Aerosol effects on shallow cumulus cloud fields in idealised and realistic simulations

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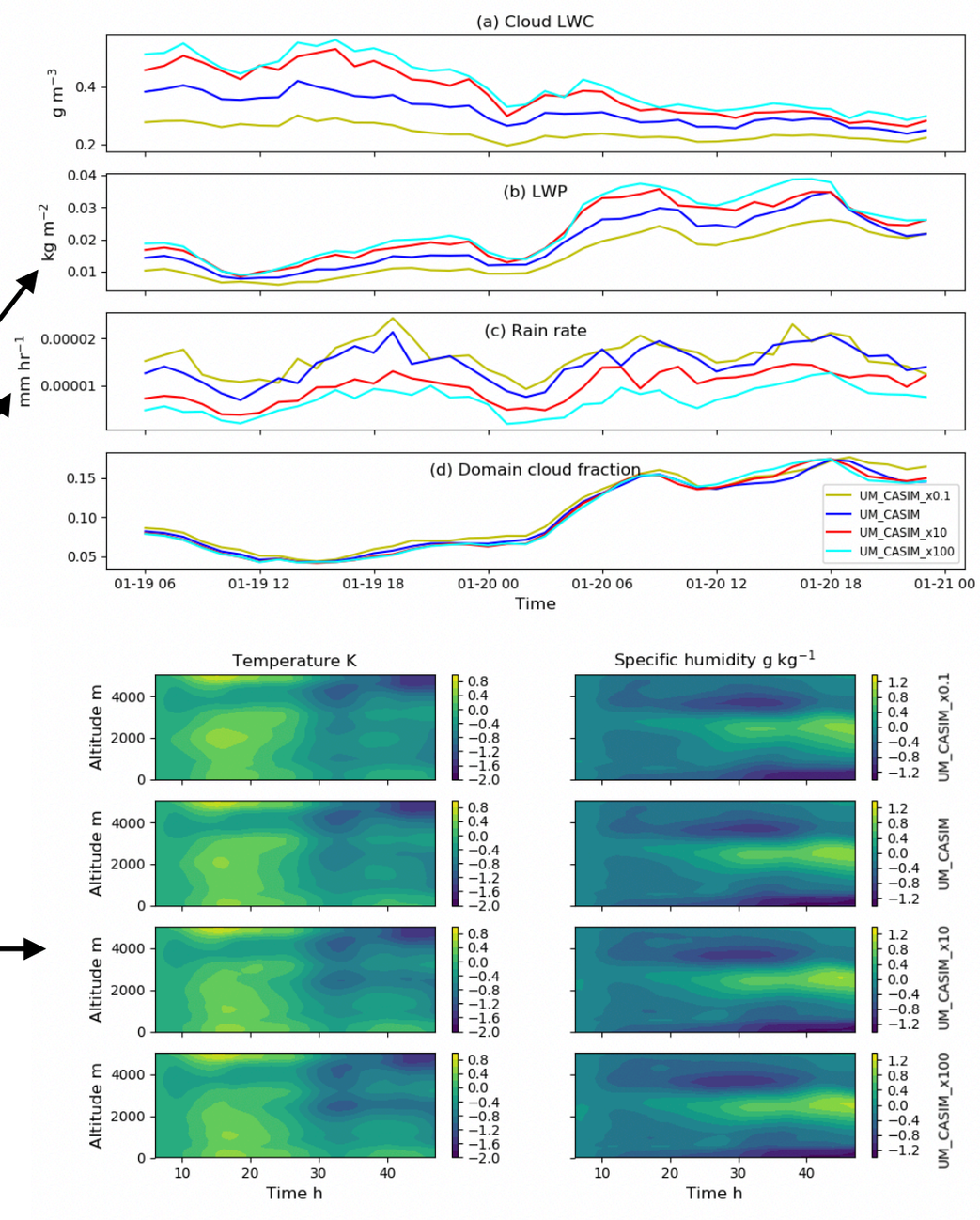
Introduction

- Typical large eddy simulations investigating the response of trade wind shallow cumuli to aerosol perturbations find a buffering effect
  - Increased aerosol suppresses the onset of precipitation
  - Leads to convective invigoration, resulting in higher peak precipitation rates
  - After some time, simulations reach a similar ‘quasi-equilibrium’ regardless of aerosol perturbations, with little difference in domain-mean properties
- LES generally use double periodic domains, along with prescribed initial conditions and constant tendencies of temperature and moisture

