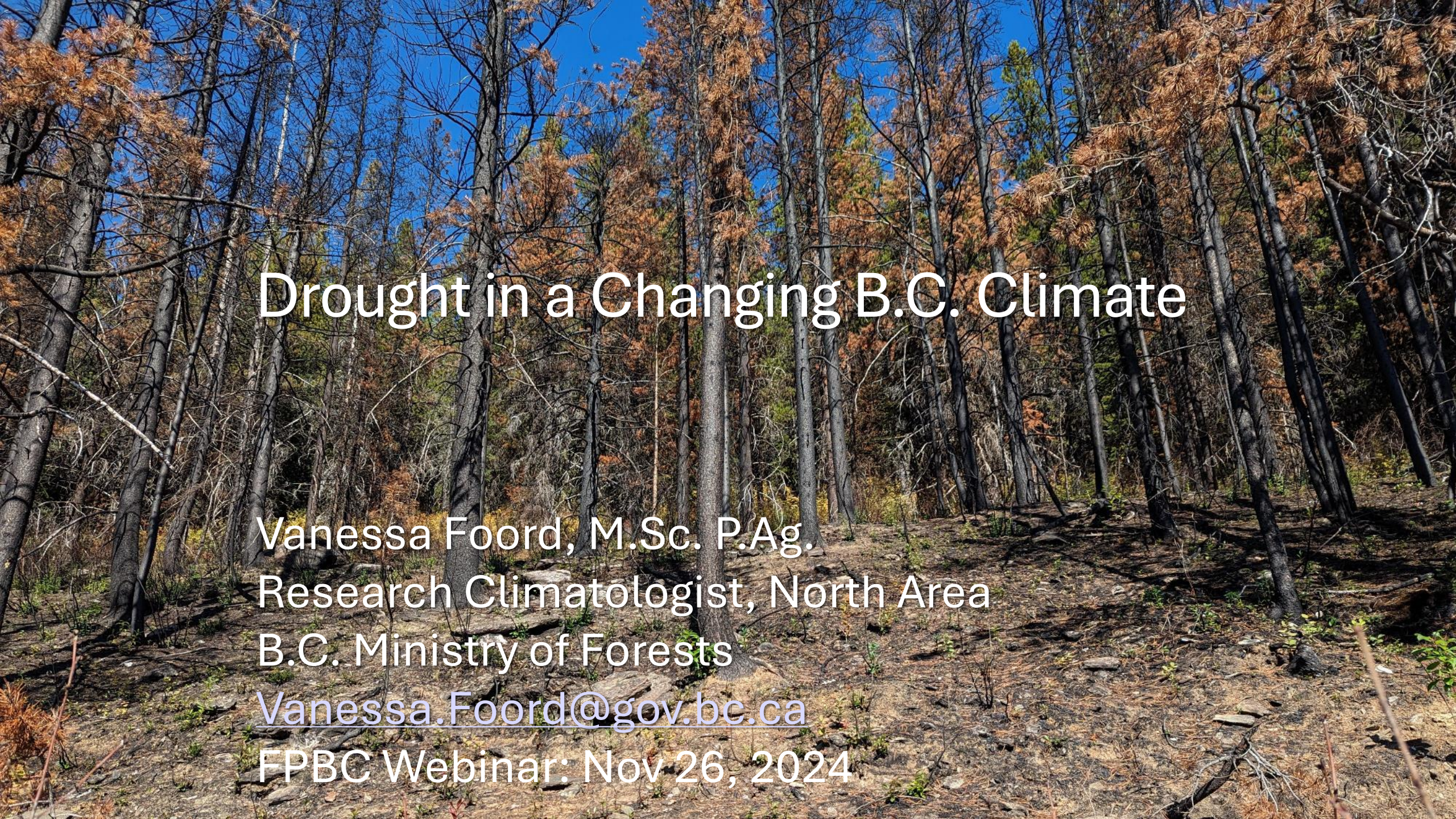

Drought in a Changing B.C. Climate

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B.C. Ministry of Forests
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FPBC Webinar: Nov 26, 2024

Presentation Goals:

To understand:

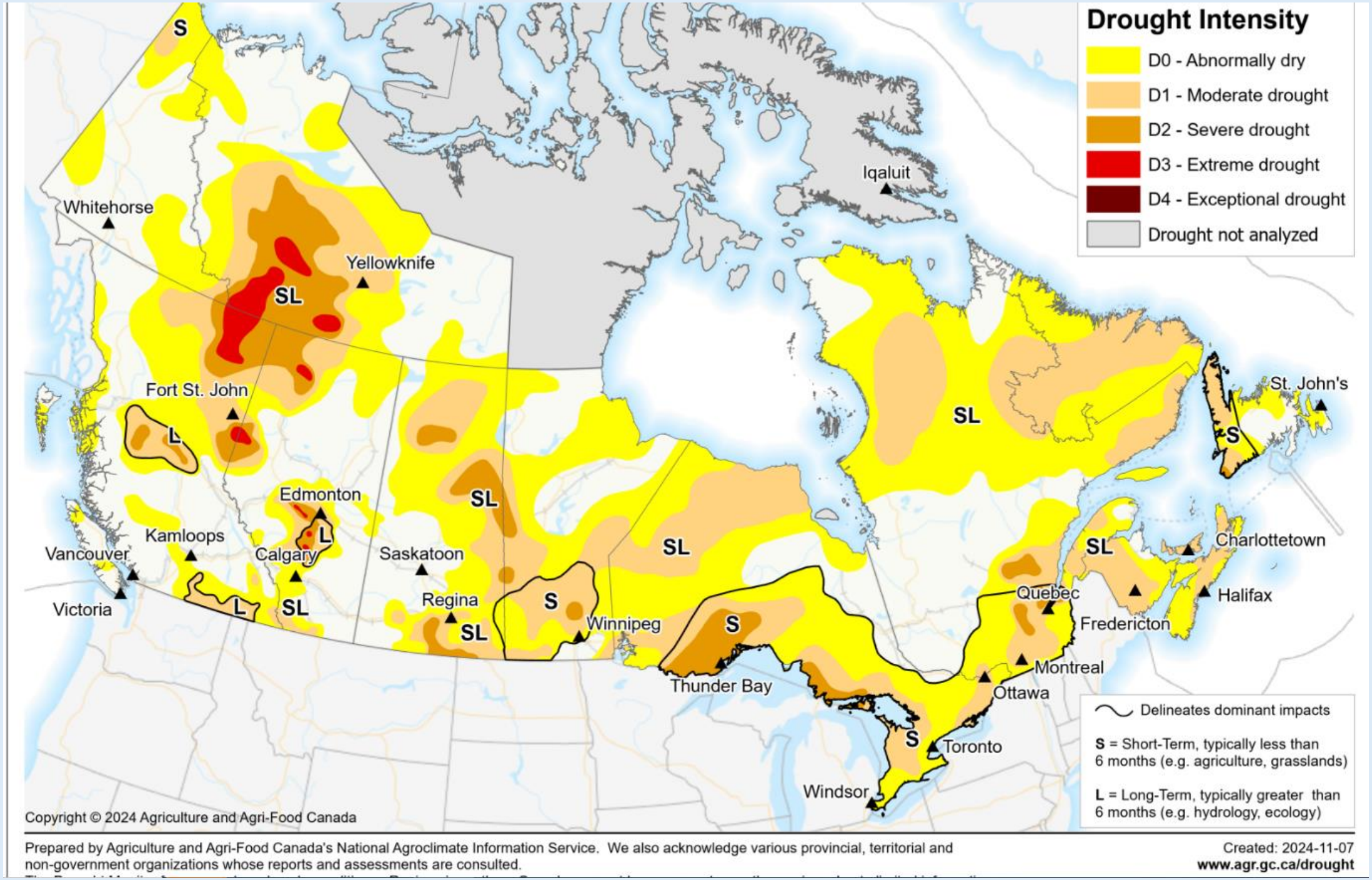
What is ecological drought?

Why is drought a concern with climate change for B.C.

Why have we had droughts in recent years?

What can we learn from relating climate conditions to forest drought impacts?

For including climate change thinking into forest practices



Prepared by Agriculture and Agri-Food Canada's National Agroclimate Information Service. We also acknowledge various provincial, territorial and non-government organizations whose reports and assessments are consulted.

Created: 2024-11-07
www.agr.gc.ca/drought

What is ecological drought?

What is drought?

= Water deficit as related to average conditions

- It is not just absence of precipitation
- It is not just this image
- It is not just below average precipitation
- It is relative to space and time
  - e.g. drought on Vancouver Island is not the same as drought in a Mexican desert
  - requires an understanding of historical conditions
  - can be expressed in various time scales

Types of Drought*

METEOROLOGICAL

Dry weather pattern dominates an area

HYDROLOGICAL

Low water supply following drought

ECOLOGICAL

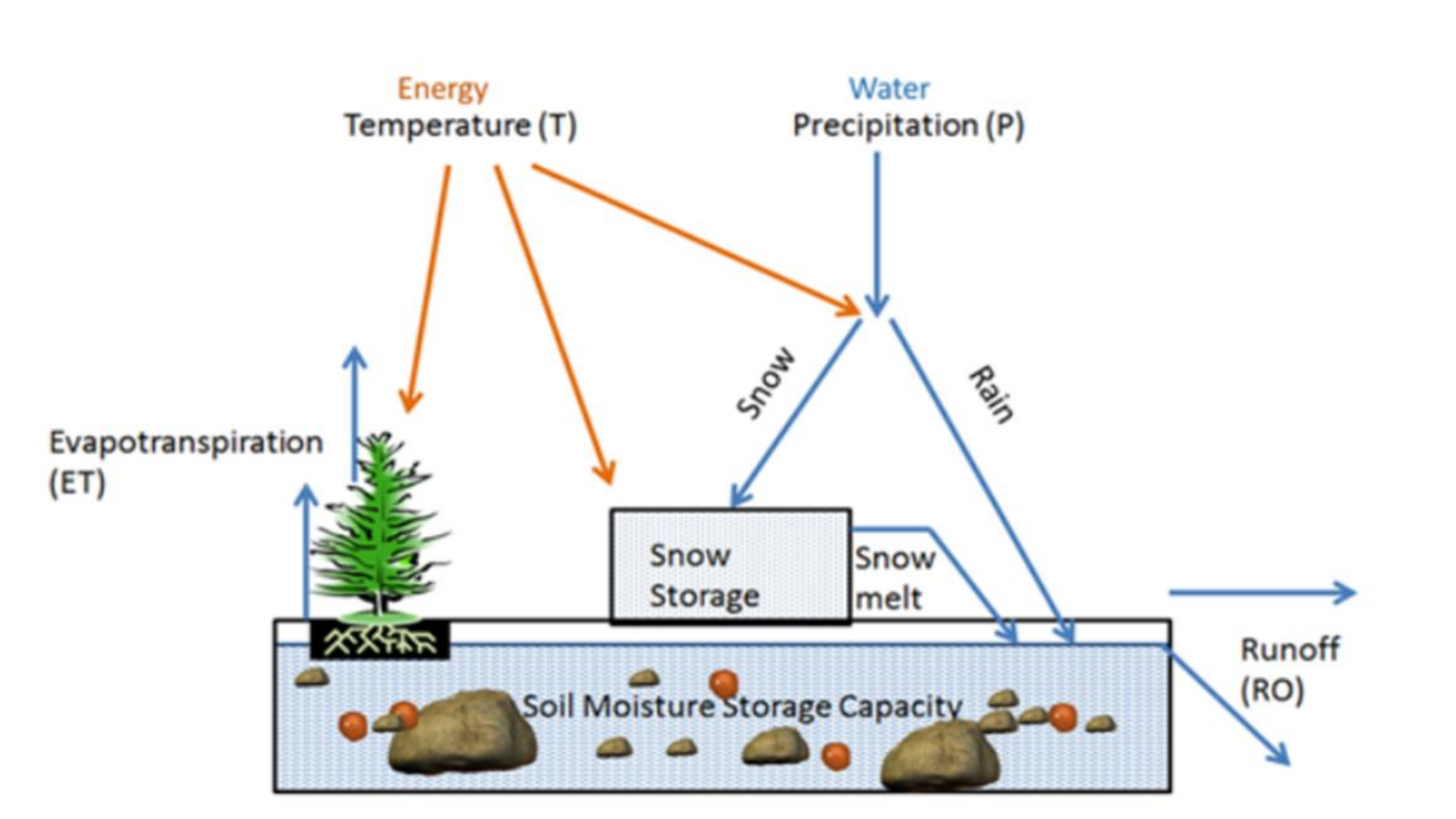
Vegetation impacted by drought

ECONOMIC

Supply/Demand of commodities to drought

*Definitions of drought courtesy of the National Oceanic and Atmospheric Administration

But it rains and snows a lot in B.C., why do we need to worry about drought?



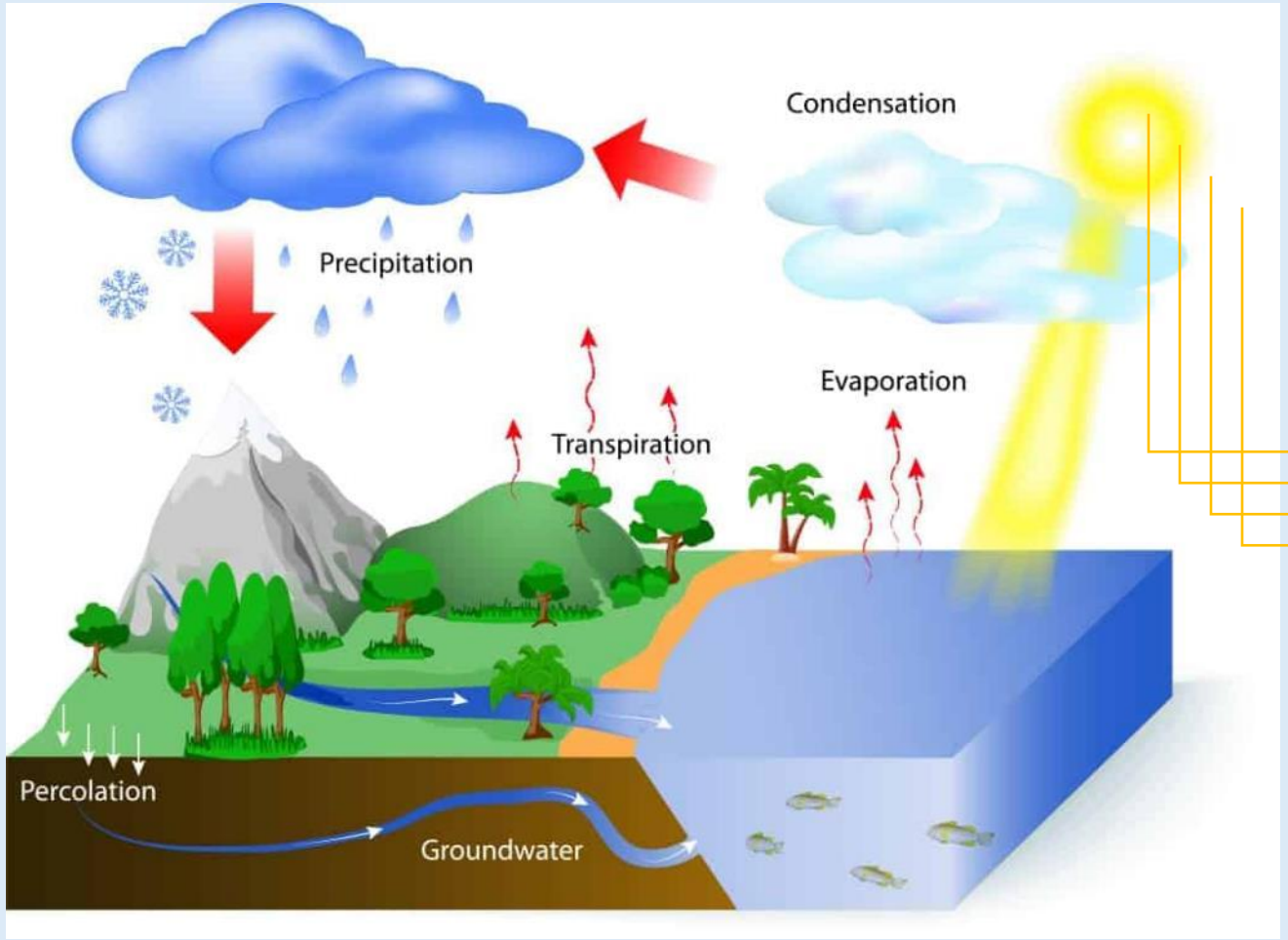
Water balance concept doesn't depend solely on precipitation

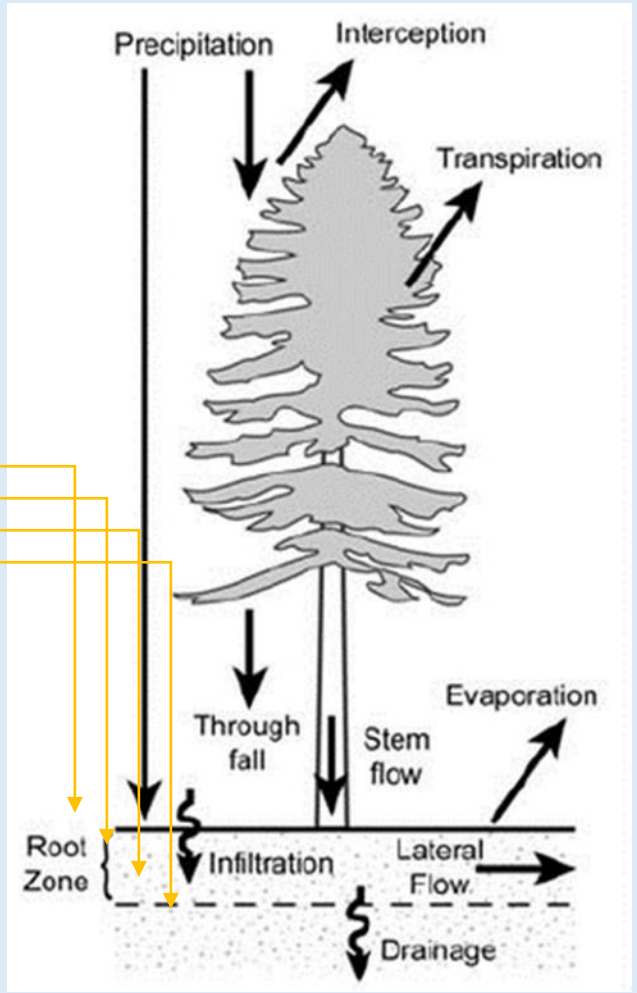
Being off balance can lead to stressed systems

https://www.nps.gov/subjects/climatechange/waterbalance.htm

Ecological Drought

- requires an understanding of evapotranspiration
- can occur in the absence of hydrological drought



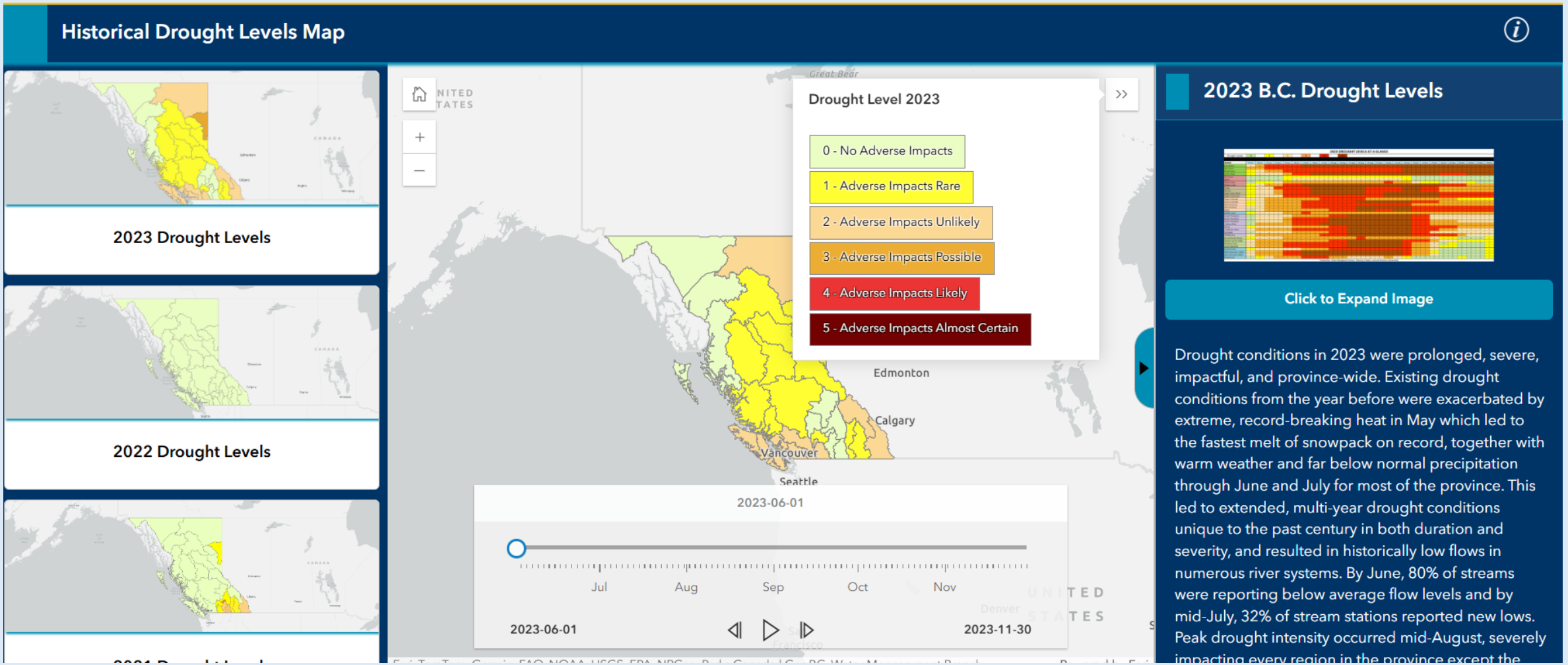


https://fruitgrowers.com/why-understanding-evapotranspiration-is-crucial-to-growers/

