REPORT OF THE IASC WORKSHOP ON CRYOSPHERIC EXTREMES

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Background

Extreme weather events commonly encompass phenomena such as heat waves, droughts, floods and storms. In cold regions, these are augmented with snow and sea-ice related extreme events, usually triggered by anomalous atmospheric or oceanic conditions.

Although extreme events are a core climate research focus, cryospheric extremes have not received much attention yet. The overarching aim of the workshop was to review our understanding of cryospheric extreme events in the past, present and future, and to identify research needs.

Topics of interest included

- Observing cryospheric extremes (CE) and their precursors
- Modelling requirements for CE
- Producing and verifying forecasts of CE
- CE and climate change
- Relevance of CE for society/users

The workshop was hosted by the Finnish Meteorological Institute. Around 50 participants from 11 countries were attending to the workshop. We discussed, ice and snow extremes in marine, fluvial and terrestrial settings, using meteorological, hydrological, glaciological, social, engineering and medical perspectives .

The planning group of the workshop included following experts

Jari Haapala, Finnish Meteorological Institute, Finland
Carolina Gabarró Prats, Institut de Ciències del Mar – CSIC, Spain
Hugues Goosse, Earth and Life Institute-Université de Louvain, Belgium
Elizabeth Hunke, Los Alamos National Laboratory, USA
Veijo Pohjola, University of Uppsala, Sweden
Steffen Olsen, Danish Meteorological Institute, Denmark
Steffen Tietsche, European Centre for Medium-Range Weather Forecasts,UK

Scientific highlights

The winter 2018 was exceptionally cold and snowy in many parts of the Europe. This unexpected “cryospheric extreme event” was named the “Beast from the East” in a public media. It also inspired many speakers of the workshop, in particular, keynote speakers Timo Vihma and Daniela Domeisen, who gave outstanding overviews on the impact of Arctic climate change on mid-latitudes weather and predictability of weather events from weekly to seasonal time scales, respectively.

Secondly, several speakers (Jouni Pulliainen, Eero Rinne, Nick Hughes) showed new methods to detect and monitor snow and sea ice parameters from space. These methods include detection of sea ice ridges from SAR images, determining risk index outcome for ice navigating vessels from radar altimeter data, sea ice edge monitoring from optical and radar data as well as snow thickness from passive microwave radiometric sensors. Pulliainen discussed also on long term changes of snow thickness and, interestingly, the satellite based timeseries he presented indicated that the Northern Hemispheric snow cover was anomalous thick and extensive in winter 2018.

In order to link new scientific results to operational forecasting, Tim Henson provided an excellent review how the ECMWF forecasting system has been developed towards statistical calculation of probabilities of extreme events.

The workshop addressed also on impact of extreme events on human health. This topic was keynoted by Joan Ballester. In this excellent and widely interesting presentation, he presented several examples of weather related impacts on mortality, and showed a very novel analysis of daily mortality at European scale and it’s correlation to the cold spell in February 2018.

Outcomes from the group discussions

One afternoon of the workshop was dedicated on brainstorming discussion. Participants were grouped by themes (snow, sea ice, rivers) and they were instructed to discuss on following topics

1) What are "cryospheric extremes" in that theme?
2) How those can be observed, (tools, in-situ, remotely)?
3) What are our modelling capability in synoptic, seasonal and climate scales?
4) Will these extremes change in future?

Following tables summarized findings of the group discussions

Snow related extreme events

Type of extreme event	Economical/ societal impacts	How it is observed ?	Modelling capabilities	Impact of climate change on extremes
Synoptic-scale snowfall	Widespread disruption + losses.	Radar + manual / automated observations (official / social media)	Mostly very good (less good in marginal rain/snow situations)	Poleward shift ?
Convective snowfall (sea-effect or lake-effect)	Localised extreme disruption + losses	Radar + manual / automated observations (official / social media)	Very poor in global models / convection resolving models much better	Not so clear
Blizzards (falling snow + wind)	Disruption + danger to life + isolated communities	manual / automated observations (official / social media)	Mostly good (but lifting of snow challenging)	Mostly reducing ?
Drifting snow (not falling)	Long-term transport network disruption	manual / automated observations (official / social media)	OK (depends on temperature / snow density / difficulties of wind speed prediction)	Mostly reducing ?
Visibility problems due to snow & drifting snow	Transient transport network disruption	manual / automated observations (official)	Relatively poor (height of lifted snow is one issue)	Similar ?
Snow depth / snow water equivalent	Collapsing roofs / trees / clearance capacity reached / environmental impacts of dumping dirty snow / winter sport disruption	Manual + automated (depth) + satellite	Quite challenging (snow model dependant)	Mostly reducing, but some increases in cold climates (some unknowns also)
Snow cover duration	Agricultural impacts / winter road maintenance costs	Manual + automated / satellite	Poor, seasonal forecasting has low skill	Mostly reducing
Out-of-season snow	Agriculture / tree damage / more pronounced travel disruption	manual / automated observations (official / social media)	Good generally (but marginal situations more challenging)	Mostly reducing (but new baseline!)
Heavy wet snow	Tree / infrastructure / power line damage	manual / automated observations	Good generally (but marginal situations more challenging)	Poleward shift?
Avalanches	Extreme localised danger to life and property. Infrastructure damage and disruption. Isolated communities.	Visual / social media (satellite?)	Risk can be modelled, pinpointing almost impossible	Generally reducing but complex

