TROPOS
Leibniz Institute for Tropospheric Research

# Details

## Addressing 3D effects of clouds for significant improvements of climate models

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New DFG research group on 3D radiation transport launched

**Leipzig. Over the next few years, climate researchers from Germany aim to achieve a breakthrough in the radiative properties of clouds by describing the corresponding processes not just one-dimensionally, as has been the case up to now, but three-dimensionally in future. Capturing clouds and radiation in 3D is seen as an important step towards undistorted remote sensing of the atmosphere and improved modelling of climate and weather. The new research group of the German Research Foundation (DFG) brings together experts in atmospheric radiation, high-resolution modelling and observation of clouds on various spatial and temporal scales. The kick-off meeting at the end of January in Leipzig at the Leibniz Institute for Tropospheric Research (TROPOS) marks the start of work on this important topic**

Clouds cover an average of two thirds of our planet's surface and are therefore the largest filter in our atmosphere, reflecting solar radiation from the sun and emitting thermal radiation back to the ground. Depending on their structure, height and time of day, clouds can therefore cool or warm. As clouds play a dominant role in the Earth's radiation budget and therefore shape the planet's climate, climate research has been making great efforts since the first weather satellites in the 1960s to record the global distribution of clouds and their radiation effects from satellite observations. However, these radiation effects and their regional and temporal distribution are still not well understood. This is mainly due to the complex spatio-temporal variability of cloud cover, cloud type and microphysical properties, which cannot yet be adequately captured by satellites or global models.

In satellite remote sensing and climate modelling, clouds are represented in a simplified form as homogeneous objects due to a lack of more precise information. However, it has been known for decades that this highly simplified cloud geometry is too imprecise and also neglects the natural spatio-temporal variability.

Although clouds are highly variable due to their complex dynamic and microphysical processes, there are now approaches to explain their radiative effects with a few averaged physical cloud properties such as liquid water path or cloud cover. A new research group now wants to bring these approaches together and develop them further in order to better understand the three-dimensional radiation effects and take them into account in remote sensing and climate modelling.

The C3SAR (Cloud 3D Structure And Radiation) research group brings together around 25 researchers from the University of Cologne (UzK), Ludwig-Maximilians-Universität München (LMU), Leibniz Universität Hannover (LUH), the German Weather Service (DWD) and the Leibniz Institute for Tropospheric Research (TROPOS), which is coordinating the work. The research group is funded by the German Research Foundation (DFG). DFG Research Units enable scientists to address current and pressing issues in their specialised fields and to establish innovative research directions. They are funded for up to eight years.

The involved researchers have high hopes for the latest generation of earth observation satellites. The third generation of Meteosat weather satellites (MTG, since 2024) and the new ESA climate satellite EarthCARE (also since 2024) enable cloud observations from space with a spatial resolution like never before. But it's not just the eyes in space that are now much "sharper", a lot has also happened on the ground in recent years: so-called atmospheric supersites such as the DWD's Richard Aßmann Observatory and other observatories in Germany and Europe are already providing valuable high-resolution cloud and radiation information as part of the EU research infrastructure ACTRIS.

As part of the C3SAR research group, a large field campaign is planned for summer 2026 at the Richard Aßmann Observatory of the DWD in Lindenberg, east of Berlin, during which the instruments of the observatory there will be supplemented by additional devices for three months. Among other things, these will record the optical and microphysical properties of clouds, cloud-related fluctuations in solar radiation on the ground and the distribution of incoming solar radiation in terms of wavelength and direction of incidence

The DWD's routine measurement programme in Lindenberg with cloud radar, ceilometer, microwave radiometer, Raman lidar, radiosondes, infrared sky camera and radiometer is supplemented by a small-scale pyranometer measurement network (PyrNet) from TROPOS, which better captures the spatial variability of solar irradiance at the Earth's surface. This pyranometer measurement network last recorded the small-scale variability of sunlight in the USA in 2023. The researchers want to install dozens of these small radiation measuring devices on and around the observatory in Lindenberg in 2026 in order to record the solar irradiance on the ground every second and compare it with the satellite observations and model results. In addition, new in-situ measurement methods from Leibniz Universität Hannover will be used to measure the spectral and directional distribution of solar radiation (radiance) with high spectral and temporal resolution. The combination of high-resolution cloud modelling, reconstructed and observed radiation and cloud data and state-of-the-art satellite data will produce unique data sets of cloud properties, irradiance and radiance for the Earth's surface and the upper edge of the atmosphere.

