UNDERSTANDING FUTURE CHANGES IN BIODIVERSITY, CLIMATE AND AIR POLLUTION IN HIGH-ALTITUDE AREAS

BIODIV-SUPPORT

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Loss of biodiversity is one of the major problems facing humanity. Among the greatest threats are

- climate change
- destruction of habitats
- air pollution exposure.

High altitude mountain regions are one of our most pristine environments, often with small historical impacts from air pollution but at risk for disproportionate impacts from climate change.

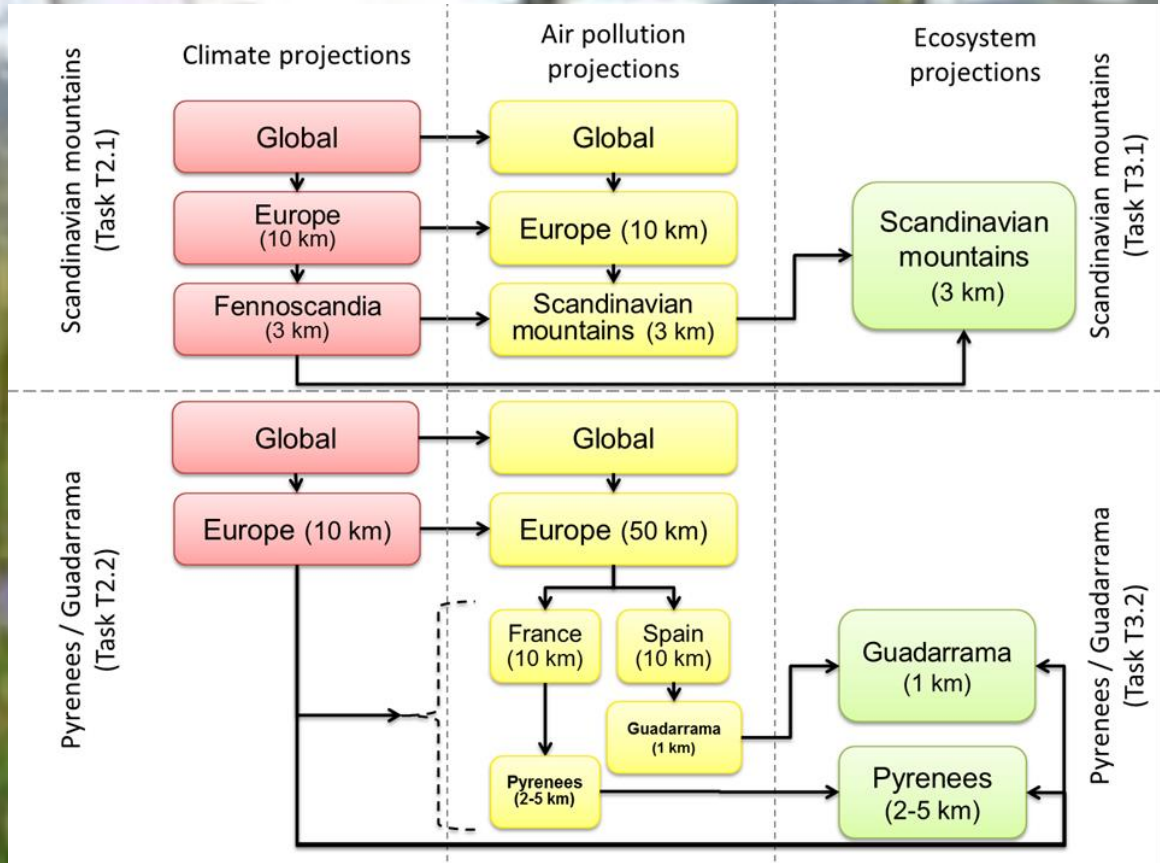
Future scenarios until **2050s** modelled on an unprecedented high resolution (up to 1-3 km) in the **high-altitude case areas** for

- **Ecosystem** development
- **Climate** development
- **Air pollution** development

Objectives

1. To improve the scientific knowledge on expected vegetation change and ecosystem service impacts, connecting the local, regional and global scales with a main focus on high-altitude mountainous areas
2. To produce a planning tool for evaluating vegetation change in mountainous areas for a range of likely future scenarios covering
    a. Climate change and air quality including deposition
    b. Socio-economic and policy development
    c. Management practices
3. To estimate and disseminate uncertainties associated with the scenarios


Scandes
Mountains
Pyrenees
Mountains
Spanish Central
Mountain System


Climate projections
Air pollution projections
Ecosystem projections
Scandinavian mountains (Task T2.1)
Global
Europe (10 km)
Fennoscandia (3 km)
Global
Europe (10 km)
Scandinavian mountains (3 km)
Scandinavian mountains (3 km)
Scandinavian mountains (Task T3.1)
Pyrenees / Guadarrama (Task T2.2)
Global
Europe (10 km)
Global
Europe (50 km)
France (10 km)
Spain (10 km)
Guadarrama (1 km)
Pyrenees (2-5 km)
Guadarrama (1 km)
Pyrenees (2-5 km)
Pyrenees / Guadarrama (Task T3.2)

Web tool, web site, newsletters

Web tool for decision support was developed in the project, in close interaction with stakeholders from e.g. forestry authority, SEPA, County Boards – e.g. for selection of indices and scenarios
https://biodivsupport-tst.smhi.se/

Visit the project web site
https://www.smhi.se/en/research/research-departments/air-quality/biodiv-support-1.145930

Read about project results and newsletters

Email: biodiv-support @ smhi.se

BioDiv-Support

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The BioDiv-Support research program started in 2019, involving eight partners from five European countries. The research project is in its final phase and this newsletter provides a summary of the results achieved in the project.

Biodiversity is an ecological concept that refers to the variety of organisms, species and interactions (and even to the genetic variation within specific species) that occurs in a certain habitat or region. High biodiversity usually means a more resilient ecosystem and a substantial contribution of basic ecosystem services vital for human survival and well-being.

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 with high biodiversity, 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 changed human activities as a result of disappearing sea ice (e.g. shipping, flaring).

