

Chapter 23

Geoweb Services and Open Online Data Repositories for North West Himalayas Studies Including Disaster Monitoring and Mitigation



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23.1 Introduction

With recent advancements in wireless communications and Internet technology during the last decade, it is promising to develop many citizen-centric new applications and services in various fields including spatial information technology. The users of geospatial technology have started to use online GIS (geographic information system) for a variety of applications by using web services and online data repositories. Internet today has emerged as one of the most suitable and quickest means for accessing, analyzing, displaying, and transmitting the geographical information and geographic knowledge. It is perhaps the only means which maximizes the potential of GIS data and software application for wider and easier access of geographical data to the planners and decision-makers. The World Wide Web, FTP (file transfer protocol), and HTTP programs make it convenient to access and transfer data files across the Internet. Internet technology in conjunction with GIS today in crisis situations allows geospatial information coming from multiple sources to be integrated in real time, interactively accessed and visualized to generate accurate and quick actionable information for emergency response teams coordinating the activity (Mansourian et al., 2005). Today the distributed and heterogeneous resources and data services can be accessed through a centralized and uniform interface using GIS-based web portals (Karnatak et al. 2007, 2012). Considering

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the different types of disasters varying from natural to man-made having diverse data requirements, a single GIS web service may not be sufficient enough to handle all requirements, and therefore specifically the web GIS-based portals available in the Internet are generally customized and developed for a particular theme keeping in mind a specific class of user(s). The availability of international data and information service standards published by the Open Geospatial Consortium (OGC) is playing an important role to achieve interoperability in data and information sharing. GIS service standards published by OGC are based on distributed service-oriented architectures (SOA). Such systems unify distributed services through a message-oriented architecture by using Simple Object Access Protocol (SOAP). The data and information services available through web portal applications have great scope of its massive utilization at user's end. Many GIS-based plans for a variety of applications can be developed using available GIS-based web services (also known as Geoweb services) and online data repositories. Some of the major advantages of Geoweb services and online data repositories include dynamic and updated data, real-time and multiuser access, and development of user-defined applications using mashup architecture (Karnatak et al. 2012). This approach is quite useful for the applications where real-time dynamic data is required for planning and decision-making such as disaster or emergency management.

Due to the large spatial extent of disasters affecting several people across the countries, geospatial technology today finds a wider acceptance and has become an important tool for decision-making process. The traditional desktop GIS-based disaster response to an emergency situation and relief operations using traditional maps has been transformed completely, with the evolution of Internet technology. Web-based GIS technologies today allow collaborative environment to access, process, and integrate real-time data flow from various sources and a number of users to generate actionable products and respond to an emergency situation much better than before. Today when the disasters have become more intense and severe, the online data repositories and information services can play a critical role in supporting all phases of disaster monitoring and mitigation. The increasing availability of free satellite imagery (like Sentinel data), GIS thematic maps (OpenStreetMap), GIS software (QGIS), and theme-specific hazard modeling software (HEC-RAS) to analyze the data offers considerable potential to decision-makers and planners to take appropriate informed decision in times of crisis. The present technology allows to access data and information from a variety of sources and also integrate it to one common platform for user-defined applications. This chapter presents a technological overview of Geoweb service and online data repositories and a list of popular open online resources and also demonstrates a case study for effective utilization of these services in flood disaster monitoring and mitigation.

23.2 Geoweb Services and Online Data Repositories

Advancements in information and communication technologies (ICT) have facilitated a new way for sharing and dissemination of geospatial data and information. The online data repositories and web applications are providing various means of data access by using the Internet and related technologies. Today, the users of geospatial data and information can use Internet platform for various geoscientific activities such as spatial queries, geo-visualization, and simple to complex computations for decision-making and virtual reality. Considering the importance of spatial data for humanitarian response during natural disasters, many agencies and individuals are hosting their data sets online, which has enhanced the outreach of geospatial data manifold. These open geo-data sets can be used for various thematic applications either as a Geoweb service or as a data product(s).

The service-oriented architecture (SOA) and related technologies for distributed GIS applications are providing interoperable platform for data sharing and disemintions. The SOA-based software systems provide independent building blocks that jointly represent the software application environment (Karnatak et al. 2012). One of the unique features of SOA-based software applications is to set up complete autonomy among different service components which is important for interoperability. The most popular SOA-based web services implementations are based on XML. The Extensible Markup Language (XML) is a markup language developed by W3C to define the set of rules for encoding the documents in plain text format. The XML is used to define the data and information and is also known as data definition language. The outcomes of XML are presented as Hypertext Markup Language (HTML) document which is known as data presentation language. The SOA architecture has three basic components, i.e., a provider, a requester, and a broker (Fig. 23.1). The provider is the owner or publisher of the service, typically the client or user is a requester, and the broker is the component which maintains the registry of available services as catalogue. The interaction between the above three components is represented as three operations, i.e., publish, find, and bind.

The SOA-based web services for geospatial data, process, encoding, and other spatial operations are very important to achieve interoperability in data and information sharing. The web service standards for geospatial and data and process are designed and developed by the Open Geospatial Consortium (OGC). OGC is an international standards organization which was founded in 1994 with the objectives of development, promotion, and harmonization of open geospatial data standards.

The web services published by OGC for geospatial data and process can also be represented as Geoweb services. The Geoweb services published by OGC can be grouped into six major categories, i.e., catalogue or registry services, processing or analytical services, encoding services, data or geo-data services, portrayal or visualization services, and other services. These services have been briefly described below:

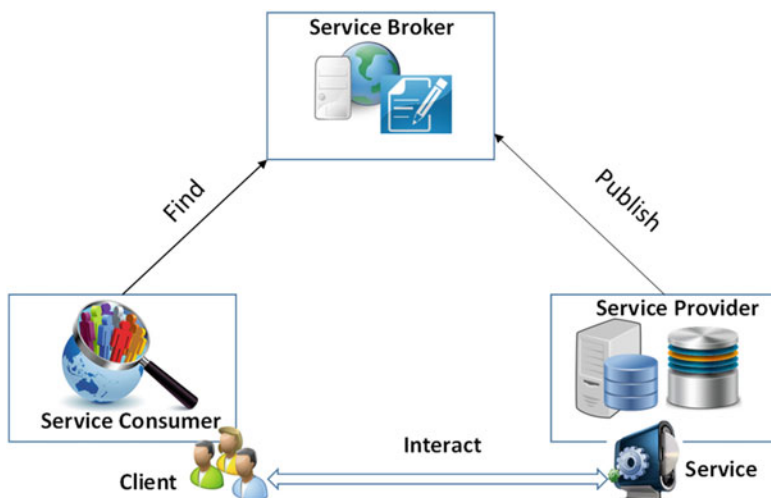


Fig. 23.1 Service-oriented architecture

23.2.1 Catalogue or Registry Services

This category of services is designed to classify, register, describe, and search the services by a user or a program. Some of the examples are CS Core, CS-WebRIM, and CS-W 19115/19119.

23.2.2 Data Processing Services

The processing services are designed to publish processes such as arithmetic operations, overlay operations, algorithms, etc. These are typically providing the capabilities of processing or transforming data-based user-defined parameters (Sahina and Gumusay 2008). The examples of WPS are Web Processing Service (WPS), Web Coverage Processing Service (WCPS), and Coordinate Transformation Service (CTS).

23.2.3 Encoding Services

Encoding is the process of putting a sequence of characters into a special format which is desired by the user for transmission or storage purposes. In GIS, encoding plays a critical role while defining the cartographic principles in spatial outputs. Typical example could be symbology to present legends in a map. Most popular

encoding standards published by OGC are Geography Markup Language (GML), Styled Layer Descriptor (SLD), KML, CityGML, etc.

23.2.4 Geo-data Services

The data services are designed to share the geospatial data (vector and raster) without any data loss. These services allow full or partial access of data based on user-defined area of interest (AOI). Some of the examples of OGC data services are Web Feature Service (WFS), Web Coverage Service (WCS), Sensor Observation Services (SOS), etc.

23.2.5 Visualization Services

The visualization services offered by OGC are typically for geo-visualization as background or overlay layer(s). These services also provide data with cartographic representations. Examples are Web Map Services (WMS) and Web Map Tile Services (WMTS).

23.2.6 Application or Job-Oriented Services

These services are designed for specific application or data requirements. Some of the examples include GeoXACML and GeoRSS.

