Royal Netherlands
Meteorological Institute
Ministry of Infrastructure and the Environment

R&D
Satellite Observations

TROPOMI
Tropospheric Monitoring Instrument

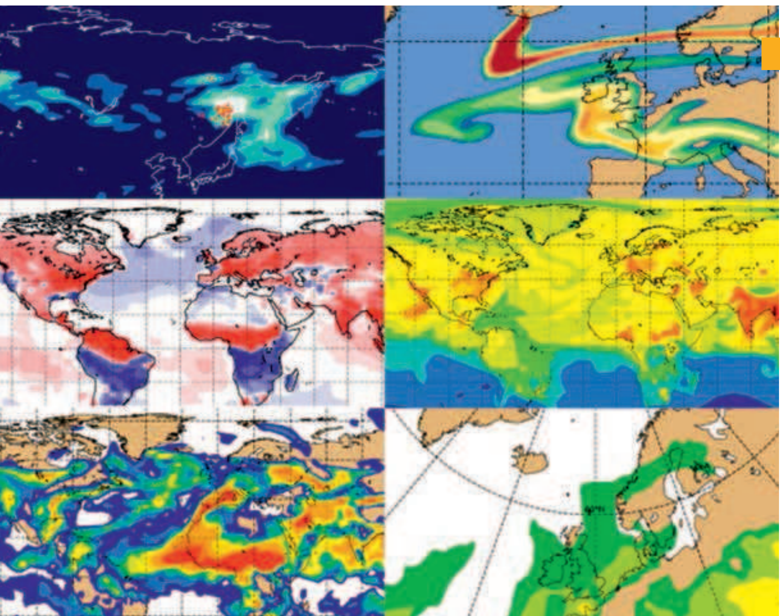
TROPOMI is a unique satellite instrument monitoring air quality, climate and the ozone layer. This instrument orbits the Earth in approximately 100 minutes at an altitude of 824 km. With a wide swath of 2600 km, TROPOMI measures the Earth's entire atmosphere within one day.

This daily global coverage is combined with a high spatial resolution of 7 km. TROPOMI measures ultraviolet, visible, and near-infrared spectra of the sunlight reflected by the Earth's surface and the atmosphere. From these measurements, the concentrations of trace gases, as well as properties of clouds and aerosols (fine particles) can be derived.

TROPOMI data is used to improve air quality forecasts and to detect whether emissions of gases into the atmosphere are rising or decreasing. Because of the high spatial resolution this is possible on the city scale. This is important because it can show how effective policy measures are. Another important application is the detection of volcanic plumes for aviation safety.

