Atmospheric stability

WindSim application in complex and flat terrain

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Sara Koller, Silke Dierer, Katharina Fross

METEOTEST

30 years of experience in the fields of meteorology, environmental studies and informatics

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  - engineers
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- office in Berne, Switzerland

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- Wind energy
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- Web applications

Wind Energy

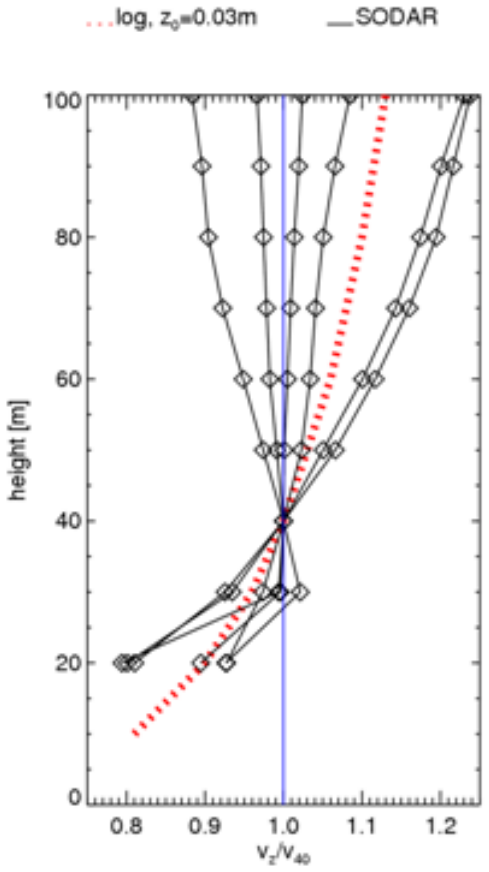
- Wind assessment
- Measurement campaigns
- LIDAR/SODAR
- CFD wind modelling
- Environmental assessments
- Icing

Outlook

- What is atmospheric stability?
- Measurements of stability:
    - Met mast
    - LIDAR
- WindSim simulation with different stabilities
- Questions

What is atmospheric stability?

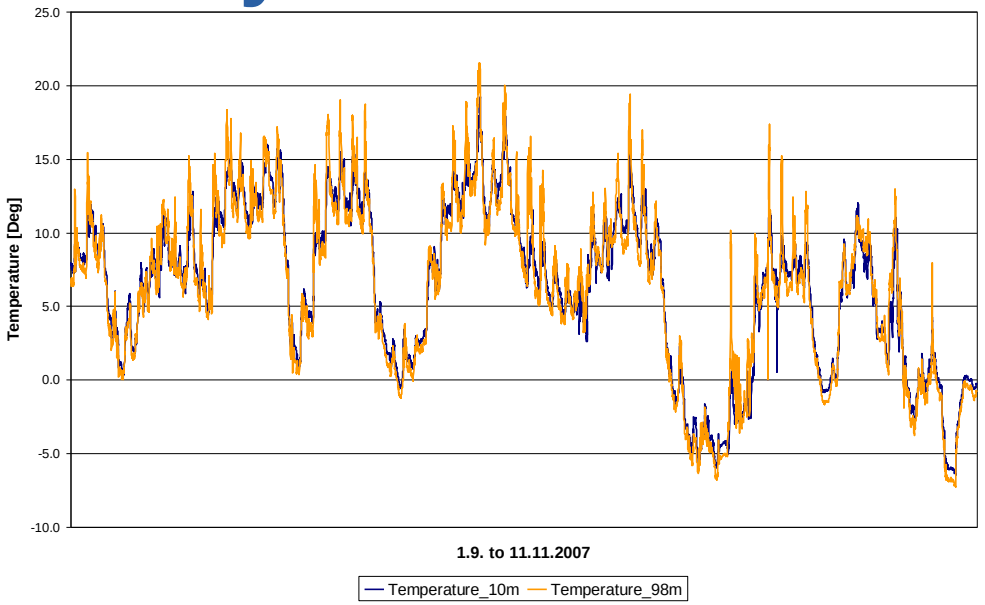
- Resistance of the atmosphere to vertical motion → stable, neutral and unstable conditions
- Atmospheric stability strongly affects the vertical wind profile
- Thus, considering stability might be important for wind assessment studies
- BUT:
  - How important is the stability effect in realilty? In flat terrain? In complex terrain?

