Extensive fires in southeastern Siberian permafrost linked to preceding Arctic Oscillation

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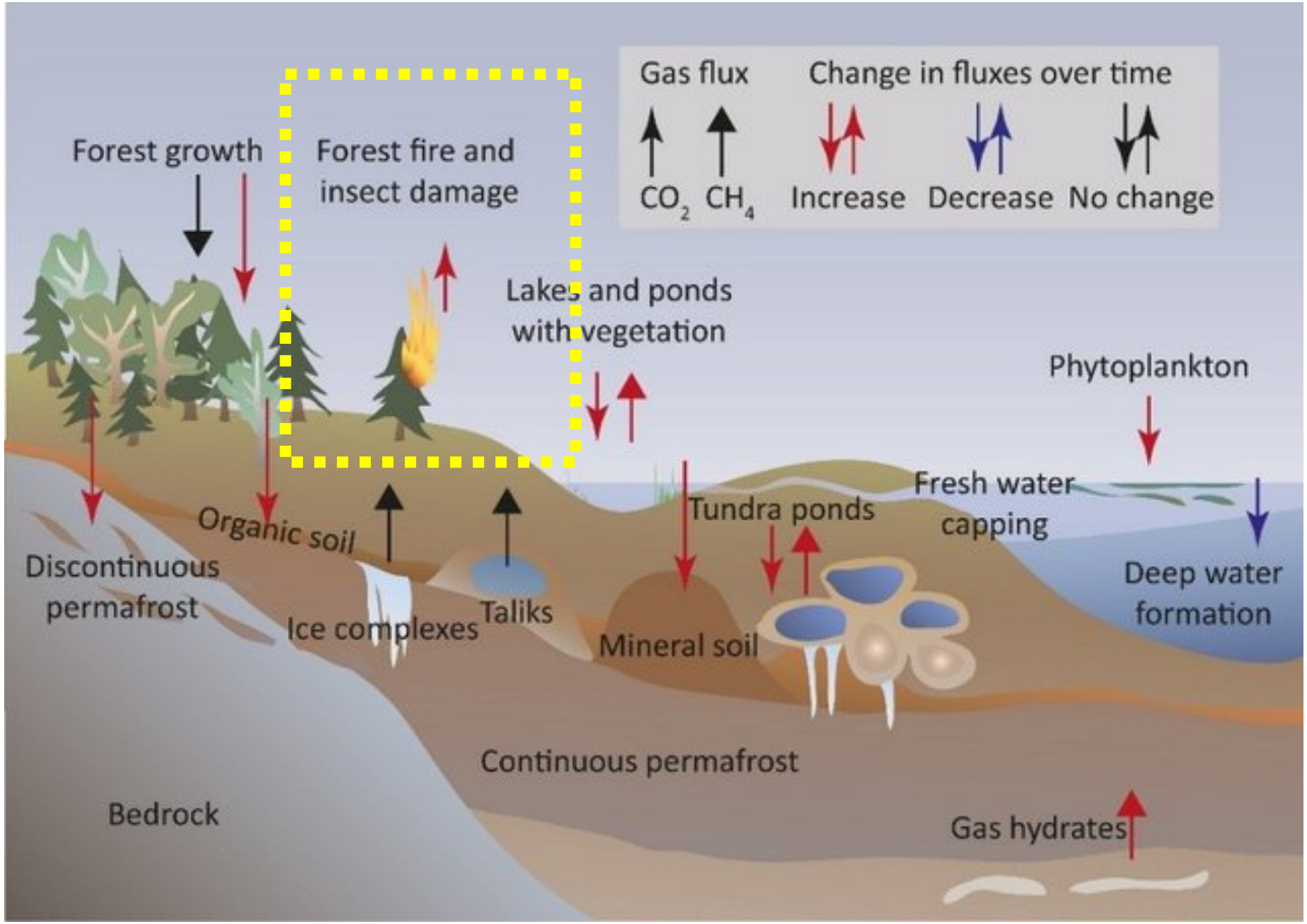
Published in Science Advances

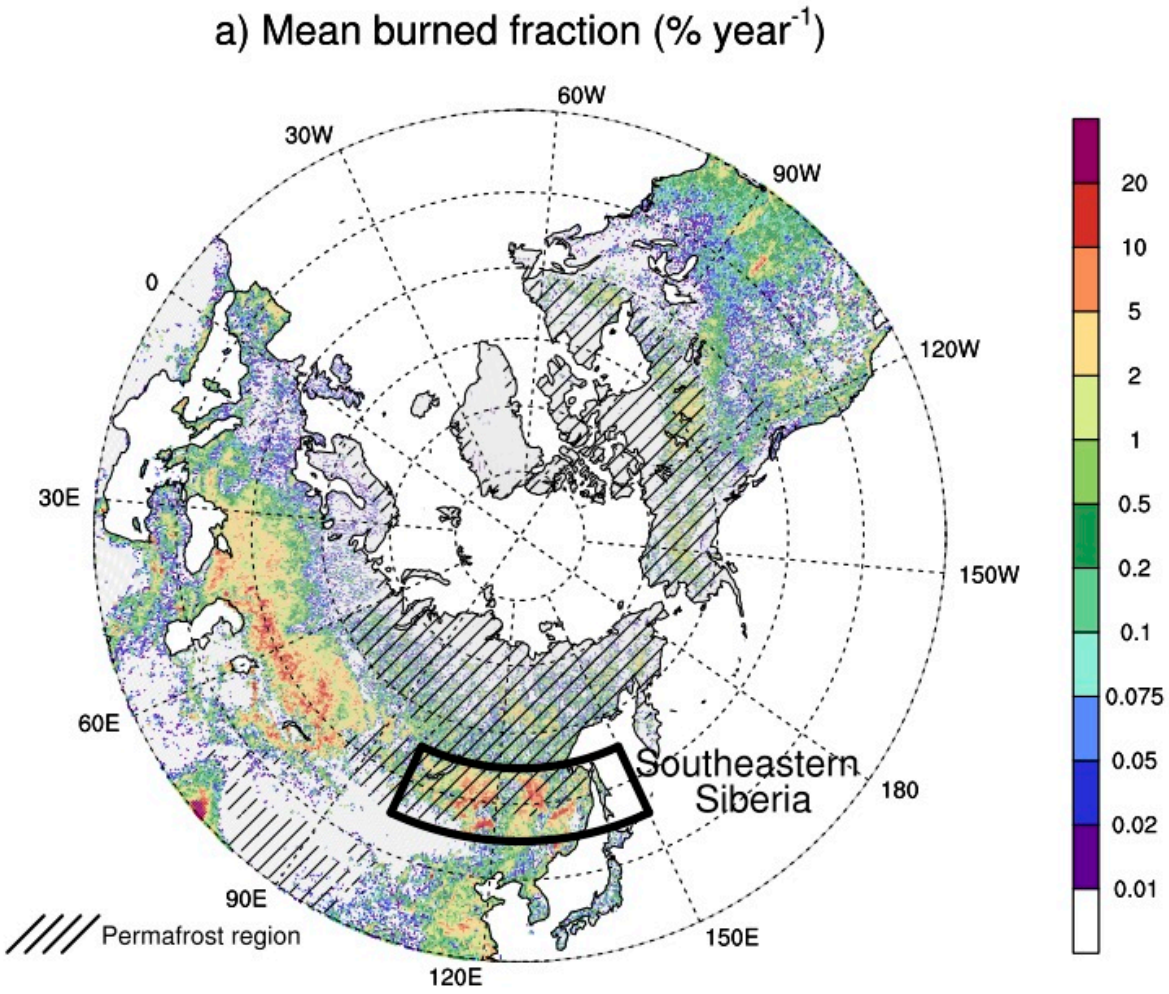
Carbon cycling in the Arctic will change as the climate warms

