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RAIN PROJECT

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Severe winter events and forest fire danger in Europe with implication for critical infrastructure

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Overview

- Identification of phenomena and assessment of impact indicators for severe winter phenomena and forest fires

- Climatology of severe winter events
  - Probabilities over the European continent / past cases
  - Predictability of severe winter events
  - Connections between the distribution of severe winter events and NAO index

- Climatology of forest fire danger
  - Probabilities over the European continent / past cases

- Concluding remarks & ongoing work

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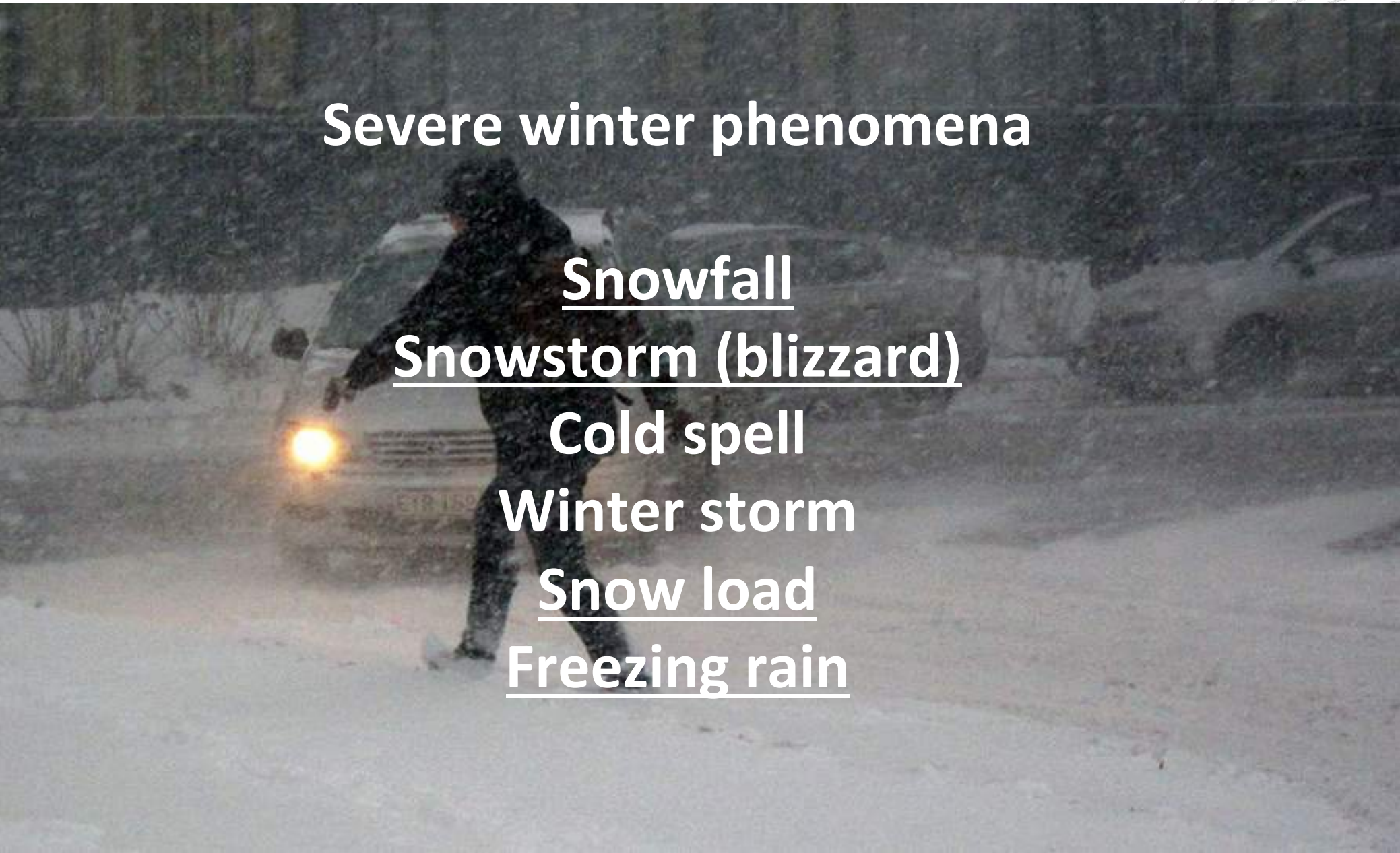

Severe winter phenomena

Snowfall

Snowstorm (blizzard)

Cold spell

Winter storm

Snow load

Freezing rain





Identification of severe weather phenomena

- **A review of severe winter phenomena and forest fires to identify their impacts and consequences on CI**

  - ✓ Previous impact studies: EWENT, MOWE-IT, EXWE
  - ✓ Literature review: over 100 research papers and reports
  - ✓ Media reports: 2000-2014
  - ✓ Surveys conducted with CI operators (28) and WS (18)
  - ✓ Past severe cases selected and analyzed
    - heavy snowfall: Helsinki, 17 March 2005
    - blizzard: South and Central Finland, 23-24 November 2008
    - heavy snow load: Central Finland, 30 Oct-1 Nov 2001
    - freezing rain: Slovenia, 31 Jan-3 Feb 2014
    - forest fires: Sweden, 31 July 2014 - 11 September 2014

↓

Assessed the impact threshold values for critical weather parameters

Selecting the impact thresholds

- The resilience of some infrastructure types vary across Europe
- The vulnerability of different CI varies, e.g. transportation ↔ power lines

→ use two thresholds for each parameters (when possible)

1st threshold: Some adverse impacts are expected, their severity depends on the resilience of the system, transportation is mainly affected

2nd threshold: The weather phenomena are so severe that it is virtually certain that some adverse impacts will occur, CI system is seriously impacted

PHENOMENA	THRESHOLDS	
	1st	2nd
Snowfall	Rs ≥ 6 cm/24h	Rs ≥ 25 cm/24h
Snow load	20 kg m-2	60 kg m-2
Freezing rain	RR ≥ 5 mm/24 h	RR ≥ 25 mm/24 h
Blizzard	Rs ≥ 10 cm/24h, Tmean ≤ 0 °C, WG ≥ 17 m/s	
Fire danger	FWI > 20	FWI > 45

for crown snow load

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Lat: 33 °N - 71°N
Lon: 11°W – 35 °E

