Using large-scale models to evaluate the hydrologic impacts of climate change

Bart Nijssen
University of Washington
2nd SWAN International Conference
Tucson, Arizona - February 17, 2016

Team

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Graduate Research Assistant

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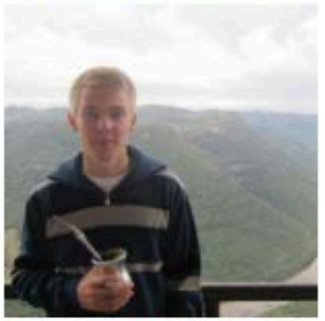

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Graduate Research Assistant

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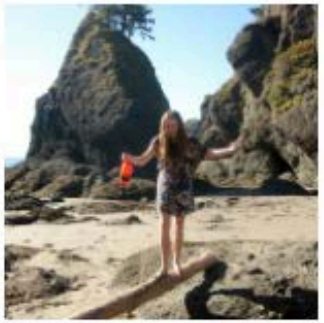
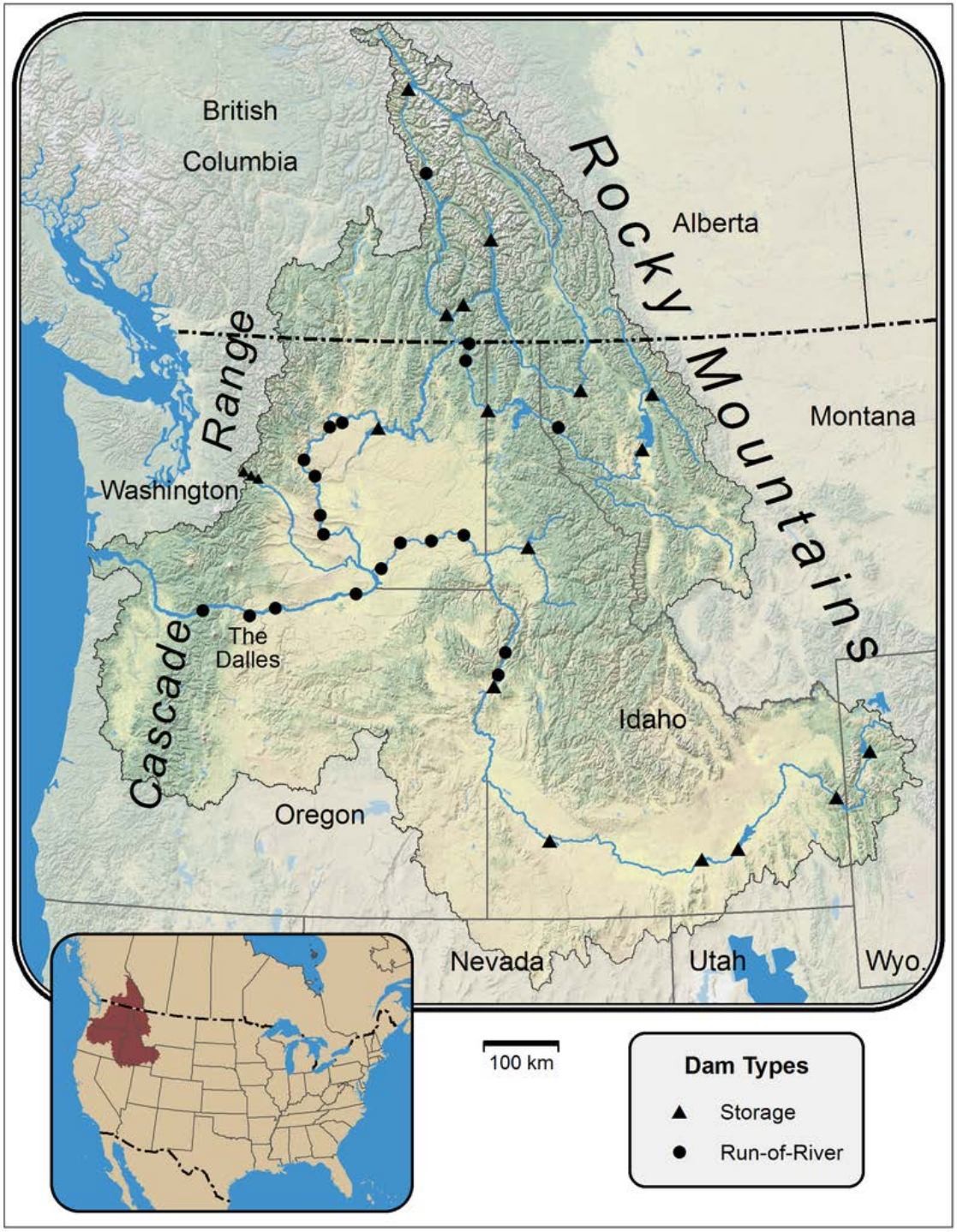
Research Scientist



Oriana Chegwidden
Research Scientist

Joanna Gaski
Systems Administrator

Columbia River Basin



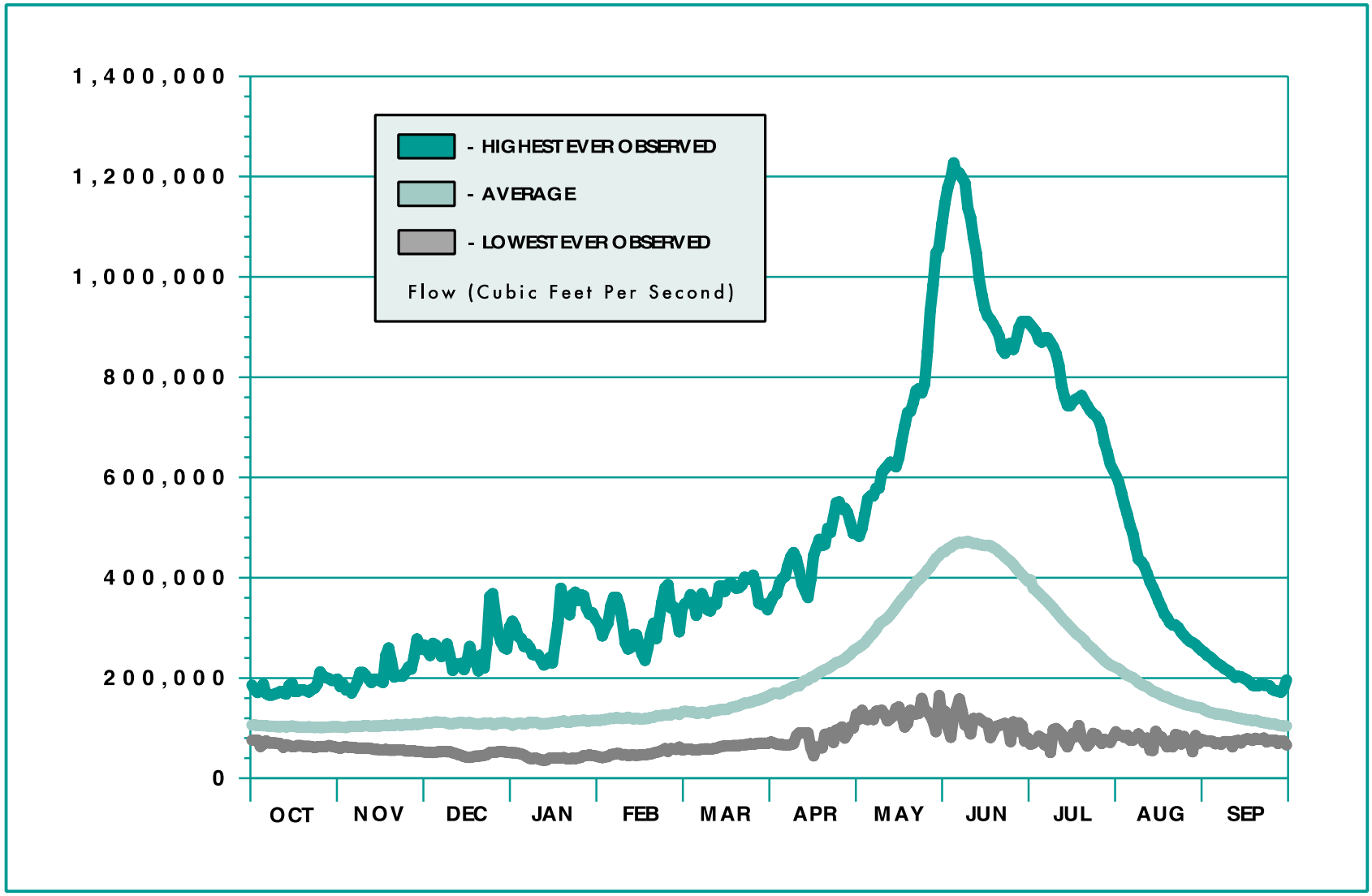
- Hydropower
  - 29 gigawatts (GW) of hydroelectric generating capacity
  - 44% of the total hydroelectric generation in the nation in 2012
- Flood control
- Irrigation
- Fisheries and ecosystem services
- Navigation
- Recreation

Annual flow volume (about 198 MAF)

Figure courtesy of Robert Norheim, Climate Impacts Group, University of Washington

