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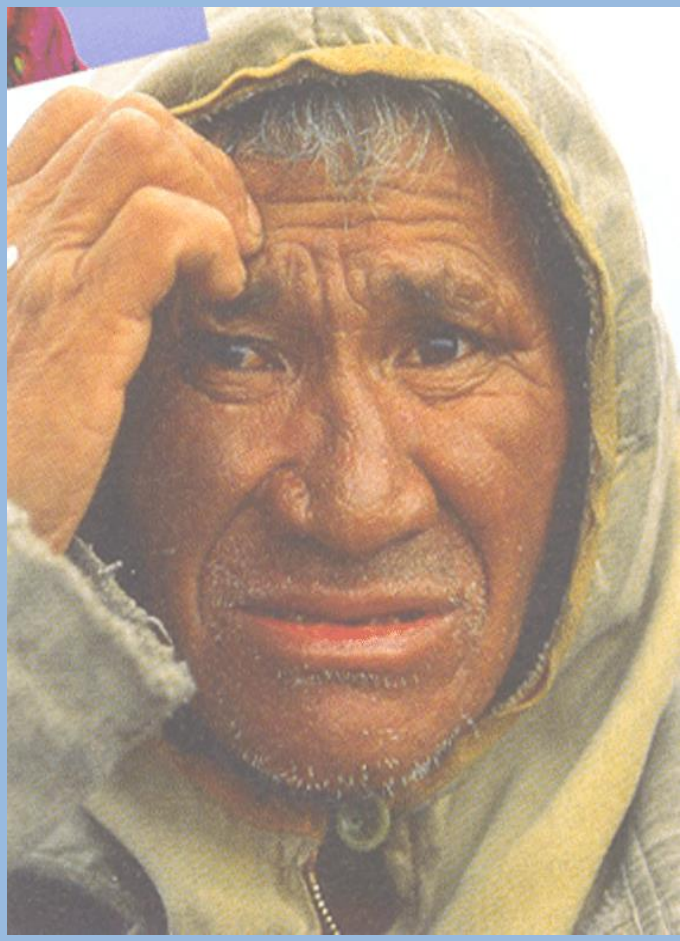
Arctic Monitoring and Assessment Programme

Arctic Pollution Issues

"From cold war to Arctic meltdown"



ICCE 2017
Oslo June

Lars-Otto Reiersen
AMAP Executive Secretary.

Thawing of the Cold war

Arctic Science related cooperation

IASC International Arctic Science Committee - 1990, 18 countries
AEPS / AC Arctic Council 1991/1996, 8 + 12 countries
EPB European Polar Board
PAG Pacific Arctic Group
FARO Forum for Arctic Research Operators
WMO/CliC Climate and Cryosphere projects of the
/WCRP World Climate Research Programme
IPY International Polar Year 2007 – 2009.
AOSB Arctic Ocean Science Board – 1984
SCANNET / INTERACT Terrestrial Network.
IASSA International Arctic Social Science Association
IPA International Permafrost Association
EU-PolarNet – part of Horizon 2020
EU, USA, Canada "The Galway agreement"

There are people in the Arctic

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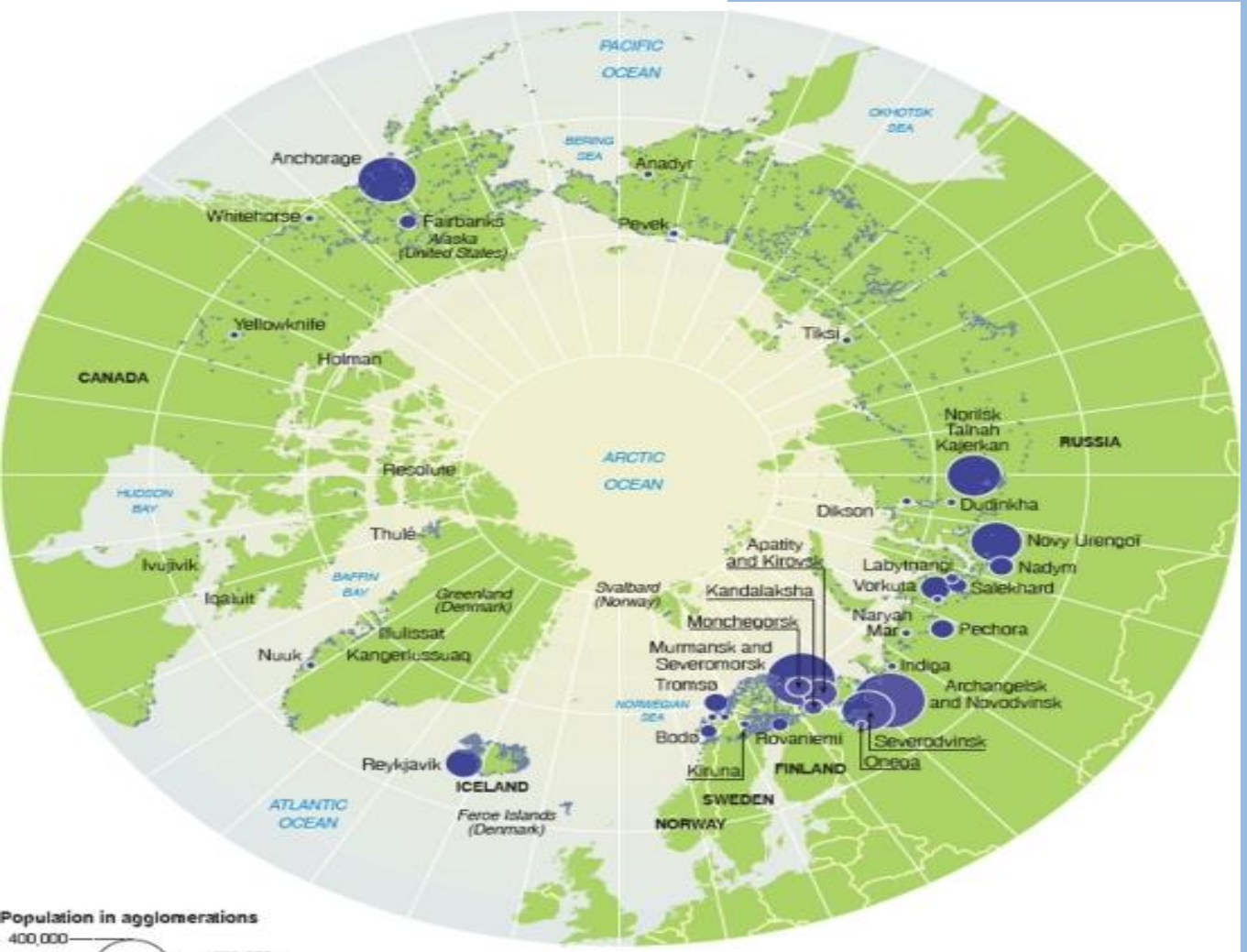

Sources : United States: US Census Bureau, 2002 and United States department of commerce 1993; Canada: Statistics Canada, 1995 and 2002; Greenland: Statistics Greenland, 1994 and 2002; Faroe Islands: Faroe Islands Statistics, 2002; Iceland: Statistics Iceland, 2002; Norway: Statistics Norway, 2002; Sweden: Statistics Sweden, 2002; Finland: Statistics Finland, 2002; Russia: State Committee for Statistics, 2003; Republican information and publication center, 1992; State committee of the Russian Federation for statistics 1992 ; World Wild Fund (WWF) Norway.

4 mill people, of these 400 000 – 1,3 mill indigenous, depending on how the Arctic is defined

Arctic Environmental Threats in 1989

Pollution must come from the USSR:

- Radioactivity
- Heavy metals
- Forest death (Atmospheric SO_2)
- Persistent Organic Pollutants

Can we Monitor anything in the Arctic?

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CANADA'S NATIONAL NEWSPAPER

The Globe and Mail

Sunrise 7:45 Sunset 4:42

Windy, flurries

High -3

Weather details on page 2

145th YEAR, NO. 43,378 ■ THURSDAY, DECEMBER, 15, 1988

Soviet, European pollution threatens health in Arctic

BY MATTHEW FISHER
The Globe and Mail

CHESTERFIELD INLET, NWT

Canadian scientists fear that the health of Canada's 22,000 Inuit has been put at risk by pollution from chemicals used primarily in agriculture and industry in the Soviet Union and Europe.

The chemicals, including PCBs and DDT, have entered the fragile Arctic ecosystem and are being found in the fish and animals that form the basis of the Inuit diet.

PCBs, polychlorinated biphenyls, have been linked to cancer in laboratory animals and to brain, liver and other defects in humans. The pesticide DDT was banned in the early 1970s in Canada and the United States.

Federally financed research conducted over the past four years in the Far North has found dozens of toxic substances in every part of the Arctic food chain, from bottom-feeding sea organisms to seals, polar bears and Inuit mothers' milk.

The potential magnitude of the problem is such that "the Inuit might have to go on a diet of chicken and beef," said Dennis Gregor of Environment Canada's water quality branch in Regina. He is in charge of a special study of toxic substances found in Arctic snow.

"That would require a huge diet and cultural change. It would not be good for them," Mr. Gregor said.

The chief medical officer for the Northwest Territories, David Kinloch, said: "We are finding a whole range of toxic substances. . . For the people of the Northwest Territories it is a very fundamental question — the contamination of their food supply."

The inter-departmental project to identify the contaminants and analyze the risk they pose to Inuit and Arctic wildlife "is our highest priority," said the program's co-ordinator, Grant Bangay, director of regional planning and resources for the Department of Indian Affairs and Northern Development.

While it is too early to draw categorical conclusions from the research, Hiram Beaubier, director-general of natural resources and economic development for the department, said: "We acknowledge the significance of the problem. We are now preparing a report on its magnitude. . . It is being looked at very, very carefully. We are taking it very seriously."

Once the situation and its effect on native northerners is better understood, the department will use "a reasoned and sensible approach" to advise those affected, Mr. Bangay said.

Both Mr. Bangay and Mr. Beaubier said they were concerned that the problem

NATIVE — Page A2

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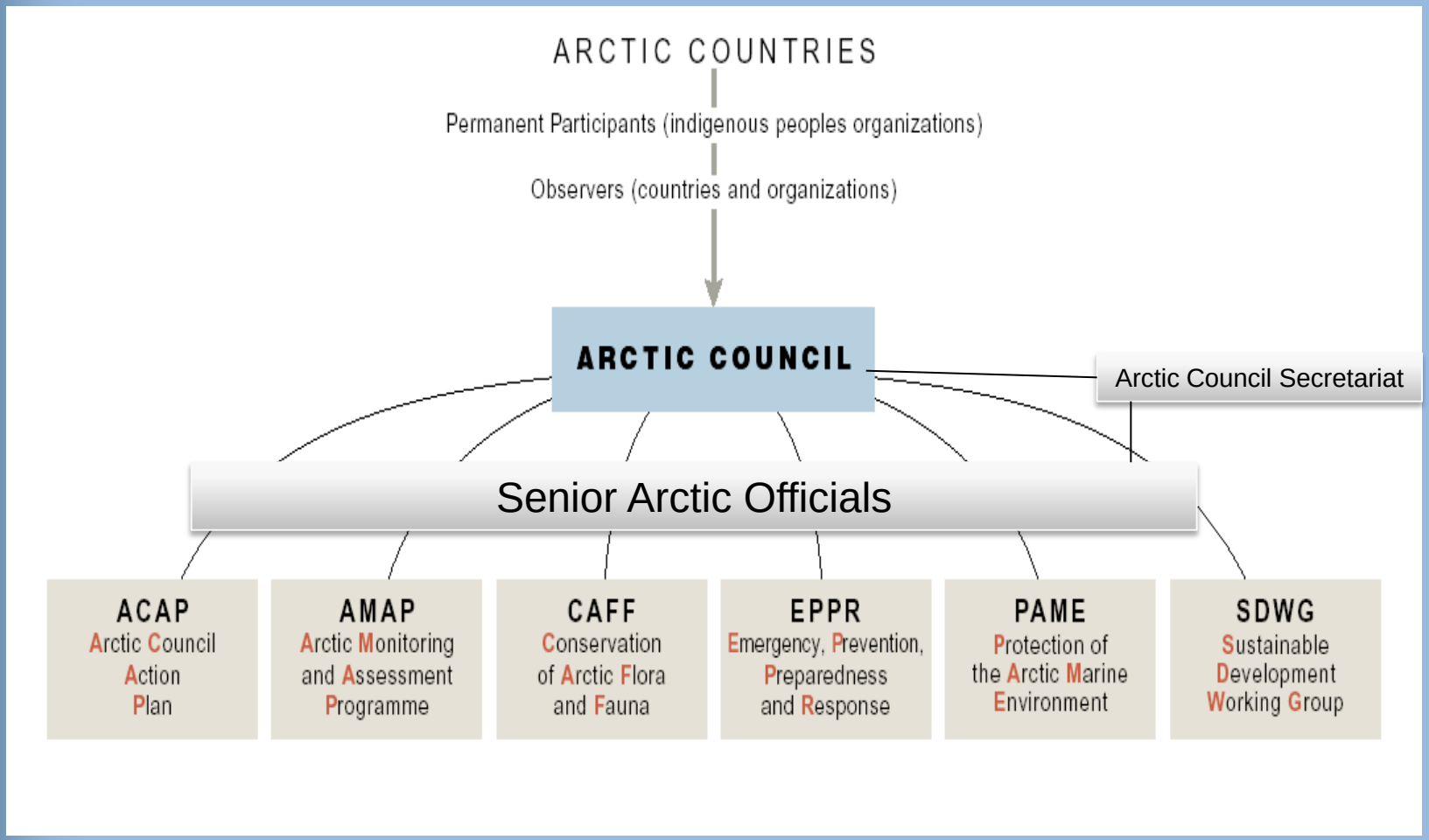
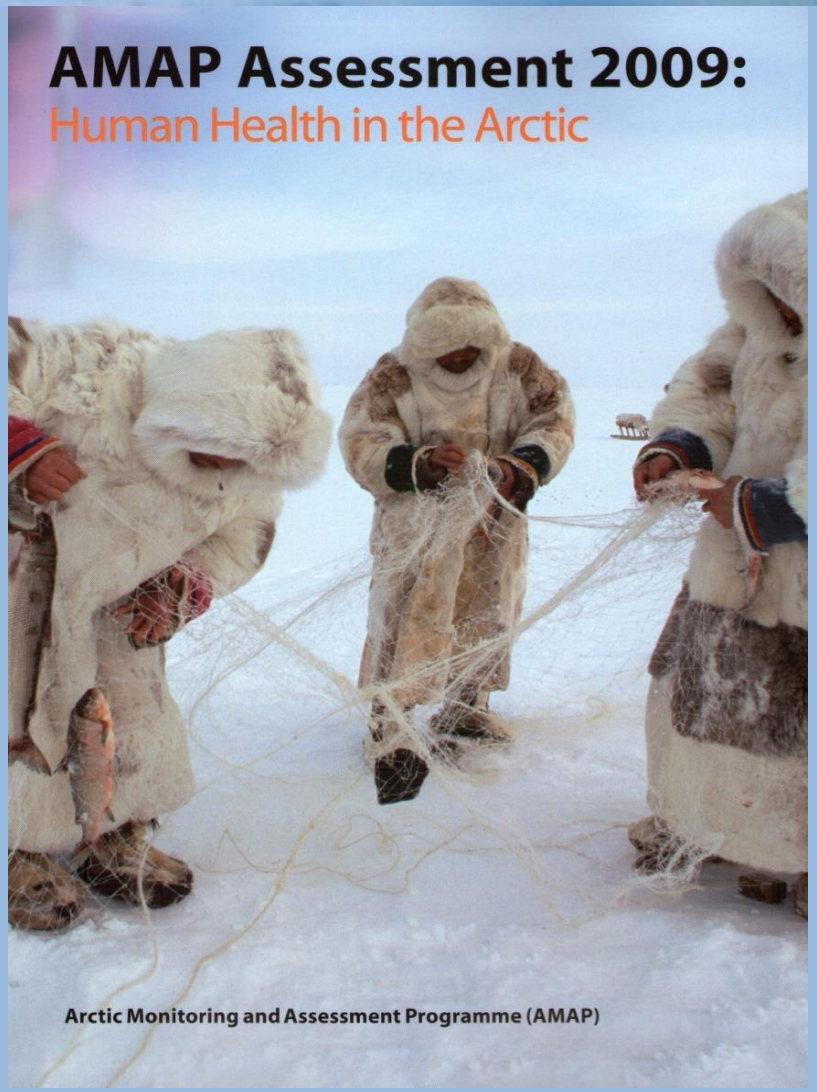


Permanent Participants (6 Arctic Indigenous Orgs):

- Aleut International Association
- Arctic Athabaskan Council
- Gwich'in Council International
- Inuit Circumpolar Council
- Saami Council
- Russian Arctic Indigenous Peoples of the North (RAIPON)



AMAP TEP - AMAP Trends and Effects

Programme for Arctic ecosystems and humans (1991):

Pollutants – Persistent Organics (POPs), heavy metals, radionuclides, petroleum hydrocarbons & acidification;

Climate change, incl. UV, ozone, black carbon, methane & ocean acidification;

Analyzing samples from: air, water, snow, ice, sediments, plankton, invertebrates, fish, birds, mammals & humans;

Perform integrated assessments of several drivers.

Provide science based policy related Actions

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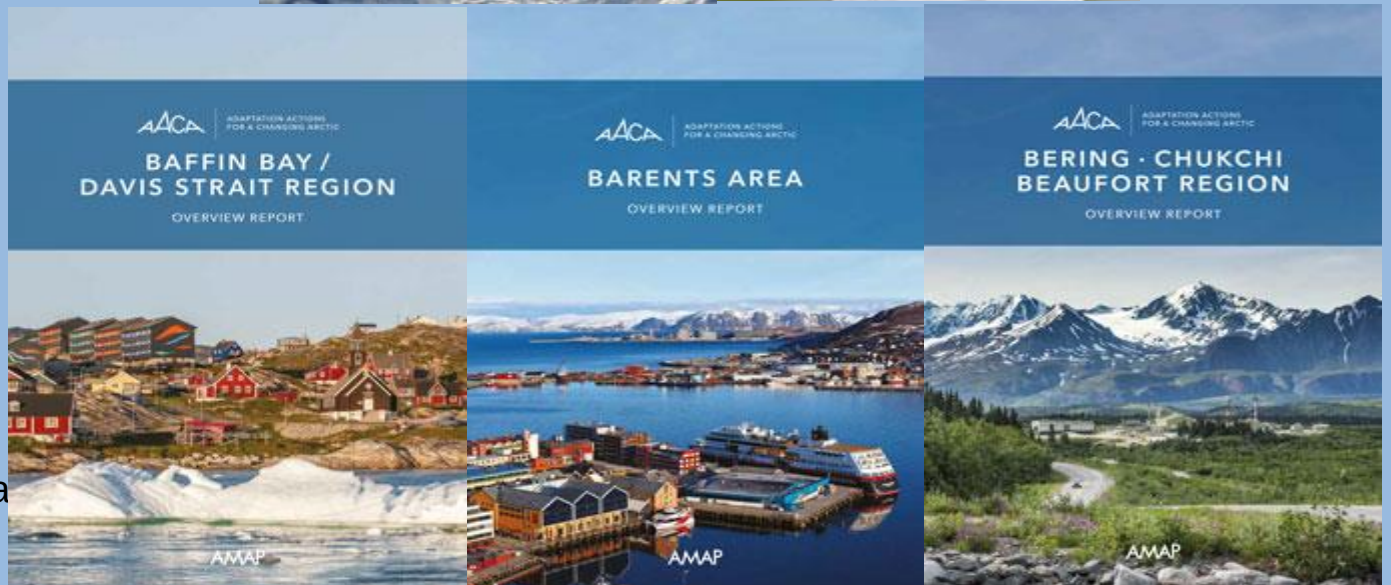
AMAP 2017 production



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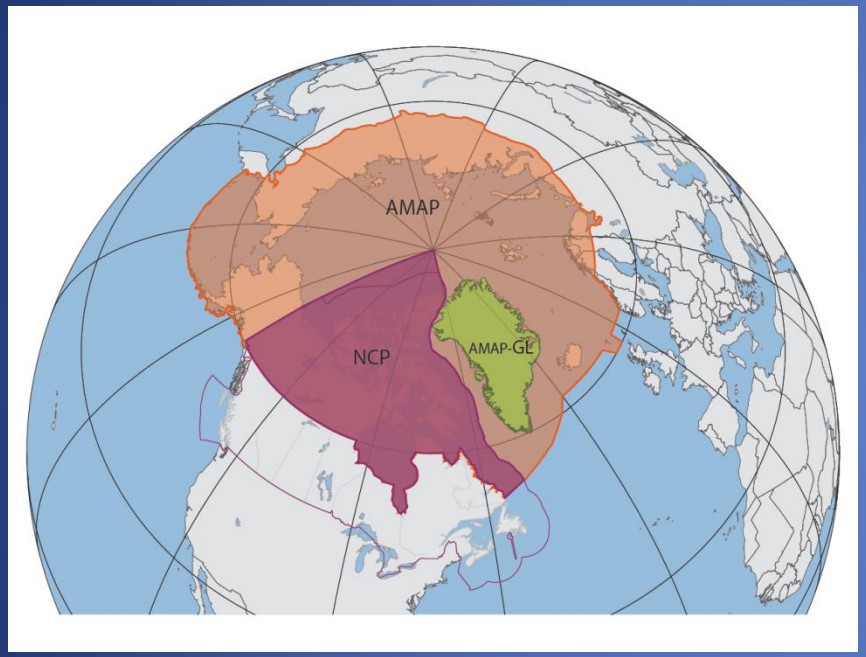
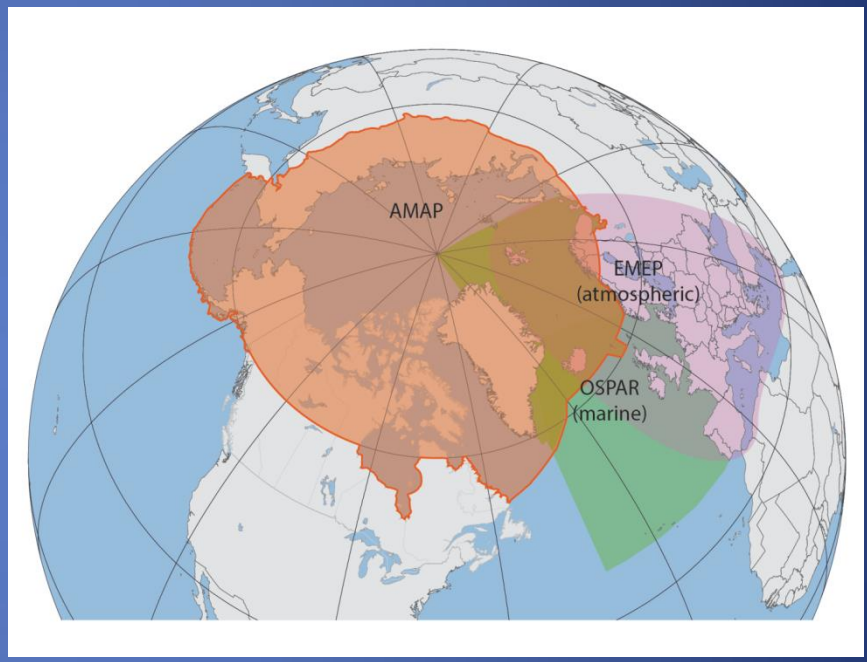
AMAP's geographical coverage

National implementation
Regional coordination



Based on national activities (e.g. Canada NCP, Greenlandic AMAP MP); Harmonization where necessary



High degree of coordination with other relevant regional monitoring programmes

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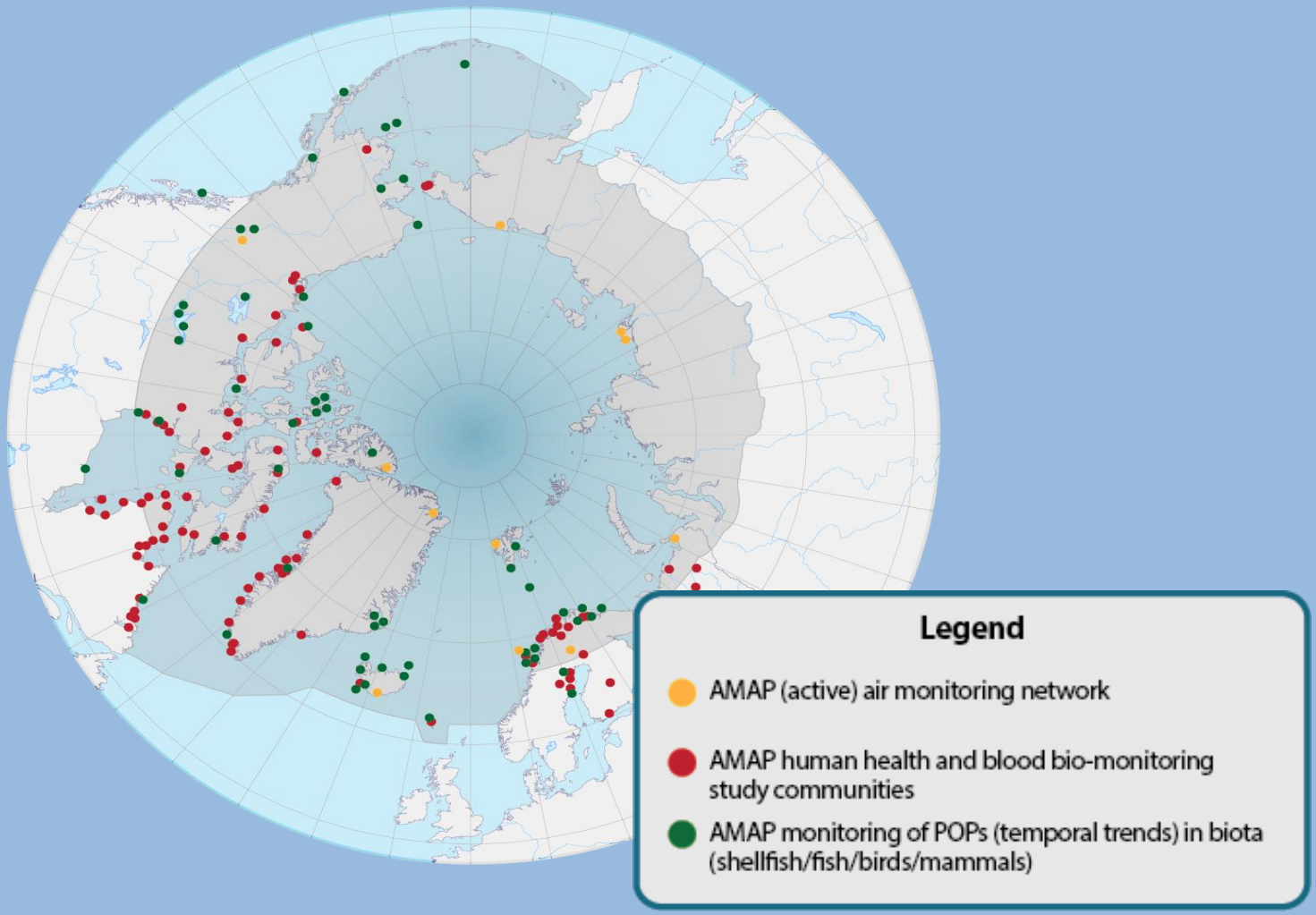
AMAP monitoring network, 2015



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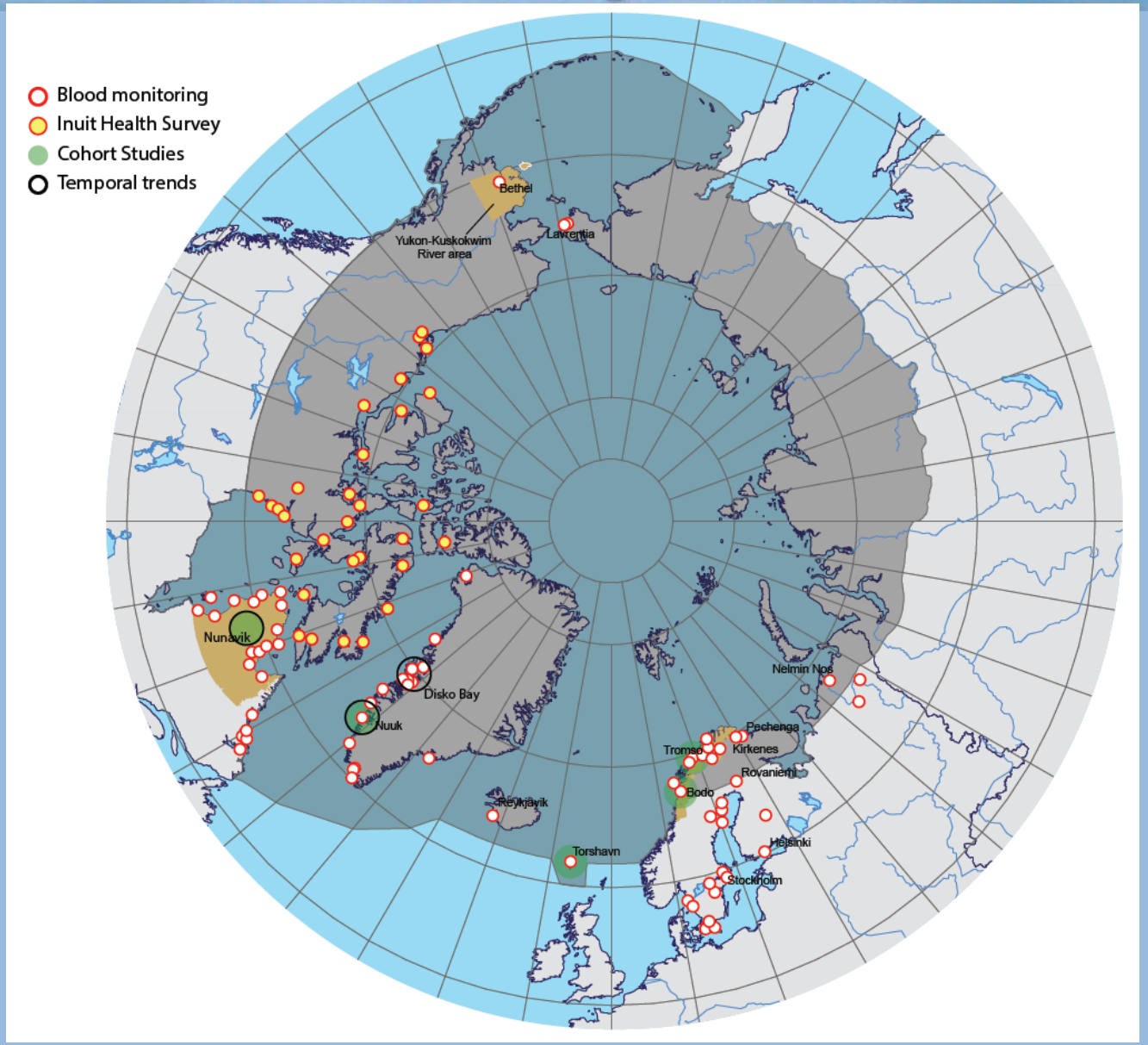
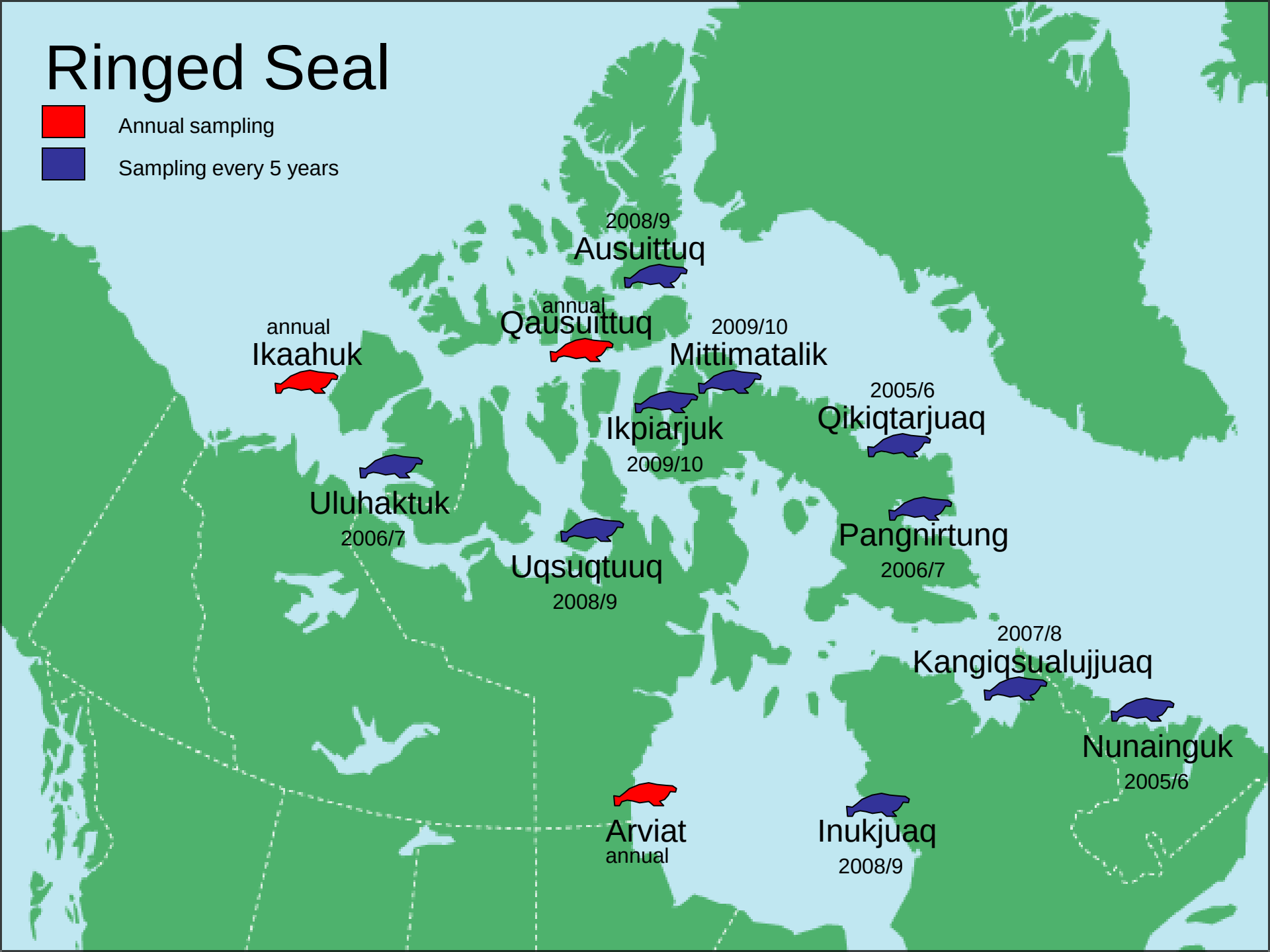
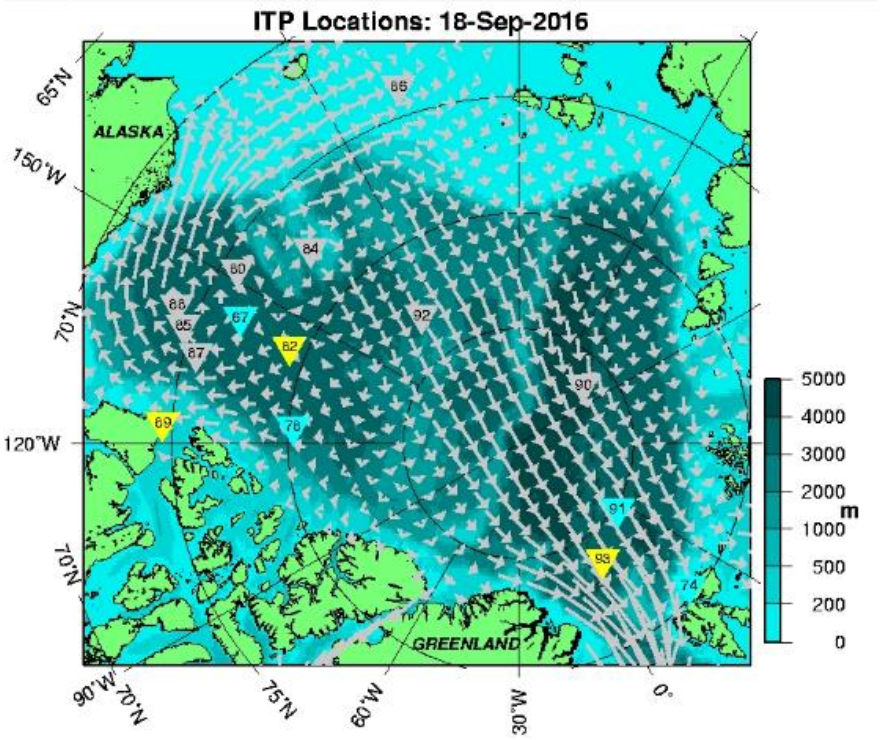



Ringed Seal
Annual sampling
Sampling every 5 years
2008/9
Ausuittuq
annual
Qausuittuq
annual
Ikaahuk
2009/10
Mittimatalik
2005/6
Qikiqtarjuaq
Ikpiarjuk
2009/10
Uluhaktuk
2006/7
Uqsuqtuuq
2008/9
Pangnirtung
2006/7
2007/8
Kangiqsualujjuaq
Nunainguk
2005/6
Arviat
annual
Inukjuaq
2008/9

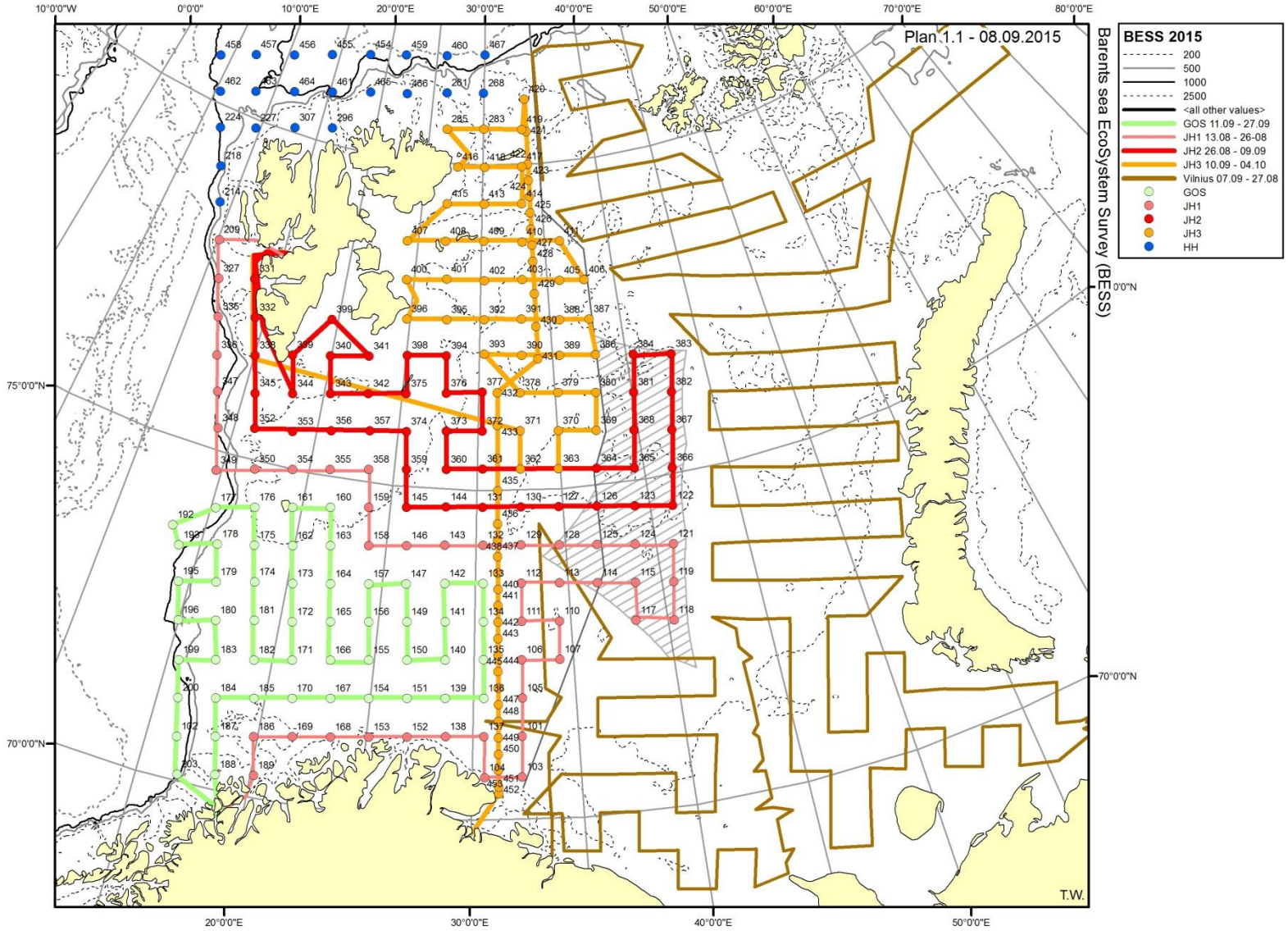
SAON
SUSTAINING ARCTIC OBSERVING NETWORKS

International Arctic Buoy Programme 16.09.16



Ice-Tethered Profiler (ITP) (Woods Hole Ocanographic Institution, http://www.whoi.edu/page.do?pid=20781)

