The following meeting notes are a product of the Columbia River Treaty 2014/2024 Review Process. Nothing recorded in the notes can be attributed to a single sovereign entity and are for reference purposes only. This document is pre-decisional.

Columbia River Treaty 2014/2024 Review
Sovereign Technical Team Climate Change Workshop

Monday, August 8, 2011, 9am – 4:30pm
Location: Columbia River Inter Tribal Fish Commission, Portland OR

Meeting Co-Chairs: Nancy Stephan, Bonneville Power Administration, and Matt Rea, U.S. Army Corps of Engineers, Treaty Review Program Managers

Meeting Facilitator: Terry Buchholz, Integrated Water Solutions

Meeting Summary

1. **Introductions, Meeting Overview and Objectives** *See Attachment One: Agenda*

   Introductions were made, and a meeting overview was given. The purpose of the meeting was to gain input from climate change (CC) experts (local and national) on how to address CC in the Treaty Review studies. The meeting objectives were to provide an overview of the Treaty Review studies; to provide an overview of the River Management Joint Operating Committee (RMJOC) work; to establish how the RMJOC work will be used in the Treaty Review Studies; and to establish next steps for the Treaty Review climate change efforts.

2. **Overview of Columbia River Treaty Review Studies** *See Attachment Two: Treaty History and Overview*

   A brief overview of the Columbia River Treaty and the Columbia River Treaty (Treaty) 2014/2024 Review was given. The purpose of the Treaty Review process is to provide a means for the U.S. Entity to consult with regional sovereigns and stakeholders regarding the future of the Columbia River Treaty. The Columbia River Treaty (CRT) 2014/2024 Review Sovereign Participation Process establishes a framework for sovereign parties to collaborate and coordinate with the U.S. Entity in the process of conducting technical studies, and developing and evaluating alternatives needed to better understand potential Treaty futures. The Treaty can be terminated as early as 2024, with 10 years advance notice. The purpose of the Columbia River Treaty (Treaty) 2014/2024 Review is to enable the United States Entity and the regional sovereigns to make an informed recommendation to the U.S. Department of State as to whether or not it is in the best interest of the U.S. to continue the Treaty, terminate the Treaty, or seek to negotiate with Canada on amendment of the Treaty.

3. **Overview of RMJOC Work** *See Attachment Three: Overview of RMJOC Work*

   The RMJOC is a subcommittee of the Columbia River Joint Operating Committee. The RMJOC climate change work was initiated so that a consistent set of climate change

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information could developed for use in future federal agency long term planning and operational studies. Reports developed by the RMJOC have been released detailing methodologies and results. Reports and more information can be found at bpa.gov/power/pgf/HydrPNW.shtml.

4. **Presentation of the Treaty Review Preliminary Data Set Development** *See Attachment Four: CRT 2014 Review Climate Change Dataset—Building from the RMJOC Work*

   Seshu Vaddey, U.S. Army Corps of Engineers, presented information concerning preliminary dataset development. The purpose of the discussion was to convey an understanding of how the datasets were created in order to choose the best methodology for incorporating climate change into the Columbia River Treaty.

5. **Framing the Treaty Review Climate Change Questions, Process and Schedule**

   Attendees of the meeting were given a brief framework, process and schedule briefing to aid in the presentation of the strawdog planning framework for incorporating climate change into the Treaty review.

6. **Presentation of the Strawdog Planning Framework for Incorporating of Climate Change into the Treaty Review** *See Attachment Five: Framework for Incorporating Climate Change into Risk Informed Decision-Making*

   A strawdog climate change planning framework was presented to answer the central question: "How will climate conditions important to the Decisions needed for CRT Review be incorporated into the planning process?" Several approaches were presented in effort to prepare for the afternoon discussion with invited climate change experts.

7. **Discussion: Integrating Climate Change into the Treaty Review Studies**

   Input was gathered from climate change experts on the approaches presented during the morning session. The Sovereign Technical Team was asked the question of whether climate change will be incorporated as a 'For Your Information' study, or the information gathered will be used to 'Inform the Treaty Review Recommendation.' Several experts mentioned that having robust information regarding climate change would build a robust recommendation—including understanding the needed flexibilities in the Columbia River System to adapt to climate change. Several experts also recommended using RMJOC work as much as possible, while building upon that information as it makes sense in the Treaty Review process.

8. **Update on Regional Next Generation Climate Scenario Work** *See Attachment Six: Regional Next Generation Climate Scenario Work*

   Phil Mote presented on the Regional Next Generation Climate Scenario Work. The next IPCC report will be released in September 2013. This report will likely be compared to the Treaty Review climate work and questions will be raised regarding how new information will inform the Treaty Review climate change analyses.

9. **Next Steps For Climate Change**

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The group determined that the next step for incorporating climate change into the Treaty Review studies would be to determine the level of analysis that would be needed for the Treaty Review. The Sovereign Technical Team will give a recommendation to the Sovereign Review Team, and characterize the costs and benefits of each level of analysis. Climate change experts also gave input on next steps for metrics, screening and prioritization of metrics, and analysis of extreme events (tipping points) of the system.

Meeting Attendance

Name	Organization
Sovereign Technical Team Members Present:	
Nancy Stephan	Bonneville Power Administration (BPA)
Matt Rea	U.S. Army Corps of Engineers (USACE)
Bob Heinith	Columbia River Inter-Tribal Fish Commission (CRITFC)
Lori Postlethwait	U.S. Bureau of Reclamation (Reclamation)
John Marsh	The Confederated Salish and Kootenai Tribes (CSKT)
Stephan Smith	Upper Columbia United Tribes (UCUT)
Rick Kruger	State of Oregon (OR)
Paul Wagner	National Marine Fisheries Service (NMFS)
Greg Fuhrer	U.S. Geological Service (USGS)
Derek Sandison	State of Washington
John Laurence	U.S. Forest Service and Bureau of Land Management
Others Present:	
Jim Heffernan	CRTIFC
Rob Lothrop	CRTIFC
Christine Golightly	CRITFC
Laura Gephart	CRITFC
Sara McNary	BPA
John Hyde	BPA
Jack Camp	USACE
Ron Malmgren	USACE
Rick Pendergrass	BPA
Marshall Gannett	USGS
Lynn Helbrecht	Washington Department of Fish & Wildlife
Alan Hamlet	University of Washington
Roger Pulwarty	NOAA
John Fazio	Northwest Power and Conservation Council

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Jim Ruff	NPCC
Kyle Dittmer	CRITFC
Seshu Vaddey	USACE
Brad Bird	USACE
Patti Low	USACE
Brian Kuepper	BPA
Chris Toole	NMFS
Jack Camp	USACE
Toni Turner	USBR
Levi Brekke	USBR
Phil Mote	Oregon State University
Agnes Lut	Oregon Department of Environmental Quality
Ann Radl	Salish Kootenai Tribes
Terry Buchholz	Integrated Water Solutions (Facilitator)
Lauren Buchholz	Integrated Water Solutions (Recorder)

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Attachment One: Agenda

Columbia River Treaty 2014/2024 Review
Sovereign Technical Team Climate Change Workshop

Monday, August 8, 2011
Location: Columbia River Inter-Tribal Fish Commission
(729 NE Oregon Street) Columbia River Room, Portland, OR

August 8, 2011
9:00 am – 4:00 pm Sovereign Technical Team Climate Change Workshop

Meeting Co-Chairs: Nancy Stephan, Bonneville Power Administration, and Matt Rea, U.S. Army Corps of Engineers, Treaty Review Program Managers

Meeting Facilitator: Terry Buchholz, Integrated Water Solutions

Meeting Objectives:

1. To provide overview and context for the Treaty Review studies
2. To provide an overview of the RMJOC work
3. To establish how the RMJOC work will be used in the Treaty Review studies
4. To discuss a preliminary planning framework for incorporating climate change into the Treaty Review Studies
5. To establish next step for the Treaty Review climate change efforts

AGENDA

August 8, 2011: 9:00 am – 4 pm

1. **Introductions, Meeting Overview and Objectives** (Matt Rea & Nancy Stephan, 15 minutes)
2. **Overview of Columbia River Treaty Review Studies** (Matt Rea, 15 minutes)
3. **Overview of RMJOC Work** (Nancy Stephan & Brian Kuepper, 30 minutes)
    a. **History and Process**
    b. **Methodology for Developing Initial Data Sets**
    c. **Key Findings for Hydropower, Flood Risk Management and Ecosystem Based Function**
    d. **Recommended Next Steps**
4. **Presentation of the Treaty Review Preliminary Data Set Development** (Seshu Vaddey, 30 minutes)

Break (15 minutes)

5. **Framing the Treaty Review Climate Change Questions, Process and Schedule** (15 minutes)
6. **Presentation of the Strawdog Planning Framework for Incorporating of Climate Change into the Treaty Review** (60 minutes)

Lunch (60 minutes)

7. **Discussion: Integrating Climate Change into the Treaty Review Studies** (120 minutes with 15 minute break in the middle)
    a. **Framework**
    b. **Identification of Objectives and Challenge**
    c. **Vulnerability Analysis**
    d. **Ways to Assess Risk**
    e. **Limitations (i.e. scientific basis, data, tools, schedule)**
8. **Update on Regional Next Generation Climate Scenario Work** (Phil Mote, 10 minutes)
9. **Next Steps For Climate Changes** (30 minutes)
10. **Wrap-Up** (20 minutes)

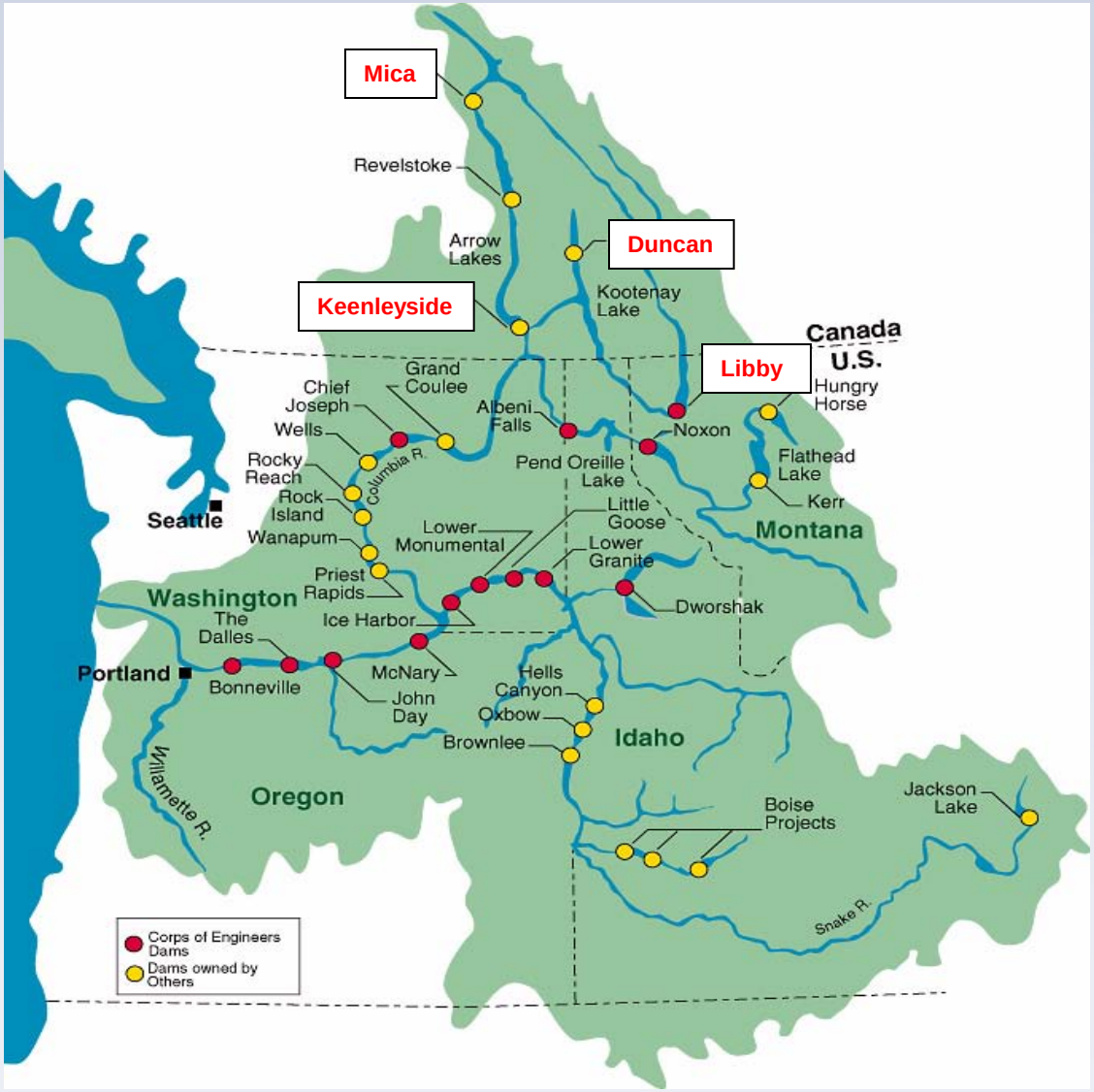
2014/2024 Review

Columbia River Treaty

Treaty History and Overview

August 8, 2011

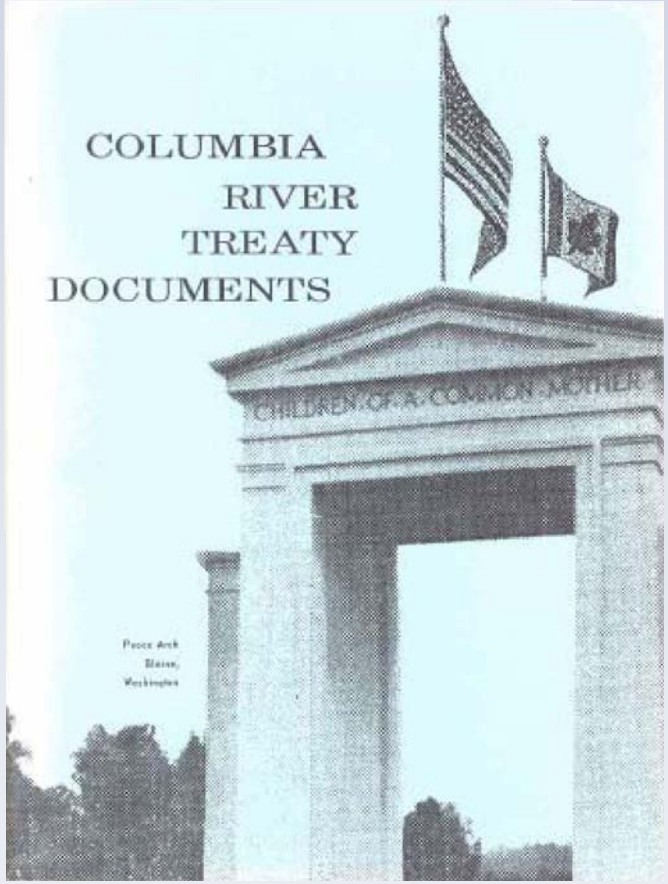
Columbia River Treaty Project Locations



Why conduct a Treaty 2014/2024 Review?

1. The Treaty has no specified end date; however, either nation can terminate most of the provisions of the Treaty as early as Sep 2024, with a minimum 10 years' written notice.

2. Current assured annual flood control operating procedures will end in 2024, independent of the Treaty termination decision.



Purpose of the Treaty 2014/2024 Review

To enable the United States Entity and the regional sovereigns to make an informed recommendation to the U.S. Department of State by September 2013 as to whether or not it is in the best interest of the U.S. to continue the Treaty, terminate the Treaty, or seek to negotiate with Canada on amendment of the Treaty.

Climate Change Objective

Assess the opportunities to provide for operational flexibility and resiliency that allows the system to mitigate for and adapt to climate change.

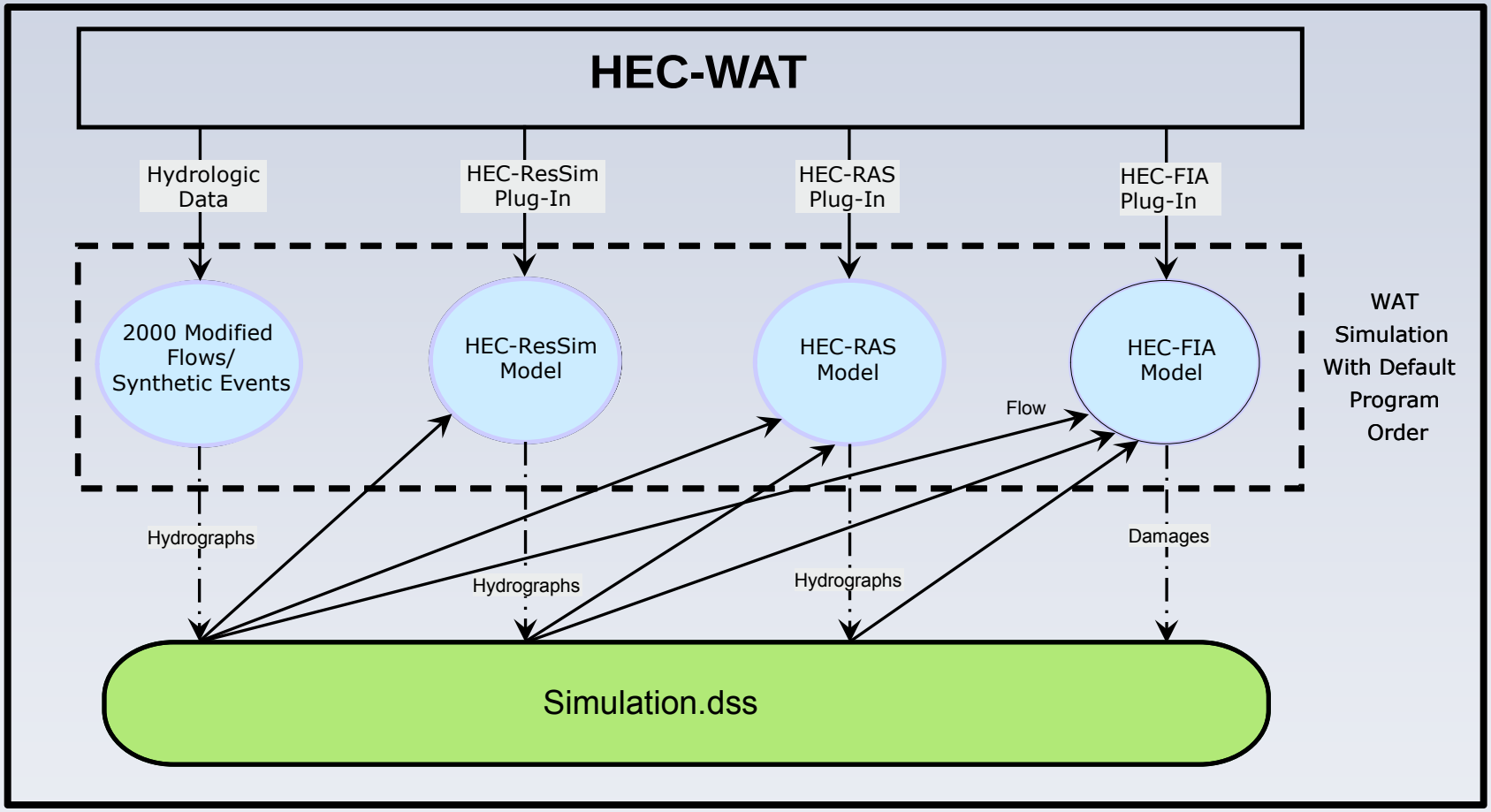
Climate Change Sideboard

Climate change will be integrated in the alternatives evaluation.

