

Novos paradigmas da modelagem do recurso eólico



I WORKSHOP BRASILEIRO SOBRE MODELAGEM DA ATMOSFERA APLICAÇÕES NA ÁREA DE ENERGIA EÓLICA

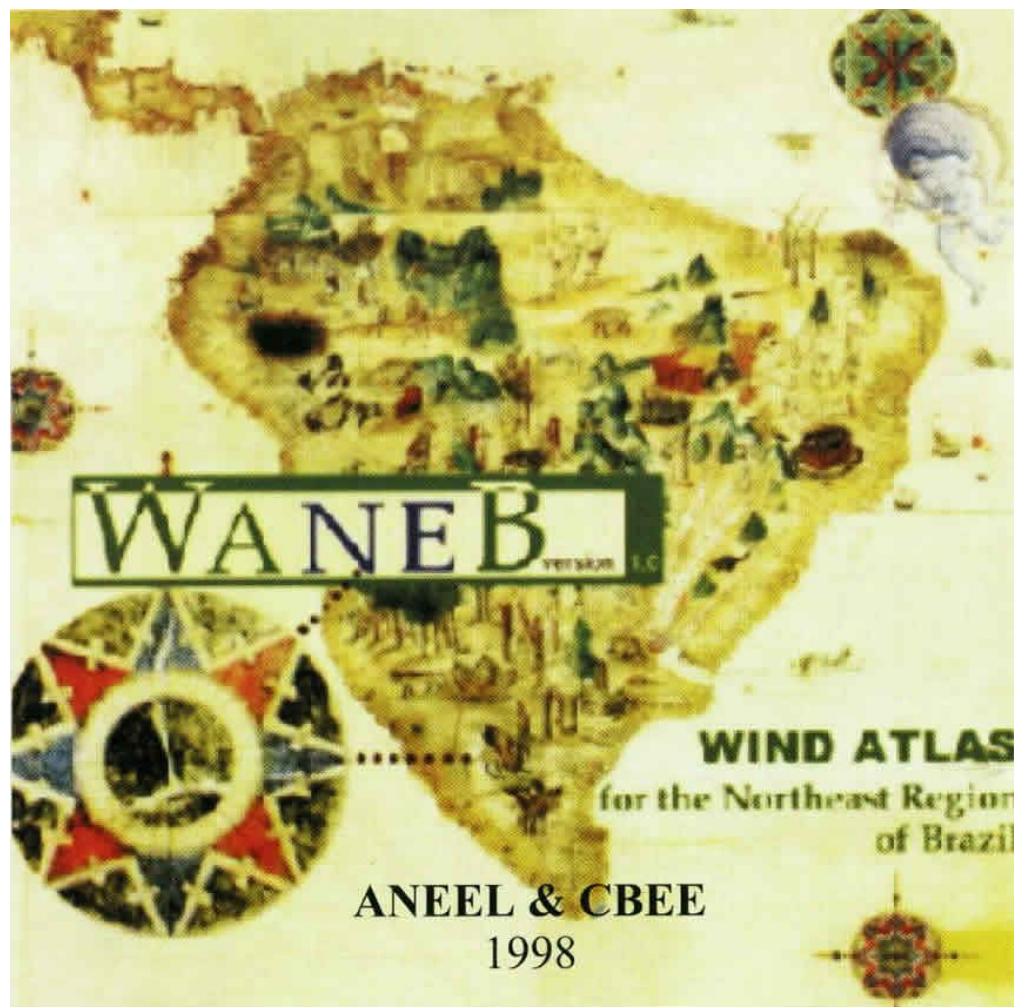
CTGAS-ER | NATAL-RN
14 e 15 junho de 2018

