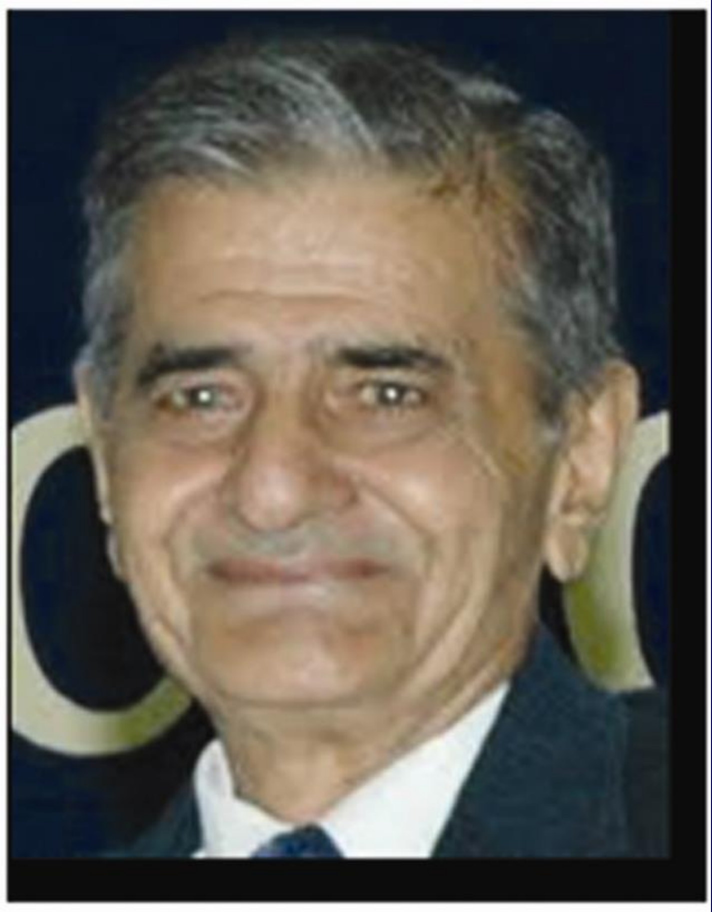
D. R. Sikka : The Monsoon Guru



1932–2017

Sulochana Gadgil
IMetSoc, Pune
29 March 2019

- It is a great honour for me to talk about Sikkasaab. With enormous contributions to our understanding of the Indian monsoon, sustained efforts devoted to nurturing atmospheric and oceanic science in the country and leadership of several national observational experiments, he was widely respected and regarded as Bhishmapitamah of our field.
- I am particularly fortunate in having had the opportunity to learn from him and collaborate with him over several decades (from 1971 until 2017) , not only in monsoon research but also on challenging tasks such as planning and execution of the Indian Climate Research Programme (ICRP).
- It is difficult to do justice to his scientific contributions in 20 minutes but I shall try.

- Sikka was born in 1932, and spent his early childhood in Jhang Mighiana, then in undivided India, now in Pakistan. Sikka’s academic performance was rated outstanding right from the first years in the primary school. Access to the excellent school library kindled his love for reading Urdu fiction (which he enjoyed throughout his life) and he developed the reading habit. This led later to his becoming a genuine scholar in the field.
- He had a vast knowledge of the works of the early pioneers such as Blanford, Elliot and Walker as well as of scientists such as Riehl, Malkus, Ananthakrishnan, Bjerknes and Charney, whose contributions led to a revolution in our understanding of tropical and monsoon meteorology during the six decades in which Sikka was active.

- Sikka’s enormous contributions to our understanding and predicting the monsoon were rooted in his profound love for and insatiable urge to delve deep into the monsoon system and its ever-varying manifestations with analysis of observations, including those with the latest technology (he was the first in the country to get interesting results about monsoon variability with analysis of satellite imagery) , and interpretation of the results on the basis of the latest advances in tropical meteorology, made possible by his deep scientific interests and genuine scholarship.
- His passionate affair (as he called it) with the Indian summer monsoon began in 1954, when he joined IMD, and ceased only with the end of his life on 18 March 2017.

- He was fortunate to have his first posting under another great monsoon meteorologist, Dr. R Anathakrishnan, and get excellent training in making careful observations with the meteorological instruments including pilot balloons and radiosondes, in identifying errors in the radiosonde temperature and filtering out data that were of doubtful quality.
- At IMD he also studied the weather charts and acquired knowledge of the pressure, wind patterns associated with different phases of the monsoon and became a leading synoptic meteorologist in the country. Dr. P V Joseph, whose contributions I shall not talk about today is the other leading synoptic meteorologist with a deep insight into the nature of the monsoon system.

