Workshop on Spatial Organisation of Convection, Clouds and Precipitation

Report of Contributions

https://indico.nbi.ku.dk/e/convective_organisation_v2021

Contribution ID: **7** Type: **Interactive presentation**

Coupling a thermal population model to a discretized spectral convection scheme

Friday, 7 May 2021 16:00 (1h 45m)

Understanding cloud-circulation coupling in the Trade wind regions, as well as addressing the grey zone problem in convective parameterization, requires insight into the genesis and maintainance of spatial patterns in cumulus cloud populations. In this study a simple toy model for recreating populations of interacting convective objects as distributed over a two-dimensional grid is formulated and coupled to a spectral EDMF convection scheme. A key element is the formulation in terms of discrete object number, for capturing binary behavior at small population sample sizes. The object birth rate is represented stochastically through a Bernoulli process, while advection of object number between gridboxes is also discrete. Implied scaling behavior is discussed a priori a simple offline application representing a population of relatively short-lived but interacting convective thermals. Adopting concepts from game theory, simple rules of interaction are introduced reflecting observed physical behavior in single cumulus clouds, including pulsating growth and environmental deformation. Under these rules, thermals can occur isolated but also part of a longer-lived cluster or chain. The realism of the self-organizing spatial patterns emerging under these rules is assessed. The associated cluster size distributions are then provided to EDMF. First results with DALES-EDMF including this population model are discussed.

Primary authors: NEGGERS, Roel (University of Cologne); Dr GRIEWANK, Philipp (University of Cologne)

Presenter: NEGGERS, Roel (University of Cologne)

Session Classification: Organisation in Shallow Convection

Track Classification: Organisation in Shallow Convection

Contribution ID: **9** Type: **Interactive presentation**

Cloud-radiation interactions in RCEMIP runs of convective self-aggregation

Thursday, 6 May 2021 16:00 (1h 45m)

Cloud-radiation interactions play an important role in convective self-aggregation in idealised simulations of radiative-convective equilibrium and in real-world organised convection. This work aims to explore the radiative feedbacks of different cloud types to enable a deeper understanding of which cloud types play key roles in aggregation. We use three domain setups of the Met Office' s Unified Model, the first two of which follow the RCEMIP protocol: a large domain (6048 x 432 km, 3 km horizontal grid spacing), a small domain (100 x 100 km, 1 km grid spacing) and another small domain with a 0.1 km grid spacing. Each domain has been run with three fixed sea surface temperatures (SSTs) of 295, 300 and 305 K. Preliminary results suggest that the key direct radiative interactions that drive aggregation are longwave interactions with anvil clouds and both longwave and shortwave interactions with water vapour (including clear-sky regions). However, the extent of these interactions are all functions of domain size, resolution, SST and level of aggregation. From these results, we can gain insight into which cloud types need to be represented well in models for aggregation/organisation to develop more realistically.

Primary authors: POPE, Kieran (University of Reading); HOLLOWAY, Christopher (University of Reading); Dr JONES, Todd (University of Reading); Dr STEIN, Thorwald (University of Reading); Dr WHITALL, Michael (Met Office)

Presenter: HOLLOWAY, Christopher (University of Reading)

Session Classification: RCE and Processes in Deep Convective Organization

Track Classification: RCE and Processes in Deep Convective Organization

Contribution ID: **11** Type: **Interactive presentation**

How is convective organization promoted by stochastic shallow convection?

The focus of my talk will be on the interaction between parameterized shallow convection and resolved deep convection in convection-permitting simulations. The shallow convection is parameterized by a stochastic approach that uses a uniform spatial distribution of clouds, so no convective organization is represented at the subgrid scales. Nevertheless, such stochastic shallow convection impacts the resolved flow dynamics and promotes the development of deeper resolved clouds that organize in a substantially different way compared to a case where shallow convection is not parameterized. Spurious organization of the convective circulations developed by under-resolved convective dynamics are now replaced by more turbulent but well-organized structures. I will discuss the physical mechanisms of coupling between the parameterized stochastic convection and resolved convection and the resulting convective organization in a case study over the tropical Atlantic and one case study over central Europe.

Primary author: SAKRADZIJA, Mirjana (Max Planck Institute for Meteorology)

Presenter: SAKRADZIJA, Mirjana (Max Planck Institute for Meteorology)

Session Classification: Modelling and Parameterising Deep Convective Organisation

Track Classification: Organisation in Shallow Convection

Contribution ID: **12** Type: **Interactive presentation**

Influence of large-scale subsidence on convective aggregation

Thursday, 6 May 2021 16:00 (1h 45m)

A series of cloud-resolving model experiments is used to investigate the response of convection to imposed large-scale subsidence. Subsidence is favorable to convective aggregation in a non-linear fashion. In our model configuration, the radiative-convective equilibrium exhibits scattered convection and this non-aggregated stationary state exists also for weak subsidence. For large subsidence, an aggregated stationary state exists, and there is a significant range of subsidence intensity for which both aggregated and non-aggregated states co-exist. The aggregated state is, in average, drier than the non-aggregated state and therefore the drying effect of subsidence is weaker on the aggregated than on the non-aggregated state, making the former more resilient to subsidence than the latter. The aggregated state can be analyze in both two-column and moist static energy frameworks, and it appears that the main adjustment to the subsidence forcing is a reduction of the area of the convective patch. We also analyze transient experiments to quantify the contributions of the different physical processes to the aggregation or disaggregation of convection.

Primary author: COPPIN, David (University of Auckland)

Co-author: Dr BELLON, Gilles (University of Auckland)

Presenter: COPPIN, David (University of Auckland)

Session Classification: RCE and Processes in Deep Convective Organization

Track Classification: RCE and Processes in Deep Convective Organization

Contribution ID: **15** Type: **Interactive presentation**

Self-Aggregation of Convection in the RCEMIP Ensemble

Thursday, 6 May 2021 16:00 (1h 45m)

The Radiative-Convective Equilibrium Model Intercomparison Project (RCEMIP) is an intercomparison of multiple types of numerical models, including atmospheric general circulation models (GCMs), cloud-resolving models (CRMs), global cloud-resolving models (GCRMs), large eddy simulation models (LES), and single column models (SCMs), configured in radiative-convective equilibrium (RCE). In addition to questions about the response of clouds and convective activity to warming, RCEMIP offers an unprecedented opportunity to examine the self-aggregation of convection and its role in climate in a consistently configured ensemble of nearly 30 models. Self-aggregation occurs robustly across large domain simulations in CRMs, GCRMs, and GCMs, but with varying strengths, spatial structures, and temporal variability. Across all models, self-aggregation acts to warm and dry the atmosphere and reduce high cloudiness. However, there is no consistent response of the degree of aggregation to warming, with half of the simulations exhibiting an increase in aggregation with warming and half experiencing a decrease. The response of aggregation to warming varies not only from model to model but from metric to metric as well. The impact of self-aggregation on the energy budget through clear-sky processes and changes in cloudiness is also explored.

Primary authors: WING, Allison (Florida State University); STAUFFER, Catherine (Florida State University); REED, Kevin (Stony Brook University); BECKER, Tobias (Max Planck Institute for Meteorology)

Presenter: WING, Allison (Florida State University)

Session Classification: RCE and Processes in Deep Convective Organization

Track Classification: RCE and Processes in Deep Convective Organization

Contribution ID: **17** Type: **Interactive presentation**

Transition to self-aggregation with enhanced variability for increasing CO2 concentration in radiative-convective equilibrium with a slab ocean

Thursday, 6 May 2021 16:00 (1h 45m)

In a general circulation model (ECHAM6) configured to represent radiative-convective equilibrium coupled to a slab ocean, we explore a wide range of CO_2 concentrations. We obtain reliable statistical quantities from thousand-year-long simulations, and we characterize the horizontal scale of ascending and subsiding regions by the so-called integral length scale of the vertical velocity field at a given atmospheric level, which is based on the horizontal autocorrelation function of that field. For moderate CO_2 concentrations, we find weak spatial organization, which comes along with unskewed temporal variations of 1–2 K in global mean surface temperature and an almost constant climate sensitivity of 2 K. At CO_2 concentrations beyond four times the preindustrial value, the climate sensitivity decreases to nearly zero as a result of episodic global cooling events as large as 10 K, in association with global-scale convective self-aggregation and relying on the appearance of a low-level stratiform cloud field in the subsiding region which constitutes the global complement of the self-aggregated ascending region. We qualitatively sketch a potential description in terms of the phenomenology of spatially extended dynamical systems for the transition between the weakly organized and the self-aggregated regime.

Primary author: DROTOS, Gabor (Instituto de Fisica Interdisciplinar y Sistemas Complejos (CSIC-UIB))

Co-authors: BECKER, Tobias (Max Planck Institute for Meteorology); MAURITSEN, Thorsten (Meteorological Institute, Stockholm University); STEVENS, Bjorn (Max Planck Institute for Meteorology)

Presenter: DROTOS, Gabor (Instituto de Fisica Interdisciplinar y Sistemas Complejos (CSIC-UIB))

Session Classification: RCE and Processes in Deep Convective Organization

Track Classification: RCE and Processes in Deep Convective Organization

Contribution ID: **18** Type: **Interactive presentation**

Searching for signatures of self-aggregation in less idealized atmospheres

Thursday, 6 May 2021 16:00 (1h 45m)

Radiative convective equilibrium (RCE) simulations have now widely demonstrated the ability of convection to organize on its own, a process called self-aggregation. Given the stark idealization of such simulations, in particular due to the use of homogeneous boundary conditions and the absence of large-scale forcing, the relevance of self-aggregation for the real world remains under debate. Here, we first introduce large-scale meridional SST gradients, as used in aquaplanet simulations, to study the interactions between SST gradients and the self-aggregation of convection. We find that the self-aggregation of convection still occurs in those simulations. It leads to a zonal contraction of the convergence line initially spin up by the meridional SST gradient, the more so, the weaker the SST gradient is. We then use reanalysis data to check this finding. As a second step, we use the reanalysis data to check another prediction from RCE simulations, i.e. the fact that a more organized Intertropical Convergence Zone is associated with drier subtropics.

Primary author: HOHENEGGER, Cathy (Max Planck Institute for meteorology)

Co-authors: Dr MÜLLER, Sebastian (Abdus Salam International Centre for Theoretical Physics, Trieste, Italy); Prof. JAKOB, Christian (Monash University, Monash, Australia)

Presenter: HOHENEGGER, Cathy (Max Planck Institute for meteorology)

Session Classification: RCE and Processes in Deep Convective Organization

Track Classification: RCE and Processes in Deep Convective Organization

Contribution ID: **20** Type: **Interactive presentation**

Extreme precipitation scaling, rain cell sizes, and the role of cold pools, and their relation to climate change

Wednesday, 5 May 2021 16:00 (1h 45m)

Dependencies of observed (sub)hourly rainfall on near surface dew point temperature show relations exceeding the Clausius-Clapeyron relation. Those so-called super CC scaling rates can be only sustained when sufficient moisture is provided to cloud systems by dynamical feedbacks. Large eddy simulation clearly show a tendency to produce large cloud structures under warmer conditions, and cold pool dynamics appear to play a key role in this process. Understanding the physics behind scaling rates, and the role of cloud feedbacks, is of utmost importance to estimate how precipitation extremes may change in future climate. In this presentation, I will discuss super CC scaling rates from surface and radar observations and convection permitting model simulations, and understanding from the recent large set of Large Eddy Simulation results under different climate conditions.

Primary authors: LENDERINK, Geert (KNMI and TUD); Mr LOCHBIHLER, Kai (KNMI and TUD); Prof. SIEBESMA, Pier (TUD and KNMI)

Presenter: LENDERINK, Geert (KNMI and TUD)

Session Classification: Modelling and Parameterising Deep Convective Organisation

Track Classification: Modelling and Parameterising Deep Convective Organisation

Contribution ID: **22** Type: **Interactive presentation**

Spatial Scales of Organisation in Southern Ocean Stratocumuli

Friday, 7 May 2021 16:00 (1h 45m)

Mesoscale-cellular convective (MCC) organisation is frequently observed in Southern Ocean (SO) stratocumuli, which exert a climate relevant cloud radiative effect in this region. Furthermore, many of these clouds are not pure liquid clouds, but contain a mixture of ice and liquid.

McCoy et al. (2017) demonstrated that the cloud albedo and thus the shortwave cloud-radiative effect of SO stratocumuli differs between different MCC manifestations. At identical cloud fraction closed-cell stratocumuli are more reflective than open-cell stratocumuli.

We investigate whether cloud phase influences MCC organisation patterns and whether such changes can be associated with substantial cloud-radiative effects. For this we are currently building and testing an algorithm identifying cellular organisation and distribution of cell size in shortwave radiance retrievals from MODIS. During this process we have tried different segmentation techniques. We currently obtain the most promising results applying the random walker (image) segmentation method in combination with a neural network classification from Wood and Hartmann (2006).