Source: The Columbia River System inside story, BPA

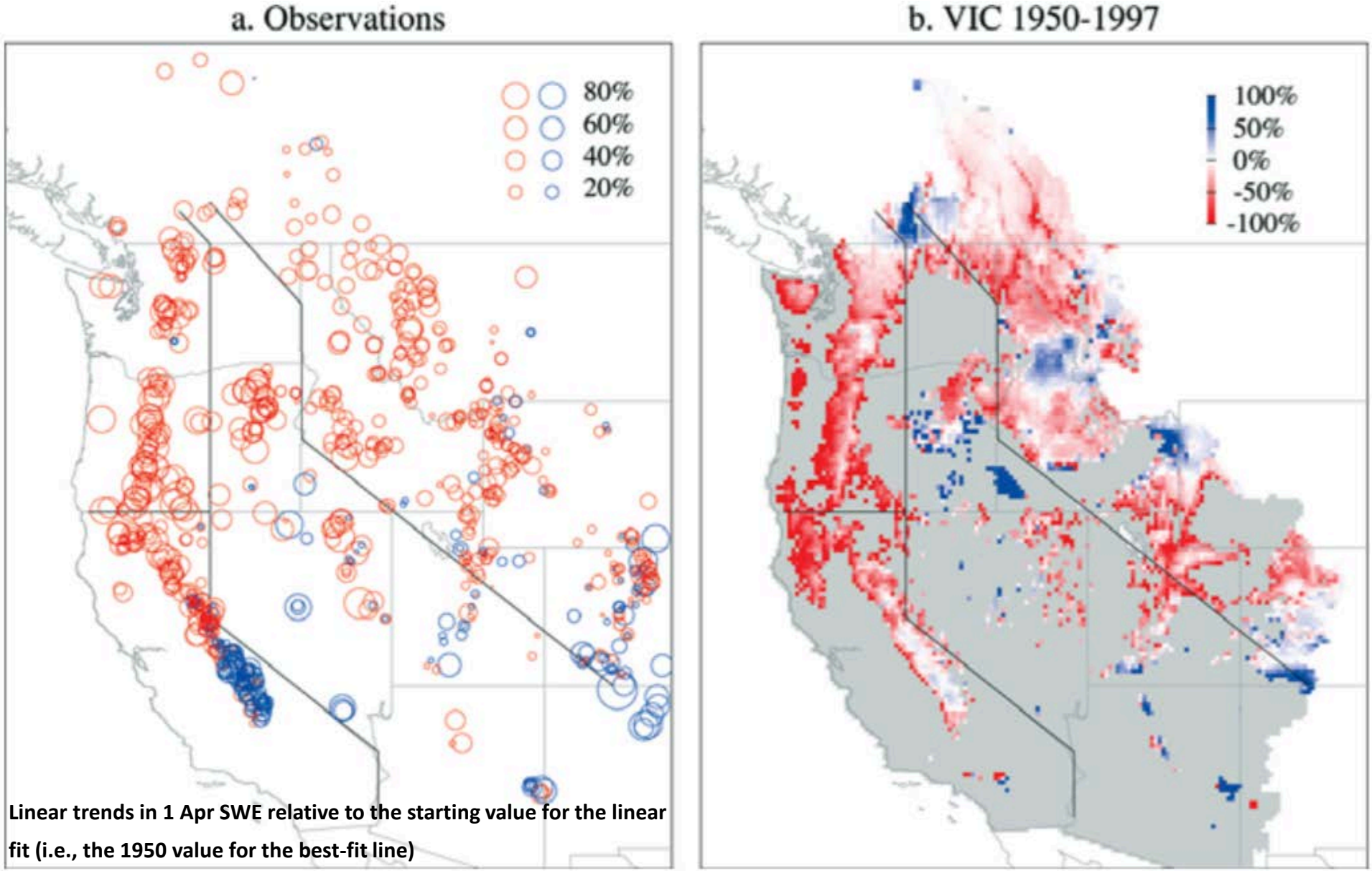
Columbia River Streamflows



Flow on the Columbia River is generally measured at The Dalles, Oregon. Historic records show an annual pattern, with peak flows in late spring.

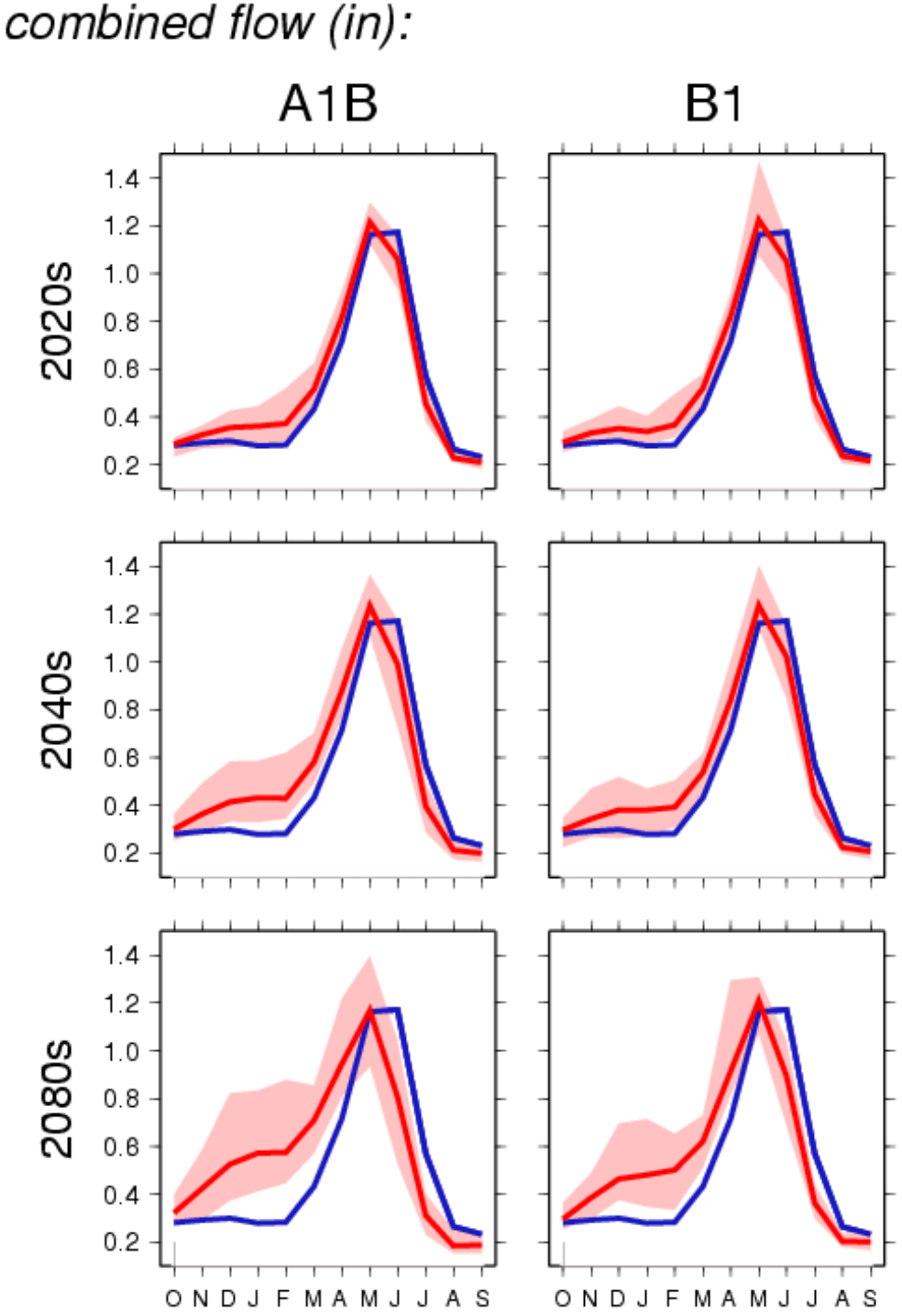
Source: The Columbia River System inside story, BPA

Historic changes in snow pack in the western US



Linear trends in 1 Apr SWE relative to the starting value for the linear fit (i.e., the 1950 value for the best-fit line)

Mote, P. W., A. F. Hamlet, M. P. Clark, and D. P. Lettenmaier, 2005: Declining mountain snowpack in western north America. *Bulletin of the American Meteorological Society*, **86,** 39-+, 10.1175/bams-86-1-39.



Columbia River at the Dalles

CMIP3 / AR4

Pacific Northwest (PNW) Hydroclimate Scenarios Project (2860), Climate Impacts Group, University of Washington

Predicting the Hydrologic Response of the Columbia River System to Climate Change

Bart Nijssen/Oriana Chegwidden – University of Washington

Phil Mote/David Rupp – Oregon State University

Stakeholders

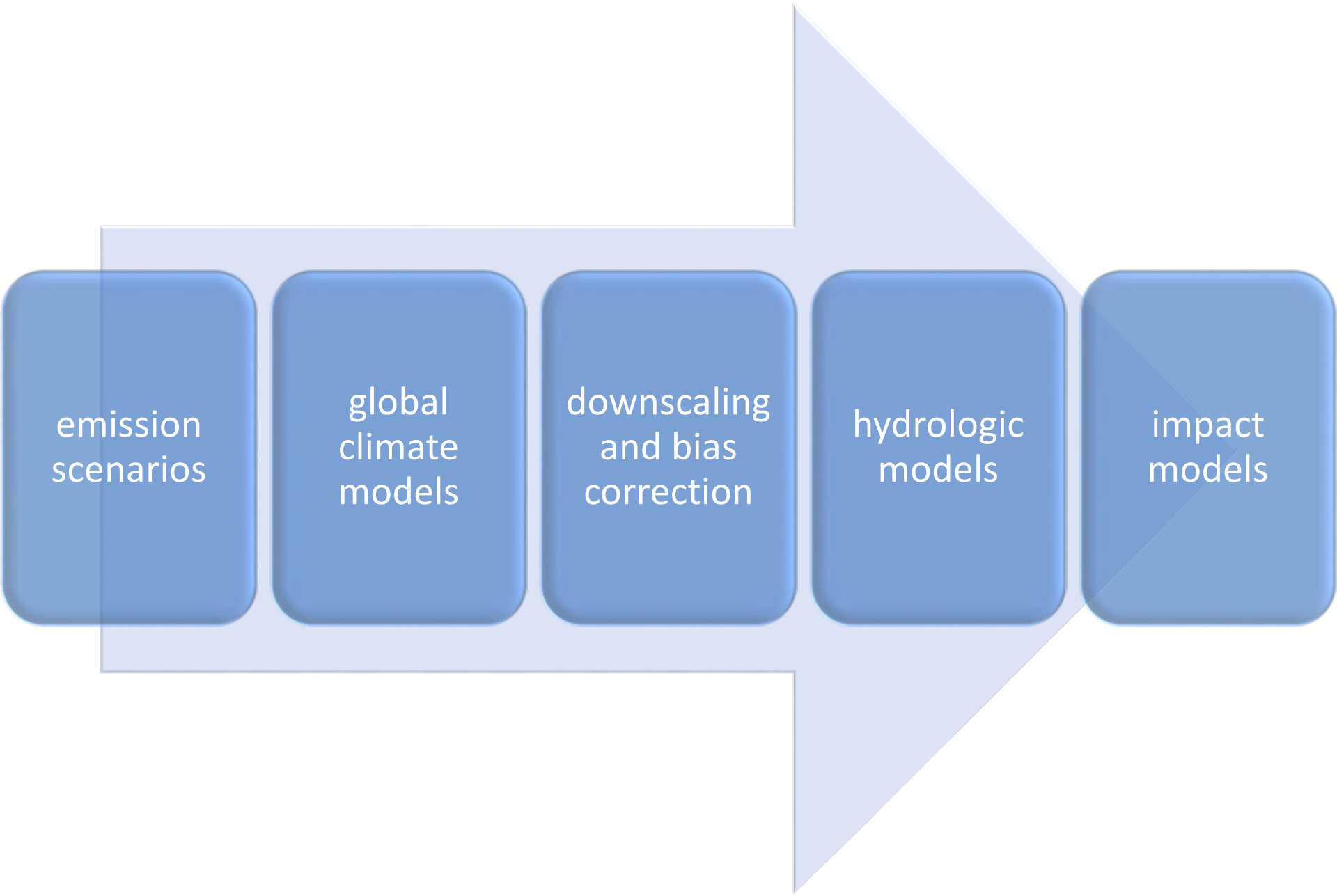
- River Management Joint Operating Committee
  - BPA (hydropower)
  - Army Corps of Engineers (flood control)
  - Bureau of Reclamation (irrigation)
- Tribes, federal, state and local governments
  - Columbia River Inter-Tribal Fish Commission
  - EPA
  - State water managers
- Others
  - Seattle City Light

