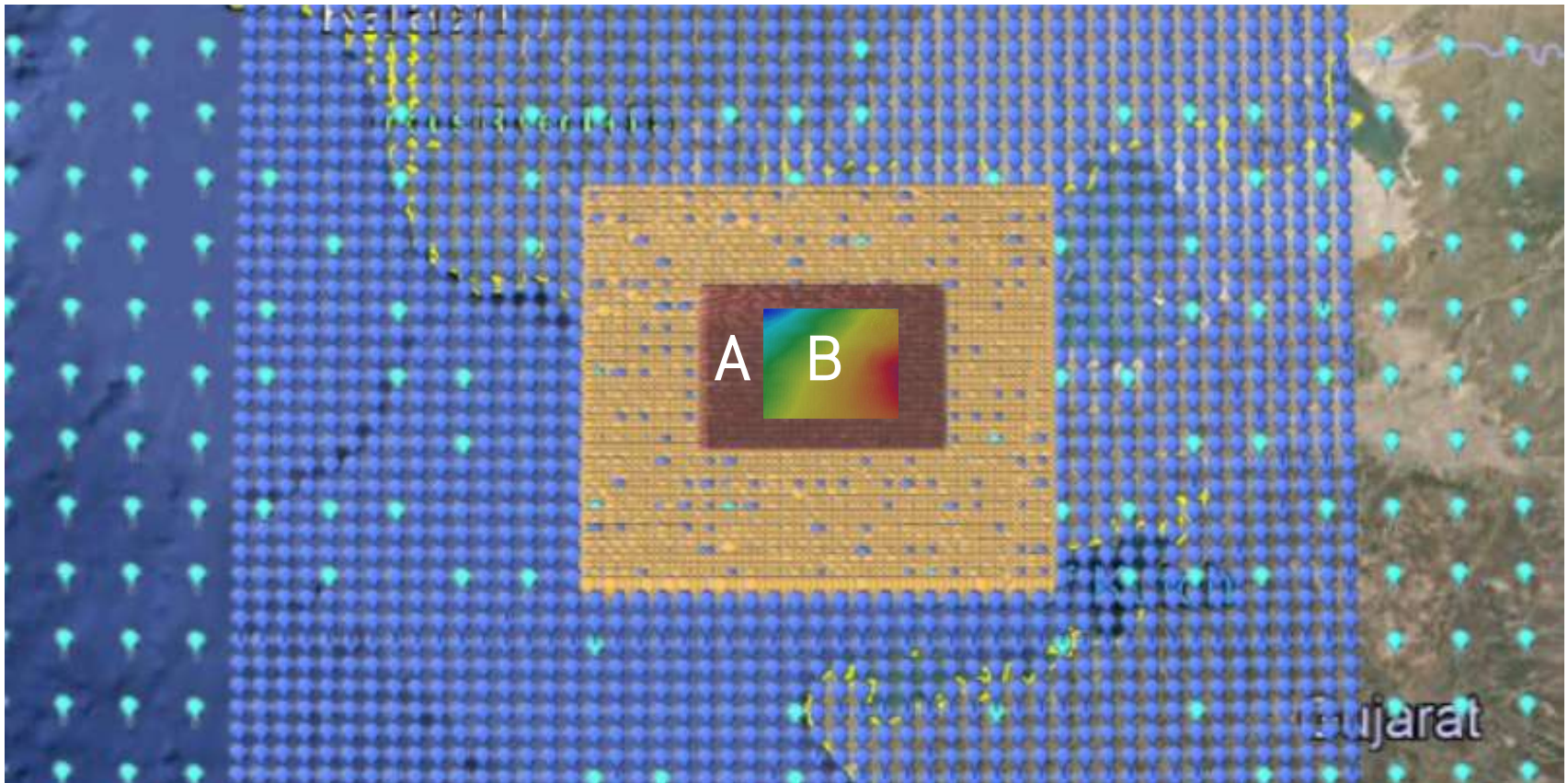
When submitting a FARM or BLOCKS run in my Vortex interface user account for area B, do I have to include area A (coast line) for a better modeling, so a better output data ?