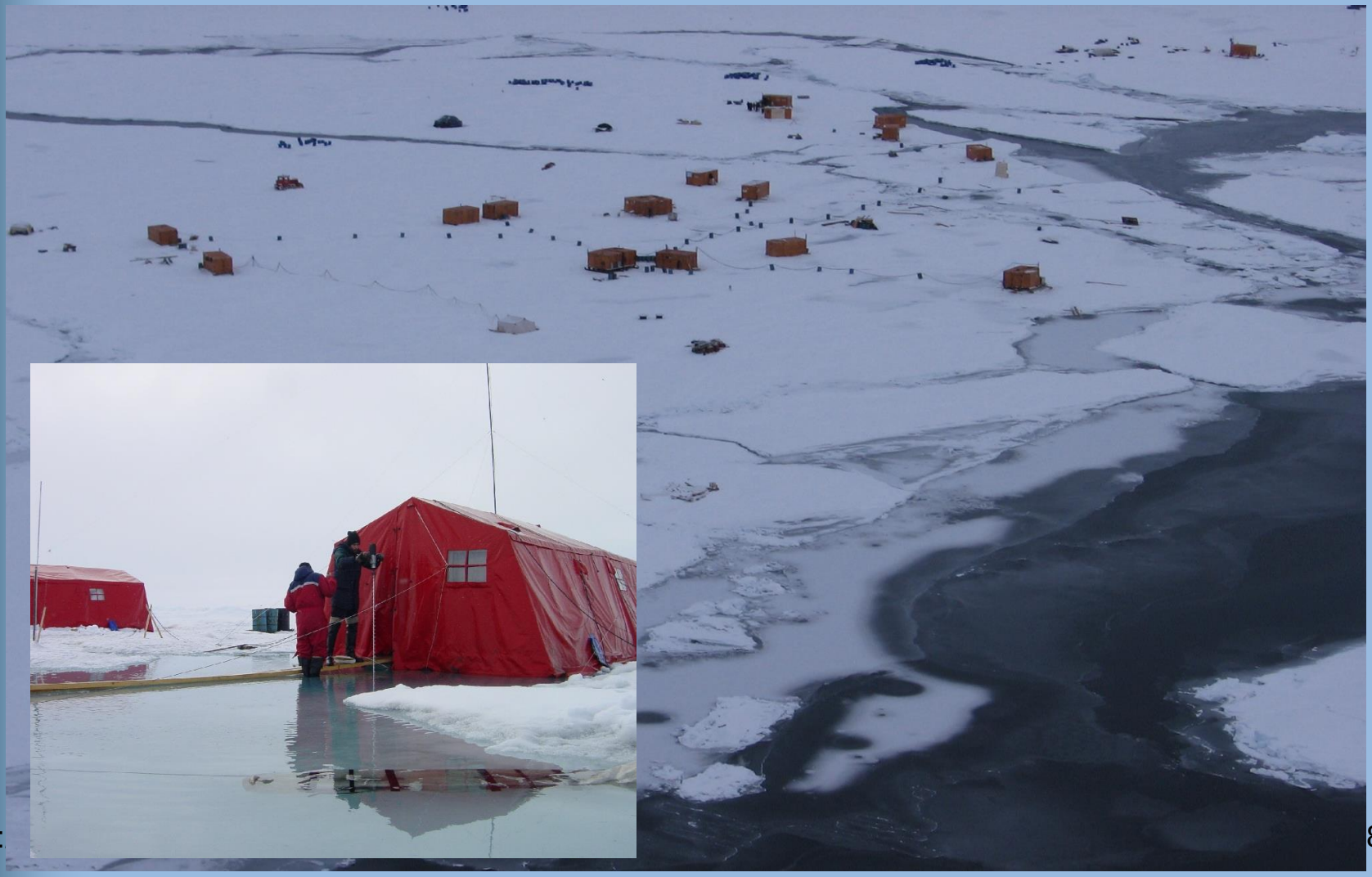
IMR-PINRO Survey design 2015



Hydrography and plankton stations

Bottom and pelagic trawl stations

Russian Floating Ice station



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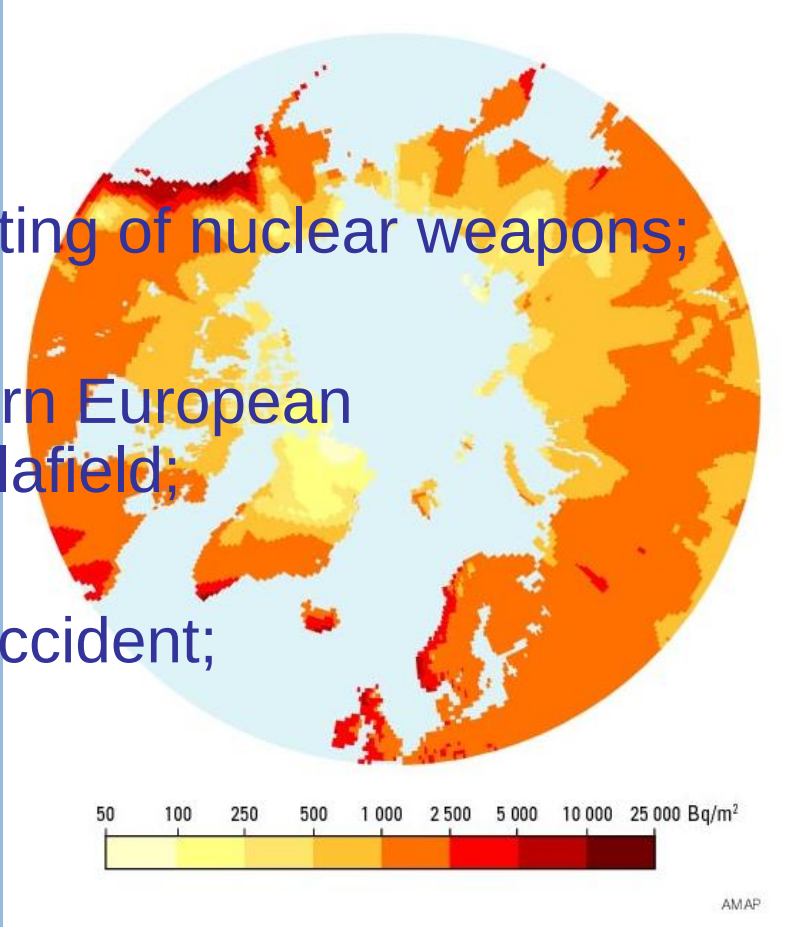
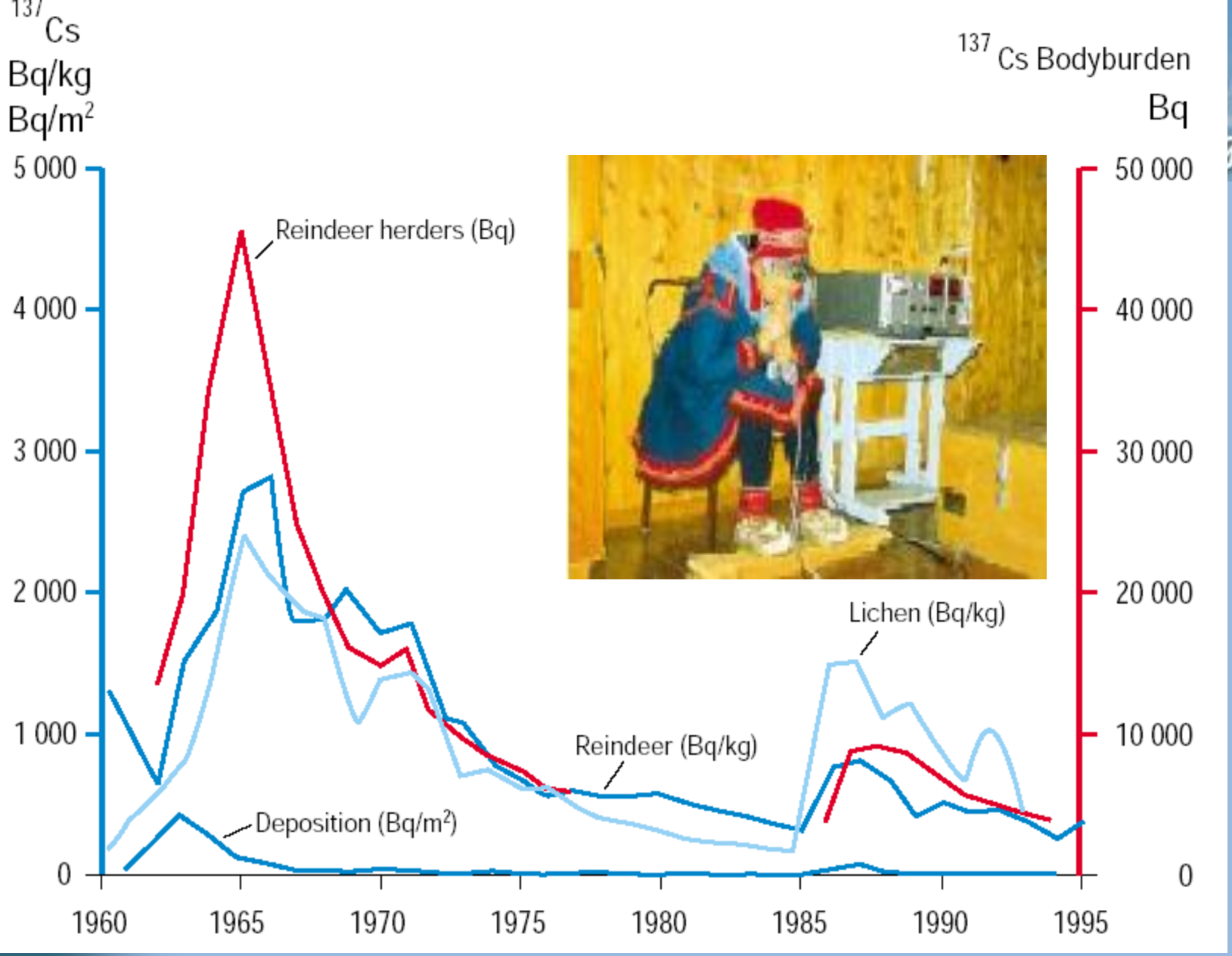
Radioactivity problems in the Arctic

Three major sources have contributed to the widespread radioactive contamination of the Arctic area:

- Fallout from atmospheric testing of nuclear weapons;
- Routine releases from western European reprocessing plants, e.g. Sellafield;
- Fallout from the Chernobyl accident;



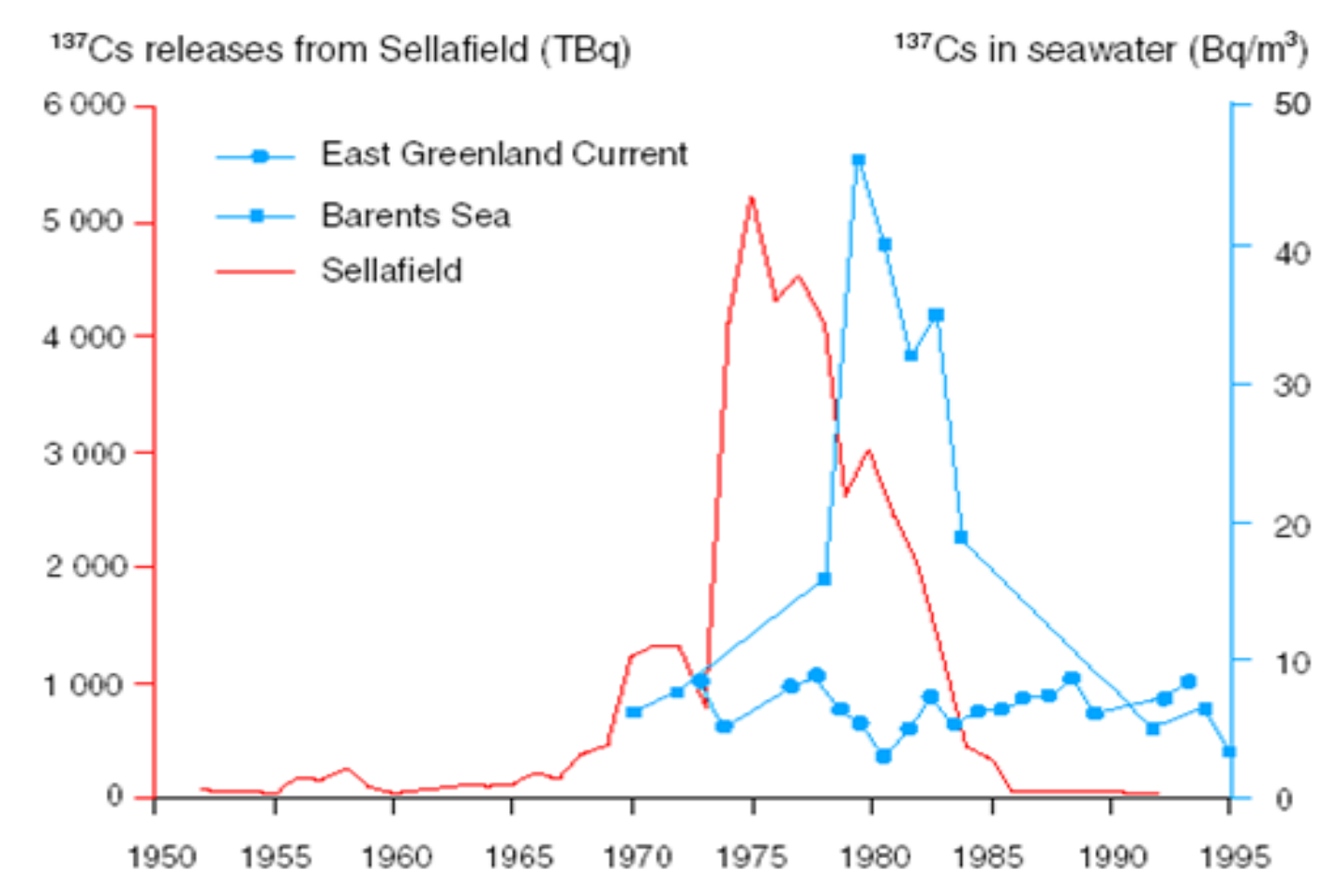

137 Cs
Bq/kg
Bq/m2
137 Cs Bodyburden
Bq
5 000
4 000
3 000
2 000
1 000
0
50 000
40 000
30 000
20 000
10 000
0
Reindeer herders (Bq)
Lichen (Bq/kg)
Reindeer (Bq/kg)
Deposition (Bq/m2)
1960
1965
1970
1975
1980
1985
1990
1995

Marine Pathways

Radionuclides

Mainly from storage and handling of spent nuclear fuel and waste, operation of nuclear power plants and vessels and military installations. Continued concern over previous releases from ‘old sins’

^{137}Cs releases from Sellafield, UK and levels in Barents Sea and Greenland currents



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Tc in Sea water, release and

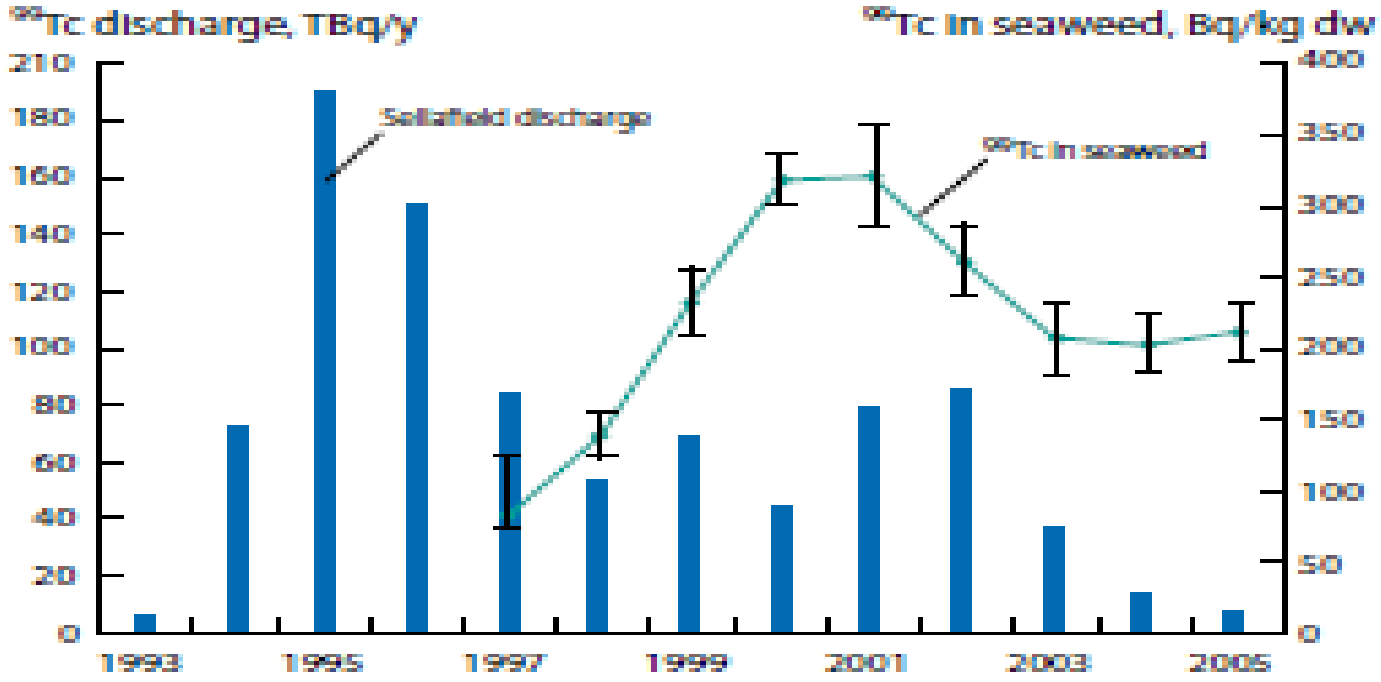

Figure 4-15. Annual average activity concentrations of ^{99}Tc in seaweed (*Fucus vesiculosus*) at Hillesøy, northern Norway, and annual discharges of ^{99}Tc from the Sellafield nuclear fuel reprocessing plant, UK, since the early 1990s.

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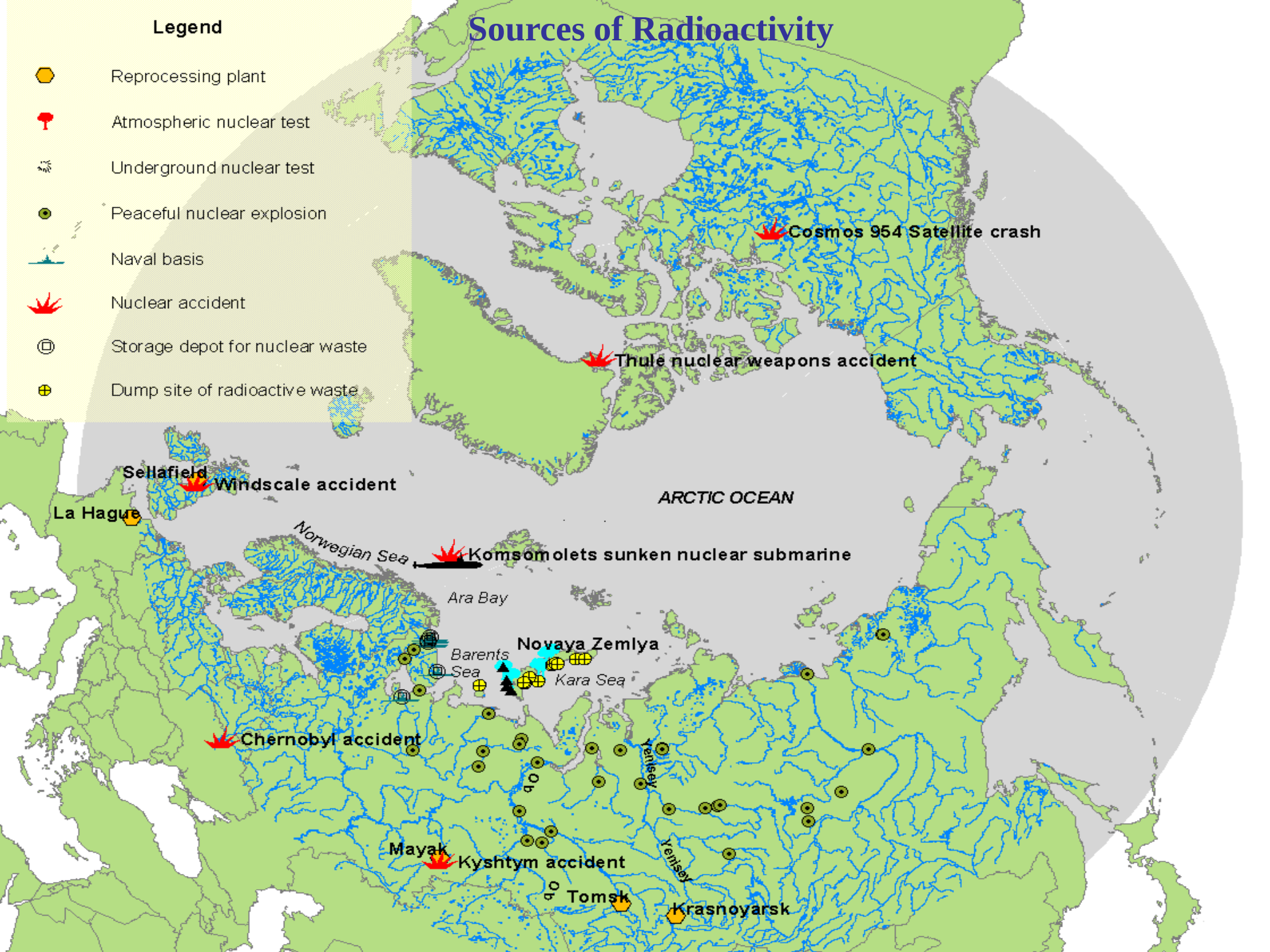
Radioactivity:
Risks identified by AMAP in 1995

- Kola Nuclear Power Plant (NPP)
- Andreva Bay - Storage of spent fuel and waste
- RTGs - Lighthouses based on Strontium batteries
- Mayak - Reprocessing plant
- Dumping sites at Novaya Zemlya
- Decommissioning of nuclear submarines
- Long time storage and transport, Novaya Zemlya



Sources of Radioactivity



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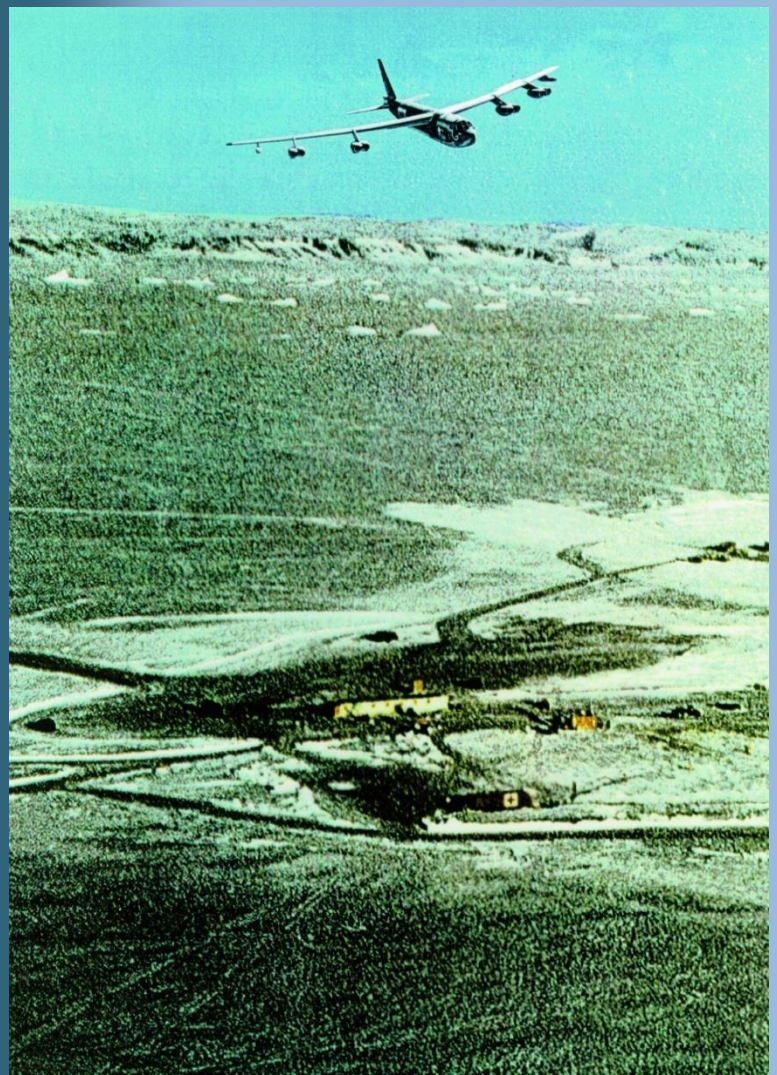
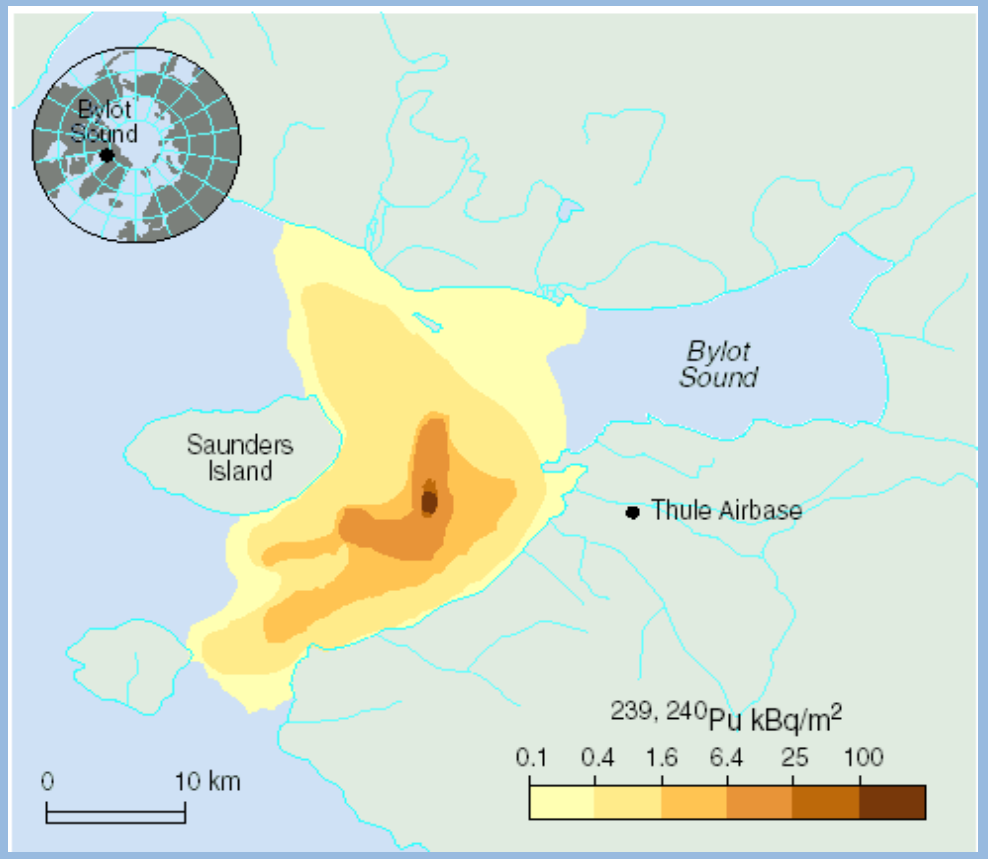
Dismantling nuclear submarines 1996 - 2011

198 Russian nuclear subs have been decommissioned,

122 of these in North-west Russia, one is waiting for dismantlement

B-52 Accident at Thule in 1968





Fukushima accident is not expected to result in adverse impacts on Arctic biota

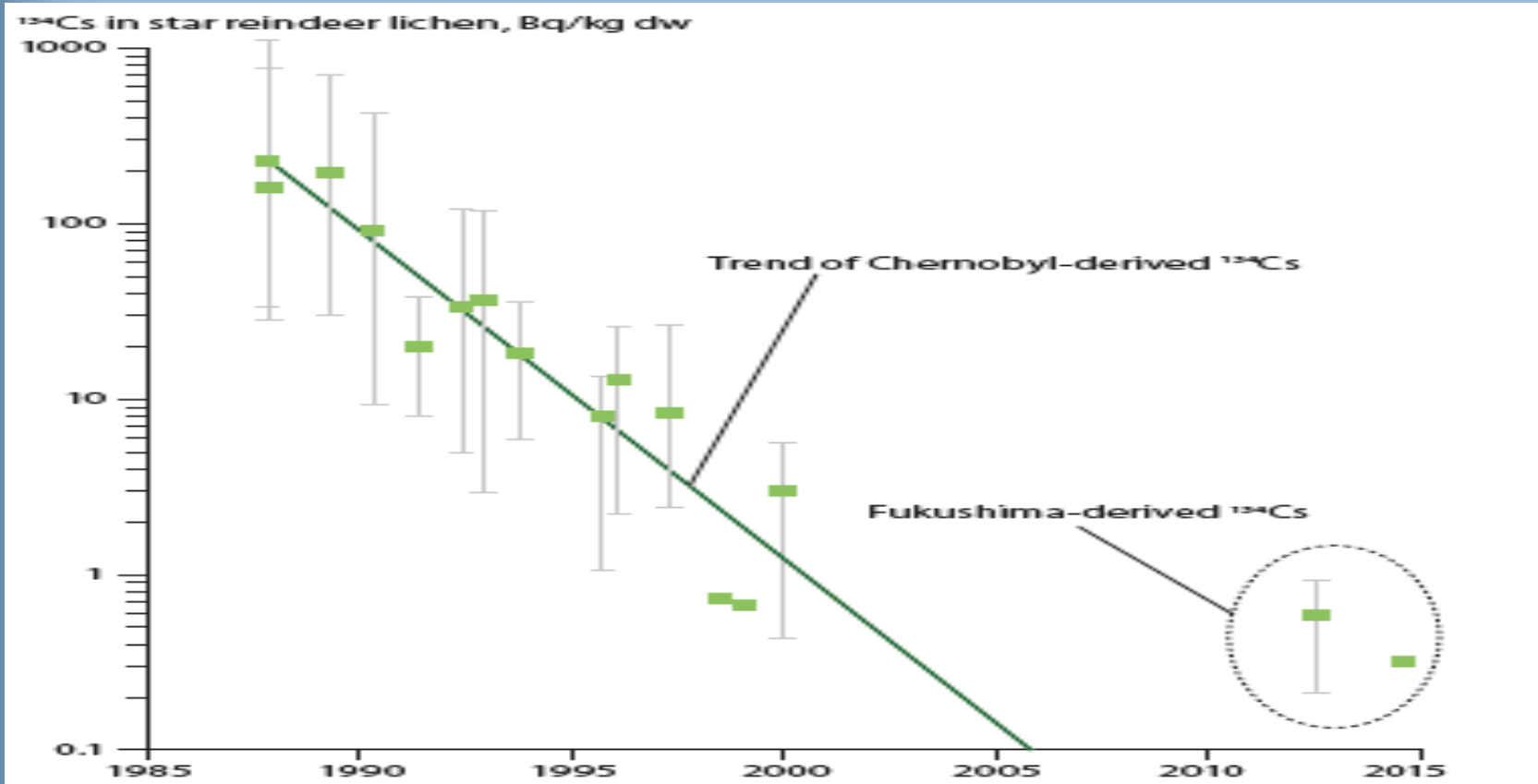


Figure 5.5 Average annual ^{134}Cs concentrations observed in star reindeer lichen *Cladonia stellaris* in northern Finland (Koivurova et al. 2015). The trend line is fitted to the data observed after the Chernobyl accident.

NORM/TENORM

Key findings

- *Increased exploitation of resources in the Arctic is expected to enhance the risk of releasing NORM/TENORM to the environment within the AMAP region*
- *Environmental impact assessments prior to the start of any undertaking that could lead to radioactive contamination of the Arctic environment are very important from a radiological perspective*
- *Climate effects (principally warming) on the behavior of NORM/TENORM in the Arctic that could affect human health should be a subject for further research*

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Floating nuclear power plant

Soon to be towed to an Arctic location for use.

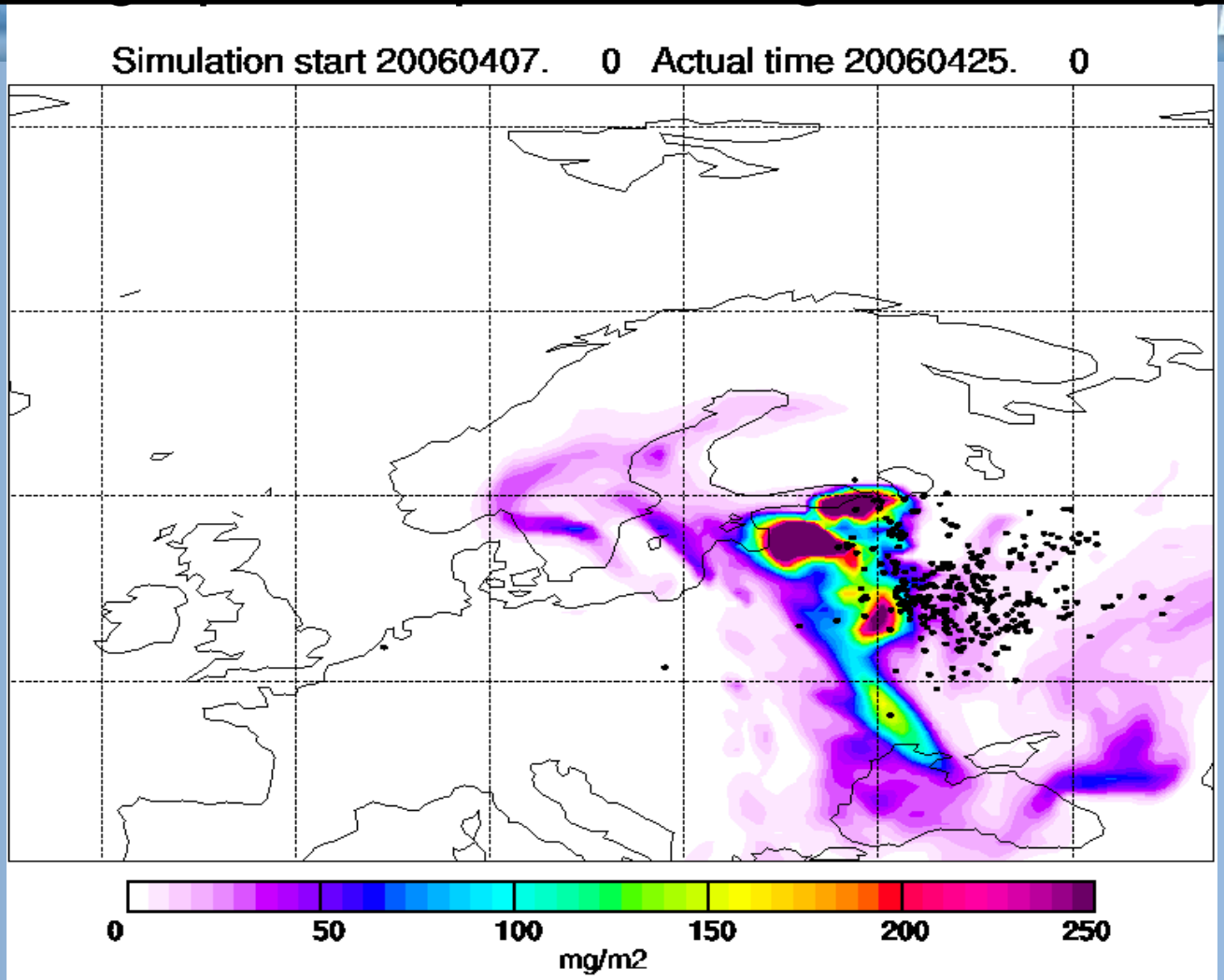
Evaluating specific episodes: PCBs at Ny-Ålesund

View from the station on a clear day…

And during the 2nd episode in May, 2006

Eckhardt et al. 2007 *Atmos Chem Phys* 7: 4527-4536

Evaluating specific episodes, e.g. PCBs at Ny-Ålesund



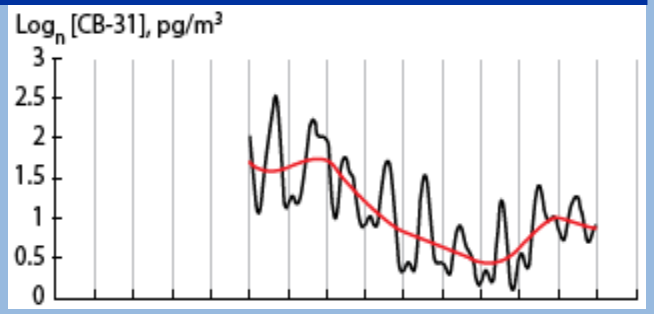
Eckhardt et al. 2007 *Atmos Chem Phys* 7: 4527-4536

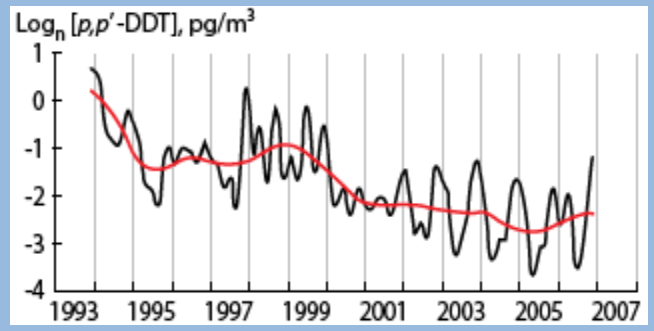
Legacy POPs – Time trends in air (AMAP 2009)

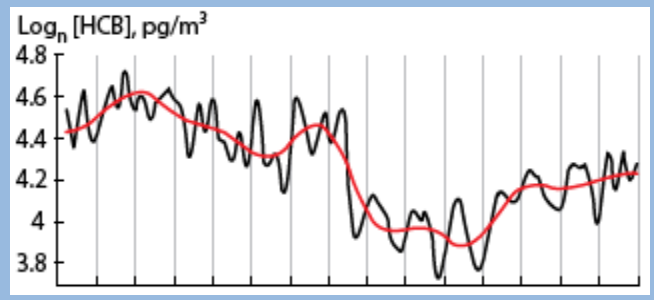
Decreasing trends in the Arctic during1970s – 2000.

PCB, DDT trends at Alert (Canada) and Zeppelin (Svalbard) show strong declines.

Indications of **slight increasing trends** for **HCB and PCB** in recent years, might be an impacts of climate change on pathways and recycling.







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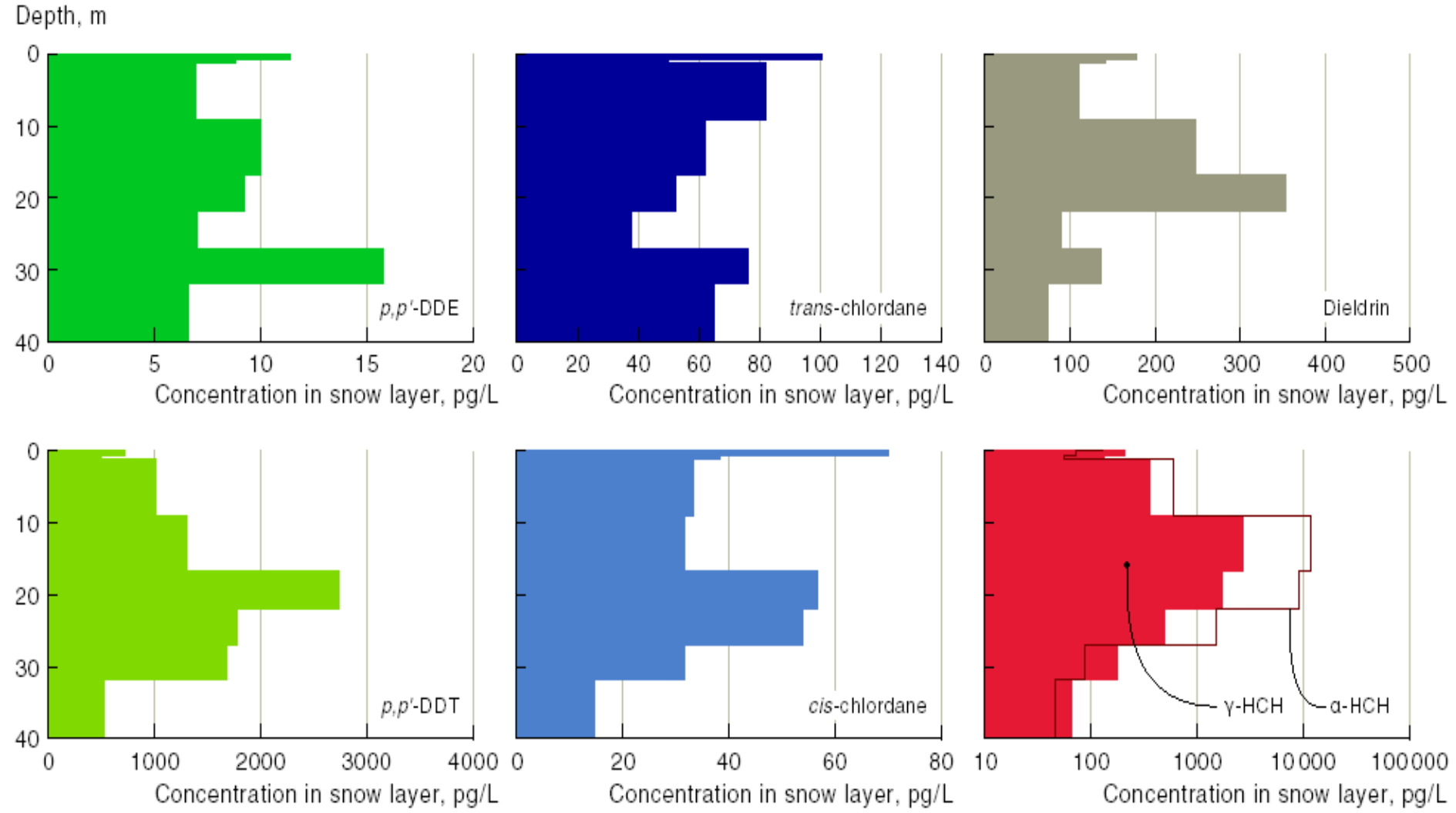
OCs in Snow cores from Svalbard



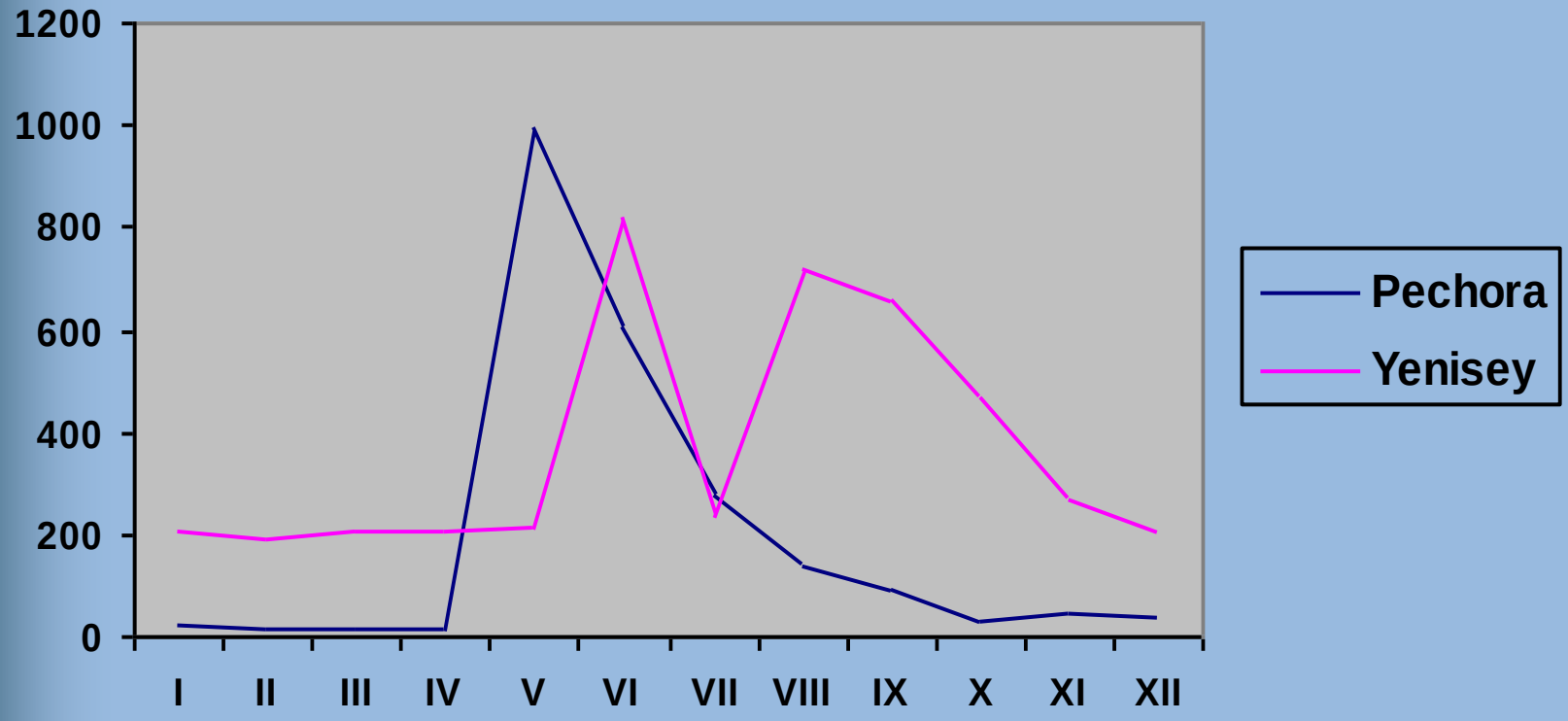
Riverine pathway

Main runoff in June

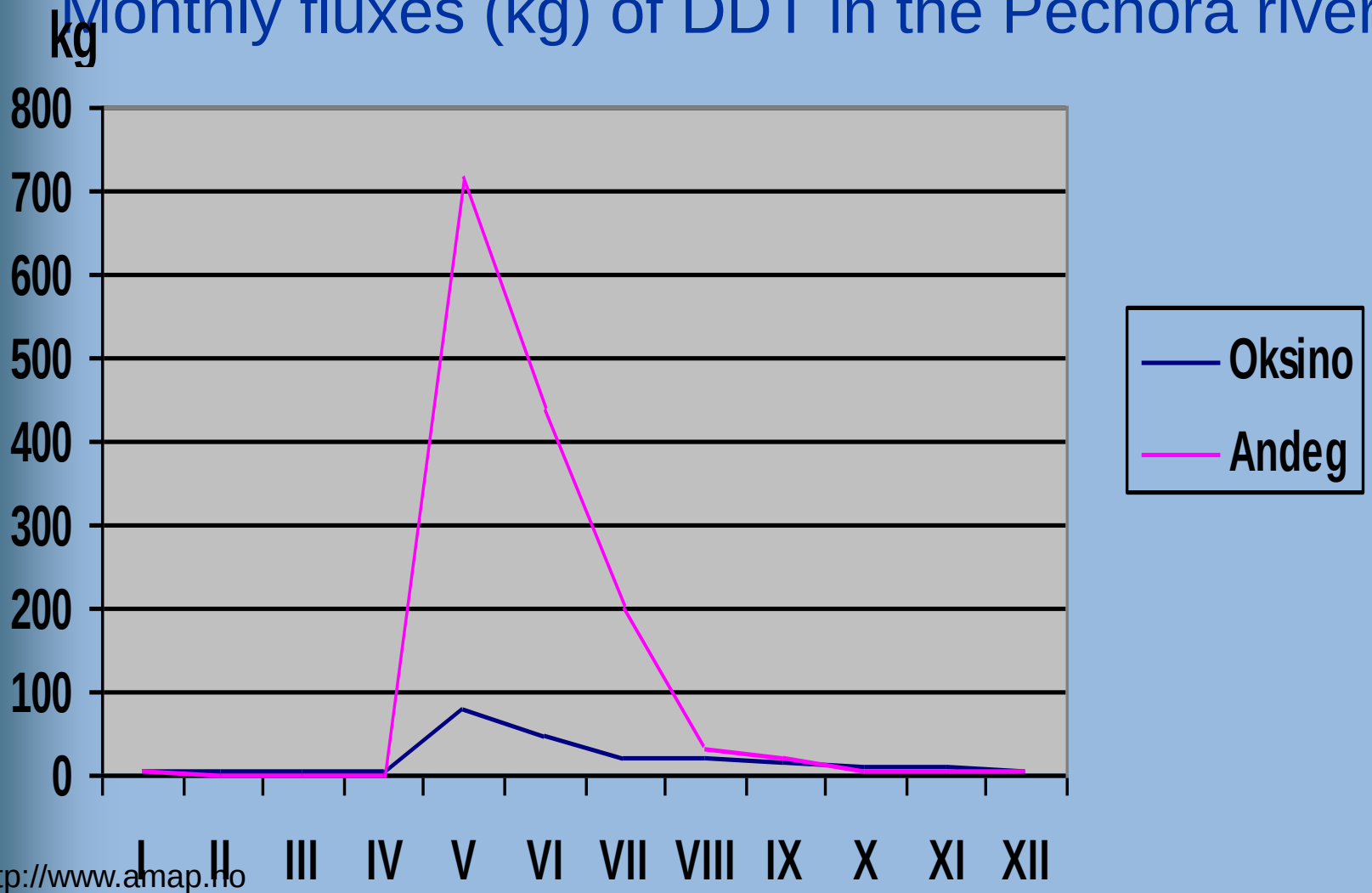
70 % of water from south of the Arctic.

