ICE AND SNOW MECHANICS DAY

Room R2, DICAM, Via Mesiano 77, Trento, 25 November 2025.

Also online and recorded event.
Link Zoom: https://unitn.zoom.us/j/89347595207?pwd=doiU0VSiiMnbgTakj4ndrRLhWd6m7n.1
ID: 89347595207; PW: 467113

9.00 Welcome

9.15 Introduction of Frameglow project, Nicola M. Pugno, with Federico Bosia (Politecnico di Torino)

9.30 Gianmarco Vallero, Development and FE implementation of a visco-plastic constitutive model for snow

Snow exhibits complex mechanical behavior arising from its porous structure, temperature sensitivity, and rate-dependent deformation. This contribution presents a novel elasto-visco-plastic constitutive model for snow, formulated within the framework of continuum mechanics. The model introduces new yield and potential functions, and incorporates key physical mechanisms such as viscosity, sintering, and mechanical degradation through time- and deformation-dependent internal variables. It is numerically implemented in the Abaqus/Standard finite element code via a fully implicit backward Euler integration scheme and Powell's hybrid method for system linearization. The model demonstrates strong predictive capability across various experimental conditions, accurately reproducing confined and unconfined compression, creep, and relaxation tests. In addition, it effectively captures critical deformation patterns in snow, notably the initiation and propagation of compaction bands, that are localized compressive regions governed by the material's strain-rate sensitivity.

Gianmarco Vallero is a building engineer, registered in the Board of Engineers of the Province of Turin, and currently a post-doctoral research fellow in the scientific disciplinary sector CEAR-06/A – Structural Mechanics (Scienza delle Costruzioni) at the Department of Structural, Geotechnical and Building Engineering of the Politecnico di Torino. After earning his Master's Degree in Building Engineering in 2017 from the Politecnico di Torino, he obtained the Ph.D. in Civil and Environmental Engineering from the same University in 2024, with a thesis entitled "A visco-plastic constitutive model for snow. Theoretical basis and numerical implementation". His research activity focuses on snow mechanics, constitutive modeling of visco-plastic materials, numerical modeling, and computational mechanics. He is also involved in structural vulnerability and risk analyses for structures and infrastructures affected by landslide and avalanche phenomena. He teaches within the courses of Structural Mechanics and Theory of Structures at the Politecnico di Torino.

10.30 Edoardo Raparelli, Applying artificial neural networks to satellite and in situ data to produce sub-kilometer meteorological forcing for snow cover properties simulation

The seasonal snowpack in mountainous terrain represents a critical water resource and serves as a key indicator of climate change. The ability to accurately model its evolution in complex terrain is challenging but also fundamental for hydrological applications and natural hazard assessment. Indeed, standard snowpack simulations, driven by coarse-resolution meteorological model outputs, often fail to capture the high spatial variability of snow cover properties at the local and slope scales. This study presents an integrated framework to address this limitation. Initially, a modeling chain has been developed by coupling a regional numerical weather prediction model with a land surface snow cover model to simulate key snowpack physical properties. To improve the accuracy of this approach, we explore the use of Artificial Intelligence to downscale and interpolate the fundamental near-surface meteorological variables. This method enhances the resolution of the meteorological forcing for the snowpack model, enabling more realistic simulations of snow-atmosphere interactions at a sub-kilometer scale. The entire framework is calibrated and rigorously validated using a comprehensive, long-term dataset of in-situ observations, which includes both automatic weather station data and manual snow pit measurements. The integration of numerical modeling, AI-based data enhancement, and robust ground-truth validation provides a powerful and replicable methodology for high-resolution snowpack estimation. This work demonstrates that such an integrated approach can significantly improve the reliability of snowpack characterization in complex mountain terrain, with important implications for water resource management and risk mitigation.

