Improved representation of Amazon precipitation by organized convection in storm-resolving simulations

Laura Paccini and Bjorn Stevens

Max Planck Institute for Meteorology

MOTIVATION

The Amazon basin is the largest rainforest in the Earth and of great relevance for the global hydro-climate and biodiversity. Over this important region large and systematic errors in precipitation simulation persist (e.g. Fiedler et al., 2020).
In this study, we use kilometer-scale "storm-resolving" simulations over large domains to assess the degree to which they reduce such biases and the extent to which this depends on the explicit representation of organized convective systems.

EXPERIMENTAL SET-UP

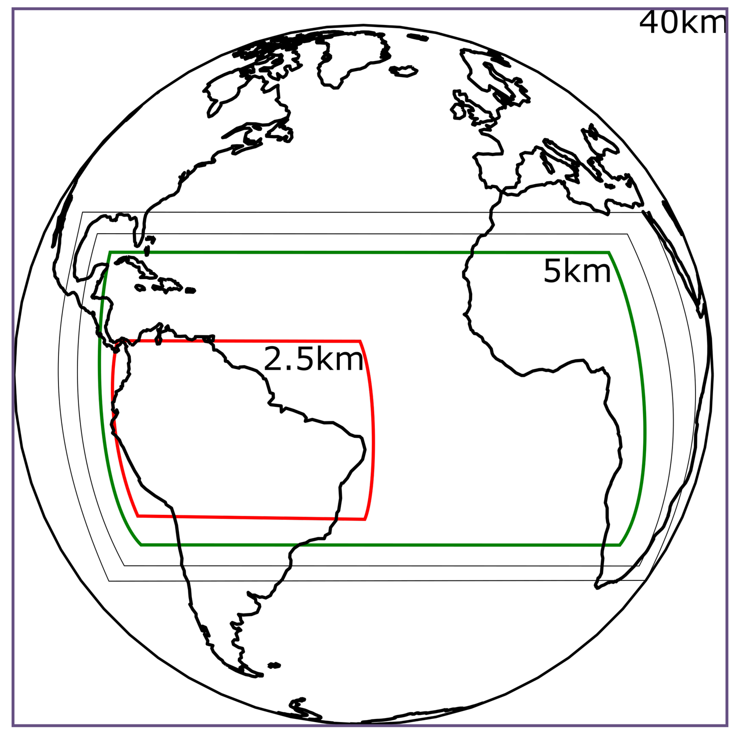

Figure1. Domain set-up for ICON simulations.

We use the ICON model (Zangl., et al 2015) in the NWP configuration. Simulations are performed first globally at 40km with the parameterized convection (Bechtold, 2017) switched on (P-CON) and then we apply a one-way nesting approach. Inner domains (Fig. 1) have the convective parameterization switched off (E-CON). An ensemble of 8-member sImulations are integrated for 40 days (March).

MAIN FEATURES AND MAJOR IMPROVEMENTS

The mean precipitation in the Amazon basin and its spatial distribution is fairly represented by both E-CON and P-CON ensembles (Fig. 3). However, the large frequency of light rain in P-CON (Fig. 2) can explain a close daily mean to observations. Also, P-CON misses precipitation in the northeast coast which is known to be important for the generation of propagating systems towards the Amazon.

The spatial heterogeneity of the diurnal cycle can also be detected in the E-CON ensemble, similar to what is found in observations (Fig. 3). The P-CON ensemble, shows a spatial distribution more homogeneous and misses the nocturnal precipitation over the central and northeast Amazon.

