Thermal Winds: the Critical Role of High-Resolution Maps in Wind Farm Development

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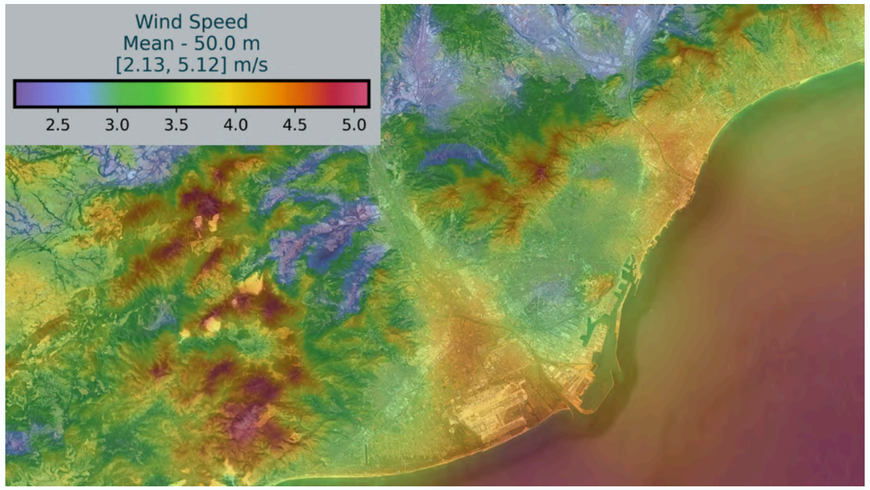
TOPICS

1. SPATIAL WIND SPEED DISTRIBUTION
2. THERMAL WINDS
    a. CASE STUDY 1: Sea breeze
    b. CASE STUDY 2
3. CALIBRATION WITH MEASUREMENTS

SPATIAL WIND SPEED DISTRIBUTION

WIND FIELD

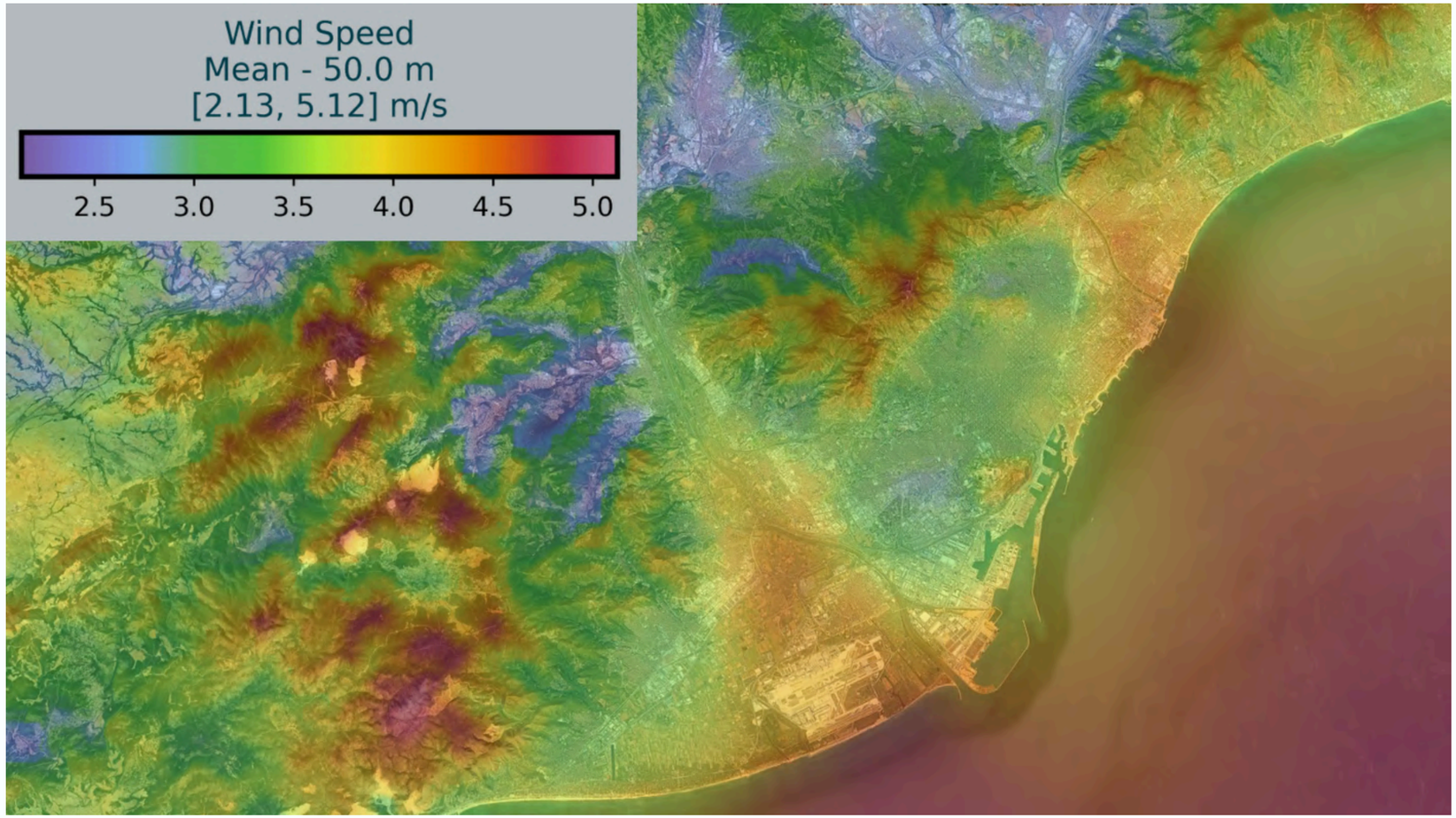


WIND MAP

WIND RESOURCE

WHAT IS THE SPATIAL WIND SPEED DISTRIBUTION?

