energie werkstatt

CONSULTING ENGINEERS FOR RENEWABLE ENERGY

IEA Wind Task 52: LiDAR Task:

Wind LiDAR in Complex Terrain

Federal Ministry
Republic of Austria
Climate Action, Environment,
Energy, Mobility,
Innovation and Technology

FFG
Promoting Innovation.

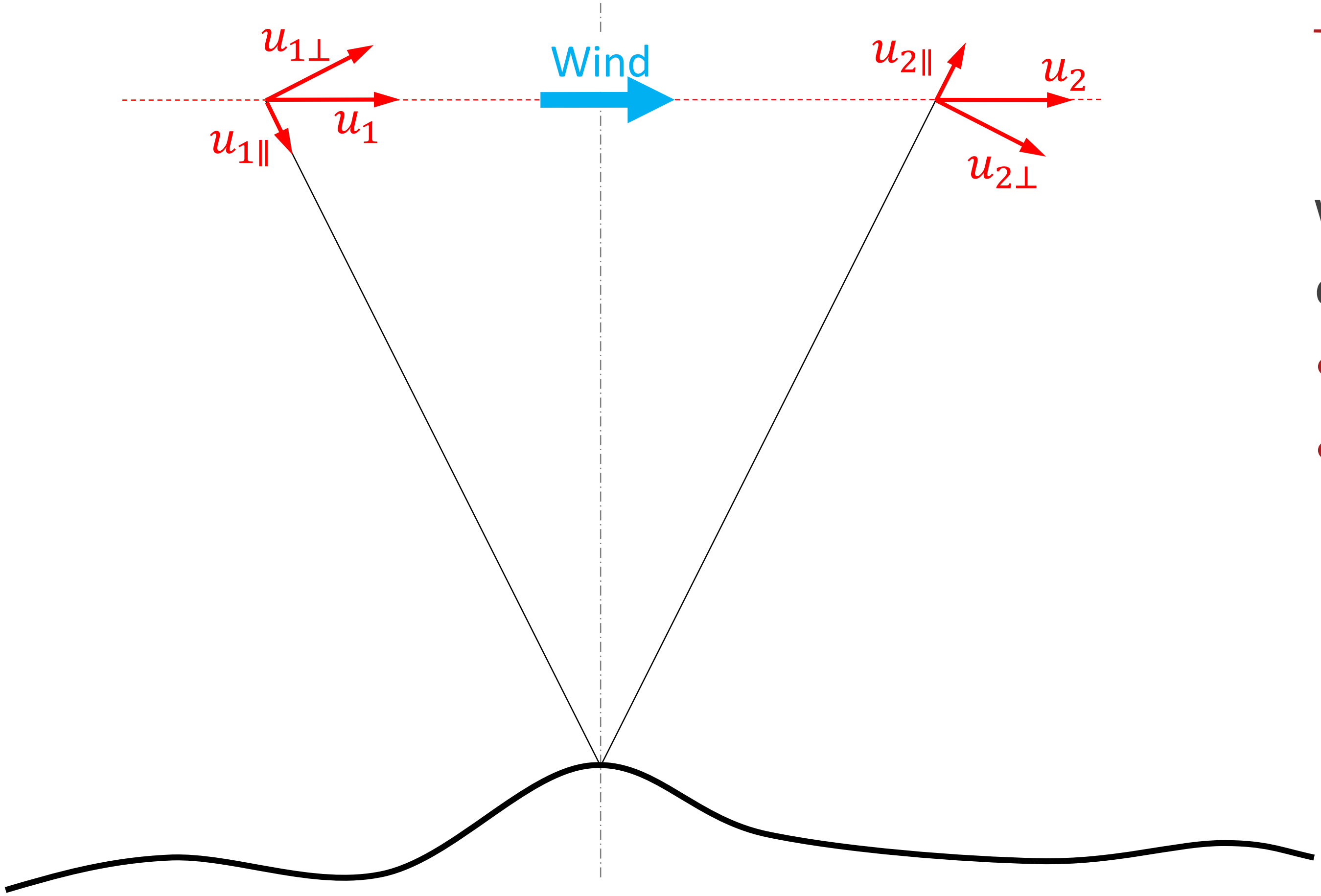
iea wind

IEA Research Cooperation
Part of open4innovation

LiDAR Task: Complex terrain working group

- One working group in Task 52, under the banner of "replacing met mast", focuses on LiDAR in complex terrain.

