2nd Workshop on Cloud Organization (WCO2)

Report of Contributions

Contribution ID: **3** Type: **Poster**

Sensitivity of Tropical Extreme Precipitation to Surface Warming in Aquaplanet Experiments Using the ICON Model

Tuesday, May 17, 2022 12:21 PM (2 minutes)

Increases in atmospheric water vapor holding capacity with temperature (7% K−1–8% K−1, CC-rate) can lead to increasing extreme precipitation (EP). Observations show that tropical EP has increased during the last five decades with a rate higher than in the extratropics. Global climate models (GCM's) diverge in the magnitude of increase in the tropics, and cloud-resolving models (CRM's) indicate correlations between changes in tropical EP and organization of deep convection. We conducted global-scale aquaplanet experiments at a wide range of resolutions with explicit and parameterized convection to bridge the gap between GCM's and CRM's. We found increases of tropical EP beyond the CC rate, with similar magnitudes when using explicit convection and parametrized convection at the resolution it is tuned for. Those super-CC rates are produced due to strengthening updrafts where extreme precipitation occurs, and they do not exhibit relations with changes in convective organization.

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Presenter: URIBE, Alejandro (Stockholm University)

Session Classification: Poster pitches

Contribution ID: **4** Type: **Talk**

Circling in on Convective Self-Aggregation

Monday, May 16, 2022 11:30 AM (15 minutes)

In radiative-convective equilibrium 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, 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 $r_{i,j} \in [R_{\text{min}}, R_{\text{max}}]$ collide, they form a new convective event. These findings imply that interactions between CPs may explain the initial stages of CSA.

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Presenter: NISSEN, Silas Boye (Niels Bohr Institute, University of Copenhagen)

Session Classification: Convective concepts

Contribution ID: **6** Type: **Talk**

Organisation of the trade-wind flower-clouds: driving processes and sensitivity

Tuesday, May 17, 2022 9:45 AM (15 minutes)

The trade-wind cumuli are a great source of uncertainty for the future climate as their net radiative effect is hardly represented in the global models. The spatial organization of these clouds, that drives their radiative effect, has been categorized into 4 major patterns: Sugar, Flower, Gravel and Fish. The processes governing their spatial organization and the relationships with the large scale environment remain however unclear. This study investigates the processes that shape the clouds organized as Flowers and observed east of Barbados on 2 February 2020, during the EUREC4A-ATOMIC campaign. These investigations are performed thanks to a Large-Eddy Simulation using the Meso-NH model and a 100-m horizontal grid-spacing, and in synergy with high-resolution cloud observations. A particular attention is paid to the realism of the simulated clouds and clear sky patterns. We show that the processes shaping the flower-clouds are wide cold pools below the clouds. At the edge of the cold pool, intense convergence of humidity drives the development of updrafts, organized in arcs. These updrafts shape the flower-cloud top and supply the cloud layer with water. The role of radiation and of meso-scale heterogeneities in determining the flower-cloud characteristics are further investigated through sensitivity studies.

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Presenter: DAUHUT, Thibaut (CNRM (CNRS and Meteo France), Toulouse, France)

Session Classification: Shallow convection

Contribution ID: **7** Type: **Talk**

How well do large-eddy simulations capture the observed co-variability of trade-wind cloudiness and its environment?

Tuesday, May 17, 2022 10:00 AM (15 minutes)

Recent observations revealed that meso-scale patterns of shallow convection in the downwind trades can be connected to specific atmospheric environments whose characteristics are not solely from within the trades but have traces from tropical or mid-latitudinal origin depending on the pattern. As a consequence of this co-variability of patterns and air-mass characteristics, a different feedback to a changing climate is anticipated and will be modulated by the observed, pattern-dependent net cloud radiative effects. By conducting large-eddy simulations we evaluate how well current climate models reproduce this co-variability in cloudiness and its environment and whether the meso-scale patterns are represented due to the observed mechanisms. To capture the full range of patterns and its processes these simulations are done on a large-scale domain with grid-spacings of 625m, 312m and 156m and focus on the EUREC4A field campaign time period for further observational process understanding.

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Co-author: STEVENS, Bjorn

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

Session Classification: Shallow convection

Contribution ID: **8** Type: **Talk**

Links between spatial organization and plume rooting in a decentralized framework for convective transport

Monday, May 16, 2022 10:05 AM (15 minutes)

In this study a spectral model for convective transport is coupled to a thermal population model on a horizontal microgrid. Thermals interact under simple rules, reflecting pulsating growth and environmental deformation. Long-lived thermal clusters thus form on the microgrid, exhibiting scale growth, spatial organization and memory. Size distributions of cluster number are diagnosed from the microgrid through an online clustering algorithm, and provided as input to a spectral multi-plume eddy-diffusivity mass flux (EDMF) scheme. This yields a decentralized transport system, with the thermal clusters acting as independent but interacting nodes that carry information about spatial structure. The main objectives are to i) provide proof of concept of this approach, and ii) to gain insight into impacts of spatial organization on convective transport. Single-column model experiments demonstrate satisfactory skill in reproducing two observed cases of continental shallow convection at the ARM SGP site. Metrics expressing self-organization and scale growth match well with large-eddy simulation results. We find that in this coupled system, spatial organization impacts convective transport primarily through the scale break in the size distribution of cluster number. The rooting of saturated plumes in the subcloud mixed layer plays a key role in this process.

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Co-author: GRIEWANK, Philipp

Presenter: NEGGERS, Roel (University of Cologne)

Session Classification: Convective concepts

Contribution ID: **9** Type: **Poster**

How well do stereo cameras observe shallow cumulus spatial organization? An evaluation combining atmospheric path-tracing and high-resolution Large-Eddy Simulations (LES)

Monday, May 16, 2022 12:08 PM (2 minutes)

Spatial organization is essential for convection parameterization in numerical weather and climate models. However, spatial organization is challenging to observe. Most ground-based measurements consist of one-dimensional profile data, often sampled by lidars or radars. A recently explored new method of obtaining multi-dimensional information is to utilize hemispheric images from networks with multiple cameras, which observe shallow cumuli in unprecedented spatial detail.

In this study, we apply an open-source Monte Carlo path-tracing algorithm to high-resolution LES cloud fields. This setup emulates a network of multiple stereo cameras, currently installed around the Jülich Observatory for Cloud Evolution (JOYCE) within the ongoing SOCLES project. Those camera snapshots were emulated based on three-dimensional LES cloud fields. Reconstructions of the cloud fields from the emulated camera snapshots were compared against the original LES-simulation, allowing precise error estimation. Our goal is to determine how many grid boxes of an arbitrary cloud field can be reliably detected by a stereo camera setup and use this information to optimize the camera network configuration.

The path tracing projections operate well in this workflow, as depicted in the figure. 81% of the reconstructable grid boxes of an LES cloud field are reconstructed by the stereo camera algorithm.

Caption:
Visualization of the reconstruction from the emulated stereo cameras (yellow grid boxes) compared to the original LES simulated grid boxes that are visible from both camera perspectives. The horizontal resolution of the grid boxes is 50 meter. The gray boxes at the bottom denote the camera position. Note that for visualization purposes those cameras are amplified.

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Presenter: BURCHART, Yannick

Session Classification: Poster pitches

Contribution ID: **10** Type: **Poster**

The impact of land-sea contrasts in the aggregation of convection

Tuesday, May 17, 2022 12:23 PM (2 minutes)

Studies on the self-aggregation of convection have identified key physical mechanisms which drive and then maintain aggregation in a range of idealised radiative-convection equilibrium (RCE) models. These models are typically run without any land, rotation, variation in sea-surface temperatures (SSTs), or a diurnal cycle. Therefore, a key recurring question is how these convective processes and mechanisms manifest in the real world. Several studies have tried to tackle this question by increasing the complexity of processes in the models, such as SST gradients, adding a slab ocean, adding a diurnal cycle, or adding an aerosol diabatic heating perturbation. Particularly, the inclusion of interactive ocean surfaces has been shown to impact the formation of aggregated clusters.

The interactions between land surfaces and aggregation are less well understood. Early studies have found that convective aggregation may favour land areas over oceans, and that soil moisture feedbacks can oppose the aggregation altogether. In this study we investigate the relationship between land, oceans, and aggregation, addressing the following questions:
1. How does the inclusion of an idealised island into a global RCE model impact the aggregation of convection and its mechanisms?
2. How sensitive are these results to our choice of land parameters?

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Presenter: DINGLEY, Beth (AOPP, University of Oxford)

Session Classification: Poster pitches

Contribution ID: **11** Type: **Talk**

Daytime convective development over land: the role of surface forcing

Wednesday, May 18, 2022 9:45 AM (15 minutes)

Diurnal cycle of solar radiation over tropical and midlatitude summertime continents forces strong evolution of atmospheric convection. As surface sensible and latent heat fluxes increase after sunrise, a dry convective boundary layer develops in the early morning hours. It proceeds with the formation of shallow convective clouds as the convective boundary layer deepens and may eventually lead to the transition from shallow to deep precipitating convection. Factors affecting shallow-to-deep convection transition have been studied in that past, but the early evolution of dry convection and how it affects development of shallow convection and eventual transition to deep convection attracted much less attention. This presentation will discuss a set of large-eddy simulations that considers the impact of the surface flux Bowen ratio, the partitioning of the surface heat flux into sensible and latent components, on the development of dry and eventually moist convection. The key point is that the Bowen ratio affects the surface buoyancy flux and thus growth of dry convective boundary layer before the moist convection onset. This has a strong impact on the development and organization of shallow convection and eventual transition to deep convection. Details of the simulation results will be discussed at the conference.

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Presenter: GRABOWSKI, wojciech (NCAR)

Session Classification: Deep convection and more

Contribution ID: **12** Type: **Poster**

The role of cold pools and microphysics schemes in the organization of convection

Tuesday, May 17, 2022 12:29 PM (2 minutes)

It has been suggested that larger coldpool radii can delay the onset of convective self-aggregation. We demonstrate that coldpool characteristics can differ between 5 of the commonly microphysical schemes used by the WRF-model. We systematically increase/decrease coldpool size by changing the evaporation of rain to observe the impact on organization. One complication in interpreting these results is that a change in the evaporation of rain also produces a change in net convective heating which could impact organization. To isolate this effect, a set of experiments is performed by increasing (decreasing) the horizontal wind speed used in the surface flux calculation for all grid points within coldpool interiors to produce a faster (slower) recovery and impact their radii. The ensemble experiments demonstrate how the coldpool size impacts the strength and even the sign of the surface latent heat contribution to aggregation. Nonetheless, the strong forcing of aggregation by radiation-feedbacks mean that the coldpool changes do not produce large modifications to the aggregation onset time. Thus the aggregation onset may be more impacted by the microphysical processes that determine the anvil size and low-level cloud cover, and thus ultimately the cloud-radiative forcing. This is under investigation in ongoing experiments that modify the ice fall speed and the autoconversion of cloud water to rain.

