Lisa Bock and Axel Lauer
DLR Institut für Physik der Atmosphäre
Münchener Str. 20
82234 Weßling, Germany
Phone: +49-8153-28-1516 or -4247
Email: lisa.bock@dlr.de or axel.lauer@dlr.de

September 29, 2023

Paulo Ceppi
*Atmospheric Chemistry and Physics Editor*
European Geosciences Union

Dear Dr Ceppi:

Thank you for handling our ACPD paper "Cloud properties and their projected changes in CMIP models with low/medium/high climate sensitivity" (egusphere-2023-1086) as topical editor. We are pleased to submit a revised version of the manuscript and a point-by-point reply to all reviewers' comments.

We would like to point out, that we disagree with the opinion of reviewer #2, who thinks "*the paper is flawed in its execution"* because we compare native model output with satellite data instead of using output from satellite simulators:

- We agree with the reviewer that a comparison of model output generated by satellite simulators with the satellite observations would be more appropriate. In CMIP5 and CMIP6, however, such output is only available from a very limited number of models. In addition, only cloud fraction is available, other variables from satellite simulators such as liquid and ice water path or radiative fluxes are not available from these models. This study is therefore not possible with the available CMIP model output generated by satellite simulators.
- The comparison of the models with satellite observations in this study does not aim at a quantitative evaluation or at assessing whether high ECS values are more realistic than low ECS values but rather at helping to interpret the projected changes in cloud properties.

Both of these points have been clarified and are now stressed in the revised version. The reviewer states, however, that he/she is not willing to change his/her mind on this topic ("*I would need to see it remedied before I could recommend acceptance*"). As there is no such data available with which this study could be conducted, we do not think it makes sense to send the revised version to the same reviewer but rather ask for advice from a third reviewer or make an editorial decision.

Once again, thank you for handling our paper and the opportunity to submit a revised version to *Atmospheric Chemistry and Physics*. We look forward to hearing from you soon.

Yours sincerely,

Lisa Bock and Axel Lauer

# <u>Answer to RC1:</u>

Review of “Cloud properties and their projected changes in CMIP models with low/medium/high climate sensitivity”

by Lisa Bock and Axel Lauer

This paper presents an intercomparison of the simulation of clouds in the CMIP5 and CMIP6 multi-model ensembles. The models are grouped in three different categories: low, medium and high Effective Climate Sensitivity. In general, high-sensitivity models tend to perform better in the metrics analysed in this study. The paper is well written and the content is adequate for publication in ACP. It provides a valuable intercomparison, making it a useful addition to the scientific literature, and I recommend publication subject to minor revision. Please see my specific comments below.

**We thank Reviewer #1 for the constructive comments that helped improving the manuscript. We think we addressed all comments in the revised version and in our point-by-point answers below (given in bold). If not otherwise noted, all line numbers refer to the “track changes” version of the revised manuscript.**

GENERAL COMMENTS

I believe the results need to be put in the context of other intercomparisons that use different types of metrics. Studies like Brunner at al. (2020) reach very different conclusions by using a metrics that incorporate information about trends. I think this different approach needs to be critically discussed.

**Following the suggestion of the reviewer, we added a paragraph about relevant studies using different approaches and metrics.**
**Lines 59-64: “The performance of CMIP models has also been investigated in other studies. For example, Kuma et al. (2023) applied an artificial neural network to derive cloud types from radiation fields. They found that results from models with a high ECS agree on average better with observations than from models with a low ECS. Jiang et al. (2021) found that the models’ ECS is positively correlated with the integrated cloud water content and water vapor performance scores for both CMIP6 and CMIP5 models. In contrast, Brunner et al. (2020) showed that some CMIP6 models with high future warming compared to other models receive systematically lower performance weights when using anomaly, variance, and trend of surface air temperature, and anomaly and variance of sea level pressure to assess the models’ performance. ”**

A more detailed description of the caveats in the comparisons of the IWP is needed. The model variable used (clivi) includes precipitating frozen hydrometeors only if the precipitating hydrometeor is seen by the model's radiation code. This is model-dependent and can introduce significant biases in the comparisons. Also, I wonder if the observational datasets chosen are representative of the diversity in observational estimates. Both ESACCI and MODIS are based on passive retrievals, and therefore will share similar caveats and biases (Waliser et al., 2009). I'd suggest using an alternative reference dataset based on a different remote sensing technology like CloudSat.