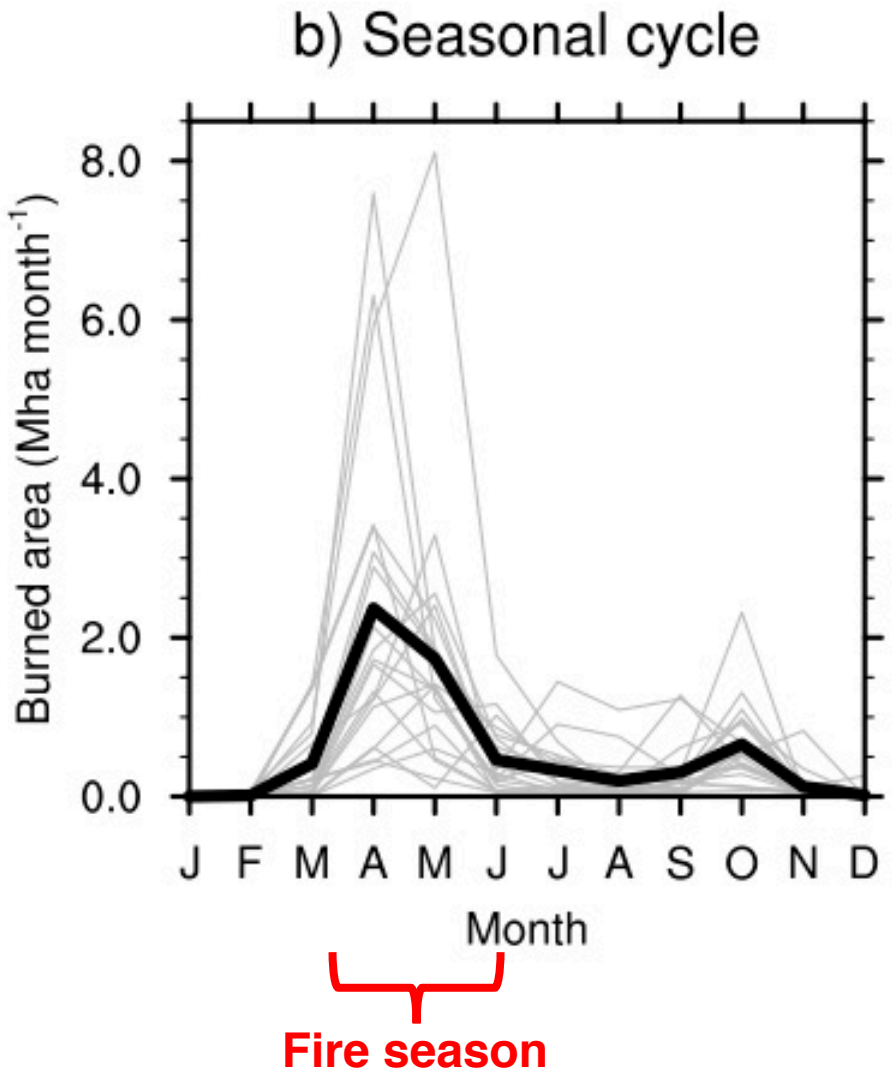


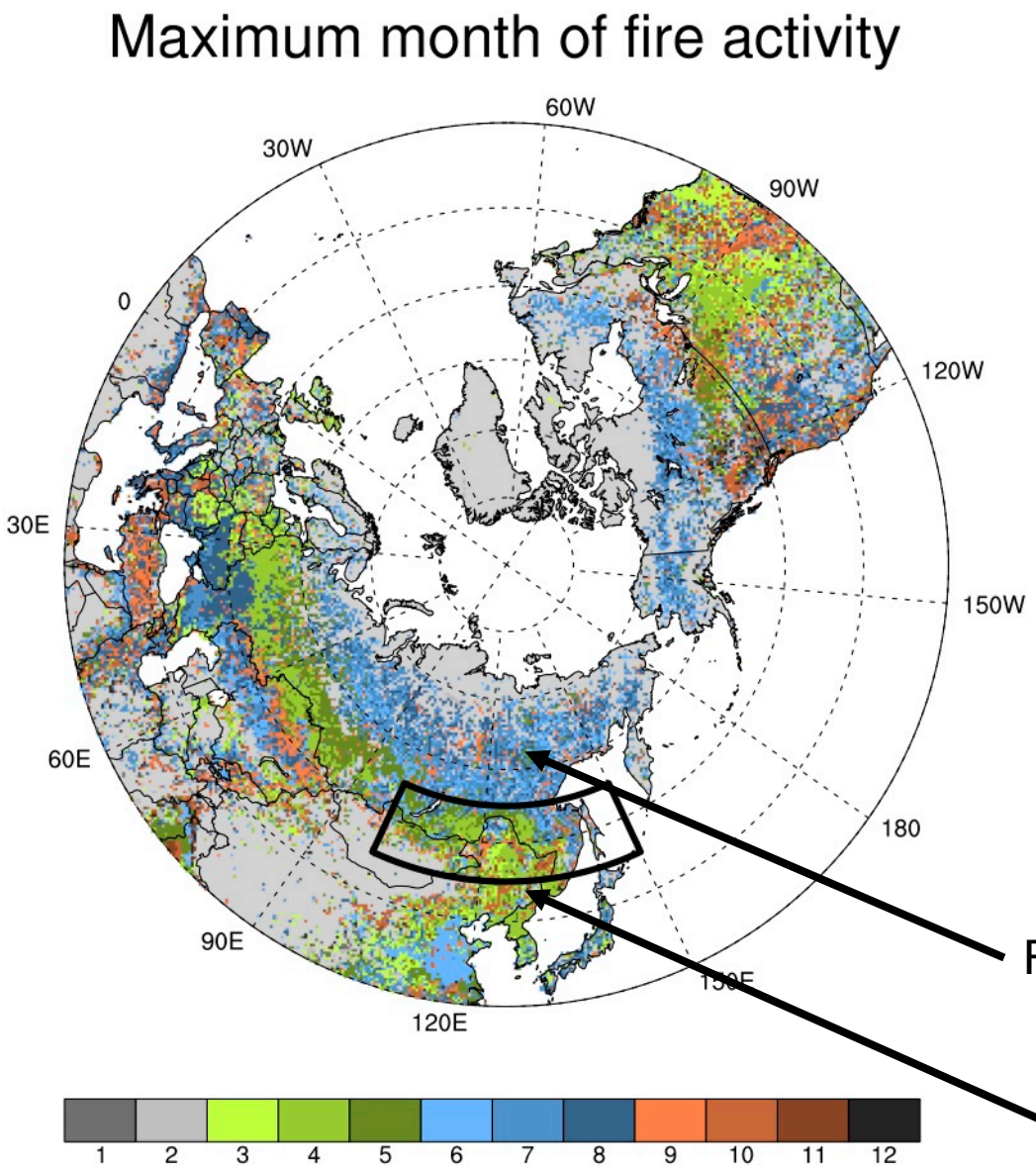
1. Always CO_2 source

2. Positive role in carbon-climate feedback

Southeastern Siberia (100°–150°E, 45°–55°N)







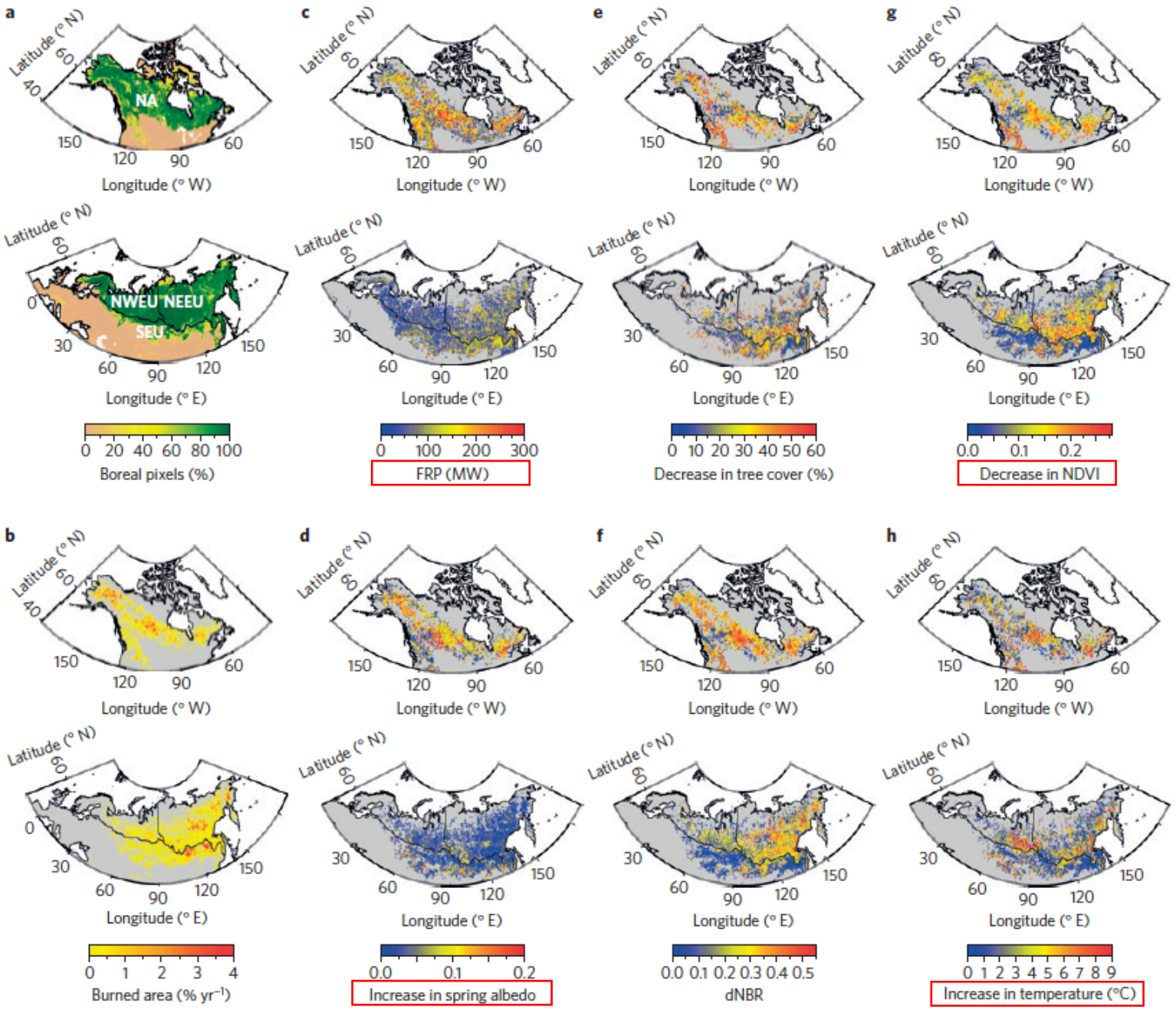
Fire season: Summer (June, July)

Fire season: Spring (April, May)

Larch forest area

Larches are conifers in the genus ***Larix***, of the family Pinaceae (subfamily Laricoideae). Growing from 20 to 45 m tall, they are native to much of the cooler temperate northern hemisphere, on lowlands in the north and high on mountains further south. Larches are among the dominant plants in the boreal forests of Siberia and Canada. Although they are conifers, **larches are deciduous trees that lose their needles in the autumn**.

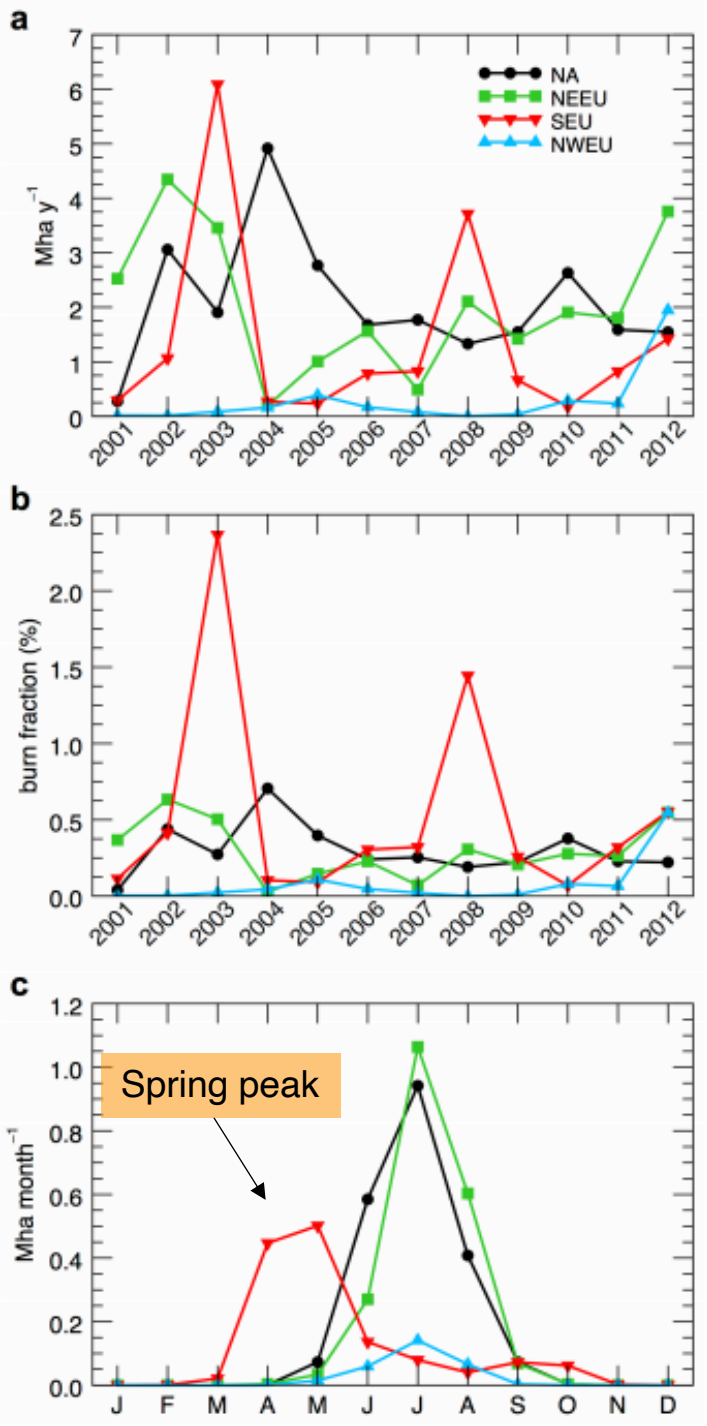
In Siberia, Dahurian Larch (*Larix Gmelinii*)



