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Monsoon Onset over Kerala 2017 & 2018: A Satellite Perspective

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ABSTRACT

This paper highlights the importance of using satellite data for the monsoon onset studies with the focus on Monsoon Onset over Kerala (MOK)-2018 in comparison with MOK-2017. The study was carried out using Special Sensor Imager (SSM/I)-F16, F17 & F18 derived Total Precipitable Water Vapour (TPW) content and Sea Surface Wind Speed, Westward Propagating of Madden-Julian Oscillations (MJO)-Based on NOAA OLR (+5 N to -5 S) latitude, in the equatorial wave guide, and NCEP-derived 850 hPa Wind fields (Low Level Jets-LLJ).While TPW is used as the precursor for determining the date of MOK, along with 850 hPa wind fields and Outgoing Longwave Radiation (OLR), based MJO, which is a significant oscillation during Monsoon Onset phase over Kerala. About 18 days before the MOK the Total Precipitable water vapor peak (which normally crosses 50 mm) over the Western Arabian Sea. We also check for the amount of TPW in the adjoining boxes also, to decide on the peak TPW.

Keywords: *Monsoon-onset, satellite, Total Precipitable Water Vapor and MJO.*

1. Introduction

Monsoon Onset Over Kerala (MOK) has been considered as the beginning of the southwest monsoon season (June to September) in India. Over 80% of the annual rainfall in India occurs during this season. The MOK is associated with a large area of organized /widespread rainfall over Kerala.The moisture required for this large area rainfall is mainly produced in the South Indian Ocean and carried to the Indian landmass by a strong cross-equatorial low-level jet stream (Findlater, (1974), Joseph. et.al. (2004).-The monsoon onset is recognized as a rapid, substantial and sustained increase in rainfall. India Meteorological Department (IMD) follows specific criteria (Pai and Rajeevan, 2008) on rainfall, wind field and OLR in order to declare the onset, -which are given below.

1. After 10th May 60% of the enlisted stations by IMD in Kerala, should report rainfall of 2.5 mm or more for two consecutive days
2. Depth of westerlies should be maintained up to 600 hPa, in the box defined by equator to 10^{o} N latitudes and 55^{o} E to 80^{o} E longitudes and the zonal wind speed over the area bounded by 5^{o}N - 10^{o}N and 70^{o}E – 80^{o}E should be of the order of 15-20 Kts at 925 hPa and
3. INSAT derived OLR value should be below 200 Wm^{-2} in the box confined by Lat. 5^{o}N – 10^{o}N and Long 70^{o}E – 75^{o}E are met then the MOK is declared.

The normal date of MOK is around 1 June with a standard deviation of about 8 days (Ananthakrishnan et. al (1988)). The northward progression of the monsoon, defined as the shifting of Maximum Cloud Zone (MCZ) from the equatorial to continental regions, Sikka, et.al. (1998) is indicative of a large-scale transition of a deep convection. By middle of July, monsoon covers the whole country.

The total integrated water vapor plays an important role in the summer monsoon circulation/activity over the Indian Ocean. By studying the changes in mid-troposphere water vapour from NOAA/TOVS for seven years over various regions of the Indian Ocean, BoB and Arabian sea, Simon and Joshi (1994), have found that the mid-troposphere water vapour (700-500 hPa) over western Arabian sea increases by about 25% in just 8-10 days before the monsoon onset over Kerala coast. In other studies by Simon et al (1994, 2001, 2006, 2008) have shown that the onset date and Total Precipitable Water vapor (TPW) content-peaking in Western Arabian Sea (WAS) box (50-65 ^{0} E & 0 -10^0 N), are highly correlated with MOK. In addition we also monitor the increasing trend (> 50 mm) in the TPW in the Southern Western Indian Ocean [SWIO] box (Figure 1A), to decide on peak TPW date in WAS region. In general monsoon onset is found to take place just within 18 ± 2 days from the occurrence of peak in TPW over Western Arabian Sea (WAS), as marked in (Figure 1B). However, this relationship is found to be disturbed by occurrence of any cyclone in Bay of Bengal (BoB) or Arabian Sea during the monsoon onset phase. The setting of Madden-Julian Oscillations (MJO)-Based on NOAA OLR (-5ºS to +5 N) latitude, in the equatorial wave guide also takes place prior to MOK.

Another feature is the setting of the cross equatorial flow (Pentad) in the Low Level Jet (LLJ) seen in the NCEP-derived 850 hPa wind fields.

Table 1. Details of TPW peaking days (2006-2018), IMD onset date, Difference from onset date to peak and predicted onset date.