Edoardo Raparelli, born in L'Aquila in 1990, earned his Bachelor's degree in Physics from the University of L'Aquila in 2015. He continued his studies by obtaining a Master's degree in "Atmospheric and Cryospheric Sciences" in 2018 from the University of Innsbruck (ACINN), Austria, carrying out his thesis work at the WSL Institute for Snow and Avalanche Research (SLF) in Davos, Switzerland. Subsequently, he earned his PhD in "Information and Communication Technologies" at the Department of Information, Electronics and Telecommunications Engineering of Sapienza University of Rome, which he completed in 2022. During his PhD, his research focused on studying the physical properties of the snowpack in the Central Apennines by integrating three complementary approaches: numerical modeling, satellite remote sensing techniques, and in-situ measurement campaigns. After completing his PhD, he continued his academic career at Sapienza with a postdoctoral position, where he focused on advancing remote sensing techniques for the study of physical snow cover properties. Since 2023, he has a postdoctoral position at the Department of Physical and Chemical Sciences at the University of L'Aquila, where his work focuses on the numerical modeling of the snowpack properties. He is the author of several publications in international scientific journals and regularly participates in major conferences in his field. He also actively takes part in important research projects and field campaigns dedicated to the study of the Earth's cryosphere. Personal website: https://edrap.github.io

11.30 Bastian Bergfeld, Fracture Mechanics of Snow

Early approaches to assess snowpack instability relied on shear strength–stress ratios, but these indices failed to predict avalanches reliably because they neglected crack propagation within weak layers. Pioneering work by McClung in the late 1970s laid the foundation for applying fracture mechanics to avalanche release. This has fundamentally reshaped our understanding of avalanche release by demonstrating that locally initiated cracks can propagate over large distances even when average stress remains below weak-layer strength. A further milestone was the introduction of the Propagation Saw Test, which enabled direct field observation of the onset and propagation of cracks, including weak-layer collapse and unexpectedly low initial crack speeds (~20 m s^{-1}). Today, avalanche release is widely recognized as a fracture process, with different modes—shear cracks, mixed-mode anticracks, and supershear cracks—playing a central role. This seminar reviews the development of fracture mechanical concepts in snow science over the past twenty years, with particular emphasis on experimental evidence, field and laboratory test methods, and their implications for estimating mechanical properties. I will also present insights from my recent research, focusing on the quantification of fracture properties and the characterization of fracture modes in snow and avalanches.

Bergfeld - Snow Science Solutions, Founder, Applications and solutions for everything snow-related — from micro-mechanics to large-scale cracking and avalanching.

12.30 Igor Chiambretti, AINEVA open data

The Italian regional/provincial avalanche warning services affiliated with AINEVA collect, through their network of observers, an average of 1,200-1,500 snowpack profiles per season in the Italian Alps and the Marche Apennines, which are associated with stability tests (ECT, RB, PST) and other parameters helpful in defining the instability/stability of the snowpack. This database can be consulted, including for research purposes, through a dedicated platform with webGIS functionality (currently under development) or via API queries. The services themselves have repeatedly produced research applied to avalanche forecasting and monitoring, analysing the characteristics of critical layers and fracture types for both spontaneous and accident-triggered avalanches, mainly for sports and recreational users.

Igor Chiambretti is a chartered geologist, registered on the Board of Italian Geologists since 2001. Since 2009, he has held the position of Technical Director of AINEVA, the Association which coordinates the activities of Italian regional and provincial avalanche warning services, organises professional courses in the sector, and acts as a centre of expertise for the National Civil Protection Department. He is also a member of the technical steering committee of EAWS (European Avalanche Warning Services) and of several national and international working groups (EAWS) on avalanches. He has supported the public prosecutor's investigation into the Hotel Rigopiano disaster. He holds a BSc and a PhD in sedimentology of gravity flows (Univ. of Turin and Padua – Italy) and has previously worked as a consultant in geological mapping and georesource exploration for several companies (Chevron UK, Shell Int. Exp. & Production). He has been a national avalanche expert and regional ski touring and telemark instructor for the Italian Alpine Club since 1996 and 2006, respectively.

13:30-14.30 Lunch (Orostube)

15 Marin Carlo, Impact of Liquid Water Content in Snow on SAR Backscattering

Accurate monitoring of snowmelt processes is essential for water-resource management in mountainous regions and for forecasting snow-related hazards such as wet-snow avalanches. This seminar will explore the snowpack energy balance and the key phases of melting i.e., warming, ripening, and output, which govern the snowmelt. Within this framework, particular emphasis will be placed on the liquid water content (LWC) of snow, a fundamental parameter controlling energy exchange, metamorphism, and the electromagnetic properties that influence radar backscattering during melt. Measuring LWC remains a major challenge due to the transient nature of melt dynamics and the strong spatial variability within the snowpack. The seminar will review the principal techniques developed to quantify LWC—from melting and freezing calorimeters to dielectric methods—and will discuss their field applications and relevance for interpreting Synthetic Aperture Radar (SAR) observations of wet snow.

