Global Fire Weather Trends

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Canadian Partnership for Wildland Fire Science

BOM : A Land of Storms, Floods and Bushfires 23-26 November 2020

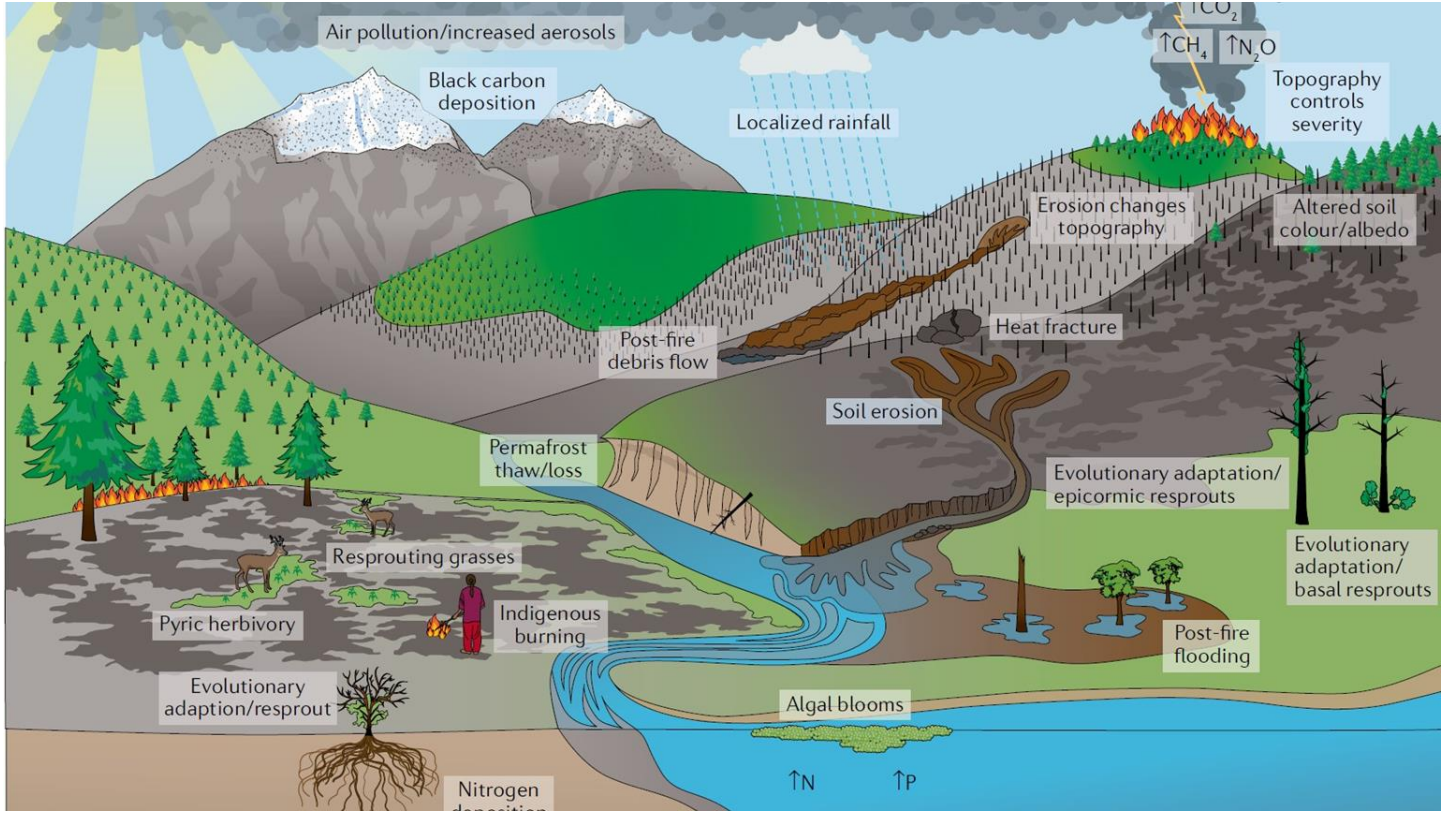
Outline

- Global Fire
- Canadian Fire Weather Index
- Fire Weather Trends
- Implications

Global Wildland Fire

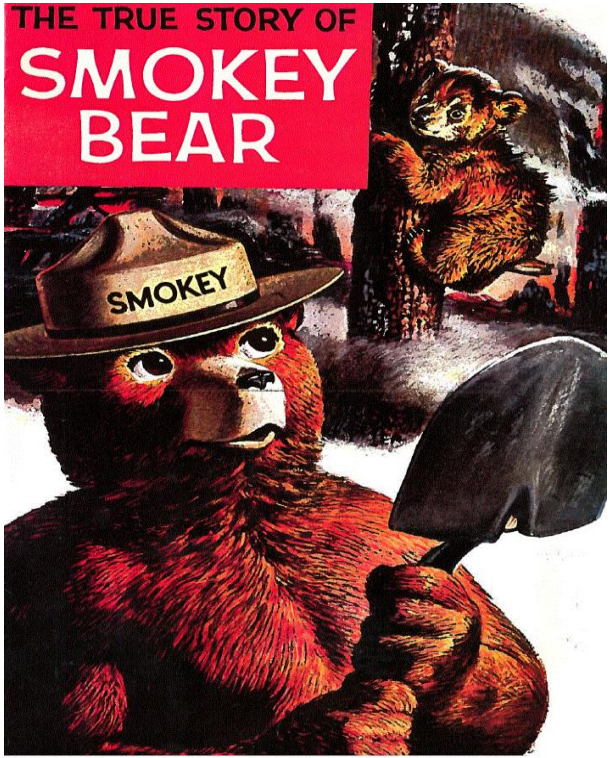
- On average about 350-450 M Ha burn every year. Larger than the size of India
- No idea as to how many fire starts though people are probably responsible for about 90+% of the starts
- Largest area burned is in grasslands and savannas
- Fire is a necessary component in some ecosystems

Global Fire activity

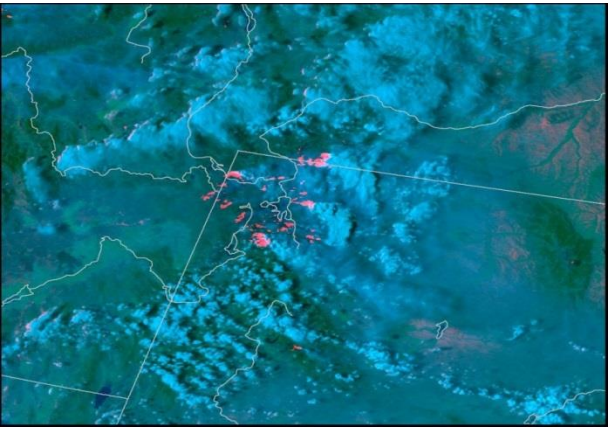


Bowman et al.2020. Vegetation fires in the Anthropocene. Nature Reviews Earth & Environment. https://doi.org/10.1038/s43017-020-0085-3

Fire Management



- Fire management agencies spend billions of dollars on fire management every year and this increasing in many regions.
- Fire Management is challenging and is becoming more challenging due to increased demands and climate change.



Forest Fires – 3 Ingredients

- Fuel – type, loading, moisture, structure.
- Ignition - human and lightning
- Weather – hot, dry windy. Extreme weather

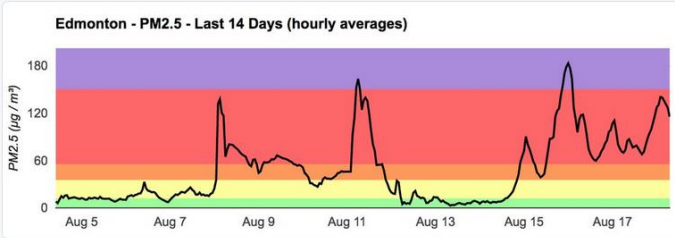
Fire Impacts

You Retweeted

Robert Rohde @rarohde · Aug 18

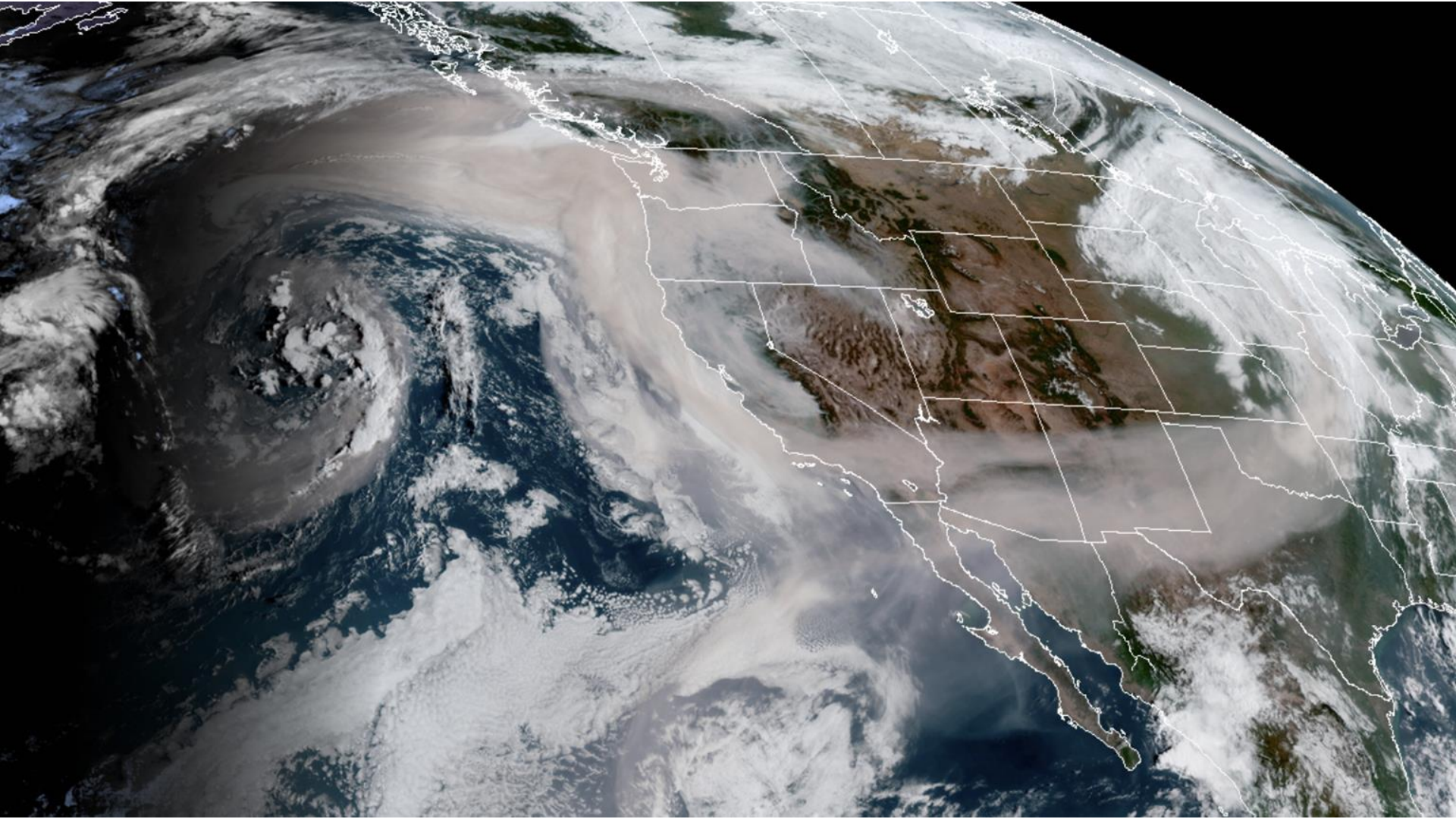
During the last 24 hours, Edmonton, #Canada (population 900,000) has had the worst air quality of any city for which we collect data, beating out places like India and China.

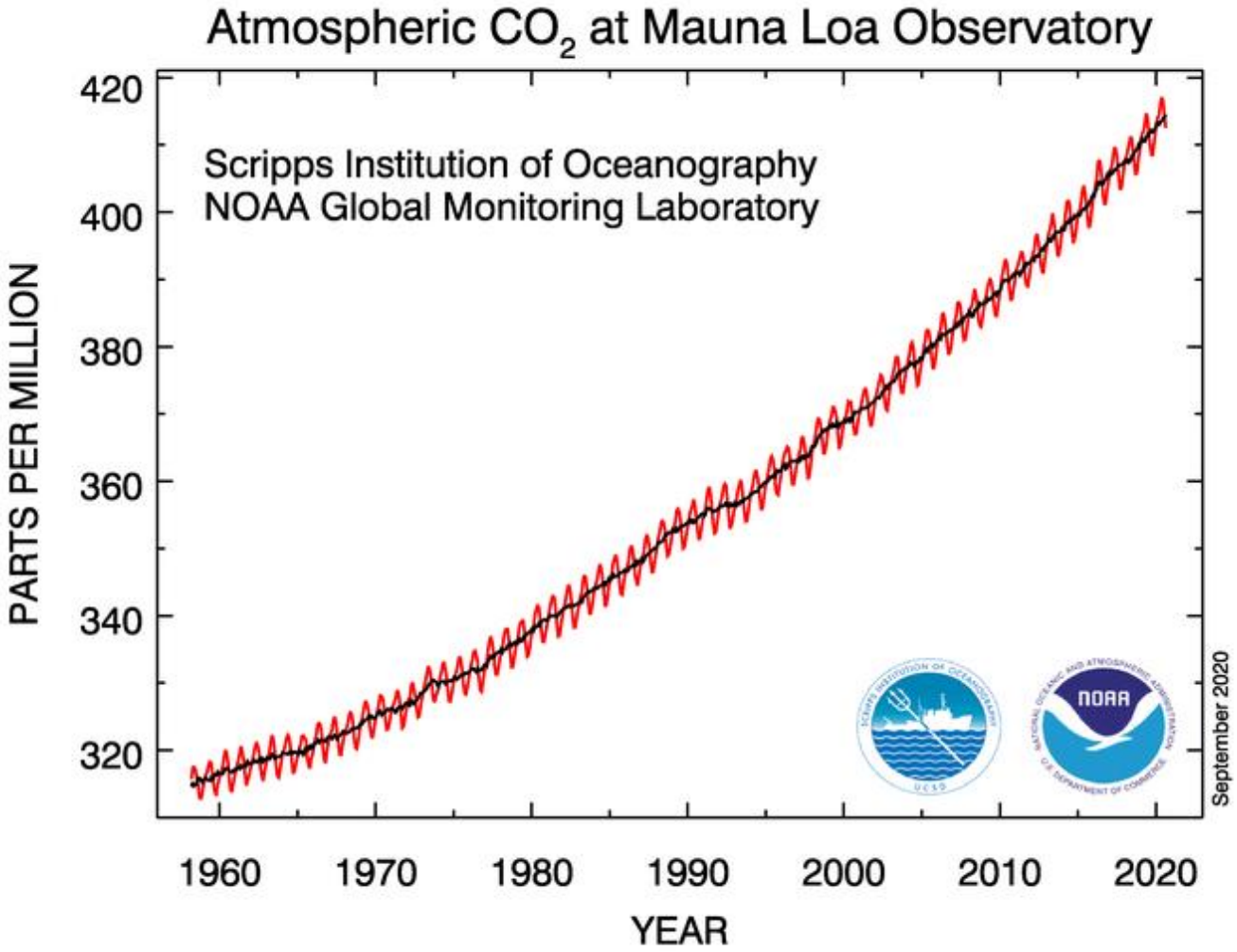
During the last 10 days, forest fires have repeatedly driven air quality to unhealthy levels.

