UTILITY-SCALE CLIMATE CHANGE ASSESSMENTS

American Rivers-NHA Climate Change Workshop

January 28th, 2010

Kenneth Westrick

Founder and CEO

3TIER

Agenda

- About 3TIER
- Climate change
  - Recent trends
- Case studies from the Pacific Northwest
  - Example 1 – Seattle City Light
  - Example 2 – Second large scale utility
- Challenges
  - Data availability
- Conclusions

Who is 3TIER

- A leading provider of renewable energy assessment and forecasting solution products
- Across all renewables: wind, solar, hydro, in the future, others
- Headquartered in Seattle, USA with offices throughout the world
- Founded in 1999, incorporated in 2001
- Over 50 percent of our staff has advanced degrees in earth sciences, engineering, and information technologies

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BACKGROUND

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Regional background of the Pacific Northwest

- Anywhere from 65 to 80 percent of the power production is from hydropower
- Columbia River is dominant river system
- Sharp difference in precipitation between east and west of the Cascade mountains
- Summer snowmelt for reservoir replenishment is an important process

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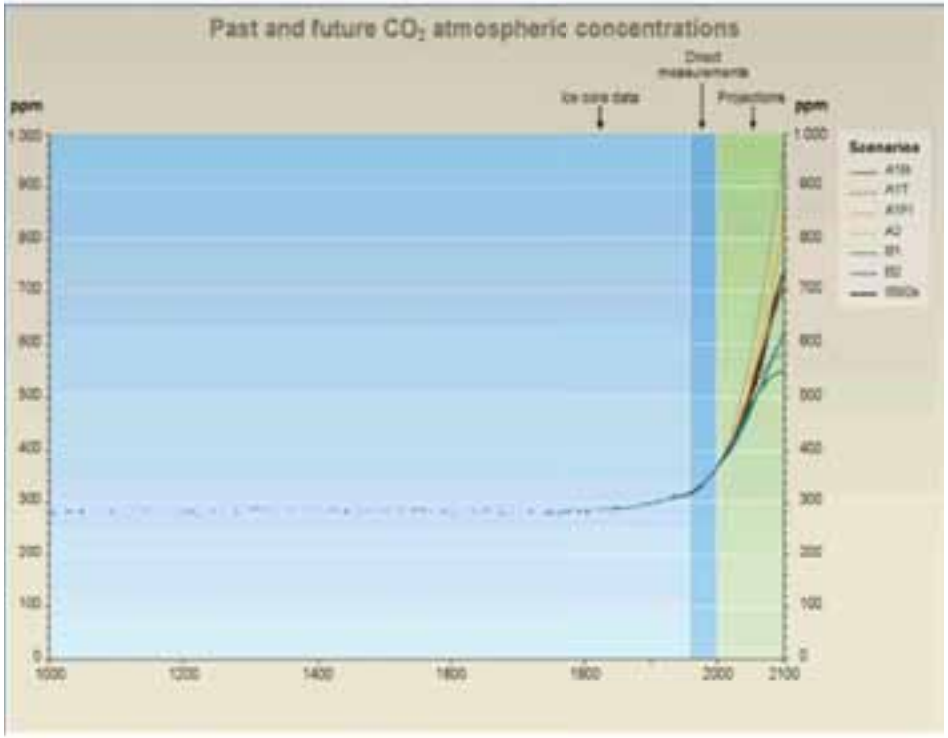
Greenhouse gases are increasing



- The equilibrium temperature in the absence of greenhouse gases is 255K (or -18C)
- Our global average temperature is 288K, this because of the greenhouse effect
- Increases in greenhouse gases increase the atmospheric radiative process, thus increasing the temperature

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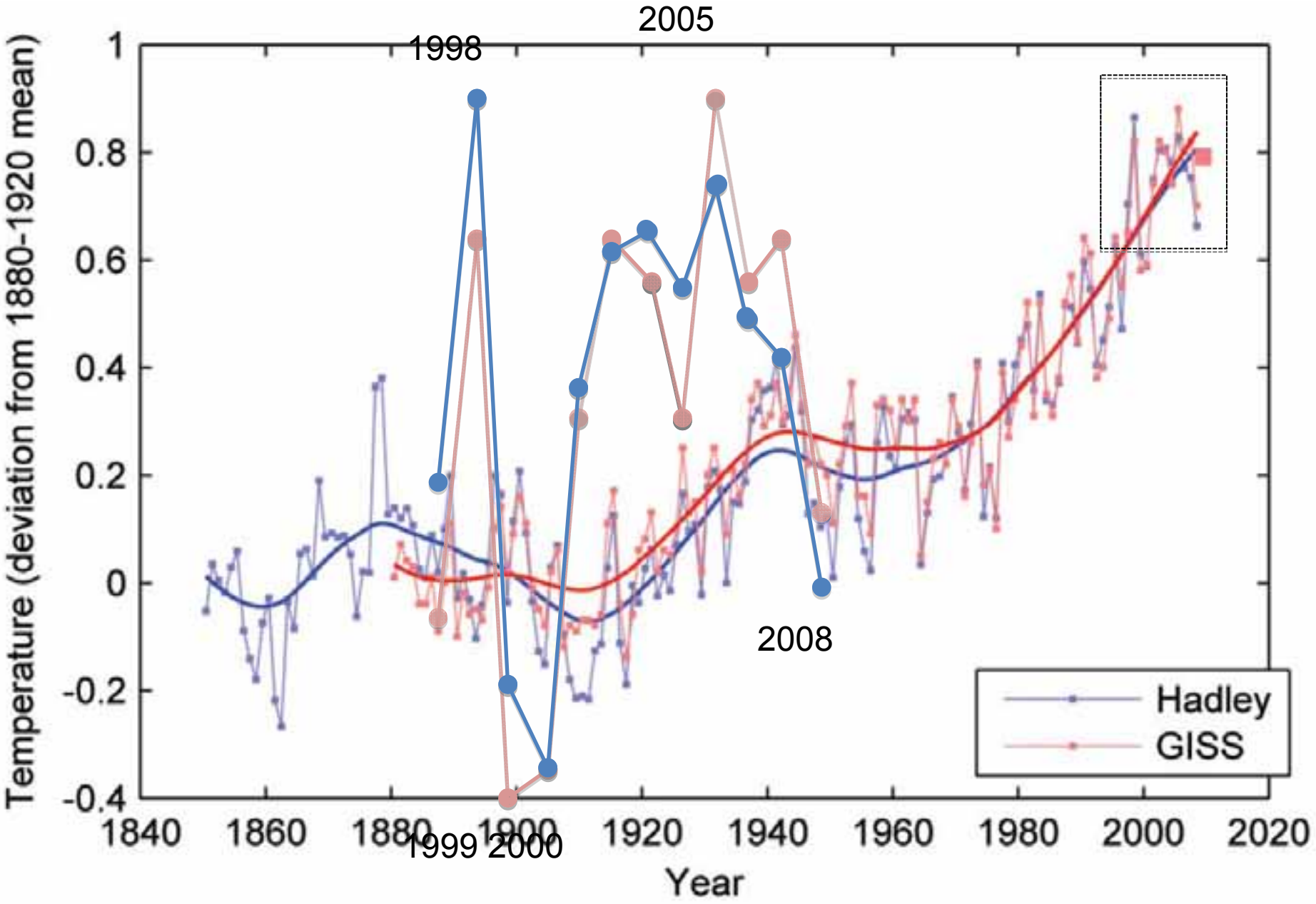

