WAsP-like statistical downscaling of mesoscale simulations with a CFD model

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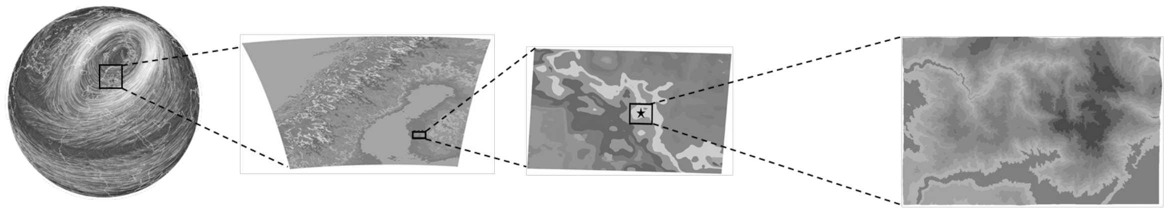
windsim

Mesoscale downscaling

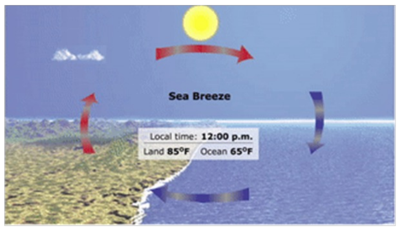


Domain size	10^7 m	10^6 m	10^5 m	10^4 m	10^3 m
Spatial resolution	10^5 m	10^4 m	10^3 m	10^2 m	10^1 m
Scale	Global circulation	Regional climate	Atmospheric boundary layer	Local area	Wind farm site
Model	General circulation models	Mesoscale meteorological models		Microscale models	

Weather simulation and good representation of thermally driven flow

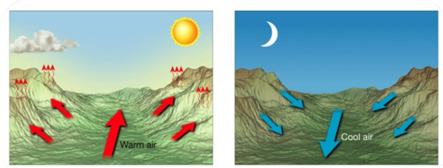
Good inclusion of orography

Land-sea breeze



Source: http://www.classzone.com/books/earth_science/terc/content/visualizations/es1903/es1903page01.cfm

Mountain-valley system



Source: https://kaiserscience.wordpress.com/earth-science/weather/regional-wind-systems/

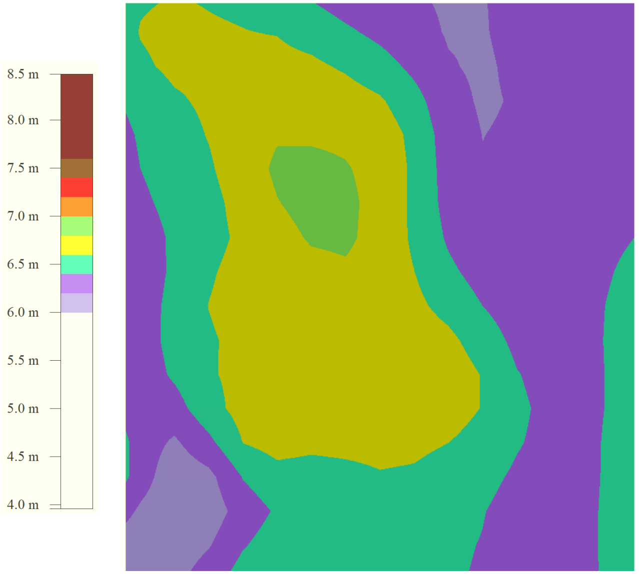
The benefits of screening with CFD

More pronounced extreme values, higher maximum and lower minimum wind speeds

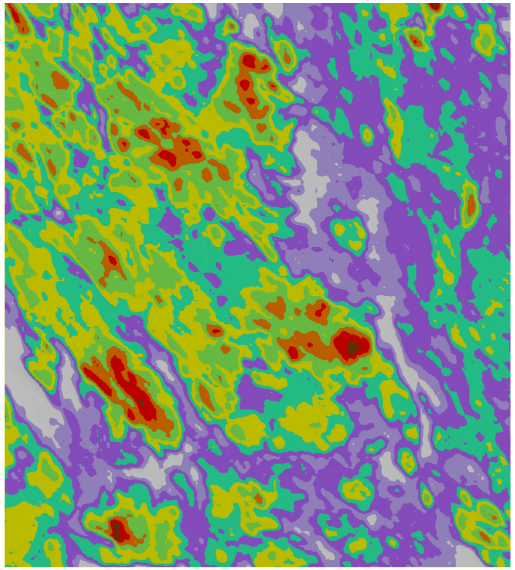
→ **Higher Annual Energy Production**

→ **Better information to deal with landowners**

NVE 1 km resolution map



WindSim 100 m resolution map



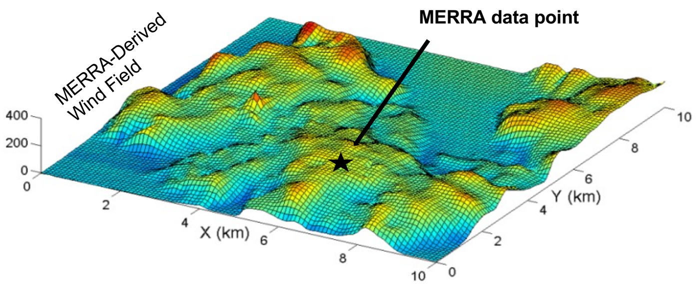
- ✓ **Early identification of high-wind spots**
- ✓ **Better consideration of terrain**

