Scale Interaction in the Simulation of Boundary-Layer Clouds

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Motivation

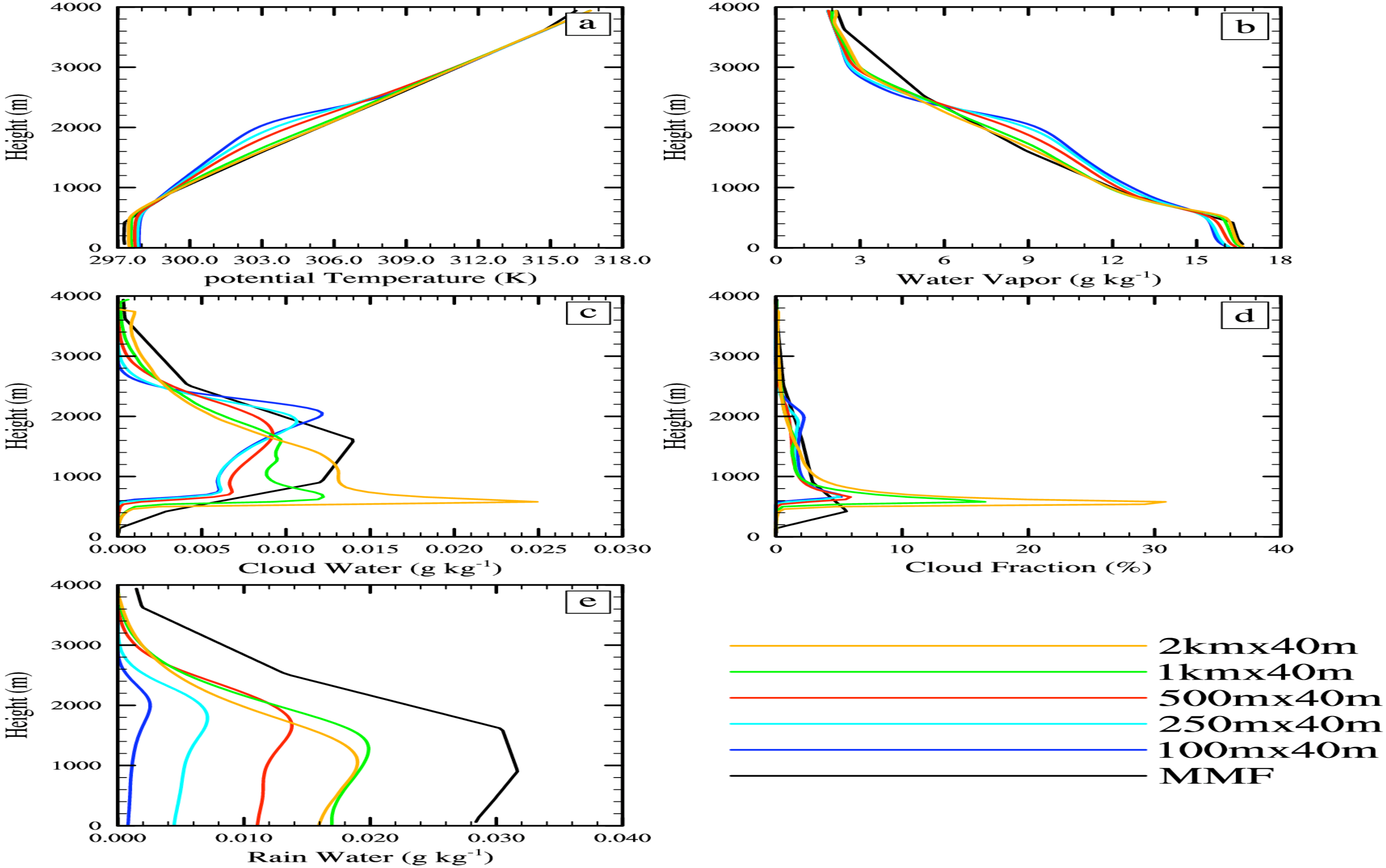
- Investigate how and why the results are degraded when the resolution decreases for the major GCSS cases
- Explore the relative importance of buoyancy and shear production, and dissipation in TKE budget since TKE equation is needed in most PBL parameterizations
- Diagnose scale interactions in different simulations
- Evaluate different PBL parameterizations

