Comments on "The Role of Mountains in the South Asian Monsoon Circulation[1]

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1. Introduction

The Geophysical Fluid Dynamics Laboratory has pioneered and leads in numerical modeling of the global atmospheric circulation. Thus a long new paper from this distinguished group (Hahn and Manabe, 1975) is an important event, not only to the meteorological world in general, but, in view of its topic, to us in particular.

In the interests of brevity, we have

1) Focused our comments on the macroscale; doubts about the validity of a model feature on this scale apply *a fortiori* to smaller scales within the feature.

2) Chosen to discuss each meteorological field in turn, rather than follow the authors' model-oriented organization, hoping that page and figure references will obviate confusion.

2. Surface pressure and wind

In Fig. 3.1, the authors compare the M-model surface pressure with an observed average for June, July, August (Newell *et al.*, 1972). However, good regional (Rao and Ramamurti, 1968) and global (Crutcher and Davis, 1968) July charts are available. The authors mention large differences between the M-model and reality such as a 2500 km misplacement of a surface low to Tibet and the computation of a trough instead of a ridge over the northeast Pacific. (How well could the model simulate the summer climate of Japan?) The model performs similarly over the North Atlantic, while from April through July (their Fig. 5.2), it shows surface pressure over China to be significantly lower than over South Asia, when in fact the reverse is true.

In the N-M model for July (Fig. 4.1) a surface pressure minimum is located over Manchuria and there is no sign of a tropical heat low. This distribution cannot be directly compared to reality; however, a summer heat low does develop near 17°S over the small, relatively flat continent of Australia.

The surface wind distribution of the M-model shows correspondingly large deviations from reality, not only in July (Fig. 3.2) but in other months as well (Fig. 5.1). For example, over the Bay of Bengal in May, light and variable M-model winds scarcely duplicate the fresh southwesterlies of reality (van Duijnen Montijn, 1952). In the N-M model southwesterlies blow at least over the southern Bay.

3. Rainfall

Where the surface pressure and winds are poorly simulated, so is the rainfall (Figs. 3.3 and 4.5). For example, why should the model show Bombay with much less rainfall than northwestern Mexico or a large gradient along the west coast of India, or an order of magnitude too little rain in the Ganges Valley?

On p. 1532, the authors state "Heretofore, the ITCZ and the monsoon trough have usually been considered as one and the same feature." The lack of coincidence between these two features has been rather extensively documented (Sadler, 1962, 1963, 1964, 1969a, b, 1975a; Sadler and Harris, 1970; Ramage, 1971). Despite observational evidence (Ramage, 1968, 1974a, b) that trough and sea surface temperature maximum coincide, the authors apparently believe that the coincidence is

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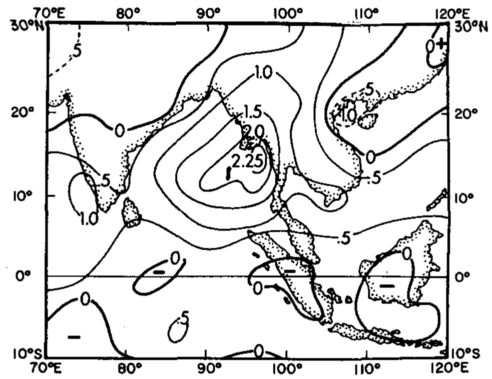

FIG. 1. Change in mean cloudiness (octas) from April to May (from 9 years of satellite data).

between ITCZ and sea surface temperature maximum. Also, there is no observational evidence for "a local maximum of mean wind speed . . . [coinciding] with the position of the ITCZ."

4. Upper tropospheric flow

In the M-model (Fig. 3.4) the subtropical ridge lies 10° too far south over South Asia and Africa, except for a small anticyclonic protruberance over Tibet and a companion cyclone over west China (Artifacts of the incorrectly positioned surface pressure minimum?). Mislocation of the ridge results in persistent westerlies near 25°N (Figs. 3.7 and 4.3). Over the North Pacific the model delineates a ridge where the Mid-Pacific trough should be and westerlies, where the sub-equatorial ridge should be. Similar errors occur over the North Atlantic.

The NM model (Fig. 4.2) is somewhat superior overall to the M-model.

