USING SATELLITE IMAGES FOR VEGETATION MONITORING

Let's consider the strengths and drawbacks of the low resolution systems…

1. spectral properties

Strengths

- Thanks to their large swath width, low resolution systems have a much **better synoptic view and temporal revisit frequency** compared to high resolution sensors.
- The individual scenes span a width of up to 3000 km, such that the entire Earth surface is scanned every day and the **specific costs** per ground area unit are **very low**.
- All the low and medium resolution sensors that have proven their validity for land surface observation and vegetation analysis do normally find their **applications also in agriculture**.

Weaknesses

- The low spatial resolution **is an intrinsic drawback** for the sensors, with pixel sizes of about 1 km^2, i.e. far above typical field sizes.
- As a consequence, recorded **spectral radiances** are mostly **mixed information** from several surface types. This seriously **complicates the interpretation** (and validation) of the signal as well as **the reliability** of the derived information products.

However, for crop monitoring, early warning and yield forecasting at the national scale a 1 km^2 resolution is quite suitable.

USING SATELLITE IMAGES FOR VEGETATION MONITORING

Please indicate whether the following statements about low resolution systems characteristics are true or false.

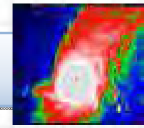
	True	False
1. One of the intrinsic drawbacks of low spatial resolution is the small swath width.	○	○
2. For crop monitoring at the national scale a $1km^2$ resolution is an adequate pixel size.	○	○
3. In low resolution systems specific costs per ground area unit are quite high.	○	○

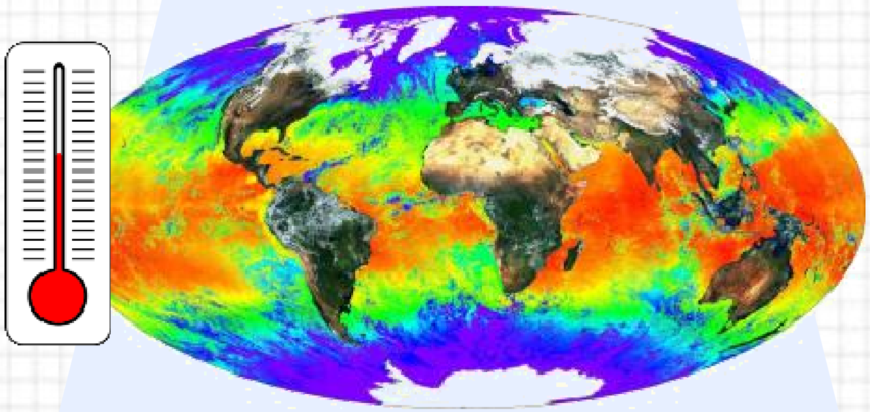
*Please select the answers of your choice. When you have finished, click on "**Check Answer**".*

USING SATELLITE IMAGES FOR VEGETATION MONITORING

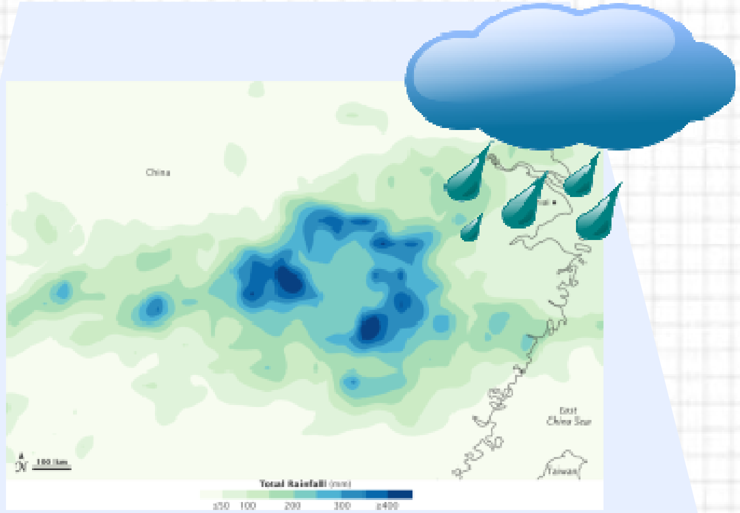
Meteorological variables such as **rainfall** and **temperatures** are measured at station level
They can also be derived from satellites, most commonly from geostationary satellites such as METEOSAT.

2. meteorological variables





Data such as land, sea and cloud surface **temperatures** are measured directly by the satellite (as infrared radiation)…



…while **rainfall data** have to be modelled based for example on cloud temperatures or other factors.

RAINGAUGES AND INTERPOLATED RAINFALL DATA

At the global scale, raster data of rainfall are available as **interpolations of rainfall stations**.

However resolution is generally low, in the range of several degrees, and rainfall data are **often not available in real time**.

Popup Window

Historical and climatological datasets: CMAP and GPCC

Examples of these datasets are:

