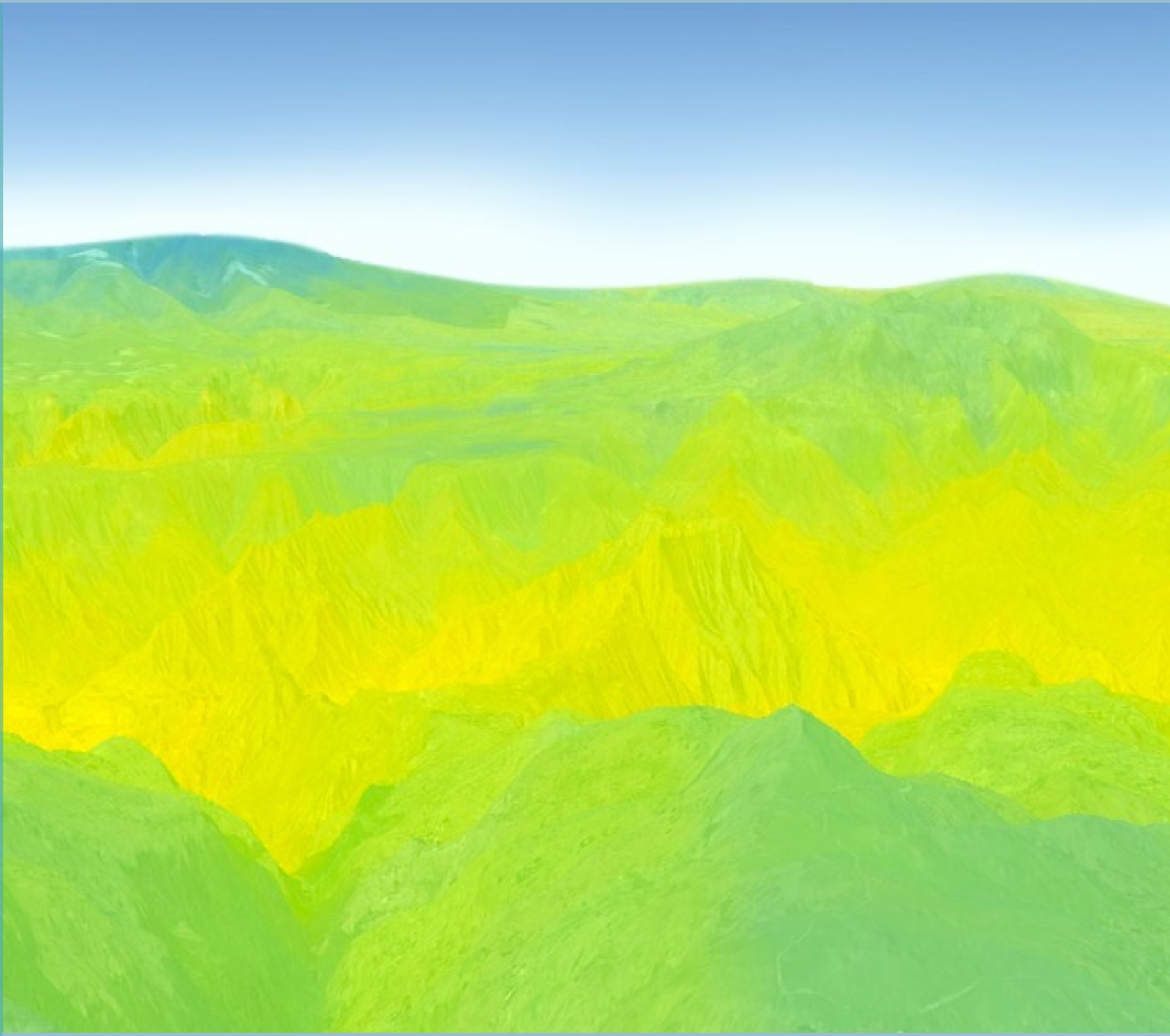
IRI Technical Report 10-04

Introduction to Remote Sensing for Monitoring Rainfall, Temperature, Vegetation and Water Bodies



