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Translating climate projections into sectoral applications for the Arctic region

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Outline

- Climate projections in FMI
  - Finnish high resolution dataset derived from CMIP5
- Sectoral applications
  - Forestry: forest management and risks
  - Agriculture: crops
  - Energy: extremes
  - Sea and safety: sea level rise – global – regional
  - Transportation: roads, railways, airports, harbours, cities
  - Infrastructure: power lines, buildings
  - Regional examples: Baltic Sea extremes and variation
  - Socio-economic scenarios of Arctic development
- Dissemination tools → ClimateGuide.fi, SmartClim (coming)

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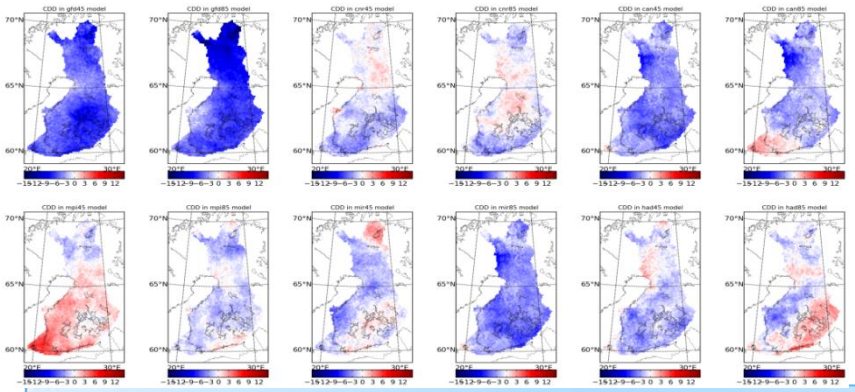
Climate projections used in FMI

Millennium simulations of the past climate

- MPI-ESM model with ECHAM5
- Spatial resolution: T31/L19
- 4824 years of a simulated past climate
- Temporal resolution: 6 hours
- FMI application: 800 AD to 2005 AD

Global Climate Models - CMIP3, CMIP5

- 35 models
- Historical and scenario simulations
- RCP2.6,RCP4.5,RCP6.0 & RCP8.5
- Monthly and daily data
- 8 variables
- Spatial resolution: 2.5°x2.5°



Changes in yearly consecutive dry days index (CDD) in CMIP5 models, 1981-2010→2071-2100

Regional Climate Models

PRUDENCE, ENSEMBLE, CORDEX

- EUR-domain
- 21 RCM-GCM pairs
- A1B emission scenario
- 9 variables
- Spatial resolution: 0.22°x0.22°
- EUR-domain
- 13 RCM-GCM pairs
- 5 variables
- RCP4.5 & RCP8.5
- Spatial resolution: 0.44°x0.44°
- Several pressure levels

Finnish high resolution data-set derived from CMIP5 models

- 6 CMIP5 models
- RCP4.5 & RCP8.5
- Temporal coverage: 1980–2099
- 7 variables
- Spatial resolution: 0.1°x0.2°
- Bias correction/downscaling procedure using quantile mapping

Bias correction: using ERA-Interim & E-OBS data, different methods, e.g. DBS method, delta change

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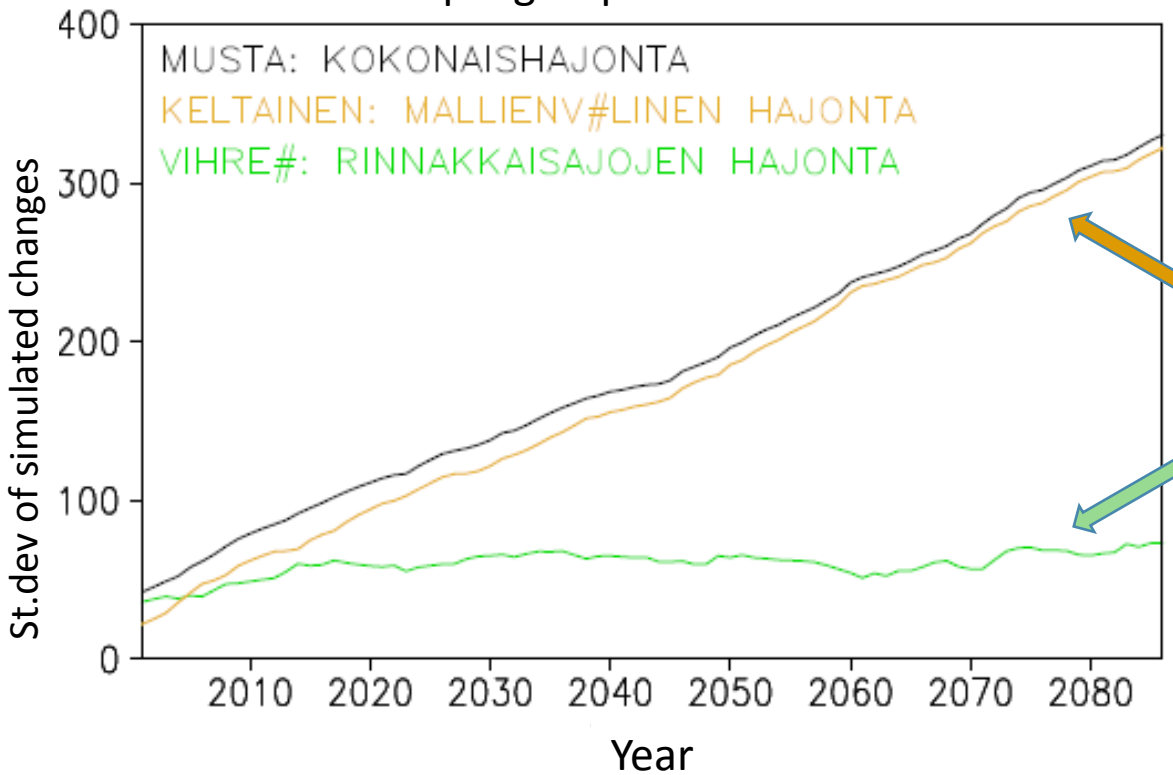
Main categories of uncertainty for the assessment of future climate change

Standard deviation in simulated increases in the growing season temperature sum at an example grid point in central Finland



Total standard deviation
Inter-model differences
Dissimilarities across the parallel runs

22 global climate models, bias-corrected, RCP8.5

Model uncertainty associated with climate models

Internal variability and initial condition uncertainty

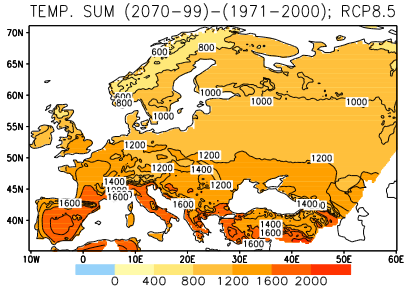
Note: **Model spread** is only a crude measure of model uncertainty
(a limited number of models; model quality and independence ignored)

In addition: **Scenario uncertainty**, due to uncertainty of future emissions of GHGs and other forcing agents