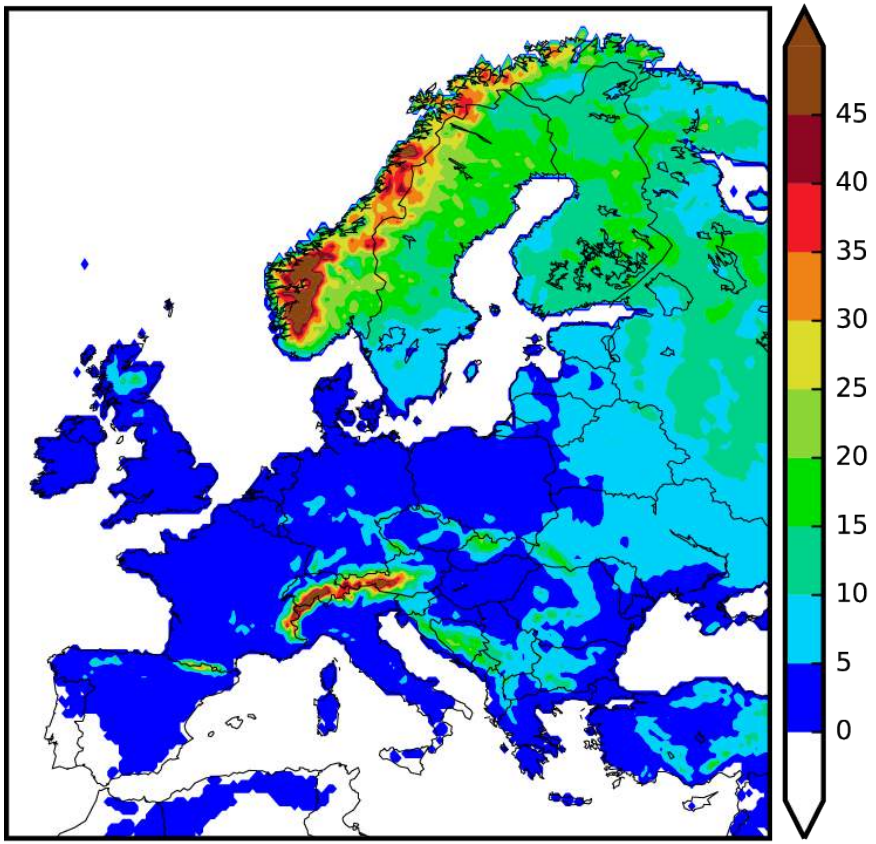
Climatology of severe winter events and wild fires, 1981-2010

Snowfall	Daily precipitation sum, mean T **E-OBS data-set (0.25°*0.25°)**	Annual exceedance probabilities/ frequencies calculated for each grid
Blizzard	6-hour wind gust, precipitation, temperature **ERA-Interim re-analysis (0.7°*0.7°) data-set**	
Crown snow load	6-hour temperature, relative humidity, wind speed, precipitation, cloudiness and solar radiation **ERA-Interim re-analysis (0.7°*0.7°) data-set**	• Crown snow load model (FMI) • Annual exceedance probabilities
Freezing rain	6-hour precipitation, surface temperature and pressure, relative humidity and temperature from 925, 850 and 700 hPa pressure level **ERA-Interim re-analysis (0.7°*0.7°) data-set**	• Identification of events • Validation with SYNOP stations (≈ 525) • Annual exceedance probabilities
Fire danger	Mid-day air temperature, wind speed, air humidity and 24h precipitation **ERA-Interim re-analysis (1.25°*1.25°) data-set**	• Danger assessment using the Canadian FWI • Exceedance probabilities: annual and summer season

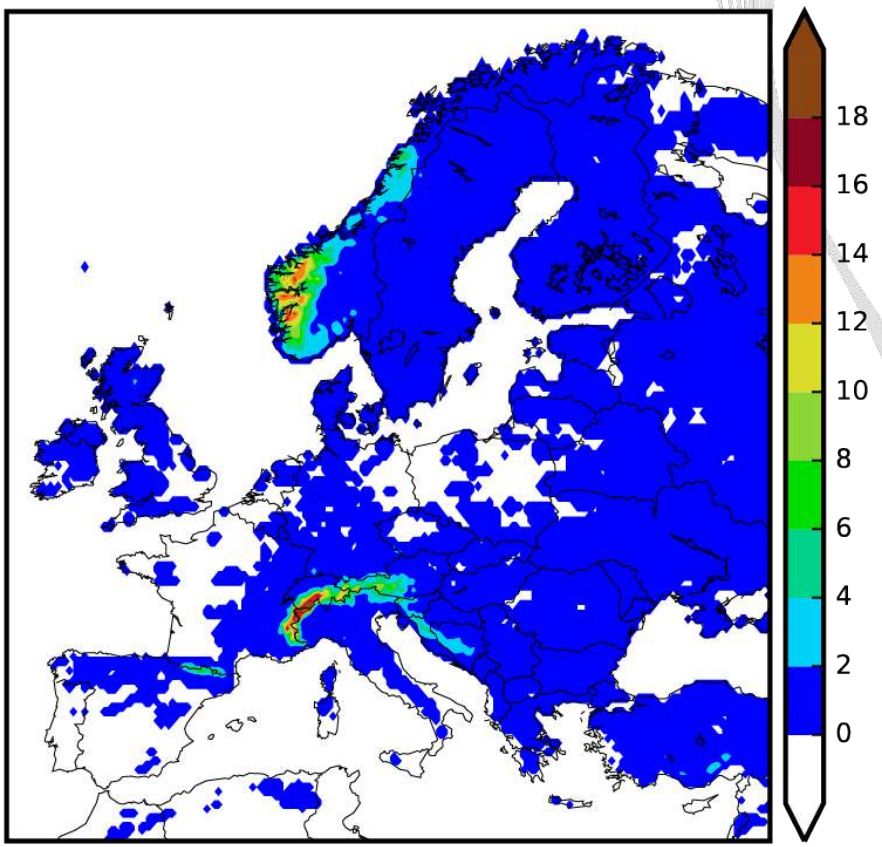
Climatology of severe winter events

Average number of days/year with snowfall exceeding

≥ 6 cm/24 h



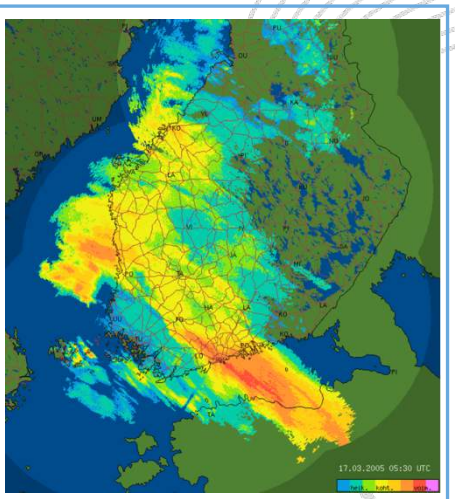
≥ 25 cm/ 24 h



Climatology of severe winter events

- Heavy snowfall during the morning rush hours after a cold night
- Reduced road grip and horizontal visibility, total snow accumulation ≈5 cm at 8.00 LT

