



Alpine region, mountain birch. Characteristic vegetation zone in the high altitude Scandes mountains. Photo: Camilla Andersson, Sarek national park.



Eutrophied river in Southern Sweden close to river outlet to the Baltic Sea. Photo: Camilla Andersson, Norrköping, Sweden.



Annual algae bloom event in the Baltic Sea.

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CAMILLA ANDERSSON, TINJA OLENIUS, HELENE ALPFJORD WYLDE,
MAGNUZ ENGARDT, WING LEUNG, LENNART ROBERTSON
AND ANA CRISTINA CARVALHO

ATMOSPHERIC NITROGEN DEPOSITION TO NORTHERN EUROPE MEASUREMENT MODEL FUSION, HISTORICAL EVOLUTION AND FUTURE SCENARIOS

FOCUS ON THE BALTIC SEA AND SWEDEN

OUTLINE

Nitrogen deposition

Focus: Baltic Sea

- Historical mapping based on measurement-model-fusion
- Future scenarios based on CLE

Focus: Sweden

- Historical mapping based on measurement-model-fusion
- National Swedish atmospheric nitrogen budget
- Future scenarios based on CLE

Focus: (northern) Europe

- Future scenarios based on CLE
- Impact of activity changes during 2020



Datasets used here



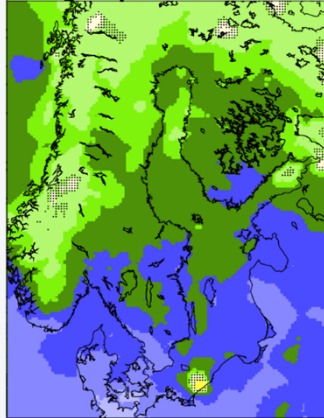
	MMF/Model	Period Region	Meteorology (GHG)	Emissions	Reference (including evaluation)
MMF- MATCHSweden- REAN	MATCH Sweden system Measurement model fusion <i>Based on EDTRENDS (MATCH)</i>	1983-2013 Northern Europe	EURO4M Meteorological reanalysis	EMEP expert Swedish national (SMED) ShipAir	Andersson, C., Alpfjord Wylde, H., Engardt, M. 2018 Long-term sulfur and nitrogen deposition in Sweden: 1983-2013 reanalysis. SMHI report in meteorology 163, 102pp.
MMF- MATCHSweden-OP	MATCH Sweden system Measurement model fusion <i>Pandemic – impact 2020</i>	2013-2019 Sweden+Norway	ECMWF IFS operational meteorological forecasting model	EMEP expert Swedish national (SMED) ShipAir	Alpfjord Wylde, H., Leung, W., Andersson, C., 2021 Nationell miljöövervakning med MATCH Sverigesystemet – utvärdering och resultat för åren 2017-2019. SMHI rapport nr 2021-22. https://www.smhi.se/polopoly_fs/1.1466271/Slutrapport_2017-2019_MATCH-Sverigesystemet.pdf
ECLAIRE-MATCH	MATCH CTM	1900-2050 Europe	Climate, RCA4 (current, repeated)	ECLAIRE	Magnuz Engardt, David Simpson, Margit Schwikowski & Lennart Granat (2017) Deposition of sulphur and nitrogen in Europe 1900–2050. Model calculations and comparison to historical observations, Tellus B: Chemical and Physical Meteorology, 69:1, 1328945, DOI: 10.1080/16000889.2017.1328945
BIODIV-ALADIN- MATCH	MATCH CTM	1987-2051 Central and Northern Europe	EC-EARTH – ALADIN (10km) RCP8.5	ECLIPSE V6b	Andersson, C., Olenius, T., et al., 2021. Manuscript.
BIODIV-AROME- MATCH	MATCH CTM	1987-1996; 2042- 2051 Scandes Mountains	EC-EARTH – ALADIN – AROME (3km) RCP8.5	ECLIPSE V6b Downscaled to 1km based on Nordic WelfAir emissions	

Nitrogen deposition to the Baltic Sea

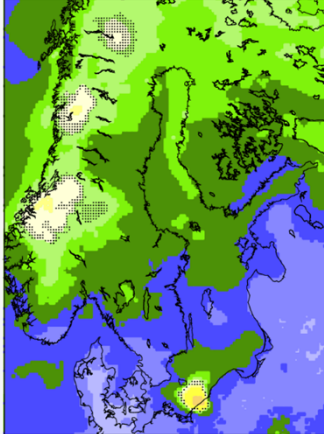


Nitrogen deposition to Northern Europe Baltic Sea

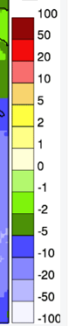
NOY N dep trend 1983-2013



NHX N dep trend 1983-2013



mg m⁻² yr⁻²

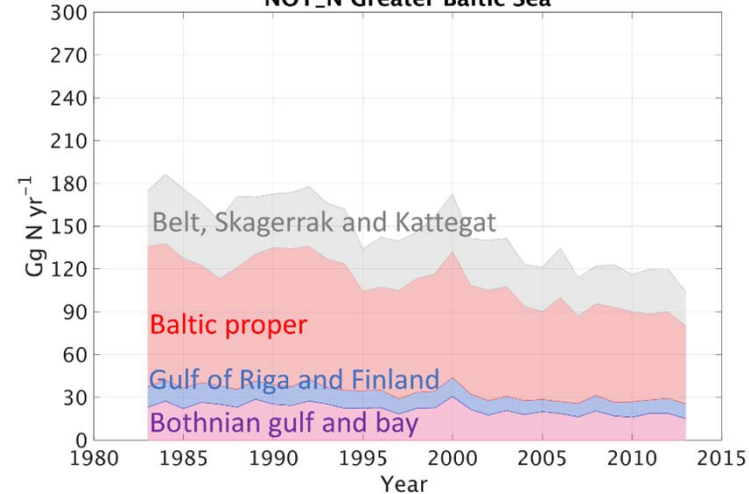


MMF-MATCHSweden-REAN

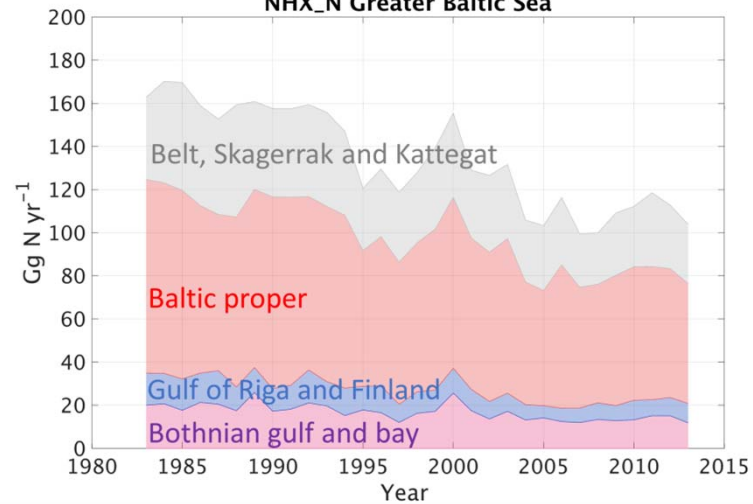
	Trend
	1983-2013 [mg m ⁻² yr ⁻²]
Nr	-10.5***
NOYN	-5.3***
NHXN	-5.2***