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Presenter: CASALLAS, Alejandro (Abdus Salam International Centre for Theoretical Physics)

Session Classification: Poster pitches

Contribution ID: **13** Type: **Poster**

Diurnal signals in flower cloud organization in the upstream Tradewind regions during EUREC4A

Monday, May 16, 2022 12:10 PM (2 minutes)

Tradewind shallow cumulus clouds cover vast areas of the subtropical oceans, and are associated with various modes of mesoscale organization. During the EUREC4A field campaign in the subtropical Atlantic in early 2020, unique in-situ and remote sensing measurements were made that allow characterization of Trade wind cloud organization as well as the large-scale environment in which this phenomenon takes place. But how exactly the boundary layer transitions from upstream stratocumulus to the observed organized fair-weather cumulus in downstream areas is still not fully understood, and requires additional information on processes taking place far upstream. To gain insight and fill this data gap, in this study high-resolution Lagrangian simulations are conducted for selected EUREC4A days. The simulations follow the transitioning low-level air mass for multiple days as it approaches Barbados, covering at least three full diurnal cycles. The mean state in the simulations is evaluated against observational data. Sensitivity experiments on domain size are conducted, suggesting that mesoscale organization converges above 100x100 km2. The simulation for 2 February 2020 features well-defined flowers in upstream regions. Interestingly, the occurrence and duration of these flower periods follow a well-defined diurnal cycle. The flower clouds are also associated with distinct mesoscale patterns in thermodynamic state. To gain further insight, various metrics are used to quantify the mesoscale patterns. We find that the organization is expressed as a distinct, well-defined isolated mode in the 2D power spectrum of thermodynamic state. A novel metric called 'SGAP' is defined to capture this behaviour, expressing the degree of organization as the spectral area above an unorganized baseline state. SGAP is then combined with cross-sectional analyses of dynamics and heat budget terms in the LES to establish which mechanism is responsible for forming and dissipating the flower structures during the diurnal cycle.

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Presenter: GHAZAYEL, Salima (University of Cologne)

Session Classification: Poster pitches

Contribution ID: **14** Type: **Poster**

Clear-Sky Turbulence and Shallow Convection: New Insights Combining SAR Images, Satellite Brightness Temperature and In-Situ Measurements

Monday, May 16, 2022 12:16 PM (2 minutes)

Studying the marine atmospheric boundary layer (MABL) processes at play to organize cloudiness through satellite products is challenging. Here, we propose an innovative approach to investigate the MABL dynamical structures by combining spaceborne Synthetic Aperture Radar (SAR) images, and brightness temperature measurements from the Geostationary Operational Environmental Satellite (GOES).

The intensive EUREC4A field campaign that took place over the Western Tropical Atlantic Ocean, in Jan-Feb 2020, provides a relevant context with reference in situ measurements co-localized with the spaceborne measurements. Focusing on February 13th, 2020. Two types of atmospheric processes are investigated : convective rolls in clear sky regions and cold pools characterizing the convective activity areas.

In a first step, the hypothesis of a sea surface roughness signature of atmospheric coherent structures in the SAR images has been validated with respect to the turbulence measurements of the ATR-42 aircraft. In a second step, the cold pools have been detected within the SAR image using object identification method. Cold pool characteristics such the size, the gust front intensity can be directly derived from the SAR image while the age or the spreading rate can then be estimated with respect to the cloud field temporal evolution provided by the GOES data.

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Presenter: BRILOUET, Pierre-Etienne

Session Classification: Poster pitches

Contribution ID: **15** Type: **Talk**

Parametrising cold-pool effects in the Met Office Unified Model

Wednesday, May 18, 2022 12:15 PM (15 minutes)

Cold pools formed by convective downdraughts can feed back onto the organisation and diurnal cycle of convection. This presentation describes a parametrisation of cold pools, C-POOL, recently developed within the Met Office Unified Model (UM). The parametrisation includes forcing by downdraughts, dissipation, and various pathways for influencing parametrised convection in the UM. It also allows the possibility of cold-pool propagation through the model domain. Results from global-model tests show that it can improve the timing in the diurnal peak of precipitation over land in the tropics. The parametrisation has also been adapted to represent sea breezes, which are of a similar nature to cold pools. In this case, the forcing is derived from coastal properties. The C-POOL infrastructure may be used to prototype the representation of other lateral flows which are separate to the mean grid-scale atmospheric wind field.

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Presenter: ROONEY, Gabriel (Met Office UK)

Session Classification: Deep convection and more

Contribution ID: **16** Type: **Poster**

Cloud size and cloud spacing distributions of trade-wind cumuli observed at cloud base for a range of mesoscale organizations

Monday, May 16, 2022 12:18 PM (2 minutes)

During the EUREC4A field campaign that took place near Barbados in Jan-Feb 2020, the French ATR aircraft flew in the lower troposphere and characterized the macrophysical, microphysical and turbulent properties of trade cumuli around the cloud-base level. Using horizontal lidar-radar observations and in-situ measurements, we characterize the cloud size and cloud spacing distributions of cumuli for a range of mesoscale organizations.
Robust features, as well as organization-dependent features, will be highlighted and analyzed in the light of turbulent and microphysical measurements. The physical interpretation of these features, as well as their comparison with large-eddy simulation results published in the literature, will be discussed.

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Presenter: MEX, Julius (LMD)

Session Classification: Poster pitches

Contribution ID: **18** Type: **Talk**

Cloud botany - shallow cumulus organization in an LES ensemble

Monday, May 16, 2022 11:45 AM (15 minutes)

Many mesoscale patterns in trade-wind cloud fields appear to result from the self-organisation of sub-mesoscale cumulus convection. To advance our understanding of these self-organising processes and the role they play in regulating radiation from the trades to space, we have run an ensemble of idealised large-eddy simulations on domains larger than 100 km using the DALES model. Each simulation is run in an environment described by six free parameters, which are co-varied over ranges that characterise the trades, including the parameter combinations observed during the 2020 EUREC4A field campaign. This demands large number of simulations on large domains; we manage the computational challenge that results by leveraging the novel Fugaku supercomputer. We quantify the cloud patterns in our simulations by using a set of organisation metrics. These metrics form a phase space, in which the simulations evolve. By analysing how cloud patterns vary over the phase space with the parameters describing the environment, we aim to better understand which portion of trade-wind cloud patterns can be attributed to small-scale processes, how these processes depend on their environment, and what their effect is on cloud feedbacks.

Figure caption: Cloud scenes located in a space of organization metrics

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Presenter: JANSSON, Fredrik (TU Delft)

Session Classification: Convective concepts

Contribution ID: **19** Type: **Talk**

Illuminating the Sub-Mesoscale Structure of Cold Pools with a Dense Station Network during FESSTVaL

Wednesday, May 18, 2022 10:00 AM (15 minutes)

Cold pools are crucial for understanding the organization of atmospheric convection. However, their detailed structure remains a blind spot of operational station networks. In summer 2021 the FESSTVaL field experiment aimed to address this observational gap and shed light on the structure and life cycle of cold pools on the sub-mesoscale (100 m to 10 km). The experiment took place in the rural surrounding of the Meteorological Observatory Lindenberg (south-east of Berlin, Germany) and featured a dense network of custom-designed low-cost measurement stations covering an area of 30-km diameter. The instrumental setup included 80 novel APOLLO stations sampling air temperature and pressure at 1-s resolution and 19 supplementary weather stations.

The FESSTVaL network recorded 43 cold pool events of different strength and size during the three-month measurement phase. Case studies demonstrate that the observations allow to capture the growth and internal temperature structure of a cold pool during its intensification phase. The spatio-temporal patterns of temperature and pressure perturbations suggests that a convective downdraft typically precedes the intensity maximum of the cold pool by about 10 to 20 minutes. Further measurements from radiosonde ascents and a X-band rain radar provide deeper insights into the cold pool dynamics and its controlling factors.

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Presenter: KIRSCH, Bastian (University of Hamburg)

Session Classification: Deep convection and more

Contribution ID: **20** Type: **Talk**

Observations and simulations of stable water isotopes and their link to the mesoscale organization of shallow trade-wind clouds

Tuesday, May 17, 2022 3:30 PM (15 minutes)

Water molecules containing a heavy hydrogen or oxygen atom have lower saturation vapor pressures and diffusivities than their light counterparts, which leads to a change in their relative abundance during phase transitions. Each process controlling the water vapor budget of shallow cumulus clouds in the trade wind region such as ocean evaporation, convective and turbulent mixing, condensation and evaporation of hydrometeors is associated with a characteristic isotopic fingerprint. Therefore, stable water isotopes are expected to inform about the relative contribution of the processes mentioned above, which possibly link to the mesoscale organisation of clouds. To test this hypothesis and assess the timescales over which the pattern-specific anomalies in water vapor isotopes emerge, we use a combination of airborne measurements of stable water vapor isotopes and high-resolution simulations with the isotope-enabled numerical model COSMOiso. The isotope measurements in water vapor were performed on the French aircraft ATR-42 during 18 flights from 25 January to 13 February 2020 as a part of the international EUREC4A field campaign. The flights were conducted over the tropical ocean near Barbados with the aircraft staying predominantly at the height of cloud base. Complementary cloud radar and lidar data as well as in-situ turbulence and microphysics measurements are used to characterise the physical environment of the studied cloud fields. Our isotope measurements and simulations reveal substantial differences between flights and mesoscale organization patterns. Discrepancies between observed and modelled stable water isotopes are used to identify processes that are poorly represented in the model. A sensitivity experiment, testing different rates for the model's autoconversion from liquid clouds to precipitation, is performed. This study provides promising process-based insights into the cloud-circulation coupling conundrum and demonstrates the potential of water isotopes to identify relevant processes.

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Presenter: VILLIGER, Leonie (Institute for Atmospheric and Climate Science, ETH Zurich, Zurich, Switzerland)

Session Classification: Shallow convection

Contribution ID: **21** Type: **Poster**

In search of ghost cold pools and moisture rings

Monday, May 16, 2022 12:00 PM (2 minutes)

Moisture rings at cold pool fronts have been identified as playing a key role in convective propagation in numerical simulations. However, it is not clear if these are features of real cold pools due to the uncertainties of model microphysics and representation of turbulence at the cold pool front. We therefore analyse more than a decade of station observations from two islands in the tropical western Pacific to identify cold pool fronts using a new wavelet based algorithm to detect both young vigorous fronts as well as weak fronts from nearly recovered cold pools. We find that moisture rings are nearly ubiquitous, found in more than 80% of fronts. Using wind gust strength as a proxy of cold pool age, we show that moisture anomalies are mostly absent for young vigorous fronts, but grow with cold pool age, indicating that surface latent heat fluxes dominate rainfall evaporation as the moisture source for cold pool rings. This finding is broadly supported by recent literature, which commonly show moisture rings in oceanic environments, but no evidence of enhanced moisture with land-based cold pool observations.

Primary authors: TOMPKINS, Adrian (ICTP); LE GALL, Enora (ICTP)

Presenter: TOMPKINS, Adrian (ICTP)

Session Classification: Poster pitches

Contribution ID: **22** Type: **Poster**

The Diurnal Evolution of Controls on Trade Wind Mesoscale Morphologies

Monday, May 16, 2022 12:32 PM (2 minutes)

The diurnal cycle in trade-wind cloudiness is thought to be driven by the diurnal cycle in the relative occurrence frequency of mesoscale cloud morphologies (i.e., Vial et al. 2021). These morphologies can be grouped by their distinct appearance and size into four categories: Sugar, Gravel, Flowers, and Fish. The diurnal cycle in cloudiness is associated with a late afternoon maximum in the smallest (Sugar) clouds that give way to larger, more vertically extensive clouds (Gravel, then Flowers) throughout the night. A remaining question is how sub-cloud dynamics evolve diurnally to facilitate this cycle in cloud morphologies and thus cloudiness.
We examine the daily evolution of winter-time trade-wind mesoscale morphologies using observations from the 2020 EUREC4A-ATOMIC joint campaign. Measurements from the Ronald H. Brown research vessel allow us to analyze differences in the daily evolution of boundary layer structure and dynamics between morphologies. We decompose Doppler lidar-derived mass fluxes into their vertical velocity and cloud fraction contributions and examine their effect on diurnal cloud evolution as well as their relationship to environmental controls (e.g., surface wind speeds, energy and moisture fluxes, stability). Relationships between environmental controls and morphologies are extended with the long-term observational record at the nearby NTAS buoy.

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Session Classification: Poster pitches

Contribution ID: **23** Type: **Poster**

How does microphysical phase relate to cloud morphology transition speed within cold-air outbreaks over the northwest Atlantic?

