BioDiv-Support Newsletter March 2021

Scenario-based decision support for policy planning and adaptation to future changes in biodiversity and ecosystem services.

The BioDiv-Support research program is a three-year project, involving eight partners from five European countries. The research is in full progress and this newsletter gives you a summary of the project so far, and an update on upcoming project activities.

Understanding future changes in biodiversity, climate and air pollution in high-altitude areas

Loss of biodiversity is one of the major problems currently facing humanity. Among the greatest threats are climate change, change of habitats and air pollution. High altitude mountain regions represent some of our most pristine environments, often with small historical impacts from air pollution, but at risk of disproportionate impacts from climate change. Arctic high-altitude regions are especially at risk from both climate change and increasing air pollution loads due to disappearing sea ice.

Meadow on the border between the national parks Sarek and Padjelanta, with blue bell in the foreground. Scandes Mountains, Sweden. Photo: Elin Sjöqvist.

We are developing future scenarios for decision makers and end users of ecosystem services to enable informed decisions for adaptation and policy on local and regional scale. The scenarios represent possible developments until the 2050s. We aim to improve the scientific knowledge on expected vegetation change and ecosystem service impacts. We will also assess uncertainties associated with the scenarios.

Locations of the mountain areas studied in the project; Scandes Mountains, the Pyrenees Mountains and the Spanish Central Mountain system.

We base our work on case studies in three mountainous regions, namely the Spanish Central Mountain System including the Guadarrama Mountains, the Pyrenees Mountains and the Scandes Mountains. We also use the results to draw conclusions about other areas, such as the Alps, the Arctic and the Nordic region.

In this newsletter you can find information from the case studies, as well as published research on the impact of model resolution on climate and air pollution estimates, the climate penalty on near-surface ozone, and the effect of future Arctic shipping on air pollution.

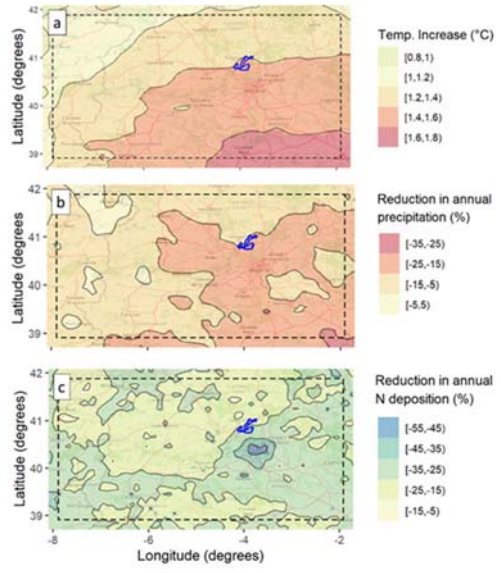
The Spanish Central Mountain system – rich biodiversity threatened by climate change and air pollution

The Spanish Central System mountain range extends more than 450 km across the centre of the Iberian Peninsula, passing approximately 50 km north of Madrid. As well as having a large number of Mediterranean plant species, the mountains also act as a refuge for species more typical of the colder climates in central Europe, leading to a rich biodiversity. Climate change is a threat to this biodiversity, since although low altitude species are able to move slowly up the mountain slopes, thus avoiding increasing temperatures and drought, those at high altitudes have no similar refuge. Air pollution is another threat to these mountain ecosystems, which are exposed to high concentrations of tropospheric ozone and high rates of atmospheric nitrogen deposition, problems that are exacerbated due to the proximity to Madrid.

Sierra de Gredos in the Central System, Spain. Photo: M. Toro.

Downscaled climate simulations at a spatial resolution of 10 km (EURO-CORDEX*), using the IPSL-CM5** climate model as boundary conditions (CMIP5 RCP8.5 scenario), suggest that during the period 2000 to 2050, mean annual temperatures in the mountains are projected to increase more than 1.4 °C and annual precipitation to decrease by up to 20%, under this low ambition greenhouse gas emissions scenario. Air quality modelling using the CHIMERE model shows that projected reductions in emissions (principally nitrogen oxides) during the same period are expected to reduce nitrogen deposition by more than 20%, as well as reduce maximum ozone concentrations, although the latter will be partly compensated by the increasing temperatures. Initial results from a dynamic vegetation model (LPJ-GUESS) suggest that the projected changes in climate will indeed favour the movement of Mediterranean species to higher altitudes to the detriment of the endemic species, increasing the risk of local extinction.

