Simulating micro-scale atmosphere at Mount Sakurajima

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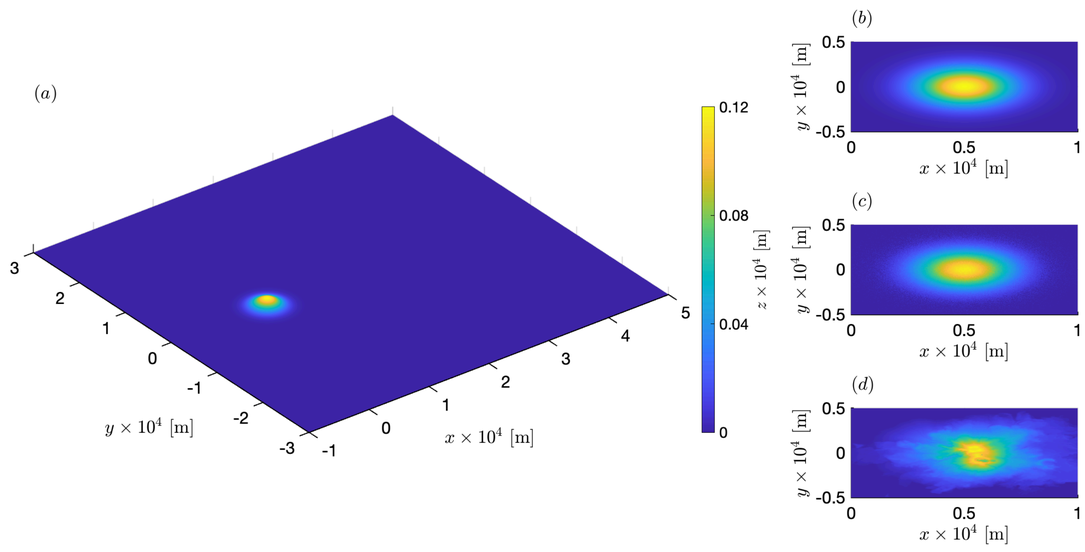
Background

Recently, many countries faced the severe weather conditions, such as typhoon and heavy rainfall.

At the same time, topography exerts a profound influence on atmospheric flows at the micro-scale (~20 m scale), shaping turbulence generation and the occurrence of local instabilities over terrains (Rohanizadegan et al. 2023).

Here, we investigate the impacts of small-scale topographies:
(i) an idealized smooth Gaussian mountain (Smooth case or Sm)
(ii) the same mountain perturbed by ±10~m surface roughness (Rough case or Ro)
(iii) a real mountain, Mount Sakujima, Japan (5-10m DEM, Sakurajima case or Sa)



Methodology

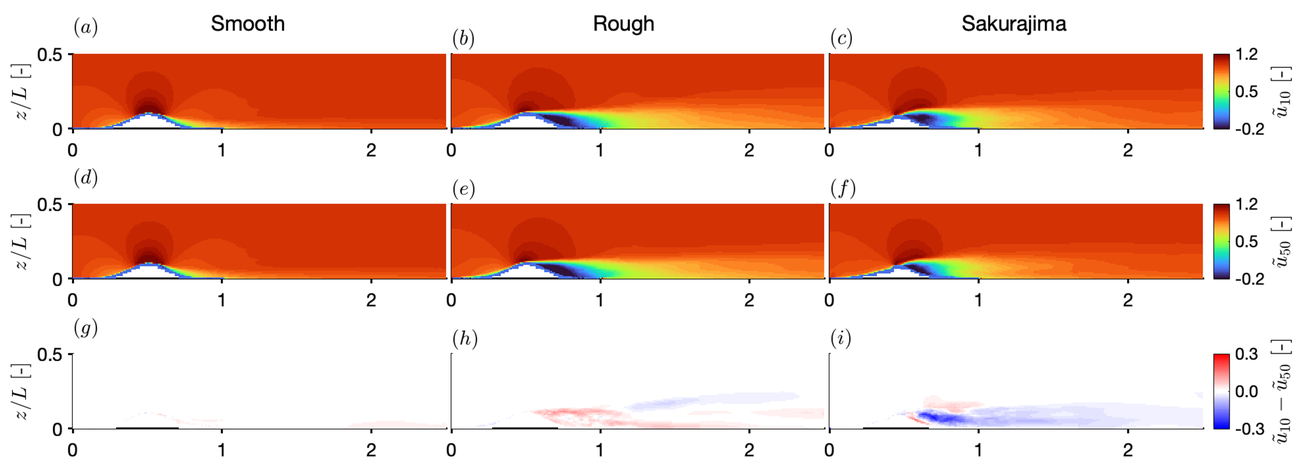
Name	structure	U_{inf} [m/s]	min. grid [m]	# of cubes	# of CPUs	NH
Sm10	Smooth	10.0	9.8	20002	10001	152460
Sm50	Smooth	50.0	9.8	20002	10001	152460
Ro10	Rough	10.0	9.8	20758	10379	158400
Ro50	Rough	50.0	9.8	20758	10379	158400
Sa10	Mt. Sakurajima	10.0	9.8	18059	11750	178922
Sa50	Mt. Sakurajima	50.0	9.8	18059	11750	178922

