



ESF funded Micro-DICE Workshop on

## **Ice microstructures and micro-deformation mechanisms**

EGU General Assembly, Vienna, 27 April - 02 May 2014

Convenor: Peter Sammonds

### **1. Workshop Summary**

The ESF Micro-DICE workshop on “Ice microstructures and micro-deformation mechanisms” was held at the European Geoscience Union General Assembly in Vienna, Austria from 27 April - 02 May 2014, organized by Professor Peter Sammonds. Over 100 research scientists from the UK, Germany, France, Belgium, Australia, Spain, USA, New Zealand, Norway, Denmark, Japan, the Netherlands and Switzerland attended the session. There were 6 oral and 9 poster presentations with two of the oral presentations and more than half the poster presentations to be made by early career scientists and invited speeches being given by Dr Ilka Weikusat (Alfred Wegener Institute, Germany) and Professor Jean - Louis Tison (Laboratoire de Glaciologie, ULB, Belgium).

The aims of the workshop were to improve the training and mobility of early career scientists and researchers and to facilitate the exchange of resources and personnel. From a research aspect, the workshop aimed to improve analysis and modelling of microstructure evolution and micro-deformation of the polar ice caps and sea ice cover through a better understanding of ice physical processes.

This workshop, with both oral and poster presentations, highlighted the recent advances and provide a platform for discussion of new observations, analyses, modelling and interpretation of snow and ice microstructures and micro-deformation mechanisms.

## 2. Scientific Content

The Influence of the pre-existing microstructure on the mechanical properties of marine ice during compression experiments was discussed by Jean-Louis Tyson. Marine ice plays an important role in the stabilisation of ice shelves so understanding its micro-physical properties is important.

Recrystallization of polar ice and its representation in diagram was presented by Ilka Weikusat. The related issue of examining crystal fabric development in ice using cryo EBSD, deformation experiments and the link to en-glacial reflectivity was presented by Matthew Vaughan. Further research using the EBSD observational technique of dynamic recrystallization mechanisms in ice was presented by . Maurine Montagnat. Application of composite flow laws to grain size distributions derived from polar ice cores was discussed by Tobias Binder. Properties of grain boundary networks in the NEEM ice core as analyzed by combined transmission and reflection optical microscopy was also presented by Tobias Binder. While the application of modern techniques of FFT simulation of dynamic recrystallization in polar ice was discussed by Maria-Gema Llorens. These, taken together, represent core themes of the Micro-DICE programme and the application to polar ice caps. The presentation illustrated the progress that has been made since the inception of Micro-DICE.

The application to large ice bodies was addressing in a presentation by Dorte Dahl-Jensen on disturbed basal ice seen in radio echo images coincide with zones of big interlocking ice crystals, linking the micro-scale physics to ice sheet processes.

Moving to applications in planetary science, the effect of rock fraction on the flow law of debris-laden ice at high confining pressures was presented by Ceri Middleton. However, research in this area is still in its infancy and the prevention set out what was needed to be done to answer some of the big questions about icy planet evolution.

Snow was addressed in two presentations with a comparison of fabric analysis of snow samples by computer-Integrated polarization microscopy and automatic ice texture analyser by Sabine Leisinger.

Micro-deformation processes in fracture and friction of ice were addressed in two presentations. The critical fracture toughness of Antarctic ice core was presented by Julia Christmann. The micro-mechanics of high speed Ice friction, at speeds of interest in winter sports was discussed by Alexandra Seymour-Pierce.

Two presentations addressed sea ice micro physics. Aleksey Marchenko discussed the influence of brine filtration on thermal expansion of saline ice in a new model which reconciles some past misunderstanding. Peter Sammonds presented a broad overview of how micro-scale sea ice processes can be incorporated in Arctic Ocean dynamic models.

### 3. Assessment and Impact of the Results

Understanding the dynamic behaviour of ice in glaciers, polar ice caps, the atmosphere and sea ice, especially in a time of changing climate, and in the icy planets, is a major challenge. The grain and sub-grain scale microstructure are crucial state variables that link atomic-scale processes to the macroscopic behaviour of ice, including its rheology and transport properties. Improved analysis, modelling and interpretation of ice microstructures are therefore imperative for a better understanding of the flow and evolution of large ice bodies, from polar ice caps, mountain glaciers, sea ice to planetary ice. In addition, linking microstructures to geophysical signals such as radar imaging and seismic profiling will enable mapping of microstructures in 3 and 4 dimensions.

From a research point of view, aim of the session is a better understanding of the deformation and evolution of snow and ice, from polar ice caps, mountain glaciers, sea ice to planetary ice and those interested in linking microstructures to geophysical profiles and sharing knowledge in cognoscent disciplines such as structural geology, planetary science, atmospheric physics and oceanography.

### 4. Programme of the Workshop (including speakers)

EGU CR5.2 Programme: “Ice microstructures and micro-deformation mechanisms”

Oral presentations

Wednesday, 30 Apr 10:30-12:00,

Chairpersons: Martin Schneebeli, Martyn Drury

6 x 15 minute presentations, with 2 invited speakers.

