Web based GIS applications to water resources

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Internet

Internet is global collection of computer networks. Internet came in existence in 1969 from four computers initially. Now, tens of millions computers are connected in internet. No one owns it. Instead, it is monitored and maintained by not- to- profit organization. The organization oversees creation of policies and protocols for internet. Internet access is provided to individual computer or organization's computer networks (called Local Area Network or LAN) by Internet Services Providers (ISP). ISPs maintain backbone network connecting various regions. These are called high level networks and these are also connected to each other. Information exchange between networks is done by routers. Routers direct information received from one network to another network so that it may reach the recipient computer. Backbone networks essentially consist of single or multiple fiber optic cables (OFC) and are designated as OC-3, OC-12 or OC-48 depending on their capacity. Typically, OC-3 and OC-48 have 155 and 2488 MBPS bandwidth.

IP (Internet Protocol) address

On Internet, each computer is assigned an IP address. An IP address is also called octets. It consists of four numbers ranging from 0 to 255. Thus, IP address occupies 32-bits. With four octets, nearly 4.3 billion IP addresses may be created. Through octets, network, host computer and classes of IP addresses may be identified.

Domain Name System (DNS)

It is cumbersome to remember IP addresses. Thus, instead of IP addresses, names are used in DNS. In designated servers, lookup tables are maintained for domain names and IP addresses. These servers translate domain names in to IP addresses for internet to work. This system was devised by University of Wisconsin in 1983. In DNS, several top (or first) level domain names e.g. com, edu, gov, org, net etc. are defined. At top level, sometimes country domain names are also used e.g. in, au etc. Other names in the domain should be unique for that class and country domain name. Redundancy and caching are maintained in DNS servers. WWW is host name in DNS.

Server and client

Servers are machines in internet which provide some services and clients are machines which connect to these services. For example, web, email, ftp servers provide internet, email and ftp services. Machines which are used to browse internet, use email or ftp services are called client machines. Servers have static IP addresses. Clients have static or dynamic IP addresses. In dynamic IP address, the addresses are fixed for a session only and are assigned by ISP.

Ports and HTTP

A server machine may provide one or more services over internet. For example, a server may provide internet, ftp and database services. For any service in a server machine, a unique port number needs to be specified. Typically port 80 and 21 are used for internet and ftp services respectively. Communication over internet follow a protocol called HTTP (Hypertext Transfer Protocol). HTTP 1.1 is commonly is use.

Common Gateway Interface (CGI)

CGI is a standard method through which web content is dynamically created by software on web server. These software could be scripts or executable files. In case scripts are used, they are interpreted through script interpreter before execution. Scripts e.g. Pearl, python, java, php etc. are commonly used. For executables, pre compiled codes of programming languages e.g. C/C++ etc. are used. Locations for scripts are known to a web server. All scripts are placed in concerned folder. The server should also have capability for supporting scripts. For running scripts, URL are formed in particular manner.

Geographic Markup Language (GML)

The specifications for GML were developed by OGC. The standard defines XML encoding of vector data and its attributes. This is useful format for both storing and transporting vector data including its attributes.

Web GIS services

Web services are standards of HTTP interface for requesting geospatial data from one or more distributed geospatial databases. Several standards e.g. Web Map Services (WMS), Web Feature Services (WFS), Web Coverage Services (WCS) etc. are defined by Open Geospatial Consortium (OGC) for this purpose. These are open standards and thus widely available for vendors for implementing in their web GIS server and client software. Main Objective of these open standards is to increase interoperability of the geospatial data. The standards are described here. For web services, geospatial data reside on web GIS servers. A request is sent from web GIS clients. Appropriate data are returned depending on type of web GIS service. For WMS, WFS and WCS services images, feature (vector data) and geospatial data itself are returned respectively.

