Wind Fields Calibration by Using Time Series: A New Approach for Avoiding Bins and Distributions

Pau Casso

Vortex Technical Director

Outline

Facts:
Mesoscale models are not perfect
Need to calibrate

Motivation:
Wind industry problems

Approach:
New methodology based on time

Results and conclusions

Facts

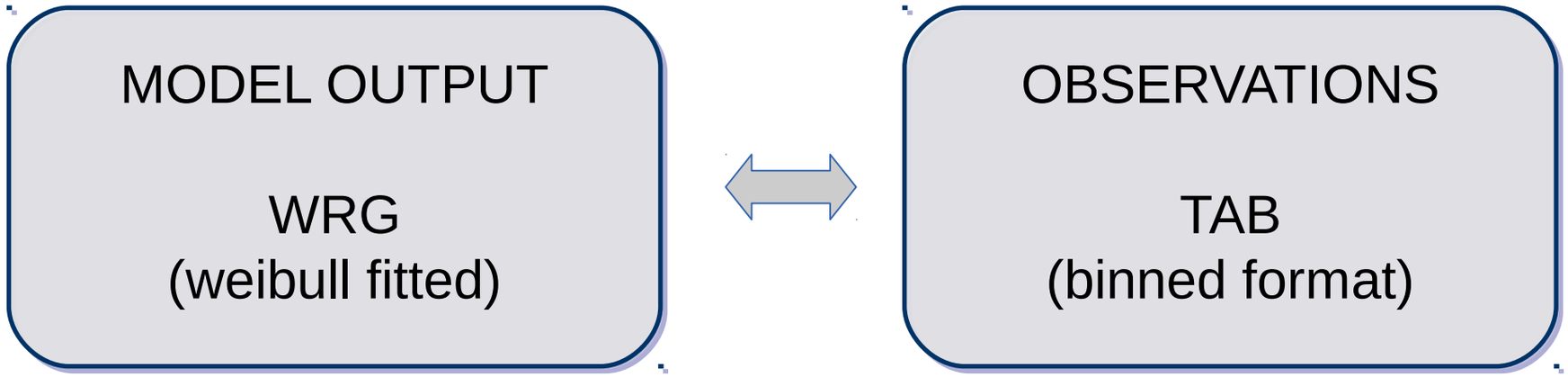
Wind models are good but not perfect

- Mesoscale, microscale, CFD models... are powerful tools but are not the reality
- Bias issues, overestimation, underestimation
- Extreme events and calms not well captured
- Weibull shake k parameter not well characterized
- Wind direction shifted or sectors missing

Need to calibrate/improve model results with observations

Facts

How can model results be calibrated with observations?



Several tools & software are used for matching/calibrating wind fields from the model with observations

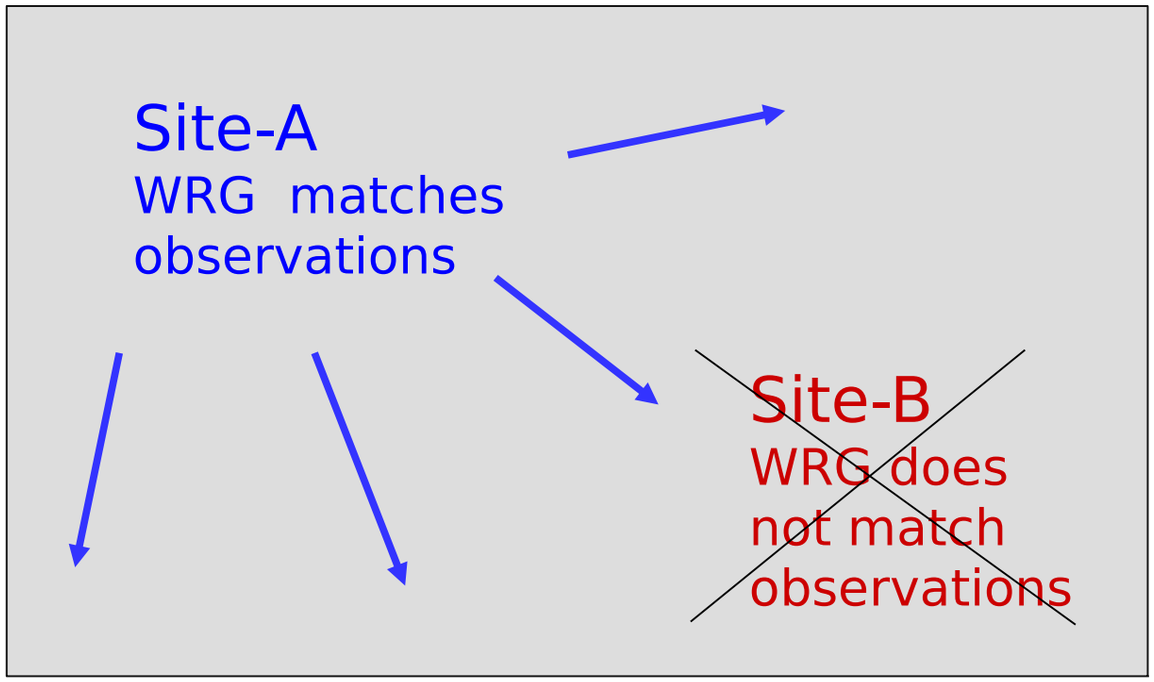
Motivation

Wind industry problem 1: from A to B vs. from B to A

Difficulty in having a wind field matching all sites. Some software can manage this problem

Possible solution: virtual tower in-between (weight issues)