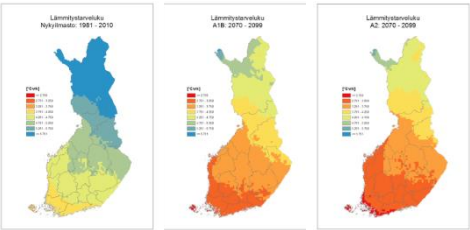
Figure source: K. Ruosteenoja

Multi-sectoral assessments

Forestry
Storm damage
Snow load damage
Forest fire danger
Growing season

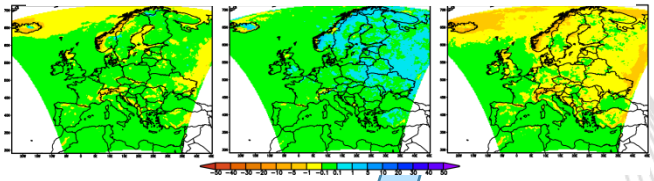


Energy and infrastructure
Heating and cooling demand
Extreme weather ↔ energy production
Extreme weather ↔ infrastructure safety
Sea level rise ↔ infrastructure safety



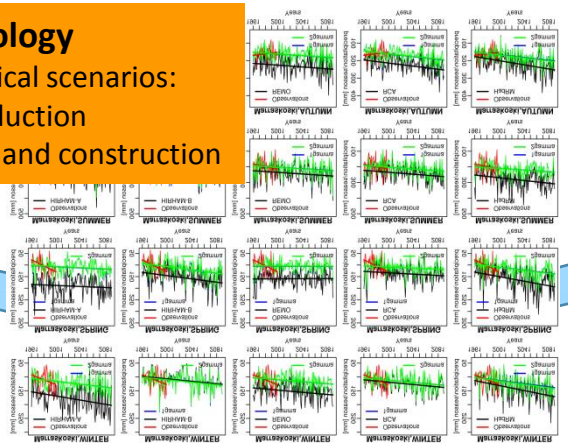
Transportation
Extreme weather ↔ transportation
Baltic sea ice conditions

Blizzard days (2041-2070)-(1971-2000)



Climate projections

Hydrology
Input for hydrological scenarios:
- hydropower production
- flood prevention and construction



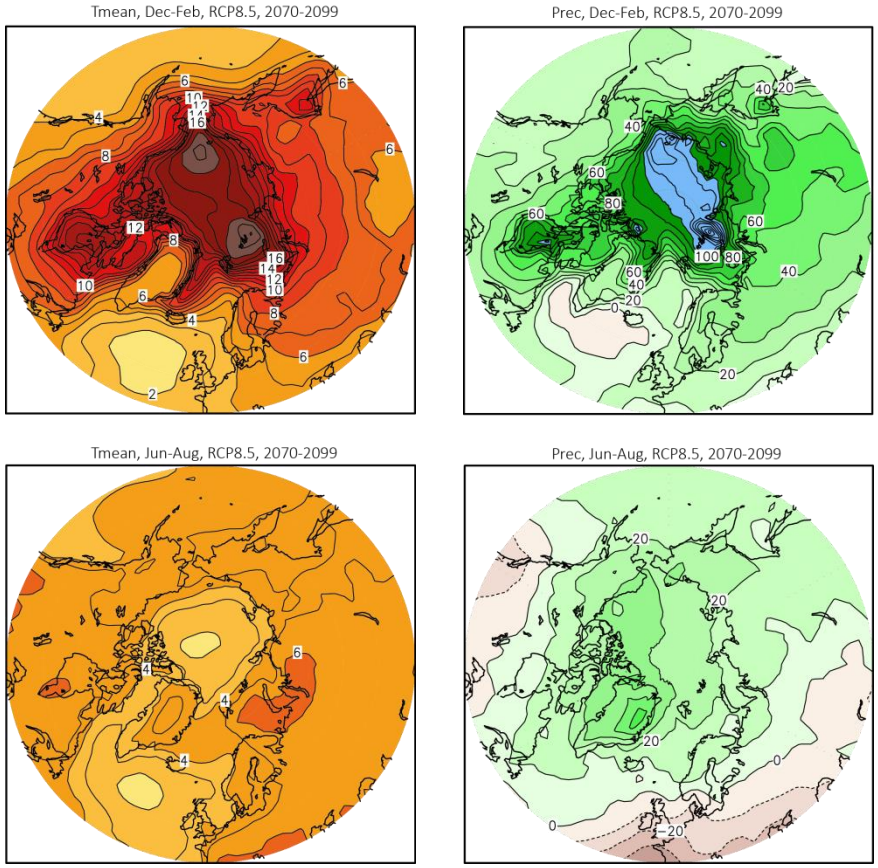
Socio-economic applications
Risk assessment
Adaptation measures
Cost and benefit assessment

Decision support tools

Future changes in forest fire danger

Changes in temperature (°C) and precipitation (%)

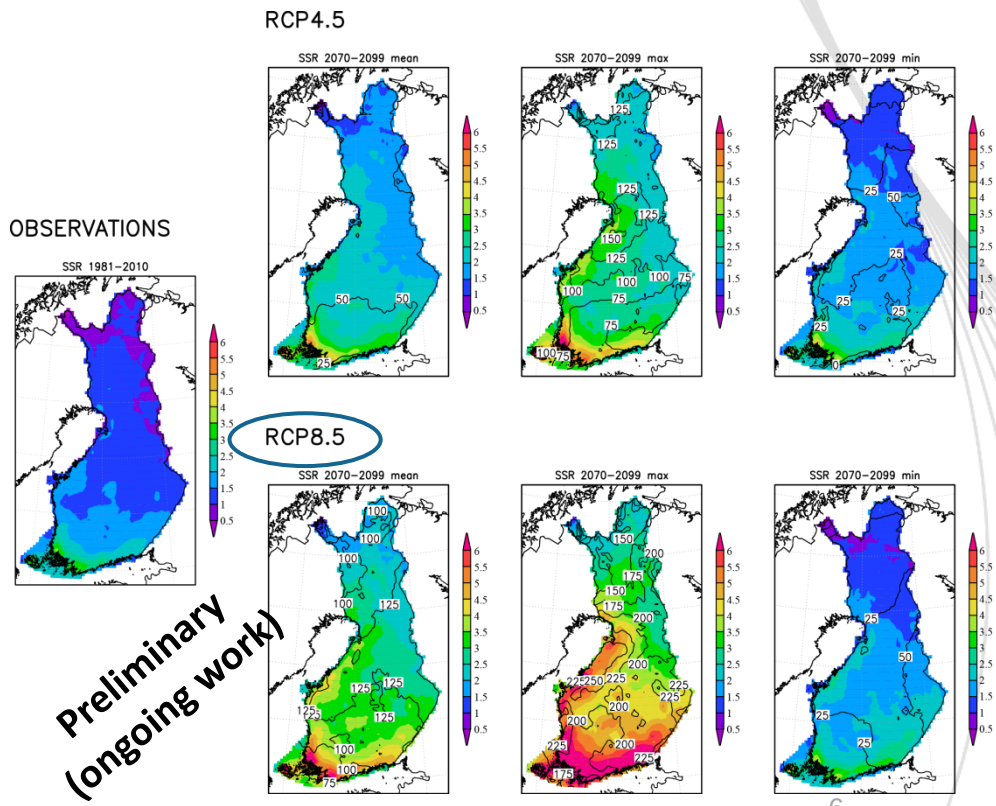
- from 1971-2000 to 2070-2099, RCP8.5, multi-model means (28 GCMs)