Key Climate Change Question to be Answered…

What are the potential effects of climate change on basin hydrology, including the volume and timing of runoff as well as potentially changing needs and demands for water in Canada and the United States?

HEC-WAT structure



Engagement Strategy

We have implemented an engagement plan to meet the needs of the region to identify and define sovereign and stakeholder interests regarding various Treaty future scenarios and evaluation. This process addresses the interests of key parties and general stakeholders.

Sovereign Review Team:

1. **Four States: OR, WA, ID, MT**
2. **15 NW Tribes (5 representatives)**
3. **Federal Agencies: NMFS, USFWS, BOR, USACE, BPA, BLM, EPA, USFS, USGS, BIA, NPS.**

NW Stakeholders:

Plan must take into consideration stakeholder concerns and input. This is being done through public Regional Listening Sessions (Two have been held to date: March 10 and June 10, 2011).

Congressional and Department of State:

The U.S. Entity has been working closely with the Department of State and briefing congressional staff over the last 2 years.

For more information:

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Nancy Stephan
Program Manager
Bonneville Power Administration
503-230-5296
nlstephan@bpa.gov

Website: http://www.crt2014-2024review.gov

RMJOC

Overview of RMJOC Work

Sovereign Technical Team Climate Workshop

Presented by: Levi Brekke, Reclamation
Toni Turner, Reclamation
Brian Kuepper, BPA
Patti Low, Corps

August 8, 2011

RMJOC

History and Process

RMJOC

RMJOC

- The Joint Operating Committee (JOC) was established through the Direct Funding Memorandum of Agreements (MOAs) between BPA, Reclamation, and the Corps for the asset planning, maintenance, and operation of the FCRPS.
- The River Management Joint Operating Committee (RMJOC) is a sub-committee specifically dedicated to reviewing the practices, procedures, and processes of each Agency to identify changes that could improve the overall efficiency of the operation and management of the FCRPS projects.

RMJOC

RMJOC Motive and Need

- Motive
  - consistent incorporation of climate projection information into Agencies' longer-term planning studies
- Need
  - adopt common dataset (climate and hydrology)
  - establish consensus methods for data use
  - efficiently use limited resources through coordinated development of data and methods

RMJOC

RMJOC Climate Change Reports

- Part I – Future Climate and Hydrology Datasets
- Part II –Reservoir Operations Assessment for Reclamation Tributaries
- Part III – Reservoir Operations Assessment
  - Columbia Basin Flood Control
  - Hydropower
- Part IV – Summary Report
- Next Steps

RMJOC

Methodology for Developing Initial Data Sets

Part I Report - Future Climate and Hydrology Datasets

Surveying available Future Climate Information:

Future climate "forcings" (multiple scenarios of greenhouse emissions!)

Future Global Econ/Tech Scenario (e.g., IPCC 2000)

↓

GHG Emissions Scenario (e.g., energy portfolios)

↓

Atmospheric GHG Concentrations (fate of emissions)

↓

…simulated global climate response (lots of models!)

NCAR CCSM | UKMO-HadCM3 | GFDL CM2.0

… 22 models from 16 centers

Run1 … Run 4

Different initial conditions!

Courtesy: Barsugli

RMJOC

Key Scoping Decisions

1. Use CIG HB2860 scenarios of future regional climate and hydrology

2. Use two types of scenarios from CIG HB2860
   - Step-change climate information (Hybrid-Delta)
   - Time-developing climate information (Transient)

3. Use only a subset of scenarios, both types

4. Conduct operations analysis using both types
   - Look at overall climate change impacts
   - Draw impressions on which types might be more appropriate for Agencies' longer-term planning

RMJOC

Data available from CIG HB2860

- Historic meteorological data at 1/16th degree (7 kilometer) from 1915- 2005
- Future climate change scenarios (Hybrid-Delta, or HD) and climate projections (Transient) specified at 1/16th degree
  - Based on monthly bias-correction and spatial downscaling of global climate projections, and then different approaches to time-disaggregate from monthly to daily weather (Hybrid-Delta vs. Transient)
- Future streamflows corresponding to HD and Transient future climates, corresponding to over 200 inflow locations, including locations relevant to RMJOC long-range operations studies
  - Streamflows simulated using the VIC hydrology model
  - Streamflows were bias-corrected to account for model error (more later)

RMJOC

Data available from CIG HB2860

"*Hybrid-Delta*" or step-change data ("climate change")

19 Climate Projections

10 Global Climate Models(*) X **A1b and B1 emission scenarios** X **sampled changes from 1971-2000 to either… 2010-2039 2040-2069**

= 38 "climate change" hydrologic scenarios, each mapped to observed 1916-2006 climate variability but reflecting future climate means… (*) one GCM simulated A1b only

"*Transient*" or time-developing

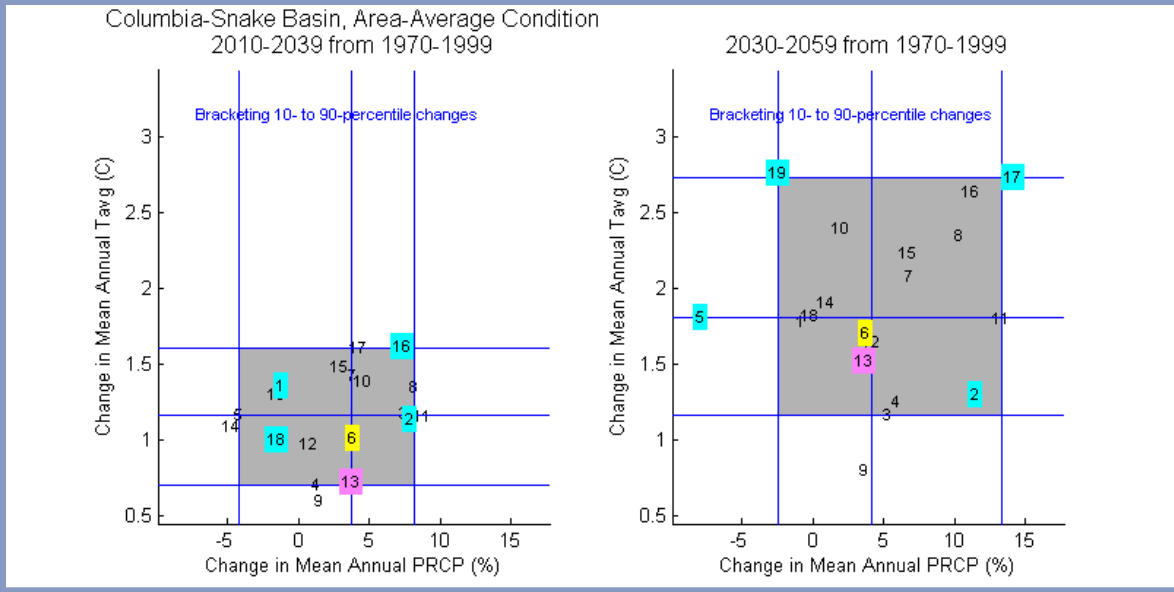
14 Climate Projections

7 Global Climate Models X **A1b and B1 emission scenarios**

= 14 hydrologic "projections", each reflecting GCM-simulated climate variability from simulated historical to projected future (1950-2099)

RMJOC

Selecting a Subset of 2020s and 2040s HD CC Scenarios



Climate Projections			"Climate Change" Hydrology (Hybrid-Delta Scenarios)						Hydrologic Projections (Transient) (x = selected, o = not selected)
			2020s			2040s			
Number	Climate Model	Emissions Scenario	Selected (RMJOC Labels) [1]	Change in P (%) [2]	Change in T (°C) [2]	Selected (RMJOC Labels) [1]	Change in P (%) [2]	Change in T (°C) [2]	
1	ccsm3	B1	MW/D	-1.2	1.4		-0.8	1.8	x
2	cgcm3.1 t47	B1	LW/W	7.9	1.1	LW/W	11.5	1.3	x
3	cnrm cm3	B1		7.5	1.2		5.3	1.2	o
4	echam5	B1		1.3	0.7		5.9	1.2	o
5	echo g	B1		-4.2	1.2	LW/D	-7.9	1.8	x
6	hadcm	B1	C	3.8	1.0	C	3.7	1.7	x
7	ipsl cm4	B1		3.8	1.4		6.9	2.1	
8	miroc 3.2	B1		8.1	1.3		10.4	2.3	
9	pcm1	B1		1.5	0.6		3.6	0.8	o
10	ccsm3	A1b		4.6	1.4		2.0	2.4	o
11	cgcm3.1 t47	A1b		8.8	1.2		13.4	1.8	o
12	cnrm cm3	A1b		0.8	1.0		4.1	1.6	o
13	echam5	A1b	MC	3.7	0.7	MC	3.7	1.5	x
14	echo g	A1b		-4.7	1.1		0.9	1.9	o
15	hadcm	A1b		3.0	1.5		6.7	2.2	o
16	ipsl cm4	A1b	MW/W	7.4	1.6		11.2	2.6	
17	miroc 3.2	A1b		4.2	1.6	MW/W	14.2	2.7	
18	pcm1	A1b	LW/D	-1.5	1.0		-0.2	1.8	x
19	hadgem1	A1b		-1.5	1.3	MW/D	-2.5	2.8	

Notes

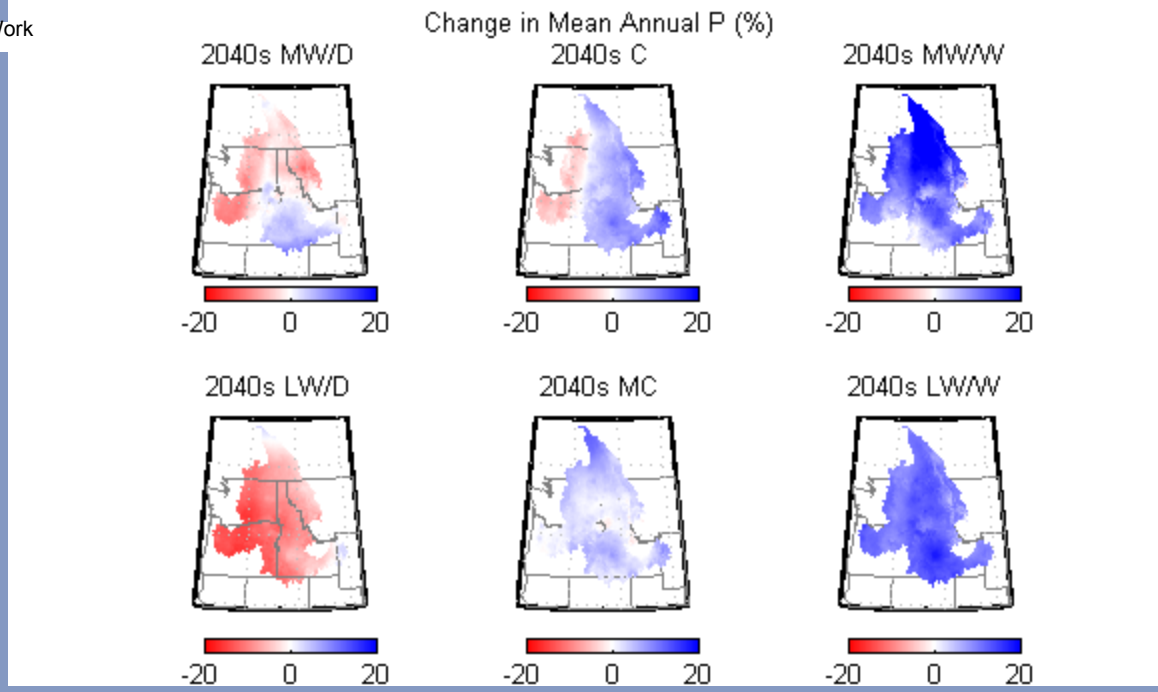
[1] RMJOC Labels: MW = More Warming, LW = Less Warming, W = Wetter, D = Drier, MC = Minor Change, C = Central Change

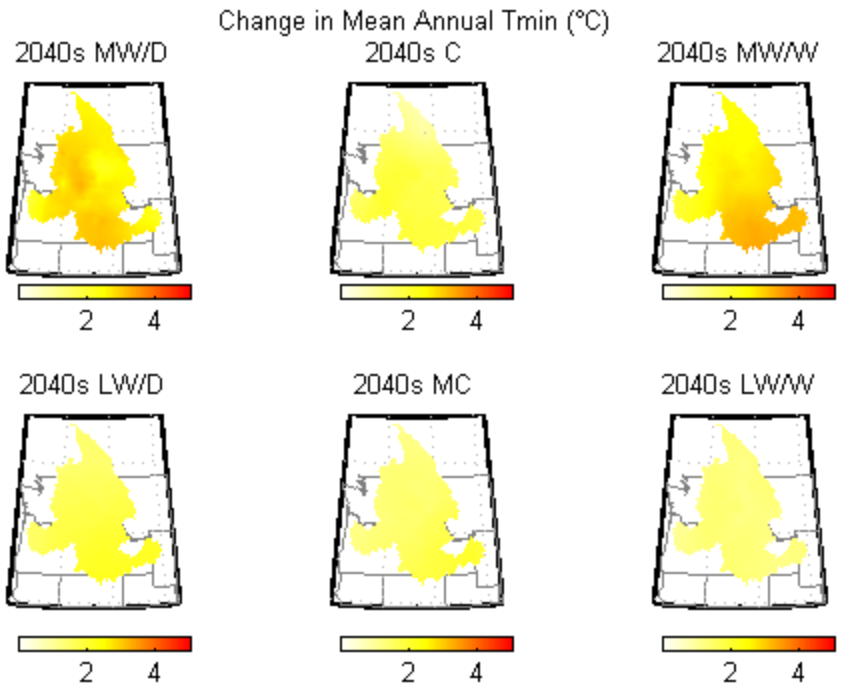
[2] P = precipitation, T = average daily temperature, "Change in" means change in 92-year period-mean annual condition. For assessing change, the reference is Observed Climate Variability, 1916-2006. The changed condition is the 92-year Observed Climate Variability sequence adjusted to reflect change in 30-year climate characteristics from observed 1970-1999 to a projected 30-year period (2020s = 2010-2039 and 2040s = 2030-2059) sampled from the given underlying climate projection (see Number).

… and then selecting an intersecting set of Transient Climate Projections

RMJOC

HD scenarios chosen to reflect spread of ***basin-wide*** CC possibilities

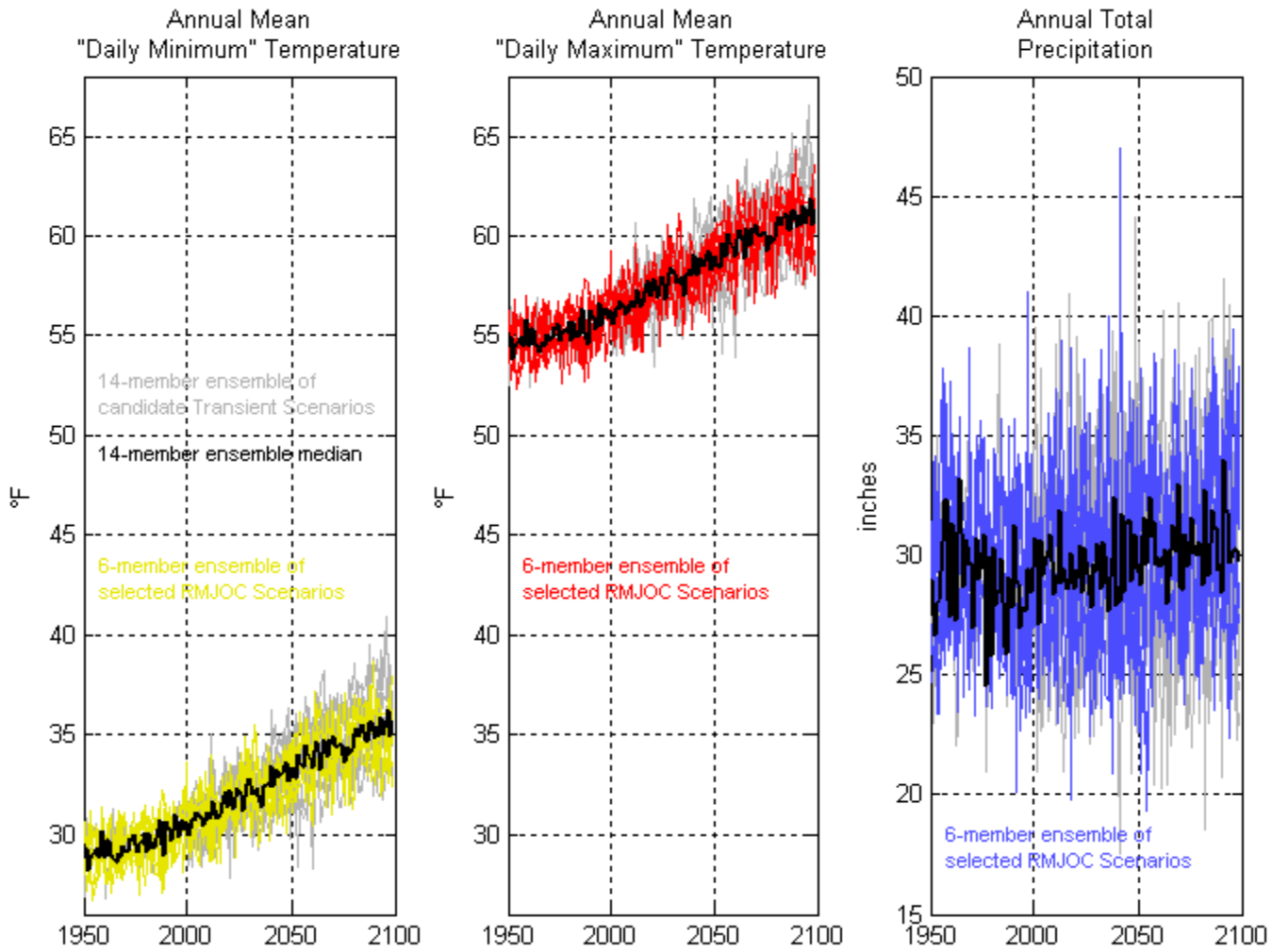




…but for each HD scenario, distributed change is complex (especially precipitation!)