Meadow on the border between the national parks Sarek and Padjelanta, with blue bell in the foreground.
Foto Elin Sjökvist

We have used a chain of state-of-the-art models to describe potential future impacts from climate change and air pollution to ecosystem development at high altitudes, focusing on three mountain regions, namely the Scandinavian Mountains (the Scandes), the Spanish Central Mountain System

BIODIV-SUPPORT PROJECT

BioDiv-Support project

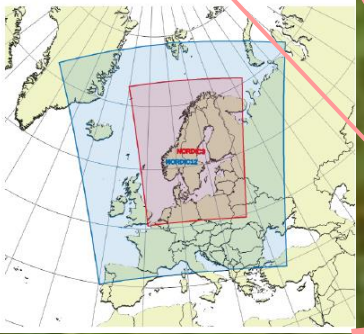
Main scientific findings of the BioDiv-Support project

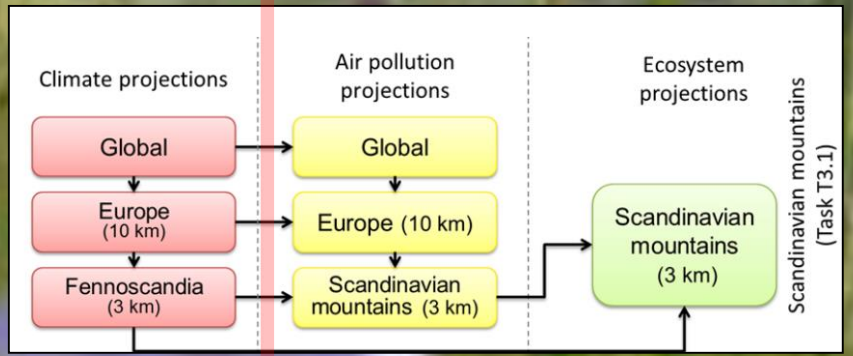
BioDiv-Support: Spanish Central Mountain system

The Scandinavian Mountains

Convective-permitting

- Periods (20 years):
  - ERA-Interim: 1997 – 2017
  - Historical GCMs: 1985 – 2005
  - Mid-century GCMs: 2040 – 2060
  - End of century GCMs: 2080 – 2100
- GCMs:
  - EC-Earth
  - GFDL
- RCP8.5 & 4.5





EC-EARTH
ALADIN
AROME
(HCLIM)

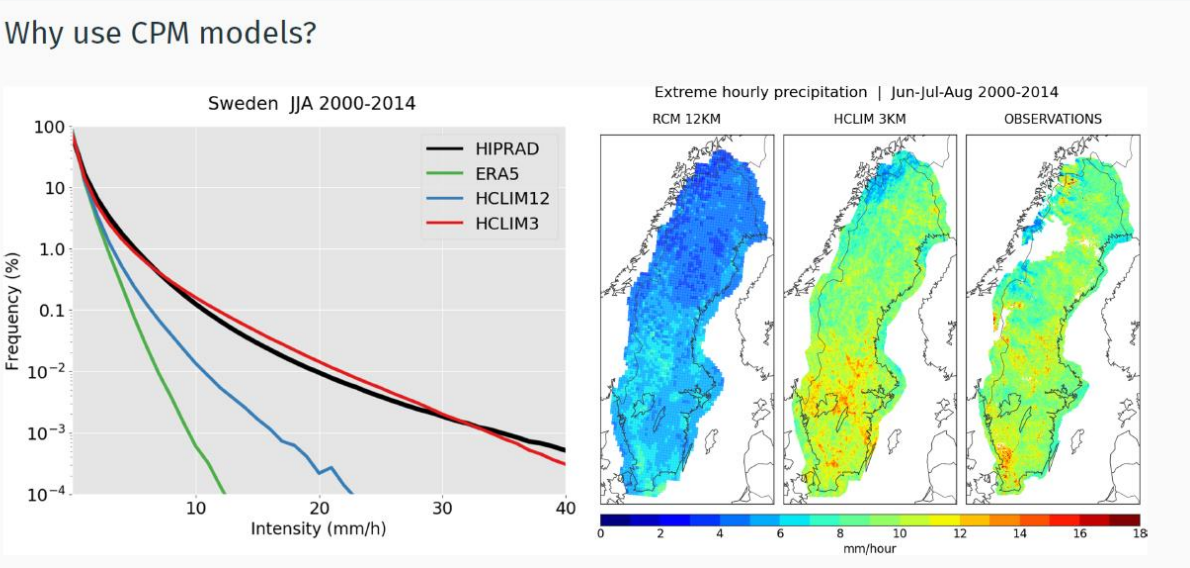
MATCH 12km
MATCH 3km

LPJ-GUESS
- Reindeer grazing
- *O3 deposition impacts*

Climate change

HCLIM Convective permitting model based on RCP8.5
3km resolution from 1990s to 2050s - 20 year averages

The unprecedented, very high spatial and temporal resolution permits an **improved assessment of the frequency and intensity for extreme precipitation events** and a wider range of climate change indicators including also in areas of complex terrain.



· Lind P, Belušić D, Christensen OB, et al (2020) Benefits and added value of convection-permitting climate modeling over fenno-scandinavia. Climate Dynamics 55(7-8):1893–1912.
· Lind, P., Belušić, D., Médus, E., Dobler, A., et al (2022) Climate change information over Fenno-Scandinavia produced with a convection-permitting climate model, Climate Dynamics. https://doi.org/10.1007/s00382-022-06589-3

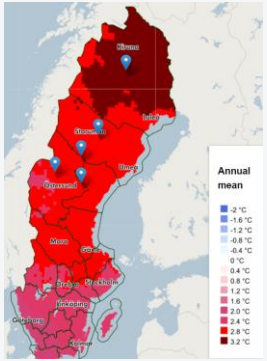
Climate change

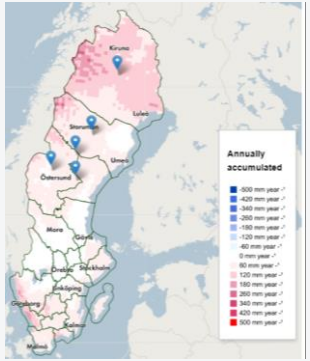
HCLIM Convective permitting model based on RCP8.5
3km resolution from 1990s to 2050s - 20 year averages