For our computation, we applied a computational mechanics solver known as CUBE, which is a generalized multiphysics software for massively parallel simulations (Jansson et al., 2019)

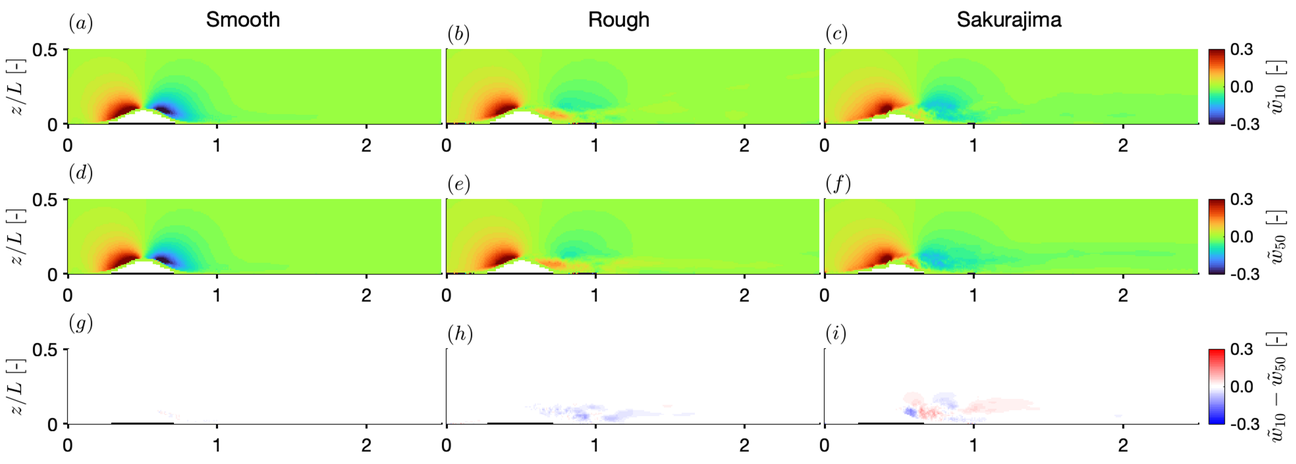
We examine above three configurations under two inflow wind speeds which is observed in Mount Sakurajima:
U_{inf} = 10 [m/s] (moderate wind conditions, seasonal wind)
U_{inf} = 50 [m/s] (strong wind conditions, typhoon wind)