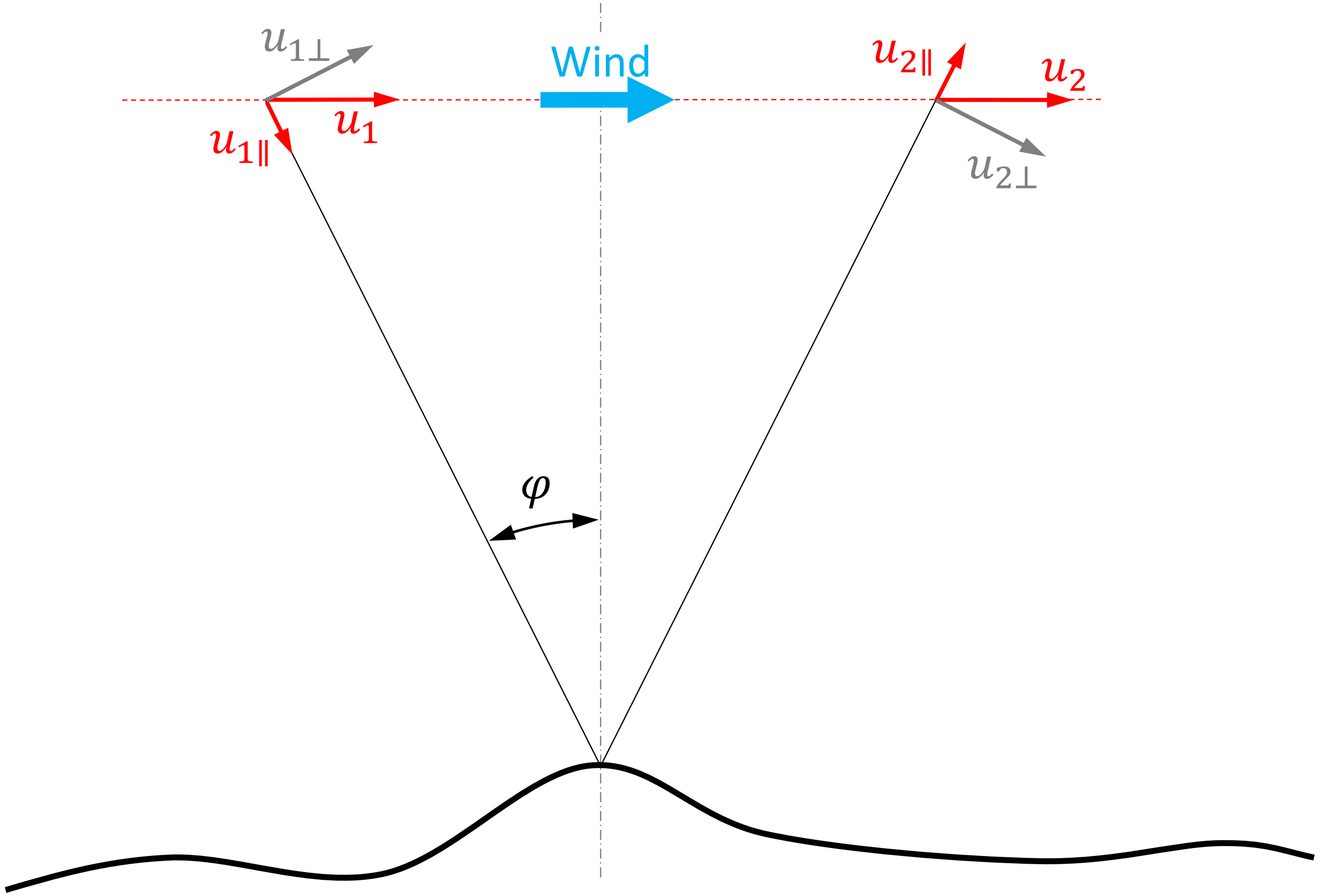
- One of the obstacles to stand-alone LiDAR measurements for resource assessment is the uncertainty related to complex terrain
  (there are others; e.g. measurement of turbulence, lack of standards, conservatism, ...)