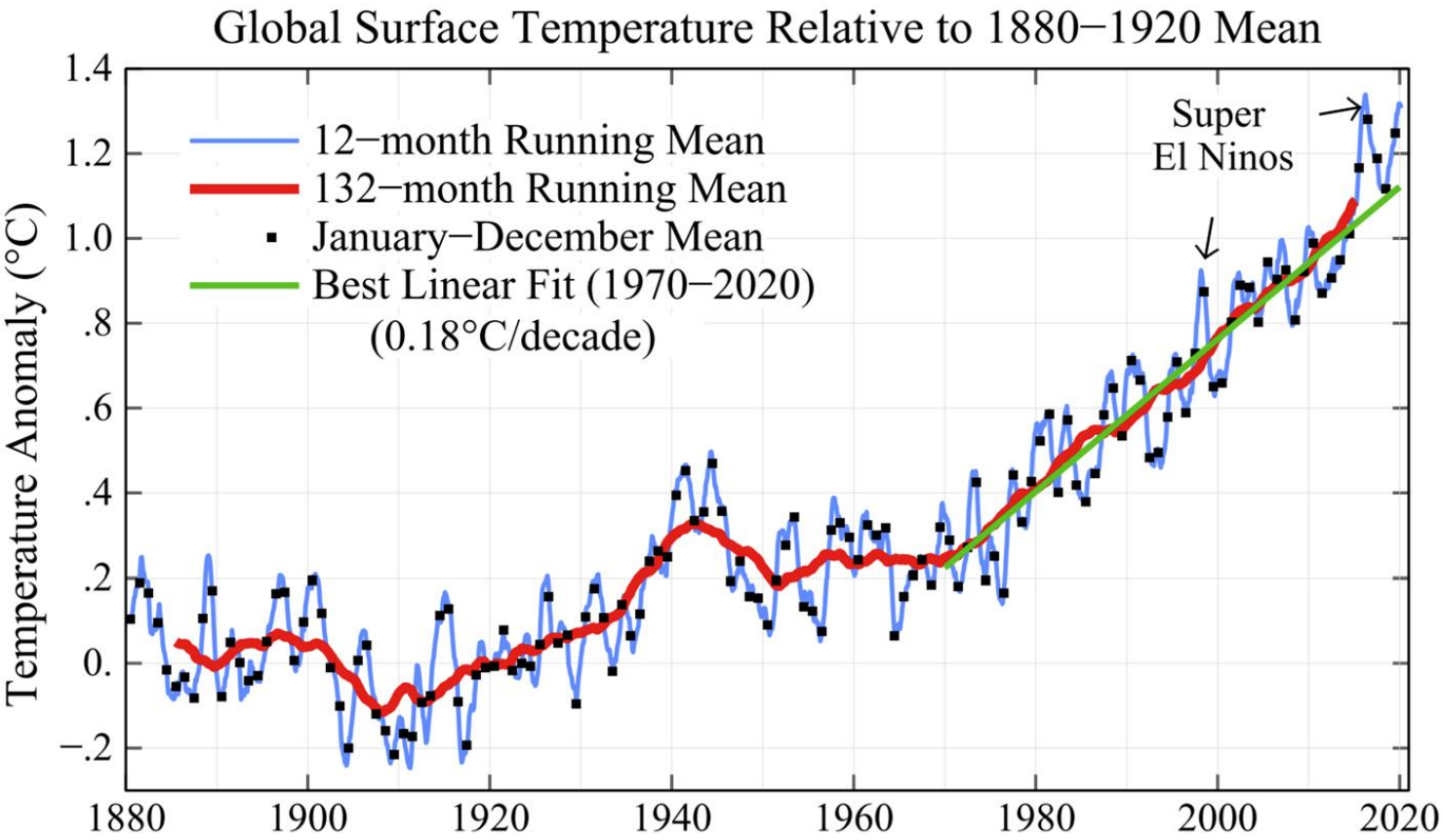


15 348 272

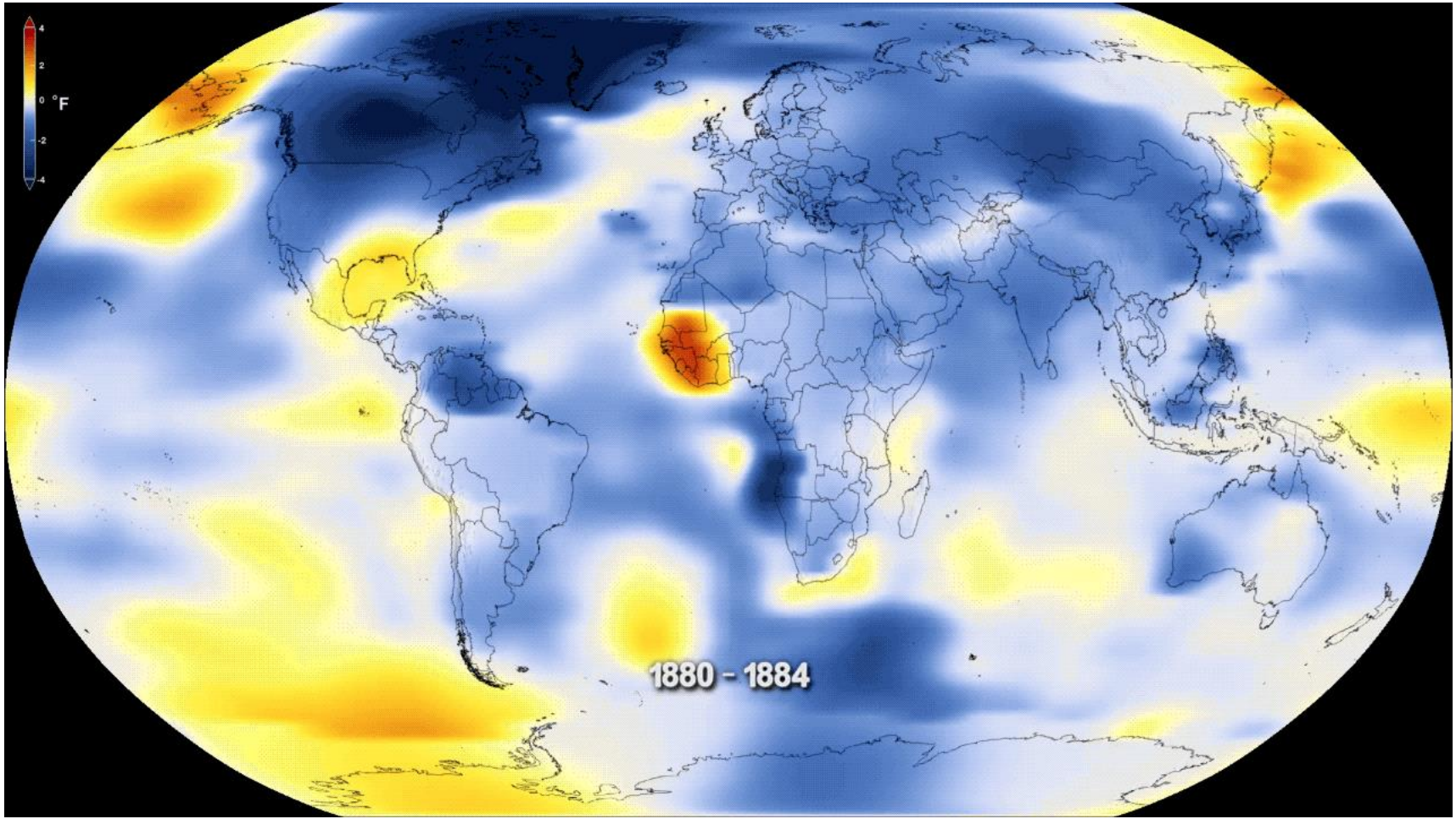
- Location, location location
- 2018 Greece, California, England, Sweden, ON and BC
- 2019 Arctic, Amazon, Alberta, Australia etc.
- 2020 Australia, Siberia, Amazon and western USA etc.
- Globally, smoke related fatalities estimated at 330,000 per year

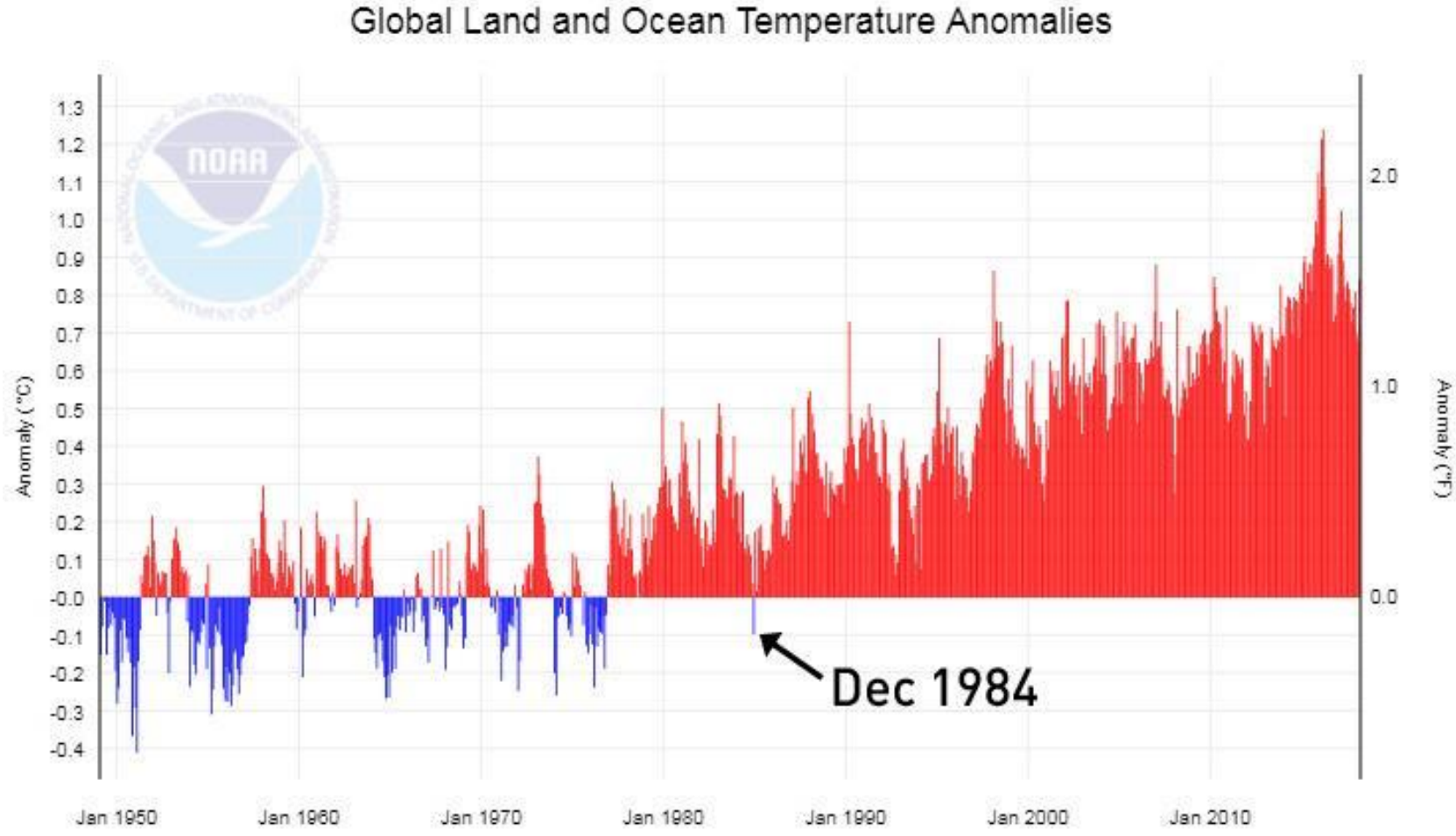



Atmospheric CO_2 at Mauna Loa Observatory
Scripps Institution of Oceanography
NOAA Global Monitoring Laboratory
PARTS PER MILLION
420
400
380
360
340
320
1960
1970
1980
1990
2000
2010
2020
YEAR
September 2020



http://www.columbia.edu/~mhs119/Temperature/

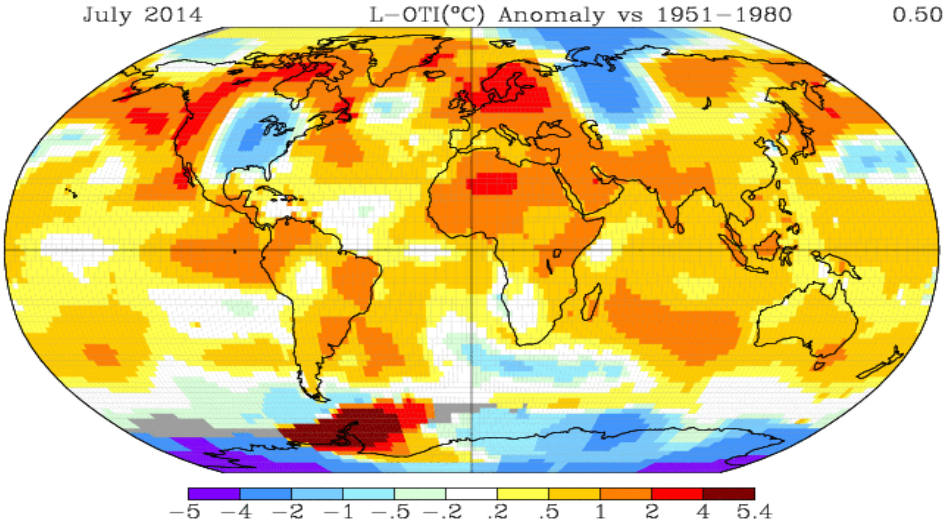

4
2
0 °F
-2
-4
1880 - 1884

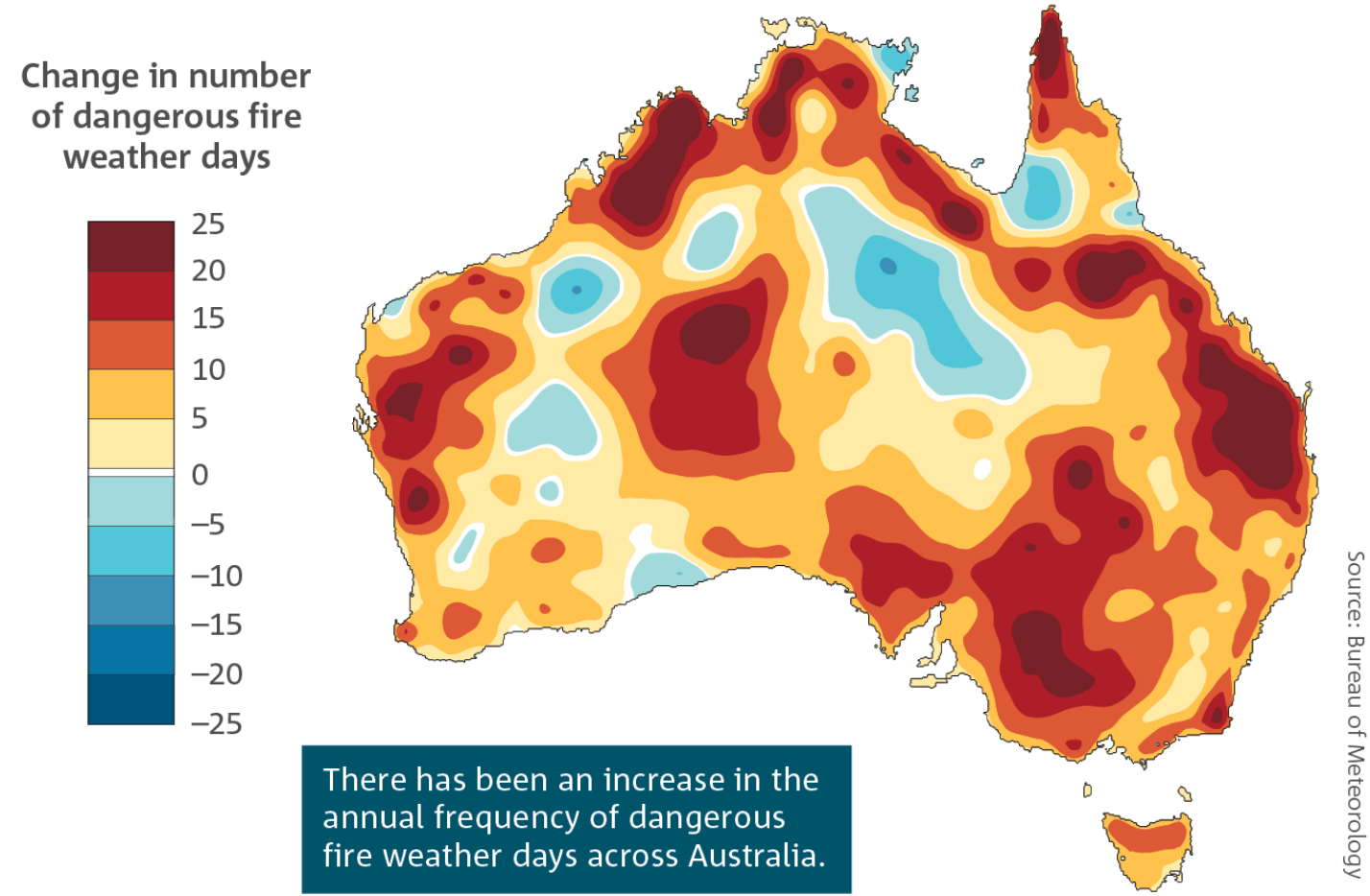

Global Land and Ocean Temperature Anomalies
Anomaly (°C)
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
-0.0
-0.1
-0.2
-0.3
-0.4
2.0
1.0
0.0
Anomaly (°F)
Dec 1984
Jan 1950
Jan 1960
Jan 1970
Jan 1980
Jan 1990
Jan 2000
Jan 2010

