Multiple equilibria in simulating stratocumulus-capped boundary-layers

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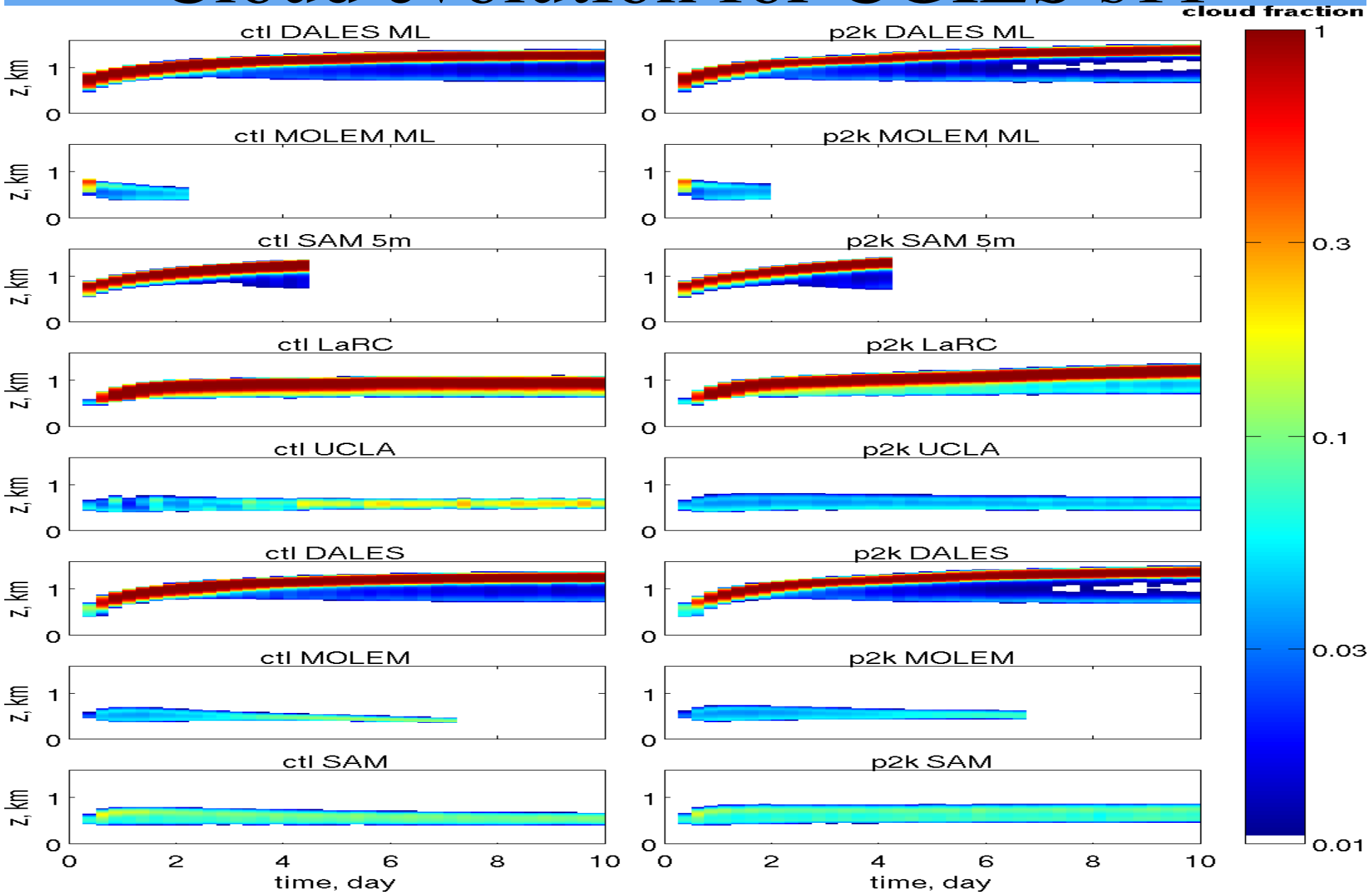
Thanks to Drs. Bretherton, Blossey, Zhang, and Stevens for useful discussions and suggestions

Introduction

- Multiple equilibira found for CGILS s11 and GCSS DYCOM intercomparison cases (Bretherton et al. 2010)
- Initial state and cloud rain droplet number concentration are found to important to determine the stable state
- This study will discuss on the roles of model advection scheme, subgrid-scale, and microphysics schemes

