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ENVIRONMENT & ENGINEERING

WaterTech 2012
Assessing the Hydrologic Impacts of Climate Change

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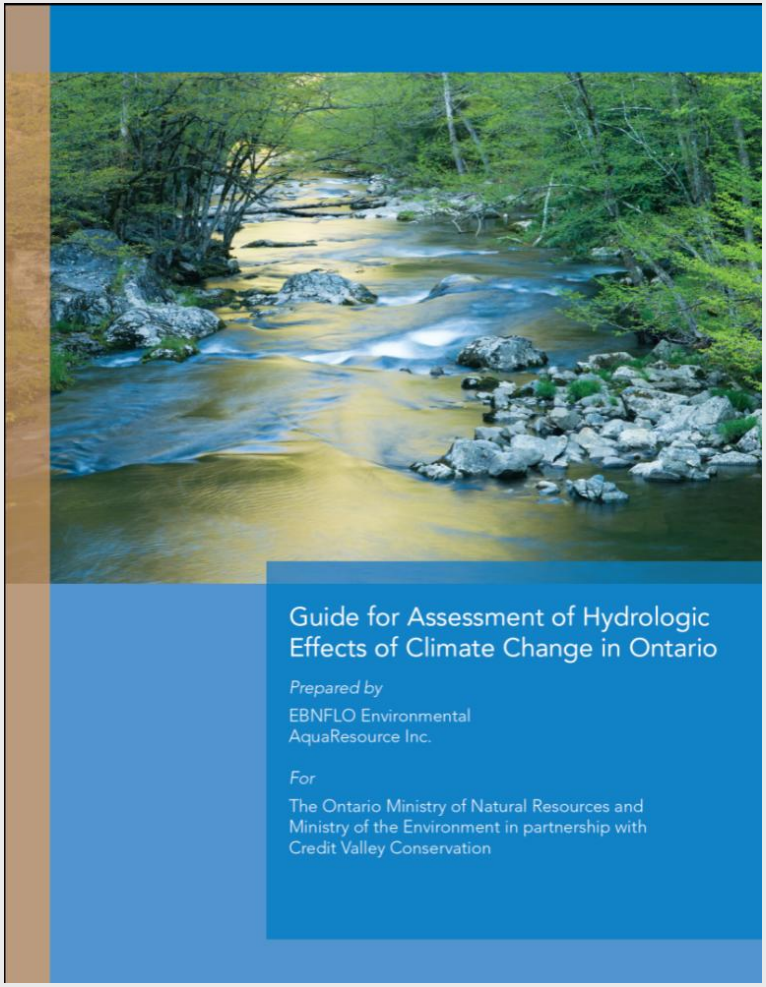
Introduction

- Hydrologic impact assessments are increasingly being required to consider climate change
  - How?
- Ontario Ministry of Natural Resources initiated a project to bridge a gap between climate science and water resources practitioners
  - Summarize climate science as it relates to hydrology
  - Develop a methodology that would assist in understanding the impacts of climate change on hydrology.
- Document's focus is on adaptation, not mitigation.



Available at www.waterbudget.ca

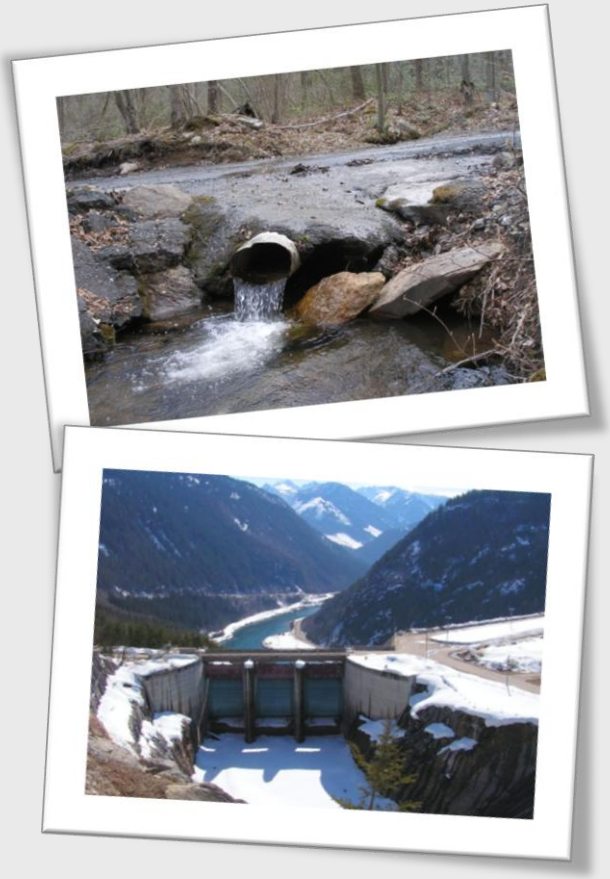
Where Can the Guide Be Applied?

