GAW-SCHWEIZ

ICE-CLOUD FORMING AEROSOLS IN THE SWISS ALPS

ETH Zurich measures ice cloud formation due to Saharan dust, frequently transported to Switzerland. By injecting aerosols into a cloud chamber installed at the Sphinx laboratory, Jungfraujoch, the impact on cloud formation and climate is studied.

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Since 2009, the Swiss Global Atmospheric Watch (GAW) Programme GAW-CH, run by MeteoSwiss, has been funding observations of aerosol impacts on climate at the Jungfraujoch in the Swiss Alps. ETH Zurich performs measurements of the influence of aerosol on ice cloud formation, particularly because the impact from aerosol – cloud – interactions on future climate remains highly uncertain[1]. To predict when ice crystals form in clouds is crucial for the lifetime of clouds, its potential to produce precipitation and for its radiative properties (i.e. how much sunlight a cloud will reflect or scatter back into space). When cloud droplets form in the atmosphere and cool down to below 0 °C, contrary to popular belief, the water droplets do not freeze at 0 °C, but can remain liquid down to temperatures of about -38 °C. The reason for this is a kinetic barrier brought about by the small volume of the cloud droplets in the atmosphere. Yet, we often observe ice crystals in clouds at temperatures warmer than -38 °C. For such droplets to freeze at temperatures warmer than -38 °C, aerosols known as ice-nucleating particles (INPs) are needed to provide a surface for ice to form within the droplet. An example of an aerosol that can do this well in the atmosphere is Saharan dust that is frequently transported to Switzerland (Figure 1). How INPs modify cloud properties depends on their number concentration in the atmosphere. Pure ice clouds in the upper atmosphere have a warming effect because they are efficient at trapping outgoing longwave radiation (heat) within the Earth's atmosphere. Ice crystals that form within supercooled liquid clouds are efficient at forming precipitation and can reduce the lifetime of a cloud causing more solar radiation to reach the Earth's surface.

At ETH in the Atmospheric Physics group, we have researched the high propensity of Saharan dust to form ice clouds since 2009, via several MeteoSwiss funded GAW-CH projects. In these projects, we installed cloud chambers for fixed periods of time, e.g. at the Jungfraujoch Sphinx Laboratory, and intensively performed measurements. However, since knowing the number concentration of INPs is important, we concluded that automating such a measurement would be crucial to continue to provide observational data for climate modeling and to perform a long-term study to monitor the number of these particles that are relevant for ice cloud formation. So, under the auspices of the latest MeteoSwiss funding round through the GAW-CH program, we embarked on the challenge of developing an automated ice cloud chamber that can be operated unmanned (Figure 2), a task that had not been done in the scientific community before. We successfully implemented this chamber in early 2020. By early 2021, we had measured the first year-long continuous data set on INP concentrations. The development of an automated ice cloud chamber was only possible thanks to several dedicated scientists, Drs. Cedric Chou, Yvonne Boose, Larissa Lacher and Cyril Brunner. Through their measurements, we discovered the importance of such measurements over the last decade. With Dr. Cyril Brunner, we automated and developed and improved ice cloud chamber[2] used for measurements at Jungfraujoch. In these cloud chambers, we can establish carefully controlled temperature and relative humidity conditions to quantify the conditions at which aerosol such as Saharan dust will form ice crystals. The automation is challenging as very refined non-turbulent flow conditions are required as well as a constant source of water vapour to supply humidity as would naturally occur in a cloud.

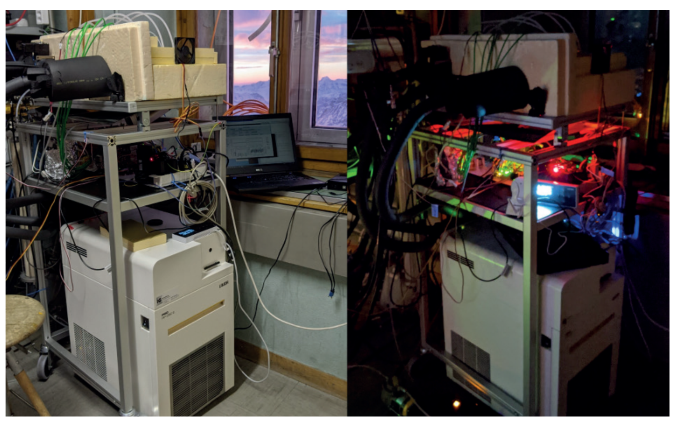

Figure 2: An image of the automated Horizontal Ice Nucleation Chamber (HINC-Auto) sampling aerosol particles directly from ambient air at the Sphinx Observatory, Jungfraujoch.

