Journal of Geomatics Vol 11 No. 2 October 2017

Dissemination of heat wave alerts using spatial mashup technology and open source GIS

Neha Sharma and Shweta Mishra
Space Applications Centre, Ahmedabad – 380015
Email: write2neha@live.com

(Received: Jul 24, 2017; in final form: Sep 28, 2017)

Abstract: Web GIS based applications and systems are becoming popular with the advancement of internet and related technologies and efforts of the open source community. Planners and decision makers are seeking web GIS based solutions as they are efficient at satisfying the needs of users in terms of availability of associated collateral information. The standards and specifications developed by the Open Geospatial Consortium (OGC) for geospatial data and services is leading to positive developments in web GIS. GIS services defined by the OGC are part of a larger effort to build distributed systems around the principles of Service. Web 2.0 technologies, particularly Asynchronous JavaScript and XML (AJAX) open APIs, XML, XHTML/CSS etc. leads towards realization of spatial mashups for GIS data and services. In this study, the spatial mashup technology has been used to disseminate near real-time heat wave alerts through a rich Graphical User Interface (GUI) based web GIS application. Further, GeoServer is used as a GIS server and Apache Tomcat version 8.0.12 is used for delivering the web services. Java and java script are used in web application development and database connectivity.

Keywords: Open source GIS, Web-based GIS, Heat wave, Spatial mashup, GeoServer, OpenLayers

1. Introduction

Web-based GIS combines the power of the internet and GIS. Internet GIS uses 'a Web browser where geographic data are displayed as maps and graphs based on user-selected criteria' (Milson and Earle, 2007). The drop in computer prices and the increased popularity of internet mapping in recent years has sparked the development of many open source GIS projects with the aim of bringing GIS technology to the general public at little or no cost (Caldeweyher et al., 2006). Development of web GIS based applications aid in decision making and planning activities, and the integration of near real time information components into the system is very essential. An application that uses and combines data or functionality from different sources to form a new service is known as web mashup. The role of web mashup technology is very important to develop further value added applications at the user end by integrating the GIS data and services from diverse sources (Karnatak et al., 2011).

The mashup architecture integrates data, information and functionality from different sources like open APIs, web services, etc. and demonstrates it as a new application. In the present study, a use of spatial mashup technology is demonstrated for disseminating heat wave alerts.

A heat wave is a period of abnormally high temperatures more than the normal maximum temperature that occurs during the summer season in India. Due to global climate change, instances of heat waves are becoming more intense in nature. Climate extremes like heat waves are of great interest due to their high impact on various sectors including health, agriculture, ecosystems and national economies. The health impacts of heat wave typically involve dehydration, heat cramps, heat exhaustion and/or heat stroke. Other impacts due to heat waves could be agricultural crop failures and power outages due to excess consumption.

The Indian landmass was struck by a severe heat wave in May-June 2015. It resulted in the death of more than 2,500 people in multiple regions. The 2015 heat wave had the highest recorded temperature since 1995. Therefore, this study was taken up to disseminate heat wave related information to users in a timely and cost effective manner so that decision makers and planners or end users can take necessary actions. Heat wave alerts which include maximum surface temperature forecasts for the next 24 and 48 hours, changes in extreme heat condition from 24 to 48 hours, and maximum surface temperature predicted from Weather Research Forecast (WRF) models are used as input in the development of a web GIS based application using spatial mashup technology. Spatial resolution of heat wave data is 5 km. GIS layers such as state, district and taluka (region) boundary, district roads, national highway, railway tracks, rivers, district headquarters, district population (as per census of 2011) etc. are used as overlay layers. Basic GIS functionality such as pan, zoom, distance and area calculation are also made available in the web application.

2. Inputs for the heat wave alert dissemination system

The Indian Meteorological Department (IMD) has given the following criteria for heat waves: 'Departure of maximum temperature from normal is +4°C to +5°C or more for the regions where the normal maximum temperature is more than 40 °C and departure of maximum temperature from normal is +5°C to +6°C for regions where the normal maximum temperature is 40°C or less (IMD – Terminologies and Glossary). A heat wave is declared only when the maximum temperature of a station reaches at least 40°C for plains and at least 30°C for hilly regions. In this context, it is also measured as a heat wave if the actual maximum temperature remains 45°C or more irrespective of the normal maximum temperature'.

