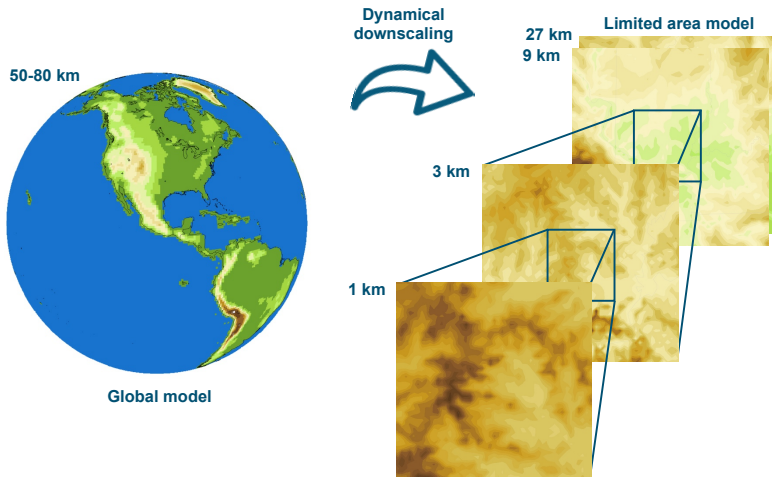


WRF-LES in 250+ real sites: Learnings and Challenges

A. Montornès¹ P. Casso¹ G. Lizcano¹ B. Kosovic²

¹Vortex, ²NCAR-RAL





CFSR	MERRA-2	ERA-Interim	ERA5
1979-present	1980-present	1979-present	1979-present
50x50 km	50x66 km	75x75 km	31x31 km
37 pressure levels	37 pressure levels	37 pressure levels	37 pressure levels
6 h	6 h	6 h	1 h

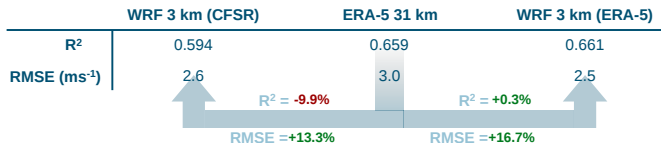
Wind speed hourly validation

38 sites - wind industry heights

Jan, 1 to Feb, 29 2016 (2 months)



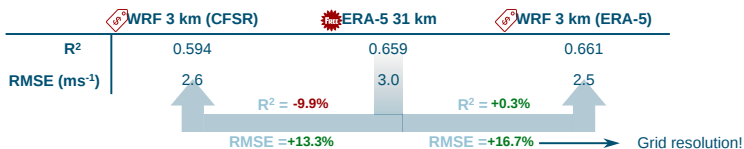
Mean values



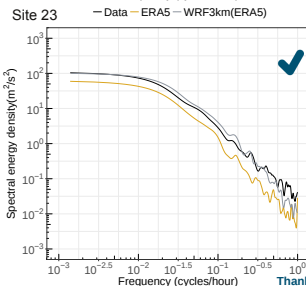
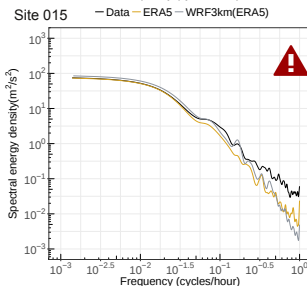
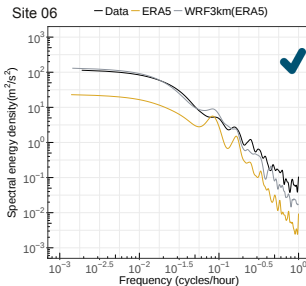
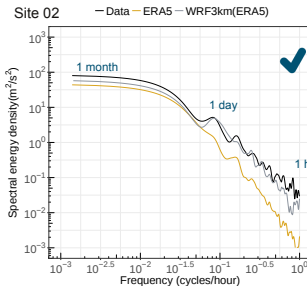
Wind speed hourly validation

38 sites - wind industry heights

Jan, 1 to Feb, 29 2016 (2 months)

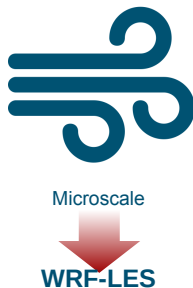
Mean values

Does this mean the end of the mesoscale models for operational forecasting and applications like wind resource assessment?

