Applications of Remote Sensing Data for Environmental Modelling and Analysis

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Abstract
As the ever growing world population continue to impose immense pressure on the environment, the dynamic balance between environmental stability and resource utilisation is continuously being threatened. Considering the global coverage of this menace, remote sensing appears to be the most economic and efficient means of data acquisition for monitoring and analysing of environmental degradation patterns. Five (5) different satellite missions and an on-line vector-based digital Soil Map have been theoretically examined with a view of evaluating their data products, spatial and spectral resolutions, applications and source of data access.

Keywords: Remote Sensing, Spatial Resolution, Image Bands and Satellite Mission.

Introduction

Considering the several natural disasters ranging from earthquakes, tsunamis, flooding, mass inundation e.t.c that have plagued our time, the modern-day environmentalist is expected to proffer dynamic solutions to these menaces. The solutions however, cannot be efficient except proper mathematical and graphical models are integrated in the solution criteria.In most cases the vast spatial extent of the study area makes the cost of data acquisition very expensive and unaffordable. This thus results in setback in environmental modelling and process analysis. Presently, advances in remote sensing technology however have provided us with several free sources of on-line global data that can be accessed for useful analysis.

Starting from the 1980's, there has been a move from experimental to operational applications as remote sensing technology was commercialised (Bengt, 1992). Remote sensing data are nowadays freely available from regional and international research institutes that work in the field of natural resources management, spatial and atmospheric interactions, and are often available at the global scale (Agnese, B et al, 2012). For this reason these datasets are often referred to as *global datasets*. Global datasets are information-rich databases that provide public and private users with detailed and sector specific quality input for data retrieval and management.

Amongst the numerous space agencies offering earth observatory data products, two missions shall be considered in this paper because they provide free on-line access to data sets with global coverage. These agencies are:

1. National Aeronautics and Space Administration (NASA) belonging to the American government. Most NASA products are distributed by the United States Geological Surveys (USGS)
2. The European Space Agency (ESA) of the European Government.

This paper therefore presents researchers with information on various forms of remote sensing data and their spatial resolution that can be accessed freely on-Line for environmental modelling and analysis. A brief overview of the satellite mission is first presented followed by information about the products they offer and their applications. Finally, we have also provided links from where such data product could be freely downloaded.

The Shuttle Radar Topography Mission (SRTM)

The SRTM was a 12-days remote sensing mission that took place in February, 2000. The National Aeronautics and Space Administration (NASA) and the National Geospatial-Intelligence Agency (NGA) participated in an international project to acquire radar data which were used to create the first near-global set of land elevations. Carrying two radar bands, (C-Band Spaceborne Imaging Radar belonging to NASA of the U.S.A and X-Band Synthetic Aperture Radar belonging to DLR with ASI participation of the German Gorvernment) the STRM used single pass interferometry technique to deduce elevation data for points on the earth surface.

Consequent upon its low resolution (1-arc seconds and 3-arc seconds i.e 30m and 90m respectively) the C-SIR has a larger spatial coverage that ranges between Latitudes 60°N and 56°S whle the X-SAR has a narrower ground track. (www.wikipedia.com)

The table 1 below shows the orbital parameters of the SRTM space mission.

Table 1

Satellite Orbital Parameters for the SRTM Satellite (adapted from Wikipedia/SRTM Page)

Launcher	Space Shuttle Endeavour
Launch date	February 11, 2000
Orbit altitude	233 km
Inclination angle	57°
Orbital period	89.2 min
Orbits per day	16.1

The SRTM data can be accessed freely online at: http://earthexplorer.usgs.gov/

Earth Explorer offers SRTM data with a regularly spaced grid of elevation points in three file formats namely Digital Terrain Elevation Data (DTED®), Band interleaved by line (BIL) and Georeferenced Tagged Image File Format (GeoTIFF) and with resolutions of 30m for the USA and 90m for other parts of the world.

