Chapter 3

Using monitoring facilities to detect climate anomalies

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The Orinoco (Venezuela). August 2006 flood. HYBAM observation system.

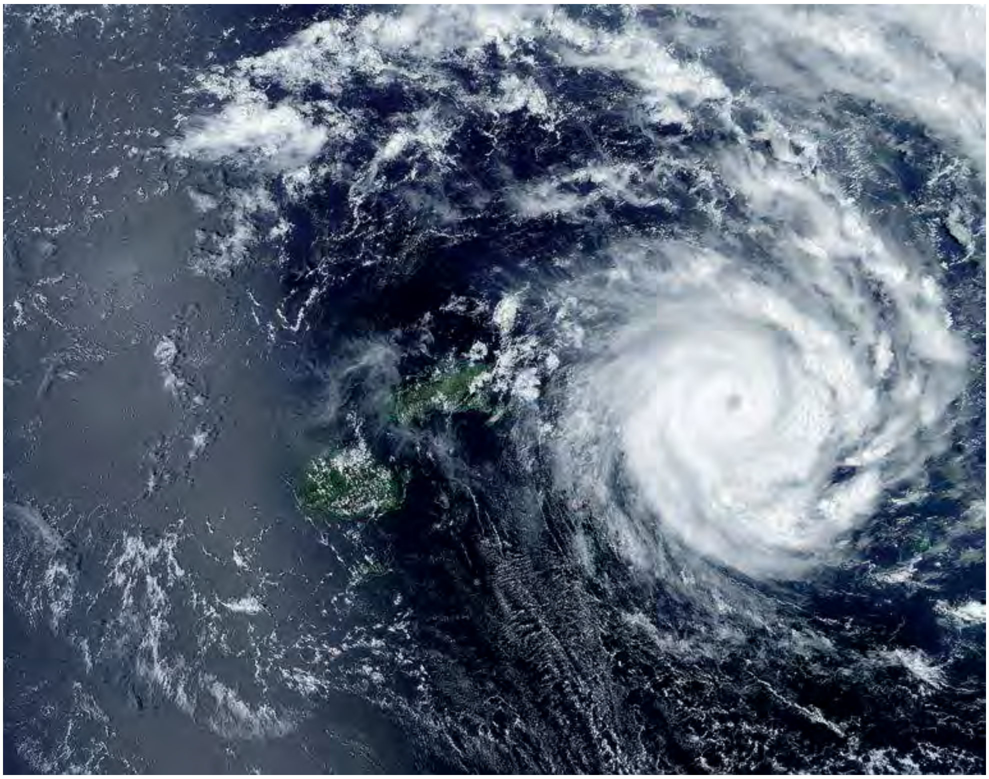
The study of climate change consists of detecting any significant climatic anomaly and then assigning possible anthropic or natural causes. This requires the ability to observe (in order to detect) and then understand (assigning a cause) to finally forecast the evolution of the print of climate change on the environment and societies.

Monitoring the evolution of our climate and more generally of our environment requires first of all observations and hence permanent multidisciplinary facilities. In addition to the quantification of climatic and environmental changes, the observations can also validate data from satellite remote sensing, evaluate models and set up new measurement techniques.

Quantifying ongoing climatic and environmental changes

The meteorological and hydrological networks allow real time monitoring of the evolution and variability of the climate system. However, these networks are not dense enough, especially in the tropics, for sufficiently accurate information over a sufficiently

Cyclone above
the Tongan archipelago
in the South Pacific.
The frequency of extreme events such as typhoons is an important indicator in the detection of climate trends.



long period concerning climate and especially the hydrological cycle. Indeed, the different components of the water balance (precipitation balance, river flows, infiltration into ground water, etc.) display strong spatial and temporal variability. The ability to assess this variability accurately is needed for the detection of possible significant trends related to climate change or other factors such as changes in land use.

Changes concerning extreme events are even more difficult to detect as frequencies of occurrence are small and so longer series of observations are required. Indeed, the evolution of extreme phenomena such as cyclones and droughts is an important indicator for the detection of long-term trends.