Source: K. Ruosteenoja

Modelled forest-fire danger in Finland in 1981–2010 and 2070–2099

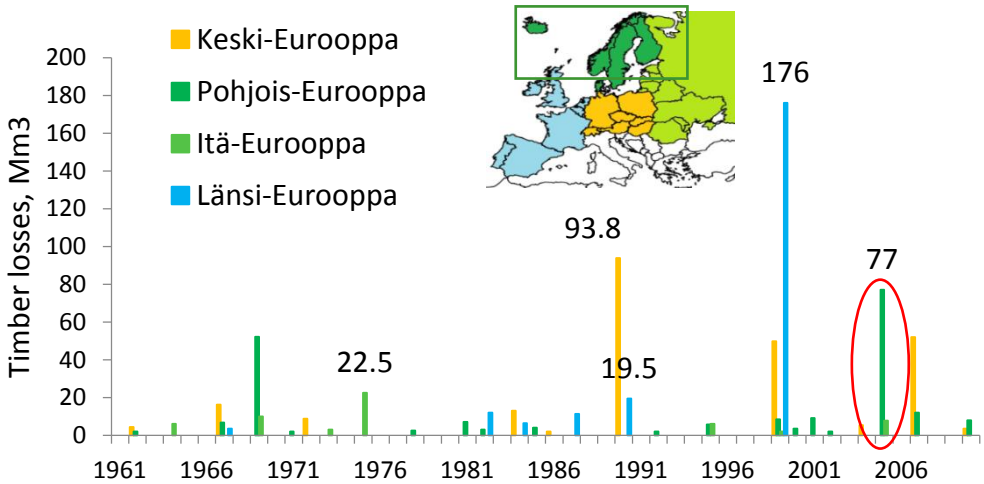
- using high resolution dataset derived from CMIP5 (SA-ADAPT)



Source: I. Lehtonen

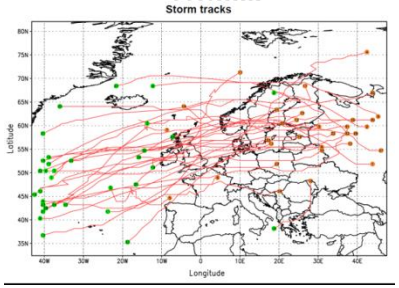
Applications to forestry

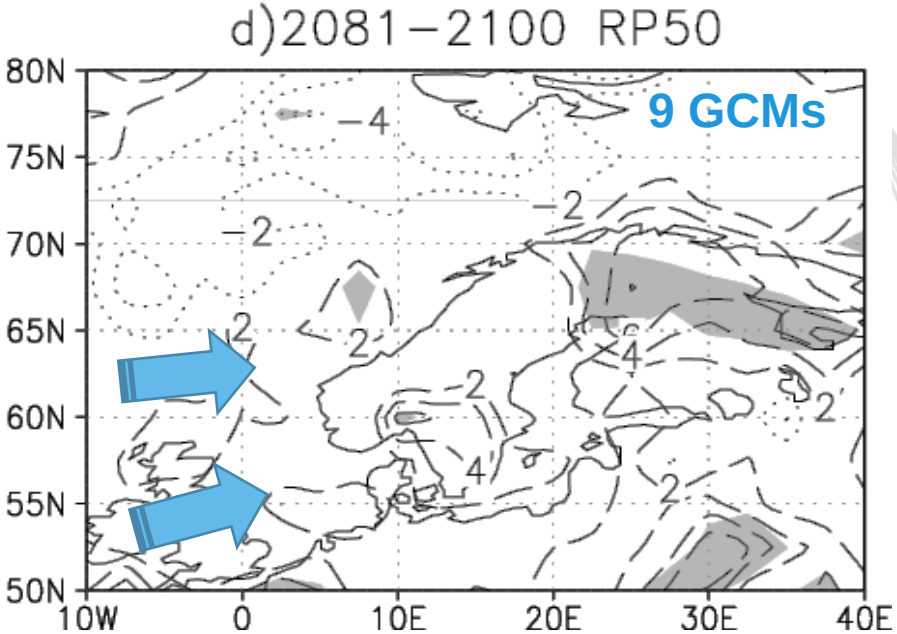
Storm induced damage in European forests has increased and is projected to increase in the storm track region



