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EXPLORING THE RELATIONSHIP OF ENSO AND RAINFALL VARIABILITY OVER SOUTHERN ZONE OF TAMIL NADU

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Abstract: Rainfall is a random hydrological event distributed unevenly in both space and time. The monsoonal rains display a large amount of internal variability and also exhibit variation with external climatic forcings, such as the El Nino-Southern Oscillation. An attempt was made to analyze the rainfall variability and the influence of ENSO events in southern zone of Tamil Nadu. The results revealed that among the seven districts studied, annual rainfall ranged between 664 to 901 mm at Theni and Pudukottai districts respectively. Since, NEM is the lifeline monsoon for Tamil Nadu, the rainfall of NEM was categorized. Over a period of 30 years studied, 6 -11 (deficit) and 1-4 (scanty) years were witnessed. The influence of ENSO events were studied for both the monsoonal periods. SWM revealed a negative relationship for El-Nino while a positive relationship for La-Nina and vice-versa for NEM. Both the monsoons had a variable response in case of neutral years. El-Nino years had an increase of 6 to 22 per cent of rainfall during NEM while a decrease of -2 to -28 per cent was observed for SWM. For La-Nina years, a decrease of -10 to 20 per cent of rainfall was observed during NEM and an increase of 17 to 53 per cent in case of SWM.
Keywords: ENSO, Rainfall variability, Southern zone, South West Monsoon, North East Monsoon.

Introduction

In recent years, the inter-seasonal and intra-seasonal variability in weather is believed to outsmart the abilities of climatologists in characterizing the limits within which the variability can be observed. Rainfall is one of the major climatic elements that affects farmer's livelihood and plays a major role in the environment and socioeconomic conditions of Tamil Nadu. It is vital for both present and future rational utilization of the economic and human resources [1]. The unpredictability nature of rainfall is also one of the climate indications denoting the trends of changes within the earth's environment that can affect the natural set up. Seasonal to inter-annual rainfall fluctuations strongly affect the success of agriculture and the abundance of water resources [2]. The Indian Ocean (IO) environs the southern part of India. A significant amount of moisture comes from the oceans, it is

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reasonable to presume that the sea-surface temperature (SST) anomalies and wind over the oceanic area would have a marked influence over the weather and climate of India [11].

El Niño is fundamentally a warming of the surface waters of the tropical eastern Pacific Ocean from South American coast to the International Date Line (IDL). It is an insidious climatic happening which was found to be associated with regional climatic variations throughout the world [10]. During an El Nino event, lower than normal pressure can be obvious over the eastern portion of the tropical Pacific Ocean and higher than normal pressure is originated over Indonesia and northern Australia. This pattern of pressure is connected with weaker than normal near-surface equatorial east to west winds. These amenities differentiate the warm phase and Southern Oscillation (SO), which is often referred as El Nino / Southern Oscillation (ENSO) phenomenon. The El Nino and SO are therefore in a way inextricably allied with each other when an El Nino event nurtures its head in the Pacific Ocean. An ENSO event is regarded as quasi-cyclical, which occurs every two to seven years and can last for up to 18 months. A normally used index for El Ni˜no is the areal averaged sea surface anomaly (i.e., deviation from normal) in the region 5 °N to 5°S, 90 °W to 150 °W. Large positive values of this index define warm El Ni˜no conditions, while large negative values indicate cold La Ni˜na conditions. It is evident that the warm surface temperatures are strongly linked to weak trade wind (negative values of the SOI) and vice versa. [8] observed that recent advances in atmospheric and oceanic research, much of it focusing on El Niño -Southern oscillation and its tele-connections made it possible to forecast climate with valuable skill with lead times of several months.

The inter-annual variability of Indian Summer Monsoon rainfall has been linked to variations of sea surface temperatures over the Equatorial Pacific and Indian Oceans, Eurasian snow cover etc as reported by [5]. Analysis of long term data suggests there is an inverse relationship between El Niño events and the Indian Summer Monsoon Rainfall (ISMR). According to the previous studies which investigated the connection between ENSO and global rainfall signals [4] most part of India has less (more) rainfall during ENSO (La Nina) years. Analysis of long term data suggests there is an inverse relationship between El Niño events and the Indian Summer Monsoon Rainfall (ISMR). The southernmost part of India confirms contradictory signals which are inclined to have wet anomalies during the ENSO (SOI negative) years. The relationship with SOI and Nino-3 SST on NEMR of Tamil Nadu concludes that the SOI is negatively correlated with NEMR in Tamil Nadu [7] and Nino-3 SST is positively correlated [6] which imply that autumn-winter precipitation over Tamil

Nadu is influenced by the global climatological signals.

