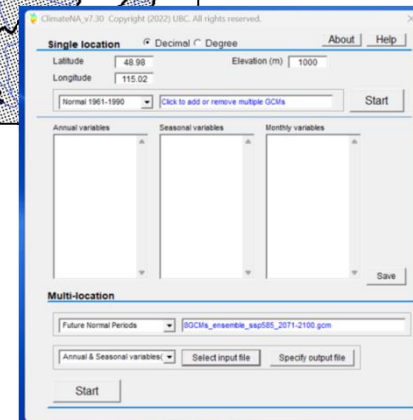
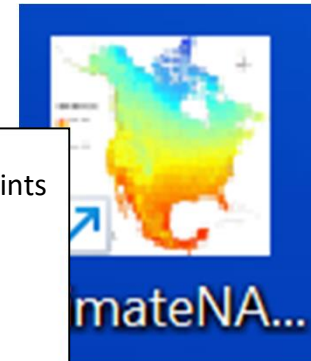
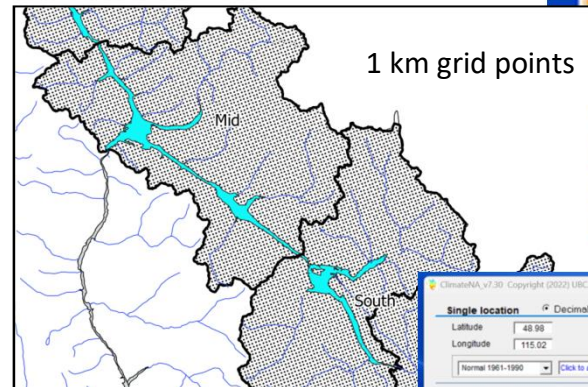
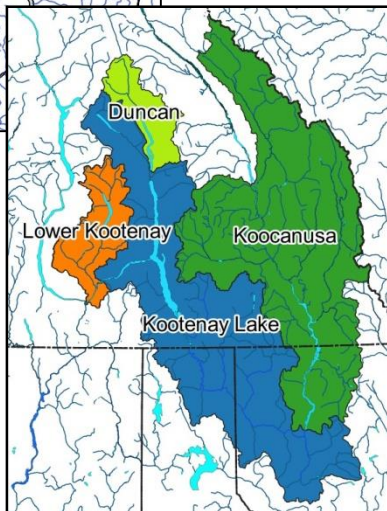
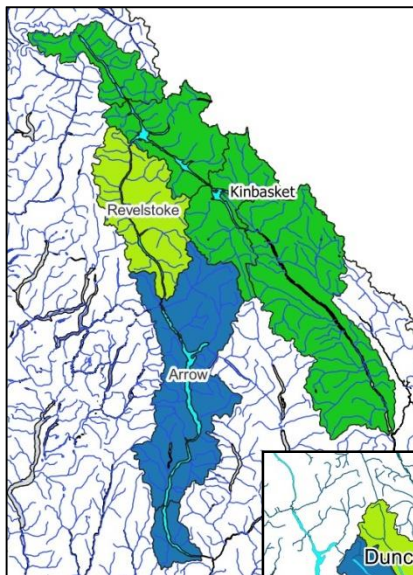


Climate Change Background

Projected Changes for the Upper Columbia / Kootenay Basins

CRT EF Steering Committee: Jan 11, 2023

G. Utzig, P. Ag.



AR5
HadGEM2-ES Dry
CanESM2 Wet
AR6
Ensemble of 8 from PCIC

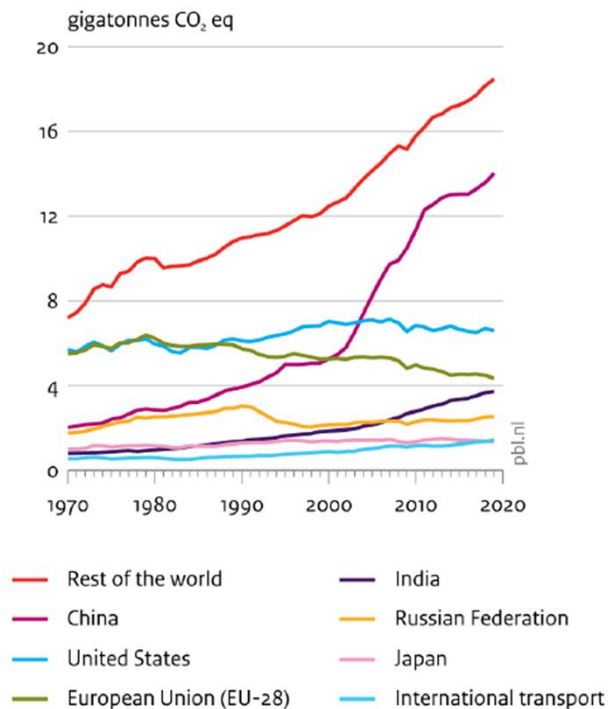
Goals for Presentation

To provide background on climate change for the Upper Columbia and Kootenay Basins with regard to:

- choice of climate change scenarios
- projected changes in temperature and precipitation
- projected changes in stream flows
- extreme events
- utilization within the CRTPM analysis framework

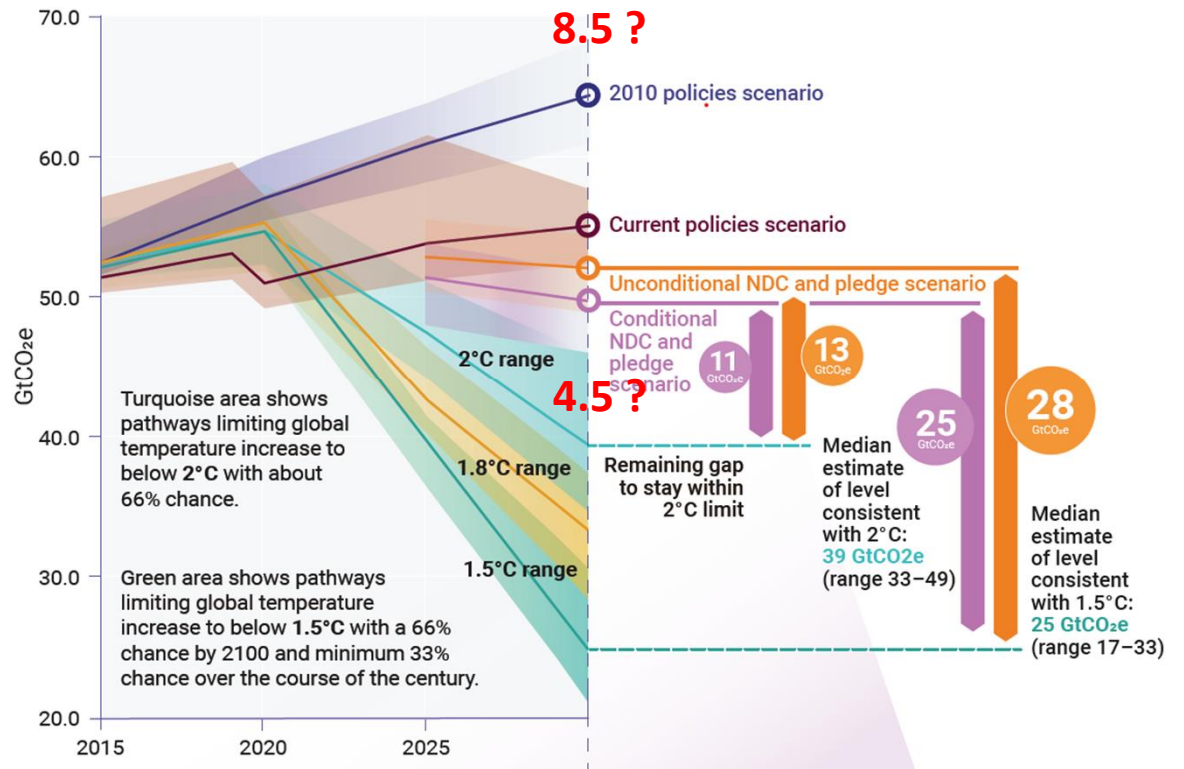
Which emission scenario?

Top emitting countries and the EU



Source: EDGAR v5.0 FT2019 (without land-use change).
both: F-gas: EDGAR v4.2 FT2019; incl. savannah fires.

