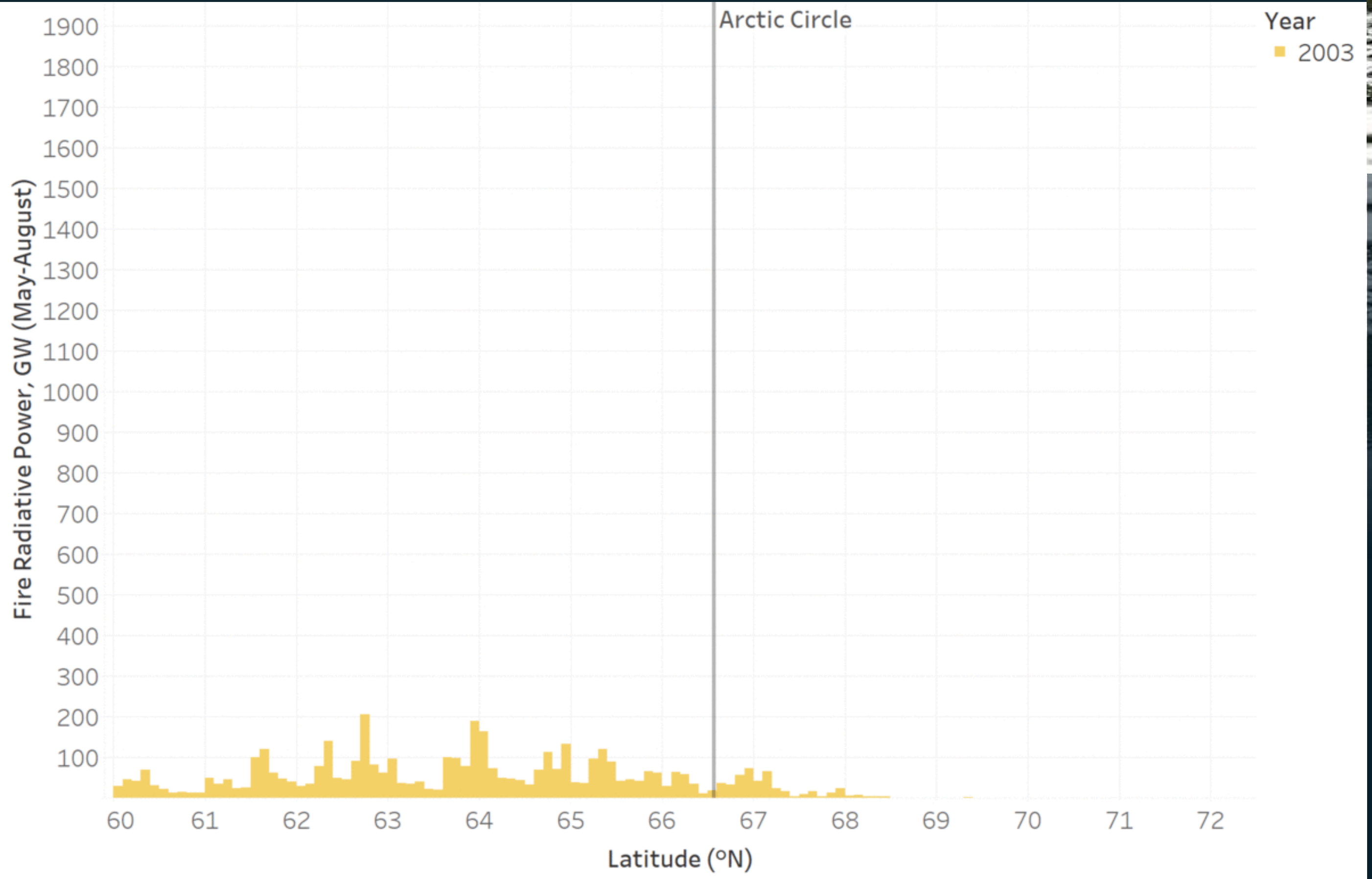
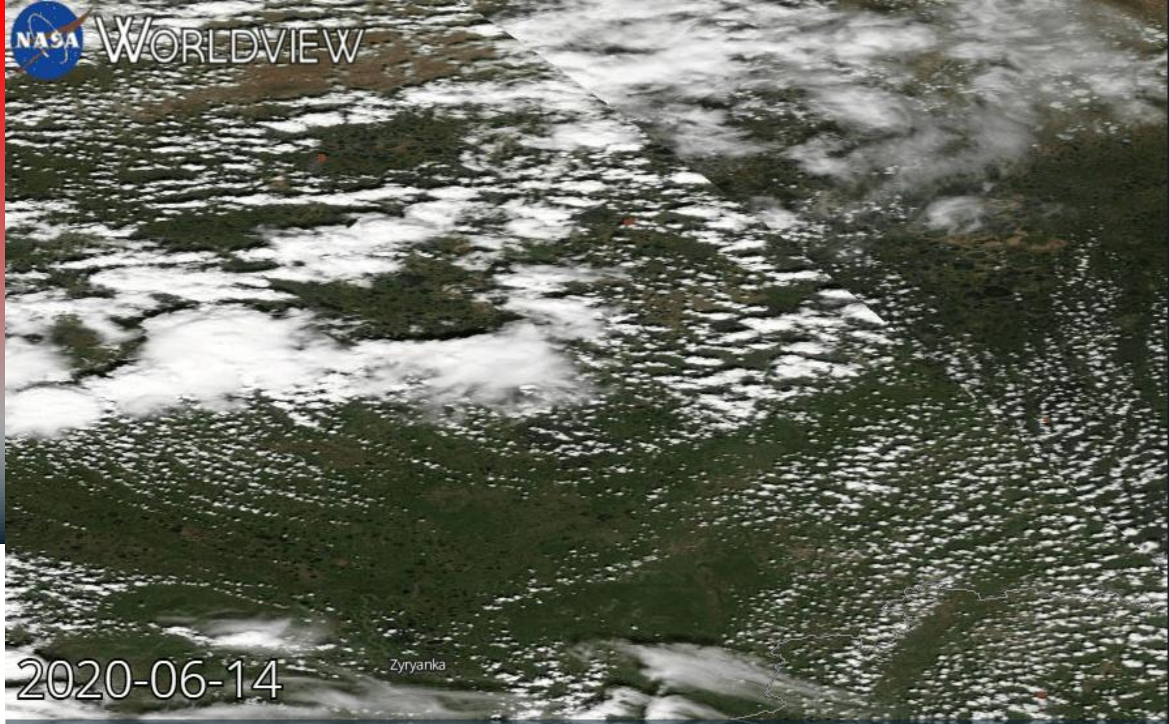
ARCTIC WILDFIRES: WHAT WE CAN (AND CANNOT) KNOW FROM SATELLITES





Dr Thomas Smith

LSE Geography & Environment

LSE

Thanks to Mark Parrington, Jessica McCarty, Merritt Turetsky, Pierre Markuse

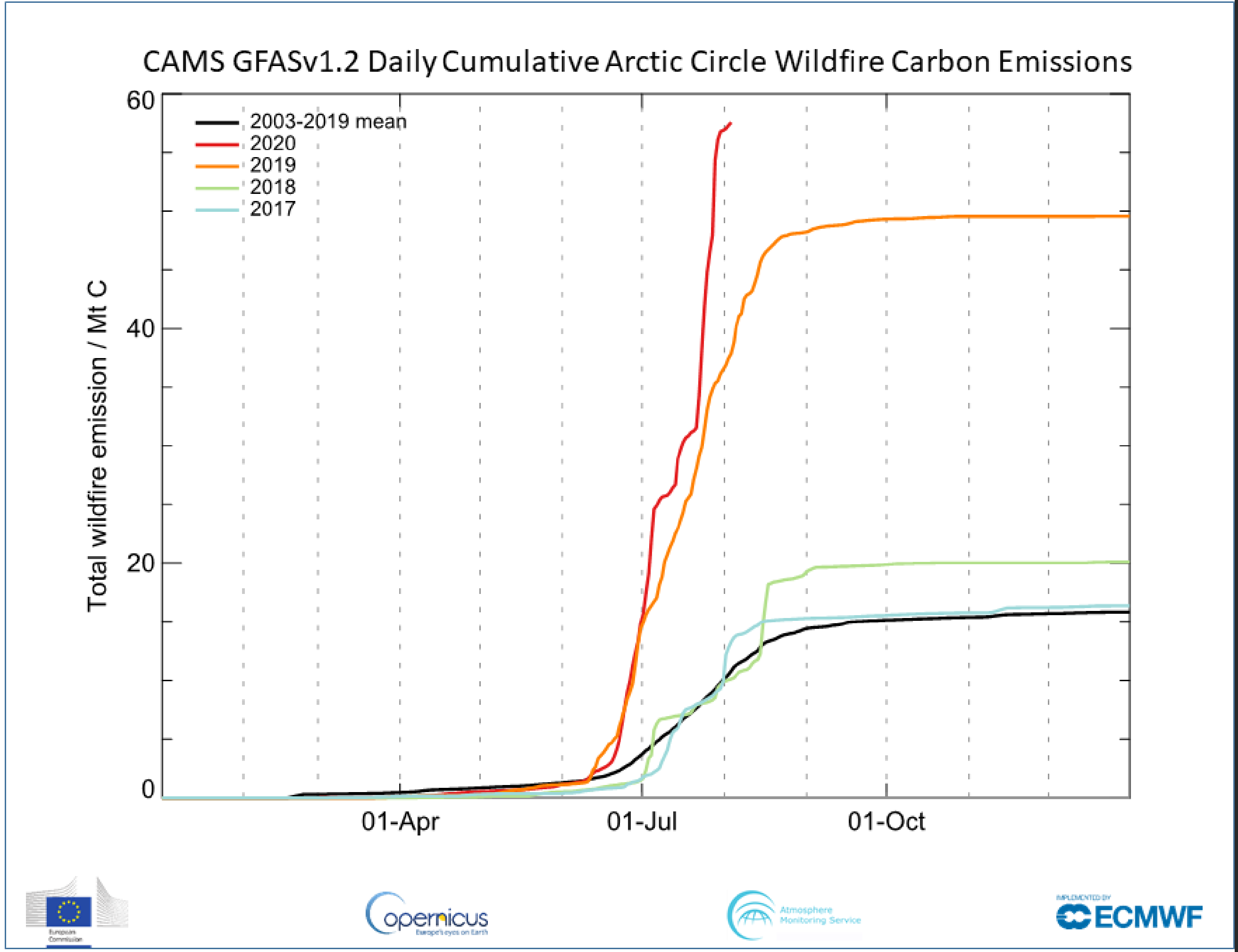
@DrTELS @LSEGEOGRAPHY

sentinelhub webinar

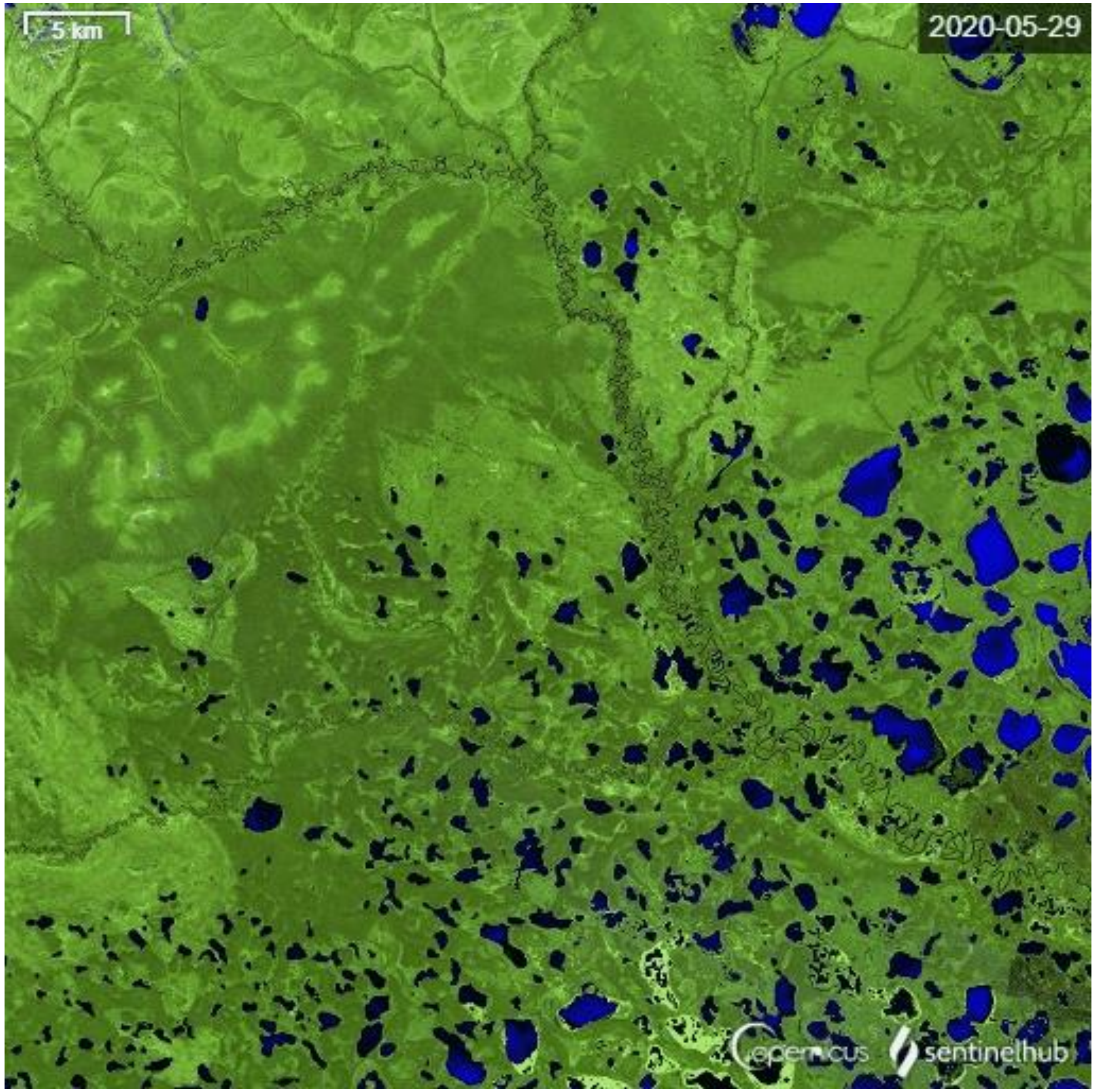
Thursday 23 April, 2023

CONTEXT:

- 2019 & 2020: Unprecedented Arctic fire activity in the MODIS record (2003–2020)
- 2021 also a big year (record year for Russia, but fires slightly further south, mostly 60°–65° N) – 18.16m Ha.

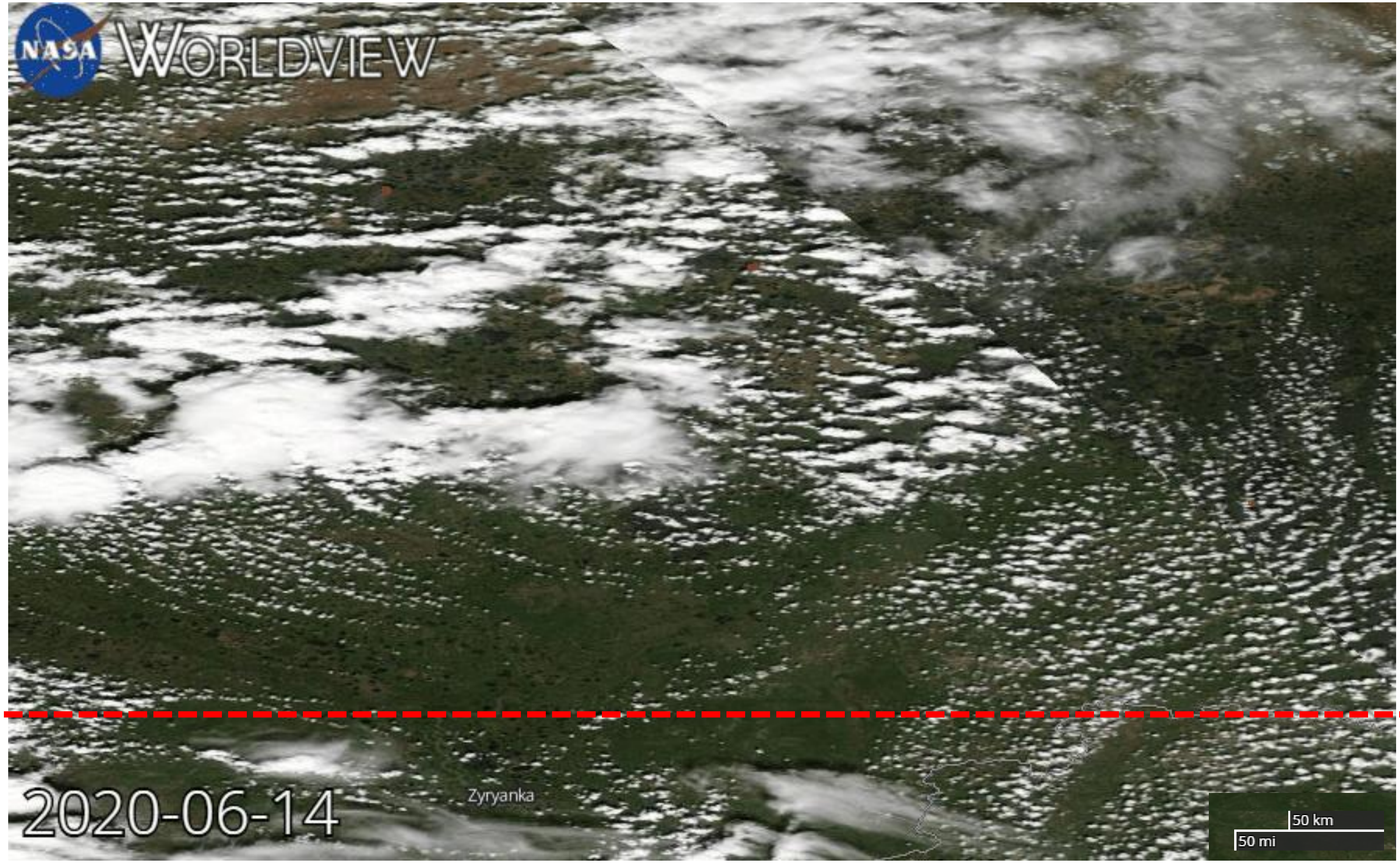


SOME OF THE LARGEST FIRES ON EARTH



Sentinel Hub 23 June 2020

JUNE 2020

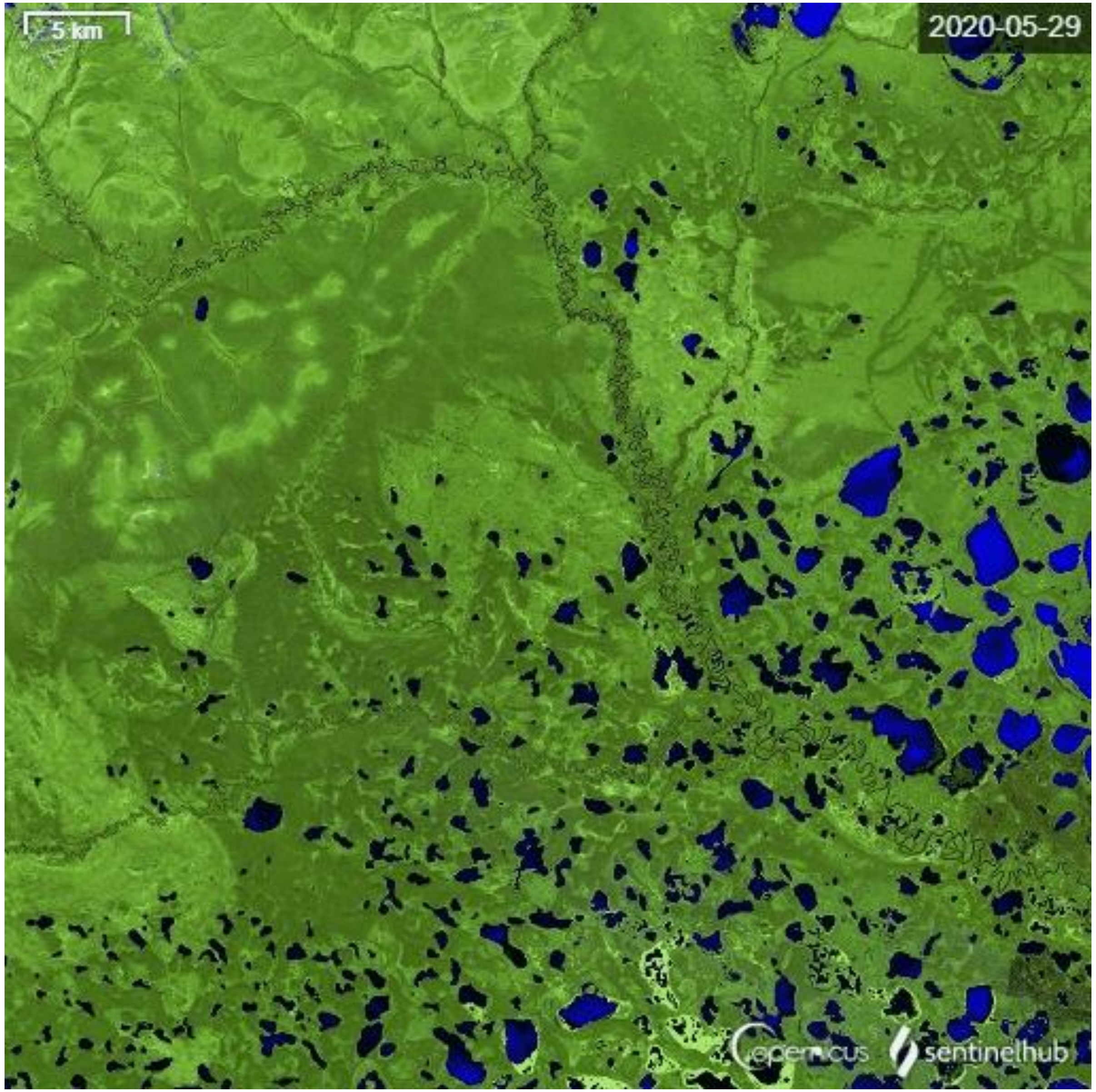


Arctic Circle

NASA Worldview 1 July 2020

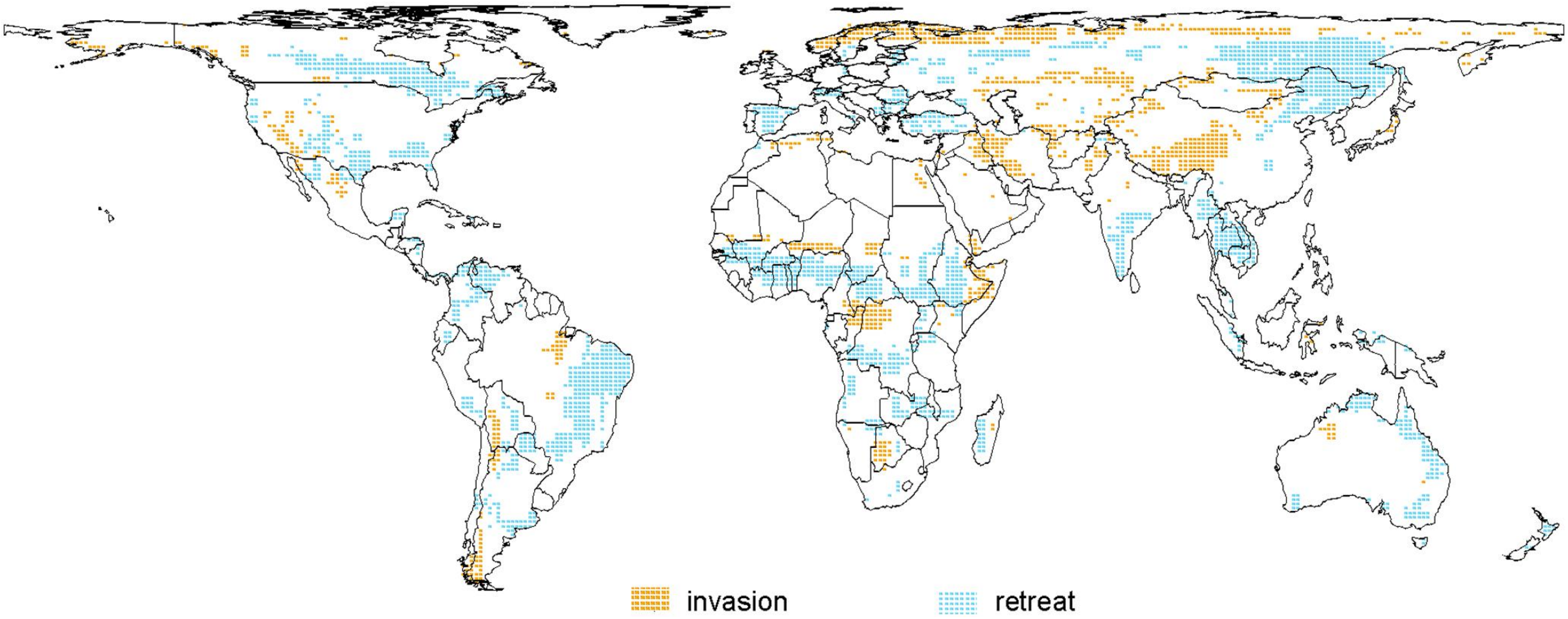
CONTEXT:

- 2019 & 2020: Unprecedented Arctic fire activity in the MODIS record (2003–2020)
- Important to understand:
  - What ecosystems are burning? (forest? tundra?)
  - What are the fuels? (larch? spruce? deciduous broadleaf?)
  - To what extent are these fires occurring on peatlands?
  - What might be the impact on permafrost soils and ice content?
- To do this:
  - Multi-spatial dataset analysis extracting information from land cover, soil, peat, and permafrost maps to investigate the nature of each fire hotspot detection north of 60°N during May–August 2003–2020, as well as May/July 2021.