International Research Institute for Climate and Society
Earth Institute at Columbia University

Contributors
Pietro Ceccato; Tufa Dinku

1. Remote Sensing

Remote sensing is the science of obtaining information about an object through the analysis of data acquired by a device (sensor) that is not in contact with the object (remote). As you read these words, you are employing remote sensing. Your eyes are acting as sensors which analyze the electromagnetic waves (visible light) reflected from this page. The light your eyes acquire is analyzed in your mental computer to enable you to explain the words. Apart from the eyes, more sophisticated sensors have been developed to measure the electromagnetic waves in domains outside the visible. By measuring the electromagnetic waves in domains from Gamma rays to Microwaves, we can retrieve information on the objects we want to study.

The images provided by the sensors are composed of pixels (short for **pic**ture **el**ement, using the common abbreviation "pix" for "pictures") which are single points in a graphic image. The pixels contain measurements of electromagnetic waves made at the sensor level. The spatial resolution of the pixel can vary from 5 km by 5 km (geostationary satellite) to 60 cm (Quickbird satellite).

2. Satellites

Satellite orbits

There are many hundreds of satellites now in space. Those which are of interest here can be classified into two types according to their orbit, namely **polar orbiting** and **geosynchronous** (also called **geostationary**). Polar orbiting satellites, as the name implies, have an orbit which passes close to both North and South poles. One advantage of such an orbit is that it is **sun-synchronous**. This means that the time of overpass is roughly the same for every point on the South to North (ascending) leg of the orbit and changes by 12 hours for the North to South (descending) leg. For example, if the time of overpass for all points on the ascending leg was 4pm, the overpass time for the same points on the descending leg would be 4am.

Geostationary satellites are positioned approximately 36 000 km above the Earth's surface. They move in the same sense as the Earth's rotation and remain vertically above a particular point on the Earth's surface. Thus a geostationary satellite sees the same view of the full Earth disc all the time.

Many satellites are now in orbit providing a vast quantity of information about the Earth and its atmosphere.

Advantages of satellite are:

- **Cost:** Some of the imagery from satellites is available effectively free of charge. The images can be downloaded from the Internet (see list in chapters 4 to 8)
- **Real-time images:** Data from geostationary satellites are generally available in near real-time; often within 15 to 30 minutes.
- **Area coverage:** Because they orbit high above the Earth, satellites can send back information covering a very large area.

Disadvantages of satellite are:

- **Reliability:** Because many of the environmental factors are sensed indirectly, estimates may not be always reliable or usable in all circumstances and may require the interpretation of a skilled operator.

- **Calibration:** Satellite estimates need calibration/validation against ground-based data. Thus the use of satellite imagery does not do away with the need for field measurements.

In spite of the disadvantages listed above, for many countries satellite imagery provides the only affordable way of monitoring environmental conditions over a large area in real-time. In the next section the sensors which are useful for environmental conditions are discussed.

3. Sensors

What sensors see

Sensors which are sensitive to different wavelength bands in the electromagnetic spectrum give us different information about the Earth and its atmosphere. The wavelengths in common use for rainfall, vegetation, soil properties, dust and land surface temperature are summarized below.

Visible sensor (wavelengths between 0.4 and 0.7 μm)

A sensor in the visible region of the spectrum acts like an ordinary camera and sees what your eyes would see if you were on the satellite. As visible radiation is just reflected sunlight, no information is obtained when the satellite is on the night time side of the Earth. In the case of cloud monitoring: thicker cloud is more opaque – i.e. less sunlight passes through it than through thin cloud and more is reflected back into space. This means that, seen from below, the base of the cloud is very dark, but seen from the satellite's point of view; the reflected light makes the cloud appear very bright. Thinner clouds (which may be either at a low altitude or a high altitude) allow through more light and so reflect less. Therefore, these appear less bright to the visible sensor on the satellite. In the case of vegetation monitoring: chlorophyll absorbs the red and blue electromagnetic wave and reflects the green. By measuring the reflectance at the sensor level in the red channel, it is possible to retrieve some information on the chlorophyll activity in the vegetation.