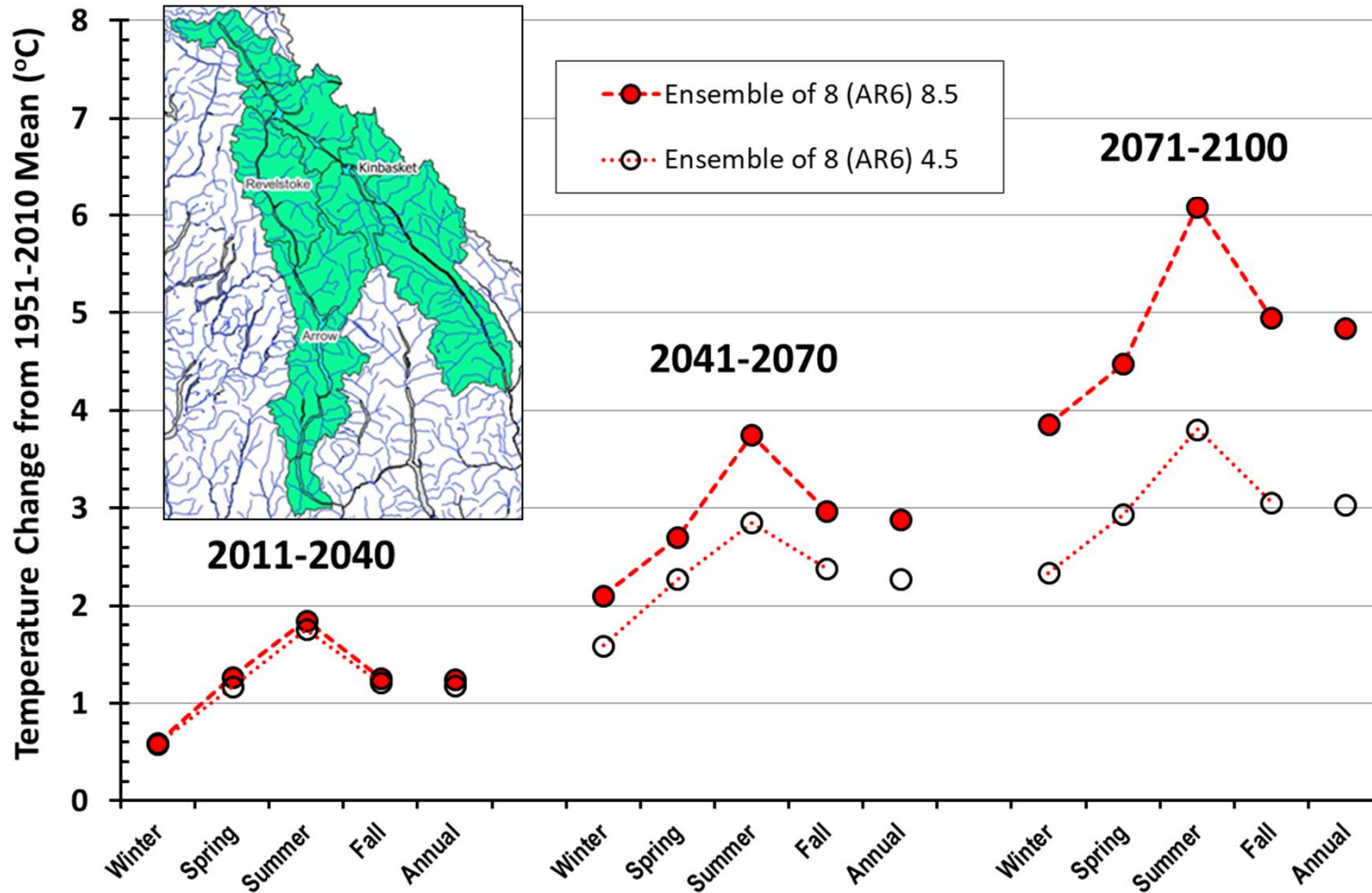
From: Olivier and Peters 2020



From: IPCC 2021 Gap Report

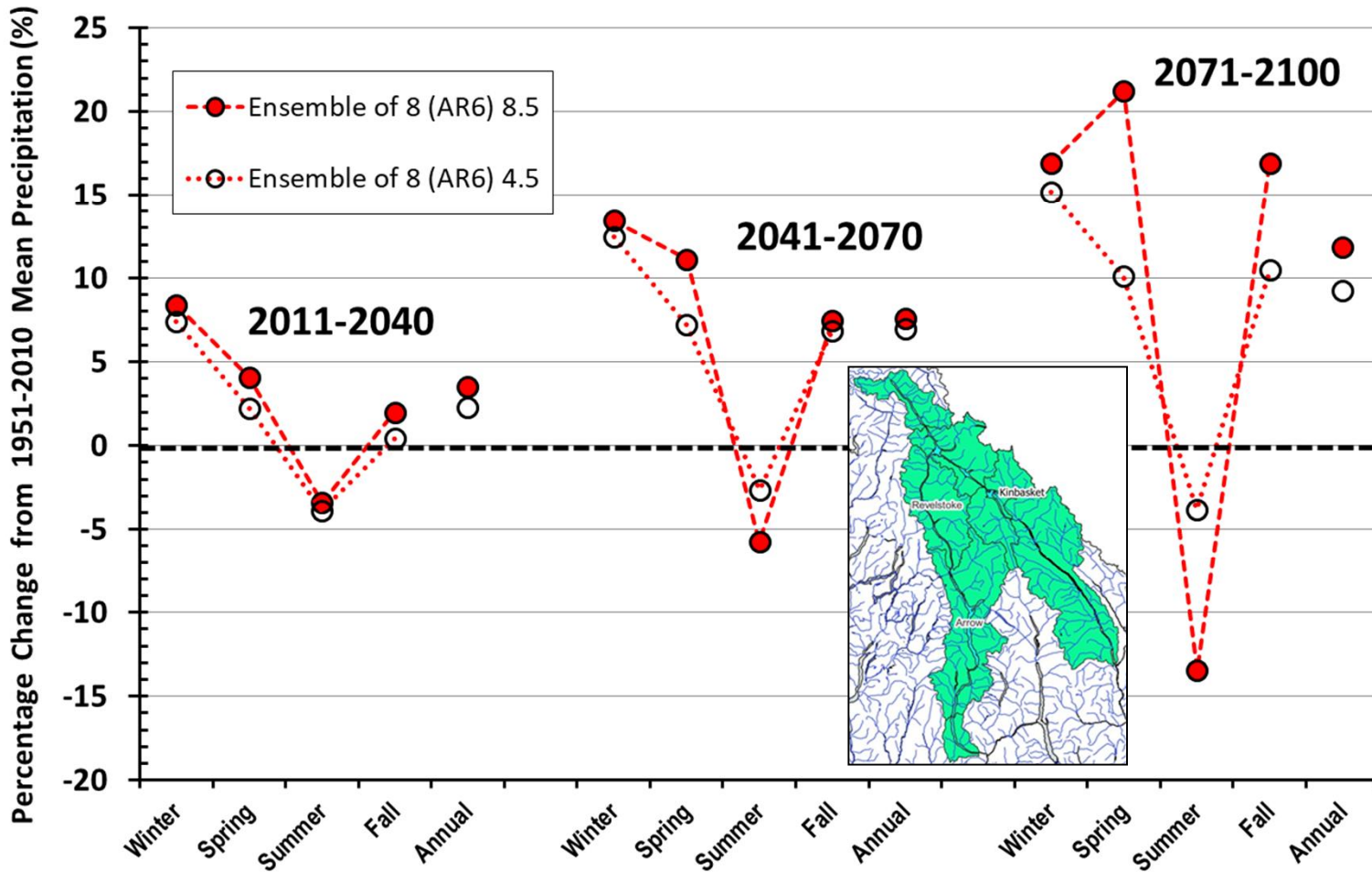
Which emission scenario?

Mean Temperature Projections - Whole Upper Columbia Basin
AR6 Ensembles ssp5-8.5/ssp2-4.5



