How do ocean temperature anomalies favor the aggregation of deep convective clouds?

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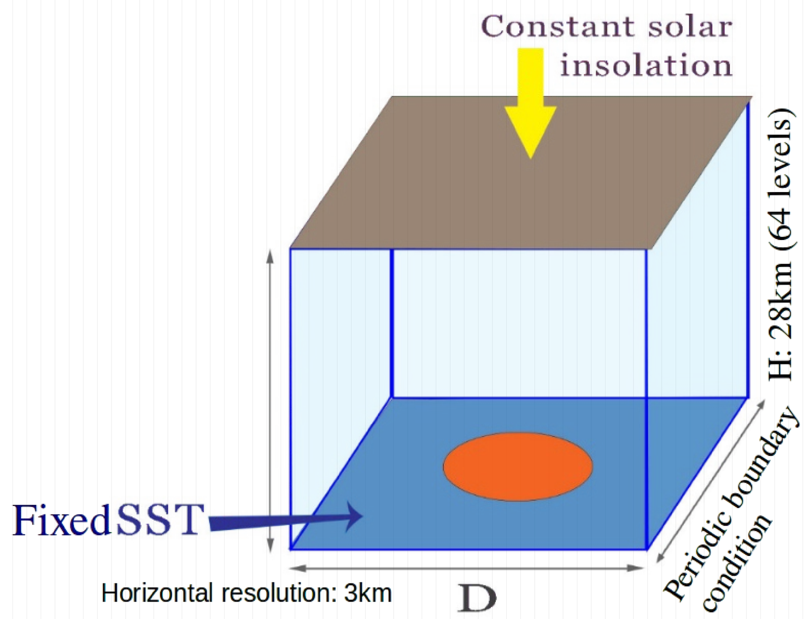
Objective

Convective clouds can sometimes spontaneously aggregate and form large clusters in high-resolution cloud-resolving simulations (Wing et al 2017). The aggregation of convective clouds significantly changes the water vapor profile, precipitation pattern and the mean radiative cooling of the domain.

Ocean warm anomalies (warm eddies, islands) can be favorable areas for the aggregation of convection, as they form a low pressure zone, yielding convergence of near-surface moist air from the surroundings (Cronin et al 2014). Ocean warm anomalies, which we refer to as hot spots, thus redistribute moisture, clouds and precipitation. A natural question then is: how these hot spots favor or accelerate the aggregation of deep clouds?

Simulation set-up

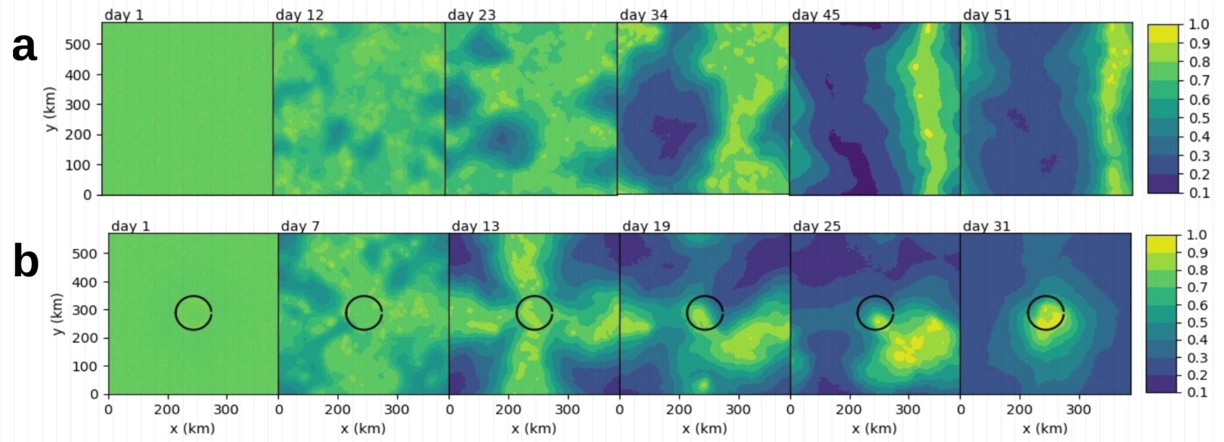


We perform 3D simulations using a cloud resolving model (System for Atmospheric Modeling) .

The hot spot (red area in the figure) is represented as an area with higher temperature than the surrounding area (blue area).

The surface temperature is fixed over both the hot spot aand the ocean. The hot spot temperature anomaly (dT), its Radius (R) and the domain mean sea surface temperature (SST) are the control parameters.

How does a hot-spot impact the organization of convection?