Near and Shortwave Infra-red ((wavelengths between 0.7 and 3.0 μm)

Near Infrared wavelengths are sensitive to leaves while the Shortwave infra-red wavelengths are sensitive to water. Using combinations of the visible and Infra-red wavelengths it is possible to derive vegetation indices that provide specific information on the vegetation status in terms of greenness or in terms of vegetation moisture. Some simple vegetation indices (such as the NDVI) have been developed to monitor vegetation greenness and quantity of biomass. A vegetation index is a simple mathematical formula used to estimate the likelihood that vegetation was actively growing at a particular location whenever it was observed. Most indices were empirically constructed in such a way that larger values correspond to higher probabilities of actually finding live green plants at the selected location and time of observation. As the name implies, the result is a non-dimensional index or indicator of the presence of vegetation. Empirical indices have often been grossly abused to estimate a wide variety of environmental variables loosely connected to the presence of vegetation.

Thermal Infra-red (wavelengths between 8.0 and 15.0 μm)

The thermal infra-red sensor registers radiation at wavelengths in which the Earth emits very strongly. The intensity of the radiation received is a good indicator of the temperature of the surface observed. The infra-red image can be viewed during the day and during the night. The temperature of the atmosphere decreases with height in a regular way throughout the troposphere (the bottom 10-15 km of the atmosphere) depending on weather conditions and the amount of moisture present. The emission of infra-red radiation is less at lower temperatures and greater at higher temperatures. The infra-red sensor therefore acts as a remote thermometer which can estimate the temperature of the cloud tops. Storm clouds show up as very cold with temperatures typically less than -40 °C and sometimes as low as –80 °C. Cirrus is also identified as very cold and lower, stratiform or inactive cumulus clouds show up at higher temperatures of between 0 °C and -20 °C.

Microwave sensor (wavelengths between 1.0 and 300 mm)

Radiation emitted at microwave wavelengths is influenced strongly by the nature of the emitting surface (whether rough or smooth, wet or dry) and the size of particles through which it passes. Microwaves are strongly affected by water drops and ice crystals in cloud. Unlike the other forms of radiation already mentioned, microwaves can actually distinguish between clouds with drops big enough to produce rain and other clouds. MW frequencies can also penetrate cirrus clouds. Thus, in general microwave frequencies are better suited for rainfall detection than infrared frequencies. However, though rainy areas show up very well over the oceans as bright against a dark background it more complicated over the land because the background emission from the surface is very variable. The wetness of the surface as well as its roughness and the kind of vegetation all cause variations in the emitted radiation. Making quantitative estimates of rainfall against this continually changing background is a challenge. However, there are promising algorithms for overland rainfall estimation from microwave sensor. It has been demonstrated that the microwave estimates have significantly better accuracy than infrared estimates. Another problem with microwave sensors is the spatial resolution in the microwave band is much coarser than in the other wavebands mentioned.

4. Monitoring Rainfall

Unfortunately, no satellite yet exists which can reliably identify rainfall and accurately estimate the rainfall rate in all circumstances. However, satellites carry sensors which can 'see' the Earth in a variety of different ways. Some sensors can make indirect estimates of rainfall by measuring things such as the thickness of clouds or the temperature of the cloud tops. These methods will be discussed in later but for the moment, it is useful to list the advantages of satellite estimation techniques in general.

Limitations of TIR-based rainfall estimates

1. Local variations in rainfall

If you look from a distance at rain from deep storm clouds, it is easy to see that the rainfall intensity varies from place to place beneath the cloud. The satellite sees the top of the cloud not the actual rainfall and so cannot pick up this variation in intensity. Thus the images produced by the satellite are not much use for giving a precise estimate of rainfall for a particular spot on the ground at a particular time. The usefulness of satellites lies in their ability to give (literally) an overview. What we can extract from satellite images with some degree of certainty is the rainfall averaged over an area of thousands of square kilometers and over a time period of days, weeks or months.