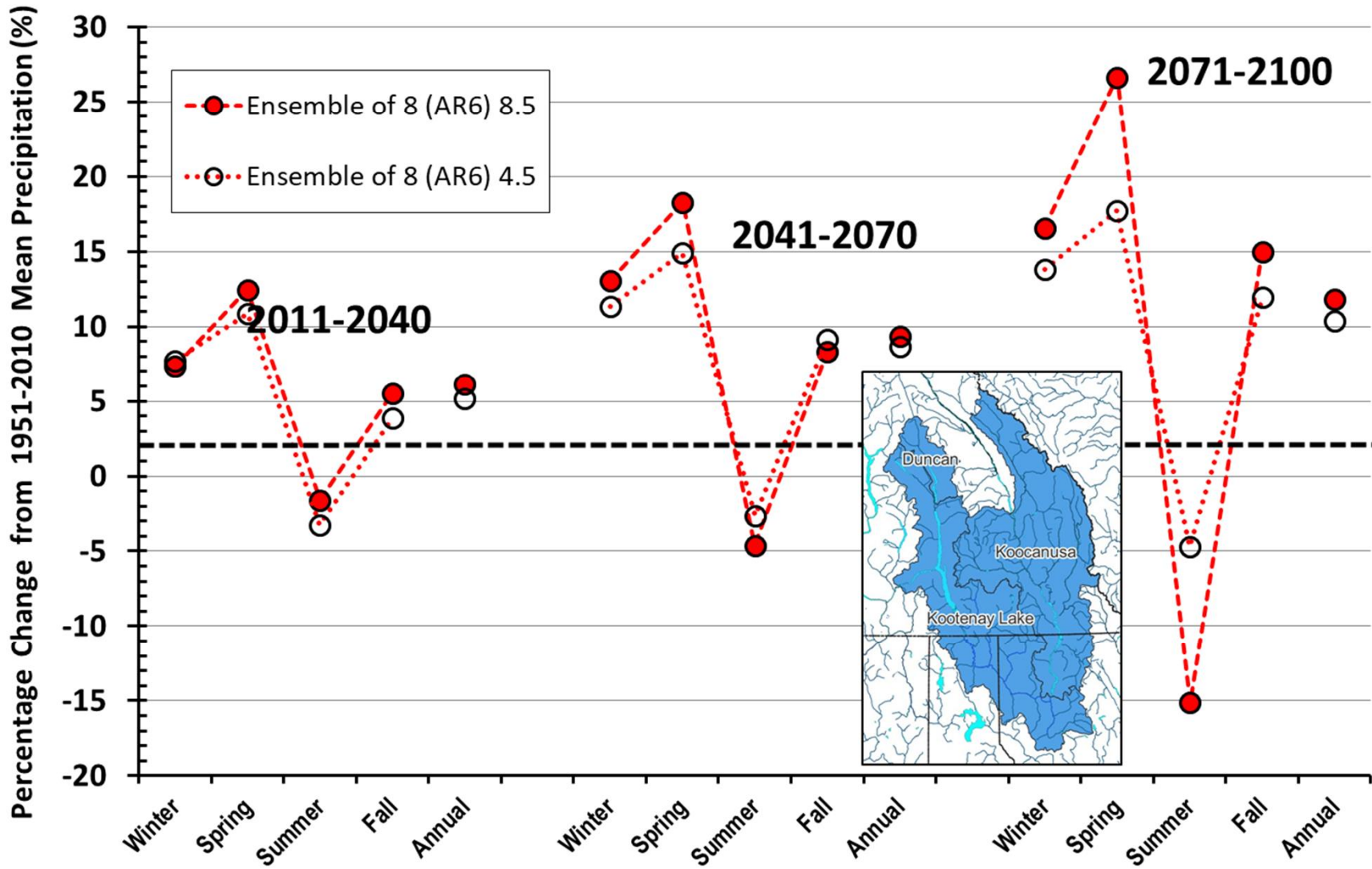
Which emission scenario?

Precipitation Projections - Whole Upper Columbia Basin
AR6 Ensembles ssp5-8.5/ ssp2-4.5



Precipitation Projections - Kootenay Lake Watershed

AR6 Ensembles ssp5-8.5/ ssp2-4.5




Cumulative Flows at Mica (2011-2100)

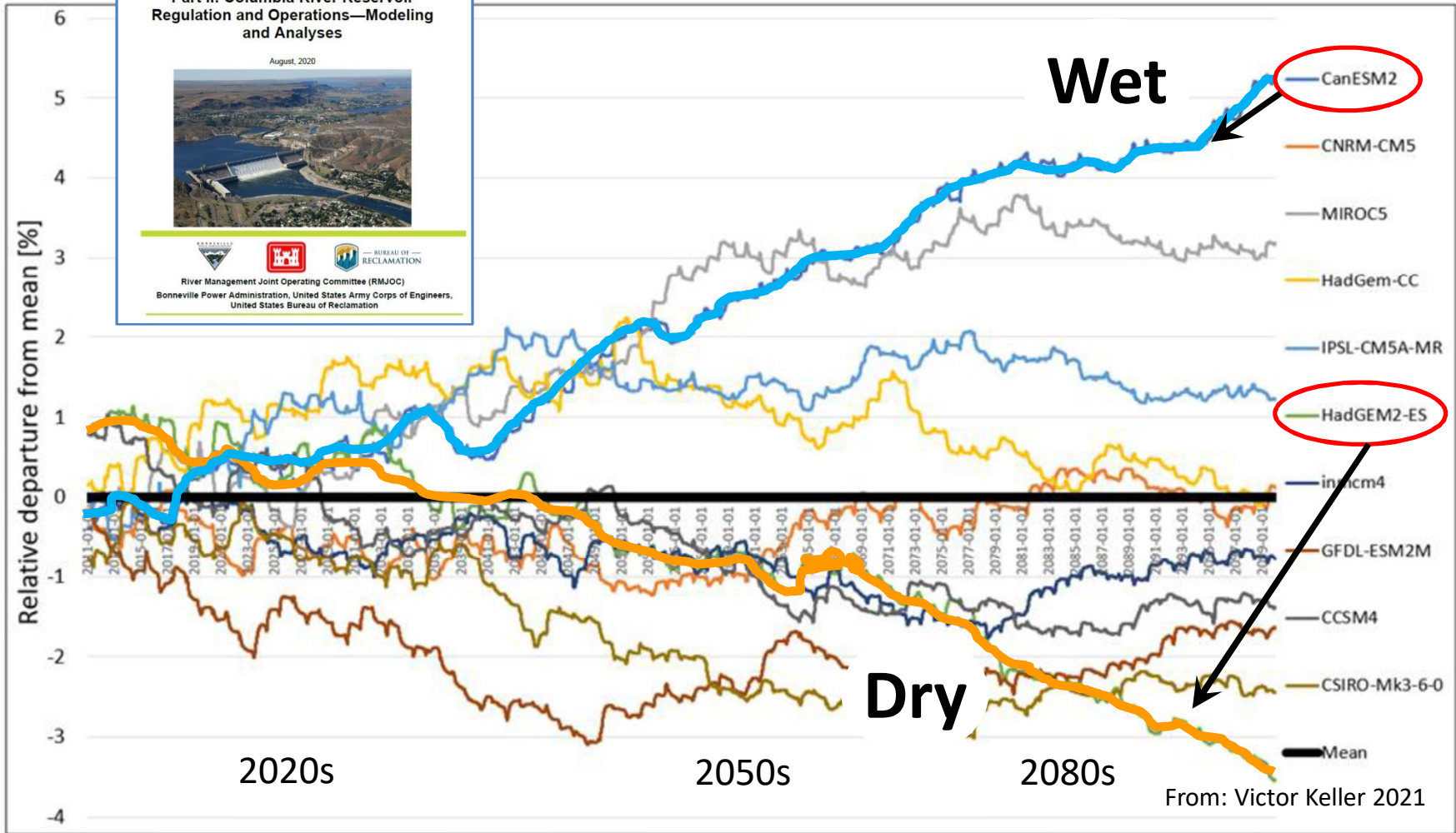
Climate and Hydrology Datasets for RMJOC Long-Term Planning Studies: Second Edition (RMJOC-II)

Part II: Columbia River Reservoir Regulation and Operations—Modeling and Analyses

