USER MEETING 2011

NON-NEUTRAL WIND CONDITIONS IN COMPLEX TERRAIN

PRESENTED BY: CATHRINE MEISSNER

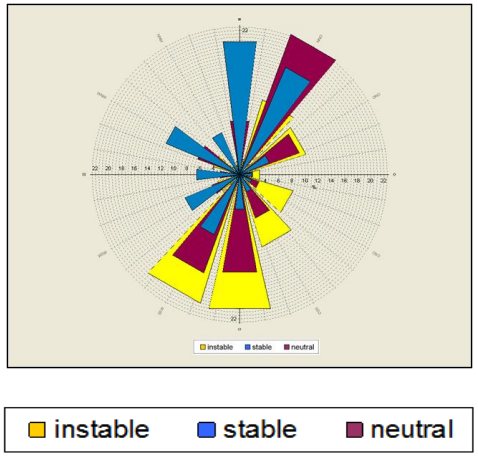
windsim

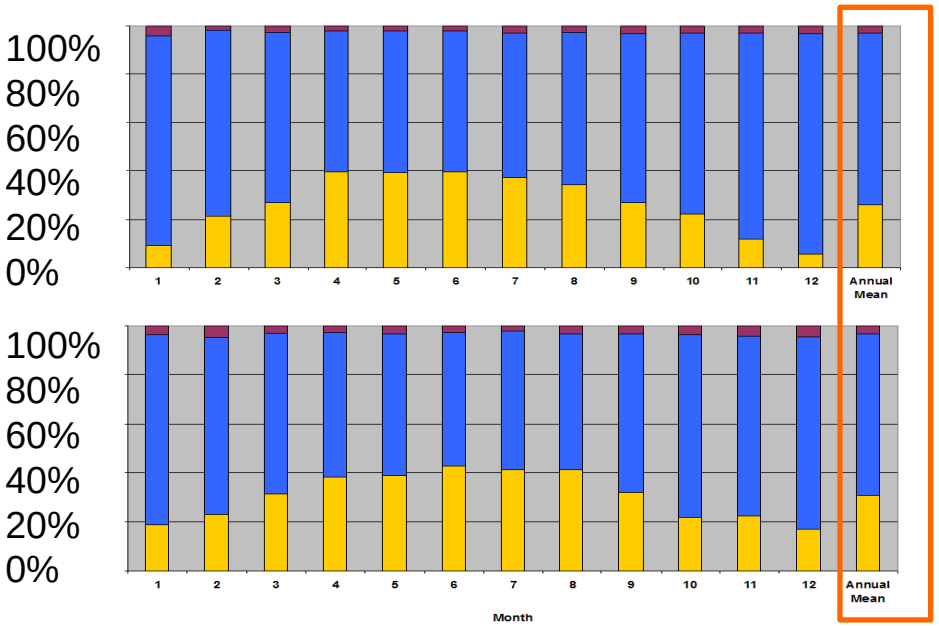
CONTENT

- **Do we need to consider non-neutral wind conditions in CFD simulations?**
- **Implementation of thermal stratification in the WindSim CFD code**
- **Validation on different sites**
  - Hundhammerfjellet: semi-complex island
  - Site 1: semi-complex forested area
  - Site 2: complex terrain
- **Conclusions**

NON-NEUTRAL WIND CONDITIONS

Do we need to consider non-neutral wind conditions in CFD simulations?





Months Annual Mean

- At many sites more stable thermal conditions prevail
- There are complex sites where the simulated neutral profiles do not fit
- CFD simulations might improve when considering non-neutral wind conditions

windsim

THERMAL STRATIFICATION

IMPLEMENTATION OF THERMAL STRATIFICATION IN THE WINDSIM CFD CODE

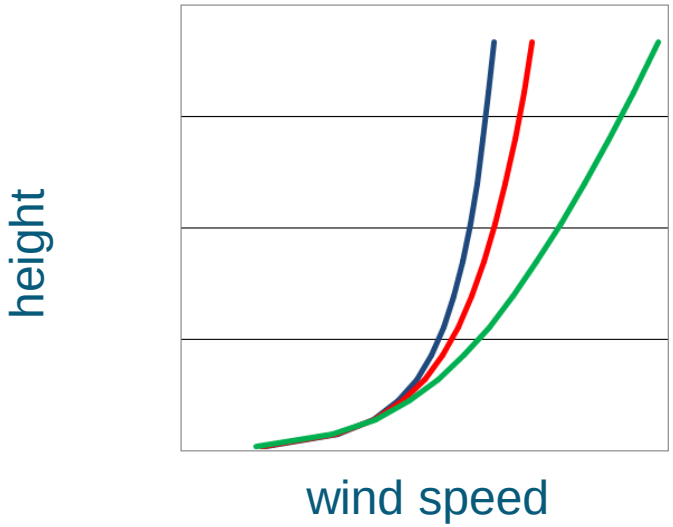
First influence of temperature on the wind field:
change of the wind speed profile at the inlet of the CFD domain