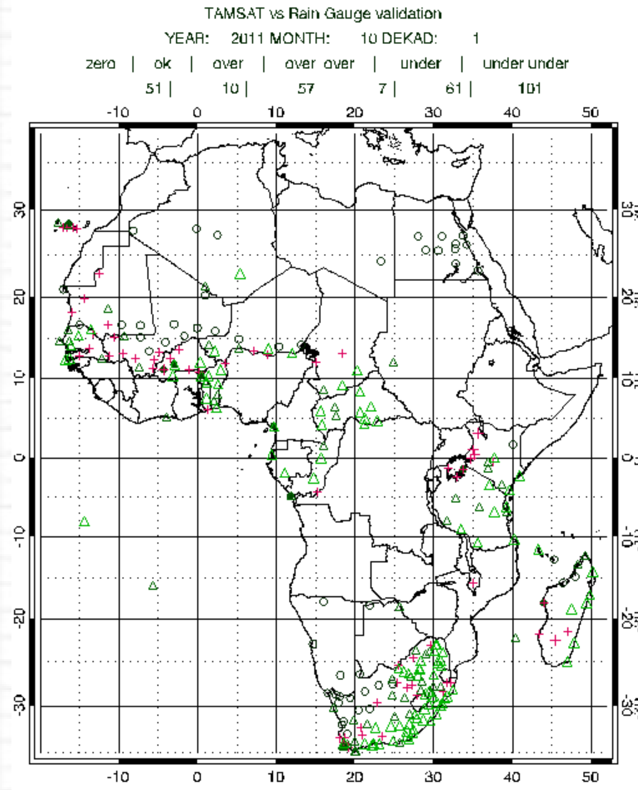
•the CPC Merged Analysis of Precipitation (CMAP) pentad and monthly data from 1979 at **2.5 degrees** resolution; and

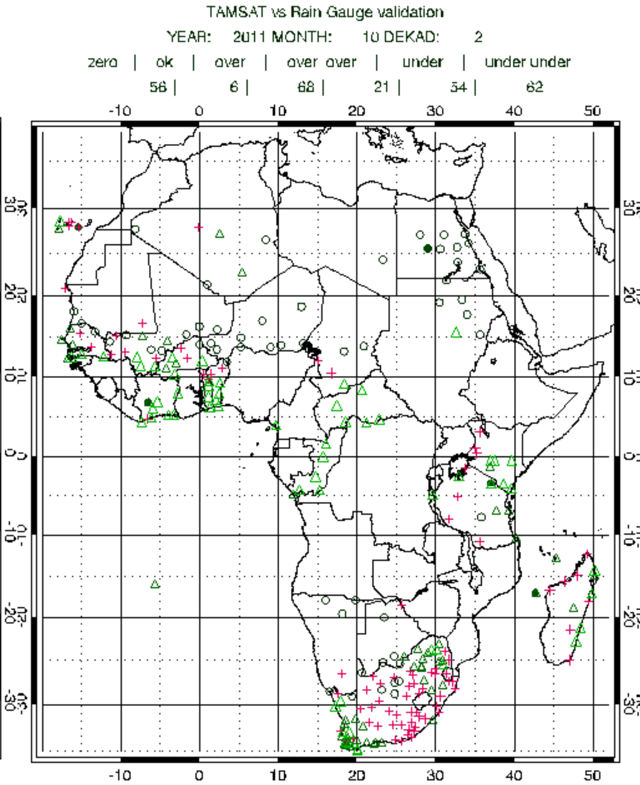
•the Global Precipitation Climatology Centre (GPCC) of the German Weather service (DWD) which provides different monthly datasets at **1 and 2,5 degrees** resolution starting as early as 1901.

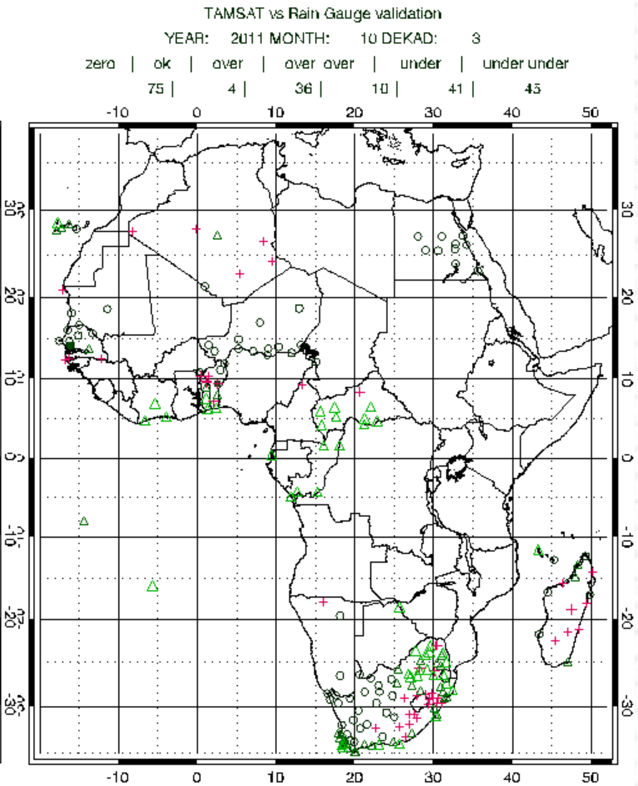
RAINGAUGES AND INTERPOLATED RAINFALL DATA

GTS station data:
example from October 2010

Africa has a **limited network of rain gauge stations** and for diverse reasons - such as economic and civil insecurity coupled with a low perceived relevance of weather services - a large number of existing rainfall records is incomplete.

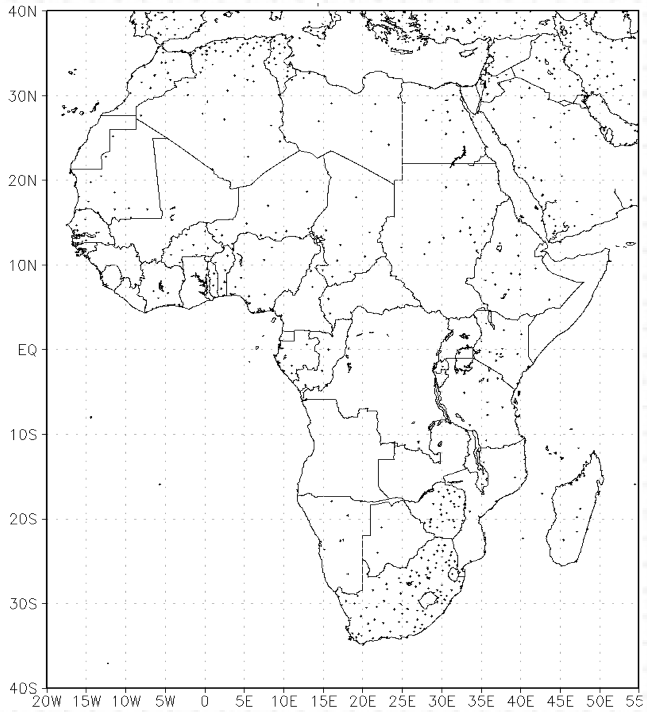






RAINGAUGES AND INTERPOLATED RAINFALL DATA

GTS Gauge locations (April 2013)