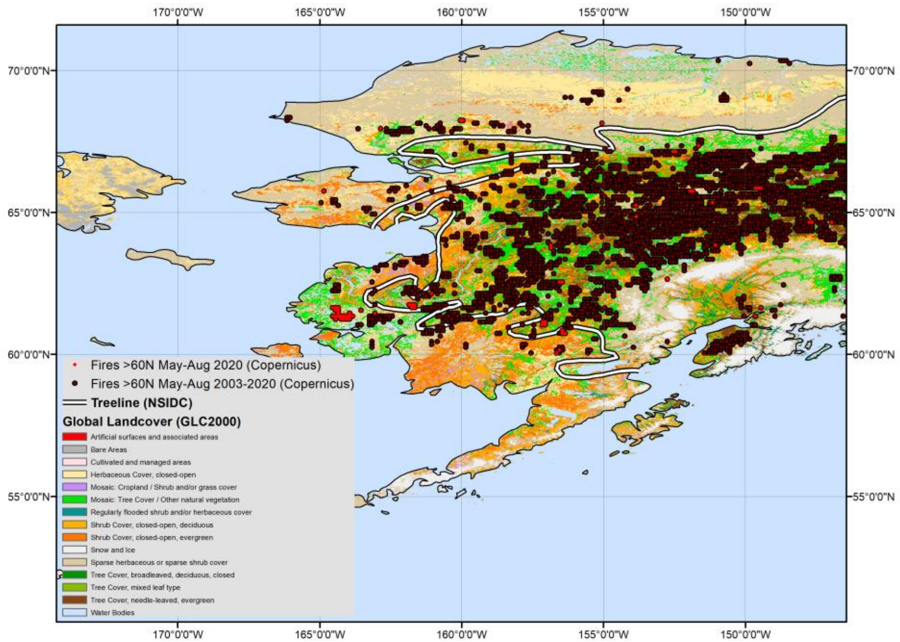
Is this an invasion?

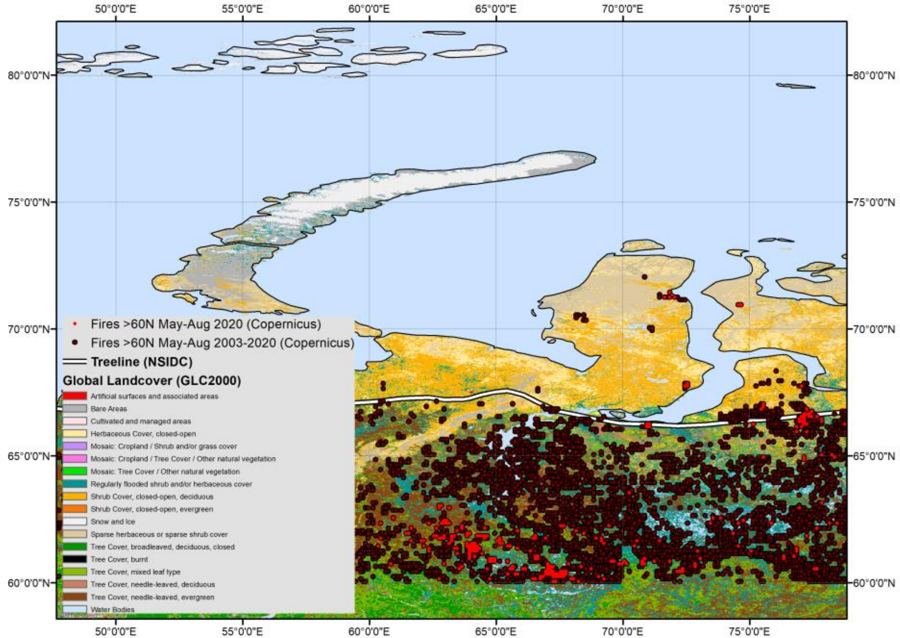
FIRE INVASION PREDICTED FOR 2010–2039

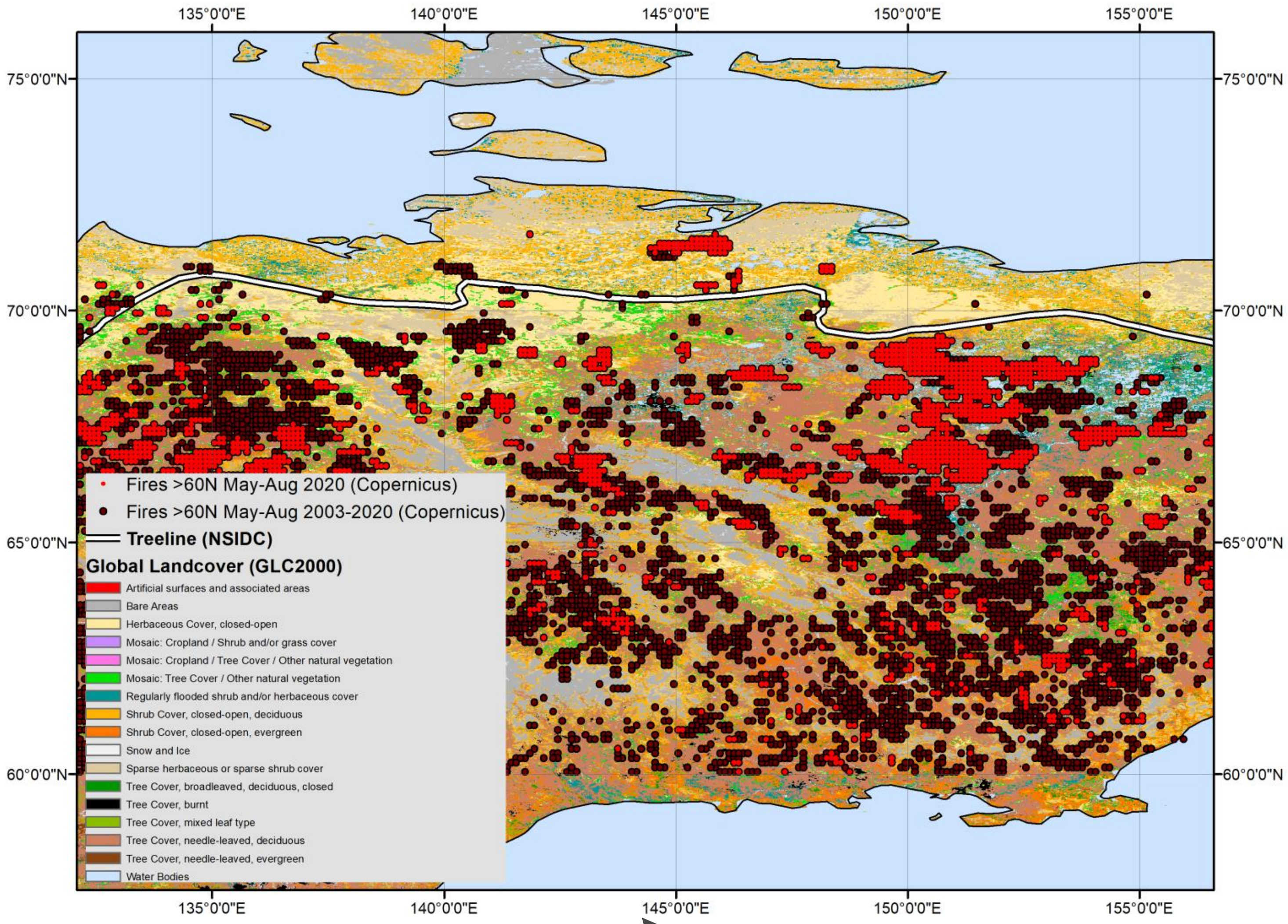


Krawchuk *et al.* (2009) *PLOSONE*

LAND COVER & TREELINE (GLC2000 + NSIDC)





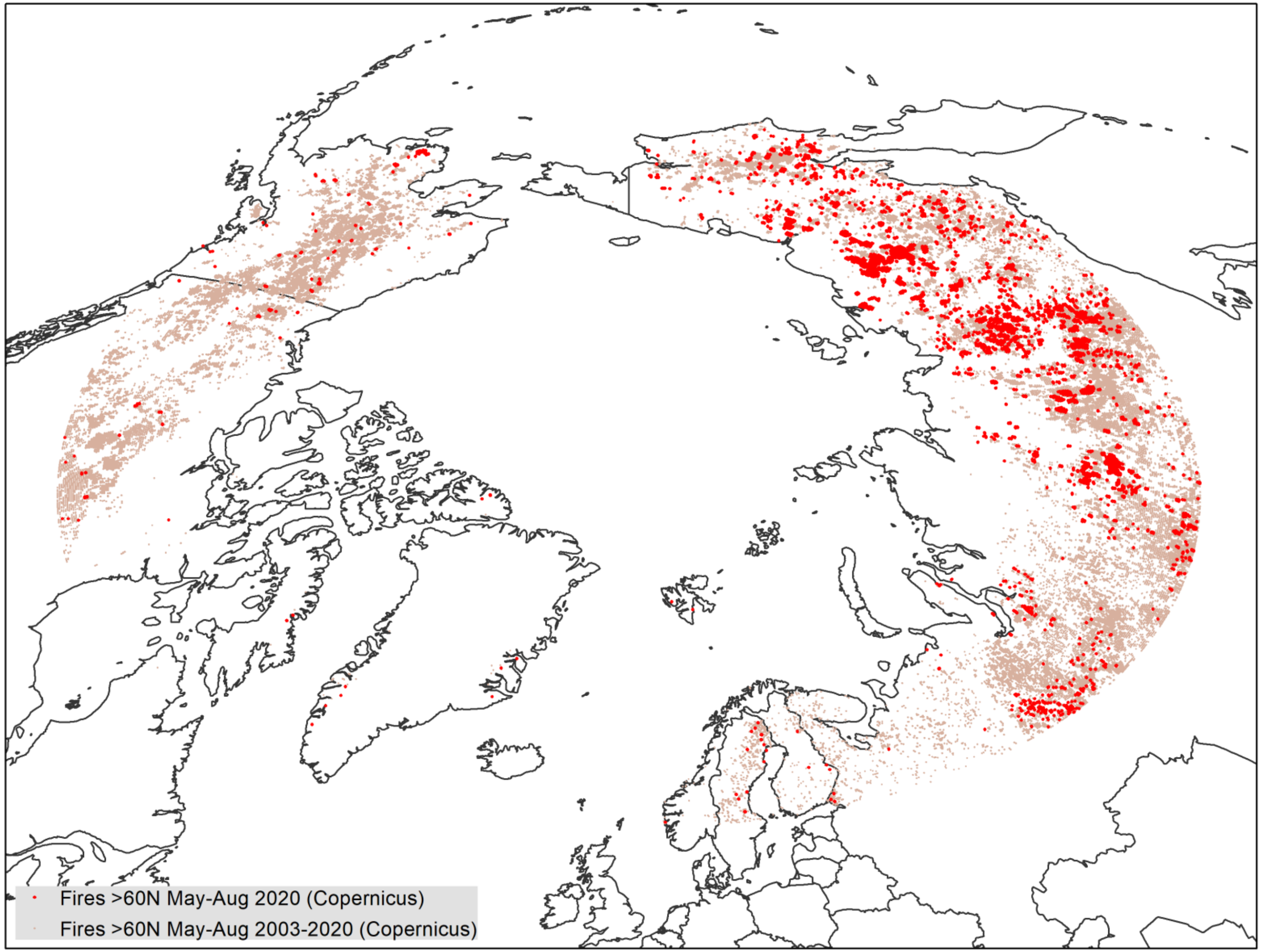


Subsets of datasets for Alaska (top) & parts of central Siberia (bottom).

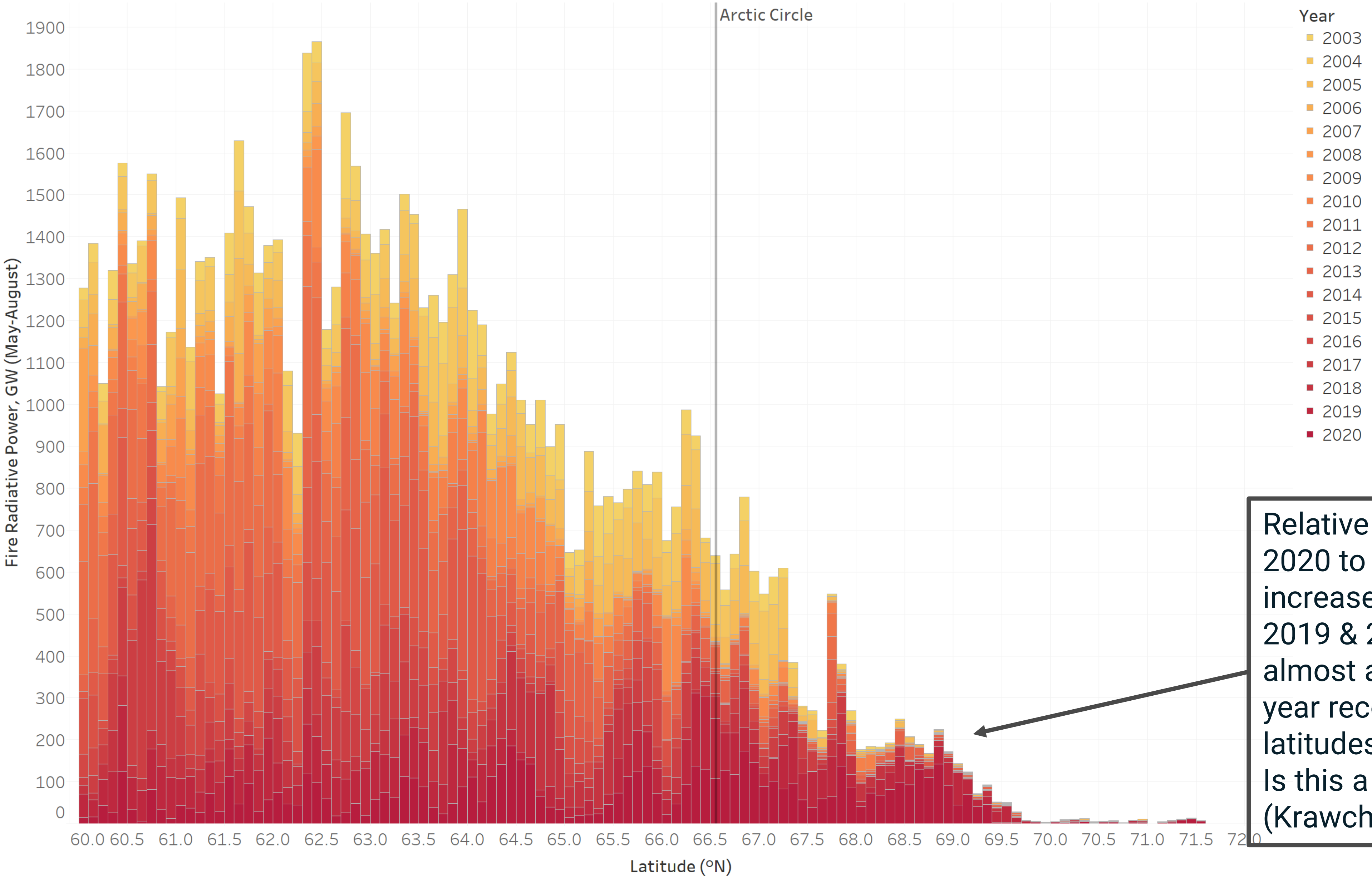
Subset of datasets for portions of eastern Siberia

DATASETS: FIRES (COPERNICUS, BASED ON MODIS)

- 0.1° × 0.1° daily total FRP observations (GFASv1.2) >60°N for May–August 2003–2020 (beige spots in the circumpolar map, red spots are the unprecedented detections in 2020).
- Thanks to Mark Parrington at the Copernicus Atmospheric Monitoring Service (CAMS) for this dataset.

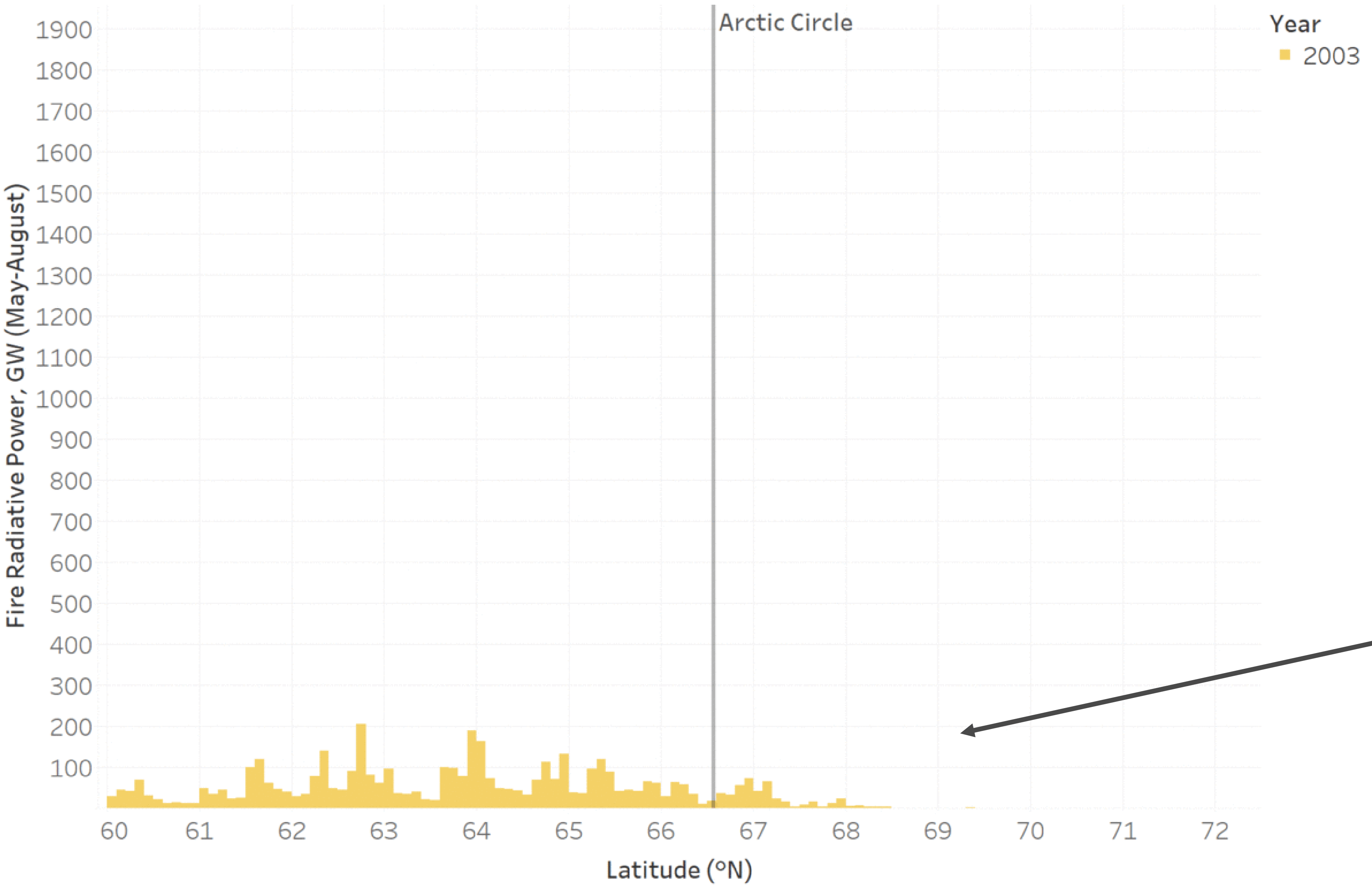


LATITUDINAL DISTRIBUTION THROUGH TIME



Relative contribution of 2019 & 2020 to 18-year total FRP increases with latitude.
2019 & 2020 accounts for almost all fire activity in the 18-year record at the highest latitudes (>68°N).
Is this a fire "invasion"? (Krawchuk et al., 2009)

LATITUDINAL DISTRIBUTION THROUGH TIME (ANIMATION)



Relative contribution of 2019 & 2020 to 18-year total FRP increases with latitude.
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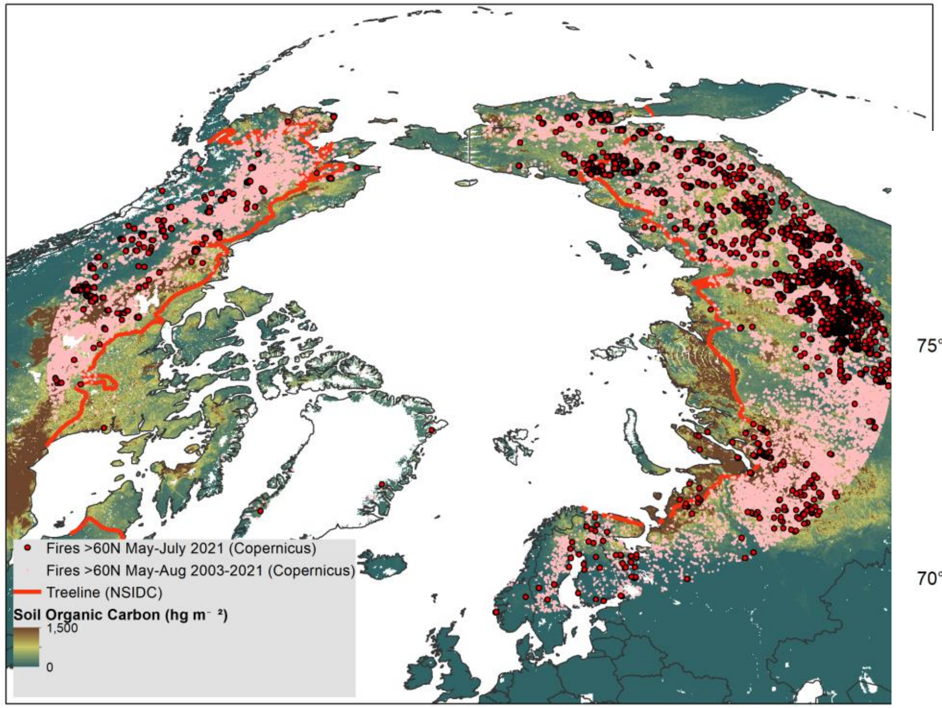
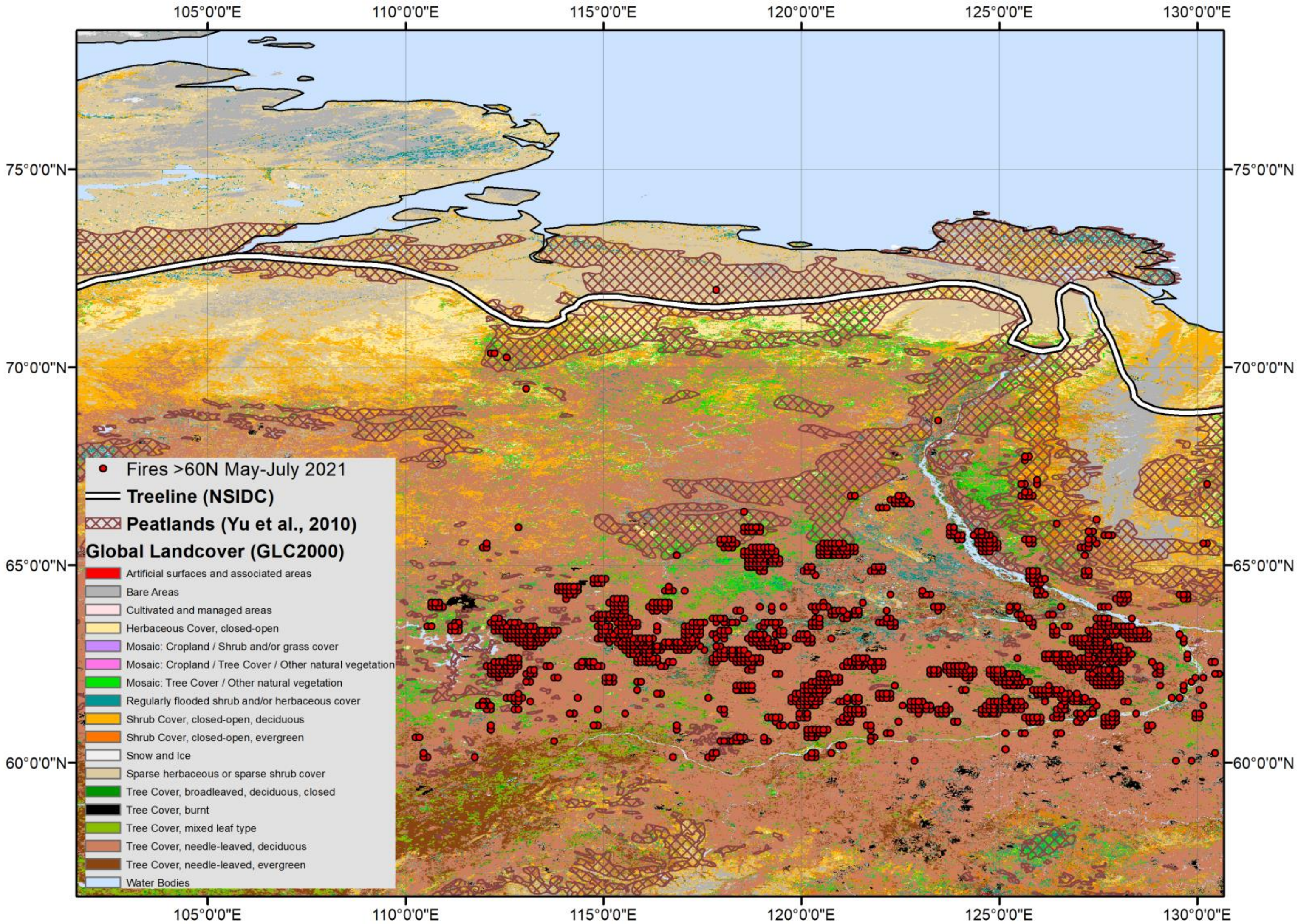
Is this a fire "invasion"?