Re-freezing of rain and meltwater (on snow)	Foraging impacted – reindeer + wildlife?	Community-based	Good (but within snowpack more challenging)	Generally increasing (probably)
Freezing rain	Paralisation of infrastructure + severe damage (e.g. power lines)	manual / automated observations (official / social media)	Quite good, but always marginal siuations. Also model dependant.	Poleward shift of events
Icy roads/paths	Transport disruption / injuries	Road sensors / manual	Generally quite good, but marginal situations very common	Poleward shift of events
Fast snowmelt	Floods	Manual + automated (depth) + satellite	Good for synoptic timescales (flood aspects more challenging)	Not clear!
Icicles	Extreme danger / property damage	Visual	No known forecast modelling (but process understood)	Not clear
Low air temperatures	Heating costs / burst pipes / vehicle breakdown / mortality	Mostly automated sensors	Quite challenging (model and location dependant)	Decreasing
Dirty snow	Health + environment	Visual	Generally not modelled	Not clear
Lack of snow	Wildlife / winter sports / excess ground freezing / summer water supply / reduced hydropower	Manual + automated (depth) + satellite	Very poor at seasonal timescales	Increasing

Knowledge gaps and research needs of snow related extreme events

Type of extreme event	Knowledge gaps	Research needs
Synoptic-scale snowfall	Some aspects of microphysics. Radar detection uncertainties.	More Obs / parametrisation development
Convective snowfall (sea-effect or lake-effect)	Some aspects of microphysics /convection /entraintment. Radar detection uncertainties.	More Obs / convective parametrisation development
Blizzards (falling snow + wind)	How to measure falling snow	Instrument development
Drifting snow (not falling)	How to distinguish from falling snow. Details of lifting thresholds. Correct modelling of snowpack.	Observations and paramnetrisation development
Visibility problems due to snow & drifting snow	Details of lifting thresholds and lifting heights and particle size.	Detailed observations / parametrisation to match
Snow depth / snow water equivalent	Correct modelling of snowpack (how many levels?).	As KG
Snow cover duration	Seasonal forecast difficulties.	Big challenge!
Out-of-season snow	Nothing in particular	-
Heavy wet snow	(Finely balanced therefore challenging)	-
Avalanches	Friction aspects within snowpack – different layers. Terrain complexities.	Better local snowfall and wind forecasts. Experimental research on friction properties. ??

Re-freezing of rain and meltwater (on snow)	Path of liquid water within snowpack	As KG – process model improvement for snowpack behaviour
Freezing rain	Boundary between ice pellets and freezing rain complex.	Observation issues – automatic quality poor. Microphysics studies. Case studies.
Icy roads/paths	Minimal	Investigate frictional properties of roads in different states?
Fast snowmelt	Minimal	-
Icicles	Minimal	New topic!
Low air temperatures	Observation issues. Physics of stable boundary layers.	Observations with high vertical resolution in and above snowpack and across different terrains.
Dirty snow	Rare, so many	Case studies
Lack of snow	-	-

