The Variation of Lower Tropospheric Temperature and Indian Summer Monsoon Onset

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Interested in Asian summer monsoon system, especially the onset of Indian summer monsoon, atmospheric heating and moisture condition over the Tibetan plateau, and their relationship. Under the framework of CEOP, working on centralized data archiving and integrating system, and developing new data integration and information fusion methods.

1. Introduction

Strong low-level westerly over the Arabian sea in summer has an important role on Indian monsoon rainfall. Krishnamurti and Ramanathan (1982) examined the time evolution of energy exchanges and differential heating in 1979. A large increase of the kinetic energy of total flow field and nondivergent component of the flow occurs over the Arabian Sea just before, or about a week prior to the onset of monsoon rains over central India. Taniguchi and Koike (2006) defined ISM onset only by wind speed at the lower layer over the Arabian sea and the definition more properly represented drastic transition of atmospheric condition and beginning of rainy season in India than time-series of water vapor and vertically integrated moisture transportation.
In this study, formation of the westerly in the lower layer are investigated in detail.

2. General features of atmospheric conditions around ISM onset

Investigation of atmospheric fields presented a importance of a rapid decreasing of potential temperature (PT) over the western coast of India in formation of the westerly. Seasonal progression of climatological atmospheric fields by NCEP/NCAR reanalysis presented a formation of large thermal contrast in the lower troposphere between the Arabian peninsula and the western coast of India. Such a significant thermal contrast is formed earlier in the lower troposphere than in middle and upper layer (**Fig.1**).
At the same time, comparison of seasonal variation of Indian rainfall, wind speed over the Arabian sea (U_a) and the thermal contrast ($\Delta\theta_{AI}$) for each year from 1997 to 2004 are compared (**Fig.2**). Results of the comparison showed that rapid start of rainy season and abrupt enhancement of U_a, or onset of Indian Summer Monsoon (ISM), is accompanied by the increasing of $\Delta\theta_{AI}$. However, increase of $\Delta\theta_{AI}$ is not so abrupt as the beginning of rainy season and enhancement of U_a. On the other hand, abrupt decreasing of lower-level PT over the western coast of India (θ_{IW}) were seen at the same time as the rapid beginning of rainy season. This correspondence was observed in whole target years and the descent of PT can be a trigger of the ISM onset.

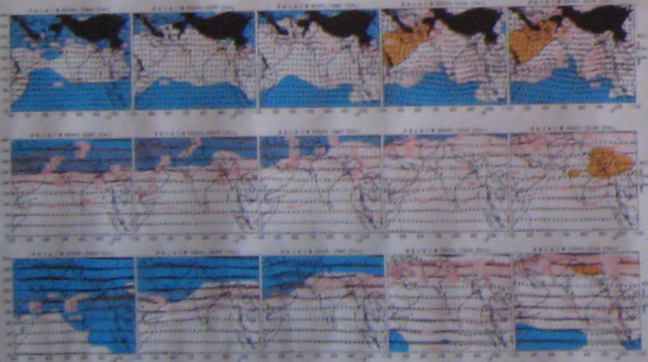

Fig.1 Seasonal variation of potential temperature, geopotential height and wind (NCEP/NCAR reanalysis data). (Upper panel) 850hPa, (Middle) 500hPa, (lower) 200hPa.

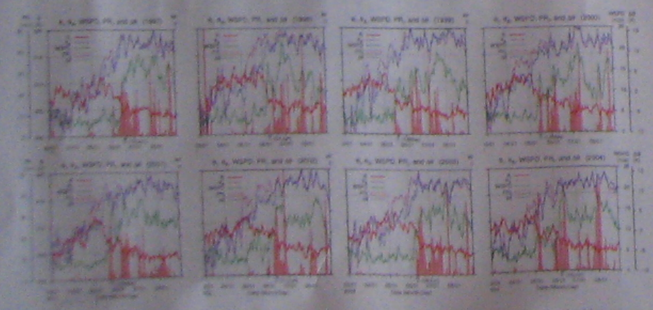

Fig.2 Time-series of 850hPa potential temperature (PT) for above the western part of India, the Arabian sea (θ_{IW}, θ_{A}, respectively), wind speed over the Arabian Sea (WSPD), GPCP precipitation in the western part of India (PRC) and difference of (PT) between the Arabian peninsula and the western coast of India (all variables

