# GEONETCast Data stream for Large River basins

## Contents




Arno van Lieshout

WRS Deparment

Faculty of Geoinformation science and Earth Observation (ITC)

University of Twente

# 1. Introduction

In 2008 ITC started to develop an open-source system to import images and products which are disseminated via EUMETCast-GEONETCast. GEONETCast is a global network of communication satellite based data dissemination systems – provides free near real-time environmental and Earth observation data (in-situ, airborne and space based) and derived products to a worldwide user community. It is part of the emerging Global Earth Observation System of Systems (GEOSS), led by the Group on Earth Observation (GEO) and has become an easy and effective way for countries to receive satellite and environmental data. EUMETCast is now also available for use by the European Global Monitoring for Environmental Security (GMES)[1] initiatives and many other environmental data providers. EUMETCast is also a contributing to the Integrated Global Data Dissemination Service (IGDDS), a component of the WMO Information System.

Earth Observation date is collected via a large number of satellites and sensors and stored on numerous locations on the worldwide web. To access the date requires a stable internet connection with a large bandwith and an elaborate action to get the required data into your own system. To overcome these obstacles ITC has jointly with other parties develop a toolbox through which data which is broadcasted through EUMETCast-GEONETCast system can easily be accessed. Fig 1. shows the overall concept of the GEONETCast toolbox plug-in to ILWIS.

The GEONETCast toolbox is integrated in the Integrated Land and Water Information System Remote Sensing and GIS software (ILWIS). ILWIS is a PC-based GIS & Remote Sensing software, developed by ITC up to release 3.3 in 2005. ILWIS comprises a complete package of image processing, spatial analysis and digital mapping. It is easy to learn and use; it has full on-line help, extensive tutorials for direct use in courses and 25 case studies of various disciplines. As per 1 July 2007, ILWIS software is freely available ('as-is' and free of charge) as open source software (binaries and source code) under the 52°North initiative (GPL license). This software version is called 'ILWIS Open' and is downloadable through http://www.itc.nl/ilwis/downloads/ilwis33.asp.

Besides the access of data through the EUMETCast-GEONETCast local receiving system a lot of data is made openly available through internet. To provide easy access to this data ITC has developed the "***In Situ* and Online Data Toolbox'** (ISOD) to easily digest these data sources, to use this obviously a stable internet connection is required. The toolbox is identical in design to the other toolbox plug-ins.

Through various projects ITC has established an active African GEONETCast community. The GEONETCast & OS Systems is widely used in various FP7 projects[2] focusing on various parts of the globe jointly with VITO, JRC and Technical University Delft. With ITC support receiving stations and dedicated training in GEONETCast Toolbox applications has been provided in among others: Lake

[1] Now called Copernicus (2013)
[2] EU FP7 projects CEOP AEGIS, GEONETCab and DEVCOCAST

Chad Basin Commission, National University Rwanda, Regional Center of Mapping for Regional Development (RCMRD-Nairobi) and the University of Western Cape.

