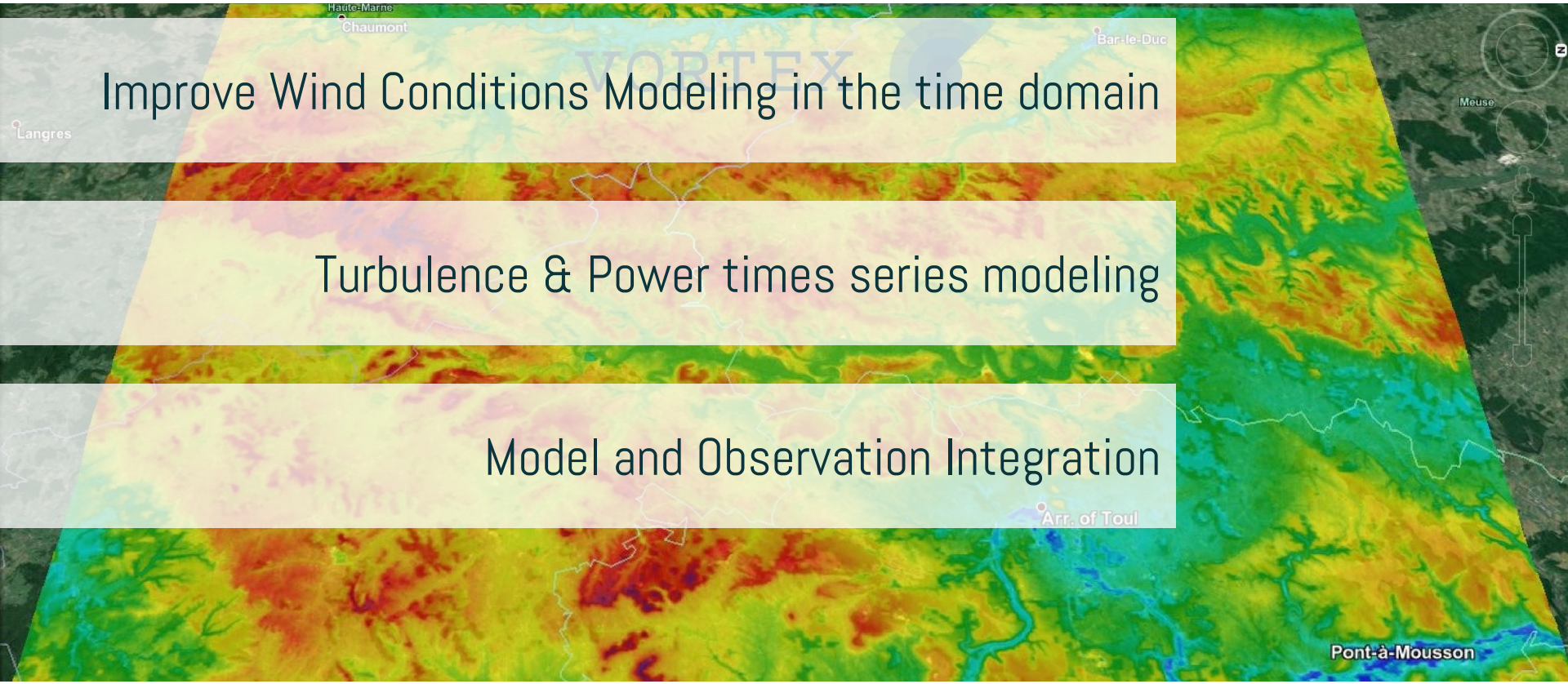
Advances in WRF-LES Modelling of Outer Range Conditions

Power Curve Working Group Meeting
Minneapolis Sep/2016

Get in touch:
gil.lizcano@vortex.es

VORTEX

Active modeling streams developments



Improve Wind Conditions Modeling in the time domain

Turbulence & Power times series modeling

Model and Observation Integration

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

WRF-LES in the context of PCWG

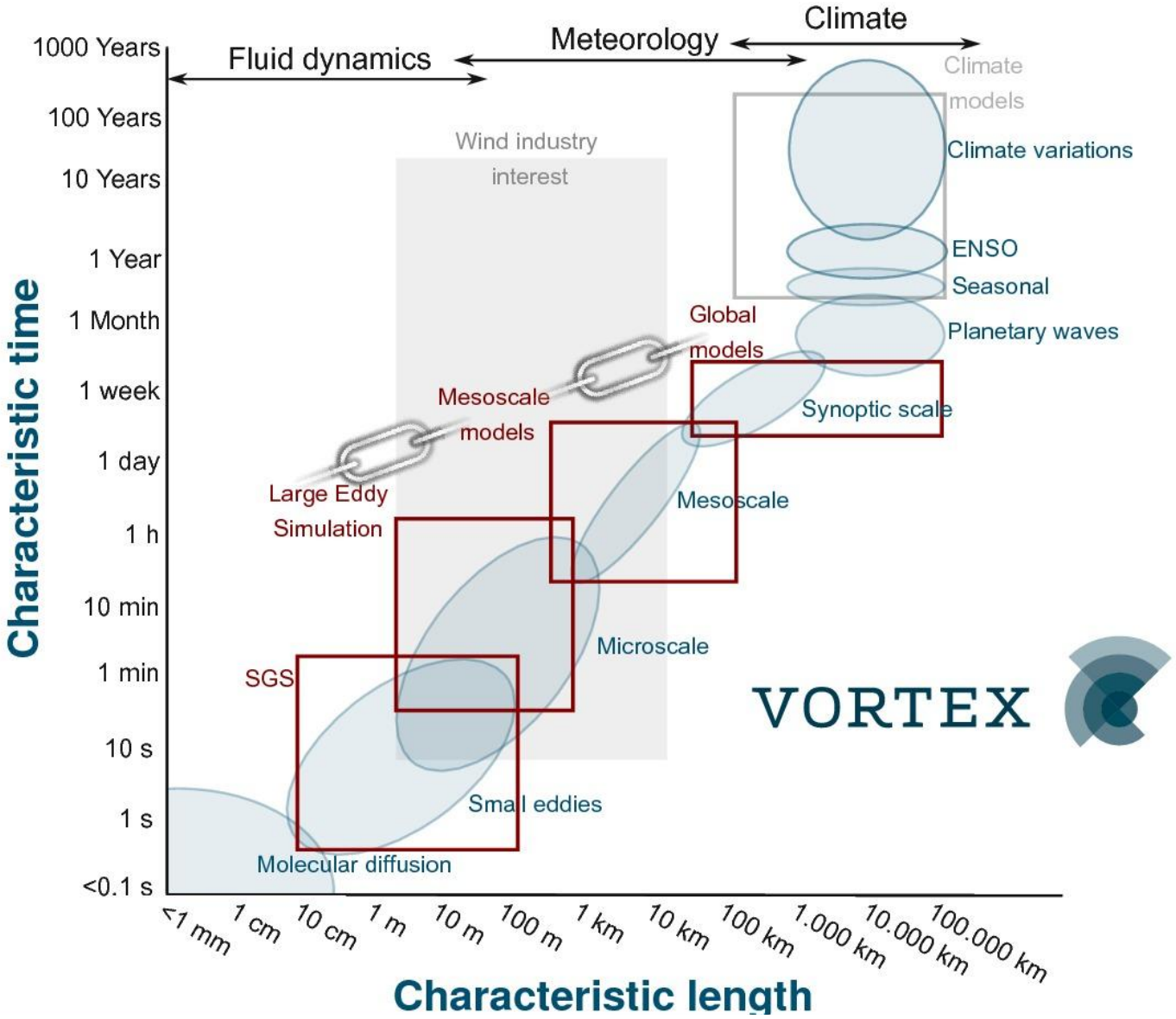
1) Spatial Variation of Wind Conditions: A key limitation of the current methods for considering outer range conditions is that they assume that the wind conditions (e.g. turbulence) at the met mast apply to all turbine locations.