Source: Gregow, 2013

Storm tracks
ERA-Interim 1979-2012



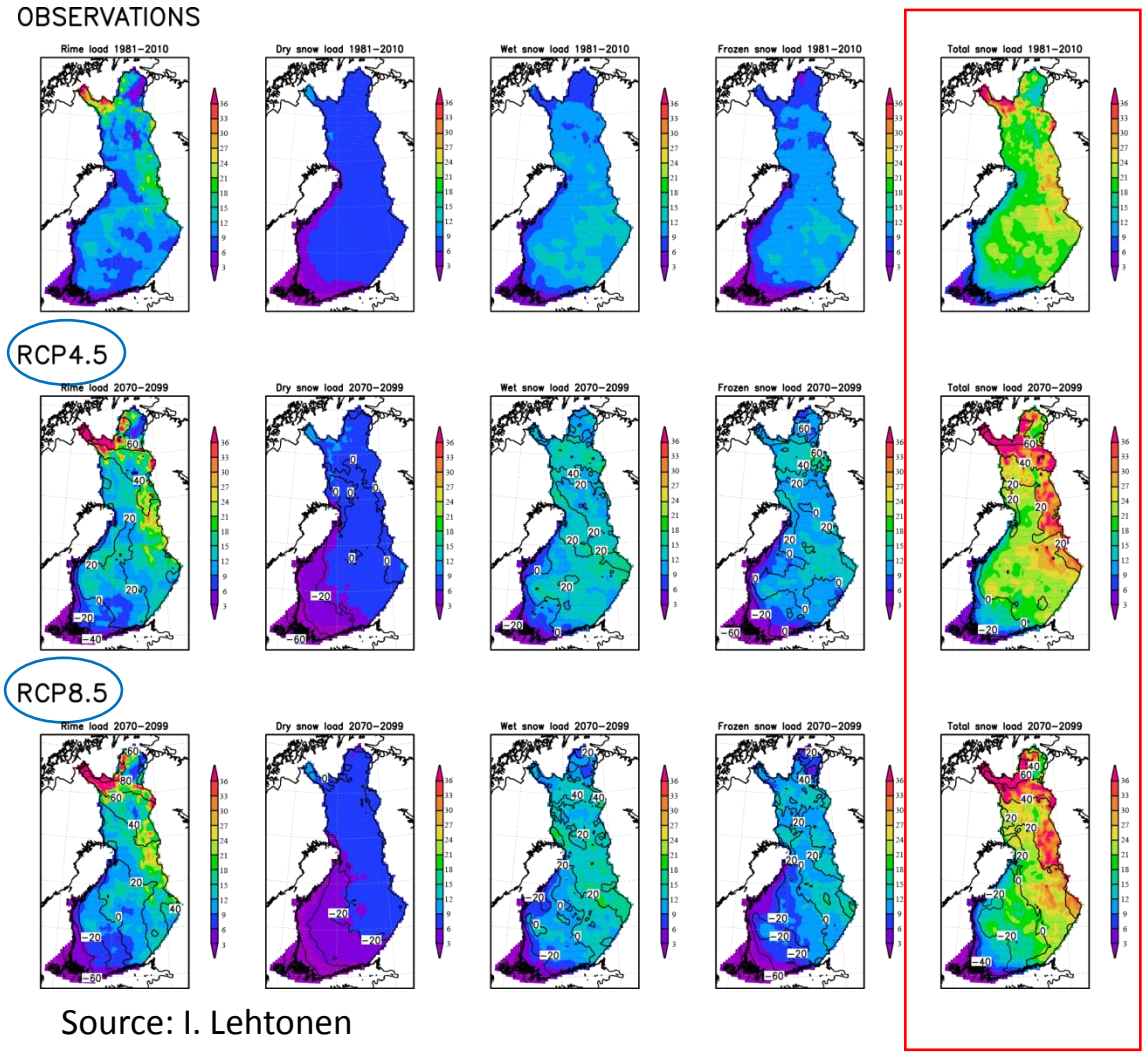


- Wind speeds of the rare (once in 10 years) to very rare (once in 50 years) increase in northern Europe by 2-6 % by 2100 (9 GCMs) and three SRES scenarios A1B, A2, B1)

Gregow et al. (2012) Changes in the mean and extreme geostrophic wind speeds in Northern Europe until 2100 based on nine global climate models.

Applications to forestry

Changes in annual average maximum crown snow load in Finland by 2070–2099



Source: I. Lehtonen

→ using high resolution dataset derived from CMIP5 (SA-ADAPT)

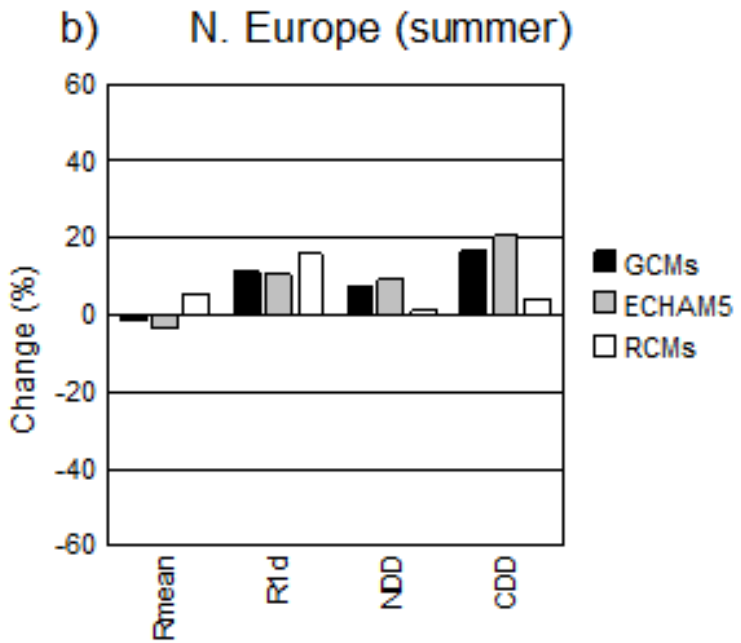
→ on-going work: assessment of changes in heavy snow load using a set of impact thresholds for critical infrastructure (EU-FP7 RAIN)

Preliminary (ongoing work)

Projections for extreme weather events

Indices for extreme events

- Maximum values
- Percentiles
- Threshold- or maxima-based indices
- Combinations of e.g., duration and intensity (drought, floods and heat waves)
- Combined events (e.g. wind and snowfall, or temperature and humidity)
- Cascading events (soil frost-wind gust-snow load, drought followed by heavy rain)



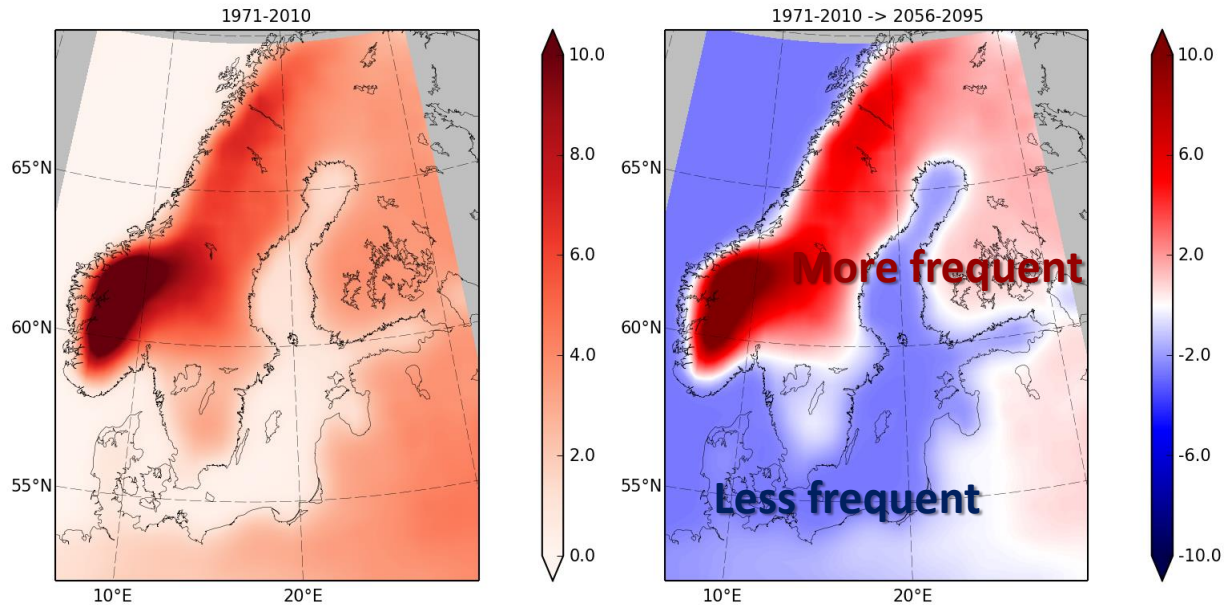
Projected changes from 1971–2000 to 2081–2100, SRES A1B

Rmean= summer precipitation total
R1d= maximum one-day precipitation
NDD= number of dry days
CDD= maximum number of consecutive dry days

If an extreme phenomena only have a small spatial and temporal scale, it may not be resolved by GCMs (or even RCMs)
→ Studies of linkages between the extreme small-scale phenomena and larger-scale (synoptic and mesoscale) conditions

Freezing precipitation and lake-effect snowfall

- ✓ Changes in larger-scale (synoptic and mesoscale) conditions that favor or can trigger smaller-scale extreme weather