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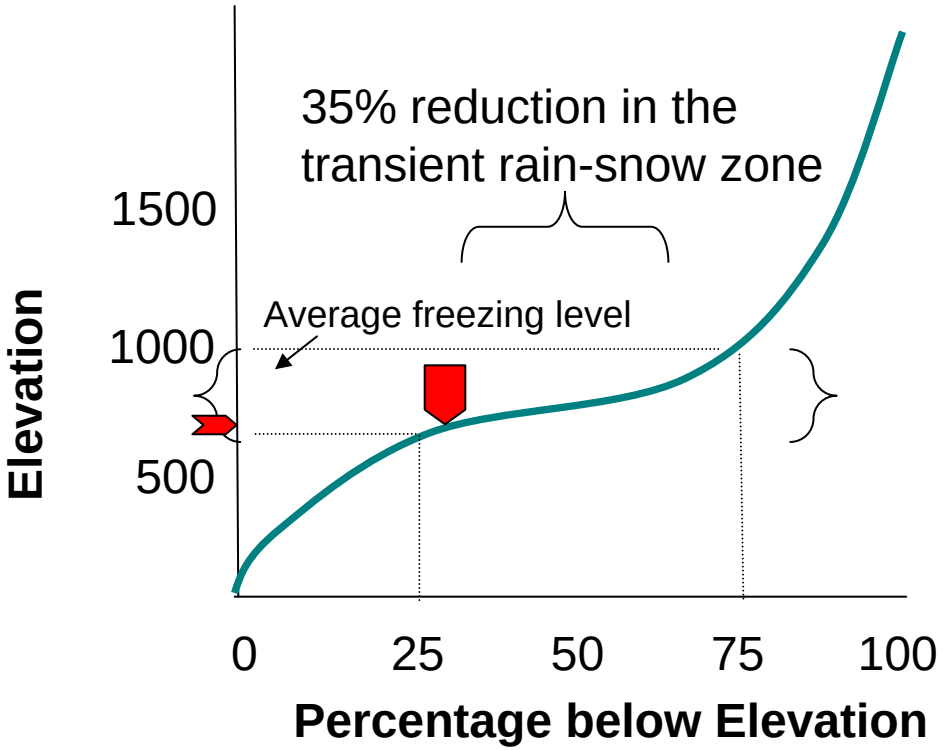
Impacts on hydro in the PNW are mostly due to SWE changes



- Annual precipitation changes are not substantial and relatively uncertain
- Biggest effects are from warmer average temperatures which translate to elevated freezing levels
- This changes the timing and amplitude of runoff
  - Summer replenishment snowpack – the second reservoir – is missing
  - Shifting of flood season to the traditional fill season
  - Not just hydropower, this impacts everything from Salmon to Agriculture

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This is ALREADY occurring!

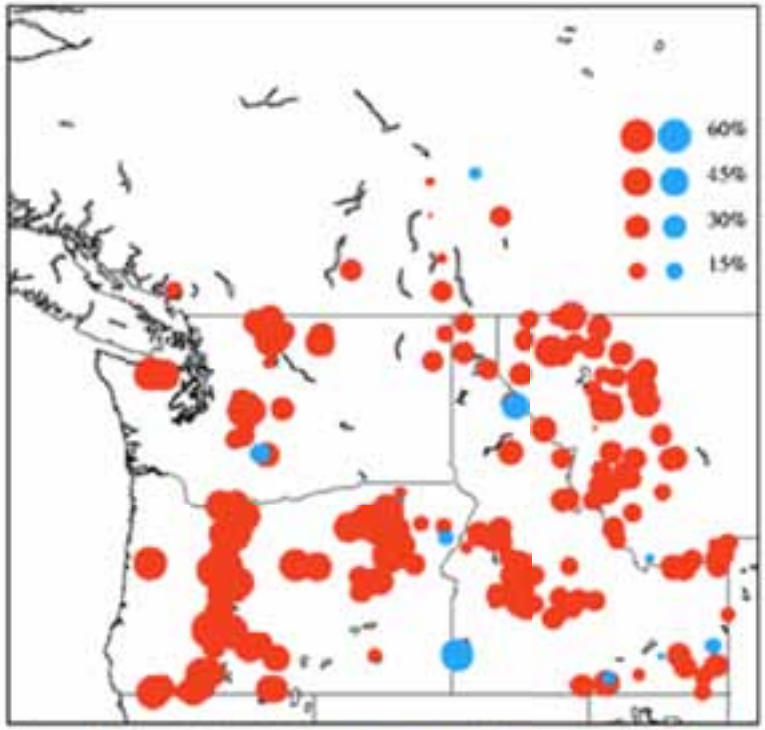

Figure 1 Trends in April 1 snow water equivalent based on data from 260 snow course collections sites. Most stations show a decline in snow water equivalent. The fact that trends are highest at low elevation sites implicates warming as a cause of the trend. From Mote 2003.

- The fact that this decrease in snowpack has become apparent in the past century has driven concern by water resource managers
- Many want to know the impacts of climate change on their operations and long range planning
- The two studies here were initiated because the two utilities understand that climate change is occurring and they want to be prepared

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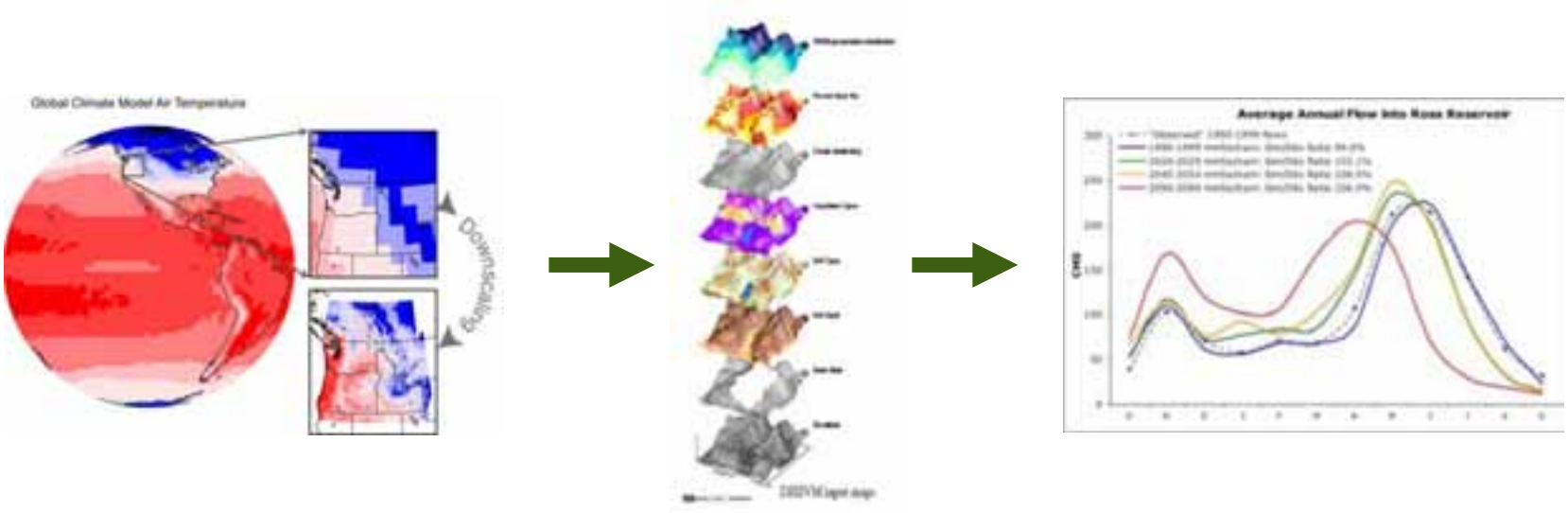
Basic methodology