At this workshop we will present the skill and limitation of this approach in obtaining cell-size statistics within the open- and closed-cell regime as well as first scientific results regarding the cloud phase distributions in open- and closed-cell SO stratocumuli.

Primary authors: DANKER, Jessica (Goethe-University); Dr SOURDEVAL, Odran (Lille University); Dr GLASSMEIER, Franziska (Wageningen University); POSSNER, Anna (Goethe University)

Presenter: DANKER, Jessica (Goethe-University)

Session Classification: Organisation in Shallow Convection

Track Classification: Organisation in Shallow Convection

Contribution ID: **23** Type: **Interactive presentation**

Do shallow cumulus clouds and convective plumes share the same statistics?

Friday, 7 May 2021 16:00 (1h 45m)

When studying the spatial organization and size distribution of shallow convection, the most widely looked at characteristic is the 2D projected cloud field. This approach has many practical benefits. 2D cloud fields can be easily detected with high precision from satellite or aerial retrievals, and generating a 2D cloud mask from model output is trivial. There are some drawbacks though. Firstly, clouds can not provide information on dry convection. And secondly, while cumulus clouds are closely linked to convective plumes there is no direct relationship between cloud and plume size, nor is it guaranteed that the number of clouds and plumes are the same. In this poster we will compare the statistics of the 2D projected cloud field against those of the 3d convective plumes in a month's worth of LES simulations over the southern great planes ARM research facility. The 3D convective plumes are diagnosed from the LES output fields with the help of a surface emitted tracer which decays over time. We will specifically look at size distribution and spatial organization, in order to estimate how well the 2D cloud fields serve as a proxy for the 3D plumes.

Primary author: GRIEWANK, Philipp (University of Cologne)

Co-authors: HEUS, Thijs (CSU Ohio); NEGGERS, Roel (University of Cologne)

Presenter: GRIEWANK, Philipp (University of Cologne)

Session Classification: Organisation in Shallow Convection

Track Classification: Organisation in Shallow Convection

Contribution ID: **25** Type: **Interactive presentation**

Radiative-convective-equilibrium as a "boutique" configuration of the Simple-Cloud-Resolving-E3SM-Atmosphere-Model (SCREAM)

Thursday, 6 May 2021 16:00 (1h 45m)

The Simple-Cloud-E3SM-Atmosphere-Model (SCREAM) is currently being developed as the high resolution (~3 km grid spacing) version of the US Department of Energy's new Energy Exascale Earth System Model (E3SM). A new suite of cloud physics parameterizations has been implemented to accommodate the partially cloud resolving resolution of SCREAM. In particular, turbulence, shallow convection, and macrophysics are handled by the Simple Higher Order Closure (SHOC) and microphysics is handled by the Predicted Particle Properties (P3) scheme.
In order to efficiently examine and scrutinize the new model's physical soundness - especially as it pertains to clouds - a Radiative-Convective-Equilibrium (RCE) configuration run on a reduced radius aquaplanet has been implemented. This presentation will highlight the utility of RCE as a testbed for new generation cloud resolving climate models and in the process of doing so will introduce a new cloud and precipitation diagnostic framework that could be used in any RCE model to quantify the sources and sinks of cloudiness.

This work was performed under the auspices of the US DOE by Lawrence Livermore National Laboratory under contract No. DE-AC52-07NA27344 IM release number LLNL-ABS-804065.

Primary authors: BEYDOUN, Hassan (Lawrence Livermore National Laboratory); CALDWELL, Peter (Lawrence Livermore National Laboratory); HANNAH, Walter (Lawrence Livermore National Laboratory); DONAHUE, Aaron (Lawrence Livermore National Laboratory); BOGENSCHUTZ1, Peter

Presenter: BEYDOUN, Hassan (Lawrence Livermore National Laboratory)

Session Classification: RCE and Processes in Deep Convective Organization

Track Classification: RCE and Processes in Deep Convective Organization

Contribution ID: **26** Type: **Interactive presentation**

The diurnal path to persistent convective self-aggregation

Wednesday, 5 May 2021 16:00 (1h 45m)

Convective self-aggregation (CSA) has attracted a lot of attention as a possible explanation for large scale tropiccal weather phenomena such as the Madden-Julian oscillation and cyclo-genesis. However, CSA is hampered in the realistic limit of fine model resolution when cold pools—dense air masses beneath thunderstorm clouds—are well-resolved.

Here we mimic the diurnal cycle in cloud-resolving numerical experiments by prescribing a surface temperature oscillation. Our simulations show that the diurnal cycle enables the formation of persistent dry patches closely resembling the early onset of CSA. In fact, the dry-patch formation is accelerated by finer resolutions. We attribute these findings to the highly non-linear dynamics of large 'combined cold pools'emerging in symbiosis with mesoscale convective systems. Our results may help connecting CSA paradigm in favor of more realistic simulations.

A preprint of the findings are available at: arXiv:2104.01132

Primary authors: JENSEN, Gorm Gruner (Atmospheric Complexity, NBI, Uni. Copenhagen); Dr HÄRTER, Jan O. (Atmospheric Complexity, NBI, Uni. Copenhagen); FIÉVET, Romain (Niels Bohr Institute)

Presenter: JENSEN, Gorm Gruner (Atmospheric Complexity, NBI, Uni. Copenhagen)

Session Classification: Modelling and Parameterising Deep Convective Organisation

Track Classification: Modelling and Parameterising Deep Convective Organisation

Contribution ID: **27** Type: **Interactive presentation**

A unified shallow-deep mass flux cumulus parameterization based on a stochastic multicloud model

Friday, 7 May 2021 16:00 (1h 45m)

Cumulus parameterization (CP) in state-of-the-art global climate models (GCM) is based on the quasi-equilibrium assumption (QEA). This view contradicts the observed organization and dynamical interactions across multiple scales of cloud systems in the tropics. The last two decades have seen a surge in novel ideas to represent key physical processes of moist convection-large-scale interaction to overcome the QEA. This led to new breakthroughs in CP. The stochastic multicloud model (SMCM) CP, in particular, mimics the dynamics of multiple cloud types that characterize organized tropical convection. Here, the SMCM is used to modify the Zhang-McFarlane (ZM) CP by changing the way the bulk mass flux is calculated. We build in a stochastic ensemble of plumes characterized by randomly varying detrainment level distributions based on the cloud area fraction (CAF) predicted by the SMCM and propose a new way to calculate entrainment and detrainment rates. The SMCM is extended to include shallow cumulus clouds resulting in a unified shallow-deep CP. The new stochastic multicloud plume CP is validated against the control ZM scheme in the context of the single column Community Climate Model of the National Center for Atmospheric Research using know test-cases.

Primary author: KHOUIDER, Boualem (University of Victoria)

Presenter: KHOUIDER, Boualem (University of Victoria)

Session Classification: Organisation in Shallow Convection

Track Classification: Organisation in Shallow Convection

Contribution ID: **28** Type: **Interactive presentation**

What determines the growth of humidity fluctuations?

Friday, 7 May 2021 16:00 (1h 45m)

Primary authors: SIEBESMA, Pier (Delft University of Technology); Dr DE ROODE, Stephan (Delft University of Technology); JANSSENS, Martin (Wageningen University); JONKER, Harm (Delft University of Technology); FREDERIKSE, Thomas

Presenter: SIEBESMA, Pier (Delft University of Technology)

Session Classification: Organisation in Shallow Convection

Track Classification: Organisation in Shallow Convection

Contribution ID: **29** Type: **Interactive presentation**

Organized Convection Parameterization for GCMs

Wednesday, 5 May 2021 16:00 (1h 45m)

The enormous exchange of energy during transitions between the three phases of water and the dominance of convection as a transport process are fundamental to Earth's weather and climate. Moist convection organizes into mesoscale systems (MCSs) but, being neither parameterized nor adequately resolved, MCSs are missing from contemporary global climate models (GCMs). This long-standing deficiency adversely affects the type, intensity, distribution, and frequency of precipitation. A new parameterization of organized moist convection based on fluid-dynamical principles of multiscale coherent structures and slantwise layer overturning provide upscale heat transport and counter-gradient momentum transport which are distinct from diffusive mixing associated with unorganized cumulus. Implementation of the parameterization in the NCAR Community Atmosphere Model (CAM) improves the Madden-Julian Oscillation and convectively coupled tropical waves; generates large-scale patterns of precipitation consistent with TRMM measurements; and displays remarkable structural invariance across a wide range of scales. Results reported in Moncrieff et al. (2017) and Moncrieff (2019) will be summarized, along with some new results of implementation in the Department of Energy (DOE) Energy Exascale Earth System Model (E3SM).

Primary author: MONCRIEFF, Mitchell (Senior Scientist (emeritus))

Presenter: MONCRIEFF, Mitchell (Senior Scientist (emeritus))

Session Classification: Modelling and Parameterising Deep Convective Organisation

Track Classification: Modelling and Parameterising Deep Convective Organisation

Contribution ID: **30** Type: **Interactive presentation**

Scale-free distributions in nature: an overview of self-organized criticality

Wednesday, 5 May 2021 16:00 (1h 45m)

Power-law distributions in nature pose a challenge for statistical physics. The paradigm of self-organized criticality (SOC), introduced by Per Bak and coworkers [1], might resolve this puzzle. SOC shows how scale-free event-size and duration distributions can arise in the apparent absence of tuning parameters, in a system of many interacting entities, each having a threshold for relaxation, under a slow external drive. This paradigm may underly phenomena such as power-law distributions in meteorology [2,3] and neuronal activity [4]. SOC in its most familiar context, the "sandpile" models, is related to a continuous phase transition to an absorbing state [5]. Together, relaxation and slow drive restrict the system to the neighborhood of the critical point, yielding power-law scaling without parameter tuning [5,6].

1. P. Bak, C. Tang, and K. Wiesenfeld, Phys. Rev. Lett. 59, 381 (1987).
2. O. Peters et al., Phys. Rev. Lett. 88, 018701 (2002); O. Peters and K. Christensen, Phys. Rev. E 66, 036120 (2002).
3. J. D. Neelin et al., J. Atmos. Sci. 66, 2367 (2009).
4. J. M. Beggs and D. Plenz, J. Neurosci. 23, 11167 (2003).
5. R. Dickman et al, Braz. J. Phys. 30, (2000) 27.
6. G. Pruessner, Self-Organised Criticality (CUP, Cambridge, 2012).

Primary author: DICKMAN, Ronald (UFMG)

Presenter: DICKMAN, Ronald (UFMG)

Session Classification: Modelling and Parameterising Deep Convective Organisation

Track Classification: Modelling and Parameterising Deep Convective Organisation

Contribution ID: **34** Type: **Interactive presentation**

Understanding the Triggering of Nor'westers over West Bengal, India

Wednesday, 5 May 2021 16:00 (1h 45m)

Every year during premonsoon season, the eastern parts of the Indian subcontinent experiences severe thunderstorms. These mesoscale convective storms are locally known as 'Kalbaishakhi' or 'nor'westers'. To forecast these organized storms with sufficient lead time it is important to know the convective initiation processes responsible for triggering these organized cloud formations. ARW-WRF model version 3.9.1.1 with a cloud resolving horizontal resolution of 1 km has been run using IITM GFS T1534 as initial condition to understand the trigger mechanism. One particular case of thunderstorm has been taken for this study that occurred on 24th February, 2019 over West Bengal, India and Bangladesh. It is observed that there is a distinctive difference between the microphysical processes over the region (Purulia [23° N, 86° E]) where the clouds started to organize with that of a region (Kolkata [22.5° N, 88° E]) where the storm moved after being fully developed. The thermodynamics and near surface dynamic processes over Purulia also show significant changes before and after the storm was triggered. Closely observing low level meteorological features of these regions can help us to identify the trigger mechanisms and will enable more accurate forecasts of thunderstorms.

Primary author: SARKAR, Rituparna (Indian Institute of Tropical Meteorology)

Co-author: Dr MUKHOPADHYAY, Parthasarathi (Indian Institute of Tropical Meteorology)

Presenter: SARKAR, Rituparna (Indian Institute of Tropical Meteorology)

Session Classification: Modelling and Parameterising Deep Convective Organisation

Track Classification: Modelling and Parameterising Deep Convective Organisation

Contribution ID: **36** Type: **Interactive presentation**

The Rainy-Bénard model: Convective organisation and equilibria in a simple framework.

Friday, 7 May 2021 16:00 (1h 45m)

We have constructed an extension of the Rayleigh–Bénard model of convection, to include latent heating due to the condensation of water vapour in clouds. Condensation occurs whenever specific humidity exceeds saturation (a nonlinear function derived from the Clausius-Clapeyron relation), and leads to heating. Condensed water is removed from the system and hence there is no evaporation. The system captures the nonlinearities between saturated (cloudy) and unsaturated (clear-air) thermodynamics.