Fire & Temperature

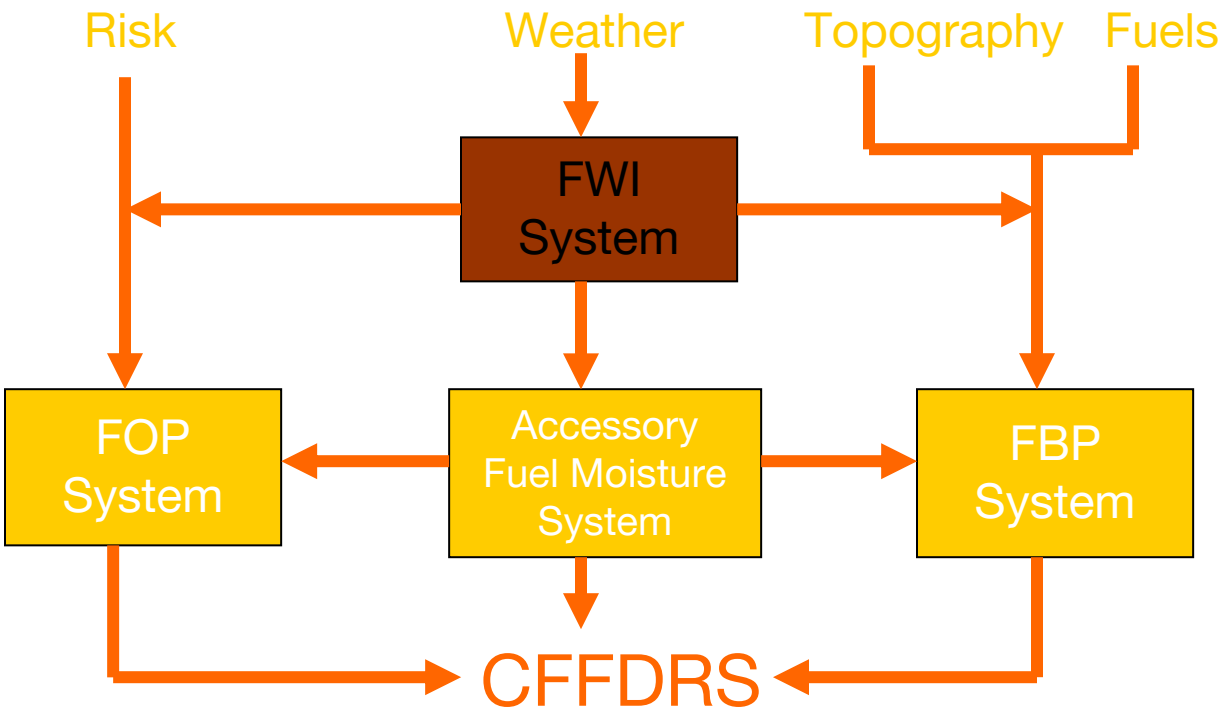
Photo credit: Government of the Northwest Territories

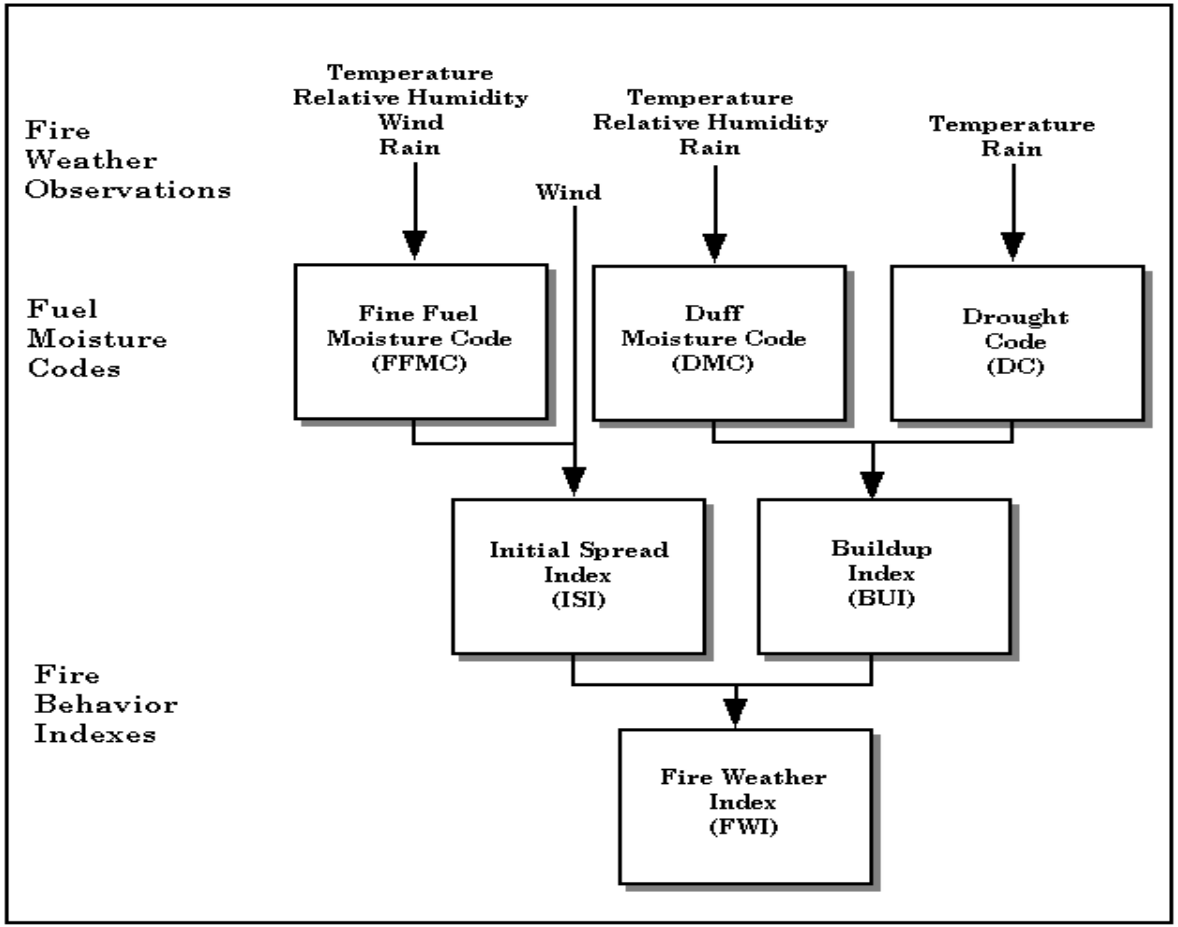
- Drier fuels
- Lightning
- Fire season




Change in number of dangerous fire weather days
25
20
15
10
5
0
−5
−10
−15
−20
−25
There has been an increase in the annual frequency of dangerous fire weather days across Australia.
Source: Bureau of Meteorology

The Canadian Fire Danger Rating System



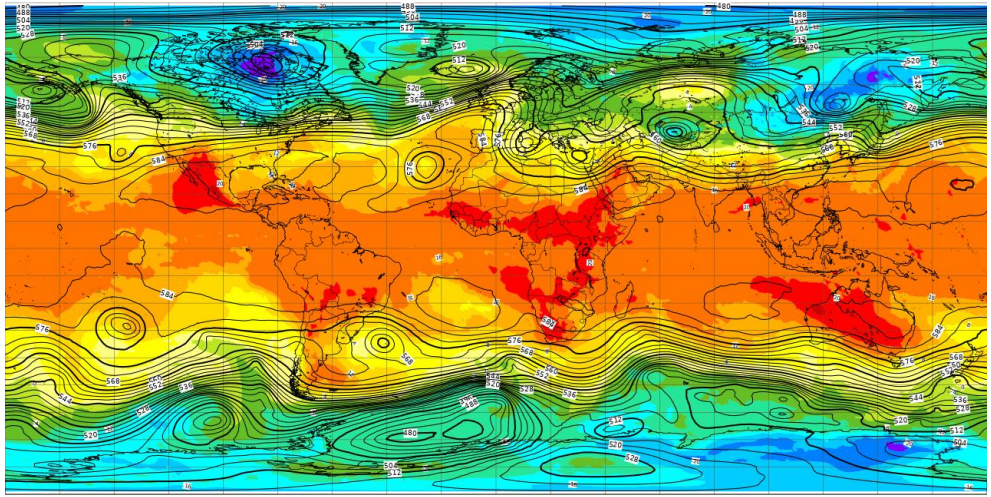

Fire Weather Observations
Temperature
Relative Humidity
Wind
Rain
Wind
Temperature
Relative Humidity
Rain
Temperature
Rain
Fuel Moisture Codes
Fine Fuel Moisture Code (FFMC)
Duff Moisture Code (DMC)
Drought Code (DC)
Initial Spread Index (ISI)
Buildup Index (BUI)
Fire Behavior Indexes
Fire Weather Index (FWI)

The FWI System :

- Fuel moisture is calculated for dead fuels in the FWI System - these fuels responds to the environment. Time lags from less than a day to around 52 days.
- Initial Spread Index (ISI) represents how fast a fire might spread.
- Fire Weather Index (FWI) represents the fire intensity.
- Both ISI, FWI have been used to define an active spread day.
- FWI System is unitless and qualitative – does not include fuel type.

ERA5 data

- **ERA5** is the fifth-generation reanalysis from the European Centre for Medium-Range Weather Forecasts (ECMWF) for the global climate and weather for the past 4 decades (1979-2020). ERA5 replaces the ERA-Interim reanalysis.
- Assimilates as many observations as possible from the upper air and near surface.
- Presented at hourly time steps at a regular lat-lon grid of 0.25 degrees (~30km).
- Here we use ERA5 hourly data from 1979 to present including 2m temperature, 2m dew point temperature, 10m wind speed, 24 hour precipitation to calculate the FWI System components.



FWI Calculation and Trend Analysis

FWI System calculated using the cffdrs package in R and we did an overwintering adjustment of the Drought Code where necessary (McElhinny et al. 2020).

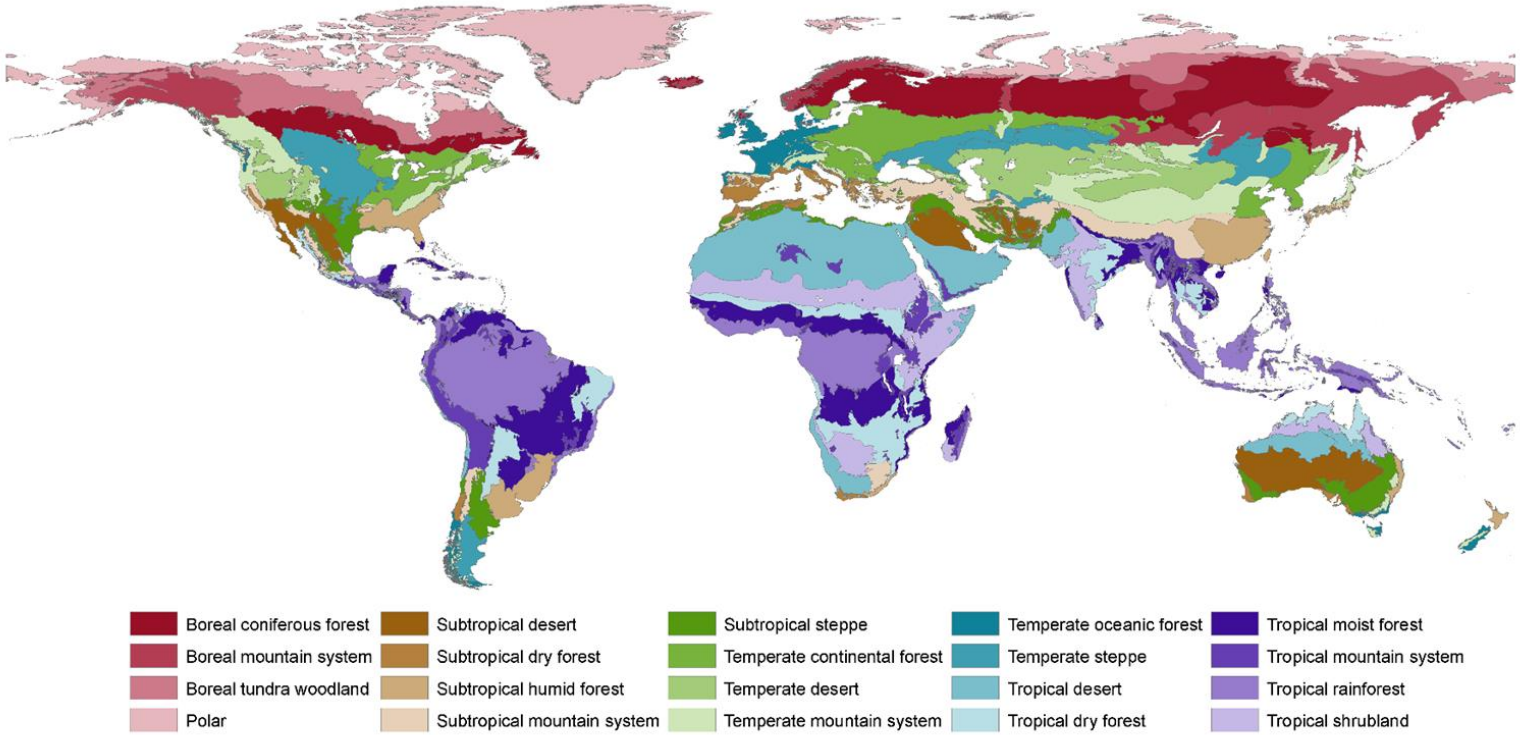
Trend analysis on the FWI System components and meteorological variables using the Mann-Kendall test.

Linear trends were determined using the Thiel-Sen estimator. Multiple testing and spatial autocorrelation were taken into account by controlling the False Discovery Rate and setting the global significance level to 0.05.

The maps only show trends significant at this 0.05 level.