Novos paradigmas da modelagem do recurso eólico

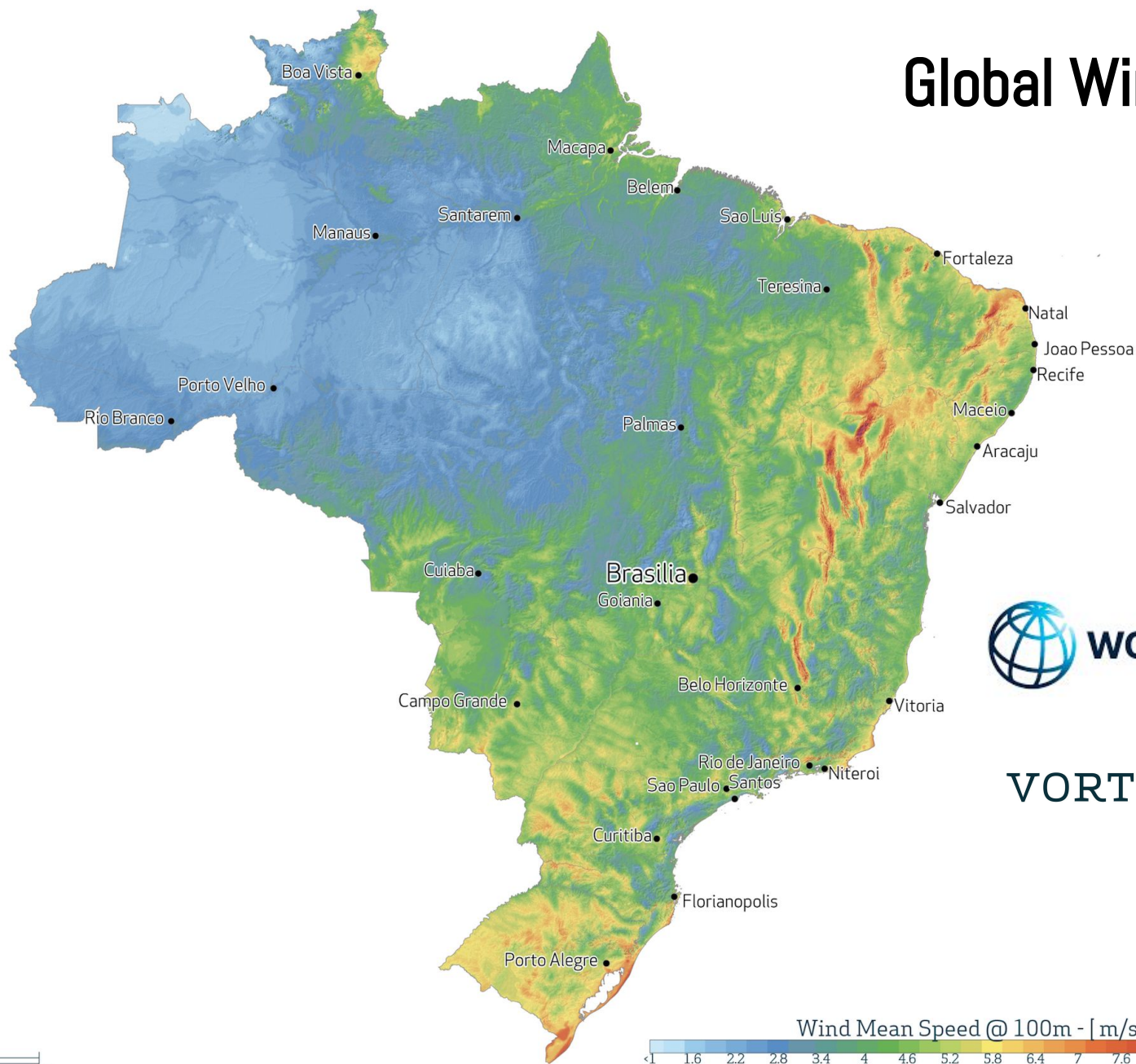
Gil Lizcano

R&D Director

VORTEX 



Global Wind Atlas 2.0

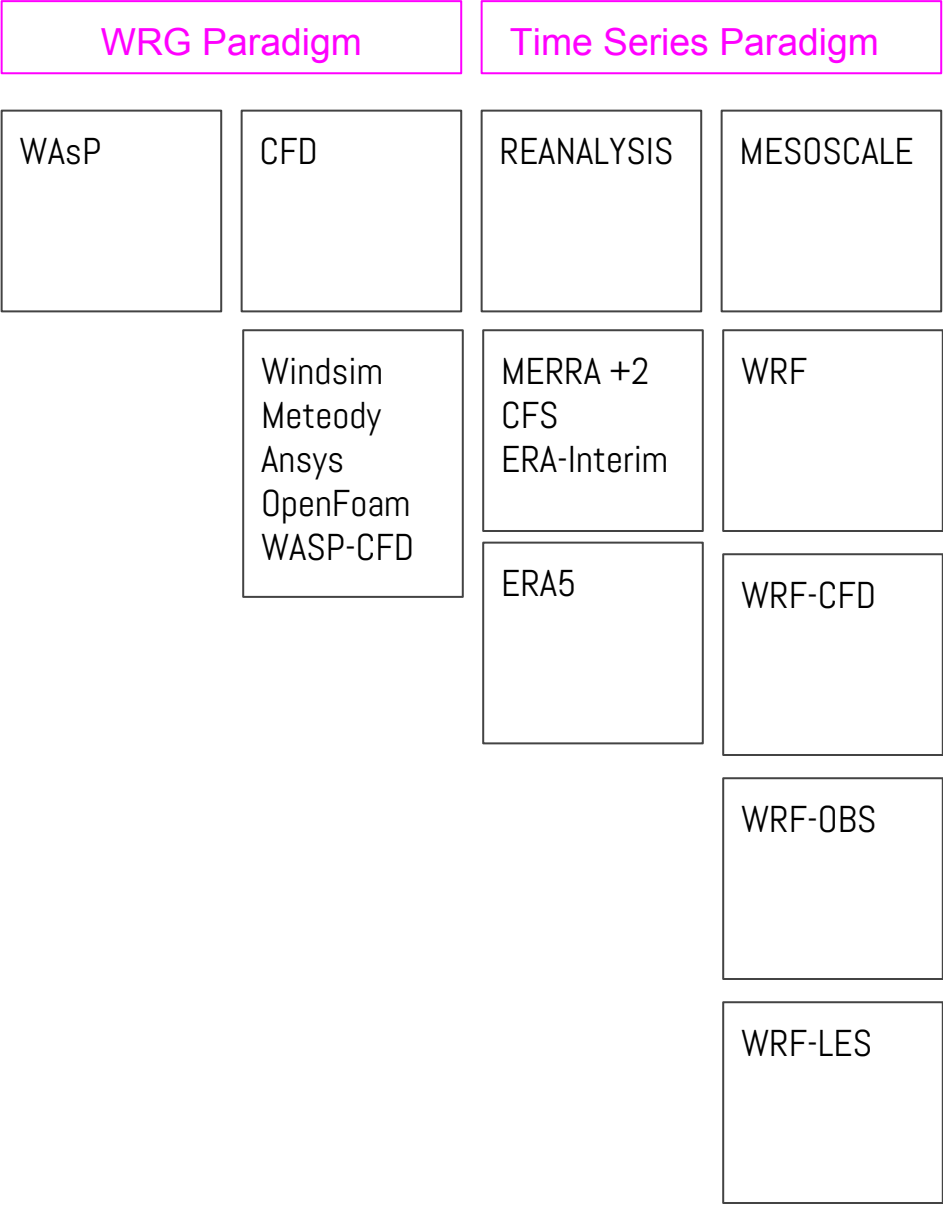


WORLD BANK GROUP

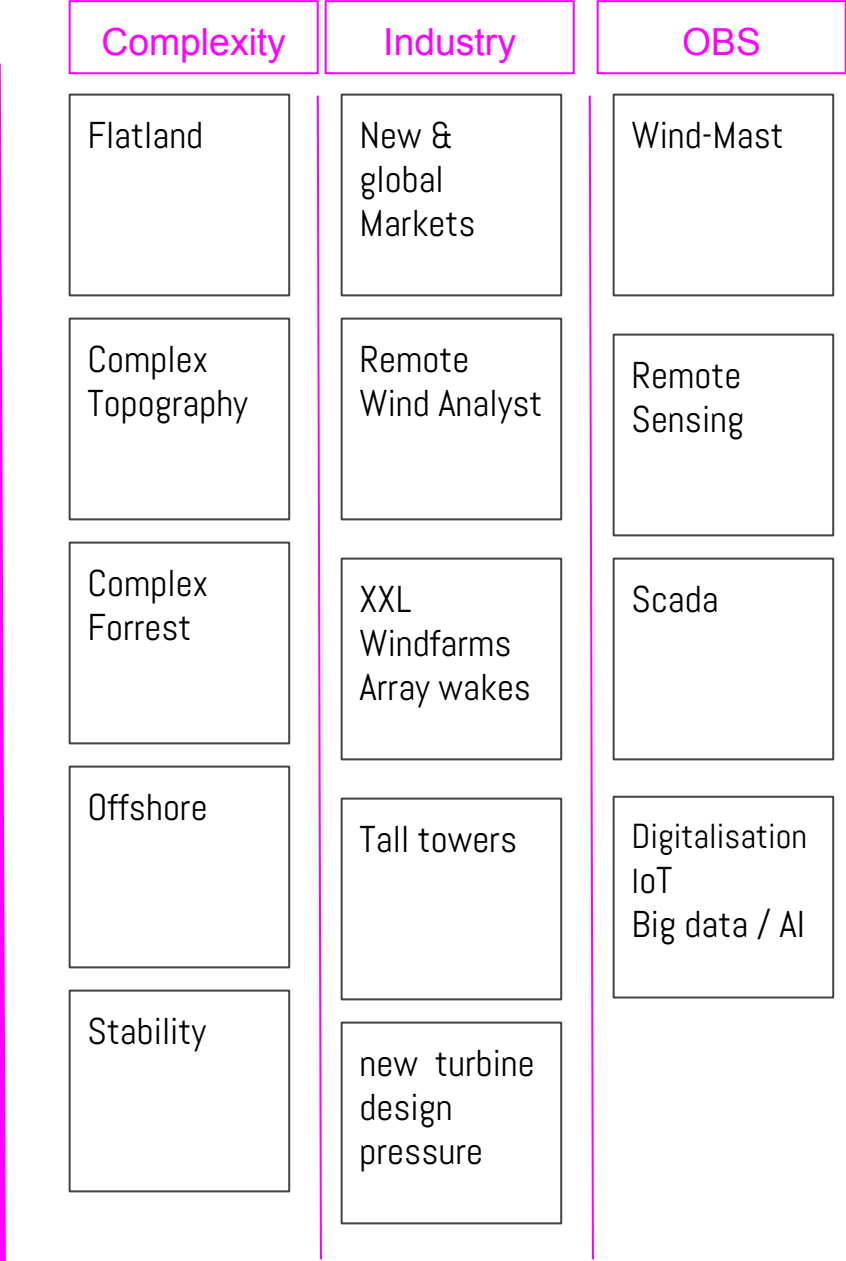
VORTEX



0 250
Km



TOOLS



+

+

DRIVERS

VORTEX

Wind Resource

Modeling Wind Resource

Mesoscale Models

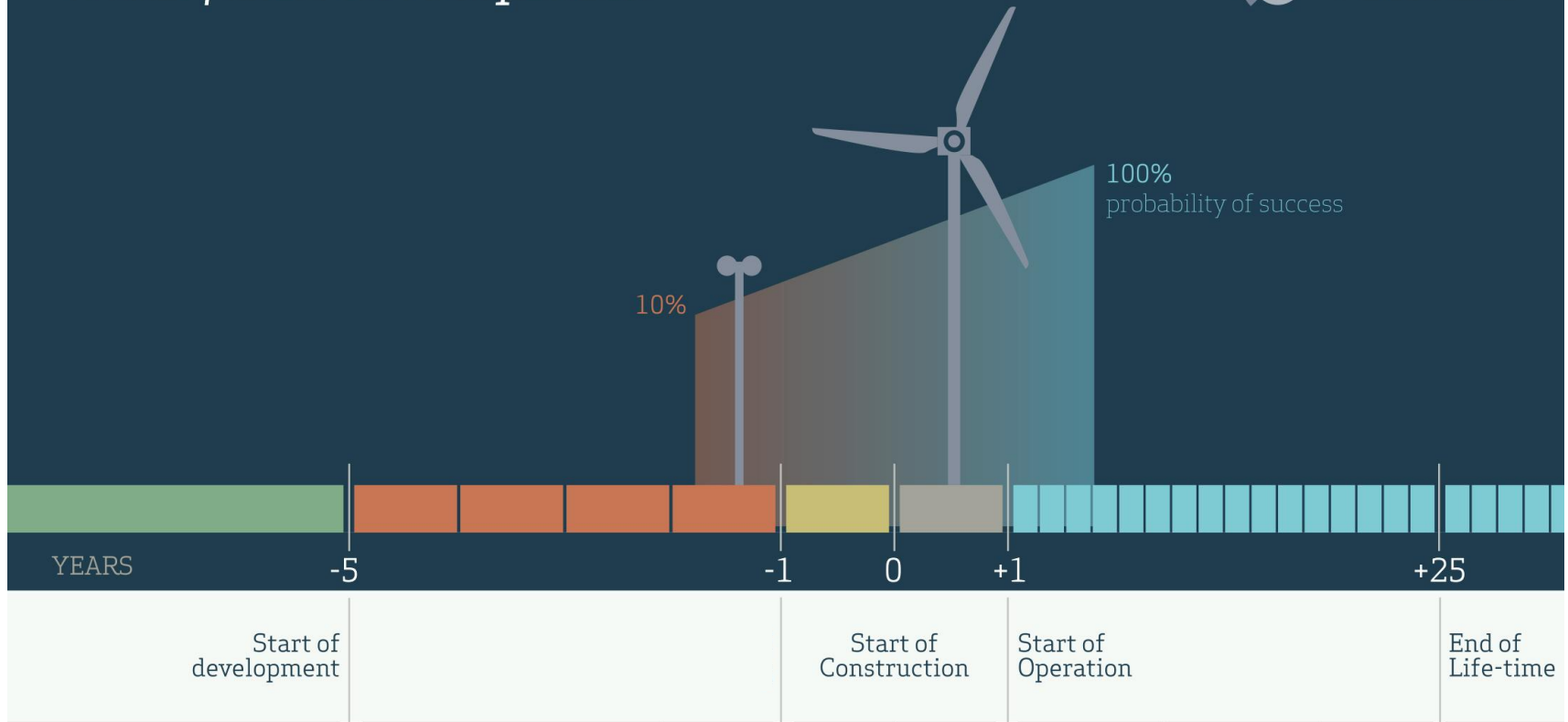
Wind Resource in the time domain

Microscale time series

Real cases

Future & Comments

Wind farm development





Which region should I focus effort on

Where I should install my met-mast

Which is the interannual uncertainty for my site ?

Where I should locate my project wind turbines?

How profitable will my windfarm be?

Which wind turbine technology should I choose ?

Wind Resource Information Service

DATA Interface

Mesoscale Model Technology

Automatization

Computing Cluster

Innovation Team



Wind Resource Information Service

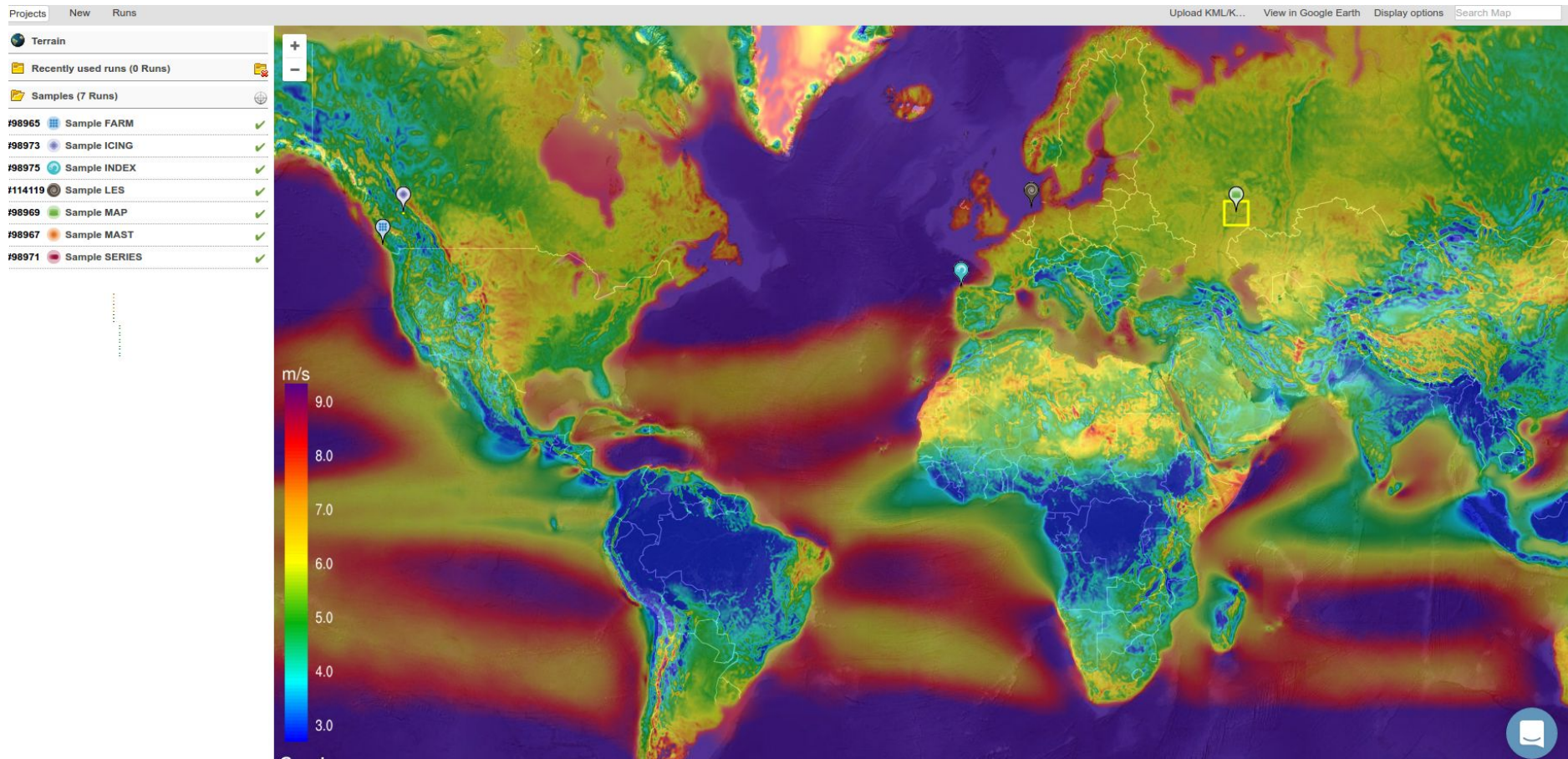
DATA Interface

Mesoscale Model Technology

Automatisation

Computing Cluster

Innovation



Leading on-demand virtual wind resource service

Supervised by a very specialised & focused team

Cloud computing using our own cluster

Barcelona, Brussels, Miami, Istanbul, Pune, Beijing

No software

No consultancy but working with consultants

No just colour maps but professional products

No measurements

Adopted as reference tool by the industry



Global

Site specific

Spatial and vertical gradients

Interannual variability control

Intermittent & turbulence

Arr. of Toul

Global

Site specific

Spatial and vertical gradients

Interannual variability control

Intermittent & turbulence

Very Sensitive *Wind2Energy* Link

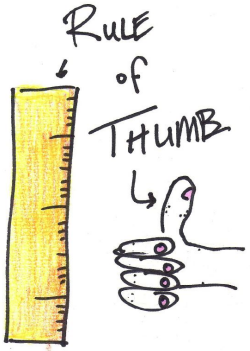
Uncertainty Penalties (P90/P50)