Other user tricks to solve the calibration process



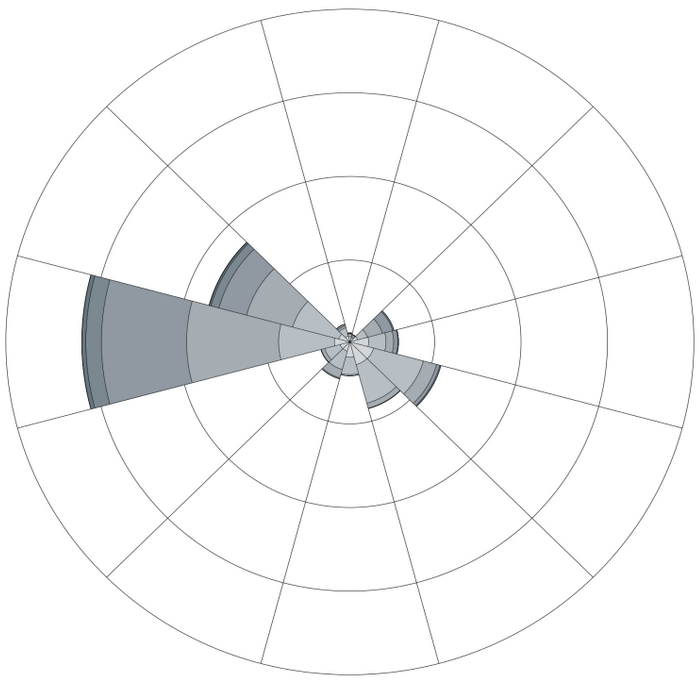
Motivation

Wind industry problem 2: Number of sectors affects the results

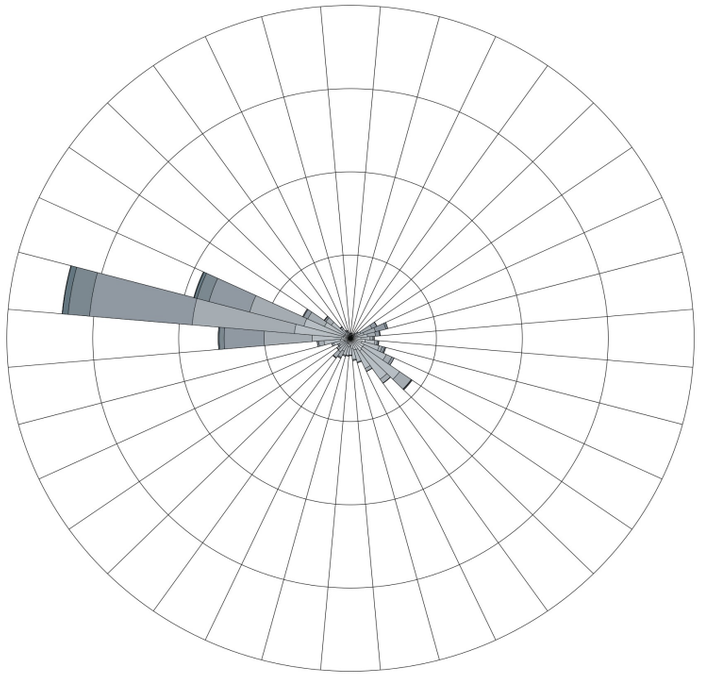
Calibration processes assume events uniformly distributed within each sector

Matching sectors between observations and model is difficult/impossible

12 Sectors



36 Sectors

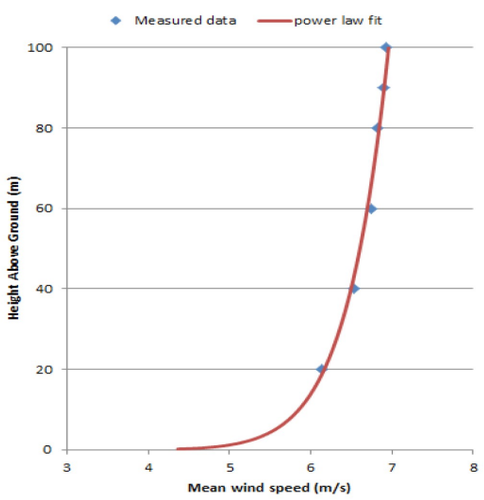


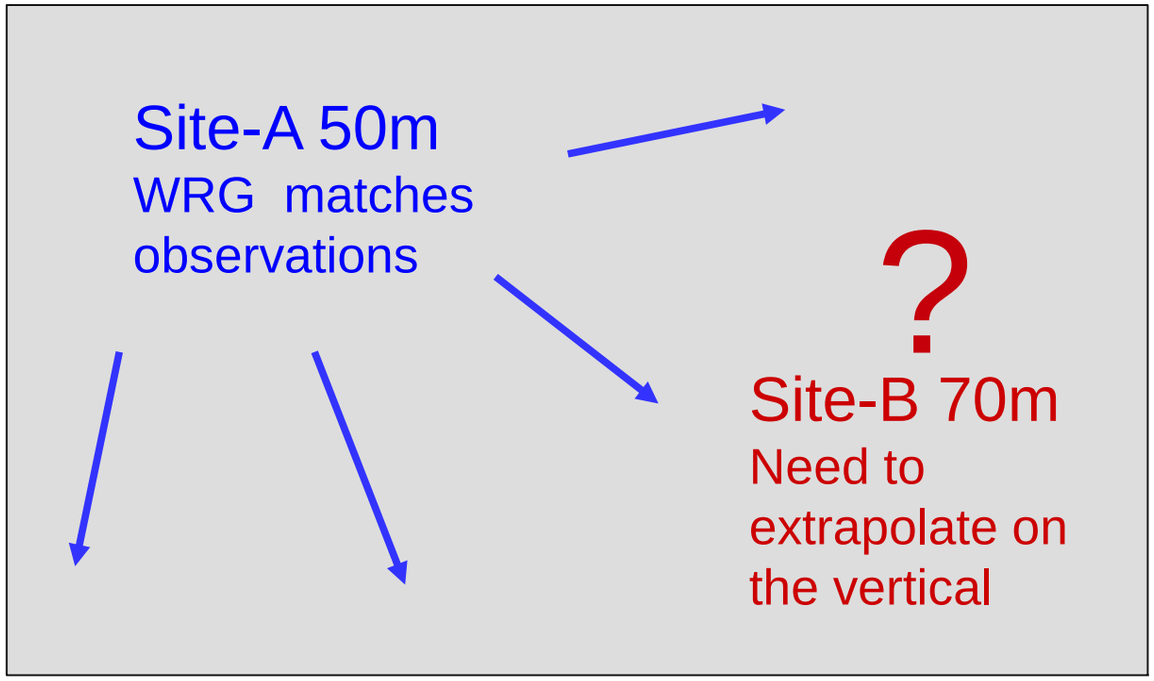
Motivation

Wind industry problem 3: Vertical Profile

How do we adjust a WRG file with observations at a different height?