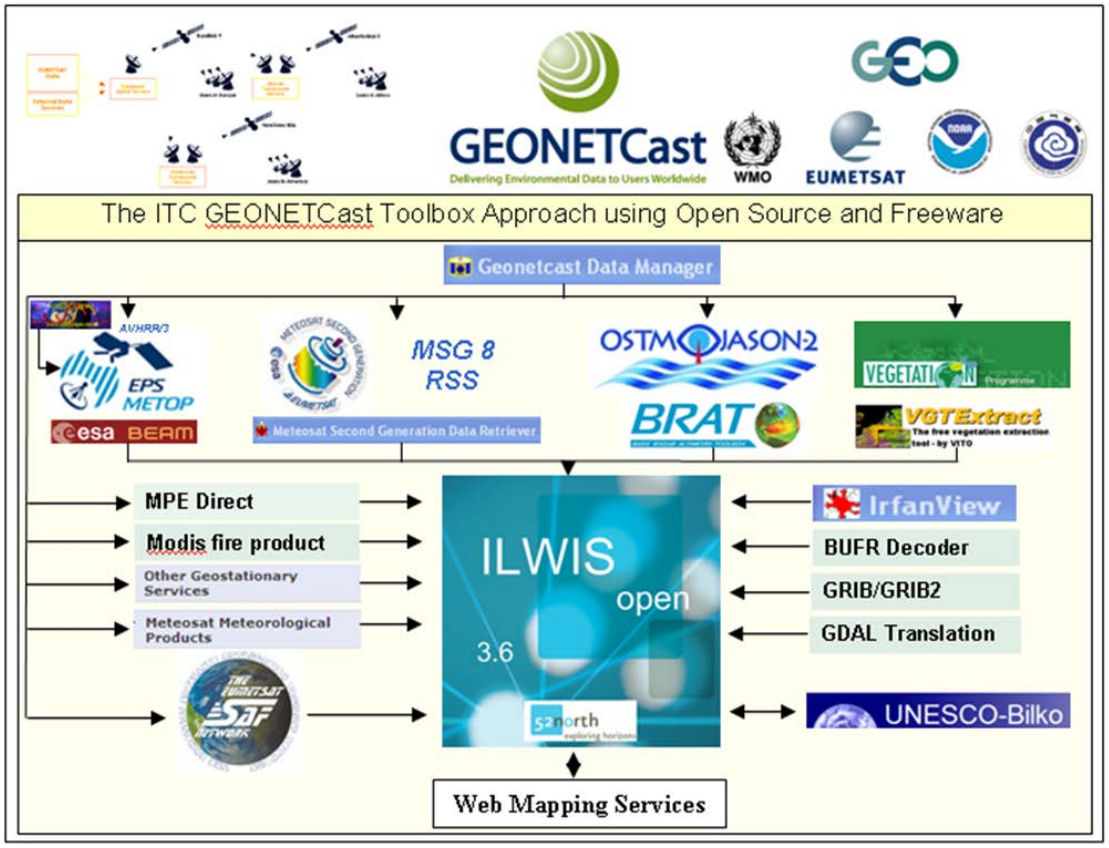


Figure 1 The GEONETCast Toolbox Approach

The ICMA has requested ITC to provide a short overview on the images available through GEONETCast for applications in River Basin Management. In addition to that some additional information will be provided related to the set-up of the system and the available training materials.

## 2. Set-up of EUMETCast-GEONETCast system

EUMETCast is a multi-service dissemination system based on standard Digital Video Broadcasting (DVB) technology for environmental data using commercial telecommunication satellites to multicast data and products. A single reception station can potentially receive all the data being transmitted from one communications satellite independent of the data provider. A typical EUMETCast reception station comprises a standard PC with DVB card inserted and a satellite off-set antenna fitted with a digital universal V/H LNB for Ku-band, or fitted with a circular polarisation feedhorn, bandpass filter

and special LNB for C-band. To decode and decrypt the DVB signal, EUMETCast Client Software and in some instances, EUMETCast Key Unit (EKU) are also required.

The cost of EUMETCast reception stations is kept to a minimum by utilizing industry open standards to the maximum extent possible thus resulting in an adaptable front-end solution to users' applications.

In addition to the front-end equipment, EUMETCast Client Software and hardware key (EKU), data processing software will be required. Before the EUMETCast/GEONETCast system works at your desk a simple registration procedure at EUMETSAT need to be followed. Delivery of data is restricted to non-commercial users.

In the table below the standard hardware and indicative costs are given:

| **Hardware** | **Cost (Euro)** |
|---|---|
| LNB/Feedhorn, Antenna for C-band Reception (2.4 meter diameter) high-end | 800 |
| DVB PCI Card | 100 |
| EUMETCast Client Software | 60 |
| 2 x PC, Hard Disk, Ethernet | 2000 |
| Data storage (initial set-up 3TB) | 300 |
| LAN Network switch box | 50 |
| EUMETCast Key Unit (EKU) | 40 |
| **Total** | **3350** |

**Table 1 Standard hardware and indicative cost for GEONETCast receiving system.**

Depending on the archiving requirements additional data storage capacity has to be purchased.

The GEONETCast-toolbox is free-ware and open source plug-in to the ILWIS package. The GEONETCast toolbox can be tailored for the data requirement of ICMA as has been done for other users such as WFP-Ethiopia and AMESD-SADC-THEMA.

# 3. Useful datastreams

In GEONETCast a wealth of environmental data is available. The strength of GEONETCast is the easy access to near-real time hydrology related earth observations. Depending on the sensor and processing which has been done the spatial and temporal resolution varies. Over 200 products are available through GEONETCast here only an overview is given of the data which is most useful for CMA's.

## 3.1.Rainfall

Of course rainfall is the most researched and 'wanted' information water managers would like to obtain with both a high spatial and temporal resolution. In the past years a lot of research has been done to access the accuracy of the satellite-based rainfall estimates (SRFE). Ebert et al. (2007) Kidd (2011) and more recently Thiemig et al. (2012) have evaluated extensive rainfall measurements and estimates to obtain reasonably homogeneous validation figures for SRFE. Thiemig gives after an extensive research over several catchments in Africa a comprehensive summary of the value of SRFE. Detectability of rainfall on an event basis and over mountainous area can be done however with a relatively low accuracy. SRFE provides a good representation of the spatial patters across basins.

