Improvement and calibration of clouds in models

Cloud Radiative Effect Session

April 14, 2021, Météo-France, Toulouse, France

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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

INVITED TALK:
Representing 3D effects in atmospheric radiation schemes
Robin Hogan

In this talk I will discuss the representation of 3D cloud radiative effects in the radiation schemes of large-scale atmospheric models, and hence the prospects for estimating the global impact of 3D radiation on the Earth system. I will start by outlining the principle of the "SPARTACUS" solver for accounting for 3D effects in an approximate but affordable way, which is available as an option in the open-source ecRad radiation scheme used at ECMWF. An improvement following from comparison to benchmark shortwave Monte-Carlo calculations is the careful inclusion of the mechanism of "entrapment", which tends to make scenes darker compared to equivalent calculations in which 3D effects are neglected. Observational evaluation of shortwave SPARTACUS will also be presented from a long-term analysis of the ratio of direct-to-total fluxes at the surface. More recent comparisons to longwave Monte-Carlo calculations imply that SPARTACUS tends to overestimate 3D radiative effects in the longwave. A mechanism to explain this is currently under investigation, and relates to the limitations of the two-stream approximation underpinning SPARTACUS, but could be improved by adding more streams. Lastly, I will summarize a new approach to using machine learning for atmospheric radiative transfer: rather than trying to emulate the entire radiation problem, which is very difficult with sufficient accuracy for NWP, we run a fast 1D radiation scheme and the emulate the "3D correction" training on the difference between SPARTACUS and the 1D scheme. This achieves close to the accuracy of SPARTACUS without incurring the 4-5 times greater computational cost.

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Question 1 Fabian Jakub: The grid scale versus subgrid scale 3D effects happen on resolutions between 5km and 100m, i.e. this is probably meant by greyzone in radiative transfer. Where, i.e. at what resolution, do you think should or do we have to switch between 3D parametrizations and explicit 3D radiative transfer. And where do you think we stand in developing schemes that solve grid- and subgrid- scale effects or is there even a need for it?

As the new solvers become available, and improve in accuracy and speed, we really need to do the experiments to work out where the hand-over scale occurs and what should be the priority for representation in models used for different purposes. I'm most familiar with the NWP application of course - here any increase in cost really needs to be justified by an improvement in forecast skill, which is good to see what really matters! But the needs/priorities of CRM and climate modelling will be different. TenStream is at the frontier of representing 3D effects in high-res models and it would be interesting to think about how to seamlessly treat in-gridbox and between-gridbox 3D effects.

(FJ) Many thanks for the great talk. I appreciate the broad overview! I found the question on what resolution 3D effects become important a really tough one because it interacts with plenty of other aspects of the model. While we can quite easily compare heating rates and flux biases with high resolution input and Raytracing models it is a tough problem to investigate the real benefit of better/more realistic and better constrained radiative transfer models when the coupling to surface, boundary layer dynamics, microphysics etc. lacks some feedback mechanisms. I would make the point that the surface<->cloud<->radiation feedbacks might need to be tightly coupled to one another. Are there any plans at ECMWF or at DWD (Sophia) to add grid scale transport to SPARTACUS and investigate these greyzone questions?

(RJH) No plans at this time at ECMWF - although something kind of in this category is to introduce a representation of orographic effects in the radiation scheme, which at high model resolution could involve some kind of communication between gridboxes, e.g. if the mountain in one gridbox shadows the valley in another. This is on my long-term TODO list!
(Sophia Schäfer) I have started implementing the NCA in ICON, but then got interrupted by something else - how far are you at LMU with implementing NCA (and TenStream) in ICON? You are probably farther along than me by now. Once we have an ICON version that can do those and ecRad (ideally with consistent gas/water/ice optics), the comparison should be straightforward.

Question 2 Fabian Jakub: Representing 3D effects is directly related to the problem that we need to have an idea how subgrid scale clouds actually look like. Do you see that as the task of the convection parametrizations or does the radiation scheme have to invent those?

Newer convection schemes and large-scale cloud schemes are beginning to have the concept of how the magnitude of the sub-grid heterogeneity and the scale of the clouds, but we really need to evaluate these against observations before trusting them more than a parameterization directly fitted to observations. In the convection scheme in particular, the concept of an updraft width in a convection scheme may not map well to the cloud scale seen by the radiation (and in any case, observations of updraft width are very difficult to obtain).

