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Automatic weather RADAR based Geo-specific severe-weather alerting system (R-ALERT)

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सार – भारत मौसम विज्ञान विभाग ने चक्रवात के मार्ग और प्रचंड मौसम प्रेक्षणों के लिए भारत में कई स्थानों पर डॉपलर मौसम रेडार (DWR) स्थापित किए हैं। डॉपलर मौसम रेडार उत्पाद उच्च स्थानिक और कालिक विभेदन वाले गर्ज के साथ तूफानों की विशेषताओं के बारे में उपयोगी जानकारी प्रदान करते हैं। इस DWR से उत्पन्न उत्पादों का उपयोग राज्य के मौसम पूर्वानुमान स्टेशनों में मौजूद पूर्वानुमानकर्ताओं द्वारा जिले और शहर में गर्ज के साथ तूफान के लिए तात्कालिक बुलेटिन जारी किया जाता है। आपदा प्रबंधक अपनी प्रशासनिक प्रणाली के माध्यम से जारी बुलेटिनों के आधार पर जनता को सचेत करते हैं। आपदा प्रबंधकों को त्वरित कार्रवाई के लिए गर्ज के साथ तूफान की घटनाओं की वास्तविक समय की निगरानी की आवश्यकता होती है। एक स्वचालित चेतावनी प्रणाली (R-ALERT) को ओपन सोर्स सॉफ्टवेयर पैकेज का उपयोग करके विकसित किया गया जो आपदा प्रबंधक को वास्तविक समय के आधार पर डॉपलर मौसम रेडार के माध्यम से प्रचंड मौसम की घटनाओं का पता लगाने में सहायता करता है। बर्फ़ीली स्तर की ऊंचाइयों पर परावर्तन थ्रेसहोल्ड का उपयोग किसी विशेष उपयोगकर्ता क्षेत्र में गर्ज के साथ तूफान की उपस्थिति का पता लगाने के लिए किया गया। यह प्रणाली अप्रैल, मई और जून के महीने में वर्ष 2019 के मॉनसून पूर्व गर्ज के साथ तूफान के मौसम के दौरान डॉपलर मौसम रेडार, विशाखापत्तनम में पायलट आधार पर चलाई गई। 4500 m की ऊंचाई पर 40 dbZ की थ्रेसहोल्ड को अलर्ट के लिए निर्धारित किया गया। जारी किए गए अलर्ट विभिन्न क्षेत्रों में गर्ज के साथ तूफान की घटनाओं के साथ मान्य किए गए और यह पाया गया कि 96% मामलों में प्रणाली स्वचालित रूप से गर्ज के साथ तूफान के अलर्ट को जारी करने में सक्षम थी। इस शोध पत्र में प्रणाली के डिजाइन, इसकी विशेषताओं और सत्यापन विवरणों पर विस्तार से चर्चा की गई है।

ABSTRACT. India Meteorological Department has installed Doppler Weather Radars (DWR) at many places in India for cyclone tracking and severe weather observations. Doppler Weather Radar products provide useful information on the characteristics of thunderstorms with high spatial and temporal resolution. The products generated from this DWR is being used by forecasters present in state weather forecasting stations to issue district and city thunderstorm warnings through now-cast bulletins. The disaster managers alert the public based on the issued bulletins through their administrative machinery. Disaster managers require real time monitoring of the thunderstorm events in the location of their interest for prompt action. An automatic alerting system (R-ALERT) was developed using open source software packages which aids the disaster manager to identify the presence of severe weather phenomena at the region of interest based on Doppler Weather Radar on real time basis. Reflectivity thresholds at freezing level heights were used to identify the presence of thunderstorm in a particular user defined region. The system was run on a pilot basis at Doppler Weather Radar, Visakhapatnam during the pre-monsoon thunderstorm season of the year 2019 in the month of April, May and June. Threshold of 40 dbZ at 4500 m height were set for generation of alerts. The alerts issued were validated with events of thunderstorm at various regions and it was found that system was able to issue automatic thunderstorm alerts with a critical success index (CSI) score of 0.96. This paper discusses in detail the design of the system, its features and validation details.

Key words – Severe weather, Thunderstorm, Geo-specific alert, Doppler Weather Radar (DWR), R-ALERT.