Cloud evolution for CGILS s11



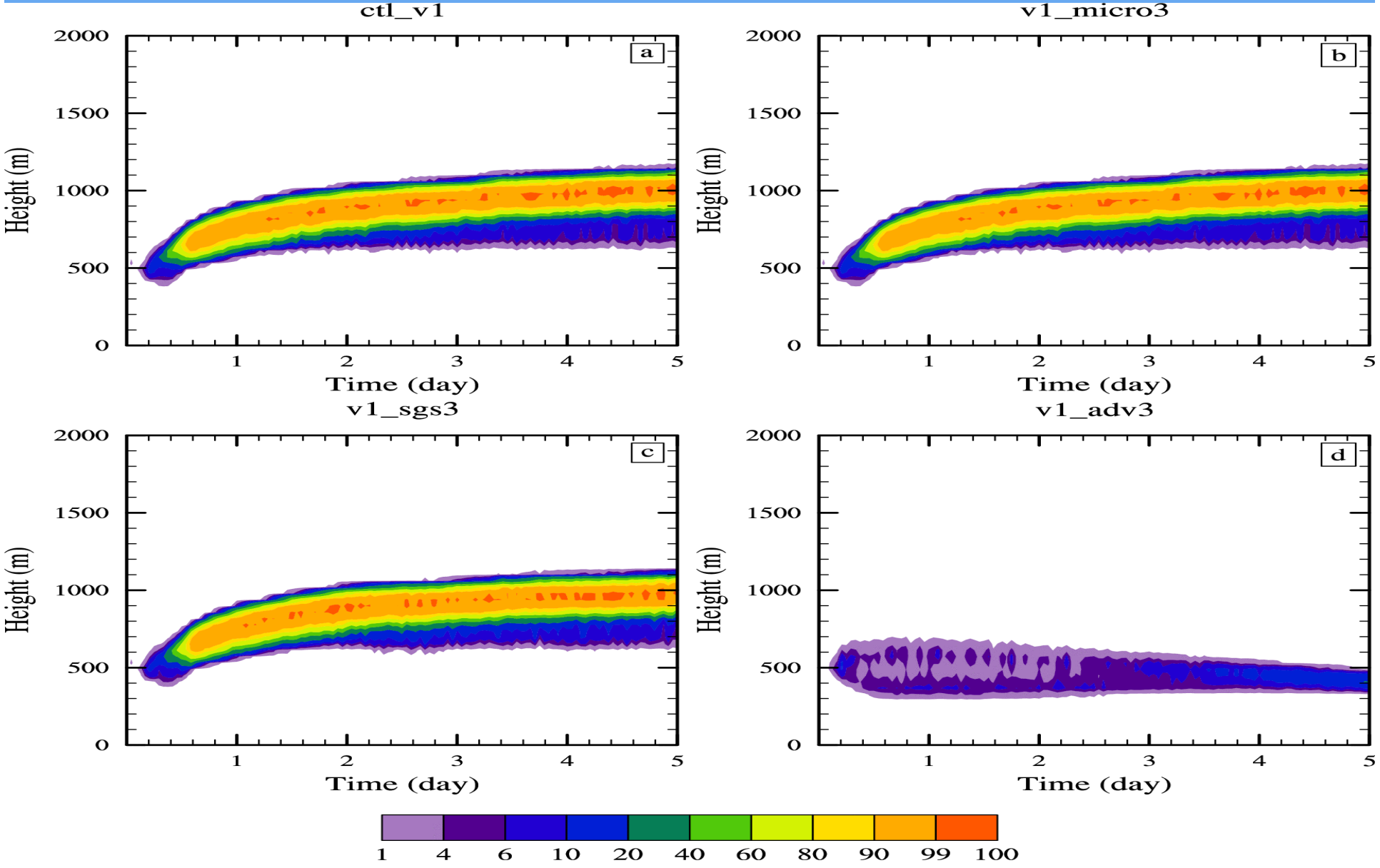
UCLA-LES version 1 and 3

- Advection scheme: v1 has a fourth-order centered difference scheme for momentum, and upwinding method for scalars, v3 has a standard fourth-order Runge-Kutta method
- Subgrid scale scheme: differences between v1 and v3 in calculating mixing length scale and cofficients
- Microphysics scheme: v1 turned on cloud droplet sedimentation, v3 turned off

