Climate Change for the Engineer: Standardized Procedure for Climate Change Integration into Engineering Design

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Saskatchewan Mining Association 45 Years

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What this Talk is About

- Climate change…for the Engineer…by the Engineer
- Real data…real facts… no motherhood statements
- Description of SRK's Standardized Procedure for Climate Change Integration into Engineering Design

The Engineer's Conundrum

- General consensus
  - Climate change is occurring
  - Engineering design should consider climate change
- No consensus
  - Which climate change prediction methods is best
  - How to consider climate change in engineering design

Current Best Practice

- New policies and guidelines developed all the time – none useful or practical to engineer
- Every engineering association has climate change policy or guideline – none useful or practical to engineer
- Some procedures has useful content
  - 1998 Environmental Adaptation Research Group (EARG) Climate Change Impacts on Permafrost Engineering Design
  - 2011 Public Infrastructure and Engineering Vulnerability Committee (PIEVC). Engineering Protocol for Climate Change Infrastructure Vulnerability Assessment

"…Engineers, under their professional code of ethics, need to be involved in addressing the impacts of changing climate on infrastructure design and operations because it affects public safety and public interest."

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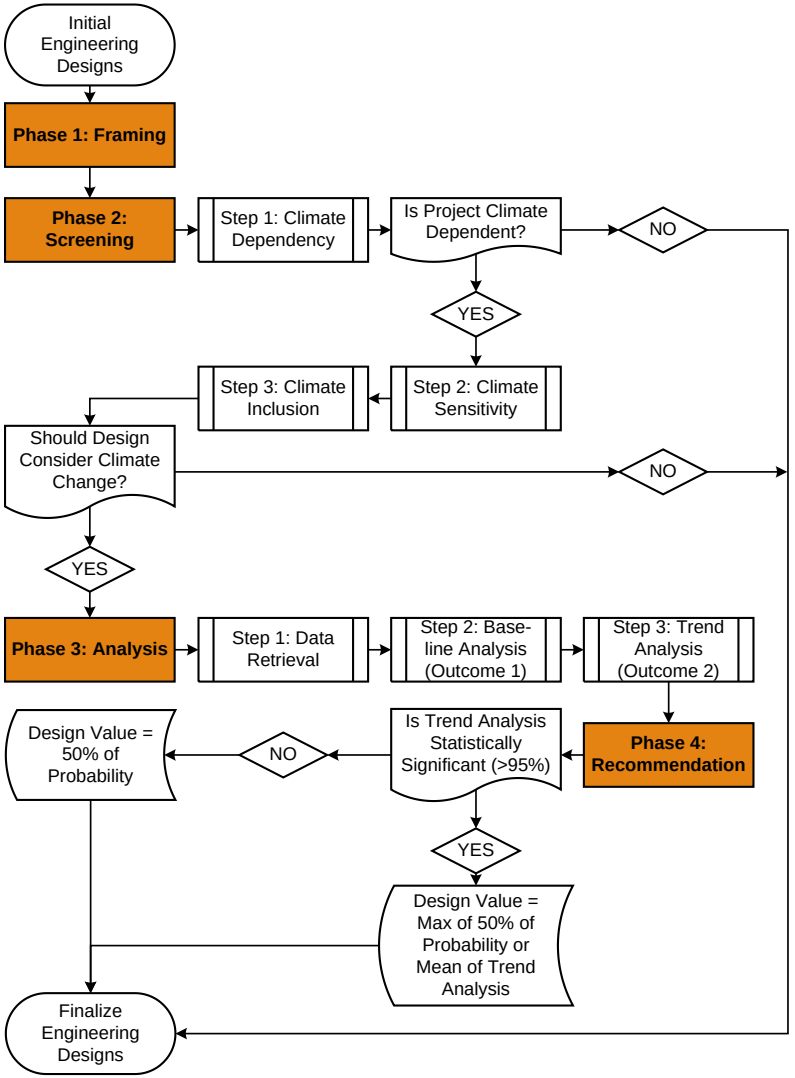
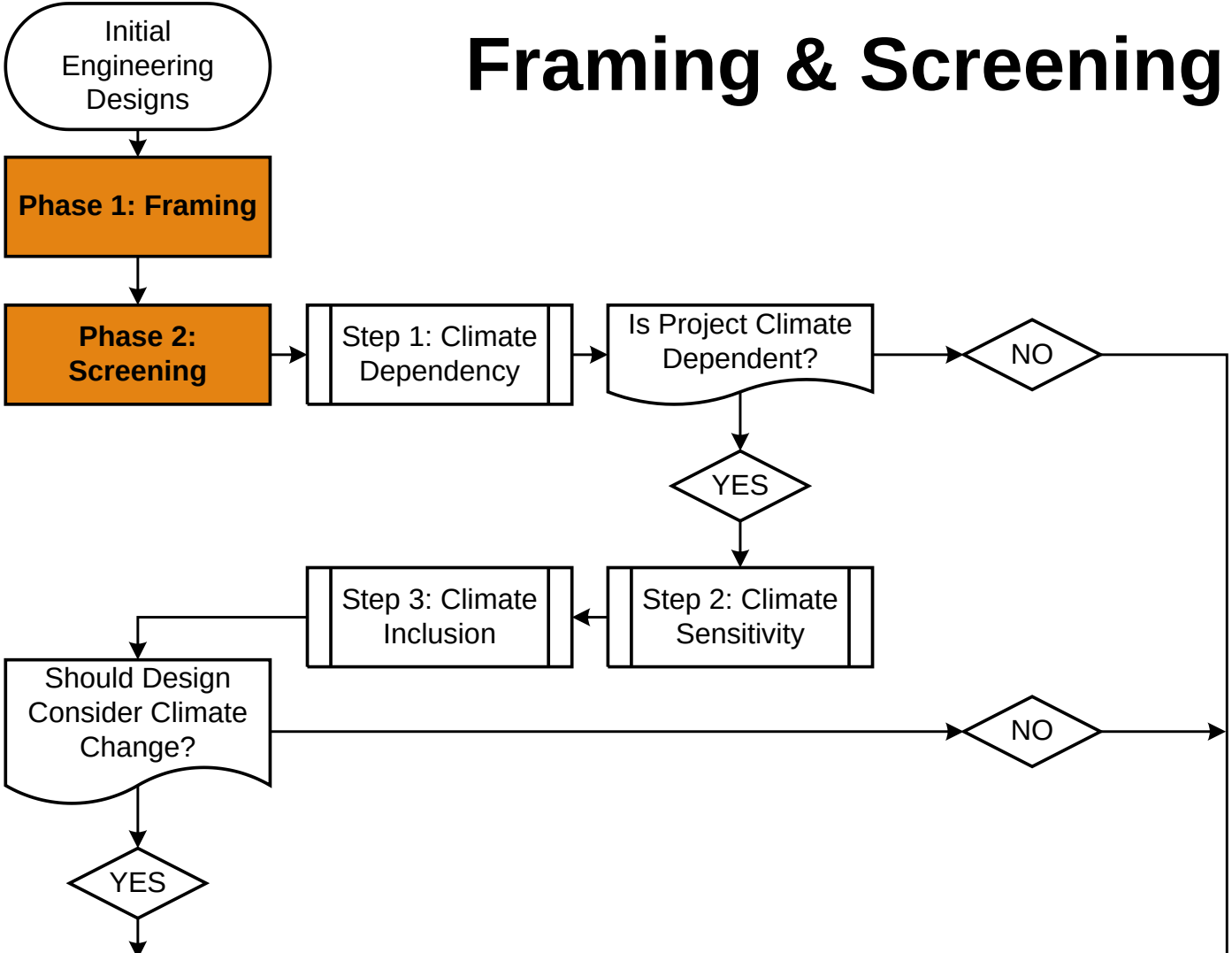
The Solution

