Wind Atlases – the latest news

Jakob Mann

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DTU Wind Energy, Roskilde, Denmark

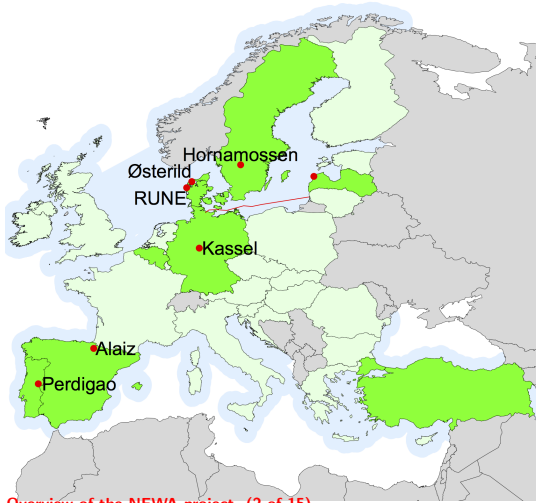
October 1, 2019

The New European Wind Atlas

- Accurate mapping of wind conditions for the estimations of resources and loads
- Development and testing of the model chain
- A series of atmospheric field experiment to validate the model and atlas.

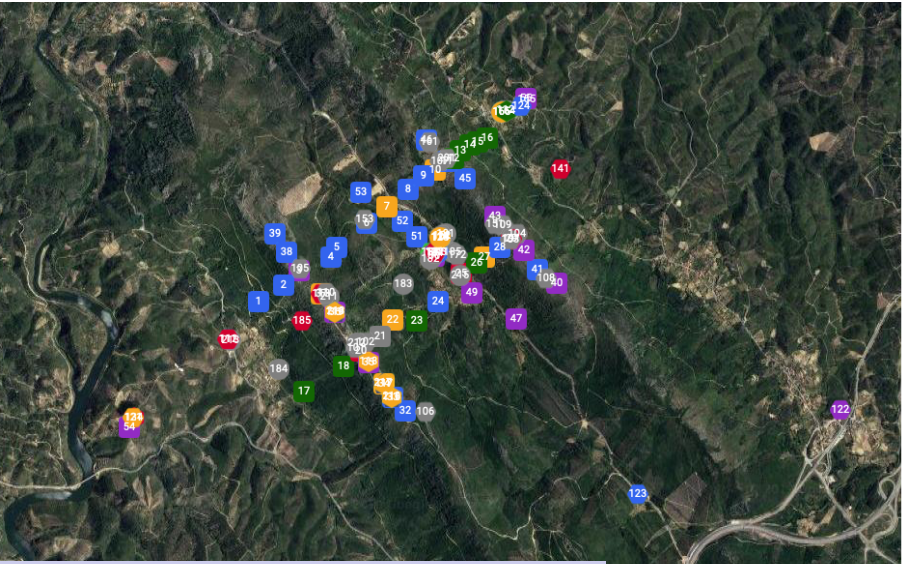
The New European Wind Atlas

- EU countries
- NEWA partners
- Offshore coverage
- Experimental sites



Largest NEWA campaign: The Perdigao Experiment

- >190 3D sonic anemometers on 50 masts
- 20 scanning lidars + 7 profiling lidars
- Various temperature profilers, ballon launched every six hours, radars, etc
- Participation from industry and partners outside NEWA
- *Most comprehensive dataset for model evaluation in complex terrain to date*



Towers-020
Towers-010
Towers-100
Towers-002

Remote sensing All None
Water vapor DIAL
SODAR - RASS
Scanning LIDAR
MWR
Profiling LIDAR
Microbarometer
Ceilometer
AERI
Profiling RADAR - RASS
Scintillometer
Profiling RADAR