Continuously algorithms for rainfall retrievals are being improved. Blending with ground observations and ground-radar images does improve the quality of the observations to a great extent. In the near future the SRFE capability will improve with the foreseen launching of the Meteosat Third Generation and Sentinel-3. Below a summary is given of the available SRFE through GEONETCast toolbox.

| **Product** | | **Resolution temporal** | **Spatial Resolution** | **Remarks** |
|---|---|---|---|---|
| MPEG | Multi-Sensor Precipitation Estimate - Geostationary | 15 minutes | 3km at nadir . ~ 6 km near SA | The Multi-Sensor Precipitation Estimate (MPE) product consists of the near-real-time rain rates in mm/hr for each Meteosat image in original pixel resolution. The algorithm is based on the combination of polar orbiter microwave measurements and images in the Meteosat IR channel by a so-called blending technique. The MPE is most suitable for convective precipitation. Applied for operational weather forecasting in areas with poor or no radar coverage. |
| MPEA | MPE-aggregated | 24 hours | " | MPEG product is aggregated for 24hrs |
| TAMSAT a | Accumulated rainfall | 10 days - monthly | 3km at nadir . ~ 6 km near SA | Combines Passive Microwave, MSG thermal images and Gauging data. Decadal and monthly aggregates are made. Long historical record available (since 1983) so also anomalies map can be generated. |
| TAMSAT Anomaly | Accumulated rainfall anomalies | 10 days - monthly | | |

**Table 2 Overview of Rainfall products in GEONETCast toolbox.**

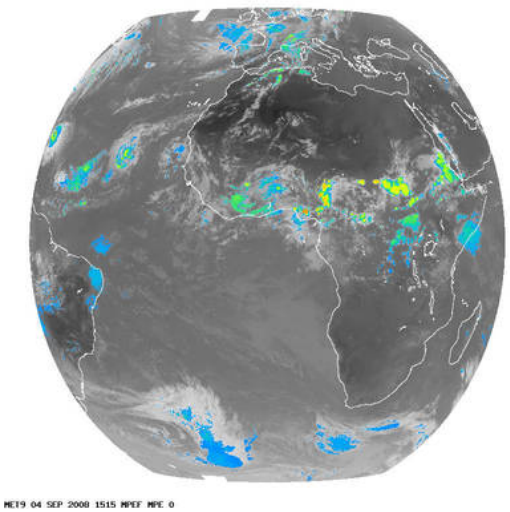


Figure 3 MPE 24 hr rainfall aggregate

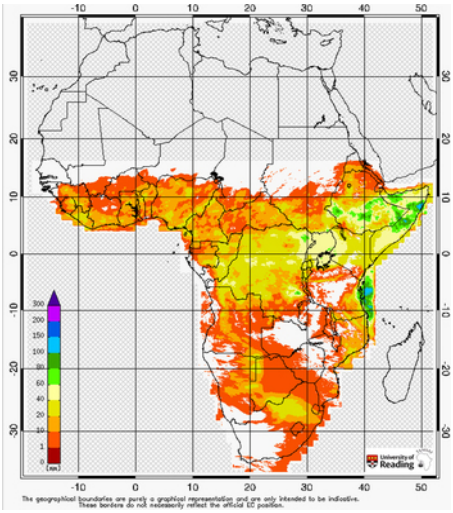


Figure 2 TAMSAT decadal rainfall product

In ILWIS aggregated rainfall for the basin can easily be obtained based on catchment boundaries. Through webmapping services daily rainfall estimates can be directly transposed over Google Earth (see fig 4).