Several appropriate observation systems are used to monitor changes in climatic variables at scales ranging from regional to local and for sufficiently long periods and to describe their impact on environments. IRD participates in this climate surveillance by developing a number of research watches with environmental qualifications, especially in the tropics (Fig. 6).

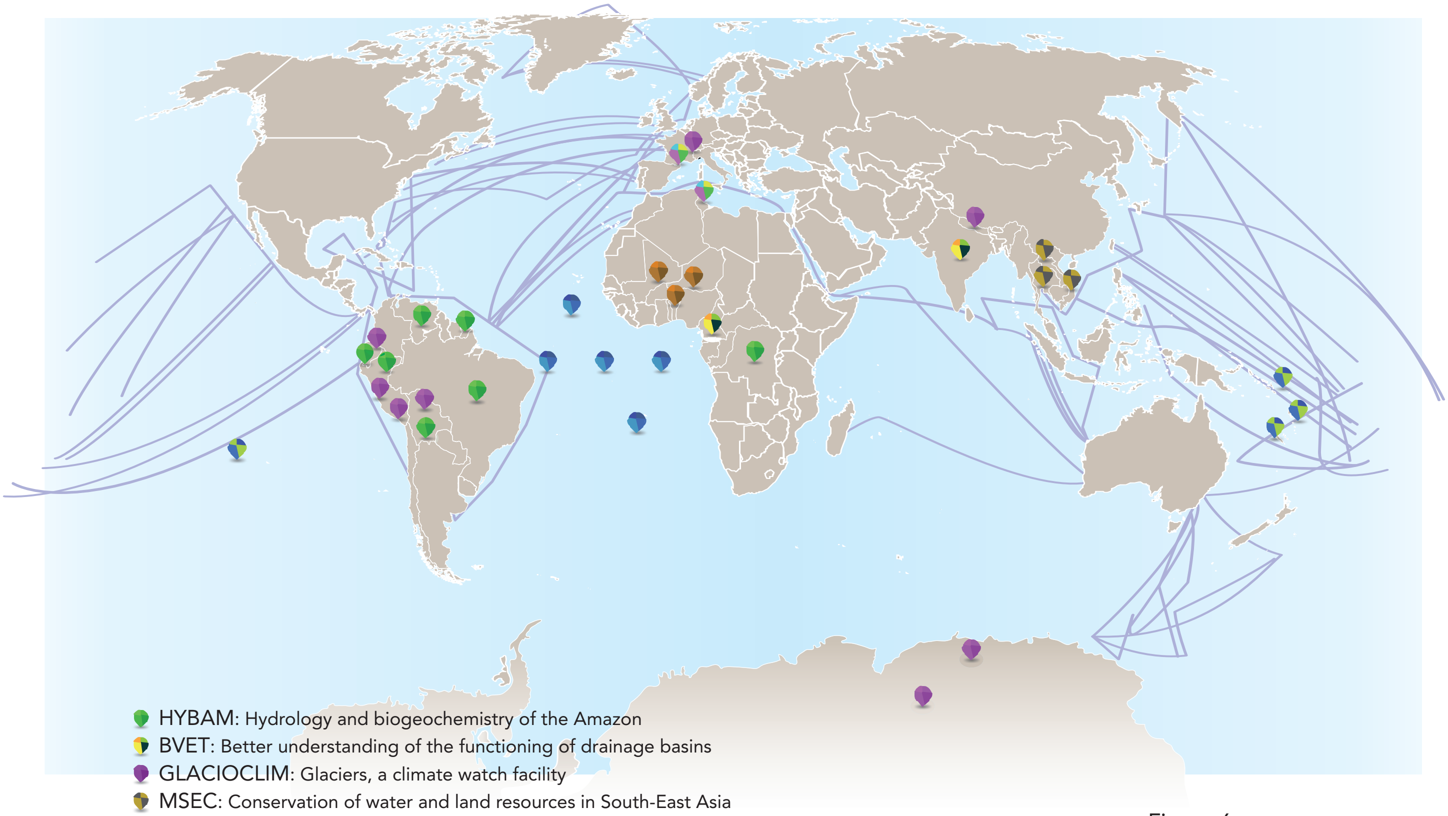


Figure 6.
Environment and climate research observatories developed by IRD and dedicated to a considerable degree to the tropics.
Source: IRD/L. Corsini.