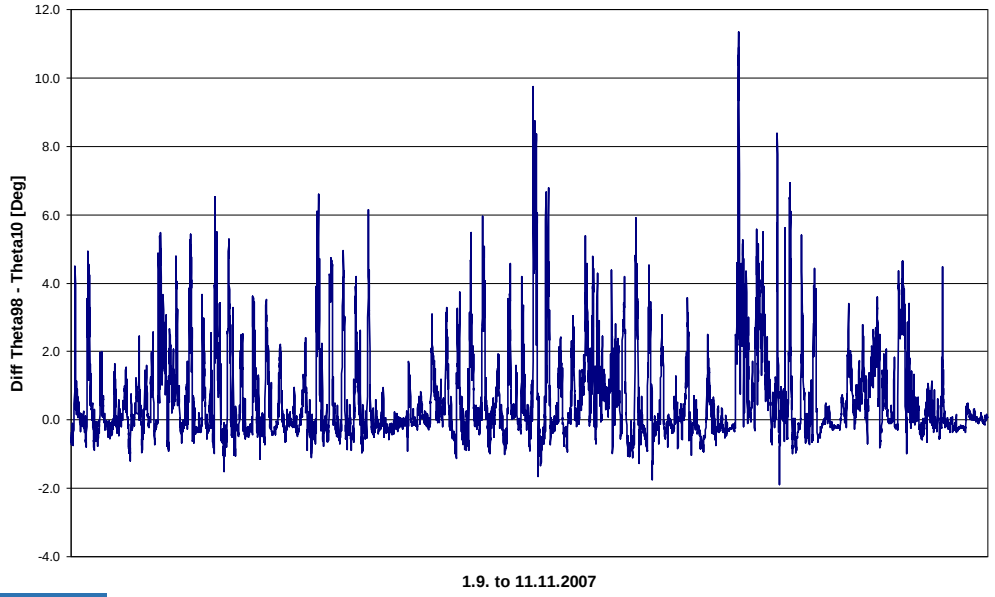


Measurements of stability: met mast

- Temperature measurements at Schwyberg (1576m asl)
- Duration: 1.9.2007 to 11.11.2007
- Heights: 10m and 98m
- 10min mean values
- Resolution: +/- 0.3K

→ a significant number of periods with strong differences of potential temperature occurred