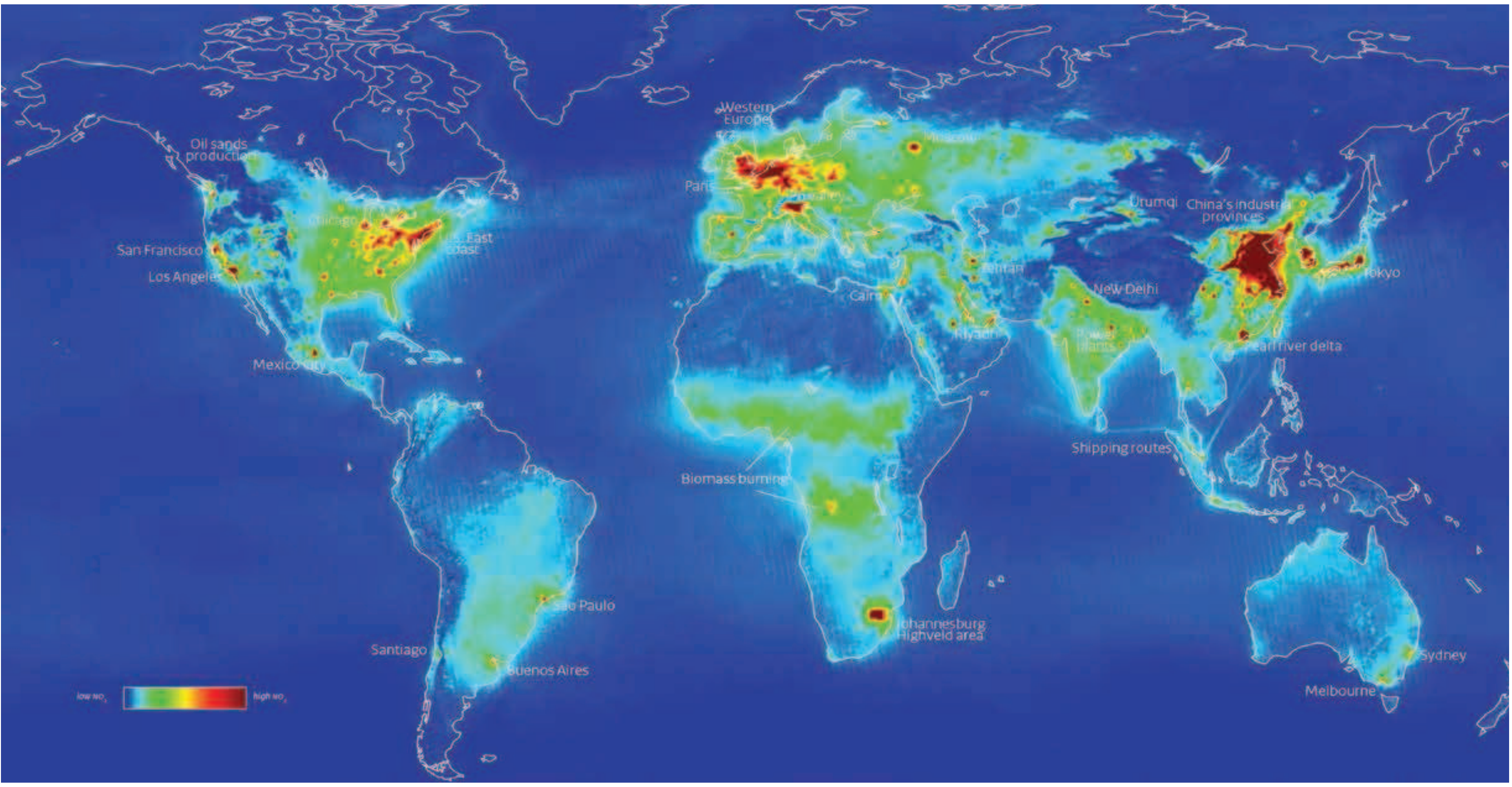
KNMI is the leading institute for TROPOMI and the RDSW department has developed, in collaboration with industrial and scientific partners, software processors to calibrate the raw data. KNMI is coordinating the development of the data products and has developed the NO_2, ozone profile, and aerosol products. KNMI is also responsible for controlling and calibrating the instrument in space and monitoring the data products.

TROPOMI is a collaboration between Airbus Defence and Space Netherlands, KNMI, SRON, and TNO, commissioned by NSO and ESA. TROPOMI is funded by the Dutch ministries of Economic Affairs, Education, Culture and Science, and Infrastructure and the Environment.



Copernicus and the atmosphere

The European Union's Copernicus Atmosphere Monitoring Service (CAMS) combines available observations—satellite data and measurements on ground and in the atmosphere—with models that describe changes in atmospheric composition. As a result, we get a detailed overview of the concentrations of air pollution, the distribution of greenhouse gases, and the current state of the ozone layer (see the figure for an impression). Daily forecasts, comparable with weather forecasts, are made for the amount of air pollution. The RDSW department provides a large contribution to CAMS through satellite data including OMI and TROPOMI, and measurements from the surface. Moreover, the department coordinates the CAMS validation project, which documents the quality of the forecasts.

