Improvement and calibration of clouds in models

LES, Observations and Parameterizations (I) Session

April 12, 2021, Météo-France, Toulouse, France

Feel free to ask your questions through this document during or after the different talks.
The objective is to be able to extend discussion as there is no real coffee break.
Please put your name when asking a question

INTRODUCTORY TALK:

Results of the High-Tune project

Fleur Couvreux, Frédéric Hourdin

As an introduction of this conference, we will present the main outcomes of the Hight-Tune project that aims at using High-resolution simulations to improve and Tune boundary-layer cloud parameterizations. In particular, we have used state-of-the-art statistical tools and advanced radiative models applied to Large-Eddy simulations to improve cloud dynamics and cloud radiative effects in atmospheric models. First, using machine learning we have built a tool for process-based calibration relying on the Single-Column Model/Large-Eddy simulation comparisons on a multicase basis. It tackles model development and calibration jointly. Second, Monte Carlo computation applied offline to LES cloud field has provided references for the cloud radiative effects thanks to an open-source library for 3-D radiative transfer computations in cloudy atmospheres. Both tools are freely available for the community and tutorials are organized during the conference.

Question 1 (Martin Köhler): Tuning often requires small formulation changes (ideas). How do you deal with that in your automatic calibration? (thanks!)

Beginning of answer (Frédéric Hourdin) : do you mean include a parameter to make something variable while the parameter was hidden in some way before ? In fact, both operations are really separated : the tuning tool automatically generates samples of values of parameters in predefined ranges (both the list of parameters and the ranges, as well as writing the script to modify their namelist or so is the responsibility of the modeler). Then everything is automatic.

(part of answer DW): We try to separate "tuning" from parameterisation development, where formulation changes can happen. The automatic calibration can test whether a formulation change works, or help to direct how to choose the formulation change. The philosophy is to allow machine learning to be used as a tool by the modeller, but not to replace the modeller and her in depth knowledge of the process by machine learning.

Martin: I agree, there is a fine line between tuning by machine learning and analysis of the results (e.g. SCM errors) and parameterisation changes. Maybe there is a parameter f(T) with the functionality unknown. I'm sure there will be ML approaches to generate that information. For now there is still room for the developer. :)

Question 2 (Yunyan Zhang): in addition to LES, do you need any observations to help constrain the model parameterization?

Answer (Fleur): Most of LES cases are derived from observations so indirectly there is an observation constraint. When using directly observations, this is possible for the tool. The issue is how to define the uncertainty on observations, but same tools can be applied to observations too.

Question 3 (Richard Forbes): Have you considered using the information on the range of values in parameters given by this method in the representation of uncertainty in a stochastic perturbation scheme?

Answer (Frédéric Hourdin) : no but we start using it to explore ranges of ECS under SCM/LES match constraint.

Answer 2 (fleur Couvreux): It may be tested at Meteo-France by Axelle Fleury in her PhD with Francois Bouttier

Question 4 (Steve Klein): Is the purpose of the radiation code development solely to efficiently compute 3D radiative transfer in LES domains?

The purpose of this radiation code was :

- to be able to compute 3D radiative metrics on LES cloud fields
- produce a renderer to visualize the clouds
- also to know very well the tool in order to have the expertise, to be able to test different assumptions and its impact on the radiative metric (choice of the resolution of the Mie function, choice of optical properties, …)

Question 5 (Steve Klein): Also that radiation code development is not interactive in the LES simulation, right? (i.e. is done through offline calculations)
No, the radiation code development is not interactive in the LES simulation. Right now, in the LES, we have a classical 2-stream radiative scheme. There is a long-term objective to develop a radiative code suited for LES using Monte-Carlo methods but this needs a lot of work.

1-Toward Lagrangian simulations of EUREC4A/ATOMIC cloud regimes

Steven Boeing1, Peter Blossey2, Leif Denby1, Roel Neggers3, Jan Kazil4, Pornampai Narenpitak4, Lorenzo Tomassini5, Romain Roehrig6, Stephan De Roode7, Leo Saffin1, Zhiqiang Cui1, Ralph Burton1, Alan Blyth1, the EUREC4A and ATOMIC teams _8

We discuss the design of Lagrangian simulations based on the EUREC4A and ATOMIC field campaigns. The simulations are informed by both the extensive campaign observations and reanalysis data (using an ensemble of trajectories), with modifications to improve the upstream boundary layer state. The aim is to provide a realistic representation of the atmosphere to study the evolution of cloud regimes, and explore the requirements for and limits of idealised models.
New tools are developed to produce simulation input based on conventions developed in the DEPHY and HIGH-TUNE projects. The case studies are coordinated with a concurrent grey-zone modelling study and target mesoscale regimes with different modes of organisation (e.g. cloud size, cloud spacing, cold pools and detrainment regions). We will discuss sensitivity experiments and possibilities for further extensions of the case design, like including SST heterogeneities, and aim to show a few initial results from large-eddy simulation.

Question 1 :DK: ERA5 fits the drop sondes surprisingly well! Fleur=> what about IFS?
IFS should be more accurate. ERA5 being more similar to drop sondes surprises me (Martin Köhler).
SB: part of the difference is also that IFS is here using 0.5 degrees for averaging forcings, wich creates strong forcings. Meanwhile, Roel is also using 2 degrees for the IFS-based setups,
Question 1 <Fleur>: How long does it take to get structures/organization in the LES along the trajectory? => more than a day

Question 2 <Daniel>: Other persons using this tool yet?
SB: So far people have mainly used output, though I don't think there is anything EUREC4A-specific to the input format (https://github.com/EUREC4A-UK/lagtraj/tree/master/input_examples). Some examples of the input format are here: https://github.com/EUREC4A-UK/lagtraj/tree/master/input_examples. We have aimed to keep installation with anaconda or pip easy.