2. The accuracy of satellite rainfall estimates

TIR images are used to distinguish raining cloud from non-raining cloud on the basis of their observed cloud top temperature. This is because it is assumed that all rain comes from deep convective clouds with cold, high tops. However, even in the tropics there is some variability in the type of clouds which produce rain. In particular, regions near the coast or in mountainous areas may experience rainfall from clouds which have not formed from vigorous local convection. Consequently they do not reach high enough into the atmosphere to register as 'cold' clouds. In such cases rainfall would indeed occur but would not appear in the satellite rainfall estimate image.

3. Cirrus clouds

After a storm we often see very high, wispy clouds called cirrus. The wispy appearance of cirrus clouds is due to the fact that they are high enough in the atmosphere to be composed of ice crystals rather than water drops. Such clouds appear as very cold to the satellite and therefore would indicate the presence of rain, although in fact the clouds are not deep enough for rainfall to develop.

Merging satellite rainfall estimates from different sensors and blending with gauge observations

As discussed in the previous section, rainfall estimates from TIR offer global coverage, higher special resolution and more repeat time. However, the accuracy of rainfall estimates from TIR is very limited. On the other hand, MW sensors offer a more accurate rainfall estimate but have limited area coverage, coarse spatial resolution and very low repeat frequency. Now there are techniques, which make the best use of the better accuracy of MW sensors and the better spatial and temporal coverage of TIR sensors. This is accomplished by optimally combining the two products. Different statistical techniques are employed by different agencies to accomplish this. Another approach towards better satellite rainfall products is blending the satellite rainfall estimates with available gauge measurements. Generally this is accomplished in two stages. In the first stage the gauge data is used to adjust satellite rainfall estimates for bias errors. Then the satellite product is blended with the gauge observation. The quality of the final product depends on the quality, number, and distribution of the gauges used.

Some semi-operational satellite rainfall products

Global Precipitation Climatology Project (GPCP)
http://precip.gsfc.nasa.gov/gpcp_v2_comb.html

The Global Precipitation Climatology Project (GPCP) combines the precipitation information available from each of several sources into a final merged product, taking advantage of the strengths of each data type. The microwave estimates are based on Special Sensor Microwave/Imager (SSM/I) data from the Defense Meteorological Satellite Program (DMSP, United States) satellites that fly in sun-synchronous low-earth orbits. The infrared precipitation estimates are obtained primarily from geostationary satellites and secondarily from polar-orbiting satellites. Additional low-Earth orbit satellite estimates also come from instruments onboard the NOAA series satellites. The gauge data are assembled and analyzed by the Global Precipitation Climatology Centre. The current products include global monthly 2.5° and daily 1° rainfall estimates. The monthly data extends from 1979 to current, while the daily product is from 1996 to present. Both products are made available with some time delay.

Data from IRI Data Library:
http://iridl.ldeo.columbia.edu/SOURCES/.NASA/.GPCP/.V1DD/
(Daily one deg).
http://iridl.ldeo.columbia.edu/SOURCES/.NASA/.GPCP/.V2/.satellite-gauge/
(Monthly 2.5 deg)

CPC Merged Analysis of Precipitation (CMAP)

http://www.cpc.ncep.noaa.gov/products/global_precip/html/wpage.cmap.htm

CMAP is produced by the National Oceanographic and Atmospheric Administration (NOAA) Climate Prediction Center (CPC) at a spatial resolution of 2.5° with pentad (five-day) and monthly aggregations. This technique produces global precipitation in which observations from raingauges are merged with precipitation estimates from several satellite-based algorithms and is very similar to that of GPCP.

Data from IRI Data Library:
http://iridl.ldeo.columbia.edu/SOURCES/.NOAA/.NCEP/.CPC/.Merged_Analysis/

CPC MORPHing technique (CMORPH)

http://www.cpc.ncep.noaa.gov/products/janowiak/cmorph_description.html

CMORPH is a very new product from NOAA-CPC and it produces global precipitation analyses at very high spatial (8km) and temporal (30 min) resolutions. This technique uses precipitation estimates that have been derived from low orbiter satellite microwave observations *exclusively*, and whose features are transported via spatial propagation information that is obtained entirely from geostationary satellite IR data. This method is extremely flexible such that any precipitation estimates from any microwave satellite source can be incorporated. Data is available starting from December 2002.