Dr. Carlo Marin received his M.Sc. (summa cum laude) in Telecommunication Engineering and his Ph.D. in Remote Sensing from the University of Trento, Italy, in 2011 and 2015, respectively. He is currently the Group Leader of the Mountain Cryosphere (MC) Group at the Institute for Earth Observation, Eurac Research. He and his team applies advanced remote sensing techniques to monitor and understand mountain snow and ice processes, with a focus on: (i) the interaction of radar signals with the snowpack, particularly during melt periods; (ii) the development of machine learning models that integrate remote sensing data, ground observations, and physically based snow models to improve snow water equivalent (SWE) estimation; and (iii) the design of innovative in situ instruments for snow property measurements.

16 Riccardo Parin, Icing dynamics in aeronautical applications: experiments, modeling and ice protection strategies

Atmospheric icing represents one of the most critical environmental hazards for flight safety and system performance in aeronautics and beyond. Ice accretion on rotating components such as UAV propellers induces strong aerodynamic penalties, vibrations and potential loss of control, making this phenomenon a key driver of experimental and numerical research over the recent years. Starting from the development and commissioning of a dedicated icing wind tunnel (IWT), experimental campaigns were carried out at terraXcube to investigate ice accretion on UAV propellers and to test innovative Passive Ice Protection Systems (PIPSs) designed to extend the time of flight (ToF) in adverse weather conditions. The last part of the talk focuses on data modeling, where ice accretion is analyzed on simplified geometries using the established numerical tool FENSAP-ICE.

Dr. Riccardo Parin holds a PhD in Industrial Engineering from the University of Padova, where he specialized in thermodynamics and two-phase heat transfer processes. After a postdoctoral position at the University of Sydney, he joined terraXcube, the extreme environment simulator of Eurac Research, where he currently leads the research group. His research applies thermodynamic principles to the study of interactions between extreme environments and complex systems, focusing on both robotic platforms and human psycho-physiology. Combining experimental campaigns and numerical modeling, his work aims to improve the resilience, efficiency and safety of human and robotic operations in harsh climatic conditions.

Online presentations

17 Jacopo Borsotti, online, Bridging the Gap Between Theoretical Models and Operational Avalanche Forecasting

The transition from theoretical to operational snow avalanche forecasting presents several scientific and practical challenges. Although theoretical models, which are usually validated through field experiments and numerical simulations, provide a robust framework for understanding avalanche release mechanisms, their direct application in operational avalanche forecasting is usually limited by model (mathematical and computational) complexity and the difficulty of measuring key input variables. This seminar examines the differences between the approaches of avalanche forecasters and snow scientists, and explores the main issues arising when moving from theory to operational avalanche forecasting. Particular attention will be given to recently developed skier–snowpack stability models designed to bridge this gap. These models, which are currently used operationally by different avalanche centers, integrate techniques from various scientific disciplines to better assess avalanche triggering likelihood and potential avalanche size. The seminar will conclude by presenting some open problems in operational avalanche forecasting, highlighting the importance of interdisciplinary collaborations to develop effective solutions.

Phd Student in Resource and Environmental Management, Simon Fraser University, Vancouver

18 David McClung, online, Alpine snow properties relevant to dry snow slab avalanche release

Dry snow slab avalanches initiate from propagating shear fractures within a relatively thin weak layer under a thicker cohesive slab. In shear, alpine snow is a pressure sensitive, dilatant strain-softening material with significant rate and temperature dependence. In avalanche release, the material is highly porous and it is typically at 95% of the melt temperature on the Kelvin scale.
It follows both quasi-brittle and quantized fracture mechanics. In this presentation, I shall outline the important physical properties both from laboratory and field measurements relevant to both dry slab avalanche initiation and dynamic fracture mechanics related to avalanche release.

Bio: Senior Research Officer, National Research Council of Canada: 1979 – 1991. Professor, Departments of Civil Engineering and Geography: 1991 – present (now Emeritus), University of British Columbia.

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https://cordis.europa.eu/project/id/101201568