Question 3 <Yunyan>: is the tool easy to be applied to other regions or campaigns?
SB: It should be quite easy to transfer it to other regions. Exceptions at the moment may be very close to the poles and the anti-meridian (though we are thinking of fixes for both). We are also working on cases over land, where topography is present (we first convert to height levels, and filter out points below topography).

Question 4 <Romain Roehrig>: can the tool be applied in a Eulerian framework?
Yes, there is an option to choose a Eulerian/stationary "trajectory" (over topography, this is probably the only option that makes sense), or a trajectory with a given velocity (not using the wind field).

2- Toward realistic cloud transitions during cold air outbreaks in ModelE

US

Florian Tornow1,2, Andrew Ackerman2, Ann Fridlind2, Brian Cairns2, George Tselioudis2

Cold air outbreaks (CAOs) often transition from near-overcast cloud streets into broken, open-cellular clouds downwind. NASA's ACTIVATE campaign collects in-situ and remote sensing observations of atmospheric constituents during CAOs in the NW Atlantic. We simulate CAOs in DHARMA LES and ModelE SCM, each using a domain following the marine boundary layer (MBL) flow and provided with MERRA-2 boundary conditions and in-situ observed aerosol profiles.

Using LES, we show that transitions are initiated by substantial rain, acting to stratify the MBL and deplete cloud condensation nuclei (CCN). We investigate the role of frozen hydrometeors to accelerate cloud transitions and further show several meteorological drivers of transitions that can vary both across and within CAO cases. Lastly, we show a first evaluation of SCM's ability to capture transition-initiating rain and CCN depletion and note outstanding uncertainties in warm and cold precipitation formation.

Question 1 <frederic.hourdin@lmd.ipsl.fr>: Any issue about specifying surface fluxes for comparison of SCM and LES ? Importance of taking into account gusts ? Using bulks at LES scales ?

FT: Setting off this comparison, we noticed differences across LES and SCM large enough to consider the setup we've used so far. We haven't investigated reasons for these differences, yet. The strong near-surface winds (~20-25 m/s) could point at difficulties with gustiness. Thanks!

Follow-up comment (not from FT): I think there is a strong issue in general with specifying SCM/LES comparisons as surface fluxes are concerned. We should probably have special procedures to make LES and SCM see winds in a way that the difference would not come from there (using domain averaged wind for instance in the LES - I know such options exist in SAM) and, on another hand, work on accounting for gustiness in the SCM. And gustiness is probably not the unique issue; Even I am not even sure we have the physical basis to parameterize surface fluxes in LES (everything relies on some quasi equilibrium considerations which may not be satisfied at the LES grid scale).

Question 2 cyril.morcrette@metoffice.gov.uk Hi: What assumptions does the SCM microphysics make about the spatial overlap (co-existence) of liquid and ice? And do your LES results provide any info about whether the ice and liquid co-exist on spatial scale of GCM (SCM) column? Thanks.

FT: Thanks for the question! Large-scale cloud fraction for liquid and ice follow Smith et al. (1990) and Wilson and Ballard (1999), respectively. As for spatial overlap of water and ice cloud, we follow the MG2 formulation and assume maximum overlap within a grid box. We haven't assessed, yet, how well phase overlap agrees across LES an SCM.

Question 3 Robert.Pincus@colorado.edu**:** What motivates the use of idealized radiation? Do you have a specific hypothesis about the roles, say, of microphysics and nucleation versus radiation in controlling cloud albedo?

FT: The simplified radiation treatment was chosen to kick off a comparison where TKE-driving mechanisms are controlled - crutches like simplified radiation will be removed later. Apart from great surface fluxes we see a smaller role of cloud-top cooling to drive MBL TKE. In line with earlier work, we see that both particle concentration and phase affect instantaneous cloud albedo. The evolution of cloud albedo - having in mind the importance of rain that we find to initiate cloud-transitions - is substantially controlled by microphysics (motivated and examined in greater detail in https://acp.copernicus.org/preprints/acp-2021-82/). Thanks!

3 - Organization development in shallow cumulus precipitating convection

US

Oumaima Lamaakel, Georgios Matheou

The development of precipitation in trade-wind shallow cumulus boundary layers is an important process because it affects the boundary layer energy balance and has the potential to strongly modulate the convective environment. The development of convective organization is studied using large-eddy simulations of the boundary layer observed during the RICO campaign. The LESs employ extensive horizontal domains, up to 160 x 160 km in the horizontal directions, and fine resolution (40 m). The analysis focuses on the rate of energy transfer to the large-scale and quantifies the time scale of convection organization. Even though horizontal integral length scales are about 15 km, clouds form organized structures of about 100 km. Boundary layer flow statistics depend on the LES domain size and change when the domain is increased from 80 km to 160 km.

Question 1 Vishal Dixit: What causes the TKE increase due to horizontal winds? How do organized circulations around clouds look like?

GM =The increase of the wind shear causes the tke increase.