Site suitability

Turbine Technology

Energy Mix

Arr. of Toul

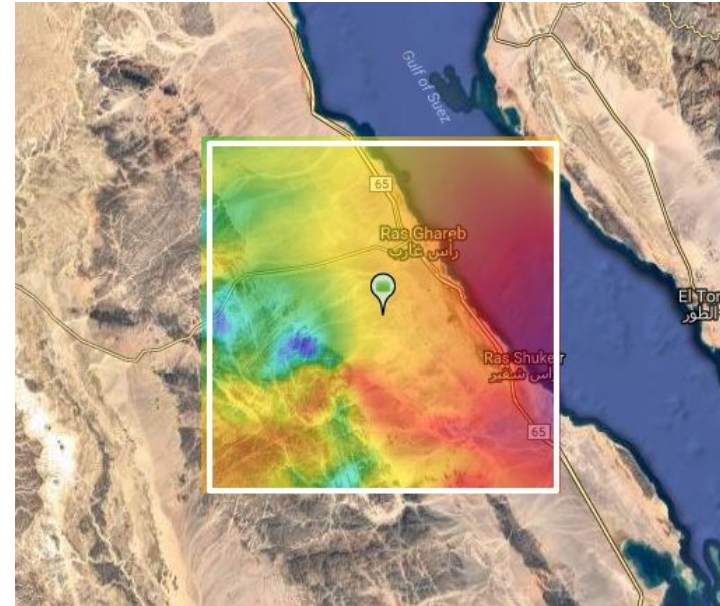
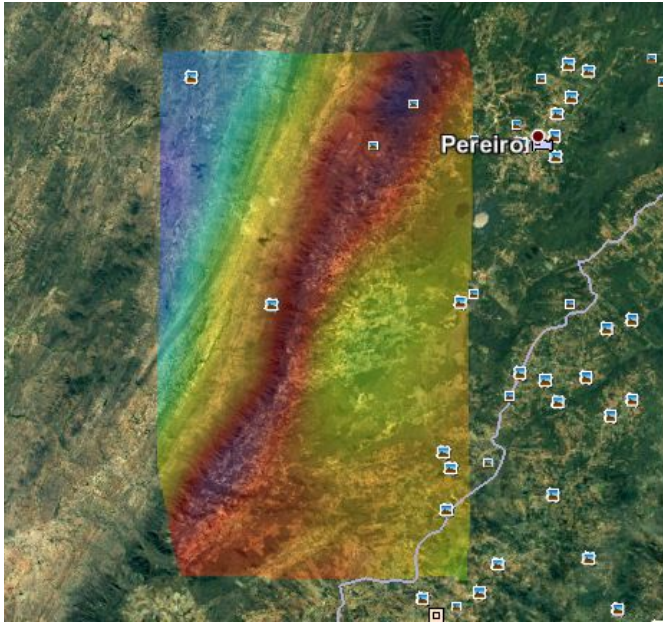


2% wind speed error 5% AEP error

1 % AEP corresponds to 1 mEUR on a 100 MW wind farm

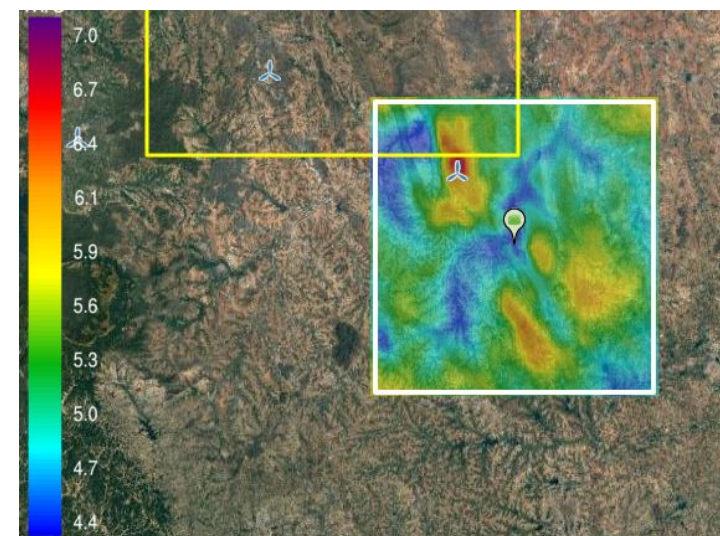
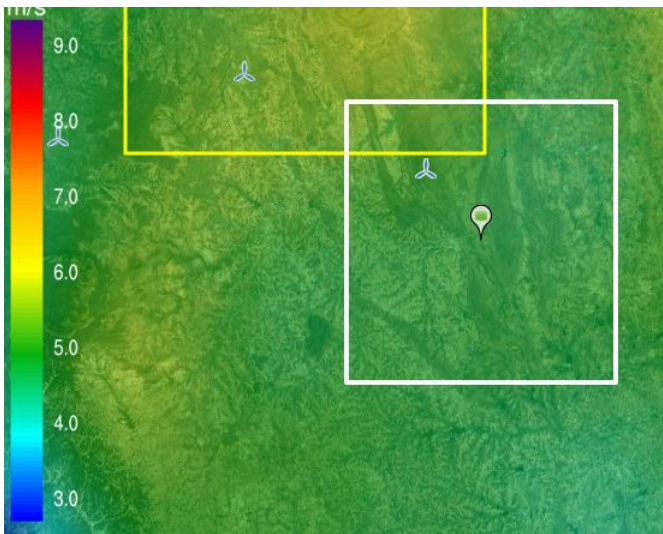
Complexity of Wind Resource

Wind is accelerated in many ways



Don't always blame terrain for flow complexity

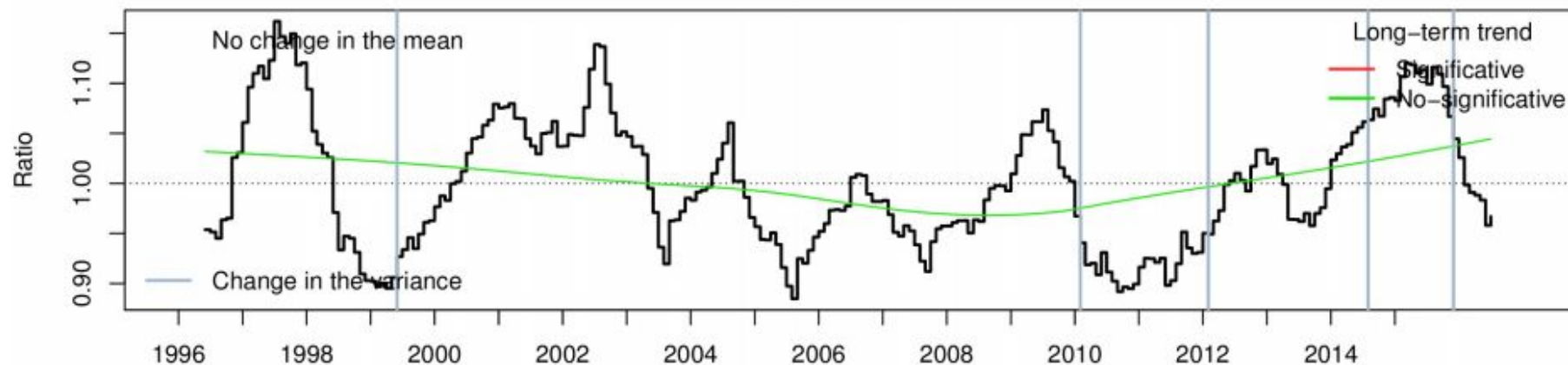
Resolution is a must



Treasure island paradigm

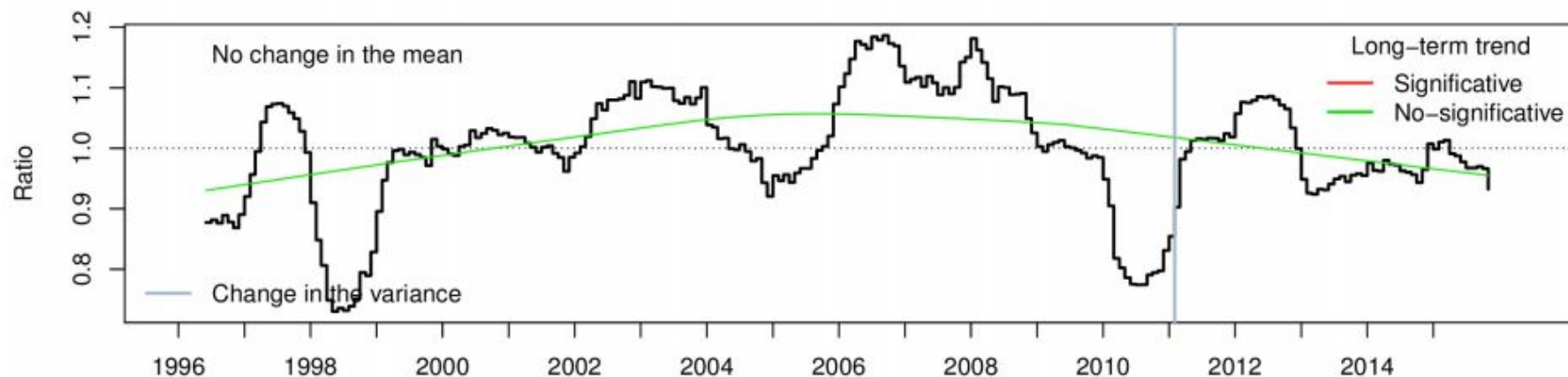
Scaled 12-month Moving Average Speed Module

MEXICO



Scaled 12-month Moving Average Speed Module

THAILAND

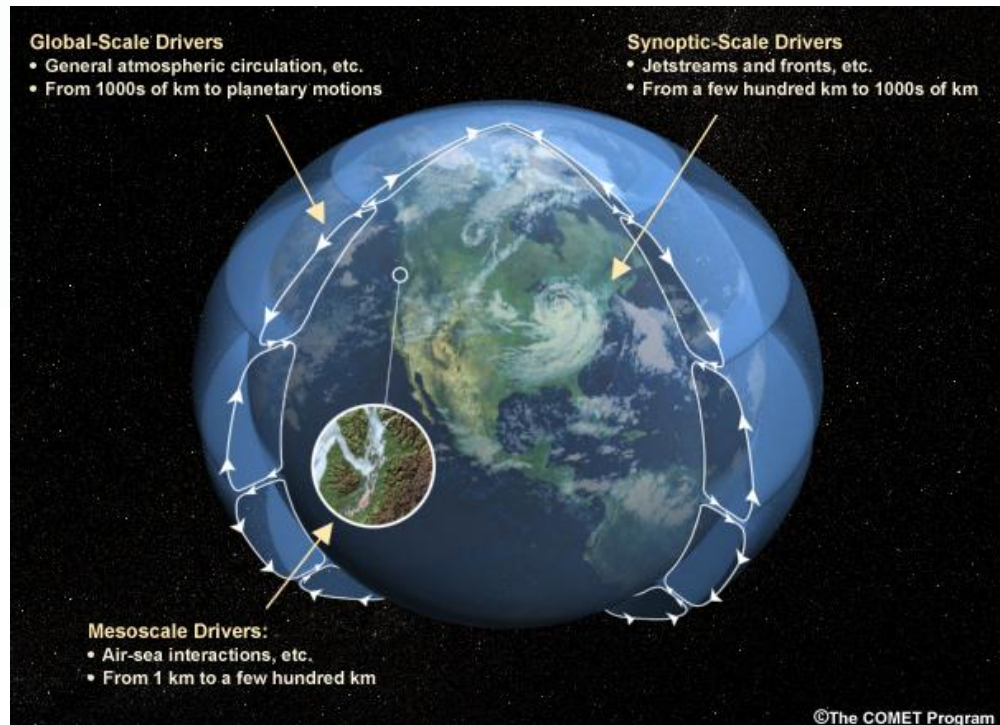




For wind industry applications, we just run the model in hindcast mode (back in time) to reproduce wind conditions over the last 20 years so we get the wind climates

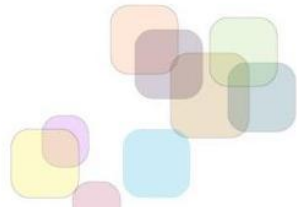
Mesoscale Model is a Weather Model

"a lot of equations translated into a large code that runs in big computers and which is driven by a large amount of *observed* input data"