Andersson et al., 2018; Andersson et al., manuscript, 2021

NOY_N Greater Baltic Sea



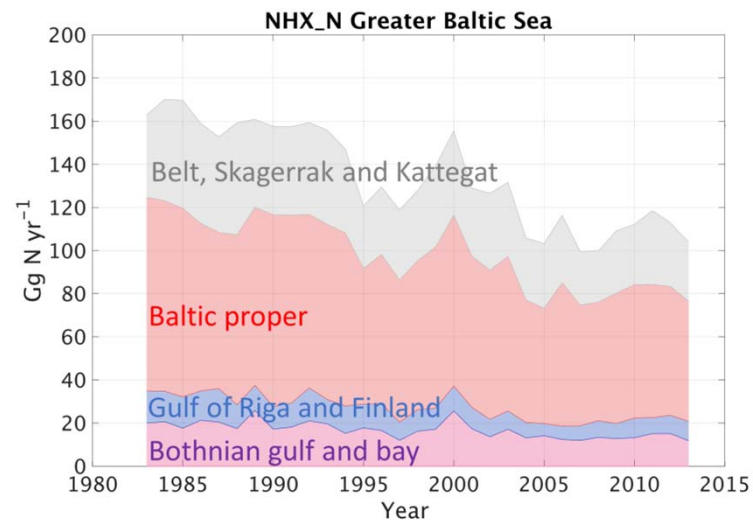
NHX_N Greater Baltic Sea



Reduced nitrogen deposition to Northern Europe historical evolution and future scenario – Baltic Sea



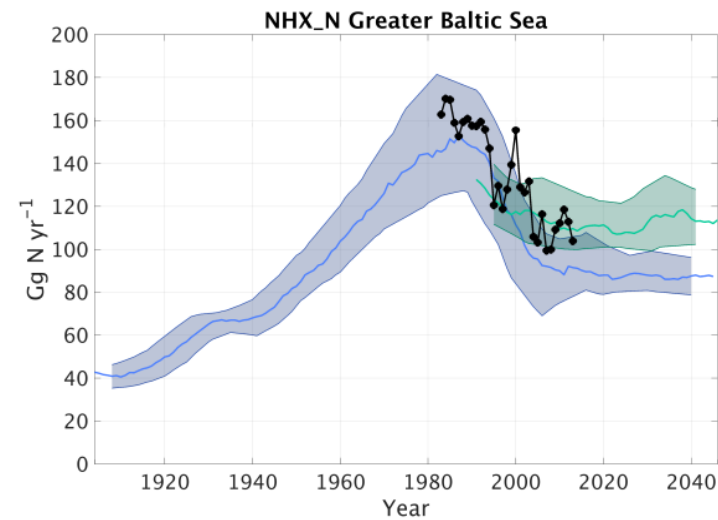
MMF-MATCHSweden-REAN



MMF-MATCHSweden-REAN

ECLAIRE

EC-EARTH-ALADIN-MATCH



Andersson et al., manuscript, 2021; Andersson et al., 2018; Engardt et al., 2017

Oxidized nitrogen deposition to Northern Europe historical evolution and future scenario – Baltic Sea

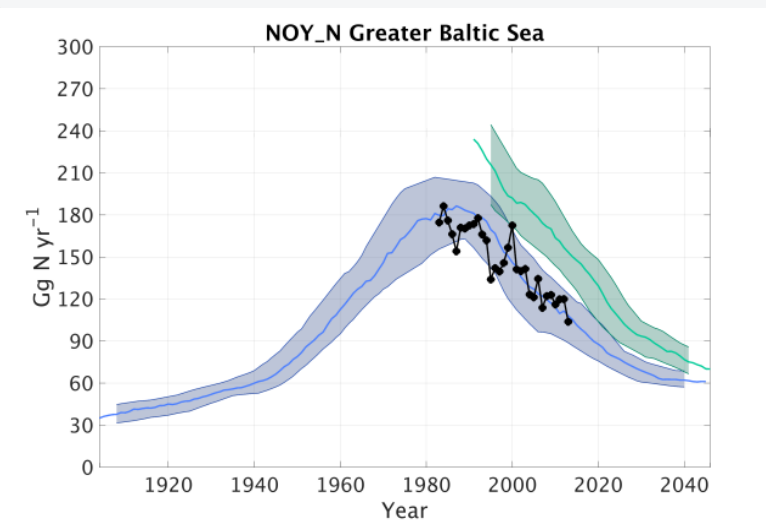
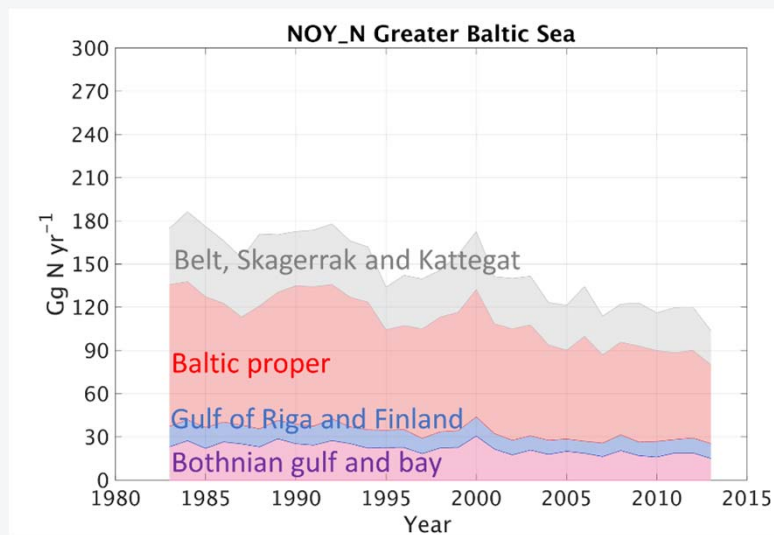


