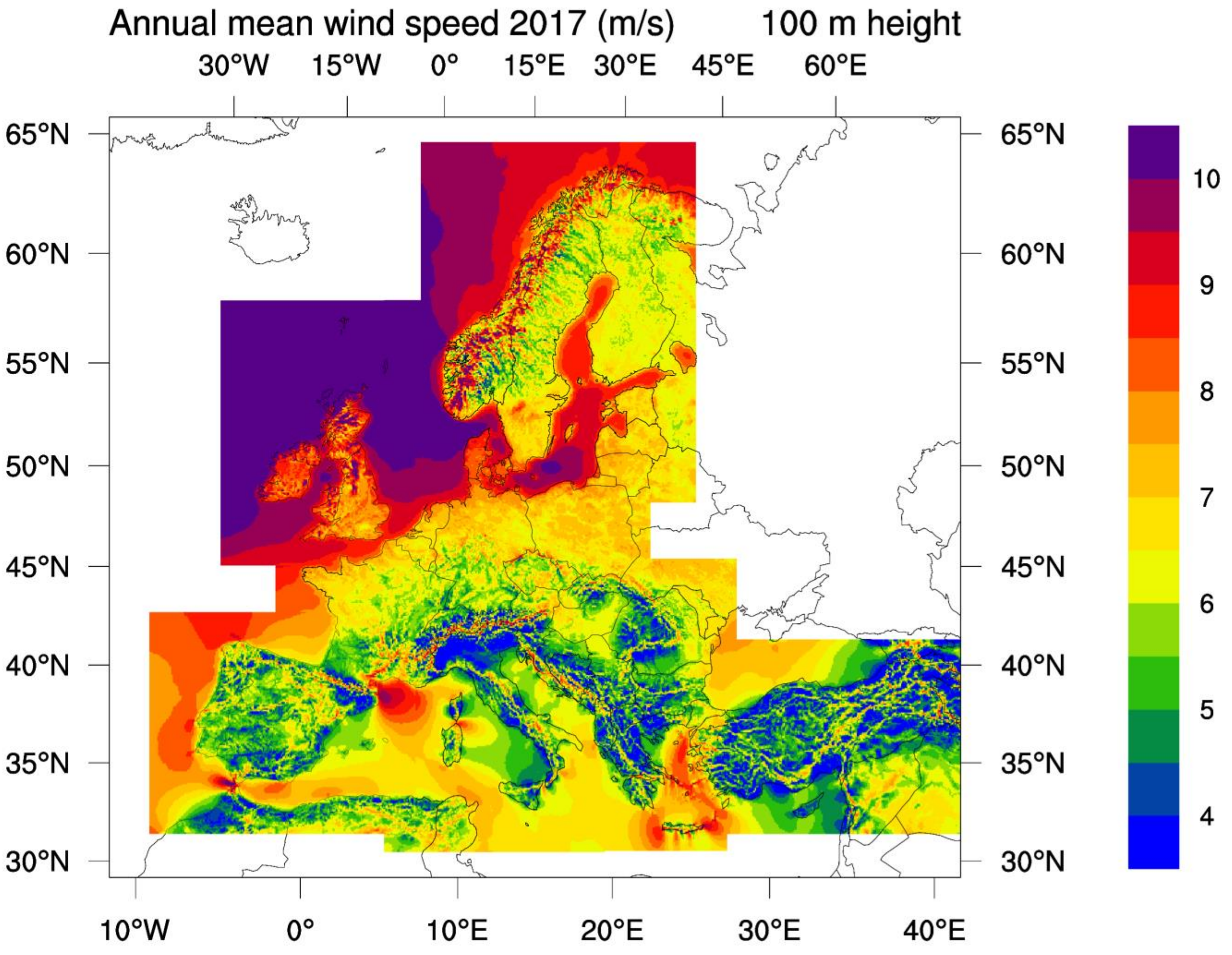
Some of the things we learned from Perdigao Winds in complex terrain

Jakob Mann, Robert Menke, and many others

October 30, 2018

DTU Wind Energy
Department of Wind Energy

The New European Wind Atlas



NEW EUROPEAN WIND ATLAS
newa

Meso-scale simulations by B. Witha (ForWind), A. Hahmann (DTU) and co-workers.

Largest experiment: Perdigao, Portugal

- 186 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*

Complex flow measurements in Perdigão

Objective

- improve understanding of flow over complex
- generation of extensive dataset for flow model validation

Instrumentation

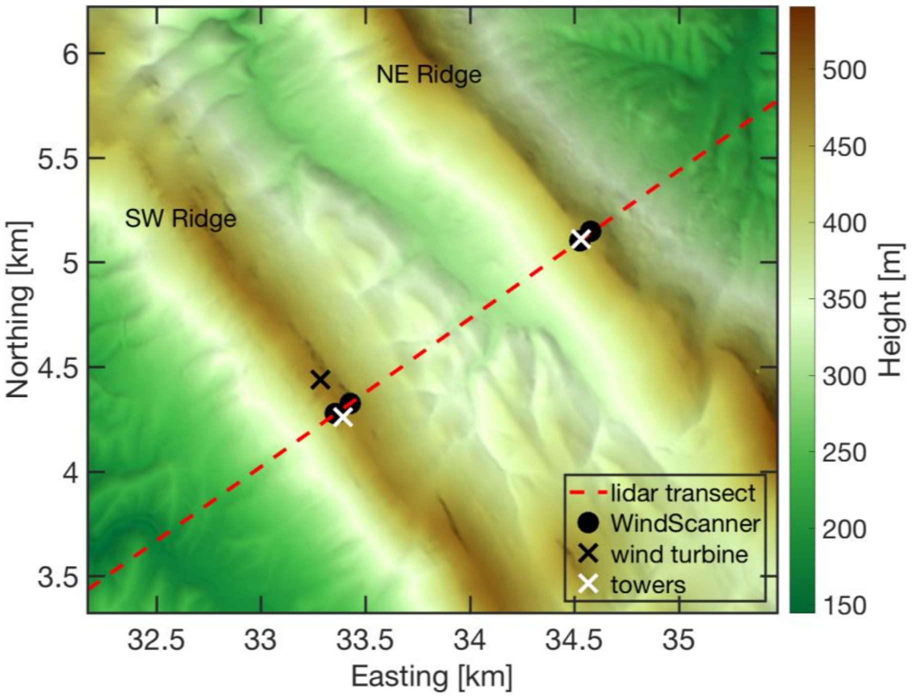
- 50 meteorological mast with 186 sonics
- 19 scanning lidars + 7 profiling lidars
- various temperature profilers, balloon launches, radars, etc