Introduction

- Previous work with the Met Office Unified Model (UM vn10.8) has found a different response
  - Investigating aerosol effect on shallow cumuli in large domains
  - Nested 500kmx500km domain, with boundary conditions given by driving global model
  - Transient forcing of large scale thermodynamics

- Response to increased aerosol shows weaker buffering, with greater changes in domain mean properties
  - Increased liquid water path with aerosol
  - Reduced domain-mean precipitation with increased aerosol
  - Little change in thermodynamic properties



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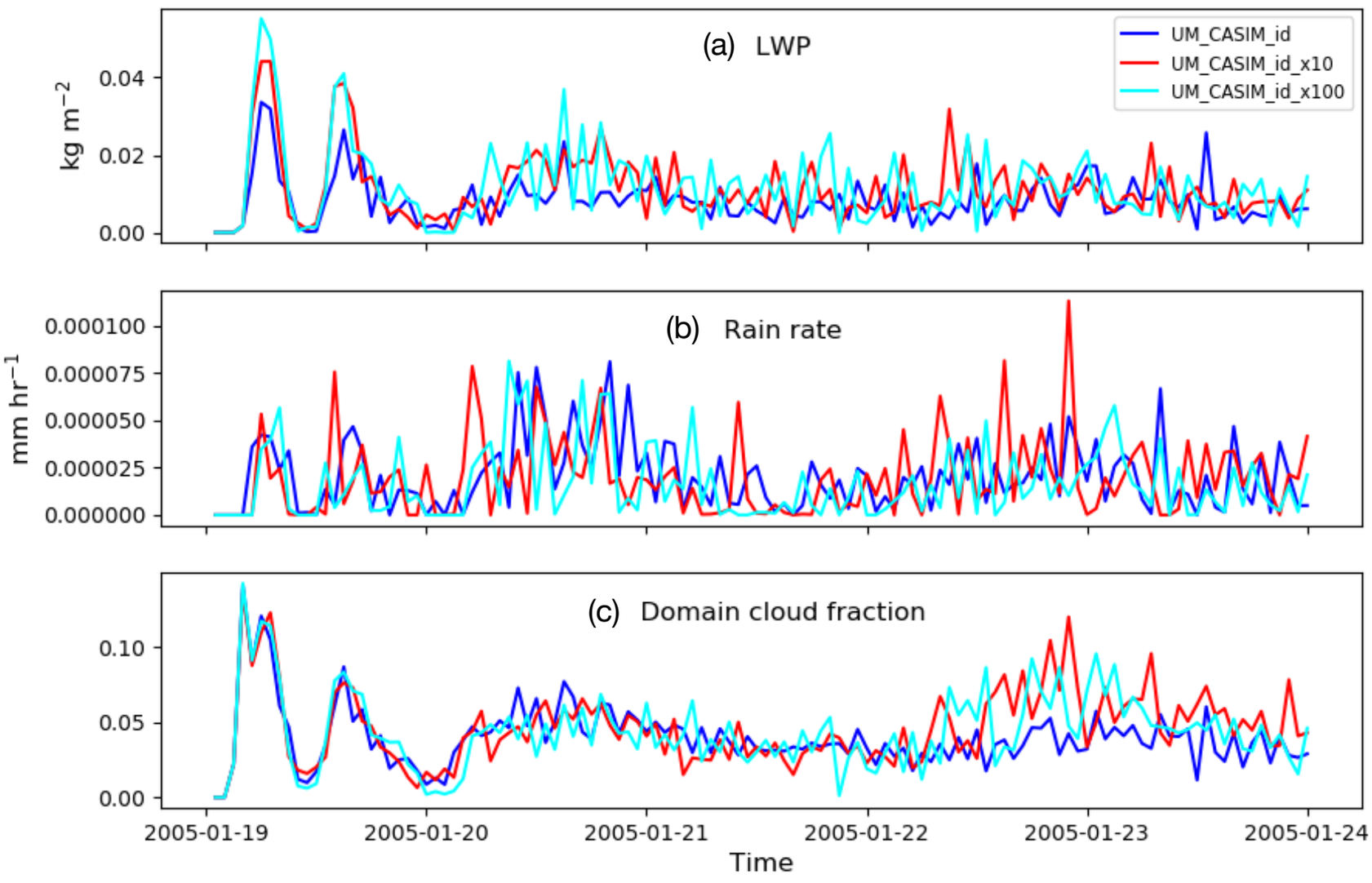
Introduction

- Is this due to nested vs. periodic domains and transient vs. constant forcings, or simply a result of inter-model differences?
- What about a more idealised configuration of the UM?

