



Deliverable D4.6 (report supplement)

Description of the Demonstration Package for Monitoring and Forecasting Water & Climate using a Triple Sensor approach

Final Draft v.0.6

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Author(s)	Chris Mannaerts, Bas Retsios, Ben Maathuis
Internal reviewer(s)	M.Blatchford, S.Njuki, P.Oberholster, B.Genthe
Contact for queries	Chris Mannaerts, c.m.m.mannaerts@utwente.nl
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Acronym List

AKVO	AKVO Foundation (The Netherlands)
AMCOMET	African Ministerial Conference on Meteorology
AMCOW	African Ministerial Conference on Water
AU	African Union
BOM	Australian Bureau of Meteorology
CPC	Climate Prediction Center(s) from US – NOAA - NCEP
CPTEC	Centro de Previsão do Tempo e Estudos Climáticos (Brasil)
ECMWF	European Centre for Midrange Weather Forecasting (Reading, UK)
ECOWAS	UN Economic Commission – Western Africa
EIP	European Innovation Partnership
ESA	European Space Agency
EUMETSAT	European Agency for Meteorological Satellites
FAO	Food & Agricultural Organization of the UN
GCOS	WMO - Global Climate Observing System
GEOSS	Global Earth Observation System of Systems
GFCS	Global Framework of Climate Services
GMES	Global Monitoring & Environmental Security
GPRS	General Packet Radio Service for GSM (Global System for Mobile phones)
ICOLD	Int'l Commission on Large Dams
IHE	UN - Institute for Water Education (Delft, NL)
IPCC	Intergovernmental Panel on Climate Change
ITC	Faculty of Geo-information Sciences & Earth Observation – Univ. of Twente (NL)
JAES	Joint Africa-EU Strategy
KS	Knowledge Sharing
M&F	Monitoring and Forecasting
MOOC	Massive Open Online Course
MoU	Memorandum of Understanding
NASA	National Aeronautics & Space Administration (USA)
NCDC	National Climate Data Centre(s) / NOAA
NOAA	National Oceanic and Atmospheric Administration – US.Department of Commerce
NCEP	National Centres for Environmental Prediction / NOAA
RBO	River basin organization
RCOF	Regional Climate Outlook Forum
SDG	Sustainable Development Goals
ToR	Terms of Reference
UNECA	UN Economic Commission of Africa
W&C	Water and Climate
WATER JPI	Joint Programming Initiative on Water
WMO	World Meteorological Organization

A major challenge in climate and water information analysis for decision-making at different spatial levels and stakeholders (i.e. ranging from governments at country level to local populations at village level) lies in the accessibility of the information sources, as well as the reliability and accuracy associated with the different data. Some people may rely heavily (or solely) on rain gauge network information, whereas others typically use satellite observations. Yet others, and especially local communities, may find crowdsourcing and citizen observatories the best choice.

In AfriAlliance, an information merging or collocation approach is proposed to support African stakeholders in their analysis of climate and weather challenges related to water resources management. This approach is derived from the principle that a single observation (e.g. on weather or water availability) at a certain location and time will be much more reliable and generally accepted if it is compared to other independent observation data sources (of the same location and time period). And as typically done in the weather forecasting and prediction world (who were the first to adopt this technique), to merge data sources and derive optimal estimates and information. This triple sensor approach launched by AA and an application tool is documented in this report.

1.3 Purpose and structure of the Report

This report describes the Demonstration package for applying a triple sensor collocation approach to 3 different information sources. The software tool (formal deliverable) contains an open source geospatial data and image analysis software (Ilwis v.385.2), and contains a specific AfriAlliance Toolbox Plug-in for analysing and collocating Triple sensor data in Africa. Next to this geospatial software, also a web-based AA triple sensor collocation demo was developed by ITC and its use is also described in this accompanying report.

The ILWIS AfriAlliance Triple Sensor Demo toolbox contained in the software is for users with some preliminary knowledge of geodata and basic skills in GIS analysis and preferably remote sensing. Use of the toolbox needs a prior quick installation (unzip) of the software on a laptop or PC system (Windows-based). The web-based Triple collocation demo is for all (incl. novice users) gremials, and demonstrates the principle of the triple sensor collocation approach. This is a zero-install web application and can be run from any browser on most platforms i.e. laptop, iPad, smartphone.

The introductory section 1, generally describes the AA project goals related to Monitoring & Forecasting Climate and Water Challenges in Africa, and introduces the novel AA 3-S approach. In Section 2, the triple sensor approach is described in some more details. In Section 3, the data sets used in the demonstration of the triple sensor approach are visited in brief. In Section 4, a hands-on guided demonstration is worked out, explaining the user how to install and use the software, acquire data and perform the data analysis. Section 4 also describes the web-based application. This report supplement to the demonstration package (toolbox) and triple collocation web-application refers extensively to the main AfriAlliance report deliverable (D4.4) on **Constraints and Opportunities for Water Resources Monitoring using a Triple Sensor approach** available on-line (www.afrialliance.org project portal > Knowledge section Tab).

2 Triple sensor collocation

2.1 Short history and proposed novel use

Triple Sensor Collocation can be used to validate 3 independent observations at a location, when the error-free true value is not known. With this you can judge, which water or climate observation, i.e. your citizen observation, conventional station data or a remotely sensed satellite look-up is most reliable.

The origins of the triple collocation of data sources originate from meteorology (e.g. Stoffelen, 1998; Roebeling et al, 2012). The technique has arisen from the need to jointly analyze e.g. ground station measurements of meteorological variables (e.g. wind speed) with weather model- and satellite-based predictions of meteorological variables. The main idea behind triple collocation (in meteorology) is to verify and/or to increase the accuracies of global weather forecast modelling output, needed and used in our daily weather bulletins, as well as for global aviation, maritime transportation, and early warning of weather hazards. The method is closely linked to other mathematical data merging approaches such as data assimilation, where typically meteorological station observations are ingested in weather forecast models to improve predictions and forecasts (Bengtsson et al, 1981).

Currently, and due to the enormous increase in data sources and information provision in all societal domains, data validation and quality control of information is becoming a necessary „must do“ step in any information gathering, analysis, interpretation and use process. Triple collocation and other control techniques are therefore receiving more attention today as a methods for data validation, and applications to other data types and sources (beyond meteorology) are getting developed (Zwiebach, 2012; McColl et al, 2016). In Afrialliance, a similar methodology for mapping the three independent information sources (sensors) for water resource monitoring has been proposed. It can be typically applied to:

- Mapping which of the information sources are available in a certain region or physical area of interest;
- Verify the agreement (in a statistical sense) among the three sensor data sources.

In the statistical sense, triple collocation is a technique for estimating the variance of the error (noise error) and correlation coefficients of the measurement systems (e.g. satellite, in-situ and citizen-based products), with respect to the unknown true value of the variable being observed (e.g. soil moisture, wind speed, rainfall, surface water occurrence, groundwater levels, etc.).

The three independent data sources in AA are: a) in-situ hydro meteorological or water resource ground station observations e.g. soil moisture, surface and shallow ground water levels, etc. b) satellite-based estimates of hydrological variables and c) citizen-based observations on water resources.

Where the basic idea behind this triple sensor collocation is seemingly simple and has certainly opportunities, the method is also subject to several constraints and challenges. An analysis of the Constraints and Opportunities can be found in the Afrialliance report D4.4 (mentioned earlier).

2.2 Short description of algorithms and triple collocation procedure

We will not detail the advanced statistical concepts used for triple collocation of spatial and temporal data. This is beyond scope of this document, aiming at a wider audience. We give here a basic explanation of the procedure applied in this project context and supply the scientific references for readers with a more advanced scientific algorithm interests.

Triple Collocation of satellite, *in-situ* station and citizen observation“ „How it works“?

The Triple Sensor Collocation can be used to validate 3 independent observations at a location, when the error-free true value is not known. With this you can judge, which water or climate observation, i.e. your citizen observation, conventional station measurement or a remotely sensed satellite look-up and retrieval is most reliable.

The method is based on statistical covariance analysis on three independent data sources and yields correlations, errors (RMSE) and permits to rank the dataset reliability.

In Triple Collocation (TC), one dataset (e.g. a 31-day time series of daily observations, as used in the demo) is compared to the 2 other sensor data sets (also time series of the same variable) and the correlation coefficients based on the covariances among the three data sets is evaluated. So, sensor 1 is evaluated against sensor (2, 3), sensor 2 against (3, 1) and sensor 3 against (1, 2). For the equations, we refer to the reference of McColl et al (2014).

The resulting correlation vector based on this covariance analysis is then ranked and assigned a weight, and the sensor with the higher correlation with respect to the 2 other sensors is considered being the most reliable.

Further, the error variance and root mean Square error (RMSE) are evaluated giving an idea on the error margins of the data.

Pls. note that due to possible extreme data ranges and possible outliers with some sensor observations, correlation coefficients and weights might get values slightly above 1, and even (non-intuitively expected) negative correlations are possible (usually due to extreme outliers vs. e.g. very low or zero values) and/or possible observation errors. Further research is being conducted on triple collocation algorithms for continuous, categorical and other types of data variables (pls. See also references).

The current method reference used for the TC in this Toolbox is based on research of McColl et al (2014), and entitled: „Extended Triple Collocation: estimating errors and correlation coefficients with respect to an unknown target“ and published in Geophysical Research Letters under DOI:10.1002/2014GL061322). The TC algorithms from McColl et al (2014; 2016) were coded first in R-code for initial verification with the sample data by the authors and further implemented in Python (currently used in the web-based demo) and VisualC++ for full integration in ILWIS. With this build-in Ilwis option, users do not need to use (install and run) R or Python on their laptops to perform triple collocation in Ilwis.

3 Description of example data sets

A limited number of data sets (and used in the demo exercise Chapter 4) were added to this Triple sensor Toolbox for demonstration purposes. For more extensive data resources (including acquisition routines), we refer to 2 other ILWIS toolboxes (i.e. GEONETCast and ISOD), which can be plugged-in as an Ilwis extension in this software (see Section 3.2.1). We refer to the Help section and “About” for more information.

3.1 *In-situ* station Data

In-situ station data represent all near surface data collected in conventional and new ground stations, by official authorities, e.g. hydro- & meteorological services, regional monitoring and research programs and projects. We refer to the scheme on Social Actors involved in data acquisition for Monitoring & Forecasting (pages 13-14) in the AA D4.4 report on Constraints and Opportunities for Water Resources Monitoring using a Triple Sensor approach available on-line (www.afrialliance.org project portal > Knowledge section Tab).

3.1.1 WMO-GTS GSOD (Global Summary of Day) Meteorological station Data

GSOD or Global Summary of Day data are daily summaries of the 6-hourly (00:00;06:00;12:00;18:00 UTC) reported data of high level synoptic station (e.g. at airports,...) from countries to the WMO (World Meteorological Org) and using the WMO-GTS or Global Telecommunication System. The global meteorological station data summaries provided are based on data exchanged under the World Meteorological Organization (WMO) World Weather Watch Program according to WMO Resolution 40. This allows WMO member countries to place restrictions on the use or re-export of their data for commercial purposes outside of the receiving country. Data for selected countries may, at times, not be available through this system.

Those countries' data summaries and products which are available here are intended for free and unrestricted use in research, education and other non-commercial activities. The data are available via <http://www.ncdc.noaa.gov/cgi-bin/res40.pl?page=gsod.html> and <ftp://ftp.ncdc.noaa.gov/pub/data/g sod>.

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. A few historical online station data files begin already in year 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.

We also refer to AfriAlliance report D4.4 paragraph 3.2.1 (pages 27-28) for more information on synoptic surface observations. [link]

3.1.2 NOAA CPC-FEWS global WMO-GTS daily Data

One important source of in-situ observed climate information used by NOAA Climate Prediction Center (CPC) and many other meteorological agencies for weather and climate applications are the gauge-



observed precipitation and temperature reports transmitted through the WMO Global Telecommunications System (GTS). Together with station reports from other national and international sources, the GTS gauge data are used to monitor and assess the climate at station locations and as inputs to define analyzed fields of global and regional precipitation and surface (station) temperature.

The Global Telecommunication System (GTS) is the coordinated global system of telecommunication facilities and arrangements for the rapid collection, exchange, and distribution of observed and processed meteorological information within the framework of the World Weather Watch (WWW). Station reports of precipitation, together with those of many other physical variables, are exchanged routinely among the World Meteorological Organization (WMO) member countries through the GTS network. At NOAA / CPC, these precipitation reports are received and processed to form a database of GTS gauge-based daily precipitation. Starting from October 1977, the GTS daily gauge database is updated on a real-time basis. On average, daily reports are available from about 6000 GTS stations. The GTS gauge network is relatively dense over United States, Western Europe, and east coasts of Australia and China, while it is very sparse over several regions including equatorial Africa and Amazon (source: Quality Control of Daily Precipitation Reports at NOAA/CPC by Mingyue Chen, Pingping Xie and CPC Quality Control Working Group, Climate Prediction Center, CPC/NCEP/ NOAA, available at <http://ams.confex.com/ams/pdfpapers/131381.pdf>).

The global station rainfall and temperature (minimum and maximum) data, up to a year before present can be obtained online from <ftp://ftp.cpc.ncep.noaa.gov/fews/gts>.

3.1.3 CPC Gauge-Based analysis of Global Daily Precipitation

This data set is a first product of the CPC Unified Precipitation Project that is underway at NOAA Climate Prediction Centre (CPC). The primary goal of the project is to create a suite of unified precipitation products with consistent quantity and improved quality by combining all information sources available at CPC and by taking advantage of the optimal interpolation (OI) objective analysis technique. The coverage is global (land only) at 0.5 degree spatial resolution. The temporal resolution is daily and the data is available from the 1st of January 1979 – Present:

- | | |
|-----------------|--|
| 1979 – 2005: | Retrospective Version (30K+ gauges)
ftp://ftp.cpc.ncep.noaa.gov/precip/CPC_UNI_PRCP/GAUGE_GLB/V1.0/ |
| 2006 - Present: | Real-time version (~17K gauges)
ftp://ftp.cpc.ncep.noaa.gov/precip/CPC_UNI_PRCP/GAUGE_GLB/RT/ |

Relevant background documents for this data set can be found in the literature references: Xie, P. et al (2007), Chen, M. et al (2008) and Chen, M., P. Xie et al (2008).

Hereunder are some examples of (research) boundary organizations co-producing secondary surface weather and climate observations and they complement the global high-level synoptic WMO-GTS station network for real time data applications.

3.1.4 SASSCAL WeatherNet

The SASSCAL or Southern Africa Science Service Centre for Climate Change and Adaptive Land Management program, covering a number of countries in the SADC or Southern Africa region, maintains a number of AWS, directly coupled (by GPRS) to the EUMETSAT Data Uplink and Retransmission service or to local GSM providers. This data communication technique permits rapid near real time (NRT) data and weather information acquisition by end-users and the public (see Figure 9).



Figure 2 Southern Africa SASSCAL near real-time weather data (web-based) access (www.sasscal.org)

The SASSCAL weathernet presents a recent initiative to increase meteorological surface observations and data collection over a number of SADC countries (Angola, Botswana, Namibia, South Africa and Zambia). The data can be accessed through the webpage www.sasscalweathernet.org. Data collected in Excel (csv) format can be read in ILWIS or other software for further use. No automatic import routines are currently available in the AA Toolbox, but the generic File>Import>Ilwis>Table (for csv-format) or .>Import >ADO>Excel in case of an Excel xls format works for people having some experience with Ilwis.

3.1.5 WASCAL Data Portal

The Afrialliance consortium partner, WASCAL (West African Science Service Center on Climate Change and Adapted Land Use) is a large-scale research-focused Climate Service Center designed to help tackle this challenge and thereby enhance the resilience of human and environmental systems to climate change and increased variability. It does so by strengthening the research infrastructure and capacity in West Africa related to climate change and by pooling the expertise of ten West African countries and Germany. Funded by the German Federal Ministry of Education and Research (BMBF), WASCAL is implemented in a collaborative effort by West African and German partners (see more on www.wascal.org).

It's data portal also guides people to research data collections across Western Africa. However, a user login name is required for data access. Otherwise, some metadata can be browsed only. For the Afrialliance Triple sensor collocation web-based demo, short rainfall data series from 5 WASCAL meteorological stations in the small Dano catchment (South west Burkina Faso) were used. These data were obtained through direct exchange with Wascal research staff, and used for demonstration purposes.

3.1.6 TAHMO - Trans-African Hydro Meteorological Observatory

The Trans-African Hydro Meteorological Observatory (TAHMO) aims to develop a vast network of weather stations across Africa.



The AfriAlliance project has received funding from the European Union's Horizon 2020 research and Innovation programme under grant agreement No. 689162. - www.afrialliance.org

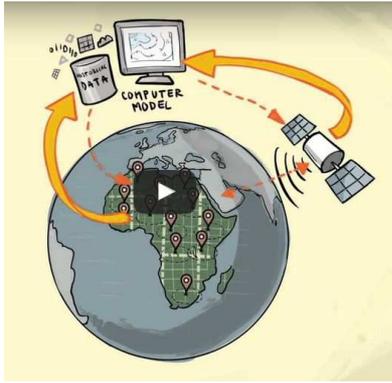


Figure 3 TAHMO network © TAHMO
<http://tahmo.org/about-tahmo-2/>

The idea behind this project is to develop a dense network of hydro-meteorological monitoring stations in sub-Saharan Africa – one every 30 kilometres. This entails the installation of 20,000 stations across the continent. By applying innovative sensor technology and ICT, TAHMO stations are both inexpensive and robust. Stations are placed at schools and integrated in educational programs, adding richness to the curriculum and helping foster a new generation of scientists. Local weather data will be combined with models and satellite observations to obtain insight into the distribution of water and energy stocks and fluxes. Currently, no automatic import routines are available in the toolbox, but authorised (registered) users, can access stations in near real time, and download data (e.g. in csv formats). Users should be authorized (cooperating or registered) members of the TAHMO network.

We refer further to the Afrialliance report deliverable (D4.4) on [Constraints and Opportunities for Water Resources Monitoring using a Triple Sensor approach](#) available on-line (www.afrialliance.org project portal > Knowledge section Tab).

DRAFT

3.2 Earth Observation satellite data

The amount of available satellite data (raw, processed and derived products) from Earth Observation platforms available today is enormous. A quick browse of the OSCAR or Observing Systems and Capability Review Tool of the WMO at <https://www.wmo-sat.info/oscar/satellites> shows the large number of geostationary and polar or lower equatorial orbiting satellite systems. Detailed description of these multiple data sources is way beyond scope of this document.

3.2.1 GEONETCast and ftp-based EO data dissemination and acquisition

We refer here to two other ILWIS GEONETCast and ISOD Toolbox plug-ins available (for this software) with more information on free and open access satellite data available through the EUMETCast near real time dissemination system (GNC Toolbox) and data available from open accessible http- or ftp data servers (ISOD toolbox). Toolboxes can be downloaded from www.52north.org. The User Manuals (see also references), available in the Toolbox Help Tabs (shown below), contain valuable data descriptions and also guided exercise to acquire (import) the data to your geospatial analysis software.