A new non-dimensional number, related to the latent heating, is defined. An analytical steady-state ("drizzle") solution exists, in which diffusion of moisture maintains a saturated atmosphere, and condensation heating balances diffusive cooling. Time-dependent numerical solutions are also shown. For low Rayleigh number, Ra, steady-state flows occur, with "chimneys"of narrow convective clouds separated by broad regions of clear-sky descent. With increasing Ra the solutions become unsteady, with transient clouds and active gravity waves. This behaviour will be explored through matching of conserved quantities in the cloudy and clear parts of the domain, and through consideration of the mean, limiting states. The results will be related to "meteorological"parameters, to explore how the simple system can shed light on the origins of equilibria and instabilities in the atmospheric environment.

Primary author: PARKER, Douglas J (University of Leeds)

Co-authors: Prof. VALLIS, Geoffrey K (University of Exeter); Prof. TOBIAS, Steven M (University of Leeds)

Presenter: PARKER, Douglas J (University of Leeds)

Session Classification: Organisation in Shallow Convection

Track Classification: Organisation in Shallow Convection

Contribution ID: **37** Type: **Interactive presentation**

Essentially Lagrangian simulation of clouds using the Moist Parcel-In-Cell (MPIC) model

Wednesday, 5 May 2021 16:00 (1h 45m)

The Moist Parcel-In-Cell (MPIC) model provides an essentially Lagrangian approach to moist convection. In this approach, parcels represent both the thermodynamic and the dynamical prognostic properties of the flow. The parcels have a finite volume and carry part of the circulation and thermodynamic attributes (liquid water potential temperature and total water content).

The representation of parcel properties is fully Lagrangian, but an efficient grid-based solver calculates parcel advection velocities. The Lagrangian approach of MPIC has a number of advantages: thermodynamic properties and their correlations are naturally conserved, and the amount of mixing between parcels can be explicitly controlled. MPIC has also been shown to parallelise well on several thousands of cores. We present results demonstrating the performance of MPIC relative to the Met Office's cloud model, MONC, for a convective cloud moving under the influence of condensation and evaporation.

We also discuss ideas for implementing precipitating microphysics and studying organisation in MPIC. For precipitation, we are planning to build on a framework developed in work by Langhans et al. (J. Atmos. Sci., 2015). For studying organisation, MPIC provides a different perspective from traditional models as it is both essentially Lagrangian and formulated in terms of vorticity.

Primary authors: BLYTH, Alan (University of Leeds); DRISCHEL, David (University of St Andrews); PARKER, Doug (University of Leeds); GIBB, Gordon (EPCC); FREY, Matthias (University of St Andrews); BOEING, Steven (University of Leeds)

Presenter: BOEING, Steven (University of Leeds)

Session Classification: Modelling and Parameterising Deep Convective Organisation

Track Classification: Modelling and Parameterising Deep Convective Organisation

Contribution ID: **40** Type: **Interactive presentation**

Objective classification of cloud organisation with unsupervised neural networks

Friday, 7 May 2021 16:00 (1h 45m)

Existing methods for characterising cloud organisation rely on metrics which measure specific features of the cloud structures present, however existing features lead to ambiguity in identifying the convective regimes and formulating new metrics which are physically relevant is a challenging task. By automatically extracting spacial features necessary to solve a specific task (here distinguishing different regimes of cloud organisation) deep neural networks provide a novel approach to measuring cloud organisation.

This work presents a unsupervised neural network model able to autonomously discover different patterns of convective organisation and classify spatial regions into distinct forms of convective organisation.

The model is here applied to study of shallow trade-wind cumulus clouds, being trained on GOES-16 imagery of the tropical Atlantic, to try and unpick the poorly understood mechanisms driving different forms of convective organisation. Shallow trade-wind clouds are focussed on because their differing behaviour between climate models accounts for majority of inter-model spread in climate projections, and the spatial organisation of these clouds appears to cause a strong impact of their radiative properties.

Primary author: DENBY, Leif (University of Leeds)

Presenter: DENBY, Leif (University of Leeds)

Session Classification: Organisation in Shallow Convection

Track Classification: Organisation in Shallow Convection

Contribution ID: **41** Type: **Interactive presentation**

Self-Aggregation from Cold Pool Interaction and Global Energy Constraints

Wednesday, 5 May 2021 16:00 (1h 45m)

Typical explanations for convective self-aggregation invoke radiative convective equilibrium and free tropospheric feedbacks of circulation and radiation, caused by horizontal moisture inhomogeneities. We here show, that these feedbacks would not be needed when considering that cold pools interact. Building a simple model for this interaction, where the probability for new convective cells is increased where cells already exist, self-aggregation can be achieved. We map out the phase diagram in terms of the interaction strength between cold pool gust fronts, and find that continuous phase transitions exist, between regions without self-aggregation (homogeneous phases) and regions with self-aggregation (segregated phases). The model shown may be observationally testable and suggests, that boundary layer feedbacks alone can be sufficient in bringing about stable, system-scale clustering as is found in convective self-aggregation.

Primary author: HAERTER, Jan (Niels Bohr Institute, Copenhagen University)

Presenter: HAERTER, Jan (Niels Bohr Institute, Copenhagen University)

Session Classification: Modelling and Parameterising Deep Convective Organisation

Track Classification: Modelling and Parameterising Deep Convective Organisation

Contribution ID: **43** Type: **Interactive presentation**

Cold Pools and the Organization of Tropical Convection in Global Cloud-System Resolving Simulations

Wednesday, 5 May 2021 16:00 (1h 45m)

The DYAMOND (DYnamics of the Atmospheric general circulation Modeled On Non-hydrostatic Domains) project produced simulations of forty days, beginning 1 August 2016, using global models with a cloud-system resolving grid spacing of 5 km or less. How might we use this set of simulations to learn more about the effects of cold pools on convection?

We have developed a global (tropical ocean) cold-pool climatology from one of the simulations. We found that a simple cold pool detection algorithm seems to perform quite well for the tropical oceans. In the oceanic ITCZs, simulated cold pool occurrence ranges from 0.1 to 0.25. Simulated gust front (or discrete cold pool) frequency ranges from 1 to 2 per day. The western Atlantic, eastern Pacific, and the western Indian ITCZs are the most active by this measure. The average cold pool duration ranges from 3 to 5 hours. There is little large-scale geographical variability within the oceanic ITCZ. We did not find an obvious correlation between cold pool activity and shear of the mean zonal wind. Convective downdraft and cold pool fractions vary with convective updraft fraction. Convective updraft speed increases with convective fraction, which suggests that updraft "demographics"(updraft sizes, environmental RH) change with convective fraction.

Our next steps will include calculating a measure of clustering or organization, such sa the radial distribution (or pair correlation) function, for the simulated convective updrafts to determine if there is a relationship between cold pools and convection organization in these simulations.

Primary authors: KRUEGER, Steven (University of Utah); KHAIROUTDINOV, Marat (Stony Brook University, School of Marine & Atmospheric Sciences, Stony Brook, NY, United States)

Presenter: KRUEGER, Steven (University of Utah)

Session Classification: Modelling and Parameterising Deep Convective Organisation

Track Classification: Modelling and Parameterising Deep Convective Organisation

Contribution ID: **44** Type: **Interactive presentation**

Cloud field organisation in trade-wind cumulus: a consequence of precipitation efficiency

Friday, 7 May 2021 16:00 (1h 45m)

The influence of aerosol on precipitation in shallow clouds is a topic of longstanding interest. We will address the case of aerosol effects on warm trade-wind cumulus and show that the cloud system develops spatial organization structures in such a way as to generate similar amounts of precipitation, regardless of the aerosol input.
In aerosol-poor conditions, precipitation formation is efficient, and the system generates widespread surface rain. As a result, divergent cold pools are small because they encounter adjacent divergent flows within a short distance.
With increasing aerosol there is a reduction in the efficiency by which precipitation is generated and the system has to generate large clusters of clouds in order to achieve a similar amount of surface rain. These large clusters are embedded in extensive, relatively cloud-free areas that are associated with divergent cold pools generated by the precipitating clusters themselves.
Finally we show that these response are not unique to aerosol perturbations; similar changes in organization result from meteorological controls such as wind shear. Thus, we view spatial organisation in trade-wind cumulus fields as a consequence of the efficiency by which rain is produced.

Primary author: FEINGOLD, Graham (NOAA ESRL Chemical Sciences Division)

Presenter: FEINGOLD, Graham (NOAA ESRL Chemical Sciences Division)

Session Classification: Organisation in Shallow Convection

Track Classification: Organisation in Shallow Convection

Contribution ID: **46** Type: **Interactive presentation**

Theory of precipitation probability distributions

Wednesday, 5 May 2021 16:00 (1h 45m)

Relatively simple mathematical models derived from climate model equations can yield insight into how the characteristic form of probability distributions arise for different measures of precipitation, including event accumulations, time averaged intensities and spatial clusters. Stochastic differential equations for moisture and energy equations under reasonable approximations yield Fokker-Planck equations for moisture in nonprecipitating and precipitating regimes. These theoretical underpinnings can guide analysis of observations and climate models, suggesting diagnostics that bolster confidence in robustness of climate model predictions for changes under global warming. Methods drawn from statistical physics prove highly useful in this pursuit. While current solutions are much more detailed than initial analogies to self-organized criticality, we point out the ways in which those analogies have informed the current state of knowledge.

Primary authors: Prof. NEELIN, J. David (University of California, Los Angeles); MARTINEZ-VILLALOBOS, Cristian (University of California, Los Angeles); Dr AHMED, Fiaz (University of California, Los Angeles); KUO, Yi-Huong (University of California, Los Angeles)

Presenter: Prof. NEELIN, J. David (University of California, Los Angeles)

Session Classification: Modelling and Parameterising Deep Convective Organisation

Track Classification: Modelling and Parameterising Deep Convective Organisation

Contribution ID: **47** Type: **Interactive presentation**

A stochastic model for tropical precipitation clustering and connections to branching processes

Wednesday, 5 May 2021 16:00 (1h 45m)

Tropical convective organization in space is here addressed by examining precipitation clusters — spatially continuous regions exceeding a threshold precipitation. The probability distributions of the area and of the cluster power —the total rainfall integrated over the cluster —follow a power law (with slope ~ -1.5) bounded by a large-event cutoff. We show how a minimal stochastic model of tropical dynamics can reproduce these probability distributions. The model prognoses column water vapor that is coupled to temperature through the weak temperature gradient approximation. Parameter perturbation experiments reveal that the power law slope of ~-1.5 is fairly robust; the model cluster size and power cutoffs are, however, sensitive to the multiple model parameters. We find that a probabilistic process called the Branching Process is a useful analog for observed precipitation clustering. This process explains the apparent robustness of the power law slope and suggests the creation of a nearest-neighbor metric that is unreasonably effective at explaining the parametric sensitivity of the cluster distribution cutoffs. Regimes exhibiting lines or blobs of precipitating points similar to those termed "self-aggregating"are examined for contrast with the regime that is a closer match to observations for which the analogy to self organized criticality is much more apt.

Primary authors: AHMED, Fiaz (University of California, Los Angeles); Prof. NEELIN, J. David (University of California, Los Angeles)

Presenter: AHMED, Fiaz (University of California, Los Angeles)

Session Classification: Modelling and Parameterising Deep Convective Organisation

Track Classification: Modelling and Parameterising Deep Convective Organisation

Contribution ID: **48** Type: **Interactive presentation**

Competition between shear-organized and unorganized convection in large-domain CRM simulations

Thursday, 6 May 2021 16:00 (1h 45m)

Multicellular organization of deep convection is commonly observed, but ignored in contemporary global circulation model parameterizations. Is it important, and if so how? In an atmosphere destabilized by homogenous forcing, would a region of more organized convection out-compete regions with spotty convection for the resulting moist convective instability?

A set of idealized simulations is built to address those questions using large-domain simulations with Cloud Model 1 (CM1), a 3D cloud-resolving model with explicit representations of both convective-scale and domain-scale circulations. A double-periodic domain as large as we can afford (currently 570 km x 570 km) is uniformly destabilized with a homogeneous cooling of -4K/day and a constant SST at 301K with fixed wind speed of 5 m/s in the bulk aerodynamic flux formula. After a spin-up time of 10 days, experimental runs are continued for another 10 days, after introducing and maintaining vertically sheared zonal wind profiles in an east-west strip covering only part of the y-domain. In the sheared area, and perhaps in the vertical vorticity-rich areas on its flanks, convection organizes. Robe and Emanuel (2000) showed that different shear profiles produce along-vertical-shear rolls or across-vertical-shear squalls. Background vertical vorticity can also be important, but the zonal mean zonal wind is fixed every time step so that convection-vorticity interactions are restricted to a zonal eddy component. If organized convection on average heats the atmosphere more (or less) than the unorganized convection in the unsheared area, zonal-mean meridional circulations develop, with rising branches in whichever regime is most efficient at converting the uniform destabilization into latent heat release. Moisture transport reinforces this development of east-west banding, cleanly isolating and then amplifying the most positive of the convection-organizing effects of a prescribed nondivergent shearflow.