Web Map Services (WMS)

This standard defined HTTP interface for map data. Maps are not data itself. These are images created from the geospatial data. The formats for the images are jpeg, png, gif etc. The geographic data from which maps or images are created could be in vector format. WMS are of two types namely basic and SLD (Styled Layer Descriptor) enabled. Operations supported by basic WMS are getCapabilities, getMap and getFeatureInfo. getCapabilities operation is used to obtain WMS metadata. GetMap request returns map or image in specified format. SLD enabled WMS support additional operations namely describeLayer, getLegendGraphics, getStyles and putStyles. describeLayer is used to obtain XML description of the geographic layer. getLegendGraphics is used to obtain legend graphics. getStyles and putStyles are used to retrieve and store user defined styles for the WMS. HTTP request methods namely get and post are supported by WMS. Get request method is mandatory. Post method is optional. WMS ability and data holding information is published in capability document. This is also referred as metadata. The document has XML format. Data holding are organized as layers and sub layers.

Various parameters required for the operation or request are version, service and request etc. Version is service version e.g. 1.1.1, 1.3.0 etc. Service is name of the service e.g. WMS, WFS or WCS. Request parameter specifies its name e.g. getCapabilities, getMap etc. The parameters required for the request are version, request, layers, styles, CRS, BBOX, Width, Height, Format, Transparent, BGColor etc. Layers, styles are comma separated list of layers and user defined styles. CRS is coordinate reference system e.g. EPSG:4326. BBox are comma separated bounding box coordinates (upper left and lower right) in CRS coordinates. Width and

height are width and height in pixels of the image or map. Format is format of the image or map. Transparent is background transparency of the image. This has logical values true or false. BGColor is background color of the image specified in RGB is hexadecimals e.g. 0XFFFFFF. Whenever request is received by WMS, the request string is parsed to extract parameter and value pairs. These are used to create appropriate output to be sent back by web server to the requesting client. WMS client do not have any official specification. Clients submit request to Web GIS servers in URL form. Clients may have interfaces for getting parameters of the requests.

Web Feature Services (WFS)

WFS is a standard for HTTP interface for requesting vector data from one or more distributed geospatial database. The standard allows editing operation on the vector data. WFS services are of two types namely basic and transaction. Basic WFS supports getCapabilities, getFeature and describeFeatureType operations. getFeature request returns vector data itself. Transaction WFS supports additional operations namely transaction and lockFeature. Transaction request contains request to modify or edit feature. Using this request, the features may be created, modified or deleted.

Web Coverage Services (WCS)

WCS defines web based retrieval of the data itself. Standard also allows subsetting of the data.

Web GIS server software

To publish geospatial data over web, Web GIS server software are needed. Many web GIS server software are available, e.g. Mapserver, Geoserver, QGIS mapserver (WMS service only) in open source category and Arc GIS Server and Apollo in commercial category. Two of the freely available server software are described here.

GeoServer

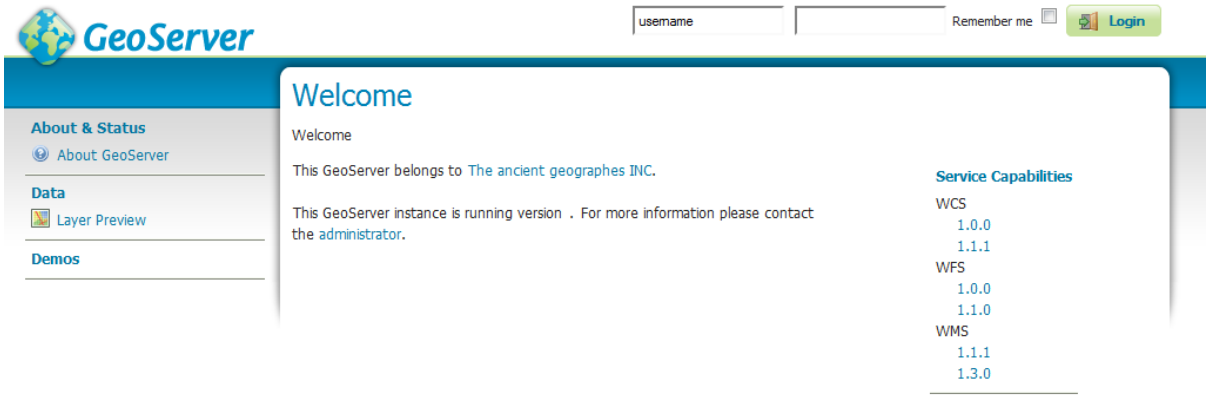
GeoServer is an open source web GIS server software. The software is written in Java. It may be used for publishing geospatial data using OGC web services namely WMS, WFS and WCS. The software was started in 2001 by a non- profit organization The Open Planning Project (TOPP) based in New York. Other parallel projects, useful in GeoServer are GeoTools, GML and web services standards by OGC, PostGIS by Refractions Research and OpenLayers by MetaCarta. GeoTools is an open source GIS toolkit written in Java and supports shape files, oracle data base and ArcSDE. PostGIS is a free and open source spatial database and uses Postgres RDBMS. OpenLayers are open source browser based map viewing utilities.