Project synopsis: goals

- **Update:** Evaluate the implications of climate change – as projected by the CMIP5 global model simulations – for the hydrology of the Columbia River Basin

CMIP5 / AR5

- **Extension:** Assess the effects of methodological choices on the hydrologic projections (e.g. hydrologic model, downscaling method, global climate model)


emission scenarios
global climate models
downscaling and bias correction
hydrologic models
impact models

Emission scenarios

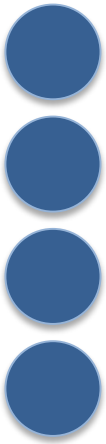
Global climate models

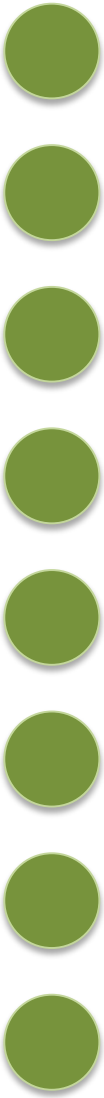
Downscaling and bias correction

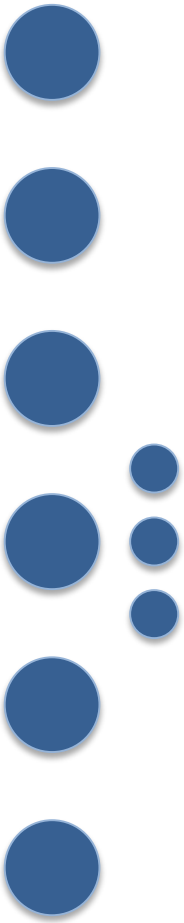
Hydrologic models

Impact models

- Hydropower
- Stream temperature
- Fisheries







Emission scenarios

Global climate models

Downscaling and bias correction

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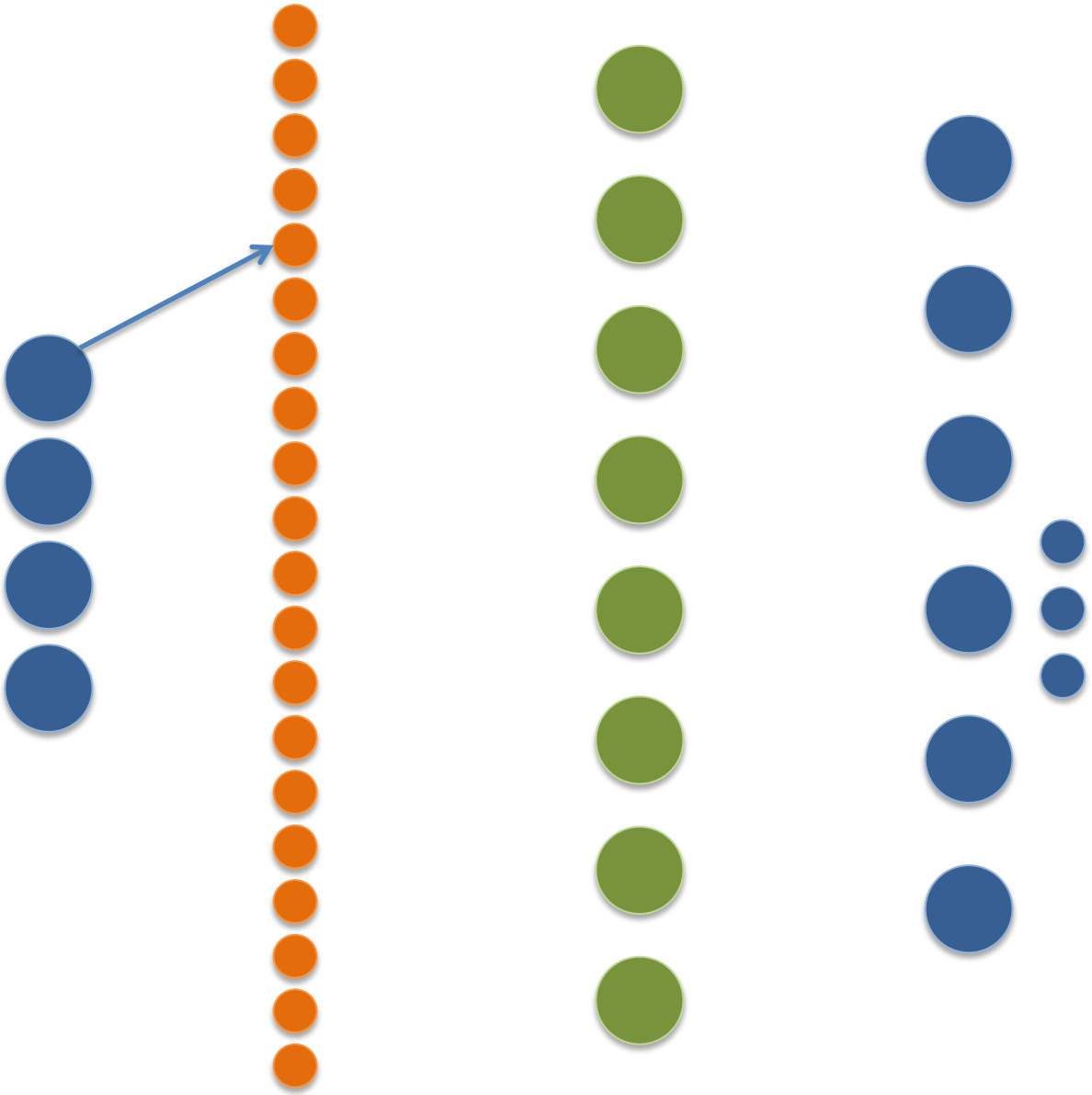

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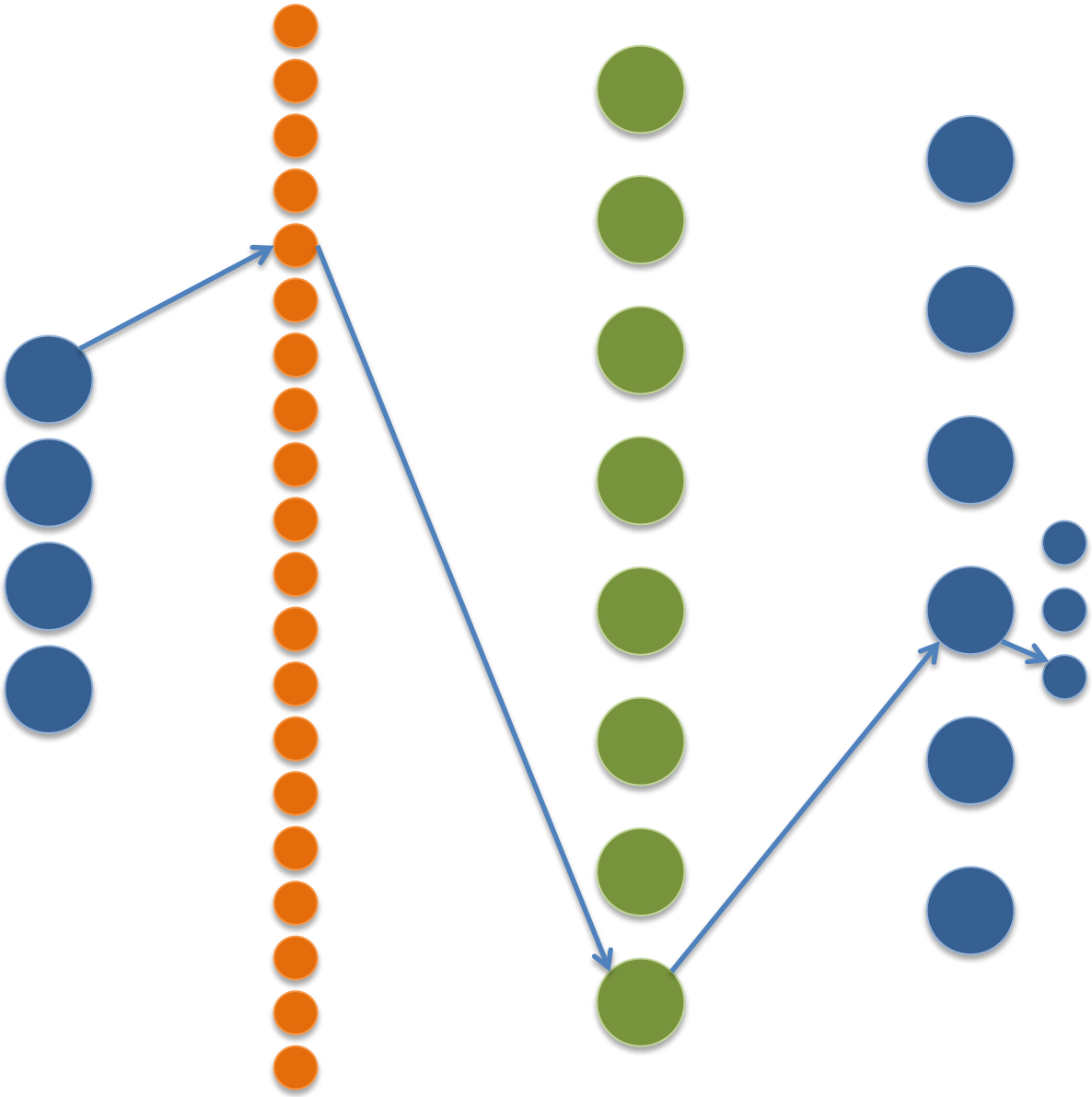
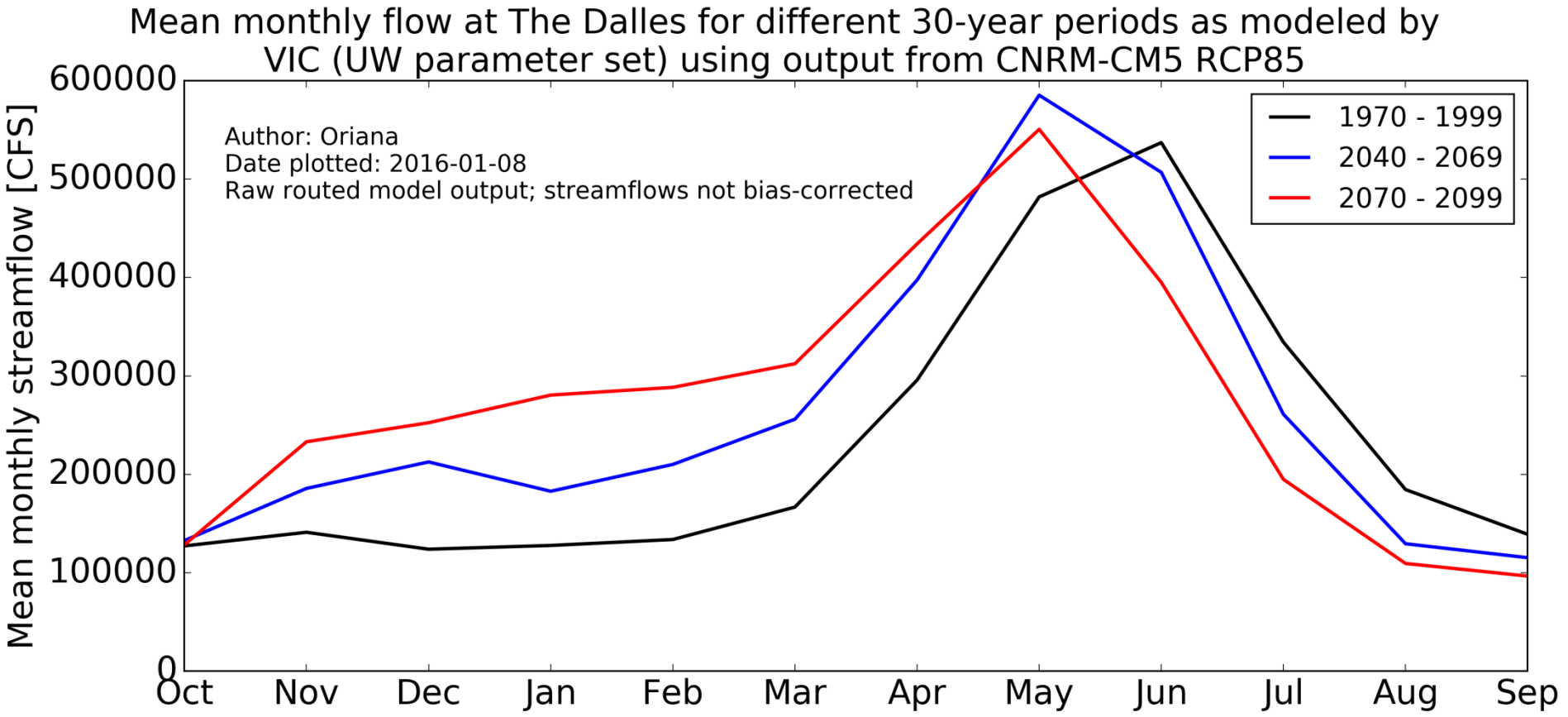