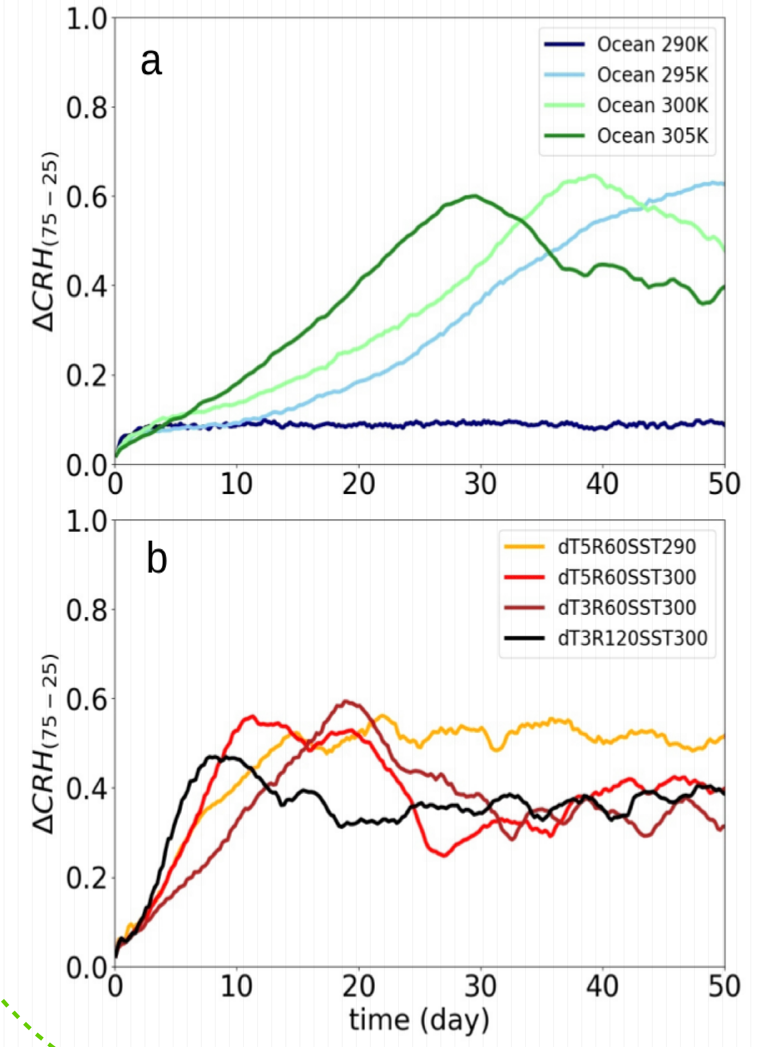


Column integrated relative humidity for: a. fixed and uniform SST at SST=300 K. b. hot spot simulation with radius=60 km and temperature anomaly = 5 and mean SST=300 K.

The main features of aggregation in the hot-spot simulation are the same as uniform SST simulation except that the hot-spot significantly accelerates the aggregation.

The different radiative profiles in dry and moist area creates a feedback that has been found to be important for aggregation. The increased radiative cooling over dry areas leads to their expansion, creating large dry patches and aggregated moist convection.

(Self-) Aggregation with radiative feedbacks



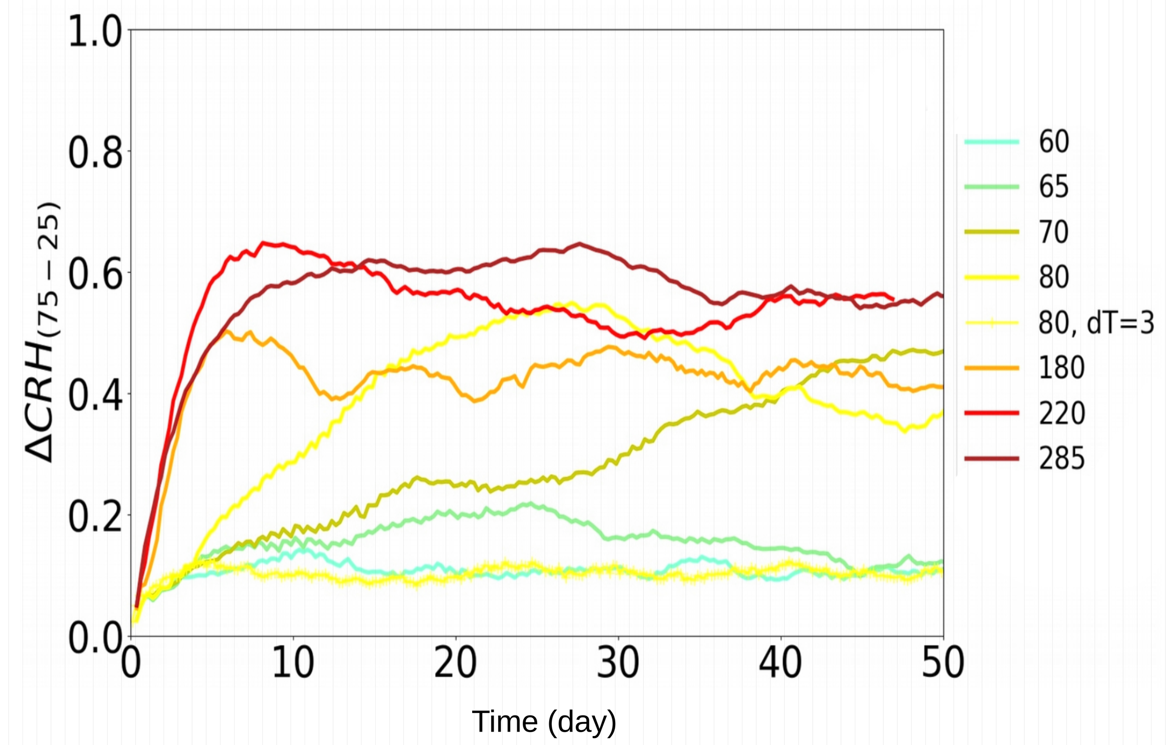
a. Aggregation index time series for fixed and uniform SST at different SST.