**Thanks for pointing that out. We changed the alternative measurement of iwp and lwp in Fig. 3 for the pattern correlation to the CloudSat dataset. We used the same version as Lauer et al. (2023), who excluded precipitating columns to estimate cloud water path values with no precipitating particles.**

**To highlight the observational uncertainties, we added:**
**Lines 175-180: "For cloud ice and cloud liquid water path the pattern correlations between ESACCI Cloud (passive instrument) and the alternative measurements of CloudSat (active instrument) show the large uncertainties of these quantities derived from satellite observations (e.g., Lauer et al., 2023). An additional uncertainty in this comparison is introduced, as some CMIP models may provide the sum of cloud ice and falling ice (e.g. snow) in the ice water path values if the falling ice is included in their radiation calculations. The number of models including falling ice radiative effects, however, is rather small and thus not expected to play an important role in the group means. An overview can be found e.g. in Li et al. (2020a), their Table 1."**

SPECIFIC COMMENTS

-L41-42: there are other studies that looked into the reasons for the increased in sensitivity in specific models, like Gettelman et al. (2019) and Bodas-Salcedo et al. (2019). It's worth noting that coupled feedbacks (e.g. sea-ice albedo) can play a significant role in some models (Andrews et al., 2019).

**As suggested, we added these citations and now mention also connections to other coupled feedbacks.**
**Lines 47-49: "They also point out that the simulated present-day mean state of cloud properties is correlated with the simulated cloud feedback but could also be connected to other coupled feedbacks (Andrews et al., 2019)."**

- Table 2. Please specify which CERES-EBAF version you've used. Also, the reference for ERA5 is missing.

**We added the version of CERES-EBAF (Ed4.2) to Table 2 and fixed the citation entry of ERA5.**

REFERENCES

Andrews, T., Andrews, M. B., Bodas-Salcedo, A., Jones, G. S., Kuhlbrodt, T., Manners, J., et al. (2019). Forcings, feedbacks, and climate sensitivity in HadGEM3-GC3.1 and UKESM1. Journal of Advances in Modeling Earth Systems, 11, 4377– 4394. https://doi.org/10.1029/2019MS001866.

Bodas-Salcedo, A., Mulcahy, J. P., Andrews, T., Williams, K. D., Ringer, M. A., Field, P. R., & Elsaesser, G. S. (2019). Strong dependence of atmospheric feedbacks on mixed-phase microphysics and aerosol-cloud interactions in HadGEM3. Journal of Advances in Modeling Earth Systems, 11, 1735– 1758. https://doi.org/10.1029/2019MS001688.

Brunner, L., Pendergrass, A. G., Lehner, F., Merrifield, A. L., Lorenz, R., and Knutti, R. (2020): Reduced global warming from CMIP6 projections when weighting models by performance and independence, Earth Syst. Dynam., 11, 995–1012, https://doi.org/10.5194/esd-11-995-2020.

Gettelman, A., Hannay, C., Bacmeister, J. T., Neale, R. B., Pendergrass, A. G., Danabasoglu, G., et al. (2019). High climate sensitivity in the Community Earth System Model Version 2 (CESM2). Geophysical Research Letters, 46, 8329– 8337, https://doi.org/10.1029/2019GL083978.

Kuma, P., Bender, F. A.-M., Schuddeboom, A., McDonald, A. J., and Seland, O. (2023): Machine learning of cloud types in satellite observations and climate models, Atmospheric Chemistry and Physics, 23, 523–549, https://doi.org/10.5194/acp-23-523-2023.

Lauer, A., Bock, L., Hassler, B., Schröder, M., and Stengel, M. (2023): Cloud Climatologies from Global Climate Models – A Comparison of CMIP5 and CMIP6 Models with Satellite Data, Journal of Climate, 36, 281–311, https://doi.org/10.1175/JCLI-D-22-0181.1.

