THE ITC GEONETCAST-TOOLBOX APPROACH
FOR LESS DEVELOPED COUNTRIES

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ABSTRACT:

Through GEOSS, by means of GEONETCast, data has come within reach of users anywhere on the globe. If no efficient processing tools are available the full strength of the system might not be utilized by non-meteorological organizations in less developed countries dealing with geo-spatial temporal data analysis. Here the freeware toolbox developed, to handle and process multiple data sets from the GEONETCast dissemination system, is discussed. Efficient processing tools are required to incorporate the data and make it available to improve national and regional policy and (timely) decision making for a better management of the natural resources and face the challenges posed by sustainable development. A number of examples are provided demonstrating the versatile nature of the toolbox processing capability using the (near real-time) data available through GEONETCast. The examples shown are highly relevant with respect to e.g. environmental monitoring and provide meaningful information to assess flood, drought and agricultural conditions, all of which are currently major issues in many regions around the world, especially in Africa.

1. INTRODUCTION

Sustainable development requires coordinated, comprehensive and sustained Earth observations for early warning, informed policies and effective decision making. In support of this objective the Group on Earth Observation (GEO) is leading a worldwide effort to build a Global Earth Observation System of Systems (GEOSS), providing Earth observations from a multitude of instruments worldwide. It is foreseen that these Earth observation data (in-situ, air and space borne) and derived products are (re) distributed via GEONETCast to a broad range of user communities. Therefore GEONETCast, bringing together the many disparate sources of environmental information, has a significant potential to enhance access to a wide range of information to users who may not previously have had access to these resources (GEO, 2007). This low cost, global, environmental information delivery system currently operates the European, African and American services and successful tests have been conducted to cover the Asia-Pacific region recently (by means of FENGYUNCast). This effort will ensure global coverage in the near future. The data stream transmitted by these communication satellites can be received using a simple and cheap ground reception infrastructure.

GEONETCast distributes images that have been used previously mainly by the Meteorological community but which are becoming an important data source to a wide variety of users that deal with environmental analysis. Sensor improvements, especially spatial and temporal resolutions, the (favorable) data distribution policy and the way the data are obtained by the user community are to be attributed in this respect. With the ongoing development of GEONETCast, broadcasting (globally) a multitude of satellite observations and associated products in conjunction with cheap ground receiving

infrastructure, the data is now at the doorstep of the user community anywhere in the world. Problems related to a limited bandwidth available in many less developed countries are overcome. Efficient processing and analysis routines are required to facilitate incorporation of these environmental data sources and products to improve national and regional policy and (timely) decision making for a better management of the natural resources and face the challenges posed by sustainable development. The low cost ground receiving segment coupled to a freeware toolbox approach discussed below is well suited for non-meteorological organizations in less developed countries dealing with environmental related application domains. The capability that has been developed is described using various data sources available in the GEONETCast data stream, import and semi-automated (multitemporal) processing routines are presented using several freeware packages in combination with generic MS-Windows functionality to easily incorporate the data into a freeware Geographical Information System which can than be used for subsequent analysis.

2. SOME ONGOING DEVELOPMENTS IN SUPPORT OF GEONETCAST

Satellite, in-situ data and products are transmitted via GEONETCast to users through communication satellites using a multicast, access controlled, broadband capability. More organizations are going to provide data and services to GEONETCast, e.g. China (Fengyun 1D/Fengyun 2C) and Russia (by means of MITRA). Primarily satellite based meteorological data will be provided, but both countries anticipate that in the future next to satellite observations also airborne and in-situ data are disseminated. Currently NOAA is actively developing the GEONETCast-Americas capability.

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Next to ongoing and continued provision of environmental products like those from Vegetation for Africa initiative (http://www.vgt4africa.org) it is also expected that more data and product providers will join in the near future, e.g. the CBERS initiative (http://www.cbers.inpe.br) to provide medium resolution satellite data for Africa as announced at the GEO-IV and Ministerial Summit in Cape Town (November 2007) and data processed by SERVIR (http://www.servir.net) for Central America. Technically the data dissemination services have obtained (near) global coverage making data available for all societal benefit areas defined under GEO. However GEONETCast is not a data processing system and therefore a gap exists between the data access through local ground receiving stations and making use of the data-processed information. For the societal benefit areas more organizations come into play than only the traditional meteorological offices who have a national mandate to process this huge stream of (near real-time) data and in general have the capability to do so (e.g. for Africa through provision of the necessary infrastructure by the PUMA-AMESD programme). This is different for the other organizations addressing the challenges covering the full range of societal benefit areas. Currently it is already difficult to cope with the data stream from e.g. the several instruments onboard of METOP and therefore the African service is not broadcasting this data at this moment. At present this data stream is only available via Hotbird, using Ku reception. This shows that a continuous data (pre) processing capability development effort is required to cope with the increasing range of environmental information disseminated by the system.

