

Variability of Rip Currents in parts of coastal Andhra Pradesh



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Variability of Rip Currents in parts of coastal Andhra Pradesh

Introduction:

Rip current is a longshore current move perpendicular to the shore and can be very strong in beaches. Rip currents form under specific conditions related to winds, waves, swell, tides and the shape of the shoreline bottom of the waves. These strong narrow seaward flowing currents extend from near the shoreline through the surf zone and out past the line of breaker zone. As waves break along a shoreline or over a sandbar, an increase in water level occurs. This increase in water level is known as a setup. The increase in water levels is especially evident as waves break over a sandbar, resulting in an increases setup of water on the landward side of the bar. Thus, waves breaking over a sandbar can result in mass transport of water between the bar and the shoreline. There is usually a difference in water heights (setup) between the bar, where the waves are breaking strongly, and the channel between bars, where little or no wave breaking occurs. One of the ways this water returns seaward is through rip currents, which flow seaward against the incoming waves. This seaward flow of water typically occurs through a break in the sandbar, where water is channelized into a narrow current known as a rip current.

Objectives:

- Study the variability of rip current strength in parts of Andhra Pradesh Coast.
- Variability of Surface parameters related to rip current.
- Validation of model output rip currents with collected drowning data.

State of art:

As many processes are involved with the formation of a rip current, accurate rip current prediction is always problematic (Calvete, et al., 2007). However, an accurate forecast system could be a valuable resource for public outreach, lifeguards and beach patrol. There have been remarkable efforts over the past two decades to develop a feasible rip current forecast model.

As a beginning study, SAC/ISRO demonstrated “Rip current forecast” for few selected Goa beach stretches in 2017, in view of its high importance in terms of beach tourism. However, as the technique relies on the observational indices and ranks assigned to each nearshore parameter (Lushine, 1991), it does not benefit from recent advances in wave modelling. In addition, the forecast was only limited to eight zones in the alongshore direction, which would create a misperception to the beach user on the risk. It relied on an operational WAVEWATCH III® (Tolman, 2007) at 10×10 km grid and MIKE 21 Spectral Wave model. Presently, that operational WW3 wave model has been enhanced to the latest version (Chawla, et al., 2013) with high resolution of 2.5×2.5 km grids in the Exclusive Economic Zone (EEZ) of India. By coupling the rip current forecast model with Rip current Likelihood forecasting, the system is able to provide a 120-hour rip current forecast at 175 major and minor beaches of India via a dedicated MOSDAC/SAC web terminal as an experimental exercise. Rip current surface state parameters will be collected from the above forecast system for study the variability of rip current in parts of coastal Andhra Pradesh.

Literature survey:

Rip currents are one of the most dangerous coastal hazards, which are typically few meters wide and extend 100-500 m within the surf zone or more towards offshore with velocities generally 1 m/s or less, occasionally may sometimes exceed 2 m/s (MacMahan, et al., 2006). They account for the highest portion of beach rescues (Lushine, 1991; Lascody, 1998; Short, 2007). In India, there is an average of 39 drownings per year estimated from online agencies and newspapers (Kumar & Prasad, 2014). In East Florida, there is an average of 21 drownings per year, which is larger than the number of deaths due to tornados, thunderstorms, lightning, and hurricanes combined. In the UK, 71% of all recorded incidents were due to rip currents. In Australia, rip currents are recognized as the major hazards to beach users and they are responsible for more than 90% of all beach rescues (Short & Brander, 1999). Many other countries like Brazil, Israel and Colombia have reported that rip currents are major hazards (Short, 2007).

In general, rip currents can be visually identified in regions without having any breaking waves in the surf zone, and are often characterized by foam or sediment-laden water eject outside the surf zone (Fig. 1). It usually has a feeder, neck and a head, with neck being very narrow of the order 10-50 m. The length of the rip current may sometimes exceed 3 times that

of the surf zone width. Rip currents were first observed in 1941 by Shepard et al., (1941), with the first complete theoretical description was provided in 1969 (Bowen & Inman, 1969).

Numerous observational studies have determined that there would be an increase in rip current activity and intensity with increasing wave height (Brander & Short, 2000; MacMahan, et al., 2005) and as wave incidence approaches shore-normal (Engle, 2003). Additionally, rip current activity increases as tidal elevation decreases (Brander & Short, 2000; Engle, 2003; MacMahan, et al., 2005; Scott, et al., 2009). The surf zone bathymetry also plays a significant role in rip current activity. Although there are ways to generate rip currents from purely hydrodynamic forcing (e.g. crossing wave trains) (Dalrymple, 1978; Fowler & Dalrymple, 1991; Johnson & Pattiaratchi, 2004), rip currents are often associated with alongshore variability in the bathymetry and more specifically in the surf zone bar (Brander & Short, 2000; MacMahan, et al., 2005).

There is a strong morphodynamic relationship between the surf zone bar system, rip current activity and the local wave conditions (Brander & Short, 2000). Previous studies showed that immediately after a large wave event, a relatively alongshore-uniform bar is developed on the outer boundary of the surf zone (Van Enkevort & Ruessink, 2003; Van Enkevort, et al., 2004). As wave energy decreases, the sand bar migrates towards shore, developing alongshore non-uniformities (Van Enkevort, et al., 2004). These non-uniformities often consist of rip channel type features and thus rip current activity will often be greater in the days following large wave events.