Most of the severe droughts over India occurred in association with El Niño events [9]. However, there is no one-to-one relationship as El Niño years have not always produced severe droughts. Distribution and the amount of NEMR are influenced by various parameters including El-Nino- Southern Oscillation (ENSO) and Indian Ocean Dipole (IOD). The relationship between ENSO events and rainfall are not same all over India, especially in the southern part of Tamil Nadu. Therefore, it is necessary to investigate the relationship between ENSO and monsoon rainfall over southern zone Tamil Nadu from a long-term point of view.

Materials and Methods

Southern agro climatic zone of Tamil Nadu is surrounded by coastal areas on the east and mountains in the west. This zone lies on the southern part of the Tamil Nadu State under rain shadow area. The elevation varies from mean sea level to 300 metres. The mean annual rainfall is 776 mm received in 43 rainy days [12]. The districts taken for the analysis is depicted in Fig 1.

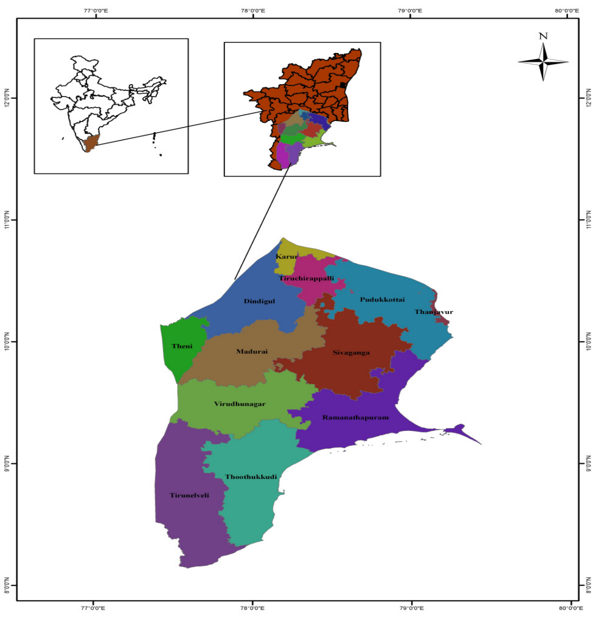


Fig. 1. Study districts in Southern zone taken for rainfall analysis

For the present analysis, 30 years of historical rainfall data from 1981 to 2010 were collected for the seven districts such as Dindugul, Madurai, Puddukottai, Tirunelveli, Virudhunagar, Tutucorin and Theni from the respective research station. In the absence of long term data for districts, data were taken from India Meteorological Department (IMD). The data were sliced for different seasons such as Cold Weather Period (CWP - January and February), Hot

Weather Period (HWP - March to May), South West Monsoon (SWM - June to September) North East Monsoon (NEM - October to December) and Annual period.

Rainfall classification for the study districts was done based on IMD and it is presented in Table 1.

Table 1. Rainfall classification, IMD

Per cent deviation (from mean rainfall)	Status
± 19	Normal
-20 to -59	Deficit
>-60	Scanty
+20 to +59	Excess
>+60	Wet

To comprehend the connection of enso and rainfall variability over southern zone of Tamil Nadu, Enso years were taken from long paddock, Bureau of Australian Meteorology [3].

Results and Discussion

To understand the rainfall climatology of southern zone (SZ), rainfall data was averaged over the years for its normal and its seasonal distribution was studied by segregating the data into seasons(Table 2 and Fig 2.). The analysis of the data from seven districts obviously pointed out that the annual rainfall of SZ varied between 664 (Theni) to 901mm (Pudukkottai). Among the seasons, NEM ascertain to be the major monsoon for all the locations contributing 42 to 61 per cent of annual rainfall. The per cent gradient of the seasons for the contribution of rainfall and the districts inclination from highest recorded rainfall to lowest recorded rainfall are given below.

