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Horizontal grid spacing in Terra Incognita on mesoscale-microscale coupling

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Evaluation of the Impact of Horizontal Grid Spacing in Terra Incognita on Coupled Mesoscale–Microscale Simulations Using the WRF Framework

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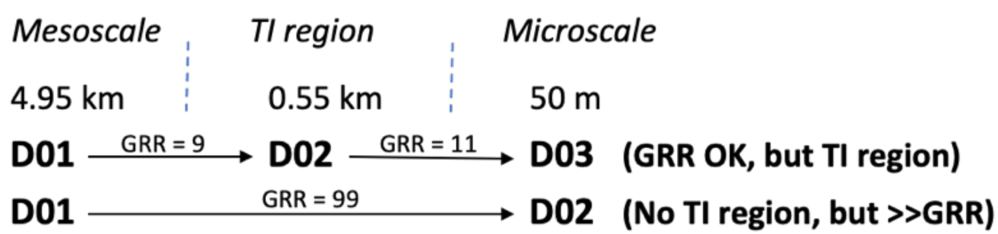
Motivations

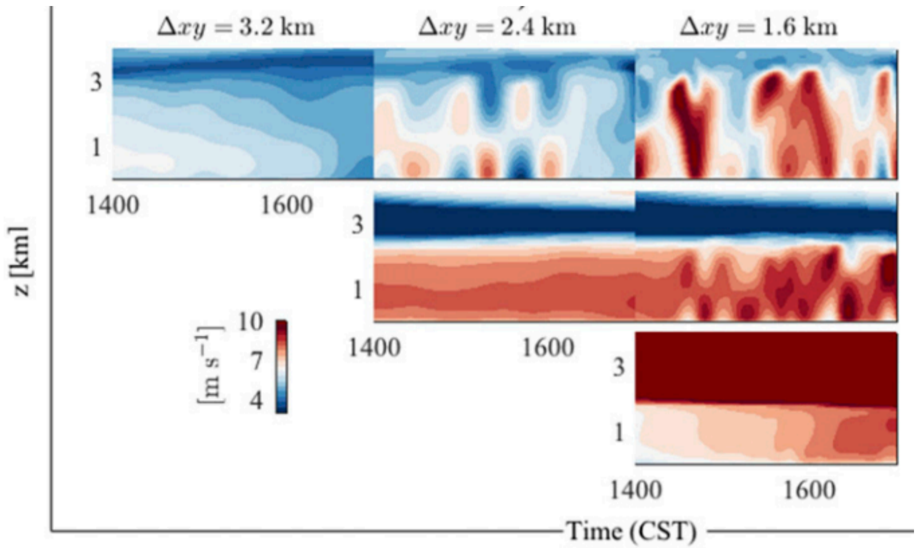
- In Terra Incognita (TI) region, the modeling of turbulence using mesoscale mode (1D vertical) or microscale mode (3D) may not work properly
- However, we cannot skip TI region in coupling through nesting due to large grid refinement ratio (GRR)

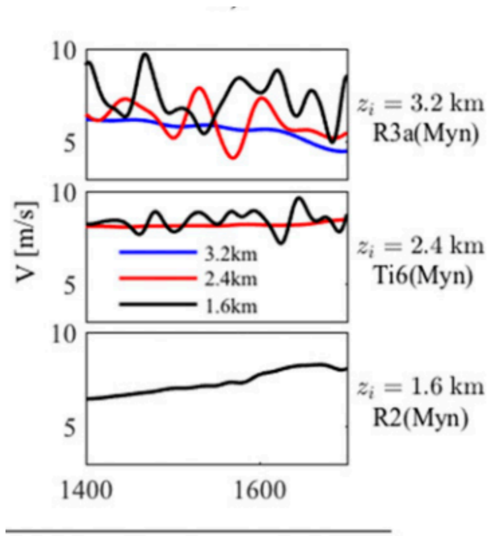


- What happens to the microscale domain (D03) result when forced by domain D02 with horizontal grid spacing within TI region?

Boundary-layer depth and grid spacing (hor.)

