

Modellierung der atmosphärischen Deposition von partikulär gebundenem Stickstoff und Schwefel in deutschen Küstenregionen unter besonderer Berücksichtigung von Schiffsemissionen

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GKSS Forschungszentrum Geesthacht

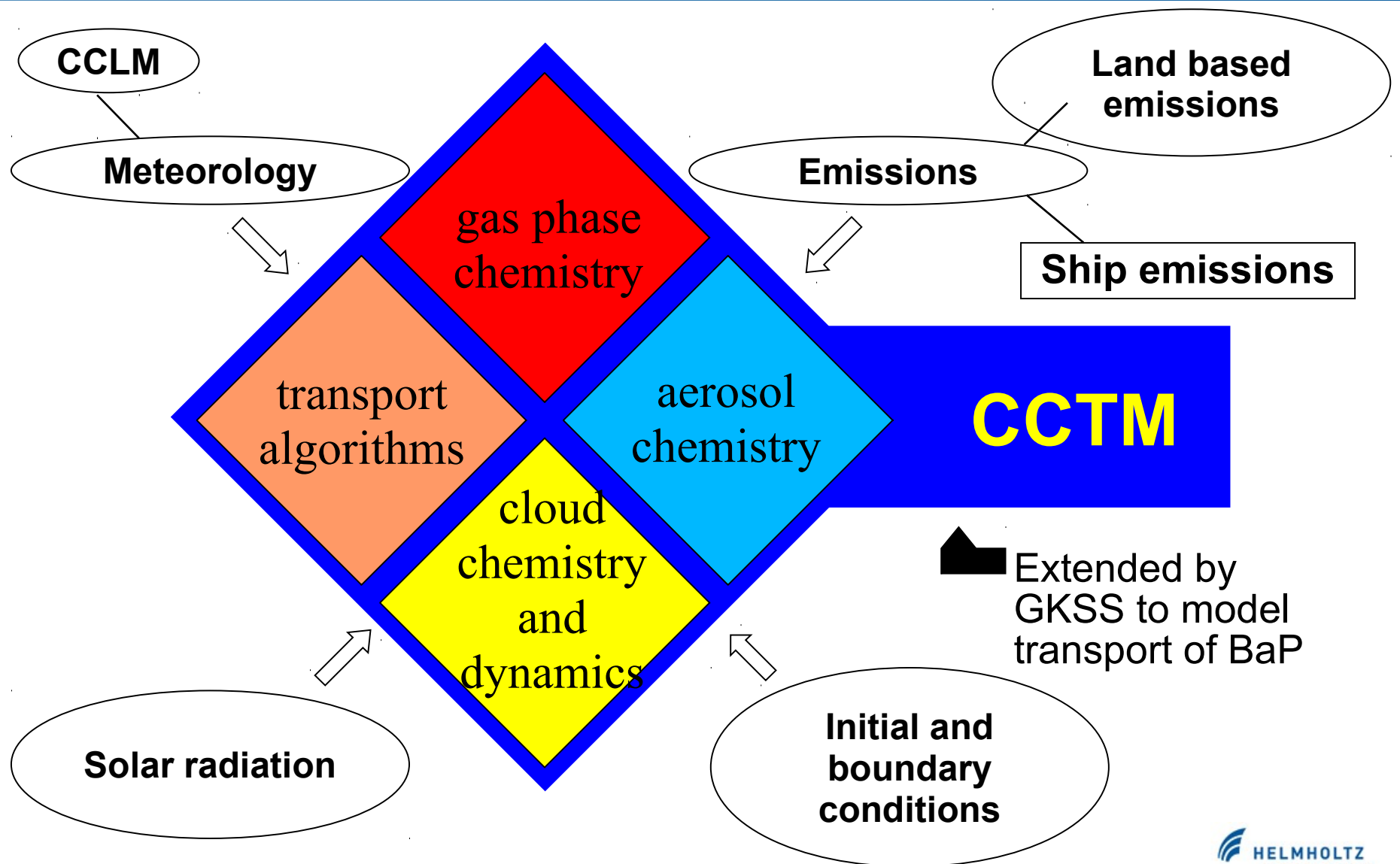


- Schiffe stellen die billigste Möglichkeit dar, Güter über weite Strecken zu transportieren.
- Mehr als 90% aller Güter weltweit werden mit Schiffen transportiert mit einer jährlichen Zunahme von ca. 3%.
- Schiffe benutzen niederwertigen Treibstoff mit hohem Schwefelgehalt (Schweröl)
- Schiffe haben möglicherweise in einigen Regionen einen hohen Einfluß auf die Luftqualität und Depositionen von Säurebildnern und Nährstoffen

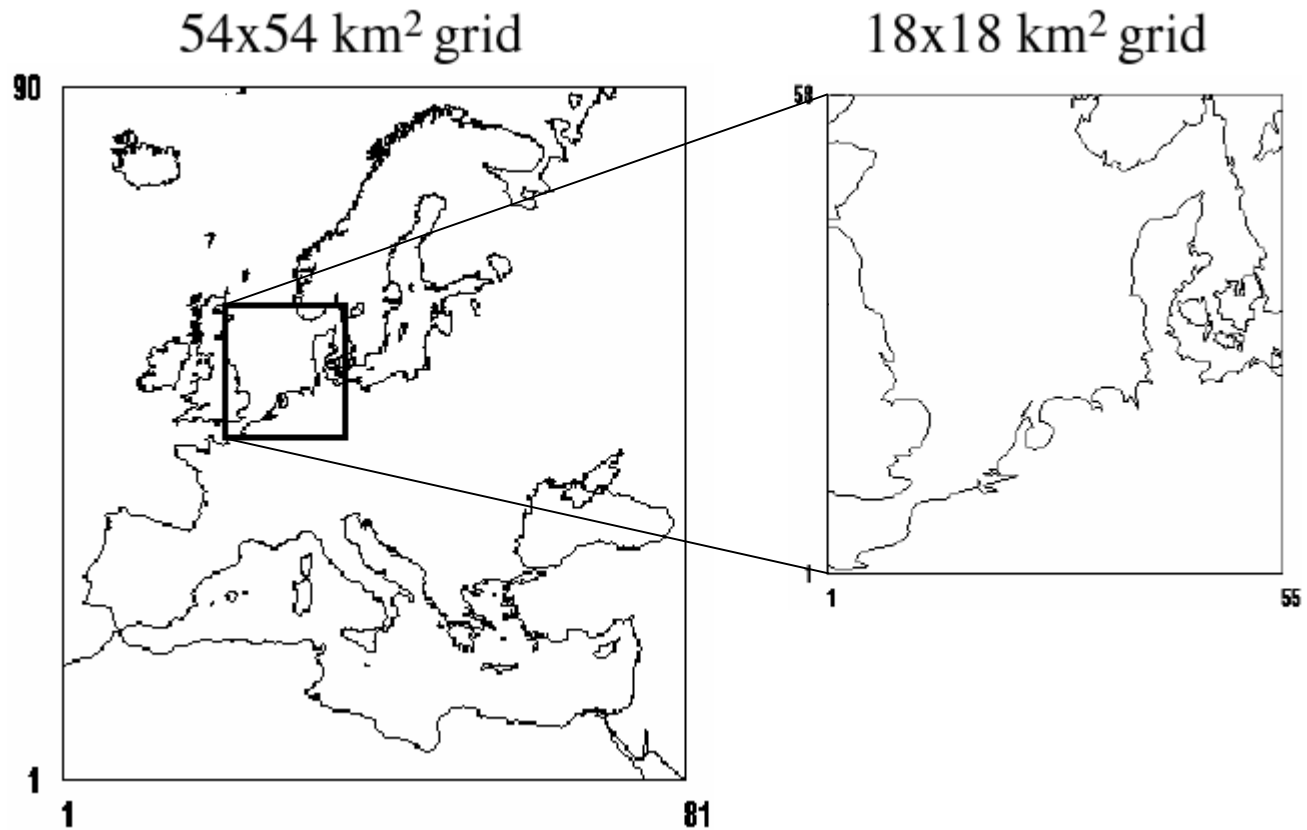


- Model System
- Schiffsemissionen
- Luftverschmutzung in Küstenregionen
- Depositionen
- Effekt von Schwefelreduktion im Treibstoff
- Zusammenfassung