Model description

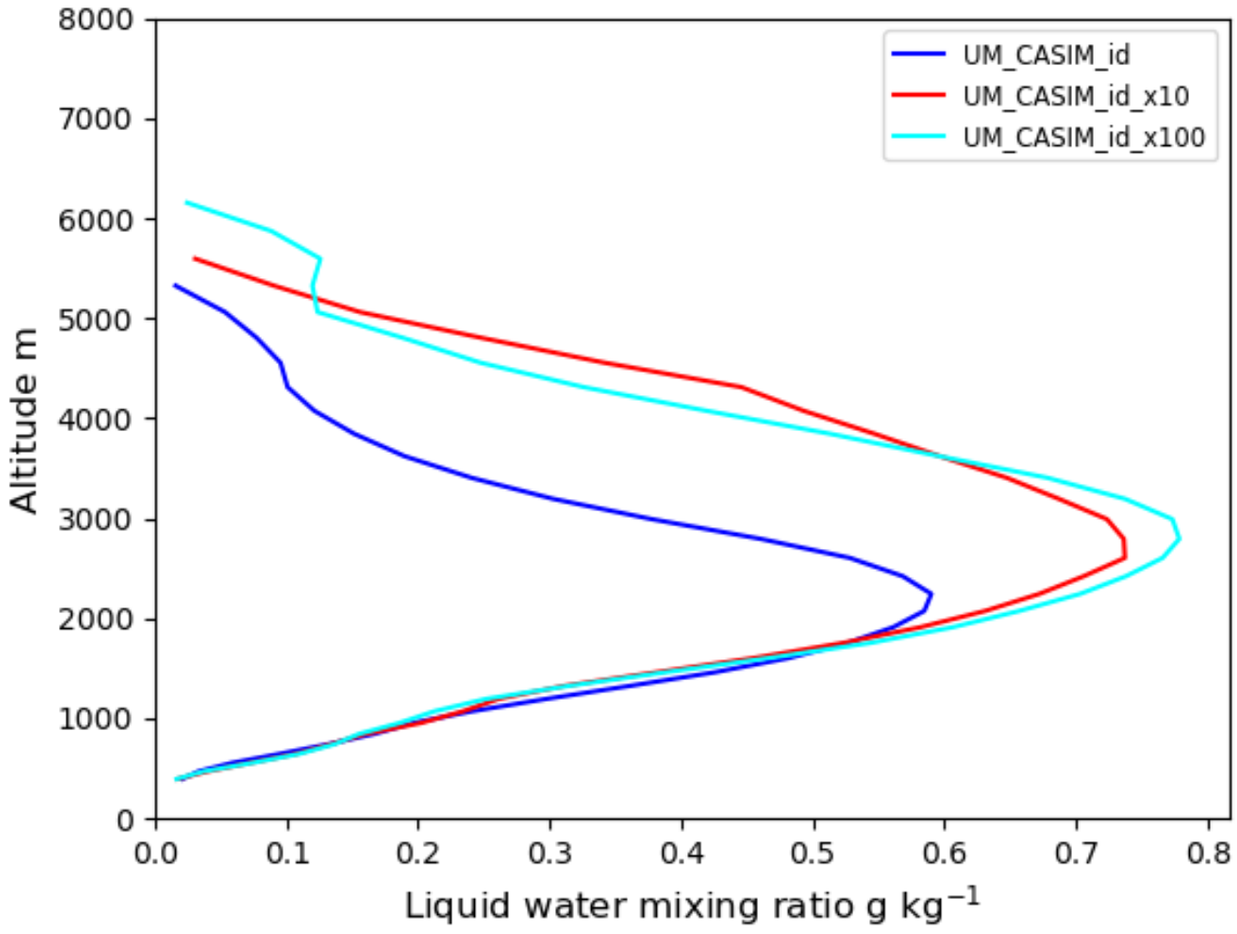
- Met Office Unified Model (UM)
  - vn11.1 idealised configuration
  - double-moment interactive microphysics (CASIM)
  - doubly-periodic 50kmx50km domain
  - 500mx500m resolution
- Case study based on RICO
  - used to provide initial conditions, and forcing of temperature, moisture, and subsidence
- Aerosol profiles also based on RICO observations
  - perturbations of factors of 10, 100.