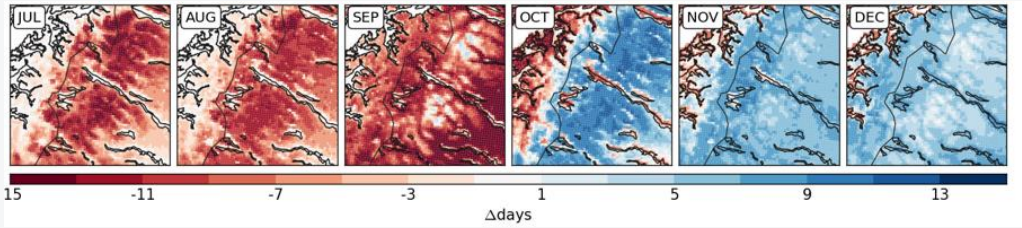
Highest temperature increase in the north

Increased frequency of extreme weather, e.g. heatwaves

Changed frequency of rain-on-snow events and zero-crossings







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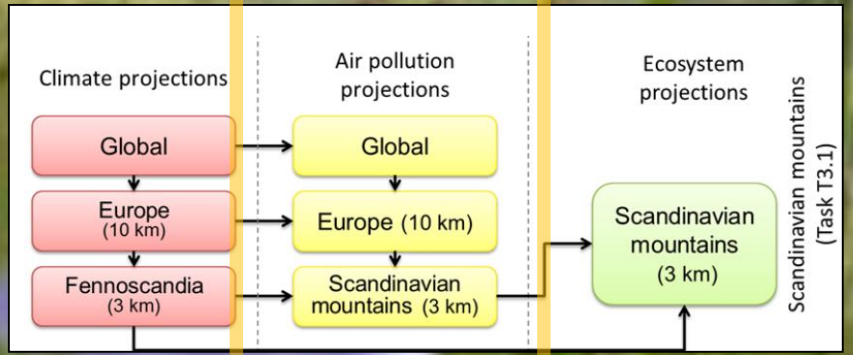
The Scandinavian Mountains



EC-EARTH
ALADIN
AROME
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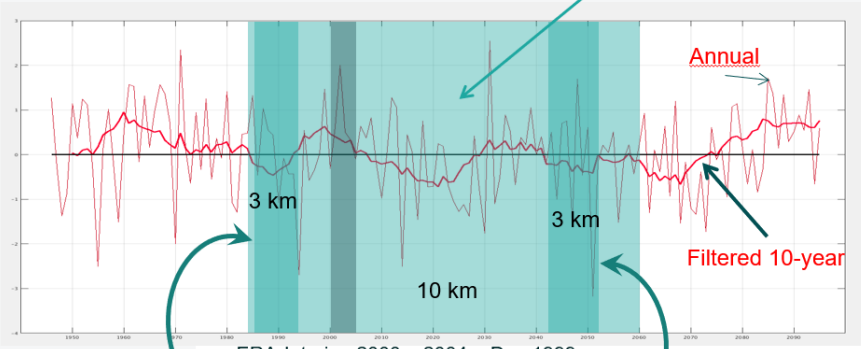
MATCH 12km
MATCH 3km

LPJ-GUESS
- Reindeer grazing
- *O3 deposition impacts*

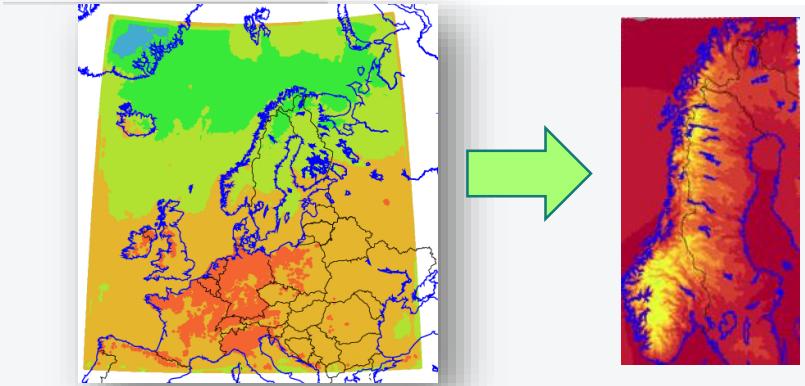
Time windows for air pollution simulations with MATCH

transient run, 10km, 1987-2051

In accordance with the NAO index

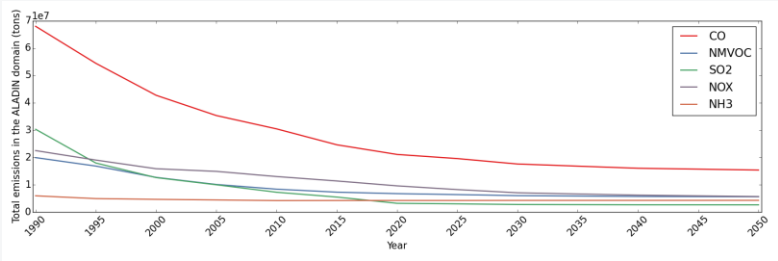


- ERA-Interim: 2000 – 2004 + Dec 1999
- Historical: 1987 – 1996 + Dec 1986
- Mid-century: 2042 – 2051 + Dec 2041
- Historical CEMIS 2050: 1987 – 1996 + Dec 1986 10km only