Unstable conditions



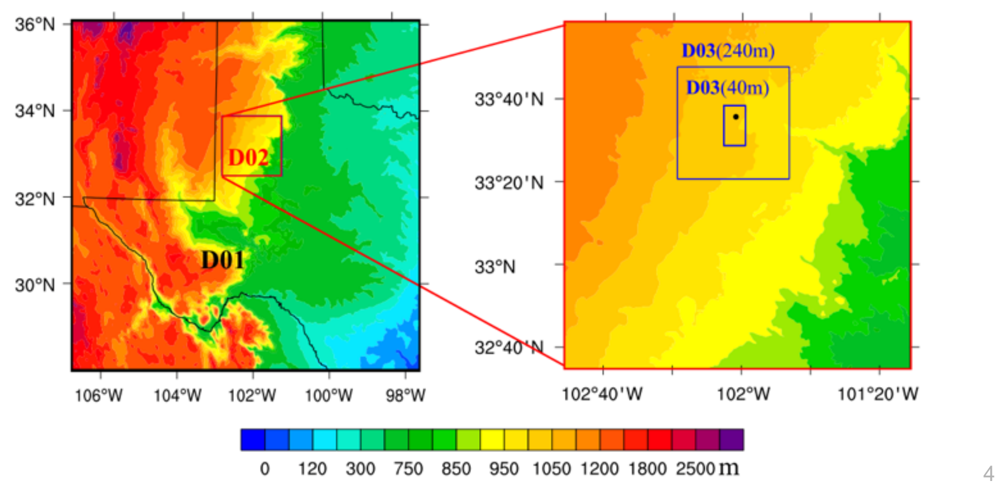


- In time-height panels (diagonal), the horizontal grid spacing (Δxy) is comparable with z_i (boundary-layer depth)
  - Velocity field is smooth
  - Minimal horizontal grid spacing needs to be at least the boundary-layer depth

Run	D01 Δxy	D01 L_x L_y	D02 Δxy	D02 L_x, L_y	D03 Δxy	D03 L_x	D03 L_y	z_i
Ti1	2.88 km	900 km	1.44 km	155 km	0.24 km	50 km	L_x	2.4 km
Ti2	3.84	900	0.96	155	0.24	50	L_x	2.4
Ti3	2.88	900	0.48	155	0.24	50	L_x	2.4
Ti4	2.56	900	0.32	155	0.04	10	18	2.4
Ti5	2.52	900	0.28	155	0.04	10	18	2.4
Ti6	2.40	900	0.24	155	0.04	10	18	2.4
Ti7	2.20	900	0.20	155	0.04	10	18	2.4