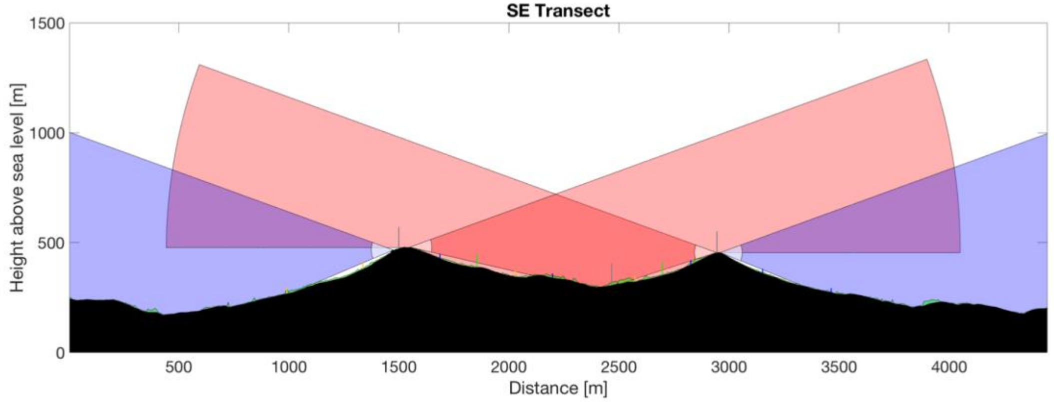
Measurement site in Portugal

Measurement setup

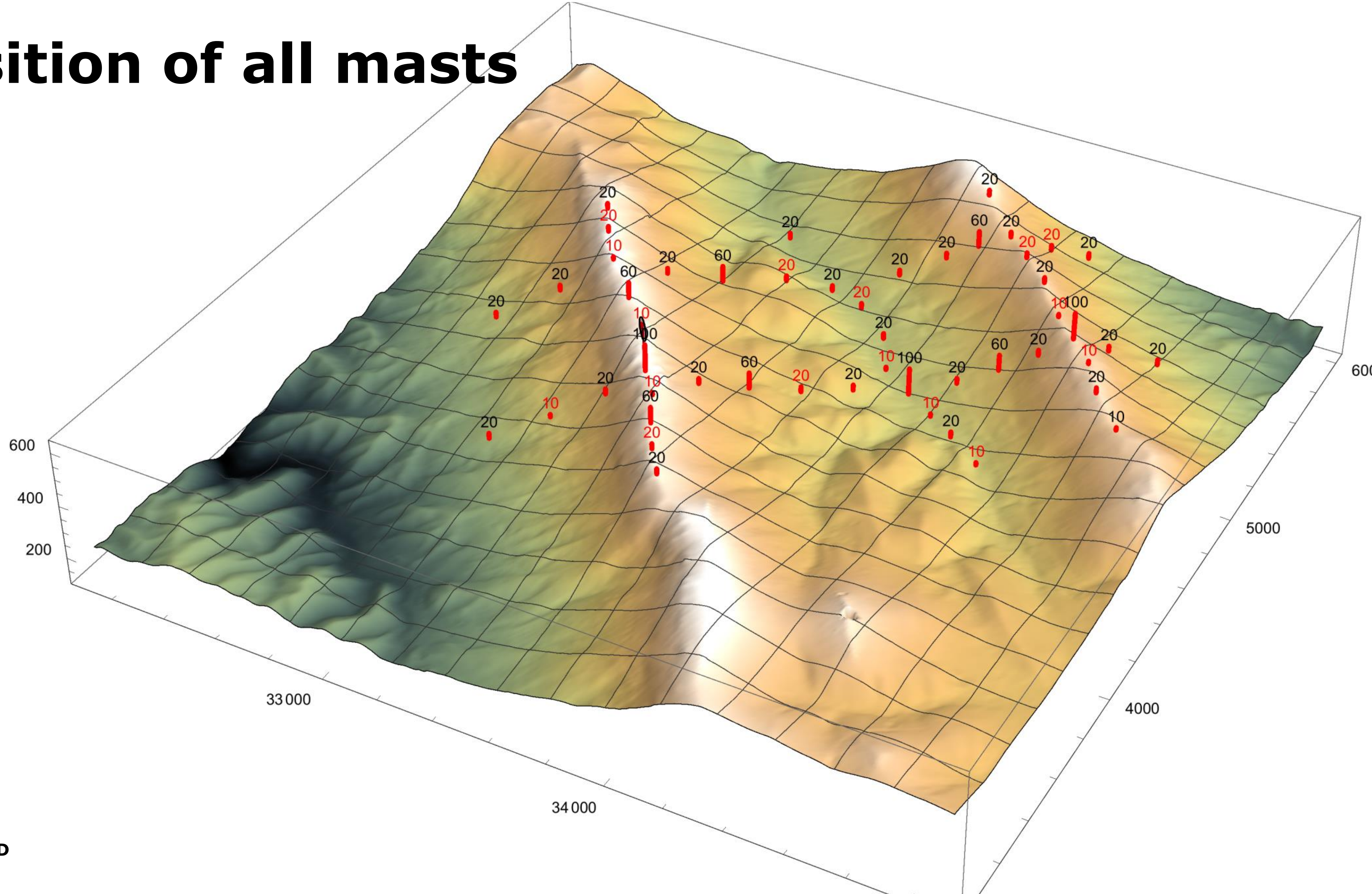
- 4 long-range WindScanners
  - modified Leosphere 200s pulsed Doppler lidars
- RHI measurement configuration
  - 3 km range
  - 194 range gates (every 15m)
  - 30 sec scan duration

- 2 meteorological towers (100m)
  - 7 x sonic anemometers
  - 7 x NCAR temperature sensors

