Effect of surface inhomogenities on the development of the urban boundary layer

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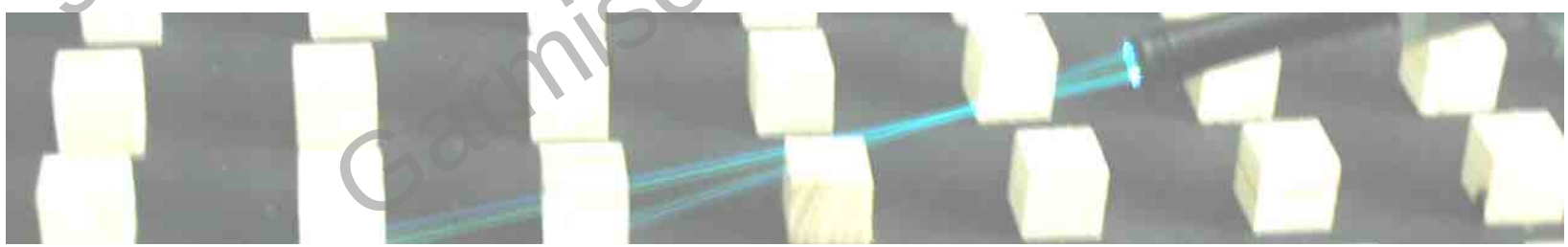
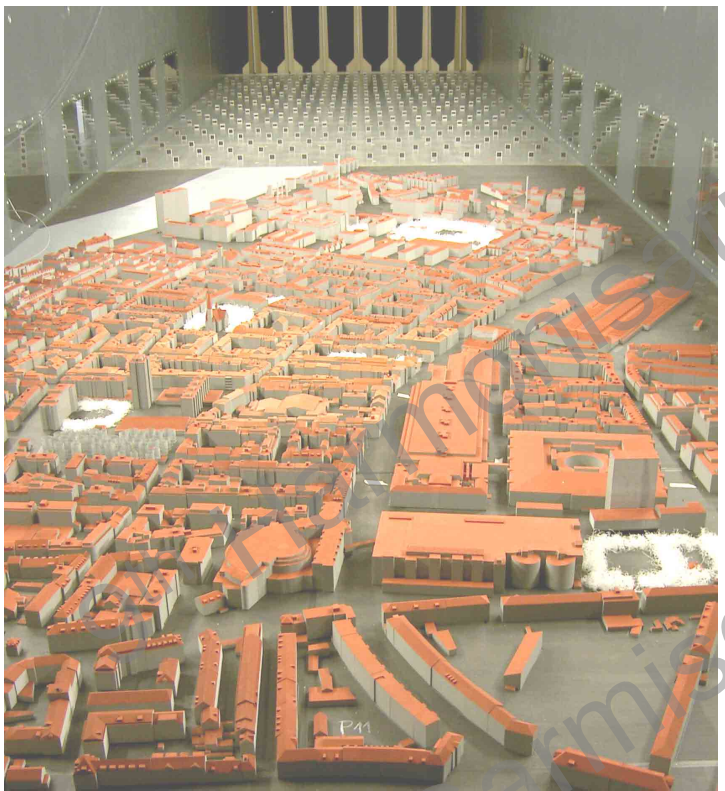


Outline

- Motivation/strategy
- Experimental setup: array of cubes
- Measurements along the centerline:
  - Vertical range of influence
  - Development of profiles
  - Development of turbulence intensity
- Local grid measurements:
  - Variation of aspect ratio L/h
  - Variation of fetch
  - Comparison modelled/no modelled approach flow
- Summary/future work

Motivation



Complex terrain:

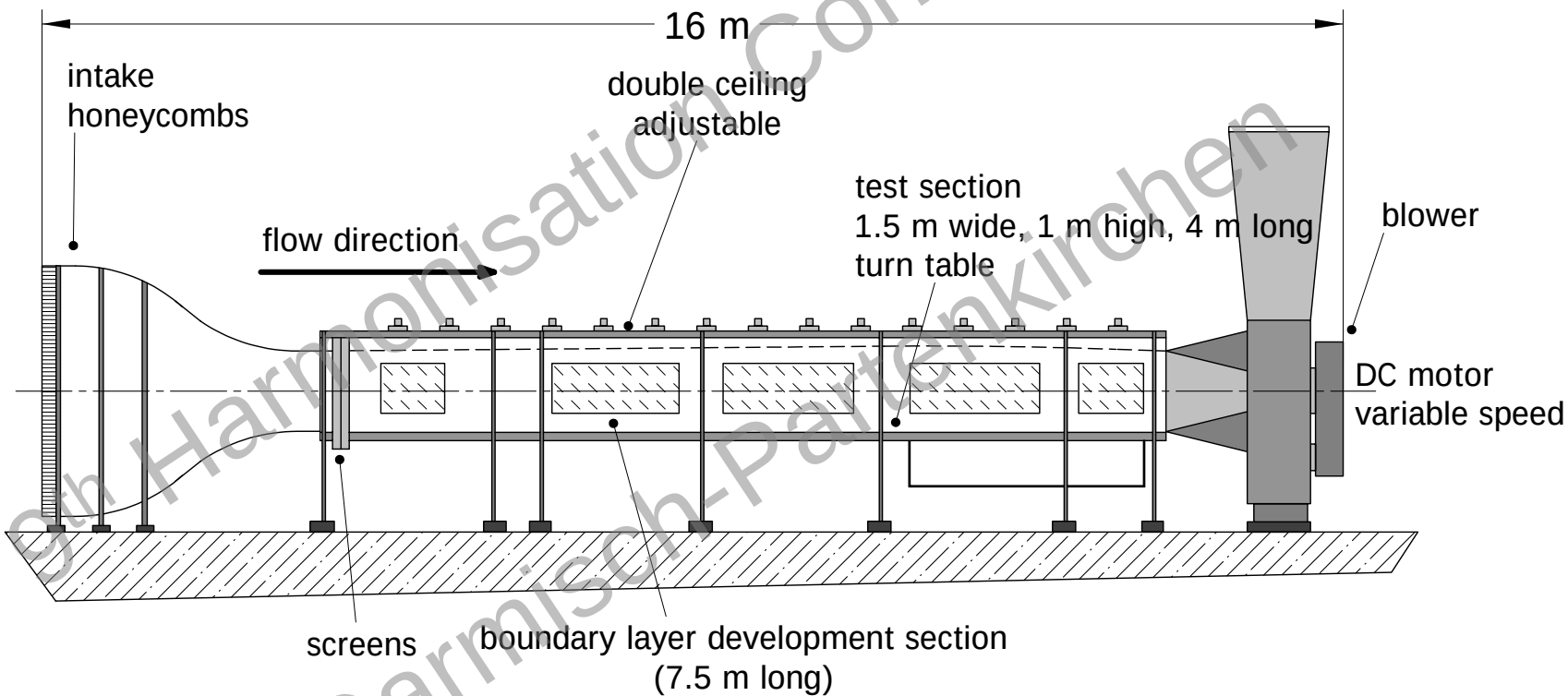
Urban Boundary layer flow influenced by individual buildings, esp. for the lowest 100m

- Which fetch is needed behind a step change of roughness for the UBL flow to gain equilibrium with the underground?
- What are the profile characteristics above buildings?
- Height of RS/IS?
- Systematic wind tunnel measurements to investigate these questions

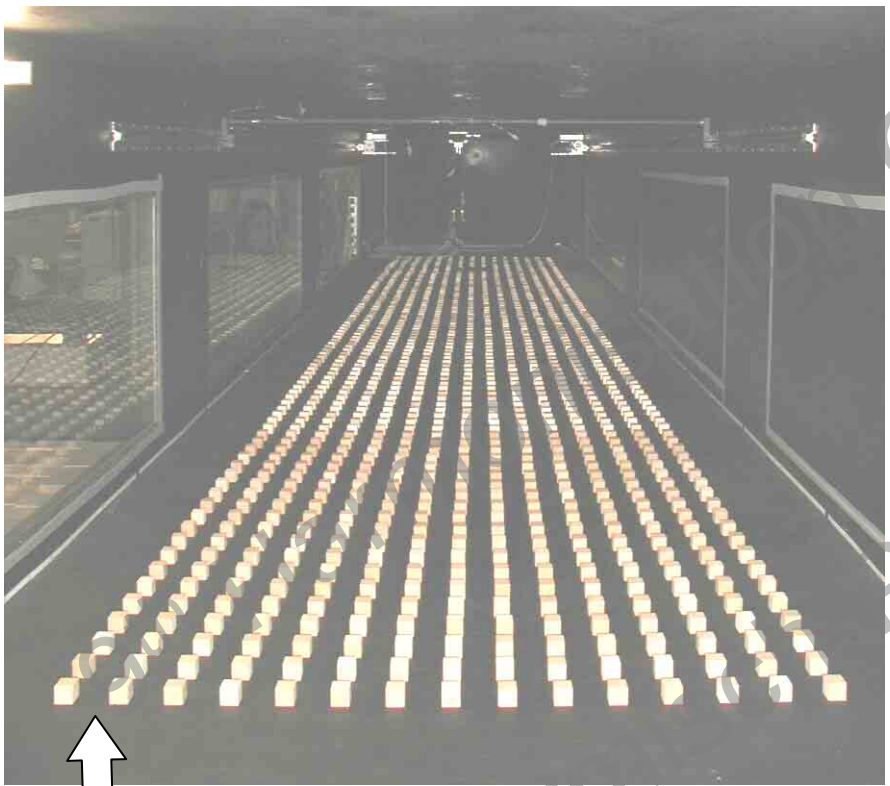
Strategy

- Investigation of an idealized case:
  - Idealized structure: array of cubes
  - Systematic measurements
  - Easy variation of different parameters
  - No modelled approach flow → influence of roughness only
- Investigation of a special case:
  - Modelling a scaled boundary layer approach flow