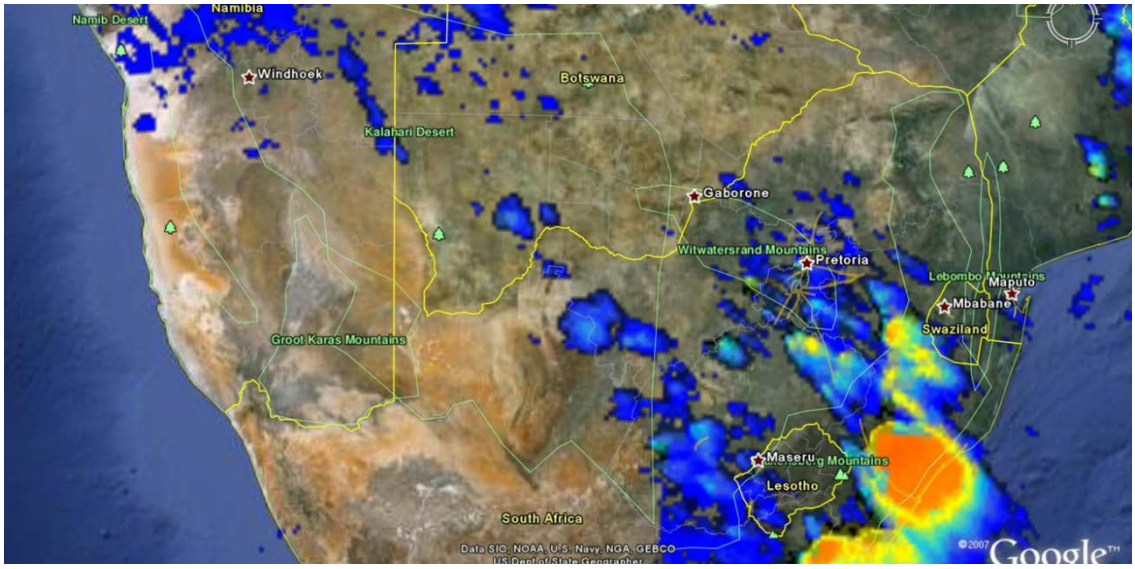


Figure 4 MPE 24 hour rainfall aggregate in Google Earth.

## 3.2.Other Rainfall products available via ISOD

| Product | | Resolution temporal | Spatial Resolution | Remarks |
|---|---|---|---|---|
| CMORPH[3] | CPC MORPHing technique | -30 min.<br><br>- 24 hr<br>- weekly | - 8 km at nadir .<br>- 0.25 degr.<br>- 0.25 degr. | Blended product of various satellites combining thermal/optical and microwave images |
| TRMM:[4] | Tropical Rainfall Measuring Mission | 3-hourly | 0.25 degr. | Derived from various EO products. The final gridded, adjusted merged-IR precipitation (mm/hr) and RMS precipitation error estimates have a temporal resolution and spatial resolution. |
| RFE2 | Africa Rainfall Estimate | Decadal | 8km | RFE 2.0 uses CCD (derived from cloud top temperature), and station rainfall data. Meteosat 7, WMO GTS data from ~1000 stations provide station rain gauge totals, and are taken to be the true rainfall within 15-km radii of each station. Plus Special Sensor Microwave/Imager and Advanced Microwave Sounding Unit are incorporated. |
| PERSIANN (NOT in ISOD)[5] | Precipitation estimated from RS Information using Artificial Neural Network. | 6-hour | 0.25 degrees | The system uses grid infrared images of global geosynchronous satellites provided by CPC, NOAA to generate 30-minute rain rates are aggregated to 6-hour accumulated rainfall. Model parameters are regularly updated using rainfall estimates from low-orbital satellites. |

**Table 3 Satellite-based rainfall products not in GEONETCast toolbox.**

CMORPH products can easily be downloaded via the ISOD-toolbox. With a 24-hour delay daily rainfall of the region can be assessed. A graph showing the rainfall at a certain pixel location can be made (see figure 5).

[3] Website: http://www.cpc.ncep.noaa.gov/products/janowiak/cmorph_description.html

