A Changing Arctic and altered Hg Cycling

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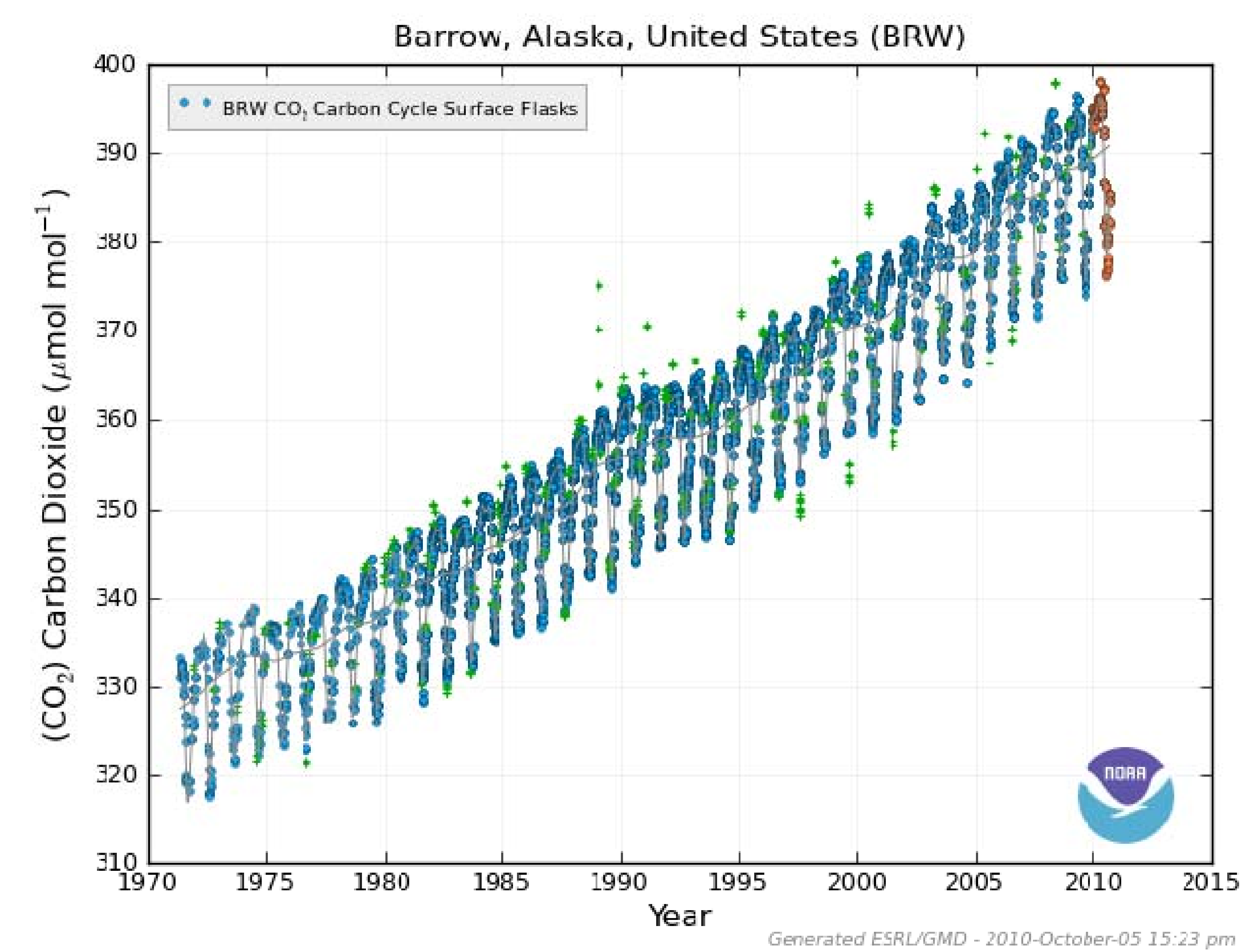
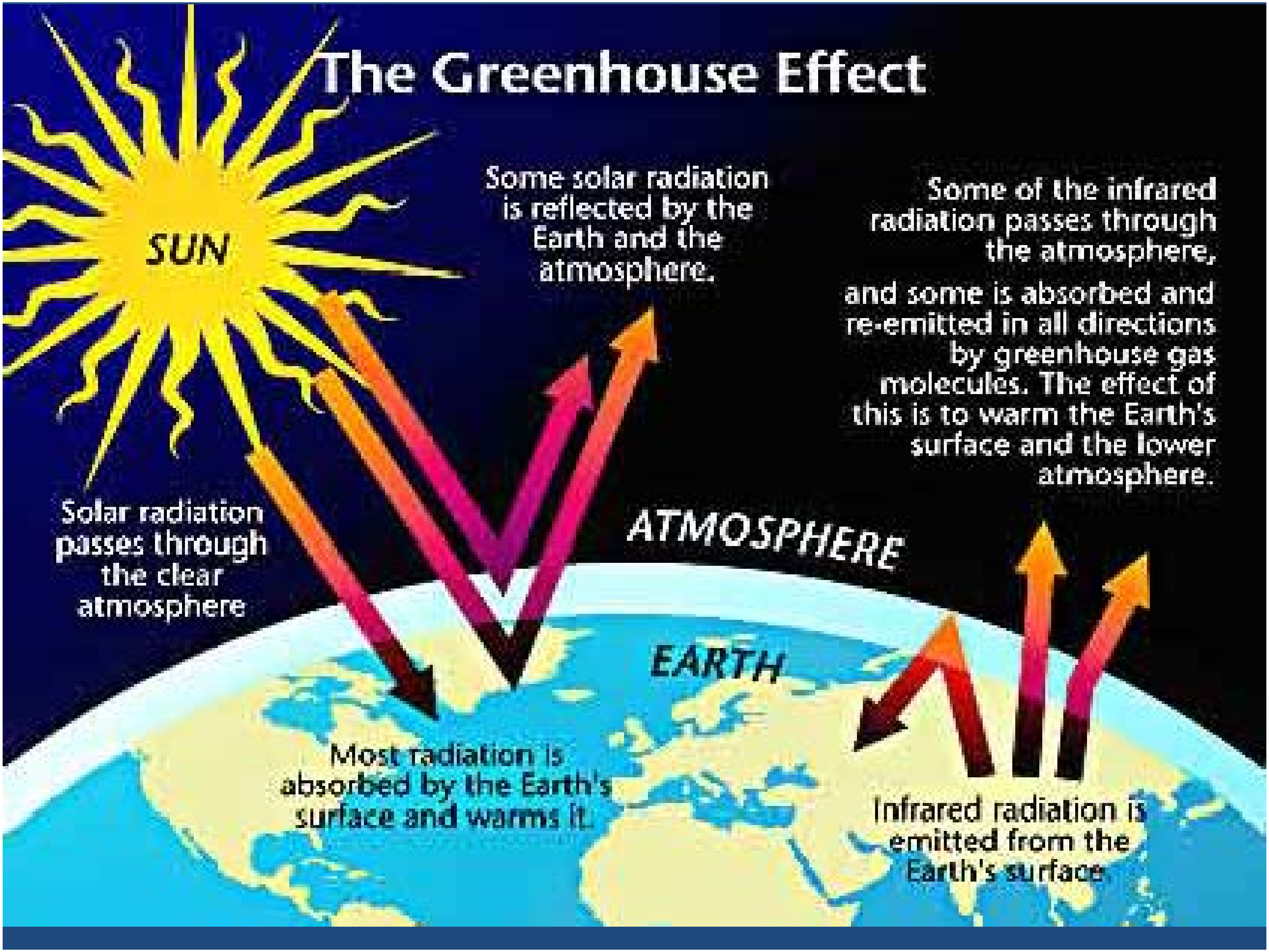
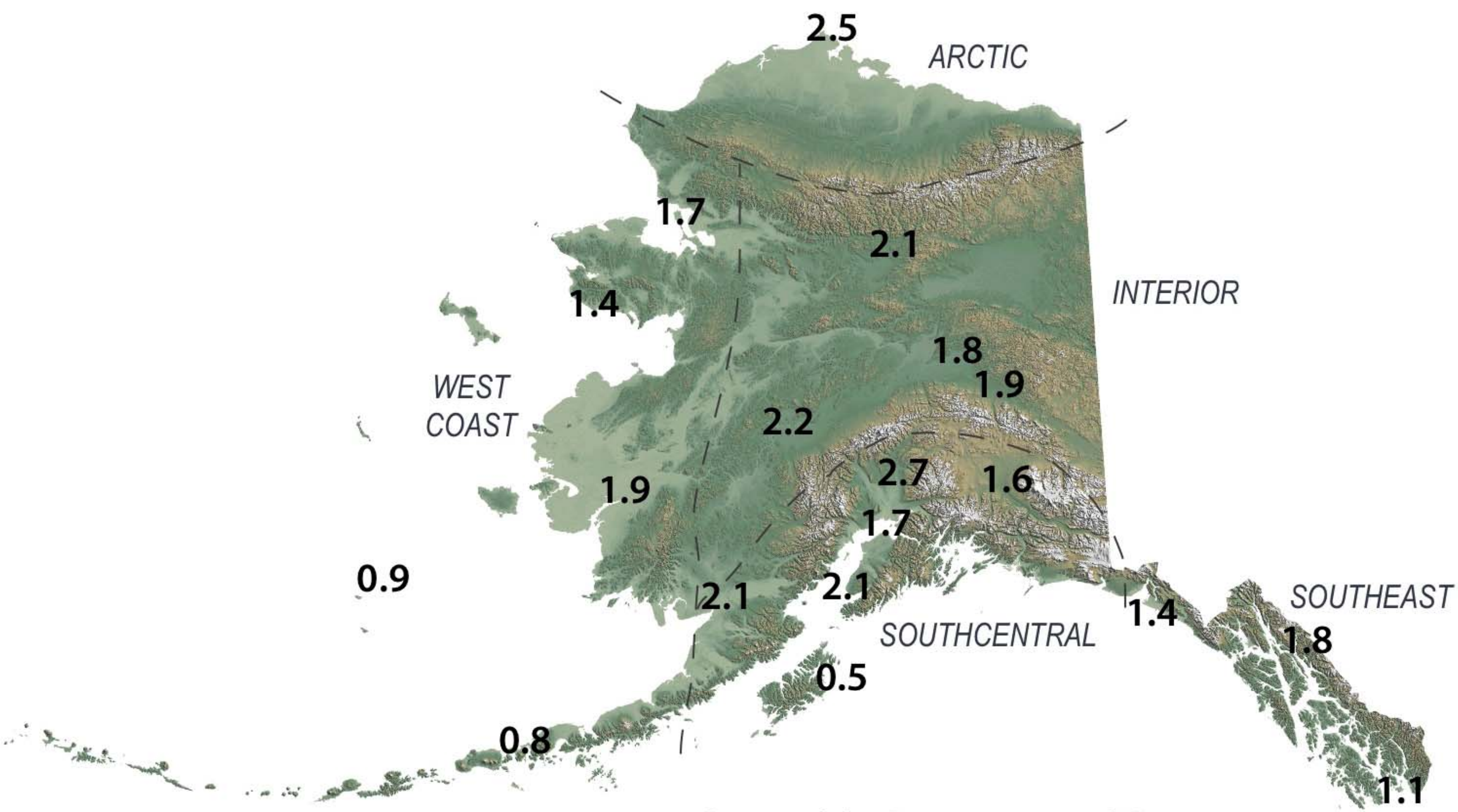
Overview

- Issues of today regarding changing climates
- What are the forms of evidence that we are in a period of change
  - Global and Arctic examples
- Mercury processes and sources in to the Arctic and Subarctic
- Food web consequences of Hg in Alaska
- Hg measuring and monitoring in the future
- Complexity in the Hg cycle in a changing environment


Barrow, Alaska, United States (BRW)
BRW CO_2 Carbon Cycle Surface Flasks
(CO_2) Carbon Dioxide (μmol mol^{-1})
Year
400
390
380
370
360
350
340
330
320
310
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
NOAA
Generated ESRL/GMD - 2010-October-05 15:23 pm


The Greenhouse Effect
SUN
Some solar radiation is reflected by the Earth and the atmosphere.
Some of the infrared radiation passes through the atmosphere,
and some is absorbed and re-emitted in all directions by greenhouse gas molecules. The effect of this is to warm the Earth's surface and the lower atmosphere.
Solar radiation passes through the clear atmosphere
ATMOSPHERE
EARTH
Most radiation is absorbed by the Earth's surface and warms it.
Infrared radiation is emitted from the Earth's surface.