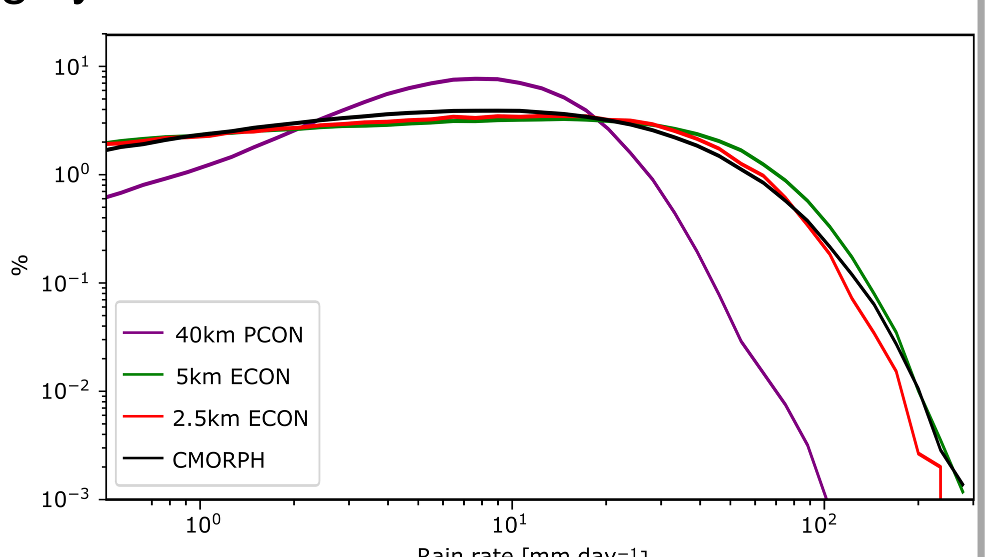

Figure 2. Distribution (%) of daily precipitation intensity greater than 0mm over the Amazon basin for observations (black line) and simulations (colored lines). Values are binned in a logarithmic scale.

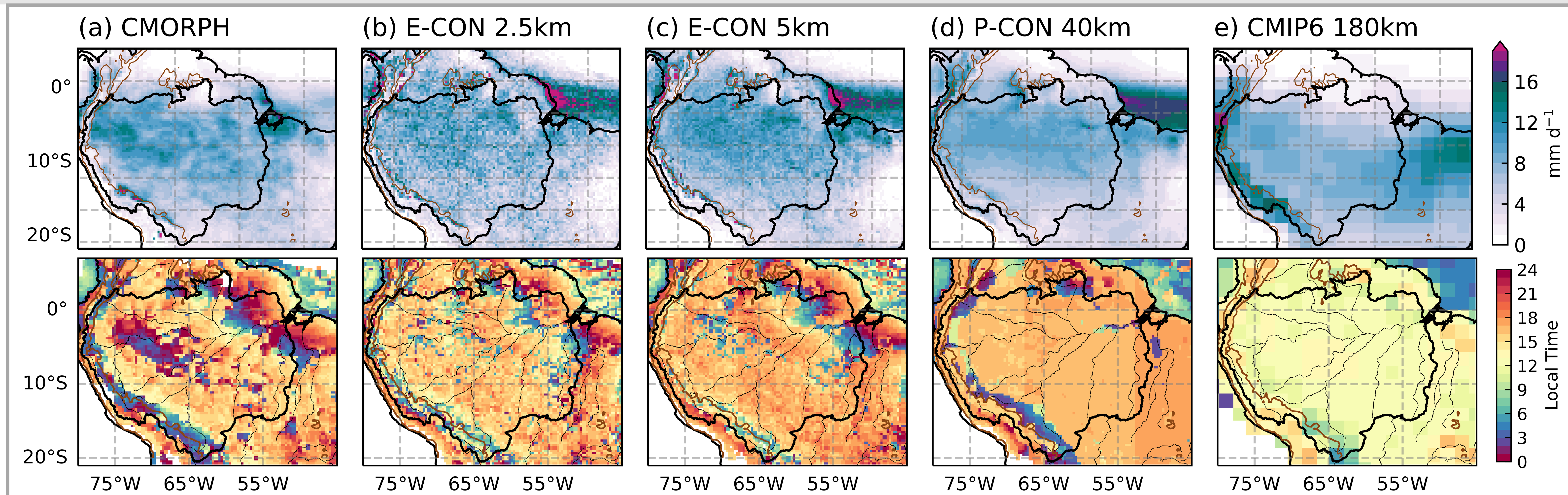

Figure 3. Upper row: Mean precipitation in March (mm/d). Lower row: Local time of maximum hourly precipitation. calculated using the hourly mean and smoothed using a second order Fourier transform per grid point. (a) CMORPH observations (climatology 2010-2019) and simulations with explicit (E-CON) convection at (b) 2.5km (c)5km, parameterized convection (P-CON) at (d) 40km and the (e) CMIP6 multi-model ensemble mean. The Amazon basin is defined as black contours as well as the rivers, and the topography at 1000m is shown in brown contours.