The software may be installed using windows installer. Detailed steps are available at http://docs.geoserver.org/stable/en/user/installation/windows/installer.html. Oracle Java Runtime Environment (JRE) is prerequisite for GeoServer. The software does not require Oracle Java Development Kit (JDK). User name and password is required for GeoServer Web Administration Interface. Web server port for GeoServer also needs to be specified. Default port is 8080. But any available port from 1024 to 65535 may be selected. The option for starting GeoServer manually or as windows service may be selected. In case manual option is selected the server needs to be manually

started. Environment variables Geoserver_data_dir and Geoserver_home are set during installation. Typical values for these are C:\Program Files\GeoServer 2.2.2\data_dir and C:\Program Files\GeoServer 2.2.2 respectively for GeoServer version 2.2.2.

The web administration interface of GeoServer may be accessed at URL having syntax as follows:
http://[server_url]:[port]/geoserver/
For example, following URL will access GeoServer at localhost and port 8080:
http://localhost:8080/geoserver/

Web administration interface displays GeoServer welcome screen. On this page, administrator's user name and password may be entered.



The interface is used for configuring web GIS services, namely WMS, WFS and WCS. Using this interface, geospatial database on one or more distributed server may be configured for access as web service. Data are organized as workspaces, data store and layers. Workspace is logical collection of data stores. Data stores are configuration of geospatial data including its location on server. Layers are web service configurations for the data store. The interface allows creation, configuration and deletion of all these objects. Data are accessed by web service as configured in layers. The layers may be previewed in the interface. Available output formats for preview are OpenLayers, KML and GML. GML format is available only for vector input data.

GeoServer data store supports various vector, raster and web services. For vector data, individual shape files, shape file directories (useful for adding multiple shape files to the store), PostGIS data etc. are supported. For raster data ArcGRID, GeoTIFF, worldimage, Gtopo30 formats are supported. External WFS and WMS stores may also be connected. Other formats support may be obtained using GeoServer Extensions. For example for vector data GML, Vector Product Format (VPF) may be supported using appropriate Extensions. VPF format is used by US Department of Defense. GML extension is legacy extension. For loading extension, relevant Extension is downloaded and files are extracted in to directory 'webapps\geoserver\WEB-INF/lib'. Versions of GeoServer and Extensions should be matched. Worldimage files are image files with accompanied world files containing georeference information. Example of world files for jpg and tif files are jgw and tfw respectively. Support for several other raster is available through GDAL Extension. Additionally, GDAL libraries are also required to be installed.

Location for the data could be absolute or relative to GeoServer data directory. Example of locations are 'file://D:\mydir\geoserverexamples\nyc_roads.shp' or

'file:coverages/arc_sample/precip30min.asc'. In the case of shape file directory, location is the absolute or relative path of the shape file directory.