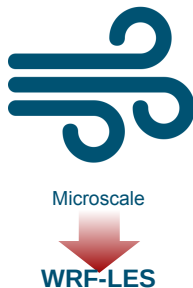


Thanks to Albert Bosch

Exploring new ways of added value...



Exploring new ways of added value...



Exploring new ways of added value...

Wind resource assessment applications



Microscale



WRF-LES

Microscale and local effects

Turbulence analysis

Wind turbine loads

Improve shear and veer

Improve stability regimes

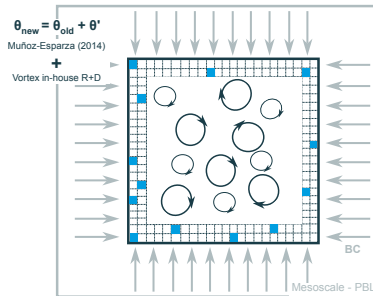
Mesoscale-Microscale coupling: limitations

Turbulence spin-up and lateral boundary conditions

Terra Incognita

Surface layer schemes

Computational resources



+ info

Munoz-Esparza, D., et al.: **Coupled mesoscale-LES modeling to improve the representation of stably-stratified atmospheric boundary layers**. 18th Annual WRF Users' Workshop. 2017. [TODAY 4.4]

Montornès A., et al.: **WRF-LES in the real world: Towards a seamless modeling chain for wind industry applications**. 17th Annual WRF Users' Workshop. 2016.

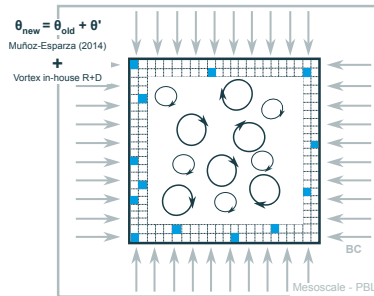
Mesoscale-Microscale coupling: limitations