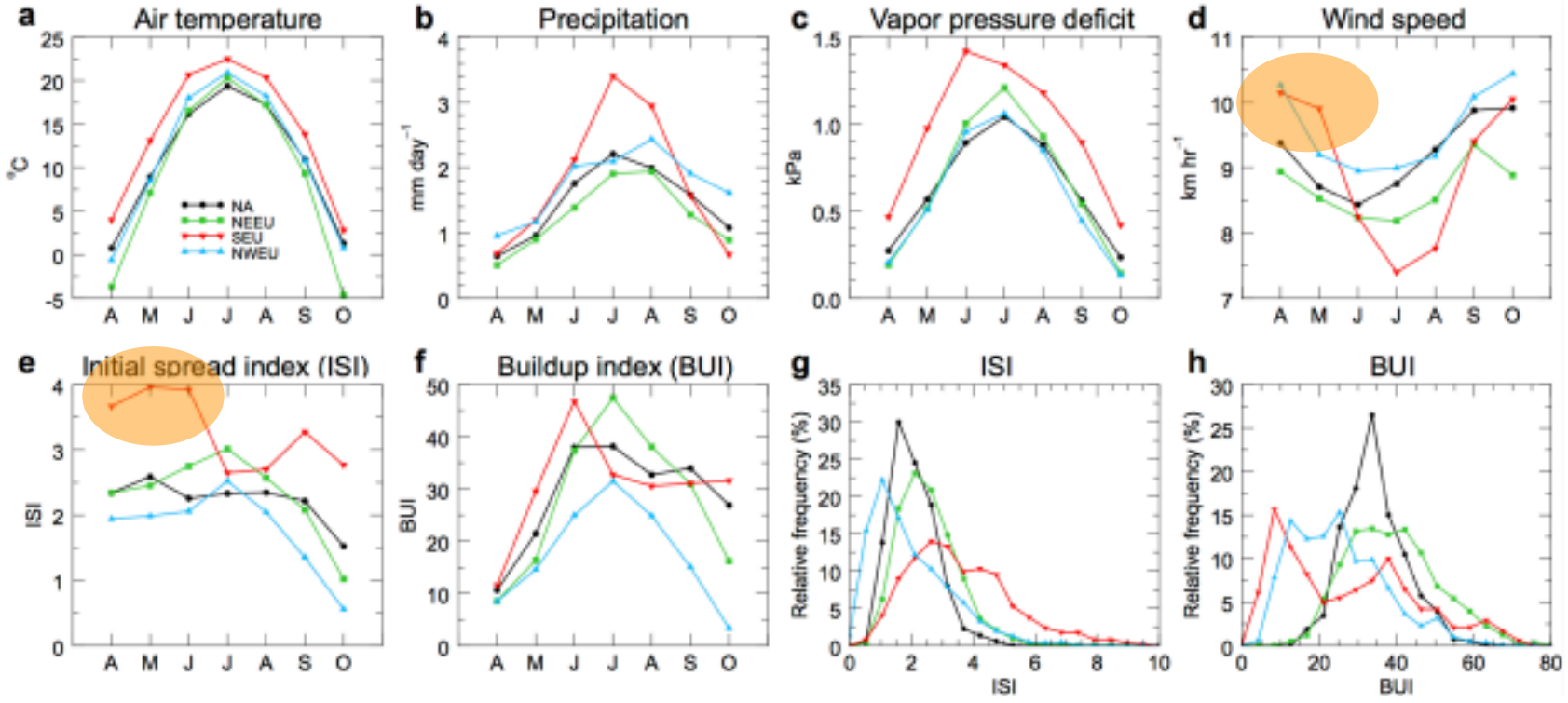
Rogers et al. 2015
Nature Geoscience

we suggest that different fire dynamics between the two continents resulted from their dominant **tree species**.

Black spruce (*Picea mariana*) in North America



Supplementary Figure 7. Monthly mean local noon 2-meter (a) air temperature, (b) precipitation, (c) vapor pressure deficit, (d) wind speed, (e) initial spread index (ISI), and (f) buildup index (BUI), and histograms of (g) ISI and (h) BUI during the fire season for each region during 2000 - 2010. In the legend, North America is represented by NA, Northeast Eurasia by NEEU, Southern Eurasia by SEU, and Northwest Eurasia by NWEU.



Fire Behavior Indices

Initial Spread Index (ISI)

- Combines FFMC and wind speed
- Varies greatly based on current wind conditions
- Represents ROS as a relative term (i.e. ISI = 17 > ISI = 10 => higher ROS)

Build-Up Index (BUI)

- Combines DMC and DC, with increased weight placed on the DMC
- Does not vary throughout the day
- Represents total fuel available for consumption

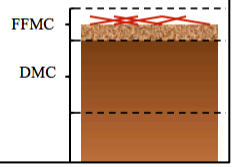
Fire Weather Index (FWI)

- Combines the ISI and BUI, with increased weight on the ISI
- Is more stable than the ISI, but varies with it throughout the day
- Represents potential fire intensity

Fuel Moisture Codes

Fine Fuel Moisture Code (FFMC)

- Litter layer, and other cured fine fuels
- 0 – 1.2 cm depth in the forest floor (0.25 kg/m^2)
- Plays a significant role in ignition probability and spread



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Reduced North American terrestrial primary productivity linked to anomalous Arctic warming

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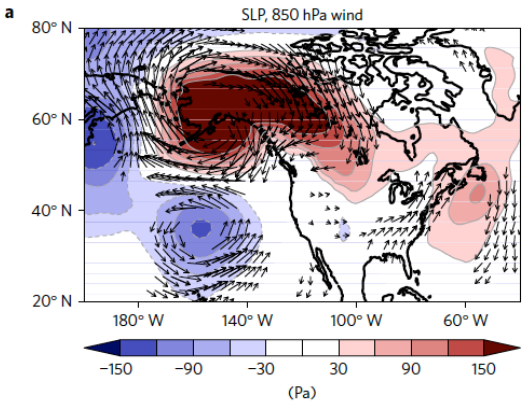
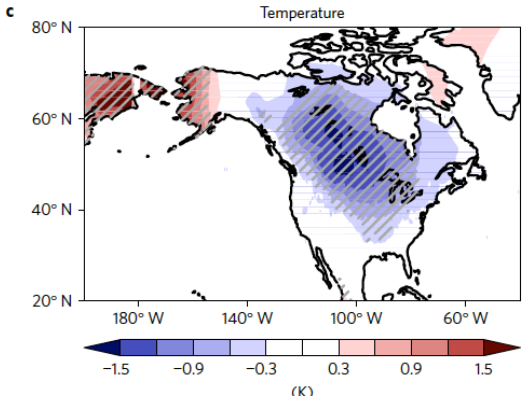
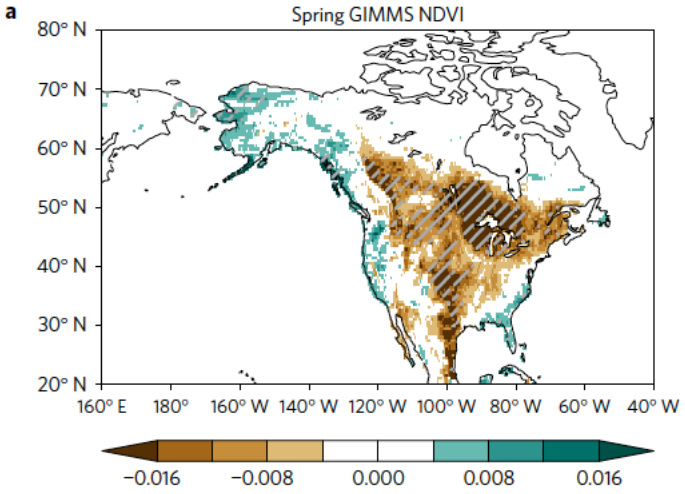