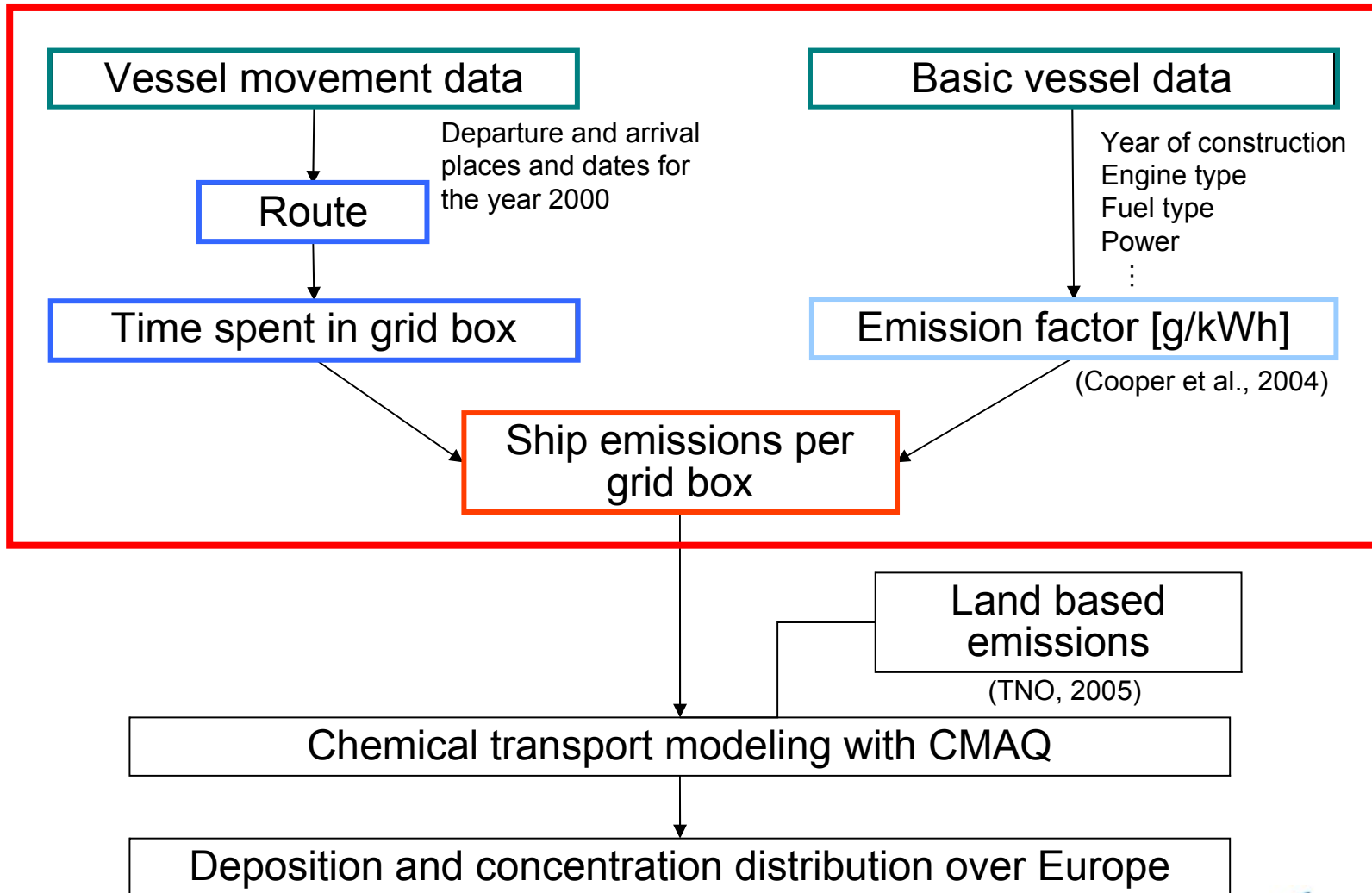
CMAQ Modelling System



Model domain:



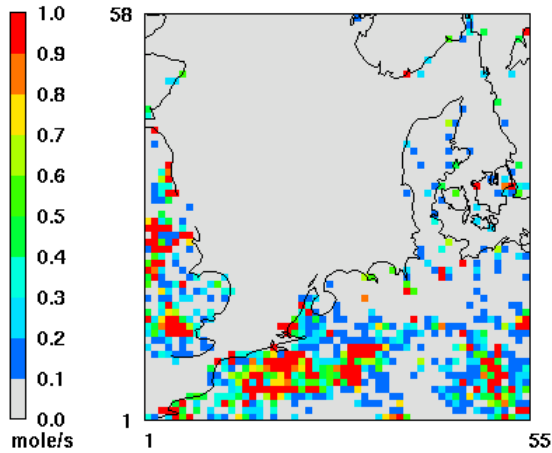
- 30 vertical layers up to 100 hPa



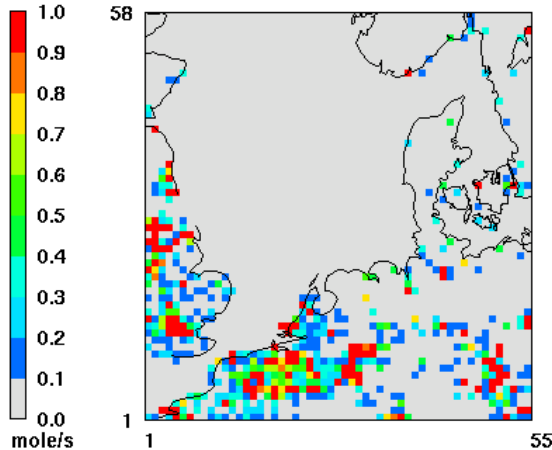
SO_2, NO_x

SO₂ emissions (excl. ships)

winter (DJF)

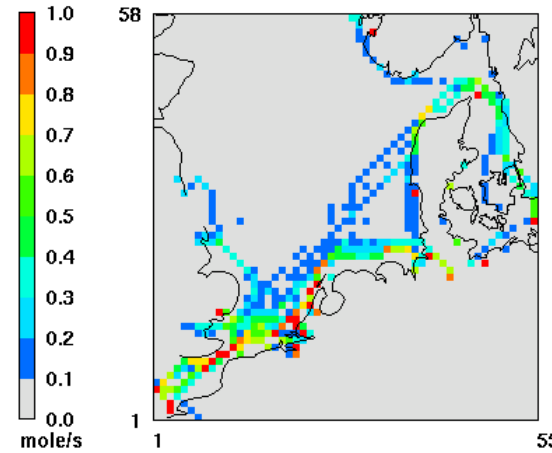


summer (JJA)

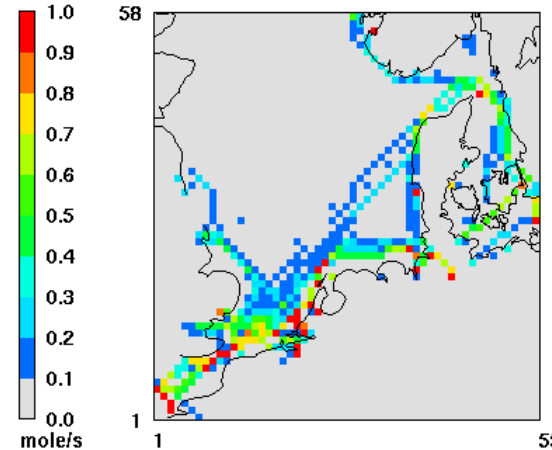


SO₂ emissions by ships

winter (DJF)



summer (JJA)

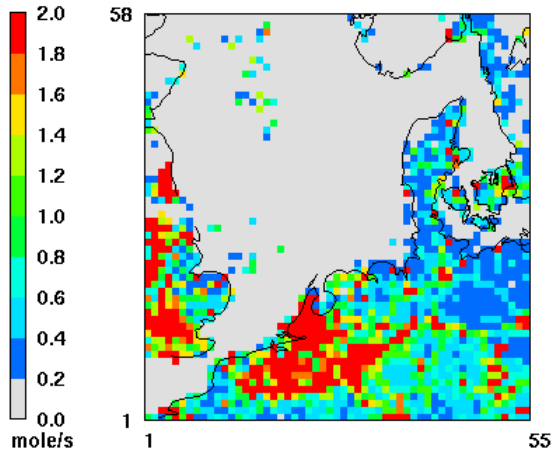


+19 %

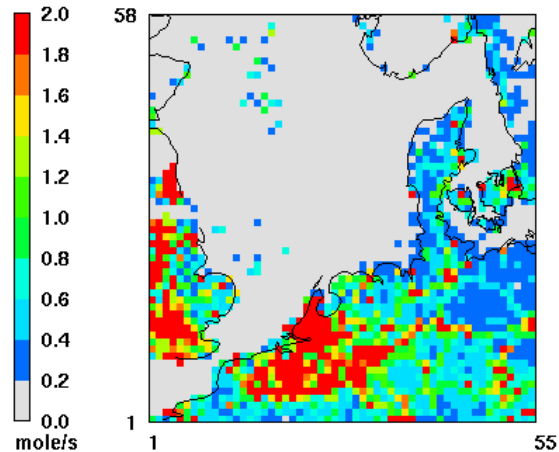
+30 %

NO_x emissions (excl. ships)

winter (DJF)

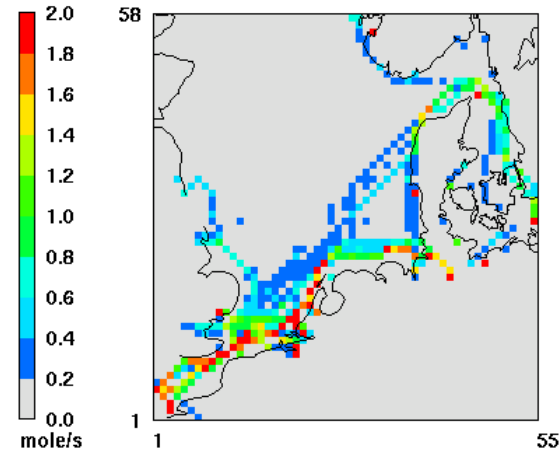


summer (JJA)



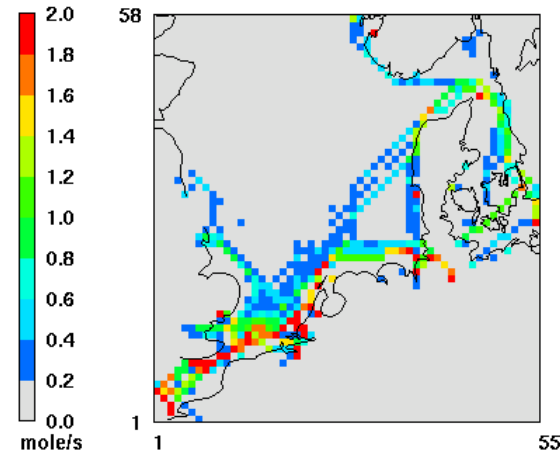
NO_x emissions by ships

winter (DJF)



+18 %

summer (JJA)



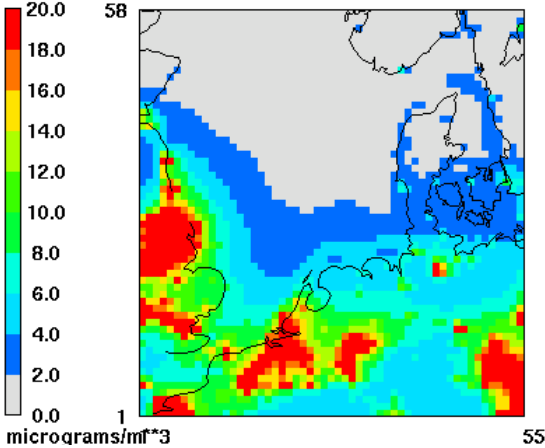
+23 %

SO₂, NO₂

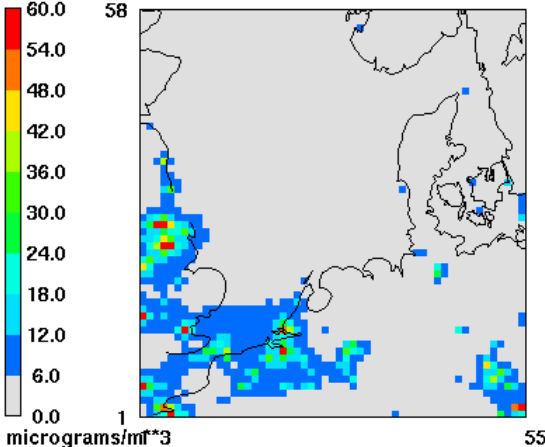
SO₂ concentration

SO₂ in lowest model layer

winter (DJF)