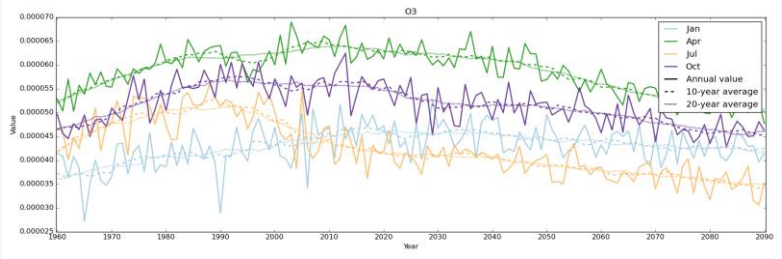


Input data to MATCH CTM

- Meteorology HCLIM
  10km and 3km resolution
- Emissions ECLIPSE V6b



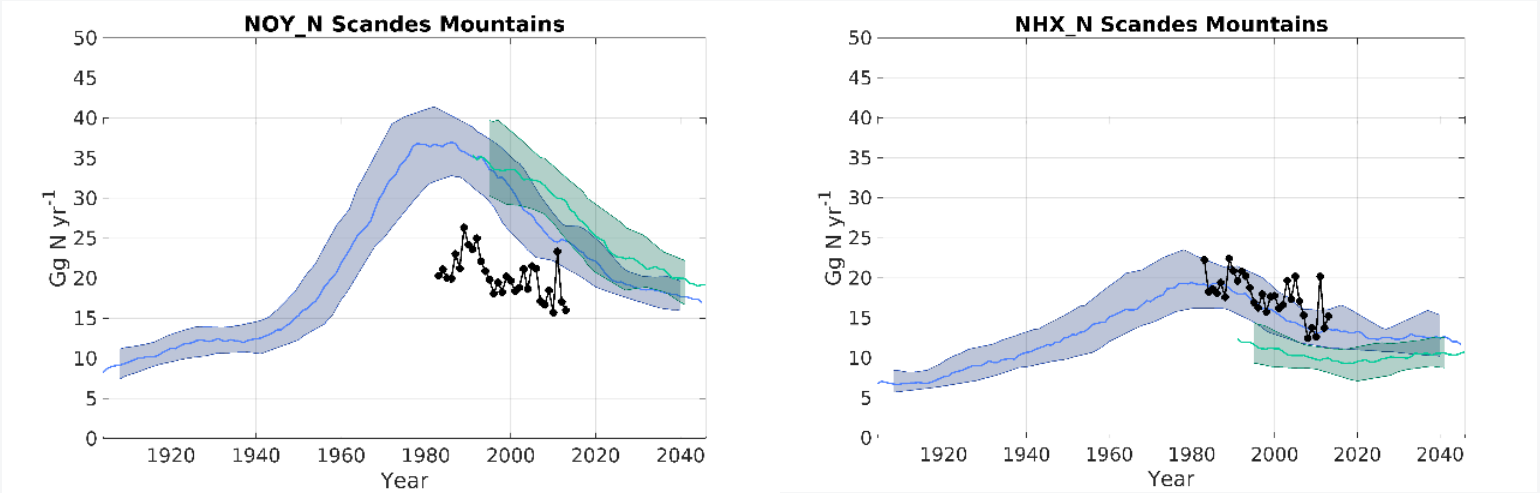
- Lateral boundary conditions LMDZ-INCA



Reduced nitrogen deposition is projected to continue at present levels in Scandinavia

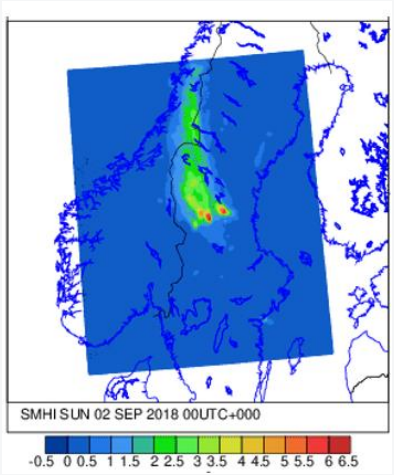
Policy has led to decreasing nitrogen deposition in Europe, but despite this the pressure is still far above preindustrial levels in most parts of Europe, also at high altitude areas such as the Scandinavian Mountains.

Critical loads of nitrogen will still be exceeded in mid-21st century in parts of Europe. Additional policy action is necessary, especially for agriculture!

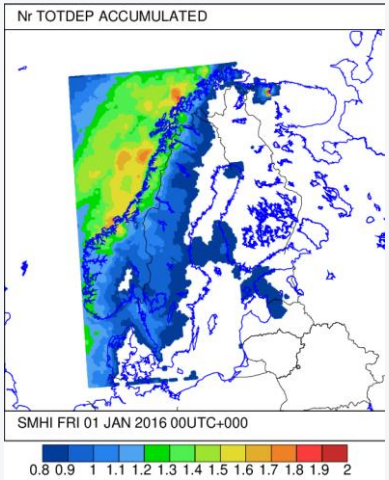


Andersson et al., 2023, in prep

Relative impact to Ndep of future potential wildfire and shipping

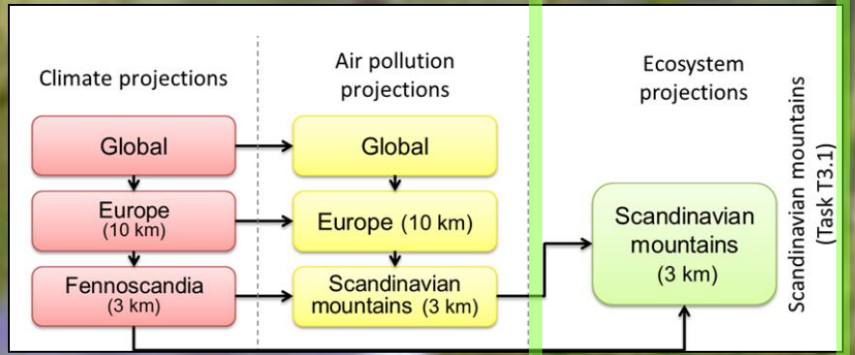


Impact from Wildfire
Factor 3-6 more deposition compared to current



Impact from future HG shipping
Factor <2 more deposition compared to current

The Scandinavian Mountains



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LPJ-GUESS
- Reindeer grazing
- *O3 deposition impacts*

