WGNE/GASS White Paper on scale-awareness, stochasticity, and convective organization

Second phase of the "Grey Zone" project based on the EUREC^{4}A and phase III of GATE field campaigns

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Although weather and climate models which include convection parameterizations are able to represent various features of the atmospheric dynamics and the general circulation reasonably well, many deficiencies remain. Four main "headline issues", where the representation of convection based on convection parameterizations may differ from explicitly resolved convection, can be identified:

(1) Convection parameterisations are in essence diagnostic, by definition they derive the characteristics of convection diagnostically from the present state of the larger scales; (2) Most present-day convection parameterizations are not designed to represent organized convection like mesoscale convective systems; (3) The coupling of convection parameterizations to the larger-scale circulation is difficult to adequately take into consideration when developing parameterizations and is therefore often problematic; (4) Many convection parameterizations include a microphysics scheme which is different from the large-scale microphysics in the model. These deficiencies of convection parameterizations can lead, among others, to incorrect diurnal behaviour, inadequate temperature dependent phase assumptions for detrained water, major issues with the land-sea distribution of rainfall and the sensitivity to warm sea surface temperatures, and thus even flawed signals in climate change simulations.

In recent years both weather and climate models have ventured into both the boundary layer as well as the convective "grey zone" of resolutions between 200 m to 10 km where turbulent and convective structures are partially resolved and partially parameterized. This generates the urgent need for the development of parameterizations which are scale-aware, and at most weather and climate modeling centers this development process has started and is now maturing. But it is not only this practical need for appropriate parameterizations which makes the investigation of the "grey zone" so interesting and exigent, it is the scientific questions about the nature and essence of convective and boundary layer processes, and their relation to the larger scales, as outlined above in the four "headline issues", which puts the "grey zone" problem at the center stage of current boundary layer and convection research. In what way exactly do explicitly resolved convective and boundary layer processes differ from parameterized convection and turbulence, particularly in relation to the larger scales and with respect to convective organization?

Scale-awareness is an essential feature of a parameterization and in a sense is not separate from the question of how to conceptually represent convective and boundary layer processes in a parameterization. Nevertheless, it is not clear whether the way in which scale-awareness is built into a parameterization really matters. For instance, there are many ways of how to reduce the convective mass flux with increasing resolution in a mass-flux convection parameterization, but the effect may be ultimately similar. Another important aspect of the problem is that at high resolutions, the sample size of statistical populations of subgrid clouds, and related turbulent and convective features, for any particular model gridbox is relatively small. This implies the need for including stochastic elements in convection and boundary layer parameterizations, which exhibit appropriate scale-aware behavior.