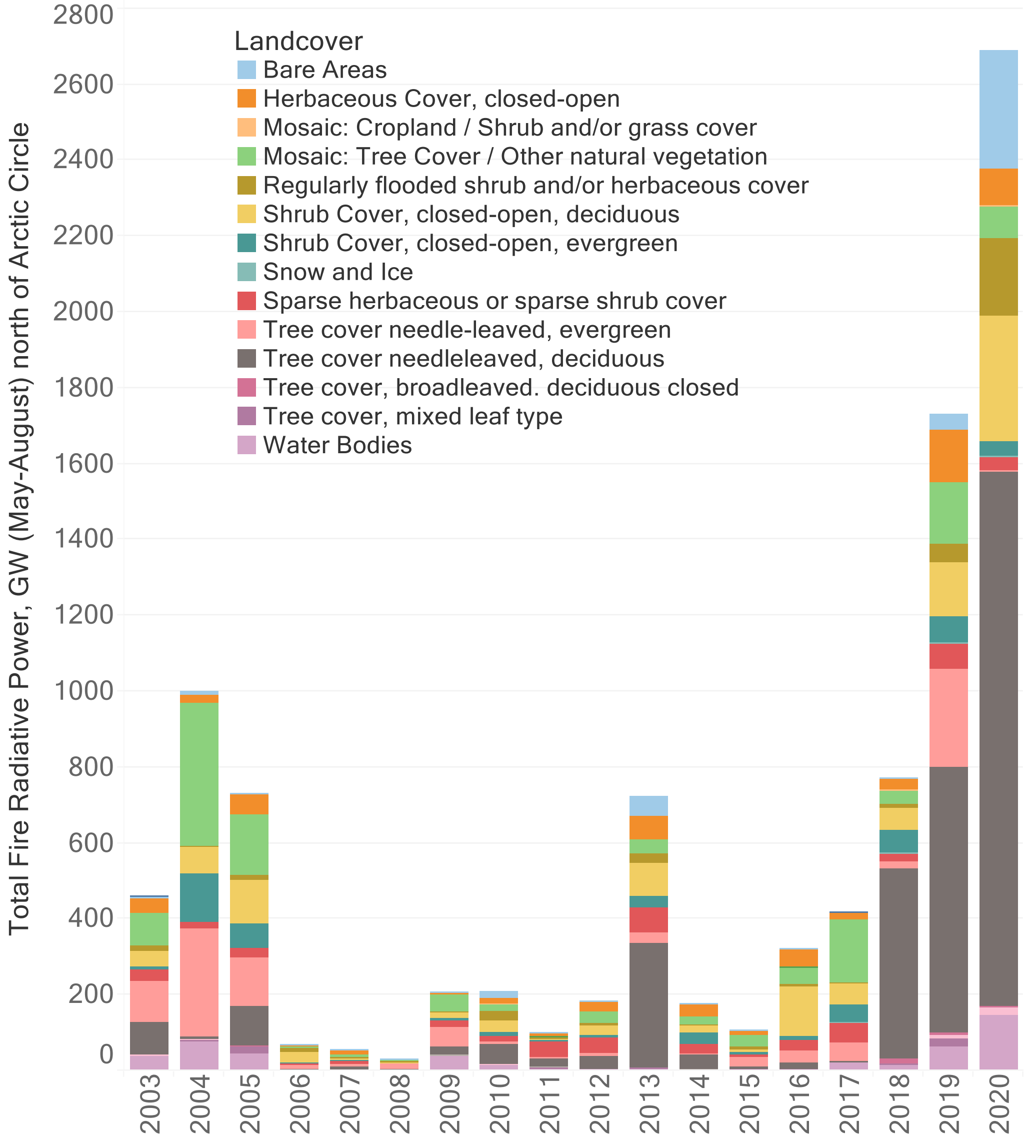
2021… MAY–JULY



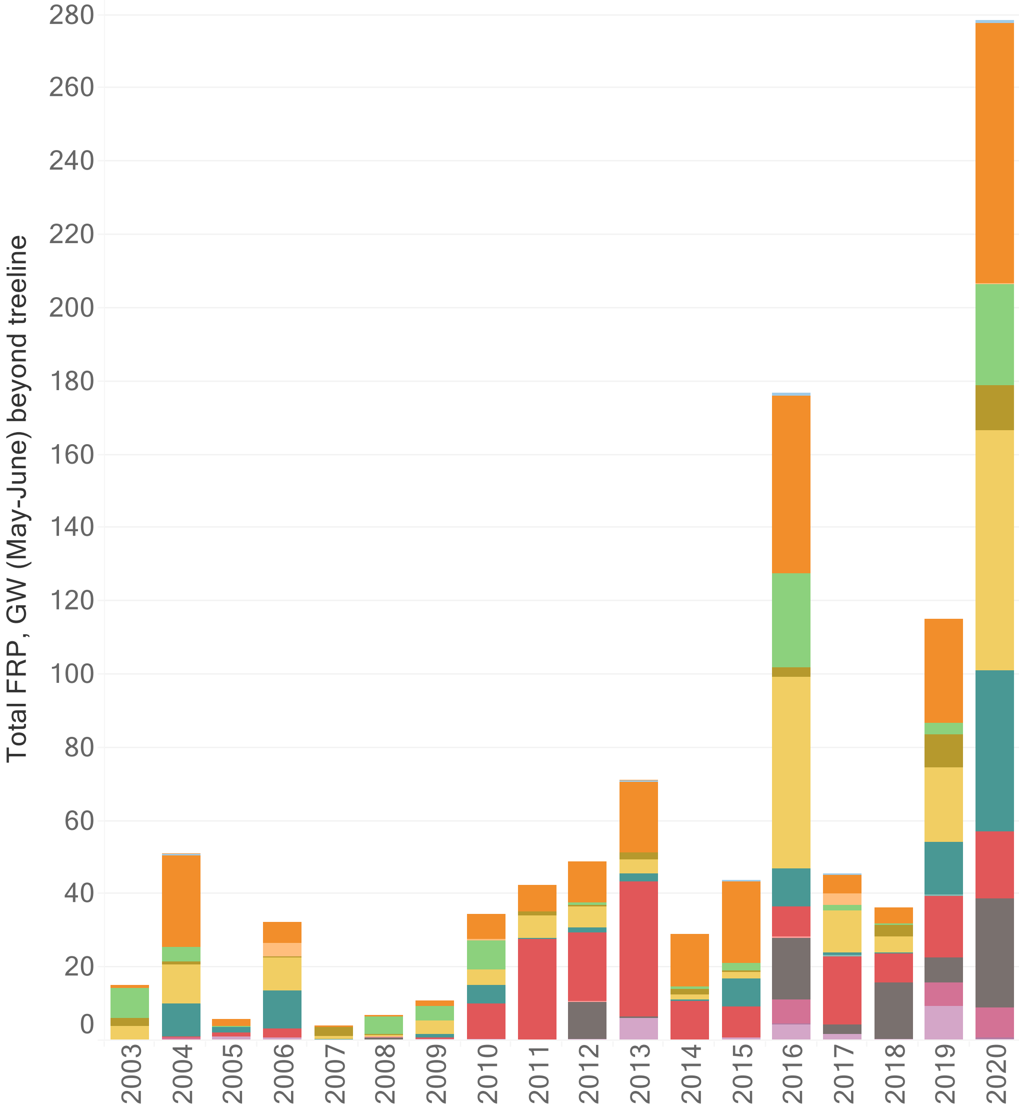


FIRES BY LANDCOVER

Two stories: Full season inside the Arctic Circle



Early fire season in the tundra (beyond the treeline)



Several wildfires in the Sakha Republic, within the Arctic Circle, Russia (Lat: 67.00475, Lng: 150.96313) - July 22nd, 2020 - Enhanced natural colors with IR overlay - Contains modified Copernicus Sentinel data [2020], processed by Pierre Markuse - Image is about 154 kilometers wide

DESCALS ET AL (2022, SCIENCE)

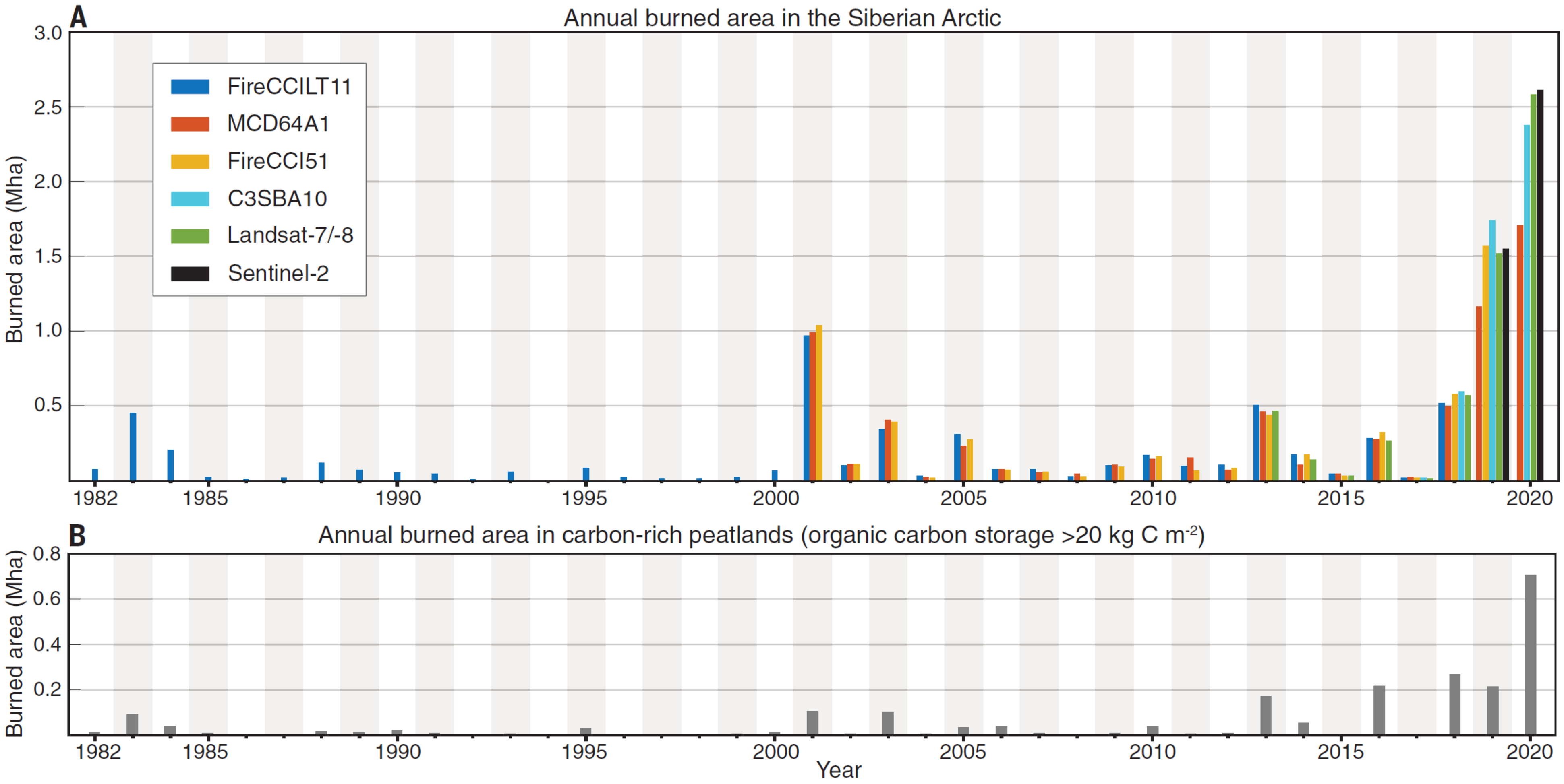
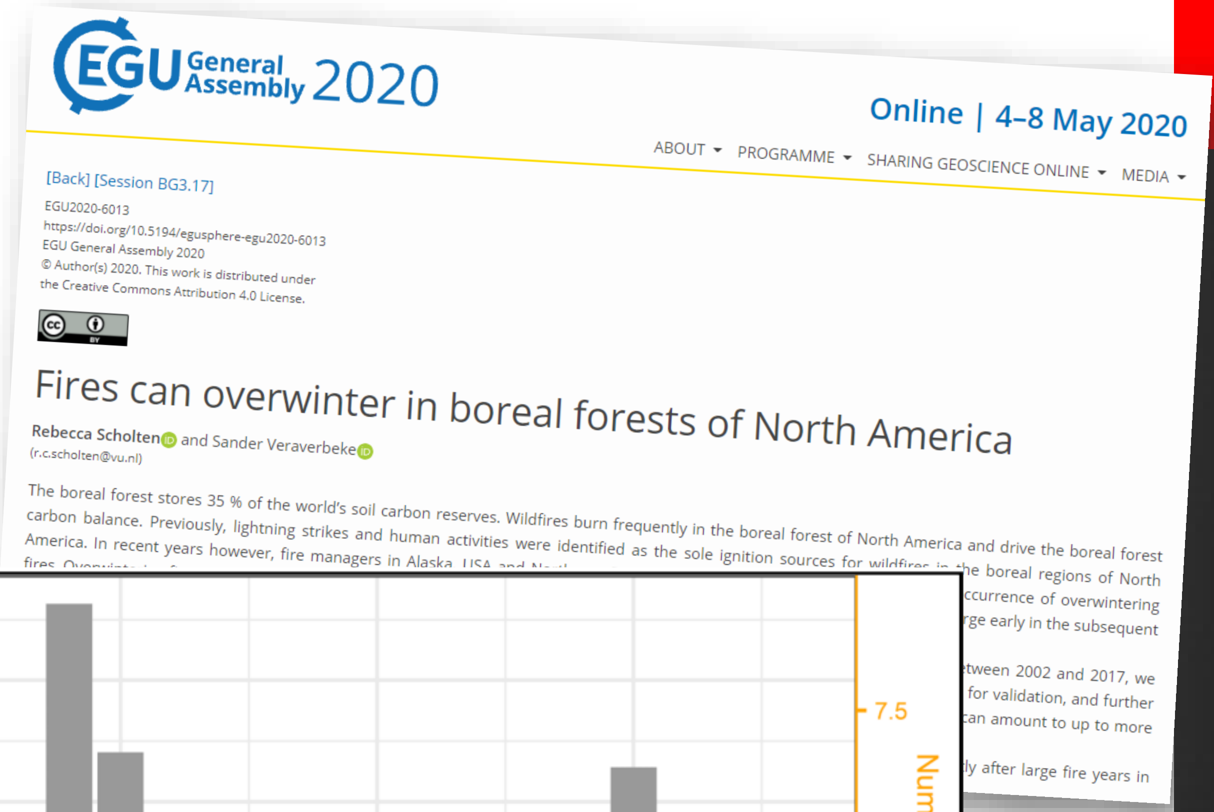


Fig. 2. Annual burned area in the Siberian Arctic and in carbon-rich peatlands for 1982–2020. (**A**) Annual burned area in the Siberian Arctic derived from remotely sensed data from six products. (**B**) Annual burned area in carbon-rich peatlands; >20 kg C m^{-2} in storage of organic carbon obtained from a reference dataset (*8*). The annual burned area in carbon-rich peatlands represents the median burned area for the available satellite products. Satellite burned-area products contain no data for 1994.

Zombies?

ZOMBIE (OVERWINTERING) FIRES

ZOMBIE (OVERWINTERING) FIRES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ABOUT PROGRAMME SHARING GEOSCIENCE ONLINE MEDIA

[Back] [Session BG3.17]

EGU2020-6013
https://doi.org/10.5194/egusphere-egu2020-6013
EGU General Assembly 2020
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Fires can overwinter in boreal forests of North America

Rebecca Scholten and Sander Veraverbeke
(r.c.scholten@vu.nl)

The boreal forest stores 35 % of the world's soil carbon reserves. Wildfires burn frequently in the boreal forest of North America and drive the boreal forest carbon balance. Previously, lightning strikes and human activities were identified as the sole ignition sources for wildfires in the boreal regions of North America. In recent years however, fire managers in Alaska, USA and North ...

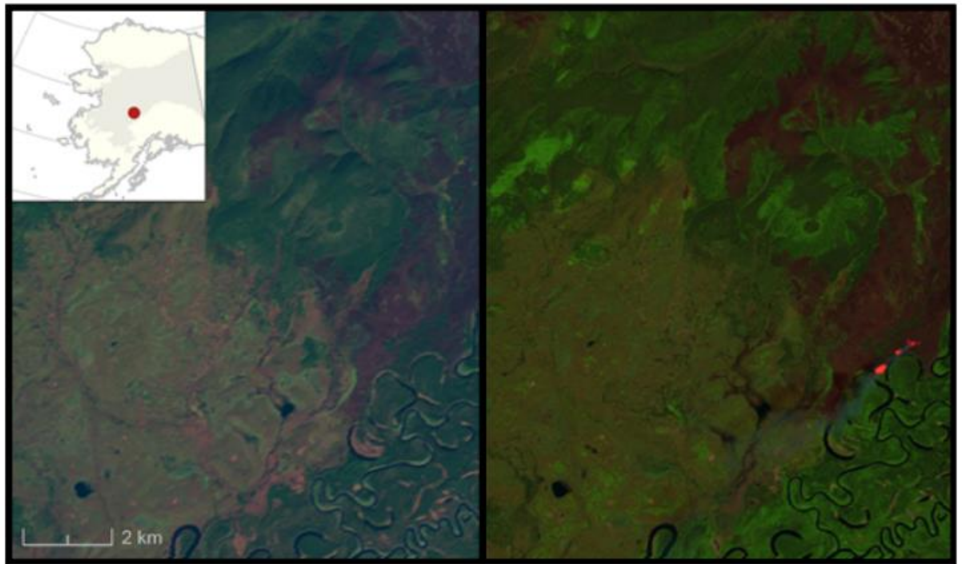

Figure 1: A fire scar (red-brown color) in interior Alaska has seemingly extinguished at the end of the fire season (left), but re-emerges early in the next fire season (right). Source: Landsat 8 imagery from September 24, 2015 (left) and Sentinel-2 imagery from May 29, 2016 (right).

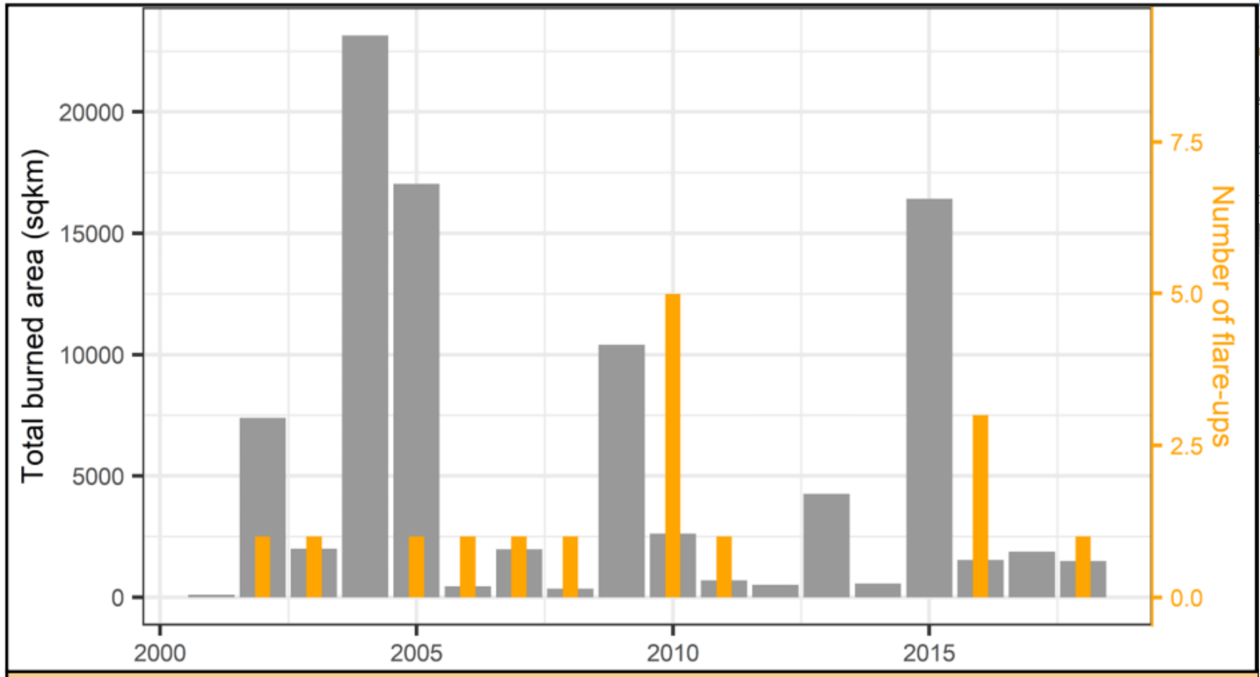

Figure 2: Years with a large burned area (grey bars) are more likely to generate overwintering flare-ups (orange bars) than years with less burned area.

https://meetingorganizer.copernicus.org/EGU2020/EGU2020-6013.html

ZOMBIES?

NASA
WORLDVIEW
Batagay
2020-04-24

11:48
72%
Thread
Dr Thomas Smith
@DrTELS
Are these 'zombie' fires? As the snow melted in Arctic Siberia last week, a number of fires have been detected by satellites. Did these fires smoulder through the winter after widespread #wildfires last summer? [short thread 1/5]
NASA
WORLDVIEW
GIF
2020-05-05
15:46 · 06 May 20 · Twitter Web App
View Tweet activity
30 Retweets 4 Quote Tweets 54 Likes

Eos Science News by AGU

ABOUT SPECIAL REPORTS TOPICS PROJECTS NEWSLETTER SUBMIT TO *EOS*

The Rise of Zombie Fires

Wildfires can smolder underground through Arctic winters, reigniting at the surface when

By Kate Wheeling 30 June 2020

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'Zombie' fires in Alaska and Canada may be becoming more common

ENVIRONMENT 19 May 2021

By Krista Charles

NATIONAL GEOGRAPHIC

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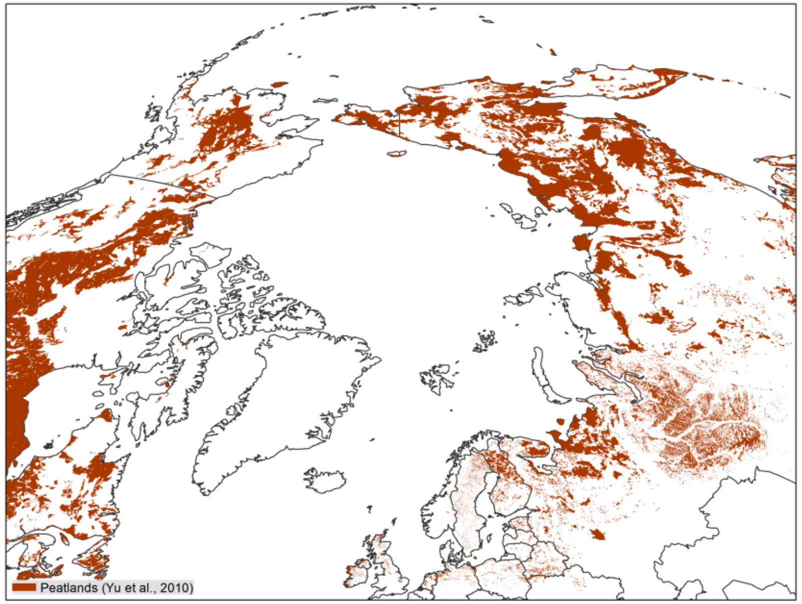
Wildfires burn in northern Russia in early May, 2021. When fires burn this early in the season, scientists try to figure out whether they were sparked by "zombie fires" that started the previous year.