In the next phase of the project we will use high-resolution climate and air quality simulations, coupled with the dynamic vegetation model to estimate the changes in the mountain biodiversity during the period 2000-2050. These results will be used to develop tools that will enable stakeholders to explore the potential impacts of these changes and develop strategies to mitigate them, whilst considering the impact of other pressures such as tourism and grazing.



Projected changes in mean annual temperature (top), annual precipitation (middle) and annual nitrogen (N; bottom) deposition for the period 2000 to 2050. The dashed line shows the modelling domain for the Central System and the blue line is the Sierra de Guadarrama National Park.

* https://www.euro-cordex.net/

** https://cmc.ipsl.fr/ipsl-climate-models/

Pyrenees Mountains – unique biodiversity with risk of reduced habitat availability

With ~130 peaks exceeding 3000 m in altitude the Pyrenees Mountains represent a natural border between France and Spain. The range is more than 450 km long and ~100 km wide, spanning in a west-east direction from the Atlantic Ocean to the Mediterranean Sea. The Pyrenees' biodiversity is rich and unique, with more than 4500 vascular plant species and 180 endemic species. The Pyrenees is one of the European plant biodiversity centers, threatened by climate change.

Pyrenees mountains.

According to our new climate simulations, the warming effect is more marked in mountain areas (the Alps and the Pyrenees). Here, the average temperature change will exceed 2°C by the middle of the century under a scenario with strong future growth in greenhouse gas emissions (RCP8.5). Climate change has strong geographic variations with 20% less precipitation on the Mediterranean side and 20% more on the Atlantic side, when comparing two extended periods for the past (1961-1991) and the future (2041-2051). Results are highly sensitive to large-scale circulation change: we rely solely on one model and one climatic scenario (RCP8.5 with the EURO CORDEX simulation by WRF-IPSL-CMIP5). We will include a wider spectrum of climate projections to reduce the associated degree of uncertainty in the next phase of the project.

Generally, we expect more extended droughts, more severe heatwaves and more frequent extreme precipitation events. More heatwaves are likely to cause more frequent high ground-level ozone events, potentially increasing plant stress and damage. Other pollutants, such as nitrogen deposition, can significantly influence plant growth over the region where nitrogen deposition currently greatly exceeds critical loads.

Assessing the combined effect on the mountain ecosystem of pollution and climate change is critical. With increased temperature, the Pyrenees' vegetation is likely to change. Our studies show marked differences in plant communities across the entire Pyrenees Mountains, with vegetation zones climbing higher up in altitude, likely resulting in reduced habitat availability for species adapted to the higher altitudes.

Although it is highly unlikely that efforts to combat climate change will have a significant effect by the middle of the century, air quality can be improved more rapidly. Our focus in the coming months of the projects will be to assess whether the benefits in air pollution could partly compensate the negative impacts of climate change.

Scandes Mountains - a part of the shrinking Arctic

The Scandes Mountain range is one of the longest in Europe, 1700 km long and up to 300 km wide, located on the western side of the Scandinavian peninsula, with substantial variations in climate depending on latitude, elevation, lee and wind side. The range includes a variety of different ecosystems, from rich and moist deciduous forests to tundra in alpine areas. Biodiversity hotspots are located in both the south and the north.

Continued temperature increase, including fewer cold and more warm extremes, is expected, including rainfall events in the winter that can change the ecological conditions. More precipitation is generally projected, but wet and dry extremes are expected to become more pronounced. Snowfall is projected to be reduced everywhere except for high-altitude sites in winter. Reduction in snow cover will amplify the climate warming.

Low alpine region, rich vegetation of low woody plants including a wide range of willow (Salix) species. Photo: Håkan Pleijel, Härjedalen, Sweden.