Total Change in Mean Annual Temperature (°C), 1949 - 2009



Statewide Average: 1.7°C

Alaska Climate Research Center

Geophysical Institute, University of Alaska Fairbanks

Total Change in Mean Seasonal and Annual Temperature (°F), 1949 - 2009

Region	Location	Winter	Spring	Summer	Autumn	Annual
Arctic	Barrow	6.7	4.5	3.0	3.7	4.5
Interior	Bettles	8.1	4.3	1.8	1.1	3.8
	Big Delta	8.9	3.4	1.2	0.0	3.4
	Fairbanks	7.4	3.6	2.3	-0.2	3.3
	McGrath	7.4	4.6	2.7	0.8	3.9
West Coast	Kotzebue	6.3	1.8	2.6	1.4	3.1
	Nome	4.2	3.3	2.5	0.4	2.6
	Bethel	6.6	4.8	2.3	0.0	3.5
	King Salmon	7.9	4.5	1.7	0.6	3.7
	Cold Bay	1.5	1.6	1.7	0.8	1.4
	St Paul	0.8	2.1	2.6	1.1	1.6
Southcentral	Anchorage	5.8	3.3	1.6	1.5	3.0
	Talkeetna	8.4	5.2	3.1	2.4	4.9
	Gulkana	7.7	2.4	1.0	0.1	2.8
	Homer	5.9	3.8	3.3	1.8	3.8
	Kodiak	0.7	2.1	1.2	-0.4	0.9
Southeast	Yakutat	4.6	2.8	1.8	0.4	2.5
	Juneau	6.2	2.9	2.2	1.4	3.2
	Annette	3.4	2.3	1.8	0.3	2.0
	Average	5.7	3.3	2.1	0.9	3.0

Permafrost temperatures are warming

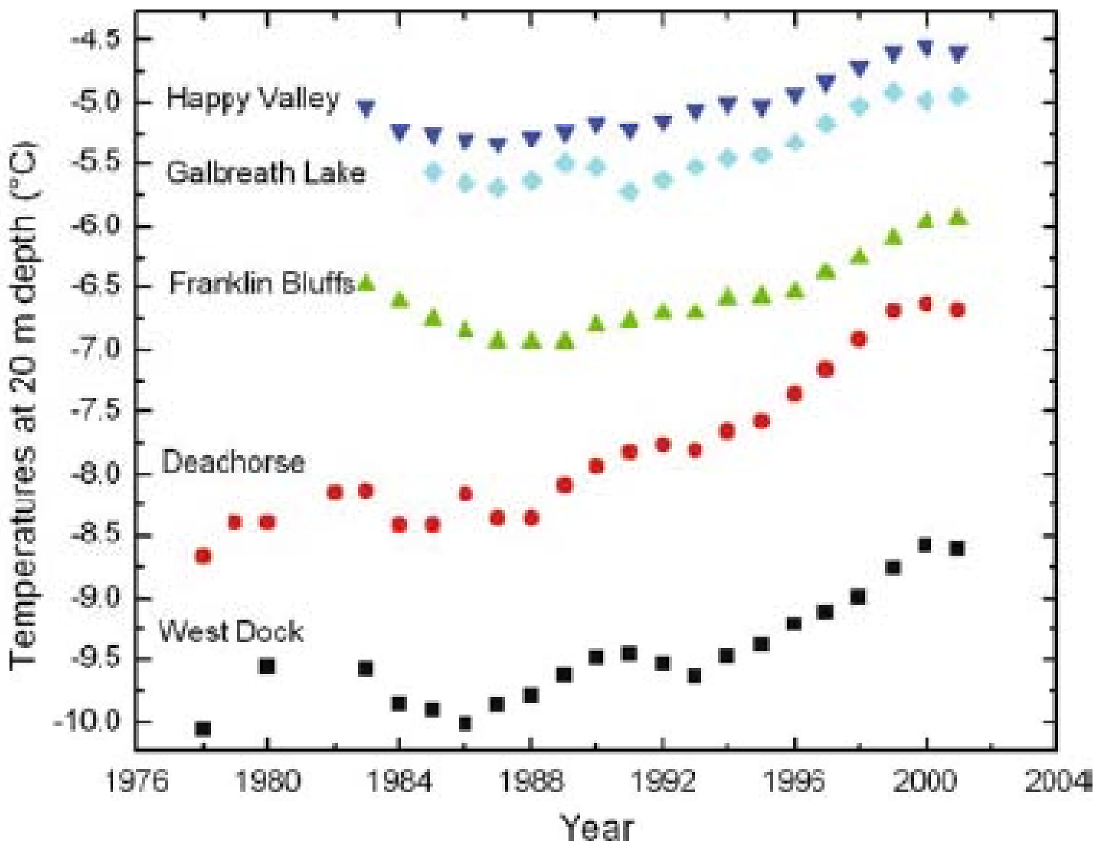


Figure 5. Temperatures measured at the 20 m depth in boreholes in permafrost on the North Slope of Alaska display broad scale warming over recent decades (Osterkamp, 2003).

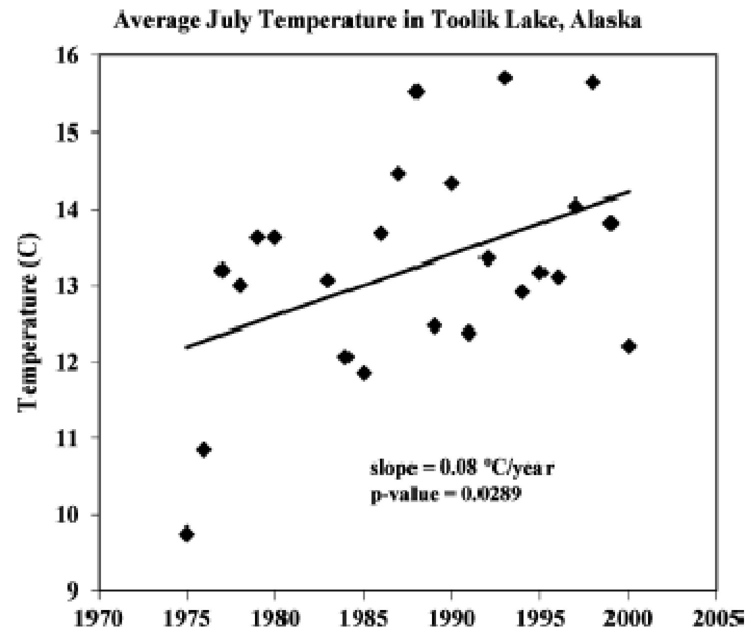
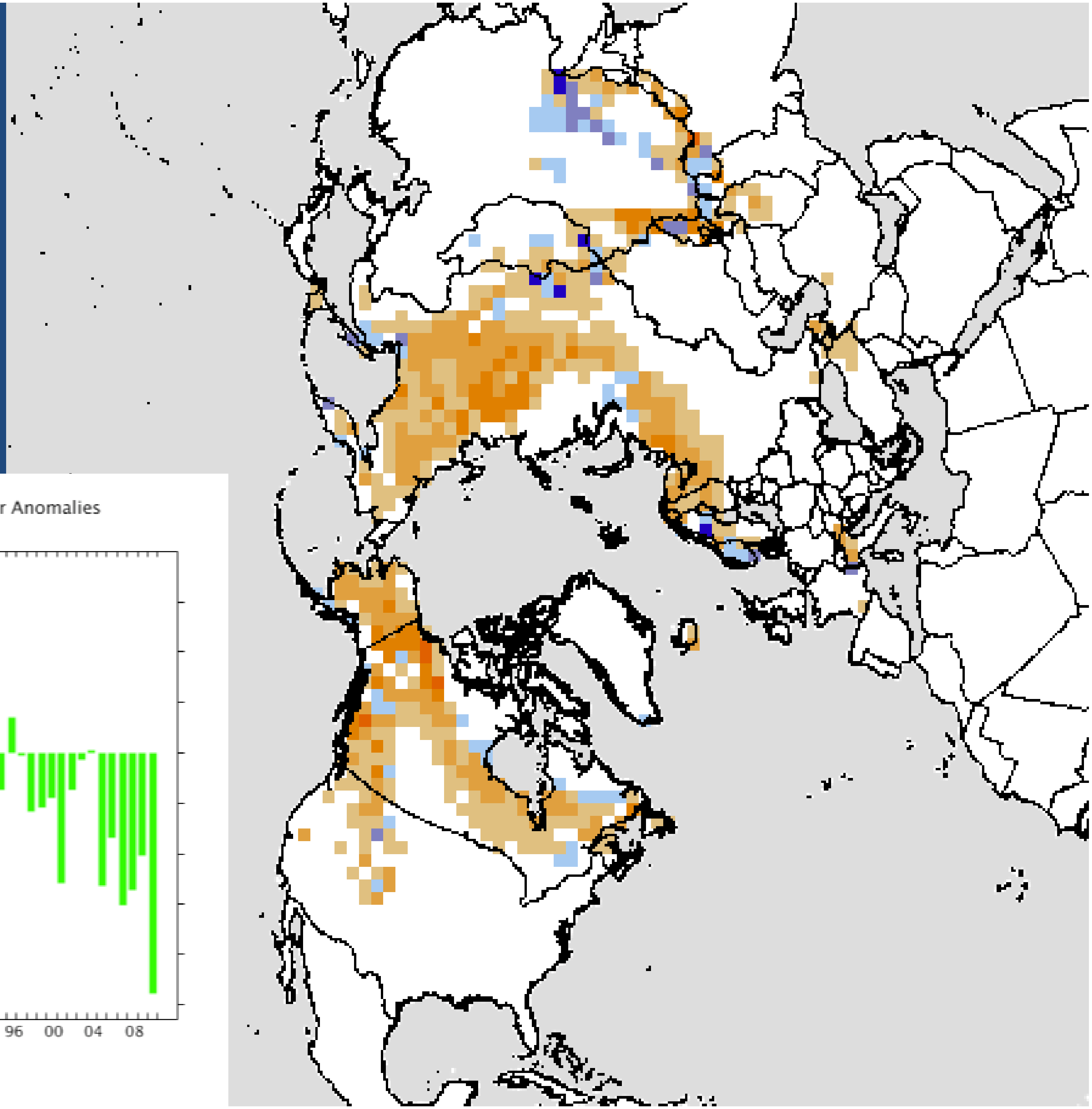
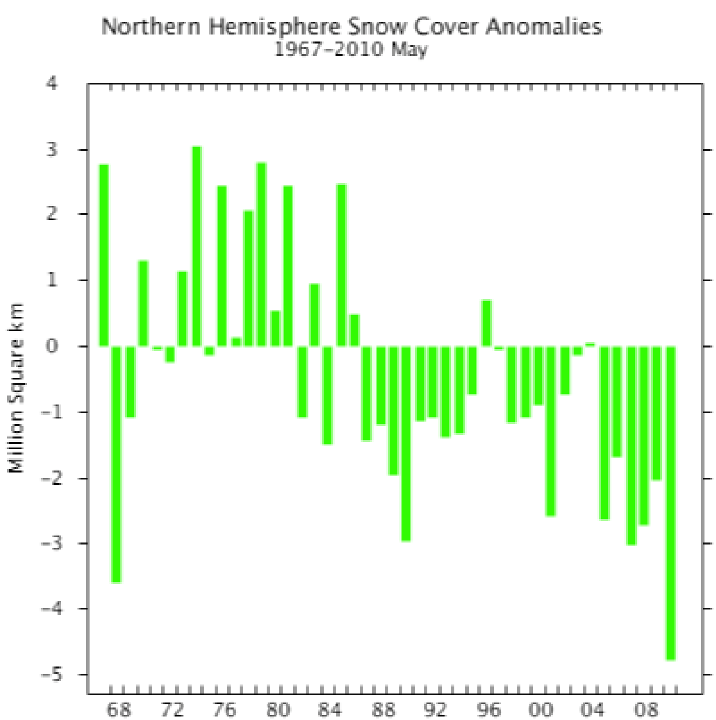


Figure 7. The average water temperature during July at 1 m depth in Toolik Lake displays an increasing trend from 1975 to 2001 (missing data 1981 and 1982). Recent years display a cooling trend, probably related to colder air temperatures and a thinner snow cover in those years.

Northern AK warming is occurring at Toolik Lake

The figure shows that the negative snow cover was wide spread in 2010. Brown is below normal





Alaska's water resources are projected to decline as evaporation exceeds precipitation

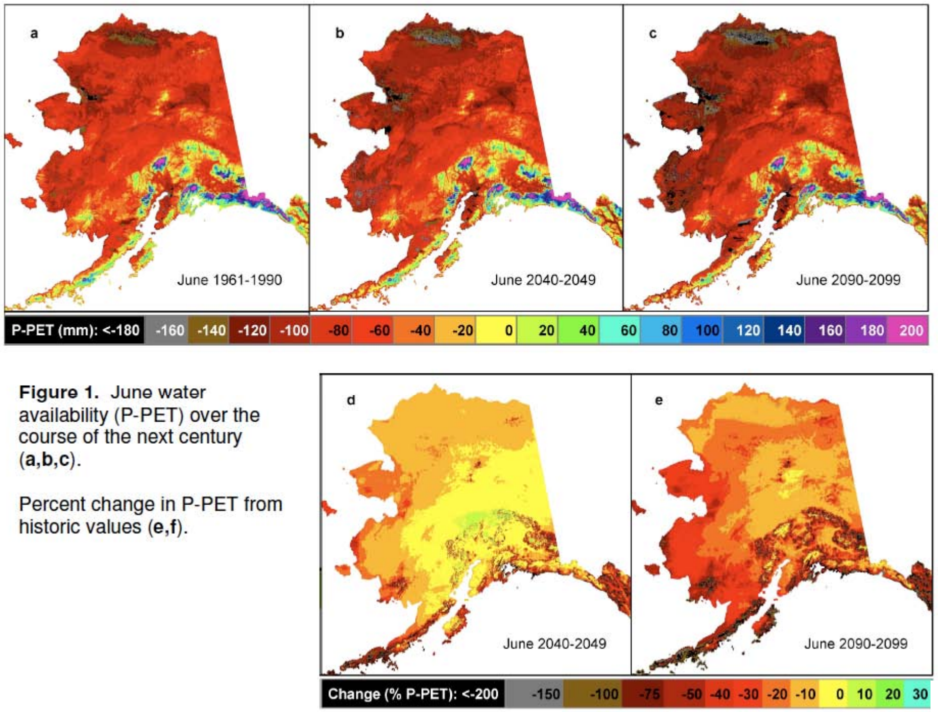


Figure 1. June water availability (P-PET) over the course of the next century (**a**,**b**,**c**).

Percent change in P-PET from historic values (**e**,**f**).