MMF-MATCHSweden-REAN

MMF-MATCHSweden-REAN

ECLAIRE

EC-EARTH-ALADIN-MATCH

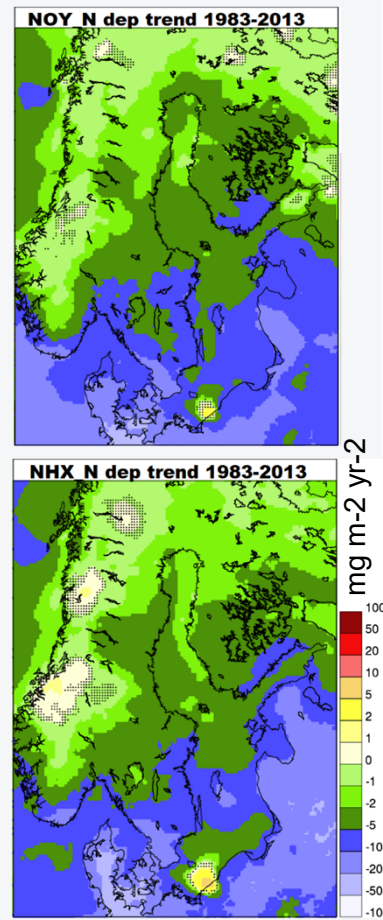


Andersson et al., manuscript, 2021; Engardt et al., 2017

Nitrogen deposition to Sweden



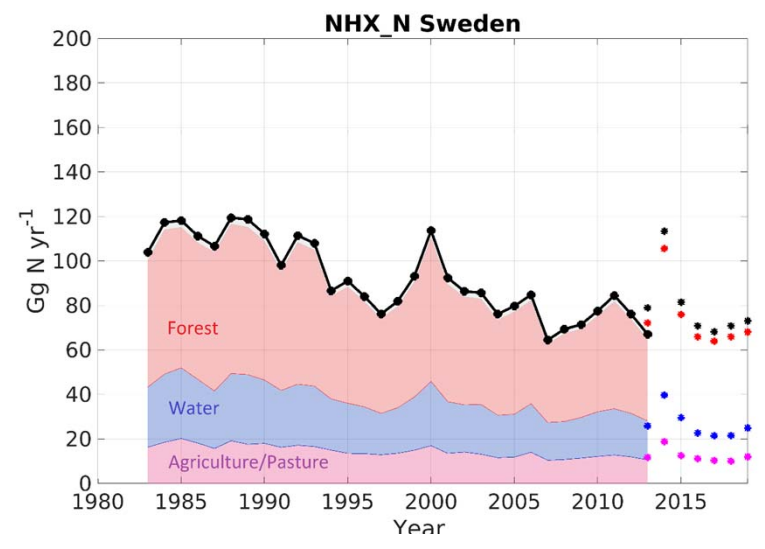
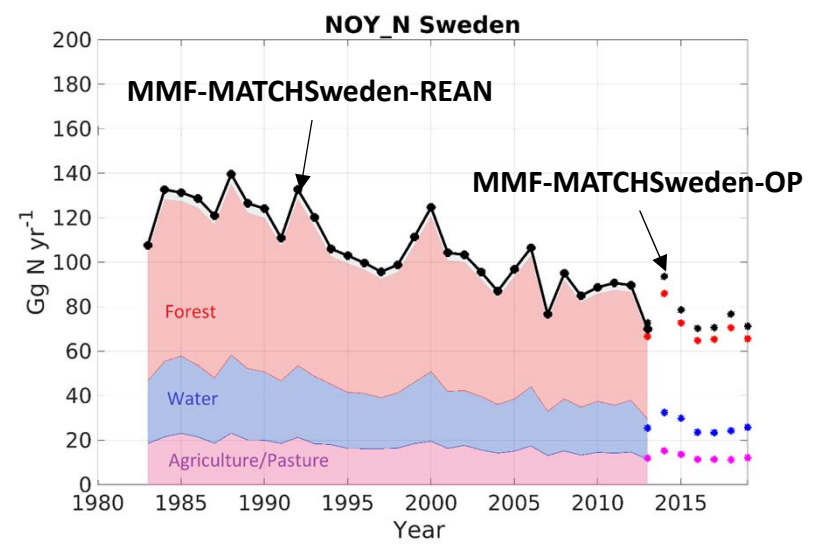
Nitrogen deposition to Northern Europe Sweden



MMF-MATCHSweden-REAN

	Trend
	1983-2013 [mg m ⁻² yr ⁻²]
Nr	-7.2***
NOY_N	-3.6***
NHX_N	-3.5***

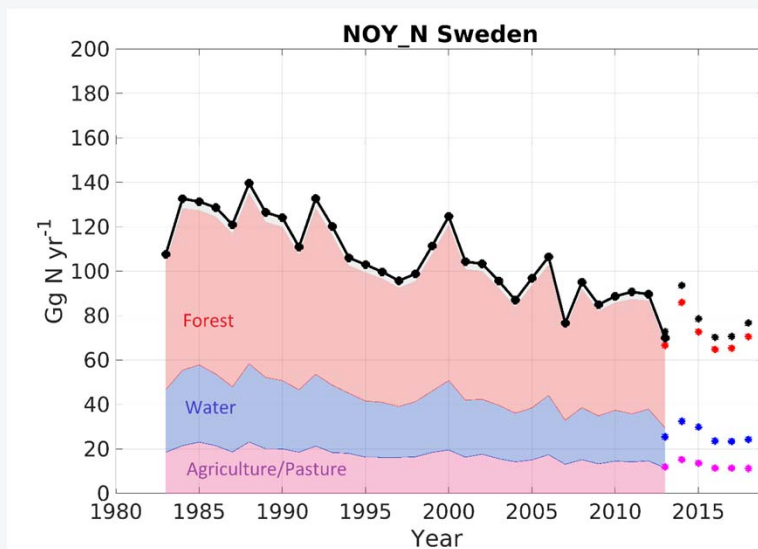
Andersson et al., 2018; Andersson et al., manuscript, 2021



Oxidized nitrogen deposition to Northern Europe historical evolution and future scenario – Sweden