5. Vertical distributions

The zonal wind section selected by the authors (Fig. 4.3) lies between two sections (along 73°E and 100°E) depicted in the IIOE Meteorological Atlas (Ramage and Raman, 1972). If *both* of the Atlas sections are used to evaluate the models, then one is forced to conclude that the NM is no worse than the M. The upper tropospheric easterlies are *stronger* in the NM model than in the M-model. This is in sharp contrast to Murakami *et al.* (1970), who computed >35 m s^{-1} with mountains and <10 m s^{-1} without mountains. Compared with south Asia, upper tropospheric summer

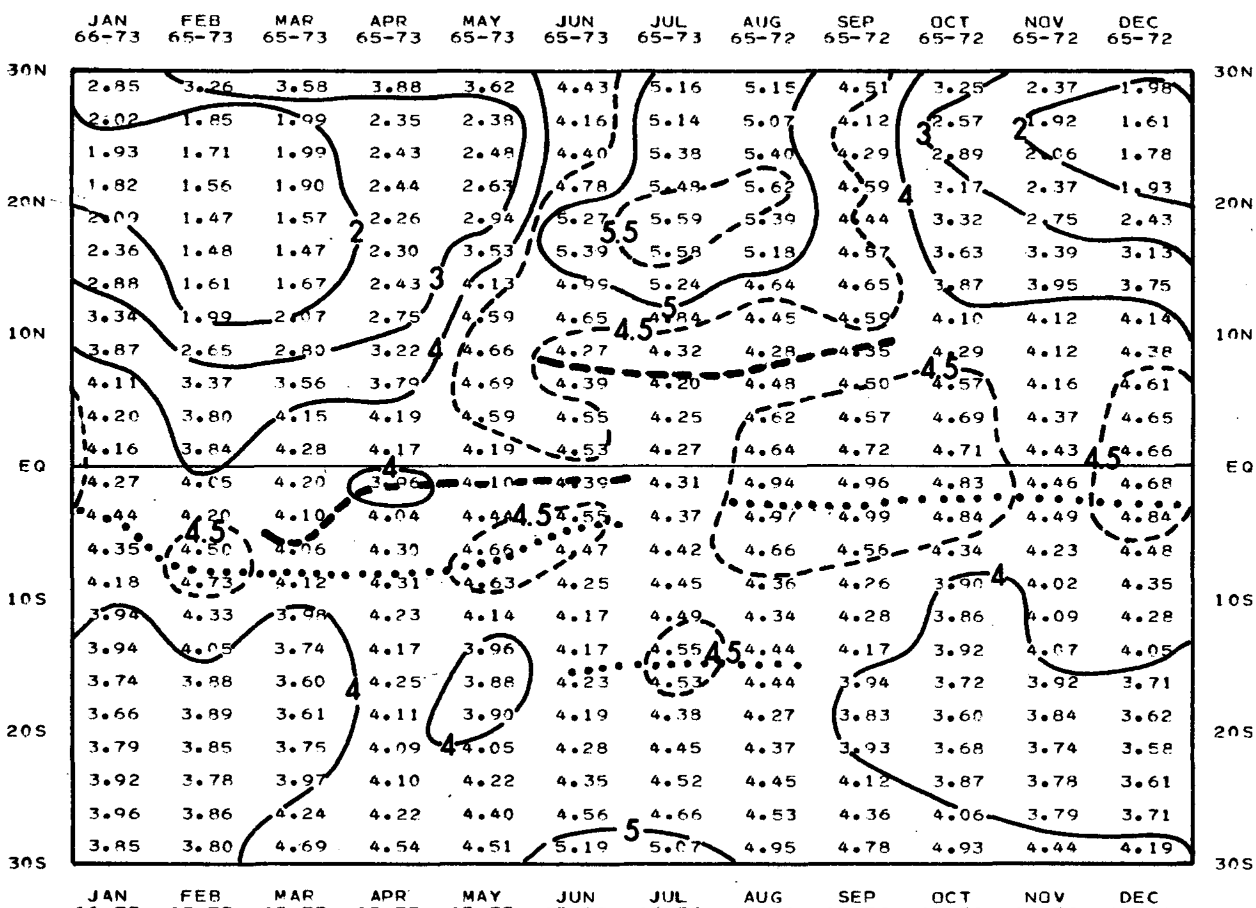

FIG. 2. Time-latitude section of mean monthly cloudiness for the longitudinal strip 85°–90°E. Minimum cloud axis is shown by the heavy dashed line and maximum cloud axis by the dotted line (from 9 years of satellite data).

monsoon easterlies are much weaker equatorward of South China and Australia, countries with insignificant mountain ranges. Why should Murakami's less sophisticated formulation lead to an apparently more realistic result?

Heaviest rain falls along the west coasts of India and Burma, where the M-model shows the air at 500 mb to be sinking (Fig. 4.6). The N-M model performs no worse.