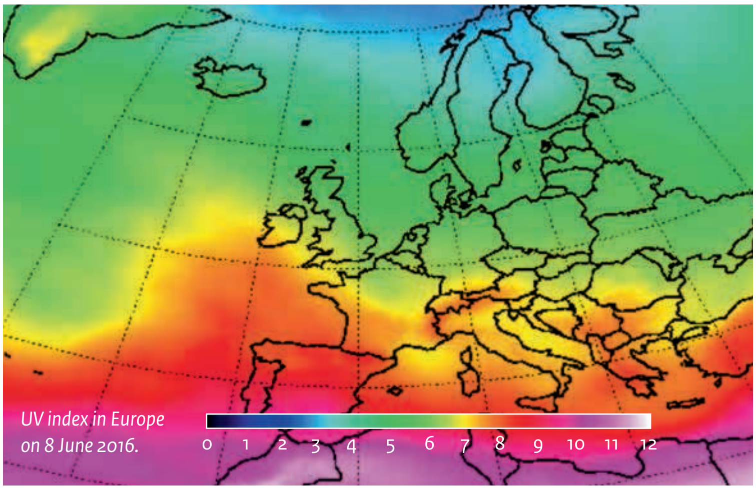


OMI and air pollution

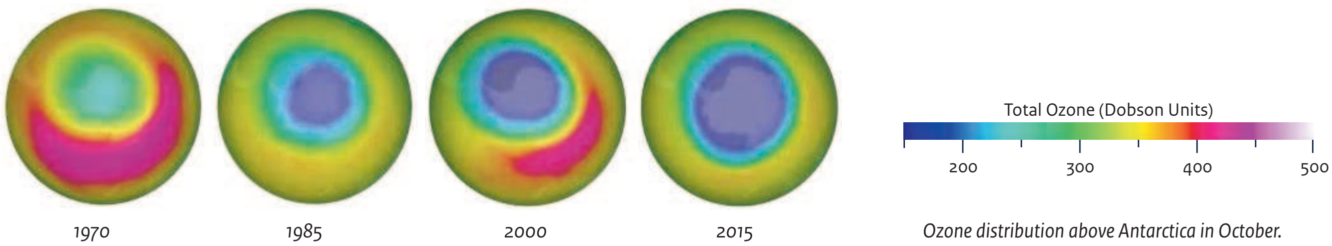
Nitrogen dioxide (NO_2) is an important ingredient for the development of air pollution. This map shows the global distribution of tropospheric NO_2, as observed by the Ozone Monitoring Instrument (OMI). Various sources of air pollution can clearly be distinguished: traffic, heavy industry, fossil fuel power plants, forest fires, oil refineries, and shipping. OMI was built by The Netherlands and Finland, and is mounted on board NASA's Aura satellite.

UV radiation

The UV index is a measure for the amount of ultraviolet (UV) radiation at the moment the sun is highest in a cloud-free sky. The UV index is determined from the global ozone distribution and gives an indication of the risk of sunburn. By using the forecast for the coming days of atmospheric wind and air pressure, we can make a forecast of the ozone distribution. From that we derive a UV index forecast as a service to the general public.



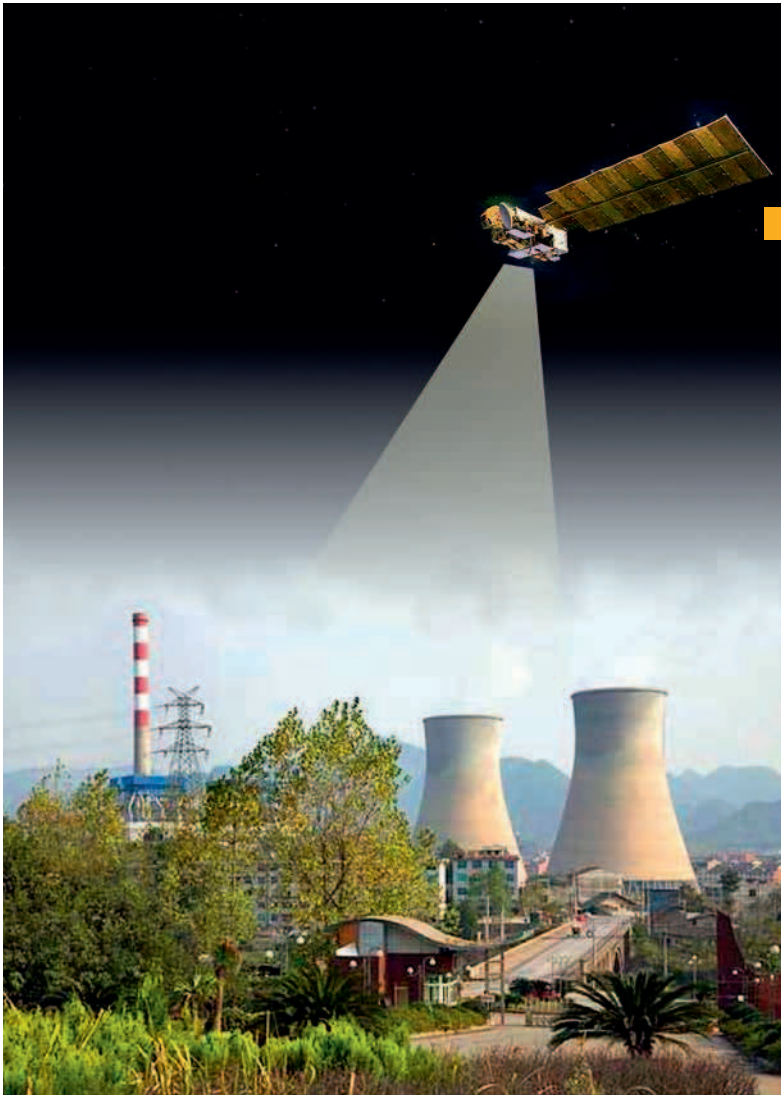
UV index in Europe on 8 June 2016.