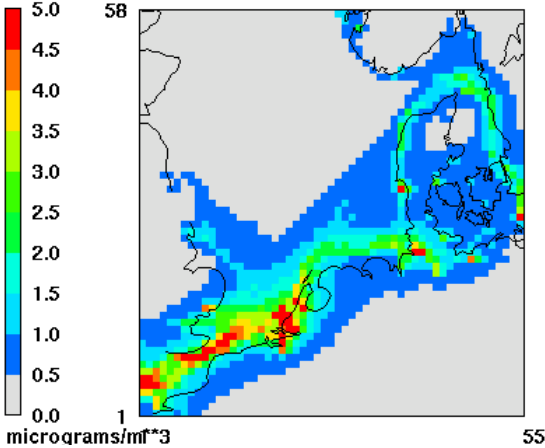


summer (JJA)

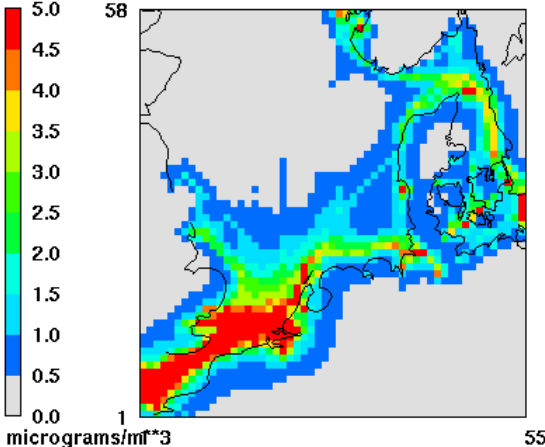


SO₂(incl. ships)-SO₂(no ships)

winter (DJF)

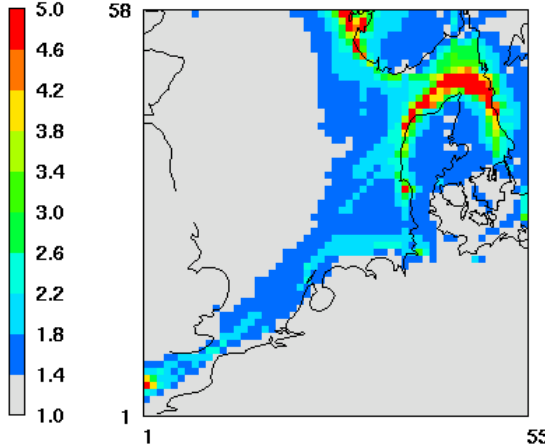


summer (JJA)

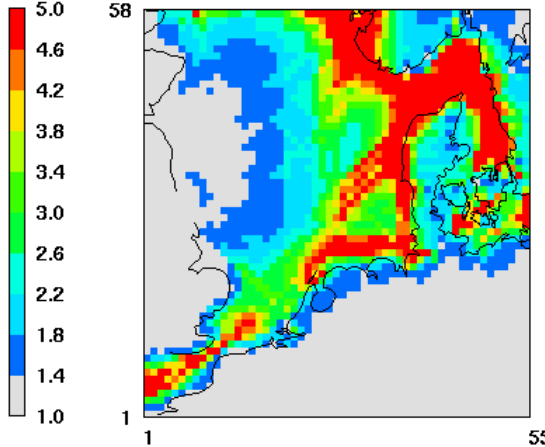


SO₂(incl. ships)/SO₂(no ships)

winter (DJF)



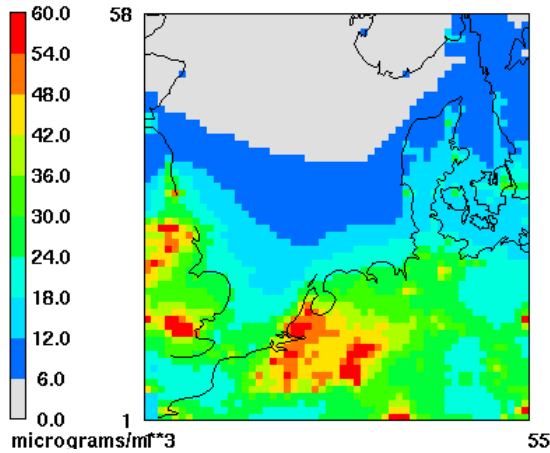
summer (JJA)



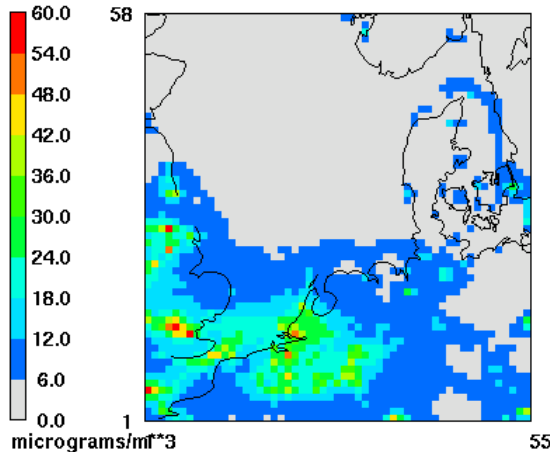
NO₂ concentration

NO₂ in lowest model layer

winter (DJF)

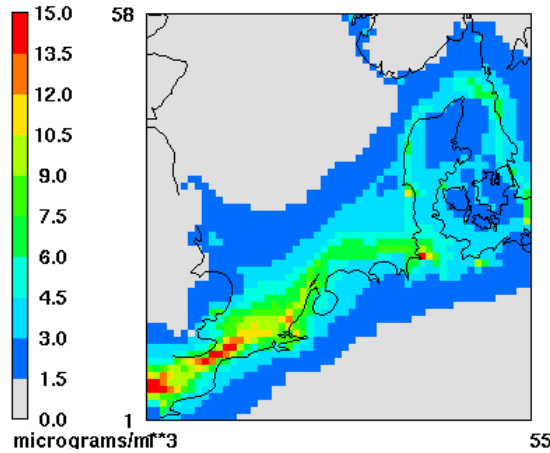


summer (JJA)

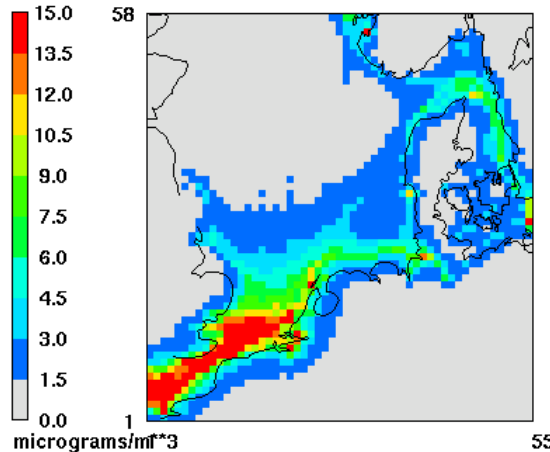


NO₂(incl. ships)-NO₂(no ships)

winter (DJF)

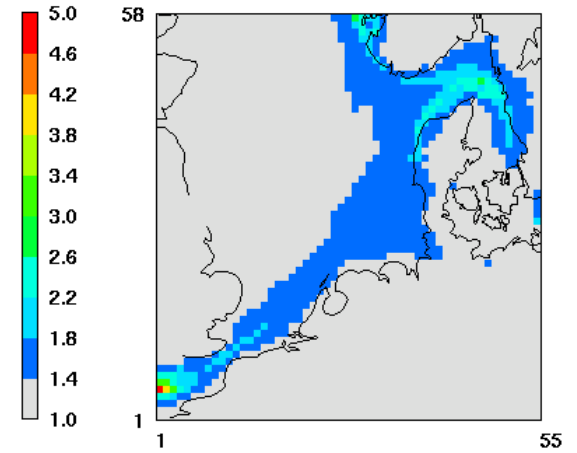


summer (JJA)

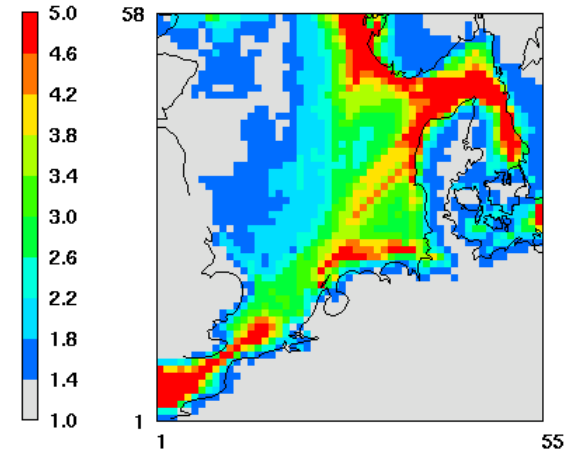


NO₂(incl. ships)/NO₂(no ships)

winter (DJF)



summer (JJA)

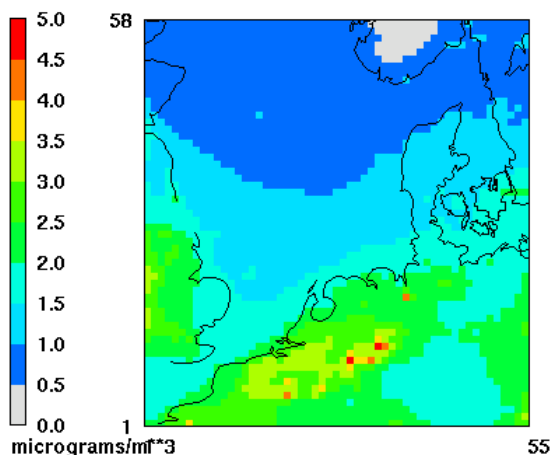


Sulfate
Nitrate
Ammonium

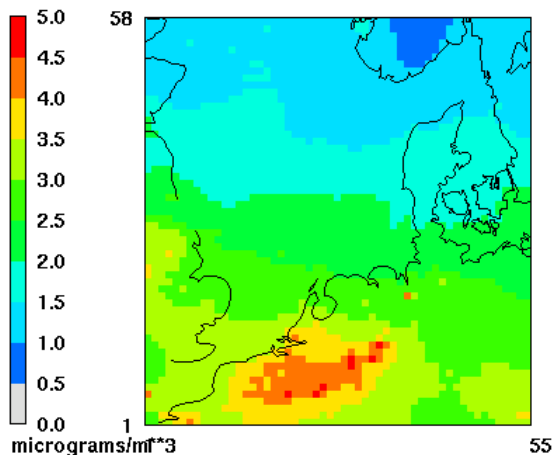
Sulfate aerosol concentration

SO₄(p) in lowest model layer

winter (DJF)