Ecosystem change
LPJ-GUESS

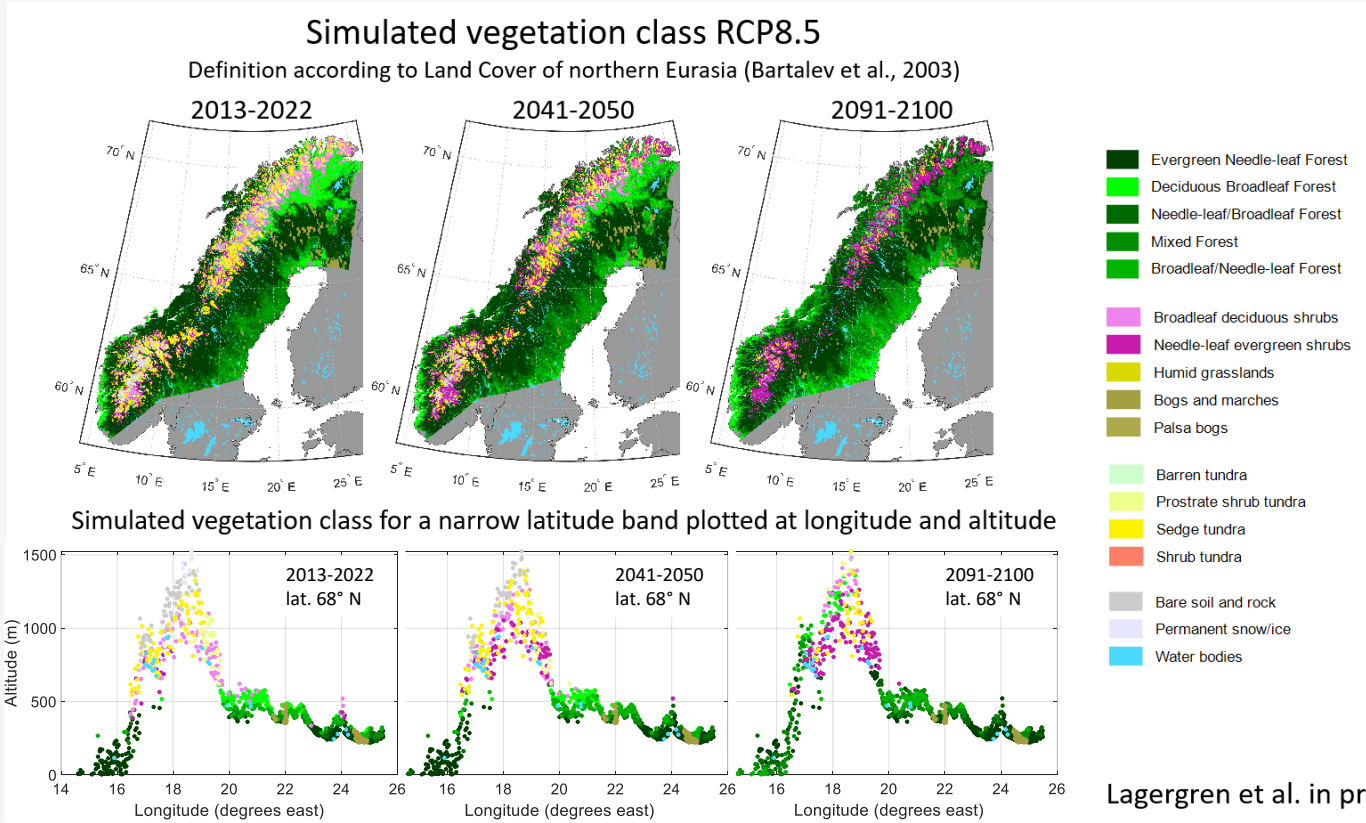
Vegetation zones are projected to shift to higher elevations and towards the north in high alpine areas

Tundra disappears almost completely in 2100 (shrubification)