Variation of wind speeds across different locations within a specific area.



VORTEX

COMPUTING SPATIAL WIND SPEED DISTRIBUTION

Methods

A - HORIZONTAL EXTRAPOLATION FROM A TIME SERIES

This method uses horizontal extrapolation from time series data, factoring in terrain and surface roughness, to predict wind speed distribution at the remaining area.

B - CFD MODELS

CFD models simulate wind flow using fluid dynamics equation over terrain, using low resolution wind and terrain data as input.

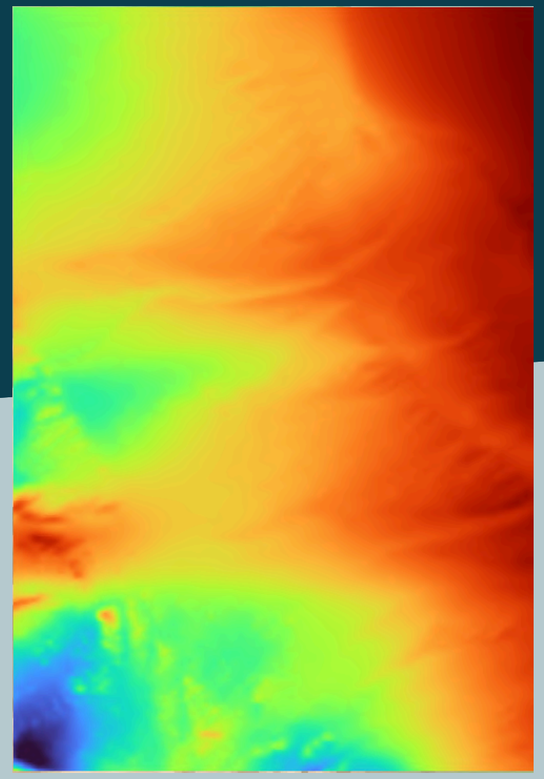
C - DOWNSCALLING WITH METEOROLOGICAL MODELS (WRF)

The WRF model downscales large-scale atmospheric data, accounting for temperature, pressure, and terrain effects to provide a comprehensive wind speed distribution.

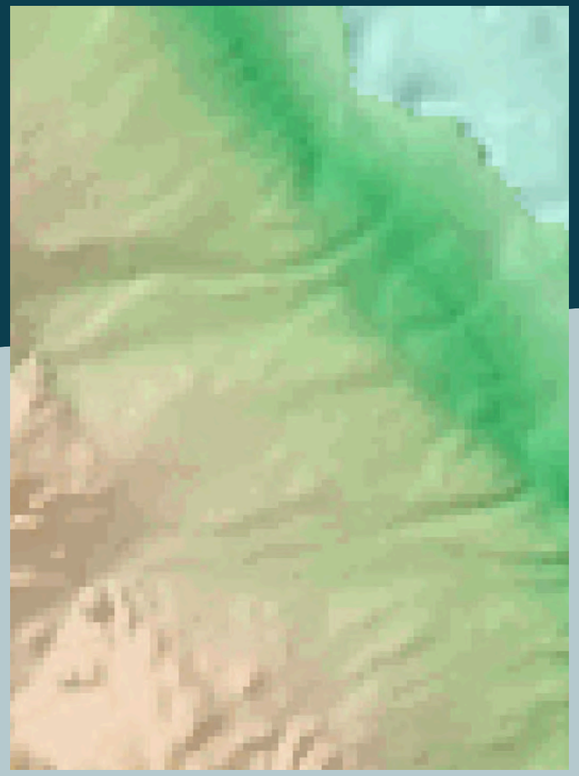
TEMPERATURE DRIVES WIND

Case 1: Sea breeze influence

Vortex WRF @ 100 m res.



Topography



WAsP

Model and resolution play a crucial role in determining wind fields.

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Case 2: Wind speed not aligned to topography