Mainly due to LRT, but also significant local inputs.

Annual distribution of PCB fluxes by Pechora and Yenisey rivers, kg (AMAP 2004)



Monthly fluxes (kg) of DDT in the Pechora river



PCB in Copepods

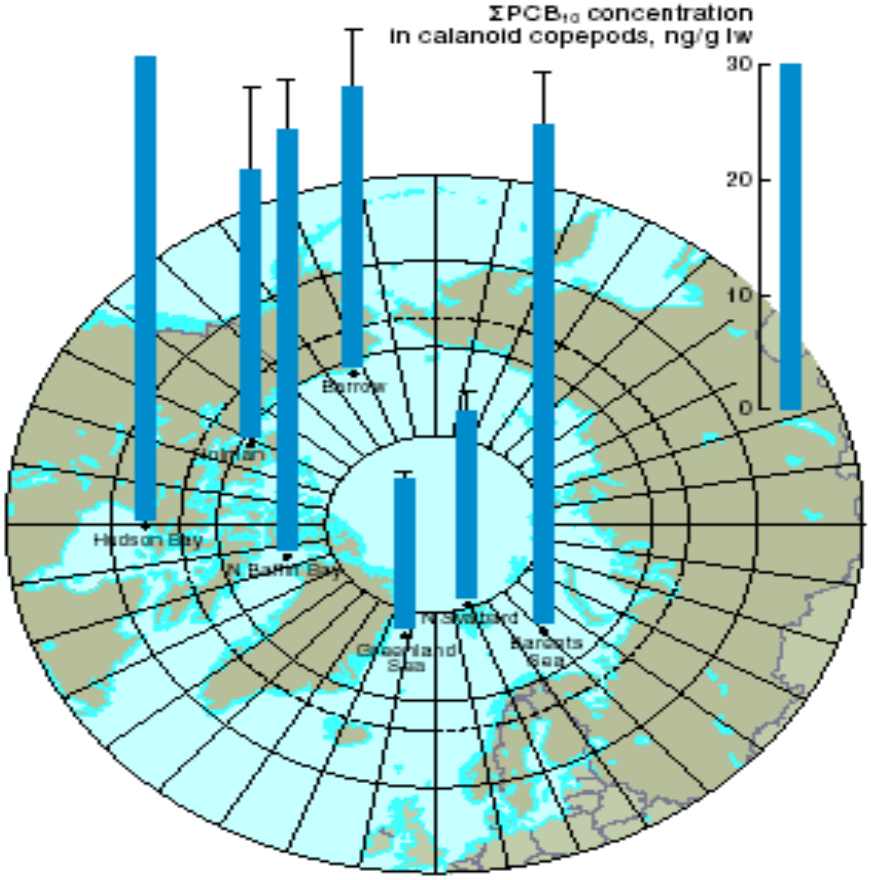
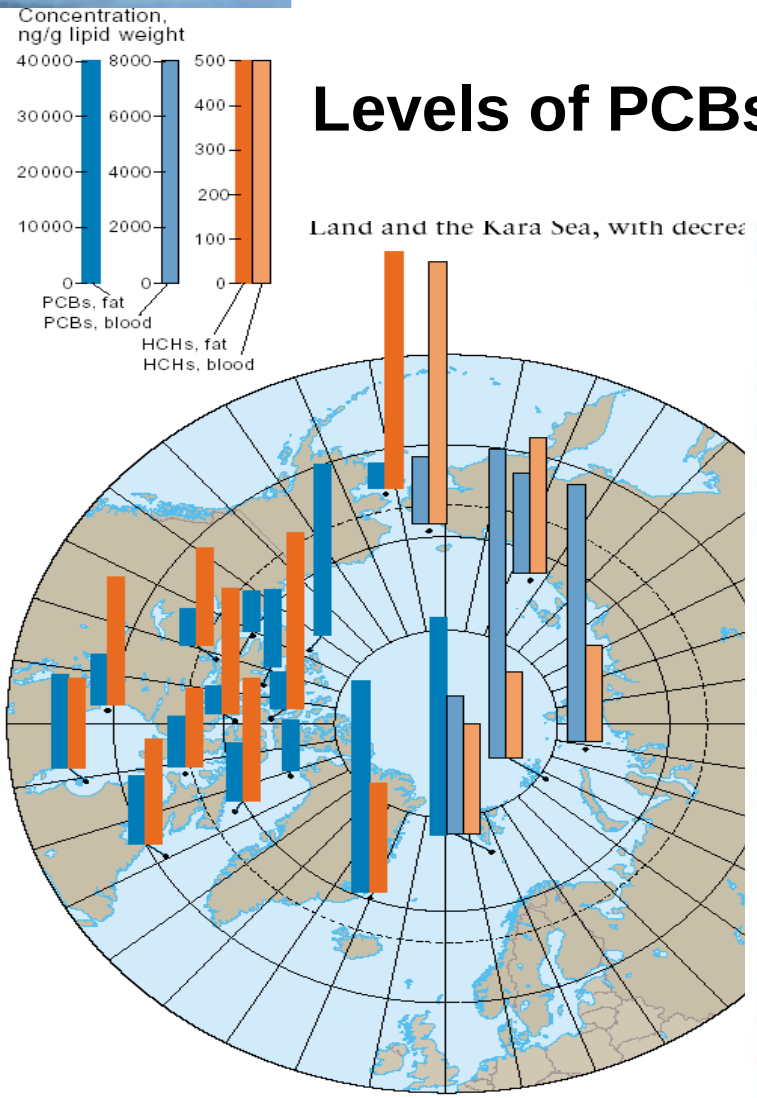
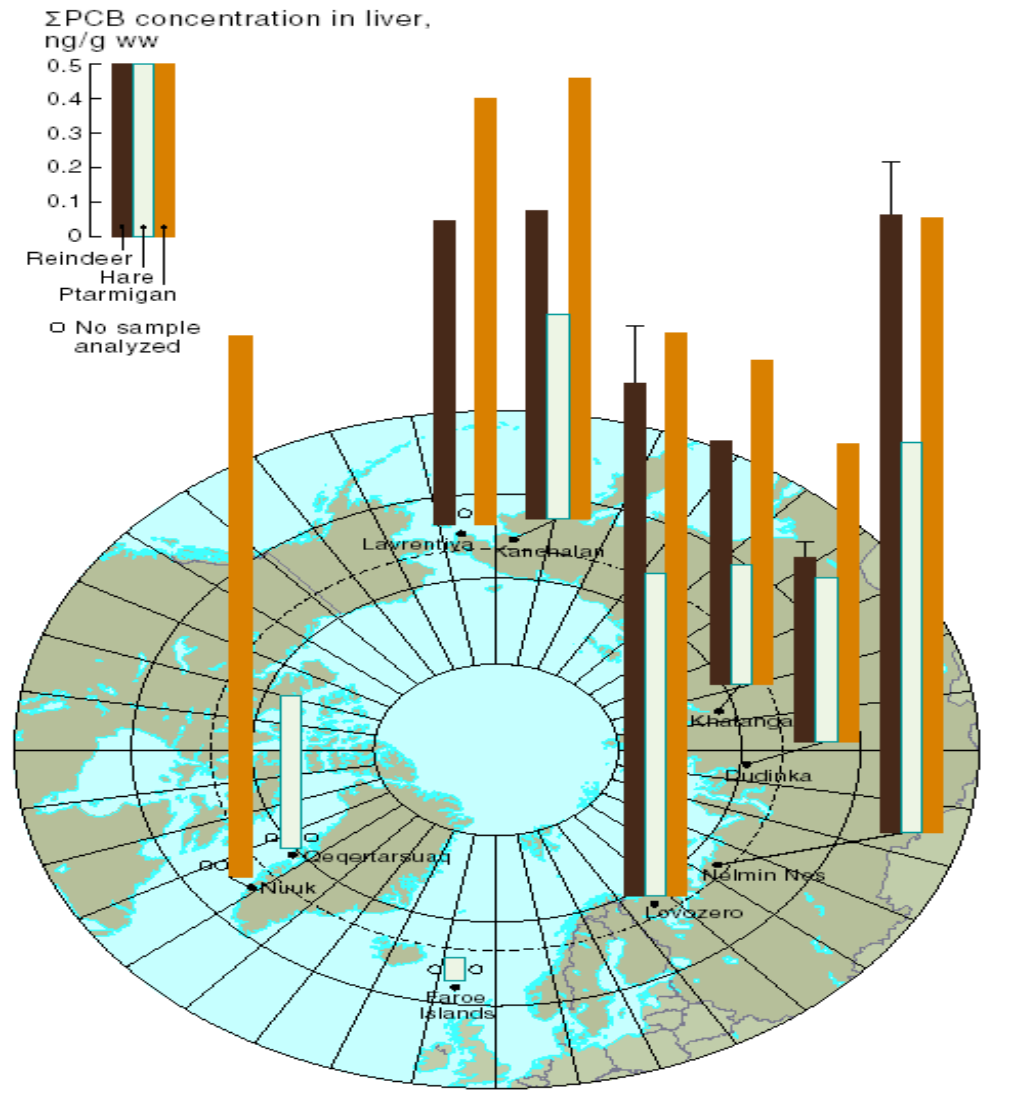


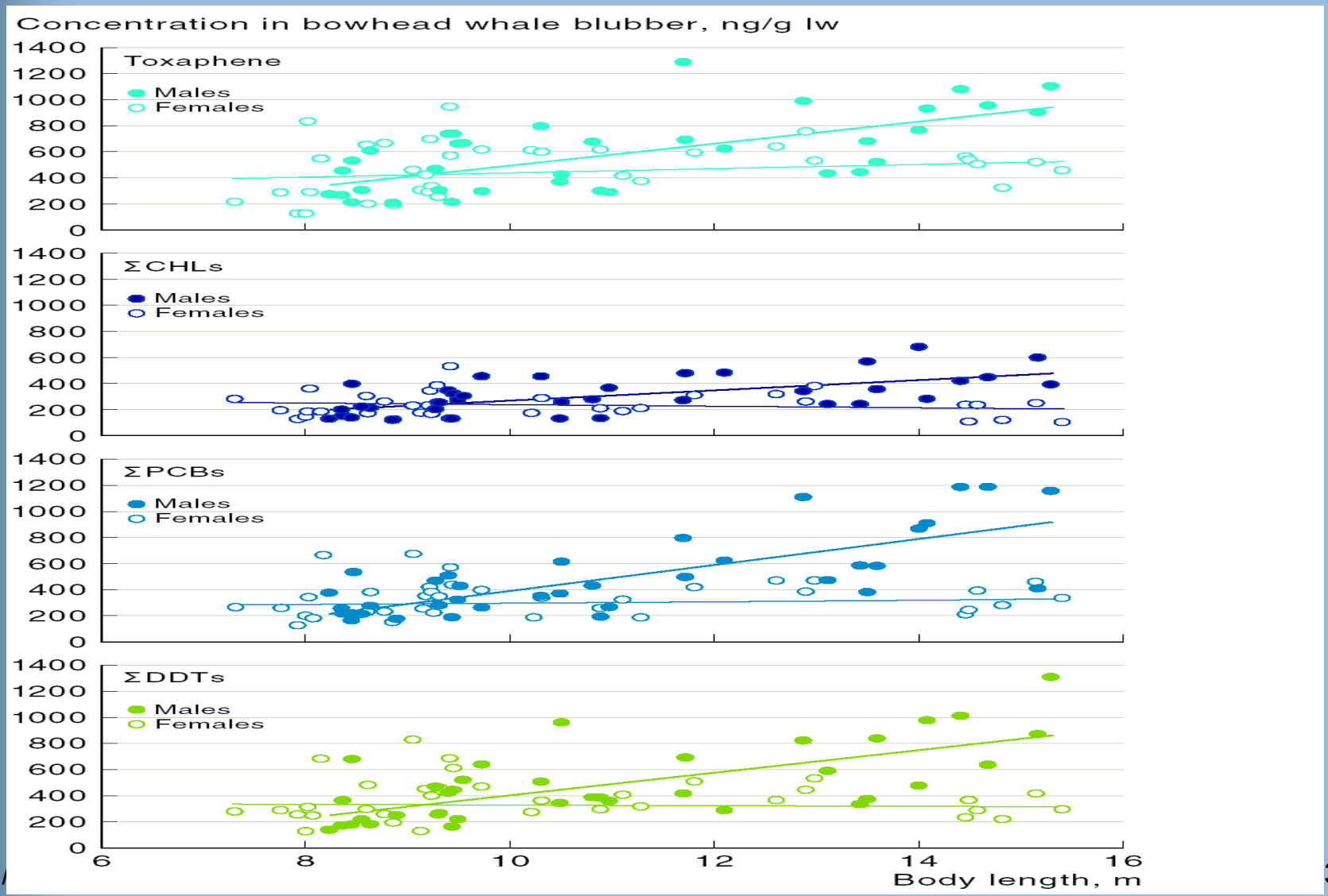
Figure 4-37. Concentrations of ΣPCB_{10} in calanoid copepods from Barrow, Alaska; Holman, NWT and Hudson Bay (Hoekstra *et al.*, 2002b); northern Baffin Bay (Fisk *et al.*, 2001a); and regions around Svalbard (ΣPCB_9, Borgå *et al.*, 2001).

Levels of PCBs and HCHs in Polar Bears

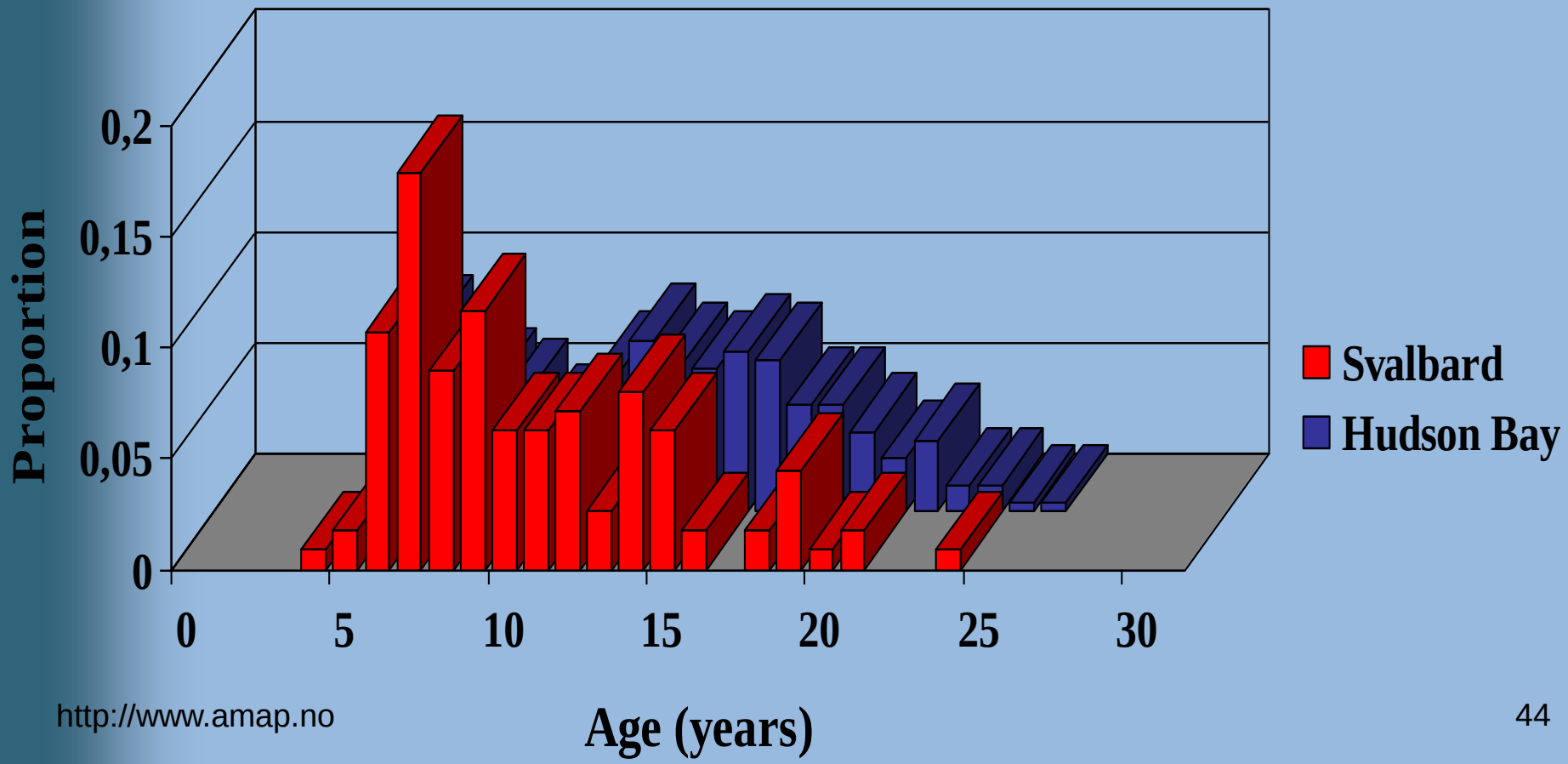


PCB in Reindeer, Hare & Ptarmigans

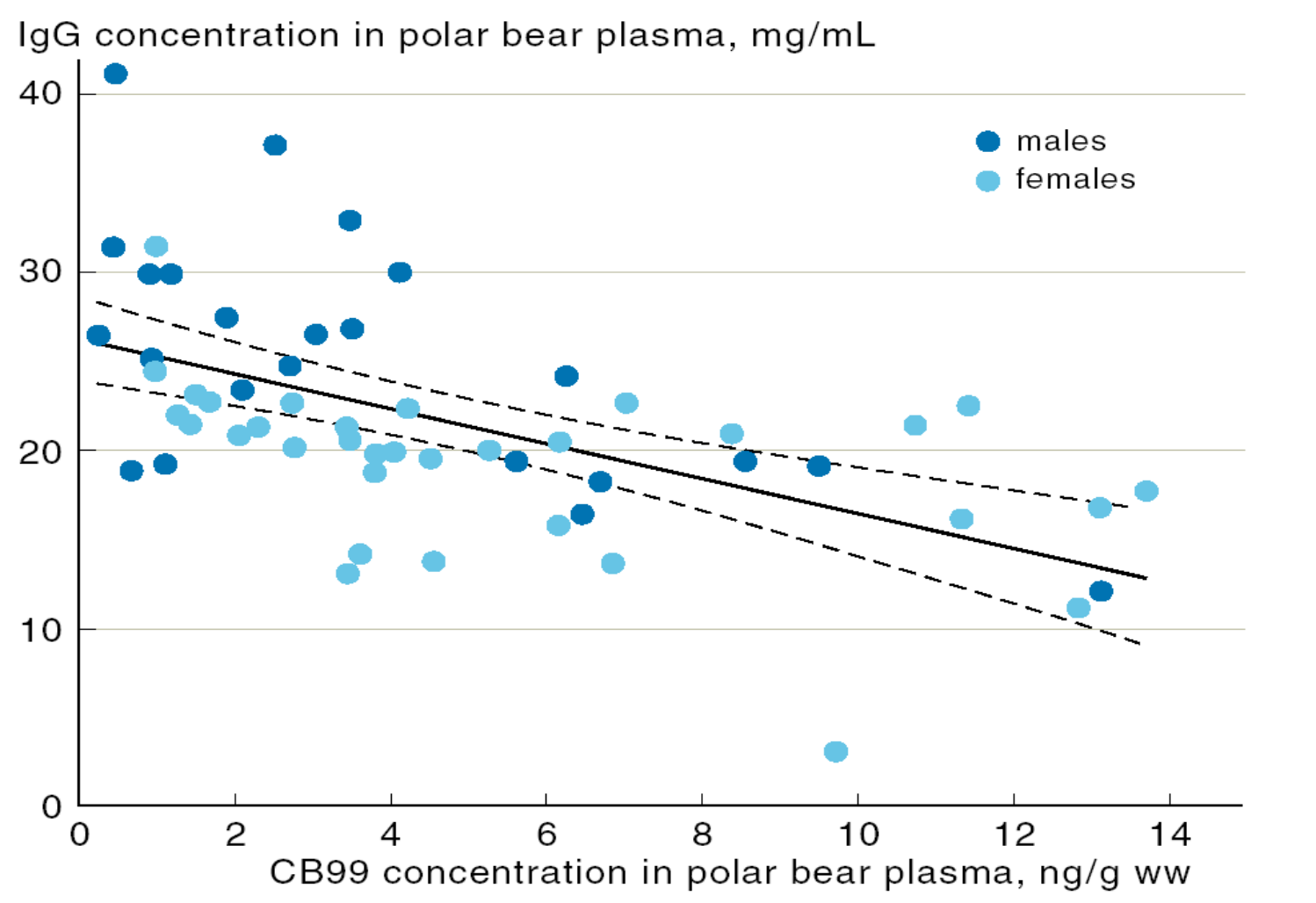



Concentration in bowhead whale blubber, ng/g lw
Toxaphene
Males
Females
ΣCHLs
Males
Females
ΣPCBs
Males
Females
ΣDDTs
Males
Females
0
200
400
600
800
1000
1200
1400
6
8
10
12
14
16
Body length, m

Age of female polar bears with cubs



Immune response & PCB



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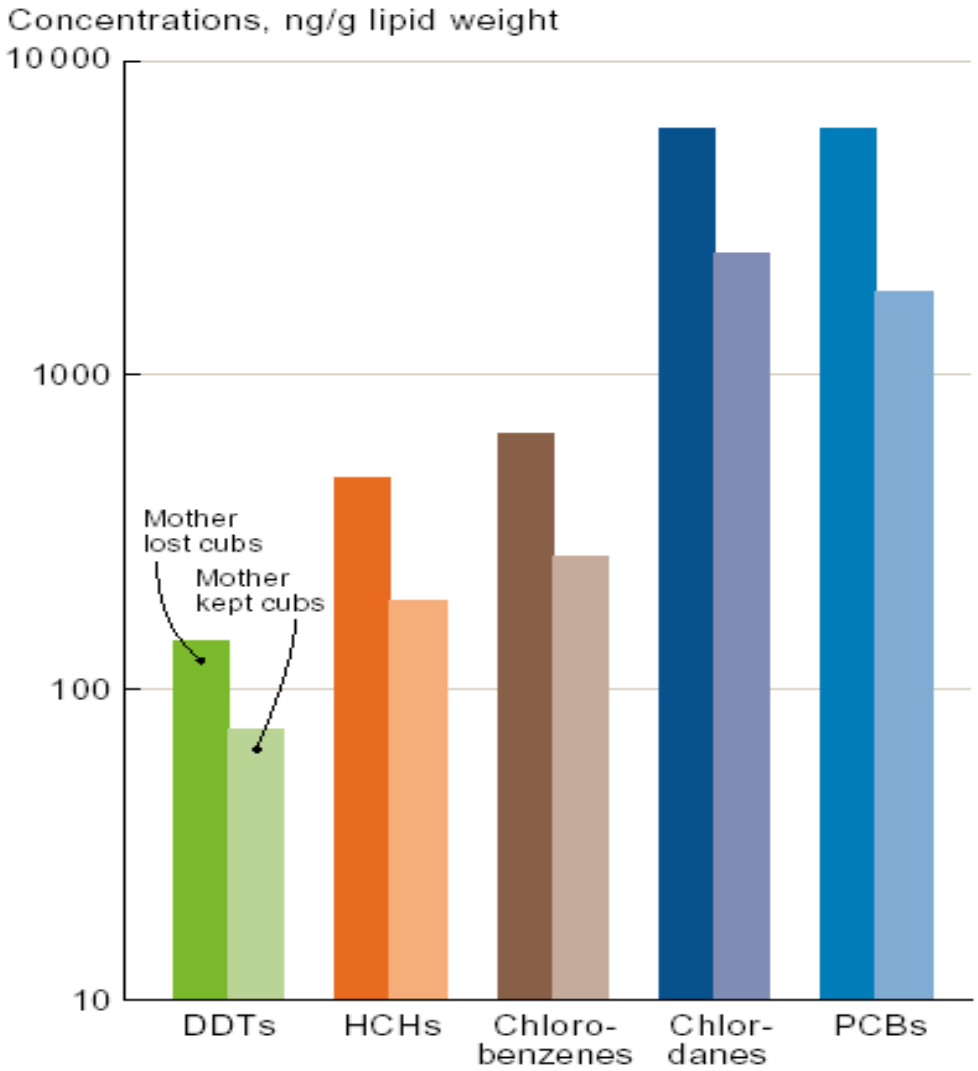
Effects of POPs on Reproduction of Polar Bears



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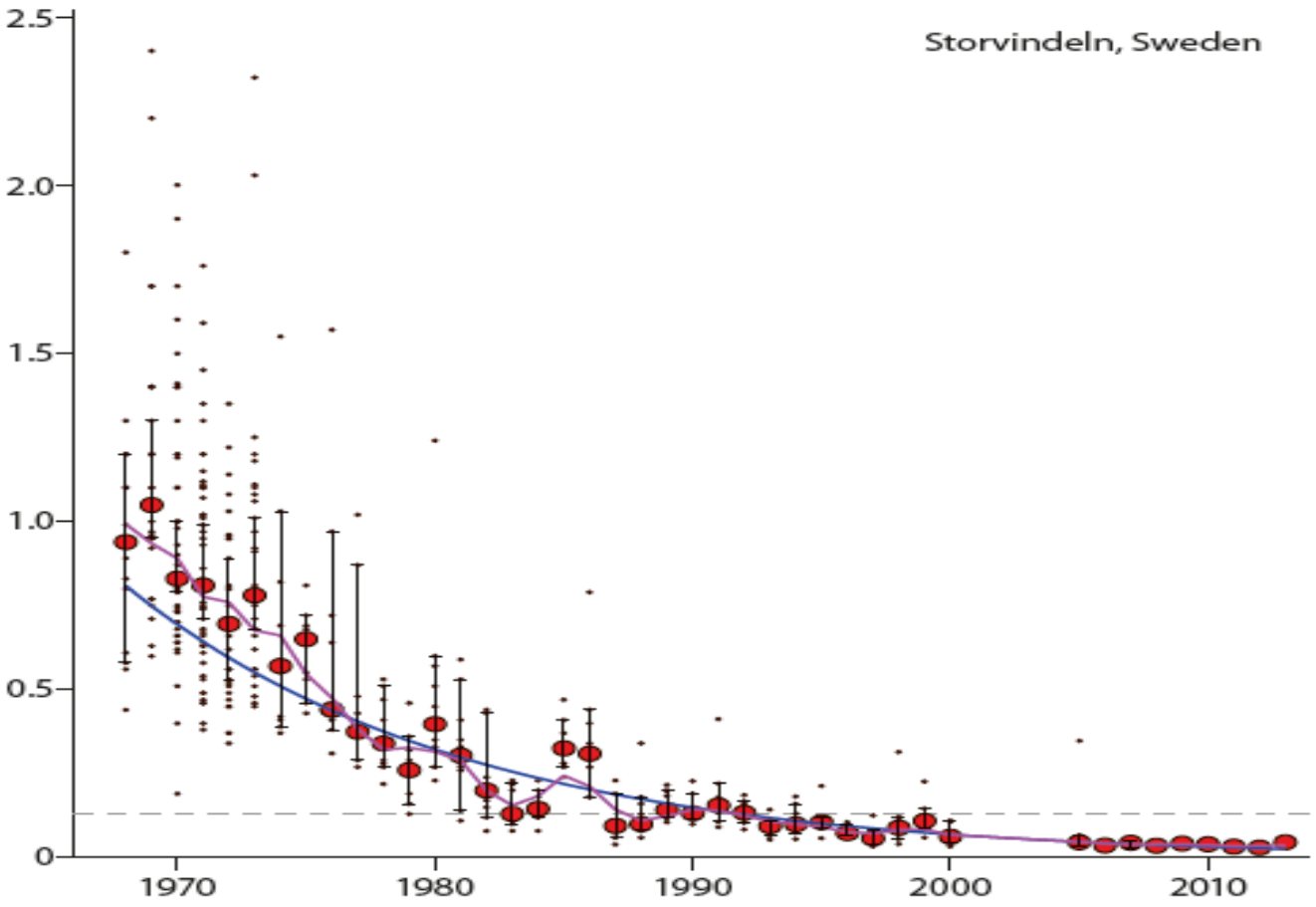
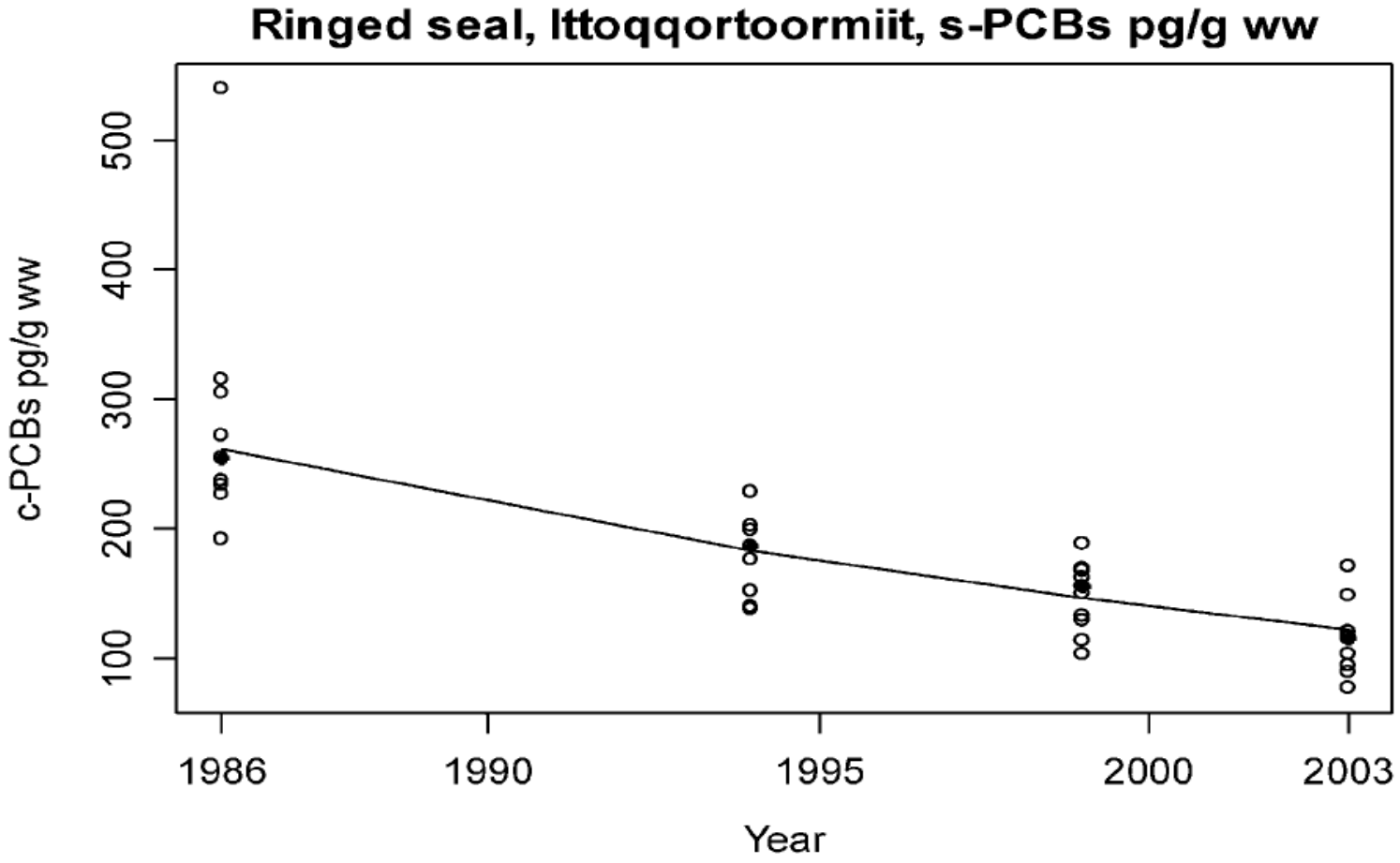


Figure 4.12 Trend in DDE concentrations in pike from Storvindeln (Sweden).



Riget et al., 2005. Mar. Poll. Bull. 2005 (50) 1523-1529.

New Concerns

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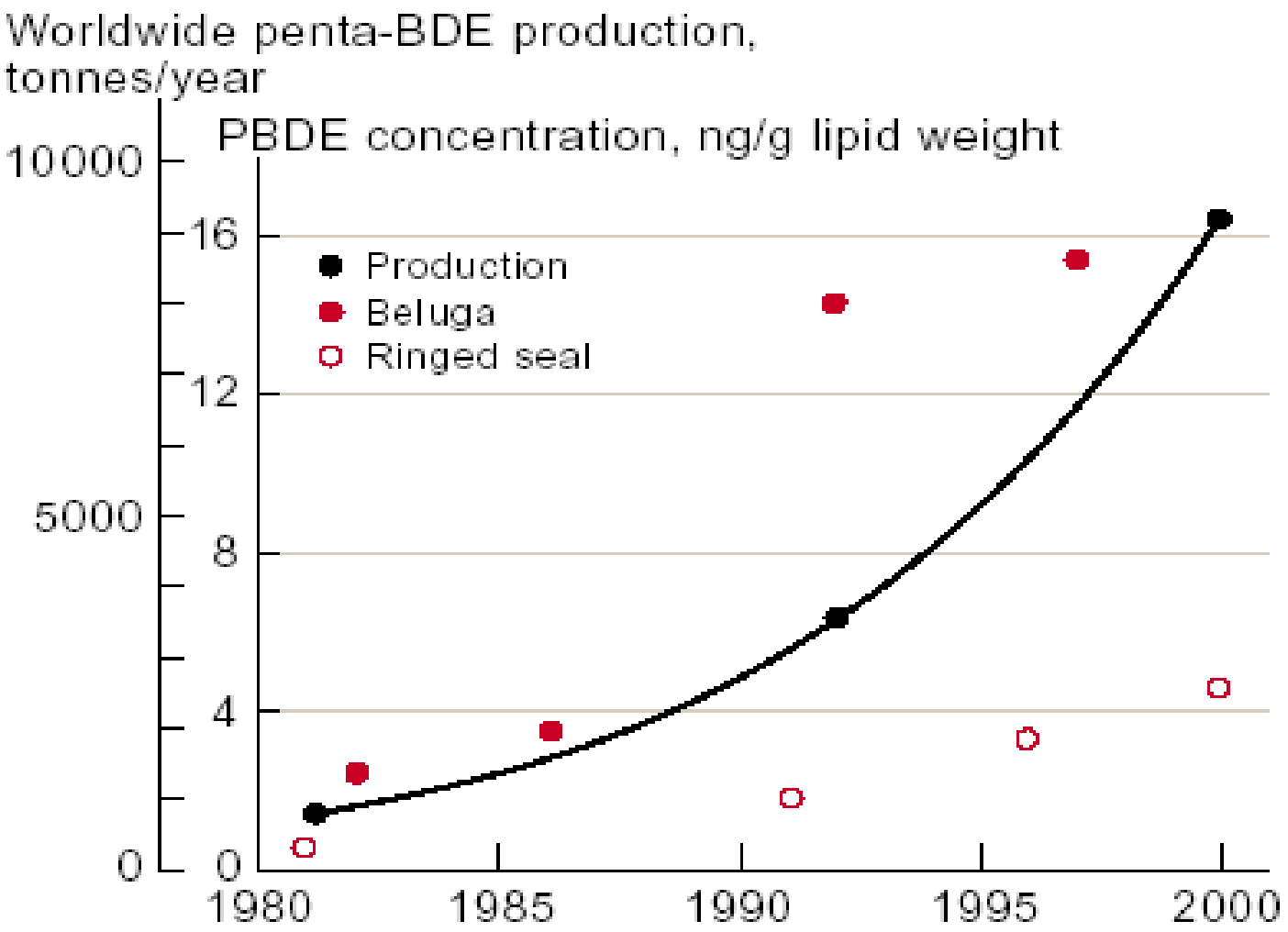


PCB11 & PBDE47 in Thick billed murre, Canada (AMAP 2015)

AMAP Technical Report No.7 (2014)

