Interannual variations of cloud system migration with diurnal cycle over Sumatera Island

*Namiko SAKURAI[1], Fumie Murata[2], Manabu D. Yamanaka[1,3], Shuichi Mori[3], HAMADA Jun-Ichi[3], Hiroyuki Hashiguchi[4], Yudi Iman Tauhid[5], Tien Sribimawati[5], Budi Suhardi[6]
(1: Kobe University, 2: Research Institute for Human and Nature,
3: IORGC, 4: RISH, 5: BPPT and 6: BMG)
* Graduate School of Science and Technology, Kobe University, Japan, 657-8501, 1-1, Rokkodai-cho, Nada Kobe Hyogo, Japan. e-mail: sakurai@ahs.scitec.kobe-u.ac.jp

Abstract

The diurnal cycle of cloud system migration is observed over the whole island of Sumatera. Seasonal variations in each migratory direction (southwest and northeast) and the relationship with larger scale phenomena such as ITCZ shown by previous study are confirmed and descrived more precisely using GMS IR1 data for extended analysis period from May 1997–April 2003. The phenomenon that the eastward migration tends to be observed in/near ITCZ is observed for all analysis period. The westward migration shows seasonal variations in *El Nino* and an area where westward one is observed shifts northward from May to September and southward from October to December in 1997. The north-south width of the appearance of westward migration is wider than that of eastward one.

Keyword: diurnal cycle, ITCZ, system migration, maritime continent.

1. Introduction

The convective activities in the tropical area are especially active in the Insonesian maritime continent. The diurnal cycle is dominant over the land in the tropics. One of the diurnal cycles, system migration during night which occurs not only in the tropics but also in midlatitude, has been studied by some researchers. The diurnal cycle of system migration is observed over the whole of Sumatera Island (Mori et al. 2004; Sakurai et al. 2004). Characteristically, system migration has two directions (southwest and northeast) over Sumatera Island, whereas system migration has one direction in other places. The phenomenon over Sumatera Island is that cloud systems develop in the afternoon along the mountain range and migrate toward the both (west and east) coastlines for several hundreds kilometers during night (Fig. 2). Sakurai et al. (2004) show seasonal variations of the diurnal cycle, as follows:

- The westward migration appears in almost all the seasons and almost all over the western part of Sumatera, except for the southmost part in August, whereas the eastward migration is observed only in a zone which is shifted northward and southward with an annual cycle (Table 1).
- The zone where the eastward migration appears is identified with ITCZ approximately. For the eastward migration they consider that it is related to features in inter tropical convergence zone (ITCZ); westerly wind in the lower troposphere is dominant and super cloud clusters are moving eastward in ITCZ around 100°E (Fig. 3).

The purpose of this study is to confirm whether seasonal variations of the diurnal cycle of cloud system migration as suggested by Sakurai et al. (2004) over the whole of Sumatera Island appear every year and describe that of detailed climatological features especially paying attention to that in *La Nina* and *El Nino*.

2. Data and analysis method

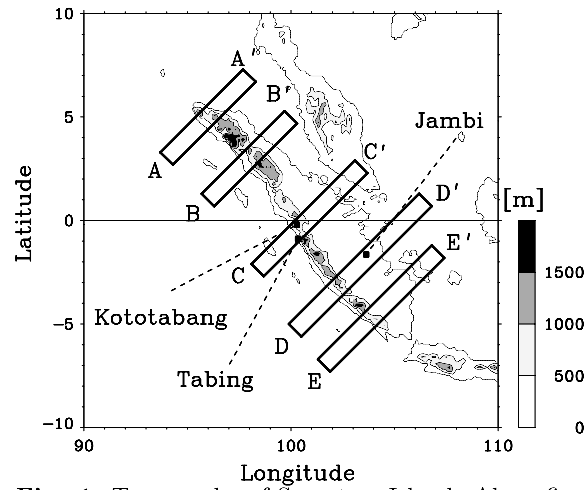

Fig. 1: Topography of Sumatera Island. Along five slabs from AA' to EE', diurnal cycle of cloud system migration is analyzed.