[4] http://disc.sci.gsfc.nasa.gov/services/opendap/TRMM/trmm.shtml

[5] http://chrs.web.uci.edu/persiann/

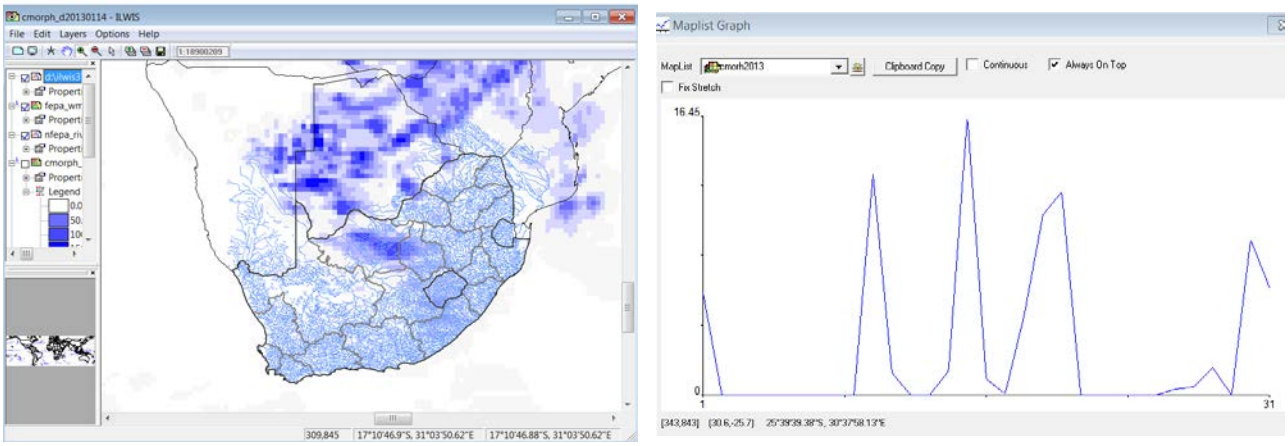


**Figure 5 CMORPH-based rainfall map 14 January 2013 incl. catchment boundaries and drainage + time series for selected pixel.**

## 3.3. Vegetation related products

The Satellite Application Facility on Land Surface Analysis (LSA-SAF) provides land surface related products derived from the EUMETSAT satellites, MSG and EPS/METOP. Fraction of vegetation cover (FVC) and Leaf Area Index are produced once a day. Evapotranspiration maps are generated every 30 minutes but can be easily aggregated in daily ET maps.

| Product | | Resolution temporal | Spatial Resolution | Remarks |
|---|---|---|---|---|
| FVC | Fraction of Vegetation cover (%) | Daily | 3 km at nadir | Fraction of area (per pixel) covered by vegetation, corrected for clouds, view and sun angles. |
| LAI | Leaf Area Index (m2/m2) | Daily | 3 km at nadir | One half the total leaf area per unit ground area. Essential input for Climate and drought conditions study. |
| ET | Evapo-transpiration (mm/hr – mm/day) | 30 min Daily | 3 km at nadir | Based on a simplified land surface, derived in near-real time, every 30 minutes. Daily ET-maps in mm aggregates over a 24 hour period. Another map calculated is showing the number of valid observations, for some events during the day the ET cannot be derived due to cloudiness and a no-data or undefined is returned. This map is useful to see if the sum ET is underestimated for some of the pixels. Time stack for a single pixel can be obtained. |

**Table 4 Selected products from Land Surface Analyses - Satellite Application Facility**

From SPOT-Vegetation images with a higher spatial resolution are obtained over. The sensors on board the SPOT are dedicated towards vegetation monitoring. A full set of products are casted through GEONETCast. A selection is given in the table below.

| Product | | Resolution temporal | Spatial Resolution | Remarks |
|---|---|---|---|---|
| NDVI | Normalized Difference Vegetation Index | Decadal | 1 km | April 1998 until now (all products older than 3 months are available on http://free.vgt.vito.be) |
| SWB | Surface Water Body | Decadal | 1 km | 5 classes: Free water, Humid area, Mixture of free water and humid area, Land with no detection, Ocean. The term humid area corresponds to pixels which spectral signal show some evidence of water, although its NDVI indicates the presence of vegetation. |

Table 5 Selection of SPOT-Vegetation products

The possibilities to get accurate soil moisture measurements with a high spatial resolution and a good accuracy are still very limited. Most products which are developed based on active microwave radar images have a spatial resolution of 25 $km^2$ with a temporal resolution of 24hr. CHECK ISOD online data from NASA.

In the near future it is expected that soil moisture products with a higher spatial resolution wil become available. The Sentinel-1 satellite (expected launch end 2013) will provide 100$m^2$ soil moisture products (http://www.esa.int/Our_Activities/Observing_the_Earth/GMES/Sentinel-1). The NASA is planning a 'SMAP: Soil Moisture Active Passive' mission (http://smap.jpl.nasa.gov/). Expected launch end 2014 and resulting in soil moisture images with a 9 km spatial and 2-3 days temporal resolution.

## 3.4. AMESD-Products

With the above mentioned rainfall and vegetation related images environmental data relevant for agriculture, drought and fire analyses from the SADC region are produced. Data products are casted through the GEONETCast through a dedicated AMESD-SADC-services toolbox. Most data is also accessible through the ISOD-toolbox when internet connection is adequate.

The data is mainly decadal data based on SPOT VGT. Since the focus is on agriculture and drought most of the products relate to Precipitation, Vegetation Indexes and Dry matter productivity. Based on long-term averages anomaly maps of for instance Water Requirement Satisfaction, Dry Matter Productivity, NDVI are produced. These images provide a clear assessment on status of agricultural lands in the SADC region.