Sounding sites All None
Tethersonde
Radiosonde

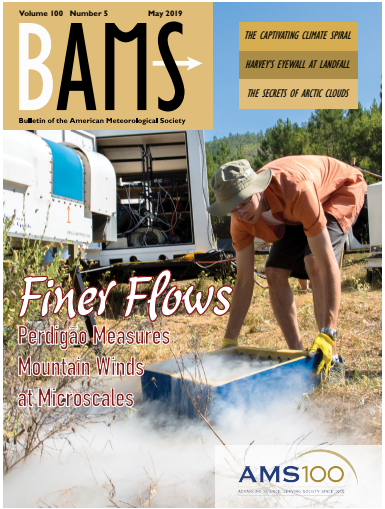
Ground sensors All None
Seismometer

Noise monitoring All None
Monitoring

Research from Perdigao

Data available through, NCAR, Uni Porto or DTU, *Fernando et al, 2019*

- Overview paper in Bull. Am. Met Soc, May 2019



Research from Perdigao

C Veiga Rodrigues *et al* 2016 J. Phys.: Conf. Ser. **753** 032025

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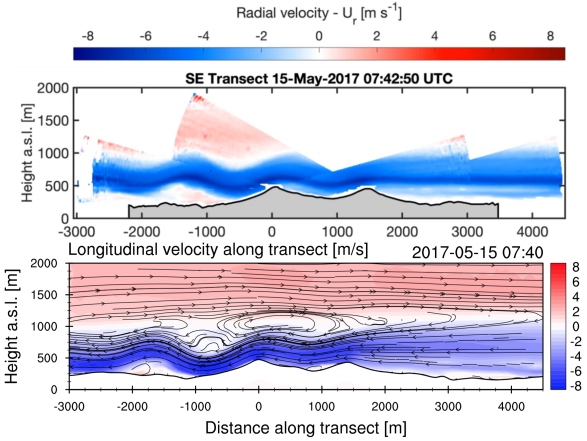


Research from Perdigao

Witze, A. World's largest wind-mapping project spins up in Portugal. *Nature*, **542**, 282–283, 2017

- Overview paper in Bull. Am. Met Soc, May 2019
- News article in *Nature*

NEWS IN FOCUS

assumptions. Until now, it was not clear that one could fully determine Earth's structure using only wave travel times.

But that is what Vasy and his team's proof shows — and the geophysical problem was a key motivation for solving the conjecture. Their assumption, which differed from Michel's, was that the curved space, or manifold, is structured with concentric layers. This allowed them to construct a solution in stages. "You go layer by layer, like peeling an onion," says Uhlmann. For practical applications, this means that researchers will not only know that there is a unique solution to the problem; they will also have a procedure to calculate that solution explicitly.

The three mathematicians circulated their 50-page paper among a small pool of experts and then posted it in the arXiv repository. Depending on the feedback they get, the authors hope to submit it to a journal in the coming weeks.

FROM THEORY TO REALITY

But applying the theory to real geophysical data will not happen immediately, says Maarten de Hoop, a computational seismologist at Rice University in Houston, Texas. One difficulty is that the theory assumes that there is information at every point. In reality, however, data are collected only at relatively sparse locations.

The theory could lead to a better understanding of known features, such as the mantle plumes underneath Iceland or Hawaii, and, perhaps, to the discovery of new ones, adds de Hoop.

As with every meaty mathematical result, it will take time to get to grips with the proof and vet it thoroughly, says Gabriel Paternain, a mathematician at the University of Cambridge, UK. Experts are taking the claim seriously, in part because it builds on a technical step from a linear form of the

EARTH OBSERVATORY

Technicians install sensors for the Perdigão wind-mapping project.

ATMOSPHERIC SCIENCE

Huge wind-flow study spins up

International team in Portugal seeks to improve models of wind patterns over rugged terrain.

BY ALEXANDRA WITZE

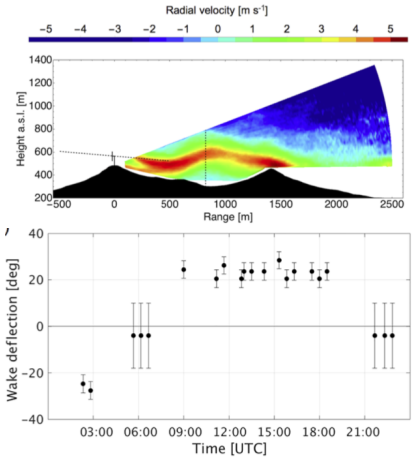
Machines have invaded a windswept rural valley in eastern Portugal. Squat white containers stare at the

project. The aim is to illuminate fundamental properties of wind flow over complex terrain, to help researchers improve atmospheric computer models and enable engineers to decide where to put wind turbines to get the most