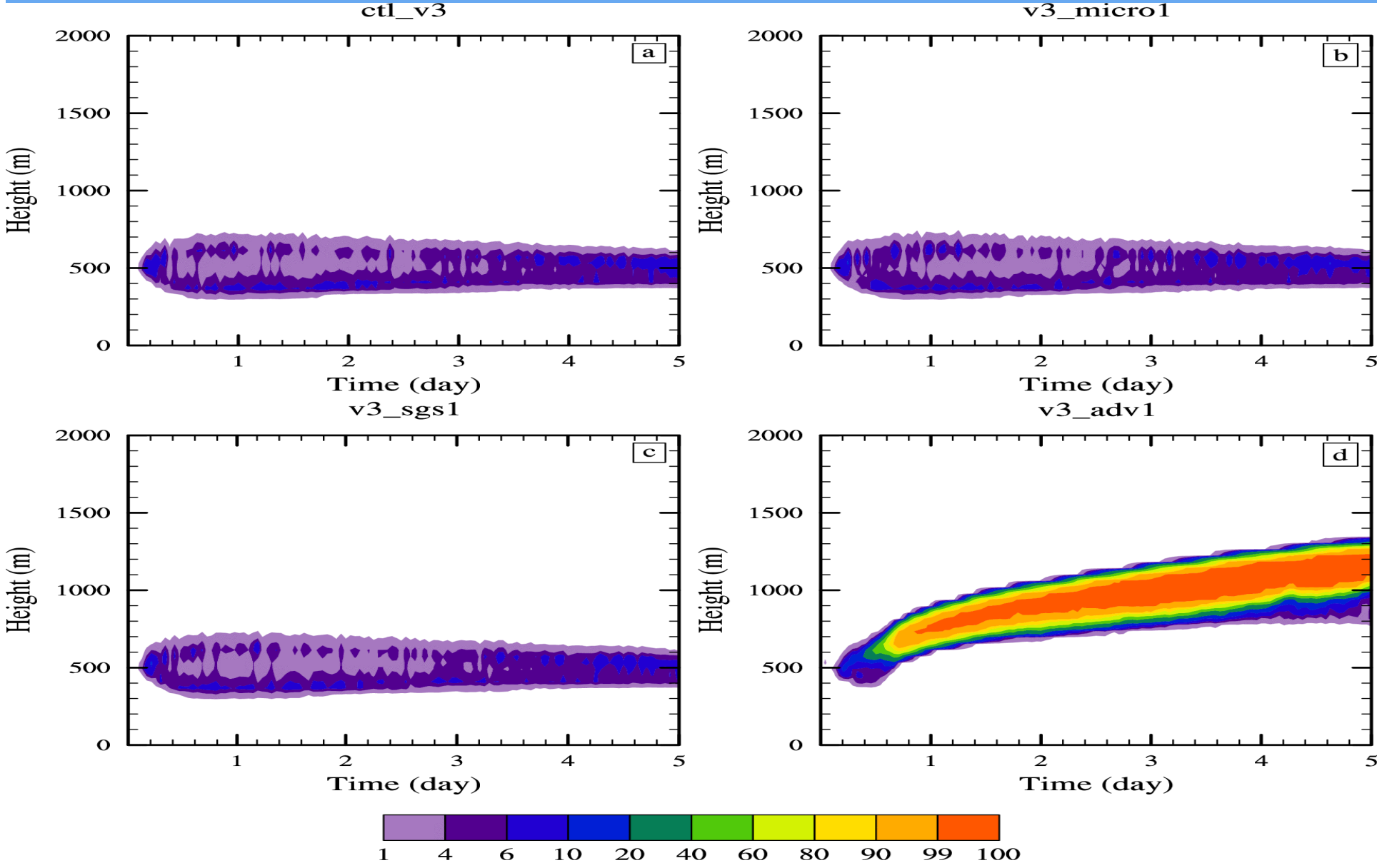
Experiment Design

- Standard initial condition and forcing for CGILS s11 case.
- Vertical grid-spacing of 25 m from surface to 2.5 km stretched to 60 m at 3 km; Horizontal grid-spacing of 50 m with domain size of 4 km.
- Integration time: five days to steady state
- Eight experiments: UCLA-LES version 1 (v1), UCLA-LES version 3 (v3), v1 with SGS of v3 (v1_sgs3), v1 with microphysics of v3 (v1_mcr3), v1 with advection scheme of v3 (v1_adv3), v3 with SGS of v1 (v3_sgs1), v3 with microphysics of v1 (v3_mcr1), and v3 with advection scheme of v1 (v3_adv1).