Water loss from the land surface increases across the state as spring and fall are warming, spring arrives earlier and fall lasts longer

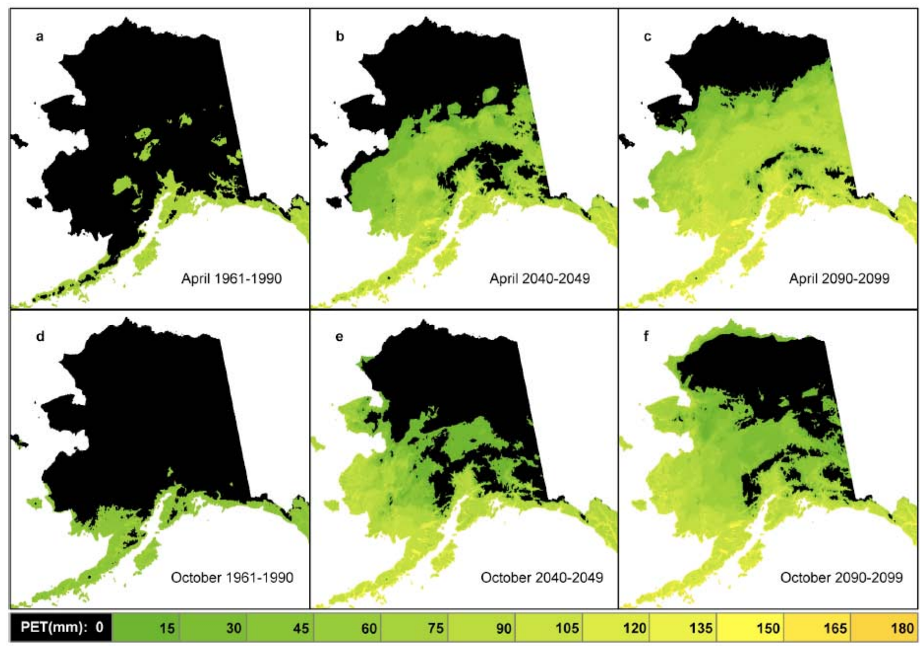
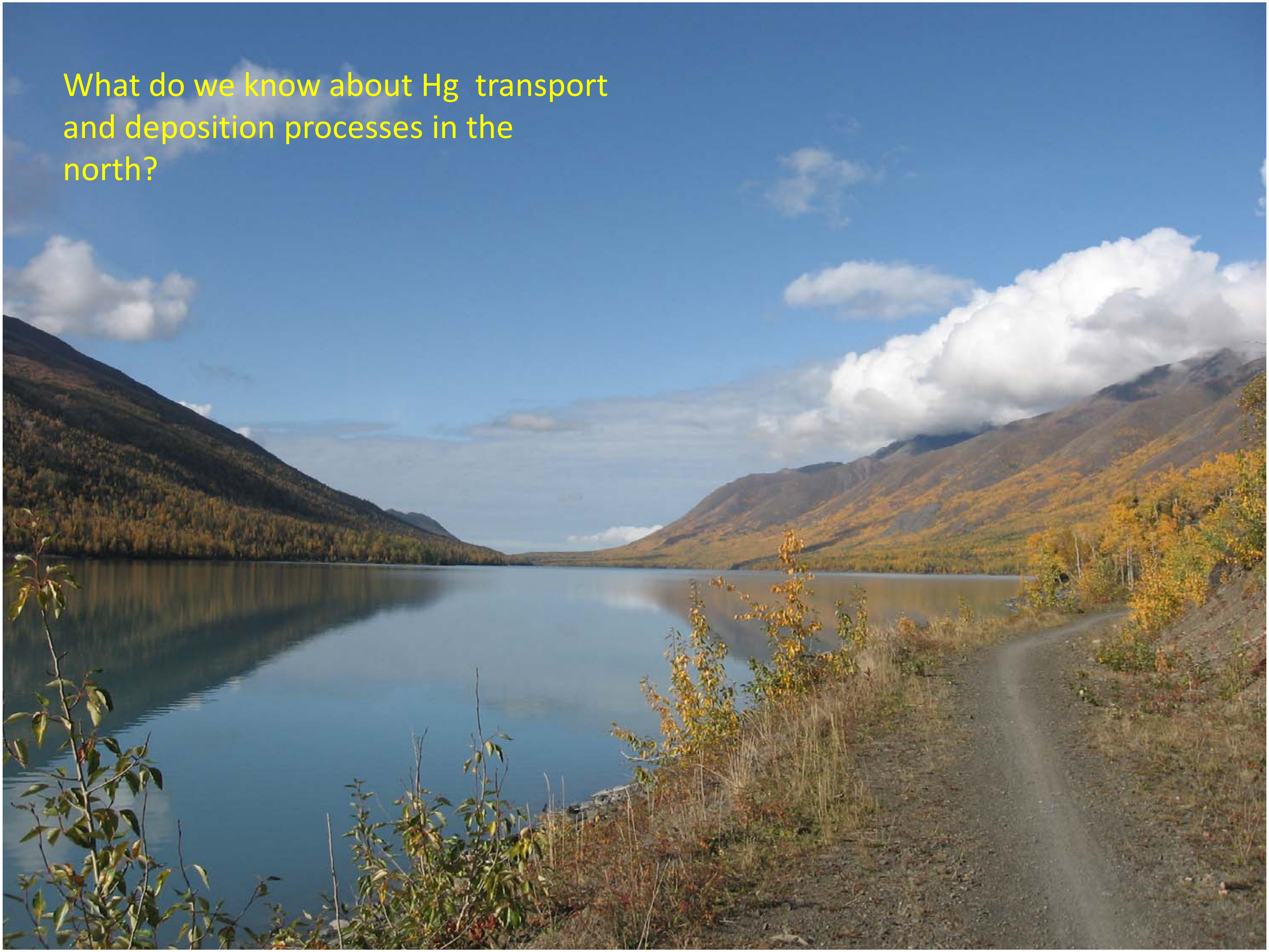


Figure 2. Historical and future estimates of PET during April (**a**,**b**,**c**) and October (**d**,**e**,**f**). Changes from black (PET=0) to color represent the activation of PET in the future as the growing season becomes longer.

What do we know about Hg transport and deposition processes in the north?



Long range transport of mercury to the Arctic and across Canada

D. Durnford, A. Dastoor, D. Figueras-Nieto, and A. Ryjkov

Air Quality Research Division, Environment Canada, 2121 TransCanada Highway, Dorval,

Atmos. Chem. Phys. Discuss., 10, 4673–4717, 2010
www.atmos-chem-phys-discuss.net/10/4673/2010/

Atmospheric Chemistry and Physics Discussions

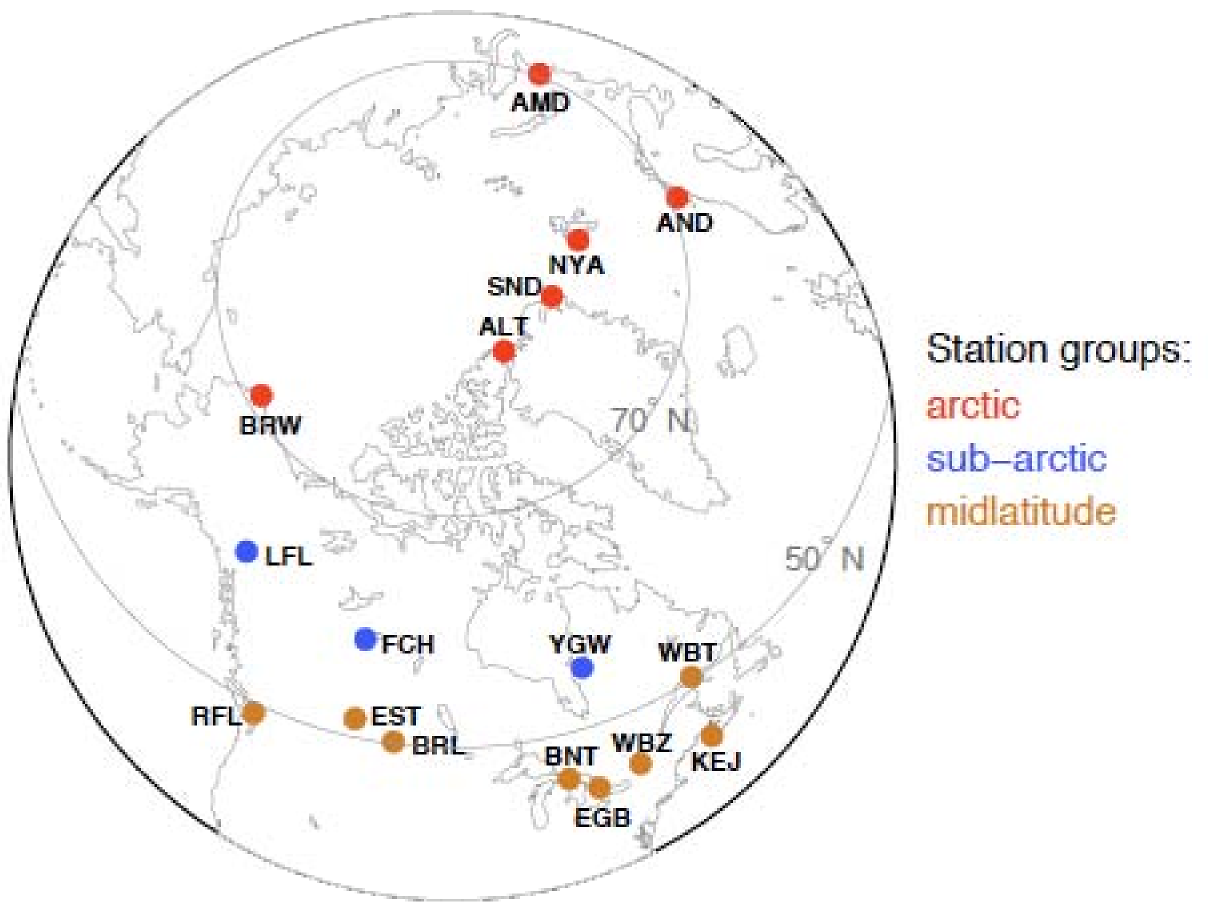


Fig. 1. Locations of verification stations. See Tables 1–3 for station names.

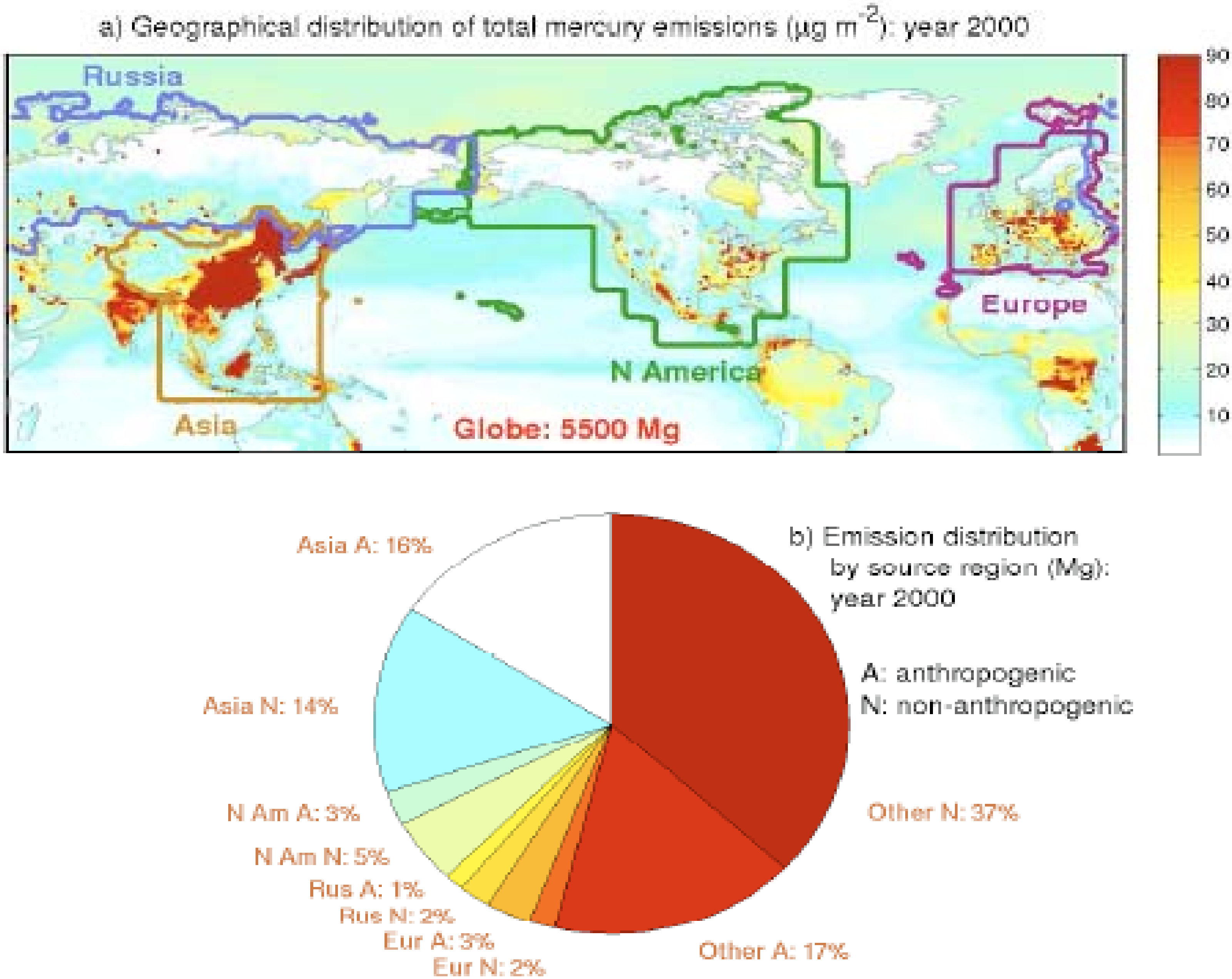


Fig. 2. Total mercury emissions for the study's four source regions and for the globe.