Wind tunnel „Blasius“



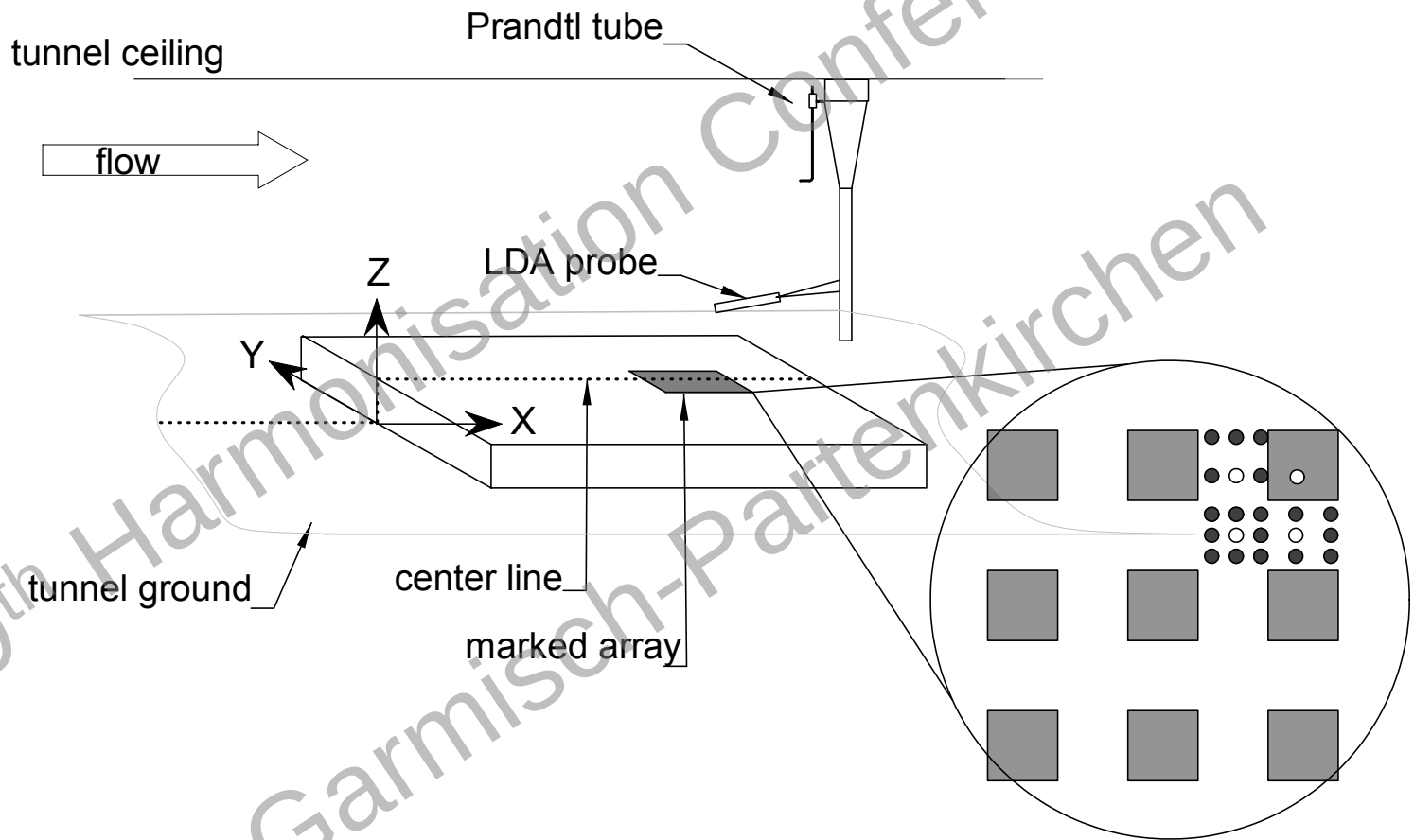
Experimental set up



flow

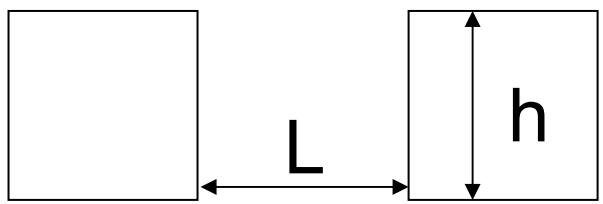
flow

Experimental set up



Experiments overview

	Aspect ratio L/h	Fetch	Measurements
No spires	0.5	35 rows	Profiles upstream of cube array
	1	35 rows	
	2	35 rows	Profiles above centreline
	2	35 rows	
	2	55 rows	
	2	75 rows	Spatially distributed
Spires	2	35 rows	Profiles above marked array



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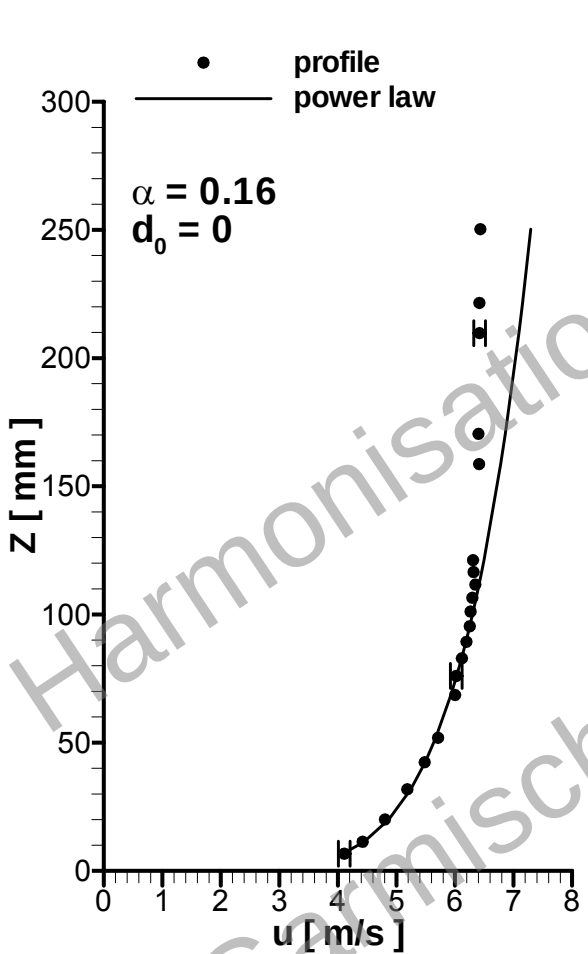
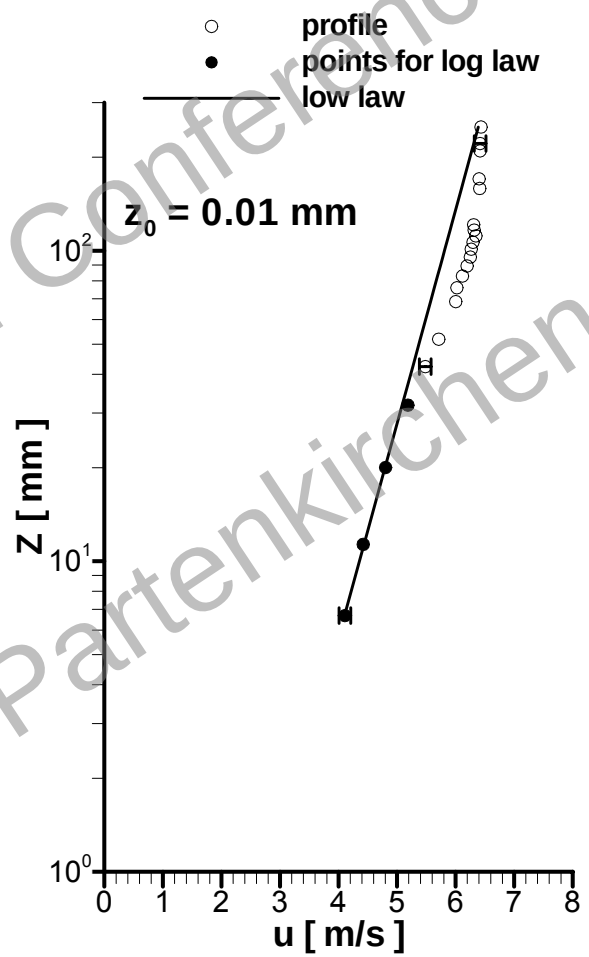
Approach flow