Question 3 Robert Pincus: It's interesting that the SW effects nearly cancel over the diurnal cycle. Is there any impact of latitude (as another control on solar zenith angle) on 3D shortwave effects?
(Najda : I've performed some MC calculations integrating 3D effects over diurnal cycle at various latitude and there is a clear signal ; but I was only using one static cloud field during the whole day so I'll need to dig more)

Sophia Schaefer has done the offline calculations on a year of ERA reanalysis data so it should be straightforward to look at the effect by latitude band (she may even have the plot in her thesis). However, because of the degree of cancelation I'm not confident even of the sign of the net 3D effect in the shortwave. This is because we are relying on the cloud statistics from the model. Our parameterization of cloud size has a resolution dependence (larger gridboxes encompass larger cloud systems so the scale goes up) but in order to compute the same global 3D radiative effect for different model resolutions, we rely on the model correctly simulating the increased occurrence of partial cloudiness (rather than cloud fraction of 0 or 1) as the gridbox size gets larger (more partial cloudiness -> more 3D effects). I'm not confident models do this correctly - at least it would need to be tested. The thing is that the two competing shortwave mechanisms depend differently on parameterized cloud scale, so to get the net effect right is asking a lot of the accuracy of our prediction of the two terms and their resolution dependence. In this sense the longwave is easier in that it warms everywhere (except over very cold surfaces)!
(Sophia Schäfer) There are zonal mean plots in my thesis (right-hand columns of Figs. 4.8 and 4.9, p. 100 / 101, http://centaur.reading.ac.uk/72752/1/20800931_Schafer_thesis.pdf). But that is an estimate from 2016, which assumed completely homogeneisation (overestimating entrapment), and also probably overestimated the longwave 3D effect, so it is significantly more positive than our current estimate - we should redo these plots.

Question 4: Catherine Rio: Any idea about the climatic impact of missing 3D radiative effects: do you expect impact on persistent biases such as double ITCZ or MJO representation?

Slides 24-25 of www.met.reading.ac.uk/~swrhgnrj/presentations/hogan_2019_gfdl.pptx show the impact of 3D effects in a climate simulation. My eye was more drawn to the polar amplification, but there is a change in the tropical precip pattern that deserves a closer look. These simulations come with a big health warning though, since we think we're over-predicting the longwave 3D radiative effect.

Question 5: Danahé Paquin-Ricard: In NWP, we often call the RT scheme only every 10-15 time steps (because it's too expansive to do it every time-steps), do you think going with SPARTACUS that cost more, would it be worth it, even if it means calling radiation even at fewer time steps? (I guess the random error in sampling every X dt is different than the errors of neglecting 3d radiation?)

Our experience at ECMWF is that (a) calling radiation every 1 h rather than 3 h leads to a significant improvement in forecast skill, although the gain from calling more frequently than 1 h is much smaller. (b) Turning on SPARTACUS in NWP tends to warm a bit everywhere - this is generally going in the right direction as the model has a cold bias at the surface, but it doesn't appear to improve genuine "skill" at getting weather systems in the right place - it just changes the bias pattern - although I need to look closer at this when we fix the longwave effect. It is worth saying that in general the model is quite well tuned and if we wanted to warm the model there would be other things that could be tuned within their uncertainty, at no computation cost. So from the perspective of NWP, the 4-5x cost would be difficult to accept, and we certainly wouldn't want to call the radiation scheme less frequently in order to include SPARTACUS. Having said this, I am working on a new much faster gas optics scheme (factor of 4?) - this would in principle allow SPARTACUS with no net increase in cost compared to the current configuration. Watch this space!
Thanks Robin, it was a really interesting talk! Looking forward for this!

Question 6 Zhihong Tan: In this talk you have focused on the TOA and SFC cloud radiative effects, and I am curious about how 3D cloud effects would influence the vertical profile of LW cooling/SW heating rates?

In the shortwave, 3D effects tend to perturb TOA and surface fluxes together, with much less of an effect on heating rates (i.e. atmospheric absorption) - compare Fig. 8c to Figs. 8a and 8b of http://www.met.reading.ac.uk/~swrhgnrj/publications/entrapment.pdf. Having said this, SPARTACUS appears to overpredict the small increase in atmospheric absorption in Fig. 8c.

In the longwave, the result for one cloud (cumulus) is shown in Fig. 6 here: http://www.met.reading.ac.uk/~swrhgnrj/publications/spartacus_part2.pdf - you can see that 3D effects increase the rate of longwave cooling. SPARTACUS predicts cumulus 3D longwave effects quite well here. Would need to look at different cloud scenes though - there may be other papers on this topic too.
Thanks Robin! These figures (5 and 6) are very helpful -- now I can see the 3D LW effects tend to cool the cumulus layer and slightly warm the subcloud layer.

Question 7, Maxime Colin: Did you say that entrainment was very important? If yes, could you explain again why? I'm sorry but I think I missed the point.