The data provided are not in a format which is commonly used by the Earth Resources Remote Sensing community (an image or product is often split into several data packages – segments, eventually compressed, etc). Therefore only a few Windows Operating System based freeware tools are currently available that provide limited or dedicated capability to incorporate data from GEONETCast, like XRIT2PIC (http://www.alblas.demon.nl) and SUMO, developed by the South African Weather Service (http://www.weathersa.co.za/SUMO). The first is capable of handling data from MSG, so called foreign satellites (GOES East and West, MTSAT1R and Meteosat-7) and METOP-AVHRR/3 and is transforming the data to pictures; the second package mainly uses MSG HRIT data for near real-time visualization, nowcasting and short range forecasting and furthermore has the option to display other ancillary information like an Instability Index and the Fire product. Both are using a data or file manager to cope with the incoming data stream. To handle data from METOP, a package called EPSView (http://www.eumetsat.int) is available, providing a quick and easy look at earth observation products from several instruments onboard of METOP and NOAA. Another freeware tools is BEAM (http://brockmann-consult.de/beam) and a plug-in exists for EPS formatted METOP-AVHRR/3 level-1B. From EPSView the data can be exported to IDL for more complex analysis. The BEAM METOP-AVHRR plug-in is offering a radiometric calibrated import capability of the AVHRR data but the geometry is currently not handled correctly. Satsignal's suite of Weather Satellite Tools (e.g. Satellite Tracking, HDF and Grib Viewer, MSG, AVHRR, Metop Manager and GeoSatSignal software tools) (http://www.david-taylor.myby.co.uk/software/wxsat.htm) is another alternative, but after a short trial period the software has to be registered and one has to pay the registration fee upon providing a hardware fingerprint for the PC where the software is to run. These routines, very comprehensive though, in general lack the export capability (apart from pictures) into common used RS-GIS

formats and the calibrated data is often only available by direct readout on the screen.

3. THE ITC GEONETCAST TOOLBOX APPROACH

In order to effectively address the challenges posed by several of the societal benefit areas not only data is required but also a set of tools which transform this data stream into information which in turn can support the decision making process. The toolbox developed and described into more detail below has to be seen as a contribution towards meeting that need. In Maathuis et al (2006) a description is provided to setup and operate a low-cost GEONETCast ground receiving station. Here a C-band receiving configuration, relevant for Africa, is described as well as initial software tools developed mainly focusing on Meteosat Second Generation HRIT data. Firstly a software tool called the MSG File Manager was developed, which moves the (selected) newly received data packages onto a storage device in a structured manner. Secondly, with the help of the MSG Data Retriever the Meteosat-8 and 9 files can be imported and used in common available remote sensing software packages. The Data Retriever uses the MSG Level 1.5 data product format and can therefore also be used in conjunction with data obtained from the EUMETSAT Archive. In the menu of the Data Retriever different options can be selected to handle the pre-processing and radiometric - geometric conversions. In this way time series of images can be easily created and for further analysis of the data, use can be made of ILWIS 3.31 and 3.4, a keyless and open source version respectively, that have recently become freely available (http://www.itc.nl/ilwis and http://52north.org). Additional tools to assist in multi temporal data analysis have been improved and integrated. Other capabilities incorporated are e.g. computation of solar and MSG satellite azimuth / zenith angles.