Li, J.-L. F., Xu, K.-M., Jiang, J. H., Lee, W.-L., Wang, L.-C., Yu, J.-Y., Stephens, G., Fetzer, E., and Wang, Y.-H. (2020): An Overview of CMIP5 and CMIP6 Simulated Cloud Ice, Radiation Fields, Surface Wind Stress, Sea Surface Temperatures, and Precipitation Over Tropical and Subtropical Oceans, Journal of Geophysical Research: Atmospheres, 125, e2020JD032 848, https://doi.org/10.1029/2020JD032848.

Waliser, D., et al. (2009), Cloud ice: A climate model challenge with signs and expectations of progress, J. Geophys. Res., 114, D00A21, doi:10.1029/2008JD010015.

## Answer to RC2:

Review of "Cloud properties and their projected changes in CMIP models with low/medium/high climate sensitivity"
By Bock and Lauer
egusphere-2023-1086

Summary

The authors compare climatological fields simulated by global climate models to those computed in observational datasets. The models are separated into high, medium, and low equilibrium climate sensitivity (ECS) categories, and it is found that for most fields examined, the high ECS models more closely resemble observations. Changes in these fields between the historical and future climate scenario are also examined, with the high ECS models showing largest changes in most location general. In general I was not impressed with this paper, for the reasons detailed below. I think the paper is flawed in its execution while also lacking a scientific motivation, and I therefore recommend rejection.

**We thank Reviewer #2 for helping to improve the paper. All points raised by the reviewer are well taken. We think we addressed all concerns in the revised version and in our point-by-point answers below (given in bold). If not otherwise noted, all line numbers refer to the "track changes" version of the revised manuscript.**

Major Comments

- The paper seems to lack any scientific question motivating the analysis or hypothesis that it is testing. Why are you evaluating these particular fields, and segregating the models by ECS? Is there a physical reason to expect the fidelity with which these fields match observations in the mean state to be tied to ECS? Do the authors believe that high ECS is more plausible than low ECS based on their results? What is the motivation for transitioning to examining how these fields change into the future? I didn't find any novel insights here that were not already well explained in the literature. In the end, I can't really understand what the point of the paper is, or why one would cite it.

  **The discussions about high ECS values from some of the CMIP6 models and the well-known large contribution of cloud feedbacks to the uncertainty range of ECS (e.g. Kuma et al., 2023; Jiang et al., 2021) motivated us to look into differences in simulated physical cloud properties and cloud radiative effects between future and present-day simulations. Of particular interest was whether there are systematic differences in these cloud-related quantities between different groups of models categorized by their ECS. Here, in particular the sensitivity of the physical properties to warming is of interest, as those give some insight into the uncertainty of the projected cloud properties and their potential contribution to cloud feedbacks and ECS. An assessment of the present-day model performance beyond a qualitative analysis to help interpreting simulated future changes in cloud properties or an assessment of differences in the plausibility of certain ECS values is not part of this study. We are not aware of any other study looking into simulated future changes in physical cloud properties from CMIP models. As the models are quite different in their sensitivity to the prescribed forcings, it makes sense to group models by certain**

**characteristics to facilitate analysis and obtain more general conclusions beyond individual models. As future changes in cloud properties are closely connected to cloud feedbacks and cloud feedbacks are strongly correlated with ECS, we use ECS as a simple proxy to group the ensemble of CMIP5 and CMIP6 models. To our knowledge, this is a novel approach and has not been published before.**

