Vulnerability Assessment of ecosystem services for Climate Change Impacts and Adaptation (VACCIA)

ACTION 3: Derivation of climate scenarios

Climate change scenarios and their final database for assessment work in Actions 5-13

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Abstract

In the VACCIA project, the main task of Action 3 was to derive observational climate data and climate change scenarios for the needs of the other Actions in the project and to provide background information and guidance concerning the use of these data. The climate scenarios are, as far as possible, consistent with those developed in 2007-2010 for purpose of climate change adaptation studies Finland. This report documents the database produced in the Action and gives information where to find more details, if required.

Table of content

1. Introduction

The VACCIA project (Vulnerability assessment of ecosystem services for climate change impacts and adaptation), running for three years (2009-2011), addresses the vulnerability to climate change of ecosystem goods and services provided by Finland's natural resources, and the possibilities for adaptation by human society. It provides both detailed descriptions about the methodology and tools for making climate impacts and adaptation assessments, as well as an inventory of realistic adaptation measures. This methodology and information can be used by stakeholders at local, regional, national and international scales. The project, funded by the LIFE+ financial instrument of the European Community, also contributes directly to the development of existing/planned national and international policies and networks in this field.

The Finnish Meteorological Institute (FMI) is a research and service agency under the Ministry of Transport and Communications. The main objective of the FMI is to provide the Finnish nation with the best possible information about the atmosphere above and around Finland. FMI produces high-quality observational data and research knowledge about the atmosphere, combining its know-how into services to benefit of mankind and environment.

In Action 3 of the VACCIA project, FMI derived observational climate data and climate change scenarios for the purpose of impacts and adaptation studies of the ecosystem goods and services at nine LT(S)ER (Long-Term Socio-Ecological Research network) areas in Finland (Fig. 1, left panel). This report documents the final database on climate change scenarios for assessment work in other Actions of the project and gives some illustrative examples.

In the kickoff meeting of the VACCIA project in January 2009, it was decided that the climate scenarios to be constructed and applied in the project should, as far as possible, be consistent with those developed for the Finland's Research Programme on Adaptation to Climate Change (ISTO) (www.mmm.fi/ISTO). These scenarios are documented by Jylhä et al. (2009). Additional information is also available in journal papers Jylhä et al. (2010) and Ruosteenoja et al. (2010), as well as in the internet (http://ilmatieteenlaitos.fi/research_climate/climate_2.html).

2. Data and methods employed

Climate scenarios are constructed based on experiments performed with climate models. The sources of uncertainty involved in climate change projections may be divided into three categories: uncertainties in future emissions (and in associated concentrations and radiative effects) of greenhouse gases and aerosols into the atmosphere, inaccuracies in model formulation, and the noise due to natural climate variability. Because of deficiencies in model formulation, climate models commonly exhibit biases in simulating the present-day climate. To minimize the influence of the bias on estimates of future impacts of climate change, it is recommended to use observed climatological means as a baseline and modify them with the simulated climate change. An implicit assumption in this procedure is that any model bias in a climate simulation is practically independent of the time evolution of radiative forcing, and hence remains unchanged in time. The observational baseline period used in VACCIA is 1971-2000.

2.1 Observations

The FMI regularly measures several kinds of observations at about 500 locations around the country (Fig. 1, middle panel). The observations are routinely stored at the FMI's climate database and are available for research purposes of the VACCIA project. However, the number of locations with comprehensive observations throughout the baseline period of 1971-2000 is considerably lower. In the lack of suitable weather stations near enough for specific data needs of an Action in VACCIA, possible shortcomings in observational network can be covered with a Finnish gridded data set (Venäläinen et al., 2005). The data set consists of daily mean, maximum and minimum temperature, precipitation, specific humidity and global solar radiation interpolated from observations onto a 10 x 10 km grid using a so-called kriging method (Venäläinen et al., 2005). The grid used in the data (Fig. 1, right panel) is based on the Finnish National Coordinate system known as YKJ.
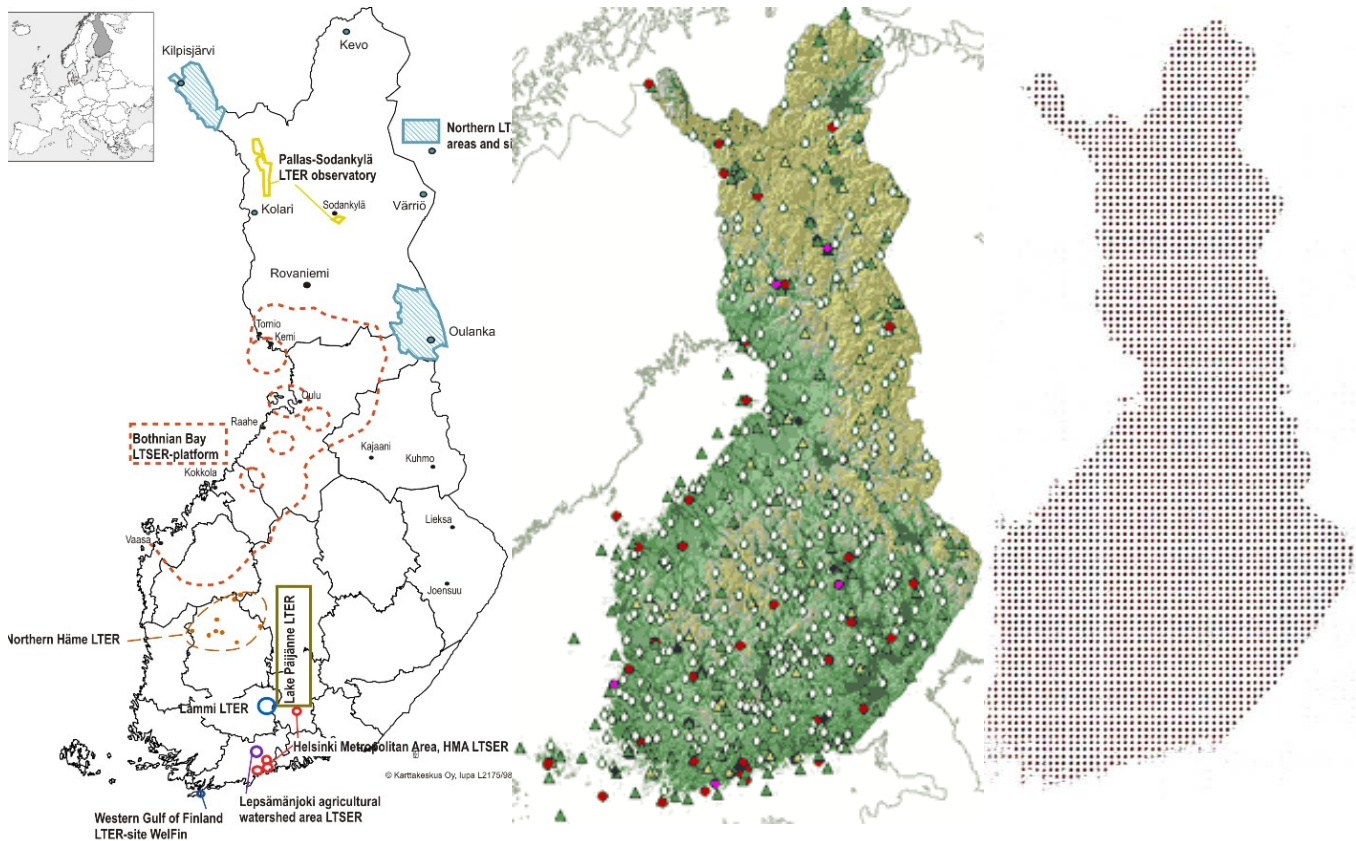