Helsinki metropolitan area, March 17, 2005



Worst chain accident: 300 cars, with several human casualties, economical costs unknown

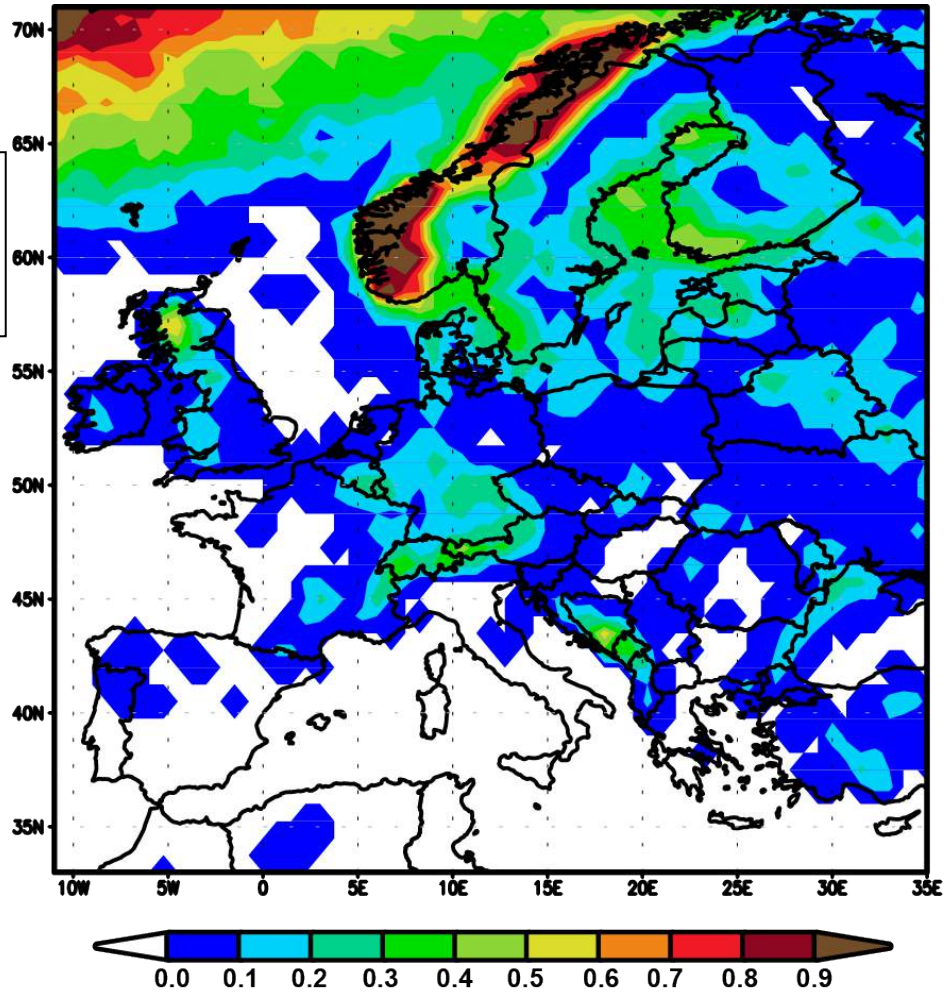
"Better medium- and long-range weather forecasting would assist transport providers and others in planning to deal with the effects of severe winter weather."

"…given the cost of transport disruption to the UK economy, … it would be beneficial if more money were spent on winter resilience. "

Report of Transport Committee (2011): Keeping the UK moving - The impact on transport of the winter weather in December 2010

Annual probability of blizzard events

≥ 10 cm / 24 h
≤ 0 °C
≥ 17 m/s



Climatology of severe winter events

Blizzard:
South and Central Finland, 23-24 November 2008

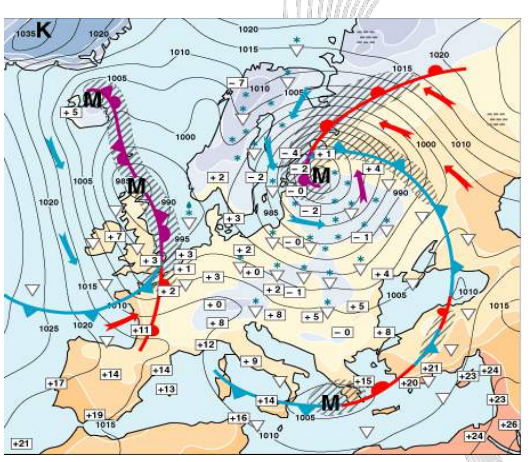
- The rapidly deepening centre of low pressure moved towards Finland → strong and cold northerly winds and heavy snowfall.

↓

WG max = 27 m/s locally in S Finland

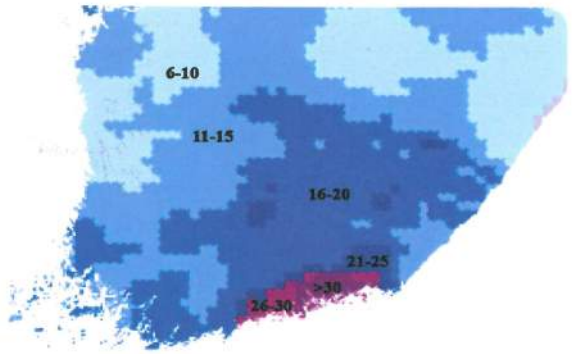
T < 0°C

snow accumulation = 10-25 cm, locally > 30 cm



Weather situation on 23 November 2008 at 12 UTC.

Forecast issued by FMI:
warnings for gusty wind, very poor driving conditions → GOOD!