Vertical interpolation will add uncertainty to the comparison





Motivation

Limitations of current calibration processes

- Wind direction and speed values are sectorized and binned
- Wind distributions in WRG file are Weibull-fitted
- Model vs Observations bins do not correspond to the same event on time
- Correction factors are applied to mathematical constructions not physical magnitudes
- A single correction factor non-time dependent is applied

Approach

Proposal:

Apply correction factors to U,V on time and space

Approach

Proposal:

Apply correction factors to U,V on time and space

Main Purpose:

- Avoid Weibull fittings

Approach

Proposal:

Apply correction factors to U,V on time and space

Main Purpose:

- Avoid Weibull fittings
- No sectors & bins

Approach

Proposal:

Apply correction factors to U,V on time and space

Main Purpose:

- Avoid Weibull fittings
- No sectors & bins
- Time dependent correction factors, synchronized with obs.

Approach

Proposal:

Apply correction factors to U,V on time and space

Main Purpose:

- Avoid Weibull fittings
- No sectors & bins
- Time dependent correction factors, synchronized with obs.
- Multiple observation sites, different heights

Approach

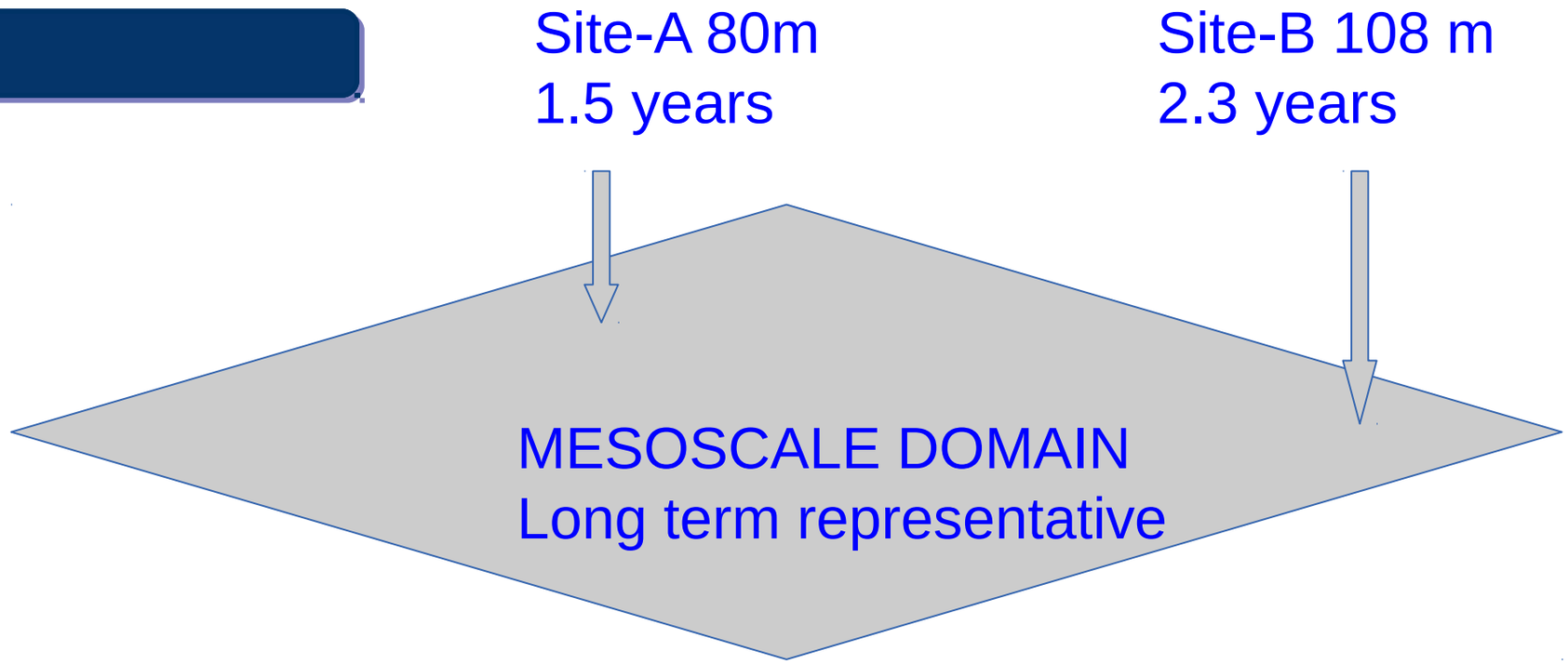
Proposal:

Apply correction factors to U,V on time and space

Main Purpose:

- Avoid Weibull fittings
- No sectors & bins
- Time dependent correction factors, synchronized with obs.
- Multiple observation sites, different heights
- Long term corrected results

Approach



Proposal:

STEP1: Extend observations on time

STEP2: Generate mesoscale output U,V(time, x, y, z)

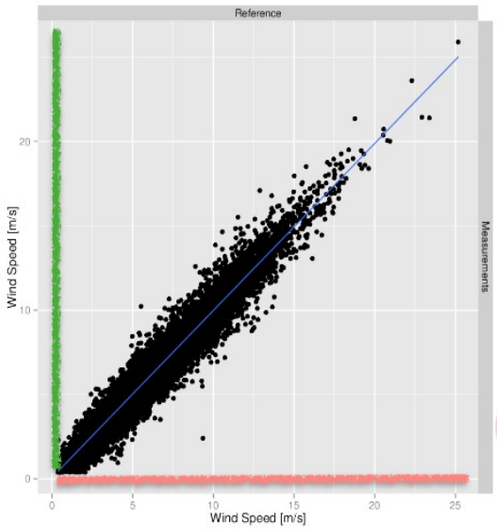
STEP3: Calculate correction factors Ucorr, Vcorr (time, x, y, z)