Described by Frederick and Gleick (1999)

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EXAMPLE 1
STUDY FOR MAJOR HYDROPOWER UTILITY

Study conducted in 2006

Approximately 700MW system with multiple reservoirs

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Reasons for commissioning the study

- An initial assessment of the vulnerabilities of this watershed to climate change
- Other regional studies, mainly around water supply rather than hydropower, raised concerns within this utility
- Operational forecasting by 3TIER allowed the use of a proven modeling system to be used to assess the relative changes

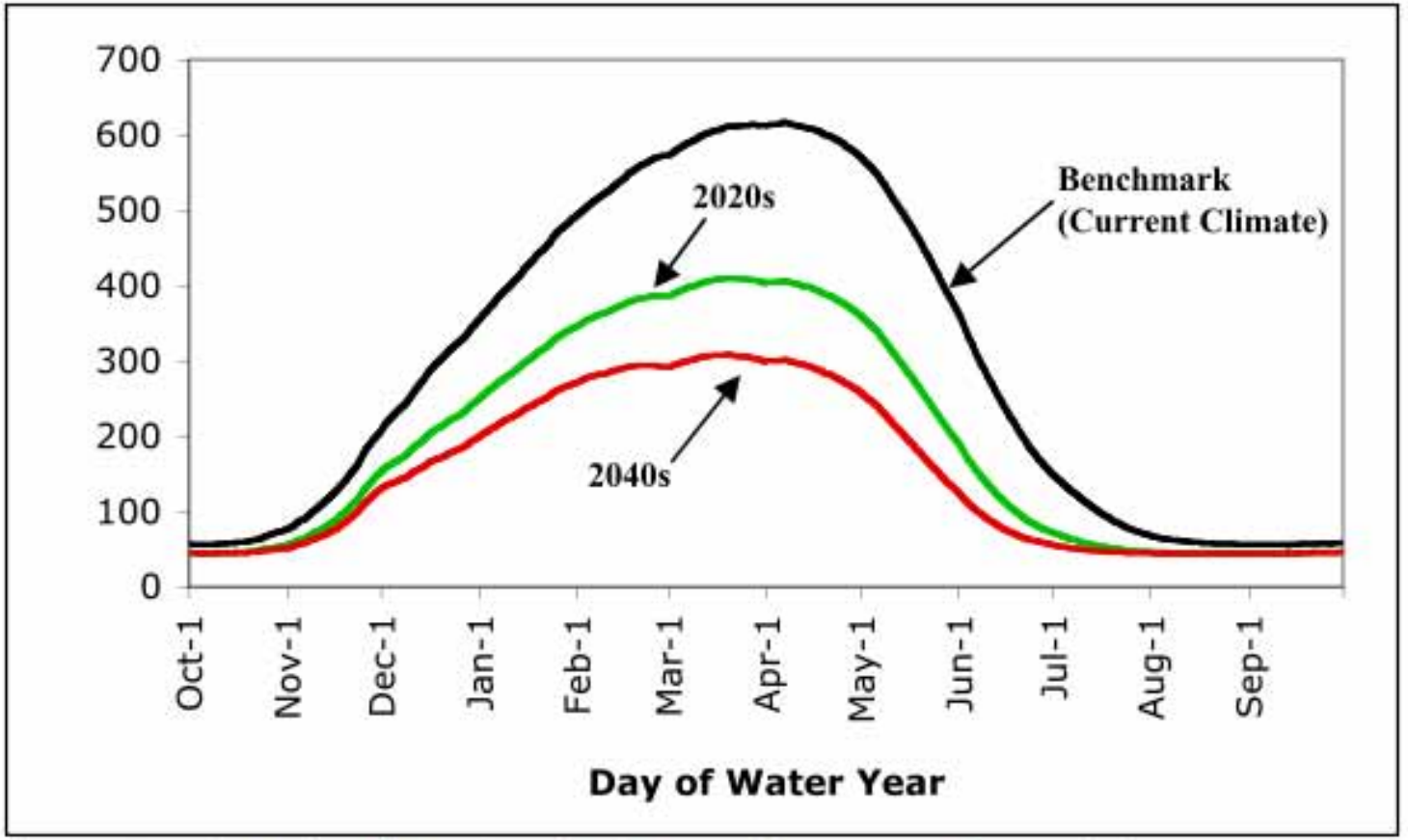

Figure 1: The Distributed Hydrology Soil Vegetation Model predicts snow cover throughout a water year for a given precipitation and temperature sequence. The model indicates that snow water equivalent over the basin will drop sharply as a result of projected climate changes in 2020 and 2040.