The open online data repositories and Geoweb services are providing data and information by using web service standards published by OGC. The websites are available either as geo-portal or online data archive. The web portals are dynamic web applications which serve data and information to its user(s) by using database server technology. In web portal applications, the data is accessed and processed using an additional middle tier at server end using any web programming language such as PHP, C#, JAVA, Python, etc. This middle tier is also known as business logic or application server. In case of GIS data, the database servers host the raster and vector data in addition to attribute data sets in a database server. The geo-portals are developed based on GIS servers which are also known as map server(s). The GIS servers typically act as middle tier in software application architecture to make geospatial data compatible with Internet client software applications such as web browsers. Some of the popular geo-portal applications, online data repositories, early warning portals, and data analysis tools are provided in Tables 23.1, 23.2, 23.3 and 23.4. The list provided is not exhaustive, and accessing of datasets or application through these portals may require registration and proper acknowledgment. The users are therefore advised to read the data policy and data sharing policies.

Table 23.1 Popular geoportal applications

Sl. no.	Web portal	Web address	Coverage	Salient features
1.	Google maps	http://maps.google.com	Global	Satellite and aerial imageries of globe in 2D and 3D environment with many citizen applications
2.	Bing map	http://www.bing.com/maps/	Global	Global satellite imageries and infrastructure maps
3.	OpenStreetMap	http://www.openstreetmap.org	Global	Large-scale vector at city-level data created using participatory approach
4.	Wikimapia	http://wikimapia.org	Global	Identified area of interest and geolocations
5.	ISRO <i>Bhuvan</i>	http://bhuvan.nrsc.gov.in	India	Geoportal of ISRO with various thematic applications at country to village level
6.	MapMyIndia	http://www.maps.mapmyindia.com	India	Point of interest and geolocations of India
8.	Biodiversity information system	http://bis.iirs.gov.in	India	National level plant biodiversity data of India
9.	Indian bio-resource information network	http://www.ibin.gov.in	India	Distributed database bio-resource of India
10.	Visualization of earth observation data and archival system (VEDAS)	https://vedas.sac.gov.in	India	Platform for utilization of information derived over land using mainly Indian space-borne sensors
10.	India-WRIS	http://india-wris.nrsc.gov.in	India	Geoportal for water resources of India
11.	NIC GIS	http://gis.nic.in	India	Geo-enabled demography data of India

23.3 Case Study: Utilization of Online Data Repositories

This section attempts to demonstrate utilization of various online data repositories and tools which could be accessed openly and will be helpful for decision-makers and planners for taking measures to mitigate the impact of flood disaster. The main objective of the section is only to give a basic idea of how resources available from various sources in open domain can be integrated for informed decision-making. Figure 23.2 shows the various portals providing online data repositories, visualization, and analysis tools which can be accessed right from disaster watch stage to preparedness stage and finally flood disaster response phase.

For a flood disaster event, the disaster manager needs to keep a watch on the cloud persistence, heavy rainfall event, and rising river water levels which indicate the

Table 23.2 Portal providing alerts, online data repository, and natural disaster-related information

Sl. no.	Web portal	Web address	Coverage	Category	Salient features
1.	Pacific disaster center (PDC)	http://www.pdc.org/	Global	Natural disasters	Multi-hazard warning and decision support tools
2.	Global disaster alert and coordination system (GDACS)	http://www.gdacs.org/	Global	Natural disasters	Satellite and ground observation-based disaster early warning alerts in RSS and KML formats
3.	Global flood monitoring system (GFMS)	http://flood.umd.edu/	Global	Natural disasters	Experimental system using real-time TRMM multi-satellite precipitation analysis (TMPA). Streamflow, surface water storage, inundation variables at 1 km resolution
4.	Global flood detection system – version 2	http://www.gdacs.org/flooddetection/	Global	Natural disasters	Near real-time flood monitoring system using satellite data
5.	Dartmouth flood observatory	http://floodobservatory.colorado.edu/	Global	Natural disasters	Flood archive records from 1985 onward. The information contains affected area, number of people killed, the number of people displaced, the cost of damages, and a measure of the magnitude of the flood are included for each flood event. The archive is updated on an ongoing basis and new flood event are added immediately.
6.	Natural Disaster Hazards	http://www.ldeo.columbia.edu/chrr/research/hotspots/coredata.html	Global	Natural disasters	Multi-hazard information on various aspects such as frequency, loss to life & economy and other information.
7.	Fire information for resource management system (FIRMS)	https://firms.modaps.eosdis.nasa.gov/firemap/	Global	Natural disasters	Near-real time active fire data using moderate resolution imaging Spectroradiometer (MODIS) and

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Table 23.2 (continued)

Sl. no.	Web portal	Web address	Coverage	Category	Salient features
					visible infrared imaging radiometer suite (VIIRS).
8.	USGS Earth-quakes Database	http://earthquake.usgs.gov/earthquakes/eqarchives/epic/kml	Global	Natural disasters	Monitoring of earthquake activities worldwide with its spatial information.
9.	Global Seismic Hazard Map	http://www.seismo.ethz.ch/static/GSHAP	Global	Natural disasters	Gridded seismic hazard risk data.
10.	NOAA/WDC Historical Tsunami Database	http://www.ngdc.noaa.gov/hazard/tsu_db.shtml	Global	Natural disasters	Spatial information on tsunami sources and run-up events.
11.	Indian National Centre for Ocean Information Services (INCOIS)	http://www.incois.gov.in/portal/index.jsp	India	Natural disasters	Near real-time tsunami information from Indian tsunami early warning Centre (ITWEC)
12.	CIMSS tropical cyclone	http://tropic.ssec.wisc.edu/#	Global	Natural disasters	Near real-time imagery, derived atmospheric analysis products.
13.	Cyclocane	https://www.cyclocane.com/	Global	Natural disasters	Data and information on cyclone active tropical storms, development potential and its tracking on map.
14.	MODIS Fire Detection Data	http://activefiremaps.fs.fed.us/gisdata.php	Global	Natural disasters	MODIS based near-real time fire location using thermal band.
15.	Lightning and Atmospheric Electricity Dataset	https://lightning.nsstc.nasa.gov/data	Global	Natural disasters	Variety of data on lightning activities such as average flashes per grid cell per year.
16.	NOAA Historical Hurricane Tracks	https://coast.noaa.gov/hurricanes/?redirect=301ocm	Global	Natural disasters	Tracking of hurricanes.
17.	Precipitation and applications viewer	https://pmm.nasa.gov/precip-apps	Global	Natural disasters	30 minutes interval updates on probable locations of landslide using landslide hazard assessment model for situational awareness (LHASA)

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Table 23.2 (continued)

Sl. no.	Web portal	Web address	Coverage	Category	Salient features
18.	Precipitation measurement missions (PMM)	https://pmm.nasa.gov/data-access	Global	Natural disasters	Precipitation data from the GPM and TRMM missions.
19.	India meteorological department (IMD)	http://www.imd.gov.in/	India	Natural disasters	Hosts information on meteorological observations, warns against severe weather phenomenon like snow, tropical cyclones, heavy rains, dust storms etc.
20.	Natural Disaster Hotspots	http://sedac.ciesin.columbia.edu/data/collection/ndh	Global	Natural disasters	Spatial data on natural hazards with frequency and economic loss.
21.	Socioeconomic and data applications center (SEDAC)	http://sedac.ciesin.columbia.edu/data/collection/ndh/sets/browse	Global	Natural disasters	Provides 209 datasets for viewing and downloading on various themes like climate, health, population, water, hazards (mortality and economic losses for flood, cyclone, drought, landslide, earthquake and volcanic hazards), etc.
22.	SEDAC's hazards mapper	http://sedac.ciesin.columbia.edu/mapping/hazards	Global	Natural disasters	Enables users to rapidly get an idea of the population, land area, dams, and nuclear power plants that could be impacted by natural events such as floods, earthquakes, fires, and volcanic eruptions
23.	International disaster database	http://www.emdat.be/	Global	Natural disasters	Core data on the occurrence and effects mass disasters in the world. The database is compiled from various sources
24.	NASA's EOSDIS	https://worldview.earthdata.nasa.gov/	Global	Natural disasters	Visualization and download of global level multi-resolution satellite

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Table 23.2 (continued)