Turbulence spin-up and lateral boundary conditions

Terra Incognita

Surface layer schemes

Computational resources

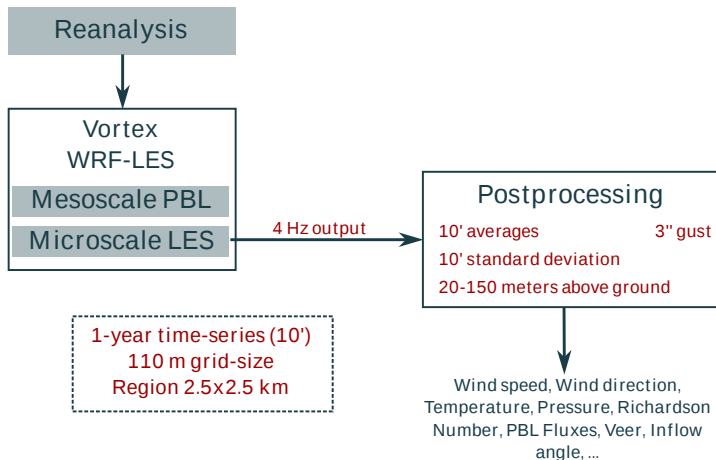


+ info

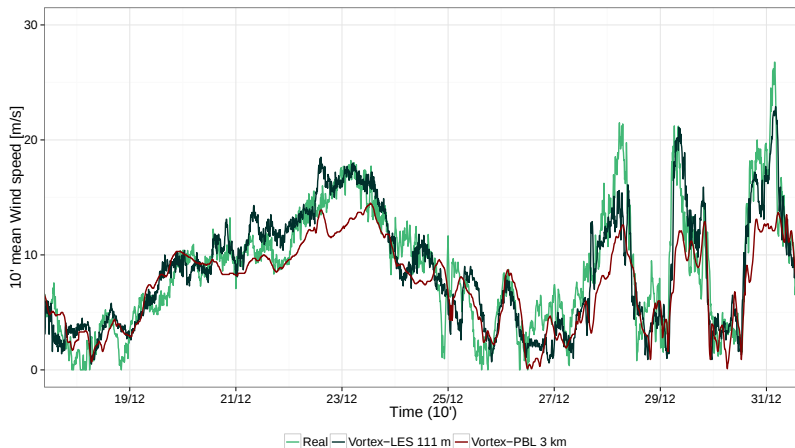
Munoz-Esparza, D., et al.: **Coupled mesoscale-LES modeling to improve the representation of stably-stratified atmospheric boundary layers**. 18th Annual WRF Users' Workshop. 2017. [TODAY 4.4]

Montornès A., et al.: **WRF-LES in the real world: Towards a seamless modeling chain for wind industry applications**. 17th Annual WRF Users' Workshop. 2016.

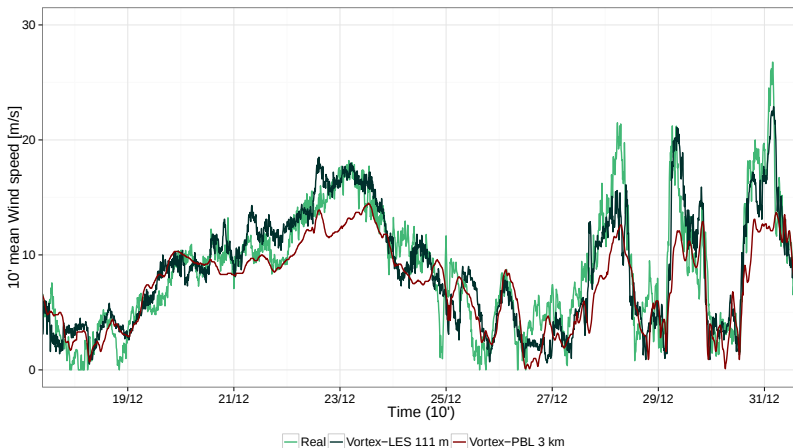
The Vortex approach



Example: 2 weeks, met-mast at 80 m



Example: 2 weeks, met-mast at 80 m



Vortex WRF-LES in numbers

50 countries

250+ sites

94.7% success

1,562.5 km²

250+ years

11,250+ computational hours

Validation exercise

3.1% Off-shore **41.7% Flat terrain** **25.0% Complex terrain** **30.2% Forest**



Anemometers: **18.1% 20-50 m** **68.1% 50-100 m** **13.8% 100-150 m**

1-year validation

Wind speed validated at 96 sites at different mast-mast heights

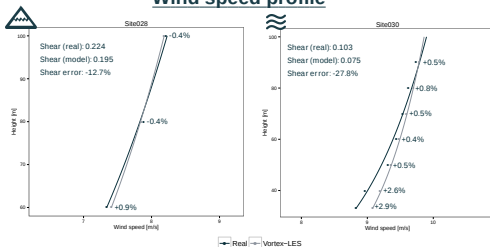
Turbulence validated at 56 sites at different mast-mast heights