1. Introduction

Thunderstorms are meso-scale systems which occur in time scales of an hour to several hours and in spatial scale of few kilometers to hundreds of kilometers. Thunderstorms and its associated weather events have the potential to cause loss of lives as well as economic loss (Selvi and Rajapandian, 2016; Bhardwaj *et al*., 2017). The

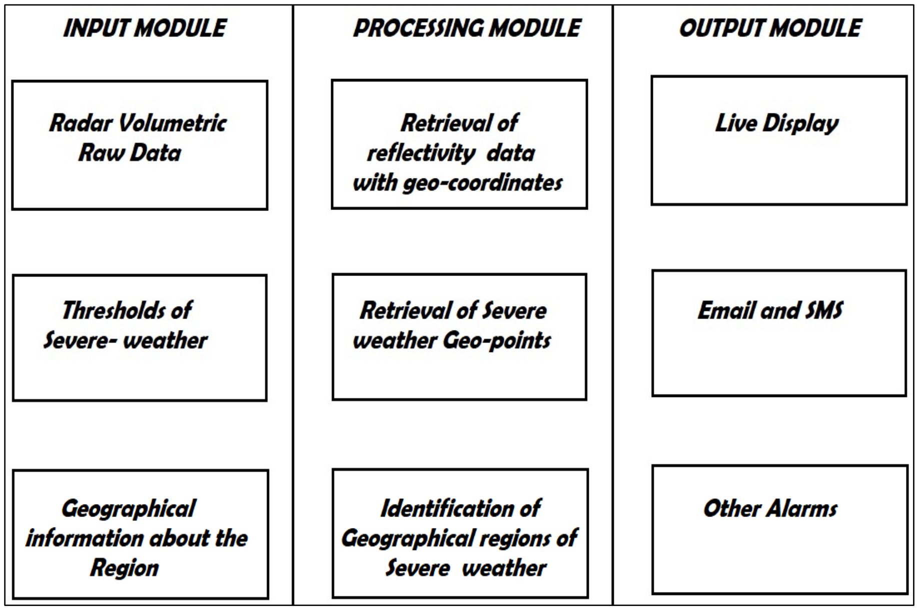

Fig. 1. System design and modules

frequency of thunderstorms increases sharply in the pre-monsoon season over entire region of India (Tyagi, 2007). State disaster management authorities expect early warning of thunderstorms to effectively reduce the casualties as well as damage to their infrastructure and agriculture crops caused by heavy rainfall, hailstorm, lightning, dust storms and strong winds which are the severe-weather phenomena associated with thunderstorms. Early warning of thunderstorm is a challenge due to their highly localized phenomena, short life period and limited observational network (Sen Roy *et al.*, 2019). Observational networks are being upgraded and expanded on a large scale for better prediction of thunderstorms.

Doppler Weather Radar has proved to be an important tool for forecasters to issue thunderstorm warnings as the DWR products provide useful information on the various characteristics of the thunderstorms. India Meteorological Department currently has installed 25 Radars in which 5 radars are dual polarized and the remaining radars are single polarized. The S band Single polarization Doppler radars have large spatial coverage of 500 km radius and provide base products such as reflectivity, radial velocity and spectrum width round the clock with a scan interval of ten minutes (Pradhan *et al.*, 2012). Dual-Polarization Radars have additional base products such as differential reflectivity, correlation coefficient and specific differential phase which can be effectively used along with single-polarization base products to classify the different hydro-meteor types observed by the Doppler radar (Lim *et al*., 2005). Many expert systems have been developed based on Doppler weather Radar products to identify the features of the radar echo and provide usable now-casts for 0-3 h period using various techniques as detailed in Sen Roy *et al.* (2019).

Forecaster's make use of data available from various observation along with expert systems to issue accurate now-cast alerts to the public/disaster management authorities. These alerts are issued for the geographical region of all districts and selected cities. The alerts are disseminated through various communication medium such as website, email and SMS. A simplistic approach for operational now-casting would be to analyze the DWR products such as MAX(Z), PPI(Z), PPI(V) every 10 minutes and find if there are any thunderstorm signatures in a particular district/city, then draft the warning message and finally update the communication channels to alert the authorities. This could take several minutes depending on time taken for DWR products to update in the website, analysis time and time taken to disseminate the information. Attempts have been made to issue automatic alerts using DWR data using various algorithms by Hering *et al.* (2015); James *et al.* (2018) and Bally (2004) to reduce the time taken for the alerts to reach the users. As thunderstorm is a meso-scale event, the lead time for warning is less and any increase in the lead time can lead to significant improvement in the response by the end users.

A system (R-ALERT) was designed using open-source libraries to issue thunderstorm alerts to the end-users automatically without manual intervention. The