Meso-microscale downscaling approaches

There are two main approaches to conduct downscaling:

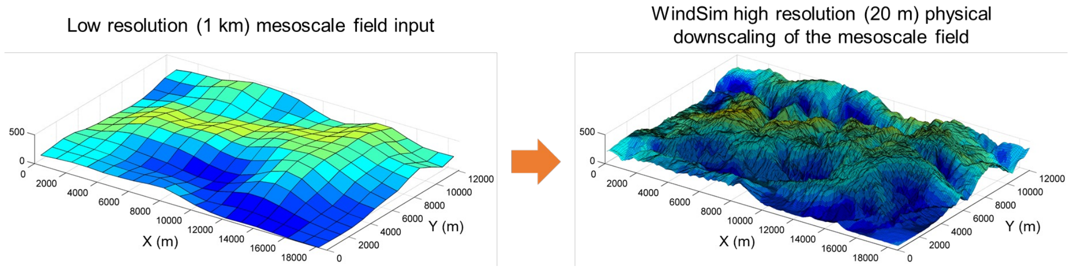
Point-like Mesoscale Data Assimilation

Use a mesoscale data point as climatology (virtual climatology) to scale the CFD model



Physical Mesoscale Downscaling

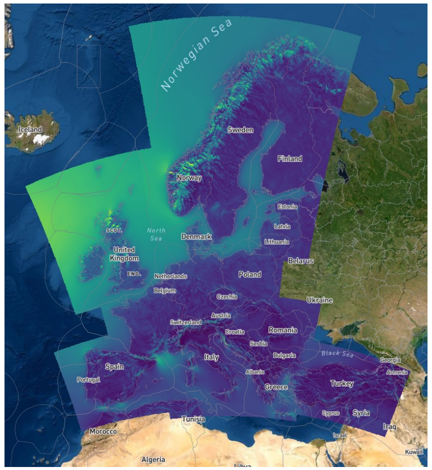
Use 3-D mesoscale results as boundary conditions for the CFD model



We use both in combination!

NEWA

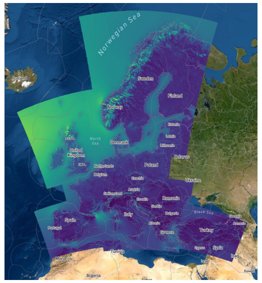
NEW EUROPEAN WIND ATLAS
newa



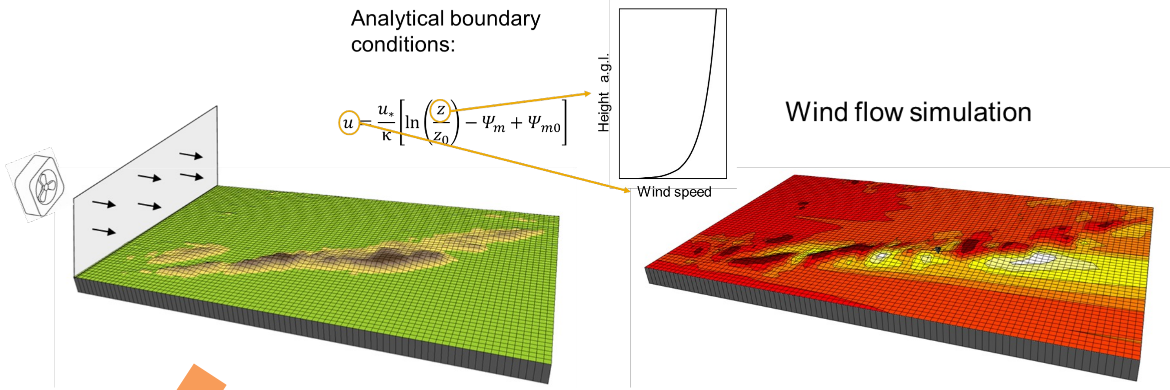
- Coverage for Europe
- Wind data every ~3km
- 14 years timeseries
  (2005 to 2018)
- Vertical levels from 50 m to 500 m