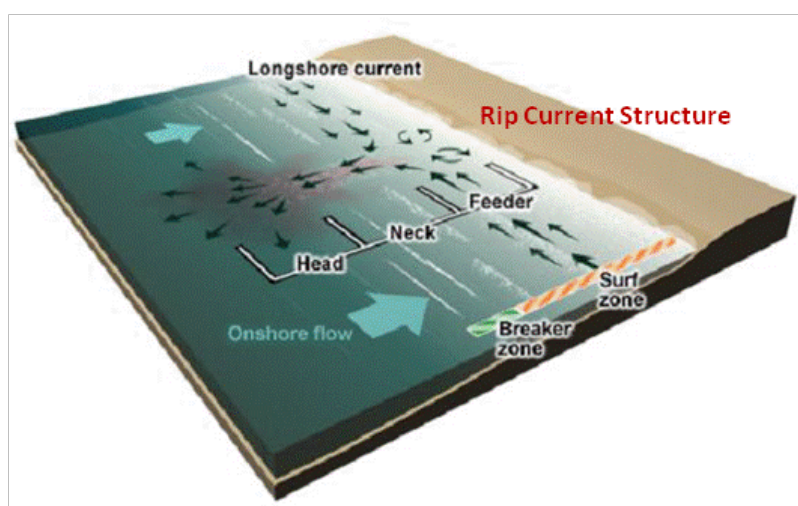


Figure-1: Schematic of Rip current structure along with different near shore zones (source: The COMET Program).

Rip current forecasting:

As many processes are involved with the formation of a rip current, accurate rip current prediction is always problematic (Calvete, et al., 2007). However, an accurate forecast system could be a valuable resource for public outreach, lifeguards and beach patrol. There has been remarkable efforts over the past two decades to develop a feasible rip current forecast model. Lushine (1991) was the first who attempted rip current prediction by correlating wind direction, wind velocity, swell height, and time of low tide to rescues at a beach in southeast Florida. He determined that rip current drownings were well correlated with increasing wind speed, shore-normal wind direction, increasing wave height and low tide. His model is known as Lushine Rip Current Scale (LURCS). Later, Lascody (1998) performed a similar analysis and modified the LURCS technique for east central Florida beaches (ECFL LURCS), based on the observation that the wave climate was more severe on this portion of the Florida coast and that wave period plays a greater role. He affirmed that rip currents were more likely during instances of long period swell (> 12 s). Engle (2003) analysed the effect of wind, waves, and tide to rip current occurrence for Daytona Beach and New Smyrna Beach in Florida to assess the accuracy of the ECFL LURCS and found that the direction of the incident waves was correlated with rip current rescues. Later, Schrader (2004) examined the application of the Engle-modified ECFL LURCS at two additional Florida beaches, including one on the Gulf of Mexico, and noticed that there are some site-specific factors for rip current prediction. Schrader found a relationship between rip current occurrence and the presence of weather systems that are accompanied by strong winds and larger waves with long periods. Using rescue data at Ocean City, Maryland, Nelko & Dalrymple (2009) had shown that the ECFL LURCS was not that successful. In addition, they stressed that the local conditions also dictate the rip current occurrences on beaches, and empirical techniques such as the LURCS and its derivatives need to be calibrated locally. The modified ECFL LURCS index (or a slight variation) is the rip current forecasting method predominantly used today by National Weather Service (NWS) Weather Forecast Offices (WFOs) (<https://www.ripcurrents.noaa.gov/forecasts.shtml>) at beaches all around the United States as part of the surf-zone forecasts in the following categories: low risk, moderate risk, and high risk. Arun Kumar and Prasad (2014) followed the similar procedure as described by the previous researchers, but slightly changed the scale in the form of ranks assigned to each parameters as weightage. This scale has been used for predicting rip current risk at Goa coast in India (https://mosdac.gov.in/rip_current_forecast).

The index method and categorical output of the old models have inherent functional limitations, for example, the output of a three-category forecast compared to a fully continuous probabilistic model. These limitations suggest significant opportunity for improving the forecast system currently in place and that any substantial improvements would require a deviation from the present forecast indexing approach. Dusek and Seim, (2013) developed a new probabilistic model using logistic regression formulation by training the model with lifeguard observations at Kill Devil Hills, North Carolina along with in-situ wave and tide observations and noticed a 67% improvement in prediction.

As a beginning study, SAC demonstrated “Rip current forecast” for few selected Goa beach stretches in 2017, in view of its high importance in terms of beach tourism. However, as the technique relies on the observational indices and ranks assigned to each nearshore parameter (Lushine, 1991), it does not benefit from recent advances in wave modelling. In addition, the forecast was only limited to eight zones in the alongshore direction, which would create a misperception to the beach user on the risk. It relied on an operational WAVEWATCH III® (Tolman, 2007) at 10×10 km grid and MIKE 21 Spectral Wave model. Presently, that operational WW3 wave model has been enhanced to a latest version (Chawla, et al., 2013) with high resolution of 2.5×2.5 km grids in the Exclusive Economic Zone (EEZ) of India. The model has been configured to assimilate the satellite altimetry derived wave height products. As a pilot study, using the 2.5 km WW3 forecasts, we have developed an experimental “Rip current Likelihood forecasting” (ReLieF) model. For this configuration, a new probabilistic rip current forecast model has been developed using logistic regression technique applied on rip current related rescues and several nearshore wave and tide parameters (Dusek & Seim, 2013). This technique would provide guidance on the likelihood of hazardous rip currents occurring (between 0 and 1) in addition to three risk categories (low, moderate and high risk). This rip current forecast model is a statistical model developed using wave, water level, and rip current observations as discussed by Dusek and Seim (2013).

The present ReLieF architecture incorporates WW3 numerical wave model outputs and inputs from predicted tide from Finite Element Solution–FES 2014. By coupling the rip current forecast model with ReLieF, the system is able to provide a 120-hour rip current forecast at 175 major and minor beaches of India via a dedicated MOSDAC web terminal as an experimental exercise. This report briefly discusses the development, validation and operationalization of rip current forecasting system.

In this study, we obtain the surface state parameters observations based on WAVEWATCH III and MIKE 21 spectral wave model with enhancement to latest adaptation for study the variability of rip currents strength in parts of Andhra Pradesh Coastal region. Along with the variability of rip current strength and surface parameters, model output (MOSDAC/SAC/ISRO) will be validated with collected drowning data. Rip current surface state parameters observation shall collected on a daily bases from MOSDAC. The parameters are Breaker wave height in meters, Peak wave period in seconds, wave direction in degrees, tidal elevation in meters and category of the rip current forecasted as well as analysis. Drowning data shall be collected from the local police/revenue Department in the vicinity of strong rip current regions.