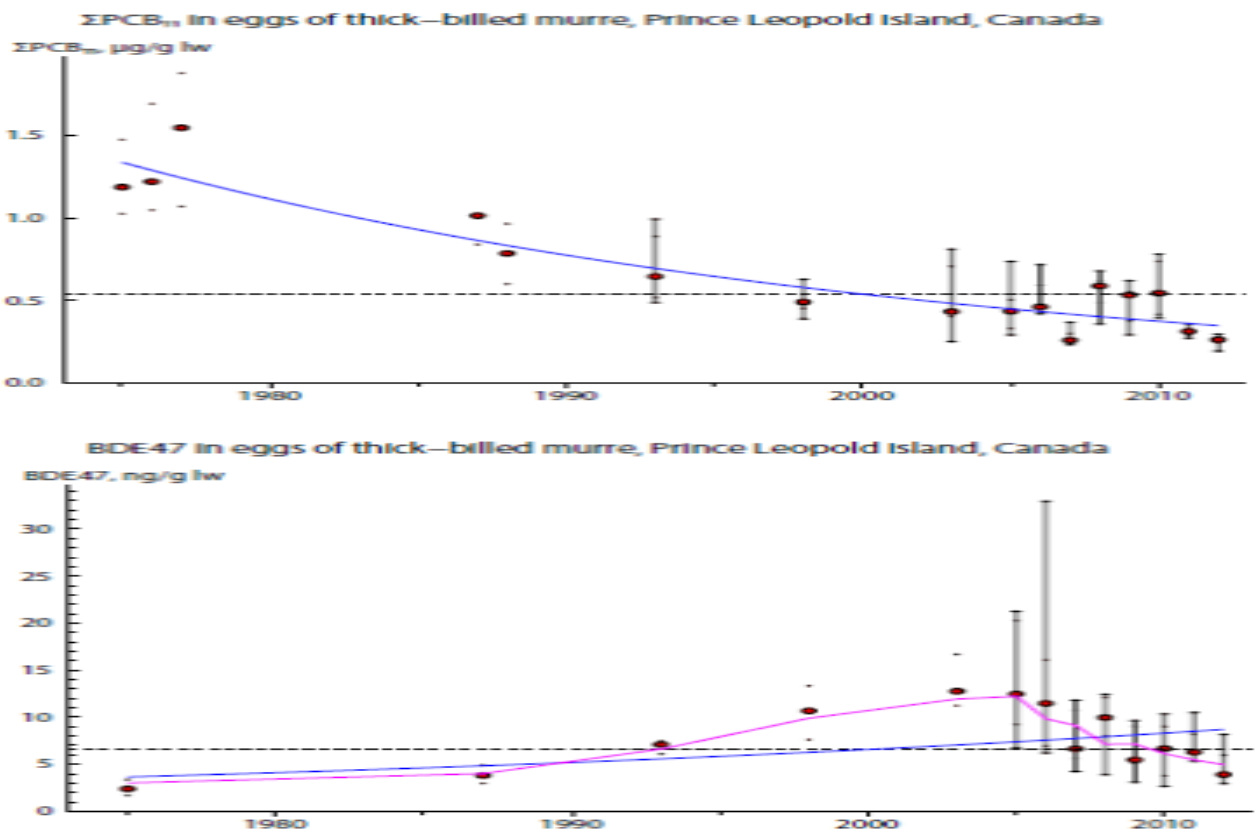
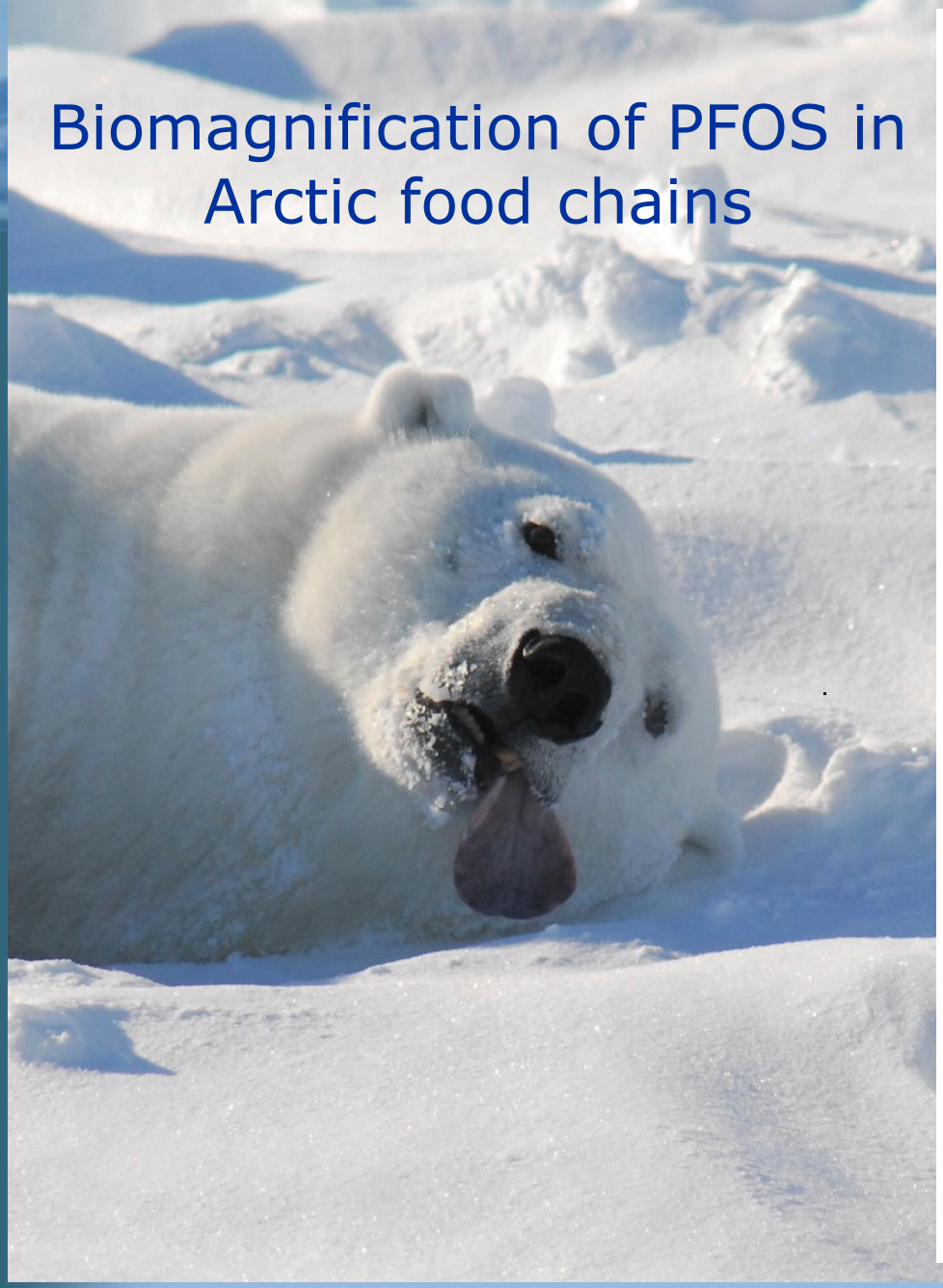
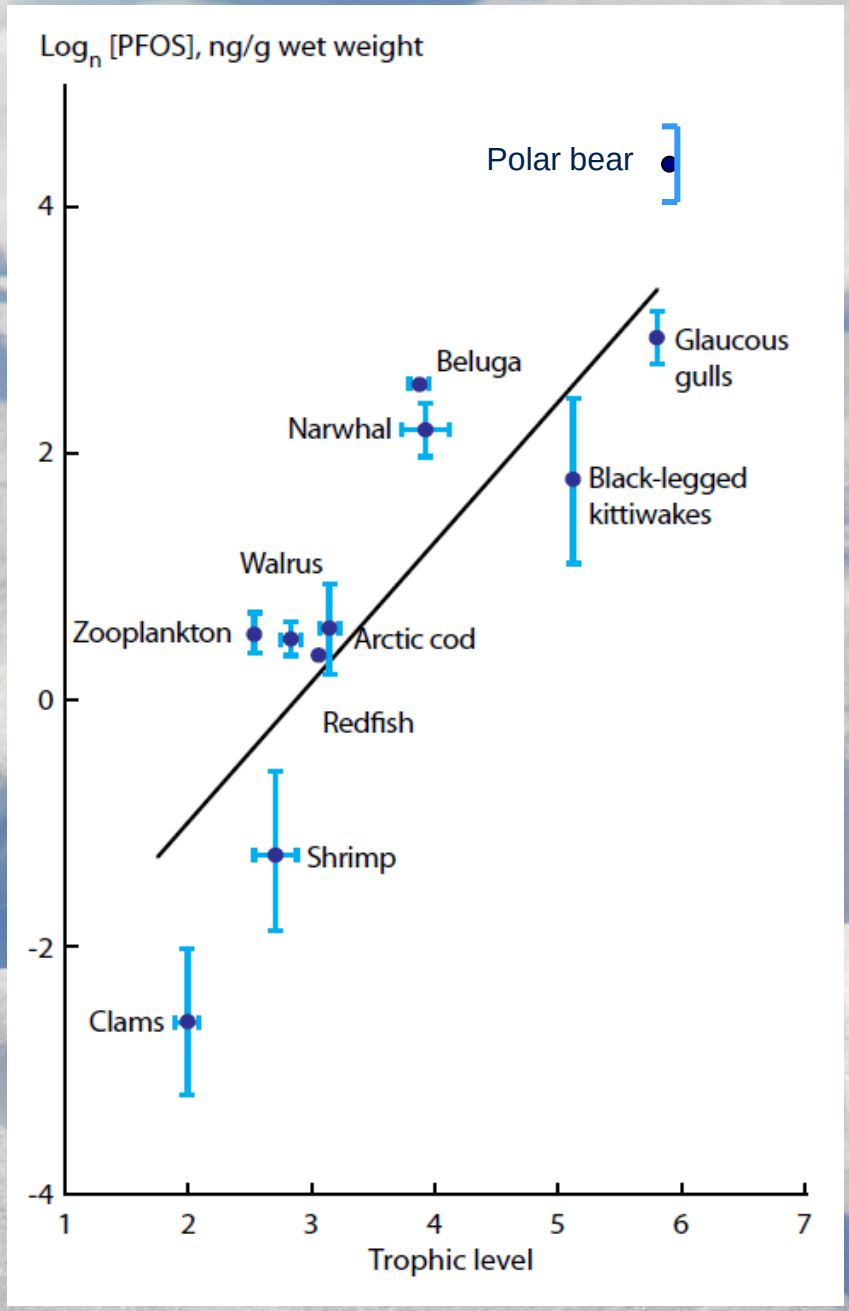


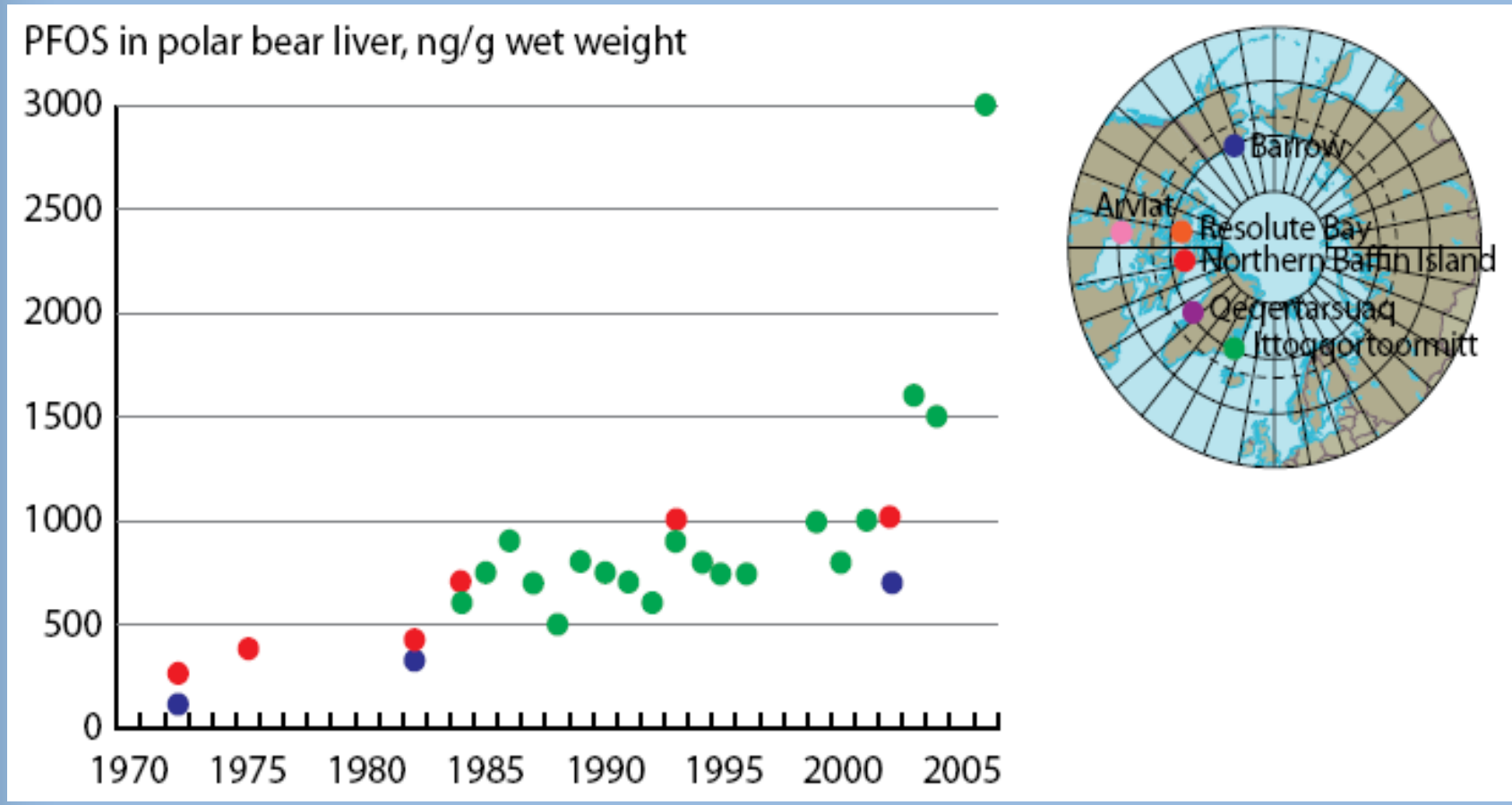
Figure 4.6. Example of trend results: PCBs (sum of 11 congeners) and PBDE-47 in thick-billed murre eggs collected at Prince Leopold Island, Canada.

Biomagnification of PFOS in Arctic food chains





Levels and Trends of New POPs in the Arctic – PFOS
'Arctic Pollution 2009'

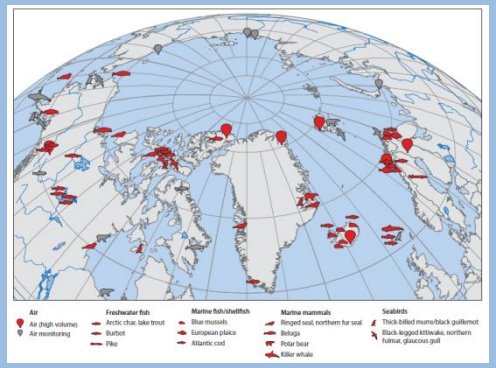


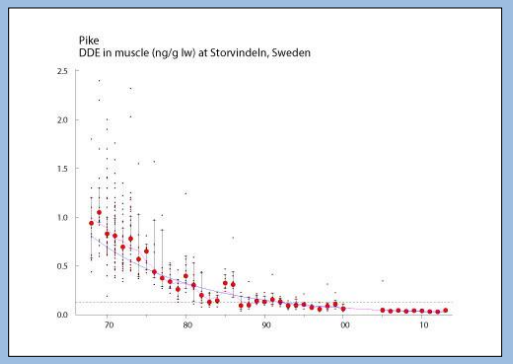
POPs Trends in the Arctic (AMAP 2015)

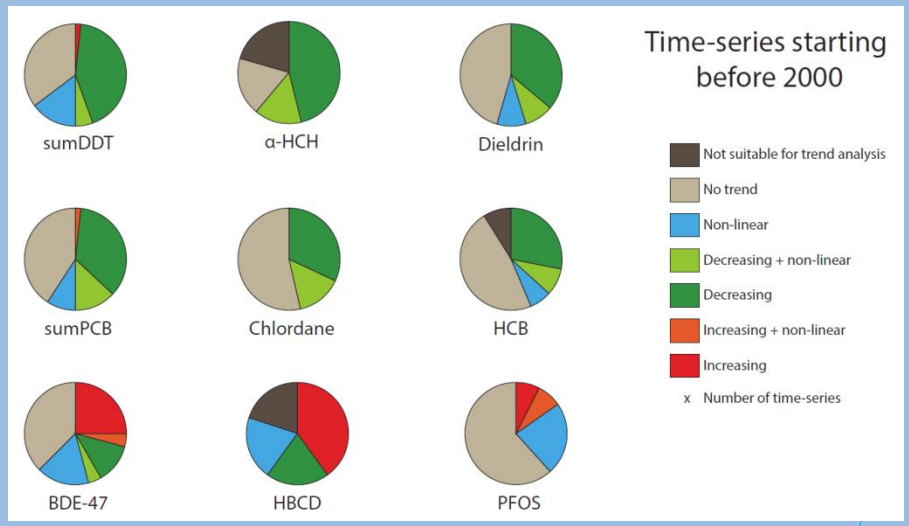
‘Traditional’ POPs consistently declining in Arctic air and biota

A more mixed picture for newer POPs

Arctic data are important in establishing, developing and implementing international agreements







http://www.amap.no

AMAP Arctic Monitoring and Assessment Programme

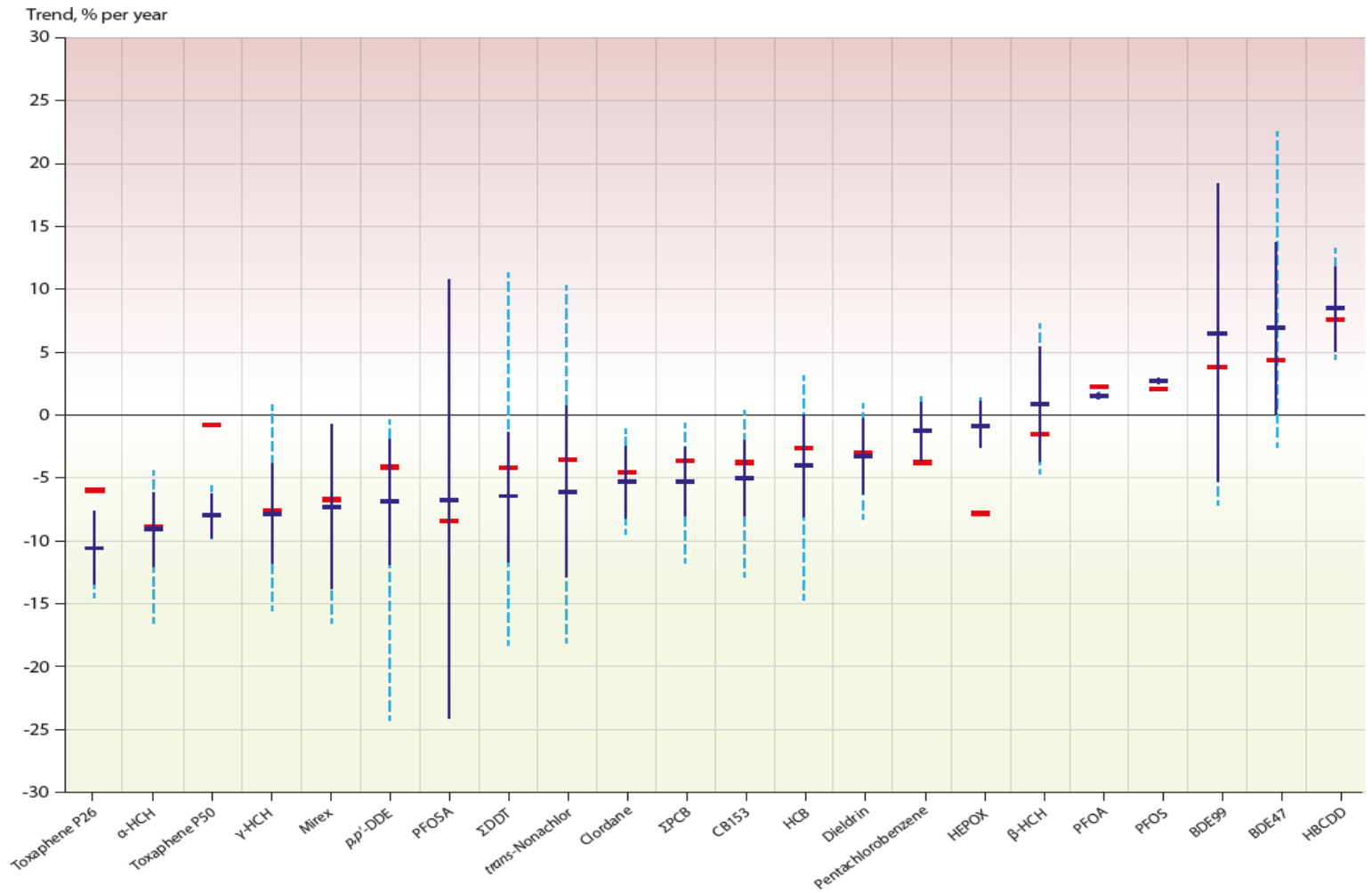


Figure 5.1 Summary of biota trends for different contaminants – results for time-series starting before 2000 where trend results were statistically significant and/or time-series were of 'adequate' power. The graphic shows the ranked mean ±SD (dark blue solid line), range (light blue dashed line); red marks indicate the mean for all runs.

Chemicals of Emerging Arctic Concern

- Per-polyfluorinated compounds (PFCAs, PFSAs, etc.)
- Brominated flame retardants (BDE-209, HBCD, DPTE, etc.)
- Chlorinated flame retardants (Dechlorane plus, Dechlorane 602, etc.)
- Organophosphate-based flame retardants and plasticisers (TnBP, TCEP, TCPP, TDCPP, etc.)
- Phthalates
- Short-chained chlorinated paraffins
- **Siloxanes**
- **Pharmaceuticals and personal care products**
- Polychlorinated naphthalenes
- Hexachlorobutadiene
- **Current used pesticides** (Dicofol, Pentachlorophenol/anisole, etc.)
- Mono-dibutyltins
- PACs (e.g. nitro-PAHs, hydroxyl-PAHs, alkyl-PAHs)
- PCB11 from smelting
- Halogenated natural products (naturally formed BDEs, OH-BDEs, MeO-BDEs, brominated dioxins etc.)
- **Microplastics**

Frantz Josef Land PCB and oil study, Graham-Bell Island, 2004

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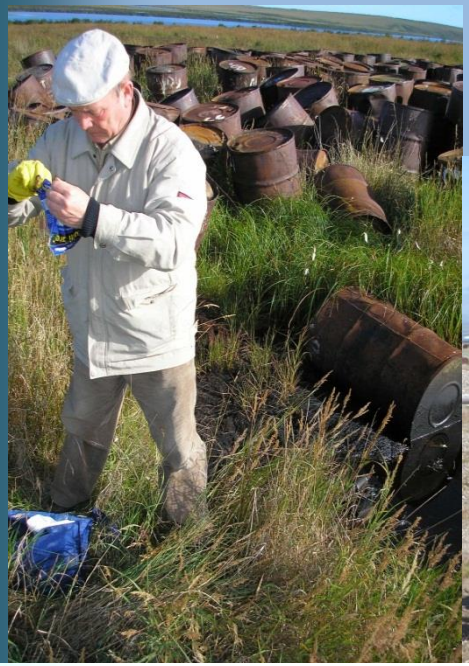
Cleanup Training!!!



Local incineration of PCB

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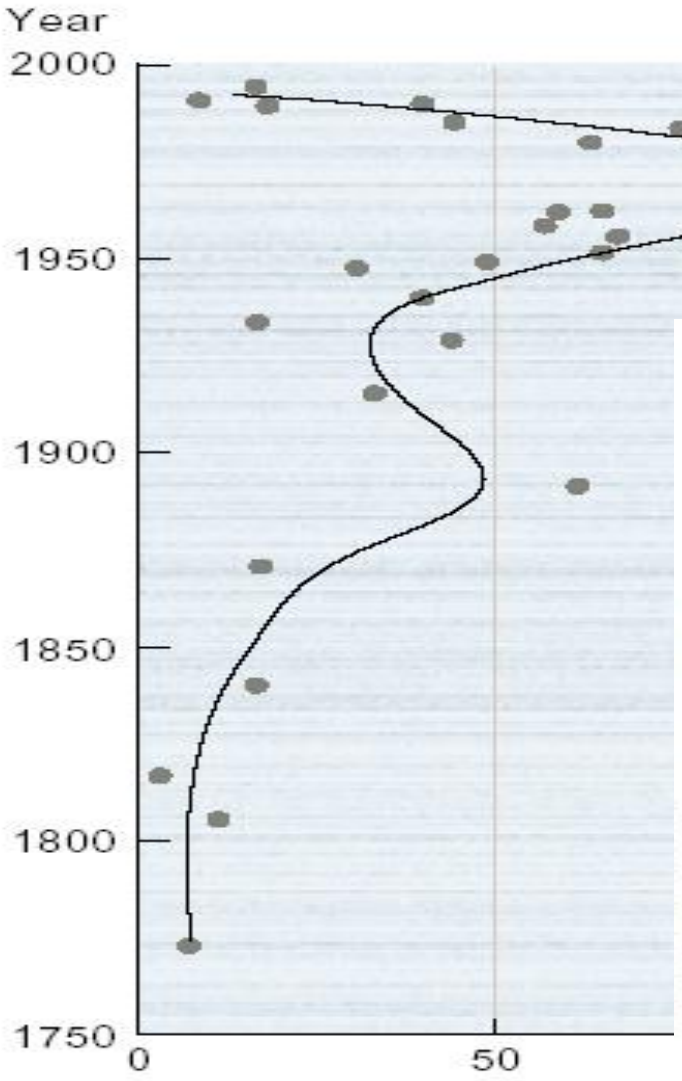
Heavy metals in Norilsk


Year
2000
1950
1900
1850
1800
1750
0
50
100
150
Lead concentration, pg/g

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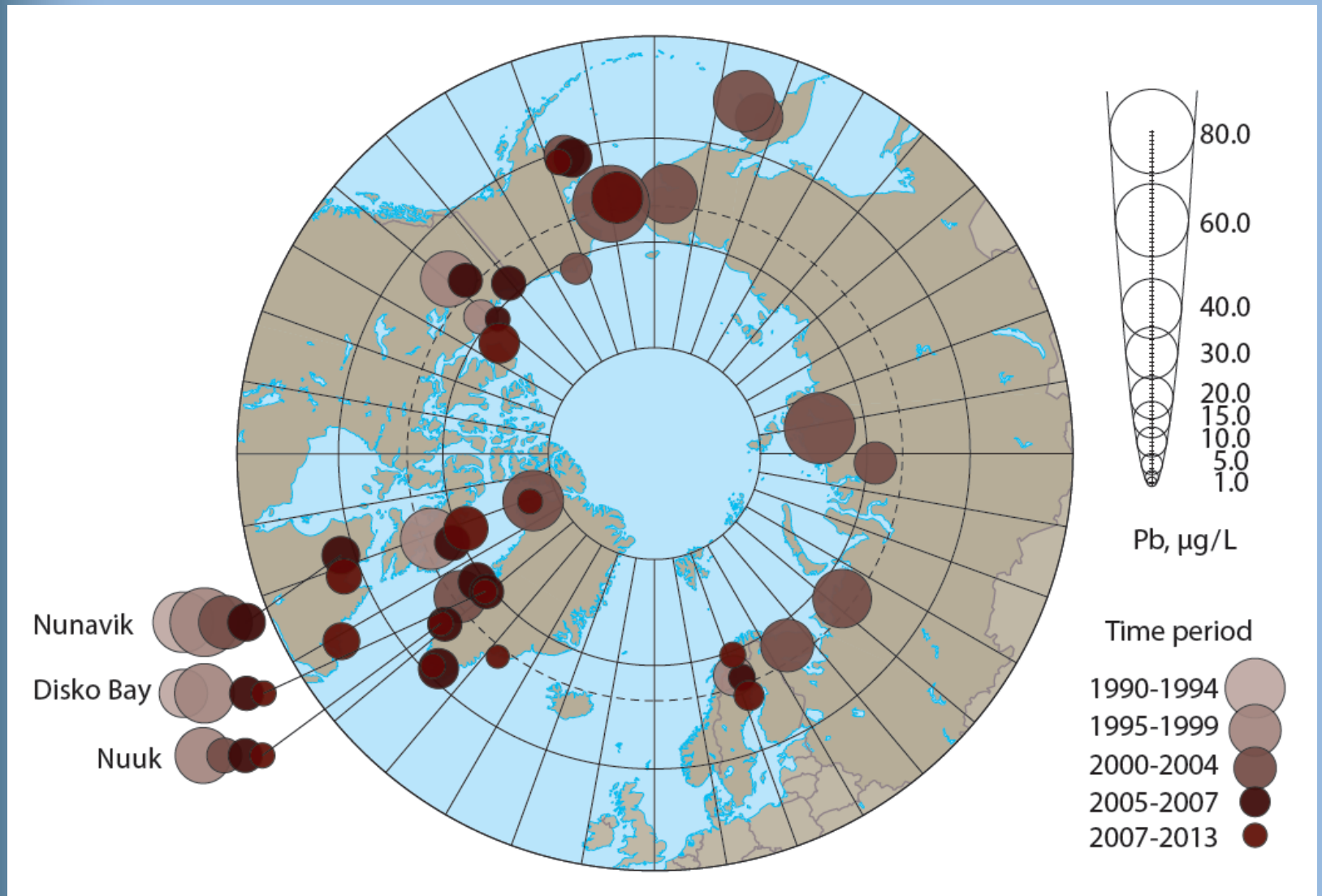
International comparisons – Pb



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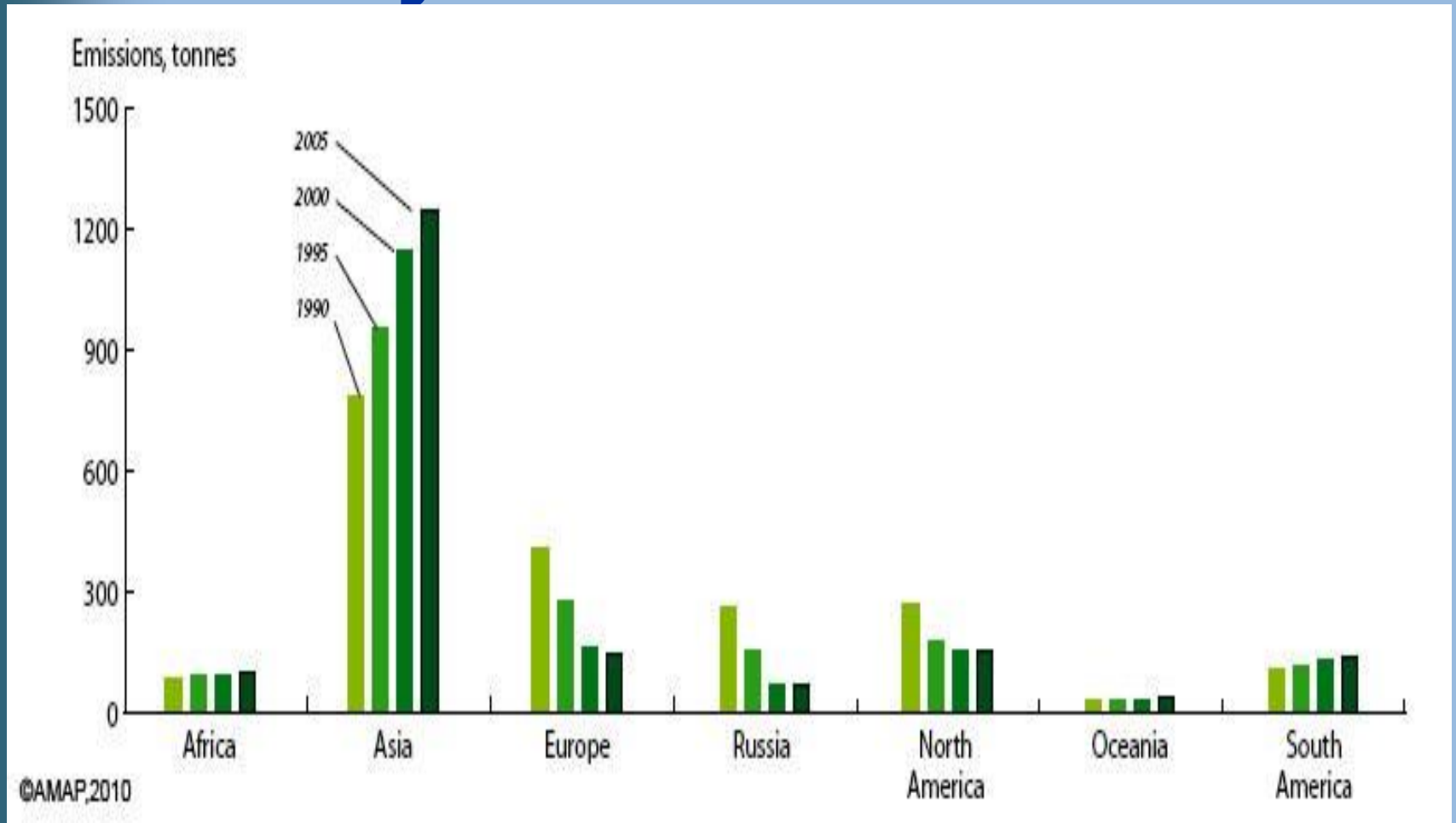
Global emissions of mercury 1990 – 2005 (AMAP 2011)



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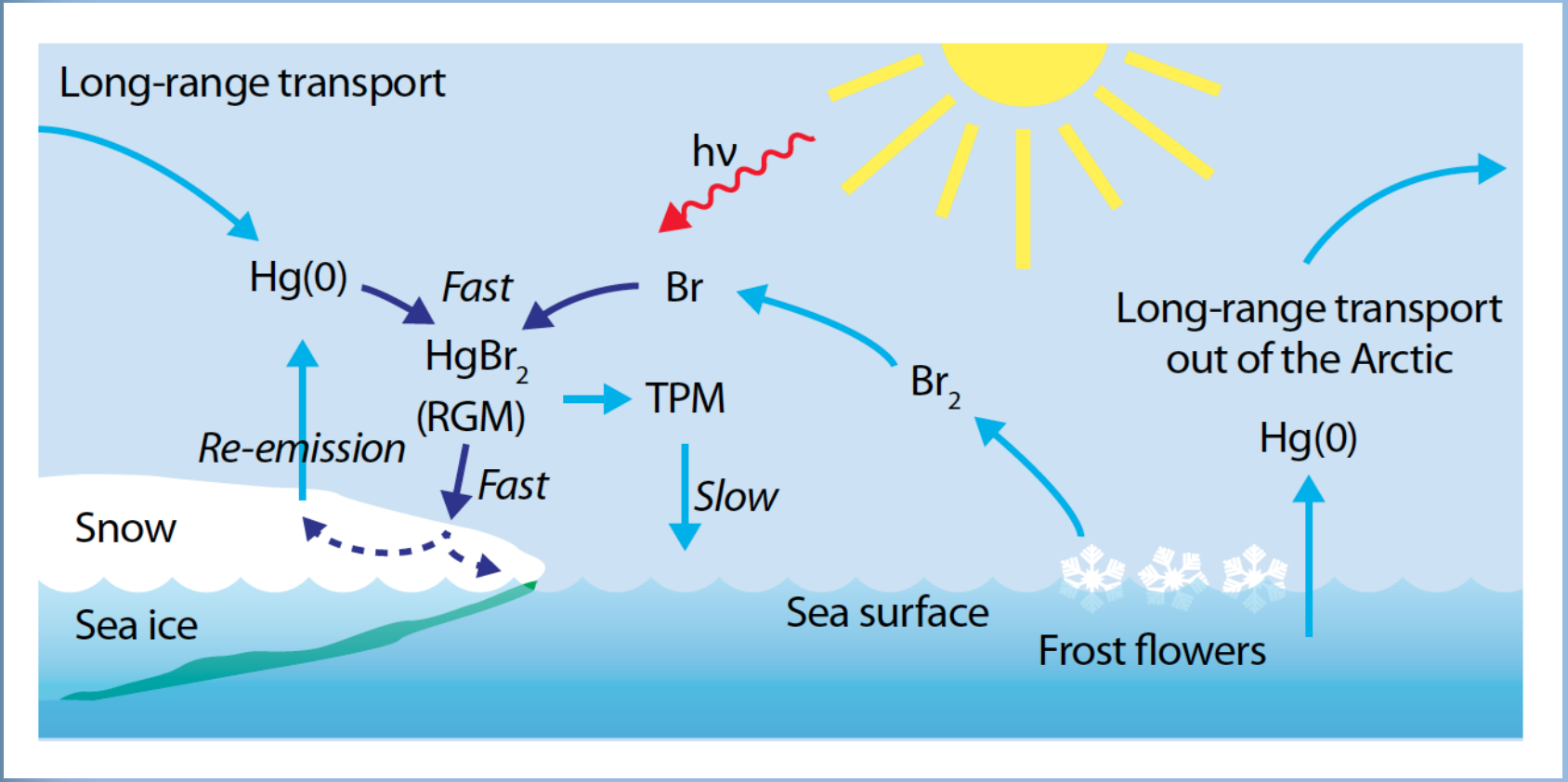
Mercury cycle in the Arctic



Combined effects, climate and Contaminants, AMAP 2012.

Mercury trends

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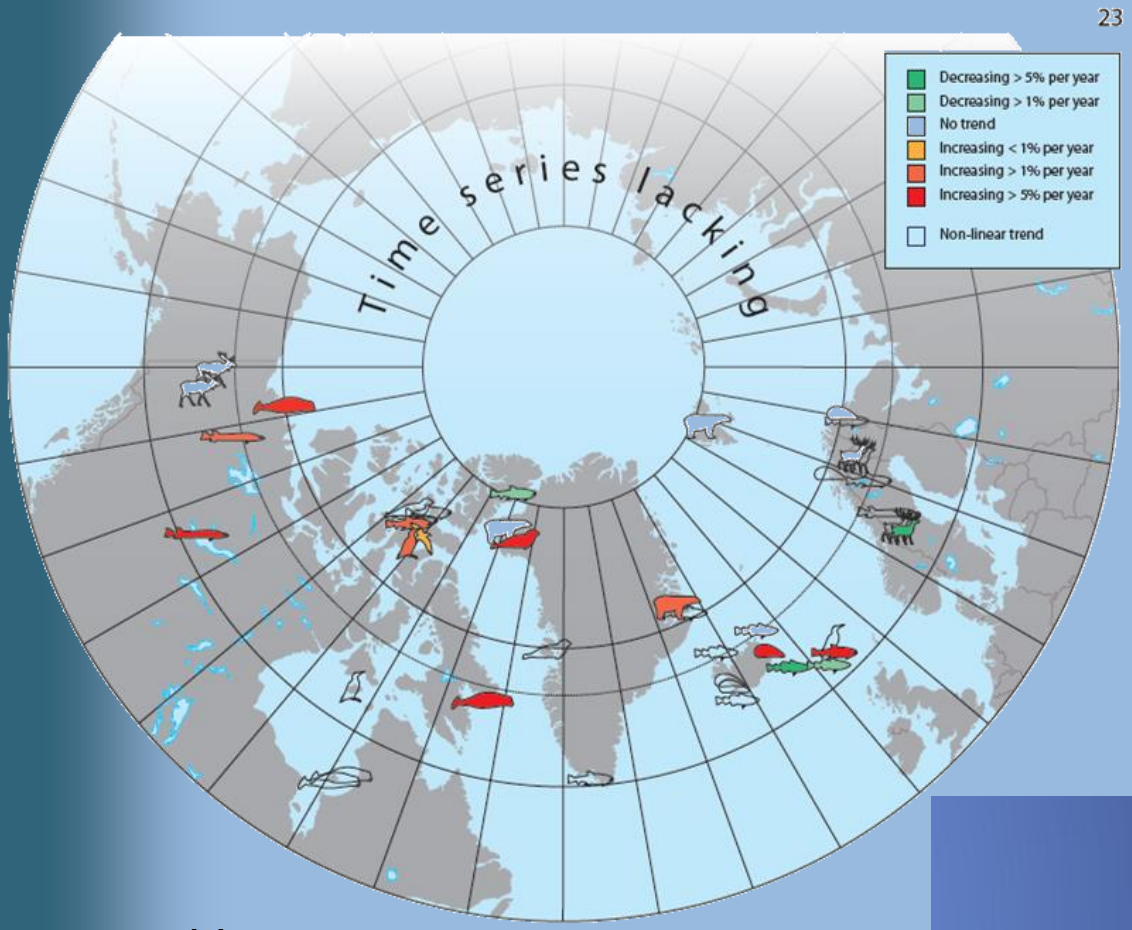

Braune et al. in press

Of the 83 recent time series (past few decades; >6 years of data)

13 (16%) significant increasing

4 (5%) significant downward

21 (25%) significant non-linear

45 (54%) no significant trend

<u>EXPLANATION – mixed pollution and climate signals</u>

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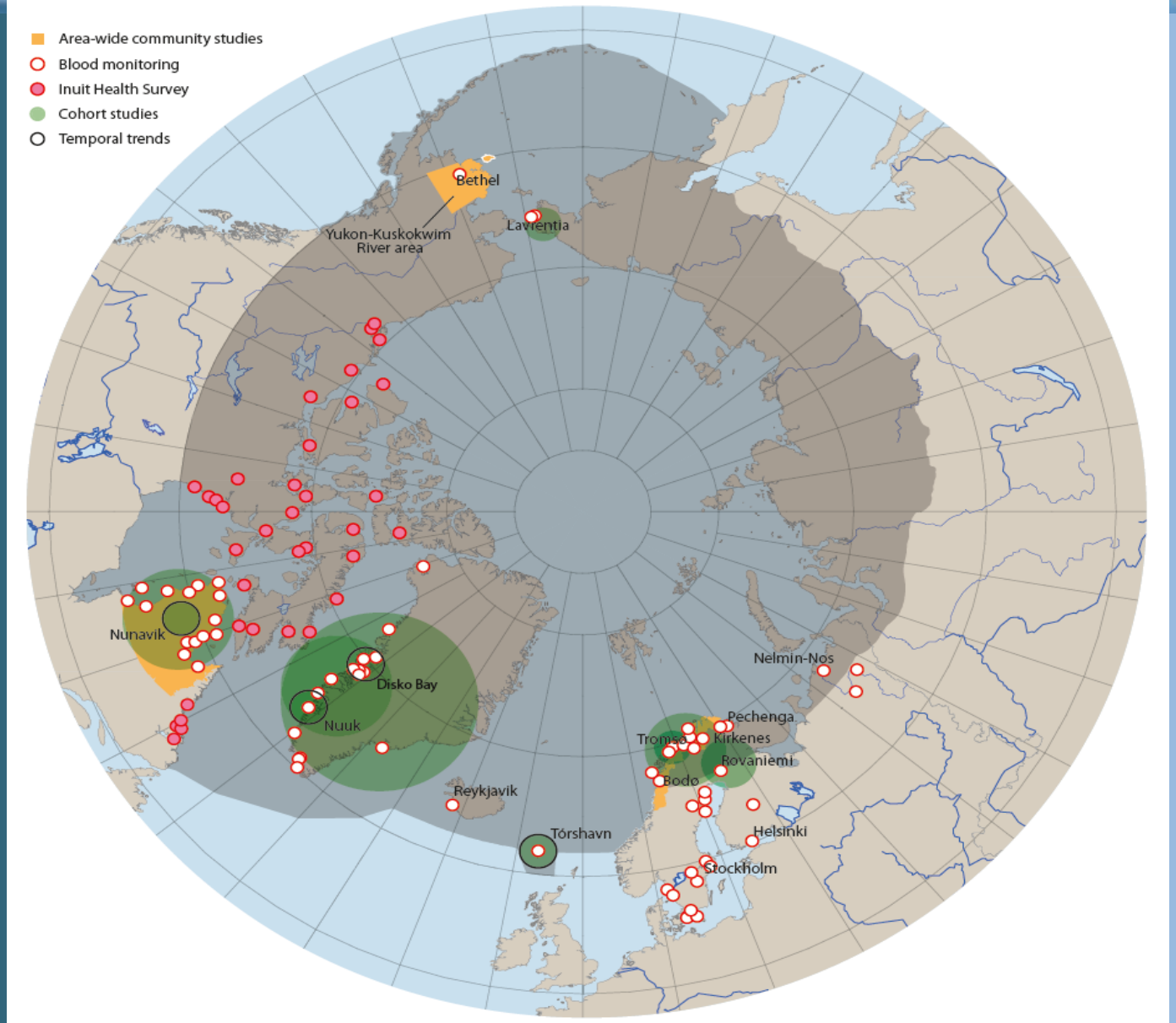