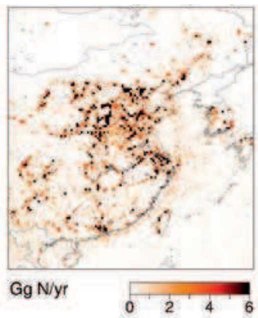
Ozone distribution above Antarctica in October.

Ozone

The ozone hole, an area above the South Pole with exceptionally low ozone values in the months from September to December, was first seen in 1983. Over the following years the ozone hole grew in size and depth. Since about 2000 the ozone hole has stopped growing, and there are signs that it is shrinking. To monitor changes in the global ozone distribution we have combined all available satellite measurements to form a consistent ozone record starting in 1970.

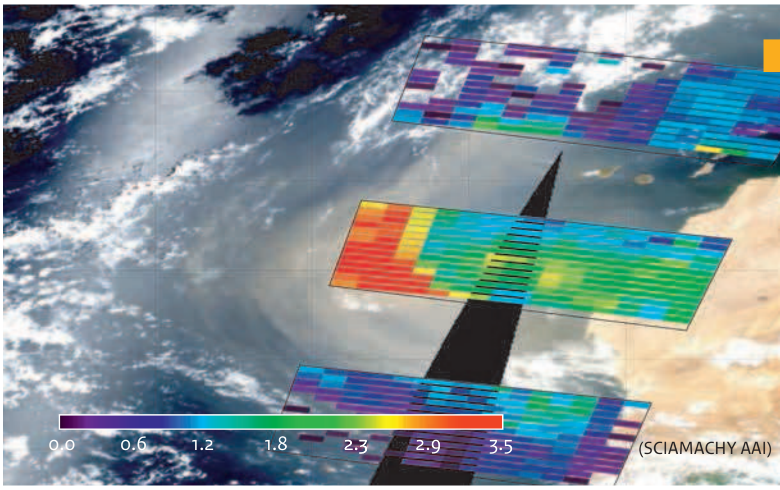


Determining emissions from satellite measurements



Nitrogen oxide (NO_x) emissions in East Asia derived from OMI measurements.

All air quality issues stem from the emission of pollutants. Therefore, up-to-date emission inventories are essential to evaluate emission reduction measures, and to make correct air quality forecasts. However, traditional emission inventories are often based on inaccurate or outdated statistical information. At KNMI, we develop advanced algorithms to estimate emissions from satellite observations. The main advantages of these emission estimates are the spatial consistency, the high resolution, and the rapid availability to the user. The KNMI satellite-derived emissions are used by research groups and policy makers worldwide.



Dust and smoke

An important subject for RDSW is the use of satellite instruments to observe desert dust, smoke from vegetation fires, and volcanic ash in the global atmosphere. These aerosols absorb sunlight and heat the atmosphere. As a result, and also through their impact on clouds, they constitute an important link in the climate system.

Desert dust from the Sahara observed by the European satellite spectrometer SCIAMACHY over the Atlantic Ocean on 25 July 2004.