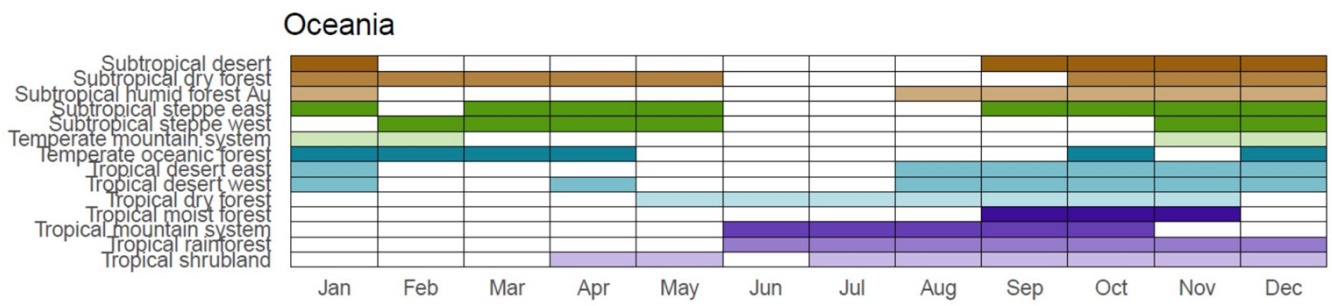
McElhinny et al. 2020. A high-resolution reanalysis of global fire weather from 1979 to 2018 – Overwintering the Drought Code, Earth Syst. Sci. Data, 12, 1823–1833. https://doi.org/10.5194/essd-2019-248

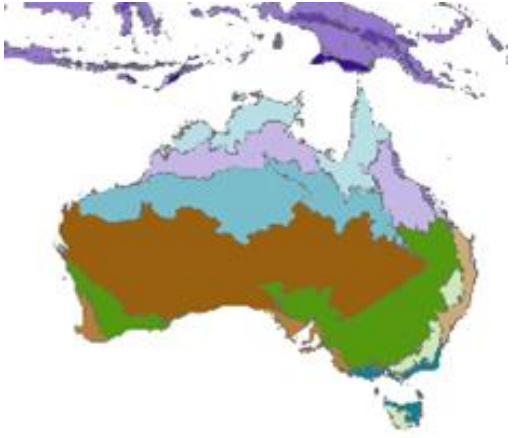
Biome classification from FAO and WWF



Fire season was calculated from the Global fire atlas

- Fire data available for 2003-2016 (Andela et al, 2019). The data was aggregated over each biome, and then fire season was defined for each biome as the minimum number of months that account for at least 90% of the area burned.





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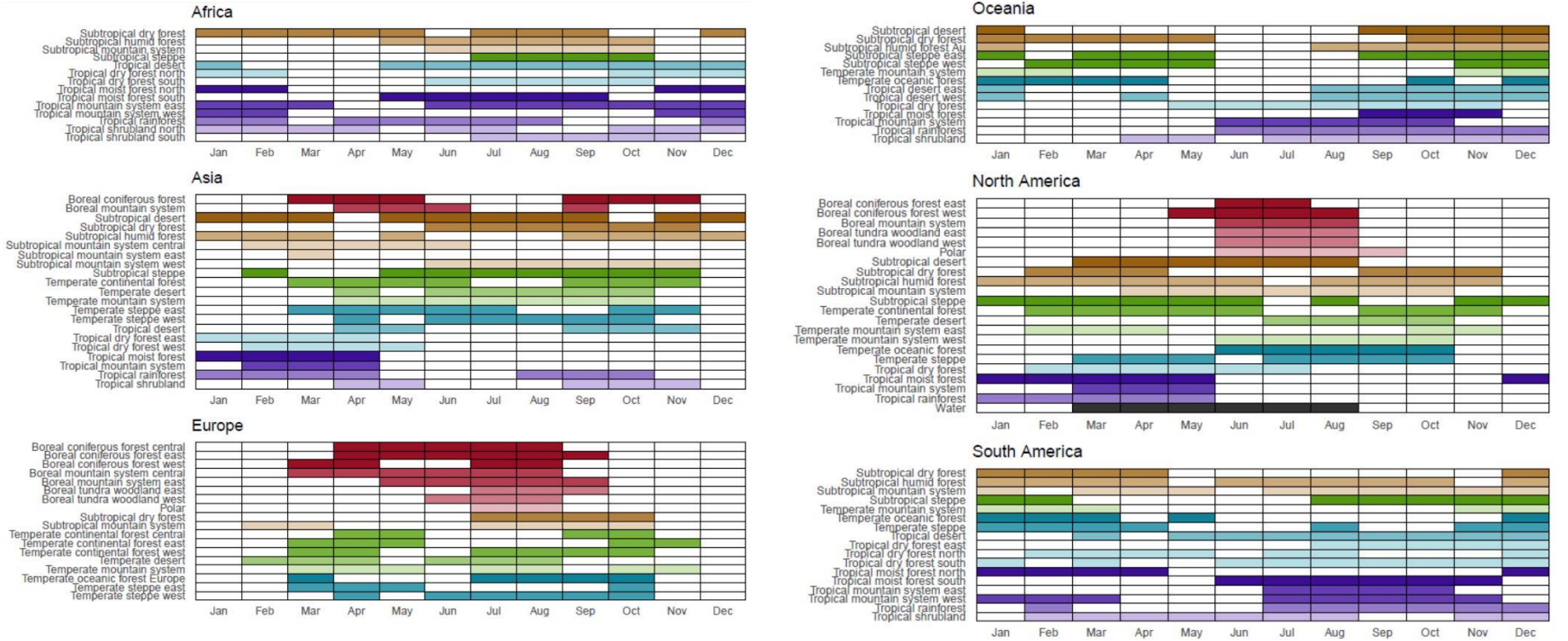
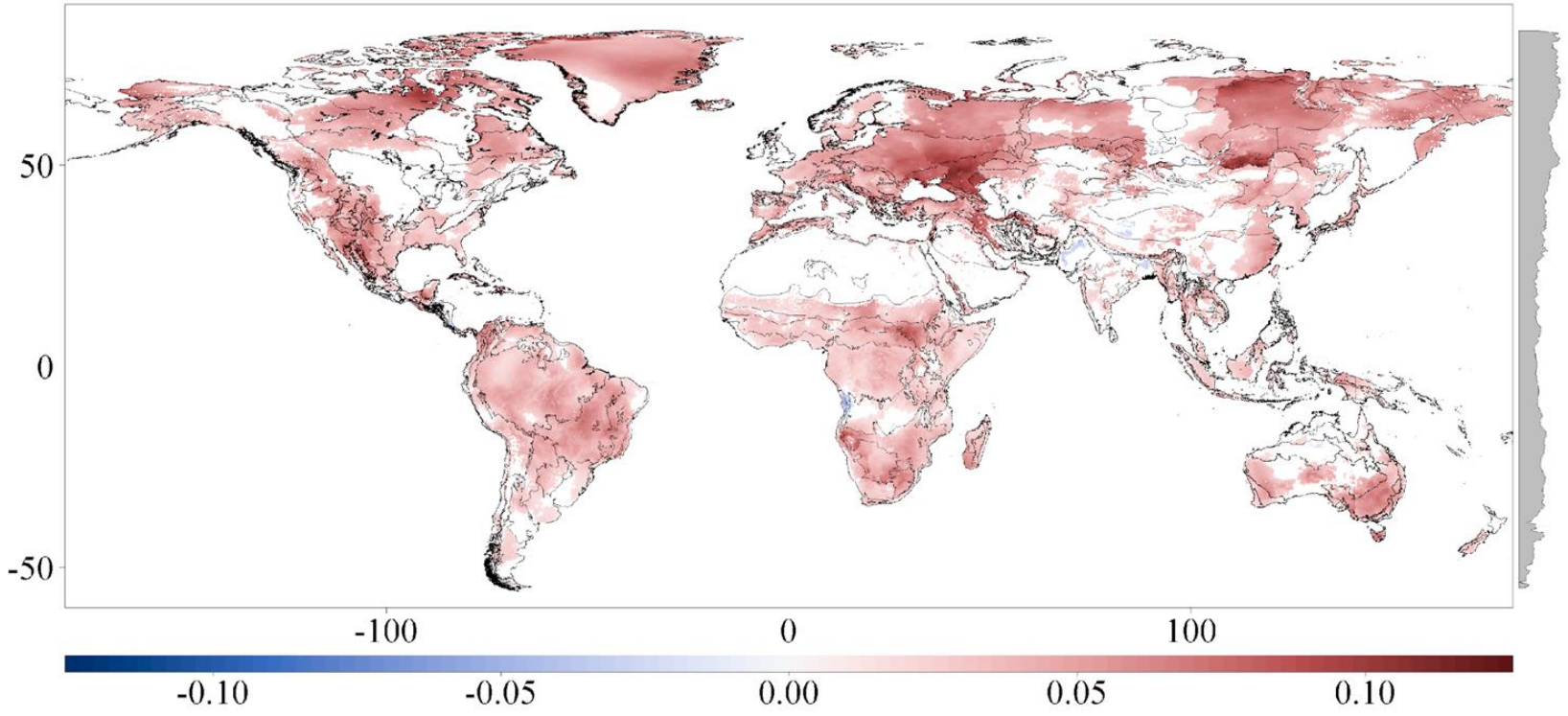
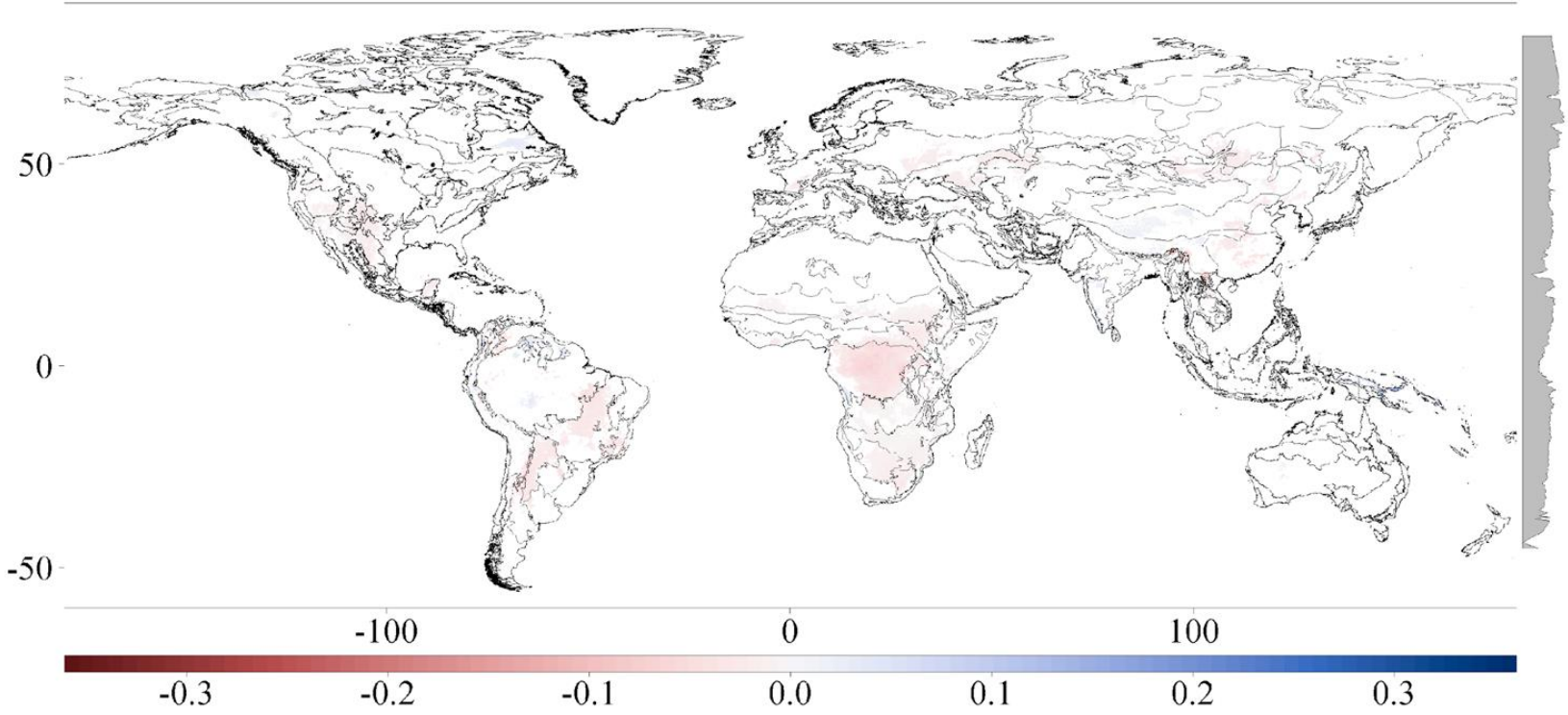