- **Sikka joined IITM in December 1962 because he wanted to devote himself to research. His active participation in the International Indian Ocean Expedition (IIOE, 1963-66) soon thereafter, led to interaction with some of the best scientists in the field and significantly contributed to his development as a meteorologist.**
- **After that, he was sent to US where he was trained in satellite meteorology as well as Numerical weather Prediction. Thus, Sikka got a good background in dynamical meteorology and the fast developing branches of NWP and satellite meteorology.**

- After this, at IITM he worked on diverse topics such application of satellite data to meteorological research, NWP, forecasting of tropical cyclones by objective techniques using persistence and analogue based climatology as well as application of non-divergent barotropic model, climatology of the tropical cyclones in the western part of south Indian Ocean etc.
- I joined IITM as a CSIR pool officer in 1971. Since Sikkasaab and I shared a deep interest in the monsoon, we began collaborating soon thereafter and in the process I began learning from him about the monsoon system. Since we brought different expertise to the table, this proved to be the beginning of a very successful collaboration, which we both enjoyed. Monsoon studies became the focus of his work thereafter.
- I consider next his two major contributions to our understanding of Monsoon Variability.

ENSO- monsoon relationship

One of Sikka's most important discoveries was that of the link between the Indian summer monsoon rainfall and the El Nino Southern Oscillation (ENSO) (with a high propensity of droughts during El Nino) revealed by meticulous analysis of the monsoon rainfall data series developed by scientists at the Indian Institute of Tropical Meteorology (IITM) and a set of indices for ENSO, which were then being developed. Even today, the ENSO-monsoon relationship is the basis of monsoon prediction by most of the state-of art dynamical models.

Proc. Indian Acad. Sci. (Earth Planet. Sci.), Vol. 89, Number 2, July 1980, pp. 179–195.

Some aspects of the large scale fluctuations of summer monsoon rainfall over India in relation to fluctuations in the planetary and regional scale circulation parameters

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MS received 19 August 1979 ; revised 19 April 1980

Prof. Pisharoty symposium at PRL (I believe)

ENSO- monsoon relationship

- Sir Gilbert Walker discovered the Southern Oscillation during his quest for predictors of the Indian monsoon.
- The link to Indian rainfall was specific in Walker’s original definition of SO “the tendency of pressure at stations in the Pacific and the rainfall in India and Java (presumably also in Australia and Abyssinia) to increase while the pressure in the Indian Ocean region decreases”.
- However, his efforts to translate the relationship to skillful prediction of the Indian monsoon were unsuccessful.

From Sikka (1980)

Walker (1924, 1928) brought into prominence a large scale oscillation in the sea level pressure over the tropics. This oscillation is known as the Southern Oscillation (S.O.) which determines the out-of-phase pressure relationship in the south Pacific/south American region with the Indonesian/Indian Ocean region. The work of Bjerkenes (1969) on the S.O. suggests that the S.O. has a role in the redistribution of heat sources and sinks in the equatorial region which in turn influence the related general circulation over the Indo-Pacific region.

- Thus Sikka realized that the most important aspect of the ENSO-monsoon link is the redistribution of heat sources.
- He pointed out Reiter's finding, on the basis of the Line island (in Central Pacific) precipitation index, that there were three distinct epochs of frequency of El Nino in the period 1910-75. The two epochs of 1911-1928 and 1963-75 are accompanied by frequent El Ninos. The third epoch 1929-1962 with irregular and infrequent occurrence of El Nino.
- Sikka showed that there is similarity with epochs of differing frequencies of droughts of Indian summer monsoon rainfall identified by Joseph (1976) by analysis of the Parthasarathy data set.