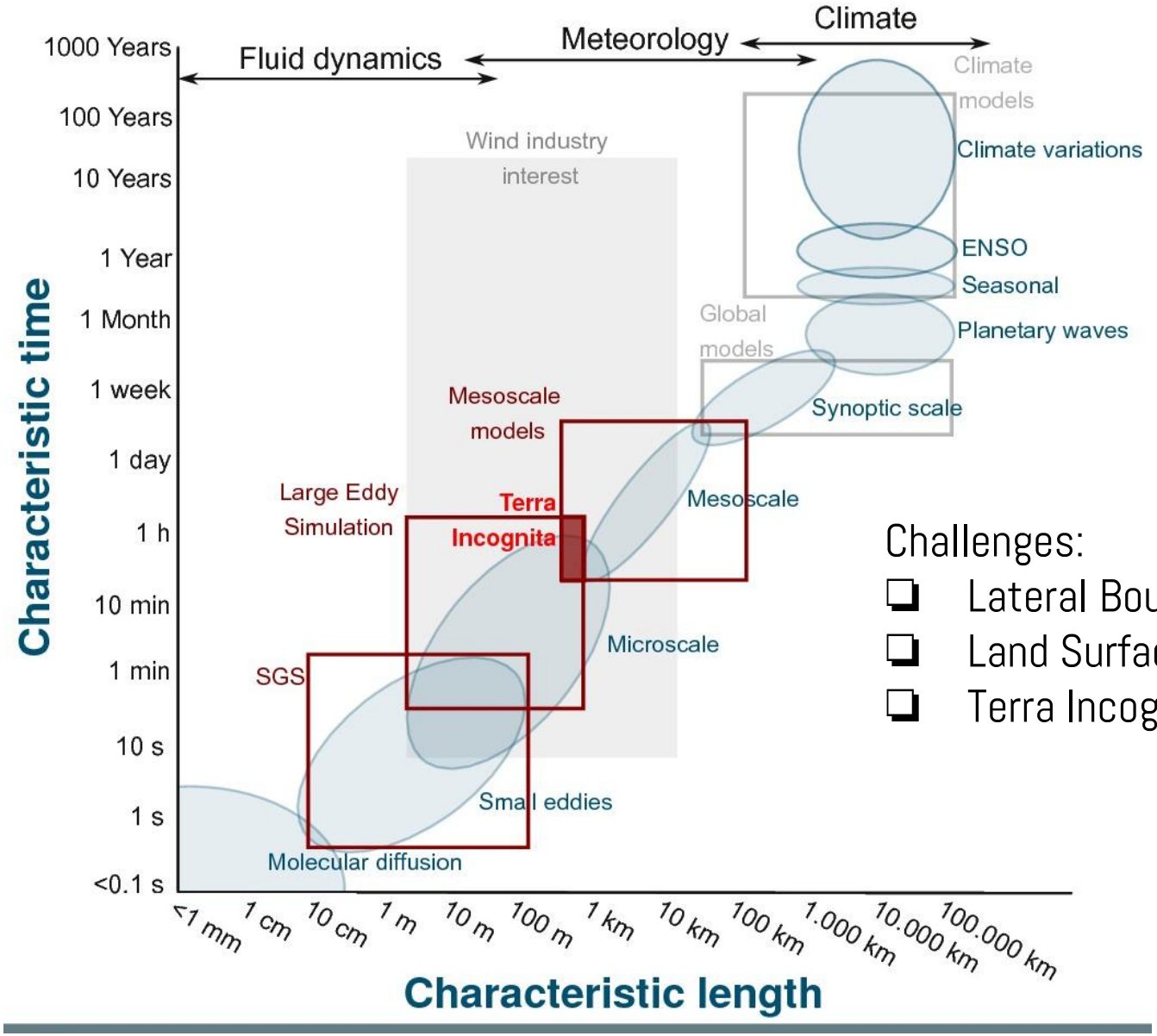
WRF-LES offers the potential to model turbine specific conditions such as turbulence & inflow in the time domain which could be used in combination with met mast data to predict turbine specific response to outer range conditions.

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)

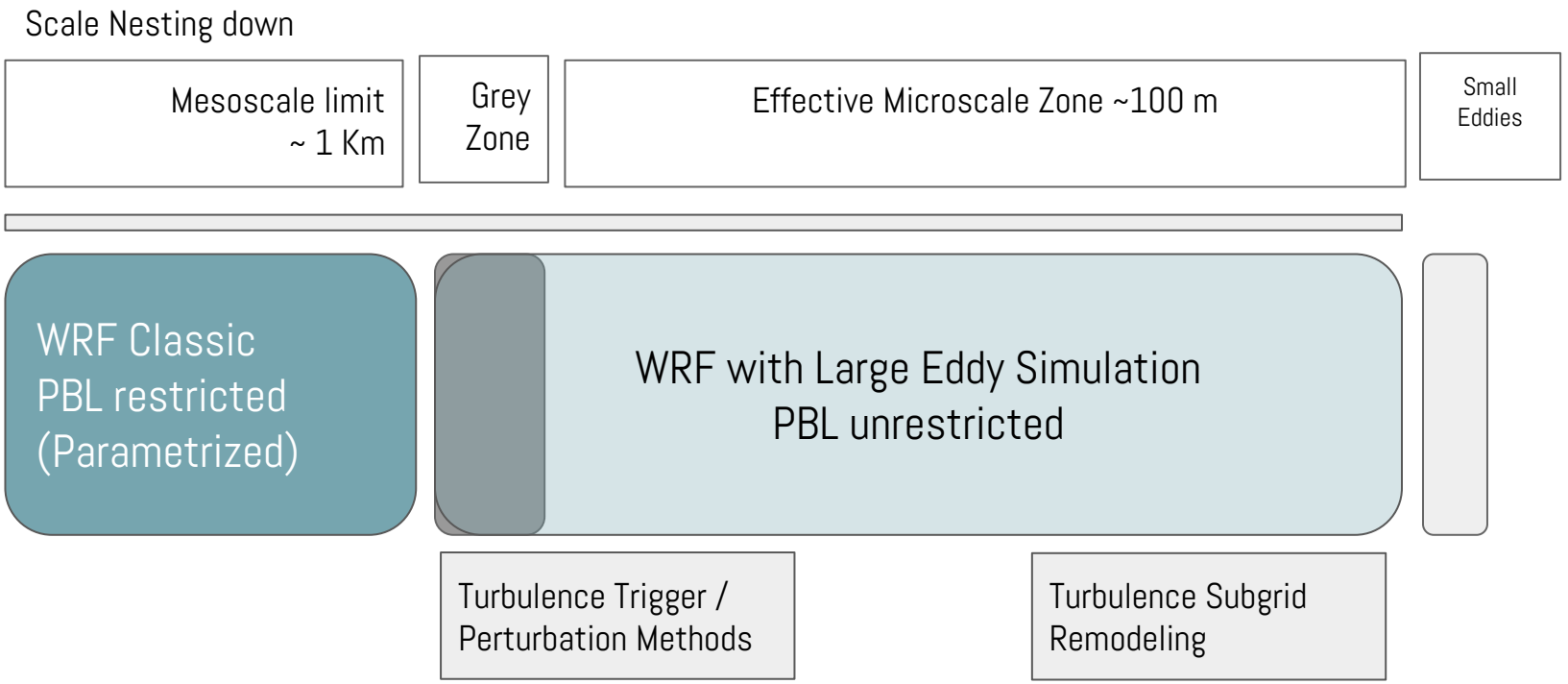

Fluid dynamics
Meteorology
Climate
1000 Years
100 Years
10 Years
1 Year
1 Month
1 week
1 day
1 h
10 min
1 min
10 s
1 s
<0.1 s
Characteristic time
Wind industry interest
Climate models
Climate variations
ENSO
Seasonal
Planetary waves
Global models
Synoptic scale
Mesoscale models
Mesoscale
Large Eddy Simulation
Microscale
SGS
Small eddies
Molecular diffusion
VORTEX
<1 mm
1 cm
10 cm
1 m
10 m
100 m
1 km
10 km
100 km
1.000 km
10.000 km
100.000 km
Characteristic length