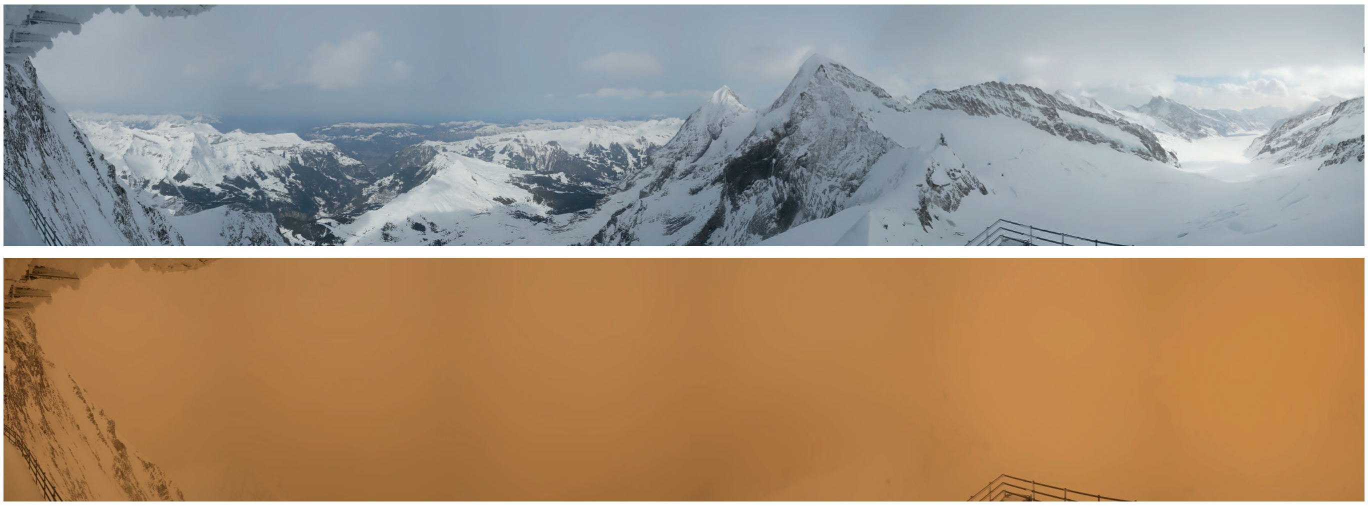

Figure 1: View of cloudiness at the Jungfraujoch (3571 m a. s. l.) in the absence of Saharan dust transported to the site (top) and with Saharan dust transported to the site (bottom).

Through the latest project[3], we also showed that the majority of INPs measured at the Jungfraujoch are likely mineral dust particles from deserts and potentially agricultural sources or construction from anthropogenic activity. We could show that this is even the case in the absence of actively transported dust from the Saharan region: using remote sensing data available from Kleine Scheidegg, we were able to frequently infer the presence of dust that contributed to ice crystal formation in the chamber installed at Jungfraujoch. In addition, we do have evidence of marine aerosol particles that were transported from the north Atlantic to central Switzerland that are also responsible for forming ice clouds. While it is already known that particles released from the ocean can also be responsible for forming ice crystals in clouds, we were surprised that such particles can be transported over such long distances retaining their ice crystal forming ability and our methods were sensitive enough to detect their influence on ice cloud formation in central Switzerland.

«WITH MONITORING THE ICE-FORMING POTENTIAL OF ATMOSPHERIC AEROSOL PARTICLES AT JUNGFRAUJOCH, THE SWISS GAW PROGRAMME HAS ONCE MORE ESTABLISHED ITSELF AS A WORLD LEADER IN AEROSOL-CLOUD RESEARCH.»

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The collected data from the automated measurements can be used to validate cloud formation in weather prediction and climate models, which struggle to accurately predict the amount of ice in the atmosphere. This is important for precipitation forecasts in weather prediction models and for projecting the warming or cooling effect of clouds depending on the cloud altitude in the atmosphere in climate models. Such continuous measurements will soon be installed at a second GAW-CH station, Payerne, as part of an Aerosol, Clouds and Trace Gases Research Infrastructure (ACTRIS) framework project within the next year. ■

REFERENCES

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2 Brunner C, Kanji ZA (2021) **Continuous online monitoring of ice-nucleating particles: development of the automated Horizontal Ice Nucleation Chamber (HINC-Auto).** Atmos. Meas. Tech. 14: 269-293.

3 Brunner C et al (2021) **The contribution of Saharan dust to the ice nucleating particle concentrations at the High Altitude Station Jungfraujoch (3580 m a.s.l.), Switzerland.** Atmos. Chem. Phys. 2021: 1-38.

MORE INFORMATION
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