?



3 - Vortex solutions for offshore projects – STANDARD

No need to worry about area A : when we set up WRF we include the area A for the downscaling process. We will deliver you wrg/wrb files and all data for area B, though



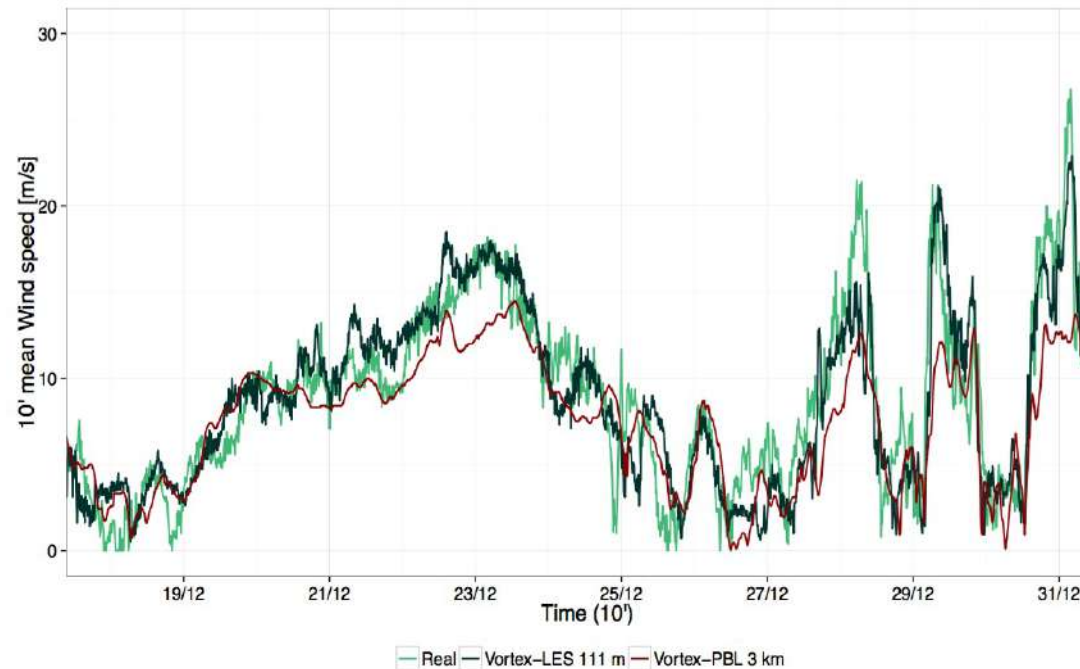
3 - Vortex solutions for offshore projects – STANDARD

LES



10-min time series

- Computed with WRF-LES
- 100m resolution
- All heights from 50m to 300m
- Wind speed AND standard deviation
- Wind direction AND standard deviation
- 3-sec gust
- Temperature & Pressure
- Richardson Number
- Vertical wind speed



- One natural year (selected by user) or Long-term representative (selected by Vortex)
- Data computed and saved every 0.25 seconds (4Hz) and aggregated into 10-min values
- Since 2016 Vortex is pioneer in commercial uses of LES for wind industry

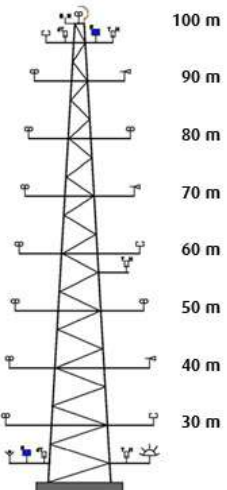
3 - Vortex solutions for offshore projects – STANDARD