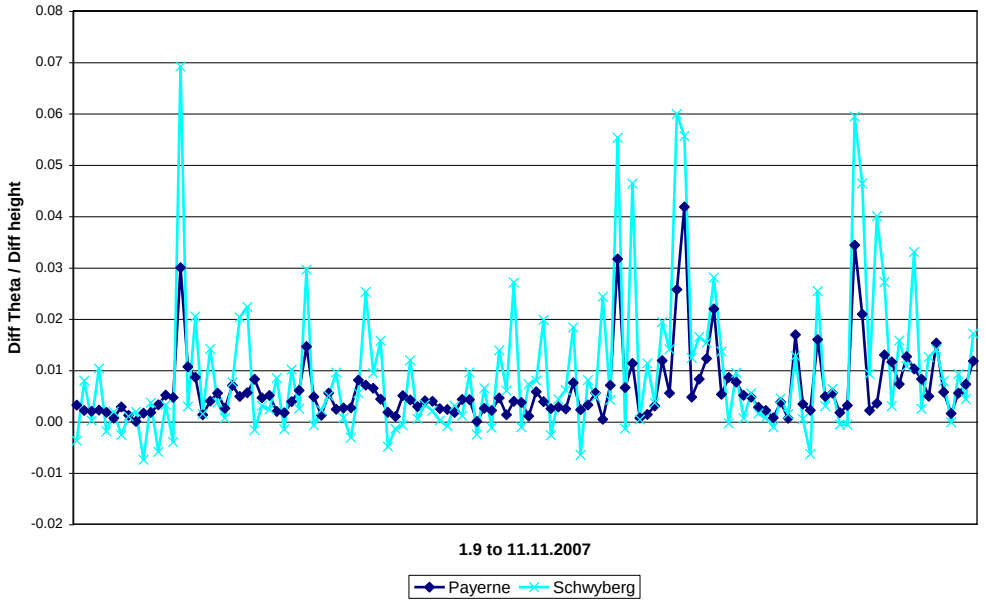


Potential temperature gradients

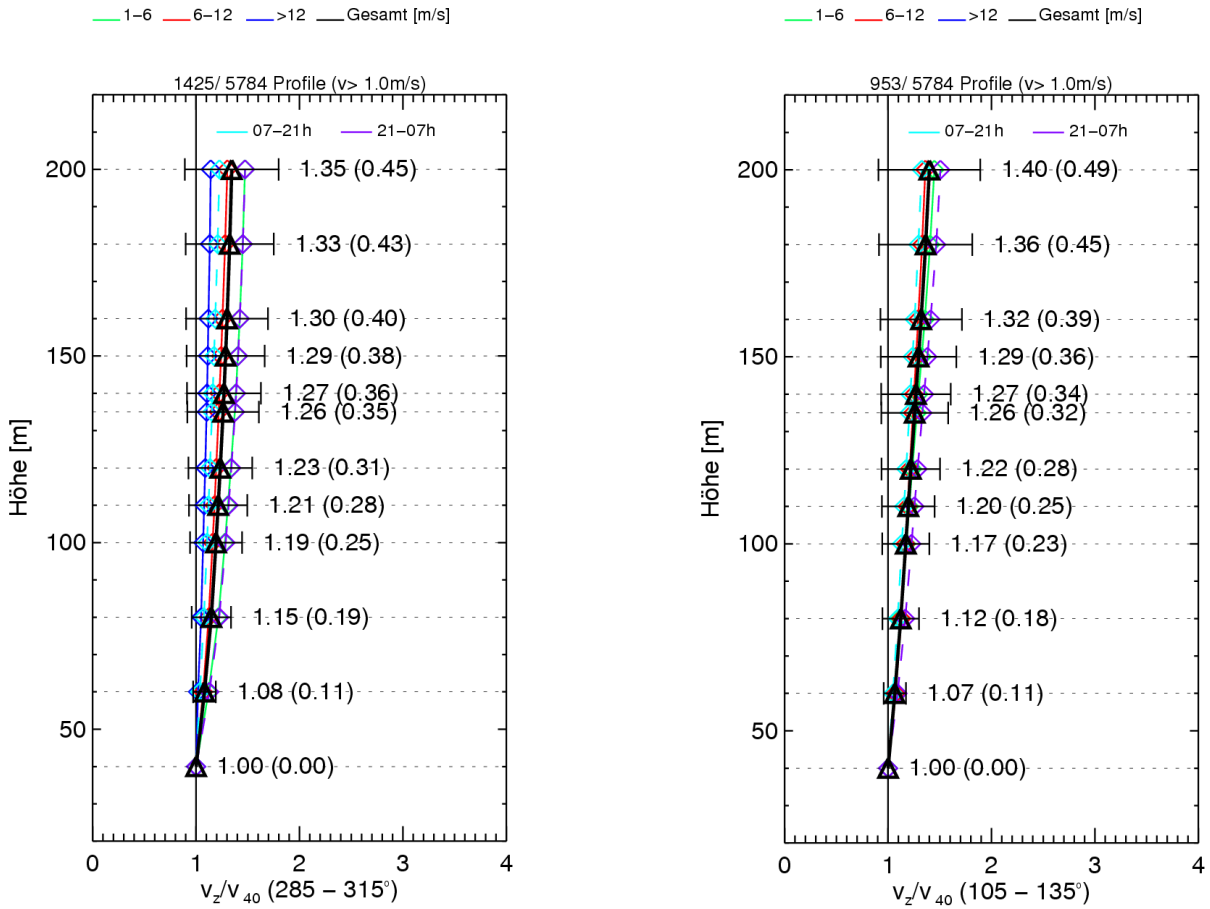
- Radio sounding at Payerne (491m asl)
- Potential temperature gradient between 1500m and 1700m

