Seasonal Variation of Active and Break Spells over the Arabian Sea and the Bay of Bengal

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1. Introduction

The south west monsoon (SWM) season from June to September is the main source of rainfall to most part of the Indian Sub-Continent. An estimated 70-90% of the total annual rainfall of most parts of India fall during these days. The north east monsoon (NEM) is also another important rainfall source which brings rainfall to the Southern peninsular India from October to December. The characteristics of rainfall varies in space and time. In the temporal scale the intra seasonal variation varies from a few days to more than a month. The intra-seasonal time scales are broadly divided into 3-7 day, 10-20 day and 30-60 day (also known as Madden Julian Oscillation). These oscillations occur in larger spatial scales but variations with less than 10 day timescales are caused by synoptic disturbances.

During the monsoon, the synoptic scale variations are classified into periods of excess rainfall called Active Spells, and periods of less or scanty rainfall called break spells. Most of the previous studies (Rajeevan et al. 2010; Rao et al. 2016) defined the Active (Break) spells as the period during which the rainfall occurrence is higher (less) than the normal rainfall at least for three consecutive days.

The study of intra-seasonal variation of rainfall is of paramount importance as it is the most important source of weather variability in India. Inter-annual variations of Active and Break spells are due to global annual cyclic environmental conditions like El Niño (Dry conditions) and La Niña (Wet conditions). Since India is an agro-based nation, predicting the occurrence of these spells is very crucial in many fields like crop yields (Prasanna 2014).

Active and Break and their variation from year to year for different parts of the country's landmass has been extensively studied (Rajeevan et al 2006; Singh and Ranade 2010; Hoyos and Webster 2007; Rao et al. 2016). Previous studies of Active and Break spells over the Indian landmass have used data from combination of a network of rain gauges and satellite data. However, over the ocean alone, there are no rain gauges and we have to depend on satellite data. Given the technological advances in satellite meteorology over the last few years the data obtained from them is very reliable and easy to access. My study will focus on these two seas, Arabian Sea and Bay of Bengal, specifically and study the characteristics of Active and Break spells during the SWM season and compare their characteristic during normal years, El Niño years and La Niña years.

2. Data

The data used in the project is obtained from The Tropical Rainfall Measuring Mission (TRMM). TRMM is a joint U.S.-Japan satellite mission to monitor tropical and subtropical precipitation. The TRMM mission was active for 16 years (1998-2013) providing the wealth of three dimensional rainfall dataset.

The TRMM Satellite is composed of 3 main instruments to measure rainfall. The Visible Infrared Radiometer (VIRS) which observes cloud coverage type and temperatures. The TRMM Microwave Imager (TMI) which records the integrated column precipitation content rain intensity and type and other rainfall parameters. The Precipitation Radar (PR) which measures the 3D rainfall distribution over both land and ocean and defines the vertical structure of precipitation. The frequencies, resolution and scanning strategy of these sensors are listed below in Table 1 and Figure 1.

Table. 1: *The frequency, resolution and scan strategy of TRMM sensors*

	TRMM Microwave Radiometer (TMI)	Precipitation Radar (PR)	Visible and Infrared Radiometer (VIRS)
Frequencies	10.7, 19.3, 21.3, 37.0, and 85.5 GHz (dual-polarized except for 21.3: vertical only)	13.8 GHz13.8	0.63, 1.601.6, 3,.715.6, 1,03.8.7, 5, and 12 µm1
Resolution	11 km X 8 km field of view at 37 GHz	5-km footprint and 250- m vertical resolution	2.5-km resolution
Scanning	Conically scanning (530 inc.)	Cross-track scanning	Cross-track scanning
Swath Width	880-km swath	250-km swath	830-km swath