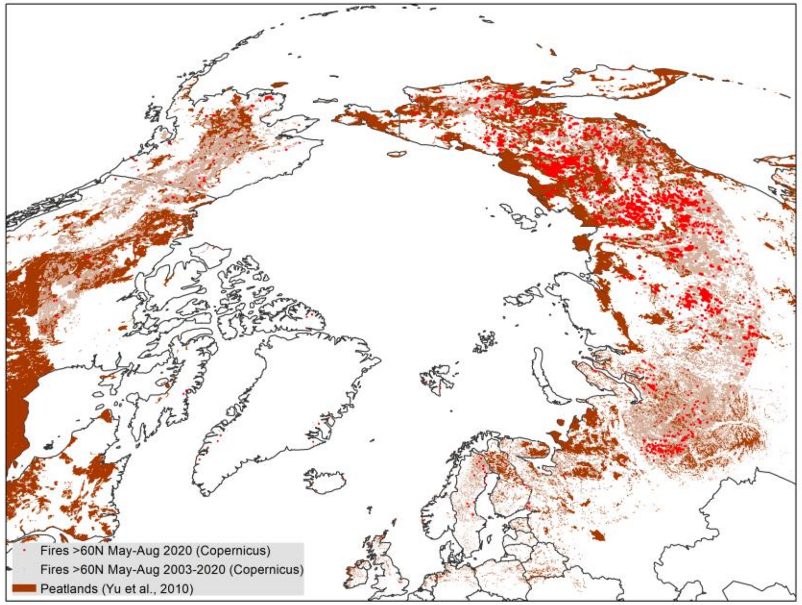
PHOTOGRAPH BY COPERNICUS SENTINEL/SENTINEL HUB PROCESSED BY PIERRE MARKUSE

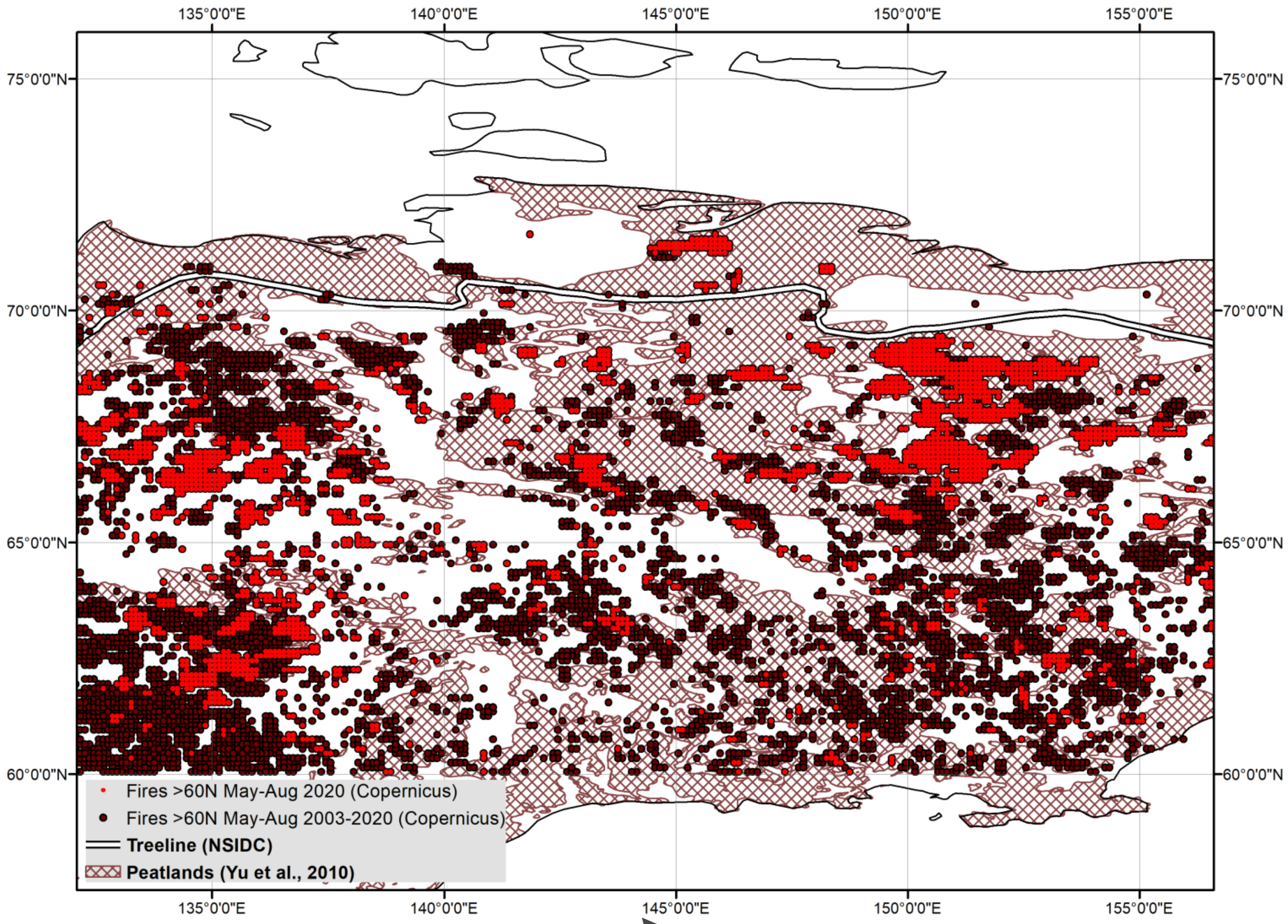
ENVIRONMENT | NEWS

'Zombie' fires in the Arctic are linked to climate change

PEATLANDS (YU ET AL., 2010)





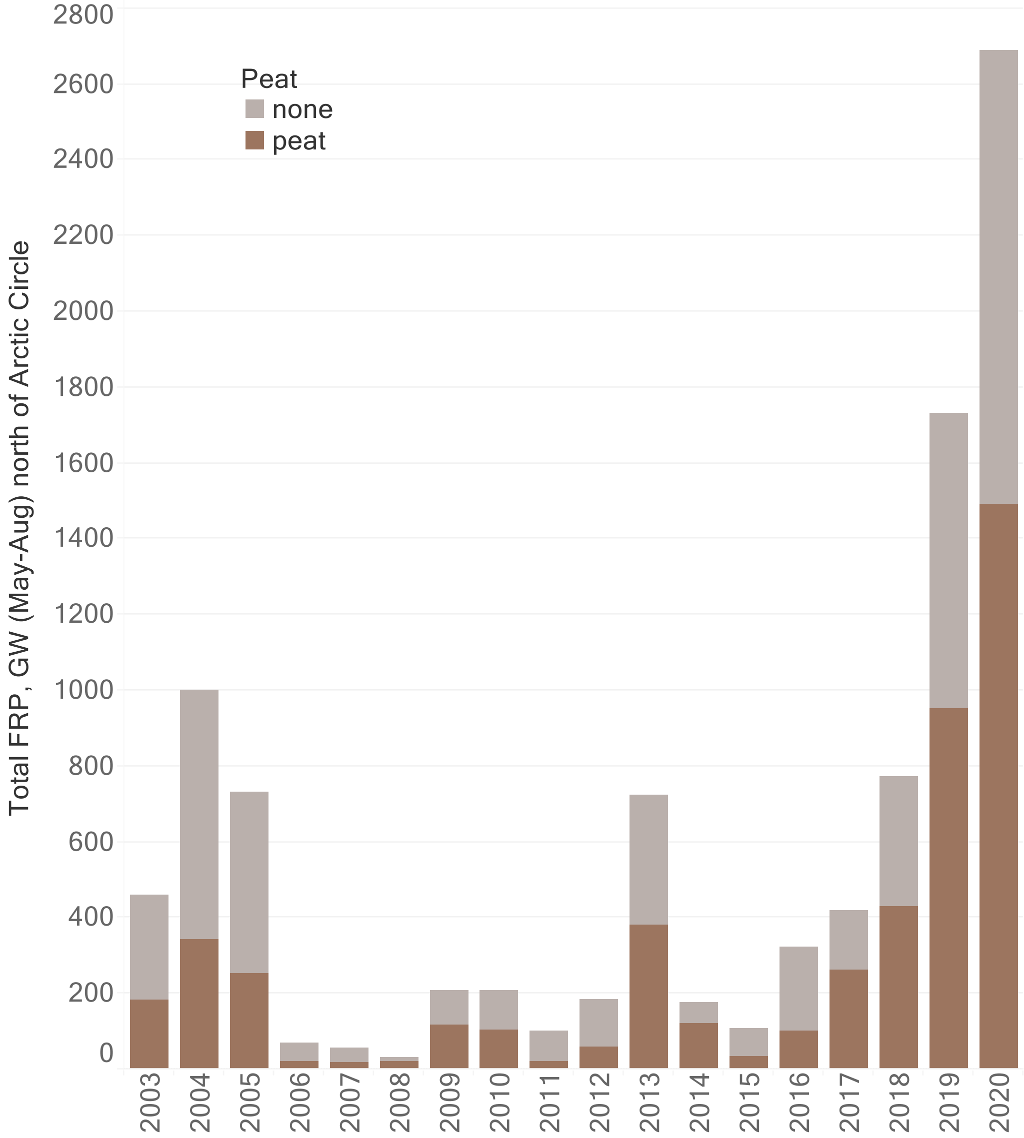


Circumpolar without (top) & with (bottom) May–August 2003–2020 fires and 2020 fires.

Subset of datasets for portions of eastern Siberia

FIRES ON PEATLANDS

Two stories: Full season inside the Arctic Circle



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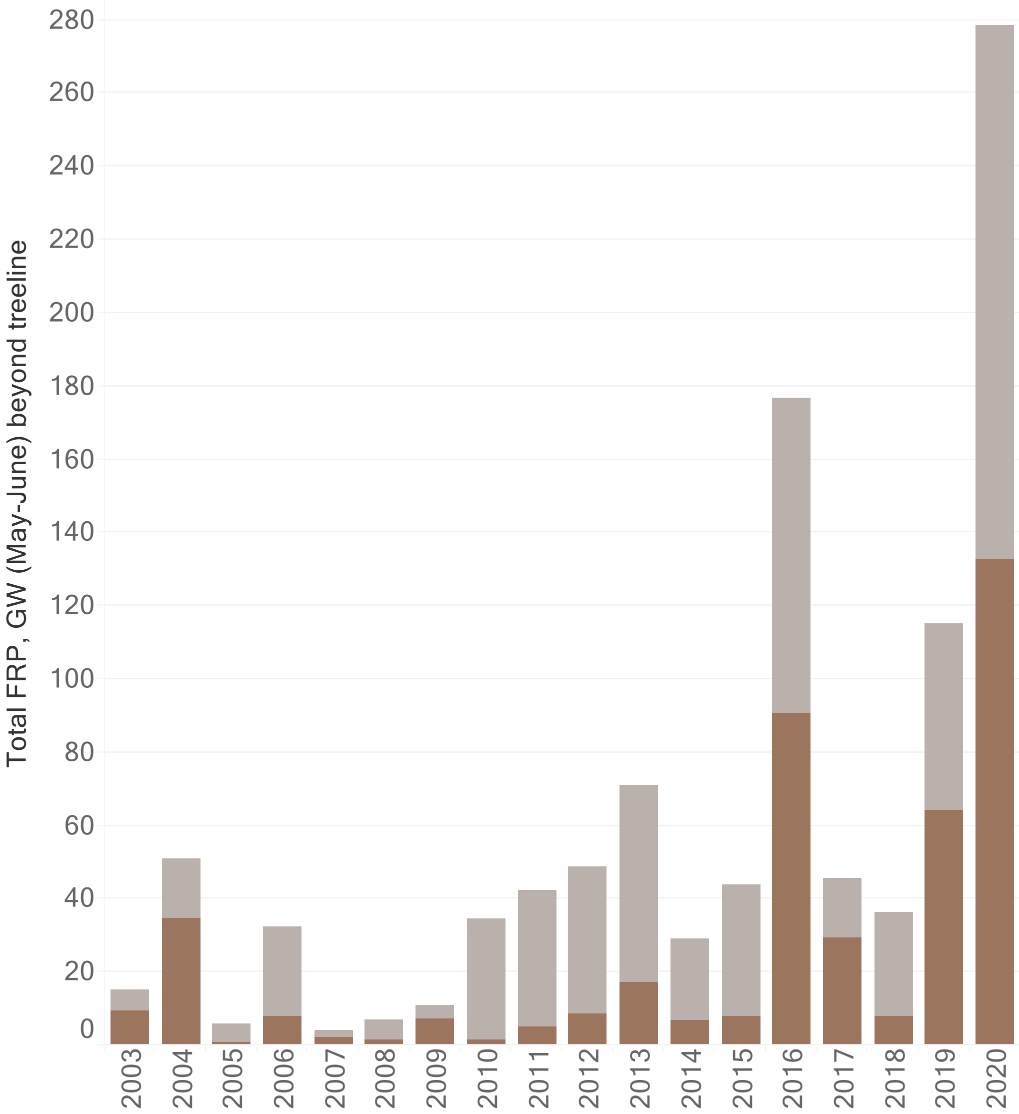
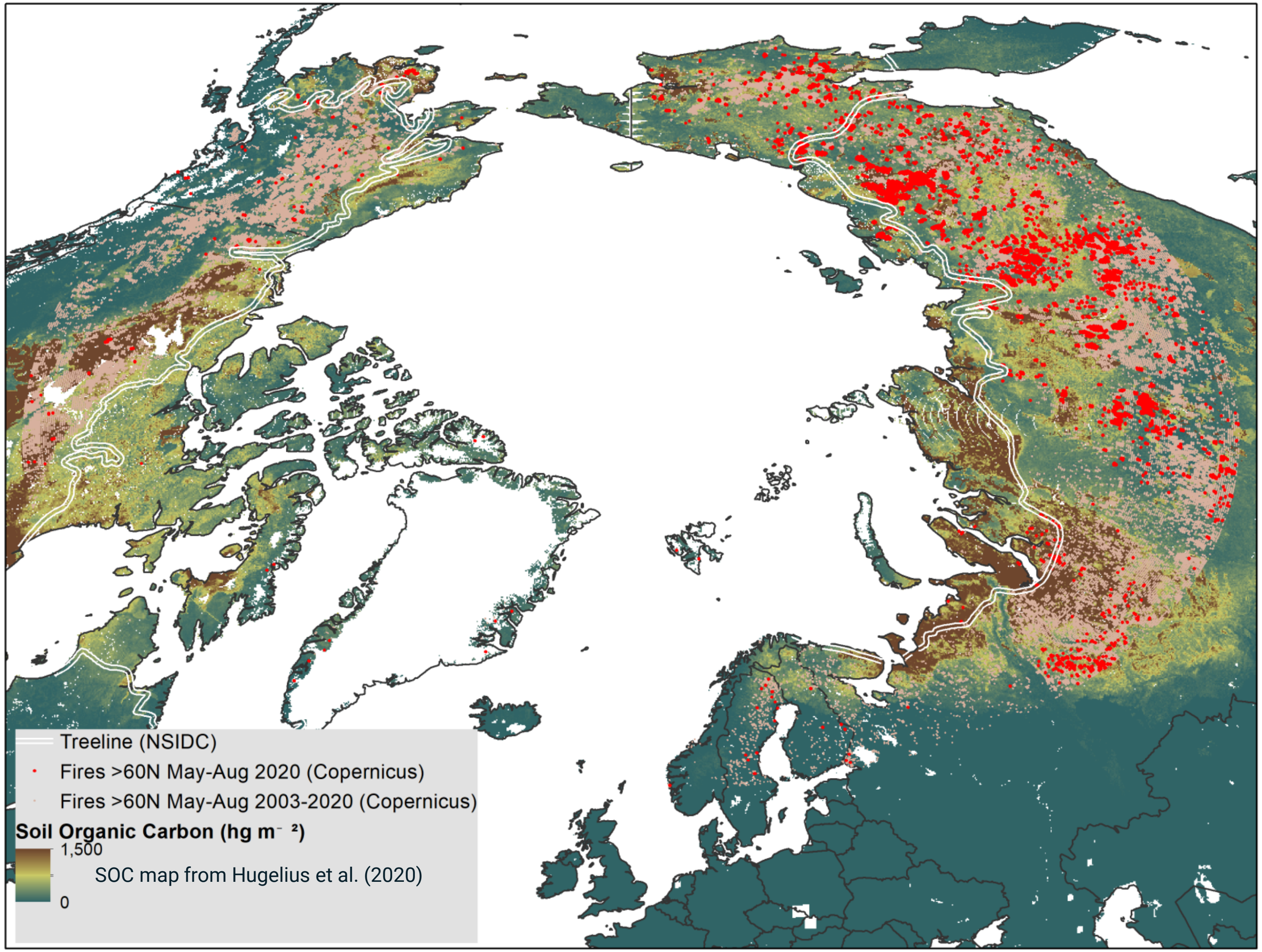


SOC AND POTENTIAL PEAT DEPTH IN FIRE-AFFECTED REGIONS

- New peat map + data from Hugelius et al. (2020)
- This analysis investigates fire activity on a range of soil organic carbon (SOC) and potential peat depth according to the Hugelius et al. (2020) dataset.
- Some speculation that fires were moving onto deeper peat from peripheral peat regions.
- Need to also investigate fire encroachment onto peatlands by using distance from peatland edge



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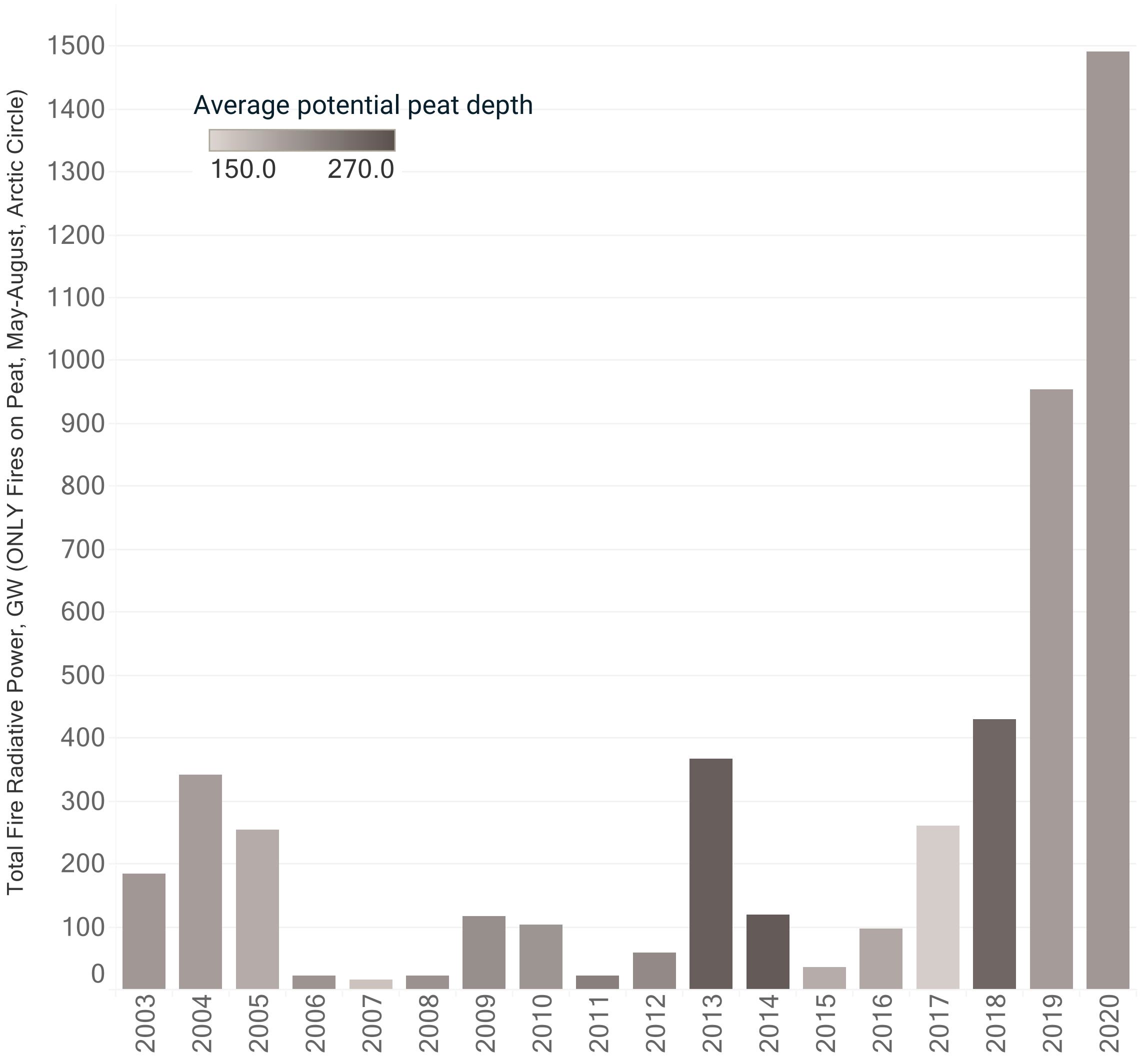
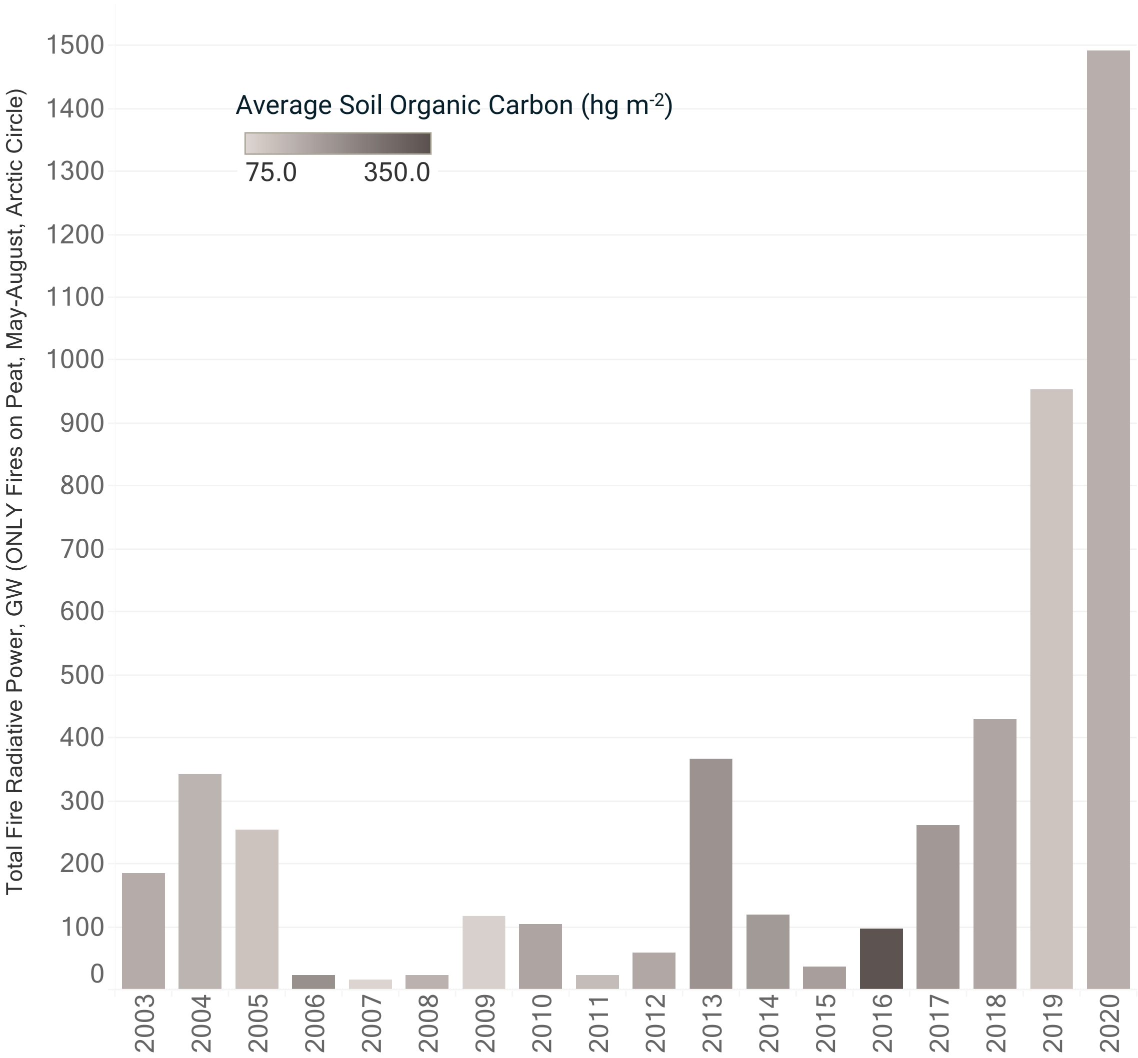
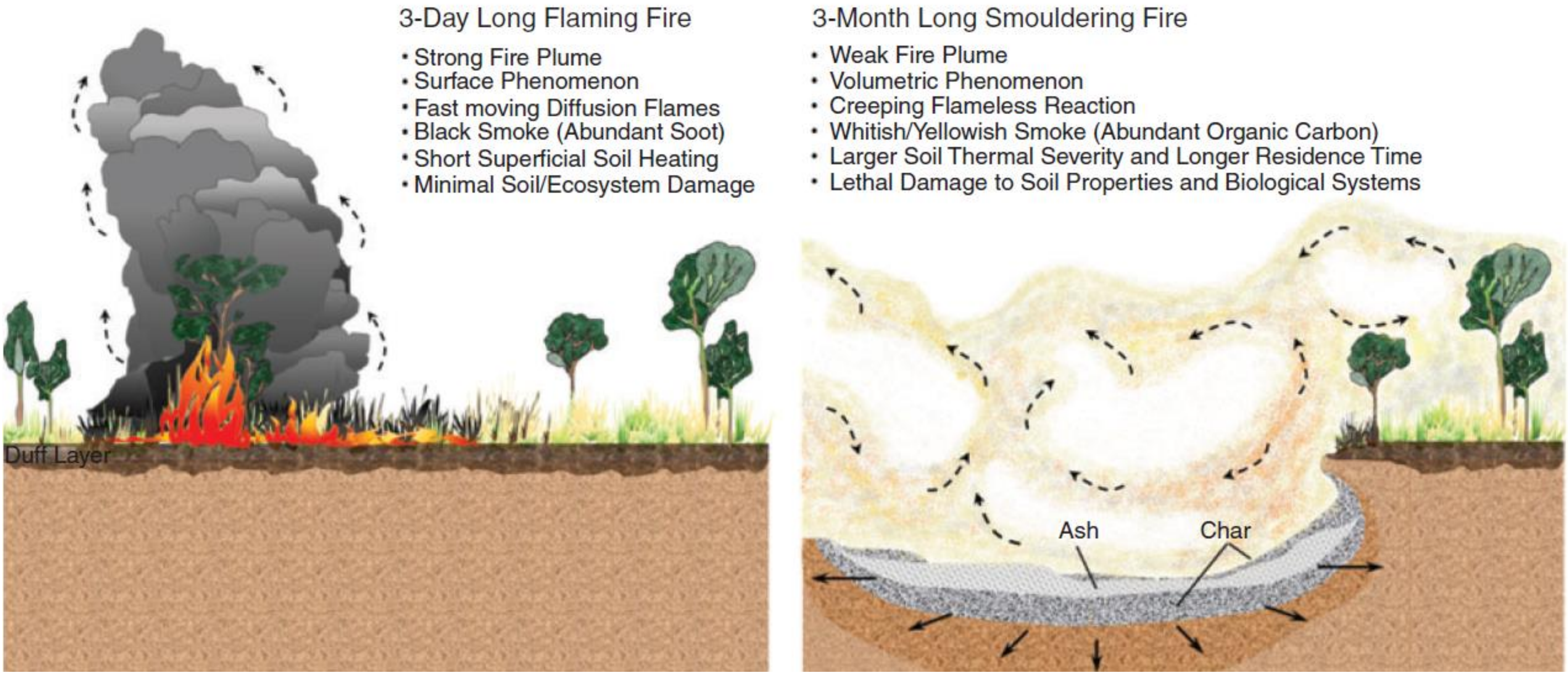