Severe heat wave conditions are declared when the maximum temperature deviate up to +6°C from the normal for regions where the normal maximum temperature is more than 40°C, and +7°C or more for regions where the normal maximum temperature is 40°C or less.

WRF model version 3.7 has been used for the generation of maximum surface temperature forecasts. For the assimilation of the WRF model, the INSAT-3D sounder and imager radiances, Sounder for Probing Vertical Profiles of Humidity (SAPHIR) radiances and INSAT-3D atmospheric motion vectors are used in this study. More details of the implementation of the WRF model can be found from Kumar et al. (2015).

The maximum temperature observations during 1981 to 2014 from IMD, India are used to generate daily climatology of maximum temperature. If the difference between the WRF model predicted maximum temperature and daily climatology (maximum temperature occurred within +5 days of reference day) of maximum temperature following the IMD guidelines, maximum temperature forecast is plotted for those regions (Kumar and Kishtwal, 2016). Model predicted 24-hour maximum surface temperatures, heat wave conditions for different forecast lengths (24 and 48 hours), and changes in heat wave conditions from 24 to 48 hours are disseminated using Web GIS based application.

3. System architecture solutions for web GIS based visualization system

Extreme weather related data dissemination with associated spatial data is more user-friendly for general public and decision makers, but the handling of spatial data is quite difficult as compared to non-spatial data. The emergence of new technologies and knowledge in open source has given impetus to the web GIS based visualization system (Sanchez et al., 2014, Karnatak et al., 2010, Sharma and Mishra, 2012). Open source software are programs whose licences allow users to use, modify and freely redistribute the software either the original or modified program without further limitations or royalty payments (Sanchez et al., 2014, Sharma and Mishra, 2012, Karnatak et al., 2010). It facilitates users to use and distribute geospatial data at affordable pricing with increased access. After detailed review and study, the software and libraries listed in Table 1 are used for carrying out this work.

Table 1: Open source tools used for development

Software / Tool / Library	Task / Activity
GeoExt, ExtJS	Web-GIS development libraries <http://geoext.org> <www.sencha.com
OpenLayers	Open-source, JavaScript library for light-weight interactive maps. <http://openlayers.org>
GeoServer	OGC compliant Open-source WebGIS Server for hosting and managing of geospatial data <http://geoserver.org>
Apache Tomcat	An open-source Web application server <http://tomcat.apache.org>
MapProxy	An open source tiling server used for caching, acceleration of map service <https://mapproxy.org>

Standard image or data formats (or non-spatial data) such as .png, .jpeg, .tiff, .html, .xml etc. can be displayed easily with the help of standard web browsers and servers. But to depict or publish GIS data (spatially enabled data) into a web browser, a special software package or program is used known as GIS or map server. Many proprietary as well as open-source products are available as GIS servers for publishing geospatial data in a web environment.

Various GIS/Map servers available are GeoServer, UMN Mapserver, Mapguide, Degree (Open source), ArcGIS Server, Skyline Globe, ERDAS APOLLO Server, Intergraph and Geo web server (Proprietary software). After study and detailed review of various WebGIS Servers, GeoServer is selected for publishing GIS data as OGC Web Services. Among these available GIS servers, GeoServer was used in this study as it is OGC compliant open source WebGIS software, has both raster and vector support and is superior in performance, security, vector support and OGC web services

(http://docs.geoserver.org/2.8.x/en/user/index.html) . GeoServer is an open source software server written in Java that allows users to share and edit geospatial data. It publishes data from any major spatial data source using open standards. GeoServer is the reference implementation of the Open Geospatial Consortium (OGC), Web Feature Service (WFS) and Web Coverage Service (WCS) standards, as well as a high performance certified compliant Web Map Service (WMS). GeoServer forms a core component of the Geospatial Web (http://geoserver.org). GeoServer allows the loading and serving of the following data formats by default:

- Vector data formats such as Shapefile, PostGIS databases, External WFS layers, Java Properties files etc.
- Raster data formats such as ArcGrid, Geotiff, Gtopo30, Image Mosaic, WorldImage etc.