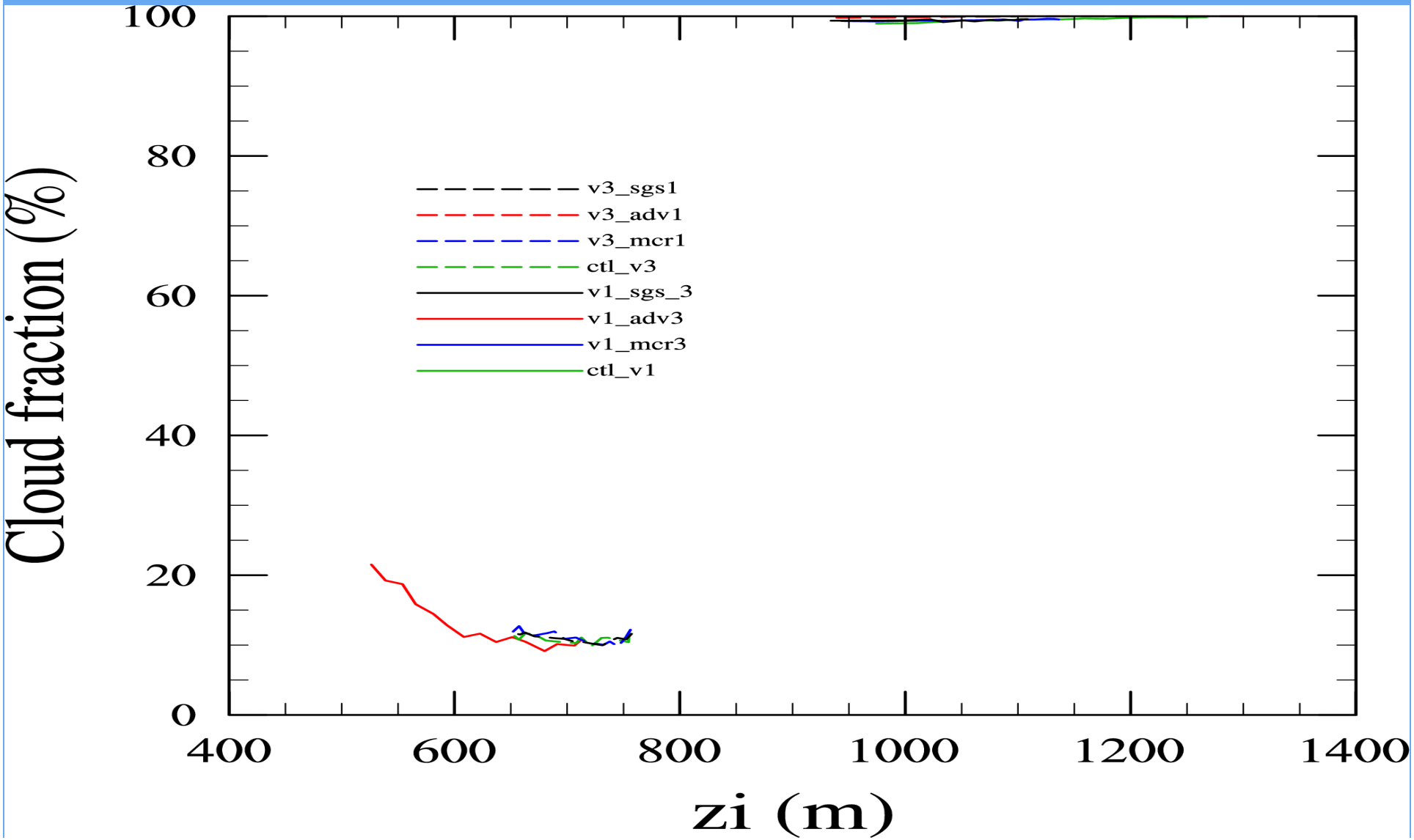
Cloud Evolution for V1



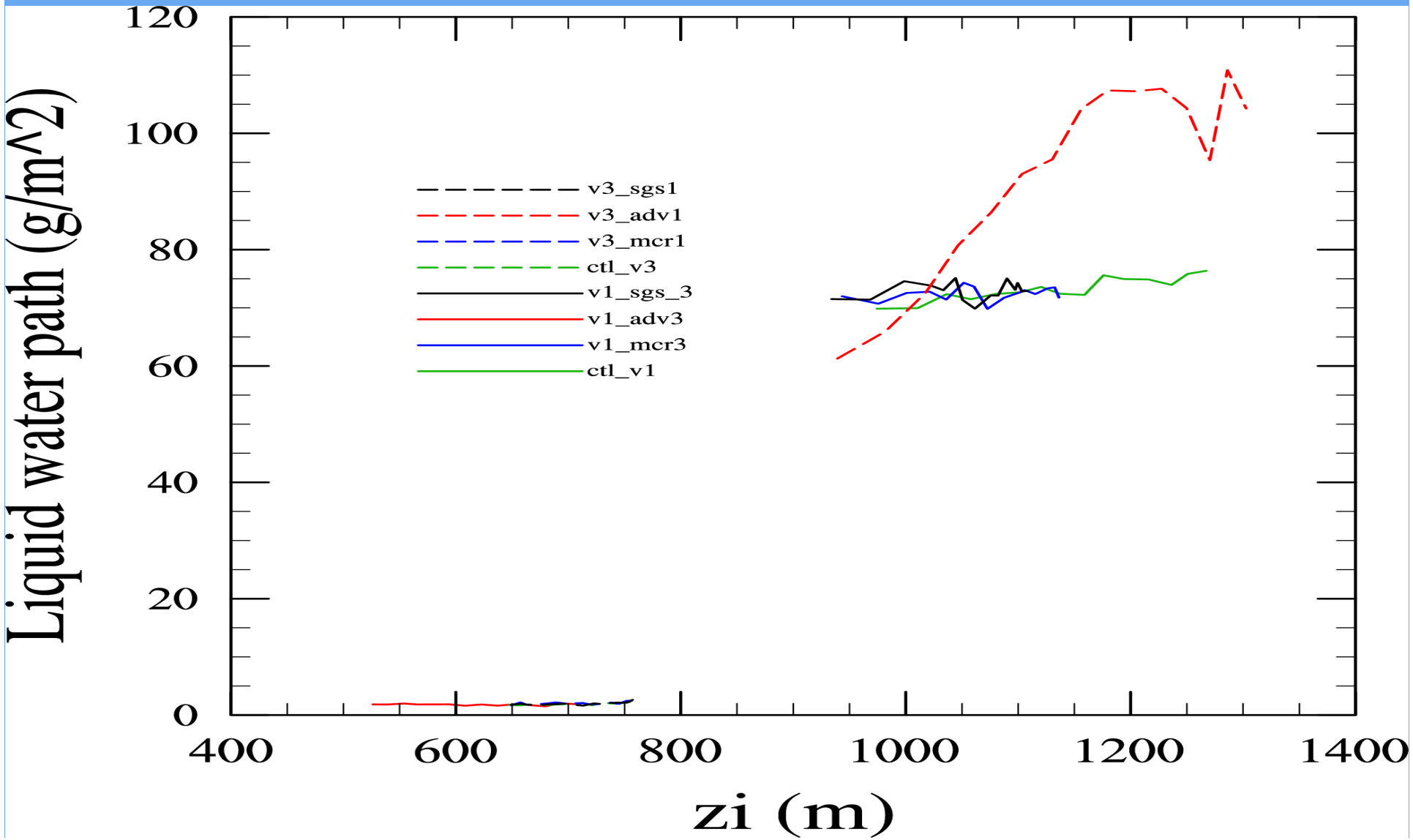
Cloud evolution for v3