Tuesday, May 17, 2022 12:33 PM (2 minutes)

Cold-air outbreaks off of the eastern US seaboard provide dramatic visual examples of cloud morphological transitions from closed-cell to more open-celled circulations. Space-based lidar and radar indicate the transitions typically involve mixed-phase clouds and precipitation, but may also remain liquid-only at times. Because the air flow moves over the Gulf Stream, significant surface turbulent fluxes also contribute to cloud deepening encouraging cloud break-up through entrainment. Cloud condensation nuclei (CCN) concentrations can also vary depending on an anthropogenic pollution loading, encouraging aerosol indirect effects on liquid-bearing clouds and perhaps affecting differences in ice production. Previous work on subtropical stratocumulus indicates high cloud LWPs support morphological transitions by encouraging precipitation and CCN depletion. Mixed-phase processes add further complexity to these mid-latitude transitions, for example larger droplets are typically thought to glaciate more quickly. The importance of mixed-phase processes relative to liquid-only processes remain uncertain.

Here we make use of recent aircraft measurements over the northwest Atlantic to make detailed fetch-dependent characterizations of five cold-air outbreaks as a function of distance from the cold edge of the Gulf Stream. The leading question is to determine which of the influences on the cloud transition are dominant, and, if so, if the parameters determining whether a transition is fast versus slow can be identified. The five cold-air outbreaks were sampled in March 2020 and January-March of 2021 by the NASA ACTIVATE campaign. The flight strategy is to fly two planes in tandem, with a lower plane making in-situ microphysical measurements and an upper plane making remote measurements using a lidar and imager and deploying dropsondes. The five cases encompass a representative phase space of conditions. The plane fully sampled two fast transition cases (determined subjectively) with different stratiform cloud liquid water paths (LWPs), and a third in which the (fast) transition region was beyond the reach of the plane. Two slower transition cases also differed in their stratiform cloud LWPs. We will ascertain the range of variability in the in-situ cloud and precipitation microphysics of the five examples. Of interest is how mixed-phase characteristics relate to the cloud LWP, if observed variability in upwind CCN concentrations can be distinguished from macrophysical (LWP) controls on the transition speed, and if ice production related to droplet size can affect the transition speed.

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Presenters: ZUIDEMA, Paquita (University of Miami); Dr CHELLAPPAN, Seethala (University of Miami); THE ACTIVATE SCIENCE TEAM; KIRSCHLER, Simon (DLR)

Session Classification: Poster pitches

Contribution ID: **25** Type: **Talk**

Evaluation of ECMWF lightning forecast over Indian subcontinent during 2020 premonsoon months

Wednesday, May 18, 2022 11:00 AM (15 minutes)

Convective cumulus clouds with vigorous updrafts and downdrafts form thunderstorms. Severe thunderstorms consist of multiple thunderclouds at different stages, and the storm itself has a longer lifetime than individual cells. As the convective clouds grow larger, the negative charge accumulates in their lower region, and the positive charge in the upper level forms a dipole. When the charge difference between the positive and negative ends becomes high enough, lightning occurs.
Indian subcontinent premonsoon months are March, April and May (MAM), sandwiched between Winter seasons and monsoon, classified as the 'Hot weather period' by the Indian Meteorology Department. During the premonsoon season, eastern and northeastern parts of India, Himalayan foothills, and southern parts of India experience extensive lightning activity. Mean moisture, surface, and upper-level winds, the sheared atmosphere in the lower level and high positive values of vertically integrated moisture flux convergence (VIMFC) create favorable conditions for deep convective systems to occur, generating lightning.
With the Indian Institue of Tropical Meteorology (IITM) Lightning Location Network (LLN) operational over more than 80 locations across India, we evaluated the ECMWF lightning forecast with a lead time of 3 days over India and analyzed the fidelity of ECMWF lightning forecast with a longer lead. Despite having some shortcomings, a newly implemented IFS lightning forecast can capture overall lightning events during MAM 2020, specifically lightning associated with large synoptic-scale events.

Primary authors: Dr MUKHOPADHYAY, Parthasarathi (Indian Institute of Tropical Meteorology); Ms SARKAR, Rituparna (Indian Institute of Tropical Meteorology)

Presenter: Dr MUKHOPADHYAY, Parthasarathi (Indian Institute of Tropical Meteorology)

Session Classification: Deep convection and more

Contribution ID: **26** Type: **Talk**

Numerical choices in Large-Eddy Simulations influence their ability to represent length scale growth in shallow convection

Monday, May 16, 2022 3:15 PM (15 minutes)

A growing body of evidence suggests that shallow circulations play a key role in organising trade-wind clouds at the mesoscales. In turn, many of these mesoscale circulations appear to emerge directly from the shallow convection itself. We infer a very simple model for explaining this feedback from Large-Eddy Simulations of a classical numerical experiment with minimal physics (BOMEX), which depends only on the turbulent transport of liquid water in cumulus clouds and the mean environment. Since the dominant scales of the cumulus convection driving the organisation are constrained around a kilometer, we hypothesise that simulations of the development of mesoscale cloud patterns through this mechanism are sensitive to choices in the numerical representation of the cumulus convection. We show that the timescale over which mesoscale cloud structures develop can more than double in our model, merely by modifying its grid spacing or advection schemes. Hence, rather high resolutions (<100m) or significantly improved unresolved scales models may be required to faithfully represent certain forms of trade-wind mesoscale cloud patterns in models, and to understand their influence on the cloud feedback more accurately.

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Co-authors: SIEBESMA, Pier (Delft University of Technology); Dr DE ROODE, Stephan (Delft University of Technology); VAN HEERWAARDEN, Chiel; Prof. VILÀ GUERAU DE ARELLANO, Jordi (Wageningen University & Research); GLASSMEIER, Franziska (TU Delft)

Presenter: Dr DE ROODE, Stephan (Delft University of Technology)

Session Classification: Convective concepts

Contribution ID: **27** Type: **Poster**

Understanding cloud systems structure and organization using a machine's self-learning capability

Monday, May 16, 2022 12:02 PM (2 minutes)

Our work aims to understand the structure and organization of cloud systems by exploiting the self-learning capability of a deep neural network. The neural network utilizes deep clustering and non-parametric instance-level discrimination for decision-making at any learning stage.

The data augmentation in the data pipeline, multi-clustering of the dense vectors, and Multilayer perceptron projection at the end of CNN help the network learn a better representation of images. We avoid the noise and bias from human labeling in a purely data-driven approach.

Over Central Europe, we use high-resolution cloud optical depth (COD) images post-processed and retrieved at a higher spatio-temporal resolution (2 km,5 min), equivalent to future MTG satellite. The retrieved COD is unaffected by high-frequency variations below SEVIRI standard resolution of 3kmX3km because of using High-Resolution Visible(HRV) as a constraint while downscaling.

We show how advances in deep learning networks are used to understand the cloud's physical properties in temporal and spatial scales. We investigate two spatial domains and two-pixel configurations (128x128,64x64). We demonstrate explainable artificial intelligence (XAI), which helps gain trust for the neural network's performance. The work also explores the uncertainties associated with the automatic machine-detected patterns and how they vary with different cloud classification types.

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Presenter: Mr CHATTERJEE, Dwaipayan (Institute for Geophysics and Meteorology, University of Cologne)

Session Classification: Poster pitches

Contribution ID: **28** Type: **Talk**

The ubiquity of mesoscale shallow circulation in the trades

Tuesday, May 17, 2022 11:30 AM (15 minutes)

From EUREC^{4}A observations, we find evidence for shallow circulations at meso-scales in the trades. Shallow circulations have been shown as one of the main drivers behind genesis and maintenance of convective aggregation. They have been studied in models, as well as been identified in moisture space. We identify similar signals for the first time in physical space. Over time-means of 3-6 hours, the mean divergence anomaly in the sub-cloud layer correlates negatively with that in the cloud layer. Here, *anomaly* means the deviation from the month-long campaign mean. Divergence fields from ERA5 reanalysis confirm these observed findings and show that these circulations exhibit a ubiquity in space and time. Moreover, the sub-cloud divergence anomaly has a strong anticorrelation with the humidity anomaly in the cloud as well as sub-cloud layers. We show that these shallow circulations create and maintain moist and dry sub-cloud layers due to the influence of vertical velocity on the cloud-layer moisture, and a subsequent change in entrainment drying efficiency. These circulations leave an imprint on mesoscale humidity and their persistence potentially impacts cloudiness. Thus, investigating these circulations can help better understand the patterns of meso-scale cloud organization within the trades.

Primary authors: GEORGE, Geet (Max Planck Institute for Meteorology, Hamburg, Germany); STEVENS, Bjorn; BONY, Sandrine (LMD/IPSL, Sorbonne Université, CNRS, Paris, Franc); VOGEL, Raphaela (LMD/CNRS Paris); NAUMANN, Ann Kristin

Presenter: GEORGE, Geet (Max Planck Institute for Meteorology, Hamburg, Germany)

Session Classification: Shallow convection

Contribution ID: **29** Type: **Talk**

Spontaneous clustering of convection in simple models, cloud resolving models and observations.

Monday, May 16, 2022 9:35 AM (30 minutes)

This talk address convective aggregation on the mesoscale in idealized cloud resolving models, in highly simplified stochastic models and in the latest observations in the tropical western Pacific.

Cloud resolving models run in idealized conditions of radiative convective equilibrium often show randomly distributed convection switching to a state in which the convection is highly clustered, leading to a much drier mean state, which in turn impacts radiative budget. If this organization of convection is sensitive to surface temperature, it could thus represent a facet of climate sensitivity missing from the current generation of climate models. The CRM experiments show that the relative strengths of diabatic feedbacks are model dependent, and therefore to increase understanding, I will present the results of a minimal physics, stochastic reactive-diffusive model for water vapour in the tropical atmosphere, which reproduces the general behaviour of the full physics models. Using this simplified model we derive a dimensionless parameter which predicts which model parameter settings, and domain/resolution frameworks, lead to clustering or random convection.

Given that clustering occurs in idealized frameworks, the next question is whether it is relevant for the real atmosphere on the mesoscale, where ocean SST contrasts driven by dynamics largely determine the distribution of convection. It has been difficult so far to assess aggregation in observations, due to the lack of ability to observe convective core location from space until Doppler radar is available, and the overlapping of cirrus anvils which complicates the assessment of convective organization from TOA longwave observations. Using a novel analysis method to examine a combination of state-of-the-art retrievals of clouds, water vapour, precipitation and sea surface temperature available since 2016, I will present observations that appear to demonstrate convective aggregation operating in the tropical western Pacific region on the sub-1000 km scale, in a region with very weak spatial gradients in sea surface temperature. Convection is generally seen to be in a highly aggregated state, but intermittently and rapidly flips to a random state when low wind conditions prevail, associated with thin mixed ocean layers which oppose aggregation. These events generally persist for a few days to a week or more before convection transitions back to a clustered state. We believe this to be the first direct evidence of this “switching” of clustering state occurring on the meso-scale in the tropics. However, a preliminary analysis indicates that the meso-scale organization actually has little overall impact on the top of atmosphere radiative budget at these scales; the reasons for which will be discussed. If confirmed, these results may indicate that convective clustering at the meso scale is much less important for assessing climate sensitivity than the idealized CRM experiments may suggest.