Neutral case

$$\bar{u}(z) = \frac{u_*}{\kappa} ln\left(\frac{z}{z_0}\right)$$

Non-neutral case

$$\bar{u}(z) = \frac{u_*}{\kappa}\left[ln\left(\frac{z}{z_0}\right) - \Psi_m\left(\frac{z}{L}\right)\right]$$



THERMAL STRATIFICATION

IMPLEMENTATION OF THERMAL STRATIFICATION IN THE WINDSIM CFD CODE

Second influence of temperature on the wind field: Buoyancy force

$$\overline{u}_j \frac{\partial \overline{\Theta}}{\partial x_j} = \frac{\partial}{\partial x_j}\left(\alpha \left(\frac{\partial \overline{\Theta}}{\partial x_j} \right) - \left(\overline{u_j' \Theta'} \right) \right)$$

$$\overline{u}_j \frac{\partial \overline{u_3}}{\partial x_j} = \frac{\Theta^*}{\Theta_0} g - \frac{1}{\rho} \frac{\partial \overline{p}}{\partial x_3} + \frac{\partial}{\partial x_j}\left(\upsilon \left(\frac{\partial \overline{u}_3}{\partial x_j} + \frac{\partial \overline{u}_j}{\partial x_3} \right) - \left(\overline{u_3' u_j'} \right) \right)$$

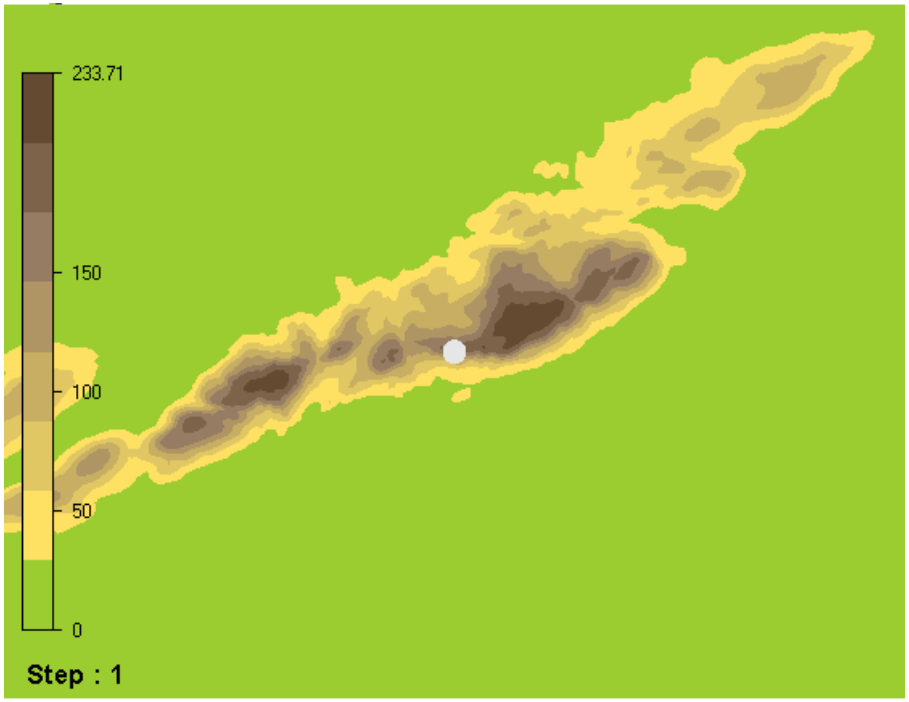
$$\Theta^* = \overline{\Theta} - \Theta_0$$