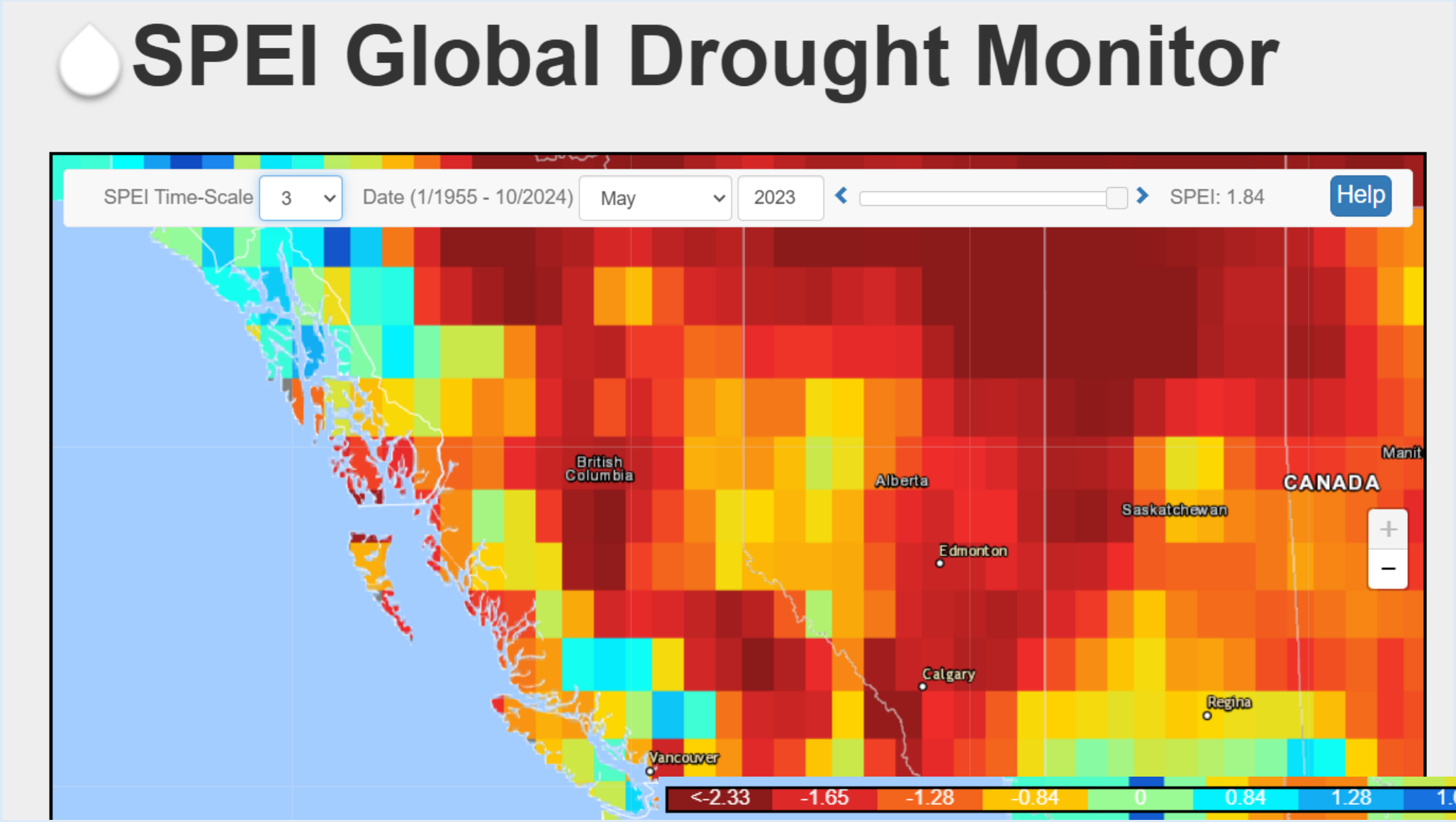
B.C. Drought Portal

- Is hydrological drought only
- Not available during winter months

https://droughtportal.gov.bc.ca/pages/drought-map



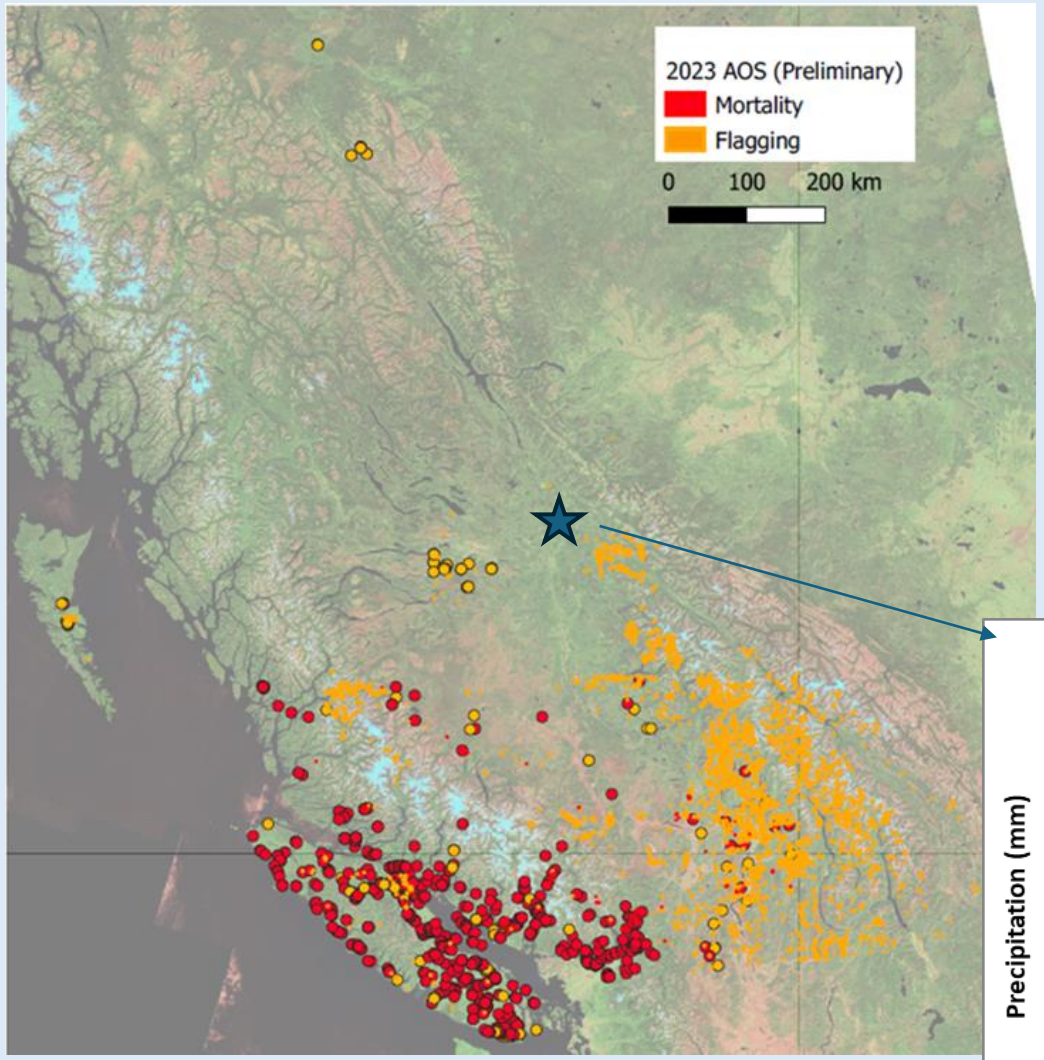
Standardized Precipitation and Evapotranspiration Index*



*Vincente-Serrano et al. 2010, *J. of Climate*

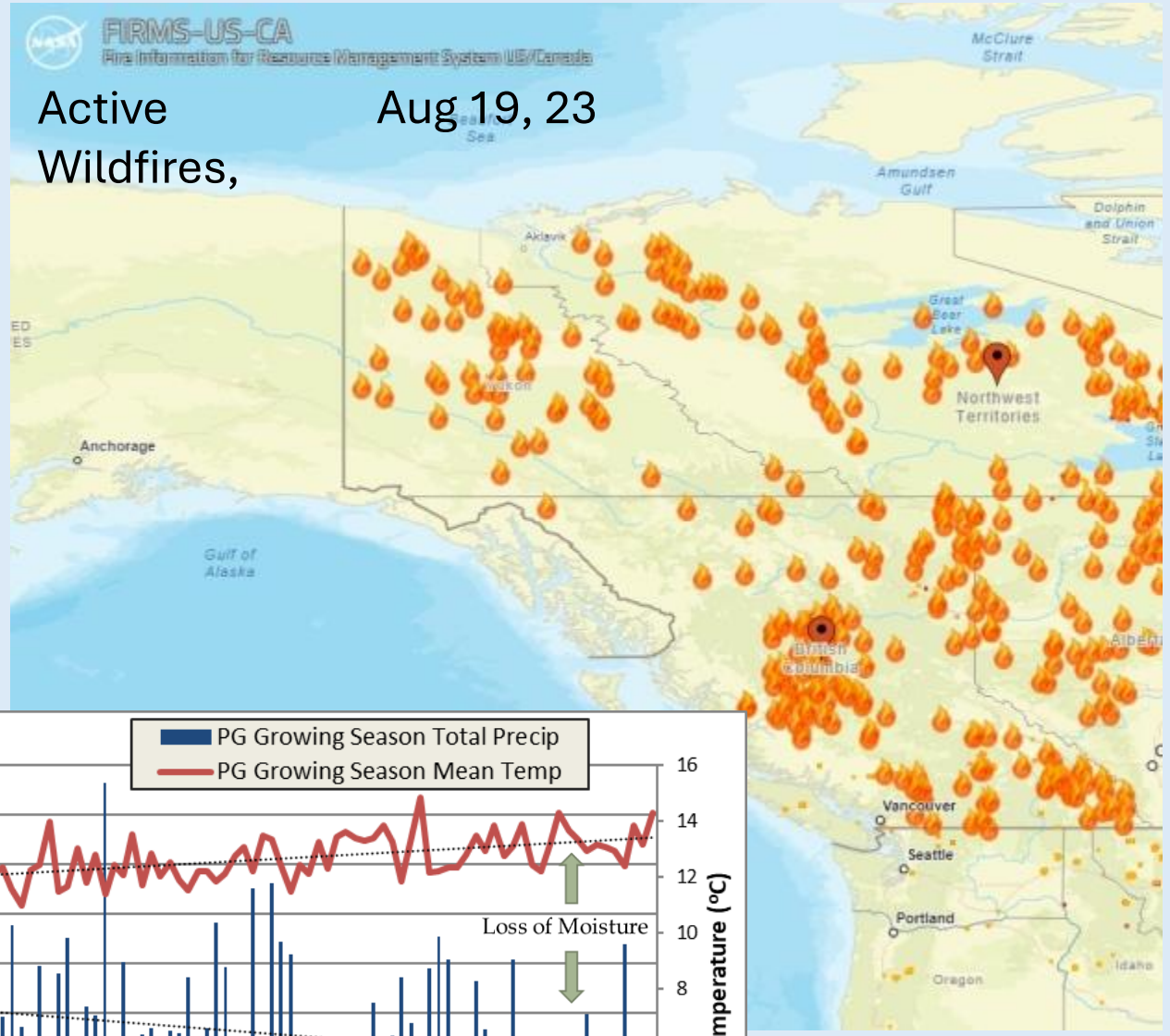
https://spei.csic.es/map/maps.html#months=1#month=4#year=2023

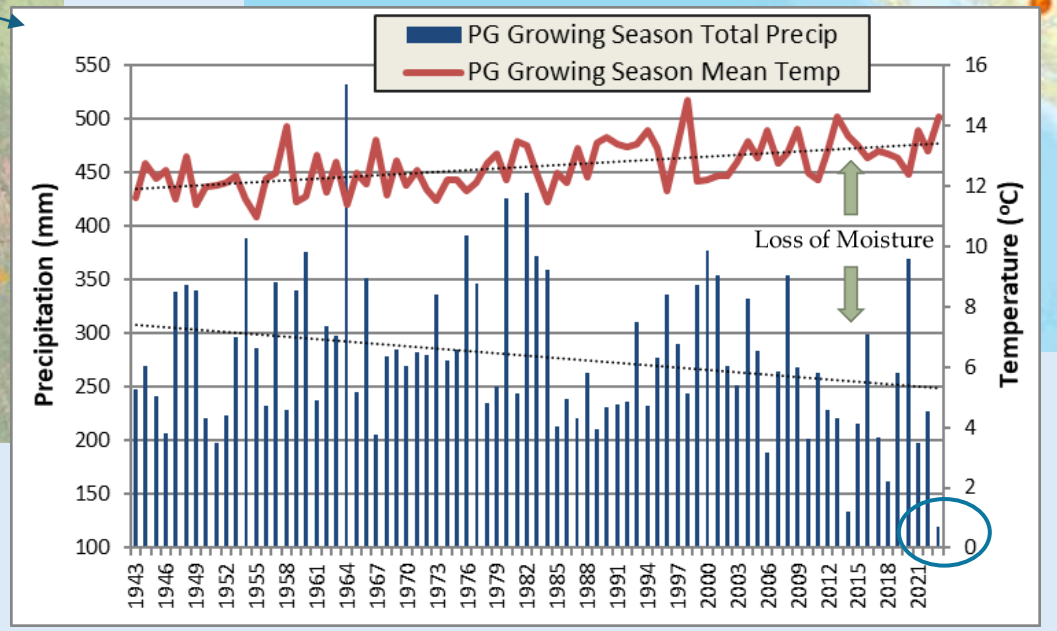
2023 Ecological Drought



2023 Aerial Overview Survey preliminary drought data (more in north but smoke?)

Map created by: Alex Bevington

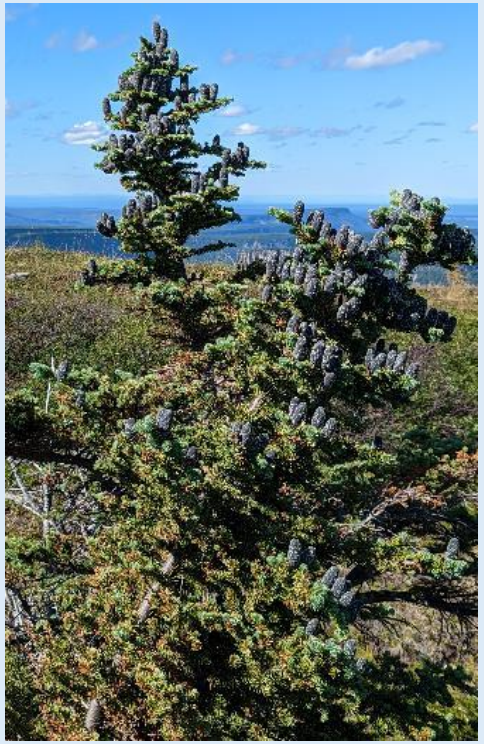




2023 driest May to Sep on record in Prince George

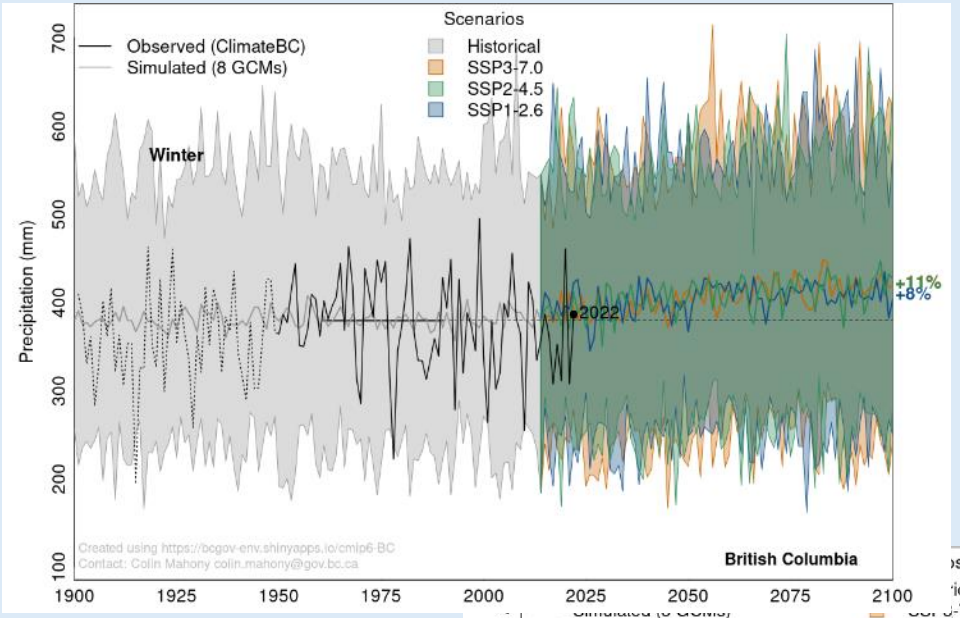
Forest Drought Impacts

- Tree mortality, dead branches, needles
- Plantation failures (seedling damage or mortality)
- Mast years – conifer cones
- Dry soils
- Build-up of dry fuels
- Reduced photosynthesis, CO_2 uptake
- Drought stressed trees: secondary disturbances
  - Wildfire
  - Insects
  - Windthrow

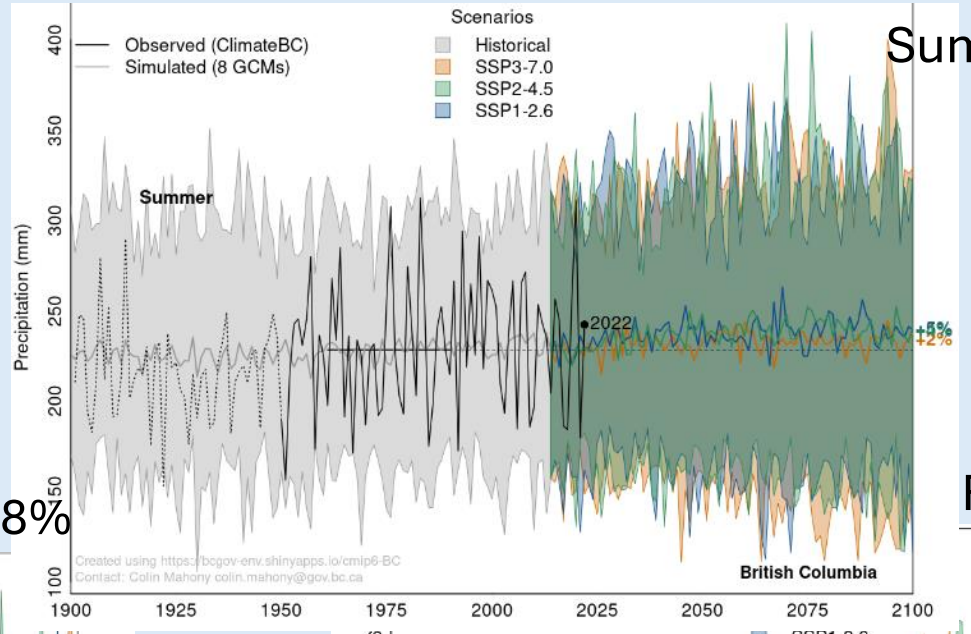


Climate Change and Drought

Isn’t precipitation supposed to increase with climate change? Why are we worried about drought?