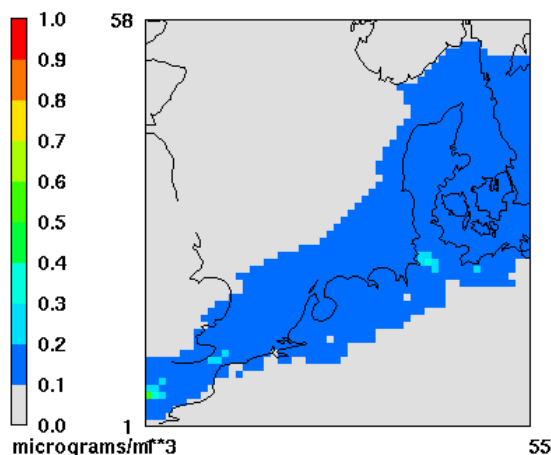


summer (JJA)

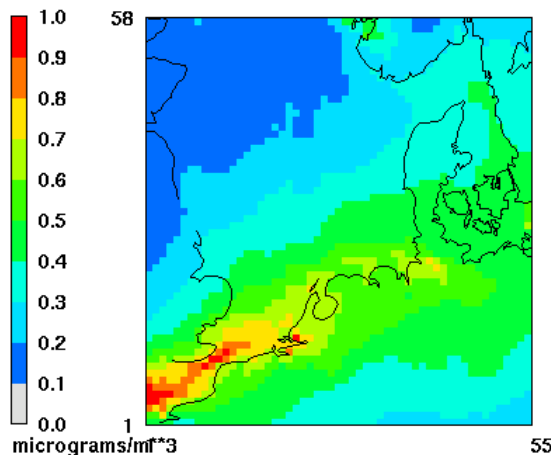


SO₄(p)(incl. ships)-SO₄(p)(no ships)

winter (DJF)

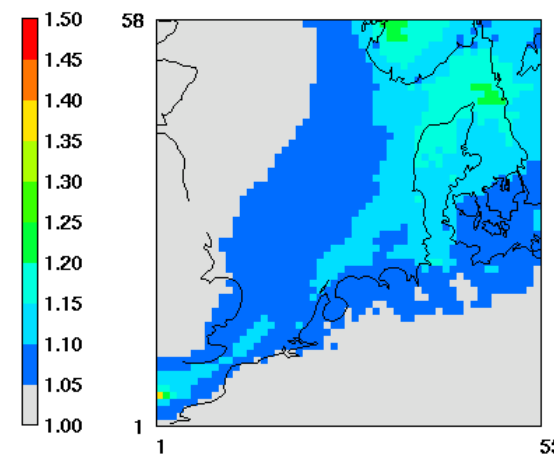


summer (JJA)

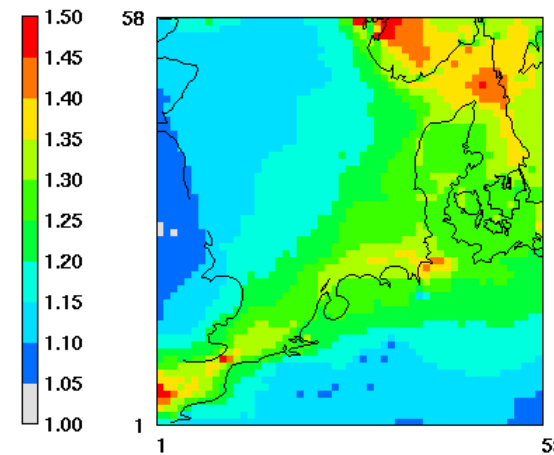


SO₄(p)(incl. ships)/SO₄(p)(no ships)

winter (DJF)



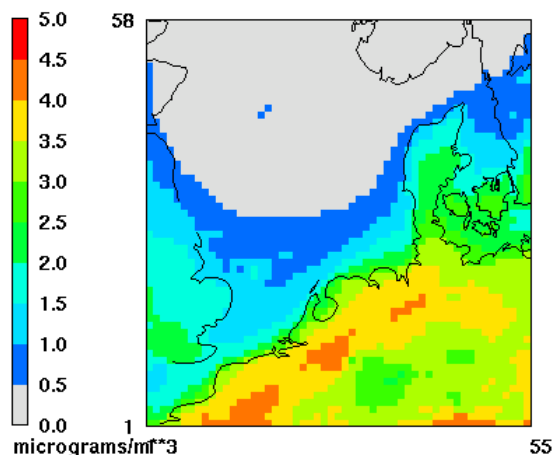
summer (JJA)



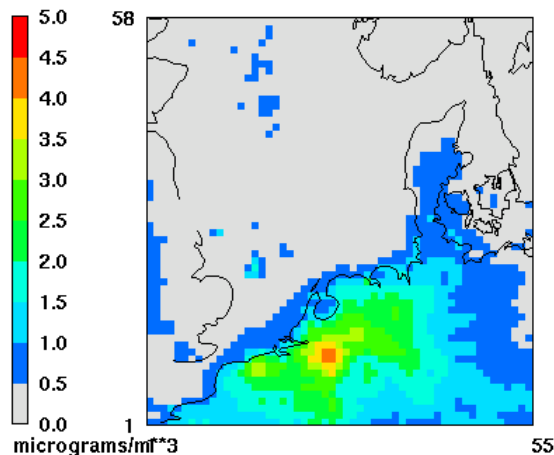
Nitrate aerosol concentration

NO₃(p) in lowest model layer

winter (DJF)

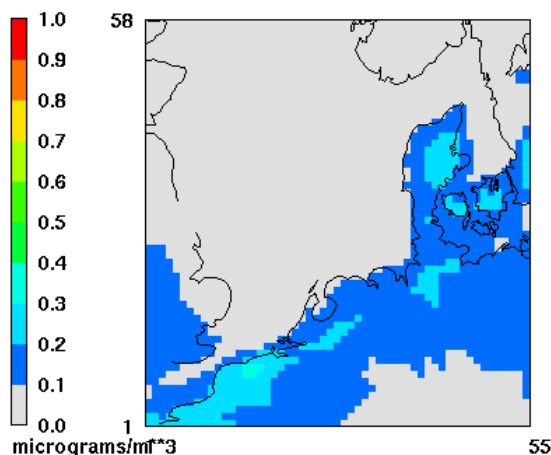


summer (JJA)

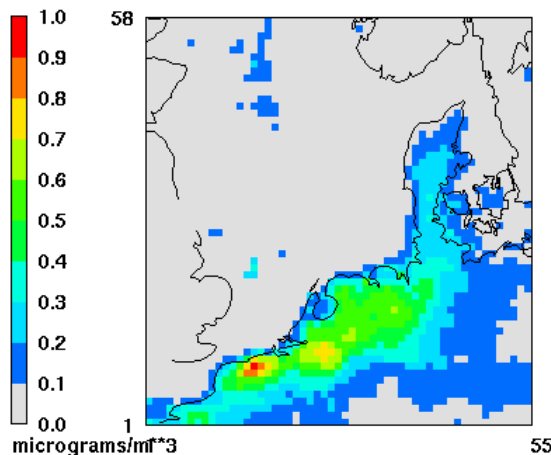


NO₃(p)(incl. ships)-NO₃(p)(no ships)

winter (DJF)

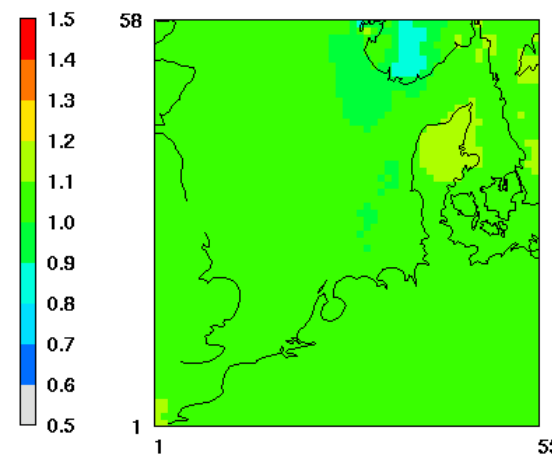


summer (JJA)

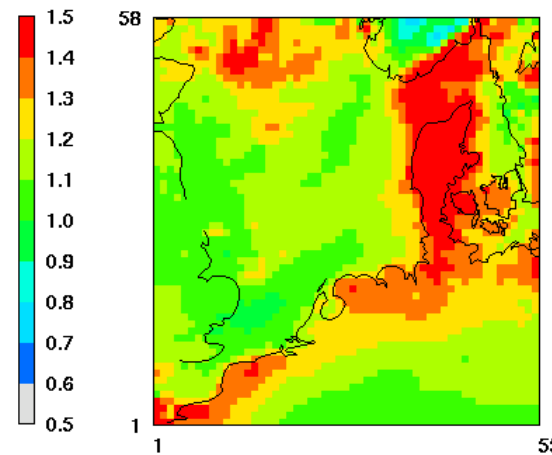


NO₃(p)(incl. ships)/NO₃(p)(no ships)

winter (DJF)



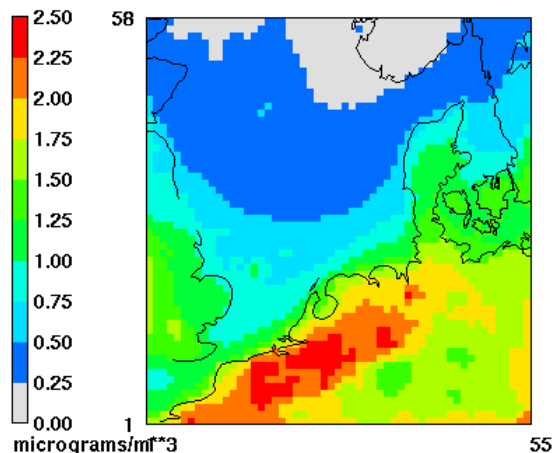
summer (JJA)