The problem:

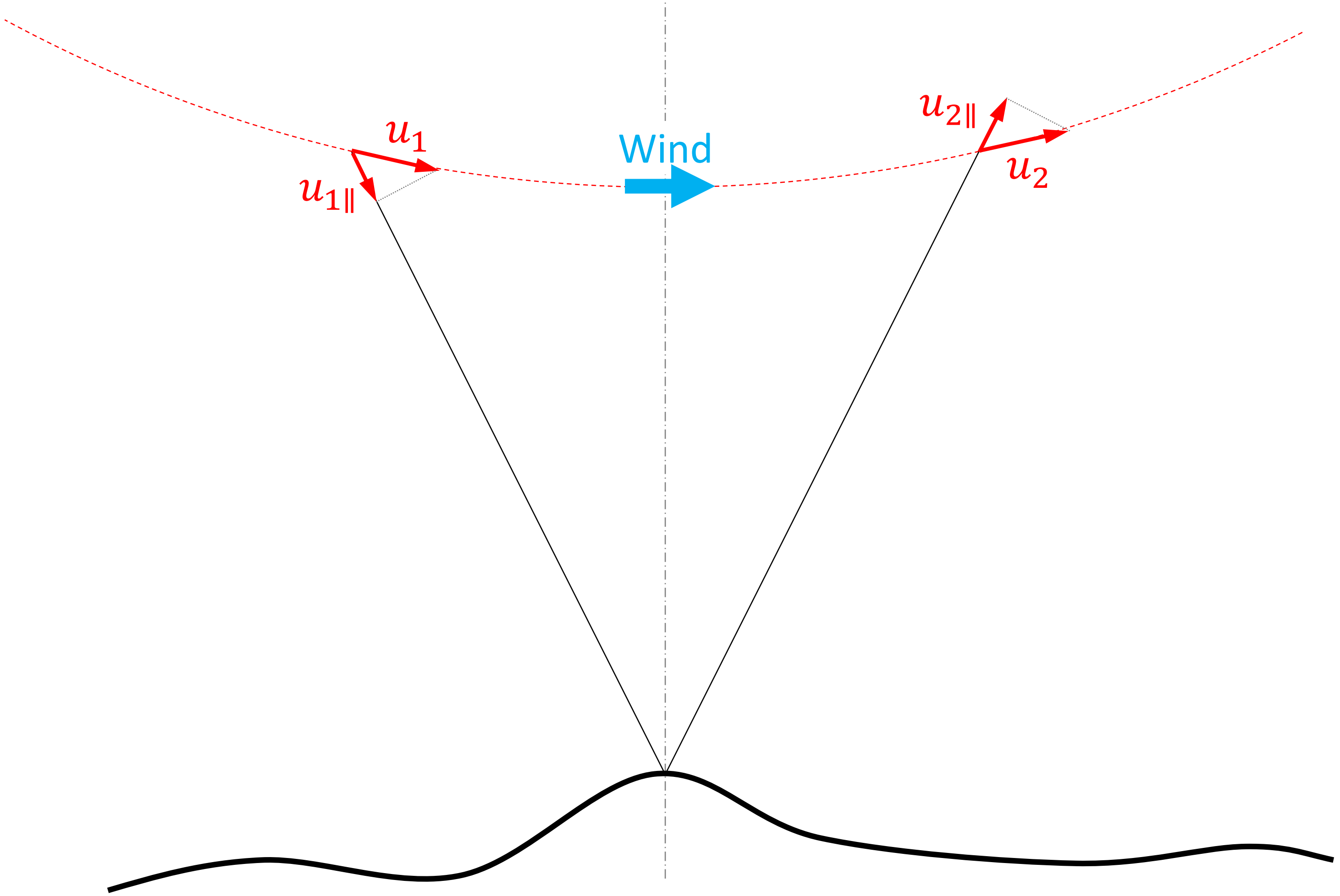
Wind speed has two components:

- Parallel to beam-axis (∥)
- Normal to beam-axis (⊥)