LES



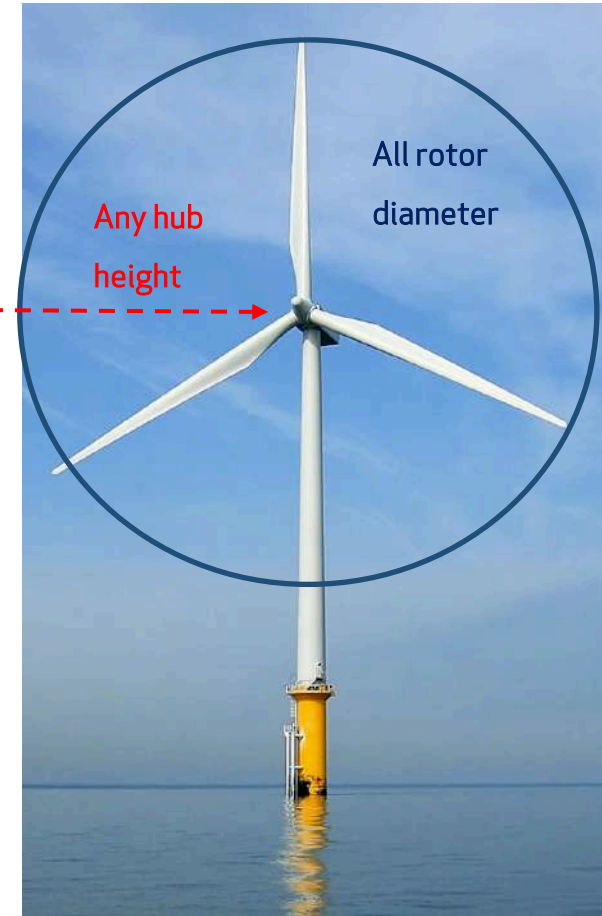
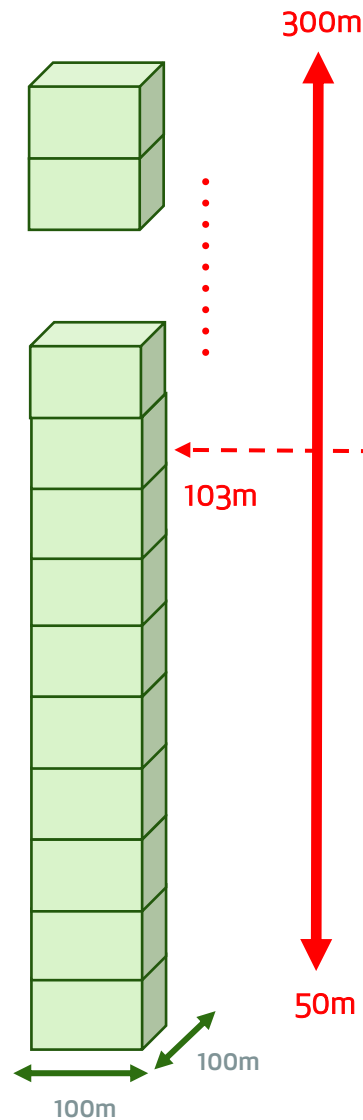
10-min time series

Met mast / lidar



Vortex-LES

- Wind speed & std.
- Wind direction & std.
- 3-sec gust
- Temperature
- Pressure
- Richardson number
- Vertical wind speed



3 - Vortex solutions for offshore projects – STANDARD

LES



When at least 1 year of measurements available...

- 1 - Get Vortex LES at met mast or lidar position for the same natural one-year period of measurements.
- 2 - Compare 'real' data (met mast/lidar) against 'modeled' (LES), so calibrating Vortex LES data.



