"Course on Ocean-Atmosphere Interaction in the Tropics"
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"Low Frequency Monsoon Variability
(Observed Characteristics)"

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Please note: These notes are intended for internal distribution only
LOW FREQUENCY MONSOON VARIABILITY

(OBSERVED CHARACTERISTICS)

HIGH FREQ.
OR SYNOPTIC
• MONSOON DEPRESSIONS
• MIDLATITUDINAL CYCLONES

LOW FREQ.

1. INTRA SEASONAL
• 10-20 DAY OSCILL.T.
• 30-50 DAY OSCILL.

2. INTERANNUAL
• RELATION WITH ENSO
• RELATION WITH EURASIAN SNOW COVER
  ETC.
OUTLINE

• WE CONCENTRATE MAINLY ON INDIAN SUMMER MONSOON.

• MAJOR FEATURES OF CLIMATOLOGICAL MEAN MONSOON CIRCULATION.

• EVIDENCES OF INTRASEASONAL VARIABILITY
  • 10 - 20 DAY OSCILLATIONS.
  • 30 - 50 DAY OSCILLATIONS.

• EVIDENCES OF INTERANNUAL VARIABILITY. (RELATIONSHIP WITH VARIATIONS OF DIFFERENT BOUNDARY CONDITIONS)
  • WITH EURASIAN SNOW COVER
  • WITH ARABIAN SEA SST
  • WITH SO
  • WITH EL ÑINO

REFERENCES.
• Krishnamurti (1990) LOW FREQUENCY MODES OF MONSOON, SPRINGER
NORTHERN HEMISPHERE WINTER MONSOONS
SEASONAL WIND REVERSAL is characteristic of monsoon circulation throughout the world, but it is most pronounced in the regions around the Indian Ocean. Note that in crossing the Equator the winds change direction, an effect of the rotation of the earth. The zone where the surface winds converge is primarily in the Southern Hemisphere in January but migrates northward with the sun in
Fig. 3.1. Climatological July surface and 850mb wind fields. 
(a) Surface wind field (110-year mean for the period 1860-1970) for July; dashed lines are isotachs (m s$^{-1}$). (From Fu et al. 1983.) (b) 850-mb wind field for July; the wind data in China are the means from 1960-69. (From Central Meteorological Bureau 1976; wind data in the other areas from Van de Hoogardaard 1977.) (c) 500-mb wind field for July. (d) 200-mb wind field for July; dashed lines are isotachs (m s$^{-1}$).
climatological wind field for July at 500 mb

climatological wind field for July at 200 mb
THE NORTHERN SUMMER MONSOON

Fig. 2.15. Geographical distribution of the mean monsoon rainfall (cm) over India, 1871–1978. (After Parthasarathy 1984b.)

Fig. 2.17. Geographical distribution of the coefficient of variation (%) of the monsoon rainfall over India, 1871–1978. (After Parthasarathy 1984b.)
Figure 1  Seasonal distribution of rainfall as a percentage of annual. After Annamalai and Rajagopalachari (1964)
Figure 1
Daily rainfall (cm/day) along the western coast (Konkan, Coastal Mysore, and Kerala) of India during the summers of 1963 and 1971. (MURAKAMI, 1972.)
Fig. 15. Daily values of monsoon rainfall averaged over central India (a) and the power spectrum for monsoon rainfall (b).

Fig. 9a. Daily mean sea level pressure over the monsoon trough. See Table 1 for the domain. The International Geophysical Year (IGY) data were used in this study. Fig. 9b. Power spectrum for the monsoon trough.
ordian (1958). His results are often re-
d to as a typical stratification of the tropical
sphere near the ITCZ. In both regions, air
lifted up from the surface is likely to
rate through 200 mb level in case of no
15 days and 4- to 5 days appear in the data of
other stations as well. The horizontal distribu-
tions of the variances due to these two period
ranges are exhibited in Fig. 6. The distribution
shown in Fig. 6a indicates that the amplitudes

Fig. 5 Vertical distributions of the power spectra of the zonal
(lef) and the meridional (right) wind components and
their mean values. Units of the power spectral densities
are (m/sec)^2 day and the values more than 100 are
shaded.

MURAKAMI
(1976)
J.M.S. Japan

Data for
1962
Fig. 8 Vertical distributions of the power spectra of the zonal (left) and the meridional (right) wind components for (a) Trivandrum (b) Nagpur and (c) Calcutta. Units are (m/sec)^2-day and contour intervals are 200 (solid line) and 100 (dashed line).
Fig. 7 Time-latitude sections of cloudiness for 72°-84°E longitude zone. Time means are subtracted from the smoothed cloudiness, and positive deviations are illustrated by the grey scale. The cloudiness difference between adjacent levels is 0.3. See text for the symbols $A'$ and $B'$. 
Fig. 8 Day latitude sections of time-space correlation coefficients for the longitude zones of (a) 12°-24°E, (b) 72°-84°E, and (c) 96°-108°E. Contour line interval is 0.4. Areas of positive values are shaded.

Fig. 9 Power spectra of cloudiness fluctuations for a block of 10°-15°N, 72°-84°E. Units are (cloudiness values)² day⁻¹.

Fig 2
Fig. 1. Selected area for spectral analysis. The area enclosed by dashed lines is adopted for 1973.