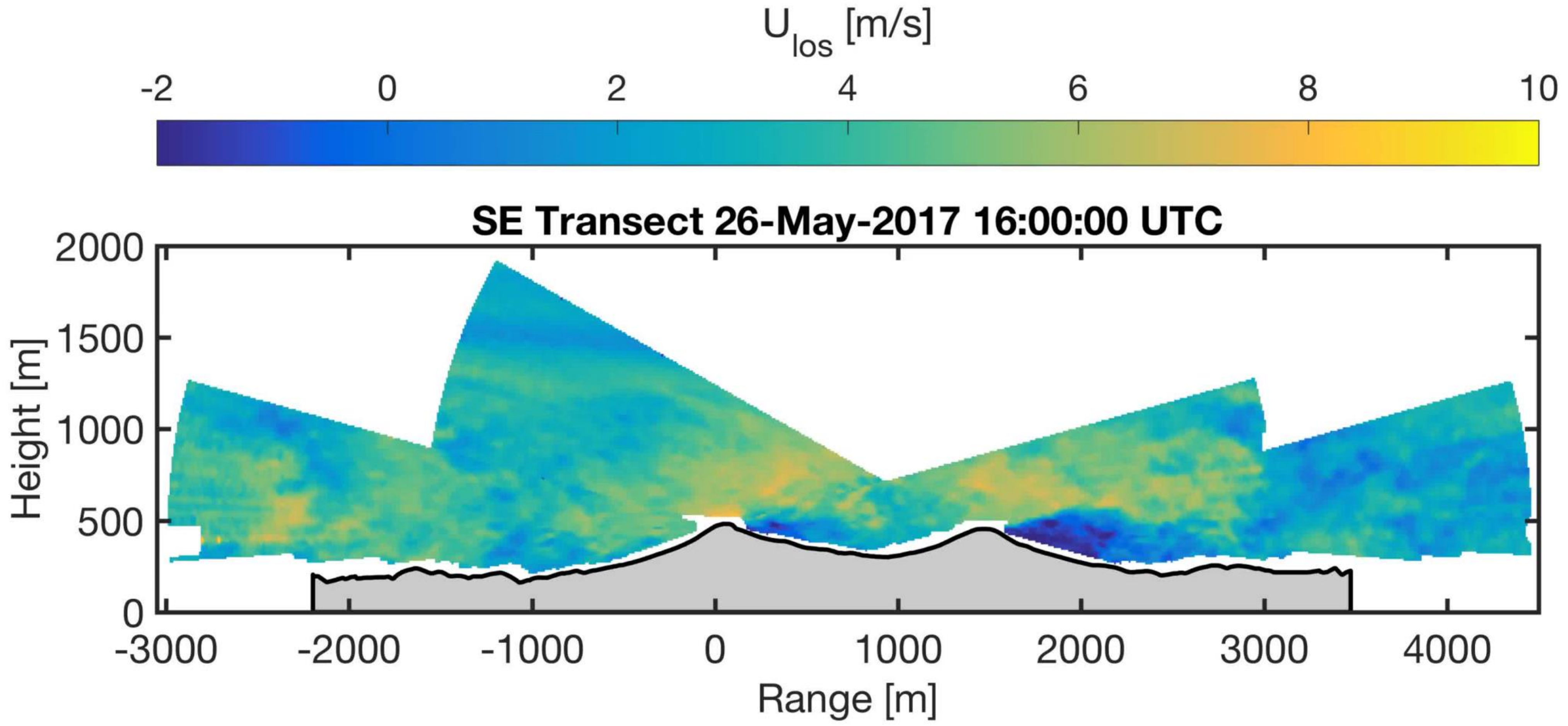




Position of all masts

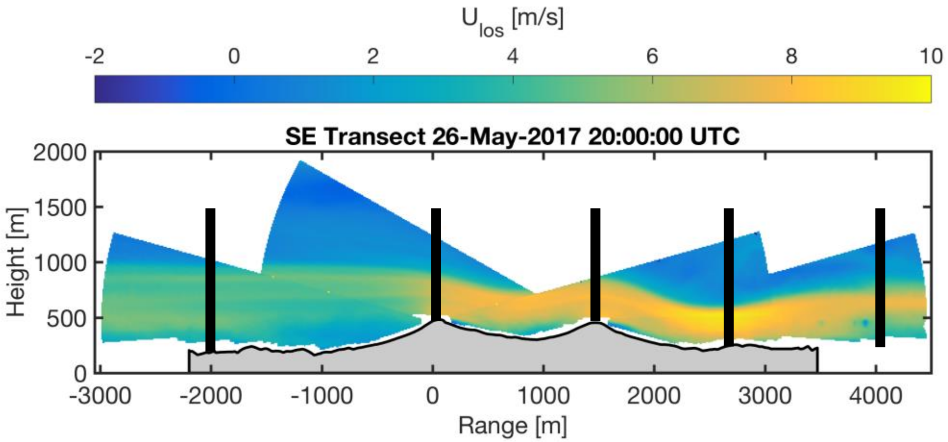


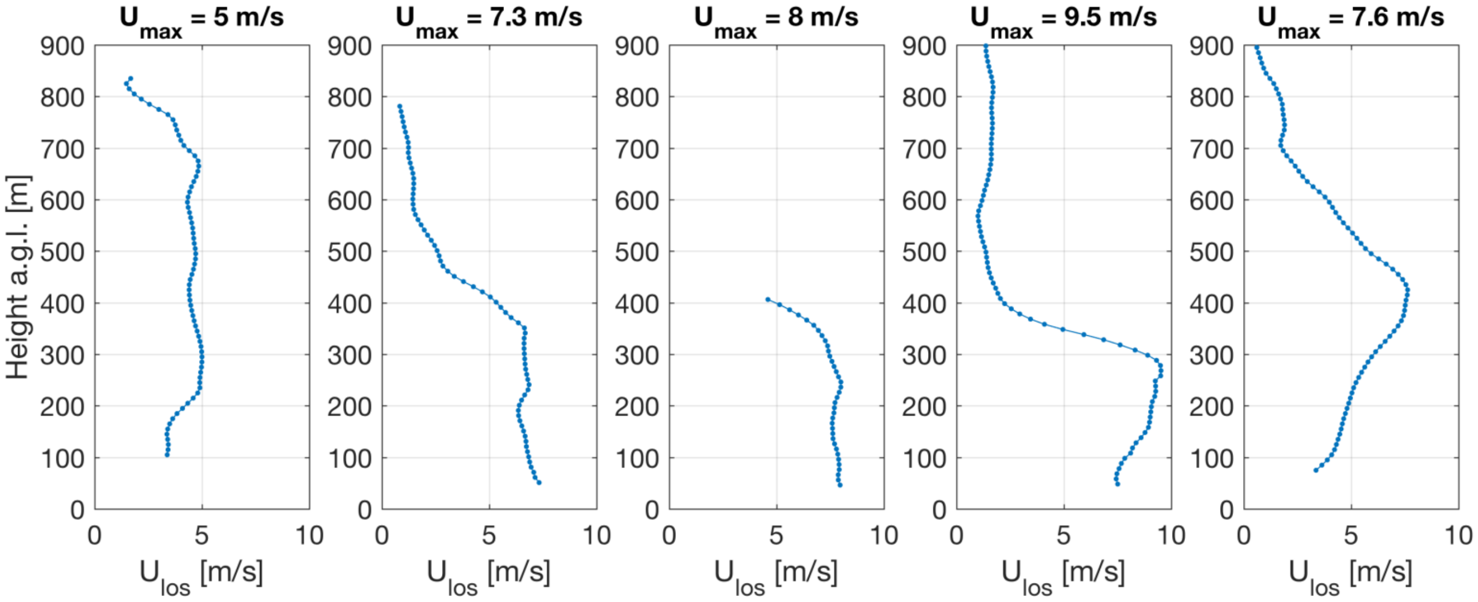
Gravity wave event on May 26, 2017



Influence on wind profile

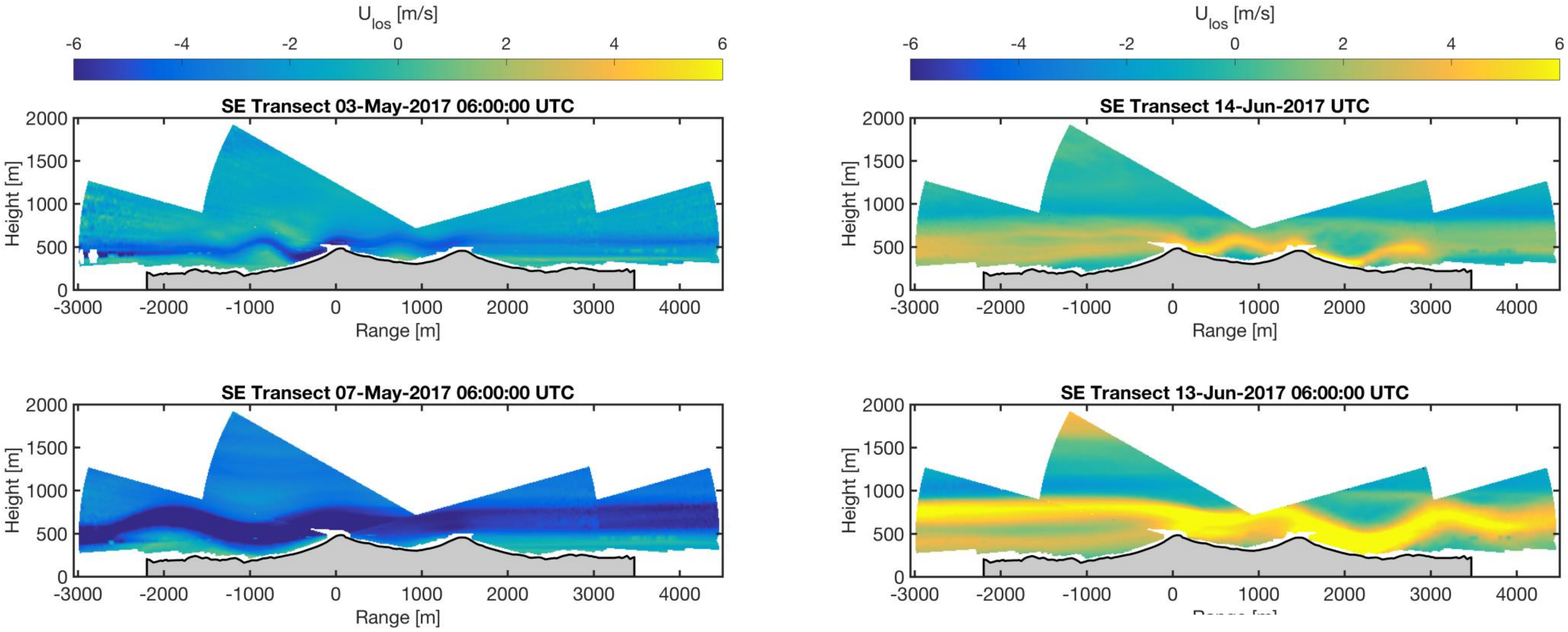
