Behavior of Convective Activity over the "Jovian-type" Aqua-Planet Experiments

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1. Introduction

Condensation heat released in the cumulonimbus over the tropics is one of the major driving force for the atmospheric general circulation. As the ocean circulation is also driven by the wind field, its role is very important for climate dynamics. Then, it becomes necessary to understand how convection will distribute under the given boundary condition.

However, there are so many factors to determine the convective activities over the tropics, such as Sea Surface Temperature (SST), stability, land surface condition and land-ocean contrast. Then, it is very difficult to clarify the mechanism by conducting usual numerical experiments (so called twin experiments). Therefore, we are planning to conduct a series of numerical experiments where a simplified boundary condition is used to investigate the distributions of convective activity corresponding to the given boundary conditions (see Table 1).

Table 1: A series of numerical experiments.

	No-int.	Int.	
Aqua-Planet type	x	?	a free mode type response
Desert-Planet type	planning	planning	
Monsoon type	x	on-going	a forced mode type response

There are two type of mechanism to determine the distribution of convection: a free mode type mechanism and a forced mode type mechanism. A free mode type mechanism is the way where the distribution of convection is determined by the internal dynamics of moist atmosphere. On the contrary, a forced type mechanism is the way where it is determined by the physics related to the boundary forcing.

An example of a free mode type response is the Aqua-Planet type experiments as conducted by Hayashi and Sumi (1986). Its purpose is to understand the characteristics of free mode of convection activity distribution. An example of a forced mode type mechanism is the Monsoon type experiment conducted by Sumi (1987). He showed that it exists a specific distribution associated with desert-like land and ocean contrast.

Even for the distribution of convective activities over the Aqua-Planet experiments there may be possible several patterns. Sumi (1989) showed the possible patterns corresponding to the SST distribution (see, Fig. 1). As numerical experiments in the extreme case where there exists the north-south SST gradient (denoted as "Earth-type" Aqua-Planet) has been

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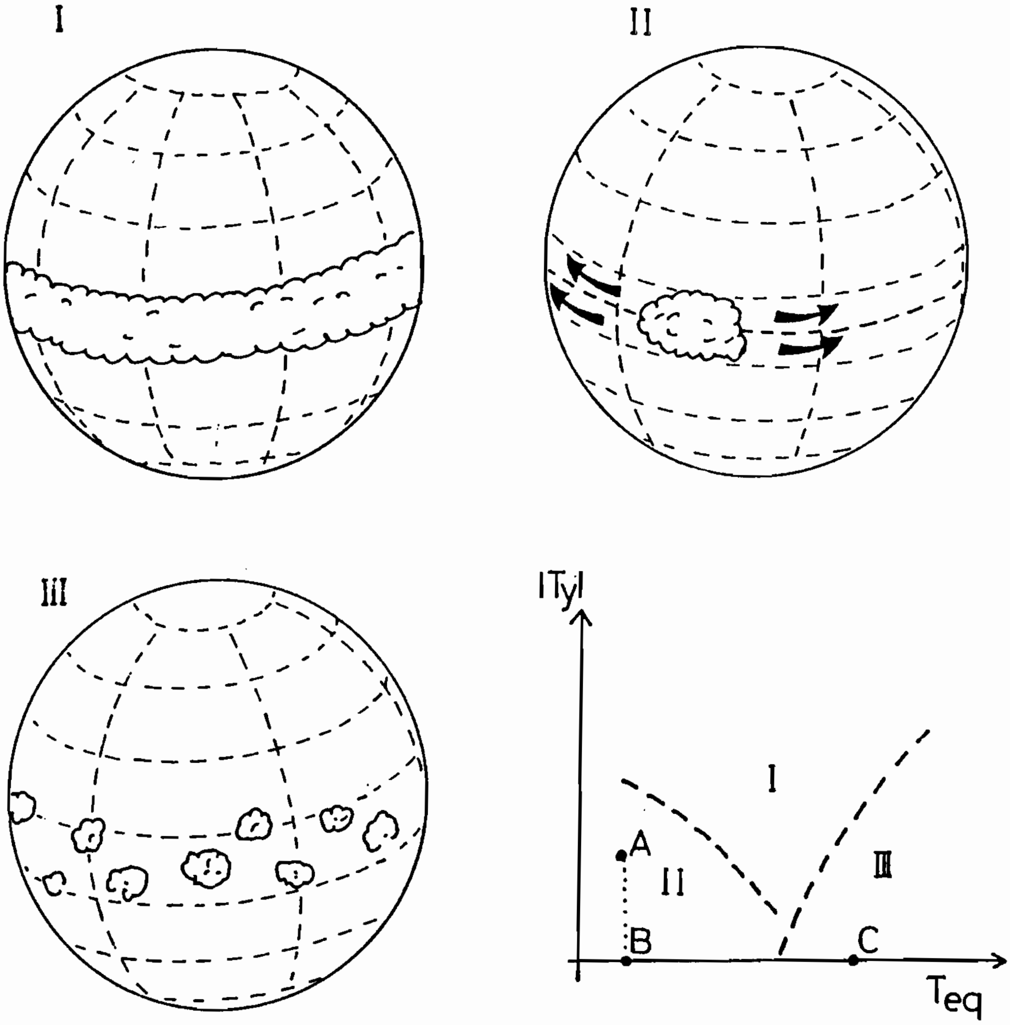