During recent decades Scandinavian mountain regions have experienced an advancement of the tree-line. Above the tree-line, a higher abundance of medium to tall shrub species is observed in moist to wet areas. In dry communities, there has been an increase in semi-prostrate evergreen shrubs like heather and crowberry. Changes in winter conditions are also common with more frequent episodes of winter warm spells, ground icing and rain-on-snow events damaging vegetation and altering ecosystem services such as carbon storage and grazing grounds for reindeer husbandry.

Initial modelling results (using LPJ-GUESS) suggest that increasing temperatures during the 21st century will likely lead to increased vegetation productivity, driven by the generally taller and denser vegetation, with shrub expansion in the milder regions, and expansion of grasses in the coldest, and the continued upwards and northward movement of tree and shrub vegetation. This advance will proceed more slowly than climate change, due to the competition from prevailing vegetation and a threshold for establishment of new species. Furthermore, the niche for cold adapted species will shrink and an overall loss of biodiversity is expected for the mountainous region of the Scandes.

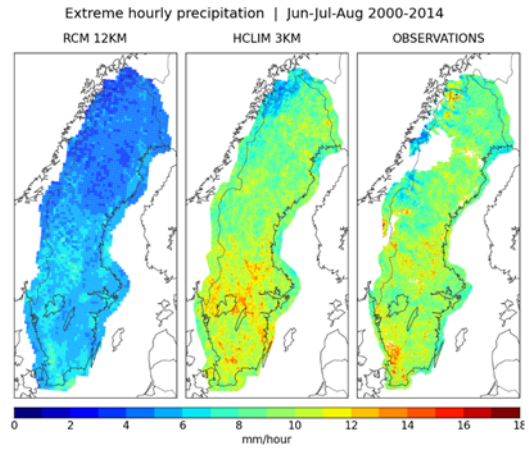
Awareness of the adverse impacts on vegetation of near-surface ozone and nitrogen deposition has been one of the drivers to decrease in human emissions of nitrogen oxides in Europe since the 1980s. This decrease is projected to continue until mid-21st century, leading to decreased nitrogen deposition and to a reduction in the highest ozone concentrations in Fennoscandia, while ozone concentrations in the low to moderate range may continue to increase. Nitrogen deposition impacts biodiversity adversely by promoting specific species over others, while the impact of ozone on wild plants in the Scandes is poorly understood.

From distant to near: Alpine region, mountain birch belt and conifer belt. Characteristic vegetation zones in the Scandes mountains. Photo: Håkan Pleijel, Härjedalen.

In the next phase we will proceed with detailed analyses of how climate change, air pollution load and management combine to impact biodiversity in the Scandes Mountains.

Improved simulation of precipitation with a new high-resolution climate model

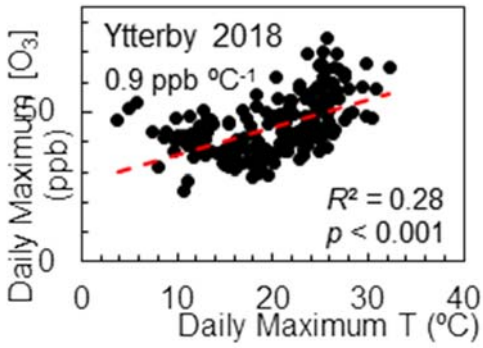
As the climate changes, climate models with high horizontal grid resolution become increasingly important as a basis for decision making. A new generation of such models, so called “convection-permitting” climate models have shown superior performance in simulating important aspects of the climate including extremes. We have published the first long-term (1998-2018) simulation over Fenno-Scandinavia with the HCLIM regional convection-permitting climate model. The results are very promising, with HCLIM (when compared with observations), providing a more realistic representation of precipitation with respect to coarser-scale climate models. Specific improvements include an increased and more realistic occurrence of higher intensity events, an improved timing and amplitude of the diurnal cycle, and an improved relative occurrence of snowfall versus rain in the Scandinavian mountains.



Intensity of extreme hourly summer precipitation in a currently available regional climate model (RCM, left), HCLIM at “convection-permitting” grid resolution (centre) and HIPRAD observations (right).