→ Some periods of similarity, many differences (r=0.48)

→ Payerne not suitable for a long term estimate, more temperature measurements necessary

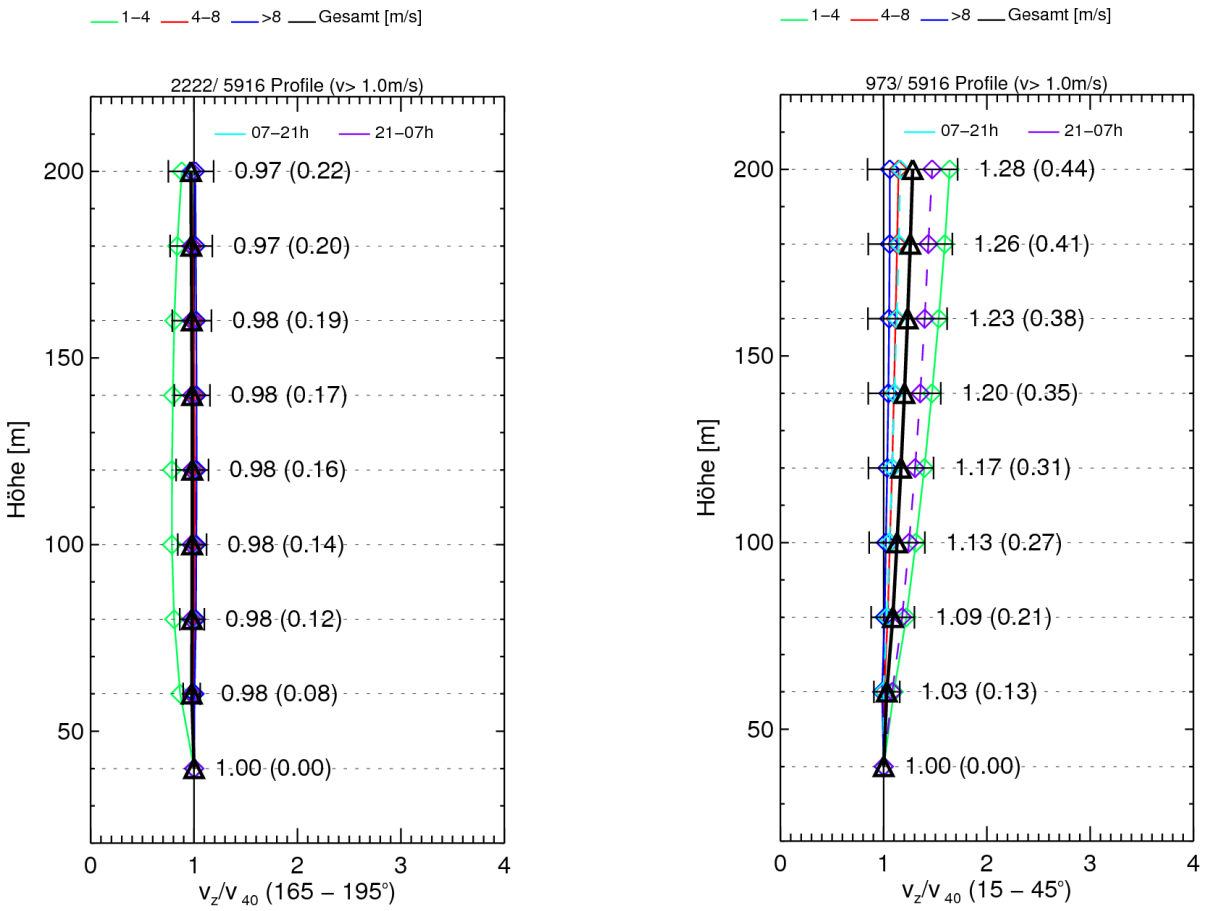


Measurements of stability: LIDAR



- Daytime and nighttime vertical wind profiles – LIDAR Austria, flat terrain
- Pronounced day-night difference for the nnw-sector (stronger increase with height for light winds and at night)
- Slight day-night difference for the ese-sector