The 24h snow accumulation based on radar measurements

Impacts on critical infrastructure:

- Power cuts in 41 000 households
- Damaged buildings, e.g. detached roofs
- Number of traffic accidents increased by 73% in S and Central Finland, in SE Finland it was fourfold
- One fatality and 112 injuries
- A lot of trees fallen on the roads

Climatology of severe winter events

Heavy crown snow load

Multiple event

→ snow and rime attaching tightly on tree crowns and other structures in freezing temperatures → high risk to powerlines

Oct 29	freezing fog, rime formation on trees
Oct 30 daytime	heavy fall of wet snow and sleet
Oct 30 night	T < 0°C => snow load frozen and tightly attached to trees
Oct 31	snowing, T > 0°C
Nov 1	snowing, T > 0°C
Nov 1 afternoon	strong gusty wind, T < 0°C (Pyry storm)

30 cm of snow

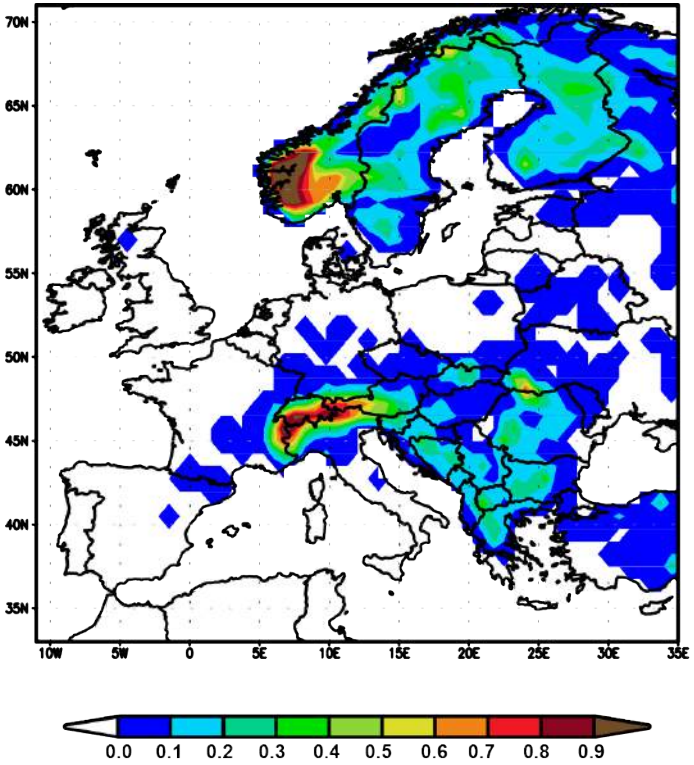
Heavy snow load combined with stormy winds, Central Finland, 30 Oct-1 Nov 2001

Impact on CI:
Severe forest damage
↓
≥ 20 000 trees fallen on the power transmission lines
↓
power outrages (177 000 houses)

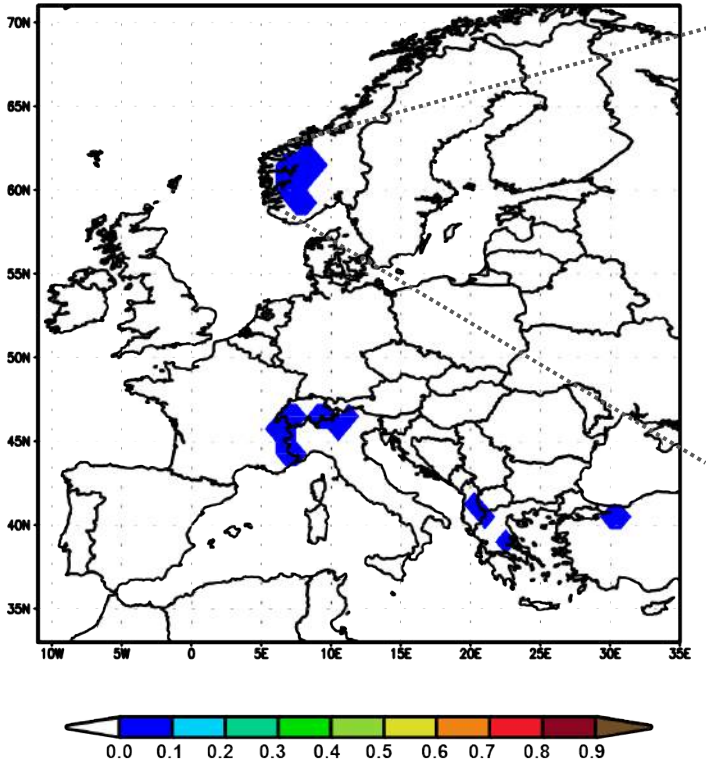
Annual probability of crown snow load

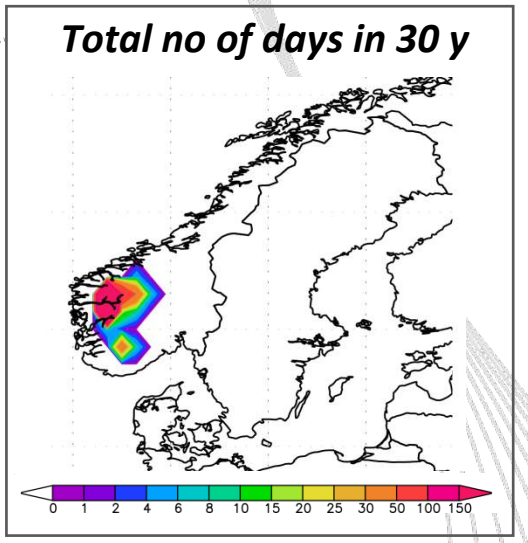
FMI crown snow load model: rime + dry snow + wet snow + frozen snow = **total snow load**

≥ 20 kg m-2



≥ 60 kg m-2





Climatology of severe winter events

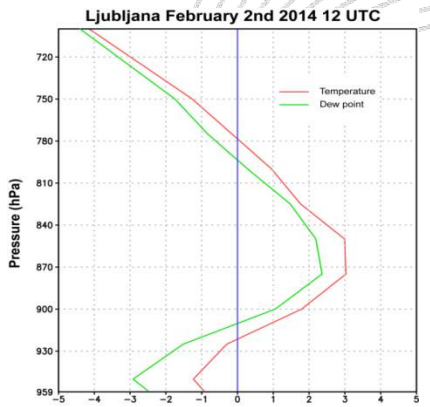
Freezing precipitation

Slovenia, 31 Jan - 3 Feb 2014

- **Freezing rain** and blizzard, the worst situation in Notranjska region (SW)
- Large amount of precipitation, 5-days RR = 100-200 mm, locally > 250 mm

↓

10 cm of ice accumulation



Vertical profile of temperature and dew point (ERA-Interim)

Massive damage to CI:

- 30 km destroyed, 170 km inoperative power-lines
- Damaged telecommunication installation
- Disruption on water supply
- Stopped railway and road traffic
- Town and villages cut off for days
- 500 000 ha of forest destroyed