Apache-Tomcat version 8.0.12 server is used as a web server whose primary function is to deliver web pages as per the user's request in the client's browser. It is an open source, Java-based web application container that was created to run servlet and Java Server Page (JSP) based web applications (http://tomcat.apache.org). Tomcat server has become the reference implementation for both the servlet and JSP specifications. It is stable and has all of the features of a commercial Web application container.

An open source tiling server MapProxy is used for caching and acceleration of map service. MapProxy accelerates existing web map service 10 to 100 times. Pre-generation of tile cache of collateral datasets has been done to obtain better performance.

Open source API's (Application Programming Interface) such as OpenLayers and GeoExt have been used for making interactive web maps. OpenLayers is a client side JavaScript library that requires no special server side software or settings (Kulawiak et al., 2010). It provides tools to develop customized web maps (http://openlayers.org). Using OpenLayers one can customize every aspect of the map—layers, controls, events, etc. It makes creating map 'mashups' relatively easy. There is a Client / Server Model and it is, essentially, the core of how all web applications operate (Hazzard, 2011). In the case of a web map application, a map client (e.g. OpenLayers) communicates with web map server (e.g. a WMS server or the Google Maps backend).

GeoExt is used for building rich, web-based GIS applications (http://geoext.org). This rapidly-developing library is built upon ExtJS and OpenLayers. It provides user interface components for building web applications along with solid underlying data components while OpenLayers is used for making interactive web maps. UI components provided by GeoExt make the web-based GIS applications extremely rich and user friendly. It can access information from OGC services, OpenLayers objects and other data sources.

4. Approach and development process

Heat wave data and associated thematic layers are stored in a GIS server i.e. GeoServer. Pre-caching of large size overlay layers was done using MapProxy tile server for fast rendering and improved performance. A web application that has been developed using JavaScript, OpenLayers API, GeoExt and ExtJS is deployed in the web server i.e. Apache. Clients interact with the web server by sending HTTP requests through the web application. The primary task of the client is to get map images from the GeoServer. OpenLayers handles the interactive GIS operations like pan and zoom via asynchronous JavaScript (AJAX) calls to GeoServer. The Web server sends a GetMap request to GeoServer, then the GeoServer sends back a response containing the map image (WMS layer). Web server sends a HTTP response to the client; finally, output is displayed in the browser. A mashup has been implemented by integrating various data layers from different sources to disseminate through a common platform. The overall methodology and system flow diagram is shown in Figure 1.

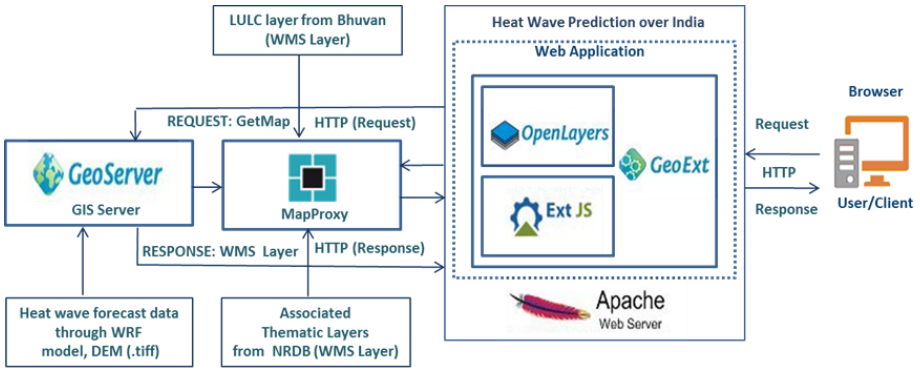

Figure 1: System flow diagram

• **Data downloading from FTP**

WRF model generates heat wave forecast on daily basis at predefined FTP area. A data downloading script has been prepared by using the java programming which automatically downloads the data from a predefined FTP area into the data directory of GIS server.