Diagnostic Method

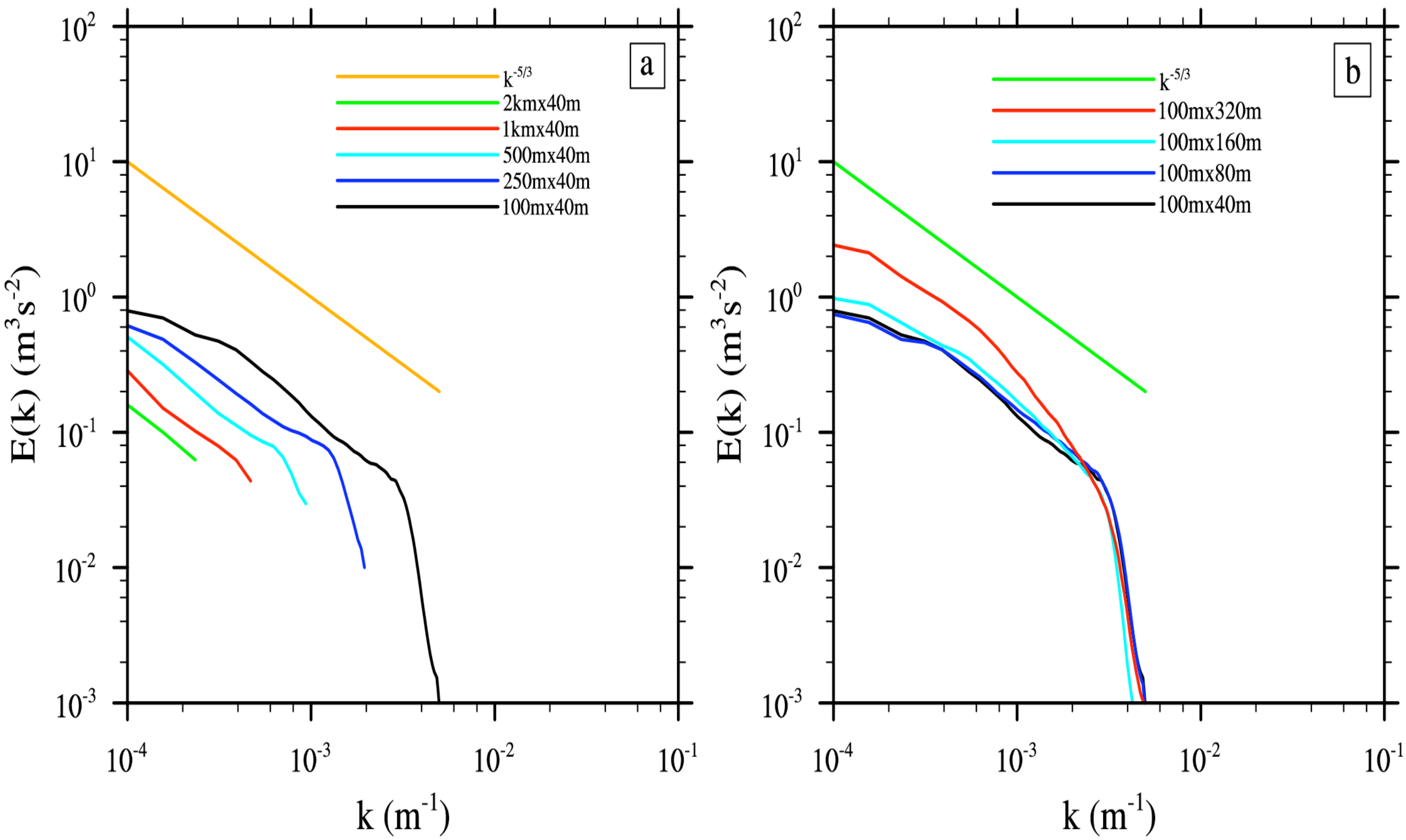
- Use Ormsby filter to separate different scales in the benchmark simulations and the results are used to compare with coarse grid-spacing runs
- Diagnose different terms in the TKE equation using the filtered and unfiltered variables. Interaction between different scales can be found using the following formula. The last two terms represent scale interactions.