Results

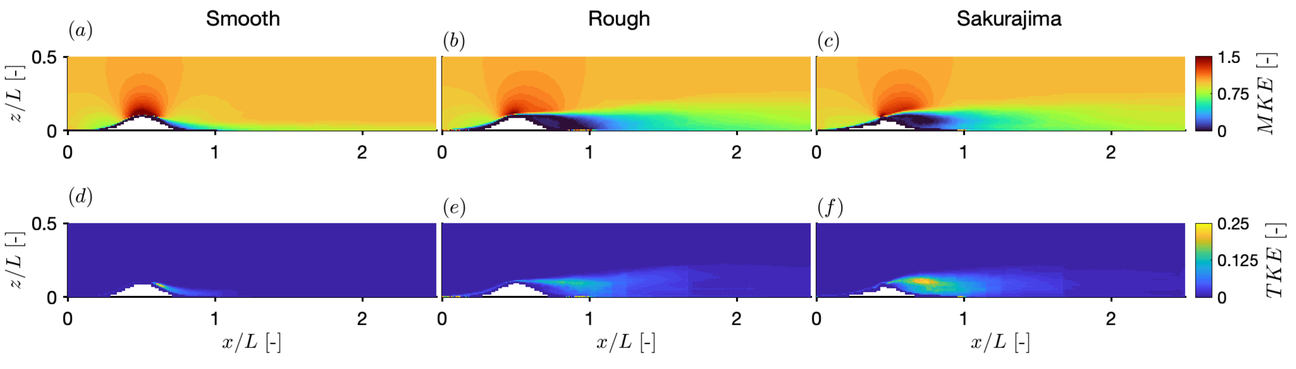
Horizontal wind



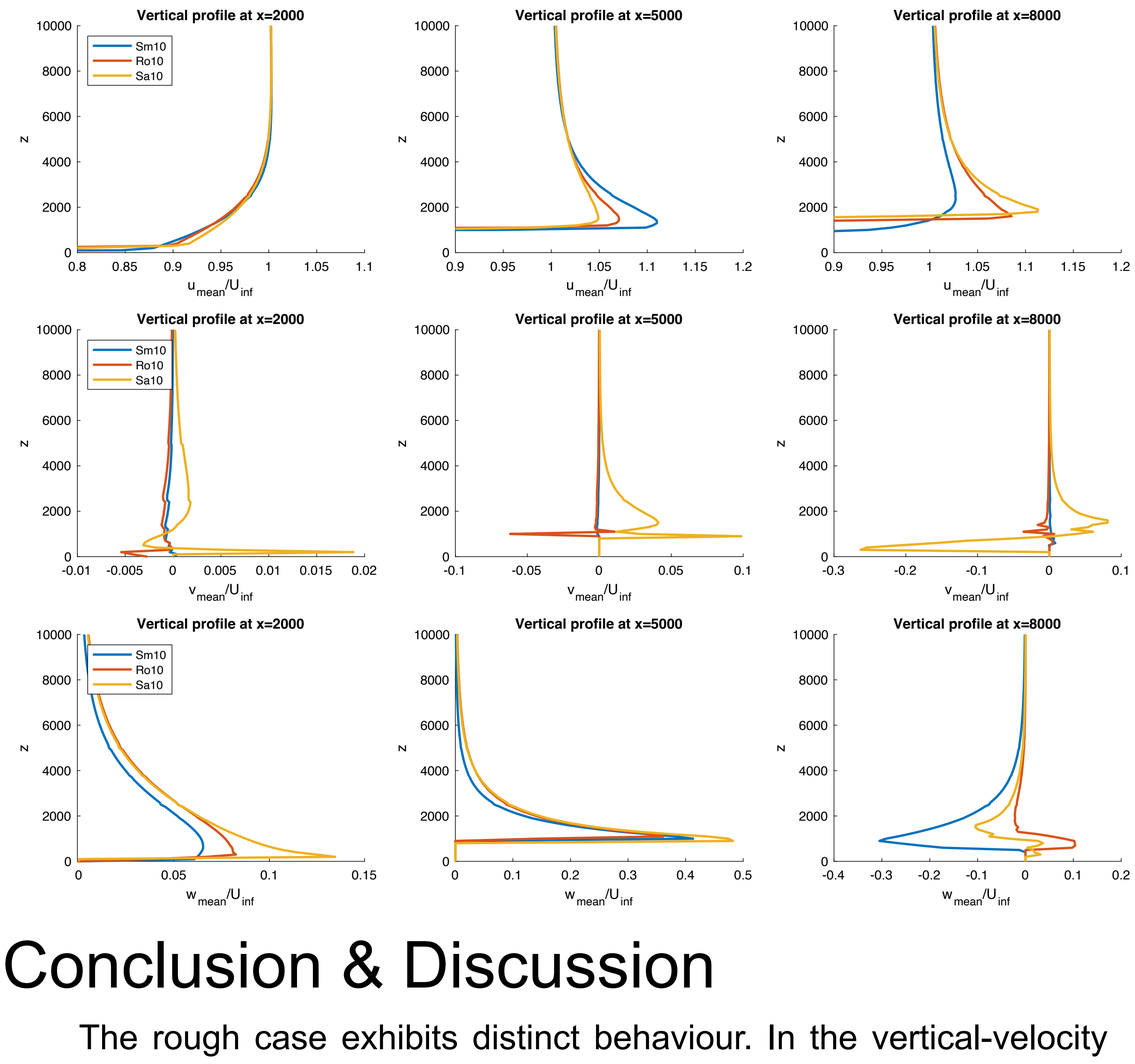
Vertical wind



Mean kinetic energy & turbulent kinetic energy



Vertical profiles



Conclusion & Discussion

The rough case exhibits distinct behaviour. In the vertical-velocity field, upward velocity emerges over the surface and is followed by an unsteady region downstream. The Sakurajima result shows qualitatively similar horizontal and vertical velocity structures, resembling those of the rough case

MKE supports the use of a simple roughness-based normalization for application to real topography, whereas TKE requires another implementation.

Acknowledgements
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References

Rohanizadegan, M., Petrone, R. M., Pomeroy, J. W., Kosovic, B., Muñoz-Esparza, D., & Helgason, W. D. (2023) *Earth and Space Science*
Jansson, N., Bale, R., Onishi, K., & Tsubokura, M. (2019) *The international journal of high performance computing applications*