deviation from the reference temperature

VALIDATIONS – SITE: HUNDHAMMERFJELLET

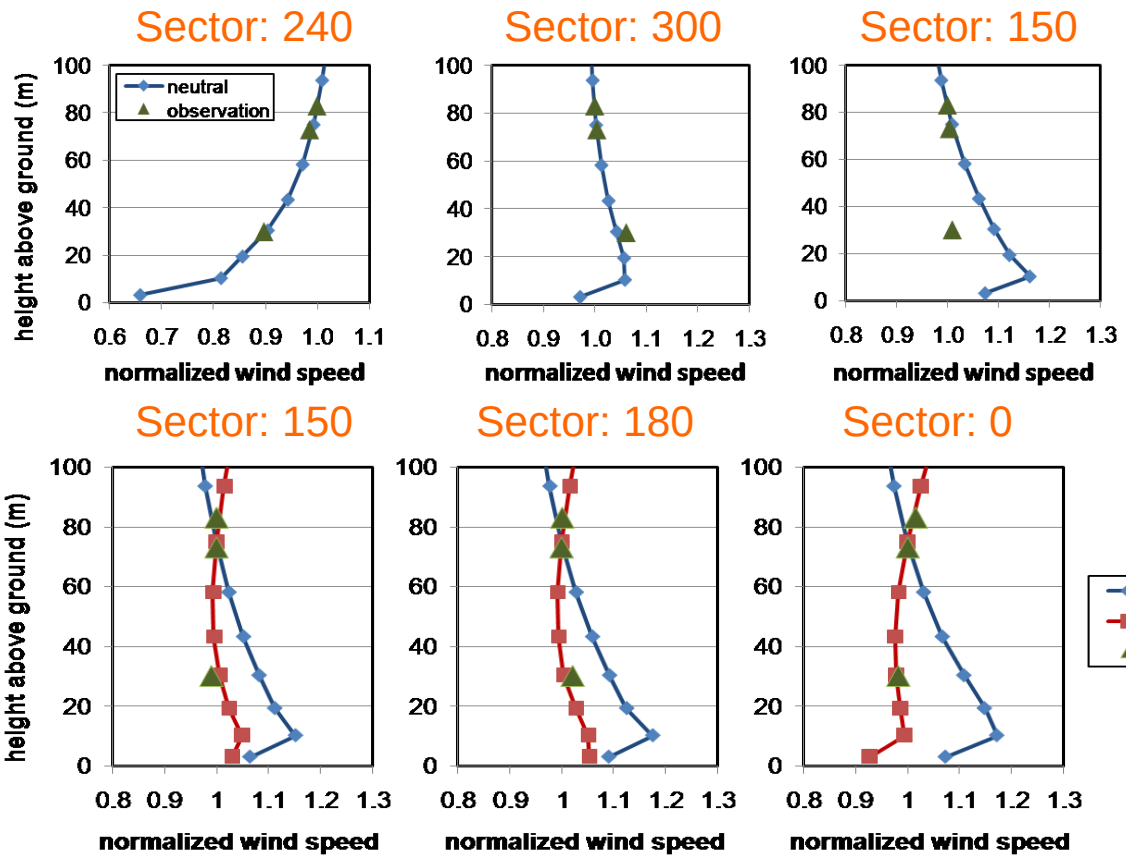
TIME PERIOD - APRIL 2006 TO JANUARY 2007:

Wind speed measurements for 30, 73 and 83m height, and temperature measurements for 50 and 83m.



Sector (°)	Stability
0	s
30	s
60	s
90	s
120	s
150	s
180	s
210	n
240	n
270	n
300	n
330	s

VALIDATIONS – SITE: HUNDHAMMERFJELLET

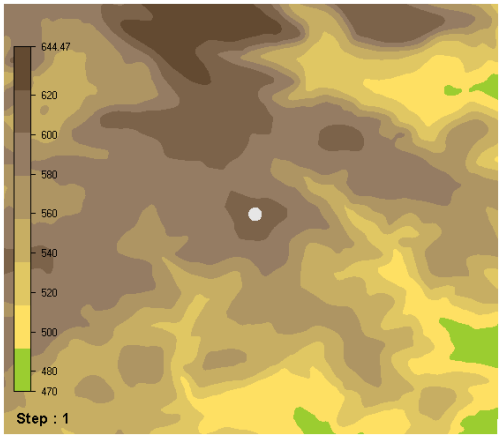


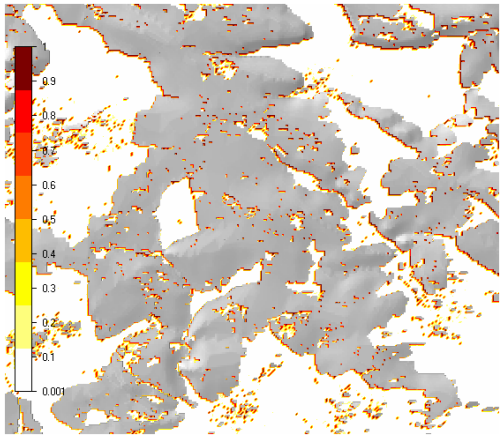
Better fit of simulated & measured profiles using stable stratification in CFD simulations

