Project: **1253**

Project title: **Investigating feedbacks between atmospheric convection and near surface processes in the ocean**

Principal investigator: **Cathy Hohenegger**

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In this project, we investigate the interactions between diurnal warm layers (DWLs) and atmospheric convection. DWLs develop in the upper meters of the ocean under low wind conditions as a response to the daily cycle in solar insolation. The main hypothesis of the first part of the project was that the enhanced diurnal cycle in SST resulting from explicitly resolving DWLs modifies the surface turbulent fluxes and potentially impacts the atmospheric state either through differential heating or due to the overall moisture increase in the mixed layer.

In the first part of the project, we conducted global coupled simulations that, for the first time, had the ability to resolve both DWLs (achieved by implementing a fine vertical resolution in the upper layers of the ocean) and shallow convection (thanks to a horizontal resolution of 5 km in the atmosphere). To trace the impact of DWLs on atmospheric variables, we performed two 5-km global coupled simulations with identical initial conditions, one having 128 vertical ocean levels with thicknesses starting at 2m and gradually increasing, and another having 139 vertical levels with a gradual thickness increase starting from 0.5m at the surface.

The first striking result of the study is that, although the thin layer configuration indeed resolves the DWLs, the magnitude of the daily SST amplitude (DSA) is largely overestimated compared to observations (in particular, from the EUREC$^4$A campaign) and the ERA5 reanalysis (see Figure 1). Apart from this, the model seems to correctly reproduce the main features of the DWLs such as the diurnal cycle of the profile and the dependence of the DSA on wind strength and incoming shortwave radiation.

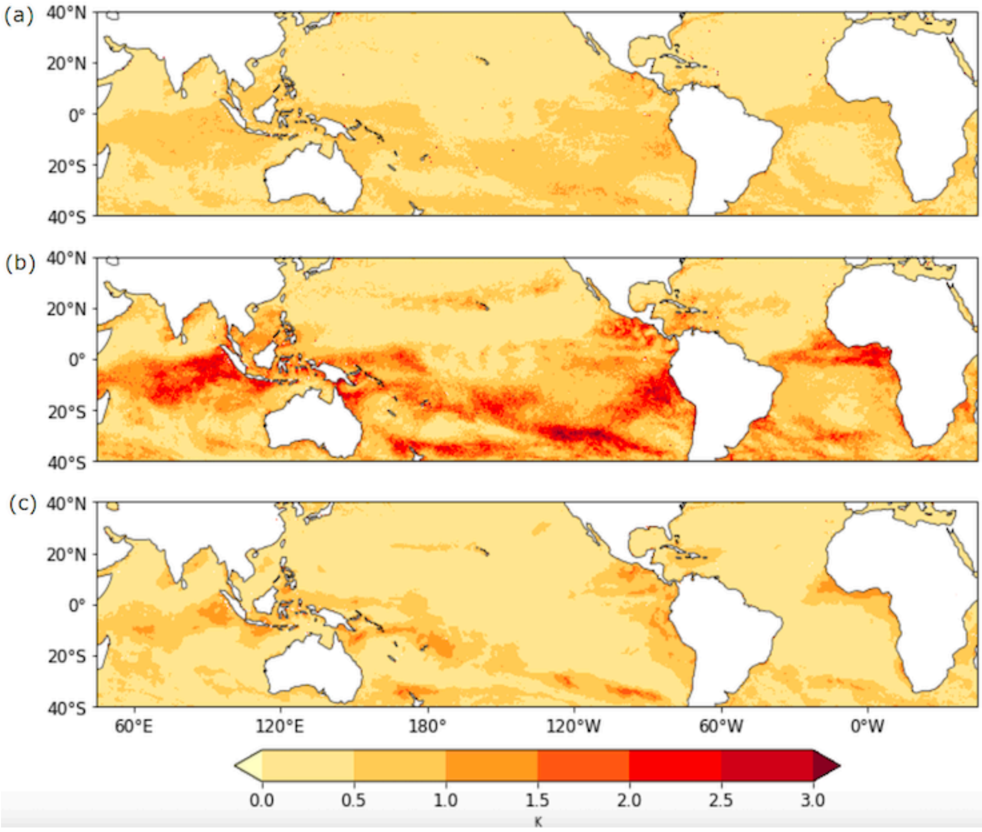


Figure 1: DSA averaged over the time period 22-31.01.2020 in (a) the coupled ICON simulation with 128 vertical ocean levels, (b) the coupled ICON simulation with 139 vertical ocean levels, (c) the ERA5 reanalysis (calculated from the skin temperature)

For the impact analysis, we compared the first four days of both simulations, as the deviation due to the natural variability can be supposed to be small. By comparing values of different atmospheric variables in places in the tropics where DWLs of a particular magnitude develop, we could confirm that the presence of DWLs is associated with an increase in the latent heat flux (LHF) of over 20W/m^2 (see Figure 2) and an increase in the integrated water vapour of over 0.4kg/m^2 for DWLs with a DSA between 1.5K and 2K. The impact on the cloud cover (CC) and the cloud liquid water content is also visible, but small and barely statistically significant: for DWLs with a DSA between 1.5K and 2K the increase in CC does not surpass 0.03 (see Figure 2).