Research from Perdigao

Menke *et al, Wind Energ. Sci.*, **3**, 681–691

- Overview paper in Bull. Am. Met Soc, May 2019
- News article in *Nature*
- Ten papers in inter-journal special issue and several other papers: Gusts, recirculation, long-term simulation, multi-lidar work, and wake studies.



Research from Perdigao

Dar *et al, Wind Energ. Sci. Discuss.*, 2019

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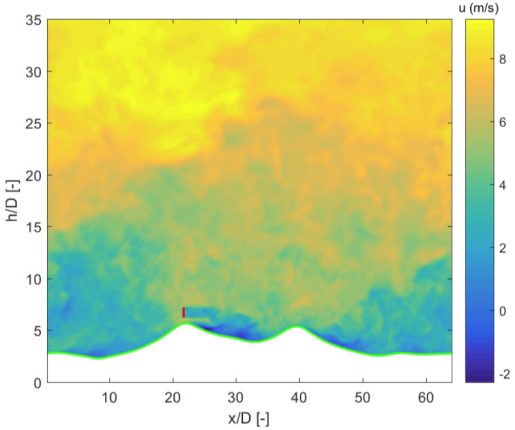

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Barthelmie & Pryor *Atmos. Meas. Tech.*, **12**, 3463–3484, 2019

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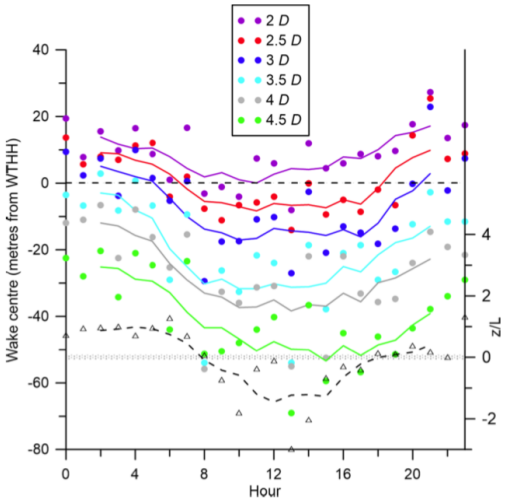

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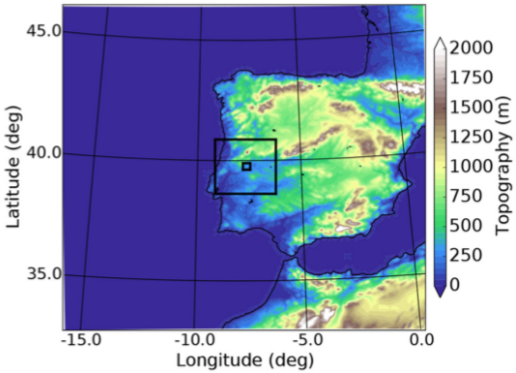

Research from Perdigao

Bjarke T. Olsen, PhD thesis, DTU, 2019

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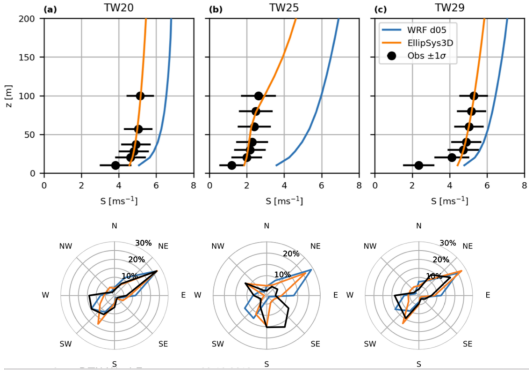