Primary authors: MAPES, Brian (University of Miami/RSMAS, Miami, FL); TSAI, W. M. (University of Miami/RSMAS, Miami, FL)

Presenter: MAPES, Brian (University of Miami/RSMAS, Miami, FL)

Session Classification: RCE and Processes in Deep Convective Organization

Track Classification: RCE and Processes in Deep Convective Organization

Contribution ID: **49** Type: **Interactive presentation**

Surface moisture exchange and its influence of self-aggregation in RCEMIP simulations.

Thursday, 6 May 2021 16:00 (1h 45m)

Under radiative-convective equilibrium (RCE) surface moisture fluxes drive convection, while convection-driven winds regulate surface fluxes. Most simulations of RCE do not resolve the boundary-layer turbulence that drives near-surface winds due to too coarse grid spacing and instead parameterize its effects by enforcing a minimum wind speed in the computation of the ocean-atmosphere exchange. We show from RCE simulations with fully resolved boundary-layer turbulence that capturing wind dynamics at low speeds impacts the spatially averaged surface moisture flux, as well as its spatial distribution. A minimum wind speed constraint of only 1 m s−1 leads to ~10% increase in spatially averaged surface flux in the evolution towards RCE and reduces the surface flux differences between windy and calm regions with more than a factor of two. Hence, the ability of simulations to let wind vanish is key in representing the wind-induced surface heat exchange feedback and is potentially important in convective self-aggregation for two reasons. First, surface fluxes reduce moisture gradients between moist and dry regions. Second, surface fluxes drive the convection that is the spatial distributor of moisture and therefore potentially play a role in setting the spatial scales at which self-aggregation happens.

Primary author: VAN HEERWAARDEN, Chiel (Wageningen University)

Presenter: VAN HEERWAARDEN, Chiel (Wageningen University)

Session Classification: RCE and Processes in Deep Convective Organization

Track Classification: RCE and Processes in Deep Convective Organization

Contribution ID: **50** Type: **Interactive presentation**

Predicting cold pool strength as a function of rain duration and intensity

Thursday, 6 May 2021 16:00 (1h 45m)

Idealised large-eddy simulations (LES) of isolated or colliding CPs have proven to be a useful tool to investigate the life cycle of CPs, their mutual interaction and the derivation of simple theories about CP properties such as the propagation speed. On the contrary, the formation of CPs by rain evaporation and specifically their relation to the parent rain event has so far gained little attention in idealized studies. This is surprising, as the 'rain –CP –rain'cycle lies at the core of the CPs'effect on the spatio-temporal distribution of convective fields. From an application perspective, understanding such relations is important in the development of cold pool parameterisations, that aim at adjusting for the enhanced convective triggering at the presence of CPs, where the triggering scales with the CP strength.
In this project we thus study the relation between rain intensity, duration and CP strength in an idealized setting. To this end, we include the temporal extent of the rain event that forms the CP through evaporative cooling by varying the duration, intensity and area of the volume that is cooled and moistened to simulate the generation of a CP. This has been neglected by most studies, who initialize the CP by an instantaneous forcing alone. These results will help to relate precipitation intensity and CP strength in observational studies, where testing the relation between rain cells and CP strength is complicated by the finite duration of rain events, and a missing understanding whether instantaneous or time-integrated precipitation statistics should be related to the CP.
Our simulations serve as a confirmation of many intuitive scaling behaviour, such as that CPs become larger and stronger the larger and more intense its parent rain cell is. However, our simulations also indicate a maximum cooling duration of approximately 20mins to be affecting the CP. Continuous cooling occurring after this does not visibly affect the CP radius and propagation speed. Consequently, the CP's effect on the environment, measured in terms of the updraft strength ahead of the CP, shows the same convergence. However, the CP interior shows enhanced radial airflow near the surface which affects the moisture uptake from the surface and thus may lead to more enhanced moisture rings. Furthermore, it acts as cold air supply, preventing the CP from early dissipation and prolonging its life-time.

Primary authors: MEYER, Bettina (Niels Bohr Institute, Copenhagen University); Prof. HAERTER, Jan (Niels Bohr Institute, Copenhagen University); FIÉVET, Romain (Niels Bohr Institute); KRUSE, Irene Livia (NBI)

Presenter: MEYER, Bettina (Niels Bohr Institute, Copenhagen University)

Session Classification: RCE and Processes in Deep Convective Organization

Track Classification: RCE and Processes in Deep Convective Organization

Contribution ID: **52** Type: **Interactive presentation**

Process-oriented evaluation of AROME-OM with a focus on its representation of organization

Friday, 7 May 2021 16:00 (1h 45m)

Since 2016, the AROME-OM model is operational over the Carribean area at a 2.5 km resolution. Availability of these operational forecasts raises several scientific questions : i) to what extent this new generation of models significantly improves the forecast in the Overseas; ii) does this huge ensemble of simulated data represent an opportunity to study the processes that govern the shallow convection in a wide range of thermodynamical situations and its spatial organization. To explore to which extend this data set can be used for process studies, an in depth assessment of the model performance is needed, with respect to different types of observations, namely i) thermodynamical profiles provided by radiosoundings and dropsondes spawned within the simulation domain, ii) cloud profiles measured continuously at the Barbados Cloud Observatory (https://barbados.mpimet.mpg.de/), iii) cloud organization inferred from GOES East geostationary satellite observations.
This study is conducted during the EUREC4a international measurement campaign (January-February 2020, http://eurec4a.eu/) that took place East off the island of Barbados (13N, 57W). During the campaign, the AROME-OM was run at 1.3 km offering an opportunity to evaluate the added value by this increase in resolution.
Comparisons at the Barbados site shows the good skill of the AROME-Antilles model to represent the double peak of cloud fraction with one peak located at the base of the cumulus and the other at the trade-wind inversion ; those two peaks are associated with the presence of very shallow cumulus and much thicker cumulus that reach 3 km with a frequent occurrence of an anvil at this altitude.
As defined in Tobin et al (2020, Journal of Climate), we will apply some metrics on the outputs of the two versions of AROME (1.3 km and 2.5 km) to characterize the spatial organization of the shallow convection and investigate the capability of the model to reproduce the different patterns of organization (sugar, gravel, fish, flower) defined by Stevens et al. (2019, QJRMS) and their associated large-scale environment as shown in Bony et al (2020).

Primary authors: BEUCHER, Florent (Météo France); COUVREUX, Florence; BOUNIOL, Dominique; FAVOT, F.; FAURE, G.; BRUNET, Y.; GUILLEMOT, A.; TESSIOT, O.

Presenter: BEUCHER, Florent (Météo France)

Session Classification: Organisation in Shallow Convection

Track Classification: Organisation in Shallow Convection

Contribution ID: **55** Type: **Interactive presentation**

How do ocean temperature anomalies favor or disfavor the aggregation of deep convective clouds?

Thursday, 6 May 2021 16:00 (1h 45m)

Convective organization at mesoscales (hundreds of kilometers) is ubiquitous in the tropics, but the physical processes behind it are still poorly understood, despite its strong societal and climatic impact. Organization can be forced by the large scales, such as surface temperature gradients. But convective organization can also arise from internal feedbacks, such as "self-aggregation" feedbacks. Self-aggregation refers to the spectacular ability of deep clouds to spontaneously cluster in space despite spatially homogeneous conditions and no large-scale forcing, in high-resolution cloud-resolving models (CRMs).

Because of the idealized settings in which self-aggregation has been studied (typically radiative-convective equilibrium (RCE) over homogeneous sea-surface temperature (SST)), its relevance to the real tropics is debated. In this presentation, we will investigate the impact of removing some of these idealizations on the aggregation process. Specifically, we will investigate the impact of inhomogeneous SSTs on convective aggregation.

In a first step, we will investigate how an idealized warm circular SST anomaly, referred to as "hot-spot", helps organize convection, and how self-aggregation feedbacks modulate this organization. The presence of a hot-spot significantly accelerates aggregation, particularly for larger domains and warmer/larger hot-spots, and extends the range of SSTs for which aggregation occurs. In that case, the aggregation onset results from a large-scale circulation induced by the hot-spot.

In a second step, we will investigate the interaction of aggregation with an interactive surface (local SST evolving according to the surface energy budget). The results will be interpreted in light of a simple model for the boundary layer circulation.

Primary authors: MULLER, caroline (CNRS/LMD); Dr SHAMEKH, Sara (Columbia University); Prof. D'ANDREA , Fabio (CNRS/LMD); Prof. DUVEL, Jean-Philippe

Presenter: MULLER, caroline (CNRS/LMD)

Session Classification: RCE and Processes in Deep Convective Organization

Track Classification: RCE and Processes in Deep Convective Organization

Contribution ID: **56** Type: **Interactive presentation**

How weakened cold pools facilitate convective self-aggregation

Thursday, 6 May 2021 16:00 (1h 45m)

In radiative-convective equilibrium (RCE) simulations, convective self-aggregation (CSA) is the spontaneous organization into segregated cloudy and cloud-free regions. Evidence exists for how CSA is stabilized, but how it arises favorably on large domains is not settled. Using large-eddy simulations (LES), we link the spatial organization emerging from the interaction of cold pools (CPs) to CSA. We systematically weaken simulated rain evaporation to reduce maximal CP radii, $R_{\max}$, and find reducing $R_{\max}$ causes CSA to occur earlier. We further identify a typical rain cell generation time and a minimum radius, $R_{\min}$, around a given rain cell, within which the formation of subsequent rain cells is suppressed. Incorporating $R_{\min}$ and $R_{\max}$, we propose a toy model that captures how CSA arises earlier on large domains: when two CPs of radii $r_{i,j} \in [R_{\min}, R_{\max}]$ collide, they form a new convective event. These findings imply that interactions between CPs may explain the initial stages of CSA.

Primary author: Mr NISSEN, Silas Boye (Niels Bohr Institute)

Co-author: HAERTER, Jan (Niels Bohr Institute, Copenhagen University)

Presenter: Mr NISSEN, Silas Boye (Niels Bohr Institute)

Session Classification: RCE and Processes in Deep Convective Organization

Track Classification: RCE and Processes in Deep Convective Organization

Contribution ID: **57** Type: **Interactive presentation**

Covariability of trade-wind cloudiness and environmental conditions in large-eddy simulations and observations

Friday, 7 May 2021 16:00 (1h 45m)

Shallow convection in the downwind trades occurs in form of different cloud patterns with characteristic cloud arrangements at the meso-scale. The four most dominant patterns were previously named Sugar, Gravel, Flowers and Fish and have been identified to be associated with different net cloud radiative effects.

By using long-term observations, we reveal that these differences can be mainly attributed to the stratiform cloud component that varies in extent across the patterns as opposed to the cloudiness at the lifting condensation level that is fairly constant independent of the patterns.

The observations reveal further, that each pattern is associated with a different environmental condition whose characteristics originate not soley from within the trades. Sugar air-masses are characterized by weak winds and of tropical origin, while Fish are driven by convergence lines originating from synoptical disturbances. Gravel and Flowers are most native to the trades, but distinguish themselves with slightly stronger winds and stronger subsidence in the first case and greater stability in the latter.

How well this covariability of cloudiness and environmental conditions is represented in simulations is important to project the occurrence of the patterns in a warmer climate and evaluated by realistic large-eddy simulations of the recent $EUREC^4A$ field campaign.

Primary author: SCHULZ, Hauke (Max Planck Institute for Meteorology)

Co-authors: EASTMAN, Ryan (University of Washington); STEVENS, Bjorn (Max Planck Institute for Meteorology)

Presenter: SCHULZ, Hauke (Max Planck Institute for Meteorology)

Session Classification: Organisation in Shallow Convection

Track Classification: Organisation in Shallow Convection

Contribution ID: **58** Type: **Interactive presentation**

Treating Deep Convective Updrafts in the Tropical Atlantic like Interacting Particles?

Wednesday, 5 May 2021 16:00 (1h 45m)

Understanding the spatial correlations and interactions between tropical clouds remains a challenge for climate research. Here, we develop and apply an analysis that treats deep convective updrafts in the Tropical Atlantic like interacting particles. We discuss how far we can reproduce our findings with simplified equilibrium statistics and which possible routes towards open, non-equilibrium systems might be taken. Our analysis is based on data from large-domain, storm-resolving ICON simulations from which updraft cells were derived via object-based techniques. After the introduction of an extended pair-correlation method, we compare simulated updraft pair numbers as a function of pair distance to a random, but heterogeneous reference. We find that the average probability is enhanced to find an updraft pair within 100 km. Additionally, the spatial arrangement of larger or stronger cells deviates more from randomness compared to smaller or weaker cells, which might be related to their stronger dynamical interaction mechanisms.