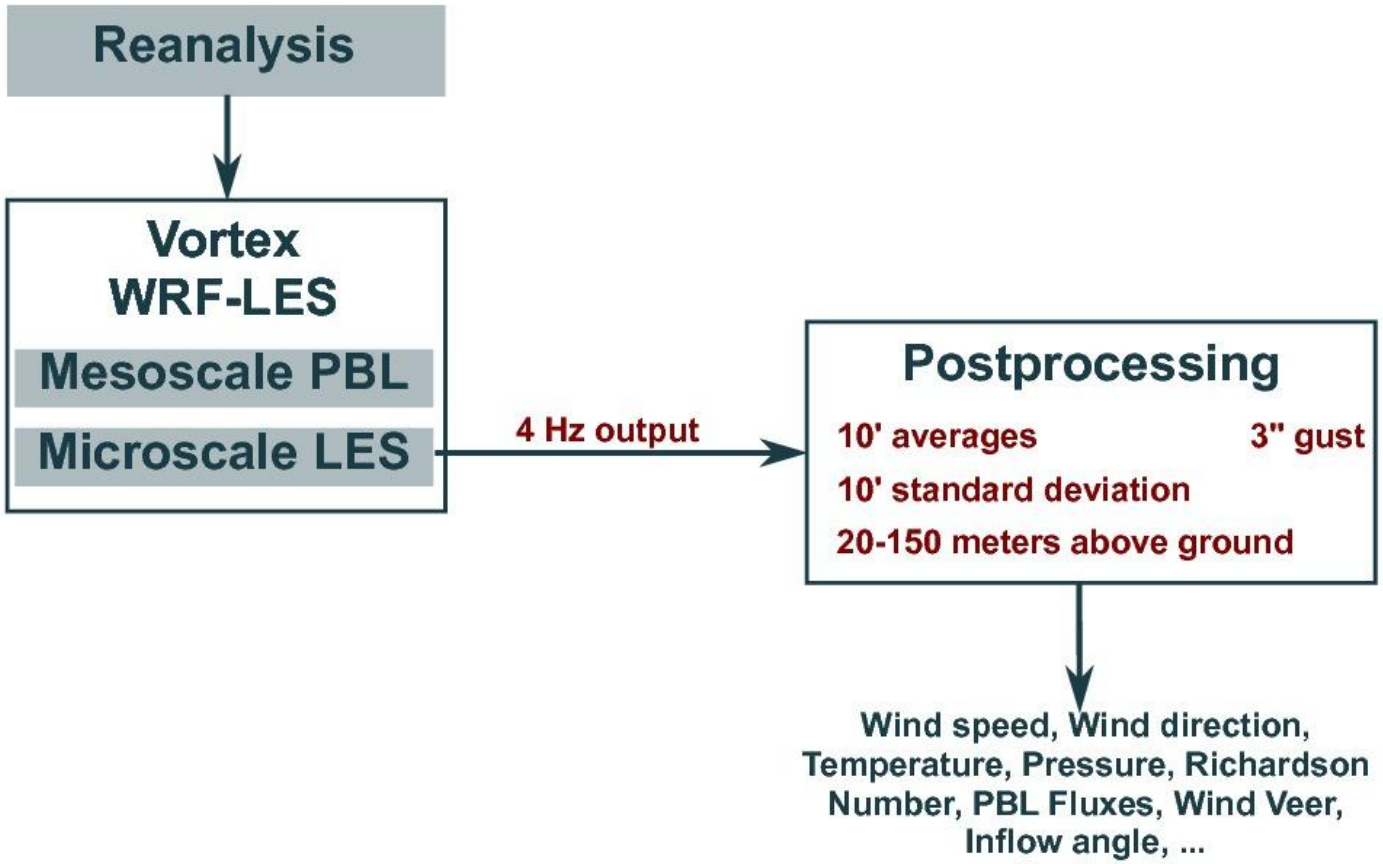
Challenges:

- ❏ Lateral Boundary Conditions
- ❏ Land Surface Model
- ❏ Terra Incognita

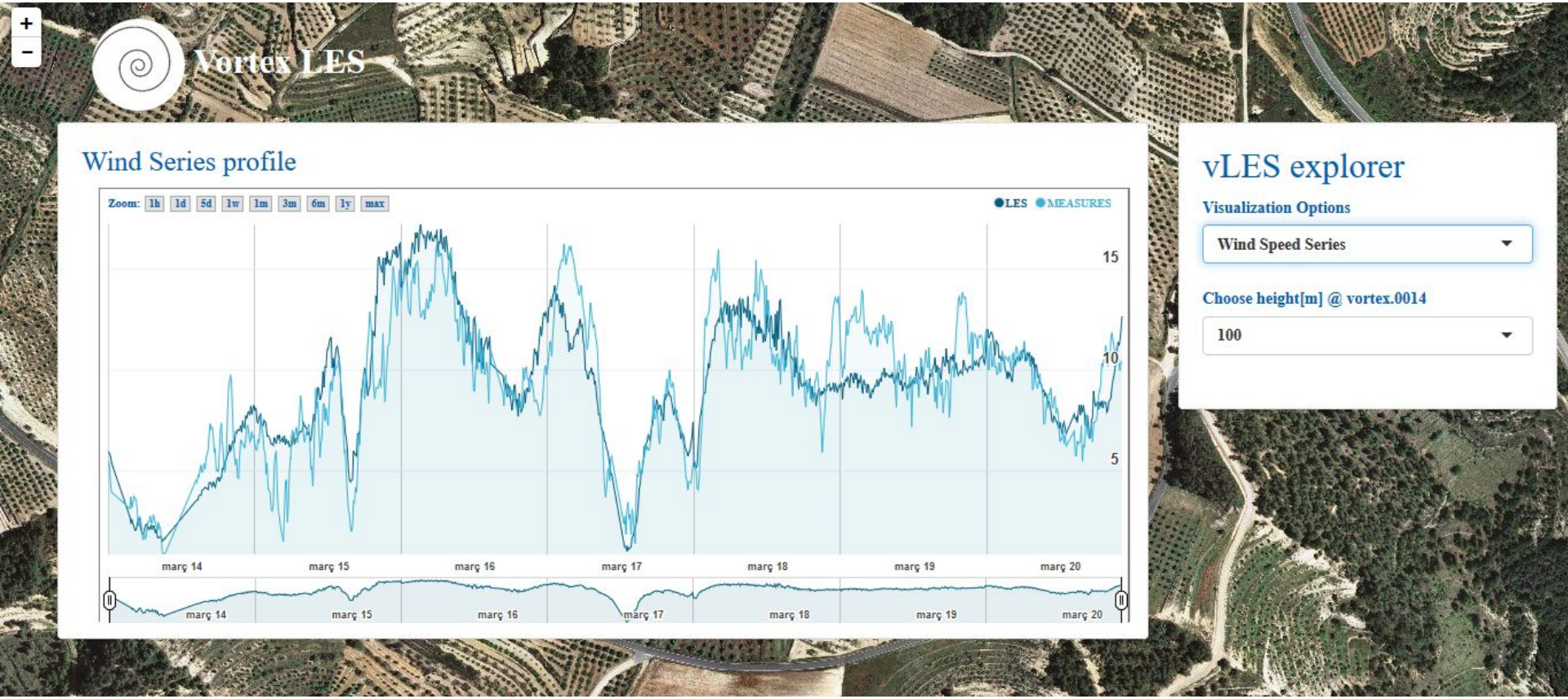
WRF-LES



VORTEX

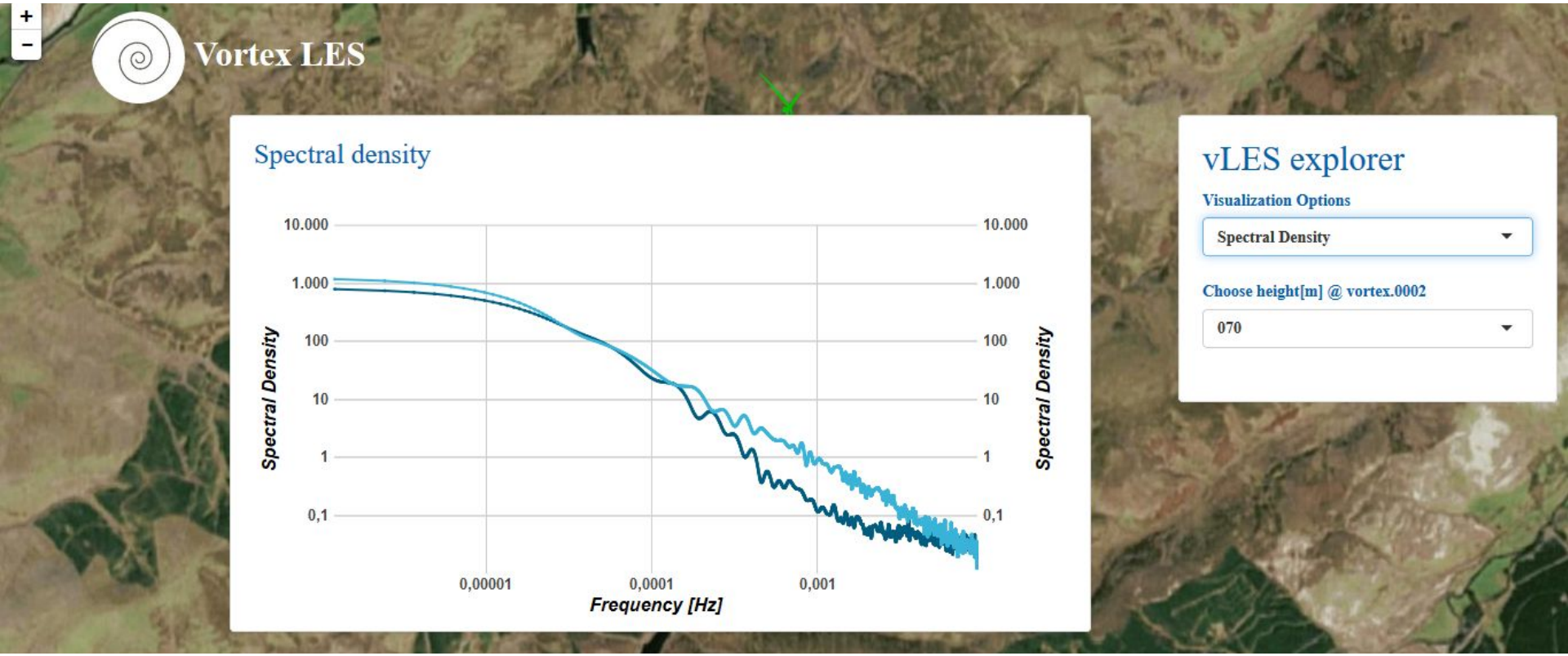

Reanalysis
Vortex
WRF-LES
Mesoscale PBL
Microscale LES
4 Hz output
Postprocessing
10' averages
3" gust
10' standard deviation
20-150 meters above ground
Wind speed, Wind direction,
Temperature, Pressure, Richardson
Number, PBL Fluxes, Wind Veer,
Inflow angle, ...