FIG.1. Schematic diagram of various pattern of convection over the "Aqua-Planet". Ordinate is the meridional gradient of SST, and abscissa denotes the magnitude of SST at the equator. A represents the condition of Hayashi and Sumi (1986), and B and C is corresponding to the case described in this paper. Case I represents the zonal distribution of convection over the warmest SST. Case II represents the case where there exists some organization and each cell is propagation eastward or westward. Case III represents the case where convection distributes randomly.

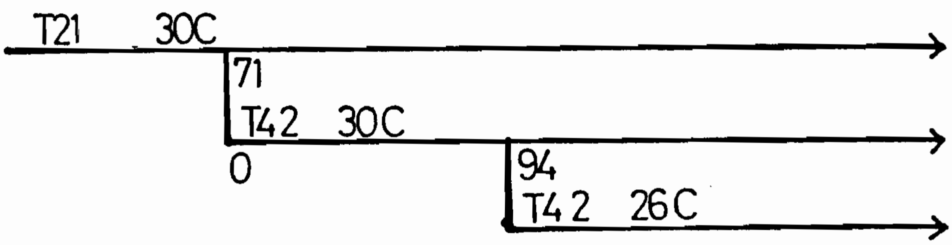

FIG.2. Experimental procedure.

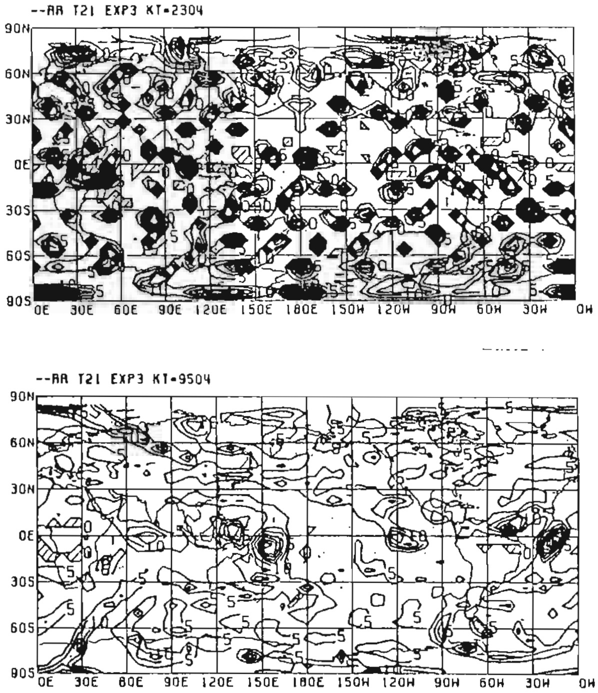

FIG.3. Daily precipitation due to the T21-model. Top is day 25 and bottom is day 325. Unit is mm.(2days)$^{-1}$.