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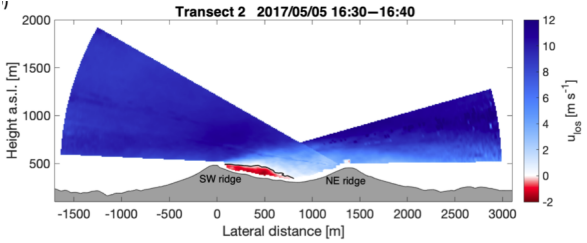


The NEWA model chains

The NEWA open-source chain

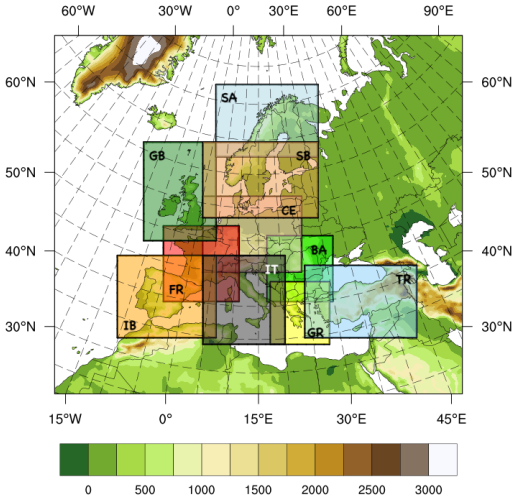
- NEWA setup of WRF
- CFDWind3 OpenFOAM library
- URANS forced with tendencies (like SOWFA)
- Code, setup and test example available on github

The NEWA production chain

- NEWA setup of WRF
- WAsP (not CFD-WAsP) run in a Python implementation on a 50 m grid
- Statistical downscaling

Meso-scale production run

Long term mean wind speed at 100 m. 30 years available.



- Sensitivity tests, evaluation on simple sites, optimal domains, ensemble runs

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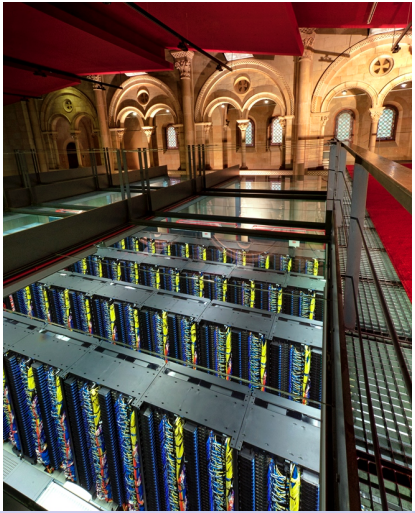

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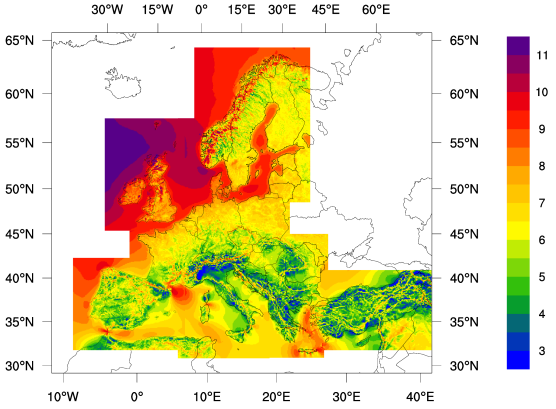

- Sensitivity tests, evaluation on simple sites, optimal domains, ensemble runs
- March 57 mio. core hours granted on PRACE's MareNostrum
- Mesoscale simulation output covering all Europe 1989-2018 on NEWA server