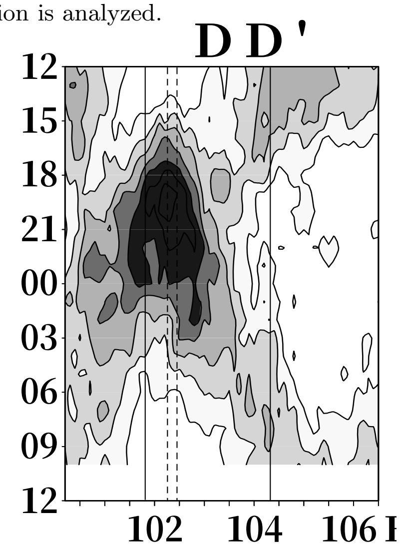

Fig. 2: Local time-longitude cross-sections of the occurrence frequency of deep cloud systems (cloud top temperature ≤ 230 K) at each pixel along the DD' slab shown in Fig. 1 during November 2001. November is in rainy season over central (equatorial) Sumatera (not all over Indonesia; see Hamada et al. 2003). Vertical solid and broken lines represent locations of coasts of Sumatera Island and 800 m MSL, respectively.

We used the data of black body temperature (T_{BB}) at $0.1^\circ \times 0.1^\circ$ grid points by GMS IR1 for six years (May 1997–April 2003) for analysis of the cloud top temperature. First (May 1997–April 1998) and sixth (May 2002–April 2003) years correspond to *El Nino*, and second (May 1998–April 1999) and third (May 1999–April 2000) years do *La Nina* in analysis period approximately. The temporal resolution is an hour. In order to discriminate deep convective clouds and omit ground temperature, a threshold value of T_{BB} was specified. The threshold value (T_{C}) 230 K is adopted in this study. 230 K correesponds to the air temperature at an altitude around 11 km.

Furthermore, in this study an occurrence frequency α of deep cloud system (T_{C}) at each pixel and time is calculated for a month, as follows:

$$\alpha \equiv \frac{(\text{The number of } T_{\mathrm{BB}} < 230)}{(\text{The total number of valid data for a month})} \times 100 , \qquad (1)$$

which indicates how frequently convective clouds penetrate above the 11 km altitude. We did not calculate a monthly value of α, if the number of lack of data exceeds 4 for one month.

(1) is also used to define ITCZ around 100°E. We use 270 K for 230 K into T_c because we define areas where cloud coverage is high ITCZ since in ITCZ the convection is always active, and analysis period is changed one month to 5 days. We defined areas where α is more than 50 % ITCZ around 100°E.

α are analyzed along five cross-sections (AA', BB', CC', DD', and EE' in Fig. 1) which are approximately perpendicular to the coastlines and mountain ridge of Sumatera Island are analyzed. The phase of seasonal variation in each cross-section may be inhomogeneous, since Sumatera Island is big island (~1,500 km in length) extended over the both hemisphere beyond the equator.

Migratory directions of cloud systems during May 1997–April 2003 are determined, based on the cross-section analysis of α. Occurrence of westward and/or eastward migrations are defined as follows: peaks of α larger than 10 % start migrating from the mountainous area during 12–24 LST and arrive at each coast until next morning (06 LST) (marked with ○). Blanks represent that α is less than 10 % or migration of cloud systems is not observed clearly in such monthly analysis, probably because convective activities are weak or diurnal cycle is not so dominant.

2. Results

2.1 Interannual variations during May 1997–April 2003

From the analysis during May 1997–April 2003 seasonal variations of eastward migration of cloud systems show same characteristics with previous study (May 2001–April 2002) that occurrence zone of eastward migration oscillates northward and southward with an annual cycle every year (not shown). However the north-south width of occurrence regions of eastward migration depends on analysis period. The area where eastward migration occurs in *El Nino* seems to be narrower than that in the other period (upper panel in Table 1 and 2).

The westward migration shows same characteristics with previous study that westward one is observed in almost all seasons and area over Sumarera Island except *El Nino*. In *El Nino* the westward migration has seasonal variations similar to that of eastward migration. In the following section seasonal variations in *El Nino* are shown comparing with results of previous study.

2.2 Comparison seasonal variations in May 2001–April 2002 with that in May 1997–April 1998

Convection in *El Nino* is much more inactive than in other periods (upper panels of Fig. 3 and 4). Convective activities along ITCZ are weak and the zone is narrow.

The north-south width of eastward migration during May 2001–April 2002 is wider than that during May 1997–April 1998. The eastward migratory distance of cloud systems in *El Nino* seems to be shorter than that during May 2001–April 2002 (lower panels of Table 1 and 2).