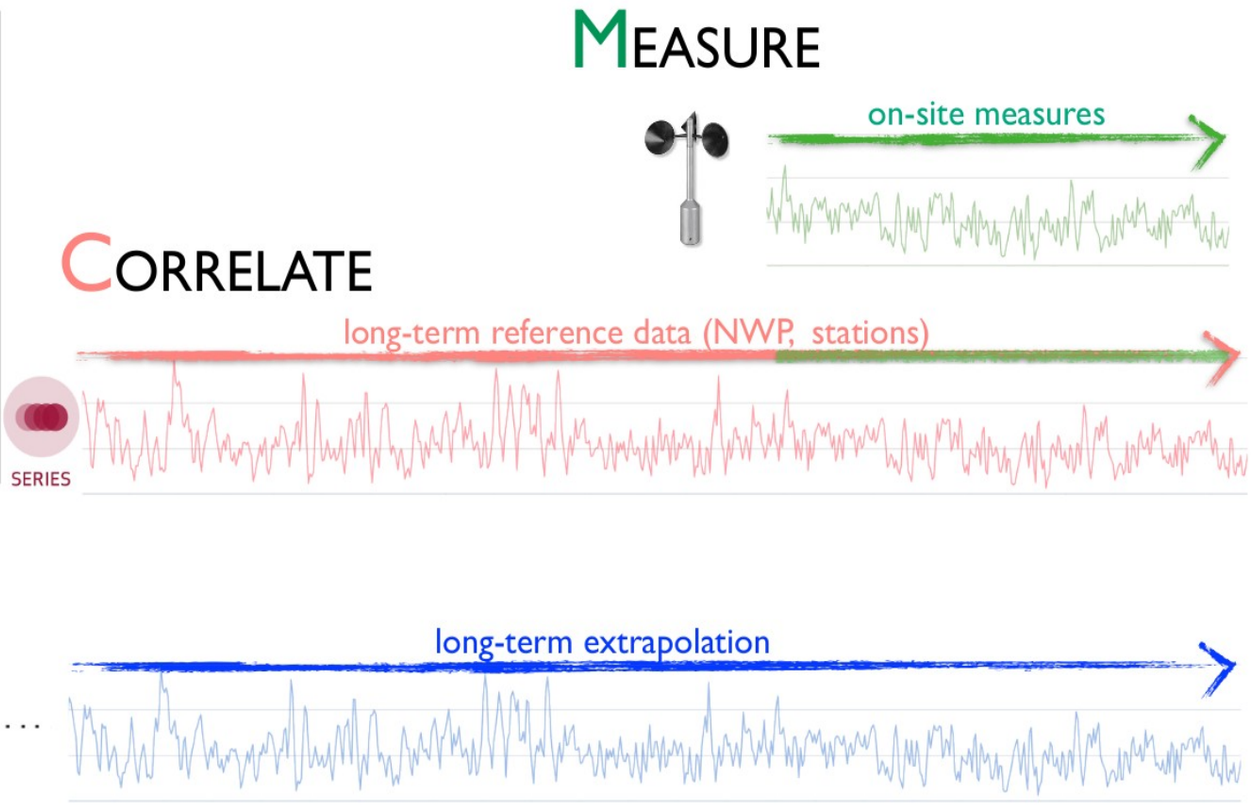
STEP4: Apply corrections and compute final distributions

Approach

STEP1: Extend observations on time -> Remodeling

On the benefit of a multivariate description of wind for a better long-term extrapolation (A. Tortosa et al. EWEA 2014)





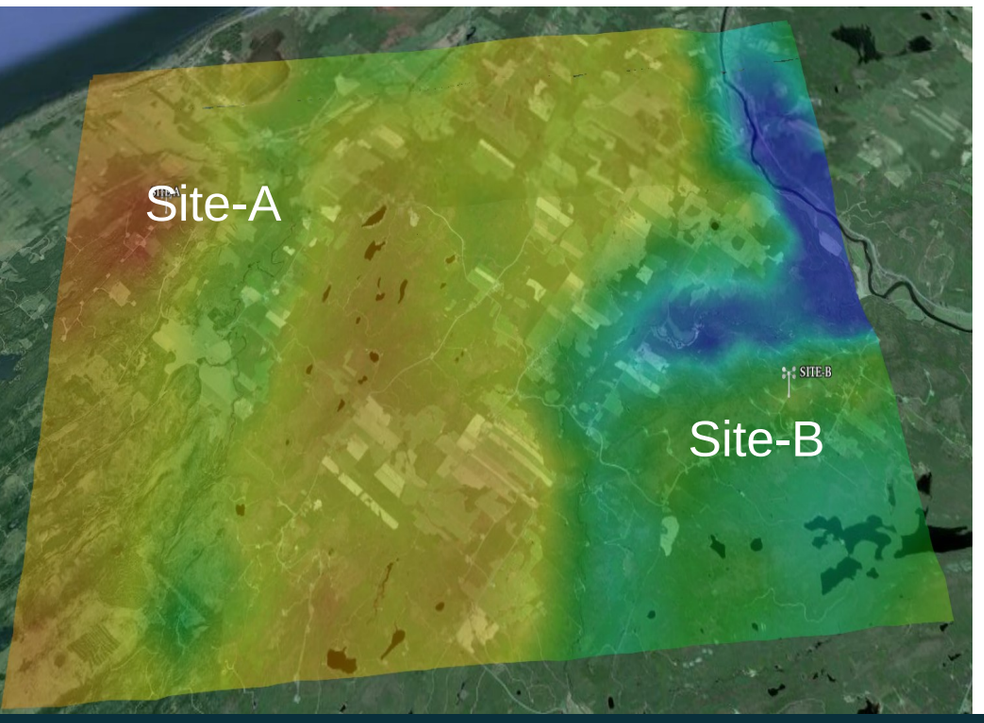
$$y_i = \beta_1 x_{i1} + \cdots$$

Long-Term extended series must be time-representative out of training period

Approach

STEP2: Generate mesoscale output U,V(time,x,y,z)