- up to 90% flow acceleration along the transect
  - 57% (3.2 m/s) increase at NE ridge





Probability of gravity wave occurrence

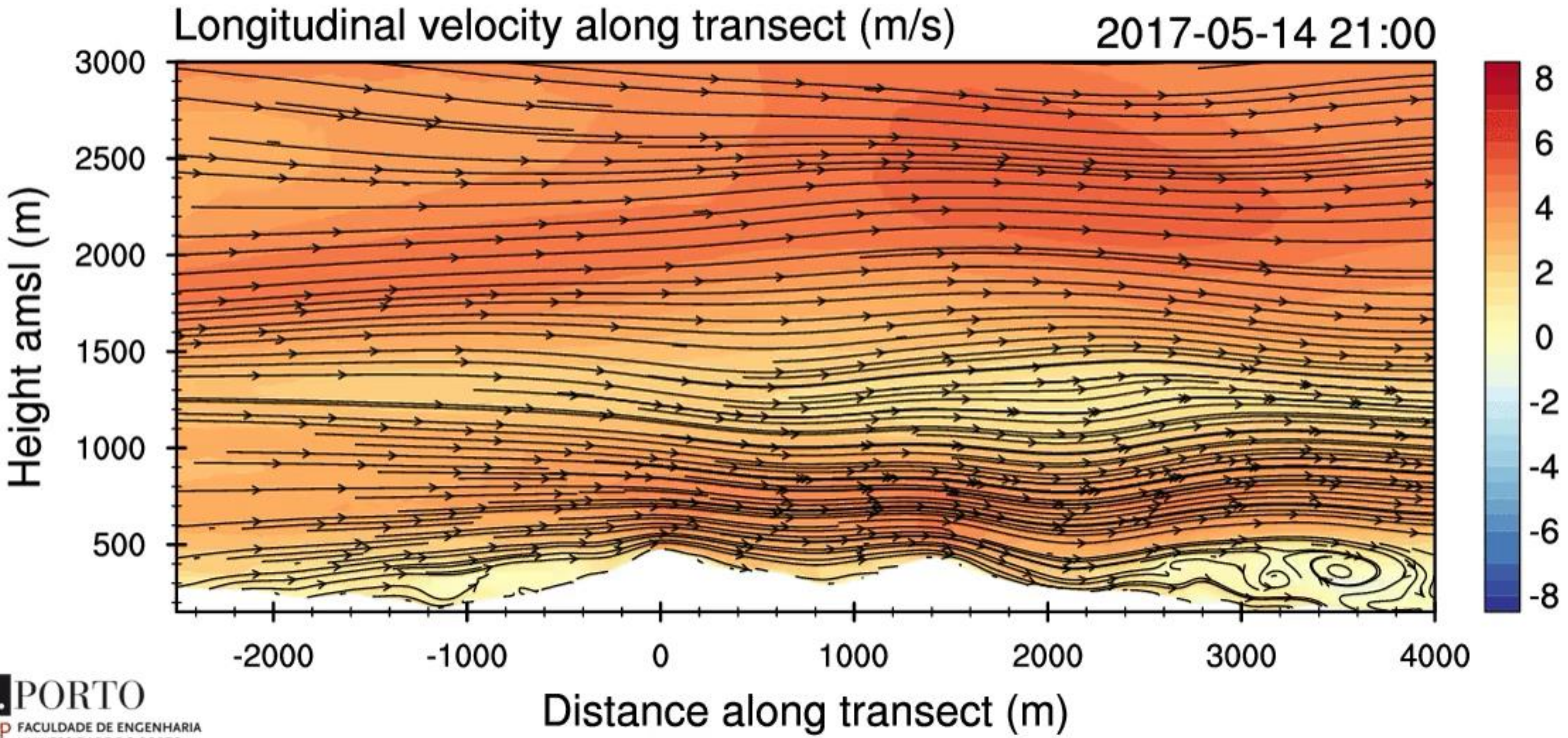
- gravity waves are observed during 50% of the 45 observation days
- presence for both north-easterly and south-westerly flow