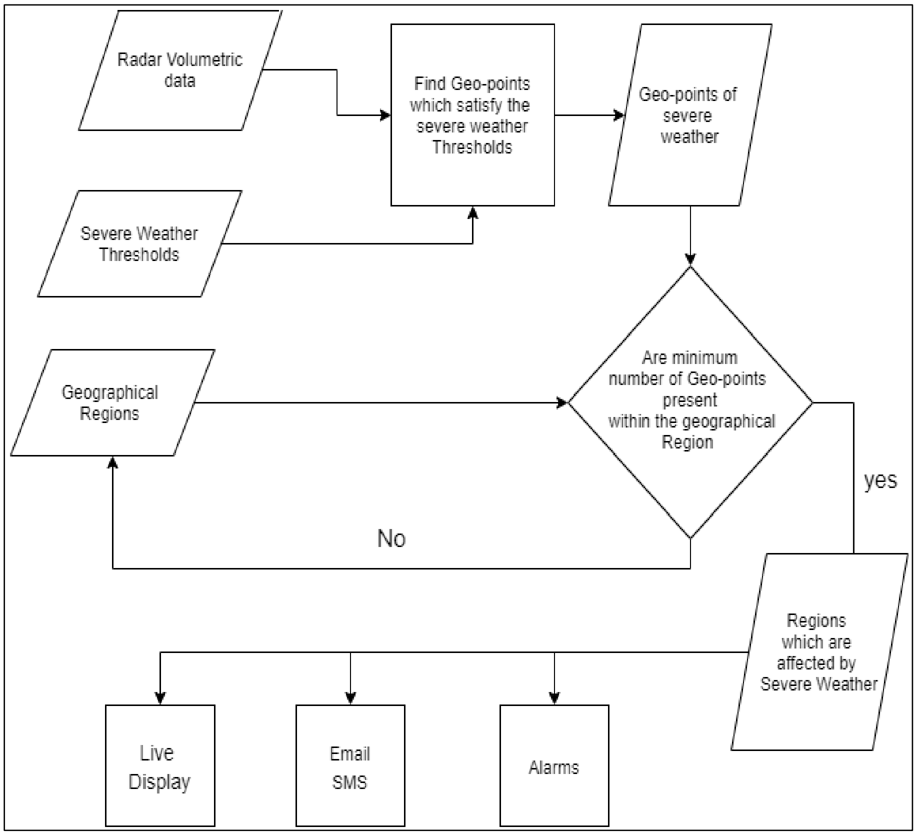

Fig. 2. Flowchart of Algorithm

volumetric data generated from the Radar is used as the primary input. Identification of severe weather like Thunderstorm, Rainfall and lightning from Radar data by applying various thresholds has been shown by Voormansik *et al.* (2017); Li *et al.* (2012); Yang *et al.* (2020) and Shi *et al.* (2019). Vincent *et al.* (2004) had provided a reflectivity and height threshold for prediction of cloud to ground lightning. A similar approach was used in the system to predict the formation of Thunderstorms. Though meteorological events are not constrained by administrative boundaries, the forecaster's at state level are entrusted with providing thunderstorm warnings for each district/city. The geographical information of each district and city is also provided as one of the input to the system. Once the analysis is done the forecaster disseminates the information through website, SMS and email. The system essentially performs the complete process automatically, based on the thresholds of the severe weather, an automatic analysis is done on the Radar data and if any signature of the severe weather is present in the given geographical boundary, the warning is disseminated to the concerned authorities through email, SMS and represented through a live Display.

2. System design and algorithm

The design of the R-ALERT system as represented in Fig. 1 and flowchart in Fig. 2 consists of three main parts, the input module which receives the various input information, the processing module which analyses the input to generate an output and the output module which disseminates the output in the form of alert in various forms. The input and processing module are coded in Python Language and the output modules are coded in both Python and PHP Languages.

2.1. *Input module*

2.1.1. *Radar volumetric raw data*

The main input for the alert system is volumetric scan data from radar. The operational scan strategy of DWRs operated by India Meteorological Department has 2 scans IMD-B and IMD-C. IMD-C is a long range (500 km) scan with 2 elevations and IMD- B is a short range (250 km) scan with 10 elevation scans (0.2°, 1.0°, 2.0°, 3.0°, 4.5°, 6.0°, 9.0°, 12.0°, 16.0°, 21.0°). IMD-B scan volumetric raw data is used as the input for the system. The volumetric raw data is represented in antenna coordinates of slant range (distance from radar), elevation angle and azimuth angle from true North. The Doppler weather Radars operated by IMD were commissioned during different time periods by different manufacturers. Hence, the native file format generated is different for different DWR manufacturer, the different formats are converted to a common format which is used as input data file for the system. A new data-set is generated every 10 minutes at the Radar station. The system is usually setup in the same radar station where the data generated from the radar server is converted into the common format and sent to the specific folder for processing. In case the system is set-up at a different location, the converted data is sent through the network connections.

2.1.2. *Thresholds for severe weather*

Thresholds which have to be applied on the Radar data must be provided to the system for processing. This is done through a configuration file. The configuration file is a text file which can be modified to enter the details of reflectivity threshold, minimum height threshold, maximum height threshold, alert validity time, details of the alert, Radar height above mean sea level and quality threshold.