The German and Italian space agencies operated the X-band hardware and processed the data independently into a separate elevation data set. The SRTM/X-SAR data may be obtained through the German Aerospace Center (DLR).

SRTM elevation data are intended for scientific use with a Geographic Information System (GIS) or other special application software. (Source: https://lta.cr.usgs.gov/SRTM2)

Landsat

The LandSat is an American-owned space mission that started with LandSat 1 launched in 1972 and the latest version LandSat 8 Launched in 2013. The LandSat 7 launched in April 1999 has a global coverage period of 16 days with a swath width of 185km and a spatial resolution of 30m. The LandSat 7 satelite is equipped with four (4) different sensor types namely: (1) Panchromatic (PAN) (2) Thermatic Beamer (MTB) (3) Multi Spectral Scanner (MSS) and (4) Thermatic Mapper and Enhanced Thematic Mapper (TM / ETM). Because of its vast spectral resolution from the Visible to the Thermal infrared region, it is mostly used in vegetation studies (due to its fairly close spatial resolution), disaster monitoring/prevention and change detection (because of continuous study of the earth since 1972), mapping of location of forest fires e.t.c

Landsat images are composed of seven different bands, each representing a different portion of the electromagnetic spectrum. The Characteristics of the various bands of the LANDSat Imagery has been given by AMNH-CBC (2003) and presented by GIF (2008).

A special application of the LandSat imagery in Agriculture is the detection of crop health and crop-yield per hectare analysis in large farm lands and measurement of Drought Indicators using the Normalised Difference Vegetation Index (NDVI) and Enhanced Vegetation Index (EVI) as a surrogate measure. Basically the NDVI is obtained by a mathematical operation of the bands 1, 2, 3 and 4. The thermal Band (Band 6) of the LandSat image is also particularly useful in estimating temperature of an area and subsequently, soil moisture with such area.

The landSat imagery can be accessed freely on-Line from: www.earthexplorer/usgs.gov.
Earth explorer provides LandSat imageries in four (4) broad categories:

1. LandSat Archive: Consists of the following imageries; (a) L8 OLI/TIRS (b) L8 OLI/TIRS Pre-WRS2 (c) L7 ETM+SLC (Scan Line Corrector)-OFF(2003 – Present) (d) L7 ETM+SLC-ON(1999 – 2003) (e) L7 ETM+Intl Ground Stations (Search Only) (f) L4–5 TM (g) L1-5 MSS.

2. LandSat CRD: Consists of the following images: (a) Land Surface Reflectance – L7ETM+ and (b) Land Surface Reflectance – L4-5 TM

3. LandSat Legacy: The images within this category are; (a) ETM+PAN Mosaics (1999-2003) Orthorectified (b)TM Mosaics(1984-1997) Orthorectified (c) ETM+PAN Mosaics (1999-2003) Sharpened and Orthorectified (d) MSS 1-5 (1972-1987) Global Land Cover-Orthorectified (e) (NALC) North American Landscape Characterisation Triplicates (f) LIMA (LandSat Image Mosaic Antarctica) (g) MSS Film Only (h) RBV(Return Beam Vidicon) Film Only (i) TM Film Only
4. LandSat MRLC (Multi Resolution LandSat Characterisation: with the following set of images; (a) MRLC/MTRS (Monitoring Trends in Burn Severity) Reflectance (b) MRLC/MTBS Radiance.

Howbeit, for other forms of application and analysis where the image bands will be individually required for manipulation, band mathematics and false colour superimposition such as in vegetation monitoring e.t.c, the separate image bands can be obtained from: http://glcf.umd.edu/data/landsat/

Advanced Very High Resolution Radiometer (AVHRR)

The **Advanced Very High Resolution Radiometer (AVHRR)** is a space-borne sensor embarked on the National Oceanic and Atmospheric Administration (NOAA) family of polar orbiting platforms (POES). Equipped to measure earth reflectance in 5 spectral bands, it senses within 0.6 micrometer to about 15 micrometers (http://en.wikipedia.org/wiki/Advanced_Very_High_Resolution_Radiometer)