Arctic warming

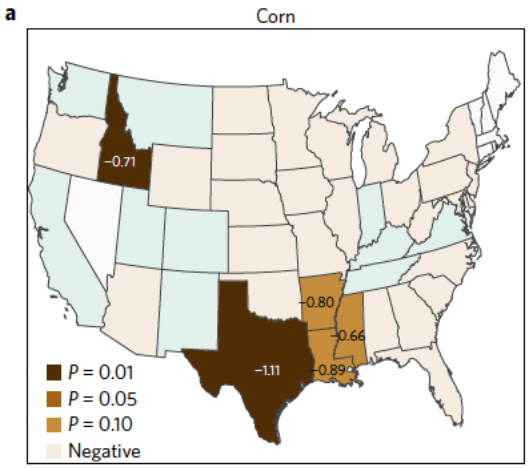


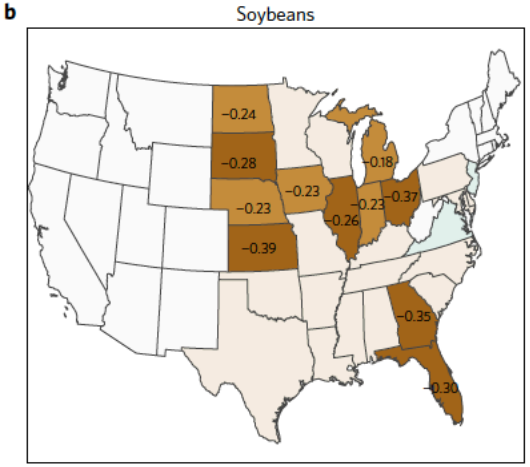
North America cooling

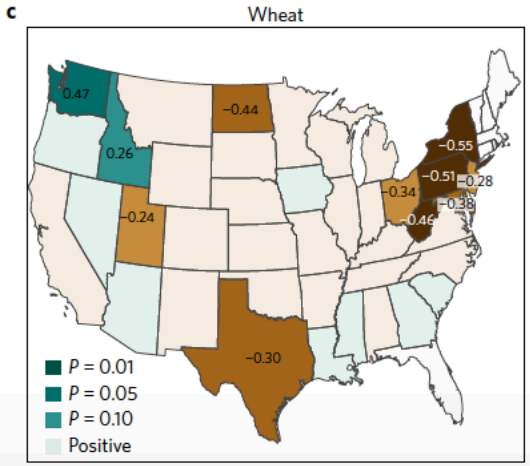


NDVI

Crop yield In US

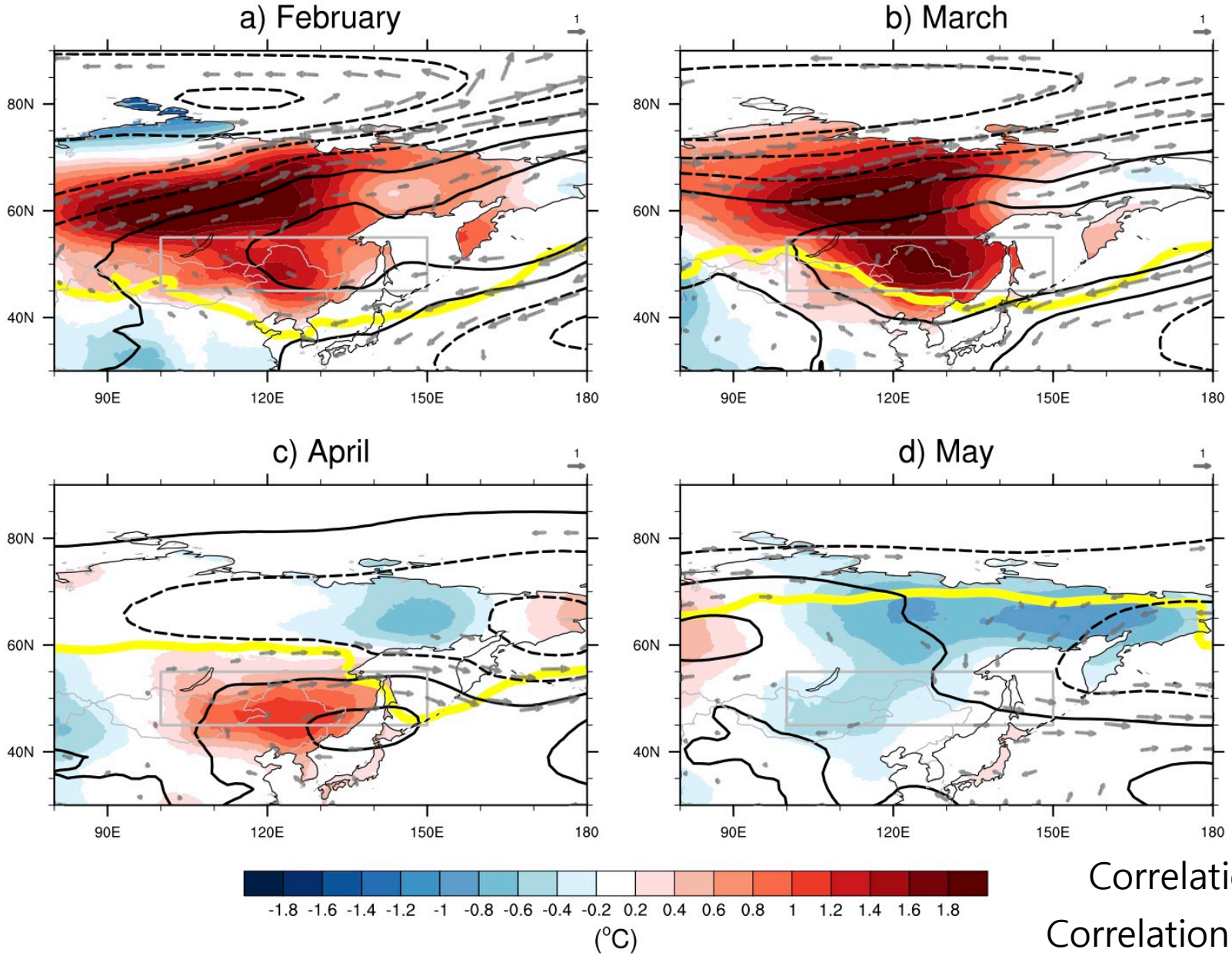




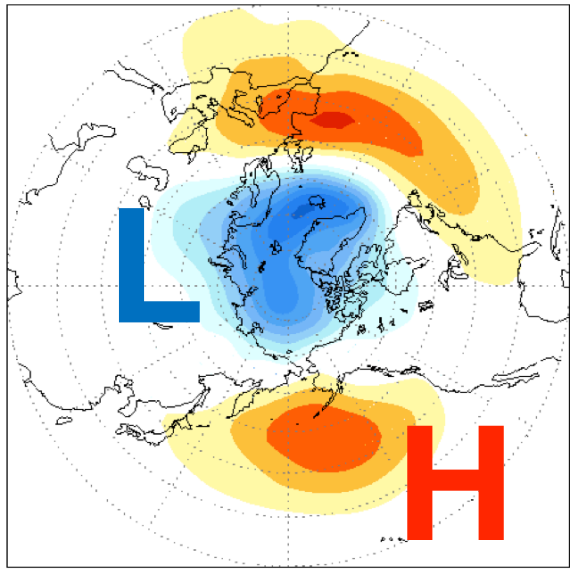


Regression of atmospheric circulation on fire activity

ERA-Interim @850 hPa

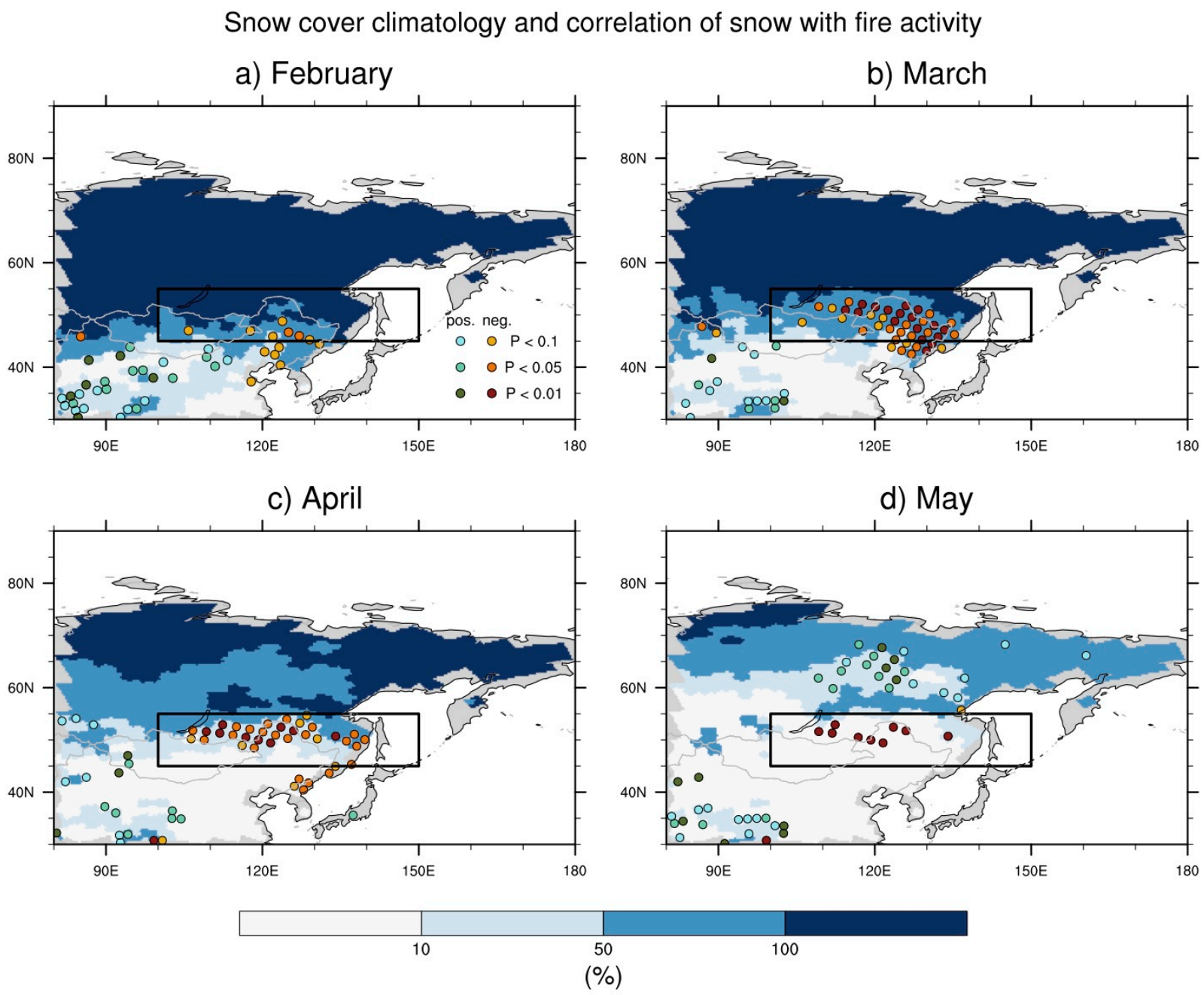


Arctic Oscillation pattern



Correlation btw FM AO & Burned area = 0.53*

Correlation btw FM 850hPa & Burned area = **0.80****



+Arctic Oscillation (AO)

