EUCLIPSE

EU Cloud Intercomparison, Process Study & Evaluation Project

Grant agreement no. 244067

Deliverable D4.6 Process-related metrics that can be used as model development and evaluation tools.

Responsible Partner: MPG

Partners involved: AA, CNRS-IPSL, METO, KNMI, ECMWF

Delivery date: 42 months

SEVENTH FRAMEWORK PROGRAMME

Deliverable 4.6: Process Related Metrics

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Aim: *Process related metrics that can be used as model development and evaluation tools.*

EUCLIPSE has underwritten studies that have developed and introduced several new metrics for model development. These are used to evaluate precipitation biases, climate sensitivity, the representation of intra-seasonal variability, biases in Atlantic basin precipitation the structure of the Pacific ITCZ, known as the double ITCZ problem, and the structure of convection both throughout the tropical atmosphere and in the trade-wind regions. They are discussed in turn below. In addition, EUCLIPSE funding helped modelling centers integrate existing metrics into their model development system, examples being the Reichler-Kim metric for coupled model performance and the MJO diagnostic which are now both actively used as part of the MPI-ESM development (Stevens et al., 2013) and also within EC-Earth. As discussed at the end, EUCLIPSE has also been instrumental in allowing the centers to develop new online diagnostics, and station output data. This capability is proving crucial to the development of tests of the model representation of the vertical structure of low clouds and factors influencing their change. All references are supported by and acknowledge EUCLIPSE funding.

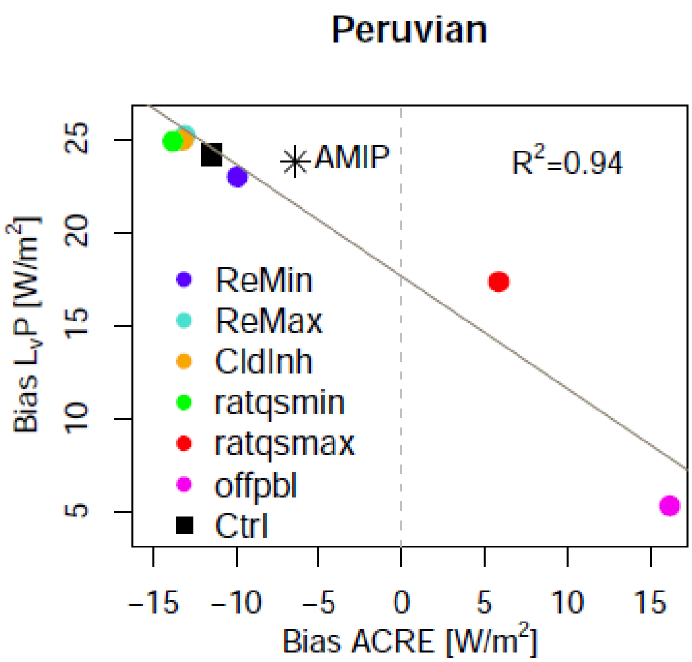

Figure 1: Relationship between the precipitation bias and the atmospheric cloud radiative effect bias of the IPSL-CM5A-LR GCM in a series of T-AMIP sensitivity tests over the south pacific stratocumulus regions (other low-cloud regions show similar results). The bias from the AMIP run is shown as the black asterisk. Taken from Fig. 9 of Fermepin and Bony (2014)

EUCLIPSE funding supported the development of the "Transpose AMIP" setup (T-AMIP) within the EUCLIPSE family of models. In T-AMIP simulations climate models are initialized with analysis, or reanalysis, data and run for a short time period (days), often with many ensemble members. The framework (see deliverable 4.3) has been used to investigate the relationship between precipitation biases in tropical subsidence regions and the representation of low-cloud radiative effects. In the IPSL-CM5A-LR model it is found that about 30% of the precip over-estimate in these regions can be explained by an overestimate of atmospheric cloud radiative effects (Fig. 1), suggesting that paying attention to ACRE in these regions might be a way to reduce the precipitation overestimate in dry regions, which is a bias exhibited by many models. The T-AMIP framework that was developed through support from EUCLIPSE for the MPI-ESM model is also being used at MPI to study biases in the representation of the Madden Julien Oscillation, and to participate in the GASS-WGNE greyzone project.

Motivated by other studies within the EUCLIPSE project Sherwood et al. (2014) introduced a new metric of convective mixing, the Lower-Tropospheric Mixing Index, and showed that it can explain a considerable amount (68 %) of the variance in climate sensitivity across the CMIP3 and CMIP5 ensembles. Their Lower-Tropospheric Mixing Index combines a stratification based measure of shallow convective mixing associated with regions of precipitating deep convection in the western pacific, and the relative strength of shallow versus deep convective overturning elsewhere in the tropics. They further show that observed values of this index are most consistent with models having a larger climate sensitivity, stating that

> The mixing inferred from observations appears to be sufficiently strong to imply a climate sensitivity of more than 3 degrees for a doubling of carbon dioxide. This is significantly higher than the currently accepted lower bound of 1.5 degrees, thereby constraining model projections towards relatively severe future warming.