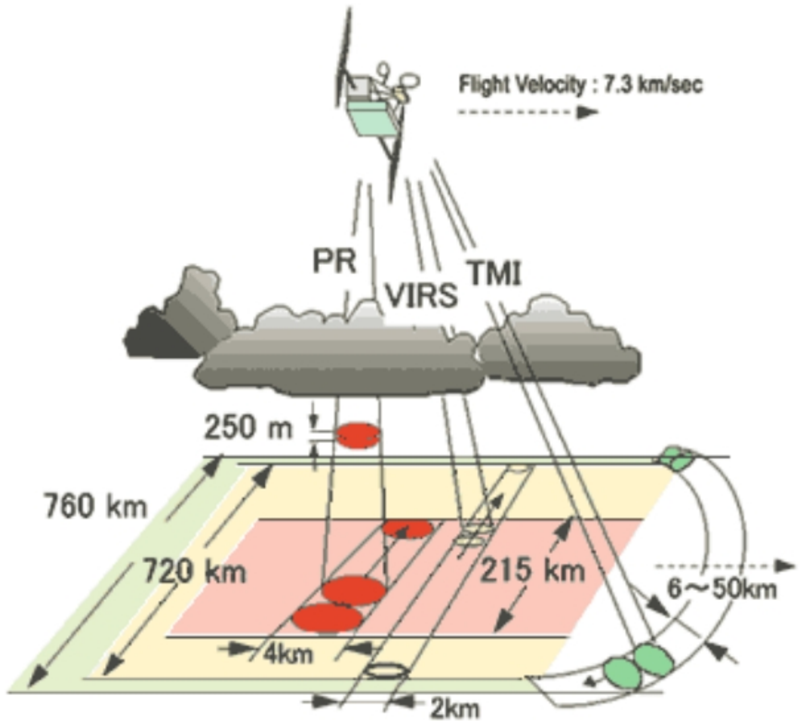


Table and image Courtesy: pmm.nasa.govwww.eorc.jaxa.jp

Figure 1: *Scan strategy of TRMM PR sensors.*

The multi satellite derived product 3B42 version 7 is used in the present study. The spatial extent of the data is divided into 1400x400 grids (0-360^{o}E, 50^{o}N-S) with a spatial resolution of 0.25^{o} and a temporal resolution of 3 hours. It uses a network of other satellites as well as on board sensors to detect precipitation. "The 3B42 algorithm combines multiple independent precipitation estimates from the TMI, Advanced Microwave Scanning Radiometer for Earth Observing Systems (AMSR-E), Special Sensor Microwave Imager (SSMI), Special Sensor Microwave Imager/Sounder (SSMIS), Advanced Microwave Sounding Unit (AMSU), Microwave Humidity Sounder (MHS), and microwave-adjusted merged geo-infrared (IR). All input microwave data are inter calibrated to TRMM Combined Instrument (TCI) precipitation estimates (TRMM product 3B31); the IR estimates are computed using monthly matched microwave-IR histogram matching; then missing data in individual 3-hourly merged-microwave fields are filled with the IR estimates. After the pre-processing is complete, the 3-hourly multi-satellite fields are summed for the month and combined with the monthly accumulated Global Precipitation Climatology Centre (GPCC) rain gauge analysis using inverse-error-variance weighting to form a monthly best-estimate precipitation rate, which is TRMM Product 3B43. The final step is to scale all the 3-hourly estimates for the month to sum to the monthly value (for each grid box separately). The final 3B42 precipitation (in mm/hr) estimates have a 3-hourly temporal resolution and a $0.25^o x 0.25^o$ spatial resolution with a spatial coverage from latitudes 50^oN to 50^oS. " (https://mirador.gsfc.nasa.gov/collections/TRMM_3B42_daily__007.shtml)

3. Methodology and Results

3.1. Identification of Active and Break spells:

For the identification of Active and Break Spells we first calculate the mean (μ) and standard deviation (σ) of rainfall per day (for monsoon season SWM), averaged spatially for the both regions i.e., Arabian Sea (63-72^oE, 8-20^oN) and the Bay of Bengal (83-92^oE, 8-21^oN) respectively. We then proceed to calculate the Standardised Rainfall Anomaly (SRA) for every individual day in the season of every year for the 2 regions, which is defined as

$$SRA = \frac{r - \mu}{\sigma}$$

SRA = Standardised Rainfall Anomaly
r = Spatially averaged rainfall per day for one year
μ = Mean spatially and temporally averaged over 16 years
σ = Standard deviation spatially and temporally averaged over 16 years

Active spells are identified as positive SRA (> 0.5) and Break spells have negative SRA (< -0.5) for at least 3 consecutive days. In addition to these days, consecutive days having SRA > 0.25 or SRA < - 0.25 are added to the respective spell (Active or Break). Further, SRA is calculated for the Normal years, El Niño years and La Niña years and compared.