Fig. 2. Piled diagrams of power spectra of cloudiness for 1966 through 1973. Units are (cloudiness values²-day). The spectral bands of 30 to 40 day period and 10 to 15 day period are indicated by dotted lines.
Fig. 5 Cross sections of the geopotential height at 850 mb along the line shown in Fig. 1, by using (a) 5-day moving averaged data, (b) data by filter 1, and (c) data by filter 2. Contour intervals are (a) 20 m, (b), (c) 5 m. The areas of negative values are shaded in (b) and (c).
Fig. 4b. Time longitude section of the sea level pressure on the time scale of 10 to 20 days. The units of pressure is mb, a subset of the annual and global calculations is shown here for the latitude belt 20S - 25N.
Fig. 8a. Time-latitude section of the sea level pressure on the time scale of 30 to 50 days. The units of pressure are mb, a subset of the annual calculation is shown here for the latitude belt 37S-30N.

Krishnamurti et al (1985) JAS
Fig. 1. Map of 1 degree latitude-longitude regions with the stations indicated by dots and the total number of stations in each region written in the center of box.
Fig. 10. Maps of (a) coherence-squared, and (b) phase, of precipitation in the 40-50 day period band, between the region 13°-14°N, 77°-78°E and all of the one-degree regions over India. Contour interval of coherence-squared is 0.1, and areas with coherence significantly different from zero at the 99% a priori level are shaded. The contour interval for phase is 20 degrees. Negative phases mean that the point in question lags behind the reference point.
STATISTICAL PROPERTIES OF ALL-INDIA SUMMER MONSOON RAINFALL SERIES (1871-1984)

- **Mean** = 852 mm
- **S.D** = 83 mm
- **Coefficient of Variation** = 9.7%
- **Lowest Rainfall** = 604 mm (1877)
- **Highest Rainfall** = 1017 mm (1961)
- **Lowest Rainfall as % of Mean** = -21%
- **Highest Rainfall as % of Mean** = 17%
Fig. 2.8. All-India summer monsoon rainfall in standard units (deviation from normal divided by standard deviation), 1871–1984.

Mooley & Shukla (1987) in Monsoon Meteorology (Eds) Chang and Krishnamurti
Fig. 2.11. Distribution of subdivisional monsoon rainfall in standard units in 1877 and 1961, the years of lowest and highest all-India monsoon rainfall, respectively.

Fig. 2.14. Distribution of subdivisional monsoon rainfall in standard units in 1899 and 1892, the years of maximum incidence of drought and flood, respectively, over India.

Moolen & Shukla (1987) Monsoon Meteorology (Eds)
Chang & Krishnamurti
FIG. 1. The oceanic region over which surface data is examined. The numbers within each box represent mean number of observations per month.

S.D. of Interannual Variations (TANG) (°C)

Rao and Goswami (1988)
MWR, 116, 558
Fig. 4. Ten-year running mean of the SST and ART anomalies over three boxes shown in Fig. 1. Also shown are the average number of observations per month for the 70 years.
Fig. 5. Correlation coefficients (×100) between whole India seasonal rainfall and SST over different boxes averaged for (a) MA (b) MAM, (c) JJA, (d) SON. Number of years for which data is available varies from box to box. Hatching denotes significance at 95% level while crosshatching denotes significance at 99% level.

Rao & Goswami (1988) MNR, 116, 558
Fig. 10. MA SST anomalies (°C) averaged for (a) eight heavy-rainfall years 1908, 1916, 1933, 1953, 1956, 1959, 1961 and 1970 (0.3°C contour is marked and negative regions shaded), and (b) ten deficient rainfall years 1905, 1911, 1918, 1920, 1939, 1951, 1965, 1968, 1972 and 1974 (−0.3°C contour is marked and positive region shaded).
Fig. 2.18. Normalized anomaly of Indian monsoon rainfall and of Eurasian December-to-March snow cover, 1967-84.

Mooley and Shukla (1987)

Monsoon Meteorology (Gds) Chang
and Krishnamurti.
Fig. 2.19. Composite of the normalized Darwin pressure anomaly (three-month running mean) for heavy monsoon rainfall years and deficient monsoon rainfall years. (After Shukla and Paolino 1983.)

Lag Correlations between IMR and SST over W. Pacific (0°–8°N, 130°E–150°E) & E. Pacific (0°–8°N, 170°W–150°W)

IMR and sea water temp. in the following January at 137°E averaged between 2°N–10°N.
• INDIAN SUMMER MONSOON HAS PROMINENT INTRASEASONAL AND INTERANNUAL VARIABILITY.

• THE INTRASEASONAL LOW-FREQUENCY VARIABILITY IS DOMINATED BY THE ACTIVE/BREAK SPELLS. THE ACTIVE/BREAK CYCLES ARE MANIFESTATIONS OF SUPERPOSITIONS OF A 10-20 DAY OSCILLATIONS AND A 30-50 DAY OSCILLATIONS.

• THE 10-20 DAY OSCILLATION IS WESTWARD PROPAGATING AND DOES NOT HAVE ANY SIGNIFICANT NORTHWARD PROPAGATION.

• THE 30-50 DAY OSCILLATION HAS A PROMINENT NORTHWARD AND EASTWARD PROPAGATION. IT MUST, HOWEVER, BE DIFFERENT FROM THE EQUATORIAL 30-50 DAY MODE AS THE MONSOONAL MODE HAS SIGNIFICANT MERIDIONAL WIND ASSOCIATED WITH IT.

• THESE INTRASEASONAL OSCILLATIONS SEEM TO BE CLOSELY LINKED WITH THE FLUCTUATIONS OF THE ITCZ IN THIS REGION.

Empirical studies of interannual variations of the monsoon rainfall show strong association with various local and remote boundary forcings such as Arabian Sea SST, ENSO, Eurasian snow cover etc. This is consistent with recent modelling studies that show that the interannual variations in the tropics, in general, are caused primarily by slowly varying boundary conditions. However, exact mechanisms through which these boundary forcings influence the monsoon circulation is not clear at all. More insightful empirical as well as modelling studies are needed to throw light on this problem.