Primary authors: SENF, Fabian (Leibniz Institute for Tropospheric Research); Dr KLOCKE, Daniel (Max Planck Institute for Meteorology, Hamburg)

Presenter: SENF, Fabian (Leibniz Institute for Tropospheric Research)

Session Classification: Modelling and Parameterising Deep Convective Organisation

Track Classification: Modelling and Parameterising Deep Convective Organisation

Contribution ID: **59** Type: **Interactive presentation**

Impact of microphysics on tropical precipitation extremes in a global storm-resolving model

Thursday, 6 May 2021 16:00 (1h 45m)

The impact of microphysics on tropical precipitation extremes is explored with a global storm-resolving model by modifying the terminal velocity of raindrops. Depending on the time scales, precipitation extremes respond differently. Hourly extremes are influenced dynamically through convective updraft speed, as a faster terminal velocity of raindrops increases the updraft speed by reducing the total rain in the atmosphere which increases the updraft buoyancy. However, the response of daily precipitation extremes is more sensitive to the microphysical modulation on convective organization. By being more organized with decreasing terminal velocity, daily precipitation extremes are enhanced due to increased precipitation efficiency and intensified updrafts. Thus, the results suggest that microphysics, despite often occurring at small scales, can influence the circulation at larger scales, and the microphysical imprint across different scales plays an important role in regulating tropical precipitation extremes.

Primary authors: BAO, Jiawei; Dr WINDMILLER, Julia (Max Planck Institute for Meteorology)

Presenter: BAO, Jiawei

Session Classification: RCE and Processes in Deep Convective Organization

Track Classification: RCE and Processes in Deep Convective Organization

Contribution ID: **60** Type: **Interactive presentation**

The Role of Cloud-Cloud Interactions in the organization shallow cumulus clouds

Friday, 7 May 2021 16:00 (1h 45m)

Some of the fundamental puzzles of climate research are related to limited understanding of the critical processes governing the organization and evolution of cloud fields. These processes include the understanding and representation of forcing of shallow convection and subsequent mixing processes. Here we tracked the Lagrangian evolution of thousands of individual shallow cumulus clouds in a large-eddy simulation for a period during the Holistic Interactions of Shallow Clouds, Aerosols, and Land-Ecosystems (HI-SCALE) field campaign in the U.S. Southern Great Plains. Results show that shallow clouds grow at the expense of the dissipation of neighboring clouds, which demonstrates the importance of the lateral interactions among clouds in the evolution of the cloud populations. Based on these interaction simple models of evolution of population of shallow clouds are derived for future parameterization applications.

Primary authors: CHEN, Jingyi; Dr HAGOS, Samson (PNNL); Dr FENG, Zhe (PNNL); Dr FAST, Jerome (PNNL); Dr XIAO, Heng (PNNL)

Presenter: CHEN, Jingyi

Session Classification: Organisation in Shallow Convection

Track Classification: Organisation in Shallow Convection

Contribution ID: **61** Type: **Interactive presentation**

The coupling of winds and clouds in organized shallow convection

Friday, 7 May 2021 16:00 (1h 45m)

Studies of deep convection have long established that environmental wind shear is important for the development of long-lived organized convection. But do we understand how winds play a role in the organization of shallow convection?
In this talk I will show idealized and realistic large-eddy simulations of precipitating shallow convection and discuss the sensitivity of convective deepening to wind shear and the role of mesoscale circulations in setting convective momentum transport and (near-surface) wind stress.

Primary author: NUIJENS, Louise

Presenter: NUIJENS, Louise

Session Classification: Organisation in Shallow Convection

Track Classification: Organisation in Shallow Convection

Contribution ID: **62** Type: **Interactive presentation**

The Role of Mesoscale Cellular Convective Cloud Morphologies in Low Cloud Feedbacks

Friday, 7 May 2021 16:00 (1h 45m)

Mesoscale cellular convective (MCC) clouds occur in large-scale patterns over the ocean, are prevalent in sub-tropical cloud regions and mid-latitudes, and have important radiative impacts on the climate system. On average, closed MCC clouds have higher albedos than open or disorganized MCC clouds for the same cloud fraction which suggests differences in micro- and macro-physical characteristics between MCC morphologies. Marine cold air outbreaks (MCAOs) influence the development of open MCC clouds and the transition from closed to open MCC clouds in the mid-latitudes. A MCAO index, M, combines atmospheric surface forcing and static stability and can be used to examine global MCC morphology dependencies. MCC cloud morphology occurrence is also expected to shift with sea surface temperature (SST) changes as the climate warms. Analysis of MCC identifications (derived from a neural network classifier applied to MODIS satellite collection 6.1 liquid water path retrievals) and ECMWF ERA5 reanalysis data shows that closed MCC cloud occurrence shifts to open or disorganized MCC within an M-SST space. Global climate models (GCMs) predict that M will change regionally in strength as SSTs increase. Based on our derived MCC-M-SST relationship in the current climate, closed MCC occurrence frequency is expected to increase with a weakening of M but decrease with an increase in SSTs. This results in a shift to cloud morphologies with lower albedos. Cloud controlling factor analysis is used to estimate the resulting low cloud morphology feedback which is found to be spatially varied and between ±0.15 W m-2 K-1. Because the morphology feedback is estimated to be positive in the extra-tropics and is not currently represented in GCMs, this implies a higher climate sensitivity than GCMs currently estimate.

Primary author: Dr MCCOY, Isabel (University Corporation for Atmospheric Research & Rosenstiel School of Marine and Atmospheric Science, University of Miami, USA)

Co-authors: Dr MCCOY, Daniel (Department of Atmospheric Sciences, University of Wyoming, USA); Dr WOOD, Robert (Atmospheric Sciences Department, University of Washington, USA); Dr ZUIDEMA, Paquita (Rosenstiel School of Marine and Atmospheric Science, University of Miami, USA); Dr BENDER, Frida (Department of Meteorology and Bolin Centre for Climate Research, Stockholm University, Sweden)

Presenter: Dr MCCOY, Isabel (University Corporation for Atmospheric Research & Rosenstiel School of Marine and Atmospheric Science, University of Miami, USA)

Session Classification: Organisation in Shallow Convection

Track Classification: Organisation in Shallow Convection

Contribution ID: **63** Type: **Interactive presentation**

Defining a cold pool-resolving scale for numerical simulations of convective self-organisation

Wednesday, 5 May 2021 16:00 (1h 45m)

In state-of-the art cloud-resolving models, convective self-aggregation (CSA) finds itself consistently hampered by finer horizontal resolutions [Muller & Held (2012), Yanase et al. (2020)]. This feature was ascribed to the effect of cold pool (CP) gust fronts in opposing the positive moisture feedback underlying CSA [Jeevanjee & Romps (2013)]. Further, recent numerical experiments [Haerter et al. (2020)] with diurnally oscillating surface temperature showed how CPs promote cloud field self-organization into mesoscale convective systems (MCS). That is, in stark contrast to CSA, strengthening CPs promotes this organization effect.

Hence, in both idealized and realistic insolation conditions, numerical simulations should go beyond the typical cloud-resolving paradigm to achieve cold pool-resolving capabilities in order to study the organisation of convection.

To this end, this numerical study examines the impact of model resolution on CP-driven circulation in order to identify a cold pool resolving lengthscale to serve as an element-size requirement for explicit simulations.

Primary author: FIÉVET, Romain (Niels Bohr Institute)

Co-authors: HAERTER, Jan (Niels Bohr Institute, Copenhagen University); Dr MEYER, Bettina (Niels Bohr Institute)

Presenter: FIÉVET, Romain (Niels Bohr Institute)

Session Classification: Modelling and Parameterising Deep Convective Organisation

Track Classification: Modelling and Parameterising Deep Convective Organisation

Contribution ID: **64** Type: **Interactive presentation**

Lagrangian LES of Cloud Organization from EUREC4A

Friday, 7 May 2021 16:00 (1h 45m)

The EUREC4A field campaign took place in the subtropical North Atlantic Ocean during January and February 2020. An array of in situ and remote sensing observations of the atmosphere and ocean around Barbados were gathered by an array of platforms including aircraft, ships, satellites and the ground-based Barbados Cloud Observatory. Our focus is on the evolution of marine boundary layer cloud and its organization along quasi-Lagrangian trajectories approaching Barbados. This evolution is studies in 2-3 day long large eddy simulations (LES) along trajectories that follow winds in the marine boundary layer. Large-scale forcing are derived from ECMWF analysis and reanalysis, and the simulations are validated against remote sensing and in situ observations gathered during the campaign.

Early results will be presented at the meeting, including case studies with observed cold pools near Barbados on February 9 and shallow cumulus with broad inversion cloud (i.e., "flowers") in an air mass that arrived near Barbados on February 2nd.

Primary authors: BLOSSEY, Peter (University of Washington, Seattle); NEGGERS, Roel (University of Cologne); GHAZAYEL, Salima (University of Cologne); BOEING, Steven (University of Leeds); DENBY, Leif (University of Leeds); Mr EASTMAN, Ryan (University of Washington); SCHULZ, Hauke (Max Planck Institute for Meteorology)

Presenter: BLOSSEY, Peter (University of Washington, Seattle)

Session Classification: Organisation in Shallow Convection

Track Classification: Organisation in Shallow Convection

Contribution ID: **65** Type: **Interactive presentation**

Subcloud layer circulation of isolated moist convection cells

Wednesday, 5 May 2021 16:00 (1h 45m)

We analyze a single diurnal cycle simulated by the two large eddy simulation (LES) models UCLA-LES and the vector vorticity model VVM in an idealized setup, which show precipitating deep convection in the course of the afternoon. Both models use the same initial conditions, horizontal and vertical grid, but show significant differences in the total amount of precipitation, and in the size of the clouds. We identify individual convection cells by rain cell tracking, and build composites of the cells. We explain the main differences between the LES models by both the surface flux calculation, and the precipitation formation in the cloud layer due to different microphysics schemes.

Although the diurnal cycles of precipitation and associated cold pools are quite different, the subcloud layer circulation about 30 min before surface precipitation onset and has a similar structure for both models, and is approximately stationary. We propose an analytic subcloud layer model (ASLM) for the flow field within the boundary layer below convective clouds which, despite some degree of idealization, is capable to describe this subcloud layer circulation as found in the LES. The analytic model features two fit parameters with a physical interpretation , one being the level of neutral buoyancy below the cloud base, and the other being the Brunt–Väisälä frequency.

Primary authors: MOSELEY, Christopher (Department of Atmospheric Sciences, National Taiwan University, Taipei 10617, Taiwan); Mr HUANG, Jin-De (Department of Atmospheric Sciences, National Taiwan University); HAERTER, Jan (Niels Bohr Institute, Copenhagen University); Prof. WU, Chien-Ming (Department of Atmospheric Sciences, National Taiwan University)

Presenter: MOSELEY, Christopher (Department of Atmospheric Sciences, National Taiwan University, Taipei 10617, Taiwan)

Session Classification: Modelling and Parameterising Deep Convective Organisation

Track Classification: Modelling and Parameterising Deep Convective Organisation

Contribution ID: **66** Type: **Interactive presentation**

The fractal nature of clouds in global convection-resolving simulations and satellite data

Wednesday, 5 May 2021 16:00 (1h 45m)

Recent years have seen an increase in the production of global convection-resolving (or at least convection-permitting) atmospheric simulations. These simulations are very realistic when compared to observations. A good example of this can be seen in images of simulated cloud condensate fields, rendered in such a way that they can be directly compared to satellite images of the Earth (e.g. Fig 2, Stevens et al, 2019). While it can be difficult at first glance to distinguish between model and observed data, on closer inspection, the satellite image can often be identified. We seek to quantify these visual similarities and differences between models and satellite data. We do this by computing the fractal dimension of clouds.

It has long been known that clouds in observations exhibit self-similarity across scales ranging from 1 to 1000 km (Lovejoy, 1982), i.e. they are fractals, but it is not known if models can reproduce this behaviour. We demonstrate the fractal nature of clouds simulated by high-resolution model simulations completed as part of the DYAMOND intercomparison project (Stevens et al, 2019). We compute the fractal dimension of the simulated clouds, and compare this to the dimension measured using Himawari satellite data. This enables us to quantify the fidelity of the multi-scale structure of convection and convective organisation across model simulations. Only by quantifying the difference between models and observations can we assess the degree to which a high-resolution model can ʻstand inʼfor observations, and thereby be used to help us understand the real atmosphere.