1-Addressing radiation and cloud uncertainties with the new radiation scheme ecRad in ICON

Sophia Schäfer1, Martin Köhler1, Robin Hogan2,3, Carolin Klinger4, Daniel Rieger1, Maike Ahlgrimm1, Alberto de Lozar1

Cloud-radiation interactions strongly impact atmospheric energy and water balance, but are challenging to capture for radiation schemes in global weather and climate models, due to cloud complexity on sub-grid scales. Simplifying assumptions are used to parametrise cloud geometry and cloud particle size, shape and scattering functions. These assumptions introduce uncertainties in cloud-radiation interaction and the climatic role of clouds.

The new modular radiation scheme ecRad significantly improves global radiation, clouds and energy balance in ICON, and also allows us to vary the parametrisations, providing a choice of solver, cloud ice and water optical properties, vertical overlap and horizontal inhomogeneity treatment. We analyse the uncertainty and impact of these radiation parametrisations and cloud parametrisations in ICON and evaluate against exact radiation models and various satellite observations, guiding improvement in the representation of clouds and radiation.

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Question 1 Danahé Paquin-Ricard: What about the effective radius of ice? Is it calculated by the microphysics and passed to the Radiation? If not, what are the assumptions about ice effective radius? The impact can be large… You just answered! thanks!

Question 2 Fabian Jakub: You focus in your talk on TOA biases. Is there similar work on the evaluation of surface fluxes and generally the energy balance in the boundary layer? Is there a similar bias?

We have evaluated surface fluxes against Era5 and see an even larger reduction in biases there than at TOA. In observations, radiative fluxes at the surface are unfortunately not as directly globally observable as at TOA (especially for LW).

Question 3 (Najda Villefranque) what parameters do you adjust to tune your model? (clouds and also radiation parameters?) Could it explain your too few / too bright bias?

The main tuning parameters are ice fall speed (and therefore ice water content), surface albedo and emissivity, particle size, and in the radiation scheme itself vertical overlap and ice optics. We are looking at the various datasets to constrain the physical cloud properties. With the parameters in the radiation scheme itself, we already have a large vertical decorrelation length compared to observation (leading to low total cloud cover), so for improving that we will look at variable parametrisations. The variable inhomogeneity (FSD) treatment improves some regional contrasts, but the effect is not that large compared to the existing biases. Particle size can have a large impact, we are working on that.

Question 4 (Ligia Bernardet) I thought it was very interesting that you pointed out a discrepancy between the results obtained from the radiation verification (at TOA, sfc) and from the cloud liquid- and ice-water path verification. In evaluations of the Unified Forecast System used by NOAA, we also observe this discrepancy and are trying to reconcile it. It seems that using a variety of verification analyses is key to conduct the evaluations. Can you say more about the different analyses you use for model verification/evaluation (CERES, CALIPSO etc.) and their pros/cons?

We use CERES TOA fluxes (directly observed, therefore quite reliable) and MODIS-CERES cloud cover (retrieval, so some assumptions), combined CloudSat-CALIPSO data for ice content (2C-ICE dataset by J. Li; retrieval assumptions, but using complementary information from visible and microwave observations to reduce uncertainty) and the CALIPSO-GOCCP cloud cover dataset (finite sensitivity, so need to also use optical depth threshold in the model cloud cover calculation for comparability).

Liquid water is especially hard from satellites since high cloud ice is in the way, we looked at the MODIS visible dataset (good for marine BL clouds without high clouds above) and MAC-LWP microwave (reliable in liquid clouds without precipitation). If any satellite experts would care to comment, I would be very interested.

(Richard Forbes) We discuss SW radiation errors (in the IFS) and the various observational datasets used for verification of different aspects of the cloud in Ahlgrimm et al. (2018) which discusses some of the difficulties (and will apply to other models too).

https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2018MS001346

(Sophia Schäfer) Thanks a lot, RIchard!

2-Process-based climate model development harnessing machine learning: III. The Representation of Cumulus Geometry and their 3D Radiative Effects

Najda Villefranque1,2,5, Stephane Blanco2, Fleur Couvreux1, Richard Fournier2, Jacques Gautrais3, Robin J. Hogan4, Frédéric Hourdin5, Victoria Volodina6, Daniel Williamson6,7

We analyze the role of cloud geometry parameters (vertical overlap, horizontal heterogeneity and cloud size) that appear in the parameterization of radiation. The solar component of a radiative transfer scheme that includes a parameterization for 3D radiative effects of clouds (SPARTACUS) is run on an ensemble of input cloud profiles synthesized from LES outputs. The space of cloud geometry parameter values is efficiently explored using the High-Tune:Explorer tool. SPARTACUS is evaluated by comparing radiative metrics to reference values provided by a 3D radiative transfer Monte Carlo model. The best calibrated configurations yield better predictions of TOA and surface fluxes than the one that uses parameter values computed from the 3D cloud fields: the root-mean-square errors averaged over cumulus cloud fields and solar angles are reduced from ~ 10 W/m^2 with LES-derived parameters to ~ 5 W/m^2 with adjusted parameters. However, the errors on absorption remain around 2 to 4 W/m^2.