Sl. no.	Web portal	Web address	Coverage	Category	Salient features
					imageries. The data products are updated within 3 hours of observation, essentially showing the entire earth as it looks “right now.” Offer variety of applications such as forest fire management, air quality measurements, and flood monitoring
25.	Copernicus Open Access Hub	https://scihub.copernicus.eu/	Global	Natural disasters	Open access to Sentinel-1, Sentinel-2, and Sentinel-3 data products
26.	USGS earth explorer	https://earthexplorer.usgs.gov/	Global	Natural disasters	Its warehouse and source of free- and open-access satellite data from different space EO missions
27.	Humanitarian Response	https://www.humanitarianresponse.info/applications/data/country-region	Human geography	General	Information management tools and services for information exchange among operational responders during emergency. It also provides freely available datasets for many countries.
28.	Bhuvan geoportal	http://bhuvan.nrsc.gov.in/disaster/disaster/disaster.php	India	Natural disasters	Address six natural disasters such as cyclone, floods, landslides, earthquakes, and forest fire required in different phases of disaster management cycle. Most of the disaster products generated on rapid response mode based on the interpretation of Indian and international satellite

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Table 23.2 (continued)

Sl. no.	Web portal	Web address	Coverage	Category	Salient features
					datasets are made available on Bhuvan for wider public access
29.	Meteorological and Oceanographic Satellite Data Archival Centre (MOSDAC)	http://www.mosdac.gov.in	India	Weather and climate	Archives and disseminates data from satellites like INSAT, KALPANA-1, Oceansat, Megha-Tropiques, and SARAL. Hosts and disseminates weather-related information services and alerts over mobile devices. Provides cyclone track prediction along with intensity and cyclogenesis over Indian ocean

possibility of the event. If there is a possibility of the event to occur, disaster manager needs to have some preparedness measures in place, like which areas are likely to get inundated based on the historic inundation and identification of low-lying areas based on digital elevation model (DEM) analysis. Finally in case if the flood disaster occurs, the disaster needs to be mapped and monitored to know the spatial extent of inundation, transport network submerged, and villages marooned. In subsequent section the above-explained requirements for the three stages (watch, preparedness, and response) are explained with the help of various online data repositories and tools considering a heavy rainfall likely to occur over Srinagar, Jammu, and Kashmir which could cause floods in the Srinagar Valley.

23.3.1 Disaster Watch

Heavy continuous rainfall could trigger floods, and therefore advance information on heavy rainfall forecast for the next coming days is essential for taking appropriate mitigation measures. The Meteorological and Oceanographic Satellite Data Archival Centre (MOSDAC) at the Space Applications Centre (ISRO) provides experimental mesoscale weather forecasts in real time using WRF model (Shah et al. 2010) which can be downloaded through <http://www.mosdac.gov.in/external/order-data>. The

Table 23.3 Other online data repositories useful for general research and analysis including disaster mitigation

Sl. no.	Web portal	Web address	Coverage	Category	Salient features
1.	Bhuvan geoportal	http://bhuvan.nrsc.gov.in/data/download/index.php	India	General	Online geo-visualization, data download, and thematic services for a variety of EO applications. Also offers various tools and services to analyze the geo-data
2.	Natural Earth – Vector	http://www.naturalearthdata.com	Global	General	Data on natural resources such as coastline, land, oceans, islands, rivers, lakes, glaciated areas, and bathymetry is available
3.	Global map	https://www.iscgm.org/gmd	Global	General	Global geo-data at 1Km resolution on base and infrastructure layers. The data includes transportation, terrain data, drainage network, vegetation map, land cover, and land use and population centers
4.	DIVA-GIS Country Data	http://www.diva-gis.org/gdata	Global	General	Repository of data collected from various sources includes administrative areas, inland water, roads and railways, elevation, land cover, population, and climate
5.	Global self-consistent, hierarchical, high-	http://www.ngdc.noaa.gov/mgg/shorelines/gshhs.html	Global	Land and ocean boundaries	Data from two databases, i.e., World Vector Shorelines

	resolution geography database (GSHHG)				(WVS) and CIA world data Bank II (WDBII). Data can be downloaded either as shape file or in a native binary format
6.	GDEM- global digital elevation mode	http://asterweb.jpl.nasa.gov/gdem.asp	Global	Elevation	Free global DEM in 30 m posting (resolution) from ASTER satellite images
7.	CGIAR-CSI GeoPortal	http://srtm.csi.cgiar.org	Global	Elevation	Free global DEM from SRTM is available in 90 meter posting (resolution)
8.	EarthEnv-DEM90	http://www.earthenv.org/DEM	Global	Elevation	A merged global DEM in 90 meter posting (resolution) from GDEM and SRTM to fill voids and smooth data
9.	ETOPO1 global relief model	http://www.ngdc.noaa.gov/mgg/global/global.html			Global relief model of Earth's surface is available at global and regional level. Hypsographic curve of Earth's surface
10.	Global Multi-Resolution Topography (GMRT)	http://www.marine-geo.org/portals/gmrt/	Global	Elevation	Multi-beam sonar data collected by the researchers and made available as a single continuously updated global elevation data at 100 m resolution
11.	WorldClim	http://www.worldclim.org	Global	Weather and climate	Global climate gridded data at spatial resolution of about 1 km ²

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Table 23.3 (continued)

Sl. no.	Web portal	Web address	Coverage	Category	Salient features
12.	NCAR Community Climate System Model (CCSM)	http://gisclimatechange.ucar.edu	Global	Weather and climate	Climate change projected data on atmosphere and land surface in GIS format
13.	Climatic research unit (CRU)	http://www.cru.uea.ac.uk/data	Global	Weather and climate	High- and low-resolution datasets such as temperature, precipitation, pressure, drought, paleoclimate, and others, from the (infamous) climate research unit at the University of East Anglia
14.	Climate change, agriculture and food security (CCAFS)	http://www.ccafs-climate.org/data	Global	Weather and climate	Climate datasets to study biodiversity, agricultural and livestock production, and ecosystem services and hydrology
15.	Global Potential Evapotranspiration and Aridity Index	http://csi.cgiar.org/Aridity	Global	Weather and climate	Global model-driven geo-enabled raster climate data related to evapotranspiration processes and rainfall deficit for potential vegetative growth
16.	Climate Monitoring satellite application facility (CM SAF)	https://wui.cmsaf.eu/safira/action/viewProduktSearch;jsessionid=C3A056A5CE0F496B16619FAD7ACE2801.ku_2	Global	Weather and climate	Near real-time and retroactively generated datasets of cloud cover, type and temperature, surface radiation budget, temperatures, etc.
17.	Climate Analysis Indicators Tool (CAIT)	http://cait.wri.org	Global	Weather and climate	Comprehensive and comparable climate and emissions data available for free and open access

18.	International Satellite Cloud Climatology Project (ISCCP)	http://isccp.giss.nasa.gov/products/d2yearsets.html	Global	Weather and climate	Average cloud cover and associated data like cloud top temperature, water path, optical thickness etc., on monthly basis
19.	IRI/LDEO Climate Data Library	http://iridl.ldeo.columbia.edu	Global	Weather and climate	Climate-related data download facility with various analytical tools through web browser environment
20.	World Ozone and Ultraviolet Radiation Data Center (WOUDC)	http://www.woudc.org/data_e.html	Global	Weather and climate	Data repository of ozone information and ground level ultraviolet irradiance
21.	HydroSHEDS	http://hydrosheds.cr.usgs.gov/index.php	Global	Hydrology	Hydrographic information at regional and global scale. The geo-data (raster and vector) such as river networks, watershed boundaries, drainage directions, and flow accumulations are available
22.	Water Isotopes	http://wateriso.utah.edu/waterisotopes/pages/data_access/data_main.html	Global	Hydrology	Global and regional data on grids of hydrogen and oxygen isotope composition of precipitation and environmental waters
23.	General Bathymetric Chart of the Oceans	http://www.gebco.net	Global	Hydrology	Gridded bathymetric datasets
24.	Earth Env Freshwater Ecosystems Environmental Information	http://www.earthenv.org/streams	Global	Hydrology	1 km resolution data on freshwater ecosystems which includes climate, land-cover, soil, and geology

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Table 23.3 (continued)

Sl. no.	Web portal	Web address	Coverage	Category	Salient features
25.	Randolph Glacier Inventory	http://www.glims.org/RGI	Global	Snow/ice	Multi-temporal global inventory of glacier outlines with specific focus on quality control
26.	USGS Land Cover Institute	http://landcover.usgs.gov/landcoverdata.php	Global	Land cover	Rich data and information repository of land cover data such as river observations, aquifers data, and ocean color information
27.	GLOBCOVER	http://due.esrin.esa.int/page_globcover.php	Global	Land cover	Global land cover dataset at 300 m resolution from the MERIS sensor of ENVISAT satellite
28.	MODIS Global Land Cover	http://visibleearth.nasa.gov/view.php?id=61004	Global	Land cover	Global land cover data in 1Km and 4Km from MODIS
29.	UMD GLC	http://glcf.umd.edu/data/landcover	Global	Land cover	Global land cover maps created using a classification tree approach from MODIS data
30.	Global Land Cover by National Mapping Organizations	http://www.isegm.org/404.html	Global	Land cover	Global land cover map with classification scheme adopted from UN FAO LCCS along with other land cover products
31.	Global Lakes and Wetlands Database	http://www.worldwildlife.org/pages/conservation-science-data-and-tools	Global	Land cover	Global GIS vector layers for lakes, reservoirs, wetlands, swamps, bogs, etc.

