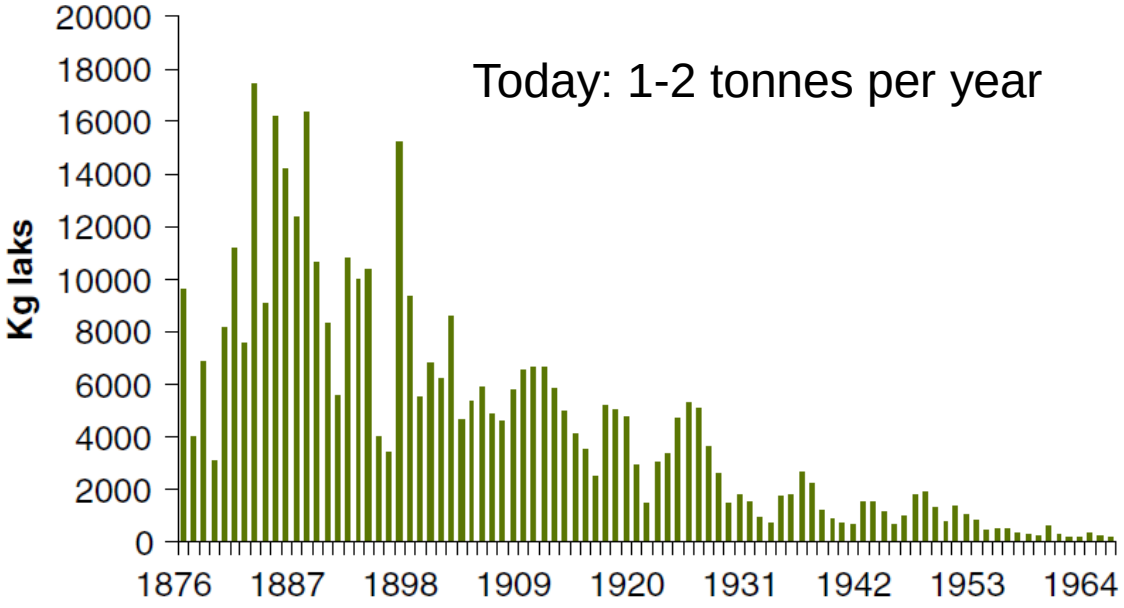
Whatever happened to acid rain?

Brit Lisa Skjelkvåle

Norwegian Institute for Water Research

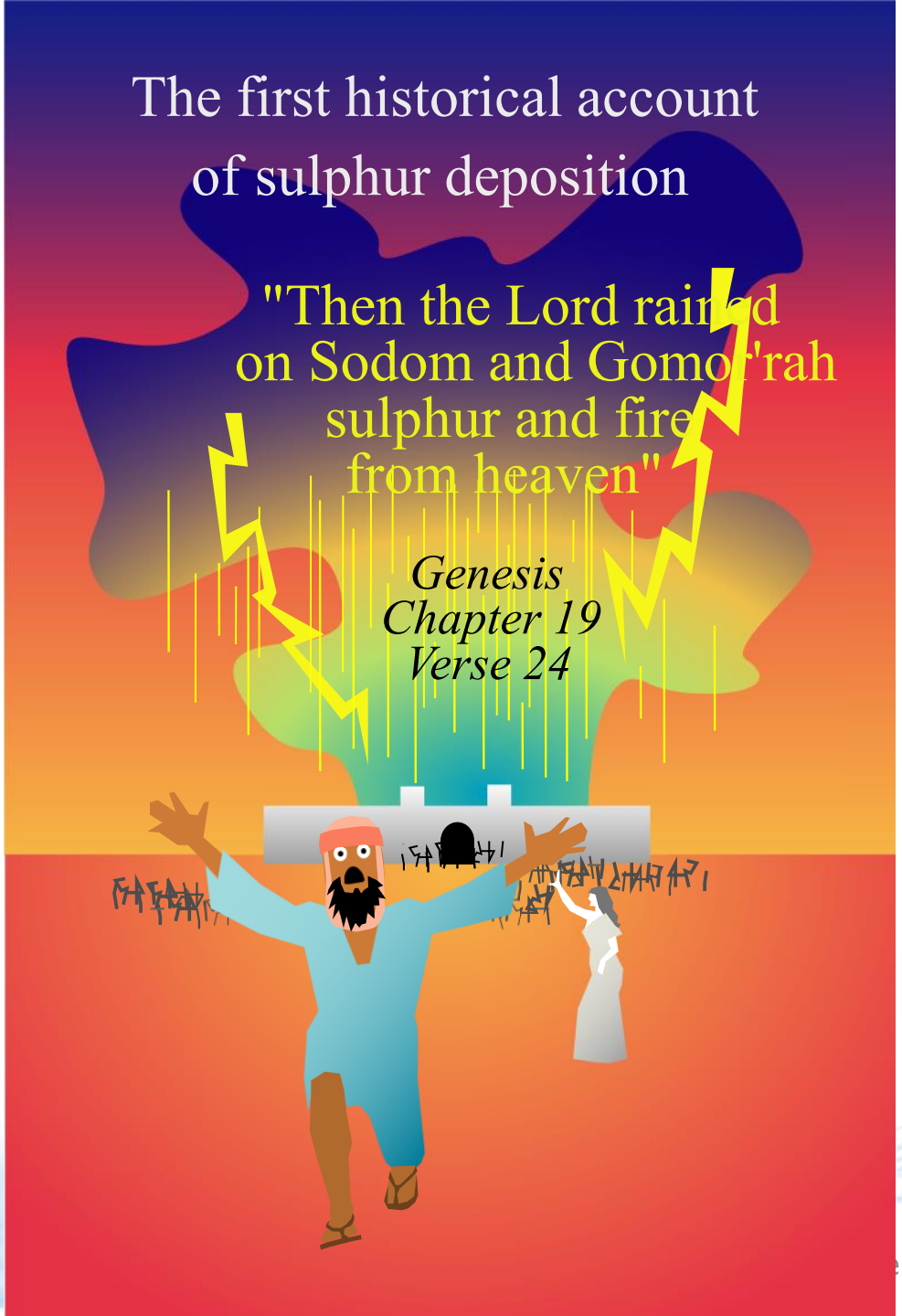

Congratulations with
25 years of monitoring in
Bayern!!!!



Fangststatistikk for Tovdalselva fra 1876 til 1964.

Et glimt fra de gode laksetider i Tovdalselva. Mr. William Radcliffe ved Boenfossen en gang i 1920-årene. I 1924 fikk han og Mr. Harold Wilson til sammen 1362 laks på to stenger i løpet av 5½ dagers fiske.

The pictures of Mr Radcliffe and the graphics is from the Norwegian report DN utredning 2003-5. Laksen er tilbake i kalkede Sørlandselver. Reetableringsprosjektet 1997-2002 (The salmon is back in rivers in Southern Norway)
The background picture is River Tovdalselva, Photo Frode Kroglund, NIVA


The first historical account
of sulphur deposition
"Then the Lord rained
on Sodom and Gomorrah
sulphur and fire
from heaven"
Genesis
Chapter 19
Verse 24

The discovery of Acid Rain I

- **1872:** Robert Angus Smith introduced the concept of "Acid Rain" in his book:
  - "Air and Rain: the Beginning of a Chemical Climatology"
  - many of the ideas we now consider part of the acid precipitation problem was presented for the first time
- **1948:** the first large scale precipitation-monitoring network was established
- **1954-1961:**
  - Barret and Brodin (1955)and Gorham (1955) began systematically to study the causes of acid precipitation and its effects on aquatic ecosystems based on data collected in Sweden, Canada and England.
  - Eville Gorham demonstrated in several papers that
    - acidity in precipitation influenced geological weathering processes and the chemistry of lake waters, bog waters and soils
    - acidity in precipitation affects the alkalinity and buffering capacity of lake and bog waters

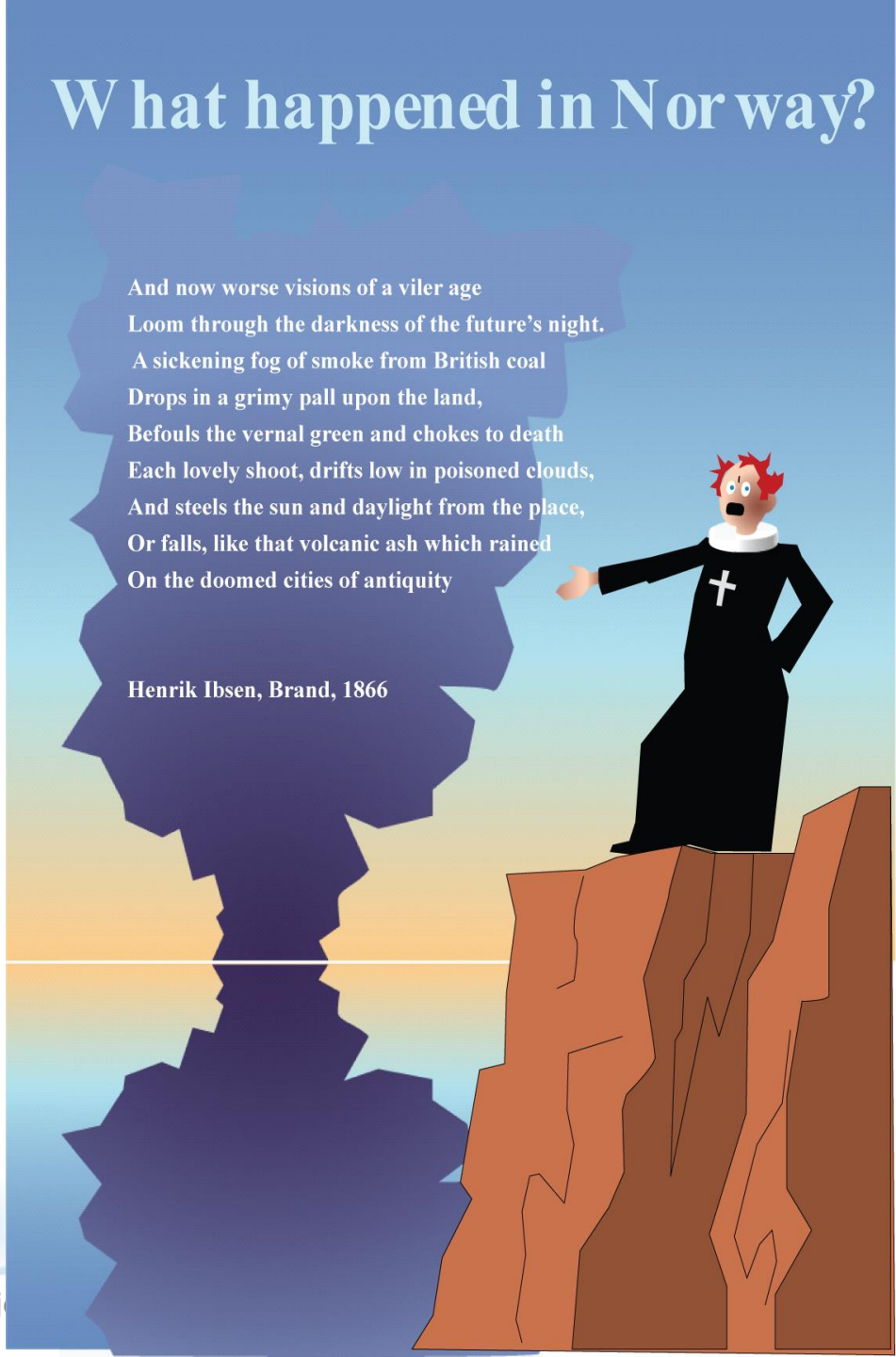
The discovery of Acid Rain II

- **1967-1968: Svante Odén** at the Agricultural University of Uppsala, Sweden.
  - Showed that acidity in precipitation in Scandinavia was attributable largely to emissions of sulphur in England and Central Europe
  - Demonstrated the increasing acidity of Scandinavian rivers
  - Postulated *acid precipitation* as probable cause of :
    - decline in fish populations
    - impoverishment of forest soils
    - decreased forest growth
    - increased disease in plants
    - corrosion and other damage to materials

Acid rain and air pollution

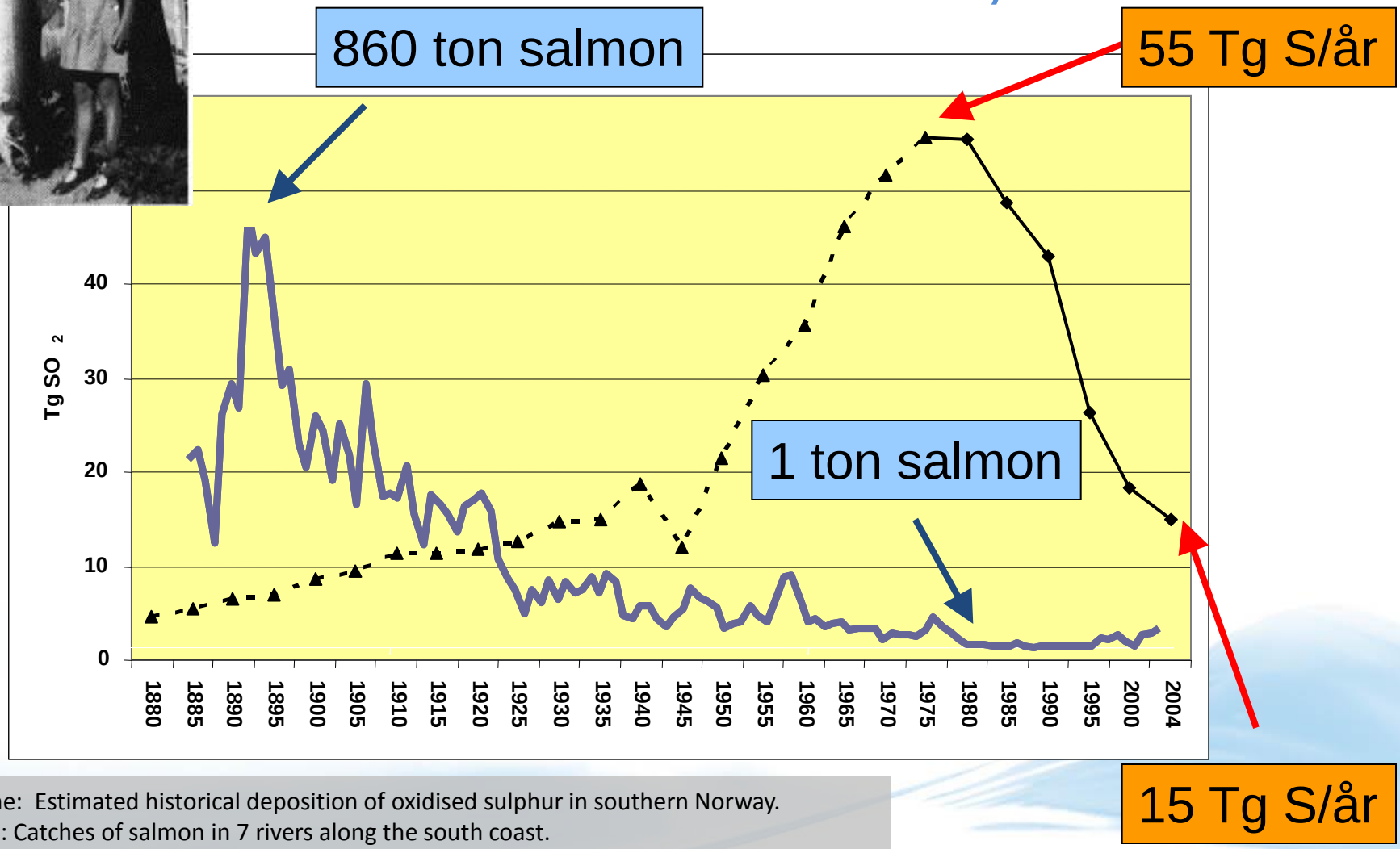
1881: C.V. Brögger observed
- "smutsig snefald" (dirty snowfall) in Norway and attributed it to either a large town or an industrial district in Great Britain

«Gutta på tur»: Waldemar Brøgger og Hans Henrik Reusch på Corsica i 1876.