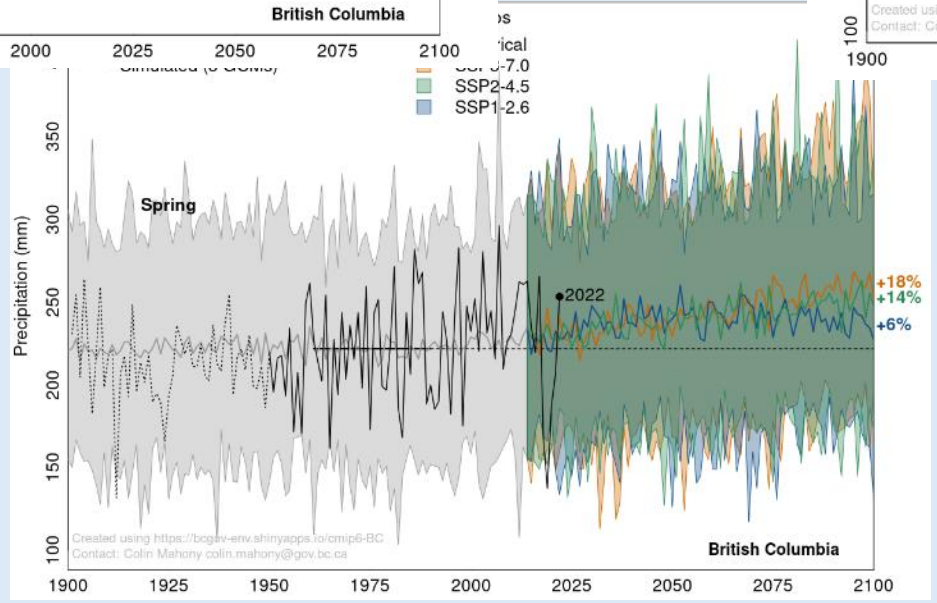


Winter = 8-11%

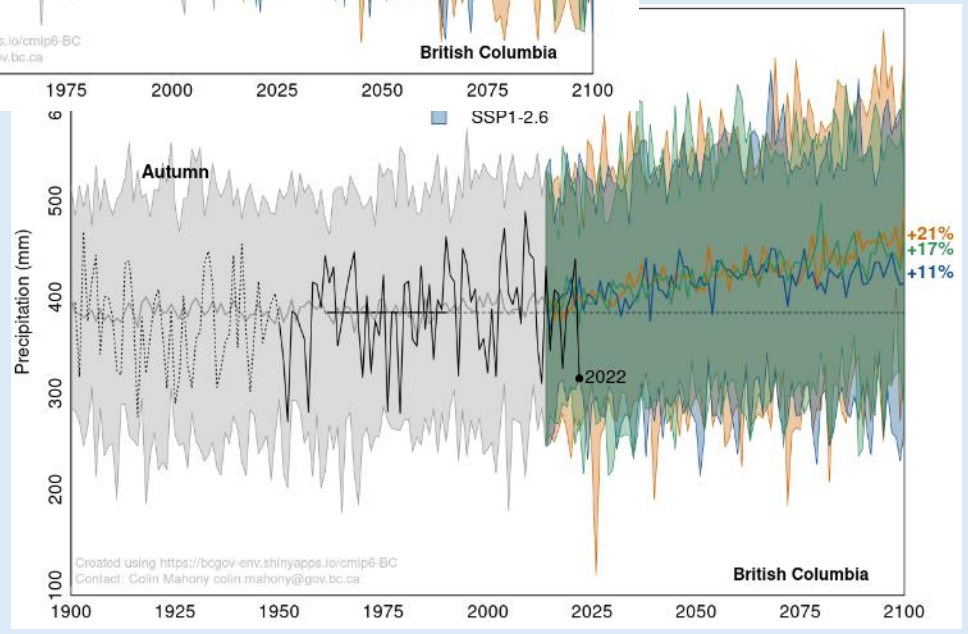


Summer = 2-5%

Spring = 6-18%



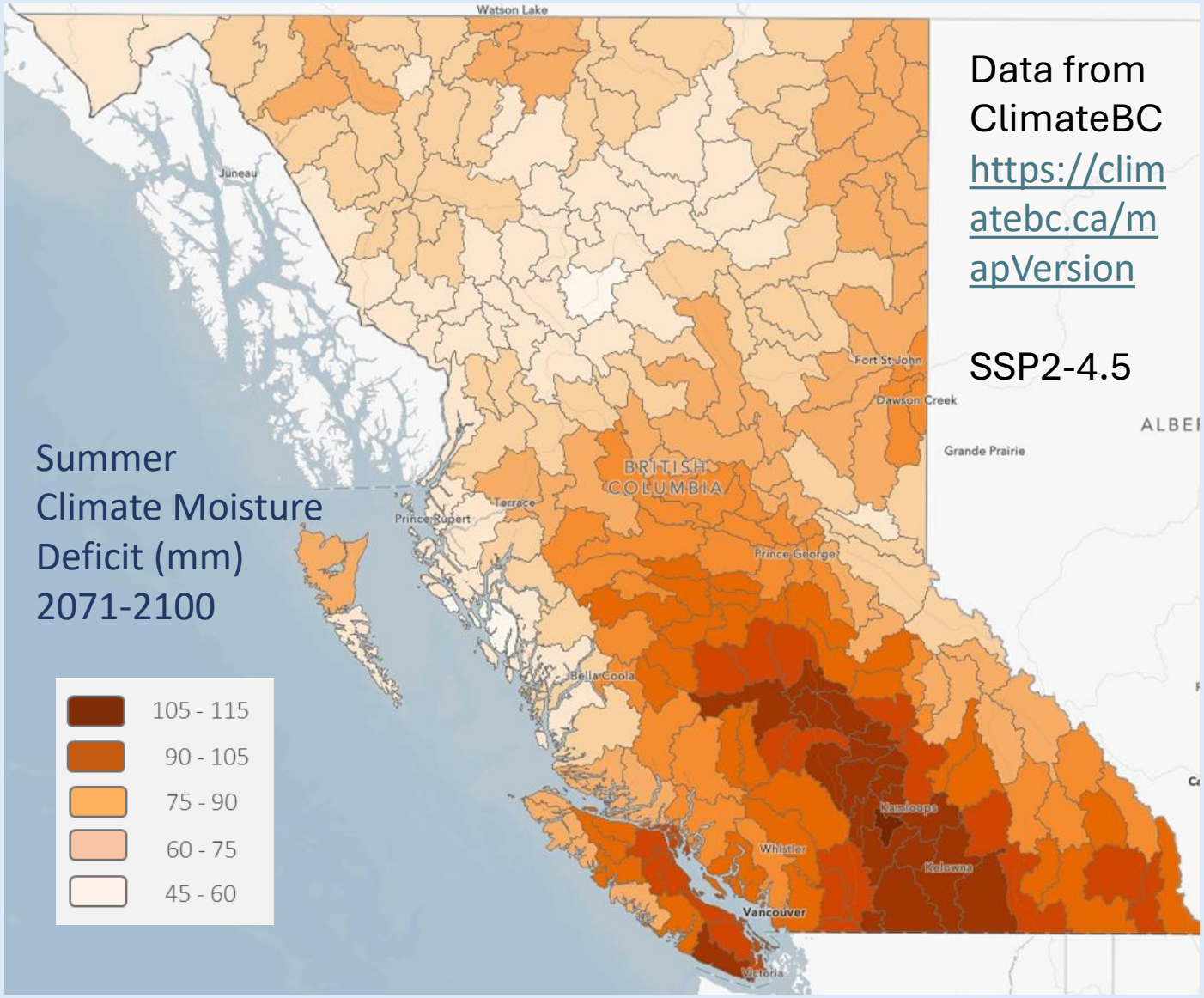
Fall = 11-21%



https://bcgov-env.shinyapps.io/cmip6-BC/

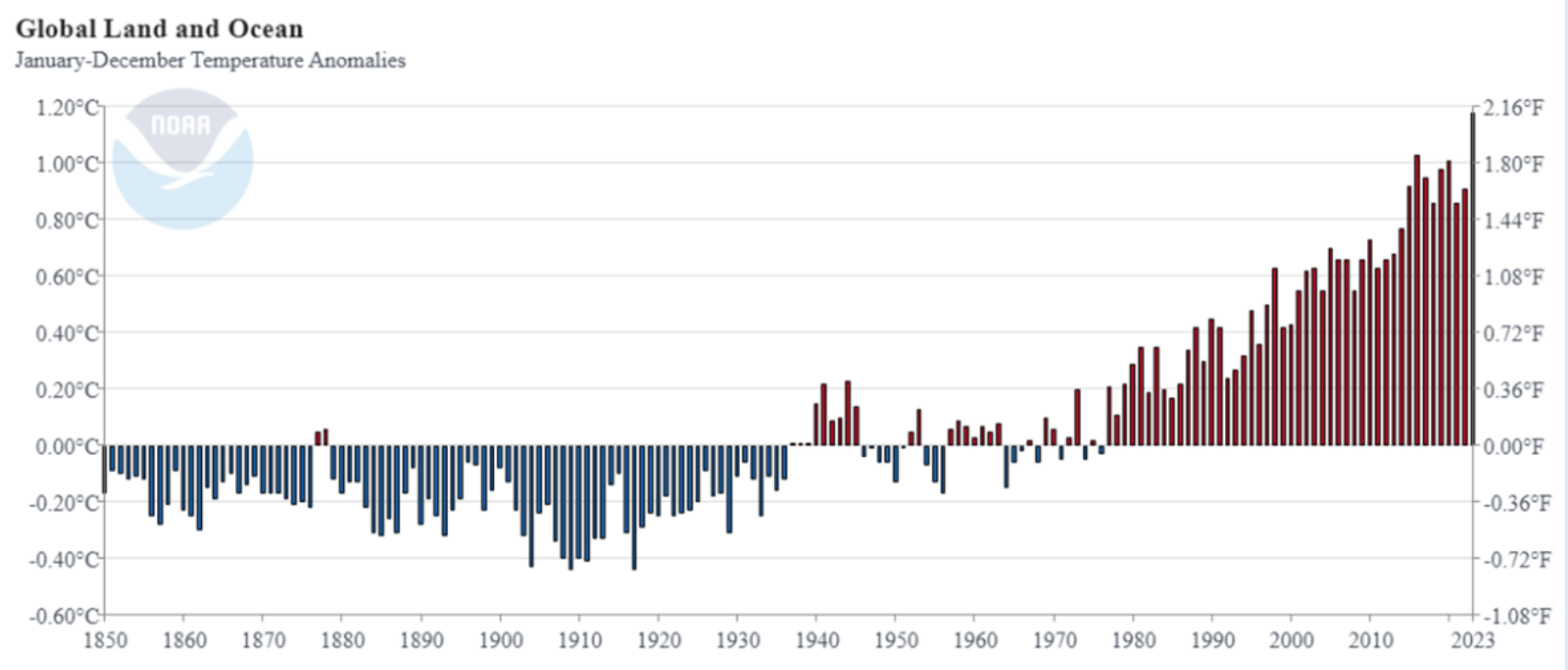
Future Climate Moisture Deficit

- Drought isn't just precipitation
- Increasing temperature will:
  - Decrease snowpacks and water storage
  - Decrease snow cover and snow season length will decrease cooling effect of snow and ice cover and further increase temperatures
  - Increase evaporation and evapotranspiration to a point, once vegetation and soils are dry this will stop, and the atmosphere will also become dry and decrease the likelihood of rainfall in a positive feedback of negative consequences



Map created by Jordan Foy, Ministry of Forests

Global Temperature Change:



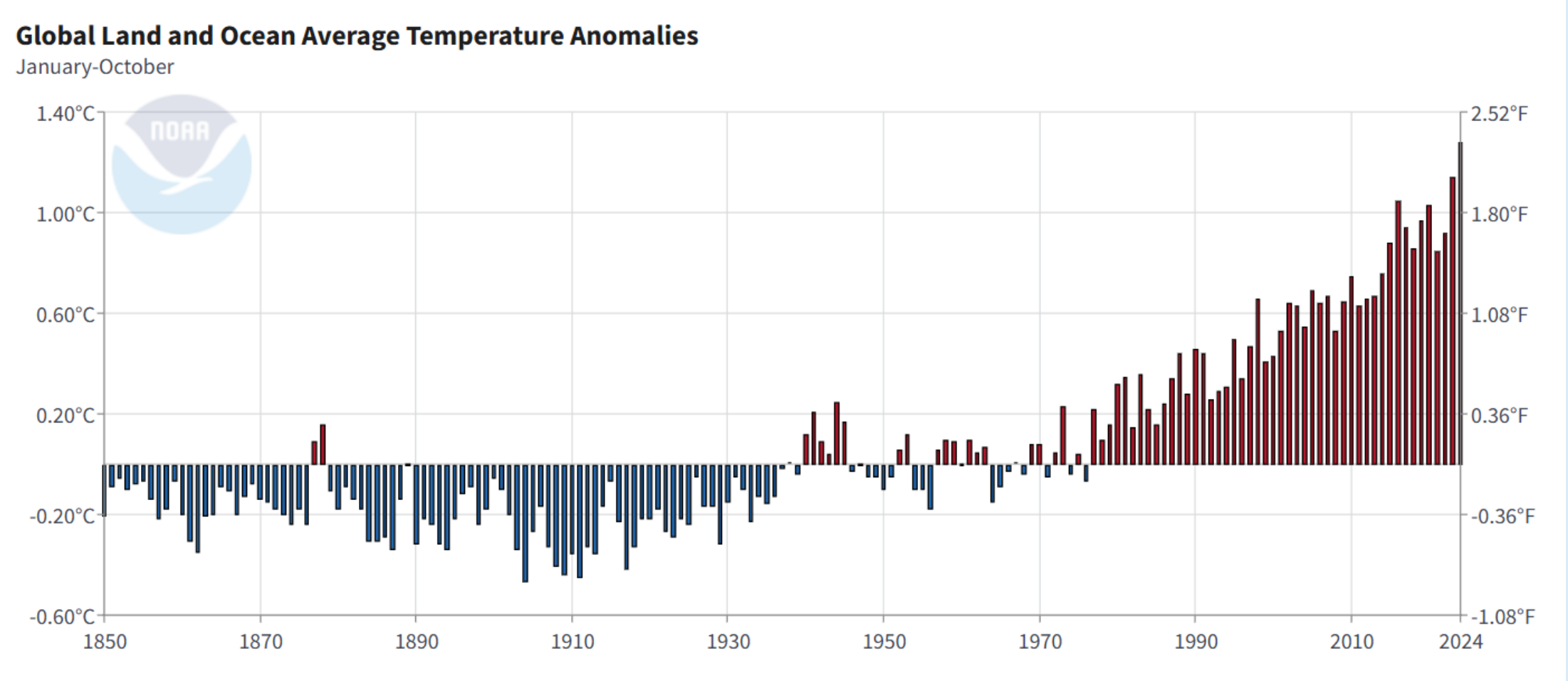
Top Ten Hottest Years:

1. 2023
2. 2016
3. 2020
4. 2019
5. 2017
6. 2015
7. 2022
8. 2021
9. 2018
10. 2014

https://www.ncei.noaa.gov/access/monitoring/monthly-report/global/202313

- October 2024 was the 548th consecutive month with temperatures above the 20th century average

2024 Temperatures to Date:

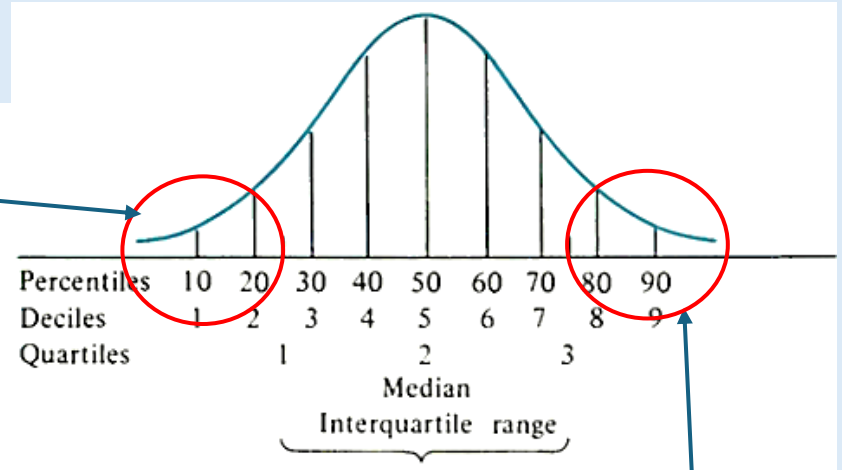


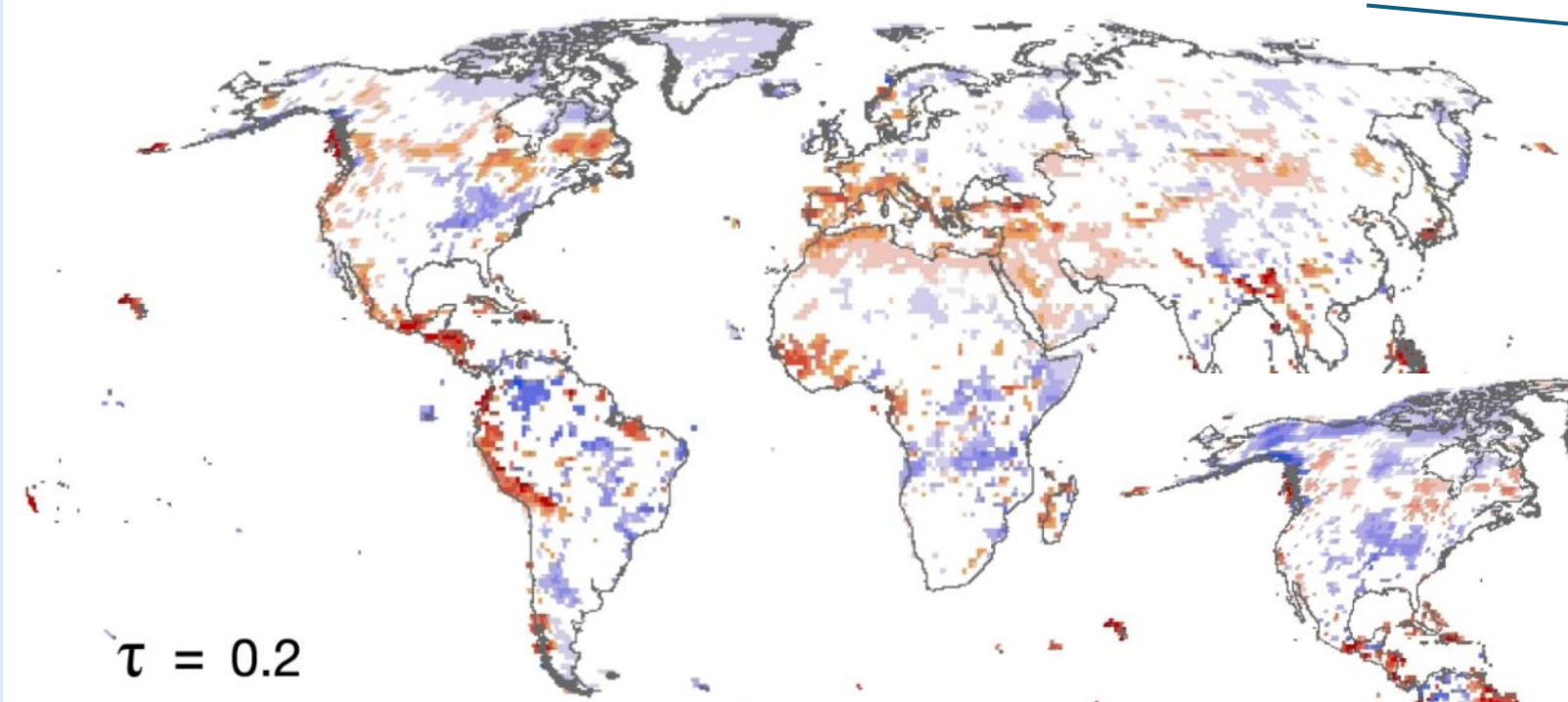
https://www.ncei.noaa.gov/access/monitoring/monthly-report/global/202410

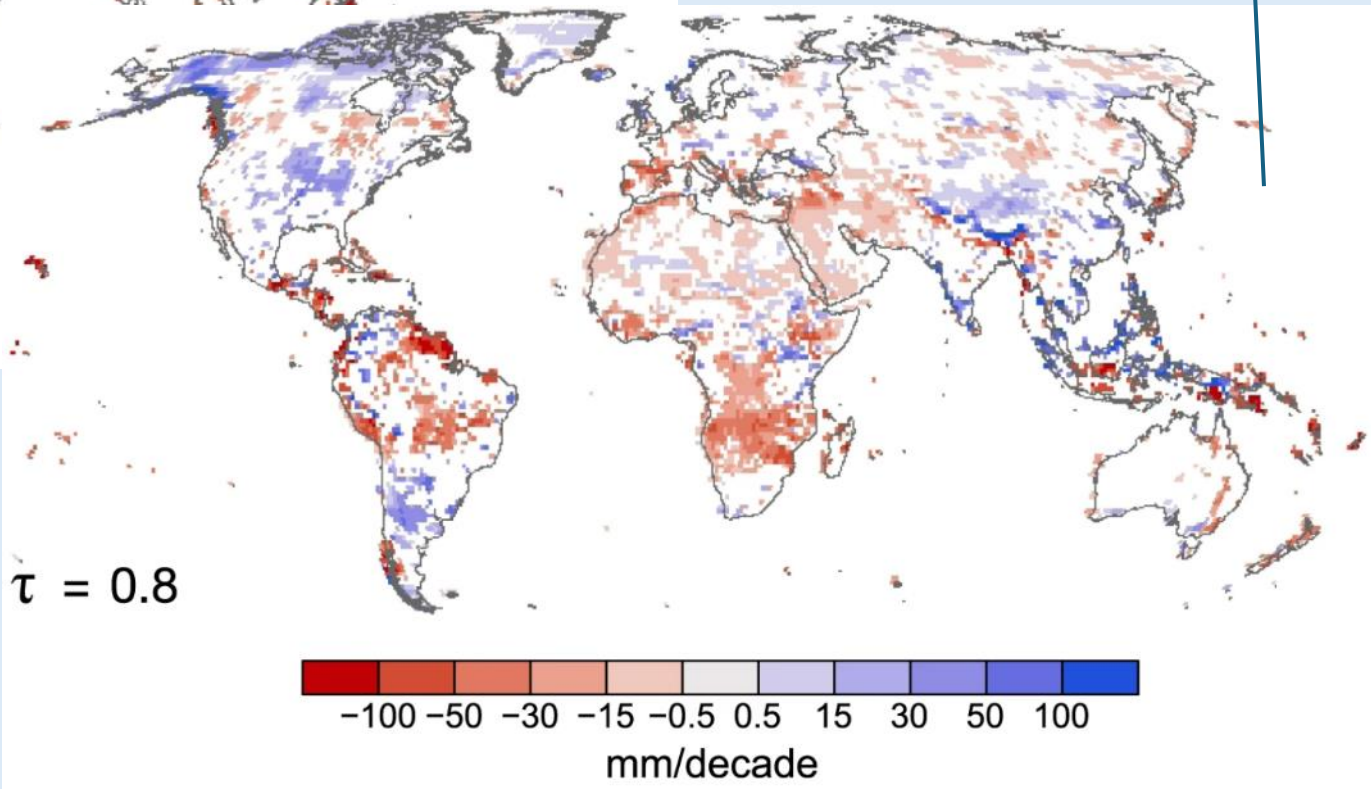
- May 2023 to Aug 2024 was a 15th month streak of record-breaking global temperatures

Global Precipitation Trends:

From: Overlooked Trends in Observed Global Annual Precipitation Reveal Underestimated Risks





