TIME TABLE

TIME	Monday	Tuesday	Wednesday	Thursday	Friday
	July 24	July 25	July 26	July 27	July 28
09.00 - 09.45	Registration	Oertel/Hoffmann	Malinowski	Miltenberger	Grabowski
09.45 - 10.30	Oertel/Hoffmann	Oertel/Hoffmann	Malinowski	Miltenberger	Malinowski
11.00 - 11.45	Oertel/Hoffmann	Grabowski	Miltenberger	Malinowski	Tordella
11.45 - 12.30	Ekman	Grabowski	Miltenberger	Malinowski	Tordella
14.00 - 14.45	Ekman	Oertel/Hoffmann	Tordella	Miltenberger	
14.45 - 15.30	Furtado	Ekman	Tordella	Grabowski	
16.00 - 16.45	Furtado	Ekman	Furtado	Grabowski	
16.45 - 17.30	Ekman	Tordella	Furtado	Furtado	
18.00	Welcome aperitif			Round Table	

ADMISSION AND ACCOMMODATION

The course is offered in a hybrid format giving the possibility to attend the course also by remote (on Microsoft Teams platform). On-site places are limited and assigned on first come first served basis.
The registration fees are:

- **On-site participation, 600.00 Euro + VAT***

This fee includes a complimentary bag, five fixed menu buffet lunches, hot beverages, downloadable lecture notes.
Deadline for on-site application is June 24, 2023.

- **Online participation, 250.00 Euro + VAT***

This fee includes downloadable lecture notes.
Deadline for online application is July 12, 2023.

Application forms should be sent on-line through the following web site: http://www.cism.it
A message of confirmation will be sent to accepted participants.

Upon request a limited number of on-site participants can be accommodated at CISM Guest House at the price of 35 Euro per person/night (mail to: foresteria@cism.it).

** where applicable (bank charges are not included)*
Italian VAT is 22%.

CANCELLATION POLICY

Applicants may cancel their registration and receive a full refund by notifying CISM Secretariat in writing (by email) no later than:
- June 24, 2023 for on-site participants (no refund after the deadline);
- July 12, 2023 for online participants (no refund after the deadline).

Cancellation requests received before these deadlines will be charged a 50.00 Euro handling fee. Incorrect payments are subject to Euro 50,00 handling fee.

GRANTS

A limited number of participants from universities and research centres who are not supported by their own institutions can request the waiver of the registration fee and/or free lodging.
Requests should be sent to CISM Secretariat by **May 24**, **2023** along with the applicant's curriculum and a letter of recommendation by the head of the department or a supervisor confirming that the institute cannot provide funding. Preference will be given to applicants from countries that sponsor CISM.

For further information please contact:
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Centre International des Sciences Mécaniques
International Centre for Mechanical Sciences

ACADEMIC YEAR 2023
The Alfred Kluwick Session

MICROPHYSICS OF ATMOSPHERIC CLOUDS

Advanced School
coordinated by

Daniela Tordella
Politecnico di Torino
Italy

Udine ***July 24 - 28*** 2023

MICROPHYSICS OF ATMOSPHERIC CLOUDS

Clouds determine precipitation and constitute the main component of the hydrological cycle. They can be very beautiful, but also emphemeral in the eyes of people, artists, but also of scientists, thereby creating a fascinating enigma.

The scientific study of clouds began with Luke Howard's classification in 1803. Throughout the 19th century, the boundary between the arts and sciences, particularly with regard to natural sciences, including meteorology, was much less rigid than it is today. For instance, the great German poet Goethe took particular interest in the scientific classification of clouds. The most original sea-and-sky scape painter of the 19th century, JWM Turner, annotated his copy of Goethe's 'Theory of Colors', and referred to it directly in the title of one of his paintings (Light and color (Goethe's theory)—The Morning After the Deluge—Moses writing the book of Genesis (The Tate Gallery, London)). And one the finest of all cloud painters, John Constable, was also well aware of the work of Luke Howard, and performed detailed cloud studies in the 1820s over Hampstead Heath.

It is now understood that, paradoxically, the global dynamics of the atmosphere and climate are very much dependent upon the micro-scale-level processes of clouds. In fact, in addition to convective heating due to the latent heat release associated with the condensation of water vapor, clouds control, to a large extent, the solar and thermal radiation balances of the atmosphere.

The present course mainly focuses on a few of the fundamental aspects concerning clouds:

- Latent heat release, which leads to convective or stratiform heating/cooling, that is, one of the main energy sources of atmospheric motions at spatial scales, ranging from local turbulence and single clouds to global circulation.

- The condensation of water vapor and the subsequent precipitation within clouds through microphysical processes that take place at cloud particle size scales, ranging from several micrometers to a few centimeters.

- The effects of clouds on radiation caused by cloud coverage, the altitude of the cloud top, the size of the cloud particles, the size distributions, and the phase.

- The effects associated with atmospheric aerosols, which play a key role in determining the properties of clouds and give rise to the formation of water droplets and ice crystals.