Study locations:

In the present study, three locations in parts of coastal AP are identified based on the previous drowning data and studies. They include- R.K. beach in Visakhapatnam, Suryalanka beach near Bapatla and Manginapudi beach in Machilipatnam were selected. It has been observed that R.K. beach is the most vulnerable potential rip current zones where 92 people were drowned in the surf zone due to rip currents during the period of 2000-2010, followed by Suryalanka and Manginapudi beaches.

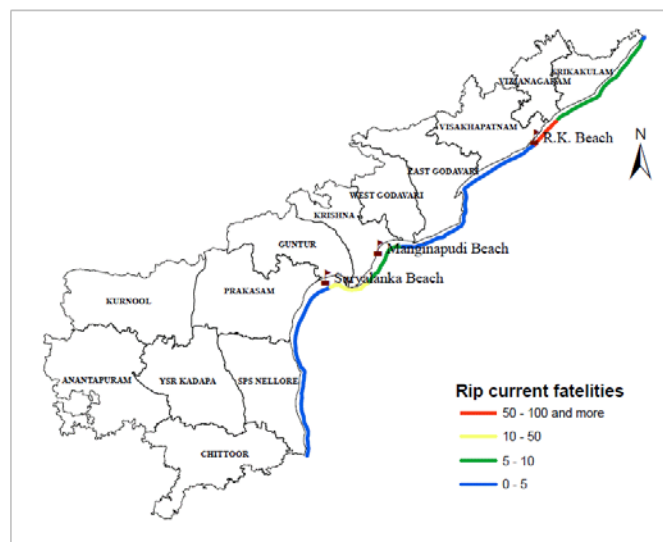


Figure-2: Study location's of rip current variability over parts of Andhra Pradesh and A Rip current-related drownings based on data collected from various sources during 2000–2010.

Methodology:

Rip currents are not only depended on the morphological structure, it includes several factors in addition to meteorological and oceanographic processes that lead to the formation of rip currents along any coast (Bowen 1969; Guza and Inman 1975; Lascody 1998; Larson et al. 2000). Out of which, topographically controlled rip currents are the major hazardous, which are forced by local geology and near-shore bathymetry (Short 1985; Larson et al. 2000) that in turn determines the number and strength of rip currents. When the sea state is favour with higher wave energies and swell, rip currents will be prominent.

In contrast, accretion rips develop in response to decreasing wind and wave energy that drives shoreface recovery and a transition from a dissipative to a reflective profile (Wright and Short 1984). The change in nearshore morphological state is driven by a change in the surf scaling parameter (ϵ) described by Guza and Inman (1975).

$$\epsilon = \frac{a_b \omega^2}{g \tan^2 \beta}$$

Where a_b is the breaker amplitude, ω is is the radian frequency of the incident waves, g is acceleration due to gravity and β is the gradient of the surf/beach zone. As wave energy decreases following a storm, the beach changes from dissipative ($\epsilon > 20$) to reflective ($\epsilon < 2.5$) by passing through each of four intermediate states: longshore bar-trough, rhythmic bar-beach, bar rip, and low-tide terrace ($2.5 < \epsilon < 20$). Each of these intermediate states is characterized (to varying degrees) by the presence of accretion rips. As the shore face evolves, there is an increase in the rip current velocity as the cross-sectional rip channel area decreases and the ability of the bar system to block return flows increases, until the innermost bar completely welds to the beach face. These rips do not have the characteristic form and may be difficult to identify from the perspective of a beach user.

In this study, we obtain the surface state parameters observations based on WAVEWATCH III and MIKE 21 spectral wave model with enhancement to latest adaptation for study the variability of rip currents strength in parts of Andhra Pradesh Coastal region. Along with the variability of rip current strength and surface parameters, model output (MOSDAC/SAC/ISRO) will be validated with collected drowning data. Rip current surface state parameters observation shall collected on a daily bases from MOSDAC. The parameters are Breaker wave height in meters, Peak wave period in seconds, wave direction in degrees,

tidal elevation in meters and category of the rip current forecasted as well as analysis. Drowning data shall be collected from the local police/revenue Department in the vicinity of strong rip current regions.

The rip currents are narrow seaward directional flows and are dynamic in space and time. In spite of the difficulty of identifying the rip currents in satellite data (due to the constraints like- timely availability, limitation of spatial resolution, cloud cover, etc.), an attempt shall be made to verify it based on the model forecast. The proposed study will be conducted in selective locations in coastal Andhra Pradesh region. A thematic flow chart depicting the methodology of work is mentioned in figure -3.

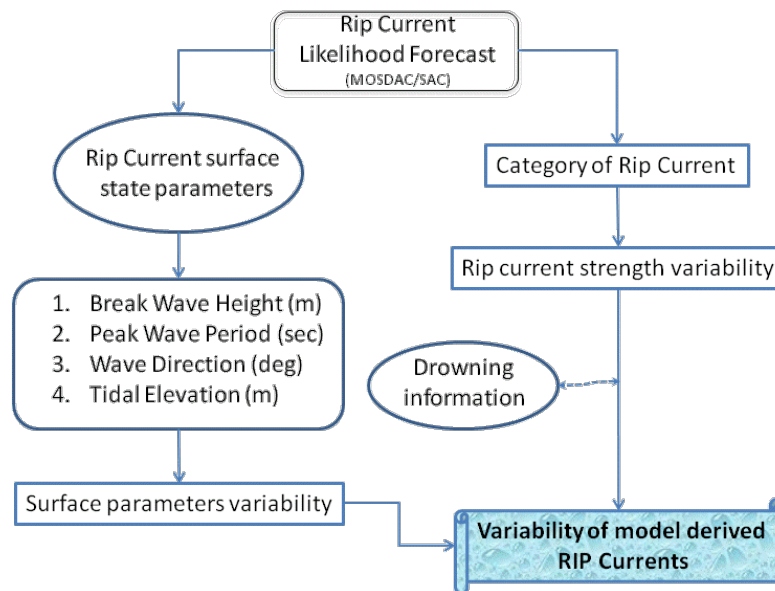


Figure-3: Thematic flow chart of the methodology of proposed work.