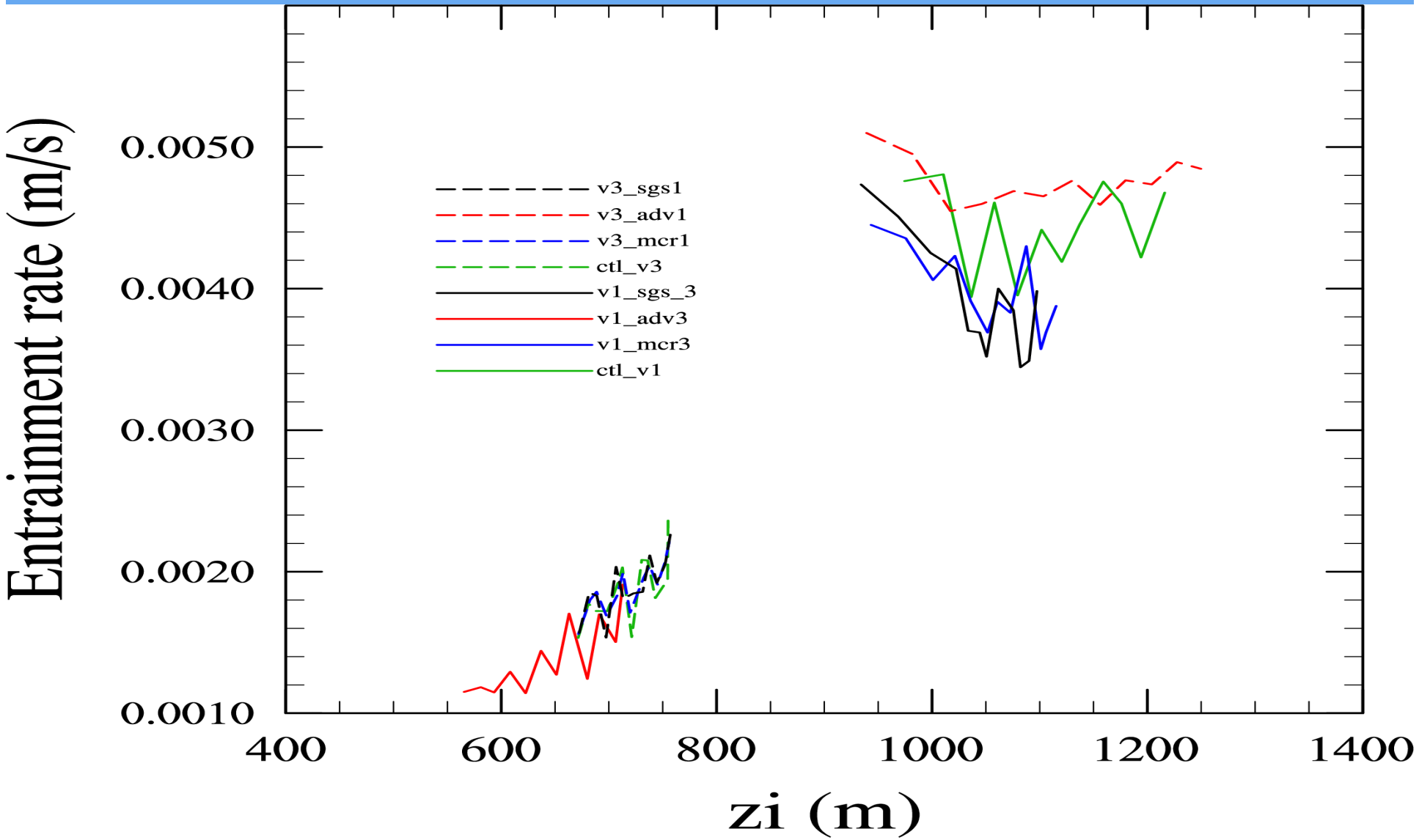
Relationship between Z_i (max|dθ/dz|) and cloud fraction for last 4 days