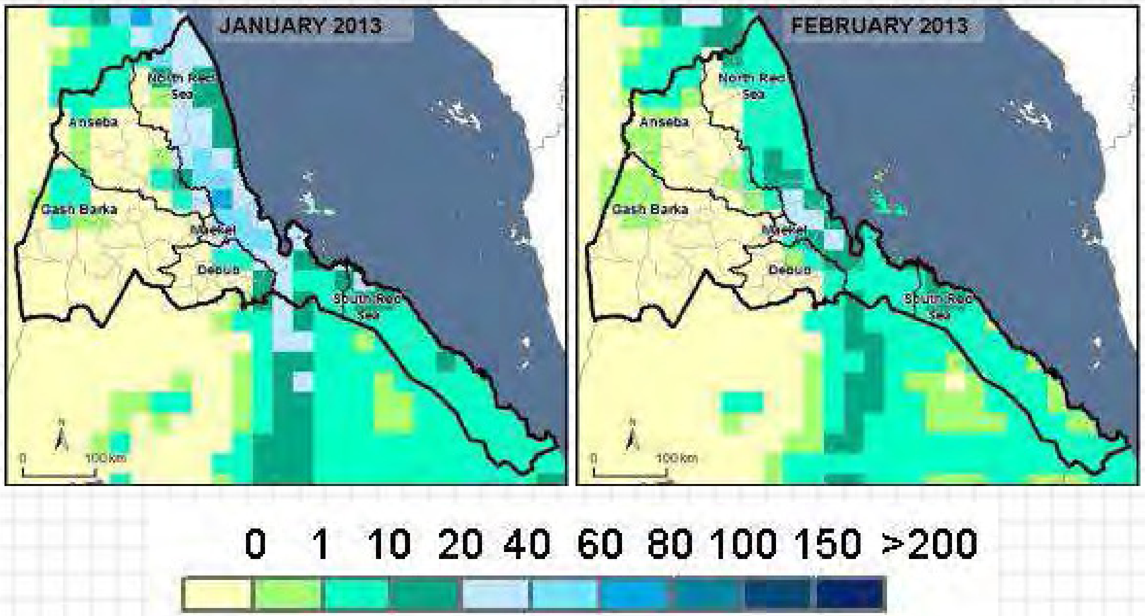


The coverage of GTS (Global Telecommunication System for Africa) of the WMO (World Meteorological Organization) includes **less than 500 regularly reporting stations** (most of them in South Africa) out of less than 1100 GTS stations

On the other side, **rainfall information is crucial** for crop growth and is therefore an important factor for the monitoring of agricultural and pastoral production and consequently for food security.

In addition to the **poor availability of rainfall records**, there is a **steady decline of the standard observation network**, which is a strong limitation for climate related research as well as for operational agricultural monitoring.

RAINFALL ESTIMATES



Because of the presented limitations in the availability and quality of measured data, **rainfall estimates** have been developed.

Rainfall estimates provide a **spatial and temporal overview of the amount of rainfall** based on a variety of input data, which generally depend on:

- satellite observations; and
- climate circulation models.

Let's have a look at them...

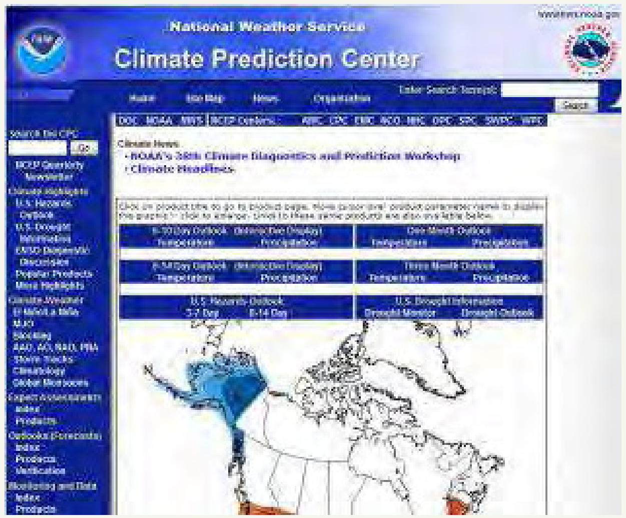
RAINFALL ESTIMATES

Two common examples of estimated rainfall data currently available for Africa - which we will discuss more in depth in a few screens - are the following:

- the **rainfall forecasts** of the European Centre for Medium-Range Weather Forecast (**ECMWF**); and

http://www.ecmwf.int

- the **rainfall estimates** (**RFE**) produced by the Climate Prediction Centre (**CPC**) of the NOAA, and used operationally by FEWS-NET.