The guide targets hydrologic impact and water resource studies; examples include:

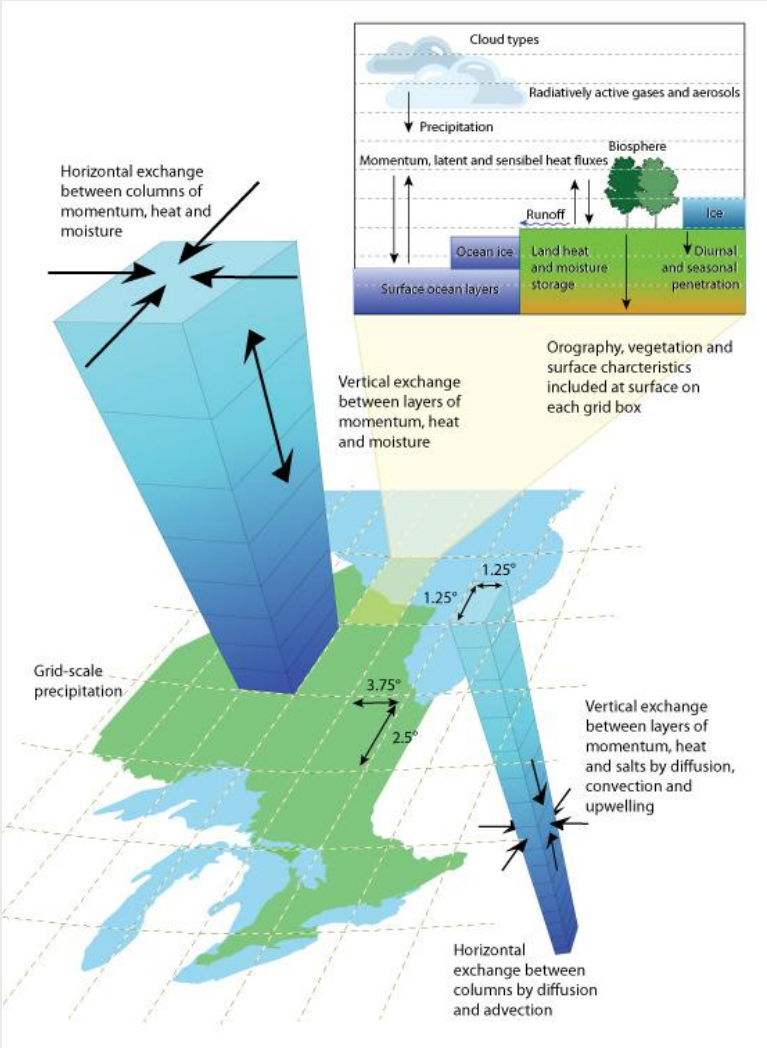
- Environmental Impact Assessments
- Water Supply Sustainability Investigations
- Water Taking/Licensing Applications
- Watershed/Subwatershed studies
- Master Drainage Plans
- Water Management Plans
- Planning and infrastructure strategies

The Guide does not

- Provide insight into future peak flows



Introduction to Global Climate Models



- Global Climate Models (GCMs) represent the atmosphere, oceans, and land surfaces in a three dimensional grid matrix.
- GCMs are models that account for the movement and transformation of moisture and energy throughout air, land and water domain
- Extremely large scale models
- Emission scenarios are combined with GCMs to predict future climate conditions

Global Climate Models

- Global Climate Models are like opinions …….. everybody has one

Country	Model ID
Australia	CSIRO-Mk3.5
Canada	CGCM3.1(T47)
China	BCC-CM1
China	FGOALS-g1.0
France	IPSL-CM4
France	CNRM-CM3
Germany	ECHAM5/MPI-OM
Germany / Korea	ECHO-G
Italy	INGV-SXG
Japan	MIROC3.2(hires) / (medres)
Japan	MRI-CGCM2.3.2
Norway	BCCR-BCM2.0
Russia	INM-CM3.0
UK	UKMO-HadCM3/HadGEM1
USA	GISS-AOM / GISS-EH / GISS-ER
USA	CCSM3 / PCM
USA	GFDL-CM2.1

IPCC Guidance on Model Selection

"Our understanding of climate is still insufficient to justify proclaiming any one model "best" or even showing metrics of model performance that imply skill in predicting the future.