32.	Grassland GIS	http://www.wri.org/publication/pilot-analysis-global-eco-systems-grassland-ecosystems#data	Global	Land cover	Spatial data grasslands with utilizations
33.	PALSAR Forest/Non-Forest map	http://www.eorc.jaxa.jp/ALOS/en/palsar_fnf/fnf_index.htm	Global	Land cover	Global forest map in 50 meter spatial resolution generated using SAR data
34.	Global Forest Change 2000-2014	http://earthenginepartners.appspot.com/science-2013-global-forest/download_v1.2.html	Global	Land cover	Global forest tree cover change map in 30 meter spatial resolution (2000 to 2014)
35.	Atlas of the Biosphere	http://nelson.wisc.edu/sage/data-and-models/atlas/maps.php	Global	Ecology	Spatial data in raster format for environmental variables such as potential evapotranspiration, soil, pH, average snow depth, etc.
36.	Lifemapper	http://lifemapper.org/?page_id=593	Global	Ecology	Species distribution maps based on climate, terrain, and land cover
37.	Anthropogenic Biomes	http://sedac.ciesin.columbia.edu/data/collection/anthromes	Global	Ecology	Gridded anthropogenic biomes data
38.	Net Primary Productivity	http://sedac.ciesin.columbia.edu/data/collection/hanpp	Global	Ecology	Global gridded net primary productivity data (NPP)
39.	World Soil Information	https://www.soilgrids.org/#/?layer=geonode:taxnwr_b_250m	Global	Ecology	Global soil data on organic carbon content, gypsum content, water capacity etc., for topsoil and subsoil. The data is available with more than 22 attributes
40.	Harmonized world soil database	http://webarchive.iiasa.ac.at/Research/LUC/External-World-soil-database/HTML/index.html?sb=1	Global	Ecology	Regional and national level soil database generated under LUC program of FAO. The spatial data is available resolution of 30 arc seconds

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Table 23.3 (continued)

Sl. no.	Web portal	Web address	Coverage	Category	Salient features
41.	ERS/MetOp soil moisture	http://www.ipf.tuwien.ac.at/404/	Global	Ecology	Soil moisture data from satellite-based scatterometer measurements
42.	Global High Resolution Soil Water Balance	http://www.cgiar-csi.org/data/global-high-resolution-soil-water-balance	Global	Ecology	Global evapotranspiration and soil water deficit data in the resolution of 30 arc seconds
43.	Carbon Dioxide Information Analysis Center	http://cdiac.ornl.gov/ftp/	Global	Ecology	Atmospheric CO ₂ concentrations, precipitation, and long-term modeling data
44.	UNEP WCMC	http://datadownload.unep-wcmc.org/datasets	Global	Ecology	Global data generated under United Nations Environment Programme such as wetlands, global distribution of coral reefs, mangrove distributions, etc.
45.	Terrestrial Ecoregions of the World	http://maps.tnc.org/gis_data.html	Global	Ecology	Terrestrial ecological data in vector GIS format
46.	Freshwater Ecoregions of the World	http://www.feow.org/downloads.php	Global	Ecology	Worldwide biogeographic classification of freshwater ecological regions
47.	Mineral Resources Data System	http://tin.er.usgs.gov/mrds	Global	Mineral resources/oil and gas	Global spatial data sets on mineral resources including names, locations, descriptions, geological characteristics, etc.

48.	Environmental data explorer	http://geodata.grid.unep.ch	Human geography	General	Spatial data repository at national, regional, and global levels on various themes such as freshwater, population, forests, emissions, climate, disasters, health, GDP, etc.
49.	World Bank Geo-data	https://vclluminformation.com/2012/01/28/google-earth-world-bank-data-and-kml-files/	Human geography	General	World bank data available as spatial layer (KML)
50.	History Database of the Global Environment-HYDE	http://themasites.pbl.nl/tridion/en/themasites/hyde/index.html	Human geography	General	Gridded time series population and land use data of last 12,000 years. Very interesting data on GDP, value added, livestock, agricultural areas and yields, private consumption, greenhouse gas emissions, and industrial production are available for public access
51.	Natural Earth	http://www.naturalearthdata.com	Human geography	Administrative boundaries	Free- and open-access geospatial data on coarse resolution at global scale
52.	GADM	http://gadm.org	Human geography	Administrative boundaries	Spatial data on administrative boundaries of different countries are available in shape file, geodatabase, KMZ, and RData format
53.	World Borders	http://thematicmapping.org/downloads/world_borders.php	Human geography	Administrative boundaries	Countries boundaries with basic attributes are available in GIS format

(continued)

Table 23.3 (continued)

Sl. no.	Web portal	Web address	Coverage	Category	Salient features
54.	World Spatial Database of Protected Areas	http://free-gis-data.blogspot.in/2009/04/world-spatial-data-base-on-protected.html	Human geography	Environmental boundaries	The spatial data on marine and terrestrial protected areas
55.	IUCN 2013 Red List	http://www.iucnredlist.org/technical-documents/spatial-data	Human geography	Environmental boundaries	IUCN red species data with geo-locations
56.	Protected Planet	https://www.protectedplanet.net	Human geography	Environmental boundaries	Provides latest and up-to-date information on protected areas across the world
57.	Human Influence and Footprint	http://sedac.ciesin.columbia.edu/data/collection/wildareas-v2	Human geography	Land use	Provides human influence index and human footprint to assess the influence of human on terrestrial ecosystems at 30 arc second resolution
58.	Global Agricultural Lands	http://sedac.ciesin.columbia.edu/theme/sustainability	Human geography	Land use	Provides global maps depicting extent and intensity of agricultural lands in 2000 based on MODIS and SPOT images together with agricultural inventory data
59.	Global Irrigated Area and Rain fed Crops Areas	http://waterdata.iwmi.org/Applications/GIAM2000	Human geography	Land use	Provides global irrigated area map, rain-fed area map, and land use/land cover at 10 km for year 2000
60.	Crop Calendar Dataset	http://nelson.wisc.edu/sage/data-and-models/crop-calendar-dataset/index.php	Human geography	Land use	Provides gridded maps on number of parameters like planting dates, harvesting dates, etc., for about 19 crops and is available at 5 minute and 0.5 degree resolution and in netCDF and ArcINFO ASCII formats

61.	EarthStat: Agricultural Land Use and potential use	http://www.earthstat.org	Human geography	Land use	Provides geographic datasets which allow users to carry out a number of applications like understanding impact of climate change on crop yields, fertilizer, manure use, etc.
62.	Global Reservoir and Dam Database (GRanD)	http://atlas.gwsp.org/index.php	Human geography	Lakes, oceans and other water sources	Provides information on all reservoirs having storage capacity of more 0.1km ³ both in polygon and point format.
63.	Gridded Population of the World (GPW)	http://sedac.ciesin.columbia.edu/data/collection/gpw-v4	Human geography	Population	Provides population estimates for the years 2000, 2005, 2010, 2015, and 2020. The GPW data collection provides openly available, licensed under the Creative Commons Attribution 4.0
64.	WorldPop	http://www.worldpop.org.uk	Human geography	Population	Provides an open-access archive of spatial demographic datasets for Central and South America, Africa, and Asia to support development, disaster response, and health applications
65.	Large Urban Areas 1950–2050	https://nordpil.com/resources/world-database-of-large-cities	Human geography	Population	Provides database representing the historic, current, and future estimates and projections with number of inhabitants for the world's largest urban areas from 1950 to 2050

(continued)

Table 23.3 (continued)