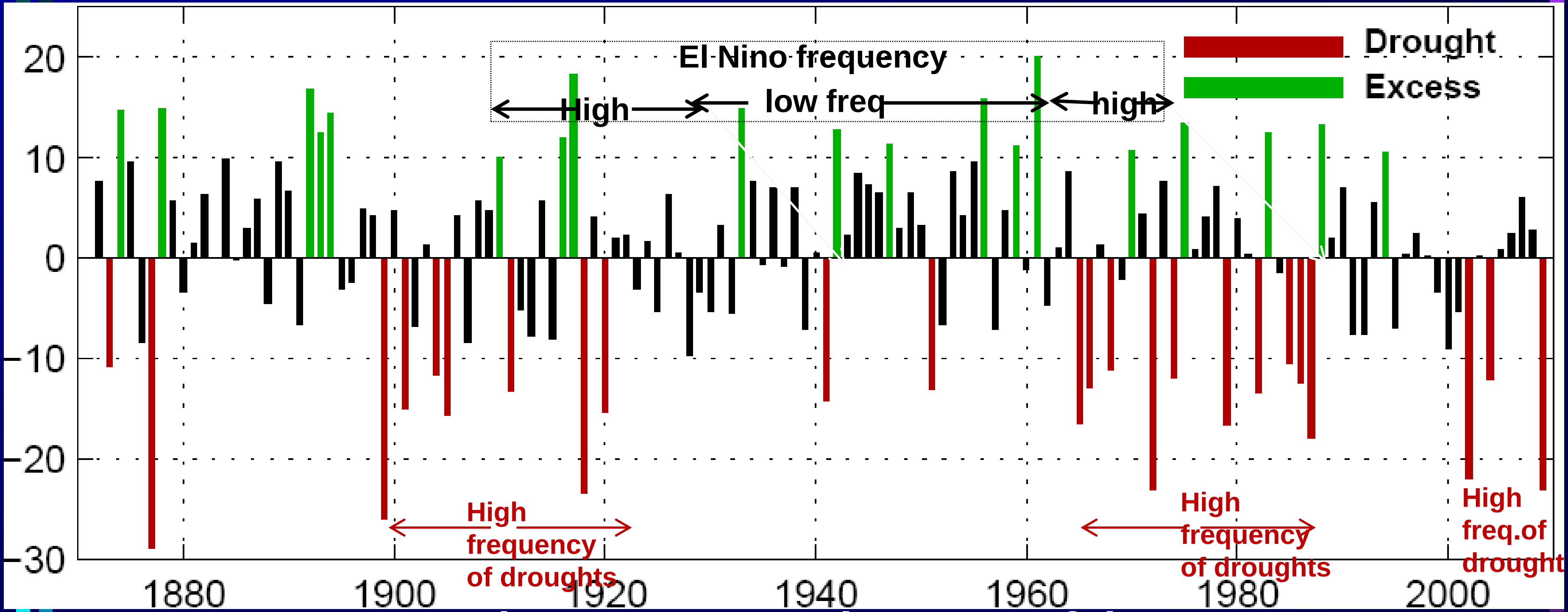
- **Frequency of El Nino and droughts**

Epoch	Freq. of El Nino	No. of monsoon droughts
1911-28	high	3 (in 18 years)
1929-62 :	low	2 (in 34 years)
1963-75:	high	5 (in 13 years)

Thus Sikka showed that epochs of high (low) frequency of droughts generally coincided with epochs of high (low) frequency of El Nino.
After the decadal scale, he considered the interannual variation of ISMR.

Interannual Variation of the anomaly of ISMR

(as % of the mean) during 1876-2010



Drought: ISMR anomaly <-10% of the mean

Excess rainfall seasons: ISMR anomaly >10% of the mean

Droughts :less frequent during 1878-98 (0 in 21years); more frequent during 1899-1920 (7 in 21 years) ; less frequent 1921-64 (2 in 44 years) ;more frequent 1965-87 (10 in 28years) and again since 2002

- Sikka also examined the El Nino events during 1875 -1909 on the basis of Southern Oscillation index, prior to the Reiter data set, based on Lines island precipitation index from 1910. By analysis of the period 1875-1975 he showed that there were
- 15 El Nino years which were monsoon failures, years; while there were 3 years of monsoon failure which were not El Nino and 7 years of El Nino but not monsoon failure : 7 years (++=15,+-=3,-+=7)
- Sikka was always aware that in complex systems such as the monsoon and ENSO, there would never be one-to-one correspondence and always calculated also the frequency of events which did not fall in line with the majority.

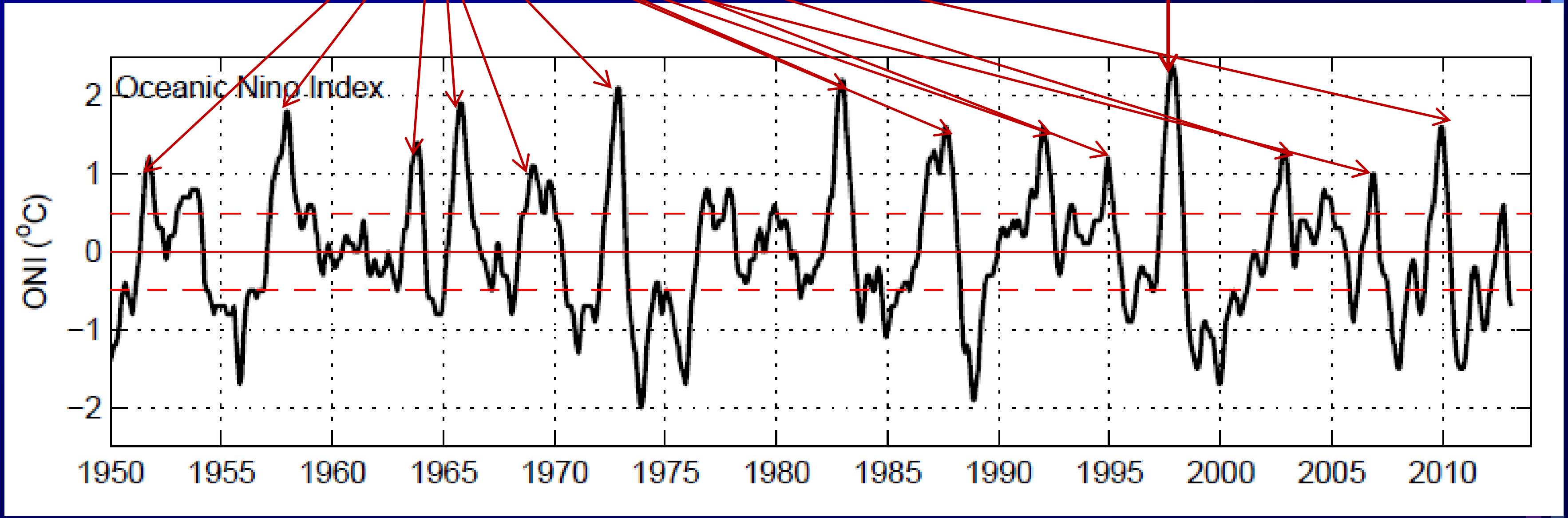
Table 1. El–Nino events and monsoon rain failures (period 1875–1975).