Fig. 1 left: The sitemap of the Finnish LTSER network (source: FinLTSER web pages). Middle: Weather stations in Finland (source: www.fmi.fi/). Right: the grid boxes used for interpolated data (Venäläinen et al. 2005).
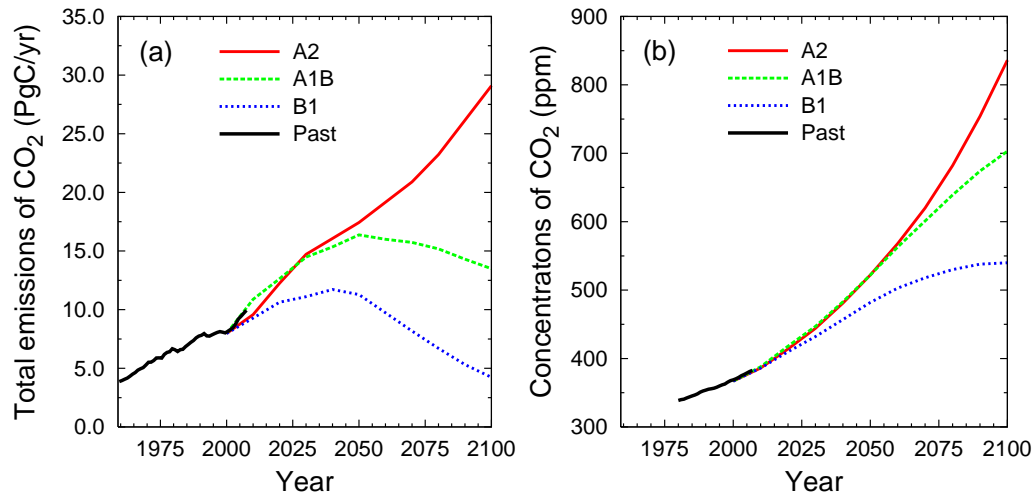
Fig. 2 Estimated temporal evolution of the emissions (a) and atmospheric concentration (b) of carbon dioxide under three SRES greenhouse gas scenarios. Observed emissions and concentrations for years 2000-2007 are depicted as well. Figures for the SRES scenarios are based on IPCC (2001) and the observational data on the Internet pages of the University of East Anglia and NOOA/ESRL.

2.2 Climate scenarios

The climate change scenarios for the VACCIA project were mainly based on research performed in the ACCLIM (Climate change survey and expert service for adaptation assessment) project (Jylhä et al. 2009) within the Finland's Research Programme on Adaptation to Climate Change (ISTO). The scenarios were constructed from output of global climate model (GCM) simulations that originated from the CMIP3 multi-model dataset (Meehl et al., 2007). The scenarios were calculated relative to the modelled 1971-2000 baseline period. For the mean temperature and precipitation, they are derived using output from nineteen GCMs (Table 1); for other climatic variables, a bit smaller ensemble of the models was utilized. Changes in temperature and relative humidity are given in absolute terms; changes in precipitation and global solar radiation are percentages. Three different greenhouse gas and aerosol emission scenarios were considered: SRES A1B, A2 and B1 (Fig. 2). In general, the projections were composed separately for each emission scenario. For scenarios of temperature and precipitation, however, an alternative method was also used: model output for all three emission scenarios were combined, using equal weights (for details, see Jylhä et al. 2009).