Organized circulation not checked yet

Question 2 <Catherine Rio>: Do you have a sensitivity of the maximum cloud cover near cloud top on the domain size?

GM: For the duration of the run, the cloud cover does not change with respect to the domain size. We did not plot cloud cover versus height (which we should). I hope I understand the question correctly…

4- The strong impact of weak horizontal convergence on continental shallow convection

JPL

Marcin Kurowski[1], Wojciech W. Grabowski[2], Kay Suselj[1], Joao Teixeira[1]

Large-scale horizontal convergence/divergence perturbations are omnipresent in the atmosphere. However, they are often too subtle to detect them by state of the art remote and in situ measurements. We examine their impact on continental shallow convection using large-eddy simulation (LES). The results show a strong sensitivity of liquid water path and cloud-top height to the perturbations. In contrast, cloud-base area coverage and mass flux are weakly affected. Those impacts are comparable to microphysical sensitivity from cloud droplet number concentration perturbations. The simulation results provide a stringent test for convection parameterizations, especially important for large-scale models progressing toward resolving some nonhydrostatic effects. One such test is performed using the multi-plume Eddy-Diffusivity/Mass-Flux parameterization. Its results show a general agreement with the LES, although some discrepancy for deceasing convection is also documented.On the use of Emulators, built from Ensembles of Large Eddy Simulations, to study Clouds and Aerosol-Cloud Interactions.

Question 1 <Yunyan Zhang>: is the perturbation added uniformly at all levels? if so, why does it act strongly on cloud top only?

Answer 1: No, large-scale vertical velocity is horizontally uniform but has a vertical profile resulting from the integration of continuity equation given the assumed profile of large-scale convergence/divergence

Question 2 <Sandrine Bony>: how do you interpret the insensitivity of the cloud-base mass flux to large-scale dynamical perturbations?

Answer 2: I think this is mostly due to the fact that large-scale dynamical perturbations don’t really affect the subcloud layer where the plumes get formed. As a result, their properties remain largely unmodified for the perturbed cases (around cloud base).

Question 3 <Chiel van Heerwaarden>: What is "short lived" in your terminology? Can we extract them from large-scale model data such as ERA5 or are you referring to structures even smaller than that?

Answer3: of the order of hours; not sure if we can get it from ERA5 as it may be too coarse

Question 4 < Fleur Couvreux> What is the altitude of H1 and H2 where if I understand correctly the vertical velocity perturbation was positive below/negative above

Answer 4: H1=1.8km, H2=4km, they define where large-scale vertical velocity increases and decreases; Those values are somewhat arbitrary (I don’t know of any observational data to support them) and I tested smaller values in the JAS paper as well with a smaller spread of the results (because of the lower maximum of large-scale vertical velocity but also due to smaller integral effects).

5-Interactions between the Amazonian rainforest and cumuli clouds: A large-eddy simulation, high-resolution ECMWF-IFS and observational intercomparison study

Jordi Vila, Xumei Wang, Xabier Pedruzo-Bagazgoitia, Martin Sikma, Anna Agusti-Panareda, Souhail Boussetta, Gianpolo Balsamo, Luiz Machado, Thiago Biscaro, Pierre Gentine, Scot Martin, Jose Luis Fuentes, Tobias Gerken

The explicit coupling at metre and second scales of the vegetation responses to the atmospheric-boundary layer dynamics drives a dynamic heterogeneity that influences surface fluxes and cloud formation. Focusing on a representative day during the Amazonian dry season characterized by a transition from a clear boundary layer to shallow cumuli, we investigated the diurnal cycle of the energy, moisture and carbon dioxide at the surface, and the coupling during this transition. Three different methodologies are applied: a large-eddy simulation technique (DALES), a high-resolution global weather model (ECMWF-IFS) and a complete observational data set collected during the GoAmazon campaign.

The overall model-observation process comparisons of radiation and surface fluxes, turbulence and cloud dynamics are very satisfactory with all the modelled variables within the standard deviation of the monthly aggregated observations.

Question 1 <Fleur>: Importance of taking into account the role of vegetation to correctly reproduce the fluxes? Importance of radiation partitioning for the vegetation?

Jordi: It is very important since there is a hysteresis of evaporation and water vapor. In other words, before midday evaporation dominates sensible heat flux. After midday with the increase of WVPD deficit there is a shift in the partitioning to higher values of SH.

Diffuse radiation penetrates better in high canopy. For relative thin clouds (cloud optical thickness less than 4) it can be optimal values of evaporation where diffuse direction can lead to higher values of LE compared to the clear sky values.

-6-Constraining Stochastic Parametrisation Schemes using High-Resolution Model Simulations

Hannah Christensen

Stochastic parametrisation is used in weather and climate models to represent model error. We present a technique for systematically deriving new stochastic parametrisations or for constraining existing stochastic approaches. A high-resolution simulation is coarse-grained to the desired forecast model resolution. This provides the initial conditions and forcing data needed to drive a Single Column Model (SCM). By comparing the SCM parametrised tendencies with the evolution of the high-resolution model, we measure the 'error' in the SCM tendencies. As a case study, we use this approach to assess the physical basis of the Stochastically Perturbed Parametrisation Tendencies (SPPT) scheme. We provide justification for the multiplicative nature of SPPT, and for the large temporal and spatial scales used in the stochastic perturbations. However, we also identify issues with SPPT. In particular we find that an alternative approach is needed to represent uncertainty in the convection scheme.