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Question 1 <Danny>: Great talk! I wonder if there is a physical justification for the difference in tuned parameters from LES/lower resolution? I suppose the question is, do these parameters actually mean something in reality, or are they “pure model” parameters? Often parameters get names (e.g. the gravitational constant) and yet the fact they should be different as resolution changes is kind of interesting.

=> I think it says more about the model than about “reality” like if you take the overlap model, you see that you constrain only how pairs of layers overlap so you don’t constrain the total cloud cover. When you look at the total cloud cover diagnosed by the solver in ecRad you find systematic overestimate of the cloud cover compared to LES-diagnosed cloud cover. So you can try to figure out why your parameter is not exactly what you thought it was, and if the parameter values that come out from you tuning process lie too far from what you would expect (eg cloud size outside the range of observed values or some other arbitrary / subjective measure of “plausible” parameter value) then you can deduce from that that a mechanism is missing from your parameterization, or that what you thought you were representing is not exactly what is in your model. So yes these parameters mean something in the sense that they helped you conceive your parameterization but then you need to accept that your model is not perfect and that your parameters do not represent reality... (oh that was you Danny??? haha here I am explaining to you your own philosophical view on tuning) I’m moving to the next question
Follow up: Nice answer! Not sure you can attribute such eloquent thoughts to me (in fact I am sure you can’t).

Question 2 Sophia Schäfer: Great work, Najda. Do you know already what regions /cloud types you are going to consider next?

=> Thanks :) I already have stratocumuls and transition from stratocu->cu LES cases so that would be the easiest ; also my MC model can’t handle ice clouds yet so I would need to include that to continue. But before going to the next cloud types I want to see if I obtain a different tuning when I couple radiation to clouds in the SCM runs!

Question 3 Quentin Libois : Do you think using the same strategy on very simple cloud fields (e.g. full coverage at a single altitude with only the impact of horizontal heterogeneity, or single circular homogeneous cloud) could help interpret the/understand the limits of the radiative parameterization, which remains so far quite puzzling?

=> Yes! I'm currently investigating (after one of Robert Pincus comments while reviewing our paper) tuning McICA and Tripleclouds (so no 3D effects) against 1D ICA Monte Carlo and against ICA "2-stream homogeneous" run on the LES columns and then averaged. To try and understand how subgrid geometry assumptions match actual subgrid clouds, and changing the reference from 1D ICA MC to ICA 2-stream homogeneous will provide information on the "structural" error that has nothing to do with geometry but with pure transport assumptions. And actually is quite interesting comparing tuning McICA vs Tripleclouds! But I need to better configure the GP part because of the noise in McICA.

Question 4, Maxime Colin: What do we mean by homogeneous clouds?

=> Homogeneous clouds is FSD (fractional standard deviation of in-cloud liquid water content) = 0 but the cloud fraction is still taken into account so that's two independent equations in the cloudy and clear-sky regions of each layer.

3 - A LES-benchmark case for surface solar irradiance variability under shallow cumulus

Chiel van Heerwaarden, Menno Veerman, Bart van Stratum, Wouter Mol, Jordi Vilà-Guerau de Arellano

Shallow cumulus clouds drive strong variability in space and time in surface solar irradiance, with shadows and bright spots due to reflection of light off cloud edges. Due to the tight coupling of the land surface, boundary-layer turbulence, cloud processes, and cloud-radiation interactions, our understanding of surface irradiance variability is still incomplete. Hence, our capacity to forecast it is limited. With large-eddy simulations we can very well simulate shallow cumulus convection, but producing realistic patterns of surface solar irradiance remains a challenge. We present here a LES-benchmark case for irradiance variability based on observations of a shallow cumulus day in August 2018 in Cabauw, The Netherlands. We compare the ability of the MicroHH model with the new 1D RTE+RRTMGP radiation code and the DALES model with the 3D TenStream solver in reproducing 1 Hz-observations of direct and diffuse radiation, near-surface meteorology, and cloud macrophysical properties.

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Question 1 <Fleur Couvreux>: what the scale used to obtain a realistic diffuse flux means about the effective size of your clouds? Did you try the same method on other cloud fields with a different cloud size?Nice talk by the way.

This is something we would like to do in the future. In the end, this case is special because the clouds are flat and wide, which means that side on which the sun shines and the shadow side of the cloud have similar 3D effects. We would like to elaborate this method further and for that we need a large ensemble of LES cases. And thanks :).