Year	Peaking Of TWV (mm)	Onset Date (IMD)	Diffe-rence	Pred. onset.
2006	11 May	26 May	15 Days	29 May
2007	11 May	28 May	17 Days	29th May
2008	10 May	31 May	17 Days	28th May
2009	7 May	23 May	16 Days	25th may
2010	3 May	31 May	28 Days	21 may
2011	12 May	29 May	17 Days	30th may
2012	18 May	5th June	18 days	5th June
2013	12 May	1st June	20 days	30th May
2014	17 May	6th June	20 days	4th June
2015	17 May	5th June	19 days	4th June
2016*	8^{t} MAY	8th June	28 days	26TH May
2017	12th May	30th May	18 days	30th May
2018	11^{h} May	29 May	18 days	29th May

The MJO consists of two parts, or phases: one is the enhanced rainfall (or convective) phase and the other is the suppressed rainfall phase. Strong MJO activity often dissects the planet into halves: one half within the enhanced convective phase and the other half in the suppressed convective phase (Maddenm et. al.(1971). MJO is monitored along the equatorial Indian Ocean, averaging NOAA derived OLR [+5N to -5S] and

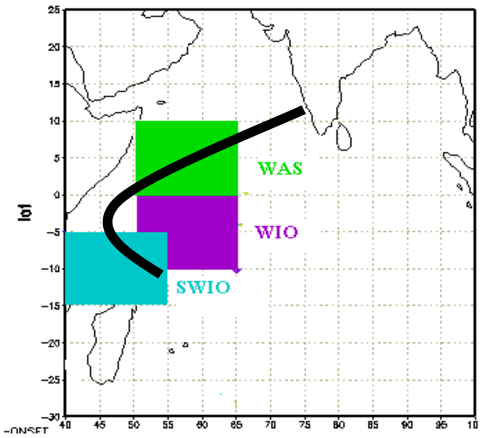


Figure 1(A): Various Segments over Indian Ocean-Monsoon Onset. Monitoring Perspective onset precursors from SSM-F16/F17/F18 & other satellite data for 2017 & 2018. AS & BoB cyclones can disturb the TPW build up during onset Phase.

plotting hovmollar diagram from 50 E to 160W. Low OLR (<220watts/m2) which is a proxy for rainfall, during an MJO moves from West to East (shown by slanted line) with a periodicity of 30-50 Days. The MJO affects the intensity and break periods of the Asian and Australian monsoons and interacts with El Niño (Joseph, et.al.(2009), Flatau, et.al. (2001). Satellites provide the global coverage of these parameters with very good temporal and spatial resolution Monitoring of net tropospheric moisture build up, mean tropospheric temperature increase and sharp rise of 850 hPa wind (LLJ), kinetic energy over Arabian Sea also serve as potential indicators for objective determination of MOK Simon (2008). This paper summarizes the "monsoon onset -2018" over Kerala, India using Special Sensor Imager (SSM/I)-F16, F17 & F18, Total Precipitable water vapor, sea surface wind speed, INSAT-3D/3DR -BT and NCEP-wind fields. The paper also gives a summary of similar observations in comparison with 'Monsoon onset- 2017'.

1. Data Used

Daily data derived from Special Sensor Imager (SSM/I)-F16, F17 & F18, Total Precipitable water vapor (TPW), Sea Surface Wind Speed (SWS), INSAT-3D/3DR -BT and NCEP-wind fields were used in this study. SSM/I data was obtained (from ftp site of http://www.ssmi.com) and analyzed in near real time during the years 2017 and 2018. This data has been used to prepare maps of total water vapour, over geographical domain of 40^{o}E -180^{o}E and 30^{o}S – 30^{o}N. NCEP reanalysis winds (from ftp site of http://www.cdc.noaa.gov) were also analysed for the above-mentioned domain of time and space. Near real time OLR for the years 2017 and 2018 starting from the month of January, were analyzed to study the MJO. Time-longitude diagrams were plotted for 50^{o}E-160^{o} W regions taking average OLR for 5^{o}S-5^{o}N latitudes. As the data used in this study have already been validated by different groups, no separate quality check was carried out for the data used in this study.