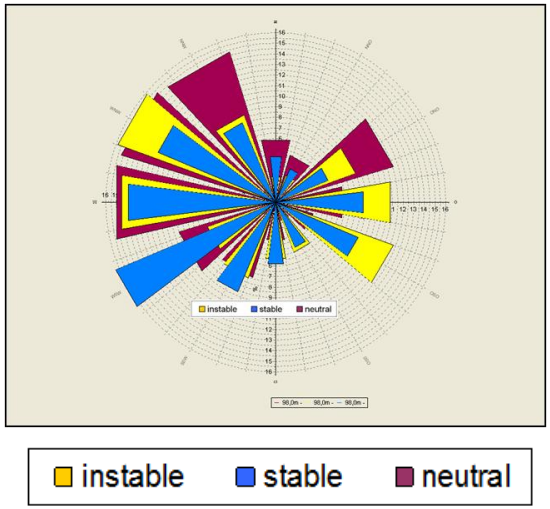
windsim

VALIDATIONS – SITE: FORESTED SITE

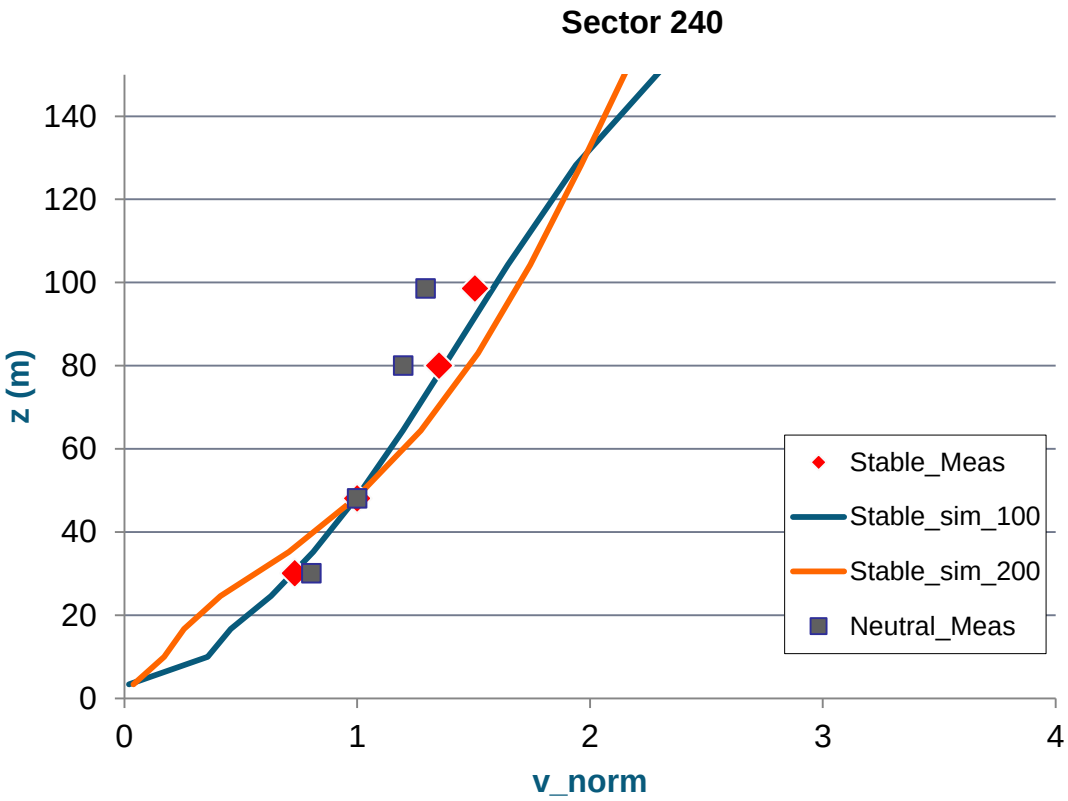
- Moderately complex, but densely forested area in southern Germany
- Wind speed measurements for 30, 48, 80 and 100m height
- Temperature measurements for 5 and 97m







