Lifecycle Analysis of Cumulus Clouds using a 3D Virtual Reality Environment

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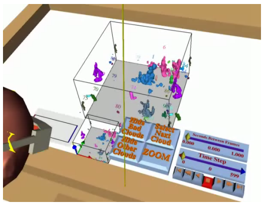
Introduction

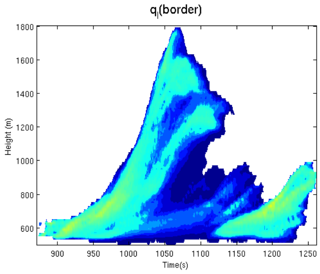
The behavior of clouds is one of the great unknowns in climate variability. In this study a new method is developed to investigate the entire lifecycle of shallow cumulus clouds in Large Eddy Simulations (LES). Since the eye is better equipped to capture and recognize the distinct time-dependent three-dimensional features of a cloud than an automated, a combination of automated constraints and human inspection in a 3D virtual reality environment (VE) is used to select clouds that are exemplary in their behavior throughout their entire lifespan. This way, the structure of the cloud can be studied in time.

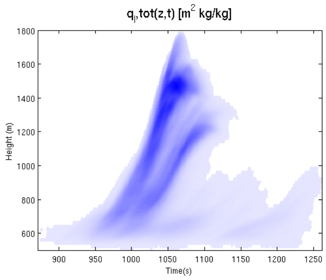
Setup of the Experiment

From an ensemble of LES runs with a resolution of 25 meter in the horizontal directions and 20 meter in the vertical 40 exemplary cumulus clouds were extracted by observation in the VE. Not only the clouds can now be studied in enormous detail, their number is also large enough to obtain reliable statistics.



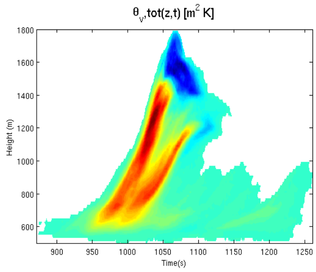
Silver Linings and Pulsating Growth

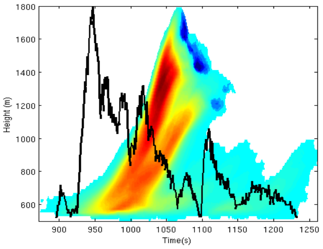




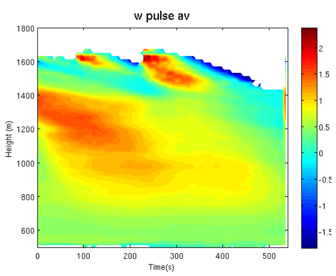
This pulsating growth dominates the dynamics of the cloud. Buoyancy (*left*) and vertical velocity (*right*) show similar footprints, while descending remnants of overshoots can smother following pulses.
The specific humidity at cloud base (*right line graph*) shows peaks at the onset of a pulse, suggesting a sub-cloud origin of the pulse

For an observer, a sharp cloud interface signifies an active cloud, while older clouds tend to have more of a silver lining, which is caused by a less humid cloud edge. Variations in humidity at cloud edge are indeed visible in the left graph, but more in pulses than with a clear trend from birth to death of the cloud; even decaying clouds can have sharp edges. Integrating the liquid water content over the entire cloud (*right*) also yields these pulses.

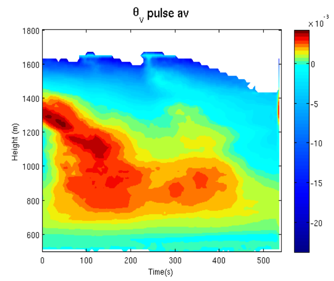




The Average Pulse



Since a cloud seems to be more of a collection of subsequent pulses than one strong homogeneous entity, statistics should be taken over pulses rather than over entire clouds. When the average time between two peaks in total water content is taken as sampling time (=540s) a clear signal arises from the data. Clearly, one can see the negatively buoyant cloud base, acceleration at mid cloud levels and negative values for buoyancy and later also for vertical velocity at cloud top.



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Further reading:

E.J. Griffith et al. 2005: Feature tracking in VR for cumulus cloud life-cycle studies. In *Virtual Environments 2005*, Kjems, E. and Blach, R., editors, 121–128.

T. Heus et al. 2006: Lifecycle Analysis of Cumulus Clouds using a 3D Virtual Reality Environment. In *Proceedings of the 17th Symposium on Boundary Layer Meteorology*

Acknowledgments: This work was sponsored by the National Computing Facilities Foundation (NCF) for the use of supercomputer facilities.

NWO Netherlands Organisation for Scientific Research

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