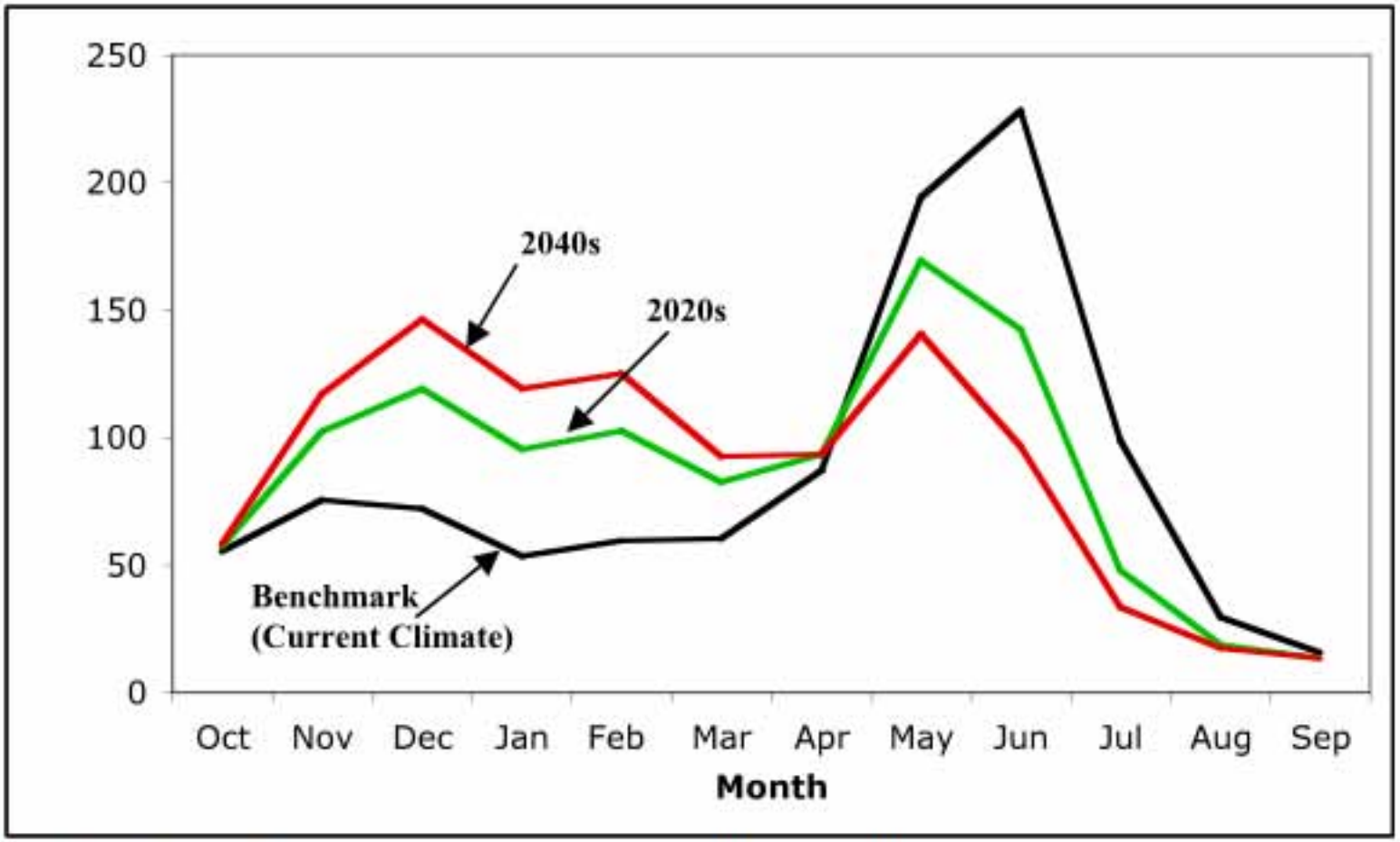

Figure 4: The average annual inflow hydrograph to [redacted] is expected to shift toward higher flows in midwinter under future climate conditions. The shift poses problems if water relied upon for future generation arrives during the season when flood control requirements limit the useable storage.

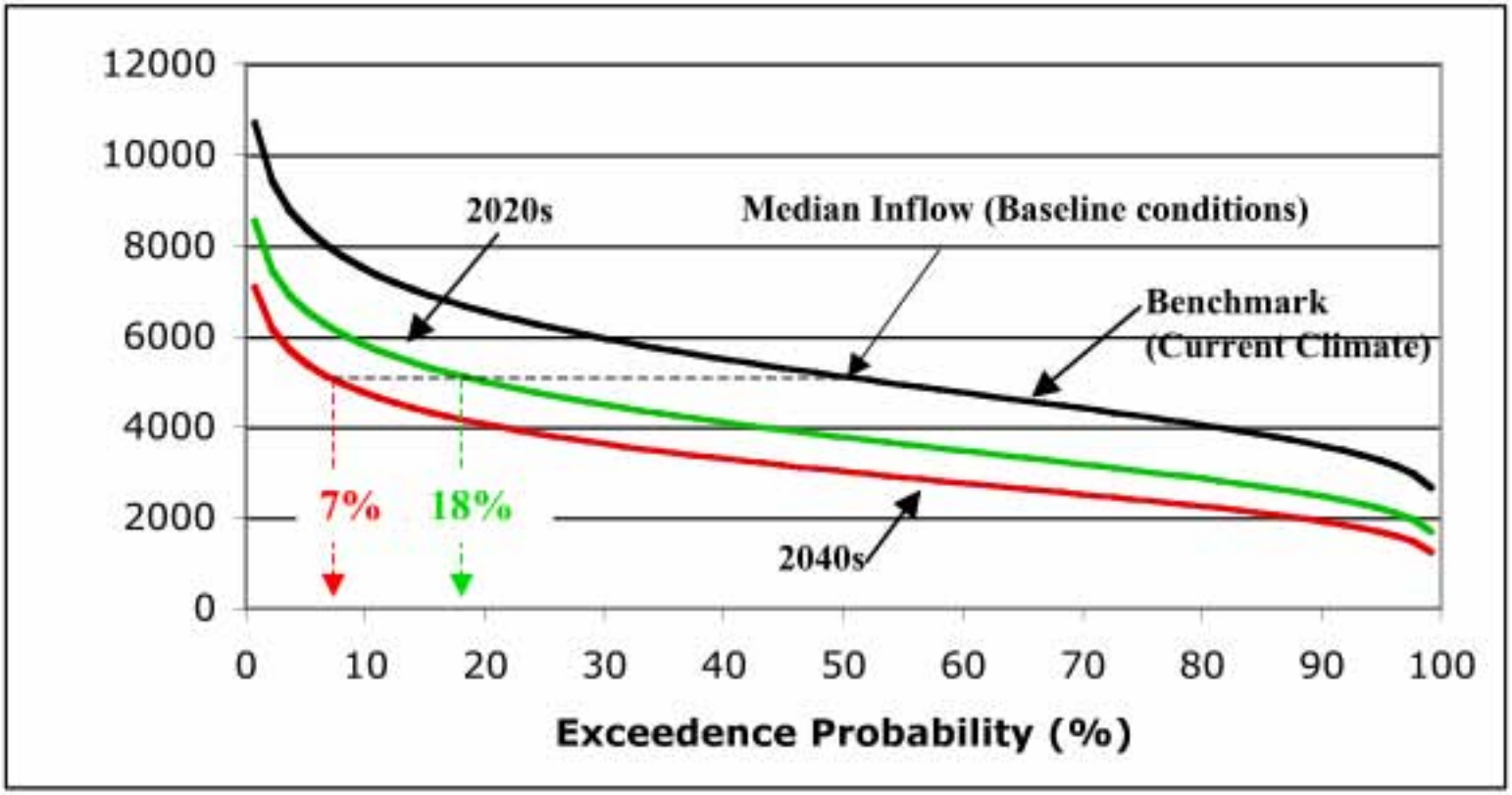

Figure 5: This chart shows the projected change in exceedance probability for monthly inflow in the refill months of April through July. The flow that is currently the median flow would be exceeded only 18 percent of the time under 2020 conditions and only 7 percent of the time under 2040 conditions.

What this particular utility learned:

- There are significant changes that could be expected to occur on this particular watershed
- Overall, the issues posed by climate change for this watershed are about water storage, not water shortage.
- Refill will have to begin earlier in the year, during the period of time when operations are currently oriented toward flood control.