Data from IRI Data Library:
http://iridl.ldeo.columbia.edu/SOURCES/.NOAA/.NCEP/.CPC/.CMORPH/

TRMM Combination

http://precip.gsfc.nasa.gov/trmm_comb.html

The Tropical Rainfall Measurement Mission (TRMM) is being flown by the National Aeronautics and Space Administration (NASA, U.S.) and the National Aeronautics and Japan Aerospace Exploration Agency (JAXA, Japan) to improve our quantitative knowledge of the 3-dimensional distribution of precipitation in the tropics. TRMM has a passive microwave radiometer, the first active space-borne Precipitation Radar, and a Visible-Infrared Scanner (VIRS), plus other instruments. Two of the products produced operationally in TRMM are the "TRMM and Other Satellites" precipitation estimate and the "TRMM and Other Sources" precipitation estimate. It optimally merges microwave and IR rain estimates to produce 3-hourly precipitation fields at quarter degree spatial resolution. Then the 3-hourly products are aggregated to monthly and merged with gauge data over land to produce the best-estimated monthly precipitation field. The data sets cover the period January 1998--present (with about a month delay).

Data from IRI Data Library:

http://iridl.ldeo.columbia.edu/SOURCES/.NASA/.GES-DAAC/.TRMM_L3/.TRMM_3B42/.v6/.three-hourly/

African Rainfall Estimation (RFE)

http://www.cpc.ncep.noaa.gov/products/fews/RFE2.0_desc.html

This is a product produced by NOAA-CPC specifically for Africa. The current version, RFE version 2.0(RFE2), started in January 2001. It replaced the previous version, RFE 1.0(RFE1), which was operational from 1995 through 2000. RFE2 uses microwave estimates in addition to continuing the use of cloud top temperature and station rainfall data that formed the basis of RFE1. Meteosat geostationary satellite infrared data is acquired in 30-minute intervals, and areas depicting cloud top temperatures of less than 235K are used to estimate convective rainfall. WMO Global Telecommunication System (GTS) data taken from ~1000 stations provide accurate rainfall totals, and are assumed to be the true rainfall near each station. RFE1 used an interpolation method to combine Meteosat and GTS data for daily precipitation estimates, and warm cloud information was included to obtain dekadal estimates. RFE2 obtains the final daily rainfall estimation using a two part merging process, then sums daily totals to produce dekadal estimates at about 10km spatial resolution.

Data from IRI Data Library:
http://iridl.ldeo.columbia.edu/SOURCES/.NOAA/.NCEP/.CPC/.FEWS/

African Rainfall Climatology (ARC)

http://www.cpc.ncep.noaa.gov/products/fews/AFR_CLIM/afr_clim.html

ARC is also produced by NOAA-CPC at 10km spatial resolution daily. It is very similar to RFE except that 3-hourly TIR data is used instead of 30-minute and it does not include microwave observations. Its objective is to create 1982-present climatology of daily precipitation over African. Currently ARC data is available starting from 1995.

Data from IRI Data Library:
http://iridl.ldeo.columbia.edu/SOURCES/.NOAA/.NCEP/.CPC/.FEWS/

5. Monitoring Temperature

Land Surface Temperature from NOAA-AVHRR

http://iridl.ldeo.columbia.edu/SOURCES/.NASA/.AVHRR-LST/documentation.pdf
The data consist of a unique daily gridded land surface temperature map of continental Africa and Madagascar for each day and each night of the 6-year NOAA-14 lifetime. The data files are organized by year, with separate folders for daytime and nighttime data (e.g., AVHRR_1995_DAY and AVHRR_1995_NIGHT). Data in the LST_UL files correspond to land surface temperature retrieved using the Ulivieri et al. (1994) split-window algorithm, in units of degrees Kelvin. A value of -999 is used for pixels where channels 4 and/or 5 reach saturation (323 K and 330 K respectively). A value of -888 is assigned if the brightness temperatures in Channels 4 or/and 5 are below a processing threshold (230 K), or for pixels with no data (e.g., at the edge of the image). These data have been scale by a factor of 10. Data in CLD files correspond to a cloud mask generated using the CLAVR algorithm (Stowe et al., 1999).