Mapserver

MapServer software was developed by the University of Minnesota in cooperation with NASA and the Minnesota Department of Natural Resources. Mapserver use Common Gateway Interface (CGI) scripts residing on the web server. The program may be installed using 'OSGeo4W' installer available at http://download.osgeo.org/osgeo4w/osgeo4w-setup.exe. The program require internet connection as it download software files from internet. The installer is downloaded from internet and run to start software download. Select 'Express Web-GIS install' option to install the software. After the installation, 'OSGeo4W' Shell command window is opened. In this window, the 'apache-install.bat' script is run to install Apache web server. The web server may be uninstalled using 'apache-uninstall.bat' script if need be. Web server is restarted using 'apache-restart.bat' from the Shell window. After the installation of the web server, the web applications are made available at 'http://localhost/' or 'http://127.0.0.1/'. The functioning of Mapserver program may be verified by loading web application 'http://localhost/cgi-bin/mapserv.exe'. The program returns HTML text 'No query information to decode. QUERY_STRING is set, but empty', when mapserver is running. Some of the output are created by mapserver are thematic map, legend, scalebar, reference and HTML documents. In addition, mapserver may also create Web GIS services. Several raster and vector geographic data are supported by the server. Default data is shape vector data. The access to this data is built in to the Mapserver program. Other data types are accessed using OGR library by the Mapserver program. Database stored in to RDBMS e.g. PostgreSQL/ PostGIS can also be accessed.

The input required by the Mapserver program, are supplied through a Map file, parameters of query string of the HTTP request or hidden form variables of HTML document accessing mapserver program. Map file is a text file and have well defined syntax. Map file also specifies location and formats of data files. The name of the map file is supplied to the mapserver program through URL request. It is a structured file and the input are organized as objects. For objects several parameters are defined. The parameters names and their values are supplied in the file. An object starts with name of the object and ends with 'end' keyword. The keywords are not case sensitive. Objects may be embedded objects. Map object is main object and contains parameters and all other objects. The parameters values are assigned for the image to be created, root directory of the data etc. 'Layer' object contains parameters for the geographic data and ways of rendering it. Objects are defined for output types. A 'symbol' object contains definition for a symbol to be used in map rendering. Layer object may contain other object namely class, label and join. The objects have specific function of attribute query, annotation and database join respectively. The Map files may be automatically created using desktop GIS systems e.g. Quantum GIS, MapWindows etc. Such created default Map files may be modified by user. In addition to the Map file, HTML Templates are used. Mapserver script replaces variables, objects etc. in the template file with their known values from Map file or HTML query string.

There are several ways in which Web GIS applications using map server may be developed. A tutorials 'Itasca' is available which may be used for developing similar

applications. The tutorial contains HTML files, Java script libraries, map files and data etc. The HTML files may be modified and map file and data may be replaced by user's own data to create a new application. The application's index page initializes the input needed by Mapserver. Subsequently, page containing application interface is opened. The page contains map pane, radio buttons for map navigation, pulldown menu for GIS data, map elements and query pane. Navigation controls consists of zoom in, zoom out and pan radio buttons. In pull down menu, one or more layer may be selected and the map is refreshed using refresh button. Box zoom is provided for the map through Java scripts. Querying allows the user to select data appearing on the map, either at a specific location, or within a bounding box drawn by the mouse.

HTML file acts as an interface between user and Mapserver. In simplest form a static image may be displayed by the Mapserver program. HTML forms are used to make dynamic applications using Mapserver and provide variables to the Mapserver program. The program is a CGI program and thus is stateless. For each map created, information needed by the Mapserver program is provided afresh. HTML files may also be templates. The templates contain Mapserver variables, attribute name of the geographic data etc. Attribute templates are used in the spatial queries.

Web GIS clients

Spatial data available as Web GIS services may be accessed by desktop client software e.g. Quantum GIS, MapWindow, uDig in Open source category and Arc GIS in commercial software category. A connection URL needs to be specified in the client software. For example for Geoserver WFS web service at local host and 8080 port the connection URL will be as follows:

http://localhost:8080/geoserver/wfs

Before connecting to a web service, internet connection and concerned server should be up and running. Title, name, abstract, projection of the web GIS layers will be displayed after connection is established. One or more layers may be opened in the desktop GIS thereafter. It is also possible to obtain subset of the layer based on current extent. The layers may be saved as GIS data and used in user's project. It is also possible to use identify GIS operation, open attribute table, visualize data on- the- fly, label, change style etc. GIS functionality may vary with client used.