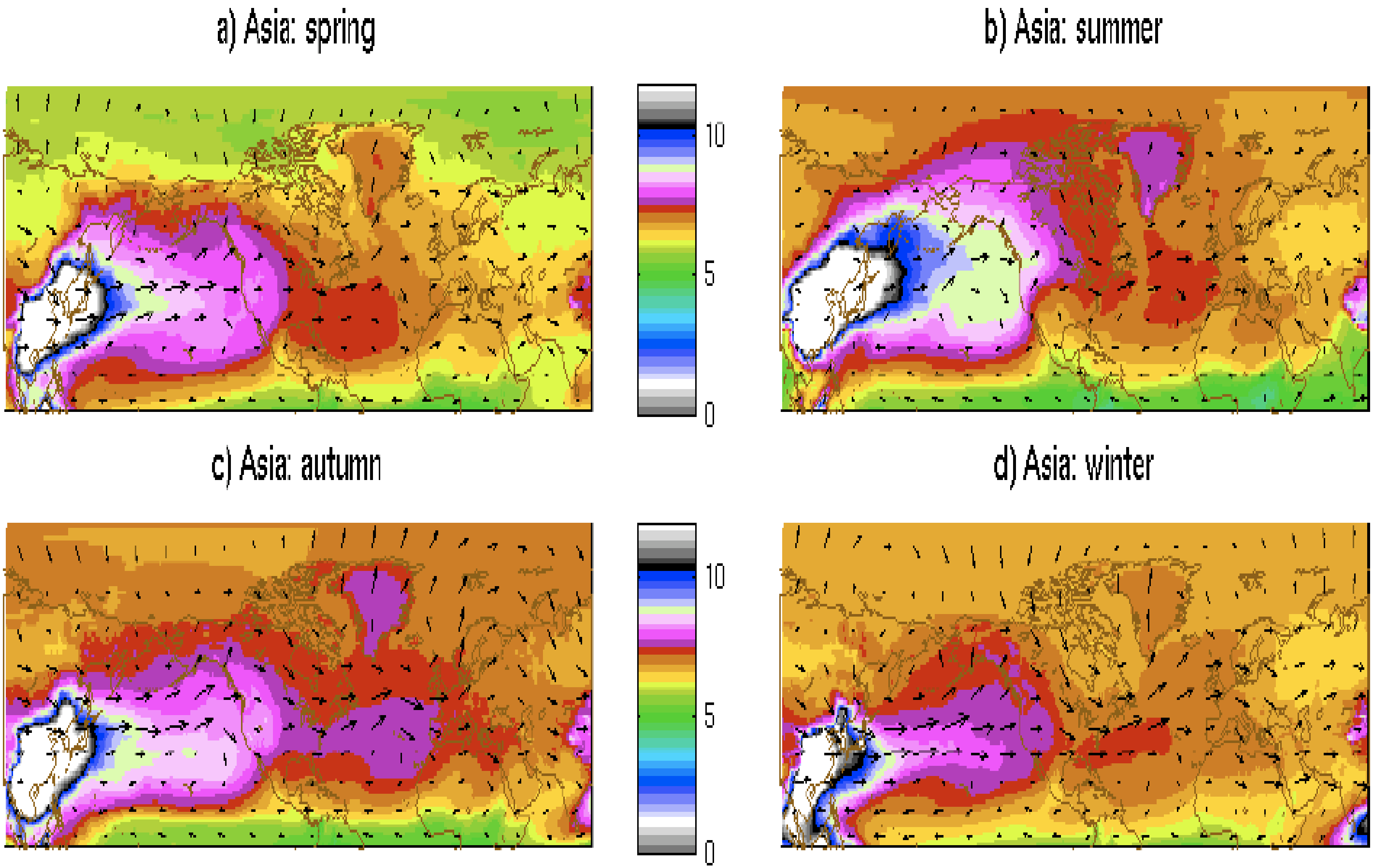
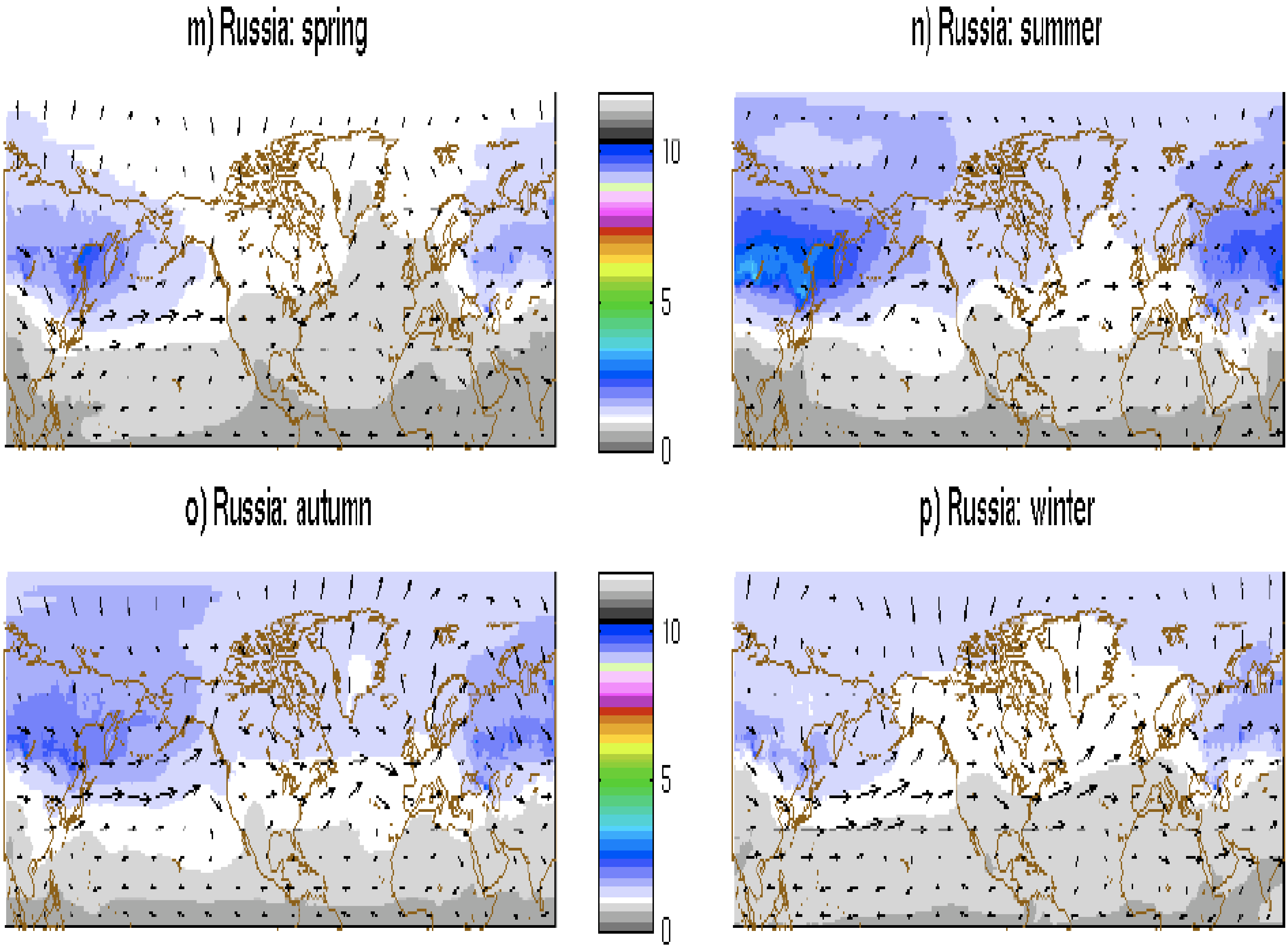
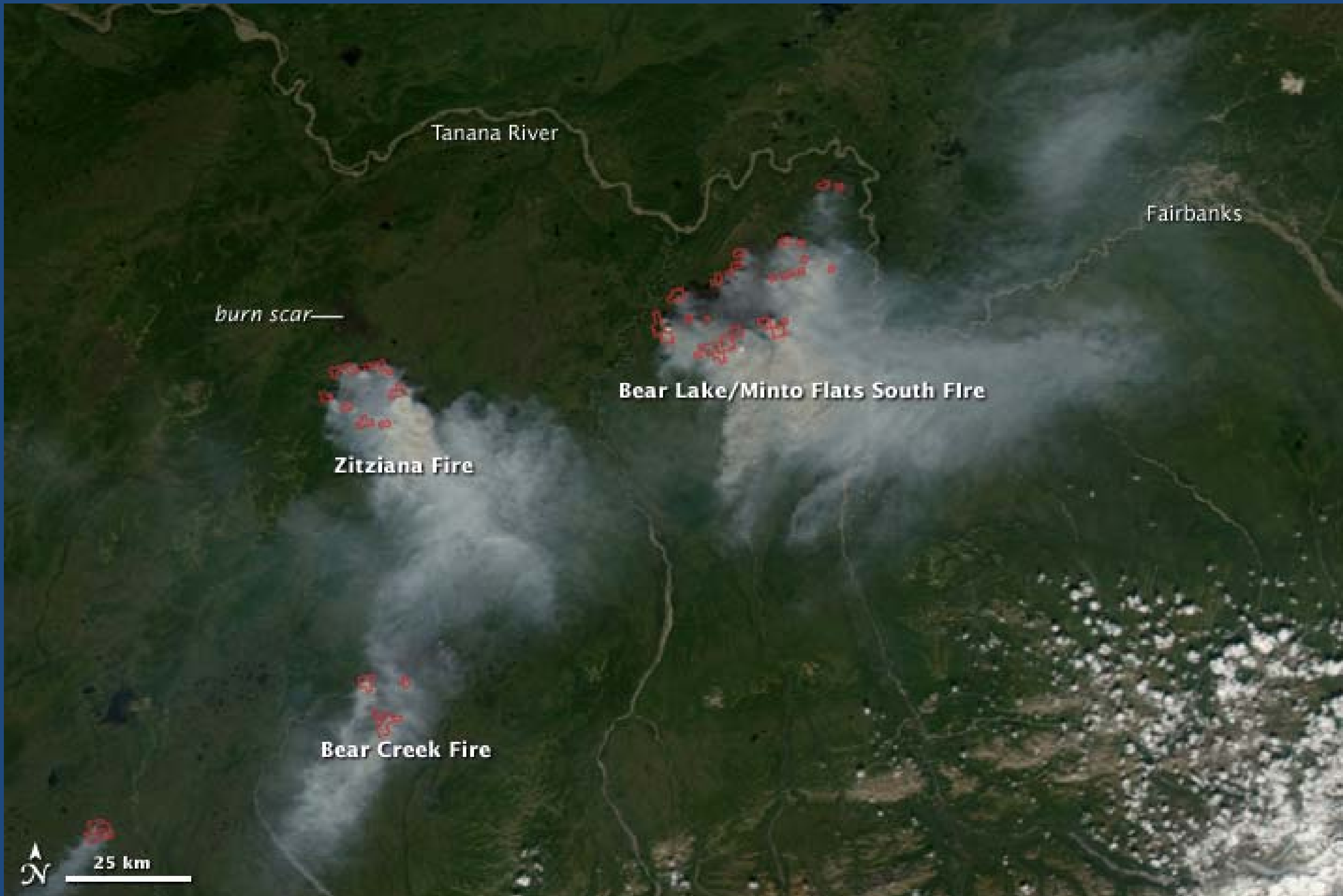


Fig. 7. Plotted for each source region and season for the year 2000 are: i) the GEM column burden (ng m^{-3}) from the surface to 516 sigma (≈523 hPa; shading interval of 0.3 ng m^{-3}), and ii) average wind directions and relative strengths calculated using winds from 925 to 400 hPa.


m) Russia: spring
n) Russia: summer
o) Russia: autumn
p) Russia: winter
10
5
0
10
5
0

Natural events can also be contributors to Hg deposition


Tanana River
Fairbanks
burn scar
Bear Lake/Minto Flats South Fire
Zitziana Fire
Bear Creek Fire
N
25 km