RMJOC

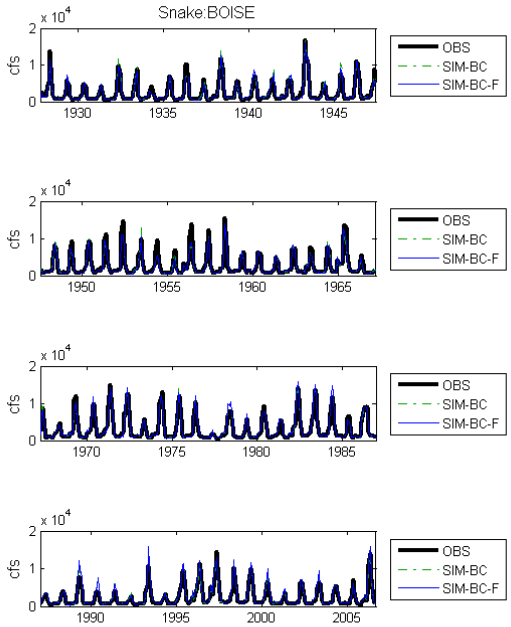
HD scenarios are meant to be viewed on an individual basis. Transient Projections are meant to be viewed as a collective through time (ensemble).



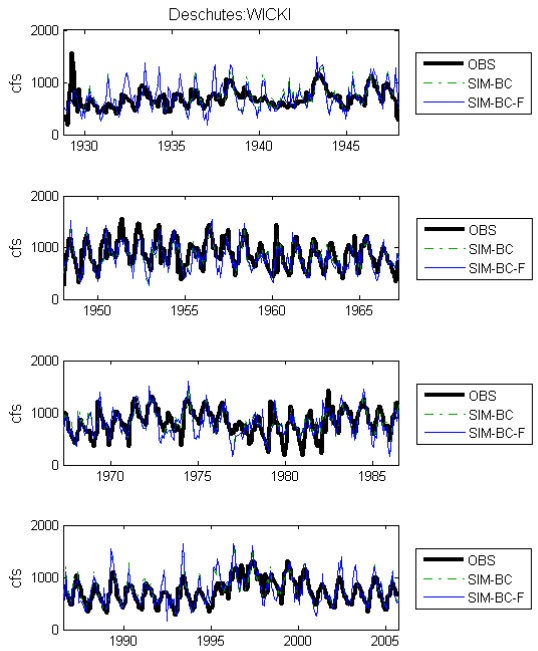
RMJOC

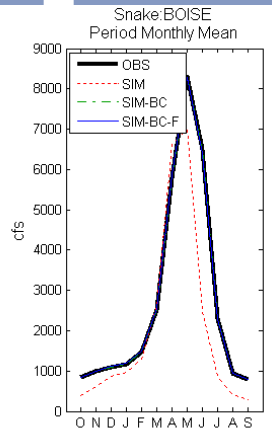
Bias-correcting VIC simulated Streamflows: Motive and Approach

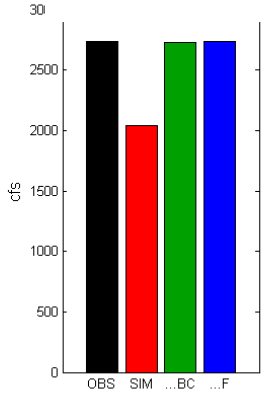
Less bias: BOISE

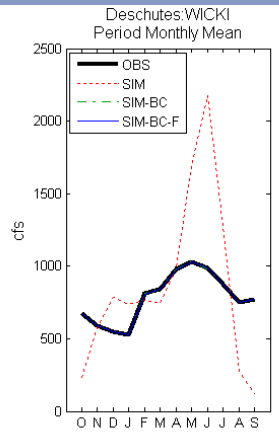


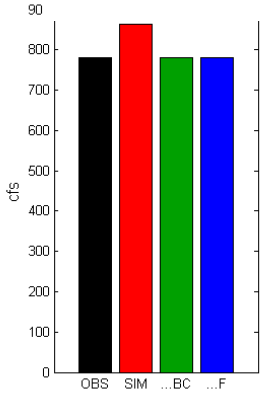
More bias: WICKI











RMJOC

Bias-correcting VIC simulated Streamflows: Other notes

- Quantile mapping approach to correct bias
- Requires adopting a streamflow target dataset:
  - Reclamation tribs: natural flow estimates from Reclamation
  - USACE/BPA: Modified Flows 2000
- Accounting for regulation effects at Brownlee
  - USACE/BPA had to account for the Brownlee regulation effect downstream to the Dalles
  - This accounting occurred after Reclamation operations studies using future streamflows

RMJOC

Other RMJOC Data Development

- Water Supply Forecasts
  - Created “synthetic” volume forecasts to reflect climate altered conditions at the time of forecast (snowpack, precipitation, runoff)
  - Also developed perfect knowledge volumes from streamflows
- Rules Curves
  - Using synthetic volume forecasts, compute synthetic rule curves (flood control, variable energy refill curves)

RMJOC

Key Findings for Hydropower, Flood Risk and Ecosystem

Part II – Reservoir Operations Assessments Reclamation Tributary Basins

Part III - Reservoir Operations Assessment

Flood Control and Hydropower

RMJOC

Part II – Reservoir Operations Assessment for Reclamation Tributary Basins

Yakima, Deschutes and Snake Rivers

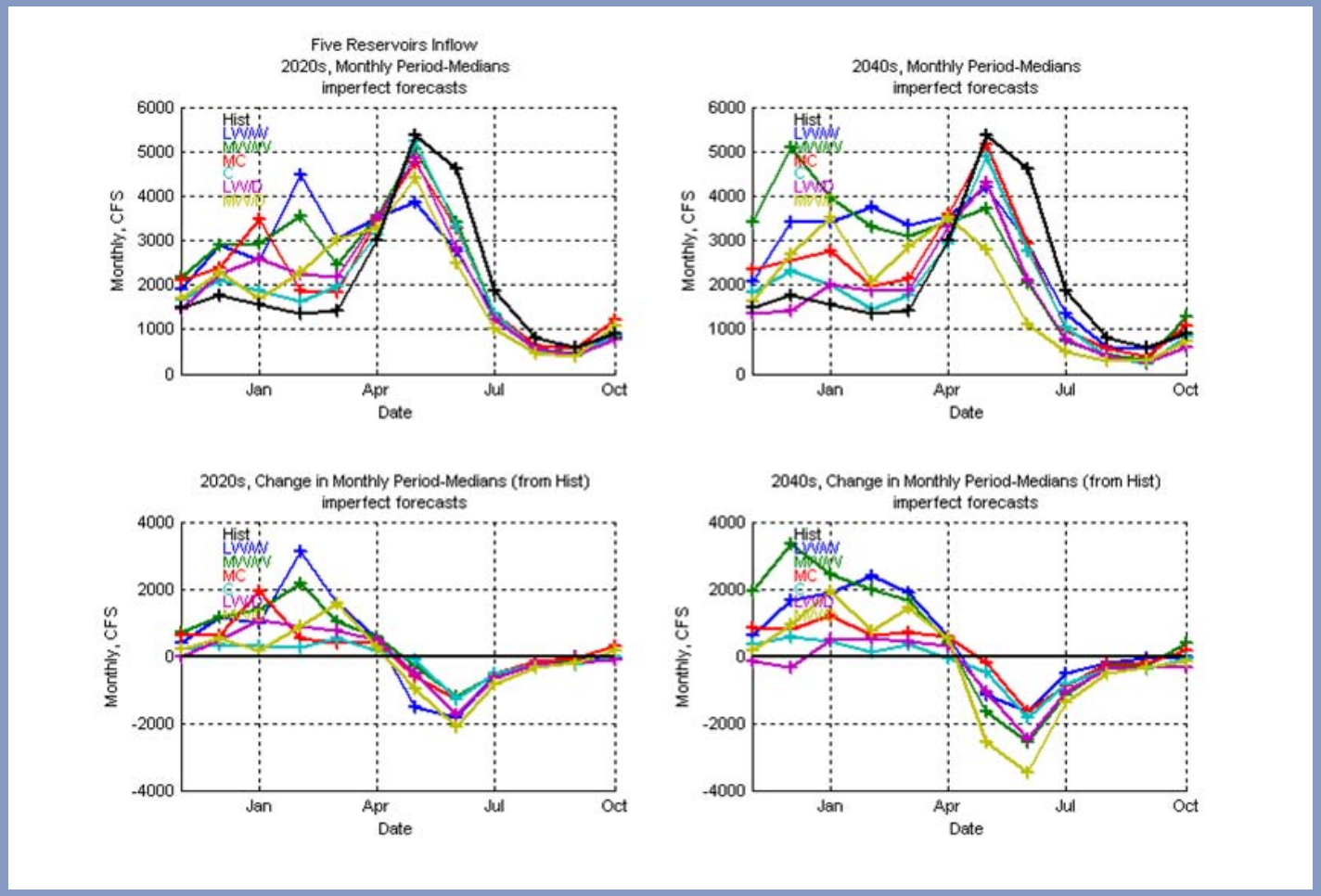
RMJOC

Reclamation Tributary Basins General Results

- Increased winter runoff, less spring/summer runoff
- Increased storage needs in the spring, greater drawdown in summer months than historically
- Reclamation flood control curves self-adjusting
- Increased reliance on stored water vs. natural flow
- Report evaluated inflow to reservoirs, end-of-month storage, flows at key locations, water delivery, environmental objectives

RMJOC

Yakima River
Inflow to Reservoirs



Familiar story: Warming leads to more winter runoff;
Less spring-summer runoff;
Lower flows in river in late summer.

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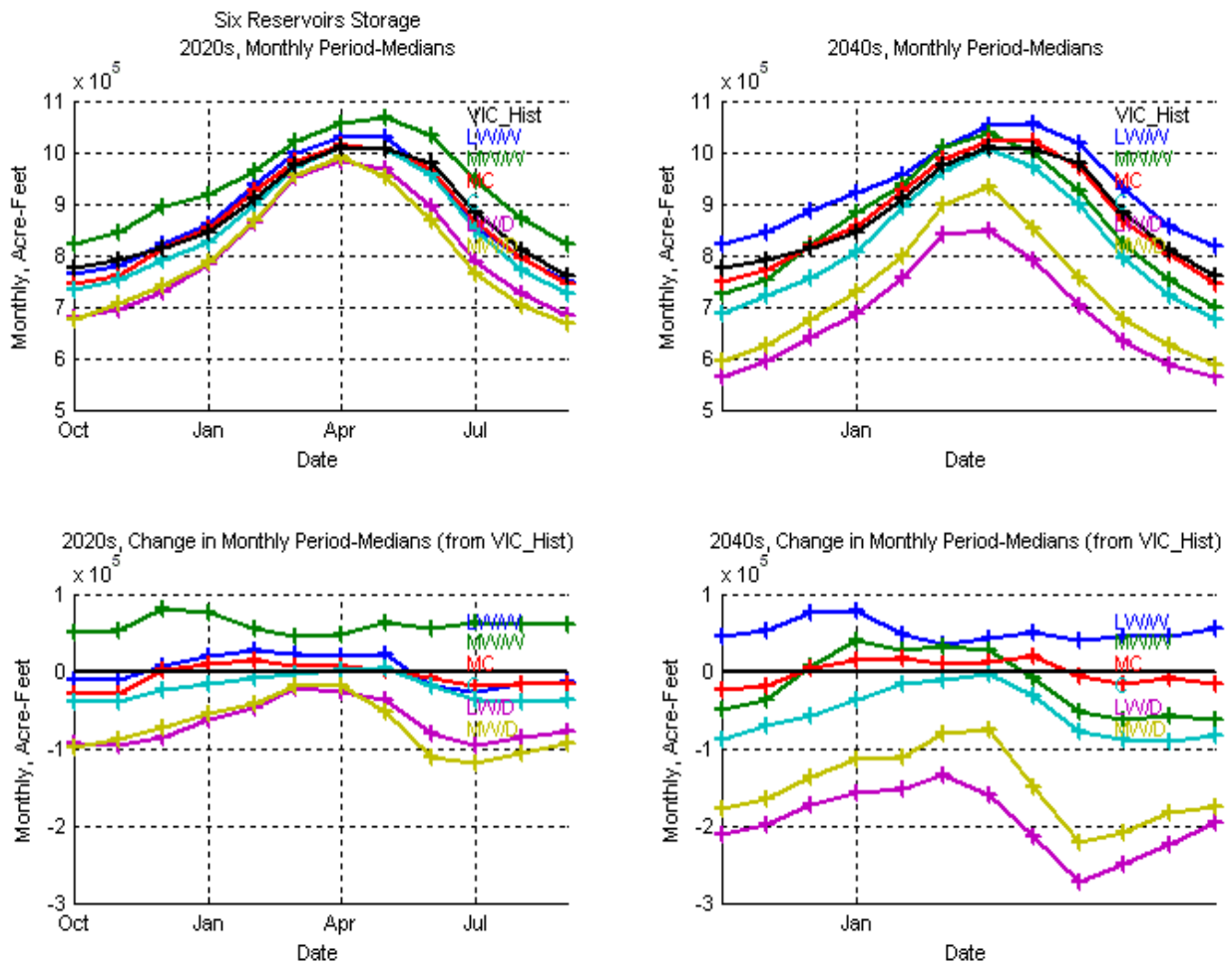
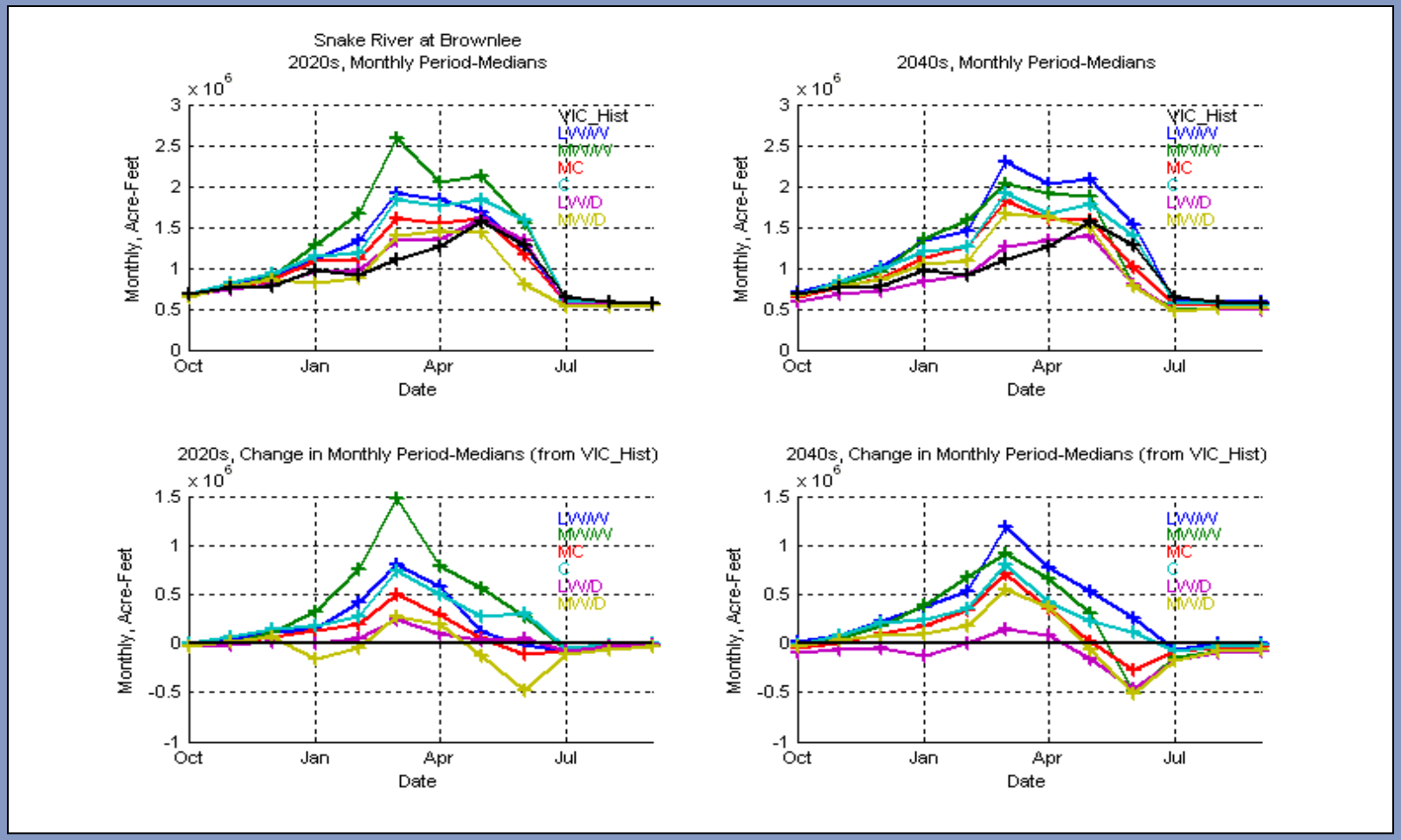
Deschutes River End-of-Month Storage