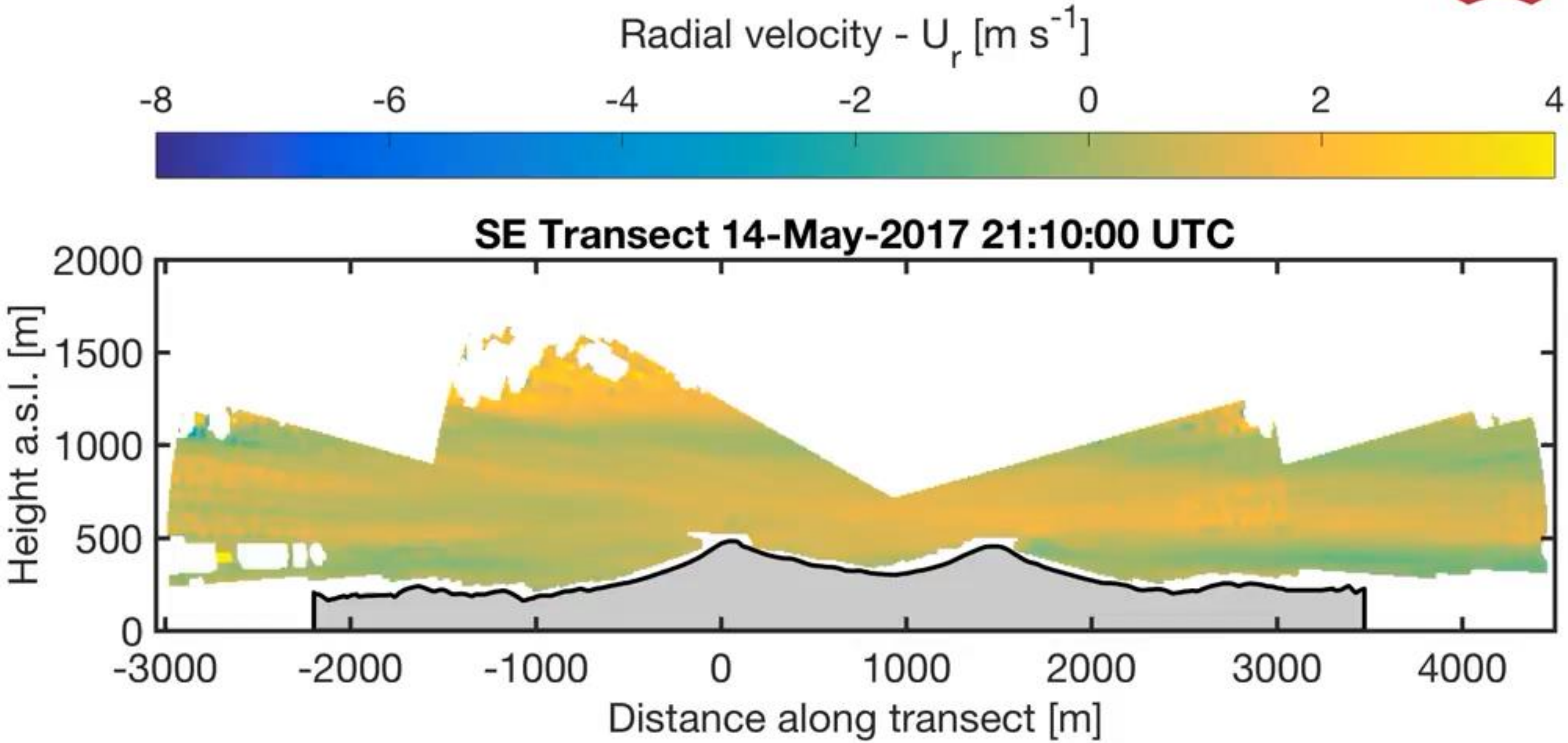


Concurrent simulation and observation

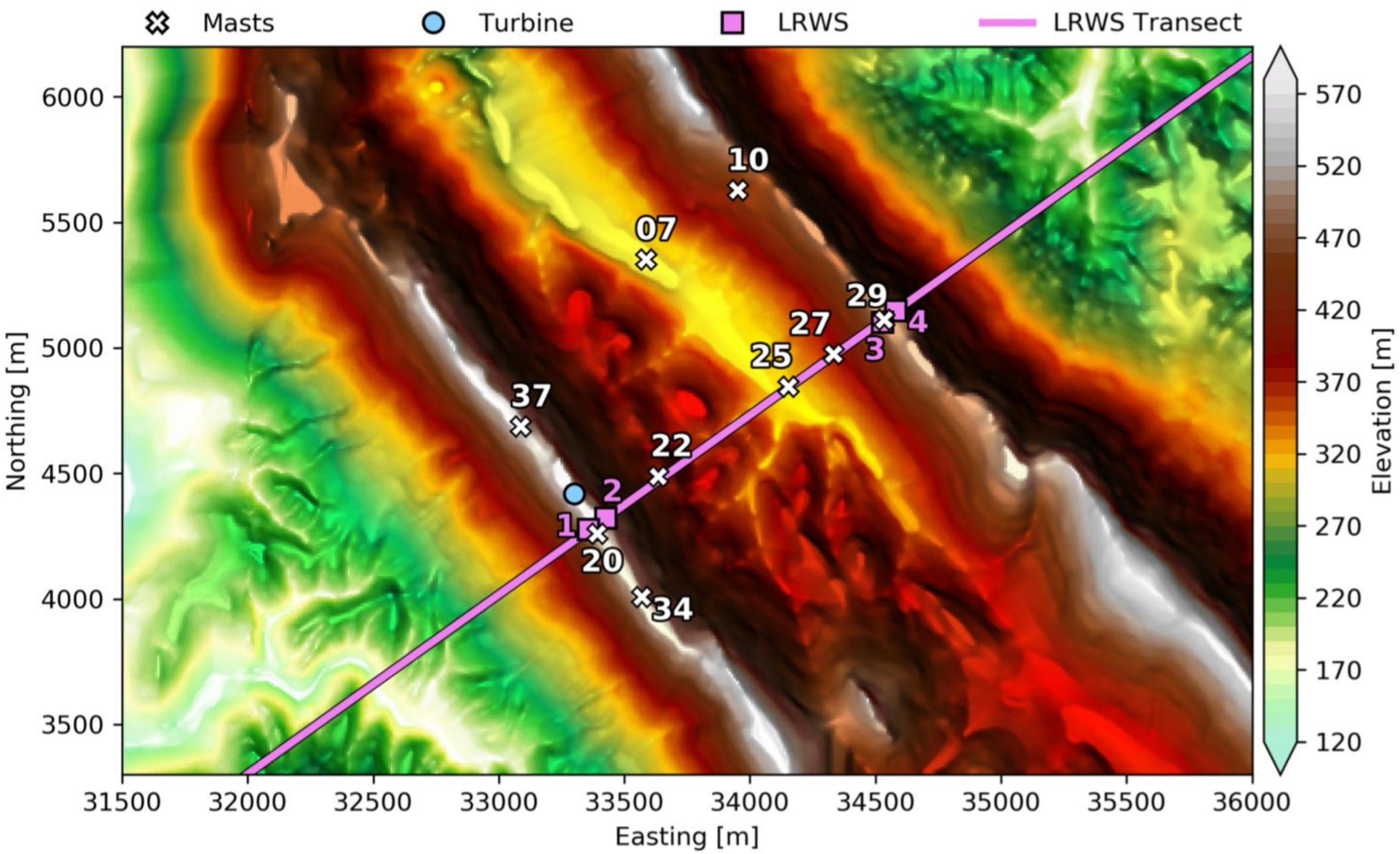
- University of Porto, J. Palma and co-workers
  - Global Forecast System (GFS) drives Weather Research and Forecasting (WRF) model
  - WRF drives VENTOS, a Reynolds Averages Navier Stokes solver that includes atmospheric stability and the Coriolis force, through lateral boundary condition
- Deutsches Zentrum für Luft- und Raumfahrt (DLR), J. Wagner and co-workers
  - 49 days of large-eddy simulation (LES) driven by WRF in two outer domains.
  - Horizontal resolution in smallest domain: 200 m
  - Low-level jet generated by sloping terrain into Spain
  - Wind statistics on ridges well represented, along valley flow underestimated
  - Nature of internal gravity waves sensitive to roughness/forest
- DTU, J. Berg et al.
  - Very high resolution LES under steady forcing conditions. Neutral and constant roughness
  - Flow depends on resolution
- UC Berkeley (T. Chow et al) DTU (B. T. Olsen et al)