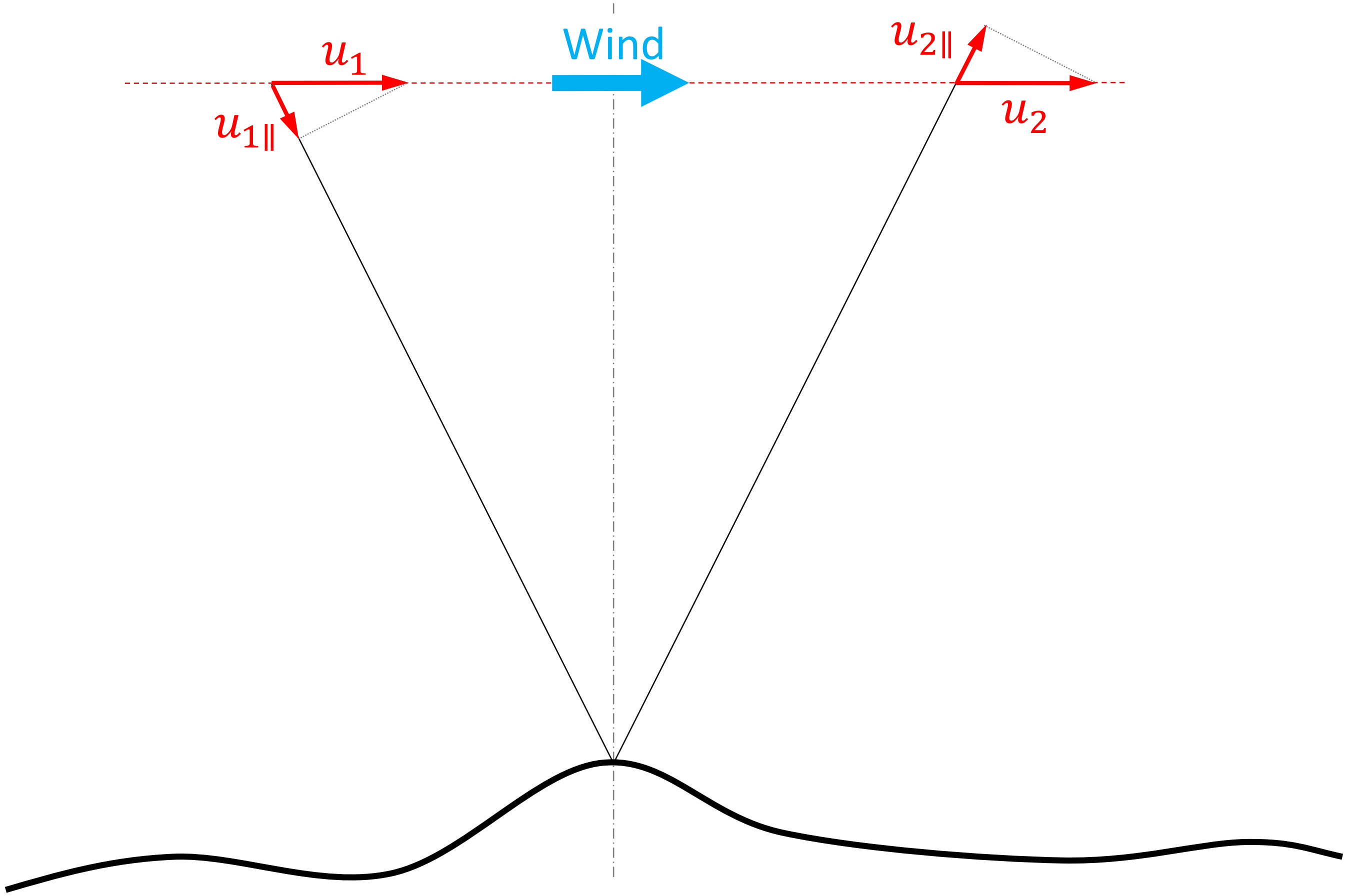
Measurement of the beam-axis component only:

$$u_{\text{measured}} = \frac{u_{1\parallel} - u_{2\parallel}}{2 \cdot \sin \varphi}$$