Wrong approach: meso data directly in WS as a virtual met mast

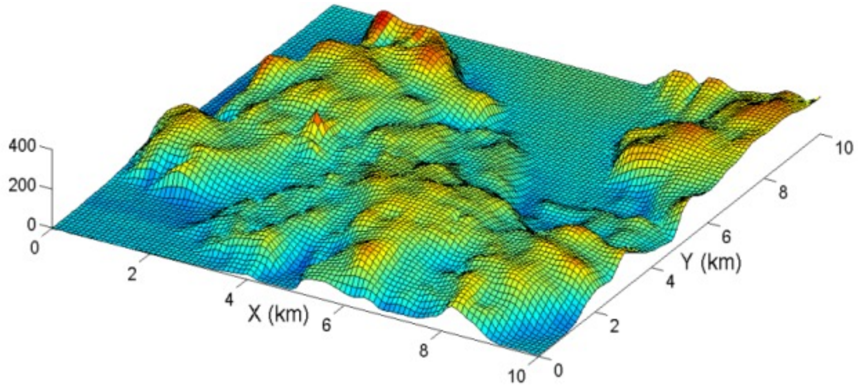
Wind data



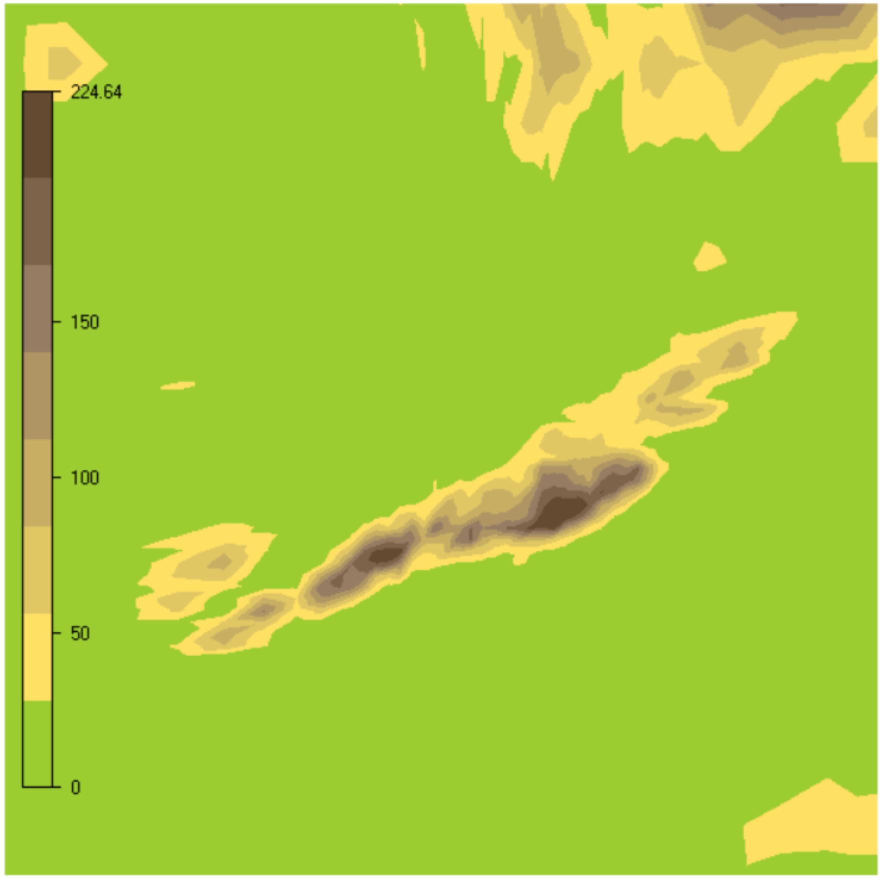
+

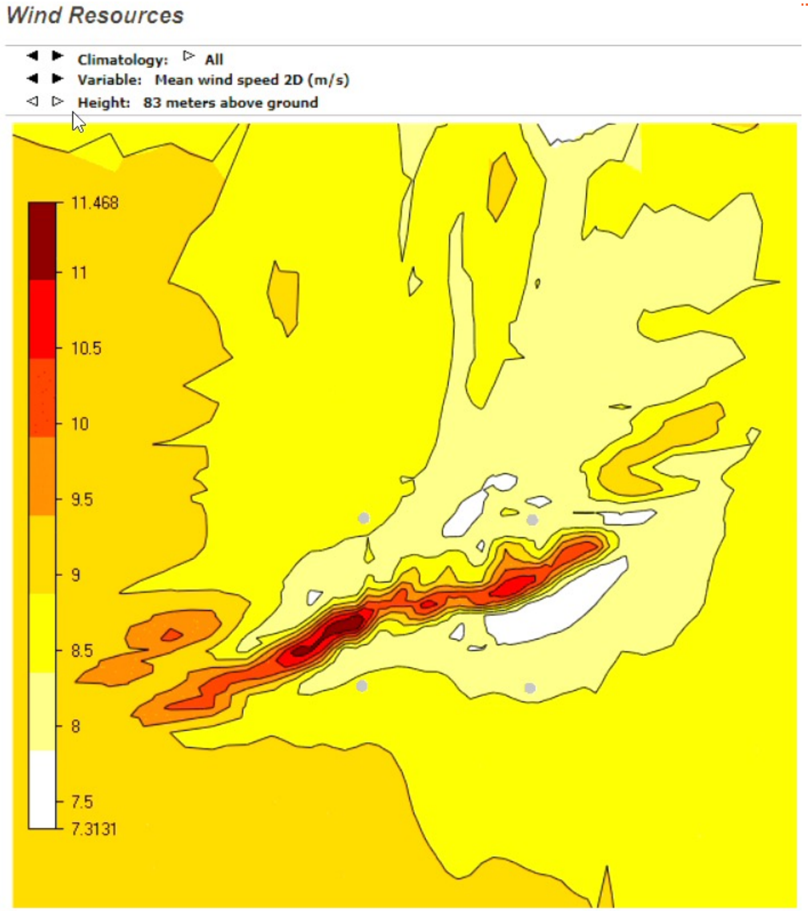


Wind resource map?