NEM (42 to 61) > SWM (11 to 41) > HWP (12 to 20) > CWP (3 to 10)

Pudukottai > Madurai> Dindigul> Virudhunagar> Tirunelveli> Tuticorin> Theni

Table 2. Annual and seasonal normal rainfall of Southern Zone

Location	CWP (mm)	% C	HWP (mm)	% C	SWM (mm)	% C	NEM (mm)	% C	Annual (mm)
Dindigul	28	3	138	16	266	30	455	51	887
Madurai	23	3	156	17	306	34	401	45	892
Pudukottai	42	5	108	12	365	41	380	42	901
Tirunelveli	84	10	149	18	93	11	517	61	845
Virudhunagar	31	4	157	18	258	30	404	47	852
Tuticorin	40	5	140	19	154	21	384	53	721
Theni	35	5	132	20	163	25	334	50	664

Note % C – Per cent Contribution

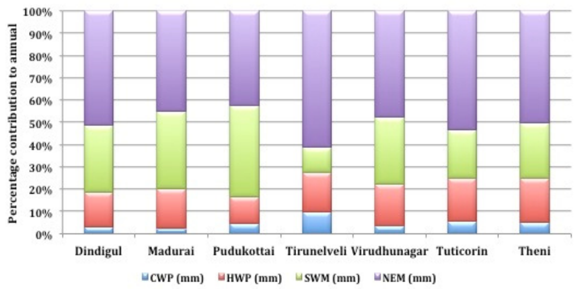


Fig.2 Annual and seasonal normal rainfall of southern zone

Thirty years of annual rainfall data was examined for the rainfall classification based on IMD criteria (Table 3) and the results showed on an average 60 per cent of the years had normal rainfall with variation ranging from 47 to 70 per cent among districts studied. Around 20 percent of the years had excess and only 1 per cent of the year had wet condition. Around 18 per cent of the years had deficit and 2 per cent years had scanty rainfall situations. Deficit years had variations ranging from 13 to 27 per cent. It is evident that 20 per cent of the years had negative rainfall situations. Further seasonal rainfall examination was considered as it decides the success and failure of crop production over the Southern Zone.

Table 3. Classification of annual rainfall based on IMD criteria

Category	Wet	% C	Excess	% C	Normal	% C	Deficit	% C	Scanty	% C
Dindigul	0	0	7	23	17	57	4	13	2	7
Madurai	0	0	4	13	21	70	4	13	1	3
Pudukottai	1	3	5	17	21	70	3	10	0	0
Tirunelveli	1	3	6	20	14	47	8	27	1	3
Virudhunagar	0	0	8	27	16	53	6	20	0	0
Tuticorin	0	0	7	23	16	53	7	23	0	0
Theni	0	0	5	17	20	67	5	17	0	0
Mean	**0**	**1**	**6**	**20**	**18**	**60**	**5**	**18**	**1**	**2**

Note % C – Per cent Contribution

Table 4a. Classification of SWM rainfall based on IMD criteria

Category	Wet	PC	Excess	PC	Normal	PC	Deficit	PC	Scanty	PC
Dindigul	2	7	7	23	11	37	8	27	2	7
Madurai	1	3	4	13	20	67	4	13	1	3
Pudukottai	0	0	9	30	10	33	11	37	0	0
Tirunelveli	4	13	8	27	5	17	8	27	5	17
Virudhunagar	2	7	5	17	13	43	7	23	3	10
Tuticorin	3	10	8	27	6	20	11	37	2	7
Theni	2	7	8	27	7	23	11	37	2	7
Mean	**2**	**7**	**7**	**23**	**10**	**34**	**9**	**29**	**2**	**7**