Question 1 <Daniel Williamson>: How important is the overlap of the key signals on coarse and high resolution runs? Can the coarse signals be in slightly different places (as we typically see in the ocean) from the target?

(HC) - I am not sure I fully understand your question - what do you mean by key signals?

(DW): Say the yellow patches of signal on your maps over indonesia. One of the differences I often see between coarse and high resolution is the location of these signals. I wondered if the idea is sensitive to them being co-located.

(HC) Thanks - I understand. Since you re-initialise the SCM forecasts at every archived timestep of the high-res model (often hourly, sometimes 3-hourly) there will be less drift - the signals will largely be co-located. I'm mostly looking at short-range errors, again considering over just an hour or a few hours. The type of errors you refer to would be measured - I'm not sure if they would manifest as random or systematic.

(DW) Thank you. I guess if the high res and low res have different attractors, some of the high res evolution will be drift back to its steady state. Would that be a concern?

@daniel and @hannah: You will have time to discuss in the 15 minute slot

Question 2 <name>:

-7- Continental shallow cumulus clouds in E3SM parameterizations against ARM observations and LES

Yunyan Zhang

Fair-weather shallow cumulus (FWSC) clouds are important but still remain a challenge for climate models to simulate. FWSC clouds are tightly coupled with the underlying land surface and strongly respond to diurnal varying surface heat fluxes. In this study, we use a set of golden FWSC days to improve our understanding on sub-cloud layer turbulence and cloud morphologies based on advanced measurements in most recent years at Southern Great Plains (SGP) site by US Department of Energy (DOE) Atmospheric Radiation Measurement (ARM) program. The performance of the single column model of US DOE Energy Exascale Earth System Model (E3SM) is assessed against both ARM data and large eddy simulation results. With this approach, we hope to identify parameterization deficiencies for potential model improvement.

This work is performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344. LLNL-ABS- 819932.

Question 1 Jordi Vila: How do you parameterize the surface fluxes? Is the coupling with the surface relevant?

Y. Zhang: They are prescribed. All single column models and LES are subject to the same forcing.

Question 2 <Fleur>: Is there a lot of variability among the different 10 cases?

Y. Zhang: yes. There are variabilities in initial conditions, surface fluxes and clouds. But large scale advections are weak for all the cases.

Question 3 (Wim de Rooy): Can you conclude that LES (cloud cover) differs considerably from obs?

Y. Zhang: I often feel that cloud cover may not be the best metric, even though we could improve cloud cover by different configurations of LES to match observations. Maybe the vertical profile of cloud fraction is somewhat better. The radiative impact is also associated with cloud depth, liquid water path and so on, which are considerably different between observations and LES in these continental shallow cumulus cases.

- 8- On the role of aerosol characteristics and parameterization schemes on Arctic mixed-phase clouds

Luisa Ickes[1], Hannah Imhof[1], Annica M. L. Ekman[2]

Arctic low-level clouds are highly sensitive to microphysical processes, which can either sustain or break down the mixed-phase state and thereby determine the longevity of the clouds and their radiative impact. They are influenced by aerosol particles, which can act as ice nuclei (IN) or cloud condensation nuclei (CCN) and the parameterization schemes used for the aerosol-cloud interactions and the microphysical processes in the cloud. In this study we investigate:

1.) the influence of the chemical composition of CCN and IN

2.) the influence of different freezing parameterization schemes

on the cloud microphysics and the evolution of a mixed-phase Arctic cloud using the large-eddy simulation model MIMICA (Savre et al., 2014).

We show that in terms of CCN activation the aerosol size is more important than chemical composition. For INP the chemical composition has a strong influence on the cloud characteristics, but these results are highly dependent on the freezing parameterization.

Question 1 <name>:

Question 2 <name>:

9- A physically-based bimodal diagnostic cloud scheme: description and evaluation

Kwinten Van Weverberg, Cyril Morcrette, Ian Boutle

The UK Met Office uses a diagnostic CFP for its operational regional forecasts (~1km grid spacing) over the UK. This scheme assumes a uni-modal, symmetric pdf of the sub-grid saturation departure variability. However, a long-standing systematic lack of cloud necessitates an empirical bias-adjustment in operational forecasts. This paper explores the origin of this bias and proposes a new physically-based, diagnostic CFP. The proposed CFP first identifies entrainment zones (EZ) near sharp inversions. In the EZ it is then assumed that air parcels from above the inversion penetrate into the mixed layer, leading to two modes of variability residing within a single grid box. Weights are assigned to each mode so as to conserve the grid-box mean saturation departure. An extensive process-based and multi-year statistical evaluation shows that the new scheme significantly improves cloud forecasts, for the right reasons, over the US Great Plains ARM site and over the UK.

Question 1 Martin Köhler: How robust is the determination of weights? And how well can the scheme distinguish between StCu and ShCu?

KVW: In principle, as the boundary-layer inversion becomes less defined, the weight of both PDFs should become more equal, leading to subdued skewness. Hence, in situations with a weaker inversion, the bimodal cloud scheme will start to behave more as a symmetric PDF scheme, although the mixed-layer mode might still be much broader than the free-tropospheric mode, due to the link with the TKE obtained from the turbulence scheme. From a 6-week comparison of the MC3E, we have noticed that in shallow cumulus, the bimodal scheme is actually fairly similar to the symmetric PDF schemes in its performance. The main benefit comes from residual layers and stratocumulus conditions, which are much better captured. One of the ongoing developments is a slightly more advanced entrainment zone definition, based on the Richardson Number, rather than the temperature gradients.