Web Services

NSIDC (National Snow and Ice data Centre), USA has prepared web site and web services for atlas of cryosphere for use during International Polar Year (2007- 08) and beyond (http://nsidc.org/data/atlas/atlas_info.html). Data are available for both northern and southern spheres. The data are available as WMS, WFS and WCS GIS web services. Typical WFS data are Greenland, North Pole and global cryosphere data in addition to geographic data of Canada and USA and global coastline etc. For Greenland elevation contours, ice core and climate station locations are available. Glacier layer source is Vector Map level 0 (Digital Chart of the World), which is in public domain. The layer depicts global snow/ ice fields and glaciers. WFS data are

available in GML format and WCS data are available in GeoTIFF format. Connection addresses for northern hemispheric data are given in Table 1. Addresses may be used in GIS web service client for accessing data.

Table 1 Addresses for NSIDC GIS web services

Web Service	Connection addresses
WMS	http://nsidc.org/cgi-bin/atlas_north?service=WMS&request=GetCapabilities&version=1.1.1
WFS	http://nsidc.org/cgi-bin/atlas_north?service=WFS&request=GetCapabilities&version=1.1.0
WCS	http://nsidc.org/cgi-bin/atlas_north?service=WCS&request=GetCapabilities&version=1.1.1

Vector Map Level 0 (DCW) are freely available since 2006. The data are global GIS data and were prepared in 1992. Primary source of the data are operational navigation charts of US Defense Mapping Agency that were in paper form and at a scale of 1: 1 M. Year of the data varies from 1960 to 1990s. Typical data are transportation network and utilities, populated places, drainage system, land cover, vegetation, political boundaries, physiography, hypsography etc. (http://en.wikipedia.org/wiki/Digital_Chart_of_the_World).

Table 2 Connection URL for various web services

Organization	Connection URL	Application
WMS		
DEMIS bv	http://www2.demis.nl/worldmap/wms.asp	Hydrology, transportation, administrative layers for world
FAO	http://geonetwork3.fao.org/ows/12691_0	countries
OneGeology	http://ogc.bgs.ac.uk/fcgi-bin/exemplars/BGS_Bedrock_and_Superficial_Geology/wms	UK geology
Lizardtech	http://wms.lizardtech.com/lizardtech/iserv/ows	USA data
GEO/ GEOSS	http://www.webservice-energy.org/mapserv/srtm	SRTM
WFS		
ICIMOD	http://geoportal.icimod.org:8080/geoserver/wfs	Nepal and Himalayan region data
OneGeology	http://ogc.bgs.ac.uk/fcgi-bin/exemplars/BGS_Bedrock_and_Superficial_Geology/wms	UK geology

Dams Information

In India, prior to independence of India, very few dams existed in the country. As per Dam safety organization of Central Water Commission (2002) many large dams (dam height more than 10 m) were constructed in the decades of 1980s and 1990s. Thereafter, the growth of large dams has reduced. As on 2002, completed or under construction dams were 4050 and 475 respectively. Up to X plan 442 major and 1230 medium projects were taken up. Out of these 276 and 1008 were completed (anticipated figures). Thus, total major and medium projects taken up and completed are 1672 and 1284 respectively. In the XI plan period the ongoing major and medium projects in the country are 166 and 222 respectively. Thus, total 388 major and medium projects are ongoing. Major and medium projects proposed are 78 and 145 respectively. Projects targeted for completion during the plan are 72 and 133. Hydropower development in the country started in 1879. First hydropower project was of capacity 200 kW and was commissioned at Sidrapong in Darjeeling. The hydropower capacity was 500 MW at the time of independence. The capacity has increased to 27410 MW in 2003 (CBIP 2003). The yearly growth rate was small up to 1960. There after the yearly growth rate has continuously increased from nearly 500 to 900 MW. The capacity at the end of 2003 was 26370 MW and 26615 MW (including uprating) for hydropower 15 MW and above. Up to 15 MW, nearly 760 MW was added at the end of the period. Thus, total installed capacity was 27375 MW.