Project Synopsis: Hydrologic Model Runs



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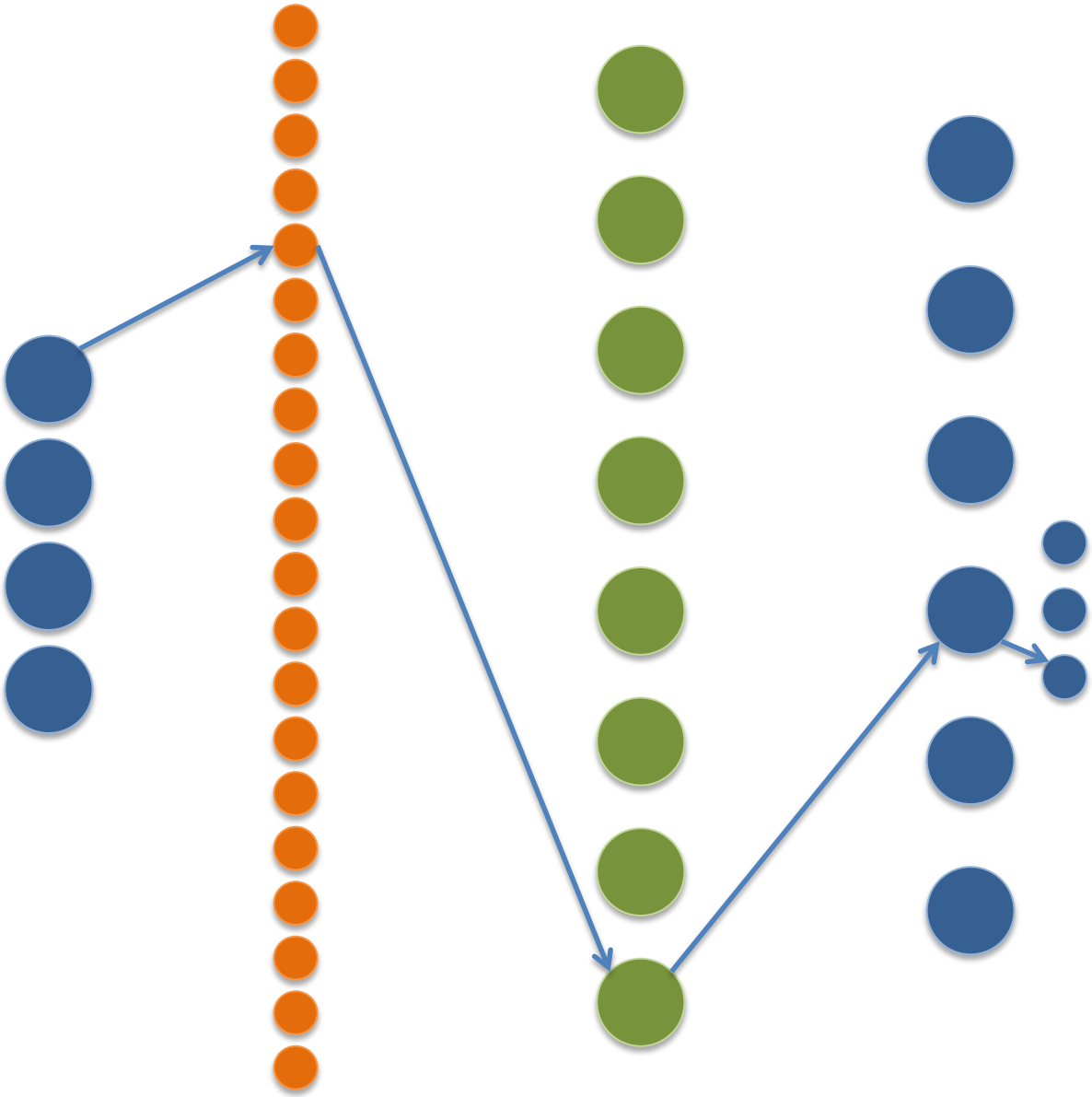

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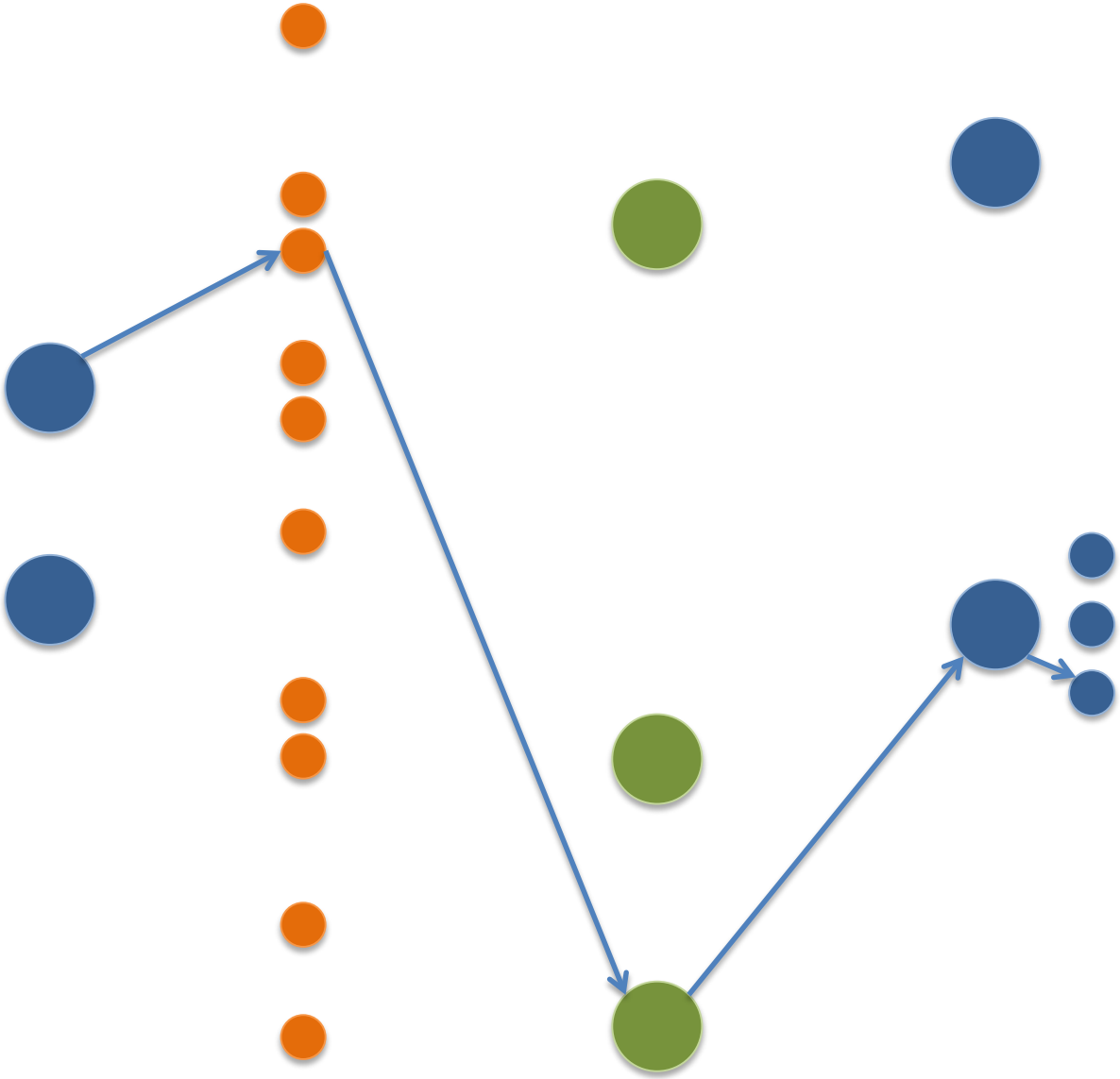