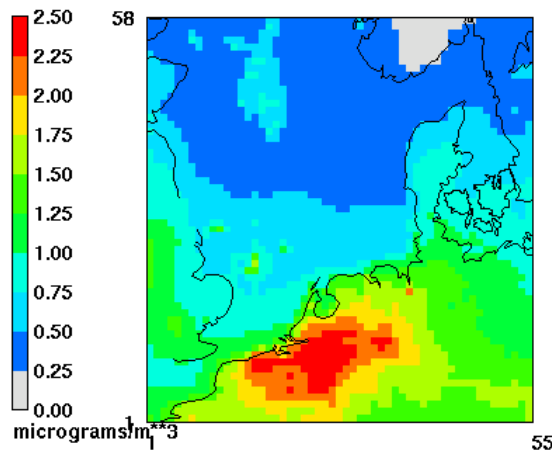
Ammonium aerosol concentration

NH₄(p) in lowest model layer

winter (DJF)

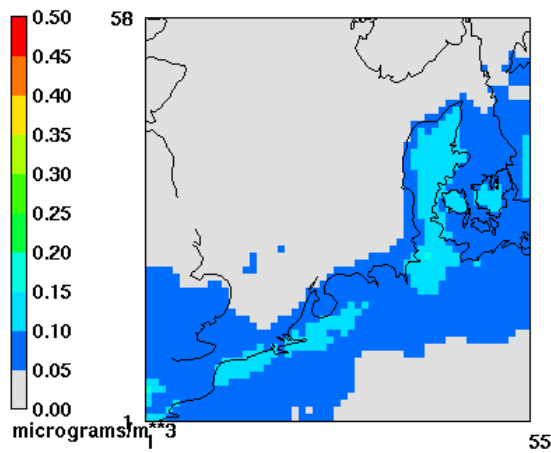


summer (JJA)

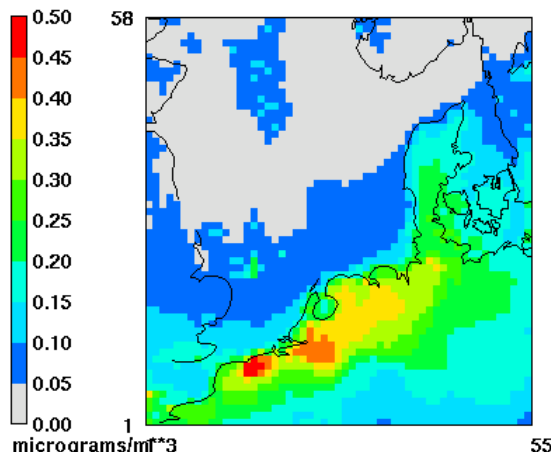


NH₄(p)(incl. ships)-NH₄(p)(no ships)

winter (DJF)

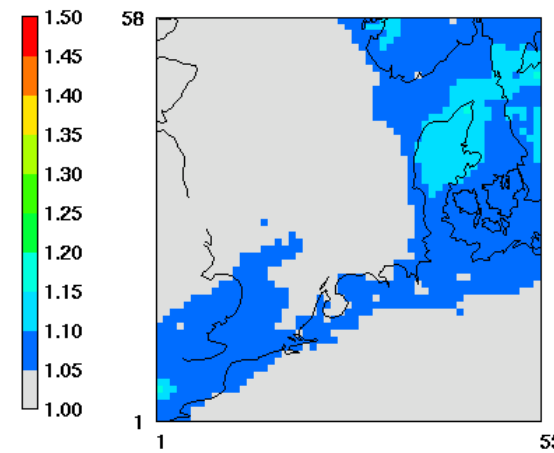


summer (JJA)

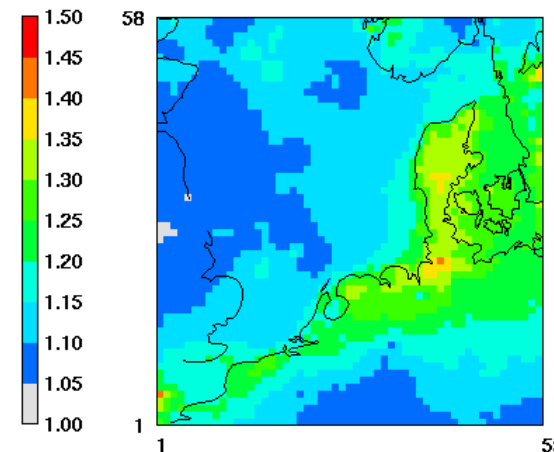


NH₄(p)(incl. ships)/NH₄(p)(no ships)

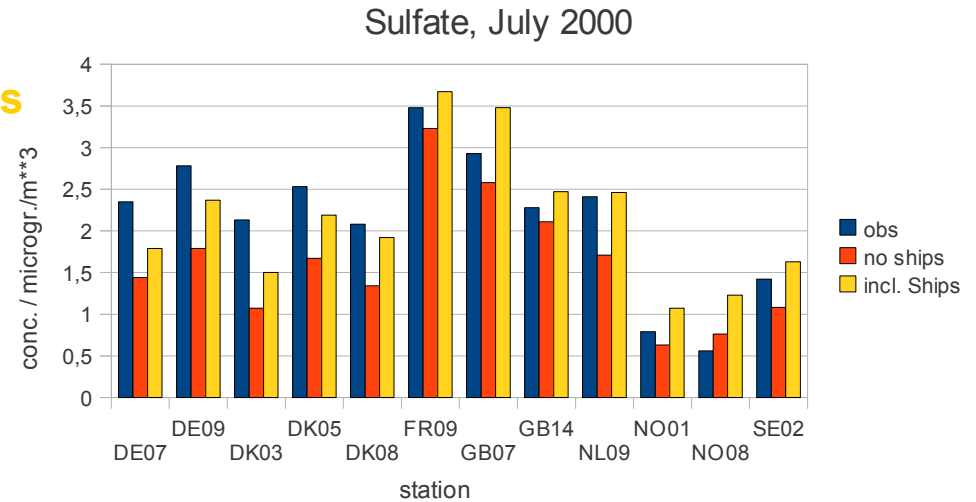
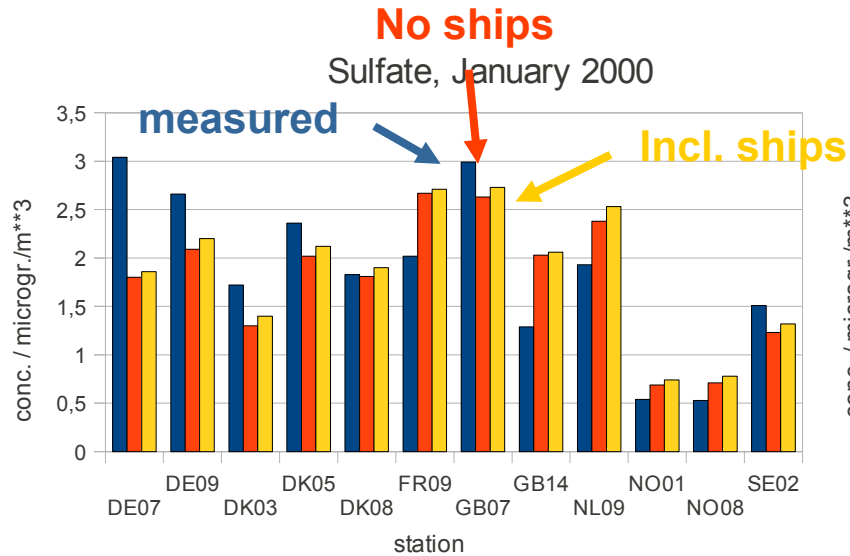
winter (DJF)



summer (JJA)



Comparison to measurements



Comparison to measurements reveals better results if ship emissions are included

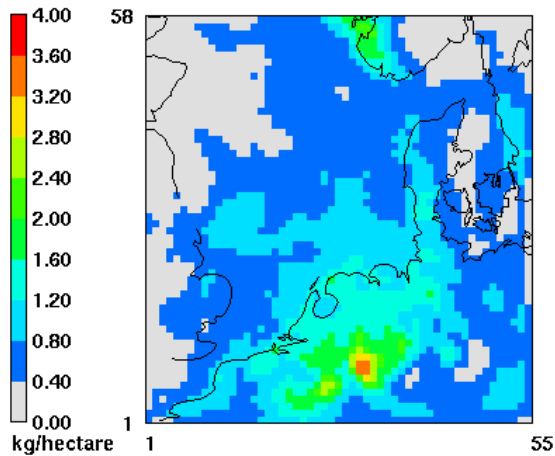
Effect is larger in summer compared to winter

Sulfate
Nitrate
Ammonium

Effects on sulfate wet deposition

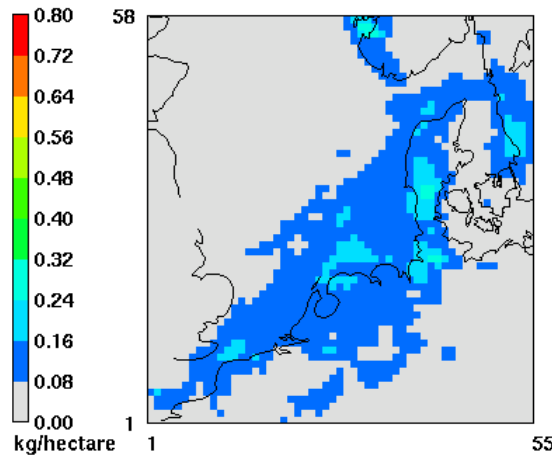
Sulfate wet deposition

total January 2000



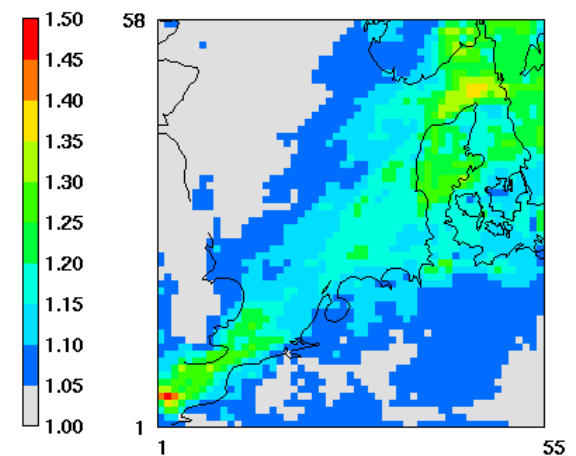
Sulfate wet deposition (ships)

total January 2000



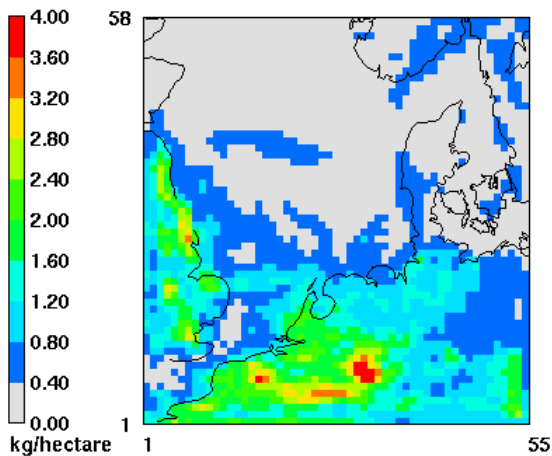
Rel. increase sulfate wet dep.