Question 2 <Axel Seifert>: Really nice study, I like the result that the simple averaging approach gives such a beautiful agreement for the PDFs! Would this mean that you will run the cloud tracking online while doing the LES to estimate the proper length scale? Sounds kind of tedious as well. Is there a simpler way to estimate the length scale, e.g., just using cloud depth?

We have been experimenting with that. Bart has done the technical work here, so he deserves the credits, but we do not take the time component of your tracking into account, and in that way, the approach gets a lot cheaper. Also, if we apply this in the GPU code, we have the whole 2D field in global memory so no expensive MPI operations are needed. We have only looked at simple metrics, maybe combined metrics that can trivially be derived will also yield good results, we need to look into that.

Question 3 <Richard Maier>: First, very nice talk combining radiation and arts (;-)). So did I get it right that your radiative transfer method is basically a modified 1D algorithm including a filtering technique for diffuse fluxes? Which 1D RT solver is it based on?

We use the RTE+RRTMGP solver (https://github.com/earth-system-radiation). We only filter the surface, so we are still missing the 3D effects in heating rates that for instance the TenStream solver can give you.

Question 4 <Fabian Senf>: A follow-up: How do you choose the filter? Gaussian with time-constant sigma? … great results ...

Indeed we use a Gaussian filter. The sigma is not time constant, but chosen such that the results for each time step match the observations as close as possible.

(FJ): I just wanted to throw in a paper reference who use the distance to the nearest cloud for an anisotropic filter kernel: DOI 10.1175/JAMC-D-12-0227.1

Thanks, we have been digging into detail in that paper and maybe will borrow some ideas in the future. Mirjam has described the similarities and the differences in her thesis, but I went probably a bit quick through it. The anisotropic filter kernels are probably necessary if we have deeper clouds that will not let much radiation escape on the shadow side.

4- To what extent does the radiative effect of low-level clouds depend on an accurate description of their vertical structure?

Raphaël Lebrun1,2,3, Jean-Louis Dufresne1,2,3, Najda Villefranque1,2,3

In this work we quantify the impact on the radiative flux of two approximations used in atmospheric models to parameterize clouds : homogeneity of cloud properties in each cell and exponential random overlap of clouds.

For this, we perform plan-parallel Monte-Carlo radiative computations with LES simulations for classical low level cloud cases.

To test the homogeneity hypothesis, we mapped the variables of the LES simulations onto a coarser vertical grid (GCM/RCM), while preserving the total cloud cover. Radiative transfer computations show that this idealized coarsening leads to a difference in cloud albedo as large as 20% for vertical layers of 100m thickness.

As we investigate the ERO approximation, we show it can be considered as a Markovian process and we compute the optimal overlap parameter for which the total cloud cover is conserved. We obtain that the ERO approximation introduces only small errors.

Finally, we use ERO to represent the liquid water heterogeneity within a coarse cell.

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Question 1 Sophia Schäfer: Nice work. Do you do the full calculation or only selected spectral intervals in the vertical sub-layers, and how much more expensive does it get?

The calculation is only done for the SW interval (LW soon to be done hopefully), only using the cloudy columns with the ICA assumption.

Question 2 Steve Klein: When doing the radiative transfer calculations with your ERO heterogeneity, is the radiative transfer solved on the GCM vertical resolution grid, or is radiative transfer solved using the sub-grid vertical grid with the idea that the fluxes would only be used in the GCM on the GCM vertical grid?

The radiative calculations are done with the Independent Column Approximation on the sub-grid vertical grid. For now the idea is to use this generation off-line from the GCM to be able to use Monte Carlo methods (actually the High Tune renderer presented this morning)

6- Introducing cloud horizontal overlap at NWP scales (1-10 km) in a fast 3D radiative transfer model

Mihail Manev1, Bernhard Mayer1, Claudia Emde1, Aiko Voigt2

Interactions between radiation and clouds are a source of significant uncertainty in both numerical weather prediction (NWP) and climate models. Here we present a hybrid radiative transfer model that combines a traditional two stream maximum random overlap (twomaxrnd) radiative solver (Črnivec and Mayer, 2019) with a Neighbouring Column Approximation (NCA) model (Klinger and Mayer, 2019), which parametrizes horizontal photon transport between adjacent grid-cells. Thereby the hybrid includes both subgrid-scale effects and grid-scale horizontal transport. In addition we introduced a horizontal cloud overlap scheme to the hybrid model. Further we assess the performance of the model at the NWP scale (1-10 km) for various realistic cloud configurations using results from the benchmark Monte-Carlo model MYSTIC (Mayer, 2009).