The *reflectivity and height thresholds* are used to identify the data points pertaining to probability of Severe Weather. The reflectivity threshold is given in dBZ and the height threshold in meters. The *alert validity time* is the duration for which the severe weather alert issued is valid and this information is used for sending emails, SMS and generating alerts and is given in hours. Details of the alert provides the information of the source of the alert. Usually the name of the Radar station and detail of the alert such as District/City are provided here which is used when sending email, SMS and generating alarms. An example of the Details of the alert is "DWRVSK- District-Thunderstorm-Warning". Radar height above mean sea level is the actual height of the central feed horn from the mean sea level in meters. As the height of radar above mean sea level is different for the different radars based on the location, this information is provided for correct calculation of the height of the different data points in the volumetric raw data. Quality threshold is used by the processing module to avoid the false alerts which may be generated by the system due to false identification of random noise signal as severe weather in the volumetric raw data. The threshold is the minimum number of data points which should satisfy the severe threshold criteria in a Geo-location for triggering the alert. The selection of thresholds depends on Probability of Detection (POD), Lead time and the False alarm ratio (FAR). Usually, when the thresholds are set to increase the lead time, the false alarm rates goes high and *vice versa*. As the alerts are automatically generated and sent to the disaster managers, the thresholds should be selected based on the feedback from disaster managers on the lead time required and acceptable number of false alarms.

2.1.3. *Geographical Information about the region*

The third input for the system is the geographical information about the region which is provided through Shape files. The regions could be anything ranging from States, districts, Mandals. Cities or user defined zones such as airports, tourist places, secured locations or villages. Geographical information of standard regions such as states, mandals and district shape files can be obtained from National/State administrative departments. User defined geographical areas can be generated by using various Geographical information system (GIS). QGIS is an open source GIS which was used to create geographical regions of interest and then to export them as shape files. Shape files may contain many regions and the details of the regions are provided in a dBase database file. The user may not have the requirement to check for severe weather in all the available regions in the shape files .In such a case, the user has the option to provide the details of the region of interest in a text file. The system will check for severe weather only in the regions which are provided in the text file and not for all the regions present in the shape file. The shape files have to be exported with ESPG:4326 (WSG 84) as the geographic co-ordinate system

2.2. *Processing module*

The processing module is a executable file which is written in python and can be executed in Windows 8 and 10. The executable file is configured to run every 10 minutes in a task scheduler. The timing of the task is modified in such a way that the task starts immediately once the input radar volumetric file reaches the location. A new input file is received every 10 minutes.

2.2.1. *Retrieval of reflectivity data with Geo-coordinates*

A single volumetric data file consists of three parameters, Reflectivity, Radial Velocity and Spectrum width. Once the data is received in a specific folder, the system reads the data and retrieves the reflectivity values from it. The reflectivity values available in Antenna coordinates are converted into Cartesian co-ordinates with the following formulas adapted from equations 2.28(b) and 2.28(c) in Doviak and Zrnic (1993).

$$z = \sqrt{r^2 + R^2 + 2 * r * R * \sin(\theta_e)} - R$$

$$s = R * \arcsin\left\{\frac{[R * \cos(\theta_e)]}{(R+z)}\right\}$$

$$x = s * \sin(\theta_a)$$

$$y = s * \cos(\theta_a)$$

where, r is the distance from radar to the center of the gate, θa is the azimuth angle, θ_e is the elevation angle, s is the arc length and R is the effective radius of Earth taken to be 4/3 the mean radius of earth 6371 km. The values x, y, z are the Cartesian coordinates of the data points. The Cartesian coordinates are then transformed to geographical co-ordinates system using an azimuth equidistant map projection based on Snyder (1987). After the transformation, each reflectivity data is Geo-tagged with a latitude, longitude and height value. A radar with a gate resolution of 250 m, beam width of 1 degree and 10 elevation levels will have 3.6 million Geo-tagged reflectivity data points for all 360 degrees of azimuth angles. The height values are corrected with respect to the location of the station by using the *Radar height above mean sea-level* information from the configuration file. Open source software package Py-ART (Helmus *et al*., 2016) was used for the retrieval of reflectivity data with Geo-coordinates