Bicycle measurements of nitrogen dioxide (NO_2)

How clean is the air we breathe while commuting to work or school on a bicycle? Since June 2015, KNMI researchers and students have been cycling in attempt to answer this question. As a part of the City-Sonde Science project, a measurement technique developed at KNMI is utilized in an innovative way. An NO_2 sensor built in-house called the NO_2-sonde was originally designed to be launched using a weather balloon, but within this project it is coupled to a mobile weather station and GPS and mounted on a bicycle.

Cabauw: validation of satellite observations

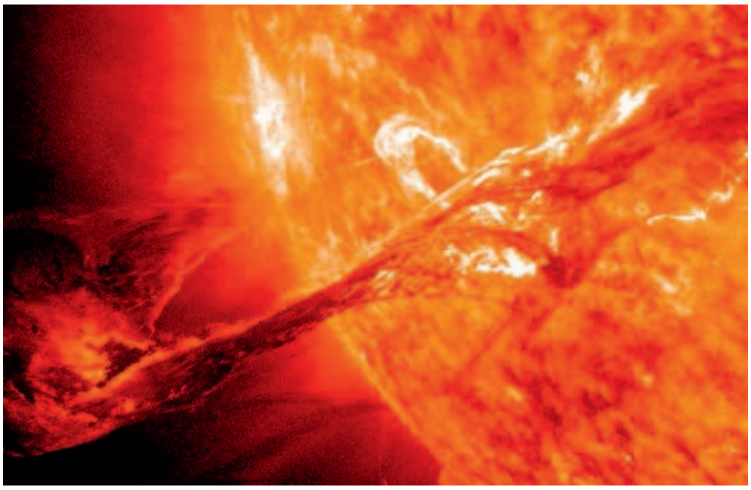
The KNMI terrain near Cabauw houses a 213 meter tall measurement tower with a large number of instruments. Using these instruments, the vertical structure of the atmosphere regarding wind, aerosols, trace gases, clouds, and radiation is characterized in detail.

The measurements are performed in cooperation with Dutch institutes in the CESAR (Cabauw Experimental Site for Atmospheric Research) consortium. CESAR delivers essential information to understand atmospheric processes and detect long-term trends. The freely available data are used to improve climate, weather and air quality models.

Within RDSW, CESAR is particularly important for the validation of the satellite observations that are conducted in the department. Regularly, measurement campaigns are organized, in which a variety of sensors is added to the standard collection of instruments. For example, in September 2016 the CINDI-2 campaign took place specifically aimed at measuring profiles of nitrogen dioxide and in preparation for the TROPOMI validation. During CINDI-2, the instruments for validating TROPOMI came from around the world to Cabauw to compare with each other. These additional measurements from the CESAR program constitute the perfect background for this essential step in satellite validation.

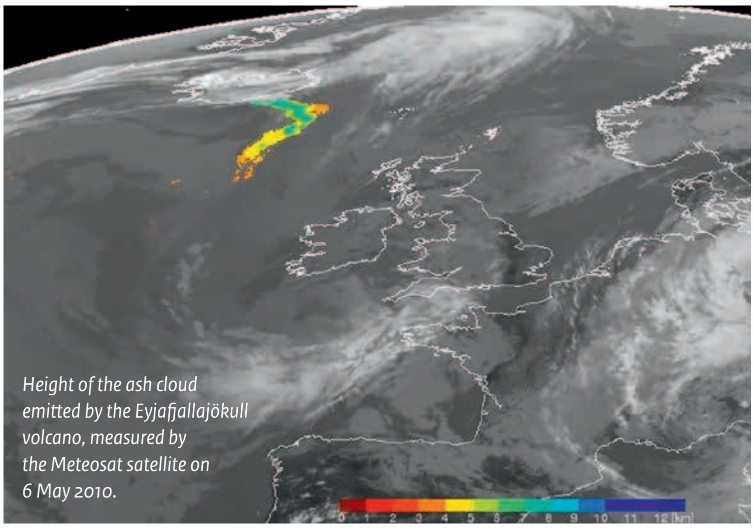
Space weather

Our sun is a magnetically active star that has a strong influence on the weather conditions in outer space. This space weather can be quite violent and had a profound influence on infrastructures like satellites, GPS, aviation, power grids, telecommunication, gas and water supplies, the financial sector, and emergency services, the so-called vital sectors that are critical for our national security and economic vitality. In addition to the well-known weather alerts, KNMI now also issues space weather alerts so that our society can be prepared for the effects of space weather. KNMI collaborates with national and international partners to provide space weather forecasts.