Wrong way

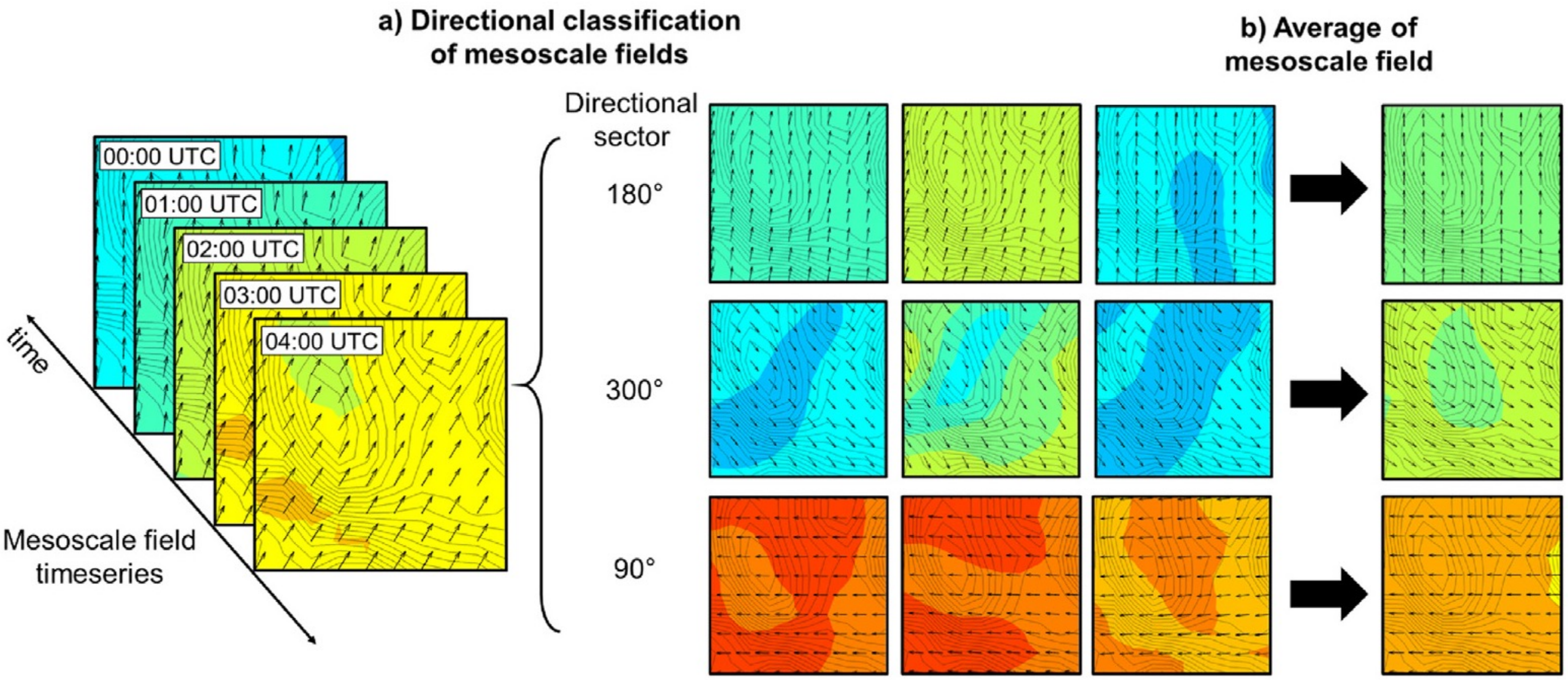

224.64
150
100
50
0


Wind Resources
Climatology: All
Variable: Mean wind speed 2D (m/s)
Height: 83 meters above ground
11.468
11
10.5
10
9.5
9
8.5
8
7.5
7.3131

Methodology – design criteria

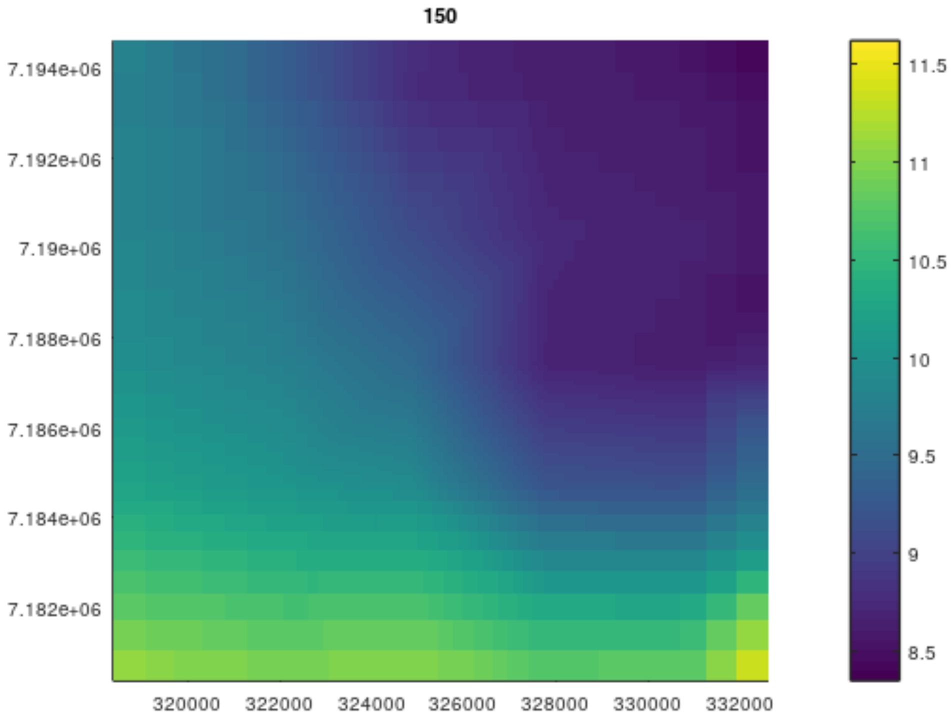
1. Use all the meso points inside a WS domain
2. Easy to communicate to WAsP users
3. Robust: no fitting parameters (e.g., machine learning)