Increased vulnerability/ extinction of species

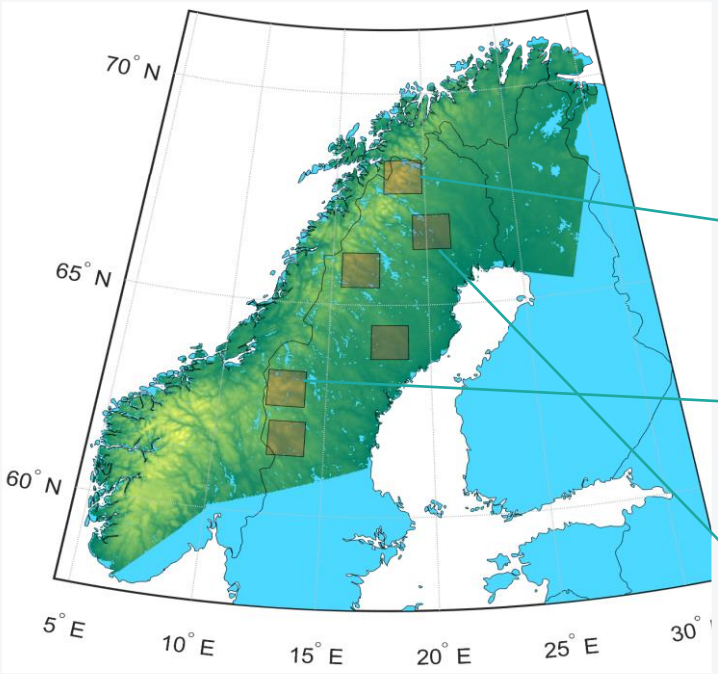
Forestry practices

Herding practices, e.g. reindeer management

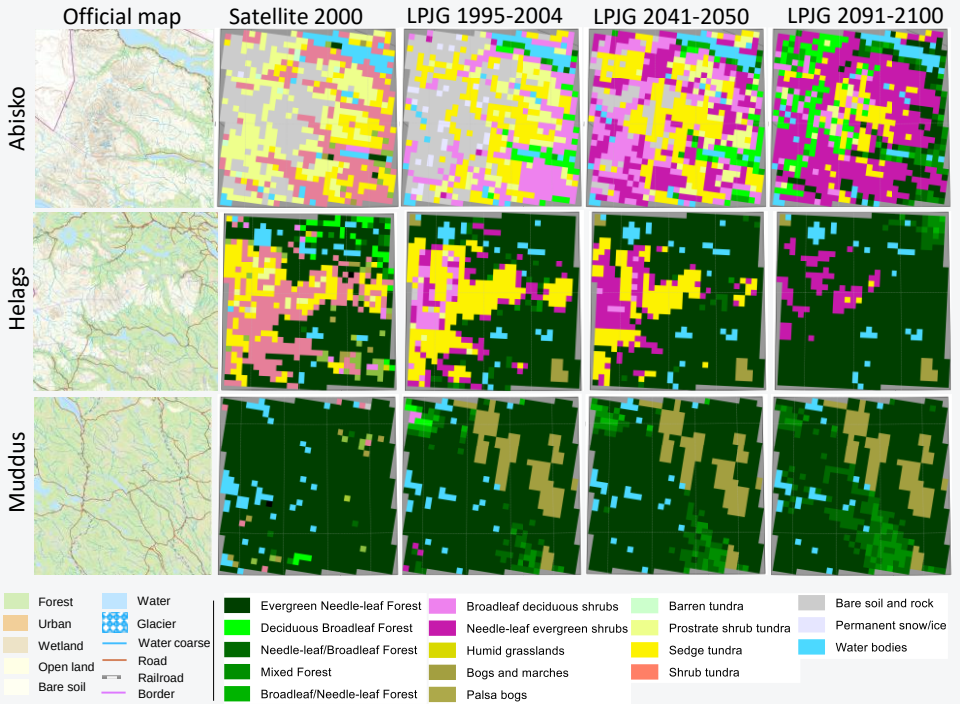


Lagergren et al. in pr

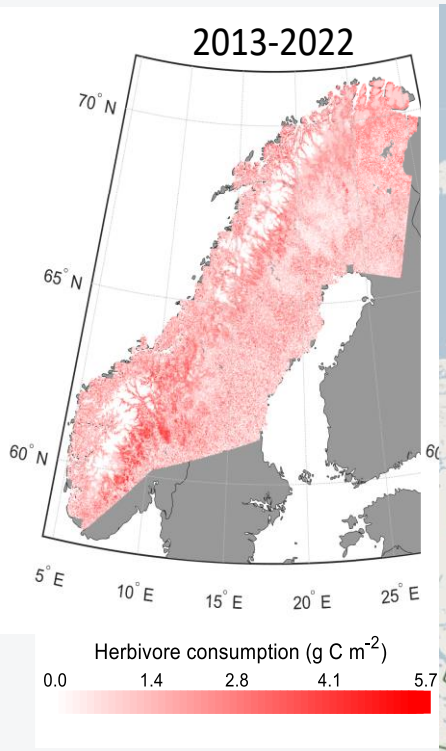
Many Alpine species will likely be added to the threatened list

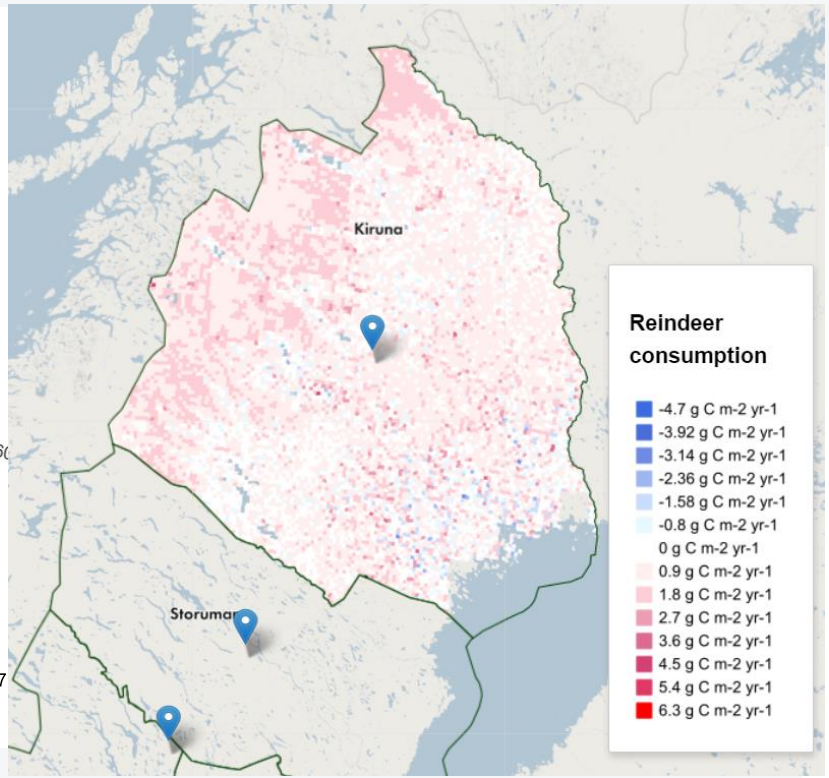


5% of 2765 threatened species in the mountains today



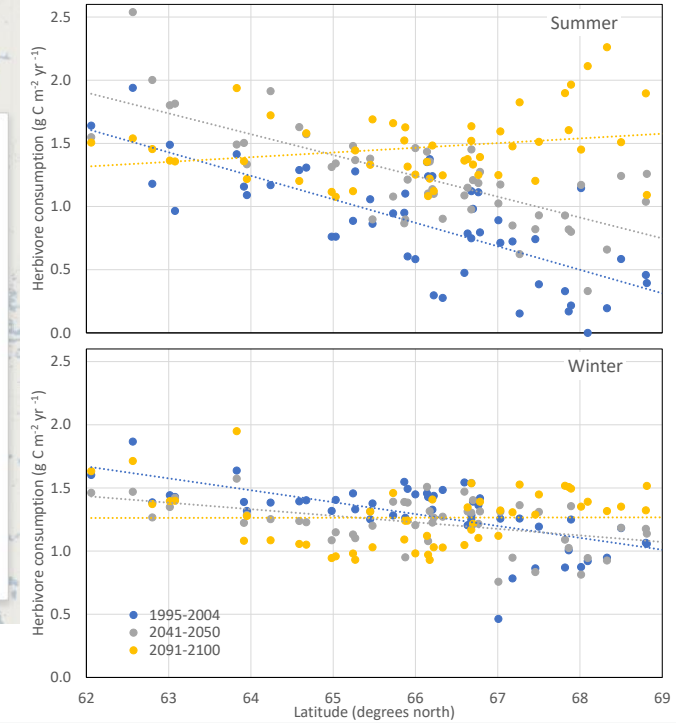
Potential reindeer feed increases, but the shift in vegetation poses a major challenge to reindeer management





Simulated potential reindeer consumption (g C m^{-2} yr^{-1}) 2013-2022 and the change to 2041-2050 and 2091-2100 based on RCP8.5.