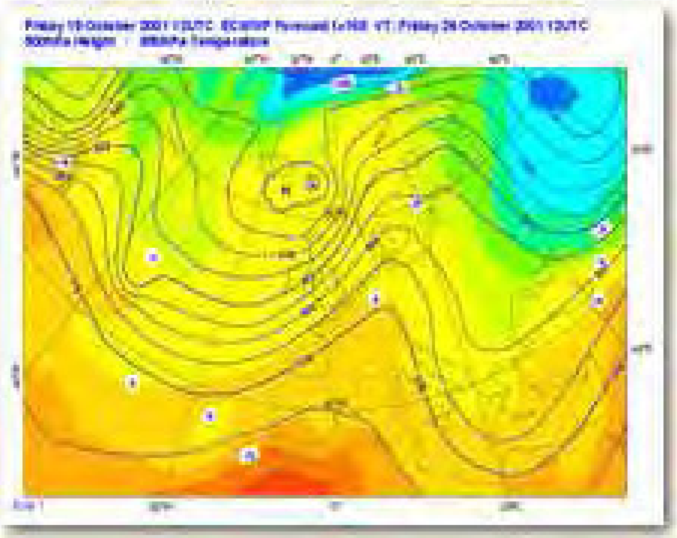


http://www.cpc.ncep.noaa.gov/

http://www.fews.net

ECMWF DATA

The European Centre of Medium-Range Weather Forecast (ECMWF), based in Reading in the UK, produces mainly **daily operational medium-range weather forecasts at the global scale**.



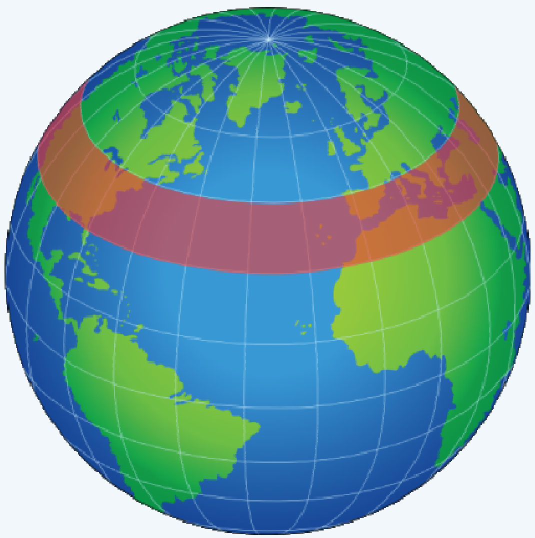
This data:

- is used for weather prediction, research and commercial purposes;
- concentrates mainly on medium-range forecasts, defined from 3 to 15 days; and
- is produced by the ECMWF's own model and assimilation system, the Integrated Forecast System (IFS).

ECMWF is also known for its seasonal weather forecasts.

ECMWF GLOBAL CIRCULATION MODELS

Global Circulation Model (GCM)

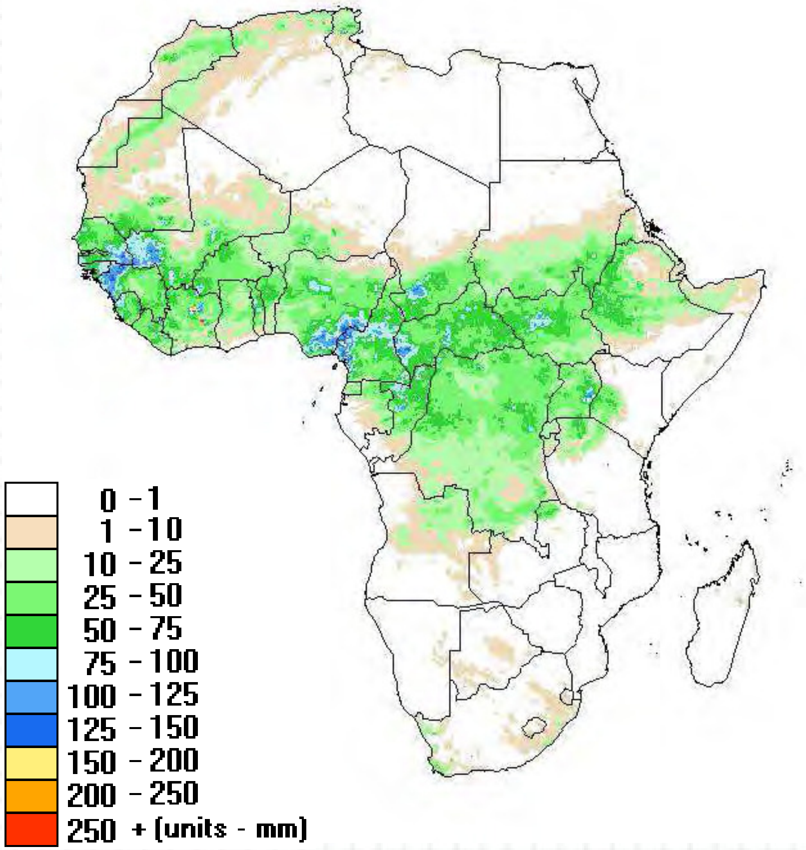


- **0,125^{0} of resolution**
- **daily forecasts**
- **10 days forecasts with a temporal resolution of 3/6 hours**

ECMWF forecasts are based on a high resolution global circulation model called HRES which simulates a series of meteorological variables at a **3 to 6 hours time steps** including rainfall, temperature…. Daily reanalysis and 10-daily forecasts are produced at a **resolution of about 16 km** (since **2008).** This model is **regularly updated / improved.**

ECMWF also builds a consistent archive with a resolution of about 80 km called ERA Interim (for ECMWF Re-Analysis). This archive starts in 1979 till present (with a 3 months delay for collecting measurements).

RFE – COLD CLOUD DURATION MODEL



The **RFE** is a rainfall estimate of NOAA's Climate Prediction Centre currently used by FEWS-NET and several United Nations agencies - such as the Food and Agriculture Organization (FAO) and World Food Programme (WFP) - for agricultural monitoring in a large number of African countries.