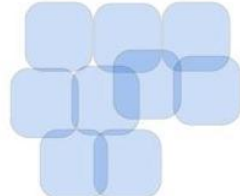


Atmospheric Input: Reanalysis

Mesoscale Model

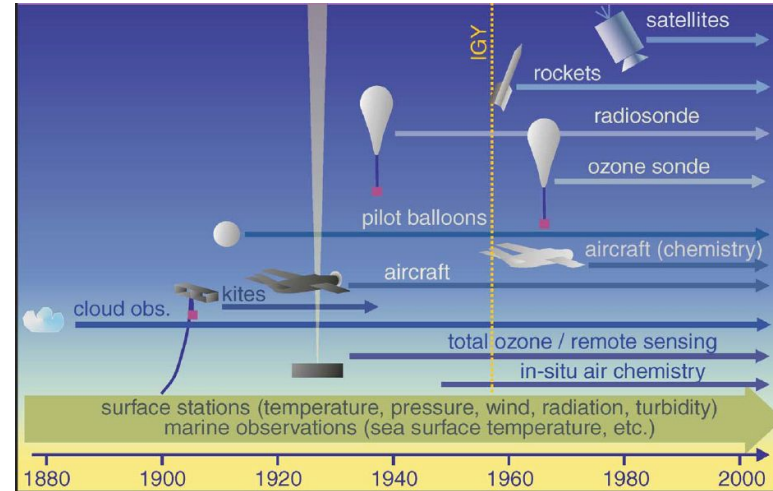


Multisource
Input Data

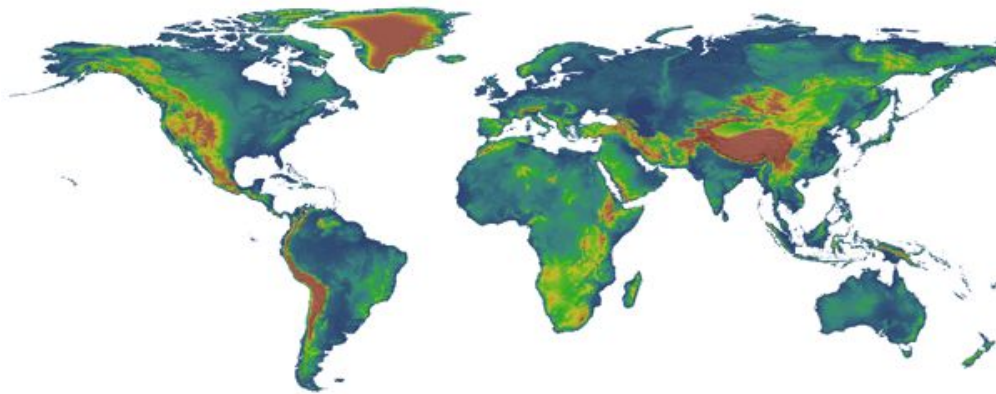


Data Mining/Assimilation
System

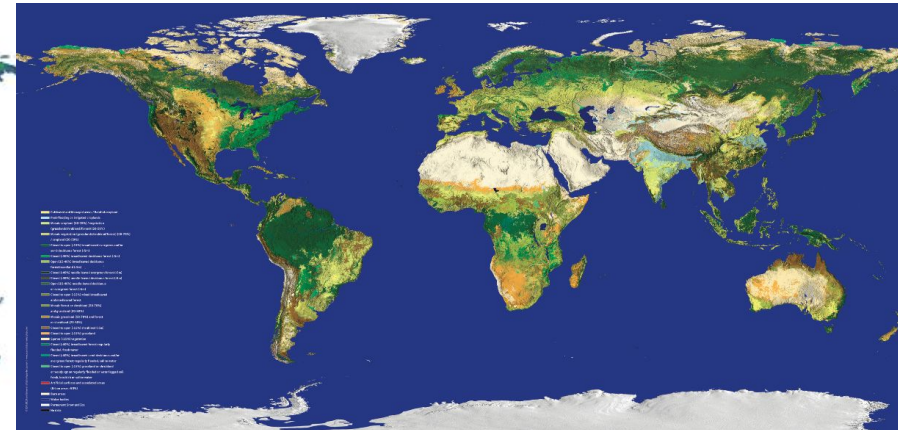
Retrospective time series of gridded data for a
panoply of atmospheric, land and ocean
variables 1979-NOW
ERA5, MERRA2 & CFS



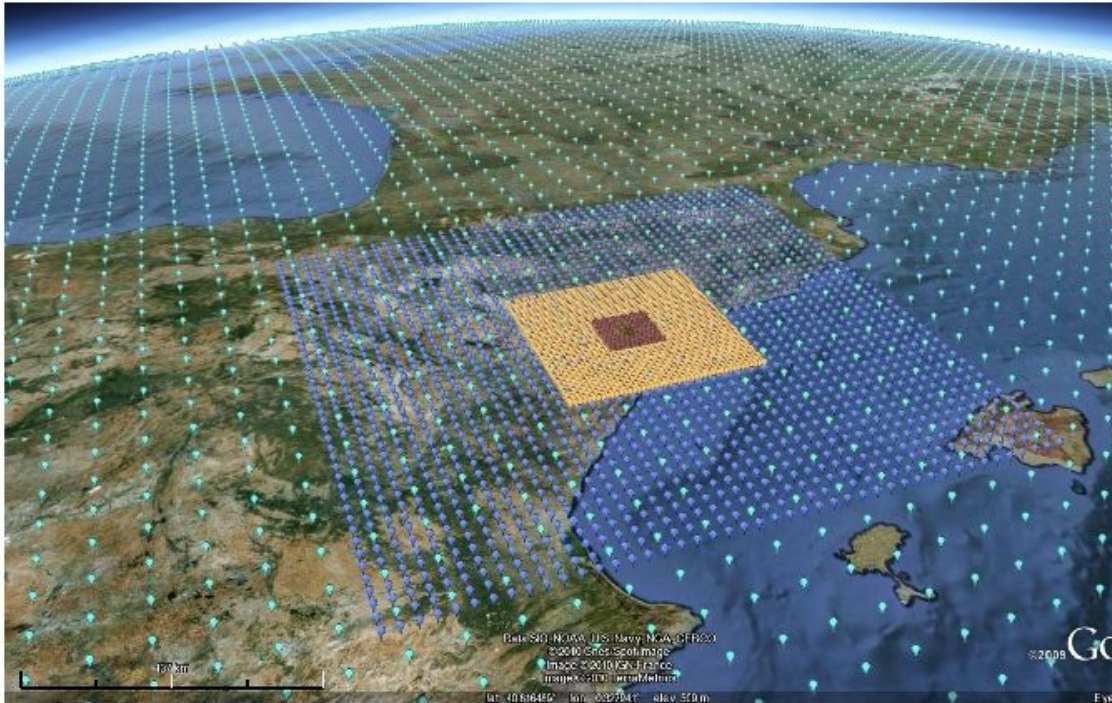
Static Input: Terrain & Land Cover



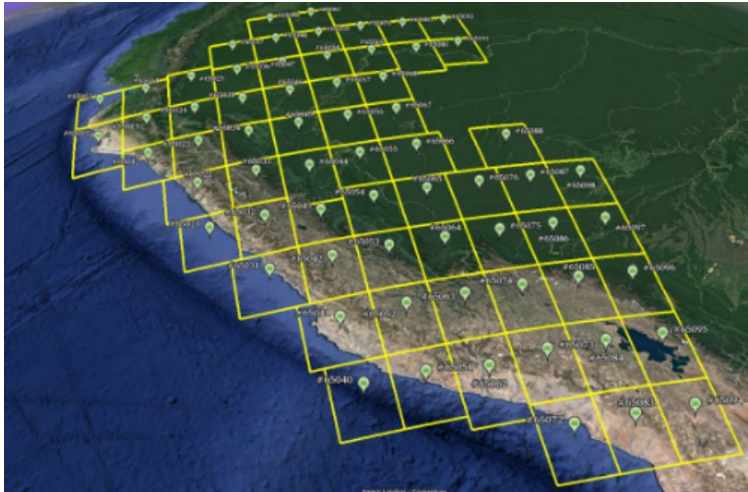
GTOPO & SRTM
MODIS/USGS/GlobCover



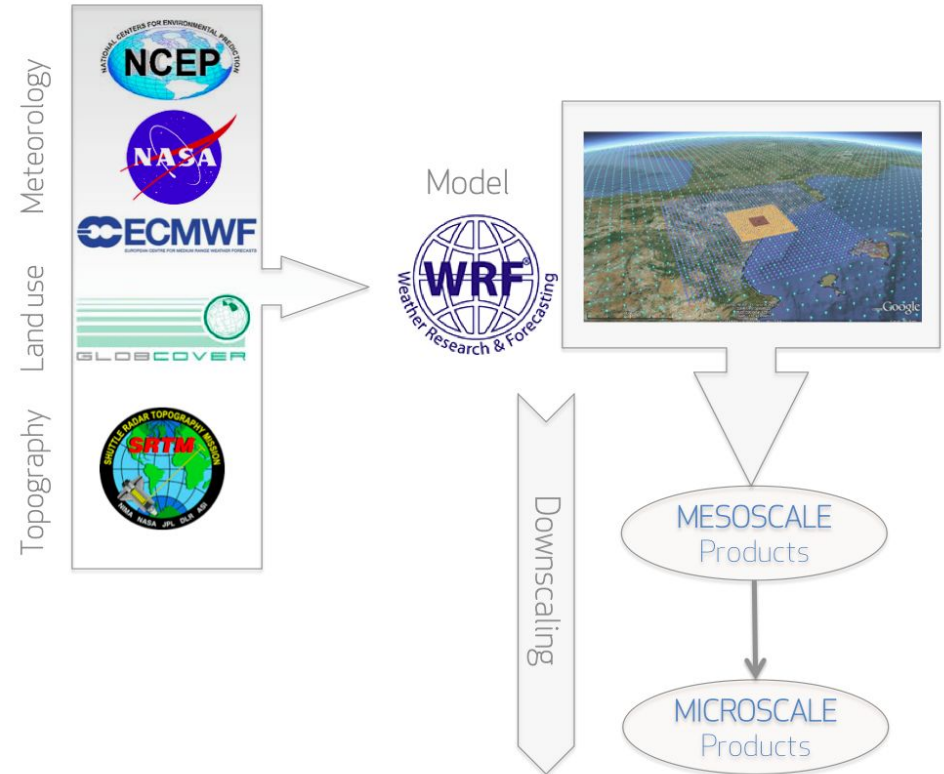
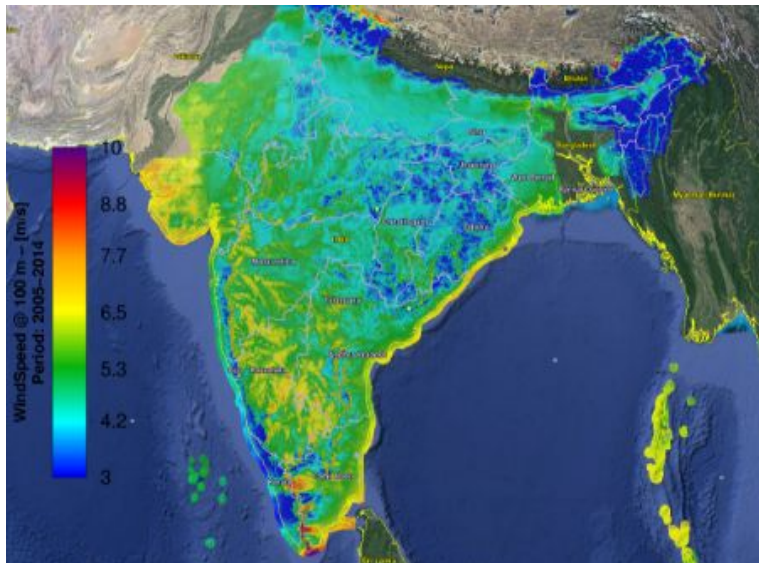
Mesoscale Modeling is a powerful downscaling tool



- ❑ Anywhere, anytime
- ❑ Zooming up to windfarm scale
3km, 1km, 500m, 100m
- ❑ Any height across the wind
turbine profile
- ❑ Time evolving information
- ❑ Turbulence and extremes
- ❑ Validated & verified
- ❑ Adopted by the industry
- ❑ Community effort



PERU Modeling Tiles (500 m resolution)

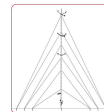


VORTEX MAP

India average wind speed at 100m (500m resolution)
(bias corrected with over 80 Met Mast)

Wind Measurement

On-site Wind Mast



Modeling

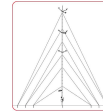
Microscale Codes (WAsP, CFD)

Wind Measurement

On-site Wind Mast

Modeling

Microscale Codes (WAsP, CFD)



Vertical and Spatial Extrapolation

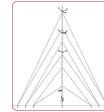
Wind Measurement

On-site Wind Mast

Remote Sensing Devices (Lidars)

Modeling

Microscale Codes (WAsP, CFD)



Wind Measurement

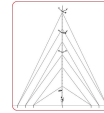
On-site Wind Mast

Remote Sensing Device (Lidars)