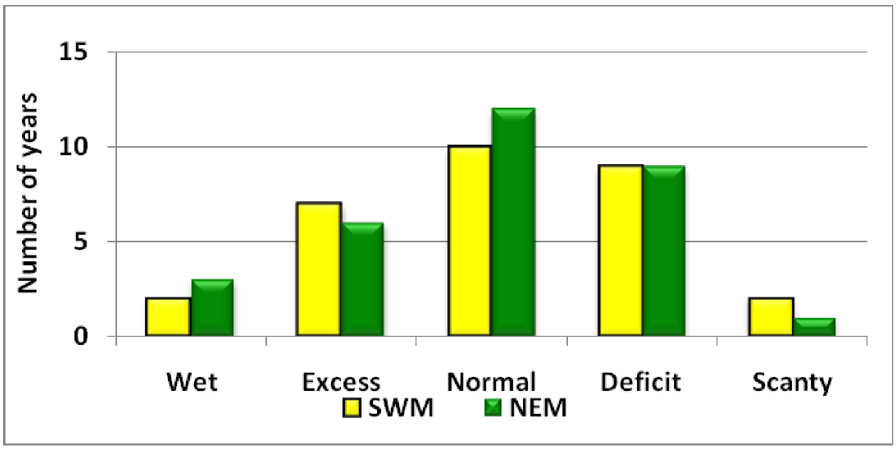


Fig. 3 Rainfall classification of monsoons based on IMD criteria

Table 4b. Classification of NEM rainfall based on IMD criteria

Category	Wet	PC	Excess	PC	Normal	PC	Defecit	PC	Scanty	PC
Dindugal	4	13	3	10	14	47	7	23	2	7
Madurai	3	10	6	20	11	37	10	33	0	0
Pudukottai	2	7	5	17	13	43	10	33	0	0
Tirunelveli	2	7	6	20	10	33	11	37	1	3
Virudhunagar	2	7	10	33	8	27	6	20	4	13
Tuticorin	2	7	7	23	11	37	9	30	1	3
Theni	3	10	4	13	15	50	7	23	1	3
Mean	**3**	**9**	**6**	**20**	**12**	**39**	**9**	**29**	**1**	**4**

When probing the monsoonal period, it is evident that monsoon rainfall has variability of higher magnitude than annual rainfall (Table 4a and 4b; Fig 3). Both the monsoons had almost similar pattern in distribution of years under the rainfall categories. About 34 per cent of the years had normal rainfall during SWM while NEM had 39 percent of normal years. SWM had 23 per cent of excess and 7 per cent of wet years while NEM had 20 per cent of excess and 9 per cent of wet years respectively. Interestingly both the monsoons had an average of 29 per cent of deficit years. SWM had 7 per cent and NEM had 4 per cent of scanty years. Overall in SWM the percentage of deficit years varied between 13 to 37 and that of NEM is 20 to 27. This result affirms that around 33 per cent of the years (one third) had witnessed rainfall deficits during NEM and 36 percent during SWM. This reiterates the need for understanding the relationship between ENSO events and seasonal rainfall.

Influence of ENSO events on rainfall of southern zone

Influence of ENSO events were studied by categorizing the years based on Allen *et al.,* 1996 as El-Nino, La-Nina and Neutral years. Rainfall occurred in these years were averaged and their deviations from 30 years normal were derived.

Annual

The deviations for El-Nino years ranged between - 6.2 to +6.2 per cent while La-Nina years had – 6.0 to +17.1 percent. La-Nina years had considerable increase than El-Nino years followed by neutral years having variations ranging from -15.2 to +2.4 percent. Except Madurai and Pudukottai districts, all other districts had negative relationship for neutral years (Table 5). Further to have an insight into the relationship, seasonal variations were studied.

Table 5. Influence of ENSO events on annual rainfall

Locations	Annual		
	El-Nino	La-Nina	Neutral
Dindigul	2.5	5.5	-5.5
Madurai	-6.2	11.7	1.7
Pudukottai	-1.3	-0.8	2.4
Tirunelveli	6.2	-6.0	-4.6
Virudhunagar	0.6	14.1	-7.3
Tuticorin	-0.7	10.4	-2.5
Theni	5.1	17.1	-15.2

Cold Weather and Hot Weather Period seasonal rainfall

Rainfall during CWP had negative relationship with El-Nino event. Except Pudukottai, other districts had deviations ranging from -34.6 to -64.8 per cent. In La-Nina years Pudukottai (-63.5 per cent) and Tirunelveli (-13.3 per cent) had negative relation. All other districts had positive relation ranging from +0.5 to +37.0 per cent. Typically neutral years had positive relation ranging from +20.1 to +53.8 per cent. In case of HWP, a mixed response was observed for all the events. During El-Nino years except Tirunelveli (+3.4 per cent) all other districts had negative deviations ranging from -1.2 to +11.4 per cent. La-Nina years had deviations ranging from -14.9 to +25.1 per cent while neutral years had -11.1 to +16.3 per cent (Table 6).