VORTEX

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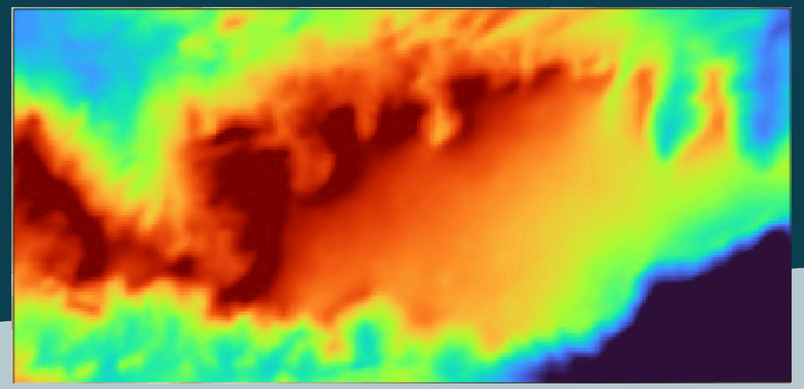
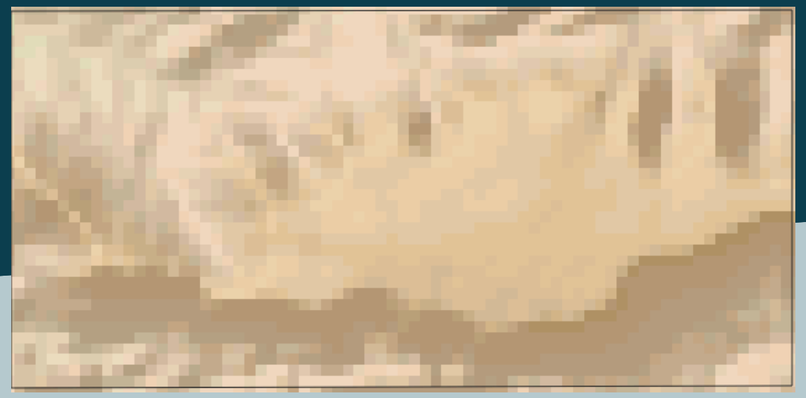
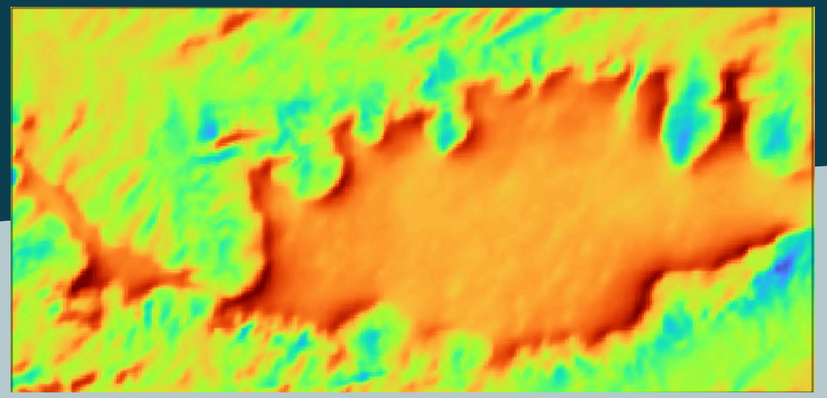
Vortex WRF @ 100 m res.



Topography



WAsP



The maximum wind speeds do not correspond with the maximum elevations as observed in the topography.

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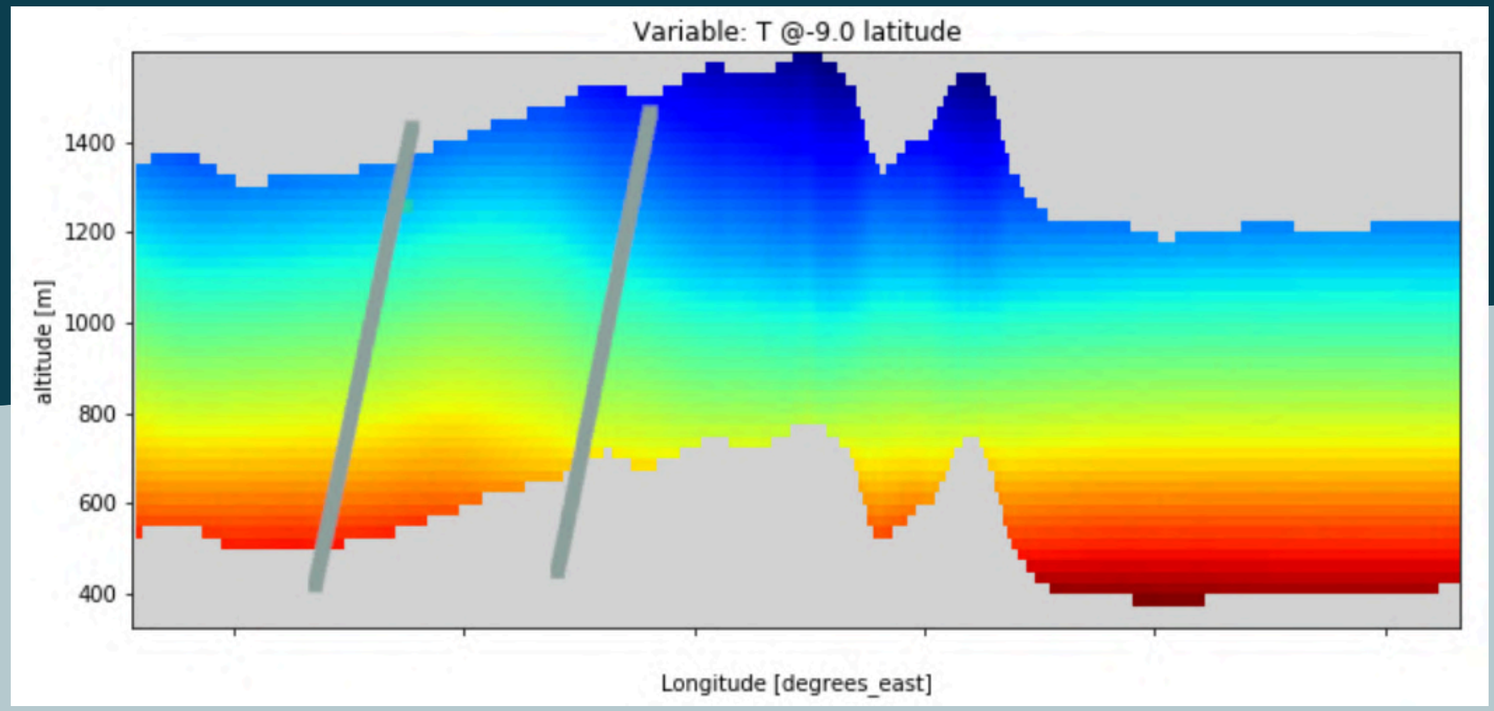
Case 2: Temperature influence