VALIDATIONS – SITE: FORESTED SITE

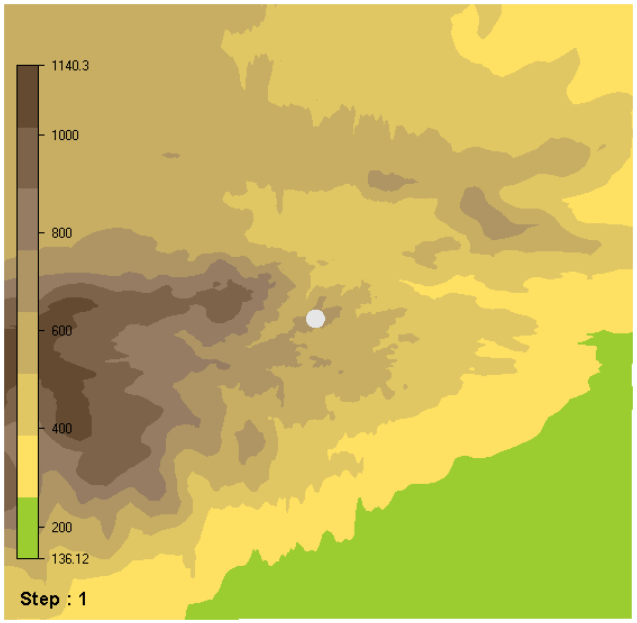


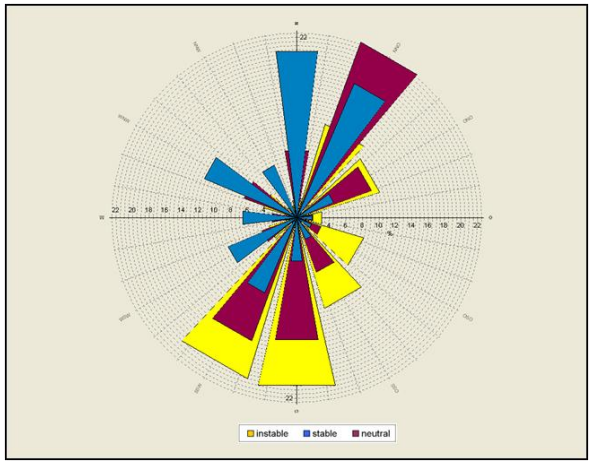
- Using the right thermal stratification is important
- Good shear prediction when using stable stratification in the simulations

windsim

VALIDATIONS – SITE: COMPLEX SITE

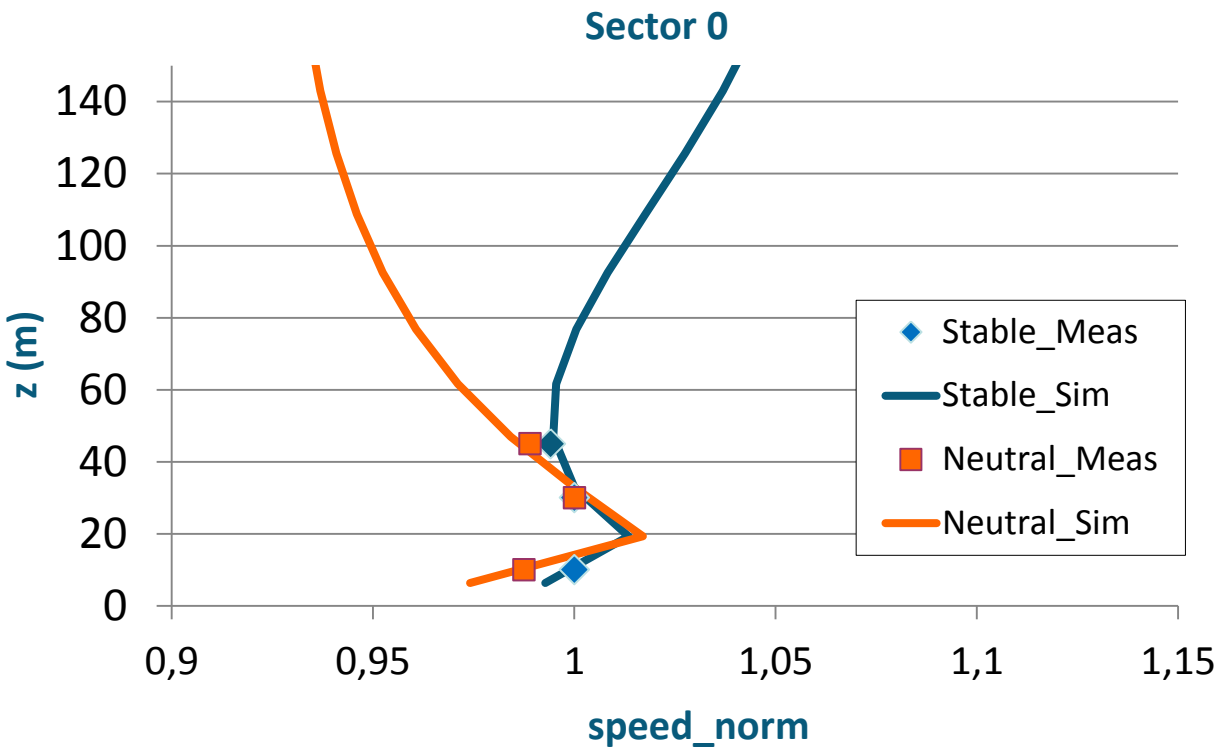
- Very complex terrain in southern Spain with land-sea breeze.
- Wind speed measurements for 10, 30 and 35m height.
- Temperature measurements for 6.5 and 45m.