Years of monsoon failure which were El–Nino years too		Years of monsoon failure but not El–Nino years.	Years of El-Nino but not monsoon failure.
El–Nino years	Monsoon failure years		
1877	1877	1901	1921–22
1899	1899	1920	1923–24
1905	1905	1966	1925–26
1911–12	1911		1930–31
1913–14	1913*		1956–58
1914–15	1915*		1963–64
1918–19	1918		1969–70
1927–28	1928		
1939–40	1939*		
1940–41	1941		
1951–53	1951		
1965–66	1965		
1968–69	1968		
1972–73	1972		
1974–75	1974		
15 years		3 years	7 years

* Years of minor failure of monsoon rainfall.

El Ninos

Strongest El Nino:
1997



El Ninos		Droughts
1962-87: (26years)	8	10
1988-2001 (14years)	2	0

- **Sikka concluded that "The preliminary relationship presented above with respect to the number of El Nino years associated with a large number of monsoon failures over India, points to the desirability of further work in this area. The very indication that in some years/epochs the out of phase relationship exists between the poor performance of the monsoon rain over India and abnormal rain over eastern/central Pacific, suggests very large scale teleconnections which operate through the displacement of the east-west circulation resulting from changes in the thermal forcing in the equatorial regions on the planetary scale."**

- **He also addressed the important question of whether the El Nino event precedes the monsoon failure or vice versa. However, the fragmentary observational evidence and few experiments with models available at that time could not provide an answer.**
- **Sikka's thought provoking study was followed by that of Pant and Parthasarathy (1981) who showed that the correlation of the area average June-August rainfall over India and a contemporaneous SO index developed by Wright (1977) was 0.59.**
- **In the more often quoted Rasmusson and Carpenter (1983) study, it was shown that there is a strong tendency for below normal summer monsoon precipitation on the all-India scale during warm episode years (WEY0) (on the basis of SST anomalies of the eastern equatorial Pacific), with negative departures in 19 out of 25 years.**

Sikkasaab's other most important contribution, which has also received worldwide recognition was one of the fruits of our collaboration. This involved discovery of important facets of the sub-seasonal variation of the monsoon revealed by analysis of daily satellite imagery.

On the Maximum Cloud Zone and the ITCZ over Indian Longitudes during the Southwest Monsoon

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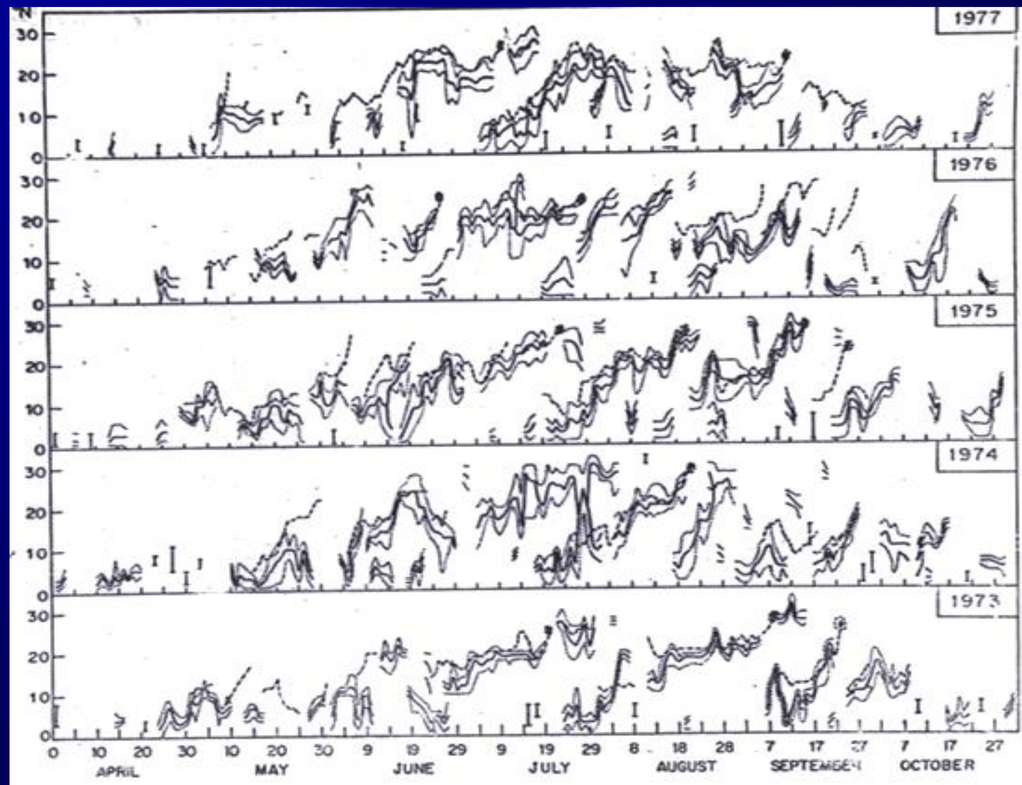
(Manuscript received 10 September 1979, in final form 4 August 1980)