Results and Discussions:

Identified the data collection location from the MOSDAC/ISRO web portal and data collection procedure was finalised. Near shore surface parameters of rip currents was collected for the month of August and September on daily basis. Obtained surface parameters (Wave Break Height (m), Peak Wave Period (Sec), Wave Direction, Tidal Elevation and category of the rip current) from MOSDAC/ISRO for the station of R.K. Beach in Visakhapatnam district and Suryalanka Beach in Guntur district. Daily one time rip current forecast was obtained from the MOSDAC/SAC and generated geo-referenced map. each month 4 days maps are provided in the following figures (4a, 4b, 4c and 4d). From these

images we will get the total Andhra Pradesh coast rip current forecast at particular time period.

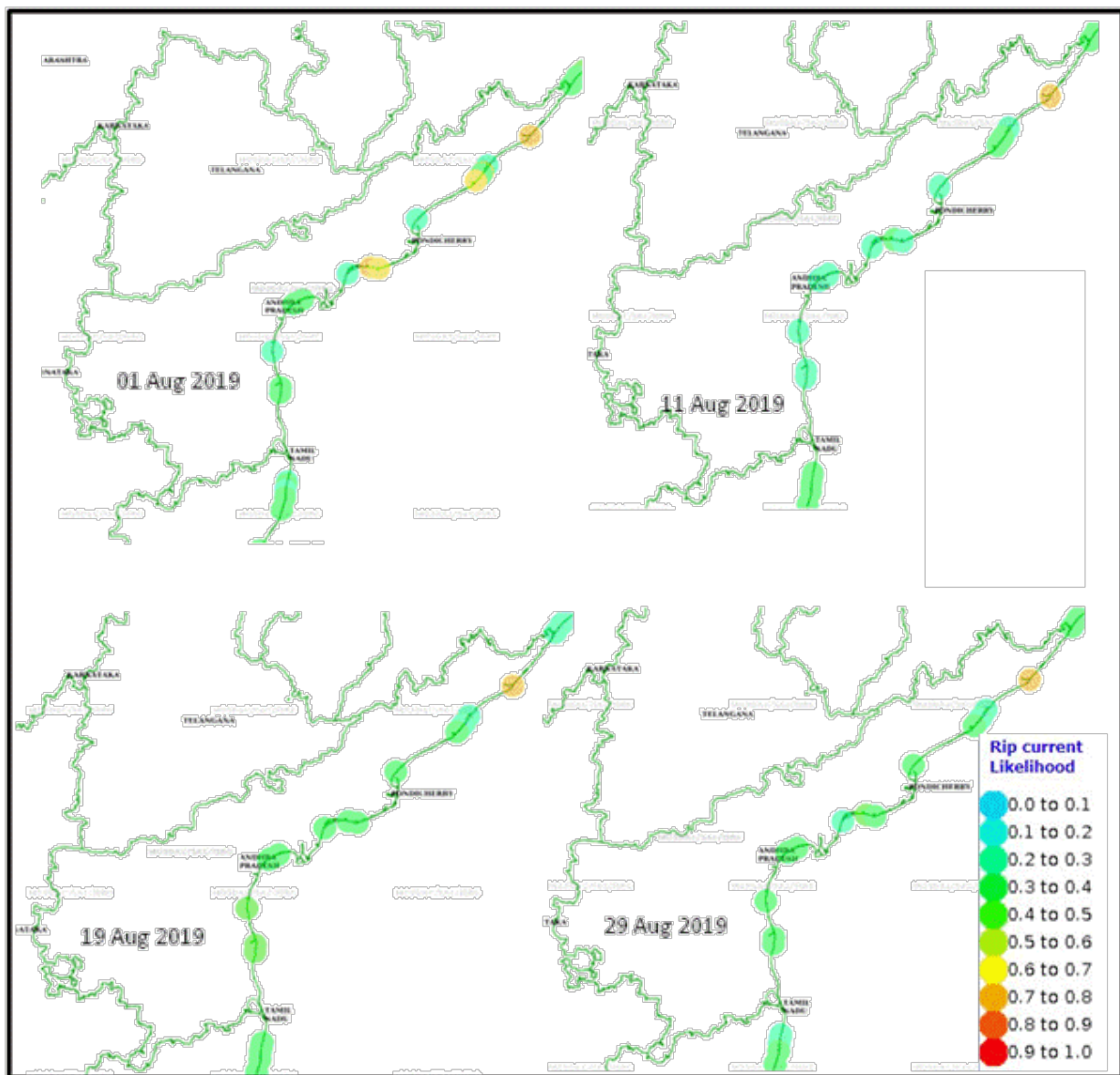


Figure-4a: Rip current forecast with rip current category during August 2019.