Volcanoes

Volcanic eruptions can be serious hazards for society, in particular for aviation because volcanic ash can cause damage to aircraft engines leading to malfunction. During the eruption of the Icelandic volcano Eyjafjallajökull in 2010, most of the European airspace was closed for six days, causing millions of stranded passengers. Monitoring global volcanic activity is thus very important. This is done by a number of Volcanic Ash Advisory Centers, who advise civil aviation authorities of dangerous flying conditions around the world. KNMI contributes to this task by providing satellite observations of gases and ash from volcanic eruptions.



Height of the ash cloud emitted by the Eyjafjallajökull volcano, measured by the Meteosat satellite on 6 May 2010.

EarthCARE

The Earth Clouds, Aerosols and Radiation Explorer (EarthCARE) satellite is a joint mission of the European Space Agency (ESA) and the Japan Aerospace Exploration Agency (JAXA). EarthCARE is focused on improving the understanding of the 3D structure of aerosols, clouds and atmospheric radiation, which is relevant for both weather and climate applications.

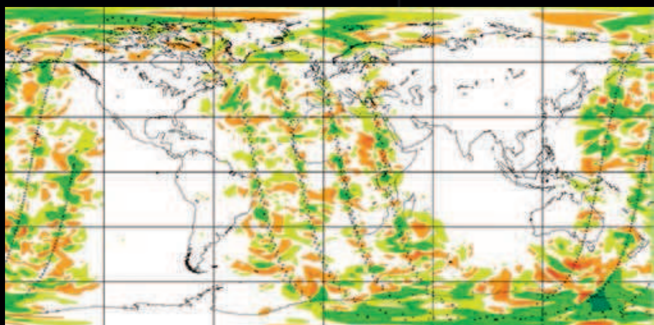
The satellite contains four instruments. The two 'active' sensors are an advanced high spectral resolution atmospheric cloud/aerosol lidar (ATLID) and a cloud profiling Doppler radar (CPR). The two 'passive' sensors are a multispectral imager (MSI) and a broadband radiometer (BBR). The algorithm development focuses on both the use of single instruments as well as the synergistic use of multiple instruments.

KNMI is co-responsible for EarthCARE advice to ESA and has developed an extensive software package for instrument simulation. In addition, KNMI is directly responsible for the development of ATLID-only algorithms as well as the management of the algorithm development for MSI and MSI + ATLID.