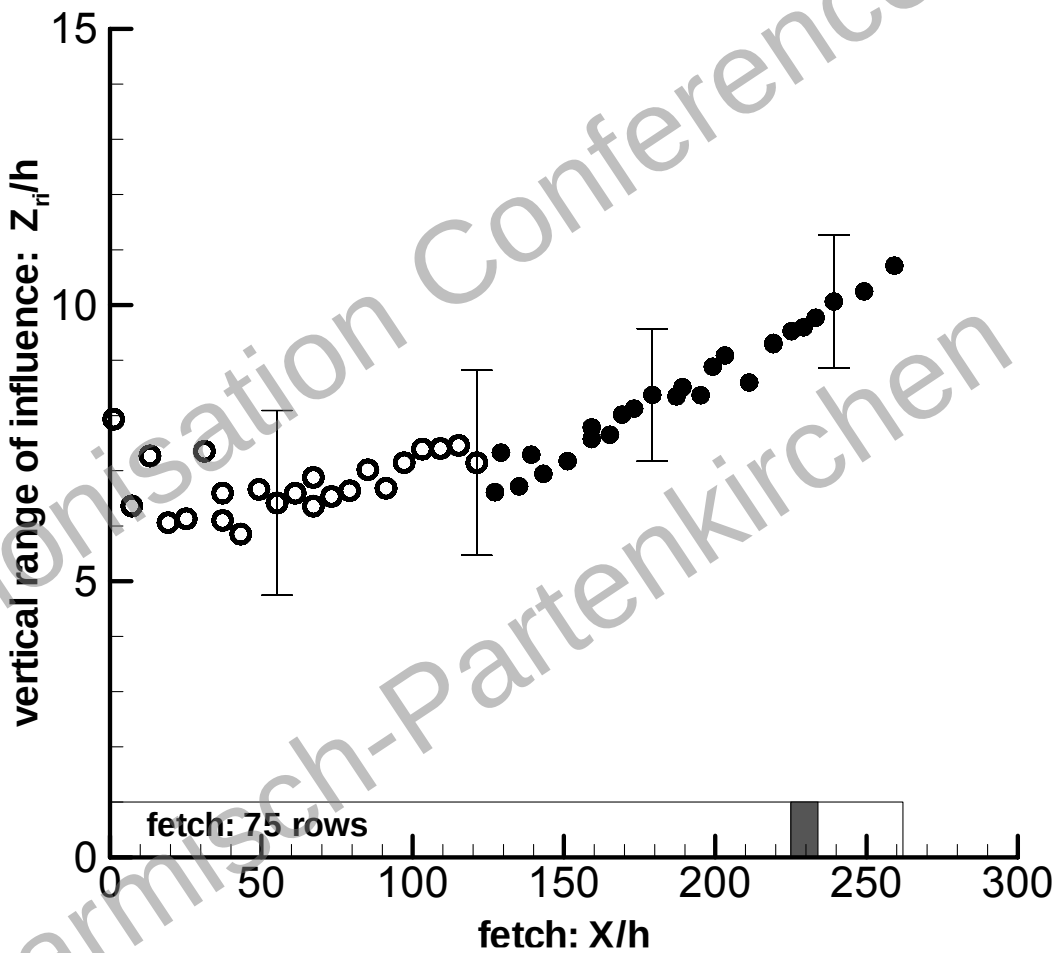




Vertical range of influence

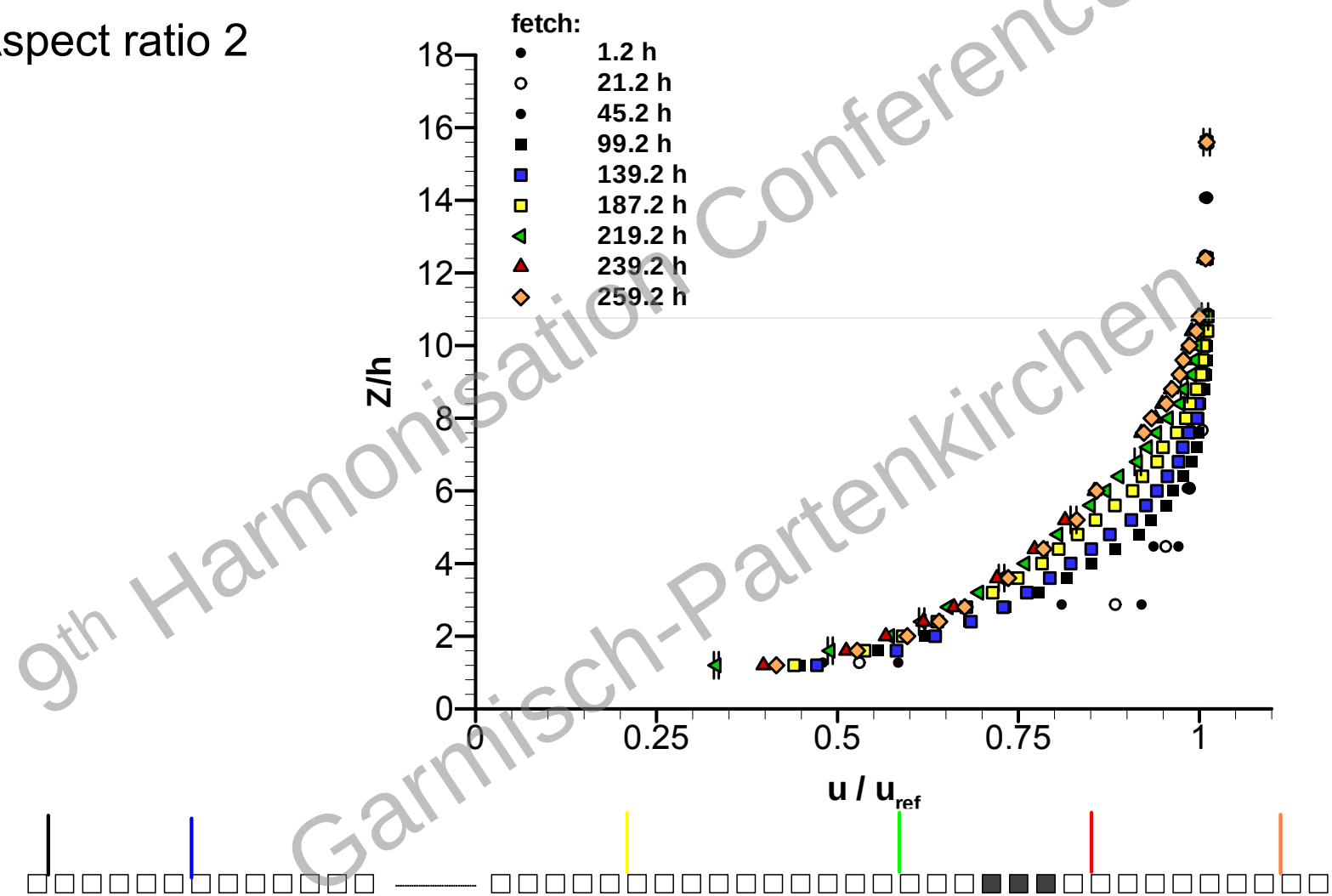
Aspect ratio 2

99% of freestream velocity u_{ref}



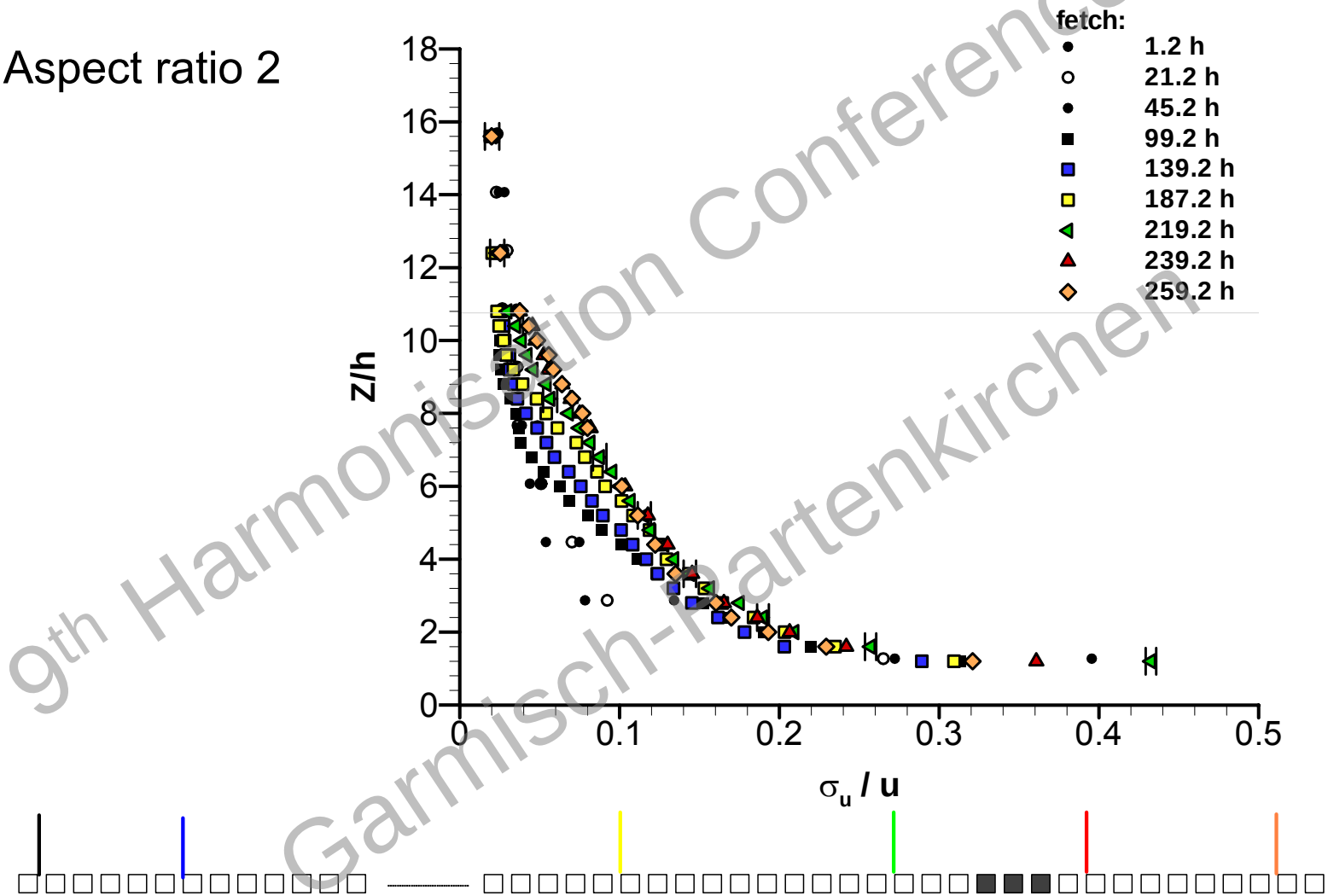
Development of U profiles

Aspect ratio 2



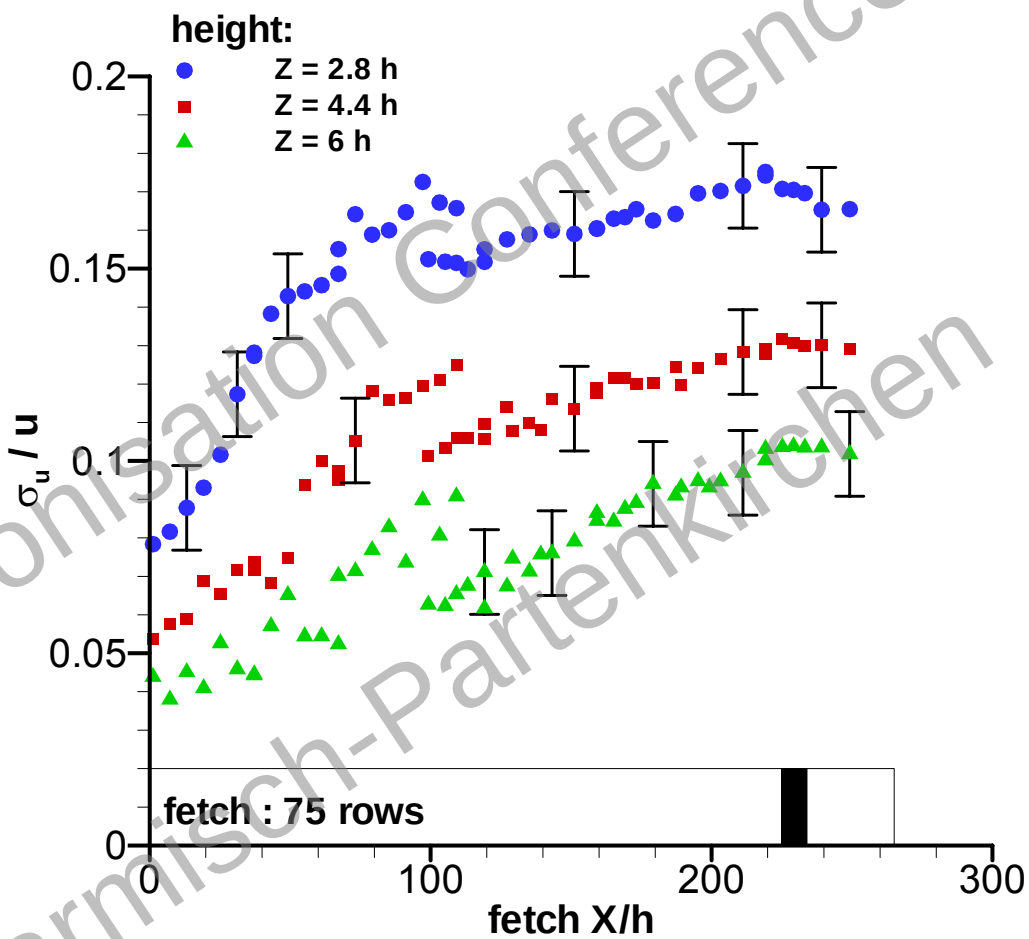
Development of Turbulence Intensity

Aspect ratio 2



Turbulence Intensity

Aspect ratio 2



summary of centerline results

- No fully developed boundary layer reached
- 80 h fetch for adjustment to new roughness