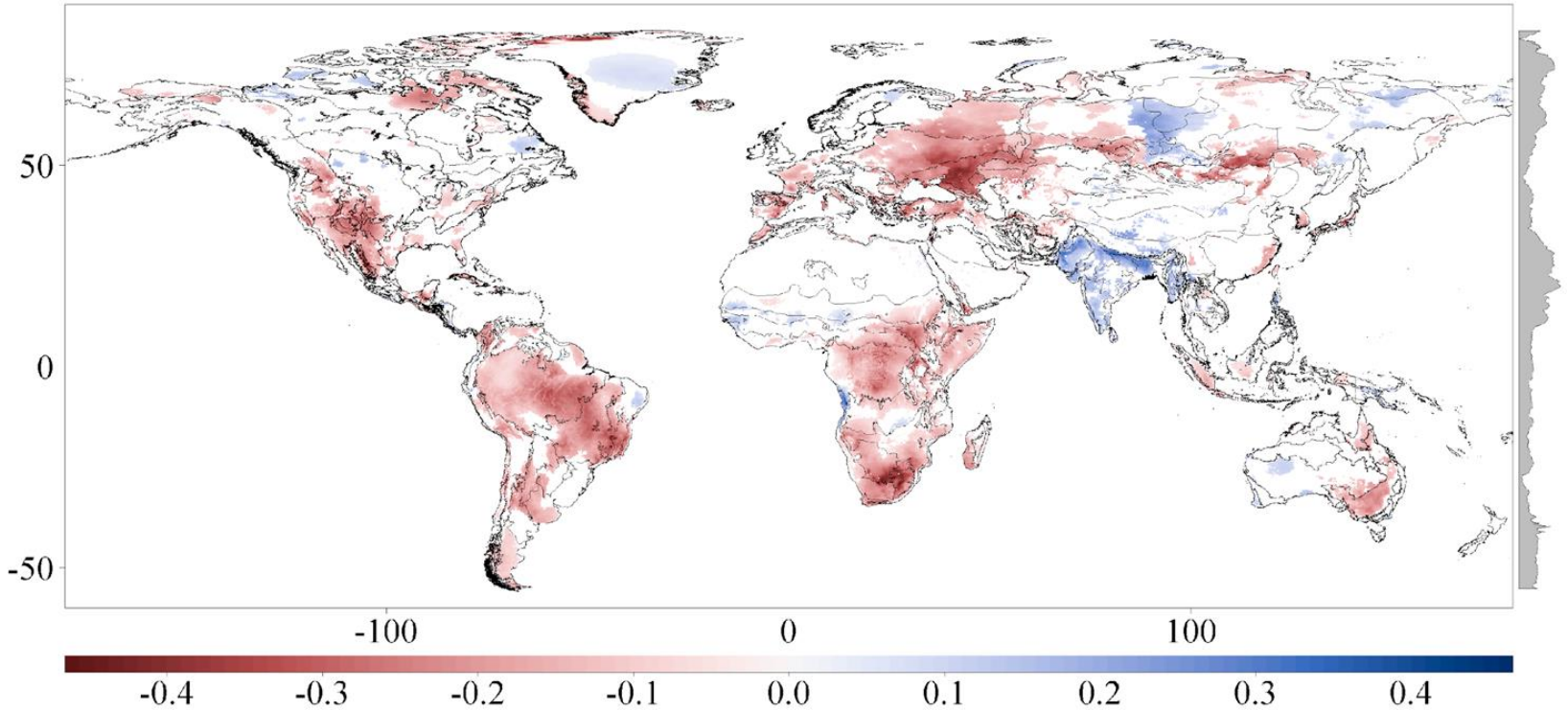
Mean Temperature Trend



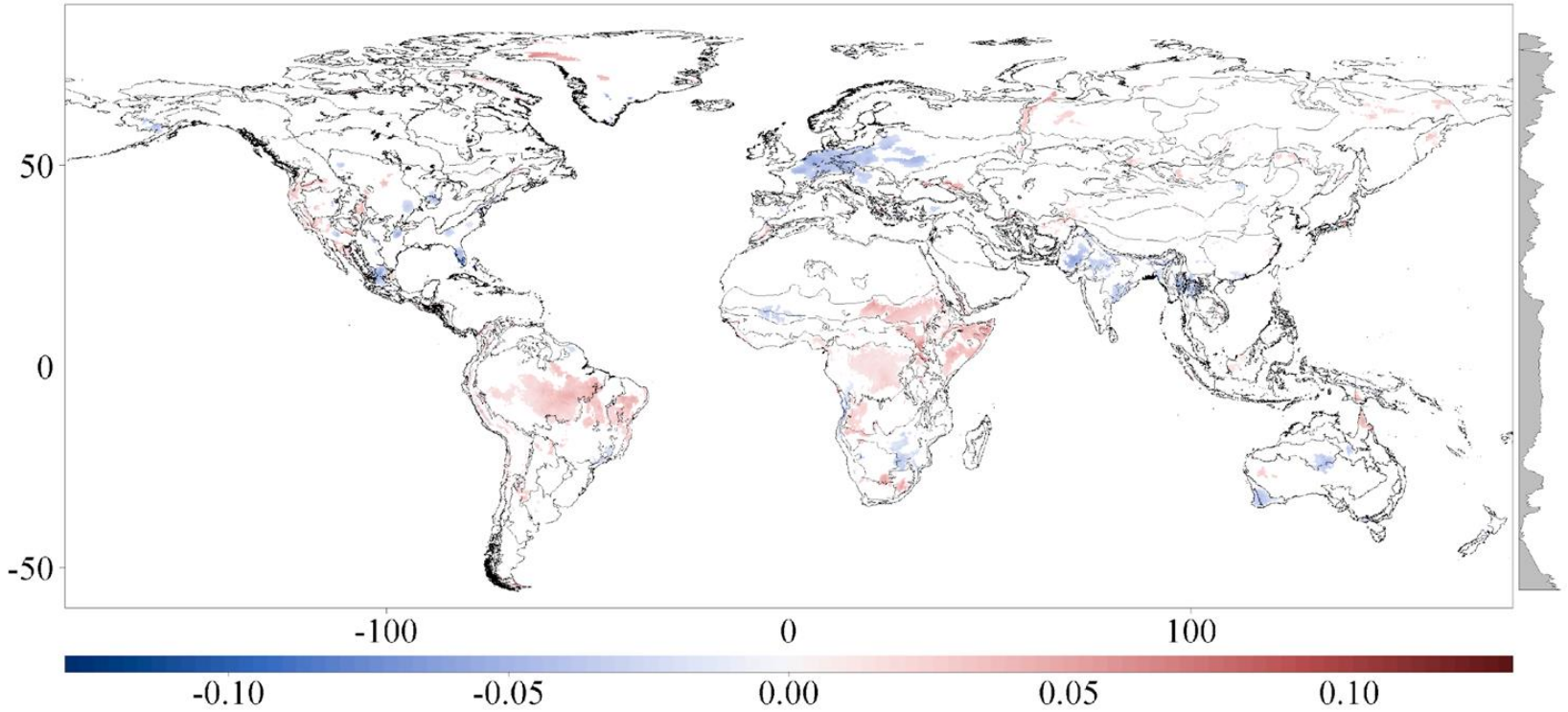
Daily Precipitation Trend



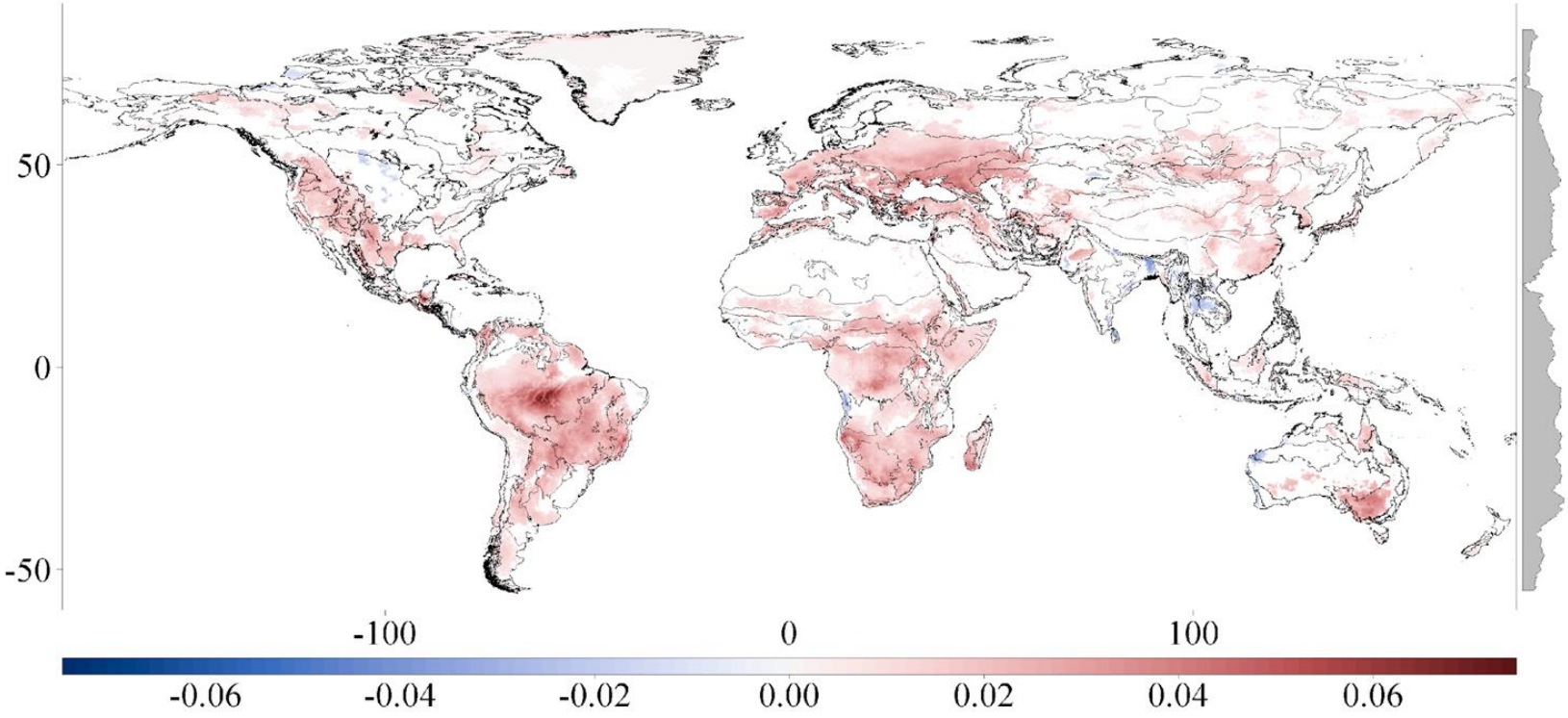
Mean RH Trend



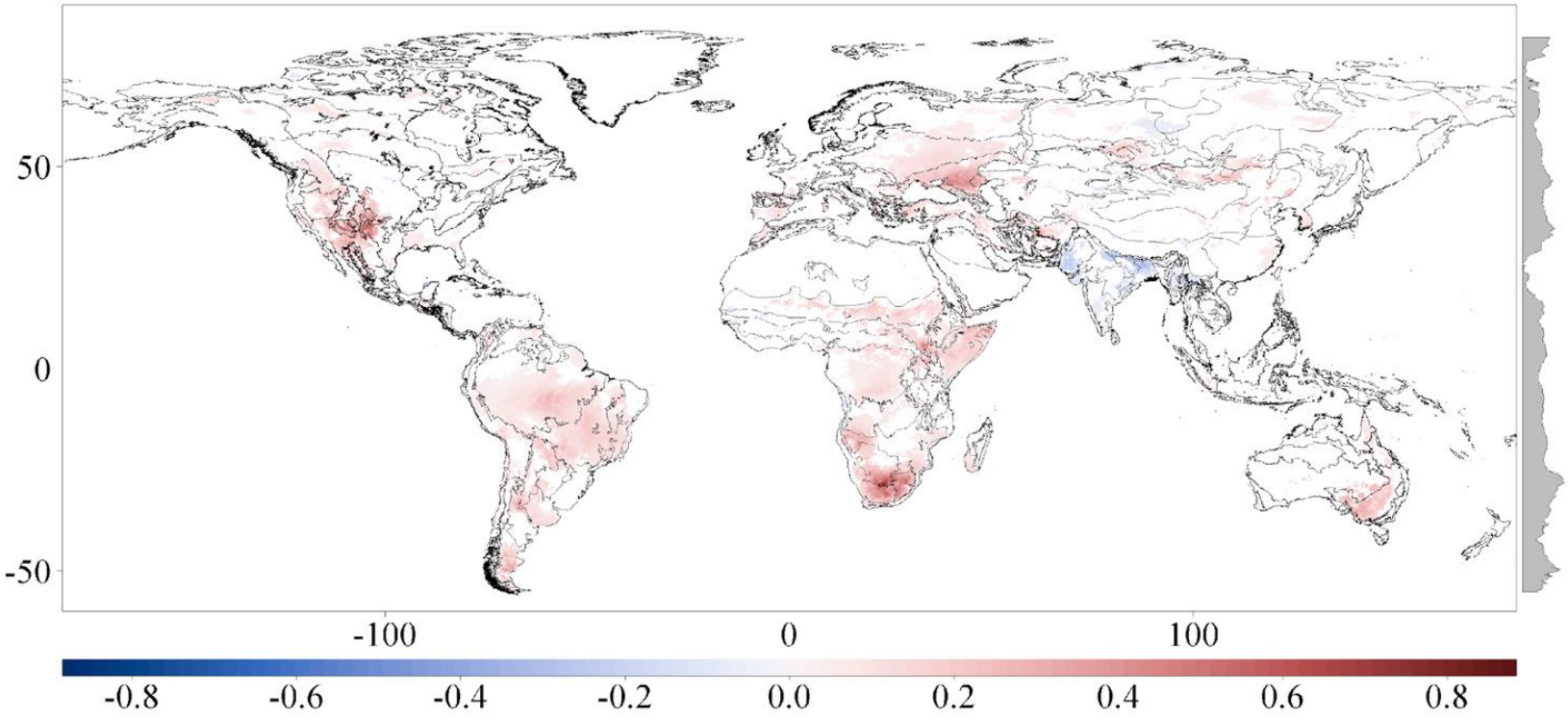
Mean Wind Trend



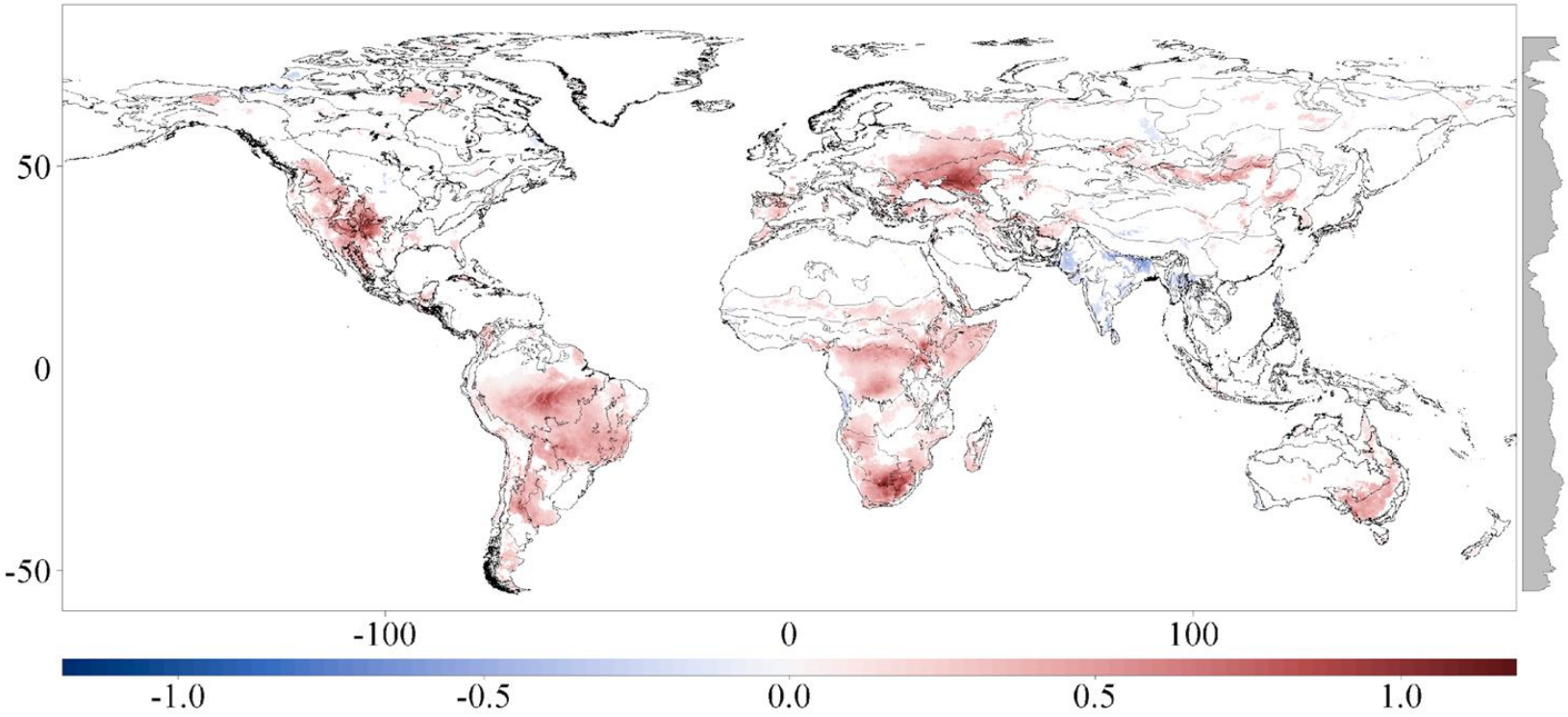
95th Percentile VPD Trend



95th Percentile ISI Trend



95th Percentile FWI Trend



Summary

- Fire and weather are strongly linked

- Many regions of the world are warming and have increasing vapour pressure deficits (vpd) due in large part to the warming. Increases in ISI and FWI suggest fires are spreading faster and burning more intensely.

- Increasing 95th percentiles means more extremes and extreme conditions drive fire activity. Increasing fire intensity will lead to more escape fires and more impacts – we have to learn to live with fire.

- Significant increases in FWI 95th percentile – much of South America, Central and Southern Africa, SE Australia, Caspian and Black Sea regions, SW USA

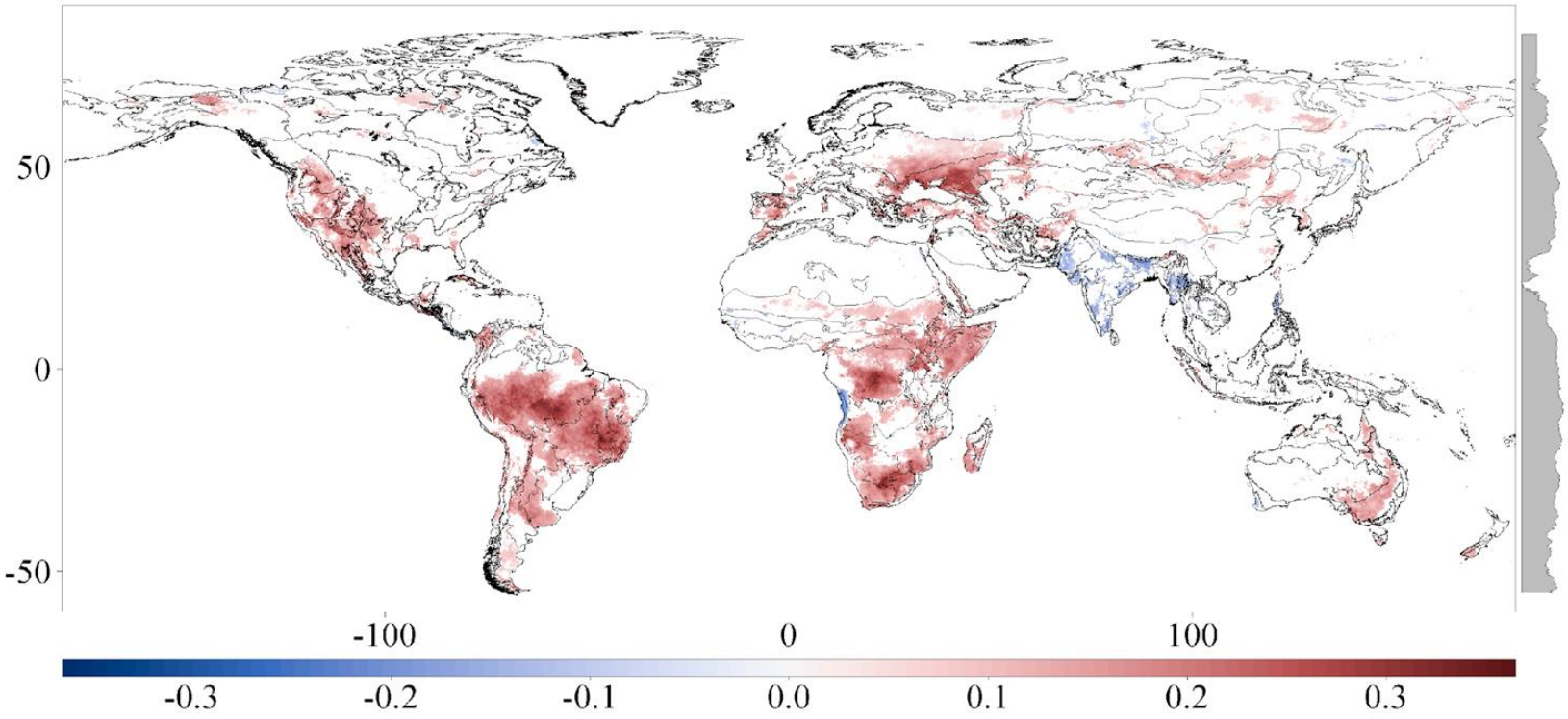
- This study does not take into account changing fire season length

