Vertical Structure of Rainfall from TRMM PR Data for Assimilation in GCM

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1.Introduction

Use of proxy satellite observations for improving the model states of divergence, humidity and temperature has gained considerable impetus in the past one decade. Various researchers (Donner, 1998,Heckley et al, 1990, Krishnamurti, 1990) have used the satellite derived rainfall and moisture fields ameliorating the spin up problem in the tropics. Physical initialization methods (Pal et al, 1999) have shown the feasibility of correcting latent heating locations in the model by assimilation of observed rainfall during initial phase of model integration.

The rainfall being a representative of integrated column heating cannot be directly assimilated into the model, because the model requires the heating profiles for different levels. In earlier studies in the absence of observed vertical profiles, modelers have derived the profiles from the total rainfall by creating a background profile from the model statistics over a large area. Separate profiles have been generated for land and oceans, because rain has different characteristics over different surfaces.

At present the vertical profile of rainfall has started becoming available from the precipitation radar (PR) in space onboard TRMM satellite. This gives an opportunity to study the vertical structure of rain corresponding to a particular rain-rate. In future Global Precipitation Mission (GPM) and Indo-French Megha-Tropiques satellite missions will provide rainfall observations. Microwave analysis and detection of Rain and Atmospheric Structure (MADRAS) sensor will provide the measurement of precipitation over land as well as over the sea.

Here we have attempted to derive the vertical structure of convective and stratiform rain using TRMM Microwave Imager (TMI) and PR combined data set. The combined data derives vertical hydrometeor profiles using the data from PR and 10 GHz channels of TMI. The vertical structure derived from these data sets can be used to determine the vertical profile of latent heating using the rain measurements from MADRAS sensor of Megha-Tropiques. The heating profile can directly be assimilated in general circulation model for dynamic physical initialization.

2. Data and Methodology

For the present study vertical hydrometeor profiles of TRMM has been used. We have used standard 2B31 product of TRMM scientific algorithm. This algorithm is referred to as "TRMM Combined" & it derives vertical hydrometeor profiles using data from PR & the 10GHz channels of TMI. Also this gives the surface rain-rates corresponding to each profile. Along with 2B31, PR qualitative product (2A23) was also used to separate out convective and stratiform type rains. In this algorithm if the rain is present then it will detect the Bright Bands (BB), determine the heights of BB and the storm and classify the rain types into convective and stratiform. The period for which the above data was used is between 11-14 July 2000 which accounted for 50 passes of TRMM.

The orbits belonging to above-mentioned period were processed and vertical hydrometeor profiles were extracted along with the convective stratiform flags from 2A23 product. In order to understand the average behavior of rain profiles for convective and stratiform situations, rain profiles corresponding to a particular surface rain-rates were separated out and further they were separated taking into account the rain-type they belonged to (convective or stratiform) using the rain flag information.

3. Results

Vertical Hydrometeor profiles for the above period were obtained separately for land and oceans. Fig1 (a). Shows one such profile of convective situation over Ocean corresponding to 10mm/hr surface rain. This profile represents rainfall accumulated from each layer. Fig1 (b) shows the profile for stratiform case over land again corresponding to 10 mm/hr surface rains. Evaporation between various layers is reflected very well from the profiles where the lower layers have less rainfall as compared to layers above it.

In this study we examined the average behavior of rain profiles and corresponding latent heat profiles. For this we analyzed data of around 50 TRMM passes and separated out convective and stratiform situations over land and oceans. Most of the rainfall during that period was convective. This may be due to the monsoon period in which most of the rainfall occurs due to convective systems. Fig2 (a) shows the average profile of accumulated convective rainfall over oceans. This profile doesn't show any evaporation in the intermediate layers as was seen when we saw individual profile (Fig1 (a)). Whereas averaged profile of stratiform rain over land (Fig2 (b)) does show some evaporation in the layers, which was also seen, in the individual profile (Fig1 (b)).