GFS + WRF + VENTOS/M simulation results

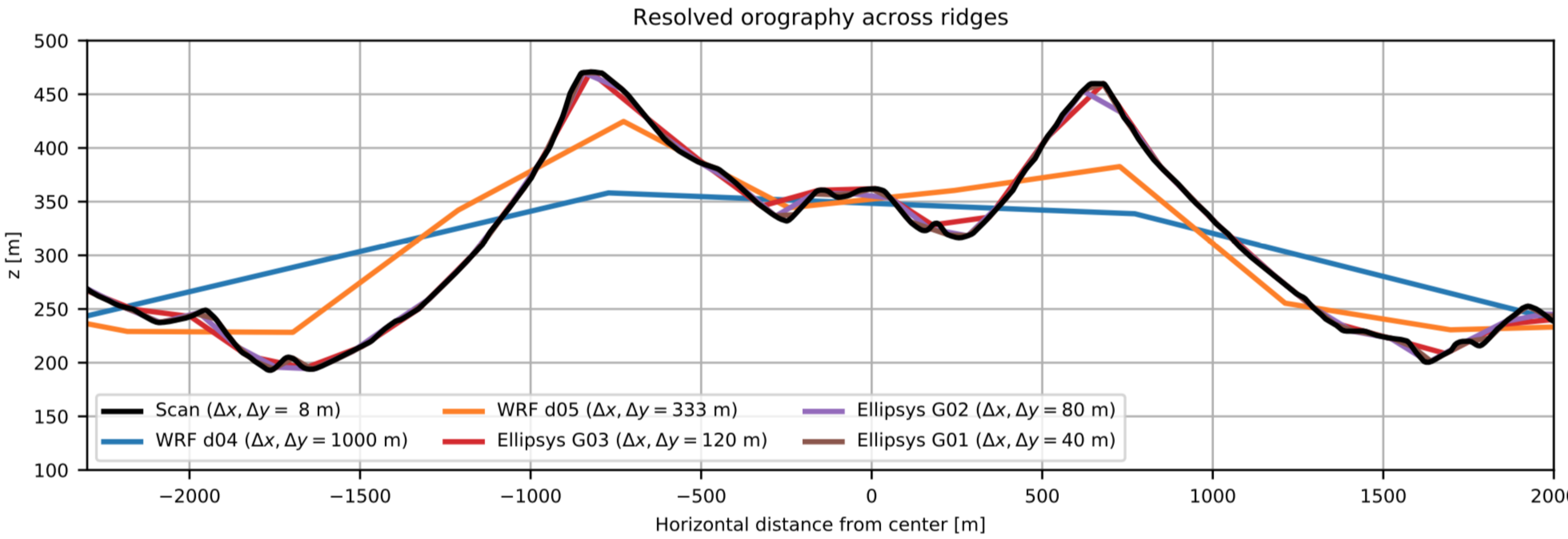



Radial velocity - U_r [m s^{-1}]
-8
-6
-4
-2
0
2
4
SE Transect 14-May-2017 21:10:00 UTC
Height a.s.l. [m]
2000
1500
1000
500
0
-3000
-2000
-1000
0
1000
2000
3000
4000
Distance along transect [m]