Lovejoy (1982). Science, 216(4542), 185–187. DOI: 10.1126/science.216.4542.185

Stevens et al, (2019), Progress in Earth and Planetary Science, 6(61), DOI: 10.1186/s40645-019-0304-z

Primary author: CHRISTENSEN, Hannah (University of Oxford)

Co-author: DRIVER, Oliver (University of Oxford)

Presenter: CHRISTENSEN, Hannah (University of Oxford)

Session Classification: Modelling and Parameterising Deep Convective Organisation

Track Classification: Modelling and Parameterising Deep Convective Organisation

Contribution ID: **67** Type: **Interactive presentation**

A climatology of trade cumulus cold pools and their link to mesoscale cloud organization

Friday, 7 May 2021 16:00 (1h 45m)

We present a climatology of trade cumulus cold pools and their associated meteorological perturbations based on ten years of in-situ and remote sensing data from the Barbados Cloud Observatory. Cold pools are identified by abrupt drops in surface temperature, and the mesoscale organization pattern is classified by a neural network algorithm based on GOES-16 infrared images. We find cold pools to be ubiquitous in the winter trades—they are present about 5% of the time and occur on two-thirds of days. Stronger temperature drops (dT) are associated with deeper clouds, stronger precipitation, stronger downdrafts and humdidity drops, stronger updrafts and wind gusts in the front, and larger cloud cover compared to weaker dT. The downdraft strength together with the cold-pool duration explains variability in dT very well (Multiple R^2=0.53).

The mesoscale organization pattern has a strong influence on the occurrence frequency of cold pools. Fish has the largest cold-pool fraction (13% of time), followed by Flowers and Gravel (10.4% and 7.4%), and lastly Sugar (1.7%). Fish cold pools are also significantly stronger and longer-lasting compared to Flowers and Gravel cold pools. The daily cycle of the occurrence frequency of Gravel, Flowers, and Fish can explain a large fraction of the daily cycle in the cold-pool occurrence, as well as the pronounced extension of the daily cycle of shallow convection into the early afternoon by cold pools. Overall, we find cold-pool periods to be ~90% cloudier relative to the average winter trades. Also the wake of cold pools is characterized by above-average cloudiness, suggesting that mesoscale arcs enclosing broad clear-sky areas are rather the exception than the rule. Better understanding how cold pools interact with and shape their environment could therefore be valuable to understand cloud cover variability in the trades.

Primary authors: VOGEL, Raphaela (LMD/CNRS Paris); Dr KONOW, Heike (University of Hamburg); SCHULZ, Hauke (Max Planck Institute for Meteorology); Dr ZUIDEMA, Paquita (Rosenstiel School of Marine and Atmospheric Science, University of Miami, USA)

Presenter: VOGEL, Raphaela (LMD/CNRS Paris)

Session Classification: Organisation in Shallow Convection

Track Classification: Organisation in Shallow Convection

Contribution ID: **68** Type: **Interactive presentation**

How do families of MCSs organize in time and space?

Wednesday, 5 May 2021 16:00 (1h 45m)

Mesoscale convective systems (MCSs), long-lived clusters of convective cells spanning more than 100 km in diameter, are known to be the dominant source of rainfall in the tropics, and the longest-lived clusters are shown to be largely responsible for tropical extreme precipitation. These systems are known to be organized and maintained by the atmospheric characteristics needed for deep convection (moisture, instability, and lift), and the presence of vertical wind shear, which, however, tends to be very weak in the tropics. (1) MCS-like structures are also shown to "spontaneously" emerge, in idealized cloud-resolving simulations that only include a diurnally oscillating surface temperature, hinting at different organizational mechanisms than the ones mentioned above. (2) In these specific simulations, the MCSs also show a negatively correlated day-to-day spatial "checkerboard"pattern.

We here aim to investigate the patterns of MCSs emerging in observational (satellite infrared) data over the tropics. To shed light on the temporal evolution of potential MCS networks, we use a database of tracked MCSs (3), and try to identify "families"of MCSs that occur in spatial proximity to one other. In this work-in-progress we look for answers to the following questions: Do the MCS families tend toward a more organized state in time?; Can we find any resemblance of the aforementioned simulated patterns?; Can we find any indication of a "preferred"size and distance between MCSs within a family, and is there a difference over land versus over the ocean? By answering these questions we hope to obtain a better understanding of the emergence of long-term clustering in the tropics and its related extreme rainfall.

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2. Haerter, J.O., Meyer, B. & Nissen, S.B. Diurnal self-aggregation. npj Clim Atmos Sci 3, 30 (2020).
3. Fiolleau, Thomas & Roca, Remy. An Algorithm for the Detection and Tracking of Tropical Mesoscale Convective Systems Using Infrared Images From Geostationary Satellite. Geoscience and Remote Sensing, IEEE Transactions on. 51. 4302-4315 (2013).

Primary authors: KRUSE, Irene Livia (NBI); HAERTER, Jan (Niels Bohr Institute, Copenhagen University)

Presenter: KRUSE, Irene Livia (NBI)

Session Classification: Modelling and Parameterising Deep Convective Organisation

Track Classification: Modelling and Parameterising Deep Convective Organisation

Contribution ID: **69** Type: **Interactive presentation**

Merge or die - how long-lived convective events develop in cold pool-suppressed self-aggregation

Thursday, 6 May 2021 16:00 (1h 45m)

Under radiative convective equilibrium (RCE), cloud populations can spontaneously segregate into cloudy and cloud-free subregions, a process known as convective self-aggregation (CSA).
Cold pools (CPs) have been shown to inhibit and sometimes prevent CSA. Here, we suppress CPs by removing the re-evaporation of rain in Large Eddy Simulations and cloud resolving simulations, which we run for 10-20 days.

Without CPs individual rain events persist up to tens of hours in the course of this modified CSA. The rain locations correspond to local convection cells, which seem to merge and grow or to shrink and fade over time. Each convective updraft corresponds to a stable fixed point of the near-surface horizontal wind field, and its 'basin of attraction'represents the area from which surface winds collect moisture. We extract the location of the updraft and the area of these basins from the data. With these two quantities we can reconstruct the main dynamics in a model by assuming an incompressible flow and homogeneous subsidence everywhere but for the point-like updrafts.

This extreme CP-free case will help understand the role of CPs in the formation of CSA and may also be relevant in occasions, when rain re-evaporation is very low, because humidity is nearly saturate in the boundary layer, which may be the case for some oceanic areas.

Primary author: Ms GRONEMEYER, Ronja (ZMT Bremen)

Co-authors: Dr JENSEN, Gorm Gruner (Niels Bohr Institute, University of Copenhagen); Prof. HAERTER , Jan O. (Leibniz ZMT, (2) Jacobs University, (3) Niels Bohr Institute, University of Copenhagen)

Presenter: Ms GRONEMEYER, Ronja (ZMT Bremen)

Session Classification: RCE and Processes in Deep Convective Organization

Track Classification: RCE and Processes in Deep Convective Organization

Contribution ID: **70** Type: **Interactive presentation**

Cloud patterns in four dimensions

Friday, 7 May 2021 16:00 (1h 45m)

Quantifying, interpreting and classifying meso-scale patterns in shallow trade-wind cloud fields has recently received considerable attention. Typical patterns have i.a. been identified by expert visual inspection, machine learning and several "organisation metrics". In this work, we compute 21 frequently used or recently developed organisation metrics for 5000 satellite-observed shallow trade wind cloud fields. By projecting this dataset onto its principal components, we show that the 21 metrics primarily vary along only four, interpretable dimensions: 1) The dominant scale of clouds, 2) the size of clear sky patches between clouds, 3) the degree to which clouds align with a dominant direction and 4) cloud-top height variance across the cloud field. Linear combinations of these dimensions form an excellent description of organisation. The corresponding organisation distribution over our dataset is unimodal, continuous and does not possess distinct classes. Finally, we relate our pattern description to cloud physical processes from LES and cloud-controlling variables from reanalysis to search for mechanisms that drive the organisation into various regimes of our distribution.

Primary author: JANSSENS, Martin (Wageningen University & Research)

Co-authors: GLASSMEIER, Franziska (TU Delft); SCHEFFER, Marten (Wageningen University & Research); SIEBESMA, Pier (Delft University of Technology); VILA-GUERAU DE ARELLANO, Jordi

Presenter: JANSSENS, Martin (Wageningen University & Research)

Session Classification: Organisation in Shallow Convection

Track Classification: Organisation in Shallow Convection

Contribution ID: **71** Type: **Interactive presentation**

Radiative controls on the speed of growth of deep convective self-aggregation

Thursday, 6 May 2021 16:00 (1h 45m)

In idealized cloud-resolving models, convective self-aggregation, or organization, develops from small dry patches that expand until they cover a large fraction of the domain. This study investigates the drying tendency associated with radiatively-driven subsidence and its possible link to the timescale of transition from a non-organized to an organized state. Indeed, understanding the dynamics involved in this transition appears as a first crucial step to connect idealized simulations with observations of the real atmosphere: making this connection has been difficult because properties of aggregated states in equilibrium depend strongly on model configuration (domain size and shape, resolution, etc.), while the growth phase provides a different and unexplored angle to look for universal properties of self-aggregation.

We perform simulations with the System for Atmospheric Modeling (SAM), with no rotation and no vertical wind shear, focusing on the dynamics of the boundary between moist and dry regions. We use a local moisture budget and choose three definitions of the moist margin in order to track some of its properties over time: (a) the strength of maximum horizontal moisture gradients, (b) the drying tendency associated with radiatively-driven subsidence in the upper troposphere close to the convecting region, and (c) the drying tendency at low levels in the driest regions that likely reinforces a shallow atmospheric circulation that strengthens aggregation.

We assess the robustness of these controls for different SSTs and different domain configurations, before commenting on the possible role of self-aggregation in strengthening humidity gradients in the tropics. These domain-independent metrics based on local thermodynamic quantities will allow for an easier comparison with observations in the future.

Primary authors: FILDIER, Benjamin (Laboratoire de Météorologie Dynamique, ENS, Paris); MULLER, Caroline (CNRS/LMD)

Presenter: FILDIER, Benjamin (Laboratoire de Météorologie Dynamique, ENS, Paris)

Session Classification: RCE and Processes in Deep Convective Organization

Track Classification: RCE and Processes in Deep Convective Organization

Contribution ID: **72** Type: **Interactive presentation**

Drivers of Lagrangian evolution of mesoscale cellular convection in eastern subtropical oceans

Friday, 7 May 2021 16:00 (1h 45m)

In order to study the Lagrangian transition of mesoscale cloud morphologies in four eastern subtropical ocean basins, over 160,000 96-hour boundary layer trajectories are produced from ERA5 winds in these regions. Mesoscale cellular convection (MCC) classifications are generated from a supervised neural network algorithm applied to MODIS daytime liquid water path (LWP) data. This algorithm classifies cloud scenes as closed cell, open cell, or disorganized MCC. The MCC classifications of cloud scenes are sampled every 24 hours along trajectories, allowing for a comprehensive study of environmental precursors to transitions from closed cells to open cells or disorganized cells.
Early results show strong differences between cloud scenes that transition from closed to open cell MCC compared to scenes that stay closed or transition to disorganized MCC. The closed to open cell transition is preceded by anomalously strong surface winds, increased precipitation, and low cloud droplet concentration. A mechanism is proposed where strong winds drive increased latent heating, water vapor flux, and humidity in boundary layers with closed cell MCC. The increased moisture and heat leads to increased precipitation and declining cloud droplet concentrations, which drive the transition from closed to open MCC. This contrasts with the closed to disorganized MCC transition, which is associated with a drying and deepening boundary layer driven by declines in overlying subsidence and humidity, a weaker inversion, and a warming sea surface.
These results highlight the importance of studying cloud changes while taking morphology into account since changes in cloud properties can be driven by different mechanisms depending on their morphology.

Primary authors: EASTMAN, Ryan (University of Washington, Dept. of Atmospheric Sciences); MCCOY, Isabel (UCAR & University of Miami, RSMAS, USA); Dr WOOD, Robert (Atmospheric Sciences Department, University of Washington, USA)

Presenter: EASTMAN, Ryan (University of Washington, Dept. of Atmospheric Sciences)

Session Classification: Organisation in Shallow Convection

Track Classification: Organisation in Shallow Convection

Contribution ID: **73** Type: **Interactive presentation**

Conceptualizing diurnal surface warming in the tropical ocean

Wednesday, 5 May 2021 16:00 (1h 45m)

Which processes cause and maintain convective organization in the tropics? Recent cloud-resolving simulations indicate that, compared to studies performed under radiative convective equilibrium, a diurnally varying boundary surface substantially changes the spatiotemporal patterns of convection. To better understand feedbacks between the atmosphere and an interactive ocean requires an accurate description of diurnal warming at the sea surface. Here we present an idealized, one-dimensional model of radiative transfer in the upper 10 meters of the ocean, forced by solar insolation and atmospheric conditions. Unlike comparable models, we treat turbulent mixing as simple diffusion combined with a second linear mixing term. This retains conceptual simplicity while resolving important processes such as wind-driven mixing, near-surface heat trapping, and skin cooling. A comparison with observations shows that the model produces key features of real diurnal temperature profiles. In turn, our results cast light on which conditions may facilitate strong diurnal surface warming of 3K and more.