August, 2020

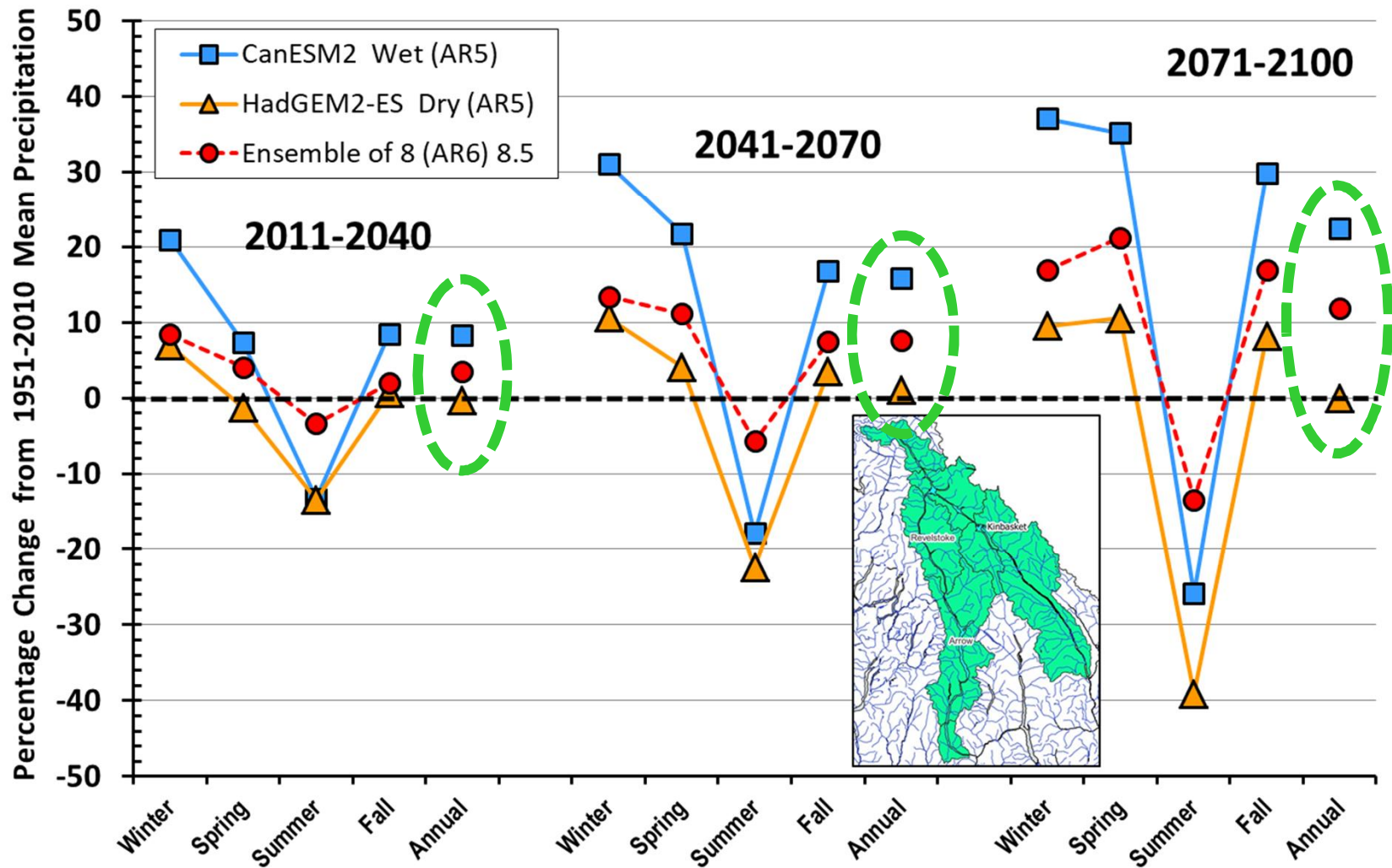


River Management Joint Operating Committee (RMJOC)
Bonneville Power Administration, United States Army Corps of Engineers,
United States Bureau of Reclamation

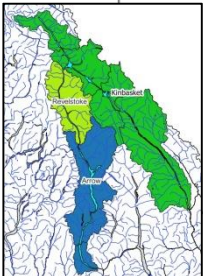
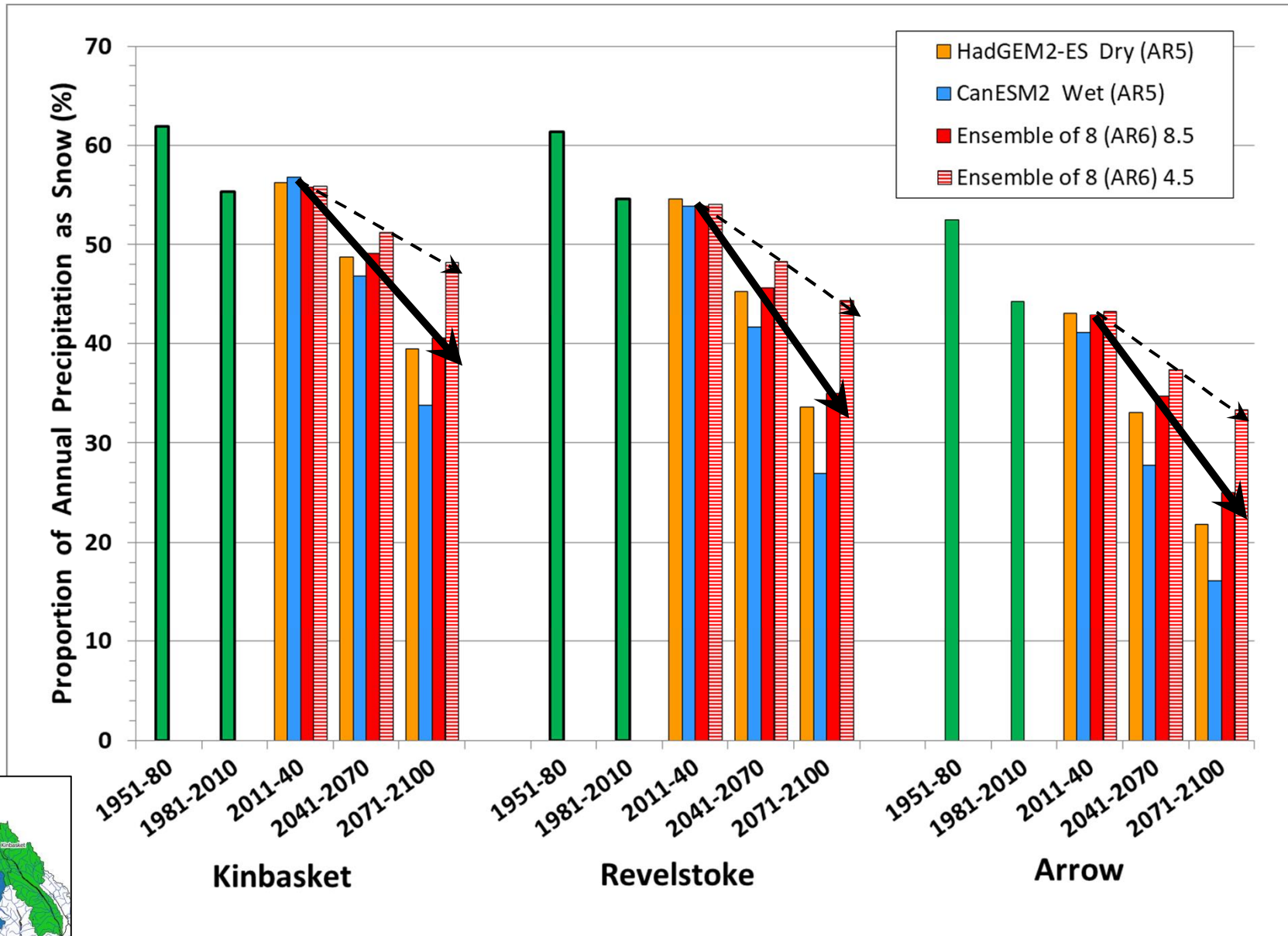


Models and scenarios from AR5 rcp8.5

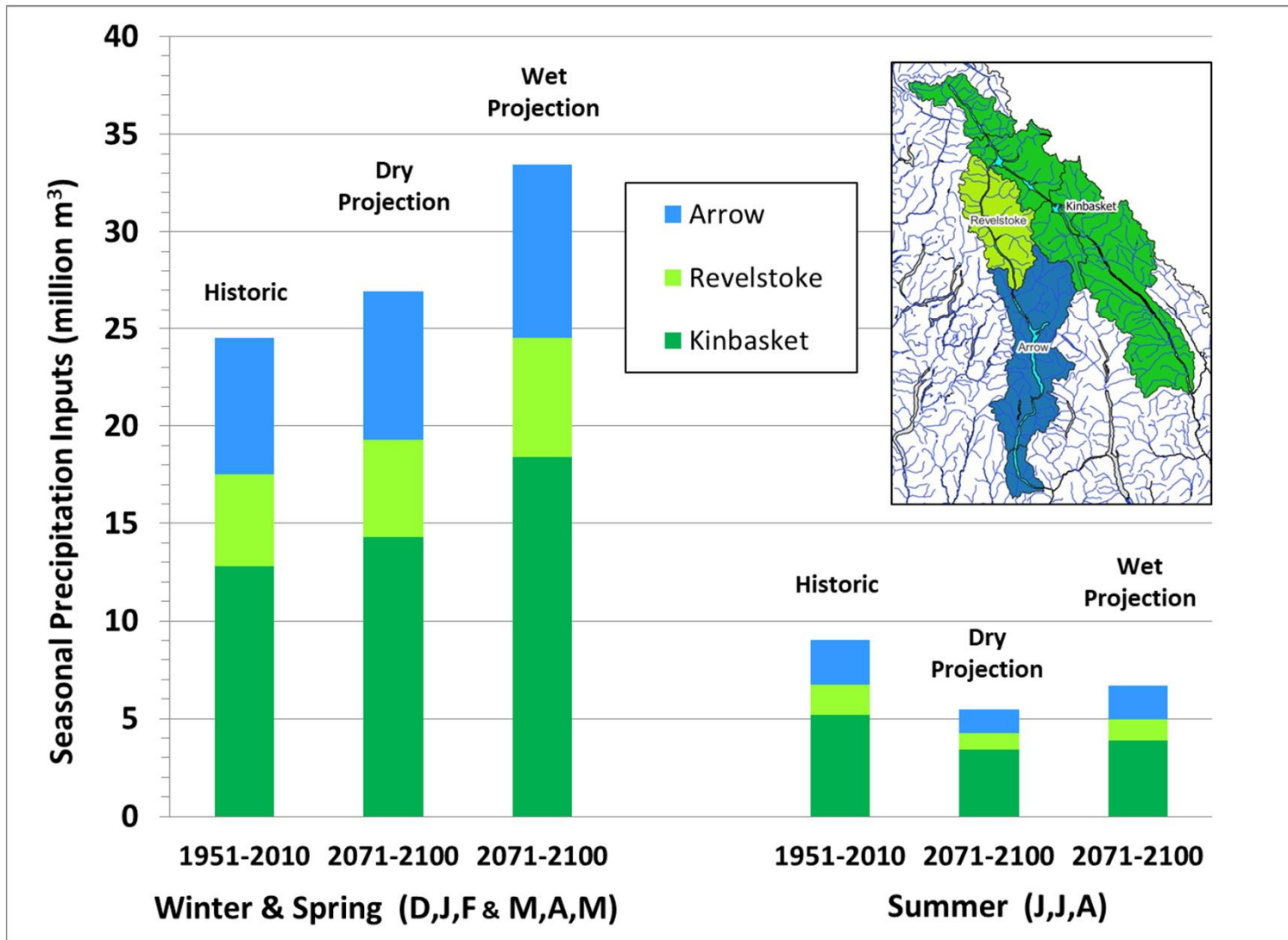
Precipitation Projections - Whole Upper Columbia Basin CRT Scenarios vs. AR6 Ensemble (rcp8.5/ ssp5-8.5)