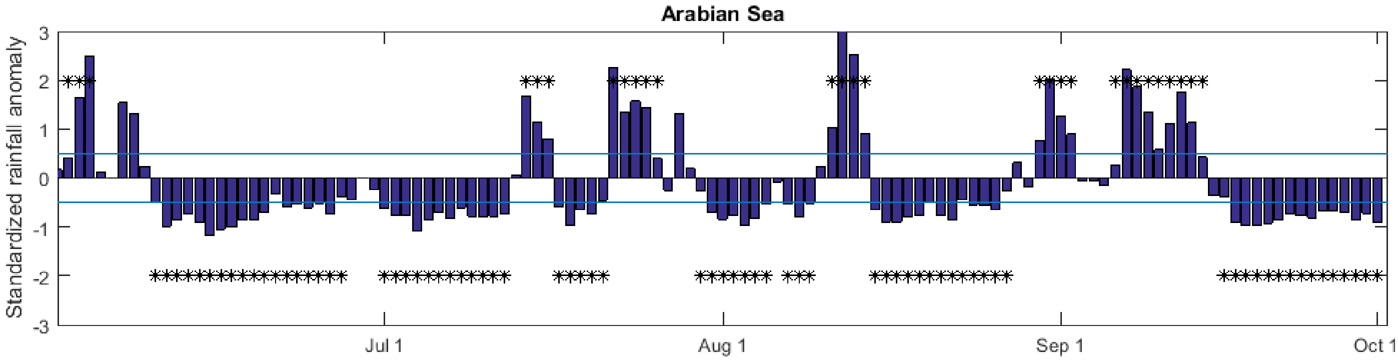
3.2. Frequency of spells

Following the procedure mentioned in section 3.1 the SRA is calculated for all days of the SWM season for all 16 years. Figure 2 shows the time series of SRA during Normal (2008) , El Niño (2004) and La Niña (2007) year respectively. We then proceed to classify and count the number of Active spells, Break spells, and the number of days these spells have occurred for separately for the Arabian Sea (63-72^oE, 8-20^oN) and the Bay of Bengal (83-92^oE, 8-21^oN) for all years. Similar analysis is repeated for the El Niño years and La Niña years.

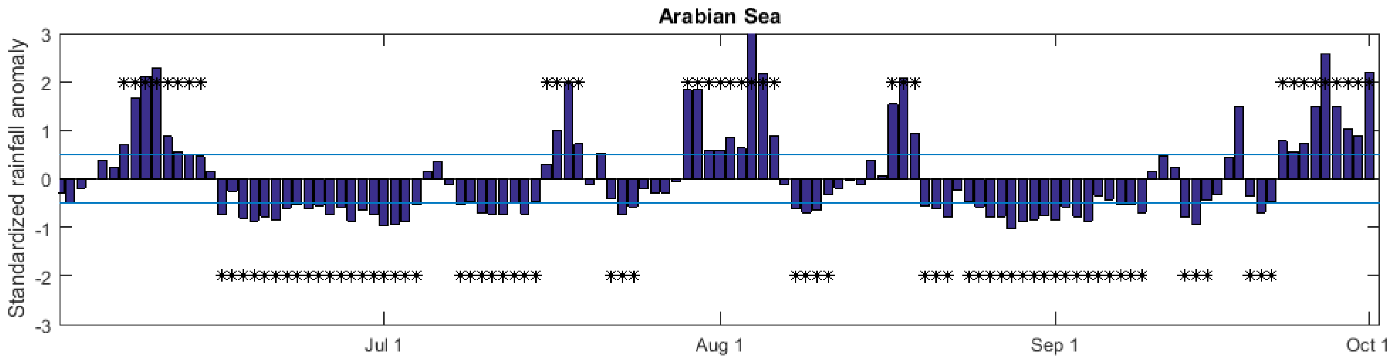
3.3. Accumulated Daily Rainfall

Accumulated Daily Rainfall (ADR) is the total amount of rainfall in a day of concerned area of study (in this study we focus on the Arabian sea and the Bay of Bengal). The rainfall over $0.25^o x 0.25^o$ grid point per day measured in mm/day is spatially averaged over the study area. In this study we explored the differences in ADR for Active and Break Spells in the Arabian Sea and Bay of Bengal during for all 16 years. El Niño and La Niña years was identified by studying ENSO(El Niño and Southern Oscillation) Index from Niño 3.4 that averages the sea surface temperature between 5°N–5°S, 120°W–170°W during the months of June July August and September. El Niño years have ENSO index > 0.5 and were found to be 2002, 2004, 2009 and La Niña years have ENSO index < - 0.5 and were found to be 1998, 1999, 2000, 2007, 2010.