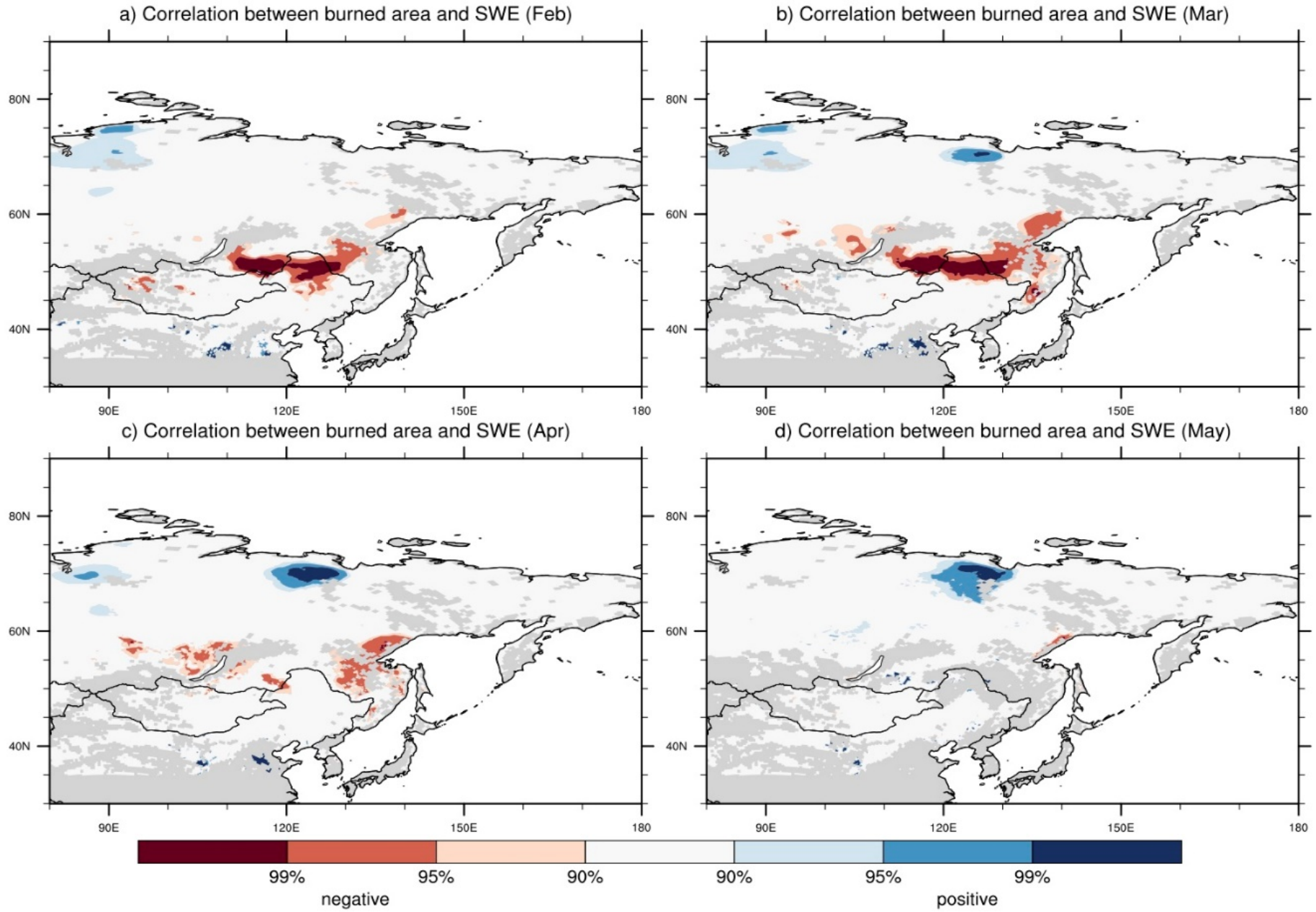
↓

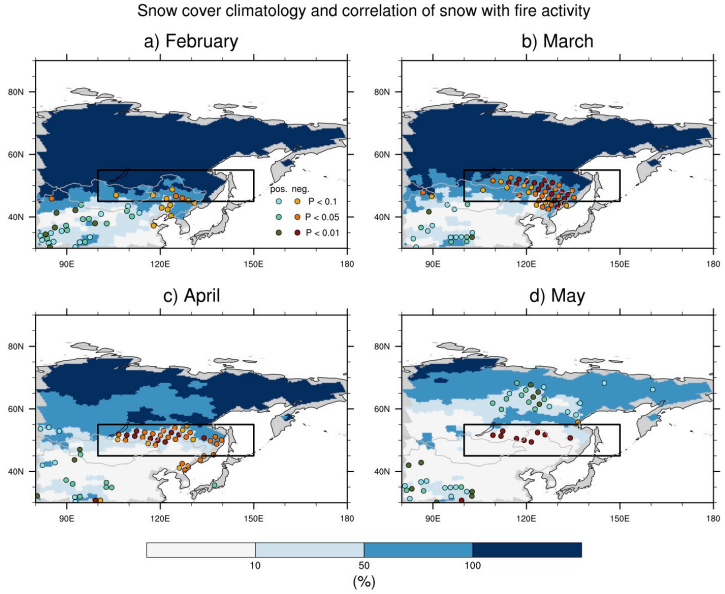
Higher surface temperature

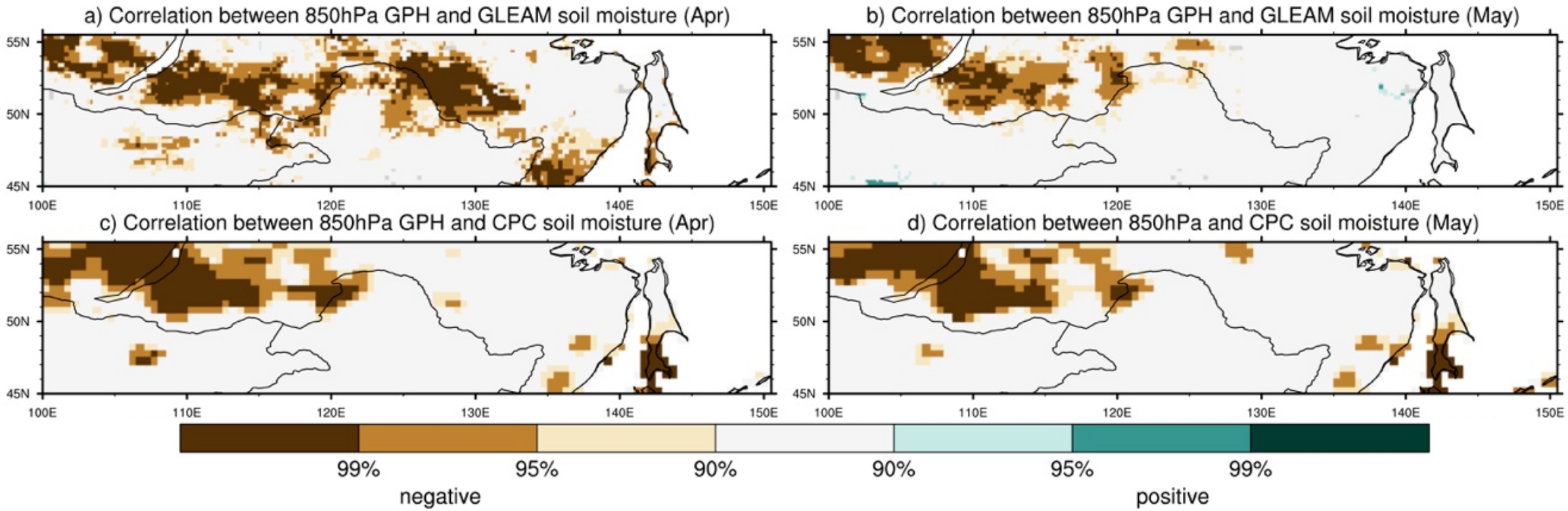
↓

Earlier snow melting

Snow Water Equivalent





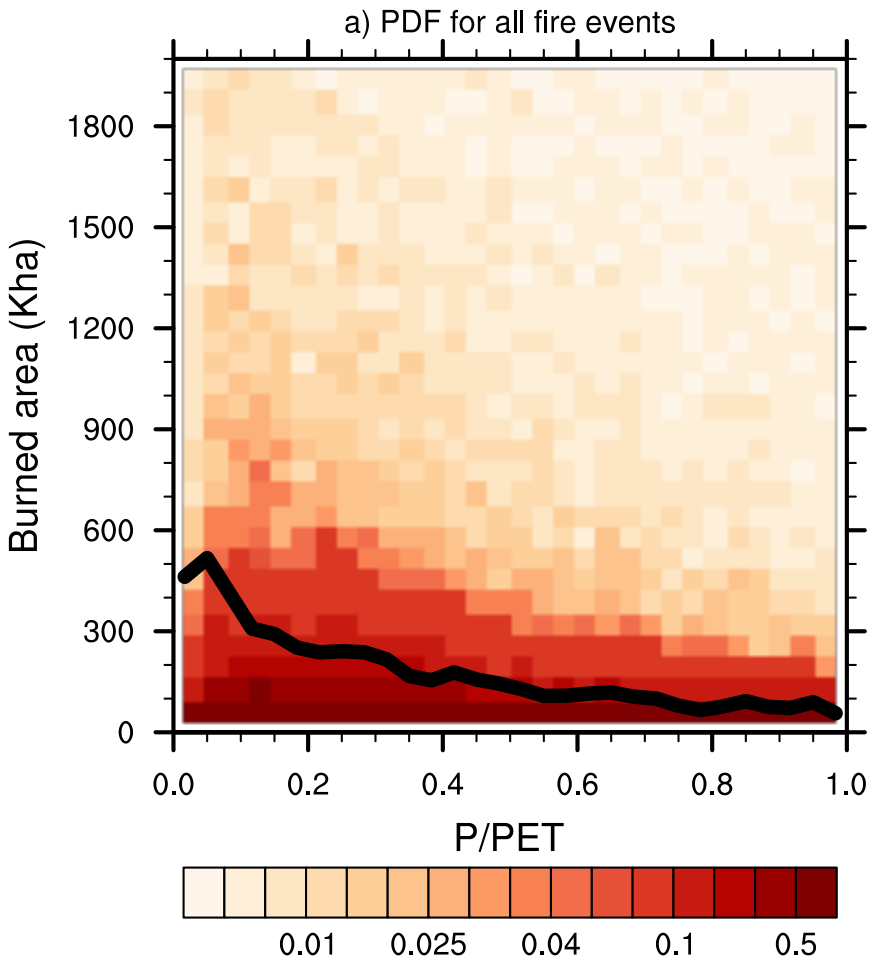


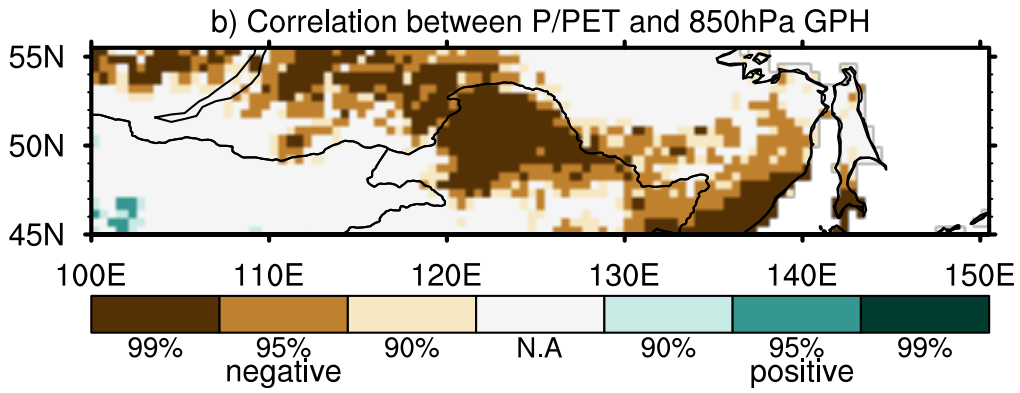
Soil moisture anomalies during high temperature case (highest 5 years) and low precipitation case (lowest 5 years) events depending on permafrost types.