2. Results and Discussion

The spatial and temporal evolution of moisture and surface wind speed over the Indian Ocean and adjacent seas is observed in near real time using the Special Sensor Imager (SSM/I)-F16, F17 & F18, products and NCEP reanalysis wind product. Total Precipitable water vapor build up over the Western Arabian Sea (WAS), 50^{o}-65^{o} E, 0^{o}-10^{o} N), and nearby region, with the deepening of the cross equatorial south-westerly

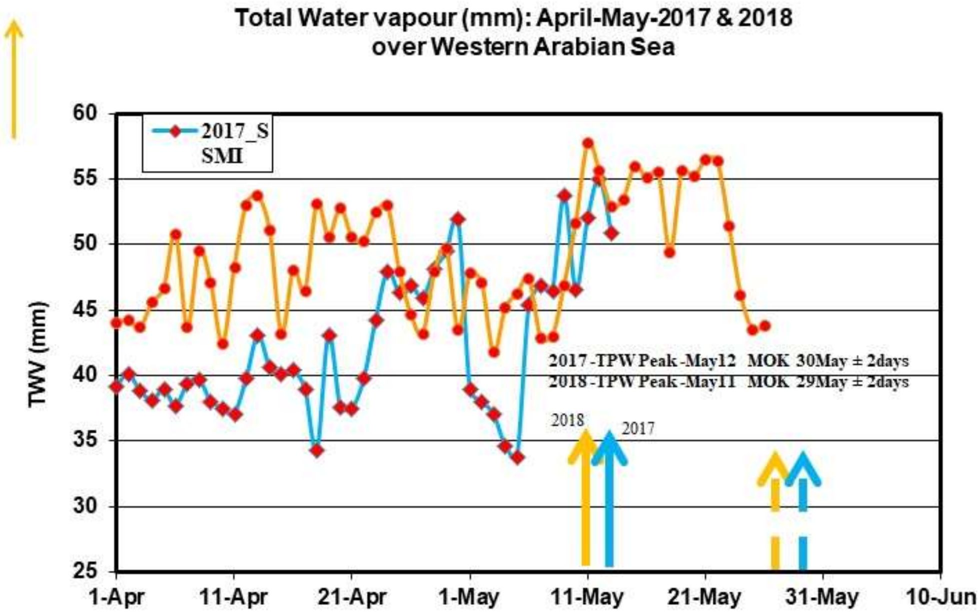


Figure 1(B): Temporal evolution of Total Precipitable water Vapour (TPW)(WAS region) for different years and date of monsoon ONSET over Kerala Forecasted

wind prior to the onset was monitored, especially in the Find later Jet area (Figure 1A). In an earlier study using TRMM/TMI for the years 1998-2014 data, it was reported that the water vapor builds up associated with onset normally exceeds 50 mm and maintains this value for few days.

The onset occurs on 18 ± 2 days after the peak in TWP is observed except for the years when there was a cyclone in Arabian Sea /BoB in mid-May (Onset phase). The pentad evolution of all the geophysical parameters from Special Sensor Imager (SSM/I)-F16, F17 & F18 (Total Precipitable water vapour and wind) were analyzed from 1st April to 30th May, for both 2017 & 2018 (Fig. 1(B).

In the case of MOK-2017, the TPW in the Western Arabian Sea (WAS) region peaked on 12th May 2017 [we also see the TPW in adjacent boxes to confirm the real peak], and then when we add 18 days from peak day and the predicted onset over Kerala is supposed to be on 30th May 2017 ± 2 days (Fig-1B). We have conveyed our forecasted dates to IMD/MOES on 14th May 2017. And the MOK came exactly dot on the predicted date (30th May 2017). The statistics of peaking of TPW, onset date by IMD, also predicted onset date by our method is given (Table-1).

In the case of the year 2018, the TWP peak inbox of Western Arabian Sea [WAS] occurred on 11th May 2018, which indicated an early onset around 29th May 2018 with an uncertainty of ±2 days (Fig. 1B). We have conveyed our forecasted dates to IMD/MOES on 13th May 2018. Subsequently IMD also declared the onset prediction on 16th May 2018, to be on 29th May 2018, and the MOK came exactly on dot on the predicted date, i.e 29th May 2018.

The large-scale monsoonal pattern is associated with the propagation of convective anomalies, evident as the eastward propagation of low OLR