Measurements of stability: LIDAR



- Daytime and nighttime vertical wind profiles – LIDAR Swiss Alps
- No night-day difference for s-sector
- Pronounced day-night-difference nne-sector (stronger increase with height for light winds and at night)

Summary

- Schwyberg
  - Significant stable stratifications occur during the 2.5 months measurement period.
  - Long-term estimate with nearby radio sounding not possible due to weak correlation.
- LIDAR profiles
  - Some flow directions show stronger increase of wind speed with height for light winds and night time profiles – probably stable stratification.
  - These probably stable profiles occurr in flat terrain as well as in complex terrain.

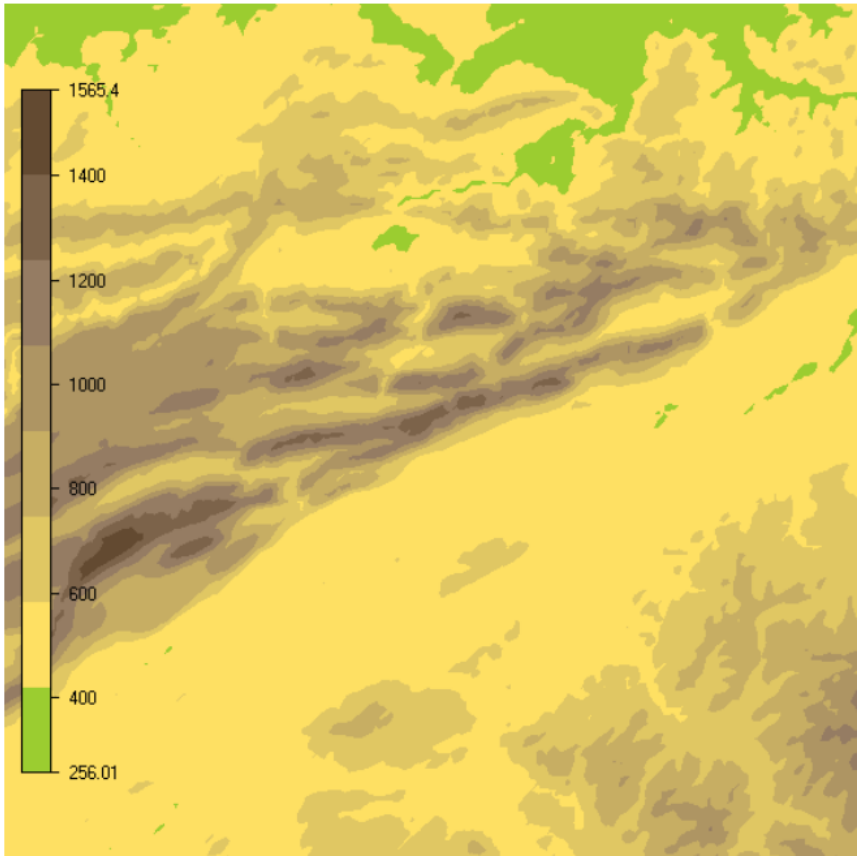
→ Further temperature measurements are necessary to quantify the importance of stability effects when averaging over all flow directions and longer time periods.