More appropriate in any assessments focusing on [climate change] adaptation or mitigation strategies is to take into account, in a pertinently informed manner, the products of distinct models built using different expert judgements at centers around the world"

Bader et al., 2008

Emission Scenarios

IPCC Special Report on Emission Scenarios (SRES) published the most recent GHG emission scenarios in 2000. The SRES scenarios incorporate:

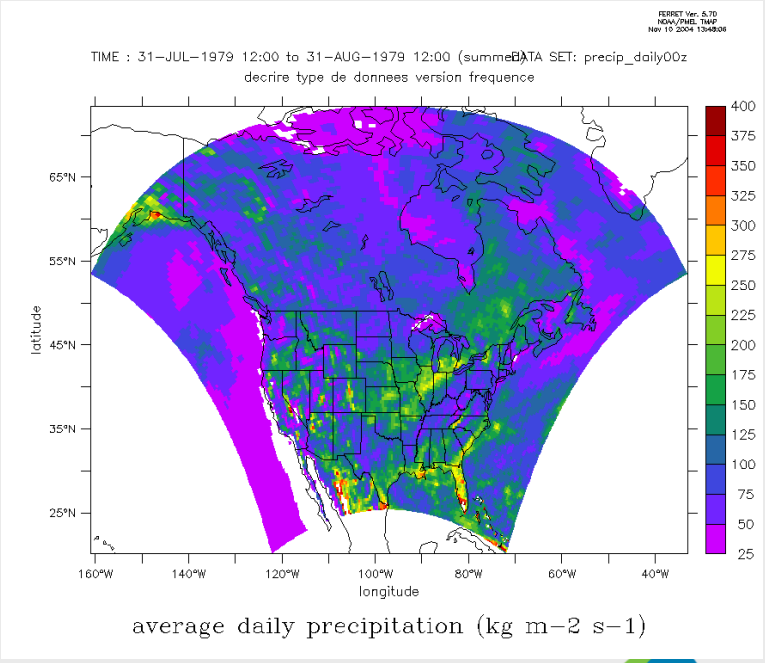
- Five storylines (A1T, B2, A1B, A2, A1F1) or “futures” each characterized by different GHG and sulphur emission rates
- Developed based on alternative future demographics, economic development, environmental considerations, technological advancement and governance models.

How Accurate are Global Climate Models?

High Confidence	Low Confidence
Confident that average annual temperature will increase.	It is difficult to project changes in the temporal variability of temperature and precipitation.
Changes in average annual precipitation are generally confident.	More extreme events (e.g., drought, storms) are expected but not readily quantifiable by climate models.
Good understanding of historical climate and climate variability and can assume that future seasonal trends are likely to continue.	Local land and water features have a profound effect on local climate and these are not well represented in predictive models.

Downscaling

- GCM output must be downscaled to allow the consideration of local-scale processes that affect climate
- Change Field/Delta Approach
  - Applies relative monthly changes in future climate to existing climate data
- Statistical Downscaling
  - Uses existing relationships between large scale climate variables and temperature/precip to predict future climate
- Weather Generators
  - Replicates the statistical sequence of the local climate
- Regional Climate Models
  - Higher resolution models (spatially & temporally) nested within GCMs

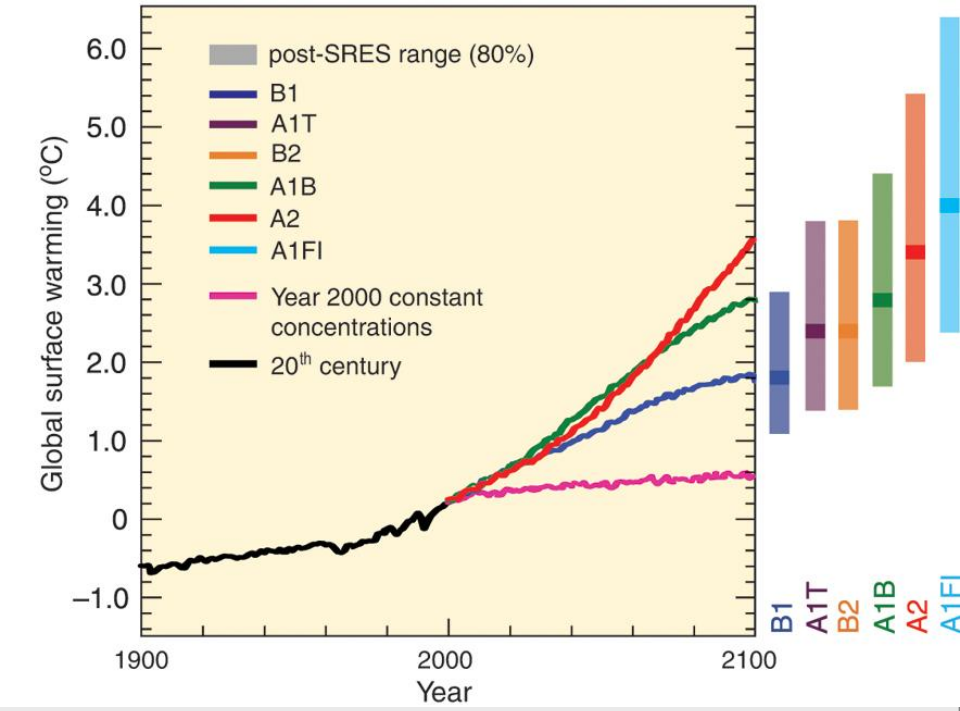


Water Resource Impacts

- Impacts of climate change on hydrology not certain.
  - Possible increase in floods
    - BUT, lower snowpack, possible smaller spring snowmelt
  - Decreased water levels due to increased evapotranspiration
    - BUT, higher recharge in winter, possible higher groundwater levels
- Need hydrologic modelling tools to assess and quantify impacts