Primary authors: TOMPKINS, Adrian (ICTP); Ms DE VERA, Michie (University of Illinois, USA); BIAGIOLI, Giovanni (University of Trieste)

Presenter: TOMPKINS, Adrian (ICTP)

Session Classification: Convective concepts

Contribution ID: **30** Type: **Talk**

Moisture transports and rain cell statistics in organised convection and their potential role in super Clausius-Clapeyron scaling

Wednesday, May 18, 2022 12:00 PM (15 minutes)

In observations of (sub)hourly precipitation, it is often found that the extremes display a dependency on (dew point) temperature exceeding the Clausius-Clapeyron (CC) relation. Such super CC behaviour is commonly explained by dynamical feedback mechanisms in convective clouds whereby enhanced latent heating (and cooling due to evaporation) could produce more vigorous, or more organised updraft motions. Haerter and Schlemmer proposed that enhanced cold pool dynamics with warming could be crucial with stronger cold pools in warmer conditions leading to larger areas where convection inhibition can be broken, and larger areas of moisture convergence. Here, we study these feedback mechanisms in a set of Large-Eddy Simulations forced by typical mid-latitude large-scale atmospheric conditions. Different weather/climate conditions are emulated by imposing perturbations in temperature and humidity. We start by analysing vertical uniform warming profiles (motivated by present climate day-to-day variability but not the most realistic in a climate change setting) which maximises the potential for dynamical feedbacks. In this set of LES simulation warmer conditions have shown to lead to larger, more organised cloud systems. Here, we specifically analyse the vertical moisture transport in these cloud systems as well as in the sub-cloud layer at the cold pool fronts as a function of cell size. The ultimate goal is to relate this back to the rain statistics in order to understand the conditions that lead to super CC scaling.

Primary authors: LENDERINK, Geert (KNMI); LOCHBIHLER, Kai; SIEBESMA, Pier (Delft University of Technology)

Presenter: LENDERINK, Geert (KNMI)

Session Classification: Deep convection and more

Contribution ID: **31** Type: **Talk**

On the relationship between precipitation and the spatial structure in trade wind convection

Tuesday, May 17, 2022 11:45 AM (15 minutes)

When trade wind convection organises into spatial patterns, it is often in conjunction with precipitation formation, raising the question of the role of convective spatial organisation for precipitation and vice versa. We analyse measurements from the C-band radar Poldirad upstream of Barbados during the EUREC4A field campaign to investigate the spatial behaviour of precipitating shallow convection and its implications for precipitation characteristics in the trades. We find that precipitation rates vary mainly independently from the spatial arrangement of precipitating cells. Mean precipitation increases with the size or number of cells, as it is closely related to the precipitating area. The cells'degree of clustering, on the contrary, is typically greatest in scenes containing rather large and few cells. Consequently, scenes that vary in the spatial structure – containing large, clustered convective structures at one time or numerous and more distributed convective structures at another time –can have similar precipitation rates. Could spatial organization, therefore, be a process to maintain precipitation rates in very different environments? We exploit large-domain realistic large-eddy simulations to investigate scenes of trade wind convection that exhibit different spatial structures but similar precipitation rates. We discuss whether the scenes differ in their environment and circulation and how this might necessitate different spatial structures to rain.

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

Session Classification: Shallow convection

Contribution ID: **33** Type: **Talk**

Explaining convective self-aggregation onset with a stochastic reaction-diffusion model of the Tropics

Monday, May 16, 2022 10:20 AM (15 minutes)

In an attempt to explain some differences existing between cloud-resolving models (CRMs) about the occurrence, under certain circumstances, of states in which convection self-aggregates, a simplified, two-dimensional, stochastic model was developed. Its prognostic equation governs the evolution of column total water relative humidity in tropical free troposphere, including convective moistening, diffusive lateral transport and subsidence drying, similar to Craig and Mack (2013), but with convection treated as a point process and stochastic variability in convective outbreak accounted for. Therefore the model allows to employ domain sizes and resolutions similar to idealized CRM simulations.

We found that, depending on the chosen parameter settings, the model can reproduce equilibrium states of strong aggregation and randomly distributed convection, analogous to CRMs. Large ensembles of experiments were performed for different values of subsidence timescale, moisture diffusion coefficient and the parameter determining convective sensitivity to background humidity, as well as for a range of domain sizes and resolutions. Using dimensional arguments, combined with empirical fits from numerical data, we define a dimensionless quantity whose value indicates whether a clustered state is likely to emerge for a given experimental configuration. This quantity contains dependencies on all the model processes and also includes domain size and resolution.

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

Presenter: BIAGIOLI, Giovanni (University of Trieste)

Session Classification: Convective concepts

Contribution ID: **34** Type: **Talk**

In-Situ Perspectives on the Sub-Cloud Layer during EUREC4A/ATOMIC

Tuesday, May 17, 2022 12:00 PM (15 minutes)

During the ATOMIC and EUREC4A campaigns, the University of Colorado RAAVEN (CU-RAAVEN) uncrewed aircraft system (UAS) was operated in the near-shore environment from Morgan Lewis Barbados. The aircraft conducted 37 research flights, capturing detailed information on the sub-cloud layer and atmospheric boundary layer between 24 January and 15 February. In this presentation, we will provide perspectives on the connection between sub-cloud layer thermodynamic and kinematic properties and cloud regimes, as observed by the RAAVEN. This includes information on momentum fluxes and turbulence, as well as sub-cloud vertical velocity distributions. We will attempt to map these properties onto different cloud regimes, as determined through a variety of observations collected during these field campaigns.

Primary authors: DE BOER, Gijs; Dr CALMER, Radiance (University of Colorado); Dr BUTTERWORTH, Brian (University of Colorado); Dr FAIRALL, Chris; Dr INTRIERI, Janet

Presenter: DE BOER, Gijs

Session Classification: Shallow convection

Contribution ID: **38** Type: **Talk**

Influence of Aerosol Perturbation Duration on the Organization of Stratocumulus: Large Eddy Simulation and Heuristic Dynamical Modeling

Monday, May 16, 2022 11:00 AM (30 minutes)

Marine boundary layer stratocumulus clouds tend to occur in two distinct organizational states: the closed cell, high cloud fraction state and the open-cell, low cloud fraction state. The selection of the state is determined by the amount of precipitation, which is in turn strongly influenced by the aerosol concentration. Natural and anthropogenic aerosol perturbations have characteristic durations, along with concomitant changes in meteorology and associated cloud conditions. In this talk we will explore the effect of the timescale of aerosol perturbations on the cloud system organization using idealized large eddy simulation as well as a heuristic model. We will explore the extent to which the amount and duration of aerosol perturbations influence transitions between states, in order to obtain insights into potential climate effects.

Primary authors: FEINGOLD, Graham (NOAA); Dr HOFFMANN, Fabian (LMU, Munich); Dr ZHANG, Jianhao (NOAA); Dr PRABHAKARAN, Prasanth (NOAA); Dr ZHOU, Xiaoli (NOAA); Prof. KOREN, Ilan (Weizmann Institute); GLASSMEIER, Franziska (TU Delft)

Presenter: FEINGOLD, Graham (NOAA)

Session Classification: Convective concepts

Contribution ID: **39** Type: **Talk**

Dependency of precipitation and cloud radiative feedback on subgrid scale clouds structure; a machine learning approach

Wednesday, May 18, 2022 11:30 AM (15 minutes)

The organization of convective clouds has been argued to have a significant impact on the atmospheric humidity and circulation, as well as precipitation and cloud radiative feedback, yet global models do not include a parameterization of unresolved subgrid cloud structure. In this study, we investigate the necessity of including subgrid scale cloud structure in the model and whether it improves the prediction of precipitation and cloud radiative feedback. We use neural networks (NN), trained on coarse-grained data from the DYnamics of the Atmospheric general circulation Modeled On Non-hydrostatic Domains (DYAMOND) intercomparison project, to learn about the dependency of precipitation, cloud cover and cloud radiative feedback on the cloud structure. Our preliminary results suggest that NNs accurately predict the mean precipitation and cloud cover by only having access to resolved state variables, yet this prediction can be improved by adding information about the subgrid structure or its previous state. Using explainable artificial intelligence, we seek to understand the underlying dynamics discovered by NNs so as to improve the conventional parameterizations, such that they include information about subgrid-scale cloud structure when necessary.

Primary author: SHAMEKH, Sara (Columbia University)

Co-authors: HUANG, Yu (Columbia Univeristy); LAMB, Kara (Columbia University); GENTINE, Pierre (Columbia University)

Presenter: SHAMEKH, Sara (Columbia University)

Session Classification: Deep convection and more

Contribution ID: **41** Type: **Talk**

The Organization and Vertical Structure of Shallow Convection in Marine Cold-Air Outbreaks, based on the Cold-Air Outbreaks in the Marine Boundary Layer Experiment (COMBLE): Observations

Wednesday, May 18, 2022 10:15 AM (15 minutes)

When cold air blows off boreal continents or the Arctic ice over open water, a well-recognized cloud pattern forms with clouds streets and, further downwind, an open cellular structure. Despite the ubiquity of this cold-air outbreak (CAO) cloud regime over high-latitude oceans, we have a rather poor understanding of its properties, including its macroscale organization. In the 2019-'20 cold season, the COMBLE campaign was conducted along the coast of northern Norway, to examine the relations between surface fluxes, boundary-layer structure, aerosol, cloud and precipitation properties, and mesoscale circulations in marine CAOs. One of the hypotheses driving the COMBLE campaign is that cloud and precipitation processes control mesoscale organization and transitions. At the coastal site, located over 1000 km from the Arctic ice, an open-cellular structure prevailed, characterized by rather high surface heat fluxes just offshore, pockets of strong updrafts and convective turbulence (alternating with decaying convective cells), occasionally high reflectivity with heavy surface precipitation rate, high cloud tops (typically >2-3 km MSL), much liquid water in the updrafts, and broken cloud cover. A less common cloud mode appears to form under weaker surface heat fluxes, and is characterized by weak vertical drafts (up- and down-drafts) and turbulence, cloud tops around 2 km MSL, widespread but low reflectivity values, light precipitation rate, nearly overcast cloud cover, rather high amounts of supercooled liquid water, and common presence of cloud top generating cells. These cloud modes will be described using data from an array of instruments, including profiling and scanning radar data,

Primary authors: GEERTS, Bart (University of Wyoming); KOSOVIC, Branko; LACKNER, Christian; XUE, Lulin; JULIANO, Timothy

Presenter: GEERTS, Bart (University of Wyoming)

Session Classification: Deep convection and more

Contribution ID: **42** Type: **Poster**

Controls on organisation with CoMorph

CoMorph is a new mass-flux convection scheme, developed at the Met Office as part of the ParaCon programme. We report on the organisation that results with this scheme across a range of scales and forcings, and the key controls on the emergent structures that form.

Primary author: STIRLING, Alison (Met Office)

Co-authors: Dr LOCK, Adrian (Met Office); Dr LAVENDER, Sally (Met Office); Dr STRATTON, Rachel (Met Office); Dr WHITALL, Michael (Met Office)

Presenter: STIRLING, Alison (Met Office)

Session Classification: Poster pitches

Contribution ID: **43** Type: **Poster**

Shallow convective organization in the Trades as seen by self-learning artificial intelligence

Monday, May 16, 2022 12:22 PM (2 minutes)

The organization of shallow convection in the trades influences precipitation development, cold pool formation, clouds'radiative effects, and, thus, climate sensitivity. Deep learning techniques, especially in computer vision and self-supervision, are suitable tools to understand cloud organization purely from a machine's perspective. Yet, the physical interpretation of the network's classes remains challenging.

We use a self-supervised deep learning neural network to assess the organization and the associated physical properties of shallow convection during the EUREC4A field study. Based on geostationary GOES-East images of cloud optical depth, we analyze images from both Barbados Cloud Observatory, and from a random selection of a larger domain across the tropical Atlantic. The network classifies each image into one of four classes of organization. Based on the neural network outputs, that is higher-order image features and corresponding labels of the image, we analyze how these relate to the four categories previously identified from human labeling by the EUREC4A community (*Sugar, Gravel, Flower, Fish*).