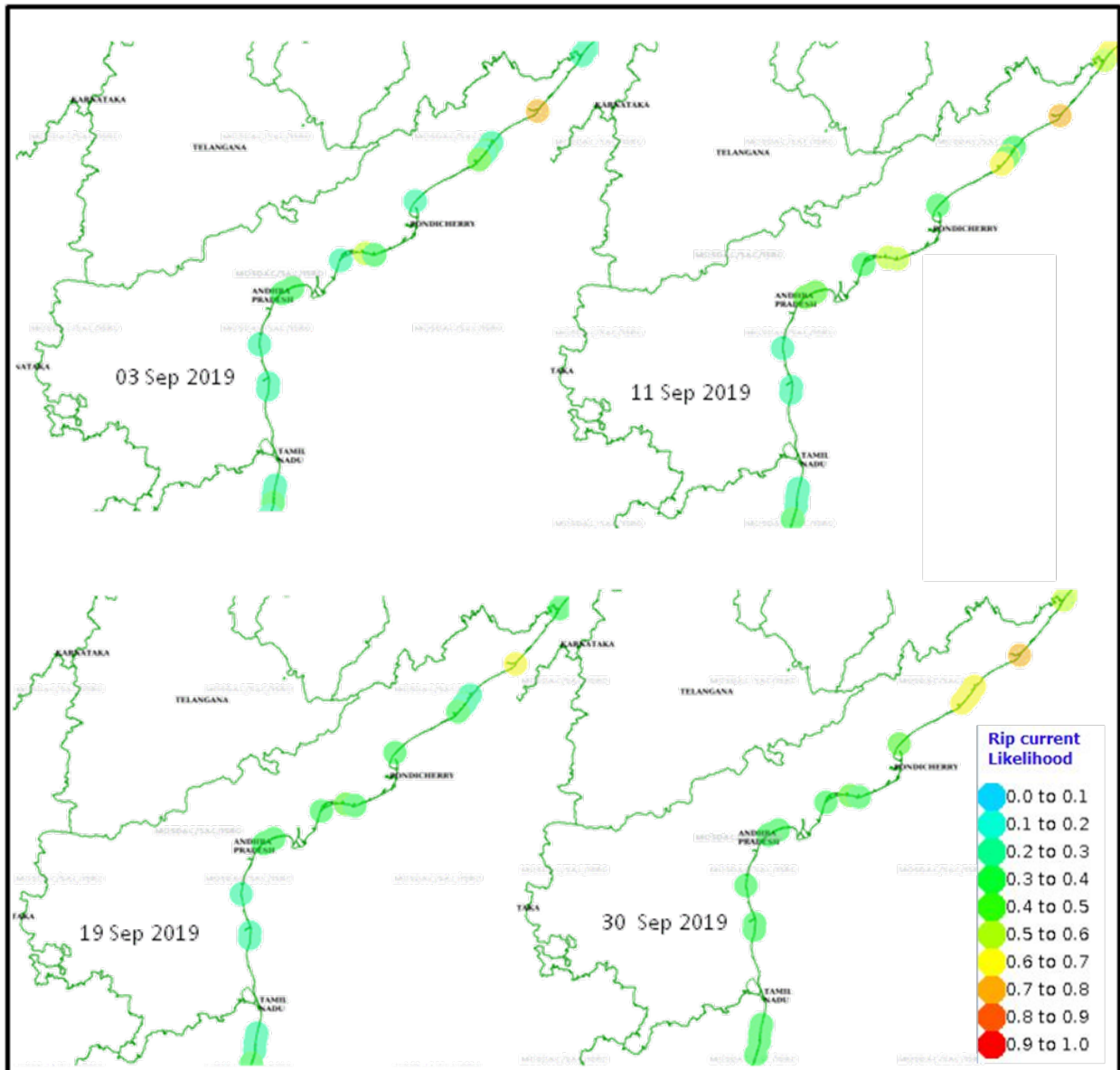


Figure-4b: Rip current forecast with rip current category during September 2019.

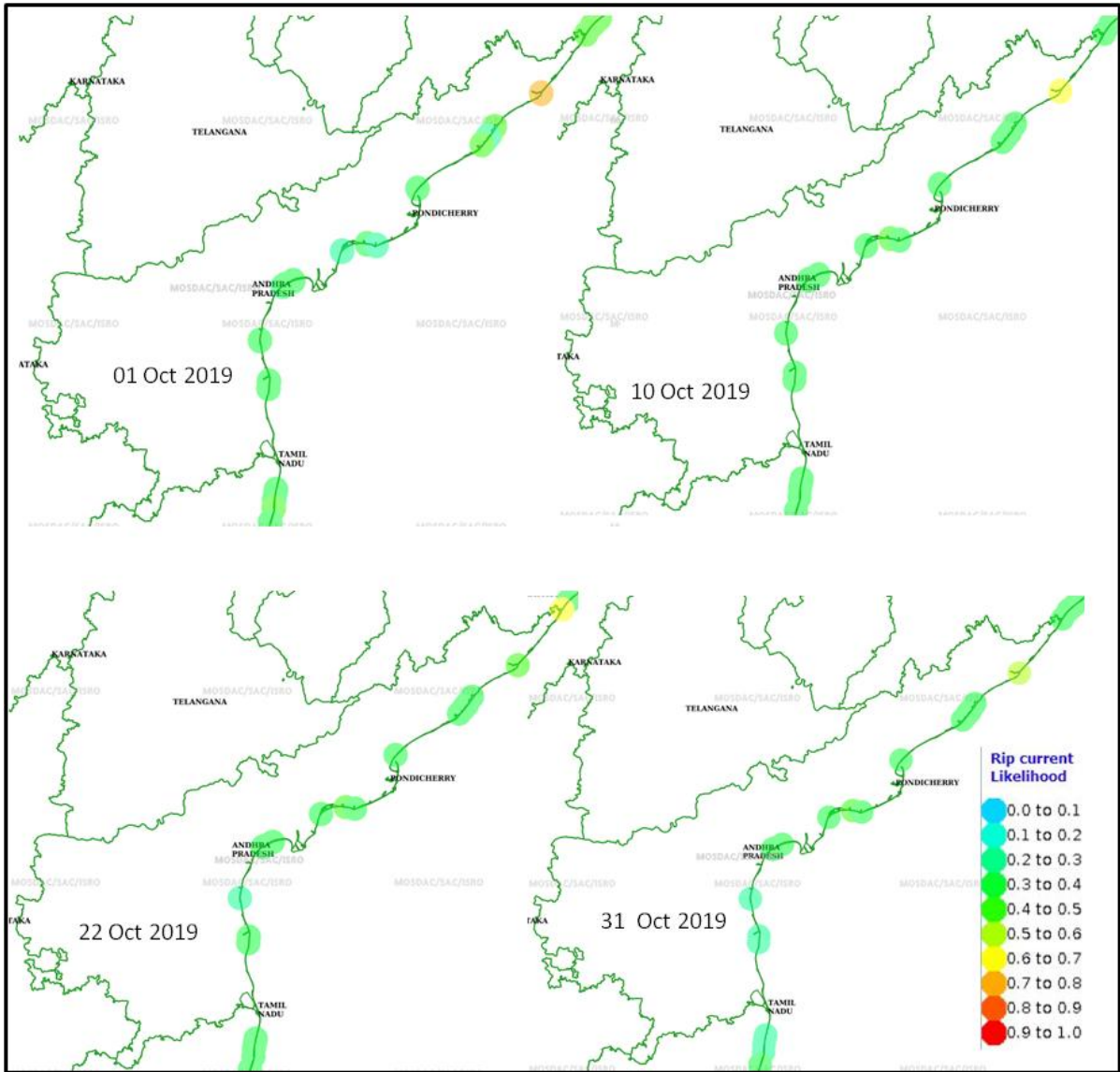


Figure-4c: Rip current forecast with rip current category during October 2019.