WRF downscaling high resolution



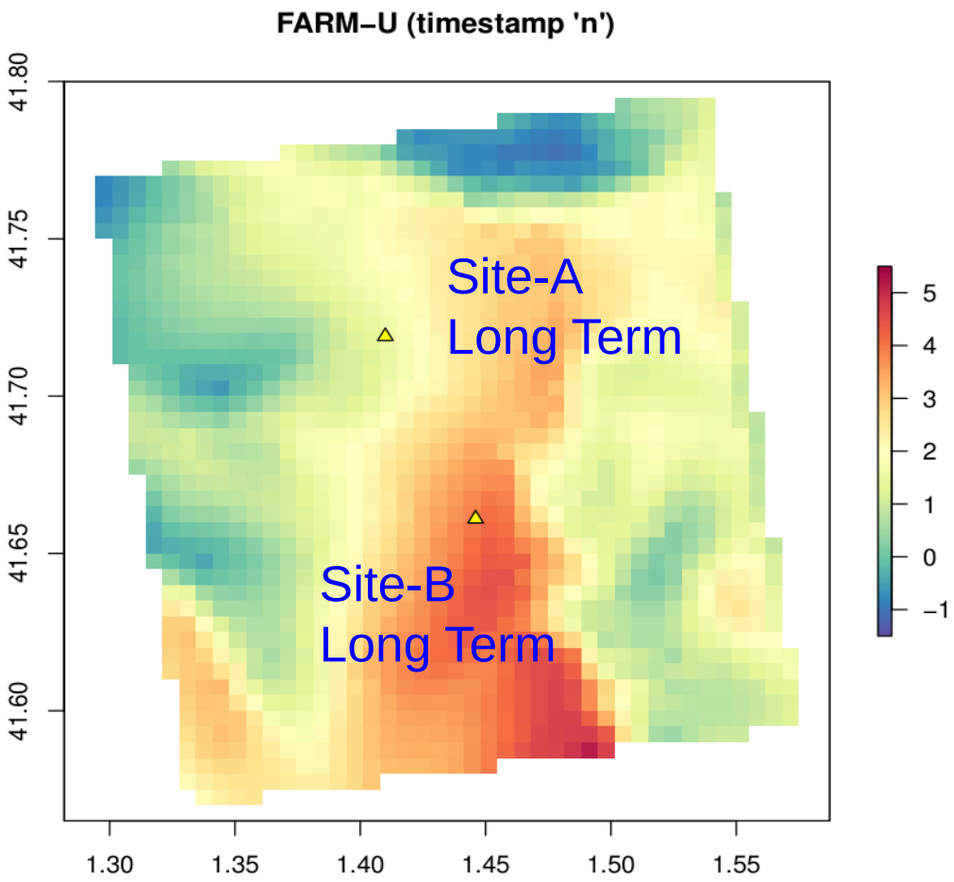
Mesoscale output needs to cover the same period than extended observations for hourly matching and thus deriving correction factors

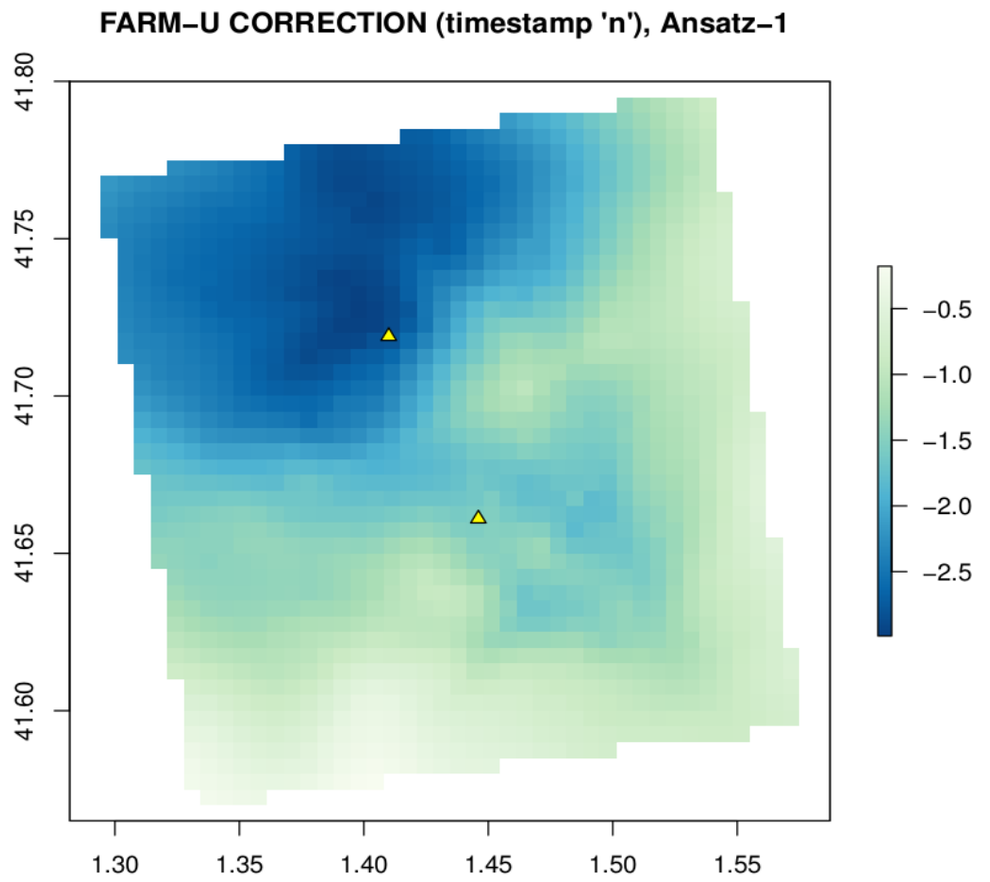
Approach

STEP3: Calculate correction factors Ucorr, Vcorr (time,x,y,z)

Data Assimilation

U & V corrected for time step ?