Standardized Procedure for Climate Change Integration into Engineering Design

Developed by srk consulting



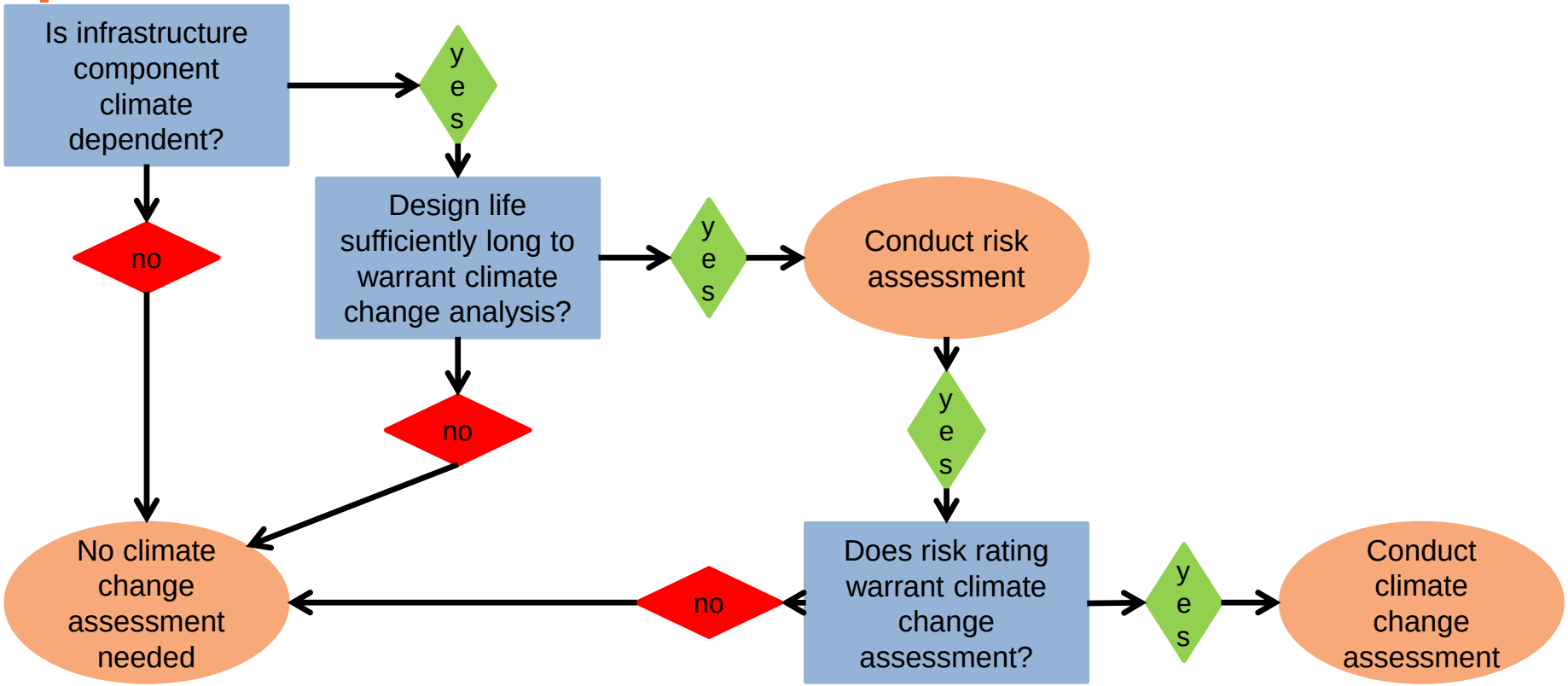
Framing & Screening



Establishing Climate Dependency

- Break each infrastructure element down into individual design components, e.g.
  - Dam = Key Trench + Core + Filter + Shell + Freeboard
- Confirm design life – consider all phases from construction to post closure
- Assess which design components are climate dependent, e.g.
  - Dam freeboard = subject to wind speed