Simulated potential reindeer consumption in reindeer-herding communities in Sweden for the summer and autumn grazing grounds, based on RCP8.5



Ecosystem change
LPJ-GUESS

Drivers of ecosystem change in the Scandinavian Mountains

Management practices mainly forestry

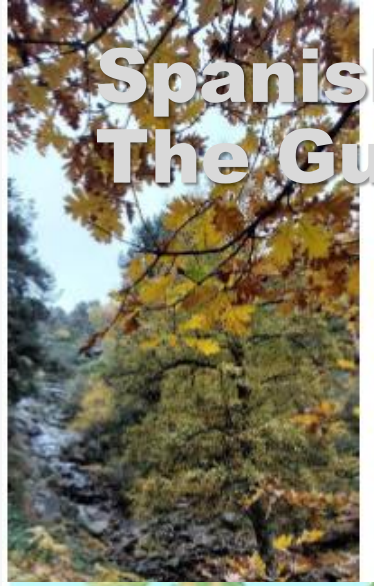
Grazing (reindeer, moose)

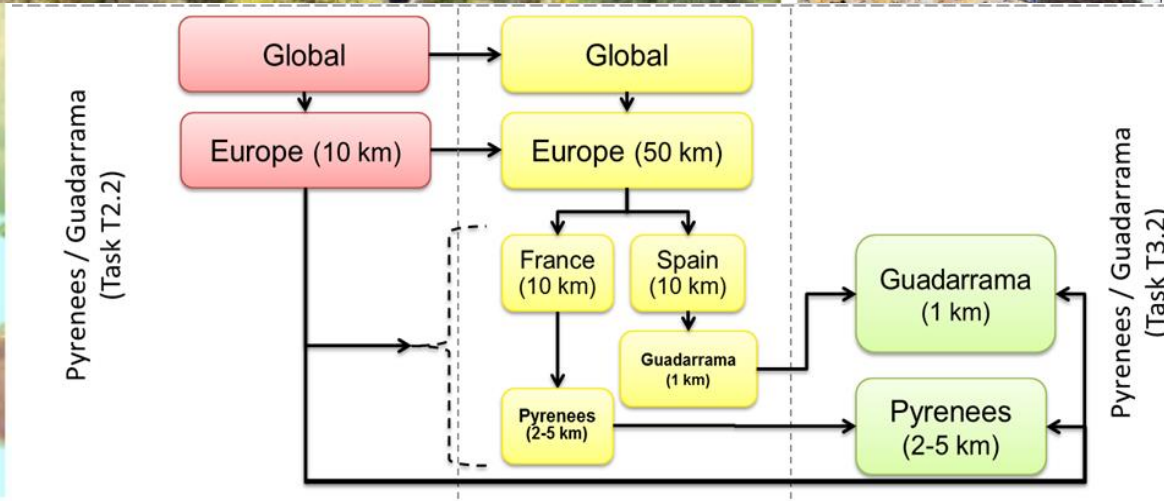
Physical change

- Temperature
- CO_2
- Nitrogen deposition

Ozone exposure impacts not included yet

Spanish Central Mountain System
The Guadarrama





1990 2000 2010 2020 2030 2040 2050

1996-2005 — *10 x 10 km² (Iberian Peninsula)* — 2046-2055

1996-2005 — *3 x 3 km² (Central System)* — 2046-2055

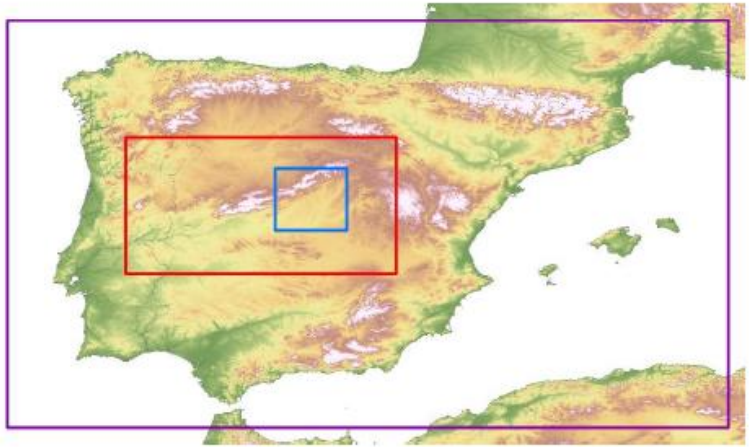
1999-2001 — *1 x 1 km² (Sierra de Guadarrama)* — *2049-2051*

+ Gap-filling of intermediate years

Emissions: ECLIPSE V6b (CLE, CLE2010)

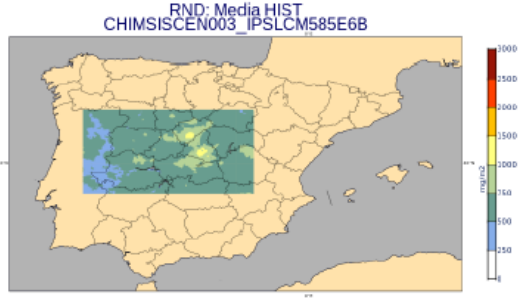
Meteorology: Downscaled (WRF)/interpolated IPSL CMIP5 (HIST, RCP8.5)

Boundaries: INERIS CHIMERE (CLE, CLE2010; ~50 × 50 km² (CORDEX44s))