- Selfsimilarity of mean wind profiles for fetch ca. 230 h (> 75 rows)
- Constant values for turbulence intensity reached up to 2.8 h above roughness

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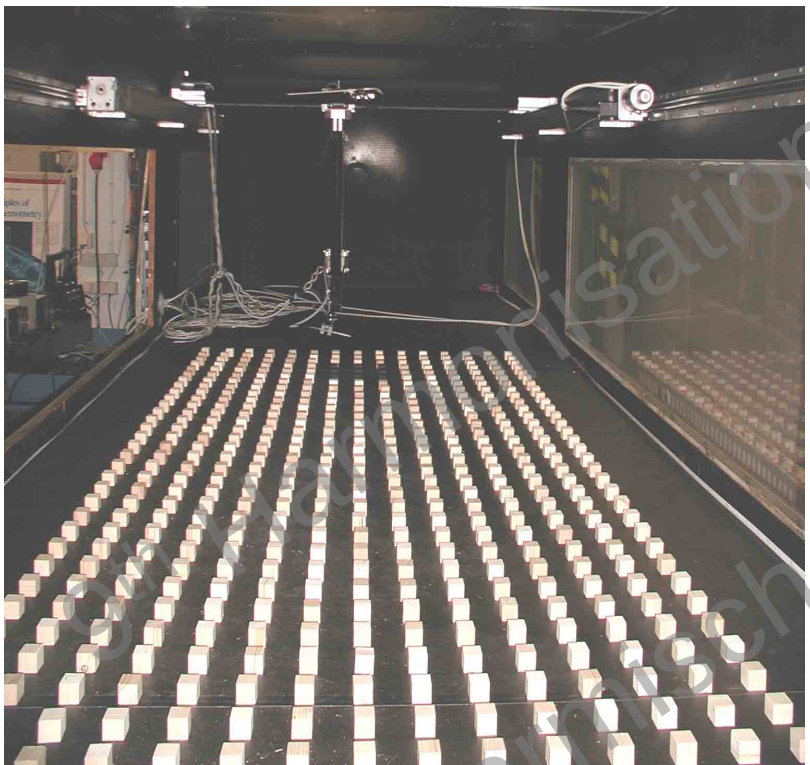
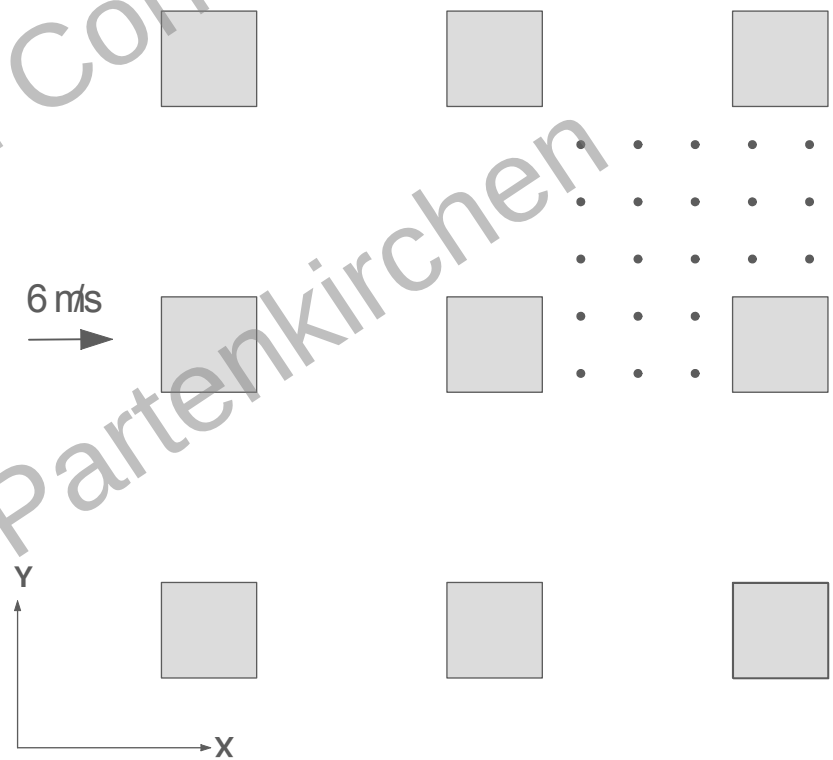
Spatially distributed fluxes

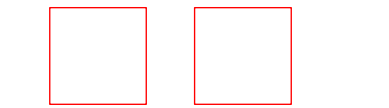
Example: Aspect ratio 2



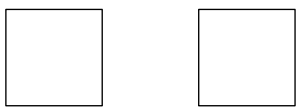


Spatially distributed fluxes

Aspect ratio:

