DAILY SCIENCE
DÉCOUVREZ LA SCIENCE, LA RECHERCHE ET L'INNOVATION "MADE IN BELGIUM"

From evaporation to precipitation: satellite surveillance of the water cycle

by Camille Stassart

Part of the “Climate as seen by satellites” series (2/5)

For billions of years, water has been making the same journey across the globe. Due to the effect of the Sun, water on Earth is transformed into vapour, which accumulates to form clouds. It then falls from the sky as rain, feeding the oceans, rivers and soils, only to evaporate back into the atmosphere, where it starts again from the beginning. This is known as the hydrological cycle.

The scientists of the Royal Meteorological Institute’s hydrometeorological modelling unit are tasked with studying the interactions between the atmospheric and terrestrial phases of the water cycle.

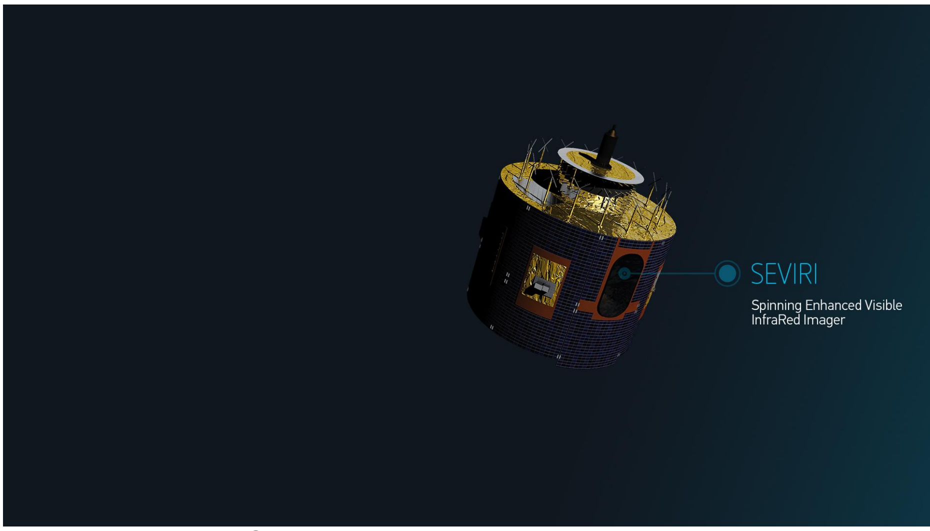
“We primarily study precipitation, soil moisture and evapotranspiration,” explains Françoise Meulenberghs, head of the research unit. With the help of numeric models, the scientists monitor these different phenomena, all of which play a major role in the weather and climate of our planet.

Evapotranspiration, a critical phase in the water cycle

One of the models developed by the team is designed to monitor evapotranspiration and heat fluxes. *“Evapotranspiration is an important part of the water cycle because it is this process that ensures that water in both soil and vegetation returns to the atmosphere.* The term ‘evapotranspiration’ describes the process of evaporation of water stored in the soil and in bodies of water (lakes, rivers, etc.), as well as plant transpiration, which allows plants to regulate their temperature and enables the circulation of sap,” explains Meulenberghs.

For this process to take place, it needs a source of energy (heat) which is supplied by either the air or the plant. *“The amount of energy needed for the process is referred to as the latent heat flux, which represents an average of 30% of total energy that reaches the ground in the form of solar or thermal radiation. The unconsumed energy either returns to the atmosphere (sensible heat flux) or heats the ground (conduction flux).”*

To calculate these variables, researchers use various satellite data obtained from SEVIRI sensors on board the second-generation Meteosat satellites of EUMETSAT, the European meteorological satellite organisation, and ESA, the European Space Agency (ESA) .