Source: M. Kämäräinen

- ✓ Daily RCM (ENSEMBLES/CORDEX) data
- ✓ Criteria for temperatures at 2 m, surface and 850 hPa, and surface precipitation

→ On-going work: assessment in changes in freezing precipitation and snow load using impact thresholds for critical infrastructure ← CORDEX simulations (FP7-RAIN)

Coastal (lake-effect) snow in Feb 2012

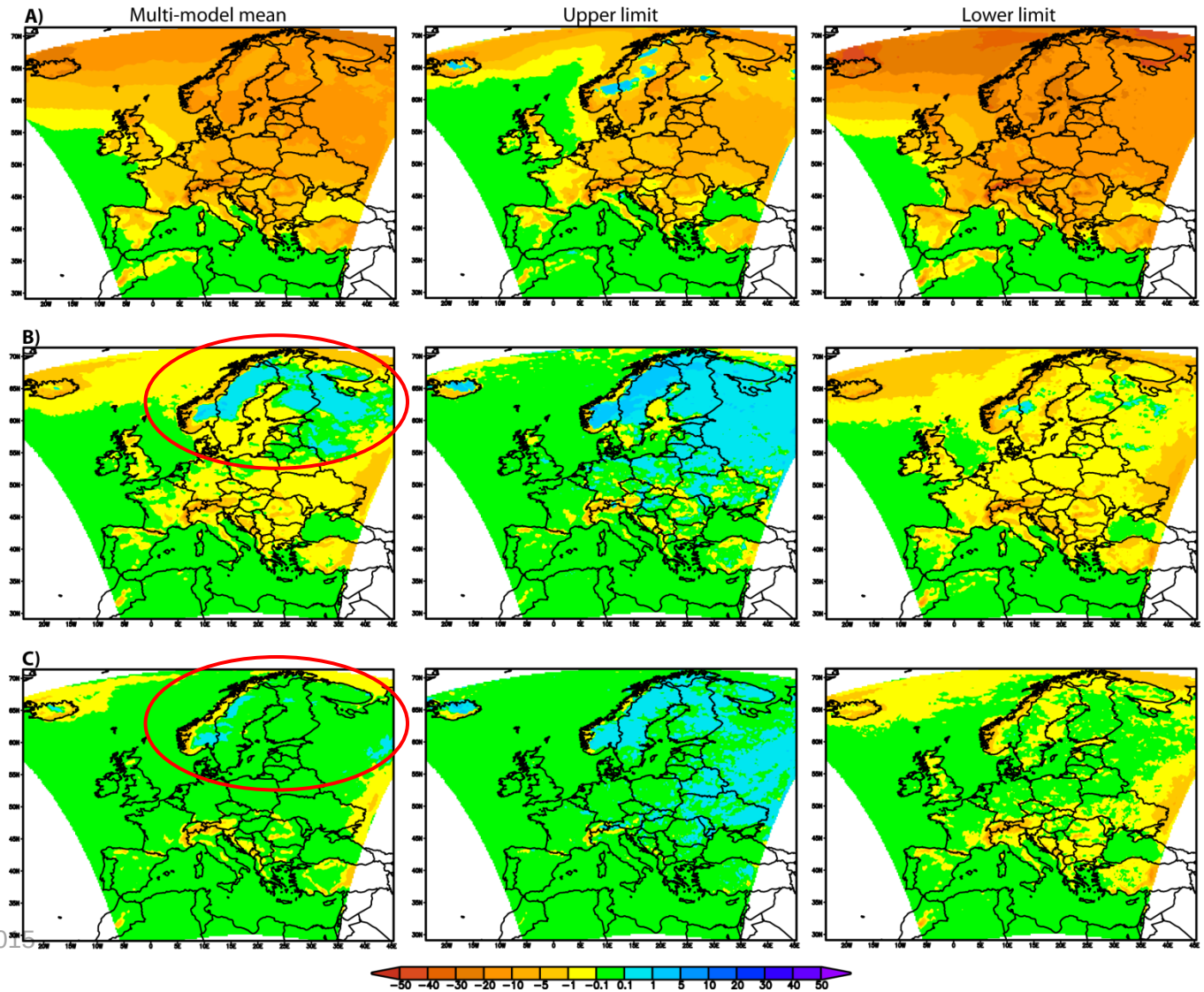
Change in annual snowfall days

From 1971-2000 to 2041-2070

≥ 1 cm

≥ 10 cm

≥ 20 cm



- ✓ 6 RCMs from ENSEMBLE
- ✓ A1B emission scenario
- ✓ Similar assessment for
  - heavy snowfall
  - wind gust
  - blizzard
  - cold spell
  - heat wave
  - heavy rainfall

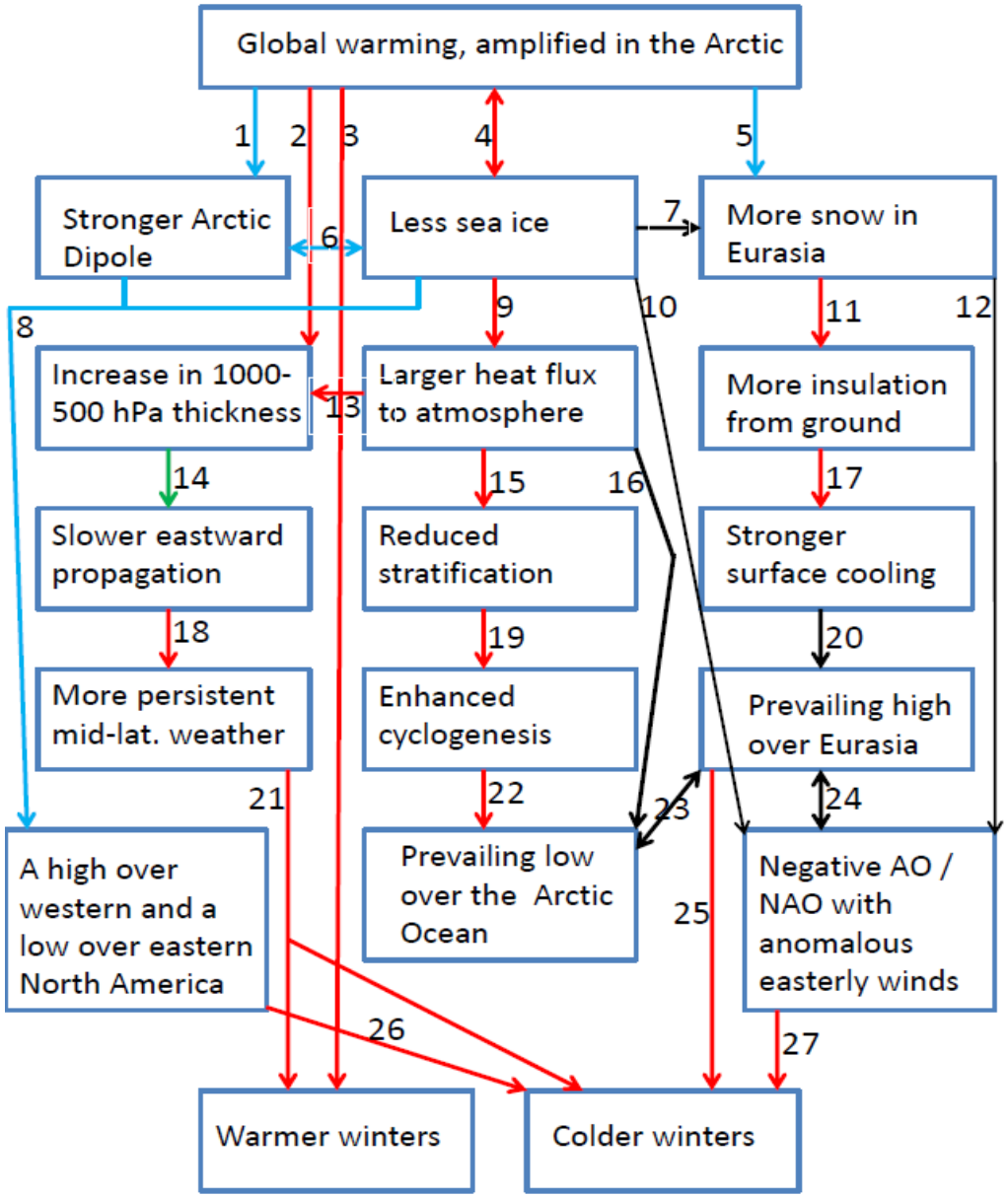
(EU-FP7 EWENT)