It basically uses satellite imagery from the geostationary Meteosat Second Generation (MSG) and **estimates convective rainfall** as a function of top of cloud temperatures and using Global Telecommunication System (GTS) stations for calibration.

RFE - COLD CLOUD DURATION MODEL

There are two versions of rainfall estimates RFE…

The **two RFE versions** are produced with slightly different methodologies and different input data:

RFE 1.0

RFE 2.0

RFE 2.0 uses additional techniques to better estimate rainfall while continuing the use of CCD and GTS. Two new satellite rainfall estimation instruments are incorporated into RFE 2.0, namely, the Special Sensor Microwave/Imager (SSM/I) on board Defence Meteorological Satellite Program satellites, and the Advanced Microwave Sounding Unit (AMSU) on board NOAA satellites.

RFE 2.0 rainfall estimates are available only from 2001.

RFE 1.0 and RFE 2.0 are not directly comparable!

RAINFALL ESTIMATES

Several other rainfall estimates exists, such as…

- **Tropical Rainfall Measuring Mission (TRMM)**
- **Tropical Applications of Meteorology using SATellite (TAMSAT)**

Other methods combine global circulation model outputs with rainfall estimates, like for example:

- **FAO Rainfall Estimate (FAO RFE) (currently stopped in 2010)**

The next screen presents an overview of the existing rainfall estimates methods…

RAINFALL ESTIMATES

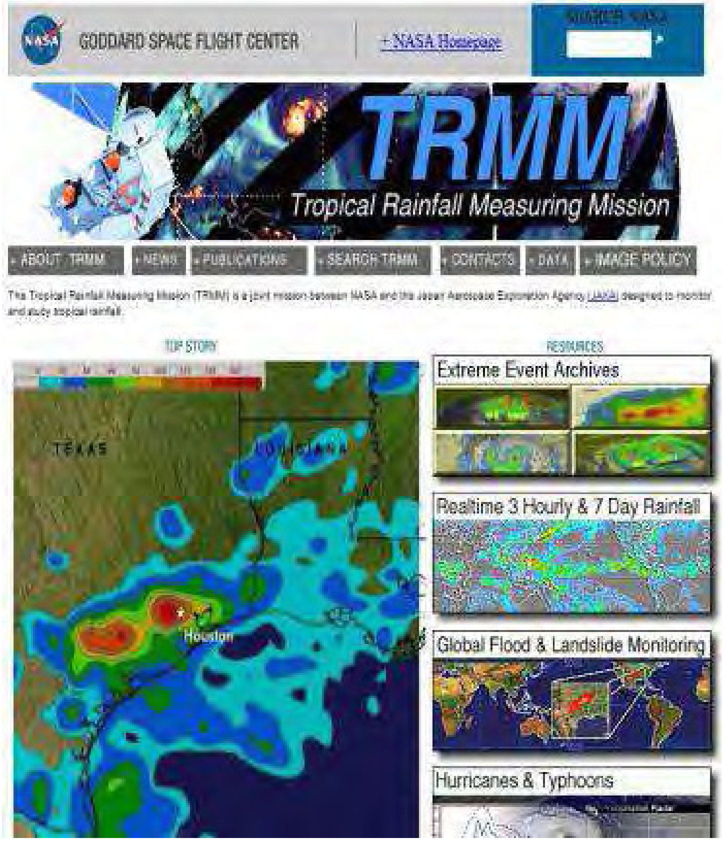
Popup Window

Tropical Rainfall Measuring Mission (TRMM)

The Tropical Rainfall Measuring Mission (TRMM) is a joint space mission between NASA and the Japan Aerospace Exploration Agency (JAXA) designed to monitor and study tropical rainfall.

The TRMM Microwave Imager (TMI) is a passive microwave sensor designed to provide quantitative rainfall information over a wide swath under the TRMM satellite. By carefully measuring the minute amounts of microwave energy emitted by the Earth and its atmosphere, TMI will be able to quantify the water vapor, the cloud water, and the rainfall intensity in the atmosphere over the tropical belt (35 degrees north and south latitudes).

More info at:
http://trmm.gsfc.nasa.gov/



RAINFALL ESTIMATES

Popup Window

Tropical Applications of Meteorology using SATellite (TAMSAT)

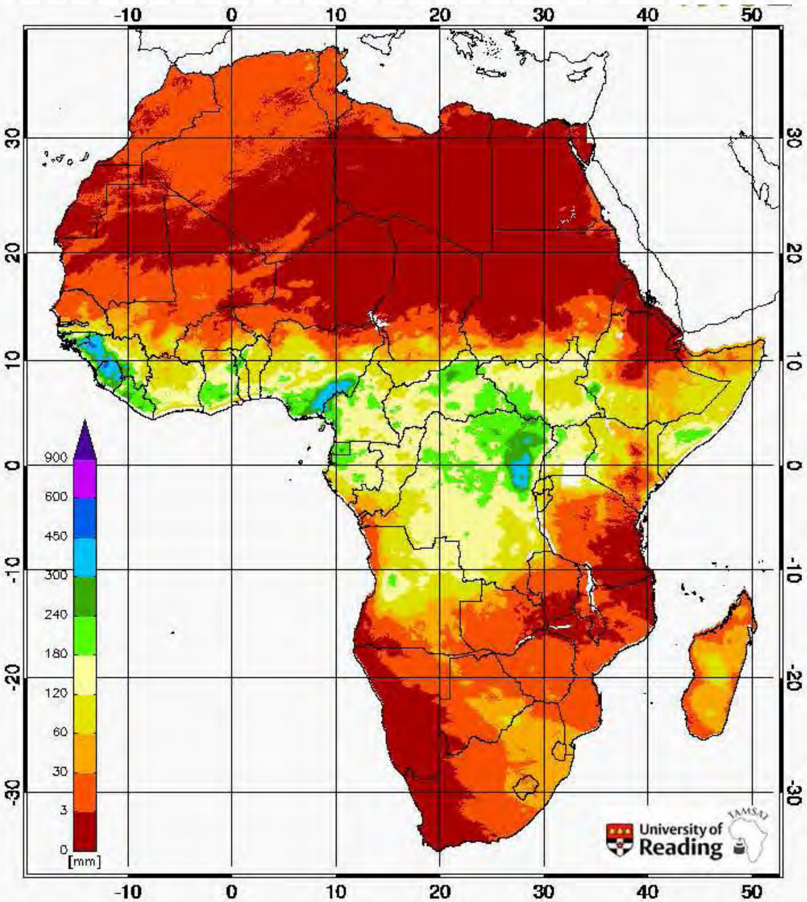
TAMSAT stands for Tropical Applications of Meteorology using SATellite data and ground-based observations and is a research group at the University of Reading (UK).