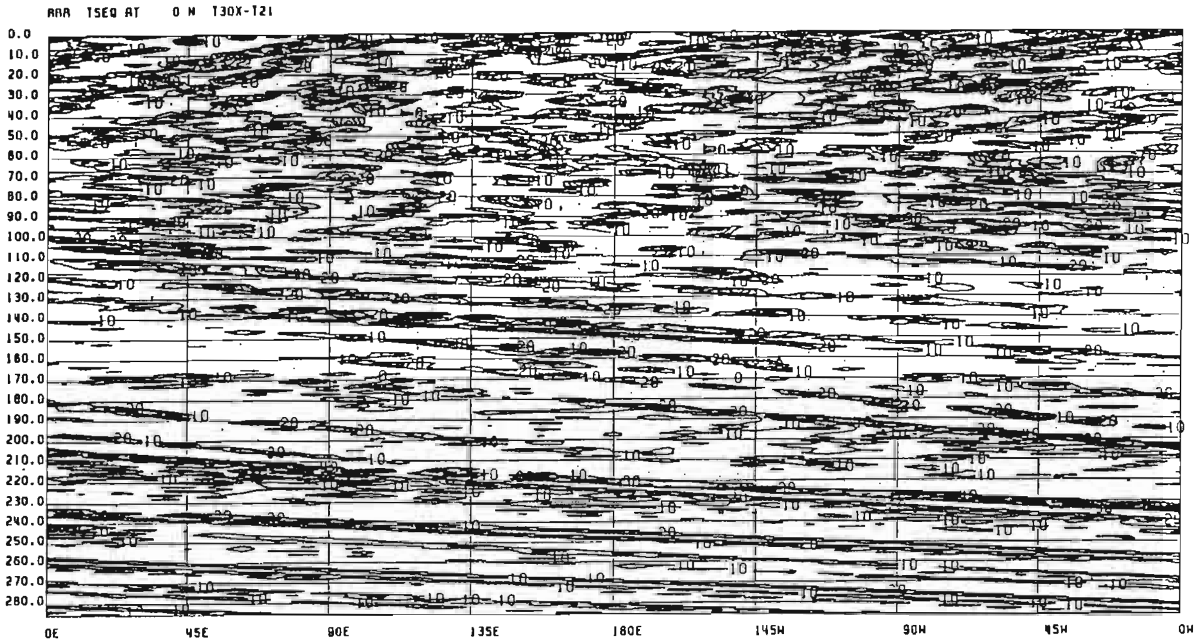

FIG.4. Zonal-time cross-section of daily precipitation on the equator (2.5°N - 2.5°S).

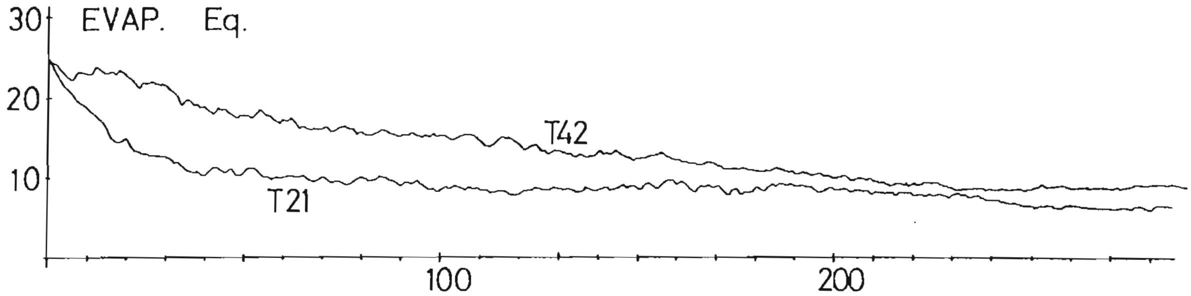

FIG.5. Zonally averaged evaporation for T21-case and T42-case. Unit is 10 W.m^{-2}.