Need for Climate Change Assessment



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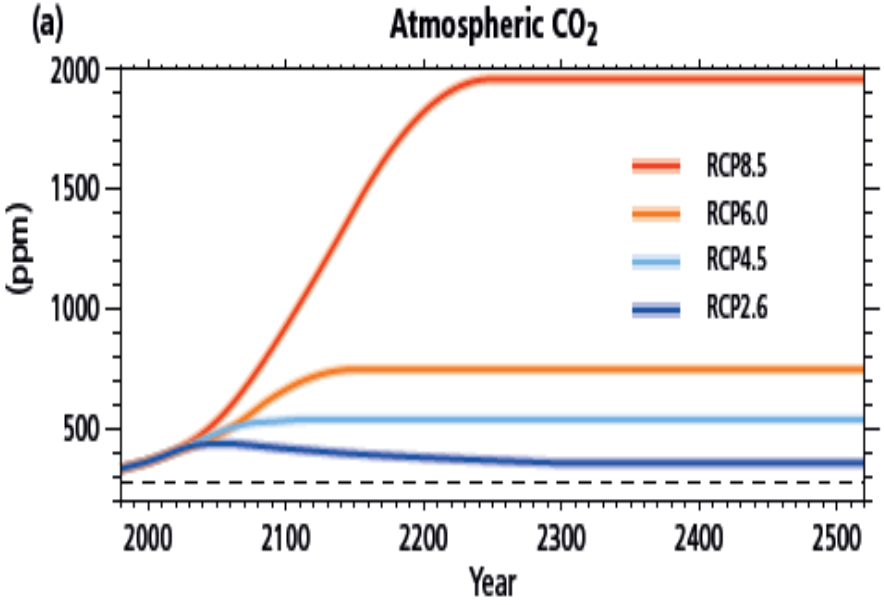
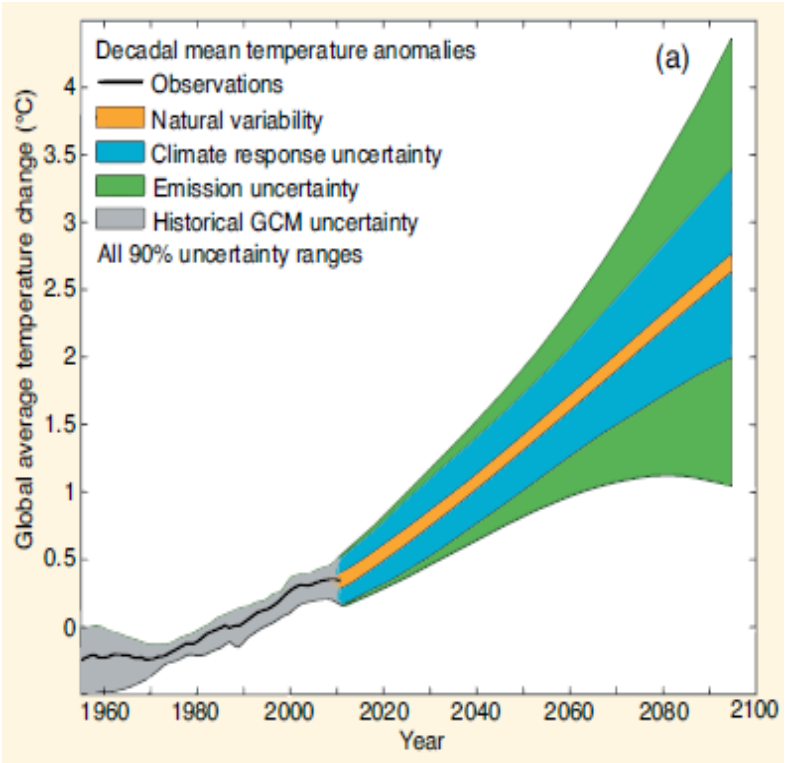
Forecasting Timespan

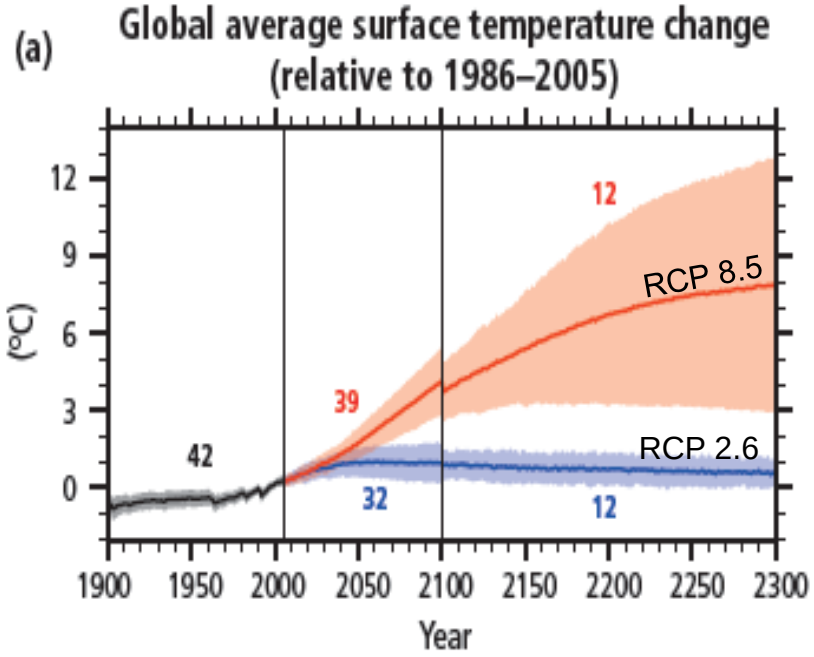


CO_2 projections based on RCPs from historical values to year 2500; extracted from IPCC (2014)



Variability associated with global temperature (IPCC 2013)

Forecasting Timespan

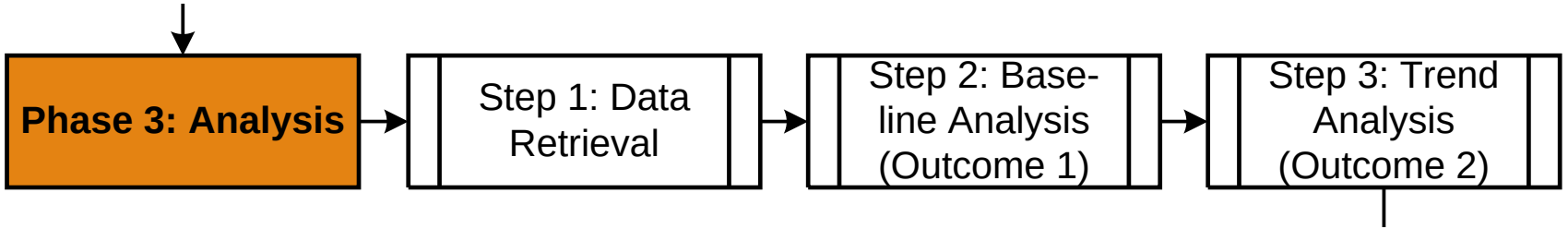


Available models for the period up to year 2300
IPCC (2014)