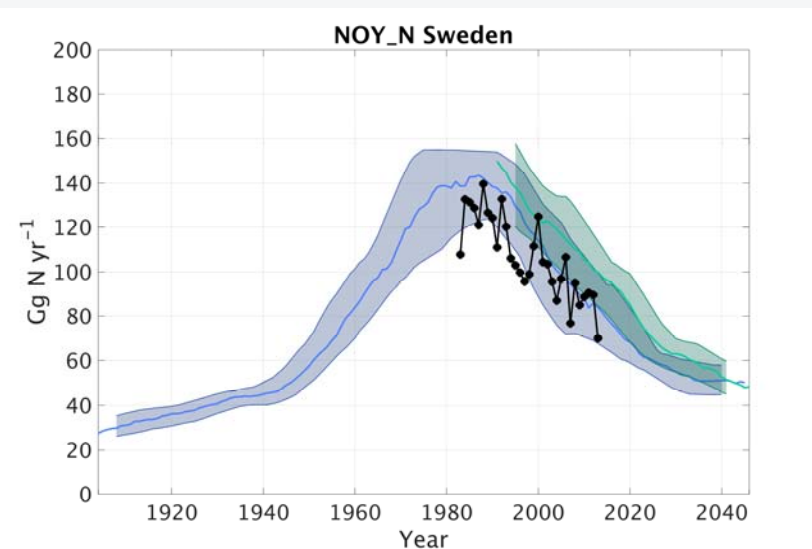
MMF-MATCHSweden-REAN



MMF-MATCHSweden-REAN

ECLAIRE

EC-EARTH-ALADIN-MATCH

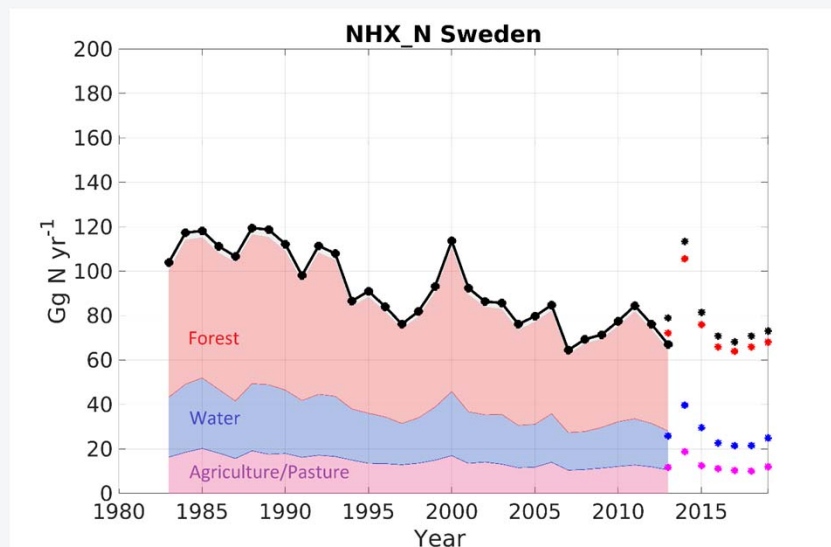


Andersson et al., manuscript, 2021; Andersson et al., 2018; Engardt et al., 2017

Reduced nitrogen deposition to Northern Europe historical evolution and future scenario – Sweden



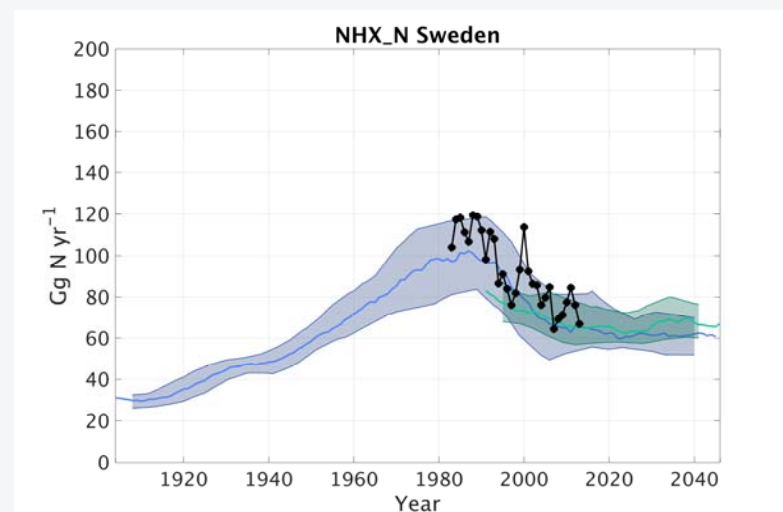
MMF-MATCHSweden-REAN



MMF-MATCHSweden-REAN

ECLAIRE

EC-EARTH-ALADIN-MATCH

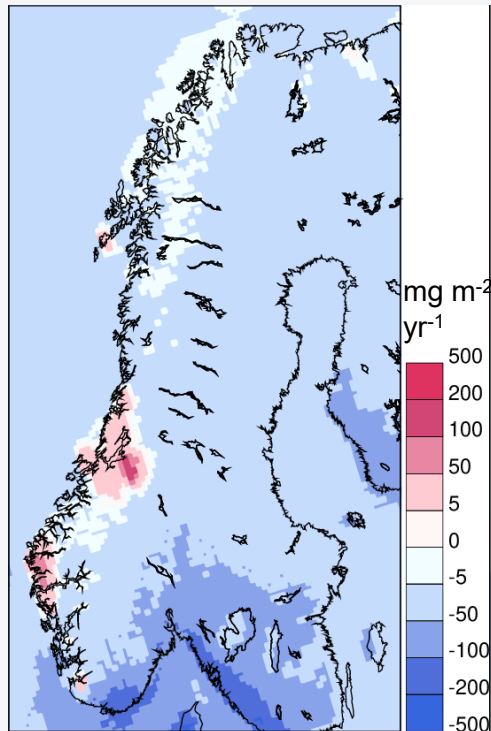


Andersson et al., manuscript, 2021; Andersson et al., 2018; Engardt et al., 2017.

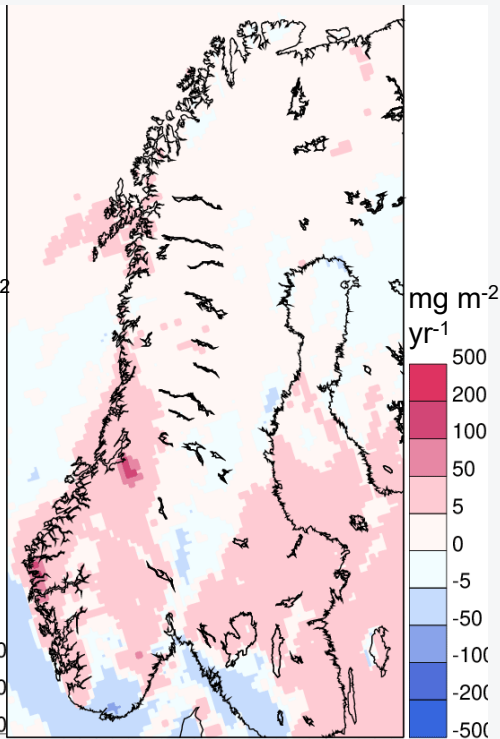
Change in annual reduced nitrogen deposition