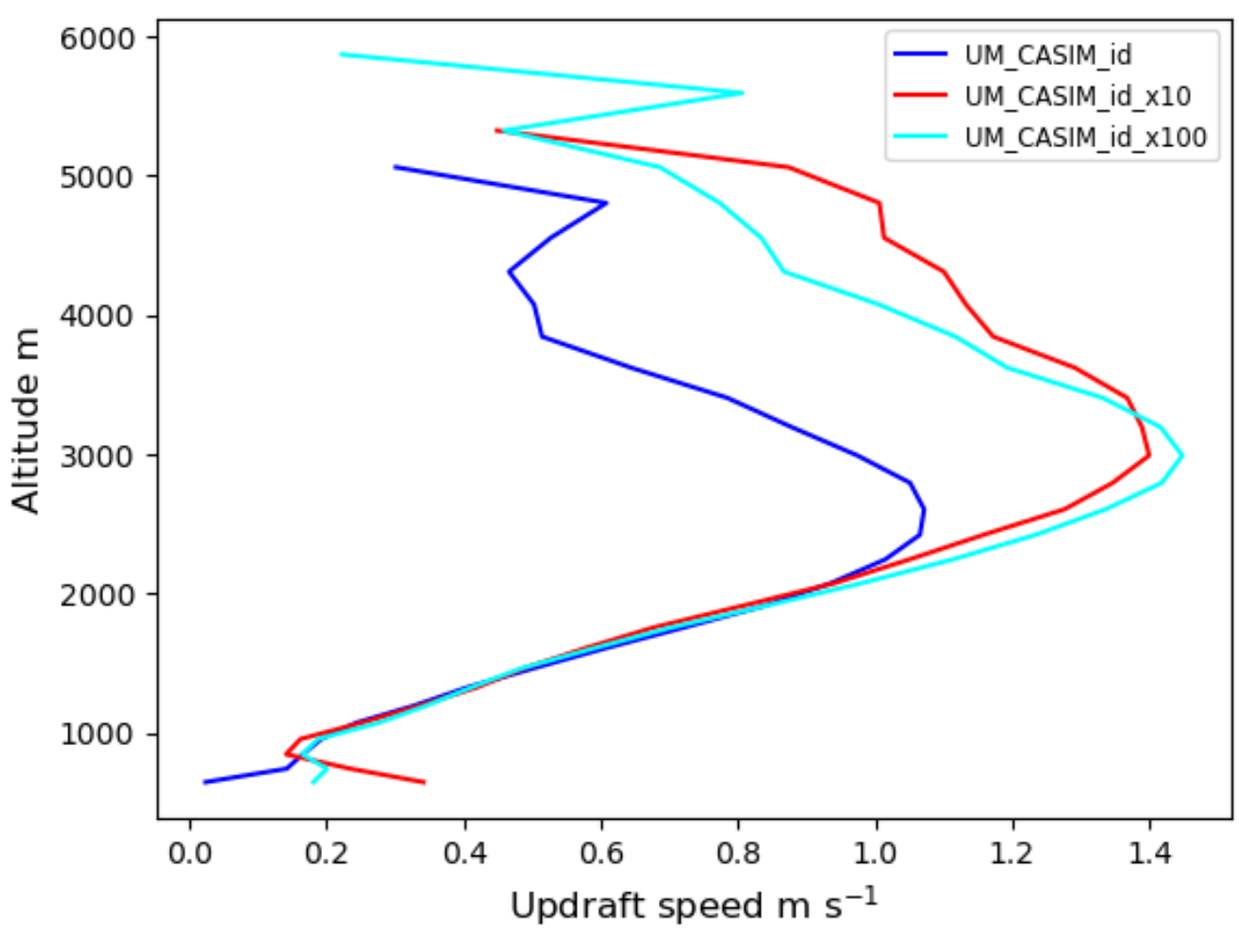
Results



- After an initial spin up, there is little difference between the simulations for domain mean properties