From TRMM we get the accumulated rainfall rates from each layer. In order to know the contribution of rain from each layer we subtracted the accumulated rainfall coming from the above layer. Rain profiles corresponding to convective situation over oceans for surface rain rate 10mm/hr were averaged and the averaged profile is shown in Fig3 (a). It can be seen that the convective rain is coming from a thick layer and the maximum rain comes from the layer 5 Km above the surface. We also calculated the heating produced by this precipitation in the vertical layers and the heating profile corresponding to Fig 3 (a) is shown in 3(b). Maximum heating comes from the layer where there is maximum precipitation due the latent heat release. Similarly the averaged profile for the stratiform situation over land was also obtained which is shown in Fig4 (a) and the corresponding heating rates in fig 4(b). We can see negative value of rain rate in a layer around 3.5 Km high above the surface. This represents evaporation of moisture from that layer and the corresponding heating rate profile shows cooling at that height.

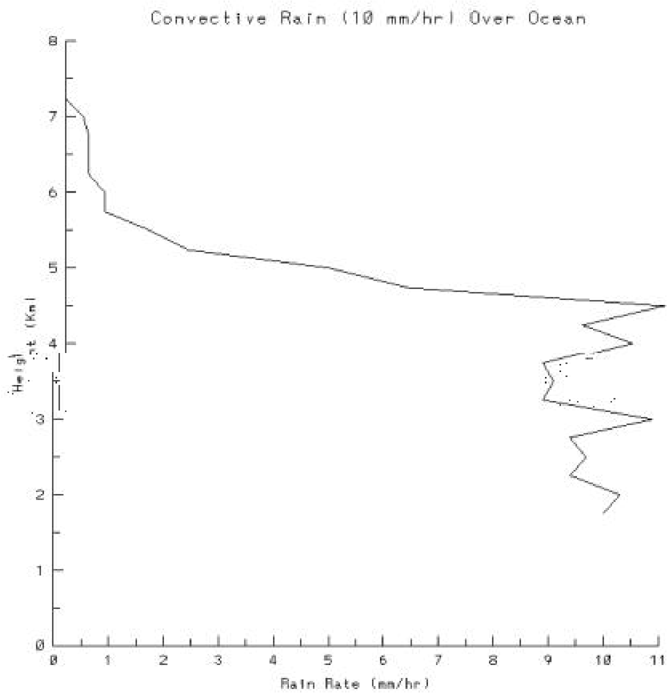
Also the maximum rain rate here too comes from a thin layer at about 5Km from the surface.

Fig 5 shows the heating profiles for various cases corresponding to 10mm/hr surface rain rate. We can see that over land the profiles for both convective and stratiform situation have a single peak whereas over oceans double peaks are seen.

4. Conclusions

Average vertical structure of rain profile has been estimated from the combined PR and TMI data of TRMM. Average characteristics profiles show that the convective

Fig 1(a)



Convective Rain (10 mm/hr) Over Ocean
0
1
2
3
4
5
6
7
8
0
1
2
3
4
5
6
7
8
9
10
11
Height (Km)
Rain Rate (mm/hr)

Fig 1(b)