From 1987-1996 to 2042-2051



From 2011-2020 to 2042-2051



EC-EARTH-ALADIN-MATCH

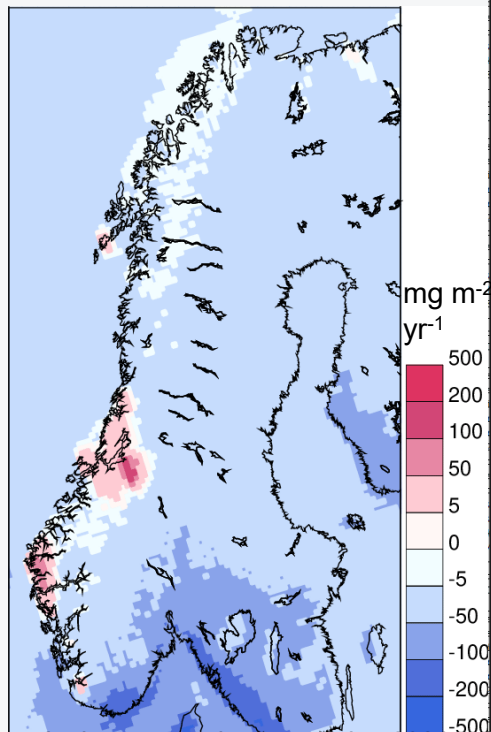
10 km resolution

- ECLIPSE V6b CLE
- EC-EARTH climate
 - Downscaled using ALADIN
 - RCP8.5

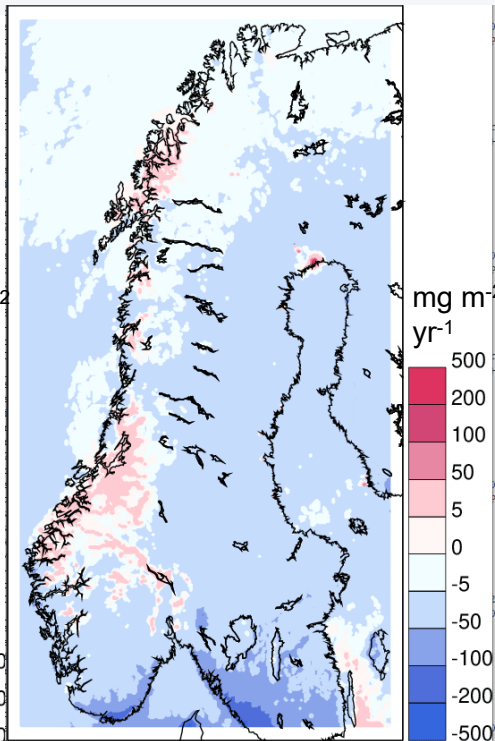
Annual reduced nitrogen deposition dependency on resolution change from 1987-1997 to 2042-2051



EC-EARTH-ALADIN-MATCH (10km)



EC-EARTH-AROME-MATCH (3km)



Andersson et al., manuscript, 2021

EC-EARTH-ALADIN-MATCH

- 10 km resolution
- ECLIPSE V6b CLE
- EC-EARTH climate
 - Downscaled using ALADIN; GHG RCP8.5

EC-EARTH-AROME-MATCH

- 3km resolution
- ECLIPSE V6b Downscaled to 3km using Nordic Welfair emission spaciation. CLE.
- EC-EARTH climate downscaled using ALADIN → AROME
 - Nonhydrostatic – captures precip frequency better (Lind et al 2020)
 - GHG following RCP8.5

Andersson et al., manuscript, 2021

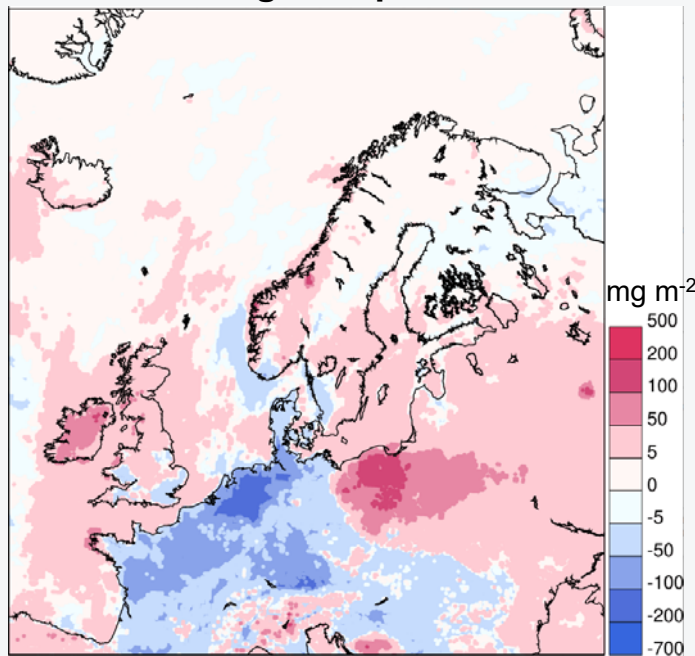
What about the rest of Europe?

Change in annual deposition

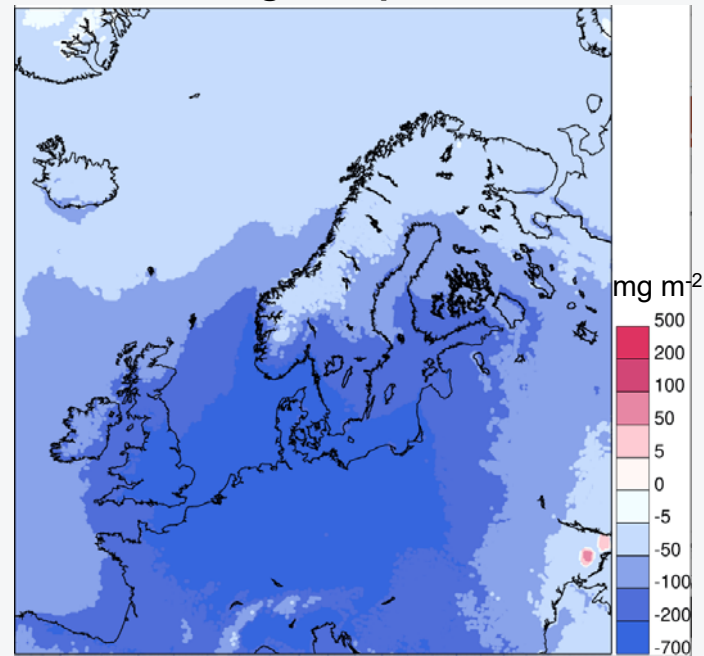
From present to mid-century (2011-2020 to 2042-2051)

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Reduced nitrogen deposition



Oxidized nitrogen deposition



Conclusions

Present nitrogen deposition to the Baltic Sea and Sweden are on the level of 1960s.

Nitrogen deposition was strongest in 1970-1990 to Sweden and to the Baltic Sea. This is supported by both pure modelling and measurement-model-fusion of atmospheric deposition.