EXAMPLE 2
STUDY FOR MAJOR HYDROPOWER UTILITY

Study conducted in 2008

Approximately 500MW system with multiple reservoirs

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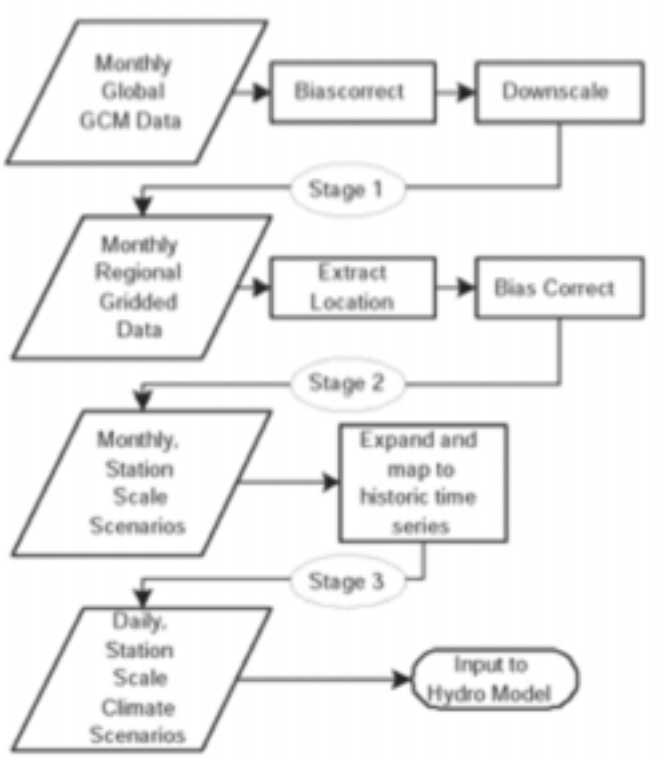
Reasons for commissioning the study

- To perform an economic analysis for long-range generation planning.
- They also performed the analysis because it was cost effective as 3TIER already had a calibrated hydro model which had been operating for years for daily and seasonal forecasting on this particular watershed.



- Process flow for downscaling and climate scenario development
  - Statistical approach is easy enough to allow for examining multiple GCMS and multiple forcing scenarios
  - Forcing scenarios are the main source of uncertainty
- Method creates a quasi-steady state time-series of flow data that is readily compatible with most traditional water resources assessment methods in that it emulates the historic time-series but under an altered climate regime.

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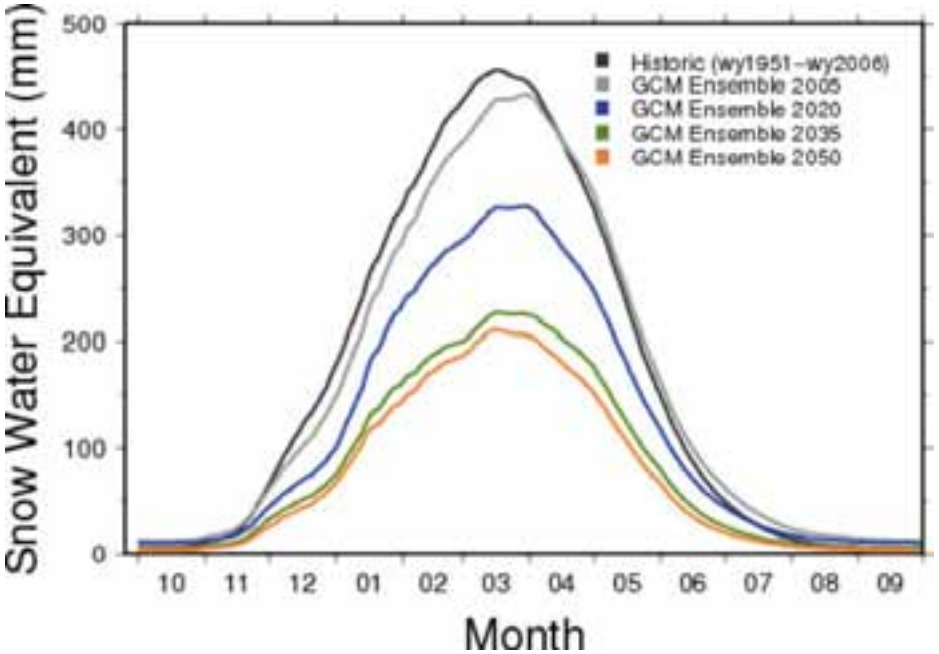

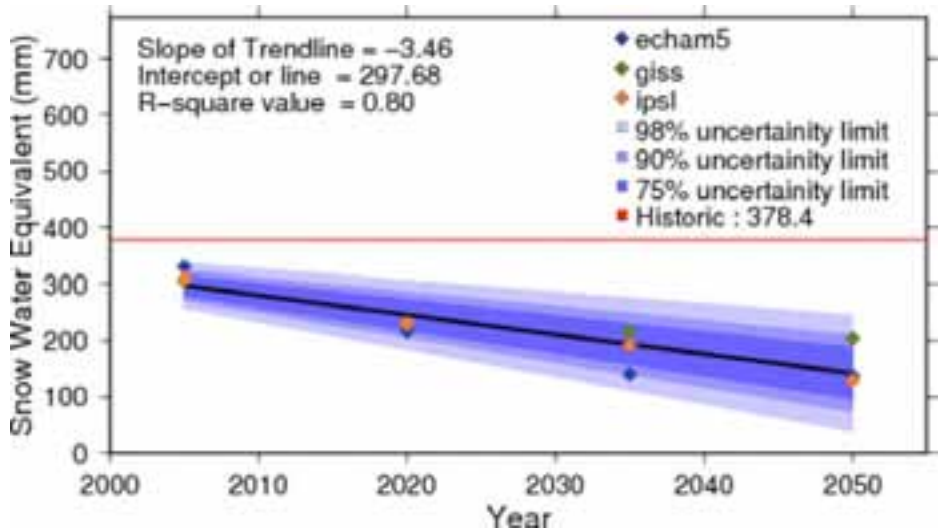

- Using Multiple GCMs and forcing scenarios allows for quantification of *some* uncertainty
- Snow Water Equivalent in a PNW Cascade Mountain watershed
  - Can use ensemble average for consensus opinion
  - Can look at the spread associated with the data and assign uncertainty boundaries