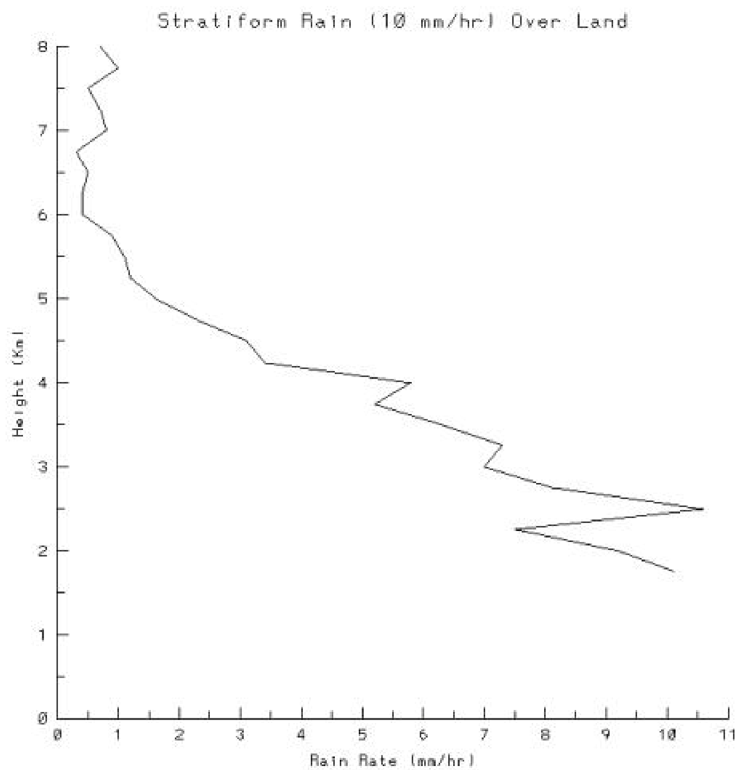
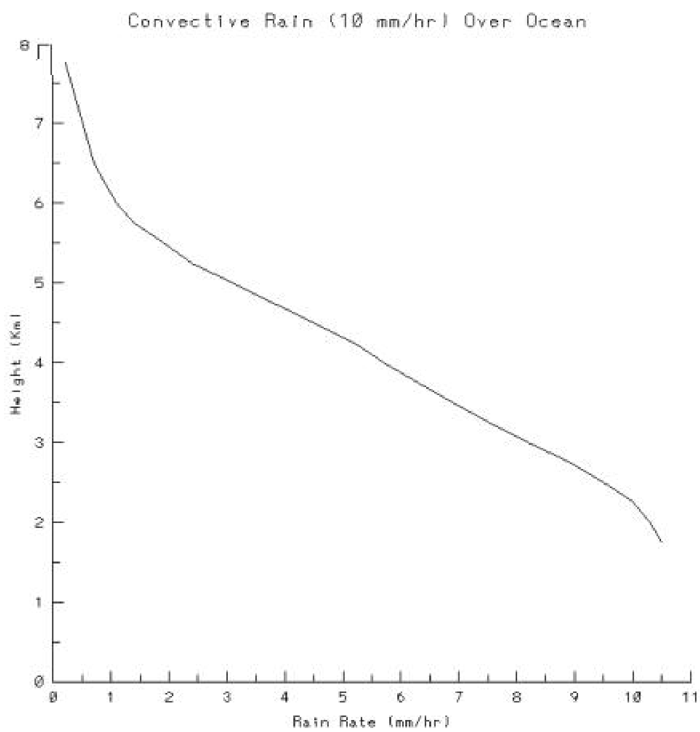

Stratiform Rain (10 mm/hr) Over Land
Height (Km)
Rain Rate (mm/hr)
0
1
2
3
4
5
6
7
8
9
10
11

Fig 2(a)



Convective Rain (10 mm/hr) Over Ocean
Height (Km)
Rain Rate (mm/hr)
0
1
2
3
4
5
6
7
8
9
10
11

Fig 2(b)