Data from IRI Data Library:
Spatial resolution: 8 km
Temporal resolution: daily
Availability: Jan 1 1995 to Dec 31 2000
Source: http://iridl.ldeo.columbia.edu/SOURCES/.NASA/.AVHRR-LST/.LST/

Land Surface Temperature from MODIS (Aqua and Terra)

http://iridl.ldeo.columbia.edu/SOURCES/.USGS/.LandDAAC/.MODIS/.1km/.8day/.version_005/

The data consist of 8-day composite land surface temperature maps of continental Africa (derived from the MODIS sensor on-board Aqua satellite) and map of South America (derived from the MODIS sensor on-board Terra satellite. The spatial resolution is 1km and maps are available for day-time and night-time images.

Data from IRI Data Library:
Spatial resolution: 1 km
Temporal resolution: 8 day
Availability: Aqua-MODIS (4-11 Jul 2002 to present) over Africa
Source:
http://iridl.ldeo.columbia.edu/SOURCES/.USGS/.LandDAAC/.MODIS/.1km/.8day/.version_005/.Aqua/
Availability: Terra-MODIS (5-12 Mar 2000 to present) over South America and New York state
Source:
http://iridl.ldeo.columbia.edu/SOURCES/.USGS/.LandDAAC/.MODIS/.1km/.8day/.version_005/.Terra/

6. Monitoring Vegetation and Water Bodies

A vegetation index is a simple mathematical formula used to estimate the likelihood that vegetation was actively growing at a particular location whenever it was observed. Most indices were empirically constructed in such a way that larger values correspond to higher probabilities of actually finding live green plants at the selected location and time of observation. As the name implies, the result is a non-dimensional index or indicator of the presence of vegetation.

Some satellite vegetation products

Global Normalized Difference Vegetation Index (NDVI) from NOAA-AVHRR

http://glcf.umiacs.umd.edu/data/gimms/

The GIMMS (Global Inventory Modeling and Mapping Studies) data set is a normalized difference vegetation index (NDVI) product available for a 25 year period spanning from 1981 to 2006. The data set is derived from imagery obtained from the Advanced Very High Resolution Radiometer (AVHRR) instrument onboard the NOAA satellite series 7, 9, 11, 14, 16 and 17. This is an NDVI dataset that has been corrected for calibration, view geometry, volcanic aerosols, and other effects not related to vegetation change.

Data from IRI Data Library:
Spatial resolution: 8km
Temporal resolution: 15-days
Availability: July 1 1981 to Dec 31 2003
Source data:
http://iridl.ldeo.columbia.edu/SOURCES/.UMD/.GLCF/.GIMMS/.NDVIg/.global/.ndvi/

Africa Normalized Difference Vegetation Index (NDVI) from NOAA-AVHRR

http://earlywarning.usgs.gov/adds/imgbrowses2.php?adds=&image=nd&extent=af
EROS processes and archives a dekadal (i.e. ~10 days, 36/year) Africa NDVI product from the NASA GIMMS group called NDVI-g. This dataset is spatially identical to the previous NDVI-e product but has less NDVI signal removed via smoothing. This has resulted in a real-time, operational NDVI product (called NDVI-rg) that can be compared to the historical archive for identification of anomalous vegetation trends. The dataset is inter-calibrated with SPOT Vegetation NDVI, and uses NOAA-17 data since January 2004. The NOAA-17 NDVI data have also been inter-calibrated with NOAA-16 and previous NDVI products. These data are now available from the ADDS server in WinDisp and generic BIL formats. Note that the NDVI data from July dekad 1, 1981 through March dekad 3, 2005 are NDVI-g. The data from April dekad 1, 2005 to present are NDVI-rg. NASA has stated that the NDVI-rg data will be updated to the archival NDVI-g product approximately every 6-12 months.