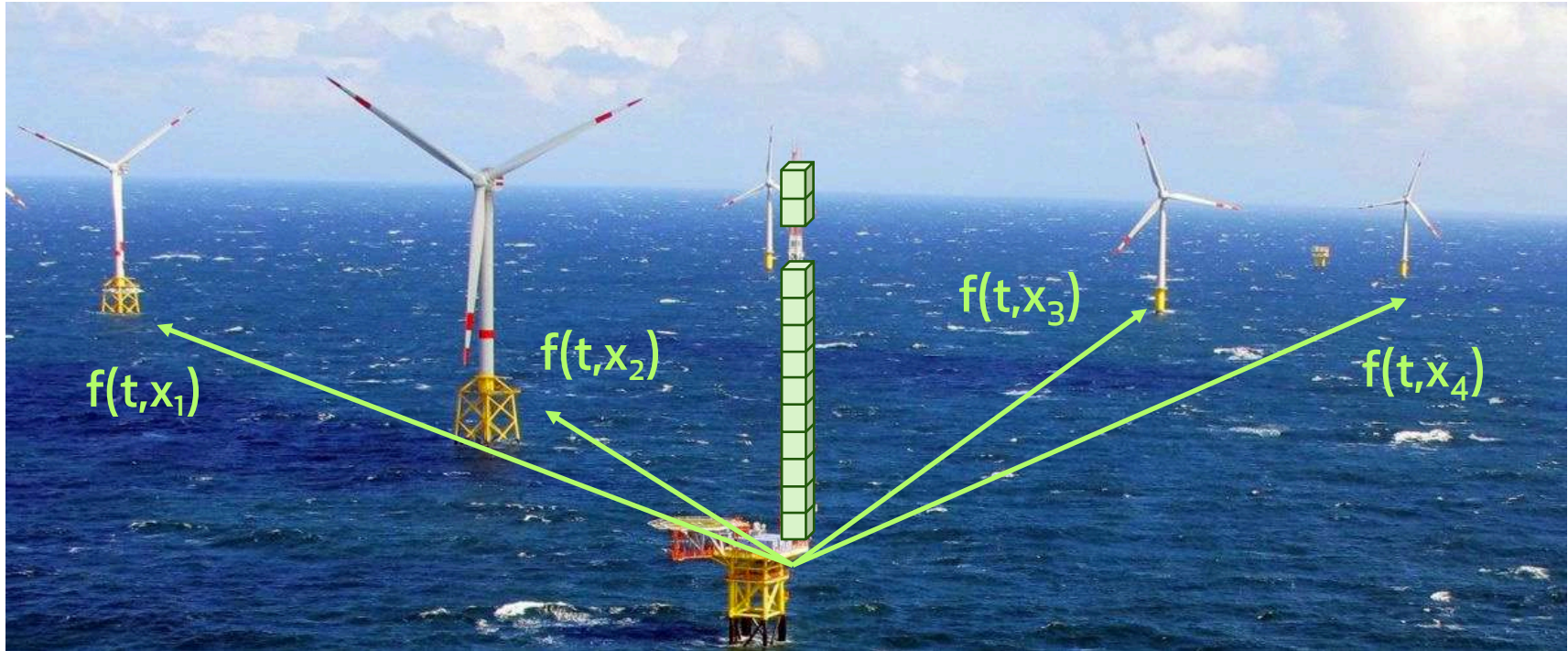
3 - Vortex solutions for offshore projects – STANDARD

LES



When at least 1 year of measurements available...

3 - If correlation is 'good' enough (criteria on customer's side) then a 'transfer function' $f(t)$ can be set up and extrapolated at each turbine position