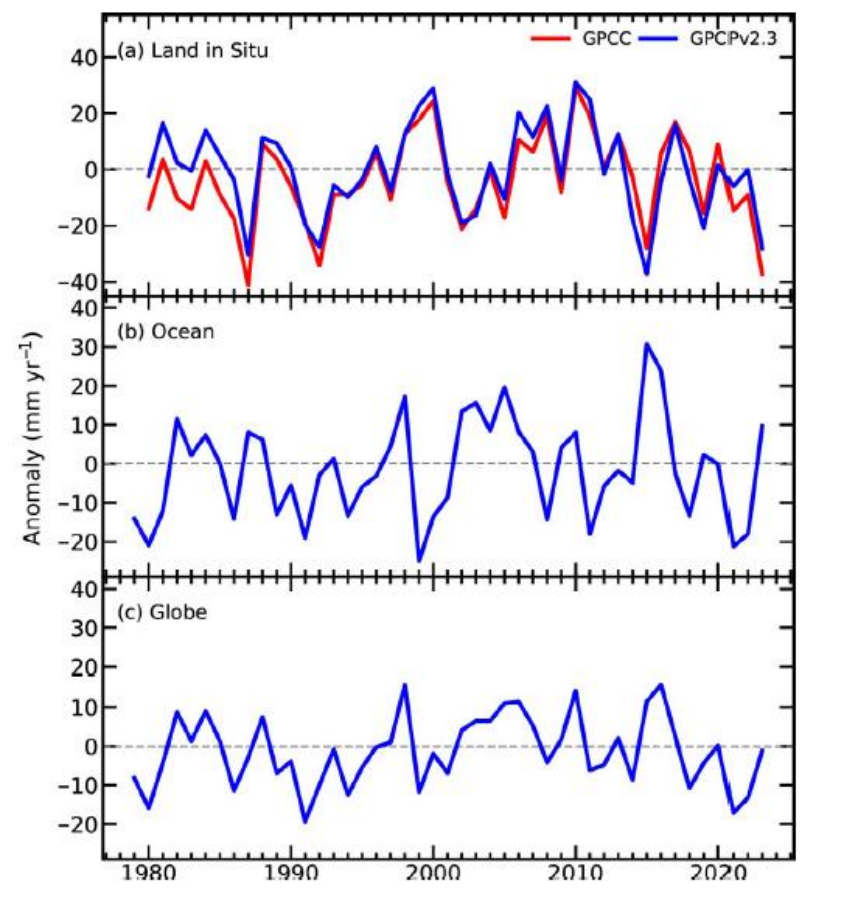


1950-2017:

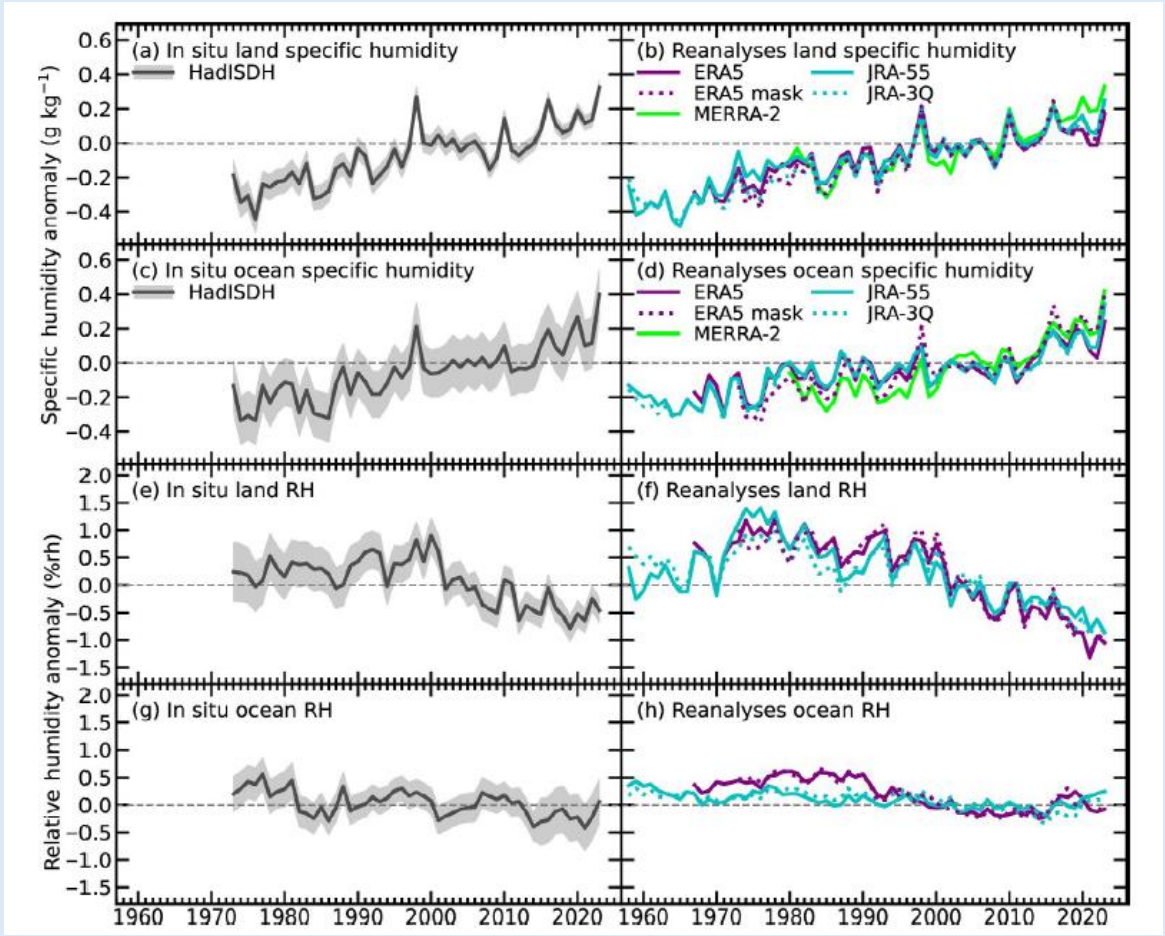
https://www.nature.com/articles/s41598-018-34993-5

Global Hydrological Cycle:

State of the Climate 2023
https://www.ametsoc.org/index.cfm/ams/publications/bulletin-of-the-american-meteorological-society-bams/state-of-the-climate/



Global precipitation 1980-2023



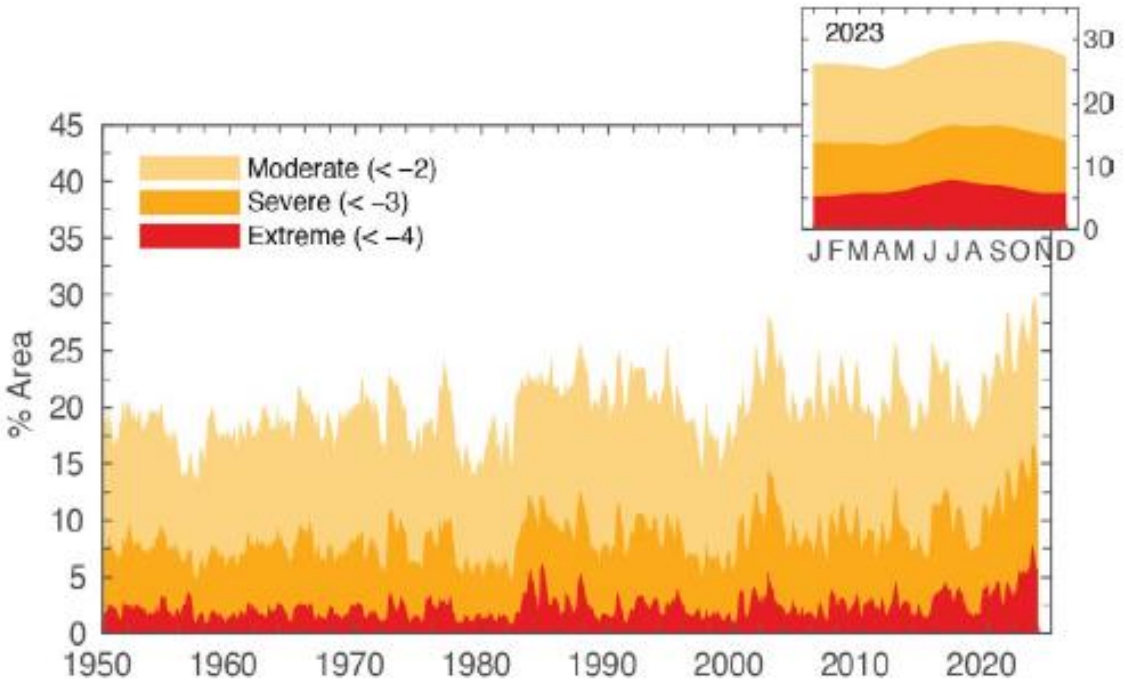
Global specific and relative humidity

Clausius-Clapeyron relation: water vapour increases ~7% for every 1°C of temperature increase

Global Evaporation and Drought

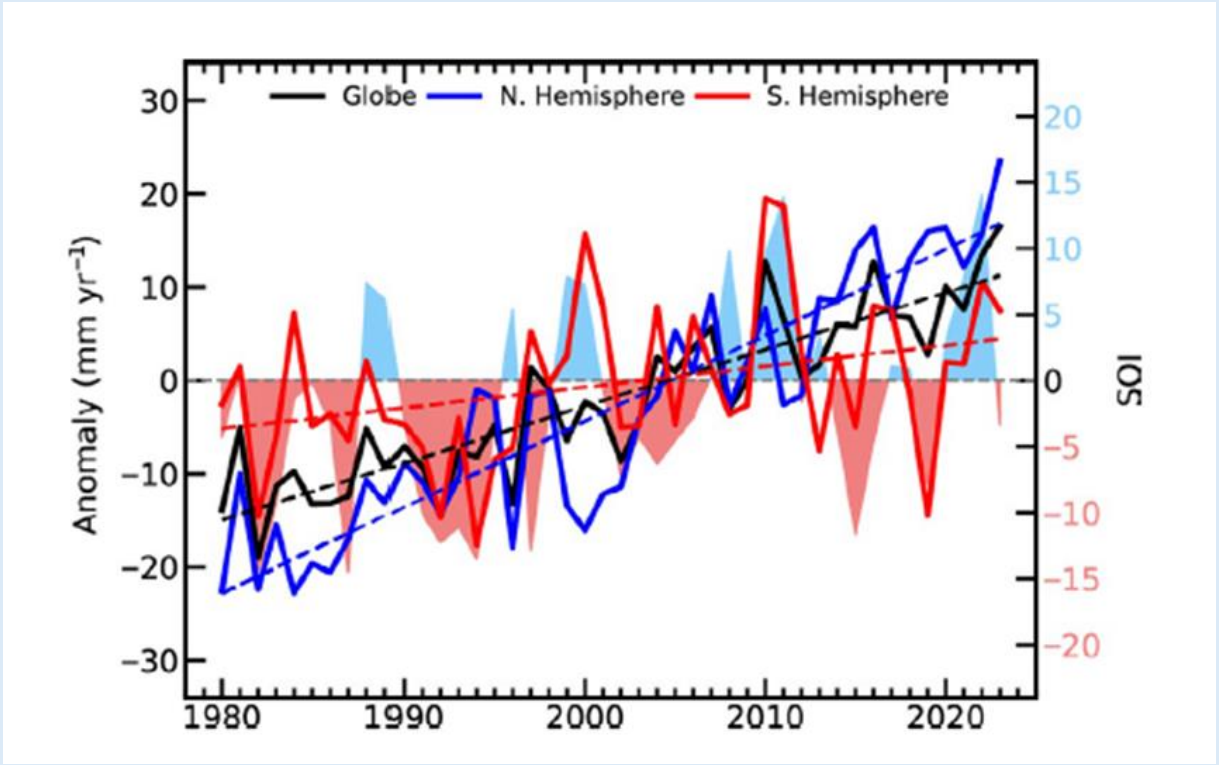
State of the Climate 2023

https://www.ametsoc.org/index.cfm/ams/publications/bulletin-of-the-american-meteorological-society-bams/state-of-the-climate/



Percentage of global land with Palmer Drought Severity Index moderate or higher

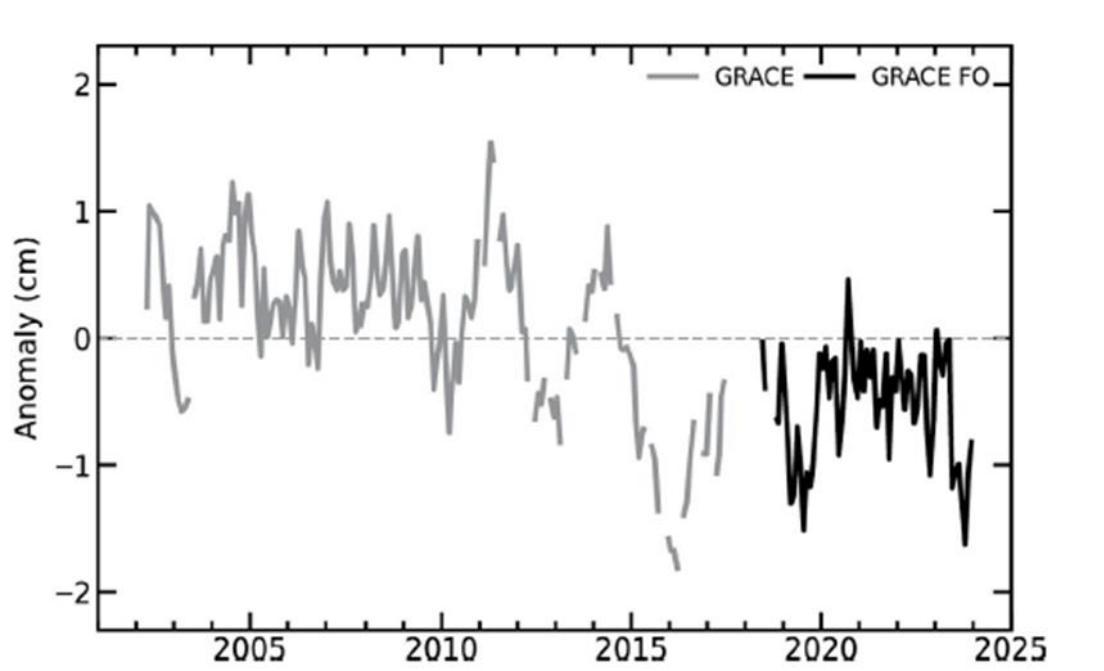
2023 Highest on Record for moderate and severe



Land evaporation anomaly, mm/yr.

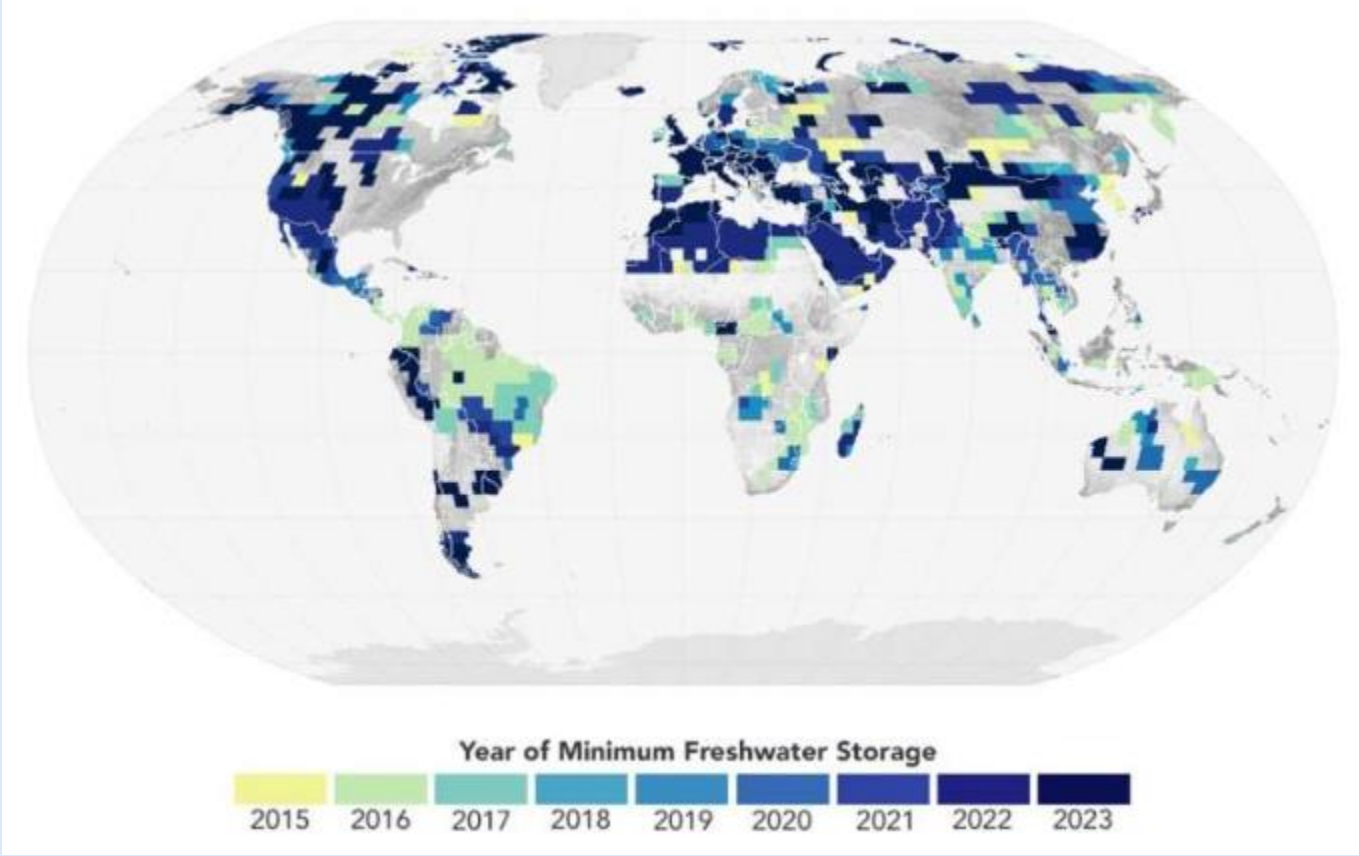
2023 Highest on Record, globally and for the Northern Hemisphere

Terrestrial water storage



Global average terrestrial water storage from GRACE: Gravity Recovery and Climate Experiment satellite

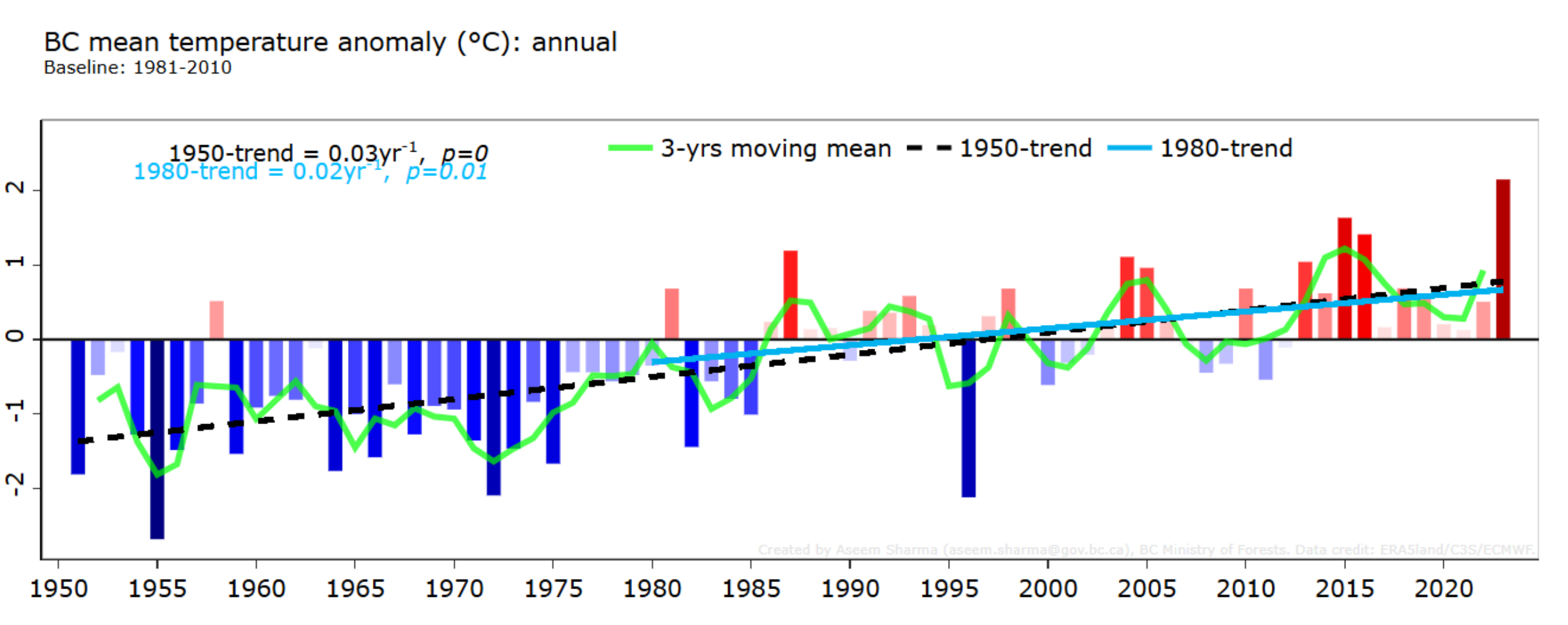
State of the Climate 2023
https://www.ametsoc.org/index.cfm/ams/publications/bulletin-of-the-american-meteorological-society-bams/state-of-the-climate/