ships, January 2000



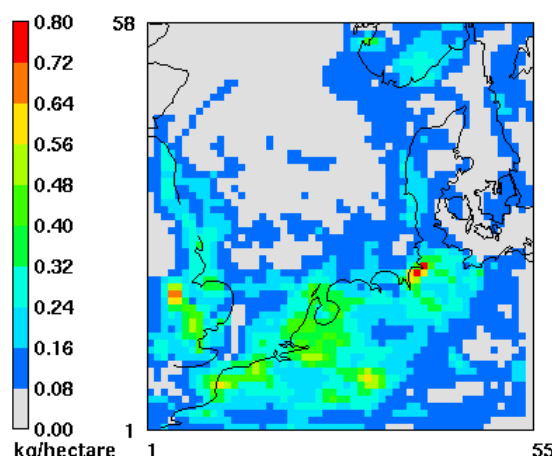
Sulfate wet deposition

total July 2000



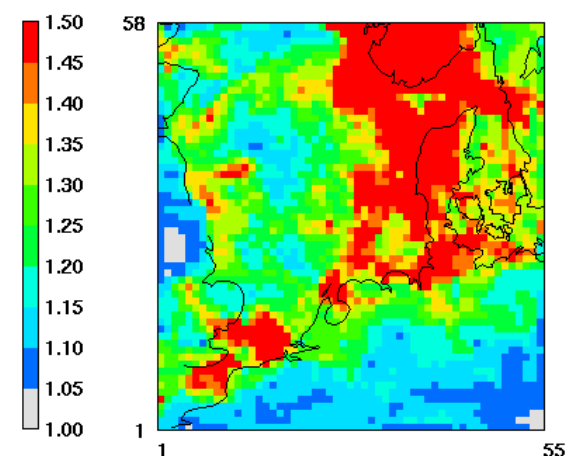
Sulfate wet deposition (ships)

total July 2000



Rel. increase sulfate wet dep.

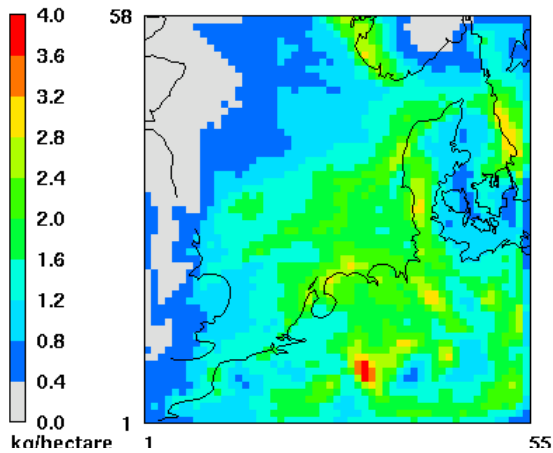
ships, July 2000



Effects on nitrate wet deposition

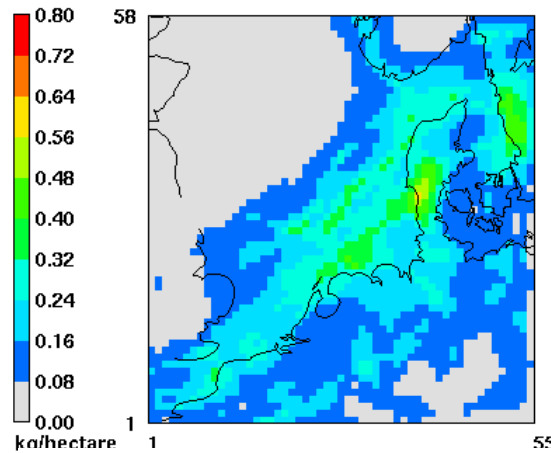
Nitrate wet deposition

total January 2000



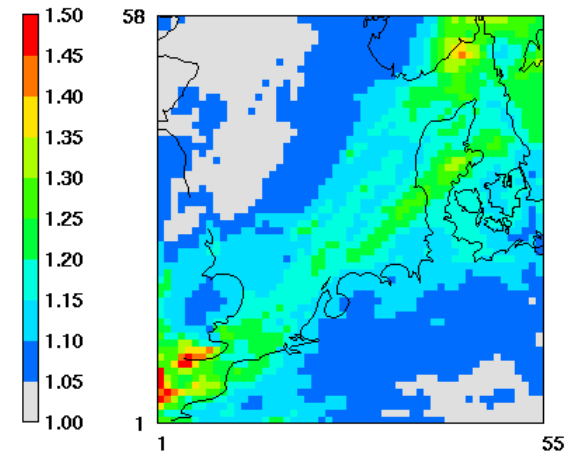
Nitrate wet deposition (ships)

total January 2000



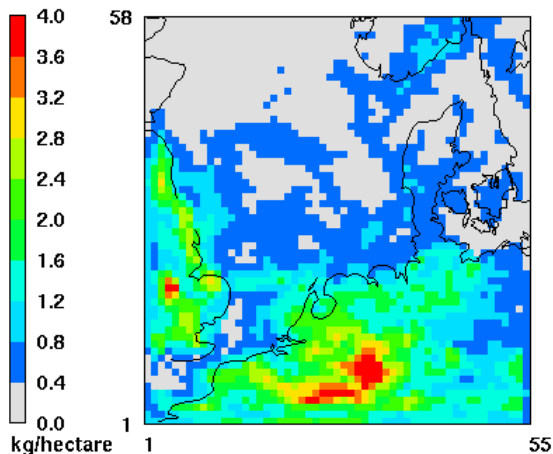
Rel. increase of nitrate wet dep.

ships, January 2000



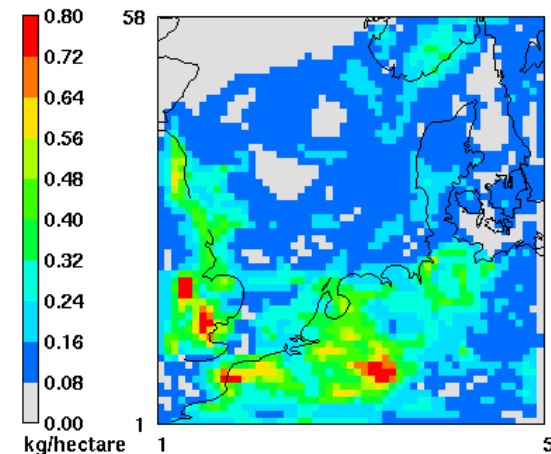
Nitrate wet deposition

total July 2000



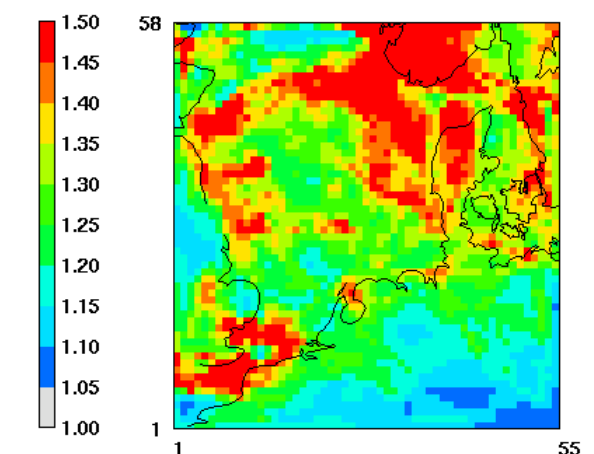
Nitrate wet deposition (ships)

total July 2000



Rel. increase of nitrate wet dep.

ships, July 2000

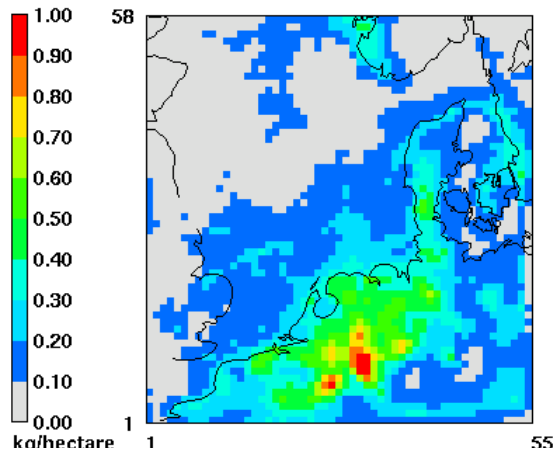


July 1, 2000 1:00:00
Min=1.06 at (55,1), Max=4.24 at (28,58)

Effects on ammonium wet deposition

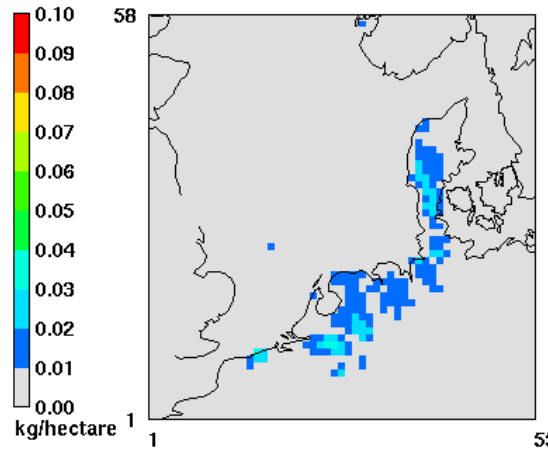
Ammonium wet deposition

total January 2000



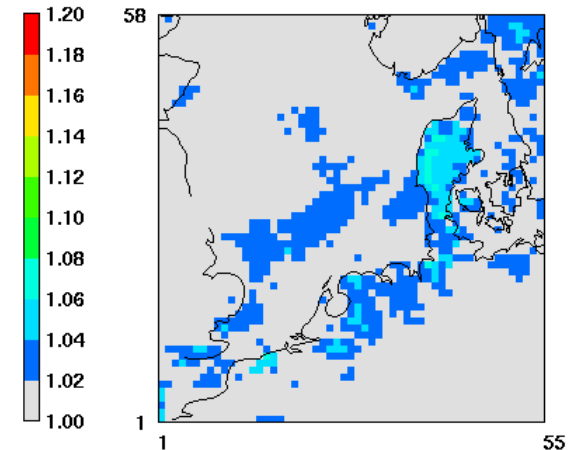
Ammonium wet deposition (ships)

total January 2000



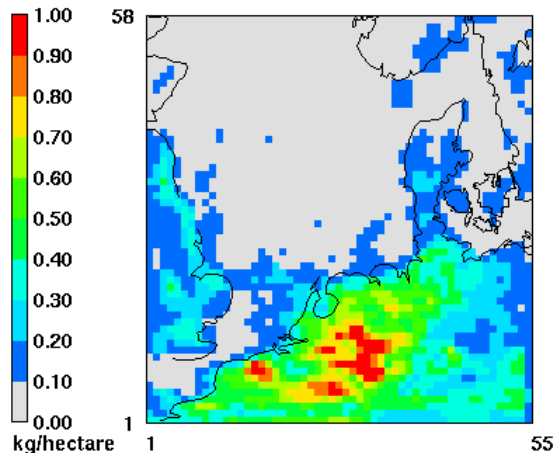
Rel. increase ammonium wet dep.