Photo credit: Xinli Cai

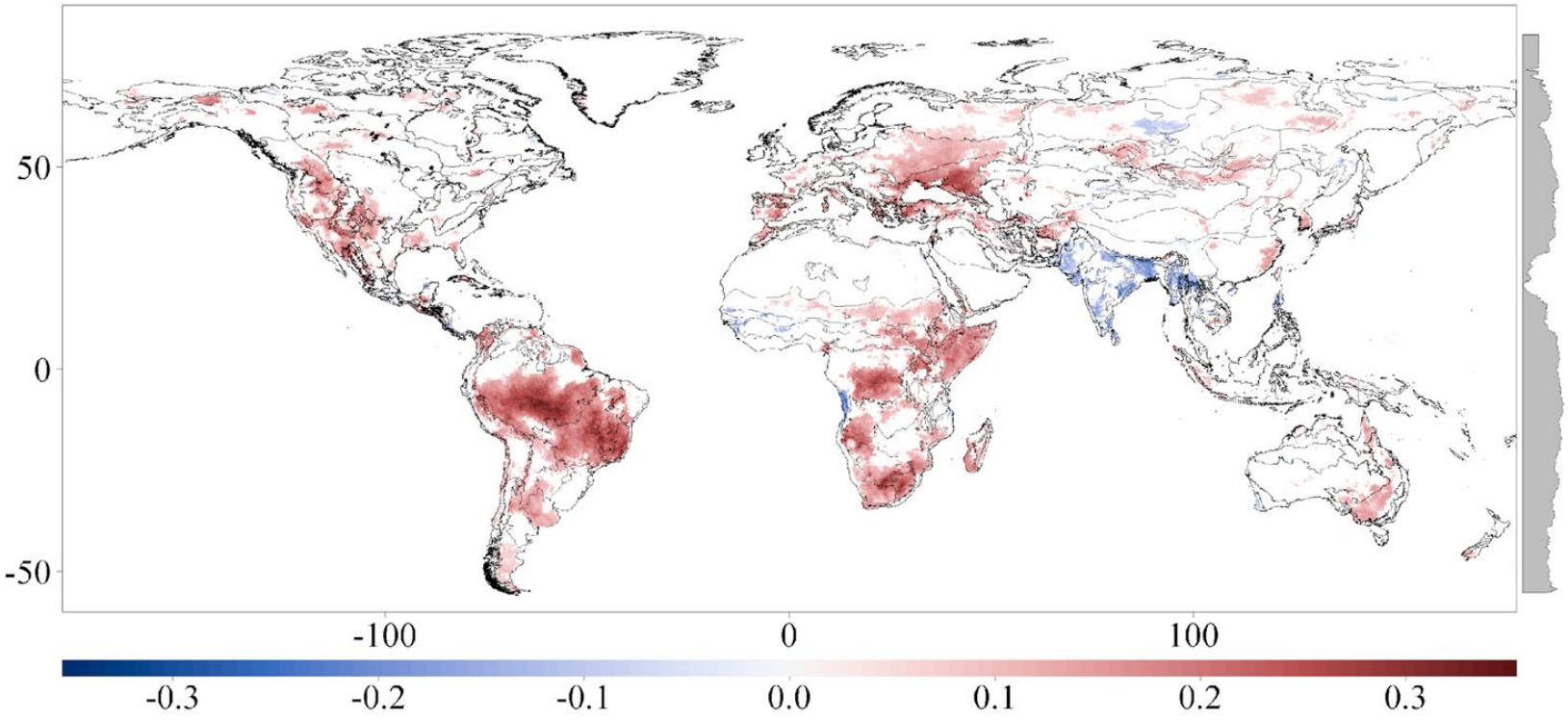
https://www.cbc.ca/listen/cbc-podcasts/422-world-on-fire

@CanadaWildfire https://www.canadawildfire.org/

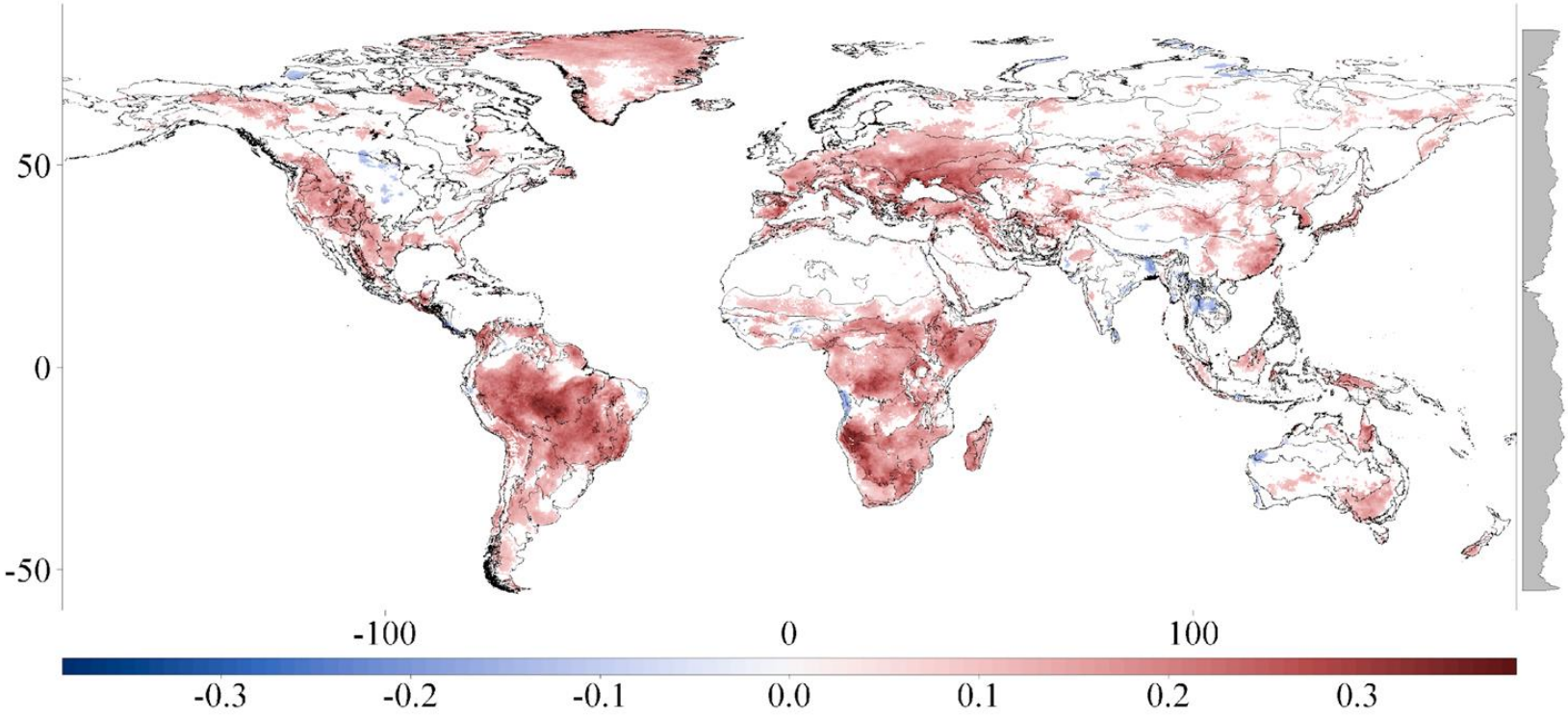
Trend test of FWI days above 1979-2019 95th as percentage of days of the fire season



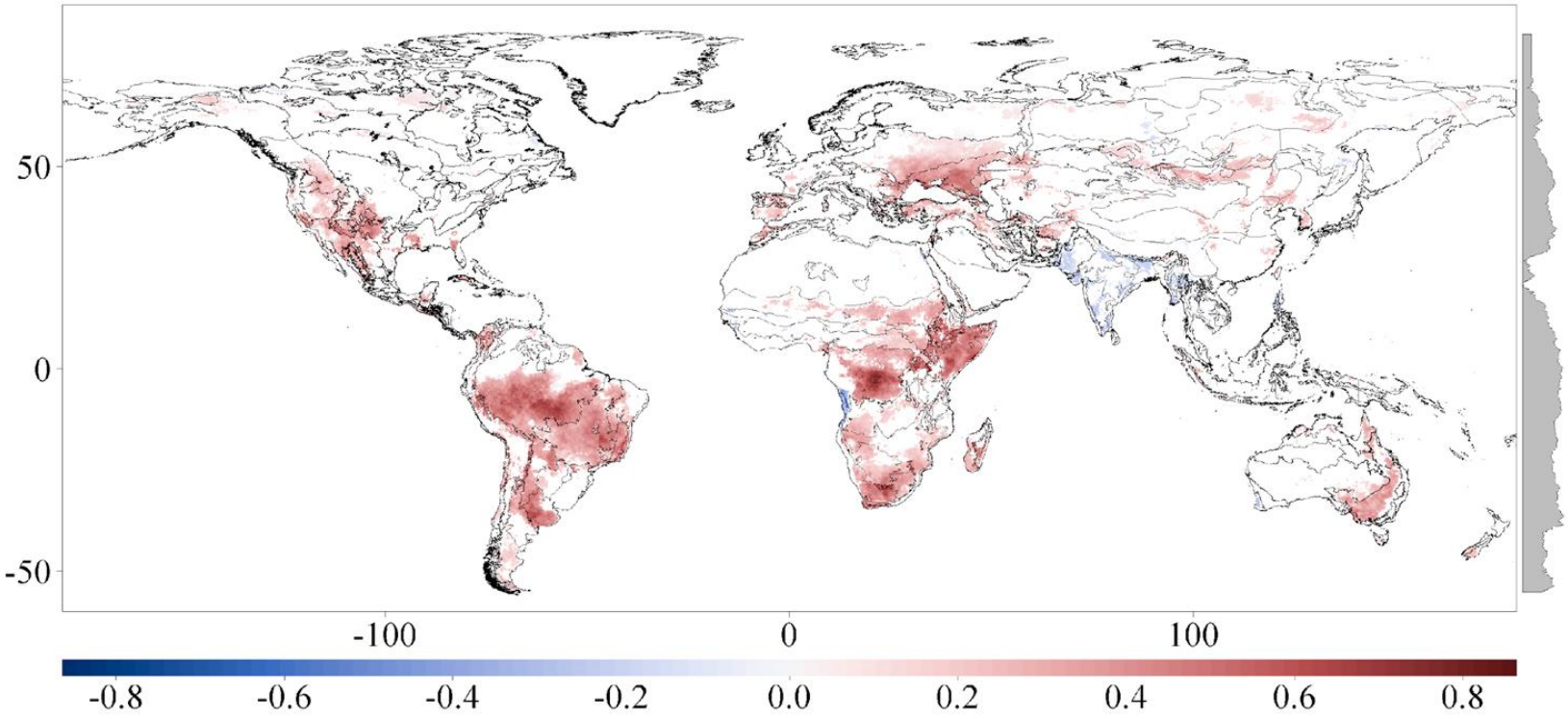
Trend test of ISI days above 1979-2019 95th as percentage of days of the fire season



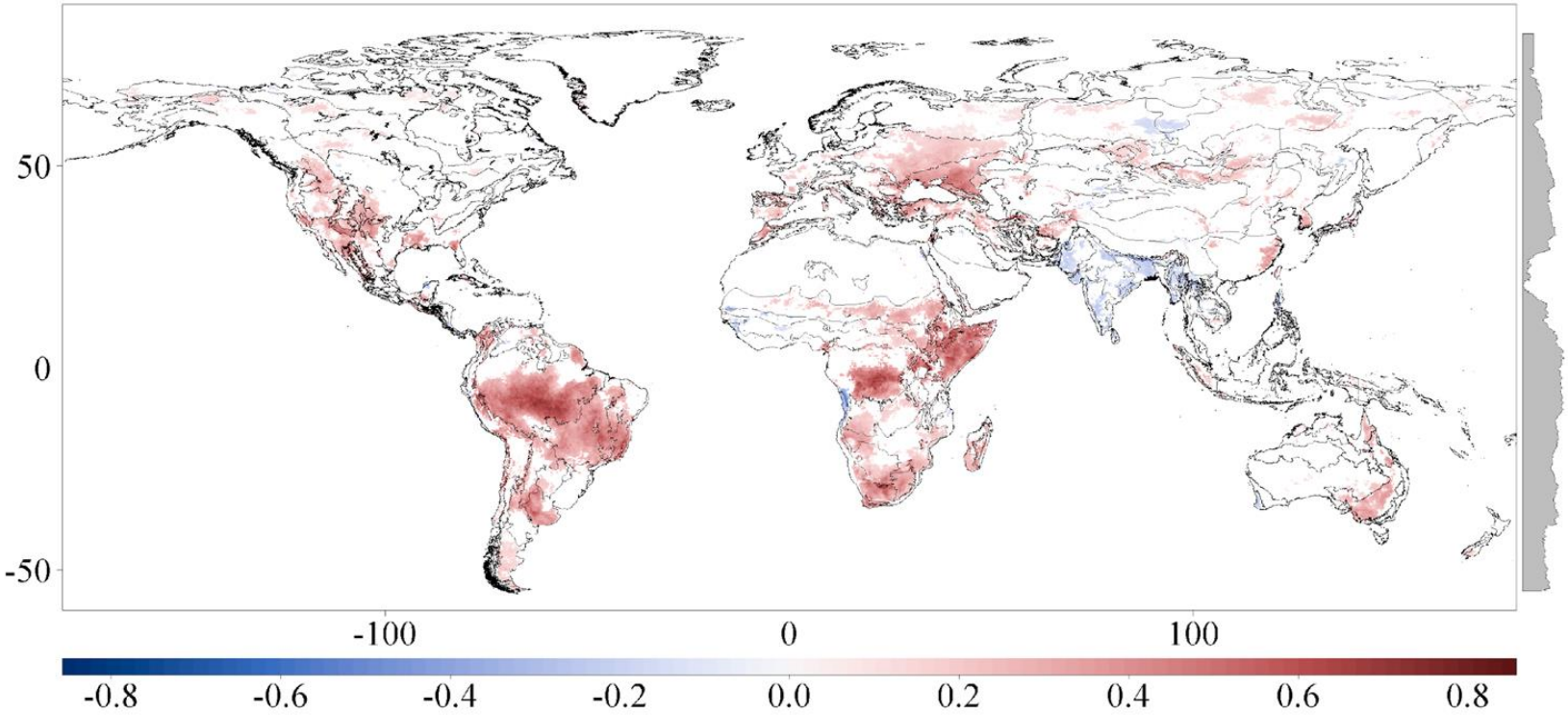
Trend test of VPD days above 1979-2019 95th as percentage of days of the fire season