Figure 4 EUMETCast near real time satellite data import library (GEONETCast Toolbox)

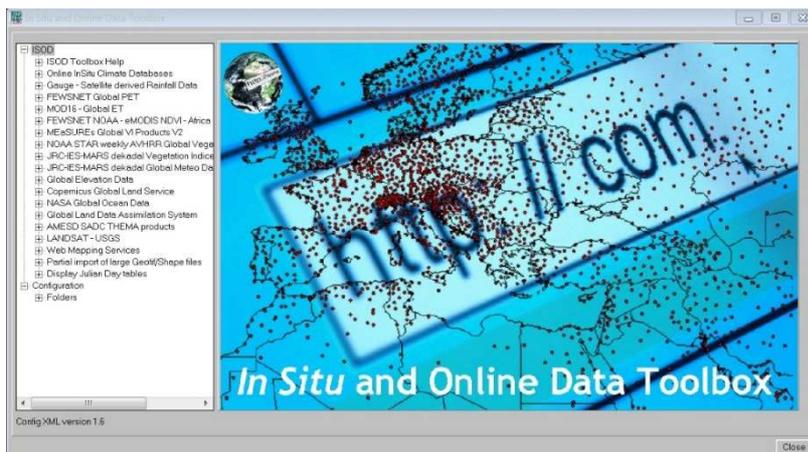


Figure 5 Ftp- or http-based *in-situ* station and Online satellite data import (ISOD toolbox)



The AfriAlliance project has received funding from the European Union's Horizon 2020 research and Innovation programme under grant agreement No. 689162. - www.afrialliance.org

Next to these ILWIS Satellite and in-situ Data access toolboxes, several http- and FTP-based satellite data web portals are today widely used. We can mention the:

3.2.2 EU Copernicus Program and other large int'l EO data portals

The **Copernicus program** currently delivers operational data and information services openly and freely in a wide range of application areas, including thematic product/data streams of Copernicus services on Land, Ocean, Atmosphere and Climate as well as near real-time and archive images acquired by the various dedicated Sentinel satellites. The observations from Copernicus Contribution Missions should also be mentioned in this respect (<http://www.copernicus.eu/main/contributing-missions>). All these contribute to operational services in the domain of Land, Marine, Atmosphere, monitoring, as well as security, emergency management and climate change services.

Access to COPERNICUS products is through online portals, for the global land service GIO2 is through:

- <http://land.copernicus.eu/global/products>.

Free access to near real time and archived data from the **ESA Sentinels 1, 2** is currently provided through the European Space Agency or ESA “Science Hub”:

- <https://scihub.copernicus.eu/>

The “Copernicus Online Data Access” Portal at EUMETSAT (Darmstadt) for **ESA Sentinel-3**:

- <https://coda.eumetsat.int>

Pls. see also the EUMETView direct ftp-access of S-3 (available in the Toolbox EO Menu).

and for Sentinel-1 and S-2 also via the French CNES mirror portal (Toulouse):

- <https://peps.cnes.fr/rocket/#/home>

or the USGS portal:

- <https://landsatlook.usgs.gov/sentinel2/viewer.html>

Examples of other **large int'l archives** for other medium to medium high resolution satellites are:

- USGS Earth Explorer at <https://earthexplorer.usgs.gov/>
- NASA Giovanni at <https://giovanni.gsfc.nasa.gov/giovanni/>
- GOOGLE Earth Engine: <https://earthengine.google.com/> (ps. also Sentinel data)
- SPOT: <https://www.theia-land.fr/en/products/spot-world-heritage>
- LANDSAT: <https://landsatlook.usgs.gov/viewer.html>
- ASTER: https://lpdaac.usgs.gov/dataset_discovery/aster
- CBERS: http://www.dgi.inpe.br/siteDgi/english/index_eng.php

The Group on Earth Observations (GEO), through its global earth observation system of systems (GEOSS) portal (<http://www.geoportal.org/>) is offering information and links to many EO resources including other data and websites (e.g. other producers, e.g., JAXA, JMA, CMA, SANSA, etc.).

Hereunder, we will only succinctly describe the data sets used in the Triple sensing collocation demo.

3.2.3 EUMETSAT - EUMETView

EUMETView is a new and rapid way to visualise EUMETSAT satellite data, in near real time. Typically the Geostationary MSG Meteosat Second Generation satellites (Atlantic main service and the IODC Indian Ocean service) are used to monitor the weather, atmosphere, land surface and oceans. Next to the MSG satellites, also the ESA Sentinel-3 polar orbiter(s) are available from EUMETVIEW. For more information, pls. Visit <https://www.eumetsat.int/website/home/Images/EUMETView/index.html>



Figure 6 EUMETView

„EUMETView is a visualisation service that allows users to view EUMETSAT imagery in an interactive way. It is currently a pilot service (EUMETSAT, 2018)“. Users can opt to download the data in „picture view“ e.g. jpg format, but also in geospatial data formats like GeoTIFF or NetCDF. This permits import and further use and processing of the data in the ILWIS software (or any other e.g. QGIS) using the standard File>Import>GDAL libraries.

EUMETVIEW is a nice web-based alternative to users not having access to an EUMETCast dish antenna receiving and data processing system. Those who have such a reception system, can use the ILWIS GEONETCast Toolbox, which contains all tools and import libraries for the HRIT and LRIT formats (standard data dissemination formats for near real time Level 1.5 MSG data).

The internet-based EUMETVIEW cannot compete with the fast download speeds (20-45 Mbits/sec) typical for EUMETCast receiving systems using DVB-S2 based data transmission. We refer to the ILWIS GEONETCast Toolbox, available at <https://52north.org/software/software-projects/ilwis-toolboxes/> for information on a HRIT/LRIT format MSG Data Retriever. EUMETVIEW will function well if one has a good internet connection.

3.2.4 CHIRPS – Rainfall (Global)

Climate Hazards Group Infrared Precipitation with Station data (CHIRPS) is a 30+ year length of record quasi-global rainfall dataset. Spanning 50°S–50°N (and all longitudes), starting in 1981 to near-present, CHIRPS incorporates 0.05° resolution satellite imagery with in-situ station data to create gridded rainfall time series for trend analysis and seasonal drought monitoring. As of May 1st, 2014 version 1.8 of CHIRPS is complete and available (source: <http://chg.geog.ucsb.edu/data/chirps/>). Data is retrieved from <ftp://chg-ftpout.geog.ucsb.edu/pub/org/chg/products/CHIRP/> and is available in pentad and monthly temporal intervals. Each pentad is consisting of 5 days, 6 pentads per month.

More detailed information can be obtained from USGS report (Funk et al 2014) and the home website of the CHIRPS data producers at <http://chg.geog.ucsb.edu/data/chirps/>.

The CHIRPS data were used as an example for satellite-based rainfall data in the Triple Collocation demonstration exercise (Chapter 4). We refer to the ISOD Toolbox for acquisition other global (or regional) rainfall data.

3.2.5 CMORPH – Rainfall - Global

CMORPH (CPC MORPHing technique) produces global precipitation analyses at very high spatial and temporal resolution. 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. At present it is incorporating precipitation estimates derived from the passive microwaves aboard the DMSP 13, 14 & 15 (SSM/I), the NOAA-15, 16, 17 & 18 (AMSU-B), and AMSR-E and TMI aboard NASA's Aqua and TRMM spacecraft, respectively. These estimates are generated by algorithms of Ferraro (1997) for SSM/I, Ferraro et al. (2000) for AMSU-B and Kummerow et al. (2001) for TMI. Note that this technique is not a precipitation estimation algorithm but a means by which estimates from existing microwave rainfall algorithms can be combined. Therefore, this method is extremely flexible such that any precipitation estimates from any microwave satellite source can be incorporated. With regard to spatial resolution, although the precipitation estimates are available on a grid with a spacing of 8 km (at the equator), the resolution of the individual satellite-derived estimates is coarser than that - more on the order of 12 x 15 km or so. The finer "resolution" is obtained via interpolation. In effect, IR data are used as a means to transport the microwave-derived precipitation features during periods when microwave data are not available at a location. Propagation vector matrices are produced by computing spatial lag correlations on successive images of geostationary satellite IR which are then used to propagate the microwave derived precipitation estimates. This process governs the movement of the precipitation features only. At a given location, the shape and intensity of the precipitation features in the intervening half hour periods between microwave scans are determined by performing a time-weighting interpolation between microwave-derived features that have been propagated forward in time from the previous microwave observation and those that have been propagated backward in time from the following microwave scan. This latter step is referred to as "morphing" (source: http://www.cpc.ncep.noaa.gov/products/janowiak/cmorph_description.html).

We further refer to the webpages mentioned and also to the ILWIS ISOD Toolbox for more information on downloading and using CMORPH rainfall data, next to several other data sets.

3.2.6 FEWSNET Vegetation cover - Africa

As an example of satellite vegetation monitoring data, we have opted here to highlight some readily downloadable medium high resolution vegetation index data based on the old-workhorses, the MODIS sensors on-board the AQUA and TERRA platforms (2000 to + - present). Pls. note that MODIS sensor is phasing out soon and is being replaced by the NASA - VIIRS sensor and also the ESA Sentinel-3 systems. Also SPOT-Vegetation and PROBAV 1-km resolution (1998 to present) time series of vegetation indices are available for the Copernicus Global data portal and through the GEONETCast near real time data dissemination systems (see also Section 3.2.2). As we are not linked to a EUMETCast receiving system or data server, we will use a secure web download for a widely used vegetation index over Africa, i.e., the FEWSNET NOAA eMODIS 250m NDVI, but obtained from the European EU-JRC-MARS download site. In eMODIS, the 250-m resolution and decadal products present valuable land cover information, for a wide variety of applications.

For those not familiar with EO-based vegetation monitoring, just a ***short note on NDVI:***

The Normalized Difference Vegetation Index (NDVI) provides a measure of the amount and vigor of vegetation at the land surface. The magnitude of NDVI is related to the level of photosynthetic activity in the observed vegetation. In general, higher values of NDVI indicate greater vigor and amounts of green biomass and vegetation. NDVI is and can be derived from many satellite sensors and platforms. The NDVI shown here is derived from data collected by the MODIS team of the National Aeronautical and Space Administration (NASA) and used by the FEWSNET network. The NDVI is basically calculated from two wavelength channels (visible Red and Near Infrared) of a satellite sensor, using the following algorithm:

$$NDVI = (NIR - VIS)/(NIR + VIS)$$

A minor modification to this basic equation is applied in case of an eMODIS NDVI. NDVI is a nonlinear function that varies between -1 and +1 (undefined when NIR and VIS are zero). Values of NDVI for vegetated land generally range from about 0.1 to 0.7, with values greater than 0.5 indicating dense vegetation. Since the late 1980's, the Famine Early Warning System (FEWS) has used NOAA - AVHRR data to produce dekadal (10-day) composite NDVI images of Africa and has built a valuable archive of these data from mid-1981 to present. Since early 2000, MODIS 1-km, 500-m and 250-m sensor resolution data have also been used. All these data can be used e.g. to monitor long term (and short term) trends in vegetation cover, and can also be linked to causal factors such as climate, land use and human impacts. SPOT-Vegetation data and its follow-up PROBAV sensor are also available and currently also ESA Sentinel-3 can also be used, but these data record starts in the '90s. NDVI's and many more vegetation related indices can be produced by many more satellite sensors at different resolutions. SPOT-VGT and currently PROBAV vegetation data can be found at the VITO (B) web portal at <https://www.vito-eodata.be/PDF/portal/Application.html#Home>.

3.3 Citizen-based data

At this stage, we did not inventory and gather large citizen-based data sets from Africa. Instead, we opted here to view and use (as an example), the Water Point Data Exchange database, available on the internet. However we do request interested persons to do research on open accessible citizen observations related to water resources (and other relevant observations) and communicate the results with the developers,

3.3.1 WPDx Water Point Database

The Water Point Data Exchange is governed by a diverse group of WASH experts, interested in monitoring water and sanitation issues and progress across the world. Citizen-based data collection methods are used to gather information and report on status of water supply points, water availability, etc. The WPDx database can be accessed freely on <https://www.waterpointdata.org/water-point-data> and data points + information can be retrieved on a country basis. In this Demo Package, we used a dataset from Burkina Faso, retrieved mid-May or 2018-05-23 from the website.

More citizen-based monitoring data will and can be added in the future, or by the user of this software and/or by the developers. As the Toolbox setup is open source, an intermediate to advanced ILWIS user can add new data entries and processing routines to the system.

3.4 Forecast and Numerical Weather Prediction model-based data

Forecasting of weather can be done at very short time interval (see e.g. METAR-TAF), but usually it is done at 6, 12 24-hr to 10-day (240-hr) time scale by the large Global Circulation models or Numerical Weather Prediction (NWP) Models at the global (and regional) weather forecasting centers (e.g. US-NCEP, EU-ECMWF, Brazil-CPTEC, Australia-BOM, China-CMA and more). Several countries have own facilities and models for weather forecasting e.g. UK (UKMET), France (Arpège), SAWS (South Africa), etc. Most countries adopt regional and/or higher resolution versions of these larger global or regional weather forecast models.



Large amounts of historical (re-analysis data such as the US-MERRA and EU ERA-interim) and current forecast data are available from servers like the European ECMWF and US-based NCEP/NOAA, GMAO and more. Besides atmospheric data, also land surface variables (e.g. soil moisture,) and other parameters are available from several large model outputs. We include here only 2 examples of data (based on global data which are useful for agriculture, water, weather and climate resources monitoring. First, a very short term weather forecast from the WMO (and ICAO) affiliated Meteo services (not model but observation based) is shown.

3.4.1 6-hourly Weather forecasts from METAR & TAF

This very short term forecasts present reports, derived from airport station observations and made by aviation meteorologists and forecasters (and not from global models). Reports from actual weather (and 6-hourly forecast) of all ICAO (Int'l Civil Aviation Organization) registered (and operational) airports are contained in 6-hourly METAR (i.e. 06.00 UTC; 12.00UTC, etc.) or Meteorological Airport Reports, and in 6-hourly Terminal Aerodrome Forecasts (TAF), respectively one hour ahead of METAR. These information's, typically used by airline pilots and other navigators is accessible through several telecom channels, but info is typically coded. A code reader - converter is therefore required. The following two web portals can be used to see what METAR and TAF is all about, incl. downloading. [<http://en.allmetsat.com/metar-taf/> ; <https://www.aviationweather.gov/metar/gis>]. Pls. see the ISOD Toolbox for retrieval. The ISOD toolbox can be used for retrieval of these short term 6-hourly weather forecasts from ICAO coded airports.

3.4.2 US - NOAA - GFS-based (10-day) Global weather Forecasts

The US - NOAA's CPC or Climate Prediction Centre (i.e. one of the National Centers for Environmental Prediction or NCEP) is providing forecasts on Weather and Climate Parameters for Africa, like Precipitation, Temperature, Winds, Heights, MSLP, Relative Vorticity, SST, etc. using their NWP Model (available at <http://www.cpc.ncep.noaa.gov/products/international/africa/africa.shtml>). The Global Forecast System (GFS) is a weather forecast model produced by the National Centres for Environmental Prediction (NCEP). Dozens of atmospheric and land-soil variables are available through this dataset, from temperatures, winds, and precipitation to soil moisture and atmospheric ozone concentration. The entire globe is covered by the GFS at a base horizontal resolution of 18 miles (28 kilometres) between grid points, which is used by the operational forecasters who predict weather out to 16 days in the future. Horizontal resolution drops to 44 miles (70 kilometres) between grid point for forecasts between one week and two weeks. The GFS model is a coupled model, composed of four separate models (an atmosphere model, an ocean model, a land/soil model, and a sea ice model), which work together to provide an accurate picture of weather conditions (source: <http://www.ncdc.noaa.gov/data-access/model-data/model-datasets/global-forecast-system-gfs>).

3.4.3 Seasonal Forecasts (90-day) from WMO - Regional Climate Outlook Forums

The analysis of seasonal weather patterns, and effects of global or regional climate phenomena (e.g. the strengths of ENSO or El Nino - La Nina, the Indian Ocean Dipole, North Atlantic Oscillation, equatorial Madden Julian oscillations and more) on our weather at the 3-monthly (90-day) time scale, and also the seasonal forecasting is done by climate centers and a number of WMO Regional Climate Outlook Forums. In Africa, the RCOFs are organized as shown in Figure 7.

Afrialliance Monitoring & Forecasting of Water & Climate Challenges – regions

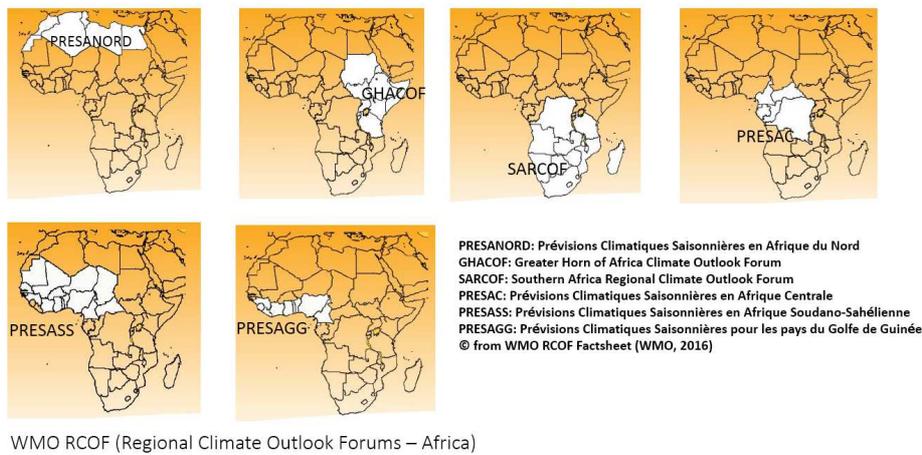


Figure 7 WMO Regional Climate Outlook Forums – Africa

The WMO allied African RCOFs are closely affiliated and in fact strongly depending for their weather forecast data and information, next to the national NMHS Services, from three main African meteorological centers, i.e. ACMAD, ICPAC, the SADC-Centre and also the SAWS (South African Weather Service) for the Southern Africa region. Pls. see also the Afrialliance Report Deliverable D4.4 for more information.

3.4.4 EU – ECMWF – IFS model based Data

Most of the European Center for Medium range Weather Forecasting (ECMWF) data derived from their IFS or “**Integrated Forecasting System**” global model are available from the ECMWF data servers at www.ecmwf.int.

The EU-JRC-IES is using these data to provide interesting data for monitoring agricultural production and food security. The Monitoring Agricultural Resources (MARS) Unit (<http://mars.jrc.ec.europa.eu/mars/>) is focusing on crop production, agricultural activities and rural development. The MARS Unit provides timely forecasts, early assessments and the scientific underpinning for efficient monitoring and control systems. Data needed for this purpose is based on various ECMWF including the ERA-Interim and the OPE (operational deterministic ECMWF model). Long time series of dekadal rainfall (from 1989 onwards at 0.25 degree spatial resolution) is made available online through JRC’s SPIRITS webpage (http://spirits.jrc.ec.europa.eu/?page_id=184). The routine provided here is merging the various windows into a global precipitation map (in mm / dekad), both for the Interim as well as the operational data. For further information also consult the MARS Crop Yield Forecasting System wiki, available at: http://marswiki.jrc.ec.europa.eu/agri4castwiki/index.php/Main_Page

The MARS ECMWF-based meteorological database is a daily weather data base based on various European Centre for Medium-Range Weather Forecasts (ECMWF) sources. The MARS ECMWF data set includes ERA-INTERIM (from 1989 to March 2013) and OPE (operational deterministic ECMWF model) data currently covering the period April 2013-April 2014. The ERA-INTERIM data set is a reanalysis of the global



The AfriAlliance project has received funding from the European Union’s Horizon 2020 research and Innovation programme under grant agreement No. 689162. - www.afrialliance.org

atmosphere. Due to this reanalysis system, ERA-INTERIM has proven to have better performance compared to previous reanalysis data sets such as ERA-40, see also 3.16.8. The following variables are available: mean temperature (C), maximum temperature (C), minimum temperature (C), ET0 (in mm, according to Penman-Monteith, based on dew point, daily radiation sum, wind speed, and temperature) and rainfall (mm). A number of pre-processing steps were developed in the MARS project, to prepare the data as input to the crop models. For instance x-hourly data are aggregated to daily time steps and a downscaling method was developed consisting of an inverse distance weight interpolation (IDW) from the 0.75 degree ERA-INTERIM grid to the 0.25 degree OPE grid and of a bias correction between the IDW-interpolated ERA-INTERIM model and the OPE model (not applied to rainfall). The dataset has a global coverage and the time series is from 1989 onwards, but from April 2014 there is currently an interruption of the service reported. Temporal resolution is daily although only the dekadal product is presently distributed by JRC. The spatial resolution: 0.25 degrees (<http://marswiki.jrc.ec.europa.eu/datadownload/index.php> and <http://spirits.jrc.ec.europa.eu/>). Dekadal format expected by the routine is yyyyymmdekdek, e.g. 20101201, for the first dekad of December.