Normal year (2008)



El Niño year (2004)



La Niña year (2007)

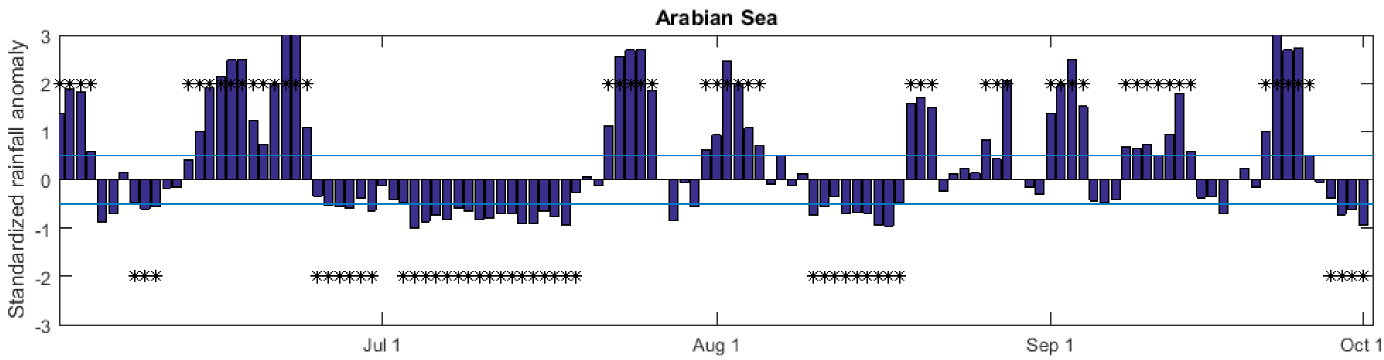
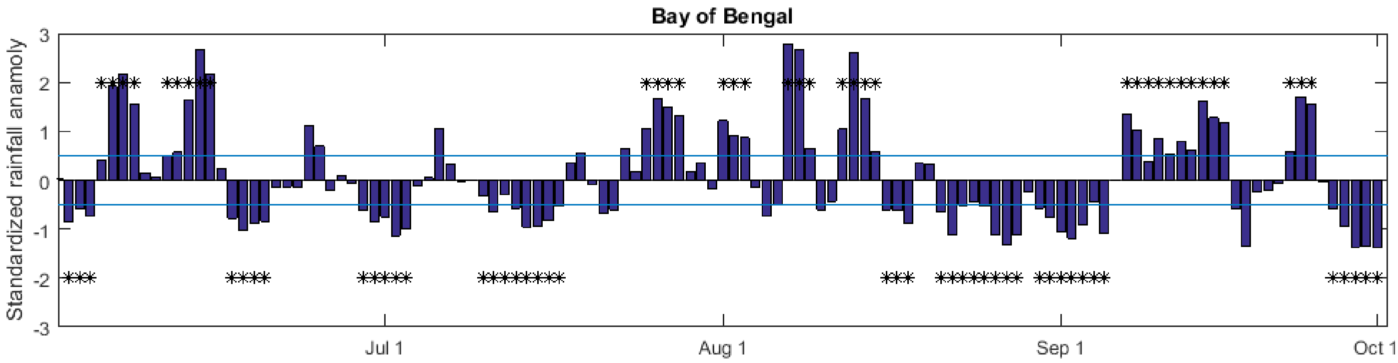
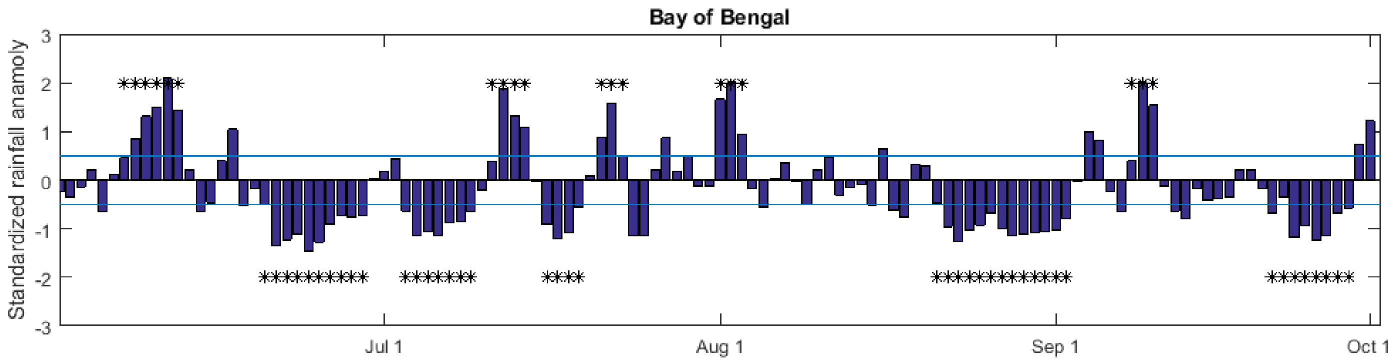