Sl. no.	Web portal	Web address	Coverage	Category	Salient features
66.	Global Urban Extent	http://nelson.wisc.edu/sage/data-and-models/schneider.php	Human geography	Population	Consists of global maps at 500 m resolution of urban extent derived from satellite data exploiting temporal and spectral information from MODIS observations over 1 year
67.	OpenStreetMap	http://www.geofabrik.de/data/download.html	Human geography	Buildings, roads, and points of interest	OSM is a collaborative project to create a free editable map of the world. Contributors use aerial imagery, GPS devices, and low-tech field maps to verify that OSM is accurate and up to date
68.	Nuclear Power Station locations	https://fusiontables.google.com/DataSource?dsrid=579353#rows:id=1	Human geography	Buildings, roads, and points of interest	Provides list of all nuclear power stations worldwide as per IAEA in a tabular format consisting of country, name, location, etc.
69.	Open Flights	http://openflights.org/data.html	Human geography	Transport and communications	Airport, airline, and route data across the globe. Data is provided as CSV files which can be easily processed to produce GIS outputs. Data includes all known airports and a large number of routes between airports

70.	Global Roads Open Access Data Set (gROADS)	http://sedac.ciesin.columbia.edu/data/set/groads-global-roads-open-access-v1	Human geography	Transport and communications	gROADS data set combines best available roads data by country into a global roads coverage, using the UN spatial data infrastructure transport (UNSDI-T) version 2 as a common data model
71.	NGIS Country Files	http://geonames.nga.mil/gns/html/namefiles.html	Human geography	Gazetteers (place/feature names)	Provides complete files of geographic names information covering countries or geopolitical areas in a special format amenable to input into geographic information systems, databases, and spreadsheets
72.	Global Rural-Urban Mapping Project (GRUMPv1)	http://sedac.ciesin.columbia.edu/data/set/grump-v1-settlement-points	Human geography	Gazetteers (place/feature names)	GRUMPv1 provides (a) gridded population data at 30 arc second resolution of 1990, 1995, and 2000, (b) urban extents based on night-time lights, and (c) a point's data set of all urban areas with populations of greater than 1000 persons

Table 23.4 Tools and models available in open domain for disaster analysis

Sl. no.	Model/tool	Web address	Category	Salient features
1.	ANUGA	https://anuga.anu.edu.au/	Tools/ models	ANUGA is a Free & Open Source Software (FOSS) having the capability to model the impact of hydrological disasters such as flooding, storm surge, dam breaks, and tsunamis
2.	Hydrologic Engineering Center's River Analysis System (HEC-RAS)	http://www.hec.usace.army.mil/software/hecras/	Tools/ models	HEC-RAS is one of the widely used free open-source software to model the hydraulics of water flow through natural rivers and other channels. It allows one-dimensional steady flow, one- and two-dimensional unsteady flow calculations, sediment transport/mobile bed computations, and water temperature/water quality modeling
3.	EPA's Stormwater Management Model (SWMM)	https://www.epa.gov/water-research/storm-water-management-model-swmm#downloads	Tools/ models	SWMM is used extensively globally in planning, analysis, and design related to storm water runoff, combined and sanitary sewers in urban areas
4.	CAPRA (Probabilistic Risk Assessment)	http://www.ecapra.org/about	Tools/ models	CAPRA Program is an initiative that aims to strengthen the institutional capacity for assessing, understanding, and communicating disaster risk, with the ultimate goal of integrating disaster risk information into development policies and programs
5.	HAZUS	https://www.fema.gov/hazus-software	Tools/ models	Hazus is a nationally applicable standardized methodology that contains models for estimating potential losses from earthquakes, floods, and hurricanes
6.	TauDEM (Terrain Analysis Using Digital Elevation Models)	http://hydrology.usu.edu/taudem/taudem5/index.html	Tools/ models	TauDEM consists of a suite of tools useful for conditioning of the DEM and the extraction and analysis of hydrological information from DEM

(continued)

Table 23.4 (continued)

Sl. no.	Model/tool	Web address	Category	Salient features
7.	Arc Hydro Tools	http://en.freedownloadmanager.org/Windows-PC/Arc-Hydro-Tools-FREE.html	Tools/ models	The Arc Hydro toolset is a suite of tools which facilitate the creation, manipulation, and display of Arc Hydro features and objects within the ArcMap environment. The tools provide raster, vector, and time series functionality, and many of them populate the attributes of Arc Hydro features
8.	Grid Analysis and Display System (GrADS)	http://cola.gmu.edu/grads/	Tools/ models	GrADS is an interactive desktop tool that is used for easy access, manipulation, and visualization of earth science data. GrADS has been implemented worldwide on a variety of commonly used operating systems and is freely distributed over the Internet
9.	Sentinel Application Platform (SNAP)	http://step.esa.int/main/download/	Tools/ models	SNAP is an open-source common architecture for ESA toolboxes ideal for the exploitation of Earth observation data. The SNAP architecture is ideal for Earth observation processing and analysis
10.	PolSARpro	https://earth.esa.int/web/polsarpro/home	Tools/ models	The polarimetric SAR data processing and educational tool aims to facilitate the accessibility and exploitation of multi-polarized SAR datasets including those from ESA (Envisat ASAR Alternating Polarization mode products and Sentinel-1) and third-party missions (ALOS-1 PALSAR, ALOS-2 PALSAR, COSMO-SkyMed, RADARSAT-2, RISAT, TerraSAR-X, and TanDEM-X)

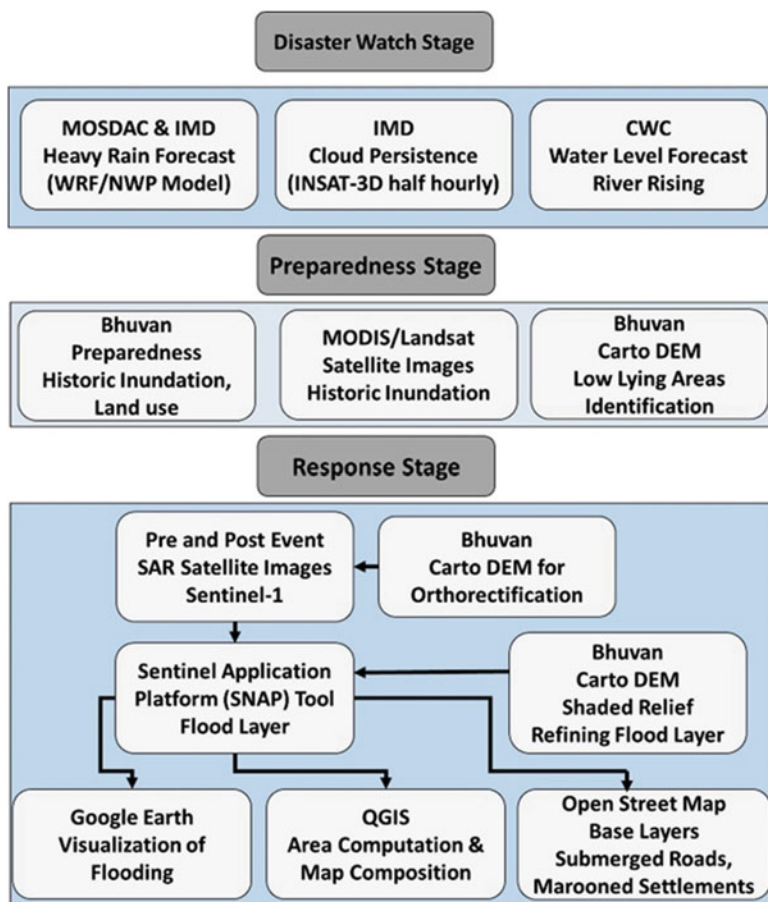


Fig. 23.2 Portals and online data repositories for flood disaster event

WRF data which is in netcdf file format can be processed, analyzed, and visualized using freely available Grid Analysis and Display System (GrADS) software accessible through <http://cola.gmu.edu/grads/downloads.php>. MOSDAC portal itself allows visualization of WRF-related parameters (rainfall, temperature, relative humidity, cloud fraction, etc.) in GIS environment (http://www.mosdac.gov.in/weather_forecast/index.jsp?param=hrf_24) which can be seen with base layers superimposed, the heavy rainfall and cloud fraction forecast for the next 3 days can give an understanding about areas likely to experience flood in coming days (Figs. 23.3 and 23.4). Further INSAT-3D images which are available every half hourly from MOSDAC (http://www.mosdac.gov.in/data/servlet/Image3d?imagename=3DIMG*_L1C_ASIA_MER_IR1.jpg) and also IMD (http://satellite.imd.gov.in/img/animation3d/3Dasiasec_ir1_3d.htm) as individual images and also as animation can help in monitoring the movement and persistence of cloud cover over the interested region (Fig. 23.5). Due to heavy rainfall in the upstream