WRF-LES, Outputs



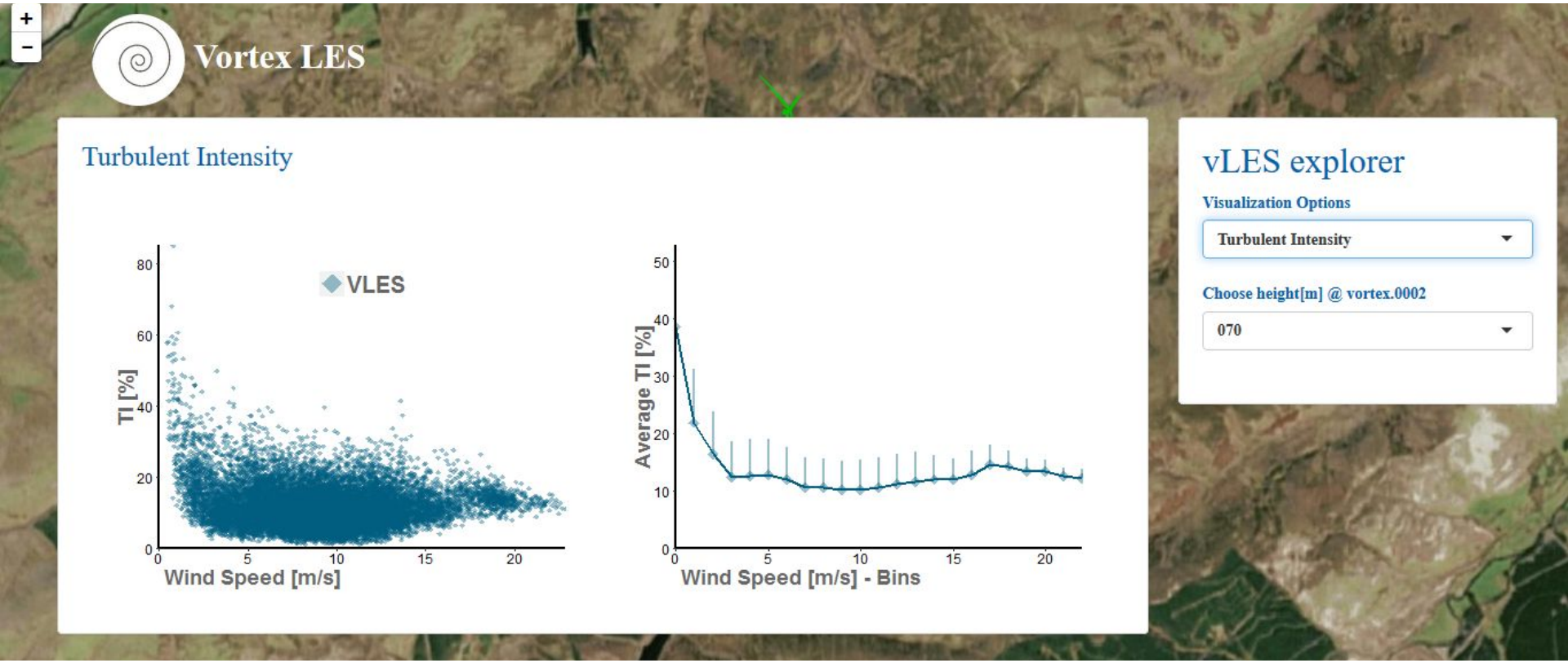
VORTEX

WRF-LES, Outputs



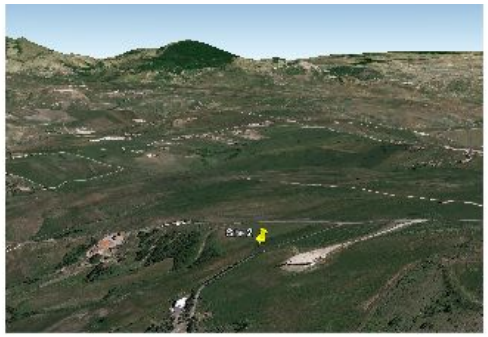
VORTEX

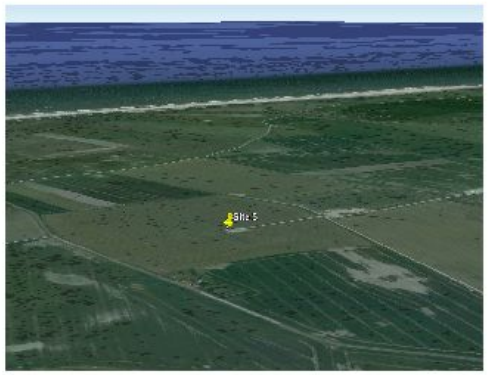
WRF-LES, Outputs

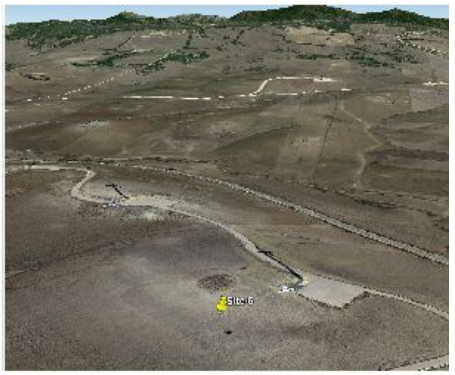


VORTEX

WRF-LES, Outputs



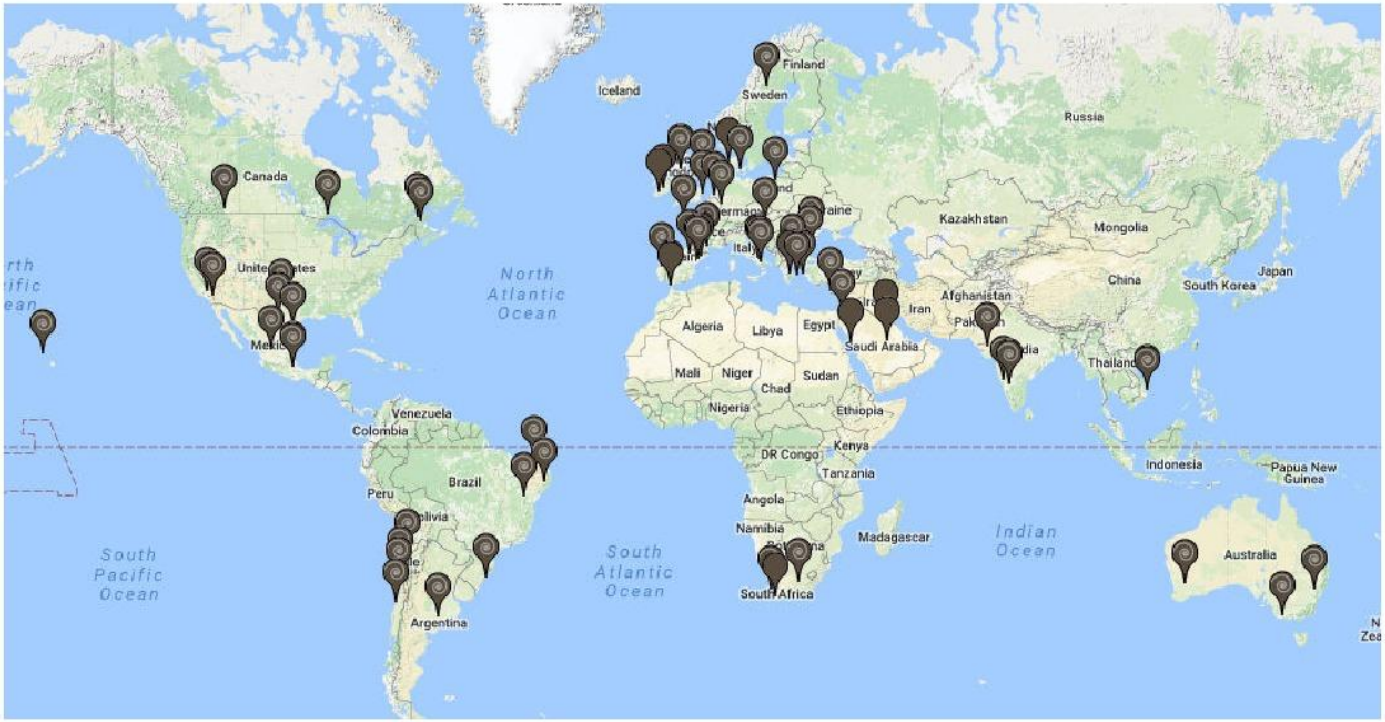




... 51 sites

VORTEX

- Wind metrics validated for **93 sites**
- Turbulence Intensity validated for **51 sites**