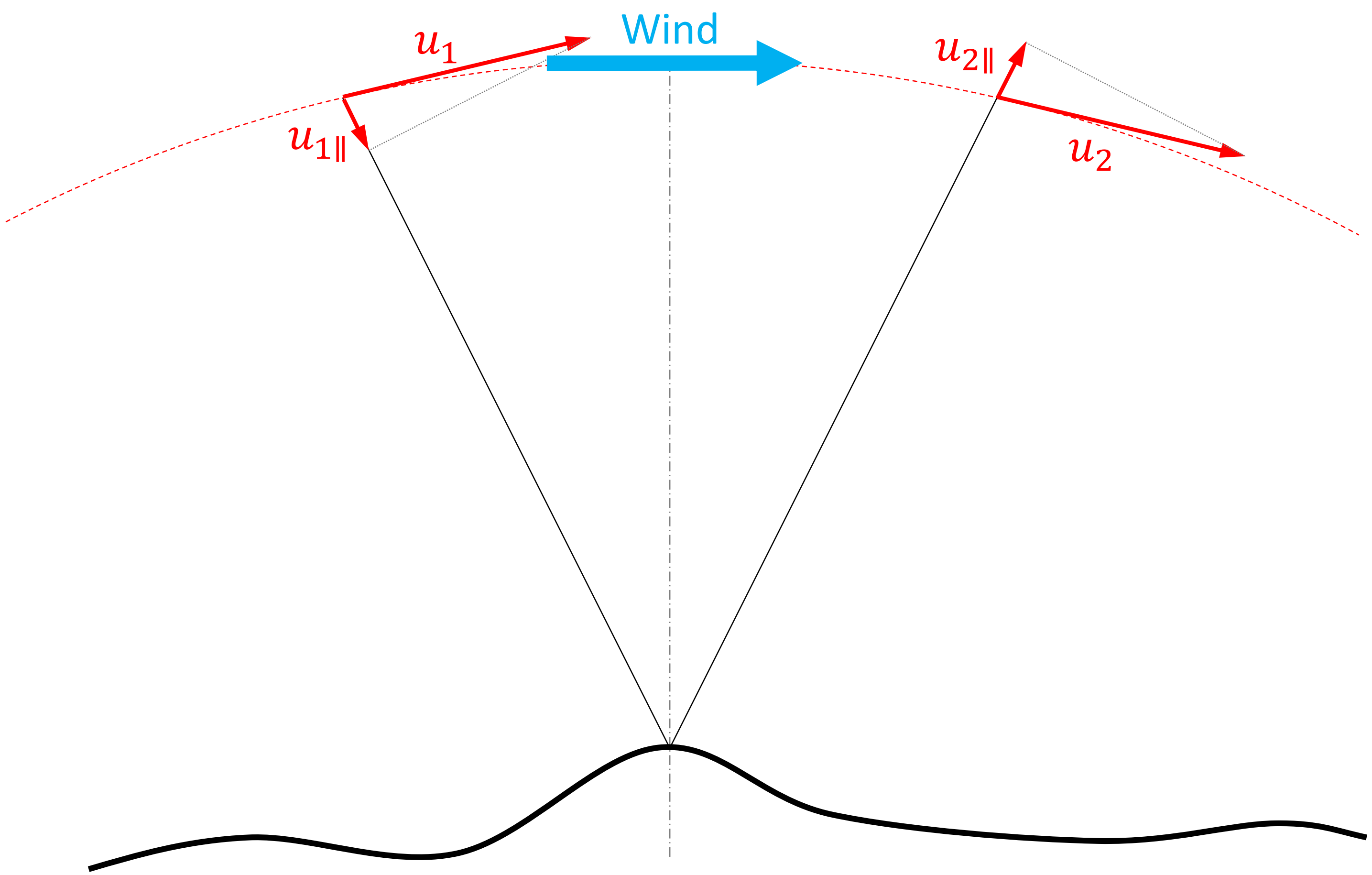
Different wind speeds with different flow geometries give same measurement result.

$$u_{\text{measured}} = \frac{u_{1\parallel} - u_{2\parallel}}{2 \cdot \sin\varphi}$$



Different wind speeds with different flow geometries give same measurement result.