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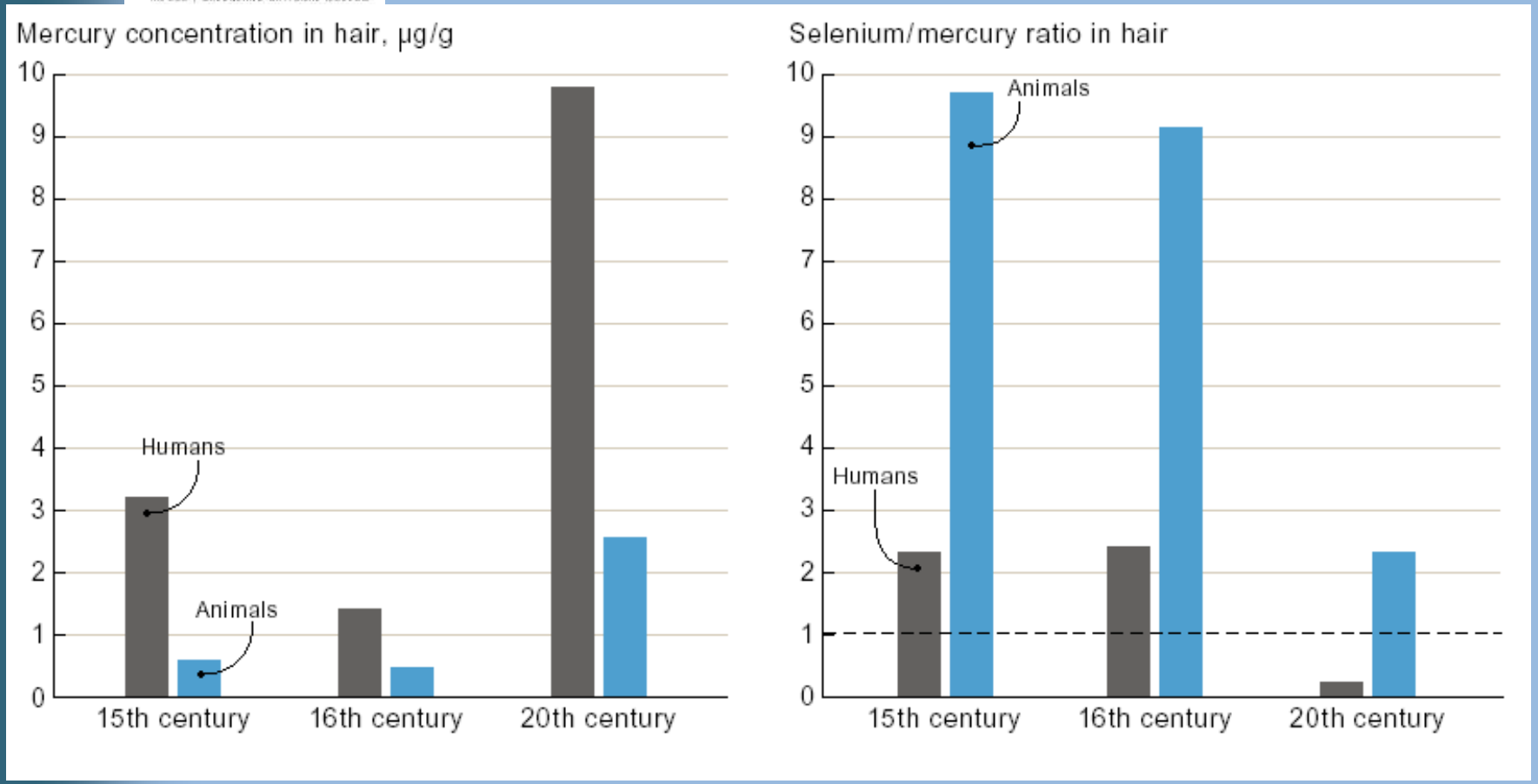
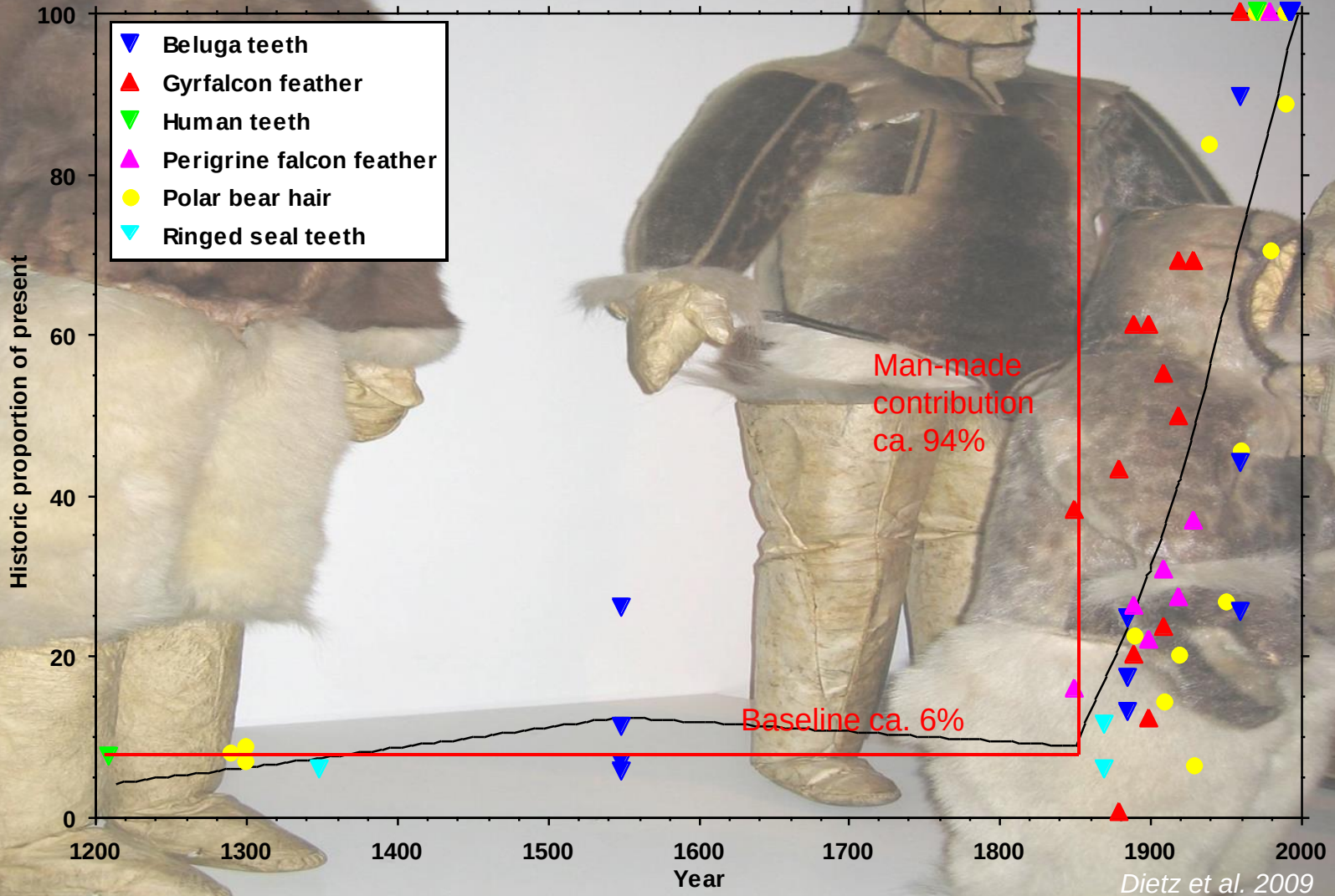
Time Trends, Mercury and Selenium in Hair from Humans and Seals in Greenland

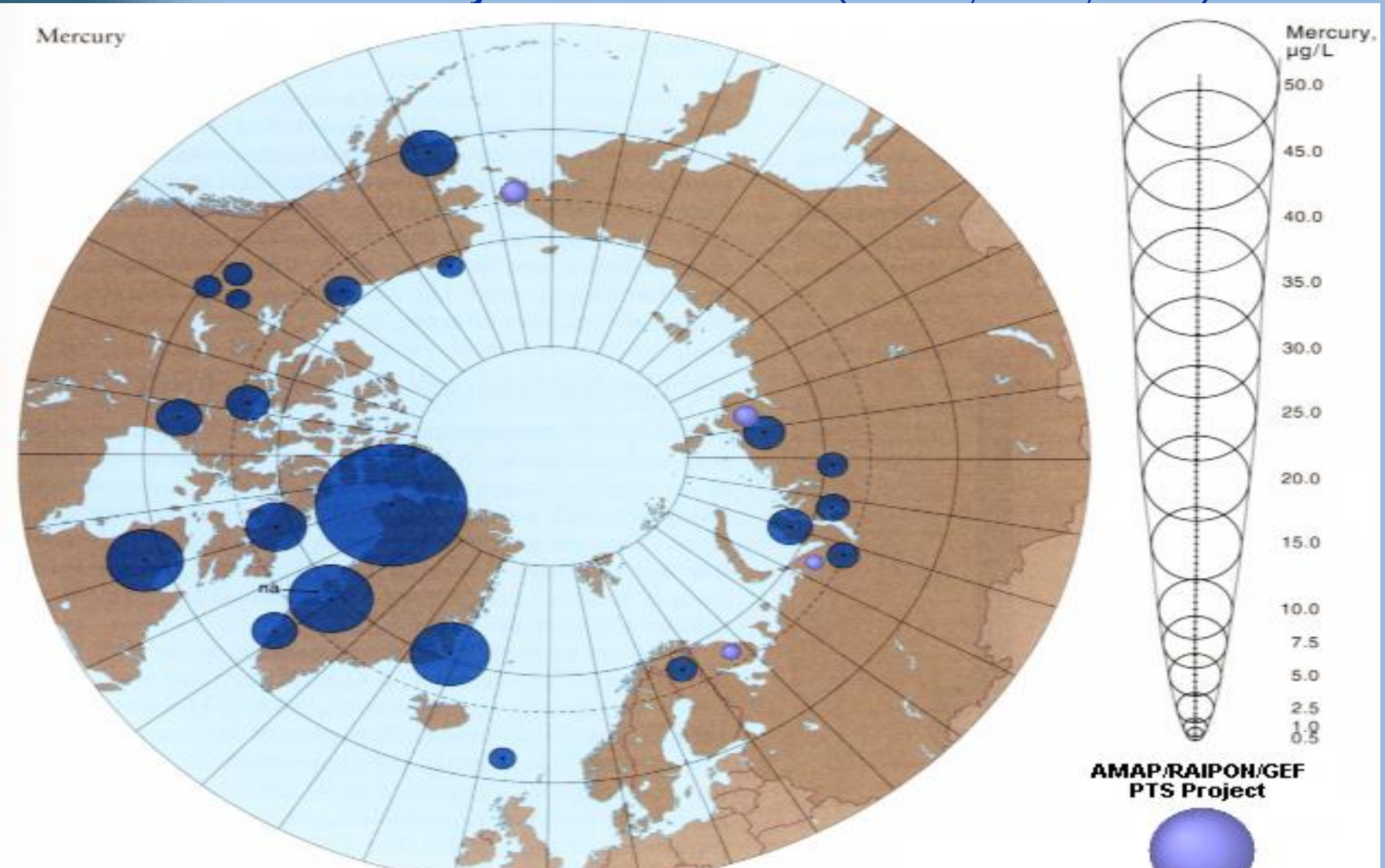


Historic Hg time-series in Arctic wildlife and humans



Dietz et al. 2009

Mercury in maternal blood (AMAP, 2003, 2004)



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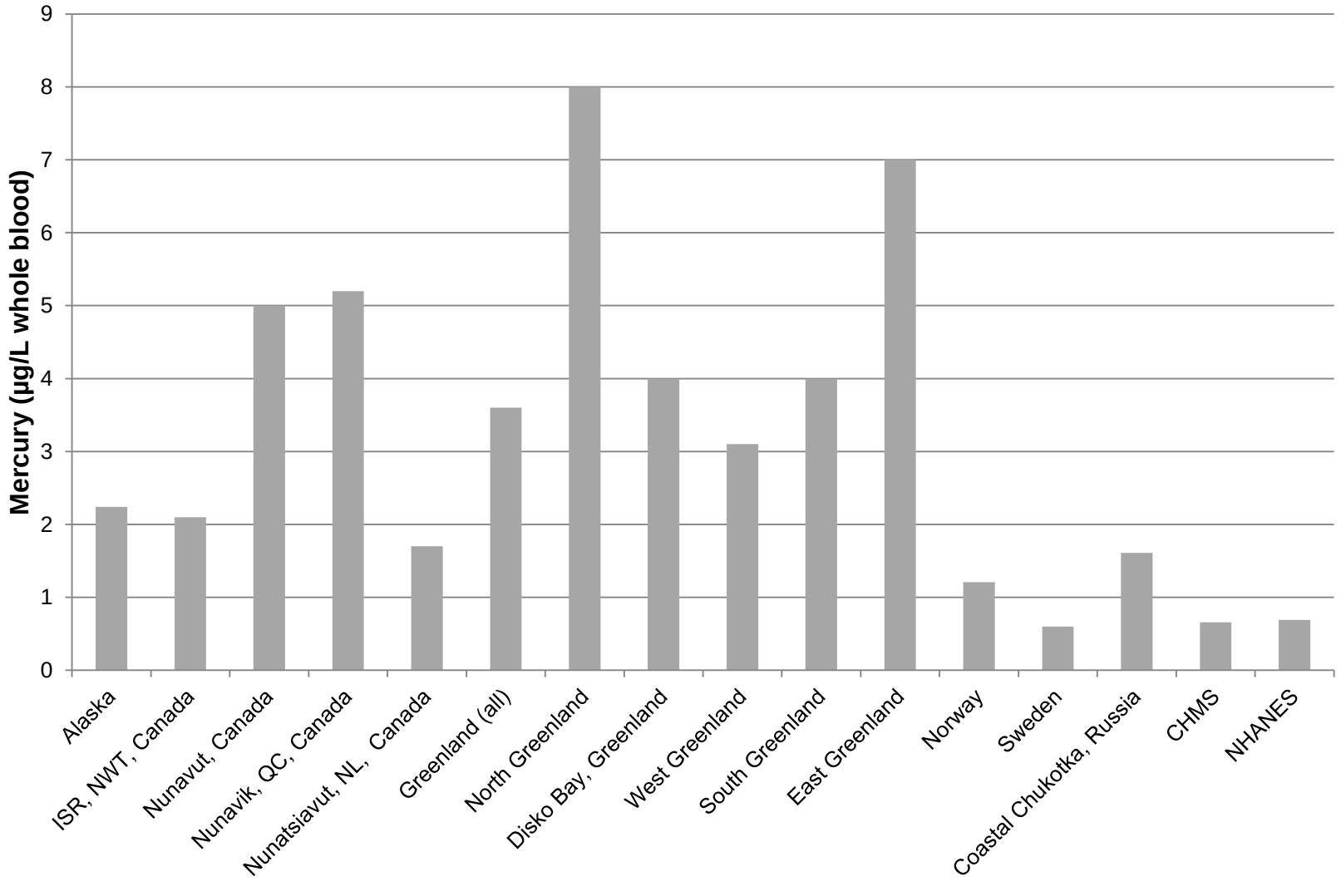
International comparisons – Human blood Hg (AMAP 2015)



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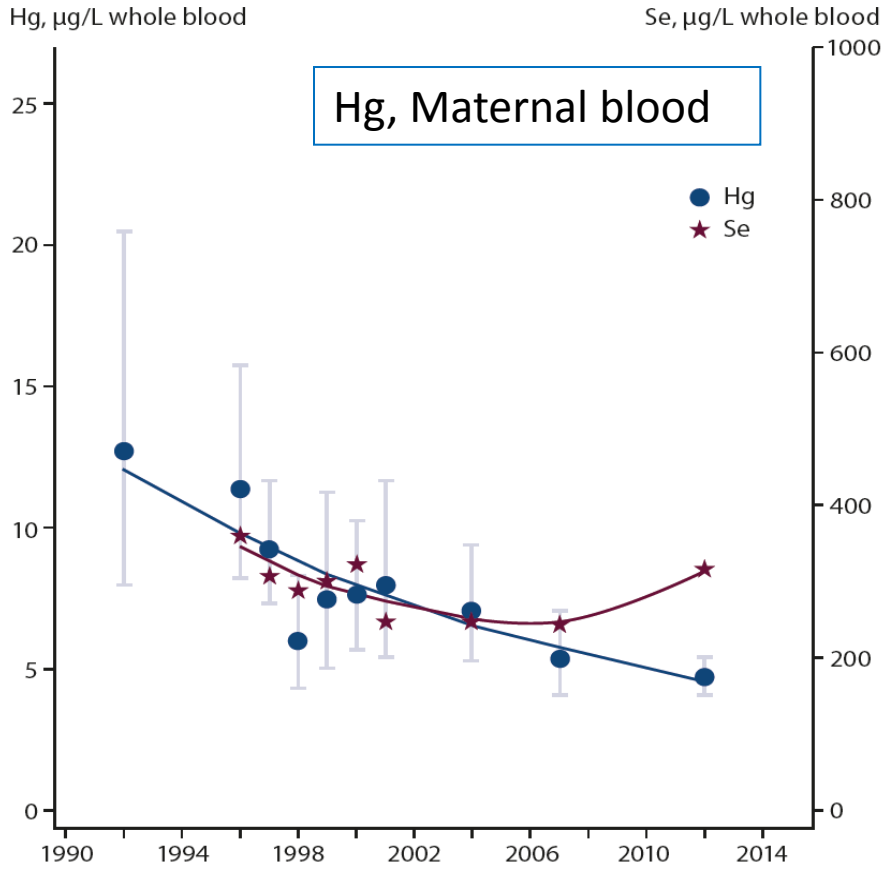
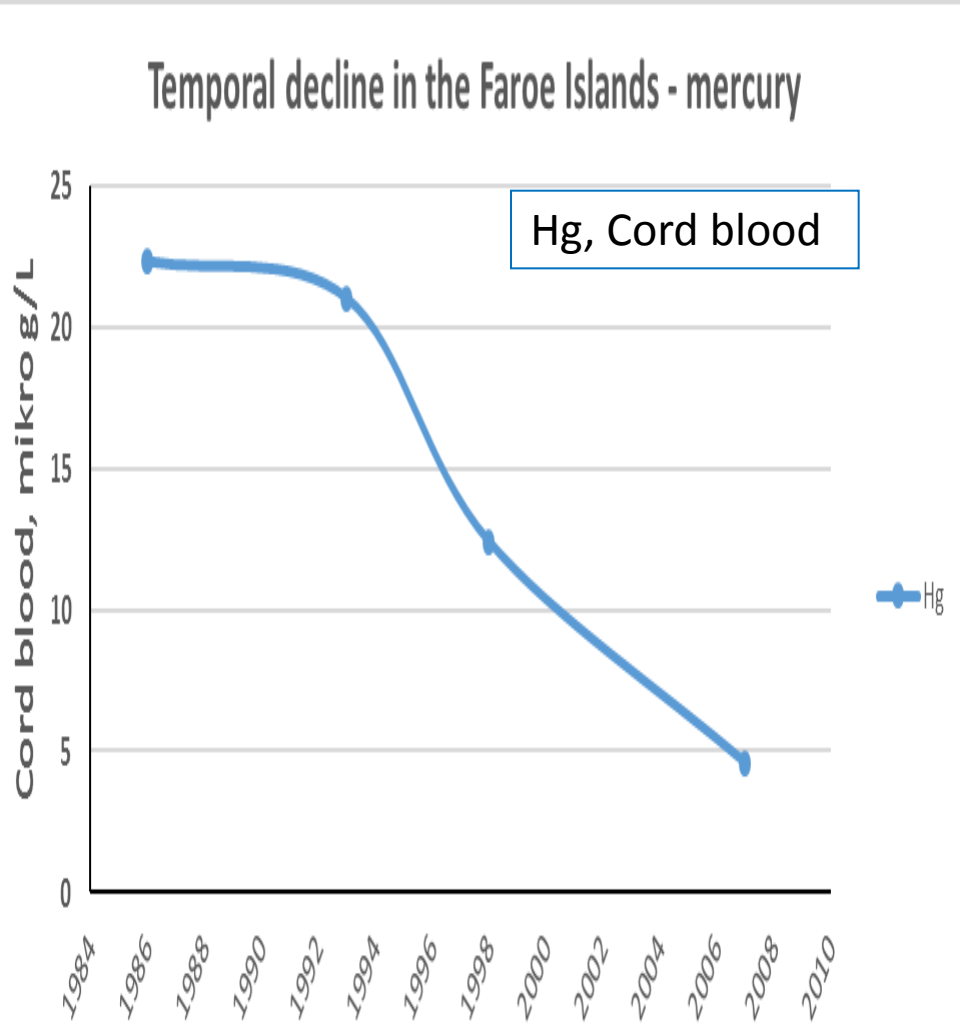


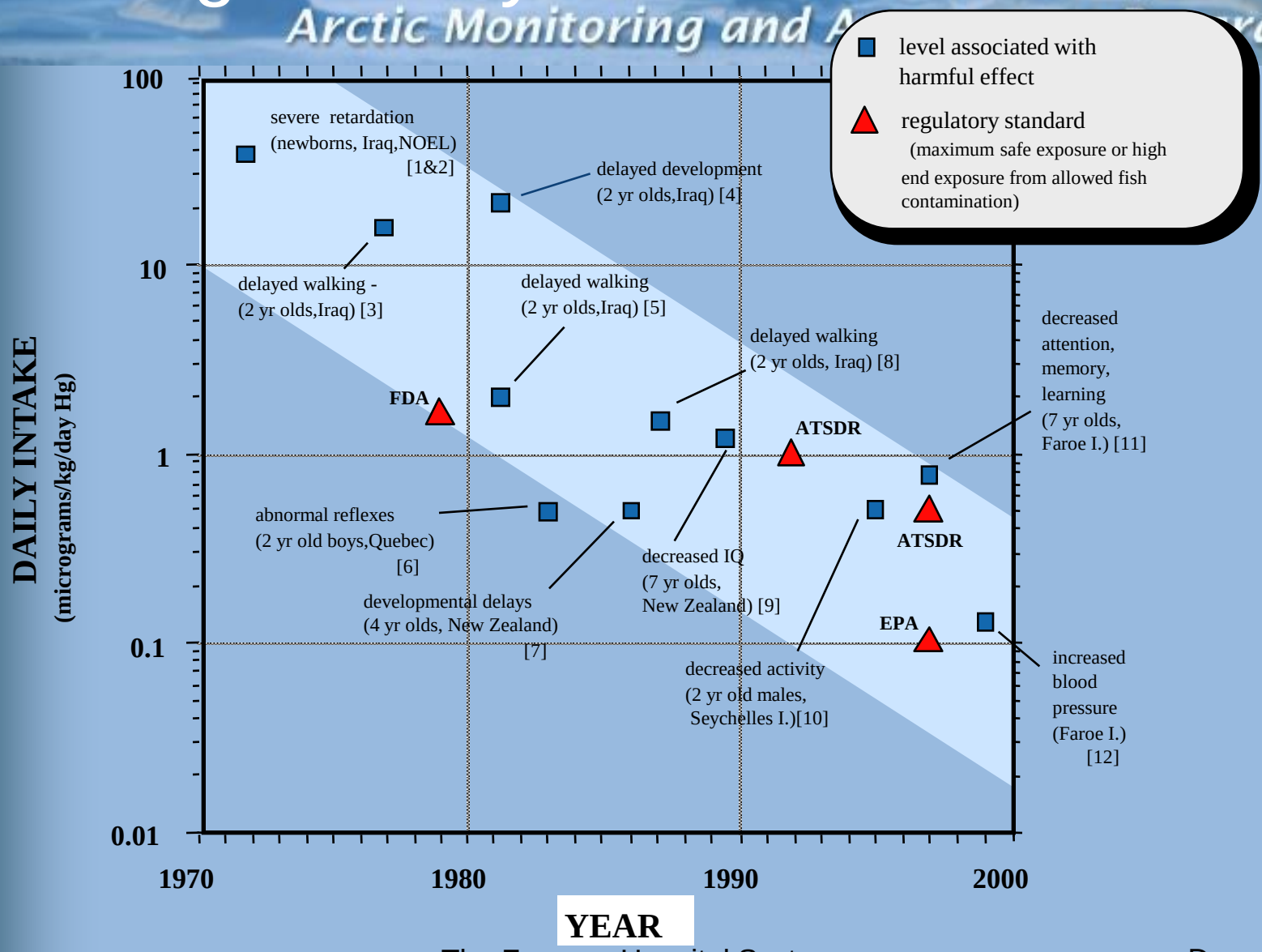


Nunavik, Northern Quebec – biomonitoring since early 1990s

Conclusions from studies on MeHg

- Neurobehavioral effects most clearly on attention, memory and language, but also visuospatial and motor functions
- Cardiovascular effects, increased blood pressure
- Prenatal generally more toxic than early postnatal exposure
- Preliminary results from age 7,14 & 22 years suggest that effects are permanent
- Food advice has reduced intake and levels
- No evidence that Se was a significant protective factor against MeHg neurotoxicity

Declining mercury threshold



CCGS AMUNDSEN

CANADIAN RESEARCH ICEBREAKER

www.amundsen.quebec-ocean.ulaval.ca

The CCGS *Amundsen*: a Canadian research icebreaker for international collaboration in the study of the changing Arctic

Canada Foundation for Innovation
Fondation canadienne pour l'innovation

Pêches et Océans Canada
Fisheries and Oceans Canada
Garde côtière
Coast Guard

UNIVERSITÉ LAVAL

Canada

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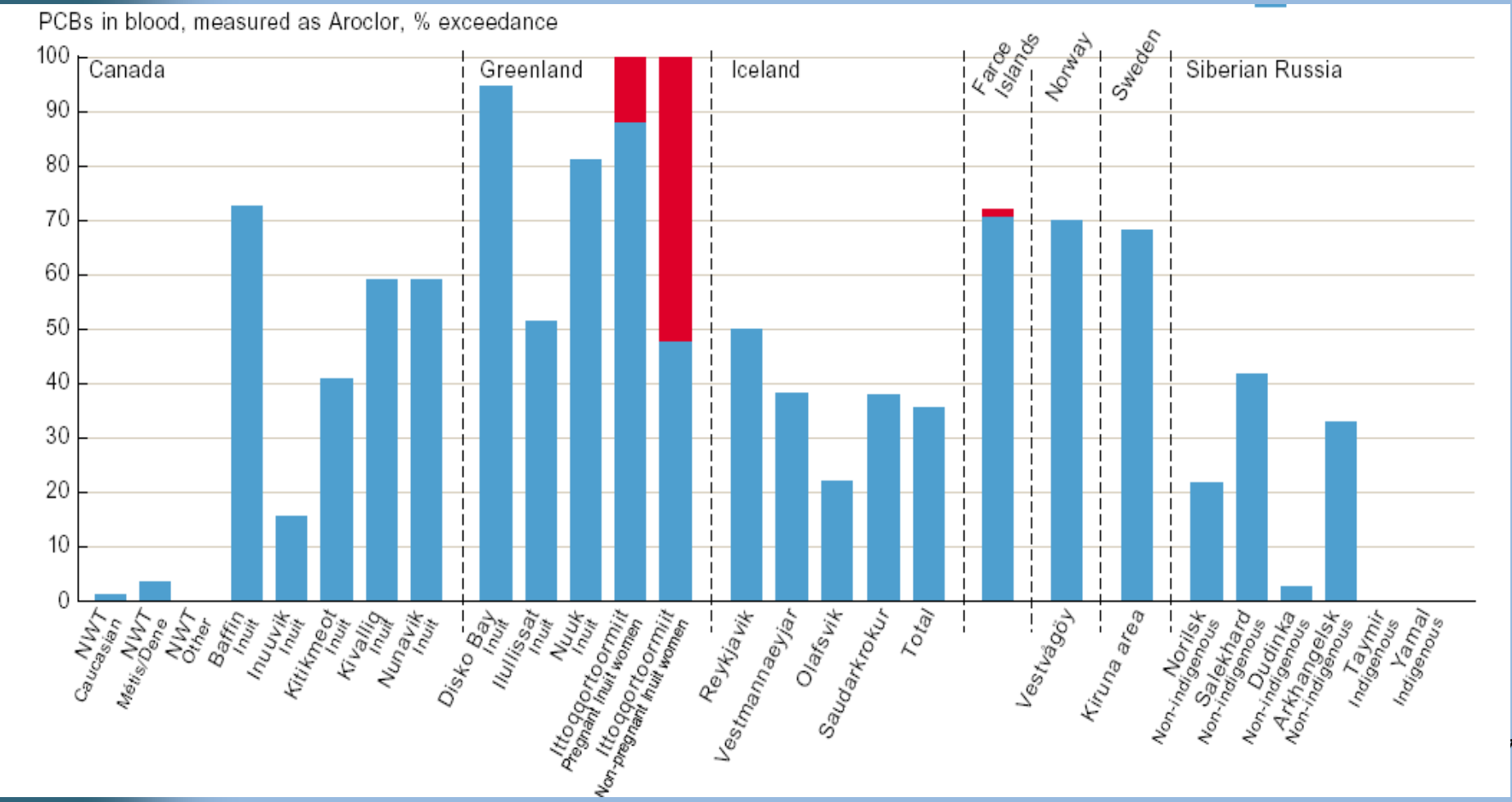
AMAP Human health POPs Methodology

- **Participation in a QA/QC program is encouraged**
  - E.g., the AMAP Ring Test – 37 analyzes (11 pesticides, 8 PBDEs, 9 PCBs, 6 PFCs, total lipids, cholesterol and triglycerides).
- **Sampled populations include**
  - Mothers and children, women of childbearing age, and women and men of all ages.
- **Data are presented as geometric means**
  - POPS, OCs and PBDEs reported as lipid weight;
  - PFCs reported in wet weight;
  - Metals reported in whole blood.

PCB in Human Blood



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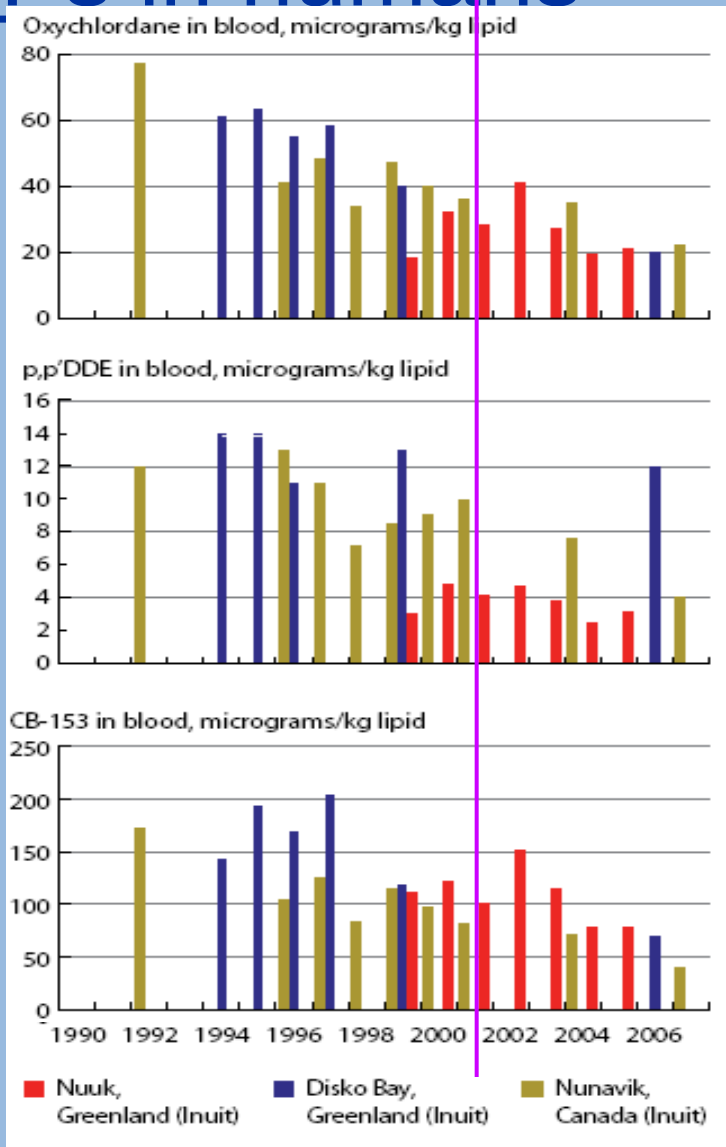
Time trends of Legacy POPs in humans

Limited data on temporal trends

Different reasons for decreases:

- Changes in diet (traditional to store-bought foods)
- Health advice to critical groups
- Lower levels of contaminations
- Need to understand reasons



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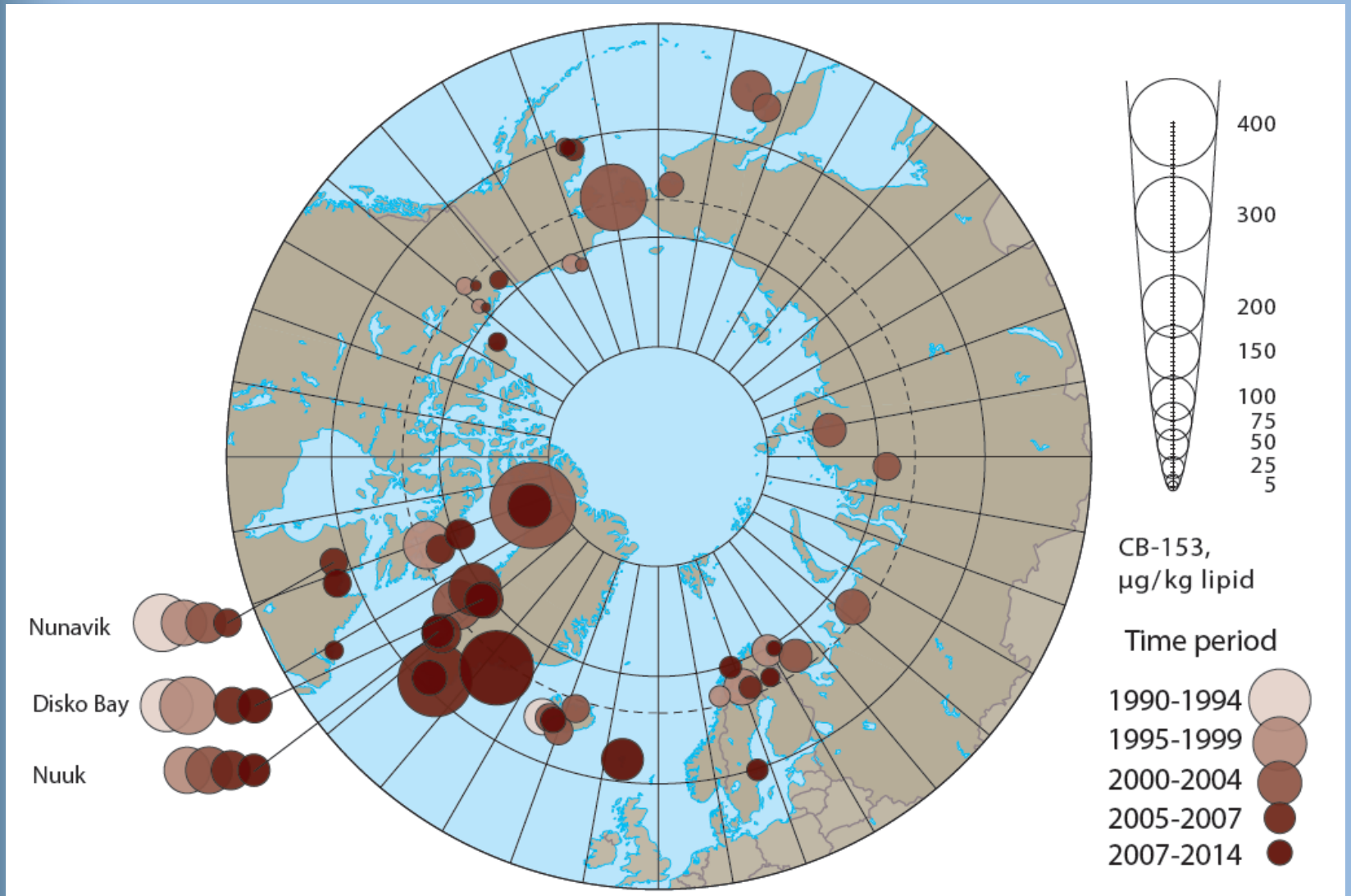
Arctic comparisons – PCB153



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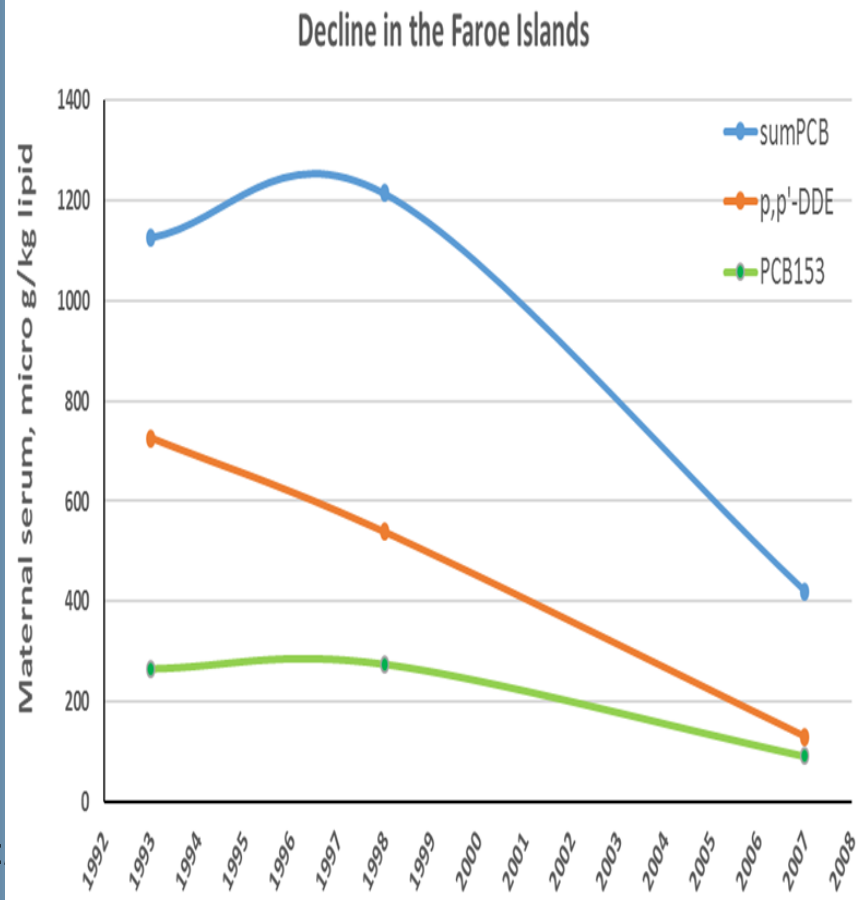
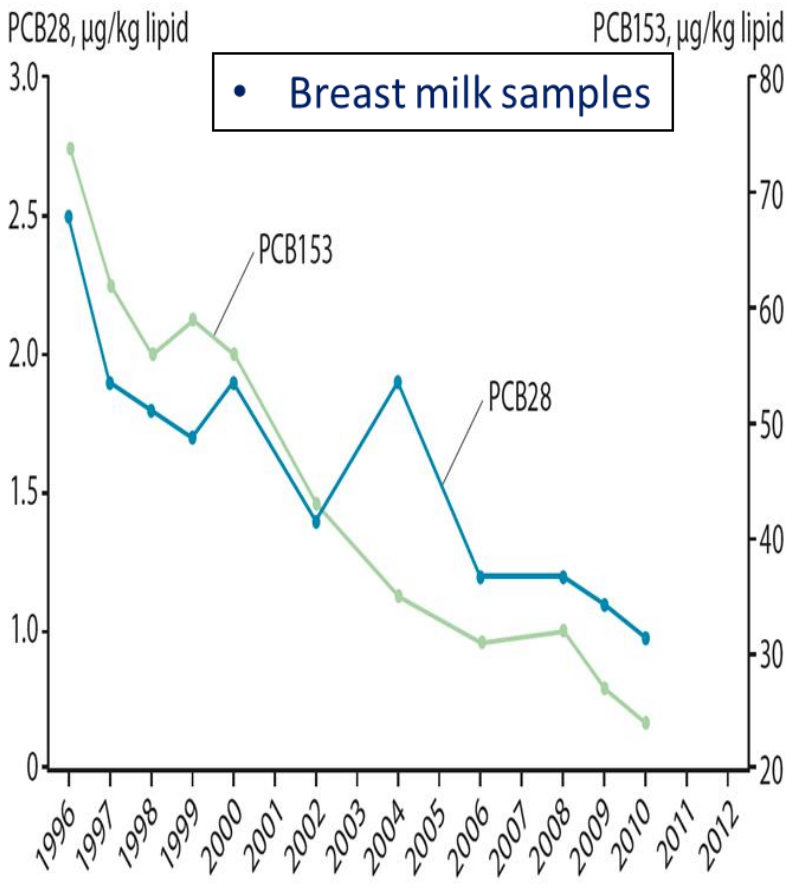
POPs in mothers





http:

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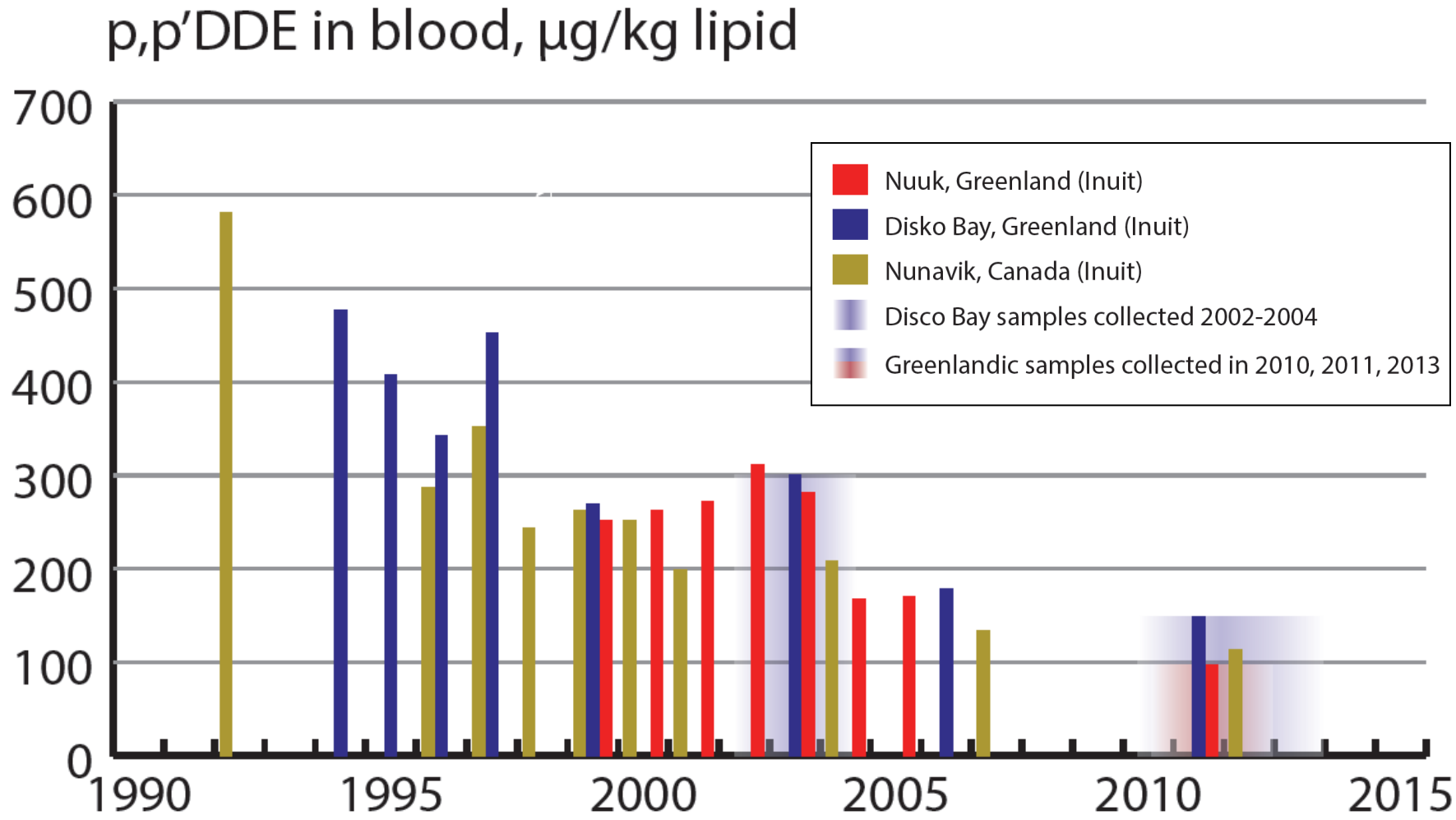
Trends – Greenland and Nunavik (*p,p'*-DDE)



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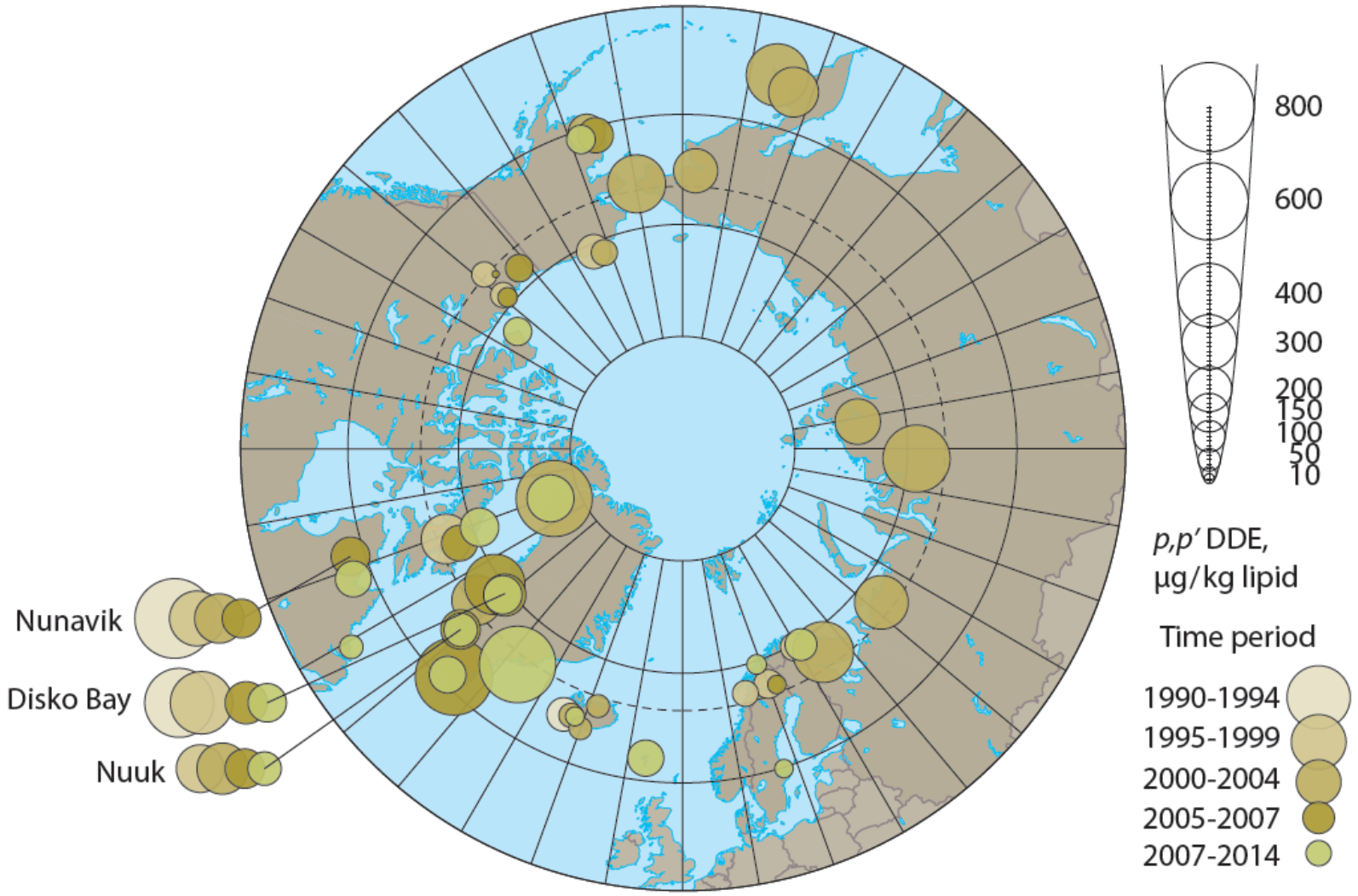
Arctic comparisons – *p,p'*-DDE