- **This paper is cited in a large number of papers as one showing the relationship of northward propagations of cloudbands to active break spells of the monsoon.**



- **However, in my view, a far more important contribution of that study is that it identified the basic system responsible for the monsoon.**

Basic system responsible for the Monsoon

Halley (1686) first suggested that the primary cause of the annual cycle of the monsoon circulation was the differential heating between the land and the ocean, caused by the seasonal march of the sun.

Ever since then, the monsoon circulation/rainfall is considered to be driven primarily by the differential heating between land and ocean by several scientists, and it is thus assumed that the ascent/ rainfall over the land will increase (decrease) with increasing (decreasing) land-ocean contrast.

For example in 'Competing Influences of Greenhouse Warming and Aerosols on Asian Summer Monsoon Circulation and Rainfall' William Ka-Ming Lau and Kyu-Myong Kim, (Asia-Pac. J. Atmos. Sci., 53(2), 181-194, 2017 DOI:10.1007/s13143-017-0033-4) state

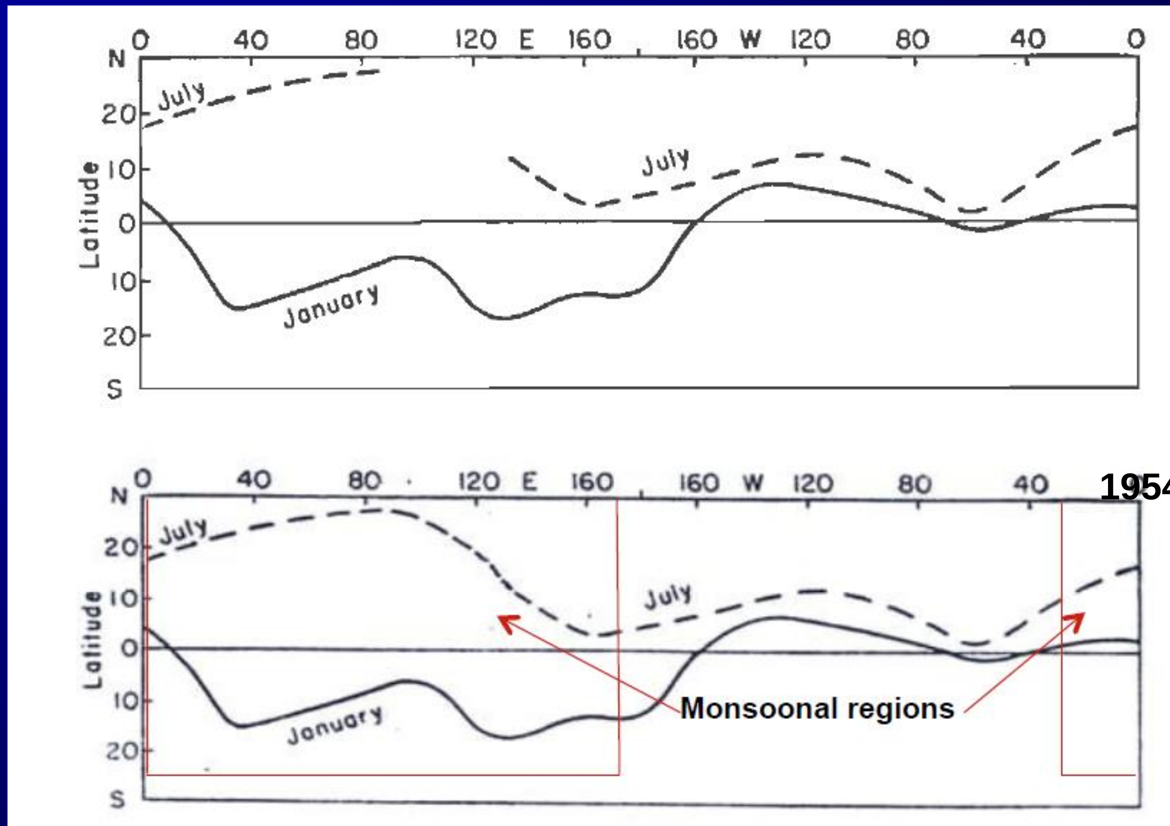
- “Under GHG-only forcing, the land warms much faster than the ocean, magnifying the pre-industrial climatological land-ocean thermal contrast and hemispheric asymmetry, i.e., warmer northern than southern hemisphere. A steady increasing warm-ocean-warmer-land (WOWL) trend has been in effect since the 1950’s substantially increasing moisture transport from adjacent oceans, and enhancing rainfall over the Asian monsoon regions.”

