# Effects of projected climatic changes on $CO_2$ and $H_2O$ fluxes in pine forest ecosystems in Karelia, Russia

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**The main goal:** To describe possible effects of proposed climatic changes in 21 century on $H_2O$ and $CO_2$ fluxes in pine forest ecosystems of Karelia in Russia using modeling and experimental data.

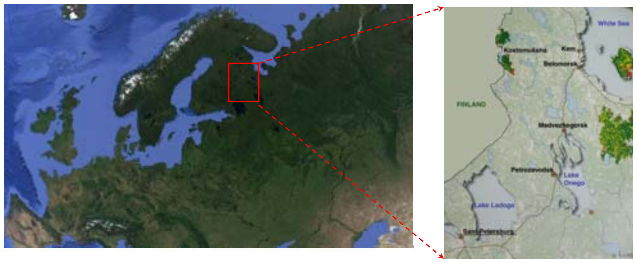

**Fig. 1:** Geographical location of the research areas.

**Climatic projections:**

Projected climate conditions for the study area in the 21 century were described using the modeling results provided by the ECHAM5 global model, MPI Hamburg, Germany (Roeckner et al. 2003). ECHAM5 reanalysis dataset (Roeckner 2004) was used to quantify present climate conditions. To generate the future meteorological conditions the moderate A1B emission scenario (IPCC 2007) was selected. In the first step, the possible century trends of the air temperature, air humidity, solar radiation, precipitation and wind speed for study area in Karelia were obtained as a difference between the predicted values for period 2080-2100 (Roeckner et al 2006) and the values taken for period 1980-2000 from reanalysis datasets (Roeckner 2004). The trends were calculated using average values from 3 model runs for four points located close to the area. In the second step, future annual patterns of meteorological conditions (with 1 hour time resolution) for the area was generated from the meteorological data set of 2000 (taken as reference) using obtained climatic trends (Fig. 3).

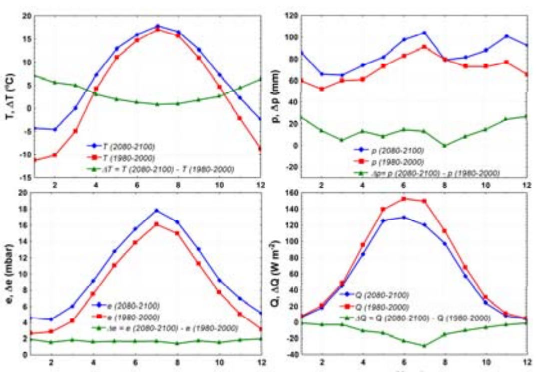

**Fig. 3:** Annual mean patterns of air temperature (T), precipitation (p), water vapor pressure (e), solar radiation (Q) and their expected changes (ΔT, Δp, Δe and ΔQ) for period from 1980-2000 to 2080-2100 projected by the ECHAM5 model according to A1B climatic scenario for the study area

**Study area:** For the modelling study the 100-150 year old pine forest located about 40 km from Petrosavodsk in the area of State reserve "Kivach" was selected (Fig. 1-2). Required biophysical and ecophysiological parameters of the trees were collected during the long-term field measurements at experimental sites of the Forest Research Institute of Karelian Research Center of RAS.

**Fig. 2:** Karelian pine forests.

**Model description:**

The Mixfor-SVAT is an one-dimensional process-based SVAT model for description of the energy, $H_2O$ and $CO_2$ exchange between vertically structured mono- and multi-specific forest stands and the atmosphere (Olchev et al. 2002, 2008, 2009). The main concept used in the model is an aggregated description of the physical and biological processes in a forest ecosystem on different spatial scales: individual leaf, individual tree and entire ecosystem. For description of the different scale processes Mixfor-SVAT uses both species specific and species averaged input parameters. The processes occurring inside of an individual leaf or tree (e.g. transpiration, water uptake, precipitation interception, water storage, photosynthesis, respiration) is described using individual species specific input parameters. Exchange processes between different tree species within each sub-layer, as well as the processes at the ecosystem scale (e.g. turbulent exchange, radiative transfer) are described using species averaged parameters. This approach allows describing both entire ecosystem $H_2O$ and $CO_2$ fluxes and also flux partitioning among different tree species and canopy layers in the forest stand.