Primary author: BÖRNER, Reyk (Atmospheric Complexity, Niels Bohr Institute)

Co-authors: FIÉVET, Romain (Atmospheric Complexity, Niels Bohr Institute); HAERTER, Jan (Atmospheric Complexity, Niels Bohr Institute)

Presenter: BÖRNER, Reyk (Atmospheric Complexity, Niels Bohr Institute)

Session Classification: Modelling and Parameterising Deep Convective Organisation

Track Classification: Modelling and Parameterising Deep Convective Organisation

Contribution ID: **74** Type: **Interactive presentation**

Convective aggregation in idealized stochastic models

Thursday, 6 May 2021 16:00 (1h 45m)

Numerical simulations of radiative-convective equilibrium (RCE) in high-resolution cloud-resolving models (CRMs) have pointed out the tendency of atmospheric convection to self-aggregate on periods of several weeks when the domain is large enough. Nevertheless, even though CRM simulations are able to identify some of the physical mechanisms driving convective clustering, the occurrence of organization seems to be dependent on the model setup and parameterizations. Robust results from simpler, idealized models may thus be used to help analyze and explain the sensitivities detected in CRM simulations.

Based on the work by Craig and Mack (2013), we developed a new simplified stochastic model able to predict the evolution of column relative humidity (CRH) in the tropical free troposphere, mimicking convective clustering in a state of RCE. Novelties with such an approach lie on the fact that the convective moistening term is not modeled as a smooth, deterministic function of the background humidity but accounts for stochastic variability, therefore the model lends itself to be run at high, convective "resolving" resolution. Numerical experiments were performed for different values of the key parameters, namely, subsidence timescale, moisture diffusion coefficient and a parameter determining the shape of the probability density function which governs the choice of convective locations.

Preliminary results are presented. It was hypothesized that subsidence timescale and diffusion coefficient can be combined together to give information about the radius of influence of convective events, i.e., how far convection is moistening. The main finding is that the radius of influence (properly rescaled) can actually be used to predict the transition between non-aggregated and aggregated states in the parameter space, that is, the instability of the RCE state of tropical convection. As already noticed in more complex, full physics CRMs, convective organization is sensitive to domain size and resolution, and the system exhibits hysteresis.

Primary authors: BIAGIOLI, Giovanni (University of Trieste); Dr TOMPKINS, Adrian Mark (ICTP)

Presenter: BIAGIOLI, Giovanni (University of Trieste)

Session Classification: RCE and Processes in Deep Convective Organization

Track Classification: RCE and Processes in Deep Convective Organization

Contribution ID: **75** Type: **Interactive presentation**

From Sugar to Flowers: A Transition of Shallow Cumulus Organization During ATOMIC

Friday, 7 May 2021 16:00 (1h 45m)

The Atlantic Tradewind Ocean-Atmosphere Mesoscale Interaction Campaign (ATOMIC) took place in January–February 2020. It was designed to understand the relationship between shallow convection and the large-scale environment in the trade-wind regime. Lagrangian large eddy simulations, following the trajectory of a boundary-layer airmass, can reproduce a transition of trade cumulus organization from "sugar"to "flower"clouds with cold pools, observed on February 2–3. The simulations were driven with reanalysis large-scale meteorology and ATOMIC in-situ aerosol data. During the transition, large-scale upward motion deepens the cloud layer. The total water path and optical depth increase, especially in the moist regions where flowers aggregate. Mesoscale circulation leads to a net convergence of total water in the already moist and cloudy regions, strengthening the organization. Stronger large-scale upward motion reinforces the mesoscale circulation and accelerates the organization process by strengthening the cloud-layer mesoscale buoyant turbulence kinetic energy production.

Primary authors: NARENPITAK, Pornampai (NOAA Chemical Sciences Laboratory / CIRES University of Colorado Boulder); Dr KAZIL, Jan (NOAA Chemical Sciences Laboratory / CIRES University of Colorado Boulder); Dr YAMAGUCHI, Takanobu (NOAA Chemical Sciences Laboratory / CIRES University of Colorado Boulder); Dr QUINN, Patricia (NOAA Pacific Marine Environmental Laboratory); Dr FEINGOLD, Graham (NOAA Chemical Sciences Laboratory)

Presenter: NARENPITAK, Pornampai (NOAA Chemical Sciences Laboratory / CIRES University of Colorado Boulder)

Session Classification: Organisation in Shallow Convection

Track Classification: Organisation in Shallow Convection

Contribution ID: **76** Type: **Interactive presentation**

Multifractal constraints on cloud and precipitation structure in LES

Friday, 7 May 2021 16:00 (1h 45m)

Coarse-gridded atmospheric models often account for subgrid-scale variability by specifying probability distribution functions (PDFs) of process rate inputs such as cloud and rain water mixing ratios (q_c and q_r, respectively). PDF parameters can be obtained from numerous sources: in situ observations, ground- or space-based remote sensing, or fine-scale modeling such as large eddy simulation (LES). LES is appealing to constrain PDFs because it generates large sample sizes, can simulate a variety of cloud regimes/case studies, and is not subject to the ambiguities of observations. However, despite the appeal of using model output for parameterization development, it has not been demonstrated that LES satisfactorily reproduces the observed spatial structure of microphysical fields. In this study, the structure of observed and modeled microphysical fields are compared by applying bifractal analysis, an approach that quantifies variability across spatial scales, to simulations of a drizzling stratocumulus field that span a range of domain sizes, drop concentrations (a proxy for mesoscale organization), and microphysics schemes (bulk and bin). Simulated q_c closely matches observed estimates of bifractal parameters that measure smoothness and intermittency. There are major discrepancies between observed and simulated q_r properties, though, with bulk simulated q_r consistently displaying the bifractal properties of observed clouds (smooth, minimally intermittent) while bin simulations produce q_r that is appropriately intermittent but too smooth. These results suggest fundamental limitations of bulk and bin schemes to produce sufficiently intermittent and rough precipitation, further implying that simulations of warm rain with Eulerian microphysics schemes are likely unable to reproduce higher-order spatial statistics of precipitation. We end by proposing a framework for development of stochastic microphysical parameterizations.

Primary authors: WITTE, Mikael (Naval Postgraduate School); Dr MORRISON, Hugh (NCAR)

Presenter: WITTE, Mikael (Naval Postgraduate School)

Session Classification: Organisation in Shallow Convection

Track Classification: Organisation in Shallow Convection

Contribution ID: **77** Type: **Interactive presentation**

The Effects of the Unified Parameterization in the CWBGFS: the Diurnal Cycle of Precipitation over Land in the Maritime Continent

Wednesday, 5 May 2021 16:00 (1h 45m)

The unified parameterization (UP) is a framework that physically adjusts the precipitation partition between the parameterized convection and the grid-scale processes based on the convective updraft fraction. This study investigates the effects of the UP on the diurnal cycle of precipitation over land in the Maritime Continent using an atmospheric general circulation model at the spatial resolution of 15 km. Three experiments are carried out; the conventional deep convection scheme (RAS), the RAS incorporated with the UP (URAS), and the no deep convection scheme (NDC). Using the short-term hindcast approach, the results show that the UP leads to drastic changes in the way moisture and energy being redistributed, resulting in the more realistic precipitation diurnal cycle and precipitation spectrum over land. As the convective instability increases during the daytime, the RAS quickly redistributes the moisture and energy solely by parameterized convection, while the URAS involves the grid-scale processes. The difference in partitioning the processes that represent deep moist convection causes the difference in moisture and cloud condensates distributions in the afternoon, thereby the difference in energy fluxes at the surface. During the evening and midnight, the grid-scale processes in the URAS can continue to produce precipitation even when the convective instability decreases. Overall, turning off the deep convection scheme leads to the delayed diurnal peak time.

Primary author: Mr SU, Chun-Yian (Department of Atmospheric Sciences, National Taiwan University)

Co-authors: Prof. WU, Chien-Ming (Department of Atmospheric Sciences, National Taiwan University); Prof. CHEN, Wei-Ting (Department of Atmospheric Sciences, National Taiwan University); Dr CHEN, Jen-Her (Central Weather Bureau, Taiwan)

Presenter: Mr SU, Chun-Yian (Department of Atmospheric Sciences, National Taiwan University)

Session Classification: Modelling and Parameterising Deep Convective Organisation

Track Classification: Modelling and Parameterising Deep Convective Organisation

Contribution ID: **78** Type: **Interactive presentation**

On the relationship between precipitation and its spatial patterning in the Trades

Friday, 7 May 2021 16:00 (1h 45m)

Scenes of trade wind convection exhibit a rich spatial variability characterized by patterns, which are often associated with precipitation. Precipitation might be a key to understand the spatial patterning in shallow convection. However, the spatial patterning of precipitation is largely unexplored. We exploit observational data from the C-band radar PoldiRad installed during the EUREC4A measurement campaign to analyse the relationship between precipitation and its spatial patterning. Do details of the spatial distribution matter for precipitation? We analyse three characteristics that shape our perception of spatial patterns - the number, size and spatial arrangement of cells and further how water vapor availability influences precipitation by mediating changes in the spatial structure.

We conclude that scene precipitation and precipitation intensity are influenced by different characteristics of the spatial structure. The scene-averaged precipitation is highest where cells are both large and numerous but do not exhibit the highest degree of clustering. Precipitation intensity on the other hand varies predominately with the size of cells, but the variation depends on the moisture regime. Highest intensities are found in scenes with a few large cells characterized by a low water vapor path. Here also clustering maximizes. This suggests that clustering is important for precipitation formation in dry environments and acts by protecting cells from their hostile dry environment which enables them to gain a certain size and rain more intense. Overall, however, scene precipitation and clustering are negatively correlated.

Primary author: RADTKE, Jule (Meteorological Institute, Center for Earth System Research and Sustainability, Universität Hamburg, Hamburg, Germany)

Co-authors: NAUMANN, Ann Kristin (Max Planck Institute for Meteorology, Hamburg, Germany); AMENT, Felix (Meteorological Institute, Center for Earth System Research and Sustainability, Universität Hamburg, Hamburg, Germany); HAGEN, Martin (Deutsches Zentrum für Luft- und Raumfahrt (DLR), Institut für Physik der Atmosphäre, Oberpfaffenhofen, Germany)

Presenter: RADTKE, Jule (Meteorological Institute, Center for Earth System Research and Sustainability, Universität Hamburg, Hamburg, Germany)

Session Classification: Organisation in Shallow Convection

Track Classification: Organisation in Shallow Convection

Contribution ID: **79** Type: **Interactive presentation**

Observed land effects on characteristics of organised convection

Wednesday, 5 May 2021 16:00 (1h 45m)

Characteristics of the land surface affect cloud development and growth through changes in heating and moistening of the lower troposphere, affecting convective stability and inducing mesoscale circulations in areas of differential heating. Our understanding of the degree to which the land surface may affect and spatio-temporally structure organised convection is still limited and predominantly based on idealised modelling. Focusing on West African mesoscale convective systems (MCSs) and using a combination of satellite observations and reanalysis data, we illustrate how mature, propagating MCSs exhibit surprisingly strong soil moisture sensitivity in intensity and extent. MCSs intensify as they propagate over drier soils on scales of the order of 200 km and upwards. At these scales, perturbed horizontal temperature gradients in the planetary boundary layer provide favourable conditions for MCS intensification through focusing moisture convergence within the West African Monsoon, and through enhanced wind shear, which helps to organise convection.
At the same time, we find that soil moisture patterns left behind by preceding MCSs can pose an important constraint on subsequent organised convection. Such land-storm feedbacks have implications for predictions of organised convection on time scales of hours to days, but may similarly contribute to increasing storm extent in the climate change context.