Recently, for import and processing of other data sources and products in the GEONETCast data stream (e.g. from the Meteorological Product Extraction Facility, the Satellite Application Facilities and 10 day VGT4Africa products) new routines have been developed. A GRIB/GRIB2 decoder was added to the Geospatial Data Abstraction Library (GDAL) (http://www.gdal.org), a translation library for raster geospatial data formats also used for HRIT data format exchange - import routines described above. Simple batch routines have been developed to import common products such as the Cloud Mask, Cloud Top Height, all imported from their original GRIB format. The individual data segments of these products received via GEONETCast are first merged together to obtain a single file (using a tool developed called joinMSG) and are subsequently imported. Cipher BUFR decoding (http://www.northern-lighthouse.com) is used to handle the BUFR encoded products from GEONETCast and the EUMETSAT archive. Products successfully imported from BUFR format are e.g. various Global Instability Indices (K-index, KO-index, Lifted index and amount of Precipitable Water) and Atmospheric Motion Vectors. A tool to delete the header lines was developed and therefore the intermediate ascii table generated, only consisting of space delimited columns, can be automatically imported into ILWIS. Using this method the header lines are removed from the 15 minutes Fire Product (FIR-A, available as an ascii table) and this product can therefore also be imported using simple batch routines.

Using a batch loop sequence the import routines can handle the import of multiple images in an automated manner (also dealing

with geometry and data conversion into appropriate unit). For these procedures ILWIS is operated from the command prompt using the ILWISComClient utility. For (near) real-time visualization batch routines that are run using the Scheduled Tasks Manager of the Windows Operating System initiate ILWISComClient and ILWIS based scripts are executed that handle the import, processing and visualization in an automated manner. Another small batch routine, called gettime.bat (developed by Frédéric Cazenave, Radar Engineer, Cotonou, Benin), handles the time (zone) and the file time-stamp offset to ensure that correct files are imported and processed. In all cases use is made of IrfanView (http://www.irfanview.net/) for visualization using the command line options in a batch routine. Having efficiently imported and (pre-) processed (and eventually visualized) the data further analysis is possible using the generic GIS, Remote Sensing and (time-series) calculation capability of ILWIS for different applications.

Next to these resources another tool was developed to directly copy, import and visualize the Multi Sensor Precipitation Estimate from Meteosat 9 without the use of GEONETCast (MPE is available at: http://oiswww.eumetsat.org/SDDI/html/grib.html), although the data is available in the data stream (MPEG). This was done to facilitate organizations that currently do not operate a ground receiving station but have internet connection. For data import into ILWIS use is made of another GRIB2 import utility (http://www.cpc.ncep.noaa.gov/products/wesley/wgrib2/index.html). The batch routine developed is configured such that it checks for a new MPE file every 15 minutes at the Eumetsat website, copies the grib file(s) to a local hard disk - directory and imports – processes the data. Using IrfanView an animated sequence of images can be visualized if the application is operated for a couple of hours. The generic ILWIS functionality, e.g. the Maplist Statistic's Sum Function facilitates computation of the 24 hr aggregated rainfall of the 96 initial MPE products. The described toolbox, or parts thereof, is currently operated at the Geographic Information Systems & Remote Sensing Research Centre (CGIS) of the National University of Rwanda in Butare, Rwanda, at the African Monsoon Multidisciplinary Analysis (AMMA) project (in conjunction with IRD, France) in Benin, University of Connecticut, USA and University of Dresden, Germany. Also a weather amateur from Wolfsberg, Austria reported that the toolbox was operational.

4. EXAMPLES FROM GEONETCAST USING THE TOOLBOX

A number of examples are provided below demonstrating the versatile capability of the toolbox. Most routines can be operated fully automatically when included in the Windows Scheduled Tasks Manager and facilitate image import, calibration and visualization at user defined time intervals. At a given system clock time a batch file is executed, a year-month-day-hour-minute string is generated and corresponding image or product from the GEONETCast data stream (or directly from the Eumetsat website) is extracted and processed. The geographic window can be easily adapted and a time stamp can be added. Figure 1 shows a pseudo natural colour transformed composite of channels 006, 008 and 016 (left) and a pseudo colour transformed image using the same low resolution channels in combination with the High Resolution Visible channel of MSG, resampled to 1 km spatial resolution. The output is exported to a tif and using IrfanView animations can

be created. It is also possible using the scroll button of the mouse to interactively visualize an animation on the screen.
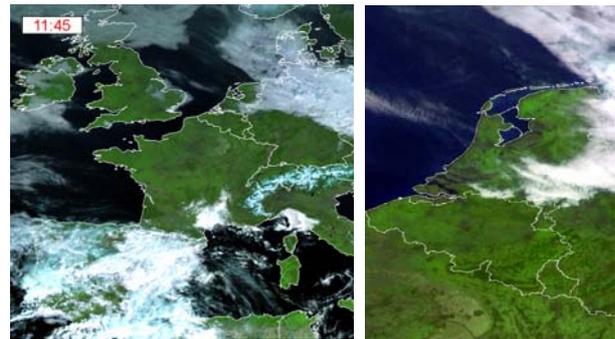