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Question 1 Sophia Schäfer: Great work. Sorry if I missed it, have you compared sub-grid and resolved 3D effects (depending on resolution)?
Answer (Mihail Manev): Thanks! No, not systematically. I also ran MYSTIC calculations on the coarse grid (these results were not shown) and there the resolved 3D effects were small. But I have not yet disentangled the sub-grid 3D effect from the effect of the sub-grid LWC distribution.

Question 2 <name>:

7-The Contributions of Shear and Turbulence to Cloud Overlap for Cumulus Clouds

Anthony Sulak[2,1], **Thijs Heus[2]**, William Calabrase[2,3], Shawn Ryan[2]

Vertical cloud overlap, the ratio of cloud fraction by area and by volume, for cumulus clouds are studied using large-eddy simulations (LES) due to the inefficient, wide-range values of cloud overlap. We can obtain information about the cloud cover of a cloud field by inspecting the individual clouds in that cloud field. We start with the maximum-random assumption and adjust this assumption for individual clouds. From this there is an underprediction which leads to the conclusion that something can be added. We extend this by considering physical factors of cloud overlap: area variability, vertical wind shear, and turbulence. We use numerical schemes to calculate the effect of each contributor based on cloud height. The resulting model shows good accuracy in modeling the cloud overlap.

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Question 1 <Yunyan Zhang>: is there any significant difference in cloud overlap between continental and marine cumulus clouds?

ARM clouds tend to be shallower, however this model can handle it.

Question 2 <Martin Köhler>: What about the overlap of disconnected clouds vertically? You see loads in LES of those.

We haven’t tested more complex situations like multi layer cloud fields; for disconnected clouds in the same field we don’t see an enormous effect on the total overlap. (It’s there, but not on the same magnitude as intra-cloud).

Question 3: <Steve Klein>: I wonder if the terms (shape, shear, turbulence) are really exclusive? To me, the way you describe the turbulence effect (by fitting a cloud hull shape), it could also include the effects of shape and shear. Maybe it is not really possible to isolate effects so cleanly.

They are not 100% exclusive, of course; the hull does indeed do some double counting as we saw in the overrepresentation of the largest clouds. I would be definitely interested in a smarter method to diagnose the turbulence effect, but this seemed to work reasonably well for a first attempt.

Question 4 <Maxime Colin>: Could the fact that you define the turbulence term from an *outward* cloud boundary (your boundary is outside the cloud) explain why the bias is clearer than for any other term? As a sanity check, have you tried to make the same analysis with an *inward* cloud boundary (drawing the boundary inside the cloud)? Or did I misunderstand what you are doing?

8-Uncertainty of shortwave cloud radiative impact due to the parameterization of liquid cloud optical properties

Erfan Jahangir, Quentin Libois, Fleur Couvreux, Benoit Vie

In general circulation models (GCMs) the shortwave (SW) cloud radiative effect (CRE) largely depends on the bulk radiative properties of clouds. These properties rely on the amount of condensed water, and the single scattering properties (SSP) of cloud particles. The SSPs, which quantify the interactions between radiation and individual cloud particles, are governed by the size and shape of the particles.In GCMs, the liquid clouds prognostic variables are generally liquid water content and total droplet concentration, but no information is provided regarding particle size. As a consequence, an assumption is required on the droplet size distribution (DSD) to diagnose the cloud particle effective radius (reff). SSPs are then parameterized in terms of reff.

To this end, new SSPs parameterizations, covering various DSD assumptions, are developed and implemented in the radiative scheme of ecRad to assess the uncertainties in CRE, resulting from the hypotheses on parameterization of SSPs.

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Question 1 Sophia Schäfer: Great work. Most droplet size parametrisations are really a chain of parametrisations: aerosol -> cloud droplet number -> size distribution. Do you have an idea which part of the chain is most uncertain?

This study is just on the effect of droplet size distribution. But if any uncertainty exists already in the cloud droplet number or aerosol concentration it can be taken into account.

As I have learned from aerosol radiative forcing studies, the effect of aerosols can impact the shape of droplet size distribution and our parameterization can be a good tool also to study the radiative impacts of aerosols on clouds since it takes into account the shape of distributions explicitly.

Question 2 Danahé Paquin-Ricard: Good presentation! At the end, you mention the connection with the microphysics scheme in meso-NH, is it only for the liquid part? and what about the other cloud schemes (if there is convection scheme or pbl clouds)? So the microphysics scheme is double-moment?

The aim of connecting microphysics and radiation in meso-NH is because there exists no consistent transfer of data from microphysics to radiation . And our parameterization allows to take a droplet size shape which can be consistent with microphysical part. This study is focused mostly on liquid clouds and for the moment (till end of thesis) there is no plan to study the connection with other schemes like convection but it seems interesting.

The microphysics that we plan to couple our parameterization with is a 2 moment scheme. It is called LIMA.

