

# **Observations of convection events and generated high frequency gravity waves over KotaTabang, Indonesia using the Equatorial Atmosphere Radar ( $0.20^{\circ}$ S, $100.32^{\circ}$ E)**

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## **ABSTRACT**

Under coupling processes in the equatorial atmosphere (CPEA) project, the intensive observations were made using Equatorial Atmosphere Radar (EAR), Boundary Layer Radar (BLR), X- Band radar, and other collocated facilities during 10 April - 9 May 2004 over Indonesia – a highly convective region around the globe with one of the objectives to investigate the convection generated high frequency gravity waves in the troposphere and their coupling to the middle atmosphere. This unique suit of observations revealed dominance of day-to-day variability in convection system and its role in forcing gravity waves of different temporal and spatial scale.

## **1. INTRODUCTION**

It is widely recognized among the scientific community that convection in the equatorial region is the main driving force for generating atmospheric gravity waves. The frequency spectrum of atmospheric gravity waves in the equatorial troposphere has a wide range of wave periods starting from few minutes to several hours. Convectively induced gravity waves play an important role in the energy transportation to the upper atmosphere [Horinouchi *et al.*, 2002, Dhaka *et al.*, 2002, 2003, 2005; Song *et al.*, 2003], and in organizing the cloud clusters [Chao and Deng, 1998]. However, the energy transportation by convectively induced gravity waves is not fully understood because observations with high temporal and vertical resolutions have been scarce especially in the equatorial region. Therefore further observational studies in the troposphere are necessary to improve the understanding of gravity wave characteristic and generation mechanism, scale selection of forcing on a particular frequency and wavelength, and the interaction with the background wind flow. We show some typical example of convection and background wind variation and briefly summarize the results.

## **2. DATA**

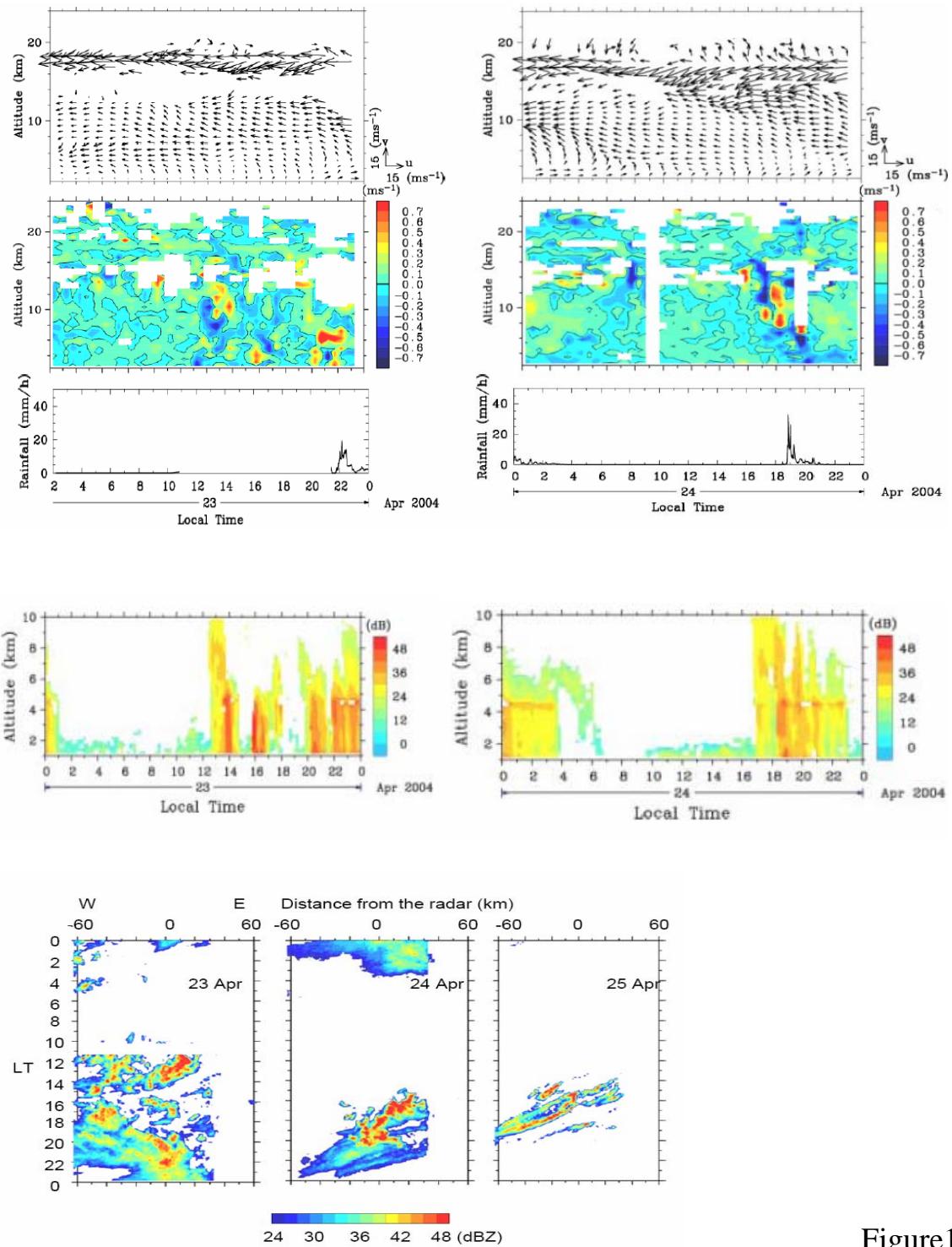
Observational data derived from EAR, weather radar, and radiosonde soundings were used in this study. EAR is a wind profiler operated at VHF-band frequency of 47.0 MHz and peak output power of 100 kW. EAR was installed at Koto Tabang ( $0.2^{\circ}$ S,  $100.32^{\circ}$ E,