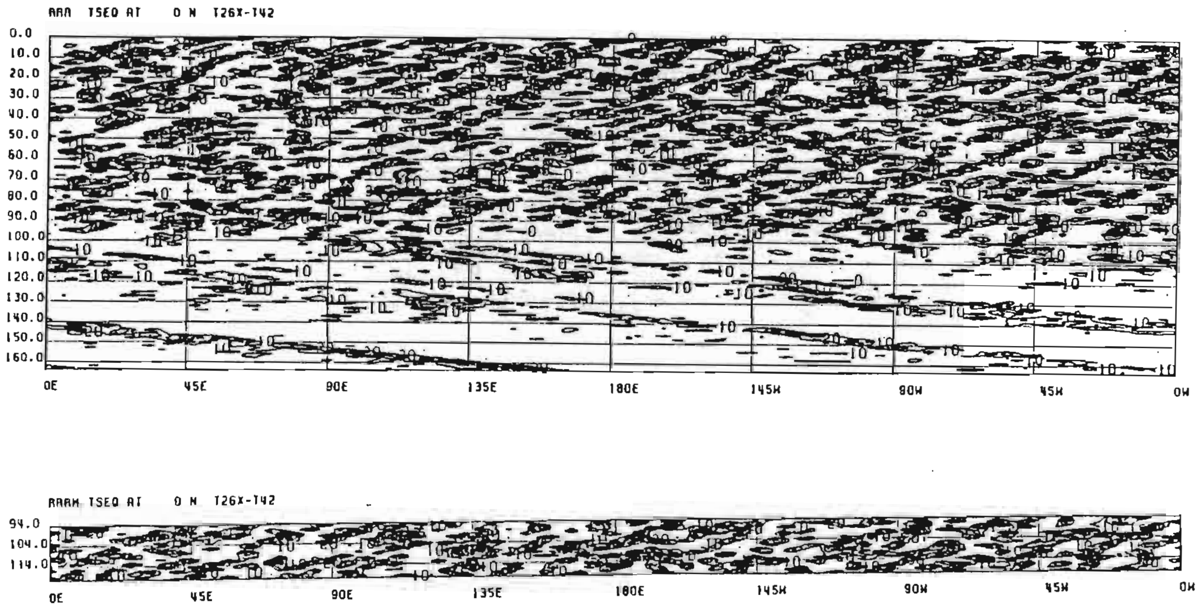

FIG.6. (Top) Same as Fig.4, except for the condition where SST was suddenly decreased from 30°C to 26°C at day 94. (Bottom) Same as above, except that drag coefficients are 10 times multiplied.

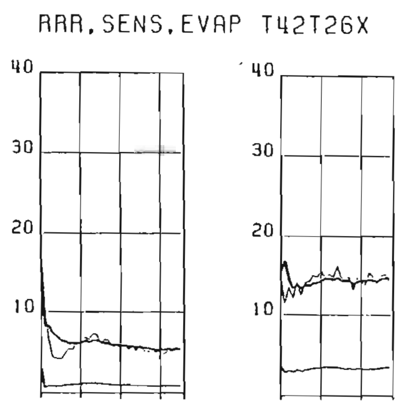

FIG.7. Zonally averaged evaporation rate (thick line). Unit is 10 W.m^{-2}. LEFT is corresponding to the case of 26°C, and RIGHT is corresponding to the case where drag coefficient is multiplied 10 times.

conducted by Hayashi and Sumi (1986), results corresponding to the other extreme where there is no north-south SST gradient (denoted as "Jovian-Type" Aqua-Planet) will be presented in this paper.

2. Experimental Procedure

The experimental procedure is the following:

1) Model is Community Climate Model (Global spectral model) of the University of Tokyo, where the low resolution version (T21) and the high-resolution version (T42) are used.

2) Vertical resolution is 12 levels.

3) Radiational process is simplified. Uniform cooling is assumed to compensate the globally averaged heating at each level. That is, global averaged vertical temperature profile is assumed to be constant.

4) SST is assumed to be 30°C. Later, 26°C experiment has been conducted.

5) Initial state is the zonally and north-south averaged state of analysis of a certain day, and 400 day time integration was conducted by using T21-model. To eliminate the influence of the initial state, day 71 is designated as day 0. T42-model was integrated from day 0 and 26°C experiment was done from day 94 by using T42-model (see, Fig.2). It should be noted that the integration was started from almost April condition.

6) Other physical processes except for radiational process are the same as those in the previous experiments (Hayashi and Sumi, 1986; Sumi, 1987).