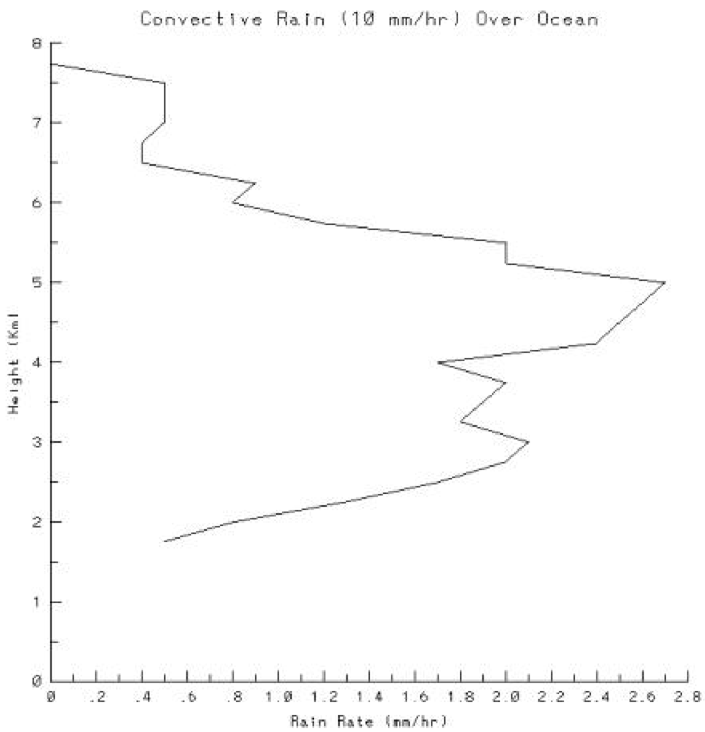

Convective Rain (10 mm/hr) Over Ocean
Height (Km)
0
1
2
3
4
5
6
7
8
Ø
.2
.4
.6
.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
Rain Rate (mm/hr)

Fig 3(a)

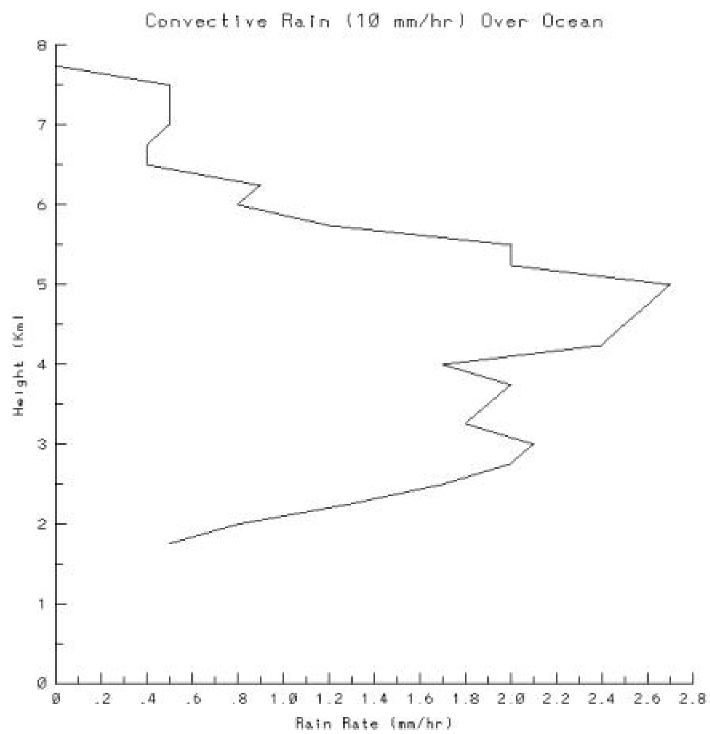

Convective Rain (10 mm/hr) Over Ocean
Height (Km)
Rain Rate (mm/hr)
8
7
6
5
4
3
2
1
0
0 .2 .4 .6 .8 1.0 1.2 1.4 1.6 1.8 2.0 2.2 2.4 2.6 2.8

Fig 3(b)