DRAFT

4 Guided demonstration exercises

The download locations for this software, documentation and demo exercises are: i> the Afrialliance Project web portal (www.afrialliance.org) or (01-Jan-2019 onwards) also from <https://52north.org/software/software-projects/ilwis-toolboxes/>. A preview of last version(s) and sample data can also be downloaded from <ftp://ftp.itc.nl/pub/52n/AfriAlliance/>. The download location contains 3 zip files:

- Softwares.zip with ILWIS3852.zip and three small ancillary Open source ware \extrasoft.zip containing install files of the utilities: Irfanview, Notepad++, and 7zip. Note that these are optional utilities.
- Sampledata.zip with 2 exercise data zip files: ilwisout.zip (data explore/import examples) and Danocase.zip (triple collocation demo data sets).
- ToolboxUserGuide.zip with reports & other Toolbox Manuals. Ps. User guide also in software Help.

4.1 Installing ILWIS Open and the Afrialliance Triple Sensor Toolbox

We use the ILWIS v3.8.5.2 version in this manual version (Nov-2018) and in software directory ..\software\ILWIS3852.zip. This version, contains a build-in first version of the Afrialliance Toolbox v1.0. If for any reason, you have already an ILWIS installation on your PC, you will still need to copy this version and put this aside or next to your other (older) Ilwis. This is not a problem, as multiple different Ilwis instances can be run on your system (one at a time). Ps. ILWIS is not a large software (30MB) and Toolbox (+- 90 MB), so not storage space hungry, Ps. the sample data may be more voluminous (+- 500 MB).

Copy and Unzip the **Ilwis3852.zip** to a working drive e.g. c:\ or d:\... or similar. **Pls. do NOT unzip the ILWIS385.zip to your D:\Program Files or Program Files (x86) Windows directories, or to your Desktop!!** These directories are usually “write protected” and the Toolboxes need read/write access to their software sub-directories. The desktop location has a very long Windows “path” which does not work with all Toolbox routines. Pls. make things easy, and unzip to an open drive e.g. C:\, D:\, E:

Browse to your newly created drive name: \ILWIS385x directory and create a “Shortcut to Desktop” of the **ILWIS.exe** application, which you will find in root of the newly created D:\ILWIS385 directory. You can also just open Ilwis by just double-clicking on this Ilwis.exe (executable windows application). Easier is however to use the Desktop Shortcut Icon to launch Ilwis. Note: you do need to unzip the ILWIS3852.zip file. ILWIS will not start if you double-click ilwis.exe inside the zip file.

Create a working or output directory for the data using e.g. Windows explorer > Create New Folder, somewhere on the root of a drive. Pls. use a short directory name e.g. .\Afrialliance or .\ilwisout..... (Your own choice). D:\ilwisout will be used as Ilwis working directory or data catalog through this manual.

Copy and Unzip the **ilwisout.zip** to your Ilwis working directory (data catalog) e.g. d:\ilwisout. Pls. first create this new folder (directory) using Windows File explorer. This zip contains Ilwis file samples of the output (generated by the ftp-based data import routines of the Toolbox. This is useful for users without good (or no) internet access and permits to browse results from the Ilwis data imports and (pre-) processing. Imports with the toolbox will generate copies of the files (in many instances i.e. if equal time stamps are used).



Open ILWIS and browse to the working directory (your Ilwis data catalog). Note that this working directory is still empty, if you didn't copy any data yet. Get some look and feel of the ILWIS GUI. Ps. if you now close and open ILWIS again, it will open with your working catalog active (visible).

On opening Ilwis v3.85.2, the following windows will be shown. Scroll down in the Operations-Tree until you find the Afrialliance Triple Sensor Icon. The data catalog should indicate e.g. d:\ilwisout or ... In case, you don't see this Folder, pls. create it first using Window File explorer > New Folder..

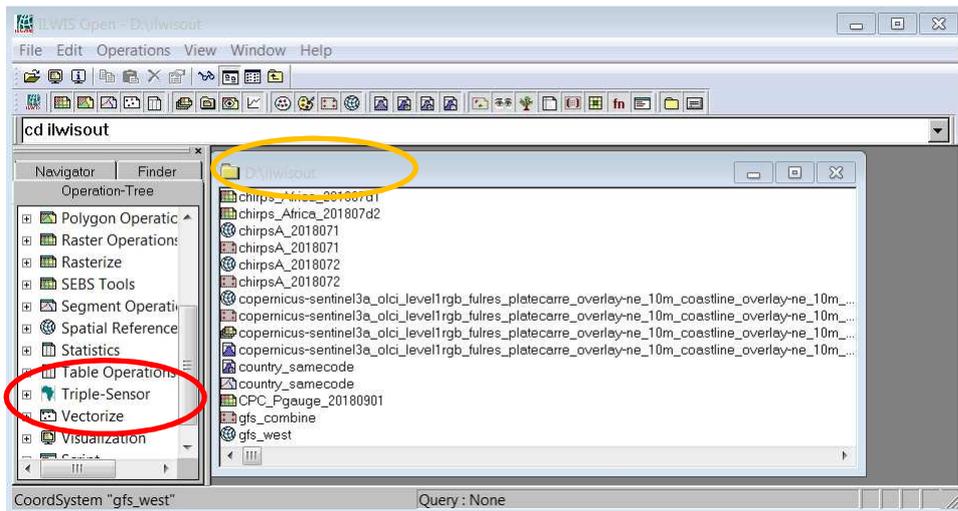


Figure 8 Ilwis v.3 GUI with Data Catalogue and Operation Tree > Afrialliance Triple Sensor Plug-in

Now Open the Triple Sensor (+) and Open the Toolbox. If you also open the Level-1 (+), then you will find this Menu structure. By clicking on the respective entries, you will be guided to the applications.

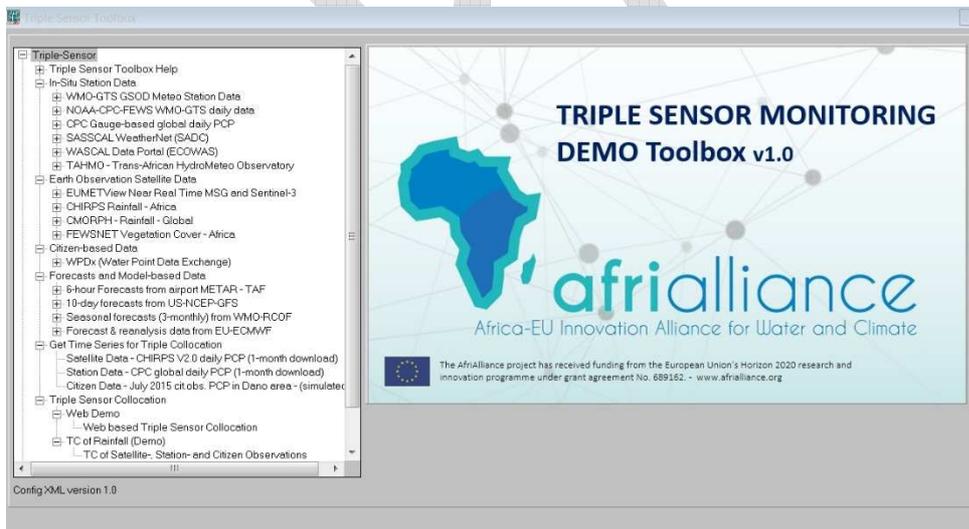


Figure 9 Triple Sensor Demo Toolbox (after opening main Tabs to Level-2 Sub-menu)

4.2 Retrieve and explore example data sets

Let's explore some data sets described briefly in Chapter 3. In order to do the data and tool explorations, users should be linked to a good internet connection (with sufficient download speed). Downloads represent typically compressed data files ranging from <1MB to 10MB. The maximum download size in this Demonstration toolbox is 100MB for 250-m resolution eMODIS Vegetation Index data.

Get your ILWIS Ready: configuration of input – output directories

Start ILWIS3852 (e.g. from your desktop Icon) and then open the “Triple-Sensor” > “Toolbox” that is found in the Operation-Tree on the left of the ILWIS window. Inspect the menu of the Toolbox and open the item “Configuration” > “Folders”.

Note that here the assumption is made that you have created, a directory called “.\Ilwisout” or any other own name on your local storage drive. For all the items under Folders (Chirps, Cmorph, CPC_gauge, GSOD,...) specify the appropriate directory “D:\Ilwisout” and press “Save” to store the ‘drive:\directory’ ilwis output setting. Close the Toolbox and use the ILWIS Navigator to move to the directory “D:\Ilwisout”. Close ILWIS and start ILWIS again, and confirm that the location of your data catalogue is “D:\Ilwisout”. Now, from the Operation-Tree, start the “Triple-Sensor” > “Toolbox”, and

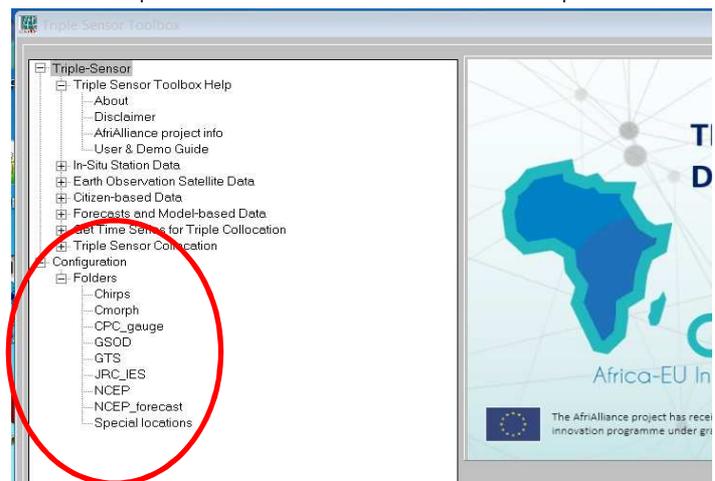


Figure 10 Configuration of your output folders (a/o Ilwis data catalogue)

you are ready to start the exercises. Note that if you have changed working directory during an active ILWIS session, it is advised to close ILWIS and start it again. This is very fast. This way ILWIS (and Windows!) will “remember” the most recently used working directories. **Pls. Note that running any data import operation with the Toolbox, with the wrong data catalogue & output folder active, will give a fatal (import) error in Ilwis.**

4.2.1 Import WMO-GTS GSOD synoptic meteorological station data

Within the Triple-Sensor toolbox, utilities are available to import data from the global meteorological data archive maintained and updated by US - NOAA - NCDC, providing „Global surface Summary Of Day“ or **GSOD** data on meteorological station variables. First a map will be visualized showing the global locations and the station numbers of the climatological stations (over 27750 records). From the “Triple-Sensor Toolbox” main menu select the “In-Situ Station Data” > “WMO-GTS GSOD Meteo Station Data” > “Stations map of Global



surface summary of day product produced by the NCDC” sub menu. Confirm (check data catalogue window name) that your “Output Directory” is “D:\Ilwisout” and press “Import”.

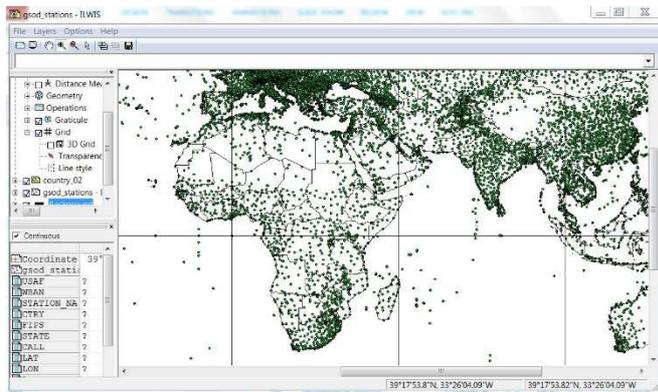


Figure 11 WMO GTS station map Africa (with active map info)

After import, a map view will be shown, indicating the locations of the stations. Moving the mouse over the map, while keeping the left mouse button pressed, provides information on the station number. Additional information (attributes) is shown at the bottom-left of the map window. Zoom into the area of interest and move the mouse over a station to see additional details about that station, such as station name, USAF number, coordinates and elevation. The **USAF station code number** should be noted as this is used during the subsequent extraction of the daily summary data.

To extract the station data, from the “Triple-Sensor Toolbox” main menu select the “In-Situ Station Data” > “WMO-GTS GSOD Meteo Station Data” > “Import GSOD station data” sub menu. Specify the “Year”, and enter the USAF number from the previous step in “Station”, confirm that the “Output Directory” is correct, and press “Import”. Here use is made of the station “Ilha do Sal”, year is “2015” and USAF station number is “085940”. Note that a 6 digit station code is required; in case the station has only a 5 digit code the station number coding should be preceded by a zero (0). The USAF station code for Praia is “085890”. Here Sal station is used for further explanation, but you can freely substitute it with ‘Praia’. (Ps. Praia has now 2 USAF codes; only one is operational; old aerodrome and new airport locations).

Additional information on the data is provided when selecting the “Metadata” option. The import routine downloads, extracts and processes the data. Additional columns are calculated providing the data in SI units, like temperature (also minimum and maximum), dew point, visibility, wind speed and maximum wind speed, precipitation. Note that if during import an error message appears that ILWIS cannot find a table, close ILWIS, start ILWIS again and repeat the import. This error occurs when navigating to another directory during the import.

When the import routine has finished, close the “Triple-Sensor Toolbox” by pressing the “Cancel” button on the bottom-right of the Toolbox, then refresh the catalogue by selecting from the ILWIS menu the option “Window” > “Refresh”. To visualize the imported station data, open the imported table by double-clicking it. Its name is formatted like “st_USAFno_year”, in this case “st_084940_2015” or “st_085940_2015”. Inspect the table content. In the menu of the table window, click on the “Graph” icon, in the subsequent popup window, don’t select an X-axis (unselect it), and for the Y-axis select the attribute to be visualized, here “Prpc_mm” and press “OK”.

Now from the graph elements on the left, the visualization properties can be changed. Double click the layer labeled “- Prpc_mm”. In the Graph options, change the name to “Precipitation”, select a “Needle” representation, instead of a point, optionally change the color to “Blue” and press “OK”.

Now from the menu of the graph window, select “Edit” > “Add Graph” > “from Columns” and select for the Y-Axis the table attribute “TempMIN_C” and press “OK”. Double click the layer “- TempMIN_C”. In the Graph options, change the name to “Minimum Temperature”, select a “Line” representation, instead of a point, optionally change the color to “Magenta”, at “Use Y-Axis” select “Right”, and press “OK”.

In the graph elements on the left, enable (double click) the “Y-Axis Right” , then double-click the item to set the Axis Text “Temperature”, set the Min-Max Interval to “-10” and “50” respectively, uncheck the

option “Show Grid”, and press “OK”. Note that the data range required can be obtained from the statistics pane which is shown at the bottom of the table.

Repeat the procedure for the attribute “tempMAX_C” and “Dewp_C”, call these “Maximum Temperature” and “Dewpoint Temperature” respectively, select as representation “line” and select appropriate colors, and ensure that the Y-Axis Right is used. In the graph window itself the title can be modified. Double click on the title in the Graph and consult figure 2.3.1 for a sample title.

The graph can be saved on disk with the “Save” button of the graph window, so that it can be re-opened as-is another time.

Figure 2.3.1 Daily Air Temperatures for Ilha do Sal airport (2015), USAF station number 085940

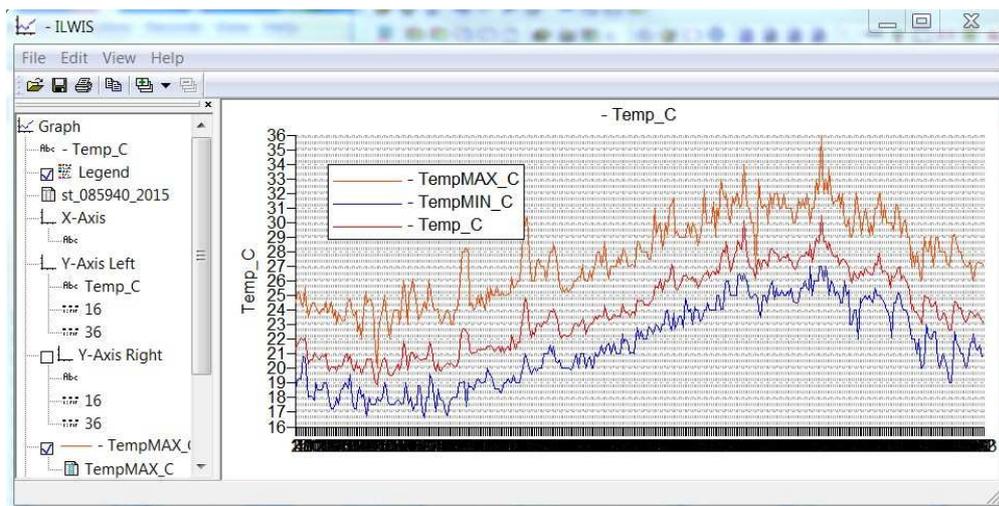


Figure 12 ILWIS table column Graphs of GSOD daily air temperatures (station code „st_085940“2015)

4.2.2 Import and analyse NOAA CPC-FEWS WMO-GTS daily station Data

This routine – in contrast to the previous GSOD import routine which imports a daily time series (one year) of one station - imports for a specified day all globally available (i.e. reporting to the WMO-GTS system) station temperature (min, max) and precipitation data. A large table will be generated by ILWIS with data columns and several thousands (+- 8000) of records of station ID data, latitude – longitude and temperature and rainfall data.



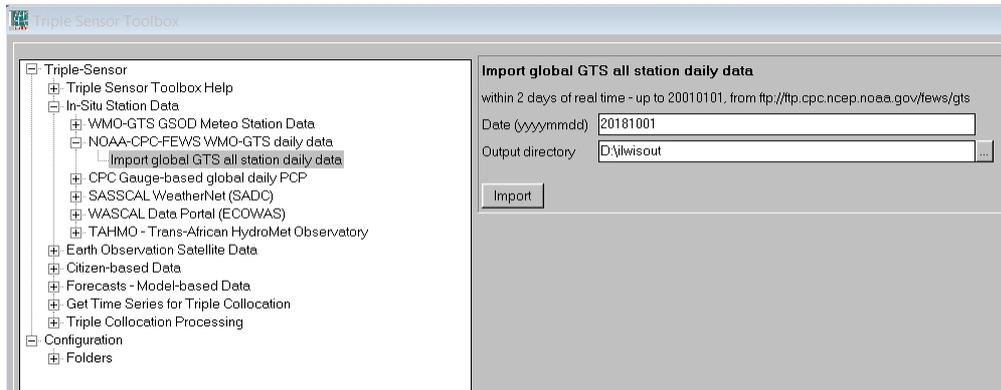


Figure 13 Import of all available global GSOD (PRECIP, TEMP) station data for a specified day

The screenshot above performs an import of 01-Oct-2018 global station data. This import will create an ILWIS table object named „gts_20181001.tbt“ in your Data Catalog. See screenshot below. The import and table generation in Ilwis will take a few to 10-30 seconds. Pls. Be patient until the routine closes.