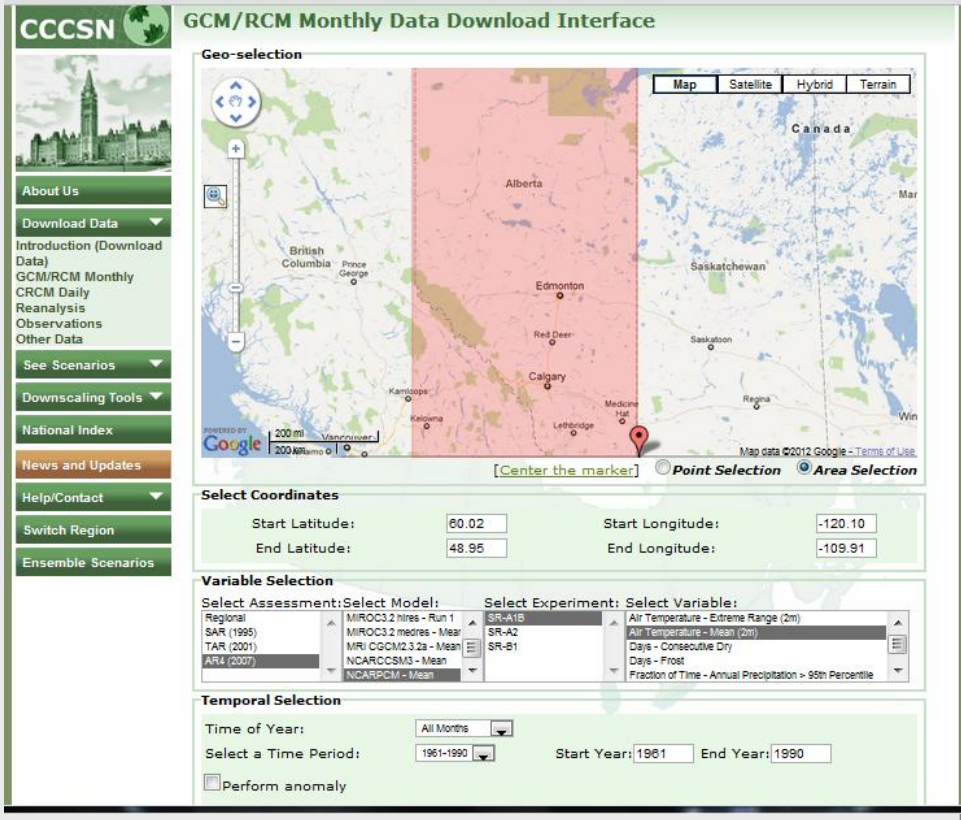
Impact Assessment

- In typical assessments, land use changes are usually well defined and certain
- Not so with climate change
  - Multiple Global Climate Models
    - 21 Models
  - Multiple emission scenarios
    - Up to 5
- Many possible "future climates"
  - All give different results
  - Which one to use?