Temperature anomaly across height



We observe a temperature increase in the leeward area with the wind coming from the east. There is a linear rise in temperature in front of the mountains, but this pattern is disrupted as the wind flow moves above the mountains.

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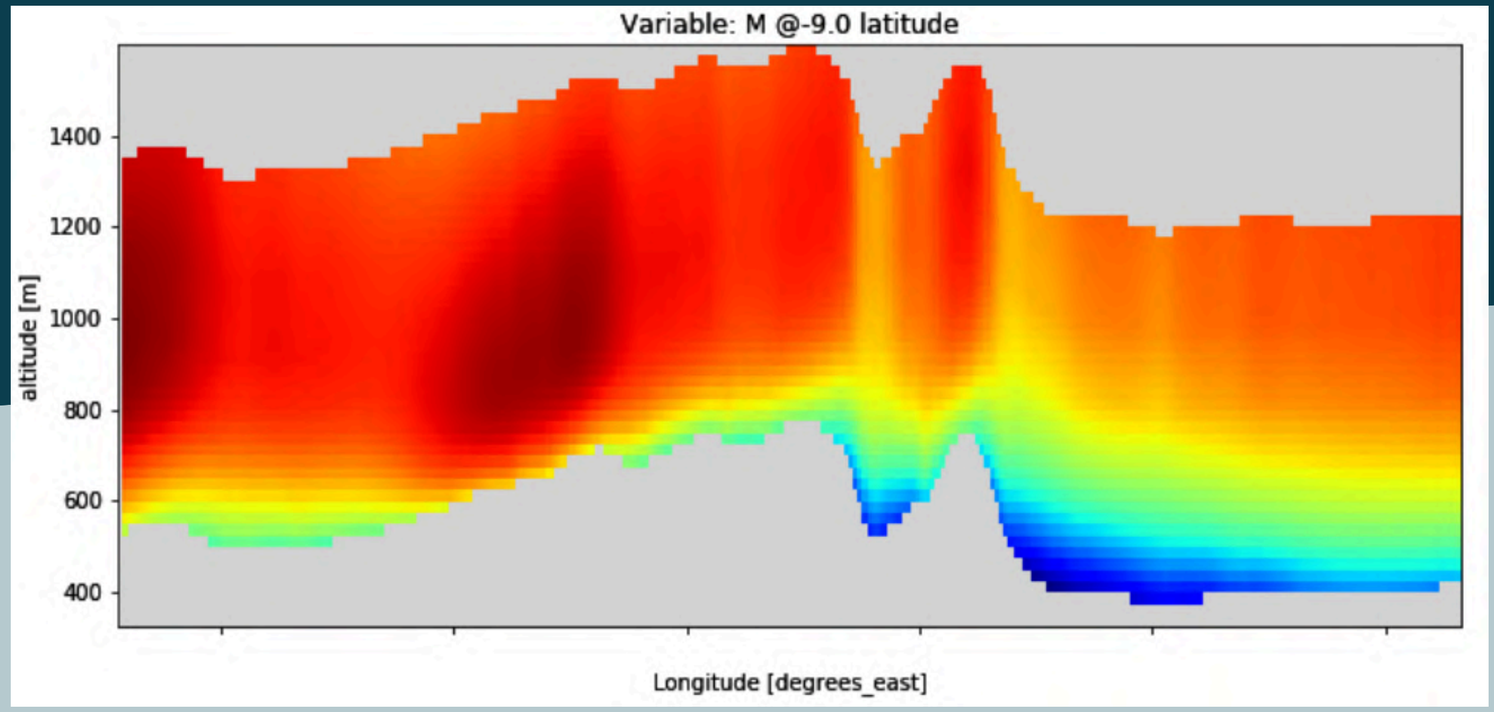
Case 2: Temperature influence

Wind speed anomaly accross height



We observe an increase in wind in the same leeward area where the temperature increase is detected.