Figure 2: *Top, middle and bottom panels represents the time series of standardized rainfall anomaly for the normal year 2008, El Nino year 2004, La Nina year 2007 over Arabian Sea respectively. The symbol (*) represents the active and break spell days.*

Normal Year (2008)



El Niño year (2004)



La Niña year (2007)

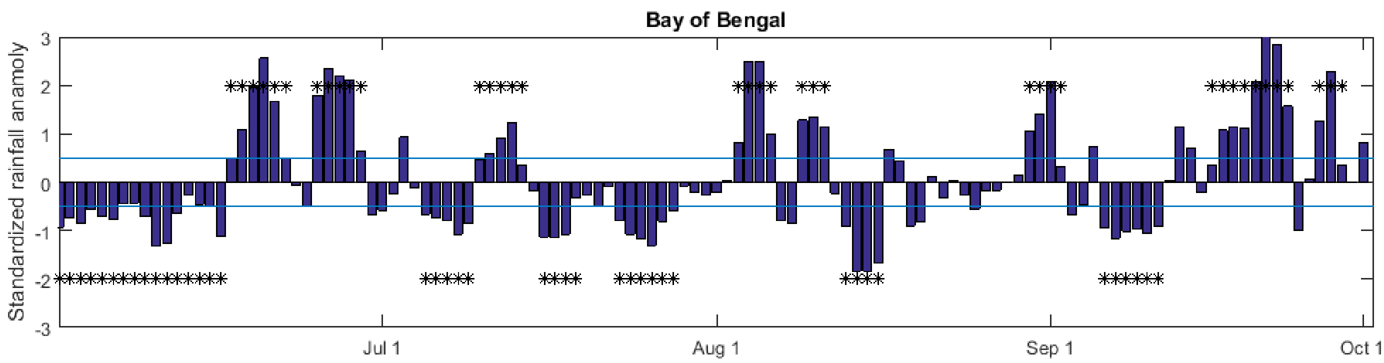


Figure 3: *Same as figure 2 but for Bay of Bengal.*

Table. 2: *The frequency of Spells and Spell Days are given for both Arabian Sea and Bay of Bengal for all years, El Niño years, and La Niña*

For all years (1998-2013)

	Arabian Sea	Bay Of Bengal
Number Of Active Spells	73	121
Number Of Break Spells	118	132
Number Of Days of Active Spells	415	384
Number Of Days of Break Spells	945	589

For El Niño years (2002, 2004, 2009)

	Arabian Sea	Bay Of Bengal
Number Of Active Spells	9	17
Number Of Break Spells	25	25
Number Of Days of Active Spells	61	66
Number Of Days of Break Spells	187	132

For La Niña years (1998, 1999, 2000, 2007, 2010)

	Arabian Sea	Bay Of Bengal
Number Of Active Spells	28	40
Number Of Break Spells	30	39
Number Of Days of Active Spells	151	139
Number Of Days of Break Spells	283	222

Accumulated Daily Rainfall

To know the differences in ADR, the histograms of ADR (with 1mm/day interval) for Active and Break Spells in the Arabian Sea and Bay of Bengal during 16 years are shown in Figure 4. It is well known that the ADR for Active spells in both regions is higher than the Break spells although the number of Break spell days are greater. It is found that, the Bay of Bengal generally having higher ADR in both Active and Break spells when compared with the Arabian Sea.