The climate change scenarios were primarily developed at a spatial resolution of 0.5° x 0.5° for the period 2001-2099. For mean temperature and precipitation, the grid resolution is 0.25° x 0.25°. Best estimates of the climatic changes, constructed separately for each greenhouse gas scenario, are simply ensemble-means of the 19 GCMs. The 90% probability intervals of the changes were constructed by fitting a normal distribution to the set of projections calculated by the various GCMs and then defined as mean±1.645×standard deviation of the GCM simulations (Ruosteenoja and Jylhä, 2007; Jylhä et al., 2009). As mentioned above, also available, but on coarser 2.5° x 2.5° spatial resolution, are scenarios for mean temperature and precipitation where differences both in GCMs and greenhouse gas scenarios are taken into account in a single probability distribution, regarding the three emission scenarios equally likely. The scenarios are presented as 30-year averages of periods 2010-2039, 2020-2049, 2040-2069 and 2070-2099, or as time-series covering this century.

Table 1. The global climate model experiments considered here, with the model acronym and country of origin. For model documentations, see Randall et al. (2007).

Model	Country
BCCR_BCM2	Norway
CGCM3.1(T47)	Canada
CGCM3.1(T63)	Canada
CNRM-CM3	France
CSIRO-Mk3.5	Japan
GFDL-CM2.0	USA
GFDL-CM2.1	USA
GISS-ER	USA
INM-CM3.0	Russia
IPSL-CM4	France
MIROC3.2(hires)	Japan
MIROC3.2(medres)	Japan
ECHO-G	Germany/Korea
ECHAM5/MPI-OM	Germany
MRI_CGCM2.3.2	Japan
NCAR_CCSM3	USA
NCAR_PCM1	USA
UKMO_HADCM3	UK
UKMO_HADGEM	UK

The period 1971-2000 has been selected to represent a baseline climatology on which to compose future projections; this climatology can be modified on the grounds of climate model projections. In the so-called delta-change method the projected increases of monthly mean temperatures are added to the observed baseline period climatological monthly means. For precipitation, the observed baseline period climatological means are multiplied by the projected relative changes. When projected future climate at single weather stations are of relevance (instead of maps or area averages), the closest point in the 0.5° x 0.5° (or 0.25° x 0.25°) grid is considered.

In some applications of the VACCIA project, monthly resolution of future climate information is not sufficient but daily data are needed. The approach applied here for developing regional climate scenarios at the sub-monthly scale follows the method used in the EU-FP6 funded project ALARM (Assessing LArge scale Risks for biodiversity with tested Methods). In that project scenario information was also primarily provided from GCMs, at a monthly time step. In order to get daily time series, climate change scenarios for monthly mean variables were combined with the inter-annual and inter-decadal variability observed during the 20th century using procedures described by Mitchell et al. (2004). The scenario time series thus incorporated future changes in mean climate but with observed inter-annual and decadal variability unchanged. This allows for a direct comparison between the baseline period and future periods (such as 2020-2049 or 2040-2069) for which only the mean climate has changed. However, it should be stressed that this approach does not account for likely changes in climatic variability with a changing climate.

In the ALARM project, scenarios based on regional climate model (RCM) simulations were also offered, including daily data, in order to offer more detailed information on possible changes in climate variability and extremes. In the current project, RCM data produced in the EU-FP5 project PRUDENCE for the period 2071-2100 may be exploited (Table 2). It has been found out that for changes in snow cover in Finland, projections based on RCM data seem to be more useful than those directly based on GCM data. Consequently, some climate scenarios in VACCIA are based on RCM simulations, although the primary source of information consists of GCM simulations.

Table 2. The regional climate model experiments considered here, with the following characteristics defined: the model acronym; country of origin; acronym of the driving GCM (see the footnotes) and the SRES scenarios employed, together with the number of ensemble simulations (in parentheses).

Model	Country	Driving GCM – SRES scenario (# of runs)
CHRM	Switzerland	H-A2
CLM	Germany	H-A2
HadRM3H	UK	H-A2
HadRM3P	UK	HP-A2(3), HP-B2
HIRHAM (dk)	Denmark	H-A2(3), E'-A2(3), E'-B2
HIRHAM (no)	Norway	H-A2, H-B2
RACMO2[1]	Netherlands	H-A2
RCA3	Sweden	E-A2, E-B2
RCAO	Sweden	H-A2, H-B2, E-A2, E-B2
REMO[2]	Germany	H-A2

[1] indicates not available for the entire domain; [2] denotes not used for summer and autumn.
Acronyms in col. 2: H stands for the HadAM3H AGCM, HP for the HadAM3P AGCM, and E and E' for two parallel runs by the ECHAM4/OPYC3 AOGCM.