Mt Bachelor Observatory-Jaffee et al. University of Washington

Mt. Bachelor Observatory-Jaffee et al. University of Washington

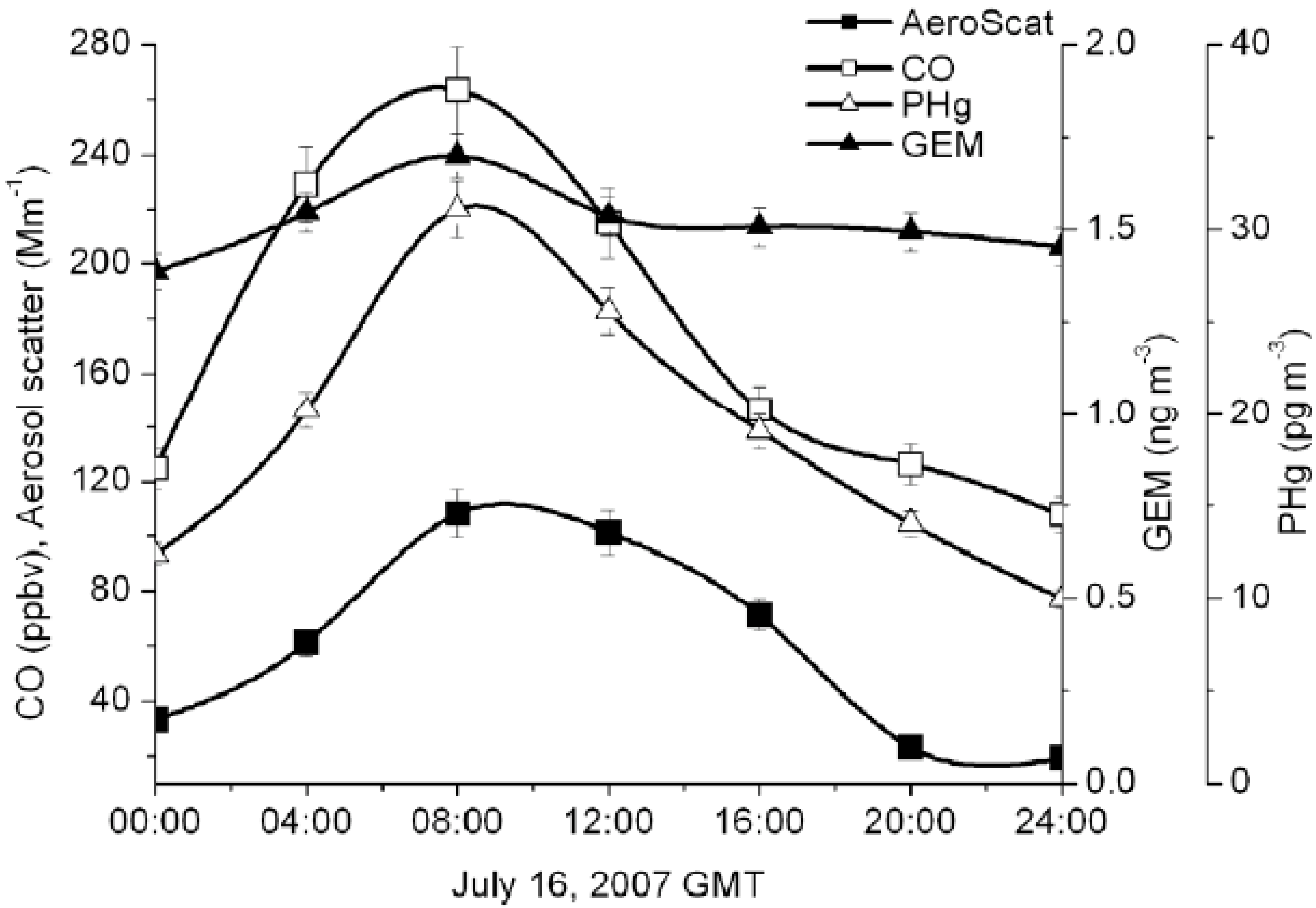


Figure 1: PHg, CO, σ_{sp}, and GEM during the PHg event on July 16, 2007 (top). PHg, CO, and σ_{sp} are well correlated. GEM is enhanced during this event and the GEM/CO ratio (0.0014 ng m^{-3} ppbv^{-1}) is consistent with biomass burning. Slopes and correlation coefficients are shown for PHg/CO (center) and PHg/σ_{sp} (bottom).

4

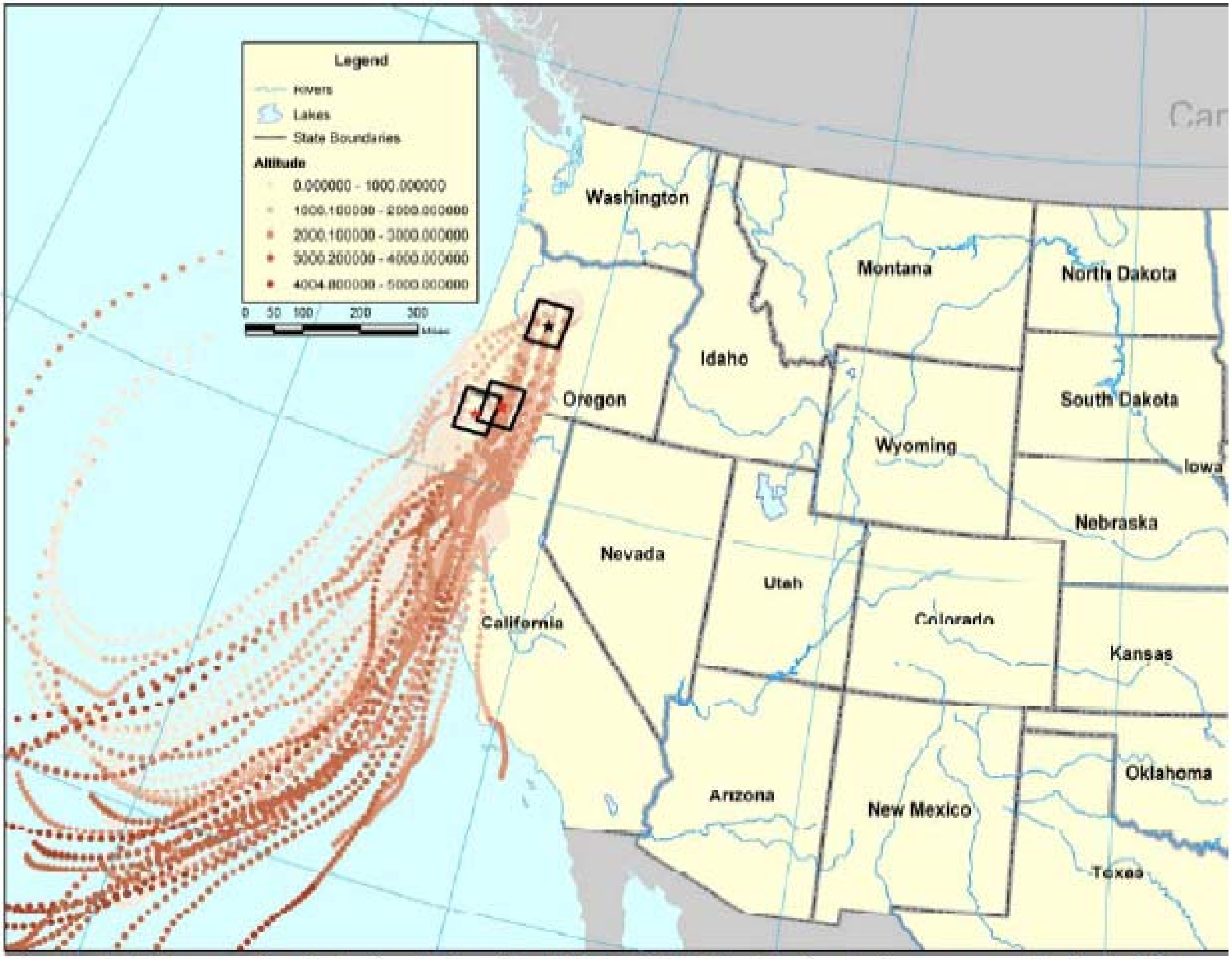
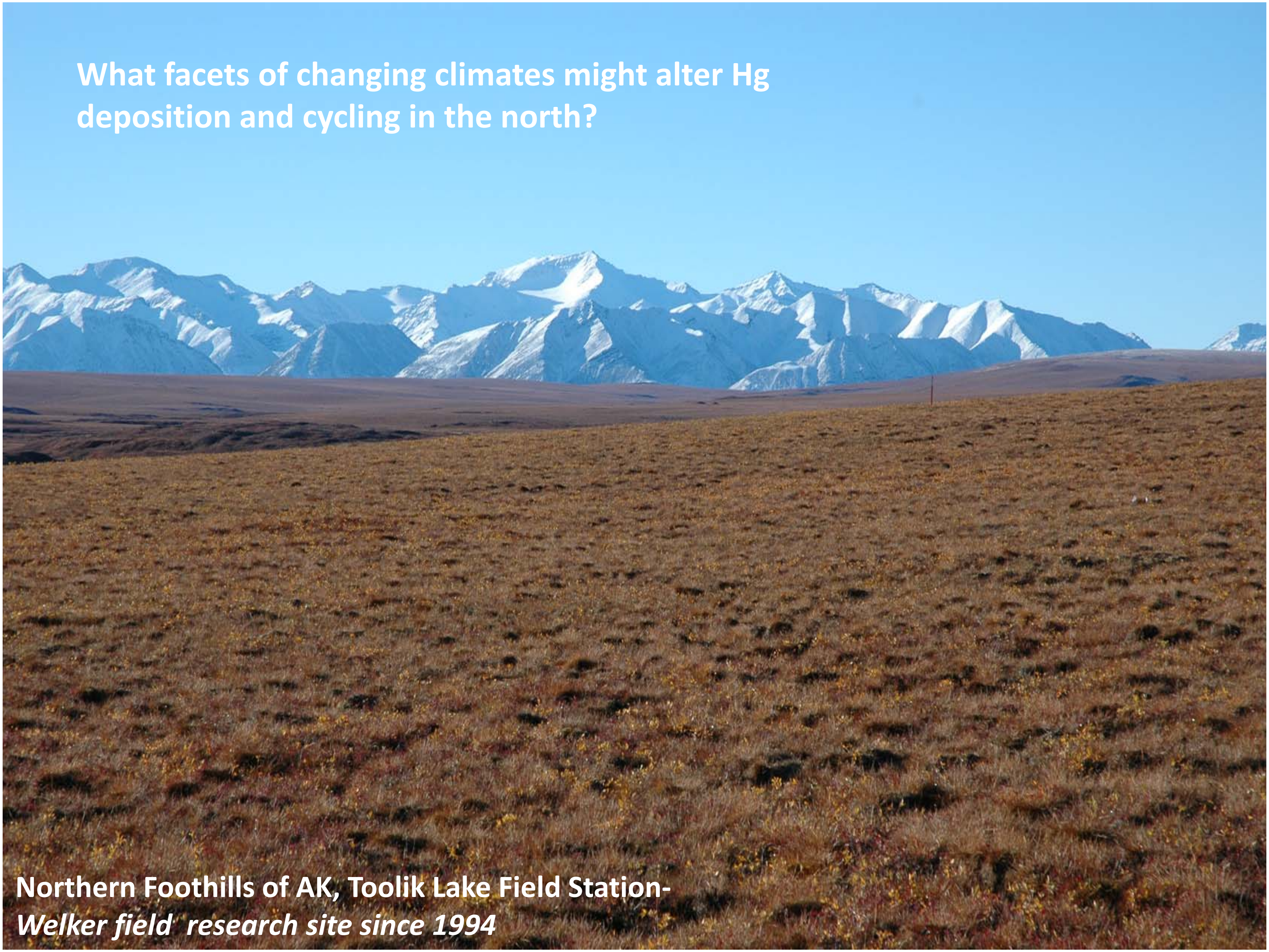
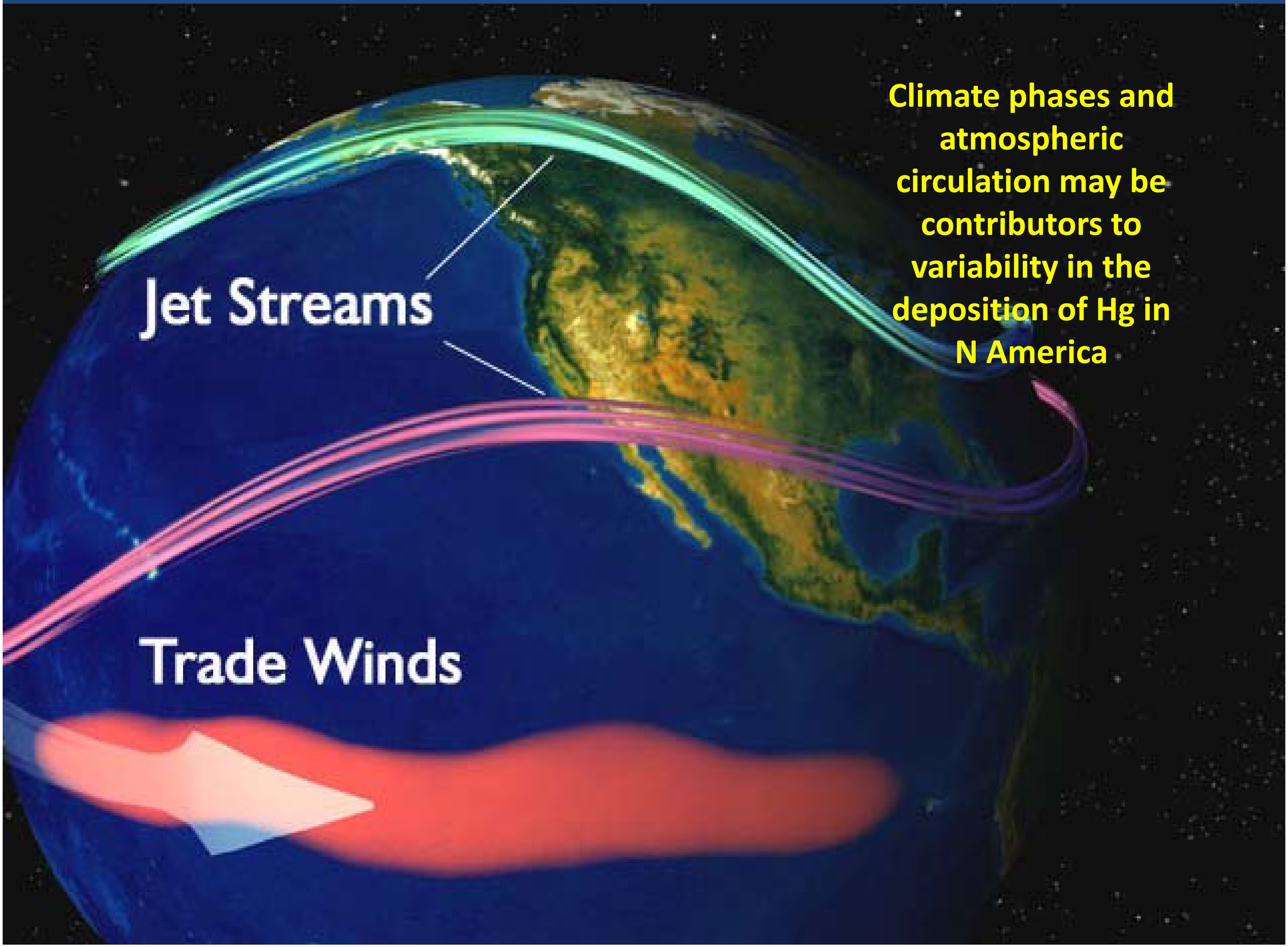
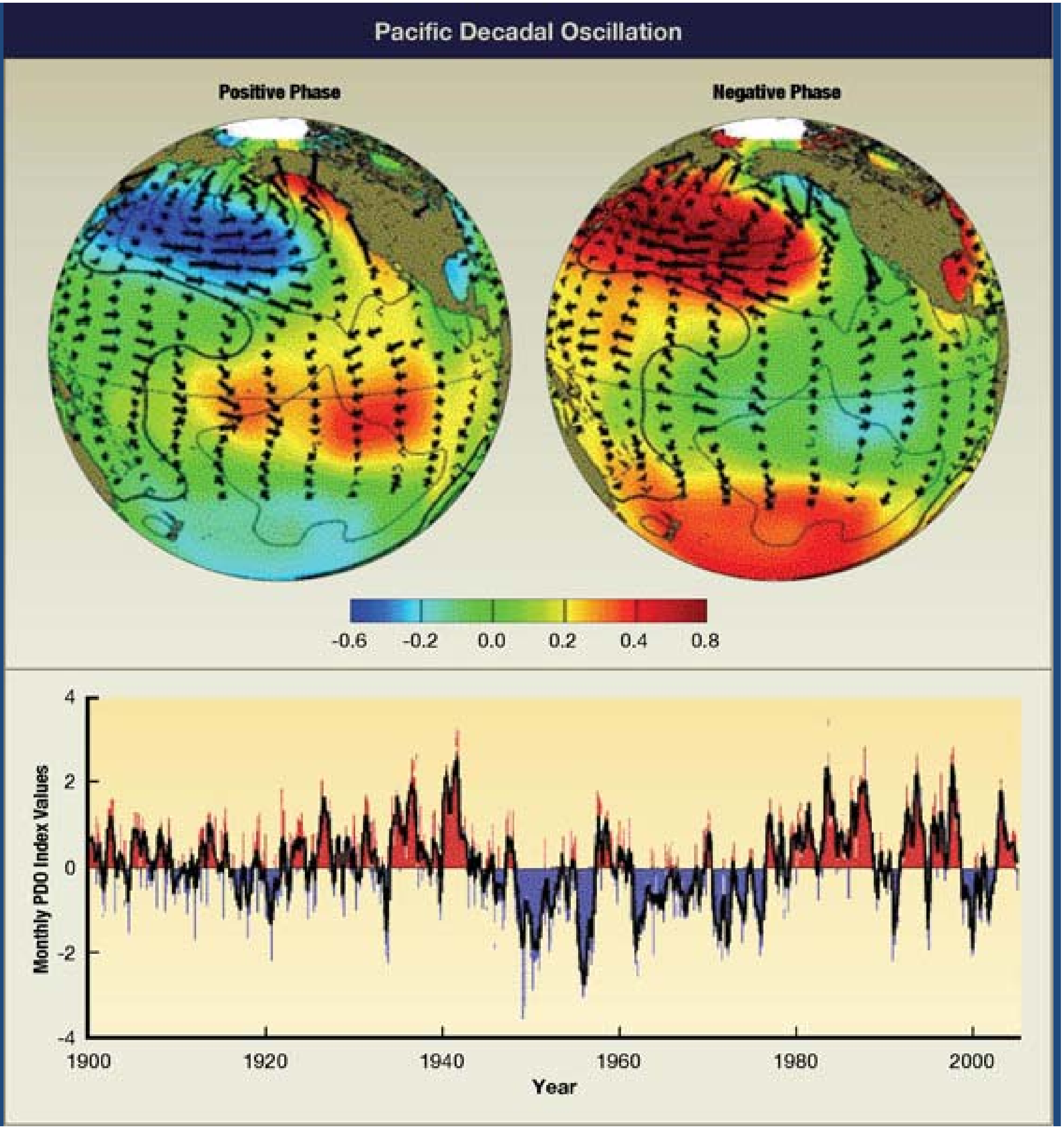