You can open the table and browse the content. The records represent the stations and columns data. E.g. browse to the reported Precipitation column.

By using the Table to Pointmap option in ILWIS, e.g. a global daily station-based rainfall map can be created. You can do this in several ways:

- Go to the Operations Tab > Table Operations > Table to Pointmap. In the box use, X, Y cols for X, Y (lon-lat) and select LATLON as coordinate system (or LATLONwgs84).
- Select Use Attribute Column as Input, and select reported precipitation.
- Give an output name e.g. gts_20181001_prpc and click Show.
- A global station pointmap with circles (stations) and with colors representing the precipitation will be shown (and created).
- Overlay the pointmap with a countryboundary using the Layer > Add Layer > Filter All> Basemaps> country_boundaries>ok.

You can change the colours using the Display Tools > Portrayal> Representation Menu. You can also change the circles by e.g. filled circles or dots using (double click) > Symbolization. Pls. Note that this whole Table to Point map operation can also be called using a Right-hand mouse click when on the Table file Object (in the Data Catalogue).

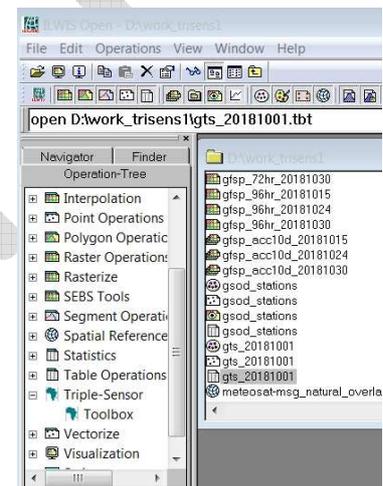


Figure 14 Example of Ilwis data catalogue with imported file objects

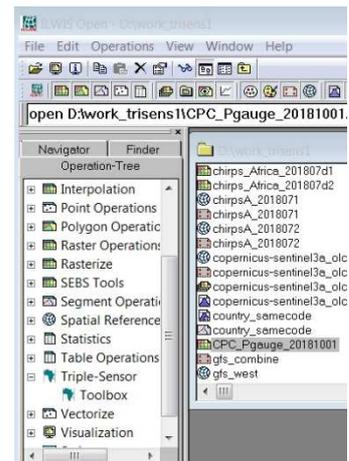
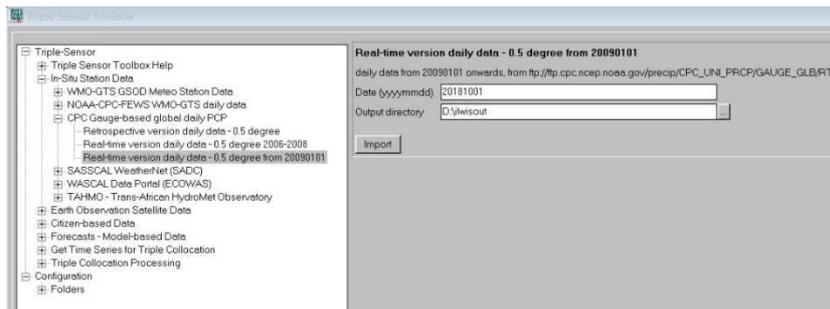


Figure 17 Import of gridded global daily precipitation data from NOAA/NCEP/CPC

A CPC-Pgauge_20181001 raster map object is created. Open this map, change the color look-up table, using the Display Tools > Portrayal> Representation (using Double-click) > Use mpe_sum as colour Look-up-Table or LUT. Then overlay the map with the country_boundaries Layer (from the Layer>Add Layer Menu>Filter All>Basemap collection). See under 4.2.2. A map as shown below is created.

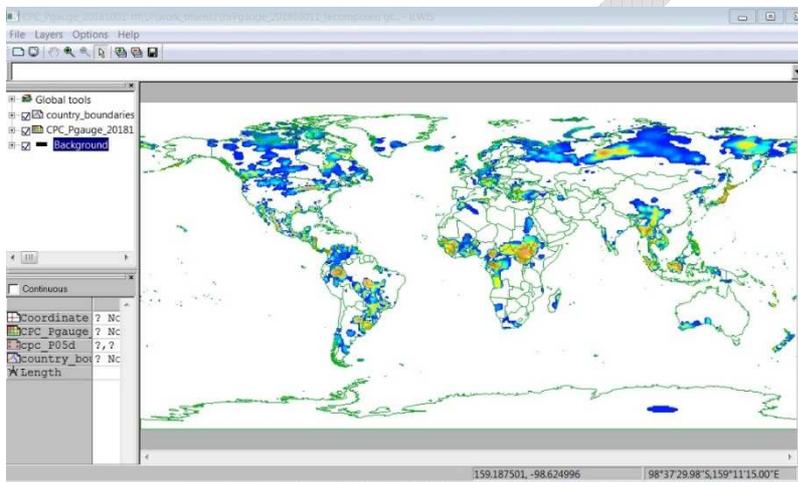


Figure 18 Map view of gridded global precipitation (01-Oct-2018), displayed using a MPE_SUM Colour LUT

If you zoom in to e.g. a country or smaller areas, then you can also use Open Street Map (OSM) as an overlay. Once, you open a map object, this OSM background map layer can be obtained from the Layer > Add Layer Menu > Filter All > Base maps > openstreetmap. You should increase the Transparency of this OSM map to be able to view the rainfall map. Do this by opening the Display Tools>Transparency Button and increase to e.g. 30%.

4.2.4 View SASSCAL WeatherNet, WASCAL an TAHMO data sources

The data from these in-situ stations, collected by these organizations, can (at this moment) not be directly imported in this Toolbox. The user has to access and browse the respective websites and download data e.g. as an Excel or .csv data files. These files can be imported as Table in ILWIS from the File>Import>ILWIS>Table Menu. Pls. See the example given by the Citizen Data Import (use case Dano, Burkina Faso).

4.2.5 View and import current satellite weather data with EUMETView

From the **Earth Observation Satellite Data** Menu, open the **EUMETView Near real time MSG and Sentinel-3** Tab, for the most recent EUMETSAT image data, and hold-on until the application is launched. This depends on your internet speed. You can now browse a variety of geostationary MSG Meteosat weather satellite image data (i.e. wavelength bands), but also derived visualized MSG products. The polar orbiting ESA Sentinel-3 is also available.

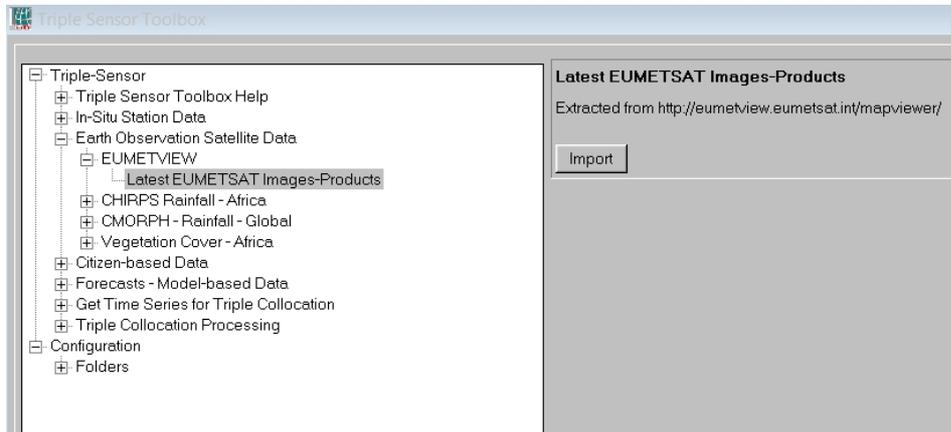


Figure 19 View and Import of Near Real Time EUMETSAT data using EUMETView - ftp

First explore some **Imagery** > Meteosat MSG wavelength bands TIR10.8, WV6.7, IR3.9 and VIS0.6. For example, the Thermal Infrared 10.8 μm channel permits to view cloud cover [day and night], whereas the visible solar 0.6 μm channel will illustrate the typical solar illumination “day-night” observation cycle.

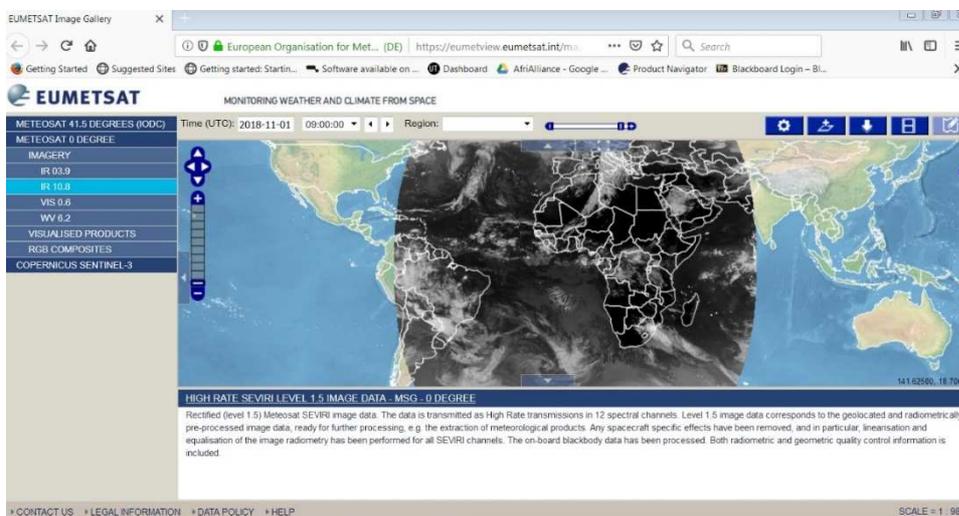


Figure 20 EUMETView screen (MSG thermal band 10.8 μm shown and Field-of-View of Atlantic Service)

Then Go to **Visualized Products** and explore near real-time MPE rainfall fields (i.e. the MSG MultiSensor Precipitation Estimate). This tells where it is raining at this moment and also the intensity of rainfall (last 15-min) from eastern Brasil to Africa. Europe and Middle east (based on the MSGMPE algorithm).The IODC service (at 41.5 lon) provides information for countries around the Indian Ocean.



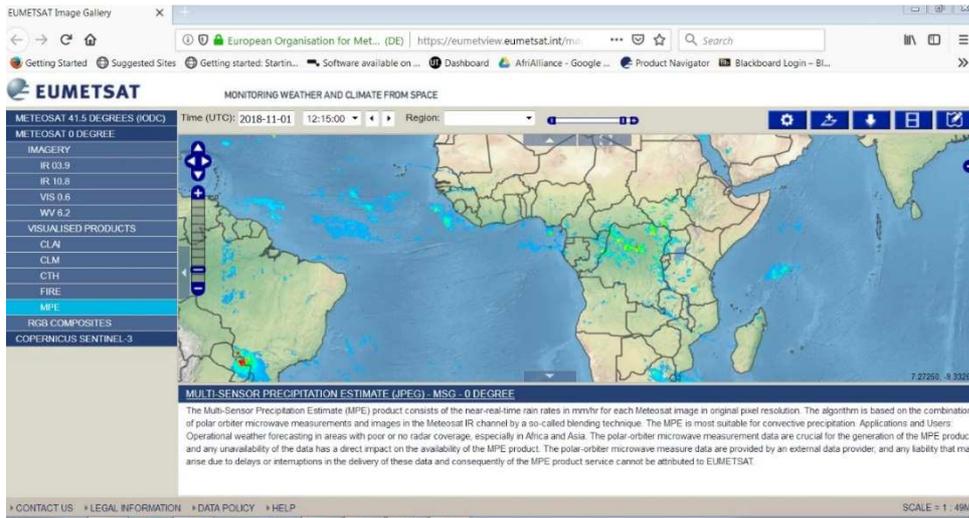


Figure 21 EUMETView of Visualized MSG data (near real time MPE Multisensor Precipitation Estimate)

From RGB composites, also explore a Daytime Natural Color Composite. You can download an image (of choice) using the Download Button ↓ (upper right) and the GeoTIFF - full resolution - option.

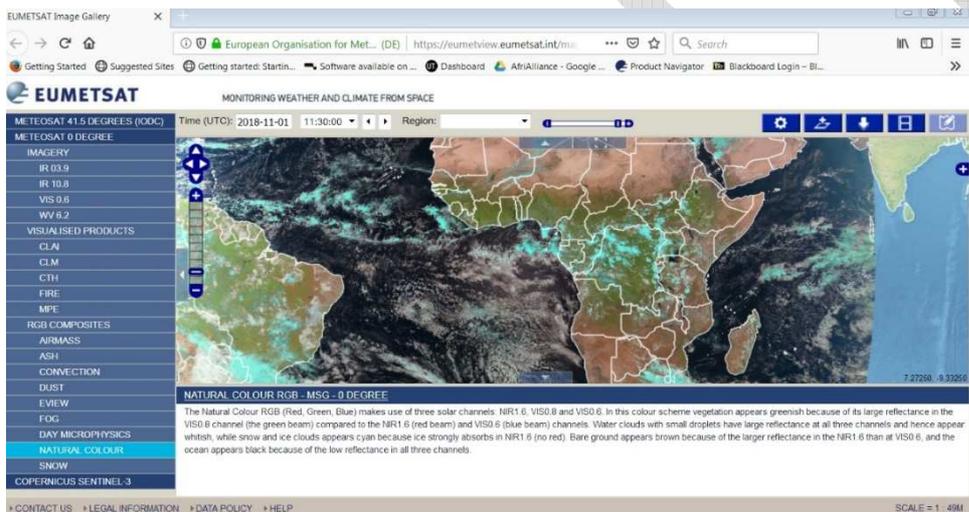


Figure 22 EUMETView of MSG Daytime Natural Colour Composite image

To import this downloaded Geotiff file in Ilwis, first locate it on your laptop (your internet browser generic download folder) and optionally copy (or move) the file from this download location to the Ilwis Data Catalog (directory). An example filename of this 55 MB map (full MSG disk image) is:

meteosat-msg_natural_overlay-ne_10m_coastline_overlay-ne_10m_admin_0_boundary_lines_land.tif

Go to the File Menu > Import Tab > GDAL > Raster > GeoTiff>... and perform the import to Ilwis (using e.g. output name matches input or a name of choice).

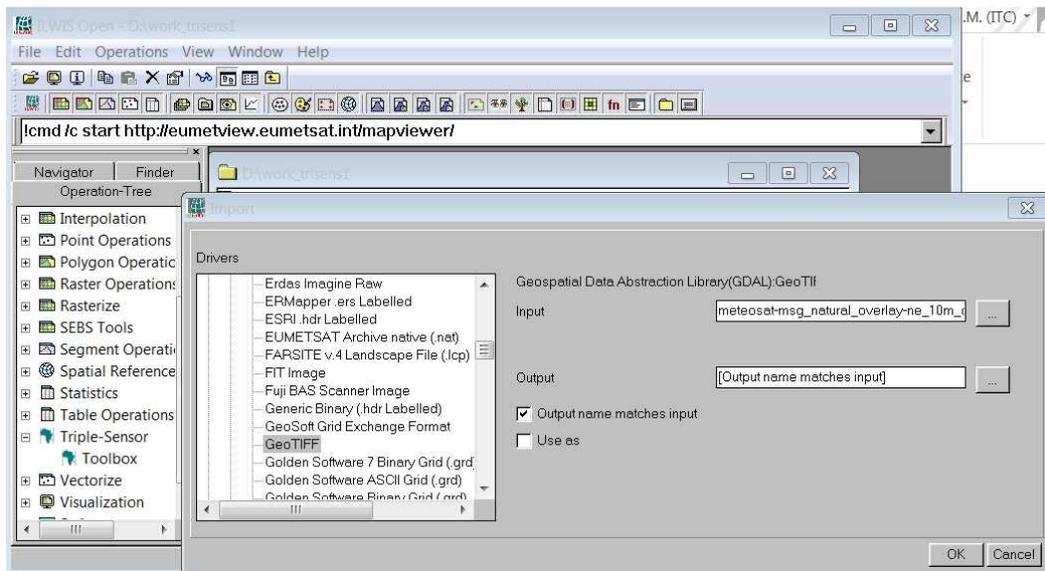


Figure 23 Import of downloaded (GeoTiff) data from EUMETView with the File>Import>GDAL Menu

A file container (containing the three RGB bands + kappa file) of the same name, a coordinate system and georeferenced file will be present in your data catalog.

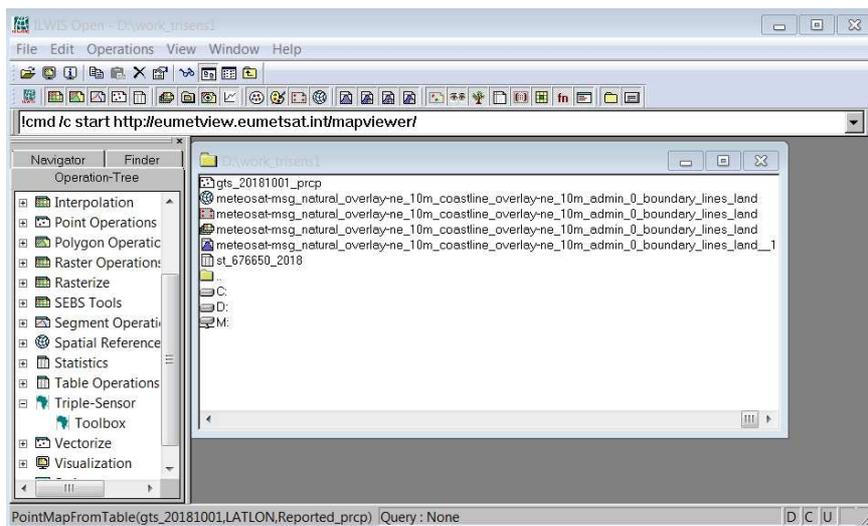


Figure 24 View of imported MSG files in Data Catalogue: coordinate, georeference, maplist, histogram files

Open the file Maplist (double click on Icon), then Open the Color Composite using Open as Maplist.

You should invert the Color Scheme (RGB 1,2,3 to BGR 3,2,1) to display the same color composite. To do this, open the Display Tools> Color Composite (Double-Click)> Select Bands and reverse the 1>3 and 3>1. Pls, overlay the map with the country boundaries (in yellow).