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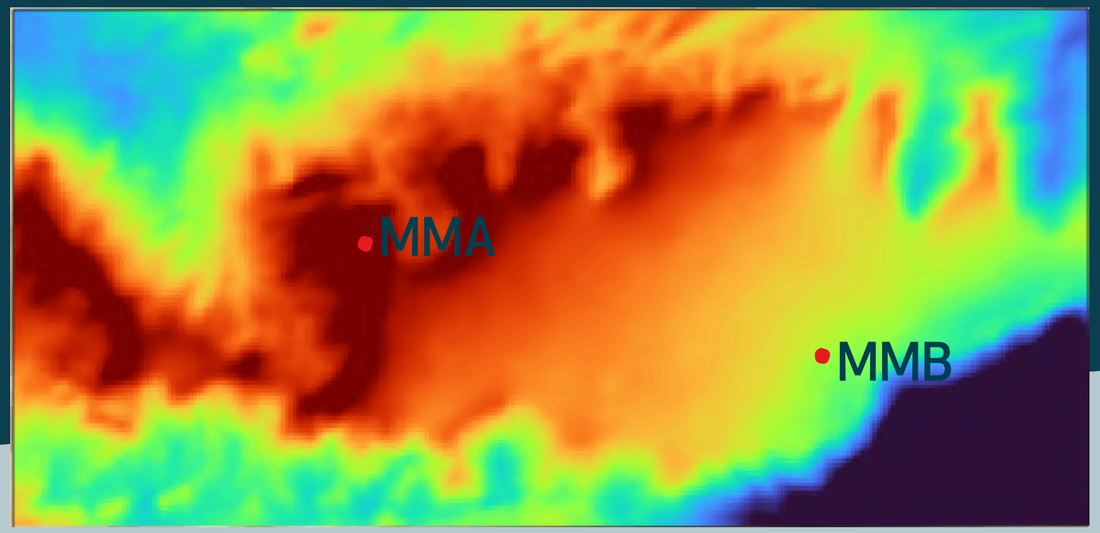
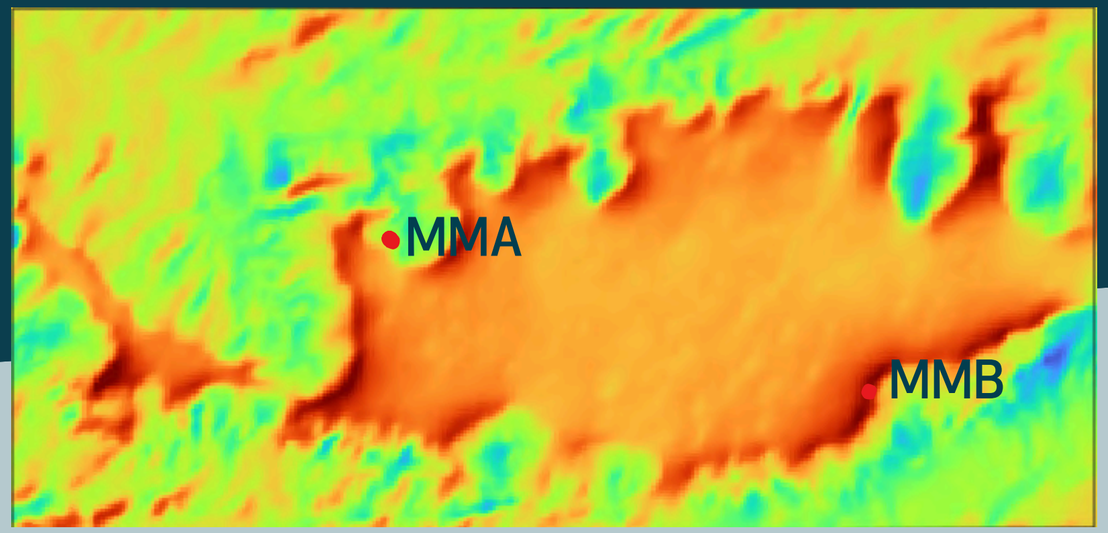
Case 2: Checking models & detecting phenomena



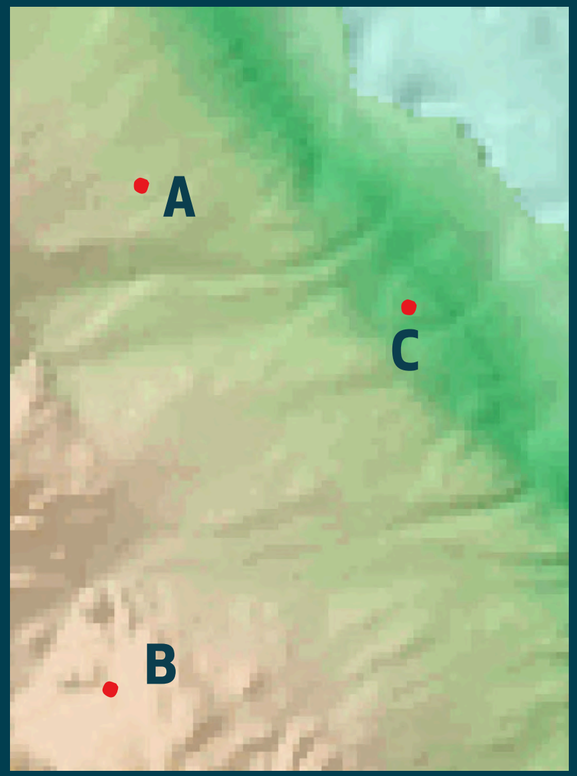


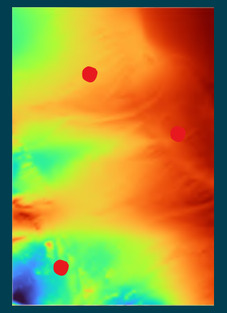
Having this data prior to the met mast campaign can help validate different wind speed maps, reducing uncertainty and saving time in the early stages.