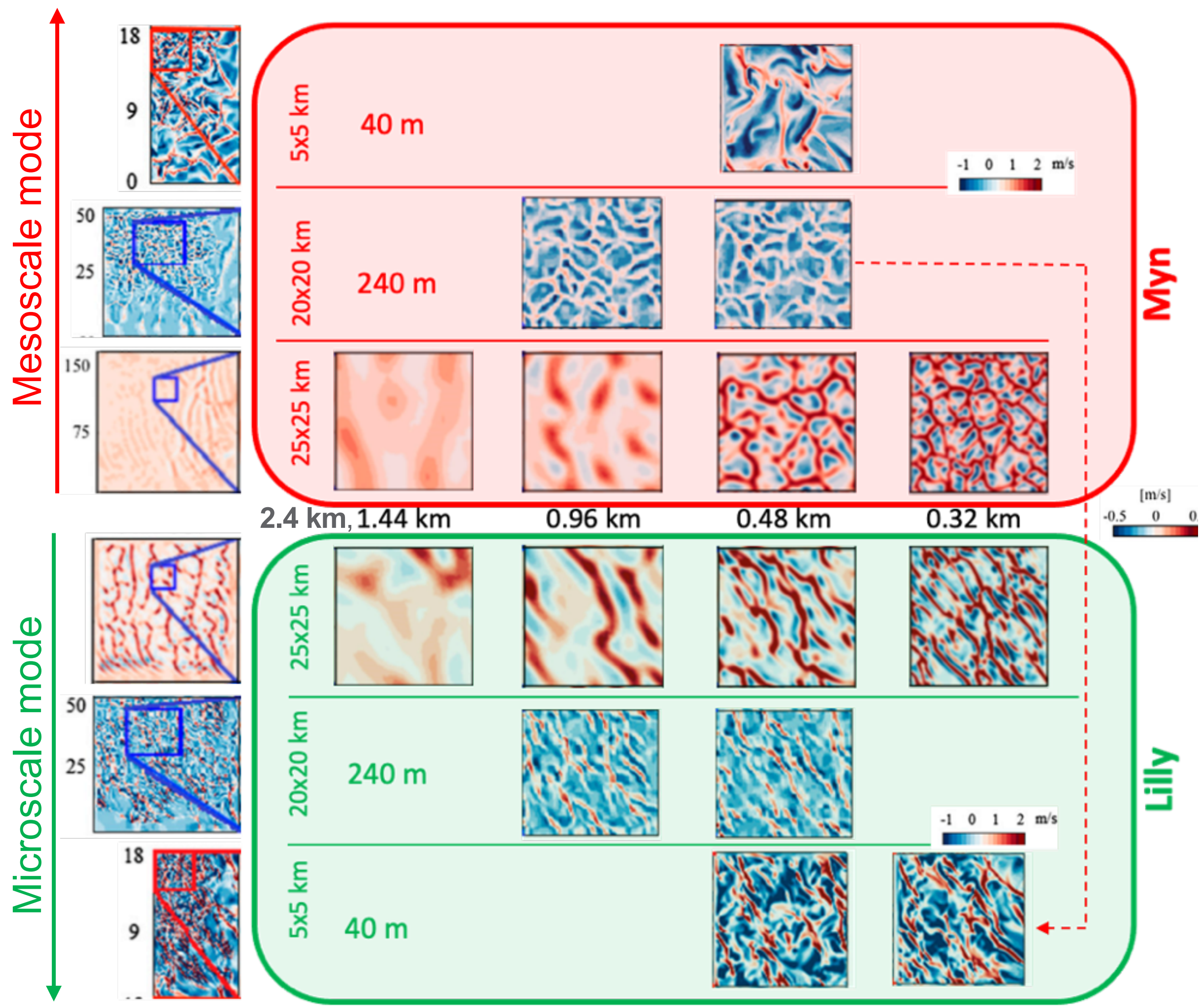
Simulations

- Ran WRF model with 7 domain configurations
  - Keeping similar domain size for D01
  - For the real-case (SWiFT site, flat terrain) with fair-weather and z_i = 2.4 km
  - Driven microscale domain D03 by D02 in TI region
  - Using turbulence model:
    - D01, mesoscale mode [Myn scheme]
    - D02 and D03, mesoscale mode [Myn scheme] and LES mode [Lilly model]
  - With no turbulence generation methods applied along the lateral boundaries