3. Results

Results are presented in this section. In Fig. 3, daily rainfall simulated by T21-model at day 25 (top) and day 325 (bottom) are displayed. Apparently, it is clear that the randomly distributed convective activity at the early stage of time integration has been organized to be a few localized convective activities. This change is also noted in the zonal-time cross-section of the daily rainfall on the equator (fig. 4). At the early stage, each convective cell is short-lived, tends to move westward or eastward, and is not well organized. In the later stage, each localized convective cell tends to live longer and finally it starts to propagate eastward; In the last, a few convective cells are selected and they are moving consistently eastward along the equator.

This feature is also noted in the results of the T42-model. However, in this case it took more time to realize this state. In order to investigate this reason, the zonally averaged evaporation rate was checked (see Fig. 5). It was found that evaporation rate had almost the same value for both cases when organization happened (about day 120 for T21 and day 220 for T42). Then, the reason of this may be considered as follows.

1) As long as sufficient moisture is supplied, many convective cells are possible and distributed randomly.

2) However, once moisture supply is below a certain level, a few convective cell is selected. Then, as environmental condition is consistent with movement of a convective cell, it starts to propagate further and further.

In order to confirm the results described above, additional experiments have been conducted, where SST was suddenly changed from 30°C to 26°C at day 94. Results are shown in Fig.6 (top). Immediately after SST decreased, convective cells have been filtered and two cells have started to propagate eastward. In this case phase speed is approximately 8 $m.s^{-1}$. Apparently evaporation has been decreased (see, Fig. 7 (left)).

To maintain the same evaporation rate of 30°C under 26°C condition, another experiment is carried out with drag coefficients multiplied by ten. The results are shown in Fig. 6 (below). In this case almost similar amount of evaporation rate is realized.

Another interesting aspect is the meridional band structure of rainfall. In Fig.7, the zonal

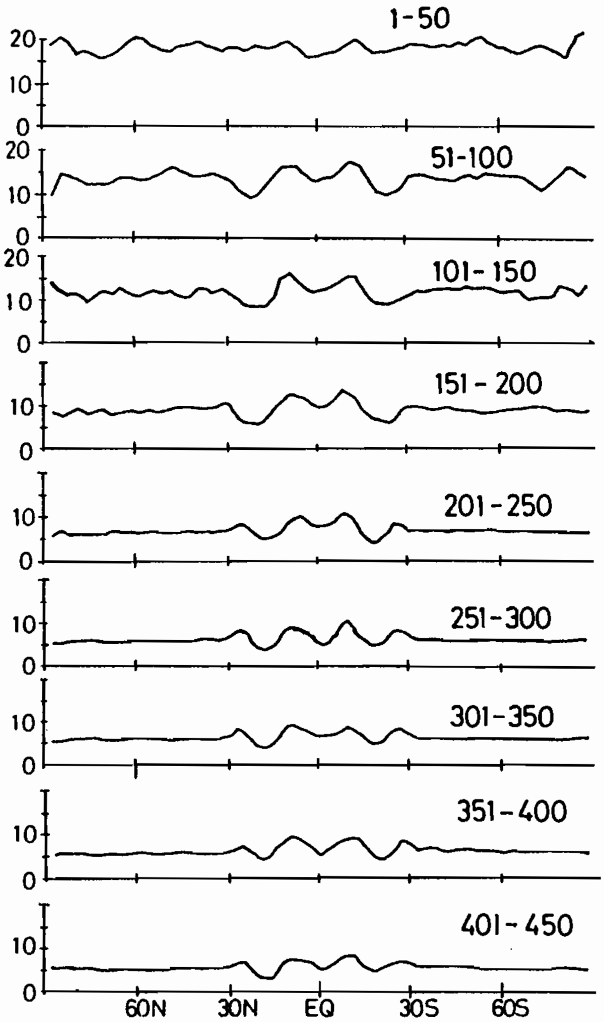

FIG.8. Zonally averaged rainfall in the T42-model.