3. Products

3.1 Database on climate scenarios

The data set including observations during the period 1971-2000 and climate change scenarios for the 21st century are stored at the FMI's databases. The VACCIA data set is linked to the FMI's database of climate observations and it consists of the following three main components: the common climate change scenario dataset, the Action-specific (or tailored) observational data, and the Action-specific climate change scenarios data (Fig. 3). The tailored climate scenarios delivered for those VACCIA Actions with specific data needs were founded on the common database, but the variables, spatial resolutions and time-scales under consideration somewhat varied among the Actions, as documented in detail in Appendices 1 to 4.
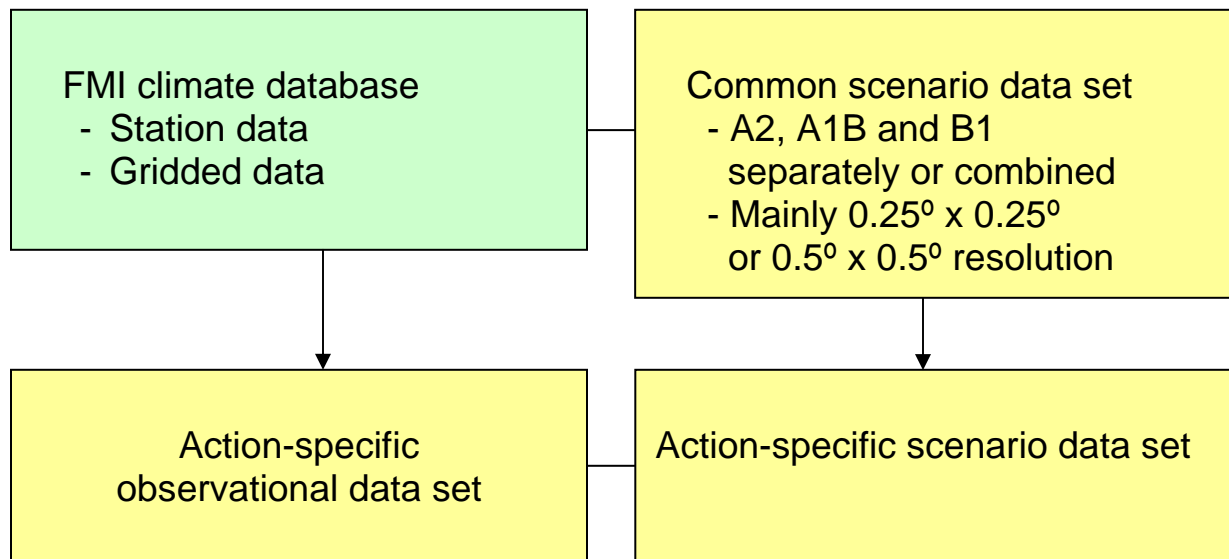
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┌─────────────────────────────┐     ┌─────────────────────────────┐
│  FMI climate database       │     │  Common scenario data set   │
│   - Station data            │─────│   - A2, A1B and B1          │
│   - Gridded data            │     │     separately or combined  │
│                             │     │   - Mainly 0.25⁰ x 0.25⁰    │
│                             │     │     or 0.5⁰ x 0.5⁰ resolution│
└─────────────────────────────┘     └─────────────────────────────┘
            │                                     │
            ▼                                     ▼
┌─────────────────────────────┐     ┌─────────────────────────────┐
│     Action-specific         │     │ Action-specific scenario data set │
│   observational data set    │─────│                             │
└─────────────────────────────┘     └─────────────────────────────┘
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Fig. 3 Database on climate data and climate change scenarios for VACCIA (yellow) and its connection to the FMI climate database (green).

3.2 Illustrative examples

To give a few visualized examples of the common scenario data set, Figures 4-6 are presented. The first one shows the best estimate of changes in annual mean temperature and precipitation across Finland and its surroundings from 1971-2000 to 2020-2049. The second figure indicates seasonal changes in mean temperature and precipitation as area averages for the whole country. Both of these figure are based on output from GCMs, whereas the last figure in derived from RCM data. It represents spatial distribution of projected changes in seasonal mean snow water equivalent in winter and spring by the end of this century.
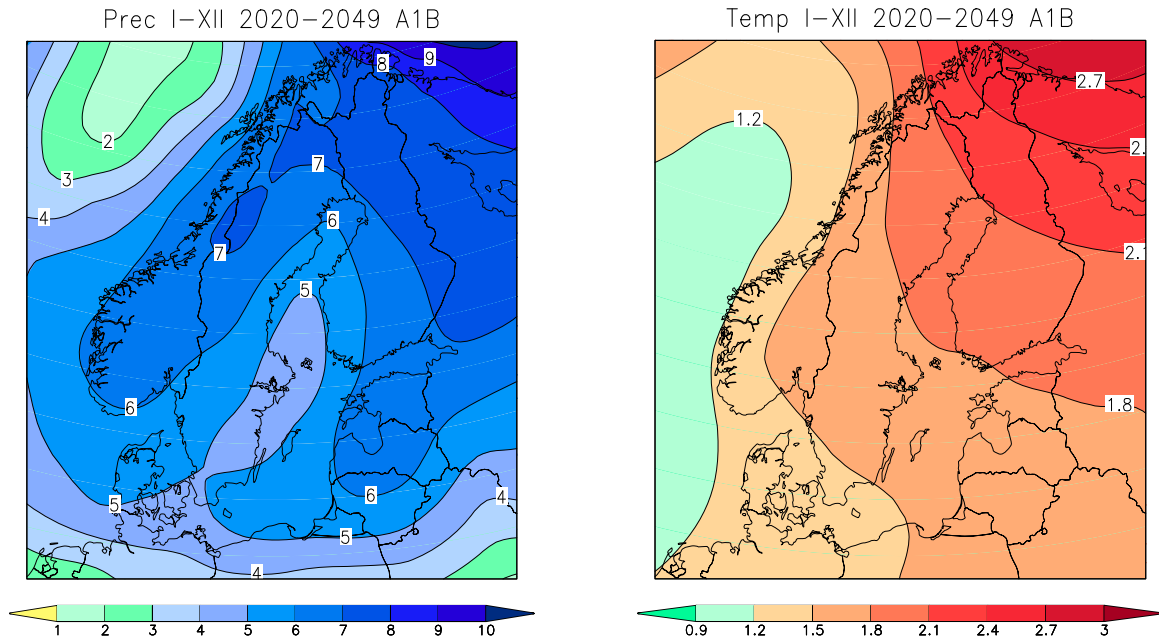
Fig. 4 Spatial distribution of projected changes in annual mean temperature (left panel, unit ℃) and precipitation (right panel, unit %) for the A1B scenario, computed as the multi-model mean difference between 2020-2049 and 1971-2000.
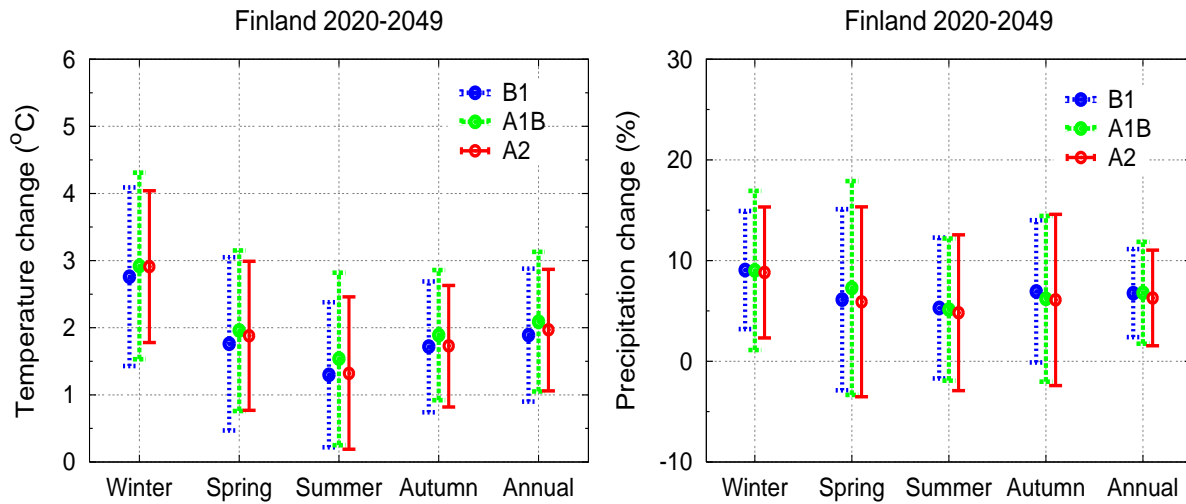

