Shallow cumulus parameterisation in the CRCM

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ABSTRACT

Shallow cumulus are ubiquitous over the tropical ocean and mid-latitude summer time boundary layer. They impact the thermodynamic structure of the lower atmosphere and, through interaction with solar radiation, influence the surface energy budget. In this work, we implement a physically based parameterisation of shallow cumulus cloud fraction and couple this with the Bechtold-Kain-Fritsch convection scheme. The scheme is incorporated into the 3D Canadian Regional Climate Model (CRCM) and the representation of shallow cumulus convection and associated cloud fields evaluated over the tropical Pacific following the Pacific Cross-Section Intercomparison (GPCI) experiment protocol.

1 SHALLOW CLOUD COVER PARAMETERISATION

Albrecht's parameterisation assumes that the decay time of shallow cumulus controls their fractional cloud cover. This decay time depends on the difference of humidity between the cloud and its environment. The total specific humidity of the shallow convective cloud is the sum of q_0, the vapor in the convection plume, and l_0, the liquid water in the plume. The mean specific humidity in the parcel $\bar{q}$ is used to represent the environment, and $\bar{q_s}$ denotes the mean saturation specific humidity. Two variables are then defined:

- the mean relative humidity in the parcel $RH = \frac{\bar{q}}{\bar{q_s}}$
- the virtual relative humidity of the cloud if all water is evaporated at constant temperature $SR = \frac{q_0+l_0}{\bar{q_s}}$

The cloud cover (σ) is computed as the ratio between the virtual sursaturation of the cloud and the difference of relative humidity between the convection cloud and its environment:

$$0 \leq \sigma = \frac{SR-1}{SR-RH} \leq 1 \qquad (1)$$

2 GPCI EXPERIMENT IN THE CRCM

We implement this parameterisation in the CRCM, following the GPCI experimentation. We see the region of study in figure 1: the simulation grid is in navy blue and , in clear blue, is the results region: the rectangle for the 2 dimensions variables and the dotted line for cross-sections.

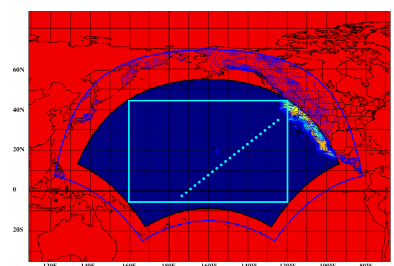

Figure 1: Region of study for the GPCI experiement.

Only cross-sections will be presented and compared to the ECMWF reanalysis (graphics taken from the paper of Siebesma and al. [1]). The period of interest is June, July and August 1998 (JJA98). CRCM uses a 180km resolution grid at 60^oN, with 29 vertical levels and 15mn timestep.

Looking at figure 2, which represents the subsidence ω, 3 regions are distinguishable: from mid-latitudes to 29^o is a region of strong subsidence (R1), after which we have light subsidence, corresponding to the shallow convection region (R2), up to the region of deep convection (R3). The latitudes at which these regimes happen are in accordance with the ECMWF reanalysis, so we know we have shallow convection happening in the good regions.

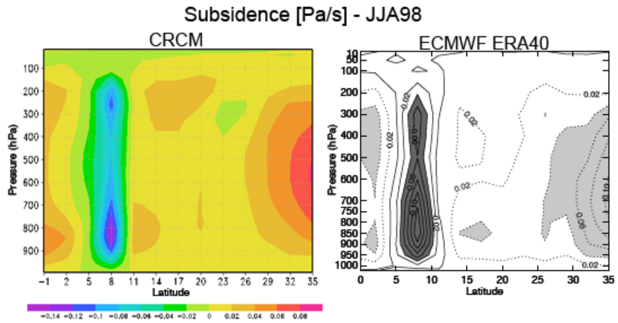

Figure 2: Subsidence for the CRCM and ECMWF reanalysis.

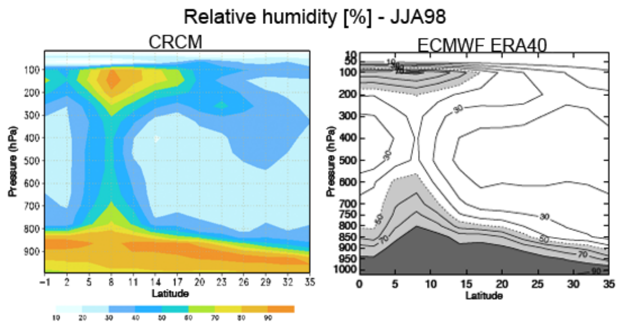

Figure 3: Vertical profile of the relative humidity for the CRCM and the ECMWF reanalysis.

Figure 3 shows that, for the R2 regions, the relative humidity is overestimated by 10% at the top of the boundary layer, and underestimated by 10% at the surface. Similarly, the liquid cloud water is overestimated in the same regions (not shown), and impacts directly the cloud cover (figure 4) which is overestimated by 15 to 20% in these regions. According to the results in the paper of Bony and Dufresne [5], the shallow clouds cover (figure 5) is overestimated by 15%, and is probably the main contribution to the overall cloud cover overestimation.

3 Discussion

In this work, we tested a diagnostic parameterisation of the cumulus cloud cover. This parameterisation is physically related to the shallow convection, and therefore influenced by its parameters, mainly the humidity. It appears that Albrecht's parameterisation gives a reasonably accurate representation of the cloud cover in a parcel. The cloud cover is overestimated by approximately 15%, which seems to be directly related to the vertical distribution of the humidity of the shallow convection. The integration of such a parameterisation in a Regional Model is important for the transferability, particularly in the Trades where the shallow convection is the dominant regime.

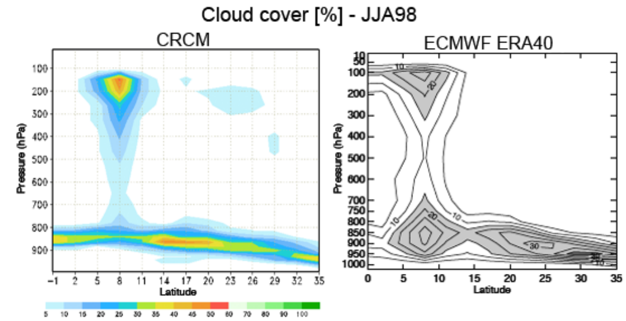

Figure 4: Vertical profile of the cloud cover for the CRCM and the ECMWF reanalysis.

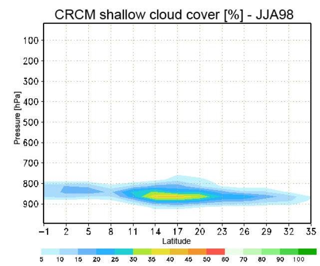

Figure 5: Vertical profile of the shallow cumulus cloud cover for the CRCM

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