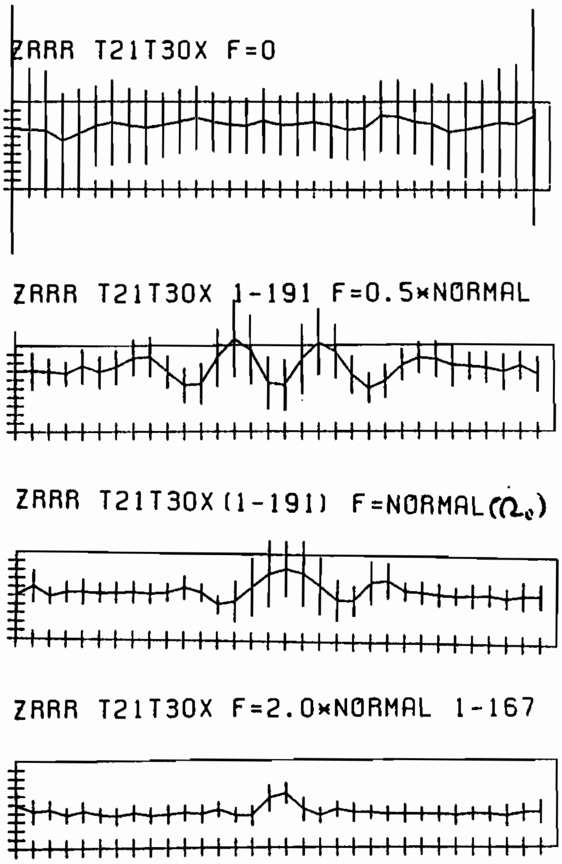

FIG.9. Zonally averaged rainfall corresponding the various Earth rotation rate (Ω_0) is the present Earth rotation rate.

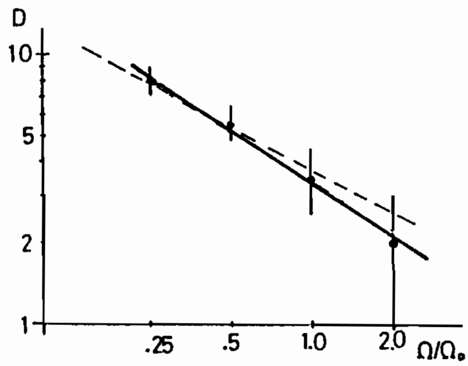

FIG.10. Relation between the location of rainfall minimum and the Earth rotation rate.

averaged rainfall distribution due to T42-model integration is displayed. Maximum symmetric about the equator are noted. However, a single maximum is noted in the T21-model. The reason for this difference is considered as follows:

1) There is a specific pattern of response due to heating in the tropics. However, if meridional resolution is not sufficient, the response in the subtropics cannot be resolved. If sufficient meridional resolution exists, we can resolve this response.

2) However, this does not mean the double ITCZ-like feature is permanent to this condition. It depends on the relative strength between the heating in the subtropics and the heating in the tropics. It is also dependent on the stability of atmosphere and amount of vapour in the atmosphere.

This band structure is supposed to be related to the Earth rotation effect. To investigate this aspect, we have conducted similar experiments where the Earth rotation rate is changed. The zonally averaged and time averaged daily rainfalls are shown in Fig. 9. It is worth noting that as the Earth rotation rate decreases the maximum of rainfall propagates poleward. The relation between the position of rainfall minimum and the rotation rate is supposed to be consistent with the relation as is expected from the formulation of radius deformation in the tropics (see, Fig. 10).

4. Conclusion

The characteristics of distribution of convective activity over the "Aqua-Planet" with the globally uniform SST has been investigated using numerical experiments.

The following conclusions were obtained;

1) As moisture supply decreases below a certain level, convective activity is selected. This filtering occurs only over the tropical area.

2) Convective activity is organized in the zonal-band structure, where its latitude may be related to the Earth rotation effect.

Further experiments will be necessary to obtain a conclusion of the pattern formation of convective activity.

REFERENCE

Hayashi, Y.Y. and A. Sumi, 1986: The 30-40 day oscillations simulated in an "Aqua-Planet" model, *J. Meteor. Soc. Japan,* **64**, 451-467.

Sumi, A., 1987: Characteristics of simulated convective activity over a tropical ocean with zonally uniform SST surrounded by the dry continents, *J. Meteor. Soc. Japan,* **65**, 113-124.

Sumi, A., 1989: Pattern formation of convective activity over the Aqua-Planet with globally uniform Sea Surface Temperature. To be submitted.

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