Step 1: Average meso runs by direction

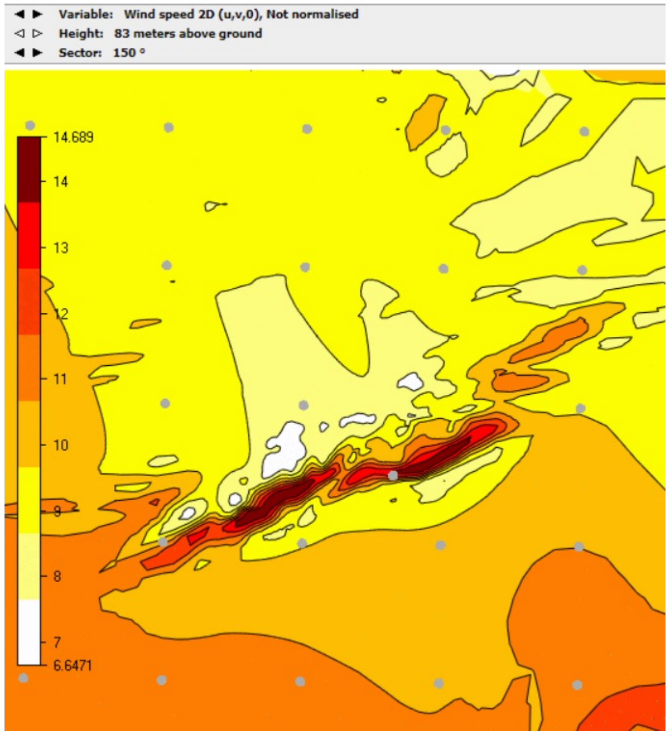


Step 2: boundary conditions to WindSim

Aver. NEWA sector 6/12: U 83m

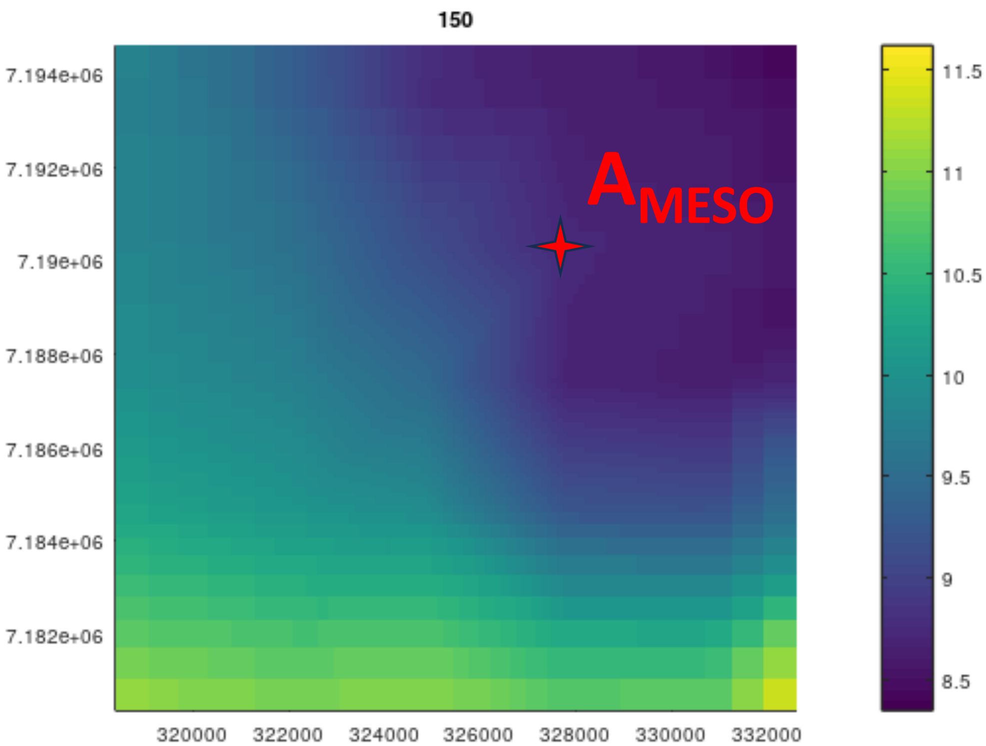


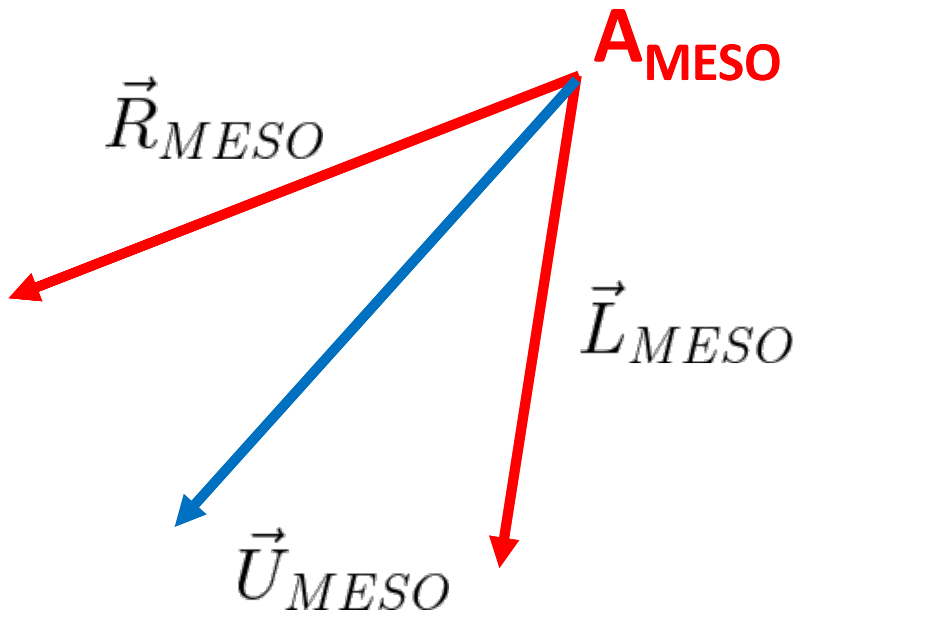
WS sector 6/12: U 83m