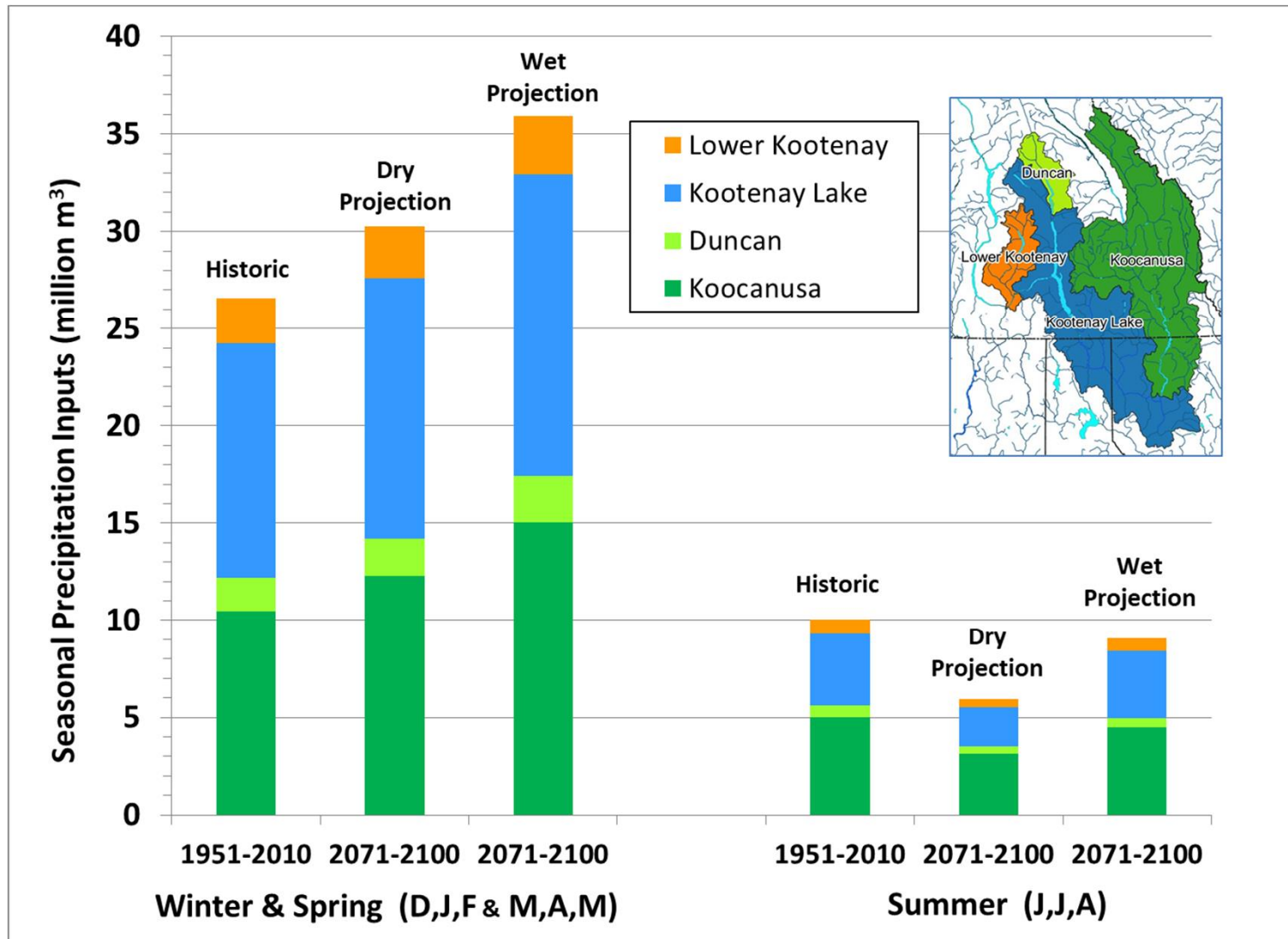
Changes in Snow as a Proportion of Annual Precipitation



Projected Changes in Seasonal Precipitation Whole Upper Columbia Basin



Projected Changes in Seasonal Precipitation Whole Kootenay Basin

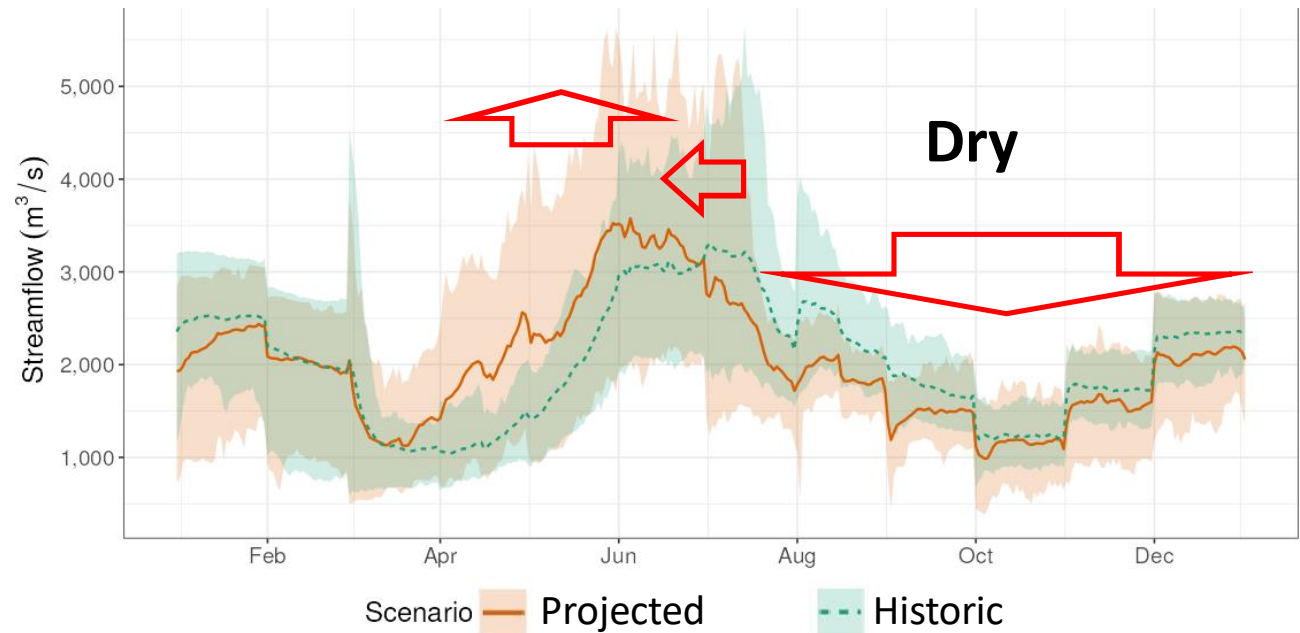
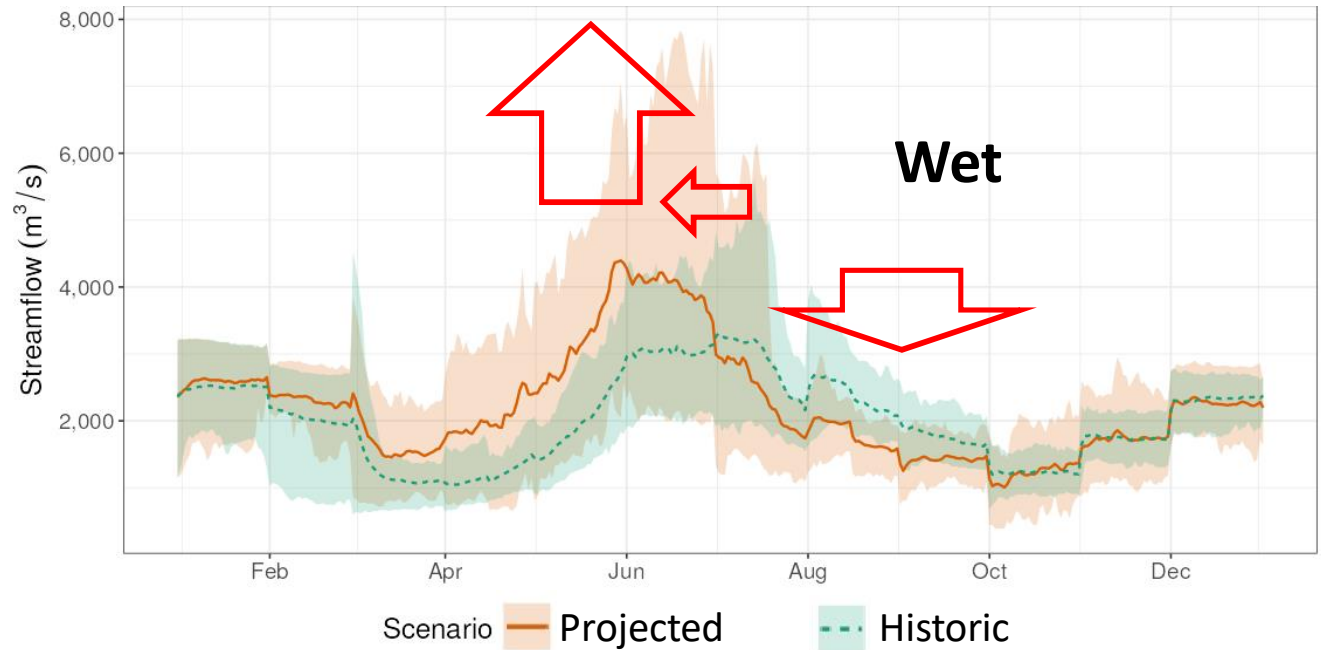