Oueslati and Bellon (2014) introduced what they call a Combined Precipitation Circulation Error (CPCE) to measure the degree to which models misrepresent the coupling between circulation and precipitation. This error measure, or metric, is strongly correlated with the southern ITCZ index (Fig. 2) suggesting that the double ITCZ bias (defined as a too zonal southern pacific convergence zone and too much convection south of the equator in the tropical eastern Pacific) in models is strongly related to the coupling between the deep overturning circulation as measured by the vertically integrated vertical velocity and the development of deep, precipitating, convection. Based on the analysis of this error it was shown that models precipitation biases can mostly be attributed in the structure of the large-scale circulation, which can in turn can be caused by too little inhibition of deep convective mixing processes. This is consistent with with the Sherwood et al. (2014) analysis which suggests that models tend to favor deep overturning at the expense of shallow circulations.

This idea, one of the outstanding contributions of EUCLIPSE, that a poor representation of deep convective mixing processes is linked to many of the biases in state-of-the-art global models is also evident in analysis of tropical intra-seasonal variability conducted as part of EUCLIPSE. Crueger et al. (2013) analyzed the Madden-Julien Oscillation in different generations, configurations and flavors of the MPI suite of models, using a new index that

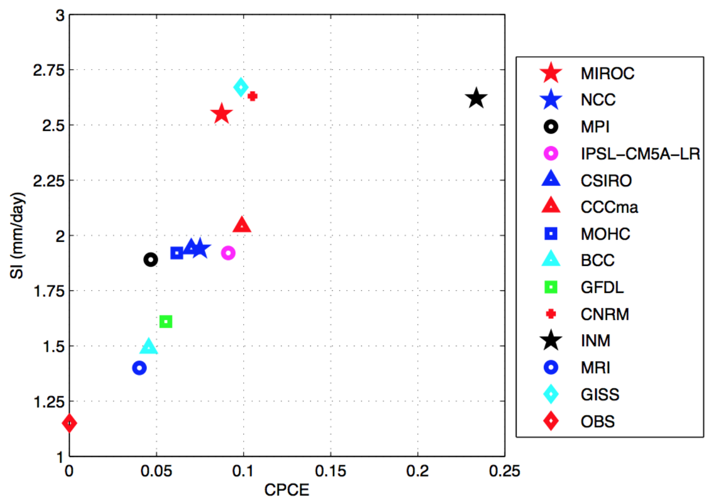

Figure 2: Scatterplot of Combined Precipitation Circulation Error and Southern ITCZ index (previously introduced as a measure for the strength of the double ITCZ bias in models) for CMIP5 AGCMs and observations. Taken from Fig. 12 of Oueslati and Bellon (2014)

combines the propagation characteristics of the MJO (by the power ratio of eastward versus westward propagation) as well as the convective signature as measured by the explained variance. This metric has been introduced into the MPI-ESM model development process and when applied to a family of models developed at the MPI over the years shows that processes which inhibit convection lead to a better representation of intraseasonal variability.

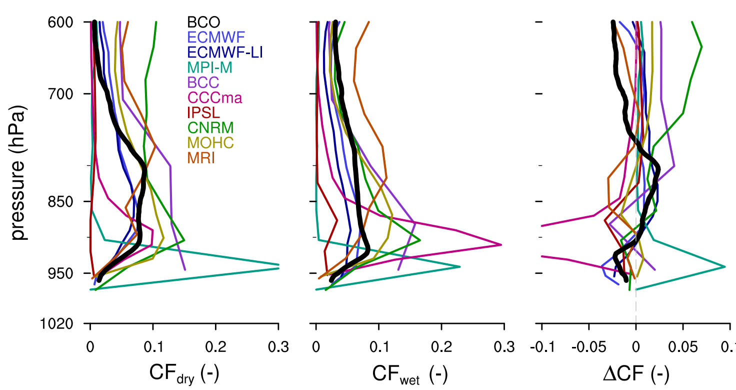

Figure 3: Vertical profile of clouds in the lower-troposphere as a function of season. Taken from Nuijens et al.

EUCLIPSE has lead to new capabilities for evaluating models, through satellite simulators and station output, and new configurations, thereby making it a core contributor to CFMIP. Many of these contributions are reviewed in the Deliverable 2.8. Here we add two further points. One is the development of the radiative convective equilibrium framework. Popke et al. (2013) showed that the structure of the tropical atmosphere in RCE is representative of that over the oceans in the fully coupled version of the MPI-ESM, thereby suggesting that this framework can be used to test the coupling between radiation, surface fluxes, clouds and convection in a way that is likely to be representative of processes occurring in more realistically configured simulations. This approach makes it possible to link the behavior of models with parameterized physics to more fundamental representations of the atmosphere, such as provided by large-eddy simulation, and thereby opens a new dimension in the testing and evaluation of atmospheric processes. Likewise, a new study that takes advantage of the station data, which many centers were able to provide through EUCLIPSE funding, to examine the seasonal variation in low-cloud amount in the maritime trades of the North Atlantic (Nuijens et al.). In this, one of the central cloud regimes explaining inter model spread in climate sensitivity, the representation of the vertical distribution of low-level clouds, and the subtlety of their seasonal cycle is mis-represented by most models (Fig. 3). We anticipate that these data, and these approaches will prove increasingly useful in the future as attempts are made to better constrain the representation of the low-level clouds essential to the climate response.

References

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