The AVHRR provides global, and consistent time series with high spectral and spatial resolution suitable for surface temperature measurement and other studies involving measurement of albedo, sea ice distribution and movement, ice sheets coastal configuration e.t.c (http://nsidc.org/data/avhrr/)

The Advanced Very High Resolution Radiometer (AVHRR) multi-purpose imaging instrument is used for global monitoring of cloud cover, sea surface temperature, ice, snow and vegetation cover characteristics, Leaf Area Index, Photosynthetically Active Radiation e.t.c. (http://www.eumetsat.int/website/home/Satellites/CurrentSatellites/Metop/MetopDesign/AVHRR/index.html)

AVHRR data are particularly relevant to study climate change and environmental degradation because of the comparatively long records of data already accumulated (over 20 years). The

main difficulty associated with these investigations is to properly deal with the many limitations of these instruments, especially in the early period (sensor calibration, orbital drift, limited spectral and directional sampling, etc.) (http://en.wikipedia.org/wiki/Advanced_Very_High_Resolution_Radiometer).
A major limitation of the AVHRR data is the 1km spatial resolution. This makes it effective only for large scale regional studies.

Data From AVHRR can also be accessed online from:www.earthexplorer/usgs.gov.

Tropical Rainfall Measurement Mission (TRMM)

TRMM is a research satellite designed for monitoring precipitation variability and distribution; it covers the tropical and sub-tropical regions of the Earth. TRMM provides much needed information on rainfall and its associated heat release that helps to power the global atmospheric circulation that shapes both weather and climate. In coordination with other satellites in NASA's Earth Observing System, TRMM provides important precipitation information using several space-borne instruments to increase our understanding of the interactions between water vapor, clouds, and precipitation, that are central to regulating Earth's climate (http://pmm.nasa.gov/node/158).
An important consideration during the design phase of the TRMM NRT was to create products that contain all the required parameters for proper use but still small enough for easy and fast network access. So, most of the diagnostic and supplementary parameters were removed from NRT products. (http://pps.gsfc.nasa.gov/tsdis/Documents/formatChangesV7.pdf)

Three products are available:
3B40rt – merged radiometer product 3-hourly product
3B41rt – *calibrated (by radiometers)* IR 1-hour product
3B42rt – 3-hourly radiometer product filled in by IR when no radiometer available
The TRMM data can be accessed freely on line depending on the kind of product required:
Swath Products
Website – trmmrt.gsfc.nasa.gov
Requirements / Entry Parameters – User: trmmreal
– Password: your email
– Anonymous ftp
– Subdirectories: VIRS, PR, TMI, documentation
TMPA realtime
Website – trmmopen.gsfc.nasa.gov
– User: anonymous
– Password: your email
– Anonymous ftp
– TMPA: pub/merged/calibratedIR, pub/merged/mergeIRMicro, pub/merged/combinedMicro
– TMPA GIS: pub/gis

Digital Soil Map:
The Food and Agriculture Organisation of the United Nations (FAO-UN) has facilitated the production and on-line availability of vector and raster based Digitalised Soil Map for all areas of the world. The vector data set is based on the FAO-UNESCO Soil Map of the World. The Digitized Soil Map of the World, at 1:5.000 000 scale, is in the Geographic projection (Latitude - Longitude) intersected with a template containing water related features such as coastlines, lakes, glaciers and double-lined rivers (http://data.fao.org/map). The Soil Map is a computer-assisted production of digital maps of soil types and soil properties. Soil mapping, in general, involves the creation and population of spatial soil information by the use of field and laboratory observational methods coupled with spatial and non-spatial soil inference systems(http://en.wikipedia.org/wiki/Digital_soil_mapping)

The World Digital Soil Map will help environmentalist in modelling soil erosion, Washing away of top soil, Crop yield per hectare, landslide e.t.c. A vectorised form of the digital soil map can be downloaded at http://data.fao.org/map?entryId=446ed430-8383-11db-b9b2-000d939bc5d8.