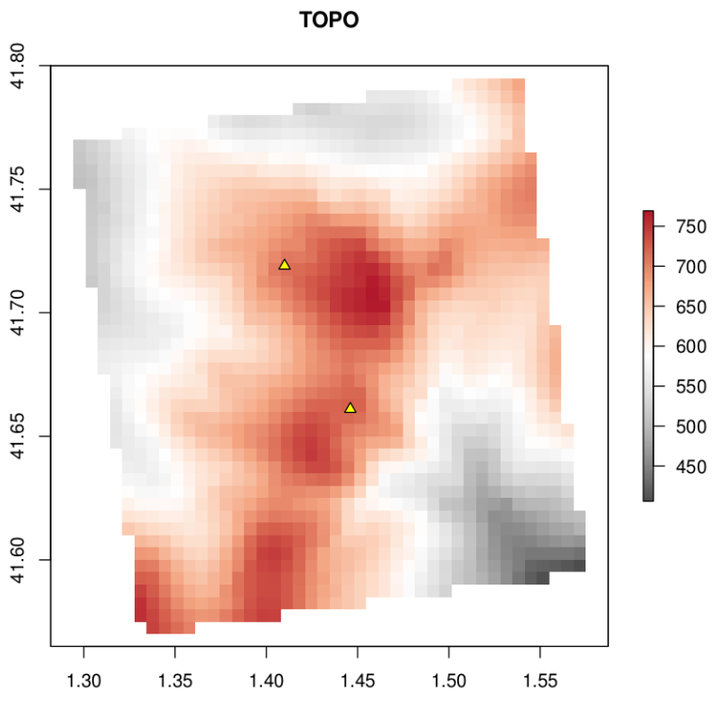


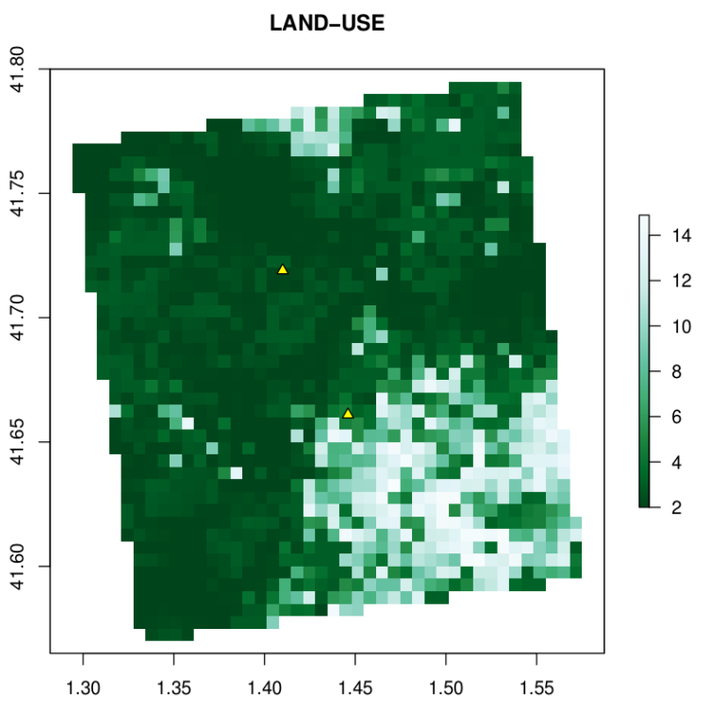


Approach

STEP3: Calculate correction factors Ucorr, Vcorr (time,x,y,z)

Data Assimilation





Use terrain descriptive variables in combination with mesoscale output

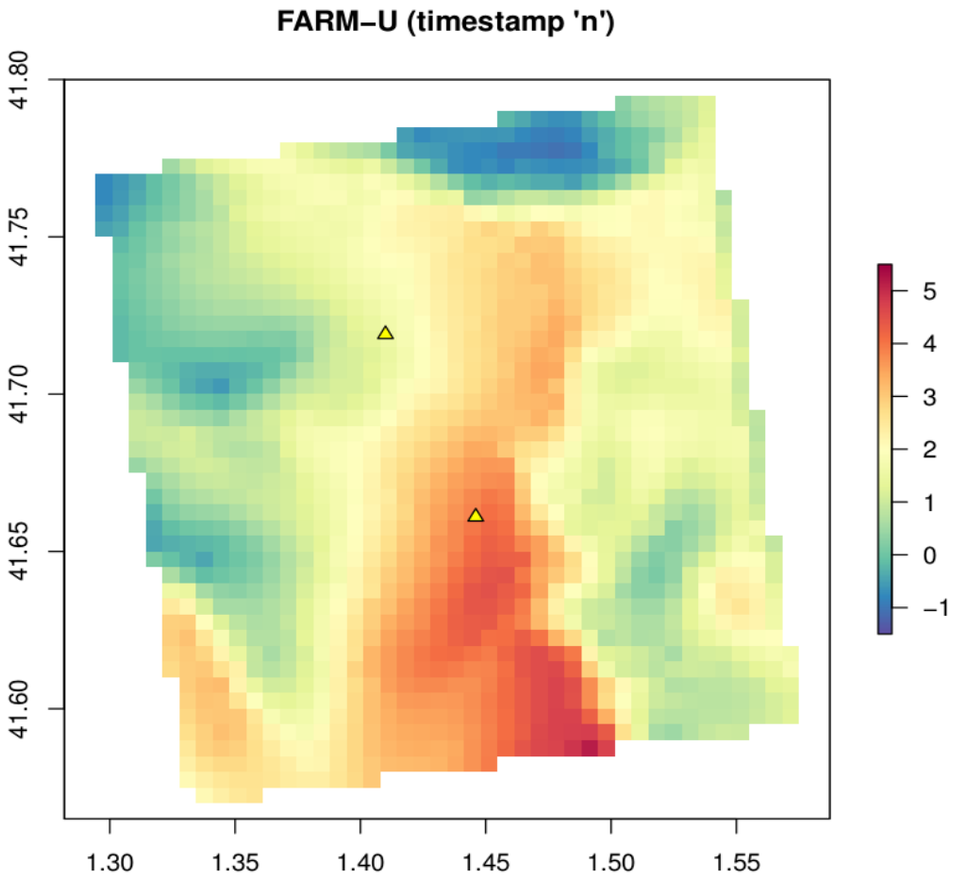
Universal Krigging for propagating the correction