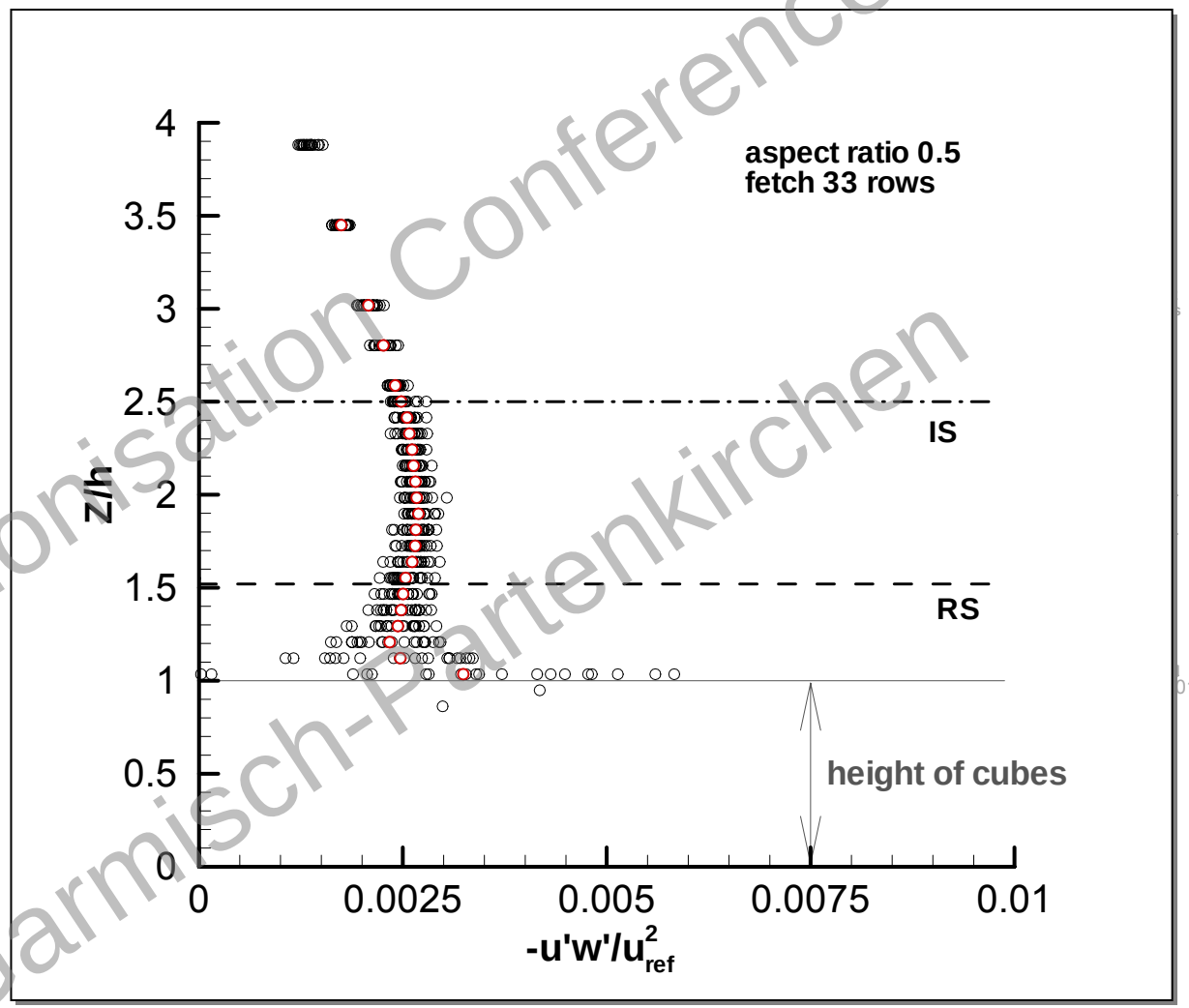


0.5



1

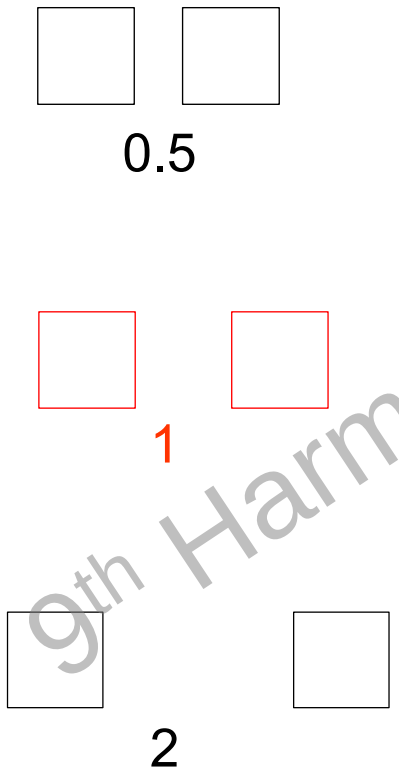
2

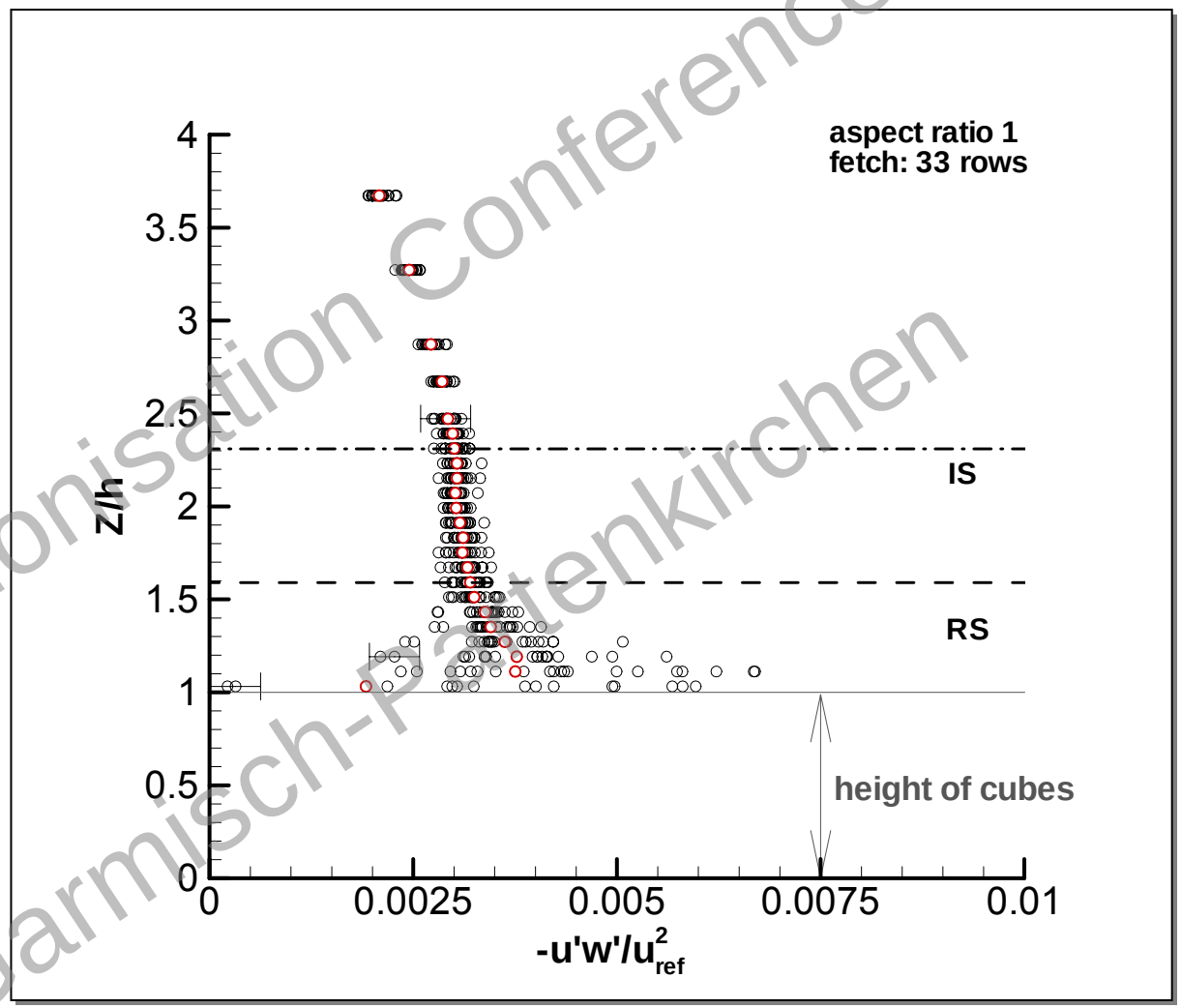


Fetch: 35 rows

Spatially distributed fluxes

Aspect ratio:

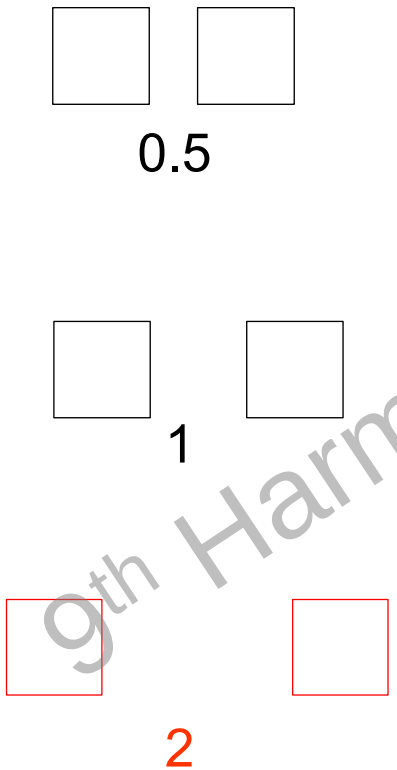


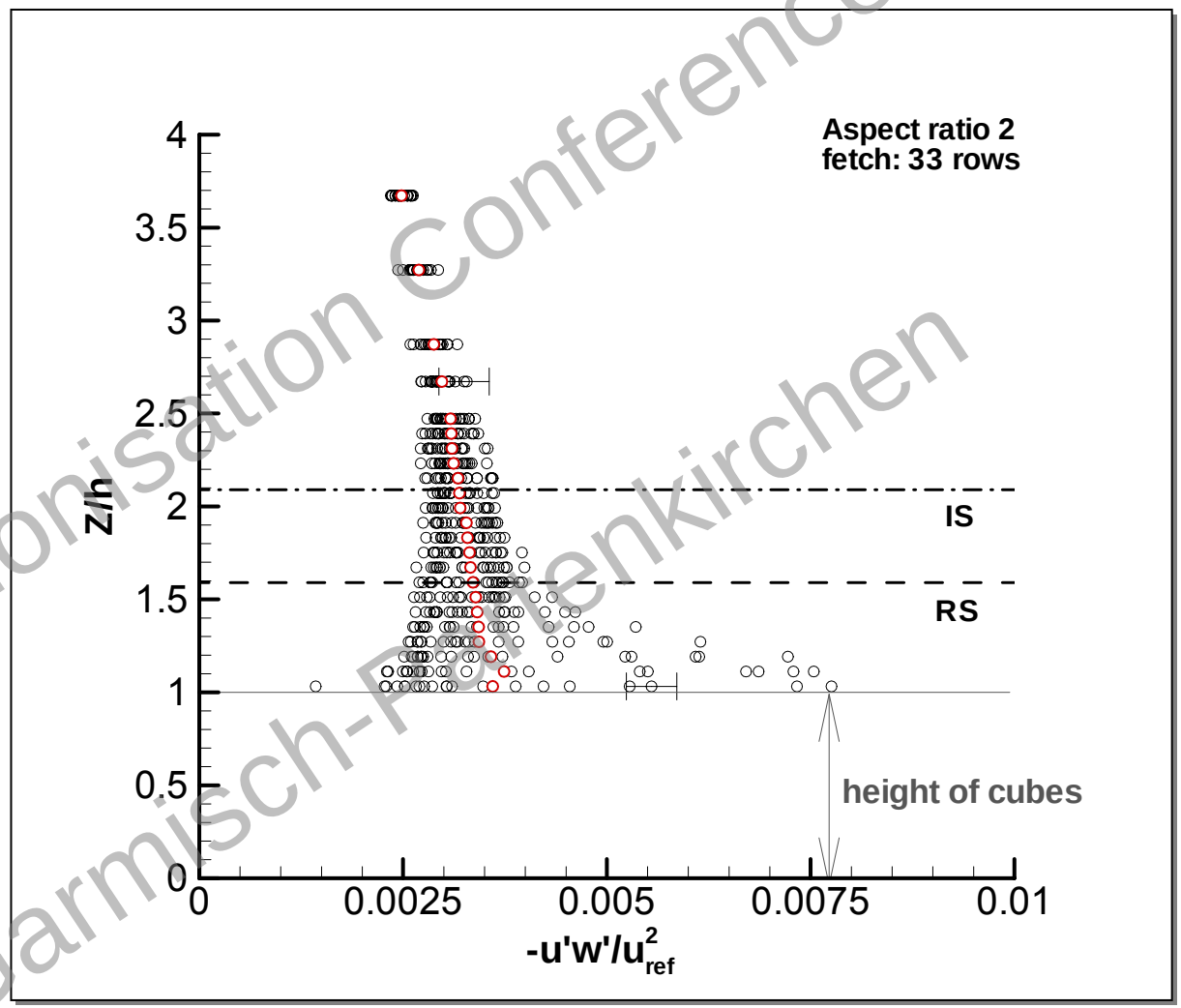


Fetch: 35 rows

Spatially distributed fluxes

Aspect ratio:



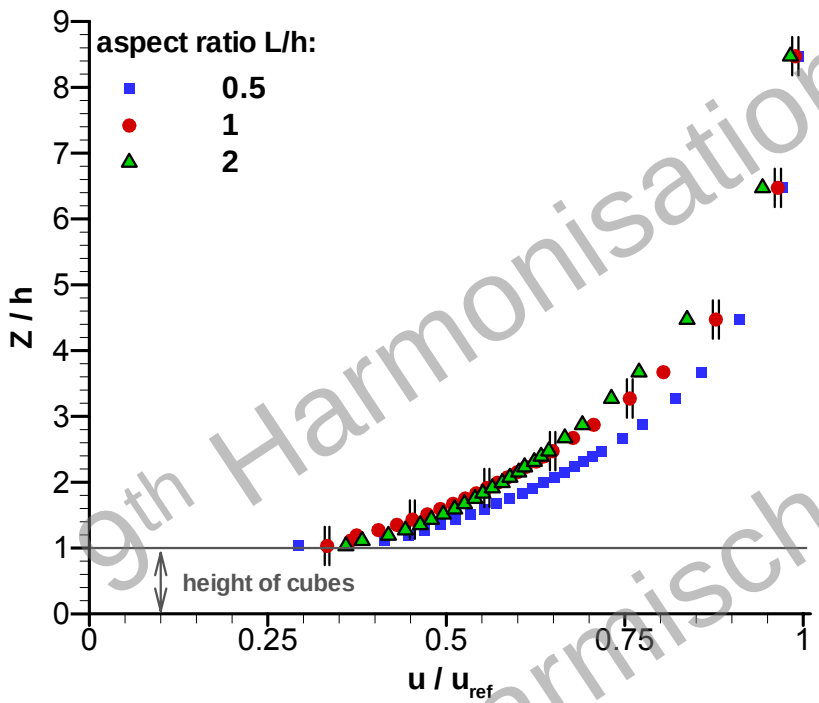


Fetch: 35 rows

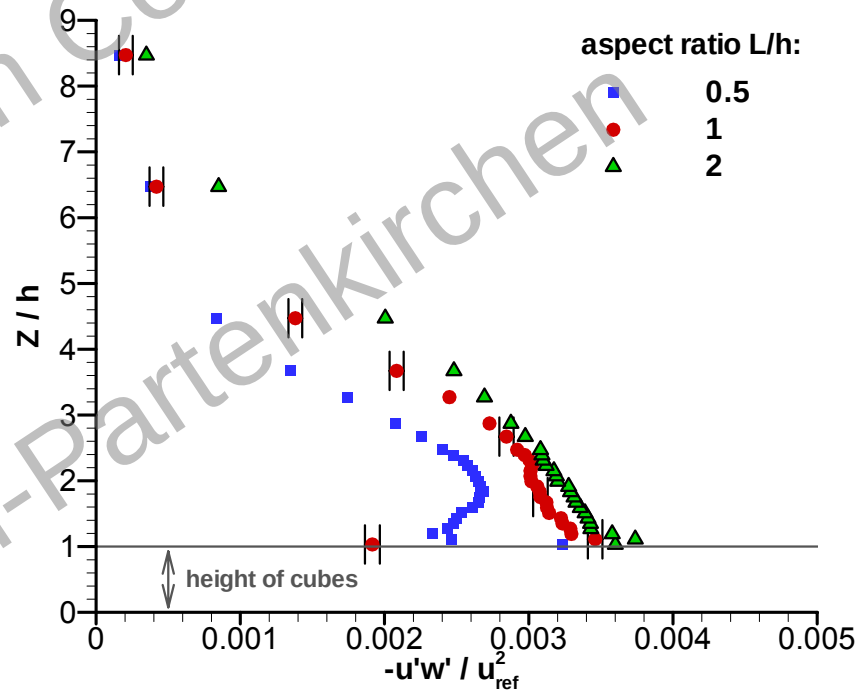
Variation of aspect ratio

Fetch 35 rows

mean wind speed u



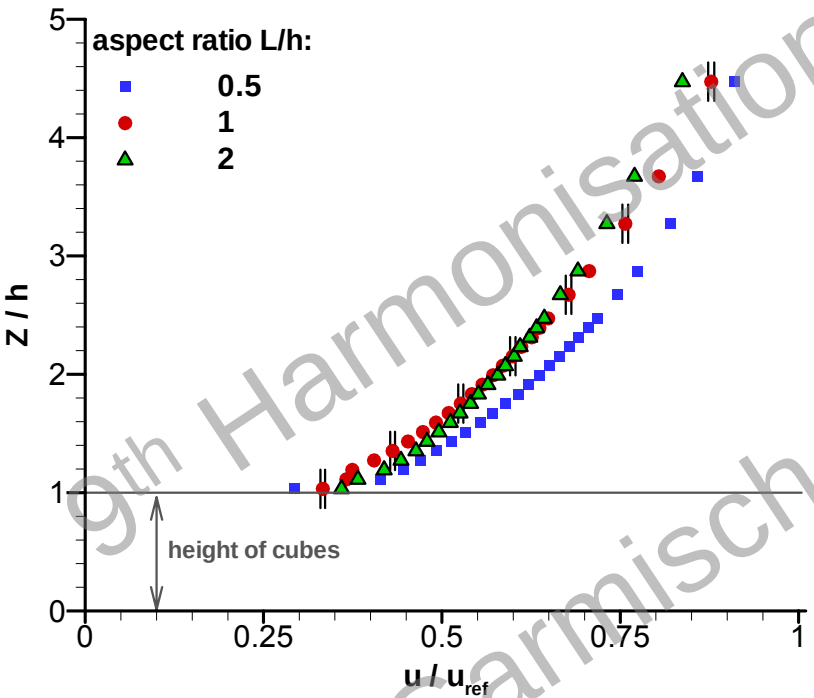
turbulent fluxes u‘w‘



Variation of aspect ratio

Fetch 35 rows

mean wind speed u



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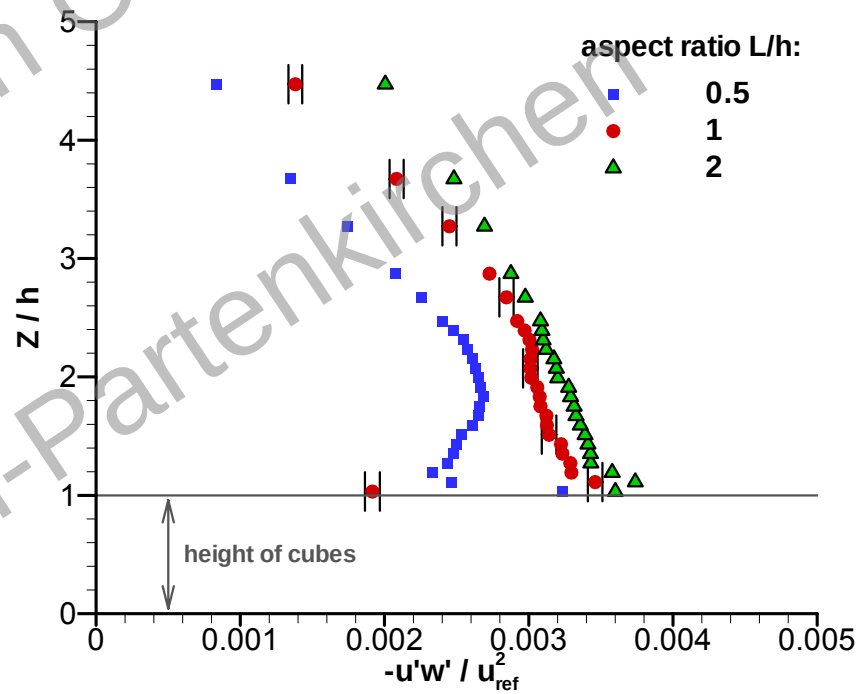
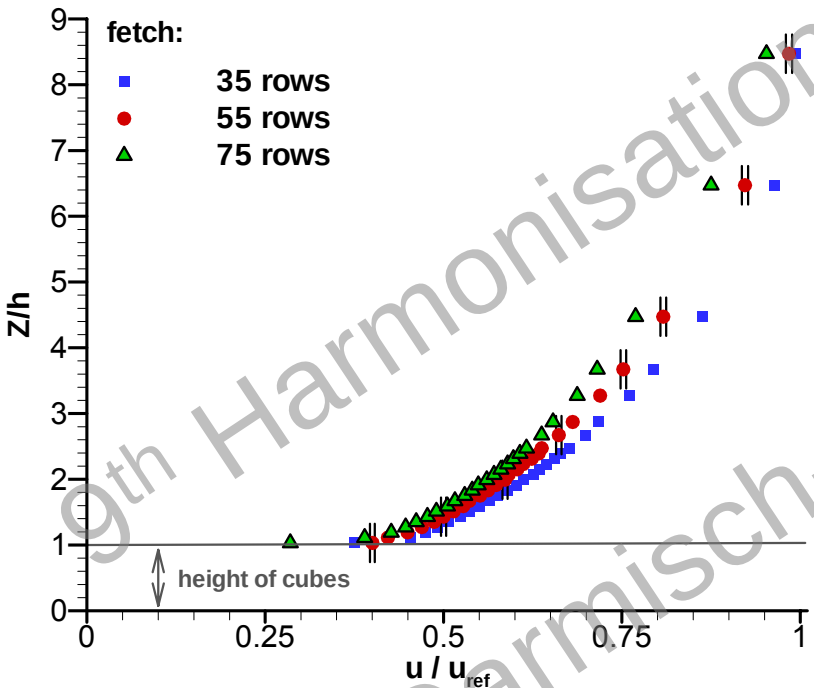