Validation exercise

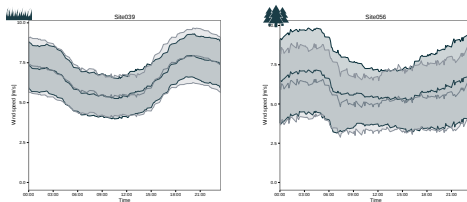
Wind speed metrics

		Bias (%)	RMSE (ms-1)	R ²
+	All (100%)			
	10-min		2.6	0.605
	Hourly	2.4	2.5	0.637
	Daily		1.7	0.807
≈	Off-shore (3.2%)			
	10-min		1.9	0.837
	Hourly	0.4	1.8	0.855
	Daily		1.1	0.937
⬆	Flat (40.9%)			
	10-min		2.5	0.593
	Hourly	-3.4	2.4	0.625
	Daily		1.6	0.811
⚠	Complex (30.1%)			
	10-min		2.9	0.590
	Hourly	7.1	2.8	0.623
	Daily		1.9	0.790
🌲	Complex Forest (25.8%)			
	10-min		2.6	0.610
	Hourly	6.5	2.5	0.646
	Daily		1.7	0.805

Wind speed profile



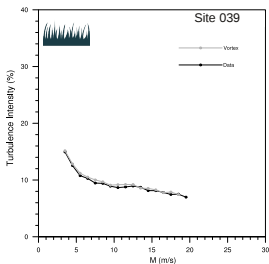
Wind speed daily cycle



Validation exercise

Wind turbulence metrics

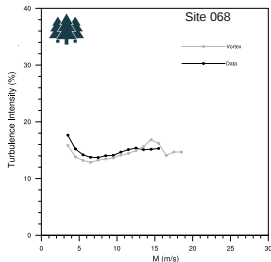
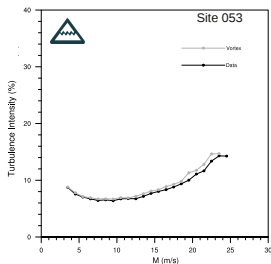
TI = resolved + SGS



Metrics 56 sites

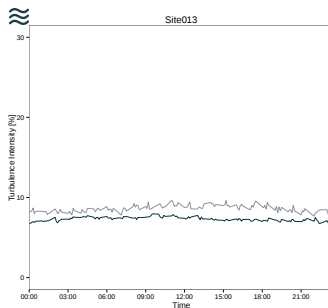
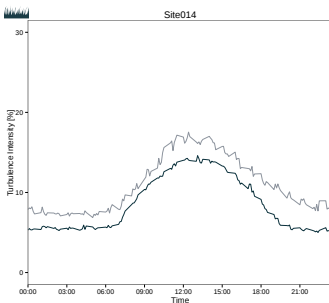
Mean MAE (weighted by bin-occurrence): **1.8%**