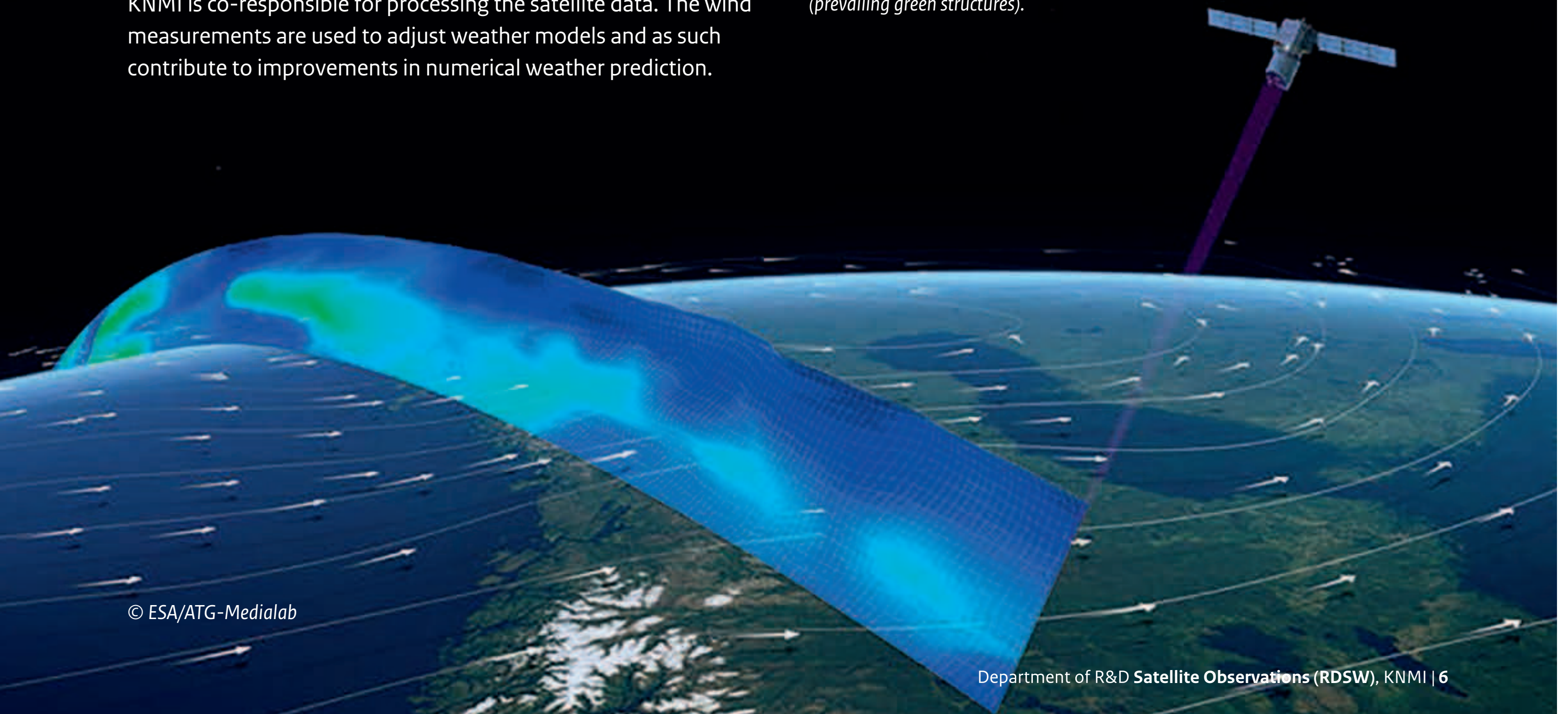
ADM-Aeolus

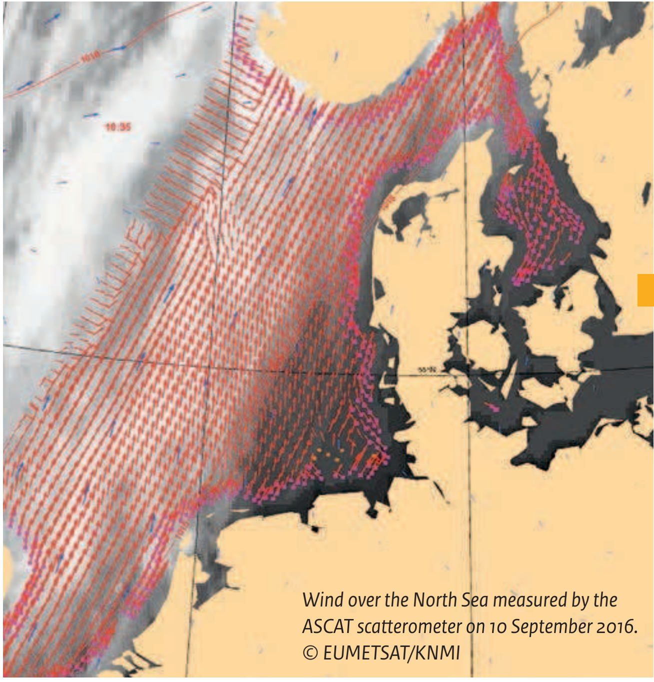
The unique satellite ADM-Aeolus of the European Space Agency (ESA) measures wind profiles from the surface up to an altitude of 30 km. The onboard lidar instrument measures the movement of clouds, aerosols and molecules in the atmosphere from which the wind can be inferred. The satellite flies in a polar orbit at 320 km altitude, yielding global coverage of wind measurements.

KNMI is co-responsible for processing the satellite data. The wind measurements are used to adjust weather models and as such contribute to improvements in numerical weather prediction.



ADM-Aeolus draws the weather model closer toward the true atmosphere (prevailing green structures).