Primary author: SCHNITT, Sabrina (University of Cologne)

Co-authors: CHATTERJEE, Dwaipayan (University of Cologne); BIGALKE, Paula (University of Cologne); CREWELL, Susanne (University of Cologne)

Presenter: SCHNITT, Sabrina (University of Cologne)

Session Classification: Poster pitches

Contribution ID: **44** Type: **Talk**

The Organization and Vertical Structure of Shallow Convection in Marine Cold-Air Outbreaks, based on Cold-Air Outbreaks in the Marine Boundary Layer Experiment (COMBLE): Developing the Framework for an Intercomparison Modeling Study

Tuesday, May 17, 2022 11:00 AM (15 minutes)

The Arctic's complex atmospheric environment remains a large source of uncertainty for numerical models across a range of scales, especially during cold-air outbreaks (CAOs). Under CAO conditions, the convective boundary layer grows rapidly with increasing fetch and intricate cloud structures transition from narrow rolls near the ice edge to cells downstream. To study the CAO cloud regime, the Cold-air Outbreaks in the Marine Boundary Layer Experiment (COMBLE) was conducted from December 2019 to May 2020. Here we study an exemplary case from 12-13 March 2020. Results from numerical simulations using a Lagrangian large-eddy simulation approach suggest that the transition from convective rolls to cells is reasonably well captured. Nonetheless, we find that discernable differences in cloud parameters important to energy and water budgets arise among two modeling platforms. Given the wealth of COMBLE data, we are motivated to initiate a community-wide intercomparison modeling study of the 12-13 March 2020 case. This presentation will first highlight initial results from our simulations of the CAO event, including model sensitivities to microphysical parameters, as well as strength of surface forcing. Then, we will provide overarching goals and plans for the proposed intercomparison study in an effort to solicit interest from various modeling groups.

Primary author: JULIANO, Timothy (NCAR)

Co-authors: FRIDLIND, Ann (NASA/GISS); GEERTS, Bart (University of Wyoming); KOSOVIC, Branko (NCAR); LACKNER, Christian (University of Wyoming); TORNOW, Florian (NASA/GISS); XUE, Lulin (NCAR); OVCHINNIKOV, Mikhail (PNNL); KOLLIAS, Pavlos (State University of New York at Stony Brook); WU, Peng (PNNL); ZHENG, Xue (LLNL); WANG, Yonggang (State University of New York at Oswego); ZHANG, Yunyan (LLNL); MAGES, Zackary (State University of New York at Stony Brook)

Presenter: GEERTS, Bart (University of Wyoming)

Session Classification: Shallow convection

Contribution ID: **45** Type: **Talk**

Low-level radiative cooling peaks in regimes of shallow convective organization

Thursday, May 19, 2022 10:00 AM (15 minutes)

In models, a local maximum of clear-sky radiative cooling in the lower troposphere often appears as a necessary condition for the development and persistence of convective organization. However, no robust understanding has been provided for the emergence and disappearance of lower-tropospheric cooling in the atmosphere. Here we propose a theoretical characterization of clear-sky radiative cooling peaks, recently calculated from over 2,000 soundings launched during the EUREC4A field campaign in various patterns of shallow organization. A suite of scaling approximations are developed from simplified spectral theory to connect the longwave cooling peak to the vertical humidity structure set by convection. Its height is controlled by local maxima in the vertical gradients of water vapor path, and its magnitude is mainly controlled by the ratio between column relative humidity above and below the peak. In contrast, the value of the Planck function and the spectral width of emission at the peak only weakly vary across soundings. However, water vapor spectroscopy implies that upper-level intrusions of moist air detrained from lower latitudes can substantially dim low-level cooling, possibly by reducing the range of the spectrum that effectively cools to space at the level of the peak. This work motivates future modeling work, formulating the hypothesis that "Fish" patterns, which embed the widest persisting dry areas, may be the most favorable conditions for radiative processes to act on the circulation. If at play, these radiative feedback mechanisms would maintain these patterns that are efficient at cooling the tropics, a type of "dry radiator fins" which could mitigate the risk of runaway climate states.

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

Session Classification: Wind, radiation and organisation

Contribution ID: **46** Type: **Talk**

Self-aggregation of convective storms

Wednesday, May 18, 2022 3:15 PM (30 minutes)

Idealized simulations of the tropical atmosphere have predicted that clouds can spontaneously clump together in space, despite perfectly homogeneous settings. This phenomenon has been called self-aggregation, and results in a state where a moist cloudy region with intense deep convective storms is surrounded by extremely dry subsiding air devoid of deep clouds. We review here the main findings from theoretical work and idealized models, highlighting the physical processes believed to play a key role in convective self-aggregation. We also review the growing literature on the importance and implications of this phenomenon for the atmosphere, notably for the hydrological cycle and for precipitation extremes.

Primary authors: FILDIER, Benjamin; YANG, Da; MULLER, caroline (CNRS/LMD); MAPES, Brian; HOHENEGGER, Cathy; RANDALL, David; CRAIG, George; HAERTER, Jan; SHAMEKH, Sara; SHERWOOD, Steven; CRONIN, Tim

Presenter: MULLER, caroline (CNRS/LMD)

Session Classification: Deep convection and more

Contribution ID: **47** Type: **Talk**

Mesoscale organization of trade-wind clouds: lessons from EUREC4A and questions

Tuesday, May 17, 2022 9:15 AM (30 minutes)

Shallow convection exhibits a large diversity of spatial organizations at the mesoscale. Over the past years, a few prominent patterns of trade-wind clouds have been identified over the tropical western Atlantic. These patterns depend on environmental conditions and exert different radiative impacts. This raises two questions: What are the physical processes underlying changes in the mesoscale patterns of shallow clouds? And does the organization of shallow convection matter for cloud feedbacks? The EUREC4A field campaign (http://eurec4a.eu) which took place in Jan-Feb 2020 near Barbados, offers a wealth of observations to help address these questions. We will review some insights from the campaign on these issues, and will show that the observations raise additional questions. We will discuss some promising directions of research, and will present a proposal for coordinated simulations of the mesoscale organization of convection with a hierarchy of models.

Primary authors: BONY, Sandrine (LMD/IPSL, CNRS, Sorbonne University); THE EUREC4A TEAM

Presenter: BONY, Sandrine (LMD/IPSL, CNRS, Sorbonne University)

Session Classification: Shallow convection

Contribution ID: **48** Type: **Talk**

Reassessing the Cohen and Craig (2006) theory: Fluctuations in an equilibrium convective cloud ensemble at horizontal resolutions ranging from 2 km to 125 m

Wednesday, May 18, 2022 11:45 AM (15 minutes)

About 15 years ago, Cohen and Craig (2006, CC06) proposed a general theory describing the fluctuations of the properties characterising a convective cloud ensemble developing under fixed external forcing. This theory later served as the basis of the Plant-Craig stochastic convection scheme which has been in particular implemented in the ICON model operated by the German weather service.
Unfortunately, due to limitations in computational power available at the time, the theory could only be validated using Cloud Resolving Model (CRM) simulations in Radiative Convective Equilibrium (RCE) at a horizontal resolution of 2 km, which can be considered as relatively coarse by today's standards. At this resolution, convection organisation is very weak, and clouds can be considered as developing randomly in space, independently of each other. It is however a common knowledge now that as resolution is increased, spatial organisation emerges specifically driven by cold pool dynamics in the boundary layer and moisture patterns in the troposphere.
In this work, fluctuations of general cloud properties are investigated in a numerical setup similar to CC06, but at horizontal resolutions ranging from 2 km to 125 m. As expected, convective organisation arising at resolutions < 1 km significantly affects the cloud number and mass flux distributions. The original CC06 theory, stating that clouds follow a spatial Poisson point process with exponentially distributed mass fluxes, no longer holds at the domain scale. It is however demonstrated that the above mentioned characteristics are recovered when individual cloud cores are isolated (the biggest clouds at high resolution are composed of several merged cores), and when restricting the analysis to regions of high cloud density where clouds appear to cluster. Even at 125 m resolution, cloud core mass fluxes are reasonably well approximated by exponential functions, whereas cloud cores appear to be randomly distributed in space (Poisson) where convective activity is the strongest. Under these assumptions, the CC06 theory therefore also provides a reasonably good description of cloud number and mass flux fluctuations occurring in an organised cloud ensemble at equilibrium.

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Presenter: Dr SAVRE, Julien (Ludwig-Maximilians-Universität Munich)

Session Classification: Deep convection and more

Contribution ID: **49** Type: **Talk**

A cold pool perturbation scheme to improve convective initiation in convection-permitting models

Wednesday, May 18, 2022 11:15 AM (15 minutes)

Cold pools are essential for organizing and initiating convection. In a recent investigation, we identified several sensitivities of cold pool driven convective initiation to model resolution within hectometer simulations. In particular, a causal graph analysis has revealed that the dominant impact of model resolution on convective initiation is a direct consequence of weak vertical velocities at the gust fronts, rather than being related to changes in the buoyancy or other properties of the cold pools.
To address this deficiency, we develop a parameterization for convection-permitting models to improve the representation of cold pool gust fronts. We enhance vertical wind tendencies within these gust fronts towards a target vertical velocity based on similarity theory. This parameterization strengthens gust front circulations and thereby enhances cold pool driven convective initiation. Consequently, precipitation is amplified and becomes more organized in the afternoon and evening.

Primary authors: HIRT, Mirjam; CRAIG, George (Ludwig-Maximilians-Universität Munich)

Presenter: HIRT, Mirjam

Session Classification: Deep convection and more

Contribution ID: **50** Type: **Talk**

How well can we simulate mesoscale cloud organisation as observed during EUREC4A ?

Thursday, May 19, 2022 9:45 AM (15 minutes)

It has become clear over the last couple of years that shallow cumulus convection over the subtropical oceans has a strong tendency to develop itself into a rich variety of spatial cloud structures. It is particular challenging to simulate these mesoscale cloud patterns. On the one hand, it requires turbulence resolving resolutions of 100 m to represent the vertical convective mixing processes while at the same time domains of several hundreds of kilometres are required to represent the large mesoscale cloud structures.
In this study we present a number of simulations techniques ranging from idealised Large Eddy Simulations (LES) with periodic boundary conditions to simulations with operational Storm Resolving Models (SRMs) and assess their capability to reproduce the mesoscale structures such as observed during the EUREC4A period.

Primary authors: SIEBESMA, Pier (Delft University of Technology); NUIJENS, Louise (TU Delft)

Co-authors: FRANS LIQUI-LUNG (Monash University); SAVAZZI, Allesandro (Delft University of Technology); JANSSON, Fredrik (Delft University of Technology); DE ROOIJ, Wim (KNMI); VAN ULFT, Bert (KNMI)

Presenters: SIEBESMA, Pier (Delft University of Technology); NUIJENS, Louise (TU Delft)

Session Classification: Wind, radiation and organisation

Contribution ID: **51** Type: **Poster**

Open cell convection in HARMONIE-AROME

Tuesday, May 17, 2022 12:31 PM (2 minutes)

With a resolution of 2.5km, HARMONIE-AROME is a NWP model that roughly resolves deep convection. It is not clear if such a model should be capable of resolving open cell convection, as can be observed above sea under unstable conditions (e.g. during a cold air outbreak). However, especially the rain associated with this type of convection, can be important if it occurs with temperatures around 0 C. For one open cell convection case, we investigated the role of momentum mixing by the shallow convection scheme, as well as the impact of microphysics. we will show that momentum mixing can attenuate mesoscale structures of the NWP model. On the other hand, increased precipitation of the shallow convection scheme supports the building up of cold pool, mesoscale structures. Although, we can increase the mesoscale cloud organisation changing these two processes, the precipitation remains underestimated. A more elaborate investigation will be done in EUREC4A.