• **Preparation of GIS database**

Thematic layers such as administrative boundaries like state, district and taluka, district roads, national highways, railway tracks, airports, district headquarters and rivers (Source: NRDB (**N**atural **R**esource **D**ata **B**ase)) at 1:250000 scale, were added as WMS layer in web application. GTOPO digital elevation model (DEM) with horizontal grid spacing of 30 arc seconds (approximately 1 km) was published on GeoServer as a WMS service. The WMS service generates map images and makes them available in different formats, for example GIF (Graphic Interchange Format) files, JPEG (Joint Photographic Experts Group) or PNG (Portable Network graphics) (picture case) or as a series of graphical elements, typically pre-determined projection and given reference and coordinate systems and with predefined associated symbols and colors. The service is composed of three basic functions, supported by three WMS interfaces: human-and computer-understandable descriptions of the available data and the parameters related to the requests accepted by the service (GetCapabilities), supply of the requested data (GetMap), request of other information (map content and attributes of map features) (GetFeaturesInfo). The data is in GCS WGS 84 projection.

Geospatial data has no intrinsic visual component. In order to see the data, it must be styled which means to specify the color, thickness, and other visible attributes. For the better visualization of datasets in GeoServer, this styling is accomplished by using a markup language called Styled Layer Descriptor, or SLD. SLD is an XML-based markup language and is a very powerful technique for preparing illustrative visual map depictions.

All India Land Use/ Land Cover layers for 2012-13 have also been added in the application as WMS layers from the Bhuvan (bhuvan.nrsc.gov.in) website. Seeding of all overlay layers were done using MapProxy for fast rendering.

• **Publishing heat wave alert data on GIS server**

Heat wave alert data is available through the WRF model in .tiff format, the main challenge was to publish it in GeoServer as a WMS service, for which data should be spatially enabled. For publishing these images, which are not georeferenced as a layer in GeoServer, WorldImage format was used.

A world file is a plain text file used to georeferenced raster map images. This file (with an extension of. jgw or. tfw) accompanies an associated image file (.jpg or .tif). Together, the world file and the corresponding image file are known as WorldImage in GeoServer. According to the extent of the image and its spatial resolution the tfw file was generated and heat wave alert data was published automatically as WMS layer in GeoServer using RESTful service. The heat wave alert data is in raster format which contains temperature values for India. The data is stored in EPSG:4326 (WGS 84-LatLong) projection system.

Heat wave alerts are disseminated by using colors ranging from green to red. Figure 2 indicates the color notation used for representing the severity level associated with weather forecast.

Figure 2: Message associated with each color for depicting heat wave alerts Adapted from http://www.metoffice.gov.uk/guide/weather/warnings

• **Development of web application**

A customized web application was developed with the help of java script, OpenLayers, GeoExt, ExtJS etc. All published GIS layers were added by using WMS method in layer class of OpenLayers. Rich GUI components like layer tree, legend panel, zoom in, zoom out, pan, distance calculator, area calculator, map print etc. were added in the application as components for the tool bar, thereby giving an interactive handle for the end user. Layer panel displays the list of overlay layers along with heat wave alerts in a tree node structure and the legend panel displays the legend of the selected layer. Map panel displays WMS layers which we can zoom and pan.

Opacity slider has been added which allows us to modify the opacity (transparency) of the selected layer which helps the users in the simultaneous visualization of two polygon/ raster layers.

Whenever the users click on a map, a GetFeatureInfo (is a WMS standard call that allows one to get information about features displayed on a map) request has been submitted to the server and the resultant response come out in a HTML format. This HTML response is used to display predicted temperature of the clicked pixel through a popup.

5. Results and discussions

Web GIS based near real-time heat wave alerts dissemination will be useful for the end users or decision makers for taking necessary actions. In this endeavour, the role of open software system architecture is very important to provide an interoperable and cost effective solutions.

Overlay layers such as land use/land cover help in understanding the spatial relationship between anthropogenic activities and extreme heat affected areas. Residential areas under the influence of extreme heat waves can be easily identified by using this application. A DEM layer gave insight about the effect of topography on temperature. Through this application, users can get information about the state/ national highways which are affected by the severe heat waves, so that users/ stakeholders can take necessary preventive measures to avoid serious health consequences.

The user interface of the web GIS based application for the dissemination of heat wave alerts is shown in Figure 3. Users can zoom, pan and calculate distance/ area using the tools given in the application. Users can also add other thematic layers such as administrative boundaries, district wise population (as per census of 2011) etc. along with Heat wave predictions which will aid in identifying affected area upto the large scale (taluka level) (Figures 4 and 5). Changes in extreme heat conditions from 24 to 48 hours and the predicted maximum surface temperature layer gives insight about the current status and very near future scenario of the heat wave over India.