Caption: SEVIRI sensor © EUMETSAT

Monitoring of the Meuse and Scheldt rivers

Since evapotranspiration is responsible for approximately 60% of the Earth's rainfall, this process is another of the variables simulated by the Royal Meteorological Institute's hydrological model 'SCHEME'. This tool calculates the precipitation/flow relationship in the Meuse and Scheldt ('*De Schelde'* in Dutch) catchment basins.

"In other words, we enter meteorological data (temperature, wind speed, solar radiation, air humidity, atmospheric pressure, etc.) into this digital model, as well, of course, as precipitation data," explain Pierre Baguis and Emmanuel Roulin, two researchers from the hydrometeorological modelling unit. *"The model can then simulate potential and actual evapotranspiration, soil humidity, the state of underground reserves and the flow in the Meuse and Scheldt rivers – on a daily basis."*

Within the framework of the EODAHR project, which is funded by BELSPO, scientists from the Royal Meteorological Institute are using satellite data to improve this model, in cooperation with KU Leuven university (Belgium) and the University of Reading (Great Britain).

"We are doing this with the help of data collected by the ASCAT, an instrument on board the EUMETSAT/ESA Metop satellites. This data enables us to update the soil moisture data calculated by the SCHEME model," says Baguis, the principal researcher on the project. The idea is to refine the calculation, thereby improving the accuracy of the model's simulations. *"The first results are promising, and we are currently conducting an in-depth analysis. Our future sim is to improve the model's forecasting capacity."*

Alongside daily simulations of the flow, SCHEME can also carry out an accurate 9-day prediction of the flow of the Meuse's and Scheldt'S main tributaries, based on the overall forecasts of the European Centre for Medium-Range Weather Forecasts. These flow forecasts are transmitted to the Walloon region authorities, who are responsible for managing the waterways and preventing flooding.

"In the days before the July 2021 flooding in the Meuse basin, the flow forecasts indicated a fairly high risk of flooding for certain rivers," recalls Emmanuel Roulin. *"However, these floods were much higher than the level calculated by the model because rainfall was stronger than what was forecast."*

Caption: Flooding in Liège, July 2021 © Anthony Dehez/European Union

Extreme weather events linked to climate change

According to the Royal Meteorological Institute, the number of days of heavy rainfall in Belgium has significantly increased over the past 30 years. An international research project in which the Institute participated has shown a link between these extreme events and climate change.

According to these researchers, bad weather – as in the case of July 2021 – usually only occurs once every 400 years. However, this probability is higher in Europe today, due to global temperature having risen 1.2°C since the end of the 19^{th} century. This has led the risk of extreme precipitation to increase by a factor of 1.2 to 9, and the intensity of extreme precipitation to increase by 3 to 19%.