April soil moisture anomaly ($m^2\ m^{-2}$)	Continuous and Discontinuous permafrost (>50%)	Sporadic permafrost (10–50%)	Isolated permafrost (0–10%)	Non-permafrost
Composite of February–March high temperature case	-6.83×10^{-3} (P=0.05*)	-8.25×10^{-3} (P=0.04*)	-8.54×10^{-3} (P=0.06)	-3.27×10^{-3} (P=0.19)
Composite of February–March low precipitation case	-0.38×10^{-3} (P=0.49)	-4.53×10^{-3} (P=0.16)	-1.19×10^{-3} (P=0.37)	-0.39×10^{-3} (P=0.45)

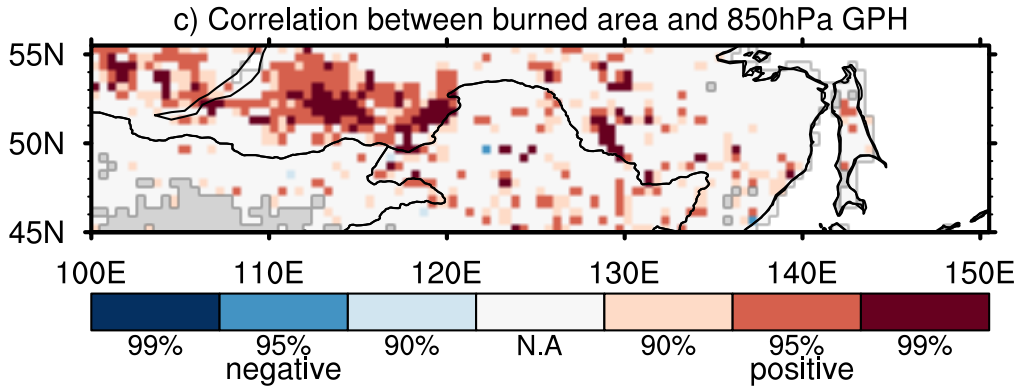
P: Precipitation, PET: Potential EvapoTranspiration,
P/PET : aridity index

High pressure←→Drier condition





Drier condition←→Fire activity



Snow

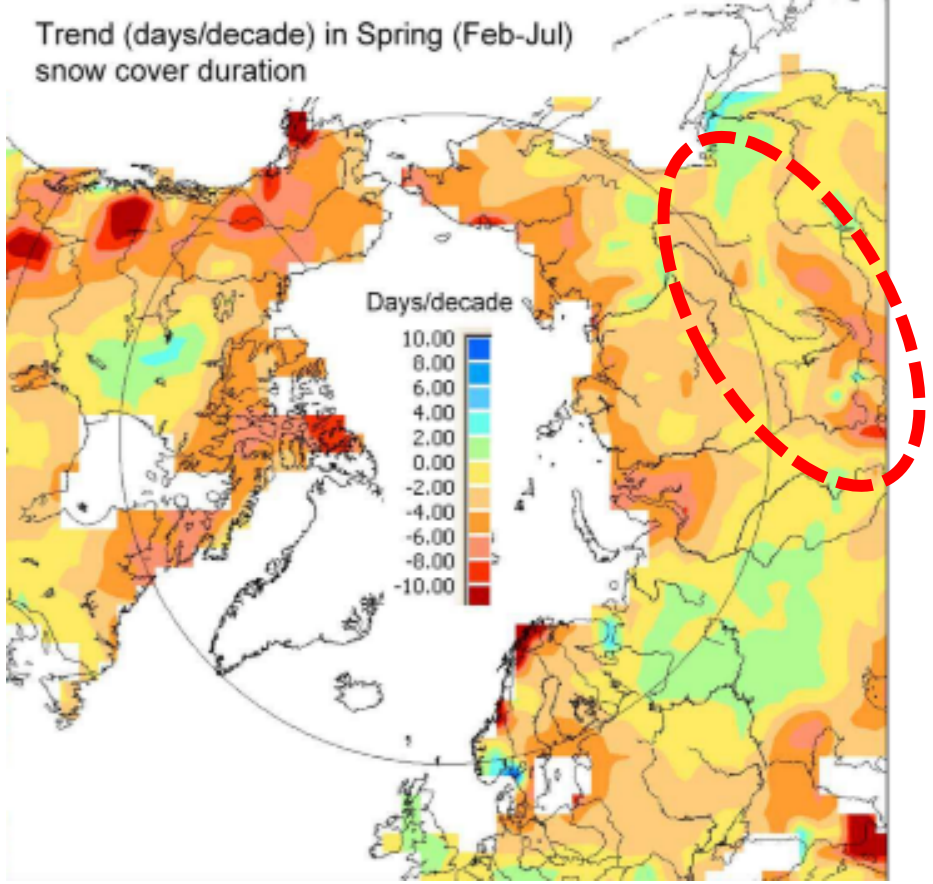
Snow melting

evaporation

runoff

Cannot be soil moisture due to permafrost

Brown et al. 2010



Pan-Arctic **warming**

– Earlier snow melt

– Stronger **fire** activity

– Additional **carbon** release

Pan-Arctic **warming** again!

(Positive feedback)

Kukavskaya et al. 2016

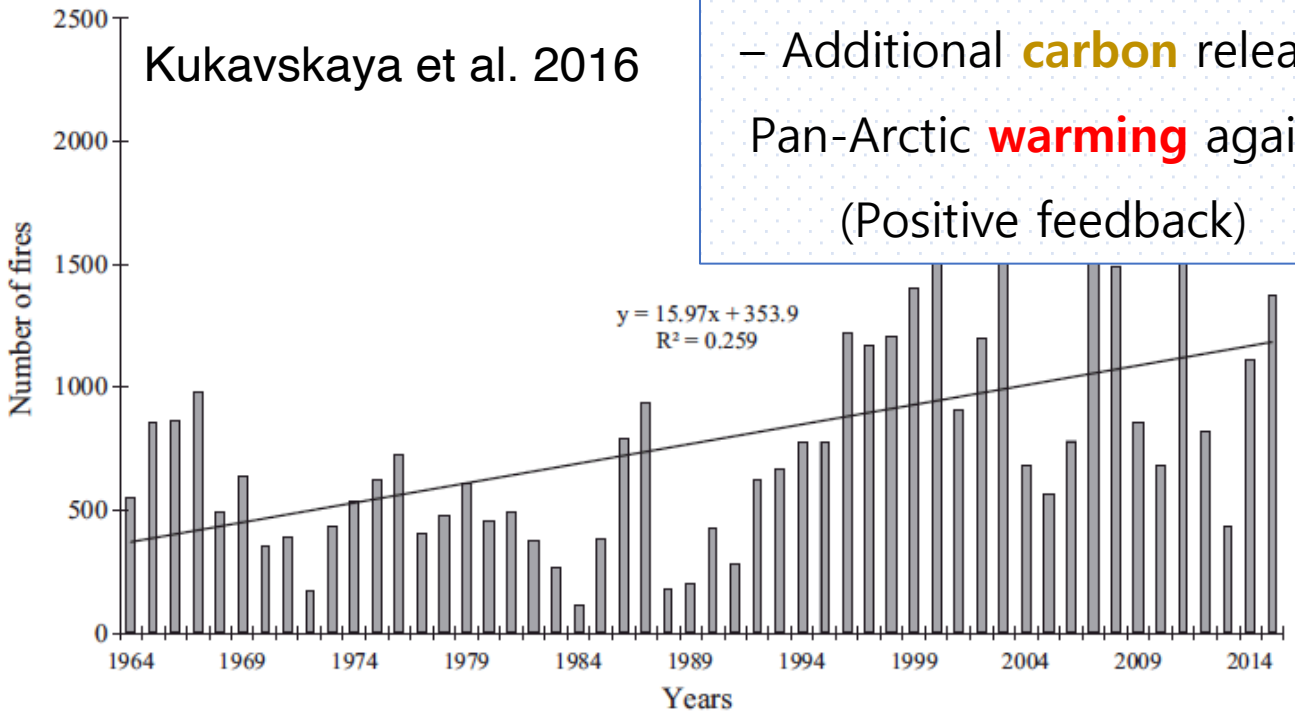


Fig. 2. Number of fires in the Zabaikal region from 1964 to 2015 (ZFFS data). Line shows trend in the annual number of fires over the period.

JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 99, NO. D9, PAGES 18,627–18,638, SEPTEMBER 20, 1994

Satellite analysis of the severe 1987 forest fires in northern China and southeastern Siberia

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Brian J. Stocks
Forest Fire Research, Forestry Canada, Ontario Region, Great Lakes Forestry Centre, Sault Sainte Marie Ontario, Canada

Joel S. Levine, Wesley R. Cofer III, and Joseph M. Pierson
Atmospheric Sciences Division, NASA Langley Research Center, Hampton, Virginia

It was quickly apparent from the imagery that the great China fire was less extensive than the fires in Siberia.

One of the four fires was **controlled early**, despite the severe weather conditions, but the other three grew quickly throughout the day.