Question 3 Robin Hogan: nice talk! Since you're doing spectral averaging and worrying about detailed effects, have you considered the fact that cloud and water vapour absorption is correlated? So band-averaged cloud properties lead to a bias - basically the parts of the band with the higher cloud absorption tend to be those where water vapour is more likely to have absorbed sunlight before it reaches the cloud - see this paper: https://doi.org/10.1175/JAS-D-10-05001.1 Might be worth considering in your work.

Thank you for your proposition. Yes I have thought about it and I will try to take that into account. For now, what I use for deriving the spectral averaging methods is a simple 2 stream method on imaginary clouds with different optical thicknesses. I have shown just one of them in my presentation which is based on the cloud with optical thickness of 1. I have done the same thing on the clouds with optical thickness of 10 and 20. I will come back to you on this subject after doing a little bit of biblio.

9- Evaluation of low-level marine tropical clouds in CMIP6 models: the ‘too few too bright’ bias

Dimitra Konsta1, Jean-Louis Dufresne2, Helene Chepfer2

Climate models tend to underestimate the cloud cover and overestimate the cloud albedo, a default referred to as the ‘too few too bright bias’. In this study we examine whether this bias is still present in the current generation of CMIP6 models for low level tropical marine clouds.

The characteristics of low-level clouds simulated by six climate models participating in CMIP6 are analyzed using the COSP simulator. Key cloud variables are evaluated against different satellite datasets: cloud cover and cloud vertical distribution from CALIPSO lidar observations and cloud optical depth from PARASOL mono-directional reflectance.

It is found that the “too few too bright bias” is still present for low level clouds of the CMIP6 models under study. Common biases are found regarding the co-variation of the cloud properties, their dependence on cloud environmental conditions and in the vertical profile of CMIP6 models, the latest being attributed to the mistreatment of the cloud heterogeneity.

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Question 1 <Claudia Stubenrauch>: How large is the chance that PARASOL reflectance includes part of clear sky within the footprint for cumulus?

Answer: When we firstly applied the methodology in order to check the sensitivity of the method to cases with small cloud sizes as you mentioned, we also used the criterion where CF was increased by 10% for the clear sky and decreased by 10% for the cloudy population. The results we obtained were close when using the criterion of CF only. For more detailed explanation you can see Konsta et al., 2012 (doi:10.1007/s00382-012-1533-7)

Claudia: Thanks, Dimitra, also for your interesting presentation. I just wanted to point out that the relationship between cloud cover and cloud reflectance may be slightly overestimated, but it looks you have done the best you can with these data to take this into account :)

Thank you Claudia for your point!

Question 2: <Richard Forbes> Why do you think the increase of cloud cover with wind speed seen in the observations is not in the models? Is it just related to the model cumulus versus stratocumulus biases in the models and how they relate to the geographical patterns of the mean wind speed?

Answer: The dependence of cloud fraction on the wind speed for cumulus clouds for the observations was also shown in Mieslinger et al., 2019. Why the models do not manage to simulate the relationship is a good question, in this case I think not related to the bias in the relationship between cloud cover and cloud reflectance, since the cloud reflectance showed no dependence with the surface wind speed both for the obs and the models. We still haven’t checked the geographical patterns of the wind speed, that would give a more complete picture of the bias indeed.

(Steve Klein) A dependence of marine low-level cloud on wind speed was also demonstrated in Scott et al. JCLI 2020 10.1175/JCLI-D-19-1028.1 for a number of satellite datasets. Of course the dependence on wind speed is weaker than for other cloud controlling factors of EIS, horizontal temperature advection, etc.

Thank you for your point!

Question 3 <Zhihong Tan>: Thanks for the very interesting talk! I am just curious why the cloud reflectance tends to zero as low cloud cover tends to zero in observations, but not in any of the six climate models. Do you have any thoughts on what may be the possible issues in the parameterization?

Answer: Thank you for your question. One hypothesis we made to explain this bias found in the models is that models manage to simulate too often small cumulus clouds with low fraction and high reflectance. But the observations show that a greater variety of low-level cloud types exists. Another hypothesis is that in the models clouds are assumed to be perfectly compact at the scale of a horizontal layer, they do not manage to take into account the sub-grid heterogeneity of cloud properties and thus do not manage to simulate enough optically thin clouds.