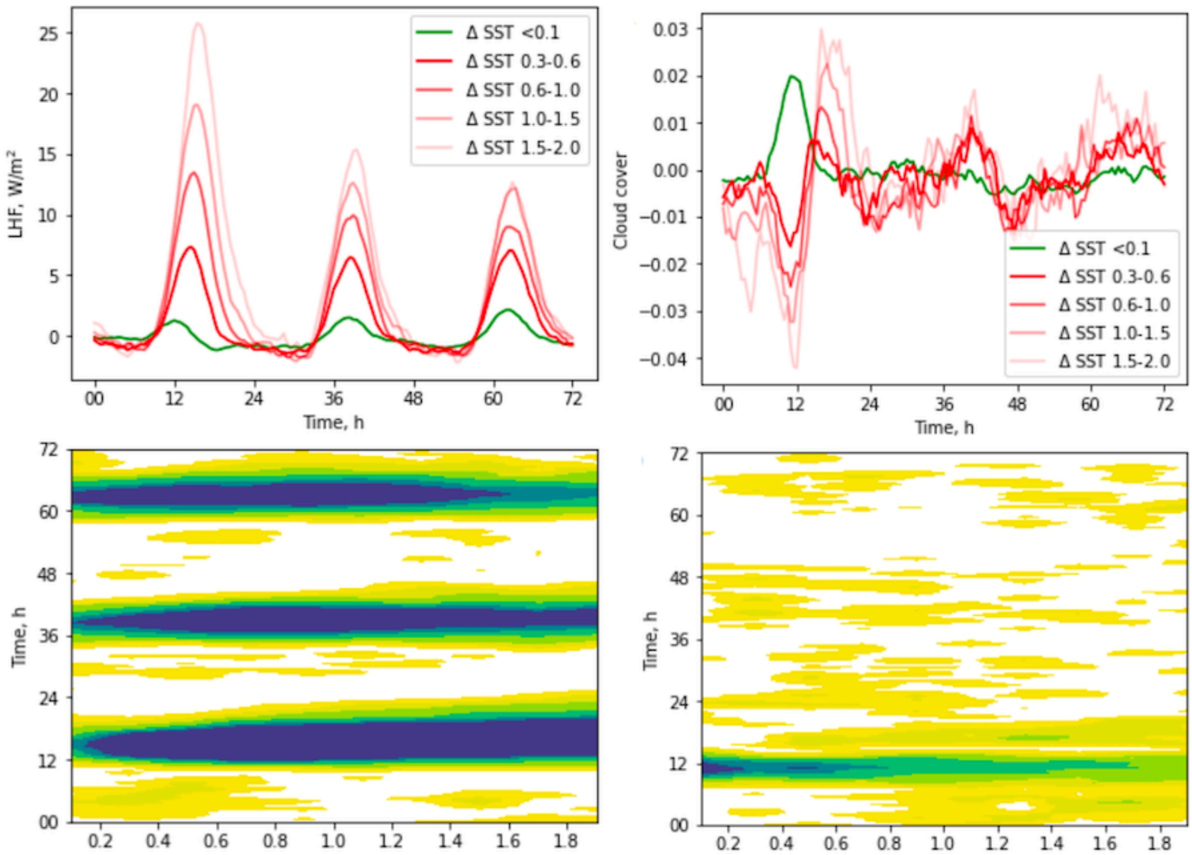


Figure 2: LHF and CC differences between the simulation with finer and coarser ocean layers averaged over areas with a specific SST difference during the first 24 hours (upper plots) and the statistical significance of these differences, white colour signifying that the p value of the t-test is above 0.05 (lower plots). The x axis of the lower plots denotes the maximal SST difference between the simulations during the first 24 hours.

To assess the impact on the diurnal cycle of the cumuli we ran both simulations for 40 days and found that DWLs indeed promote an increase of cloud cover in the afternoon. However, even though in areas with a particularly high DSA a statistically significant change in CC is observed, the impact of DWLs on the global average appears to be small: the difference between the daily averages of CC of the two simulations over the entire area of the tropics is below 0.01.

There are other investigations to be made to understand why the change in LHF does not have a larger influence on the increase in CC and what mechanisms cause this increase. A further step of the study is a validation of the results with 2.5-km coupled runs. See the proposal for details on the planned analysis.