In Web GIS application, thematic maps and attribute tables are needed. Thematic maps are displayed in map form and the attribute tables are used in querying the geographic data. Thematic maps used in the dams application were basins, river and dams. Typically, topographic maps, index maps, atlases, reports etc. are potential data source. However, considering large extent and limited resource employed, topographic maps were not used. The geographic data are converted in to GIS data from time to time for scientific and commercial use by several organizations. But, these data are not readily available. For the present application, atlases are selected as primary source of the data. GIS data prepared at the Institute from several of atlases were available and these were used in the study. In all, the vector data of dams has nearly 1195 points.

Salient features of the dams and diversions in India are available from reports, web sites, books etc. Central Bureau of irrigation and Power (CBIP) and Central Water Commission (CWC) have brought out publications, which provide salient features of dams and diversions, hydropower station etc. in India (CWC 2002, CBIP 1979, 2003). The information available in the publication is detailed and not available is database format. The database was prepared for 603 dams and diversions. Out of these, 237 dams and diversion the database was also linked with the thematic map table. For 196 dams, both the storage and geographic location and for 363 dams the storage data are available. For 77 stations, both the hydropower and geographic location and for 161 stations the hydropower data are available.

Drought indices

National Commission on Agriculture and Irrigation Commissions have identified 99 districts in 14 states as drought prone districts. These districts have cultivable area of about 77 m ha which is about 42% of the country's total cultivable area of 184 m ha. Among the States, Gujarat and Rajasthan are the most droughts prone followed by Karnataka and Maharashtra. Drought Area Study and Investigation Organisation of CWC studied 99 districts. Out of 108 M. ha area of 99 districts, only 51.12 M. ha (nearly one sixth area of the country) spread over 74 districts have been identified as drought districts. In the present study, rainfall for SPI classes will be provided for the districts in the country.

Standardized Precipitation

This is a simple index which is equal to standard normal variate for rainfall measurements. It uses two parameters, namely mean and standard deviations of the rainfall data for a given time scale. The disadvantage of the index is that the index does not reflect the probability of occurrence of a drought event.

Standardized Precipitation Index (SPI)

An SPI value correspond of a specific probability of occurrence of a given precipitation value. The disadvantage of Standardized Precipitation (SP) is overcome in this index. The accumulated precipitation time series have skewed probability distribution. Thus, normal probability distribution is not suitable for the data. Two parameter gamma distributions (Eq. 1) have been found to fit well with the data. The index is arrived at first determining the cumulative non exceedance probability for a rainfall magnitude and then determining standard normal variate for this probability value using inverse normal probability distribution function. Gamma probability distribution function has two parameters, namely α (shape factor) and β (scale factor). The parameters are estimated using maximum likelihood estimator as given by Thom (Eq. 2- 4). The cumulative probability distribution function is given by Eq. 5.

$$g_x = \frac{1}{\beta^{\alpha}\Gamma(\alpha)} x^{\alpha-1} e^{-x/\beta} \qquad (1)$$

$$\alpha = \frac{1}{4A}\left(1+\sqrt{1+\frac{4A}{3}}\right) \qquad (2)$$

$$\beta = \frac{\bar{x}}{\alpha} \tag{3}$$

$$A = \ln(\bar{x}) - \frac{\sum \ln(x)}{n} \tag{4}$$

$$G_x = \int_0^x g_x dx = \frac{1}{\beta^\alpha \Gamma(\alpha)} \int_0^x x^{\alpha-1} e^{-x/\beta} dx \tag{5}$$

Where, α (shape factor) parameter of the gamma probability density function

β (scale factor) parameter of the gamma probability density function

n is number of precipitation observations,

$\bar{x}$ is mean precipitation

Typically, monthly rainfall data are used in SPI estimation. Using this data, the data for various time scales, e.g. 3, 6, 12, 24 and 48 month may be derived. The data points are computed for each month. For example, in three month time scale data, the rainfall for January 2011 is cumulative value for months from November 2010 to January 2011. From this data, the dataset for each month is extracted and SPI are computed for these data. Typical SPI of 3, 12 and 48 month represent seasonal, intermediate term and long term droughts.