Figure 1. Near real-time Meteosat visualization

Figure 2 shows the result of a classification using MSG channel 108 and 062, applying a threshold on the temperature difference of less than 11 Kelvin (an empirically determined threshold by Kidder et al, 2005) giving an approximation of the clouds that have a high likelihood of precipitation (left). The centre picture shows the cloud phases using MSG channel 108 brightness temperature (Tb); classified as cloud and Tb above 261 K, Tb between 243 and 261 K, Tb between 233 and 243 K and Tb below 233 K, in blue, green, orange and red respectively. These classes represent mainly water vapour–water droplets, mixture of water droplets and ice crystals, predominantly ice crystals and ice cloud respectively (thresholds after Strahler, 1968, pp. 187). The left hand picture shows the clouds, classified using the Cloud Top Height product. The height range class thresholds are according to Strahler (1968) to assist in the identification of clouds types based on altitude (<500 m, 500-1500 m, 1500-3000 m, 3000-6000 m, 6000-10000 m, > 10000 m; from low to very high respectively).
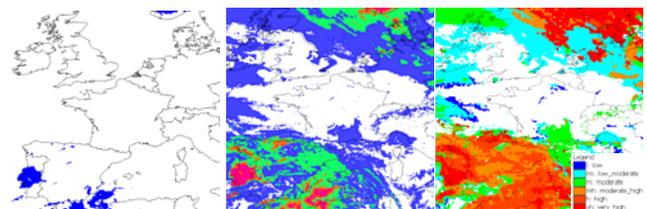

Figure 2. Cloud properties

Instability indices contained in the GII product provide some information concerning the vertical stability of the atmosphere. Air mass parameters can be used to issue severe weather warnings by a skilled forecaster if a certain index exceeds a threshold (which is not a fixed value and varies from season to season). The retrieval algorithm only works for clear sky conditions, no instability data is inferred for cloudy pixels (Eumetsat, 2007). Figure 3 shows an example of the K-index (left), K values over 30 are indicative of strong convection potential and if K values over 40 are observed severe storms are to be expected. The resolution is 45 km/pixel (average of 15 by 15 MSG pixels). Using the combination with precipitable water (right) has as advantage that also an idea can be obtained of possible rainfall as more significant precipitation events are associated with higher precipitable water values (Dostalek and Schmit, 2001). Also on a 3 hour basis the Cloud Analysis Image is available with a cloud type classification (bottom).
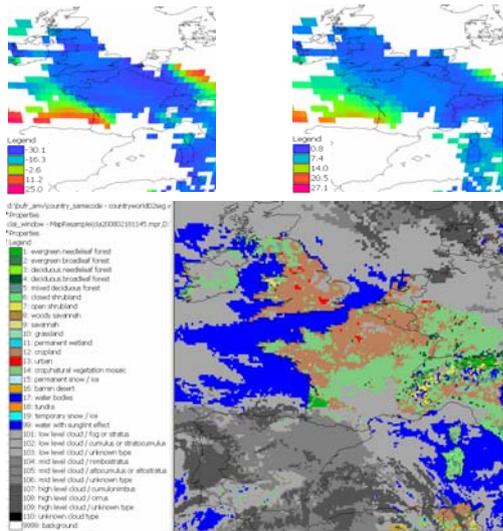
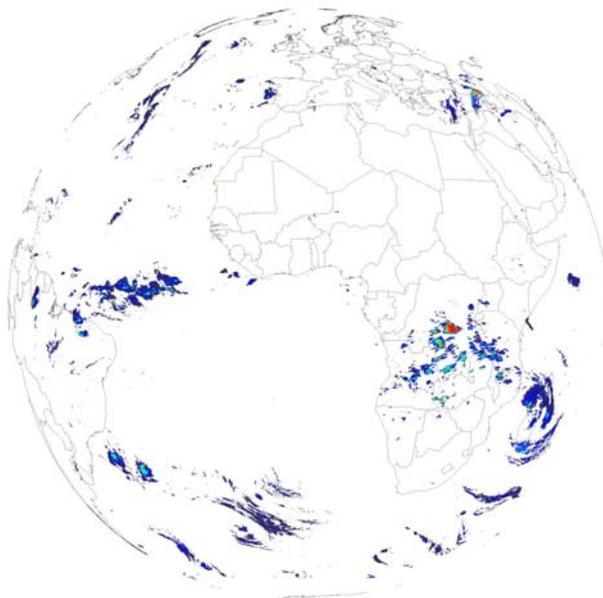Figure 3. K-index, precipitable water and cloud analysis image