Primary authors: KLEIN, Cornelia (UK Centre for Ecology and Hydrology | University of Innsbruck, Austria); TAYLOR, Chris (UK Centre for Ecology and Hydrology); ANDERSON, Seonaid (UK Centre for Ecology and Hydrology)

Presenter: KLEIN, Cornelia (UK Centre for Ecology and Hydrology | University of Innsbruck, Austria)

Session Classification: Modelling and Parameterising Deep Convective Organisation

Track Classification: Modelling and Parameterising Deep Convective Organisation

Contribution ID: **80** Type: **Interactive presentation**

The impact of cold pools on the transition from shallow to deep convection over land

Friday, 7 May 2021 16:00 (1h 45m)

Large-eddy simulation is used to investigate the effects of cold pools driven by rain evaporation on the shallow-to-deep convection transition over land. The applied methodology allows for obtaining a time-dependent reference ensemble without cold pools for interactive surface fluxes. The reference ensemble, in the spirit of one-dimensional single-column models, eliminates cold pools by horizontally homogenizing negative buoyancy production due to rain evaporation. Two additional ensembles complement the reference cold-pool-free ensemble by including cold pools and by applying either interactive or prescribed surface fluxes. Contrasting these ensembles suggests possible improvements of convection parameterization in large-scale models of weather and climate. Without cold pools, the reference ensemble preserves key features of buoyancy-driven cellular convection associated with a field of convective plumes, as assumed in a typical convection parameterization. With cold pools, a significant enhancement of surface heat and moisture fluxes and about an hour delay of their daily maxima is simulated. Cold pools enhance near-surface temperature and moisture standard deviations as well as maxima of the near-surface updraft velocity. They also lead to the reduction of cloud lateral entrainment, deeper vertical development of the cloud layer, and a few-times-larger accumulated surface precipitation. Interactive surface fluxes provide a damping mechanism that noticeably suppresses all these effects. The most important effects are incorporated in the multi-plume Eddy-Diffusivity/Mass-Flux convection parameterization and shown to improve its representation of the transition from shallow to deep convection over land.

Primary authors: KUROWSKI, Marcin (JPL/Caltech); GRABOWSKI, Wojciech (NCAR); SUSELJ, Kay (JPL/Caltech); TEIXEIRA, Joao (JPL/Caltech, JIFRESSE UCLA)

Presenter: KUROWSKI, Marcin (JPL/Caltech)

Session Classification: Organisation in Shallow Convection

Track Classification: Organisation in Shallow Convection

Contribution ID: **81** Type: **Interactive presentation**

In search of ghost cold pools and moisture rings

Wednesday, 5 May 2021 16:00 (1h 45m)

Past work with numerical models has suggested that convectively generated cold pools can play a fundamental role in the triggering of new convection, even in situations of low wind shear, through their determination of the boundary layer moisture field (although cold pool collisions can still add a dynamic element to this thermodynamic picture). The models show cold pool spreading until they were almost fully recovered in temperature, with very limited gust front wind velocities, but exhibiting a ring of higher moisture and associated moist static energy where new convection triggers. Due to their limited dynamical activity at the front, we refer to these near-recovered events as "ghost cold pools".

Despite the growing interest in this cold pool mechanism, a definitive observation of systematic moisture rings in cold pools observations is lacking. Part of the reason for this could be the tendency for observation-based work to focus on intense cold pool events. Even the recent work of Kirsch et al (2021), which intended to document weaker cold pools, used a temperature drop threshold of 2 degrees C; still too large to identify ghost cold pools.

Here we introduce a new method to detect ghost cold pools fronts, using a wavelet decomposition of temperature data from the tropical western Pacific ARM site to identity cold pool candidates, which are then subject to a quality control process based on the Bordoni change-point analysis and a low-pass filtering technique to reject turbulent fluctuations falsely identified as cold pools. This new technique is shown to reliably identify cold pools fronts with temperature drops as little as 0.2 degrees C (close to instrument sensitivity) even in day-time highly turbulent conditions, an order of magnitude smaller than any previous observational work, thus enabling us to document the statistics of ghost cold pools. Using this new technique we show that moisture rings are ubiquitous in ghost cold pools over tropical oceans and we will document how the structure of the cold pool changes as a function of the cold pool age.

Primary authors: TOMPKINS, Adrian (ICTP); Ms LE GALL, Enora (Ecole Normale Supérieure, Paris)

Presenter: Ms LE GALL, Enora (Ecole Normale Supérieure, Paris)

Session Classification: Modelling and Parameterising Deep Convective Organisation

Track Classification: RCE and Processes in Deep Convective Organization

Contribution ID: **82** Type: **Interactive presentation**

Impact of a mixed ocean layer and the diurnal cycle on convective aggregation

Thursday, 6 May 2021 16:00 (1h 45m)

We investigate ocean feedbacks and the diurnal cycle impact convective aggregation, introducing a new adaptive Q-flux method to control SST. Aggregation onset occurs after 25 days with thick ocean layers that suppress feedbacks. Thinner ocean layers slow the onset of clustering, with a 1m ocean layer needing around 43 days, but with clustering onset time also becoming more variable. The delay is due to enhanced solar radiation in clear sky regions, causing surface warming, increasing latent and sensible heat fluxes, acting to oppose low level convergence into convecting regions. Once clustering onset starts, the SST forms a 3 zone structure, with the convective region surrounded by moist, clear sky regions with the hottest SSTs, towards which convection constantly migrates, while a cold SST patch forms under the very dry subsiding regions due to the dominance of longwave emission. Next, the ocean is permitted to also undergo a diurnal cycle of 2.5^{o}C in response to solar forcing, with drift still eliminated. Convective rainfall shifts from a weak morning maximum to a sharper evening peak, reminiscent of undisturbed tropical observations. This shift reduces SW forcing of SST spatial variably in the pre-aggregated state, while the sharper diurnal variation leads to more even distribution of moisture sources. These feedbacks oppose each other and both reduce in magnitude over time, as convection reverts to a weak early morning maximum. The imposition of the mean diurnal cycle has no statistically significant impact on the mean timing of clustering onset.

Primary authors: TOMPKINS, Adrian (ICTP); Dr SEMIE, Addisu (LMD)

Presenter: TOMPKINS, Adrian (ICTP)

Session Classification: RCE and Processes in Deep Convective Organization

Track Classification: RCE and Processes in Deep Convective Organization

Contribution ID: **83** Type: **Interactive presentation**

Significant amplification of instantaneous extreme precipitation with convective self-aggregation

Thursday, 6 May 2021 16:00 (1h 45m)

Convective organization has been associated with extreme precipitation in the tropics. Here we investigate the impact of convective self-aggregation on extreme rainfall rates. We find that convective self-aggregation significantly increases precipitation extremes, for 3-hourly accumulations (+70%) consistent with earlier studies, but also surprisingly for instantaneous rates (+30%). We show that this latter enhanced instantaneous precipitation is mainly due to the local increase in relative humidity which drives larger accretion efficiency and lower re-evaporation and thus a higher precipitation efficiency.
An in-depth analysis based on an adapted scaling of precipitation extremes, reveals that the dynamic contribution decreases (- 25 %) while the thermodynamic is slightly enhanced (+ 5%) with convective self-aggregation, leading to lower condensation rates (- 20 %). When the atmosphere is more organized into a moist convecting region, and a dry convection-free region, deep convective updrafts are surrounded by a warmer environment which reduces convective instability and thus the dynamic contribution. The moister boundary-layer explains the positive thermodynamic contribution. The microphysic contribution is increased by + 50 % with aggregation. The latter is partly due to reduced evaporation of rain falling through a moister near-cloud environment (+ 30 %), but also to the associated larger accretion efficiency (+ 20 %).
Extreme rainfall intensity, frequency and duration are all important for floods and risks. And the role of aggregation may depend on the time scale chosen, as suggested by larger amplification of rainfall accumulations than rainfall rates with aggregation, a result in line with recent studies.
Thus, the change of convective organization regimes in a warming climate could lead to a significantly different evolution of tropical precipitation extremes than expected from thermodynamical considerations.
Improved fundamental understanding of convective organization and its sensitivity to warming, as well as its impact on precipitation extremes, is hence crucial to achieve accurate rainfall projections in a warming climate.

Primary authors: DA SILVA, Nicolas (Centre for Ocean and Atmospheric Sciences, School of Environmental Sciences, University of East Anglia, Norwich, Norfolk, NR4 7TJ, United Kingdom); Mrs SHAMEKH, Sara (Columbia University, New York 10032, USA); MULLER, caroline (CNRS/LMD); FILDIER, Benjamin (Laboratoire de Météorologie Dynamique, ENS, Paris)

Presenter: DA SILVA, Nicolas (Centre for Ocean and Atmospheric Sciences, School of Environmental Sciences, University of East Anglia, Norwich, Norfolk, NR4 7TJ, United Kingdom)

Session Classification: RCE and Processes in Deep Convective Organization

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Contribution ID: **84** Type: **Interactive presentation**

Cold pool dynamics shape the response of extreme rainfall events to climate change

Thursday, 6 May 2021 16:00 (1h 45m)

There is increasing evidence that local rainfall extremes can increase with warming at a higher rate than expected from the Clausius-Clapeyron (CC) relation. The exact mechanisms behind this so-called super-CC scaling phenomenon are still unsolved. Recent studies highlight invigorated local dynamics as a contributor to enhanced precipitation rates with warming. Here, cold pools play an important role in the process of organization and deepening of convective clouds. Another known effect of cold pools is the amplification of low-level moisture variability. Yet, how these processes respond to climatic warming and how they relate to enhanced precipitation rates remains largely unanswered. Unlike other studies which use rather simple approaches mimicking climate change, we present a much more comprehensive set of experiments using a high-resolution large eddy simulation (LES) model. We use an idealized but realistically forced case setup, representative for conditions with extreme summer precipitation in mid-latitudes. Based on that, we examine how a warmer atmosphere under the assumption of constant and varying relative humidity, lapse rate changes and enhanced large-scale dynamics influence precipitation rates, cold pool dynamics, and the low-level moisture field. Warmer conditions generally lead to larger and more intense events, accompanied by enhanced cold pool dynamics and a concurring moisture accumulation in confined regions. The latter are known as preferred locations for new convective events. Our results show that cold pool dynamics play an increasingly important role in shaping the response of local precipitation extremes to global warming, providing a potential mechanism for super-CC behavior as subject for future research.

Primary authors: LOCHBIHLER, Kai; Dr LENDERINK, Geert (KNMI and TUD); Prof. SIEBESMA, Pier (TUD and KNMI)

Presenter: LOCHBIHLER, Kai

Session Classification: RCE and Processes in Deep Convective Organization

Track Classification: RCE and Processes in Deep Convective Organization

Contribution ID: **85** Type: **Interactive presentation**

Role of subsidence vertical structure for stratocumulus precipitation and mesoscale organization - a CLARIFY case study

Friday, 7 May 2021 16:00 (1h 45m)

Large scale subsidence co-determines lower tropospheric stability, boundary layer height, and entrainment into the boundary layer, and hence boundary layer cloud properties. Observations show substantial vertical structure in large scale subsidence in the lower troposphere. Such vertical structure is also present in global simulations. Here we examine the relationship between the vertical structure in large scale subsidence and stratocumulus properties, with a focus on precipitation and mesoscale organization. Specifically, we address the question whether the vertical structure in large scale subsidence is required to reproduce observed cloud properties. We use Lagrangian large eddy simulations that realistically simulate a transition from the closed- to the open cell stratocumulus state observed during the CLARIFY field campaign. The simulations match the satellite-retrieved cloud optical depth and effective radius over the course of the two-day simulations, and are consistent with aircraft in-situ profiles at its end. The simulations are driven by ERA5 reanalysis meteorology, which provides large scale subsidence. To study the role of vertical structure in large scale subsidence, we vertically homogenize it between the surface and 4000 m. Preliminary results indicate that the vertical structure in large scale subsidence in ERA5 is required to reproduce the observed stratocumulus evolution.

Primary author: KAZIL, Jan (University of Colorado / NOAA)

Co-authors: Dr YAMAGUCHI, Takanobu (NOAA Chemical Sciences Laboratory / CIRES University of Colorado Boulder); Dr CHRISTENSEN, Matthew (University of Oxford); Dr ABEL, Steven (Met Office); FEINGOLD, Graham (NOAA ESRL Chemical Sciences Division)

Presenter: KAZIL, Jan (University of Colorado / NOAA)

Session Classification: Organisation in Shallow Convection

Track Classification: Organisation in Shallow Convection

Contribution ID: **86** Type: **Interactive presentation**

Identification and visualization of (high-impact) vortices on different scales

Wednesday, 5 May 2021 16:00 (1h 45m)

In this work, we will present a vortex identification method that is able to identify vortices in different data sets of various grid spacings from global reanalysis data to convection-permitting small scale simulations. The method is based on a kinematic analysis of the flow field using the dimensionless kinematic vorticity number Wk. Wk identifies and extracts vortex areas or vortex tubes from the continuous flow field. An advantage of this method is that there is no need to adjust thresholds for different data sets. Additional knowledge of the vortex size allows to determine different vortex intensity measures such as the circulation or an averaged vorticity within the vortex boundaries. We will show for a winter storm (Kyrill) that vortex visualization based on the proposed intensity measures can help to pinpoint high-impact situations.

Primary authors: SCHIELICKE, Lisa; Dr GATZEN, Christoph (ESSL)

Presenter: SCHIELICKE, Lisa

Session Classification: Modelling and Parameterising Deep Convective Organisation

Track Classification: Modelling and Parameterising Deep Convective Organisation