10-Increasing resolution and resolving convection improves the simulation of cloud-radiative effects over the North Atlantic

Fabian Senf1, Aiko Voigt2,3, Nicolas Clerbaux4, Hartwig Deneke1, Anja Hünerbein1

Numerical experiments were carried out using the ICON model with varying grid spacings between 2.5 and 80 km and with different subgrid-scale parameterization approaches. Simulations have been performed over the North Atlantic with either one-moment or two-moment microphysics and with convection being parameterized or explicitly resolved by grid-scale dynamics. Simulated cloud-radiative effects are compared to products derived from Meteosat measurements. Furthermore, a sophisticated cloud classification algorithm is applied for a decomposition of cloud-radiative effects. It is found that flux biases originate equally from clearsky and cloudy parts of the radiation field. Simulated cloud amounts and cloud-radiative effects are dominated by marine, shallow clouds, and their behaviour is highly resolution dependent. Bias compensation between shortwave and longwave flux biases, seen in the coarser simulations, is significantly diminished for higher resolutions.

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Question 1 Danahé Paquin-Ricard: thanks for this overview! when you switch to 2-moment microphysics, do you link it to the radiation at the same time? (I mean, passing the information of effective radii from the microphysics to the radiation?) Is it 2-moment for liquid and ice? Thanks!

<Fabian Senf> Thanks for your question! In the model version, we used, effective radius in the radiation was inconsistently defined in the radiation scheme. Thus, the change in the microphysics is not appropriately considered and only impacts the cloud macrophysics. Because of this, we did not use the better detail in the forward operator as well. We hope that we foster the development of a more consistent treatment of microphysics and radiation in ICON.

Two-moment scheme is following Seifert-Beheng (2006), i.e. additional number conc. for ice and droplets.

Question 2 <name>:

11- Development of a Fast Three-Dimensional Dynamic Radiative Transfer Solver for Numerical Weather Prediction Models

Richard Maier, Bernhard Mayer, Claudia Emde, Fabian Jakub

The increasing resolution of NWP models makes 3D radiative effects more and more important. These effects are usually neglected by the 1D independent column approximations used in most of the current models.

To address these issues, we present a new „dynamic“ approach of solving 3D radiative transfer. Building upon the existing TenStream solver (Jakub and Mayer, 2015), radiation in this 3D model is not solved completely in each radiation time step, but is rather only transported to adjacent grid boxes. For every grid box, outgoing fluxes are then calculated from the incoming fluxes from the neighboring grid cells of the previous time step. This allows to reduce the computational cost of 3D radiative transfer models to that of current 1D solvers.

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Question 1 <name>:
Question 2 <name>:

12-Emergent Constraints on Regional Cloud Feedbacks

Nicholas James Lutsko1, Max Popp2, Robert Nazarian3

Low-cloud based emergent constraints have the potential to substantially reduce uncertainty in Earth's Equilibrium Climate sensitivity, but recent work has shown that previously-developed constraints fail in the latest generation of climate models, suggesting that new approaches are needed. Here, we investigate the potential of emergent constraints to reduce uncertainty in regional cloud feedback, rather than in the global-mean cloud feedback. Strong relationships are found between the monthly/interannual variability of tropical clouds and the tropical net cloud feedback. When combined with observations, these relationships substantially narrow the uncertainty in the tropical cloud feedback, and show that the tropical cloud feedback is likely > 0. Promising relationships are also found in the 90°-60°S and 30°-60°N regions, though these relationships are not robust across model generations and we have not identified the associated physical mechanisms.

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Question 1 <Yunyan Zhang>: what causes the difference between cmip5 and cmip6 in general? any consistent changes in models cause this?

cloud microphysics, middle latitude feedback changes

Question 2 <name>:

13- Effects of different cloud overlapping parameters on simulated total cloud fraction over the globe and East Asian region

Haibo Wang

The cloud overlapping parameter (vertical decorrelation length, Lcf) from CloudSat/CALIPSO is implemented in BCC_AGCM2.0 to reduce the uncertainty in radiation field. Comparing the results obtained by using the constant Lcf of 2 km with those using the above retrieved Lcf, it is found that the total cloud fraction simulation has been obviously improved by using the satellite-based Lcf. The error of global mean total cloud fraction between simulations and CERES is decreased by 1.6% in both the winter and summer, of which the positive deviation of total cloud amount at tropical convection area and the negative deviation in subtropical region both are significantly reduced. In East Asia, using the satellite-based Lcf can decrease the error of average total cloud fraction by 1.8% (1.4%) in the winter (summer). Overall, using Lcf from CloudSat/CALIPSO satellite data can improve the simulation of total cloud fraction and thus obtain more accurate simulation of radiation field.

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***Talk withdrawn**

Discussion:

High-Tune:RenDeRer tutorial

Training material:
https://www.lmd.jussieu.fr/~nvillefranque/pub/formations/htrdr-2021.pdf

Follow-up session on Friday 10 am at:
https://gather.town/app/dounBToM8YBQ0e5I/labLMDZ

Put your name here if you would be interested in having a late session on Friday evening French time (normal day time in the West)

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Ask your questions or comments here!

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