Mean MAE (bin 15 ms⁻¹): **1.9%**

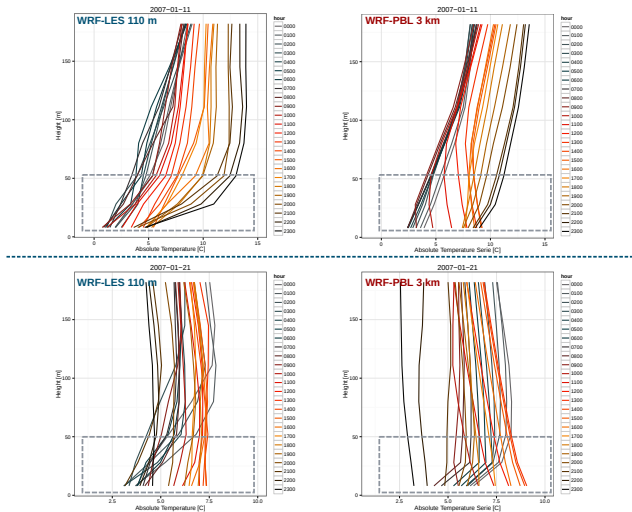


Validation exercise

Wind turbulence daily cycle



Challenges: Surface temperature



Challenges: Surface temperature

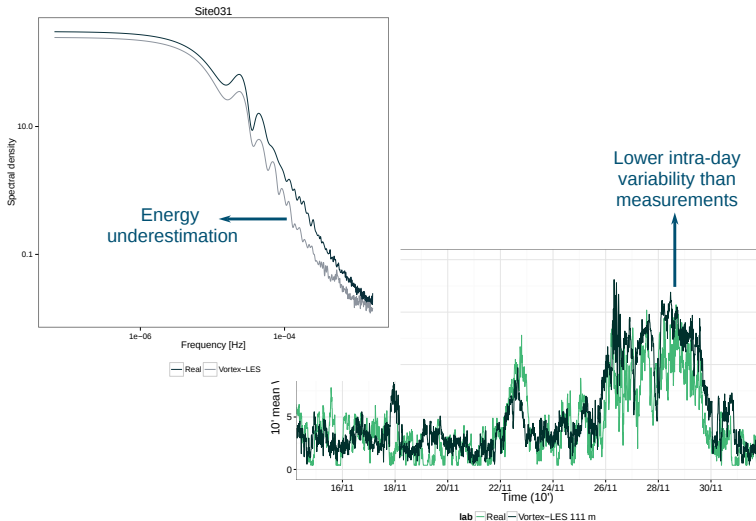
a) Problems in the temperature perturbation? **X**

b) Problems in the surface layer scheme? 

c) Problems in the SGS? 

Subroutine tke_km

Challenges: Terra-Incognita

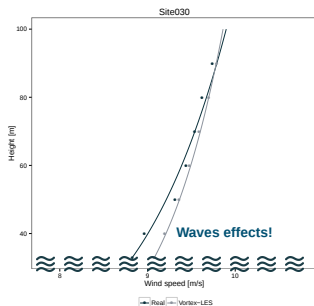


Challenges: Terra-Incognita

a) PBL/LES schemes at 333 m?

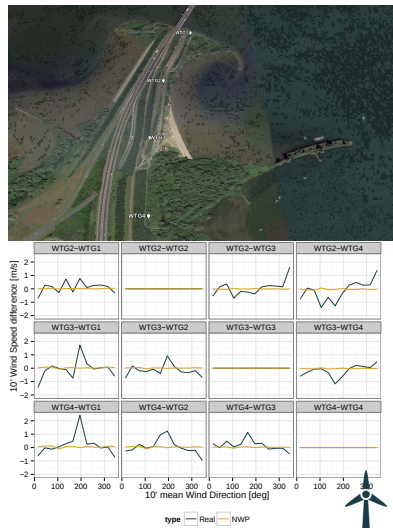
b) Perturbation grid size?

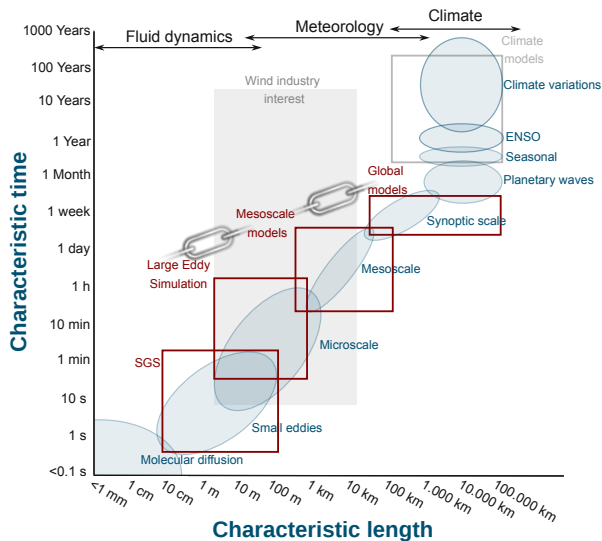
Challenges: Others



New horizons

- Waves
- Forest canopy





WRF-LES in 250+ real sites: Learnings and Challenges

A. Montornès¹ P. Casso¹ G. Lizcano¹ B. Kosovic²

¹Vortex, ²NCAR-RAL