Self-aggregation occurs only for SST > 295 K and is faster for higher SST.

b. Aggregation index time series for hot-spot simulations

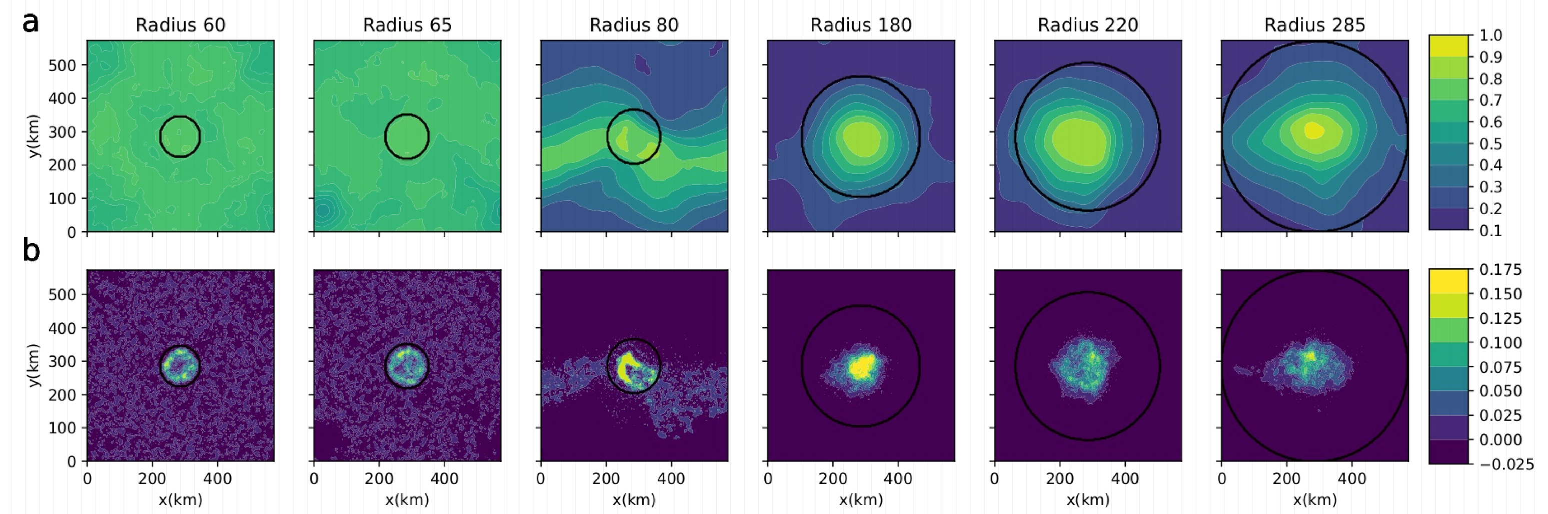
The acceleration of aggregation depends on the hot-spot temperature anomaly and on its radius. The larger/warmer the hot-spot the faster the aggregation. A hot-spot can also extend the range of domain mean SST for which aggregation is favored.

Hot-spot aggregation without radiative feedbacks



Aggregation index time series for hot-spot simulations with dT=5 and mean SST=300 K.

We remove the radiative feedbacks by horizontally homogenizing the radiation at each time step. The figure above shows the aggregation index for different hot-spot radius. With a hot-spot, we find that the aggregation can occur even in the absence of radiative feedbacks only if the hot-spot is warm and large enough.



a. CRH and b. W500 (m/s) averaged between day 35 and day 50 of the simulations for hot-spot of different sizes (the plot on the top).

The convection over the hot-spot is stronger than over the environment but for aggregation to occur, the hot-spot should be large enough to build up a large scale circulation which suppresses the convection in the environment by enforcing a sufficiently strong subsidence drying .

The speed of aggregation can be scaled with the fractional area covered by the hot-spot.