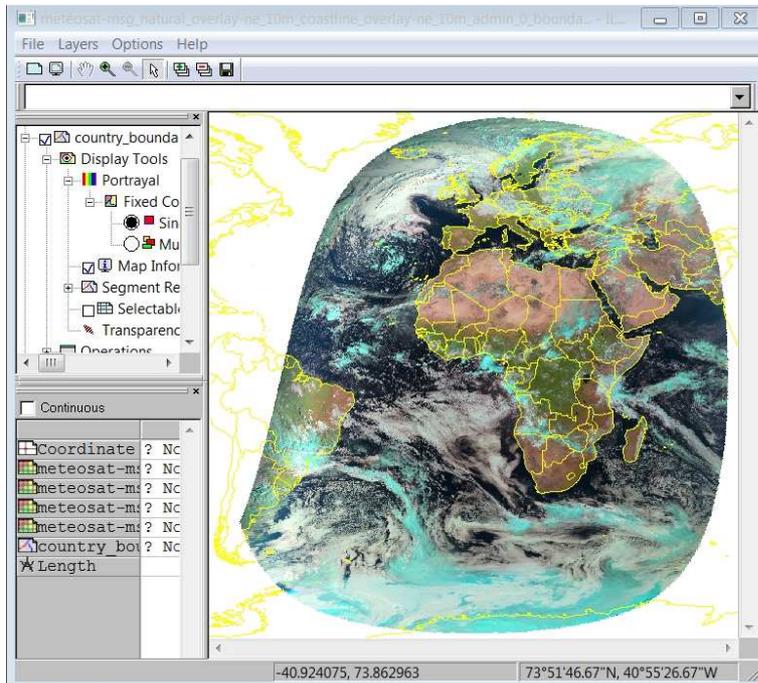


Figure 25 Meteosat MSG Field of View (3-km resolution DNC colour composite)

From this large MSG 3-km resolution map, sub maps e.g. for all countries or regions of interest in the field of view of MSG (Atlantic Service shown here) can be made with Ilwis (File > Submap menu in view window). Also the Indian Ocean IODC service is available as well as the global ESA-Sentinel-3 OLCI sensor orbital data.

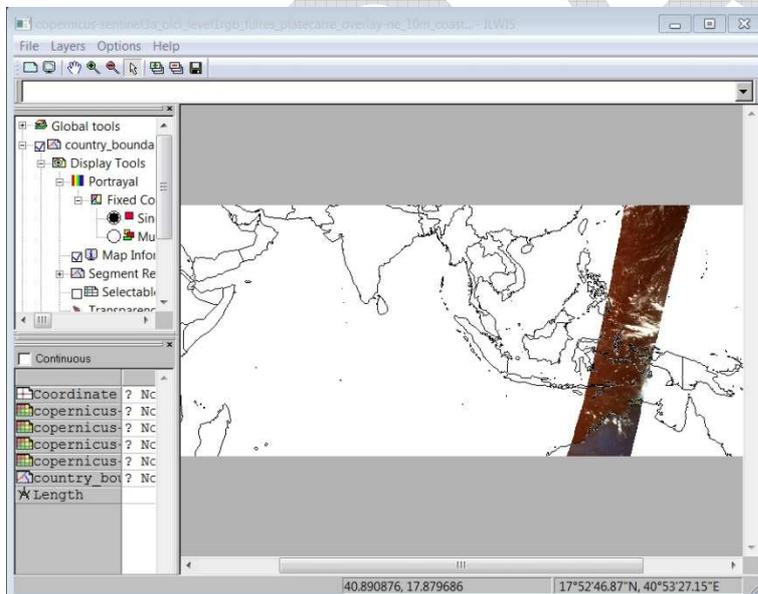
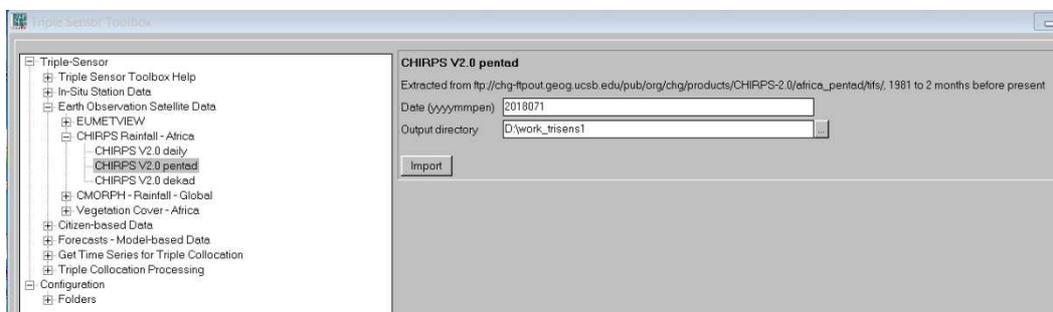


Figure 26 ESA-SENTINEL-3 OLCI orbital quick look (shown in false colour LUT)

4.2.6 Import CHIRPS rainfall data

To import CHIRPS precipitation data for Africa, select from the “AFRIALLIANCE” > “Toolbox”. Main menu the item Earth Observation Satellite Data and further to the >“CHIRPS – Rainfall - Africal” sub menu. In this case only the “Date” field and the “Output Directory” need to be specified. Pls. work in your data catalog, as specified in the Toolbox configuration for CHIRPS. The CHIRPS v2.0 data are delayed (+2 months), due to merging with stations.

Go to CHIRPS V2.0 Dekad (10-day) and select a Date stamp select e.g. “2018071” and press “Import”. This is the first dekad (day 01-10) of August 2018. After the import has been completed, display the newly created map “chirps_201007d1”, using as Representation “Pseudo” (see Display Tools). Add the country boundaries (no Info, boundaries only) and use pixel information to inspect the values. If you use the PSEUDO Color Look-up table, you better apply a color Stretch (reduce the max. value) for a better view (from the Display Menu). You can also use a rainfall MPE-sum Representation for a nicer look. Change this using the Portrayal – Representation settings from the Display Tools Menu.



To import the data from the CHIRPS pentad precipitation data (aggregated to 5 days)

“CHIRPS V2.0 pentad” sub menu. There are 6 pentad per month, so use 1 to 6 after the year-month data stamp, e.g. Date stamp select “2018076” (for the last pentad of July 2018) and press “Import”. After the import has been completed, display the newly created map “chirps_201007p6”, using as Representation “MPE-sum”. Add the country boundaries (no Info, boundaries only) and use pixel information to inspect the values.



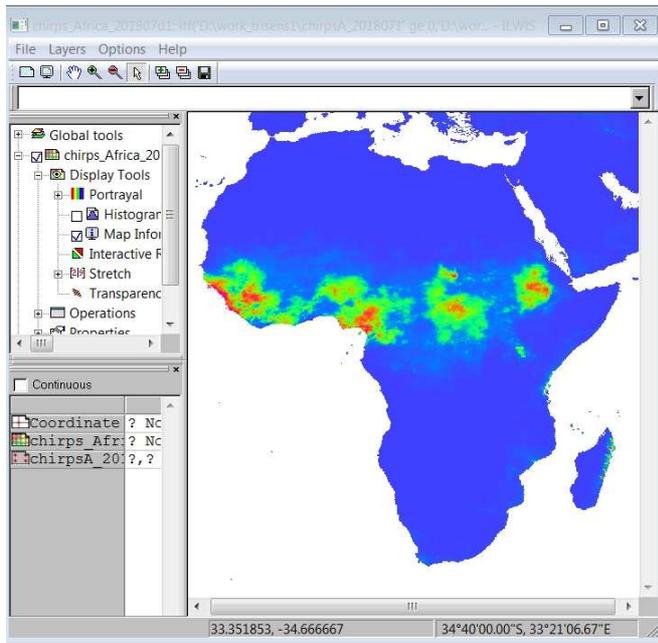


Figure 27 CHIRPS v.2 daily precipitation (01-July-2018) displayed using a stretched “Pseudo” Colour LUT

To import the data from the CHIRPS daily precipitation data, go to the

“CHIRPS V2.0 daily” sub menu. Use a Date stamp select “20180701” (for 01-July-2018) and press “Import”. After the import has been completed, display the newly created map “chirps_20180701”, using as Representation “Pseudo or MPE-sum”. If using the Pseudo Color LUT, you should stretch the color range (e.g. reduce the max. value), using the Display Tools Stretch Menu. Add the country boundaries (no Info, boundaries only).

Pls. note that for multiple imports, i.e. time series, other automated (batch file) ILWIS-based routines exist. See also Triple Collocation Menu and/or also the GEONETCast Toolbox User Guide v.1.6 (par.4.1 p.125-128) or contact the developers.

4.2.7 Import CMORPH global rainfall data

Using the CMORPH Tab will permit you to import a range of global satellite precipitation data based on the CMORPH algorithms. The procedure is similar to CHIRPS. We advise to get first familiar with the several data sets available (see Chapter 3) and also the information websites and references supplied. For import of CMORPH rainfall data, we further refer to the ISOD Toolbox User Guide (also included in the Documentation, and/or downloadable from the www.52north.org together with the ISOD toolbox.

4.2.8 Import FEWSNET Vegetation Cover data for Africa

From the Earth Observation Satellite Data sub-Menu, this import routine will permit you to import FEWSNET eMODIS 250-m NDVI vegetation index data. As a 250-m resolution yields rather large file size, the import is done per four quadrants of Africa North, East, South and West.

Pls. for Zambia, Go to Dekadal NDVI – Southern Africa – last 3 dekads and perform an import. Pls. note that import will take a while (e.g. > 60 seconds to several minutes in slow internet environments, due to large raw i.e. +100MB data size). You need to find of course the dekad equivalent number [0-36 dekads in a year] and specify this after the year as dekad number. E.g. the 10-day periods or dekads of January have numbers: 01 (day 01-10), 02 (day 11-20), and 03 (day 21-31) and June have numbers: 16, 17, 18 and so on. Here a view of a last dekad of July 2018 import for eMODIS NDVI of Southern Africa.

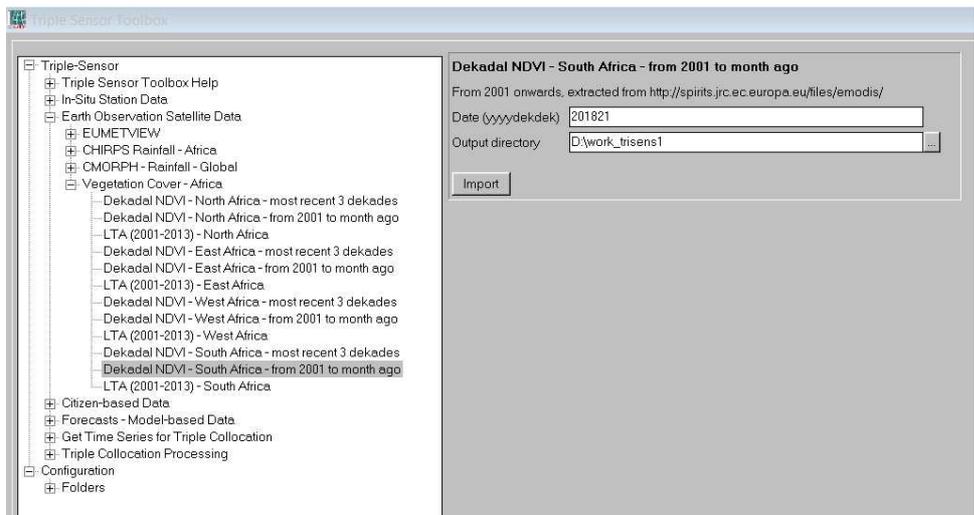


Figure 28 Import of FEWSNET 250-m vegetation index (NDVI) data (e.g. Southern Africa region)

After importing a vegetation cover (index) map, pls. apply an adapted NDVI1 Color LUT to the map, as shown below (a Southern Africa eMODIS, 2nd dekad September 2018). All maps in ILWIS can be easily sub mapped using the File>Submap function, available in the Display window (top left). You can then save this as a separate map (see below e.g. a subset of Zambia, Zimbabwe, NE Mozambique of the eMODIS NDVI Vegetation Index map). Pls. note that dark green colors indicate more dense green vegetation, yellowish less dense and white pixels represent no data values (cloud coverage did not permit uptake of an image during that decade at satellite overpass). Negative values e.g. on water surfaces may be observed in NDVI maps, as water surfaces typically absorb NIR near Infrared more than Red wavelengths. Large waterbodies are usually masked out of NDVI land cover data. Also time series can easily be generated.

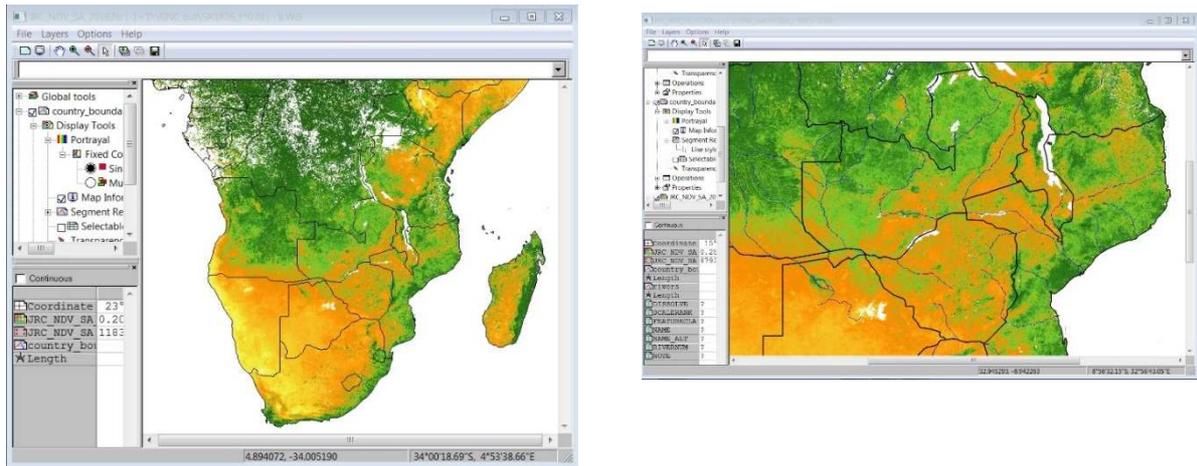


Figure 29 Ilwis map views of 250-m NDVI vegetation index data (using an NDVI1 Colour LUT)



4.2.9 Import Citizen WPDx (WaterPointData Exchange) data

As an example for importing citizen-based observations, we show here the import of a dataset of Burkina Faso (used later under 4.3) , downloaded from the WPDx WaterPointData exchange database at <https://www.waterpointdata.org/water-point-data>. Just select “Burkina Faso” as the country and click “Download country data” to download the data as excel.csv formatted file. Depending on the moment that you download the file, it will have a name that looks like “wpdx_data_export-2018-11-01T08-48-14.csv”. Ps. For sake of speed and practice, the datafile is supplied with the demo in the sub-directory .\sampledata. Copy the file to the “Working Directory” e.g. “D:\Ilwisout”.

Then start ILWIS, and navigate to the “Working Directory”. The file is not visible in the ILWIS Catalog because it still has to be imported into the ILWIS file format. To do so, in the ILWIS menu, choose “File” > “Import” > “ILWIS” > “table” > “Comma delimited”. The form has entries for (among others) Input and Output. At Input, click the “...” button on the right, and select the wpdx_data_export...csv file. Then click “Options...”. In the first screen, just confirm the preview of the selected file, and click “Next”. In the second screen titled “Import Table Wizard - Edit Column Details”, change the “Nr. of Header lines” to 2 (instead of 0). ILWIS uses the first 10 lines of the table to estimate the data-types of the columns. Some corrections are required:

Change the “Domain Type” of row “water_source” to “string”. To do so, double-click the current domain type “value”, select “string” from the list, then click on any other item (e.g. on “water_tech”) to confirm the change.

Apply the same (change to string domain type) for rows “status_id”, “pay”, “installer”, “adm1”, “adm2”, “photo_lnk”, “fecal_coliform_presence” and “subjective_quality”.

For row “install_year” change the Columns “Min”, “Max” and “Precision” to resp. 1900, 2050, 1, for row “lat_deg” change the “Min”, “Max” and “Precision” to resp. -90, 90, 0, and for “lon_deg” change the “Min”, “Max” and “Precision” to resp. -180, 180, 0 .

Optionally you can also choose not to import all 30 columns of the table. When importing less columns, the last columns will be omitted. However keep the columns “lat_deg” and “lon_deg”.

Click “Finish” to confirm the choices. Then click “OK” to perform the actual Import of this csv file into the ILWIS Table format. If you haven’t changed the Output filename, the ILWIS file will have the same name as the original csv file.

Note: WPDx may change the columns in their csv files over time. If this happens, above instructions must not be taken literally.

Double-click the table to open it and have a look at its content.

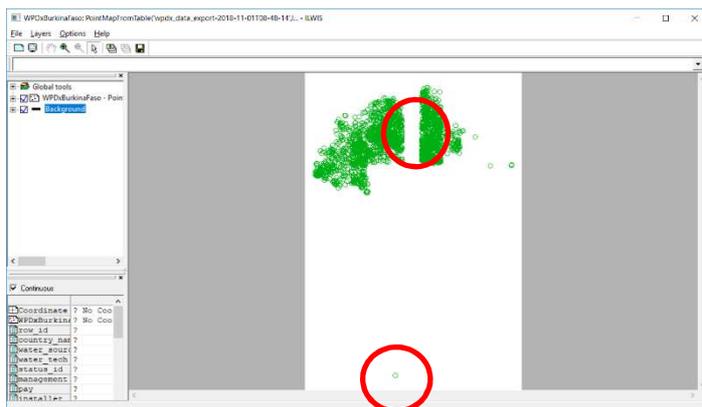
row_id	country name	water_source	water_tech	status_id	management	pay
1	400152 Burkina Faso		flywheel pump	yes		no
2	400153 Burkina Faso		water tap	yes	Direct Gov	no
3	400154 Burkina Faso		pedal pump	yes		no
4	400155 Burkina Faso		flywheel pump	yes		no
5	400156 Burkina Faso		lever pumps	no		no
6	400157 Burkina Faso		lever pumps	no		no
7	400158 Burkina Faso		large diameter	no		no
8	400159 Burkina Faso		lever pumps	yes		no
9	400160 Burkina Faso		flywheel pump	no		no
10	400161 Burkina Faso		pedal pump	yes		no
11	400162 Burkina Faso		large diameter	no		no
12	400163 Burkina Faso		lever pumps	yes		no
13	400164 Burkina Faso		lever pumps	yes	Private Op	yes
14	400165 Burkina Faso		lever pumps	yes		no
15	400166 Burkina Faso		pedal pump	yes	Private Op	yes

Figure 30 View of Citizen Water point data table (Burkina Faso; imported from WPDx.org, 01-Nov-2018)

Click with the Right mouse button on “status_id” (the header of the column), and from the menu that appears choose “Properties”. In the form that appears, click the button “Create new Domain from Strings in column”. Just click “OK” in the form that pops up.

Close the table. Back in the ILWIS Catalog, confirm that two new items appeared, both named “status_id”, but with a different icon. The one is Domain Class “status_id” and the other is Representation “status_id”. Double-click the Representation “status_id” and change the colors so that “no” = Red, “unknown” = Yellow and “yes” = green.

Close the representation. In the ILWIS Catalog, click on the table with the Right mouse button. From the menu that appears, choose “Table Operations” > “Table to PointMap...”. In the “Table to PointMap” form that appears, change “X Column” to “lon_deg”, “Y Column” to “lat_deg”, and in “Coordinate System” choose “LatlonWGS84” from the list. In “Output Point Map” type the output filename, e.g. “WPDxBurkinaFaso”. Then click “Show” to create the pointmap. It will automatically open in a new Map Window when done.



In this point map, one can clearly see the challenges of importing complex tabular data from open databases. Some outliers (one extreme at 0 (zero) latitude is visible). Also are there no WPDx observation points from [0 to 1 degree] west from the 0- longitude meridian. This data flaws are also visible in the raw WPDx.csv file. Of course, raw data can be inspected and cleaned or corrected in Ilwis (or Excel).

Figure 31 Observer point coordinate issues detected in WPDx data (@ Greenwich 0-longitude meridian)

A better view is obtained when adding „OpenStreetMap“ as a background map.



Note: this step assumes that you have an internet connection. Alternatively any other of the background maps can be used as a background.

Click with the Right mouse button on the white space in the layer-management area on the left, below “Background”. From the menu that appears, choose “Add Layer...”. Change the “Filter” to “Base maps”. From the list above, select “openstreetmap”, and click “OK”.