3 - Vortex solutions for offshore projects – STANDARD

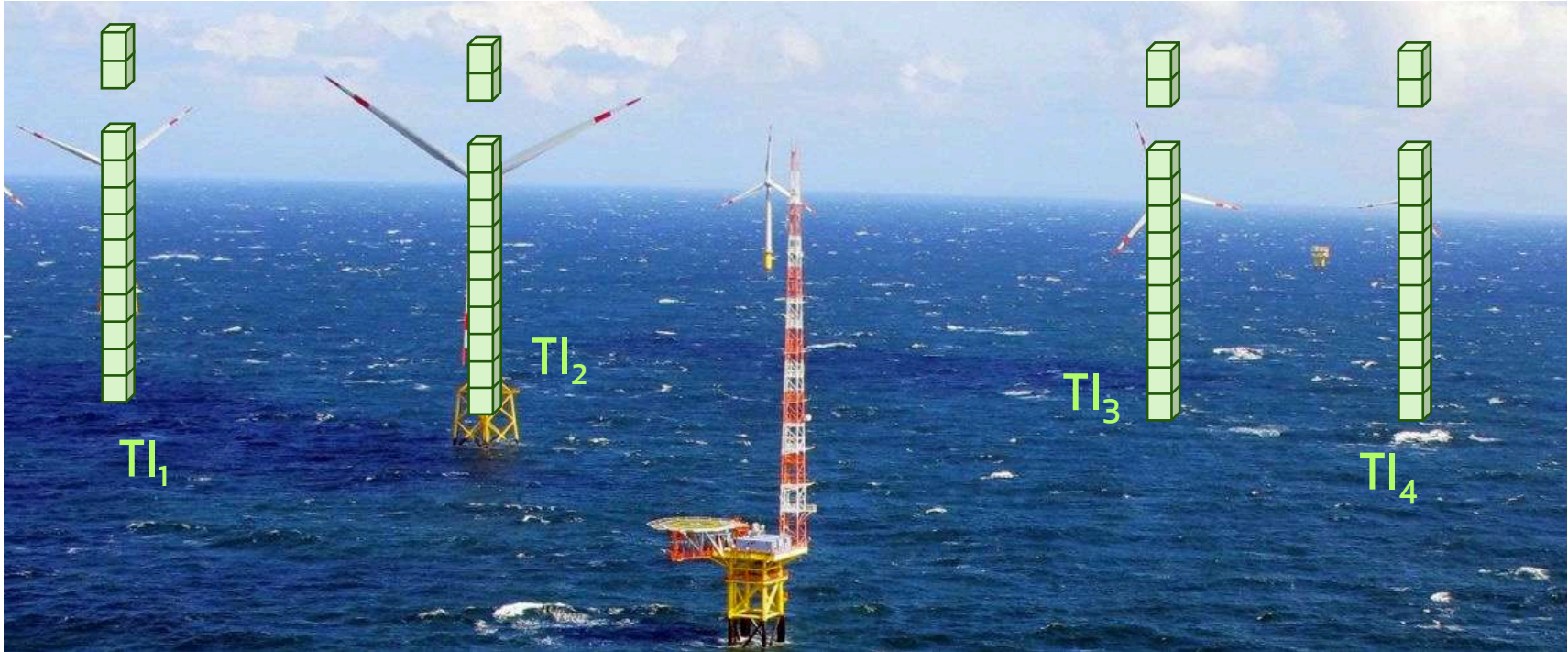
LES



When at least 1 year of measurements available...

4 - Get Vortex LES at the those turbine positions underperforming and apply $f(t)$ to the data. Then modeled TI data is obtained (calibrated with measurements), always referred to “clean” wind.

5 - Analyze TI_1 , TI_2 , TI_3 and TI_4 and conclude if there is any ambient turbulence issue.



3 - Vortex solutions for offshore projects – STANDARD

LES



When NO measurements available...

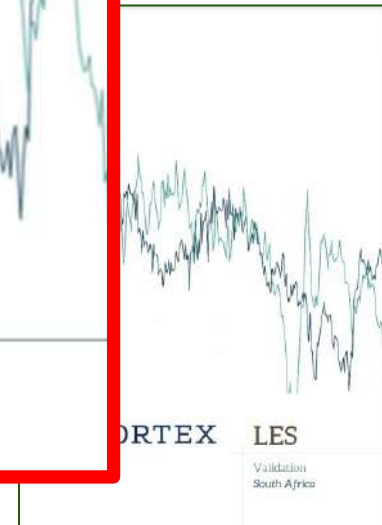
1 - Get Vortex LES (Long-term representative) at the those turbine positions underperforming. Then modeled TI data is obtained although NOT calibrated with measurements, always referred to “clean” wind.