RMJOC

Snake River Flow at Brownlee



RMJOC

Part III – Reservoir Operations Assessment: Columbia Basin Flood Control and Hydropower

RMJOC

Part III Flood Control

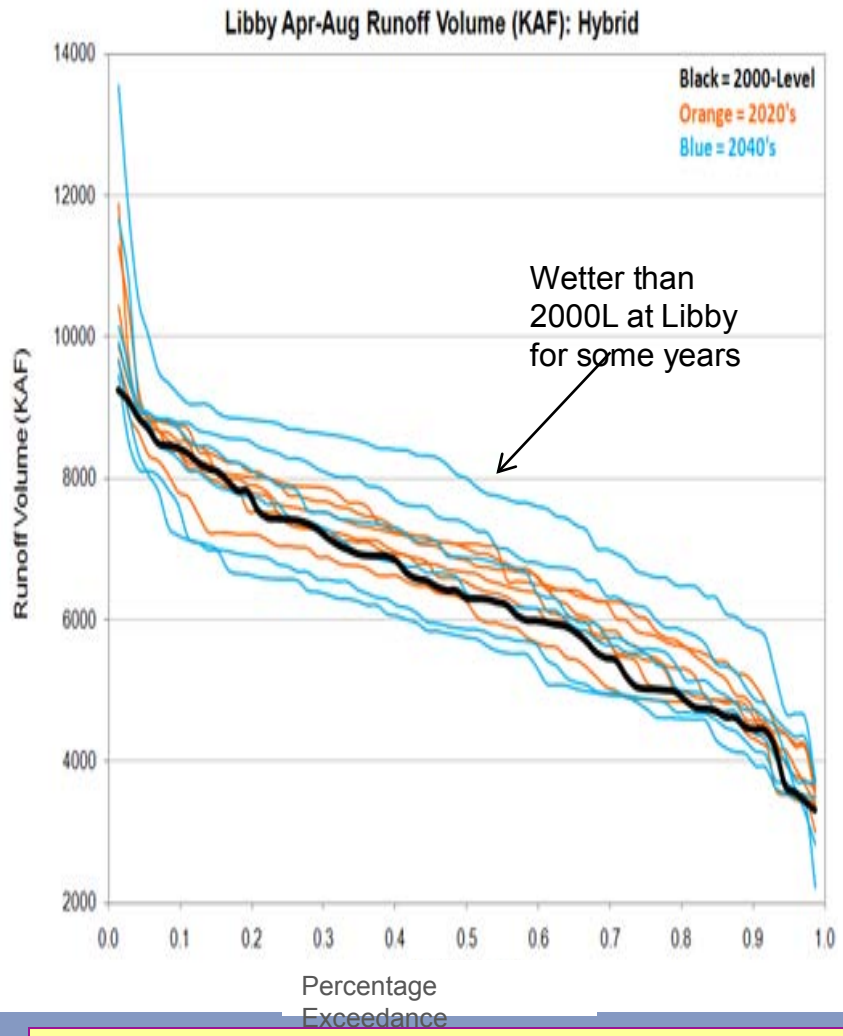
RMJOC

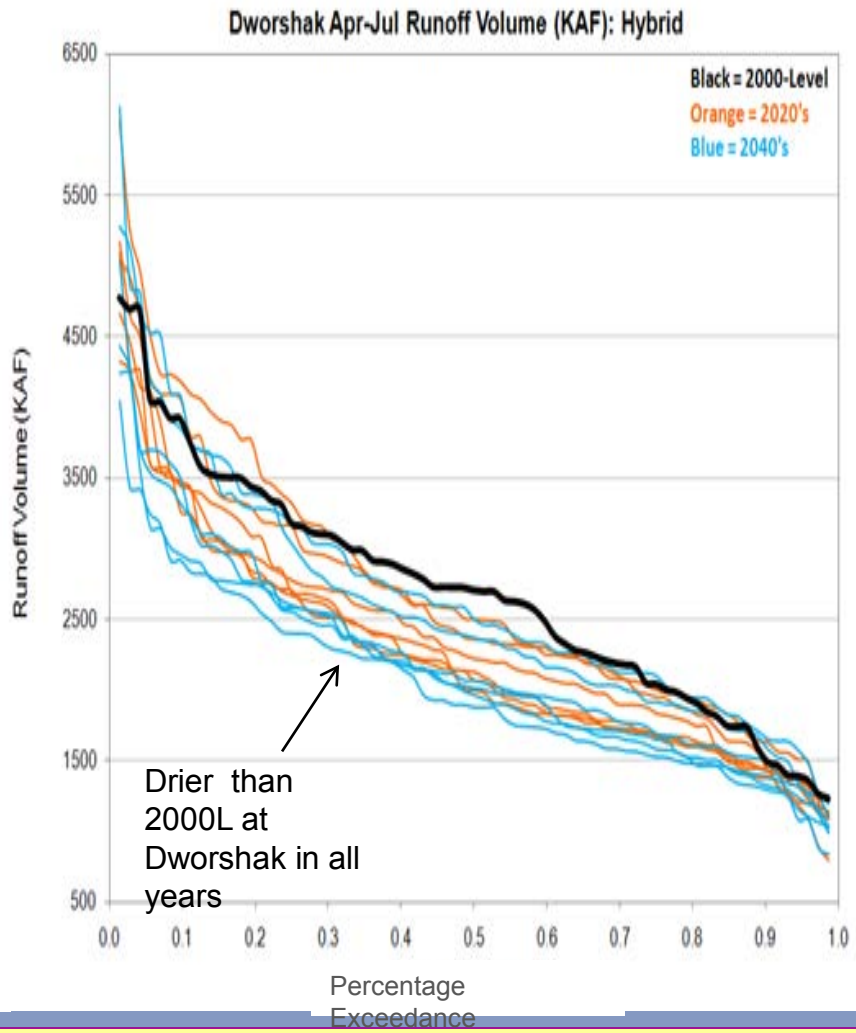
Flood Control – Approach and Limitations

- Monthly time step and 70-year streamflow period rather than daily modeling due to time, data, and model limitations
- Assumed use of current flood control storage reservation diagrams & procedures rather than developing new diagrams/procedures in response to climate change
- Analysis focused on end-of-month flood control requirements during evacuation period and only estimated flood control requirements during the refill period

RMJOC

Summary of Results of Climate Change Data for Libby and Dworshak Reservoirs

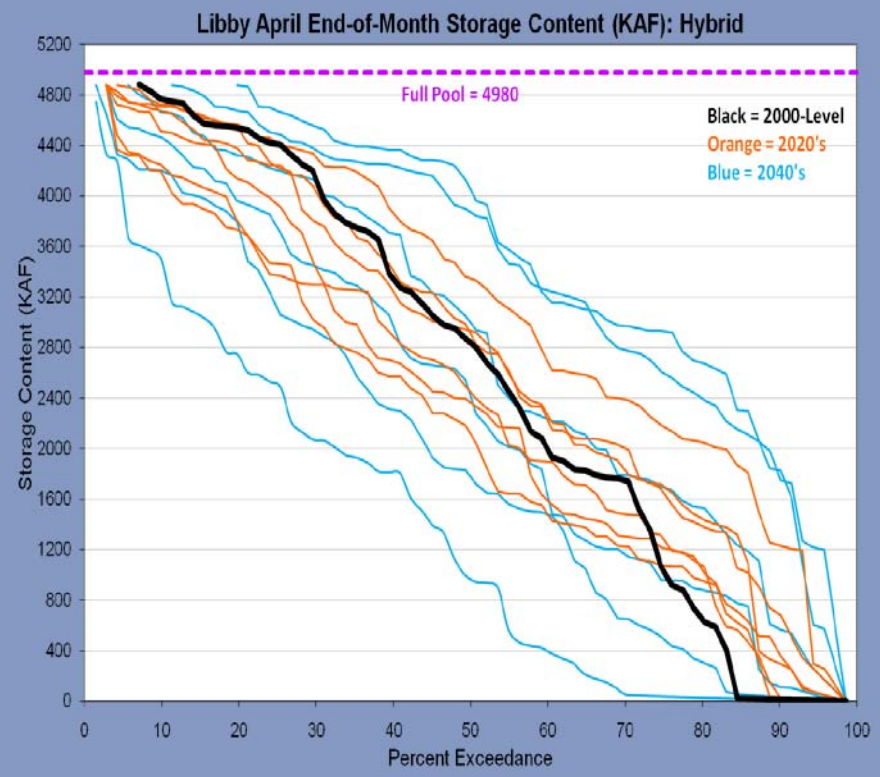


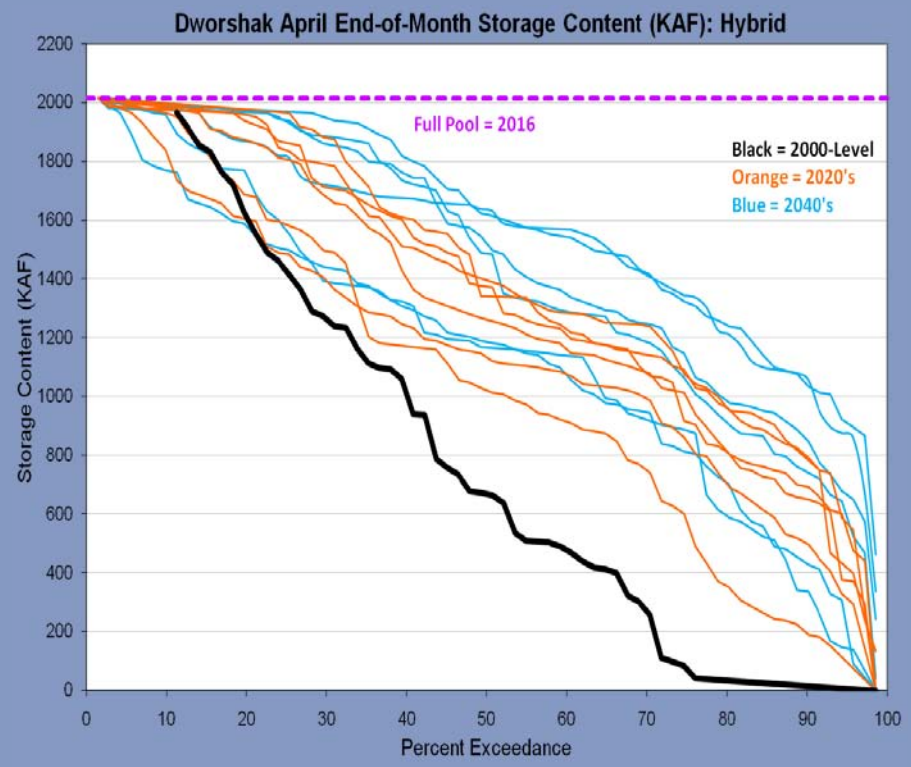


Changes in hydrologic patterns in one basin are not necessarily the same as in another basin

RMJOC

Climate Change Flood Risk Curves For Libby and Dworshak Reservoirs





RMJOC

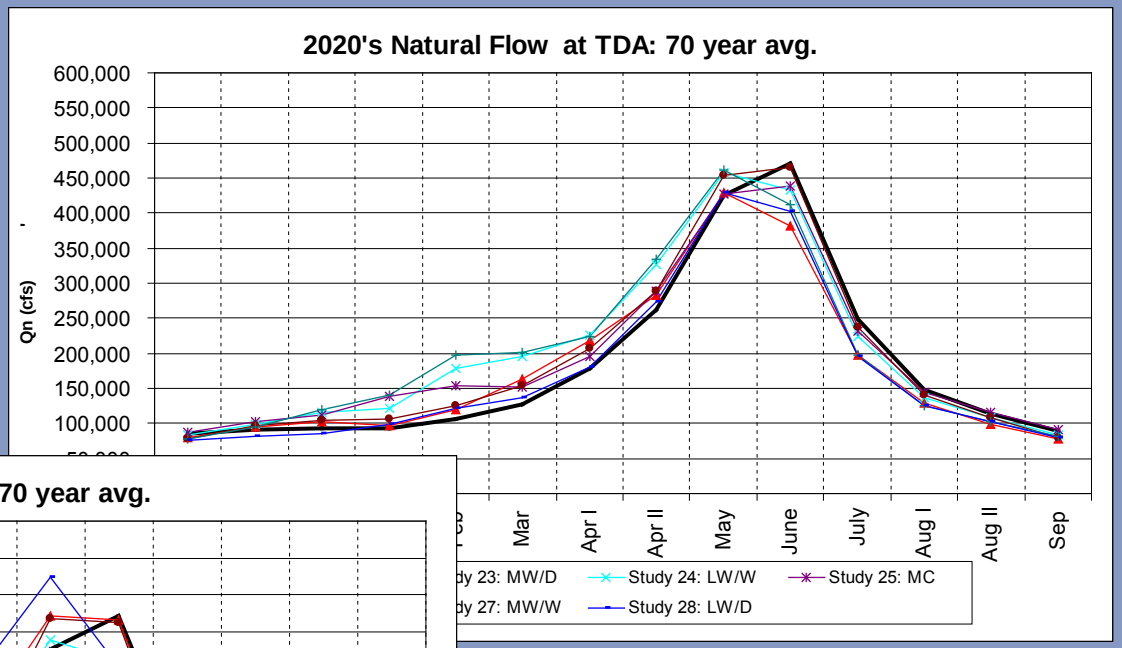
Part III – Hydropower

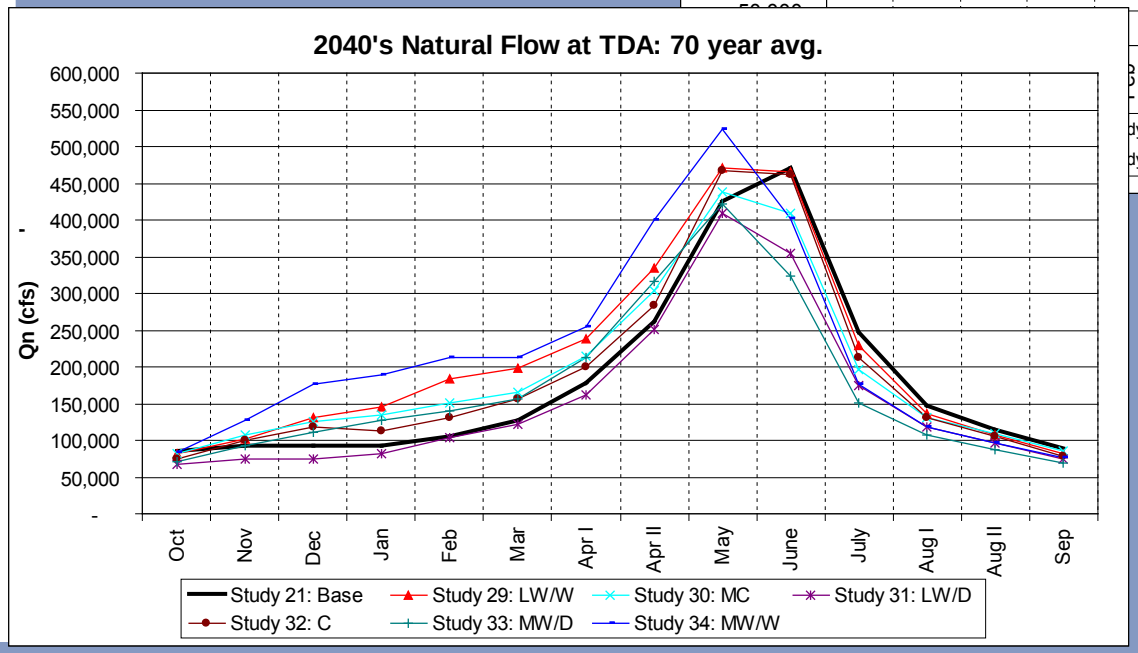
RMJOC

Model Input: Natural Streamflows at The Dalles for 2020's & 2040's

Climate Change scenarios result in higher natural streamflows in the winter to spring period…