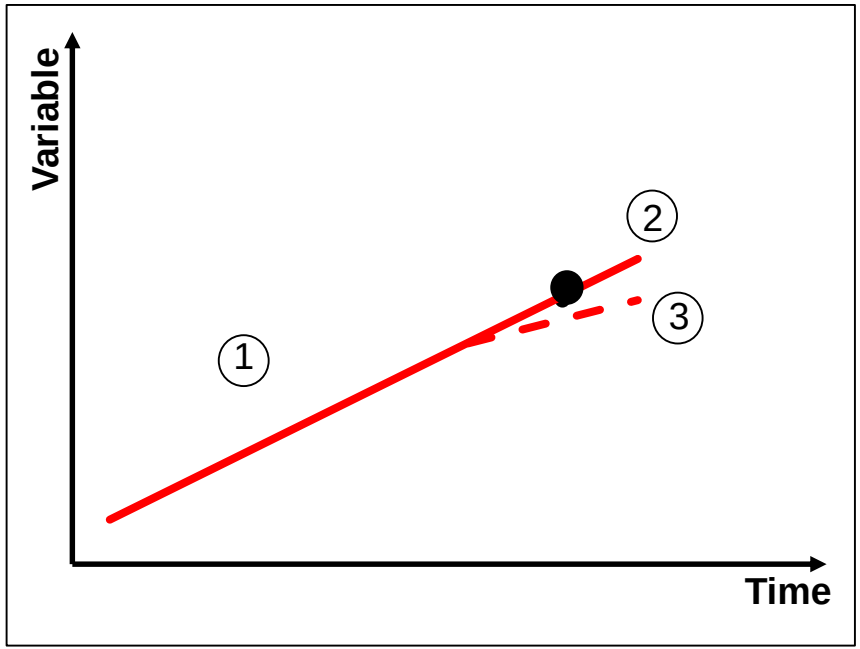
- Climate change predictions beyond year 2100 has extreme uncertainty
- Environment Canada only presents data to year 2100 based on all ARs for all models
- Currently the maximum reasonable time frame to which to extend climate change prediction is year 2100

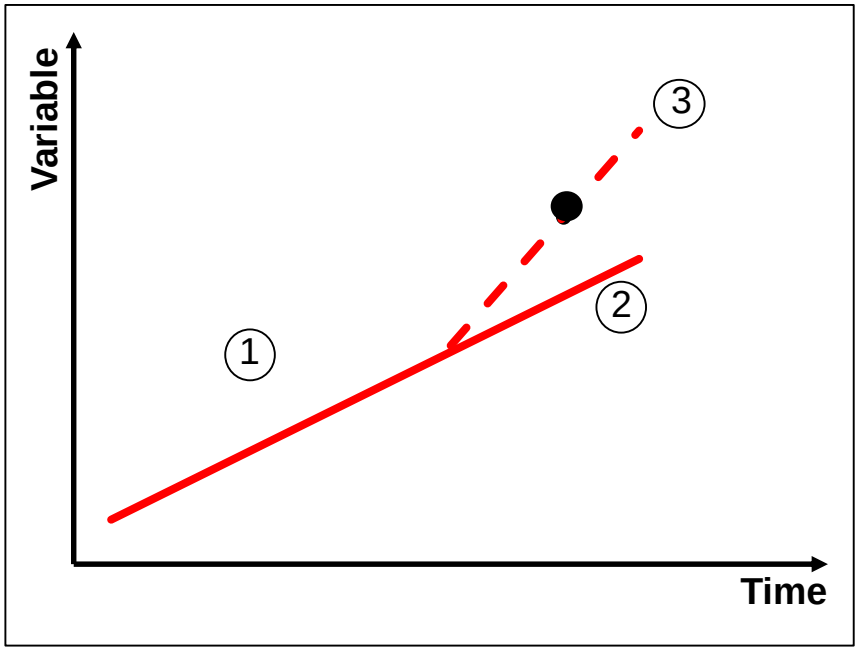
Approach to Climate Change Analysis

- Data Retrieved
  - Models from all 5 Assessment Reports – ECCC website
  - Baseline climate data supplemented with reanalysis data (ERA Interim)
- Baseline and Trend Analysis
  - Completed with purpose built code using “R” software



Climate Change Trends vs. Models





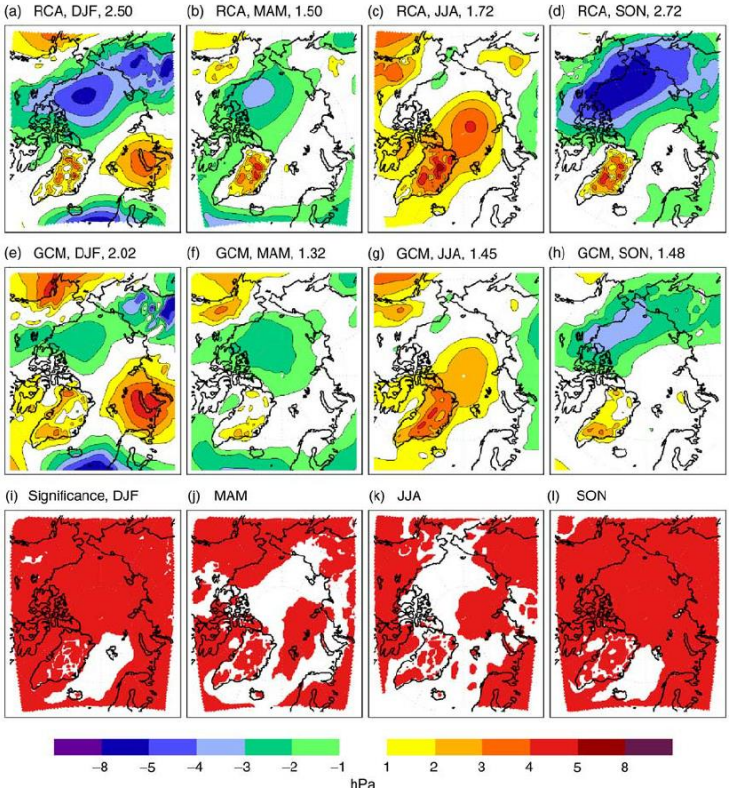
Climate change trends from (1) historical data, (2) forecasted historical trend, (3) climate change models. Black dot represent climate change design value

IPCC Assessment Reports (ARs)

- 5 IPCC reports
- Collectively 100’s of different global climate change models (and scenarios)
- No individual models or scenario is superior over another
- Newer Assessment Report models not more reliable than older ones