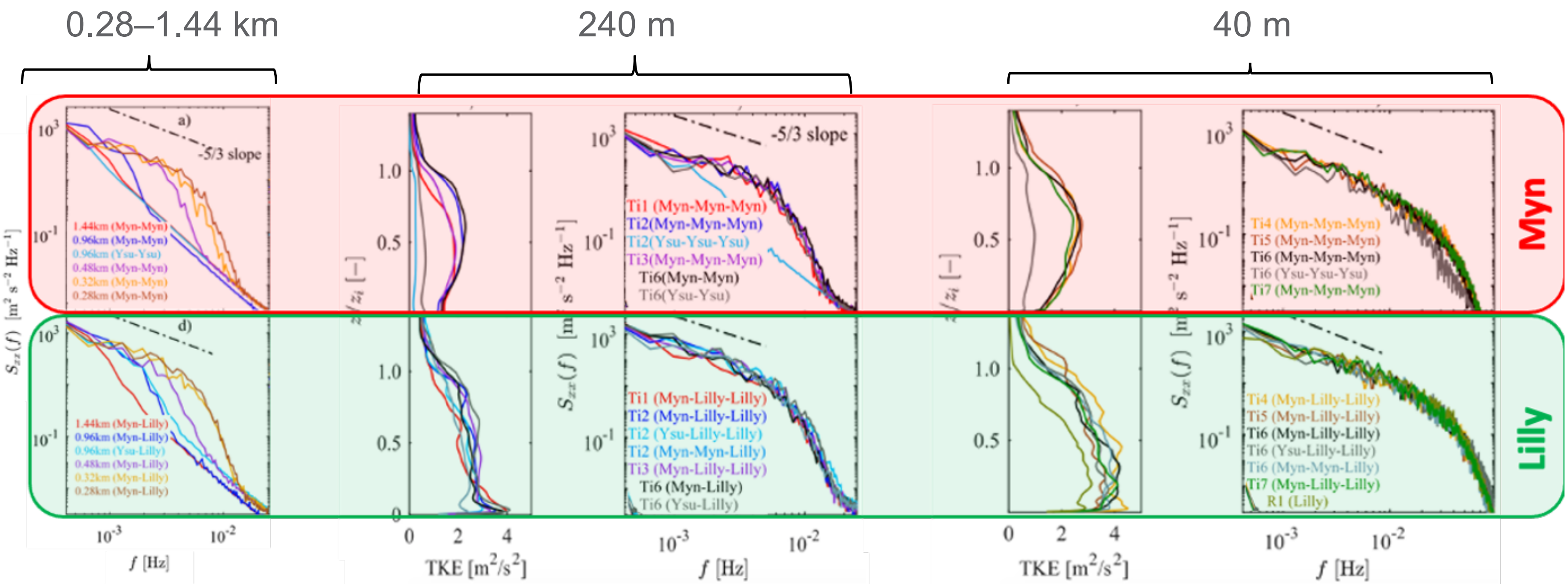


Horizontal snapshots

- Flow structures above 90 m from the surface
  - Cellular structures with Myn scheme
  - Streak-like structures with Lilly model
- Structure in D03 depends on the scheme used to model the turbulence