Daily Streamflow at Birchbank:

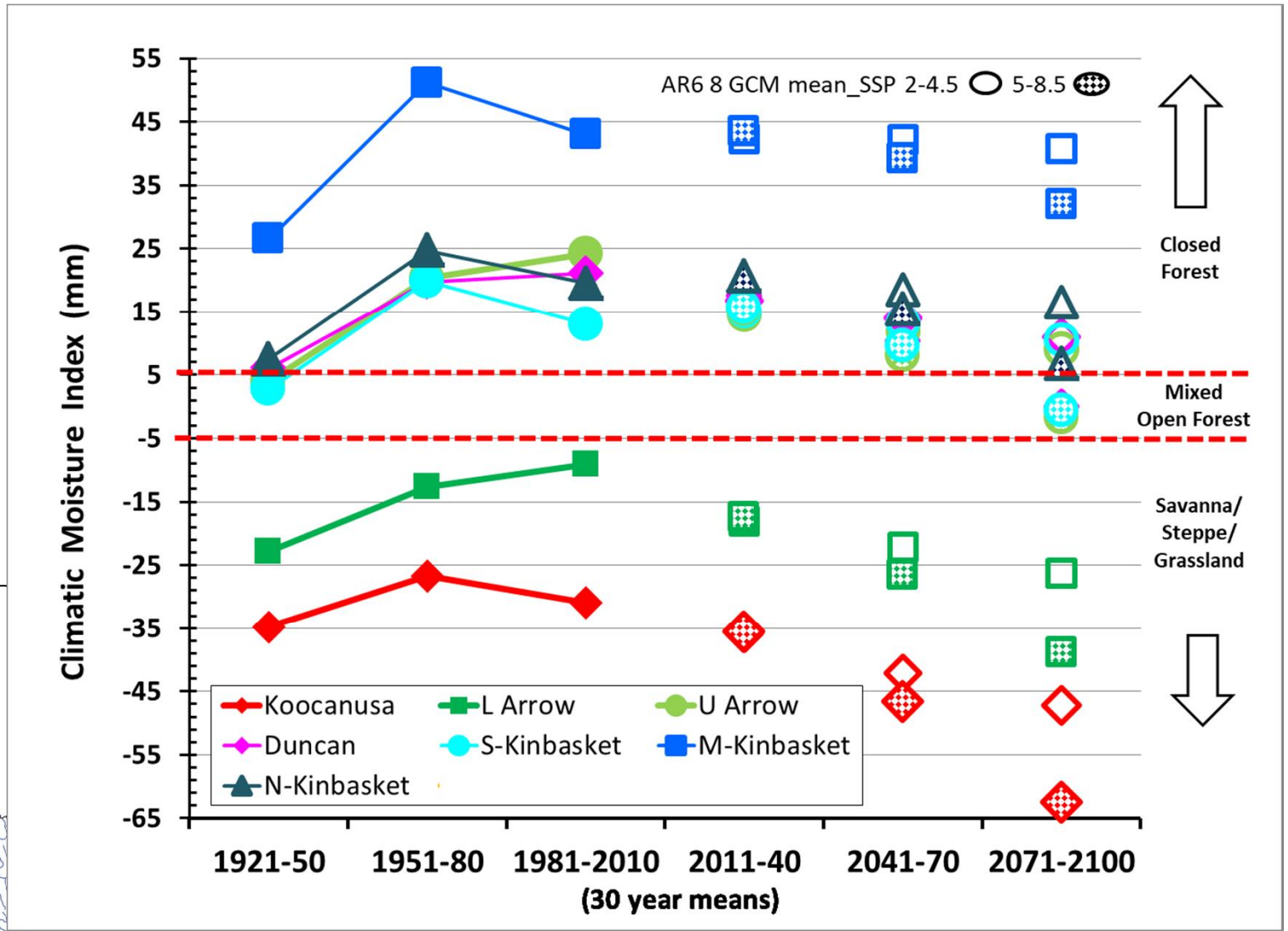
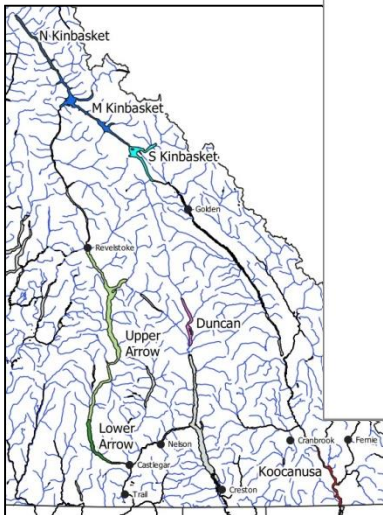
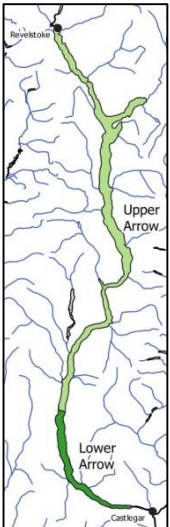
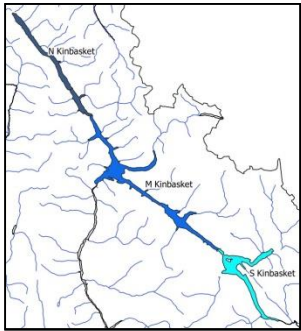
Historical Inflows
and Projected Inflows
WET CanESM2
DRY HadGEM2Es