Primary author: DE ROOY, Wim (researcher)

Presenter: DE ROOY, Wim (researcher)

Session Classification: Poster pitches

Contribution ID: **52** Type: **Poster**

Dependence of Cloud Radiative Effect on Cloud Organization in the Trades

Monday, May 16, 2022 12:14 PM (2 minutes)

Shallow cumuli are the most frequent types of clouds over the subtropical oceans where they occur in several shapes and patterns. These types of clouds potentially play a major role in regulating the radiative budget of the Earth system. An important question is to what extent cloud patterns alter under climate change and how this will feedback onto a rising of temperature. In this study, we aim at finding how cloud feedback depends on the macro-physical characteristics of cloud fields. To this end, we investigate the relationship between different organization metrics derived from shallow cloud fields and the net cloud radiative effect of the associated fields.

Primary author: ALINAGHI, Pouriya (TU Delft)

Co-author: GLASSMEIER, Franziska (TU Delft)

Presenters: ALINAGHI, Pouriya (TU Delft); GLASSMEIER, Franziska (TU Delft)

Session Classification: Poster pitches

Contribution ID: **54** Type: **Talk**

Natural selection by buoyancy and the ecology of pattern in convection

Monday, May 16, 2022 3:30 PM (30 minutes)

A conceptually guided literature review will be offered, in an attempt to frame the issue of pattern formation in evolutionary terms. Gravity is omniscient about density variations, and rewards them with a conversion from potential to kinetic energy. Some of that kinetic energy can induce further density patterning, with a pattern and scale dependent efficiency, by shaping latent heat release and the redistribution of sensible heat. Although fluid information storage lacks the long time reservoirs of biological life, winning strategies that coordinate lateral interaction mechanisms in complex patterns can persist, outcompete naive unicellular bubble strategies, and perhaps replicate remotely through faster-than-wind wave communication.

Primary author: MAPES, Brian (University of Miami)

Presenter: MAPES, Brian (University of Miami)

Session Classification: Convective concepts

Contribution ID: **56** Type: **Poster**

The role of mesoscale convective organization in the generation of extreme precipitation over Europe

Tuesday, May 17, 2022 12:17 PM (2 minutes)

Mesoscale Convective Systems (MCS) are common over Europe during the warm season (Morel and Senesi, 2002b) and are able to produce severe weather such as extreme precipitation leading to flash floods (Fiori et al., 2014). Studies analyzing the climatological characteristics of MCS over Europe are rare and were often based on only a few years of data or were focused on a limited area of Europe. In their recent research, Surowiecky and Taszarek (2020) showed that MCS over Poland can frequently adopt typical morphology of mid-latitude extreme-rain producing MCS (Schumacher and Johnson, 2005).
With the recent Integrated Multi-satellitE Retrievals for Global Precipitation Measurement (IMERG; Huffman et al., 2019) satellite precipitation climatology, we identify and track MCS for nearly 20 years over Europe. Our detection/tracking algorithm is inspired from the one proposed by Feng et al. (2021). Cell-tracking from precipitation data is not straightforward, especially for fast moving and small systems. Here, we make use of a spatio-temporal filter and track cells according to the overlapping of filtered precipitation patches between two consecutive time steps. We fit an ellipse to the precipitating patches for a quick scan of their morphology and orientation. The algorithm distinguishes between non-convective rain bands from convective rain patches by using lightning data, thus reducing potential identification errors.
We use this new European MCS climatology to evaluate their main characteristics in Europe and their potential evolution over the last 20 years. In particular, we examine their occurrence frequency in extreme rainfall events in this region and the environmental conditions leading to these extremes, with respect to other (non-MCS) convective systems. This work contributes to better understanding the role that convective organization plays in driving extreme rain in mid-latitudes from an observational perspective.

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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: Poster pitches

Contribution ID: **57** Type: **Talk**

Cold pool and mesh refinement: what is gained at higher resolutions?

Tuesday, May 17, 2022 11:15 AM (15 minutes)

It is well-recognized that triggering of convective cells through cold pools is key to the organization of convection, as reviewed in Zuidema et al. (2017). Yet, numerous studies have found that both the characterization and parameterization of these effects in numerical models is cumbersome - in part due to the lack of numerical convergence ($\Delta x \longrightarrow 0$) achieved in typical cloud-resolving simulators. Through a comprehensive numerical convergence study, we systematically approach the $\Delta x \longrightarrow 0$ limit in a set of idealized large-eddy simulations capturing key cold pool processes: propagation, merging and collision of gust fronts. We characterize at which Δx convergence is achieved for physically relevant quantities, namely accumulated upwards water mass fluxes, integrated vortical rates and gust front's group velocity.
We hope that the understanding gained from this analysis can help develop robust subgrid models for CP dynamics able to sustain their growth and combat artificial numerical dissipation and dispersion.

Primary authors: MEYER, Bettina; FIÉVET, Romain (Niels Bohr Institute); HAERTER, Jan (Niels Bohr Institute, Copenhagen University)

Presenter: FIÉVET, Romain (Niels Bohr Institute)

Session Classification: Shallow convection

Contribution ID: **58** Type: **Poster**

Network approaches to the geometric structure of shallow cloud fields

Monday, May 16, 2022 12:06 PM (2 minutes)

The cellular structure of stratocumulus clouds decks and their evolution has been modeled by describing them as cellular, nearest-neighbor networks (Glassmeier& Feingold, 2017, PNAS). We review this approach and discuss options and challenges for its generalization to shallow cumulus cloud fields.

Primary authors: ALINAGHI, Pouriya (TU Delft); FEINGOLD, Graham (NOAA); GLASSMEIER, Franziska (TU Delft); JANSSENS, Martin (Wageningen University & Research)

Presenter: GLASSMEIER, Franziska (TU Delft)

Session Classification: Poster pitches

Contribution ID: **59** Type: **Poster**

Self-organized quantization and oscillations on continuous fixed-energy sandpiles

Monday, May 16, 2022 12:04 PM (2 minutes)

Atmospheric self-organization and activator-inhibitor dynamics in biology provide examples of checkerboard-like spatio-temporal organization. We study a simple model for local activation-inhibition processes. Our model, first introduced in the context of atmospheric moisture dynamics, is a continuous-energy and non-Abelian version of the fixed-energy sandpile model. Each lattice site is populated by a non-negative real number, its energy. Upon each timestep all sites with energy exceeding a unit threshold re-distribute their energy at equal parts to their nearest neighbors. The limit cycle dynamics gives rise to a complex phase diagram in dependence on the mean energy μ: For low μ, all dynamics ceases after few re-distribution events. For large μ, the dynamics is well-described as a diffusion process, where the order parameter, spatial variance σ, is removed. States at intermediate μ are dominated by checkerboard-like period-two phases which are however inter-spersed by much more complex phases of far longer periods. Phases are separated by discontinuous jumps in σ or $\partial\sigma/\partial\mu$ —akin to first and higher-order phase transitions. Overall, the energy landscape is dominated by few energy levels which occur as sharp spikes in the single-site density of states and are robust to noise.

Primary authors: Dr JENSEN, Gorm Gruner (Niels Bohr Institute); HAERTER, Jan (Niels Bohr Institute, Copenhagen University)

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

Session Classification: Poster pitches

Contribution ID: **60** Type: **Poster**

The spacing and thermodynamics of updraughts in organised shallow cumulus

Monday, May 16, 2022 12:12 PM (2 minutes)

We consider the clouds that form in Lagrangian high-resolution and single-column model simulations based on different days of the EUREC4A/ATOMIC field campaign. These simulations are driven using ERA5 reanalysis, and contain examples of flower type and gravel type organisation. In particular, we consider the spacing and thermodynamic properties of updraughts and detrained air during different regimes of convective organisation, at different stages during the life cycle of the cloud. We also test the sensitivity of these properties to the LES forcings.

Primary authors: DENBY, Leif (University of Leeds); BOEING, Steven (University of Leeds); BLOSSEY, Peter (University of Washington, Seattle); NEGGERS, Roel (University of Cologne); GHAZAYEL, Salima (University of Cologne)

Presenter: BOEING, Steven (University of Leeds)

Session Classification: Poster pitches

Track Classification: Mesoscale organization of shallow and deep cumulus convection

Contribution ID: **61** Type: **Talk**

Properties and transitions of mesoscale convective organisation during EUREC4A using unsupervised learning

Tuesday, May 17, 2022 3:15 PM (15 minutes)

The representation of shallow tradewind cumulus clouds in climate models accounts for the majority of inter-model spread in climate projections, highlighting an urgent need to understand these clouds better. In particular, their spatial organisation appears to cause a strong impact of their radiative properties and dynamical evolution. The precise mechanisms driving different forms of convective organisation which arise both in nature and in simulations are, however, currently unknown.

Using unsupervised learning for identifying regimes of convective organisation in the tropical Atlantic, we will show results from analysing: a) what the radiative properties of different forms of organisation are, b) what atmospheric characteristics coincide with different forms of organisation and c) what transitions occur when following air-masses along Lagrangian trajectories. Specifically, we find: a) net radiation changes significantly between different forms of organisation, b) agreement with previous studies on the importance of boundary layer wind-speed and to some degree atmospheric
stability, and c) we are able to succinctly capture what transitions occur between regimes.

Primary author: DENBY, Leif (University of Leeds)

Presenter: DENBY, Leif (University of Leeds)

Session Classification: Shallow convection

Contribution ID: **62** Type: **Talk**

The role of three dimensional radiation in transitions from shallow to deep convection

Tuesday, May 17, 2022 10:15 AM (15 minutes)

While radiative transfer through cloud fields is a 3D process, we generally solve this only in 1D due to the high computational costs involved. As a consequence, large-eddy simulations with 1D radiation have highly simplified shortwave heating and longwave cooling in clouds. Also, surface fields of direct radiation have cloud shadows at the wrong location and surface diffuse radiation is too concentrated below the clouds.

We have investigated whether the above mentioned shortcomings have an impact on the transition from shallow to deep convection over land using large-eddy simulations with 3D radiation solvers of different complexity. First, we show with large-eddy simulations using the TenStream solver that simulations with 3D radiative transfer develop larger and thicker clouds, which we attribute to modified land-atmosphere interactions. Also, we find that with 3D radiative transfer, the spatial variability of the surface fluxes is considerably larger than with 1D radiative transfer. The liquid water path is also dominated by larger length scales, hinting that 3D modifies cloud organization. Second, with GPU-accelerated large-eddy simulations with a coupled ray tracer, we quantify the necessity of having very accurate surface solar irradiance fields in producing correct clouds and cloud organization.

Primary authors: Dr VEERMAN, Menno (Wageningen University); VAN HEERWAARDEN, Chiel

Presenter: VAN HEERWAARDEN, Chiel

Session Classification: Shallow convection

Contribution ID: **63** Type: **Poster**

Momentum transport and the organization of shallow convection

Monday, May 16, 2022 12:20 PM (2 minutes)

Simulations of a marine cold air outbreak with the mesoscale weather model HARMONIE suggest that parameterized shallow convective momentum transport acts to diminish circulations that accompany cellular cloud structures. In this study we test this hypothesis in the trade-wind region where various type of shallow cumulus cloud patterns occur using a hierarchy of model simulations of the EUREC4A campaign.
We select a ten-day period within EUREC4A and run the Dutch Atmospheric Large-Eddy Simulation (DALES) on a 150 km x 150 km domain with a resolution of 100 m. Its boundaries are forced hourly with dynamical tendencies from the mesoscale weather model HARMONIE. HARMONIE is also run on a 3200 km x 2000 km domain with 2.5 km resolution, in runs with shallow convective momentum transport on and off.
First, we validate the model output with observations. Observations from EUREC4A suggest that in early February, deeper cumulus mediocris and larger cloud structures are associated with a different profile of eddy momentum flux divergence than days with shallower cumulus humilis. Second, we analyze the profiles of eddy momentum flux associated with turbulence, convection, and mesoscale flows. We show the momentum budget associated with different patterns of cloud organization and, lastly, we evaluate whether momentum transport has a significant influence on shallow cloud organization.