Rodell et al. 2024

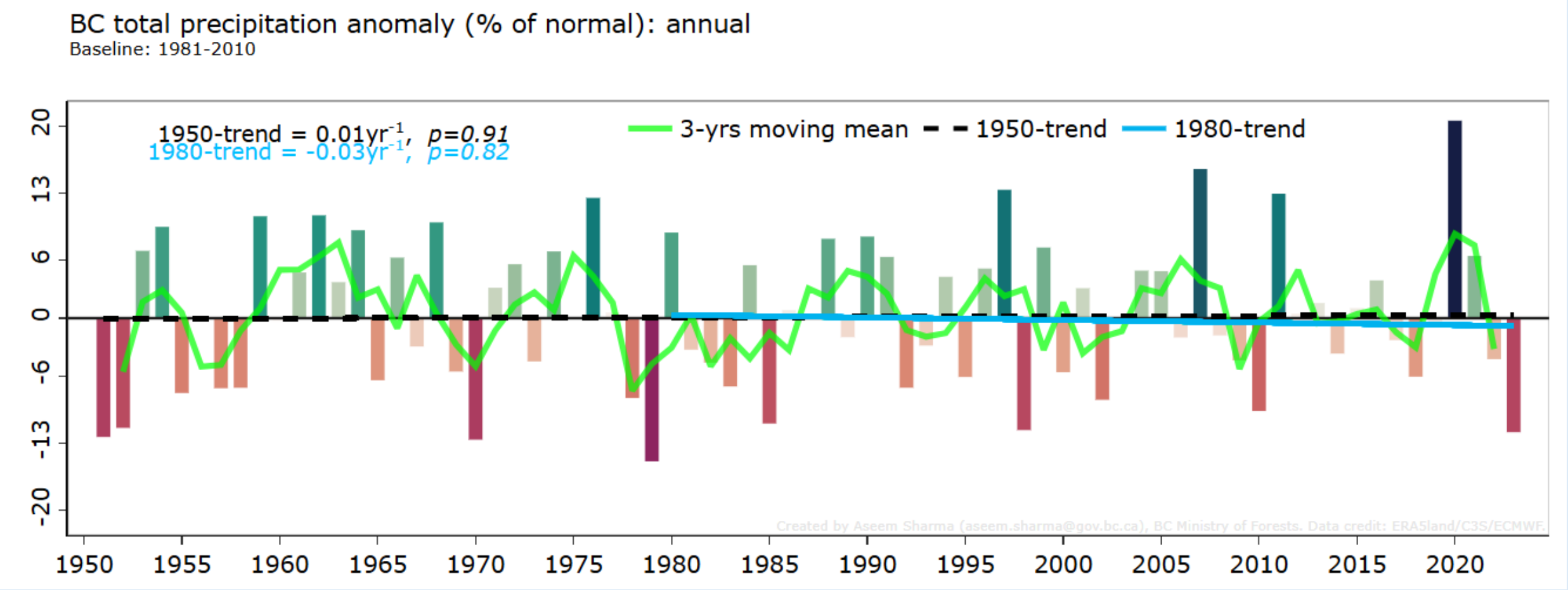
https://link.springer.com/article/10.1007/s10712-024-09860-w

B.C. Temperature Trends



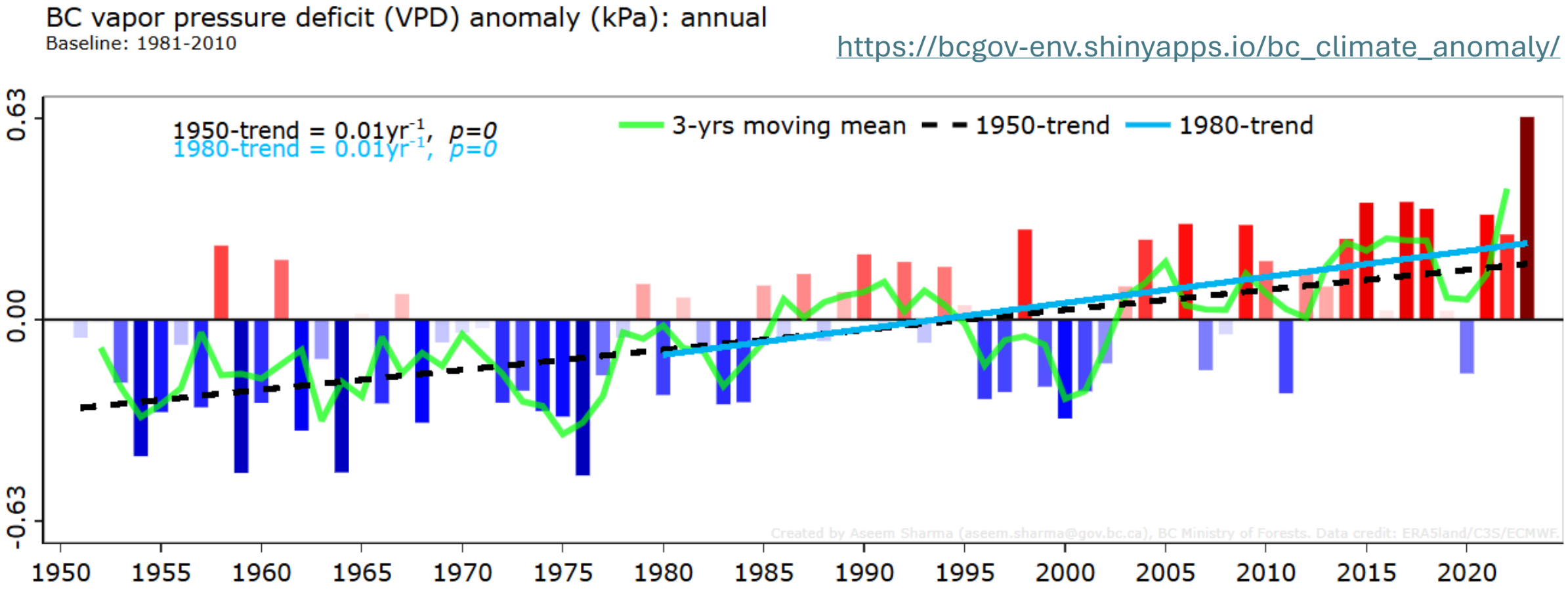
https://bcgov-env.shinyapps.io/bc_climate_anomaly/

B.C. Precipitation Trends



https://bcgov-env.shinyapps.io/bc_climate_anomaly/

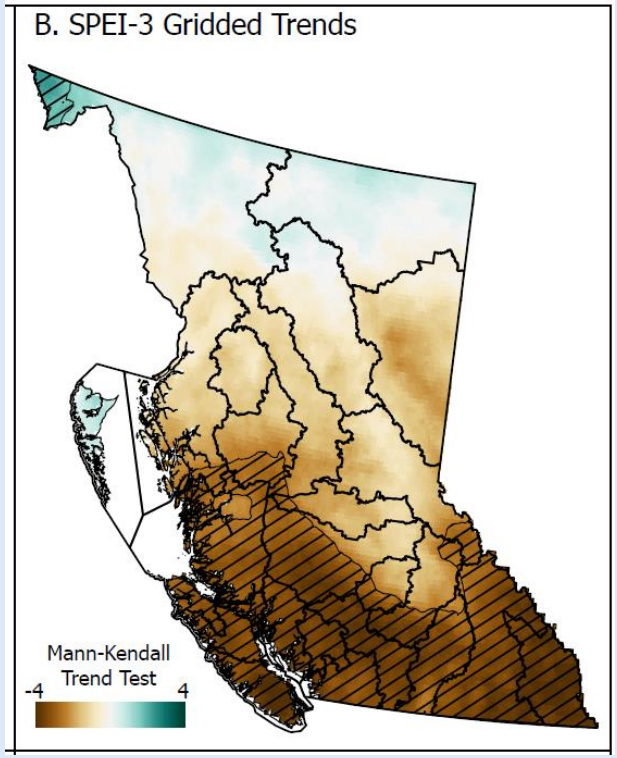
B.C. Vapour Pressure Deficit Trends



Vapour Pressure Deficit = Indicator of plant transpiration and water loss, i.e. Ecological Drought

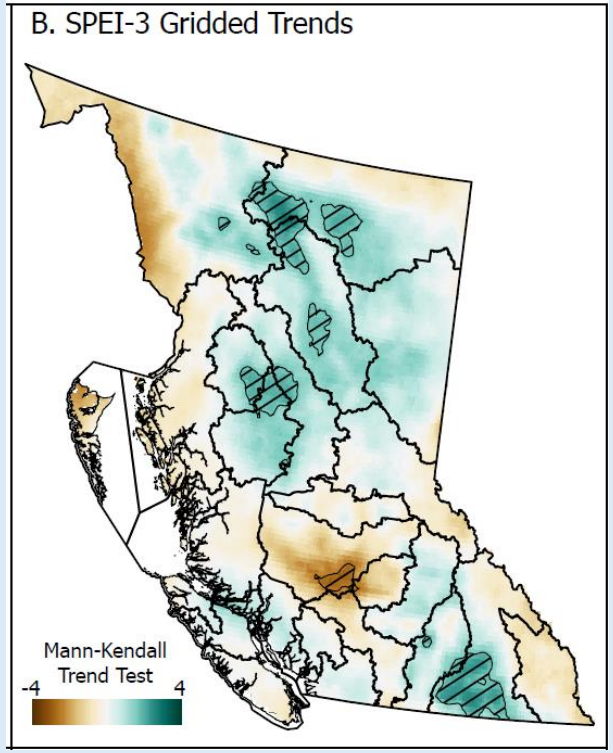
VPD = difference between the amount of moisture in the air and the amount the air could hold when saturated

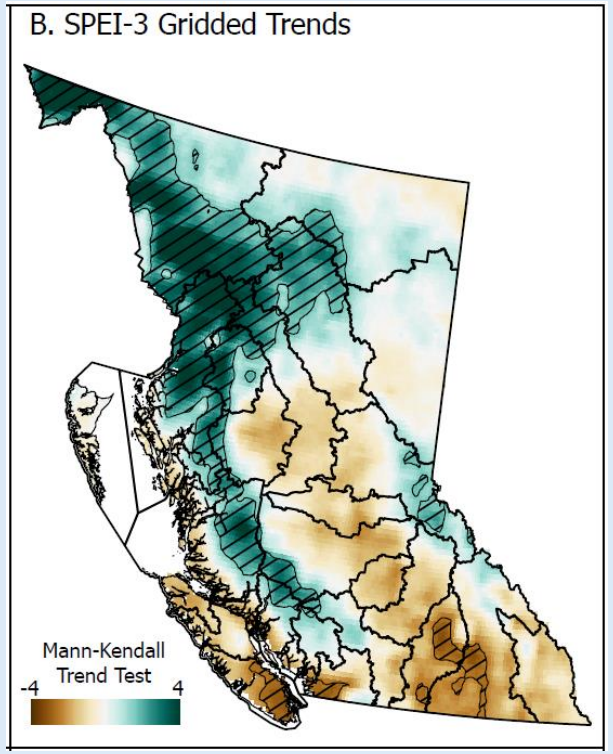
SPEI-3 month Seasonal Drought Trends (1950-2023)



Winter (Dec, Jan, Feb)

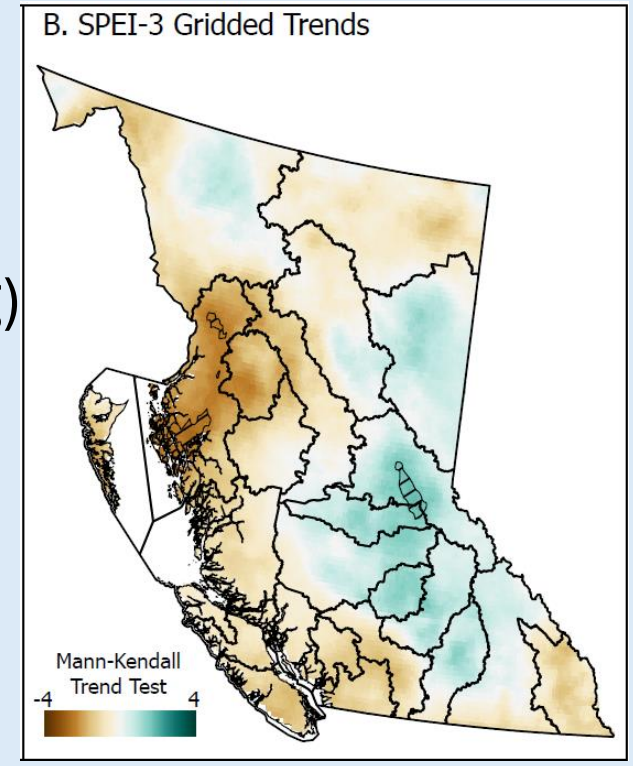
Spring (Mar, Apr, May)

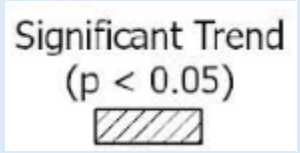




Summer (Jun, Jul, Aug)

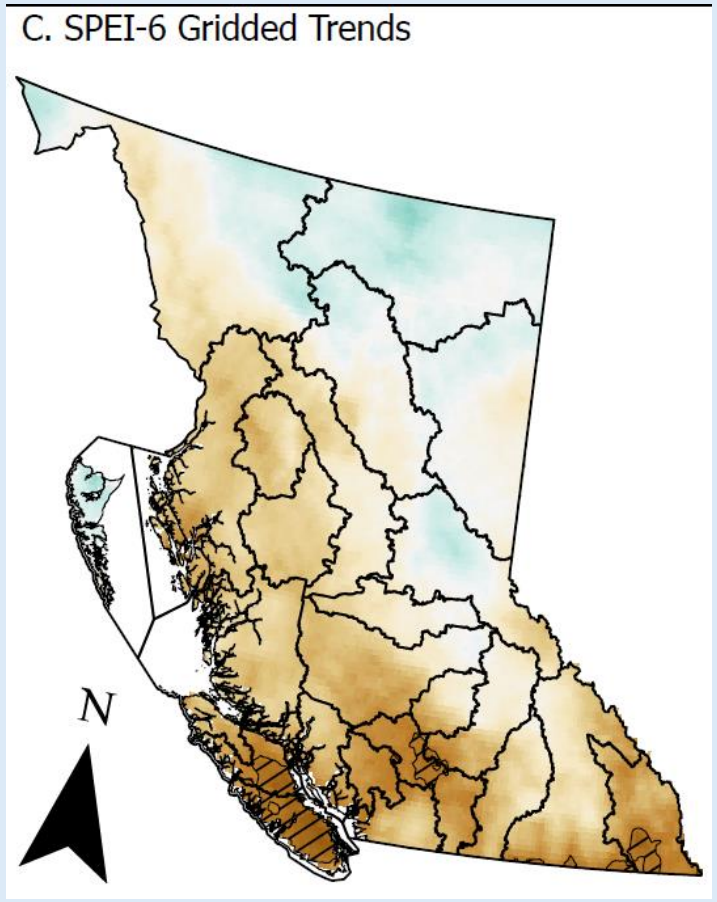
Fall (Sep, Oct, Nov):



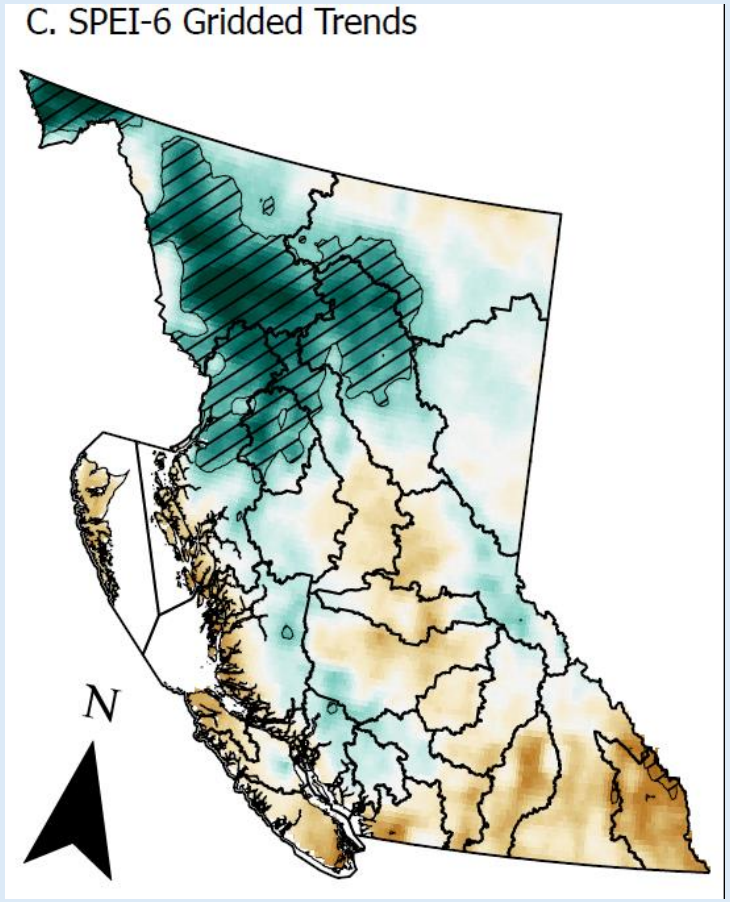


Mood et al. *in prep*

SPEI Drought Trends (1950-2023)

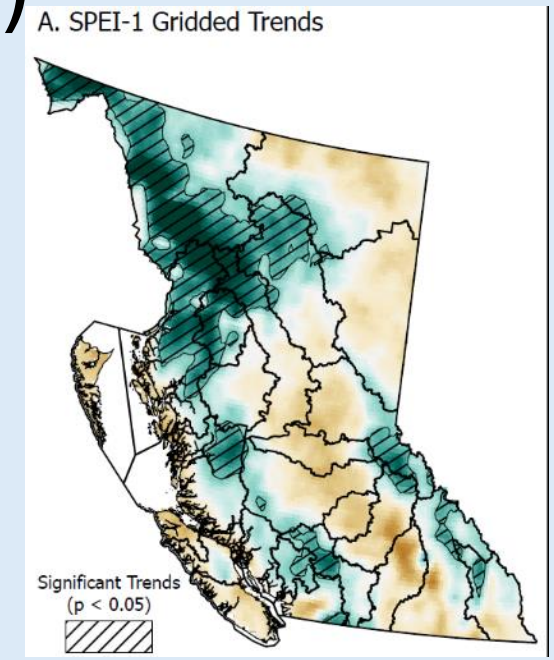


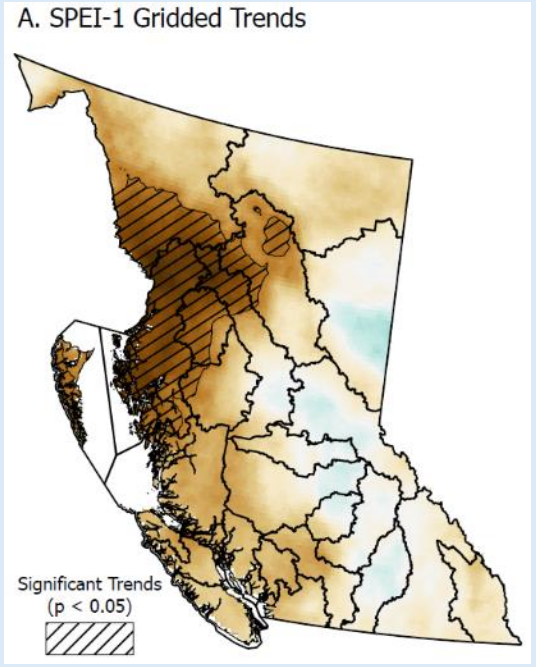
Mar SPEI-6 (Oct-Mar)
Cold Season



Sep SPEI-6 (Apr -Sep)
Growing Season

June
SPEI-1





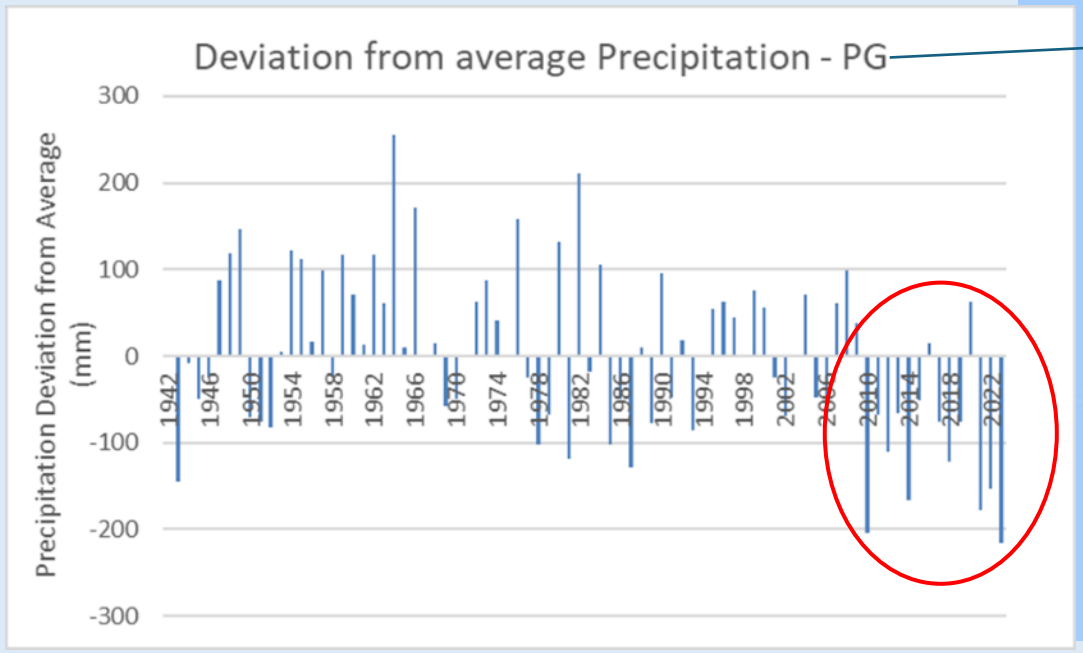
October
SPEI-1

Mood et al. *in prep*

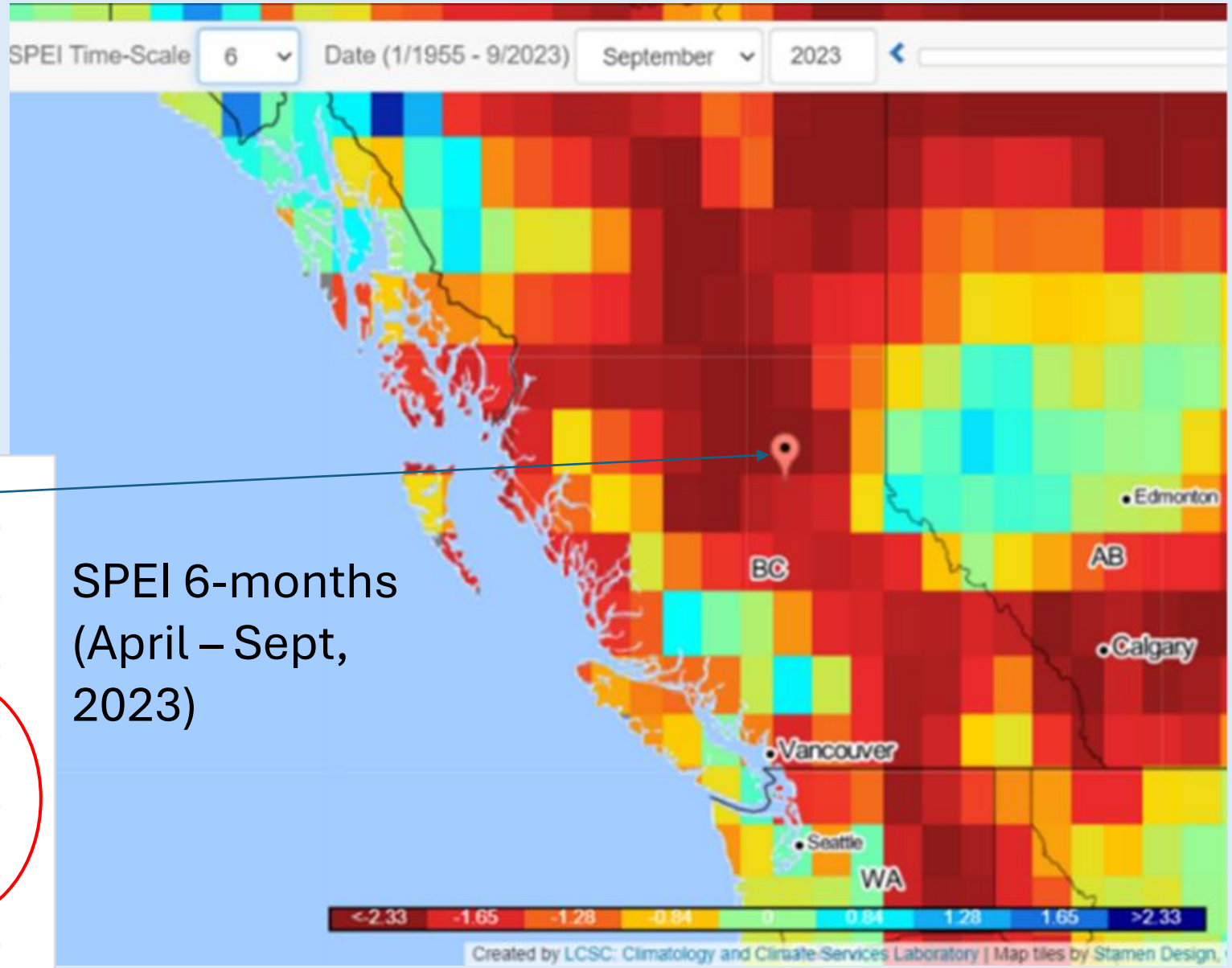
Why have we had droughts in recent years?