Calibration and validation of data sent by satellite remote sensing

The documentation of global environmental changes (with reference to climate and also hydrology, soil science, oceans, etc.) therefore requires first the basing of diagnoses on precise observations and second the possession of measurements that are representative of variabilities at the regional scale. *In situ* field measurements and satellite data are extremely complementary here: the former allow the direct but local surveillance of phenomena while the latter provide global information and document spatial variability. In the tropics, where operational networks are sparse and fragile, synergy between the two types of information is essential in order to understand climate changes and their environmental impacts. The major watches and their long series of high-quality field data also provide observations for the calibration and validation of satellite data.

Box 5

The Amazon basin observatory combines field data and satellite measurements

Since 2003, the HYBAM observatory (geodynamic, hydrological and biogeochemical control of erosion/alteration and material transport in the Amazon basin) has gathered hydrological, sediment and geochemical data, combining *in situ* and spatial observations and a network of laboratories. This information makes it possible to understand the functioning of the largest drainage basin in the world and to assess the impact of hydroclimatic variations and human activities.

17 stations are thus distributed from the foothills of the Andes in the Amazon basin to the Atlantic. Local readings are coupled with a 'virtual' network of data gathered by satellites and covering both the quantity and quality of the water.

To measure river water levels, altimetric satellites (Jason 2 and Saral) make regular radar sweeps of the points monitored to provide an accurate assessment of the quantity of water flowing. Water quality and the presence of sediments are covered by satellite imaging.

Probes (Modis) on the satellites Terra and Aqua analyse the spectrum of the solar light reflected by rivers and show the composition of their water.

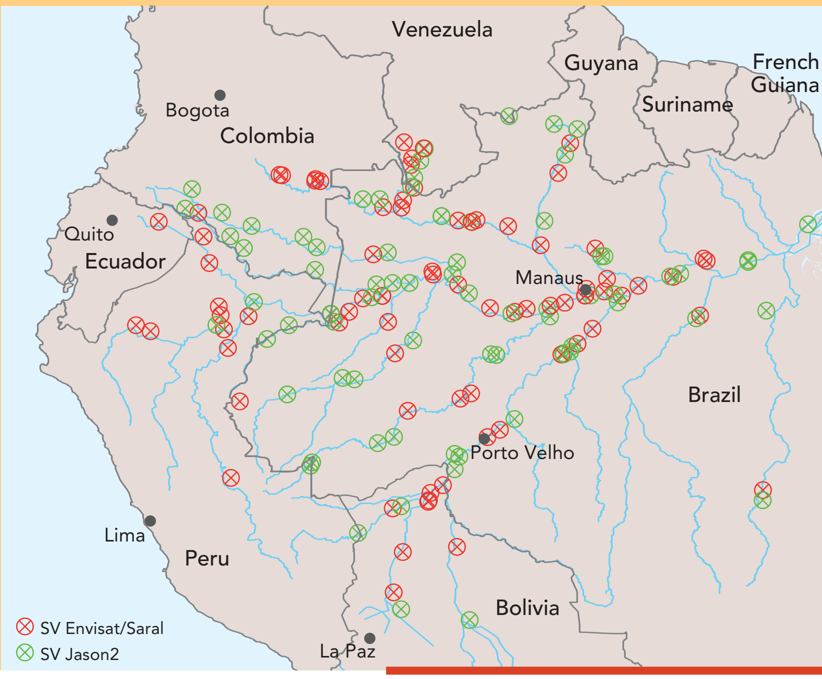
These innovative techniques were calibrated and validated using the hydro-sediment databases maintained by the observatory. Automated processing sequences now provide satellite information on the website in record time.