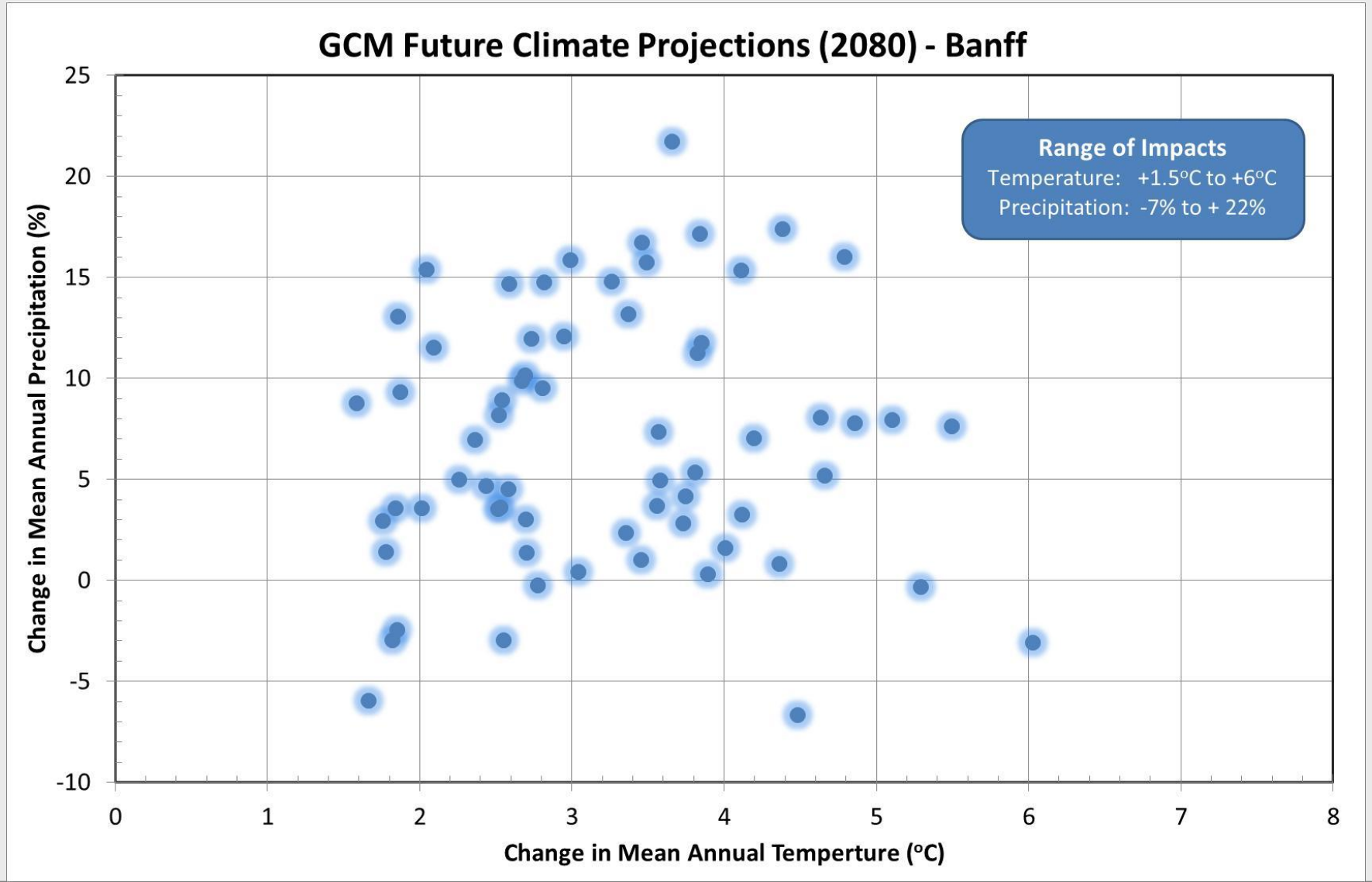


Future Climate Projections

- Environment Canada has consolidated GCM output
- Developed a data distribution website
  - cccsn.ca.
- Output from most GCMs available for download