FISKE-REDSKAPER FOR
SALT-OG FERSKVAND

Historic emissions of SO_2 in Europe and Salmon catch in seven main rivers in southern Norway



Black line: Estimated historical deposition of oxidised sulphur in southern Norway.
Red line: Catches of salmon in 7 rivers along the south coast.
Sulphur deposition in southern Norway in 1890 was 400 mg S/m2.
From: Mylona 1993 (deposition) and Kroglund et al. 1994 (salmon catch)

Acidification in Norway

- **1920's:** The first lakes with fish death was reported before 1920 in the county of Rogaland, and the reason for this was it a large mystery

THE EFFECTS OF ACID WATER ON TROUT FRY.

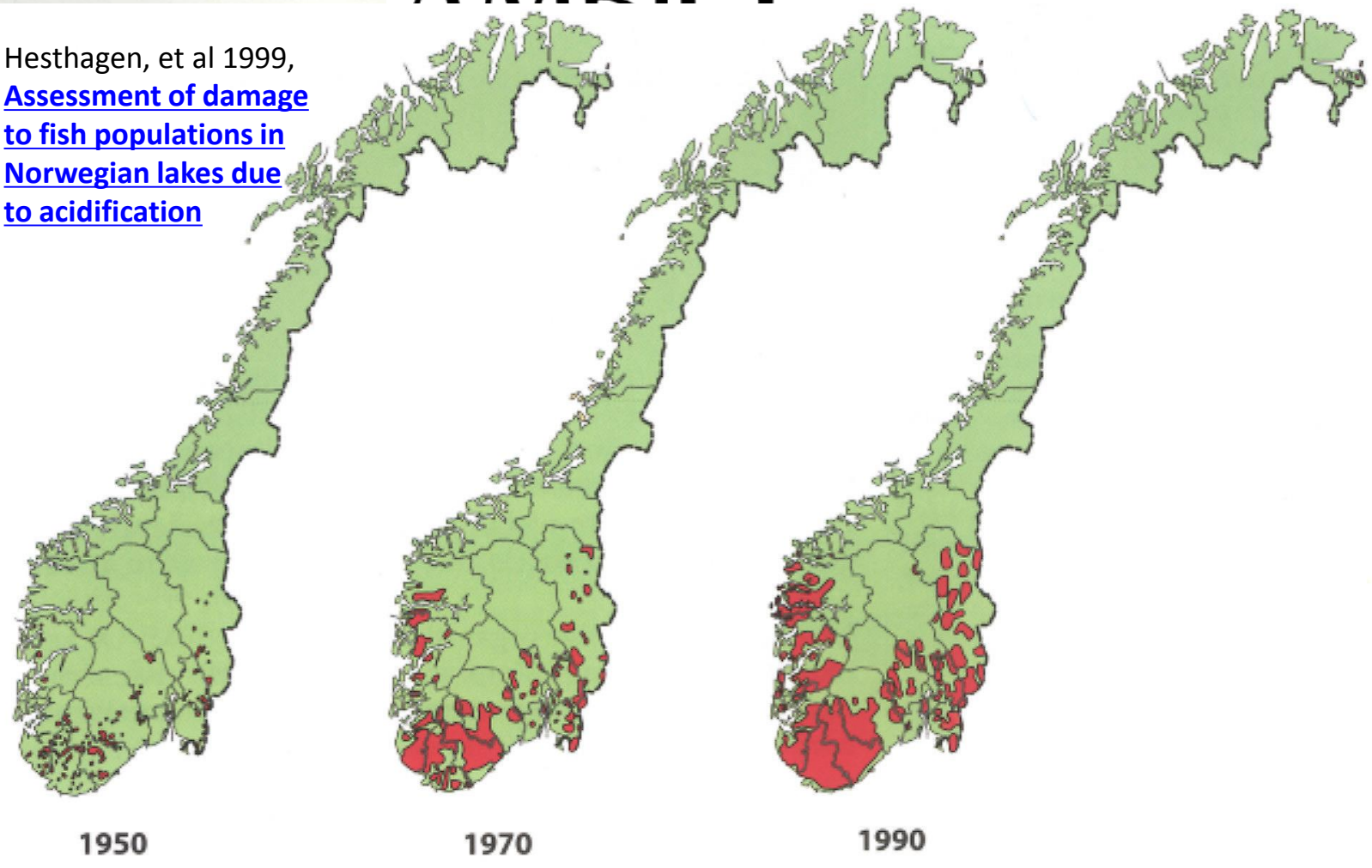
By Professor Dr. Knut Dahl.

36 *SALMON AND TROUT MAGAZINE* Vol. 46 (1927)

Fairly strong indications thus appear to point to the fact that the acidity of the water may have something to do with the bathymetrical distribution of the lower animal life in the lakes and may influence the seasonal migrations of the fish. In my opinion, the further investigation of these questions of fish life in relation to the acidity of the water will prove a large field for future, and probably well rewarded reseach.

Acidification of lakes and rivers in Norway

Hesthagen, et al 1999,
Assessment of damage to fish populations in Norwegian lakes due to acidification



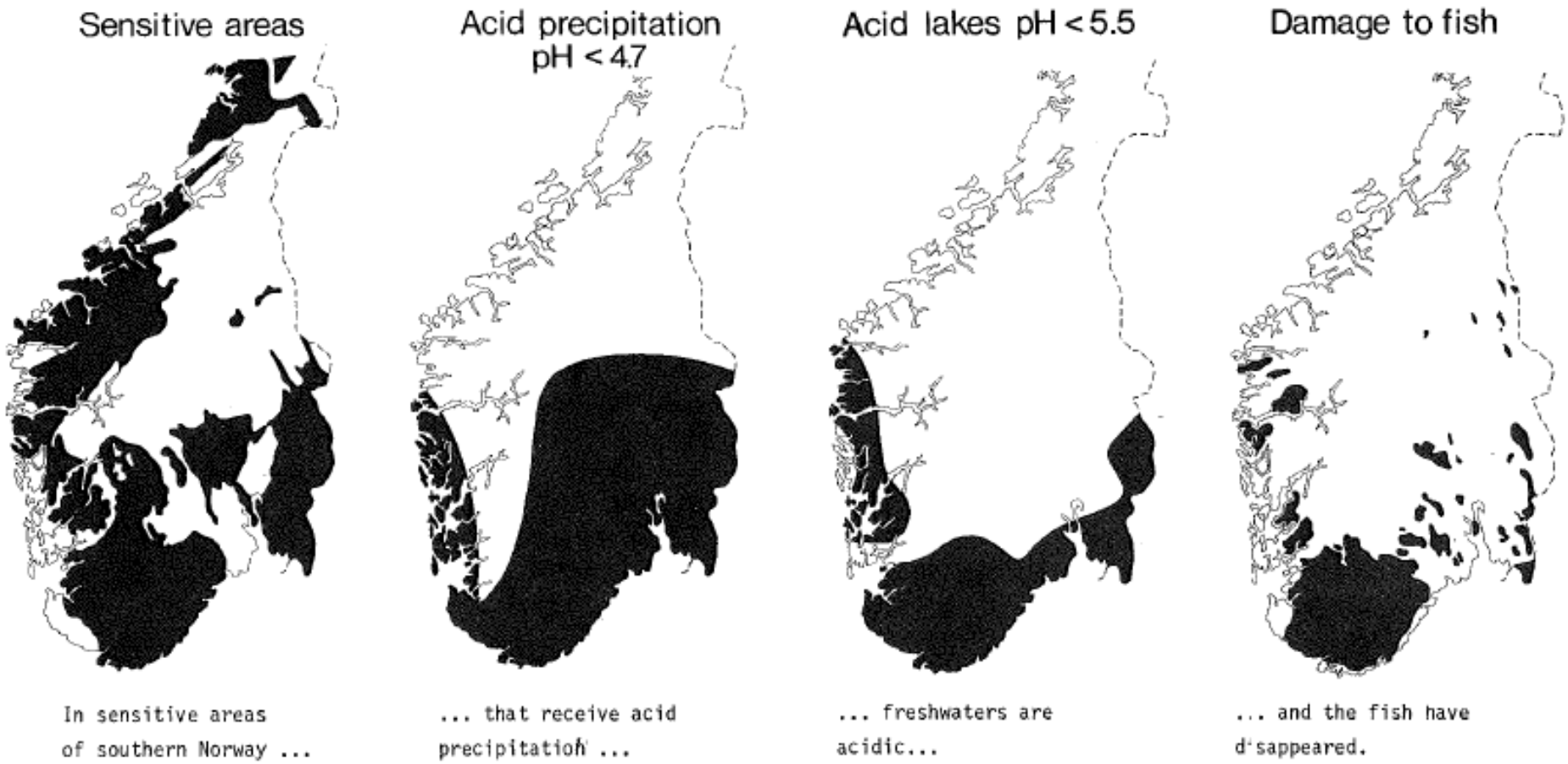


Figure 6. (after Likens 1976, data from Wright and Henriksen 1978, and Sevaldrud *et al.* 1980).

Source: Wright 1983 Water Qual. Bull.

...and elsewhere in Europe

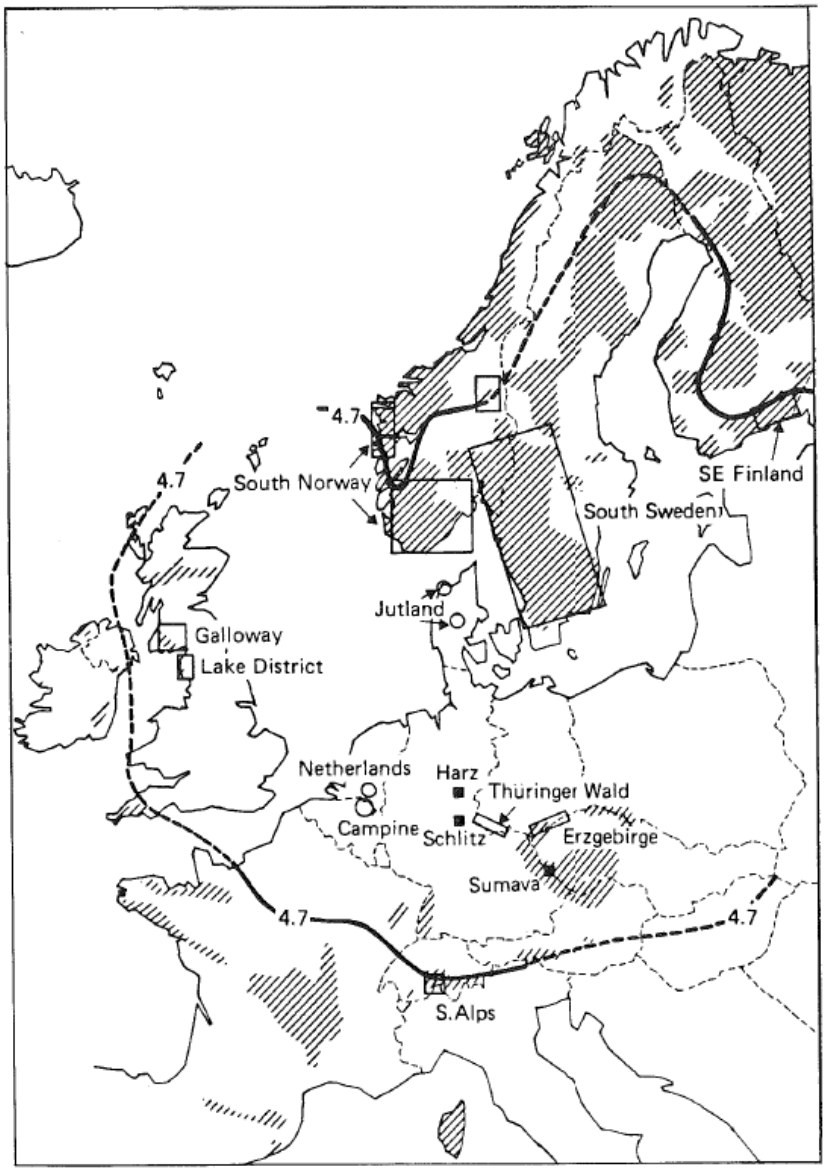
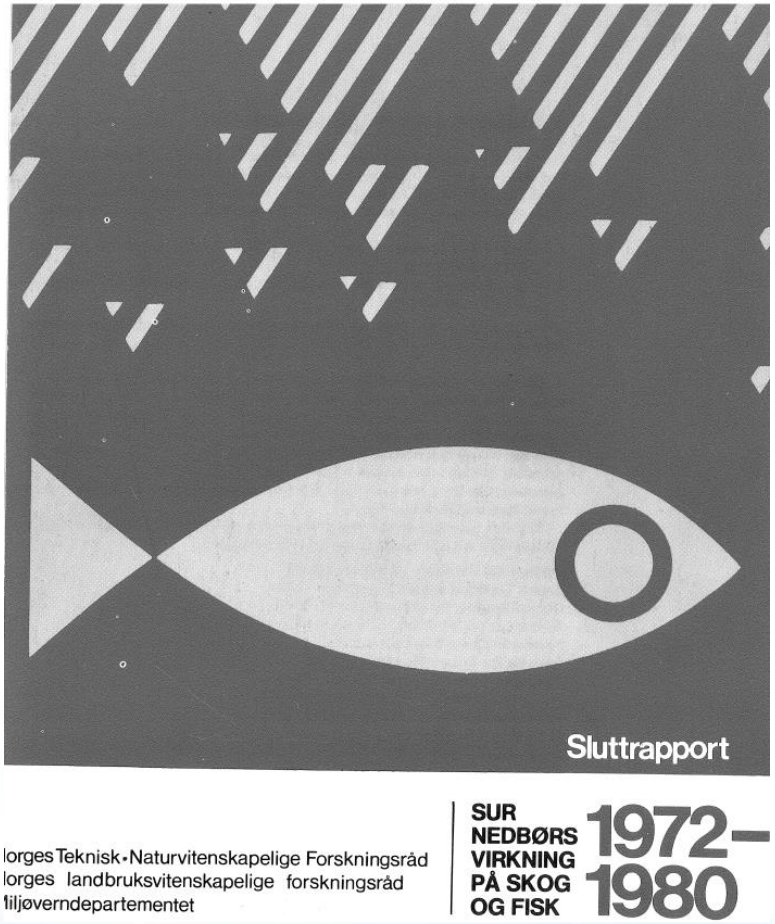