2.2.2. *Retrieval of severe-weather Geo-points*

The thresholds defined in the configuration file are applied to the Geo-tagged data. Three main thresholds are used to filter the severe-weather points. They are reflectivity, minimum height threshold and maximum height threshold. The combination of the three thresholds can be used to identify the areas where the there is a probability for severe weather. For example, In case of Cloud-ground Lightning prediction, Yang and King (2010) had found that 40dbZ at -10 Deg isotherm height has a higher CSI than other thresholds. To apply the same threshold in the system, the reflectivity threshold should be set as 40dbZ. The -10 Deg Isotherm height h can be obtained from the vertical temperature profile of upper air sounding data. The minimum height threshold can be set at $h - x$ and the maximum height threshold can be set at $h + x$ where x is the buffer height. The system will find out all the Latitude and Longitude locations which have 40dbZ and above in the height between $h - x$ and $h + x$. Region specific thresholds which are obtained based on empirical analysis can also be applied to generate the alerts. Hailstorm warnings are issued by operational forecasters when 55dbZ and above are observed between 3000 m to 10000 m. Heavy rainfall warnings are issued when 45dbZ and above values are observed in lower elevations such as below 3000 m. Generalized thresholds can be applied for various severe-weather which can be fine-tuned further based on the lead time, POD and False alarm rates of the severe-weather. After the thresholds are applied to the data points containing reflectivity, latitude, longitude and height, only the latitude and longitude of the points where the severe weather is likely to happen are extracted. There is a possibility of random noise values and Anomalous Propagation (AP) echoes being present in the reflectivity data which can be misinterpreted as weather echoes. The AP echoes which are predominant in the lower altitude can be filtered by the minimum height threshold but the echoes in higher altitudes and noise figures cannot be completely filtered in a single polarization radar with velocity filter as certain AP echoes have higher velocity components [Bibraj *et al.* (2020)]. These invalid data points attributed to Noise and AP echoes can also satisfy the severe-weather thresholds and their latitude, longitude values are also included along with valid data points. The effect of these invalid data points to trigger the alert for a geographic region is minimized using quality threshold.

2.2.3. *Identification of the geographical regions where severe-weather is likely to occur*

The Geographical regions of interest which are within the coverage of the radar are already defined through the shape files. The regions can be of irregular shapes like states, districts and mandals or could be user-defined buffer zones of a location or region of Interest. The shape files contain the geometry of the region represented with the number of points and meta data. This geometrical information is retrieved from the shape file using an open source package pyshp (https://pypi.org/project/pyshp/1.2.3/). The geometry of each of the regions have specified boundaries. Each latitude and longitude points where the severe weather is likely to occur are verified if it is within the geometric boundaries of the region. This is done through a open source library Shapely which is an python package for manipulation and analysis of geometric objects in the Cartesian Plane [Gillies *et al.* (2007)]. As the latitude, longitude points include the invalid data points due to noise and AP echoes, this may cause the region being marked to have severe -weather even though no weather is present in the region. To minimize the effect of these invalid data points, the number of severe-weather latitude-longitude points which lies within the region is also calculated. In case of severe weather happening in a region, the number of data points satisfying the threshold criteria is very high compared when there is only noise with no severe-weather in a particular region. A quality threshold is used to verify if minimum number of severe-weather points is present within the region to trigger the alert so that false alarms which are triggered due to few random noise values in a