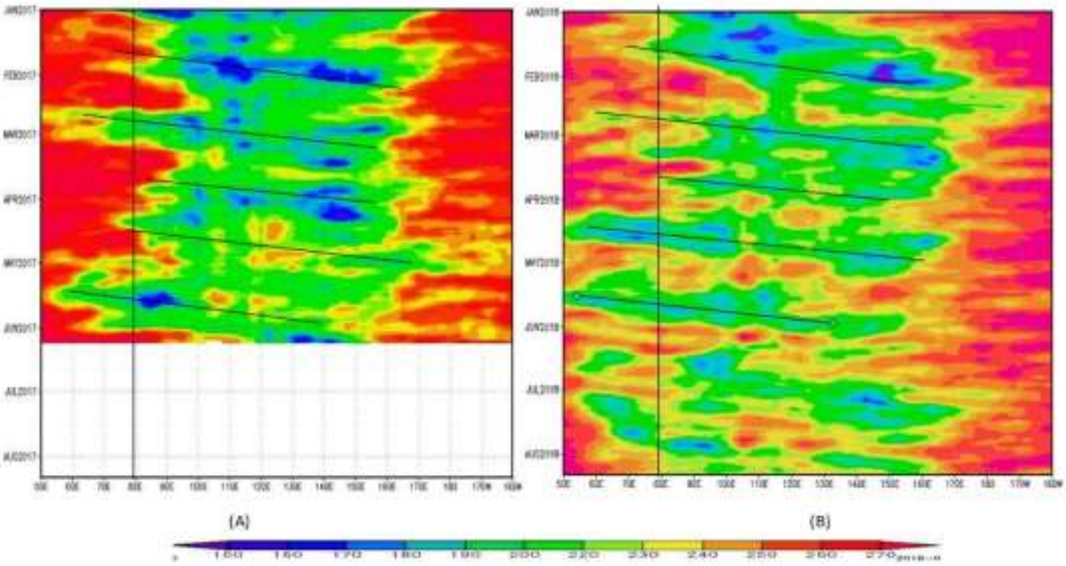


Figure 2: Madden Julian Oscillations [MJO] -5 to +5 N for the years 2017 (A) and 2018 (B) using NOAA derived OLR (Watts/m2)

belt in Indian and western Pacific Ocean. These oscillations also known as MJO or 30-60 day oscillations are studied for the years 2017 and 2018. An MJO wave travels periodically from west to east in upper atmosphere (here represented by OLR) with alternating dry (suppressed rainfall) and wet (rainy weather) phases. NOAA-OLR data, starting from 1st January to 30th May 2017/2018 were analyzed for this purpose. In the year 2017, the first MJO (Pre-monsoon) which was very weak (Figure2A). This early cloudiness (depicted by low OLR) is known to be associated with the pre-monsoon showers in peninsular India. After a lull period of nearly 40 days another phase of low OLR started around 10th May which was later found to be associated with the MOK (Figure 2A).

In the current year 2018, the first MJO, which corresponds to the pre-monsoon showers, appeared only after 15th April. However, the MJO related to monsoon onset over Kerala (MOK-2018) started on 15th May 2018. Overall the MJO periodicity was of the order of 30days, which clearly show the significance of MJO during MOK.

We have also analyzed the cross equatorial wind flow at 850 hPa–Low level Jet (LLJ) in both 2017. (Figure 3). During 21st-25th May pentad, in 2017, the cross equatorial LLJ flow began to strengthen, when compared to previous pentad, and it sustained in the next Pentad (26th-31st May), which was also, the onset pentad. Deep convective clouds were also observed over Kerala Coast around 30th May in 2017 (Figure 4), which eventually brought. Substantial sustained rainfall in the area. MOK-2017 was declared as 30st May 2017 by IMD, as it fulfilled all criteria laid out for MOK. Deep convective clouds were also observed over Kerala Coast around 29th May in 2018 (Figure. 4), which eventually brought substantial sustained rainfall in the area. MOK-2018 was declared as 29th May 2018 by IMD.

3. Conclusions

The monsoon onset over Kerala in 2018 was examined using Special Sensor Imager (SSM/I)-