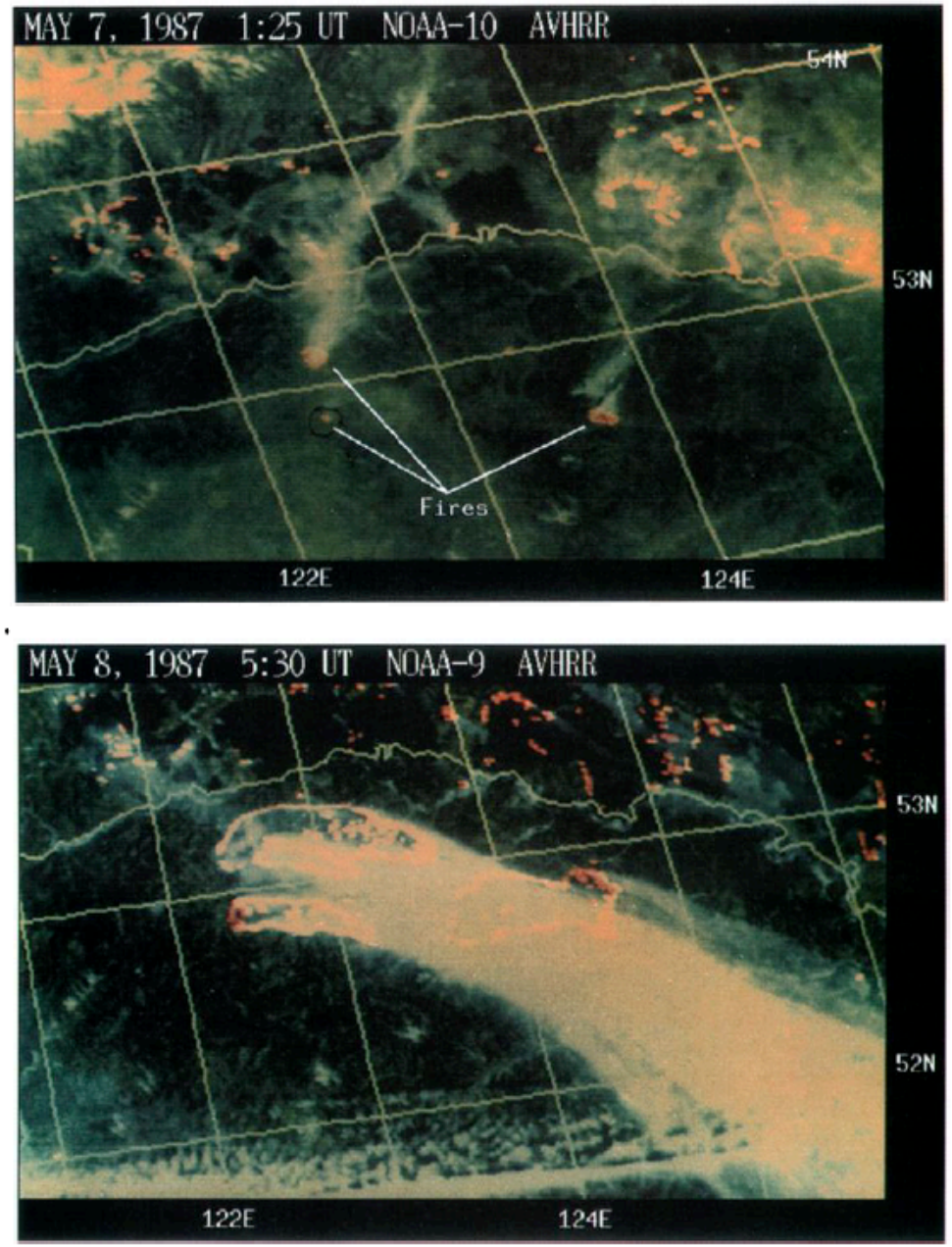
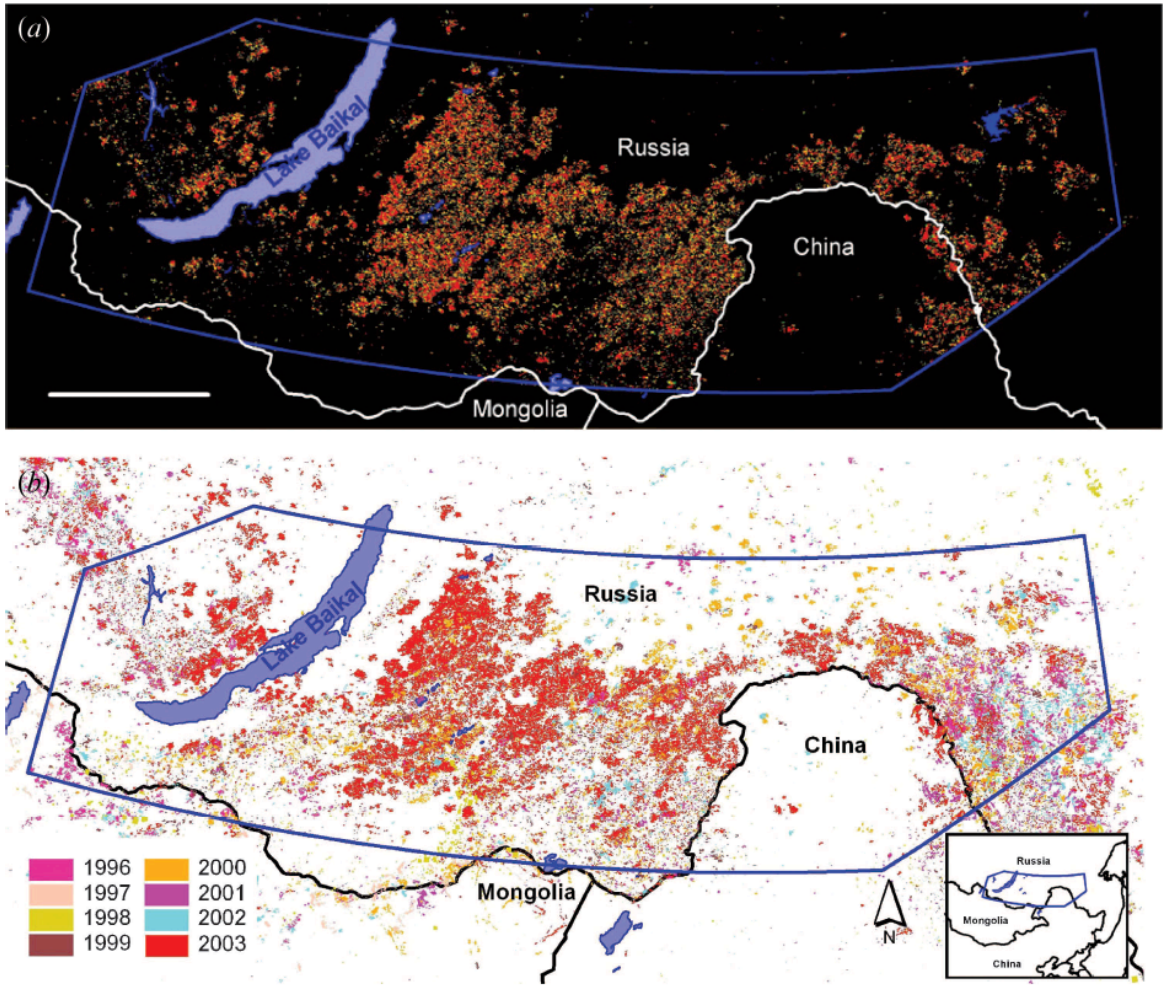
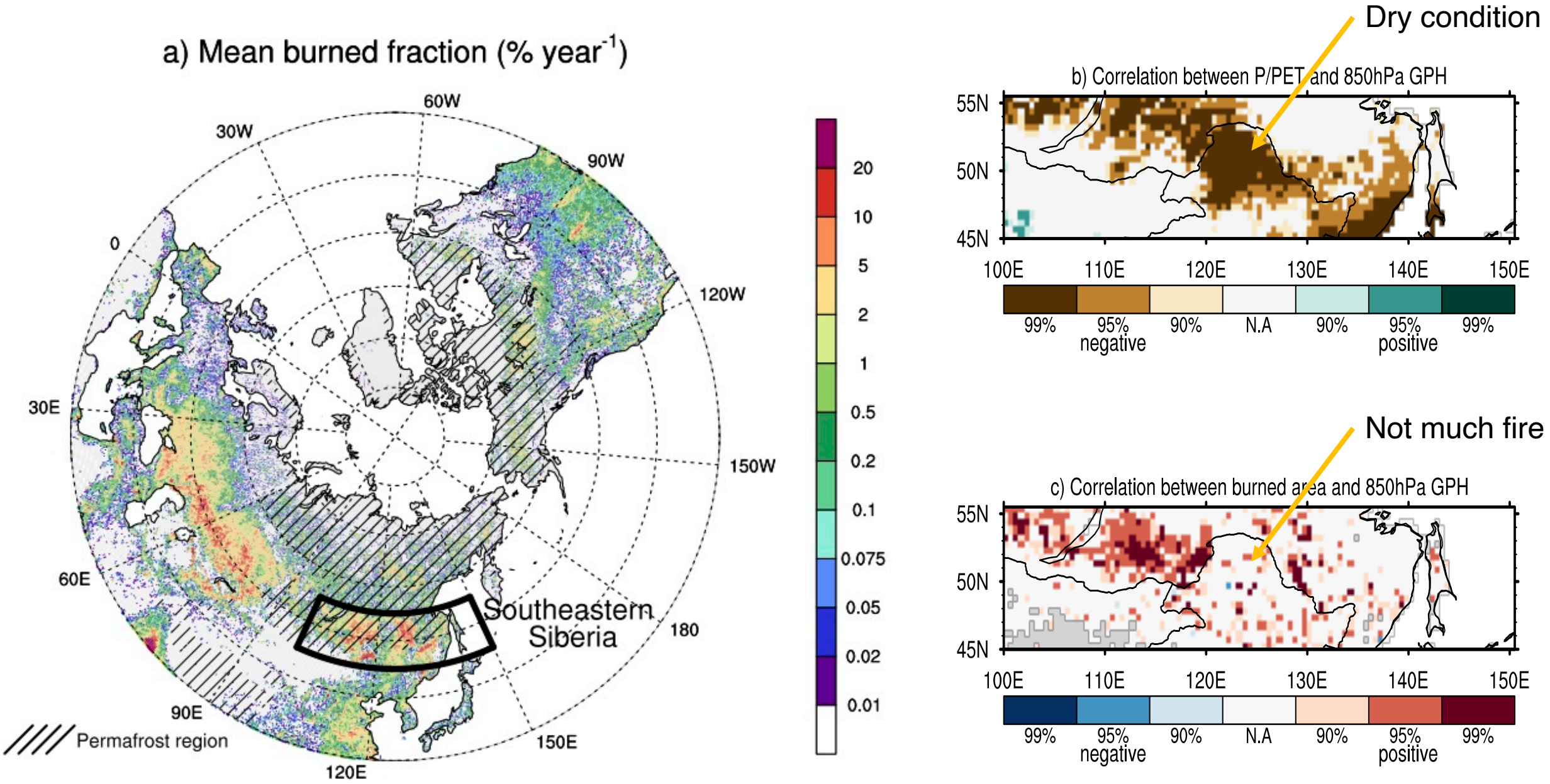


Plate 2. Two AVHRR satellite images showing the rapid initial spread of the great China fire: (top) image from May 7, with the China/Russia border along the Amur River shown through the middle; (bottom) image from May 8, with the border appearing in the upper third. Active fires (red) can be seen on both sides of the border. On May 8 the outer fire perimeter is clearly visible, and smoke is being transported rapidly southeastward by strong winds.