- “According to the IPCC 5th Assessment Report, global monsoon rainfall is likely to increase-----. The enhanced monsoon rainfall has been attributed to increased land-sea contrast, and more abundant precipitable water in a warmer climate.”

A revival of Indian summer monsoon rainfall since Qinjian Jin and Chien Wang, 2002, **Nature Climate Change, 24 JULY 2017 | DOI: 10.1038/NCLIMATE3348**

"---we show that monsoon rainfall has increased in India at 1.34mmd^{-1} decade^{-1} since 2002. This apparent revival of summer monsoon precipitation is closely associated with a favourable land–ocean temperature gradient, driven by a strong warming signature over the Indian subcontinent and slower rates of warming over the Indian Ocean."

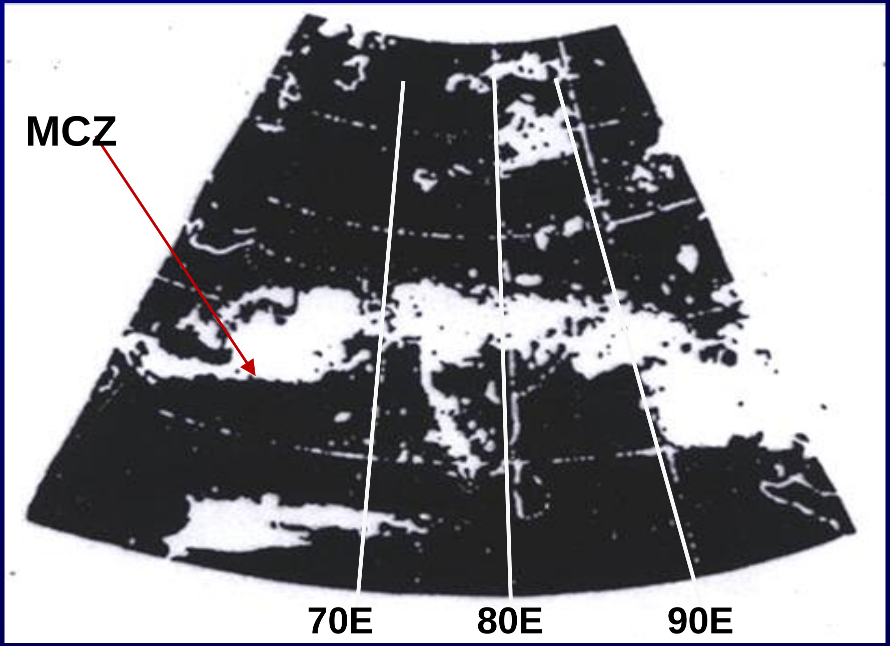
However, Blanford (1886) had opposed the idea of land-ocean contrast being considered the prime cause of the monsoon. He ***suggested that the system responsible for the monsoon is the ITCZ (a la Charney 1971) or the equatorial trough (a la Riehl). Charney also believed that the system responsible for the monsoon was the ITCZ. Riehl realized it sometime between 1954 and 1979.***



1979

Clearly it is important to unravel the role of land-ocean contrast in the mean monsoon as well as its variability and identify the basic system responsible for the monsoon.

Support for the hypothesis of the basic system responsible for the Indian summer monsoon being the ITCZ, was provided by Sikka and Gadgil's (1980) study of the daily satellite imagery during April-October 1973-77. They analyzed the daily variation of (i) the location of the maximum cloudiness zone (MCZ) over the Indian longitudes of 70^0, 80^0 and 90^0E,



8 July 1973
Active monsoon day

and (ii) of the 700 hPa trough over the Indian region, which is known to be associated with intense convergence in the lower troposphere and maximum non-orographic rainfall.

They showed that

(i) the dynamical characteristics of the MCZ (*a prominent zonally oriented region of moist convection)* over the Indian region on an active monsoon day are the same as those of the ITCZ, with intense cyclonic vorticity at 850 and 700 hPa