2 – Analyze uncalibrated TI_1 , TI_2 , TI_3 and TI_4 and conclude if there is any ambient turbulence issue.



3 - Vortex solutions for offshore projects – STANDARD

LES



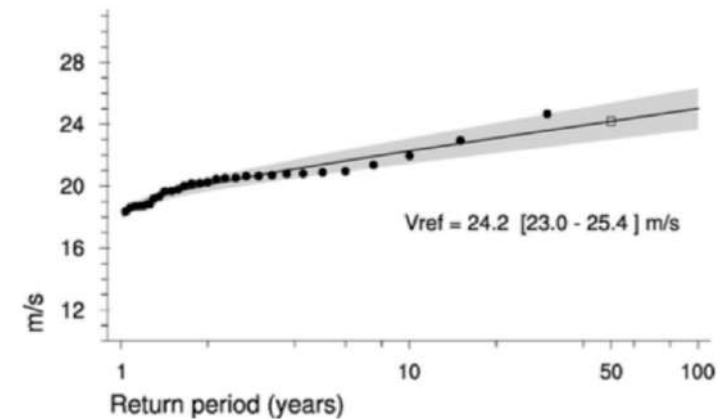
3 - Vortex solutions for offshore projects – STANDARD

EXTREMES



180 days 10-min time series (6 complete days - maximum wind speed registered - per year for the last 30 years) with data computed and saved every 0.25 seconds (4Hz) and aggregated into 10-min values.

- Computed with WRF-LES
- 100m resolution
- All heights from 50m to 300m
- Wind speed AND standard deviation
- Wind direction AND standard deviation
- 3-sec gust
- Temperature & Pressure
- Richardson Number
- Vertical wind speed
- Hurricane and typhoon report based on storms track data provided by NOAA



CALIBRATION : if measurements available,
enhancing EXTREME data is possible

- The calibration process provides a complementary output : additional 180-day 10-min time series adjusted (calibrated) to measurements.
- Load assessment engineers can analyze extreme wind speeds and calculate the V_{ref} magnitude, under different return periods, with a statistical methodology that specifically adjust the maximum wind speeds for a more accurate V_{ref} estimation

1. VORTEX offshore experience

2. WRF model

3. VORTEX solutions for offshore projects:

- Standard
- Customized

Contact us : david.ponsa@vortexfdc.com

3.1 - Offshore Wakes Grid Maps

- Designed for offshore sites
- 1km resolution (recommended)
- Customized or long-term period
- WRG files or time series at every location
- Two simulations are delivered:
 - WRF **regular** parametrization
Fitch scheme **OFF**
 - WRF **wakes** parametrization
Fitch scheme **ON**



Offshore Wakes Grid Maps



The effect of existing wind farms in the wind flow of a region can be modelled in WRF (Fitch's Scheme) and provide accurate wake effects estimation in offshore areas.

3 - Vortex solutions for offshore projects – CUSTOMIZED

3.1 - Offshore Wakes Grid Maps

Methodology : to run the simulation using the Fitch Scheme, the selected region has to include all existing wind turbines not only in **your wind farm** but also surrounding wind farms, if possible