Figure 1. Map of Europe showing areas sensitive to freshwater acidification (from bedrock geology). Areas within the pH 4.7 isoline receive precipitation of acidity exceeding the "threshold" for ecological effects in the most sensitive waters. Areas from which acid freshwaters (pH less than 5) have been reported lie on sensitive bedrock (square) or on siliceous sands (circles).

From Wright in:
Physical and Chemical Weathering in Geochemical Cycles
edited by A. Lerman, M. Meybeck 1988

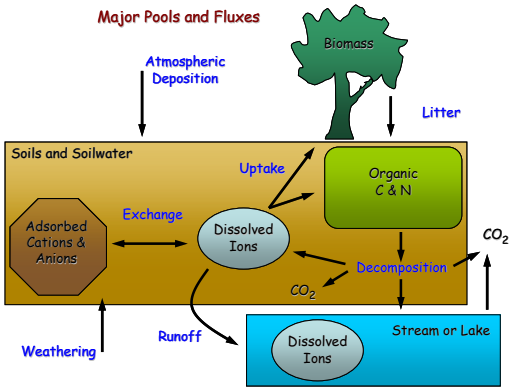
SNSF project 1972-1980
acid deposition: effects on forest and fish

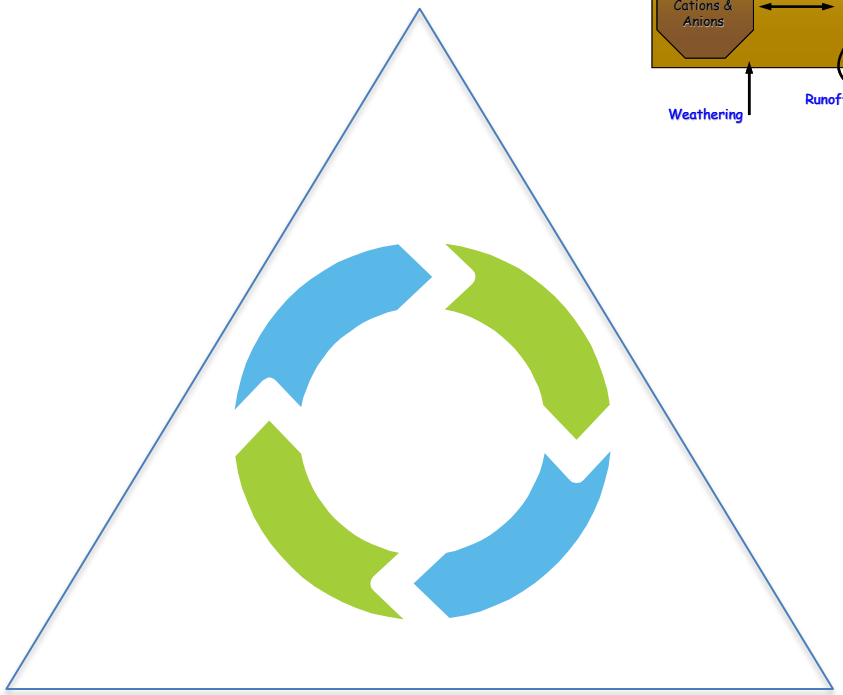


- NIVA – Norwegian Institute for Water research
- NILU –Norwegian Institute for Air Research
- NVE Norwegian Water Resources and Energy Directorate (NVE)
- NISK - Norwegian institute for forest research (NISK)
- +several others

- 150 scientists
- 300 reports

Models





Experiments

Monitoring

SNSF project:

Main Scientific conclusions

- Acid precipitation is the major cause of the regional acidification of rivers and lakes in Scandinavia and other parts of Europe
- No significant damage to forest

Other important outcome

- New scientific knowledge
- Interdisciplinary co-operation, national and international
- Basis for national monitoring programs
- Basis for international negotiations
- Important database for future research

Acid rain? – really?

Krug and Frink, 1983, Nature

Acidity from acid rain is buffered by 'natural acidity' from DOC

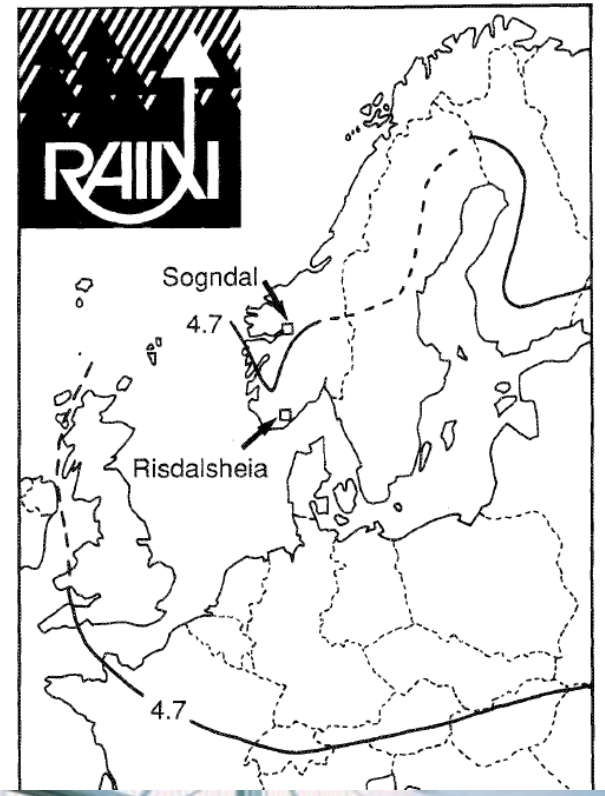
Acid Rain on Acid Soil: A New Perspective

Edward C. Krug and Charles R. Frink

RAIN project 1983: Reversing Acidification In Norway

all pictures from the RAIN-project

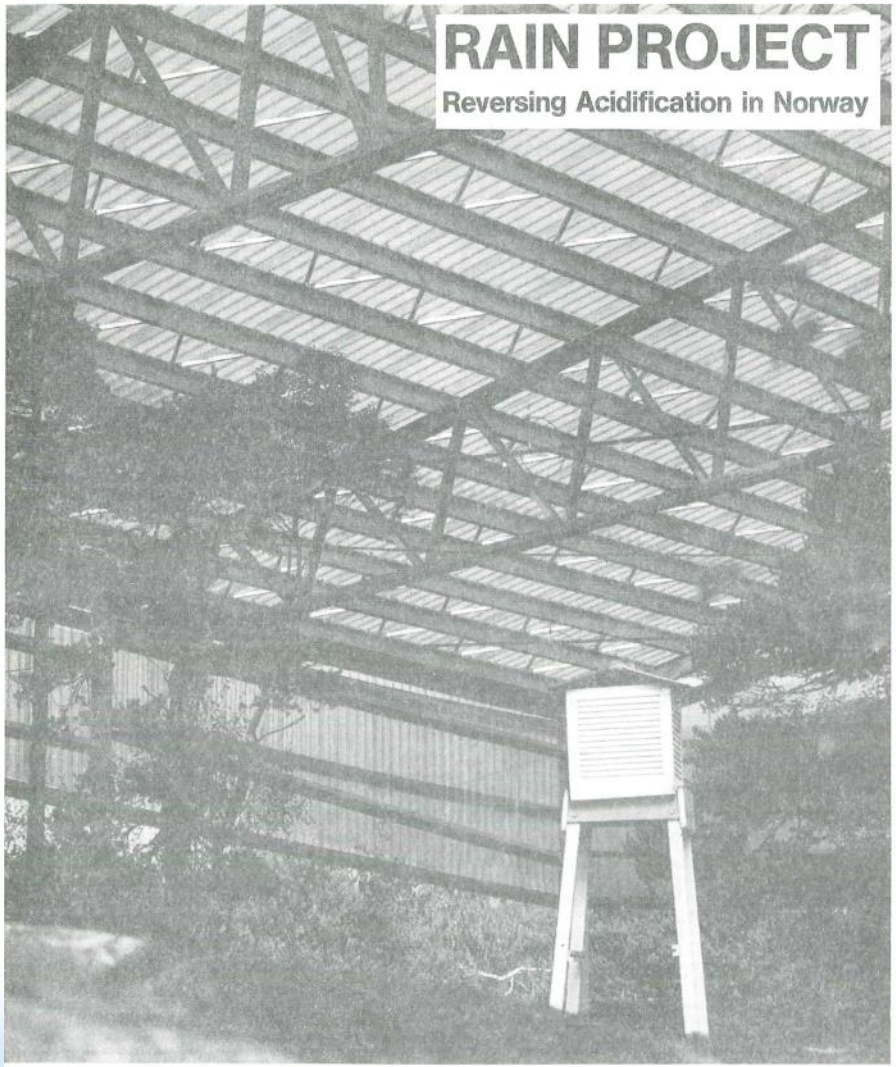
- an experiment to show that the cause of acid water is acid rain

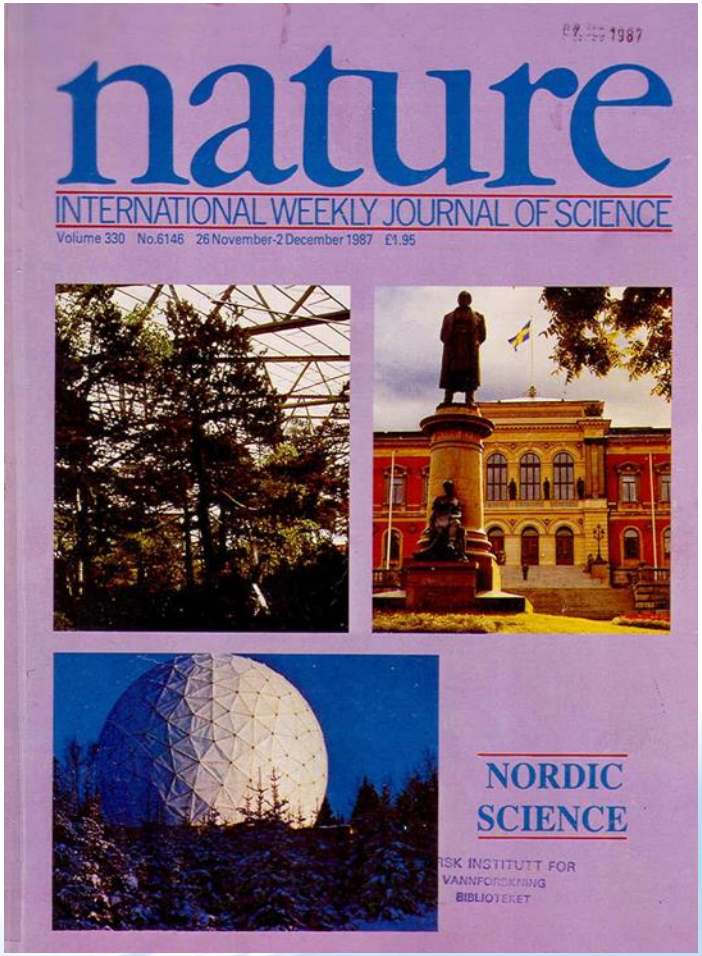


Reversibility of acidification shown by whole-catchment experiments

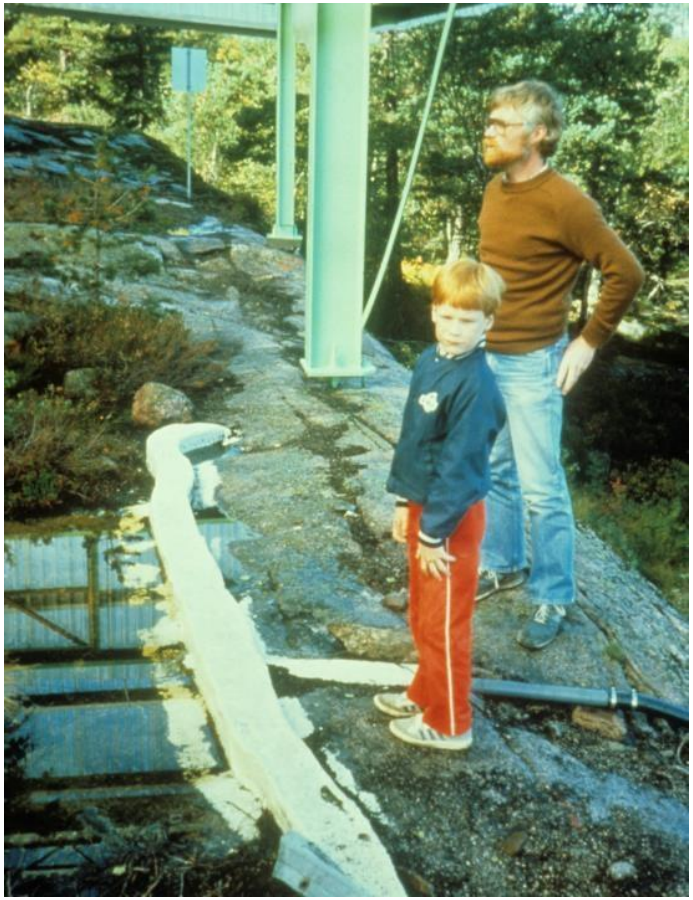
R. F. Wright*, E. Lotse† & A. Semb‡
* Norwegian Institute for Water Research, Box 33 Blindern, 0313 Oslo, Norway
† Department of Soil Sciences, Swedish University of Agricultural Sciences, 75007 Uppsala, Sweden
‡ Norwegian Institute for Air Research, Box 64, 2001 Lillestrøm, Norway