Estimated total damage: 430 million €

Climatology of severe winter events

Freezing precipitation

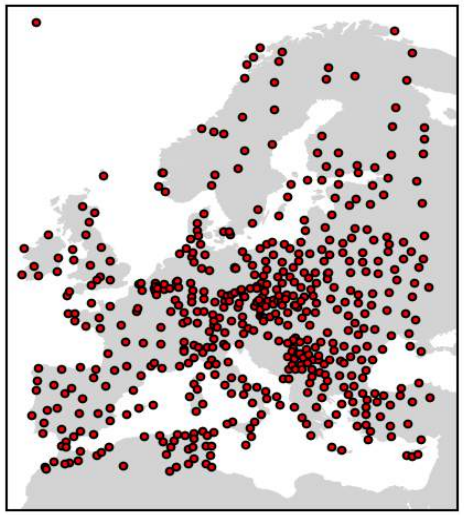
Small spatial and temporal scale → changes in larger-scale (synoptic and mesoscale) conditions that favor or can trigger smaller-scale extreme weather

Identification of event:

- ERA-Interim data (T, RH from 1000, 925, 850 and 700 hPa, near surface T, P, RR)
- identification of melting & freezing layer and their thicknesses + identification of moist layer => freezing rain predicted

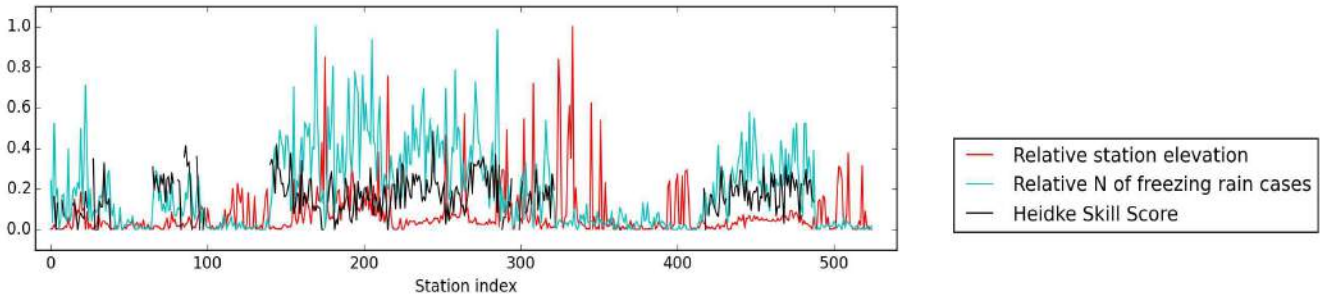
Validation and calibration:

- 6h SYNOP observations (525 stations)
- ERA-Interim data in station locations
- Numerical optimization of the Heidke Skill Score metric with different threshold values => HSS = 0.21