Hu, Fernandez-Anez, Smith, Rein (2018, IJWF)
tinyurl.com/HuPeat18

…BUT IS THE PEAT BURNING?

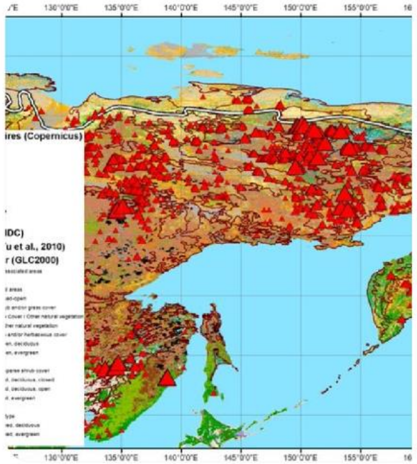


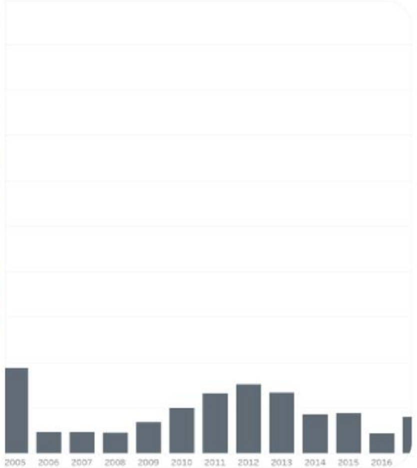
land clearance fire on peat near Pekan, Pahang, Malaysia

Prescribed forest fire in Alberta, Canada

Dr Thomas Smith 🔥🌏
@DrTELS

New spatial analysis of wildfires across the Arctic in May/June 2020, and how they compare to the satellite record (2003-2020). What is burning? Are there peat fires? What about permafrost? 🔥🛰️thread in collab with @m_parrington @CopernicusECMWF #ArcticFires [1/9]





Adam Vaughan and 7 others

10:57 · 21 Jul 20 · Twitter Web App

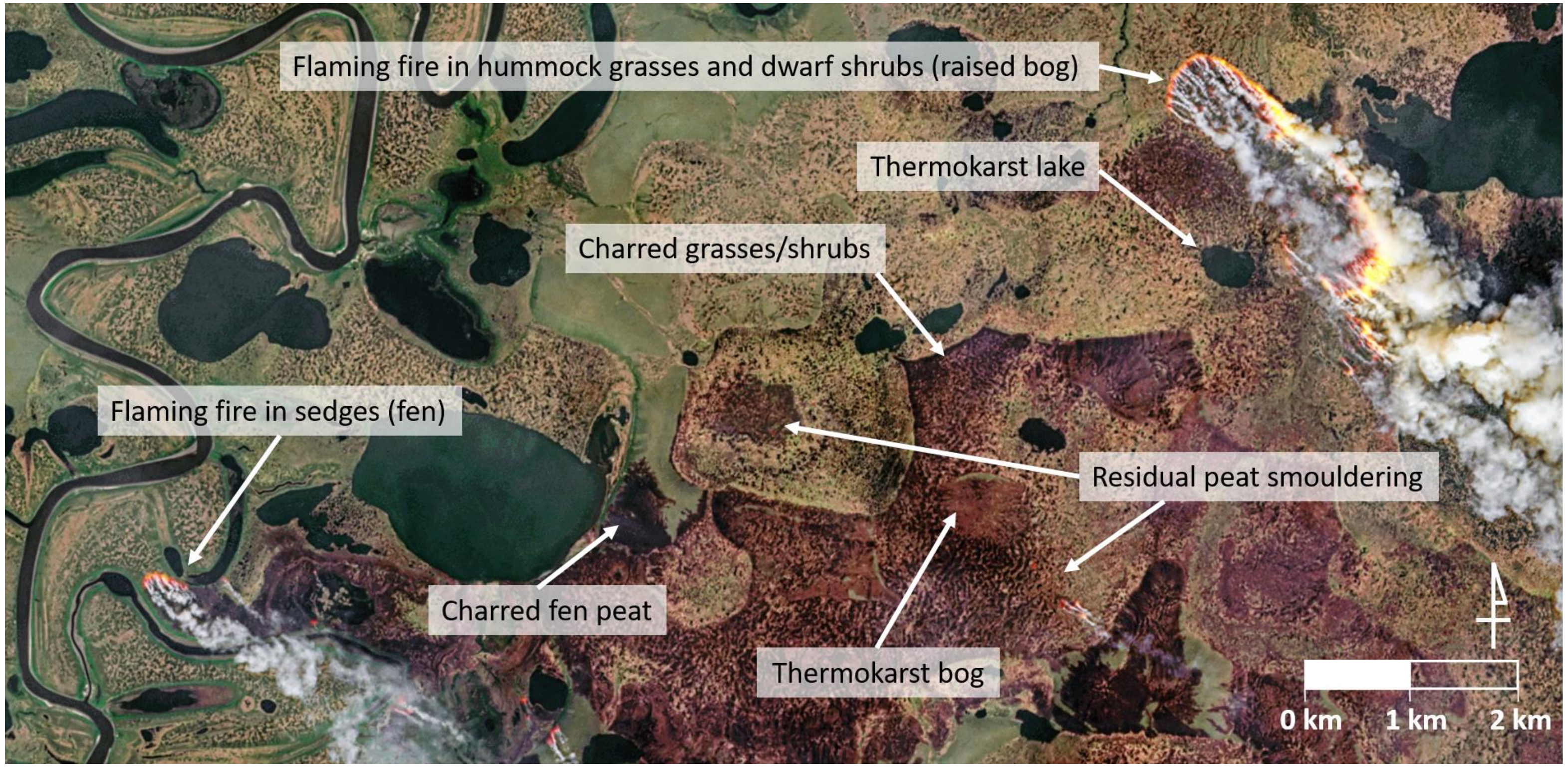
View Tweet activity

144 Retweets **20** Quote Tweets **176** Likes

MCCARTY ET AL. (2020, NATURE GEOSCIENCES)

- Here we discuss the major questions remaining about fires in the high latitudes.
- We demonstrate evidence for fires in peat soils (see figure from McCarty et al., 2020)
- Yet, automated detection of peat fires still very limited. While our evidence suggests fires in Arctic peatlands, it is currently not possible to confidently confirm fires that have ignited peatlands.

- Canopy cover
- Ash and debris cover
- Underground spread
- Low temperature
- Cloud cover



Wildfire in the Sakha Republic, within the Arctic Circle, Russia (Lat: 68.7076, Lng: 152.2710) - May 28th, 2020 - Enhanced natural colors with IR overlay - Contains modified Copernicus Sentinel data [2020], processed by Pierre Markuse - Image is about 35 kilometers wide

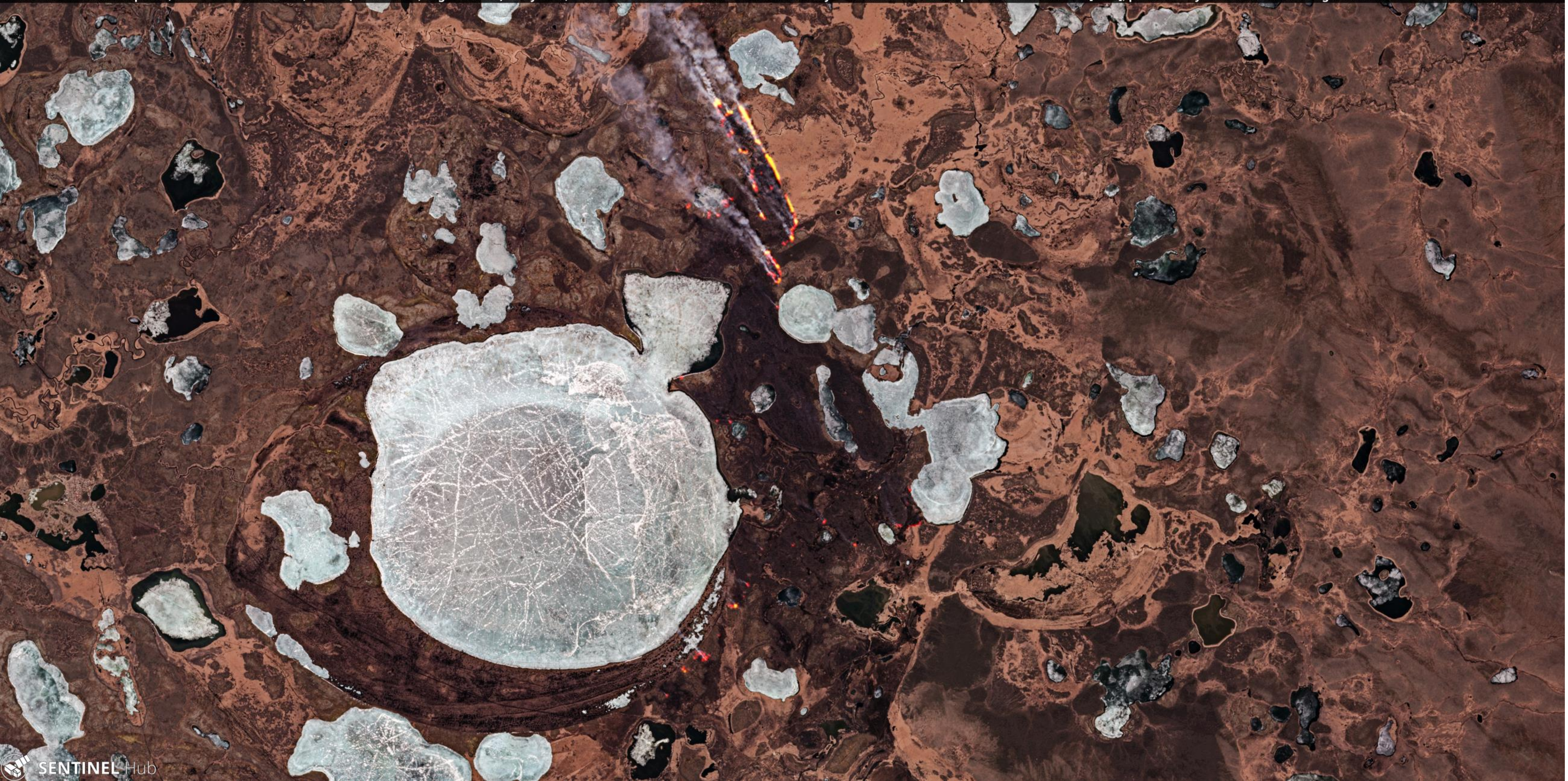


Photo © Irina Vorobyova / Greenpeace

Photo © Maria Vasilieva / Greenpeace

DESCALS ET AL (2022, SCIENCE)

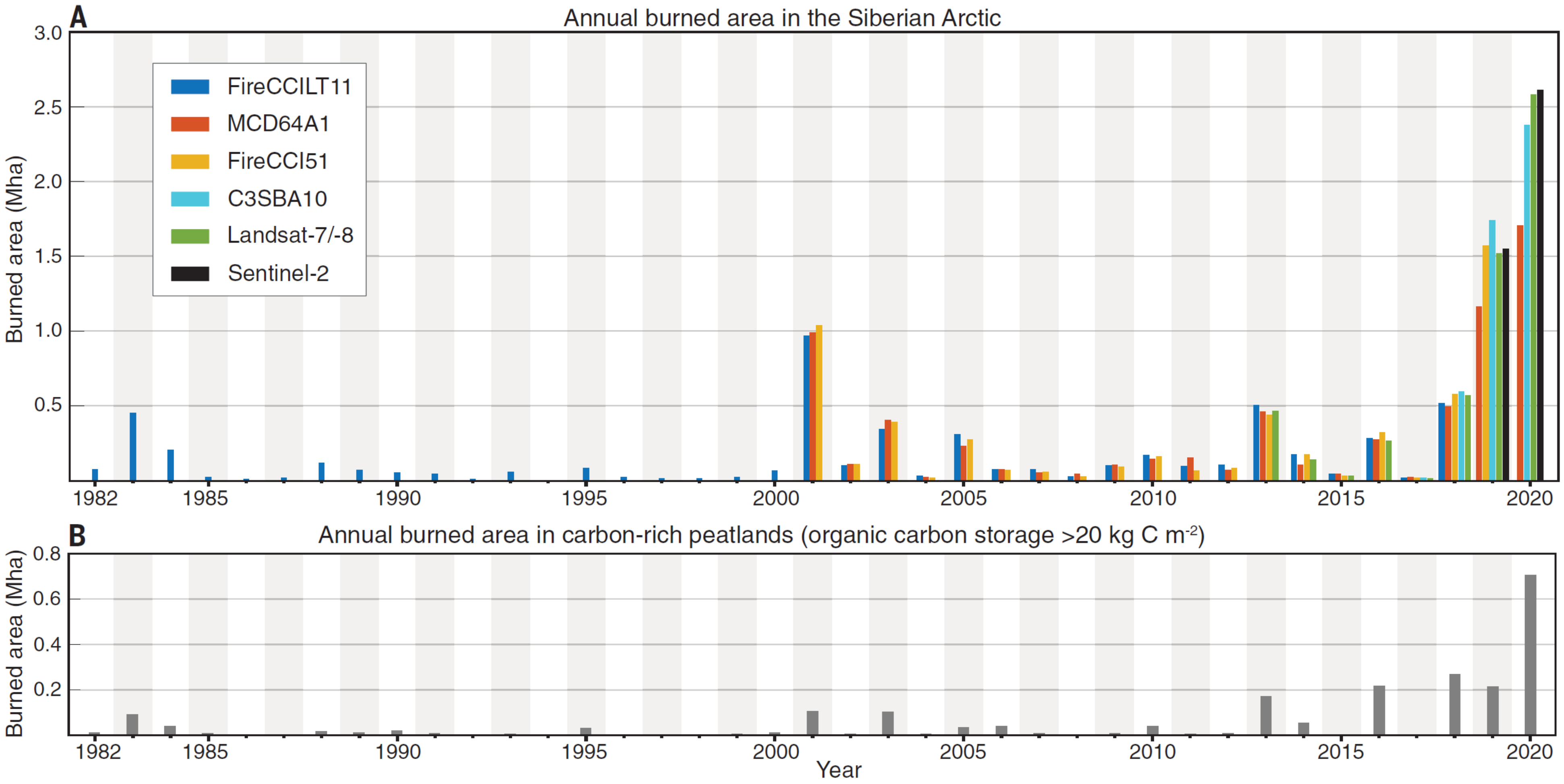
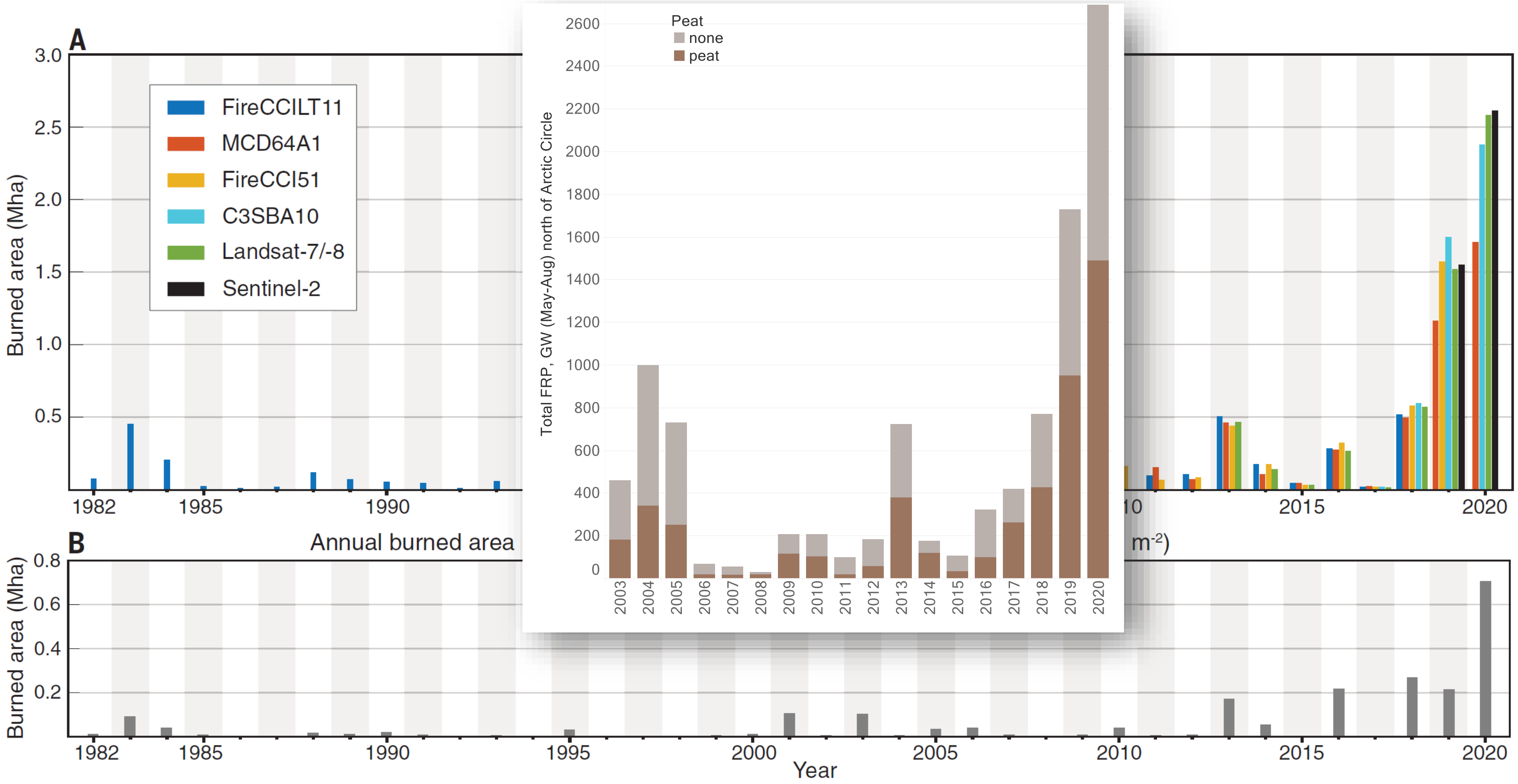


Fig. 2. Annual burned area in the Siberian Arctic and in carbon-rich peatlands for 1982–2020. (**A**) Annual burned area in the Siberian Arctic derived from remotely sensed data from six products. (**B**) Annual burned area in carbon-rich peatlands; >20 kg C m^{-2} in storage of organic carbon obtained from a reference dataset (*8*). The annual burned area in carbon-rich peatlands represents the median burned area for the available satellite products. Satellite burned-area products contain no data for 1994.