In appendix 1 the full list of products supported by AMESD-SADC toolbox is provided

## 3.5. ISOD Toolbox

The ISOD toolbox allows import of various web based environmental data resources through a graphical user interface (see fig. 6). Via the online toolbox Online *In Situ* climate databases (NCDC and NOAA COC-FEWS GTS), FEWSNET products including Potential evapotranspiration and global elevation data can be assessed. It not only relates to earth observation images and products but also

to data observed at WMO-registered weather stations. The data summaries provided here are based on data exchanged under the World Meteorological Organization (WMO) World Weather Watch Program according to WMO Resolution 40. The input data used in building these daily summaries are the Integrated Surface Data (ISD), which includes global data obtained from the USAF Climatology Centre. The latest daily summary data are normally available 1-2 days after the date-time of the observations used in the daily summaries. The online data files begin with 1929, and over 9000 stations' data are typically available. The daily elements included in the dataset (available for each station) are: mean temperature, mean dew point, mean sea level pressure, mean station pressure, mean visibility, mean wind speed, maximum sustained wind speed, maximum wind gust, maximum temperature, minimum temperature, precipitation amount, snow depth and indicator for the occurrence of: fog, rain or drizzle, snow or ice pellets, hail, thunder and tornado/funnel cloud. Upon import the data is converted to SI units.

The daily global potential evapotranspiration (PET) is calculated from climate parameter data that is extracted from Global Data Assimilation System (GDAS) analysis fields. The GDAS data are generated every 6 hours by the National Oceanic and Atmospheric Administration (NOAA). The GDAS fields used as input to the PET calculation include air temperature, atmospheric pressure, wind speed, relative humidity, and solar radiation (long wave, short wave, outgoing and incoming). PET is computed for each 6 hour period and then summed to obtain daily totals. The PET data have a 1 degree ground resolution. Yearly global PET data is available from 2001 onwards up to the last full year. Monthly data can also be extracted from 2001 onwards. Daily global PET data can be retrieved up to a year before present. Upon retrieval / import the data is converted to mm / per day. Find below the ISOD structure. In appendix 2 an overview is given which data is available through this toolbox.

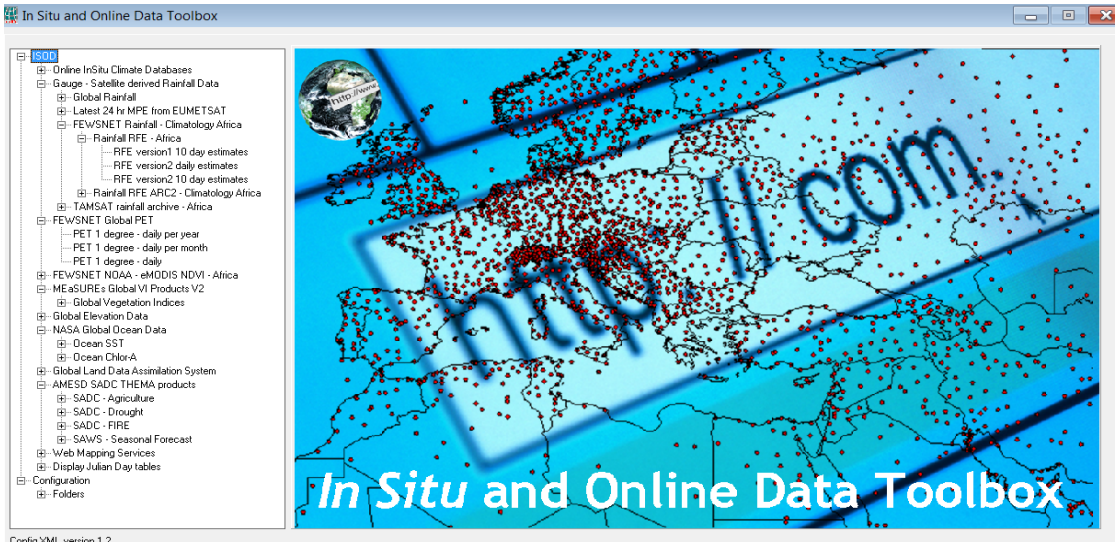


**Figure 6 ISOD main and submenu structure.**

# 4. Available training materials

A full set of training materials for GEONETCast and ISOD plugins have been developed. For the toolboxes an extended manual including powerpoints and data sets are available. For various projects ITC has developed 1-2 week training modules. ITC has developed 2 online E-learning courses. One introducing the participant to the basic Earth Observation and GIS principles needed to understand the GEONETCast concept and products. The other course focusses on application of GEONETCast for Water and Food Security. Also in the regular MSc education at ITC GEONETCast toolbox plays a pivotal role. Also a Moodle based Capacity Building portal, the "Earth Observation Capacity Building Portal" is under construction, providing a lot course materials provided during various workshops conducted.