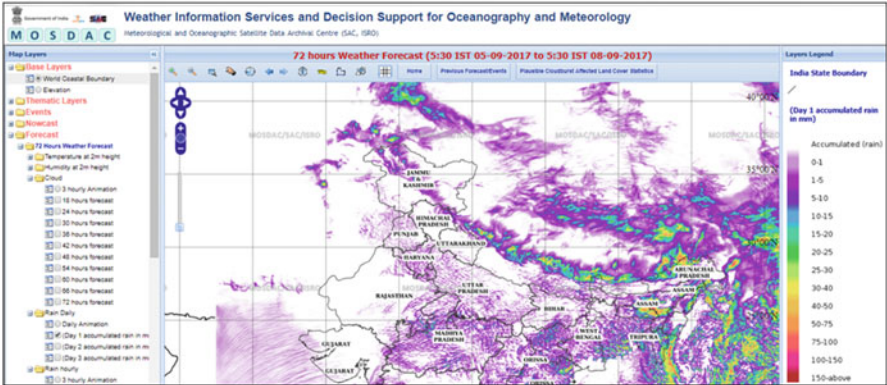


Fig. 23.3 MOSDAC portal showing daily rainfall (mm) accumulation forecast

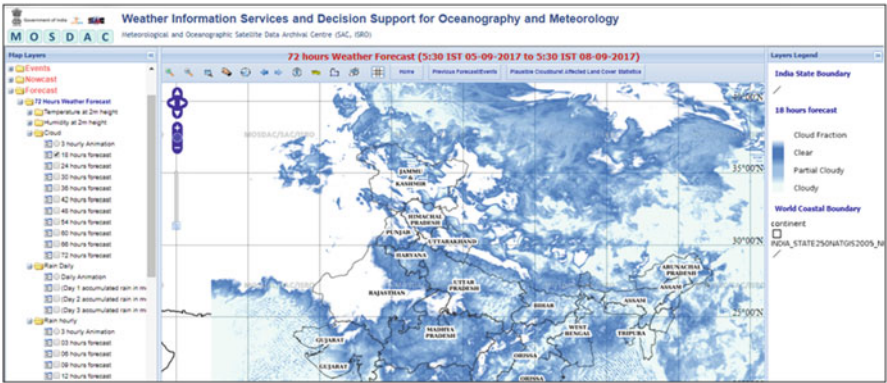


Fig. 23.4 MOSDAC portal showing daily cloud conditions forecast

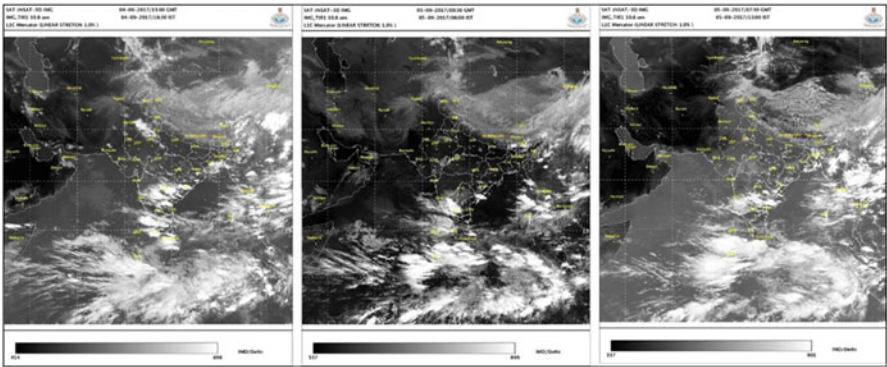


Fig. 23.5 IMD portal showing cloud persistence available from INSAT-3D images



Fig. 23.6 CWC portal showing river gauge data for Sangam, Jammu, and Kashmir station

catchment areas, the water level in the rivers also starts rising which can be monitored using the Central Water Commission (CWC) gauge station information on current level and previous water level accessed through <http://www.india-water.gov.in/eSWIS-MapViewer/>. The portal provides information in spatial format as well as in hydrograph format. Figure 23.6 shows that by clicking on the gauge station, information on the warning level, danger level, highest flood level (HFL), date of occurrence of HFL, present water level, and trend could be observed.

23.3.2 Disaster Preparedness

With the basic information obtained from rainfall forecast, cloud persistence, and gauge height by accessing various online portals, disaster manager gets a fair idea about the likely scenario for flood event to take place in advance can be made and can help to make plans for preparedness before the event actually happens. Knowing that there is a possibility of flood event, the decision-maker needs to have some idea about the regions that are likely to get flooded to take precautionary measures on ground for safe evacuation of the inhabitants staying in those areas. ISRO DMS services in tandem with ISRO's Geo-portal, Bhuvan, in public domain are a unique demonstration of EO data and geospatial technology utilization for visualization, understanding, effective planning, and decision-making for disaster management. Bhuvan supports management of disasters like cyclone, floods, landslides, earthquakes, forest fire, and drought, which is useful for various phases of disaster management including preparedness and response. Figure 23.7 shows historic flood inundation layers extracted from multi-temporal (08–23 Sept. 2014) satellite images during Srinagar floods in Jammu and Kashmir during September 2014 and available through Bhuvan Disaster Services (<http://bhuvan-noeda.nrsc.gov.in/disaster/disaster/disaster.php#>). This information can be visualized together

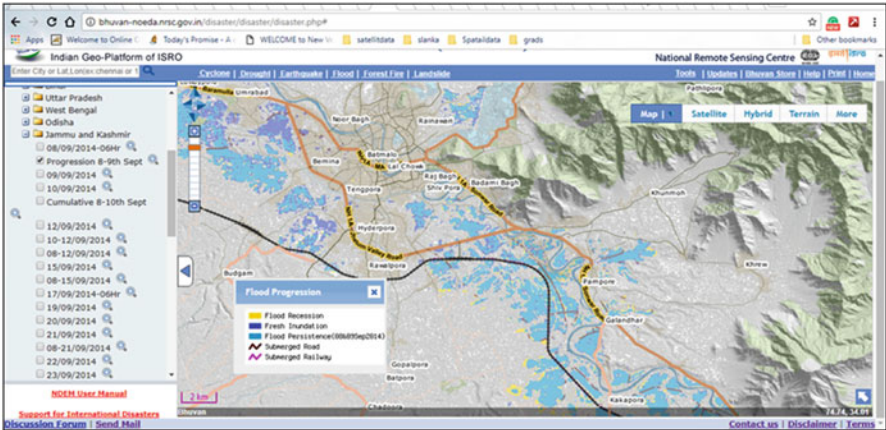


Fig. 23.7 Bhuvan portal showing historic inundation (08–23 Sept. 2014) experienced in Srinagar Valley during floods of September 2014

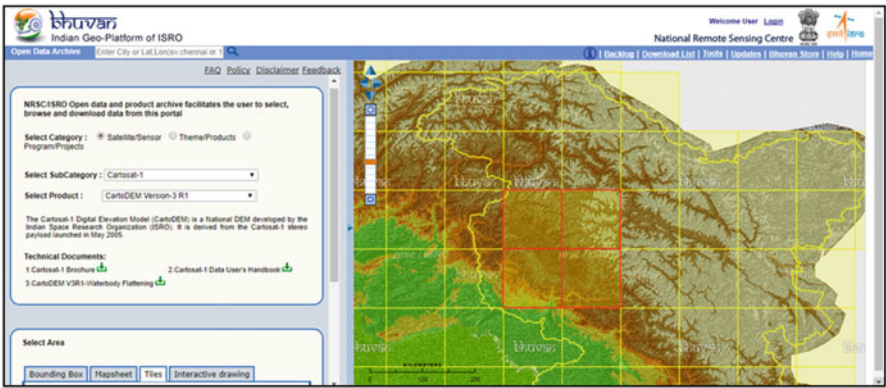


Fig. 23.8 Bhuvan portal showing CartoDEM tiles highlighted (red color) over Srinagar, Jammu, and Kashmir for downloading

with various other thematic information available with Bhuvan like land use and administrative boundaries to gain insight about areas which have experienced flood in past and also the land use that will get affected in those areas and also visualize the terrain with help of Bhuvan 3D. In addition to the available historic inundation, low-lying areas with the help of freely available digital elevation data of Cartosat DEM (~30 m) from Bhuvan (<http://bhuvan.nrsc.gov.in/data/download/index.php>) or SRTM elevation data (~30 m) from USGS earth explorer (<https://earthexplorer.usgs.gov/>) can be identified which could help in providing additional information on areas likely to get affected which may have not been affected during past floods. Figure 23.8 shows the downloading of CartoDEM through Bhuvan portal. DEM could also be utilized to derive various hydrological layers