instable stable neutral

VALIDATIONS – SITE: COMPLEX SITE



- Simulations are able to capture the negative shear
- Using stable conditions in the simulation is improving the results
- Higher measurements necessary for good assessment

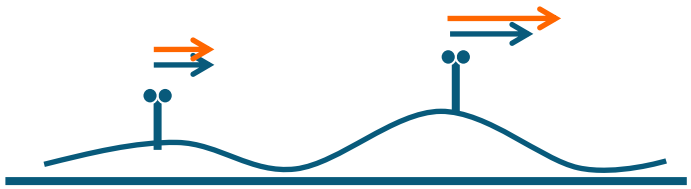
CONCLUSIONS

- CFD simulations need to consider non-neutral thermal stratification in complex terrain
- WindSim introduced the thermal effects via changed analytical boundary conditions and the Boussinesq approximation
- Validation shows that simulated wind speeds fit better to measured ones in stable conditions when the simulations consider thermal effects

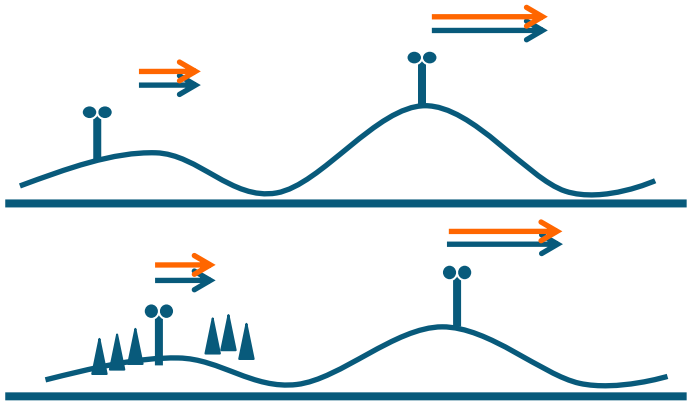
WORD OF WARNING: STRATIFICATION ANOTHER TUNING OPTION

What to do when the simulations → doesn't fit the measurements → ?

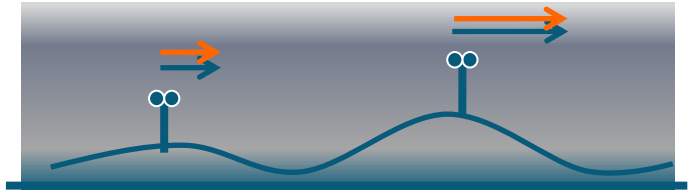
Historically elevation and roughness has been adjusted to compensate for incomplete modelling



Simulations doesn't fit measurements



It is important to establish proper stratification models capable of reproducing reality.
If not, stratification will become another tuning option, not improving our modeling capability and our understanding of the flow behavior



ACKNOWLEDGEMENTS

- WindSim would like to thank Theolia AG and Nord-Trøndelag Elektrisitetsverk for providing the measurement data for this presentation
- This work was done in cooperation with Carolin Schmitt during her time at Theolia AG (now JUWI).