- Influence of the pre-existing microstructure on the mechanical properties of marine ice during compression experiments (invited)  
Jean-Louis Tison, Marie Dierckx, Mark Peternell, and Christian Schroeder
- Recrystallization Diagram for Polar Ice (invited)  
Ilka Weikusat, Nobuhiko Azuma, and Sérgio H. Faria
- Examining Crystal Fabric Development in Ice: Cryo EBSD, Deformation Experiments and the Link to En-glacial Reflectivity.  
Matthew Vaughan,  
David Prior, Meike Seidemann, Andrew Gorman, Kat Lilly, Pat Langhorne, Richard Easingwood, Narayana Golding, and Bill Durham
- EBSD observations of dynamic recrystallization mechanisms in ice.  
Maurine Montagnat, Thomas Chauve, Fabrice Barou, Benoît Beausir, Claude Fressengeas, and Andrea Tommasi
- The effect of rock fraction on the flow law of debris-laden ice at high confining pressures.

A. Middleton, Peter M. Grindrod, Peter R. Sammonds, A. Dominic Fortes, and Ian G. Wood

- Brittle fracture in dry snow: Laboratory experiments and numerical simulations.  
Bernadette Köchle and Martin Schneebeli

#### Poster presentations

Display Time: Wednesday, 30 Apr, 08:00-19:30

Attendance Time: Wednesday, 30 Apr 17:30-19:00

Chairpersons: Maurine Montagnat, Ceri Middleton

9 poster presentations

- Comparison of fabric analysis of snow samples by Computer-Integrated Polarization Microscopy and Automatic Ice Texture Analyzer.  
Sabine Leisinger, Maurine Montagnat, Renée Heilbronner, and Martin Schneebeli
- Application of composite flow laws to grain size distributions derived from polar ice cores. Tobias  
Binder, Hans de Bresser, Daniela Jansen, Ilka Weikusat, Christoph Garbe, and Sepp Kipfstuhl
- Critical Fracture Toughness Measurements of an Antarctic Ice Core.  
Julia Christmann, Ralf Müller, Kyle Webber, Daniel Isaia, Florian Schader, Sepp Kipfstuhl, Johannes Freitag, and Angelika Humbert
- High Speed Ice Friction.  
Alexandra Seymour-Pierce, Peter Sammonds, and Ben Lishman
- Influence of brine filtration on thermal expansion of saline ice.  
Aleksy Marchenko and Ben Lishman
- Disturbed basal ice seen in radio echo images coincide with zones of big interlocking ice crystals.  
Dorthe Dahl-Jensen, Sivaprasad Gogineni, and Christian Panton
- Micro-scale sea ice processes in Arctic Ocean dynamic.  
Peter Sammonds
- Properties of grain boundary networks in the NEEM ice core analyzed by combined transmission and reflection optical microscopy.  
Tobias Binder, Ilka Weikusat, Christoph Garbe, Anders Svensson, and Sepp Kipfstuhl
- FFT simulation of dynamic recrystallization in polar ice.  
Maria-Gema Llorens, Albert Griera, Ilka Weikusat, Paul D. Bons, Jens Roessiger, Lynn Evans, and Ricardo Lebensohn

## Participants (convenor, presenters and co-authors):

Peter Sammonds	UCL	UK
Jean-Louis Tison	Université Libre de Bruxelles	Belgium
Ilka Weikusat	Alfred Wegener Institute	Germany
Alexandra Seymour-Pierce	UCL	UK
Ceri Middleton	Université Libre de Bruxelles	Belgium
Ben Lishman	UCL	UK
Aleksey Marchenko	UNIS	Norway
Marie Dierckx	Université Libre de Bruxelles	Belgium
Mark Peternell	Johannes Gutenberg University Mainz	Germany
Christian Schroeder	University of Stirling	UK
Nobuhiko Azuma	Nagaoka University of Technology	Japan
Sérgio H. Faria	Basque Centre for Climate Change	Spain
Matthew Vaughan	University of Otago	New Zealand
Maurine Montagnat	University of Grenoble	France
Thomas Chauve	University of Grenoble	France
Fabrice Barou	CNRS/Univ. Montpellier II	France
Benoît Beausir	University of Lorraine	France
Claude Fressengeas	University of Lorraine	France
Andrea Tommasi	CNRS/Univ. Montpellier II	France
Peter M. Grindrod	Birkbeck University of London	UK
Dominic Fortes	UCL	UK
Martin Schneebeli	WSL Institute for Snow and Avalanche Research	Switzerland
Sabine Leisinger	WSL Institute for Snow and Avalanche Research	Switzerland
Martin Schneebeli	WSL Institute for Snow and Avalanche Research	Switzerland
Tobias Binder	University of Heidelberg	Germany
Hans de Bresser	Utrecht University	Netherlands
Christoph Garbe	University of Heidelberg	Germany
Julia Christmann	TU Kaiserslautern	Germany
Ralf Müller	TU Kaiserslautern	Germany
Kyle Webber	TU Darmstadt	Germany
Daniel Isaia	TU Darmstadt	Germany
Florian Schader	TU Darmstadt	Germany
Angelika Humbert	Alfred Wegener Institute	Germany
Dorthe Dahl-Jensen	University of Copenhagen	Denmark
Christian Panton	University of Copenhagen	Denmark
Anders Svensson	University of Copenhagen	Denmark
Maria-Gema Llorens	University of Tübingen	Germany
Paul D. Bons	University of Tübingen	Germany
Jens Roessiger	University of Tübingen	Germany