$$\overline{w\theta_v} = \overline{w''\theta_v''} + \overline{w^*\theta_v^*} + \overline{w''\theta_v^*} + \overline{w^*\theta_v''}$$

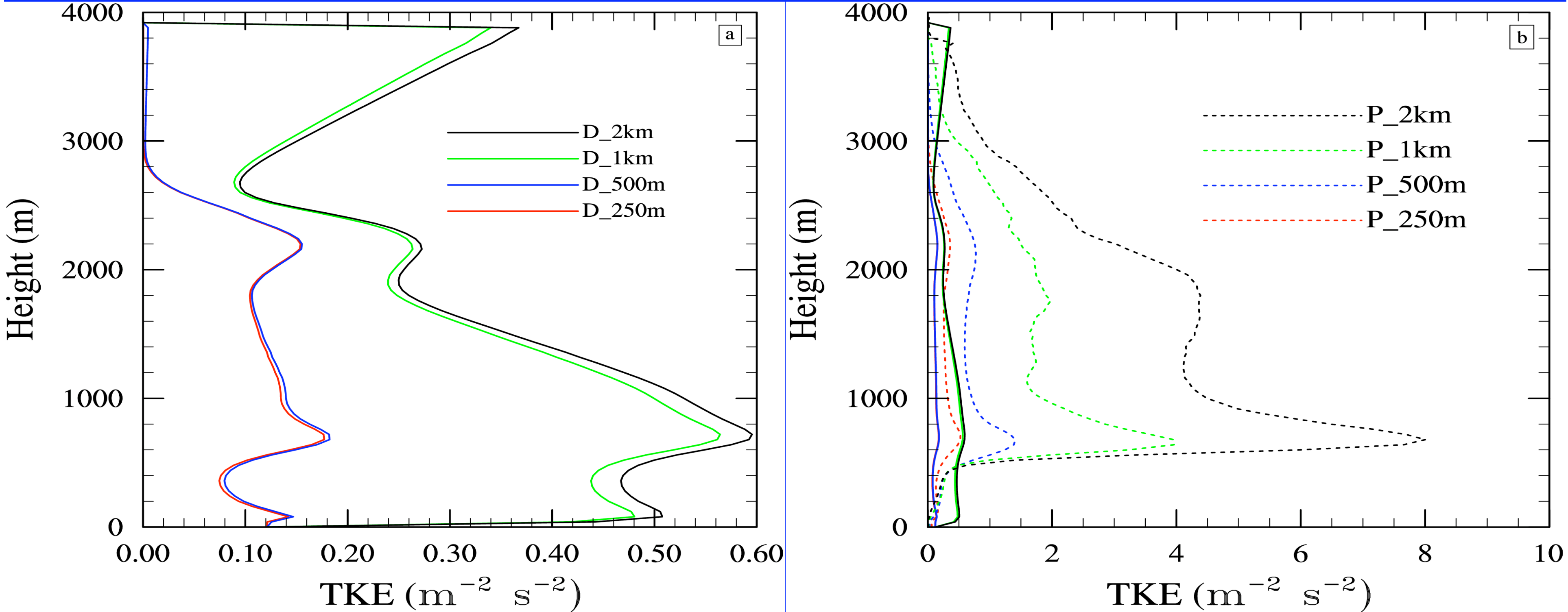
Resolution Dependence for RICO