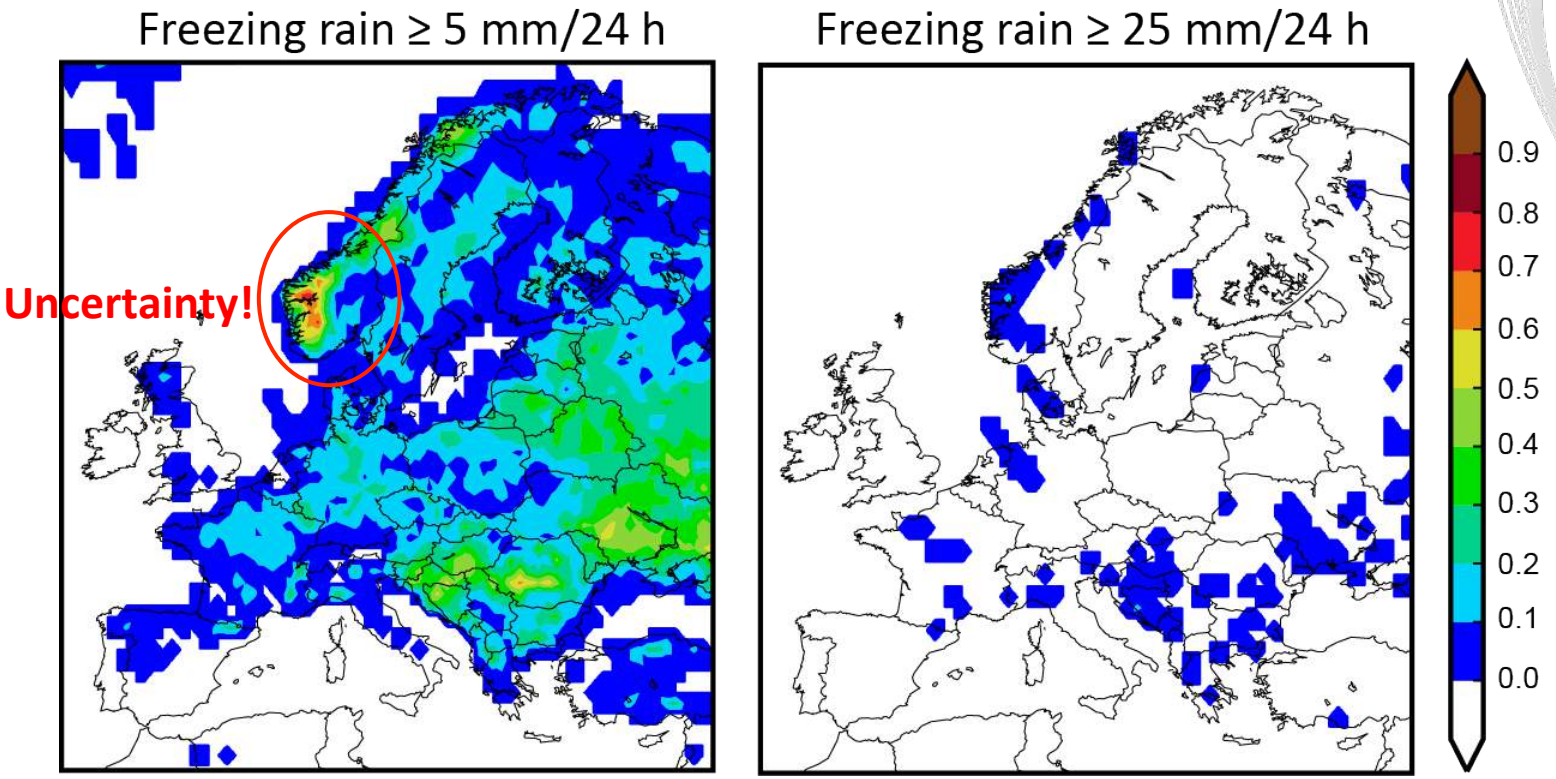


The 525 quality controlled SYNOP stations

The Heidke Skill Score of the FMI algorithm

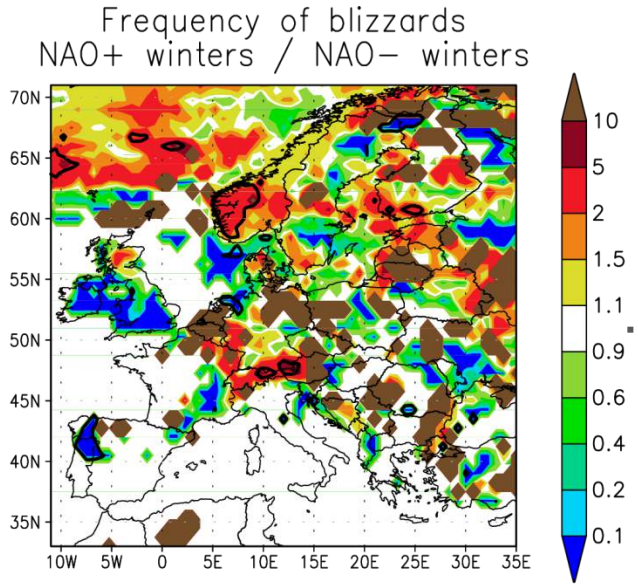


Annual probability of freezing precipitation



Climatology of severe winter events

Frequency distribution of severe winter events / large scale patterns



events during NAO+ winters

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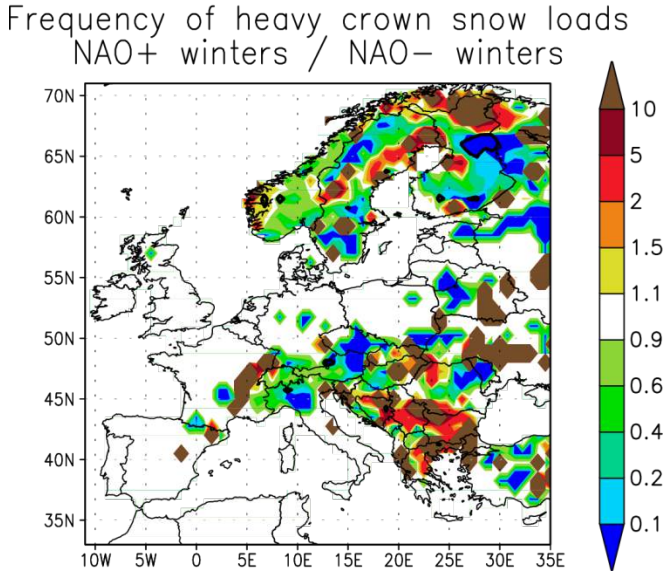
events during NAO- winters



events during NAO+ winters

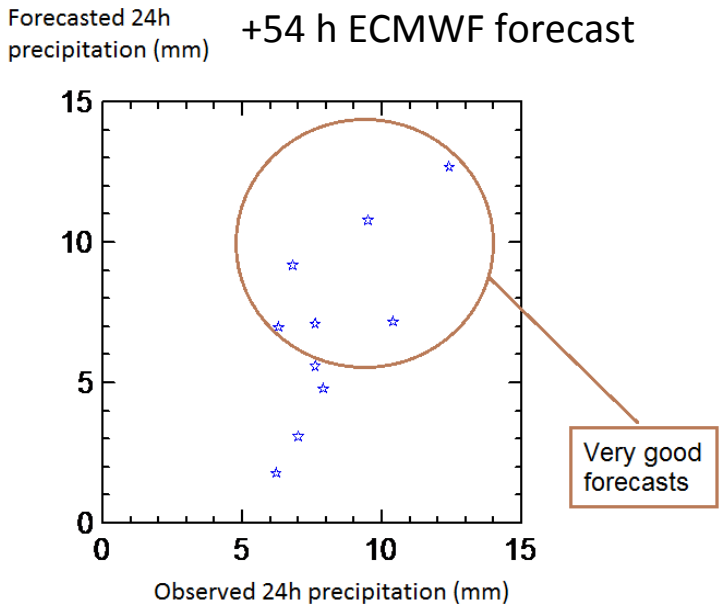
.....

events during NAO- winters

- Over the mountain areas near the SW coast of Norway blizzards are more common during NAO+ phase
- Not sufficient cases to find any significant connections

Predictability of severe winter weather events

- The improved skill of NWP models made possible the warning of severe events several days (i.e. 2-5 days) in advance (outlooks and early warnings)
- Severe winter weather (e.g. heavy snowfall, blizzards, snow loading) often related to large scale low pressure systems => well captured by NWP models
- Moderate prediction in the short range for local phenomena, e.g. sea-effect snowfall, freezing rain.



Observed and forecasted heavy snowfall events (T ≤ 0°C, RR ≥ 6 mm) at Helsinki airport during winters (2011/12-2014/15, November-March).

Source: I. Juga

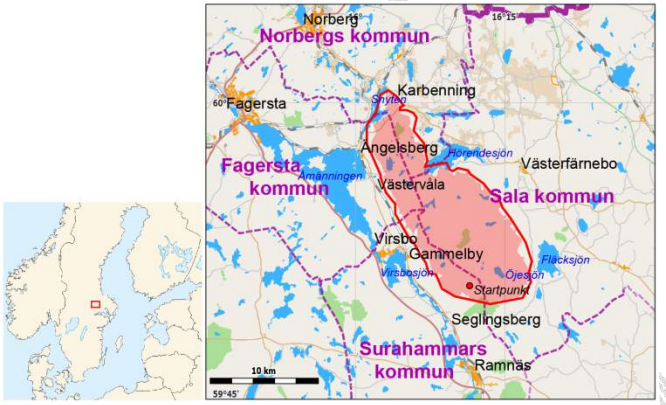
Climatology of forest fire danger

Mediterranean region: about 50000 fires/year → severe damage of CI and large economical losses, their risk is expected to increase in the future climate

Northern Europe: probability of conflagrations is lower + efficient fire prevention, warning and suppression systems

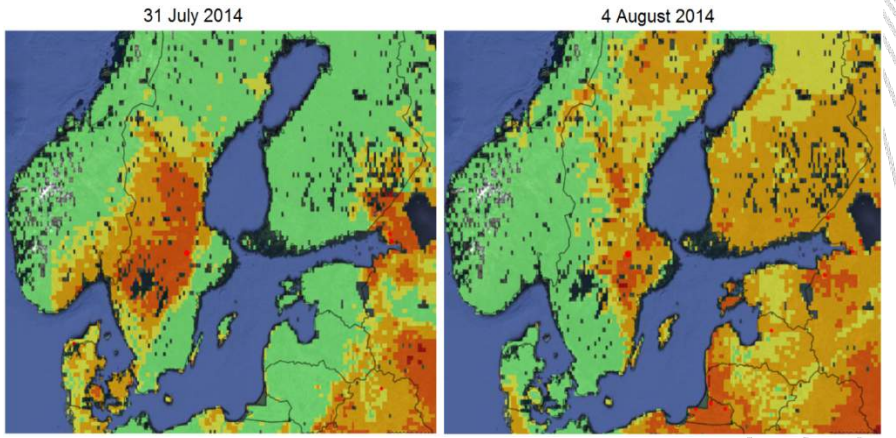
Wildfire in Västmanland, Sweden, 31 Jul-11 Sep 2014