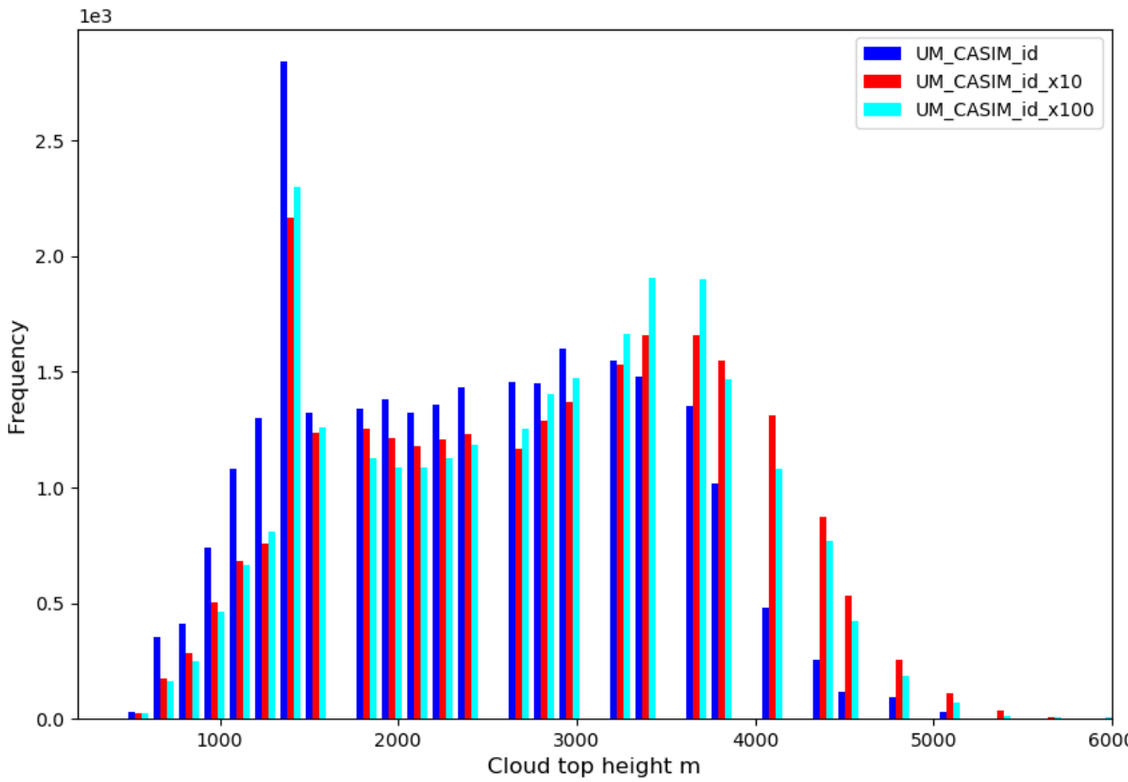
Results

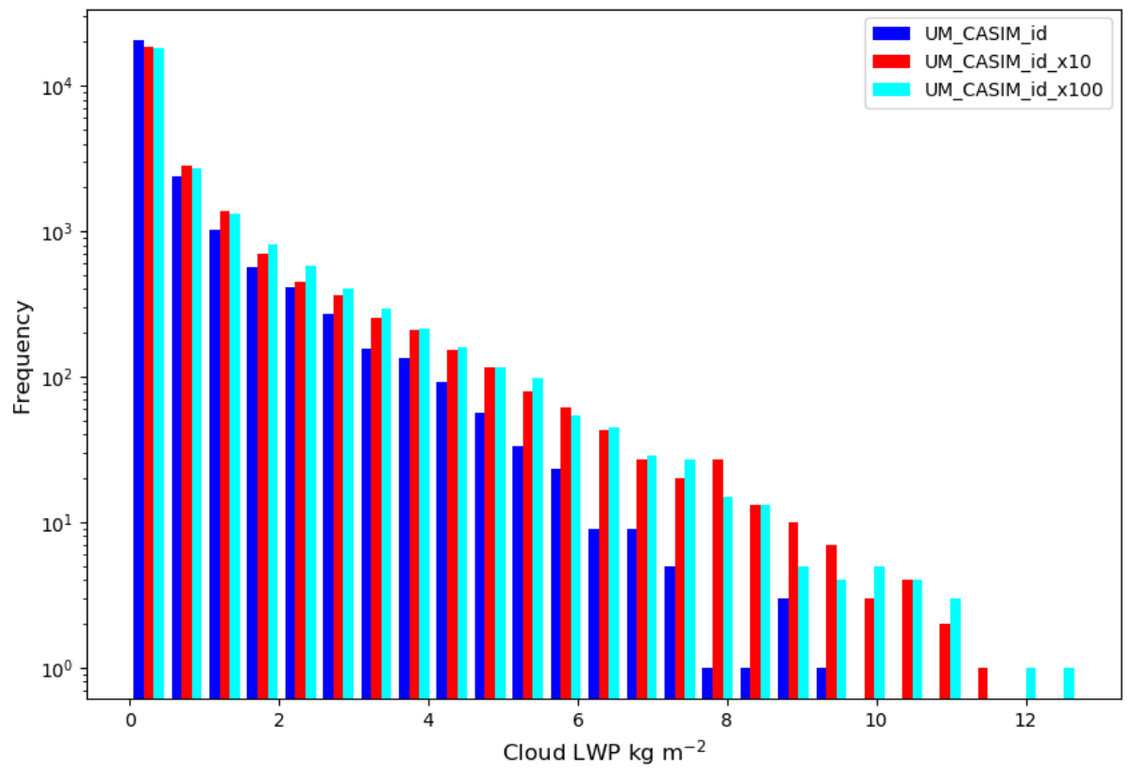




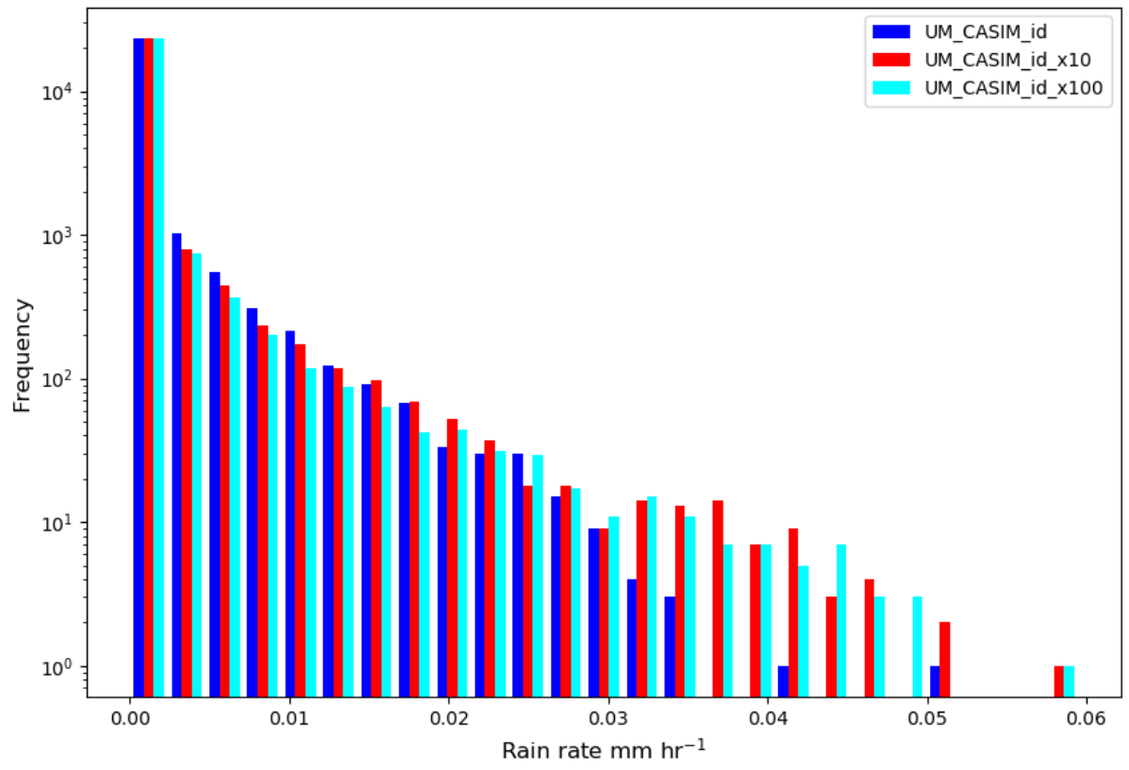
- Vertical profiles of liquid water and updraught speed suggest that with increasing aerosol we see convective invigoration and deepening