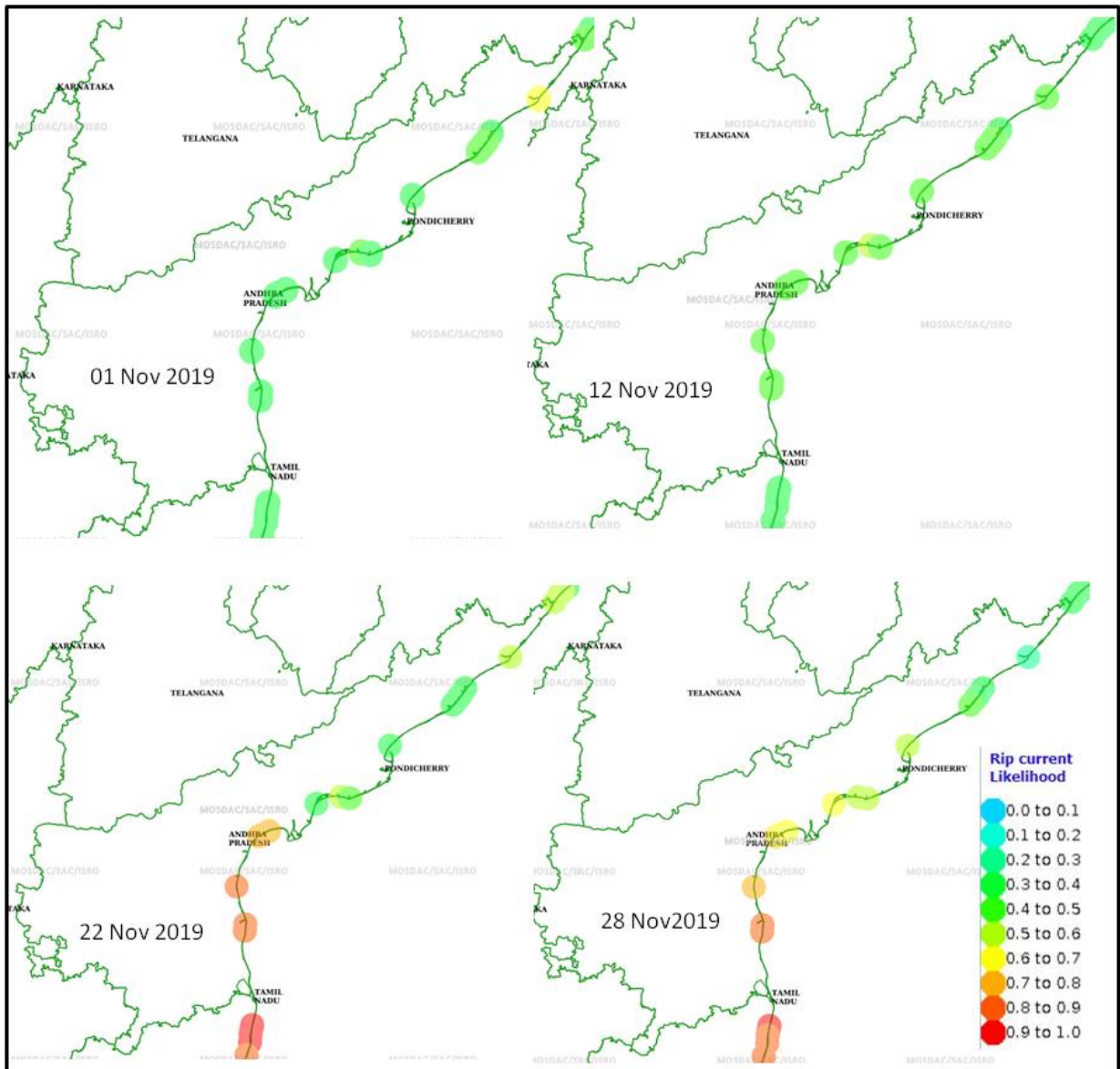


Figure-4d: Rip current forecast with rip current category during November 2019.

Surface parameters were obtained for the month of October on daily basis for the stations of R.K. Beach in Visakhapatnam district, Suryalanka Beach in Guntur district and Manginapudi Beach in Krishna district. Analysed wave break height with respective to rip current category on diurnal basis in the month of August 2019 for the station of R.K. Beach in Visakhapatnam district and Suryalanka Beach in Guntur district.