$$u_j \frac{\partial u_i}{\partial x_j} = -\frac{1}{\rho}\frac{\partial p}{\partial x_i} - \frac{\partial \overline{u_i u_j}}{\partial x_j} - \boxed{r\left(u_i - u_{i,meso}\right)}$$

Step 3: Generalization





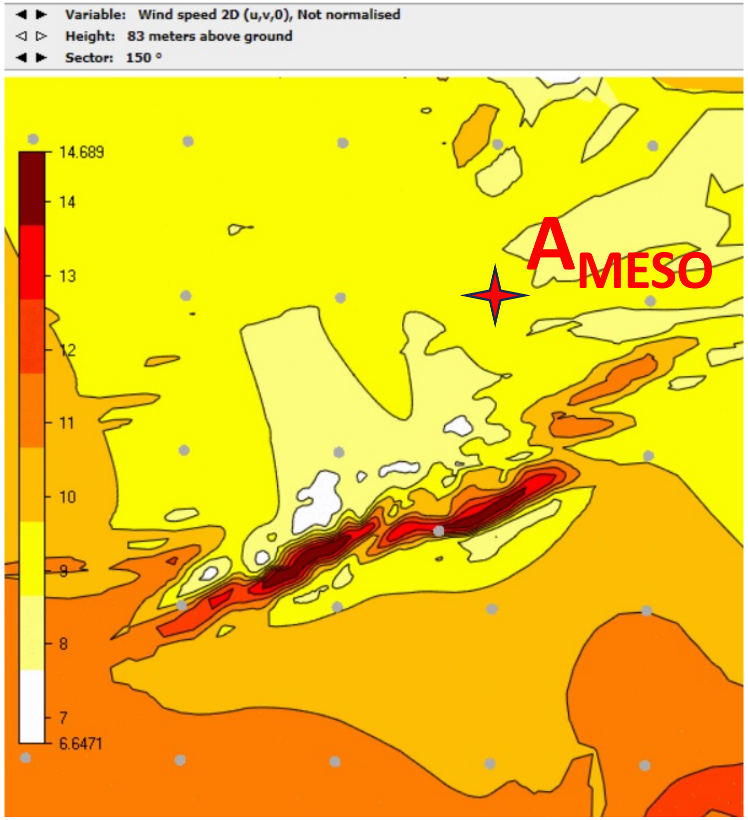
$$\vec{U}_{MESO} = \underline{C_L}\vec{L}_{MESO} + \underline{C_R}\vec{R}_{MESO}$$