DESCALS ET AL (2022, SCIENCE)



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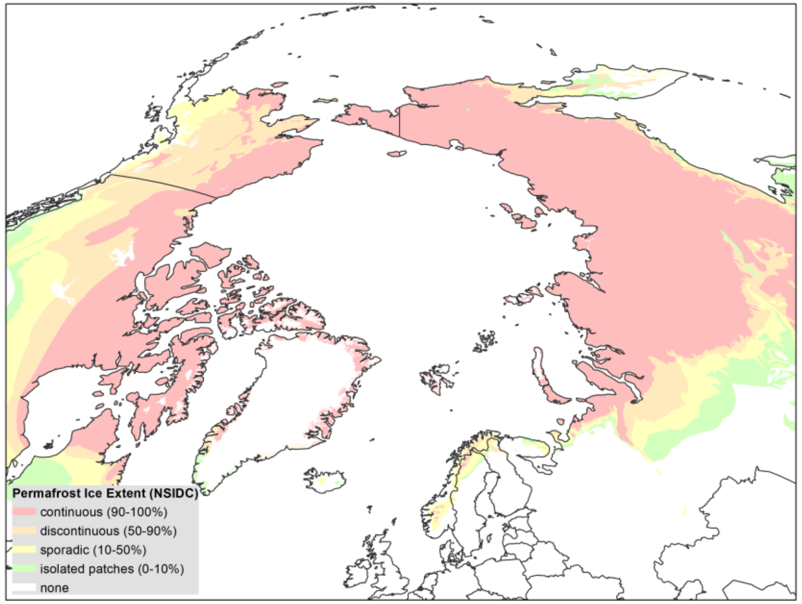
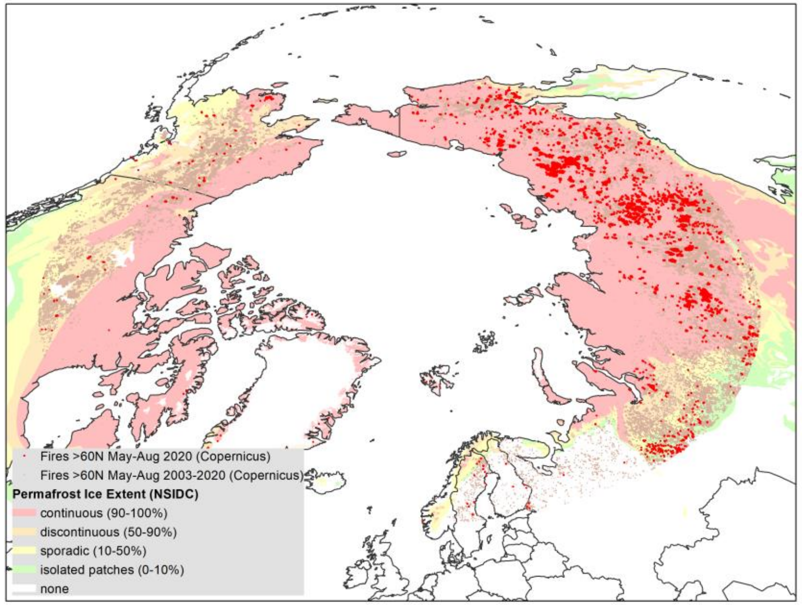
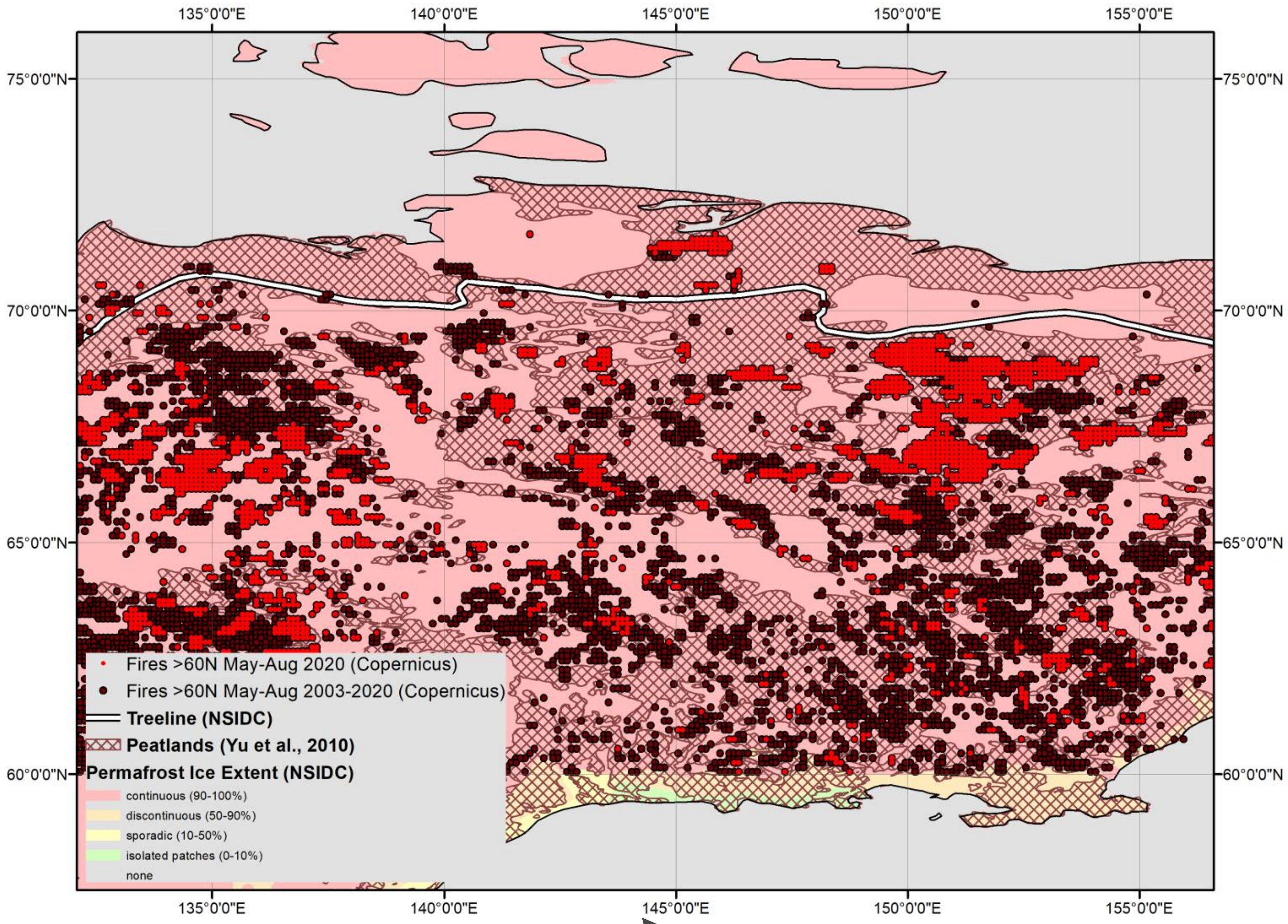
PERMAFROST COVER (NSIDC)



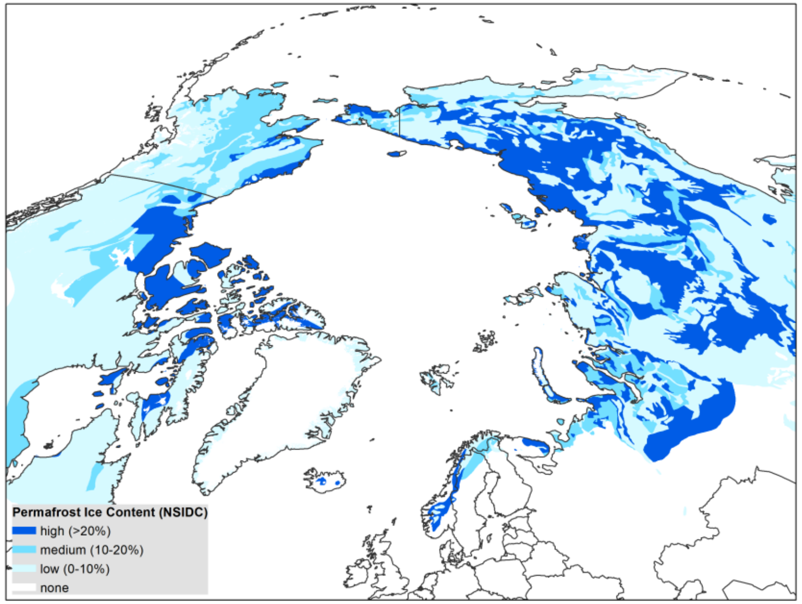


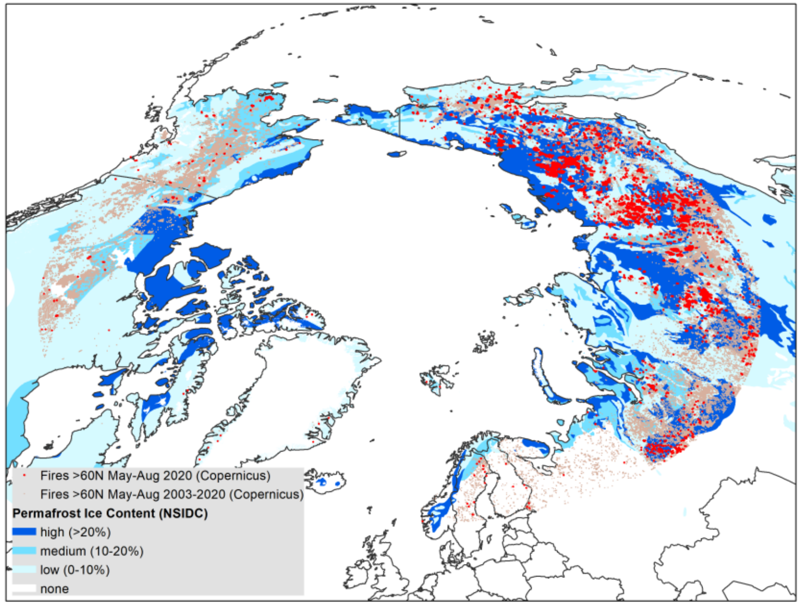


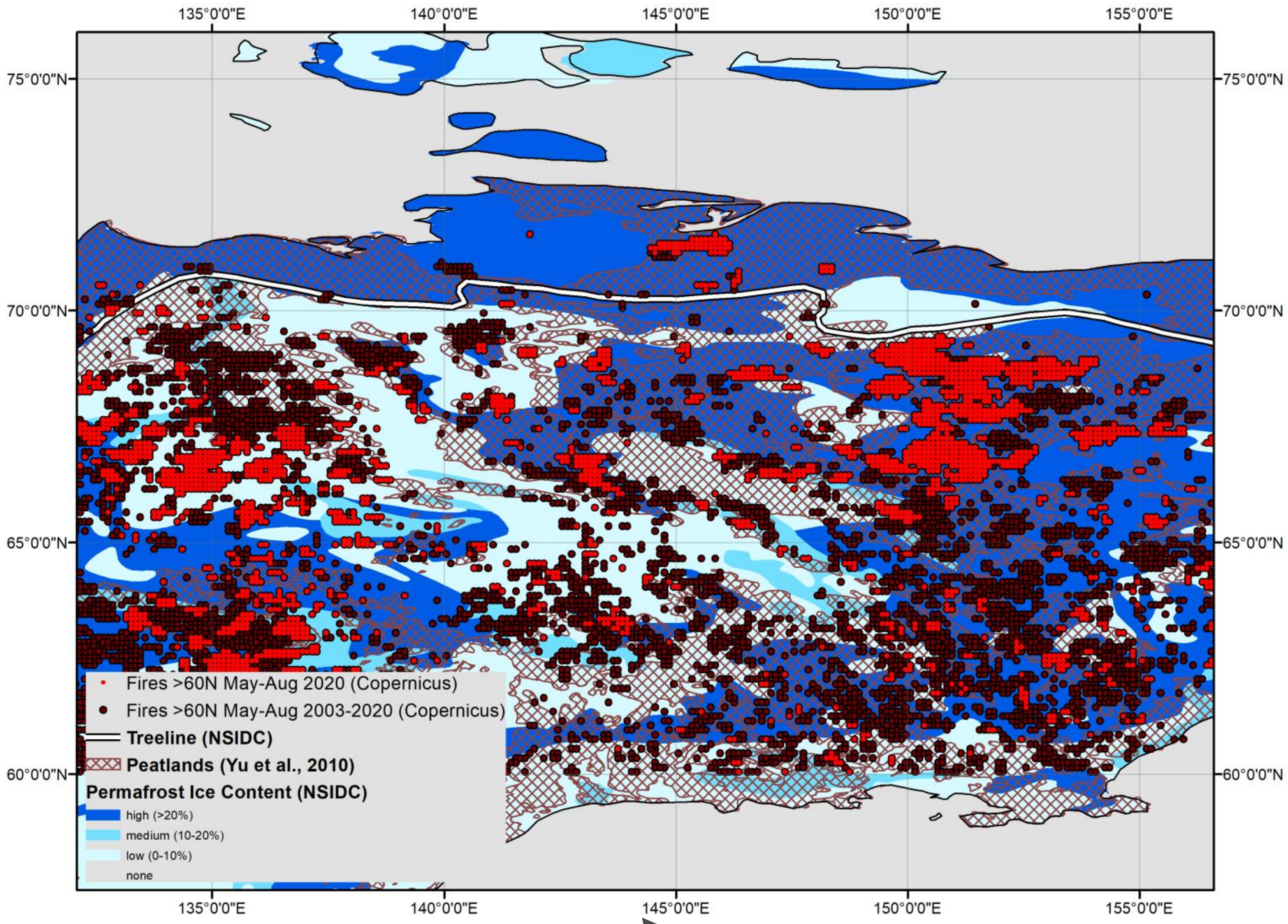
Circumpolar without (top) & with (bottom) May–August 2003–2020 fires and 2020 fires.

Subset of datasets for portions of eastern Siberia

PERMAFROST ICE CONTENT (NSIDC)







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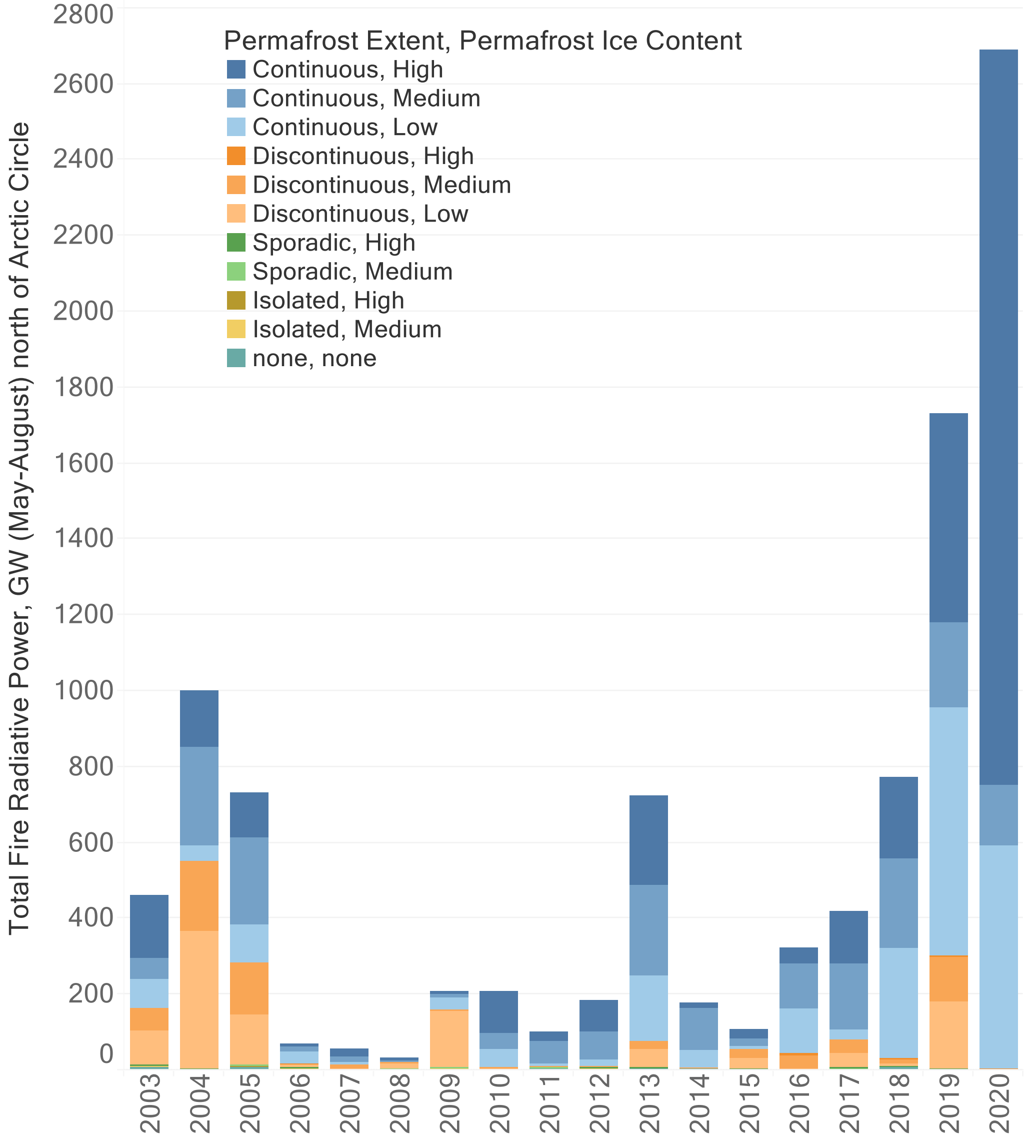
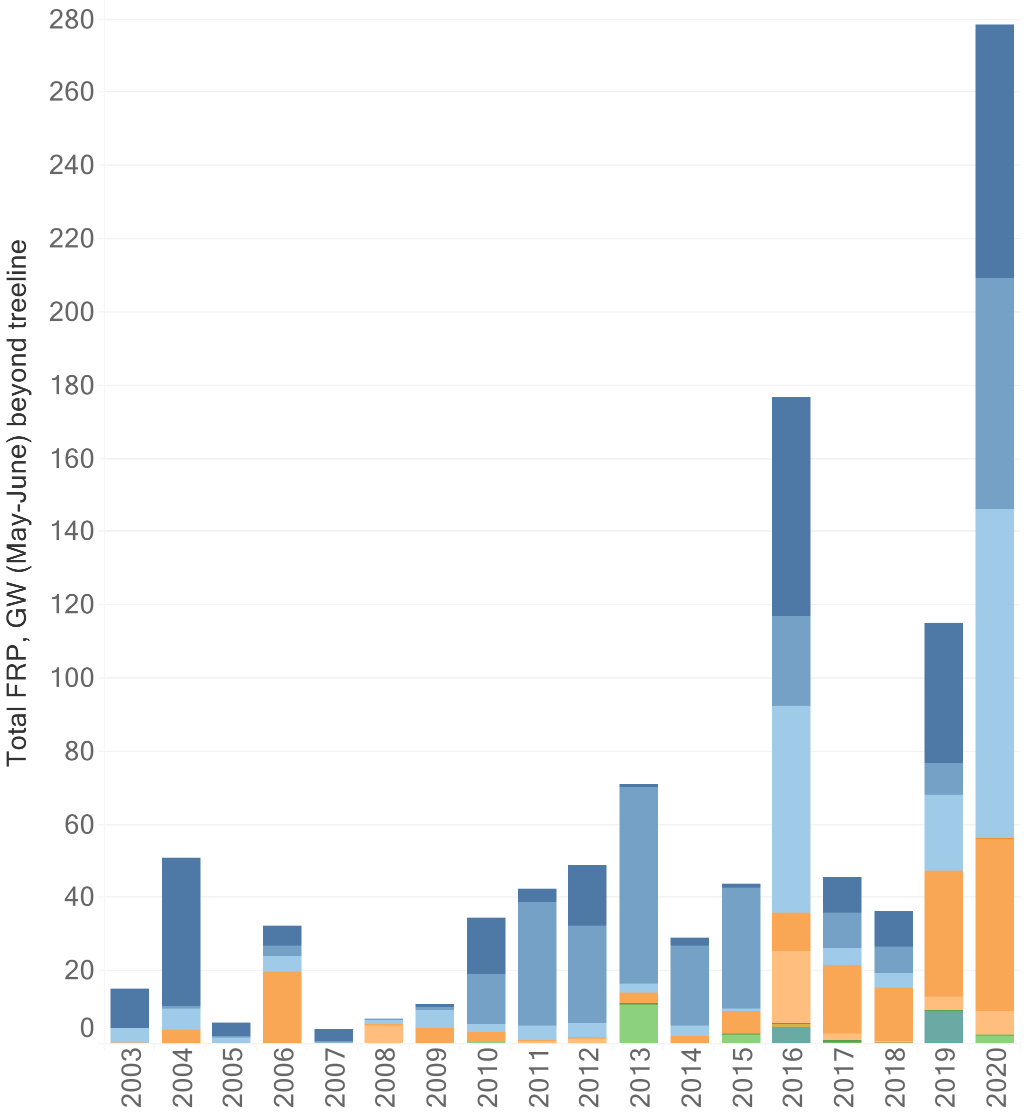
FIRES ON PERMAFROST

Two stories: Full season inside the Arctic Circle — Early fire season in the tundra (beyond the treeline)





and climate change?

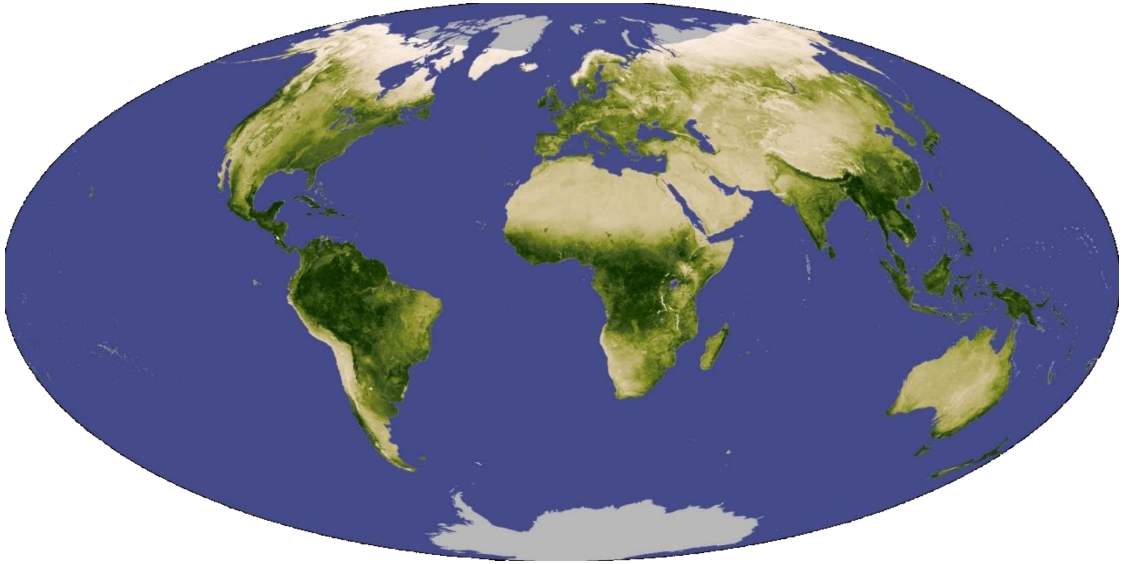
(climate change-wildfire feedbacks)

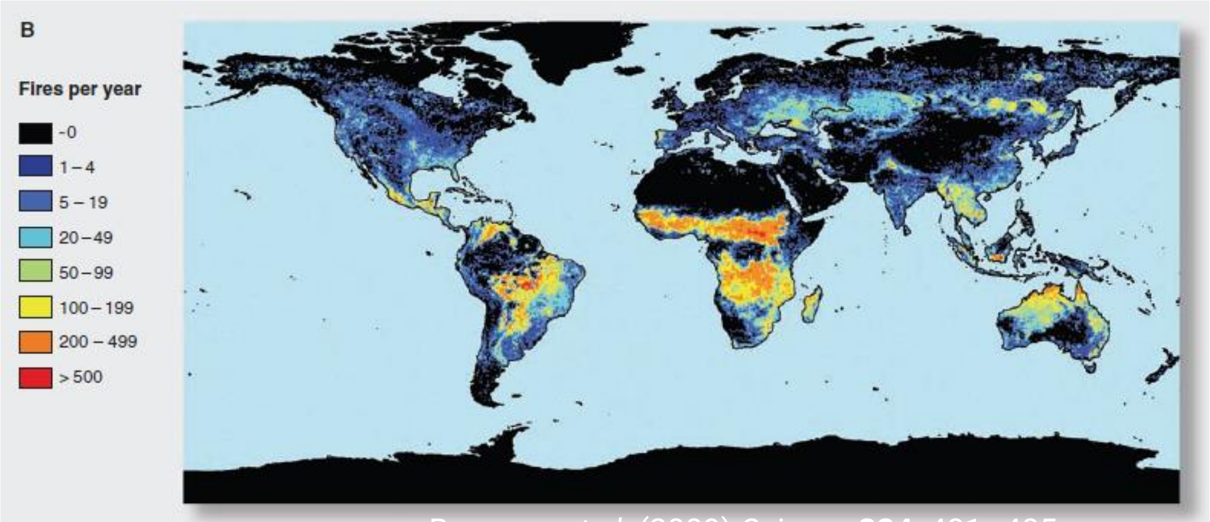
PYROGEOGRAPHY – THE ECOLOGY OF FIRE

Three factors are used to explain the distribution and abundance of organisms/fire:

Organisms
Resource availability
Physiologically appropriate environmental conditions
Dispersal ability

Fire
Flammable vegetation
Fire-conducive weather patterns and their climate
Ignitions