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ROLE OF ORGANIZED CONVECTIVE SYSTEMS (OCS)

Organized convective systems (OCS) are defined following an object-based approach. Precipitation objects are identified as contiguous grid cells (8-way connection) with a minimum size of 10000 km^2 and minimum intensity of 2 mm/hrs.

The OCS explain most of the spatial heterogeneity in the diurnal cycle of precipitation and high-intensity rain rates in observations. These features are absent in the P-CON ensemble, whereas the similarity between E-CON and observations improves in both the distribution of precipitation intensity and diurnal cycle when only considering OCS (e.g. Fig. 4). Diurnal precipitation peaks during the day seem to improve with increased resolution, nocturnal precipitation peaks associated with OCS remain similar between 2.5km and 5km ensembles and delayed a few hours in contrast to observations.
Despite the overall good representation of the diurnal cycle and distribution of precipitation intensity associated with OCS, they are still less frequent, smaller and more intense than observed.

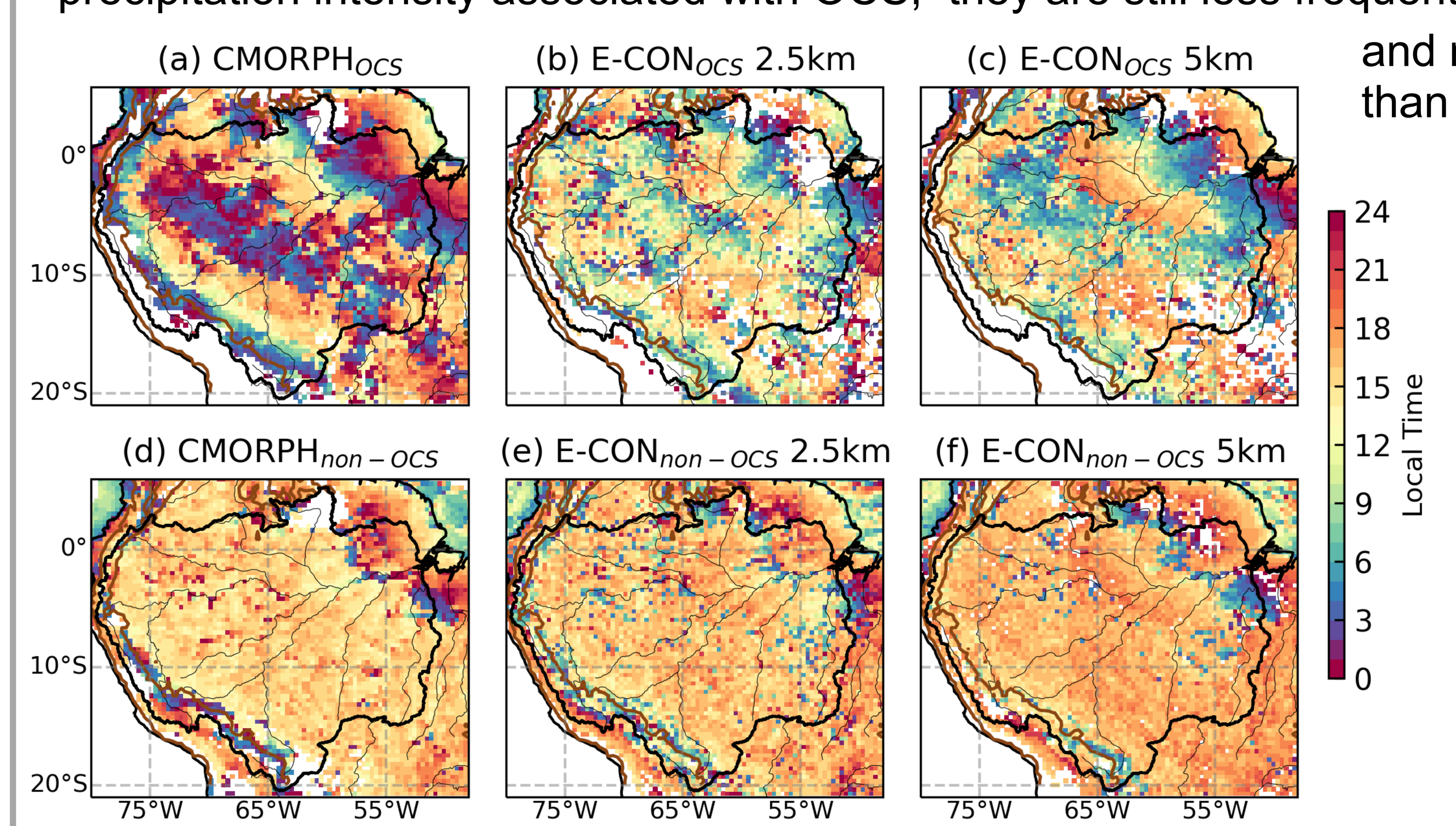

Figure 4. Local time (hour) of maximum precipitation (a, b, c) considering only organized convective systems (OCS) and (d, e, f) only non-organized precipitation ("non-OCS"} for (a, d) CMORPH, (b, e) 5km E-CON and (c, f) 2.5km E-CON simulations. The Amazon basin is defined as black contours as well as the rivers, and the topography at 1000m shown in brown contours.