Overview of training materials (all are downloadable from the web):

- GEONETCast Toolbox. Installation, configuration and user guide of the GEONETCast toolbox plug-in for ILWIS 3.7.2. (Maathuis (1) et al., (2012)) http://www.itc.nl/library/Papers_2012/general/GNC_Toolbox.pdf
- *In Situ* and Online Data Toolbox. Installation, Configuration and User Guide. ((Maathuis (2) et al., (2012)) http://www.itc.nl/library/Papers_2012/general/ISOD_Toolbox.pdf
- AMESD SADC THEMA,TOOLBOX PLUG-IN FOR ILWIS 3.7.2 Installation, configuration and user guide. http://www.itc.nl/library/Papers_2012/general/AMESD_SADC-toolbox.pdf

# 5. The way forward

The ILWIS GEONETCast software is the 'software'-backbone for the near-real time environmental data retrieval. The data has to be accessed via a receiving station or a directly through the web if the internet connection is very reliable and the bandwith is good. A separate ICMA plug-in can be developed through which the ICMA relevant data can be assessed and downloaded.

An alternative to an ICMA plug-in is to arrange the access of relevant products through the HydroNet portal. Through dedicated apps selection of near-real time data streams can be organized. Which data will be retrieved, the frequency of the images and the type of analyses done will be have to be decided by ICMA in collaboration with the relevant stakeholders.

Staff of ICMA needs to be trained in the operation of the ILWIS software, the set-up of the 'ICMA-toolbox' and the development of software routines to automatize certain retrievals and analyses.

# Appendix 1 Current products supported by the AMESD-SADC toolbox, XML version 1.1

Current products operationally disseminated through GEONETCast-EUMETCast are indicated using italics; these import routines have been validated using the disseminated products)

| Agricultural Service |
|---|
| AP01: Agriculture Mask |
| AP02: Crop Statistics Map |
| AP03: Crop Specific Maps |
| *AP04: Current Conditions Rainfall Map* |
| *AP05: Current Condition Cumulate Rainfall Map* |
| *AP06: Current Conditions - Air Temperature Map* |
| *AP07: Graph of Rainfall Events in the Current Season* |
| *AP08: Map of current Rainfall compared with the LTA, Max and Min values (mm)* |
| *AP09: Map of current Rainfall compared with the LTA, Max and Min values (%)* |
| *AP10: Map of current Cumulate Rainfall compared with the LTA, Max and Min values (mm)* |
| *AP11: Map of current Cumulate Rainfall compared with the LTA, Max and Min values (%)* |
| AP12: Graph of Cumulate Rainfall of the current season compared to the LTA, LTMax, LTMin |
| *AP13: Map of current Air Temperature compared with the LTA, Max and Min values (oC)* |
| *AP14: Current Rainfall Estimates Map* |
| *AP15: Rainfall Estimates Compared with average [difference]* |
| *AP16: Rainfall Estimates Compared with average [%]* |
| *AP17: Cumulate Rainfall Map* |
| *AP18: Cumulate Rainfall Map compared with Average (% Anomaly)* |
| AP19: Vegetation Index Map |
| *AP20: Vegetation Index Compared with average [difference]* |
| *AP21: Vegetation Index Compared with average [%]* |
| AP22: Crop / Vegetation performance Graphs |
| *AP23: Current Water Requirements Satisfaction Index (WRSI) Map* |
| AP24: WRSI Anomaly maps |
| *AP25: Onset of Rains Maps* |
| *AP26: Onset of rains anomaly maps* |
| *AP27: Soil Moisture Index Maps* |
| AP28: Current dry matter productivity map |
| *AP29: Cumulate dry matter productivity map* |
| AP30: Cumulate dry matter productivity graphs |
| *AP31: Cumulate dry matter productivity comparison with average maps(%)* |

| Drought Service |
|---|
| *DP01: NDVI difference* |
| DP02: Long-term average NDVI |
| DP03: Long-term average cumulative NDVI |
| DP04: Long-term standard deviation of NDVI |
| DP05: Long-term maximum of NDVI |
| DP06: Long-term minimum of NDVI |
| *DP07: VCI* |
| *DP08: SDVI* |
| *DP09: PASG* |
| DP10: Total cumulative rainfall – monthly, seasonal |
| DP11: Long-term average rainfall – Ten-daily |
| DP12: Percentage of long-term average rainfall – Ten-daily or longer period |
| DP13: Drought risk map (Boolean type) |
| DP14: Drought risk map (Graded type) |
| DP15: Graphs – based on average value of summarizing polygon |
| DP16: Graphs – Based on area within polygon where an index is lower than a specific cut-off value. |