Standardized Precipitation Evapotranspiration Index* (SPEI)

Drought Categories:
< -1.0 Moderate Drought
< -1.5 Severe Drought
< -2.0 Extreme Drought



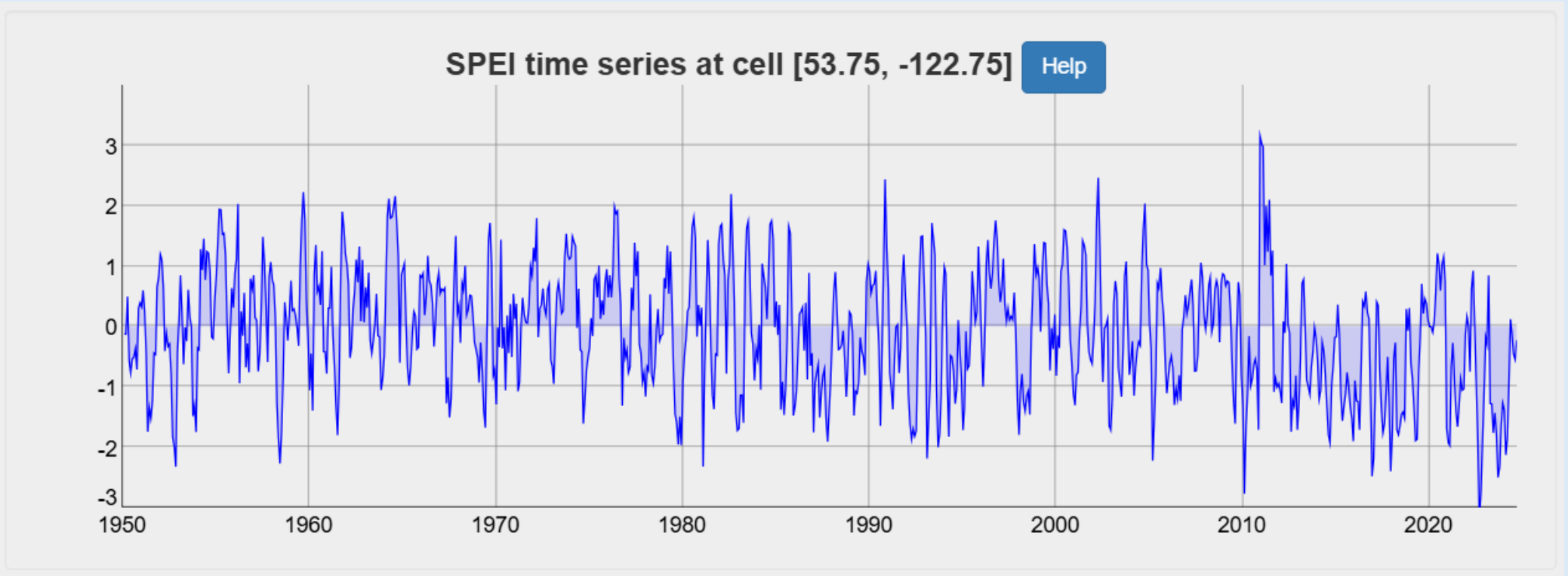
SPEI 6-months (April – Sept, 2023)



*Vincente-Serrano et al. 2010, *J. of Climate*

https://spei.csic.es/index.html

3-month SPEI – Central Interior B.C.



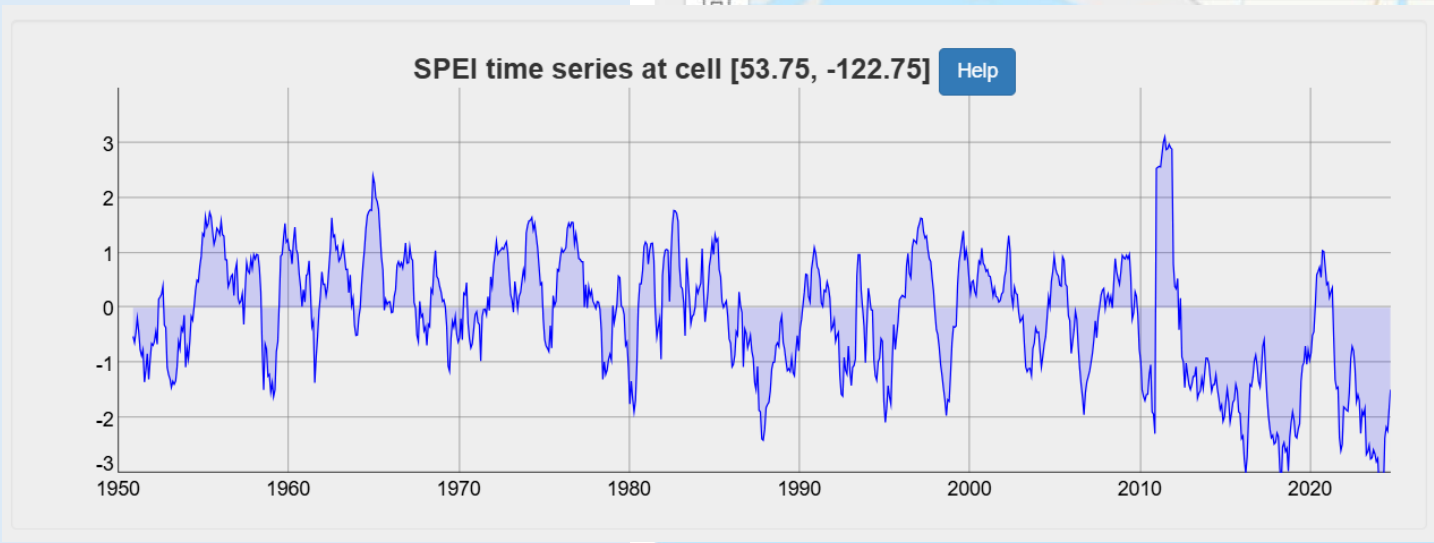
Seasonal Meteorological Drought

https://spei.csic.es/map/maps.html#months=1#month=9#year=2024

- Extreme Drought is uncommon
- Most of the <-2 SPEI values are during the winter months
- Summer Extreme Drought:
  - July 1958 (May-Jul)
- Fall Extreme Drought:
  - 2022
  - 2023
- More frequent moderate to severe drought in recent years

Canadian Drought Monitor

12-Month SPEI - Central Interior

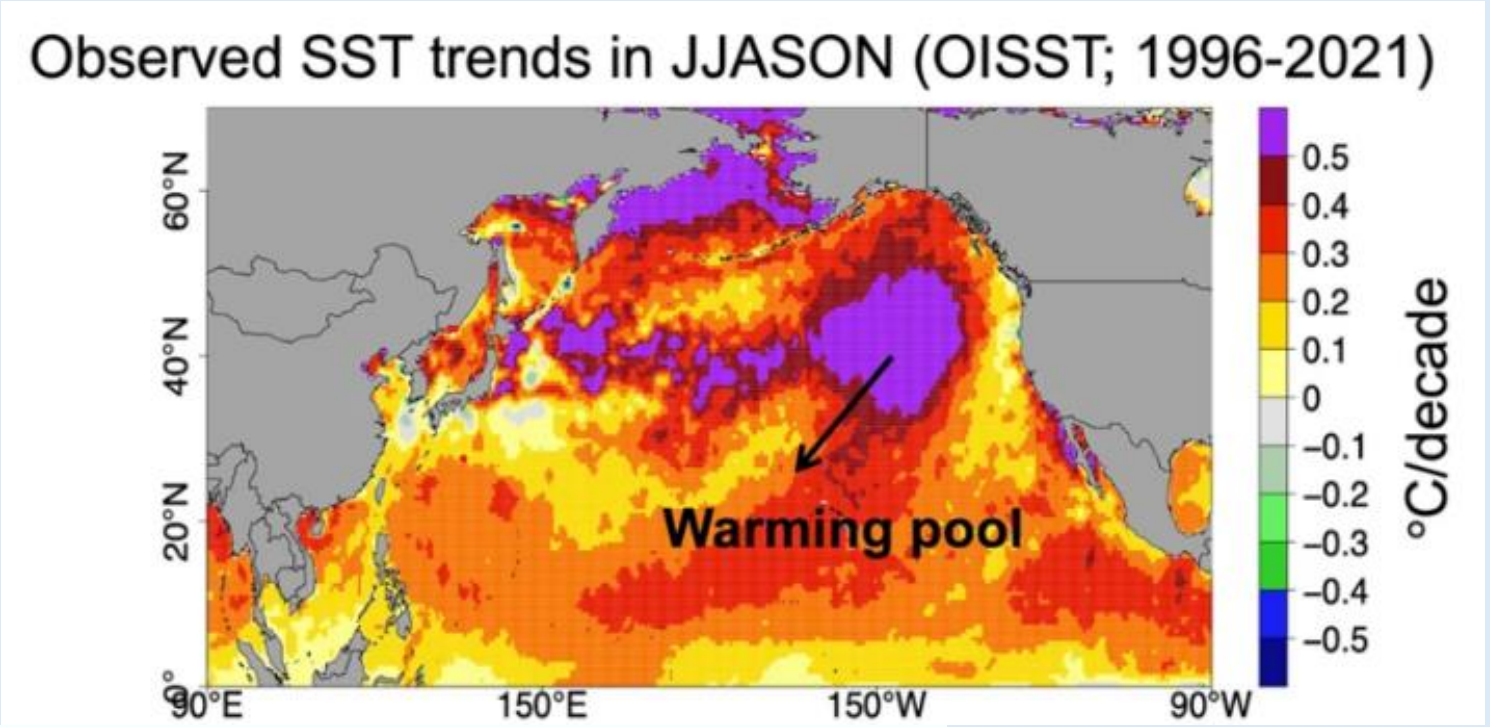


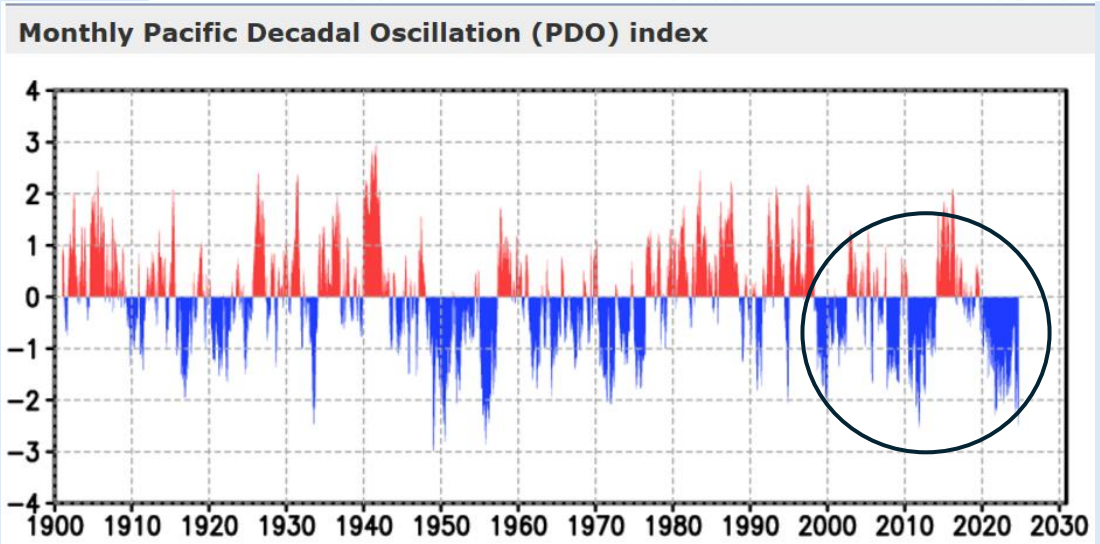
https://agriculture.canada.ca/en/agricultural-production/weather/canadian-drought-monitor/current-drought-conditions

Why drought in recent years?

Sea Surface Trends: Jun-Nov

- Climate change?
- Natural climate variability?
- Snow season decrease?
- Land-use change?
- Marine Heat Waves?
- Jet stream changes?



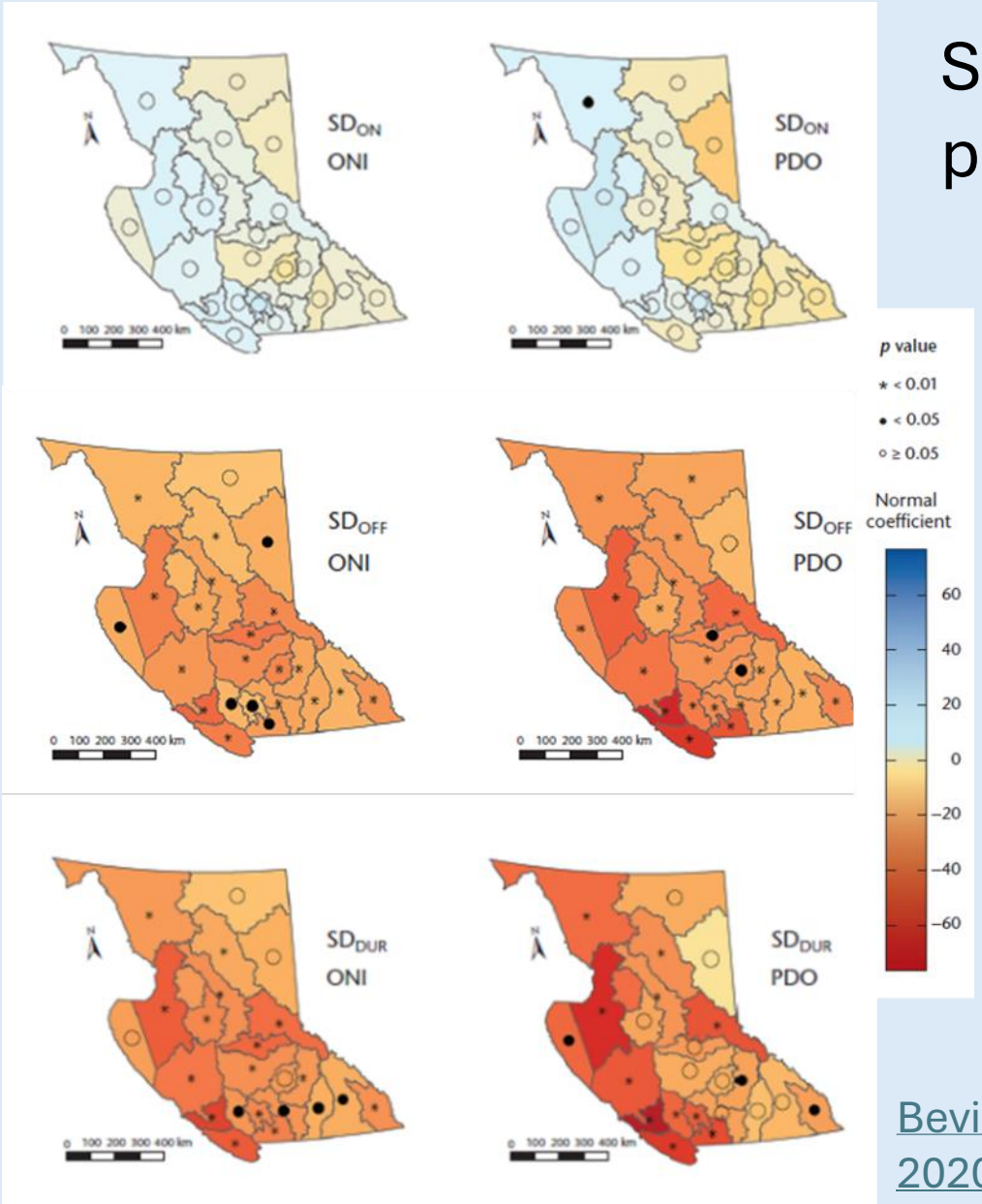


Barkhordarian et al. 2022. https://www.nature.com/articles/s43247-022-00461-2

- Generally, in negative (dry) Pacific Decadal Oscillation Pattern ~20 years
- Exception in 2013-2016 with an extreme marine heat wave “The Blob”

https://ds.data.jma.go.jp/tcc/tcc/products/elnino/decadal/pdo_month.html

Teleconnections and Snow Season



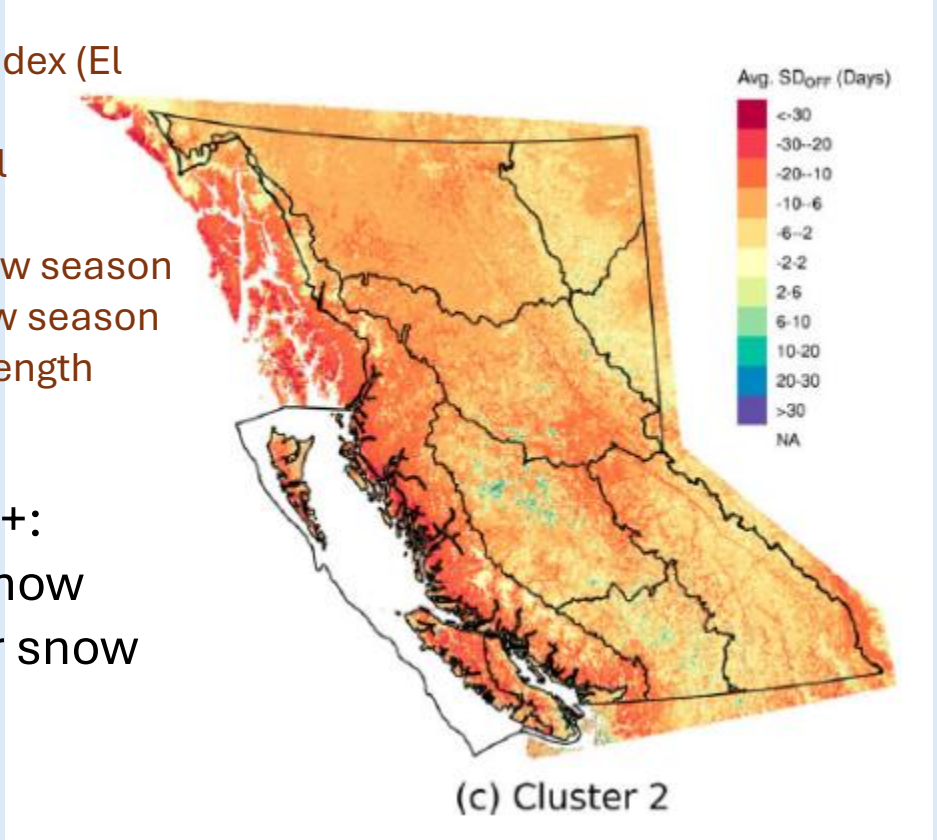
Bevington et al. 2020

Spring drought potential?