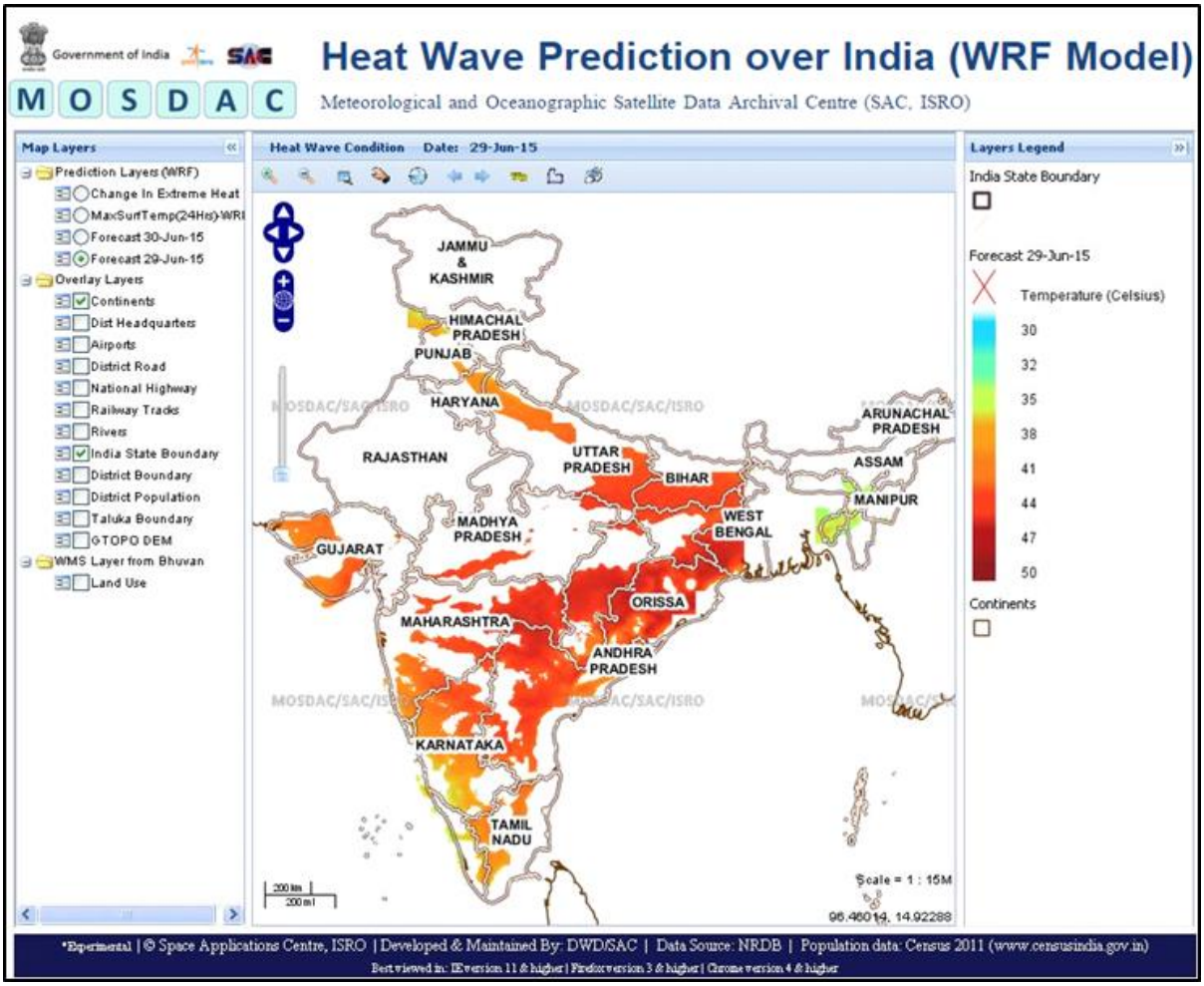

Figure 3: User interface of web GIS based application showing heat wave forecast for 29-June-2015