Non- exceedance probabilities for SPI values are given in Table 1.1. It signifies the chance the Z- score for rainfall remains less than or equal to the specified value. The probability is expressed in percentage. Further, probability is also expressed as '1 in n', where n represents number of time steps. Drought intensities are arbitrarily defined for SPI classes as given in Table 1.2. Probability of occurrence of the rainfall in the classes is also given.

Table 1.1 Non- exceedance probability for SPI

SPI	Non- exceedance probability in %	Chance 1 in n
-3	0.1%	714
-2.5	0.6%	161
-2	2.3%	44
-1.5	6.7%	15

-1	15.9%	6
-0.5	30.9%	3
0	50.0%	2

Table 1.2 Drought categories based on SPI

SPI	Drought category	Probability
0- -0.99	Mild	24.0
-1.0- -1.49	Moderate	9.2
-1.5- -1.99	Severe	4.4
<=-2.0	Extreme	2.3

District wise monthly precipitation data was available from India Water Portal (http://www.indiawaterportal.org/metdata) for period 1901 to 2002. The data is based on Climate Research Unit (CRU) TS2.1 dataset, of the Tyndall Centre for Climate Change Research, School of Environmental Sciences, University of East Anglia in Norwich, UK. An interpolated data set is available at 0.5 degree latitude-longitude grid from global monthly rainfall. Apart from rainfall temperature, humidity and cloud cover data are also available. The dataset was processed in GIS software GRASS (Geographic Resources Analytical Support System) on an Ubuntu Linux operating system. GRASS GIS modules along with Linux scripting were used to extract data for Indian subcontinent. The district-wise meteorological data was obtained as average of the gridded data for grids within a district. For data gap of 25% of the district area or less, an approximation was done. For data gap larger than 25%, data was left blank. It is recommended that local data should be used where ever available. It is suggested that the data could be useful for regional studies (http://indiawaterportal.org/node/7160). The data was available as MS excel sheets and was downloaded.

India-WRIS (Water Resources Information System)

The Web GIS system is being development by National Remote Sensing Centre (NRSC) for Central Water Commission (CWC), Ministry of Water Resources, Government of India. The system is to utilize nearly 30 spatial layers for water resources data dissemination. New geographic data at scale of 1:50,000 are under creation. Existing geographic data will also be deployed. LCC map projection with WGS84 datum is selected for data creation. Data sources for new and existing geographic data constitute SRTM (90 m) DEM, SOI topographic maps, National Resources Data Base (NRDB) of different years and miscellaneous data sources

including that of NRSC. For dams and diversion in the country CWC's National Register of large Dams (2009) is used. Both locations and salient features are taken from the data. Various information incorporated are major and medium irrigation projects command areas including waterlogged and salt affected area, point soil information in the projects, district wise irrigation statistics, ground water well and their water level data etc. Several thematic maps e.g. Land use, land degradation, wetlands, surface water bodies (selected states), wasteland maps etc. generated by NRSC in past have also been incorporated in to WARIS. Other data area inland waterways, hydrometeorological, meteorological, evaporation and water quality stations etc. are also incorporated.

The geographic data in the WARIS are scale dependent. A DEM is displayed in background. Administrative, transportations, hydrological, command etc. vector layers are displayed. Labels are displayed for town, basins and state. Geographic data information is displayed using identity tool, e.g. soil ph and EC, ground water depth for wells etc. Tools for navigations, bookmark etc. are available. Search, layer selection and legend are provided.

Separate applications are provided for the water resources projects, monitoring stations etc. The applications include e.g. projects salient features. The salient features displayed are name, type, river, purpose, year, location, volume, storages and area. Some features are not available in the dam's info. Displays are provided for major and medium, hydroelectric and multi- purpose project. Maps of meteorological and district rainfall stations are available. Information e.g. location, river, administrative data, catchment, metadata etc. for the hydrometeorological and water quality stations are provided. Maps of land degradation, land use and cover, waste land and waterways are provided (http://www.india-wris.nrsc.gov.in/webgis.php#app=a118&69f8-selectedIndex=1).