Reanalysis Data

- Reanalysis covers entire planet
- Reanalysis more readily available for longer time periods than regional meteorological stations
- When available, regional date are compared with reanalysis data to validate the reanalysis data
- ERA-Interim reanalysis data
  - Spans 1979 to 2016
  - 6-hour time interval
  - based on 0.75° x 0.75° grid



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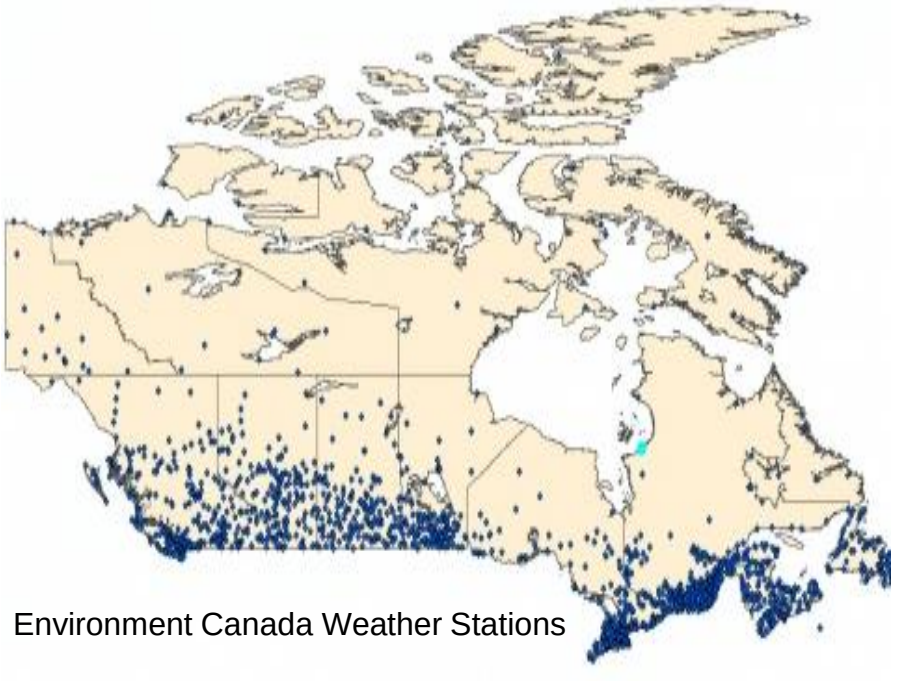
Baseline Analysis

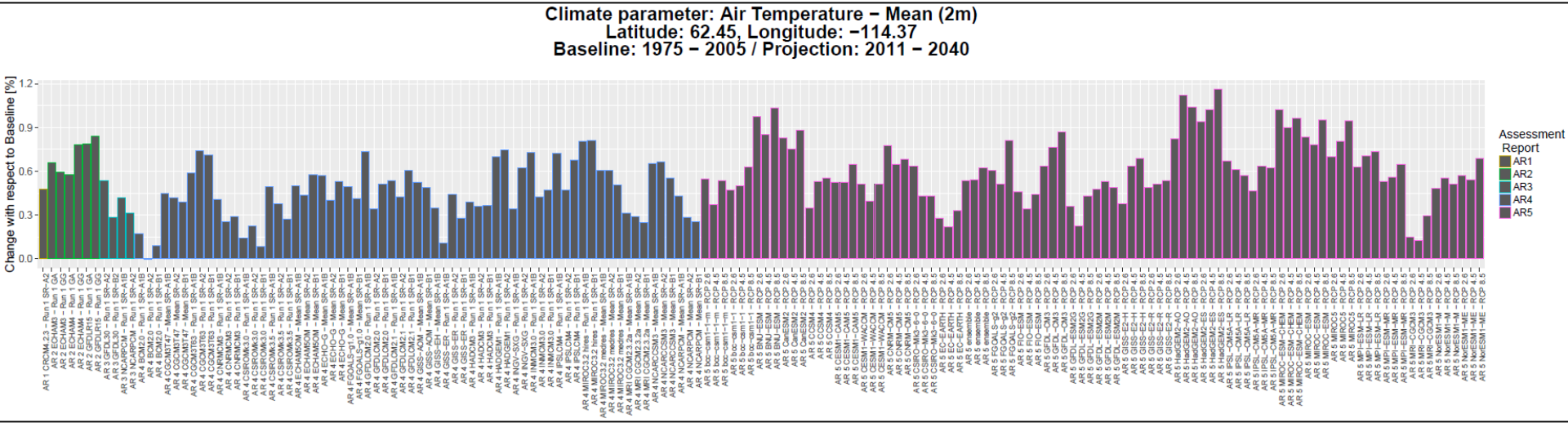
- Climate change projected with respect to set baseline condition spanning at least 30 years (1975-2005)
- Generally accepted as the minimum time period deemed statistically significant
- Assess three projection periods
  - 2011-2040
  - 2041-2070
  - 2071-2100