**We rephrased and clarified our motivation and our approach in the revised version, references to previous work have been extended.**
**We added to the abstract: "ECS is used as a simple metric to group the models as the sensitivity of the physical cloud properties to warming is closely related to cloud feedbacks, which in turn are known to have a large contribution to ECS." (Lines 8-10) and "In order to help interpreting the projected changes, model results from historical simulations are also compared to observations." (Lines 12-13)**
**We added a paragraph to the introduction: "As future changes in cloud properties are closely connected to cloud feedbacks and cloud feedbacks are known to be strongly correlated with ECS (see Sect. 3.1), we use ECS as a simple proxy to group the ensemble of CMIP5 and CMIP6 models for this analysis. This facilitates the analysis and allows for obtaining more general conclusions beyond individual models that can vary widely in their sensitivity to the prescribed forcings. A particular focus of this study is whether there are systematic differences in cloud-related quantities between the different ECS groups. The sensitivity of the physical properties to warming is analysed, as this gives some insight into the uncertainty of the projected cloud properties and their potential contribution to cloud feedbacks and ECS." (Lines 50-56)**
**We added to the summary: "Furthermore, historical simulations of the models were compared with satellite data to obtain a qualitative overview on the performance of the three model groups in simulating observed cloud patterns and properties." (Lines 380-382)**
**We also clarified that an assessment of the present-day model performance beyond a qualitative analysis to help interpreting simulated future changes in cloud properties or an assessment of differences in the plausibility of certain ECS values is not part of this study: "A qualitative assessment of the present-day model performance by comparing key cloud properties with satellite data is done to help interpreting simulated future changes in cloud properties. We would like to note that conclusions on the plausibility of certain ECS values cannot be drawn from this comparison and are thus not an aim of this study." (Lines 57-59).**

- Most of the fields examined involve cloud properties (fractional area coverage, ice and liquid water path) or precipitation, but the evaluation is done without satellite simulators that ensure apples-to-apples comparisons of the geophysical fields (Bodas-Salcedo et al., 2011). It is well established within the community that one cannot simply compare a model cloud field to something retrieved from space, which has sampling biases, detection thresholds, scale differences, etc. Papers by Jen Kay, Greg Cesana, and others have made this point many times for several fields (G. Cesana & Chepfer, 2013; G. V. Cesana et al., 2021; J. E. Kay et al., 2012; Jennifer E. Kay et al., 2016, 2018). Even cloud radiative effect (clear- minus all-sky fluxes at the TOA) cannot be easily compared between models and observations because of differences in how clear-sky fluxes are provided in models vs observations (B. J. Sohn et al., 2010; B. J. Sohn & Bennartz, 2008; B.-J. Sohn et al., 2006). To facilitate more appropriate comparisons, adjusted clear-sky fluxes are now being provided by the CERES team (Loeb et al., 2020). For me, this decision to use raw model output to compare to satellite-retrieved fields is the most egregious flaw of the paper and I would need to see it remedied before I could recommend acceptance.

**We agree with the reviewer that a comparison of model output generated by satellite simulators with the satellite observations would be more appropriate. In CMIP5 and CMIP6, however, such output is only available from a very limited number of models (historical simulation: 15 CMIP6 models + 10 CMIP5 models; scenario simulation: 7 CMIP6 models + 2 CMIP5 models). In addition, of all variables investigated here, only total cloud fraction is available, other variables from satellite simulators such as liquid and ice water path or radiative fluxes are not available for these models. This study would therefore not be possible with the available CMIP model output generated by satellite simulators.**
**The main aim of this work to investigate whether there are systematic differences in present-day and projected cloud properties between different groups of models sorted by their ECS and if so, to quantify and document these differences. The comparison of the models with satellite observations does not aim at a quantitative evaluation of the different model groups or assessing whether high ECS values are more realistic than low ECS values but rather to help interpreting the projected changes in cloud properties.**

**We clarified this in the revised version and emphasized the qualitative aspect of this comparison. The limitations of this comparison because of the lack of output from satellite simulators has been extended and highlighted: "Most of the CMIP5 and CMIP6 historical simulations, however, do not provide such output. Of all variables investigated here, only total cloud fraction is available, other variables from satellite simulators such as cloud liquid and ice water path or radiative fluxes are not available for these models. … We would like to note that this limitation restricts a quantitative assessment of differences between models and observations as an unknown error is introduced by comparing two not fully equal quantities regarding their definition (e.g. observational thresholds) as well as temporal and spatial sampling. An assessment of the present-day model performance beyond a qualitative analysis to help interpreting simulated future changes in cloud properties or an assessment of differences in the plausibility of certain ECS values is therefore not possible." (Lines 191-201)**