Primary author: SAVAZZI, Alessandro Carlo Maria (Delft University of Technology)

Co-authors: LOUISE NUIJENS (Delft University of Technology); DE ROOY, Wim (researcher); SIEBESMA, Pier (Delft University of Technology)

Presenter: SAVAZZI, Alessandro Carlo Maria (Delft University of Technology)

Session Classification: Poster pitches

Contribution ID: **65** Type: **Poster**

Convective organization from the interaction between cold pools and thermally induced mesoscale circulations

Tuesday, May 17, 2022 12:19 PM (2 minutes)

Land surface conditions can influence the onset and strength of convective systems. This is because sharp gradients in land surface properties result in differential latent and sensible heat fluxes, which leads to the development of mesoscale atmospheric circulations similar to the circulations present in land-sea breezes. These mesoscale circulations play an important roll in controlling the location of the initiation of deep convection in various ways. Studies have shown how different land surface heterogeneities may influence afternoon convective cloud sizes (and thus timing of initiation), precipitation duration and amount and cold pool modification. Cold pools may thus be altered to be more efficient at triggering further convective events. However, to synthesize all these effects that arise from land surface gradients and its control on rainfall distributions has been neglected.

Motivated by the modeling framework from previous studies (e.g. Huang and Margulis, 2012; Rieck et al., 2015; Schneider et al., 2019) we employ a checkerboard of alternating extremely dry vs. wet soil moisture patches in an idealized cloud resolving model coupled to a land surface model. The checkerboard approach has previously been used to show how the PBL, cloud size, precipitation duration and amount are all influenced by different strength and length scales of the land-surface gradients. Using this setup, mesoscale circulations induced by surface heterogeneities are therefore overlaid with cold pool circulations from subsequent afternoon convection. Our aim is to understand the complex of interactions between the land surface (e.g soil moisture), cold pools and thermal mesoscale circulations to organize diurnal moist convection. In particular, we aim to determine how these phenomena interact to 1) bring rain to conditionally unstable regions 2) organize convection into more localized extremes of rainfall and 3) allow the upscale growth of scattered convection in an environment where background wind is absent. These questions may give insight into the mechanisms that allow land use changes, such as deforestation and urban environments, to alter rainfall patterns that become locally more extreme.

Primary author: ENGELBRECHT, Edward (Jacobs University Bremen/Leibniz ZMT)

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

Presenter: ENGELBRECHT, Edward (Jacobs University Bremen/Leibniz ZMT)

Session Classification: Poster pitches

Contribution ID: **66** Type: **Talk**

Cloud response to higher warming conditions over the Tropical Atlantic using the COSMO model

Tuesday, May 17, 2022 3:45 PM (15 minutes)

Using the COSMO model, as part of the EUREC4A modeling project, we present a set of convection-resolving simulations of current and future climate over the EUREC4A study area. The main objectives of these simulations are: 1) to evaluate the capacity of the convection-resolving COSMO model to capture tropical-cloud characteristics from January 1 to March 1 2020; 2) to assess future changes in tropical clouds under the CMIP6-projected global warming, specifically using a pseudo-global warming (PGW) approach based on the GFDL-ESM4 model; and 3) to share this data as initial and boundary conditions for large eddy simulations (LES) over the region. We will present preliminary results regarding the PGW approach.

Primary authors: Dr TORRES-ALAVEZ, Abraham (ETH Zürich); Prof. SCHÄR, Christoph (ETH Zürich); Dr LEUTWYLER , David Leutwyler (ETH Zürich)

Presenter: Dr TORRES-ALAVEZ, Abraham (ETH Zürich)

Session Classification: Shallow convection

Contribution ID: **67** Type: **Poster**

Competition between convection of mesoscale patterns and its impacts on self-organization in idealized CRM simulations

Monday, May 16, 2022 12:28 PM (2 minutes)

This study first aims to address why mesoscale convective patterns are important and investigate the effects on both dynamics and thermodynamics using a cyclic cloud-permitting model, CM1. A set of idealized experiments to address the competition between isolated and agglomerated, organized convection using large-domain simulations with explicit representations of both convective-scale and domain-scale circulations. The atmosphere is uniformly destabilized with homogeneous forcing and with convective forms across the entire domain (organization gradient) modulated by vertical wind shear. Even without interactive radiation and surface fluxes, interactions among two regimes of cloud ensembles in different mesoscale forms lead to the formation of large-scale circulations, with intensified precipitation supported by the upwelling branch of overturning. Large-scale circulations tend to be more amplified as organization gradient increases, implying an essential role in dynamics and a faster process in preconditioning convective organization in more complex physical processes. From fully interactive RCE in domains initialized with different wave-like convective patterns but similar domain-wise thermodynamic states, we further show that convective patterns of a small wavenumber, analogy as larger organization gradient, fasten the drying effect by expanding dry patches with time. This control experiment implies that a more rapid self-aggregation process (separation between moist and dry regimes) through convective-radiative feedbacks may be bolstered by the presence of more distinct convective patterns.

Primary authors: MAPES, Brian (University of Miami); TSAI , Wei-Ming (University of Miami)

Presenter: TSAI , Wei-Ming (University of Miami)

Session Classification: Poster pitches

Contribution ID: **68** Type: **Poster**

Interactions between aerosol, clouds and circulation in high-resolution, cloud-resolving simulations with an imposed SST gradient

Tuesday, May 17, 2022 12:15 PM (2 minutes)

The coupling between clouds and circulation has long been recognised both as an essential aspect of tropical circulations as the circulations that accompany clouds are also known to play a role in their spatial organization. For example, mesoscale circulations driven by the heating contrast between convecting and non-convecting regions can drive moisture aggregation in the convecting region.

To study the two-way coupling between clouds and circulation in the tropics, it is desirable to have minimal models in which they can interact realistically. One such approach is to run large-domain, cloud-resolving simulations without rotation and with an imposed sea-surface temperature (SST) gradient, thereby generating an overturning circulation between regions of deep and shallow convection.

In this study we aim to understand how radiative cooling (from clouds and humidity) and latent heating (from precipitation) influence the temperature profiles in the subsiding branch of the circulation and thus the strength of the overturning circulation. As clouds and precipitation are both influenced by aerosol, we approach this question by varying the aerosol concentrations in the subsiding branch, which we hypothesize will alter the circulation strength by changing the cloud optical depth as well as the height at which convection begins to precipitate.

Primary authors: WILLIAMS, Andrew (University of Oxford); HOHENEGGER, Cathy; DAGAN, Guy (Fredy and Nadine Herrmann Institute of Earth Sciences, The Hebrew University of Jerusalem, Jerusalem, Israel); NUIJENS, Louise (TU Delft); STIER, Philip (University of Oxford)

Presenter: WILLIAMS, Andrew (University of Oxford)

Session Classification: Poster pitches

Contribution ID: **69** Type: **Poster**

Factors controlling precipitation in idealised monsoon simulations over an aquapatch

Monday, May 16, 2022 12:30 PM (2 minutes)

The traditional view of monsoons as continental sea breezes generated by land-sea contrasts was shown to have serious limitations. Therefore, it remains unclear if the surface temperature contrast matters for the monsoon precipitation, and why there is a non-linear intensification of precipitation intensity with surface temperature forcing. Here, we aim to determine if monsoon non-linearities with surface forcing come from convective processes, dynamical feedbacks, or from non-linearities in the forcing themselves.

Idealised studies such as aquaplanets often help improve our understanding of basic mechanisms. But there are very few idealised simulation studies of monsoons at high resolution. So we devise a modular framework to simulate idealised monsoons at convection-permitting resolution with the WRF model, in a domain based on an aquapatch (rectangular mini-aquaplanet), but in which we can gradually add more realistic components, such as an interactive land surface. The model is forced by a meridional contrast of surface temperature, with comprehensive physics, rotation, and symmetric boundary conditions at the North and South boundaries. In particular, we analyse a series of aquapatch experiments with varying Sea Surface Temperature (SST) gradients, varying SST peak locations, with and without rotation.

Primary authors: HAERTER, Jan; COLIN, Maxime (Leibniz Centre for Tropical Marine Research)

Presenter: COLIN, Maxime (Leibniz Centre for Tropical Marine Research)

Session Classification: Poster pitches

Contribution ID: **70** Type: **Talk**

Land effects on organised convection –mechanisms and applications

Wednesday, May 18, 2022 9:15 AM (30 minutes)

Different from oceans, the land surface can dry out, creating strong gradients in surface fluxes and temperatures. 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. On larger scales, land surface conditions can affect the positioning of atmospheric features such as dry lines, zones of atmospheric moisture convergence and regions of high wind shear, creating environments that are known to favour convective organisation. Furthermore, the partitioning of turbulent surface fluxes is closely tied to surface conditions such as vegetation cover and soil moisture, which can be heavily altered by humans via land use change and have a direct impact on storm patterns. Global warming is another anthropogenic factor that is expected to increase surface temperature gradients, particularly in semi-arid regions, which has already been found to intensify organised convection in the Sahel via increasing wind shear. On shorter time scales, the memory of the land surface relative to the atmosphere implies a level of storm predictability from land surface conditions that promises applications in storm forecasting from hourly to seasonal time scales. At the same time, even our latest convection-permitting forecasting and climate models may still struggle to capture key processes.
On the example of West Africa, a region known to exhibit strong land-atmosphere interactions, I will discuss our current understanding of land surface effects on organised convection and its drivers, the human component in driving trends, and how we may use our knowledge for improved storm predictions. Finally, I will illustrate why process-based model evaluation is crucial and outline the relevance for other hotspots of land-based organised convection.

Primary author: KLEIN, Cornelia

Presenter: KLEIN, Cornelia

Session Classification: Deep convection and more

Contribution ID: **71** Type: **Poster**

A high-level analysis of complex Arctic mixed-phase cloud dynamics

Tuesday, May 17, 2022 12:25 PM (2 minutes)

Mixed-phase clouds play an important role in the Arctic climate system. However, accurate climate projections are seriously hampered due to uncertainties in representing these clouds. Understanding their dynamical behavior based on first principles is a challenging task which requires the disentanglement of mixed-phase micro-physical complexities and a multitude multitude of cloud–surface–boundary layer interactions. Here we take an alternative route towards describing the cloud system and adopt a dynamical-systems perspective. Such an approach has already been successfully applied to describe and model a wide range of complex systems. This research focuses on data obtained at the permanent observatory in Ny-Alesund, Svalbard. We present our results concerning the analysis of distinct signatures of two preferred states. Further, preliminary results on the interdependence of the key variables and their temporal evolution are presented.

Primary authors: Dr VAN HOOFT, J. Antoon (TU Delft); EKMAN, Annica (Stockholm University); DEWEY, Maura (Stockholm University); GLASSMEIER, Franziska (TU Delft)

Presenter: Dr VAN HOOFT, J. Antoon (TU Delft)

Session Classification: Poster pitches

Contribution ID: **72** Type: **Talk**

Wind-responsive diurnal sea skin temperature for large-eddy simulations

Thursday, May 19, 2022 10:15 AM (15 minutes)

The diurnal variability of sea skin temperature (SST) is suspected to play an important role for convective organization above the tropical ocean, from driving cumulus congestus convection to triggering the active phase of the Madden-Julian Oscillation. Recent cloud-resolving simulations demonstrate how imposed diurnal SST oscillations strongly impact mesoscale convective aggregation, particularly at fine horizontal model resolution. In spite of this, many idealized modeling studies of tropical convection either assume a constant, homogeneous SST or represent the upper ocean by a responsive slab with fixed thickness.

In this work, we show that such single-layer slabs are incapable of capturing the wind-dependence and time profile of observed diurnal warming. To address this, we present DiuSST, a simple one-dimensional model of diurnal temperature evolution in the upper few meters of the ocean, forced by atmospheric conditions. We implement this model in the System for Atmospheric Modeling (SAM), offering a more realistic interactive boundary condition for cloud-resolving simulations, and study the impact this additional feedback has on mesoscale organization.