Comparison of statistics
Thesis by Bjarke T. Olsen, DTU

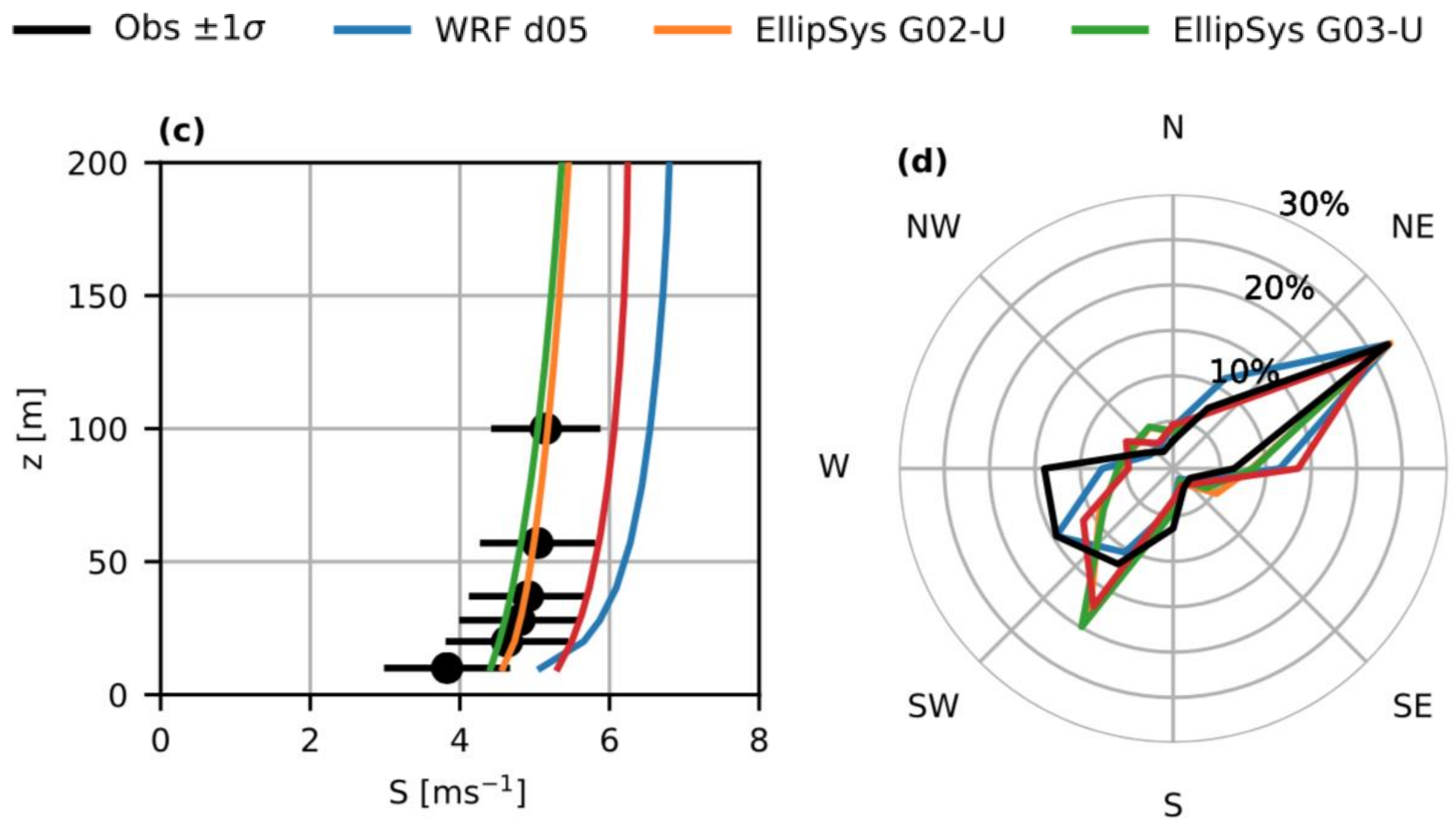


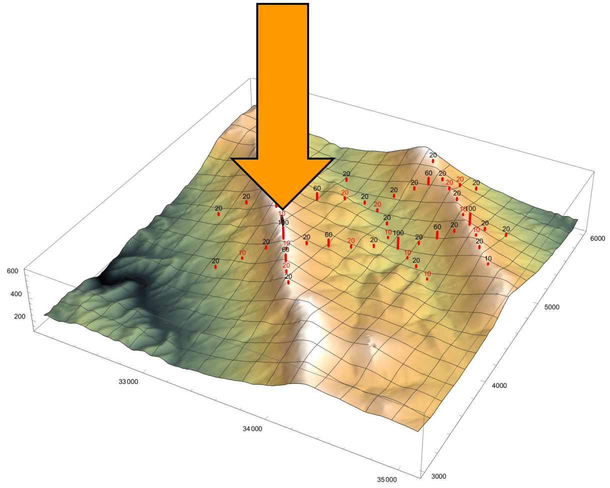
EllipSys3D URANS with stability and Coriolis nested into WRF domains forced by tendencies