- The development of improved observational techniques to study microphysical processes and bulk cloud properties and to measure the physical and optical properties of atmospheric aerosols.

- The interplay between the continuously increasing resolution of large-scale and mesoscale atmospheric models and the treatment of the intrinsic unsteady evolution of individual clouds.

The design of this PhD course in part stems from activities associated with the Marie Sklodowska Curie Action Innovative Training Network, COMPLETE, which was a Cloud-MicroPhysics-Turbulence-Telemetry shared inter-multidisciplinary research training environment for enhancing the understanding and modeling of atmospheric clouds. The network was financed under the Horizon 2020 Framework Program (2016-2021, GA 675675) and coordinated by Daniela Tordella, www.complete-h2020network.eu.

PRELIMINARY SUGGESTED READINGS

M K Yau, R R Rogers, A Short Course in Cloud Physics, ELSEVIER, 3rd Edition - January 1, 1989, eBook ISBN: 9780080570945.

Dennis Lamb, Johannes Verlinde, Physics and Chemistry of Clouds, Cambridge University Press, October 2011, Online ISBN: 9780511976377, DOI: https://doi.org/10.1017/CBO9780511976377.

IPCC INTERNATIONAL, the Intergovernmental Panel on Climate Change. United Nations Environment Programme (UNEP) and the World Meteorological Organization (WMO). Clouds and Aerosols, Coordinating Lead Authors: Olivier Boucher (France), David Randall (USA) , 2012. https://pure.mpg.de/rest/items/item_2007900/component/file_2007948/content.

Grabowski, Wojciech W. and Wang, Lian-Ping, Growth of Cloud Droplets in a Turbulent Environment, Annual Review of Fluid Mechanics, VOL 45, 2013, 10.1146/annurev fluid-011212-140750.

Andreae MO, Rosenfeld D, Aerosol-cloud-precipitation interactions. Part 1. The nature and sources of cloud-active aerosols, Earth-Science Reviews, JUL 2008, vol. 89, issues 1-2, pages 13-, DOI 10.1016/j.earscirev.2008.03.001.

Kaufman YJ, Tanre D, Boucher O, A satellite view of aerosols in the climate system, NATURE, Sept. 12 2002, vol. 419, issue 6903, pp. 215-223, DOI 10.1038/nature 01091.

LECTURES

All lectures will be given in English. Lecture notes can be downloaded from the CISM web site. Instructions will be sent to accepted participants.

INVITED LECTURERS

Annica Ekman - Stockholm University, MISU, Sweden
5 lectures on: homogeneous and heterogeneous freezing processes in the atmosphere; ice crystal growth processes and secondary ice formation; the structure of mixed-phase low-level Arctic clouds; high-resolution modeling of mixed-phase low-level Arctic clouds and model evaluation.

Kalli Furtado - MET Office, Exeter, United Kingdom
5 lectures on: parametrization of ice and mixed-phase clouds, evaluation of models against satellite and aircraft observations and role of cloud-microphysics in convection-permitting weather and climate simulations; parametrization of extreme at convective clouds and lightning; climate model biases traced to atmospheric model cloud errors; MET office unified model of global atmosphere.

Wojciech W. Grabowski - NCAR, Boulder, Colorado, USA
5 lectures on: fundamentals of cloud microphysics modeling, reviewing simple warm-rain and mixed-phase Eulerian approaches, more sophisticated Eulerian methods and particle-based Lagrangian methods; applications of various modeling approaches to study cloud microphysics and microphysics-dynamics coupling in natural and laboratory clouds; impact of turbulence on cloud droplet initiation and growth.

Fabian Hoffmann - LMU, Munich, Germany
and **Annika Oertel** - KIT, Karlsruhe, Germany
5 lectures on: cloud microphysics; aerosol-cloud interactions, aerosol impact on cloud structure as a key uncertainty in the climate impact of aerosol; emulation-based approach as a tool for summarizing complex data about the sensitivities of cloud properties; Stratocumulus Clouds patterns and cooling effects by reflection of the solar radiation.

Szymon Malinowski - University of Warsaw, Poland
5 lectures on: the nonstationary, nonuniform, anisotropic nature of clouds; convective clouds: cumulus and stratocumulus, turbulence in the atmospheric boundary layer, then stratocumulus and finally cumulus; measurements and analysis methods, what we have learned fromairborne turbulence measurements and remote sensing in clouds in the last 20 years.

Annette Miltenberger - Johannes Gutenberg University Mainz, Germany
5 lectures on: analysis of cloud microphysics parametrisation uncertainty in numerical weather; Lagrangian analysis of cloud microphysics; the impact of clouds on short- to medium- range predictability (with a focus on deep convection and warm conveyor belts).

Daniela Tordella - Politecnico di Torino, Italy
5 lectures on: cloud-clear air interfaces: intermittency, stratification effects, water droplet population dynamics, turbulence and supersaturation fluctuations and relevant temporal micro-scales, innovative mini radiosondes for Lagrangian measurement of temperature, pressure, humidity fluctuations inside clouds.