ENVIRONMENTAL CONDITIONS OF OCS

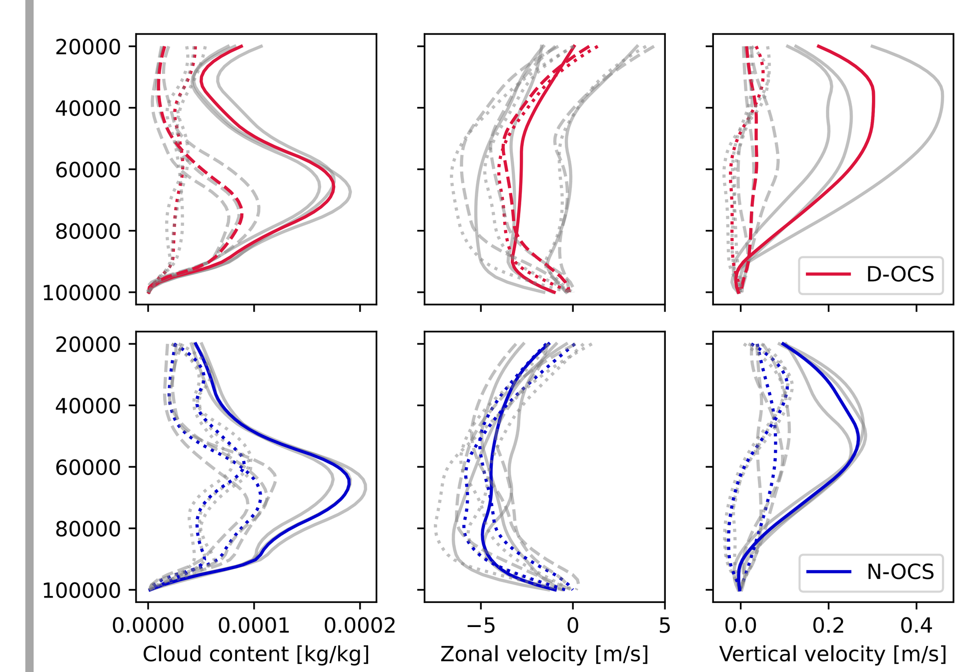

Figure 6. Vertical profile of composite OCS. Solid contours represent the mean vertical profiles at the moment of object detection (time 0), dashed lines represent 3 hours before the detection and dotted lines, 3 hours after time 0. Diurnal (D-OCS) and nocturnal (N-OCS) OCS are located in the upper and lower row, respectively. Grey contours represent individual clusters.

The environment of the nocturnal versus diurnal OCS differs systematically. Diurnal OCS are less persistent and display more enhanced convective activity. Strong surface temperature perturbations that propagate with the OCS suggest its coupling with surfaces processes (e.g. cold-pools). Nocturnal OCS are more persistent and less intense, consistent with stratiform features. They are associated with stronger easterlies in the lower troposphere (850hPa) possibly forming part of the Amazonian low-level jet.

CONCLUSIONS

- The explicit representation of convection at storm-resolving scales and OCS enable improvements in the distribution of precipitation intensity and spatial variability of diurnal cycle in the Amazon basin.
- Surface processes influence the propagation of diurnal OCS and strong low-level easterlies are related to the occurrence of nocturnal OCS.
- Remaining biases show insensitivity to two fold refinement in horizontal mesh, indicative of the importance of much smaller scale processes.

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laurapaccini@gmail.com