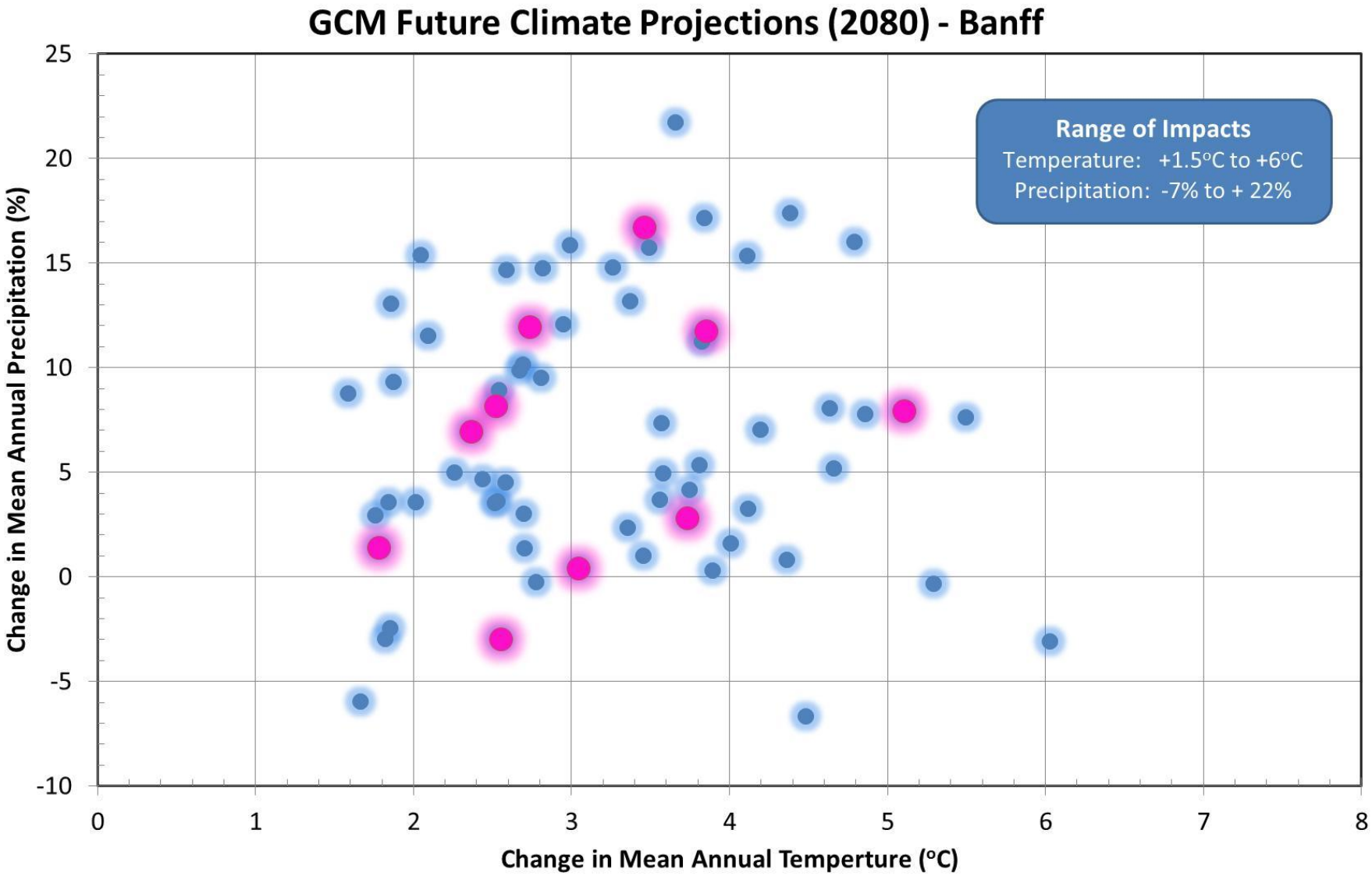
Future Climate Projections



Guide's Suggestion for Selecting Future Climates

- A single scenario is not sufficient
- Recommend multiple scenarios downscaled using Change Fields
  - Aim to sample the range of "possible futures"
- Select scenarios using "Percentile Approach"
  - Rank all future scenarios by mean annual change in Temperature
  - Select the 5th, 25th, 50th, 75th, 95th percentiles for analysis
  - Repeat for Precipitation
- Where possible, also consider other downscaling methodologies