Power Spectra of E at Cloud base

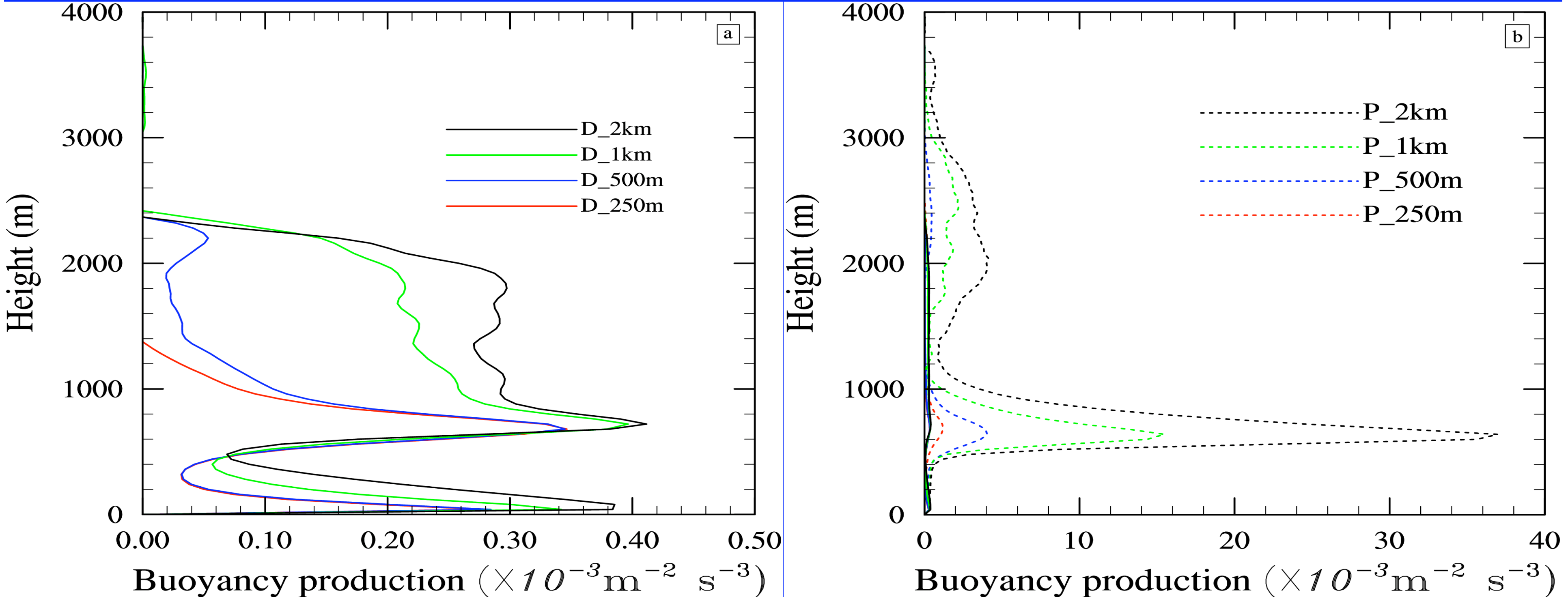


Diagnosed and Parameterized E



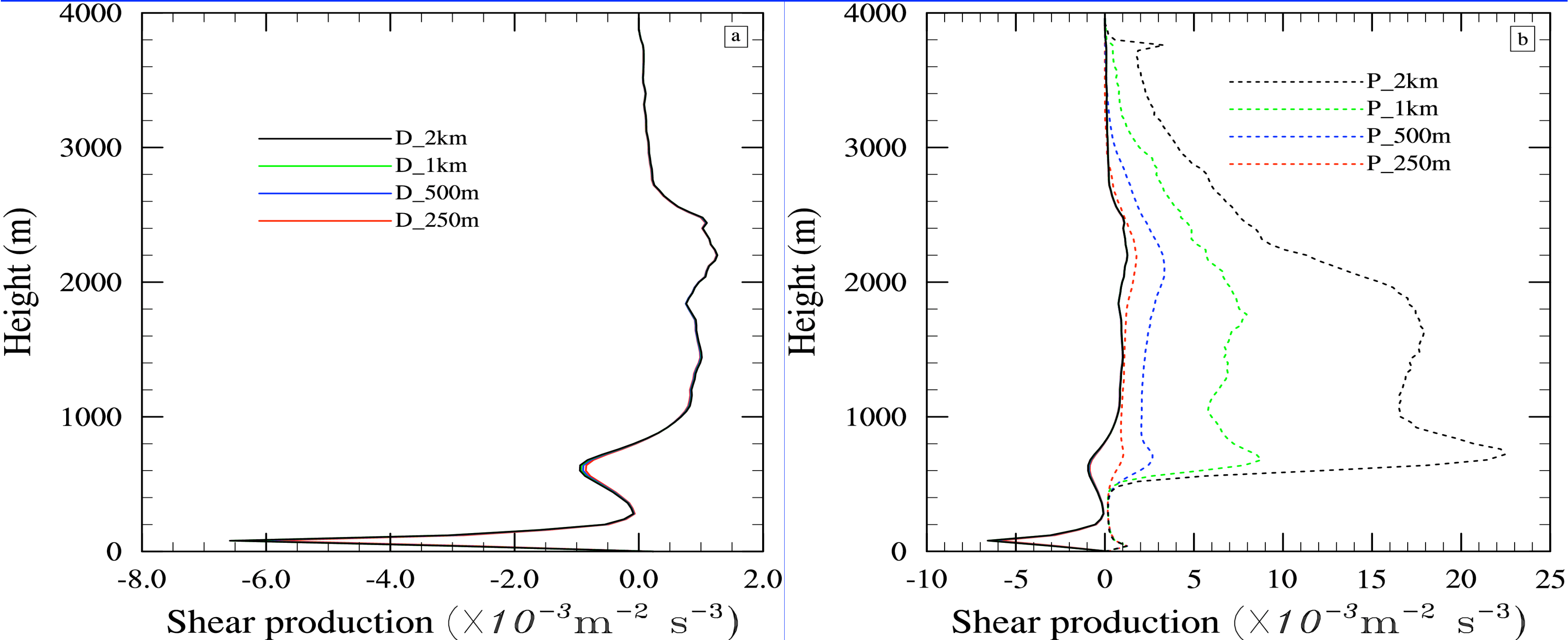
- D_ represents diagnosed subgrid-scale variables (TKE) from LES, while P_ represents parameterized variables by a LOC scheme (HOC will be investigated in future).
- How and why LOC/HOC scheme is wrong/right? What kind of improvement is needed?