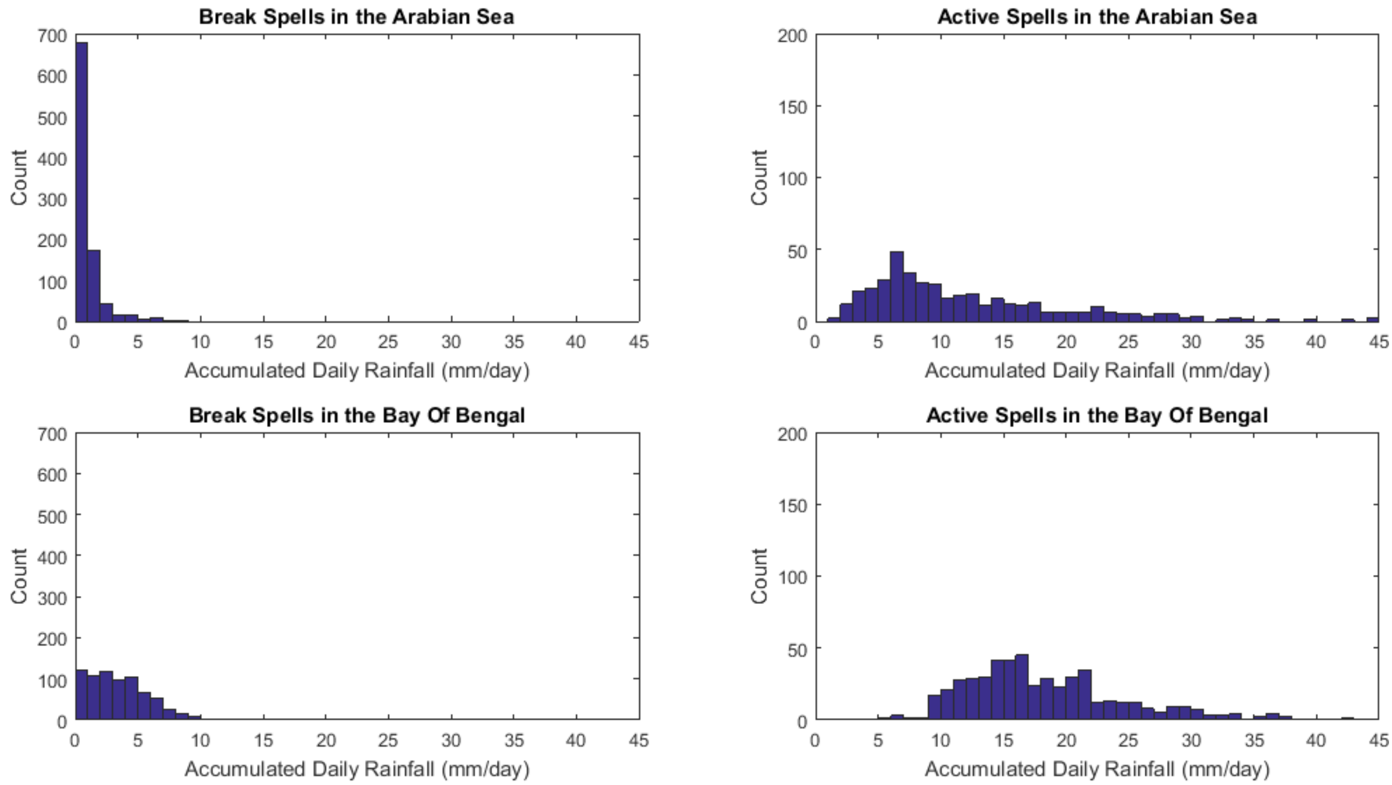


Figure 4: *Left and right panels represents the histograms of accumulated daily rainfall during break and active spells over Arabian Sea and Bay of Bengal respectively during 1998-2013.*

Frequency of spells

The Table 2 shows us the counts of Active and Break spells for all the 16 years along with the number of spell days. We can see that the Bay of Bengal has a higher count of both Active(121) and Break spells(132) but the number of spell days (945 for Active and 415 for Break) is more in the Arabian Sea.