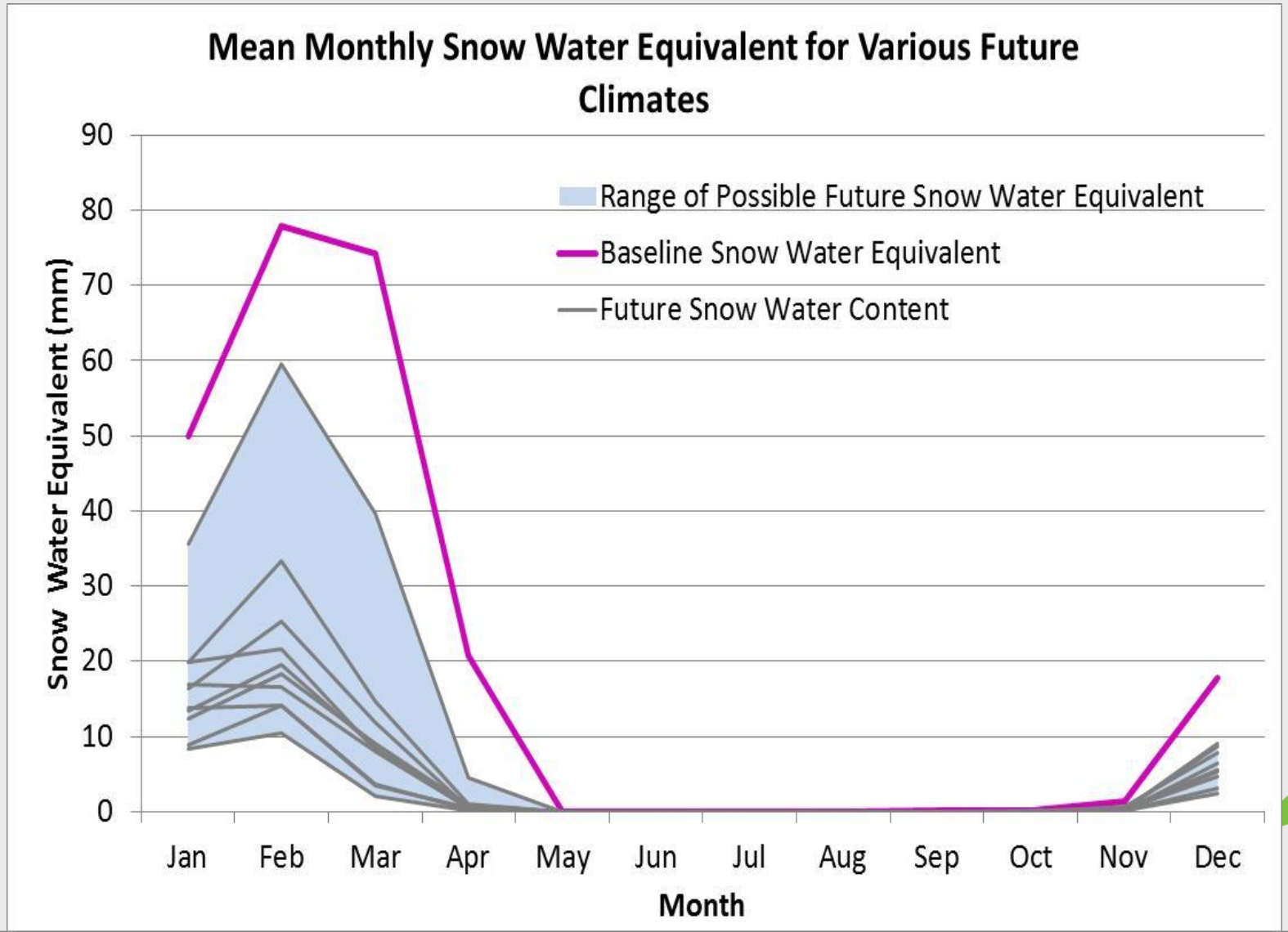
Climate Selection - Percentiles



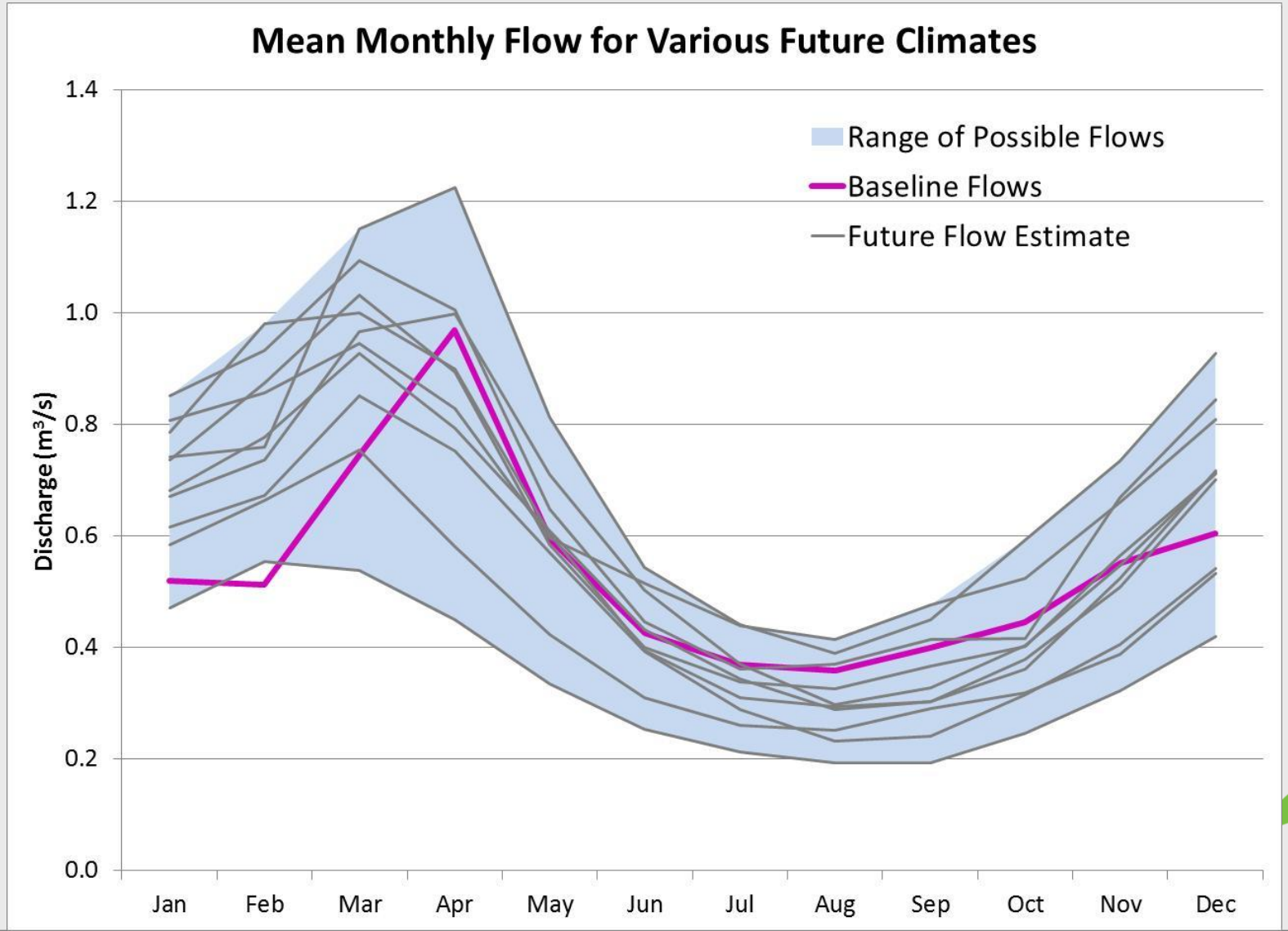
Impact Assessment

- Assessing climate change impacts is similar to other impact assessments
  - Change is adjusted climate datasets
- Utilize a hydrologic model to estimate hydrologic impact caused by shifted climate datasets
- Due to uncertainty associated with future climate projections, modeller must adapt to reporting a range of impacts.