These sophisticated spatial technologies are of special interest in Amazonia where the distances and the scale of water resources require steep budgets for ground-based monitoring that are not matched by the budgets available.

The monitoring and supply of information about water resources respond to needs of all sorts among economic and institutional stakeholders, water boards, electricity production and river traffic—navigable waterways form the main communication network in the Amazon basin.

HYBAM is associated with numerous university and technical partners in the southern countries (Brazil, Bolivia, Peru, Ecuador, Colombia, Venezuela and the Congo).

Figure 7.
The 'virtual' network of hydrological measurements in Amazonia.
Source: SO HYBAM (IRD/INSU/OMP)



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Orbiting SMOS satellite launched on 2 November 2009 by the European Space Agency (ESA).
It is the first global climate change observation satellite designed to monitor world marine salinity and soil moisture content.

Uncertainty with regard to the 'real situation' on the ground: a question of scale

Rainfall is intense in the tropics and varies within a few kilometres or a few hours, with local consequences that are sometimes violent (floods). This extreme variability is a challenge for observation using both classic ground measurements and satellite remote sensing. The uncertainty involved decreases—without disappearing— for the comparatively coarse space and time scales of hydro-climatology (a few months, several thousand sq. km) but is still very strong at the scales used in local hydrology. Probabilistic approaches must be used to allow for uncertainties. In West Africa, IRD and its partners have shown the need to allow for uncertainty in the 'real situation' on the ground for precipitations, that is to say high resolution spatio-temporal *in situ* measurements to evaluate the performance of satellite data for reporting rainfall. The results showed a high performance level for all observations at scales of 3 to 5 days and more modest performance for some of these daily scale observations. The latest generation of satellite facilities provides accurate quantitative information on time scales from 1 day to 6 hours, spatial scales of 10,000 to 2,500 sq. km and also gives a very good representation of the daily cycle.

Developing new probes in the tropics

Setting up dense network of measurements on a long-term basis is not sufficient, given the fragility of operations networks in the tropics and the need for the high resolution documentation of climate processes. New types of probes or original approaches should also be developed to enhance measurements and sampling for monitoring climate and environmental changes.

Box 6

Mobile telephony is taking over

While observation networks are still inadequate in Africa, this is not the case of mobile telephone relays. To monitor the quality of networks, the telephone companies record disturbances of signals partly caused by precipitation. Researchers thus had the idea of profiting from this mass of data to improve the monitoring and spatialisation of rainfall.

Meteorological and climatic measurements networks are expensive to set up and maintain and are inadequate in Africa. The density of operational networks has even tended to decrease since the 1990s and the problem is even more acute in the Sahel because of the political tensions there. How can the evolution of rainfall and extreme events with impacts on the population be monitored under these conditions? Strongly developed in Africa, mobile telephone networks have provided a solution.

Indeed a method for measuring rainfall using mobile telephone networks has been tested successfully in Africa. The method makes use of a property of rainfall that is well-known to telecommunications professionals: drops of water cause the weakening of the radio signal between two aerials. The mobile telephone companies measure and record these disturbances to keep track of their state of functioning at all times. They thus have a large amount of information about rainfall in the countries covered by their networks.

Developed since the 2000s in Europe and Israel, use is starting to be made in Africa thanks to a first pilot site set up in Burkina Faso in 2012 by IRD and its partners.

RainCell Africa, a network of scientists and national meteorological offices, was then set up in partnership with mobile telephone operators. The first international workshop on rainfall estimation using mobile telephone networks was held in Ouagadougou in April 2015 and was attended by participants from 18 countries (Benin, Burkina Faso, Cameroon, Côte d'Ivoire, France, Germany, Ghana, Israel, Kenya, Mali, the Netherlands, Niger, Nigeria, Senegal, Switzerland, Tanzania, Togo and the USA) and from inter-governmental organisations (CILSS, UNDP and UNESCO).