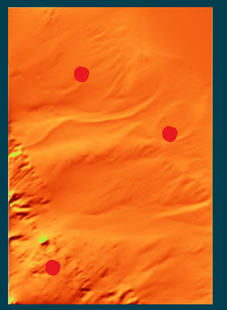
VORTEX

FROM IMAGES TO NUMBERS

Quantify spatial distributions







Speed Ups	Model A	Model B	Met Mast
A/B	1.23	0.98	1.15
A/C	0.92	1.03	0.95

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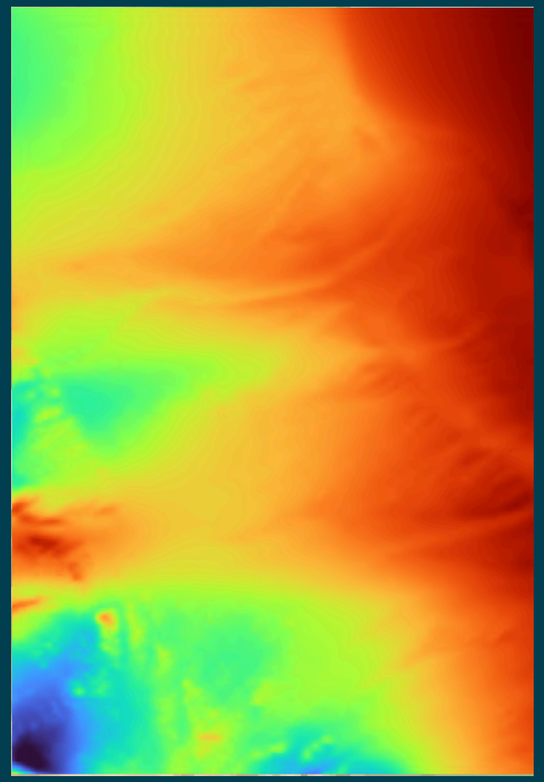
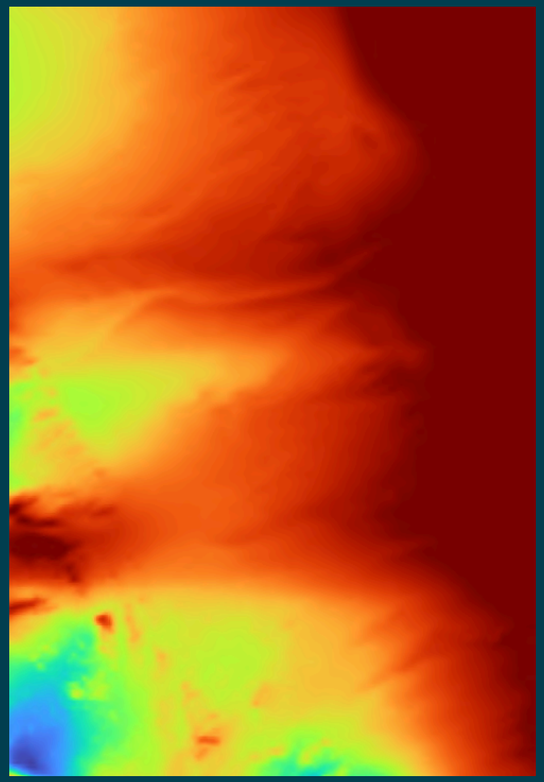
FIX SPATIAL DISTRIBUTION

No easy method



Increase x 10%



We can correct easily bias with measurements, just change the scale.
Not spatial wind distribution.

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REFINING MAPS USING MEASURED DATA

Remodeling

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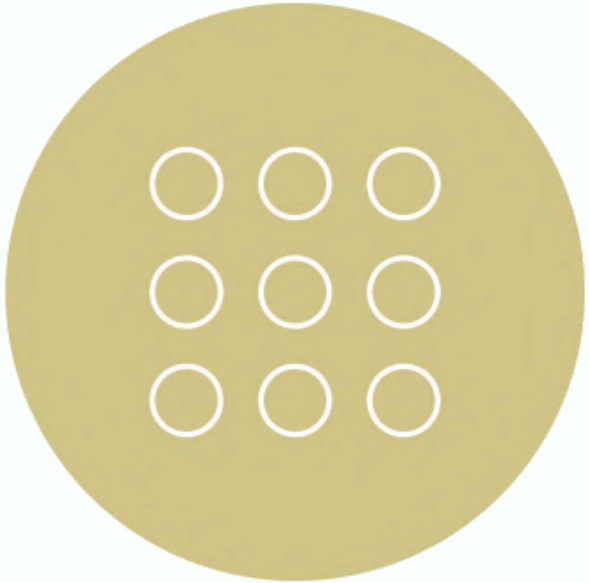
VORTEX HIGH RESOLUTION MAPS