Results

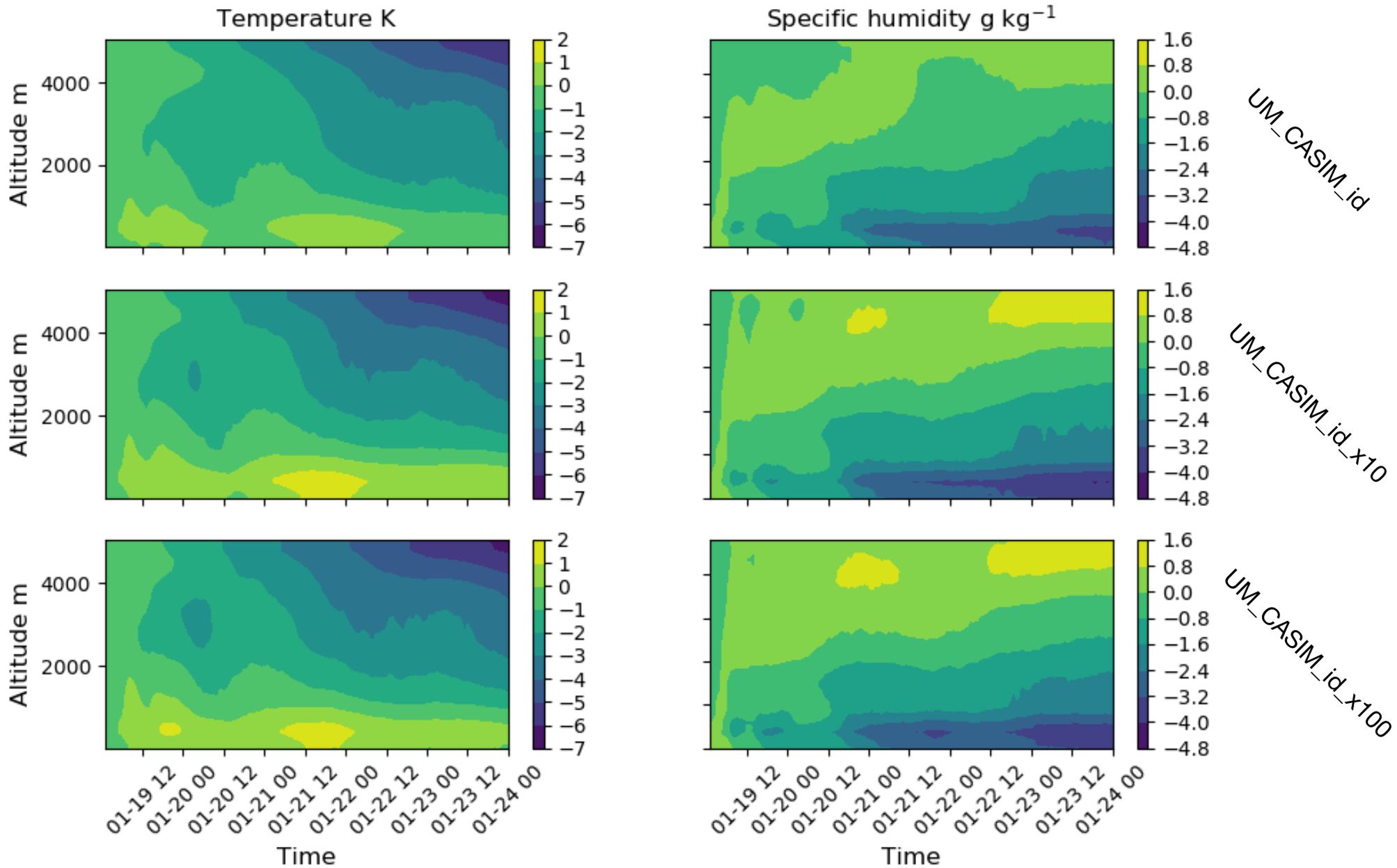




- An increase in higher cloud top heights and LWP also indicates invigoration and deepening
- Increase in frequency and magnitude of higher precipitation rates