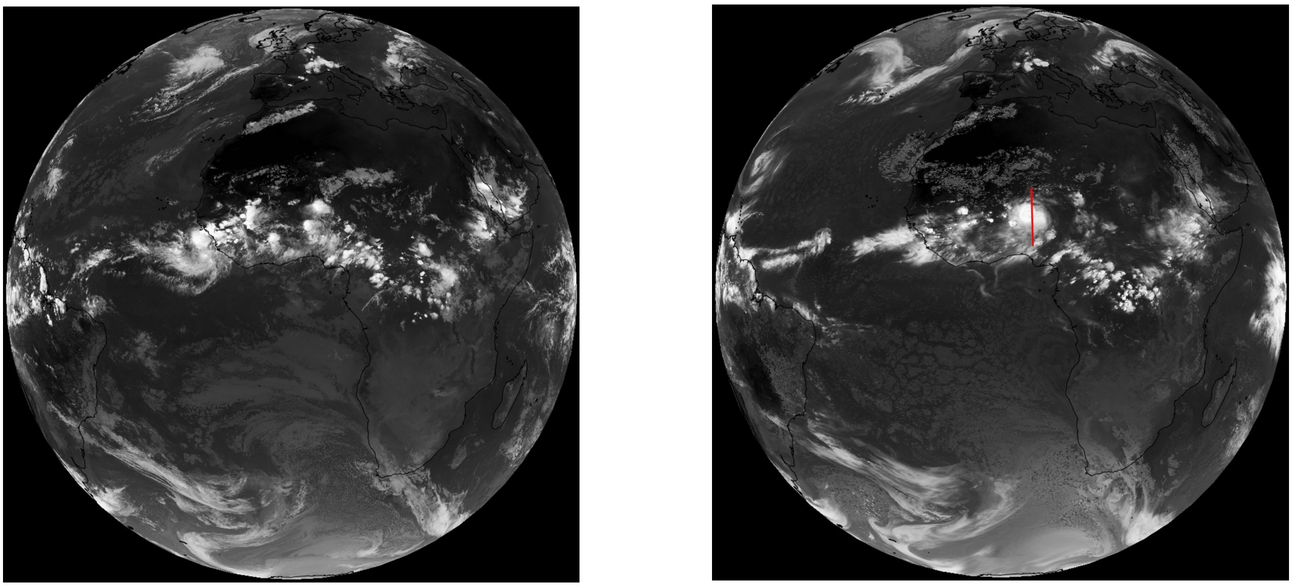

Figure 1: The left panel shows irradiances at 10.8 μm from the SEVIRI instrument on the Meteosat Second Generation satellite from July 10, 2010, at 18:00 UTC. The right panel depicts the same quantity based on a forecast with the Met Office Unified Model at 5 km global resolution. In the model simulation the convection parameterization was partially suppressed. The red line indicates the location of the trough of an African Easterly Wave. The mesoscale convective system ahead of the trough is qualitatively well simulated by the model, but shows a too organized and “blobby” appearance.

The fact that many modeling centers now are in the process of developing scale-aware convection and boundary layer parameterizations would make a model intercomparison a fruitful and enlightening enterprise. Moreover, one can now draw on the experience of the first phase of the “Grey Zone” project (Tomassini et al., 2017; Field et al., 2017) and better specify the required output diagnostics.

The first phase of the “Grey Zone” project centered around a maritime cold air outbreak in the extratropics. The second phase is proposed to investigate (sub-)tropical environments. Acknowledging that the “grey zone” can encompass both smaller-scale structures in the atmospheric boundary layer as well as larger, deep-convective systems, the second phase of the “Grey Zone” project is envisaged to have two parts: a part focussing on shallow convection, and a part exploring deep convection.

It is essential that intercomparison cases are built around field campaigns which provide suitable observations. The EUREC^{4}A field campaign will take place between 20th January and 20th February 2020 east of Barbados over the western tropical Atlantic. The field study investigates how shallow cumulus clouds respond to changes in the large-scale environment, and examines the factors controlling shallow-convective aggregation (Bony et al., 2017). The Global Atmospheric Research Program's Atlantic Tropical Experiment (GATE) was conducted in the summer of 1974 and was one of the largest and most comprehensive meteorological field campaigns in history. The central objective of GATE was to understand the scale interactions between convection and the large-scale atmospheric circulation, and to elucidate the mechanisms of deep-convective organisation. Phase III of GATE took place over the eastern tropical Atlantic and covered the period from 30th August to 18th September 1974. We propose that the second phase of the “Grey Zone” project is based on case studies built around EUREC^{4}A and phase III of GATE.

In a second phase of the “Grey Zone” project we would aim at ambitious high-resolution simulations including “real case” nested large-eddy simulations at *O*(100m) resolution and global convection-permitting model forecasts of *O*(5km) resolution (see the “ECMWF road map for 2025”, and Figure 1). Convection and boundary layer statistics, which are used in parameterizations, such as the distribution of cloud sizes and vertical velocities, would be compared across the model simulations and linked to the larger-scale circulation. Another aspect of research can be the interaction between the larger-scale circulation and momentum transport, both in shallow as well as deep convection. This would relate to the activities in the proposed GASS project on surface drag and momentum transport, specifically the EUREC^{4}A-Wind initiative.

Moreover, in recent investigations of the convective and boundary layer "grey zone", complementary radiative convective equilibrium simulations have proved to be a useful additional tool (for instance Becker et al., 2017). The fact that currently there is a RCE model intercomparison (Wing et al., 2017) under way in which many modeling centers participate might provide an opportunity to link the proposed second phase of the "Grey Zone" project to the simulations generated for the RCE intercomparison. For instance, this would allow for investigating the "blobbiness" of convective features in many convection-permitting models in greater depth.

The planned ParaCon convection conference at the Met Office from 15th to 19th of July 2019 (http://sites.exeter.ac.uk/convection-workshop/) could be used to discuss various aspects of the case study in more detail with the wider community, and to start preparations for the intercomparison.

References:

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Grey Zone Project web page: www.metoffice.gov.uk/research/collaboration/grey-zone-project