Question 2 <Wim de Rooy>: It seems that with the bi-model scheme your meso-scale organisation related patterns in cloud cover are reduced/get lost. Is this indeed the case?

KVW: This is something we haven't specifically looked into, but my feeling is that the mesoscale structures should be mainly affected by the turbulence parameterization. It's definitely an interesting question to further look into. The bimodal scheme is included in the MetOffice NWP simulations for EUREC4A and I think Lorenzo Tomassini might show some results later this week.

Question 3 <Richard Forbes>: Could the bi-modal scheme also potentially improve cloud simulation at lower resolution?

Cyril: In the global model (using PC2) rather than using the Smith Scheme to do the PC2 initiation, we have tried to use bi-modal to do the initiation. Results are looking promising.

Richard: MetUM marine stratocu decks are already very good!

Question 4 <Graham feingold> How sensitive are results to vertical resolution?

KVW: We did include a section in the paper (part II) on sensitivity to vertical resolution and the sensitivity appears to be fairly small. Our model has about 70 vertical levels and appears to resolve the stratocumulus layers fairly well in the vertical.

10- Prediction of the bulk liquid fraction of mixed-phase particles in the Predicted Particle Properties (P3) microphysics scheme

Mélissa Cholette1, Julie Mireille Thériault2, Jason Milbrandt1, Hugh Morrison3

The accurate prediction of freezing rain, ice pellets and wet snow, is a principal source of uncertainty in weather forecasting because mixed-phase particles involved in their formations are neglected in microphysics parameterizations. A new approach to predict the liquid fraction of mixed-phase particles in the Predicted Particle Properties (P3) microphysics scheme is described. The objective is to show the impacts of the predicted liquid fraction on the precipitation types produced during the extreme North American 1998 Ice Storm simulated with the Weather Research and Forecasting model (WRF). A decrease in freezing rain and an increase in solid accumulations are obtained when the liquid fraction is predicted because of smaller raindrop sizes from partial melting and larger ice particle sizes from refreezing. The predicted liquid fraction impacts the simulated precipitation properties and atmospheric conditions while permitting the realistic representation of new precipitation types.

Question 1 <Fleur Couvreux>: what kind of observations can you use to evaluate your new developments?

MC: Some observations available south of Quebec, hope to use radar in future work

Question 2 <Richard Forbes> This development also should give an improved melting layer when near the ground and possibility for bright band for radar reflectivity. Have you looked at this?

11-CLUBB+MF in CAM6: implementation and evaluation of shallow convection cases

Mikael K. Witte[1,2,3], Adam Herrington[4], Marcin Kurowski[2], Joao Teixeira[2], Maria Chinita[2,3], Kay Suselj[2], Julio Bacmeister[4]

An eddy diffusivity/mass flux (EDMF) type combination of the Cloud Layers Unified By Binormals (CLUBB) and JPL stochastic multi-plume mass flux schemes has been implemented in the National Center for Atmospheric Research Community Atmosphere Model version 6 (CAM6). In this implementation, termed CLUBB+MF, CLUBB uses a double-Gaussian representation of the sub-grid thermodynamic probability density functions (PDFs) while the MF plumes represent extremely skewed events associated with the convective tail of the PDFs. Using archetypal single column model case studies of non-precipitating shallow convection, we demonstrate the improved performance of CAM6 CLUBB+MF with respect to reference LES solutions in terms of vertical fluxes, boundary layer depth and cloud macrophysical properties. Specifically, the MF component increases vertical transport, thus accelerating boundary layer growth and cloud penetration.

Q1: For ARMCU, the CLUBB +MF does not seem to capture the growing of cloud base and shallow cumuli at the early stage of development of clouds? Any idea for that?

MKW answer: the plumes are assumed at steady state, and their mixing can sometimes be "too" efficient and kill off premature development of convection

Q2: Did you look at cases with diurnal cycle of clear BL?

MKW: yes, so far we've looked at dry cases from Siebesma et al. 2007; also planning to look at GABLS and we've been working a bit with a "new" case developed at NCAR for LES intercomparison. CLUBB actually has a really hard time with these dry cases in its default configuration.

CLUBB seems to capture this growing.

Yes, CLUBB gets the general structure, but doesn't penetrate deep enough and produces too little cloud. Consistent with Song et al (2018, https://journals.ametsoc.org/view/journals/clim/31/6/jcli-d-17-0277.1.xml) and Kubar et al (2020, https://doi.org/10.1029/2019GL084498), CLUBB tends to make cloud in about the right place, but often with far too little condensate, leading to radiative biases compared with satellite observations.

Question 3 <Yunyan Zhang>: what is missing in CLUBB then? Does this work hint at any further improvement of CLUBB?

MKW: As we've started to dig into the CLUBB code, we've found all sorts of fun things to work on! Many at the level of the interface between CLUBB and CAM. But the main "deficiency" we see in CLUBB is that it has trouble in environments with strongly skewed w. This is in part because of the necessity for numerical limiters, but could also be a more fundamental limitation of the double Gaussian approach - yes, it introduces some skewness, but it's still nontrivial to capture extremes of the distribution.