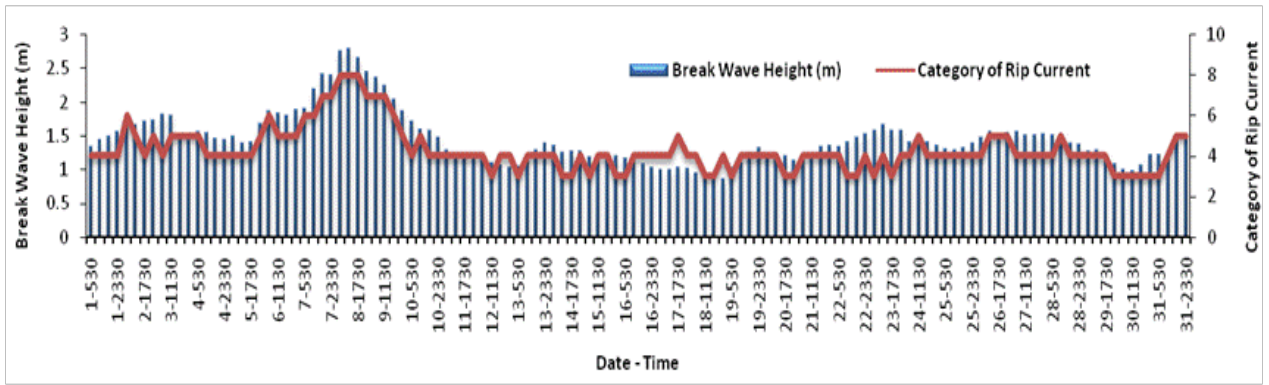


Figure-5: Variability of Break Wave Height with respect to Rip Current Category in the region of R.K Beach during August 2019.

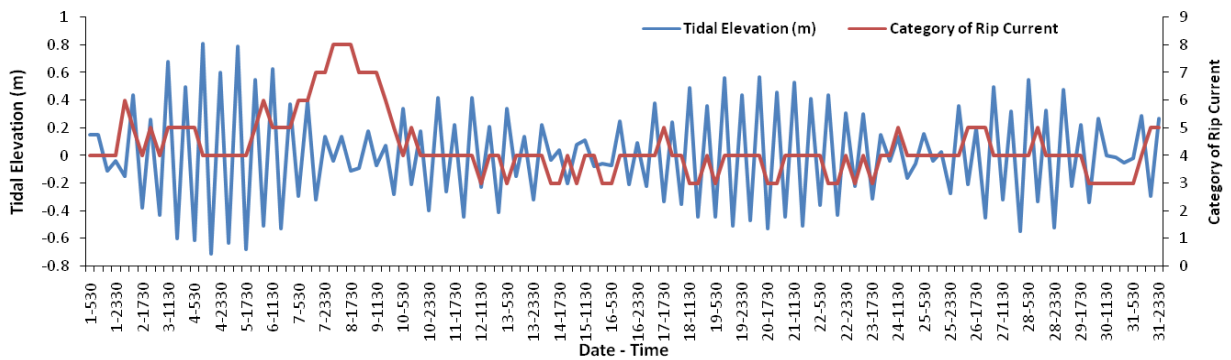


Figure-6: Variability of Tidal elevations with respect to Rip Current Category in the region of R.K Beach during August 2019.

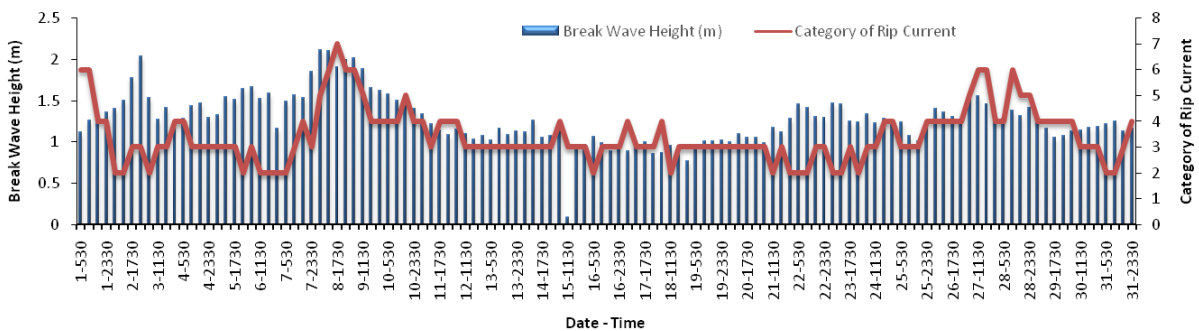


Figure-7: Variability of Break Wave Height with respect to Rip Current Category in the region of Suryalanka Beach during August 2019.

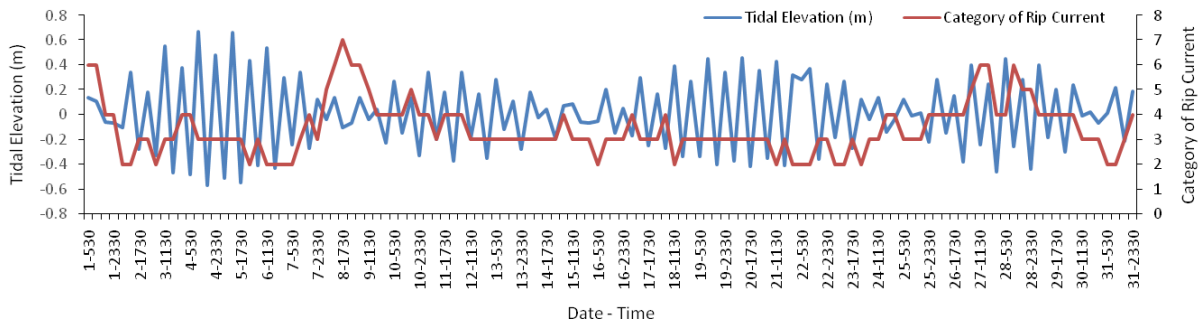


Figure-8: Variability of Tidal elevations with respect to Rip Current Category in the region of Suryalanka Beach during August 2019.