Reprint from :
nature
25 August 1988
Vol. 334 Issue no. 6184





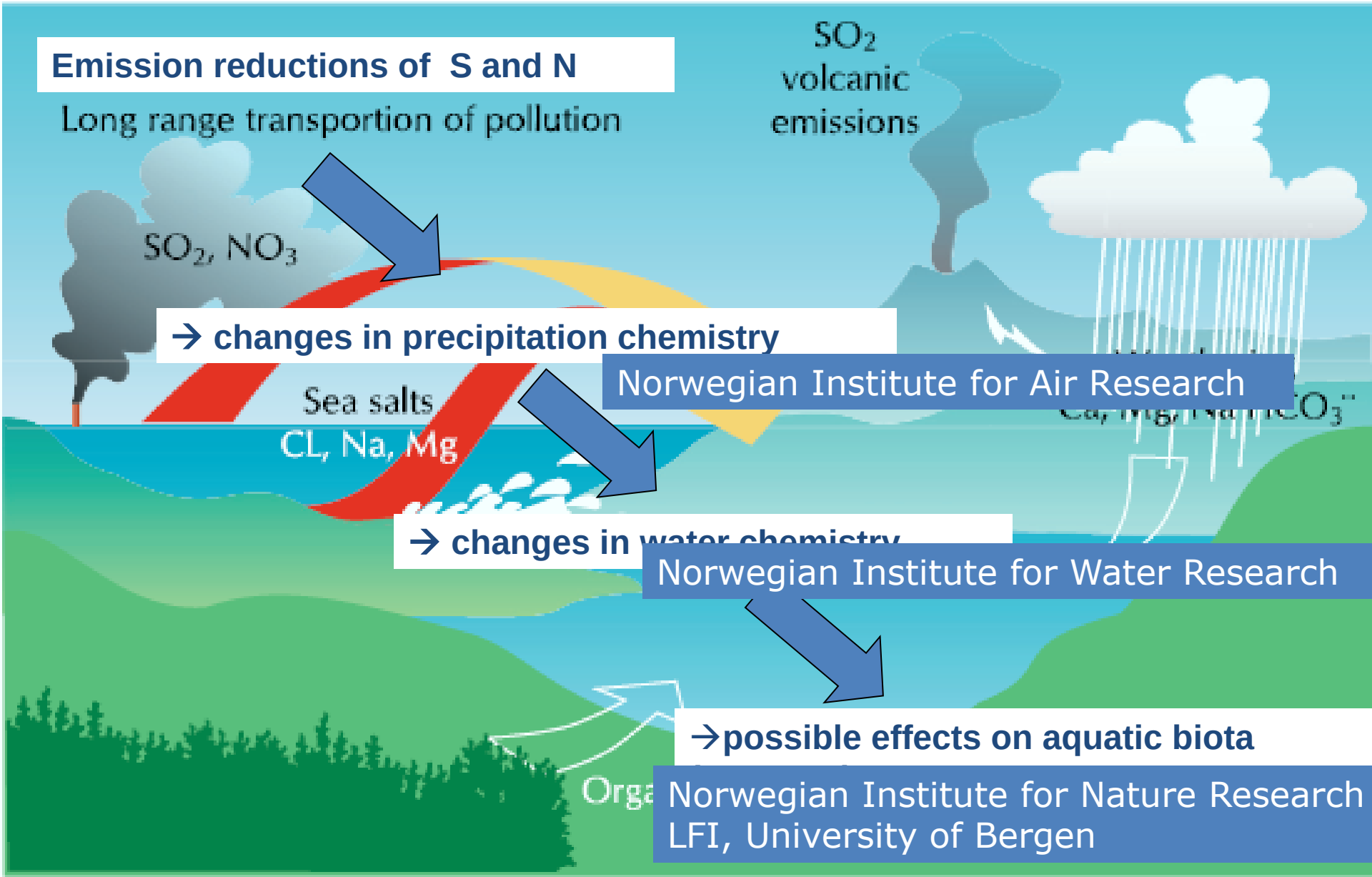
A long-term experiment (1983-1995)
Richard F. Wrigth and his son at the start and in the end of the project



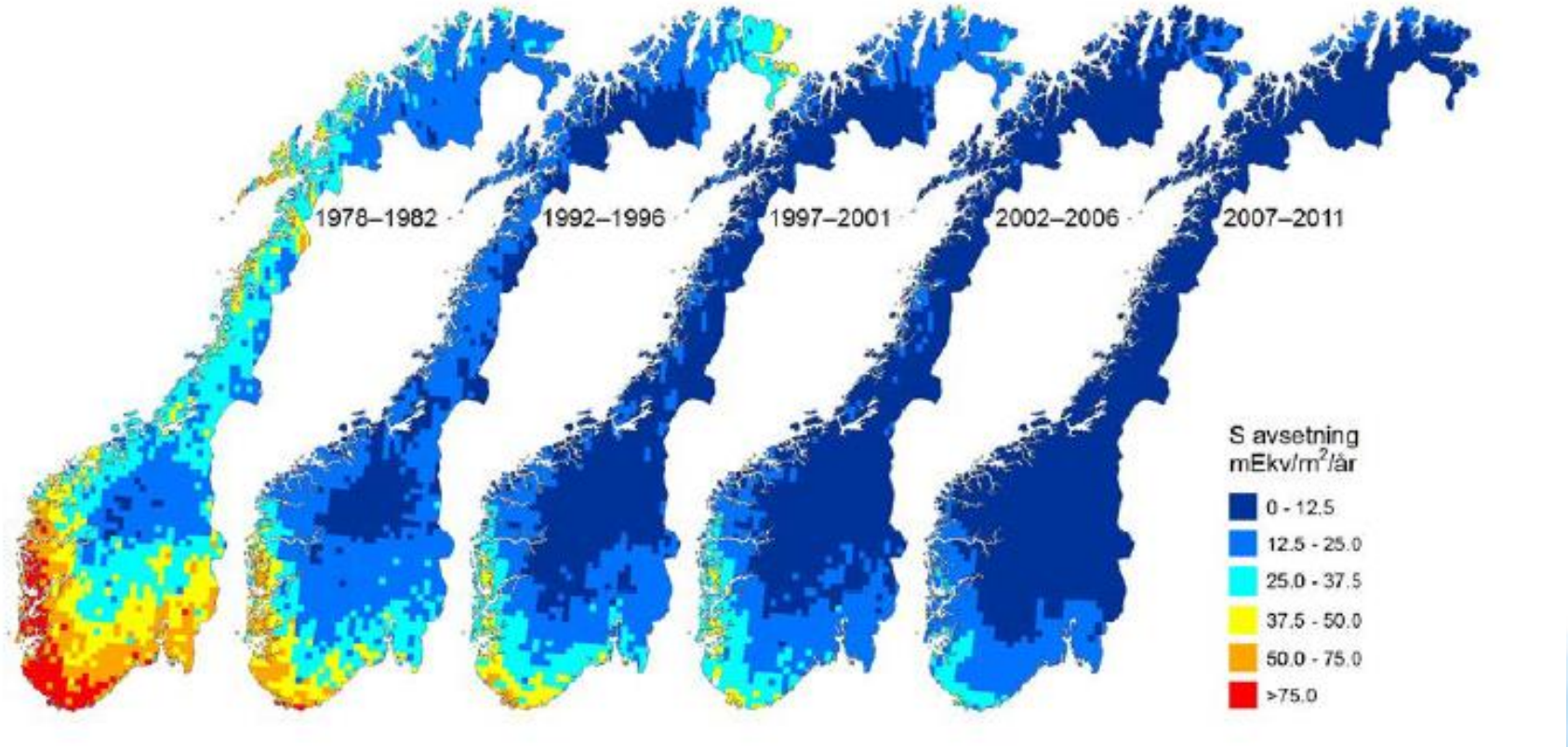
1984

1992

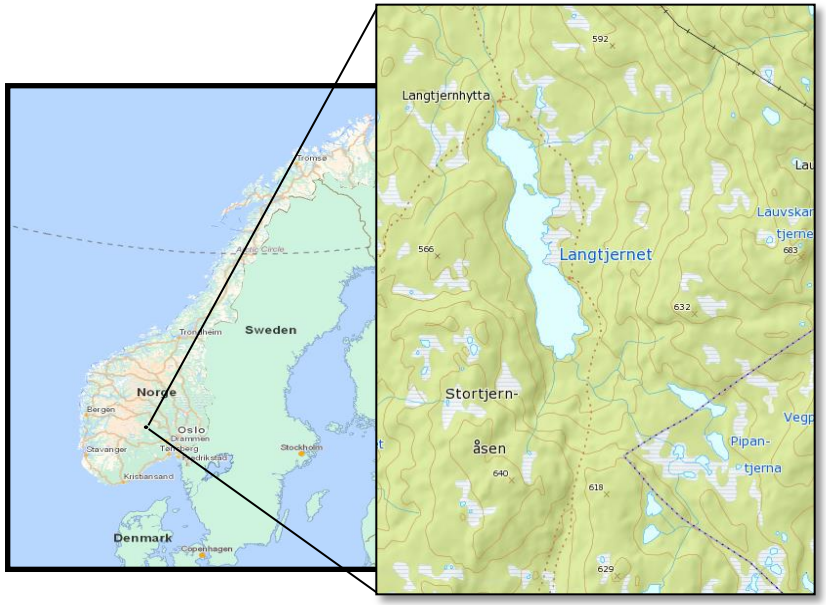
The Norwegian monitoring network in operation since 1980