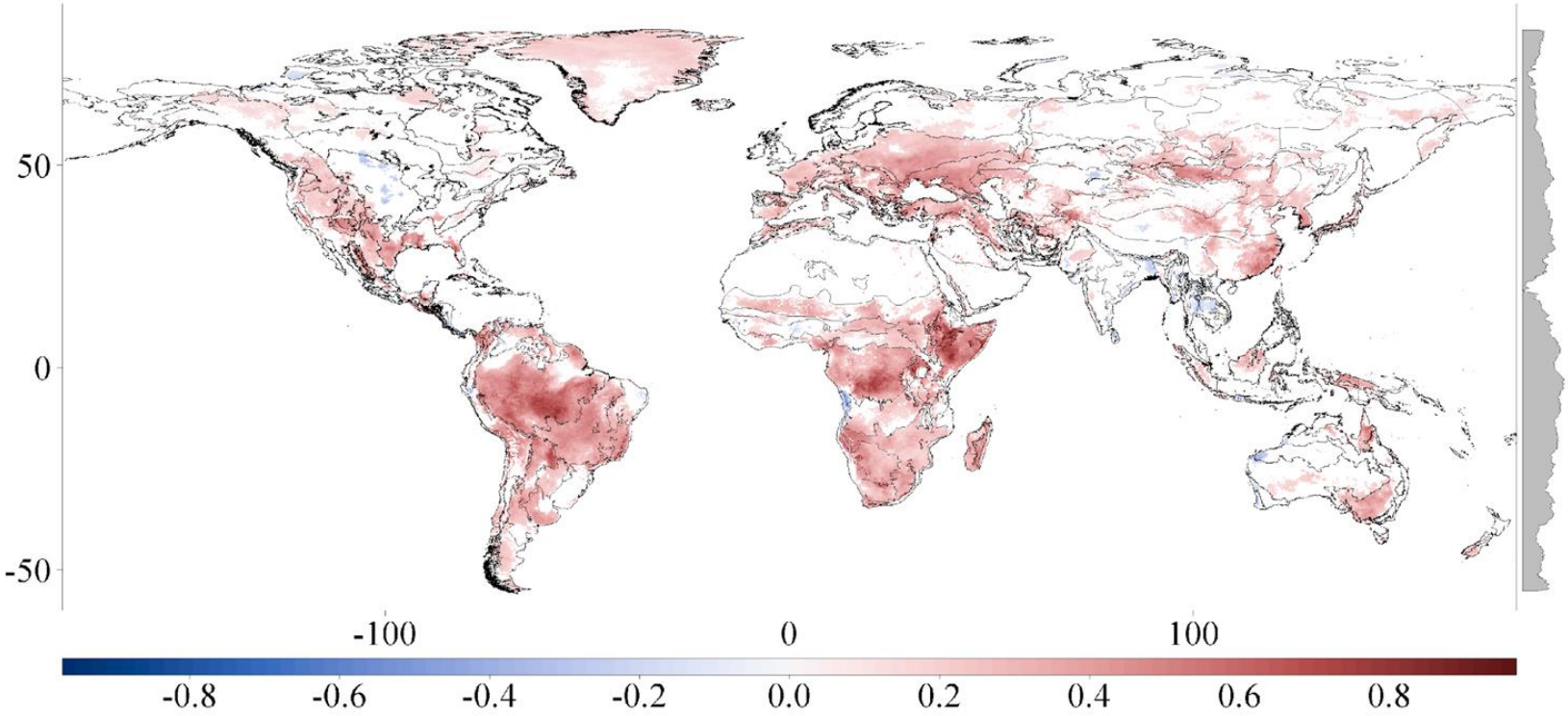
Trend test of FWI days above 1979-2019 95th



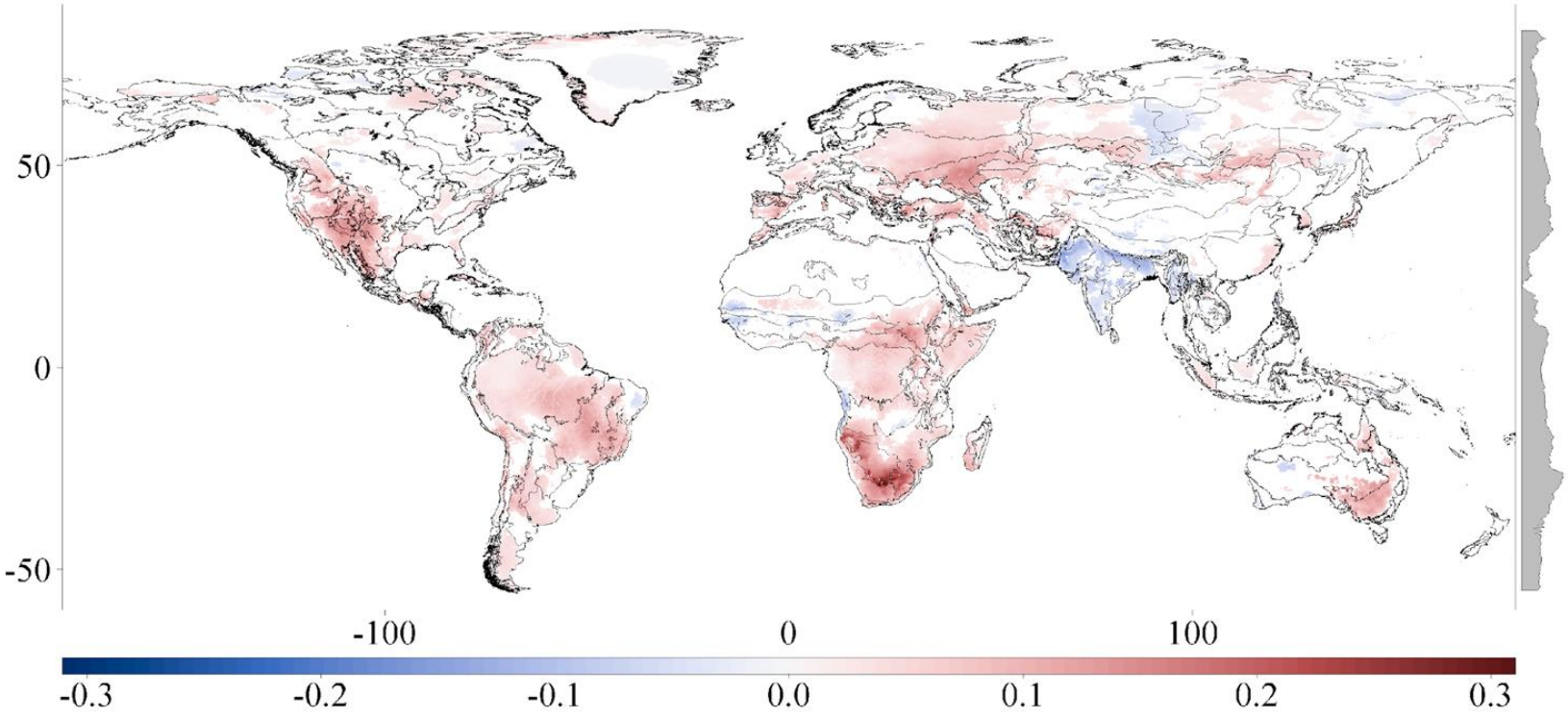
Trend test of ISI days above 1979-2019 95th



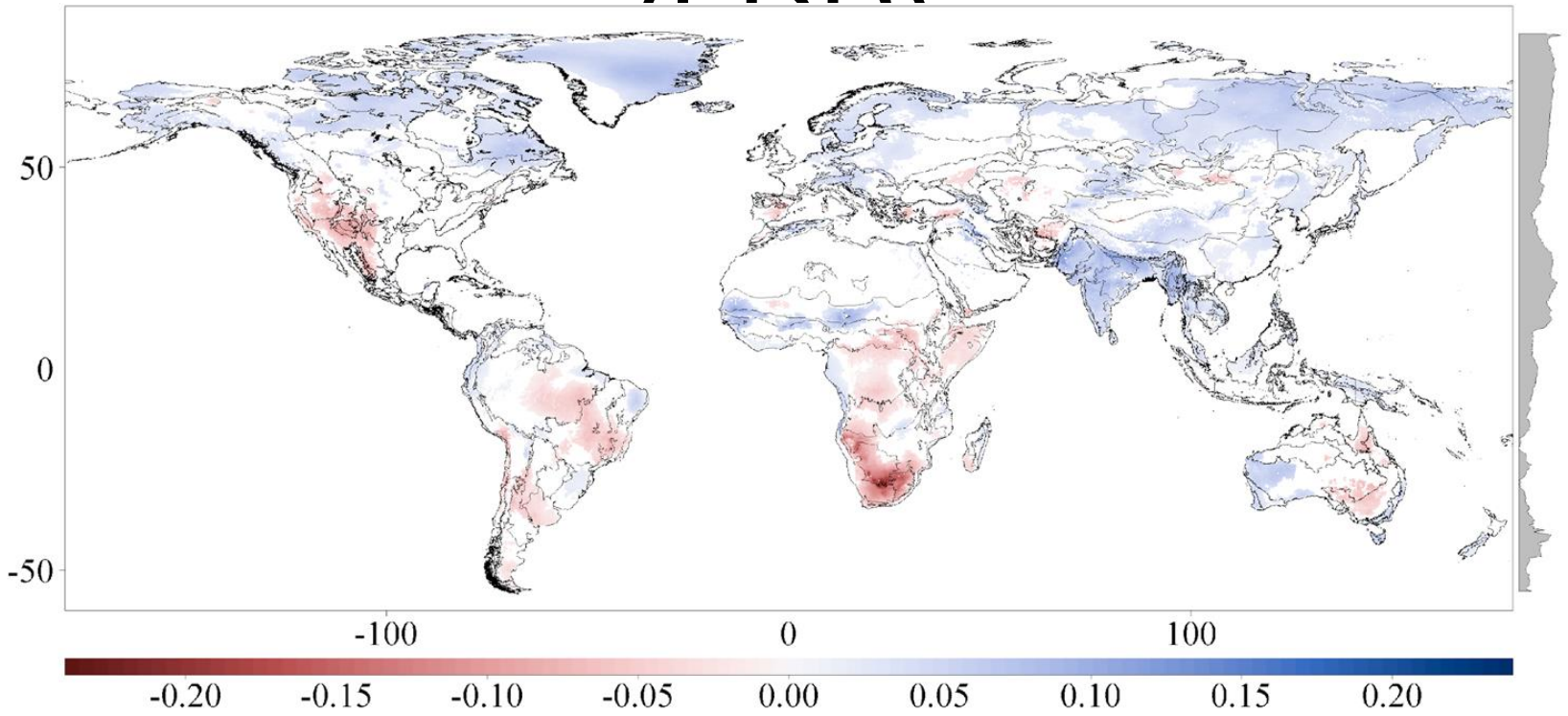
Trend test of VPD days above 1979-2019 95th



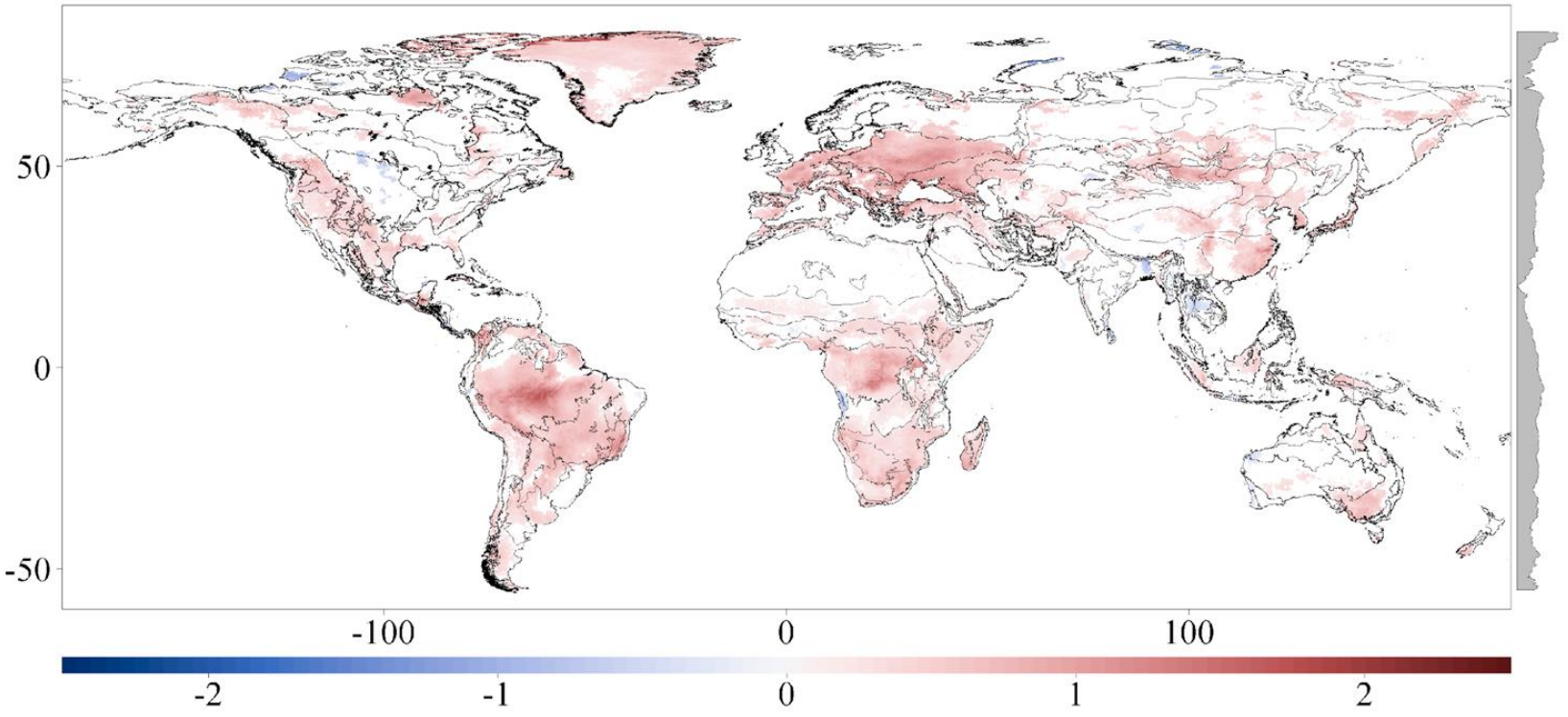
Trend test of difference between temperature and dew point temperature



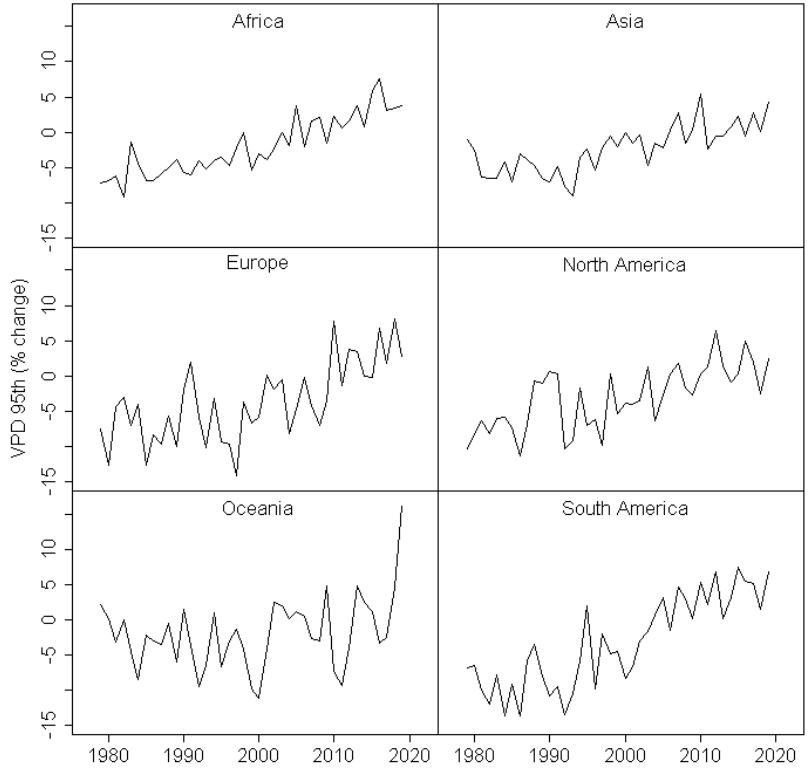
temperature mean with significance level adjustment (FDR)