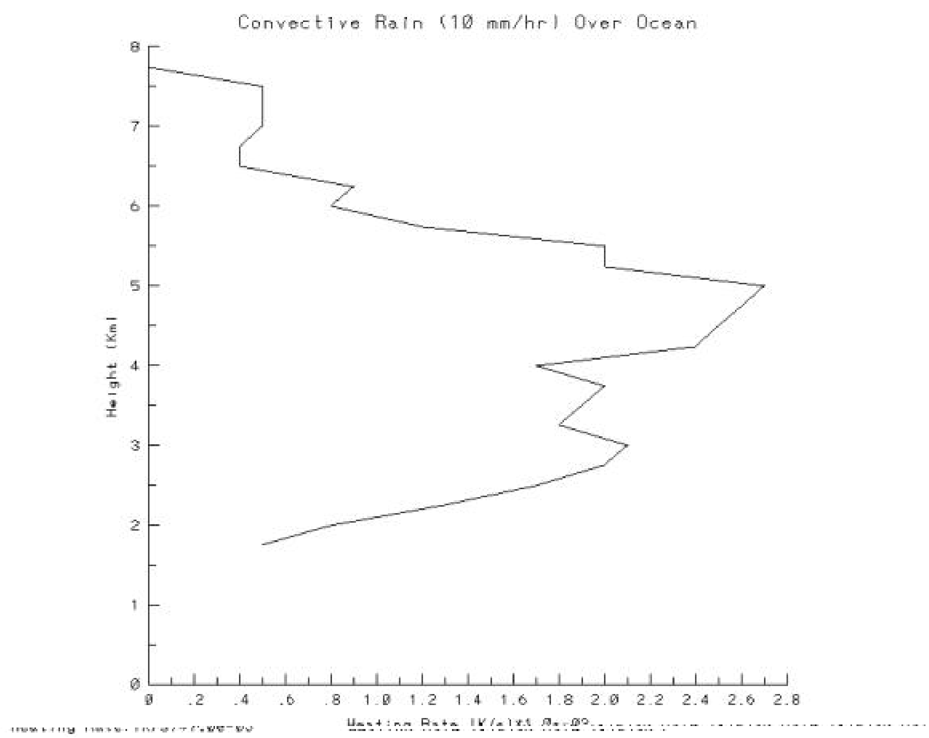
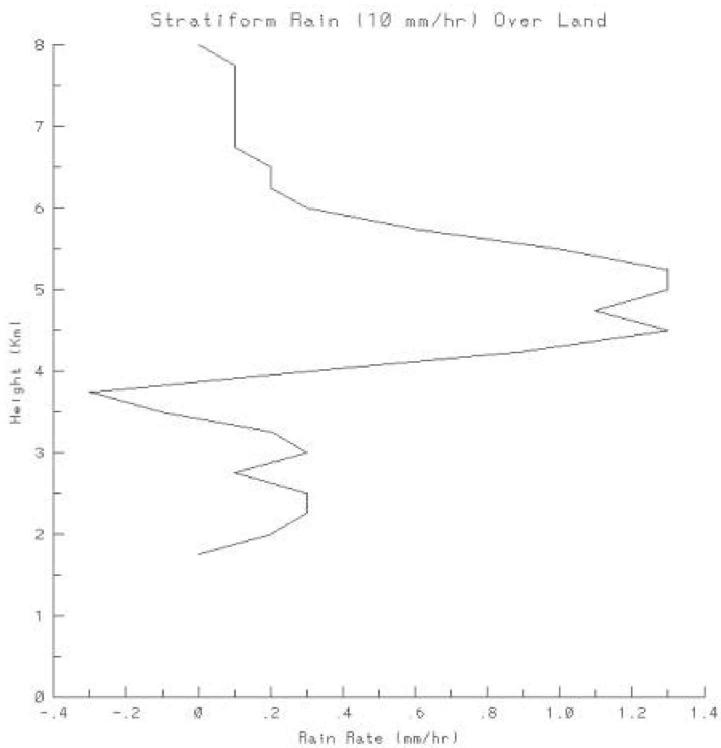

Convective Rain (10 mm/hr) Over Ocean
Height (Km)
0
1
2
3
4
5
6
7
8
0 .2 .4 .6 .8 1.0 1.2 1.4 1.6 1.8 2.0 2.2 2.4 2.6 2.8

Fig 4(a)



Stratiform Rain (10 mm/hr) Over Land
Height (Km)
Rain Rate (mm/hr)
8
7
6
5
4
3
2
1
0
-.4
-.2
0
.2
.4
.6
.8
1.0
1.2
1.4

Fig 4(b)