AR5: rcp8.5
Under AOP22++

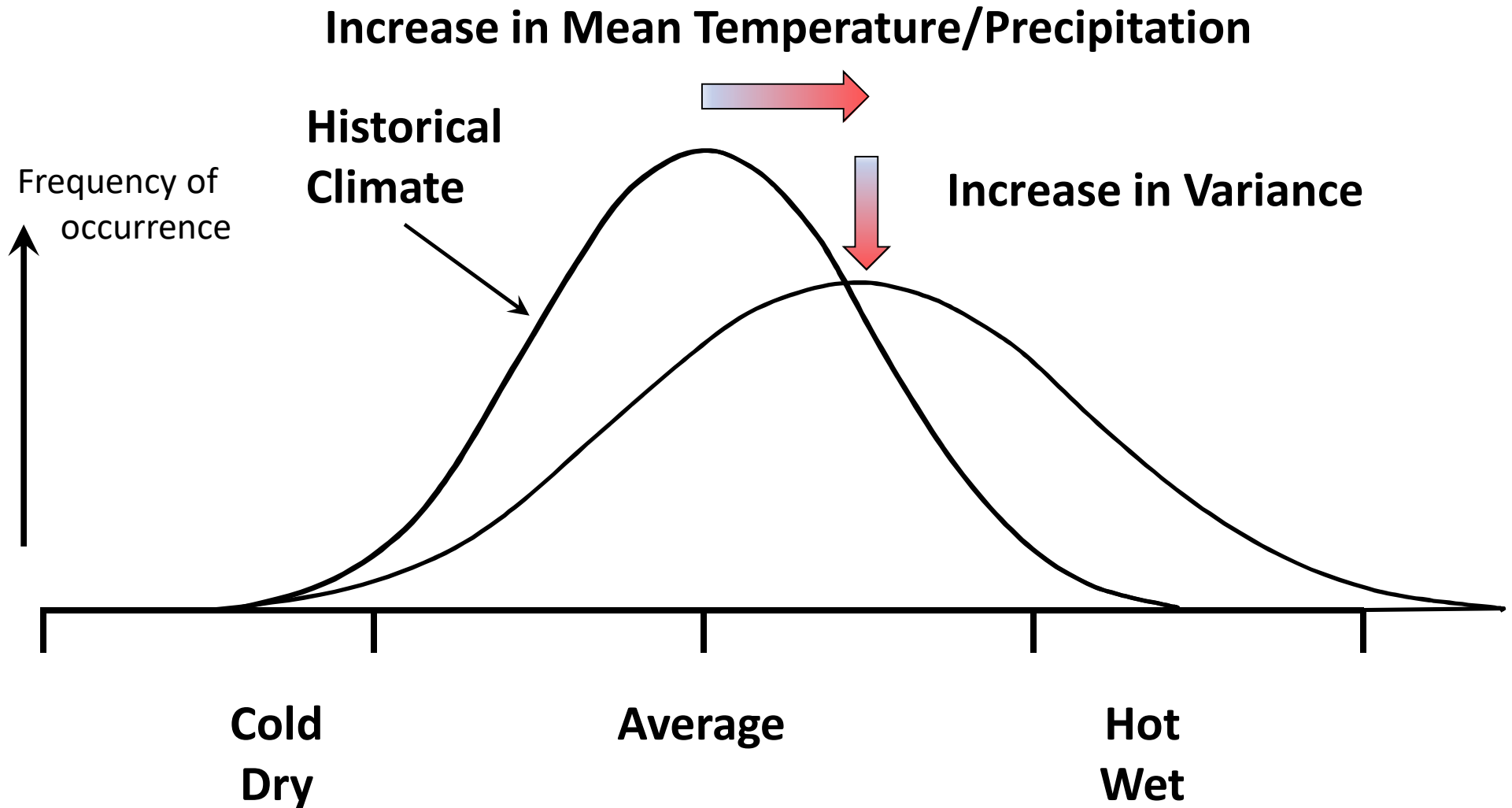
Earlier peaks
Higher extreme peaks
Higher average peaks
Decreased low flows



Projected Changes in Climatic Moisture Index by Reservoir/ Reservoir Subregion

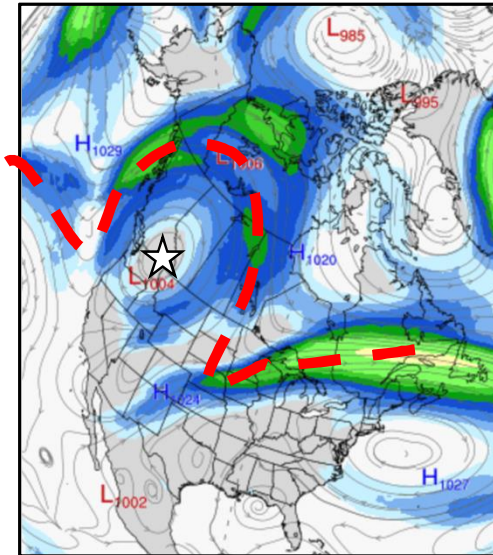


Global Warming or Climate Disruption?

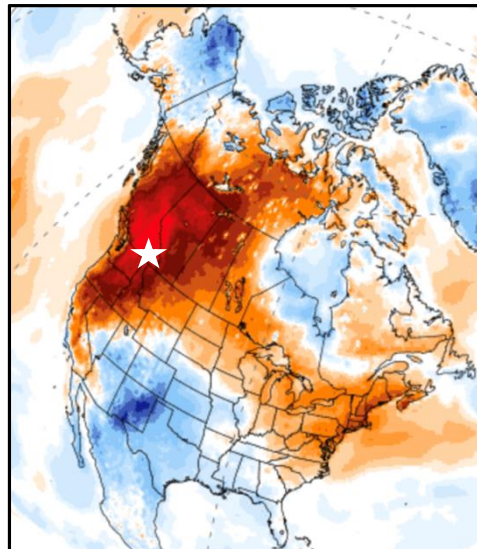
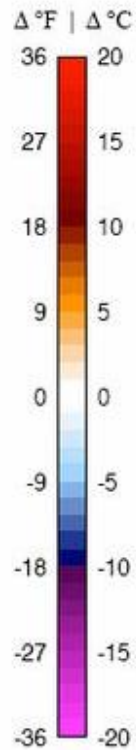


Adapted from: Reasoner 2012

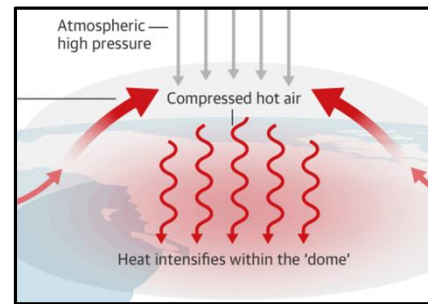
BC Extreme Heat/ Fire 2021



Late June 2021

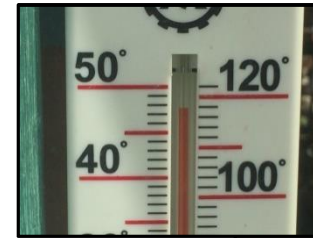


Jet Stream Configuration

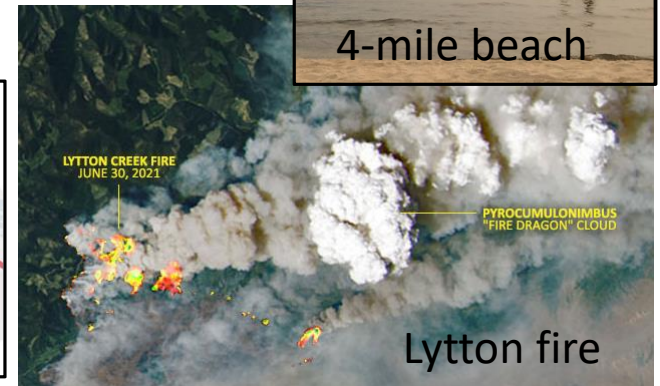


Heat Dome

Temperature Anomaly Compared to 1979-2000 Average



4-mile beach



Lytton fire

Attribution analysis:

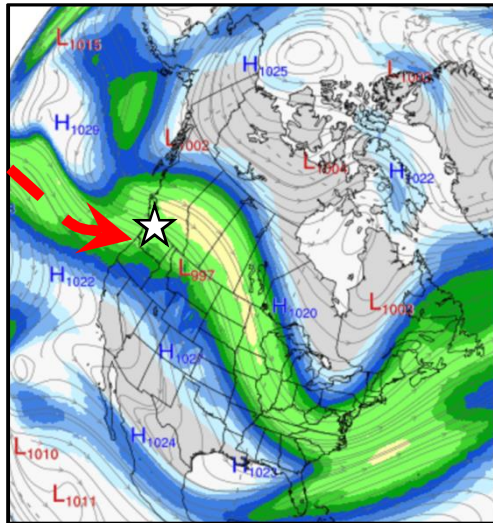
- “ 1 in 1000 year event but 150 times more likely with climate change
- “ with 2°C warming – every 5-10 years by 2050

Images from Climate Reanalyzer, Climate Change Institute, U of Maine, USA <http://cci-reanalyzer.org>

Other Sources: Sjoukje et al. 2021; NASA Earth Observatory; The Guardian.