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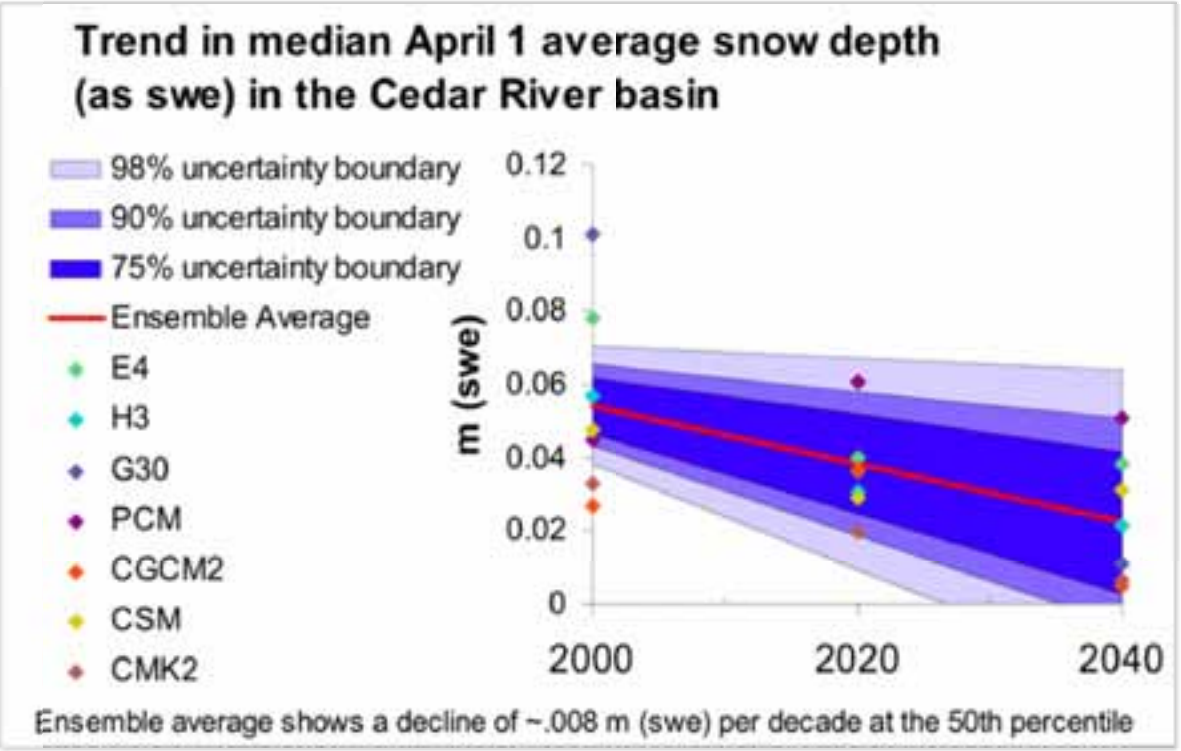
Impacts of Climate Change
Snowpack

- Average annual maximum seen to decrease by as much as 50% by 2040.
- Timing of peak shifts earlier in year.
- Extreme event more common.
- Uncertainty in trends



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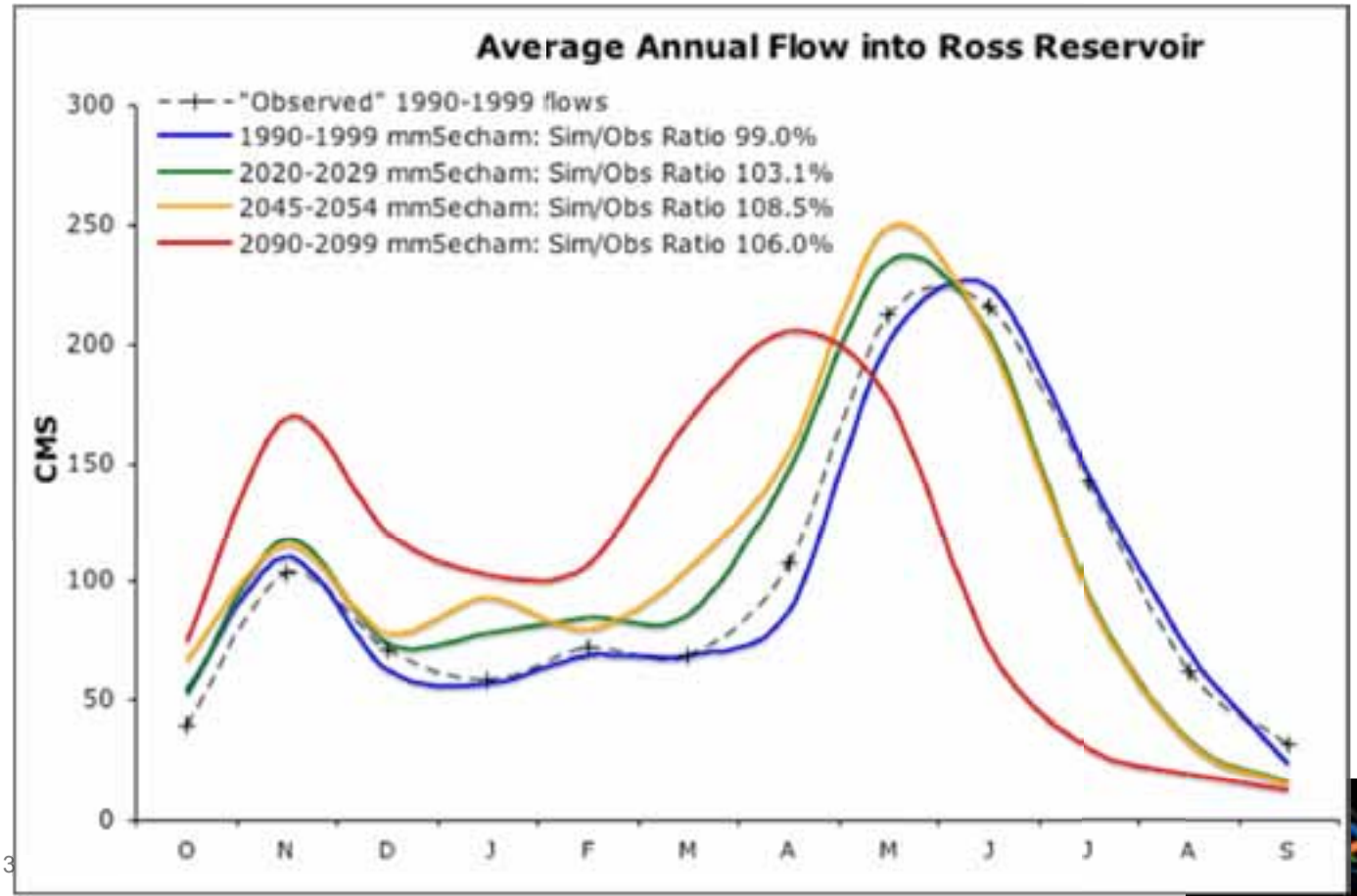
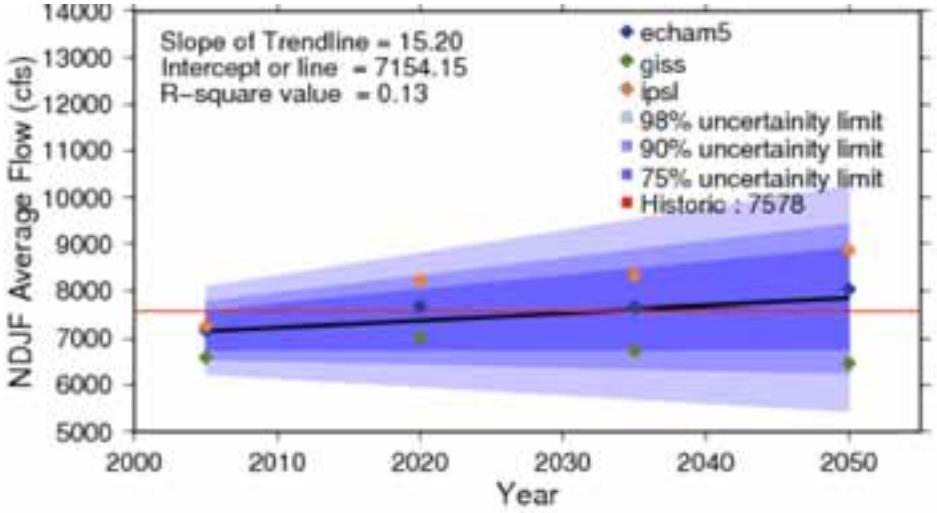
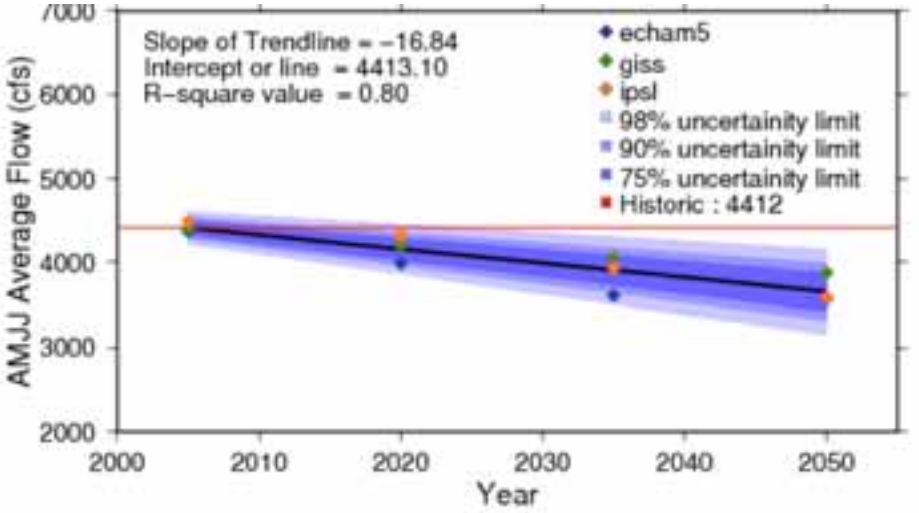
- Streamflow – North Cascades hydropower basin
- Slightly more flow, but earlier in the year
- Used MM5 for downscaling (done by UW). Found similar results as with statistical approaches, but was much computationally intensive and limited to single GCM simulation.