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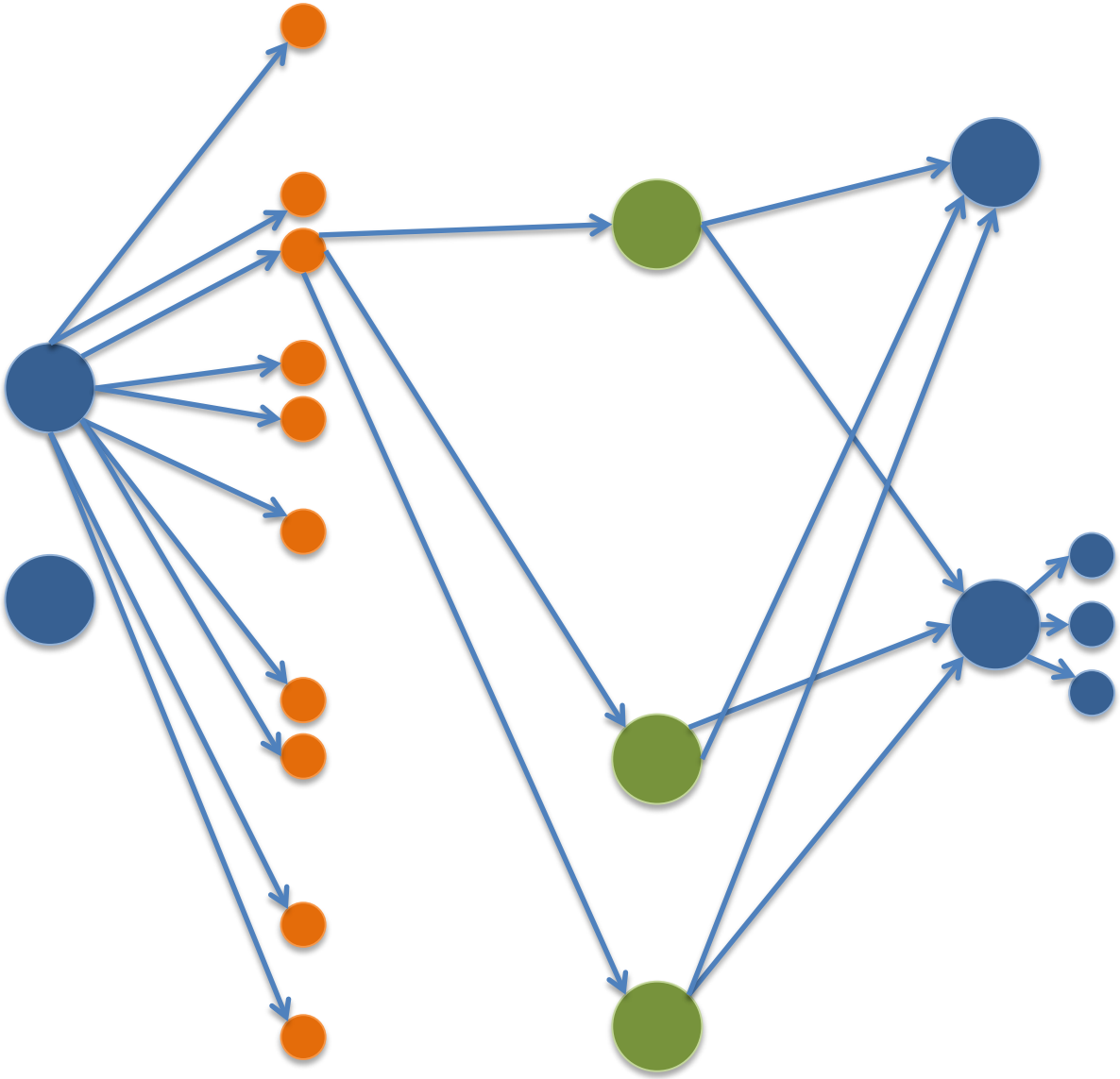


Project synopsis: study overview

Period: 1950-2100

Two hydrologic models with multiple different parameter sets

Three downscaling methods

Ten global climate models

Two representative concentration pathways

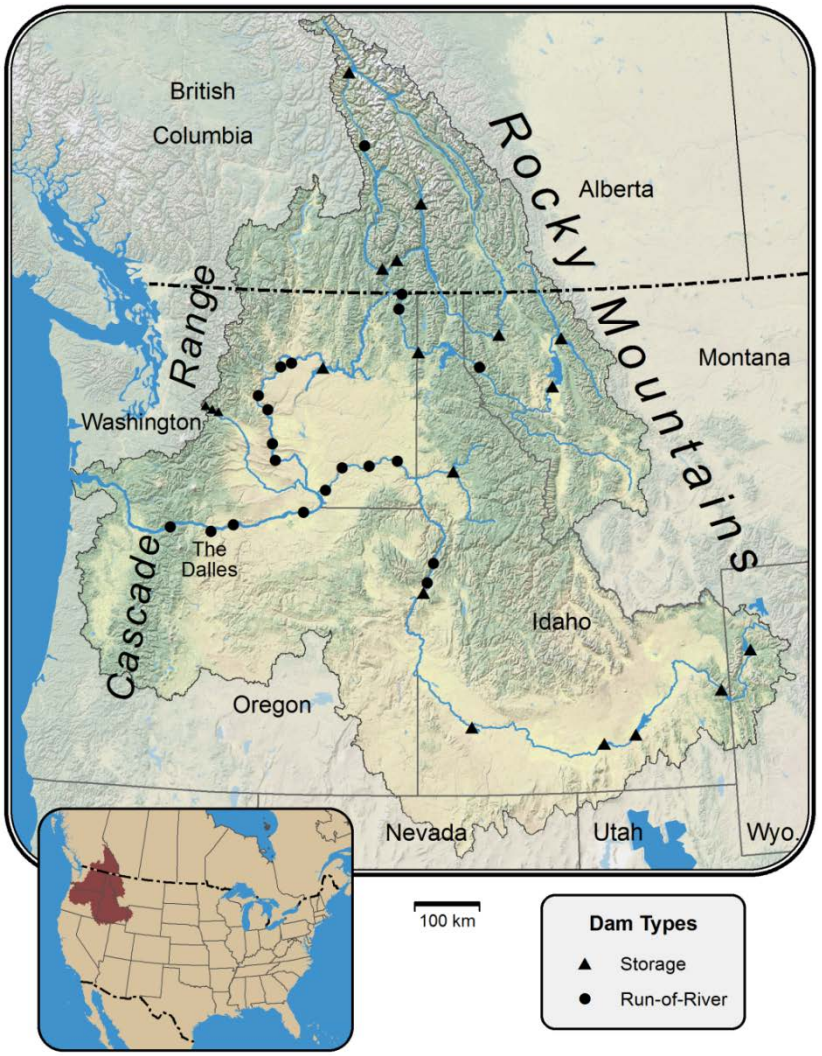


Figure: Robert Norheim, Climate Impacts Group, University of Washington

172 future hydrologic scenarios

Project synopsis: study overview

Period: 1950-2100

Two hydrologic models with multiple different parameter sets

Three downscaling methods

Ten global climate models

Two representative concentration pathways

Still not a true measure of uncertainty in the projections, but a measure of the effects of methodological choices on the spread of the projections