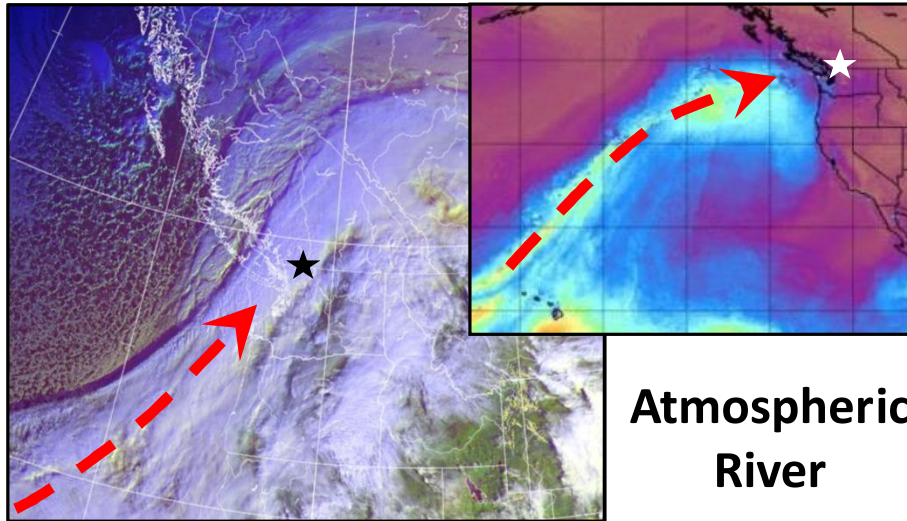
G. Utzig, P. Ag. 2/10/22 Kutenai Nature Investigations Ltd.

BC Extreme Precipitation 2021



November 15, 2021

November 13, 2021

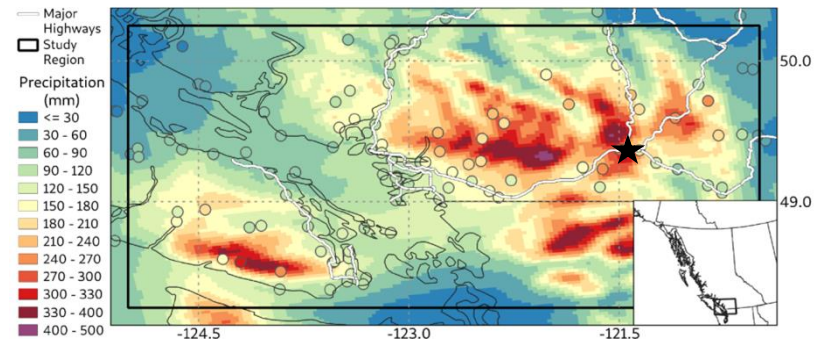


Atmospheric River

Jet Stream Configuration
Mid November



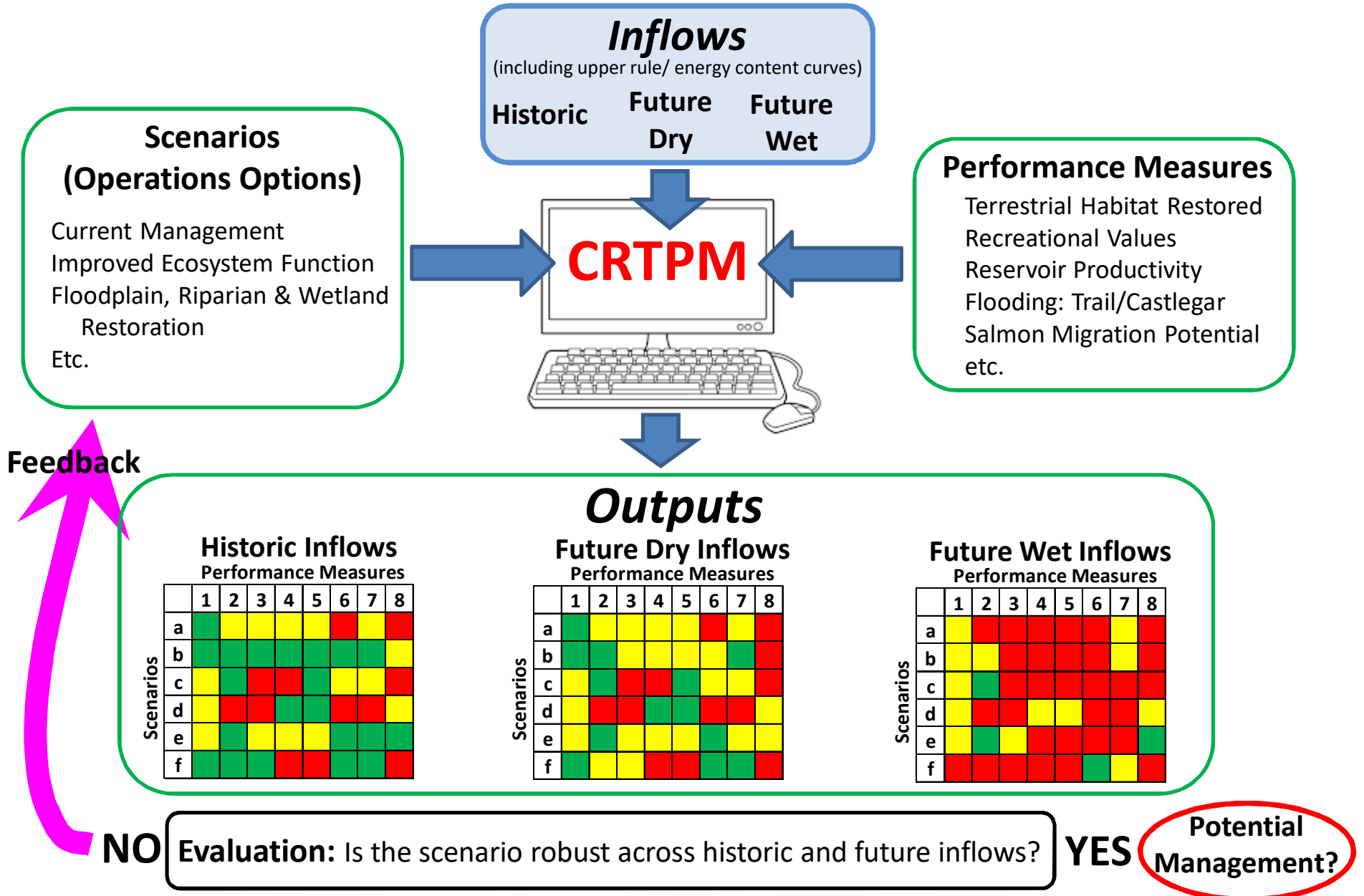
Precipitation Nov. 14-15



Attribution analysis – with climate change:

- “ atmospheric river of this magnitude 1 in 10 year event but 60% more likely
- “ 2-day precipitation 1 in 50-100 year event but 50% more likely
- “ extreme streamflow 2 to 4 times more likely
- “ wet soils and rain-on-snow also contributed

Climate Change Inflow Applications



Climate Change “take-aways” #1

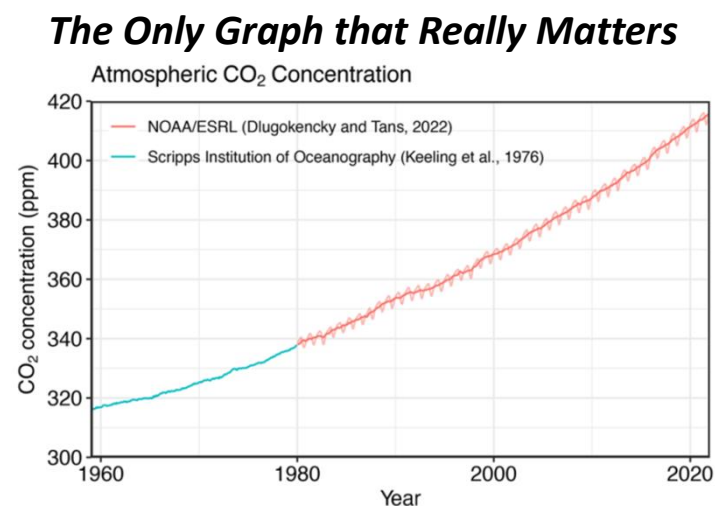
Climate Change is Happening

- “ Changes in seasonality in all projections: drier summers, wetter other seasons, less snow/ more rain, earlier snowmelt
- “ Annual inflow projections vary: wet scenario projects significant annual increases, while dry scenario has minor increases
- “ “Stationarity” is dead, changes will increase over time (hotter/wetter/drier as time proceeds)
- “ Rapidly reducing our GHG emissions could reduce future impacts – especially loss of snow and the frequency and magnitude of future flooding

Climate Change “take-aways” #2

Scenario Evaluation

- “ CRTPM analyses will include climate change projections to assess the resilience of operations scenarios to projected future conditions (i.e. a “stress test”)
- “ Most projections do not capture extreme events well so looking at more extreme projections is wise



From: Friedlingstein 2022

Planning and Operations

- “ Potential for increased flood risk
- “ Increased inflow variability will make planning more complicated and seasonal operations more variable
- “ Embrace uncertainty – expect the unexpected