- Changes in seasonal flow volumes, South Cascades, Washington
- Increased flows in NDJF, but with greater uncertainty
- Decreased flows in AMJJ have strong model





What this particular utility learned:

- While there are hydrologic changes predicted, they are not significant enough, or their system is robust enough in terms of terms of available storage, that the change did not effect their planned operations.

OTHER CHALLENGES

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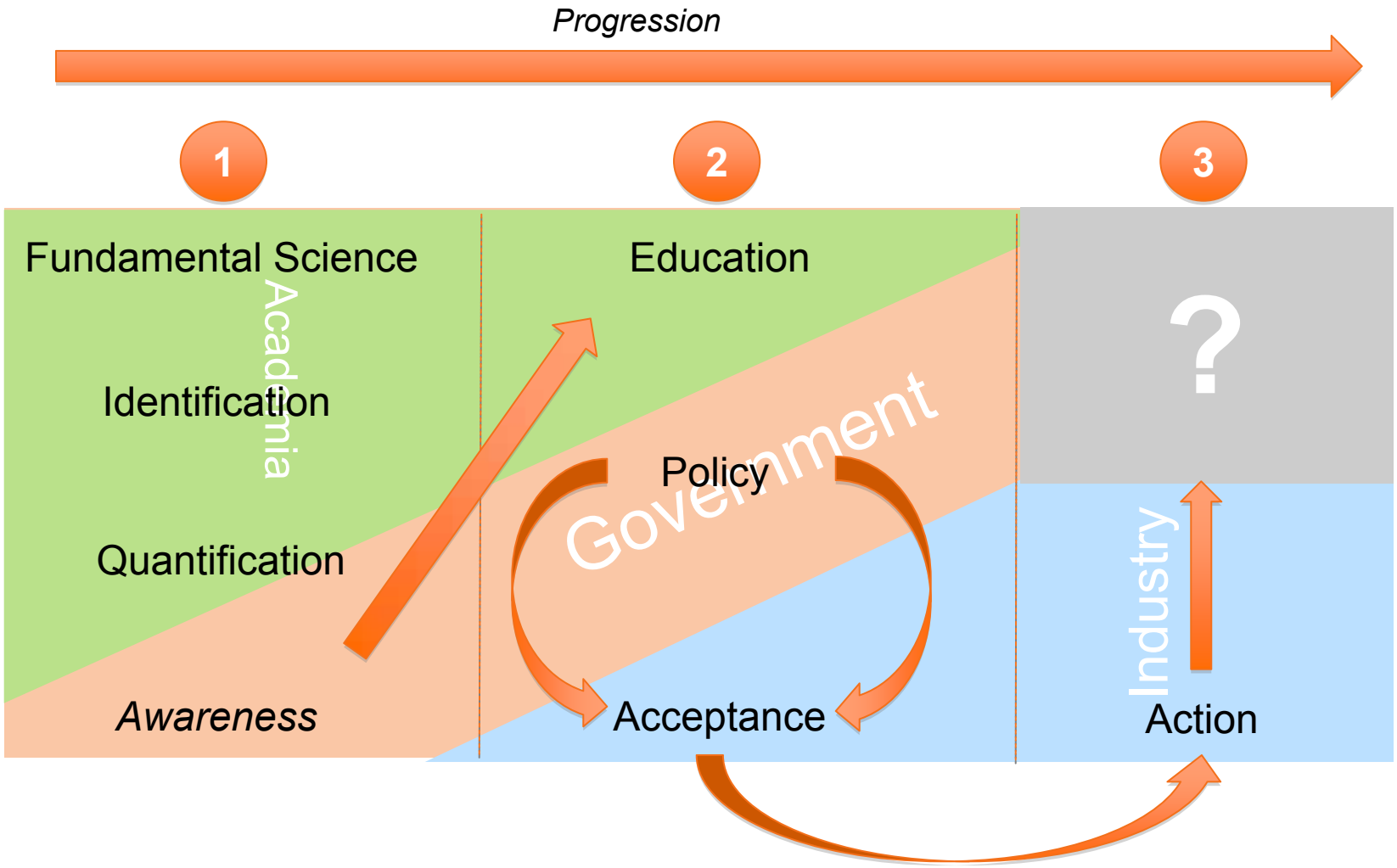