Wind over the North Sea measured by the ASCAT scatterometer on 10 September 2016. © EUMETSAT/KNMI

Wind over sea

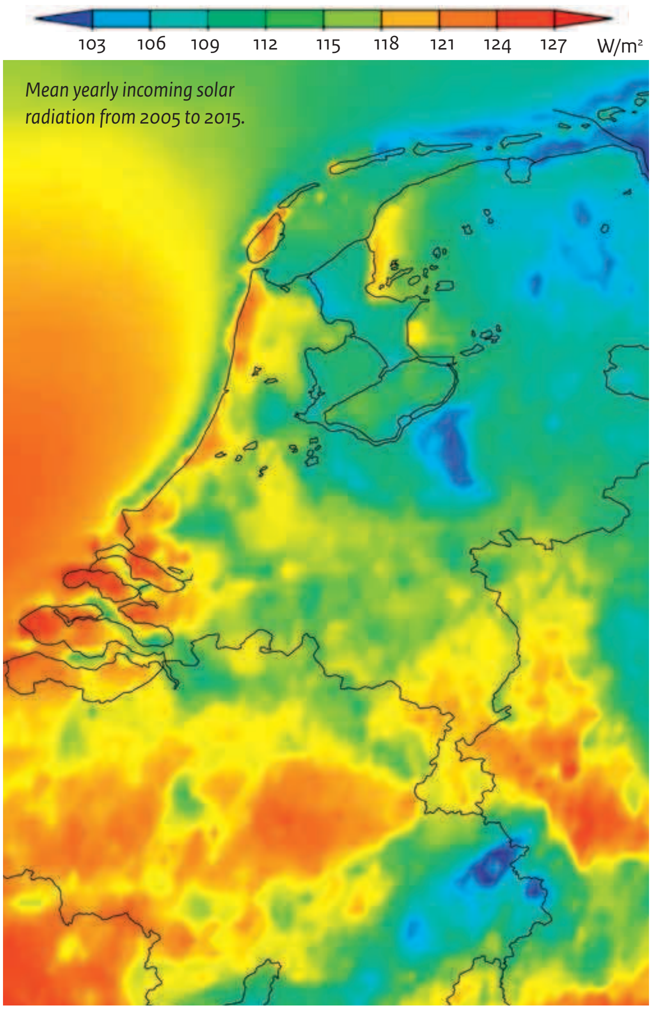
A scatterometer is a radar instrument on board a satellite capable of measuring the wind over the oceans. The principle is simple: a radar beam is sent from the satellite to the sea surface, and from the amount of backscattered radiation the roughness—the wave pattern—of the sea can be determined.

The sea roughness is a measure for the wind speed and direction. On a daily basis, scatterometers deliver many thousands of unique wind measurements, which cannot be obtained in any other way.

KNMI is world leader in calculating winds from scatterometer satellite measurements. RDSW is involved in various international projects aiming to gather the valuable measurements and optimize their usage. There are many weather and climate related applications, including weather, wave, and storm surge forecasts, wind energy, wind atlases, air-sea interaction, climate change, and oceanography.

Clouds and solar radiation

Every 15 minutes EUMETSAT's Meteosat satellites take detailed pictures of the earth, both from visible and infrared light. In the RDSW department these images are used to derive information about cloudiness, precipitation, and solar radiation. These data are important for investigating variations and trends in cloudiness and for evaluation and improvement of the KNMI weather model HARMONIE. Moreover, these data are used for various practical applications, such as monitoring the efficiency of solar panels.



Mean yearly incoming solar radiation from 2005 to 2015.

Colofon

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Additional information / data access

TROPOMI & OMI
http://www.tropomi.nl | http://www.tropomi.eu
http://projects.knmi.nl/omi

ESA missions ADM-Aeolus and EarthCARE
http://www.esa.int/Our_Activities/Observing_the_Earth/
The_Living_Planet_Programme/Earth_Explorers/

CAMS (Copernicus Atmosphere Monitoring Service)
https://atmosphere.copernicus.eu/

TEMIS: Data atmospheric composition
http://www.temis.nl

Scatterometer: Data wind over sea
http://www.knmi.nl/scatterometer

Meteosat: Data clouds, precipitation, and solar radiation
http://msgcpp.knmi.nl