Trend test of VPD 95th value of each year as percentage of 1979-2019 95th value



VPD 95th value of each year as percentage of 1979-2019 95th value



The FWI System : Fire behavior potential indices

- ISI – initial spread index RelativeThese indices follow (in a conceptual way) Byram's classic fireline intensity formula:

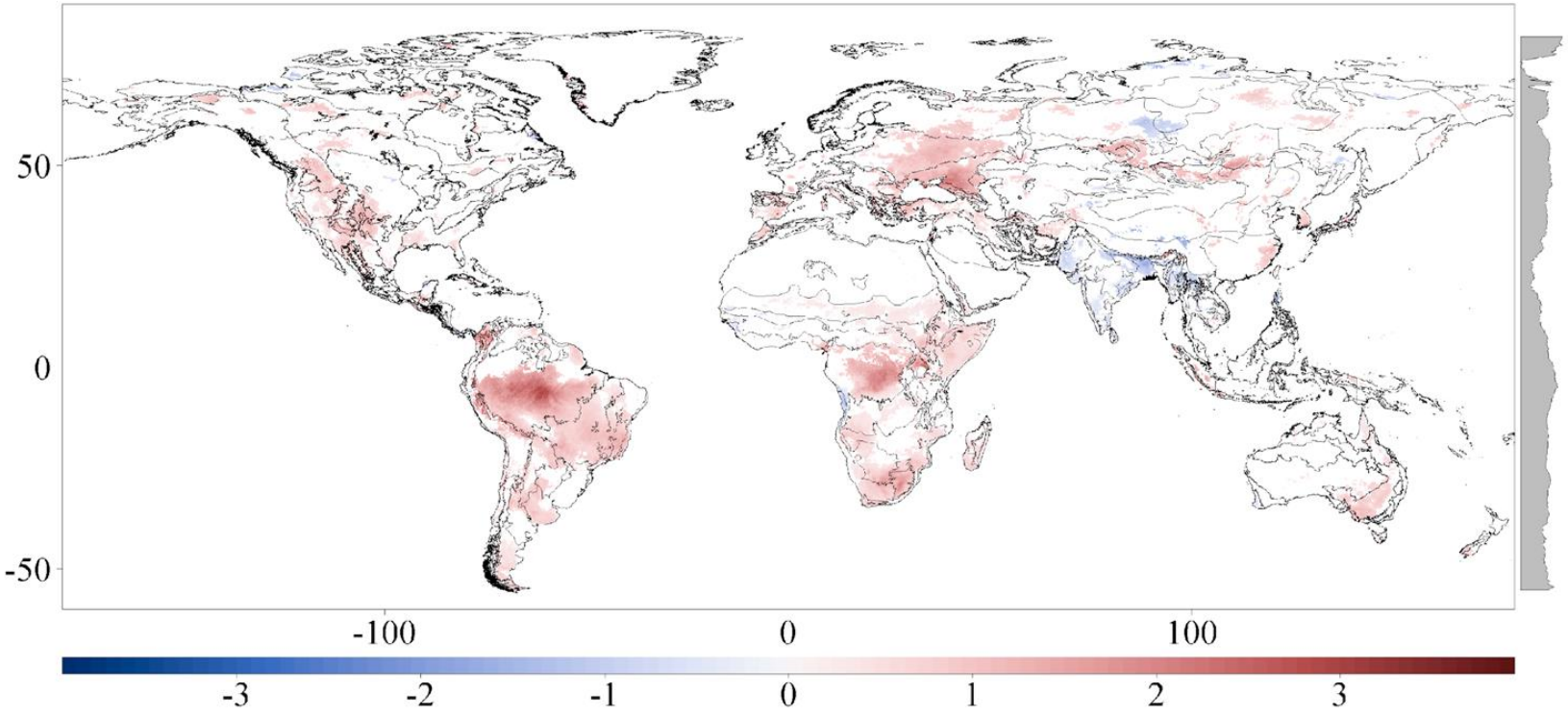
$$I_B = H \cdot W \cdot R$$

H is a constant…..the heat of combustion (~18000 kJ/kg)

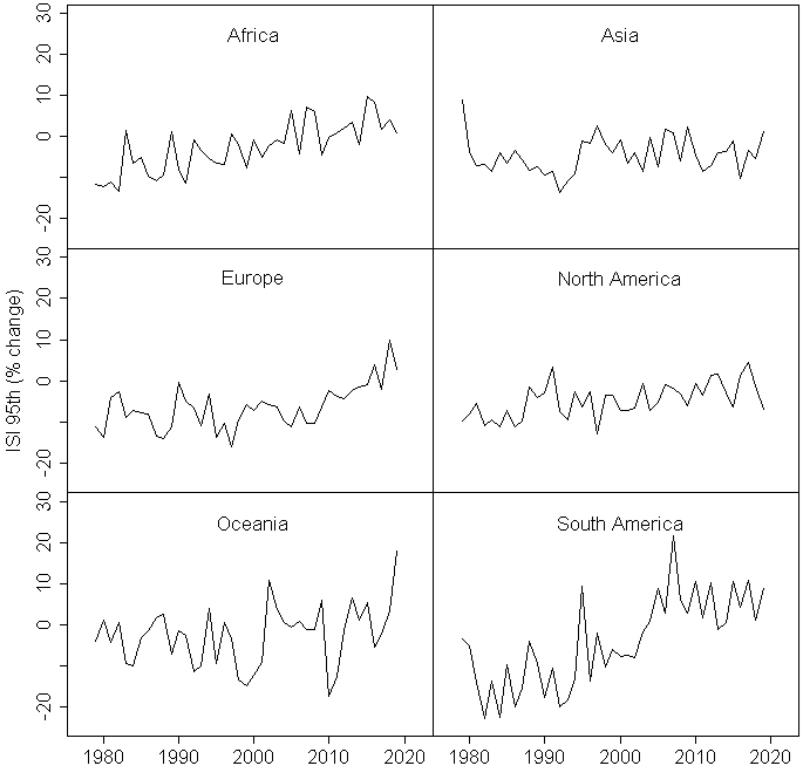
W is the weight of fuel consumed (kg/m^2)

R is the rate of spread (in m/s)

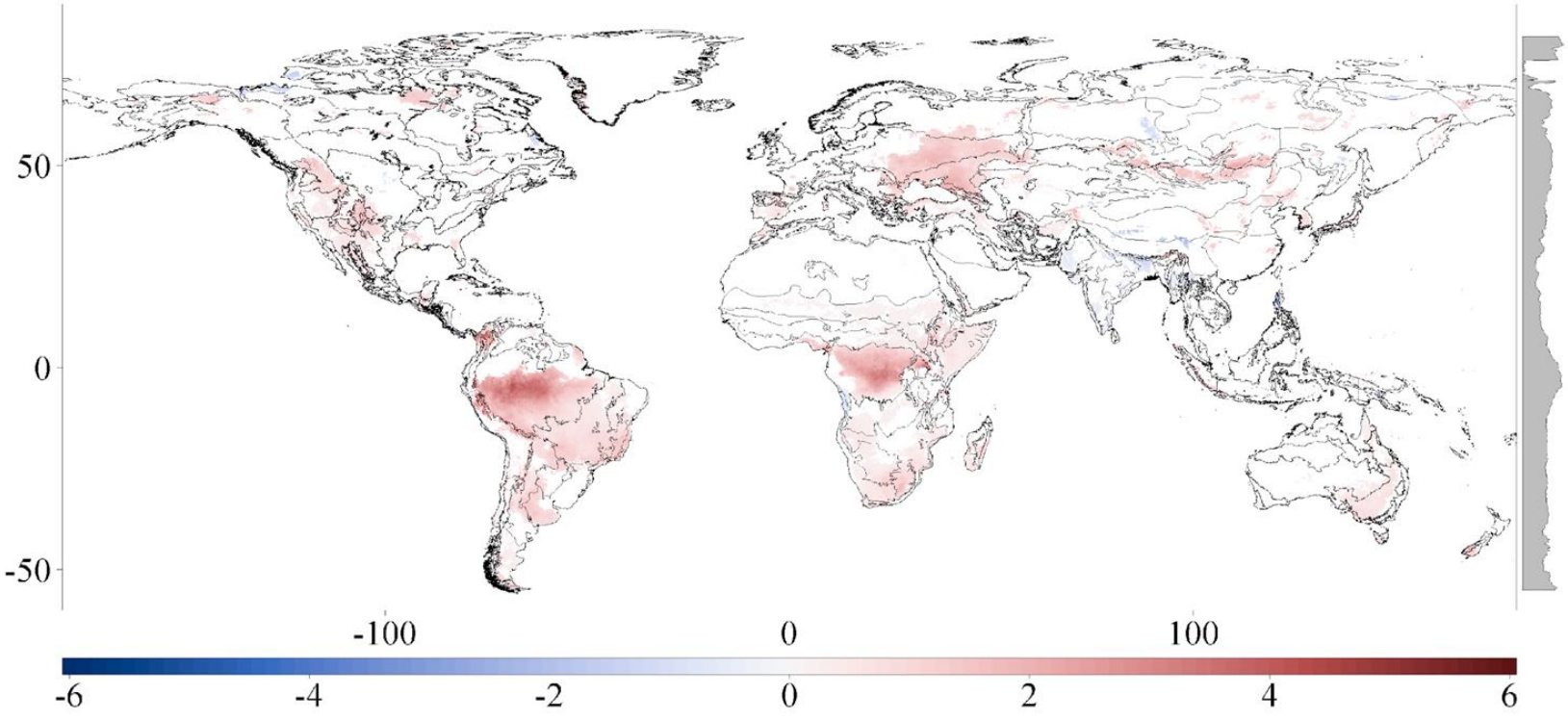
Trend test of ISI 95th value of each year as percentage of 1979-2019 95th value



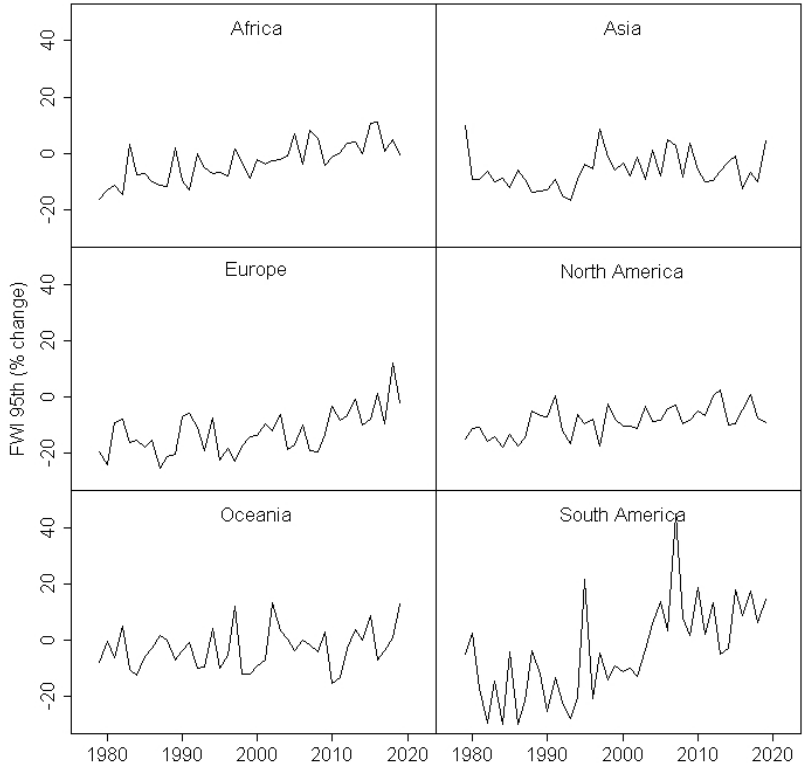
ISI 95th value of each year as percentage of 1979-2019 95th value



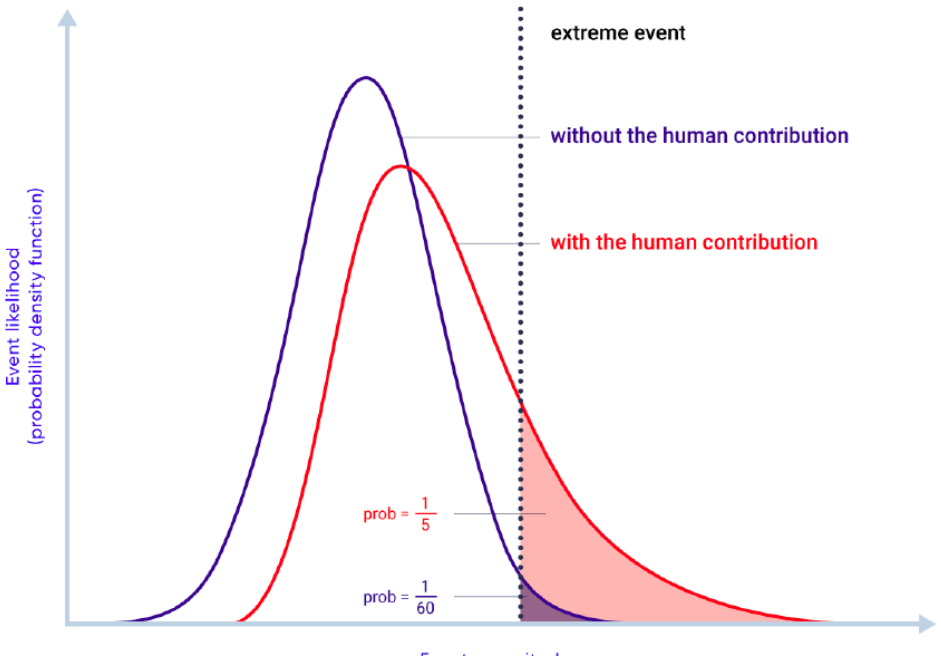
Trend test of FWI 95th value of each year as percentage of 1979-2019 95th value



FWI 95th value of each year as percentage of 1979-2019 95th value

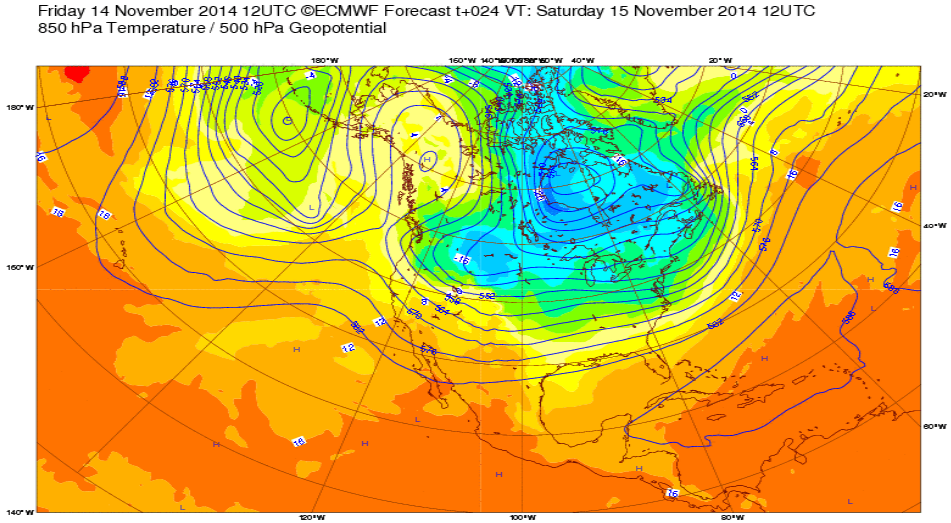


Escaped Fires….



- Increased wind events with 20-30% more days with wind gusts above 70 km/h.
- Strong winds are a key factor for wildfires.
- Research suggests that these extremes will result in very substantial increases in burned area due to increases in escaped fires
  - Driven by the change in frequency of being above fire intensity thresholds

A wild card – the Jet Stream



- Band of fast moving air – energy derived from the temperature difference between equatorial regions and polar regions.
- Jet streams determine the strength and movement of the synoptic weather systems.
- Climate change is causing a weakened of the jet stream as the temperature difference between the equator and poles decreases.
- Atmospheric patterns – stagnate, meandering – more extremes – droughts, floods, heat and cold.