During the El Niño years there are more or equal number of Break spells as compared to Active spells in both the seas and the corresponding number of spell days are also consistent with at least 60 more days of Break spells. During the El Niña years the reverse can been seen with more Active spells compared to Break spells.

4. Discussion and conclusion

In this project Active and Break Spells were classified from the raw TRMM 3B42 data product and the SRA was calculated individually over the Arabian Sea and Bay of Bengal for the 122 days of the SWM season for all 16 years. The analysis gave us the list of all days in which Active and Break spells have occurred.

On studying the daily rainfall during these days the Accumulated Daily rainfall was calculated for all spells days of both Active and Break Spells in the two seas. As results show the Active spells have a higher ADR than Break Spells which is expected from their very definition. The Bay of Bengal generally has higher ADR in both Active and Break spells when compared with the Arabian Sea and this is consistent with previous findings (Rao et al 2016).

On comparing SRAs we find our results to be as expected La Niña having more (less) active (break) spells than the normal. The further analysis has to be done to know the causes in these differences.

Table 2 shows the frequency of spells, for all years and Figs. 2-3 for El Niño (2004) and La Niña (2007) years specifically are also evidence to support this hypothesis. During the El Niño year there are less active spells in both the seas and during the La Niña year the reverse can been seen with more Active spells and less break spells. For all 16 years, we can see that the Bay of Bengal has a higher occurrence of spells but the duration of spells is more in the Arabian Sea. This can be attributed to the type of weather systems that exist over these seas during this time by further analysis of TRMM PR three dimensional data.

In order to analyse the data and draw the relevant plots for this project I have made use of the programming language and plotting tool MATLAB v2016. It had took me almost a month to learn the language and then write the relevant algorithms and codes to obtain the results and produce the relevant figures.

In conclusion, this study has highlighted the various facets of intra seasonal variation and showed the differences in space and in time. The observed differences enable us to probe into more deeper questions such as the causal mechanisms and the variation of atmospheric variables during these spells, the vertical structure and the type of rain in two spells. These further projects will be undertaken by me in my master's thesis. All these studies enable us to understand the monsoons better and improve weather forecasting and monsoon prediction which have far reaching effects to the country's growth and development.

References

- Rao TN, Saikranthi K, Radhakrishna B, Rao SVB 2016 Differences in the climatological characteristics of precipitation between active and break spells of the Indian summer monsoon. J Clim 29(21):7797–7814

- Prasanna, V., 2014: Impact of monsoon rainfall on the total food grain yield over India. J. Earth Syst. Sci., 123, 1129–1145, doi:10.1007/s12040-014-0444-x.

- Rajeevan, M., J. Bhate, J. D. Kale, and B. Lal, 2006: High resolution daily gridded rainfall data for the Indian region:
  Analysis of break and active monsoon spells. Curr. Sci., 91, 296–306.

- Rajeevan, S. Gadgil, and J. Bhate, 2010: Active and break spells of the Indian summer monsoon. J. Earth Syst. Sci., 119, 229–247,doi:10.1007/s12040-010-0019-4

- Singh, N., and A. Ranade, 2010: The wet and dry spells across India during 1951–2007. J. Hydrometeor., 11, 26–45, doi:10.1175/2009JHM1161.1.

- Hoyos, C. D., and P. J. Webster, 2007: The role of intraseasonal variability in the nature of Asian monsoon precipitation. J. Climate, 20, 4402–4424, doi:10.1175/JCLI4252.1.

- Saikranthi, K., Radhakrishna, B., Satheesh, S.K., Rao TN 2018: Spatial variation of different rain systems during El Niño and La Niña periods over India and adjoining ocean. Clim Dyn 50: 3671.

- Roxy, M., 2014: Sensitivity of precipitation to sea surface temperature over the tropical summer monsoon region—and its quantification. Climate Dyn., 43, 1159–1169, doi:10.1007/ s00382-013-1881-y.