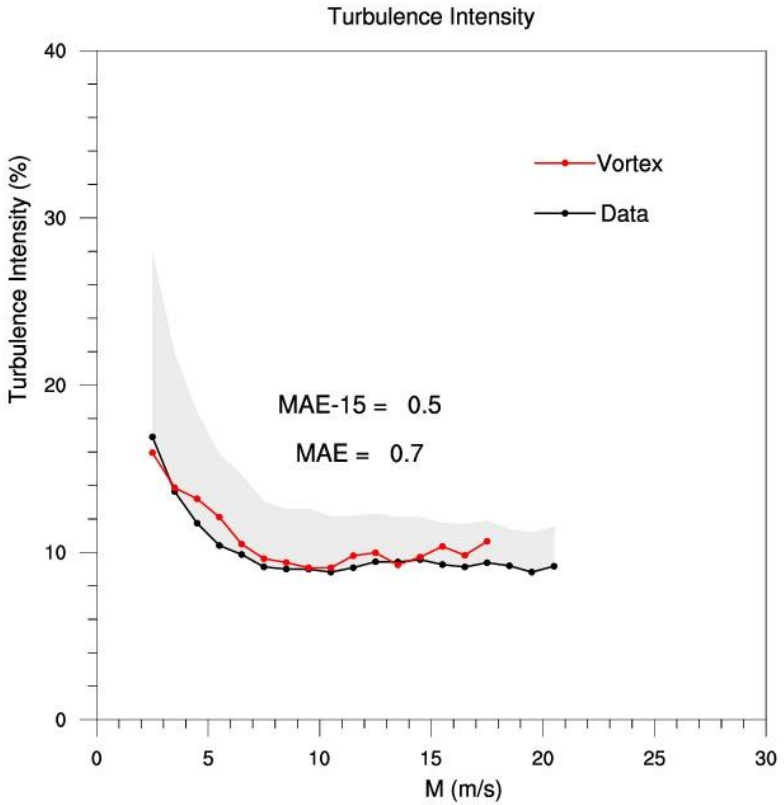
VORTEX

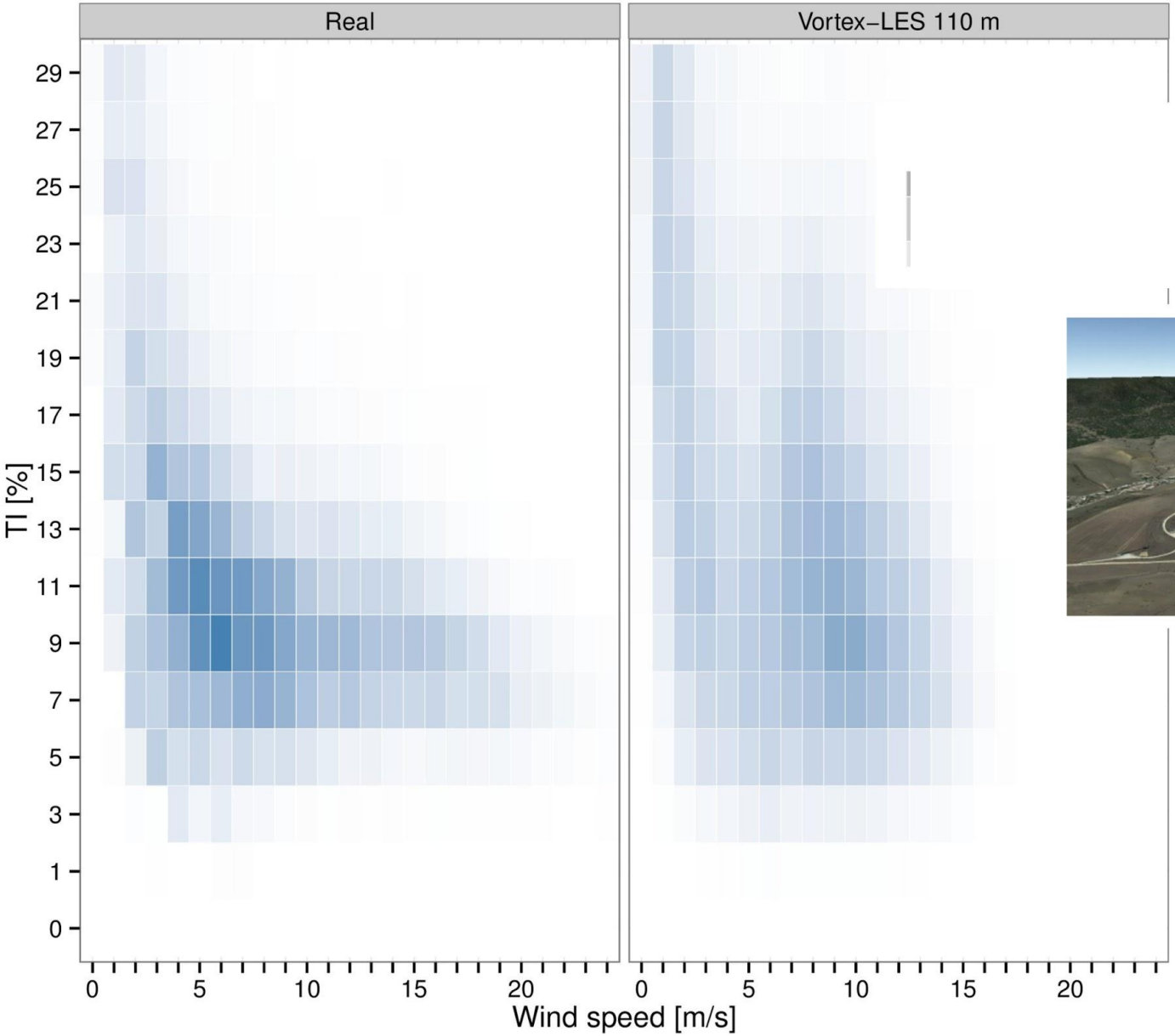
TI(%) validated for **51 sites**

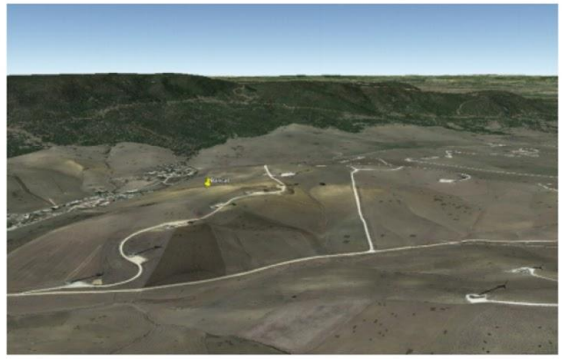
Which metric to use?

1. MAE between TI-model against TI-obs weighted by bin-ocurrence
2. MAE at 15 m/s bin

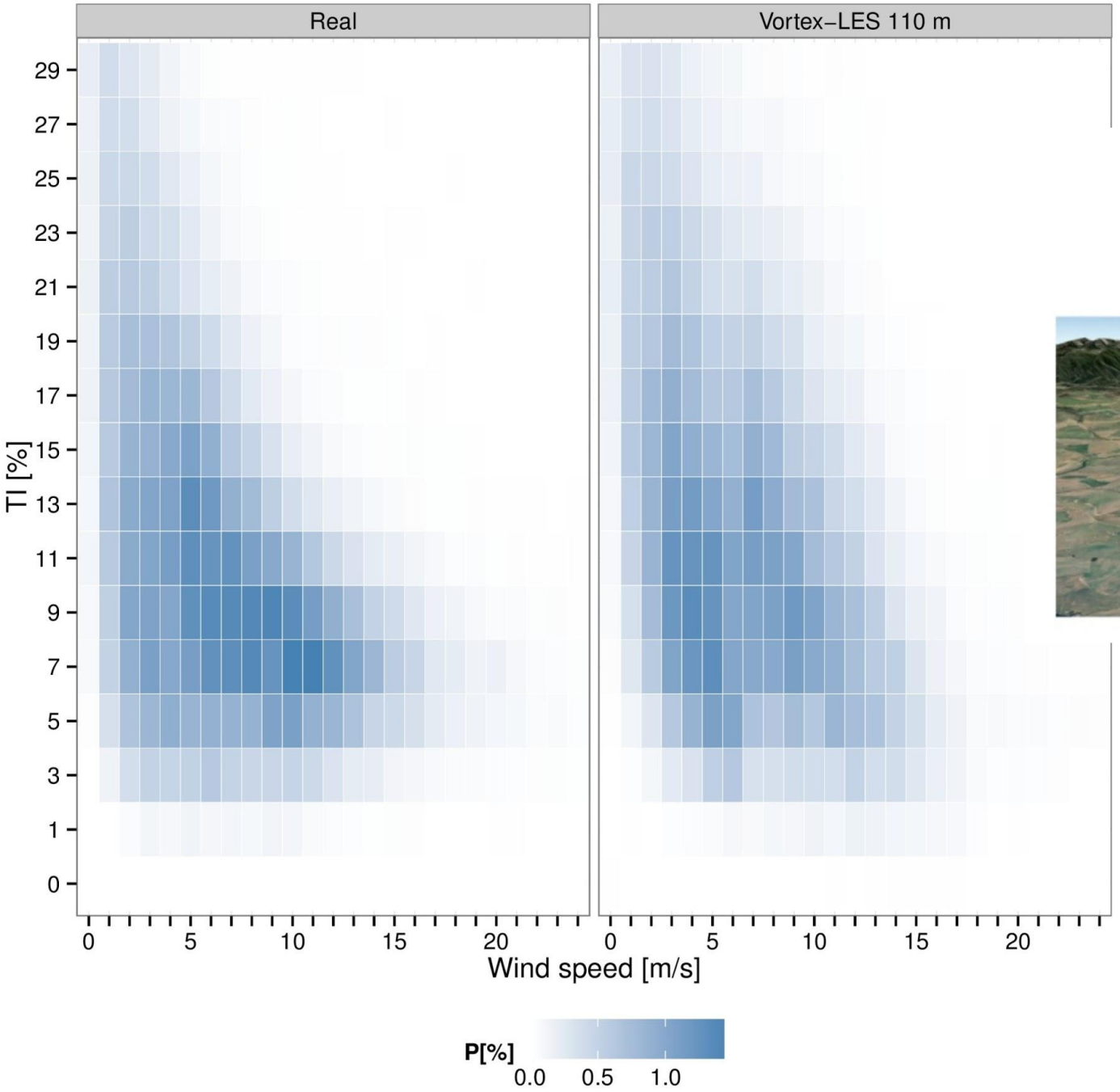
	Average	Std Dev
MAE	1.8	0.9
MAE-15	1.9	1.1