Modeling

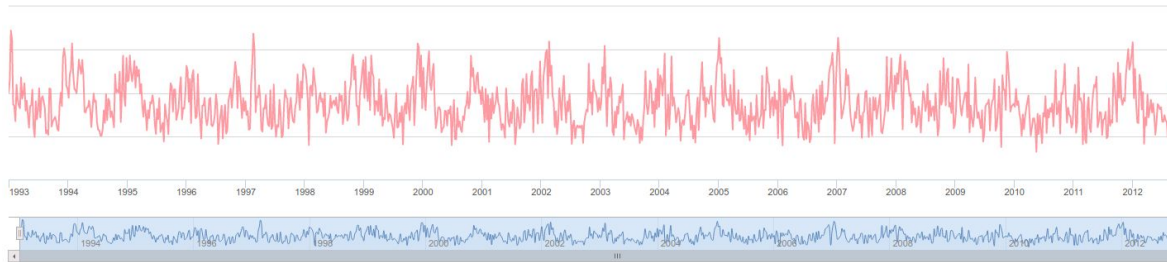
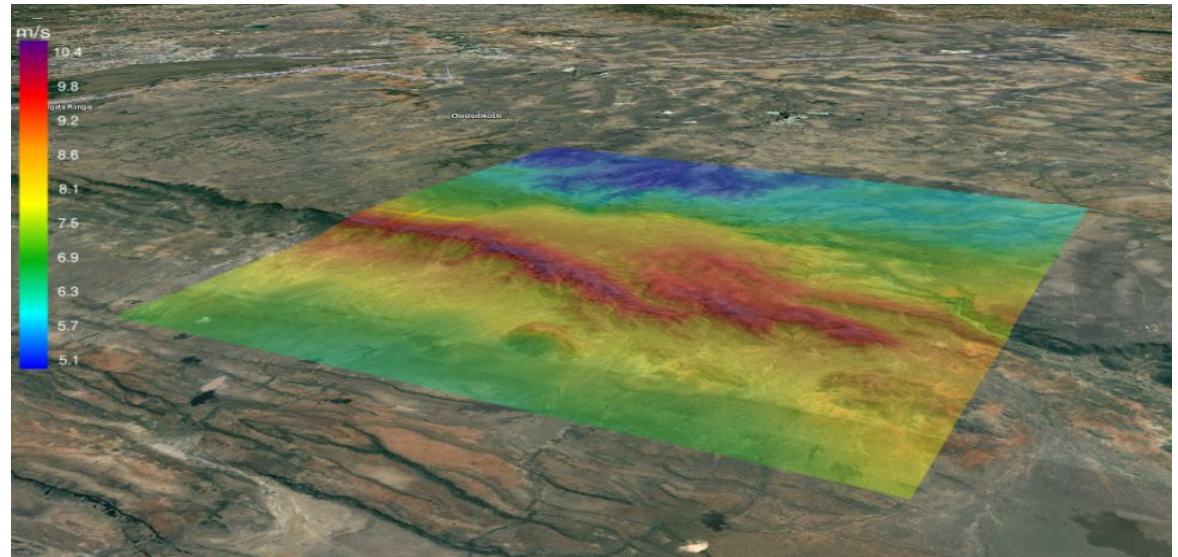
Microscale Codes (WAsP, CFD)

Mesoscale Modeling

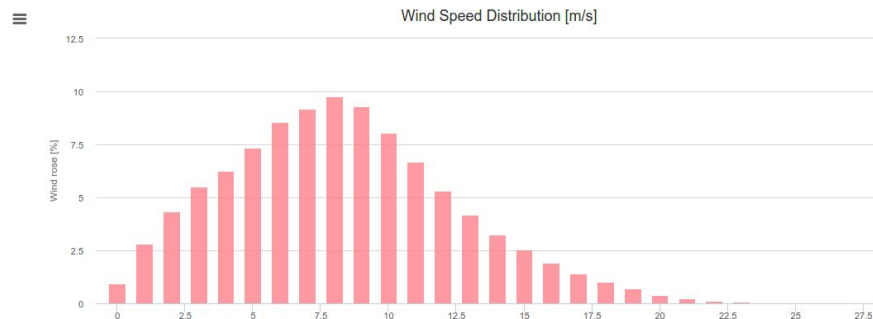
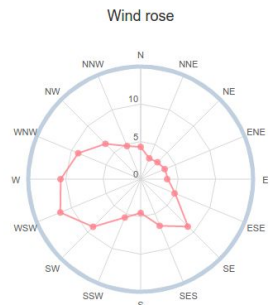


Global and Country-wide mapping
Virtual Time Series
High resolution Wind Conditions
Microscale Wind Resource Grid
Calibrated with Observations
Extremes and Turbulence
Environmental Conditions

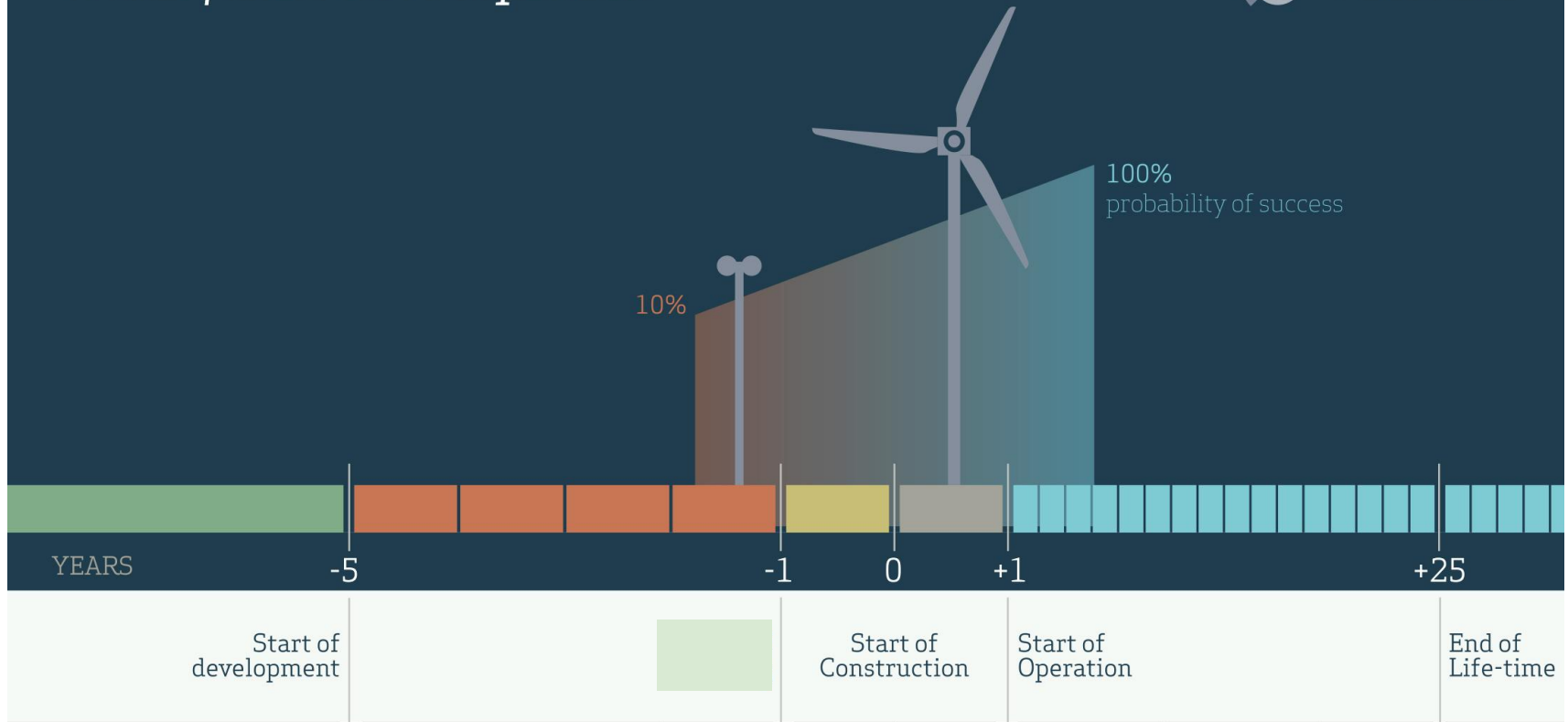
VORTEX FARM
Wind Resource Grid at
100m resolution, 80m
above ground
Site located in East Africa



VORTEX SERIES
Hourly Time SERIES
spanning over 1997-2016
period for Wind Speed and
Direction
Site located in South
America