The authors suggest that conditions during a monsoon "break" are duplicated by the N-M model of the July meridional circulation (Fig. 4.7) and by the 5–9 July period of the M-model (Fig. 5.6). Unfortunately, during a true monsoon "break" just the reverse occurs—rainfall increases over northern and southern India and diminishes over central India (Koteswaram, 1950; Ramaswamy, 1962; Ramamurthy, 1969). M-model flow above the mountains remained unchanged from 20 June–19 July (Fig. 5.6), although there were significant changes farther south. Does this mean that the mountains exert little direct effect in the M-model?

6. Monsoon onset

In the M-model, rain is very scanty over the Bay of Bengal from April to early June (Figs. 3.6a and 5.4). In fact cloudiness and rainfall increase dramatically from April to May (our Fig. 1) and in the latter month and in June, are greater there than elsewhere over the northern Indian Ocean and South Asia (Sadler and Harris, 1970). On p. 1524 the authors state that in the M-model surface convergence persists along the equator through 25–29 June and then breaks down (Fig. 5.4). The N-M model, though not good, agrees better with reality south of 20°N (our Fig. 2). There is an equatorial cloudiness *minimum* in April, May and June, while the mean resultant surface winds there are predominantly divergent in May and much less divergent in July (Hantel, 1970).

Fig. 3.7 does not support the authors' contention that the monsoon circulation sets in abruptly toward the end of May. The figure shows two belts of westerlies along about 25° and 45°N. The former gradually weakens and the latter fluctuates as summer advances. Actually the N-M model sequence (Fig. 5.3) more nearly duplicates climatology (our Fig. 3). In any case, Yin's (1949) contention that the monsoon "bursts" when the subtropical jet abruptly shifts north of Tibet has been seriously questioned by others (Ramamurthi and Jambunathan, 1967).

7. Concluding remarks

The M-model *has failed* to simulate the large-scale surface, upper air and vertical circulations and the rainfall distributions associated with the South Asian summer monsoon. Because of this failure, smaller scale features of the model, such as the monsoon trough over

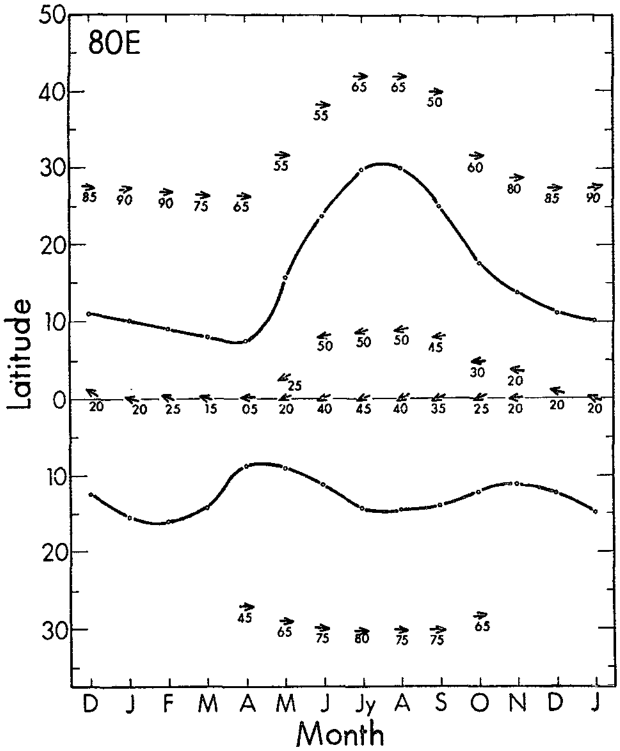

Fig. 3. Time-latitude section along 80°E of mean monthly features at 200 mb. The ridge is shown by the full line. The latitude of the major currents is indicated by the short arrows with speed to nearest 5 kt. Wind velocity along the equator is also depicted (Sadler, 1975b).

northern India, monsoon "onset" or monsoon "breaks" defy evaluation. We are at a loss to account for this performance, but suspect that it stems not merely from inadequate formulation of the mountain effects, but from inherent deficiencies in the basic model [see, e.g., Fig. 4.1 (bottom)].

REFERENCES

Crutcher, H. L., and O. M. Davis, 1968: *U. S. Navy Marine Climatic Atlas of the World*, Vol. VIII, *The World*. NAVAIR 50-1C-54, Naval Weather Service Command, Washington, D.C., 179 charts.

Hahn, D. G., and S. Manabe, 1975: The role of mountains in the South Asian monsoon circulation. *J. Atmos. Sci.*, **32**, 1515–1541.