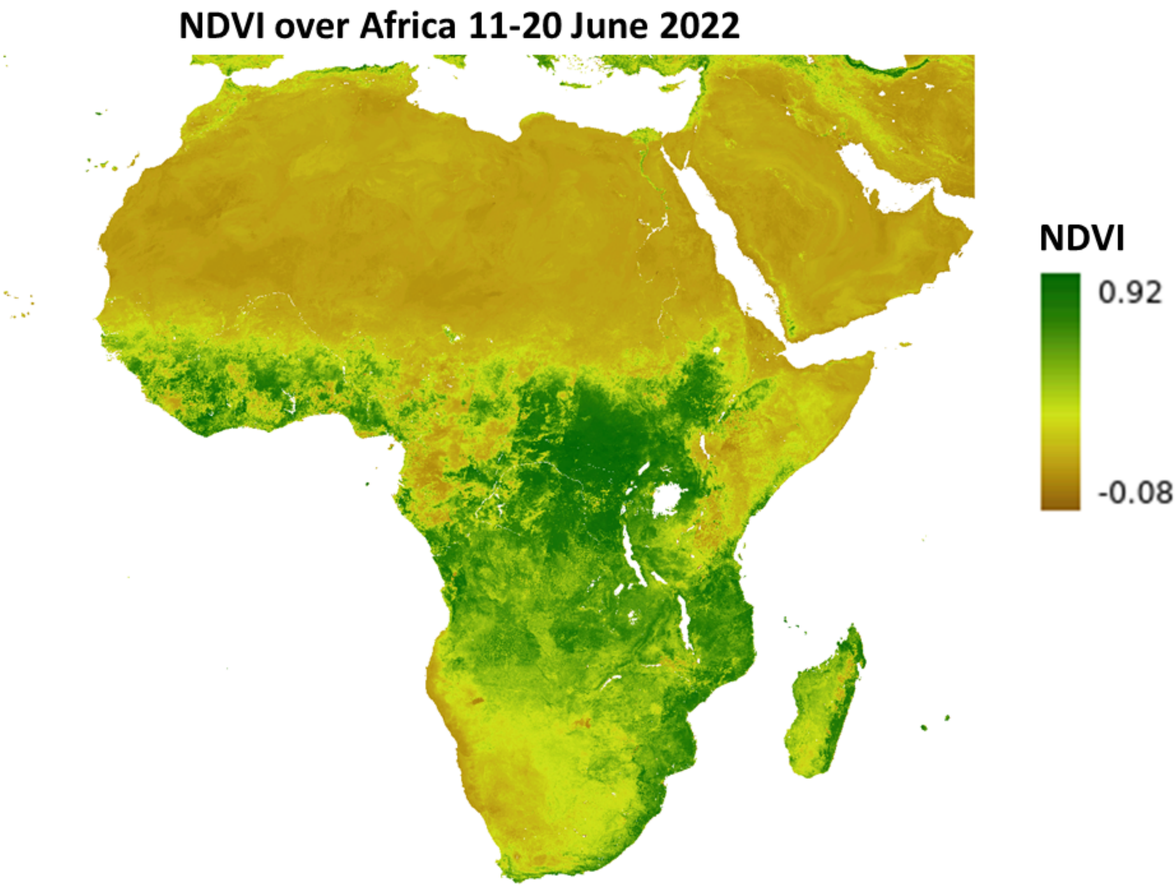
In contrast, the Mediterranean basin and tropical/intertropical regions are seeing an increase in the intensity and frequency of drought periods, which has a direct impact on plant health. The Vito Remote Sensing group – part of VITO, the Flemish Institute for Technological Research – produces data for the most widely recognised parameter used for monitoring the state of global vegetation, the ENDVI (Enhanced Normalized Difference Vegetation Index).

“The observations recorded by the AVHRR instrument on board the Metop satellites are fed into this index on a daily basis. This enables us to produce computer-generated images for 10-day periods,” explains Bart Deronde, geographer and head of the Remote Sensing Applications team.

Based on fifteen years’ worth of data, the researchers have been able to identify certain trends: *"We can see that drought has been affecting the region of eastern Africa for several years – and it’s the same in eastern Brazil.”*

Caption: Computer-generated imagery of Africa for a 10-day period (11–20 June 2022), produced by the ENDVI (Enhanced Normalized Difference Vegetation Index) © VITO-EUMETSAT

Planet Earth is overheating



Using satellites to monitor changes in vegetation cover is useful for climate models, “because the vegetation layer plays a key role in the radiation balance, i.e. the amount of energy received and lost by the Earth,” explains Deronde.

In fact, faced by drought, plants will limit their transpiration in order to survive. This results in a lower volume of vapour in the atmosphere, which, in turn, results in reduced cloud formation. However, these clouds play a key role in the planet’s radiative balance by reflecting a considerable amount of the sun’s radiation back into space. In other words, when the vegetation layer is stressed due to a lack of rain, this indirectly leads to the Earth absorbing more solar radiation than it emits back to space. This, in turn, accelerates the warming of the climate system, which underlines the importance of satellite observations and mathematical models for calculating and predicting processes related to the hydrological cycle and the effects that these processes have on the climate, both today and in the future.