Wind farm development



MAPS



MAST



LES



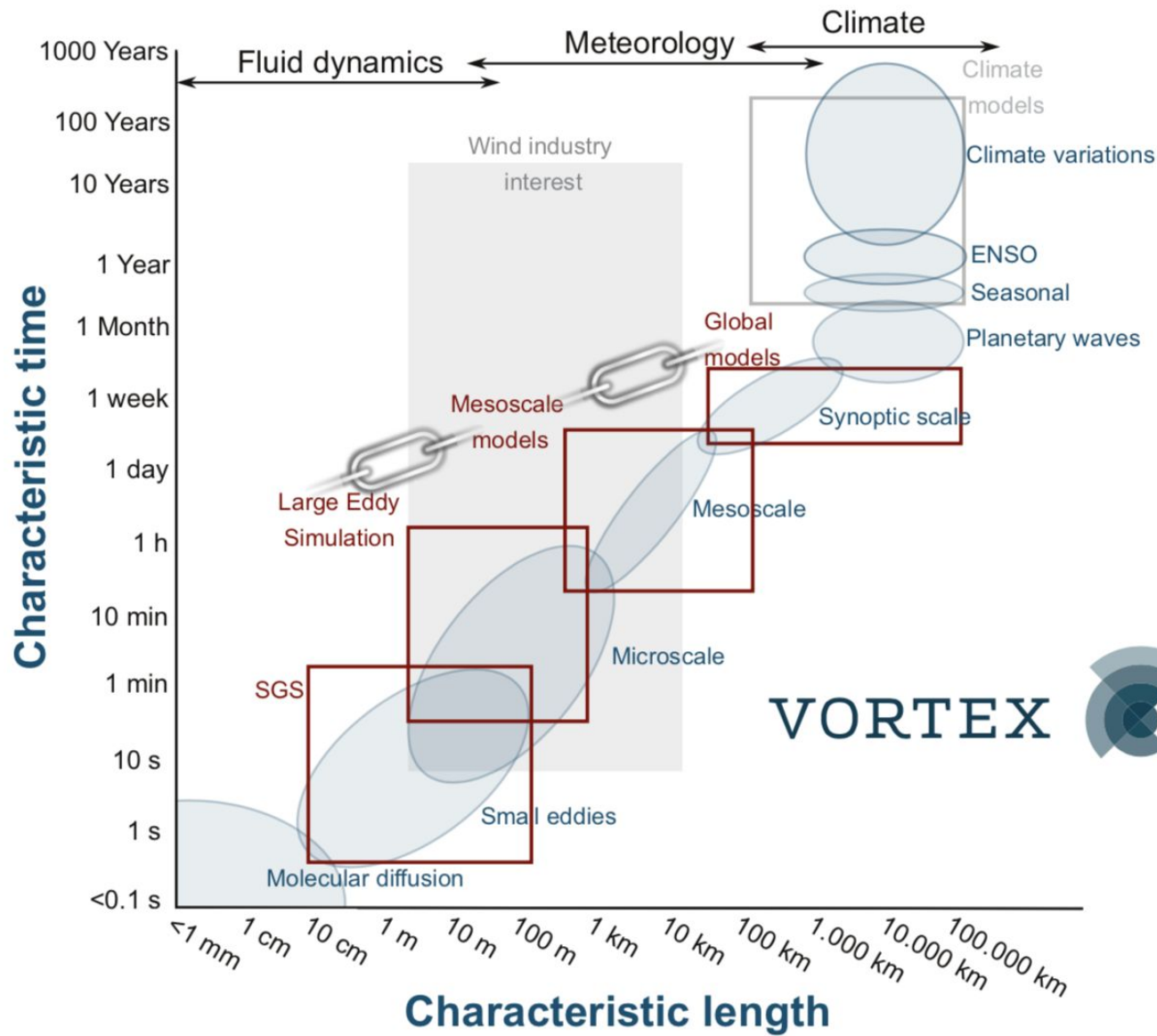
FARM



SERIES



INDEX



WRF-LES Modeling Stream

More and more realistic turbulence

Able to determine shear and veer

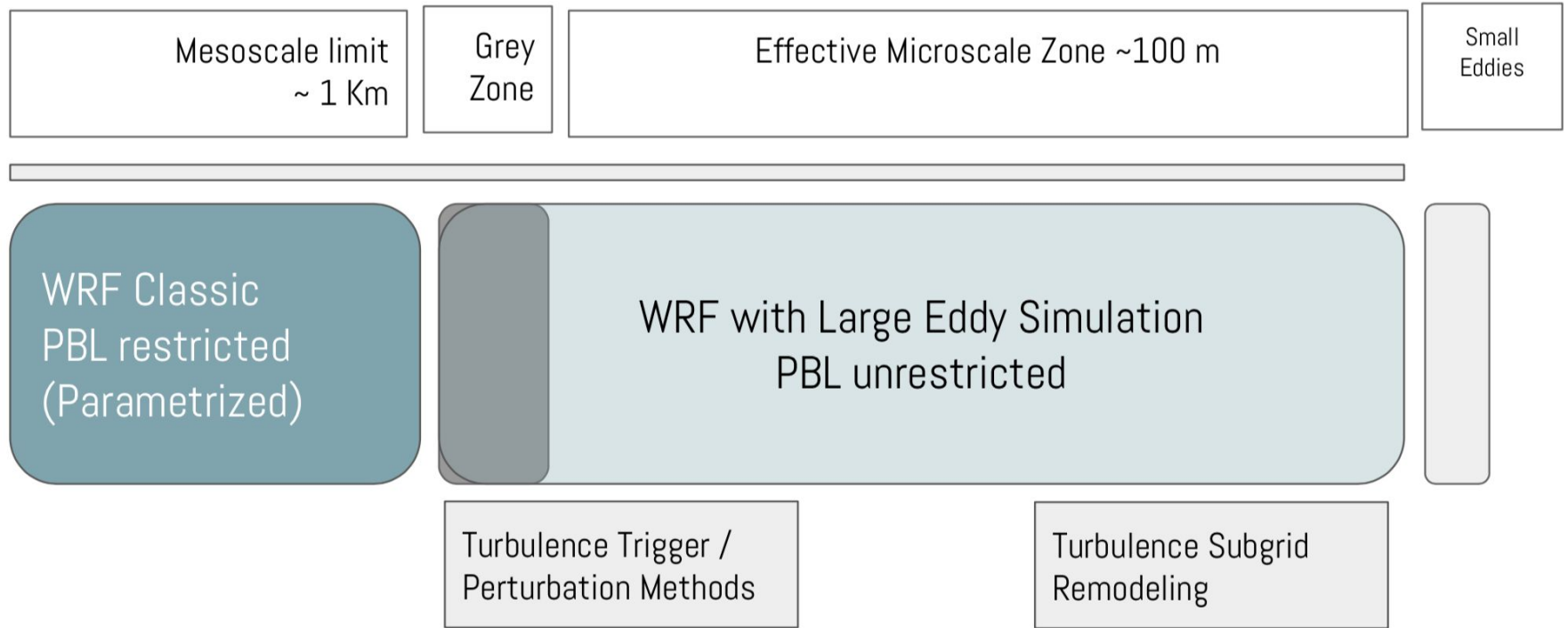
Accurate tails (high and low winds)

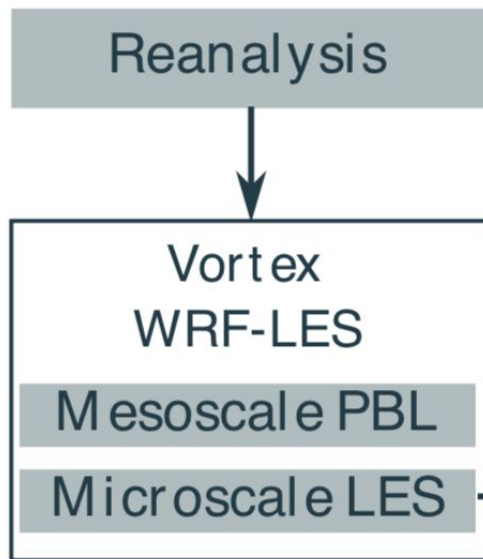
Everything within the 10' life

A safer site classification tool

Indistinguishable model and observation

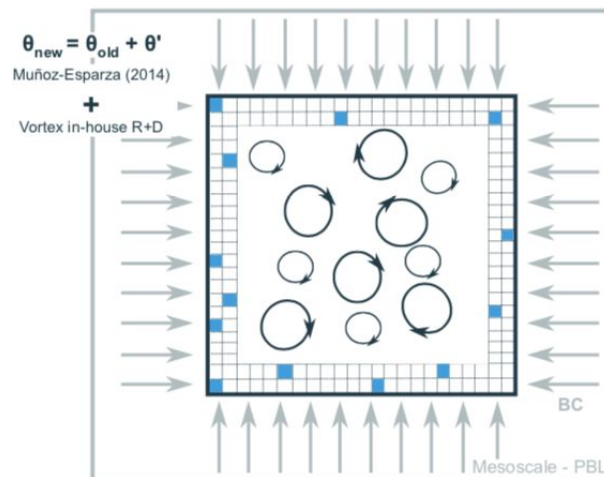
Scale Nesting down





4 Hz output

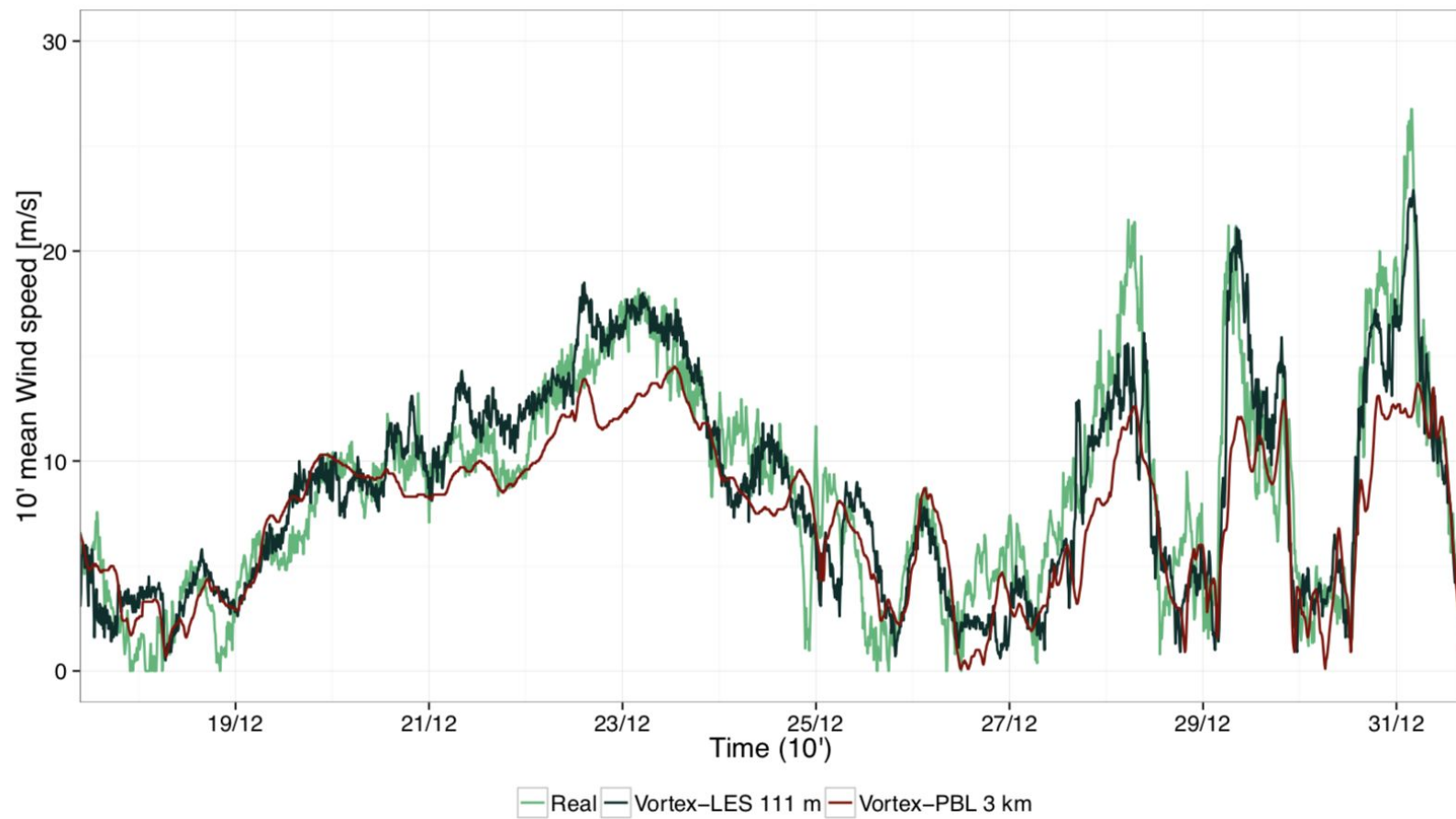
1-year time-series (10')
110 m grid-size
Region 2.5x2.5 km



Post processing

10' averages
10' standard deviation
20-150 meters above ground
3" gust

Wind speed, Wind direction,
Temperature, Pressure, Richardson
Number, PBL Fluxes, Veer, Inflow
angle, ...



3.1% Off-shore 41.7% Flat terrain 25.0% Complex terrain 30.2% Forest



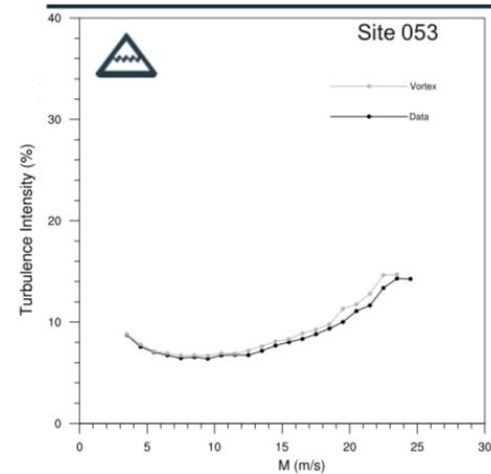
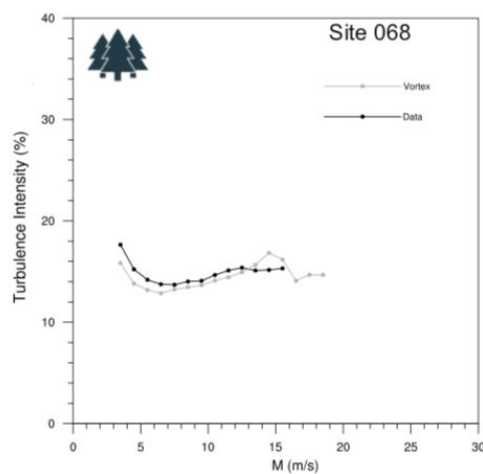
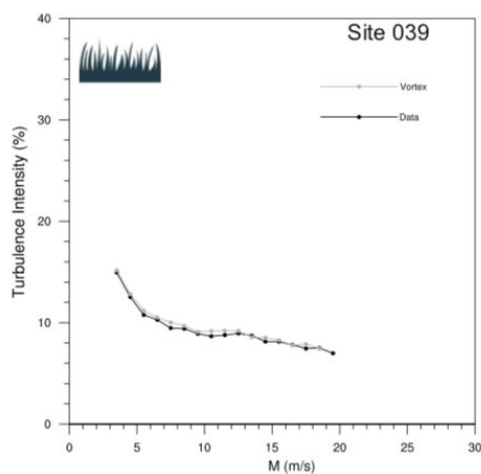
Anemometers: 18.1% 20-50 m 68.1% 50-100 m 13.8% 100-150 m