Mixfor-SVAT was calibrated and validated using results of ecophysiological and micrometeorological measurements in different types of forest ecosystems of Karelia and showed a good agreement of modeled and measured fluxes.

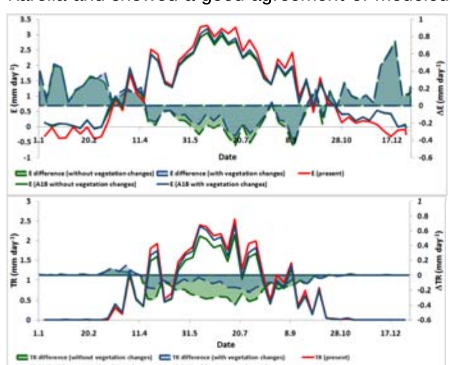

**Fig. 4:** Modelled patterns of evapotranspiration (E), and transpiration (TR) for present and future (A1B) climatic conditions with/without changes of vegetation biomass.

**Results:**

Modelling experiments to estimate an impact of projected climatic changes on $CO_2$ and $H_2O$ fluxes in pine forest ecosystems were carried out for two scenarios of vegetation changes. The first scenario assumes keeping of present vegetation properties, and the second one assumes changes of LAI, root density and stem diameter of trees due to climatic changes and in accordance with predicted trend of NPP changes. LAI under these conditions is estimated by an iteration method taking into account that:

$$\frac{\left(NPP_{A1B} - NPP_{present}\right)/NPP_{present}}{\left(LAI_{A1B} - LAI_{present}\right)/LAI_{present}} \approx 1.0$$

Results of modelling experiments show quite varied patterns of possible changes of $CO_2$ and $H_2O$ fluxes caused by climatic and vegetation changes (Fig. 4-5, Table 1).

Increases of $CO_2$ concentration, air temperature and precipitation are the main factors responsible for future increasing the NEE, GPP, NPP and RE of pine forests. Despite of the expected warming and moistening of the climate the modeling experiments indicate a relatively weak increase of annual ET and decrease of TR of forest ecosystems probably due to expected reduction of incoming solar radiation and water vapor deficit.

Provided modelling experiments may be a very useful for solution of the different theoretical and applied tasks, e.g. forecasting of the future dynamics of vegetation cover, forest canopy, water and carbon cycles, and ecological expertise.

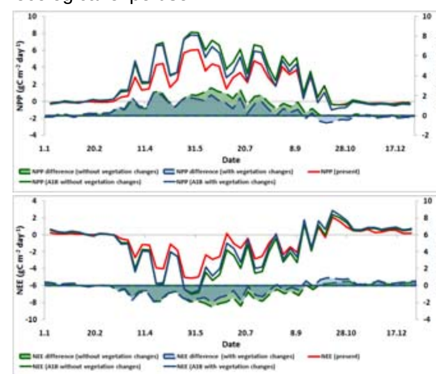

**Fig. 5:** Modelled patterns of Net Primary Productivity (NPP) and Net Ecosystem Exchange (NEE) for present and future (A1B) climatic conditions with/without changes of vegetation biomass.

**Table 1:** Modelled annual E, TR, NEE, GPP and NPP for present and future (A1B) climatic conditions with/without changes of vegetation biomass.

| | E (mm) | TR (mm) | NEE ($gC\ m^{-2}$) | GPP ($gC\ m^{-2}$) | RE ($gC\ m^{-2}$) | NPP ($gC\ m^{-2}$) |
|---|---|---|---|---|---|---|
| **Present conditions** | 418.5 | 263.7 | -312.9 | 1441.1 | 1128.2 | 599.1 |
| **End of 21 century (A1B without vegetation changes)** | 426.1 | 229.2 | -522.6 | 1805.9 | 1283.3 | 903.9 |
| **End of 21 century (A1B with vegetation changes)** | 437.6 | 247.3 | -433.7 | 1895.2 | 1461.5 | 787.8 |

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