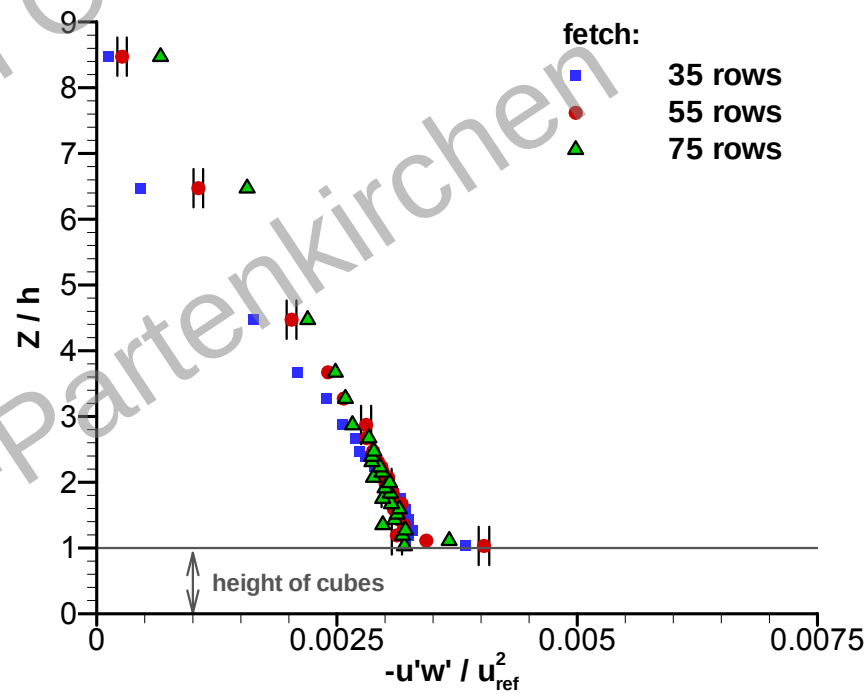
Increase of fetch

Aspect ratio 2

mean wind speed u



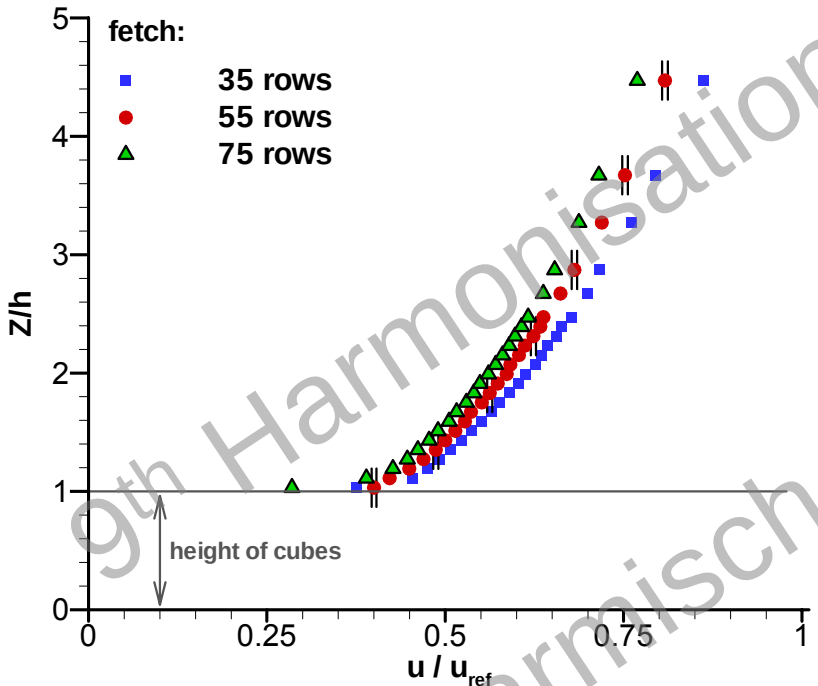
turbulent fluxes u‘w‘



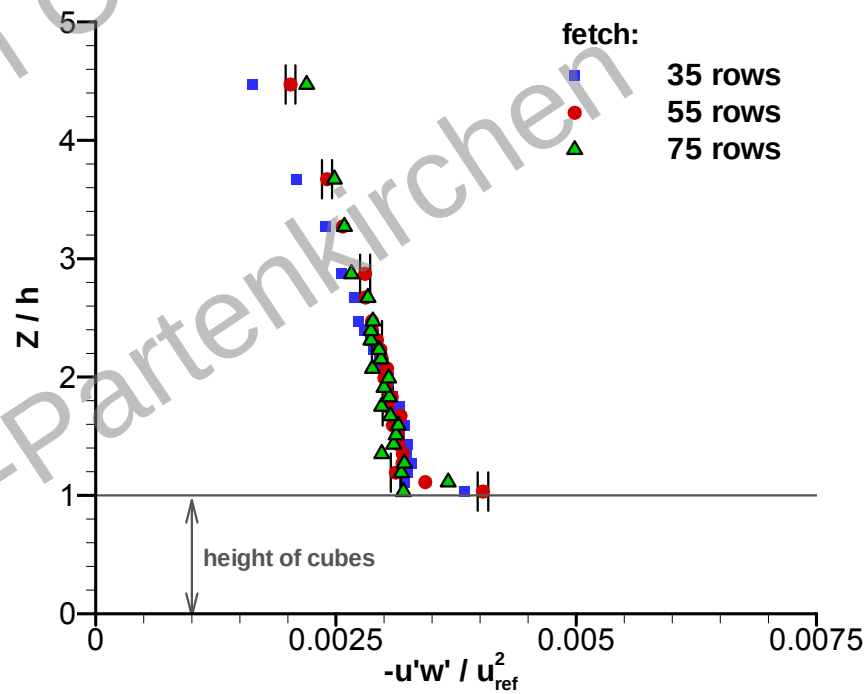
Increase of fetch

Aspect ratio 2

mean wind speed u

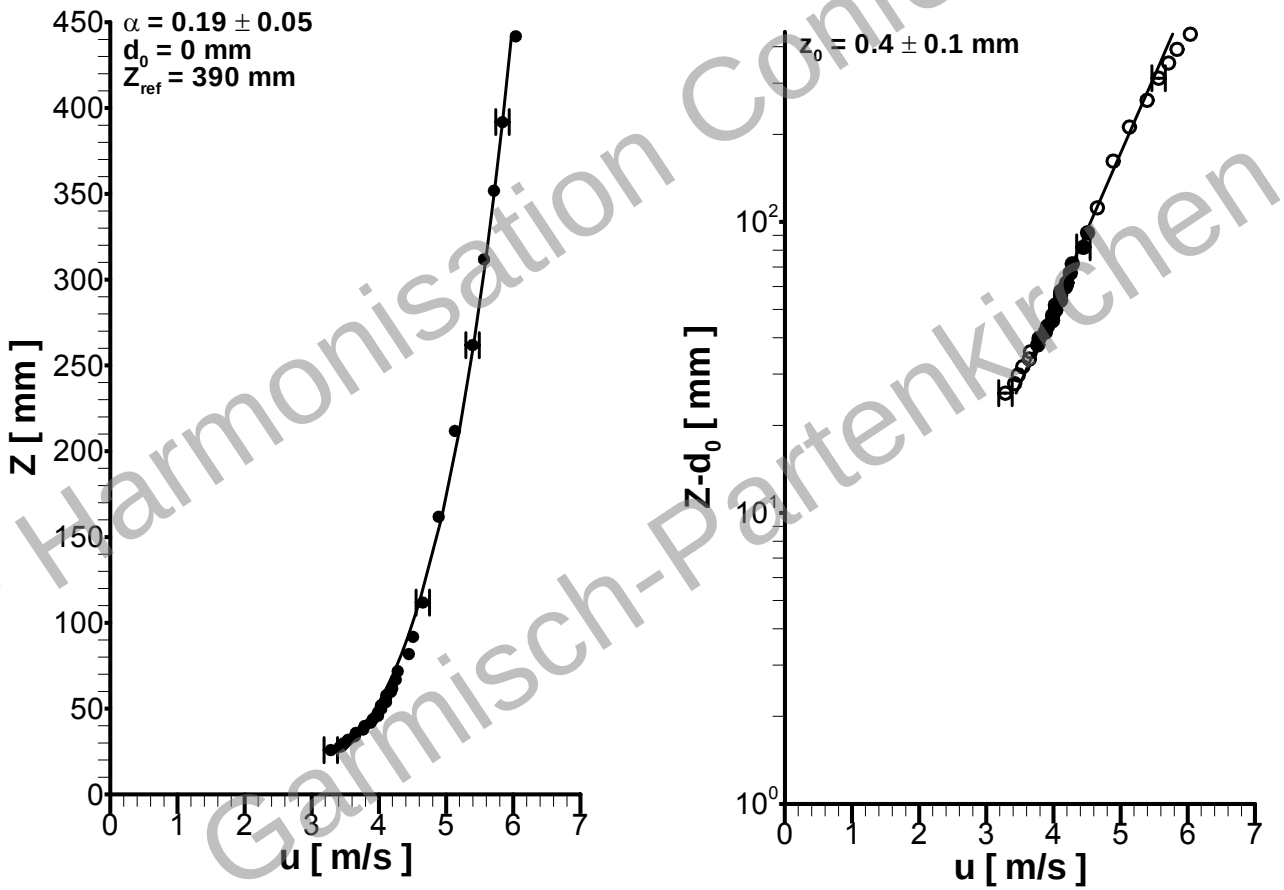


turbulent fluxes u‘w‘



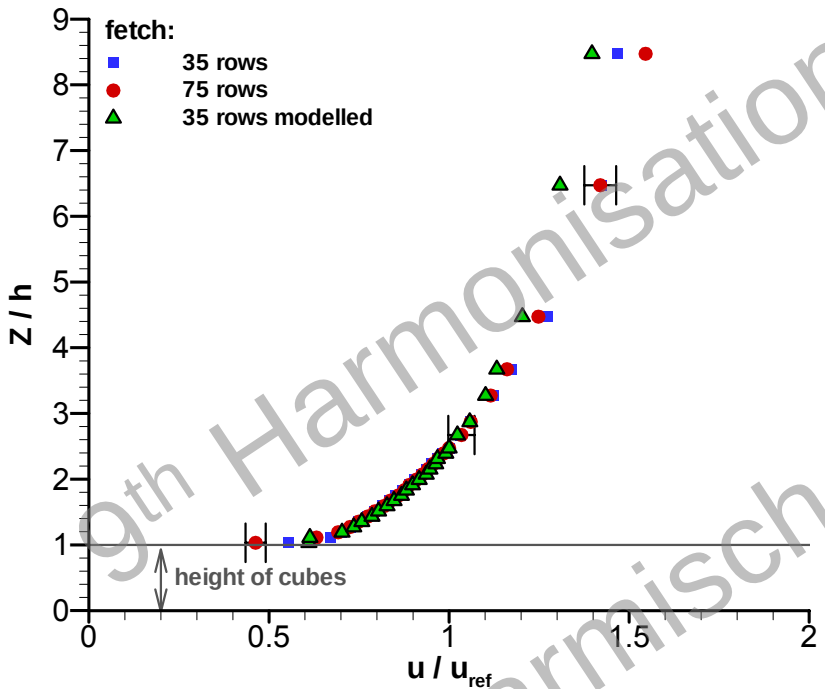
Modelled approach flow

profile exponent α = 0.19 VDI roughness class: rough/moderate rough

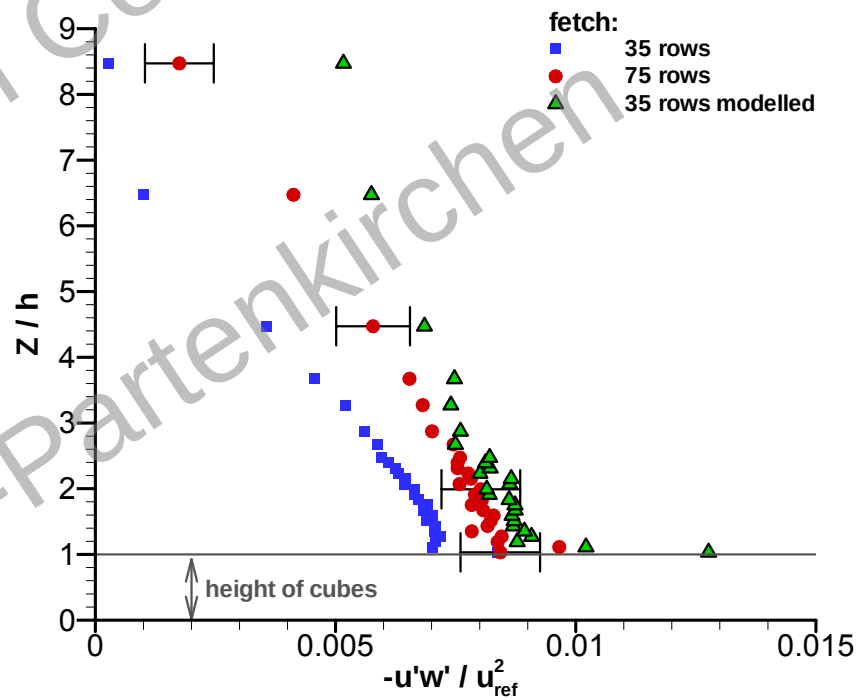


Modelled/no modelled flow

mean wind speed u



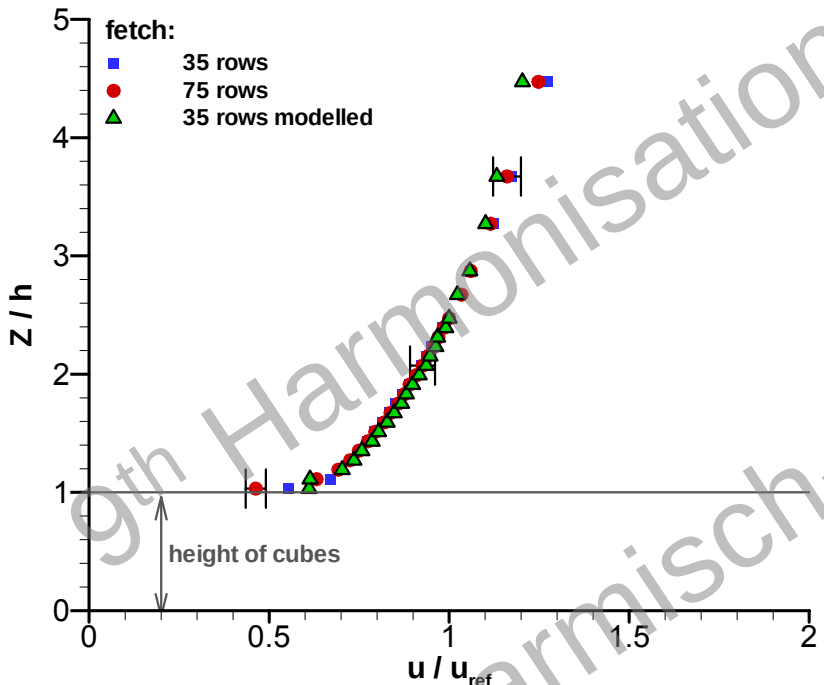
turbulent fluxes u‘w‘



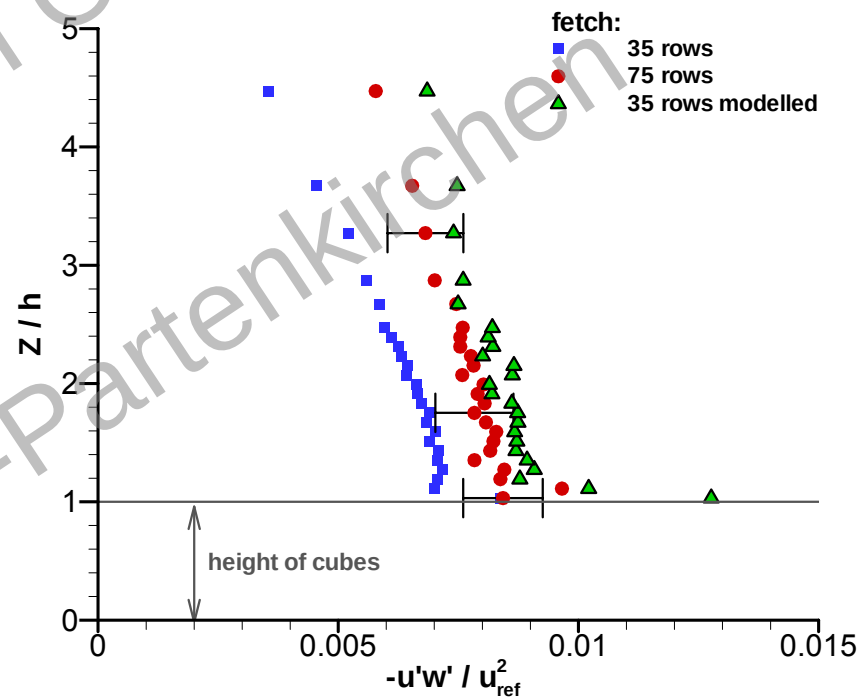
u_{ref} at z = 2.4h !

Modelled/no modelled flow

mean wind speed u



turbulent fluxes u‘w‘



u_{ref} at z = 2.4h !

Summary

- Dense packed homogeneous roughness acts like a rough surface
- Higher aspect ratios: influence of individual obstacles increases
- Extension of roughness sublayer seems not to be a function of aspect ratio.

- Modelled scaled boundary layer approach flow compensates fetch.

Future plans

- More measurements with higher resolution needed to confirm the results
  - New measuring method PIV
  - more variations

- Adjust the modell to more realistic conditions
  - Non uniform roughness height
  - Turbulence generating features like roofs
  - etc. .....

Acknowledgements

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Thank you for your attention !