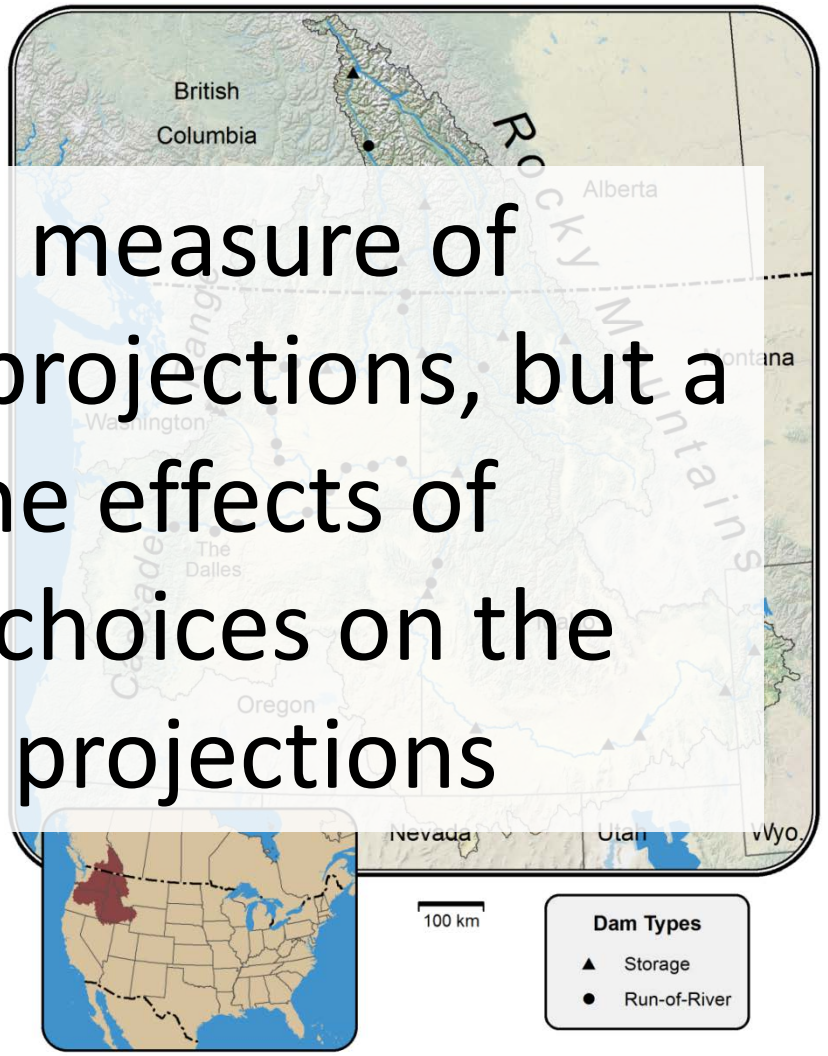
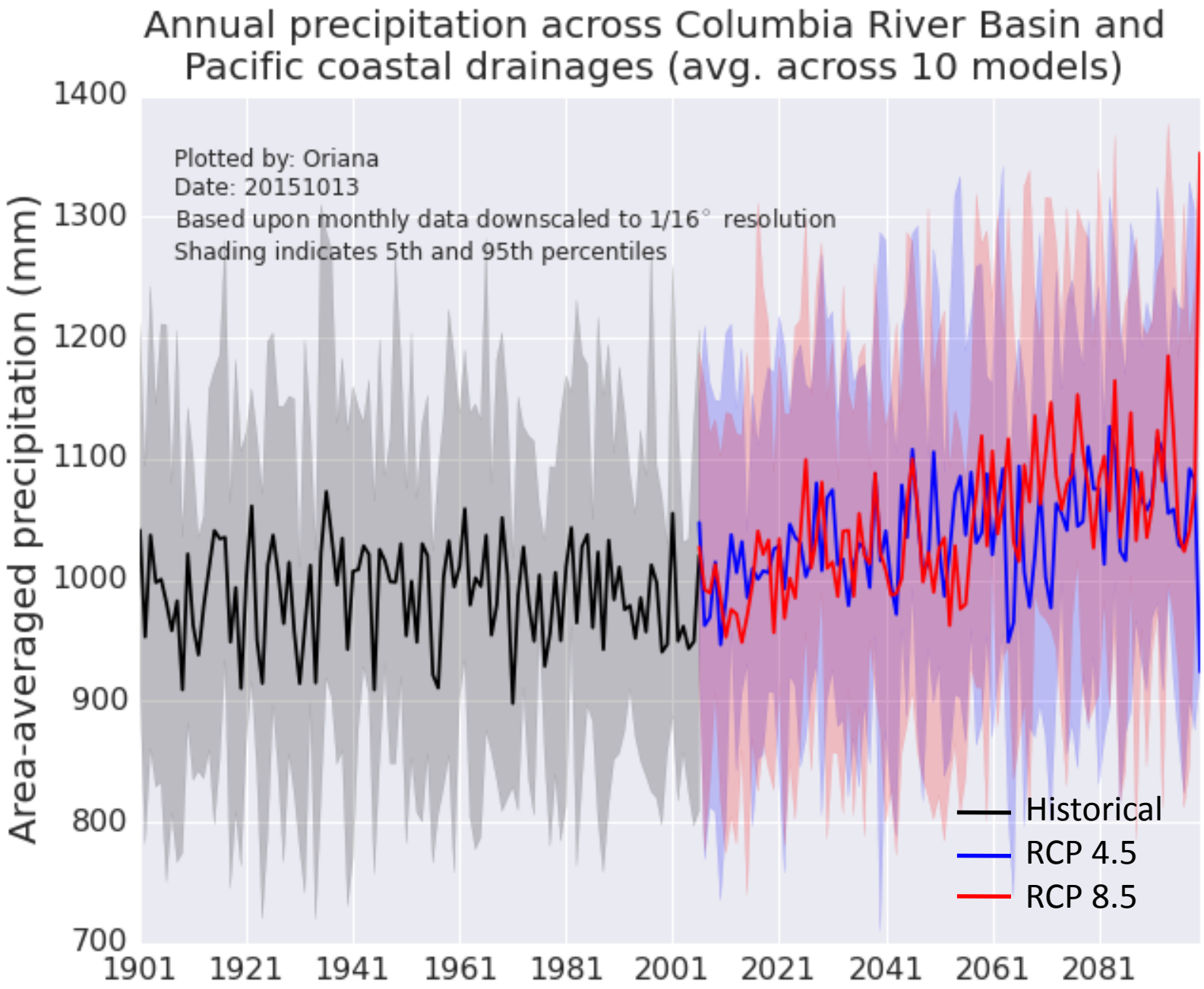
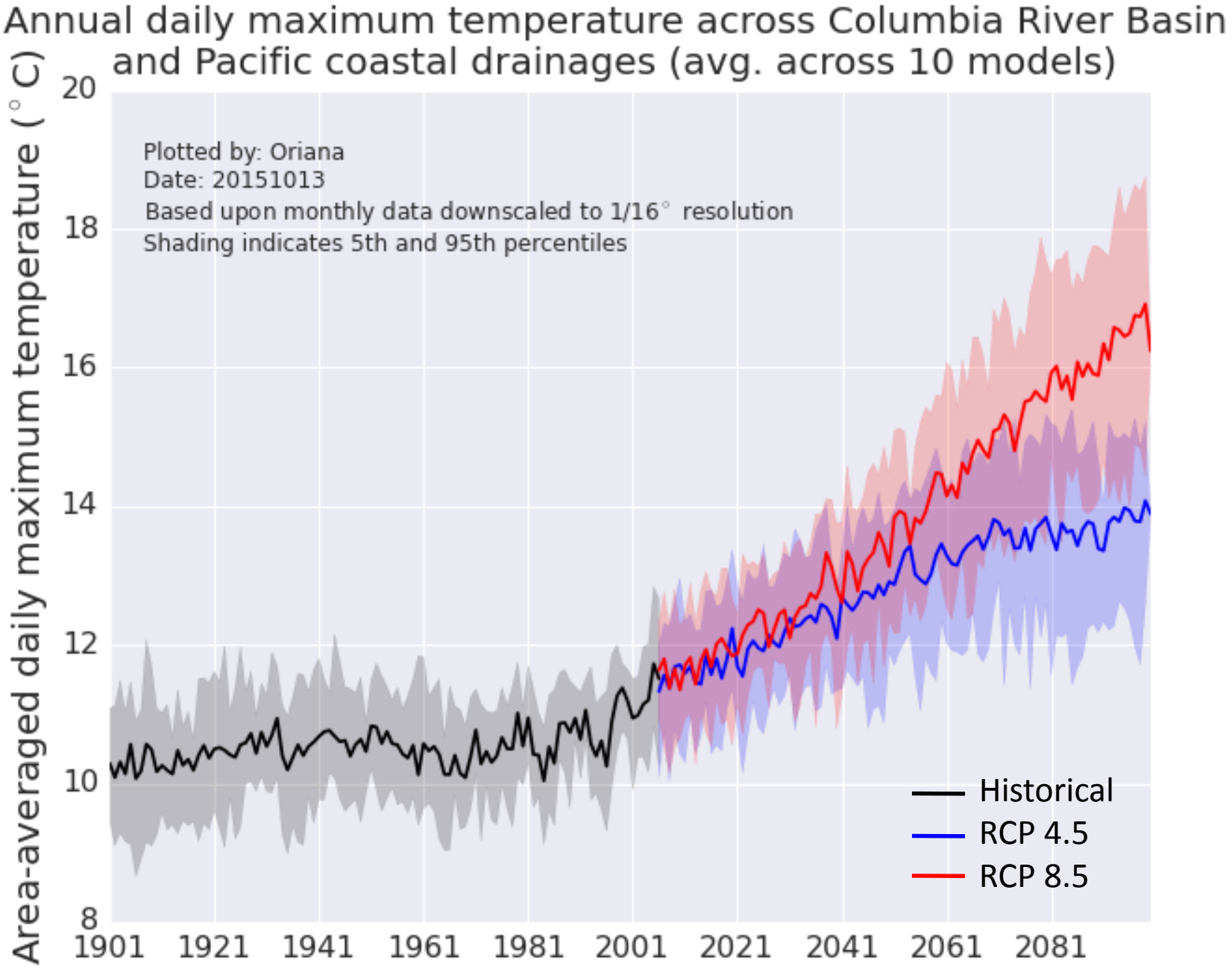


Figure: Robert Norheim, Climate Impacts Group, University of Washington

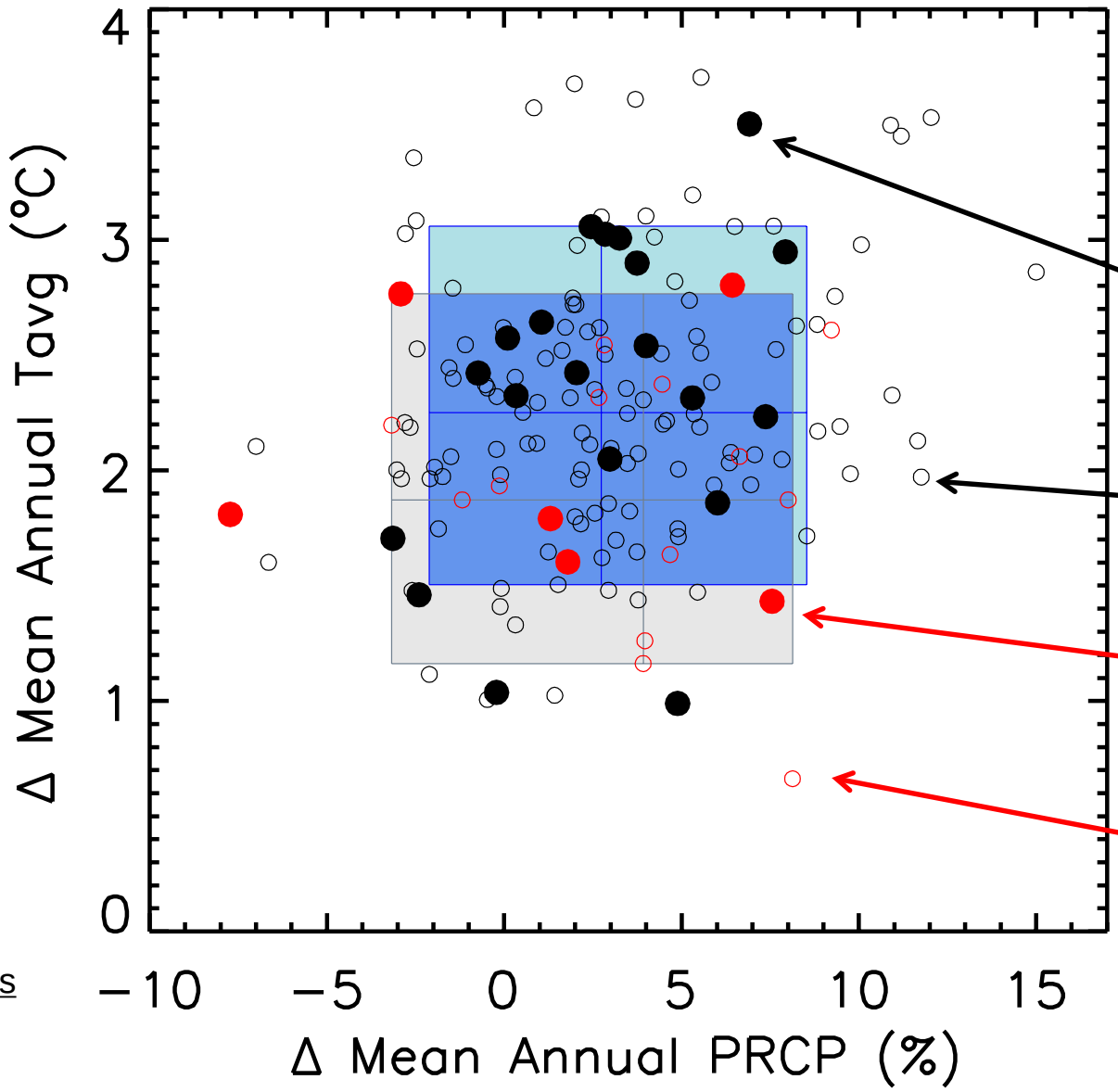
172 future hydrologic scenarios


Annual precipitation across Columbia River Basin and Pacific coastal drainages (avg. across 10 models)
Plotted by: Oriana
Date: 20151013
Based upon monthly data downscaled to 1/16° resolution
Shading indicates 5th and 95th percentiles
Area-averaged precipitation (mm)
1400
1300
1200
1100
1000
900
800
700
1901
1921
1941
1961
1981
2001
2021
2041
2061
2081
Historical
RCP 4.5
RCP 8.5