This initiative placing information and communication technology at the service of the climate attracted great interest in Africa and, more widely, in the tropics. It should develop considerably in the coming years.

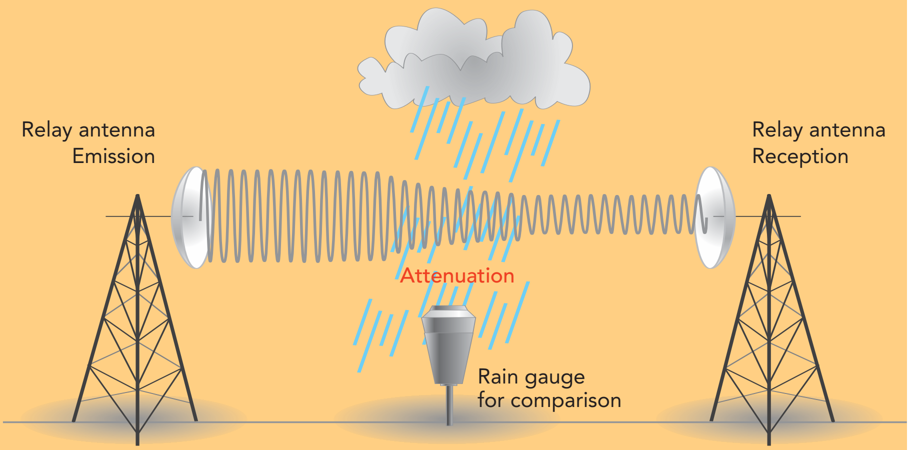

Figure 8.
The principle of rainfall measurement using mobile telephone networks.
Fluctuations in signals between relay aerials are recorded by telephone operators. The measurements could be used to plot small-scale rainfall fields in practically real time to monitor rainfall and the accompanying risks at the scale of a town or a country.
Source: IRD/F. Cazenave and M. Gosset

Box 7

Measurement of emissions by tropical hydroelectric dams

Estimates of greenhouse gas emissions by dams used for hydroelectricity vary considerably from one study to another as not all the sources of carbon dioxide and methane released are taken into account. A study carried out by the CNRS and IRD proposes new tools for improving readings.

The submersion of continental land for the creation of fresh water reservoirs is not neutral in terms of carbon dioxide (CO_2) and methane (CH_4) emissions at the global scale. Hydroelectric reservoirs are not an exception to this, with numerous sources of emissions: the gases are released at the level of the soil between high and low water levels, at the surface of the reservoir and downstream of dams. Methane can be emitted by bubbling. However, very little work takes into account all the CO_2 and CH_4 emission pathways to the atmosphere and this accounts for the considerable differences between estimates. Moreover, the time steps in studies of reservoirs is generally too long to capture intra-day and seasonal variations of emissions.

Emissions from dams are sometimes greater than those of thermal power stations

In an innovative set-up for monitoring methane emissions at Nam Theun 2 dam in Laos, vertical wind speed and the methane concentration are measured continuously. This high-frequency measurement method (every 30 min) has shown that daily variations in atmospheric pressure and variations in the water level control emissions by continental aquatic ecosystems by triggering the release of the gas trapped in submerged soils. The strong variations during the course of the day also make a significant contribution to the total emission balance. This suggests that bubbling (a source of methane emission) in tropical reservoirs has been underestimated in the past.

Accurate measurement of total greenhouse gas emissions from hydroelectric dams is of major strategic importance for developing countries where there is strong potential for installation. Indeed, depending on local environmental conditions, emissions from impoundments may be smaller or greater than emissions from fuel-fired power stations with equivalent energy production. The choice of hydroelectricity as alternative energy to stabilise greenhouse gas emissions in 2050 must therefore be discussed, especially for the tropics where emissions are greatest.

Submerged funnels for trapping methane bubbles rising from the bed of a reservoir.
Nam Theun 2 Dam, Laos.

Martinez Jean-Michel, Gosset Marielle, Guérin Frédéric. (2015).

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