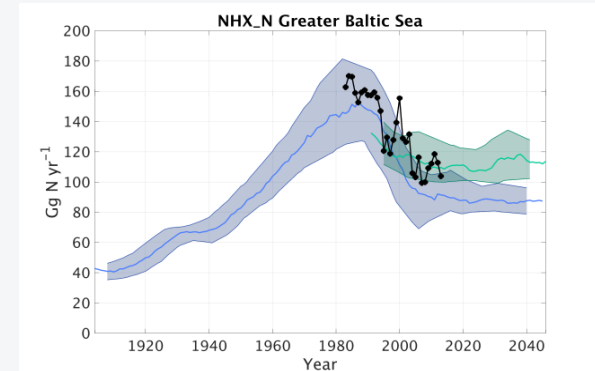
We project continued decrease in **oxidized nitrogen deposition**, but **still at levels exceeding the pre-industrial level in 2050**.

We project **increased reduced nitrogen deposition from present to mid-century** in parts of Europe including Sweden and the Baltic Sea, with **stronger signal compared to previous estimates** using the ECLIPSE V6b CLE emissions projection.

Our estimates (trends/levels) compare well to observed (reanalyzed) deposition.

Need of continued efforts to further decrease nitrogen emissions to the atmosphere for protection of the terrestrial and aquatic environment, not the least as ecosystems are under additional pressure of climate change and more intensive management.

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Acknowledgements

This work was funded by

- the Swedish EPA through the research programme "Swedish clean air and climate" (SCAC) and operational environmental surveillance
- the Swedish research council FORMAS, through the international collaborative research network BioDiv-Scen and its corresponding network partners Belmont forum and biodivERsA.



A scenic landscape photograph featuring a purple flower in the foreground, slightly out of focus. The background shows a valley with a river, surrounded by mountains with patches of snow under a blue sky with white clouds. Tall grasses are visible in the foreground.

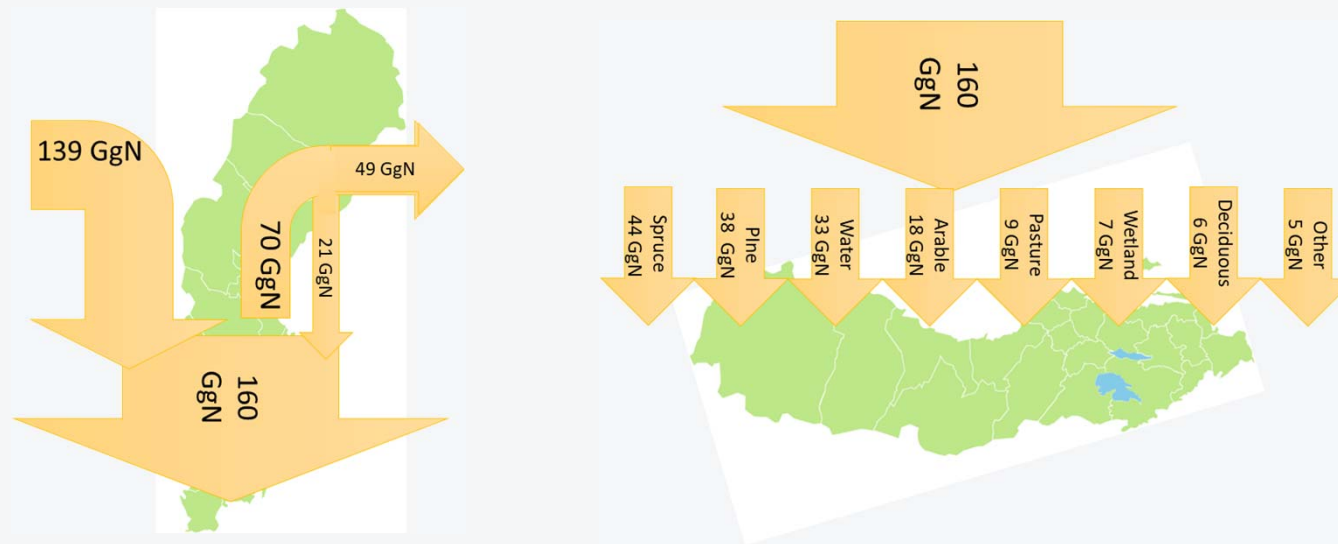
THANK YOU FOR LISTENING!

CONTACT: CAMILLA.ANDERSSON@SMHI.SE

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Supporting material

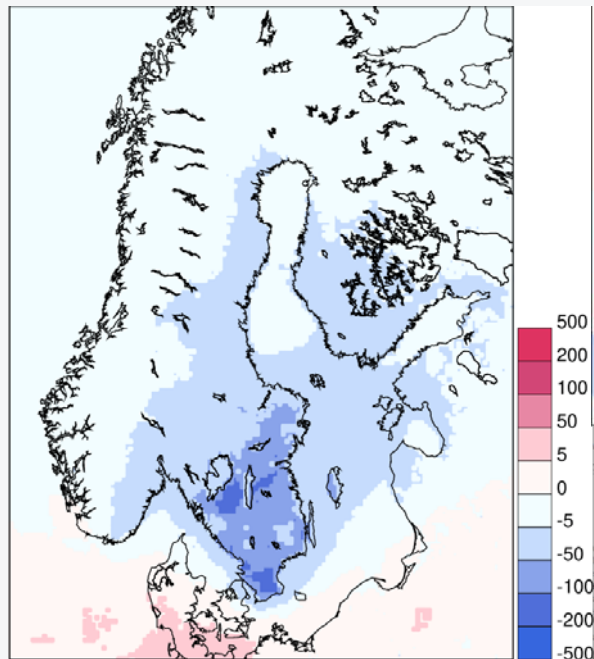
Measurement model fusion of atmospheric nitrogen deposition to Sweden - national budget 2015



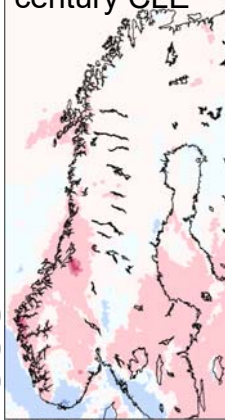
Impact of activity changes due to the 2020 Covid-19 pandemic on annual nitrogen deposition