Environment Canada Weather Stations

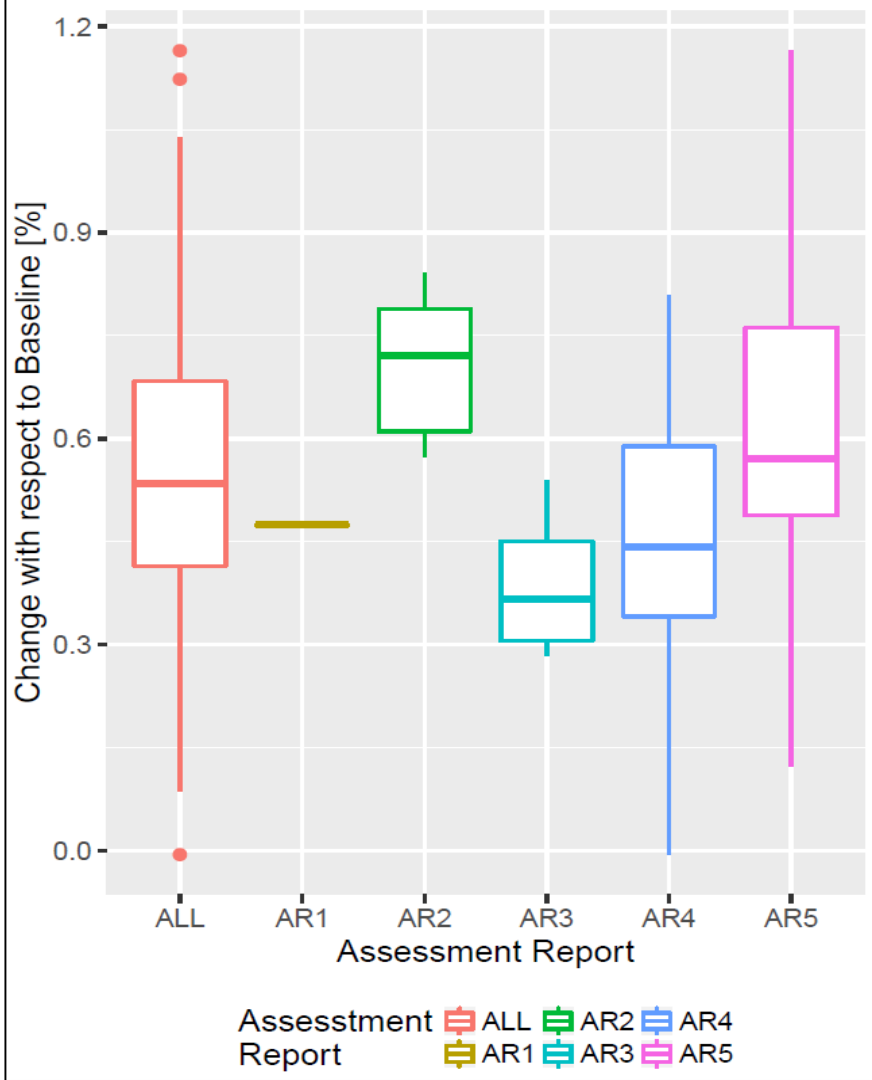
Example Outcome

- Projected air temperature relative to baseline conditions
- Each bar represents individual climate change model or scenario
- Different colors represent each of the five Assessment Reports



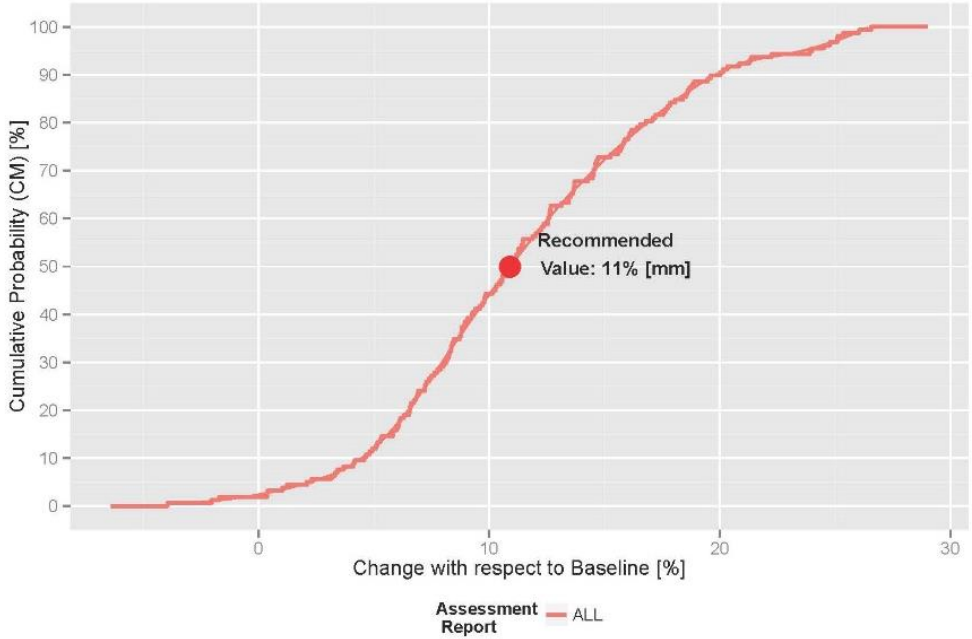
Box-Whisker Plot

- Same data presented as box-whisker plot
- Box centerline represents median value
- Upper and lower borders represent the third and first quartiles, respectively
- Whiskers span maximum and minimum values
- Demonstrates why newer ARs are not better than older ones



Cumulative Probabilistic Curve

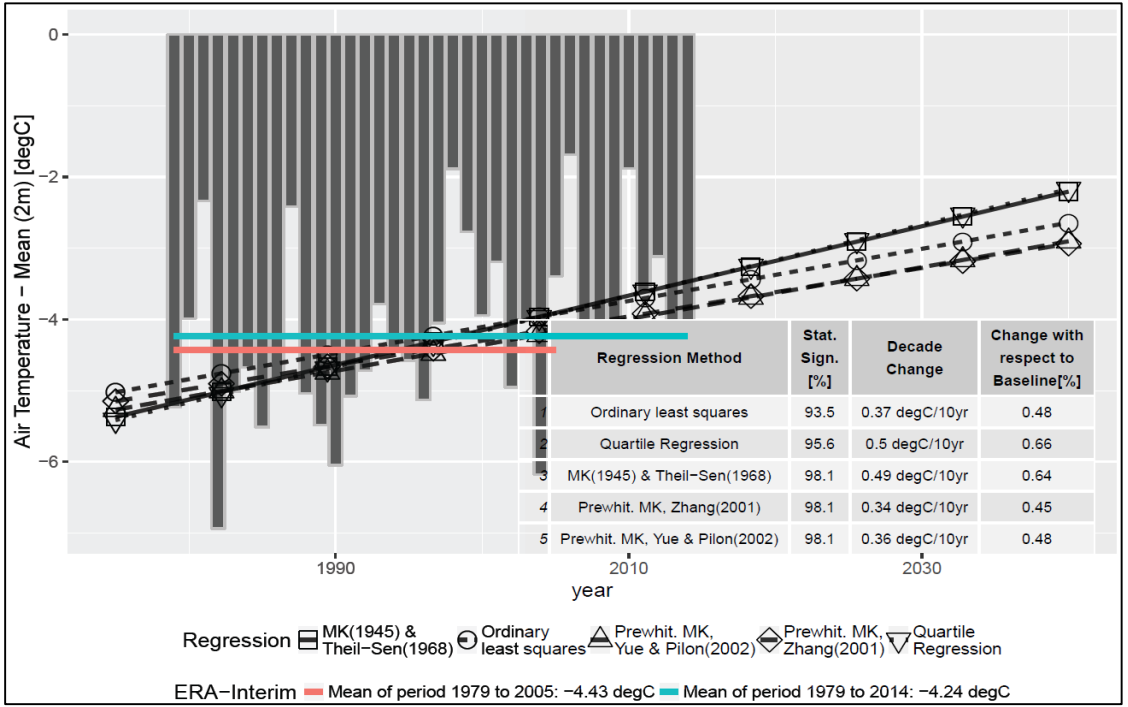
- Only overall cumulative probabilistic curve associated with data from all the available Assessment Reports combined is needed
- All climate change models are equally weighted