and lower streamflows in the summer, generally speaking

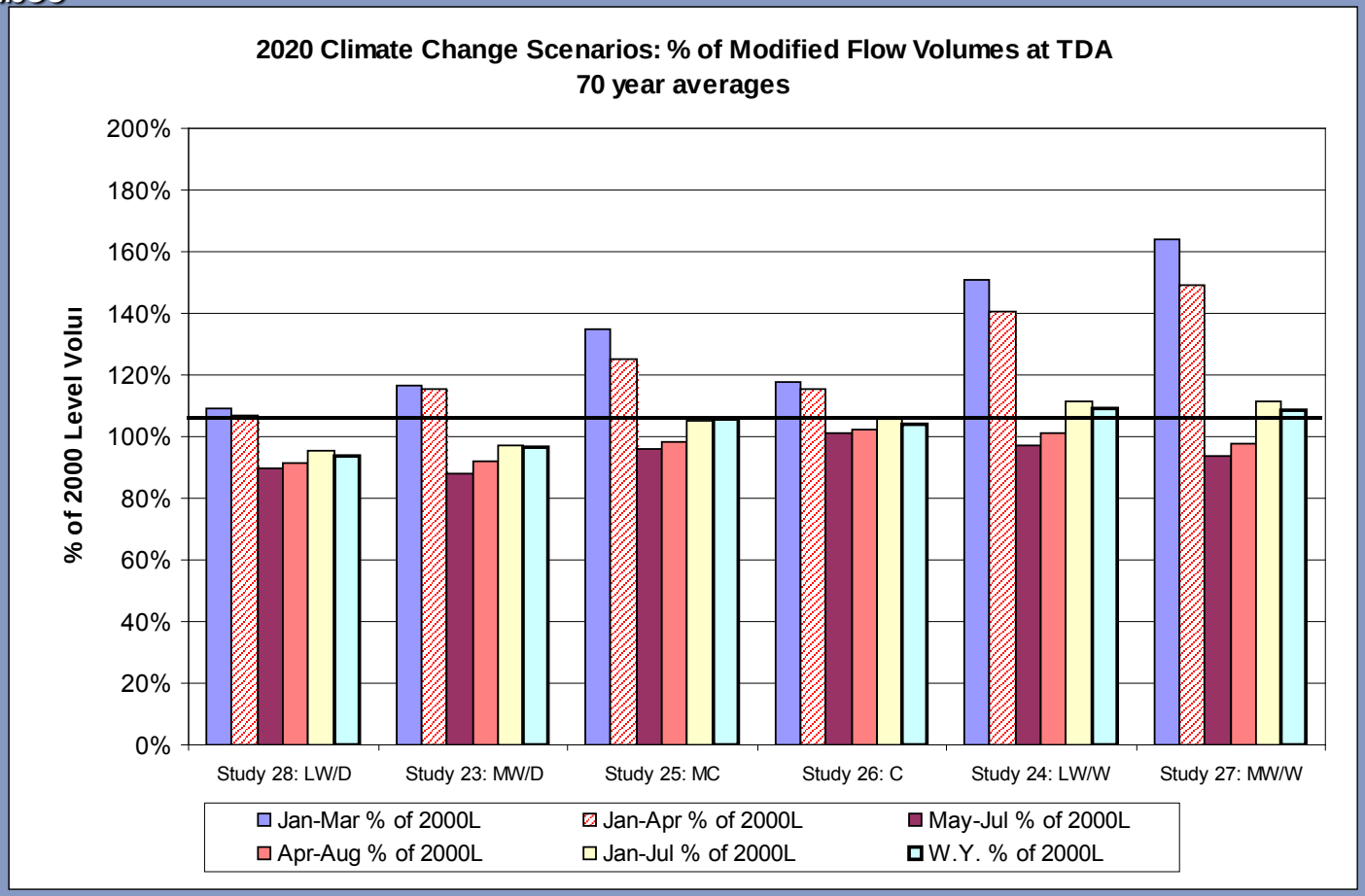




RMJOC

Model Input: Shape of Runoff for 2020's

Note that the 2040's have similar shaping characteristics



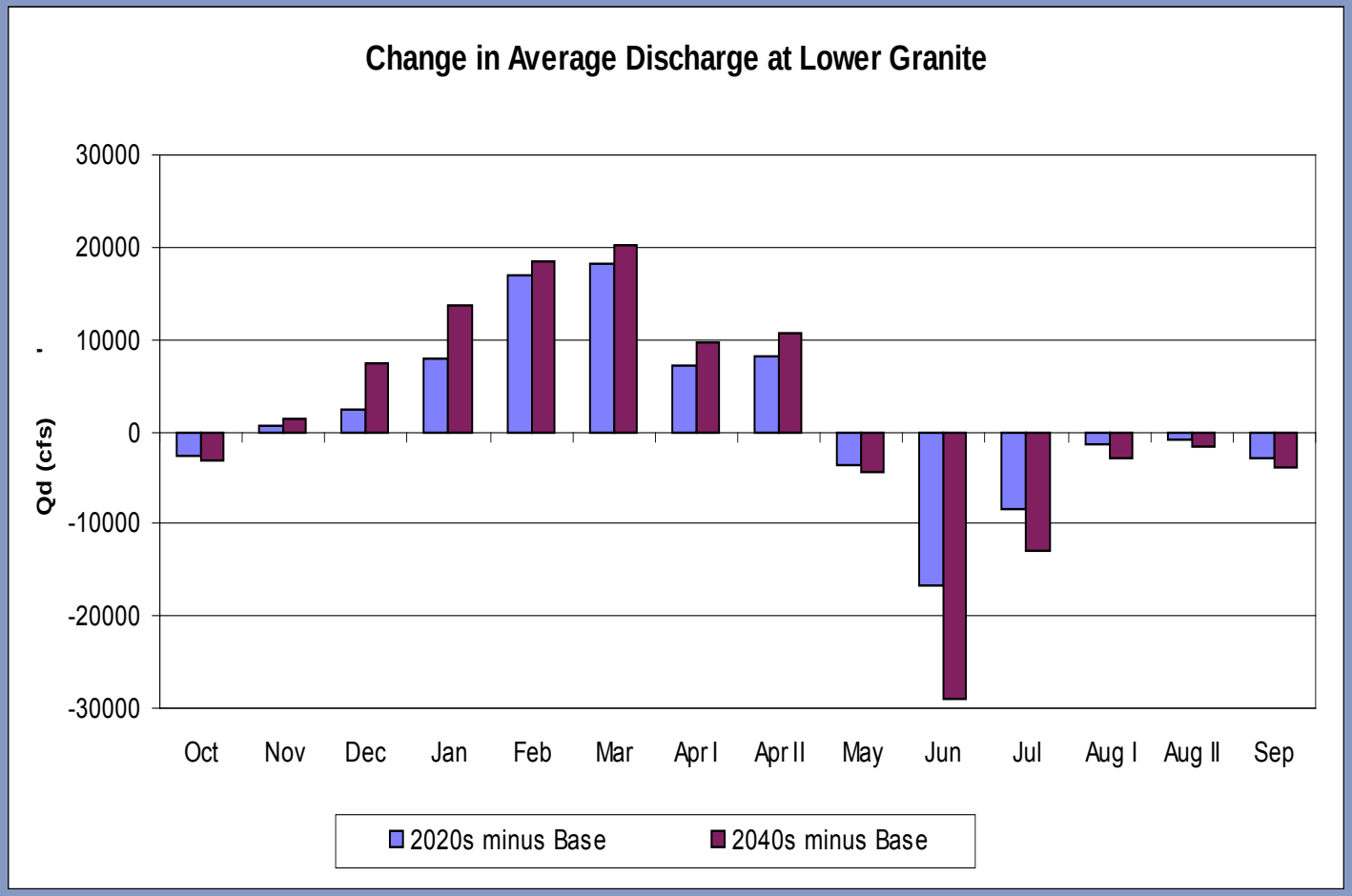
2000L Base Case Volumes @ TDA

Period	Vol (MAF)
Jan-Mar	19.5
Jan-Apr	32.5
May-July	69.4
Apr-Aug	90.5
Jan-July	101.9
Oct-Sep	131.7

Note that the Jan-April period is higher than current levels, the May-July period is lower (earlier runoff)

RMJOC

Lower Granite Discharge Comparisons to Base Case

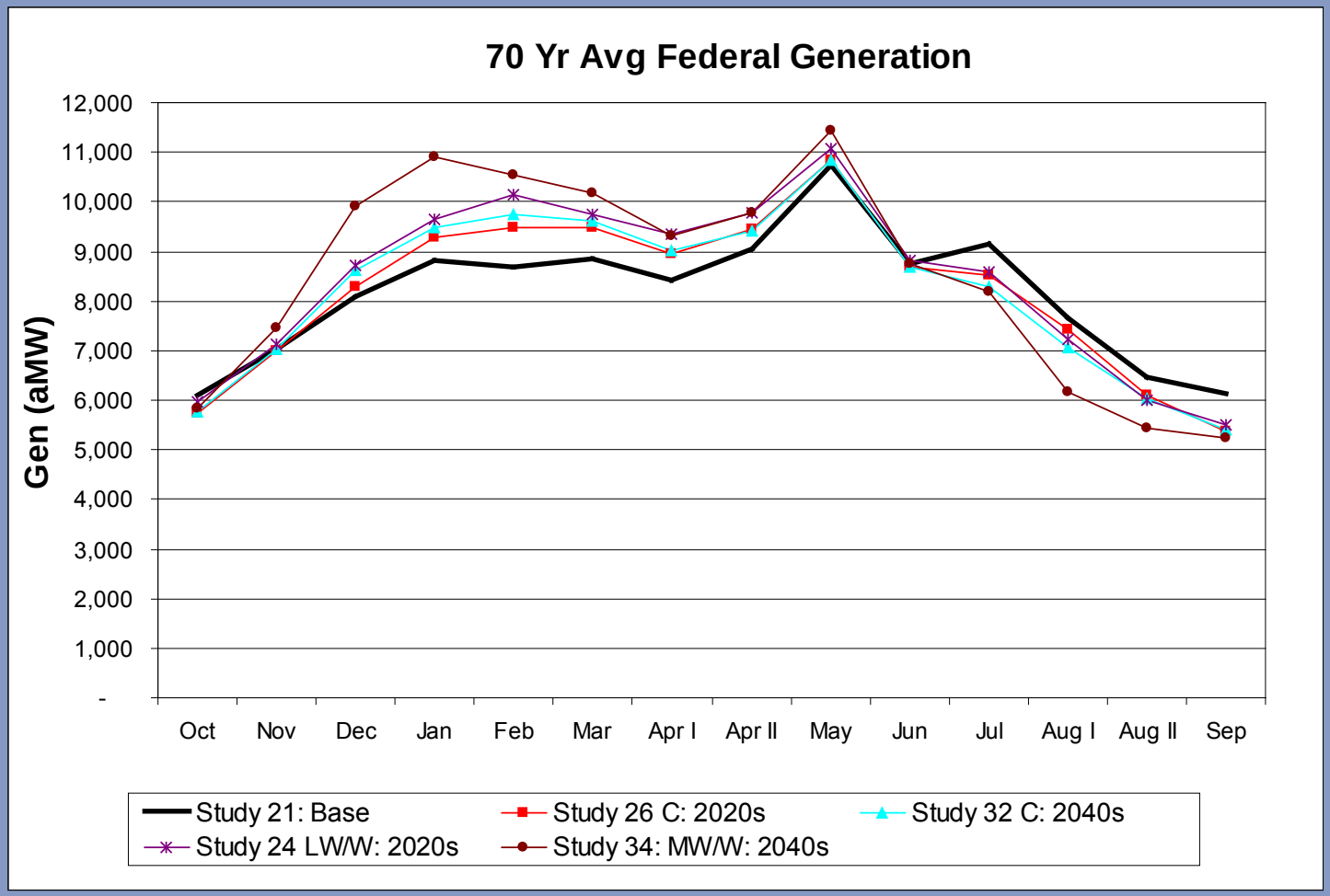


RMJOC

McNary Discharge Comparisons to Base Case

RMJOC

Federal Generation Comparisons for Two Central and Two Wet Scenarios



All four scenarios were modeled using the same load assumptions as the Base Case (2012 load projections)

RMJOC

Part IV Summary

- Summarizes Parts I, II, and III
- Draft report out for public comment
- Comments due August 19th, 2011
- Reports available at http://www.bpa.gov/power/pgf/HydrPNW.shtml

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Recommended Next Steps

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Next Steps
Short-Term < 10 Years

It is premature to include current climate change science in current operations. It is however, the time to start the conversation and plan for the future. Proposed actions include:

- Refining daily data to enable better analysis of flood risk.
- Conduct 2010 Modified Flow analysis (to be published this fall).
- Conduct backcasts (or use peer-reviewed backcasts already conducted) of temperature, streamflow, and seasonal streamflow ratios
- Establish criteria for when “change” warrants adjustments to current operations and planning processes (e.g. adopt climate change as the base case).
- Once IPCC’s 5th datasets are available (about 2013), identify and conduct new studies to update current, downscaled climate change scenarios.
- Coordinate and share climate change information with other Federal agencies and regional stakeholders.

RMJOC

Next Steps
Long-Term Planning >10 Years

- Long-term planning processes will continue to use the 70 or 80 year modified streamflow record as the base case.
- Scenario analysis using the climate change data sets will be performed to look at the range of potential outcomes and to identify risks.
- Future long-term contracts and processes need to be flexible and adaptable to include actual climate information, especially when they span several decades.
- Some examples of future long-term planning processes that should have climate change analysis include.
  - Columbia River Treaty (2014/2024)
  - Corps Flood Risk Management Studies
  - Future BiOps
  - NEPA processes that require hydro regulation studies
  - Asset Planning for Hydro Asset Strategy
  - Maintenance planning practices and guidelines
  - BPA's Resource Program
  - Reclamation storage studies

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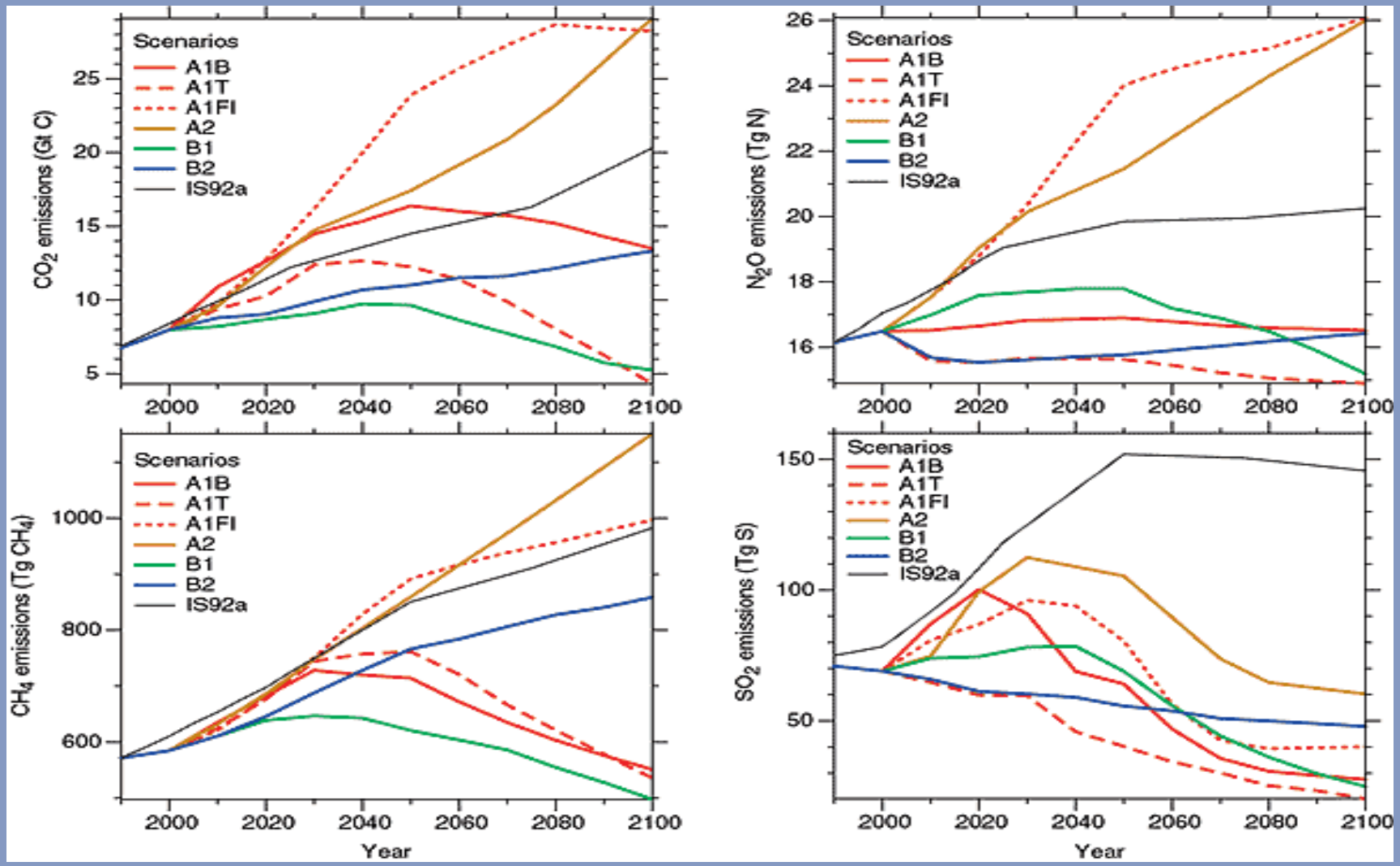
Extras

Emission Scenarios

RMJOC



CRT 2014 Review Climate Change Dataset

Building from the RMJOC Work

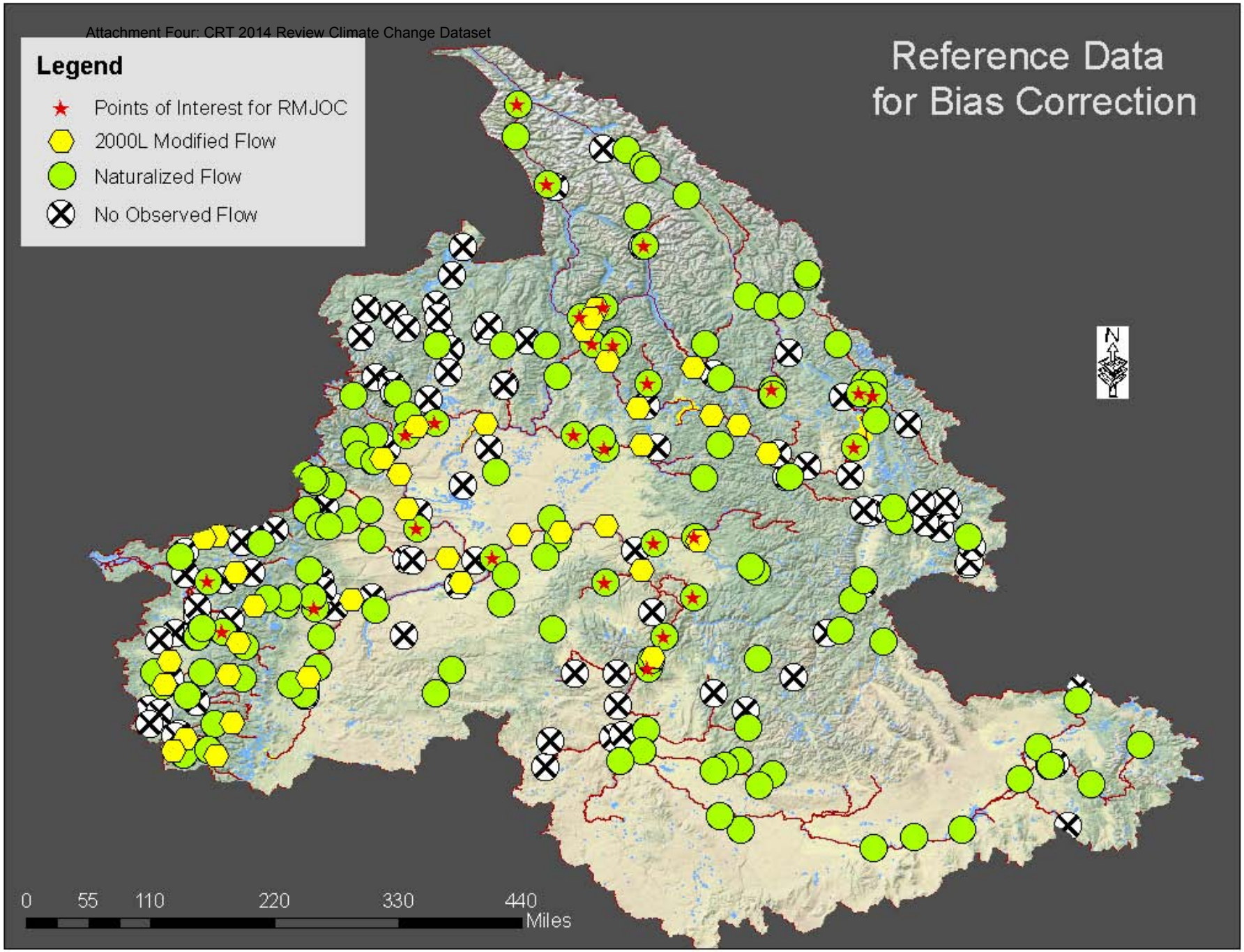
Seshu Vaddey

Issues for CRT 2014 Review

- Daily data was not part of RMJOC work
- The RMJOC process resulted in monthly and 14-period flows used for modeling
  - Reclamation used Monthly data
  - BPA used 14-period data
- Daily data is needed by USACE for Flood Control modeling

Issues with Available Daily data from UW

- UW Columbia Basin Climate Change Scenarios Project (CBCCSP)
  - Daily data was provided as part of this project
  - But, does not meet the needs for USACE
- Bias correction of the VIC hydrology was done using a mix of 'naturalized' and Modified Flows
  - The Mix of BC data does not work for the models used by USACE
  - We need a consistent bias correction throughout the Basin.