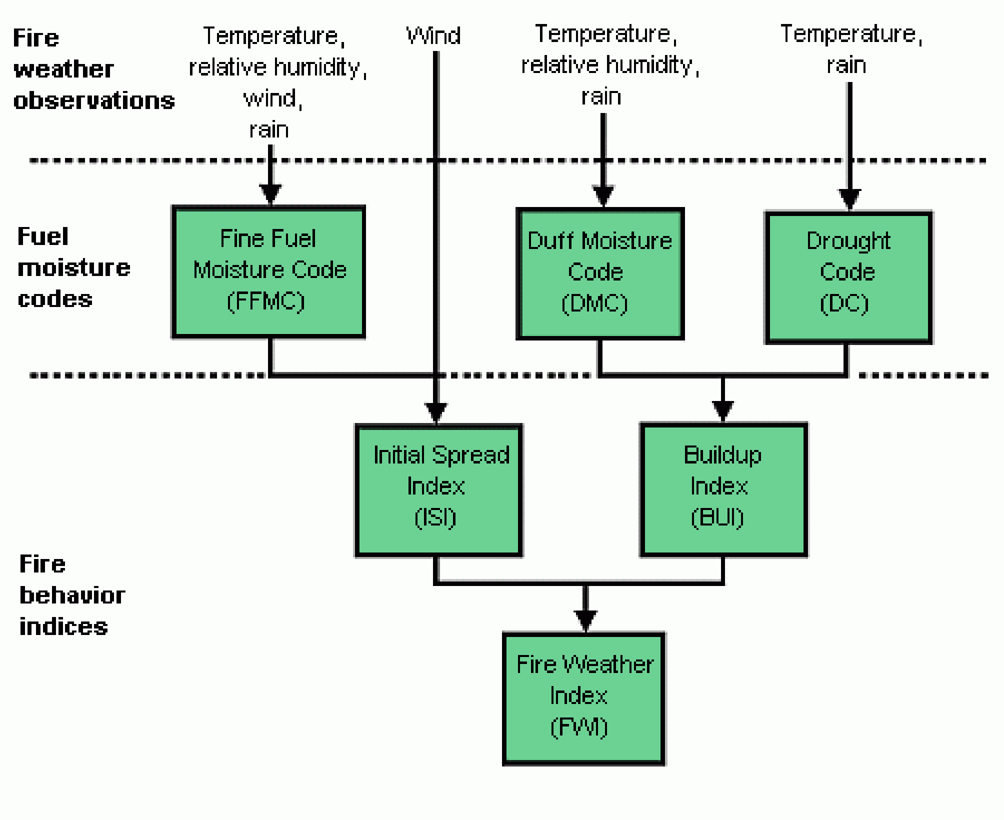
Bowman *et al.* (2009) *Science* **324**: 481–485

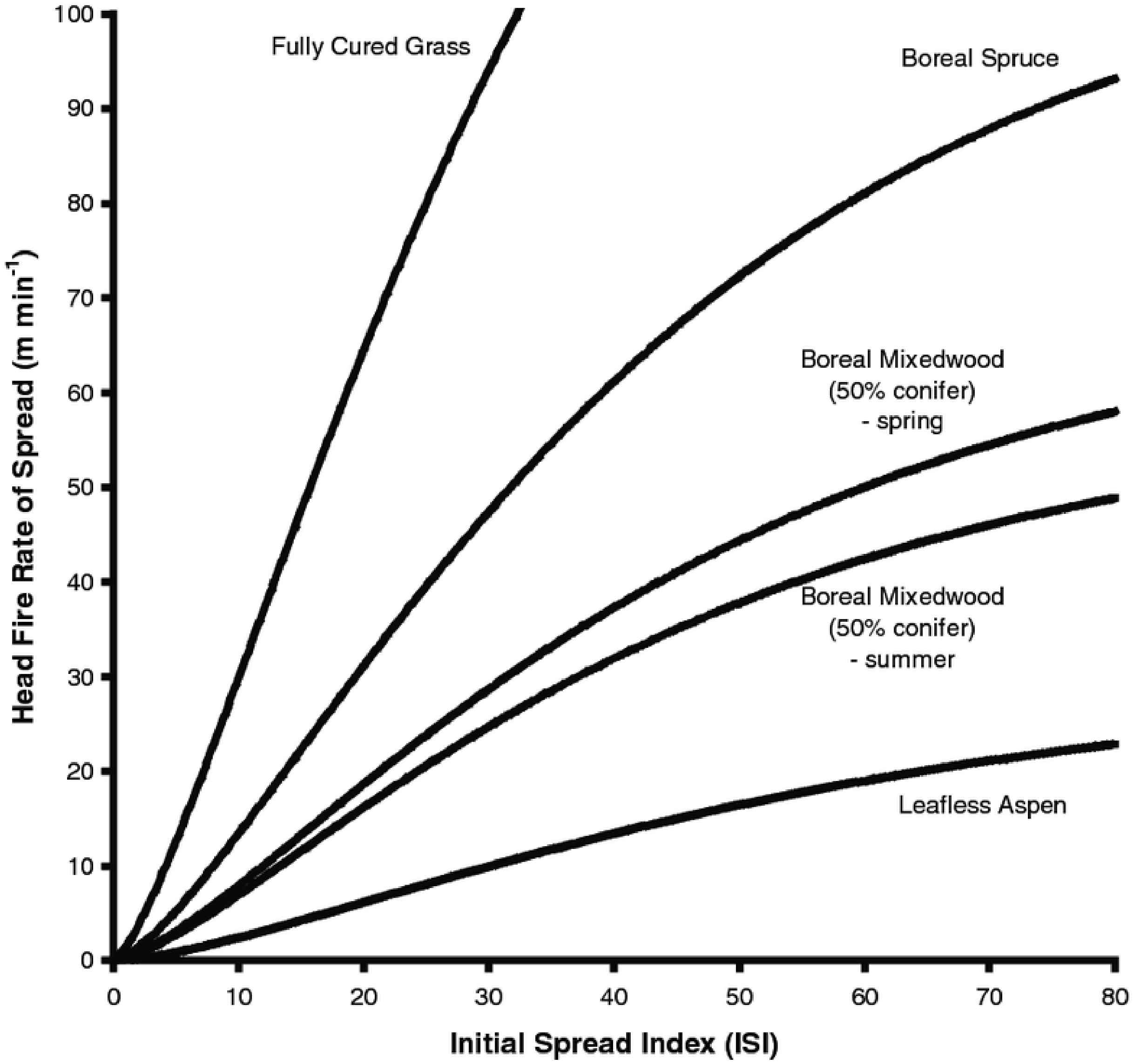
CLIMATE CHANGE AND PYROGEOGRAPHY

Fire
Flammable vegetation
Fire-conducive weather patterns and their climate
Ignitions

- Vegetation (fuel) availability
  - Increases in atmospheric CO_2 (CO_2 fertilisation)
  - Changes in moisture
    - More drought = less fuel, but greater rate of spread
    - Less drought = more fuel, greater interval between fires
- Fire weather
  - Temperature
  - Rainfall
  - Humidity
  - Wind
- Ignitions
  - Self-heating tendency (especially in peat)
  - Lightning?

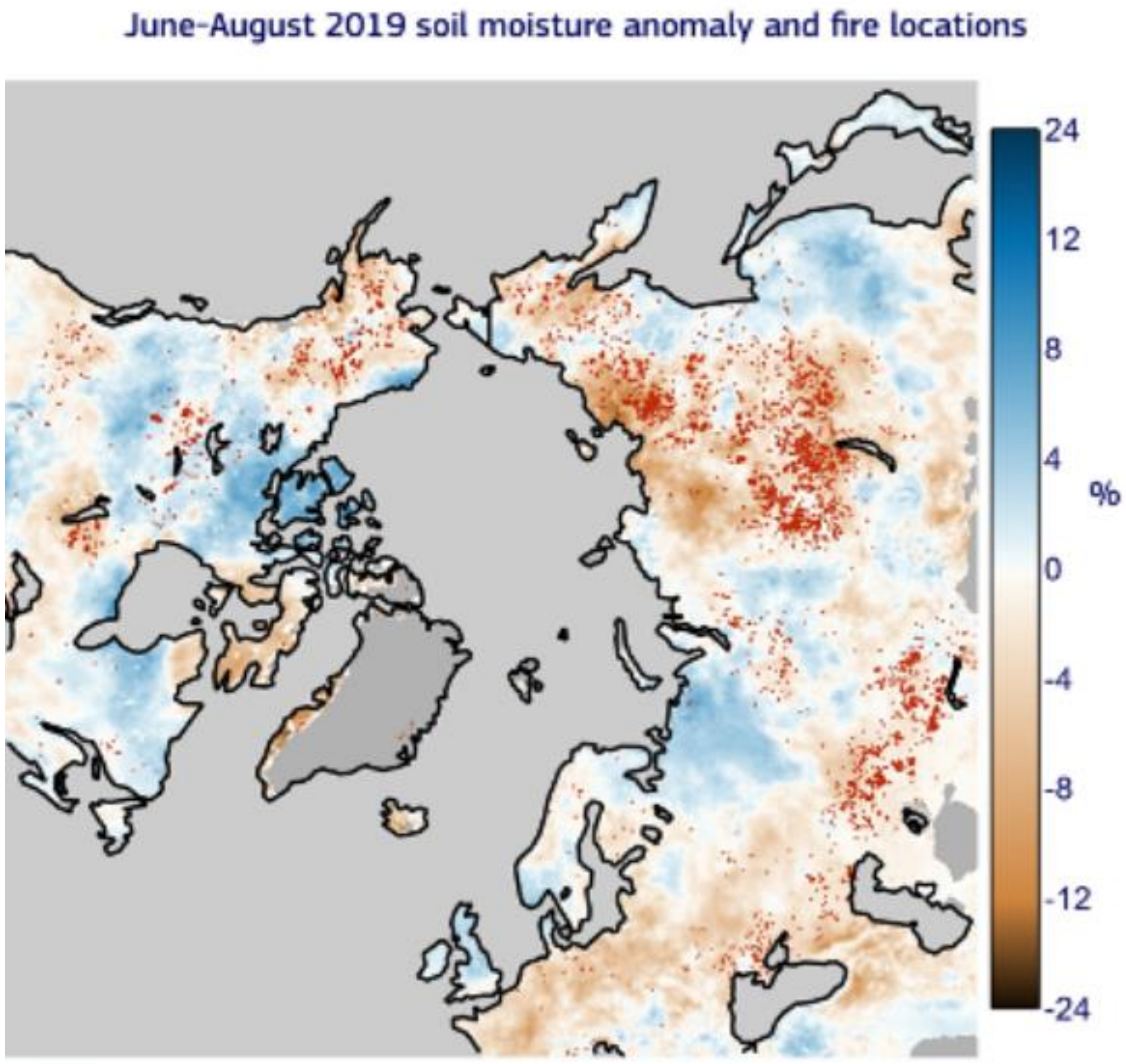
WARMER/DRYER CLIMATE = BIG FIRES

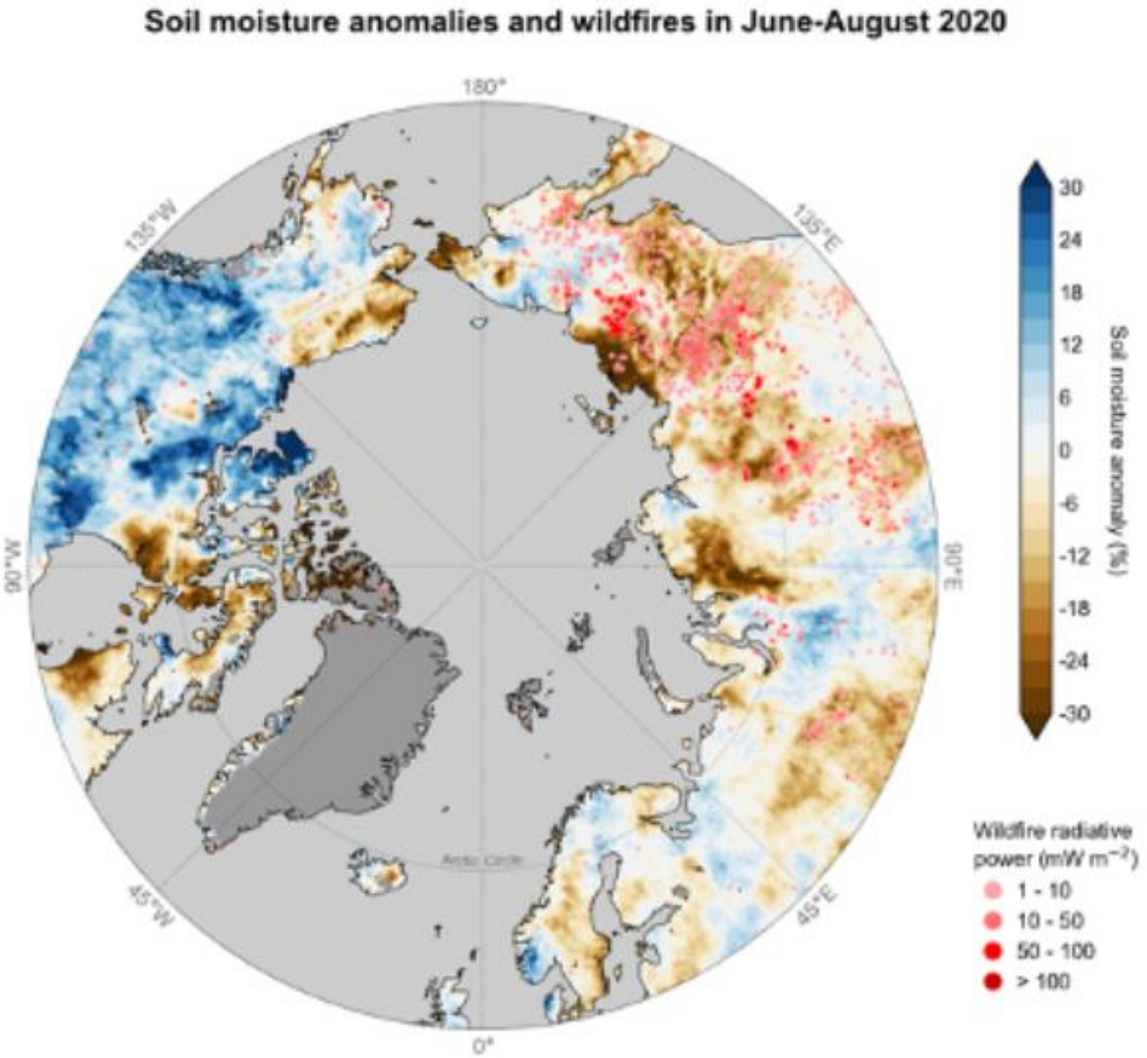




- Ignitions start fires
- Abundance of vegetation allows fires to set and take hold
- Weather (extremes more likely with anthropogenic climate change) allows the fires to spread

CLIMATOLOGICAL CONTEXT





https://www.copernicus.eu/en/news/news/observer-copernicus-services-enable-civil-authorities-anticipate-spread-wildfires-and
https://climate.copernicus.eu/esotc/2020/heat-siberia

DESCALS ET AL (2022, SCIENCE)

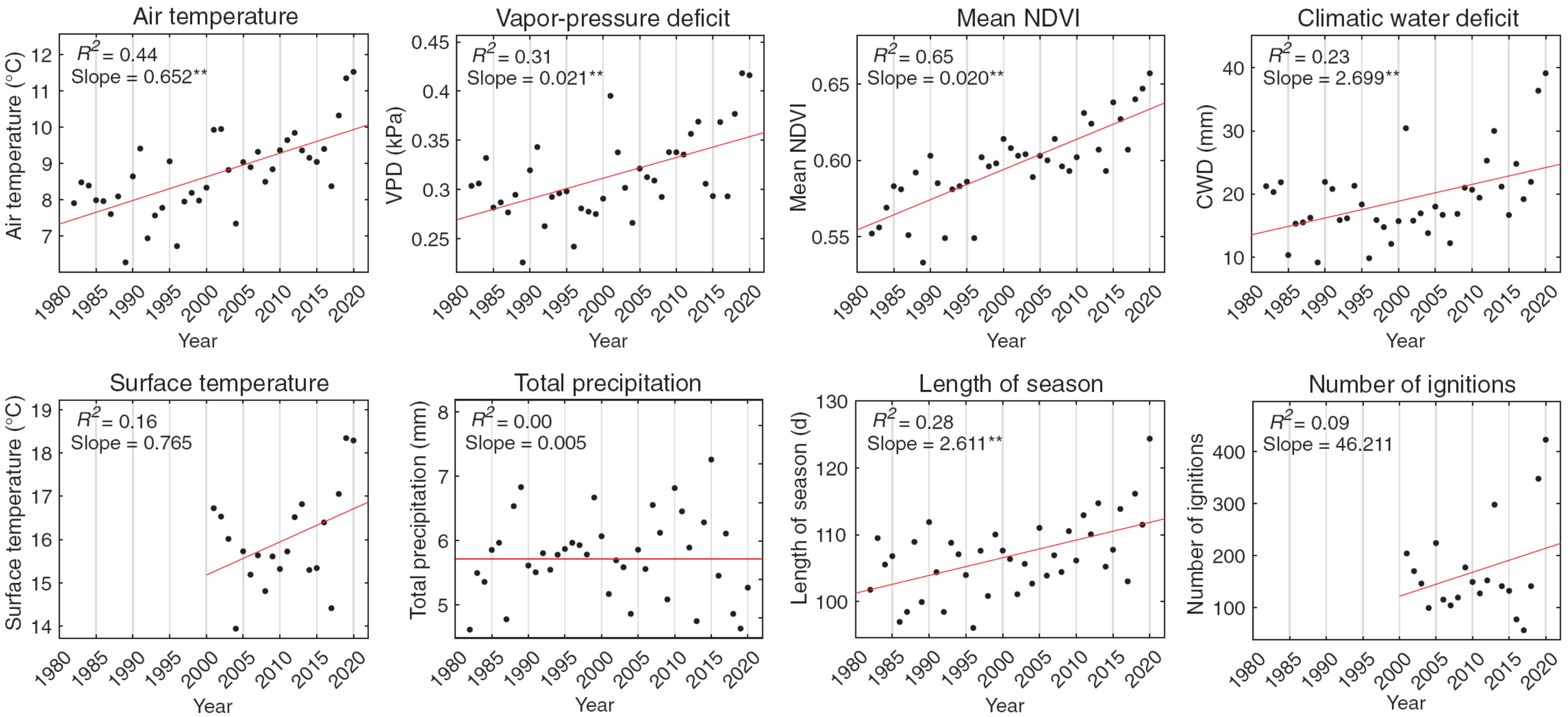


Fig. 3. Trends of eight fire factors in the Siberian Arctic during 1982–2020. Factors are the mean summer air and surface temperature, mean VPD, total summer precipitation, mean CWD, mean NDVI depicting vegetation green biomass, the length of the growing season, and the number of detected ignitions. The red lines are linear regressions; slopes are estimated on a decadal time scale. *$p < 0.05$; **$p < 0.01$.

DESCALS ET AL (2022, SCIENCE)

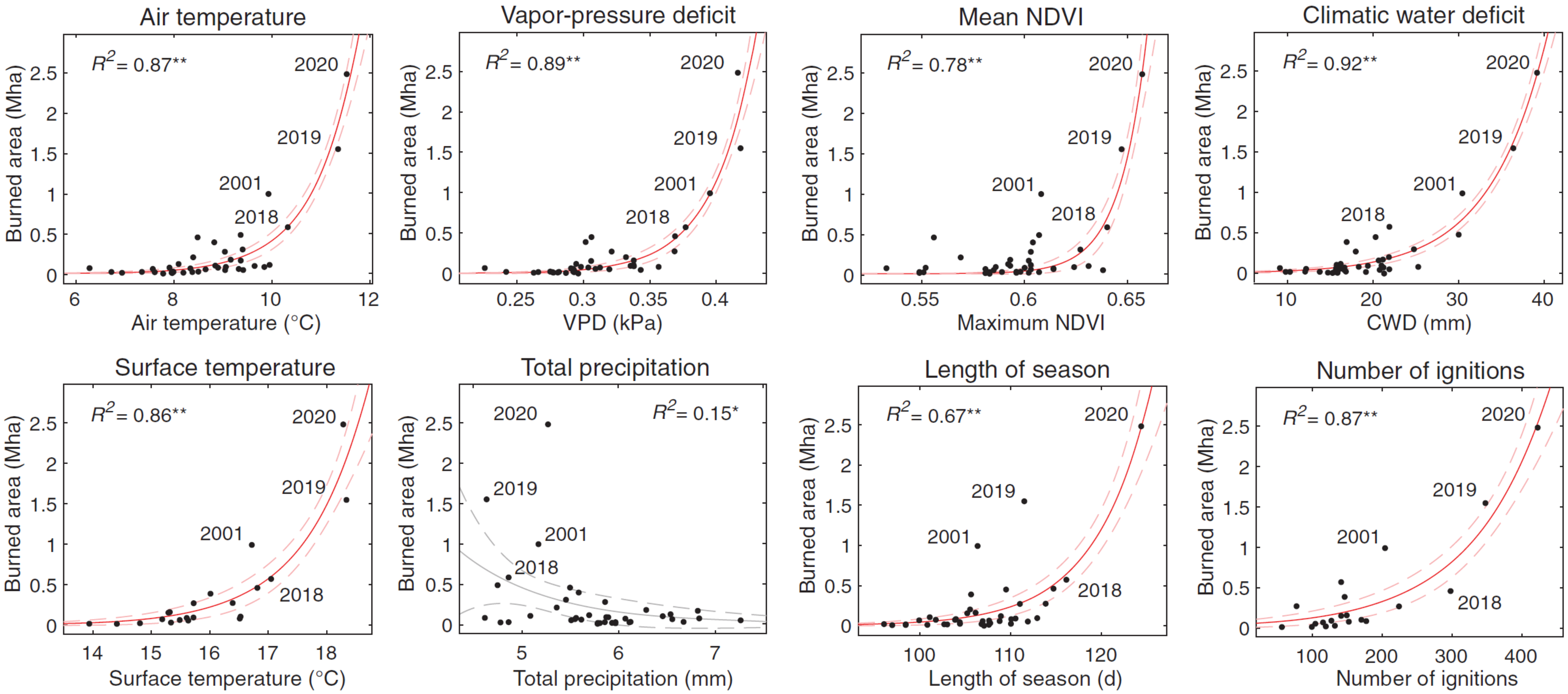
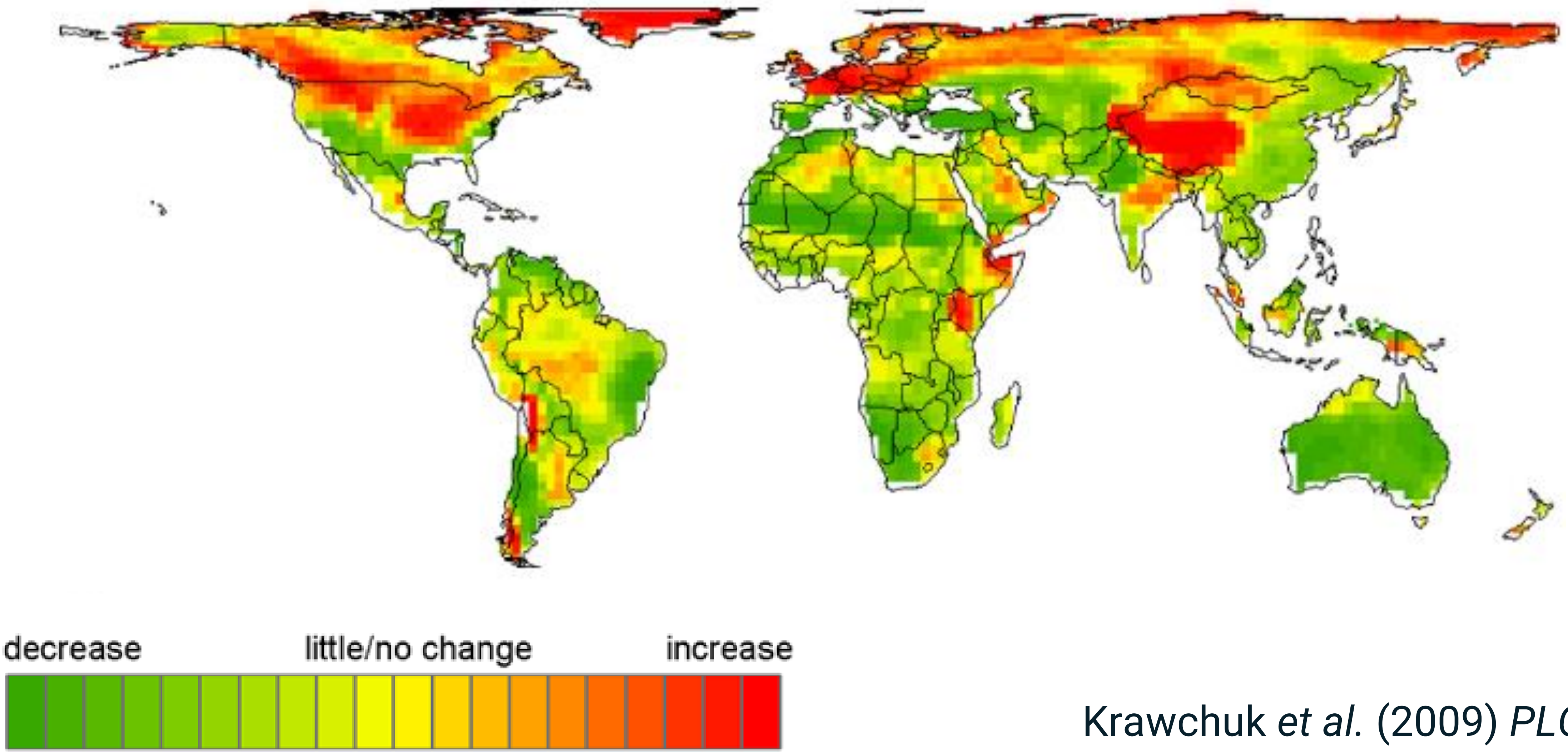


Fig. 4. Regression between the annual burned area and eight fire factors in the Siberian Arctic during 1982–2020. Solid lines are the best regression (linear or exponential), based on the coefficient of determination (R^2; $^*p < 0.05$; $^{**}p < 0.01$). The best regression model was the exponential for all the factors. The annual burned area is the median burned area for the available satellite products. The factors are the mean summer air and surface temperature, mean VPD, total precipitation, mean CWD, mean NDVI depicting green biomass, the length of the growing season, and the number of ignitions. Red solid lines depict a fit with a significant correlation ($p < 0.01$). The dashed lines are the 95% prediction limits of the regressions.