Figure 4. Multi Sensor Precipitation Estimate

The multi sensor precipitation estimate (MPE) is directly retrieved from the Eumetsat Website, so even organizations not operating a ground receiving station can utilize this information, as this important parameter is affecting people in a very direct way. To derive the MPE use is made of the relationship between cloud temperature and rainfall intensity, as colder clouds are likely to produce more rainfall. The MPE uses a statistical matching algorithm in temporal and geographical windows to correlate the SSM/I instrument derived rain rates with Meteosat IR brightness temperature images. The obtained relationship is lateron converted to the full Meteosat-9 temporal resolution and a MPE product is generated each 15 minutes. The algorithm performs well for the tropical and subtropical convection areas. The relationship is based upon SSM/I – Meteosat co-located pixels from 40 degree North to 40 degree South (Heinemann et al, 2002). With the DMSP program (two satellites in polar-orbit array), a given location on Earth is

revisited every 6 hours, allowing 4 brigthness temperature versus rain rate calibration events on a 24 hr basis. The MPE example presented in figure 4 is of the same day-time as those given for figures 1, 2 and 3.
Figure 4: The multi sensor precipitation estimate

Atmospheric motion vectors are available at a lower temporal resolution as the product is generated by applying a correlation algorithm to a sequence of images. By tracking of the movement of the cloud field or humidity structures, winds can be extracted. Height is determined from the infrared temperature and converted to pressure (http://www.eumetsat.int). The para-meters extracted from the BUFR file are longitude, latitude, pressure, wind direction, wind speed and temperature. The wind direction is classified into three classes using pressure thresholds (< 35000 Pa, 35000-65000 Pa and > 65000 Pa) for the high, medium and low wind vectors which are displayed in red, green and blue respectively. The approximate elevation in meter (z) is derived according to an equation as given by Lunde (1980) ($z = -1/0.00001184*(\ln(Pa/101325))$ assuming normal pressure at sea level. For visualization a predefined ILWIS MapView is used, containing the country boundaries and the classified wind direction vectors are shown, scaled according to the wind speed.
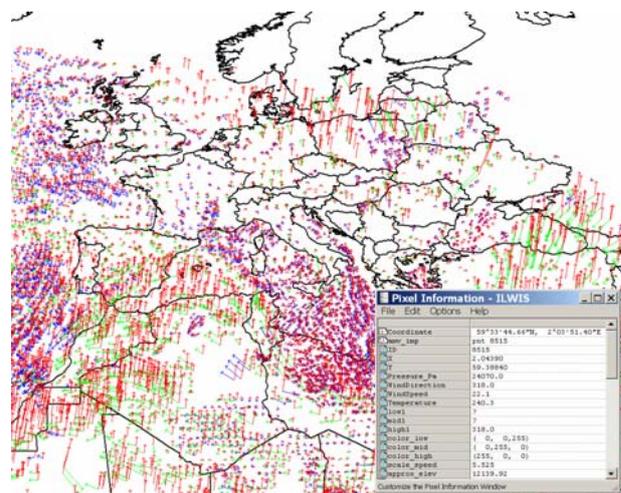