Annual daily maximum temperature across Columbia River Basin and Pacific coastal drainages (avg. across 10 models)
Area-averaged daily maximum temperature (°C)
Plotted by: Oriana
Date: 20151013
Based upon monthly data downscaled to 1/16° resolution
Shading indicates 5th and 95th percentiles
Historical
RCP 4.5
RCP 8.5
20
18
16
14
12
10
8
1901
1921
1941
1961
1981
2001
2021
2041
2061
2081

Climate Projections for the Columbia River Basin*

1970–1999 to 2030–2059



*Above The Dalles

10%-90% percentiles

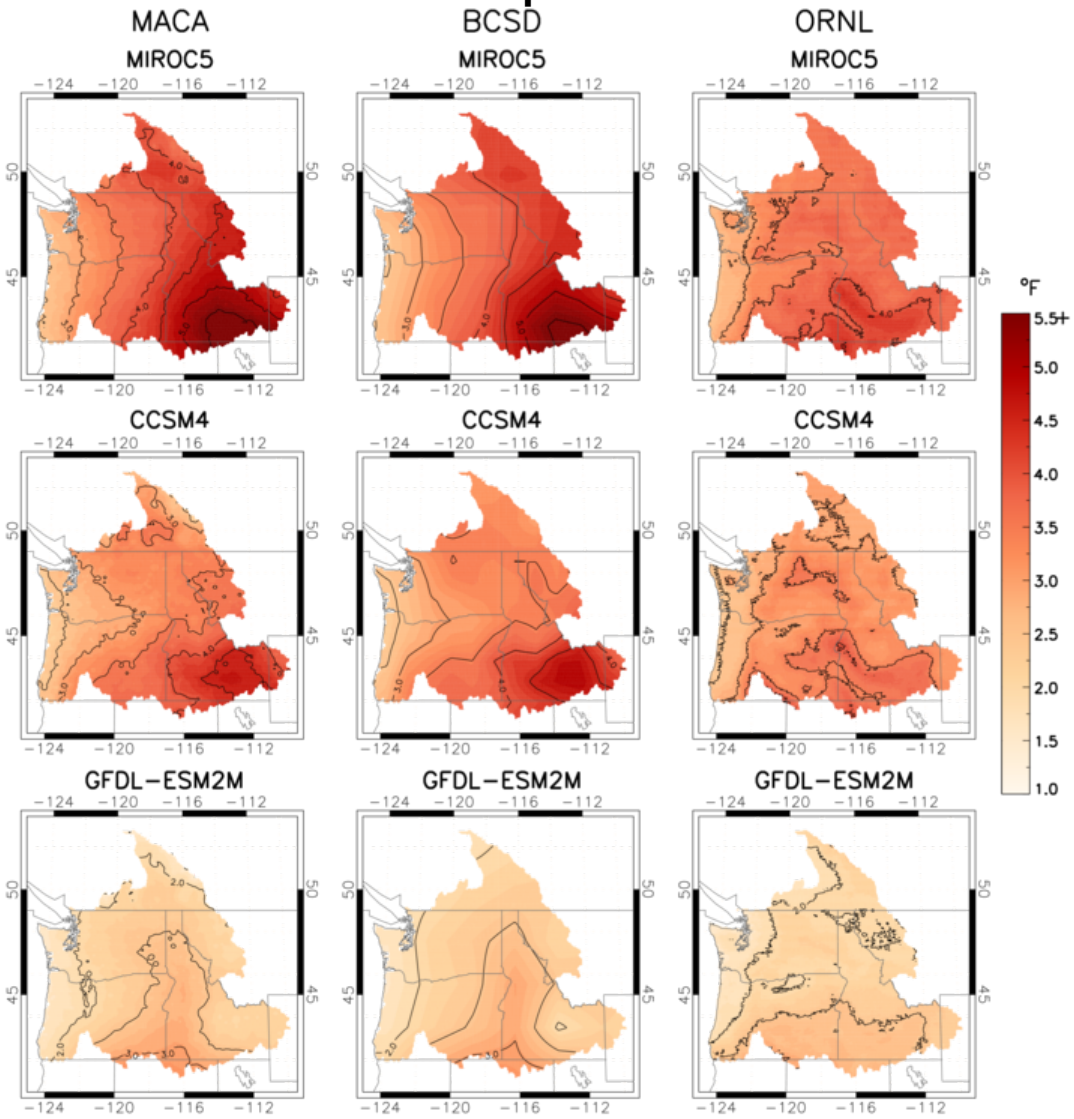
Gray: CMIP3

Light blue: CMIP5

Blue: overlap

Project Synopsis: GCM Downscaling

Mean annual temperature changes for three downscaling methods and three GCMs for period 2010-2049 and RCP 8.5



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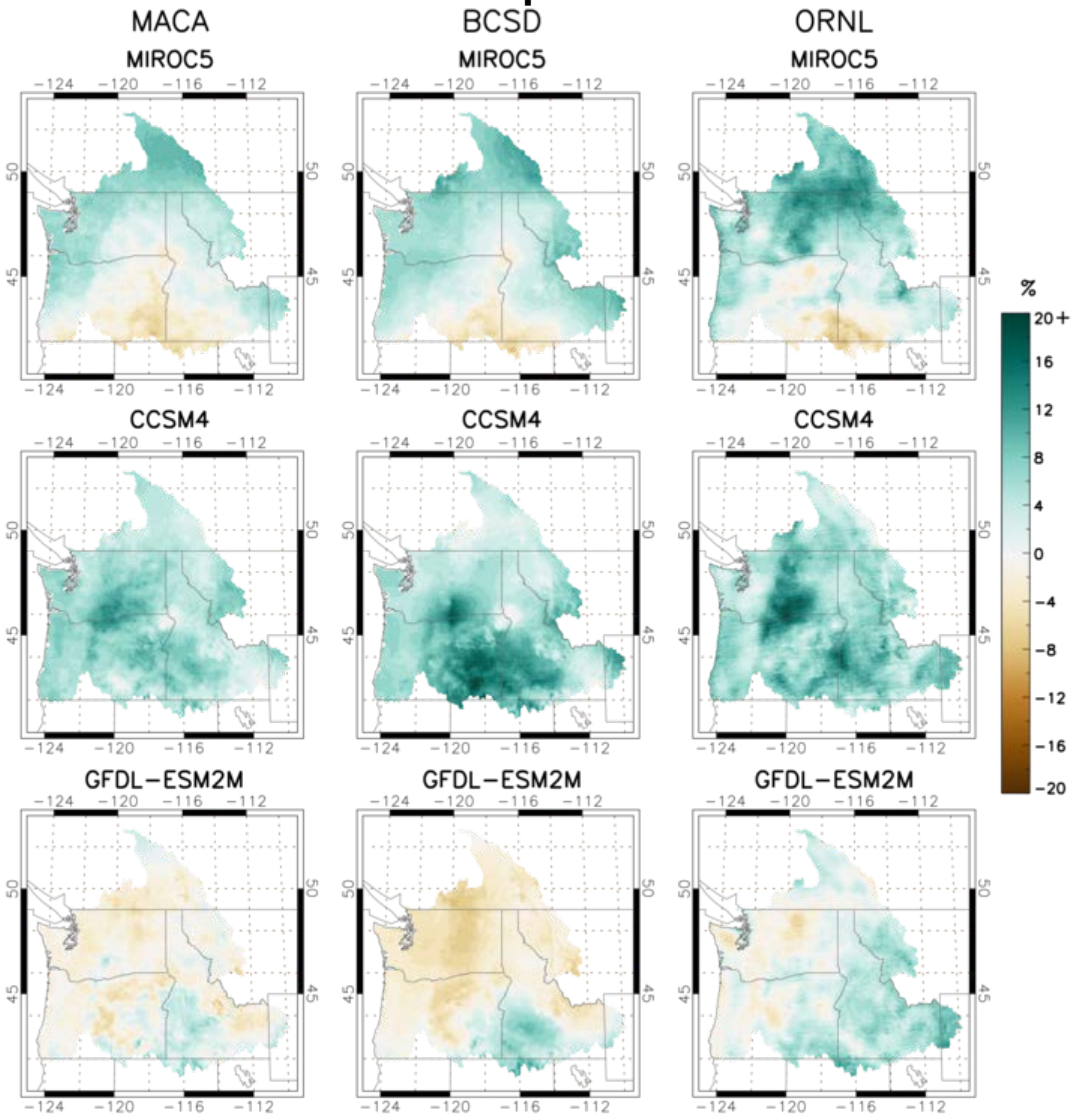
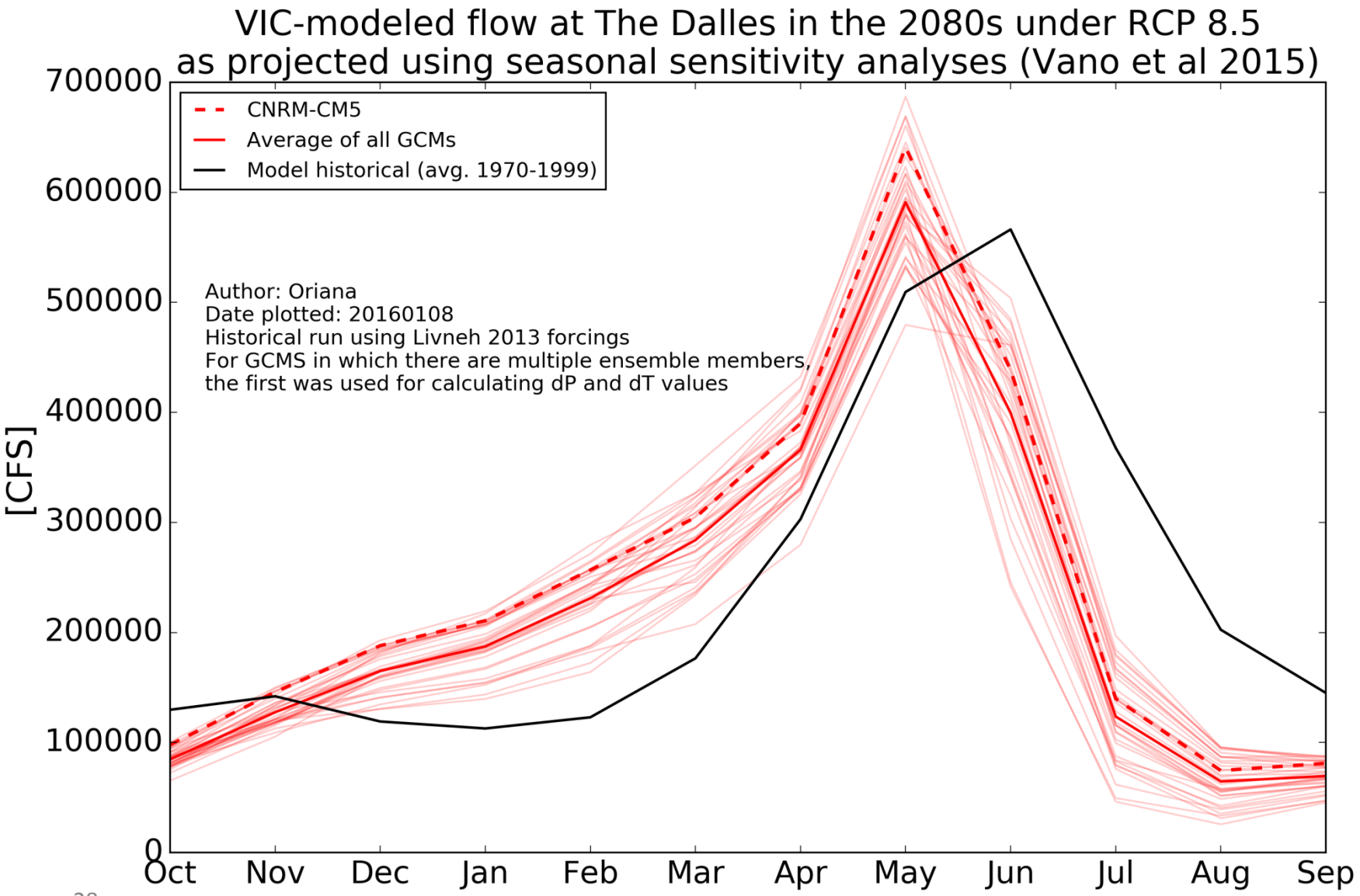