3. Case studies – details about the variation of atmospheric conditions

Investigation of seasonal variation of low-level atmospheric field showed two possible patterns of θ_{IW} decreasing. In one case, strong wind by a cyclone over the Arabian sea transports cooler air from over the ocean to the Indian subcontinent, and then, θ_{IW} decreases rapidly (**Fig.3**). In another case, spatial distribution of θ_{IW} changes gradually (not brought by cyclone). This gradual decrease of θ_{IW} is supposed to have several patterns. In the case of 2001 (**Fig.4**), enlargement of $\Delta\theta_{AI}$ forms weak southwesterly over the Arabian sea, and the southwesterly brings cooler air mass into over the Arabian sea and the western coast of India. Then $\Delta\theta_{AI}$ becomes larger and the southwesterly is intensified. This synergic effect of $\Delta\theta_{AI}$ and the southwesterly attains ISM onset.
Comparison of time-series of θ_{IW} and outgoint logwave radiation (OLR) in the same region for non-cyclone ISM onset presented that even high OLR period (or inactive cumulus convection), θ_{IW} decreases (**Fig.5**). This result also indicates the atmospheric cooling over India is not a result but possible trigger of ISM onset. In such PT decreasing, horizontal advection is supposed to be a possible cause to change distribution of PT around the Arabian sea.

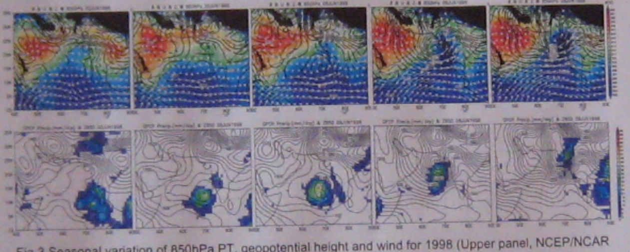

Fig.3 Seasonal variation of 850hPa PT, geopotential height and wind for 1998 (Upper panel, NCEP/NCAR reanalysis data) and geopotential height and GPCP precipitation for the same period (Lower panel).

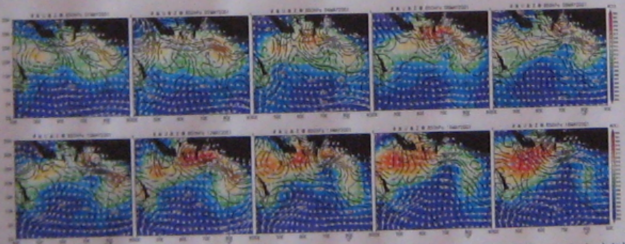

Fig.4 Seasonal variation of 850hPa PT, geopotential height and wind for 2001 (NCEP/NCAR reanalysis data).

Fig.5 Time-series of OLR and PT at 850hPa in the western part of India (2001). ↓ and the date indicates the onset of ISM.

Fig.6 Visible channel images of METEOSAT for 2001. There is no clear cloud activity around the western part of India during PT decreasing phase.

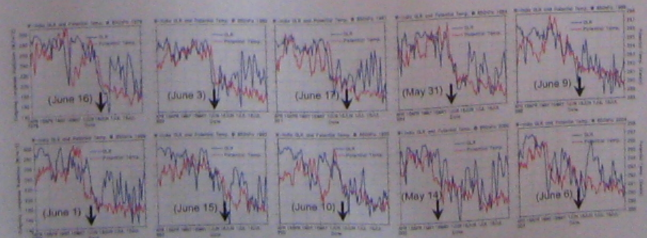

Fig.7 Same as Fig.5 but for the cases of non-cyclone-caused ISM onset.

4. Cyclogenesis over the Arabian Sea

Cyclogenesys over the Arabian Sea are also investigated by using satellite observation data and NCEP/NCAR reanalysis data. There is large temperature gradient around the coastal area of the Arabian Peninsula, and baroclinic instability by the horizontal temperature gradient in that region easily generates a seed of cyclone at 850hPa (**Fig.8**). Regarding development of the cyclone, water vapor and sensible heat flux do not show significant difference between development and non-development case. On the other hand, coupling of upper and lower layer disturbances are considered to be more important.