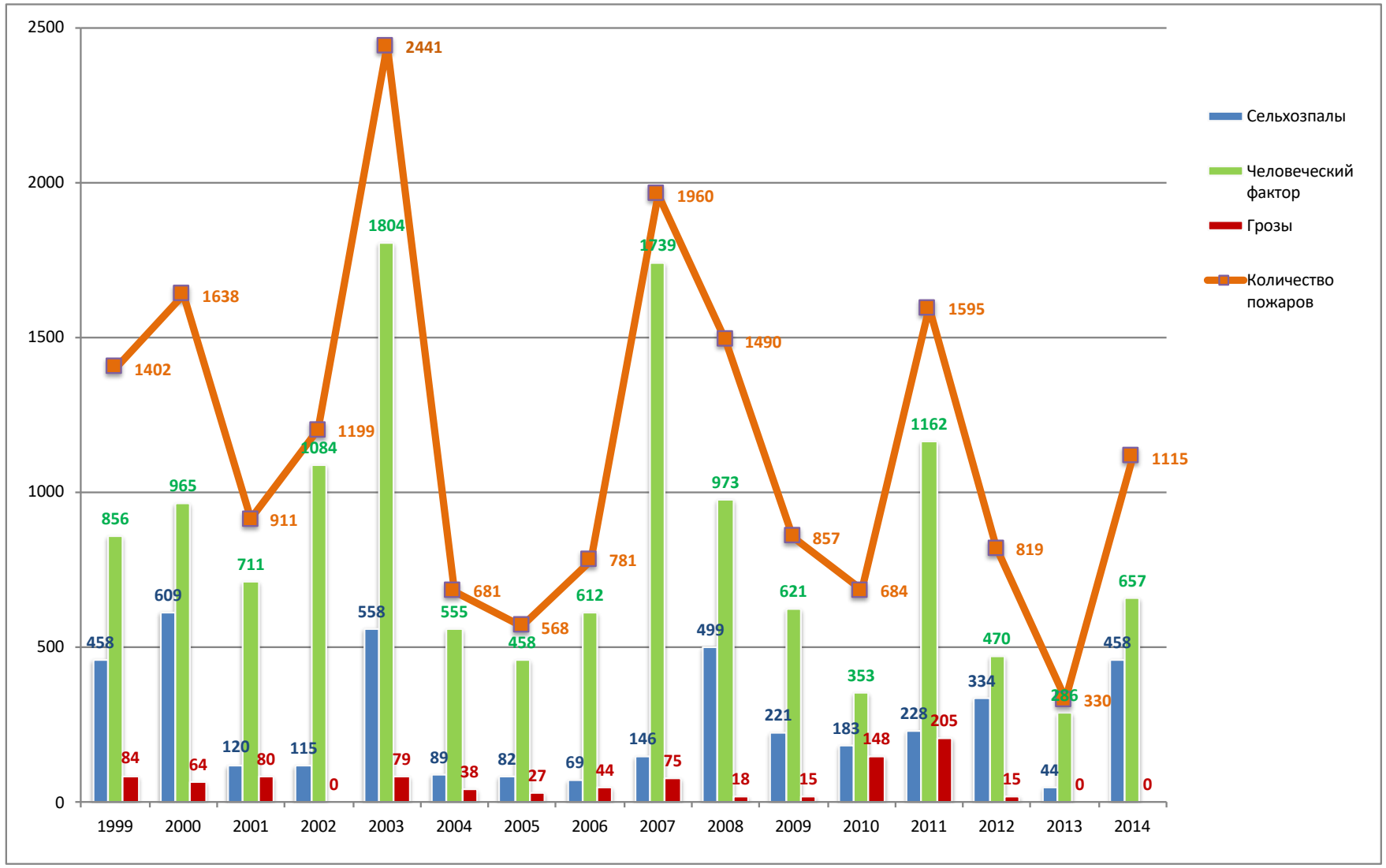
Huang et al. 2009 Int. J. Remote Sens.

Fire management capabilities have been decreased due to insufficient budgets for operation of the Aerial Forest Fire Protection Service. The depletion of China's forest resources and the increasing demand for timber products prompt the local people to set arson forest fires in order to increase the permissible salvage logging areas. The large-scale clear-cuts from the 1990s have resulted in large areas dominated by pure grass stands that are maintained by regular fires. The human influence can be reflected in figure 1, where many hotspots were detected in Siberia, while very few recorded in north China. The high human impact on the forest through fires owing to lack of control, ineffectual fire-management policies and new socioeconomic conditions was also studied by Mollicone et al. (2006). They showed that there were more fires in years during which the weather was anomalous, but more than 87% of fires in boreal Russia were started by people.


a) Mean burned fraction (% year-1)
60W
30W
90W
0
120W
30E
150W
60E
180
90E
150E
120E
Southeastern Siberia
Permafrost region
20
10
5
2
1
0.5
0.2
0.1
0.075
0.05
0.02
0.01
Dry condition
b) Correlation between P/PET and 850hPa GPH
55N
50N
45N
100E
110E
120E
130E
140E
150E
99%
95% negative
90%
N.A
90%
95% positive
99%
Not much fire
c) Correlation between burned area and 850hPa GPH
55N
50N
45N
100E
110E
120E
130E
140E
150E
99%
95% negative
90%
N.A
90%
95% positive
99%

Причины лесных пожаров в Забайкальском крае (1999-2014 гг.)

Causes of forest fires in the Trans-Baikal Territory



Agricultural

Human Factor

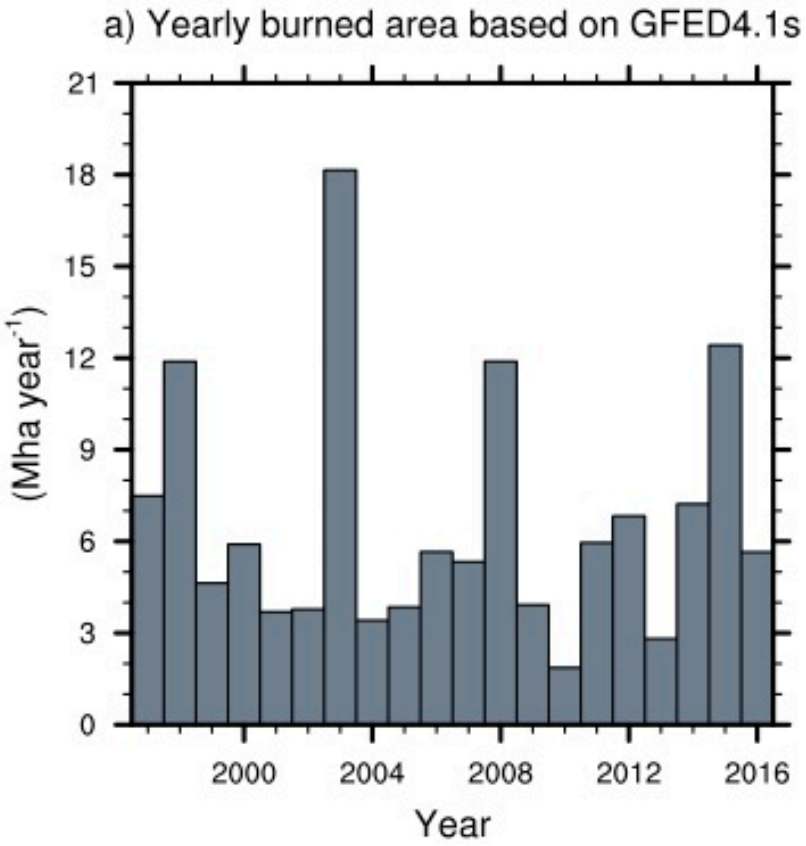
Thunderstorms

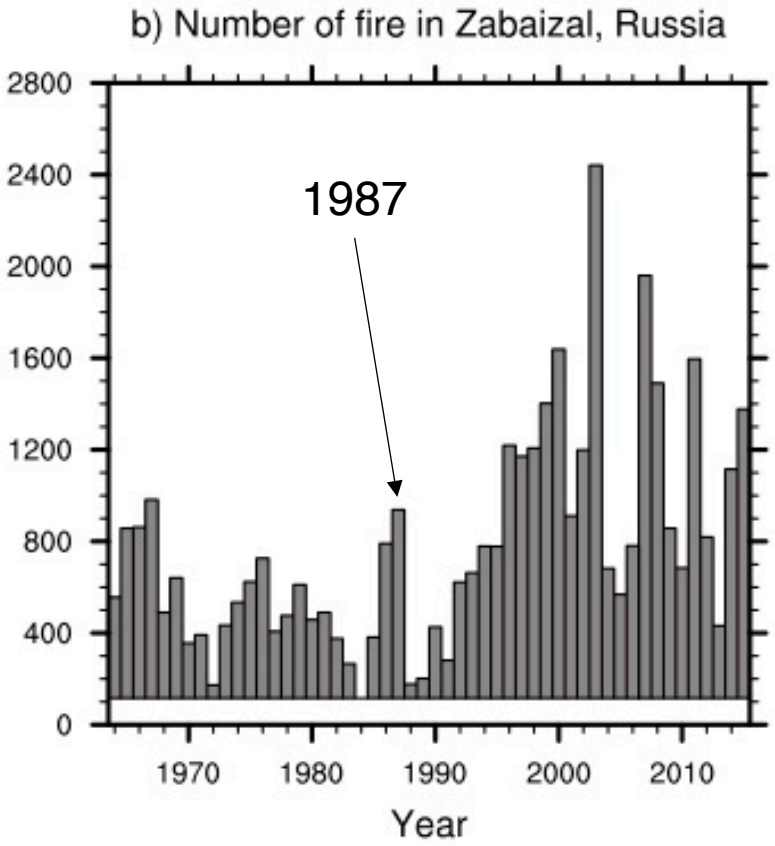
Number of fires

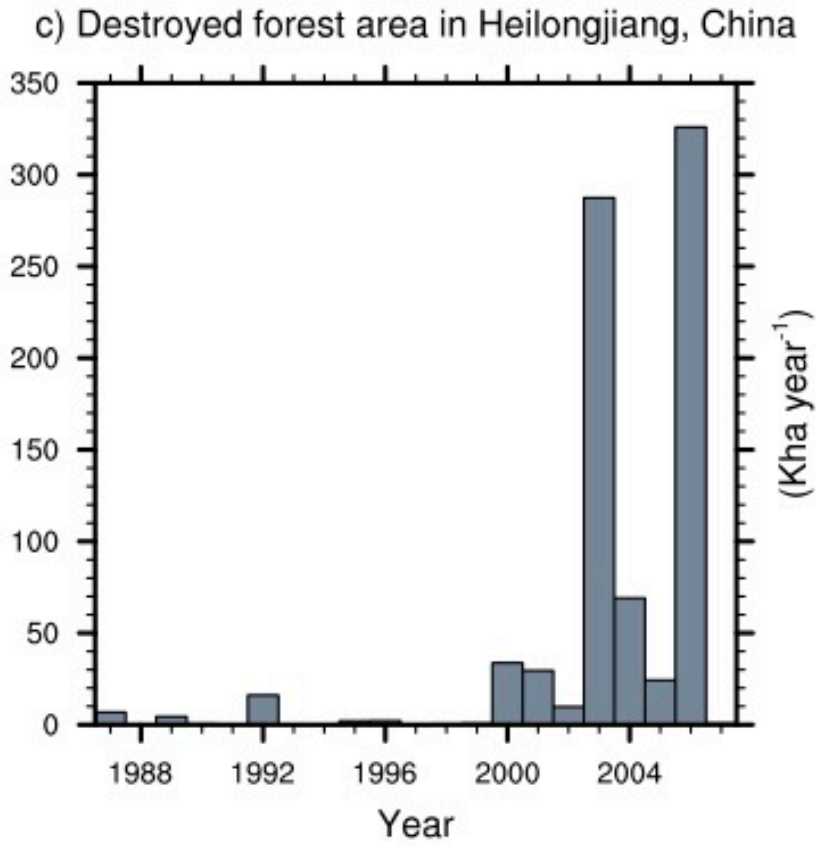
Negative trend?

Positive trend?

Positive trend?







1997 to 2016 (20 years)

1964 to 2015 (52 years)

1987 to 2008 (21 years)

Thank you for your attention!

https://sites.google.com/view/climatesystem/