Testing the effect of stability in WindSim simulations

- WindSim version 4.9.1
- Stability prescribed by Monin-Obukhov length
- Prescription by temperature gradient not possible (lateral boundary conditions not properly implemented - still the same?)
- Segregate solver should be used (Problems of coupled solver at the outflow boundaries – still the same?)
- Convergence wizard used
- Monin-Obukhov prescribed in big domain, nesting uses stability information from outer domain

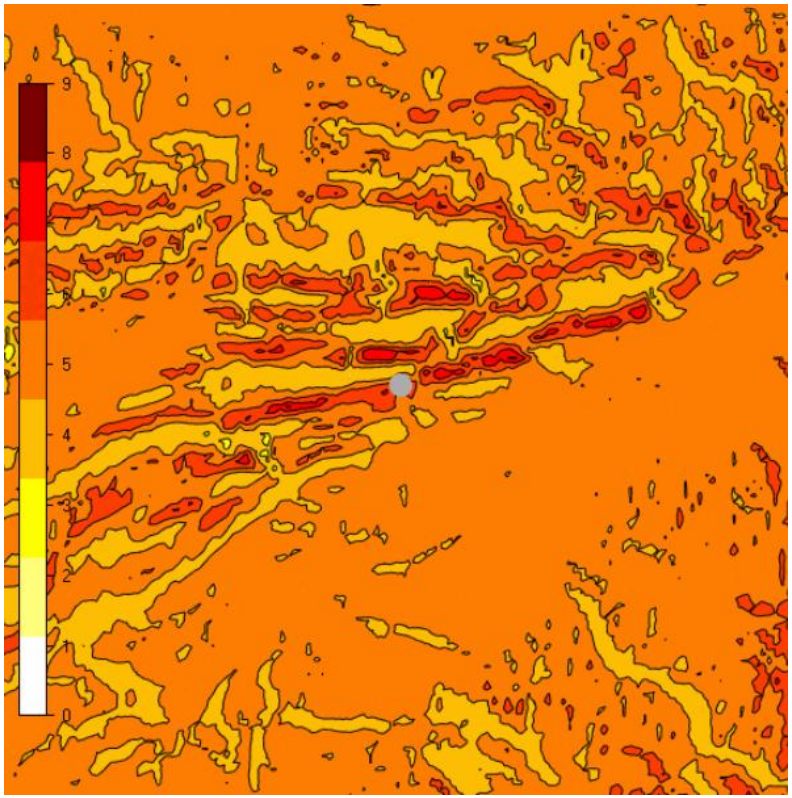
Influence of density

- Domain size: 16 x 16km
- Grid size: 100 m
- Monin-Obukhov length: 100m (= very stable)
- Wind direction: 240deg
- Sensitivity study:
  - Density 1.00 kg/m^3 instead of 1.225 kg/m^3

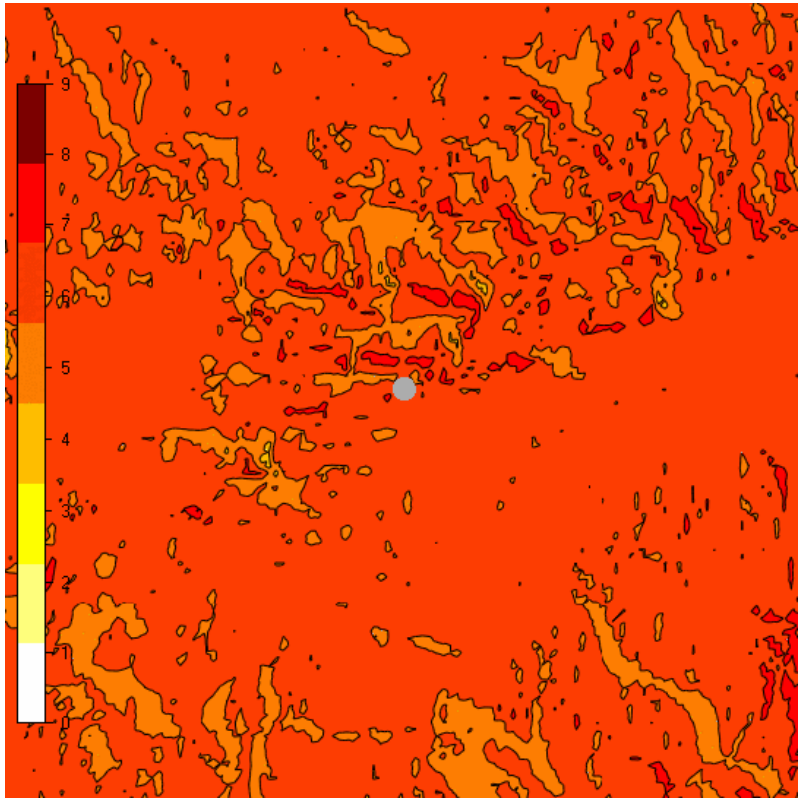


Orography of the big domain

Influence of density



Density: 1.225 kg/m^3 (~170m asl)