Table 1 Date and location of seeds of cyclone generated around the coastal area of the Arabian peninsula

Year	Date	Lon, Lat	Coupling	Year	Date	Lon, Lat	Coupling	Year	Date	Lon, Lat	Coupling
1980	May-20	57,5E, 15N	△	1988	June-4	55E, 15N	※	1996	May-30	57,5E, 15N	△
1981	May-25	57.5E, 17.5N	△		June-9	55E, 20N	※		June-7	60E, 17.5N	○
	June-12	60E, 25N	△	1989	May-22	55E, 17.5N	×	1998	June-2	57.5E, 17.5N	○
1982	May-28	65E, 17.5N	×		May-27	55E, 17.5N	×	2000	May-13	65E, 20N	○
1983	June-5	52.5E, 15N	×		May-31	65E, 17.5N	○	2001	May-14	52.5E, 12.5N	×
	June-13	65E, 20N	○	1990	May-13	60E, 15N	○		May-17	52.5E, 17.5N	×
1984	May-25	52.5E, 12.5N	△	1991	June-2	55E, 17.5N	×		May-21	47.5E, 12.5N	△
	May-29	55E, 17.5N	○	1992	June-3	50E, 10N	×	2002	May-17	57.5E, 17.5N	×
1985	May-22	55E, 17.5N	×		June-13	55E, 15N	△		May-28	50E, 12.5N	×
	May-26	55E, 15N	○	1993	May-22	50E, 10N	×		May-31	52.5E, 17.5N	×
1986	May-26	55E, 15N	×		May-26	55E, 17.5N	△		June-3	52.5E, 17.5N	△
	June-4	57.5E, 15N	○		May-29	52.5E, 15N	×		June-10	57.5E, 17.5N	○
1987	May-30	52.5E, 12.5N	○		June-1	52.5E, 17.5N	○	2003	May-20	55E, 15N	×
1988	May-24	55E, 15N	△	1994	May-31	55E, 15N	△		June-5	52.5E, 15N	○

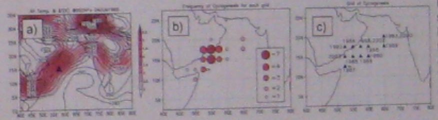

Fig.8 Characteristics of cyclone-seed. a) Air temperature and horizontal gradient of air temperature at 850 on 4 June 1986 (▲ indicates a cyclone seed). b) Frequency of cyclone seed generation c) Locations of developed cyclone seeds.

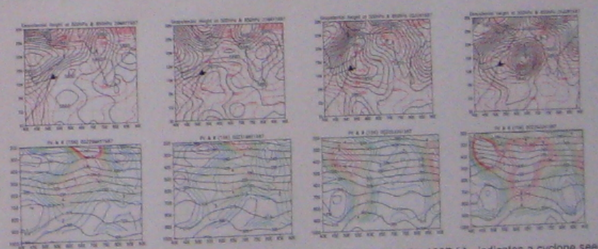

Fig.9 (Upper) Geopotential height at 500hPa (black) and 850hPa (red) for 1987 (▲ indicates a cyclone seed). (Lower) vertical profile of potential vorticity (color) and potential temperature (black) along 15N.

5. Conclusions

In this study, seasonal variation of atmospheric field around the onset of the Indian summer monsoon and cyclogenesis over the Arabian Sea were investigated in detail and following conclusions are achieved.

- Rapid decreasing of θ_{IW} is a possible cause of the formation of low-level westerly or ISM onset.
- Rapid decreasing of θ_{IW} is caused by two different processes;
  - a. Strong wind accompanied by a cyclone over the Arabian Sea brings colder air mass from over the ocean
  - b. θ_{IW} decreases gradually by some synergetic process between wind and temperature distribution.
- Large temperature gradient around the coastal area of the Arabian Peninsula makes baroclinic instable condition and a seed of cyclone at 850hPa is easily generated in such a region.
- Occurrence of air disturbance in middle-upper troposphere and coupling of upper and lower air disturbances are considered to be important for the development of cyclone over the Arabian Sea

References

Taniguchi, K., and T. Koike (2006). Comparison of definitions of Indian summer monsoon onset: Better representations of atmospheric conditions, Geophys. Res. Lett., 33, L02709, doi:10.1029/2005GL024526
Taniguchi, K., and T. Koike (2006). A Study on the cyclogenesys and its development over the Arabian Sea Vol.50, pp.391-396, Annual. J. Hydraulic Eng., JSCE (in Japanese).