- ONI = Oceanic Niño Index (El Niño/La Niña)
- PDO = Pacific Decadal Oscillation
- SD_{on} = start day of snow season
- SD_{off} = end day of snow season
- SD_{dur} = snow season length

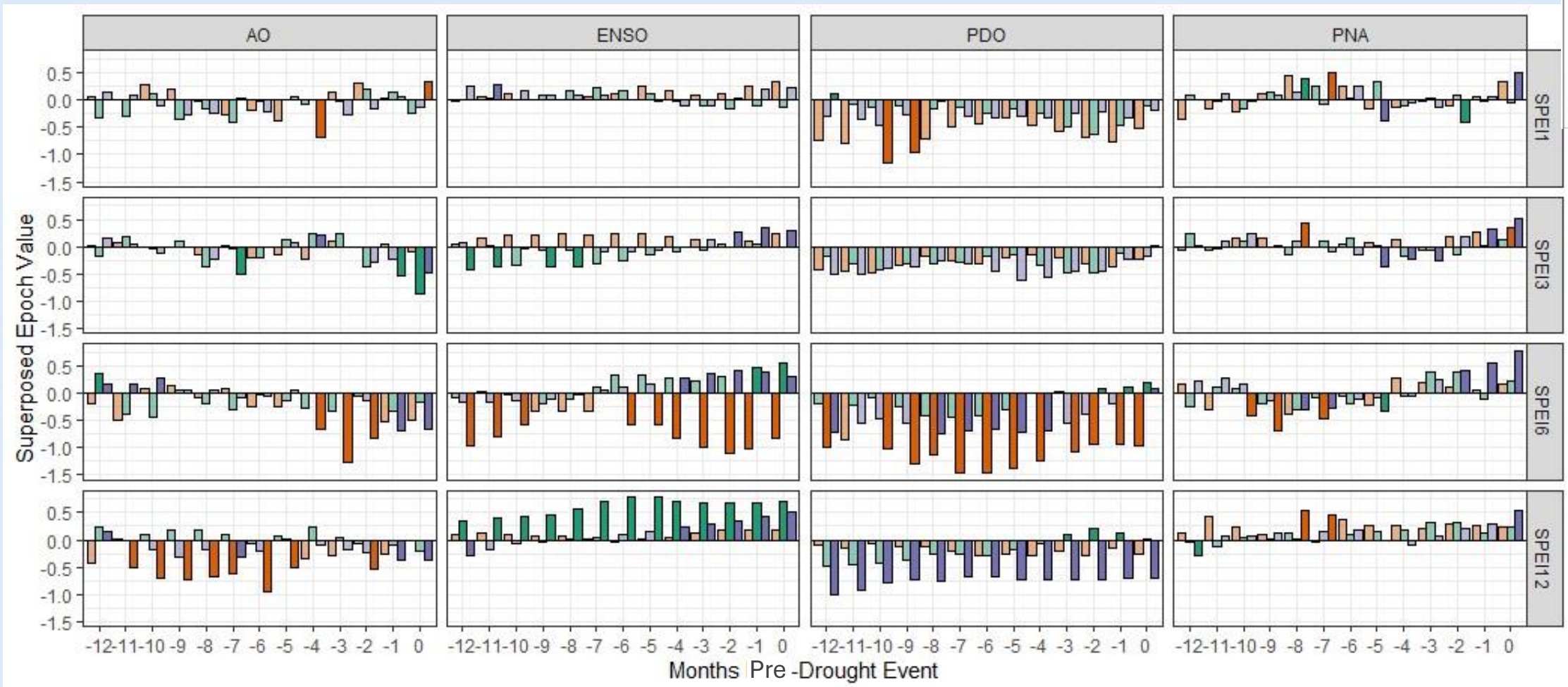
- e.g. El Niño, PDO+: Earlier end to snow season, shorter snow season

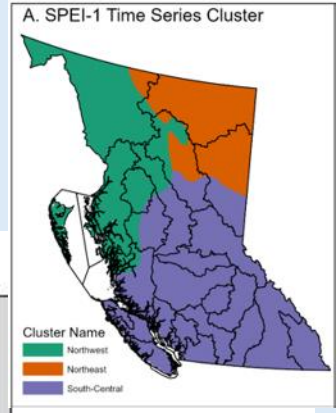
Mean Sea Level Pressure averaged (Sep-Nov 2023): Earlier Snow Off Date 2024



Gleason et al., 2020. *Atmosphere-Ocean* https://www.tandfonline.com/doi/full/10.1080/07055900.2020.1845116

Teleconnections and Extreme Drought





Cluster Name
- Northeast
- Northwest
- South-Central

Darker colours = $p < 0.05$

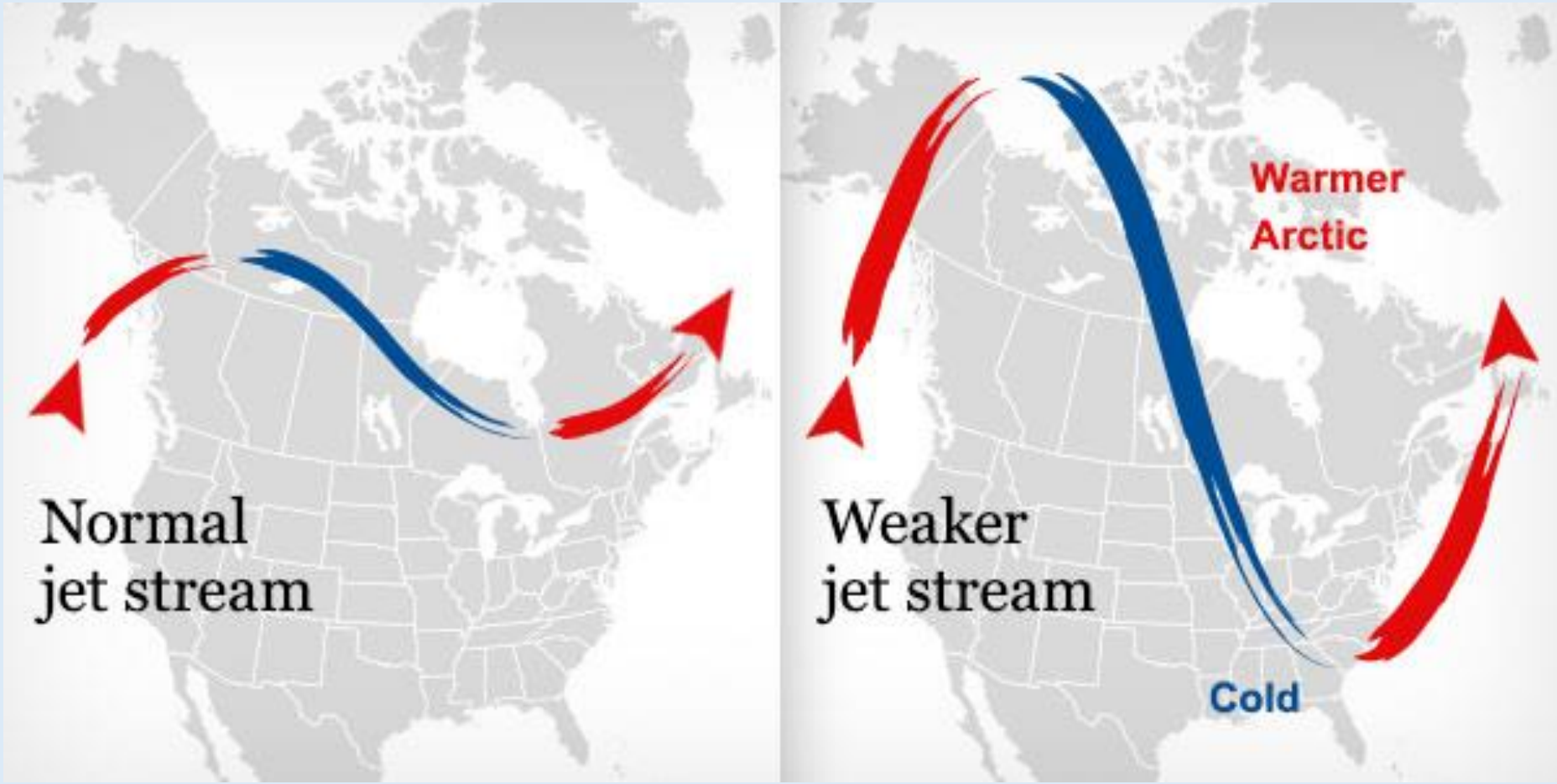
Mood et al. *in prep*

SPEI <= -2 as related to Arctic Oscillation (AO), Pacific Decadal Oscillation (PDO), Pacific North American pattern (PNA), Multivariate El Nino Southern Oscillation index (ENSO)

Changing Weather Patterns

- Evidence to support changes to jet streams resulting from climate warming
- Weaker, slower
- Increased wave height
- Persistent weather conditions
- Extreme weather

- Ecosystem stress:
  - E.g. Summer in northern B.C. is the wet season, shift to hot and dry?

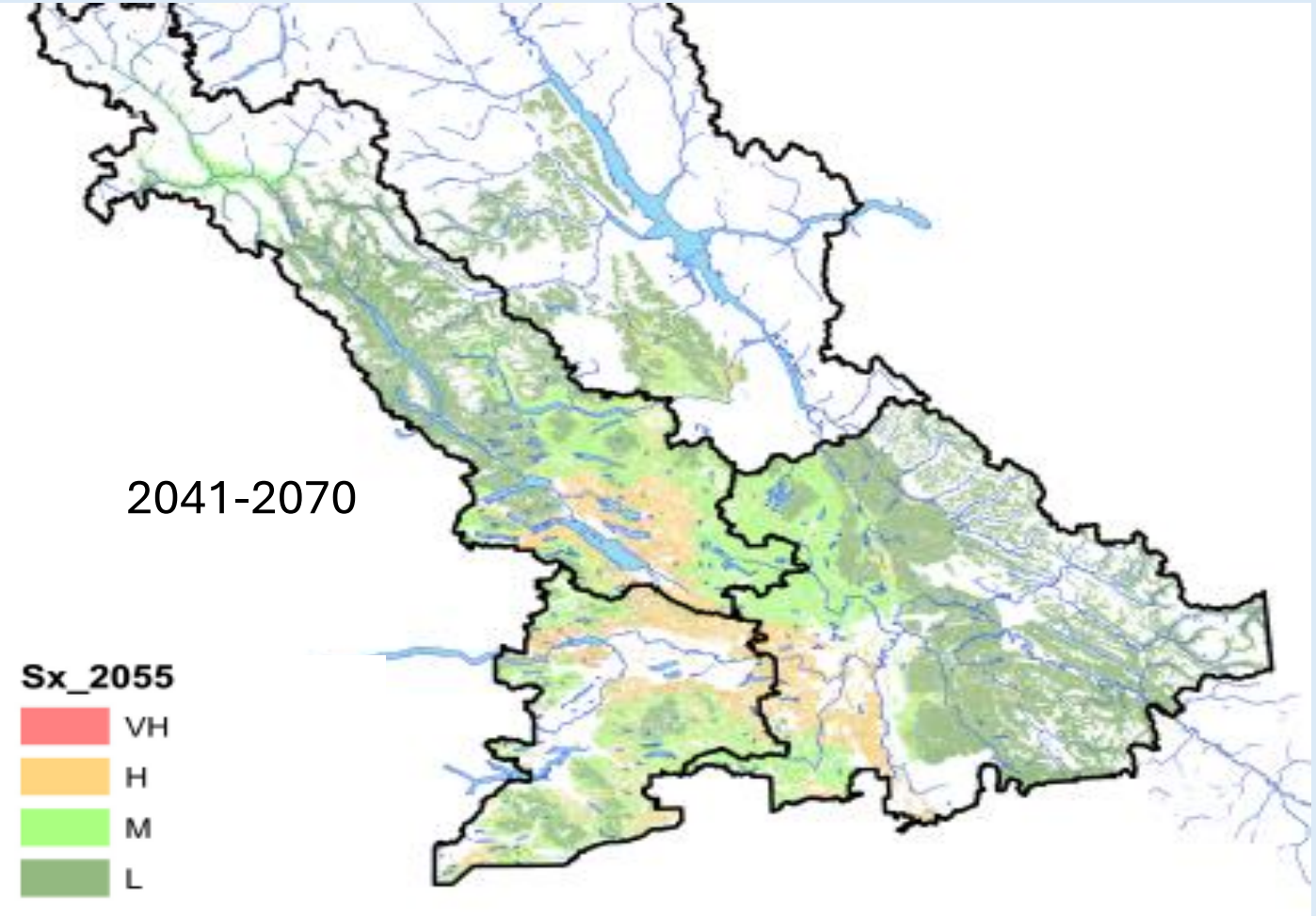


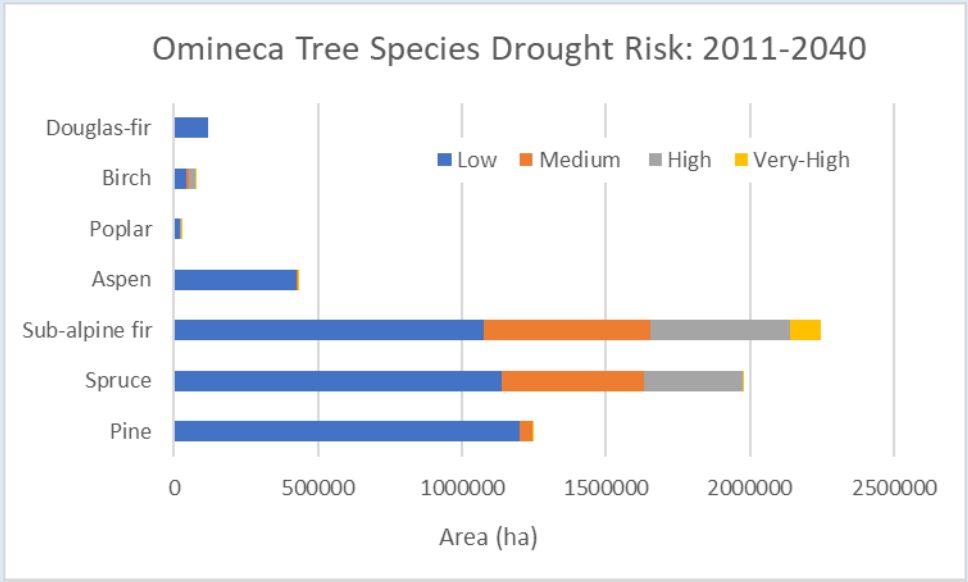
https://www.edf.org/card/4-reasons-climate-change-still-happening-despite-cold-weather?card=4

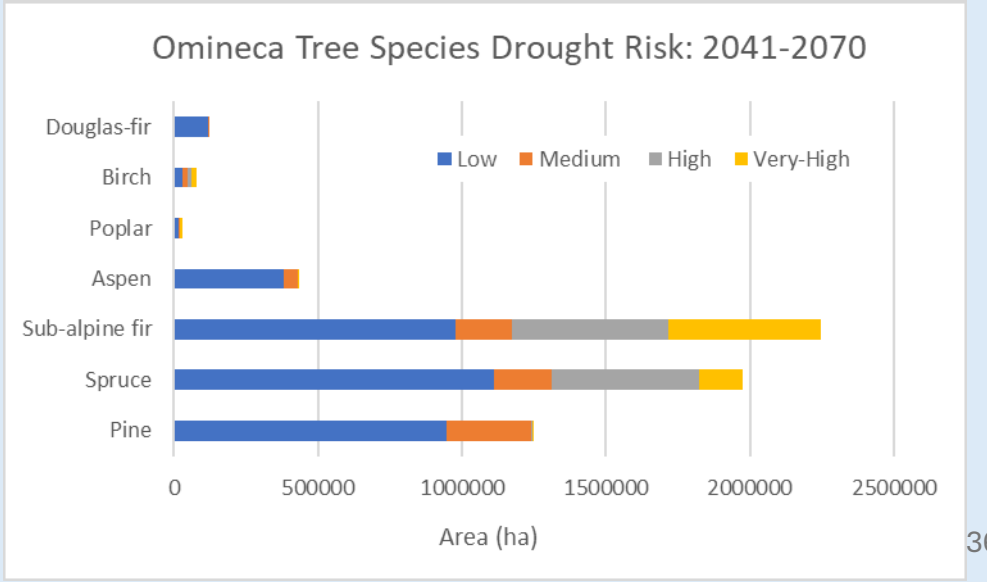
Relating climate conditions to drought driven forest impacts

Forest Drought Risk Assessment Tool

- Identify potential risk of mortality and or drought stress in mature trees currently and for future climates
- Example: Hybrid Spruce risk - Omineca

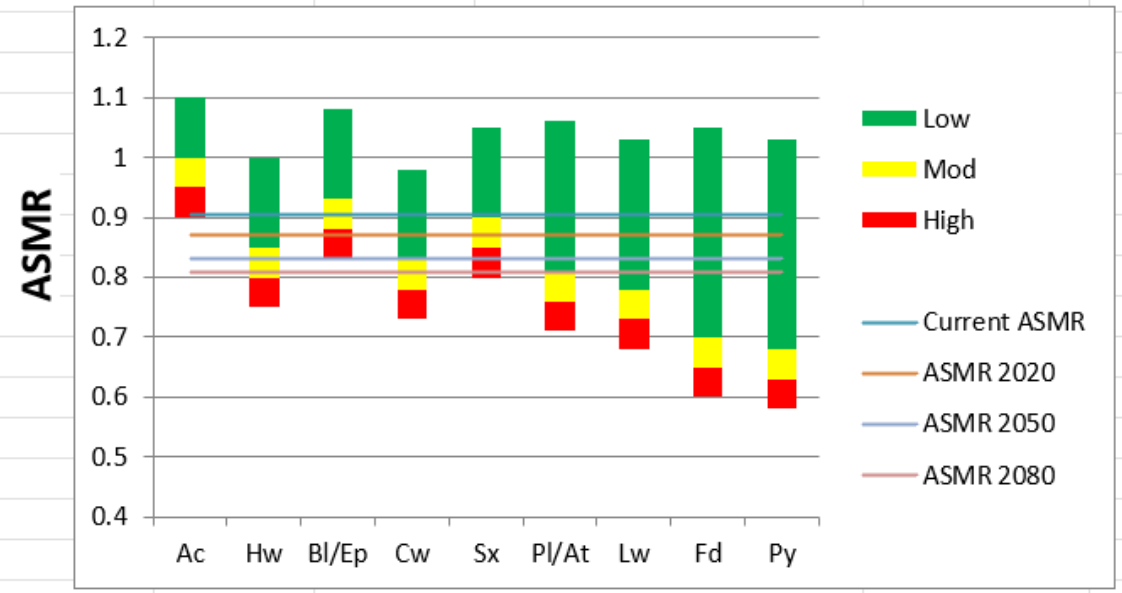






Forest Drought Risk Assessment Tool

BEC	SBSdk		Bigeoclimatic Unit
RSMR	4		Relative Soil Moisture Regime
			Actual Soil Moisture Regime
Values			
Current ASMR	ASMR 2020	ASMR 2050	ASMR 2080
0.90	0.87	0.83	0.81



Ac

https://www2.gov.bc.ca/gov/content/environment/natural-resource-stewardship/natural-resources-climate-change/natural-resources-climate-change-adaptation/tools

Recent work:

- R Shiny app
- Daily gridded weather data
  - Increase in BEC units
- Soil moisture assessment
- Field validation

Future work:

- Mapping and analysis products
- Compare output with plantation drought observations

DeLong et al. 2019:
https://www.for.gov.bc.ca/hfd/pubs/Docs/Tr/Tr125.htm
DeLong et al. 2022:
http://library.nrs.gov.bc.ca/digipub/TR0141.pdf

Drought impacts – case study

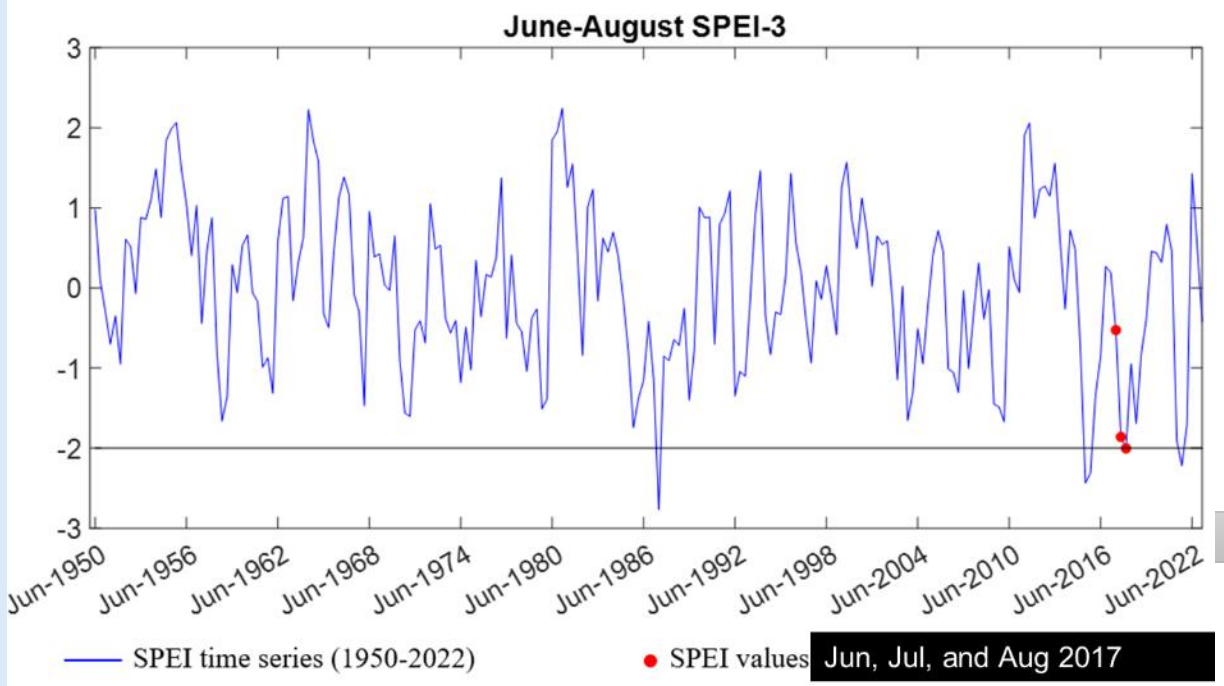
- West Fraser spreadsheet of observed drought impact in plantations, 2017-2021
  - District, location, block, BEC, drought year, stand age, management, site prep, area impacted, drought severity
  - To relate to climate indicators of drought severity, such as the SPEI index, minimum requirements are:
    - Latitude
    - Longitude
    - Year
    - Area/Drought severity