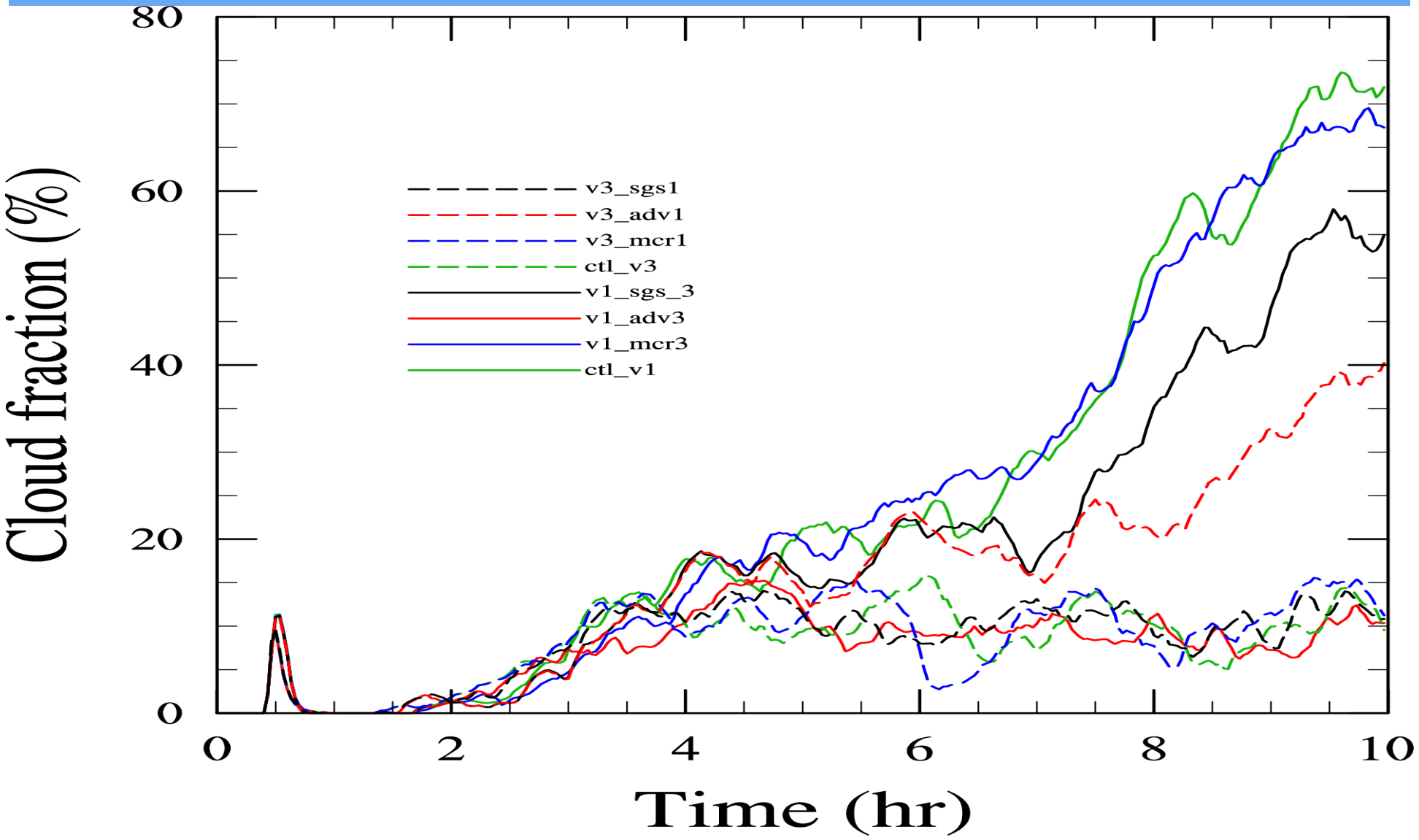
Relationship between Z_i and LWP for last 4 days