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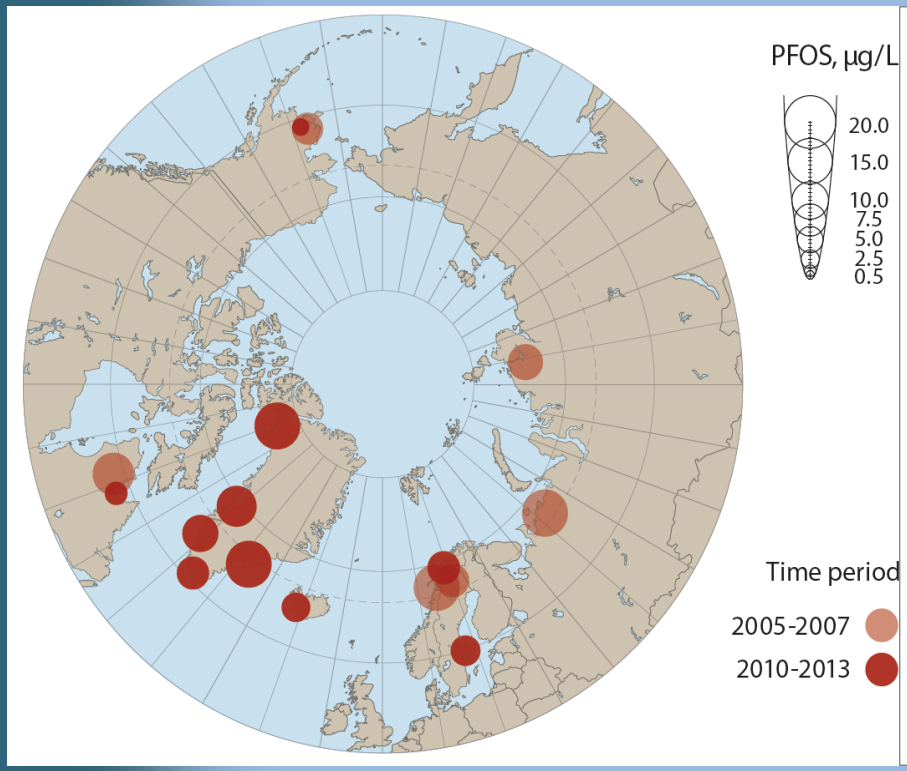
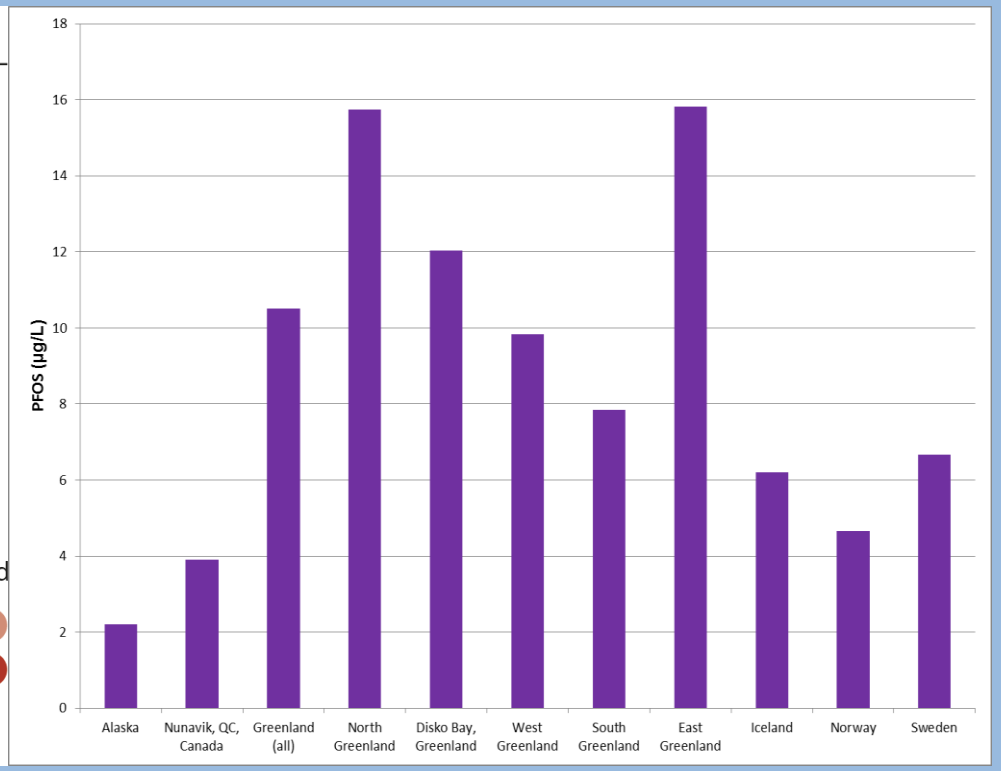
PFOS, International comparisons





Maternal blood

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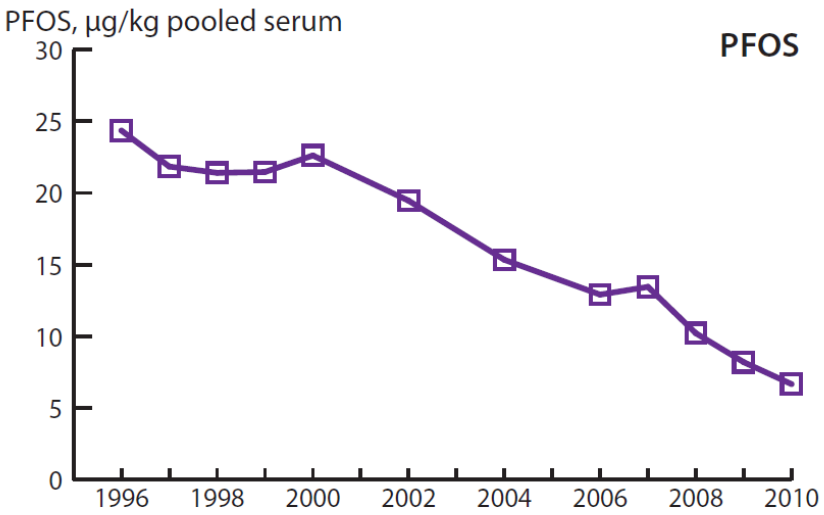
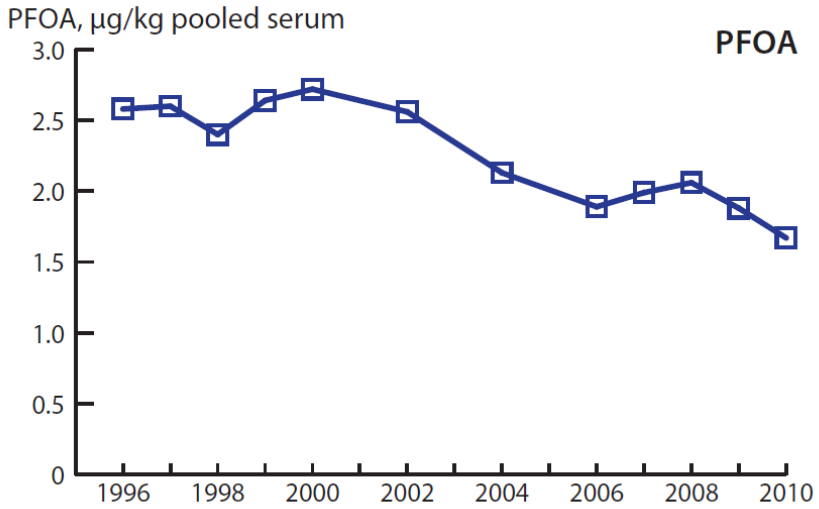
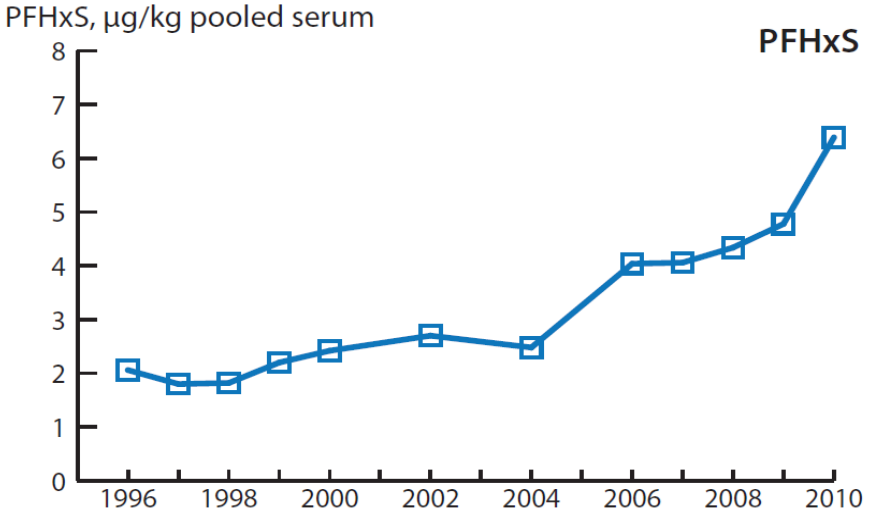
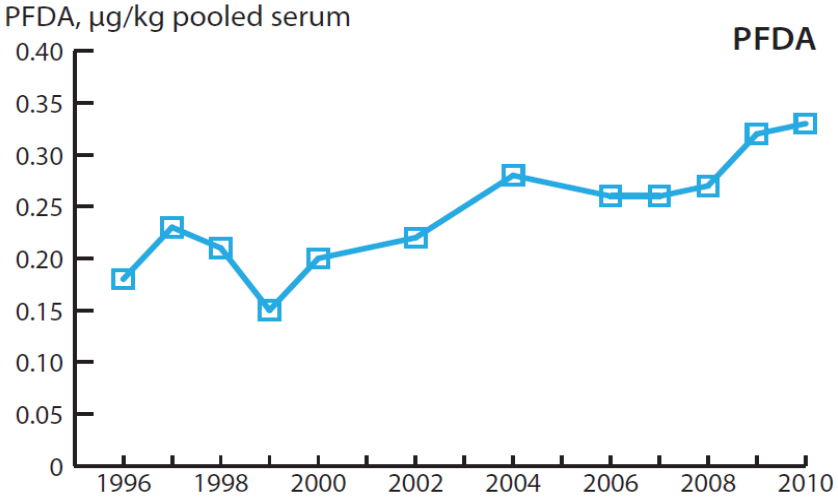
Trends – Sweden (PFCs)(AMAP 2015)

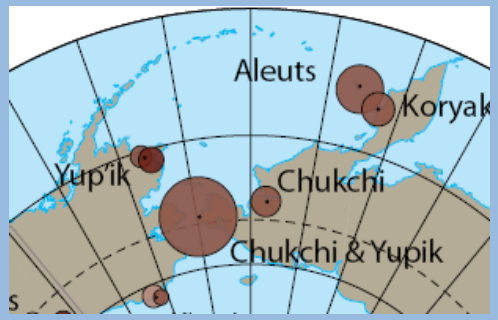


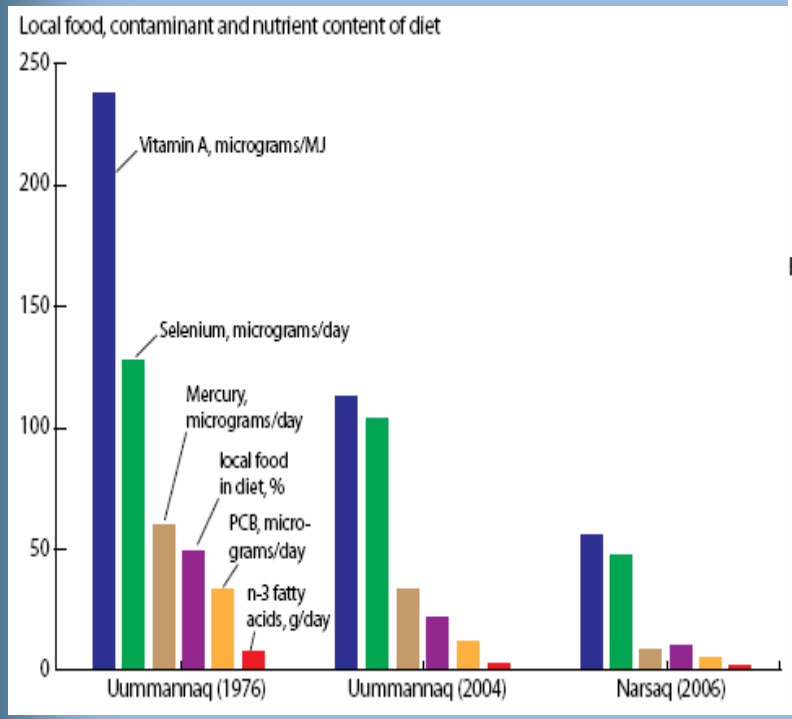


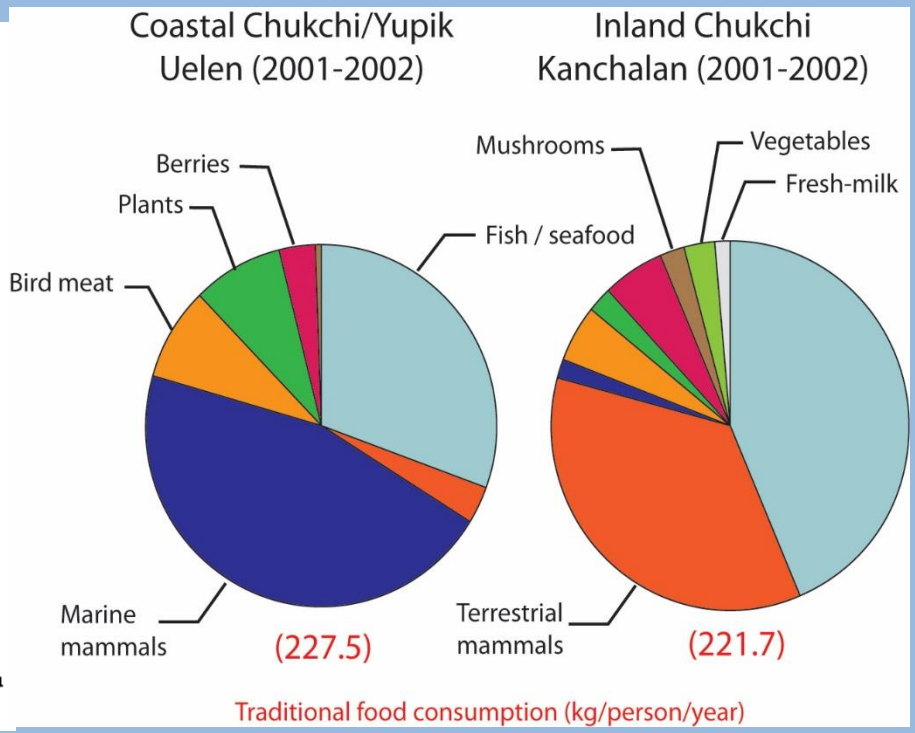




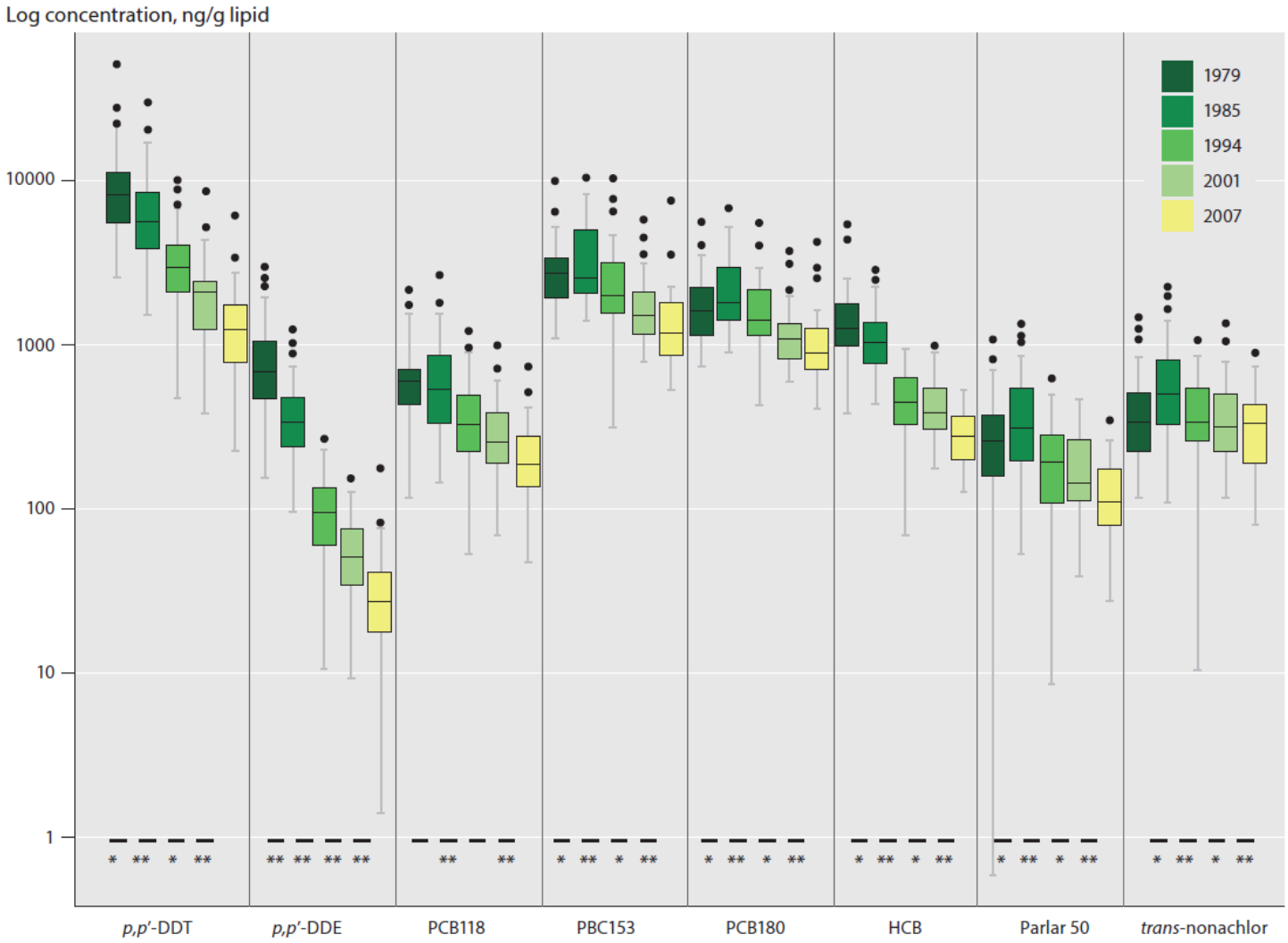
Exposure via dietary intake







Trends – Norway (POPs)



Conclusions

- Levels of **legacy POPs and toxic metals are decreasing**
- **Northern populations** have elevated levels compared to those in the south
- **Risk communication** is important (social, economical and cultural factors)
- **Populations** in the eastern Arctic of Canada and in Greenland are experiencing high body burdens of contaminants.
- Current **blood levels of mercury** in Nunavik and Nunavut are higher than levels found in the general Canadian population.
- **Monitoring data is missing** in main parts of Russia
- Monitoring of **new contaminants, effects of climate change**
- Continue analytical programs, external **QA/QC is critical**

Geometric mean concentrations of PTS in maternal blood by gender of newborns

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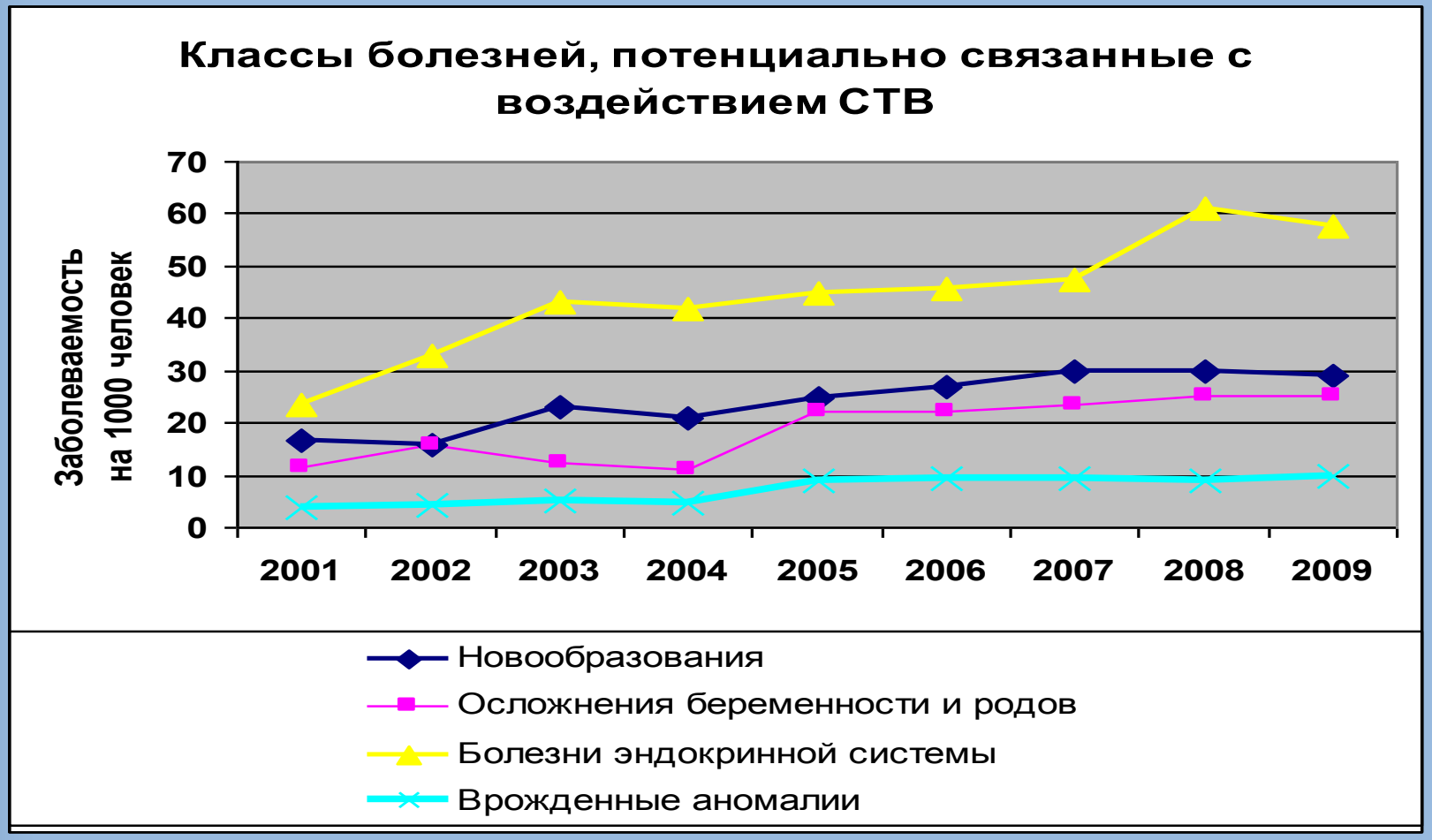
Contaminants	Blood concentrations in maternal blood	
	Boys	Girls
Total PCBs, ng/g	391± 61	471 ± 79
Aroclor 1260, ng/g	872± 142	1089 ± 230
Sum of HCHs, ng/g	279 ± 74	413 ± 66
Sum of Clordanes,ng/g	48 ± 27	78 ± 18
Sum of DDTs, ng/g	618 ± 51	773 ± 92
HCB, ng/g	160 ± 49	187 ± 41
Sum of Tox, ng/g	18 ± 7	22 ± 8
Cd, µg/L	0,9 ± 0.1	1,0 ± 0.2
Pb, µg/L	45 ± 7	50 ± 11
Total Hg, µg/L	1,9 ± 0.4	2,2 ± 0.3

Trend in prevalence of diseases potentially associated with the PCB exposure in a cohort of Chukotka (- diabetes)



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Temporal Trends in Human Exposure to POPs (as measured for serum concentrations, µg/L).

Cohort of Indigenous Adult Males of Arctic Russia

Epidemiology in the Arctic needed to focus on key contaminants and target organs

- Brain: Highly vulnerable during prenatal development, and even minor damage is permanent and affects education and income
- Immune system: Mainly vulnerable early postnatally, possibly involved in causation of multiple diseases
- Endocrine system: Highly relevant due to epidemics of obesity and diabetes

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Focus areas of health and well-being

New diseases (e.g. Infections, animal-transmitted diseases; obesity and diabetes)

Marginalisation, violence, alcohol, suicides

Birth rates, causes of death, still low expectancy of life (especially in men)

More holistic view: health, social work & well-being

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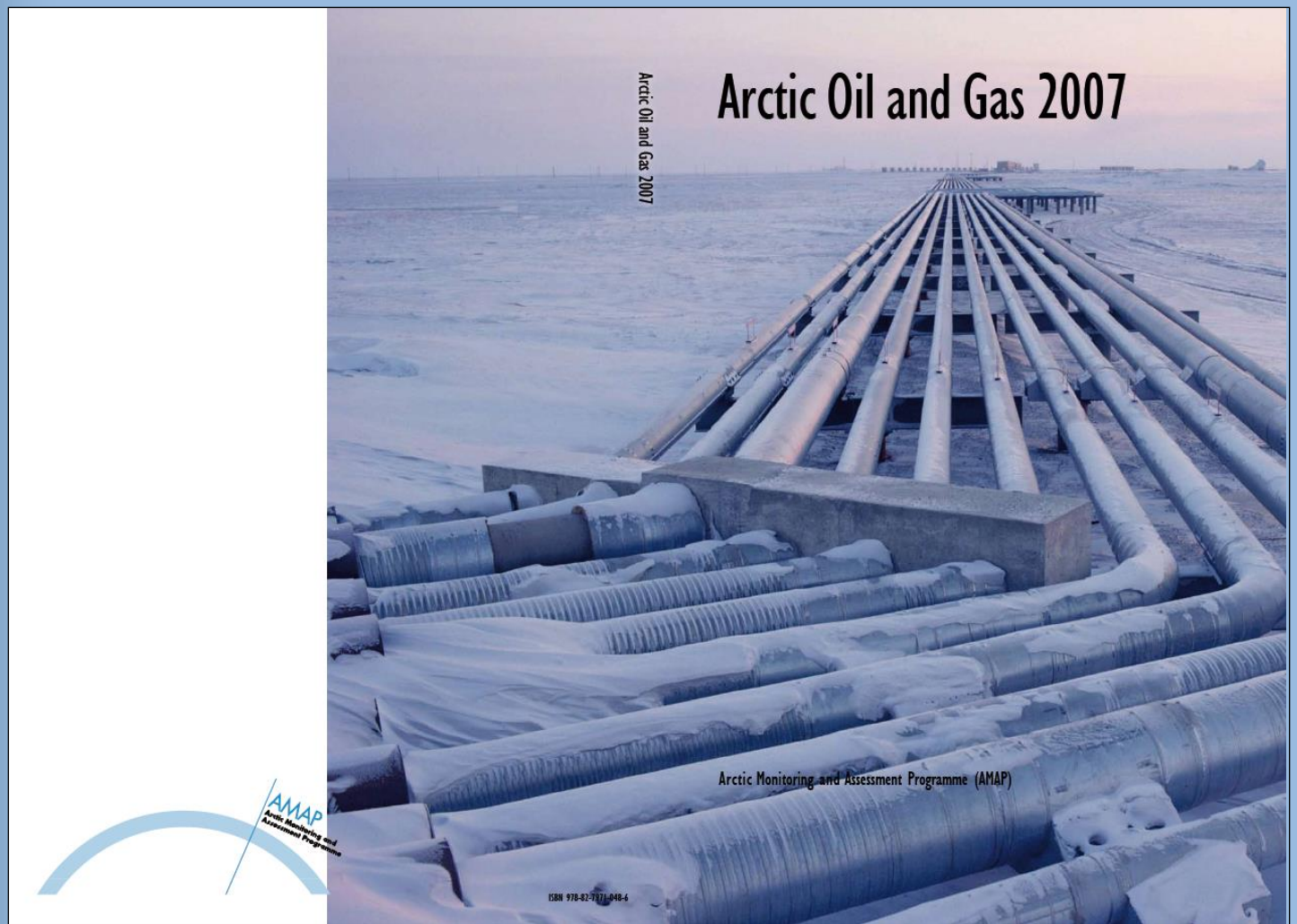
Arctic Oil and Gas 2007

Results of the 2007 Assessment of

Oil and Gas Activities in the Arctic: Effects and Potential Effects



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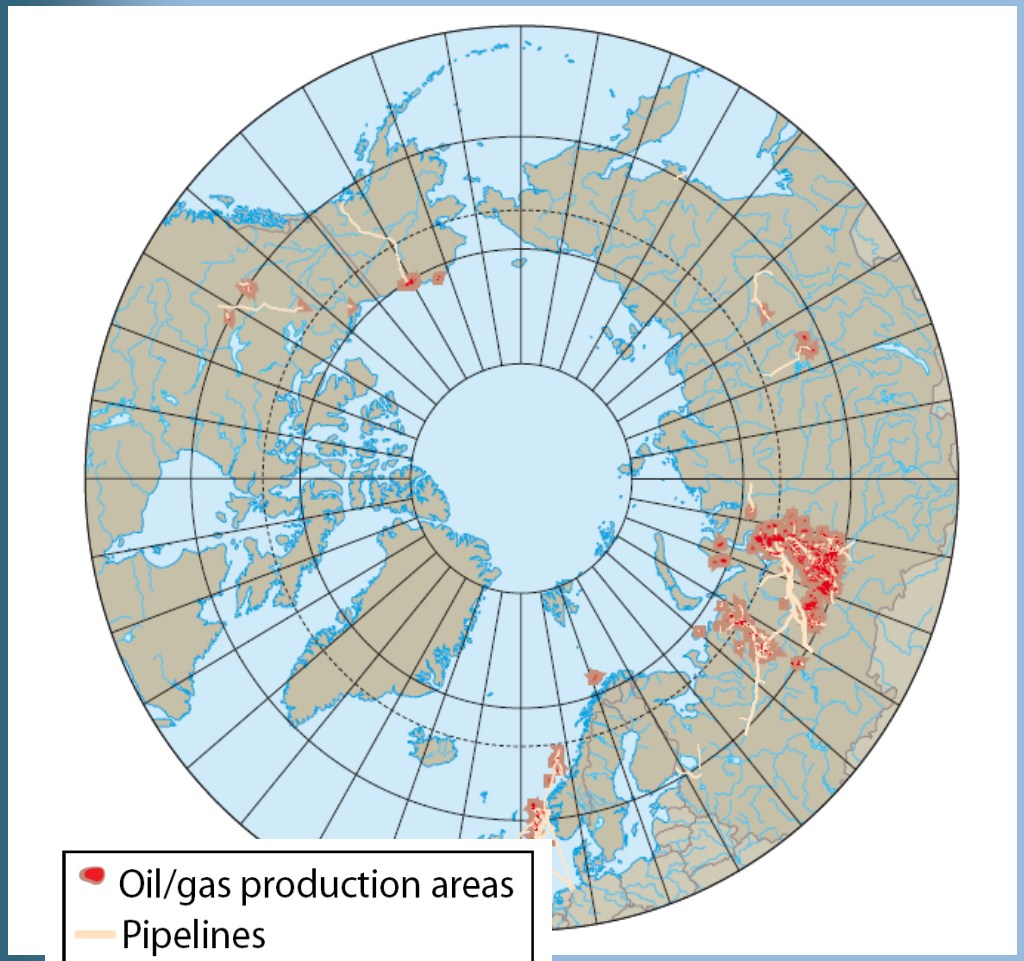
Key Finding #1. Oil and gas activity has occurred in the Arctic since the 1920s, with much oil and gas produced and much remaining to be produced



Key Finding #2.
Natural seeps
are the major source of petroleum hydrocarbon contamination in the arctic environment

Aerial view of Simpson **oil seep**, Alaska

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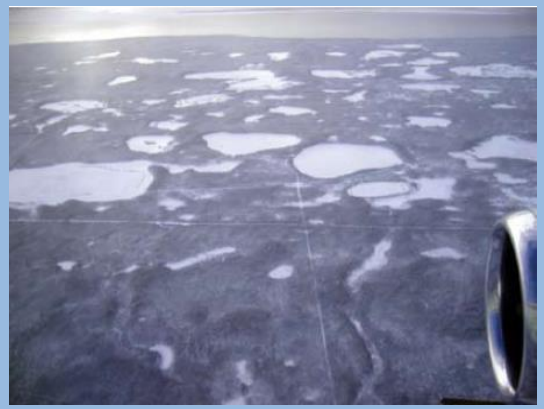
Key Finding #4.
Main effects On land - physical disturbances

Oil spills continue to pose a threat to local ecosystems.

Seismic surveys can leave scars on the tundra that persist for decades.

Modern practices, such as the use of **ice roads can reduce impacts**, but only during certain seasons.



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Key Finding #5. Main effects In marine environment - the oil spills

A spill that occur in a time and place that animals were aggregated could be especially disastrous

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Oil in ice

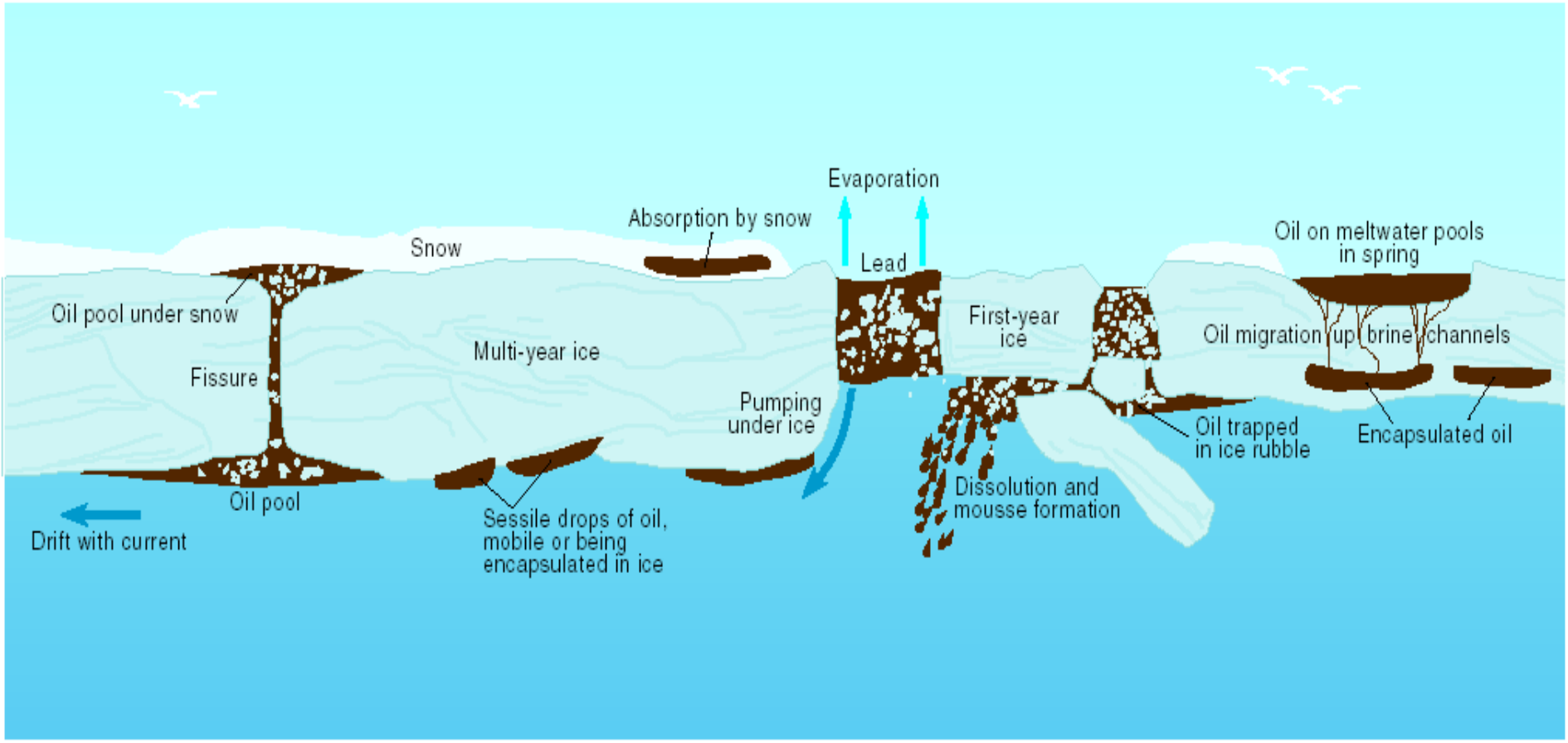
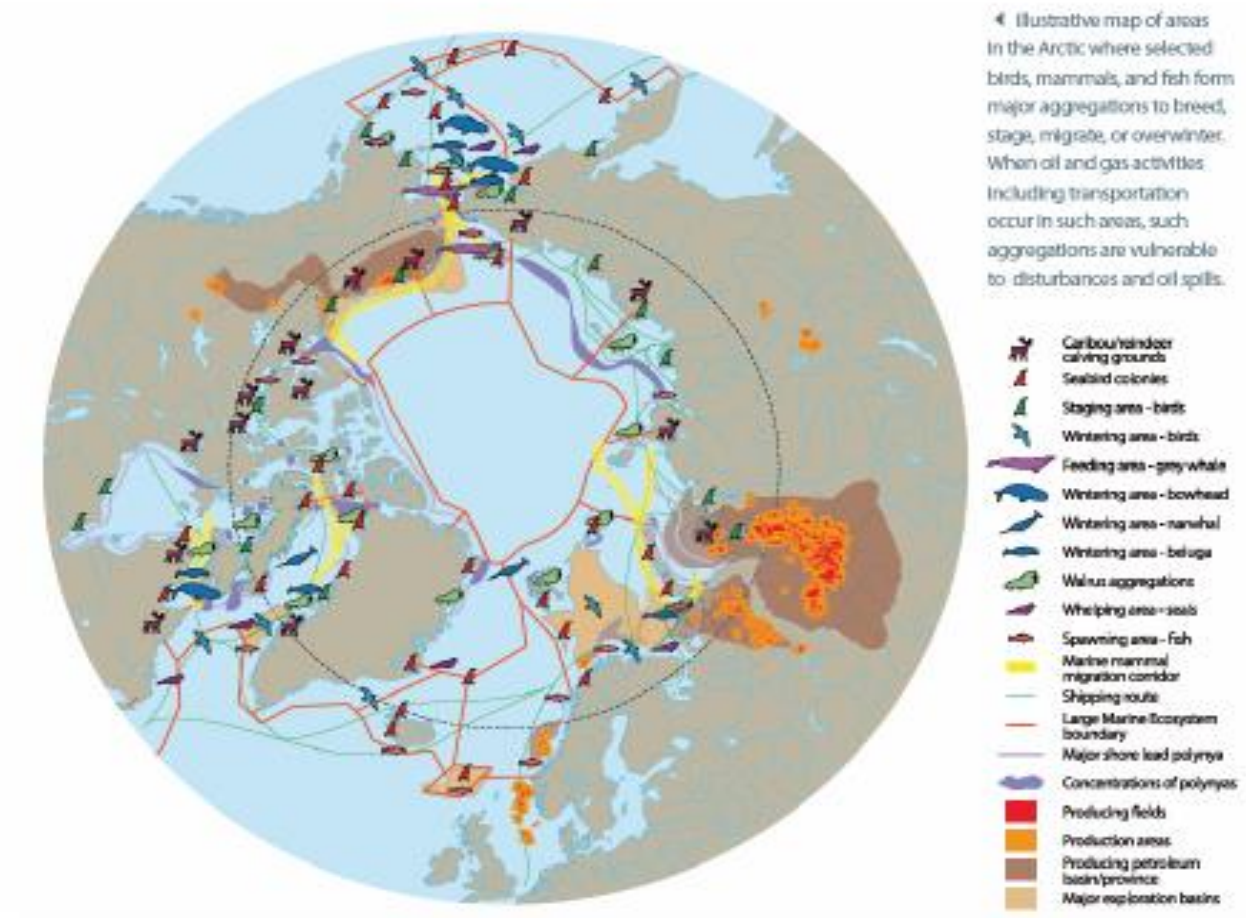


Figure 10·5. Sequence of oil-ice interaction including drops under the ice, new ice growth below the oil, oil appearing on the surface in the spring, wind herding of oil on melt pools, and the appearance of emulsified oil on top of the ice (after original figure by Bobra and Fingas).

Handling of oil spills in the Arctic

Vulnerability of the Arctic



Species aggregations are vulnerable to the effects of oil and gas activities.

Shaken not stirred!