Learn more: Lind et al. 2020. https://doi.org/10.1007/s00382-020-05359-3

Heat wave promoting high ozone



Relationship between daily maximum ozone concentration and temperature in the summer of 2018. Ozone increased by 0.9 ppb $^{o}C^{-1}$ in this year. For the period 2013-2017 the corresponding figure was 0.4 ppb $^{o}C^{-1}$.

During the summer of 2018 large parts of Europe were affected by a long-lasting heat wave. Johansson et al (2020) showed that the heatwave conditions promoted high ozone concentrations in south-west Sweden. In comparison with the preceding 5-year period, it was also observed that the rate of increase in summer ozone concentration with temperature was stronger in 2018. A possible explanation for this pattern is that the dry conditions prevailing during the heatwave significantly reduced the stomatal uptake of ozone by vegetation, thus enhancing ground-level concentrations of ozone.

Learn more: Johansson et al., 2020. http://www.borenv.net/BER/archive/pdfs/ber25/ber25-039-050.pdf

Mid-21st century Arctic shipping projected to cause negative impacts in the Nordic region

International initiatives have successfully brought down the emissions from shipping in Emission Control Areas, thus reducing the associated negative impacts on environmental and human health. The question is if this is enough to mitigate the expected future increase in shipping activities. We have studied the impact of future shipping

scenarios on air pollution exposure in the Arctic and the Nordic region.

Arctic ice bergs.

From our air pollution exposure calculations, we estimate that 850 people die prematurely yearly in the Nordic region due to shipping. This shipping contribution is projected to decrease to 700 cases by 2050 in a business as usual air pollution scenario based on the ECLIPSE V5 emission inventory, while a heavy fuel oil ban would decrease the shipping-related premature deaths to 550. A high-growth scenario in arctic shipping, with no additional regulation and high growth leads to a small increase in shipping-related premature deaths (900).

Learn more: Geels et al., 2021. https://doi.org/10.5194/acp-2020-1274

Sulfur in high-Alpine ice cores confirm the need for a high model resolution

Atmospheric chemical transport modelling of sulfate in precipitation at different high-Alpine sites shows that depending on the spatial model resolution (50 km or 12 km), concentrations either differ (50 km) or compare well (12 km) to observations extracted from ice cores. This shows that the high-resolution modelling in this project improves the representation of deposition in high altitude areas.

The alps.

Learn more: PSI annual report 2020 https://www.psi.ch/en/luc/annual-reports

A web tool to plan for adaptation and damage control and project web site

We are developing a planning tool for evaluating vegetation change in mountainous regions for a range of likely future scenarios, covering changes to climate and air quality, socio-economic and policy development, and management practices. Stakeholders and end users are being engaged to investigate which climate, air pollution and ecosystem indices are of most interest, as well as the design of the web service.

In the next phase of the project we will use high-resolution climate and air quality simulations, coupled with the dynamic vegetation model to estimate the changes in the mountain biodiversity and ecosystem services during the period 2000-2050. These results will be used to continue the development of the tool that will enable stakeholders to explore the potential impacts of these changes and develop strategies to mitigate and adapt to them, while considering the impact of other pressures such as tourism and grazing. A prototype of the web tool will be published on the project web page shortly.

Visit the project web page to keep updated on the project:
http://smhi.se/research/biodivsupport

Acknowledgement

The project is funded through the 2017-2018 Belmont Forum and BiodivERsA joint call for research proposals, under the BiodivScen ERA-Net COFUND programme, and with the funding organisations AKA (contract no 326328), ANR (ANR-18-EBI4-0007), BMBF (KFZ: 01LC1810A), FORMAS (contract no:s 2018-02434, 2018-02436, 2018-02437, 2018-02438) and MICINN (through APCIN: PCI2018-093149).

Contact: biodiv-support@smhi.se

PIs

Camilla Andersson, SMHI, Sweden
Augustin Colette, INERIS, France
Robert Björk, UGOT, Sweden
Thomas Hickler, BiK-F, Germany
Jukka-Pekka Jalkanen, FMI, Finland
Paul Miller, LU, Sweden
Gunhild Rosqvist, SU, Sweden
Marta Vivanco, CIEMAT, Spain