$$E\{Z(x)\} = \sum_{k=0}^{p} \beta_k f_k(x)$$

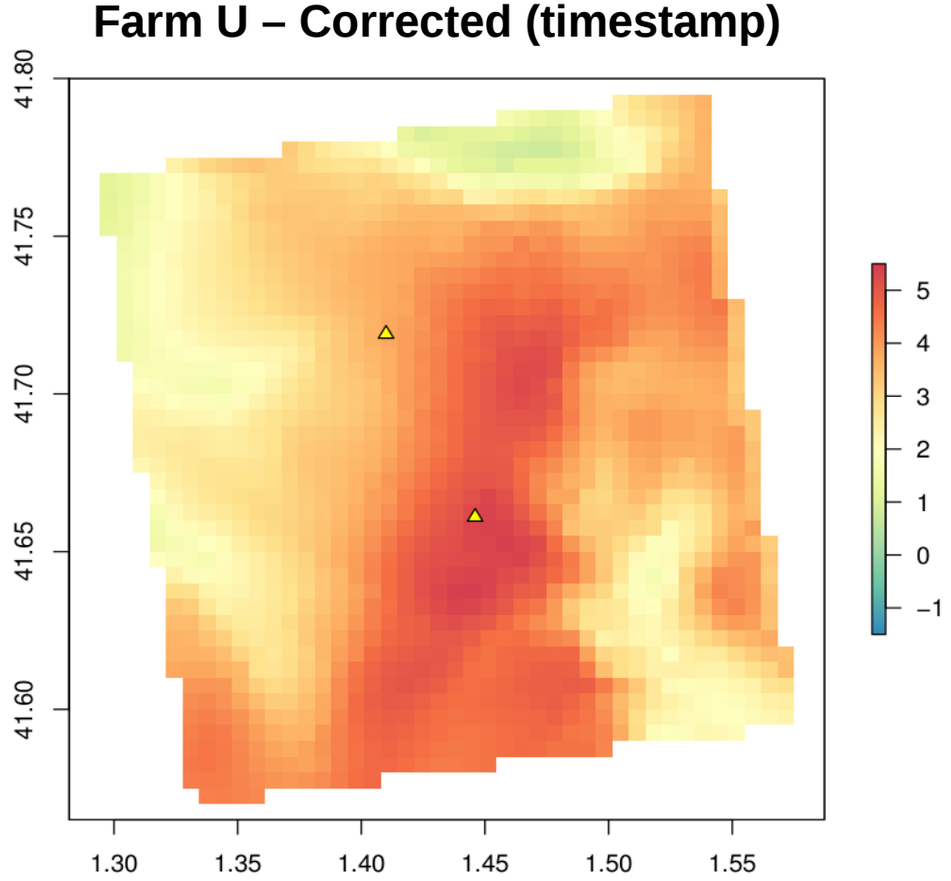
Approach

STEP3: Calculate correction factors Ucorr, Vcorr (time,x,y,z)

Data Assimilation

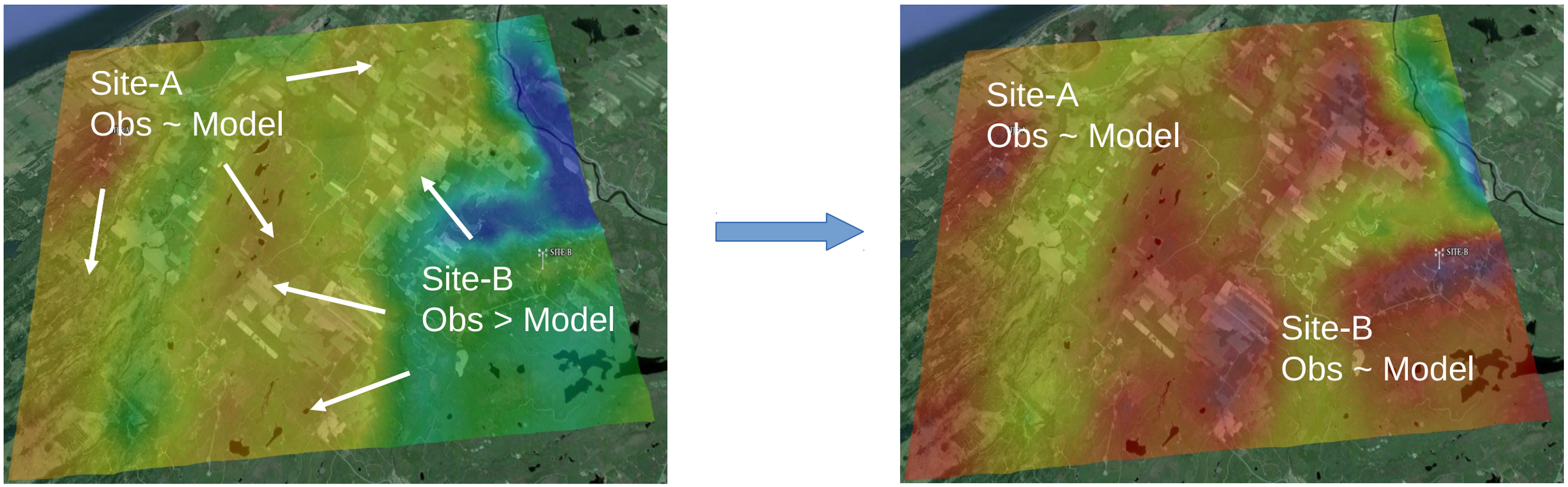


U & V are corrected for each time step



Results and Conclusions

STEP4: Apply corrections and compute final distributions



- No problems in the intersection
- Correct wind rose
- Better fitting for K-shape

Results and Conclusions

Validation Exercise Setup for 15 x 2 paired sites:

Distance: 2 – 15 km
Availability: 2 – 4 years
Height: 50 – 120 m
Terrain Type: Flat, Complex, Forest, Coastal