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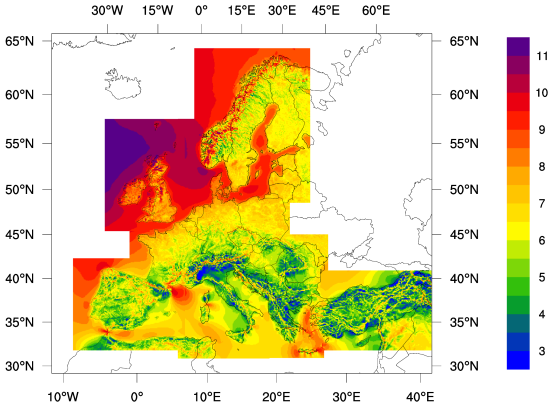
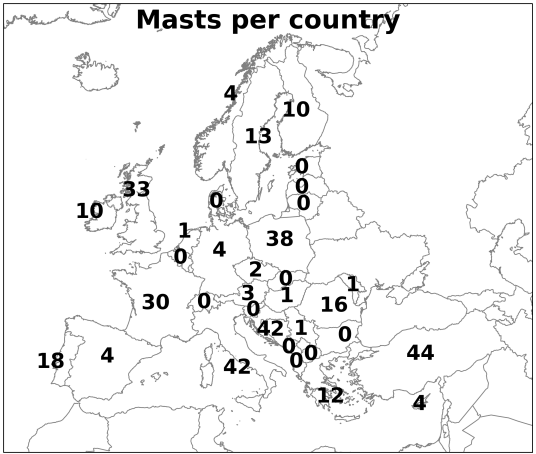


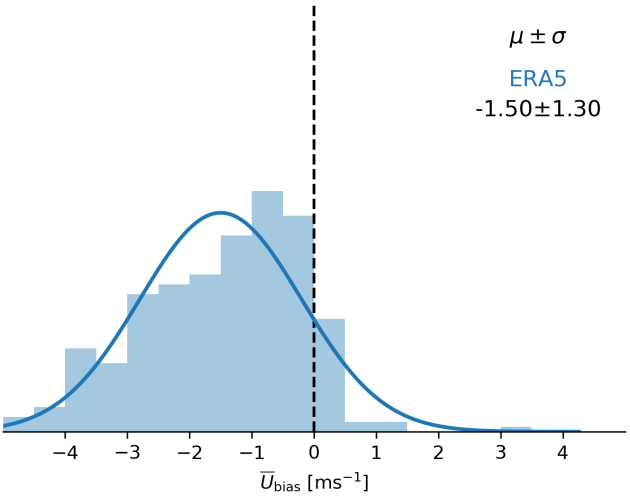
- 10 overlapping inner domains ($\Delta x = \Delta y = 3$ km) with shared outer domain
- Model setup chosen through test on masts in flat terrain
  - ERA5 Boundary conditions
  - MYNN-MO PBL-SL Scheme
  - NOAH LSM
  - CORINE land-use
  - OSTIA SST
  - spectral nudging in outer domain only above PBL
  - Weekly simulations with 1 d spin-up, one-way nesting

Systematic atlas validation with Vestas masts

- Site locations not available outside Vestas
- 291 masts selected based on $40 < z < 150$ m and high availability
- Results based on groups of masts will be published in Wind Energy Science



Validation results: $\overline{U}_{bias} \equiv \overline{U}_{model} - \overline{U}_{obs}$



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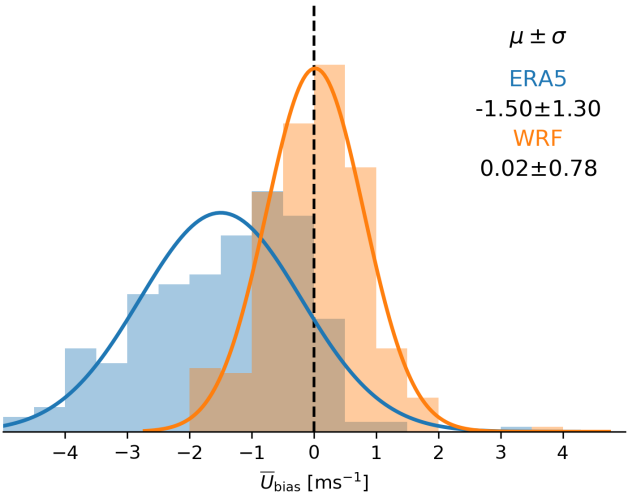