S.No.	District	Location	Licence	CP	Block	SU	Lat (DMS)	Long (DMS)	BEC	Observed Drought Yea	Area Impacted (ha)	SPEI_ 2017 & 2021					Observed Drought Severity	Analyzed Drought Severity (Based on SPEI Global Drought Monitor)		
												Month	SPEI	SPEI_3	SPEI_6	SPEI_12		SPEI_1	SPEI_3	SPEI_6
												May	-0.87	-1.65	-1.15	0.02		Mild	Severe	Moderate
												June	-1.92	-2.62	-2.01	-0.73		Severe	Extreme	Extreme
1	DKA	HartRidge	A18690	312	1	A	50 59'24.75	-121 29'17.64	IDFxw	2021	171.1	July	-1.78	-2.55	-2.77	-1.63	High	Severe	Extreme	Extreme
												Aug	-0.18	-1.87	-2.18	-1.42		No	Severe	Extreme
												Sept	-0.10	-1.35	-2.04	-1.18		No	Moderate	Extreme
												May	-0.87	-1.65	-1.15	0.02		Mild	Severe	Moderate
												June	-1.92	-2.62	-2.01	-0.73		Severe	Extreme	Extreme
2	DKA	HartRidge	A18691	312	1	B	50 59'24.75	-121 29'17.64	IDFdk3	2021	12.5	July	-1.78	-2.55	-2.77	-1.63	Moderate	Severe	Extreme	Extreme
												Aug	-0.18	-1.87	-2.18	-1.42		No	Severe	Extreme
												Sept	-0.10	-1.35	-2.04	-1.18		No	Moderate	Extreme
												May	-0.87	-1.65	-1.15	0.02		Mild	Severe	Moderate
												June	-1.92	-2.62	-2.01	-0.73		Severe	Extreme	Extreme
3	DKA	Scottie Creek	A18690	720	8	A	51 2'58.07	-121 20'54.5	IDFdk3	2021	39.9	July	-1.78	-2.55	-2.77	-1.63	Moderate	Severe	Extreme	Extreme
												Aug	-0.18	-1.87	-2.18	-1.42		No	Severe	Extreme
												Sept	-0.10	-1.35	-2.04	-1.18		No	Moderate	Extreme
												May	-0.85	-1.95	-2.44	-1.18		Mild	Severe	Extreme
												June	-1.85	-2.47	-3.09	-1.96		Severe	Extreme	Extreme
4	DKA	Frog Lake	A18694	731	1	A	50 55'10.71	-120 44'19.29	IDFdk1	2021	3.8	July	-1.61	-2.25	-2.73	-2.55	High	Severe	Extreme	Extreme
												Aug	-0.14	-1.72	-2.12	-2.03		No	Severe	Extreme
												Sept	0.06	-1.15	-1.79	-1.74		No	Moderate	Severe

Preliminary Results

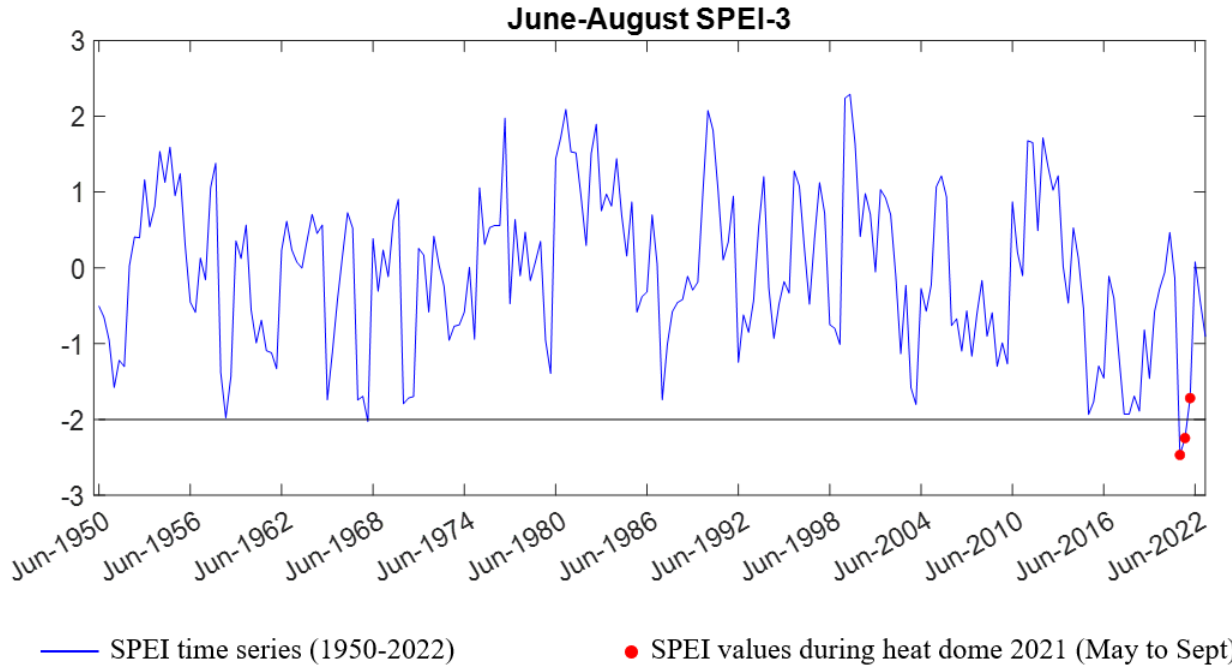
- 70 locations of observed drought provided
  - All had SPEI values that indicated drought, but when?
- Where “High” and “Very High” drought impacts were observed, average SPEI values less than -1.5 (severe drought) found in:
  - SPEI-1 month = June, July
  - SPEI-3 month = July, August, September
- Where “Moderate” drought impacts were observed
  - Evidence of SPEI values indicating moderate drought throughout the growing season, many severe and extreme SPEI values
- 2021 SPEI values were less than 2017 SPEI values
  - i.e., 2021 meteorological drought was more severe than 2017
- This work will be repeated with 2023 observed drought information provided by licensees

Location 6: SPEI Values with SPEI during summer season (June to August)



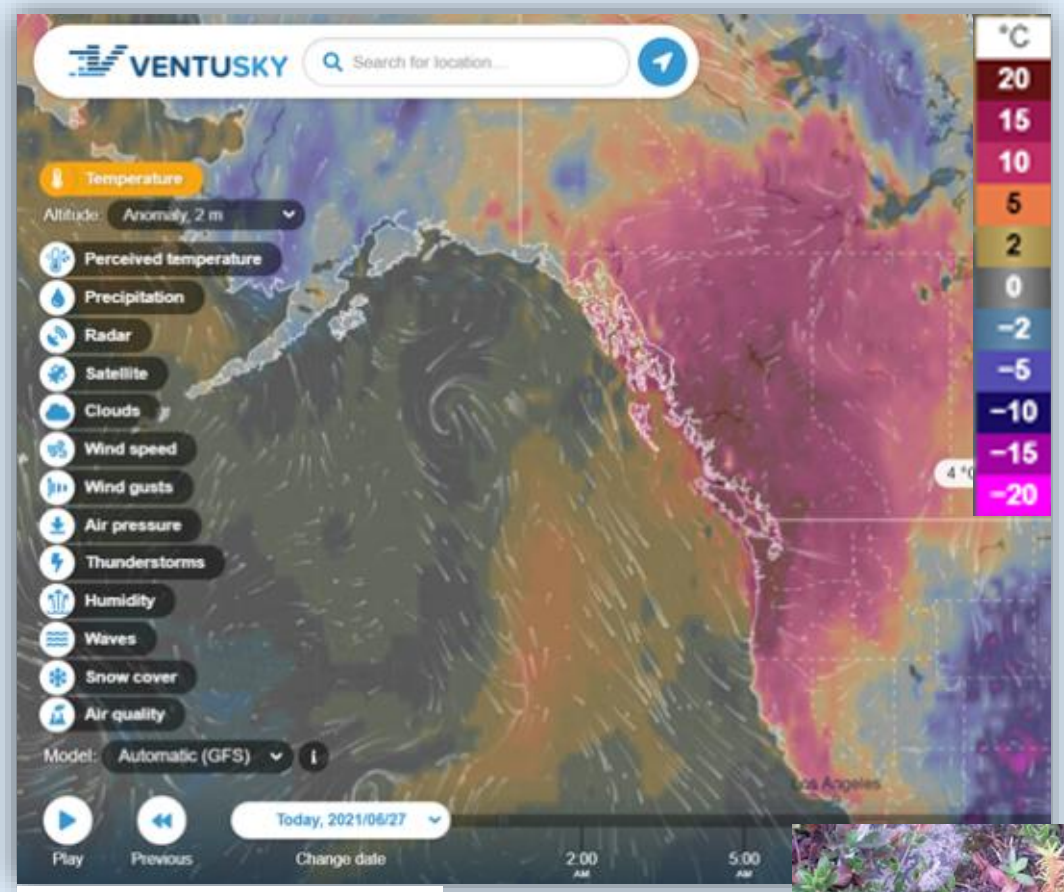
- Example of locations of observed forest drought impacts in 2017
- August 3-month SPEI (average of Jun, Jul, Aug SPEI) was Extreme drought

Location 2: SPEI Values with SPEI during summer season (June to August)

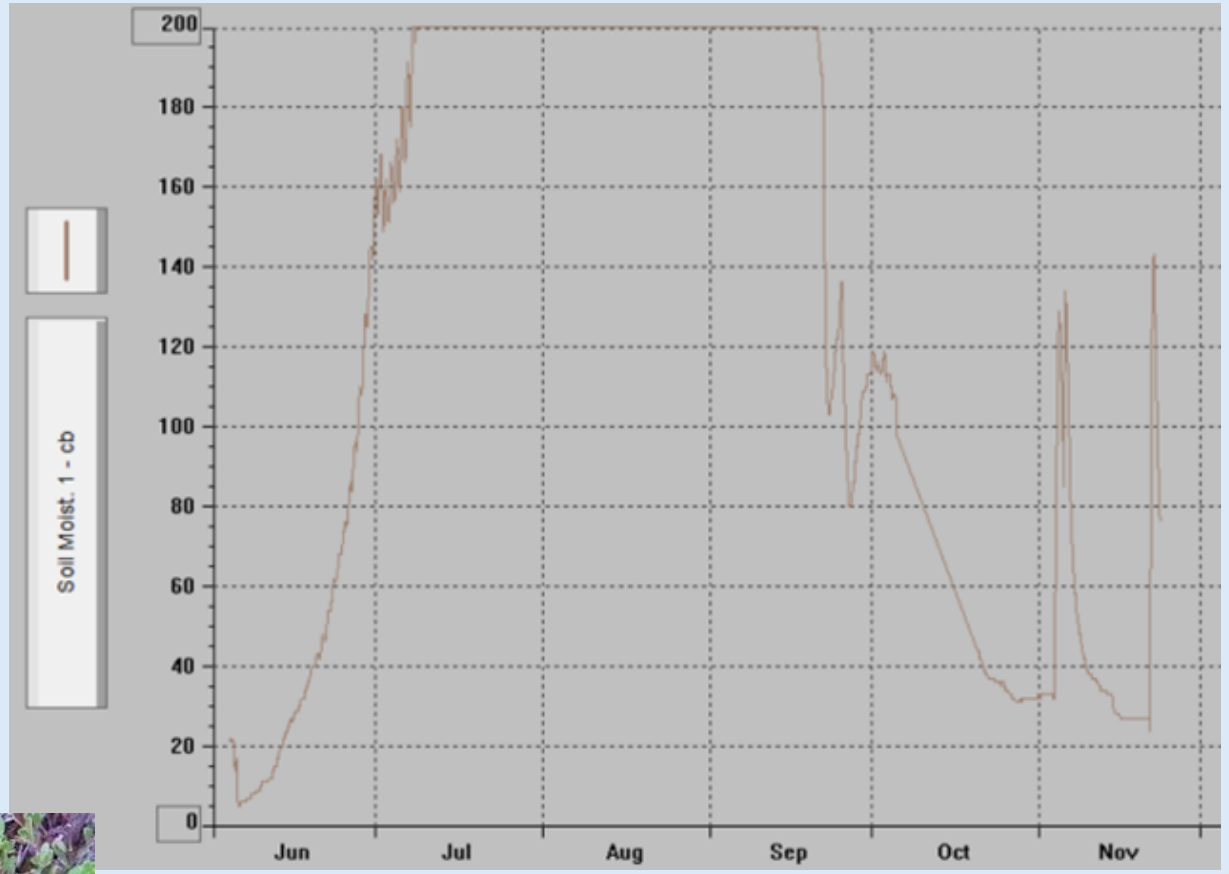


- Example of locations of observed forest drought impacts in 2021
- Lowest Jun, Jul, and Aug SPEI 3-month values on record in 2021
- First time in Extreme drought category.

2021 HEAT DOME - June 25th to July 3rd



https://www.ventusky.com/



Soil moisture @ 20 cm depth

Flash Drought

Tree scorching

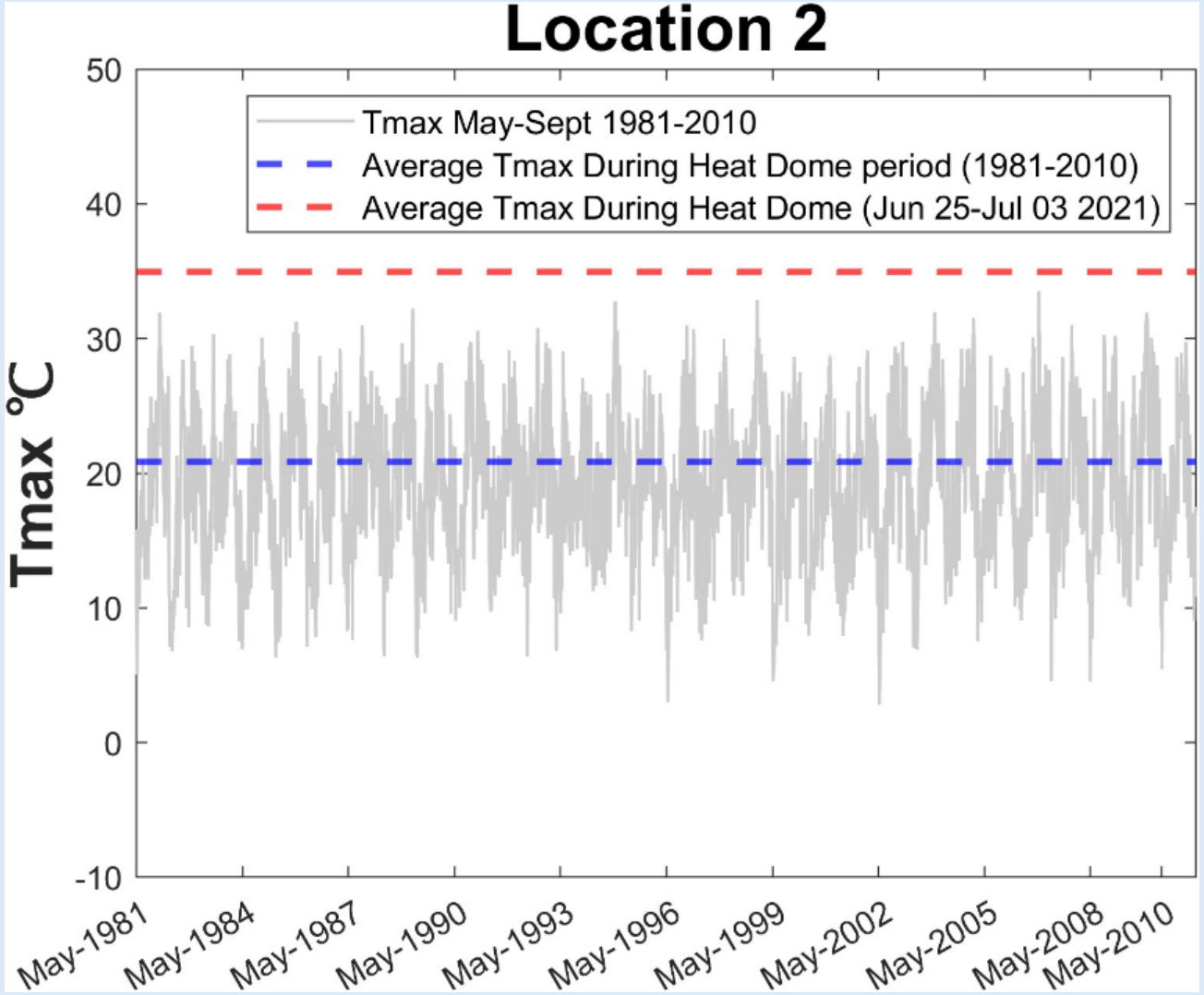
Hydrophobic soils remainder of growing season?

41

Heat Dome Temperatures

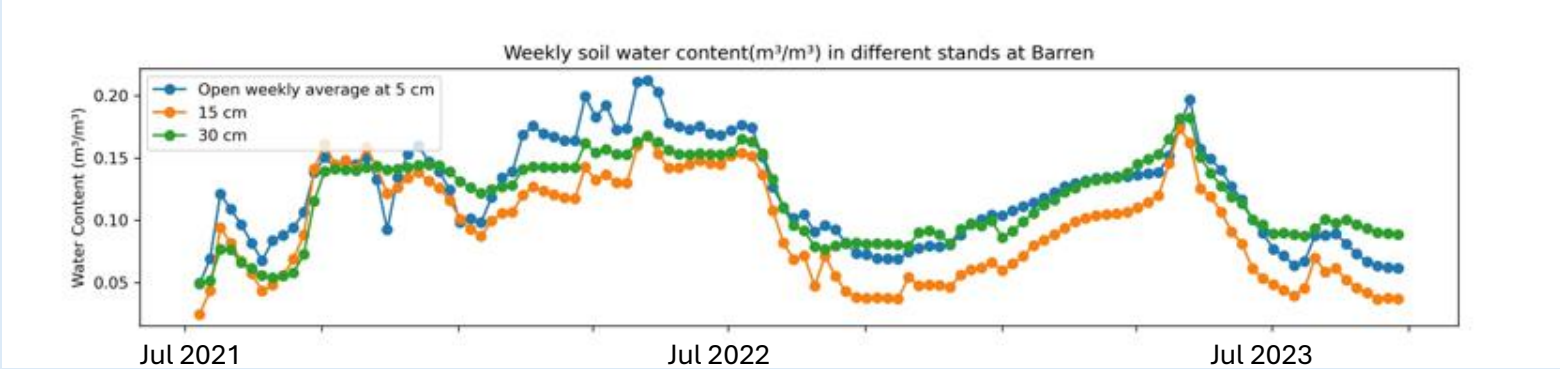
Gridded climate data was used to explore maximum temperatures June 25 to July 3, 2021 compared to the 1981-2010 averages, for all the West Fraser sites with observed drought impacts in 2021

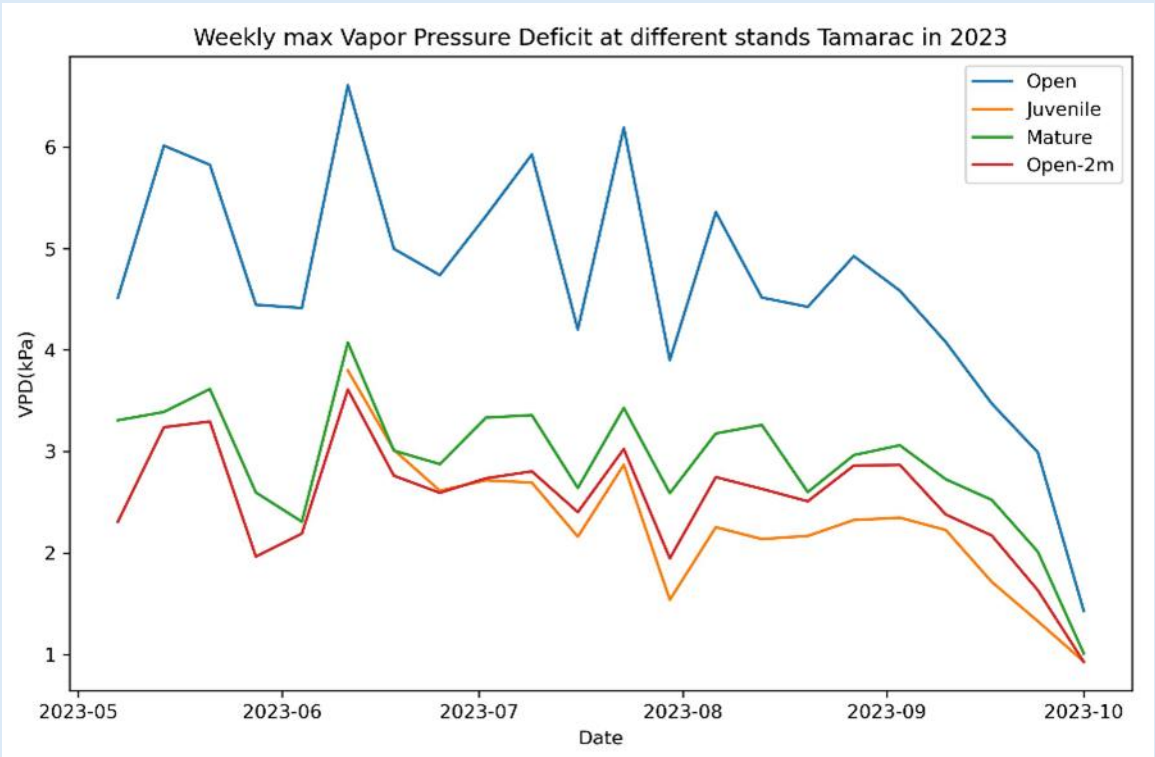
- All the locations of observed drought in 2021 had graphs like this:
- Maximum temperatures were 10-15 degrees above average for those days in 2021
- Temperatures the seedlings experienced could have been 10-15°C higher (>50°C)
- Bad timing for trees just planted or just flushed



Other Forest Drought Related Work

- Forest climate, microclimate monitoring
  - Soil moisture
  - Vapour pressure deficit
  - Fire weather indices
- Research to understand impacts of 2021 heat dome and 2023 drought
- Support for
  - Remote sensing of forest drought
  - Tree response to drought
  - ForDRAT in timber supply modelling
  - ForDRAT in Forest Landscape Planning





Summary

- Experienced meteorological droughts in recent years
  - Extreme drought is uncommon historically
- Future temperature increase likely to increase the frequency and severity of drought
  - Natural climate variability, depending on the phase, will exacerbate or provide some relief
- Still learning about ecological drought impacts
  - We do know our current forests and understanding of forestry were established during moister conditions
  - Must bring climate change (drought) thinking into forestry decisions to reduce impacts

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