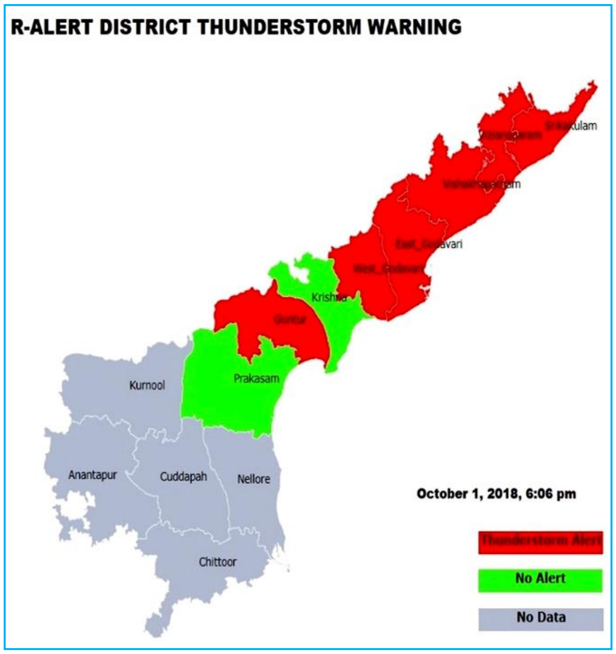

Fig. 3. District alert of live display

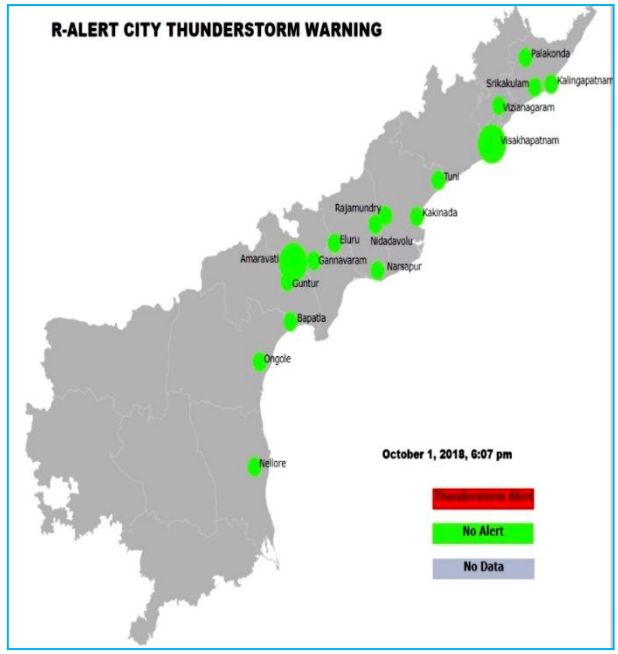

Fig. 4. City alert of live display

region are reduced. However, AP echoes in higher altitudes may affect a relatively higher number of data points compared to noise and may cause false alarms. Although these invalid data points caused by noise and AP echoes can be filtered using correlation-coefficient values in case of dual polarization radars, there is a limitation when it comes to single-polarization Radars. The regions which are marked having severe-weather based on the above thresholds are written on the region text file with time and date. These text files are overwritten when the new data comes into the system every ten minutes. Additionally, all the latitude and longitude points which are marked as severe-weather locations are written in a comma separated value (CSV) file.

2.3. *Output module*

The output module consists of 3 different units. The first unit is a live display map representing the alerts, the second unit is automatic Email and SMS alerts and the third unit is an external alarm

2.3.1. *Live Display*

Each weather Radar covers a geographical range of nearly 250 km or around 196000 sq.km. A State weather forecasting office issues alerts for the geographical areas within the political boundary of the State or a State disaster Management authority takes action based on the presence of severe weather within their State. A single Radar range may cover the geographical area of multiple States or multiple Radars may be required to cover the geographical area of single State. The live display of the system is represented through a web page designed in PHP. The web-page has a pictorial representation of State map with predefined regions of interest with clear boundaries and labels The text files which contains the details of regions marked for severe weather are sent to the live display system on real-time basis. In case of States covered by multiple Radars, text file from multiple Radar station is sent to the live display system. The algorithm in the live display system finds the latest file from each Radar station and highlights the geographical locations in the display with alert as shown in Fig. 3 for district alert and Fig. 4 for city alert. Figs. 3&4 show the alerts for district and city for the same time, It can be seen that though few district are given thunderstorm alert but the cities inside the district are not given alert. This is because the severe weather points are outside the limits of the city but within the limits of the district. It helps the disaster managers to segregate the region of interest and take action accordingly. In case the file is not available or is not the latest one, the same is indicated as no data. In case of multiple States covered within a range of single Radar, the output file from a single Radar is sent to multiple State forecasting offices. The live display refreshes every 5 minutes. In case same regions covered by two Radars, even if one radar reports severe weather, the live display updates the region as having severe weather. Districts not covered by Radar are shown as no data.