Data from IRI Data Library:
Spatial resolution: 8km
Temporal resolution: Monthly and 10-days
Availability: July 1 1981 to Dec 31 2004
Source data:

Monthly:
http://iridl.ldeo.columbia.edu/home/.ciph/.USGS/.NDVIG/.monthly/.maximum/.deg0p1/.NDVI/

Dekadal:
http://iridl.ldeo.columbia.edu/home/.ciph/.USGS/.NDVIG/.dekadal/.maximum/.deg0p1/.NDVI/

Vegetation indices from TERRA-MODIS and single channels (blue-red-NIR-SWIR)

http://lpdaac.usgs.gov/modis/mod13q1v4.asp

The Moderate Resolution Imaging Spectroradiometer (MODIS) VI products are designed to provide consistent, spatial and temporal comparisons of global vegetation conditions that can be used to monitor photosynthetic activity. Two MODIS VIs, the normalized difference vegetation index (NDVI) and the enhanced vegetation index (EVI), are produced globally over land at 16-day compositing periods. Whereas the NDVI is chlorophyll sensitive, the EVI is more responsive to canopy structural variations, including leaf area index (LAI), canopy type, plant physiognomy, and canopy architecture. The two VIs complement each other in global vegetation studies and improve upon the detection of vegetation changes and extraction of canopy biophysical parameters.

The MODIS NDVI is referred to as the "continuity index" to the existing 20+ year NOAA-AVHRR derived NDVI time series, which could be extended by MODIS data to provide a longer term data record for use in operational monitoring studies. The AVHRR-NDVI has been widely used in various operational applications, including famine early warning systems, land cover classification, health and epidemiology, drought detection, land degradation, deforestation and in relating large-scale interannual variations in vegetation to climate. The enhanced vegetation index (EVI) is an 'optimized' vegetation index with improved sensitivity in high biomass regions and improved vegetation monitoring through a de-coupling of the canopy background signal and a reduction in atmosphere influences.

Data from IRI Data Library:
Spatial resolution: 250m
Temporal resolution: 16-days
Availability: April 6 2000 to present "updated automatically every 16 days"
Source: http://iridl.ldeo.columbia.edu/SOURCES/.USGS/.LandDAAC/.MODIS/ and Maproom http://iridl.ldeo.columbia.edu/maproom/index.html within Health, Food Security, Fires

7. Merging IRI products with other Remote Sensing Data using NASA-USAID-SERVIR

Users of IRI's Malaria Map Room and desert locust monitoring tools for Africa can take advantage of SERVIR, NASA/USAID's high-tech satellite visualization system, thanks to a new plug-in developed by scientists at the Institute for the Application of Geospatial Technology [IAGT] and IRI.

In helping to port over the data sets to SERVIR, IRI researchers have also expanded the capabilities of the tool: the ability to click on any point on the map to get detailed time series of rainfall and other data.

As with other mapping browsers such as Google Earth, SERVIR allows users to zoom from satellite altitude to any place on Earth, and even tilt their viewing angle so that they can "fly" across a 3-D terrain. What's more, the software taps into dozens of high-resolution satellite-image sources such as MODIS and Landsat. Users can add layers that show temperature, rainfall, and cloud cover over the entire globe. They can even overlay animated weather events, such as hurricanes.

Not only is SERVIR very user-friendly and easy to navigate but it gives Map Room users the opportunity to explore data sets not currently available in IRI's Data Library, such as fire activity, volcanoes and floods.

The ability to render a terrain in 3-D is extremely useful for some societal applications. For example, a pilot who uses the desert-locust monitoring maps to determine which areas to spray can first make a virtual flight, to see exactly where those areas fall in the local topography.

This is only the first step, the next step is to further the collaboration with SERVIR to provide access to all the environmental, climate and forecasting products developed at IRI.