Trend Analysis

Trends in reanalysis data assessed using 5 methods

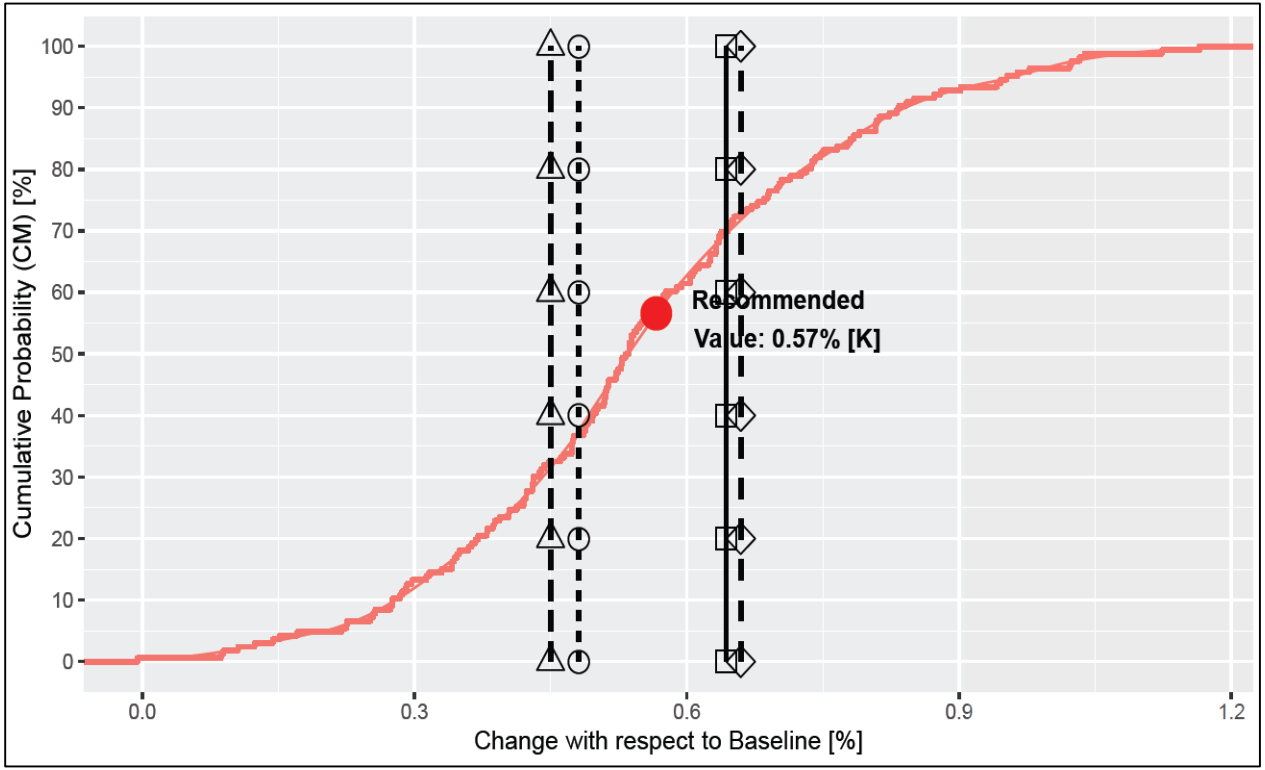
- ordinary least square
- quantile regression
- Mann-Kendall and Theil Sen
- Zhang
- Yue and Pilon



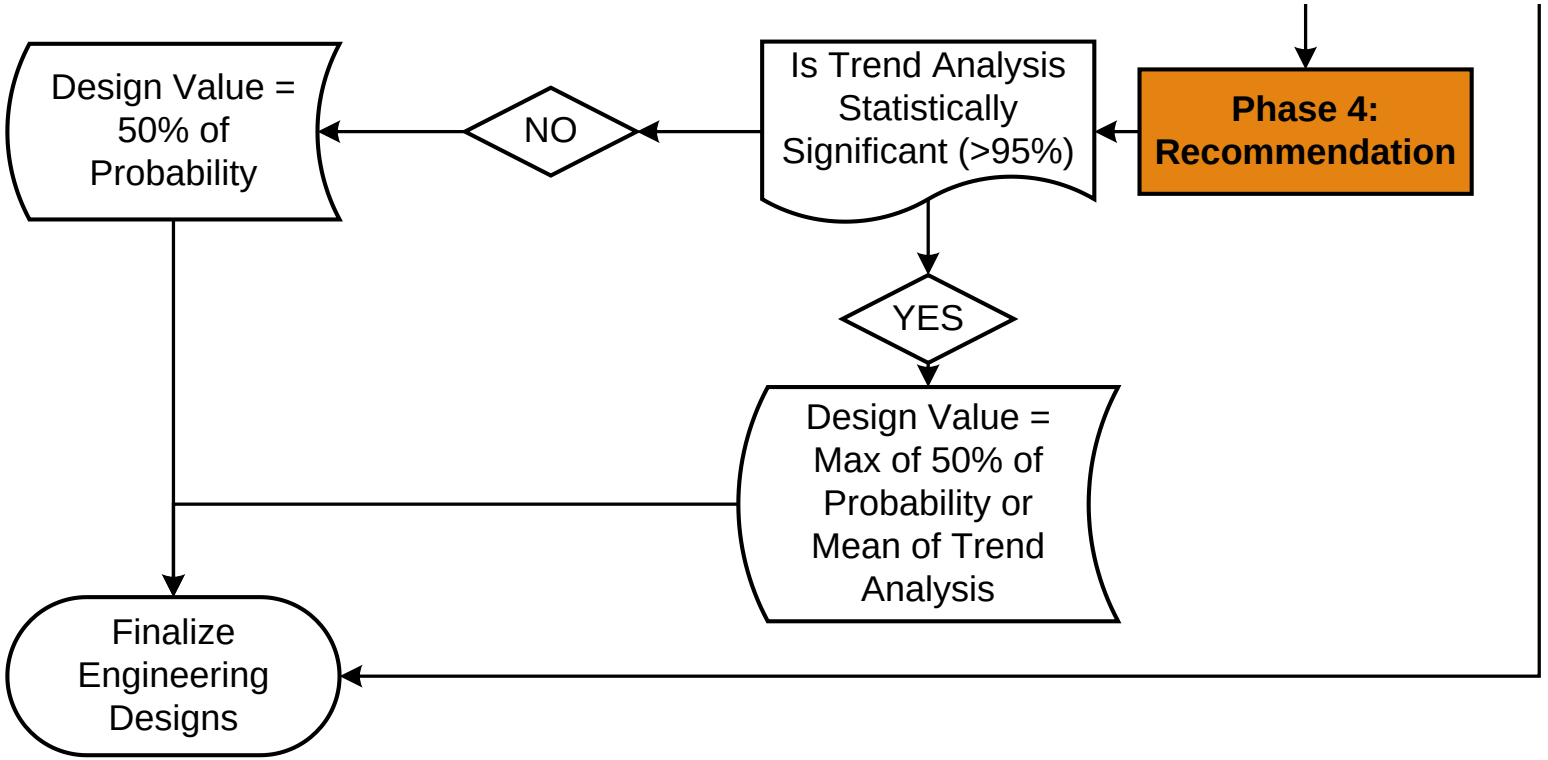
	Regression Method	Stat. Sign. [%]	Decade Change	Change with respect to Baseline[%]
1	Ordinary least squares	93.5	0.37 degC/10yr	0.48
2	Quartile Regression	95.6	0.5 degC/10yr	0.66
3	MK(1945) & Theil−Sen(1968)	98.1	0.49 degC/10yr	0.64
4	Prewhit. MK, Zhang(2001)	98.1	0.34 degC/10yr	0.45
5	Prewhit. MK, Yue & Pilon(2002)	98.1	0.36 degC/10yr	0.48