Fig. 5 Seasonal and annual mean temperature (in °C, left panel) and precipitation (in %, right panel) responses in Finland to the SRES A1B, B1 and A2 forcing. Means of the responses simulated by the 19 GCMs are denoted by open circles, 90% probability intervals (mean ±1.645× the standard deviation of the simulations) of the change by vertical bars. All changes are given for the period 2020-2049, relative to the baseline period 1971-2000.
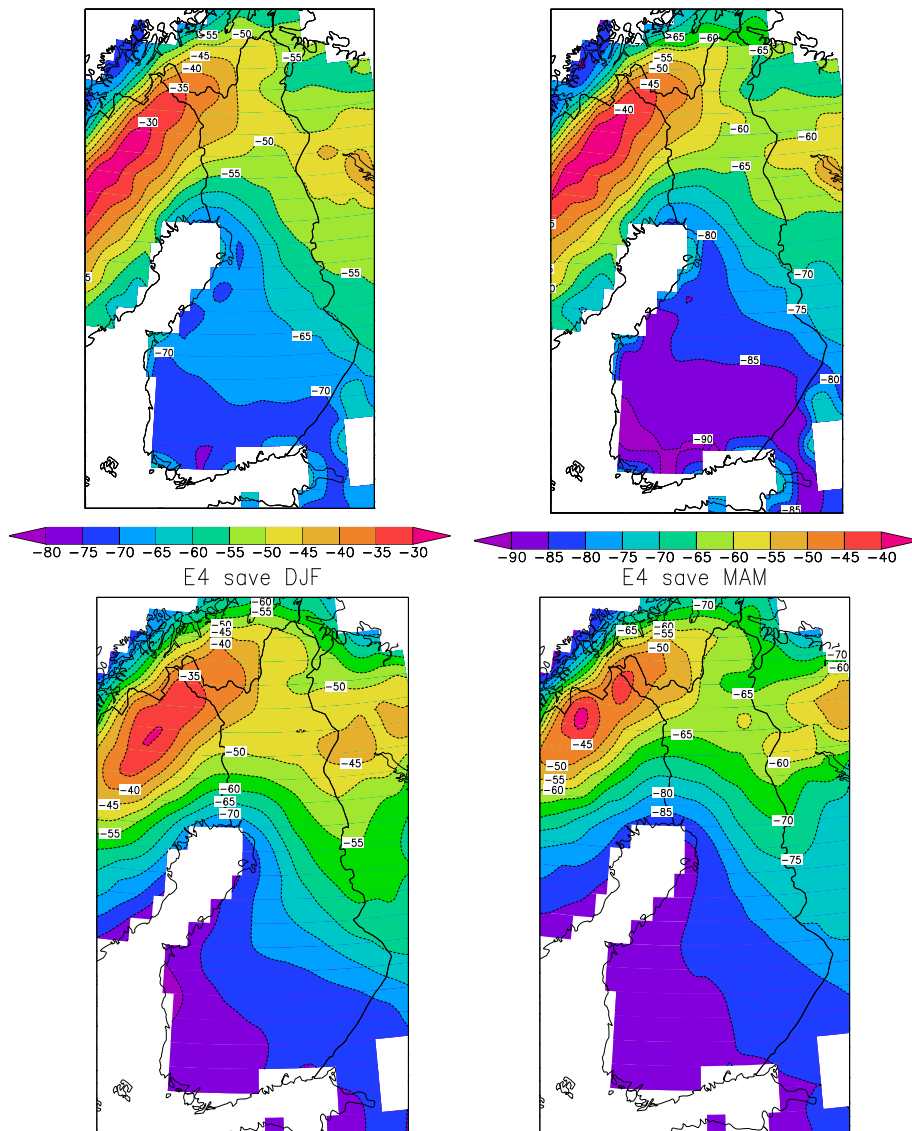
Fig. 6 Spatial distribution of projected changes in seasonal mean snow water equivalent in December-February (left panel) and March-April (right panel) for the A2 scenario, computed as the multi-model mean difference between 2071-2100 and 1961-1990. The first row: based on simulations performed with six RCMs under the lateral boundary forcing from the HadAM3 global climate model. The second row: based on simulations performed with three RCMs under the lateral boundary forcing from the ECHAM5/MPI-OM global climate model. (unit %)