Question 4 <Richard Forbes> Maybe I misunderstand, but isn't the high-order turbulence approach in CLUBB trying to remove the need for a mass-flux equation. If there isn't double-counting in the CLUBB-MF approach (as you mentioned), then is the CLUBB approach flawed or missing something? How resolution dependent is this?

MKW: Indeed, the point is precisely to remove the need for MF. Ironic, since all "operational" implementations of CLUBB still rely on MF-type closures for deep convection. Vince's group has

been working on these issues with the “CLUBB-SILHS” approach (SILHS = subgrid importance Latin hypercube sampling) that basically creates subcolumns with a somewhat handwave-y mechanism for vertical coherence.
MKW, part 2 (is CLUBB flawed?): yes, but I’m not at a point to do a full accounting yet. A double Gaussian is a convenient way to try and span as much of a “real” joint PDF as possible, but it’s not perfect. I think that’s the biggest takeaway.
MKW, part 3 (resolution dependence): yes, primarily in terms of numerical stability of the plumes and ability to represent sharp gradients/inversions - we’re working on the former, and a bit stuck on the latter (excited to see the refined vertical resolution talks at the end of the week!)

Question 4: <Thijs Heus> Does CLUBB-MF outperform ‘regular’ EDMF as well? What is the added benefit of the more complex turbulence scheme for these cases?
MKW: Hi Thijs! There’s a paper from Marcin Kurowski in Atmosphere with a more “standard” EDMF in CAM5 (https://www.mdpi.com/2073-4433/10/9/484). The performance improvements over standard CAM5 fit with what I described. The choice to work with CLUBB was partially a practical consideration (since CLUBB is the default mixing/macrophysics scheme in CAM6) and partially an experiment to test the hypothesis that CLUBB doesn’t “do it all.” The UCLA/JPL group has other implementations that use “traditional” ED - with Mellor-Yamada or our own TKE-based scheme - and some with other assumed PDF schemes (i.e. SHOC). It would be interesting to have a “bake-off” to see what the “objectively” best combination is, but the aforementioned practical considerations usually constrain how much time we have to do that kind of work. In addition, interactions with other parameterizations make the response to EDMF changes model-dependent.

12- Towards operational implementation: A stochastic shallow convection scheme

Maike Ahlgrimm1, Alberto De Lozar1, Daniel Klocke2, Mirjana Sakradzija1=> P1

Even at storm-resolving resolutions, shallow boundary layer clouds cannot be explicitly resolved. However, traditional convection parameterisations typically rely on assumptions that are no longer valid at these scales either. To address this problem, a stochastic convection scheme for shallow clouds was developed in cooperation between the Max-Planck-Institute (Hamburg) and the German Weather Service (DWD).

After initial tests and case studies during the development process, the scheme has undergone further development with a view towards operational implementation in the ICON limited area model. A version of the scheme using stochastic differential equations was developed as an alternative, computationally more efficient option. Tests in hindcast-mode over Germany and the Atlantic during the EUREC4A campaign show promising results, reducing systematic errors related to low cloud properties while rendering a number of resolution-dependent tuning parameters and limiters unnecessary.

Question 1 Hannah Christensen: Nice talk!

Few questions. Two quick ones: what is the relative cost of the scheme - percentage added to runtime - both for SDE version and original version. Follow up from your answer - can you reduce the SDE runtime by doing the first TB call on a coarser grid, as opposed to having overlapping coarser regions?

Answer: The explicit scheme is about 3x the computational time of the default scheme, the SDE version about 2.1x. ICON is now running on a vector machine, and I'm not sure it would be faster to do the first call to T-B on a coarser grid because there'd be more communication between vector engines, vs. just crunching numbers locally. But I'm looking into streamlining the first call to the T-B scheme: since we only need the cloud base mass flux calculation, there are some parts of the calculations (producing tendencies etc.) that are not needed on the first call, and could be skipped.

Update: I had another idea on how to avoid the double call to convection and did a bit more testing last night. It looks like I can avoid it altogether, and my quick test run suggests I can get the runtime down so the SDE scheme takes only 1.1x as much runtime as the standard convection. Standard convection is about 3% of total runtime, with SDE it would be 3.33% (based on a single day hindcast, so not very representative, but indicative I think). Thanks for prompting me to revisit this topic!

Q2: How difficult would it be to implement in a different model?

Answer: I think it should be fairly straight-forward. The stochastic element is a separate piece of code that is called between the two calls to T-B convection. In principle, it should be possible to call that same code between calls to any type of mass flux scheme. A slightly tricky part is the random number generation, which I've tried to optimise for vector machines. This might need some modification on different architectures.

Q3: And a longer question - any plans to improve/change the TB scheme to deal with the issues you mentioned?

Answer: Yes, this is what I'm working on at the moment. I'm trying to improve the shallow aspect of the T-B scheme to work better within ICON without (as much) tuning/limiters etc. I'm particularly looking at alternatives/modifications to the closure and the assumptions for lateral entrainment/detrainment.

13- Improved parametrization of the boundary layer in Harmonie-Arome with a focus on low clouds

Wim de Rooy

The turbulence, convection and cloud scheme form the core of the HARMONIE-AROME boundary layer parametrization. These schemes are tightly coupled. Hence, an integral approach is needed to develop and optimize these parametrizations together. Substantial modifications are based on a wide variety of argumentations ranging from theoretical considerations, in-depth comparison of 1D model results with LES, and optimizations of uncertain parameters by evaluation of 3D model results.