Figure 2: Air mass back-trajectories for July 16, 2007. Trajectories were calculated for the time of peak PHg concentration (0800 GMT) at five vertical heights. The black star is the Mt. Bachelor Observatory and the red stars are wildfires. The black boxes are 1°x1° and are centered on MBO and the fires. Air sampled at this time was significantly influenced by these two fires.

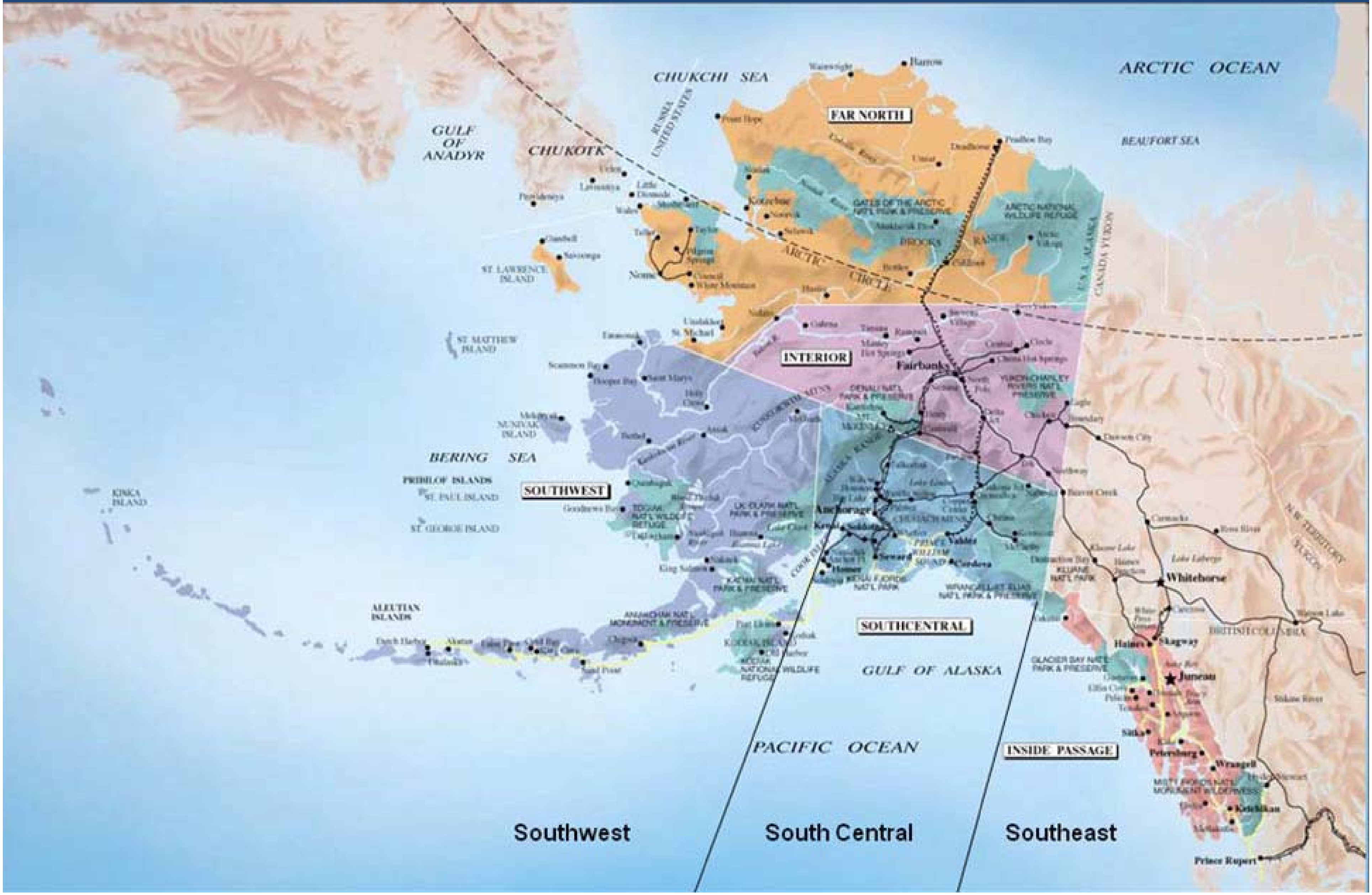

What facets of changing climates might alter Hg deposition and cycling in the north?
Northern Foothills of AK, Toolik Lake Field Station-
Welker field research site since 1994


Climate phases and atmospheric circulation may be contributors to variability in the deposition of Hg in N America
Jet Streams
Trade Winds

Pacific Ocean currents change patterns on decadal time periods which shifts the sources of moisture for the US and the temperatures of those moisture sources. Collectively these oscillations may explain in part the long-term patterns in the Hg in precipitation in the US.



Changing conditions in Alaska that have consequences for Hg cycling



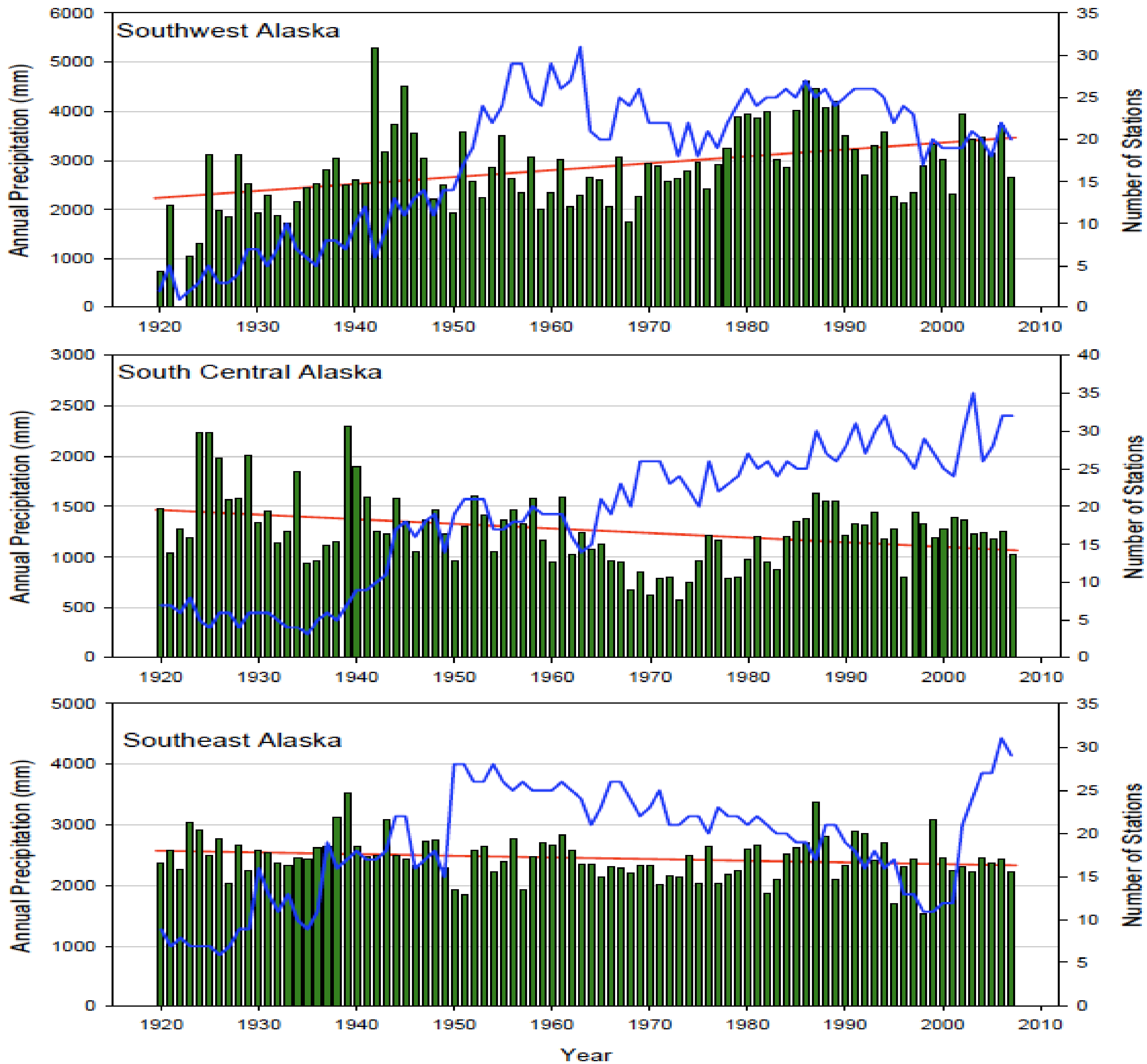


Figure 2. Annual precipitation for three southern coastal regions of Alaska based on GHCN-Daily data: Southwest (t
South Central (middle), and Southeast (bottom). Red line denotes linear regression for each time series and blue
denotes number of stations used in the analysis for each region.