Primary authors: BÖRNER, Reyk (University of Reading); HAERTER, Jan; Dr FIÉVET, Romain (Niels Bohr Institute)

Presenter: BÖRNER, Reyk (University of Reading)

Session Classification: Wind, radiation and organisation

Contribution ID: **73** Type: **Talk**

Mesoscale organization of shallow convection: the role of rain and cold pools

Thursday, May 19, 2022 9:15 AM (30 minutes)

Shallow-convective organization and rain are two sides of the same coin. The mesoscale organization of shallow convection tends to increase rain rates, and rain is an important ingredient for organising shallow convection. Rain induces mesoscale organization preferentially through evaporatively-driven downdrafts, which trigger cold pools that spread out at the surface as density currents. Cold pools are not only important for the triggering of new and deeper convection, but might also play a role in regulating cloud cover in the trades –a regime responsible for much of the uncertainty in climate sensitivity. In this talk I will summarize what we know about trade cumulus cold pools from observations and models, discuss how cold pools are linked to cloud cover, and highlight important open questions.

Primary author: VOGEL , Raphaela

Presenter: VOGEL , Raphaela

Session Classification: Wind, radiation and organisation

Contribution ID: **74** Type: **Poster**

MCS longevity in the transition from land to sea

Tuesday, May 17, 2022 12:27 PM (2 minutes)

Mesoscale convective systems (MCSs) are organized clusters of thunderstorms spanning more than 100 km horizontally, persisting often for multiple hours. They are known to be the dominant source of rainfall in the tropics, and the longest-lived MCSs are shown to be largely responsible for tropical extreme precipitation [Roca and Fiolleau, 2020]. Globally, the most extreme storms tend to be located over land, and the most intense storms over oceans tend to be adjacent to land, where motion is favored from land to ocean, e.g. tropical West Africa and the adjacent Eastern Atlantic Ocean [Zipser et al., 2006]. The mechanisms behind the intensification or dissipation of MCSs advected from land to sea are not well established yet, and hurricanes in the Western Atlantic can often be traced back to MCSs originating off the African coast.

We here investigate the evolution of MCSs emerging from satellite data over tropical Africa and the Eastern Atlantic Ocean. We use a 5-year database of tracked MCSs from infrared satellite data, TOOCAN [Fioellau and Roca, 2013]. We focus on the Atlantic hurricane season (June-November) and on all MCSs that are formed over land and cross over to sea. We look for relationships between MCS longevity, the time of crossing, and the surface temperature. We compare the results to CRM simulations of deep convection over a land surface (oscillating surface temperatures) progressing to sea surface (constant surface temperatures).

Primary author: KRUSE, Irene Livia (NBI)

Co-authors: HAERTER, Jan (Niels Bohr Institute, Copenhagen University); FIÉVET, Romain (Niels Bohr Institute)

Presenter: KRUSE, Irene Livia (NBI)

Session Classification: Poster pitches

Track Classification: Mesoscale organization of shallow and deep cumulus convection

Contribution ID: **75** Type: **Poster**

Process Oriented evaluation of the oversea AROME configuration: focus on the representation of cloud organisation

Monday, May 16, 2022 12:26 PM (2 minutes)

This study evaluates the ability of the French Convection-Permitting model AROME-OM to represent shallow cumulus and their main organisations for boreal winter conditions in the North Atlantic trades.
It uses a set of three winter seasons (January-February 2018-2020) of high-resolution (1.3 and 2.5 km) simulations over the Caribbean domain (9.7-22.9°N, 75.3°W-51.7°W).
The model is assessed against soundings at Grantley Adams Airport and remote-sensing observations at a site located on the east coast of Barbados which is representative of downwind trades regimes.
The thermodynamic environment of the model fits the observations overall but the boundary layer is slightly too deep, resulting in a weak cold and dry bias.Both model and observations clearly exhibit a double peak of cloud fraction,
a first peak near the cloud base and a second one near the cloud top. The tops of the deepest cumuli around 2 km contain more variance with a higher sensitivity to the environment.
We then take advantage of the EUREC4A field campaign which took place in January-February 2020 to assess the ability of the model to reproduce the four main mesoscale patterns (Stevens et al., 2020)
and to characterize the air-masses in which they occur. All the observations confirm the capacity of the model to predict the different mesoscale organizations and the environment in which they develop.
I will also present new results from a free-running AROMEOM simulation over the EUREC4A period over a domain that extends to Cape Verde.
The main motivation being to investigate the main causes of large-scale variability that drive mesoscale organizations.

Primary author: BEUCHER, Florent (Météo-France)

Presenter: BEUCHER, Florent (Météo-France)

Session Classification: Poster pitches

Contribution ID: **76** Type: **Poster**

Dependency of mesoscale organization on grid anisotropy in large-eddy simulations at Gray Zone resolutions

Tuesday, May 17, 2022 12:37 PM (2 minutes)

A new generation of operational atmospheric models operating at horizontal resolutions in the range 200 m up to ~ 2 km is becoming increasingly popular for operational use in numerical weather prediction and climate applications. Such grid spacings are becoming sufficiently fine to resolve a fraction of the turbulent transports. Here we analyze LES results of a convective boundary layer obtained by coarsening horizontal grid spacings up to 800 m. The aim is to explore the dependency of the mean state and turbulent fluxes on the grid resolution. Both isotropic and anisotropic eddy diffusion approaches are evaluated, where in the latter case the horizontal and vertical eddy diffusivities differ in accord with their horizontal and vertical grid spacings. For coarsening horizontal grid sizes entrainment at the top of the boundary layer tends to get slightly enhanced for isotropic diffusion. An analysis of the energy spectrum shows that anisotropic diffusion causes relatively more dissipation of variance at smaller length scales. This leads, in turn, to a shift of spectral energy towards larger length scales. This can also be clearly seen from the different kinds of spatial organization. The present study therefore suggests that details with regards to the representation of processes at small scales might impact the organization at length scales much larger than the smallest scales that can be resolved by the model.

Primary authors: DE ROODE, Stephan (Delft University of Technology); SIEBESMA, Pier (Delft University of Technology); JANSSON, Fredrik (Delft University of Technology); JANSSENS, Martin (Wageningen University & Research)

Presenter: DE ROODE, Stephan (Delft University of Technology)

Session Classification: Poster pitches

Contribution ID: **77** Type: **not specified**

Monday discussion (Adrian Tompkins, Graham Feingold, Brian Mapes, Franziska Glassmeier)

Monday, May 16, 2022 4:00 PM (1 hour)

Session Classification: Convective concepts

Contribution ID: **78** Type: **not specified**

Tuesday discussion (Sandrine Bony, Bjorn Stevens, Pier Siebesma)

Tuesday, May 17, 2022 4:00 PM (1 hour)

Session Classification: Shallow convection

Contribution ID: **79** Type: **not specified**

Wednesday discussion (Caroline Muller, Cornelia Klein, Jan Haerter)

Wednesday, May 18, 2022 3:45 PM (1 hour)

Session Classification: Deep convection and more

Contribution ID: **80** Type: **not specified**

Thursday discussion (Raphaela Vogel, Louise Nuijens)

Thursday, May 19, 2022 11:00 AM (45 minutes)

Session Classification: Wind, radiation and organisation

Contribution ID: **81** Type: **Poster**

Arrival and registration

Monday, May 16, 2022 9:00 AM (30 minutes)

Contribution ID: **82** Type: **Poster**

A new conceptual picture of the transition layer

Monday, May 16, 2022 12:24 PM (2 minutes)

In the trades, the transition layer above the mixed layer top has long been observed and simulated. Yet its origins remain little investigated. The transition layer is often associated with an about 150 m deep layer between the mixed and subcloud layer tops that acts as a barrier to overlying convection. Using extensive observations from the EUREC4A field campaign, we propose a new conceptual picture of the transition layer. Strong jumps at the mixed layer top, as expected from cloud-free convective boundary layers, are only found rarely and when they occur, they tend to occur in large cloud-free areas. We show that small clouds with their bases above the mixed layer top maintain the transition layer, in analogy with the maintenance of the trade-wind inversion by deeper clouds. Small clouds appear to play an active role in vertical mixing, which is based on the ability to engender evaporative cooling when these small clouds detrain within the transition layer.

Primary author: ALBRIGHT, Anna Lea

Presenter: ALBRIGHT, Anna Lea

Session Classification: Poster pitches

Contribution ID: **83** Type: **Talk**

A short History of Cloud Observations in Art and Science

Tuesday, May 17, 2022 7:30 PM (1h 15m)

Looking up. Our eyes are drawn to the sky. The sky can promise rain, sunshine, storms, clouds in a variety of forms … in this talk, we trace a history of observing the sky, particularly the history of observing clouds and observing air pollution. In the 19th century, an amateur meteorologist, Luke Howard, gave clouds their names (cumulus, stratus, etc), which grew into the first International Cloud Atlas in 1896. Today, a team of scientists has forged a new language of the skies in the tradition of Howard and the Cloud Atlas (with names such as fish, flower, gravel, and sugar), whose changing forms play a role in predicting climate change. Recent work also suggests that the language of the sky has imprinted its historical evolution, and hence past climate changes, on art and culture. We show how trends in air pollution can be identified through the paintings of J.M.W. Turner and Claude Monet, who painted scenes of London and Paris in the 19th century during early industrialization. We discuss how art and science are both products of human observation and imagination and give complementary perspectives about the natural world and our role as actors and observers of environmental change.

Primary authors: STEVENS, Bjorn; ALBRIGHT, Anna Lea

Presenters: STEVENS, Bjorn; ALBRIGHT, Anna Lea

Session Classification: Evening Session

Contribution ID: **84** Type: **Poster**

Investigating extreme precipitations in tropical squall lines

Tuesday, May 17, 2022 12:35 PM (2 minutes)

Squall lines are the consequence of the interaction of low-level shear with cold pools associated with convective downdrafts, and beyond a critical shear, squall lines tend to orient themselves. It has been shown that this orientation has the effect of reducing the incoming wind shear to the squall line and maintains equilibrium between wind shear and cold pool spreading (Abramian et al 2021).
While the mechanisms behind squall line orientation seem to be increasingly well understood, few studies have focused on the implications of this organization. However, Roca & Fiolleau 2020 shows that mesoscale convective systems, including squall lines, are disproportionately involved in rainfall extremes in the tropics. One may then question whether the orientation of squall lines has an impact on the rainfall extremes, and if so, then how and why.
Using a CRM, we perform simulations of tropical squall lines by imposing a vertical wind shear in radiative convective equilibrium. Our results show that the extreme precipitation in the squall lines is more intense in the critical organized case. With a scaling of the precipitation extremes (Muller & Takayabu 2019, Da Silva et al 2021), we show that the condensation rates control the precipitation extremes in tropical squall lines. It seems that the critical case is also optimal for the vertical dynamics, a hypothesis that we further investigate here.

Primary authors: RISI, Camille (Laboratoire de Météorologie Dynamique); ABRAMIAN, Sophie (Institut Pierre-Simon Laplace); MULLER, Caroline (Institute of Science and Technology Austria)

Presenter: ABRAMIAN, Sophie (Institut Pierre-Simon Laplace)

Session Classification: Poster pitches

Contribution ID: **86** Type: **not specified**

Group photo

Wednesday, May 18, 2022 12:30 PM (15 minutes)

Contribution ID: **87** Type: **not specified**

Boat to dinner

Wednesday, May 18, 2022 5:15 PM (18h 15m)

Contribution ID: **88** Type: **not specified**

Ice breaker at NODA (in the library)

Monday, May 16, 2022 5:30 PM (1 hour)

Contribution ID: **89** Type: **not specified**

Final discussion

Thursday, May 19, 2022 11:45 AM (45 minutes)

Session Classification: Wind, radiation and organisation