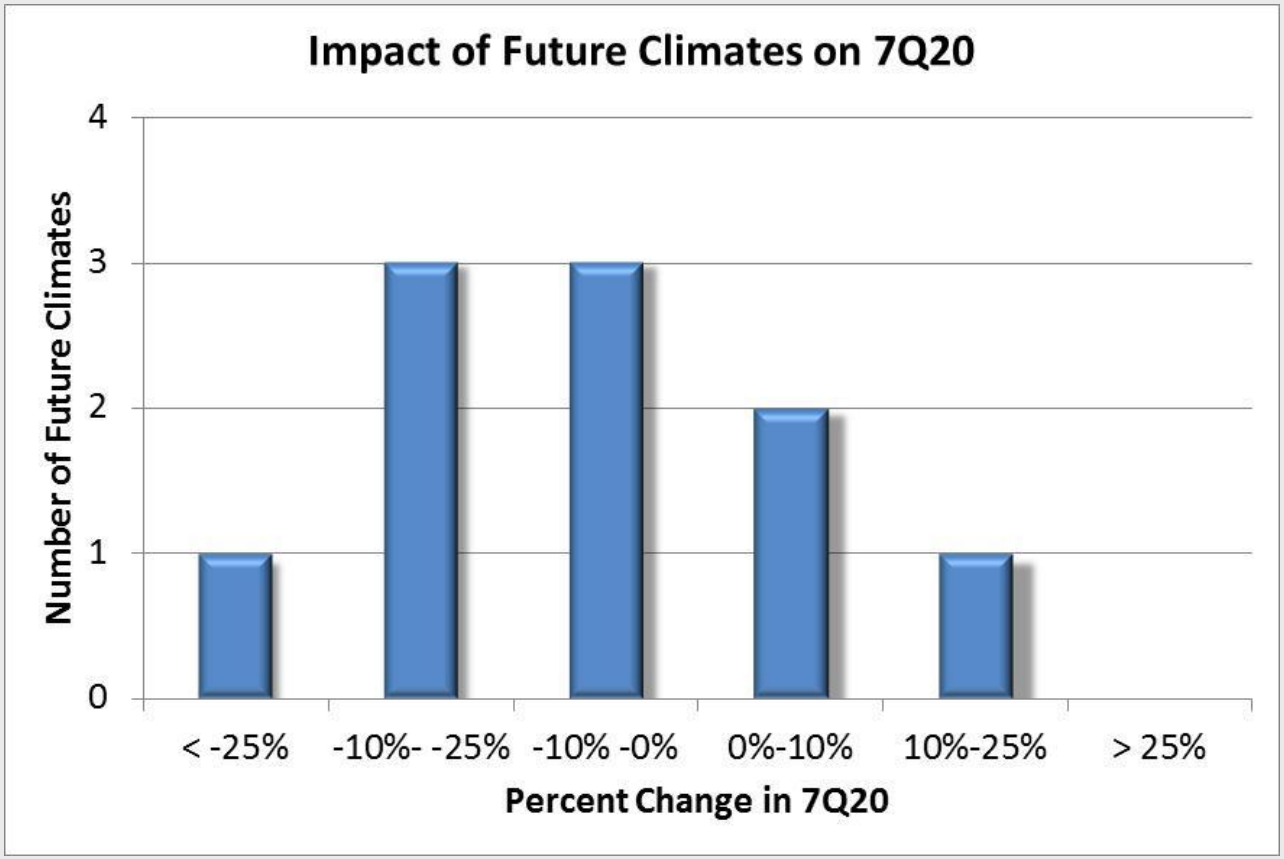
Snow Water Equivalent



Streamflow


Mean Monthly Flow for Various Future Climates
Range of Possible Flows
Baseline Flows
Future Flow Estimate
Discharge (m³/s)
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

Streamflow Statistics - 7Q20



- Range of possible impacts ±25%
- 7 out of 10 scenarios predict a reduction in 7Q20

Outstanding Questions

- Intensification of precipitation events
  - Frequency and magnitude shifts
- Inter-event duration (days between measurable rainfall events)
  - If, and how, does it shift
- Can the range of future climates be reduced?
  - Are some Global Climate Models better than others?

Thank you!

- Acknowledgements
  - Mike Garraway – Ontario Ministry of Natural Resources
  - David Van Vliet – Matrix Solutions
  - Bob Walker – EBnFLOW
  - Linda Mortsch – Environment Canada

Questions?