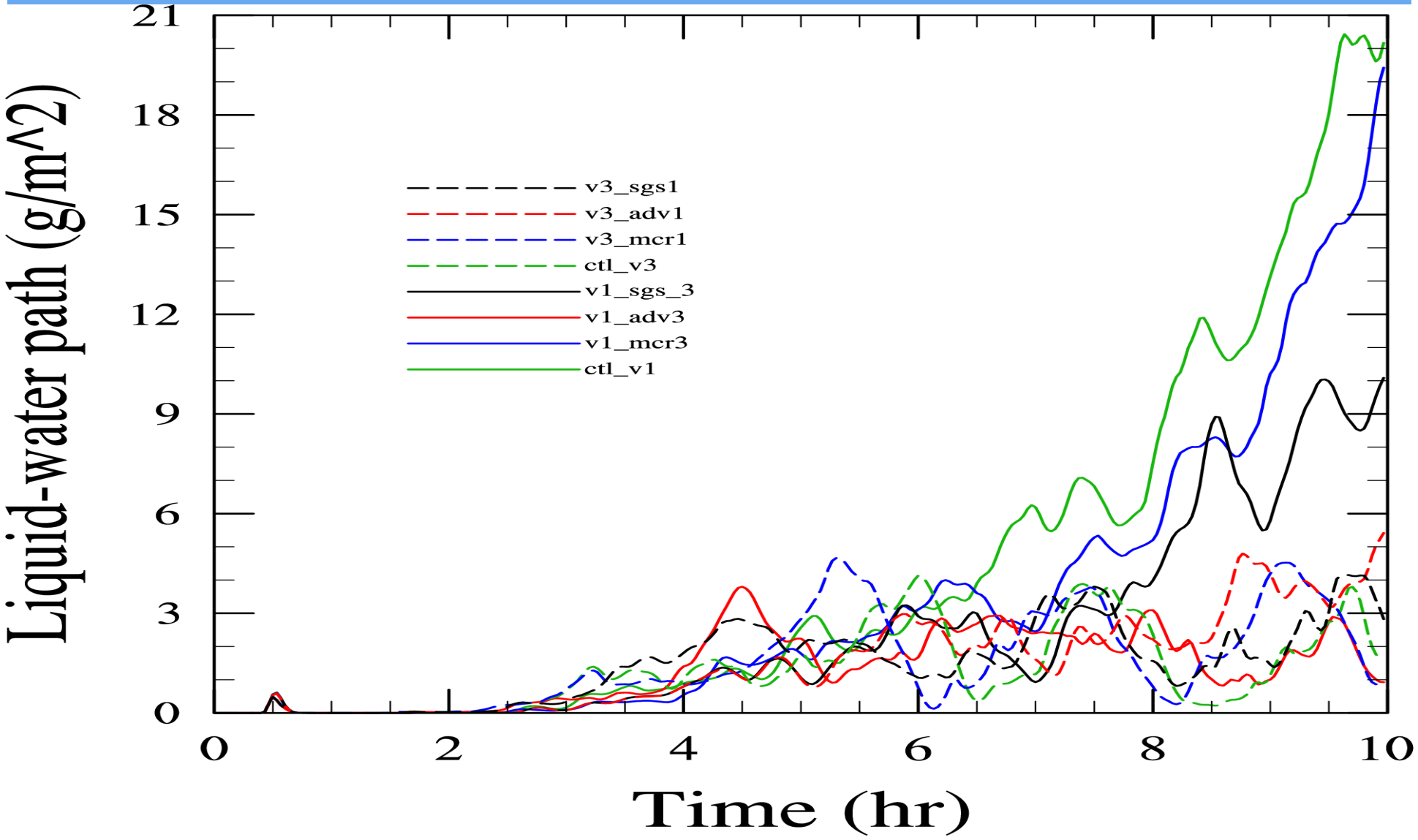
Relationship between Z_i and entrainment rate for last 4 days