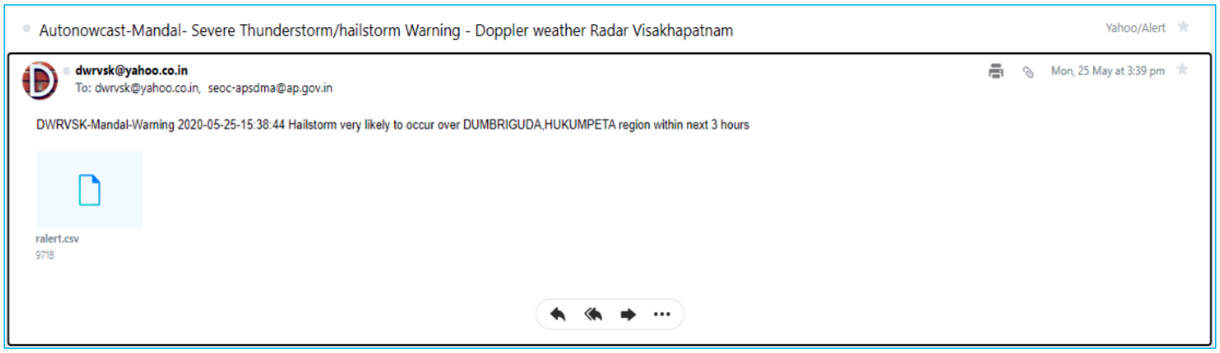

Fig. 5. Email alerts issued

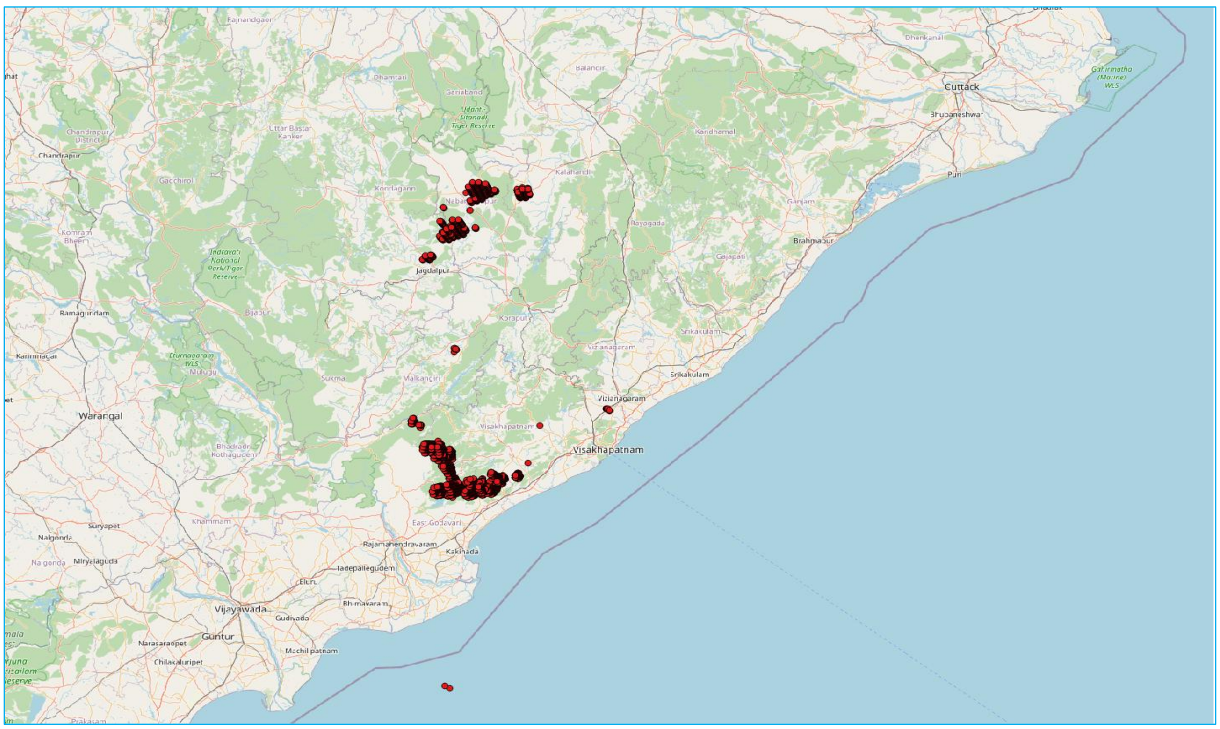

Fig. 6. Severe weather points on GIS

2.3.2. *Email and SMS*

The alerts can also be configured to be sent as Email and SMS. The alert typically contains the time of issue, the details of the sending Radar station and regions affected in the body of the Email/SMS as shown in Fig. 5. An Email/SMS configuration file is present through which this automatic Email/SMS feature can be enabled/disabled. The file also has the option to set the subject of the Email which generally provides the warning type and the sender of the warning. The email login credentials of the user account and the corresponding SMTP settings with port number of the email service provider has to be included in the configuration file. A separate configuration file is also available for SMS where the API key provided by the SMS service provider for web based SMS dissemination has to be included. Each region defined by geographical information like district, city or a zone is provided with an Email address and phone number of the disaster manager/forecaster of the region. When an alert is identified at a particular region, an automatic Email/SMS is send to the concerned officials. Once an alert is sent through Email/SMS, the next alert for the same region is sent only after the cooling off period even though the alerts are generated every 10 minutes. This is done by recording the time of the

Email/SMS sent for a particular region. The cooling off period is defined as the alert validity time in the threshold configuration file. When alerts are generated for a region, the last email/SMS alert time for the region is verified with the alert validity time and the new alert is sent only after the expiry of the alert validity time. This is done to avoid repeated Email/SMS alerts in a short span of time which occurs when a severe weather persists in the same region. There are also cases, when one disaster manager monitors severe-weather for multiple regions and in case the Severe-weather is present in multiple regions, only one email is sent to the receiver with combined details of multiple regions and not individual email for each region. The same concept applies for the SMS also. Some disaster managers may require the latitude-longitude points of the severe-weather to be overlaid in their own GIS platform as shown in Fig. 6. In such cases, a CSV file which is generated in the processing module is attached with the Email. This option can also be enabled/disabled in the configuration file. The sending of emails is integrated to the processing module and is sent directly from the Radar station unlike the live Display output where a text file is sent to Forecasting offices which is then processed to be represented in the display. This is done to avoid any unexpected bottlenecks in transfer and processing of data in multiple locations.

2.3.3. *Other alarms*

The output of the processing module is designed in a such a away that it can be used for various other kinds of user preferred alarms. The CSV file generated can be used for real time updates on a GIS Map. The latitude longitude values are represented as dots in a GIS map as shown in Fig. 6. This will help the users to identify the extent of the severe weather over the region and also their severity based on the density of the points.