Environmental Satellite (ENVISAT)

The Envisat mission, launched in March 2002, is a continuation of the ERS 1 and ERS 2 space missions. The ERS-1 and 2 missions were launched with objectives including the study of Earth resources, physical oceanography, ice and snow, land surface, meteorology, geodesy/gravity, environmental monitoring, and atmospheric chemistry.

The ENVISAT therefore has same objectives but with enhanced suite of instruments building on the heritage of the ERS 1 and 2 (ENVISAT and ERS Missions-Data Guide, 2011).
Consequent upon its wide range of applications, the ENVISAT carries several instruments to satisfy its enormous applications which include:

1. AATSR (Advanced Along Track Scanning Radiometer): Efficient for measurement of sea surface Temperature.
2. ASAR (Advanced Synthetic Aperture Radar): Has four (4) different data gathering modes with different spatial resolution. It is used for measuring changes in surface height to milimeter precision.
3. DORIS (Doppler Orbitography and Radio-positioning Integrated by Satellite): Used for measurement of Satellite Orbit to within 10cm.
4. GOMOS (Global Ozone Monitoring by Occultation of Stars): The **GOMOS** instrument uses a star occultation technique to measure atmospheric constituents and dynamical parameters by exploiting the Ultra Violet, visible and short wave infrared star spectrum. It thus provides global observations of total ozone, nitrogen dioxide, minor trace gases and related cloud information based on UV and visible radiation.
5. LRR (Laser Retro-Reflectors):
6. MERIS (Medium-Resolution Imaging Spectrometer): The **MERIS** radiometer offers a spatial resolution of about 1 km for ocean applications and 300 m for land and costal applications with objective to monitor marine biophysical and biochemical parameters as well as measuring atmospheric properties, such as cloud and water vapour, and to monitoring vegetation conditions on land surfaces. (ENVISAT and ERS Missions-Data Guide, 2011).
   The observations are also used to derive estimates of the concentration of chlorophyll and sediments in suspension in the water, for instance. These measurements are useful to study the oceanic component of the global carbon cycle and the productivity of these regions, amongst other applications.
   The characterization of atmospheric properties (gaseous absorption and aerosol scattering) is essential to derive accurate information over the oceans because they contribute to the bulk of the signal measured (under clear skies) or simply because clouds prevent the observation of the underlying surface.
   The instrument is as well useful to monitor the evolution of terrestrial environments, such as the fraction of the solar radiation effectively used by plants in the process of photosynthesis, amongst many others applications (http://en.wikipedia.org/wiki/MERIS)
7. MIPAS (Michelson Interferometric Passive Atmosphere Sounder): Is a Fourier transforming infrared spectrometer which provides pressure and temperature profiles, and profiles of trace gases nitrogen dioxide (NO_2), nitrous-oxide (N_2O), methane (CH_4), nitric acid (HNO_3), ozone (O_3), and water (H_2O) in the stratosphere. The instrument allows coverage across the Earth in all seasons and at equal quality night and day. MIPAS has a vertical resolution of 3 to 5 km (2 to 3 mi) depending on altitude (the larger at the level of the upper stratosphere) (http://en.wikipedia.org/wiki/Envisat)

8. MWR (Microwave Radiometer): Measures Water Vapour in the atmosphere.
9. RA-2 (Radar Altimeter 2): Radar altimeters are active sensors that use the ranging capability of radar to measure the surface topography profile along the satellite track. They provide precise measurements of a satellite's height above the ocean (ENVISAT and ERS Missions-Data Guide, 2011). A variety of parameters may be inferred using the information from altimeter measurements which include: time-varying sea surface height (ocean topography), the lateral extent of sea-ice and the altitude of large icebergs above sea level, as well as the topography of land and ice sheets, and even that of the sea floor.
10. SCIAMACHY (Scanning Imaging Absorption Spectrometer for Atmospheric Chartography): An imaging spectrometer whose primary mission objective is to perform global measurements of trace gases in the troposphere and in the stratosphere exploiting the UV, visible and short wave infrared radiation.