As an example of information produced for a specific Action, Fig. 7 shows observed and projected future development of December and July mean temperature and precipitation in Lahti under the three emission scenarios. Information available via the internet of FMI already prior to the VACCIA project was also disseminated, such as Fig. 8.
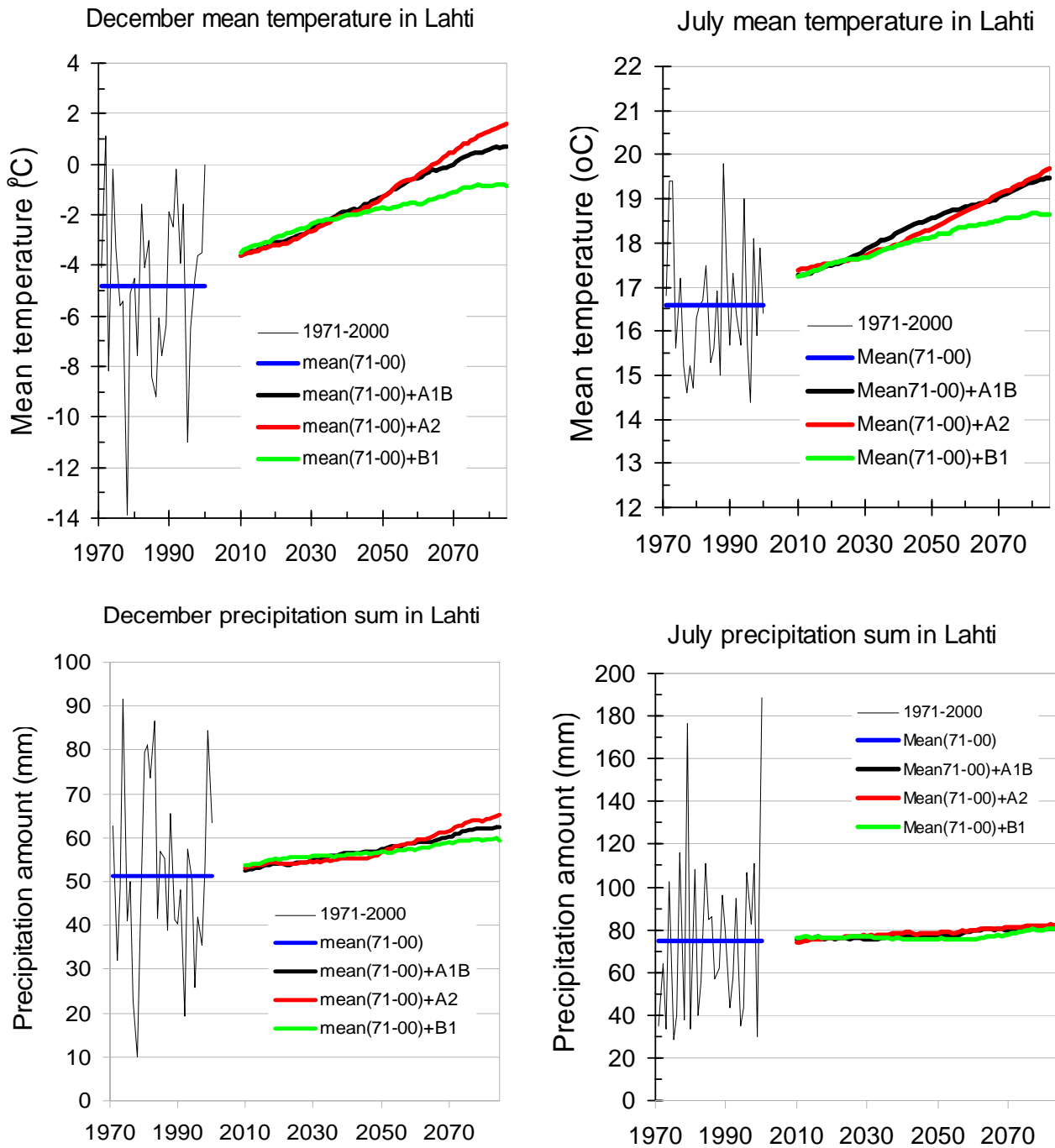
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Fig. 7 Observed time series of December and July mean temperature and precipitation in Lahti (thin black curve) during period 1971-2000, the observed 30-year average (black line) and three future projections (2010-2085) for SRES-emission scenarios B1 (green), A1B (red) and A2 (blue).
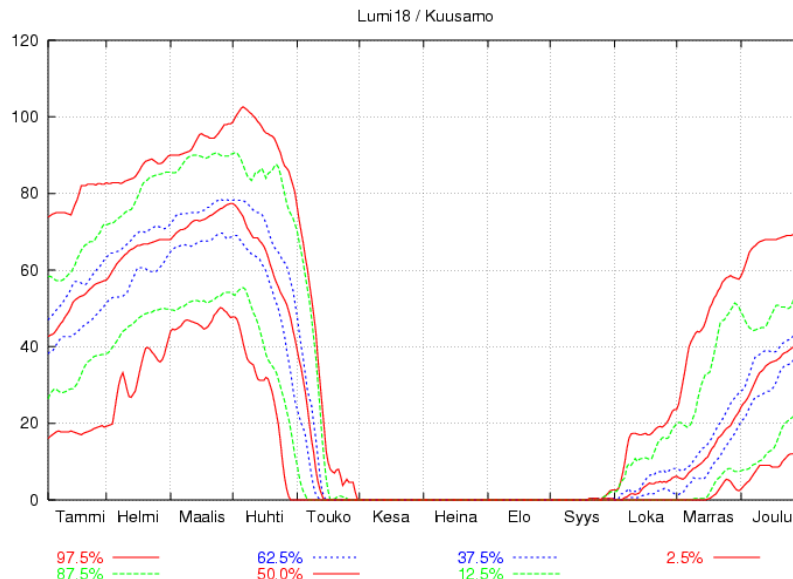
Fig. 8 Observed frequency distribution of snow depth (in cm) during calender days of the year (from January 1 to December 31) in Kuusamo based on observations in 1961-2000. The curves from the bottom to the top give percentiles of 2.5%, 12.5%, 37.5%, 50% (median), 62.5%, 87.5% and 97.5%. Source: Finnish Meteorological Institute.