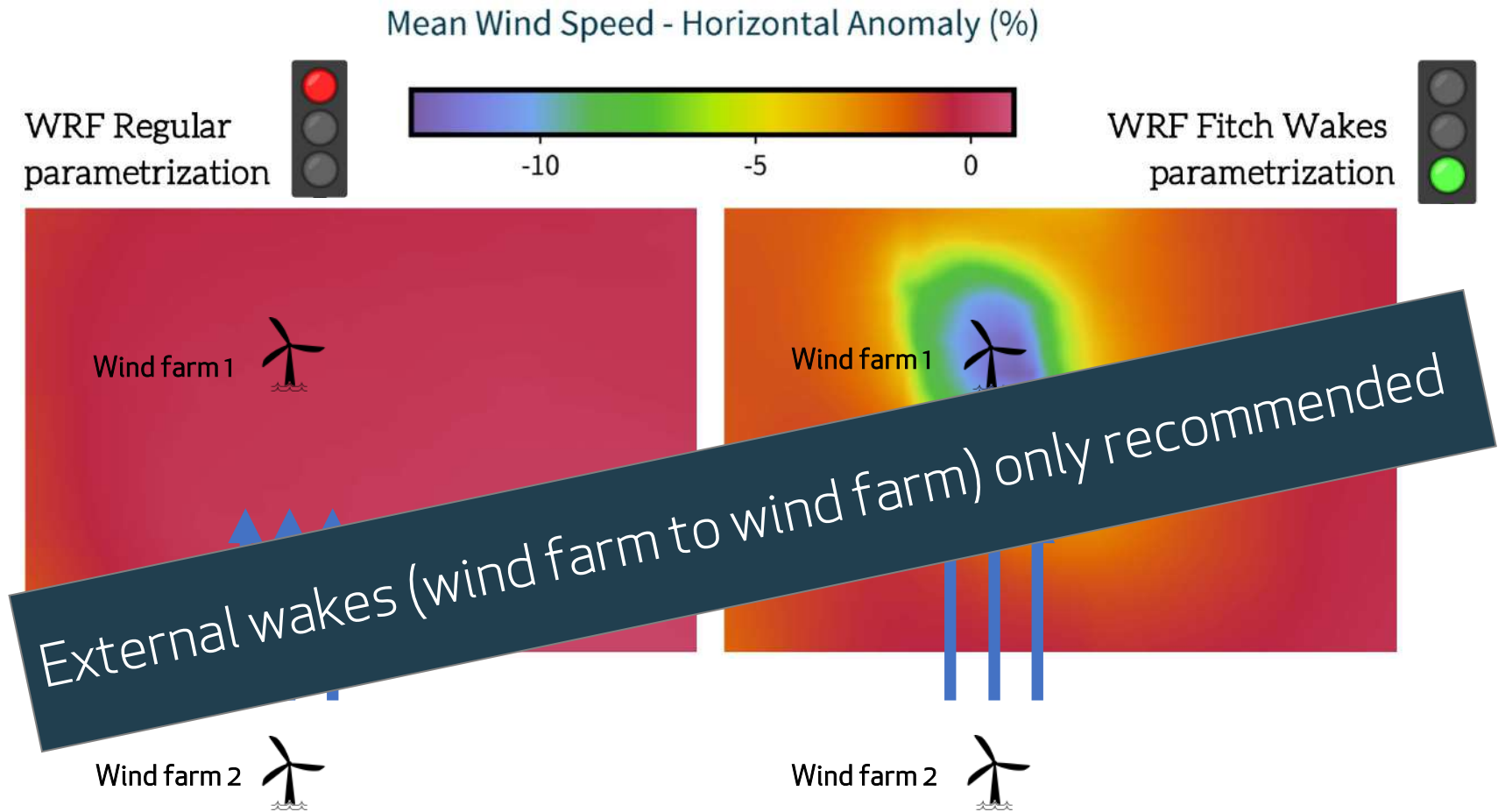
- Wind farm lay-out
- Nominal power (MW)
- Hub height (m)
- Rotor diameter (m)
- Thrust coefficient (C_t)
- Table with power production