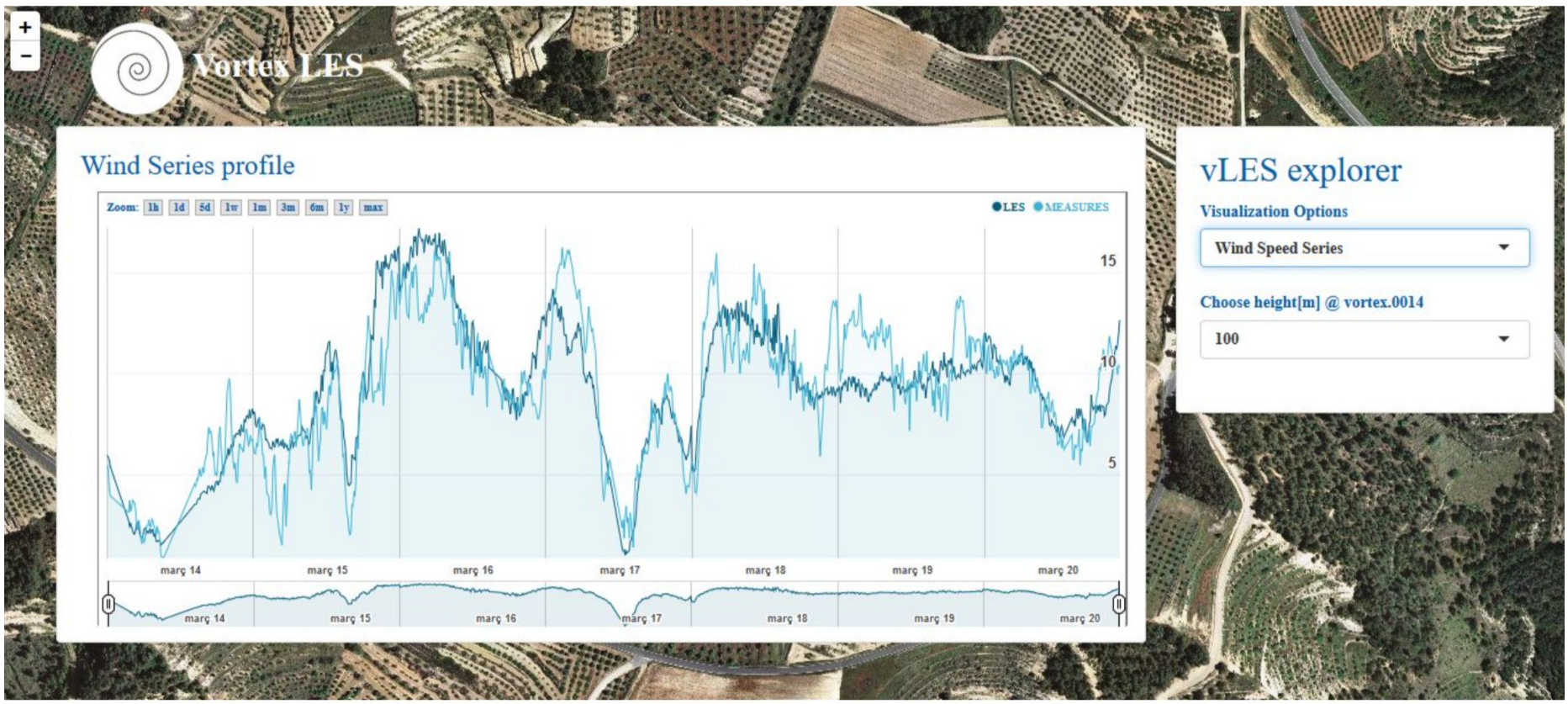
1-year validation

Wind speed validated at 96 sites at different mast-mast heights

Turbulence validated at 56 sites at different mast-mast heights

			Bias (%)	RMSE (ms-1)	R ²
+	All (100%)	10-min		2.6	0.605
		Hourly	2.4	2.5	0.637
		Daily		1.7	0.807
≡	Off-shore (3.2%)	10-min		1.9	0.837
		Hourly	0.4	1.8	0.855
		Daily		1.1	0.937
🌿	Flat (40.9%)	10-min		2.5	0.593
		Hourly	-3.4	2.4	0.625
		Daily		1.6	0.811
⚠️	Complex (30.1%)	10-min		2.9	0.590
		Hourly	7.1	2.8	0.623
		Daily		1.9	0.790
🌲	Complex Forest (25.8%)	10-min		2.6	0.610
		Hourly	6.5	2.5	0.646
		Daily		1.7	0.805





vLES explorer

Visualization Options

Wind Speed Series ▼

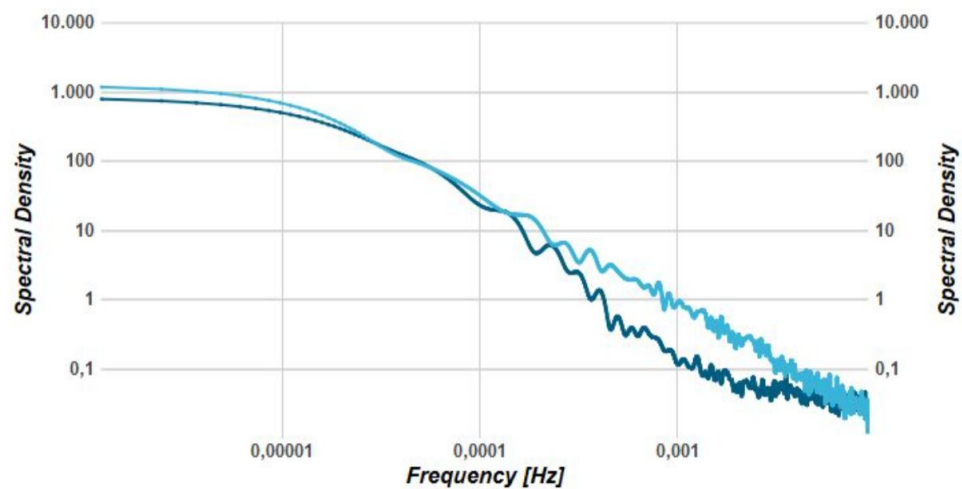
Choose height[m] @ vortex.0014

100 ▼



Vortex LES

Spectral density



vLES explorer

Visualization Options

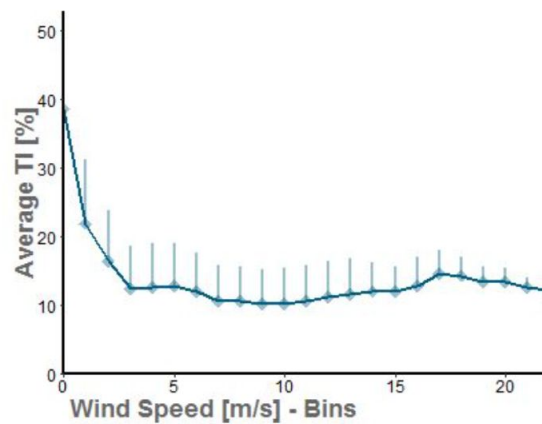
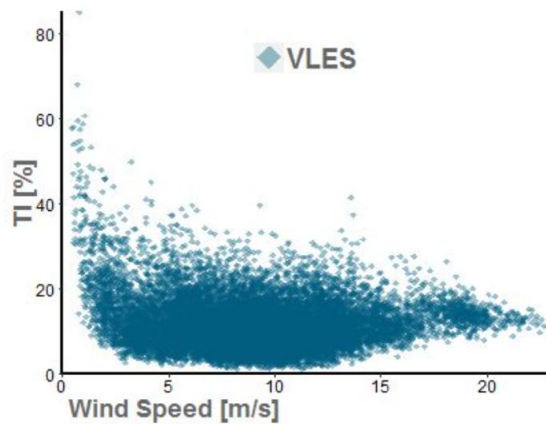
Spectral Density

Choose height[m] @ vortex.0002

070



Turbulent Intensity



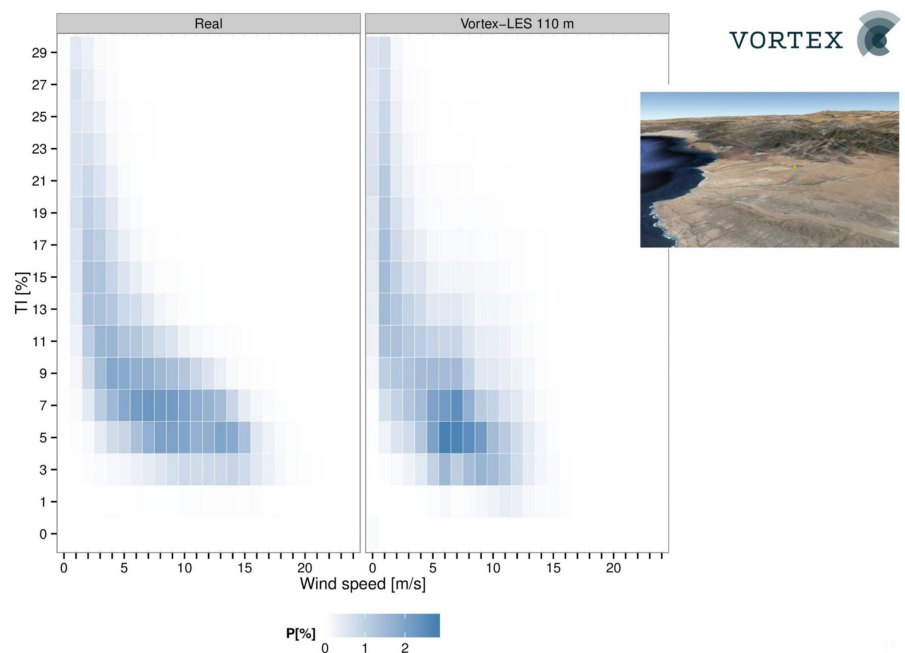
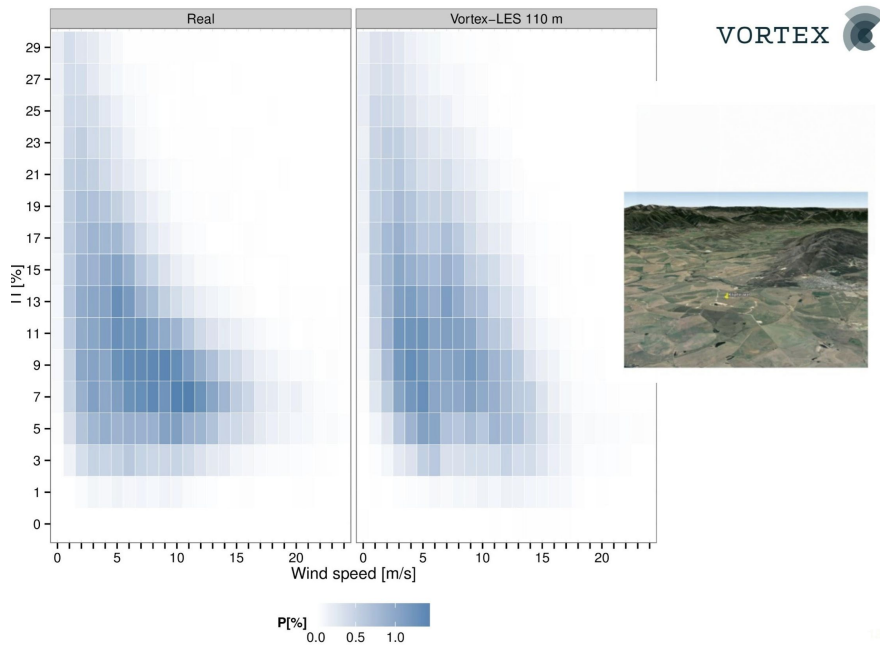
vLES explorer

Visualization Options

Turbulent Intensity

Choose height[m] @ vortex.0002

070



1) Spatial Variation of Wind Conditions: A key limitation of the current methods for considering outer range conditions is that they assume that the wind conditions (e.g. turbulence) at the met mast apply to all turbine locations.

WRF-LES offers the potential to model turbine specific conditions such as turbulence & inflow in the time domain which could be used in combination with met mast data to predict turbine specific response to outer range conditions.

2) Vertical Profile Information: Currently relatively few sites have LiDAR data. LES could provide a cost effective alternative to using LiDAR to obtain information about the vertical profile across the full rotor.

Is WRF-LES able to incorporate both the energy content and the shape of the profile (compared to that obtained with a LiDAR)?