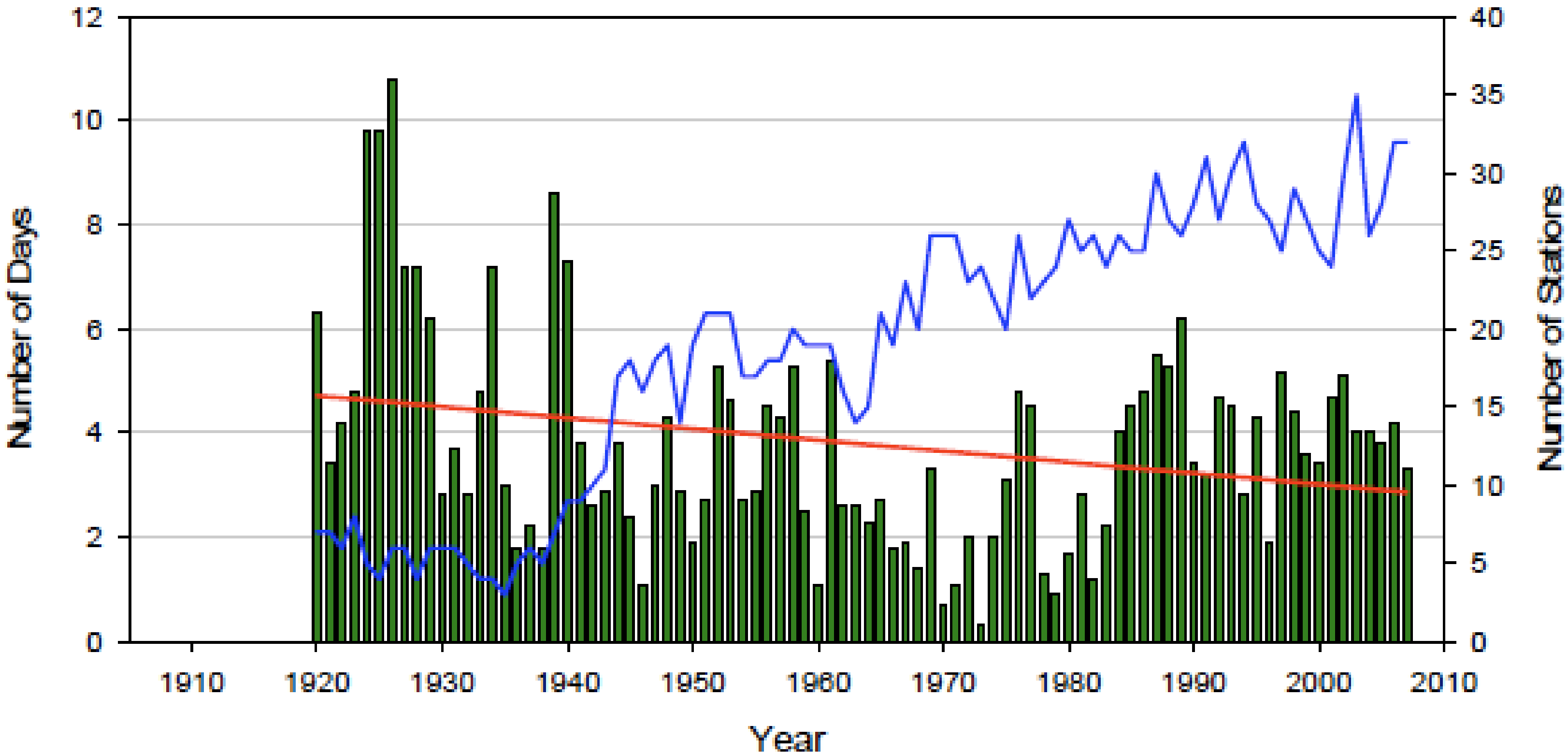
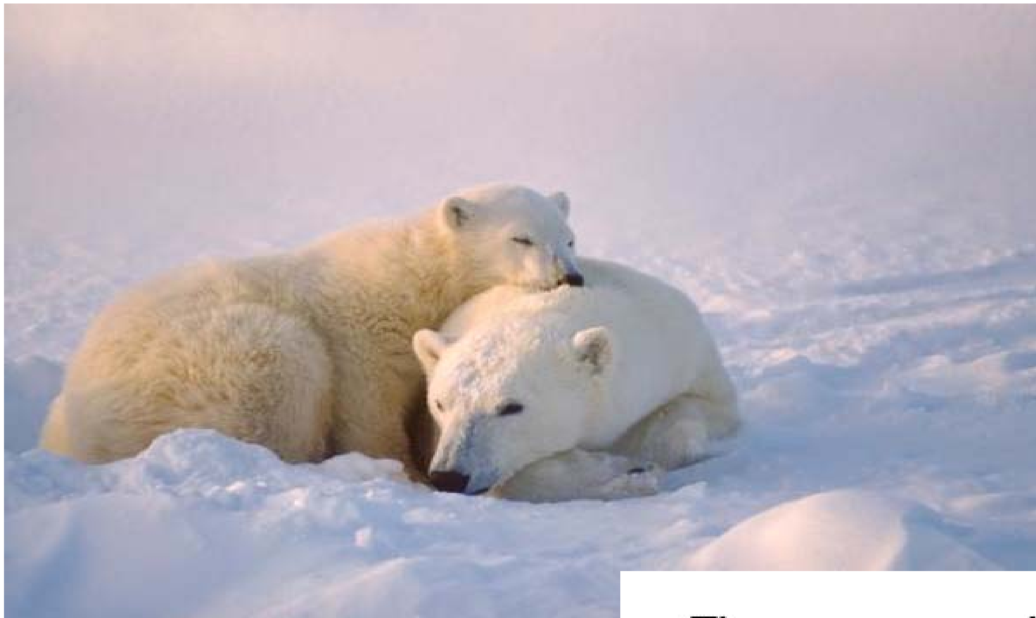
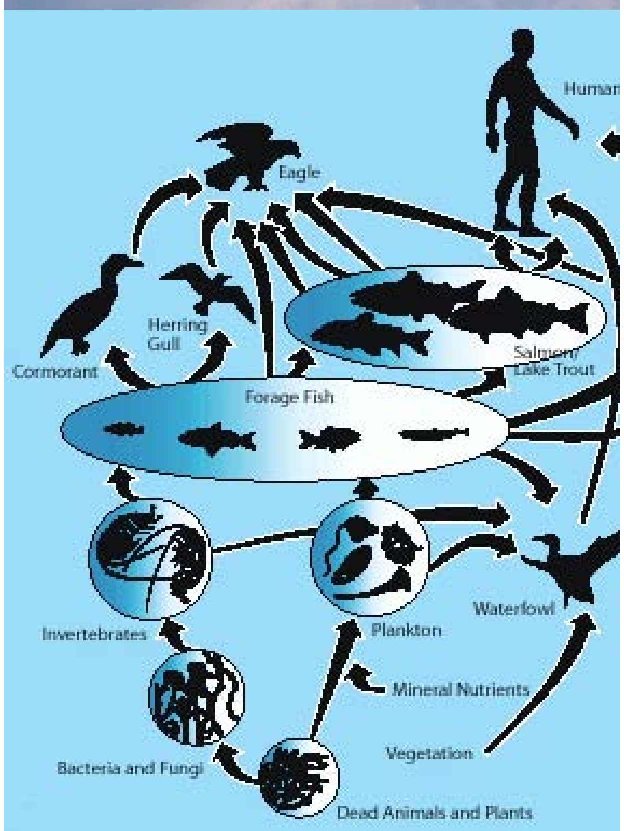


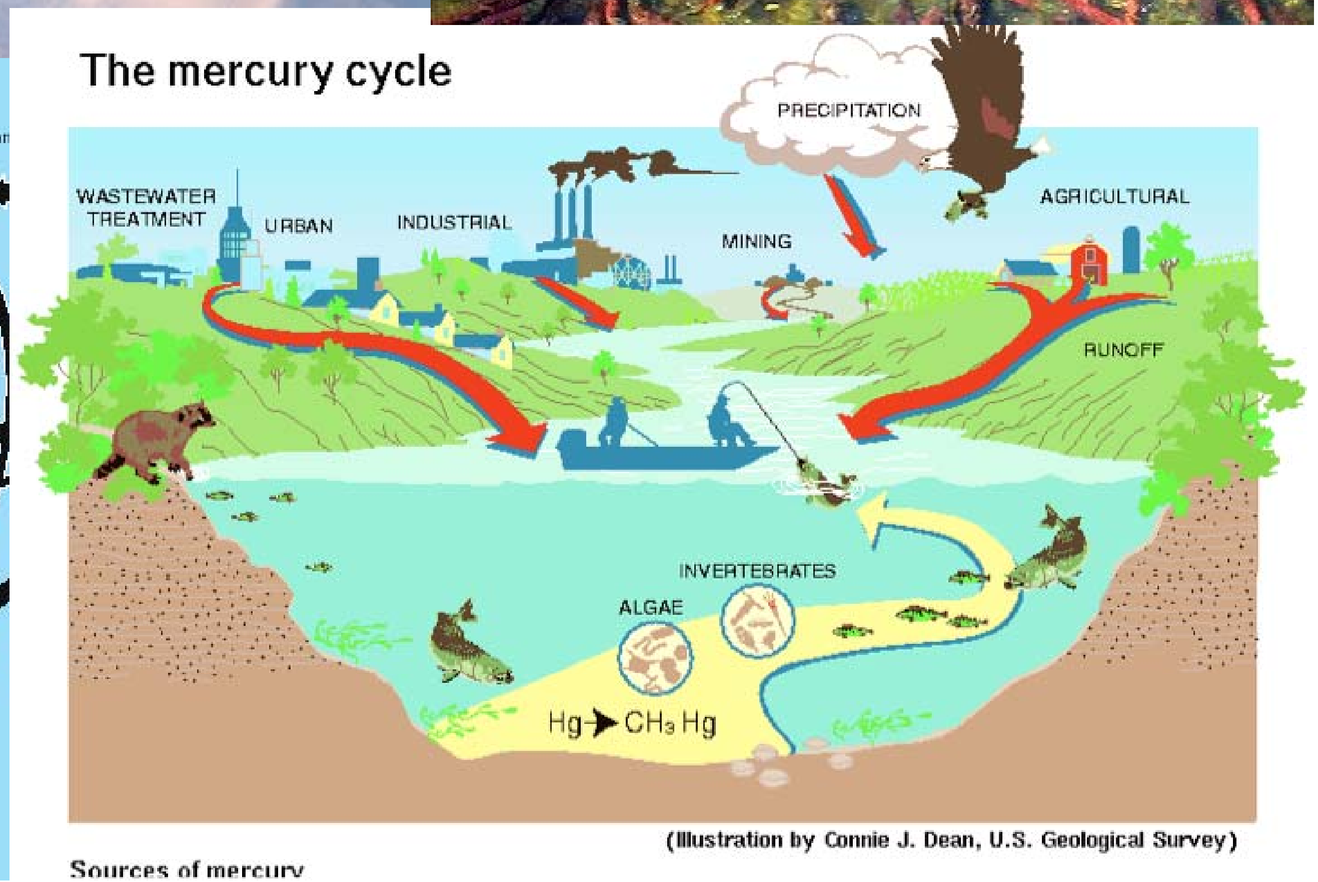
Figure 4. Precipitation indices for South-Central Alaska based on GHCN-Daily data. Top panel: SDII, middle panel: annual number of days with >10 mm of rain, and bottom panel: annual number of days with >50 mm of rain. Red line denotes linear regression, and blue line denotes number of stations used in the analysis.

Large precipitation events are declining in SC and SE AK


Food Webs and Hg in the North



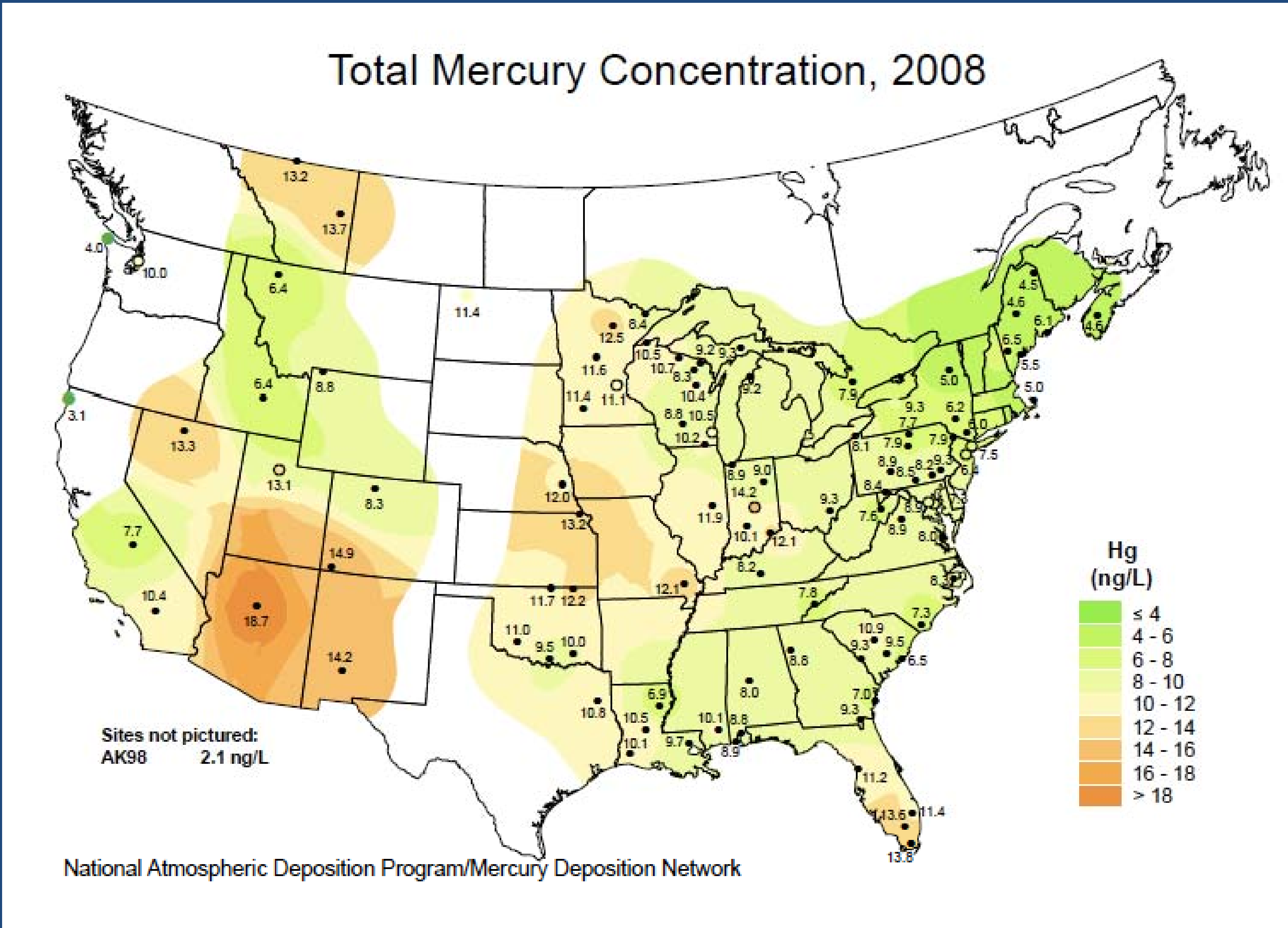

Eagle
Herring Gull
Cormorant
Salmon/Lake Trout
Forage Fish
Invertebrates
Plankton
Waterfowl
Mineral Nutrients
Vegetation
Bacteria and Fungi
Dead Animals and Plants