$$u_{\text{measured}} = \frac{u_{1\|} - u_{2\|}}{2 \cdot \sin \varphi}$$



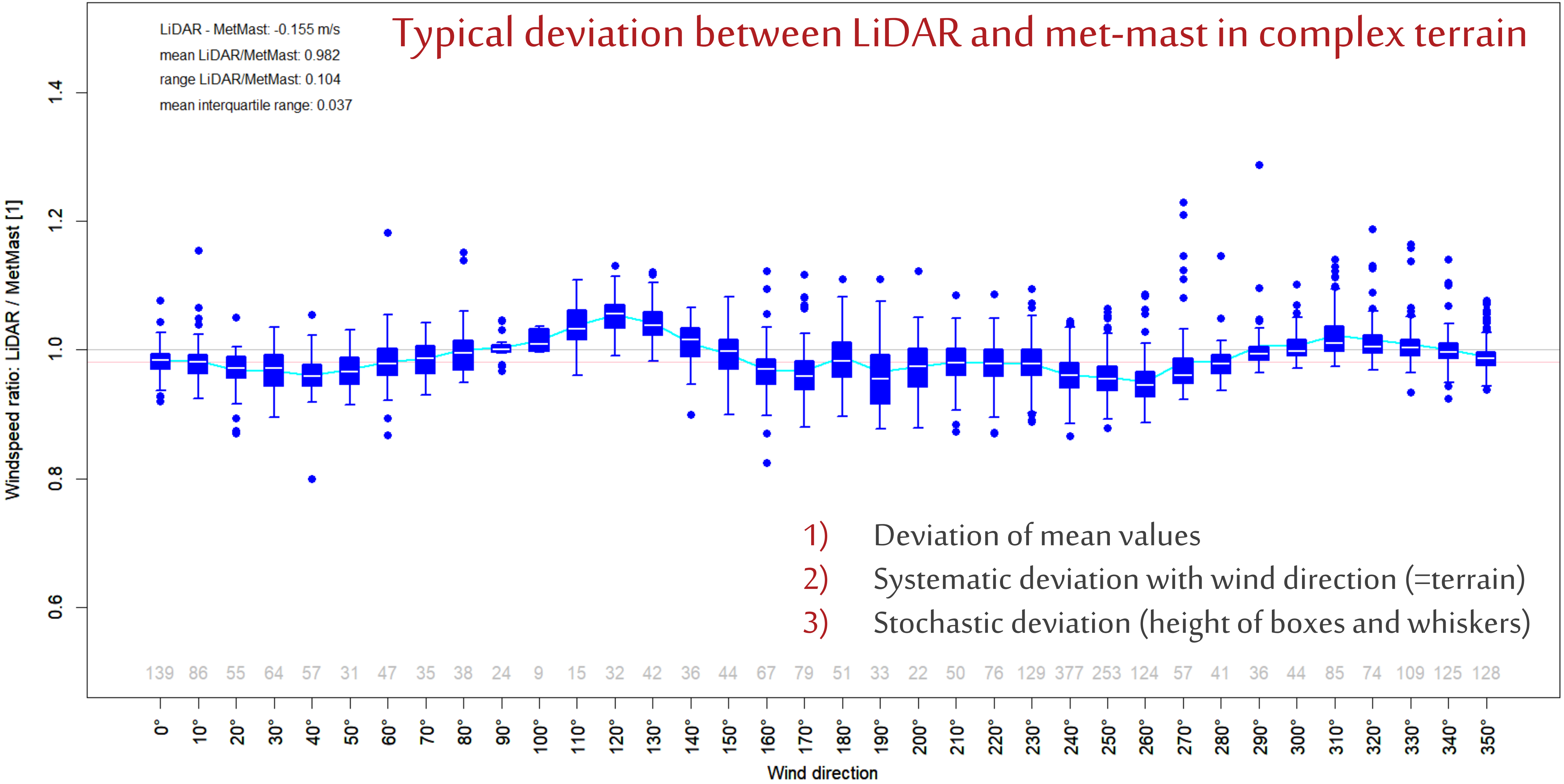
Different wind speeds with different flow geometries give same measurement result.

$$u_{\text{measured}} = \frac{u_{1\parallel} - u_{2\parallel}}{2 \cdot \sin\varphi}$$