SERVIR software can be downloaded at http://servirtest.nsstc.nasa.gov/downloads.html. *The IRI plug-in can be downloaded from:* http://earthissquare.com/2007/12/17/international-research-institute-for-climate-and-society-iri-plug-in-for-worldwind/

The SERVIR software and IRI plug-in can also be downloaded from:

http://esdevelopment.iagt.org/servirviz/SERVIR_Viz_2.1.7_Full.exe

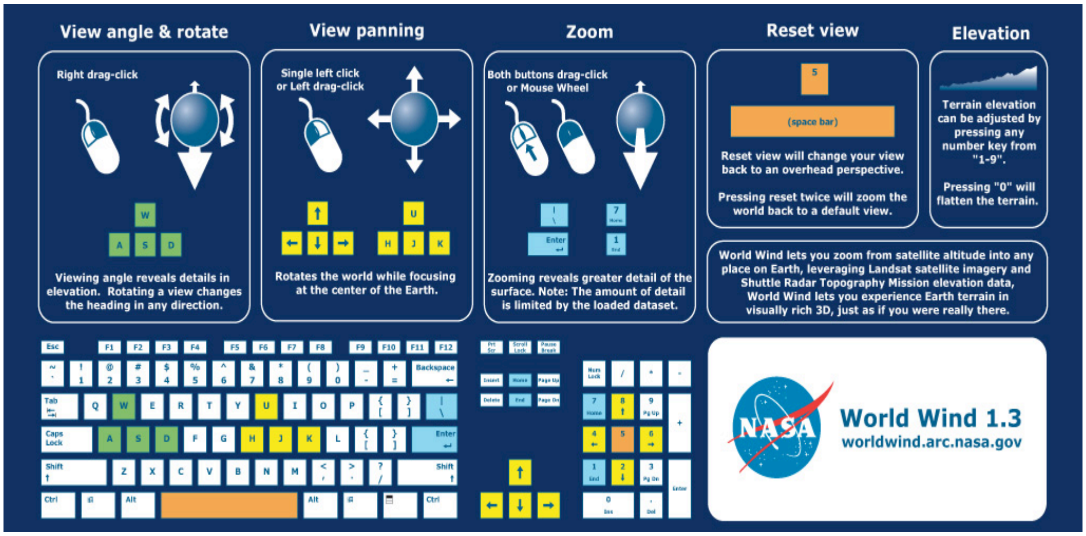
<u>Some Basic Capabilities for Using SERVIR</u>

To begin moving around try left-drag-clicking and moving the mouse. This pans around the Earth while keeping you at the same distance. You can also try single-left-clicking and letting go at any point on the Earth. World Wind will automatically move you to that spot. (You can use the arrow keys on your keyboard instead of a mouse)

To rotate, try right-drag-clicking and moving the mouse. This will spin the perspective around. Please note, single-right-clicking does not work in this mode. (You can use the W, A, S, D keys on the keyboard instead of a mouse)

To zoom in and out, use the mouse wheel to scroll up and down. If you don't have a mouse wheel, you can hold both left & right mouse buttons down at the same time, then move up or down on the mouse. (You can use the Insert and End keys on the keyboard instead of a mouse)

That's all you need to get started! World Wind's advanced features can be accessed through the tool bar (the one that says File, View, Library, and Help). Some of these options can be accessed through the key chart seen below.



Viewing angle reveals details in elevation. Rotating a view changes the heading in any direction.

Rotates the world while focusing at the center of the Earth.

Zooming reveals greater detail of the surface. Note: The amount of detail is limited by the loaded dataset.

Reset view will change your view back to an overhead perspective.

Pressing reset twice will zoom the world back to a default view.

Terrain elevation can be adjusted by pressing any number key from "1-9".

Pressing "0" will flatten the terrain.

World Wind lets you zoom from satellite altitude into any place on Earth, leveraging Landsat satellite imagery and Shuttle Radar Topography Mission elevation data, World Wind lets you experience Earth terrain in visually rich 3D, just as if you were really there.