The OpenStreetMap tiles are downloaded and appear on-top. Use the mouse to re-arrange the layers in the layer-management, so that “openstreetmap” is under “WPDxBurkinaFaso”.

Change the colouring of the Burkina Faso water points.

In the layer-management, click on the “+” (plus) before the “WPDxBurkinaFaso” Point Map to open it. Then click on the “+” before “Display Tools”, and then on the “+” before “Display Attribute”. Change the “Display Attribute” to “status_id”. The colors of the points change, but we need to change the symbols. For this, double-click “Symbolization”, change the “Symbols” to “filled-circle”, click “Apply” and then “Close”. The green locations represent the working water points in Burkina Faso. Note that some points are not placed where expected. This is because of errors in the WPDx csv file that must be manually corrected. Also for some reason we don’t know yet, there are no points between -1 and 0 degrees longitude.

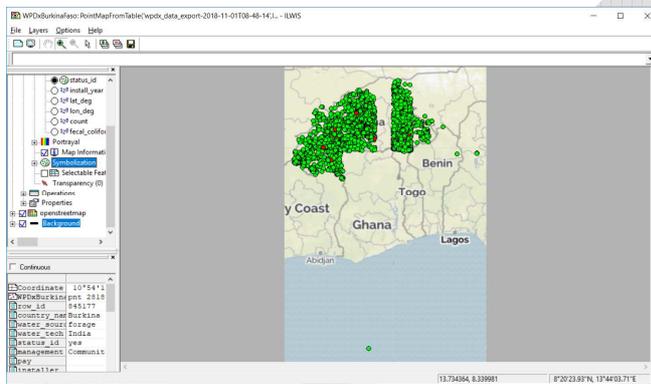


Figure 32 WPDx data visualization using Open Street Map (as background)

The display of specific groups of points can easily be enabled/disabled. Click the “+” before “Portrayal”, and then click the “+” before “Representation”. Unselect e.g. the “yes” to hide all working water points. Only the non-working and the ones with an unknown status remain on the map. Use the “Zoom” and “Pan” buttons of the Map Window to change the mouse action, and zoom-in to a specific location.

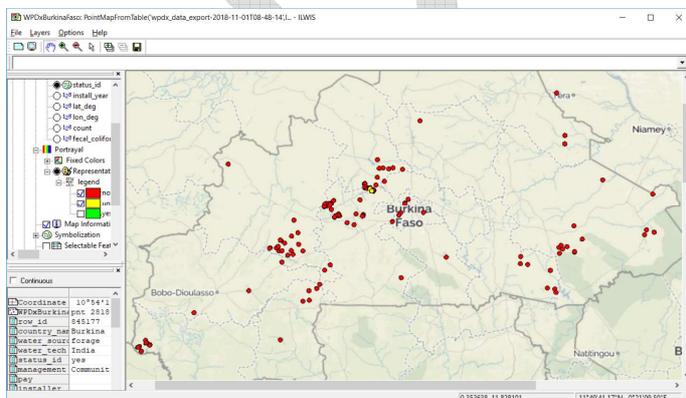


Figure 33 WPDx „working water points” only, visualized from WPDx Burkina Faso dataset

4.2.10 View 6-hourly (current) weather forecasts at airport locations

Decoded METAR or TAF reports from civil airports (using a ICAO-ID code) are requested in this routine from the [https://aviationweather.gov/..](https://aviationweather.gov/), an US-NOAA-NWS National Weather Service linked website. Other download sites and options are possible, but this site delivers continuous up-to-date (present time) data.

Run the application which goes to the [Aviation Weather Service](#) website. Browse (move and scroll) the global map to your Region of Interest (ROI) and check for available (actively reporting airport stations). A coded METAR report will be shown when pointing (clicking) on a station. To get the decoded report (readable data by non-aviation meteorologists), request the decoded METAR a/o including TAF report (issued 1-hour ahead of the 6-hourly METAR. To do so, first Look-up the IDs or ICAO code (e.g. GVAC is Sal Island, Cape Verde; EHAM for Schiphol airport, etc.), and Use [Request](#) METAR data (See data entry on webpage under station map). You can also find ICAO airport codes on the internet (Tabular information).

The METAR report will give you the current (assumed valid for 6-hours ahead) air temperature, dew temperature, air pressure, Rel. Humidity %, wind speed and direction, rainfall including type, cloud base and ceiling, and octets (i.e. cloud cover), and more information supplied to aviation pilots etc. Also the TAF report can be included.



Figure 34 View & retrieval of METAR and TAF reports from Aviation Weather Center web portal

4.2.11 Import NOAA - GFS Global Forecasting System (10-day) weather Forecasts

You can import and derive (from present to max. 240-hours ahead or 10-days), forecasts of the global weather e.g. rainfall and temperature for the whole world from the US-based - NCEP - CPC Numerical Weather Prediction model(s). ILWIS downloads, imports and creates own maps, which can be used later, and also displayed as a Slide show animation (e.g.), using the maplist View Menu.



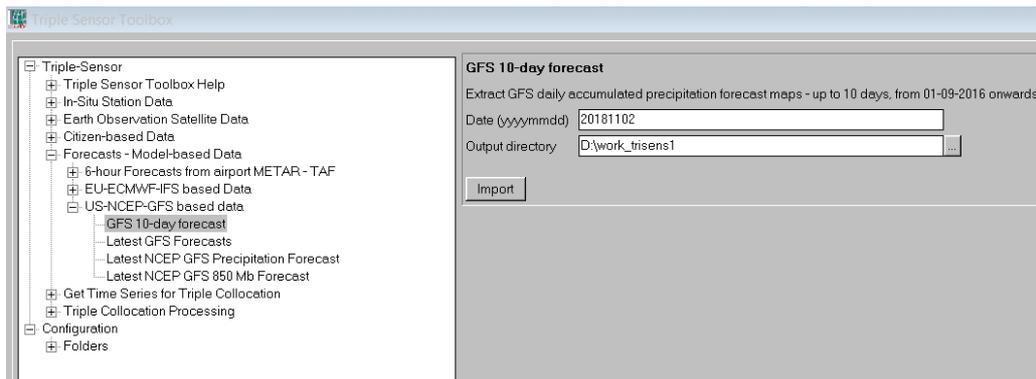


Figure 35 Import of Global Forecasting System GFS - current to 10-day - forecasts (precipitation)

The window above shows an import of a 10-day global rainfall forecast time series (24-hr, 48-hr, 72-hr and so on until 240-hr) derived from the US GFS forecasting system for 02-Nov-2018 to 10 days ahead.

The import will generate 10 global daily (1 to day 10) forecast maps in your Data Catalog.

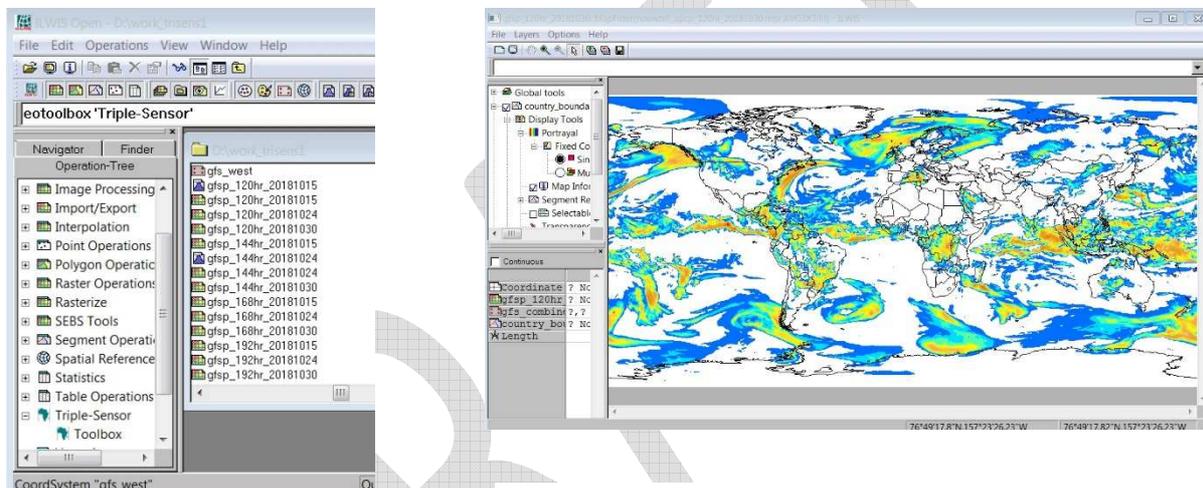


Figure 36 Imported GFS files [24-hr to 240-hr] (left) and view of a single day global forecast (right)

A visual time series animation can be created, after storing all the 10 maps in a maplist (using File>Create>Maplist) and then using the maplist Open and Visualization (open as Animation function). Also first add the country boundaries and select a good Color LUT (e.g. MPE-SUM shown here). Then click on the Display Tools and then Run. The animation menu will appear.

4.2.12 View Seasonal Forecasts from WMO – RCOF (Regional Climate Outlook Forums)

The Toolbox allows to look-up web-based seasonal (90-days ahead) forecast information from the WMO RCOFs (See also Section 3.4.3). Basic information on the WMO-RCOF institutions, using the Toolbox, can be obtained from the next Toolbox open/import:

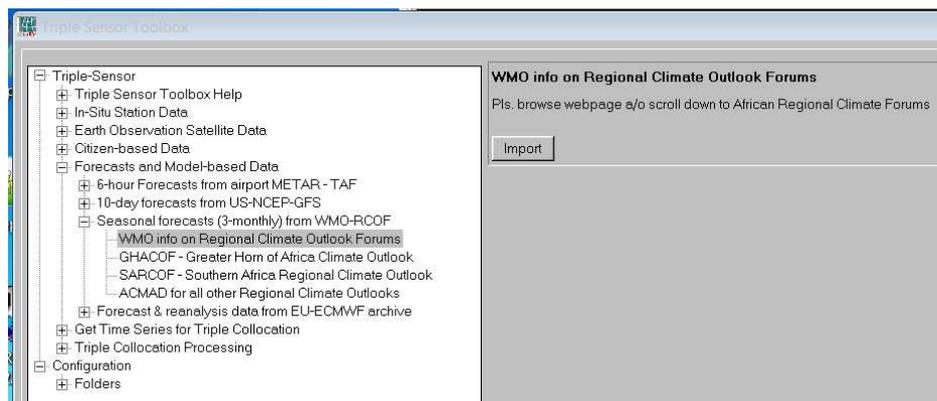


Figure 37 View access to WMO-RCOF information (from WMO, ICPAC, ACMAD, SADC-centre)

A few web mapping services are implemented in the toolbox e.g. see GHACOF, SARCOF etc., permitting access to the different Regional Climate Outlooks for Africa. The up-to-date aspect of this seasonal forecasts and information depends on the web dissemination service quality of the information providers (pls. see also Disclaimer in the Toolbox Help).

4.2.13 Import EU-JRC-MARS dekadal global agrometeorological data

Check the output directory (when starting a new data import, it is wise to do this small check).

From the ILWIS Operations-Tree, open the Afrialliance “Triple Sensor” Toolbox and go to the left hand menu tree (bottom) and open the item “Configuration” > “Folders”. For the Folder item under “JRC_IES” specify your appropriate Ilwis output directory (e.g. d:\Ilwisout) and press “Save” to store the drive: \directory settings. Move to the working directory using the ILWIS Navigator. Close ILWIS and open it again.

Import an ECMWF-based MARS Operational Agrometeorological data of Africa.

Open the “Triple Sensor” Toolbox and select the Forecasts – Model-based Data sub Menu. Go to the option “EU-ECMWF-IFS based Data” and then “JRC-IES-MARS AgroMeteo Operational” > and then “10-day Temperature – Average (C)”. Note that the routine expects a year-month dekad input, e.g. specify for last dekad of August 2018 the following time stamp: “20180821”. Note the dekads are number 01, 11 and 21, for the 1st, 2nd and last dekad of the month respectively. Check the output folder and press “Import”. After the import has been completed display the new map created: “ope_africa_tav_20180821”, use as Representation “Pseudo” and press “OK”, add the country boundaries (no Info, boundaries only) and using the mouse with the left button pressed inspect the map values. Note the unit is in degree Celsius.

If other products are imported note the file name conventions; the prefixes used are ‘int’ and ‘ope’, indicating the Interim and Operational products, region names are self-explanatory and product variables are defined as: rain, evpt, rad, tav, tmax and tmin for the rainfall, evapotranspiration, global radiation sum, average temperature, maximum temperature and minimum temperature. When importing multiple time steps of the same variable for the same region, note that the time step can also be changed in the ILWIS command line and the routine can be executed by pressing <enter>.

The pictures below show two ECMWF Operational Data imports e.g. Average air temperature (10-day) during 3rd dekad of August 2018 and 10-day accumulated rainfall of the 3th dekad of October 2017. Both



maps were displayed using a Pseudo Color LUT, but stretched. Pls. Note that this are quick „open map“ routines and full output maps can also be made with legend, coordinate windows, northing, scale bar etc...

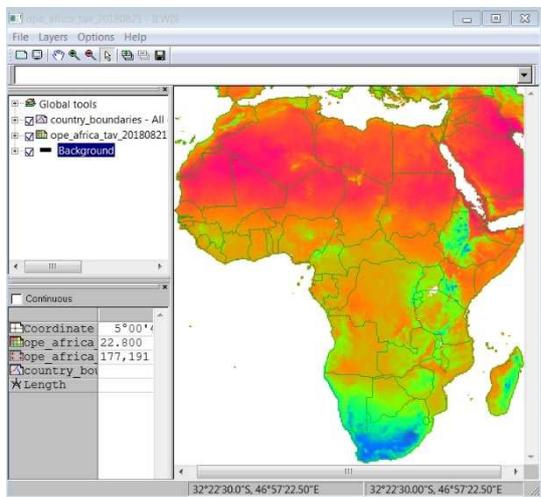


Figure 38 Dekadal 2-m average air temperature from ECMWF Operational archive (e.g. 21-31 August 2018)

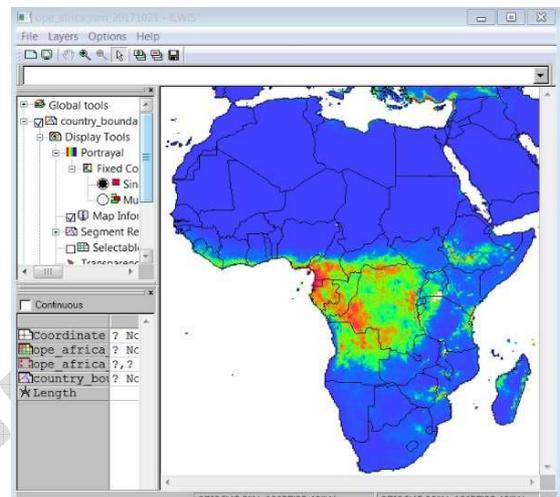


Figure 39 Dekadal (10-day) precipitation sum from ECMWF Operational archive (e.g. 21-31 Oct 2017)

DRAFT

4.3 Triple Collocation demo exercise

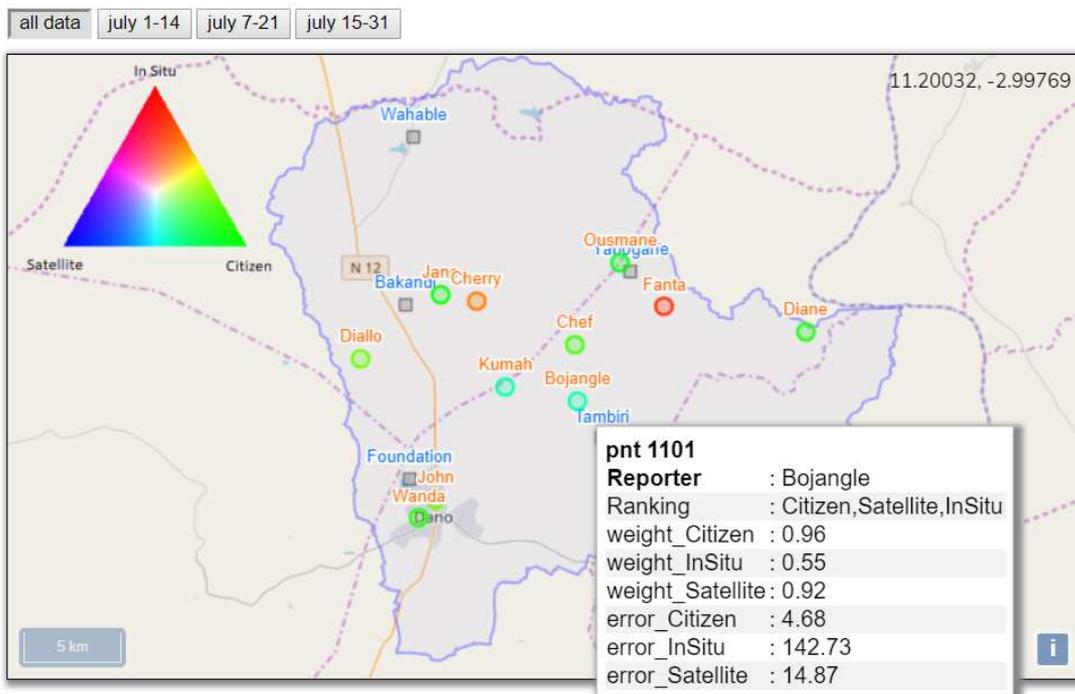
4.3.1 Running the web-based Afrialliance Triple Collocation Demo

The Afrialliance web-demo illustrates the technique for rainfall observations (July 2015) near Dano in Southwest Burkina Faso, a research area of West African Afrialliance partner WASCAL. Citizen locations were extracted from the Open access WPDx or Water Point Database. Citizen names were adapted (privacy) and rain data were simulated for demo purposes. Observed meteorological station data were obtained from WASCAL.org and CHIRPS2 was used as open access satellite precipitation. Pls. Go to the following web-address to open the demo: <http://afrialliance.itc.utwente.nl/triplesensor/>

www.afrialliance.org

Run the Demo

Change the observation period and view which data source is most reliable in that period (compare the color of the symbols to the color triangle legend). Scroll map and move mouse pointer over Citizen location(s) for evaluation statistics.



Method and references

The method is based on statistical covariance analysis on three independent data sources and yields the errors (RMSE) and correlations and permits to rank the dataset reliability.

Figure 40 View of the web-based Triple Sensor Collocation Demo application

The references of the current Triple Collocation approach and statistical method applied can be found in: McColl et al (2014). Extended Triple Collocation: estimating errors and correlation coefficients with respect to an unknown target. Geophysical Research Letters. 10.1002/2014GL061322.



The AfriAlliance project has received funding from the European Union's Horizon 2020 research and Innovation programme under grant agreement No. 689162. - www.afrialliance.org

Mannaerts, C.M., Maathuis, B., Wehn, U., Gerrets, T., Riedstra, H., Becht, R. and Lemmens, R. (2017) - Afrialliance Project Report Deliverable 4.4: Constraints and Opportunities for Water Resources Monitoring & Forecasting using the Triple Sensor approach. Available here [link]

The data sources used in the web-demo are from Wascal (2018) <http://www.wascal.org> ; Chirps (2018) <http://chg.geog.ucsb.edu/data/> and WPDx (2018) <http://www.waterpointdata.org> (see this Toolbox).

4.3.2 Performing Triple Collocation using the Ilwis Triple Sensor Toolbox

We hereafter describe the ILWIS geospatial analysis procedure to perform the Triple Collocation as shown in the Web-based application. When using Ilwis, the user is “in command” of his datasets, and also eventually other Triple Collocations can be done, with different data sets, (as shown), and/or in different geographic Region of Interest (ROI) or study areas, and also with other satellite, station and citizen sourced or forecast model-based data. We will illustrate here two demonstration use cases.