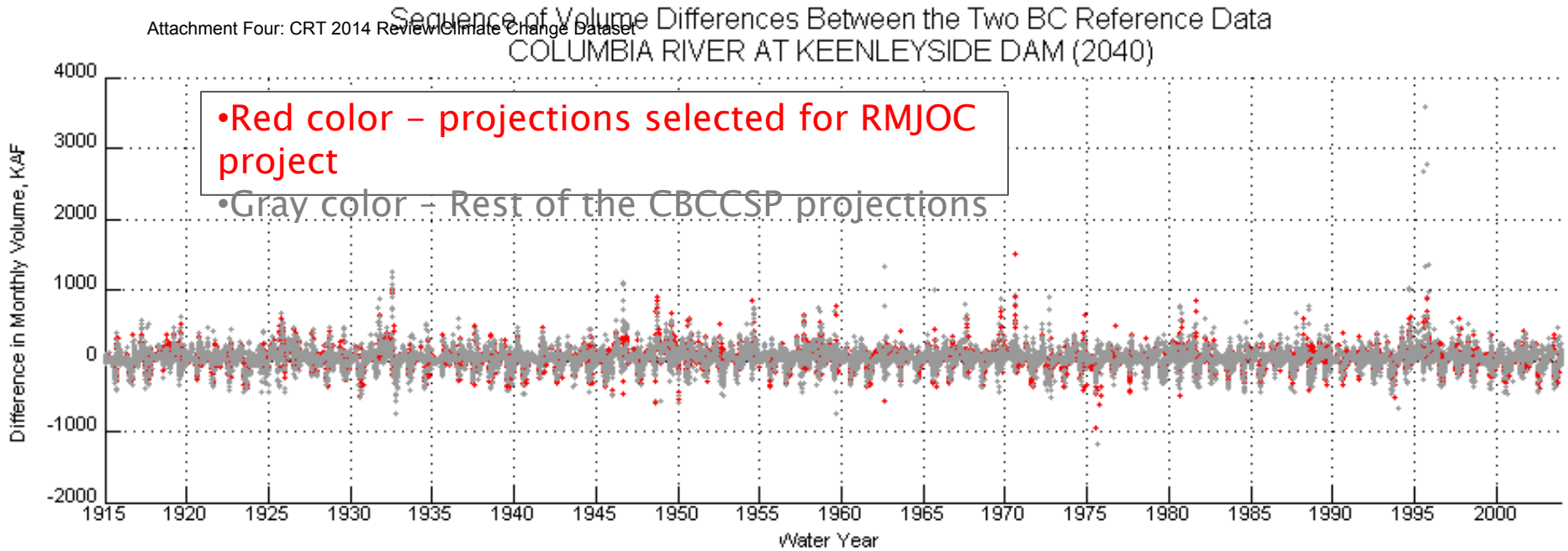

Reference Data
for Bias Correction
Legend
Points of Interest for RMJOC
2000L Modified Flow
Naturalized Flow
No Observed Flow
N
0
55
110
220
330
440
Miles

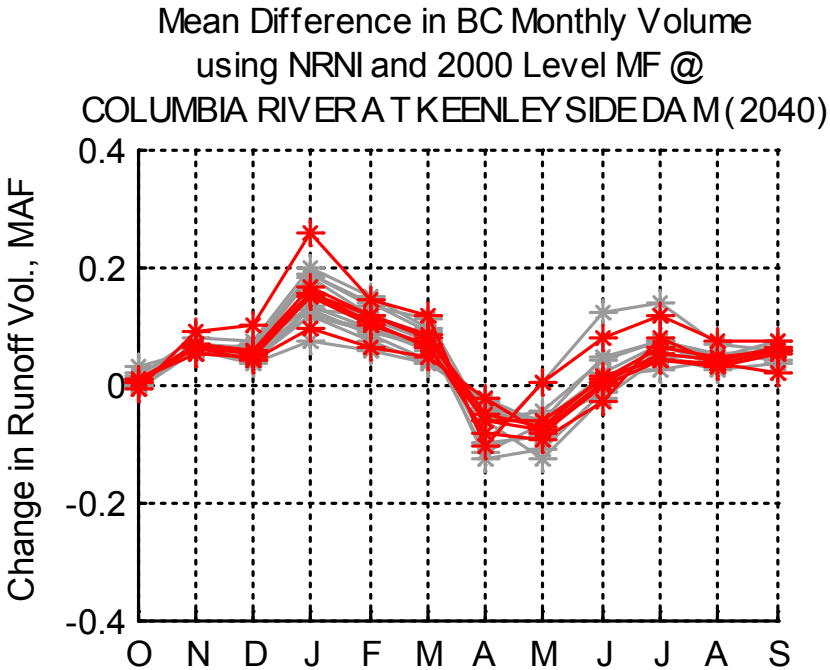
CRT 2014 Solution

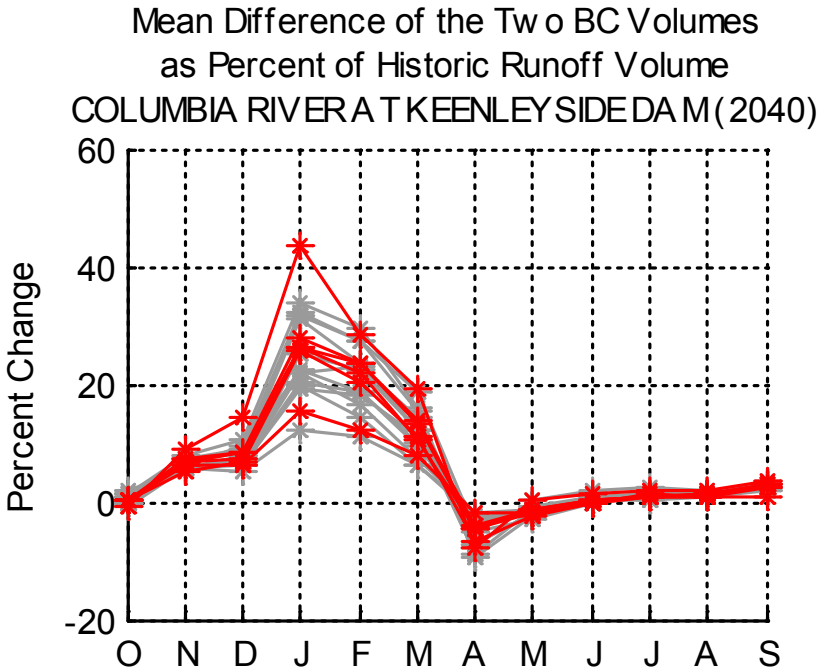
- Re-perform the bias correction process
  - To generate Daily data for CRT 2014 Program
- Reference data for the BC process
  - No Regulation No Irrigation (NRNI) flows
  - Rather than 2000 Level Modified Flows
- NRNI flows were developed as part of the CRT 2014 Phase 2a work

Benefits of the Solution

- Performing BC with NRNI provides several benefits
- Consistent with the approach used in other climate studies
  - As well as by Reclamation in the Snake, Yakima & Deschutes
- Changes in streamflow can be attributed more to climate conditions
  - Rather than changes in irrigation levels or evaporative loses
- Provides more flexibility in supporting analysis needs of CRT 2014 Review
  - Separating out elements of Irrigation Diversions and Evaporative losses from Reservoirs
- Able to re-construct Modified Flows to support monthly & 14-period analysis needs and have it based on a more robust approach


Sequence of Volume Differences Between the Two BC Reference Data
COLUMBIA RIVER AT KEENLEYSIDE DAM (2040)
•Red color – projections selected for RMJOC project
•Gray color – Rest of the CBCCSP projections
Difference in Monthly Volume, KAF
4000
3000
2000
1000
0
-1000
-2000
1915
1920
1925
1930
1935
1940
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
Water Year


Mean Difference in BC Monthly Volume
using NRNI and 2000 Level MF @
COLUMBIA RIVER AT KEENLEYSIDE DAM (2040)
Change in Runoff Vol., MAF
0.4
0.2
0
-0.2
-0.4
O N D J F M A M J J A S


Mean Difference of the Two BC Volumes
as Percent of Historic Runoff Volume
COLUMBIA RIVER AT KEENLEYSIDE DAM (2040)
Percent Change
60
40
20
0
-20
O N D J F M A M J J A S

Questions?

Framework for Incorporating Climate Change into Risk Informed Decision-Making

TREATY REVIEW PROGRAM

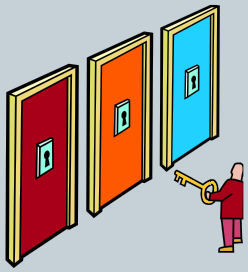
SESHU VADDEY

The Central Question

- How will **Climate Conditions** that are important to the **Decisions** needed for CRT 2014 Review be incorporated in the **Planning Process**?
- Will Climate Change be an FYI study

Or

- Will it provide information that has an influence on a Decision?



The Climate Change Plan

3

Identify Objectives & Challenges

- Using Primary Driving Purposes
  - Flood Risk
  - Power Generation
  - Ecosystem Function
- Establish System Performance Indicators & Thresholds
- Objectives for Climate Change Analysis & Decision Process

Vulnerability Analysis

- Sensitivity Analysis
- Explore the Climate Space
- Results showing impacts on System Performance

Climate Informed Risk Assessment

- Quantify results of Vulnerability Analysis
- Establish Climate States based on Thresholds
- Analysis reveals climate sensitivity of each Alternative
- Use comparison methods to determine a preferred alternative

The Climate Change Plan

4

Identify Objectives & Challenges

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Identify Objectives & Challenges

- Building from the Primary Driving Purpose Objectives
  - Flood Risk
  - Power Generation
  - Ecosystem Function
- Address questions such as
  - What benefits are expected to come from the Study?
  - If the system were to fail what would it look like?
  - Under what circumstances (decisions) can climate change risks be ignored?
- Establish Climate Change Metrics
  - System Performance Indicators (SPI)
  - Thresholds of success / failure

Climate Change Plan How to: Working with an example

- System Refill is an important function
  - Possible Answers to Questions posed
    - Reliable refill is an important benefit to system operations
    - Failure to refill will have cascading impacts on Ecosystem Function & Power Generation in Summer months
    - Starting refill too early can impact flood control operations

- What are good indicators of system performance & how will we know good performance from poor performance?
  - **System Performance Indicator (SPI)**: System Refill Reliability
  - **Thresholds:** Successful performance is 95% reliability or above; marginal but acceptable is 85-95%; unacceptable below 85%

Climate Change Plan How to: Working with an example

- More System Performance Indicators need to be established to support CRT 2014 Program

- Other possible Performance Indicators that can be considered by the Sovereign Technical Team are:

The Climate Change Plan

Identify Objectives & Challenges

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Climate Informed Risk Assessment

- Quantify results of Vulnerability Analysis
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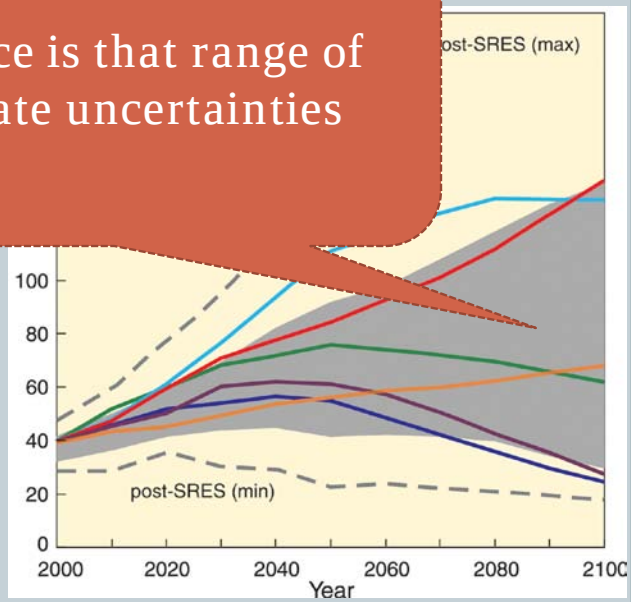
- Use comparison methods to determine a preferred alternative

Vulnerability Analysis

- A Vulnerability Analysis is intended to get us to the point of understanding how to distinguish between these Climate States
  - Climate Driven Decisions
  - Climate Influenced Decisions
  - Climate Independent Decisions

Climate Space is that range of future climate uncertainties



- Accomplished by performing a Sensitivity Analysis
  - Explore the **climate space**
    - And resulting impact on System Performance Indicators
    - Use model systems available to CRT 2014 Program

So how exactly do we perform a Sensitivity Analysis?

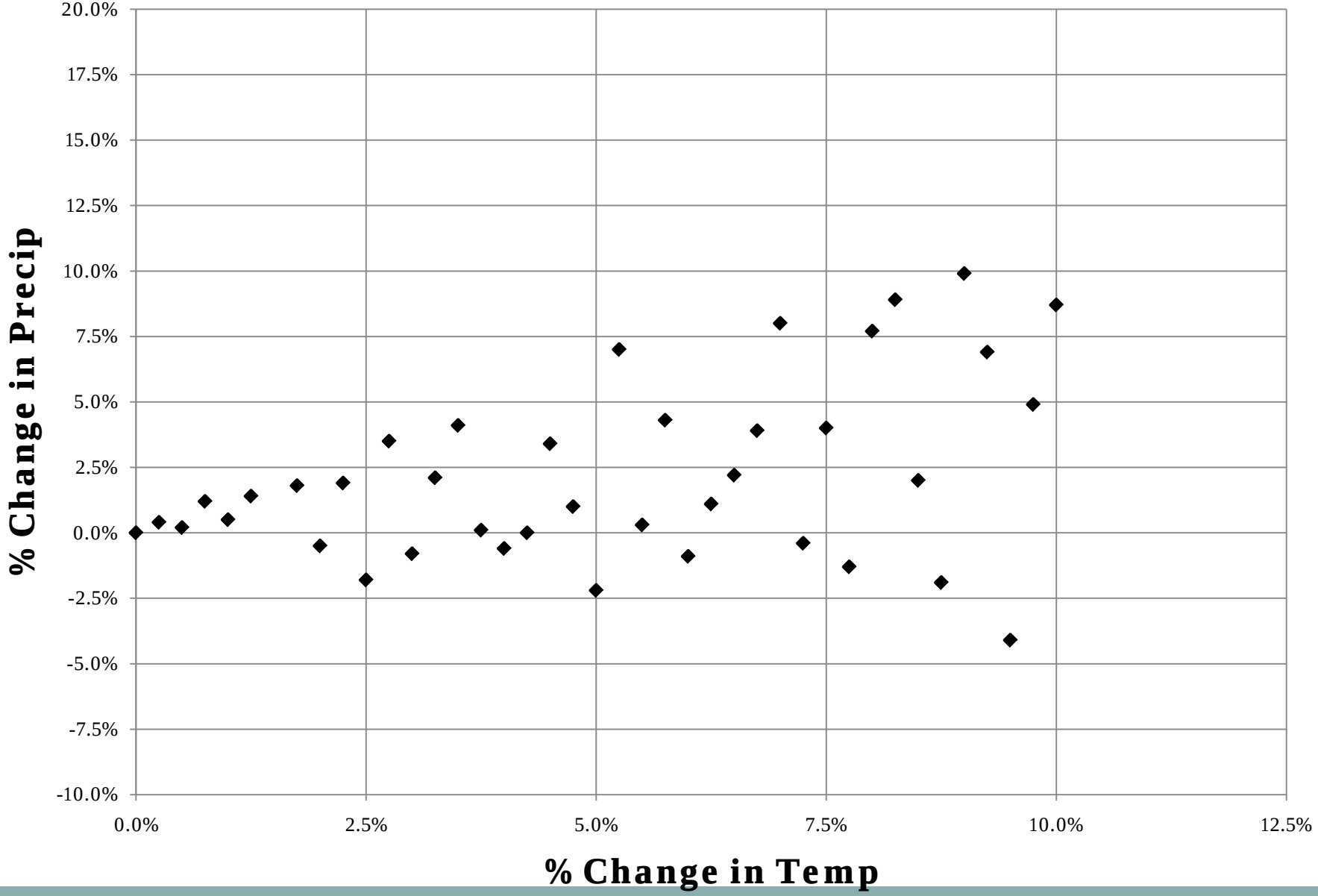
Vulnerability Analysis

- Use Period of Record analysis
  - Reference Case
    - Run Historic Hydrology thru Models
    - Run Future Climate Change hydrology thru Models w/o Alternatives
  - Alternative Assessment
    - Repeat Reference Case process for Future Climate Change hydrology but w/ Alternatives
- Climate impacts measured by
  - Changes in System Performance Indicators between historic conditions and climate change conditions
- How do we ensure the Climate Change data encompasses the full range of possible climate conditions?
  - So that we can fully understand our Vulnerability Domain.
  - Presented below are 2 Approaches to defining the Climate Space

Approach 1 – GCM Altered Hydrology

- The UW Columbia Basin Climate Change Scenarios Project dataset provides GCM altered hydrology
  - 57 sets of period change data (Hybrid-Delta)
  - 14 sets of time-developing data (Transient)
  - GCM based datasets
    - Explicitly links projection of changes in streamflow to changes in Temperature & Precipitation (climate factors)
- Approach 1 would use VIC streamflows
  - For Historic & all Hybrid-Delta (2020, 2040 & 2080) projections
  - Transient projections