865 m above sea level). See *Fukao et al.* [2003] for the system description of EAR. During observation, Doppler velocity data obtained by five radar beams (eastward, westward, northward, and southward with a zenith angle of 10° and vertical) were recorded every 2 minutes with a vertical resolution of 150 m. Doppler velocity data were averaged every 10 minutes for computing the wind components. BLR and X-band radar reflectivity data were used to infer the vertical and horizontal growth of convection. Using radiosonde soundings at Koto Tabang at 6-hour intervals horizontal wind, temperature, and humidity were computed. Blackbody brightness temperature ( $T_{BB}$ ) data derived from GOES-9 (GOES stands for Geostationary Operational Environmental Satellite) was used to investigate the horizontal distribution of large convection around Sumatra (90-110°E longitude).

### 3. RESULTS AND DISCUSSION

We show typical examples of varying horizontal wind and vertical wind along with rainfall on 23 and 24 April 2004 (top panel of the figure 1). BLR radar reflectivity and X-band reflectivity data are shown in the middle and bottom panel, respectively that represents the convection intensity in the vertical and horizontal around EAR region. It is inferred from the figure that horizontal winds get deformed in the troposphere while convection was intense in the vertical. Vertical winds enhanced during convection and were observed with increased magnitude up to 15 km heights. Impact of enhanced vertical wind is seen even up to higher heights in the form of short patches created by small scale gravity waves. Vertical wind remained higher for several hours once they are triggered due to convection formation.