The Alerts in text format are published in a file which can be converted to an audio file using text to speech third party software's. This audio file is played through the audio system as an alarm. The generation of alerts in text format also follows the alert validity time in the threshold configuration file. So that repeated alerts are not announced in the audio system. This audio alarms were tested in operational mode in Doppler weather Radar station and Cyclone warning center, Visakhapatnam and the performance was consistent. Automated CAP alert generation is planned in future versions.

3. Validation of the system

The system was run on pilot basis during the pre-monsoon season of 2019 at Doppler weather Radar Station, Visakhapatnam in operational mode for validation. It is a Gematronik GmbH, 10 cm wavelength non-polarimetric radar located at a height of 148 m above mean sea level in the co-ordinates Lat. 17°44' N Long. 83°22' E. Ten Geographical regions representing the cities where now-cast warnings are being provided were generated using QGIS. The Regions defined were Kalingapatnam, Srikakulam, Palakonda, Vizianagaram, Visakhapatnam, Tuni, Kakinada, Eluru, Nidadavolu, Narsapur. This GIS information was provided to the system. The minimum Reflectivity Threshold was set to 40 dBZ, the Minimum height threshold at 4500 m and the Maximum height threshold was 18000 m and quality threshold of 20 for identification of Thunderstorms. Email alerts for all the regions were configured to be sent to the designated email address. The Email alerts were generated for the month of April, May and June when the Thunderstorm activity is more in the North Coastal Andhra Pradesh. These Alerts were analyzed with the occurrence of Thunderstorms reported by IMD observations of Forecast Demonstration Project (FDP) storm Bulletin. The time of generation of alerts and the time of thunderstorm occurrence mentioned in the FDP storm bulletins were also compared. It was found that in the month of April, only one thunderstorm event was reported within the defined regions and the email alert was issued in the same time. In the month of May, a total of 35 thunderstorm events were reported in the regions and 40 Thunderstorm alerts were issued through the email. 35 email alerts coincided with the time of occurrence thunderstorm in the FDP bulletin but no thunderstorm event was recorded when the remaining 5 email alerts were generated. In the month of June, 80 thunderstorm events were reported and 80 thunderstorm alerts were issued at the same corresponding time. The reason for 5 email alerts triggered during the month of May when no thunderstorm was recorded in FDP bulletin was analyzed with the help of Max (Z) pictures of DWR, Visakhapatnam and it was found that it was due to AP echoes which were identified as thunderstorms. Out of the total 116 recorded thunderstorms, alerts were issued automatically through the email for all of them and in addition 5 more alerts which were False alarms. The verification scores for thunderstorm alerts with the provided thresholds were 1.0 for POD, .04 for FAR and 0.96 for CSI. The verification scores reflect the accuracy of the thresholds in identifying the severe-weather from weather echoes and also the performance of the system in differentiating between the weather echoes and non-weather echoes. In the above case, the thresholds were selected with high accuracy to find the performance of the system independent of the accuracy of the thresholds. It was evident that the false alarm rate was only due to the limitation of the system in differentiating weather and non-weather echoes caused by AP and there was no false alarm in differentiating thunderstorm from weather echoes due to the thresholds. The verification scores can drastically reduce when a less efficient threshold is used in the same system. Thresholds also indirectly affect the performance of the system, For Example, setting the minimum height threshold close to the ground will cause more non-weather echoes to be identified as weather echoes [Bibraj *et al*. (2020)]. However, the verification exercise had proven useful in identifying that performance of the system is affected only by the non-weather echoes and it is likely that the system will contribute only to the increase in false alarm rate in addition to the false alarm rate due to the severe-weather thresholds. If dual-polarization radars are used, the non-weather echoes can be removed and the verification scores would be the true reflection of the accuracy of the severe-weather thresholds.

4. Conclusions

The R-ALERT system was developed to reduce the time to issue the alerts to the disaster managers. Severe weather like thunderstorms and lightning occur in a very short span of time. Early alerts are crucial to minimize damage and save lives. It also aids forecasters in decision making for issuing now-cast weather bulletins. As the system generates alerts without any user-intervention, it reduces the burden on the disaster managers to do manual analysis of Radar products every 10 minutes. The live display integrates the output from multiple Radars into one unified alert display which reduces the need for disaster managers from non-meteorological background to look into multiple Radar products. The system is designed to focus only on regions of interest. This helps the disaster managers to segregate the region more vulnerable to severe weather and concentrate on them. The system was designed to run with computing capability as available in normal personal computers. It takes 90 seconds for every ten minutes to complete the whole processing from reading of the volumetric file to sending of emails in a 64 bit, 4 GB RAM, Intel Xeon processor machine. The system is currently operational with live display at State now-casting office Andhra Pradesh and Telangana within the range of DWRs Visakhapatnam, Machilipatnam, Hyderabad of India Meteorological Department.

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