Table 6. Influence of ENSO events on Cold Weather and Hot Weather Period seasonal rainfall

Locations	CWP			HWP		
	El-Nino	La-Nina	Neutral	El-Nino	La-Nina	Neutral
Dindigul	-64.8	37.0	30.1	-8.6	-7.0	6.4
Madurai	-34.6	0.5	21.3	-6.7	-14.9	16.3
Pudukottai	1.8	-63.5	20.1	-11.4	3.7	7.8
Tirunelveli	-63.5	-13.3	53.8	3.4	2.3	-6.8
Virudhunagar	-58.4	34.1	27.2	-3.2	-9.2	4.7
Tuticorin	-62.6	1.9	46.5	-2.3	16.0	-11.1
Theni	-53.3	34.7	21.6	-1.2	25.1	-7.5

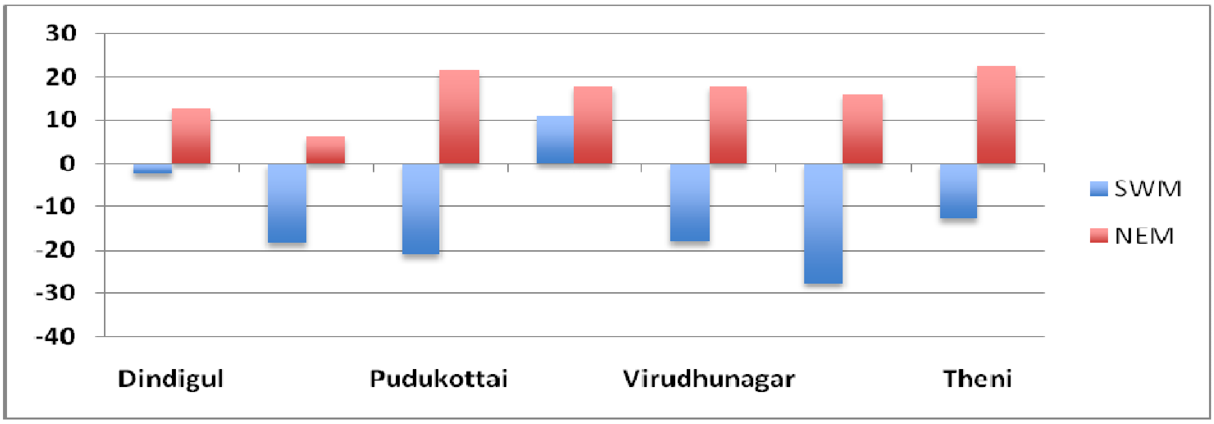
Monsoon rainfall (SWM and NEM)

Monsoon seasons had well-defined and accountable relationship with the ENSO events (Table 7; Fig 4). SWM (-2.5 to -27.7 per cent) had negative relationship with El-Nino years while NEM (+6.2 to +22.3 per cent) had a positive relation for all the districts studied. This clearly discriminate the seasonal shift in the dynamics of monsoons and tele-connections. In case of La-Nina years, SWM had strong positive relationship with deviations ranging from +11.6 to +52.9 per cent and NEM had almost a mixed response. For neutral years SWM had a mixed response while NEM had a negative response ranging from -8.4 to -20.8 per cent for all the districts except Dindigul (+2.8 per cent).