On the other hand, westward one has different characteristics in *El Nino* from the result of previous study. In *El Nino* period (May 1997–April 1998) the westward migration oscillates with an annual cycle; the north-south width of the areas where the westward migration appears is narrower than that of Sumatera Island, and looks like shifting northward from May to September. It extends southward from October to December (upper panel of Table 2).

Wind variation in the lower troposphere during May 1997–April 1998 is different from that during May 2001–April 2002. The width of easterly wind in the lower troposphere in *El Nino* is narrower and weaker than that during May 2001–April 2002. Easterly wind in ITCZ blows during October 1997–February 1998. The eastward migration tends to be observed when westerly wind or weak easterly wind blows in the lower troposphere as shown by previous study.

3. Summary

One diurnal cycle that cloud systems develop in the afternoon along the mountain range of Sumatera Island and migrate toward the both (west and east) coastlines for several hundreds kilometers during night is focused on. Using GMS IR1 data for six years (May 1997–April 2003) the relationships between eastward migration of cloud systems and the position of ITCZ pointed by Sakurai et al. (2004) is confirmed. The tendency of seasonal variations of eastward migration and the relationship with ITCZ is observed every year. On the other hand the westward migration in *El Nino* has different characteristics from results of previous study, and it shows seasonal variations similar to eastward one.

To discuss interannual variations more precisely it is need to add the information such as the occurrence frequency of cloud system migration. Because this analysis (Table 1 and 2) shows whether system migration occurs or not and the area where system migration occurs. Furthermore making use of GMS data with high spatial and temporal resolution and long period, environment condition will be cleared quantitatively and statisticaly in each migratory direction. In the presentation the relationships between eastward migration and the passage of super cloud cluster will be shown.

		Westward migration											
		2001								2002			
		M	J	J	A	S	O	N	D	J	F	M	A
N	AA'	○	○	○	○	○	○	○	○	○	○	○	○
↑	BB'	○	○	○	○	○	○	○	○	○	○	○	○
EQ	CC'	○	○	○	○	○	○	○	○	○	○	○	○
↓	DD'	○	○	○	○	○	○	○	○	○	○	○	○
S	EE'	○	○	○		○	○	○		○	○	○	○

		Eastward migration											
		2001								2002			
		M	J	J	A	S	O	N	D	J	F	M	A
N	AA'	○	○		○	○	○	○	○				○
↑	BB'	○	○		○		○	○	○				○
EQ	CC'	△	○				○	○	○			△	○
↓	DD'		△				○	○	○			△	△
S	EE'	○	△				○	○	○	○	○	○	○

Table 1: Seasonal-'meridional' distributions of occurrence of westward (upper panel) and eastward (lower one) migrations (see text for definitions) of deep cloud systems (cloud top temperature ≤ 230 K) during May 2001–April 2002. For CC', DD' and EE' along which the distance between mountain range and eastern coast line is wider than in the other cross-sections, some cloud systems do not arrive at the eastern coast, though they migrate eastward from mountainous area (marked with $\triangle$ in Table 1 and 2).

		Westward migration											
		1997								1998			
		M	J	J	A	S	O	N	D	J	F	M	A
N	AA'	○	○	○	○	○	○	○	○	○	○	○	○
↑	BB'	○	○	○	○	○	○	○	○	○	○	○	○
EQ	CC'	○	○	○				○	○	○	○	○	○
↓	DD'	○	○					○	○	○	○	○	○
S	EE'	○							○	○	○	○	○

		Eastward migration											
		1997								1998			
		M	J	J	A	S	O	N	D	J	F	M	A
N	AA'	○	○	○			○	○					
↑	BB'	○	○	○	○			○					
EQ	CC'	○							○				
↓	DD'										△	○	△
S	EE'								△	△	△	○	△

Table 2: Same as Table 2 but for during May 1997–April 1998.