In the middle troposphere, updrafts (upward vertical wind) and downdraft (downward wind) were formed in sequence associated with intense convection from below. One can see from BLR radar reflectivity data that convection crossed the bright band structure (around 5 km) on both days due to strong convection events. As a result the medium becomes turbulent that shoots up the impact of the air mass up to tropopause level. Such kinds of events were also reported at Gadanki, a tropical station, by *Dhaka et al.*, [2002]. Bottom panel shows that convection was organized within 100 km of radar area in such a way that it indicates both east to west and later west to east movement on 23 April. However, on 24 and 25 April convection trails were formed from east to west direction. In such an environment above 14-15 km heights, short vertical wavelength gravity waves are observed. Their upward propagation is depending upon the wind shear present around 20 km height. Dissipation of such gravity waves seems favorable under large wind shear and therefore they assume significance in playing a major role to accelerate/ de accelerate the mean flow. It is therefore highly desirable to prepare the statistics of such events and assess their contribution to control the atmosphere dynamics in the upper troposphere and lower stratosphere (UTLS) region. Following points are summarized from the analysis: Diversity in convection growth was extremely dominant over the Indonesian region. Convection had shown a tendency to grow in the vertical direction up to 10-15 km rapidly with rainfall (typical time was less than an hour).



**Figure 1.**

Upper Panel – Horizontal wind, vertical wind and rainfall, middle panel – BLR radar reflectivity, and lower panel – X- band radar reflectivity data on 23 and 24 April 2004.

In other convection cases, which exclude rainfall, convection growth took place horizontally as well as vertically but not as steep as with rainfall. Gravity waves (oscillations with few tens of minutes) identified above 15 km, were generated mostly in the middle troposphere by strong convection events, which modulated the vertical winds for several hours (about 6-8 hours). The convection impact on vertical wind was clearly seen growing upward from its core up to the tropopause level. In general, gravity waves above convection tend to have dominant periods in the range of 10 –100 minutes with short vertical wavelength 1- 3 km. In addition, the intensity of convection and its shape reflected in vertical winds in the form of updraft is also important to show its impact in forcing the reasonably well-developed gravity waves.

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## References

- Chao W. C. and L. Deng, Tropical intraseasonal oscillation, super cloud clusters, and cumulus convection schemes. Part II: 3D aquaplanet simulations, *J. Atmos. Sci.*, 55, 690-709, 1998.
- Dhaka, S. K. , R. K. Choudhary, S. Malik, Y. Shibagaki, M.D. Yamanaka and S. Fukao, Observable signatures of convectively generated wave field over tropics using Indian MST radar at Gadanki (13.47N, 79.18E) , *Geophys. Res. Lett.*, 29, 1872-1875, 2002.
- Dhaka, S.K., M. Takahashi, Y. Kawatani, S. Malik, Y. Shibagaki and S. Fukao, Observations of deep convective updrafts in tropical convection and their role in the generation of gravity waves, *J. Meteor. Soc. Japan*, 81, 1185-1199, 2003.
- Dhaka, S. K., M.K. Yamamoto, Y. Shibagaki, H. Hashiguchi, M. Yamamoto and S. Fukao, Convection - induced gravity waves observed by the Equatorial Atmosphere Radar (0.200 S, 100.320E) in Indonesia, *Geophys. Res. Lett.*, accepted May 2005, doi:10.1029/2005GL022907, 2005.
- Fukao, S., H. Hashiguchi, M. Yamamoto, T. Tsuda, T. Nakamura, M.K. Yamamoto, T. Sato, M. Hagio, and Y. Yabugaki, The Equatorial Atmosphere Radar (EAR): System Description and First Results, *Radio Sci.*, 38(4), 1053, doi:10.1029/2002RS002767, 2003.
- Horinouchi, T., T. Nakamura, and J. Kosaka, Convectively generated mesoscale gravity waves simulated throughout the middle atmosphere, *Geophys. Res. Lett.*, 29(21), 2007-2010, doi:10.1029/2002GL016069, 2002.
- Song, I.-S., H.-Y. Chun, and T. P. Lane, Generation mechanisms of convectively forced internal gravity waves and their propagation to the stratosphere. *J. Atmos. Sci.*, 60, 1960-1980, 2003.