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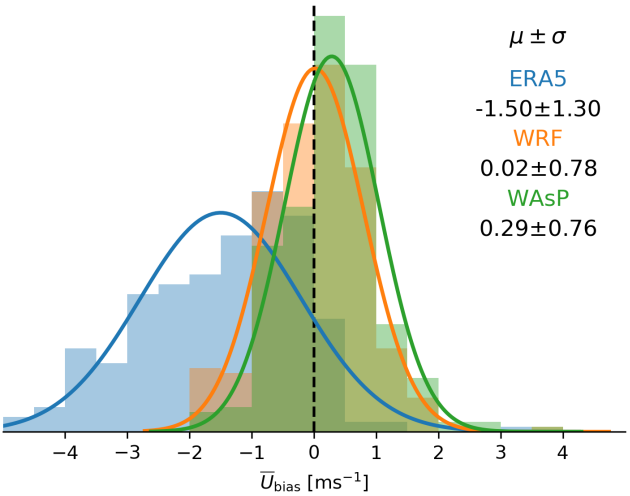

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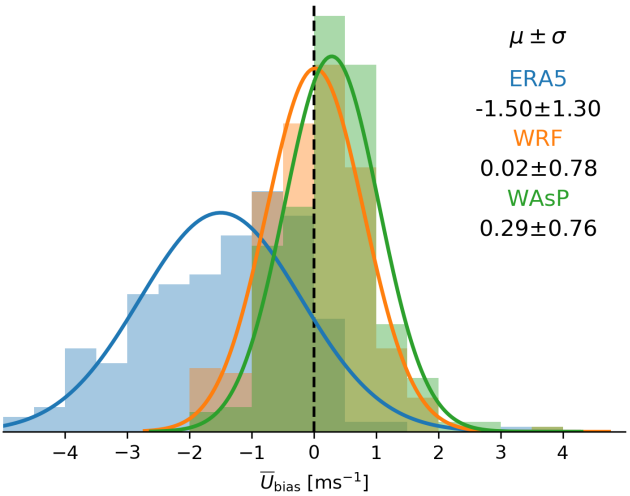

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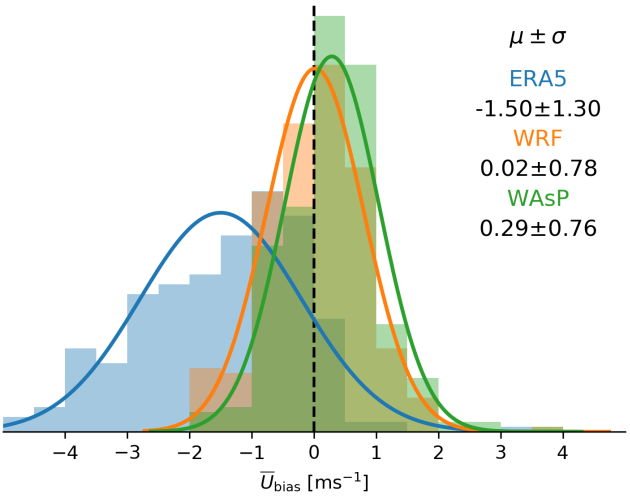
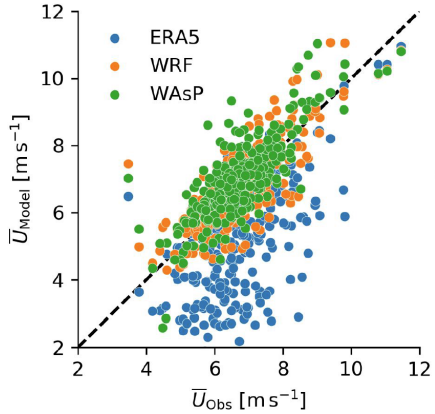
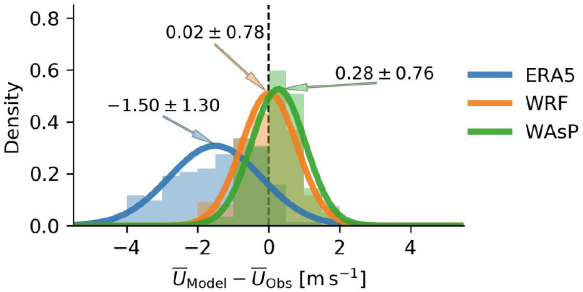