The mercury cycle
PRECIPITATION
WASTEWATER TREATMENT
URBAN
INDUSTRIAL
MINING
AGRICULTURAL
RUNOFF
INVERTEBRATES
ALGAE
Hg → CH_3 Hg
(Illustration by Connie J. Dean, U.S. Geological Survey)

Monitoring and measuring Hg inputs into US landscapes

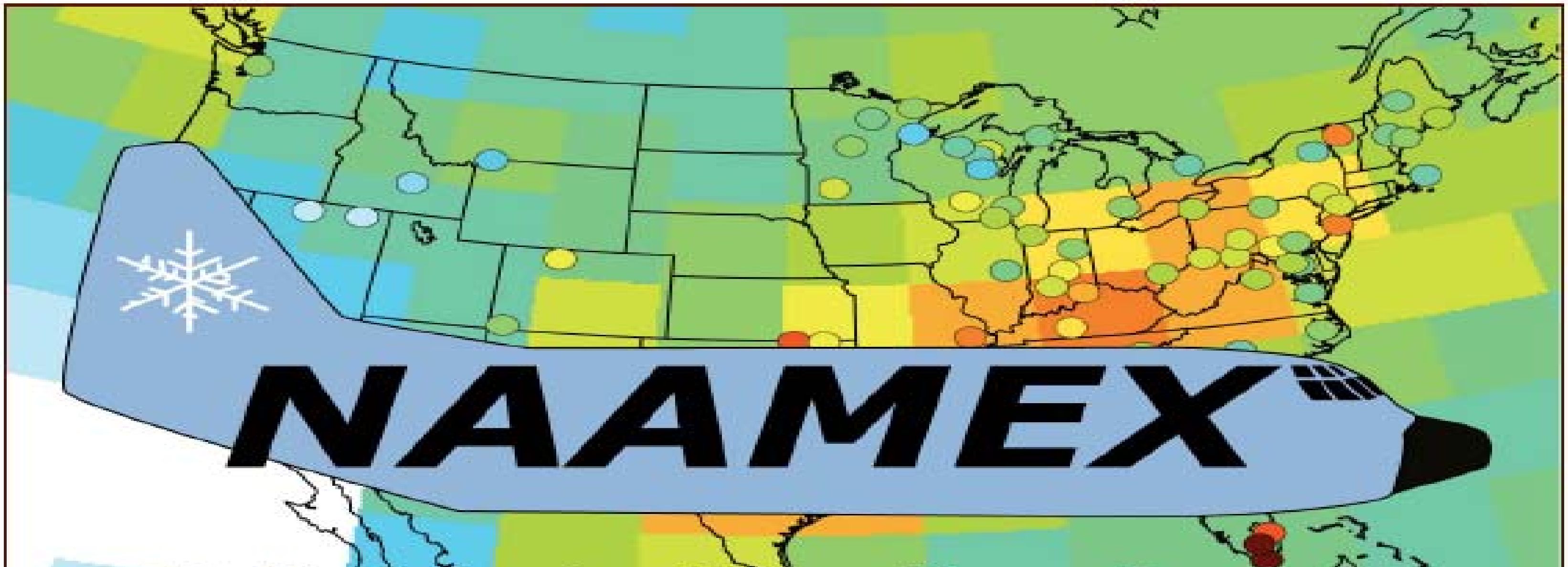
NADP-AMNet-National Atmospheric Deposition Program-Atmospheric Mercury Network

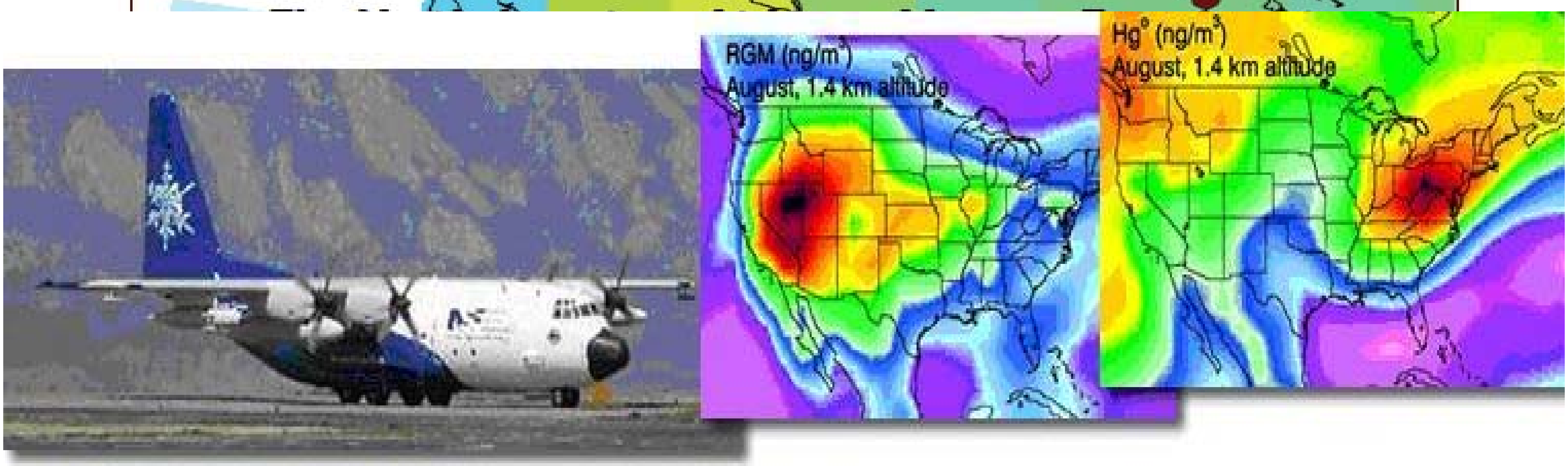
Established in 1999-M Welker


Total Mercury Concentration, 2008
Hg (ng/L)
≤ 4
4 - 6
6 - 8
8 - 10
10 - 12
12 - 14
14 - 16
16 - 18
> 18
Sites not pictured:
AK98 2.1 ng/L
National Atmospheric Deposition Program/Mercury Deposition Network

The North American Airborne Mercury Experiment (NAAMEX) White Paper: Science objectives and experimental plan

February 1, 2010 version



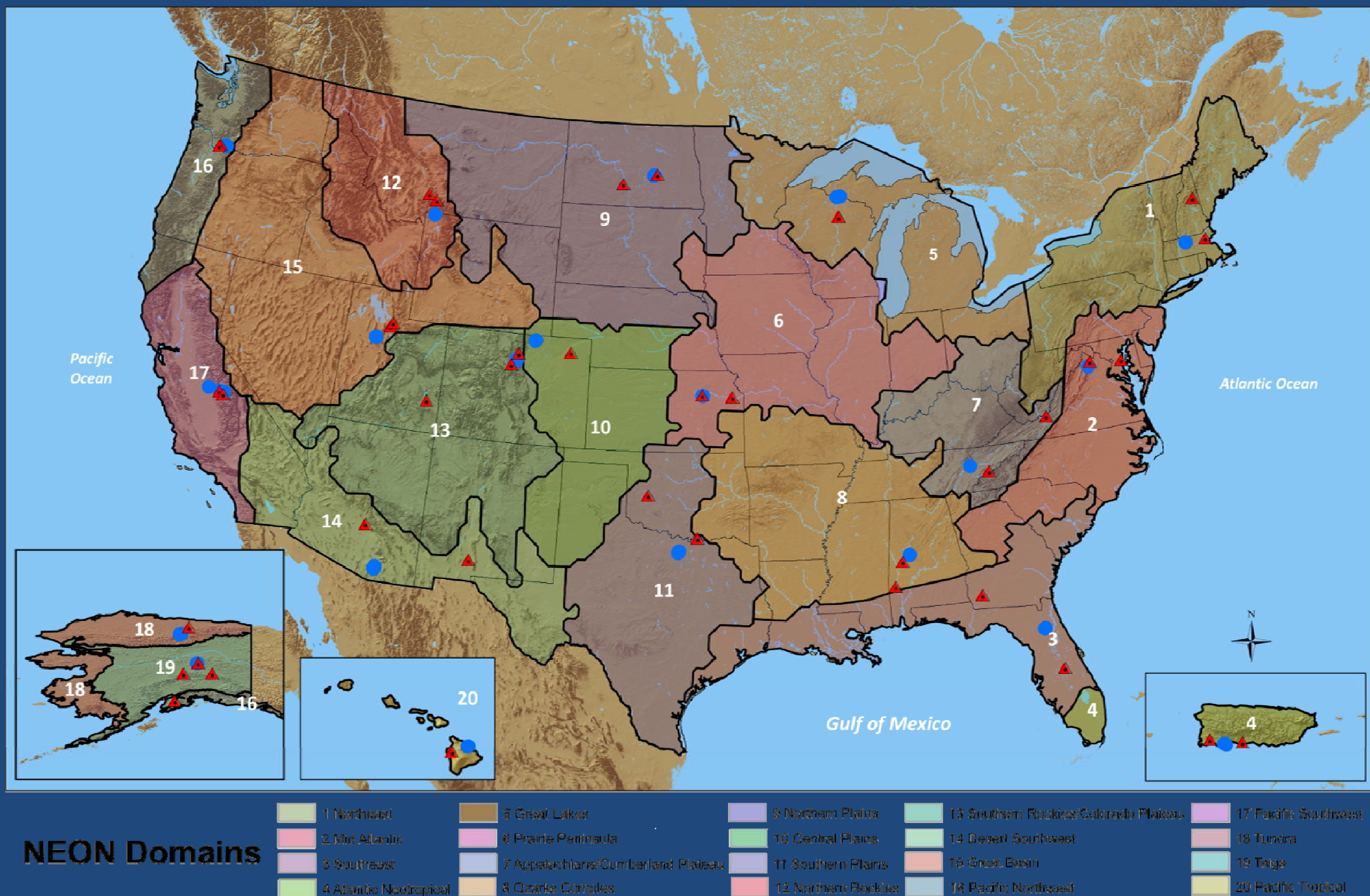


The **N**ational **E**cological **O**bservatory **N**etwork

Building an Ecological Observatory Network for Regional- to Continental-Scale Research—NEON, the National Ecological Observatory Network

A long-term study of climate and land use changes across the US

A National Observatory: 20 Eco-climatic Domains



NEON Goals

The overarching goal of NEON is to enable understanding and forecasting of climate change, land use change, and invasive species on continental-scale ecology *by providing infrastructure* to support research in these areas.

- **Information infrastructure:** Consistent, continental, long-term, multi-scaled data-sets and data products that serve as a context for research and education.

- **Physical Infrastructure:** A research platform for investigator-initiated sensors, observations, and experiments providing physical infrastructure, cyberinfrastructure, human resources, and expertise, and program management and coordination.

NEON Deployment

- Headquarters (incl. CI, labs, etc.) - Boulder
- 20 Domains
  - 20 Core sites (wildland)
  - 40 Relocatable sites (land-use sites)
- 10 Mobile laboratories (AK, HI, CONUS+PR)
- 3 Airborne Observation Platforms
- Land Use Analysis Package
- STREON Experiment

Spatial Scaling Strategy (Multi-scaled observations)

LUAP

AOP

FIU

Mobile Labs

FSU+ AQS

Ecological Forecast models

Key NEON Data

- Bioclimate Suite
  - Temperature, precipitation, humidity, radiation
- Biodiversity Suite (includes invasive spp.)
  - Abundance and diversity (mosquitoes, aquatic invertebrates, beetles, fish, birds, plants, …)
  - Phenology (mosquitoes, beetles, plants)
  - Microbial function and diversity (functional genes, metagenomes)
  - Bioarchive (all taxa, substrates)
- Biogeochemistry Suite
  - Carbon stocks, fluxes, isotopes
  - Nutrient stocks, fluxes, isotopes
  - Chemical climate (N-deposition, Ozone)

Key NEON Data

- Ecohydrology Suite
  - Water balance components (storage and flows)
- Infectious Disease Suite
  - Disease prevalence (Dengue, Hanta virus, Lyme disease, West Nile Virus)
- Land Use and Land Cover Suite
  - Remote sensing data (vegetation performance and structure)
  - Geographic data (topography, historical climate, etc.)
  - Statistical data (human geography)

Complexity in the Hg cycle of northern habitats