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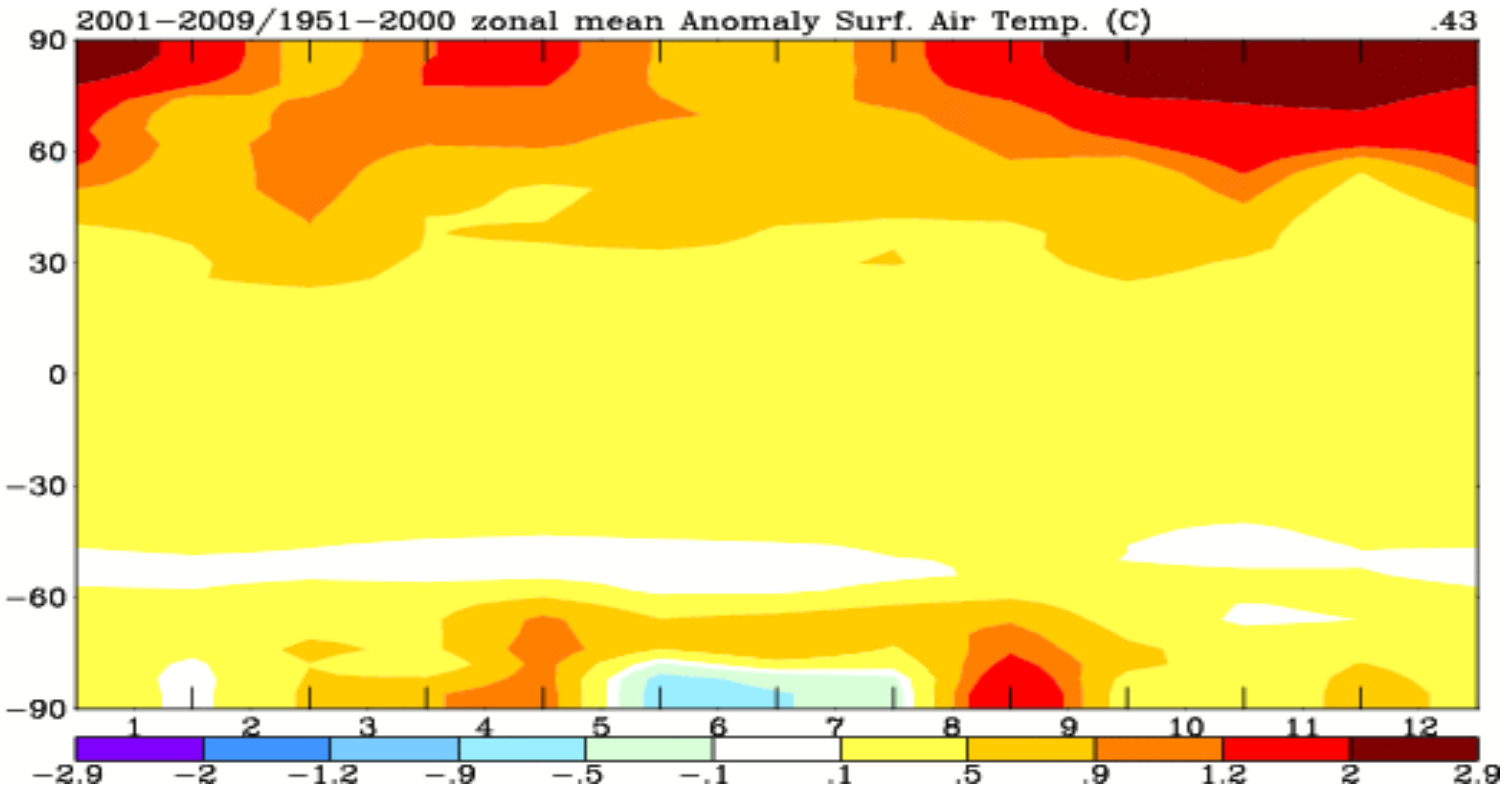
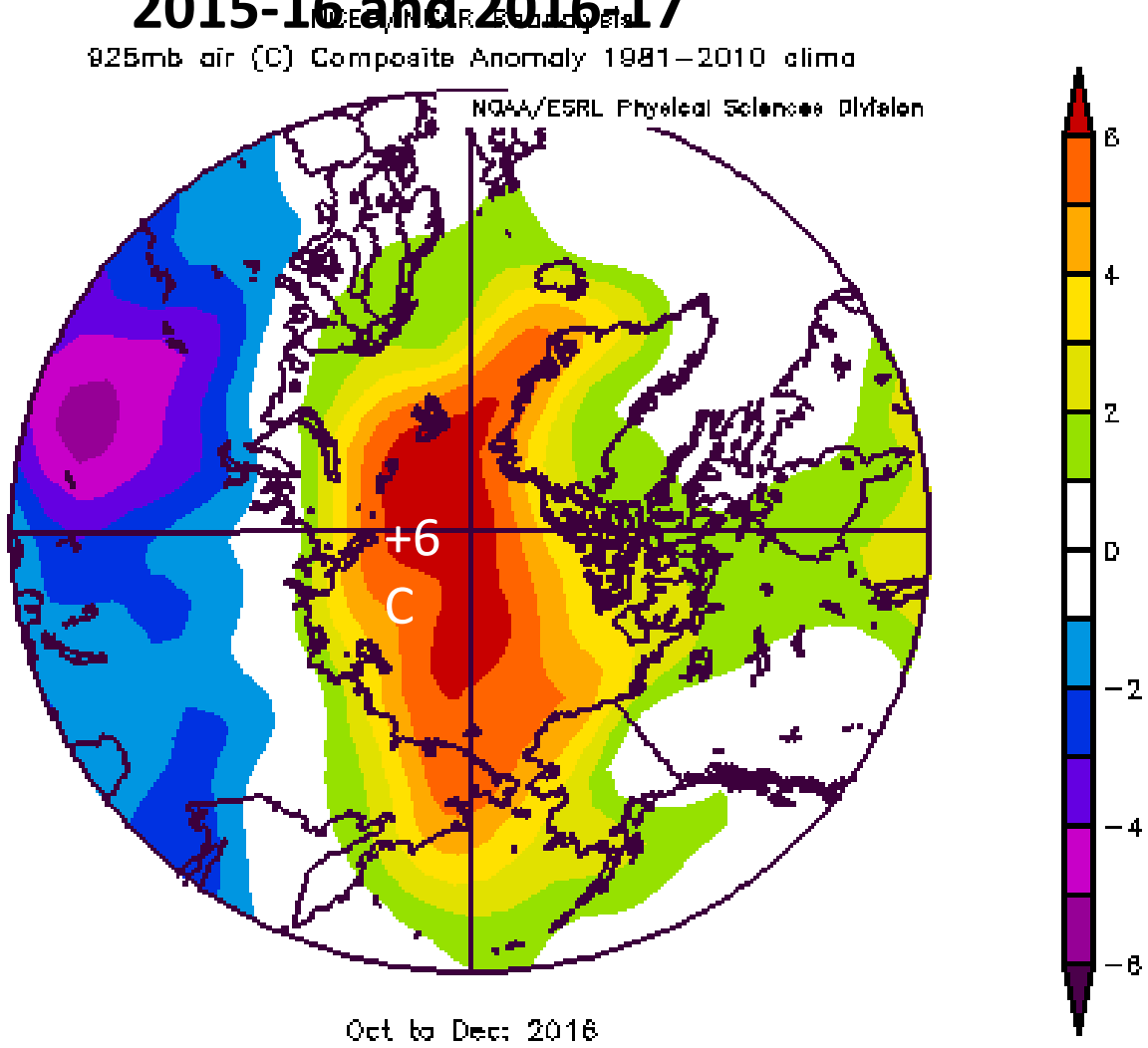
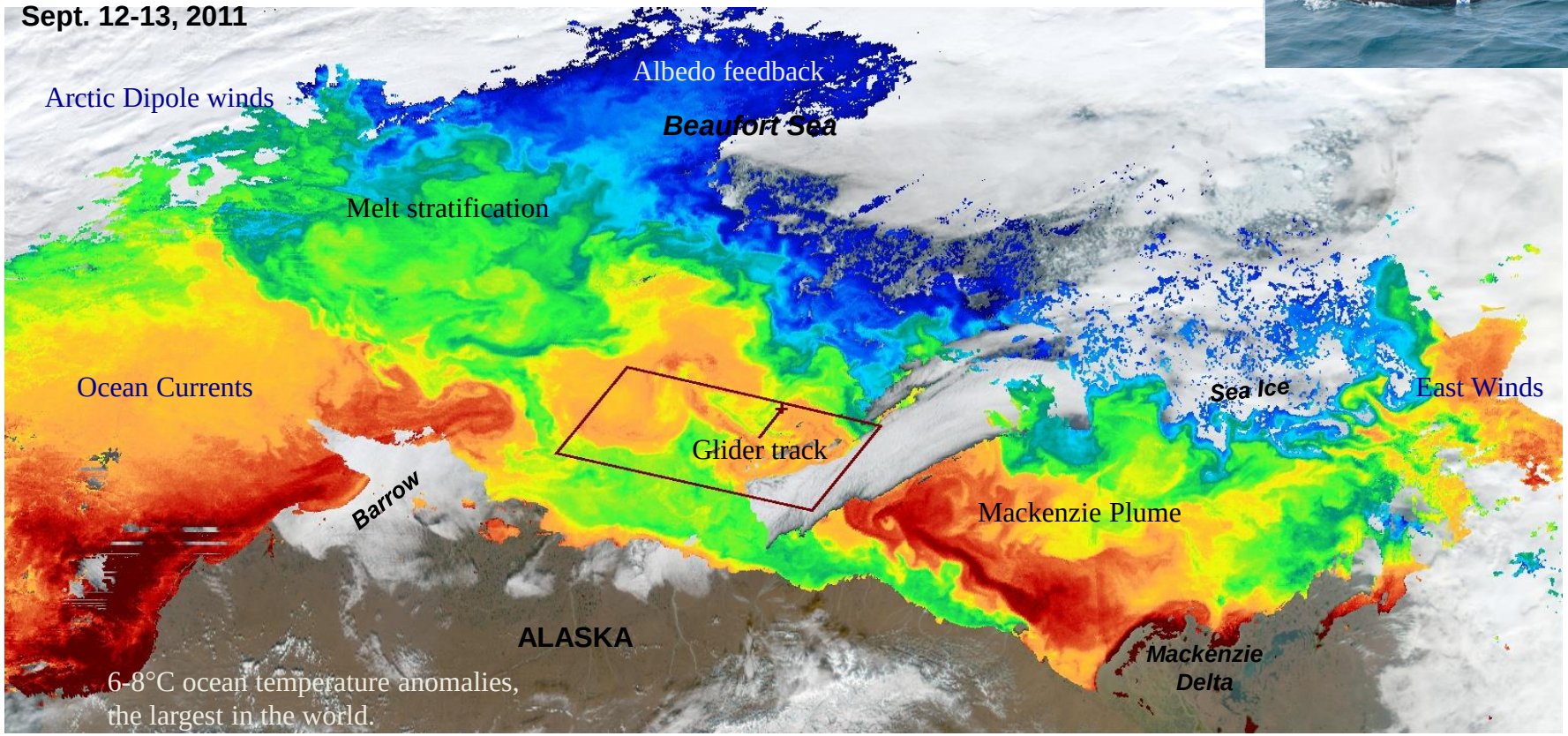
Latitude-month dependence of temperature anomalies, 2001-2009



Back-to-Back Record Warm Arctic Temperature Anomalies Fall/Winter 2015-16 and 2016-17



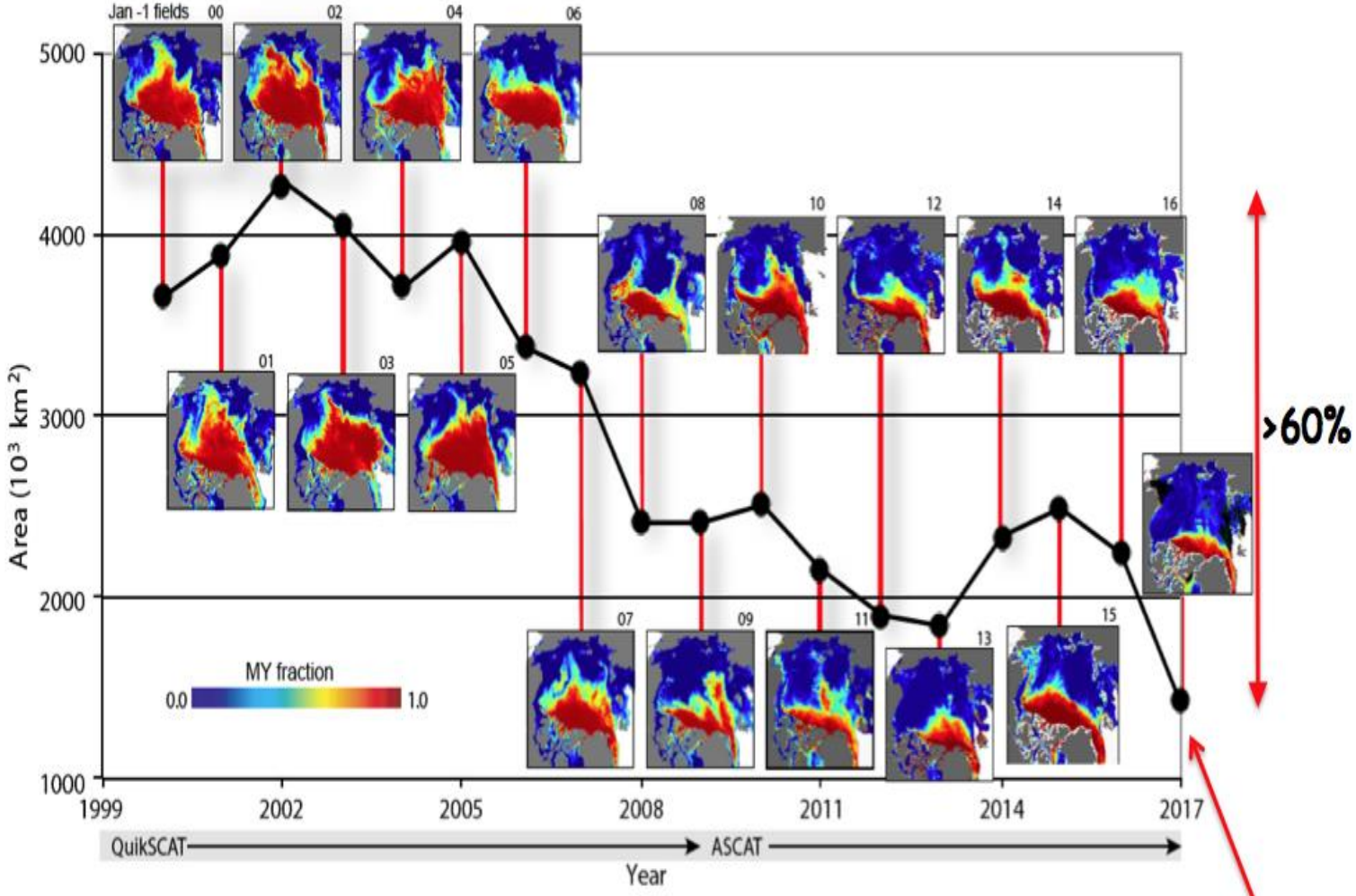
Pacific Arctic Ocean Heat Storage



MODIS sea surface temperature (colors) and true-color composite image (land, sea ice, and clouds)

Temperature Color Scale

Loss of Multiyear Sea Ice (from Satellite Scatterometers)



Ron Kwok

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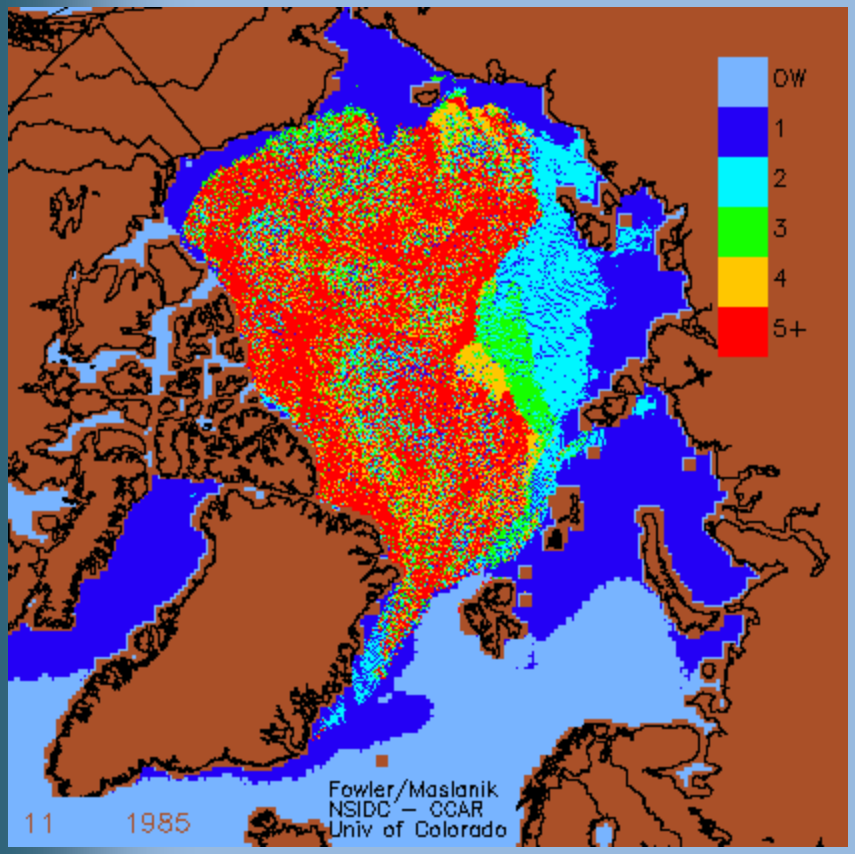
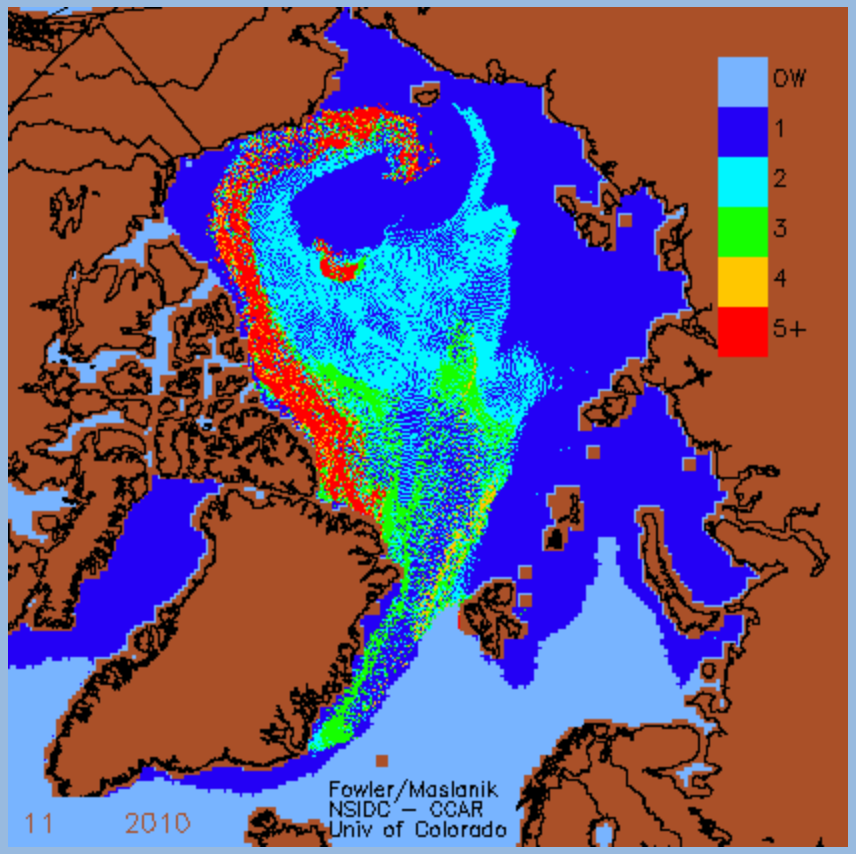
Ice is getting younger and thinner

Much of older, thicker ice north of Alaska now melting away during summer

Mar 1985 – Mar 1986

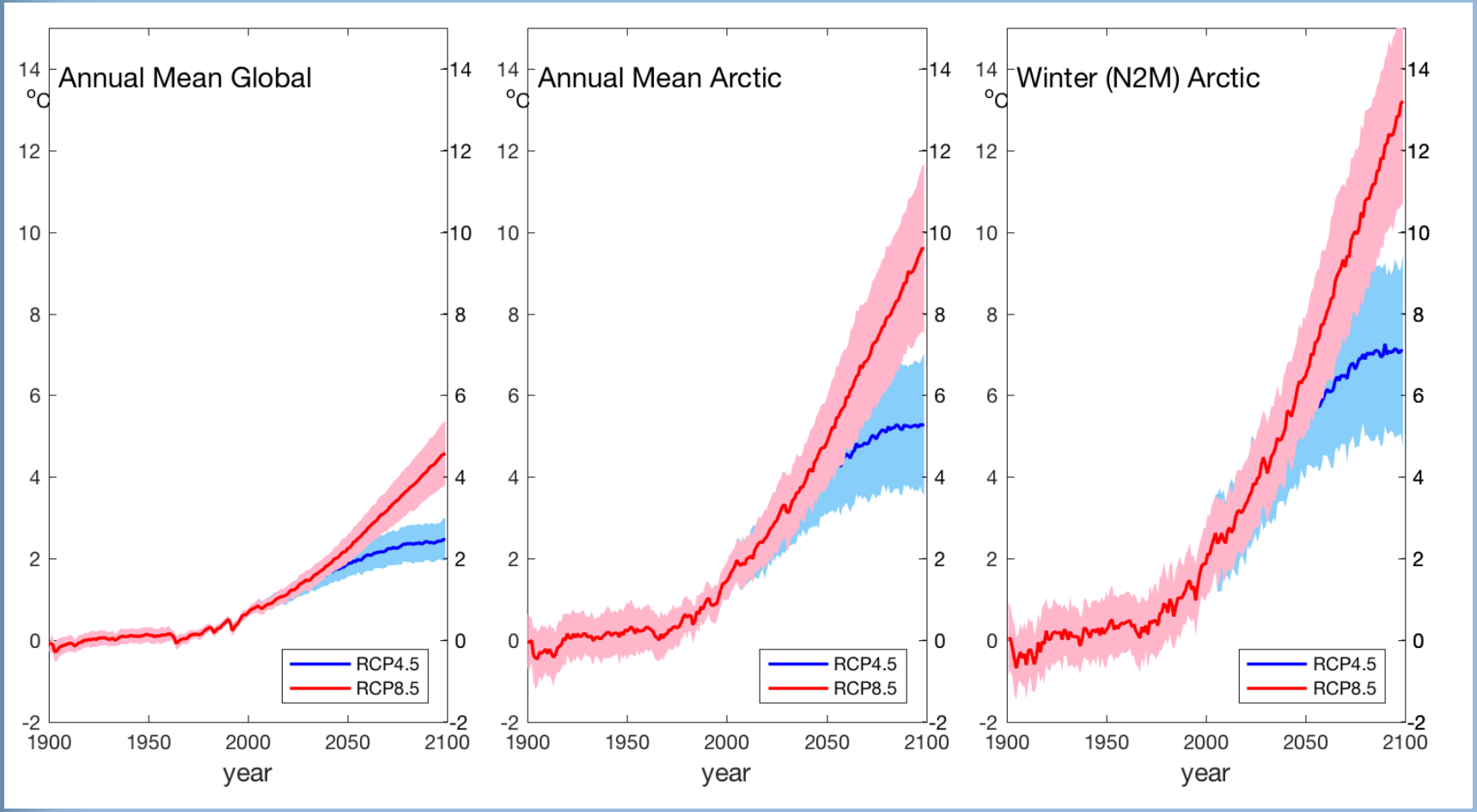


Mar 2010 – Mar 2011



Based on satellite observations; from J. Maslanik, C. Fowler, Univ. Colorado

Air temperature 1900 -2100



ARCTIC WARMING NOT A NEW IDEA

"temperature of the Arctic regions would rise about 8 degrees or 9 degrees Celsius, if the carbonic acid increased 2.5 to 3 times its present value"

Svante Arrhenius, 1895

Kalving Jakobshavn isbre på Grønland, Juni 2007

Jason_5june_coregv1_Title_forweb.mov

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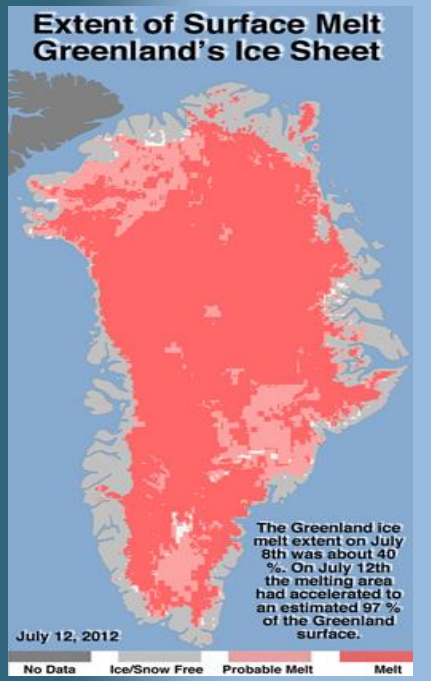
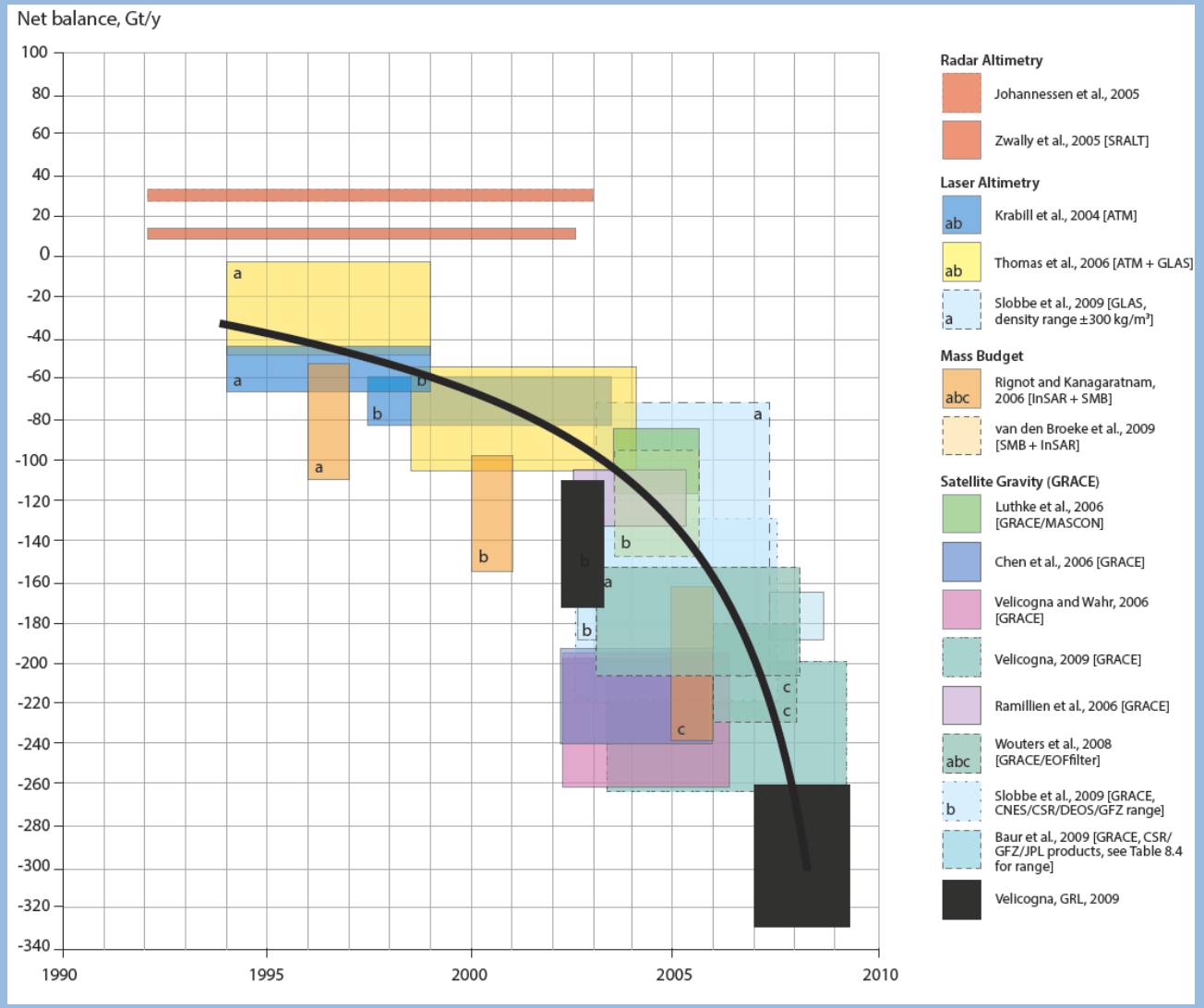
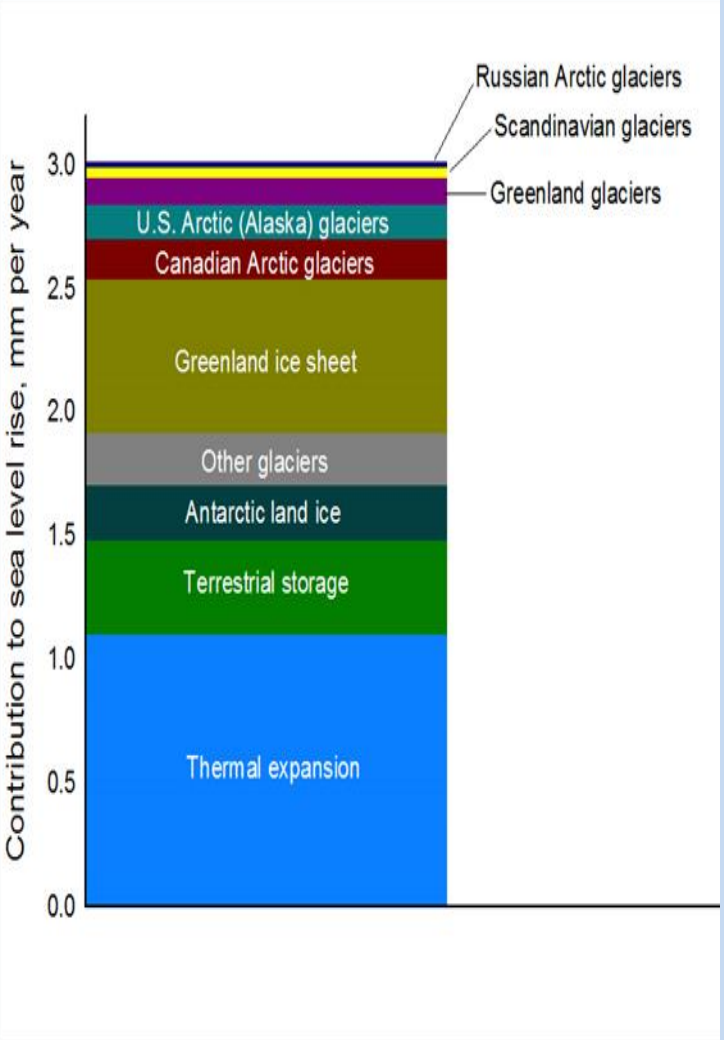
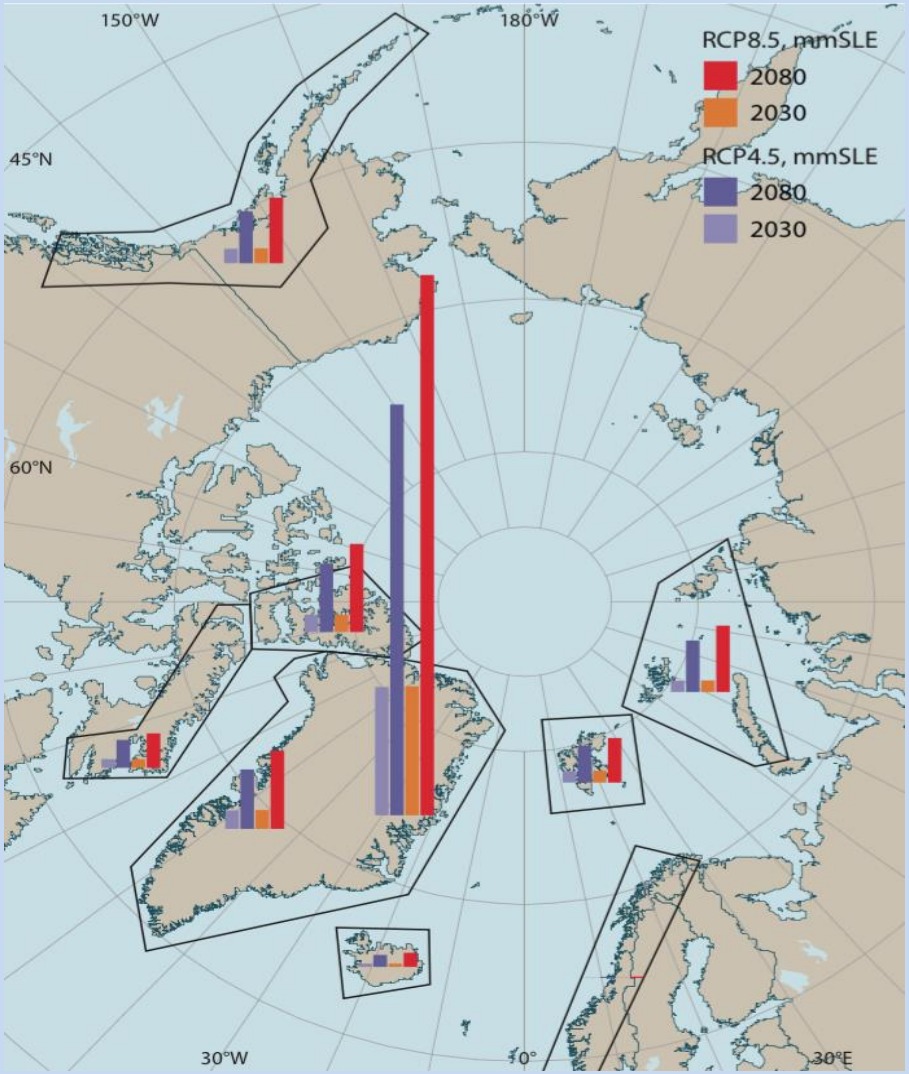
Greenland Mass Balance



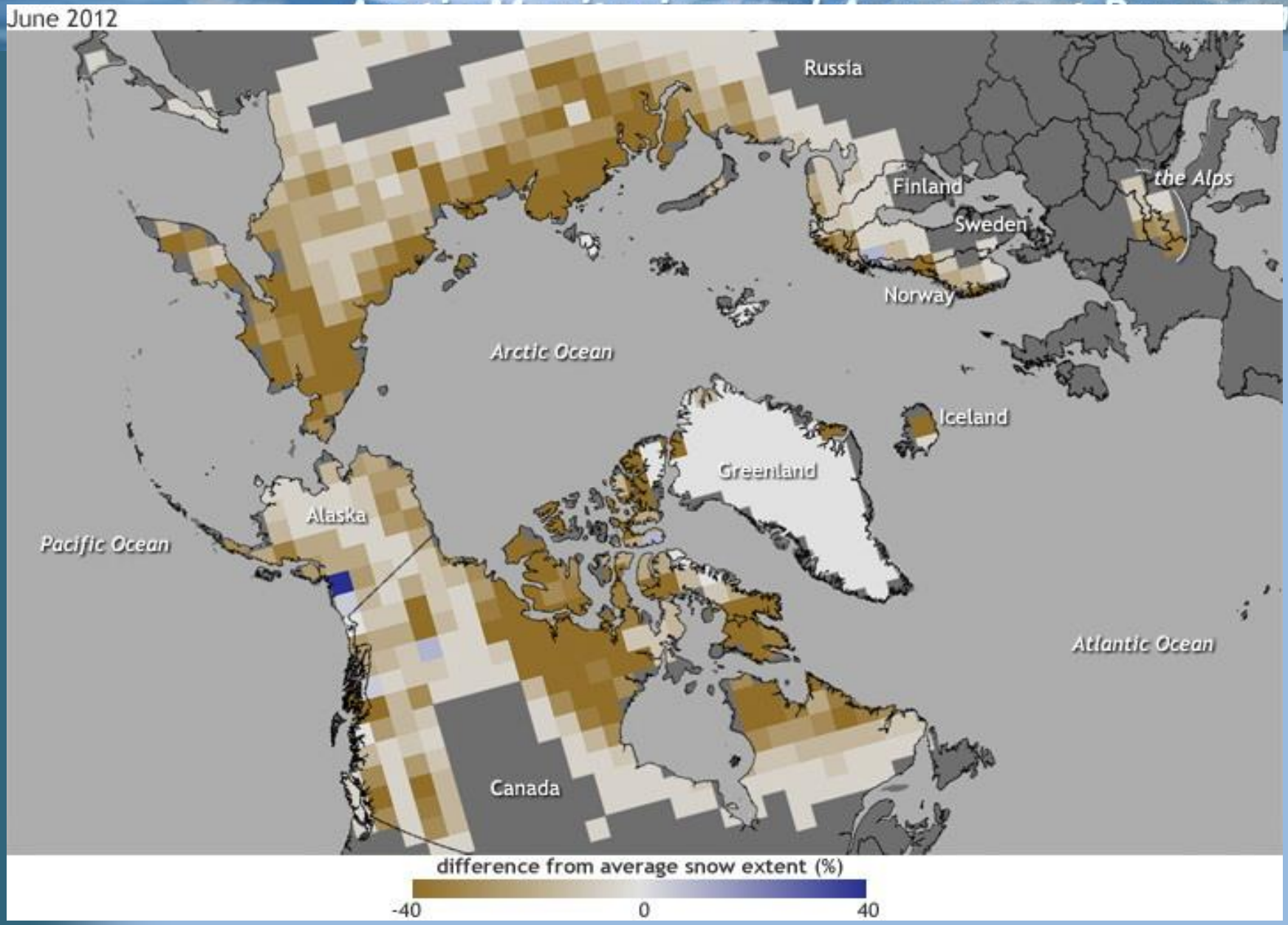


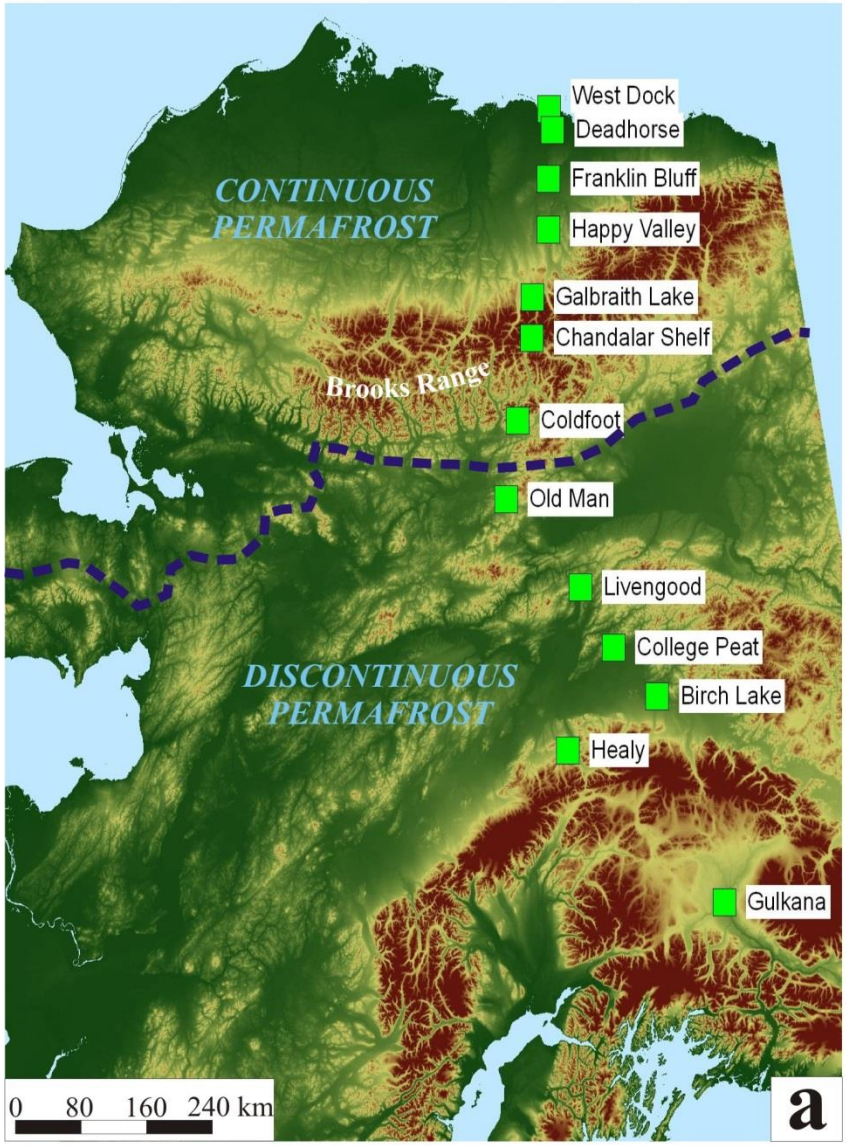
Sea level rise

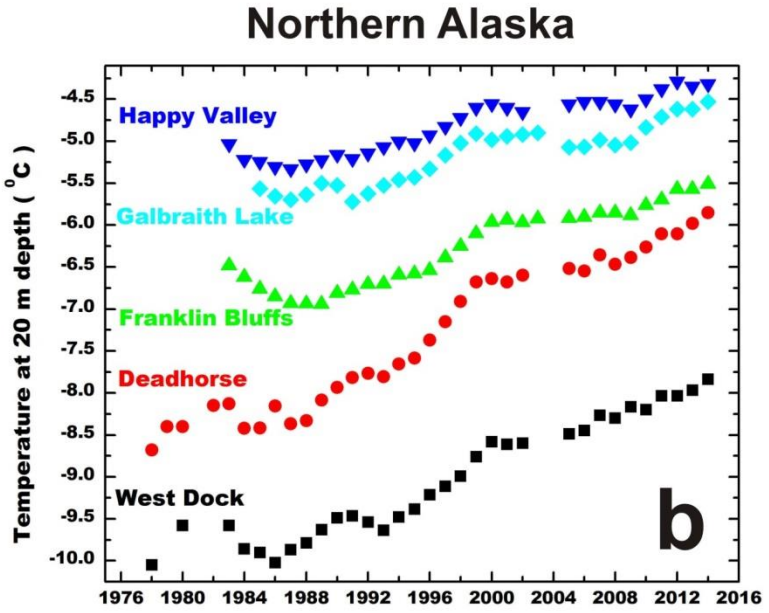


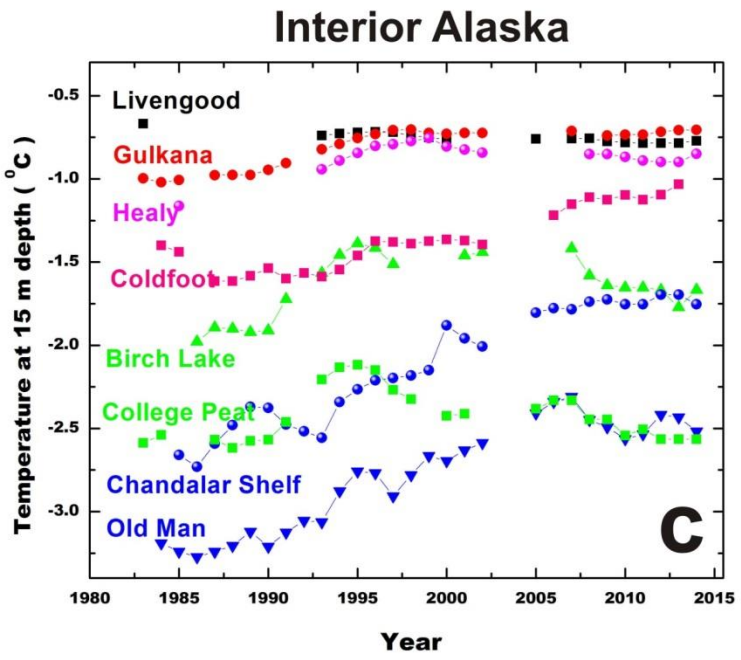


June Snow Cover 2012 relative to 1971-2000

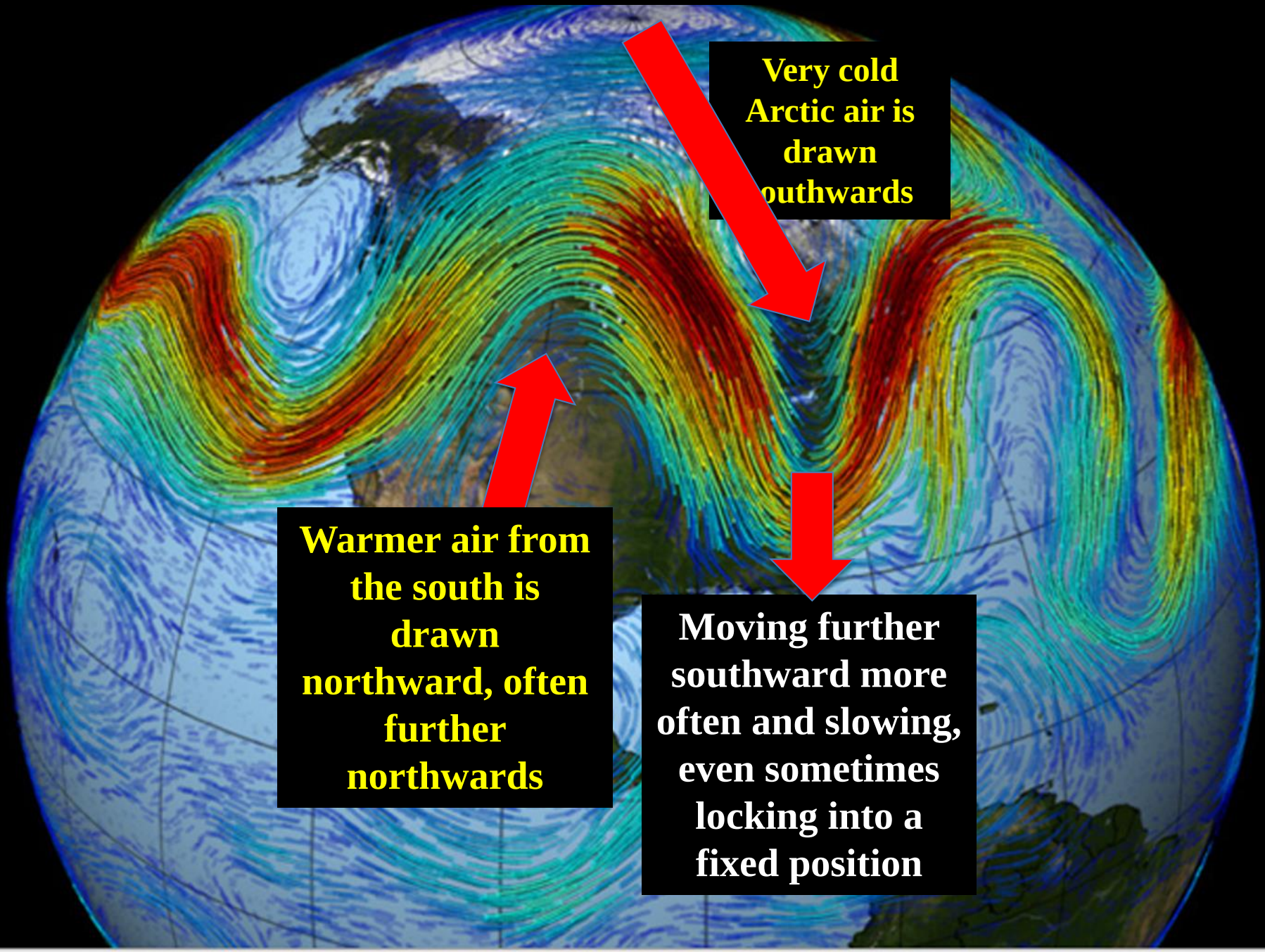



West Dock
Deadhorse
Franklin Bluff
Happy Valley
Galbraith Lake
Chandalar Shelf
Brooks Range
Coldfoot
Old Man
Livengood
College Peat
Birch Lake
Healy
Gulkana
CONTINUOUS PERMAFROST
DISCONTINUOUS PERMAFROST
0 80 160 240 km
a


Northern Alaska
Happy Valley
Galbraith Lake
Franklin Bluffs
Deadhorse
West Dock
Temperature at 20 m depth (°C)
-4.5
-5.0
-5.5
-6.0
-6.5
-7.0
-7.5
-8.0
-8.5
-9.0
-9.5
-10.0
1976 1980 1984 1988 1992 1996 2000 2004 2008 2012 2016
b


Interior Alaska
Livengood
Gulkana
Healy
Coldfoot
Birch Lake
College Peat
Chandalar Shelf
Old Man
Temperature at 15 m depth (°C)
-0.5
-1.0
-1.5
-2.0
-2.5
-3.0
1980 1985 1990 1995 2000 2005 2010 2015
Year
c

Climate Changes Appears to Increase the North-south Range of the Jet Stream



SWIPA 2017 Key findings

- **Record high** Arctic temperatures in the last decade
- **Confirm trends** of temporal and spacial phase shift, which in some cases have **accelerated**
- Cryospheric/hydrological **changes continue**
- By mid and late 2100 **Arctic will be very different**
- Arctic contributions to **global SLR** better quantified
- **Mitigation can stabilize parts** of the Arctic cryosphere towards end of 21st century and dampen speed
- Underscores **urgency of global mitigation action**.