(*) Quoting Peter Stuart (personal communication)

1 site

Output at 4 Hz

1 day + 12 h spin-up

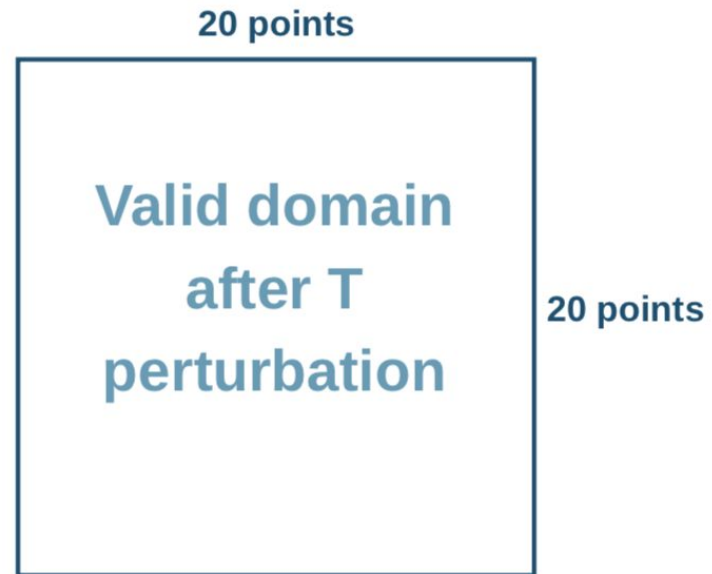
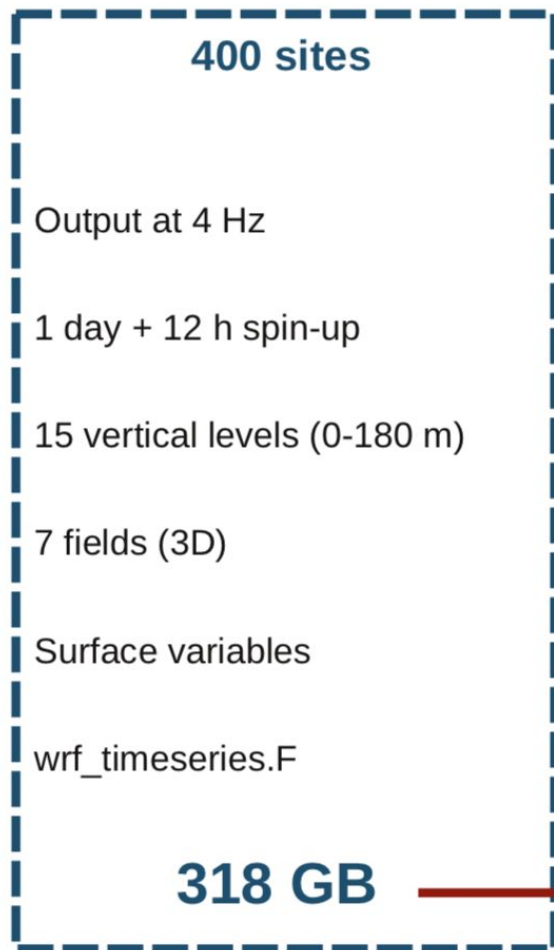
15 vertical levels (0-180 m)

7 fields (3D)

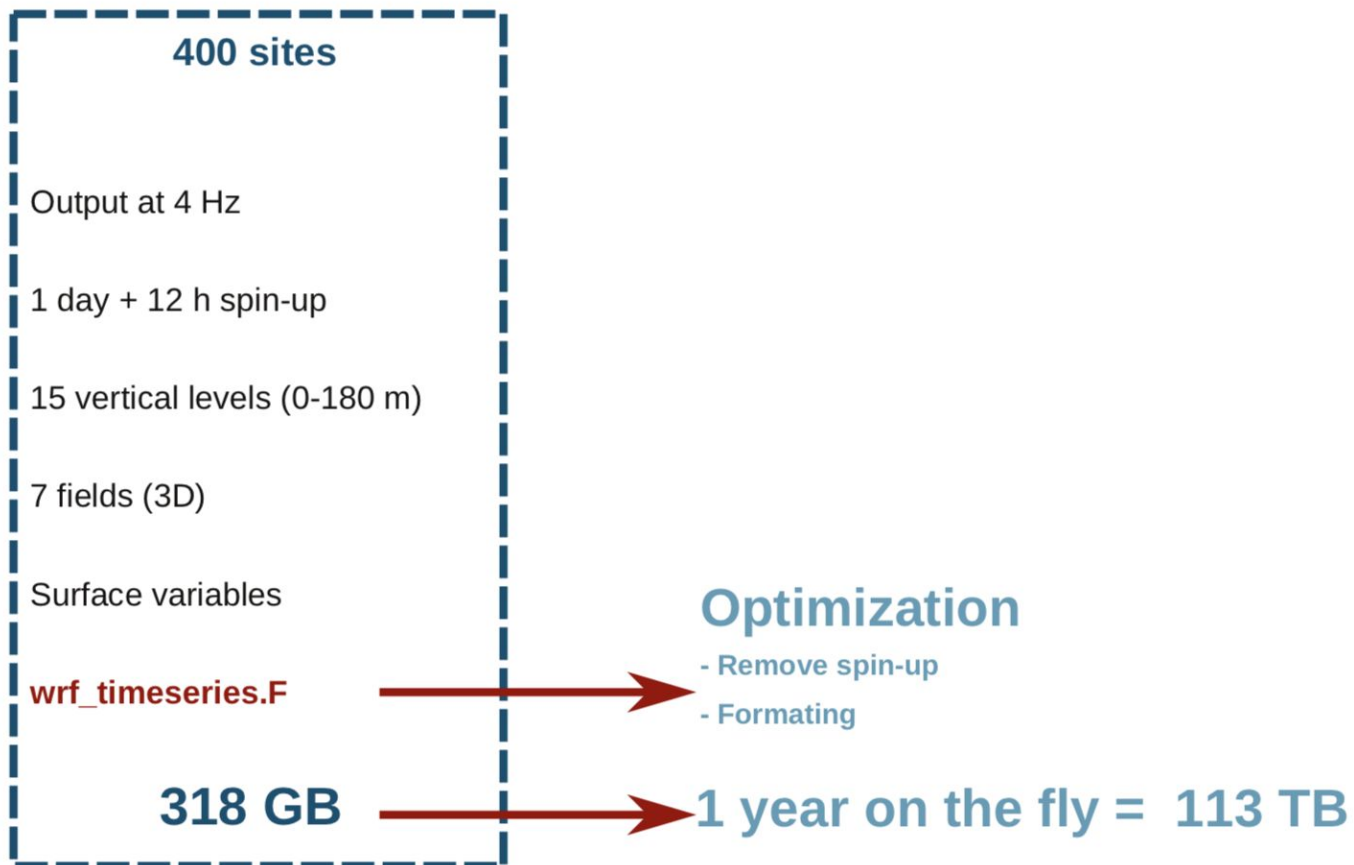
Surface variables

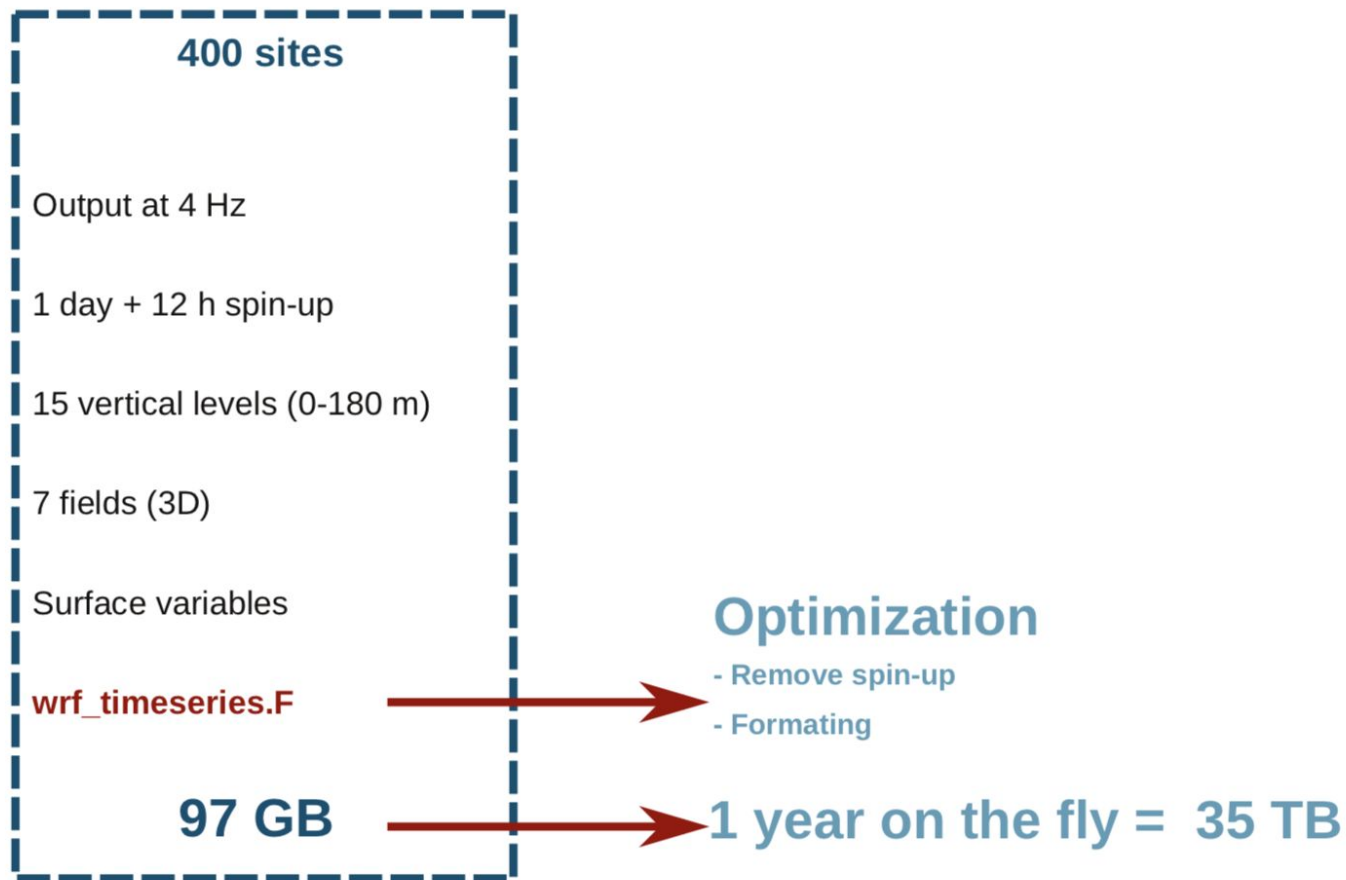
wrf_timeseries.F

815 MB



→ 1 year on the fly = 113 TB





400 sites

Output at 4 Hz

1 day + 12 h spin-up

15 vertical levels (0-180 m)

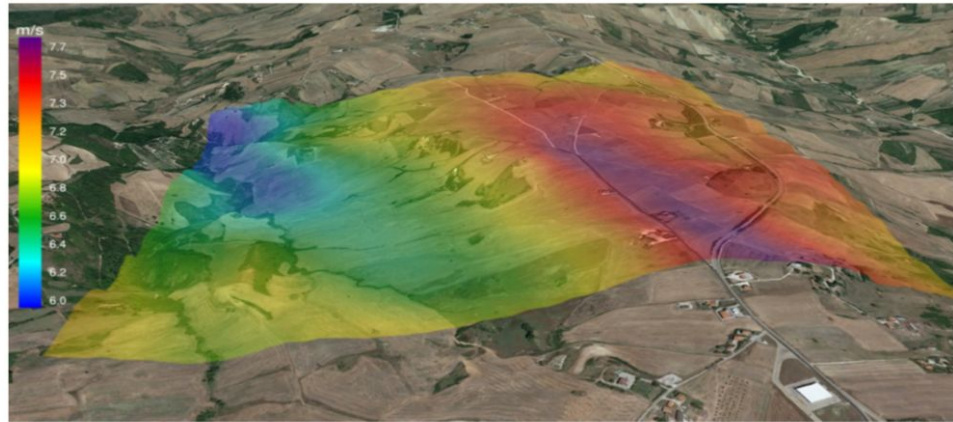
7 fields (3D)

Surface variables

wrf_timeseries.F

97 GB

1-y mean wind speed



Optimization

- Remove spin-up
- Formatting

1 year on the fly = 35 TB

New frame: WRF-LES to enable high resolution time series

Positive results :

- ★ Bias / Turbulence
- ★ Efficient (time) and feasible (cpu/storage/energy)

Work in progress:

- ★ Grey zone
- ★ Initialisation
- ★ Land Surface Model



Improve Wind Conditions Modeling in the time domain

Turbulence & Power times series modeling

Model and Observation Integration



I WORKSHOP BRASILEIRO SOBRE MODELAGEM DA ATMOSFERA

APLICAÇÕES NA ÁREA DE ENERGIA EÓLICA

CTGAS-ER | NATAL-RN

14 e 15 junho de 2018

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