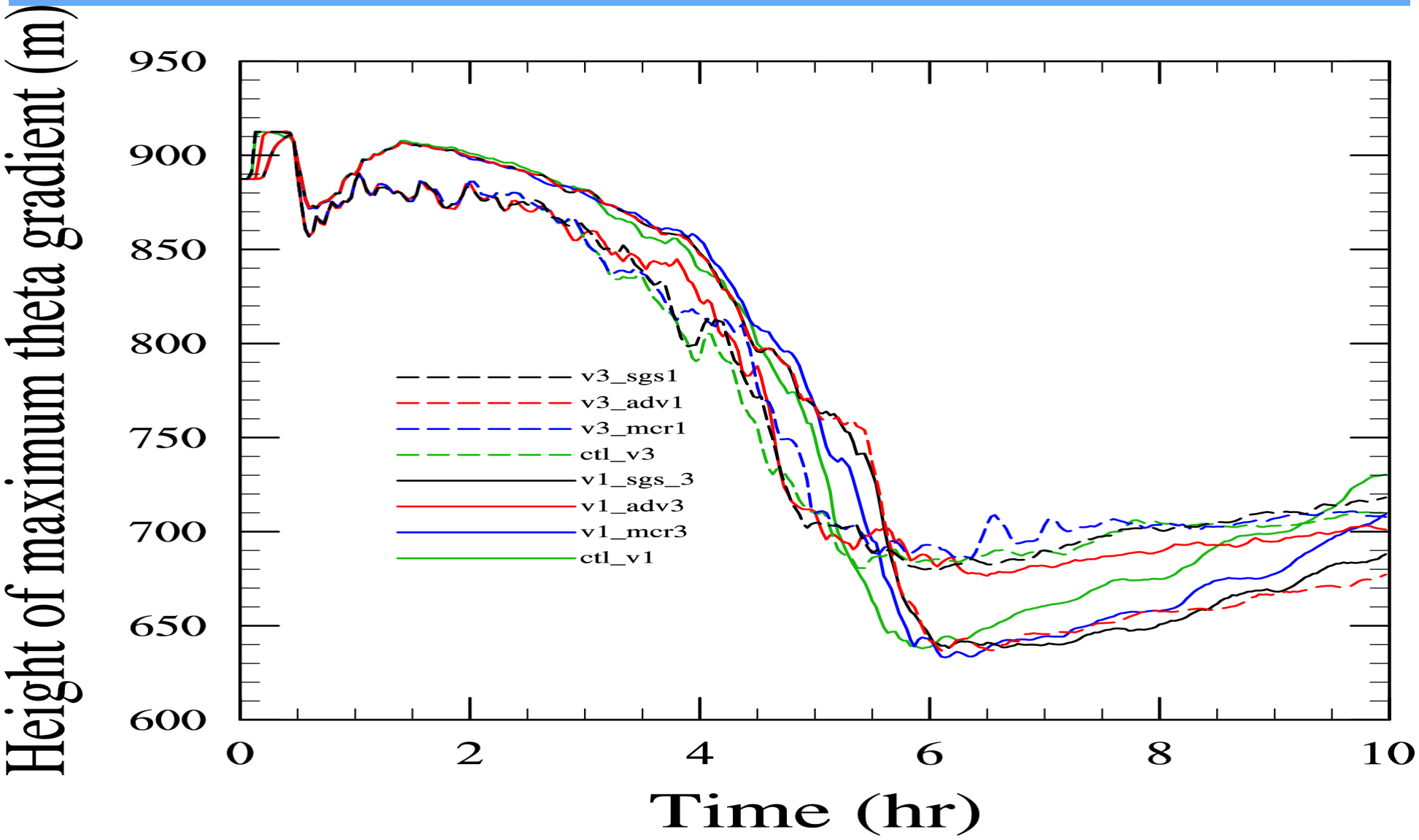
Cloud evolution



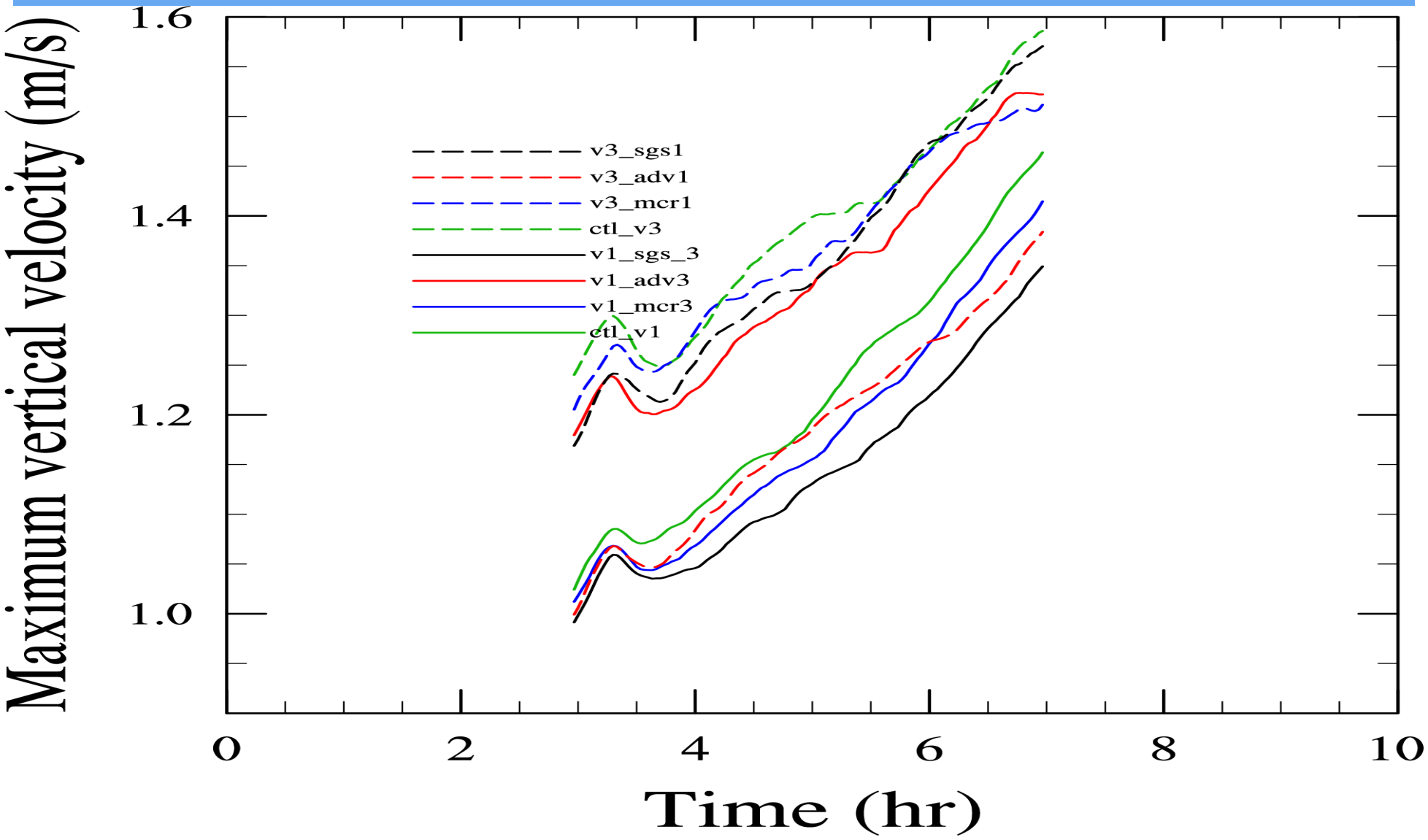
Time series of LWP



Time series of Z_i



Time series of w_{max}



Summary

- Multiple equilibria exist for an LES simulating a stratocumulus capped boundary-layer: either shallow cumulus or stratocumulus
- In the context of the standard CGILS setup with vertical grid-spacing of 25 m, the numerical algorithm is a key factor to determine the steady state
- The smaller cloud top entrainment rate associated with the weak LES-scale circulation, represented by the domain maximum vertical velocity, enhances the production of stratocumlus cloud near cloud top, causing the steady state to be stratocumulus.

Time series of entrainment rate