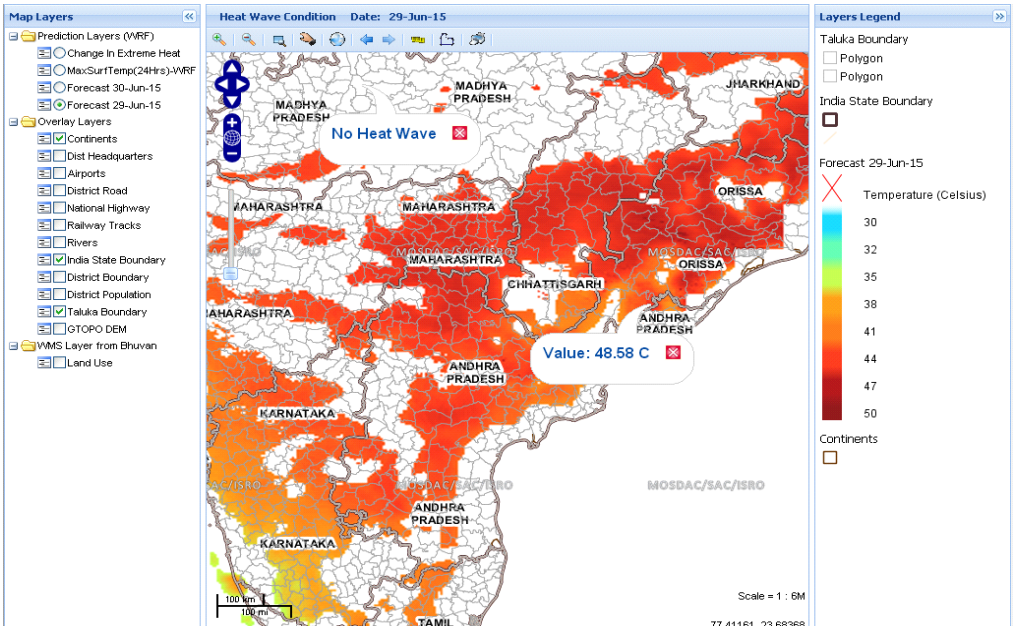

Figure 4: Heat wave forecast for 24 hour overlaid with taluka boundary and popup displaying predicted temperature of clicked pixel

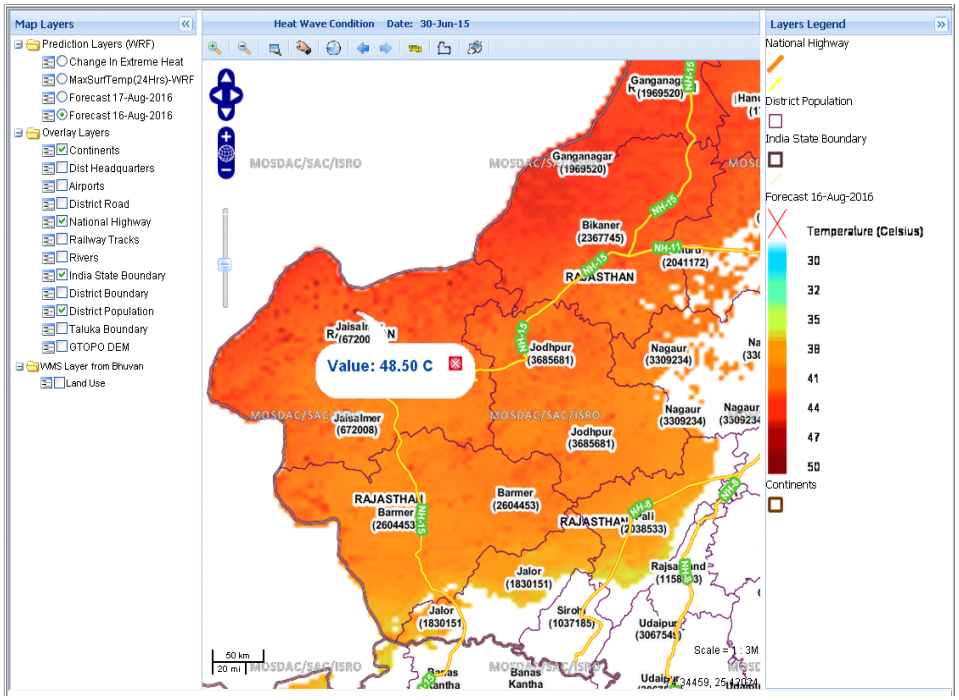

Figure 5: Heat wave forecast for 48 hours overlaid with district population and national highway