**Regarding the evaluation of the cloud radiative effect we updated the reference dataset CERES EBAF from version Ed2.7 to Ed4.2. Starting at v4.1, the dataset provides adjusted clear-sky fluxes which are now defined in a manner that is more in line with how clear-sky fluxes are represented in climate models. Figure 3, Table 4, Figure 7 and 9 have been updated accordingly.**
**There are differences in the net cloud radiative forcing using v4.2 instead of v2.7 which are largest in the Tropics. The decrease of the netcre in the Tropics results from a larger lwcre (more warming) and a weaker swcre (less cooling) in the newer version. As we compare the different model groups in first place, these changes have no influence on the conclusions made in the paper.**

- I found it very disconcerting that the authors did not ensure a common time period for their model-observation comparisons. Why are the climatologies from the various observational products different from each other and from the models (1985-2004)?

  **We choose the time period 1985-2004 for the climate models as this period is covered**

**by both, the CMIP5 and CMIP6 historical model runs making it consistent to include both model generations in each ECS group. The time period of the reference datasets depends on the data availability for the specific reference dataset. While this choice of model years is somewhat arbitrary and does not match the years of the observations exactly, we found that it has very little impact on the multi-year group averages. This is not surprising as ESMs are not expected to reproduce the exact observed phase of climate modes largely controlling present-day variability of clouds but rather their statistical properties.**
**This has been clarified in the revised version by adding: "We would like to note that the time period from the models used for comparison with the observations (see Sect. 2.1) does not match exactly the observed years. It is not surprising, however, that this has very little impact on the multi-year group averages as ESMs are not expected to reproduce the exact observed phase of climate modes largely controlling present-day variability of clouds but rather their statistical properties." (Lines 96-99)**

- The Observations section was literally 3 sentences, none of which actually explained the datasets, their version/collection, nominal resolution, what instrument (on which satellite) is measuring each geophysical quantity, etc. This is unacceptable for a scientific manuscript in which models are being evaluated against observations. The recurring cloud product with the acronym ESACCI is not even defined anywhere.

  **Following the reviewer's comment, we extended the observations section now giving a brief description of all datasets used, including references for more detailed information (Lines 100-114). We prefer to keep these descriptions short in order to not simply repeat other studies and lengthen the paper unnecessarily.**

- In stark contrast to the 3-sentence Observations section, Section 2.3 reads like an advertisement for the ESMValTool. Most of this information regarding the software you used to perform your analysis is meant for the Code and data availability section.

  **We shorten the section as suggested now mostly referring to other studies for details on ESMValTool.**

- The changes in cloud properties are computed by differencing the future scenario with the historical scenario. While this will provide the total change in clouds, those changes will be due to an ambiguous mix of causes: responses to warming, decreases in aerosol loading, and adjustments from changes in other forcing agents. High ECS models typically also have large aerosol-cloud interactions (Kiehl, 2007; Wang et al., 2021), so a portion of their change between historical and future climates will be due to a recovery from being strongly affected by aerosols in the historical period, and will not be purely attributable to cloud feedback processes.

  **In this paper we investigate whether there are systematic differences in simulated cloud properties between the three ECS groups. The aim is to quantify and document such differences. For a better comparability of the different model groups, we also calculate the change in cloud properties per degree of surface warming. An attribution, however, to differences in cloud feedbacks is beyond the scope of this paper for the reasons given by the reviewer and therefore not done in this study.**

  **We corrected "cloud feedback" with "cloud radiative effect" in Line 18 and Line**

**444.**

Specific Comments

- Author list: both authors' names are in reverse order

  **Thanks for spotting. We fixed that.**

- L7 and throughout: "both, cloud physical" the comma after both is not needed; this typo recurs throughout the paper (e.g., L26, 140)

  **Thank you for pointing this out. We deleted all commas after "both".**

- L99: what simulations are being used here? Also, it should be caveated that the change in cloud radiative effect is not the same as the cloud feedback owing to changes in clear-sky fluxes that are not related to clouds (Soden et al., 2004)