- exceptionally warm and dry July & August
- fire started by a spark from a forestry machine, spread rapidly
- under control on Aug 11 → extinction ended on Sep 11



Impacts on critical infrastructure:

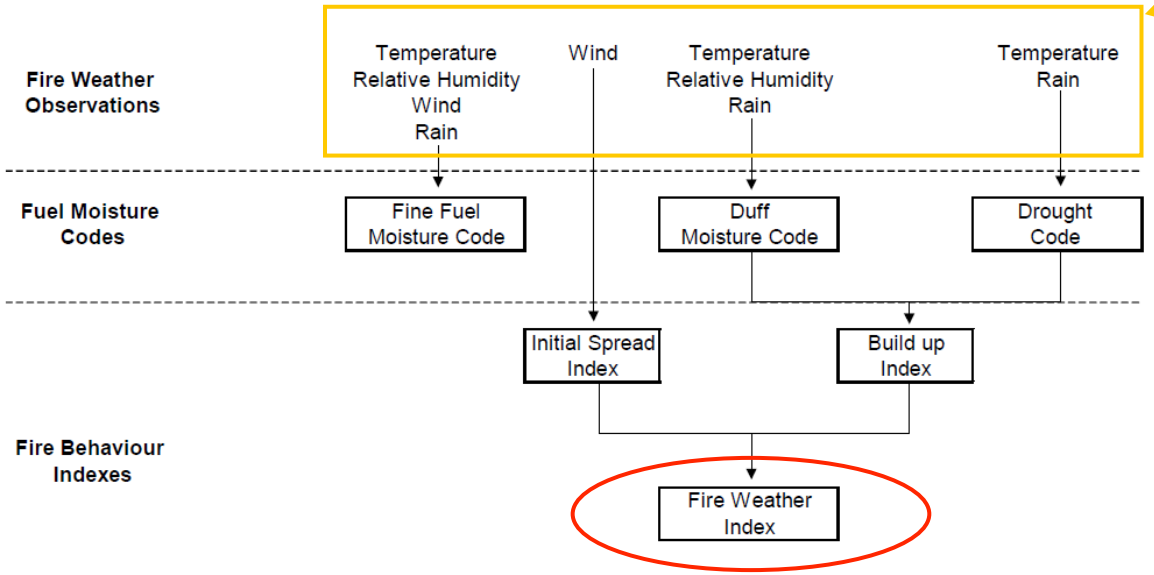
- 13 800 ha of forest burned
- disturbed rail, road, air and boat traffic
- 1 200 people evacuated, > 25 houses burned
- high economical costs



Climatology of forest fire danger

Forest fire danger assessment

Canadian Forest Fire Danger Rating System



ERA-Interim re-analysis data-set

The original FWI class ranges

Danger class	FWI range
Extreme	> 29
Very High	17-29
High	9-16
Moderate	5-8
Low	2-4
Very low	0-1

FWI > 20 → Central and Northern Europe

FWI > 45 → Southern Europe

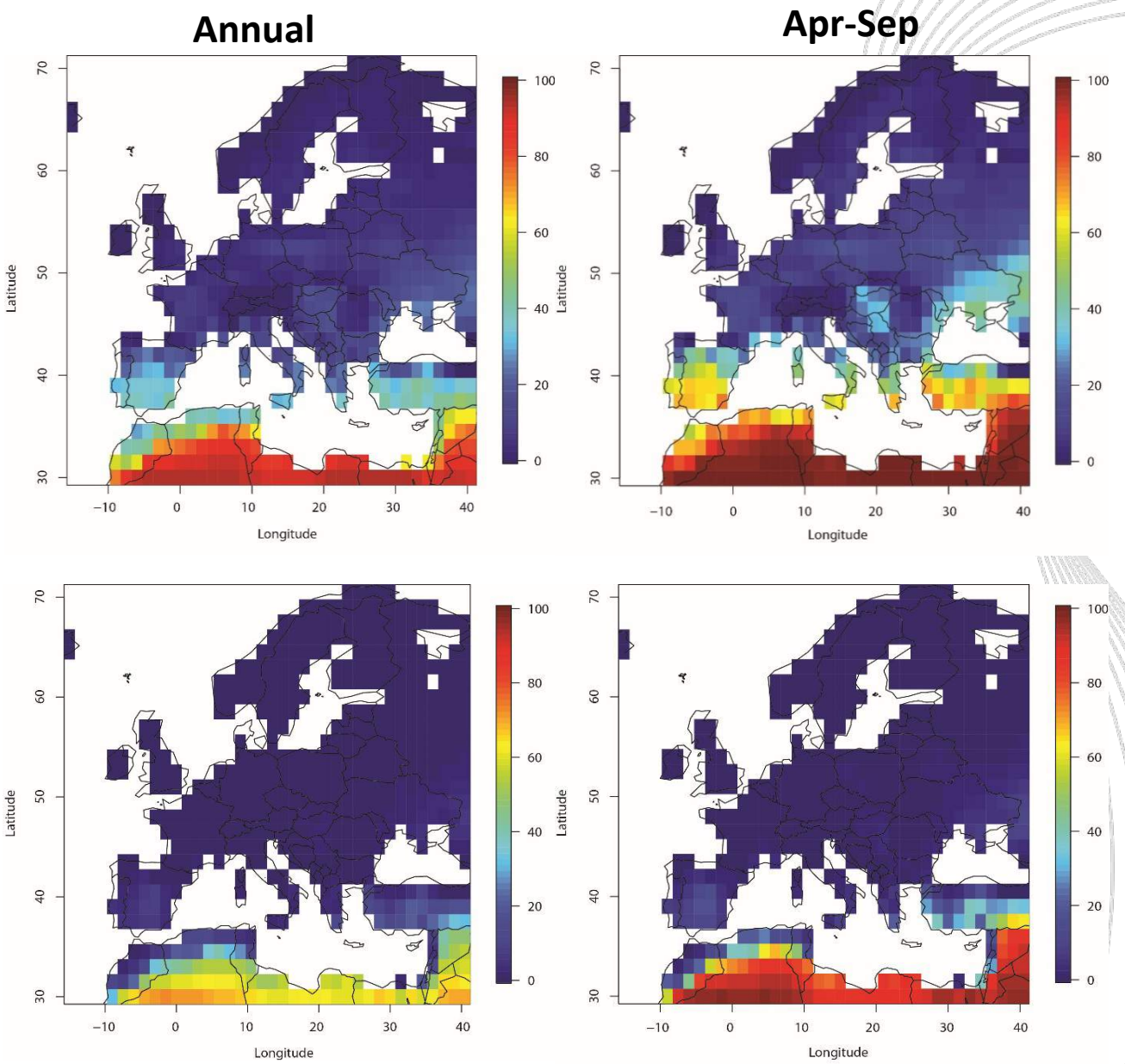
Mediterranean region:
Extreme → FWI > 45
(Moriondo et al. 2006)