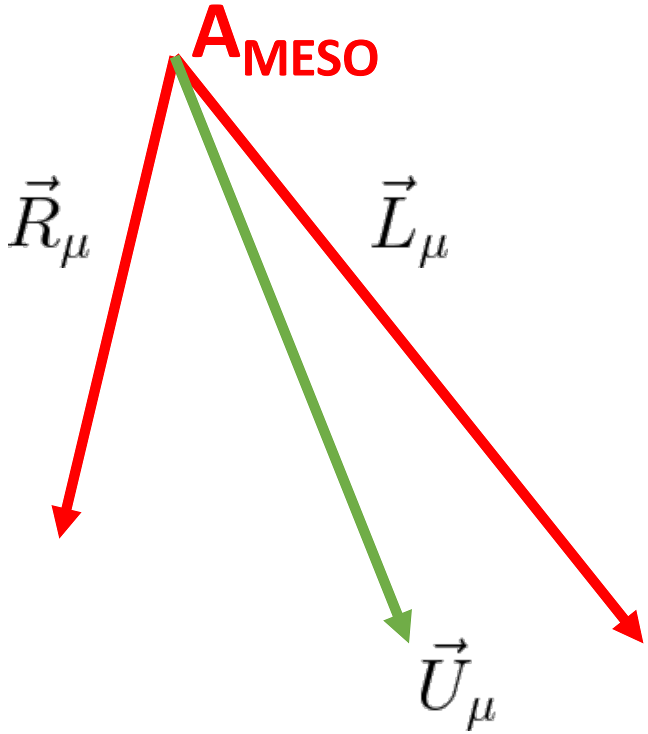
Step 3: Generalization

Time series of coefficients for each meso point

Time	L	R	Coeff. L	Coeff. R
0	3	4	1.2	0.2
…	…	…	…	…
17520	12	1	0.3	0.9

Step 4: Application

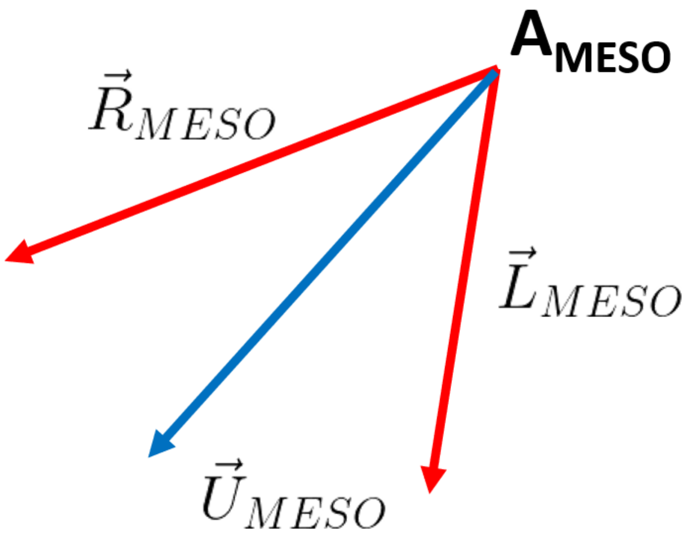




$$\underline{\vec{U}_\mu} = C_L \vec{L}_\mu + C_R \vec{R}_\mu$$

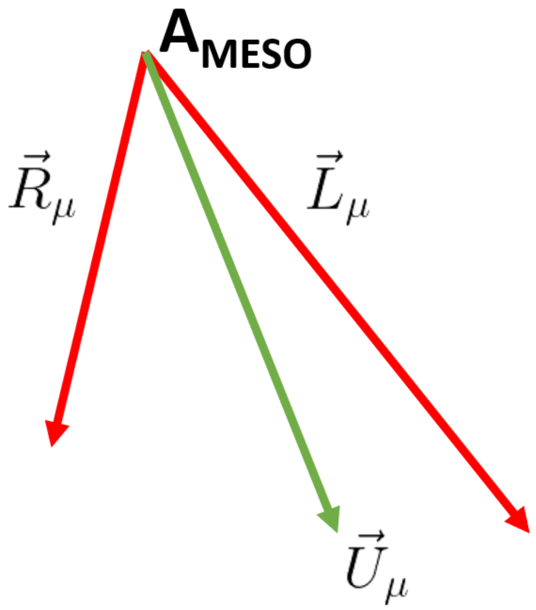
WAsP-like

Generalization



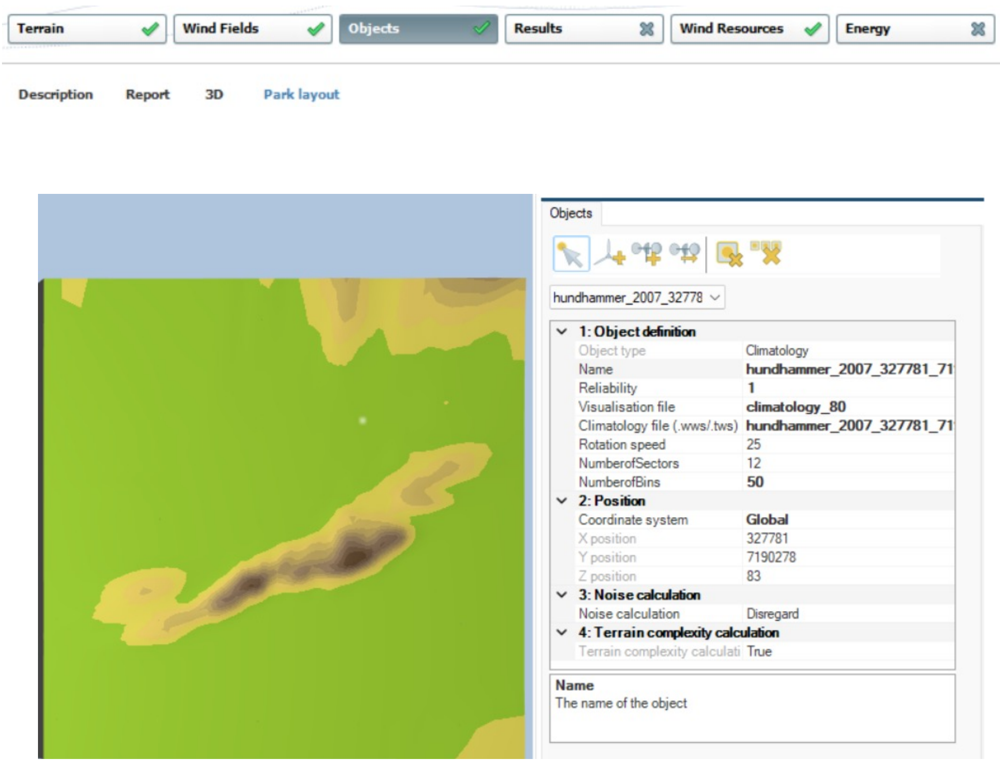
$$\vec{U}_{MESO} = \underline{C_L}\vec{L}_{MESO} + \underline{C_R}\vec{R}_{MESO}$$