4. Dissemination

In addition to data in digital format, information on climate change scenarios was also provided as figures (such as Figs. 6 and 8) and as power point presentations. Listed below are oral presentations that are given by the authors and refer to the VACCIA project (most of them in Finnish):

22.01.2009   Ilmastoskenaarioiden laadinta ekosysteemitarkasteluja varten. VACCIA-hankkeen aloituskokous, Helsinki, K. Jylhä

29.01.2009   ”Kuinka ilmastomme arvioidaan muuttuvan”, Hortonomian Yhdistyksen kurssipäivä, Tilastokeskus, M. Laapas.

04.02.2009   “Sataako vielä lunta – miltä näyttää Suomen tuleva ilmasto?” Toimittajakoulutus, Ilmasto muuttuu – missä mennään? Koulutus toimittajille, Helsinki, K. Jylhä

27.05.2009   “Uncertainties in climate scenarios.” Joensuu Forestry Networking Week 25 – 29 May 2009, K. Jylhä

06.10.2009   “Hämeen ilmasto tulevaisuudessa.” Valuma-alueiden ja vesistöjen herkkyys ja sopeutuminen ilmastonmuutoksen vaikutuksiin –seminaari, VACCIA, Lammi, K. Jylhä ja M. Laapas

27.10.2009   “Current climate change scenarios and risks of extreme events for Northern Europe.” Network of Climate Change Risks on Forests (FoRisk), SNS Workshop, Tvärminne. K. Jylhä

26.11.2009   “Miksi meillä on talvi?” II Talvitutkimuspäivät, Koli, K. Jylhä

08.02.2010   “Ilmastoskenaarioiden laadinta ekosysteemitarkasteluja varten (Työpaketti 3).” VACCIA, Lammi, 8.-9.2.2010. M. Laapas

14.04.2010   Ilmastonmuutos ilmiönä ja vaikutukset Suomessa. Studia Generalia–luentosarja Ilmastonmuutos uhka vai mahdollisuus, Joensuun yliopisto. K. Jylhä

07..09.2010   ”Miten Keski-Lapin ilmasto muuttuu?” VACCIA Action 13 seminar, Pallas, 7.-8.9.2010. K. Jylhä

References

Jylhä, K., Ruosteenoja, K., Räisänen, J., Venäläinen, A., Tuomenvirta, H., Ruokolainen, L., Saku, S., Seitola, T., 2009: Changing climate in Finland: estimates for adaptation studies. ACCLIM project report 2009. Finnish Meteorological Institute, Reports 2009:4 (extended abstract and captions of figures and tables in English; in press).

Jylhä, K., Tuomenvirta, H., Ruosteenoja, K., Niemi-Hugaerts, H., Keisu, K. and Karhu, J.A., 2010. Observed and projected future shifts of climatic zones in Europe, and their use to visualize climate change information. *Weather, Climate, and Society*, 2:2, 148-167.

Meehl, G. A., Covey, C., Delworth, T., Latif, M., McAvaney, B., Mitchell, J. F. B., Stouffer, R. J. and Taylor, K.E., 2007. The WCRP CMIP3 Multimodel Dataset: A New Era in Climate Change Research. *Bull. Amer. Meteor. Soc*. 88, p. 1383-1394.

Mitchell, T.D., Carter, T.R., Jones, P.D., Hulme, M. and New, M. 2004. A comprehensive set of high-resolution grids of monthly climate for Europe and the globe: the observed record (1901-2000) and 16 scenarios (2001-2100). *Tyndall Centre Working Paper 55*, Tyndall Centre for Climate Change Research, University of East Anglia, Norwich, UK, 30 pp.

Randall, D.A., R.A. Wood, S. Bony, R. Colman, T. Fichefet, J. Fyfe, V. Kattsov, A. Pitman, J. Shukla, J. Srinivasan, R.J. Stouffer, A. Sumi and K.E. Taylor, 2007: Climate Models and Their Evaluation. In: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M.Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Ruosteenoja K. and K. Jylhä, 2007: Temperature and precipitation projections for Finland based on climate models employed in the IPCC 4th Assessment Report. Third International Conference on Climate and Water, Helsinki, Finland, 3-6 September 2007. Proceedings, p. 404-406.

Ruosteenoja, K., Räisänen, J. and Pirinen, P., 2010. Projected changes in thermal seasons and the growing season in Finland. International Journal of Climatology, n/a. doi: 10.1002/joc.2171.