Climatology of forest fire danger

Probability (%) of forest fire danger

FWI >20

FWI >45



Projected climate changes

Changes in temperature (°C) and precipitation (%) from 1971-2000 to 2070-2099, RCP8.5, multi-model means (28 GCMs)

What are the projections for severe winter events and forest fire danger?

EURO-CORDEX simulations

- 3 RCMs: RCA, CCLM, WRF
- Spatial resolution: 0.44°
- Time resolution: 6 h
- Scenarios: rcp2.6, rcp4.5, rcp8.5
- Time period: 2021-2050
  2071-2100

Ongoing work

Source: K. Ruosteenoja

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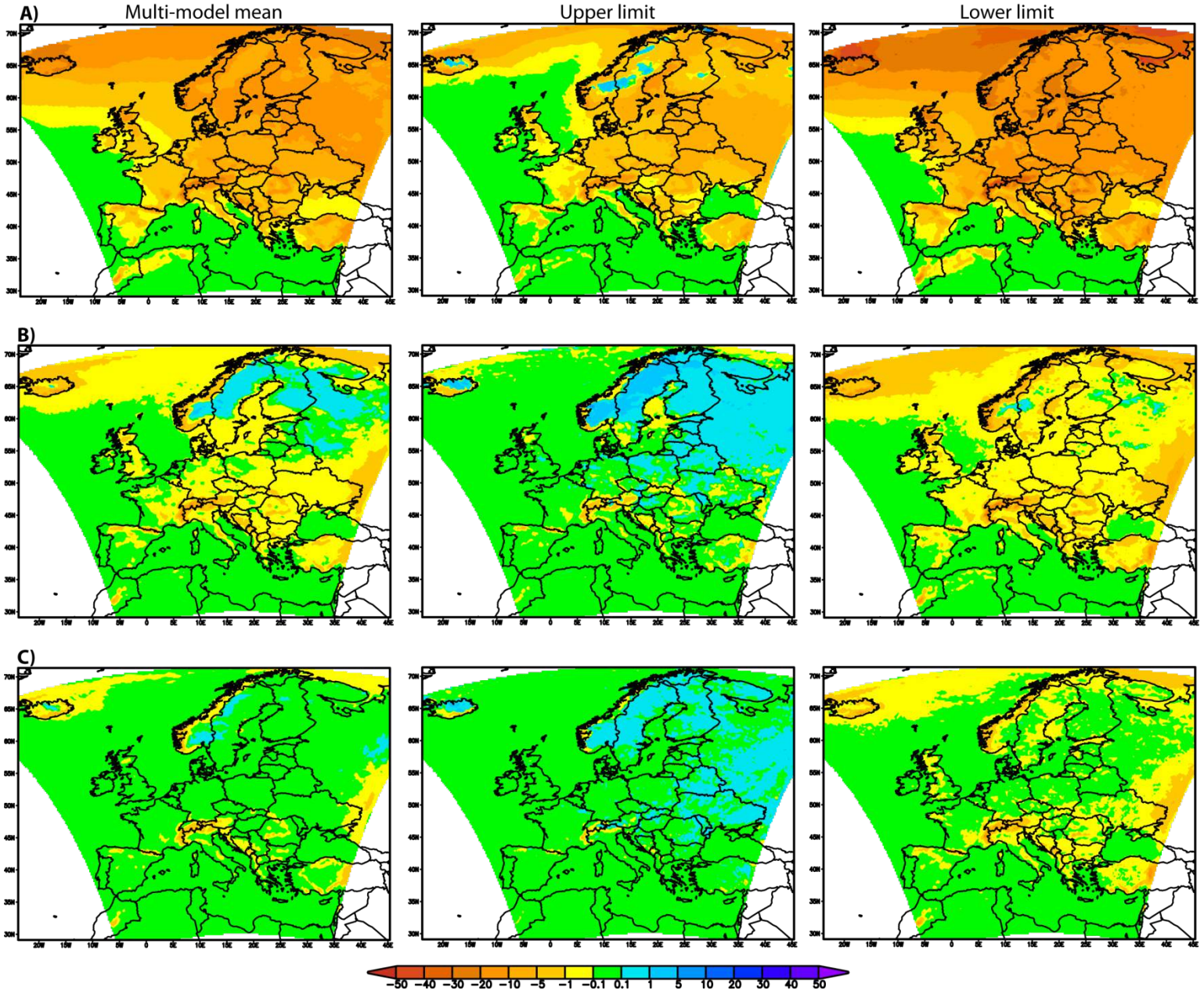
Changes in annual snowfall days from 1971-2000 to 2041-2070



EU FP7 EWENT

Vajda et al. 2011

Concluding remarks

- Newly defined impact indicators provide valuable information to CI stakeholders, allowing the management of risks and the improvement of the cost-efficiency
- Problems with the climate data: temporal/spatial resolution, reliability, ”non-existent” → *Improvements in data collection and exchange are needed.*
- The probability of severe snow events is the highest in Northern Europe and the Alpine region, while the probability of freezing precipitation is higher in Eastern Europe
- The probability of extreme fire risk is very small in most of the Europe, with high values only in the Mediterranean
- The severity of disruptions and damages caused by these phenomena highly depends on the resilience of CI types and preparedness of the country

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Terminology

- **Severe** - Events that result in high socio-economical losses or with destructive effects on the environment

  Risk = f(Hazard, Exposure, Vulnerability)

May not be rare or extreme

- **Rare** - Events that have a low probability of occurrence

- **Extreme** - Events that often cause large damage or consequences to society, can be generalized as having an all-time maximum value and/or exceeding a previously measured high or low threshold

- **High-impact events** - Severe events that can be either short- or longer-duration events

Ref.: Stephenson D.B. (2008)

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