Several results are shown with the updated set of parameterizations. Most striking is the improvement on the most important deficiency of the current Harmonie-Arome model, namely the underestimation of low stratus clouds and the overestimation of the cloud base height. Other improvements concern the triggering of rain and the representation of the stable boundary layer. As illustrated, most improvements can be related to a better preservation of atmospheric inversions.

Question 1 <Fleur Couvreux>: What are the main modifications that you made for the new version?

Wim: Turbulence scheme is optimized in terms of non-dimensionalized flux gradient relationships (according to Peter Baas BLM procedure) for neutral to stable conditions. Also change of asymptotic free-atmospheric length scale. Both turbulence changes better preserve atmospheric inversions. But also reveal better stable profiles (GABLS1). Other important changes are energy cascade from convection to turbulence. Cloud scheme: With mods, now a correct set up of the cloud scheme (e.g. thermodynamic coefficients were wrong in previous AROME-Harmonie) and now including covariance contribution from convection.

Question 2 <Fleur>: Your turbulence scheme is a tke-scheme? right? you modified the length-scale?

Wim: Yes it is TKE-l (Lenderink 2004 QJRMS) called HARATU (instead of CBR in Arome). There are 2 length scales: A common stable length scale and an integral length scale (see paper) and in the neutral to slightly stable conditions we have to interpolate between these 2 length scales. This was done inversely linear but now inverse quadratic (leading to more mixing) but at the same time decreasing the proportionality constant for the stable length scale (reducing mixing). This combination improves the mixing characteristics against MO flux profile relationships and has a large impact on preservation atmospheric inversions.

14- Local impact of stochastic shallow convection on clouds and precipitation in the tropical Atlantic

Mirjana Sakradzija1,2, Fabian Senf3, Leonhard Scheck2,4, Maike Ahlgrimm5, Daniel Klocke5,2

The local impact of stochastic shallow convection on resolved convection, clouds and precipitation, isolated from its remote impact through the large-scale circulation, is tested in a case study over the tropical Atlantic on 20th December 2013. A stochastic shallow convection scheme is compared to the operational shallow convection and a case with no representation of shallow convection in ICON at a convection-permitting resolution. In the stochastic case, convective heating is substantially increased in the subcloud layer, the boundary layer is deeper, while evaporation is enhanced at the expense of sensible heat flux at the ocean's surface. As a result, the stochastic case proves to be superior in reproducing low-level cloud cover, deep convection and its organization, as well as the distribution of precipitation in the Atlantic ITCZ. The local stochastic convection invigorates the resolved convection and is crucial for a better representation of resolved deep clouds.

Question 1 <Wim de Rooy>: Can you tell what output worsens when MF shallow was removed?
Answer: If we do not use the shallow convection (or the stochastic version), we see the error in cloud cover (20-30% on average), resolved convection is weaker, deep clouds are shallower, precipitation band in the ITCZ is too narrow... the impact is really substantial.
Wim: I would expect resolved convection becomes stronger without shallow parameterization… As you do not remove atmospheric instability
Answer: The shallow convection scheme enhances the surface turbulent fluxes, and heats the subcloud layer significantly. The temperature tendencies that result from the scheme invigorate the resolved convection.
Question 2 <Richard Forbes>: Do you see any detrimental impacts when removing the mass-flux limiter?
Answer: We did not have any problems with stability of the simulations. However, localized temperature tendencies get unrealistically high at a number of points. We also tested what the effects of mass-flux limiters are if set to some higher values than what is used in the operational setup. These limiters can be put back into effect without causing negative impact on the results if they do not cut off a large part of the M distribution tail (we tried with a limit at 5 and 10 m/s).
(Maike, also on that question): Removing the limiter isn't a problem for stability primarily, it mostly just affects the forecast scores. This wasn't so much a problem last year, but since fixing a bug this summer (which affected the model state strongly) the limiter is now playing an even bigger role at artificially reducing the MF, so removing the limiter has a more detrimental effect on scores now compared to last year.
Question 3 <Sandrine Bony>: In your stochastic parameterization, did you prescribe a lifetime for clouds? (or it is interactive?)
Answer: The lifetimes depend on the average cloud mass flux (of each cloud). A power-law relationship is prescribed tau = a * m**b, where a and b are estimated based on LES (RICO case).
Question 4 < Fleur Couvreux>: how this relationship tau=a*m**b holds for other LES cases? By the way, very nice work.
Answer: Thank you very much! The relationship does change. I however looked only in two LES cases, RICO and ARM (Brown et al. 2002). The most drastic change we found was that in the oceanic case, active and forced/passive shallow cumuli show distinct relations (so these two group should be treated separately if one would wish to be absolutely consistent), while overland this

difference was not noticable. The scaling however, showed significant scatter as well, so it was not possible to determine the fitting parameters with high certainty.

15- Impacts of a change in deep convection scheme on the ARPEGE data assimilation system

Antoine Hubans, Yves Bouteloup, Cécile Loo, Pascal Marquet

In this work, we focus on the evaluation of the physical parametrization of deep convection in the French model ARPEGE. We evaluate the direct impact of this parametrization in a forecast only study as well as the indirect impact with a 4D-Var and the study of the analysis. We have replaced the previous parametrization by the one used in the Integrated Forecast System (IFS) developed at the ECMWF. We seize the opportunity of using an other model parametrization to rearrange physical tendencies in the same way as in the IFS. This diagnostic is new for the ARPEGE environment and it leads to an intercomparison between the two model physics. To evaluate the coupling, we use several ARPEGE 4D-Var to compare the change in analysis with an estimate of the analysis error. Those studies show a significant impact of the new scheme both in the tendencies and in the analysis.