This paper demonstrates the architecture, functionality and applications of web GIS based visualization system for disseminating extreme weather related products in near real time. This visualization system includes automatic update, integration of collateral data from various sources to create a mashup and visualization in the Web environment which enables remote sharing of geospatial information in an understandable way. It is planned to provide heat wave alerts as notifications on Android based handheld

devices and extend the theme for cold wave conditions.

6. Conclusion

The geo-visualization of heat waves events presents a simple/ user-friendly way to demonstrate the complex results of algorithms which are beyond the understanding of users. The present study also shows the use of spatial mashup technology and capability of open source GIS technology in the development of a near real-time web GIS based visualization system. It demonstrates the practical usage of tools and techniques of open source utilities to make available geographic information to the end users in a cost-effective manner. For a country like India where severe heat wave incidents occur frequently, the above-developed web GIS based application will be useful for decision makers and planners. This study also shows that the web based technology is emerging as a platform where various technological and applications oriented solutions can be provided without any software, data or hardware dependency at the user end.

Acknowledgements

The authors express their sincere gratitude to Mrs. Pushplata B. Shah, former Head, DWD/MRG/EPSA for her guidance and advice which proved to be very effective. Sincere thanks to Shri. Tapan Misra, Director, Space Applications Centre and Dr. Raj Kumar, Deputy Director, EPSA/SAC for their support and encouragement. The authors would also like to acknowledge Dr. Prashant for providing heat wave forecast.

References

Caldeweyher, D., J. Zhang and B. Pham (2006). OpenCIS—Open Source GIS-based web community information system. International Journal of Geographical Information Science, 20:8, 885-898.

Hazzard, E. (2011). OpenLayers 2.10 beginner's guide. Packt Publishing Ltd, Birmingham, B27 6PA, UK, ISBN 978-1-849514-12-5

http://docs.geoserver.org/2.8.x/en/user/index.html
http://geoext.org
http://geoserver.org
http://openlayers.org
http://tomcat.apache.org

India Meteorological Department -Terminologies and Glossary, Available at http://imd.gov.in/section/nhac/termglossary.pdf

Karnatak, H.C., R. Shukla, V.K. Sharma, Y.V.S. Murthy and V. Bhanumurthy (2011). Spatial mashup technology and real time data integration in geo-web application using open source GIS – A case study for disaster management. Geocarto International, 27:6, 499-514.

Karnatak, H.C., S. Saran, K. Bhatia and P.S. Roy (2010). Geospatial database organization and spatial decision analysis for biodiversity databases in Web GIS environment. Geocarto International, 25:1, 3-23.

Kulawiak, M., A. Chybicki and M. Moszynski (2010). Web-based GIS as a tool for supporting marine research. Marine Geodesy, 33:2-3, DOI:10.1080/01490419.2010.492280, 135-153.

Kumar, P., B.K. Bhattacharya and P.K. Pal (2015). Evaluation of Weather Research and Forecasting model predictions using micrometeorological tower observations. Boundary-Layer Meteorology 157, no. 2, 293-308.

Kumar, P. and C.M. Kishtawal (2016). Heat wave predictions over Indian landmass using Weather Research and Forecasting model. Scientific report, SAC/EPSA/AOSG/ASD/SR/08/2016.

Milson, A.J. and B.D. Earle (2007). Internet-based GIS in an inductive learning environment: A case study of ninth grade geography students. Journal of Geography, 106 (6):227–237.

Sanchez, R.M., G. Anderson, J. Cruz and M. Hayden (2014). The potential for the use of open source software and open specifications in creating Web-based cross-border health spatial information systems. International Journal of Geographical Information Science, 21:10, DOI: 10.1080/13658810701300113, 1135-1163.

Sharma, S.A. and S. Mishra (2012). Web-GIS based monitoring of vegetation using NDVI profiles. Journal of Geomatics, Vol.6 No.2, 109-112.