Sea ice related extreme events

Type of extreme event	Economical/societal impacts Know hazards ?	How it is observed	Modelling capabilities	Impact of climate change
Rapid ice edge movement	- some cases from North of Svalbard - small for shipping and fishery - potential hazard for off-shore drilling operations and cruise shipping	- satellites - ship & coastal radar	- high resolution forecasting models are available, validation ?	Hypothesis is that the ice pack will be thinner and more mobile → ice edge will experience larger variability
Ice pressure/compression	- Baltic 2010, 2011 - stated as the only effect to besetting of the most powerful vessels	- ship observations - stress buoys - satellites could provide indirect information	- preliminary - not operationally use	Open
Ice formation in a region which is typically ice free (North Sea coast, Azov Sea, South of Caspian Sea).	- Prevents navigation of non-ice class ships, no fishing activities - need investments on ice breaking	- satellites	- Reasonable well in weekly time scale	Open, depends of region

Unexpected break-up of fast ice	- seasonal ice roads can be utilized - Threat to indigenous people	- satellites after the event	Poor, only few papers available	Fast ice regions are becoming more vulnerable to break
Icebergs in an area where those aren't expected and inside the pack ice	- Titanic - White Rose near miss	- satellites - aircraft - coastal and ship radars	- fairly poor - initial condition and local meteorological and ocean forcing difficult to obtain	- more icebergs

"Freak pressure ridges", floeberg and MYI within the FYI pack	- cause damages on the ship and off-shore structures - increase risk in ice navigation	- difficult to detect even from the hires- SAR images - visual observations from ships and aircrafts and drones - big MYI can be detected by satellites	- after detections, tracking and nowcasting should be feasible	Open
Ice river	- rare event	- visual observations from ships	- none	Open

Icing, sea spray	- 1980's severe events occurred in the Baltic - potential hazards in Barents/Kara sea when winter traffic increased	- in-situ	- forecasting models available	Reduced at least in the Baltic.

Knowledge gaps and research needs of sea ice extremes

Type of extreme event	Knowledge gaps	Research needs
Iceberg	- climatology - modelling of breaking of iceberg and acting stresses due to the shape of the iceberg - iceberg/waves, iceberg/pack ice interaction	- detection from satellites - improved drift modelling - more in-situ data
Ice pressure/compression	- horizontal variability of stress field - effect of floe size and g(h) on ice pressure - Effect of material strength	- enhance buoy observations - lab experiment - development of satellite retrieval methods - high resolution models
Ice formation in a region which is typically ice free	- Will cold Arctic outbreaks be more common or seldom in future ? - Sea ice climatology in changing climate	- improve monthly and seasonal forecasting systems - Understanding weather regimes and impact of Arctic amplification on mid-latitudes weather

River ice related extreme events

Type of extreme event	Economical/societal impacts	How it is observed	Modelling capabilities	Impact of climate change
River Ice damming: Unprecedented maxima of an annual occurring phenomenon: freeze up, dam up, break up	Hydropower, drinking water, flooding events, ecosystem feedbacks, damage to infrastructure with break up, ice related flooding is not as predictable as open water flooding, some fatalities. Few studies reported and assessed scientifically	Remote sensing products, airborne observations, time lapse cameras, observers along the river, river stages, manual ice drillings.	Previous (calibrated) data driven models, now more hydraulic models driven by remote sensing (scenario driven analysis) Forward modeling of risks are used. Ice jam forecast are issued (statistical models). Fully thermodynamic models seldom used. To mitigate, blow up of jams, increase turbulence by divergence, tributaries to decrease frazil ice build up. Build sub aquaeous dams to stop ice floes entering down stream populated areas.	Motion of damage upstream, where damage control awareness may not be optimal.

Knowledge gaps in river ice extreme events

Quantification of ice volumes, lack of observational data, impacts of climate change, how will extreme events develop in a warmer wetter world – issue for forward hydrological models
Difficult to make rating curve sin hydro models for frozen systems.

Agenda

IASC Workshop on
Knowledge Gaps of Cryospheric Extremes
Finnish Meteorological Institute, Helsinki Finland
25th - 27th April, 2018

Wednesday 25th April

9.00 - 10.00 registration, coffee

10.00 Opening words by Director Sami Niemelä (FMI)

10.15 Goals of the workshop, Jari Haapala

10.30 - 12.45 Session 1: <u>Observing cryospheric extremes (CE) and their precursors</u>
Chair : Jari Haapala

10:30 Keynote: Timo Vihma, (FMI)
Impact of Arctic changes on extreme weather in mid-latitudes

11:15: Yang, Shuting (Danish Meteorological Institute)
Arctic sea ice loss and extreme cold winters in Europe: revisited

11:45: Graham, Robert M. (Norwegian Polar Institute)
Legacy of extreme winter storms in the Arctic Ocean.