Additional complications

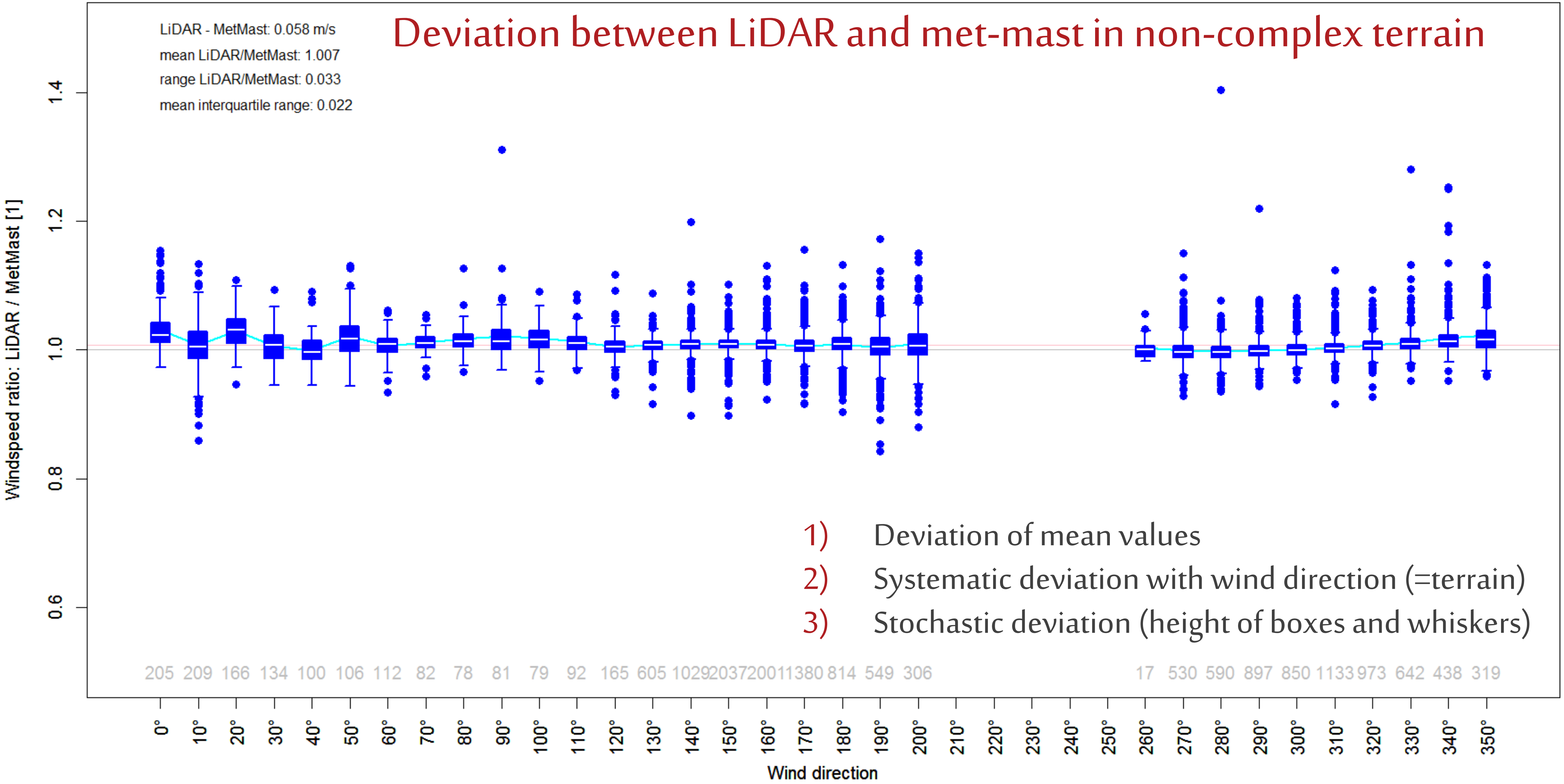
- Point vs. volume measurement
- Temporal & spatial flow inhomogeneities (i.e. beyond curvature)
- Speed-up effect
- Turbulence measurement with LiDAR is complicated…
- Position offset between LiDAR and met-mast

Typical deviation between LiDAR and met-mast in complex terrain



1) Deviation of mean values
2) Systematic deviation with wind direction (=terrain)
3) Stochastic deviation (height of boxes and whiskers)

Deviation between LiDAR and met-mast in non-complex terrain



1) Deviation of mean values
2) Systematic deviation with wind direction (=terrain)
3) Stochastic deviation (height of boxes and whiskers)

Addressing the problem

Two things can be done:

- Trying to estimate the likely flow geometry in order to predict the uncertainty 1 to 3 (or feasibility, respectively) of a LiDAR measurement at a given site.
- Using a modeled flow geometry to calculate corrections to the measured wind speed (could in theory address 1 and 2).

Has been worked on in the previous phase, will be topic for the present one (to be discussed on Wednesday).

Verification depends on parallel and co-located datasets of LiDAR and met mast measurements.

Characterizing „complexity"

In order to measure, predict, or correct the effect of complexity on wind measurements, it is necessary to have a system for the description and the quantification of site complexity.