Vajda et al. 2011

Snow cover and sea ice

The consequences of climate change, retrain of arctic sea ice and multiple chain reactions are very complex and difficult to model (Vihma, 2014, Surv. Geophys.)

It is projected that variability in winter conditions, large scale pattern prevalence and predictability may change during the next decades →increases uncertainty in seasonal to annual scale variation.



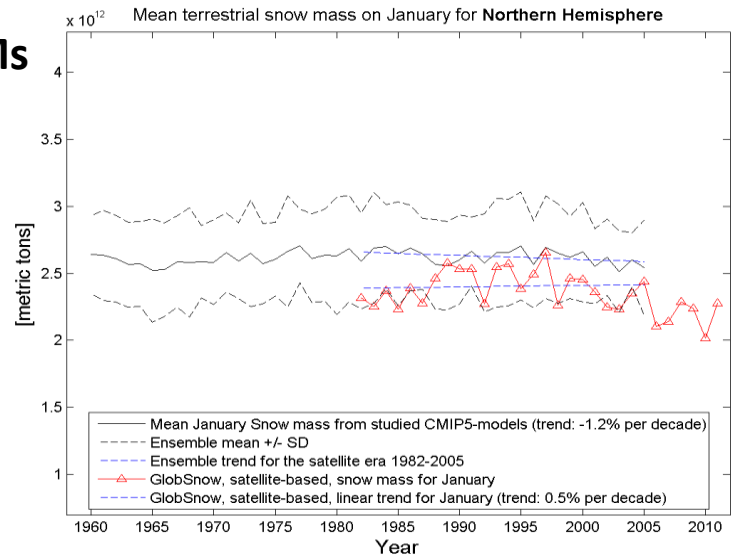
Level of certainty

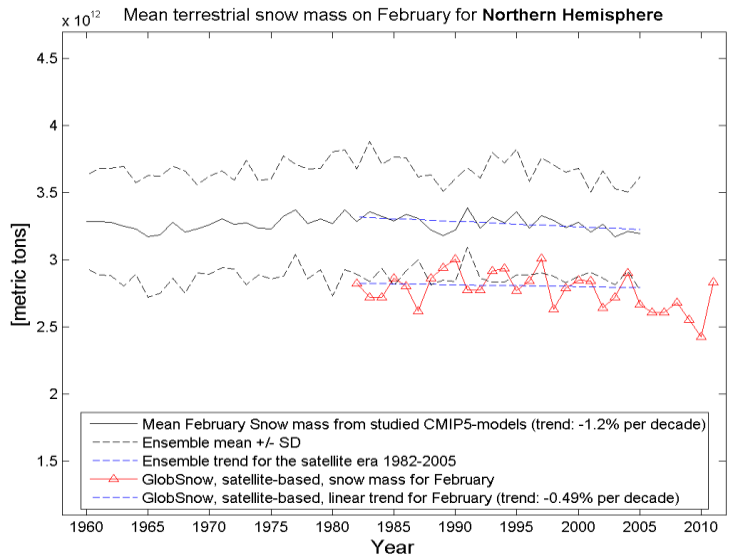
- High
- Intermediate
- Low / intermediate
- Low

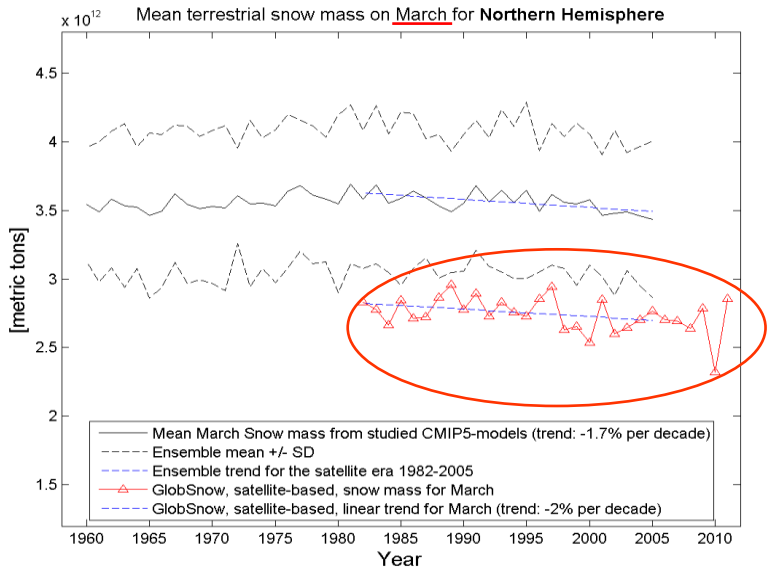
Snow cover and sea ice

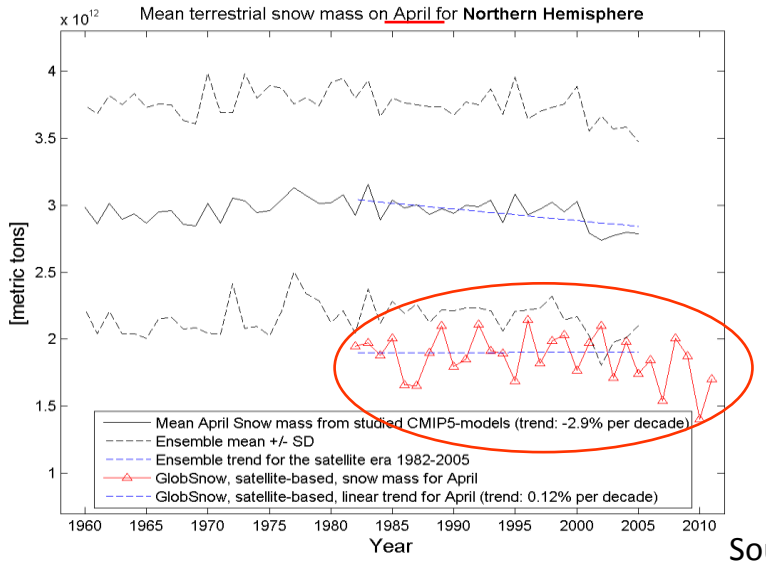
CMIP5 vs. GlobSnow SWE 1982-2005 (Jan-Apr)