Figure 5. Atmospheric motion vectors

Figure 6 shows the extracted Fire product. The header lines in the original ascii file are removed and the space delimited columns are imported into an ILWIS table, which subsequently is transformed into a point map an visualized with the country boundaries. A different symbol size is used for the possible and probable fires given in the table. The temporal resolution of this product is also 15 minutes, which makes it ideal for a fire monitoring system.
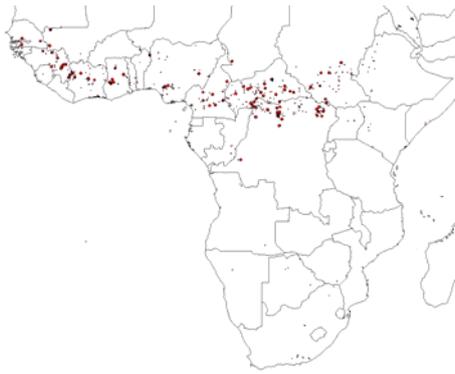
Figure 6. The fire product

Another product available at a 15 minutes interval is the Land Surface Temperature (LST), generated by the LandSAF (Meteo Portugal, http://landsaf.meteo.pt). The data is compressed and delivered in a HDF5 format. Using FWtools version 2.1.0 (http://fwtools.maptools.org) the HDF can be converted to ILWIS and additional script routines are incorporated to attach the proper projection information to the northern and southern African windows, glue to maps to cover the whole continent, convert the data to temperature in degree Celsius and finally re-assigns the pixels covered by water and clouds. The import procedure starts with a decompression which is facilitated using bzip2 (http://www.bzip.org/downloads.html) from within the batch routine. An example of the imported product is given in figure 7. More LandSAF products are to be expected in the future (e.g. an evapotranspiration product) which can subsequently be imported anticipating only slight adaptations to the batch routine developed for the LST product.
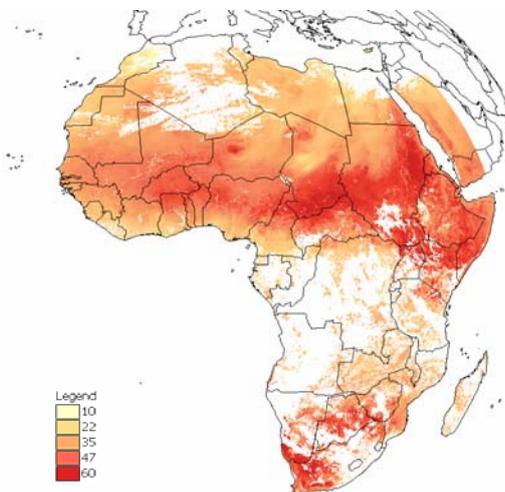

Figure 7: Land Surface Temperature

Other import routines developed deal with the Low Rate Image Transmission data (LRIT) in the GEONETCast data stream from the so called foreign satellites. An example is given in figure 8, displaying a global mosaic of images taken from GOES-West, GOES-East, MSG, Meteosat-7 and MTSAT-1R. The radiometry of GOES is also handled to convert the respective spectral channels in albedo and temperature. First the data received via GEONETCast is decompressed, the segments of the images are glued together and the data is imported, the 10 bit data of GOES is transformed to 16 bit prior to import.

Within a three hour period global composites can be made of images acquired by these geostationary satellites.
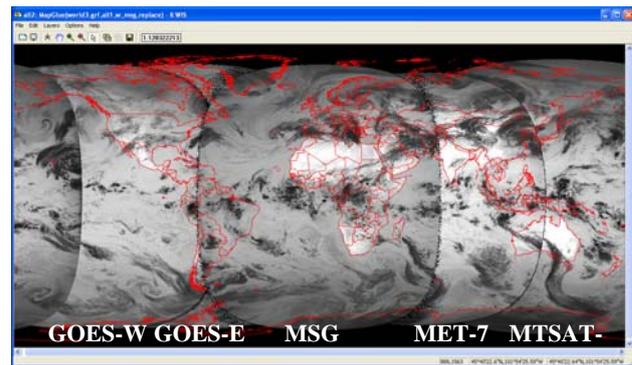