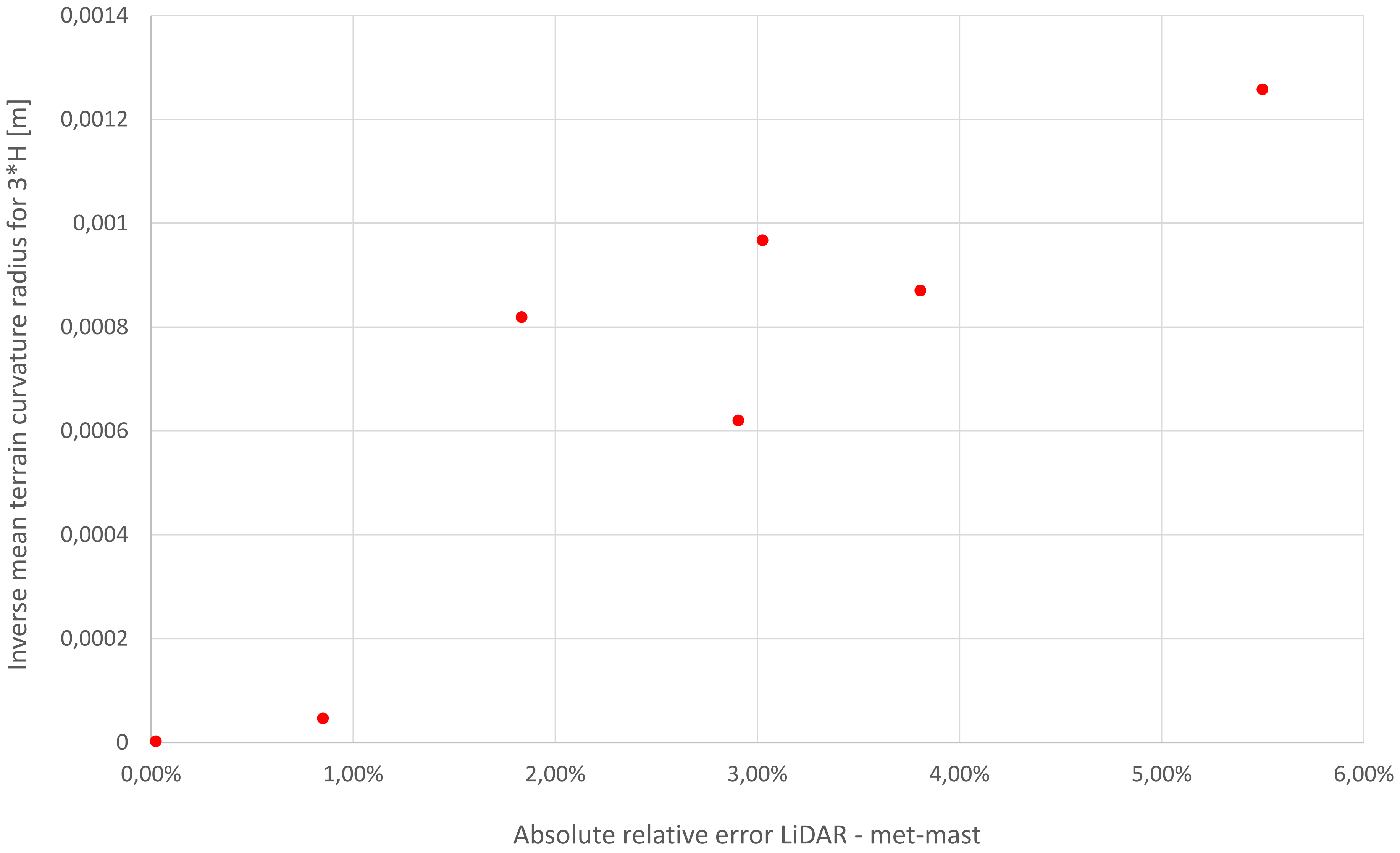
There are two ways to assess the flow complexity at a site:

- From terrain characteristics (e.g. slope, curvature, RIX, 61400-12-1, …)
- From the characteristics of the flow as measured (e.g. shear, turbulence, flow inclination)

The former is obviously preferable for the planning of measurement campaigns.

Complex terrain working group: results and conclusions from previous phase

- Looked at LiDAR errors and a number of different correction methods based on parallel LiDAR and met-mast data from five sites.
- The five sites, chosen for their great complexity, proved to be too complex to allow a reliable correction.
- Five sites, all rather complex and from one region, are insufficient for the identification of thresholds.
- Modeling results seem to be suitable indicators for the amplitudes of complexity errors.
- There are candidates for suitable terrain characteristics.


Inverse mean terrain curvature radius for 3*H [m]
0,0014
0,0012
0,001
0,0008
0,0006
0,0004
0,0002
0
0,00%
1,00%
2,00%
3,00%
4,00%
5,00%
6,00%
Absolute relative error LiDAR - met-mast

Challenges are:

- Depends on a suitable way to characterize terrain complexity.
- Sites and conditions are very divers, complexity is not a one-dimensional thing.
- Many datasets are needed to draw universal and robust conclusions.
- Suitable data is hard to come by.
- Met-mast anemometers aren't perfect either.
- Nature is more complicated and variable than models.
- …

Complex terrain working group: current phase and future

- More datasets are needed to draw robust conclusions. Evaluations without sharing data might help.
- Better understanding of the effect of reconstruction and averaging schemes, Improvements of numerical models and parametrization.
- Publishing of recommendations for LiDAR measurements in complex terrain and the use of correction methods.
- Ultimately, LiDAR in complex terrain should get covered by a standard (61400-50-2).

Thanks for your attention!

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