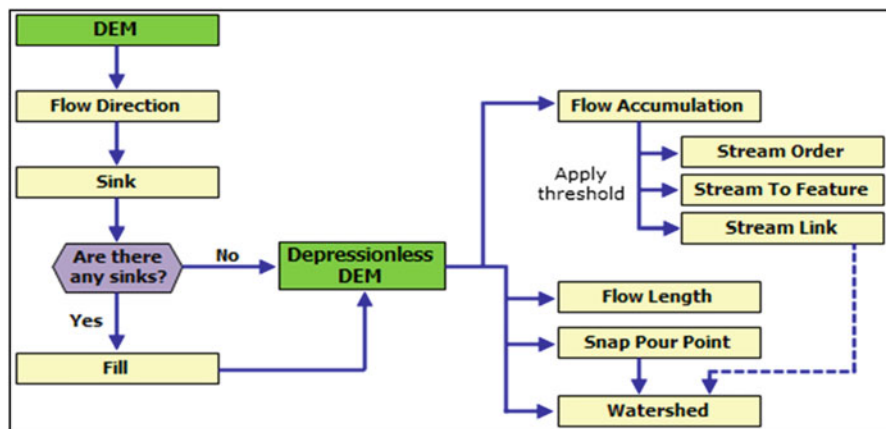


Fig. 23.9 Flowchart showing hydrological information derived from DEM

(Fig. 23.9) like flow direction, flow accumulation, slope, aspect, and basin boundaries using freely available (<http://hydrology.usu.edu/taudem/taudem5/index.html>) tools like TauDEM (Terrain Analysis Using Digital Elevation Models). TauDEM is a collection of tools for the extraction of hydrological information from DEM. This hydrologic information could be further utilized for advanced analysis like hydrological modeling to get extent of inundation based on varying discharge data and generate inundation scenarios using free hydrological modeling software's like HecRAS (<http://www.hec.usace.army.mil/software/hecras/>). HecRAS models the hydraulics of water flow through natural rivers and other channels. Apart from disaster preparedness during the disaster, the above information also could be utilized for planning long-term disaster mitigation measures and preparing disaster management strategies. In this effort archived satellite images freely available from MODIS (https://lance-modis.eosdis.nasa.gov/imagery/subsets/?project=fas&subset=FAS_India1), Landsat (<https://earthexplorer.usgs.gov/>), and Sentinel (<https://vertex.daac.asf.alaska.edu/#>) also could be accessed to prepare flood hazard zonation maps of the area. Figure 23.10 shows flood inundation extent captured from Modis Aqua image of 10 Sept. 2014 over Srinagar Valley. This one of the severest floods (Bhatt et al. 2016) could be very helpful in disaster management planning.

23.3.3 Disaster Response

Freely open data repositories and tools are very important in providing response to a disaster. For floods particularly SAR (synthetic aperture radar) data is useful because it can image the Earth through clouds and allows dynamic hydrological events like

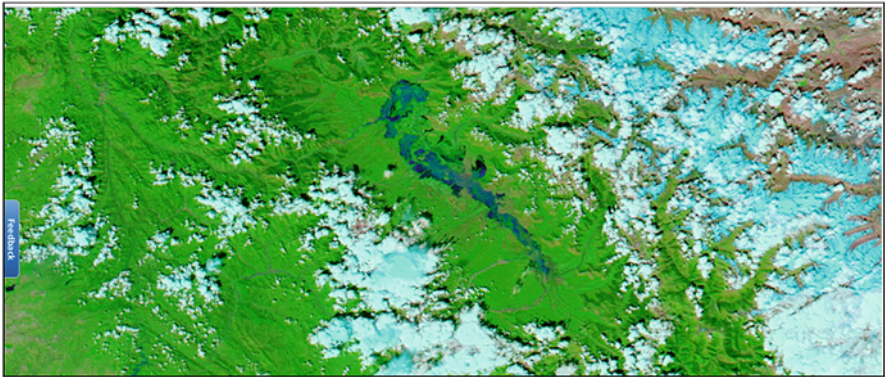


Fig. 23.10 Flood inundation captured from Modis Aqua image of 10 Sept 2014 over Srinagar Valley (https://lance-modis.eosdis.nasa.gov/imagery/subsets/?project=fas&subset=FAS_India1.2014253.aqua.721.250m)

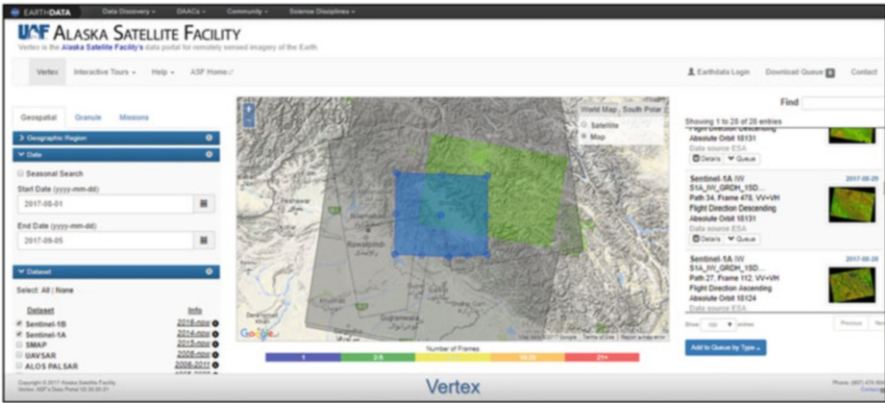


Fig. 23.11 Availability of Sentinel data over Srinagar region (area of interest) for archival and current period shown as footprint (center) and also as browse images (right side)

floods to be captured. Due to persistent cloud cover during monsoon season optical data does not provide much support in monitoring of flood events. Availability of SAR data since 2014 from Sentinel-1, a SAR mission from ESA, available free of charge, has equipped the disaster managers with a powerful dataset especially for flood disasters to respond to flood situation quickly than to wait for cloud-free optical data. Sentinel-1 data can be downloaded by registering at the Sentinels Scientific Data Hub (<https://cophub.copernicus.eu/dhus/>) and by specifying the area of interest, product type, sensor mode, and sensing period, among others (Fig. 23.11). The data can also be accessed by registering at Vertex (<https://vertex.daac.asf.alaska.edu/#>) which is the Alaska Satellite Facility’s data portal for remotely sensed imagery of the Earth. Through these, portals archival (before

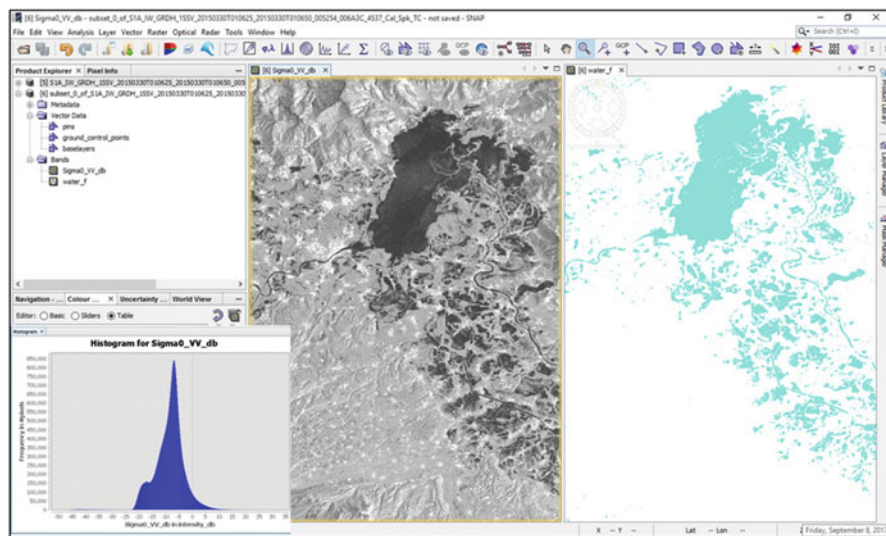


Fig. 23.12 Sentinel 1A SAR data over Srinagar region (left panel) and water layer extracted (right panel) using SNAP software

flood event) and latest (during flood event) Level-1 Ground Range Detected (GRD) Sentinel-1 data in C-band in VV and VH polarizations, which incorporates already some basic preprocessing, can be accessed for analysis. The pre- and during event Sentinel data provides (a) pre-flood river extent and waterlogged areas, and (b) present spatial extent of inundation.