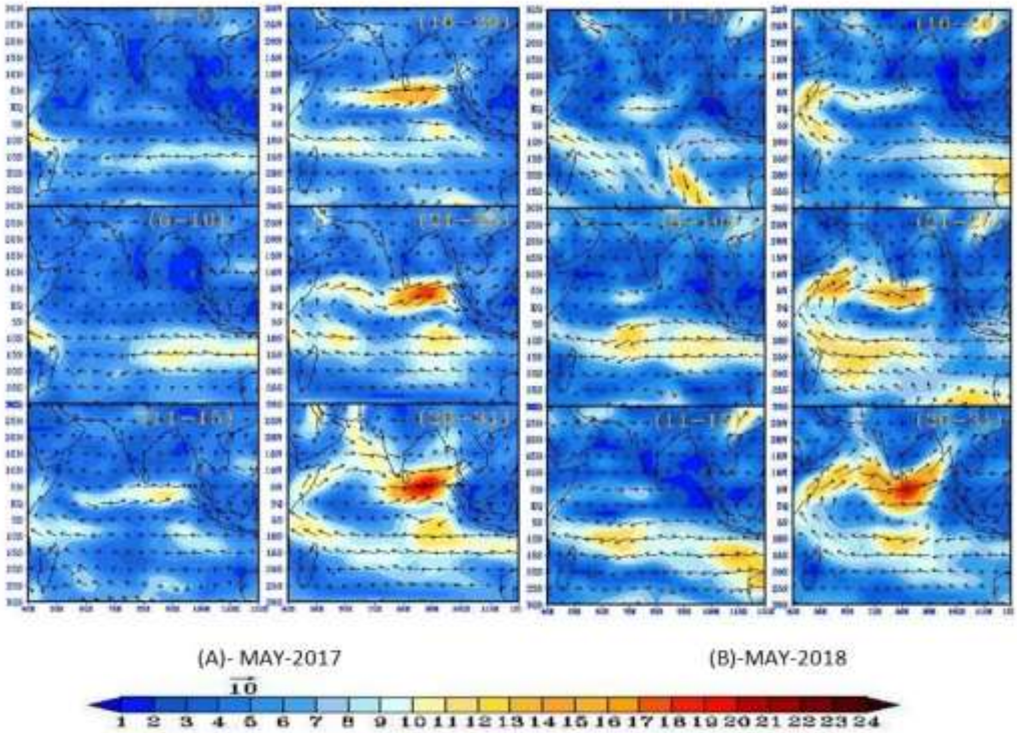
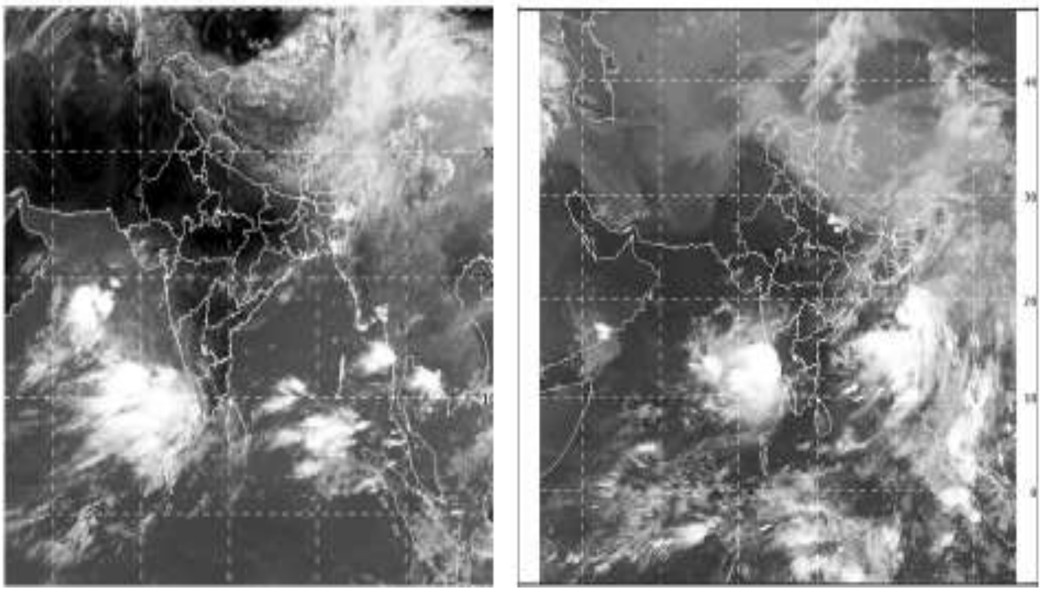


Figure 3: Pentad evolution of 850 hPa wind field (NCEP) in the month of May-2017(A) & May-2018(B).



(A) (B)

Figure 4: INSAT 3D/3DR VHRR image on the onset dates i.e. 30th May 2017 (A) & 29th May 2018 (B)

F16, F17 & F18 derived TPW along with NCEP reanalysis wind and NOAA-OLR data. This study was compared with the MOK during the year 2017.

The time series analysis over WAS area showed that TPW associated with MOK-2018 started increasing around 7th May with a peak (57 mm) around 11th May, thereafter stabilizing above 55 mm. Based on earlier studies, the TRMM/TMI and Special Sensor Imager, TPW along with the westward propagating (Based on OLR) MJO observed in the equatorial wave guide, indicated the possibility of onset on 29thMay ± 2 days.

In both the years 2017 and 2018, the typical cross-equatorial wind pattern was observed in the predicted time period i.e. 26th -31st May pentad in 2017 & 2018.

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