Biodiversity

This is a comprehensive Web GIS application on biodiversity in India. Google Earth DEM, transportation network, town, contours etc. are displayed in background. The maps are labeled. The visibility of geographic maps is controlled by Maximum and minimum scale. Layers may be toggled on or off and metadata may be accessed in the Table Of Content (TOC). The geographic data are organized as per theme, geography and participants. Several All India and project specific geographic data are available. Administrative unit are available up to Tehsil level. Information is organized as details, images and facts. For example information on landmark trees are provided with images. Identify operation provide information for polygon maps are organized as summery and detailed information. Several biodiversity information are organized in conservation, land use land cover and species themes. Uttarakhand related information are provided specifically. Distance measurement, search and legend menus are available. The application is a part of biodiversity portal. The portal is built on recommendation of National Knowledge Commission through collaborative effort. The lead institution is Ashoka Trust for Research in Ecology and Environment (ATREE) (http://indiabiodiversity.org/map).

Orissa GIS

An application is developed by GIS Division of National Informatics Centre (NIC), Bhubaneswar to provide statistical data of the Census 2001 and Directorate of Economics and Statistics (DES) at state, district, block and village levels. Layers may be selected using TOC and tabular information may be displayed. DES data are available at district level. Other useful layers are soil, forest and river. Source of the soil layer is Soil Survey of India. Description of soil polygon is displayed interactively. In state map, districts and tabular socioeconomic data e.g. population, literacy etc. are displayed for by mouse hover.

A Mapserver based application is also developed to disseminate thematic and attribute information of the state. District wide Census 2001 and DES statistics are disseminated. For soil map, information in soil units is provided. Maps may be navigated and toggled on or off. Layers e.g. districts, soils may be queried. Similar applications are developed for few districts (http://gis.ori.nic.in/).

Uttar Pradesh GIS

A Web GIS application is created to disseminate information up to village level. Attribute information from Census 2001 are used. Various thematic maps prepared under Natural Resource Information System (NRIS) are used. These include forest, drainage, canals, soil, lithology, geomorphology, lineament, land use, groundwater, settlements, watersheds, road, rail etc. Thematic maps are provided in land category sub heading. Access to the Web GIS is restricted and required registration.

Spatial and attribute query is provided for Villages. In spatial query village name, household and population are displayed. Rivers are classified as dry and perennial. Administrative blocks are labeled. Watersheds are classified in to catchment, sub catchment, watershed and micro watershed levels. All India Soil and Land Use Survey (AISLUS) codes, link code, project specific codes and names (up to the watershed levels) are returned in spatial queries. Geomorphology is classified in to three levels. At the level one, classes e.g. Alluvial Plain, Structural hills etc. are provided. At level two Alluvial Plains are classified in to Alluvial Plain- Old, Upper etc. At level three, Alluvial Plain Old/ Upper is sub divided in to Paleao, abandoned channels, Ravines etc. The settlements, water bodies etc. are also mapped. Taxonomical classification is provided up to sub group. Soil physicochemical characteristics e.g. sand fraction, Mg, Na, K and Ph are also available both as geographic data and table. Groundwater is classified as excellent, very good, moderate to good, poor, poor to Nil etc. Maps may be navigated using tools.

For Chitrakoot district, drinking water source maps are provided in Web GIS. Thematic maps of dry spell for year 2008 and 2009 for months May, June and July are developed. Dry spell is classified in 0-9, 10-15, 16-20 and >20 days classes. Information is displayed district

wise. Tube wells of the Irrigation department are mapped and organized at district level (http://gis.up.nic.in:8080/srishti/).

Transportation network

An application is developed by Maptell Geosystems Pvt. Ltd., Thirivanthpuram, Kerala, India for geographic data e.g. roads, cities, reservoirs etc. The details are scale dependent and map navigation is possible. Attribute query is also provided for city. Map API may be provided by the firm for integrating maptell maps to third party mapping, vehicle tracking and mobile resource management applications. Technologies e.g. KaMap, Mapserver, Openlayers, PostGIS etc. are used (http://www.maptell.com/index.php?option=com_content&task=view&id=61&Itemid=198).