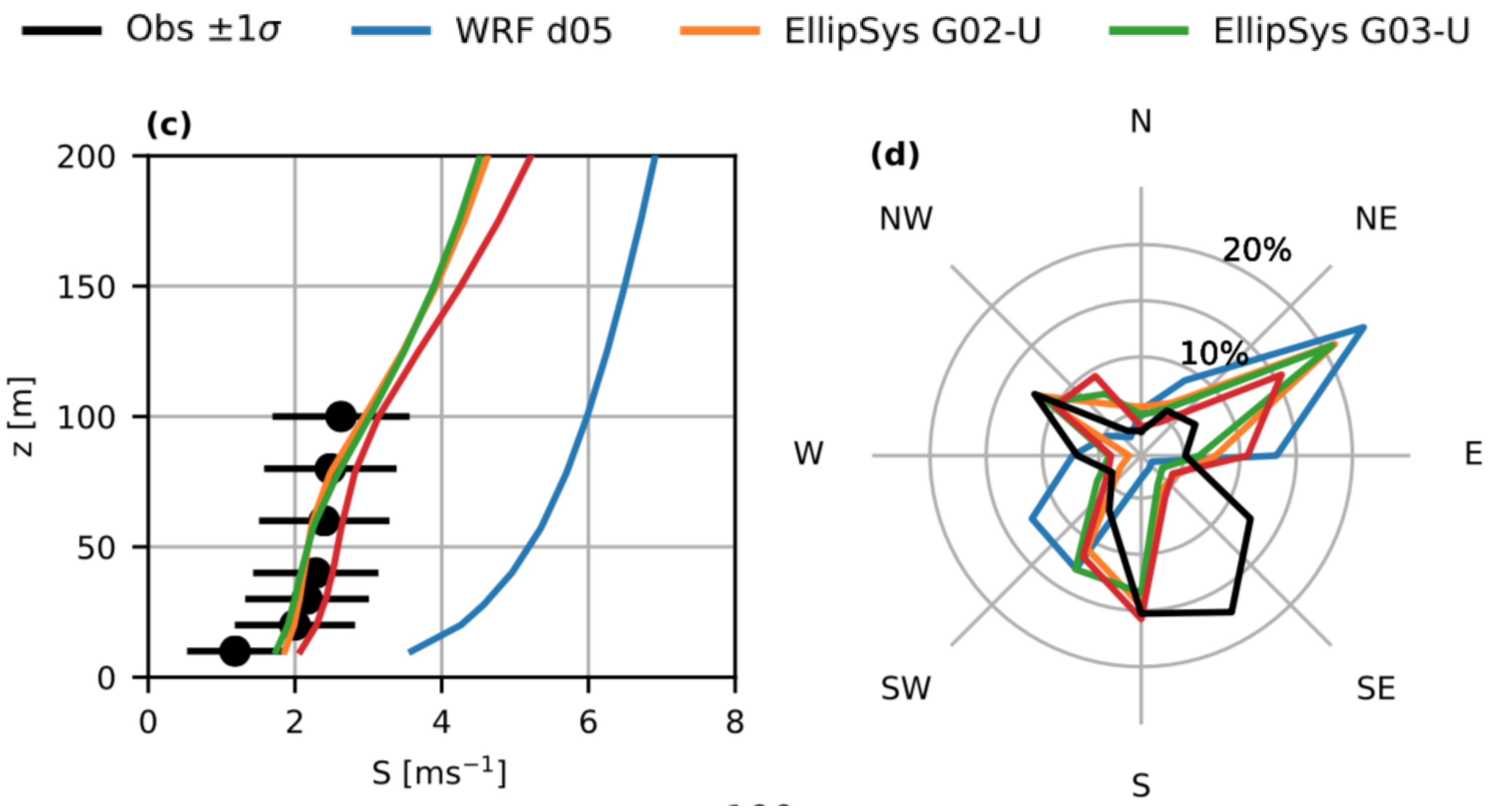
Simple roughness description

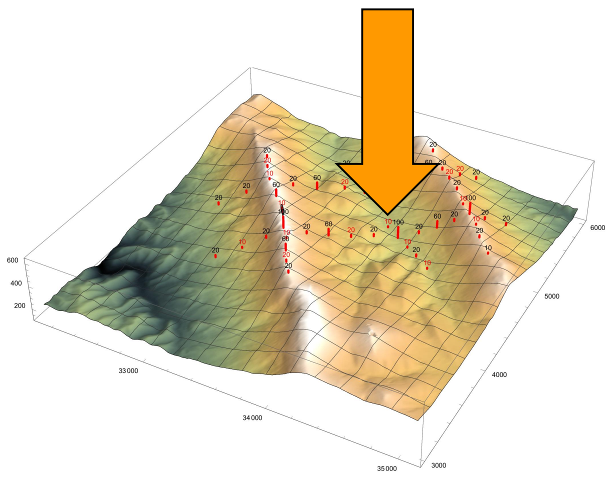
Mast on SW ridge



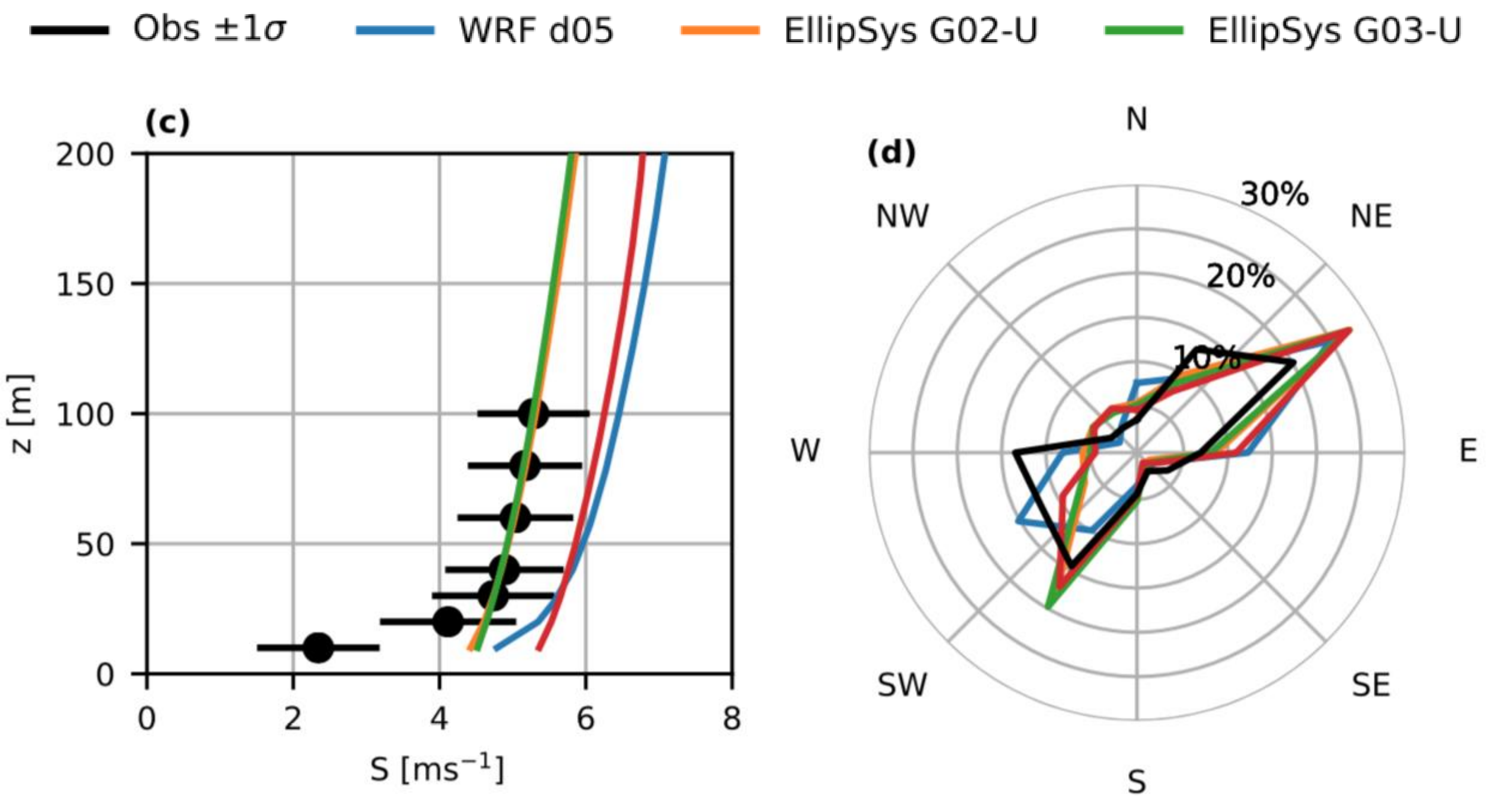


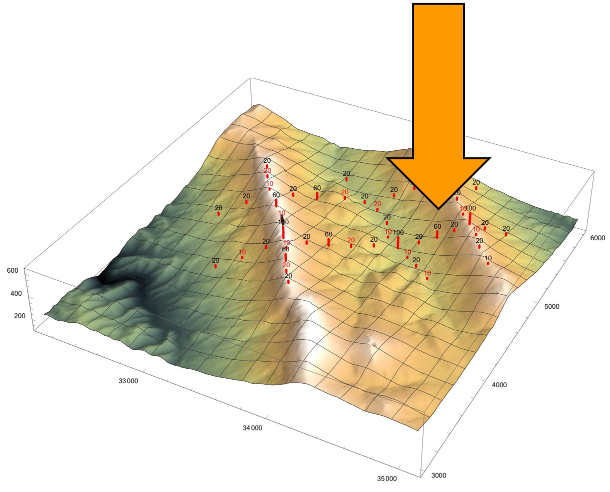
Mast in the center of the valley





Mast on NE ridge





Conclusions

- The Perdigao Experiment builds on trans-Atlantic collaboration and provides the a huge dataset for validation of wind energy flow calculations
- Lidar measurements are complementing traditional mast measurements to understand complex flow
- Gravity waves are observed frequently at the Perdigão site
- Resolution of terrain and simulation grid, convergence of solutions, procedure of nesting, description of vegetation, and other things impact the final results.

Thank you for your attention!