  **In order to calculate the cloud feedback, we use the simulations forced by an abrupt quadrupling of $CO_2$ (abrupt-4 × CO2) and the preindustrial control simulations (piControl). The same model simulations are used to obtain ECS. We clarified this in the revised text.**
  **We would like to stress, that we do not investigate cloud feedbacks beyond our motivation that ECS is correlated with cloud feedbacks. Quantitative analyses of cloud feedbacks are not performed is study.**

  **Line 84: We added "…and cloud feedbacks…".**
  **Lines 134/135: We added "…from abrupt-4×CO2 simulations compared to the corresponding piControl simulations."**

- L111: it doesn't matter which direction one is going; delete "when going from south to north"

  **Removed as suggested.**

- L111-113: these statements are made without providing any evidence of the role of changing cloud phase; suggest either deleting, citing the appropriate literature, or providing evidence.

  **We added the reference Ceppi et al. (2017) as citation for this statement (Line 153).**

- Figure 1: Given that ECS is strongly dependent on cloud feedback, it seems odd to plot cloud feedback on the y-axis, which is typically thought of as the dependent variable.

  **We modified Figure 1 as suggested by swapping the x- with y-axis.**

- L209: "clouds are warming" should be re-stated

  **We rephrased the sentence to: "Clouds have a warming radiative …" (Lines 263).**

- L226 vs L227: "largest positive bias" ..." too strong net cloud radiative effect" – I'm confused about what these mean. The net CRE is negative, so if it is "too strong" I'd expect that to mean that the negative magnitude is too large, but this would not be a positive bias. Please restate.

**The "largest positive bias" could be found over the stratocumulus regions, which means that the negative cloud radiative effect is too weak in the models over these regions. Beside these regions there is a "too strong net cloud radiative effect" in the Tropics between 30°N and 30°S. This means the netCRE is more negative in the models than in the observations. So the two statements mentioned by the reviewer do not belong together. We clarified this in the revised manuscript by adding "Apart from that, …" (Lines 281/282) in the beginning of the second sentence.**

- Figure 10 and elsewhere: I'm not sure what is meant be "relative change". How is this computed?

  **Thanks for spotting that. We added the definition to the text and the caption of Figure 10.**

  **Lines 294/295: "The relative changes (calculated as the differences between the scenario value and the historical value divided by the historical value)…"**

- Figure 11: if liquid water path is denoted as lwp rather than clwvi, it seems that ice water path should be denoted as iwp rather than clivi. Should one care about IWP over the stratocumulus regimes?

  **We replaced "clivi" with "iwp" in the text as suggested as well as in the Figures 5, 10 and 11.**
  **Please note that "clwvi" is defined as the sum of the cloud liquid and ice water path. Liquid water path is calculated as lwp = clwvi - clivi.**

  **We show iwp in the Figure 11 for completeness. As iwp values are close to zero in the stratocumulus regions, relative changes can be large but are physically not relevant. This has been added to the text: "We would like to note that ice water path values are typically very small in the stratocumulus regions. Relative changes can therefore be large without being physically relevant." (Lines 340-342)**

- L383-384: In this sentence, every possible regime on the planet is listed; is this really informative or helpful? If you quantified more rigorously the regimes that are strong contributors to inter-model spread in cloud feedback or ECS, you would find that not every location on the planet contributes equally.

  **The reviewer is right, our results show that not a single but rather all cloud regimes are important. We clarified this in the revised manuscript by extending the corresponding sentence (Line 446): "…in all different global cloud regimes, …"**

References


Bodas-Salcedo, A., Webb, M. J., Bony, S., Chepfer, H., Dufresne, J. L., Klein, S. A., et al. (2011). COSP Satellite simulation software for model assessment. Bulletin of the American Meteorological Society, 92(8), 1023–1043. https://doi.org/10.1175/2011bams2856.1

Ceppi, P., Brient, F., Zelinka, M.D. and Hartmann, D.L. (2017), Cloud feedback mechanisms and their representation in global climate models. WIREs Clim Change, 8: e465. https://doi.org/10.1002/wcc.465

Cesana, G., & Chepfer, H. (2013). Evaluation of the cloud thermodynamic phase in a climate model using CALIPSO-GOCCP. Journal of Geophysical Research: Atmospheres, 118(14), 7922–7937. https://doi.org/10.1002/jgrd.50376