Hantel, M., 1970: Monthly charts of surface wind vergence over the tropical Indian Ocean. *Bonn. Meteor. Abhand.*, **14**, 32–79.

Koteswaram, P., 1950: Upper level "lows" in low-latitudes in the Indian area during SW monsoon season and "breaks" in the monsoon. *Ind. J. Meteor. Geophys.*, **1**, 162–164.

Murakami, T., R. V. Godbole and R. R. Kelkar, 1970: Numerical simulation of the monsoon along 80°E. *Proc. Conf. Summer Monsoon Southeast Asia*, C. S. Ramage, Ed., Navy Weather Res. Facility, Norfolk, Va., 39–51 [NTIS No. AD-876-667].

Newell, R. E., J. W. Kidson, D. G. Vincent and G. J. Boer, 1972: *The General Circulation of the Tropical Atmosphere and Interactions with Extratropical Latitudes*. The MIT Press, 258 pp.

Ramage, C. S., 1968: Problems of a monsoon ocean. *Weather*, **23**, 28–37.

——, 1971: *Monsoon Meteorology*. Academic Press, 296 pp. (see pp. 194 and 201).

——, 1974a: Monsoonal influences on the annual variation in tropical cyclone development over the Indian and Pacific Oceans. *Mon. Wea. Rev.*, **102**, 745–753.

——, 1974b: Structure of an oceanic near-equatorial trough deduced from aircraft traverses. *Mon. Wea. Rev.*, **102**, 754–759.

——, and C. R. V. Raman, 1972: *Meteorological Atlas of the International Indian Ocean Expedition*, Vol. 2. National Science Foundation, Washington, D. C., 121 charts.

Ramamurthi, K. M., and R. Jambunathan, 1967: On the onset of the southwest monsoon rains along extreme southwest coast of peninsular India. *Proc. Symp. Meteor. Results Int. Indian Ocean Expedition*, P. R. Pisharoty, Ed., India Meteor. Dept., New Delhi, 350–361.

Ramamurthy, K., 1969: Monsoons of India: Some aspects of the "break" in the Indian southwest monsoon during July and August. *India Meteorological Department Forecasting Manual*, Part IV, No. N-18.3.

Ramaswamy, C., 1962: Breaks in the Indian summer monsoon as as a phenomenon of interaction between the easterly and the subtropical westerly jet streams. *Tellus*, **14**, 337–349.

Rao, Y. P., and K. S. Ramamurti, 1968: Climate of India. *India Meteorological Department Forecasting Manual*, Part 1, No. I-2.

Sadler, J. C., 1962: The first hurricane track determined by meteorological satellite. *Ind. J. Meteor. Geophys.*, **13**, 29–44.

——, 1963: Utilization of meteorological satellite cloud data in tropical meteorology. *Proc. First Intern. Symp. Rocket and Satellite Meteor.*, North Holland Publ. Co., Amsterdam, 333–356.

——, 1964: TIROS observations of the summer circulation and weather patterns of the eastern North Pacific. *Proc. Rotorua Symp. Tropical Meteor.*, J. W. Hutchings, Ed., New Zealand Meteor. Service, Wellington, 553-571.

——, 1969a: Average cloudiness in the tropics from satellite observations. *International Indian Ocean Expedition Meteor. Monogr.*, No. 2, East-West Center Press, 22 pp.

——, 1969b: Mean circulation and cloudiness during the development of the southwest monsoon over India and Southeast Asia. *Proc. Conf. Summer Monsoon of Southeast Asia*, C. S. Ramage, Ed., Navy Weather Res. Facility, Norfolk, Va., 13–28 [NTIS No. AD-876-667].

——, 1975a: The monsoon circulation and cloudiness over the GATE area. *Mon. Wea. Rev.*, **103**, 369–387.

——, 1975b: The upper tropospheric circulation of the global tropics. UHMET 75-05, Dept. Meteor., University of Hawaii, 35 pp. [Available from the Department of Meteorology, University of Hawaii].

——, and B. E. Harris, 1970: The mean tropospheric circulation and cloudiness over Southeast Asia and neighboring areas. AFCRL-70-0489 and HIG-70-26, Hawaii Institute of Geophysics, University of Hawaii, 38 pp. [NTIS No. AD-715912].

van Duijnen Montijn, J. A., 1952: *Indian Ocean Oceanographic and Meteorological Data*, 2nd ed. Roy. Netherlands Meteor. Inst., de Bilt, No. 135.

Yin, M. T., 1949: A synoptic-aerologic study of the summer monsoon over India and Burma. *J. Meteor.*, **6**, 393–400.