Application

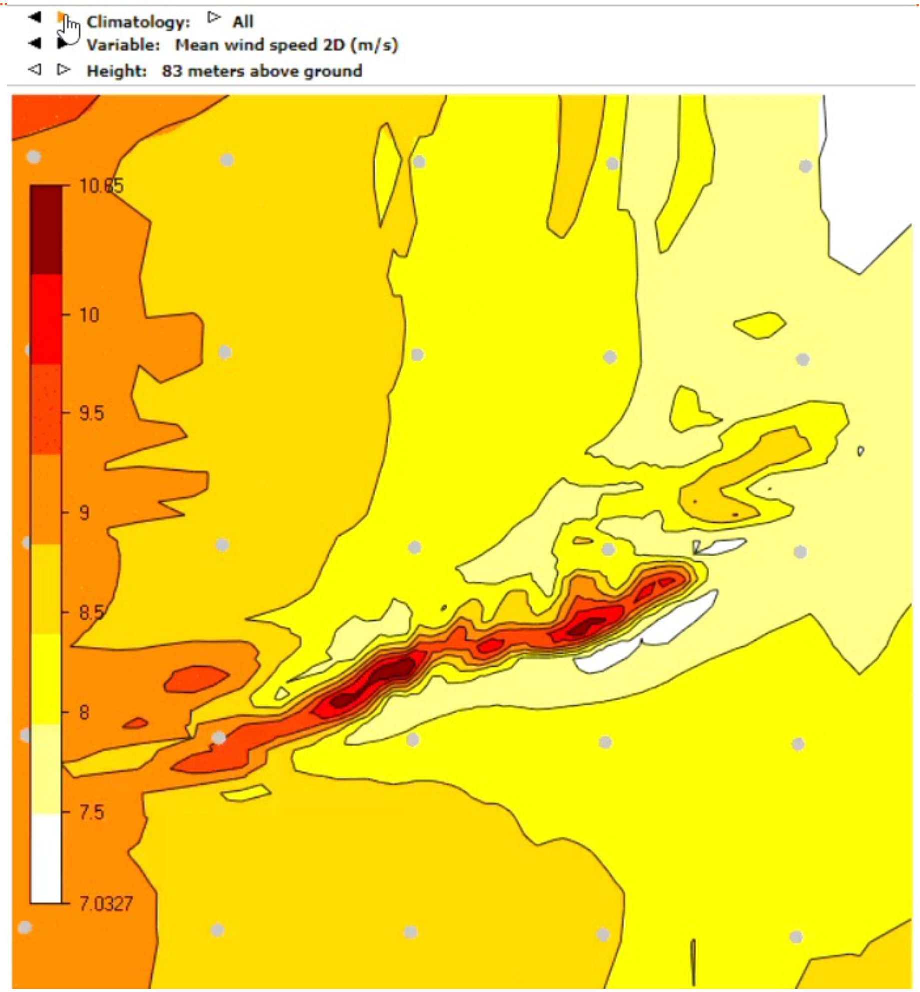


$$\underline{\vec{U}_{\mu}} = C_L\vec{L}_{\mu} + C_R\vec{R}_{\mu}$$

Use as virtual met masts



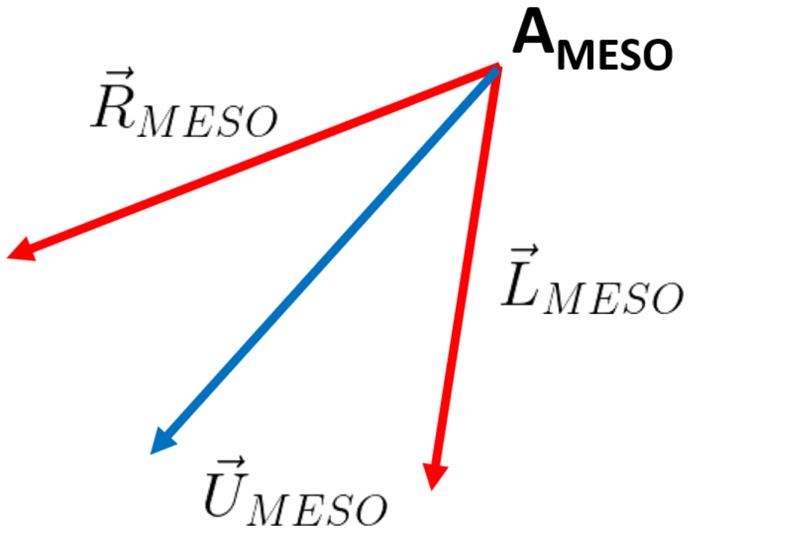
New downscaling



- Max power density
  a. Naïve virtual met mast:
     1476 ± 180 W/m^2
  b. WAsP-like downscaling:
     1461 ± 42 W/m^2

New downscaling

- WAsP-like downscaling with WindSim
- Reduce micro downscaling uncertainty in wind atlases
- Validation ongoing
  - More accurate screening in complex terrain?



$$\vec{U}_{MESO} = \underline{C_L}\vec{L}_{MESO} + \underline{C_R}\vec{R}_{MESO}$$