Example of Climate Space Investigated by GCM Data



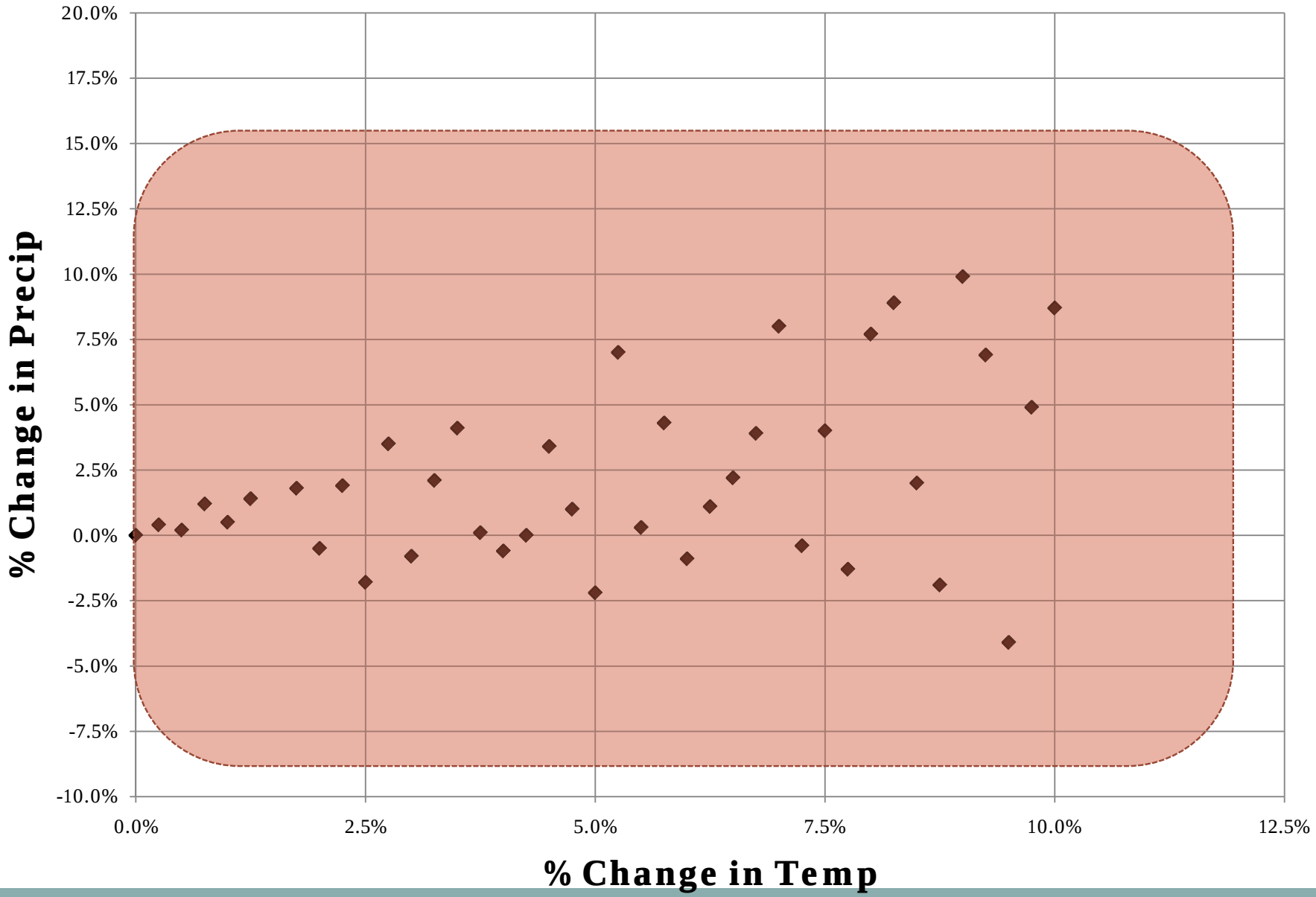
Approach 1 – GCM Altered Hydrology

- Benefits
  - Rich array of changes in streamflows across temporal and spatial domains.
  - Able to capture timing shifts and spatial changes explicitly linked to climate change
- Weaknesses
  - Range of uncertainty is small.
  - There may be events not in a GCM record that could adversely affect System Performance Indicators

Approach 2 - Parametrically Alter Hydrology

- Parametric approach expands range of available climate change conditions
  - Create a large array of hydrologic conditions suitable for Monte Carlo analysis of climate conditions
  - Parametrically scale volume, shape, timing shifts & spatial variability of hydrographs
  - UW CIG work provides correlation between T & P changes and streamflows
    - To construct the parametric scaling function

Example of Climate Space Investigated by GCM Data



Approach 2 - Parametrically Alter Hydrology

- Benefits
  - Much fuller range of variability for exploring climate uncertainties
  - Conducive to more robust risk analysis with probability connecting vulnerability analysis to System Performance
- Weaknesses
  - Scaled streamflows will not explicitly be linked to climate dynamics.

What is Discussion of Approaches about?

Value of

- GCM:
  - ***Exploring a smaller range*** of climate uncertainty with a ***higher degree of credibility in impacts*** with a ***lesser degree of confidence in climate sensitivities***

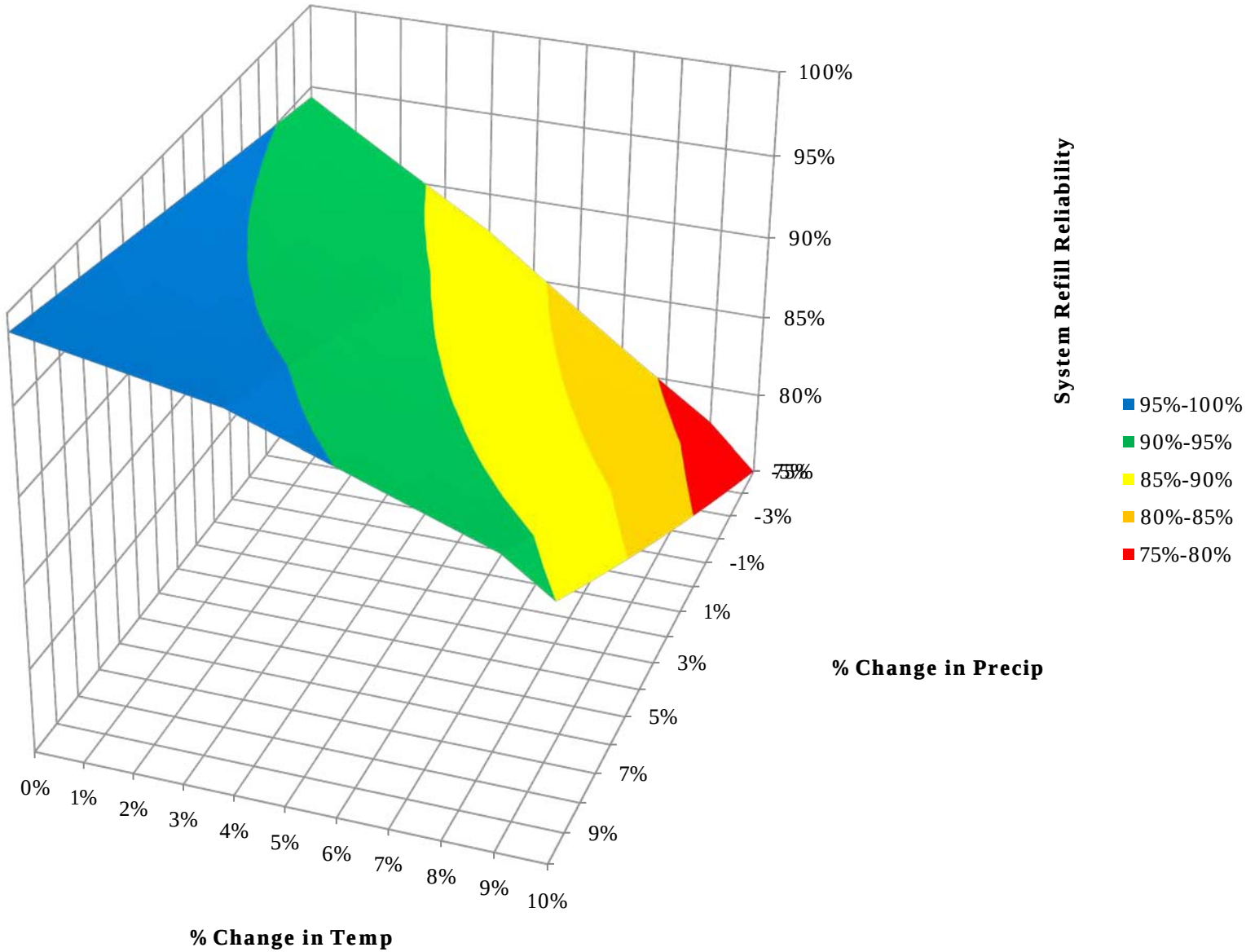
vs.

- Parametric:
  - having a ***broader range of change to explore*** climate impacts, providing ***higher confidence in climate sensitivities*** of the system but ***more uncertainty in confidence of hydrology***

2 Climate Change Plan How to: Working with an example

- Regardless of which Approach is used
- Working with System Refill Reliability
  - Setup & run our operations models using Historic Conditions
    - Models must be configured to calculate the SPI – System Refill Reliability
  - Next, setup & run models with Climate Change data
    - Period change data (2020's, 2040's, 2080's)
    - Time-developing data (1951-2099)
- Produce climate response curves to our System Performance Indicators
  - For Base Condition (Reference Case)
  - And for Alternatives

Example of System Refill Reliability Curve



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Climate Informed Risk Assessment

- Quantify results of Vulnerability Analysis
- Establish Climate States based on Thresholds
- Analysis reveals climate sensitivity of each Alternative
- Use comparison methods to determine a preferred alternative

Climate Informed Risk Assessment

- From Step 2, both approaches will deliver a Vulnerability Analysis
- The 3rd step involves pulling the results of the Vulnerability Analysis together
  - Main Sovereign Technical Team goal is to support the Alternative Assessment process
- Establish Climate States based on Comparison Thresholds defined earlier
  - Climate Driven Decisions
  - Climate Influenced Decisions
  - Climate Independent Decisions
  - Purpose of this step is to explore the climate states relative to metrics established in the 1st step in terms of where/how to draw thresholds

Climate Informed Risk Assessment

- Analysis will reveal the climate sensitivity for Alternatives
  - Including under which climate conditions they perform poorly
- A variety of comparison methods could be used to determine which alternative might be preferred
  - For example, the alternative that performs best over the widest range of climate conditions could be considered the most robust

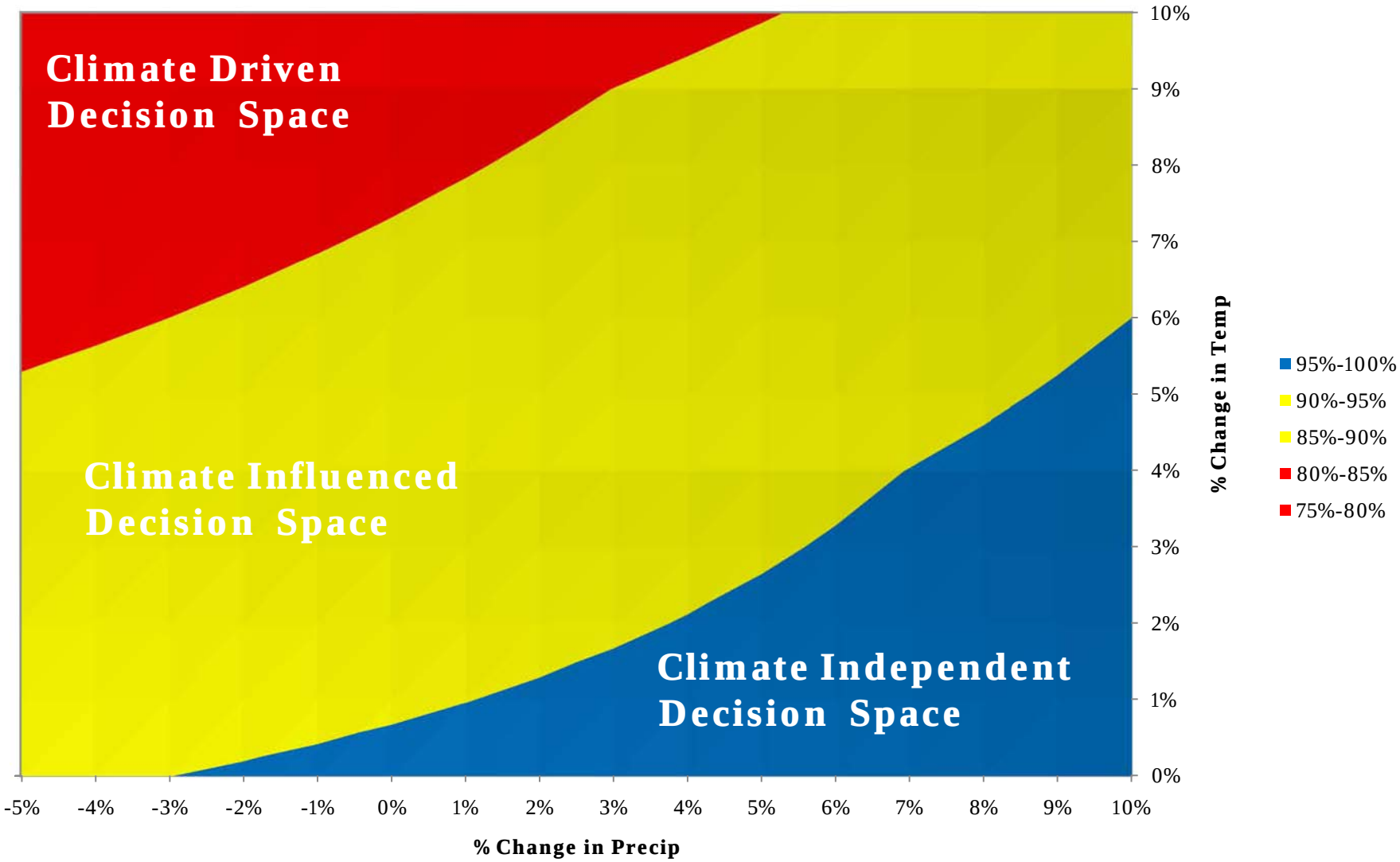
Or,

  - Probabilities could be derived from the GCM projections to estimate a probability weighted performance for each alternative
- Ultimately, there are many ways to compare alternatives and it makes sense to do it in many ways to get the best sense of their relative performance

Climate Change Plan How to: Working with an example

- System Refill Reliability
  - Our threshold was 95% for successful refill
  - 85 – 95% is marginal but still acceptable
  - Below 85% results in severe degradation of System Objectives

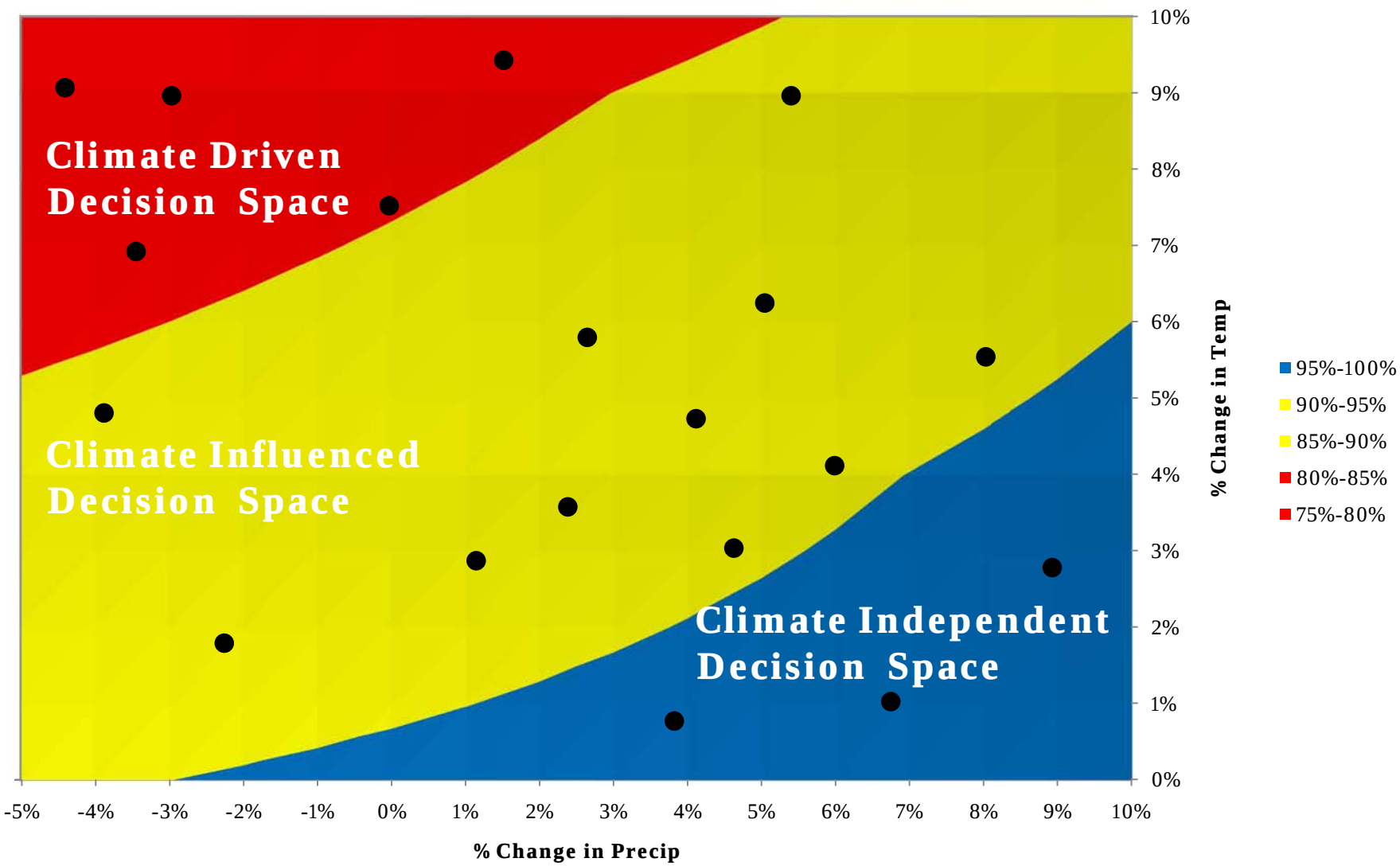
Example of System Refill Reliability for an Alternative



3 Climate Change Plan How to: Working with an example

- System Refill Reliability
  - Super-impose GCM climate factors on top of our Climate States
    - To understand the probability of climate conditions that contribute to poor system performance

Example of System Refill Reliability for an Alternative



Step 4: The Decision Process

- Presented here is was a 3-step framework for Climate Analysis
- What remains are the steps associated with integrating these results into the Decision process

Questions?

