Ultra-high resolution modeling of the tropical atmosphere

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1.Backgrounds

In spite of its crutial importance in the energy and hydrological cycle of the earth's atmosphere, due to its smallness in temporal and spatial scales, cumulus convection is only implicitly represented by way of parameterization in most of the GCM's. As a result, many ambiguities are introduced to the climate modeling. However, estimated computational resource requirement for cumulus resolving GCM exceeds 1,000,000 times that of the present day supercomputers, making such attempts almost impossible in the near future. Still, more thorough understandings of cumulus convection are heavily desired. Here, I try such cumulus resolving calculation in a highly limitted framework.

2.Methods

In order to survey possible behaviors of such ultra high resolution atmospheric models, a two-dimensional large-domain cloud model is constructed. Its high spatial resolution (2km) and inclusion of cloud microphysical processes allows cumulus convection to be represented explicitly. At the same time, it covers 16384km, which is as large as the longitudinal size of the pacific. The time marching is continued 10days or longer.

3. Results

A number of model simulations with various set-ups are done, but only one example is presented here. More complete decriptions of the results will be presented in Nakajima(1993).

a) 16384km WISHE experiment

As a mechanism for 30-60day oscillation of the tropical atmosphere, Emanuel(1987) and Neelin *et al*(1987) proposed so-called WISHE — wind induced surface head exchange mechanism, that is, large scale wave disturbance can amplify through the horizontal inhomogeniety of energy flux from underlying ocean induced by horizontal wind anomaly constituting the wave disturbance itself. The theory predicts that such waves should propagate to the upwind direction of the mean low-level wind. Although original theories are considered in three-dimensions, it is evident that the mechanism can work also in two-dimensional set-up.

In order to activate WISHE mechanism, easterly mean wind of 3m/s is introduced. Initial condition includes a weak anomaly in low level moisture field, which excites wave number one modulation in the cloud development. The experiment is continued to 18days. 135MB storage and 34hour CPU time were required using SX-3.

b) Large-scalce structure

Fig. 1 shows the time evolution of precipitaion intensity. Just after the beginning of the simulation, a great many clouds develop. A weak wave number one inhomogeniety of the cloud density due to the initial moisture anomaly is evident. After about one day, the inhomogeniety grows, and cloud development becomes restricted to half of the domain. In the following several days, precipitation further concentrate to a region whose width is about 3000km. At the same time, phase propagation to the east (upwindside) becomes quite pronounced. The propagating large-scale precipitation region continues to amplify in the remaining interval of the simulation. Its propagation speed is about 21 m/s. Evaporation (not shown) is enhanced in the eastern side of the precipitation region, whereas it is suppressed in the western side.

Fig.2 (a-d) show the time mean of the horizontal wind, temperature, specific humidity and rainwater mixing ratio, taken referring to the coordinate frame that follows the propagating disturbance. Low level wind, converging to the concentrated precipitation region, is easterly in the eastern side. Because the mean low level wind is specified to the easterly, the absolute wind speed takes maximum there, contributing to evaporation enhancement. Some of the moisture supplied there accumulates in the surface mixed layer, where maximum humidity lies just before the precipitation region. The temperature field contains low level signature resulting from the inhomogeneous surface heat flux and upper level wave number one distribution that is consistent with the propagating wind distribution. Overall structure described above seems to be grossly in agreement with the predictions of the WISHE theories.

c) Substructures in WISHE wave

Close examination of the result reveals rich hierarchical structure. If fig.1 is carefully examined, the 3000km scale precipitation region is seen to be composed of a number of line-like feature, which have life time of a few days. Fig.3 shows a close-up of such O(100 hour) time scale structures, which are now resolved into smaller scale subsystems of O(10 hour) lifetime and O(100 km) width. As shown in fig.4, these are composed of further smaller scale convection elements whose lifetime is O(1 hour). These hierarchical structure in the model bears close resemblance to the hierarchicy found in the real atmosphere.

4.Conclution

Even in two-dimension, farely realistic space-time structure of moist convection is found to be reproduced. These model can provide unique dataset which covers wide area with uniformly high resolution that will never be accessible by observations

Figure 1: Time evolution of rainfall intensity. All of the 16384 km domain is shown. Time goes down from 0 h to 432 h.

of the real atmosphere. Considerning its potential contribution to theoretical, observational, and application meteorology, these two-dimensional ultra-high resolution modeling should be persued even if we cannot clearly say when three-dimensional modeling become possible.

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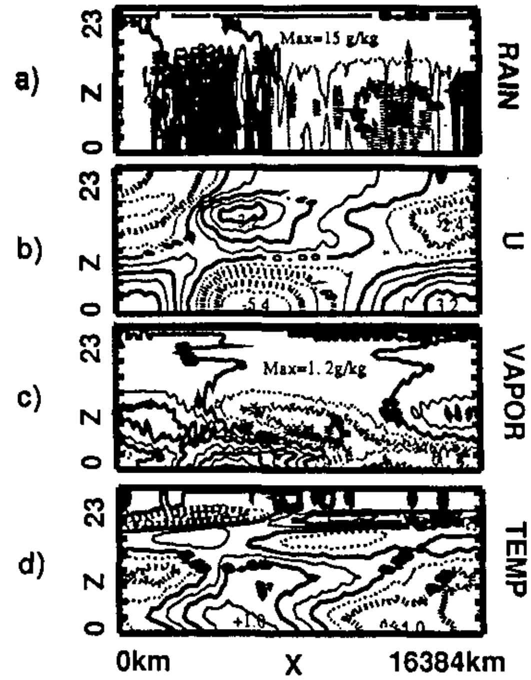

Figure 2: composite structure of disturbance.

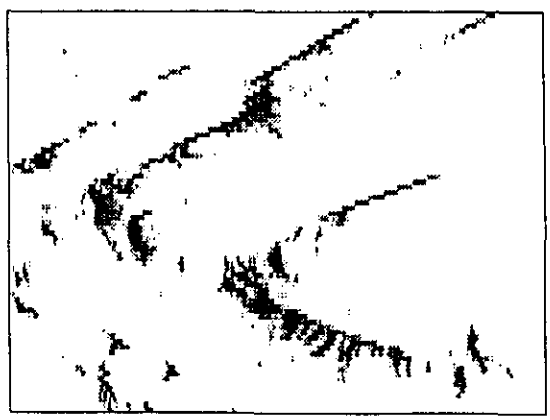

Figure 3: Rainfall in X:7394-8454km T:226-303 h.

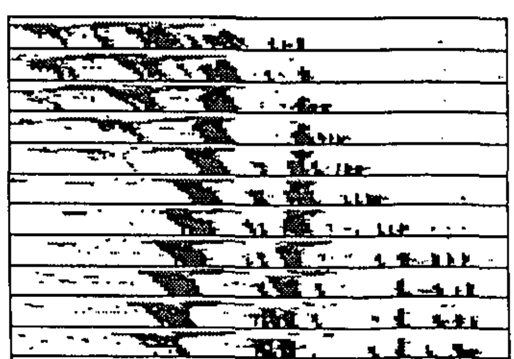

Figure 4: cloud evolution with 20 minutes intervals. (X:7900-8200km T:288h-292h.)