Cesana, G. V., Ackerman, A. S., Fridlind, A. M., Silber, I., & Kelley, M. (2021). Snow Reconciles Observed and Simulated Phase Partitioning and Increases Cloud Feedback. Geophysical Research Letters, 48(20), e2021GL0948ti6. https://doi.org/10.1029/2021GL094876

Jiang, J. H., Su, H., Wu, L., Zhai, C., and Schiro, K. A. (2021): Improvements in Cloud and Water Vapor Simulations Over the Tropical Oceans in CMIP6 Compared to CMIP5, Earth and Space Science, 8, e2020EA001 520, https://doi.org/https://doi.org/10.1029/2020EA001520

Kay, J. E., Hillman, B. R., Klein, S. A., Zhang, Y., Medeiros, B., Pincus, R., et al. (2012). Exposing Global Cloud Biases in the Community Atmosphere Model (CAM) Using Satellite Observations and Their Corresponding Instrument Simulators. Journal of Climate, 25(15), 5190–5207. https://doi.org/10.1175/JCLI-D-11-00469.1

Kay, Jennifer E., L'Ecuyer, T., Chepfer, H., Loeb, N., Morrison, A., & Cesana, G. (2016). Recent Advances in Arctic Cloud and Climate Research. Current Climate Change Reports, 2(4), 159–169. https://doi.org/10.1007/s40641-016-0051-9

Kay, Jennifer E., L'Ecuyer, T., Pendergrass, A., Chepfer, H., Guzman, R., & YePella, V. (2018). Scale-Aware and Definition-Aware Evaluation of Modeled Near-Surface Precipitation Frequency Using CloudSat Observations. Journal of Geophysical Research: Atmospheres, 123(8), 4294–4309. https://doi.org/10.1002/2017JD028213

Kiehl, J. T. (2007). Twentieth century climate model response and climate sensitivity. Geophys. Res. Lett., 34. https://doi.org/10.1029/2007GL031383

Kuma, P., Bender, F. A.-M., Schuddeboom, A., McDonald, A. J., and Seland, O. (2023): Machine learning of cloud types in satellite observations and climate models, Atmospheric Chemistry and Physics, 23, 523–549, https://doi.org/10.5194/acp-23-523-2023

Loeb, N. G., Rose, F. G., Kato, S., Rutan, D. A., Su, W., Wang, H., et al. (2020). Toward a Consistent Definition between Satellite and Model Clear-Sky Radiative Fluxes. Journal of Climate, 33(1), 61–75. https://doi.org/10.1175/JCLI-D-19-0381.1

Soden, B. J., Broccoli, A. J., & Hemler, R. S. (2004). On the use of cloud forcing to estimate cloud feedback. J. Climate, 17, 3661–3665. https://doi.org/10.1175/1520-0442(2004)017<3661:OTUOCF>2.0.CO;2

Sohn, B. J., & Bennartz, R. (2008). Contribution of water vapor to observational estimates of longwave cloud radiative forcing. J. Geophys. Res., 113. https://doi.org/10.1029/2008JD010053

Sohn, B. J., Nakajima, T., Satoh, M., & Jang, H. S. (2010). Impact of different definitions of clear-sky flux on the determination of longwave cloud radiative forcing: NICAM simulation results. Atmos. Chem. Phys., 10(23), 11641–11646. https://doi.org/10.5194/acp-10-11641-2010

Sohn, B.-J., Schmetz, J., Stuhlmann, R., & Lee, J.-Y. (2006). Dry Bias in Satellite-Derived Clear-Sky Water Vapor and Its Contribution to Longwave Cloud Radiative Forcing. Journal of Climate, 19(21), 5570–5580. https://doi.org/10.1175/JCLI3948.1

Wang, C., Soden, B. J., Yang, W., & Vecchi, G. A. (2021). Compensation Between Cloud Feedback and Aerosol-Cloud Interaction in CMIP6 Models. Geophysical Research Letters, 48(4), e2020GL091024. https://doi.org/10.1029/2020GL091024