Routine products of the group are a ten-daily (dekadal), monthly and seasonal rainfall estimates for Africa derived from Meteosat thermal infra-red (TIR) channels based on the recognition of convective storm clouds and calibration against ground-based rain gauge data.
Since 01/2014, daily estimates are also produced (daily rainfall is needed for e.g. flood monitoring, weather index based insurance…)

More info at: http://www.met.reading.ac.uk/~tamsat/about/

COLD CLOUD DURATION MODEL

TAMSAT rainfall estimates for October 2012



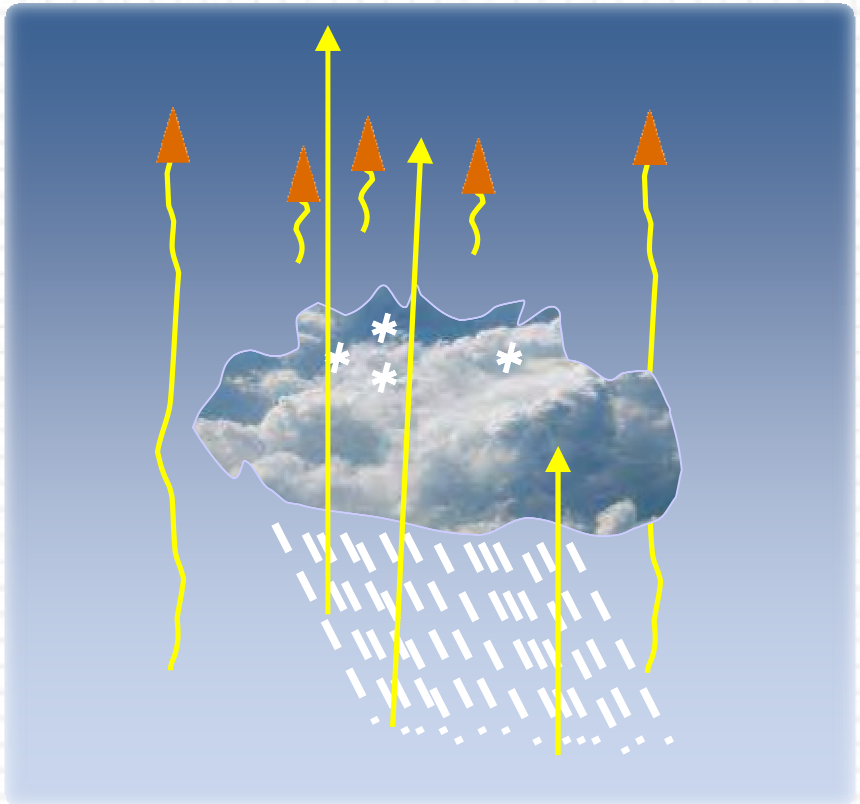
The **TAMSAT** group at the University of Reading produces rainfall estimates also based on the **cold cloud duration** model, but differently from the RFE algorithm, historical gauge data are used for calibration which is done at the level of geographical calibration windows.

The advantage is that the product is n**ot influenced by the available GTS station data** and is therefore consistent over time

The disadvantage is that the fixed calibration windows sometimes lead to **sharp transitions between windows**. It may also be poorly calibrated in areas with few gauge data.

TAMSAT data are available as 10-daily and monthly data for Africa since 1983 and the operational production of the data at continental level has been supported by the JRC.

COLD CLOUD DURATION MODEL



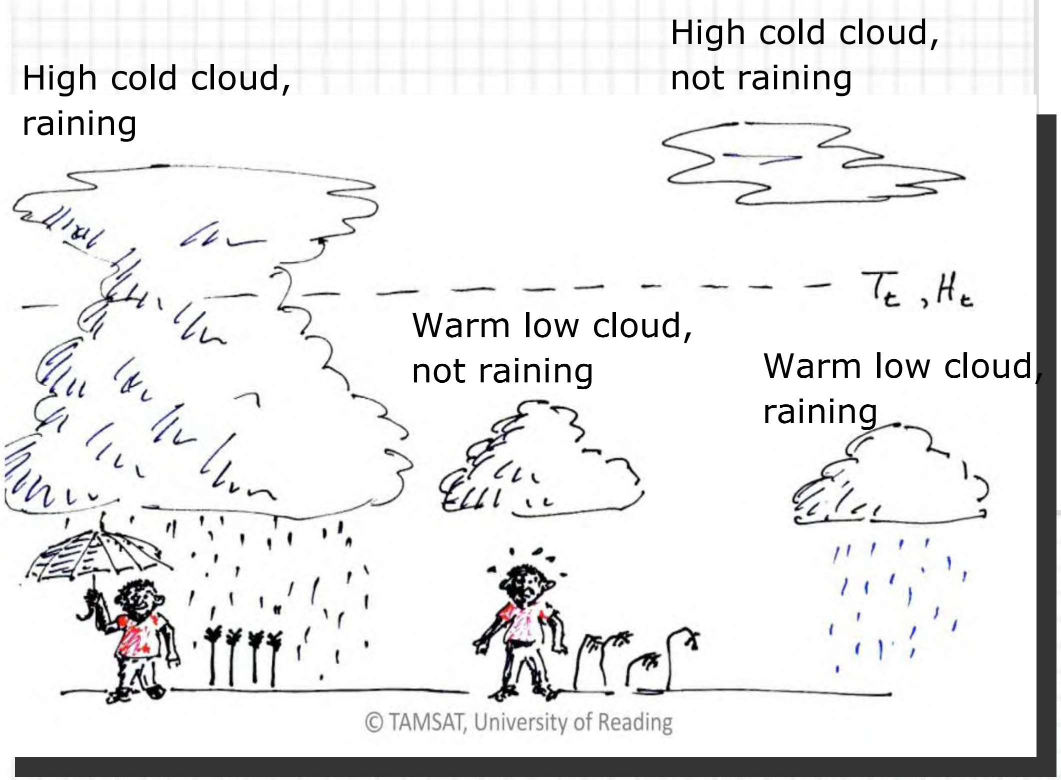
In tropical Africa, rain is mostly created by convective storms and the clouds below a given temperature produce rainfall.