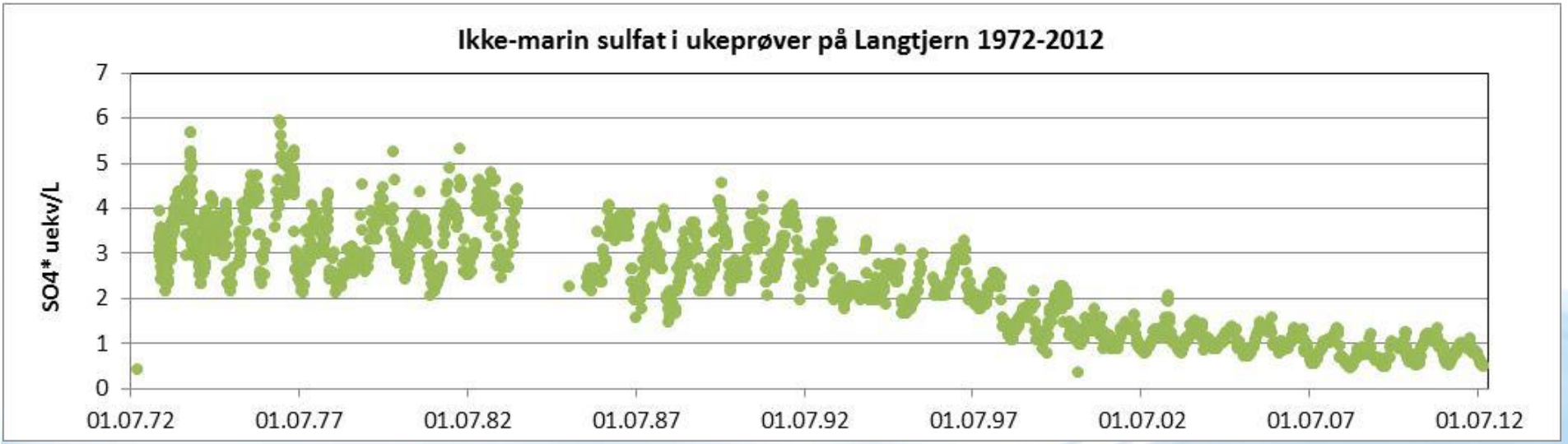


S-deposition from 1978 to 2011



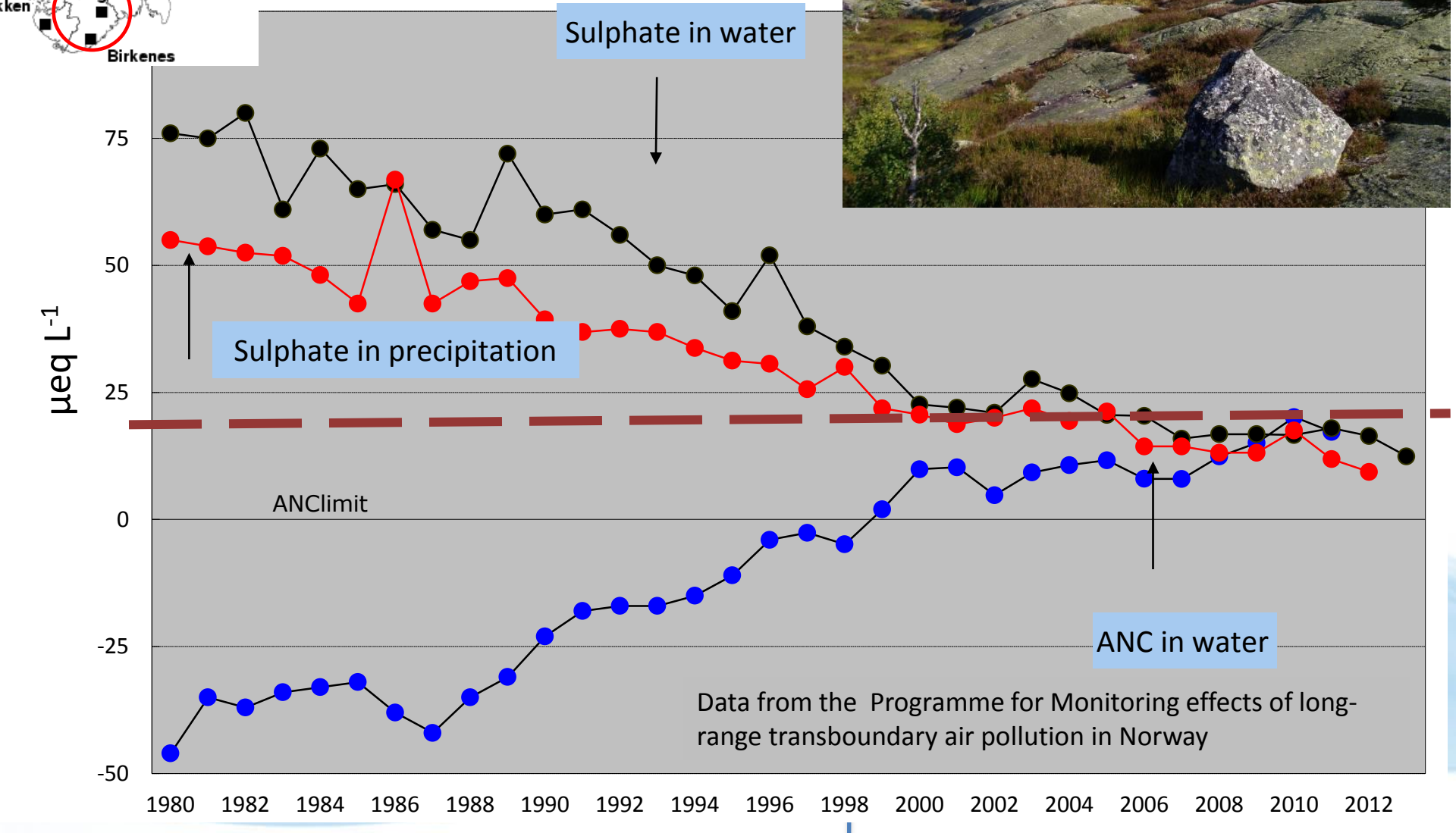
Map from Lund et al 2012, data from NILU





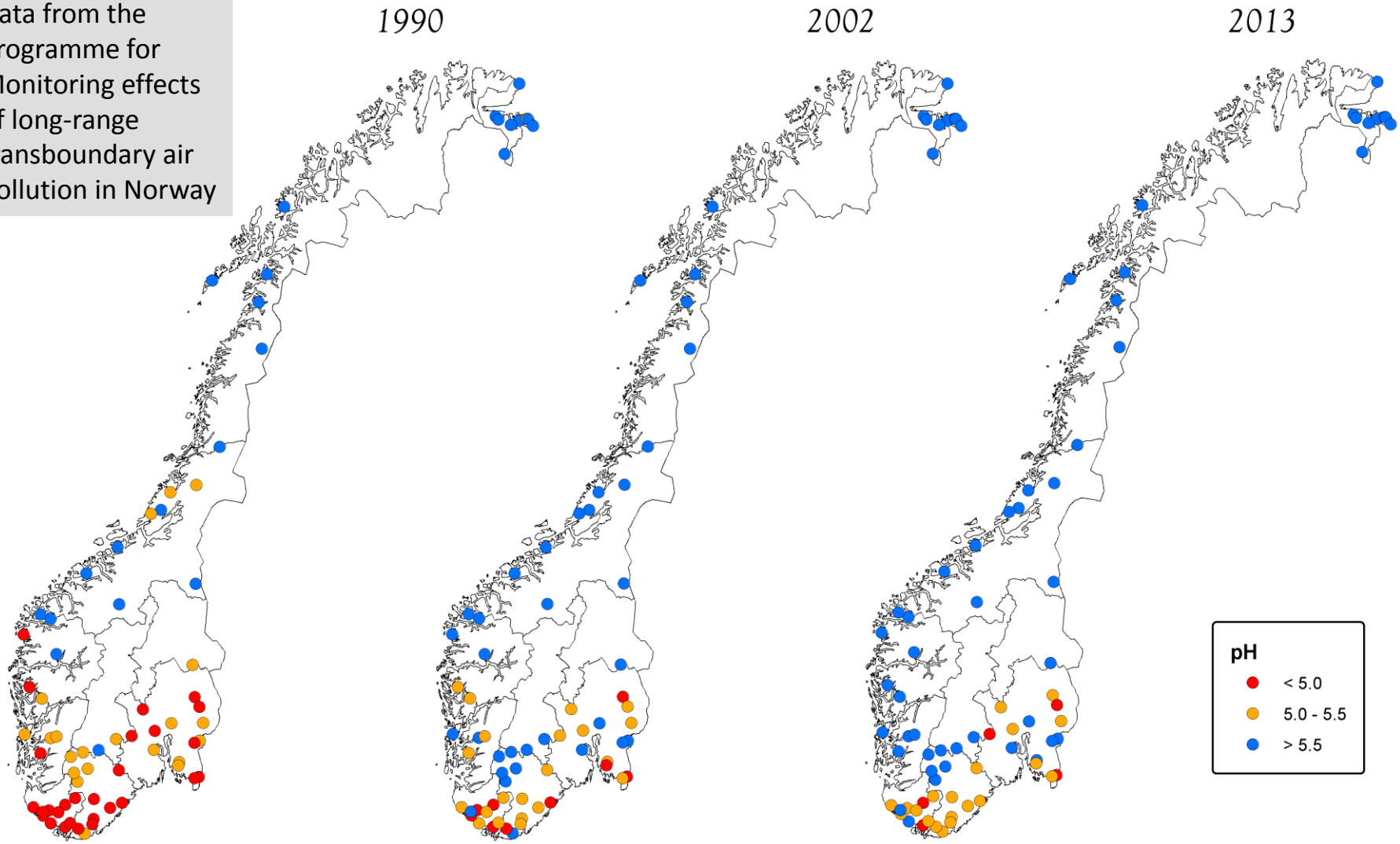
Data from the Programme for Monitoring effects of long-range transboundary air pollution in Norway

Lake Storgama in Southern Norway

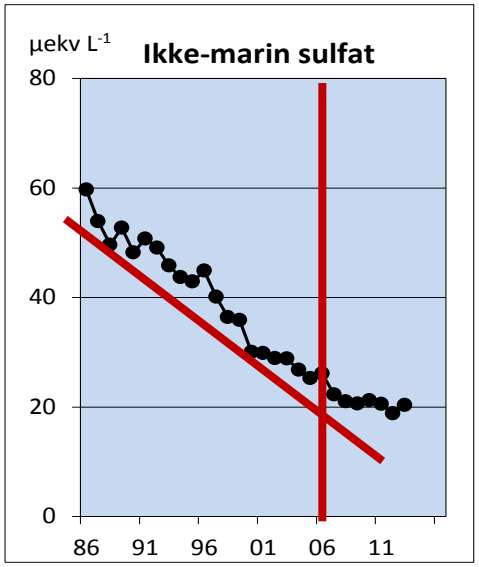


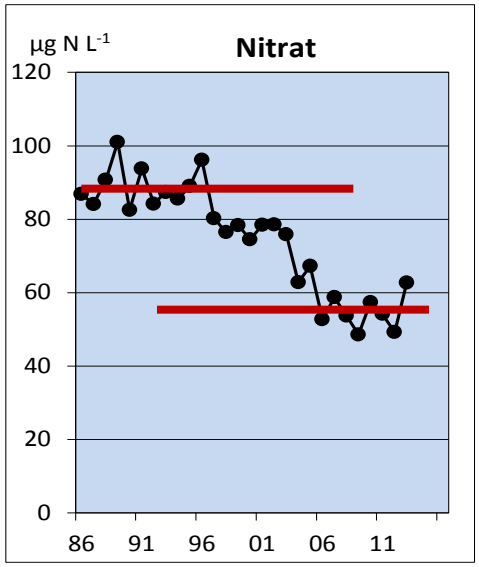
pH in 78 Norwegian lakes

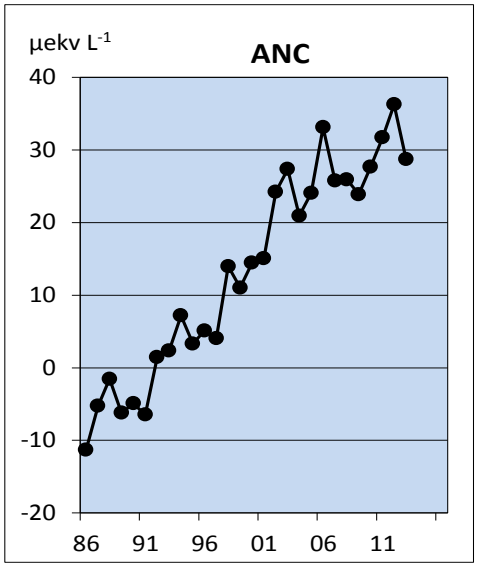
Data from the Programme for Monitoring effects of long-range transboundary air pollution in Norway

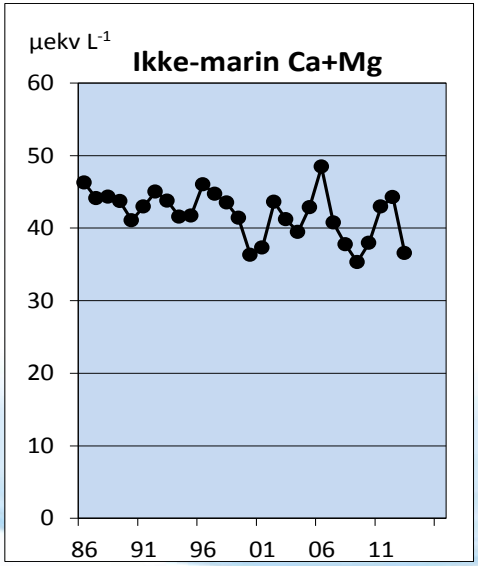


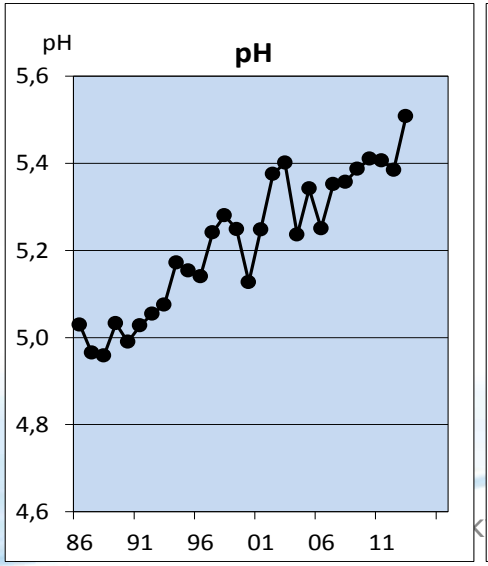
Changes in water chemistry in 78 upland lakes from 1986-2013

