scientists and engineers meet every six months to review the updated CyberShake hazard model. Blue Waters enables SCEC to meet this schedule because a full CyberShake simulation can run within one review cycle.

SCEC plans to expand use of its most advanced modeling from southern California to more regions. Several specific goals, including a statewide California CyberShake seismic hazard model, will require the computing capabilities of the next generation of Track-1 systems.

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SIMULATING CUMULUS ENTRAINMENT: A RESOLUTION PROBLEM, OR CONCEPTUAL?

Allocation: BW Professor/0.245 Mnh

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EXECUTIVE SUMMARY:

Understanding and predicting the rate at which cumulus clouds deplete their water content by the entrainment of dry air, affecting their development, longevity, and ability to precipitate, has been elusive. Simulations performed on Blue Waters are enabling us to investigate if the problem lies in our ability to represent the smallest scales of turbulence in our models, or if our underlying conceptual models of the physics of entrainment are flawed, or both.

INTRODUCTION

Deep convective clouds produce the majority of the Earth's precipitation, and yet it is difficult to predict if developing cumulus clouds will attain the depth and longevity required to produce heavy rainfall. Entrainment is the process by which clouds bring dry air from outside the cloud inward. It can initially favor precipitation formation; eventually, it dilutes the cloud and encourages its demise. A long-standing problem in meteorology has been to reproduce how quickly entrainment dilutes a cumulus cloud. Currently, all models fail. This has long been assumed to be a problem of inadequate spatial resolution, where the smallest scales of turbulence must be parameterized and their effects are improperly represented. It could also result from a fundamental problem in our conceptual understanding of the entrainment process. Our goals are to test both possibilities.

METHODS & RESULTS

We've run numerous simulations at relatively coarse (50 m) resolution in order to see how entrainment in a single cumulus cloud differs due to basic physical parameters, such as the strength of the cloud forcing, the size (width) of the cloud, and the amount of wind shear (the change in wind speed with height) in the atmosphere surrounding the cloud. We've also developed tools to quantify the entrainment that is occurring in the simulated clouds as they grow in time. As predicted from laboratory and theoretical models of thermals, narrower clouds are diluted by entrainment more quickly, helping to validate the cloud model results. However, contrary to theoretical models, weaker clouds, i.e. those having weaker updrafts, also appear to be diluted more quickly than stronger clouds. This finding is perplexing, and we continue to explore related parameter spaces to determine if the result is physically viable or due to a computational artifact in cloud models. Future comparison of the simulation results with aircraft observations of real cumulus clouds will also be key to understanding these findings.

WHY BLUE WATERS

Our Blue Waters allocation is essential for testing the resolution-dependency of the entrainment process and in particular for determining the sizes of the eddies that are most critical to represent in simulations of cumulus entrainment. Blue Waters–with its huge number of nodes, its high speed, and its large storage capability for high-resolution model output and analysis–allows us to push the spatial scale limit much farther than in the past. We intend to increase the resolution to as high as 5 m (over domain sizes of 10 km or greater) in order to understand any computational issues related to cumulus entrainment, in addition to improving our knowledge of the underlying physics. The computational demands of these large simulations quickly supersede the limits of most computers

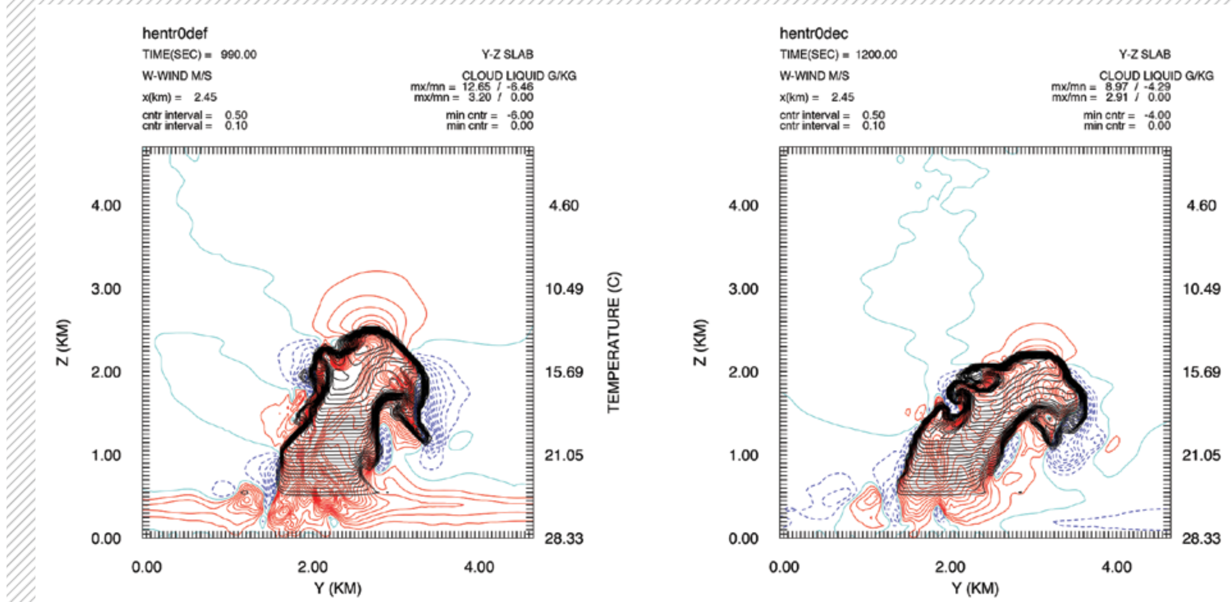

FIGURE 1: Vertical cross-sections through two cloud simulations, showing the difference in vertical configurations of the clouds with respect to initial cloud forcing. Vertical velocities are contoured in increments of 0.5 m s-1, where red indicates upward motion and blue indicates downward motion. Black contours indicate cloud water mass in increments of 0.1 g per kg of air. The left panel shows results for stronger cloud forcing, producing a more upright cloud, and the right panel shows results for weaker cloud forcing, where the cloud is more susceptible to leaning due to the ambient wind flow (not shown). The leaning cloud appears to entrain more dry air than the former, for similar cloud top heights.