Important Notice: *The data for this Triple Collocation demo are available from the SAMPLEDATA \ Danocase.zip and should be available (unzipped) in your work directory e.g. “..\ilwisout”, d:\Danocase...*

4.3.2.1 Triple Collocation of Satellite CHIRPS, WASCAL station meteo and Citizen WPDx Dano

In this first triple collocation analysis (TC), we will simulate exactly the same situation as in the web-demo in the Dano catchment, Southwest Burkina Faso. The data sources here are:

- CHIRPS satellite rainfall : period: 01 to 31-July 2015; daily interval; 5Km spatial resolution grid
- WASCAL station rainfall data; 5 stations with 01-31 July 2015 observed rainfall
- CITIZEN WPDx location (11 reporters): 01-31 July - 11 citizen observer locations (simulated data);

Note that the citizen rainfall data were generated for test purposes. Reporter names were also changed for privacy reasons. The locations are real WPDx documented water observation points. The WASCAL meteo station data were spatially interpolated (using an inverse-distance weighted or IDW interpolation algorithm, standard available in Ilwis) to gridded station daily rainfall maps. Data are present as a map list (31 days), similar to the CHIRPS data. Pls. note that the current triple collocation application in Ilwis requires two gridded data sets and one point data set (e.g. citizen’s observations).

Start ILWIS, and confirm that the location of your data catalogue is “D:\ilwisout” (or any other directory with your sample data). If this is not the case, navigate to make this the current “Working Directory”.

From the Operation-Tree, start the “Triple-Sensor” > “Toolbox”.

From the “Triple-Sensor Toolbox” main menu select the “Get Time Series for Triple Collocation” sub menu. In there, three sub-entries are found: “Satellite Data – CHIRPS V2.0 daily PCP ...”, “In Situ Data – CPC global PCP data ...” and “Citizen Data – July 2015 PCP of Dano area ...”.

In this first demo exercise with the sample data, the first 2 download steps for “Getting Time Series for Triple Collocation” i.e. internet download of satellite and station data, must be skipped (as we use data available from disk).

Only choose the third sub-entry “Citizen Data – July 2015 PCP of Dano area ...” confirm that the “Output Directory” is “D:\ilwisout” and press “Import”. As mentioned earlier, only daily data of July 2015 is provided. The data will be copied to “D:\ilwisout”. Also a Polygon Map of the Dano catchment area “DanoCatchment” will be copied to your working data catalog “D:\ilwisout”.

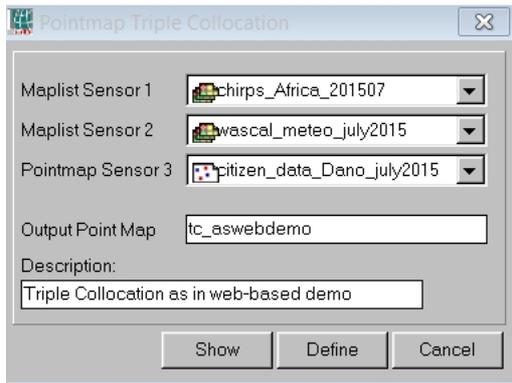


Figure 41 Input Menu for performing Triple Collocation of 3 sensors

And a (created) point map will be opened (as shown below).

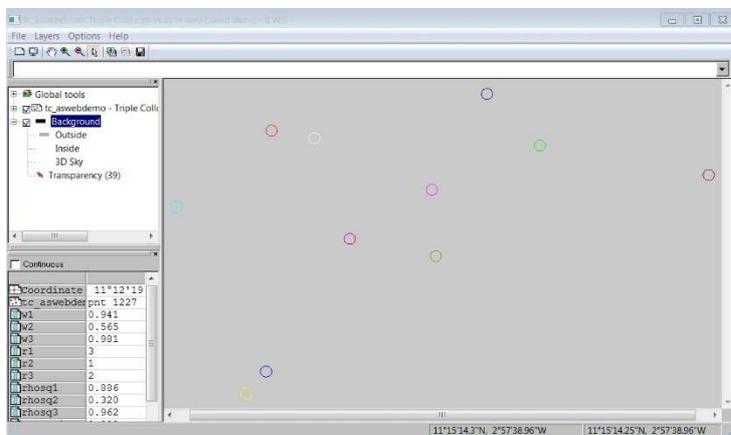


Figure 42 Resulting point map (initial output with point statistics bottom left)

Now proceed to **Section 4.3.3 for TC data analysis and visualization** (as this procedure is equal for the second use case below, with internet data imports).

4.3.2.2 Triple collocation of Satellite CHIRPS, CPC-Gauge based global PCP and Citizen WPDx Dano

In this second demonstration of a triple collocation analysis (TC), we will simulate a situation similar to the web-demo in the Dano catchment, but using other in-situ station data. The data sources here are:

- CHIRPS satellite rainfall : period: 01 to 31-July 2015; daily interval; 5Km spatial resolution grid
- CPC Gauge-based Global PCP analysis data: 01-31 July 2015 ; WMO-GTS gauge observed rainfall
- CITIZEN WPDx location (11 reporters): 01-31 July - 11 citizen observer locations (simulated data);

Pls. note that the CPC-Gauge based PCP has been interpolated to a 0.5 degree gridded map surface (see section 3.1.3.).



Important Notice: *Pls. note that this internet ftp-based satellite and station time series data import will be time consuming, pending largely on your internet download speed (approx. 5- 10 min to). Use previous TC (section 4.3.2.1) if you want to proceed more rapidly with TC data analysis (and go to Section 4.3.3).*

Start ILWIS, and confirm that the location of your data catalogue is “D:\Ilwisout”. If this is not the case, navigate to make this the current “Working Directory”.

From the Operation-Tree, start the “Triple-Sensor” > “Toolbox”.

From the “Triple-Sensor Toolbox” main menu select the “Get Time Series for Triple Collocation” sub menu. In there, three sub-entries are found: “Satellite Data – CHIRPS V2.0 daily PCP ...”, “In Situ Data – CPC global PCP data ...” and “Citizen Data – July 2015 PCP of Dano area ...”. Go through all three entries and download the corresponding data. Note that since the Citizen Data provided is daily data of July 2015, also the Satellite Data and the In Situ Data must exactly correspond to this (daily observation) time window or date-range. Otherwise the Triple Collocation cannot be performed correctly.

Choose the first sub-entry “Satellite Data – CHIRPS V2.0 daily PCP ...”, confirm that the “Output Directory” is “D:\Ilwisout”, in “Date (yyyymm)” type “201507” and press “Import”. Depending on the speed of your internet connection and of your computer, this may take around 15 to 30 minutes.

Now choose the second sub-entry “In Situ Data – CPC global PCP data ...”, confirm that the “Output Directory” is “D:\Ilwisout”, in “Date (yyyymm)” type “201507” and press “Import”.

At last choose the third sub-entry “Citizen Data – July 2015 PCP of Dano area ...”, confirm that the “Output Directory” is “D:\Ilwisout” and press “Import”. As mentioned earlier, only data of July 2015 is provided. The data will be copied to “D:\Ilwisout”. Also a Polygon Map of the Dano catchment area “DanoCatchment” will be copied to “D:\Ilwisout”.

Back in the “Triple-Sensor Toolbox” main menu select the “Triple Collocation Processing” > “TC of Rainfall” > “TC of CHIRPS, CPC and Citizen Data” sub menu, and press “Open”. The form “Pointmap Triple Collocation” will pop-up. Tip: this form can also be started outside the toolbox, by selecting the corresponding application in the “ILWIS Point Operations”.

Proceed by selecting the appropriate input for the form. Click the box next to “Maplist Sensor 1” to open the file selector, and select the item “chirps_Africa_201507”. Then click the box next to “Maplist Sensor 2”, and similarly select the item “CPC_Pgauge_201507”. Also click the box next to “Pointmap Sensor 3”, and select the item “citizen_data_Dano_july2015”. Then enter a name for the output filename (e.g. “tc_Dano_july2015”), and click “Show” to perform the Triple Collocation computations, and create the pointmap. It will automatically open in a new Map Window when done.

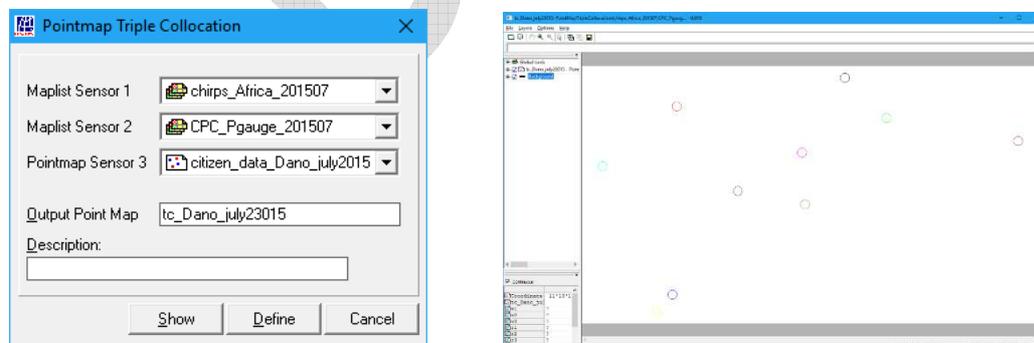


Figure 43 Triple Collocation Input Menu screen and initial point map output

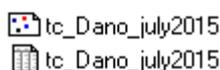
Proceed to section 4.3.2.3 for TC data analysis and visualization.

4.3.3 TC demo data analysis, interpretation and visualization

Hereunder, a detailed Ilwis procedure to analyze and visualize TC output is given. This can be done for both use cases (Triple collocations under 4.3.2.1. and 4.3.2.2). The procedure below uses the last CHIRPS –CPC - Citizen-WPDx data (i.e. Section 4.3.2.2 filenames). Pls. Use other file names (i.e. table and pointmap names from Section 4.3.2.1) to analyse the Section 4.3.2.1 use case.

The locations are the same as the ones of the “citizen_data_Dano_july2015” Point Map, and the coloring of the points is the default of ILWIS for this type of map, which is one distinct color per point. However the new Point Map “tc_Dano_july2015” was assigned an attribute table that was computed by the Triple Collocation application. Keep the Point Map “tc_Dano_july2015” open, but close the Triple Sensor Toolbox. Then in the ILWIS catalog, double-click the table “tc_Dano_july2015” to open it. This is the attribute-table that corresponds to the Triple Collocation Point Map.

Note the difference with the Point Map “tc_Dano_july2015”, the filename is the same, but the icons differ. The first item is the Point Map, the second is the table:



After opening the table, explore the attributes that were computed by the Triple Collocation application. You can resize the columns if some text is not readable.

	w1	w2	w3	r1	r2	r3	rhosq1	rhosq2	rhosq3	errvar1	errvar2	errvar3
pnt 608	0.814	0.839	1.065	3	2	1	0.662	0.703	1.135	33.924	32.239	-16.037
pnt 610	0.768	0.876	1.000	3	2	1	0.599	0.767	1.001	34.129	25.953	-0.063
pnt 611	0.640	1.050	0.876	2	3	1	0.410	1.103	0.767	48.505	-11.187	39.667
pnt 619	0.705	1.021	0.882	2	3	1	0.497	1.043	0.778	46.324	-3.693	36.912
pnt 620	0.598	1.090	0.873	2	3	1	0.357	1.189	0.762	53.644	-20.530	64.867
pnt 648	0.592	1.215	0.725	2	3	1	0.351	1.477	0.526	59.780	-41.454	82.730
pnt 1019	0.577	1.134	0.790	2	3	1	0.333	1.285	0.625	54.425	-31.023	82.455
pnt 1100	0.823	0.897	1.004	3	2	1	0.678	0.784	1.008	21.931	18.548	-0.714
pnt 1101	0.982	0.744	0.912	1	3	2	0.965	0.554	0.832	2.959	38.741	10.687
pnt 1163	0.910	0.769	1.062	3	1	2	0.828	0.592	1.128	17.427	35.465	-12.560
pnt 1227	0.953	0.687	0.969	3	1	2	0.907	0.472	0.939	7.560	57.371	5.360
Min	0.577	0.697	0.725	1	1	1	0.333	0.472	0.526	2.959	-41.454	-16.037
Max	0.982	1.215	1.065	3	3	2	0.965	1.477	1.135	59.780	57.371	82.730
Avg	0.760	0.938	0.924	2	2	1	0.598	0.906	0.864	34.592	9.075	26.664
Std	0.149	0.174	0.108	1	1	0	0.230	0.331	0.197	19.772	32.267	36.776
Sum	8.361	10.313	10.160	26	26	14	6.577	9.971	9.501	380.507	99.829	293.304

Figure 44 View of Triple Collocation output table with point statistics

The attributes w1, w2 and w3 are the weights that are assigned to each of the inputs that were used (“Maplist Sensor 1”, “Maplist Sensor 2” and “Pointmap Sensor 3”). They are computed based on the three 31-days time-series for each location. A higher weight indicates a higher confidence in the data of the corresponding sensor.

The attributes r1, r2 and r3 indicate the ranking of the sensors. For instance, in the first row, the third sensor (“Pointmap Sensor 3”, which represents the citizen-data) received rank 1, since it has the highest weight out of the three sensors.



The attributes rhosq1, rhosq2 and rhosq3 are the squares of the weights.

Finally the attributes errvar1, errvar2 and errvar3 are the error variances of the weights.

Now we are going to compute colors for each of the points that correspond to the triangular red-green-blue triple-collocation legend that was introduced in the web-demo of the previous paragraph.

The goal is to compute Red, Green and Blue values for each location, ranging from 0 to 255, using the following formulas, and add them as an RGB Color attribute to the table, that will then be used for coloring the points.

$$\text{Red} = 255 * \text{rhosq2} / \max(\text{rhosq1}, \text{rhosq2}, \text{rhosq3})$$

$$\text{Green} = 255 * \text{rhosq3} / \max(\text{rhosq1}, \text{rhosq2}, \text{rhosq3})$$

$$\text{Blue} = 255 * \text{rhosq1} / \max(\text{rhosq1}, \text{rhosq2}, \text{rhosq3})$$

Explanation:

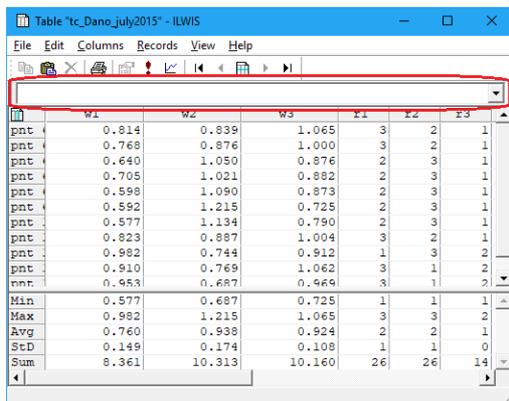
High weights for Satellite data (w1) contribute to the Blue color

High weights for In Siitu data (w2) contribute to the Red color

High weights for Citizen data (w3) contribute to the Green color

We use rhosq1, rhosq2 and rhosq3 (the squared versions of w1, w2, w3) to get a higher contrast in the colors. Close the Point Map "tc_Dano_july2015", but keep the table "tc_Dano_july2015" open.

In the table, the white space between the buttons and the column-headers is named "table command-line". It is a space where a command can be entered. It is marked in red in the following picture.



	W1	W2	W3	E1	E2	E3
pnt	0.814	0.839	1.065	3	2	1
pnt	0.768	0.876	1.000	3	2	1
pnt	0.640	1.050	0.876	2	3	1
pnt	0.705	1.021	0.882	2	3	1
pnt	0.598	1.090	0.873	2	3	1
pnt	0.592	1.215	0.725	2	3	1
pnt	0.577	1.134	0.790	2	3	1
pnt	0.823	0.887	1.004	3	2	1
pnt	0.982	0.744	0.912	1	3	2
pnt	0.910	0.769	1.062	3	1	2
pnt	0.453	0.687	0.464	3	1	2
Min	0.577	0.687	0.725	1	1	1
Max	0.982	1.215	1.065	3	3	2
Avg	0.760	0.938	0.924	2	2	1
STD	0.149	0.174	0.108	1	1	0
Sum	8.361	10.313	10.160	26	26	14

Figure 45 Command line (in Ilwis Table operations)

In this "table command-line", enter the following formula (if you have the digital version of this document, it is preferred to use copy/paste, for preventing typing mistakes). The formula is to be typed in one line, despite the fact that in this document the lines are wrapped, unintentionally splitting the formula in 3 lines.

```
color_tc := COLOR( 255 * rhosq2 / max( rhosq1 , rhosq2 , rhosq3 ) ,  
255 * rhosq3 / max( rhosq1 , rhosq2 , rhosq3 ) ,  
255 * rhosq1 / max( rhosq1 , rhosq2 , rhosq3 ) )
```

Explanation: this formula uses the same computations as before, creating the RGB values in a single step.

After typing or pasting the formula, the table will look similar to this:

Table "tc_Dano_july2015" - ILWIS

File Edit Columns Records View Help

hosq2/max(rhosq1,rhosq2,rhosq3), 255*rhosq3/max(rhosq1,rhosq2,rhosq3), 255*rhosq1/max(rhosq1,rhosq2,rhosq3)

	w1	w2	w3	r1	r2	r3	rhosq1	rhosq2	rhosq3	errvar1	errvar2	errvar3
pnt 608	0.814	0.839	1.065	3	2	1	0.662	0.703	1.135	33.824	32.238	-16.037
pnt 610	0.768	0.876	1.000	3	2	1	0.589	0.767	1.001	34.129	25.353	-0.063
pnt 611	0.640	1.050	0.876	2	3	1	0.410	1.103	0.767	48.505	-11.187	39.667
pnt 619	0.705	1.021	0.882	2	3	1	0.497	1.043	0.778	46.324	-3.693	36.912
pnt 620	0.598	1.090	0.873	2	3	1	0.357	1.189	0.762	53.644	-20.530	64.867
pnt 648	0.592	1.215	0.725	2	3	1	0.351	1.477	0.526	59.780	-41.454	82.730
pnt 1019	0.577	1.134	0.790	2	3	1	0.333	1.285	0.625	54.425	-31.023	82.455
pnt 1100	0.823	0.887	1.004	3	2	1	0.678	0.786	1.008	21.931	18.548	-0.714
pnt 1101	0.982	0.744	0.912	1	3	2	0.965	0.554	0.832	2.959	38.741	10.687
pnt 1163	0.910	0.769	1.062	3	1	2	0.828	0.592	1.128	17.427	35.465	-12.560
pnt 1227	0.953	0.687	0.969	3	1	2	0.907	0.472	0.939	7.560	57.371	5.360
Min	0.577	0.687	0.725	1	1	1	0.333	0.472	0.526	2.959	-41.454	-16.037
Max	0.982	1.215	1.065	3	3	2	0.965	1.477	1.135	59.780	57.371	82.730
Avg	0.760	0.938	0.924	2	2	1	0.598	0.906	0.864	34.592	9.075	26.664
StD	0.149	0.174	0.108	1	1	0	0.230	0.331	0.197	19.772	32.267	36.776
Sum	8.361	10.313	10.160	26	26	14	6.577	9.971	9.501	380.507	99.829	293.304

Double click to change column properties of rhosq3

Figure 46 View of active command-line (in Ilwis Table operations)

Press <ENTER> to execute the formula. If it was typed correctly, a "Column Properties" window will pop-up, asking for confirmation that a new column named "color_tc" is to be created from this formula.