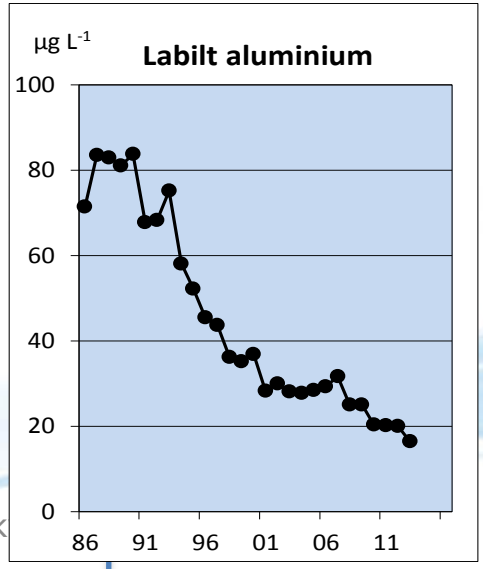










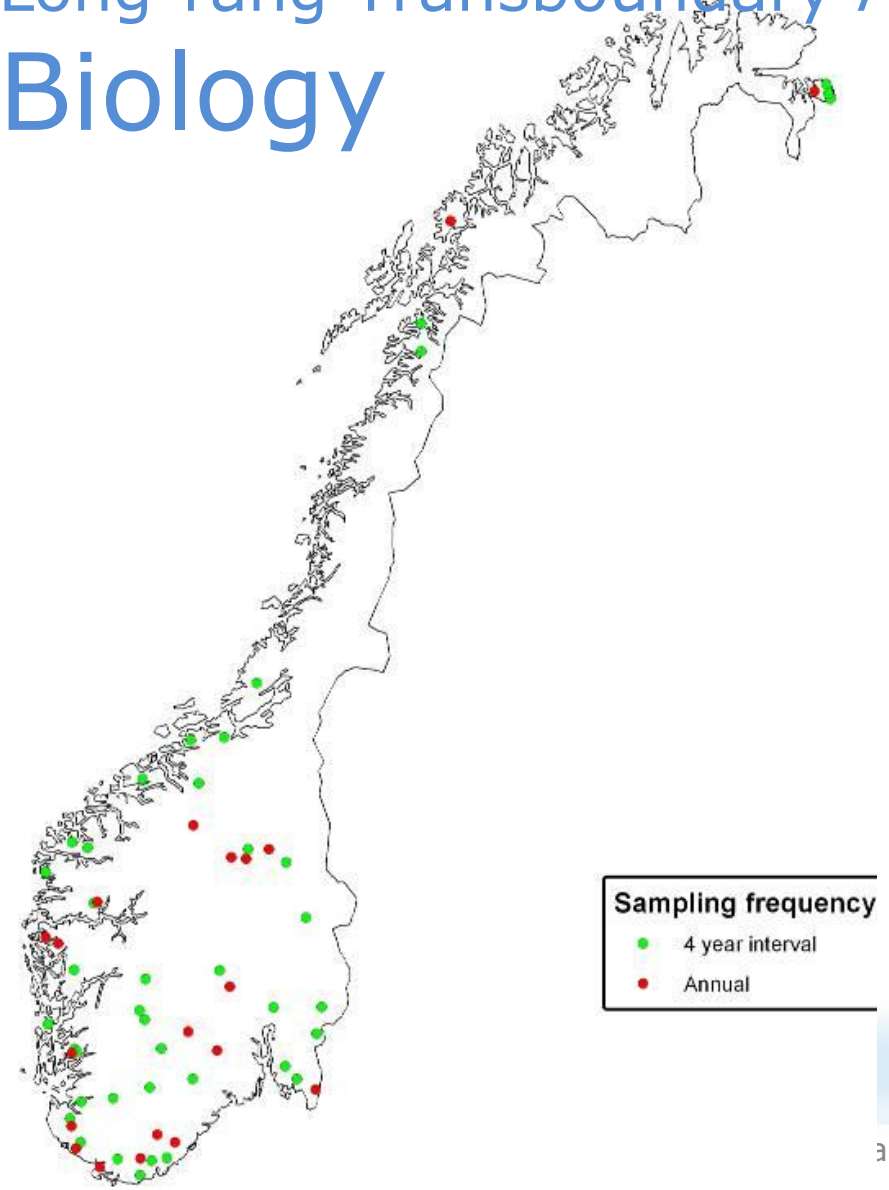


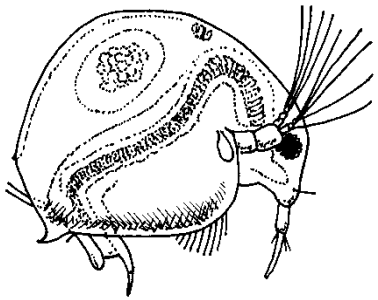
Data from the Programme for Monitoring effects of long-range transboundary air pollution in Norway

The Norwegian programme for monitoring effects of Long-rang Transboundary Air Pollution

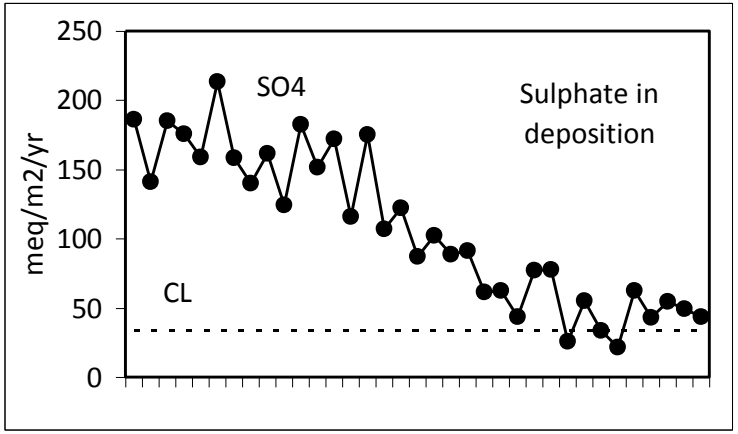
Biology

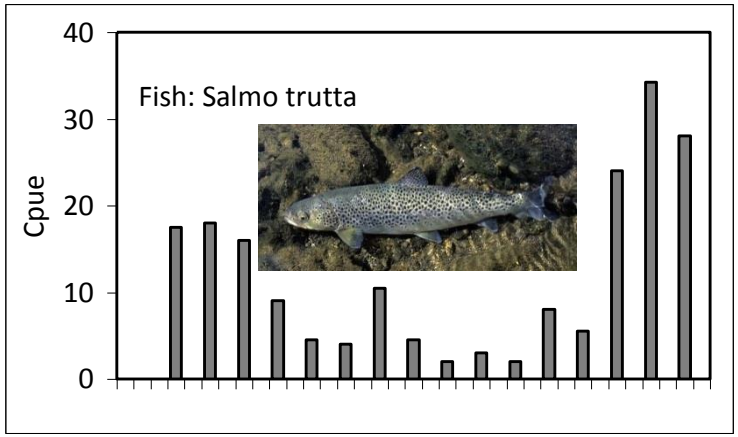
Macroinvertebrates:
LFI - University of Bergen





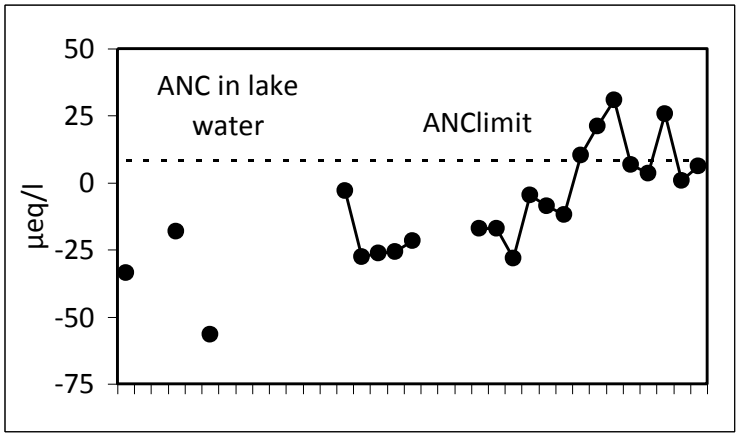
Microcrustaceans and fish
Norwegian Institute for Nature Research

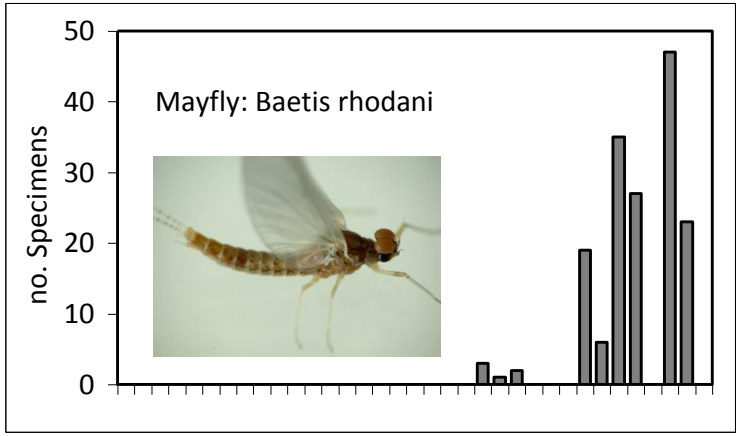


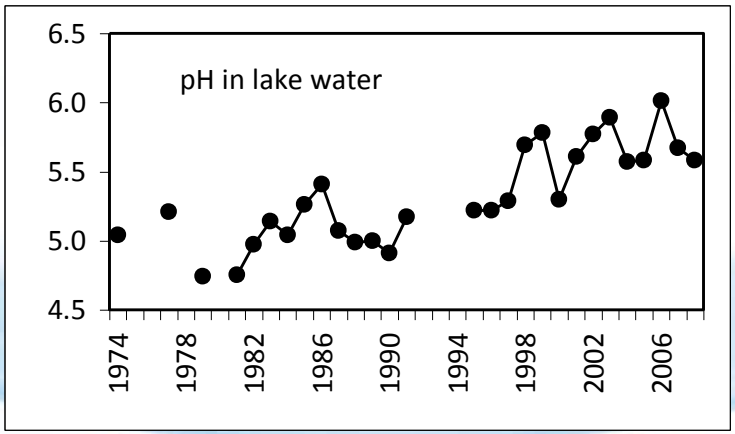


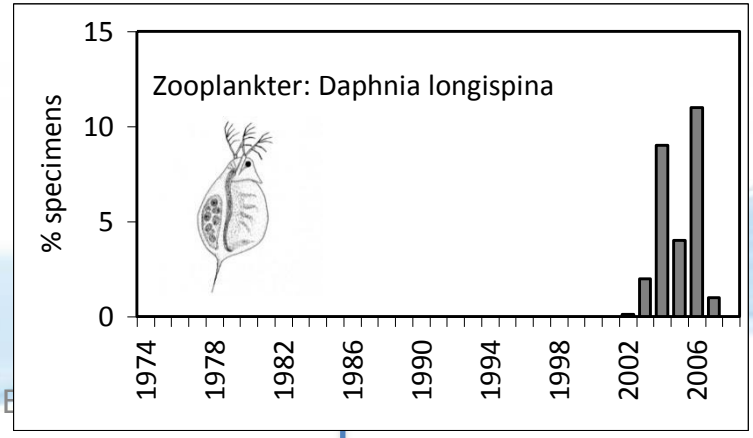
Observations L.Saudlandsv Southern Norway