By combining state-of-the-art ground- and satellite-based remote sensing with high-resolution radiation and atmospheric modelling, the researchers believe that there will be an opportunity in the coming years to integrate the spatial structure of clouds into global climate models and remote sensing from space, thereby closing a gap in cloud research that has been known for decades. Specifically, the project aims to make it possible for the first time to correct errors in climate modelling and cloud remote sensing based on observations, which can be traced back to an oversimplification of the complex geometric nature of clouds.

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**Further information and links:**

DFG Research Unit
FOR 5626: Cloud Structure and Climate - Closing the 3D Gap

https://gepris-extern.dfg.de/gepris/projekt/513446258

EU research infrastructure ACTRIS

https://www.actris.eu/

The German contribution to the European research infrastructure ACTRIS

https://www.tropos.de/forschung/actris-d

Meteorological Observatory Lindenberg - Richard-Aßmann-Observatory (MOL-RAO) of the DWD

https://www.dwd.de/DE/derdwd/standorte/observatorien/mol/mol.html

&

https://www.dwd.de/SharedDocs/broschueren/DE/presse/standorte/mo_lindenberg_pdf.pdf;jsessionid=8D9F35A4C8B77E6EA5DDF1BC59A1867D.live31093?

TROPOS pyranometer network (PyrNet)

https://www.tropos.de/forschung/grossprojekte-infrastruktur-technologie/technologie-am-tropos/pyranometer-netzwerk

Small-Scale Variability of Solar Radiation (S2VSR 2023 in Oklahoma, USA)

https://www.tropos.de/aktuelles/messkampagnen/blogs-und-berichte/s2vsr-2023

EarthCARE & atmo4ACTRIS

https://www.tropos.de/aktuelles/pressemitteilungen/details/earthcares-lidar-zeigt-detailliert-partikel-in-der-atmosphaere

Characterisation of the spatio-temporal development of clouds, aerosols and radiation

https://www.tropos.de/institut/abteilungen/ag-satellitenfernerkundung/charakterisierung-der-raum-zeitlichen-entwicklung-von-wolken-aerosolen-und-strahlung

BMBF research project "High Definition Clouds & Precipitation in Climate Prediction" - HD(CP)2

https://www.tropos.de/forschung/grossprojekte-infrastruktur-technologie/verbundprojekte/hdcp2

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*The financial volume amounts to 2.2 billion euros. They are financed jointly by the federal and state governments. The basic funding of the Leibniz Institute for Tropospheric Research (TROPOS) is provided by the Federal Ministry of Education and Research (BMBF) and the Saxon State Ministry of Science and the Arts (SMWK). The institute is co-financed by tax revenue on the basis of the budget approved by the Saxon State Parliament.*

*www.leibniz-gemeinschaft.de*
*www.bmbf.de*
*www.smwk.sachsen.de*

*New DFG research group C3SAR on 3D radiation transport launched. Photo: Tilo Arnhold, TROPOS*

*Measuring clouds and radiation in 3D is considered an important step towards unbiased remote sensing of the atmosphere and improved modelling of climate and weather. Photo: Patric Seifert, TROPOS*

*Clouds cover an average of two thirds of our planet's surface and are therefore an important factor in the Earth's climate. Photo: Bomidi Lakshmi Madhavan, TROPOS*

*As with the HOPE measurement campaign, C3SAR will again involve radiation measurements in and around the DWD observatory in Lindenberg. Photo: Bomidi Lakshmi Madhavan, TROPOS*

*Clouds are highly variable due to their complex dynamic and microphysical processes. Photo: Tilo Arnhold, TROPOS*

*However, the radiation effects and their regional and temporal distribution are still not well understood. Photo: Tilo Arnhold, TROPOS*

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