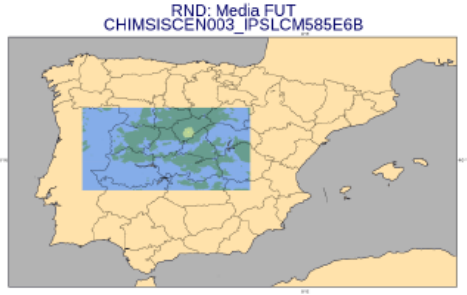


Total Reactive Nitrogen Deposition

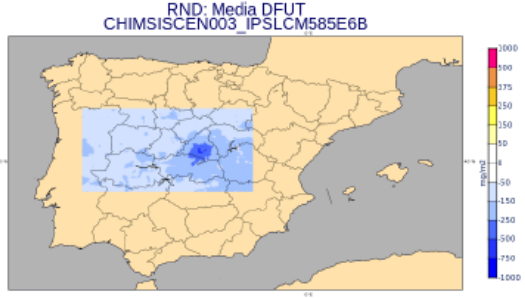
Changing emissions and climate



HIST

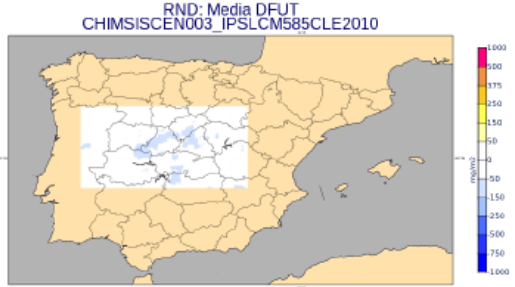


FUT



Change (HIST-> FUT)

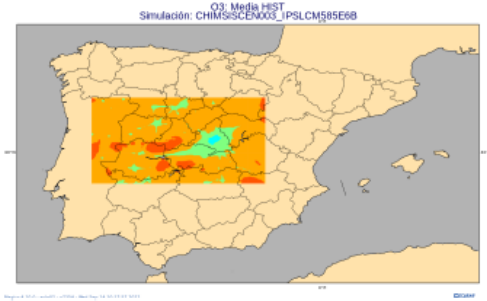
Changing climate only



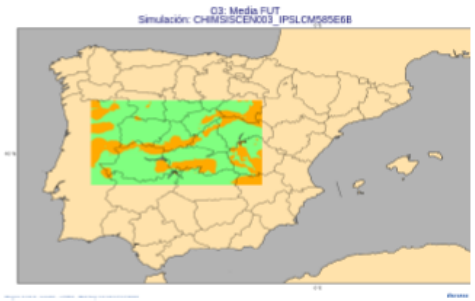
Change (HIST-> FUT)

Mean O_3 concentrations

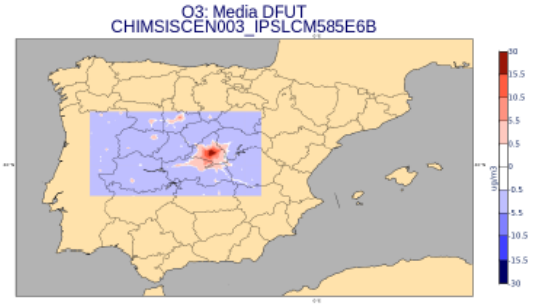
Changing emissions and climate



HIST



FUT



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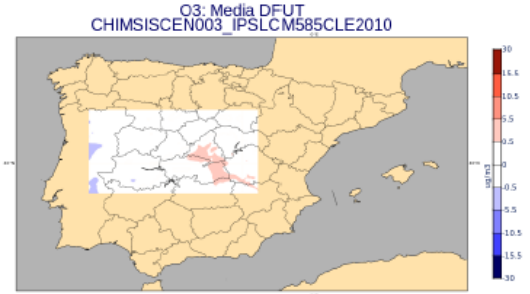
Changing climate only



Change (HIST-> FUT)

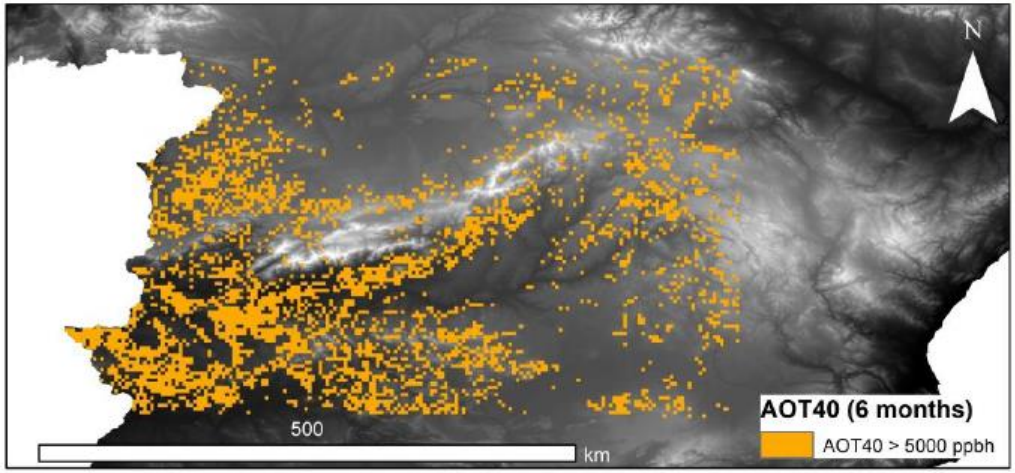
Risk Assessments for vegetation of the Central System

AOT40 -O_3 exposure- based indicators

AIR CONVENTION
Critical level for
- **DECIDUOUS FOREST**
- **PERENNIAL PASTURES**

6-month AOT40
10 000 μg m^{-3} h (5000 ppb h)

FUTURE



- ✓ Whole DECIDUOUS FOREST and PERENNIAL PASTURE lands under ozone risk
- ✓ No improvement in the future

The Spanish Central System is expected to meet the target value for impacts to vegetation set out in the current EU Air Quality Directive, but not the corresponding long-term objective.

Conclusions

- Vegetation zones/types are projected to shift to higher elevation and towards the north in high alpine areas
  - Thundra and bare soil will disappear to a large degree
  - Likely expanded list of vulnerable Alpine species
  - Major shift in reindeer management needed
- Additional policy action is necessary for air pollution mitigation, especially for agriculture and traffic emissions
  - Critical loads of nitrogen will still be exceeded in mid-21st century in parts of Europe.
- Higher resolution in climate models leads to improved models, including frequency for extreme precipitation events
- We have developed a decision support tool, newsletters and a web site

Thank you for the attention!
Contact: camilla.andersson@smhi.se

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