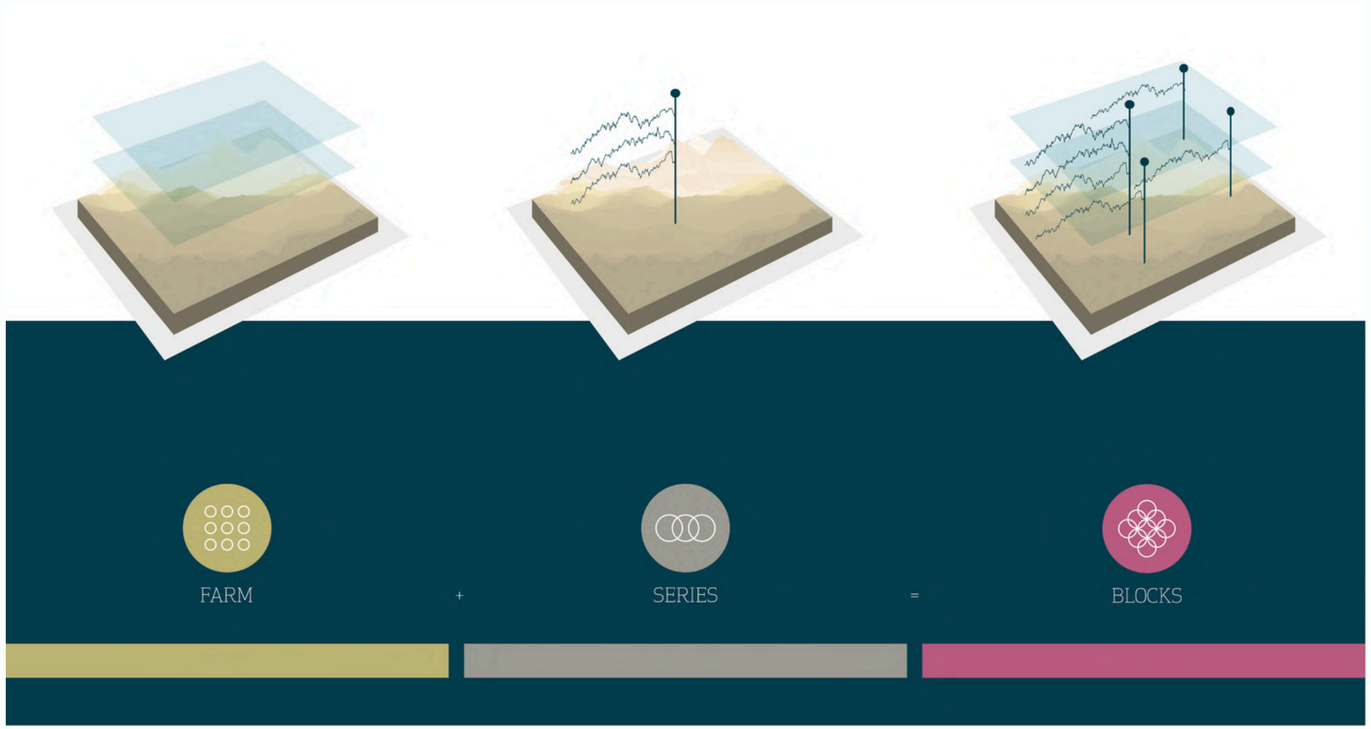
FARM

BLOCKS

CALIBRATION

INPUTS

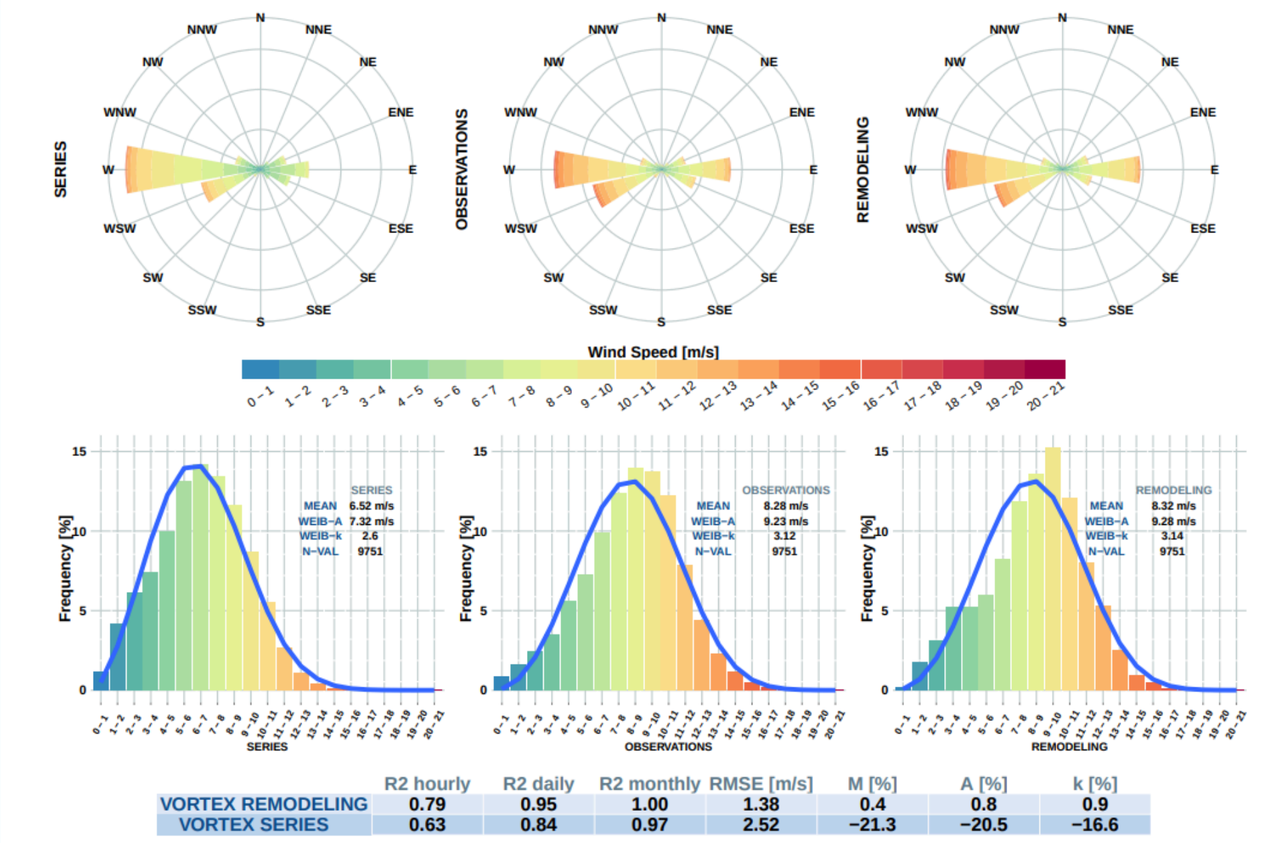
- A simulation for an area includes time series data for each point at a 100m resolution across the entire region.
- A minimum of one met mast, and preferably at least one year of data, is required for effective calibration of the simulation.