ships, January 2000



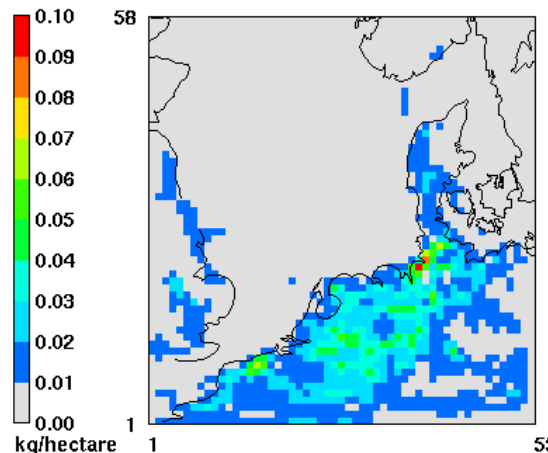
Ammonium wet deposition

total July 2000



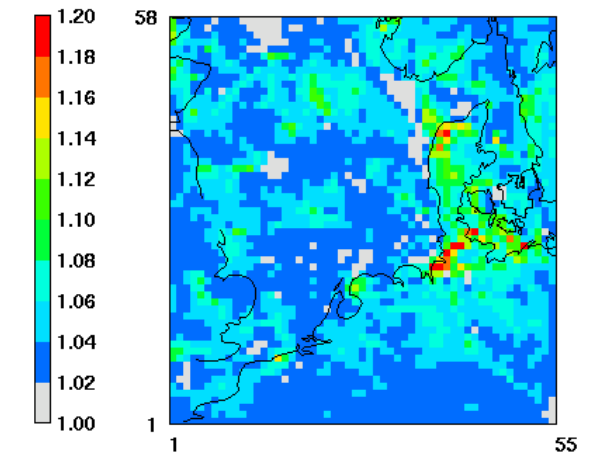
Ammonium wet deposition (ships)

total July 2000



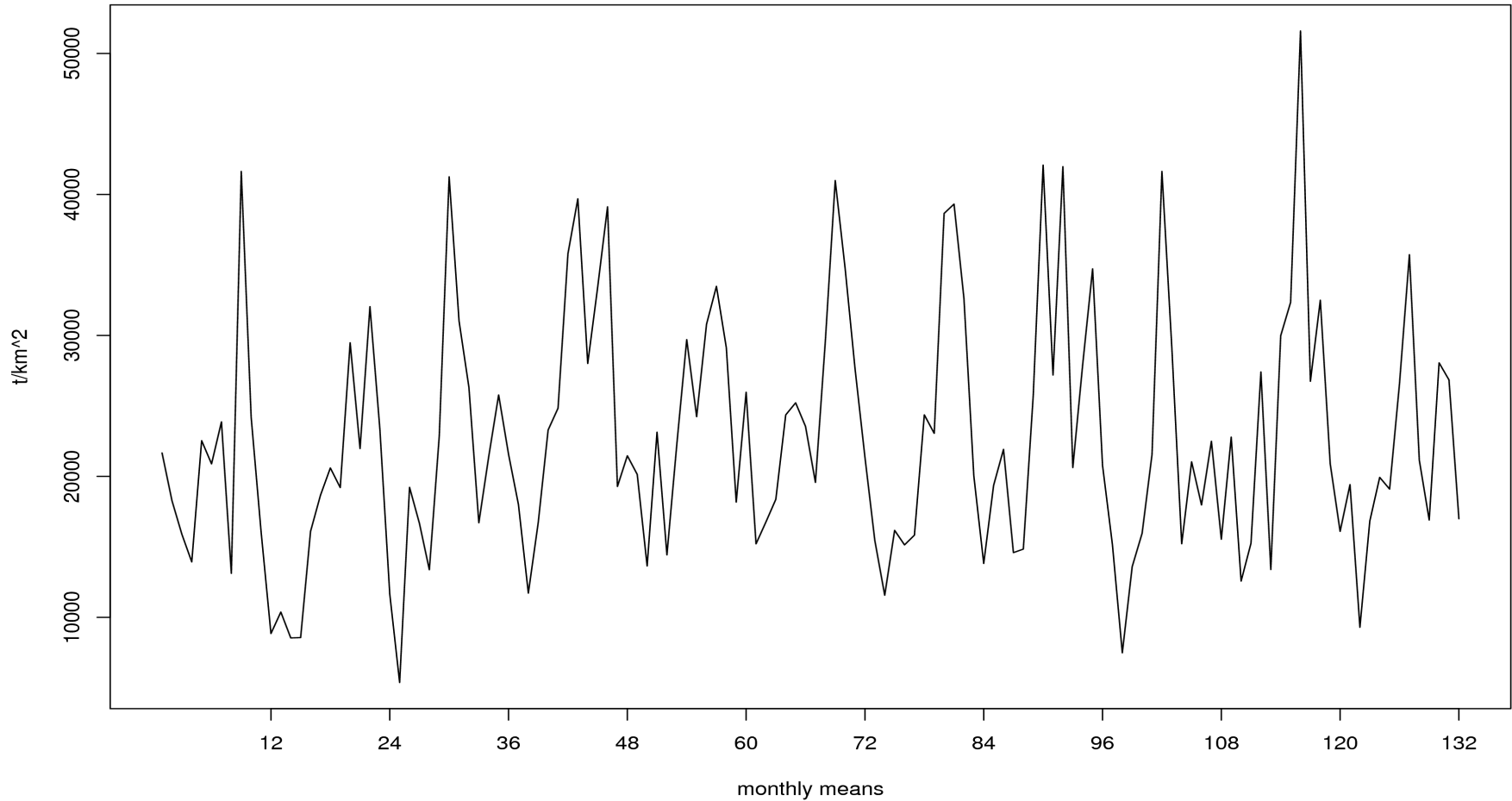
Rel. increase ammonium wet dep.

ships, July 2000



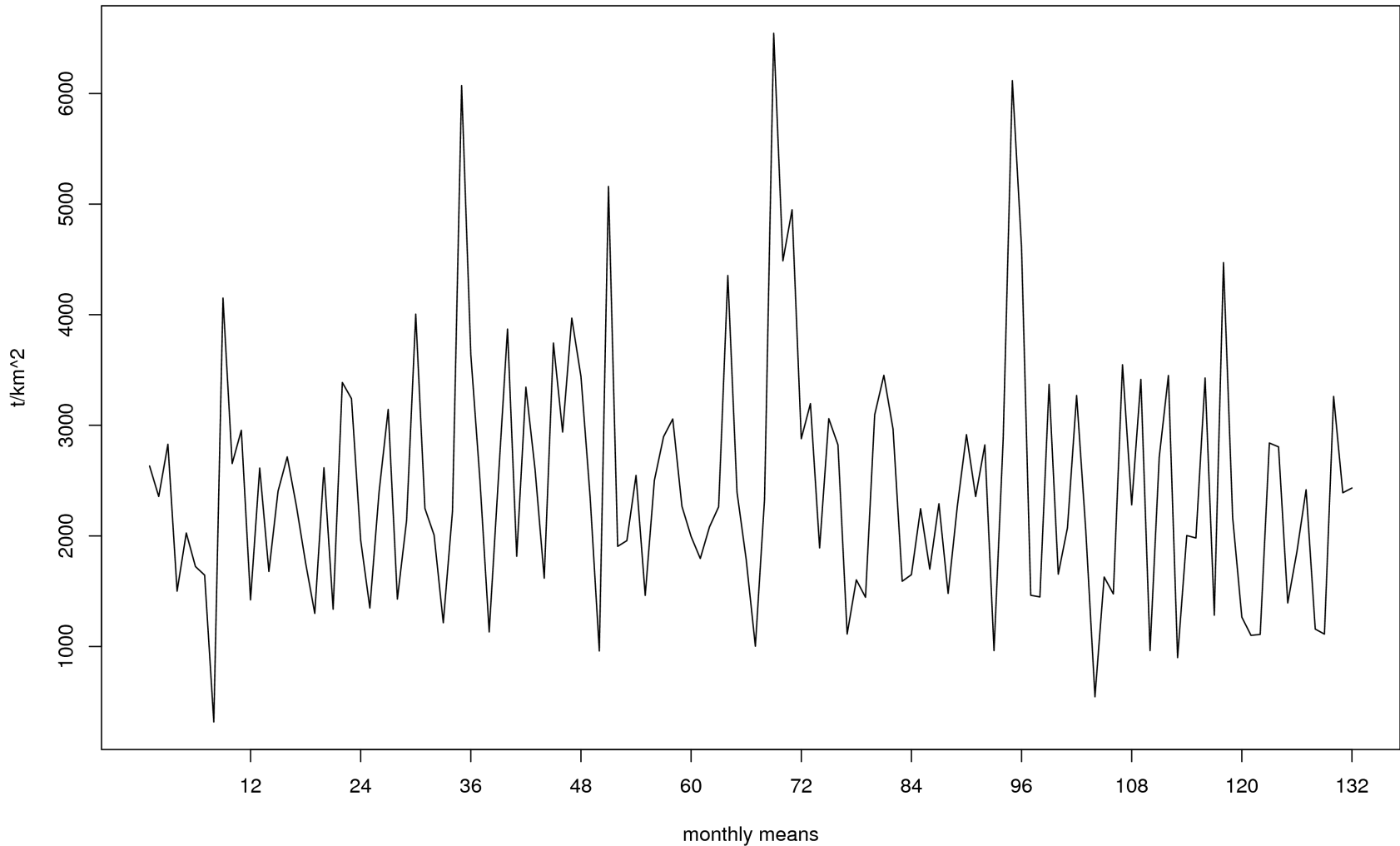
Trend of depositions into the North Sea between 1995 and 2005

