DAILY SCIENCE
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Satellites' key role in forecasting weather and air quality

by Camille Stassart

Part of the "Climate as seen by satellites" series (4/5)

Since the beginning of time, people have been trying to predict what the weather will do tomorrow. Not surprisingly, given the impact that the weather has on our everyday lives – on travel, on leisure activities and on the quality of the air that we breathe. Extreme weather events and the catastrophes associated with them can also put people's safety and their property at risk.

Today, scientists have access to a wide range of technologies that are able to predict the behaviour of the atmosphere. These technologies are spearheaded by the EUMETSAT satellites, EUMETSAT being the European organisation for the exploitation of meteorological satellites.

The Earth monitored from every angle

The Royal Meteorological Institute (RMI) in Belgium has been using these satellites for the past 50 years. "Their invention truly revolutionised the sector," says Nicolas Clerbaux from the MRI's space-based remote sensing department. *"Without them, forecasts would be much less reliable and would contain a lot more errors."*

Forecasters rely heavily on data from the Meteosat 10 and 11 satellites, which are second-generation satellites from EUMETSAT and the European Space Agency (ESA). The main instrument that these carry on board is the SEVIRI radiometer. *"This instrument is capable of observing the Earth in 12 different spectral bands, ranging from visible to thermal infrared, at a spatial resolution of one to three kilometres."*

Some channels are used for detecting and tracking cloud masses, and for studying land masses. Others are used for locating low clouds and night fog, for example.

Human interpretation still necessary

In order to produce a weather forecast for the next few hours, the satellite data needs to be extrapolated by scientists. The practice of producing these types of weather forecast is known as nowcasting. "For this type of forecast, extrapolation generally delivers better results than numerical weather prediction models," adds Clerbaux.

Numerical models are primarily used to forecast the weather for the next few days, which they do by using satellite data to simulate the evolution of the atmosphere. Forecasts for the next 2 to 4 days rely on regional atmospheric models, such as ALARO. When it comes to 14-day forecasts, the MRI uses global models.

"All of these models deliver raw information, which ideally needs to be interpreted and, sometimes, corrected. The models may be affected by systematic biases, such as the temperature in certain towns and cities. This is why it is important to correct the data before releasing a forecast. Human interpretation is also key to ensure that information about dangerous phenomena, such as thunderstorms, is communicated correctly."

Satellite data is combined with in situ measurements

Although satellites play a key role in forecasting weather, this practice also relies on other observation devices. The RMI, for example, detects lightning with its own system – BELLS, the Belgian Lightning Location System.

"We also have around fifteen weather stations that deliver data that satellites simply can't supply, such as relative humidity, the temperature 2 metres off the ground, wind speed and direction at an altitude of 10 or 30 metres, underground temperature and atmospheric pressure," explains Clerbaux. "Furthermore, sounding balloons also analyse temperature, humidity and wind direction up to an altitude of 35 kilometres three times a week.

By contrast, weather radars are able to predict very short-term rainfall.

(Image from the new Wideumont radar, May 2022): https://youtu.be/MXXKzX7wtg4

A third generation of satellites is ready to be launched

The third generation of Meteosat satellites, the first of which is planned to be launched at the end of November, will be able to produce improved images with a spatial resolution of 500 metres, 1 km or 2 km, depending on the band. "This will enable us to monitor fog formation in the Meuse valley more effectively, for instance," says Clerbaux.

These new satellites will also help forecasters calculate the intensity of thunderstorms more accurately, as well as predict severe storms. EUMETSAT also confirms that "the lightning detection imager will monitor all electric activity above Europe and Africa on a permanent basis – something that's never been done before.". This will enable the meteorological service in charge of air traffic to minimise the response time for issuing and lifting warnings, which will reduce financial losses for both airlines and airports.

Specially designed models for forecasting pollution peaks

In the 1970s, Belgium became interested in forecasting another increasingly worrying phenomenon – air pollution – on which meteorological conditions have a direct impact.

Similarly to weather forecasts, air quality is predicted with the help of mathematical models. "The main aim is to produce maps showing the concentration of pollutants for the current day and those that follow," explains a spokesperson from the Belgian Interregional Environment Agency (CELINE), which is responsible for studying air quality in Belgium.

The models used include CHIMERE, a model that simulates the physical and chemical processes in the atmosphere. *"The simulations of this model are based on meteorological forecasts, pollution emissions and land use data."*

One phenomenon that CHIMERE is able to predict is the concentration of particulate matter in the air. PM 2.5 – fine particles that measure no more than 2.5 micrometres in diameter – are monitored very closely given the considerable dangers they present to our health. Given their small size, they penetrate deep into our respiratory system and are suspected of being a possible cause of cardiovascular problems and certain cancers.

A substantial percentage of PM 2.5 can be traced back to ammonia (NH_3) emissions in the atmosphere, which are the result of fertilisers used by the farming industry. However, a recent study by Martin Van Damme, a researcher at both ULB (Free University of Brussels) and the Royal Institute for Space Aeronomy, has shown that the amount of NH_3 in the atmosphere in Europe increased by 21% between 2008 and 2018.

Satellites improve predictions of PM 2.5 concentrations

Over the past few years, scientists have been tracking this pollutant using the IASI instrument carried on board EUMETSAT's Metop satellites.

"It wasn't until 2008, two years after the first satellite in the series was launched, that we found out that it could measure the amount of NH3 released during a forest fire. IASI measurements enabled us to ascertain the first overview of this compound's global distribution. We weren't expecting this at all, especially since ammonia has a very weak spectral signature in the infrared." explains Van Damme.

Following this discovery, Van Damme and his team at the ULB put algorithms in place so that the instrument could reproduce NH_3 concentrations in virtually real time. *"This has definitely opened up a new area of research."*

A publication to which Van Damme recently contributed explains that the data collected by IASI could improve the way NH_3 emissions are represented in the CHIMERE model, which will, in turn, improve the predictions of PM 2.5 concentration.

Interestingly, the latest study by Van Damme reveals a 'weekend' phenomenon that impacts total NH_3 emissions measured by IASI above the European regions with the highest concentrations (including northern Belgium). *"We notice a 15% decrease in concentrations on Saturdays, compared to the weekly average.* If we take this type of fluctuation into account when we use models like CHIMERE, we will be able to improve predictions of fine particle pollution periods in the future," concludes the researcher.