Density: 1.00 kg/m^3 (~2100m asl)

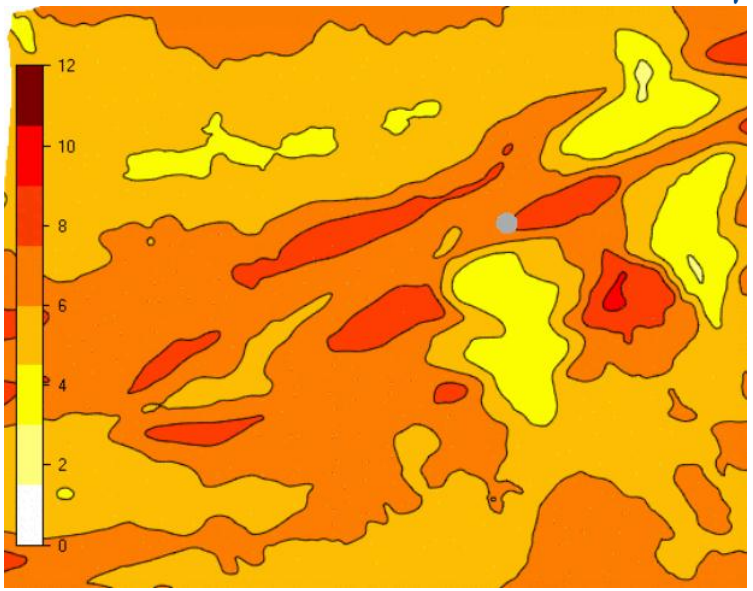
- Similar pattern, but higher velocities with lower density

→ friction velocity increases with decreasing density

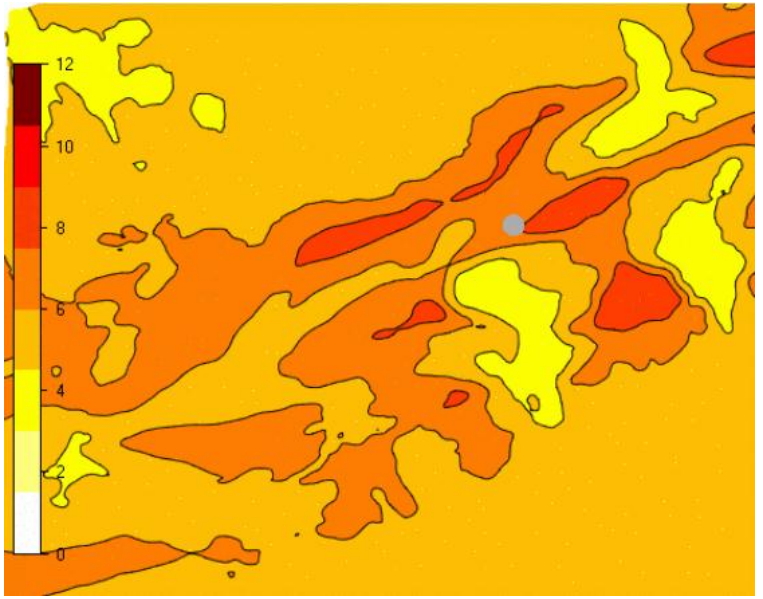
- How to handle big density differences in the model domain?