Diagnosed and Parameterized Buoyancy Production



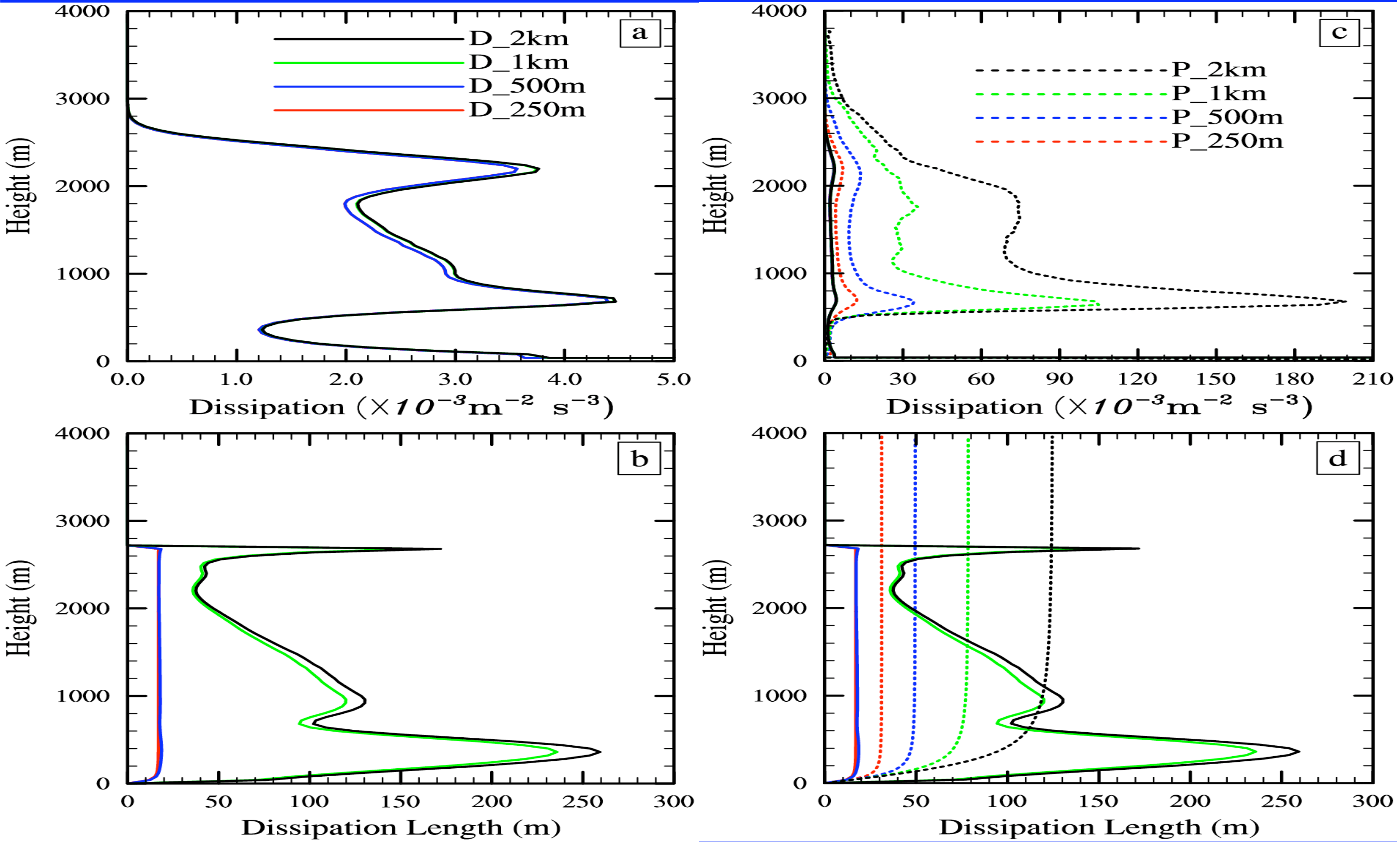
- There is a large gap of buoyancy production between the scales of 500 m and 1 km in cloud layer because the sizes of large eddies are between 500 m and 1km.
- LOC scheme has no buoyancy production below cloud layer, but too much buoyancy production in cloud layer