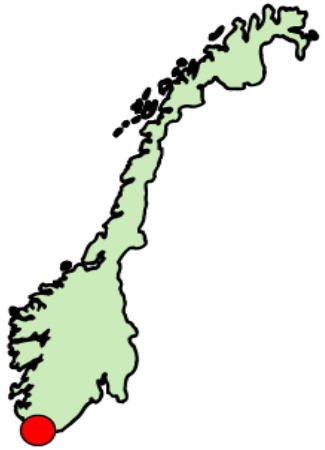
Hestagen et al 2011, STOTEN

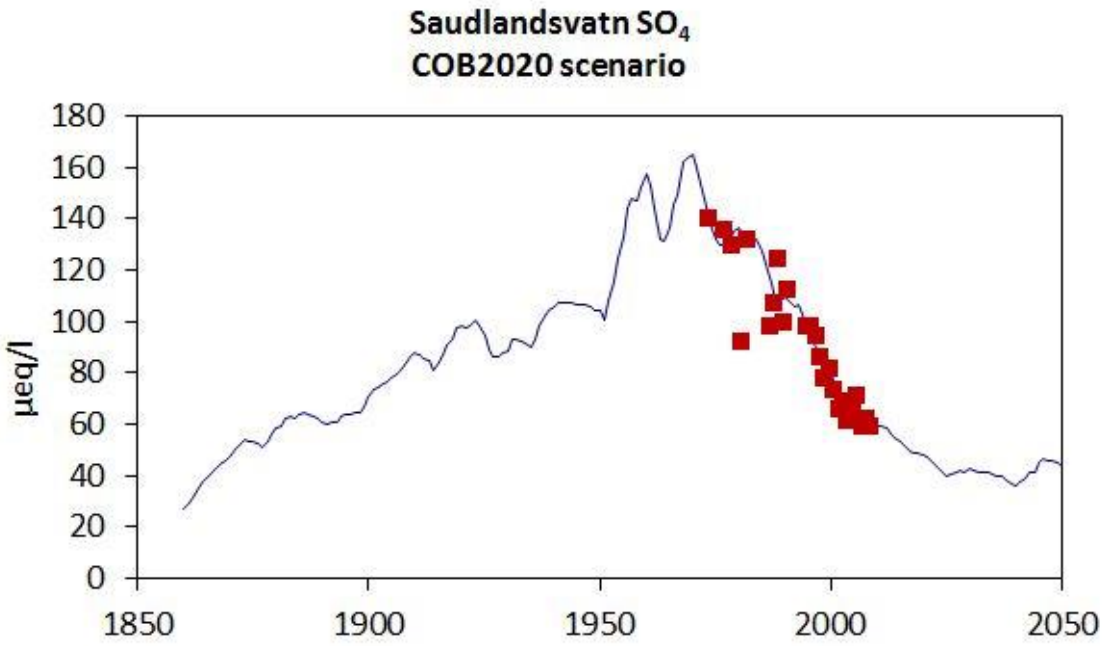






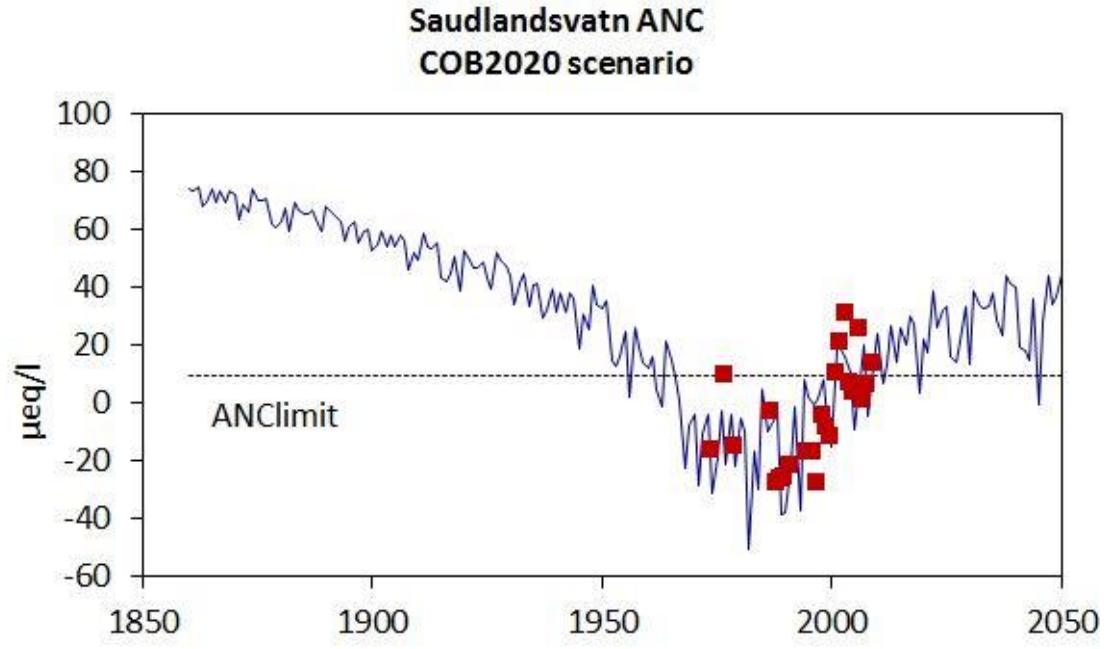






Future water chemistry scenarios for
Lake Saudlandsvatn using the MAGIC model

Hestagen et al 2011, STOTEN



CONVENTION ON LONG-RANGE TRANSBOUNDARY AIR POLLUTION

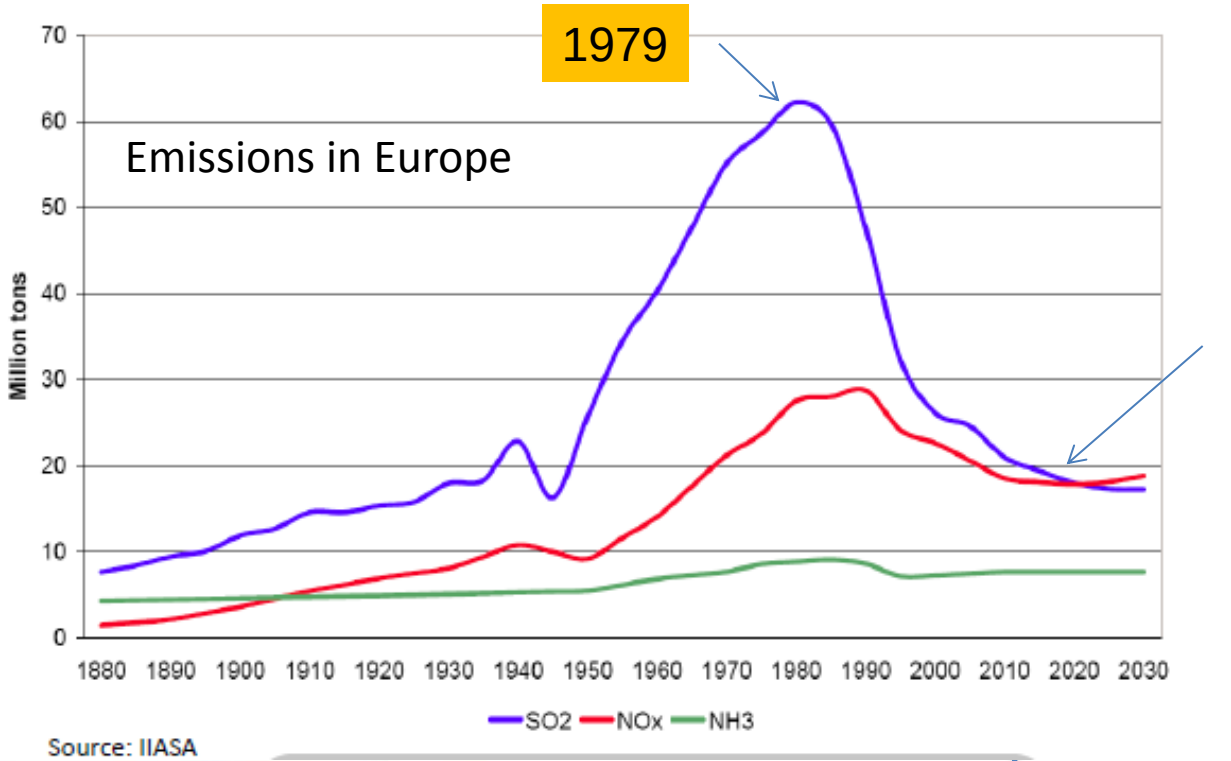
UNITED NATIONS ECONOMIC COMMISSION FOR EUROPE

- Signed 1979, in force 1983
- 51 Parties
- 8 Protocols
- Covers SO2 , NOx, VOC, NH3, PM , HMs, POPs
- Effect based agreements
- Close interaction between science and policy

LRTAP 25th Anniversary
Long-range Transboundary Air Pollution

International agreements to reduce air pollution

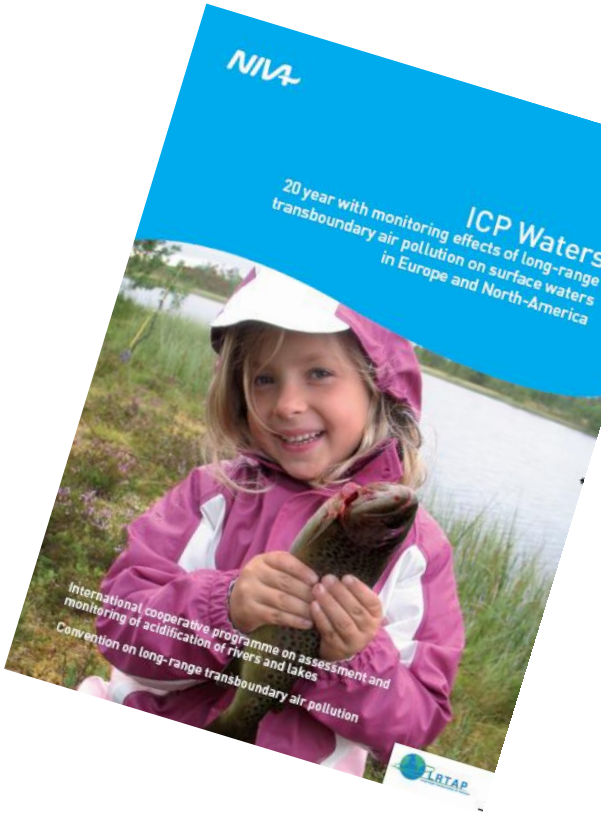
- 1979 Convention on Long-range Transboundary Air Pollution (UN ECE)
- 1985 Protocol on the Reduction of Sulphur Emissions by at least 30 per cent
- 1988 Protocol concerning the Control of Nitrogen Oxides
- 1994 Protocol on Further Reduction of Sulphur Emissions
- 1999 Protocol to Abate Acidification, Eutrophication and Ground-level Ozone
  - The 2012 amendment to the Protocol to Abate Acidification, Eutrophication and Ground-level Ozone



Source: IIASA

The ICP Waters programme
- an example of a long-lasting international cooperation

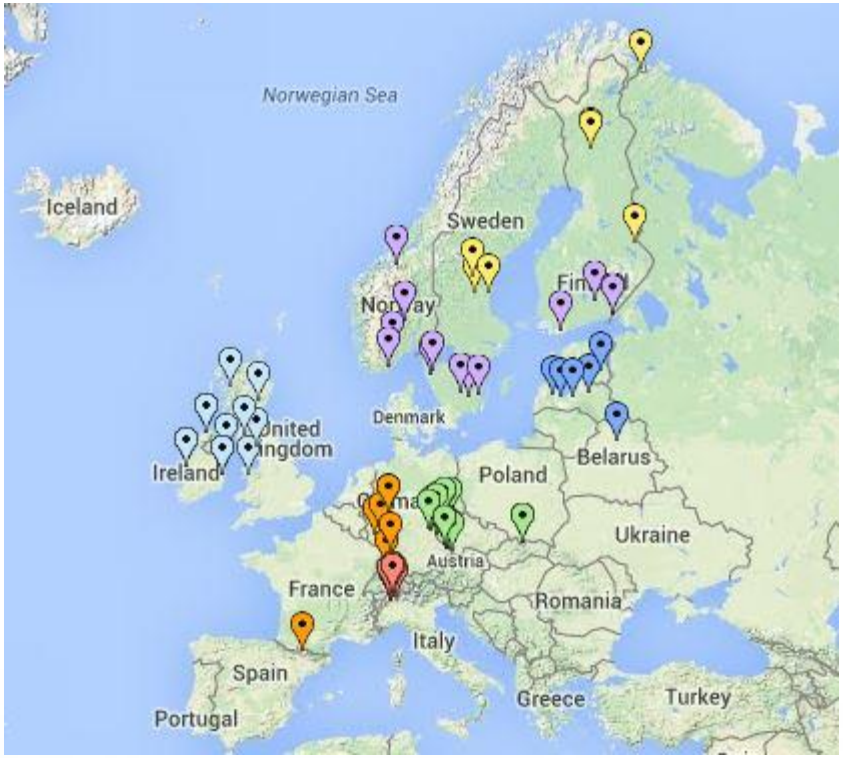
ICP Waters = International Cooperative Programme on Assessment and Monitoring Effects of Air Pollution on Rivers and Lakes



TF no.	Year	Place	Country	No. of countries
1	1986	Grafenau	Germany	9
2	1986	Oslo	Norway	9
3	1987	Togliatti	Russia	12
4	1988	Korpilampi	Finland	11
5	1989	Freiburg	Germany	14
6	1990	Skøvde	Sweden	12
7	1991	Galway	Ireland	12
8	1992	Winnipeg	Canada	14
9	1993	Oisterwijk	Netherlands	15
10	1994	Budapest	Hungary	18
11	1995	Zelena Ruda	Czech Republic	15
12	1996	Silkeborg	Denmark	15
13	1997	Pitlochry	Scotland	16
14	1998	Zakopane	Poland	15
15	1999	Pallanza	Italy	17
16	2000	Riga	Latvia	14
17	2002	Lillehammer	Norway	16
18	2002	Moskva	Russia	16
19	2003	Lugano	Switzerland	16
20	2004	Falun	Sweden	16
21	2005	Tallin	Estonia	20
22	2006	Bergen	Norway	19
23	2007	Nancy	France	19
24	2008	Budapest	Hungary	19
25	2009	Burlington	Canada	16
26	2010	Helsinki	Finland	17
27	2011	Sotchi	Russia	14
28	2012	Pallanza	Italy	13
29	2013	Cesky Krumlow	Czech Republic	15
30	2014	Grimstad	Norway	14

Stations

Europe

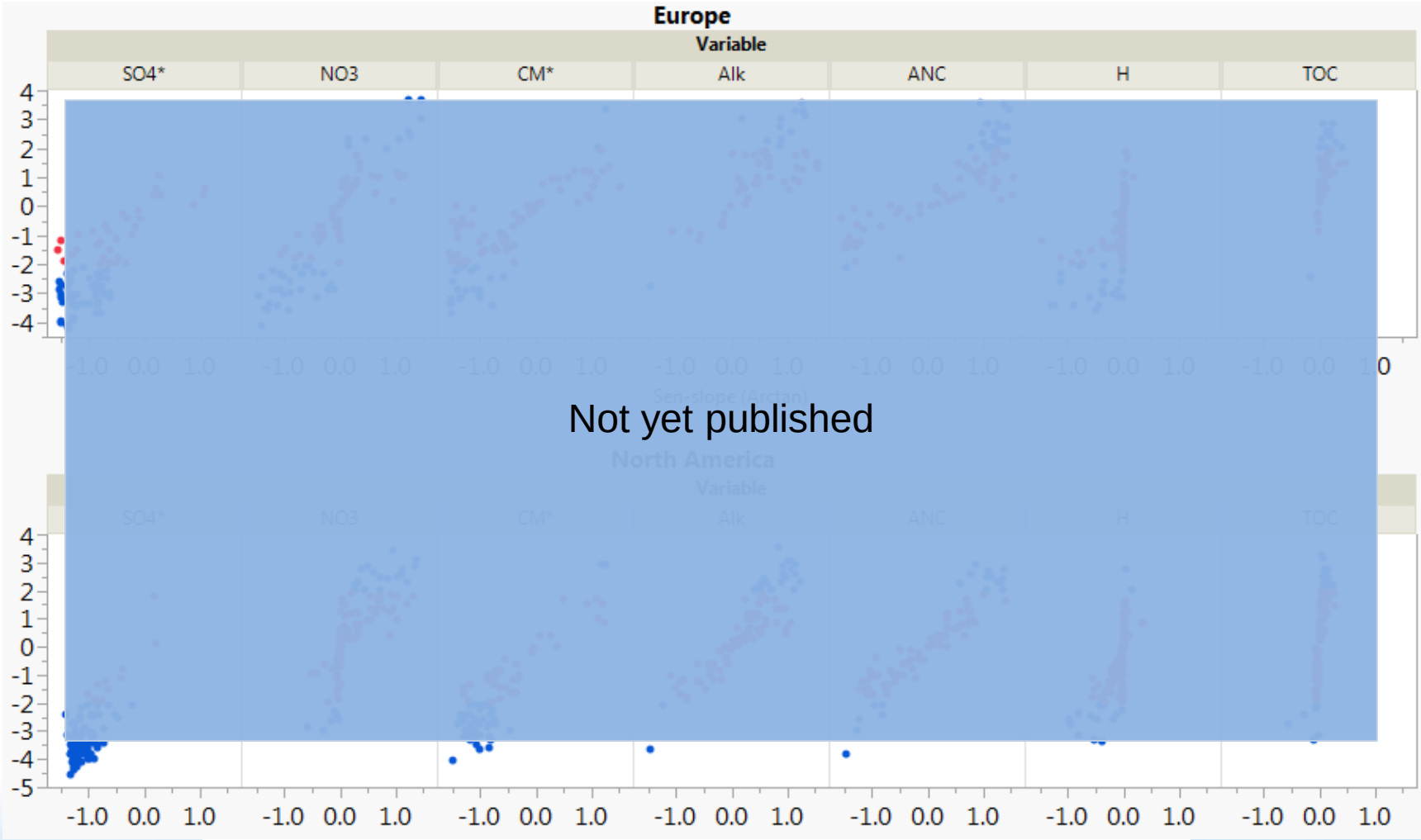


92 stations

North America

106 stations

Trend slopes and significance 2000-2011



Trend slope, µEq/L (mg/L for TOC). NB: Arctan transformed

From ICP Waters report in prep Garmo et al

Biological recovery

Trends in precipitation chemistry, surface water chemistry and aquatic biota in acidified areas in Europe and North America from 1990 to 2008 (ICP Waters report 106/2011) Skjelkvåle, B.L.; de Wit, H.A.