For the analysis of Sentinel data, freely available tool from ESA's Sentinel Application Platform (SNAP) can be downloaded (<http://step.esa.int/main/download/>) and used. The user needs to have basic to intermediate knowledge of image processing and basic knowledge of SAR theory for working with the SAR images. SNAP software can be used for preprocessing of data like calibration (calibrated values of the backscatter coefficient), speckle filtering, ortho-rectification, and thresholding. To separate water from non-water histogram of the filtered backscatter coefficient image is analyzed. Low values of the backscatter in the histogram correspond to water, and high values shall correspond to the non-water class. Sentinel 1A SAR data over Srinagar region (left panel) and water layer extracted (right panel) using SNAP software (Fig. 23.12). The classified layer can be fine-tuned using shaded relief generated from CartoDEM. Pre-flood water bodies can be extracted using similar approach from the pre-event data and can be subtracted from the classified water layer to generate the flood inundation layer. This layer then can be used in a GIS software for area computation and map composition. QGIS is a cross-platform free (<http://www.qgis.org/en/site/forusers/download.html>) and open-source desktop geographic information system (GIS) application that supports viewing, editing, and analysis of geospatial data (Fig. 23.13). Once the flood inundation layer is available, apart from inundated area computation, a decision-

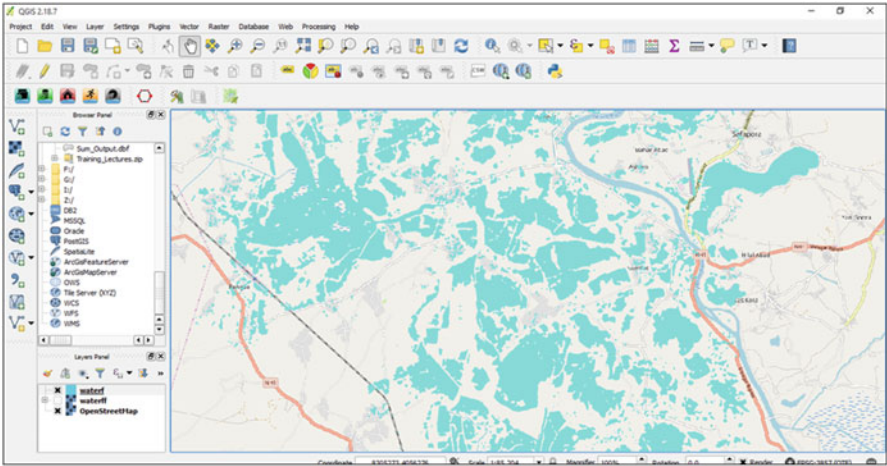


Fig. 23.13 Flood layer extracted can be visualized using OpenStreetMap as plugin using QGIS

maker is also interested in knowing the roads and rail network submerged and districts affected. OpenStreetMap (OSM) which supports and enables the development of freely reusable geospatial data can be used for downloading (<https://www.openstreetmap.org/>) base data like roads, rail, points of interest, and administrative boundaries and can be integrated with inundation layer for flood-related analysis and map composition.

23.4 Popular Geoweb Services and Online Data Repositories

This section provides a list of freely available resources like online data repositories, tools, and software that could help decision-makers in disaster monitoring and mitigation. The lists have been categorized into popular geoportal applications (Table 23.1), portal providing alerts, online data repository and natural disaster-related information (Table 23.2), other online data repositories useful for general research and analysis including disaster mitigation (Table 23.3), tools and models available in open domain for disaster analysis (Table 23.4), and freely available GIS software's available for geographic data analysis during disasters (Table 23.5). The information and list of websites provided for free geospatial data, software, and other datasets may not be exhaustive, and the users are requested to refer and update with more web resources and the license policy of the providers.

Table 23.5 Freely available GIS software available for geographic data analysis during disasters

Sl. no.	Software	Web address	Category	Salient features
1.	Quantum GIS (QGIS)	http://www.qgis.org/	GIS analysis	QGIS is a user-friendly and easy-to-install free- and open-source cross-platform desktop geographic information system application and is one of the most viable alternatives to proprietary desktop GIS software
2.	System for Automated Geoscientific Analyses (SAGA)	http://www.sagagis.org/en/index.html	GIS analysis	SAGA is GIS software specializing in advanced physical geography applications. There exists about over 300 modules involving various GIS operations like manipulating raster and vector data to storing, managing, and creating spatial data
3.	Geographic Resources Analysis Support System (GRASS)	http://grass.fbk.eu/	GIS analysis	GRASS is a free- and open-source geographic information system (GIS) software suite used for geospatial data management and analysis, image processing, graphics and maps production, spatial modeling, and visualization
4.	Integrated Land and Water Information System (ILWIS)	http://52north.org/communities/ilwis http://www.ilwis.org	GIS analysis	ILWIS is a window-based open-source software supporting vector and raster processing and is freely available
5.	gvSig	http://www.gvsig.org/web/	GIS analysis	gvSIG is a GIS desktop-based application which can handle a variety of vector and raster files, databases, and remote services required for planning and management
6.	MapWindow	http://mapwindow.org/	GIS analysis	MapWindow includes a free- and open-source desktop geographic information system (GIS) and includes most of GIS required operation like map viewer, identify features, processing tools, and print layout, including some higher-level tools such as TauDEM
7.	Whitebox GAT	http://www.uoguelph.ca/~hydrogeo/Whitebox/	GIS analysis	Whitebox GAT an open-source desktop GIS and remote sensing software package for general applications of geospatial analysis and data visualization

(continued)

Table 23.5 (continued)

Sl. no.	Software	Web address	Category	Salient features
8.	uDig	http://udig.refractory.net/	GIS analysis	User-friendly desktop Internet GIS (uDig) is an open-source GIS software program, built with Eclipse Rich Client (RCP) technology. It allows spatial data viewing/editing using Open GIS standards for Internet GIS, Web Map Server (WMS), and Web Feature Server (WFS) standards
9.	GeoDa	http://geodacenter.github.io/	GIS analysis	GeoDa is a free GIS software program for spatial data analysis, and its main functionality includes geostatistics, perform autocorrelation, descriptive and regression statistics
10.	LandSerf	http://www.landserf.org/	GIS analysis	LandSerf is a freely available geographic information system (GIS) for the visualization and analysis of surfaces. Applications include visualization of landscapes, geomorphological analysis, GIS file conversion, map output, archaeological mapping and analysis, surface modeling, and many more

23.5 Challenges and Gaps

Geoweb services and online open data repositories have surpassed the barrier of data availability for scientific studies in geospatial domain. Today, huge amount of geospatial data and information are available in different formats, scale, and resolution from global to local scale.

Geoweb services can bring and integrate vast amount of data from heterogeneous sources to generate effective information required to address different applications. Geospatial technology and geospatial data available in open domain today find a wider acceptance among decision-makers and planners especially for responding to disasters and other emergency events. Freely available information and tools now searchable and accessible through portals have become an important tool for decision-making process during natural disasters which have large spatial extent, affecting several people across countries and involving large number of different agencies to work in tandem. However there are still gap areas which restrict the effective use and scope of these data repositories and services. The major gaps are lack of awareness, capacity building of application user(s), and availability of network bandwidth for high-speed data transfer, online computation, algorithm development, etc. Capacity building for the development of skilled manpower

who has the technical know-how about the data availability through Geoweb services, data sharing, data mining, and analysis is the major challenge that hinders the effective utilization of the technology. Internet connectivity is another major concern particularly in developing countries which prevents the full utilization of these resources. During the last decade, the data-originating organizations have come forward to share their data using geoportals and related applications, but still the data and information are available mainly for geo-visualization and querying using basic services standards such as WMS and WMTS. The data access using data service standards such as WFS, WCS, WFS-T, etc. are very limited which are restricting the use of these resources by geospatial professionals. Utilization of Web Processing Services (WPS) for scientific studies is one of the exciting areas where more focus needs to be given. The WPS-based solutions provide online mode of data analysis and processing without physical download of data at user's end.

Acknowledgments This document is a compilation specifically intended for enhancing knowledge on freely available geospatial information on open-source domain which could be used by decision-makers for disaster mitigation. The data content is compiled from various web sources and all the resources considered are gratefully acknowledged.

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