Control Test

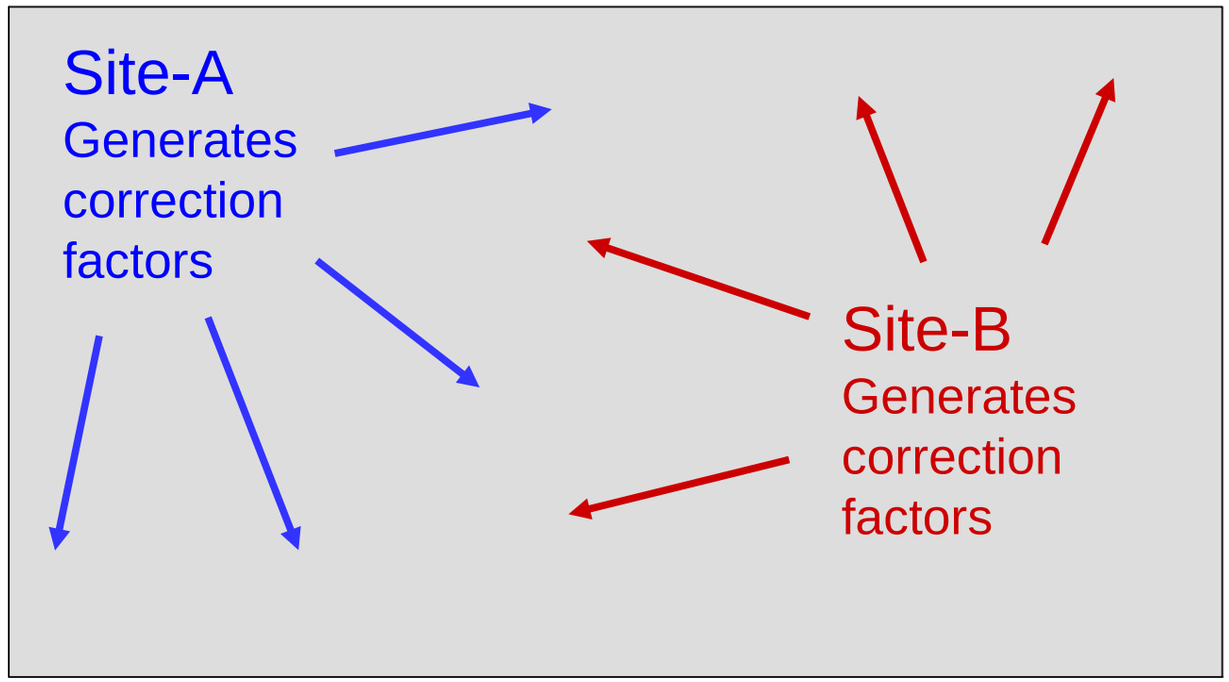
Blind Crossed Test

Results and Conclusions

Control Test

- All (15 x 2) sites adjust to measurements in terms of wind speed and direction
- k-shape-Weibull parameter is improved significantly
- No strange patterns are generated in the intersection zone

	Default	Calibrated	Units
U-MAE	0.82	0.09	m/s
A-MAE	0.95	0.11	m/s
k-MAE	0.28	0.07	-

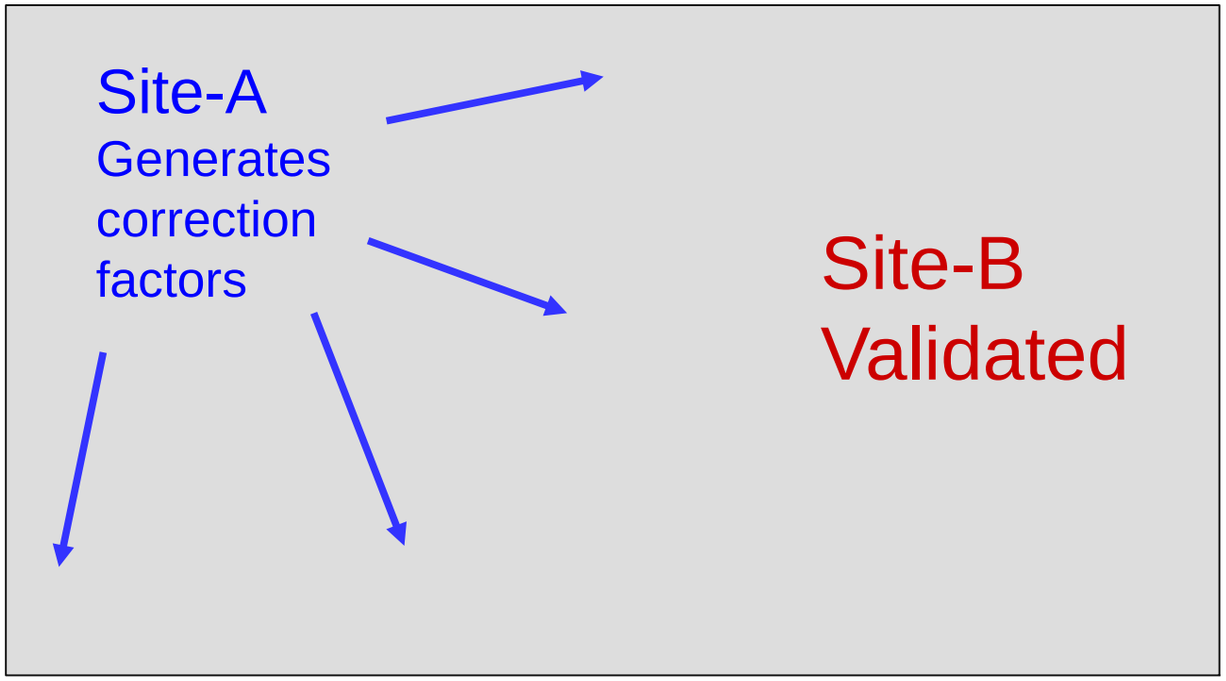


Results and Conclusions

Blind Crossed Test

	Default	Calibrated	Units
U-MAE	0.82	0.39	m/s
A-MAE	0.95	0.51	m/s
k-MAE	0.28	0.13	-

- 80% of the sites improve WSP
- 100% sites change wind direction in the right direction
- k-shape-Weibull parameter is improved -> correction factors on time better adjust events



Final remarks

-Model + Obs -> Improved results

-Compact methodology:

- multi-tower (different heights) calibration
- long term corrected
- no linear effects considered (k-shape)

-No wind fields hot spots and smooth intersections if multi-tower

-Correct wind direction veer thanks to non-binned data and adjustment of U,V (physical magnitudes) instead of distributions

Further work

-Extend the validation to more sites (offshore sites, very-biased sites...)

-Multi test tower -> blind test with 3 or more sites

-Qualitative/quantitative comparison against other methodologies (WasP, WindPro, Openwind...). Difficult to be objective due to very different initial conditions such as roughness and topography

Thank you for you attention