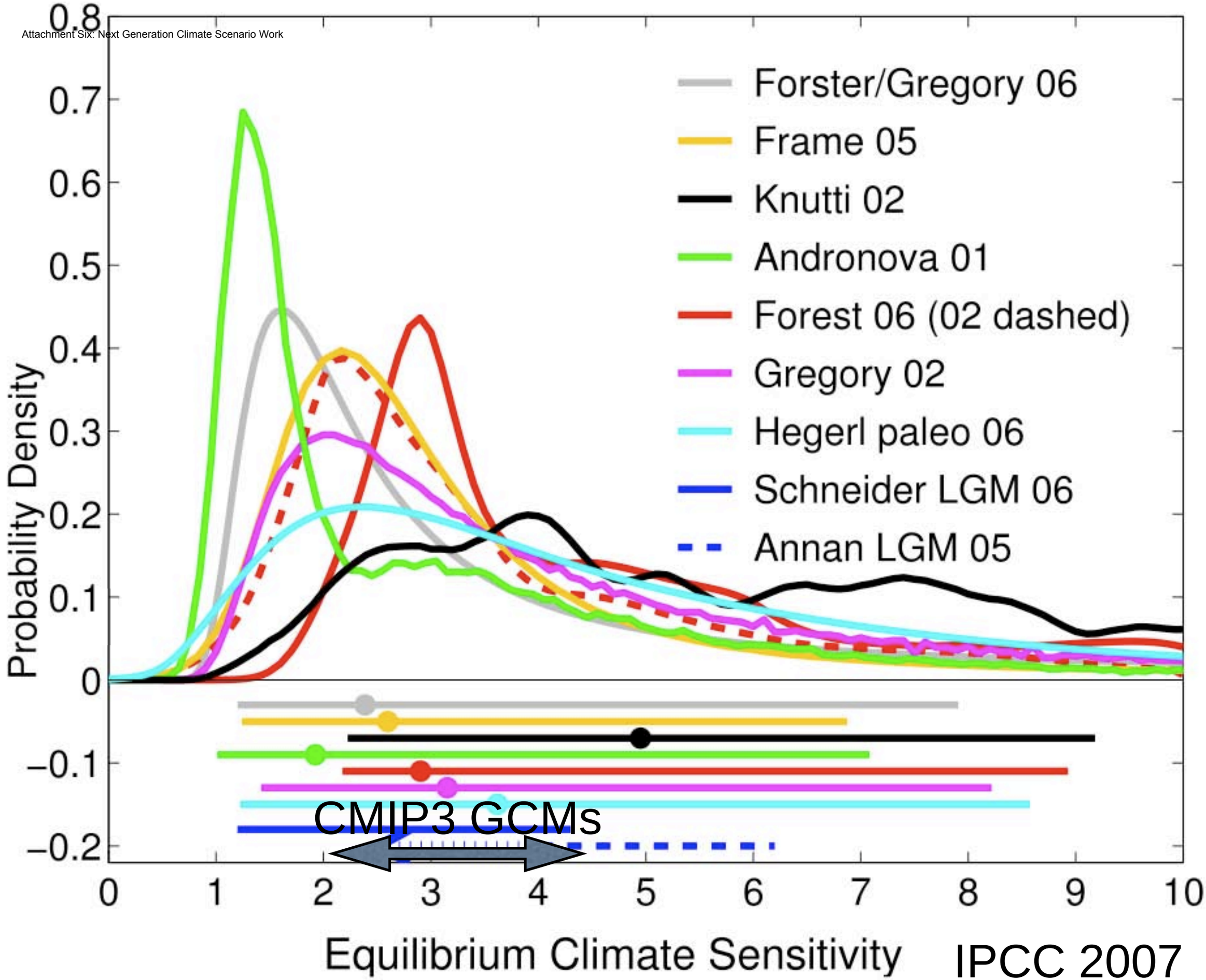
Next generation scenarios

Philip Mote
OCCRI.net

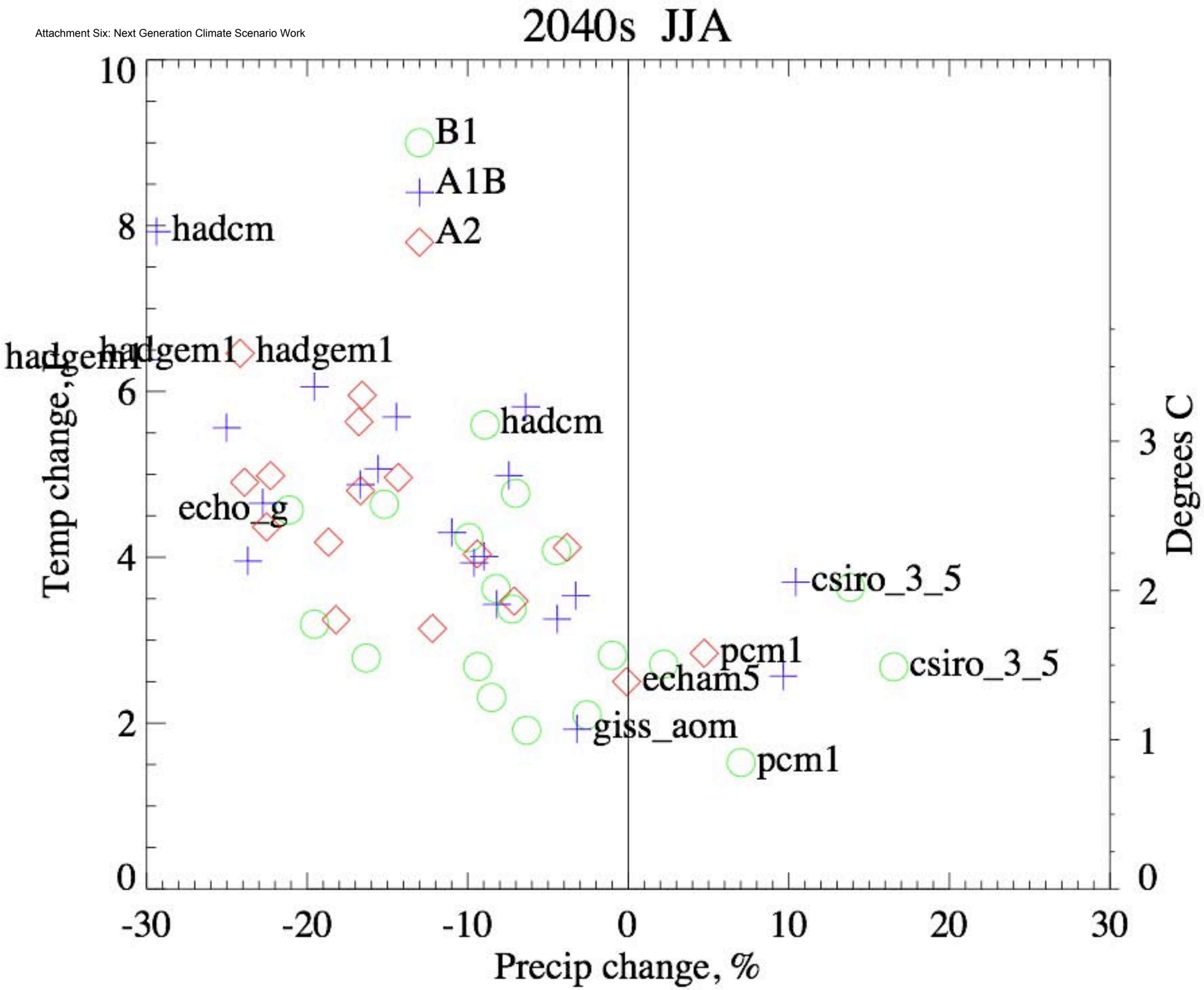
NOAA Clim Decision Support Consortium	DoI Climate Sci Center
One of 11	One of 8
OSU-BSU-UI-UO-UW	OSU-UW-UI
Funded 9/2010-8/2015	
PIs Mote and Lach	PIs Mote and Graumlich
Applying climate science to improve resilience	Applying climate science for habitat, landscape, & species mgmt
Defining research agenda	
Coordinating with other RISA and CSC efforts	

Defining the ‘cone of uncertainty’

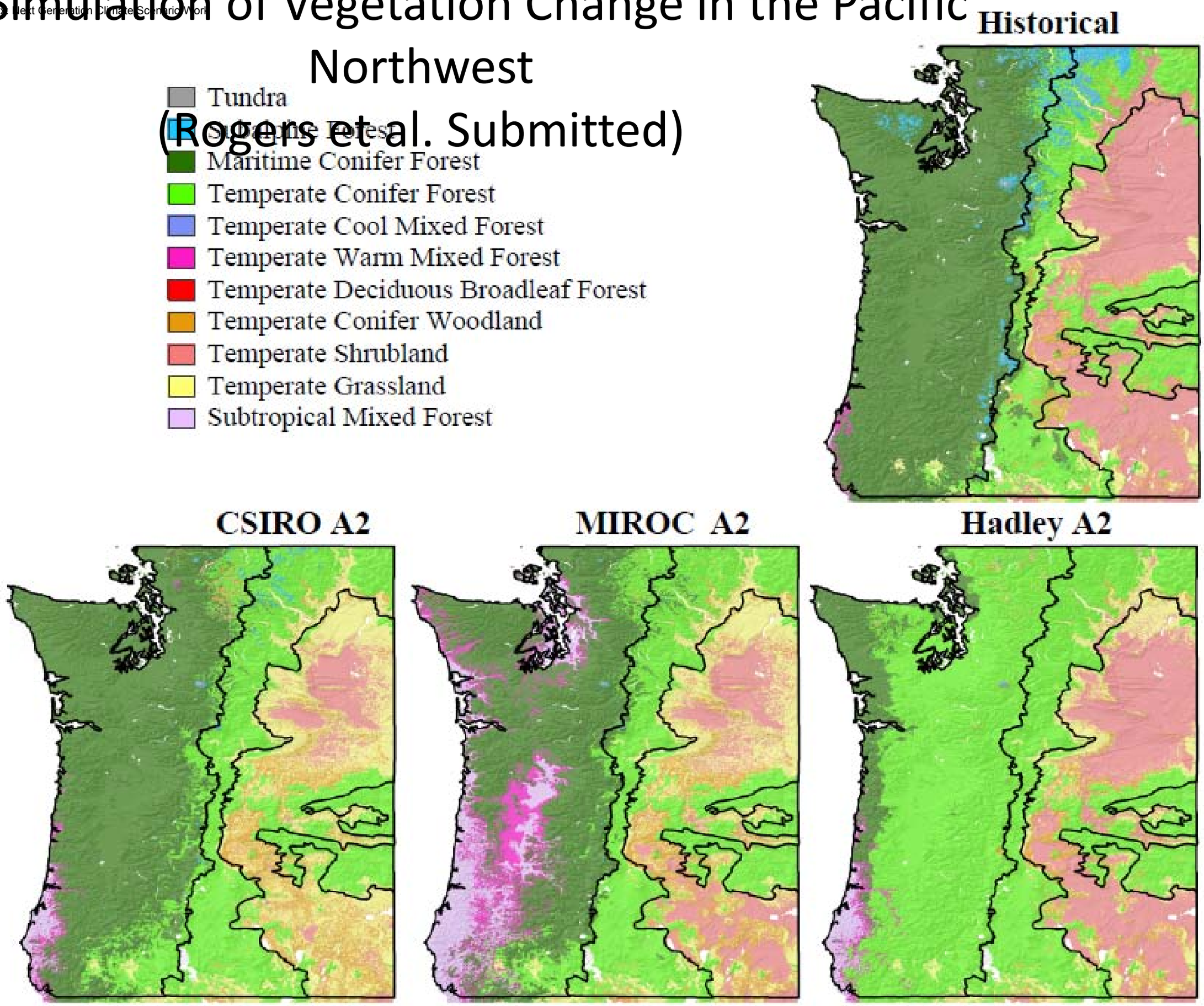
- Emissions uncertainty
- Climate sensitivity (global and regional)
- Finer-scale (stat or dynamical downscaling)
- Hydrologic response
- Other factors - vegetation, surprises


Forster/Gregory 06
Frame 05
Knutti 02
Andronova 01
Forest 06 (02 dashed)
Gregory 02
Hegerl paleo 06
Schneider LGM 06
Annan LGM 05
Probability Density
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
−0.1
−0.2
0
1
2
3
4
5
6
7
8
9
10
CMIP3 GCMs
Equilibrium Climate Sensitivity

IPCC 2007

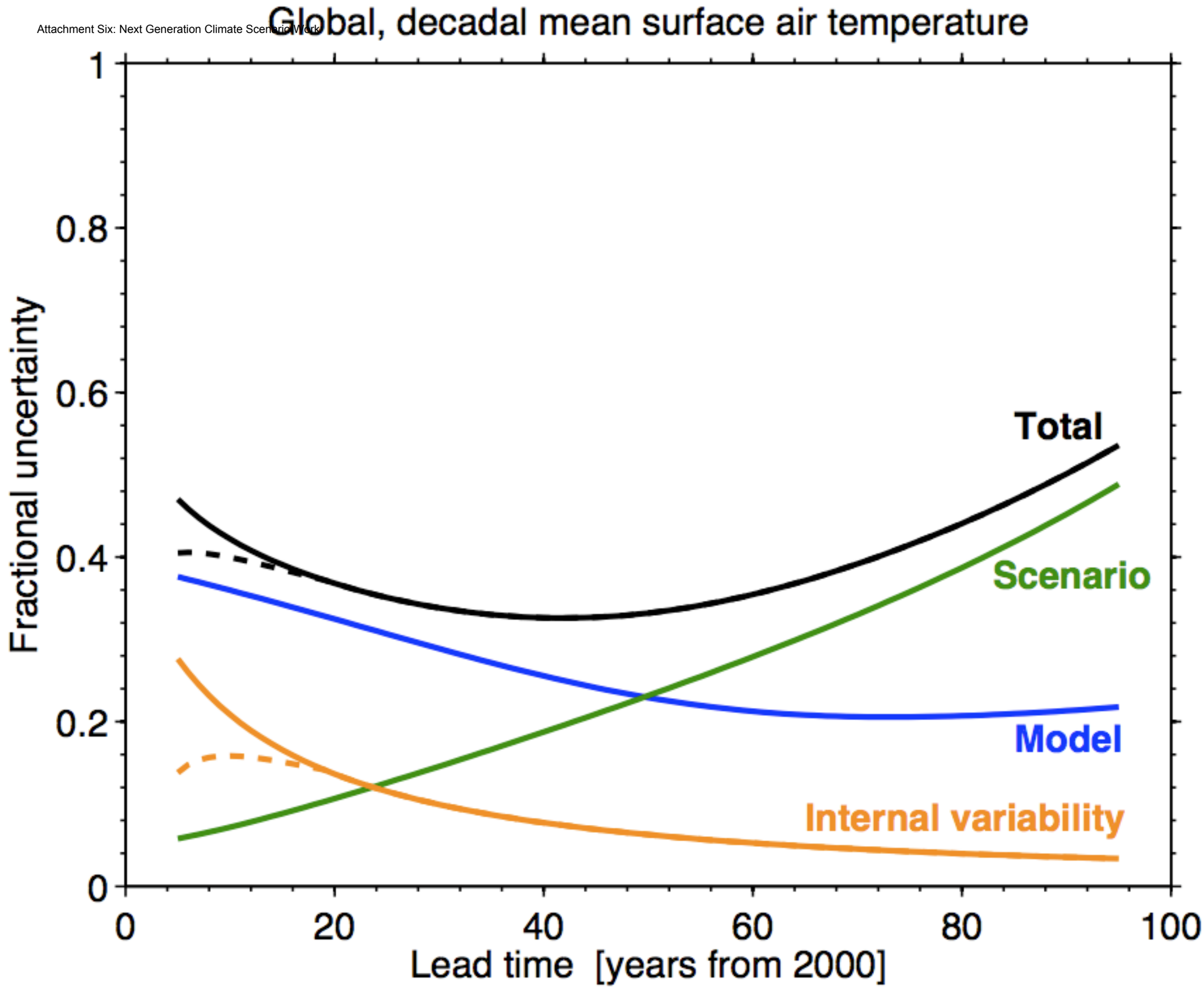

2040s JJA
B1
A1B
A2
hadcm
hadgem1
hadgem1
hadgem1
hadcm
echo_g
csiro_3_5
pcm1
csiro_3_5
echam5
giss_aom
pcm1
Temp change, C
Degrees C
Precip change, %
10
8
6
4
2
0
3
2
1
0
-30
-20
-10
0
10
20
30

MC1 Simulation of Vegetation Change in the Pacific Northwest (Rogers et al. Submitted)



Previous generation	Next generation
SRES (c. 1999)	RCP (c. 2009)
GCM ensemble of opportunity (CMIP3 c. 2005)	GCM ensemble of oppty (CMIP5 c. 2011)
RCMs piecemeal	RCM superensemble
Monthly 3-vbl downscaling	Daily 6-vbl downscaling
1 hydrologic model	4? hydrol models, with sensitivity analysis and intercomparison, +Modflow
	vegetation modeling
	uncertainty & probability analyses
separate efforts	broad coordination across West

SRES=Special Report on Emissions Scenarios RCP=representative concentration pathway GCM=general circulation model, or global climate model RCM=regional climate model CMIP=coupled model intercomparison project



Hawkins and Sutton 2009

Recommendations

- Use alternatives 1 and 2
- Use as much CMIP5 as possible - AR5 also released Sept 2013
- Use results of hydrol sensitivity analysis and intercomparison