Question 1 <Ligia Bernardet>: Can you provide any references wrt this very interesting work? Is this a type of piggy-backing, in which you drive the ARPEGE with convective tendencies produced beforehand by another model (IFS)? I believe you said that (deep?) convection is the parameterization that leads to the largest errors in ARPEGE - how was this determined?

<Antoine HUBANS> Thank you for your interest and your question. This study is going to be submitted in the next few months but I don't have a reference yet. We seize the opportunity of working with an environnement close to IFS to compare the tendencies of our physics and we see that deep convection as well as gravity wave drag present the biggest difference between the two models. But here I present only the impact of a change of scheme on the analysis. We haven't shown that the deep convection is the parameterization that leads to the largest errors in ARPEGE, what I try to say is that an other study (BERRE 2019) shows that the analysis error come from several contribution, the model, the observations and the background error which is a cumul from previous cycle and it conclude that the model play the biggest role.

<Ligia> Thanks for your answer. By "environment", you mean physical environment (such as a certain weather regime)?

<Antoine> No sorry I mean coding environnement, where we were able to take the code from IFS to integrate it in ARPEGE.

<Ligia> OK, thanks, I see, computational environment. In my experience, it can be very informative to swap a parameterization in a given model - you can review how tendencies and the forecast change. But it is also tricky, since the rest of the physics suite is not *tuned* to work with the new scheme.

<Antoine> Yes for sure, people from my team have worked to tune the scheme for our system, the deep convection scheme will be included in a future operational version of ARPEGE. To work well it has been necessary to also change tuning on the flux on the ocean. I'm not very clear on how it was changed but it took a few tries and errors. In my work though I try to study only the change on deep convection, I'm not as interested at tuning it as to evaluate how it modifies analysis. It is more a theoretical study.

16-A Unified Eddy-Diffusivity/Mass-Flux Approach for Modeling Atmospheric Convection

Kay Suselj, Marcin Kurowski, Joao Teixeira

We describe a fully unified parameterization of boundary layer and moist convection. The new parameterization is based on the stochastic multi-plume eddy-diffusivity/mass-flux approach. The convective plumes represent both surface-forced updrafts and evaporatively driven downdrafts. The type of convection (i.e., dry, shallow, or deep) represented by the updrafts is not defined a priori, but depends on the near-surface updraft properties and the stochastic interactions between the plumes and the environment through lateral entrainment. Such a formulation is void of trigger functions and additional closures typical of traditional parameterizations. The updrafts are coupled to relatively simple warm-, mixed-, and ice-phase microphysics. The downdrafts control the development of cold pools near the surface that can invigorate convection. The new parameterization is validated against large-eddy simulations for precipitating marine and continental cases.

Question 1 <Fleur Couvreux>: How your scheme behaves for stratocumulus and transition from Stocu to Cu?

Kay: Please see our 2013 paper (https://journals.ametsoc.org/view/journals/atsc/70/7/jas-d-12-0106.1.xml) where we test our parameterization for the idealized transition between Sc and Cu convective PBL.

(from Mikael Witte): we will have a couple papers coming out in the next year or so on shallow cloud transitions (subtropical and postfrontal) constrained by ARM observations

Question 2 <Fleur Couvreux>: how does your cold pool feedback to your updraft properties?

Kay:

(1) The key effect of the cold pools is modification (i.e. decrease) of entrainement rate for the convective plumes. We argue that the cold pools help organize convection, which leads to horizontally larger convective updrafts, which are less exposed to the environment. Because in our parameterization we do not represent the horizontal size of convective plumes convection organization is modeled through modification of entrainment rate.

(2) In our model, the cold pools modify surface updraft buoyancy and moisture properties. However, we show that this effect is minor compared to the cold pool modification of entrainment rate.

Question3 < Fleur Couvreux>: can you detail more about the length scale?

Kay: I believe this question is about the mixing length formulation for the ED TKE parameterization in order to represent the transition between Sc and Cu convection. I think the key here is limiting the ED length for the stable layer in order to control the entrainment of the free tropospheric air into the boundary layer. For this, we use the length scale that depends on the Brunt Vaisala frequency. Please see our above cited paper for details.

Discussion:

Catherine Rio:
It seems to me that some talks have shown that we need to go to more complex parameterizations as we go to higher resolution:
- variance and skewness are higher, this has to be taken into account for cloud schemes
- mass-flux approaches need stochastic approach + temperature and moisture effects associated with a given cloud-base mass-flux might need to be revisited

- microphysics scheme also are more complex

Any comment on this as high resolution is also often seen as a solution for parameterization weaknesses?

Mirjana: deep convection is even not good for being not deep enough?

Fleur Couvreux: nice proposition of discussion. Also the assumption that we represent a population of drafts? stochastic is a possibility I like the approach explained by Maike Alhgrimm where the distribution is derived for larger-scale resolution and then chosen for the high-resolution among this distribution

Daniel Klocke:

Do we need stochastic parameterizations for high res modeling?

Yunyan Zhang:

How could we connect case studies with global tuning?

Kwinten Van Weverberg: importance of consistency among the different parameterizations