It is possible to derive estimates of rainfall by measuring the **cloud top temperatures** and the length of time a cloud is below the critical threshold temperature. This methodology is based on the Cold Cloud Duration (CCD) derived from TIR data.

The threshold below which a convective cloud is precipitating is determined for a given region (or calibration area) by comparing the cases of rain / no rain versus CCD > 0 / CCD = 0 (contingency table). For rainy pixels (containing gauges), the dekadal rainfall is then regressed against their dekadal CCD.

This **calibration against historical gauge data** allows to estimate rainfall in **near-real time** without any station data.

COLD CLOUD DURATION MODEL



Popup Window

CCD method's validation

To establish the utility of the method, it **must** subsequently **be validated** by comparing estimates and gauge data from some area or period distinct from that used for the calibration.

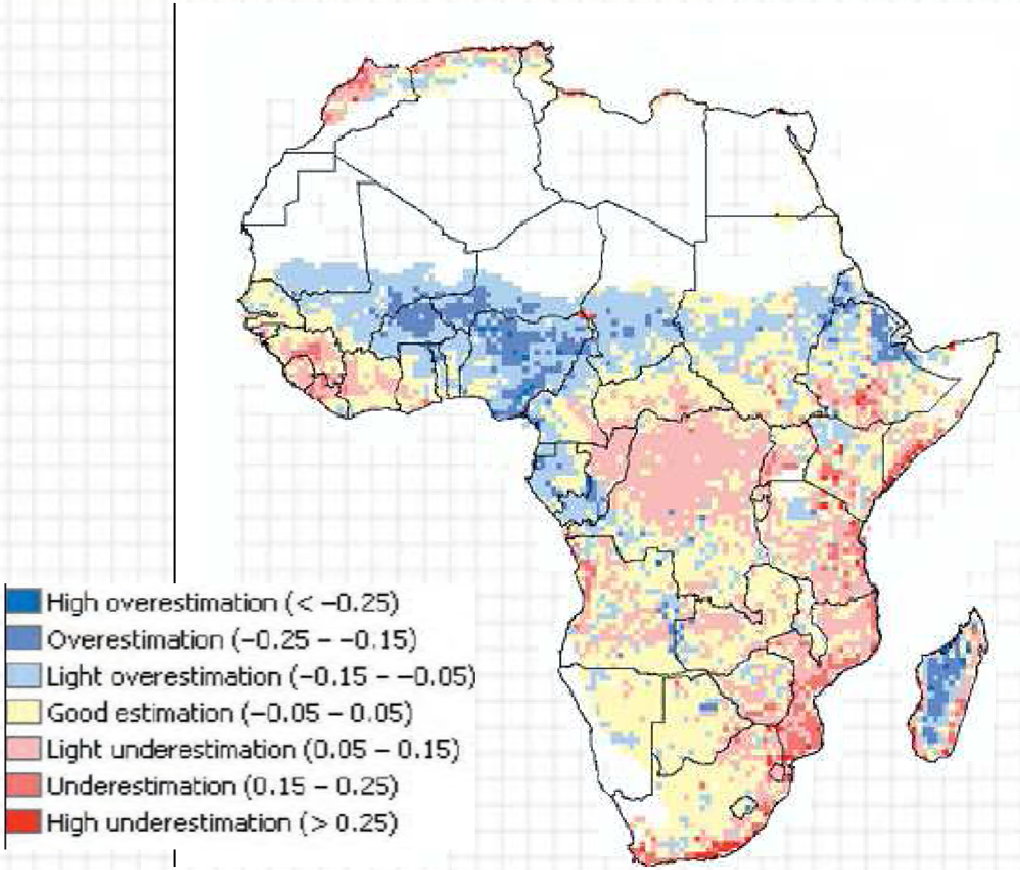
Alternatively, validation may consist of testing the use of the estimates in a quantitative application, such as a catchment runoff model, again using a separate period or area from that used for the calibration. Within the estimation procedure there are many decisions to be taken and numerical values to be assigned.