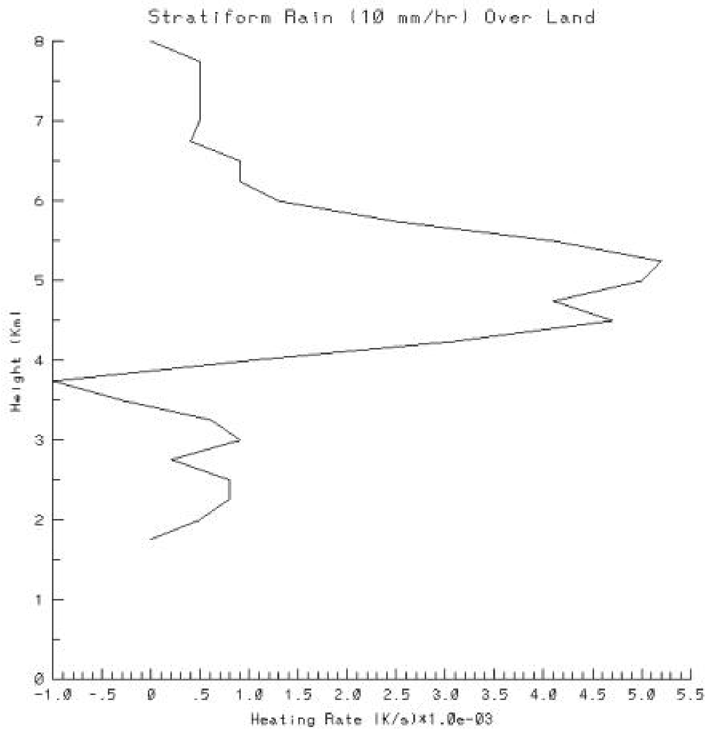
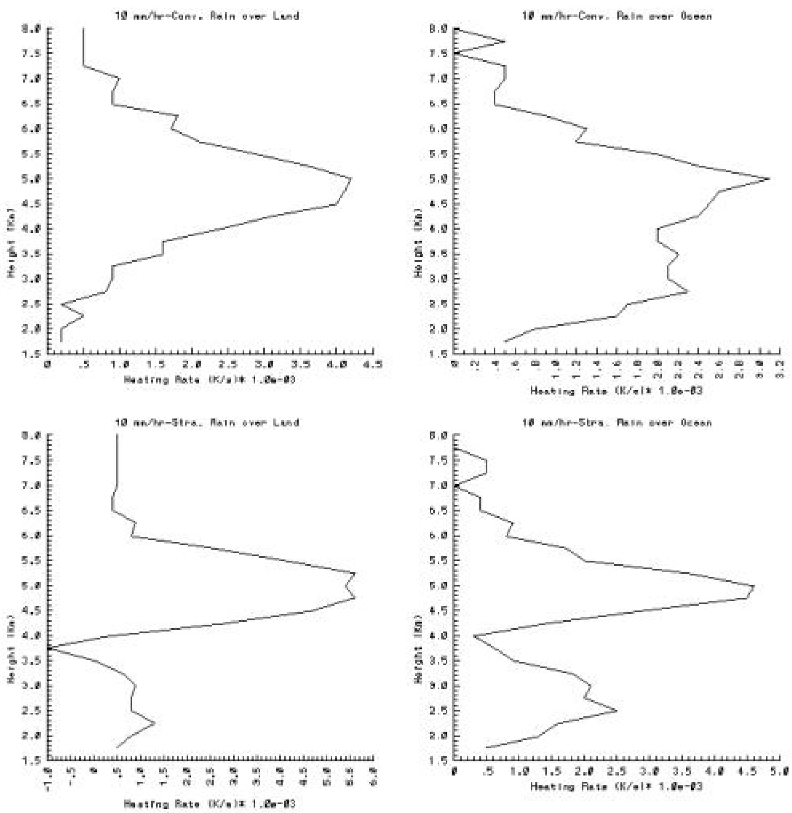

Stratiform Rain (10 mm/hr) Over Land
Height (Km)
8
7
6
5
4
3
2
1
0
-1.0 -.5 0 .5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0 5.5
Heating Rate (K/s)*1.0e-03

Fig 5



10 mm/hr-Conv. Rain over Land
10 mm/hr-Conv. Rain over Ocean
10 mm/hr-Stra. Rain over Land
10 mm/hr-Stra. Rain over Ocean
Height (Km)
Heating Rate (K/s)* 1.0e-03