6 GCMs









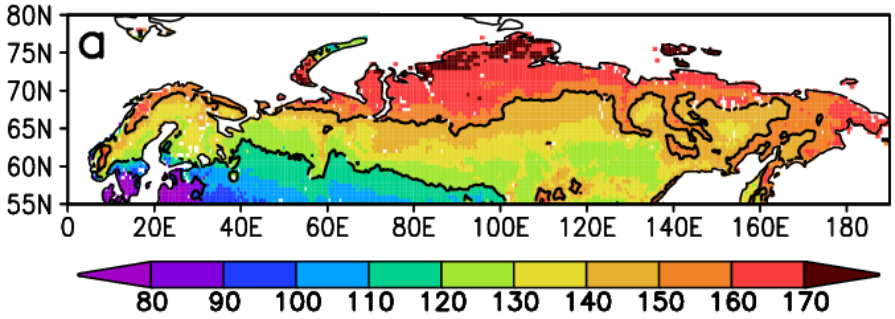
Source: K. Luojus

Snow cover and sea ice

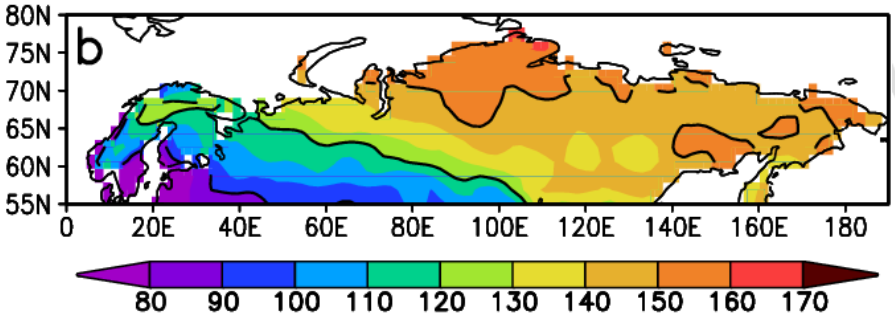
How reliably can climate model simulations assess the snow cover?

→ snow-off dates in the ECHAM5, 1979-2006

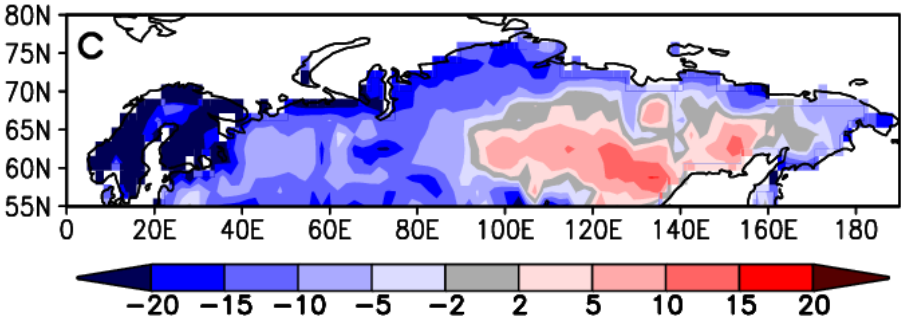
Satellite



REF: Mean value of three ECHAM5 simulations



REF - Satellite



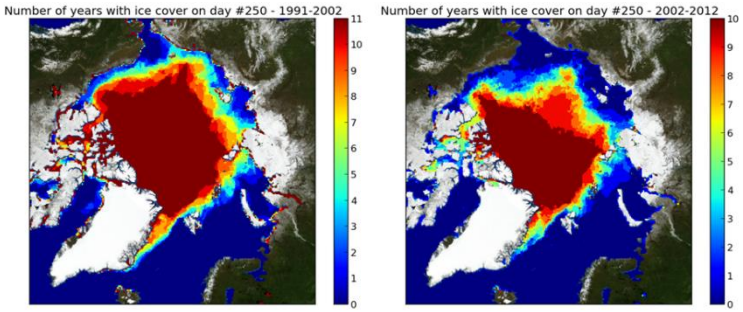
Räisänen et al., 2014

Snowmelt occurs at too low temperatures in simulations!

- surface energy budget is not computed separately for the snow-free and snow-covered parts of the grid cell
- inaccuracies in modeling surface albedo: unrealistically low albedo for “warm” snow, insufficient shadowing of the snow surface by the canopy

Socio-economic scenarios - Arctic

Will Arctic shipping substantially increase in the coming years?



→ expected increase in the open extent and time of the Northern Sea Route (NSR)

Distance of NSR and other sea routes (sea miles)

	From Hamburg to:			
	Vancouver	Yokohama	Hong Kong	Singapore
NSR	6653	6920	8370	9730
Suez Canal	15377	11073	9360	8377
Cape of Good Hope	18846	14542	13109	11846
Panama Canal	8741	12420	12920	15208

Yet many critical factors limit the feasibility of NSR

- Savings in distance does not correspond to equal cost savings
- Low bathymetry → limitations in speeds and types of vessels
- Russian icebreaker fleet fees are not unified
- Constructing ice classed ships is costly
- Weather and ice conditions still pose risks
- Lack of infrastructure and porting facilities
- Competing routes such as Trans-Siberian Railway, Suez Canal etc.
- Geopolitics in Arctic

Source: Perrels et al.

→ **Scenario development has many angles**

Dissemination

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Research

Research

Climate Research

Climate Service Centre

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Marine Research

Earth Observation

Arctic Research

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Science news

The Finnish Meteorological Institute is a leading expert in meteorology, air quality, climate change, earth observation, marine and arctic research areas. FMI's researchers publish about 300 peer-reviewed articles annually. In Science News we publish current information about FMI's studies on the weather, the sea and the climate.