Figure 8: Foreign Satellite thermal infrared global composite

5. PRODUCTS FROM EXTERNAL DATA PROVIDERS IN GEONETCAST

Already for some time a number of derived products based on the SPOT Vegetation Instrument are disseminated via GEONETCast. At a 10 day interval several of the Vegetation for Africa products can be received. The free VGTExtract tool (http://www.vgt4africa.org) can be used to unzip the data, transform it e.g. into an ENVI hdr file using the appropriate calibration coefficients (VGT4Aftrica User Manual, 2006). But the VGT products can also be directly imported into ILWIS using batch routines to decompress the files (using pkunzip, available at: http://www.freewarehof.org/olhof.html), read the HDF4 formatted data (using the FWtools utility as described above) and transforming the data into the appropriate units and assigning the projection information. Figure 9 shows a number of decadal products from VGT4Africa.
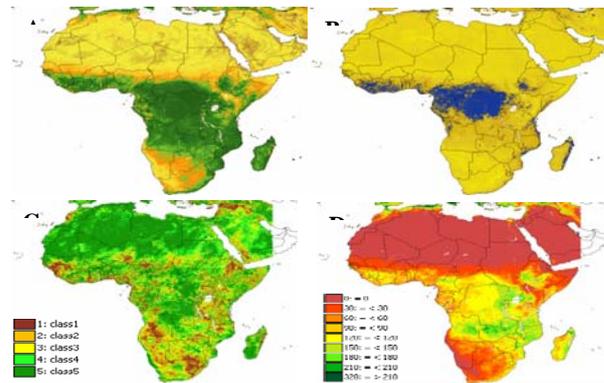

Figure 9: VGT4Africa products in GEONETCast

(A): Normalised Difference Vegetation index, (B): Normalised Difference Water Index, (C): Vegetation Production Indicator, (D): Dry Matter Productivity

The NDVI is calculated by comparing the visible and near-infrared sunlight reflected by the surface. The NDWI is a dimensionless index that indicates the presence or absence of water on the surface and is calculated by comparing the shortwave and near-infrared sunlight reflected by the surface. The VPI is used to assess the overall vegetation condition and is a categorical type of difference vegetation index, whereby the actual NDVI is referenced against the NDVI percentiles (in 5

classes) of the historical year. The classes represent below (class1), normal (class 3) and above (class 5) normal vegetation conditions respectively. Finally, the DMP is an indication of the dry matter biomass increase (growth rate) and is expressed in kg/dry matter/ha/day. More details are given in the user guide.

The examples shown demonstrate the versatile nature of the freeware toolbox using the (near real-time) data available through GEONETCast. This is highly relevant with respect to e.g. environmental monitoring and provides meaningful information to assess flood, drought and agricultural conditions, all of which are currently major issues in Africa. Using simple batch routines additional toolbox functionality can easily be created to address the specific User's need. As more data-information will be released through GEONETCast it is anticipated that more import and preprocessing routines will be developed. Using off the shelf equipment to build a low cost ground receiving station, in conjunction with free data (when applying for a research and education license through EUMETSAT) and the freeware toolbox described here a number of essential prerequisites are fulfilled to develop (through capacity building) a sustainable basis for regular operations and research. Dowman (2008) stated that: "Disasters are not only physical; they may occur when potentially valuable initiatives collapse due to inadequate resources". GEONETCast is such a potential initiative and the toolbox described here provides a resource to incorporate a variety of basic environmental data of various formats (MSG-level 1.5, BUFR, GRIB/GRIB2, HDF4/5, ascii tables) for further spatial and temporal analysis into a GIS.

6. CONCLUSIONS

Through GEOSS, by means of GEONETCast, data has come within reach of users anywhere on the globe. If no efficient processing tools are available the full strength of the system might not be utilized. The toolbox development effort described here is a low-cost alternative to retrieve regular data and products relevant to a broad range of environmental and hydrological applications by non-meteorological organizations in less developed countries dealing with geo-spatial temporal data analysis. It is anticipated that these tools are further developed using Open Geospatial standards and are integrated in IWLIS 3.4 by means of a convenient user interface. To overcome the limitation of 24/7 real time transmission – reception, especially with respect to construction of time series (and the investment needed for local storage) it should be considered that GEONETCast will also be used to provide data from e.g. the Eumetsat archive. A user in need of e.g. 1 year of 12.00 UTC daily MSG images should be able to send this request and the data is delivered to this user via GEONETCast. Furthermore, there is a need to expand the local receiving capability, especially at universities in less developed countries. Strengthening the role of the universities will guarantee the supply of graduates that utilize the potential of GEONETCast and can apply their knowledge and skills later as employees of the different organizations dealing with the societal benefit areas.

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Remark: all web addresses presented in the article have been accessed during the last week of February 2008.