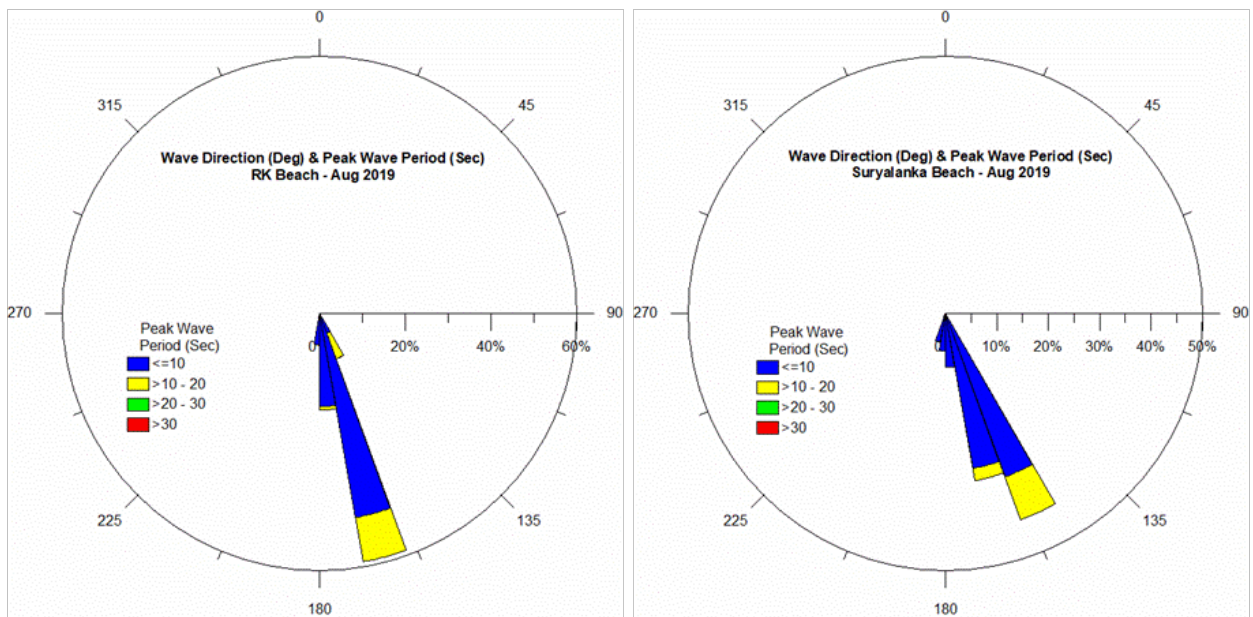


Figure-9: Wave Direction and Peak Wave Periods in the study regions of R.K Beach and Suryalanka Beach during August 2019.

Analysed tidal elevation with respect to the rip current category on diurnal basis in the month of August 2019 for the station of R.K. Beach and Suryalanka Beach. Observed high category of rip current during the 6th to 9th of August 2019 (figure-5). Based on Break wave height with respect to rip current category analysis, high rip currents are following the trend of breaking wave height. It's clearly observed during high wave breaking height period during the month of Aug 2019 in R.K. Beach study location. During the high rip current category period, low tidal elevations were observed in the same location (figure-6). Similarly high rip current category period, low tidal elevations were observed in the Suryalanka beach during the month of Aug 2019 (figure-8). Analysis of Wave direction and peak wave period also carried out for the station of R.K. Beach and Suryalanka Beach during the month of Aug

2019 (figure-9). Observed maximum peak wave periods are in between 10 to 20 seconds and wave direction are from south east and south southeast directions for the stations of R.K. Beach and Suryalanka Beach.

Drowning data was collected during the months of August and November 2019 from the news papers. Based on these reports, Visakhapatnam region is observed more occurrences.

Table-1: Drowning occurrences during the months of August and November 2019 over Andhra Pradesh region.

Reported Date	Incident Date	District	Mandal/Village	No. Of persons drowned
02-08-2019	01-08-2019	East Godavari	Allavaram	02
06-09-2019	06-09-2019	Srikakulam	Etcharla(m)/Budagatalapalem(v)	02
04-10-2019	03-10-2019	Visakhapatnam	Visakhapatnam/RK Beach	02
31-10-2019	31-10-2019	Visakhapatnam	Bheemunipatnam (m/v)	02
11-11-2019	10-11-2019	Visakhapatnam	Kalingapatnam	04
12-11-2019	11-11-2019	Guntur	Suryalanka	01

During the study period 13 drowning occurrences are observed as per news paper reports over the parts of Andhra Pradesh coastal region. Highest drowning occurrences are observed in Visakhapatnam district during the months of October and November 2019. One drowning case was observed on 11 Nov 2019 in Suryalanka beach, Guntur district. During the drowning period, Break wave height was observed 0.7 meters, Peak Wave Period is 9.02 seconds, wave direction 152.77 degrees from north, tidal elevation is observed 0.24 and category of rip current was declared as 4 based on surface state parameters taken from the MOSDAC/ISRO rip current forecast system.

Conclusions:

The variability of rip current was studied using the surface state parameters over the regions of R.K. Beach in Visakhapatnam district and Suryalanka Beach in Guntur district for the month of August 2019. Observed high category of rip current during the 6th to 9th of August 2019 over R.K. Beach. During the high rip current category period, low tidal elevations were observed. From the analysis of Wave direction and peak wave period maximum peak wave periods are in between 10 to 20 seconds and wave direction are from south east and south southeast directions for the stations of R.K. Beach and Suryalanka Beach. The continuation of this study in more parts of coastal region will give more confident and understanding on

the rip current strength and its high impact duration. Similar kind of study in more parts of coastal regions will help in saving the lives from the rip current threat.

Future Scope:

Based on the validity of the rip current forecast, rip current data can be used as an advisory in future. It would also help to collaborate with various agencies including Space Application Centre, Ahmadabad which is a prime member of rip current forecast in the country.

The forecasted method can be adopted /followed by bringing awareness in the user Departments viz; Tourism Department, Disaster Management Authority, local authorities (Municipalities/ Panchayats/village level) and Marine Police.

INCOIS is working on rip currents from long back and they come up with new technique to record the rip currents using video cameras in the shore areas and identify the hotspots. One can collaborate with the premier institute to work together for better understanding of rip currents strength and its variability.



Figure-10: Coastal video monitoring: description of applications; (a) 5-camera system for Biscarrosse (France); (b) Spatial-temporal post- processed image showing wave dynamics. The image is generated from the high frequency acquisition of a cross-shore array of pixels. (source: . Marchesiello et al. / Ocean Modelling 96 (2015) 36–48).

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