- WRF preforms extremely well
- So far a systematic downscaling from such a good starting point has not lead to an improvement in the prediction

Terrain complexity: All masts, $n = 291$

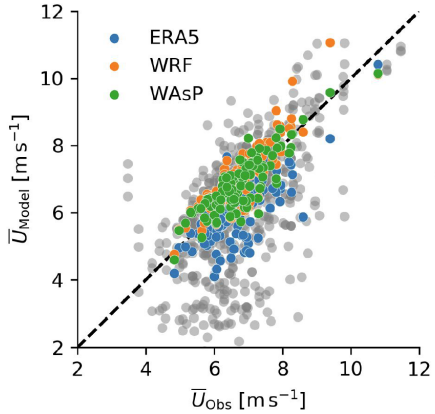
RIX: Fraction of slopes within 3500 m radius above 16.7°

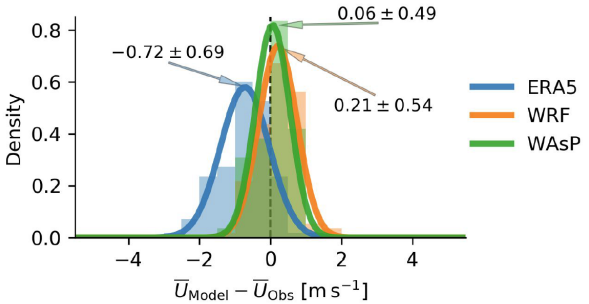




Terrain complexity: Low, RIX = 0%, $n = 110$

RIX: Fraction of slopes within 3500 m radius above 16.7°





Terrain complexity: Meidum, $0 < \mathrm{RIX} < 2\%$, $n = 96$

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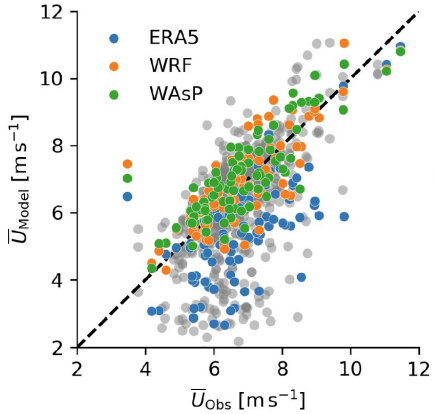

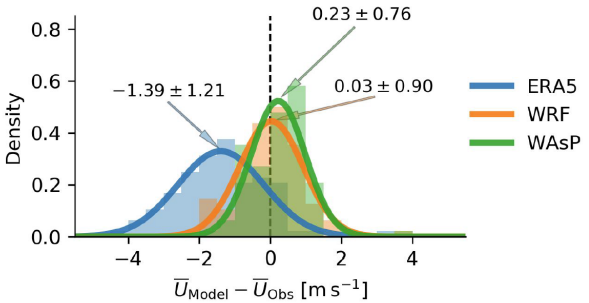

Terrain complexity: High, RIX $> 2\%$, $n = 85$

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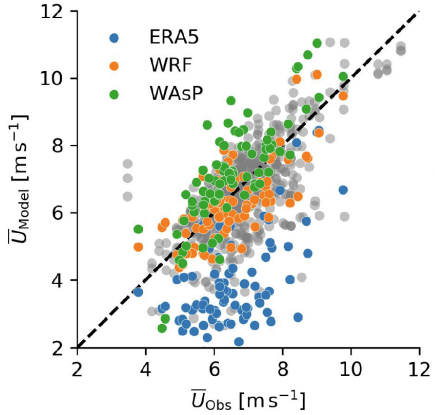
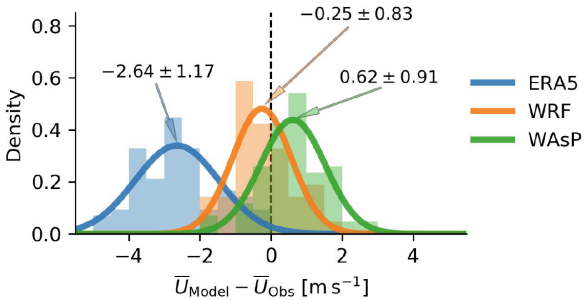