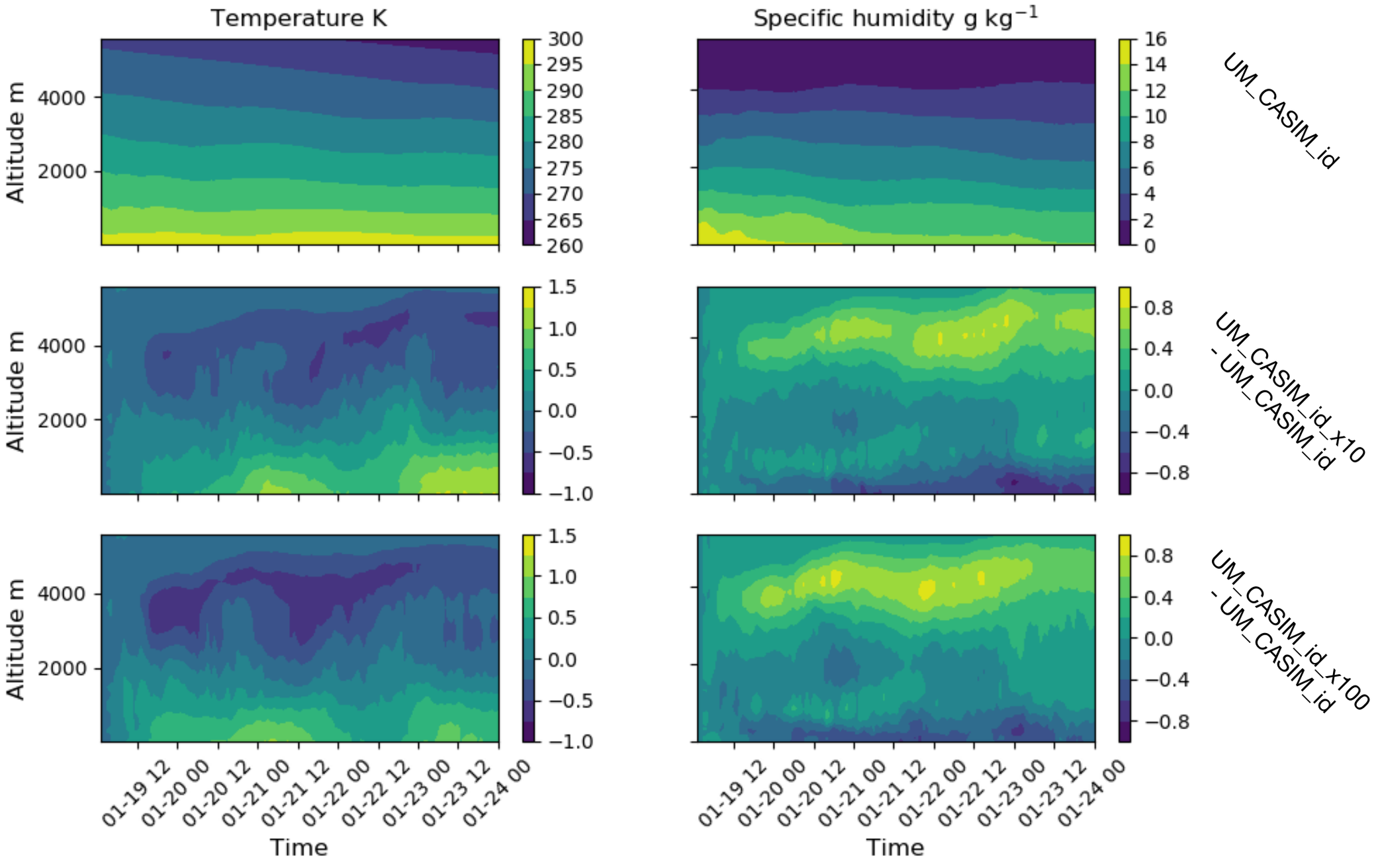


Results



- Hovmoller plots of the thermodynamic evolution of the simulations show increased cooling and moistening above ~2km

Results



- Taking the difference between the perturbed simulations and the baseline illustrates further the changes in the thermodynamic environment

Discussion and conclusions

- In an idealised configuration of the UM, with periodic boundaries and constant forcings, the response of shallow cumuli follows a familiar buffering pattern
  - Convective deepening and invigoration
  - Higher peak rain rates and more frequent higher rain rates
  - Marked changes in the thermodynamic evolution of simulations with perturbed aerosol
- Hypothesis - the nature of the response to aerosol perturbations is affected by the structure of the model setup, in particular how it represents large scale thermodynamic forcing

Discussion and conclusions

- Hypothesis - the nature of the response to aerosol perturbations is affected by the structure of the model setup, in particular how it represents large scale thermodynamic forcing
  - In an idealised periodic domain with constant forcing, perturbed clouds are able to affect their thermodynamic environment to a greater extent, amplifying the buffering effect and leading to a quasi-equilibrium
- In contrast, in nested domains with more realistic transient forcing from an external driving model, aerosol perturbations have a weaker invigoration effect
  - No quasi-equilibrium is reached
  - Persistent changes in domain-mean properties

Discussion and conclusions

- Further work investigating the possible impacts of other differences, such as domain size, between the idealised simulations presented here, and more realistic model configurations previously employed will be required to test this hypothesis in more depth