CLIMATE CHANGE & FIRE: 2070–2099



Krawchuk *et al.* (2009) *PLOSONE*

DESCALS ET AL (2022)

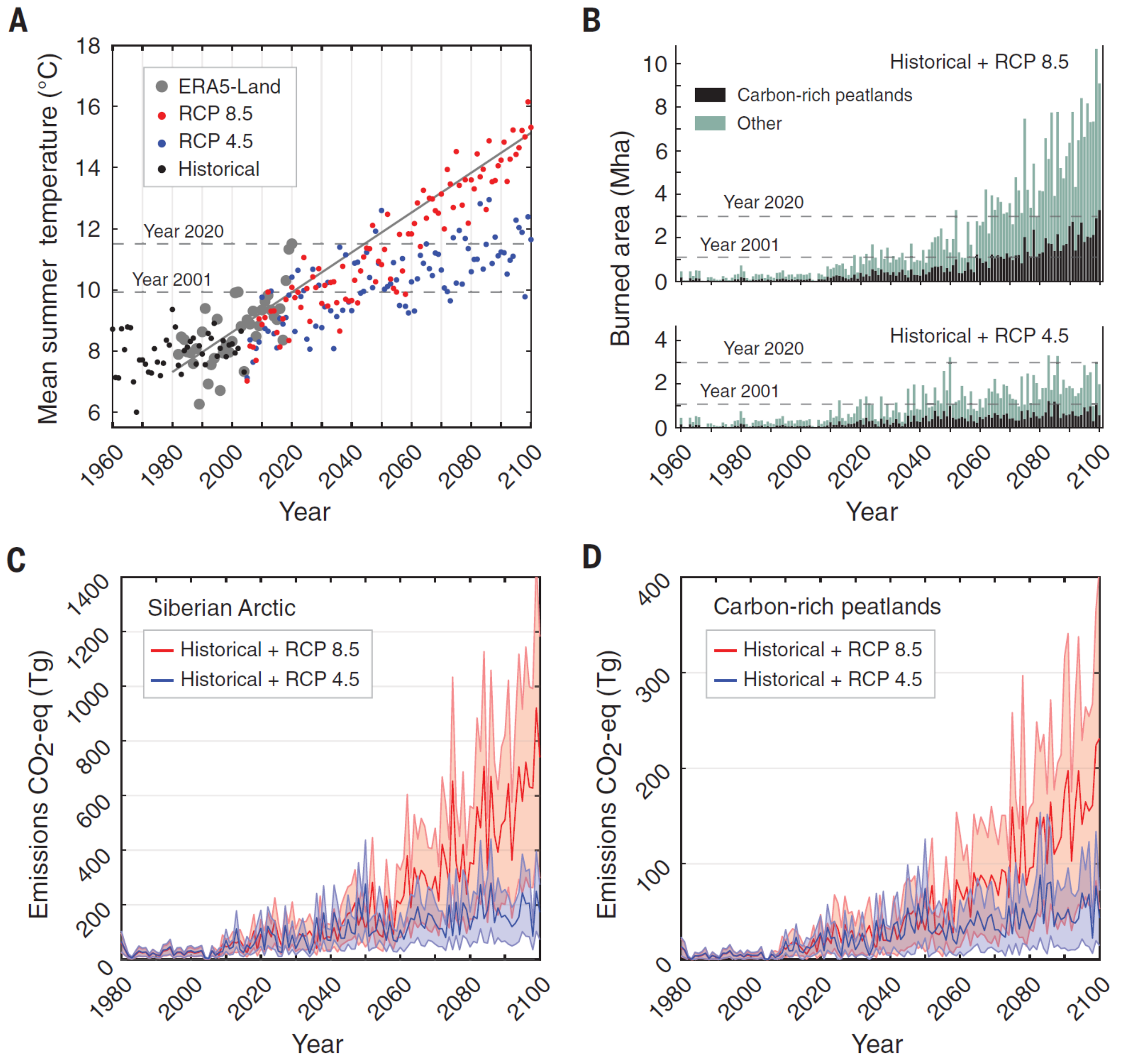
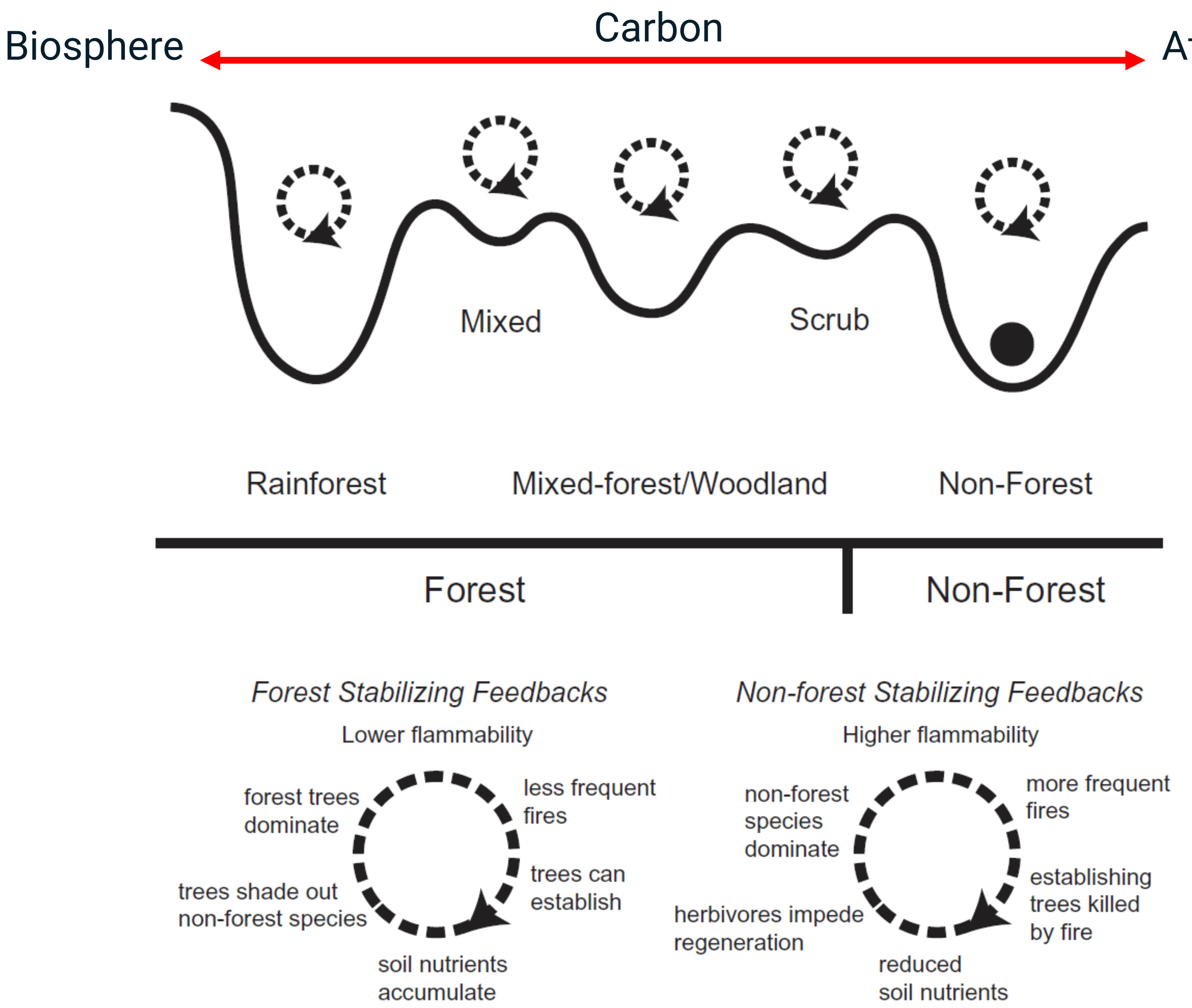


Fig. 6. Projected temperatures, annual burned areas, and emissions from fire in the Siberian Arctic. (**A**) Mean summer air temperatures from climate reanalysis (ERA-5 Land) during 1982–2020 and historical and projected temperatures under the RCP 4.5 and 8.5 scenarios based on HadGEM2-CC model. (**B**) Annual burned areas for the historical period and under the RCP 4.5 and 8.5 scenarios for carbon-rich peatlands (organic carbon storage >20 kg C m^{-2}) and other regions of the Siberian Arctic. (**C** and **D**) Projected CO_2-eq emissions under the RCP 4.5 and 8.5 in the Siberian Arctic (C) and carbon-rich soils (D).

CLIMATE CHANGE FEEDBACKS?

- Will the forests grow back? Has there been a change in wildfire regime?
  - Stand replacement frequency
  - Fire intensity/severity
- What happens to a more fire-prone tundra ecosystem?

FIRES, CARBON AND ECOSYSTEM/REGIME CHANGE

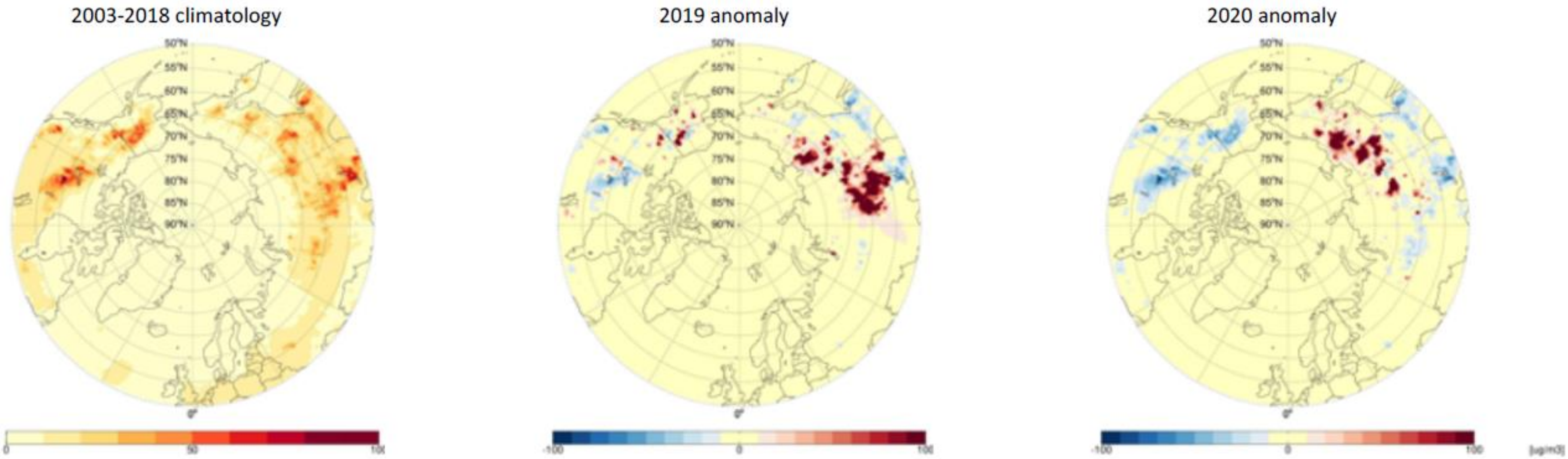


McWethy *et al.* (2013)
Glob. Ecol. & Biogeo.

CLIMATE CHANGE FEEDBACKS?

- Will the forests grow back? Has there been a change in wildfire regime?
  - Stand replacement frequency
  - Fire intensity/severity
- What happens to a more fire-prone tundra ecosystem?
- Is peat on fire?
  - What role for the zombies?
  - A significant driver of permafrost thaw? Or just isolated phenomenon?
- What do fires on permafrost mean?
  - A geomorphological agent?
  - How deep does the thaw extend? What are the GHG impacts?
- Black carbon particulate matter
  - How significant is the ‘black carbon on snow/sea-ice effect’?
  - Or does the smoke cover help to shade the Arctic?

PM2.5


2003-2018 climatology
2019 anomaly
2020 anomaly
50°N
55°N
60°N
65°N
70°N
75°N
80°N
85°N
90°N
0°
0
50
100
-100
0
100
-100
0
100
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ARCTIC FIRES REMAIN A SIGNIFICANT 'MMM' PROBLEM

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Arctic fires re-emerging

Jessica L. McCarty, Thomas E. L. Smith & Merritt R. Turetsky

Nature Geoscience **13**, 658–660 (2020) | Cite this article

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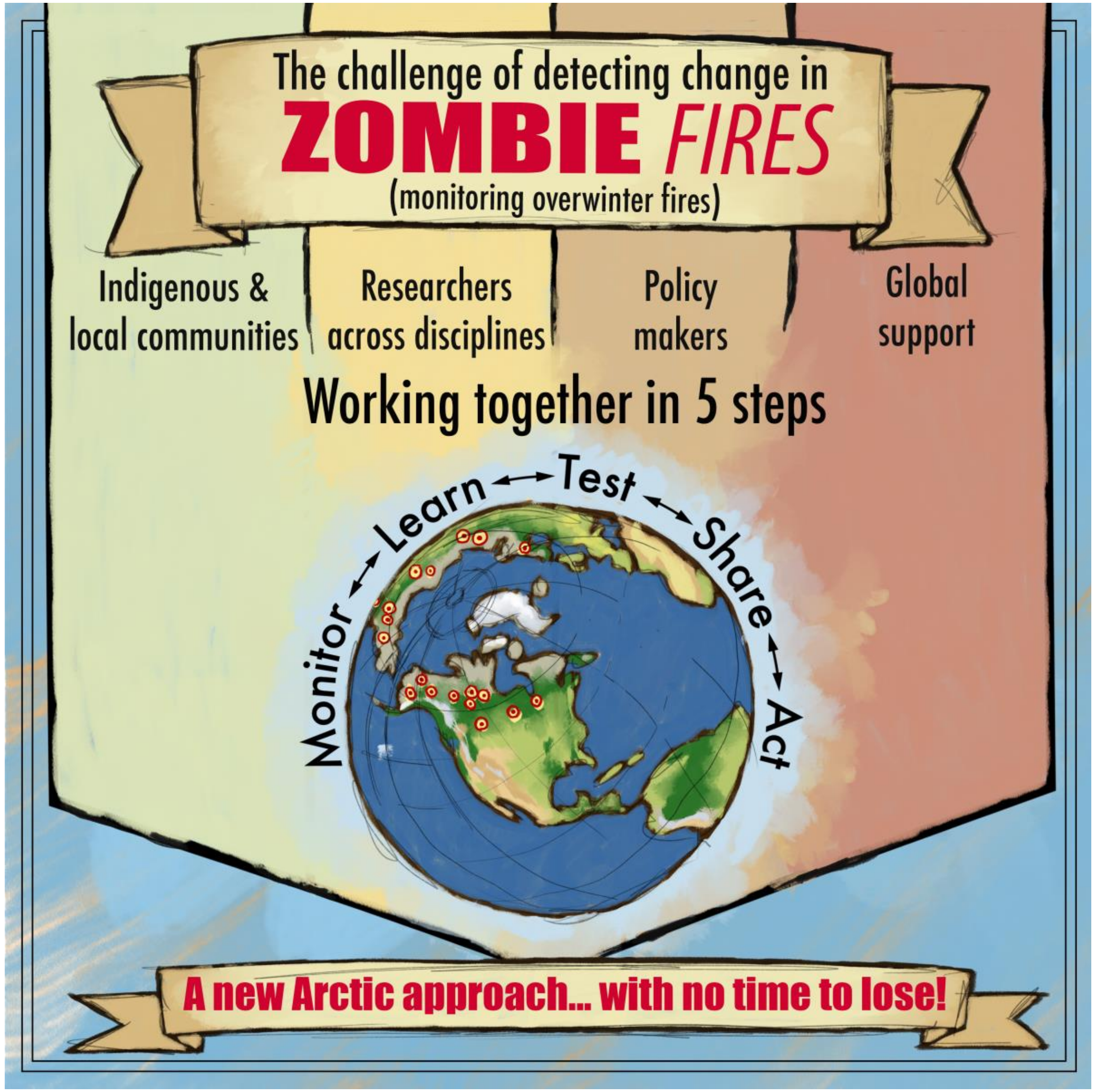
Underground smouldering fires resurfaced early in 2020, contributing to the unprecedented wildfires that tore through the Arctic this spring and summer. An international effort is needed to manage a changing fire regime in the vulnerable Arctic.

Wildfires are not a novel phenomenon in the Arctic; however, 2020's fire season began two months early and has been far more severe than usual. While increasing fire activity in boreal forests to the south[1,2] and an unusually warm winter in the Arctic[3] have led some to suggest that this uptick in wildfires was inevitable, there is still uncertainty about their source and their local and global impact. Here, we discuss how the wildfires in the Arctic are changing and how the input and expertise of local and Indigenous communities will be essential to determine whether this year is an anomaly or the beginning of a new fire regime.



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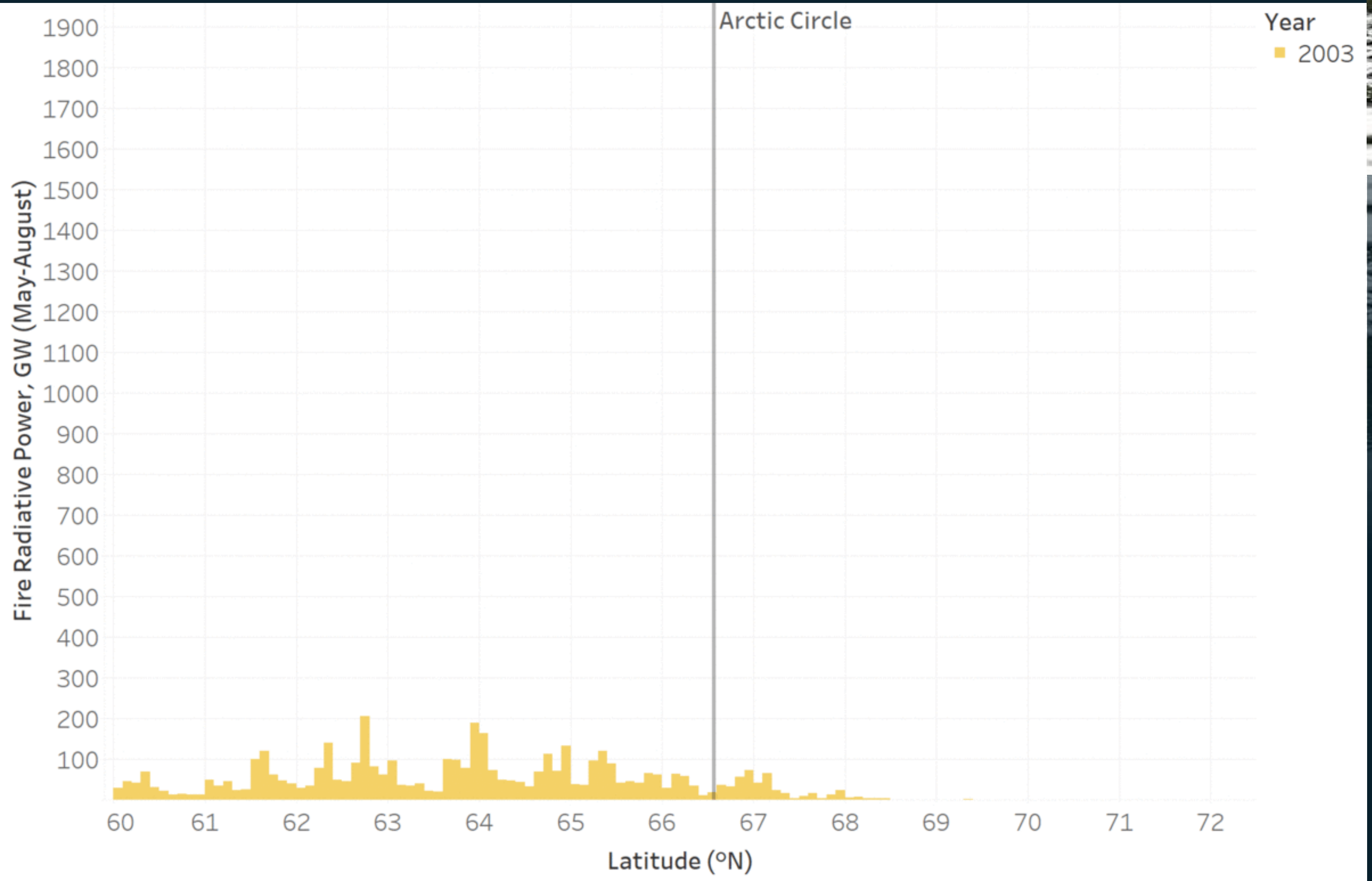

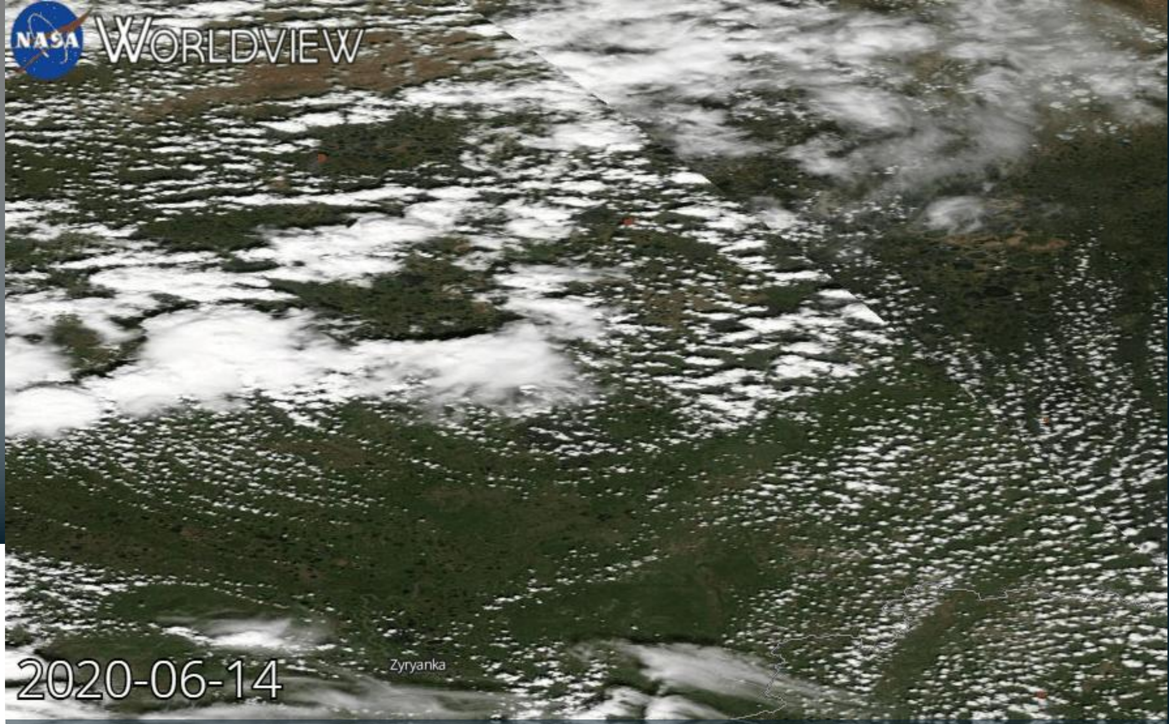

Dr Thomas Smith

LSE Geography & Environment

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Thanks to Mark Parrington, Jessica McCarty, Merritt Turetsky, Pierre Markuse

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Thursday 23 April, 2023