Diagnosed and Parameterized Shear Production

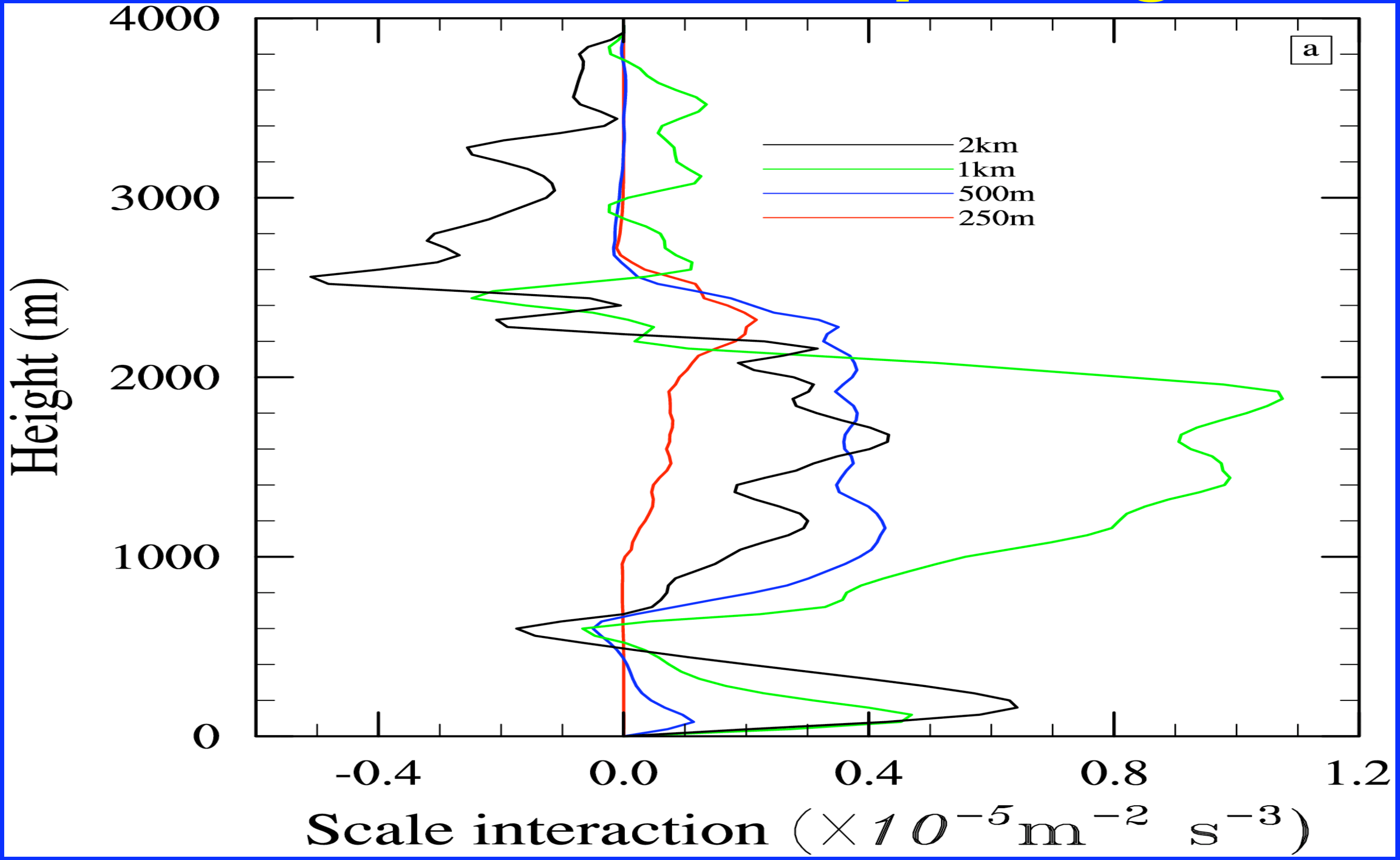


- Shear production is mainly due to scale less than 250 m. Negative production in subcloud layer means downscale energy transport.
- Shear production in cloud layer contributes to the large energy in cloud layer for LOC parameterization

Diagnosed and Parameterized Dissipation & Length



Scale Interaction Strength of Different Grid-spacing



- Scale interaction becomes strong when scale is larger than 500 m.
- Cloud layer and subcloud layer are separated.

Discussions

- There is a large energy gap between the scales of 500 m and 1 km caused by buoyancy production of large eddies. The diagnosed dissipation length scale also increases sharply from 500 m to 1km.
- The scale interaction bewteen sugrid-scale and grid-scale is weak for 250 m resolution, but is strong for coarser resolutions.
- The power spectra of the resolved scale motion largely follow the -5/3 slope for various resolutions. So the degrading of results by the coarse resolution is mainly due to the subgrid-scale parameterization.
- Buoyancy and shear productions are the main contributors to the deviation of the parameterization of the subgrid-scale processes. The dissipation length-scale of a simple scheme is relatively reasonable.

Thank You!