RAINFALL ESTIMATES

Commonly available satellite derived rainfall estimates

DEFINITION	Distributed by	Coverage	Resolution	Frequency	Archive
NOAA RFE V2	NOAA-CPC FewsNet	Africa	0.1 deg	daily, dekadal	2001-present
ARC V2	CPC	Africa	4 km?	Daily, dekadal	1983-present
TRMM 3B42-RT V7	NASA	Global	0.25 deg	3 hourly	1998-present
CMORPH	CPC	Global	0.25 deg	Daily (3hr averages)	2002 - present
PERSIANN	University of Arizona, USA	Global	10 km	6 hourly	2000-present
Tropical Applications of Meteorology using Satellite data and ground-based observations (TAMSAT)	University of Reading, UK	Africa	0.04º (4 km)	Dekadal, monthly Now daily	1983-present
Multi Sensor Precipitation Estimate (MPE)	EUMETSAT	Africa, Europe	4 km	5, 15 and 30min	2006-present

Need for validation of RAINFALL ESTIMATES



Overestimation or underestimation of RFE (according to RFE/NDVI relationship).

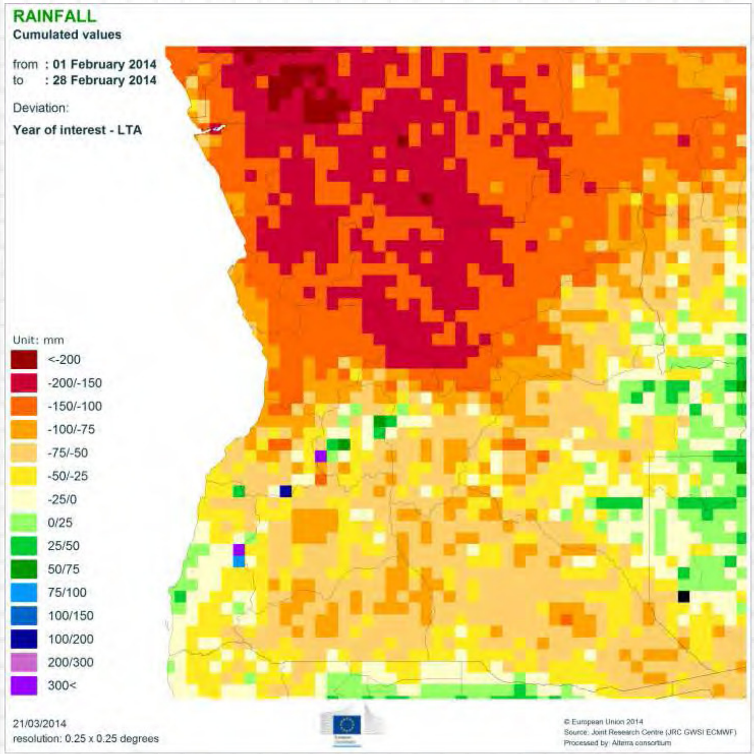
All the data described in the previous screens are estimates and do therefore contain **errors** and show **deviations** in different regions of Africa.

At the same time, **validation** or better calibration of these estimates is again hindered by the **scarce availability of ground measurements**.

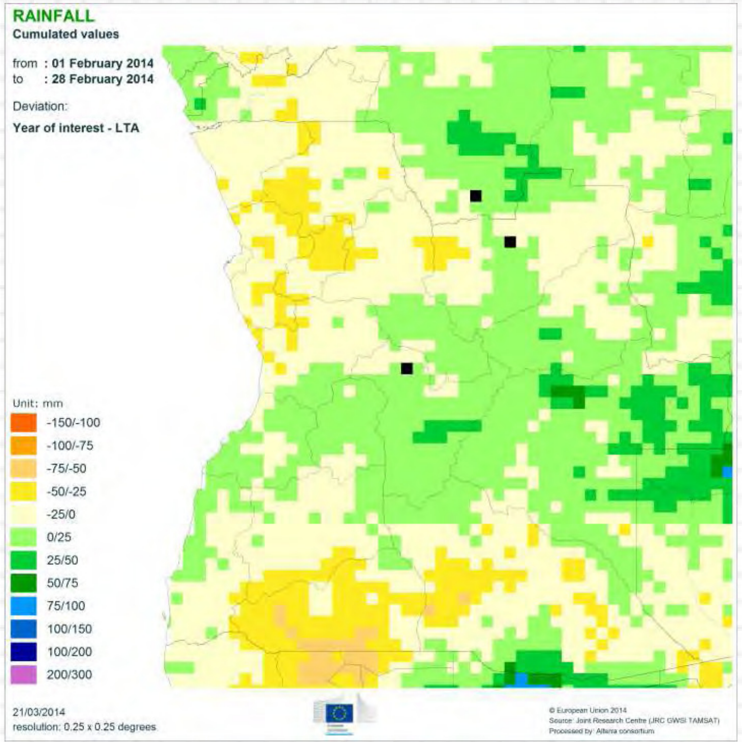
This makes it extremely difficult to **assess the quality or reliability** of each dataset and can have important implications for food security applications.

Need for validation of RAINFALL ESTIMATES

Example of Angola Feb 2014



ECMWF Rainfall anomaly



Tamsat Rainfall anomaly

Need for gauge data to validate the different rainfall products

RAINFALL ESTIMATES

Why is the use of rainfall estimates especially important in Africa?

- ☐ Meteo stations are not available on the market in Africa.
- ☐ Low density meteorological network.
- ☐ Incomplete rainfall records.
- ☐ Rainfall estimates are more accurate than rain gauge data.
- ☐ Limitations in sharing ground station measurements.

*Please select the option of your choice (2 or more) and press "**Check Answer**".*

COLD CLOUD DURATION MODEL

Combine each rainfall estimates method with its related characteristic.

1. It uses the Special Sensor Microwave/Imager (SSM/I), and the Advanced Microwave Sounding Unit (AMSU).
2. It uses historical rainfall data from stations for calibration.
3. It uses rainfall data from stations for the dekadal estimates.

RFE 1.0

RFE 2.0

TAMSAT

*Click each option, drag it and drop it in the corresponding box. When you have finished, click on "**Check Answer**".*