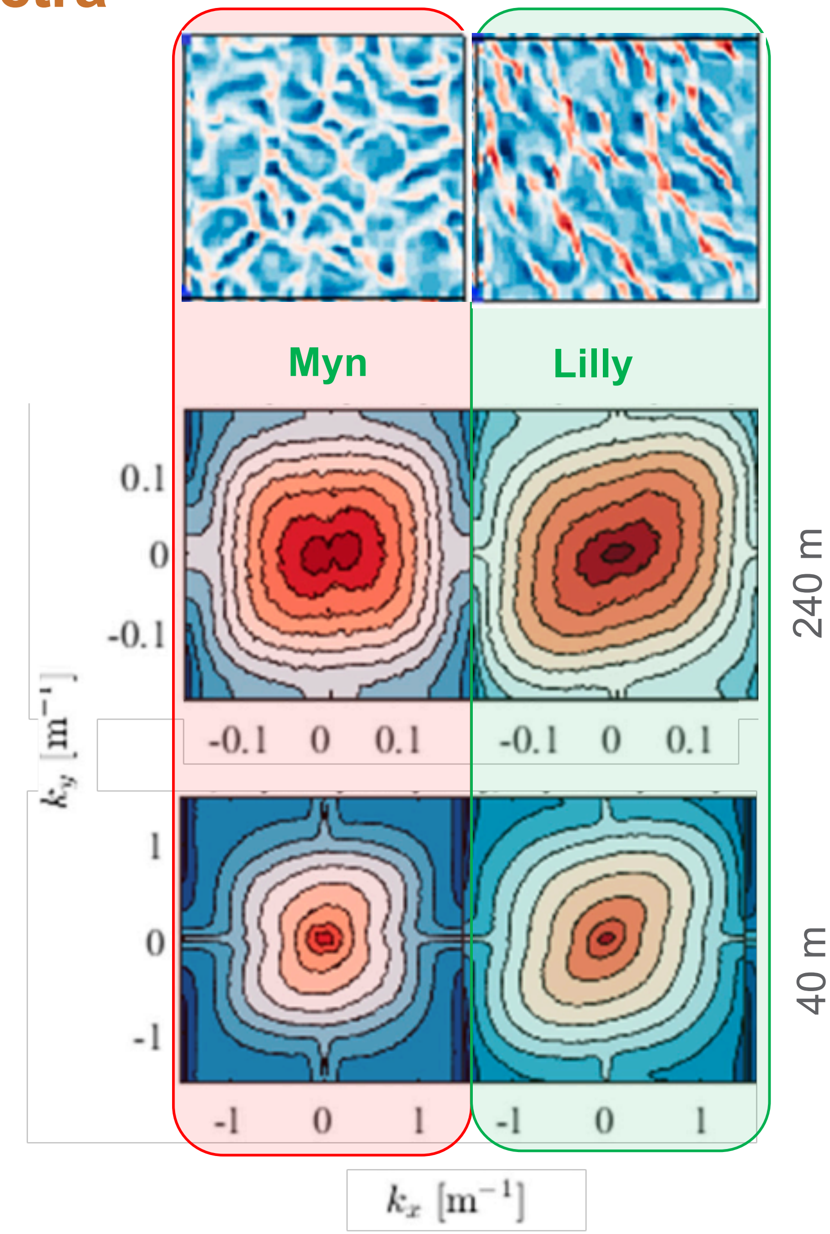
Turbulence spectra: u-velocity



- Myn scheme resolved less turbulence in the flow than the Lilly model

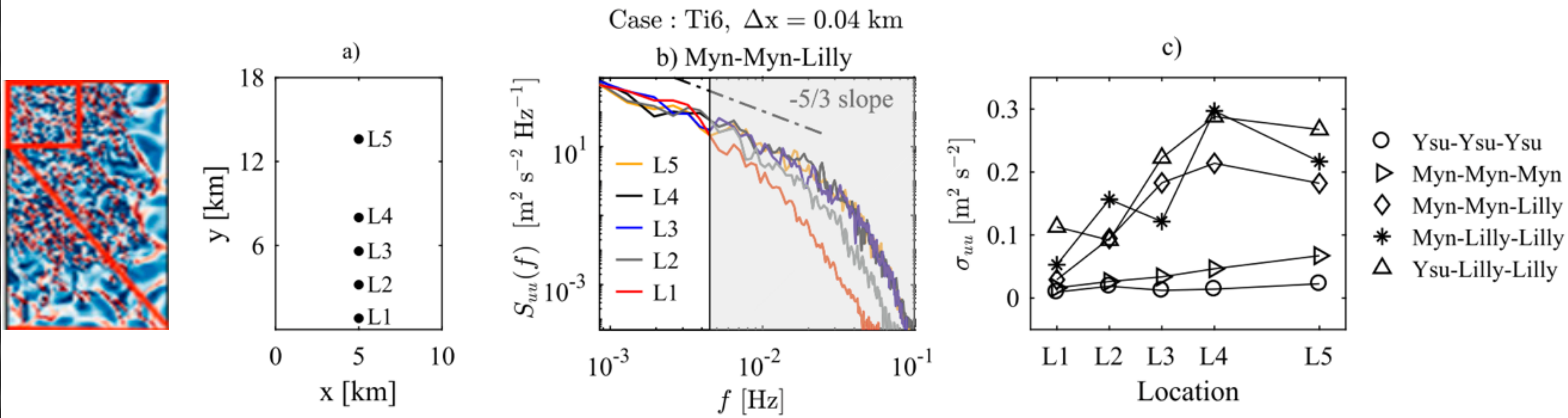
Flow structure: 2D spectra

- Lilly model (LES, microscale) squeezed the wave number diagonally
  - Due to the elongated structures near the surface layer
- For moderate wind speed and heat flux conditions in the shear dominated region, elongated structures along mean wind are common



Turbulence development

- Without perturbation, for unstable conditions
  - Fetch, after 2/5 of domain length 18 km
    - Turbulence generation plays role here



Conclusions

- Size of horizontal grid spacing in the mesoscale simulation needs at least the boundary-layer depth
- The flow structures in nested microscale domain D03 under unstable condition depend
  - On the turbulence model used in the microscale domain (D03)
  - Not on the type of turbulence model and size of grid horizontal spacing used in the driving domain (D2)
    - Horizontal grid spacing impacts on fetch