Project Synopsis: Hydrologic Model Runs

		MACA		BCSD		ORNL
		RCP 4.5	RCP 8.5	RCP 4.5	RCP 8.5	RCP 8.5
VIC	Parameter Set 1	■■■■■ ■■■■■	■■■■■ ■■■■■	■■■■■ ■■■■■	■■■■■ ■■■■■	■■■
	Parameter Set 2	■■■■■ ■■■■■	■■■■■ ■■■■■	■■■■■ ■■■■■	■■■■■ ■■■■■	■■■
	Parameter Set 3	■■■■■ ■■■■■	■■■■■ ■■■■■	■■■■■ ■■■■■	■■■■■ ■■■■■	■■■
PRMS	Parameter Set 1	■■■■■ ■■■■■	■■■■■ ■■■■■	■■■■■ ■■■■■	■■■■■ ■■■■■	■■■

Each ■ represents a different hydrologic simulation based upon distinct meteorological forcings

Project Synopsis: Sensitivity Analyses



Stakeholders

- River Management Joint Operating Committee
  - BPA (hydropower)
  - Army Corps of Engineers (flood control)
  - Bureau of Reclamation (irrigation)
- Tribes, federal, state and local governments
  - Columbia River Inter-Tribal Fish Commission
  - EPA
  - State water managers
- Others
  - Seattle City Light

Stakeholder involvement

- Monthly phone calls with RMJOC
- Periodic updates to CRFG
- Approximately annual Transboundary Workshops
- Annual presentations to BPA T&I program
- Active involvement of RMJOC in evaluating research results

CHPS - Bonneville Power Administration (Stand alone)

Tools Options Help

Data Viewer

- CSIROMk360_R
- CSIROMk360_R
- GFDLESM2M_RC
- GFDLESM2M_RC
- HadGEM2CC_R
- HadGEM2CC_R
- HadGEM2ES_RC
- HadGEM2ES_RC
- inmcm4_RCP45
- inmcm4_RCP85
- IPSLCM5AMR_R
- IPSLCM5AMR_R
- MIROC5_RCP45
- MIROC5_RCP85
- Daily Quality Control
- Historical Data
- Live Data
- Preprocessed PIXML
- Temp QC groupings
- QC'd data

- SLM 1 m
- SMH 1 m
- SNYI 1 m
- SPD 1 m
- SUV 1 m
- SVN 1 m
- SWAI 1 m
- SWF 1 m
- TDA 1 m
- TEAI 1 m
- TMY 1 m
- TOM 1 m
- TRB 1 m
- TRY 1 m
- TUMO 1 m
- UBK 1 m
- UMTW 1 m

QME – River Discharge Obs
SQME – River Discharge Sir

Sample <Select a sample function> Functions < Select a statistical function >

GMT	A QME (CFSD) nrni TDA 1 m TDA Import_nrni	B SQME (CFSD) MIROC5_R TDA 1 m TDA Import_UW [1]
10-13-1994 00:00	59960	138
10-14-1994 00:00	59765	116
10-15-1994 00:00	59119	103
10-16-1994 00:00	59699	111
10-17-1994 00:00	61129	119
10-18-1994 00:00	60880	110
10-19-1994 00:00	60030	88
10-20-1994 00:00	58759	76
10-21-1994 00:00	58778	80
10-22-1994 00:00	60578	96
10-23-1994 00:00	62197	122
10-24-1994 00:00	62493	134
10-25-1994 00:00	61358	128
10-26-1994 00:00	60785	129
10-27-1994 00:00	63030	124
10-28-1994 00:00	71456	108
10-29-1994 00:00	77609	91
10-30-1994 00:00	78074	81
10-31-1994 00:00	76303	74
11-01-1994 00:00	76328	70
11-02-1994 00:00	78173	72
11-03-1994 00:00	77274	84
11-04-1994 00:00	74319	105
11-05-1994 00:00	71857	130
11-06-1994 00:00	70829	119
11-07-1994 00:00	68611	99
11-08-1994 00:00	65669	95
11-09-1994 00:00	63548	91
11-10-1994 00:00	63058	98
11-11-1994 00:00	62590	122
11-12-1994 00:00	61562	127
11-13-1994 00:00	61371	134
11-14-1994 00:00	60611	150
11-15-1994 00:00	60792	146
11-16-1994 00:00	60816	126

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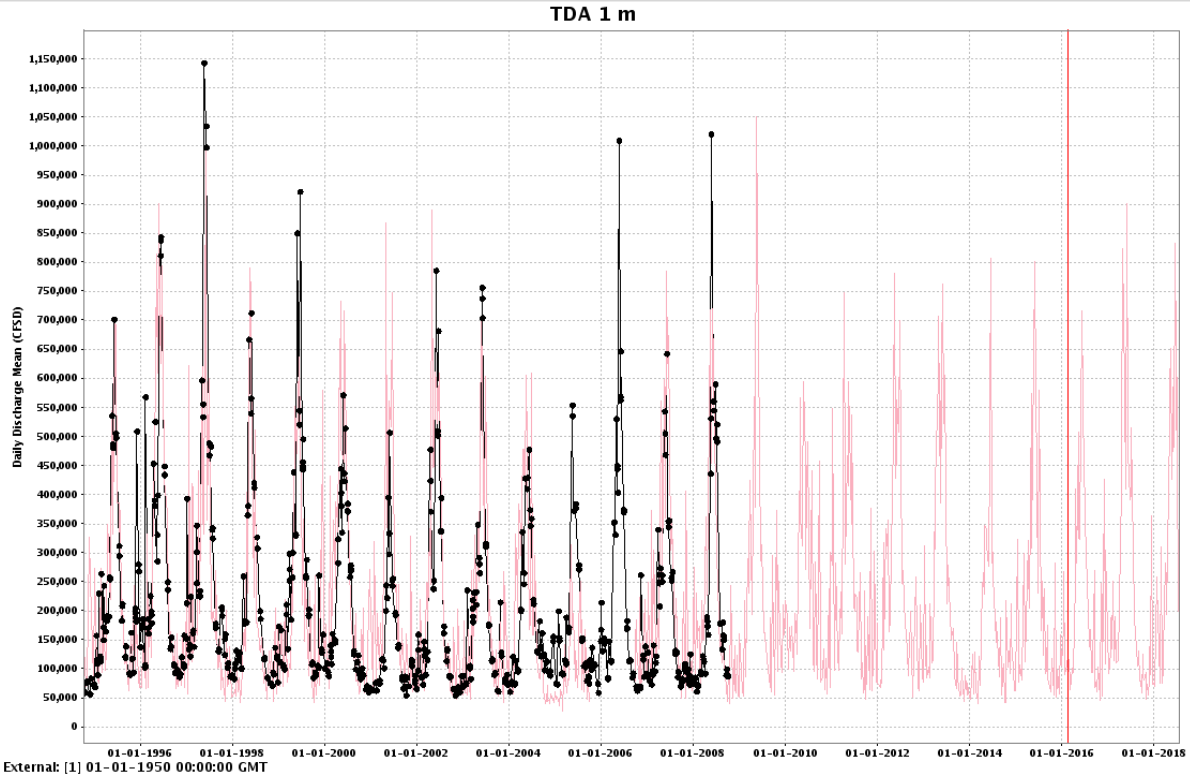

External: [1] 01-01-1950 00:00:00 GMT

Map Plots Topology Modifiers Forecaster help viewer

8 : Forecaster help

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Follow-up opportunities and questions

Questions from conveners

- How will interacting vulnerabilities in water resources management systems change at local and state levels in a warming world?
- What measures are needed to increase the water resiliency […] and to anticipate projected changes and interactions between water resources and other systems?
- How can the human factors [...] be fully included in the future projections of the regional water cycle in earth system models?