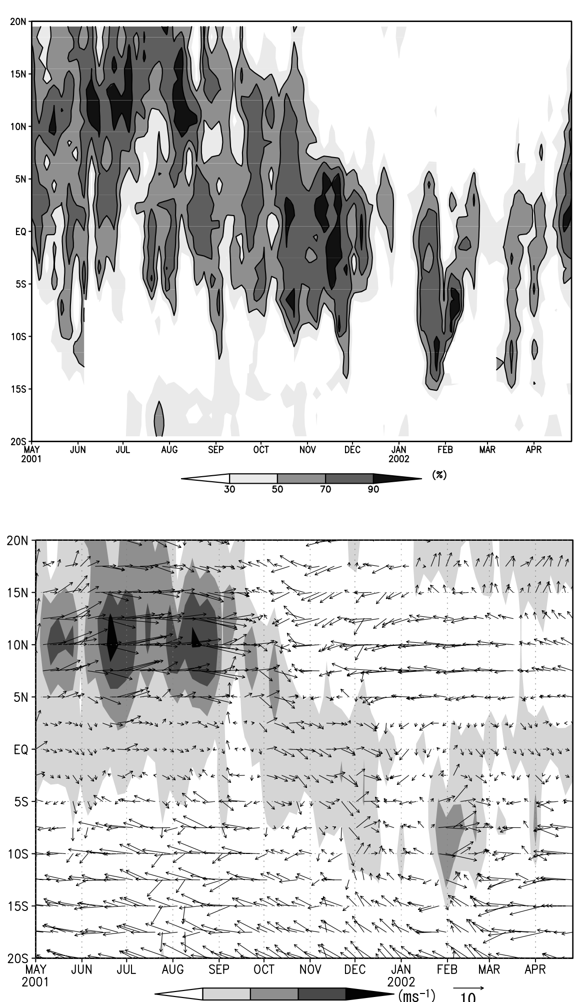

Fig. 3: Latitude-time cross-sections (around 100°E, spatial width is 2.5° during May 2001–April 2002) of occurrence frequency α of cloud systems (cloud top temperature is between 170 and 270 K) (upper panel), and 850-hPa horizontal wind (arrows: upward is northward; shaded represents westerly) (lower one) based on the NCEP/NCAR objective analysis data.

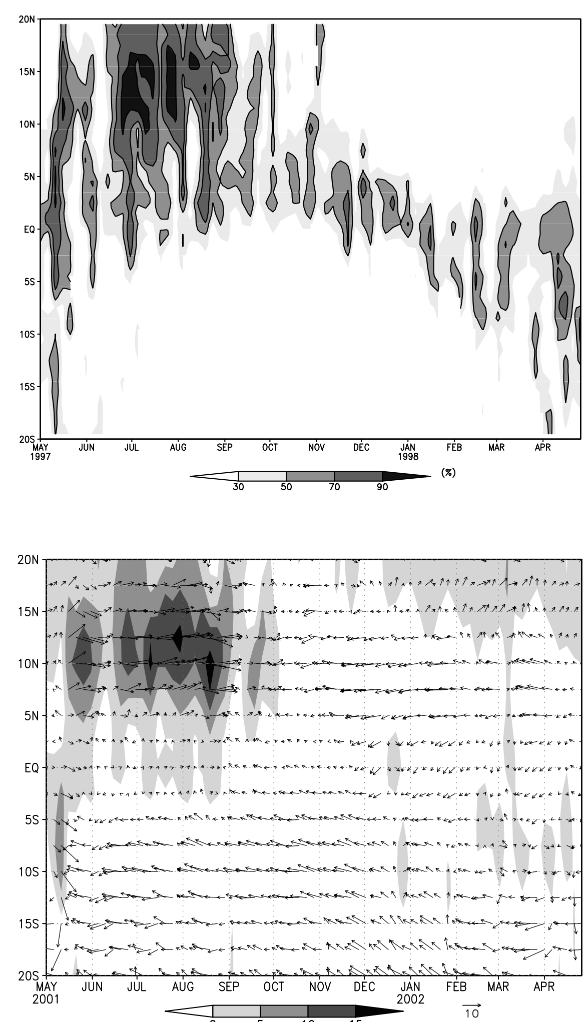

Fig. 4: Same as Fig. 2 but for during May 1997–April 1998.

References

Mori, S., Hamada, J.-I., Y.I. Tauhid, M.D. Yamanaka, N. Okamoto, F. Murata, N. Sakurai, and T. Sribimawati, Diurnal land-sea rainfall peak migration over Sumatera Island, Indonesia maritime continent observed by TRMM satellite and intensive rawinsonde soundings. *Mon. Wea. Rev.*, **132**, 2021-2039, 2004.

Sakurai, N., F. Murata, M.D. Yamanaka, S. Mori, Hamada J.-I., H. Hashiguchi, Y.I. Tauhid, T. Sribimawati, and B. Suhardi, Diurnal cycle of cloud system migration over Sumatera Island. *J. Meteor. Soc. Japan*, revised.

Hamada, J.I., A climatological study on rainfall variations over the Indonesian maritime continent. Doctoral thesis, Graduate School of Science, Kyoto University.