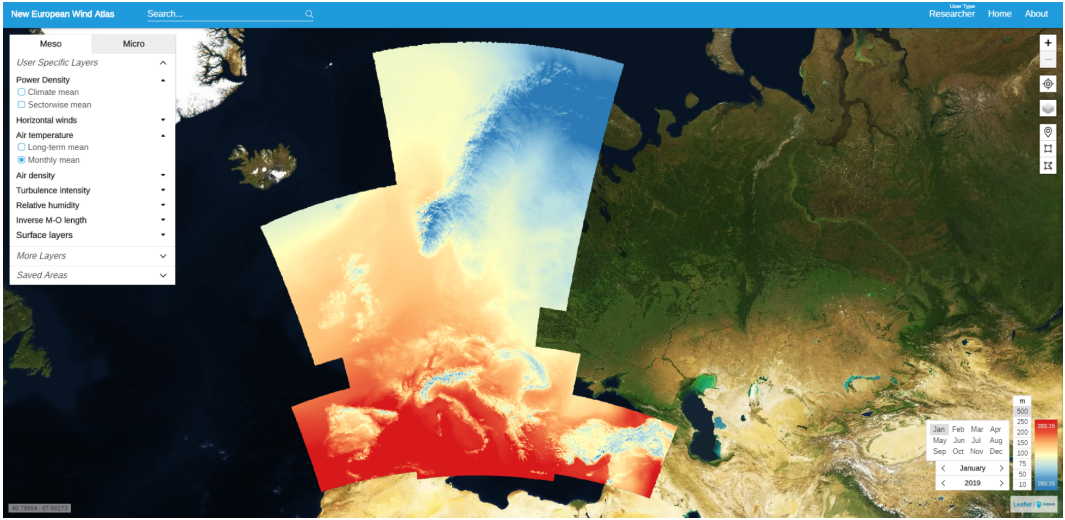


What happens is we arbitrarily change the roughness?

Multiplying the roughness translation table by 1/2, 1 or 2

Metric	RIX Cat.	WRF-WAsP RCT-B $\mu \pm \sigma$			Units
		$1/2z_0$	z_0	$2z_0$	
$\overline{U}_{\text{bias}}$	All (291)	0.61 ± 0.78	0.28 ± 0.76	$\mathbf{-0.11 \pm 0.75}$	$[\text{m s}^{-1}]$
$\overline{U}_{\text{bias}}$	Low (110)	0.37 ± 0.50	$\mathbf{0.06 \pm 0.49}$	$-0.30 \pm \mathbf{0.49}$	$[\text{m s}^{-1}]$
$\overline{U}_{\text{bias}}$	Medium (96)	0.57 ± 0.78	0.23 ± 0.76	$\mathbf{-0.18 \pm 0.75}$	$[\text{m s}^{-1}]$
$\overline{U}_{\text{bias}}$	High (85)	0.98 ± 0.92	$0.62 \pm \mathbf{0.91}$	$\mathbf{0.21 \pm 0.91}$	$[\text{m s}^{-1}]$
$\overline{P}_{\text{bias}}$	All (291)	23.93 ± 29.10	13.28 ± 27.36	$\mathbf{0.88 \pm 25.38}$	[%]
$\overline{P}_{\text{bias}}$	Low (110)	18.21 ± 19.83	7.33 ± 17.56	$\mathbf{-5.15 \pm 15.76}$	[%]
$\overline{P}_{\text{bias}}$	Medium (96)	24.15 ± 27.76	13.13 ± 25.11	$\mathbf{0.11 \pm 22.81}$	[%]
$\overline{P}_{\text{bias}}$	High (85)	31.08 ± 37.78	21.16 ± 36.66	$\mathbf{9.56 \pm 34.24}$	[%]

Interface to NEWA map.neweuropeanwindatlas.eu



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- Downscaling to microscale leaves room for improvement.
  1. Direct, physical surface description, not land-use classes
  2. Better downscaling model

Acknowlegdments

Thanks to NCAR for the appointment as an affiliate scientist