| Fire service Service |
|---|
| *FP01: MSG Active Fire Product* |
| *FP02: MODIS Burned Area product* |
| *FP03: Canadian Fire Weather Index* |
| *FP04: Lowveld Forest Fire Index* |
| *FP05: MODIS True Colour Images* |
| *MODIS-AFIS Fire product-Aqua* |
| *MODIS-AFIS Fire product-Terra* |

| Long Range Forecast (LRF) Support Service |
|---|
| LRF01: Seasonal Rainfall Forecast (Above-Normal) |
| Seasonal Rainfall Forecast (Below-normal) |
| Seasonal Rainfall Forecast (Normal) |
| LRF02: Seasonal Maximum Temperature Forecast (Above-Normal) |
| Seasonal Maximum Temperature Forecast (Below-normal) |
| Seasonal Maximum Temperature Forecast (Normal) |
| LRF03: Seasonal Minimum Temperature Forecast (Above-Normal) |
| Seasonal Minimum Temperature Forecast (Below-normal) |
| Seasonal Minimum Temperature Forecast (Normal) |

# Appendix 2 Overview of selected data available through the ISOD-toolbox

Online In Situ Climate Databases
- NCDC Integrated Surface Data (ISD)
- NOAA Climate Prediction center FEWS GTS Data (0.5 degrees, daily)
- Current Weather Conditions from TAF

Gauge based and Satellite derived Rainfall Data
- CPC Gauge-Based Analysis of Global Daily Precipitation (0.5 degree real time, daily )
- CMORPH (8km-30 min to 0.25 degree weekly)
- QMORPH (8km – 30 min)
- TRMM (0.25 degr. – daily)

Latest 24 hour MPE from EUMETSAT

FEWSNET RAINFALL AND CLIMATOLOGY FOR AFRICA
- Rainfall Estimates (0.1 degree, daily – decadal)
- Rainfall Mean (0.1 degree, daily-decadal-monthly)

TAMSAT Rainfall archive for Africa
- Rainfall (Decadal – monthly)
- Rainfall (Decadal – monthly anomaly)

FEWSNET Global Potential Evapotranspiration
- PET (1 degree – daily)

FEWSNET NOAA - eMODIS NDVI for Africa
- NDVI and anomaly – (monthly and bimonthly)

Global Elevation Data
- GMTED 2010 (max 250m)
- SRTM Version 4 (90m)
- ASTER GDEM Version 2 (30m)

Global Land Data Assimilation System (GLDAS)
- GLDAS-NOAH 0.25 degree 3hr
- Surface Soil Moisture from TRMM

AMESD SADC THEMA products
- Agriculture
- Drought
- Fire
- Seasonal Forecast

# References

Ebert, E.E., Janowiak, J., Kidd, C. Comparison of near-real-time precipitation estimates from satellite observations and numerical models. Bull. Amer. Meteor. Soc, 88, 47-64.

Kidd, C. and Levizzani, V. Status of satellite precipitation retrievals. Hydrol. Earth Syst. Sci., 15, 1109-1116, 2011

Maathuis (1), B.H.P., Mannaerts, C.M., Schouwenburg, M.L., Retsios, B. and Lemmens, R. (2012) GEONETCast toolbox : installation, configuration and user guide of the GEONETCast Toolbox plug - in for ILWIS 3.7.2 : XML version 1.3 : e-book. Enschede, University of Twente Faculty of Geo-Information and Earth Observation (ITC), 2012.

Maathuis (2), B.H.P., Mannaerts, C.M., Schouwenburg, M.L., Retsios, B. and Lemmens, R. (2012) In Situ and online data toolbox installation, configuration and user guide : XML version 1.1 : e-book. Enschede, University of Twente Faculty of Geo-Information and Earth Observation (ITC), 2012

Maathuis (3), B.H.P., Mannaerts, C.M., Schouwenburg, M.L., Retsios, B. and Lemmens, R. (2012) Water and food security Ethiopia toolbox : installation, configuration and user guide of the WFS - Ethiopia toolbox plug - in for ILWIS 3.7.2 : XML version 1.0 : e-book. Enschede, University of Twente Faculty of Geo-Information and Earth Observation (ITC), 2012.

Thiemig, V. and Rojas, R. and Levizzani, V. and De Roo, A. Validation of satellite-based precipitation estimates over different African River Basins, EGU General Assembly Conference 2012,