A secondary challenge

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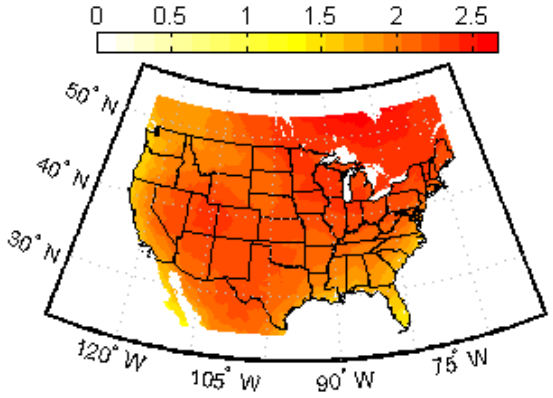
Are climate change data accessible? Yes and No

Yes – large archives of climate scenario outputs exist: e.g.,

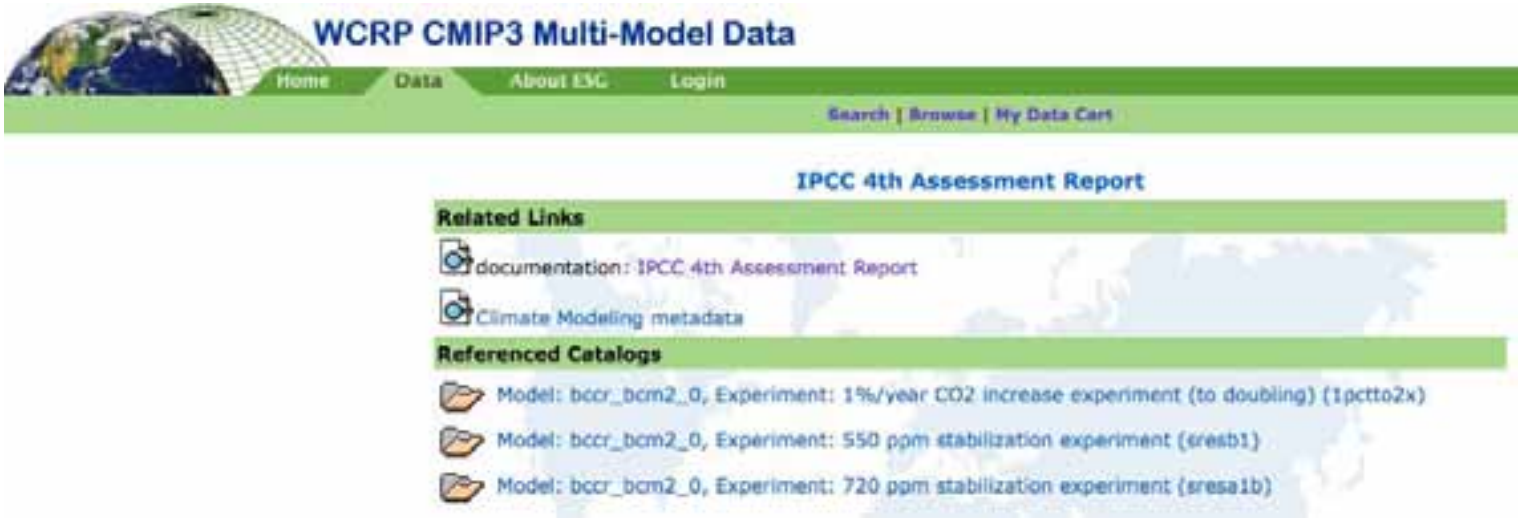


»[at LLNL: http://gdo-dcp.ucllnl.org/](http://gdo-dcp.ucllnl.org/)

downscaled_cmip3_projections/

dcpInterface.html

[DOE PCMDI: http://www-pcmdi.llnl.gov/](http://www-pcmdi.llnl.gov/)



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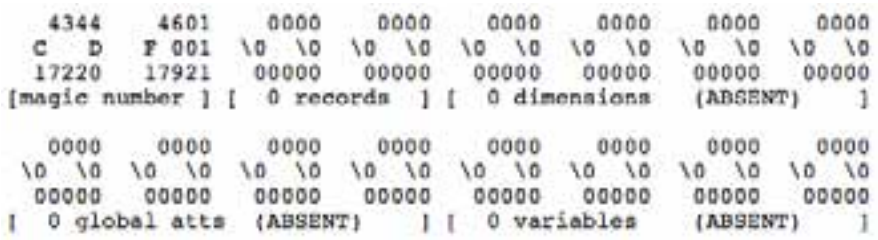
Are climate change data accessible? Yes and No

No – data formats may be difficult for industry

NETCDF example:



and GRIB, large binary files for continental-scale domains.

This situation is improving – new sites like

The Nature Conservancy | ClimateWizard

help with data subsetting and conversion.

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Are climate change data accessible? Yes and No

No! – Most Terms of Use PROHIBIT COMMERCIAL USE

Current IPCC restrictions are one example:

> These data are for use in research projects only. A 'research project' is any project carried out by an individual or organized by a university, a scientific institute, or similar organization (private or public) for non-commercial research purposes only. Results based on these data must be submitted for publication in the open literature without any delay linked to commercial objectives.
>
> An additional restriction is that the UK Met. Office / Hadley Centre requires strict adherence to the conditions set forth in their "License Statement", which applies to their model output:
>
> "These data are licensed for use in Research Projects only. A 'Research Project' is any project organised by a university, a scientific institute, or similar organisation (private or public), for non-commercial research purposes only. A necessary condition of the recognition of non-commercial purposes is that all the results obtained are openly available at delivery costs only, without any delay linked to commercial objectives, and that the research itself is submitted for open publication.
>
> Data provided by the UK Met. Office / Hadley Centre are expected to be acknowledged by:
>
> (c) Crown copyright 2005, Data provided by the Met Office Hadley Centre"

Current usage policies **do not allow** consulting firms to provide decision support to many industries – hydropower, agriculture, viticulture, recreation (e.g., ski resorts), commercial fisheries, and more.

Are climate change data accessible? Yes and No

Key Recommendation

- IPCC Assessment Report 5 (due in 2014) work is now getting underway
- A multi-industry, multi-agency coalition must push for a loosening of the usage restrictions on climate change data in parallel to the AR5 work
- Open access for commerce will allow the hydropower industry and other sectors to begin to factor climate change analysis into planning and decisionmaking
  - …without having to depend on an agency or a grad student, or have the results immediately published

CONCLUSIONS

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Takeaways

1. "[the] warming of the climate system is *unequivocal, as is now* evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level." IPCC
2. Climate models show skill and consistency in many areas in predicting climate. While uncertainty does exist, models increasingly are exhibiting skill and observations are agreeing with model predictions
3. Translation of future climate scenarios through distributed models, which have shown significant skill in operational forecasting, are relevant for assessing changes in runoff volumes and timing
4. The implications of these changes are basin specific, and in snowmelt dominated watersheds, depending on the physical characteristics, the impacts can be substantial. The issue is not one of shortage but of storage and the required changes to operations.
5. These changes are occurring now and will likely accelerate into the 21st century and this knowledge should be incorporated into relicensing decisions as it may have a significant impact on operations.