Short Lived Climate Forces (SLFCs)

Emissions from gas flaring contribute 42% to Arctic-mean BC surface concentrations

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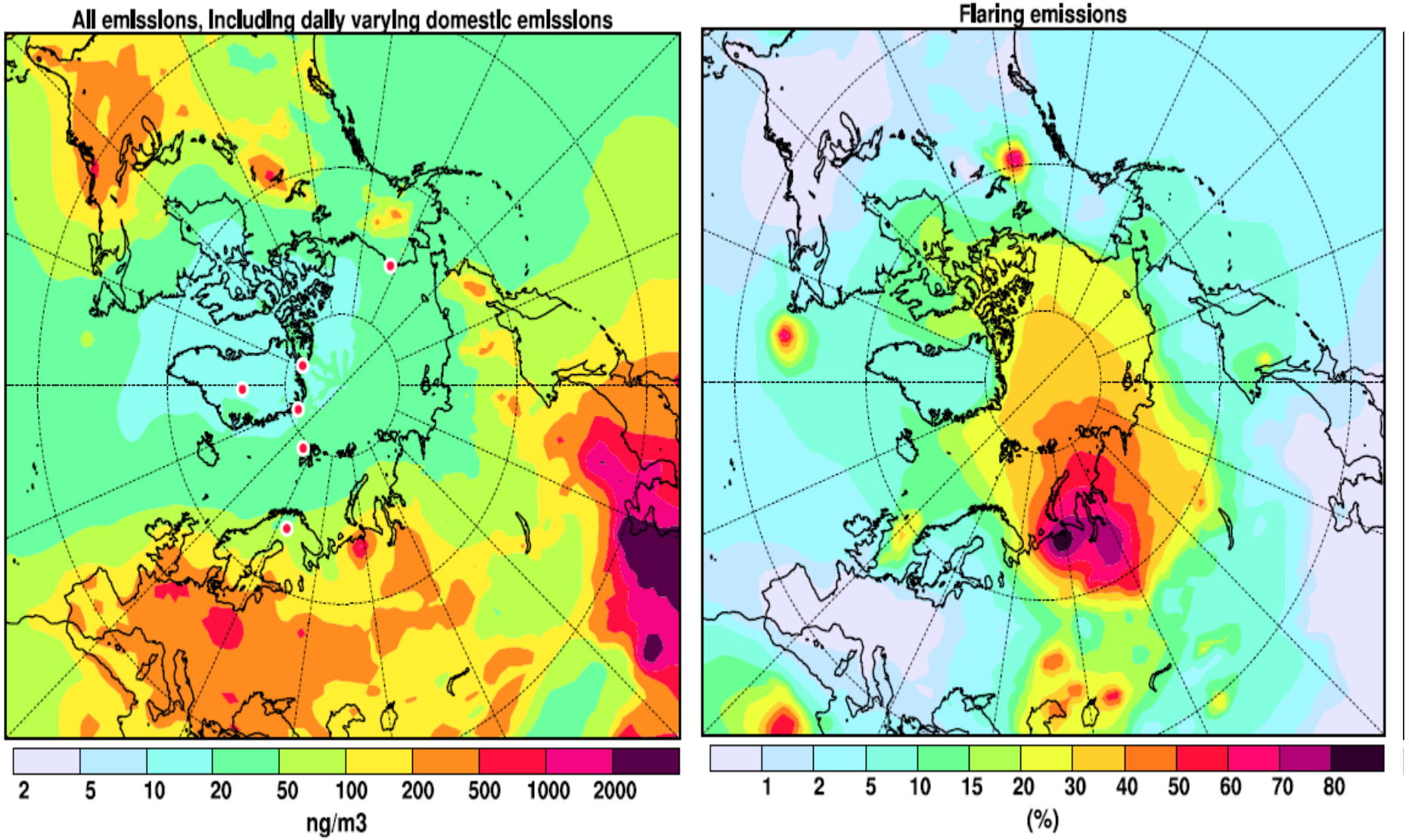
left panel: total BC surface concentrations; right panel: relative contribution from



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Effects due to Action on SLCF by 2050

Arctic warming due to all climate forcers of approximately 2 C.

Mitigation of SLCF - complement (not replace) CO_2 reductions.

Reducing BC and co-emitters globally may slow warming by 0.25 C.

Global mitigation of all SLCFs
(methane, BC and co-emitters) could reduce warming by roughly 0.5 C.

Arctic warming - partly a result of SLCFs emitted outside of the Arctic;

Fully effective mitigation require engagement of non-Arctic countries.

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Biological impacts

Extinction of some Arctic endemic species highly likely if current trends in sea ice continue

- 2/3 reduction in polar bear population by 2050
- Walrus and seal populations threatened also

Yamal Peninsula, November 2013: freezing rain event causes more than 60,000 reindeer deaths

(Forbes et al., 2016., Biology Letters)

Fate of Anthropogenic CO_2 Emissions (2010 Data)

~90%

~10% +

Sources

Goes to these 3 Places

~ 50%

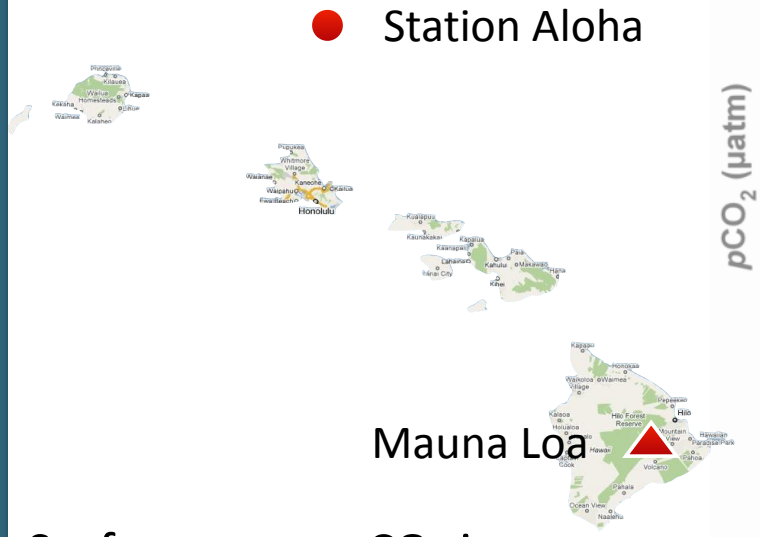
~ 25%

~ 25%

Here's the New Problem

Global Carbon Project 2010; Updated from Le Quéré et al. 2009, Nature Geoscience; Canadell et al. 2007, PNAS

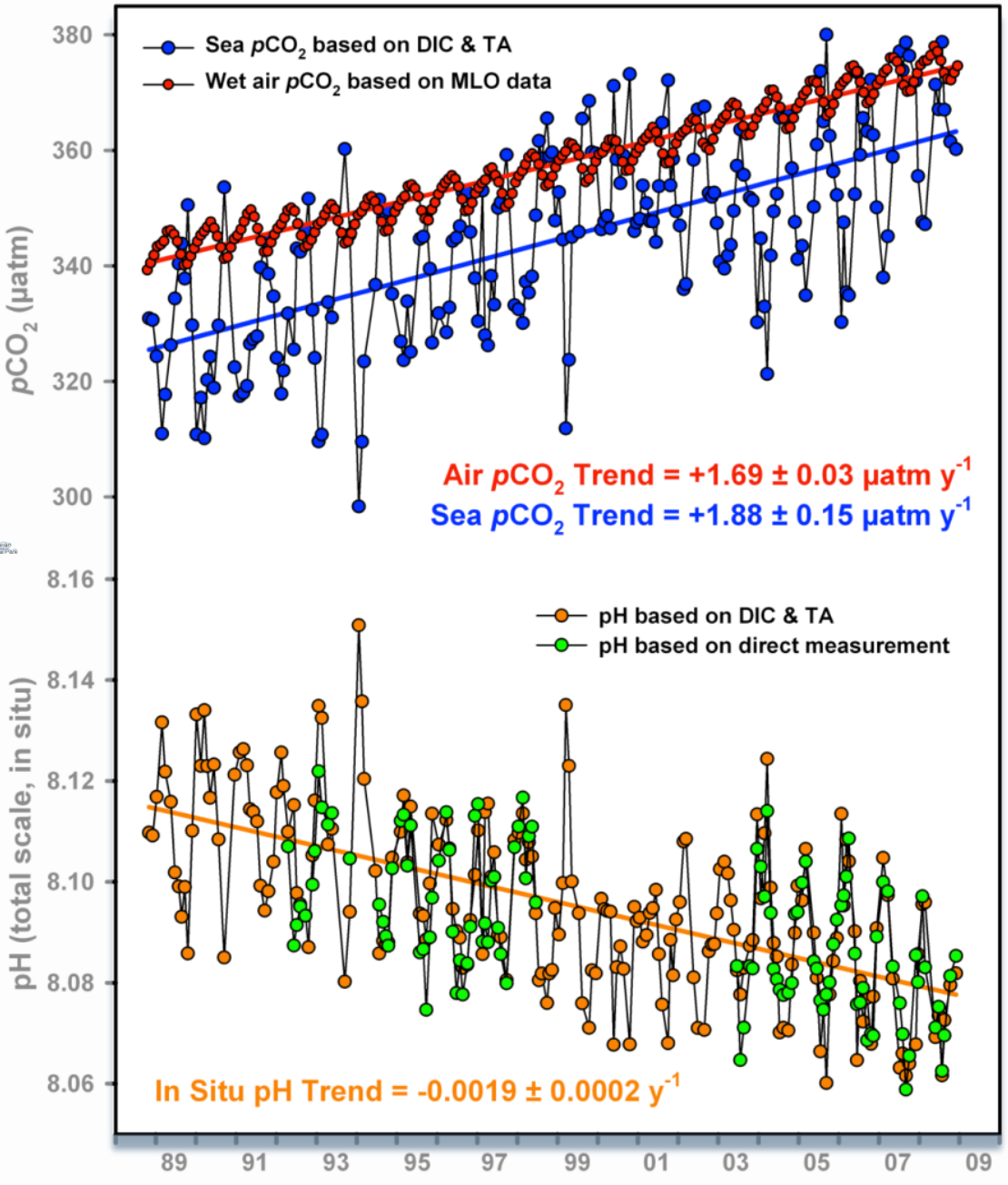
Carbon Changes at the Hawaii Ocean Time-series (HOT) site



Surface water pCO_2 is increasing at about the same rate as atmosphere

We see a commensurate decrease in pH with the rise in surface water pCO_2

Doney, Science 2010
Dore et al., PNAS 2009



Key Findings: Ocean Chemistry

Arctic Monitoring and Assessment Programme

Key finding 1
Arctic marine waters are experiencing widespread and **rapid ocean acidification**

Key finding 2
The **primary driver** of ocean acidification is uptake of carbon dioxide emitted to the atmosphere by **human activities**

Key finding 3
The Arctic Ocean is especially **vulnerable** to ocean acidification

Key finding 4
Acidification is **not uniform** across the Arctic Ocean

pH	H+ (moles per liter)	change in acidity
7.2	6.3×10^{-8}	+900%
7.3	5.0×10^{-8}	+694%
7.4	4.0×10^{-8}	+531%
7.5	3.2×10^{-8}	+401%
7.6	2.5×10^{-8}	+298%
7.7	2.0×10^{-8}	+216%
7.8	1.6×10^{-8}	+151%
7.9	1.3×10^{-8}	+100%
8.0	1.0×10^{-8}	+58%
8.1	7.9×10^{-9}	+26%
8.2	6.3×10^{-9}	

Average global surface ocean pH has fallen from a pre-industrial value of 8.21 to 8.10, corresponding to an increase in acidity of 28.8%. Values of 7.8–7.9 are expected by 2100, representing a 100–150% increase in acidity (NOAA/PMEL)

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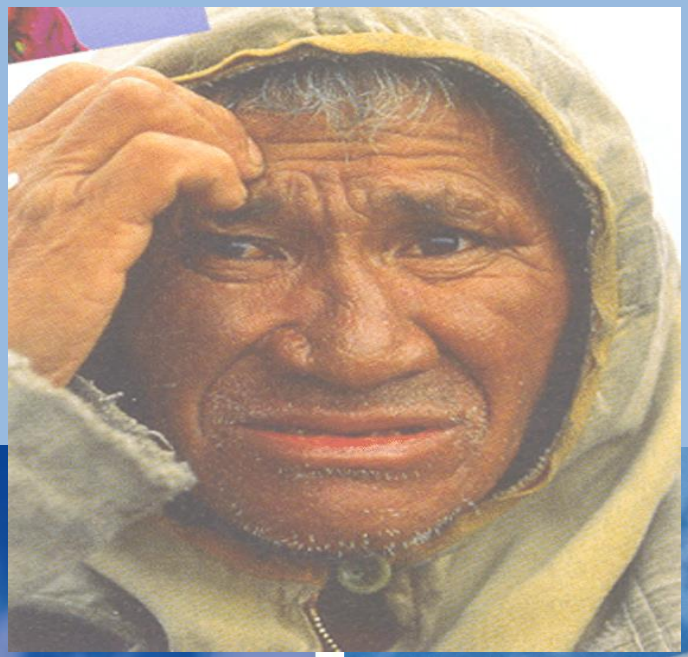
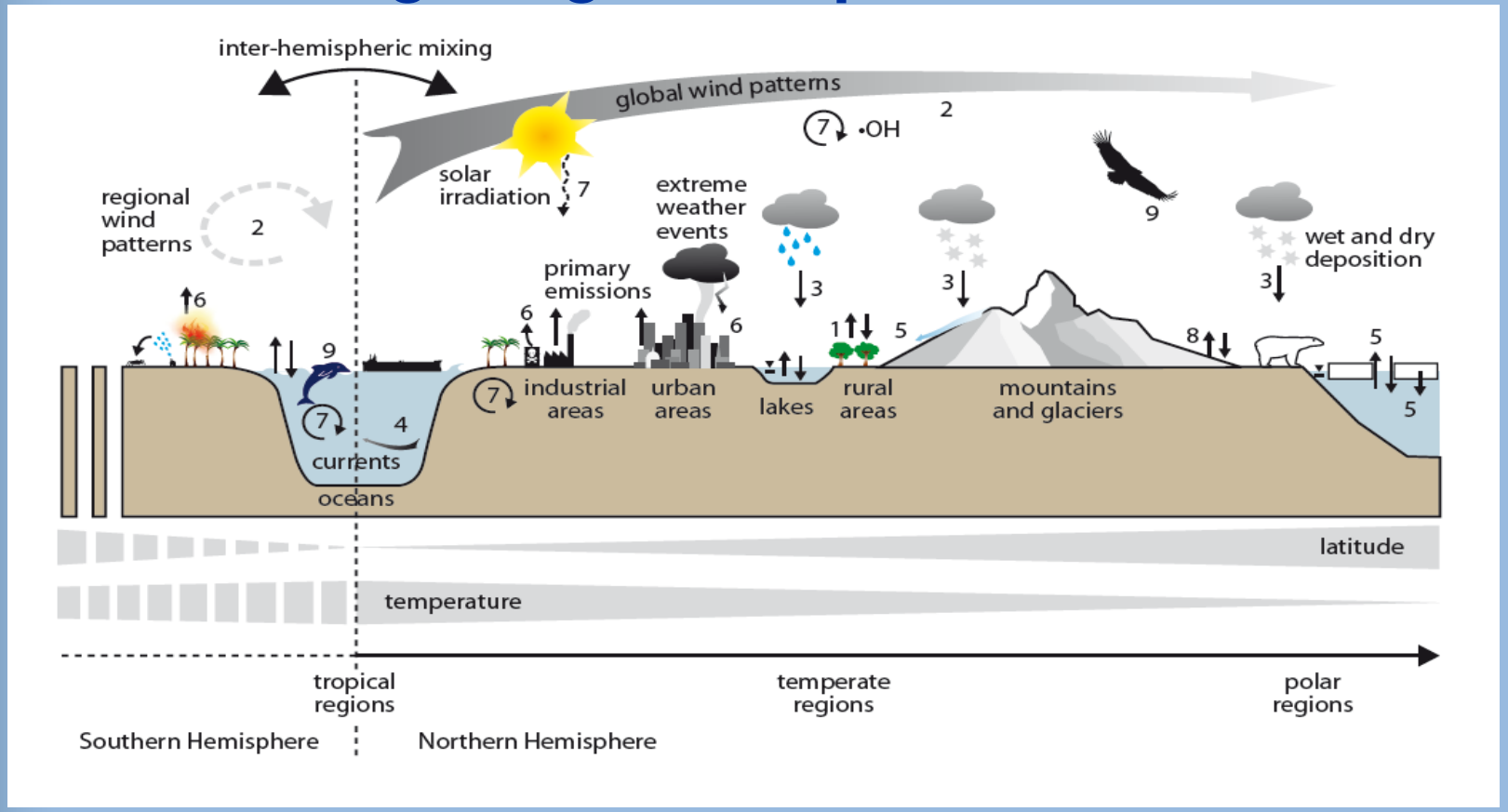
What are the combined effects of climate change, contaminants and other stressors?



Impact of Climate change on environmental fate and long-range transport



Combined effect of climate change on releases of stored POPs in the North

- Thawing of permafrost
- Melting of mountain glaciers & ice caps
- Melting of Greenland Ice Sheet
- Flooding
- Forest fires

- Photo: Business week Aug. 2004

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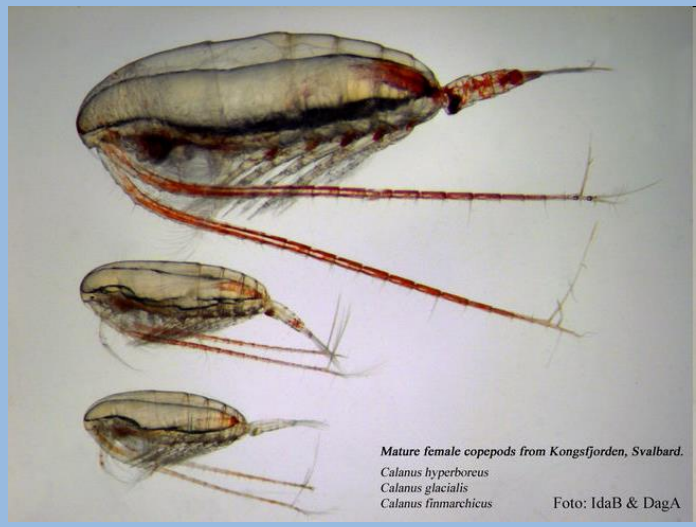
Climate change and effects on contaminant accumulation

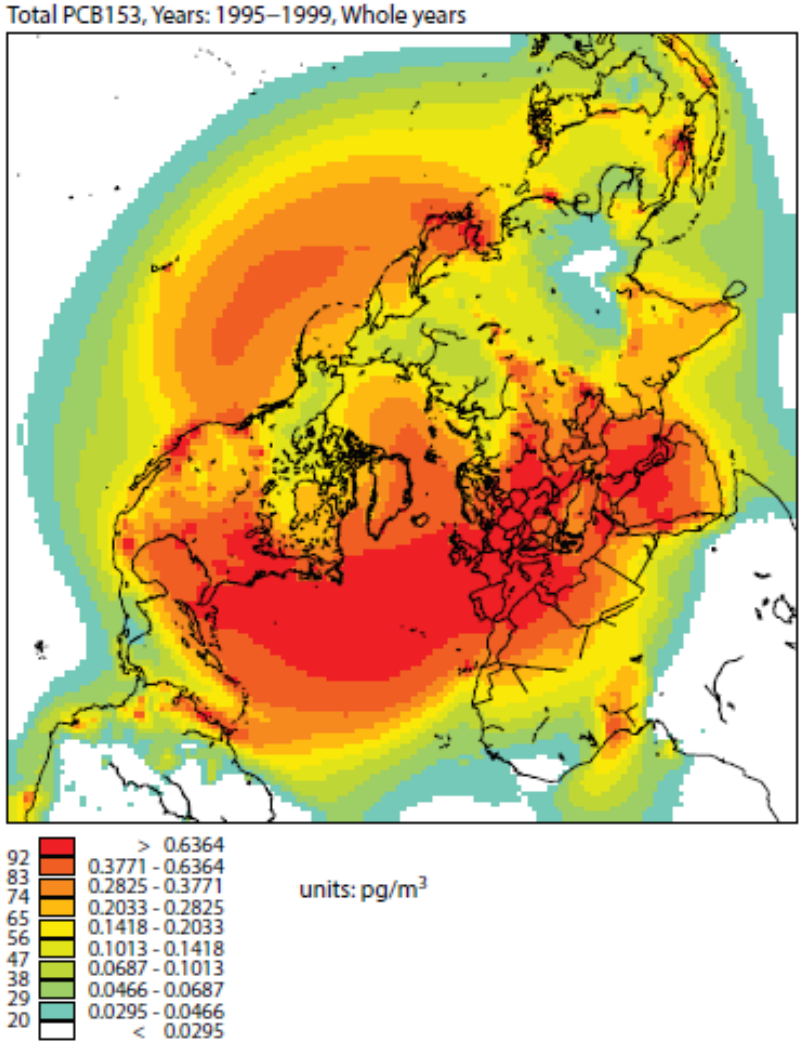
Food web structure:

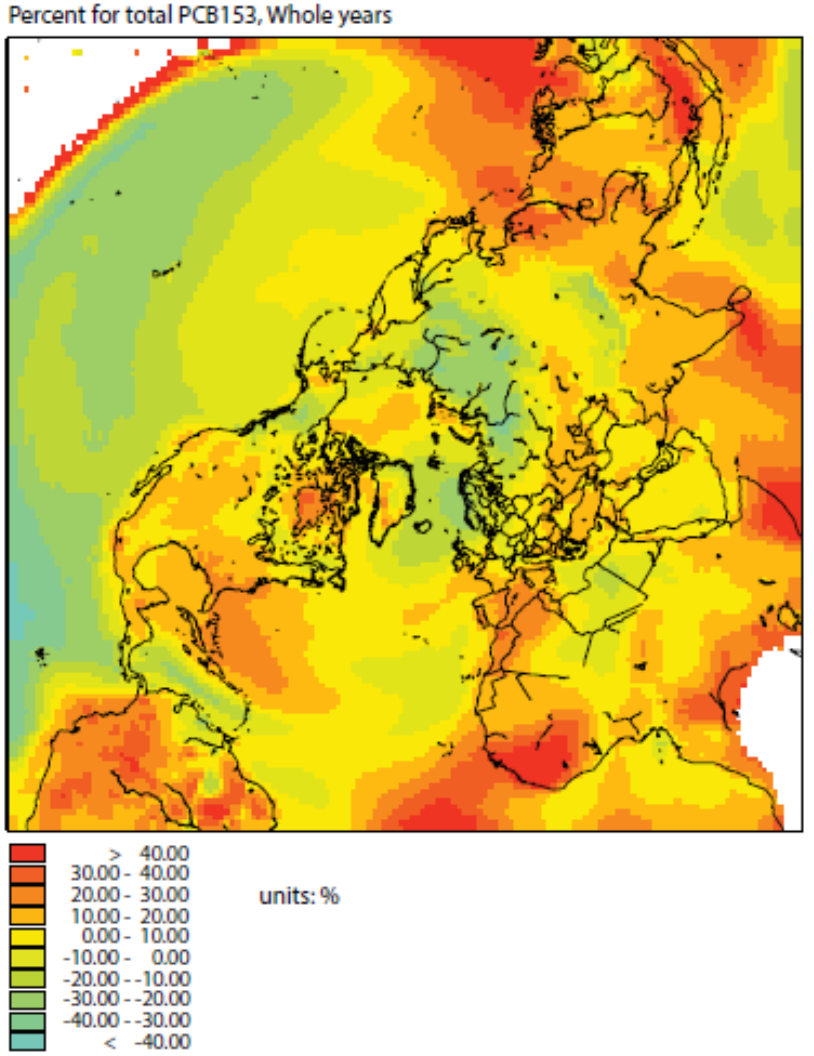
- Southern species and Northern
- Changed primary production
- Dietary and direct uptake of contaminants

Bioaccumulation process rates:

- Direct partitioning/respiration, dietary uptake
- Growth, direct partitioning/respiration, , egestion, biotransformation
- Temperature dependency







Total yearly mean concentration of PCB153 in the lowest atmospheric model layer for the period **1995–1999 (left)**, and the **percentage change** from the mean of **1995–1999 to** the mean of **2095–2099 (right).**

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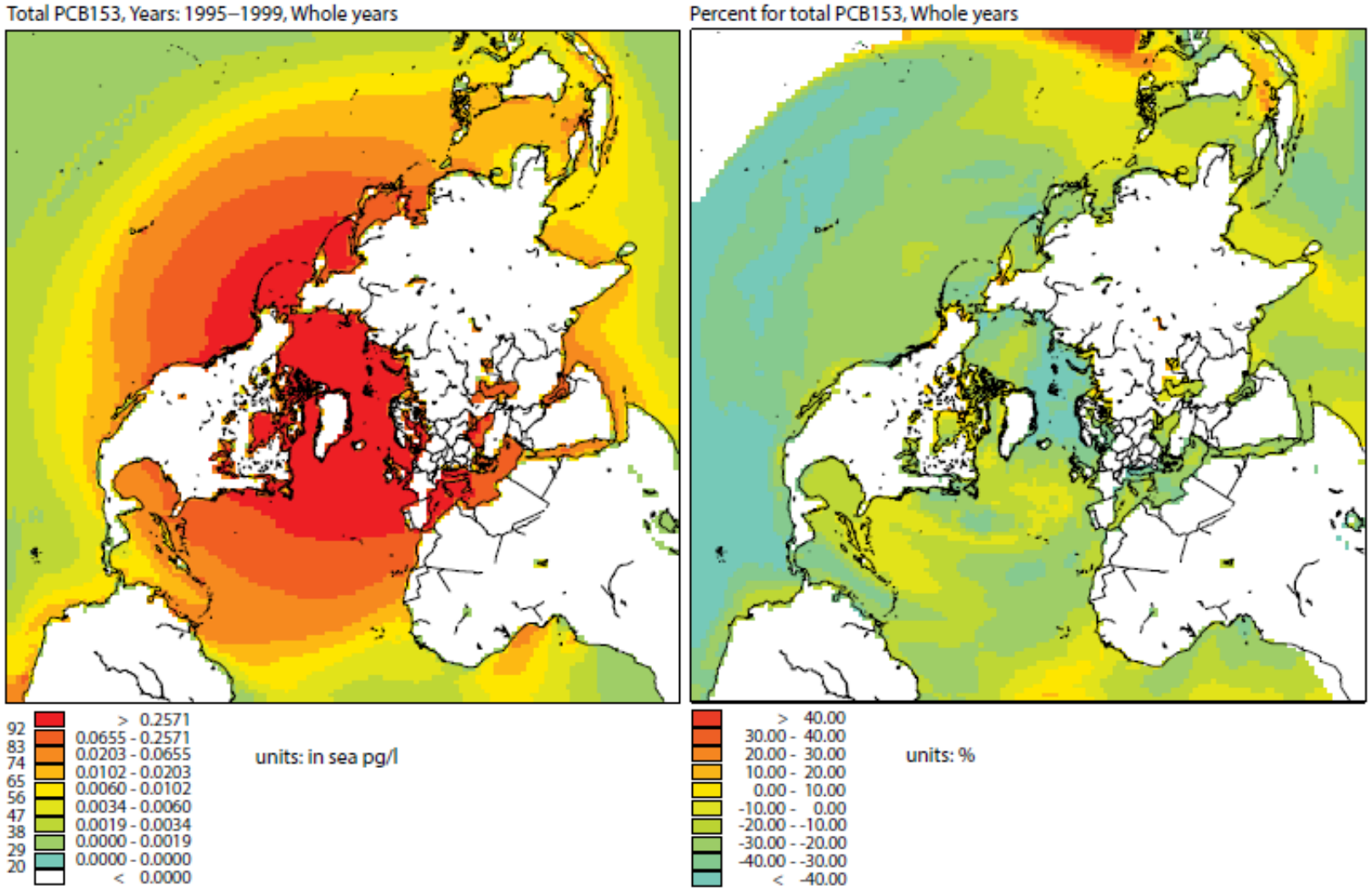

Total yearly mean concentration of **PCB153 in the ocean model layer (upper 75m**) for the period 1995–1999 (left), and the percentage change from the mean of 1995–1999 to the mean of 2095–2099 (right).

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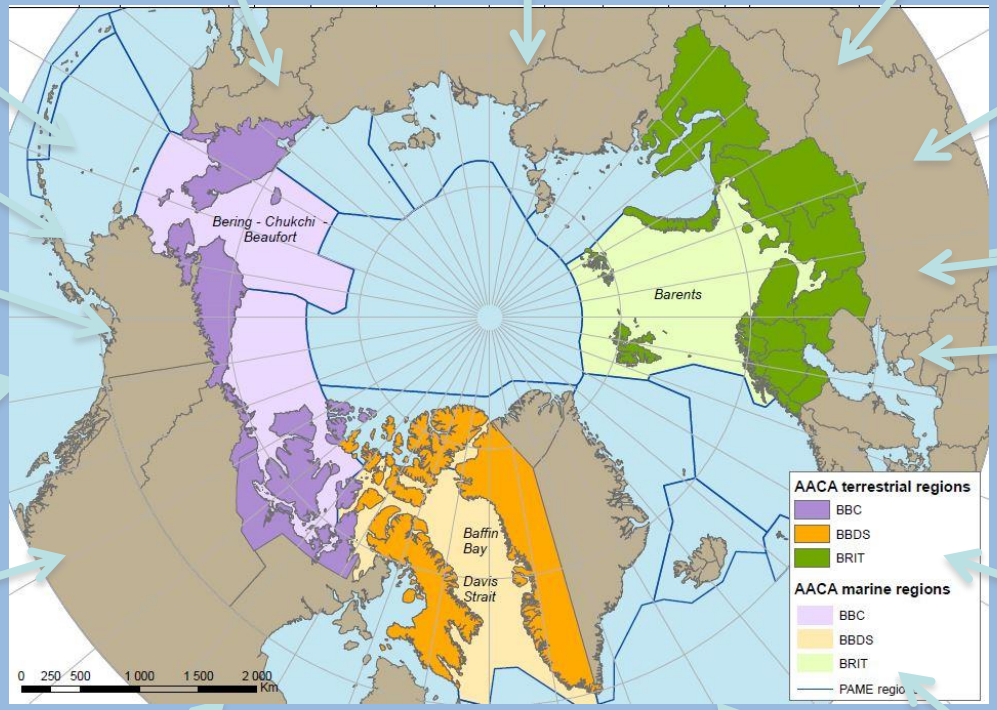
Adaptation Action to a Changing Arctic (AACA)

Drivers of Arctic Change

Ecosystem change
Erosion
Recreation and tourism
Mining
Population
Climate change
Oil and gas
Ocean acidification
Global economic development
Local development
Transport and shipping
Technology development
Migration
Fisheries
Infrastructure
Global pollution
Loss of sea ice



Adaptation Actions for a Changing Arctic - key messages:

ARCTIC MONITORING AND ASSESSMENT PROGRAMME

Arctic residents and stakeholders need to know what to adapt to. **Adaptation is a continuous process.**

Adaptation to Arctic change can take place on **local, regional and national levels.**

Climate change has shown not always to be the primary driver of Arctic change. **Socio-economic drivers** can be equally important to Arctic residents.

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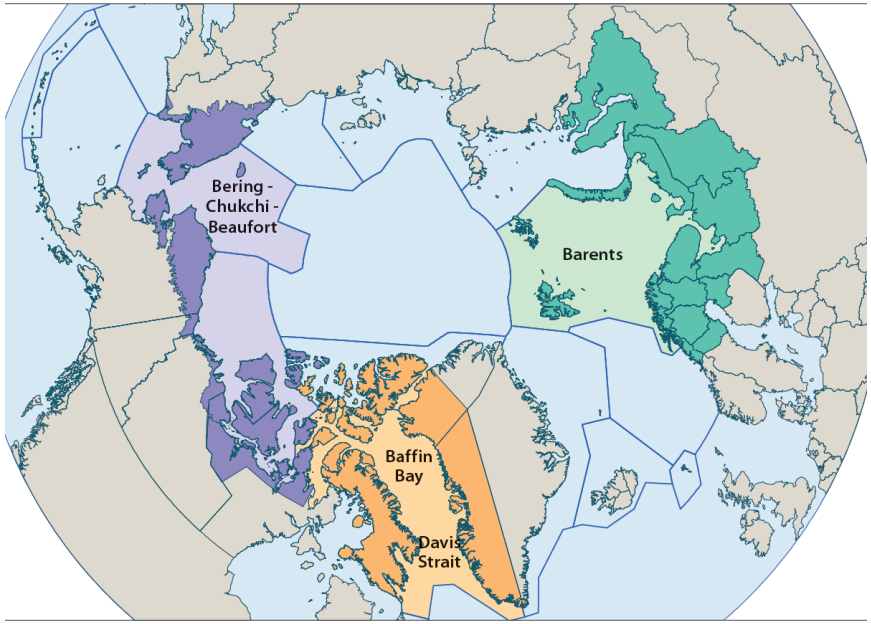
Adaptation Actions for a Changing Arctic (AACA)

We have assessed **the impacts and consequences of drivers of Arctic change** and the options how to adapt to the changes.

We have produced one science report and one overview report from each of the three pilot regions.
The reports contain **a wealth of material** that can help **inform decision makers** in government, civil society, business and academia as they prepare to adapt to anticipated change in the Arctic.

The reports **outlines adaptation options**, not specific adaptation recommendations



Adaptation Actions for a Changing Arctic - key messages:

ARCTIC MONITORING AND ASSESSMENT PROGRAMME

Laying the foundations for adaptation:

•Ecosystems and people face a complex, **interrelated range of impacts** from climate and other drivers

•**Integrating traditional and scientific knowledge** is vital for decision makers to produce tools and strategies for successful adaptation

•**Adaptation actions** should be better integrated into decision making

•**Education, communication** and infrastructure plays crucial roles in Arctic futures

•**Food and water security** is an important element and measure of adaptation success

•There is a need for **better links between scientists and decision-makers**. Understanding adaptation options requires an acknowledgment of barriers and limits

•Initiatives to focus on **adaptation tools** like guidelines, protocols, processes and techniques could facilitate adaptation practices

•There are **knowledge gaps** both about current and future conditions, how they might change and what the key factors of change are

From Production to Action
- a long story

Substance to Market	2-5 y
Substance to Problem	5-10 y
Market to Problem	10-20 y
Problem to Regulation	20-30 y
Regulation to Effect	5-10 y

Ramon Guardans 2010

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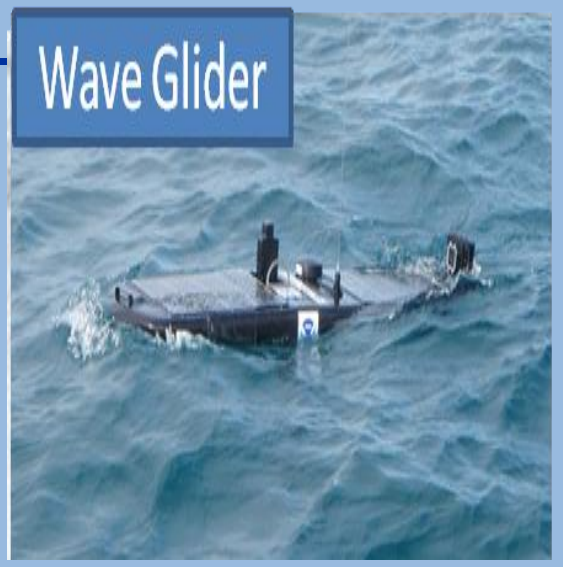
From Science to Policy:

- Radioactivity - reduce risk (1995 -)
- Food advice to Arctic peoples
- UNECE Århus protocol, PoPs & HMs (1998)
- UNEP Stockholm Convention on POPs (2001)
- UN FCCC& IPCC (AR# 4 & 5) (2004 -
- UNEP Global Mercury Minamata (2017)

Monitoring and Observation Needs

- A more comprehensive all-year network of stations in the Arctic, especially for ocean
- Drifting & moored platforms – surface & deep ocean
- Unmanned Aircrafts
- New sensors to analyze new variables in situ
- New models to respond to combined effects in the Arctic – marine and terrestrial



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Arctic – the barometer of the globe


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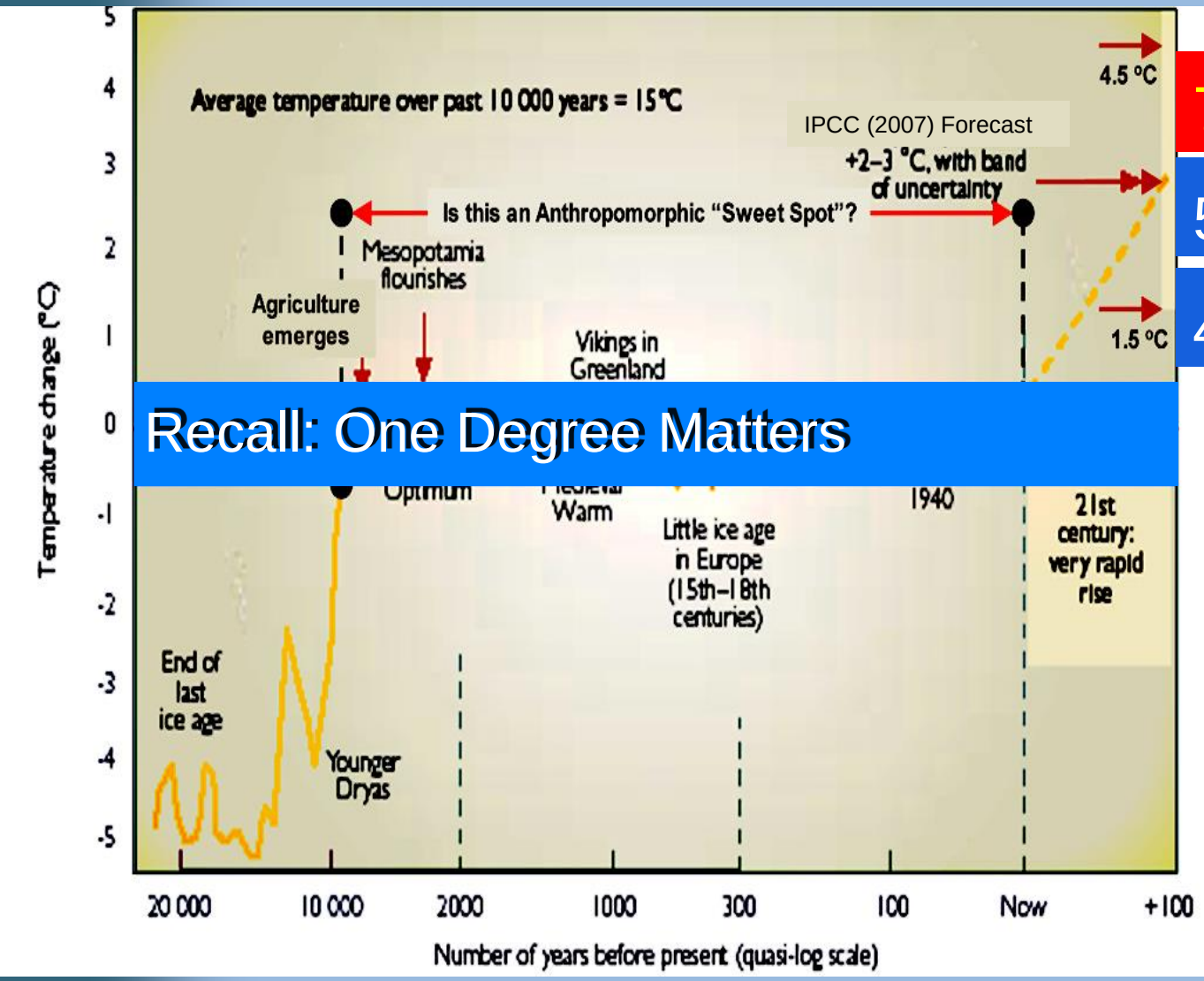
AMAP Brainstorming and Future Vision Session

September 19 - 20, 2010

Helsinki, Finland





700 ppm ~ 4 ^{0}C

550 ppm ~ 3 ^{0}C

450 ppm ~ 2 ^{0}C

Recall: One Degree Matters

There is the potential that the climate is likely, as projected by the IPCC, to take humankind where it has never been