Deposition of part. SO₄-S into the North Sea between 1995 and 2005



Trend of depositions into the North Sea between 1995 and 2005

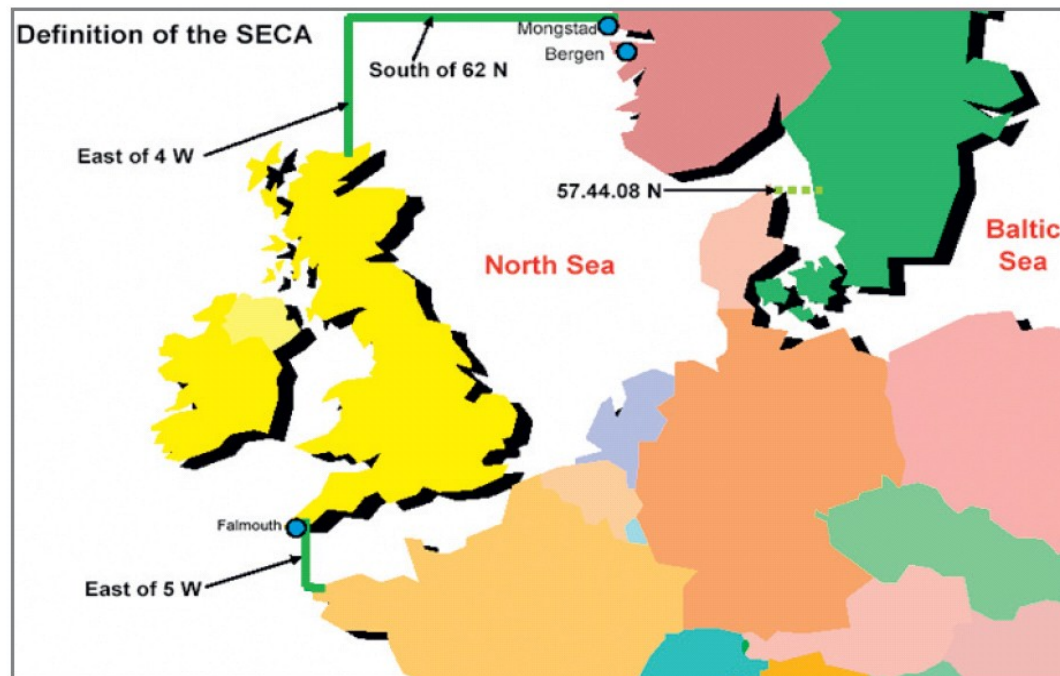
Deposition of part. NO₃-N into the North Sea between 1995 and 2005



Comparison between 1995 and 2005

tons	Sulphate-S		Nitrate-N		Ammonium-N	
	S	NoS	S	NoS	S	NoS
1995	20081	19897	2184	1947	909	905
2005	21402	21146	1990	1638	800	795

SO_x emission control area (SECA)



Karte: Verband Deutscher Reeder

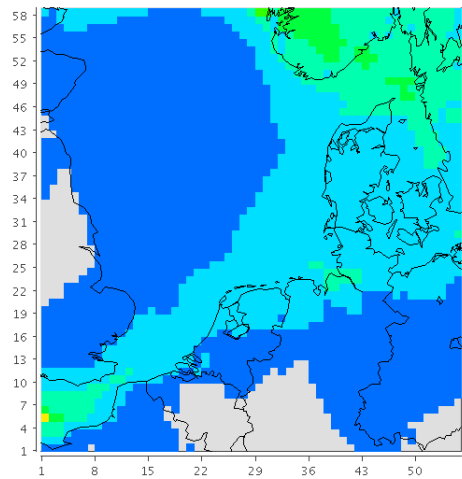
Ships have to use sulfur reduced fuels (max. 1.0% S since 1 July 2010)
SO₂ emissions by ships are reduced by 63 % within SECAs

From 2015 on, only 0.1 % S will be allowed

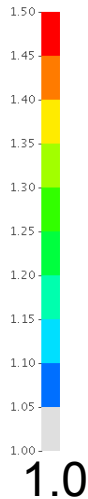
Sulfur reduced fuels (1.0%) in North and Baltic Sea SECAs: Aerosol concentrations in summer

Sulfate

SO₄(p)(ships 1.0% S)/SO₄(p)(no ships), JJA



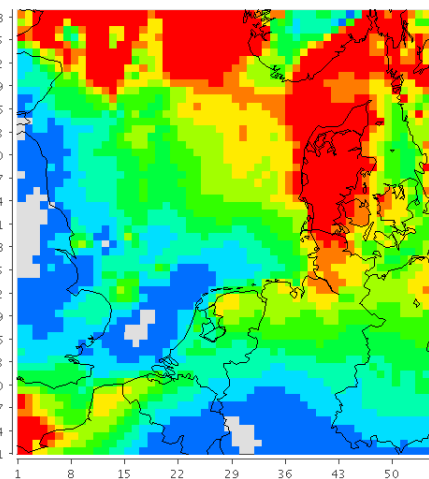
1.5



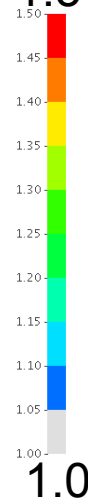
1.0

Nitrate

NO₃(p)(ships 1.0% S)/NO₃(p)(no ships), JJA



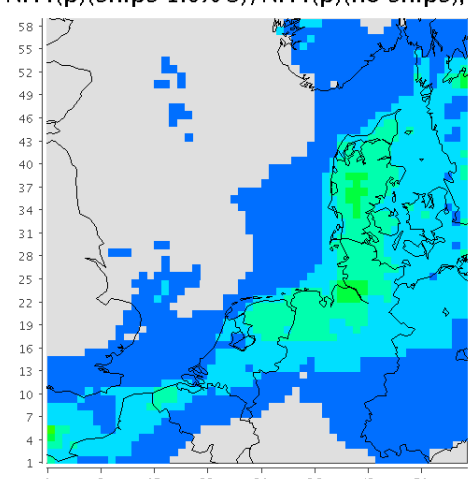
1.5



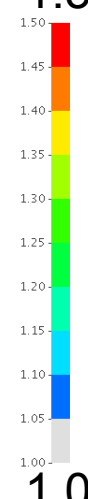
1.0

Ammonium

NH₄(p)(ships 1.0% S)/NH₄(p)(no ships), JJA



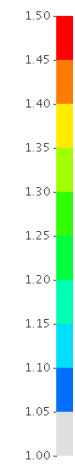
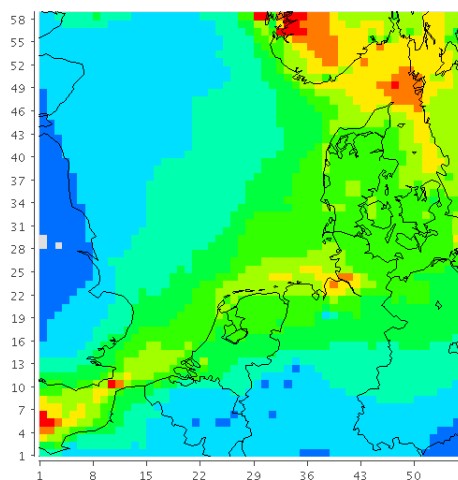
1.5



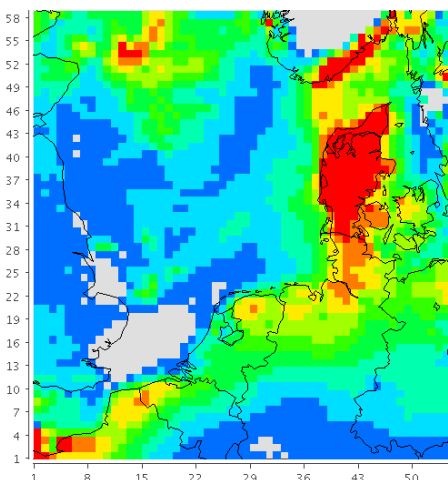
1.0

For comparison: Fuel with high sulfur content (standard heavy fuel oil)

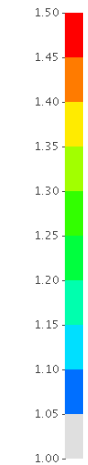
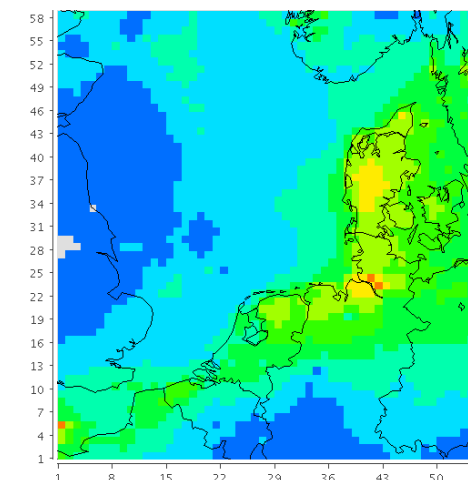
SO₄(p)(incl. ships)/SO₄(p) (no ships), summer (JJA)



NO₃(p)(incl. ships)/NO₃(p)(no ships), summer (JJA)



NH₄(p)(incl. ships)/NH₄(p)(no ships), summer (JJA)



Zusammenfassung

- Es wurde ein detailliertes Emissionskataster inklusive Schiffsemissionen erstellt.
- Simulationen mit dem Chemie-Transport Modell weisen auf deutlich erhöhte Schadstoffkonzentrationen in Küstenregionen in Folge des Schiffsverkehrs hin.
- Durch verstärkte Aerosolbildung kommt es zu erhöhten Depositionen von Säurebildnern und Nährstoffen (bis zu 50%).
- Schwefelarme Treibstoffe zeigen erwartete Reduktionen bei partikulärem Schwefel führen aber in manchen Regionen zu erhöhten Nitratkonzentrationen.

Publikation: V. Matthias et al. (2010): “The contribution of ship emissions to air pollution in the North Sea regions”, *Environmental Pollution* 158, 2241-2250