Influence of stability on flow simulation

- Domain size: 6.4 x 5km
- Grid size: 25m
- Wind direction: 240°
- Sensitivity study:
  - Slightly stable (Monin-Obukhov length 1000m)
  - Neutral
- Pattern slightly different, but all in all very similar



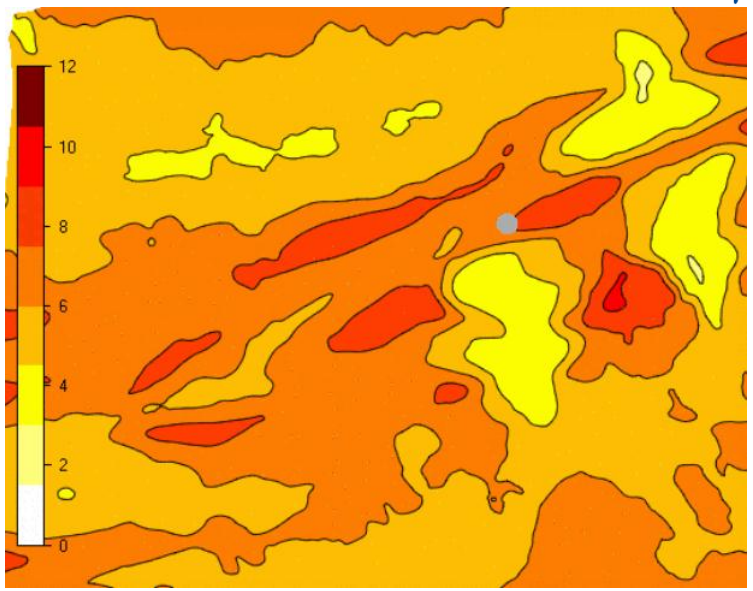
neutral



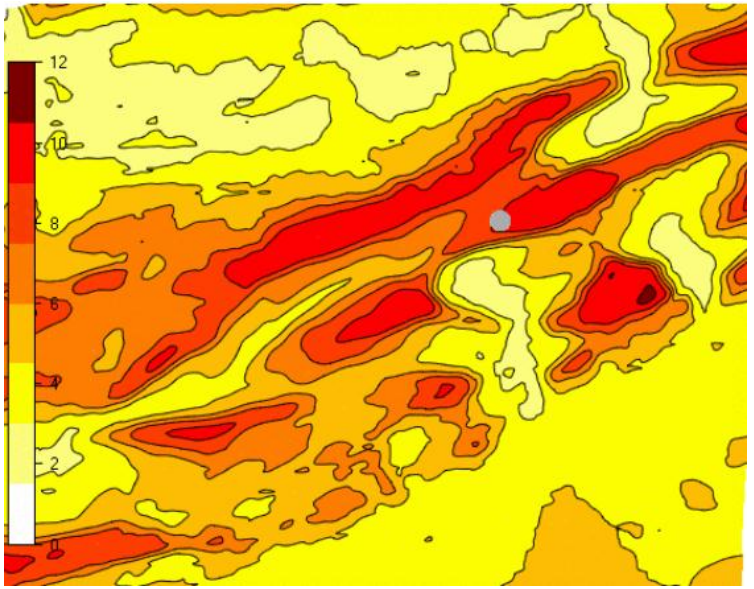
slightly stable

Influence of stability on flow simulation

- Domain size:
- Grid size: 25 m
- Wind direction: 240°
- Sensitivity study:
  - Monin-Obukhov length 20m (= very stable)
  - Neutral
- Pattern remain similar, but huge differences in wind speed
- Very stable stratification: strong wind speed differences



neutral



very stable

Summary

- Differences between neutral and slightly stable stratification are small
- Differences between neutral and very stable stratification significant
- If a significant number of periods with very stable stratification exists, this might affect the wind assessment

Thanks for your attention!

METEOTEST

Fabrikstrasse 14
CH-3012 Bern
www.meteotest.ch

Questions

- Do you consider stability effects in wind assessment studies?
- How would you integrate the stability effect in a wind assessment study?
  - Running a neutral and a stable WindSim simulation?
  - Creating a neutral and a stable wind climatology?
  - Creating a neutral and a stable wind resource map and calculate a weighted mean?