Table 2 gives an overview of the various data products obtainable from ENVISAT and the instrument used for the data acquisition:

Table 2
ENVISAT Instruments and their Data Products (Adapted from ENVISAT and ERS Missions-Data Guide, 2011)

PRODUCT TYPE	ENVISAT INSTRUMENT
Radar and Scatterometer Data	ASAR (No Scatterometer)
Multispectral Optical Data	ASTSR and MERIS
Altimetry Data	RA-2 and MWR
Atmospheric Data	GOMOS, MIPAS and SCIAMACHY

The ESA ENVISAT Data come in Five (5) Levels ranging from the "Raw Data to Level 3". End-users are advised to go for Level 2 and Level 3 Data because they would have been corrected for all radiometric and geometric distortions. Level 3 data are complete and consistent (missing points interpolated and complete region mosaiced together).

Envisat AATSR complete mission has been reprocessed, with details of the dataset available at http://earth esaint/object/index cfm?fobjectid=5908
Other ENVISAT products can be accessed on-line at: http://earth esaint/EOLi/EOLi html.

Conclusion

Six Major sources of remotely sensed data for Environmental monitoring have been presented in this paper. Table 3 gives a quick summary of the satellite missions, their data products, the applications and the means of on-line access.

Table3
On-Line Sources of Remote Sensing Data for Environmental Monitoring (Author Research)

S/N	SPACE MISSION	SPATIAL RESO.	SPECTRAL XTICS	APPLICATIONS	ON-LINE ACCESS
1	SRTM	90m 30m	C-Band SIR	Provides Global Terrain Elevation Data useful for: Flood Vulnerability Analysis Topograhic Wetness Index Line of Sight Analysis e.t.c	www.earthexplorer.usgs.gov
2.	LANDSAT	30m	TM / ETM MSS MTB PAN	Vegetation Studies Disaster Monitoring and Control Change Detection Urban Sprawl Analysis Forest Fire Analysis	www.earthexplorer.usgs.gov http://glcf.umd.edu/data/landsat/
3.	AVHRR	1km	Red (0.6mm, 500THz) NIR(0.9mm, 300THz) 3:5 mm Thermal Radiation (11 -12mm)	Climate Change Environmental Degradation Cloud Cover Monitoring Sea-Surface Temp. Measurement Ice, Snow and Vegetation Cover Leaf Area Index Photosynthetically Active Radiation	www.earthexplorer/usgs.gov
4.	TRMM	2.5Km 4.3Km	Precipitation Radar (PR) TRMM Microwave Imager (TMI) Visible&Infrared Scaner (VIRS) Cloud and Earth Radiant Energy Sensor (CERES) Lighting Image Sensor (LIS)	Measurement of Water Vapour Rainfall Data Global Atmospheric Circulation	trmmrt.gsfc.nasa.gov trmmopen.gsfc.nasa.gov
5.	DSMW	N/A	Vector Data N/A	Soil Type Soil Characteristics: (a) Phase (b) Conductivity (c) Permeability e.t.c	http://data.fao.org/map?entryId
6	ENVISAT				http://earth esaint/EOLi/EOLi html
	(a)AATSR		Visible Infrared	Measurement of Sea Surface Temperature	
	(b) ASAR	30 – 150m 30 – 150m 400m 1Km 150m	AP Image Wave Suvi Global Wide Swath	Detection of Change in Surface Height to submilimeter Precision	
	(c)DORIS			Determination of Satellite Orbit to centimetre accuracy level	
	(d)GOMOS	3Km	Ultra Violet Visible Short Wave Infrared	Measure atmospheric constituent and dynamical parameters. Provides global observations of total ozone, nitrogen -dioxide, minor trace gases and aerosols.	
	(e) LRR				
	(f) MERIS	300m	Solar Range(390 to 1040 nm)	monitor marine biophysical and biochemical parameters. Measurement of atmospheric Properties	