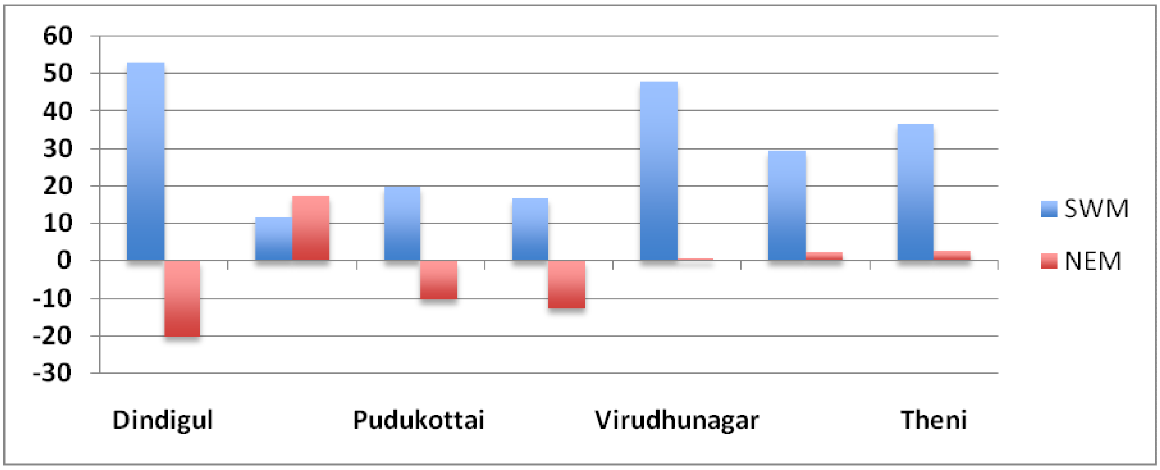
Table 7. Influence of ENSO events on Monsoon rainfall

Locations	SWM			NEM		
	El-Nino	La-Nina	Neutral	El-Nino	La-Nina	Neutral
Dindigul	-2.5	52.9	-22.1	12.9	-20.3	2.8
Madurai	-18.3	11.6	9.4	6.2	17.2	-9.6
Pudukottai	-20.9	19.6	11.7	21.7	-10.4	-8.4
Tirunelveli	10.9	16.6	-13.4	17.9	-12.8	-11.6
Virudhunagar	-18.1	47.9	-10.0	17.9	0.4	-12.6
Tuticorin	-27.7	29.3	14.2	16.0	2.4	-10.6
Theni	-12.7	36.6	-3.6	22.3	2.5	-20.8

Relationship of El-Nino years and seasonal rainfall



Relationship of La-Nina years and seasonal rainfall



Relationship of Neutral years and seasonal rainfall

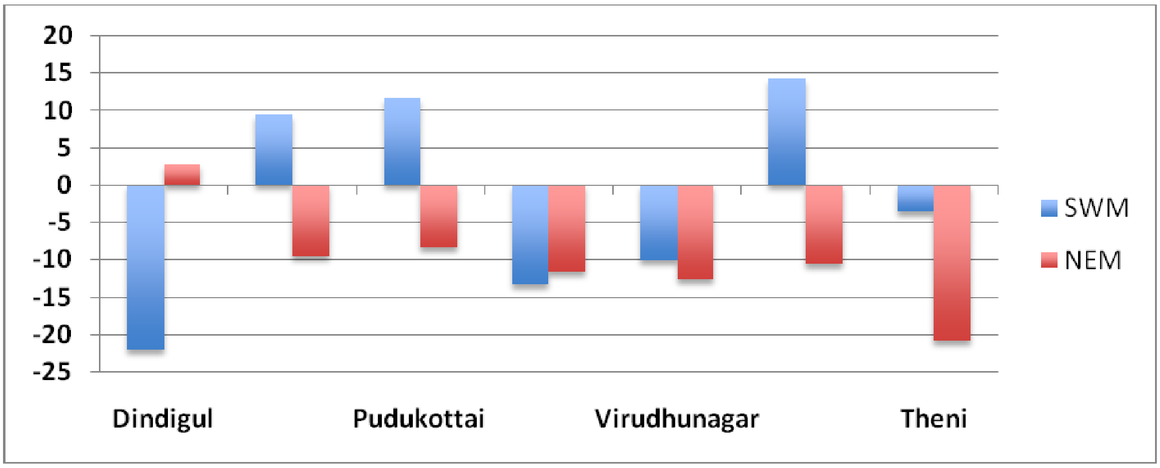


Figure 4. Influence of ENSO events on Monsoon rainfall

Conclusion

It is evident from the results that monsoon season rainfall is highly variable in southern zone. The ENSO events had a marked influence on the rainfall with typically inverse relationship for NEM from rest of the India. This understanding will be useful and will be utilized in seasonal forecasting and crop planning in the southern zone. Further the dynamics of ENSO events and monsoon should be studied with more data to consider ENSO as a tool in seasonal forecasts.

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