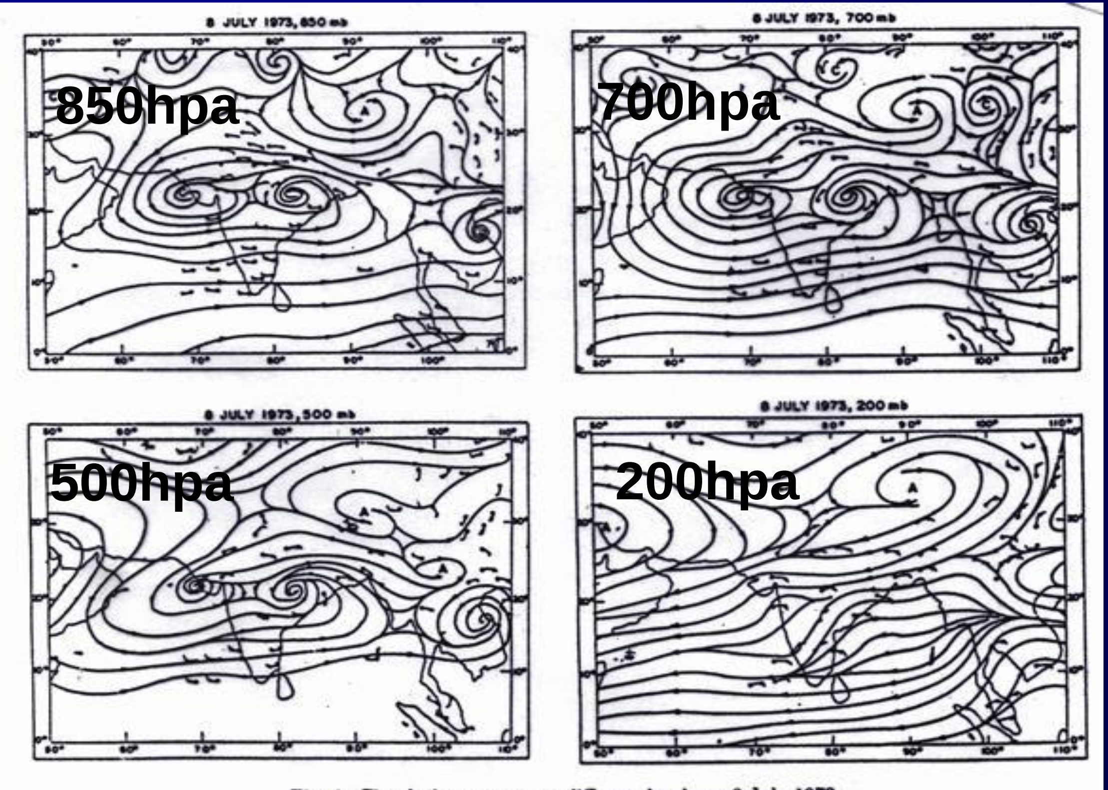


Fig. 1. Circulation pattern at different levels on 8 July 1973.

and

(ii) there is a high correlation between the axis of the MCZ and that of the 700 hPa trough.

Thus the MCZ over the Indian region on an active monsoon day resembles the ITCZ, being associated with cyclonic vorticity at 850 and 700 hPa, and there is a high correlation between the axis of the MCZ and that of the 700 hPa trough which is known to be associated with intense convergence in the lower troposphere and maximum non-orographic rainfall. Hence, Sikka and Gadgil (1980) concluded:

"Putting all this together, it becomes clear that the organized moist convection associated with the monsoon may be attributed to an ITCZ over the region."

Sikka's perception of the monsoon system: planetary scale system ITCZ in which synoptic and smaller scale systems are embedded. Active phase of the ITCZ is associated with frequent genesis and longer lifespan of these systems.

- **The paper of Sikka (1980) famous for elucidating the ENSO-monsoon link also has detailed information on the circulation features of good and bad monsoon years which shows that they differ mainly in the number of low days (and not in the number of depression days).**

Composited years type	No. of systems		Depression days	Low days	Two system days	No. of disturbed days	No. of undisturbed days
	Depression	Lows					
Good monsoon (average for 5 years)	21 (4·1)	85 (17·0)	82 (16·4)	150 (30·0)	25 (5·0)	232 (46·4)	78 (15·6)
Bad monsoon (average for 5 years)	20 (4·0)	54 (10·8)	83 (16·6)	88 (17·6)	10 (2·0)	171 (34·2)	139 (27·8)
Ratio of good and bad monsoon years composites	1·1	1·6	1·0	1·7	2·5	1·4	0·6

- **Thus the critical feature of the basic system is the multi-scale interaction. Thus it is expected that variation of the seasonal rainfall with ENSO will be associated with changes in the frequency, life span, tracks etc. of synoptic scale systems.**
- **Note the difference in approach to that promoted vigorously by BN Goswami of two components of monsoon variability: the seasonal which has deterministic component and intraseasonal which is the chaotic element which limits the predictability. We heard yesterday that in a recent study by him with several IITM scientists, there has been some change in this approach and a higher limit of predictability discovered.**

- **Thus Sikka and Gadgil suggested that the monsoon should be considered to be a manifestation of the seasonal migration of the ITCZ in response to the seasonal variation of the solar radiation.**
- **That the Indian/South Asian monsoon is a manifestation of the seasonal migration of the ITCZ is now accepted by several scientists.**
- **For example, in a recent review Schneider et. al (2014) 'Migrations and dynamics of the intertropical convergence zone', 4 September, Vol. 5 1 3 | N AT U R E |p45) state :**

'Over the Indian Ocean and adjacent land surfaces, the ITCZ swings more dramatically between average latitudes of 20^0N in boreal summer and 8^0S in boreal winter, prompting the seasonal rainfall variations of the South Asian Monsoon. Monsoon'.