Venäläinen A., Tuomenvirta H., Pirinen P. and Drebs, A., 2005: A Basic Finnish Climate Data Set 1961-2000 – Description and Illustrations. Finnish Meteorological Institute Reports 5.

Appendix 1: Delivered data for Northern FinLTSER area of Action 12

Data is stored in FMI to \\kori\jakelu\IlmaPalvelu\VACCIA-data

Observational data in areas of Kajaani and Kuusamo (northern Finland)

Daily observations at the weather stations of Kuusamo (65° 59' N, 29° 13' E) and Kajaani (64° 16' N, 27° 40' E) (the latter is close to Sotkamo):

- Daily temperature observations from Kuusamo (1959-2008) and Kajaani (1951-2008), including minimum, maximum and mean values.
- Daily precipitation and snow depth observations from Kuusamo (1959-2000) and Kajaani (1951-2000).
- Variables derived from observations.
  - Monthly and annual mean temperatures (1971-2008).
  - Monthly and annual precipitation sums (1971-2000).
  - Annual amount of days with snow depth over 5 cm and 20 cm (1971-1999).
  - Annual amount of hot days (daily maximum temperature above 25 °C) (1971-2008).
  - Annual amount of days with intense frost (daily minimum temperature below -20 °C) (1971-2008).
  - Annual amount of thaw days (daily minimum temperature above zero) during mid winter (December-February) and period from November to March (1971-2007).

Climate scenarios for areas of Kainuu and Kuusamo (northern Finland)

Future scenarios of changes in monthly, seasonal and annual temperatures and precipitations for three SRES greenhouse gas emission scenarios (B1, A1B and A2), covering period 2010-2085, based on mean results of 19 global climate models:

- Absolute (temperature) and relative (precipitation) changes compared to the 1971-2000 baseline period at the grid points (0.25° x 0.25° grid) closest to Kuusamo and Kajaani.
- Time series of projected development of annual (Kajaani as an example in Fig.6), April, July and December mean temperature and precipitation sum in B1-, A1B- and A2-scenarios.

Additional climate information in central and southern Finland

Data at more southern weather stations of Lahti (60° 57' N, 25° 38' E) and Jämsä (61° 51' N, 24° 47' E) were delivered to act as a comparison.

- Annual, April, July and December mean temperature and precipitation sum observations for period 1971-2000.
- Time series of projected development of annual, April, July and December mean temperature and precipitation sum in B1-, A1B- and A2-scenarios.

Appendix 2: Delivered data for the Lake Päijänne FinLTER area of Action 10

Data is stored in FMI to \\kori\jakelu\IlmaPalvelu\VACCIA-data

Observational data for Lake Päijänne area

Daily observations at the weather stations of Jyväskylä (62° 24` N, 25° 40` E), Lahti (60° 57` N, 25° 38` E) and Jokioinen (60° 48` N, 23° 30` E), covering period 1971-2000 include:

- Daily mean temperature, precipitation, snow depth, mean relative humidity, mean amount of cloud cover, mean sea level air pressure and mean wind speed for all three stations.
- Daily amount of global radiation for Jyväskylä, Jokioinen and Asikkala (close to Lahti)

Climate scenarios for Lake Päijänne area

Daily future scenarios of mean temperature, precipitation and global radiation in Lahti and Jyväskylä.

- Daily scenarios are produced from monthly climate change data by using so-called delta change method, which means that simulated monthly climate change signal is added to daily observations of 1971-2000.
- Climate change signal is based on mean results of 19 global climate models using SRES-B1, SRES-A1B and SRES-A2 greenhouse gas emission scenario.
- Nine 30-year data sets for both locations.
    - o 2010-2039_B1, 2010-2039_A1B, 2010-2039_A2
    - o 2040-2069_B1, 2040-2069_A1B, 2040-2069_A2
    - o 2070-2099_B1, 2070-2099_A1B, 2070-2099_A2

Appendix 3: Delivered data for VACCIA Action 7 and Action 8

Data is stored in FMI to \\kori\jakelu\IlmaPalvelu\VACCIA-data

Climate scenarios for Lepsämänjoki agricultural watershed area FinLTSER and Lammi FinLTER

- Future scenarios of changes in monthly mean temperatures and precipitation sums for periods 2010-2039, 2040-2069 and 2070-2099.
- Climate change signal is based on mean results of 19 global climate models using SRES-B1, SRES-A1B and SRES-A2 greenhouse gas emission scenarios.

Appendix 4: Delivered data for uncertainty assessment in VACCIA Actions 7, 8 and 10

Data is stored in FMI to \\kori\jakelu\IlmaPalvelu\VACCIA-data

Daily mean temperature observations (1971-2000) at the weather stations of:
- Jyväskylä 62° 24` N, 25° 40` E (northern part of Päijänne LTER).
- Lahti 60° 57` N, 25° 38` E (southern part of Päijänne LTER).
- Lammi 61° 03` N, 25° 02` E (Lammi LTER).
- Vihti 60° 25` N, 24° 24` E (Lepsämänjoki LTSER).

For collective uncertainty assessment between Actions 7, 8 and 10, daily temperature scenario data with median and the 90% probability intervals of the changes were produced by combining results of 19 GCMs in all three emission scenarios considered.

Daily future scenarios of mean temperature in Jyväskylä, Lahti, Lammi and Vihti were produced using the so-called delta change method. The resulting data include:
- 30 years of daily data for period 2040-2069.
- Three different climate change signals (5th, 50th and 95th percentiles) from probability distribution combining results from 19 GCMs and three SRES emission scenarios (B1, A1B and A2).