and thrust coefficient for each wind



3 - Vortex solutions for offshore projects – CUSTOMIZED

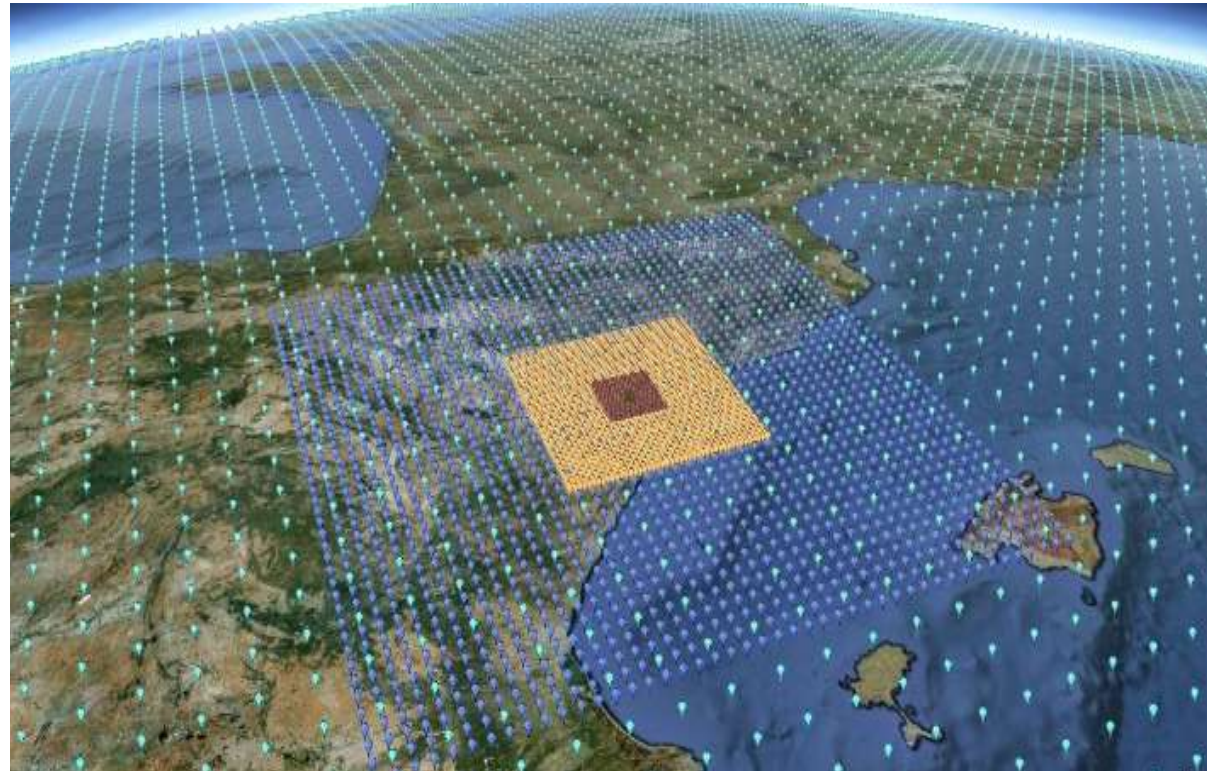
3.1 - Offshore Wakes Grid Maps



3 - Vortex solutions for offshore projects – CUSTOMIZED

3.2 - Low resolution grids

1. Prospecting large areas
 2. Waves analysis
- Long-term gridded time series (10y, 20y, 30y or 38y)
 - 3km or 1km resolution available
 - NetCDF files are delivered



1. Vortex has supplied data for most offshore projects worldwide
2. Standard offshore solutions:
 - WRF modeled : SERIES, FARM, BLOCKS
 - WRF-LES modeled: LES and EXTREMES.
3. Extensively validated both internally and by third parties
4. Customized offshore solutions (request yours if any other)
 - Offshore wakes grid maps
 - Low resolution grids
5. Find many offshore related documents in our *Knowledge Center*
 - <https://vortexfdc.com/knowledge>

See you in San Antonio, Texas...



...and Remember The **Booth 1633**



May 16 - 18, 2022 | San Antonio, Texas

Energy	EDF Renewables	Infrastructure and Energy Alternatives, Inc.
1	1740	1841
Bradley Construction Management		
1538		
SkySpecs	Stantec Consulting	Avid Controls, Inc.
1532	1634	1733
	Vortex Inc.	Capps Van & Truck Rental
	1633	1833
Morgan Advanced Materials	L&H Industrial,	Nordex Group
Phazebreak Coatings, Inc.	TPI Composites.	