- There are major differences in the implications for monsoon variability of the two hypotheses about the basic system of the monsoon i.e. land-sea breeze or ITCZ.

- Simpson (1921) pointed out that observations of the space-time variations of the monsoon over the Indian region are not consistent with the expectation that the ascent/rainfall over land will increase with increasing land-ocean contrast.
- Kothawale and Rupakumar (2002) showed that the land surface temperature anomaly is positive for droughts and negative for excess monsoon seasons.
- Two recent studies have suggested that the time has come to abandon the land-sea breeze hypothesis.

“The monsoon system: Land–sea breeze or the ITCZ?”,

By

Sulochana Gadgil

***J. Earth Sys. Sci.*, Indian Academy of Sciences, 2018 127(1),**

In this paper, the land-sea breeze hypothesis and its implications for the variability of the monsoon are discussed and it is shown that the observations of monsoon variability do not support this popular theory of the monsoon.

It is shown that an increase in the monsoon rainfall is generally associated with a decrease in the temperature above the land surface. This suggests that rather than the land surface temperature determining the rainfall, it is itself determined by the rainfall (or lack thereof).

Furthermore, an increase in the monsoon rainfall is also generally not associated with an increase in the land–ocean temperature contrast as expected from the land–sea breeze model, but a decrease in the land–ocean temperature contrast, although the relationship is weak.

An alternative hypothesis (whose origins can be traced to Blanford's (1886) remarkably perceptive analysis) in which the basic system responsible for the Indian summer monsoon is considered to be the Intertropical Convergence Zone (ITCZ) or the equatorial trough, is then examined and shown to be consistent with the observations.

Role of Land-Ocean Contrast in the Indian Summer Monsoon Rainfall

By

Sulochana Gadgil, P A Francis, K Rajendran, Ravi S. Nanjundiah and Suryachandra A. Rao

Chapter in the WMO-sponsored book "The Multiscale Global Monsoon"

- **The relationship of ISMR and the surface temperature over the Indian subcontinent, over the surrounding ocean, equatorial Indian Ocean and the difference between the land and ocean temperatures, for the period (1981-2008) in observations and model simulations has been investigated.**
- **observations: the surface temperature observations at IMD, and HadI-SST, the 2m temperature over land and ocean from NCEP reanalysis and rainfall data from IMD grid data, ISMR data from Parthasarathy et. al and CMAP data**
- **Model simulations: (i)Retrospective predictions with April initial conditions with High resolution version of NCEP CFS2 developed at IITM under the Monsoon mission viz. CFS2-T382 (Ramu et. al. 2015), and (ii) runs of a much higher resolution (TL-959) MRI AGCM (Mizuta et. al. 2006) , with observed SST.**

observations: the surface temperature observations at India Meteorological Department (IMD, from Srivastava et.al. 2008), and HadI-SST, the 2m temperature over land and ocean from NCEP reanalysis and rainfall data from IMD grid data, ISMR data from Parthasarathy et. al and CMAP data

Model simulations:

(i) Retrospective predictions with April initial conditions with High resolution version of NCEP CFS2 developed at IITM under the Monsoon mission viz. CFS2-T382 (Ramu et. al. 2015) hence forth CFS , and

(ii) runs of a much higher resolution (TL-959) MRI AGCM (Mizuta et. al. 2006) , henceforth MRI, with observed SST.

It has been shown that for observations and models, the relationship of the land-ocean contrast with the monsoon rainfall is opposite to what is expected from the land-sea breeze hypothesis. The land-sea breeze hypothesis focuses primarily on the impact of the high land surface temperature on the atmospheric circulation and rainfall. However, the system is an interactive one with the atmosphere also having an impact on the temperature of the land.

The relationship between monsoon rainfall and surface temperature over the land in observations and models suggests that, in both, the impact of the atmosphere on land surface temperature is dominant in the land-atmosphere interaction. *It, therefore, appears that land temperature responds to the variation of the monsoon rainfall, rather than determining it.*

- **I would like to conclude this lecture with a few remarks on Sikkasaab's enormous contributions nurturing atmospheric and oceanic sciences and also to the planning and execution of several observational experiments: MONTBLEX in 1979, and BOBMEX,ARMEX and CTCZ under the ICRP, to name a few.**
- **I believe that what made this sustained effort over several decades possible, was his deep scientific understanding, broad interests and genuine patriotism.**
- **After the IIOE, he actively participated in other international experiments in 1973, 1977 and by the International Summer Monsoon Experiment (SMONEX, 1979).**

About the SMONEX experience, Sikka has remarked

'the Indian scientists participating in the SMONEX remained on the periphery as they were not well prepared for research studies and hence much of the credit of the excellent monsoon research emerging out of SMONEX went to the US scientists; clearly, it is essential for India to build its own capabilities for launching field programmes.'

Over the next three and half decades he worked very hard to contribute to nurturing such talent at different centres in the country and planning and launching world-class national field programmes with all the expertise provided by Indian scientists.

I have no doubt that this extraordinary scientist will be a source of inspiration to one and all in this hall.

Thank you