Column properties

Column Calculate "color_tc"

Thursday, November 8, 2018 1:31:04 PM

Read Only

Expression
 COLOR[255*rhosq2/max(rhosq1,rhosq2,rhosq3)]

Domain Defaults

Color Domain

Position

Width

Description:
 color_tc = COLOR[255*rhosq2/max(rhosq1,rhosq3)]

Click OK to proceed computing the new column. It will be added to the table.

Figure 47 View of new Column (color_tc) properties



	w2	w3	r1	r2	r3	rhosq1	rhosq2	rhosq3	errvar1	errvar2	errvar3	color_tc
pnt	0.839	1.065	3	2	1	0.662	0.703	1.135	33.824	32.238	-16.037	(158,255,149)
pnt	0.876	1.000	3	2	1	0.589	0.767	1.001	34.129	25.353	-0.063	(195,255,150)
pnt	1.050	0.876	2	3	1	0.410	1.103	0.767	48.505	-11.187	39.667	(255,177, 95)
pnt	1.021	0.882	2	3	1	0.497	1.043	0.778	46.324	-3.693	36.912	(255,190,122)
pnt	1.090	0.873	2	3	1	0.357	1.189	0.762	53.644	-20.530	64.867	(255,164, 77)
pnt	1.215	0.725	2	3	1	0.351	1.477	0.526	59.780	-41.454	82.730	(255, 91, 61)
pnt	1.134	0.790	2	3	1	0.333	1.285	0.625	54.425	-31.023	82.455	(255,124, 66)
pnt	0.887	1.004	3	2	1	0.678	0.786	1.008	21.931	18.548	-0.714	(199,255,171)
pnt	0.744	0.912	1	3	2	0.965	0.554	0.832	2.959	38.741	10.687	(146,220,255)
pnt	0.769	1.062	3	1	2	0.828	0.592	1.128	17.427	35.465	-12.560	(134,255,187)
pnt	0.687	0.969	3	1	2	0.907	0.472	0.939	7.560	57.371	5.360	(128,255,246)
Min	0.687	0.725	1	1	1	0.333	0.472	0.526	2.959	-41.454	-16.037	
Max	1.215	1.065	3	3	2	0.965	1.477	1.135	59.780	57.371	82.730	
Avg	0.938	0.924	2	2	1	0.598	0.906	0.864	34.592	9.075	26.664	
StD	0.174	0.108	1	1	0	0.230	0.331	0.197	19.772	32.267	36.776	
Sum	10.313	10.160	26	26	14	6.577	9.971	9.501	380.507	99.829	293.304	

Figure 48 View of new „color_tc“ column (added by command line operation)

Now go back to the ILWIS catalog and double-click the Point Map “tc_Dano_july2015” to open it.

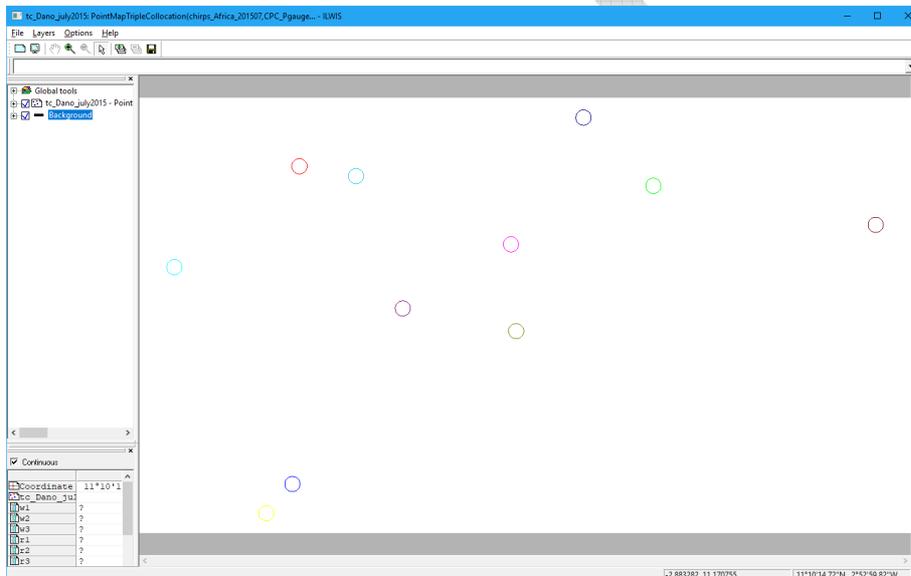


Figure 49 Point map (initial) view with new color_tc colour scheme

The colors are still the same as before, the ILWIS default of one distinct color per point.

Now change the colouring of the “tc_Dano_july2015” points, to the colours that we computed earlier.

In the layer-management of the Map Window, click on the “+” (plus) before the “tc_Dano_july2015” Point Map to open it. Then click on the “+” before “Display Tools”, and then on the “+” before “Display Attribute”. Change the “Display Attribute” to the newly created “color_tc”. Then double-click “Symbolization”, change the “Symbols” to “filled-circle”, and the “Symbol scale” to 0.7, and click “Apply” and then “Close”.

Add the Dano catchment polygon map as a background layer.

Click with the Right mouse button on the white space in the layer-management area on the left, below “Background”. From the menu that appears, choose “Add Layer...”. Select the item named “DanoCatchment”, enable “Extend Map Boundaries” and click OK.

The Dano catchment polygon map is added on-top. Use the mouse to re-arrange the layers in the layer-management, so that “DanoCatchment” is under “tc_Dano_july2015”.

Change the colouring of the “DanoCatchment” Polygon Map.

In the layer-management of the Map Window, click on the “+” (plus) before the “DanoCatchment” Polygon Map to open it. Then click on the “+” before “Display Tools”, then on the “+” before “Portrayal” and then on the “+” before “Fixed Colors”. Change the selection to “Single color”, then double-click on “Single color” to select a new color. Change it to “Magenta”. Click Apply and Close.

Under the “Display Tools” of “DanoCatchment”, click the “+” before “Boundaries”, then double-click the item labeled “Line style”. Change the Line thickness to 2, and the Line Color to “SkyBlue”. Click Apply and Close.

Under the “Display Tools” of “DanoCatchment”, click the “+” before “Areas”, then double-click the item under “Areas” that is labeled “Transparency (0)”. Change the transparency to 95. Click Apply and Close.

Adding OpenStreetMap as an additional background layer.

Click with the Right mouse button on the white space in the layer-management area on the left, below “Background”. From the menu that appears, choose “Add Layer...”. Change the “Filter” to “Base maps”. From the list above, select “openstreetmap”, and click “OK”.

The OpenStreetMap tiles are downloaded and appear on-top. Use the mouse to re-arrange the layers in the layer-management, so that “openstreetmap” is under “DanoCatchment”.

Now the colors are as similar as possible to the web-demo. The differences are only attributed to slight difference in the data-sources used for the web-demo, which were reduced in size for performance reasons (and a different OpenStreetMap server is used).

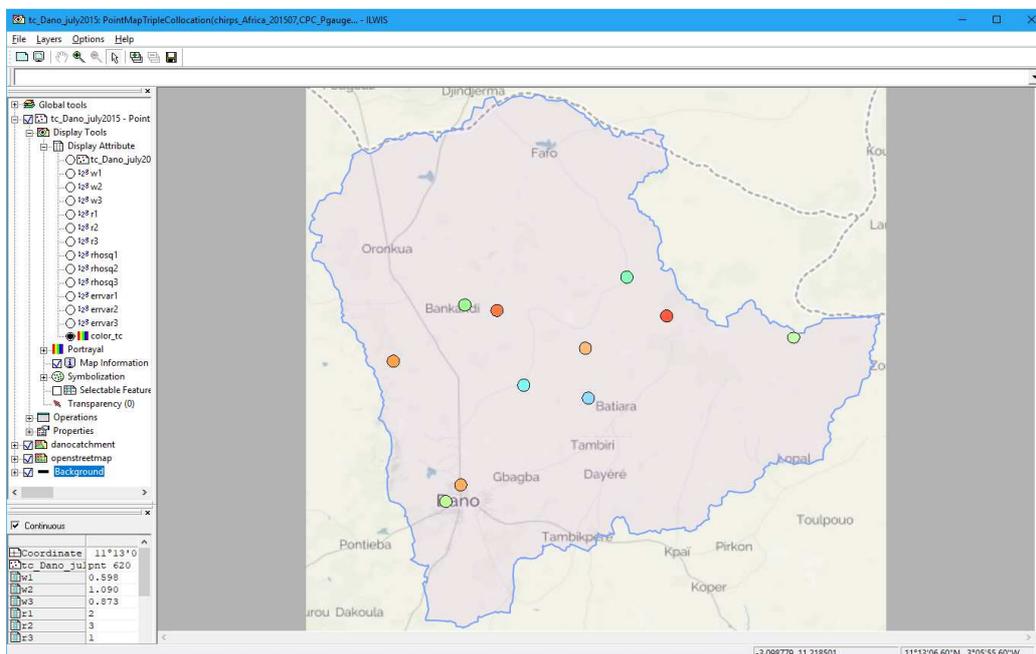


Figure 50 Final view of TC output (with Open Street Map background and Triple sensor colour scheme)

Further Data exploration: On the bottom-left of the Map Window, ensure that “Continuous” is enabled. Move the mouse over the TC locations, and (when the mouse is close to a point), the Triple Collocation



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attributes of that location (w1, w2, w3, ranking, etc.), are shown at the bottom-left of the map window. Optionally increase the size of the attributes box for better visibility.

4.3.4 Running triple sensor collocation analysis with own data.

The Triple Sensor Toolbox and Triple Collocation processor in ILWIS permit in principle to perform a TC in any region or area of interest on the globe. Data at all spatial scales (e.g. village level, province, catchment, country or region) and any time period length and interval can be analysed with high precision.

Using the extensive projection and coordinate system libraries of Ilwis, all areas of the world can be projected. In this Afrialliance Triple Sensor toolbox, focus is however on African Regions of Interest (ROI).

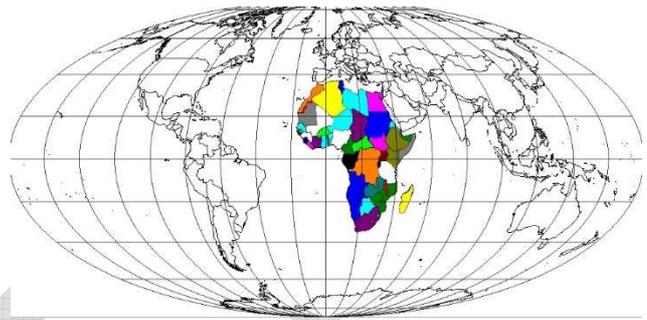


Figure 51 Global application potential of the Triple Sensor toolbox (world country boundaries using Mollweider projection in Ilwis)

When you wish to use Triple Collocation with your own datasets, you will need to supply time series from three different sensor sources that have overlap in space (i.e. same ROI), and match also exactly in time. Time periods can be any time interval, but this interval and time step (of observation) must be equal for all three sensors. Of course, time series pre-processing can be done on the data (where needed). It is also essential that the data sources collocate in the spatial domain (window).

We also assume that data are accessible (via internet or other source). In case of downloading and generation of satellite or large image time series, a fast internet connection is recommended (to speed up pre-processing and the generation of time series).

Two of the three sensor time series must be raster-based i.e. gridded data sets (and available as ILWIS Map Lists). The number of bands in the two Map Lists must be the same, and correspond to the same time-unit, e.g. 1 band = 1 day, or 1 hour, or 15 minutes. Pls. note that Ilwis users can generate Ilwis map lists using GDAL routines (www.gdal.org) from e.g. netCDF, GeoTiff, grib and most other data formats.

The third time series supplied must be Point-based data (i.e. an ILWIS Point Map with Attribute Table). Each record in the table must correspond to one point (1-to-1 relationship between point map and table). The points must preferably be inside the boundaries of both Map Lists. Points that are outside the boundaries of one or both Map Lists will be considered as having one or two sensors less (no data for one or two sensors), which is not suitable as “input” to the Triple Collocation algorithm.

The time series data of the points must be placed in value-columns. The number of columns must be the same as the number of bands in each Map List. Each column will correspond to one band. E.g. the first column will be matched with the first band of the first Map List, and with the first band of the second Map List. It is allowed for the Point Map to have more columns than the number of bands in the Map Lists. Then it is considered that the first columns contain metadata (e.g. the location name, the observer name, etc.), and they will be ignored. Thus for a time series of N time steps, the last N columns of the Point Map will be used in the Triple Collocation computations.

It is not possible to supply one Map List and two Point Maps to the Triple Collocation application. If you have this, one of the two Point Maps must be interpolated and rasterized into a Map List (each column

must result into one raster band), and interpolated, e.g. by a “Moving Average”, kriging or other spatial interpolation algorithm (e.g. see also use case with WASCAL station meteo data).

The order in which the three time series are supplied to the Triple Collocation application is not important. The output attribute table will contain columns named w1, w2, w3 etc., corresponding to resp. the first, second and third time series supplied.

The current Triple Collocation application is unable to verify temporal incompatibility. For instance, if one Map List has 24 bands corresponding to 24 days, and the second one has 24 bands corresponding to the 24 hours of a day, it will just execute. However, the results will not make sense.



5 References

5.1 Literature references

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5.2 Web references (using page number reference)

All web pages were visited during the last 90-days (01-Sep to 30-Nov 2018). Pls. read also the disclaimer in the ILWIS Tripe Sensor Toolbox User Help (Tab) for some additional information.

Page 11

- <http://www.ncdc.noaa.gov/cgi-bin/res40.pl?page=gsod.html>
- <ftp://ftp.ncdc.noaa.gov/pub/data/g sod>.

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- <http://ams.confex.com/ams/pdfpapers/131381.pdf>
- <ftp://ftp.cpc.ncep.noaa.gov/fews/gts>.
- ftp://ftp.cpc.ncep.noaa.gov/precip/CPC_UNI_PRCP/GAUGE_GLB/V1.0/
- ftp://ftp.cpc.ncep.noaa.gov/precip/CPC_UNI_PRCP/GAUGE_GLB/RT/

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- <http://www.sasscal.org>
- <http://www.wascal.org>
- <http://tahmo.org/about-tahmo-2/>

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- <https://www.wmo-sat.info/oscar/satellites>

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- <http://www.copernicus.eu/main/contributing-missions>
- <http://land.copernicus.eu/global/products>.
- <https://scihub.copernicus.eu/>
- <https://coda.eumetsat.int>
- <https://peps.cnes.fr/rocket/#/home>
- <https://landsatlook.usgs.gov/sentinel2/viewer.html>
- <https://earthexplorer.usgs.gov/>
- <https://giovanni.gsfc.nasa.gov/giovanni/>
- <https://earthengine.google.com/> (ps. also Sentinel data)
- <https://www.theia-land.fr/en/products/spot-world-heritage>
- <https://landsatlook.usgs.gov/viewer.html>
- https://lpdaac.usgs.gov/dataset_discovery/aster
- http://www.dgi.inpe.br/siteDgi/english/index_eng.php
- <http://www.geoportal.org/>

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- <https://www.eumetsat.int/website/home/Images/EUMETView/index.html>
- <https://52north.org/software/software-projects/ilwis-toolboxes/>
- <http://chg.geog.ucsb.edu/data/chirps/>
- <ftp://chg-ftpout.geog.ucsb.edu/pub/org/chg/products/CHIRP/>
- <http://chg.geog.ucsb.edu/data/chirps/>.
- http://www.cpc.ncep.noaa.gov/products/janowiak/cmorph_description.html

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- <https://www.vito-eodata.be/PDF/portal/Application.html#Home>
- <https://www.waterpointdata.org/water-point-data> (also Page 39)

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- <http://en.allmetsat.com/metar- taf/>
- <https://www.aviationweather.gov/metar/gis/> (Also on Page 42)
- <http://www.cpc.ncep.noaa.gov/products/international/africa/africa.shtml>.
- <http://www.ncdc.noaa.gov/data-access/model-data/model-datasets/global-forecast-system-gfs>.

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- <http://www.ecmwf.int>.
- <http://mars.jrc.ec.europa.eu/mars/>
- http://spirits.jrc.ec.europa.eu/?page_id=184
- http://marswiki.jrc.ec.europa.eu/agri4castwiki/index.php/Main_Page

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- <http://www.52north.org>
- <http://www.afrialliance.org>
- <ftp://ftp.itc.nl/pub/52n/AfriAlliance/>

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- <http://afrialliance.itc.utwente.nl/triplesensor/>

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- <http://www.wascal.org>
- <http://chg.geog.ucsb.edu/data/chirps/>
- <http://www.waterpoint.org/download/>

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- <http://public.wmo.int/en/our-mandate/climate/regional-climate-outlook-products>

6 Appendixes

6.1 APPENDIX 1: ILWIS v.3x tips and tricks

- [Installing ILWIS v3x]: Ilwis Open v.3 with Toolbox (supplied as a zip-file) doesn't need to be installed through a Windows setup (msi or setup file), but can just be unzipped to a drive on your system, using a folder with a short path name, without empty spaces in the path, e.g. „d:\ilwis385“ or similar.
- [STARTING ILWIS OPEN]: When starting to work with Ilwis 3, first Open Ilwis, then navigate to your working directory, close and re-open Ilwis. Ilwis has now registered itself in Windows registry, and remembers it's program locations and the data catalogue (directory) path(s).
- [COPY and DELETE Ilwis FILES]: You can best **delete** Ilwis files using the Edit Menu > Delete option. This removes all (hidden, non-displayed ancillary files) from your system. Also always **copy Ilwis files** (to other disks or directories) using the Edit Menu > **Copy Object to ...** option, in order to copy the object dependencies also.
- [REFRESH MEMORY]: Pls. use the **Refresh** (or **F5**) from the Window Menu, if you do not find a filename of something you just created. This is a refresh Memory operation in Ilwis.
- [RESTORE DEFAULTS]: If you worked much on data and e.g. did overwrite filenames or tried operations which are not possible or allowed etc. and if Ilwis is getting slow (or seems to hang), you can refresh (clean) the entire *Ilwis memory* by **File > preferences > Advanced > Restore Defaults**. This **resets Ilwis**. You will need to navigate back to your work directory for the first time again, after resetting Ilwis.
- [CLOSE APPLICATION]: **Kill Ilwis** in case of “hanging”. By some not allowed operations, Ilwis Open might not work further. In worst case, pls. use the Windows Task Manager from the Windows Task Bar to “End Task” -> Ilwis run operations. This is “brute” Windows forced close program, but efficient if really needed. Just Re-open Ilwis again.
- [FILE DEPENDENCIES]: GIS files in general (e.g. also ArcGIS) have much earlier created file dependencies and heritages or lineages, which can sometimes be cut, but sometimes also may not be removed. The Ilwis Properties button is an important info source to see the dependencies of your Ilwis object. Especially earlier Georeferences used to create the (sub)object are important file heritages or lineages in Ilwis.
- [DISPLAY SETTINGS]: Sometimes your **Defaults Display settings** for e.g. Raster maps looks not good (e.g. gtdmax). This raster representation is not nice (in the Ilwis default settings) and should by preference be set to *Pseudo* (colour Look-up). Use File > Preferences > Map Window> Display > Default Representations to adapt.
- [SERVICE OBJECTS]: Pls. remember that in ILWIS, the **Domain** (-> data type) and **georeference, coordinate systems** are most important Service Objects to take care off. They basically determine what you can do on an object. If a certain RS/GIS operation does not work (or you cannot activate it), pls. first check the domain type, georeference and dependencies of the objects you are working with (or combining, etc.)...
- **ILWIS HELP Menu**: Ilwis contains a very well documented Help Menu ! Don't forget to use it (in case more explanation is needed).