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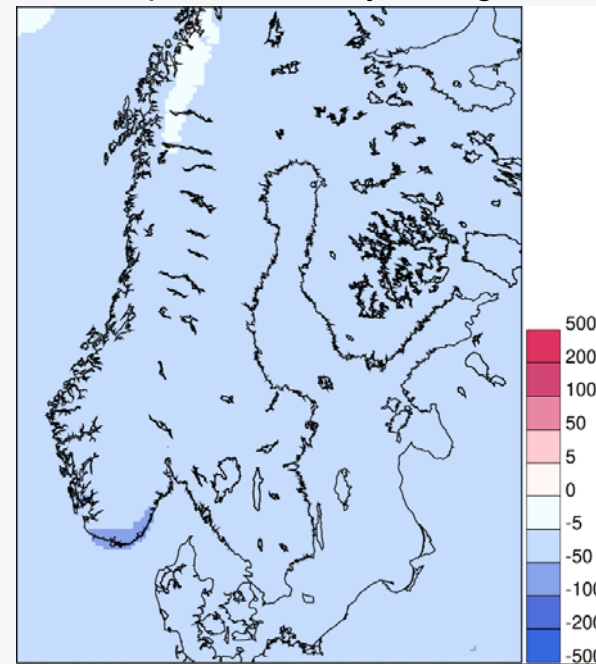
Reduced nitrogen deposition
2020 impact of activity changes



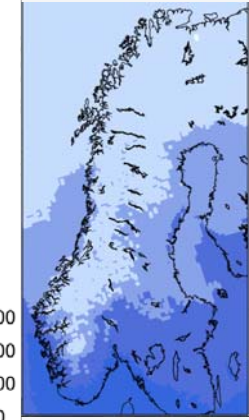
Change to mid-century CLE



Oxidized nitrogen deposition
2020 impact of activity changes

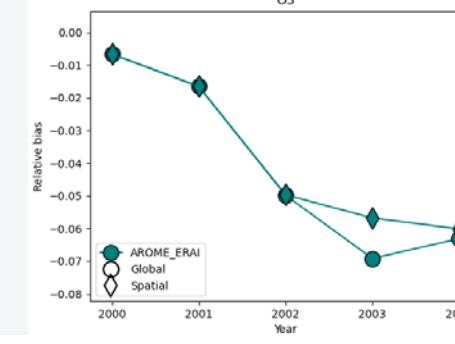
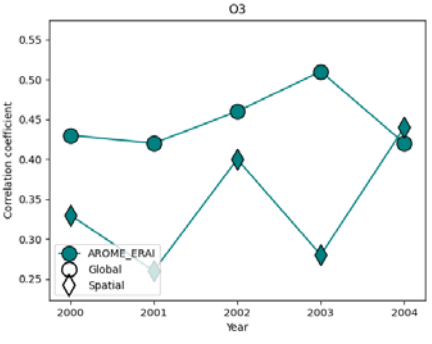
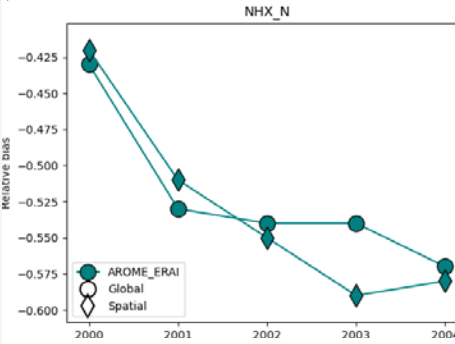
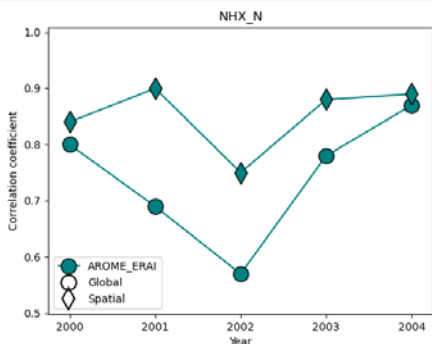
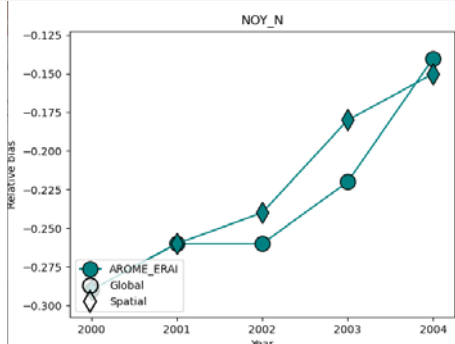
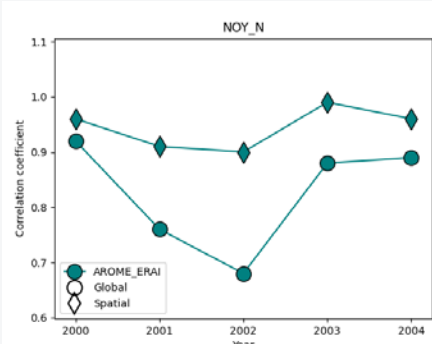


Change to mid-century CLE



Evaluation ERAI-AROME-MATCH

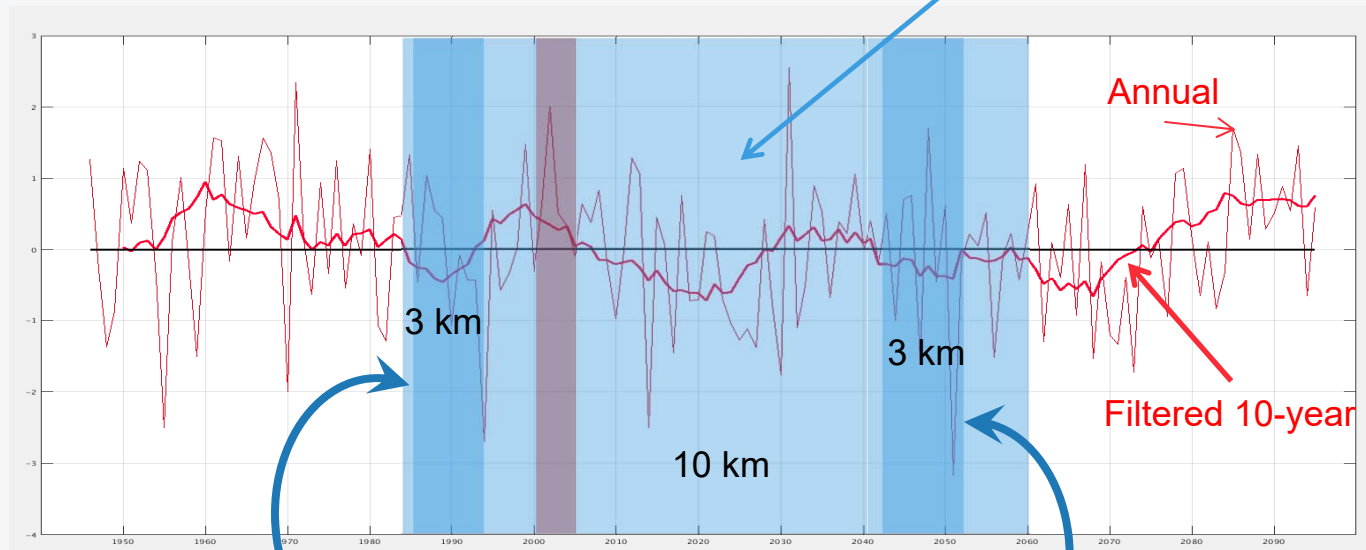
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Time windows for air pollution scenarios