CALIBRATION

Step 1: Time

Calibrate the time series at the measurement location, similar to an MCP approach, but using Vortex's remodeling methodology.

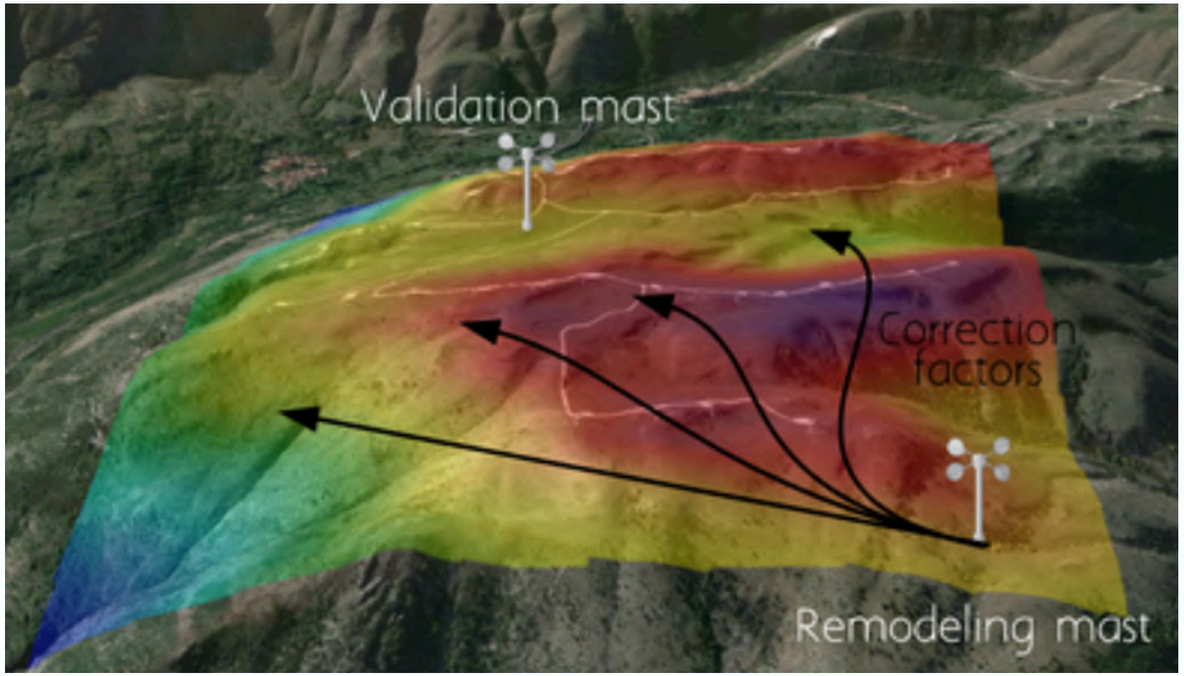


	R2 hourly	R2 daily	R2 monthly	RMSE [m/s]	M [%]	A [%]	k [%]
VORTEX REMODELING	0.79	0.95	1.00	1.38	0.4	0.8	0.9
VORTEX SERIES	0.63	0.84	0.97	2.52	−21.3	−20.5	−16.6

CALIBRATION

Step 2: Space

Adjust the area's time series based on the calibrated time series at the measurement location. This enables adjustments throughout the area by considering similarities to the measurement site, with correlations in local topography and wind patterns defining the degree of similarity for each point.



CALIBRATION

Remodeling

Adjusting time series allows for the correction of histograms (A and k) and wind directions, not just the mean wind speed.

The inclusion of the similarity method helps correct speed-ups and prevents the creation of 'bubbles' in the data, enhancing spatial wind distributions.

The accuracy of this method improves with the availability of more met masts.

SUMMARY

1. Wind speed spatial distribution and bias have independent accuracies.
2. Different models can produce different results in terms of bias and spatial distribution.
3. Model spatial fields can be improved with well designed met mast campaigns and a correct calibration method.

Thank you!

Any questions?

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