Region	Country	Biota	period	Trends	recovery potential reached?
North Nordic	Finland	Fish	1985-2007		no information
		Periphyton	n.d.		yes
South Nordic	Norway	Zoobenthos	1982-2010		no
	Sweden	Phytoplankton	1988-2008		no
		Zoobenthos	1988-2008		no
	Finland	Fish	1985-2007		no
		Zoobenthos	n.d.		no
		Periphyton	n.d.		no
East Central Europe	Czech rep.	Phytoplankton	1990-2009		no
		Zooplankton	1990-2009		no
		Zoobenthos	1990-2009		no
		Macrophytes	2004-2010		no
	Germany	Zoobenthos	1982-2010		no
West Central Europe	Germany	Zoobenthos	1982-2010		no
Alps	Switzerland	Zoobenthos	2000-2009		no information
		Zoobenthos	2000-2009		no information

Main conclusions from ICP Waters trend reports

Up to 2008

- **Significant declines in non-marine sulphate** in about 70 % of the investigated sites the time spans 1990-1999 and 1999-2008. The rates of decline tend to be smaller in the latter period.
- **No significant trends in nitrate** for either of the time spans 1990-1999 and 1999-2008.
- **Full biological recovery** is not documented anywhere.

Up to 2011 – in prep

- Sulphate, base cations and H+ concentrations have decreased
- Increasing trends are more prevalent than decreasing trends for alkalinity, ANC and TOC
- The pattern in nitrate concentration is more varied

Main results from the trend analysis on chemistry and biology

- Improvements in acidification of surface waters are related to lower acid deposition
- Reductions in precipitation are larger and quicker than the observed improvements in water chemistry
- Increase in pH, alkalinity and ANC indicate that biological recovery can be expected
- Biological recovery is documented in many regions in Europe
  - Full recovery is not documented anywhere.
  - A return to pre-industrial biodiversity is unlikely
- Future reductions of both S and N deposition would be necessary to achieve biological recovery not influenced by acidification.

Is the problem solved?

Why continue monitoring?

1. The problem of air pollution effect on surface water quality and aquatic biota is not over
   - …and International cooperation still needs input to continue the cooperation and negotiation
2. Monitoring is «ground truth» and important for:
   - Research
   - Water framework directive
   - Study, follow and understand new and emerging problems such as
     - climate change
     - browning of surface waters

Discovery of increasing trends of DOC - from monitoring networks!

- Bouchard 1997 WASP
- Skjelkvåle ea 2001, HESS
- Monteith ea 2001, WASP
- Stoddard ea 2003, EPA

- Quebec (1985-1993)
- Finland, Sweden, Norway (90-9
- UK (88-98)
- North America (90s)

- What is the reason for the increase?

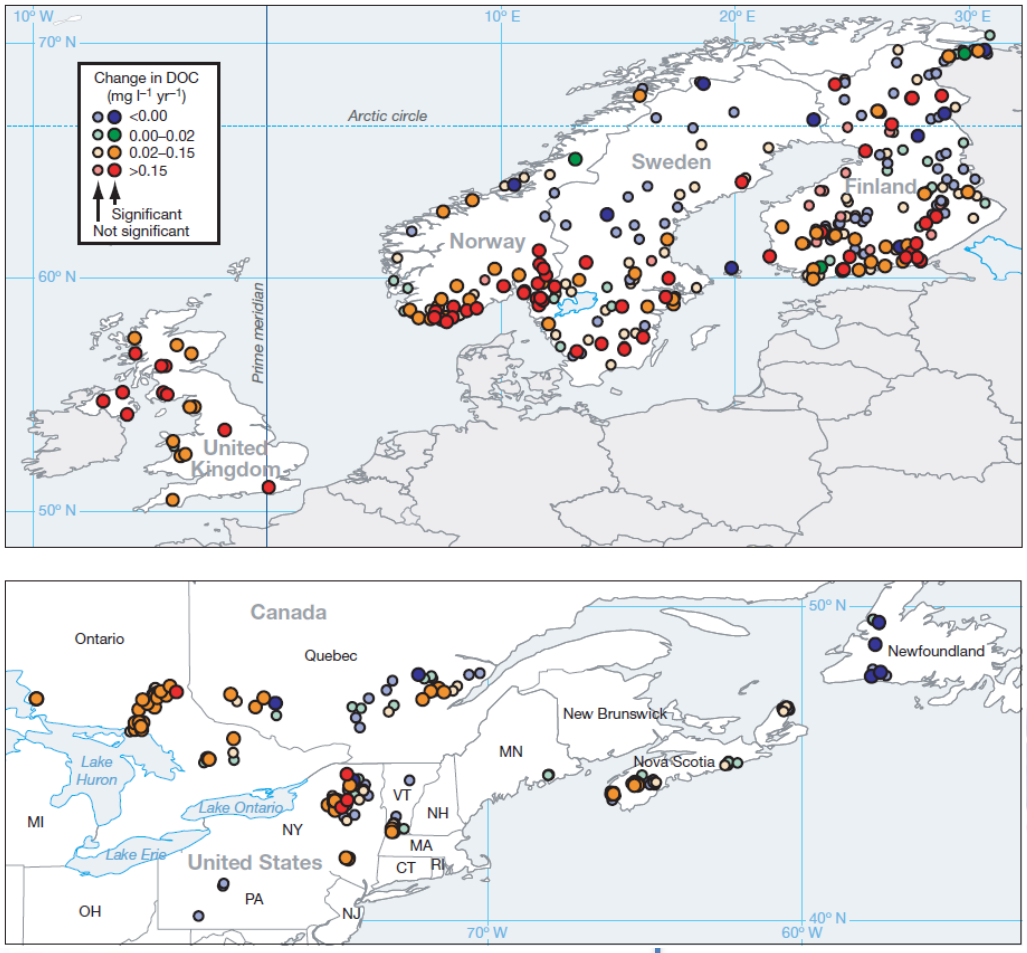
Photo: NIV

Several different hypothesis (from Heleen de Wit)

- Microbiologists:
  - Microbes! Warmer climate
  - Atmospheric CO_2 enrichment!
- Soil biologists:
  - Worms! Warmer climate!
- Hydrologists:
  - Hydrology! Wetter climate! Drier climate!
- Limnologists:
  - In-lake processes! Climate change!
- Biogeochemists:
  - Nitrogen deposition!
- Acid rain community:
  - Acid rain?

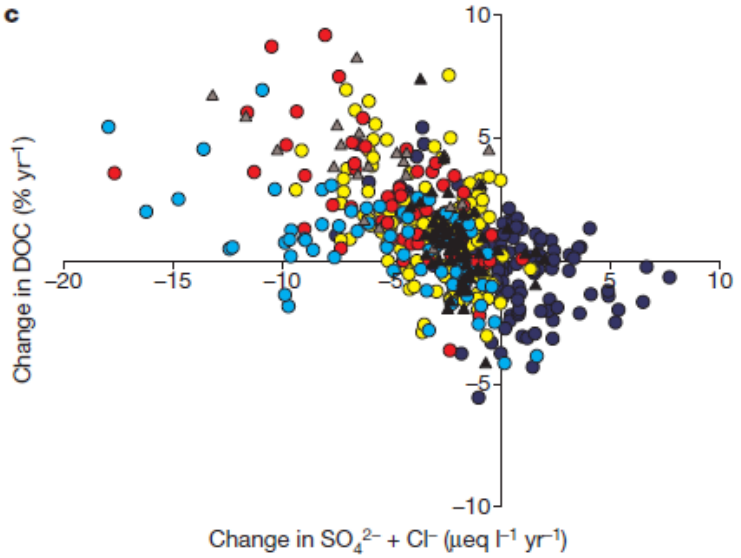
Browner water 'all over' boreal and temperate northern ecosystems?

Trends 1990-2004 Monteith et al 2007 Nature



Monteith et al., 2007, Nature

- The wide-spread pattern in browning of surface waters is related to reduced acid deposition (and seasalt deposition)



Vol 450|22 November 2007|doi:10.1038/nature06316 nature

LETTERS

Dissolved organic carbon trends resulting from changes in atmospheric deposition chemistry

Donald T. Monteith[1]*, John L. Stoddard[2]*, Christopher D. Evans[3], Heleen A. de Wit[4], Martin Forsius[5], Tore Høgåsen[4], Anders Wilander[6], Brit Lisa Skjelkvåle[4], Dean S. Jeffries[7], Jussi Vuorenmaa[5], Bill Keller[8], Jiri Kopácek[9] & Josef Vesely[10]‡

Statu up:

Acid News

Home » Acid News » Acid News 2014 » No. 3, October 2014

Air pollution still harms ecosystems

Air quality has impr ere is still work to be done to protec cultural heritage and to contribute to ge.

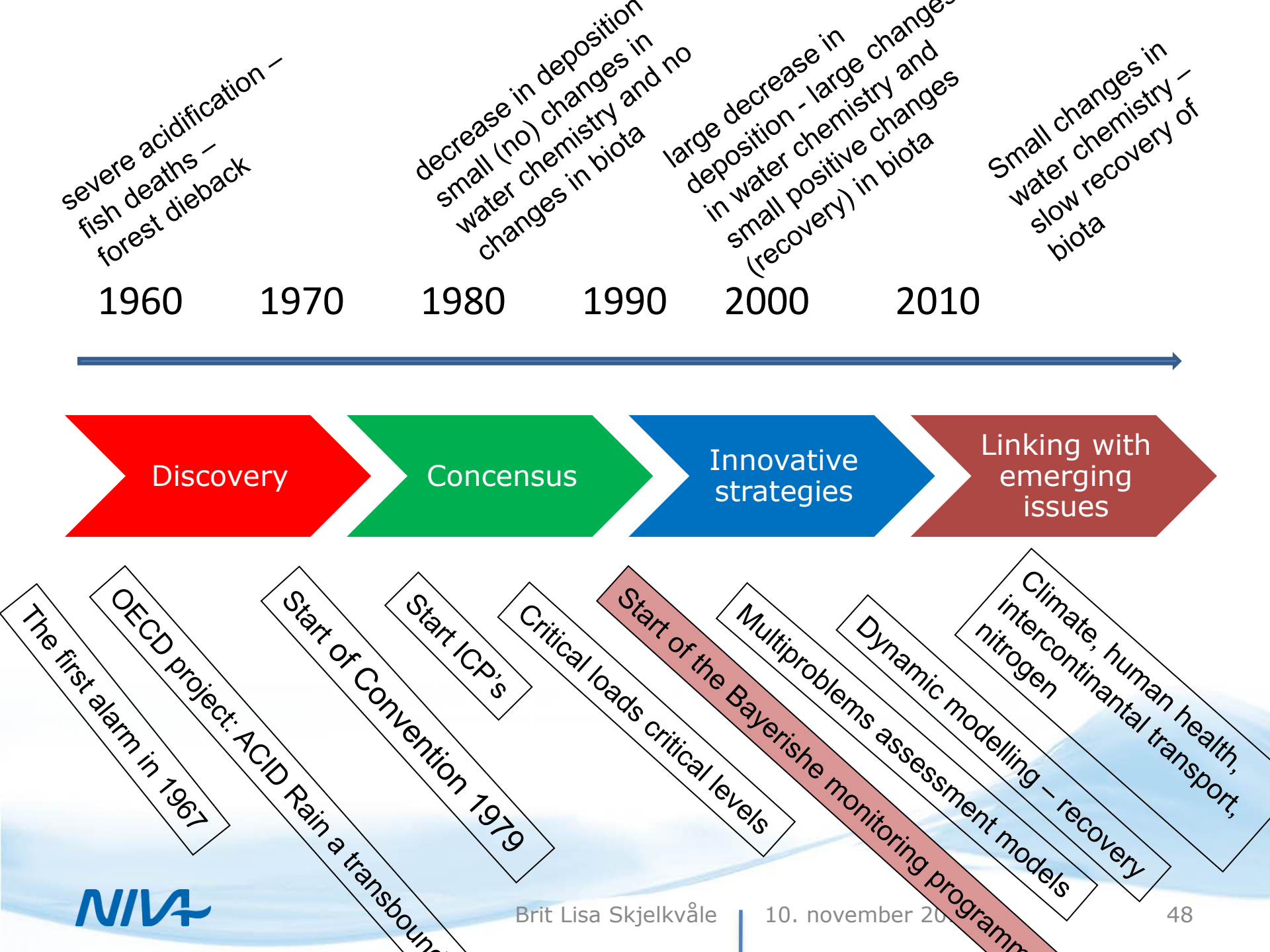
The effect-based ap onvention on Long-Range Transb d remain the basis for further ste

The «Saltsjøbaden workshop 2013» Future directions of policy and science – Three most imortant points for the future

- No net loss of biodiversity
- Use the concept of Ecosystem services
- Involve ECCA (East European and Caucasian countries)

More reccomendations….

- **Effects are the basis for emission reductions**
  - Monitoring of effects represent the ground truth and is the basis for the science that drives the negotiations...
  - …even though the use of effect-based results may not always be visible in negotiations of emission reductions
  - Present monitoring networks are already so curtailed that further reduction will jeopardize their existence
  - The WS recommend the parties of the Convention to sustain a viable number of monitoring sites
  - Especially since results from the WGE are also used by other institutions (outside the Convention)


severe acidification – fish deaths – forest dieback
decrease in deposition small (no) changes in water chemistry and no changes in biota
large decrease in deposition - large changes in water chemistry and small positive changes (recovery) in biota
Small changes in water chemistry – slow recovery of biota
1960
1970
1980
1990
2000
2010
Discovery
Concensus
Innovative strategies
Linking with emerging issues
The first alarm in 1967
OECD project: ACID Rain a transboun
Start of Convention 1979
Start ICP's
Critical loads critical levels
Start of the Bayerishe monitoring programm
Multiproblems assessment models
Dynamic modelling – recovery
Climate, human health, intercontinantal transport, nitrogen

Eeh……Acid rain? – was it really a problem?

Acid Rain Then, Global Warming Now — An All Too Familiar Pattern For Environmental Scares

Source: Lew Rockwell.com

The New York Times and Lies about 'Acid Rain'

by William L. Anderson

Second, as is the case with most environmental scares, so-called acid rain was not having much of an effect on anything, from what scientists could say. Unfortunately, Congress, the George H.W. Bush White House, and most of the mainstream media were not thrilled with the fact that the End Of The World As We Know It and let it be known that anything less than Apocalypse Now was unacceptable.

The story of Acid Rain is the successes story of good and tight cooperation between research and policy-making to solve a serious environmental problem through international cooperation


Thank you for
your attention!
Keep up the good
monitoring work!


Tank also to my helpful colleges from NIVA;
Heleen de Wit
Øyvind Garmo
Richard F. Wright
Arne Henriksen
Liv Bente Skancke
Photo NIVA