12:15: Meinander, Outi (FMI)
Snow–Dust Storm: Unique case study from Iceland, March 6–7, 2013.

12:45 -13:30 Lunch

Chair : Veijo Pohjola

13:30 : Rokaya, Prabin (Global Institute for Water Security, University of Saskatchewan) Changing patterns in ice-jam floods

14:00: Rinne,Eero (FMI)
Detecting Sea Ice Extremes from Satellites - Key Results of H2020 SPICES

14:30 Pulliainen, Jouni (FMI)
Extremes in hemispheric snow cover based on satellite data analysis

15:00-15:30 Coffee break

15:30 – 16.30 **Keynote speaker: Ballester, Joan (Barcelona Institute for Global Health) Human health and mortality in winter**

16:30 – 19:00 Poster session with refreshments
19:00 – 21:00 Sentinel-3B launch party

Thursday 26th April

Session 2: Modelling, producing and verifying forecasts of CE
chair : Steffen Tietsche

9:00 **Keynote speaker: Hewson, Tim (ECMWF, UK)**
ECMWF Strategy for predicting Extreme Weather - the Challenges and the Solutions

9:45 Hughes, Nick (Norwegian Ice Service**)**
Monitoring and forecasting extreme movements in the sea ice edge and relevance to navigational safety

10:15- 10:45 Coffee break

10:45 Mikko Lensu (FMI)
Baltic ice conditions with extreme navigational difficulty

11:15 Jafarov Elchin (Los Alamos National Laboratory, USA)
2D Modeling of an arctic hillslope: Can open talik influence groundwater discharge?

11:45 Uusikivi, Jari (Finnish Environment Institute**)**
Forecasting frazil ice events in Finnish rivers.

12:15 -13:30 Lunch

13:30 – 17:30 Group discussion and wrap-up

Groups :
a) snow, b) sea ice, c) glaciers and d) permafrost

Discussion topics :

1) What are "cryospheric extremes" in that field
2) How those can be observed, in-situ, satellite ?
3) What is our modelling capabilites in synoptic, seasonal and climate scales ?
4) Will these extremes change in future ?

17:30 – 22.00 Excursion to the ice breaker and dinner

Bus transportation from the FMI
Icebreaker : Arctic ltd, Laivastokatu 9, Helsinki (arctia.fi)
Dinner : Restaurant Wellamo, Laivastokatu 18, Helsinki (http://www.wellamo.fi/)

Friday 27th April

Session 3: CE and climate change

Chair : Robert Graham

9:00 **Keynote speaker: Daniela Domeisen (Institut für Atmosphäre und Klima)**
Sub-seasonal to seasonal predictability of the Arctic

9:45 Pohjola veijo (Uppsala University)
Long time trends of snow pack stratigraphy in Abisko with respect to synoptic warming.

10:15 Das, Apurba (University of Saskatchewan, Canada)
Ice-jam flood delineation under future climatic scenarios along a northern river in Canada.

10:45- 11:15 Coffee break

11:15 Uotila, Petteri (University of Helsinki)
Atmospheric and oceanic conditions and the extremely low Bothnian Bay sea ice extent in 2014/2015

11:45 Khalid, Bushra **(**Institute of Information Technology, Islamabad, Pakistan**)**
Climatic and hydrological changes over the cryospheric Himalayan region for 21st century.

12:15 -13:30 Lunch

13:30 – 14:30 Concluding remarks and next steps

Posters

Boccolari, M (UNIMORE) and Parmiggiani Flavio (ISAC-CNR),
Regional extremes/anomalies in Sea Ice Area minimums/maximums in the Arctic, 1979- 2016.

Shevnina, Elena (Finnish Meteorological Institute)
Probabilistic projections of extreme floods in the Eurasian North.

Lazarev Anton (Lomonosov Moscow State University)
Evaluation of snow avalanches contribution into glacier accumulation

Luomaranta, Anna (Finnish Meteorological Institute)
Severe sea-effect snowfall on Finnish coast

Välisuo, Ilona (Finnish Meteorological Institute)
Interannual variability of atmospheric conditions and surface melt in Greenland in 2000-2014

Alsarraf Hussain (American University of Kuwait)
Using the CCSM4/ WRF Regional Climate Model to Simulate Future Summer time Wind Speed Changes over the Arabian peninsula by 2060

Lappalainen, Hanna. (University of Helsinki, FMI)
PEEX Program

Reija Ruuhela (FMI)
Temperature-related mortality in Finland