Trend Analysis

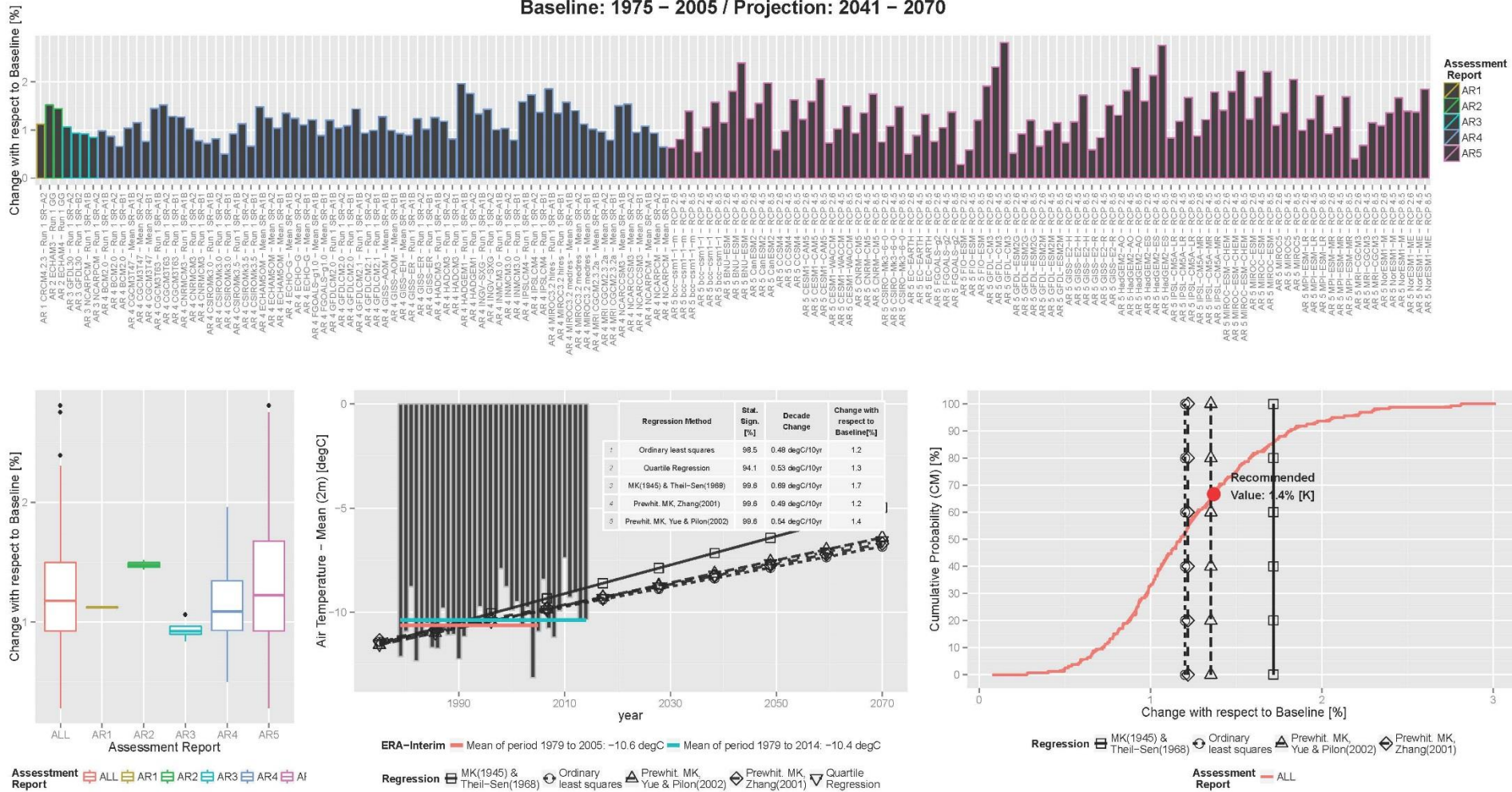
- Significant trends (i.e., trends > 95%) are displayed on the cumulative probabilistic curve



Design Value



Climate parameter: Air Temperature − Mean (2m)
Latitude: 65.544, Longitude: −106.493
Baseline: 1975 − 2005 / Projection: 2041 − 2070



Conclusion

- Procedure is transparent, repeatable, consistent and unbiased
- Tested on 3 projects in Canada that went through Environmental Assessment and therefore subject to considerable peer review by both scientists and engineers
- Tool is practical and useable for the engineer