transient run,
10km, 1987-
2051

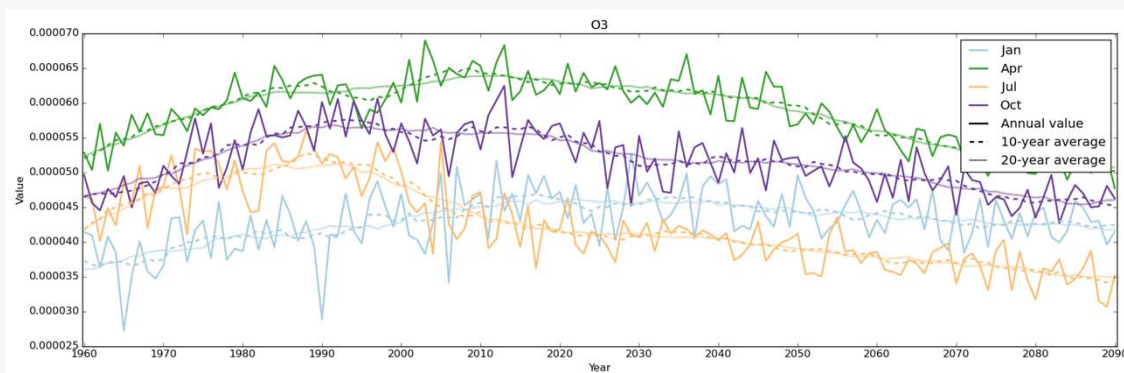
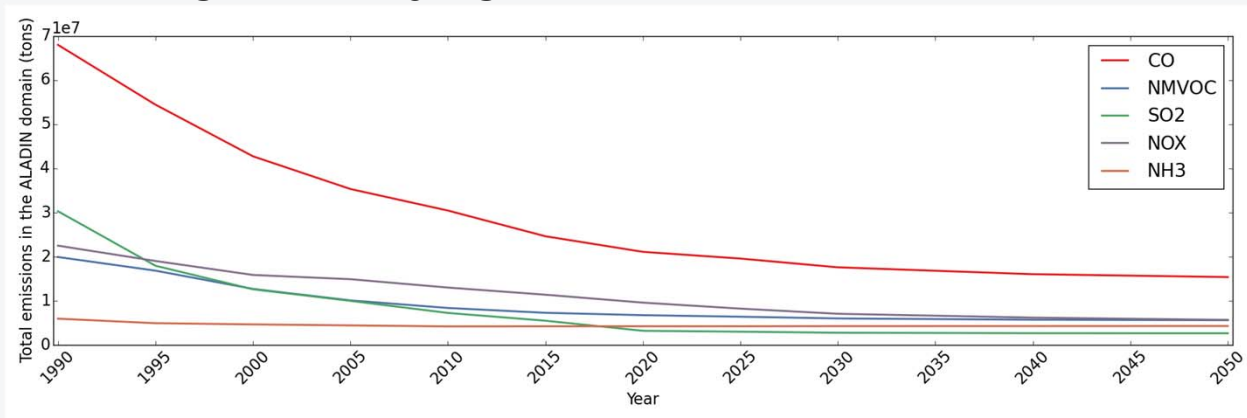
In accordance with the NAO index

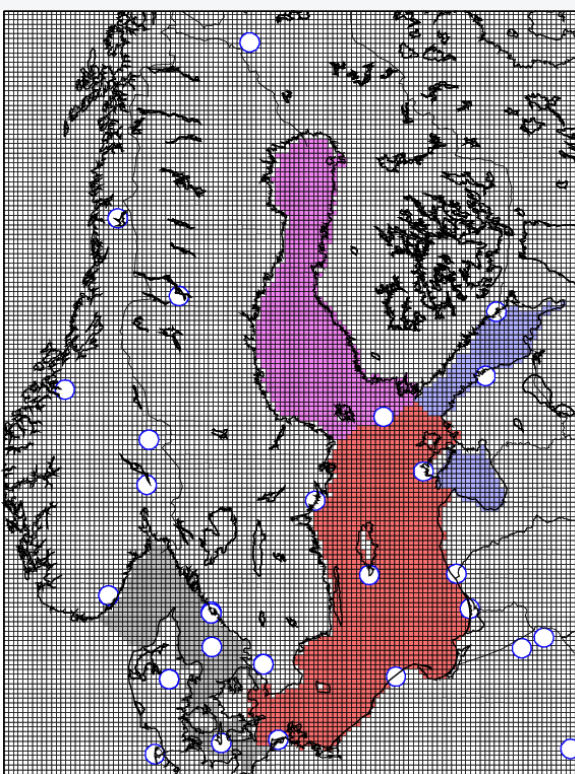
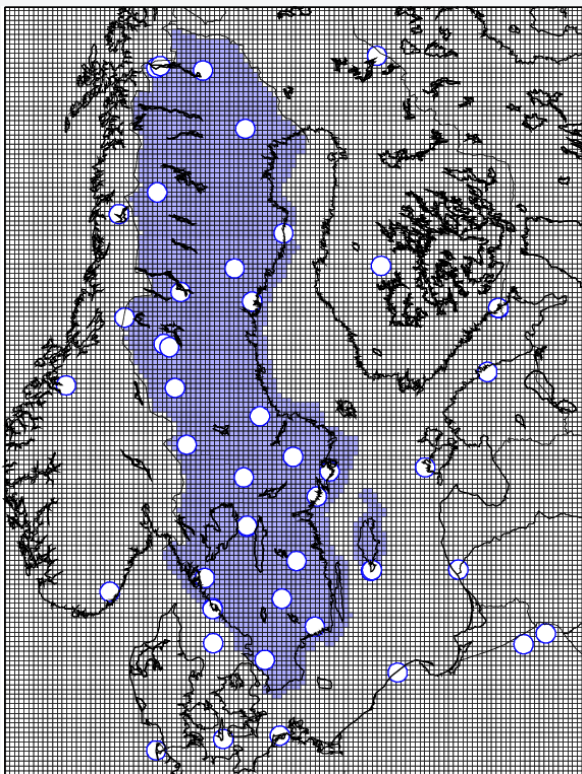


- ERA-Interim: 2000 – 2004 + Dec 1999
- Historical GCMs: 1987 – 1996 + Dec 1986
- Mid-century GCMs: 2042 – 2051 + Dec 2041

Emissioner

- ECLIPSE V6b CLE





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