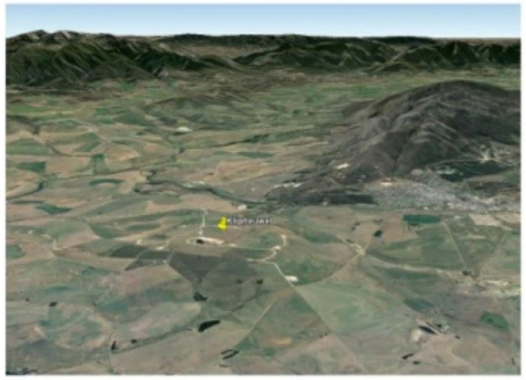


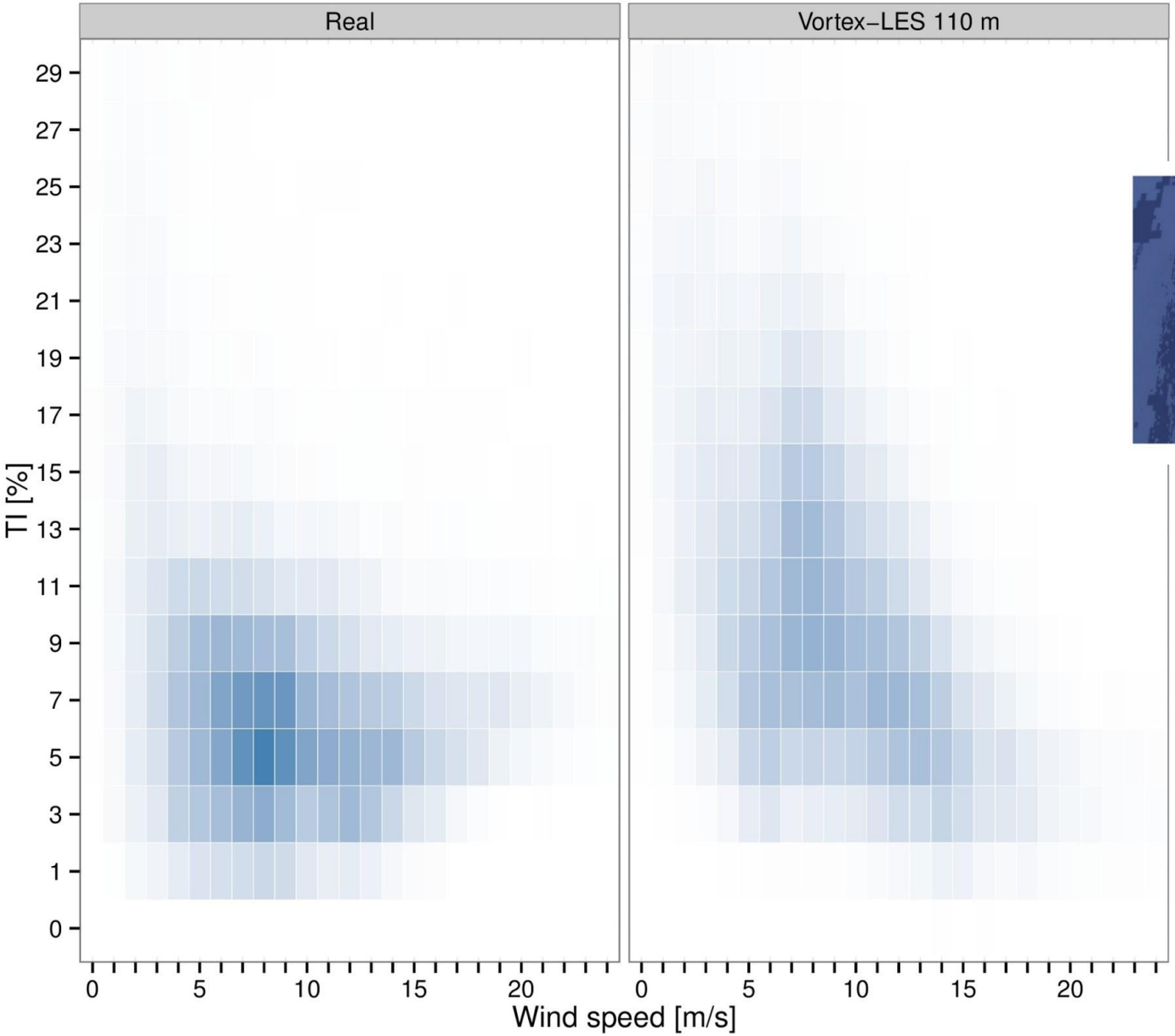

Real
Vortex−LES 110 m
TI [%]
29
27
25
23
21
19
17
15
13
11
9
7
5
3
1
0
0
5
10
15
20
Wind speed [m/s]
P[%]
0.0 0.5 1.0 1.5 2.0

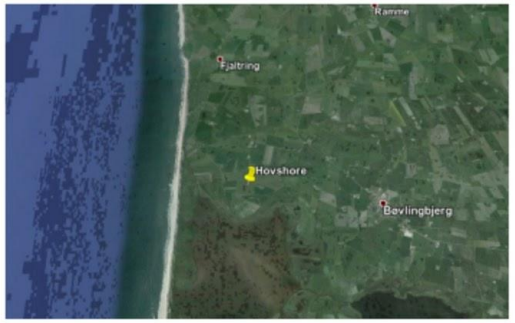


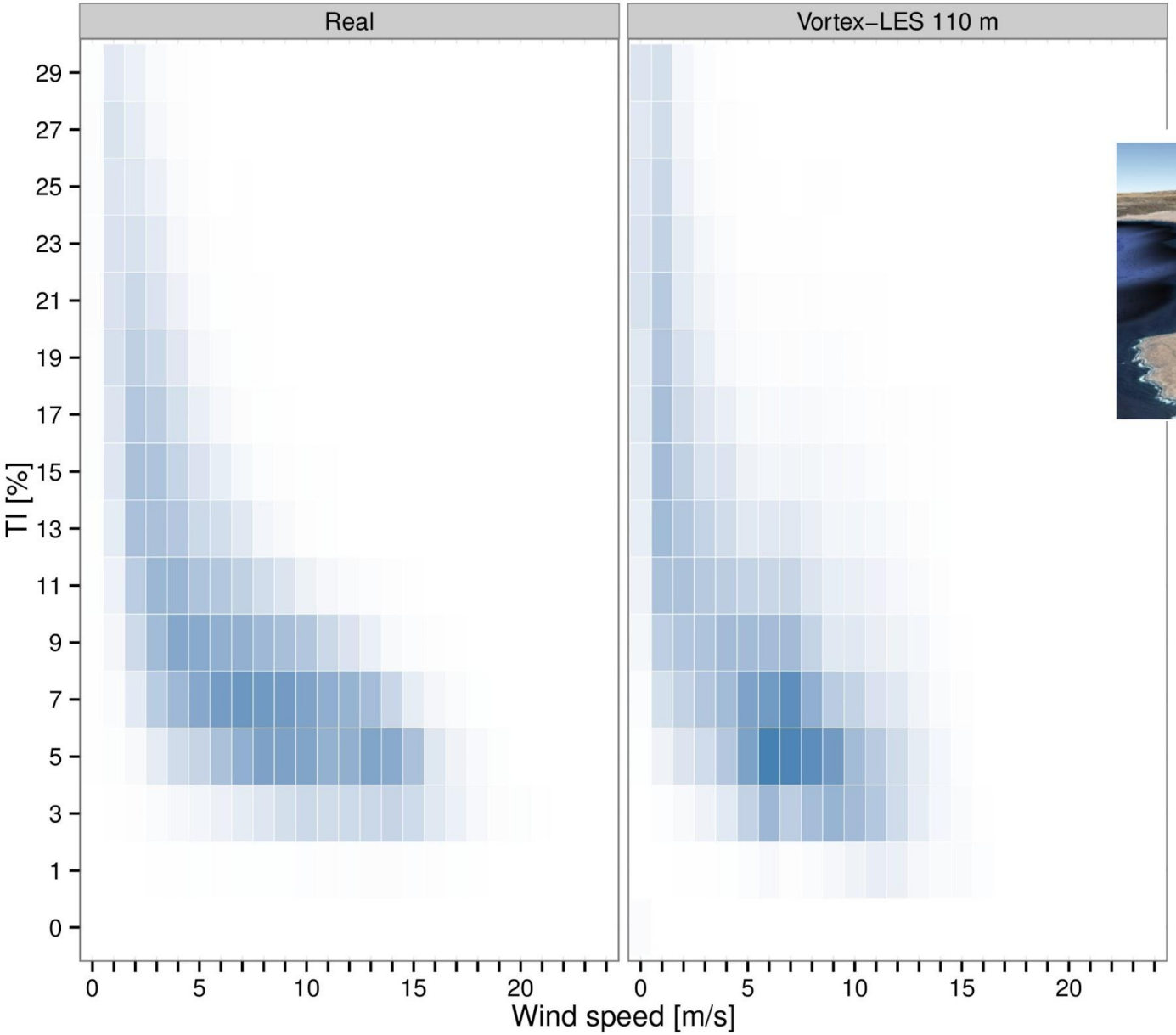
VORTEX

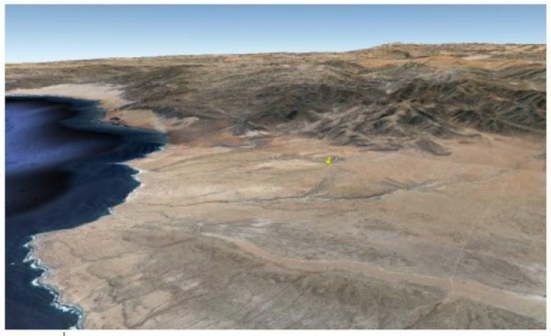

Real
Vortex−LES 110 m
TI [%]
29
27
25
23
21
19
17
15
13
11
9
7
5
3
1
0
0
5
10
15
20
Wind speed [m/s]
P[%]
0.0
0.5
1.0




Real
Vortex−LES 110 m
TI [%]
29
27
25
23
21
19
17
15
13
11
9
7
5
3
1
0
0
5
10
15
20
Wind speed [m/s]
P[%]
0
1
2


Rønnø
Fjaltring
Hovshore
Bovlingbjerg


Real
Vortex−LES 110 m
TI [%]
29
27
25
23
21
19
17
15
13
11
9
7
5
3
1
0
0
5
10
15
20
Wind speed [m/s]
P[%]
0
1
2