New model for volcano ash light scattering
4/8/15

Marine aerosol trends dominated by transport and wet removal, not emissions
3/31/15

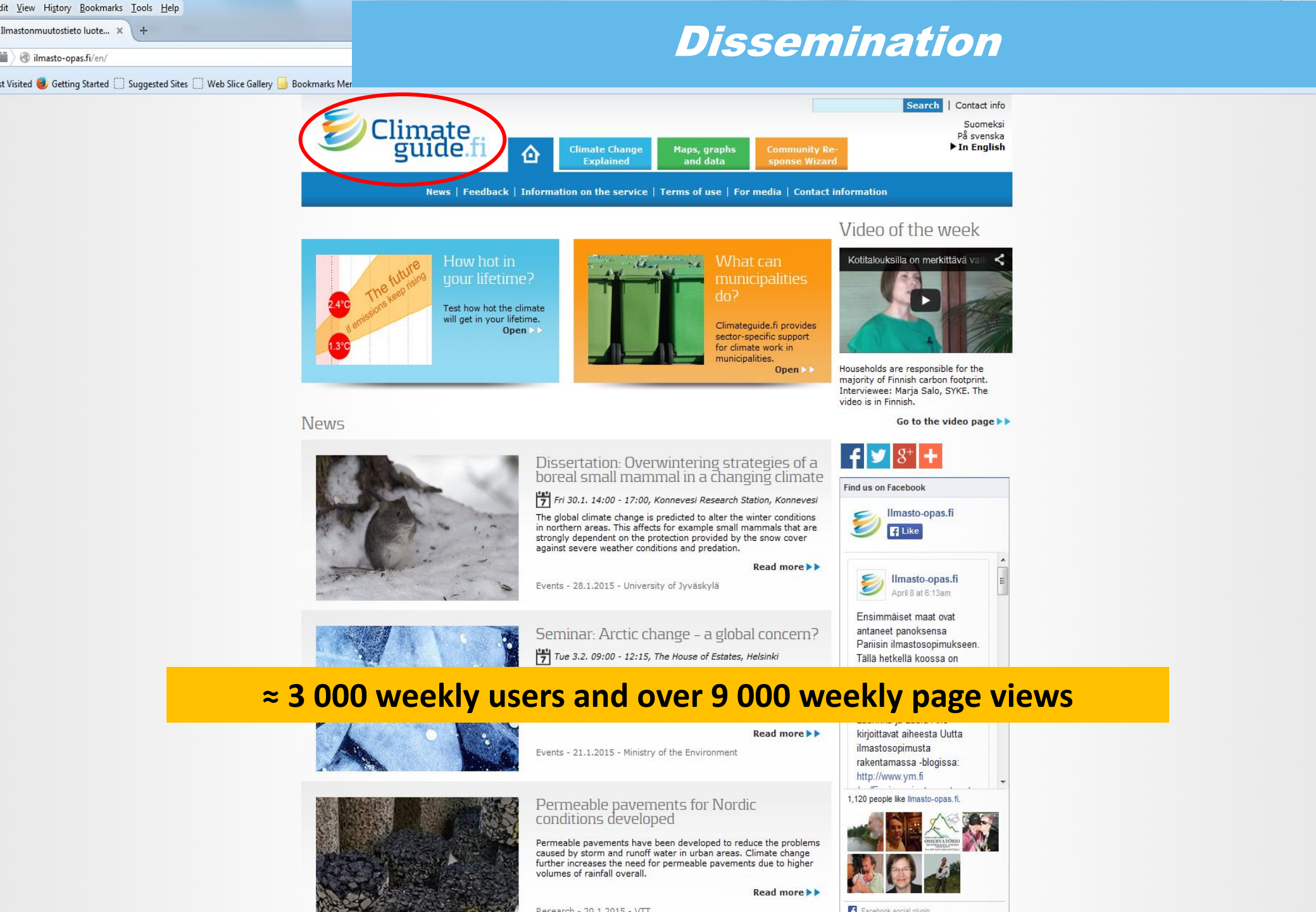
Composition of Nucleated Particles Revealed at CERN CLOUD experiment
3/31/15

The Finnish Meteorological Institute's background measurements of air quality are used extensively - including in a watercourse study
3/31/15

Science news archive

- All science news

Dissemination



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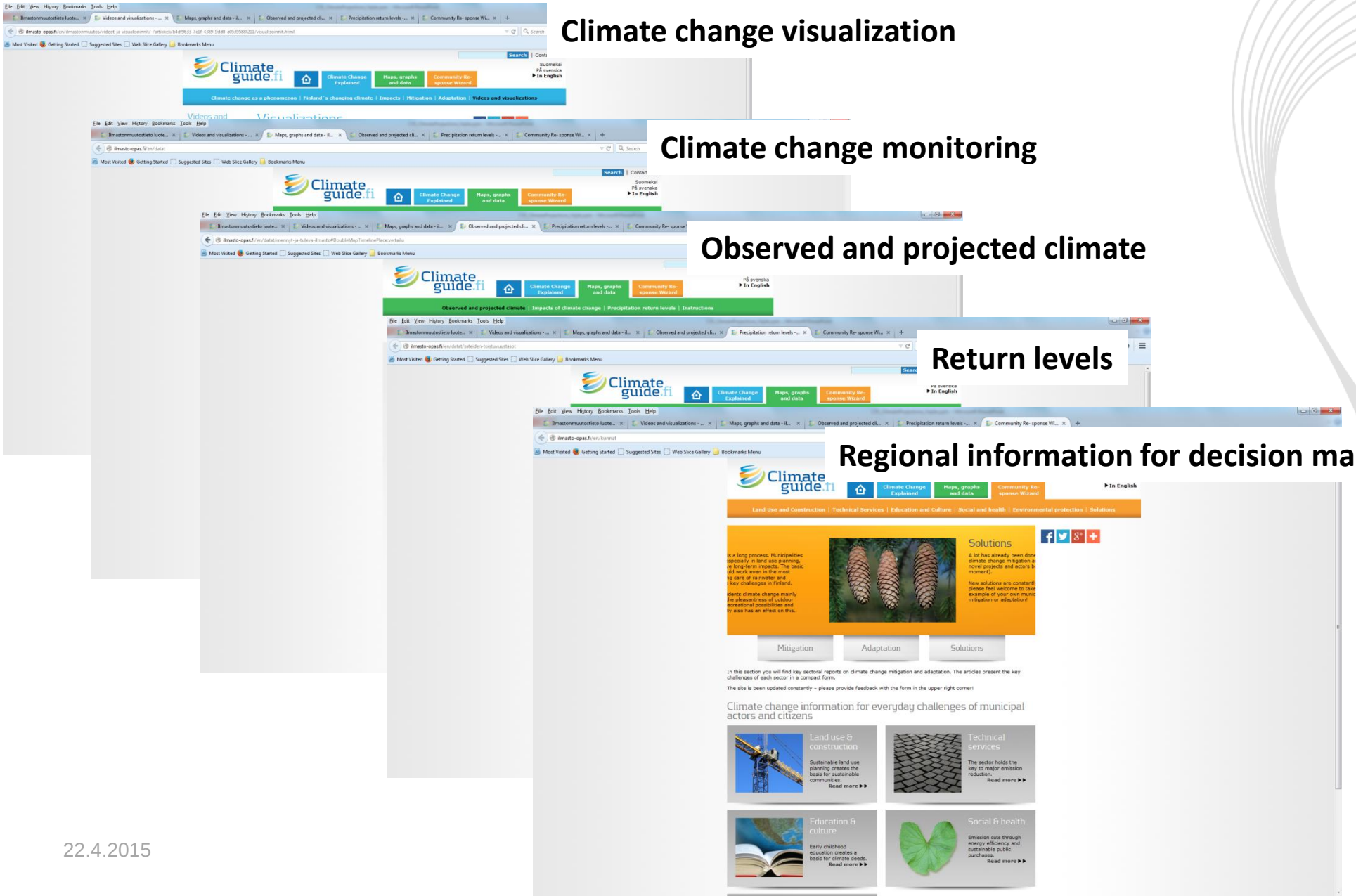

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