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From Calm to Storm: Selected Details of Various Phases in the Evolution of a Hector Storm from a High-resolution Coupled Atmosphere-Biosphere Model Experiment

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Atmospheric convection, clouds and aerosols constitute a major source of uncertainties in climate predictions and global feedback studies. They also represent a significant weather forecasting issue, due to their role in the formation of precipitation and corresponding questions about water resources availability, severe weather events and aviation safety. Many fundamental issues related to the understanding of real clouds and their temporal and spatial evolution remain unsolved.

Here, we discuss results from a very-high resolution numerical modelling project which aims at contributing to the identification of the relative importance of various meso- and microscale diabatic processes (notably surface fluxes and cloud microphysics) in triggering, organizing and intensifying tropical deep convection via their impacts on local circulation, convergence zones and dynamics. We seek to clarify to what extent the complexity of these processes must be captured to understand the evolution of convective storm clouds.

To this end, simulations have been performed with the non-hydrostatic Active Tracer High resolution Atmospheric Model ATHAM, a cloud-resolving model. Active tracers, such as various types of hydrometeors and potentially aerosols, modify density and heat capacity of the grid box averages, and thereby feed back on the dynamics of the system, which is particularly relevant for the formation of precipitation drag and cold pool downdraughts and hence the organization of mesoscale systems. Prognostic aerosol-cloud-precipitation effects are the subject of a parallel project.

To elucidate the effects of surface-atmosphere interactions and land use patterns, we have coupled ATHAM to the mechanistic vegetation dynamics model HYBRID capturing turbulent boundary layer fluxes of energy and matter in a truly two-way interactive fashion. Exchanges between the dynamic diurnally varying surface layer of water bodies and the atmosphere are modelled with the COARE sea flux algorithm . We have also adopted a GIS-based approach to retrieve and process observed surface initialization data allowing for rapidly transposing this coupled model system model into any necessary (or wanted) scenario.

We will present various phases in the evolution of a tropical island Hector storm, which we were able to identify using appropriate data analysis and visualization techniques, during a model validation pilot study designed to test the methodology in the well-documented test-bed of the Tiwi islands, Australia. Using the coupled model in a non-idealized mesoscale simulation, we resolved the sea-breeze and stability driven evolution of boundary layer horizontal convective cloud rolls into a cellular convection pattern, their merging into Hector storm clouds transporting boundary layer air and moisture into a tropopause layer deformed by a gravity wave, the spawning of daughter clouds on the gravity current front produced by a cold pool precipitation downdraught and the splitting of a storm cell due to counter-rotating vorticity within the Hector cloud. We are therefore confident of the model's capabilities to capture individual storm cells' self-organizing dynamics and to model mesoscale convective systems and structures. This offers the possibility to evaluate and improve the performance of models with parametrized boundary layer and/or convection.