Advances in WRF-LES Modelling of Outer Range Conditions

- Improve the analytics of the validation
- Use more that one Mast/OBS per site
- Compare against lidar/sodar
- inflow/shear/veer
- Metrics
- Sharing initiative

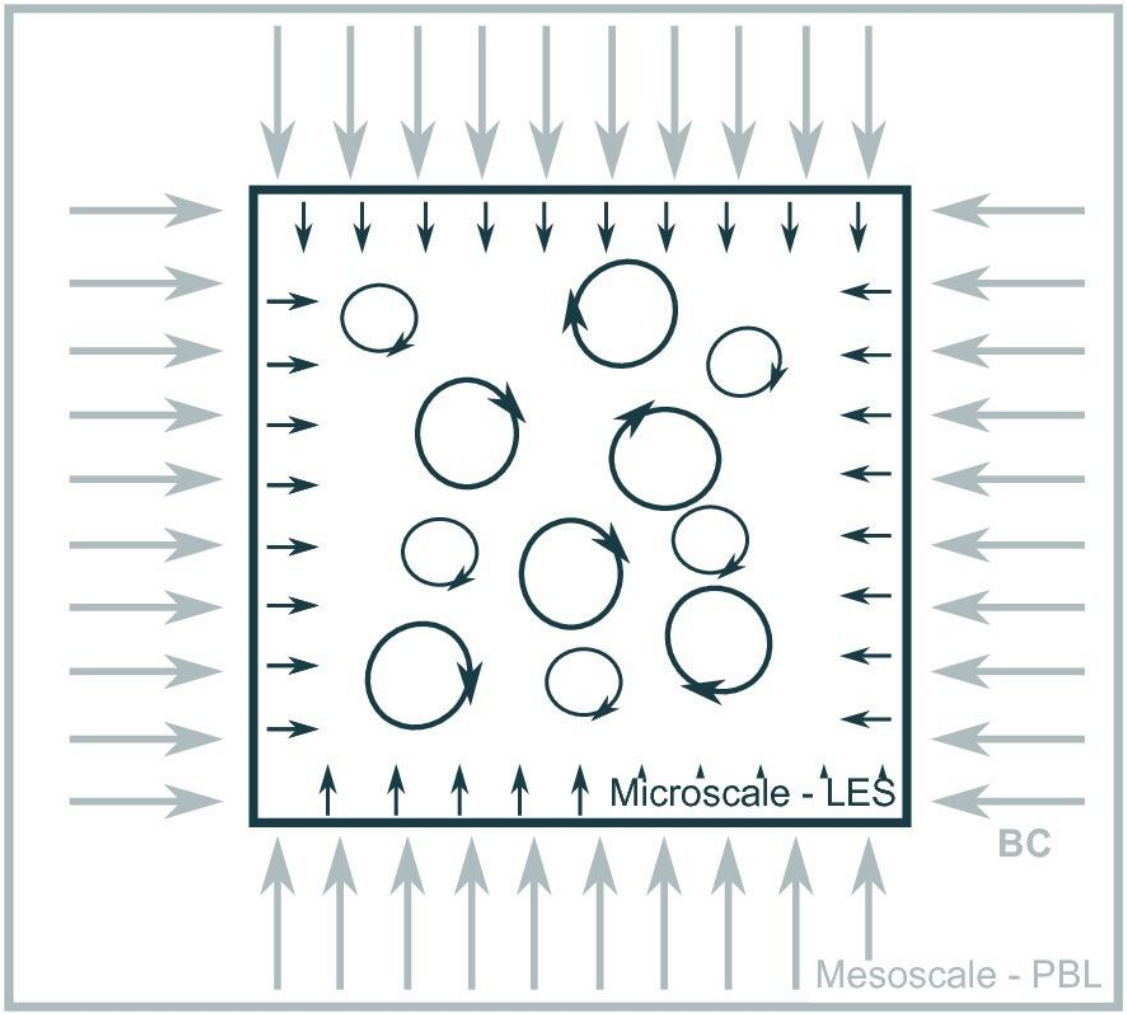
Advances in WRF-LES Modelling of Outer Range Conditions

Model & Analysis by: Alex Monternes, Pau Casso & Gil Lizcano

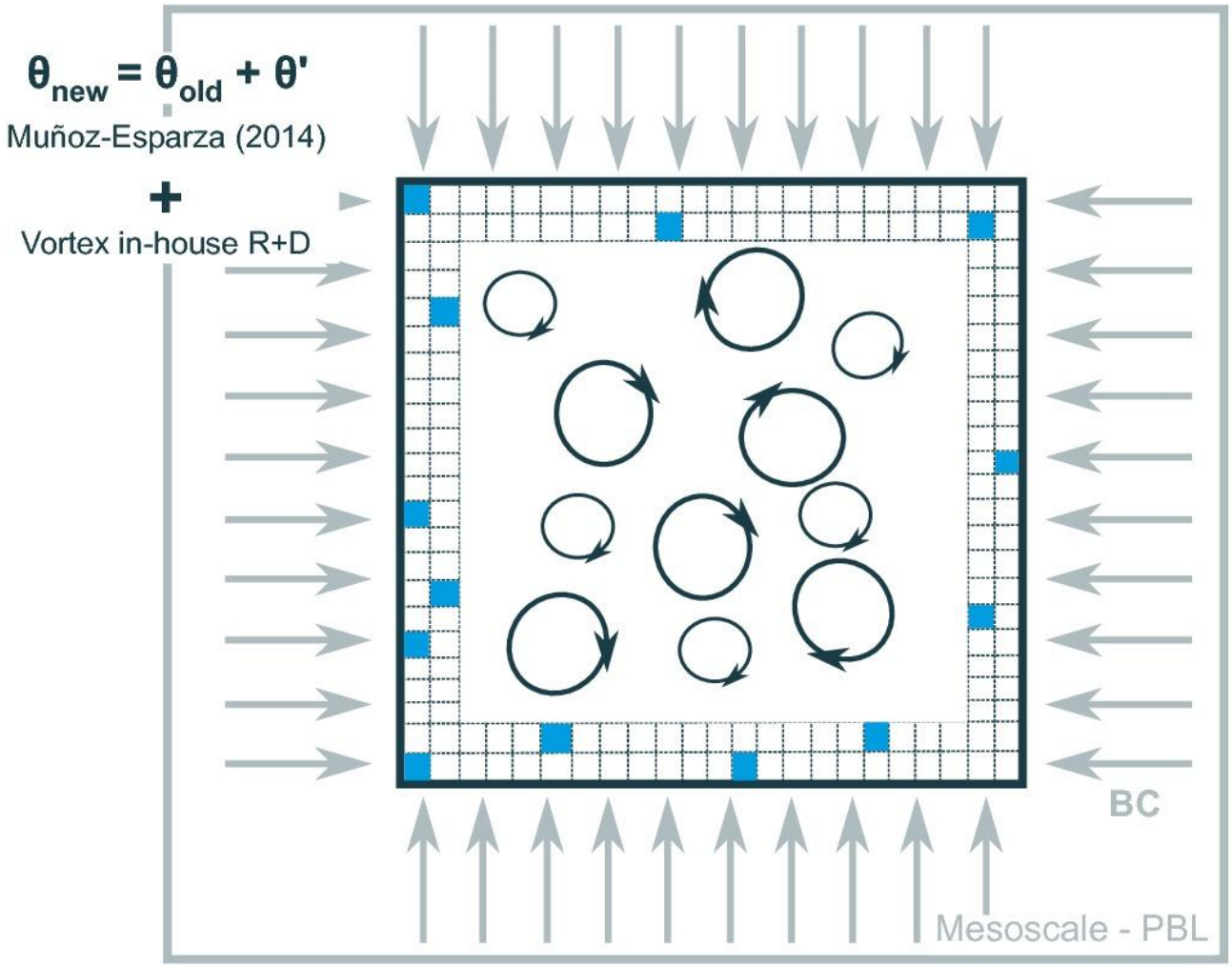
gil.lizcano@vortexfdc.com

VORTEX

WRF-LES, turbulence & lateral conditions



WRF-LES, some background



VORTEX