Iteration #2 Results

Estuary Sub Group of the Ecosystem-Based Function Work Group

SELFE and Delft3D

SRT Meeting – March 14, 2013

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Outline

- Do the alternatives and components lead to significant changes in the estuary?
- Are specific alternatives and components distinctive in how they change the estuary?
- Are the changes beneficial or harmful to the estuary?
- Are any of the changes particularly striking?
- What other major lessons have we learned?
- Other considerations

Overview

Do the alternatives and components lead to significant changes in the estuary?

Domain

Alternatives & Components

- **Yes!**
- The analysis of three salmon-relevant metrics show statistically and ecologically significant differences

Salinity Intrusion Length (SIL)

$-40\% < \Delta SIL < 15^{+}\%$

Plume Volume (PV)

$30\text{-}800^{+}\%$ of RC-CC

Salmon Habitat Opportunity (SHO)

$-100\% < \Delta SHO^{*} < 200\%$

Overview

Are specific alternatives and components distinctive in how they change the estuary?

- **Yes!**

- 2A-TC: Generally trivial changes throughout the water year
- 2B-TC & E5: Moderate changes during select seasons
- 2A-TT & E3 : Moderate with seasonally significant changes
- E1 & E2b: Large changes during much of the water year

Overview

Are the changes beneficial or harmful to the estuary?

- **Depends on timing, location and specific estuarine function/service**
- Even components (E1 and E2b) that move the estuary toward pre-development flow conditions, do so for a different estuary and global conditions

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May/June

- Ocean entry conditions for yearlings — 2A-TT, E1, E2b, E5
- Habitat opportunity for subyearlings — All

July-September

- Estuarine hypoxia and acidification — 2A-TT, E1, E2b E3

?

Overview

Are any of the changes particularly striking?

- **Yes!**
- Components E1 and E2b dramatically increase the plume volume in June*, with potentially strong benefits for the smolt-to-adult ratios for specific stocks
- This is achieved through a larger and later freshet. The price is a reduced capability to curtail estuarine hypoxia and acidification in July* through September

Note: Several other changes are statistically and ecologically significant – but not as striking based on our analysis to date

Overview

What other major lessons have we learned?

- **Changes are best evaluated against a target set of specific estuarine functions/services**
  - In Iteration 3, analysis would benefit from a list of priority functions/services
- **The estuary is used year-round, but different functions/services have different timing**
  - In Iteration 3, analysis would benefit from the mapping of priority functions/services to specific times of the water year

Overview

What other major lessons have we learned?

- **The lower and upper sections of the estuary respond differently to changes in the Bonneville hydrograph**
  - In Iteration 3, analysis would benefit from the mapping of priority functions/services to locations within the estuary
- **There is a very strong seasonal and inter-annual variability in the changes introduced to the estuary**
  - From the perspective of the estuary, the duration and tailing-off characteristics of the freshets might be a particularly important feature to consider in the design of Iteration 3 alternatives

Overview

What other major lessons have we learned?

- **Preliminary results from sediment transport model (during falling limb of freshet Jul-Sept) show small changes in discharge can cause large changes in sediment erosion/deposition & grain size**
  - 2A-TC & 2A-TT cause moderate increases in erosion in the Federal Navigation Channel, and mixed erosion and deposition in off-channel areas
  - E1 & E2b cause large increases in erosion in Federal Navigation Channel, and larger increases in erosion and deposition in off-channel areas
  - Scenarios that cause more erosion induce sediment coarsening and areas like side channels and bays that have increased deposition become finer

Overview

Other considerations

- **Available tools and approaches would – if/when desirable – support a broader scope of questions:**
  - In addition to the question "what changes occur in the estuary for alternative X?" it would also be possible in Iteration 3 to address the question "how could alternative X be changed to optimize estuarine function/service Y?"

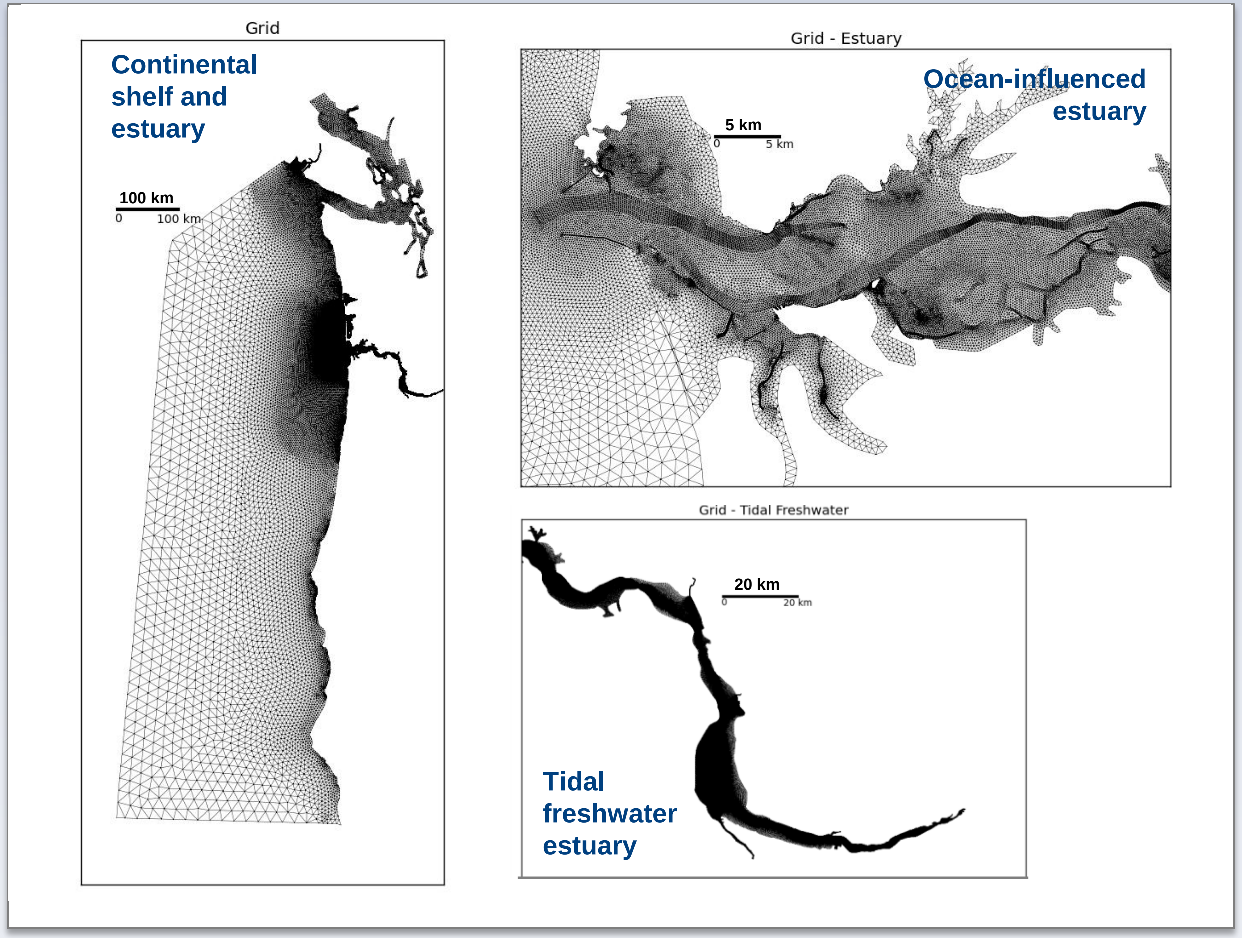
We would be happy to address any additional questions

Support slides (2nd tier)

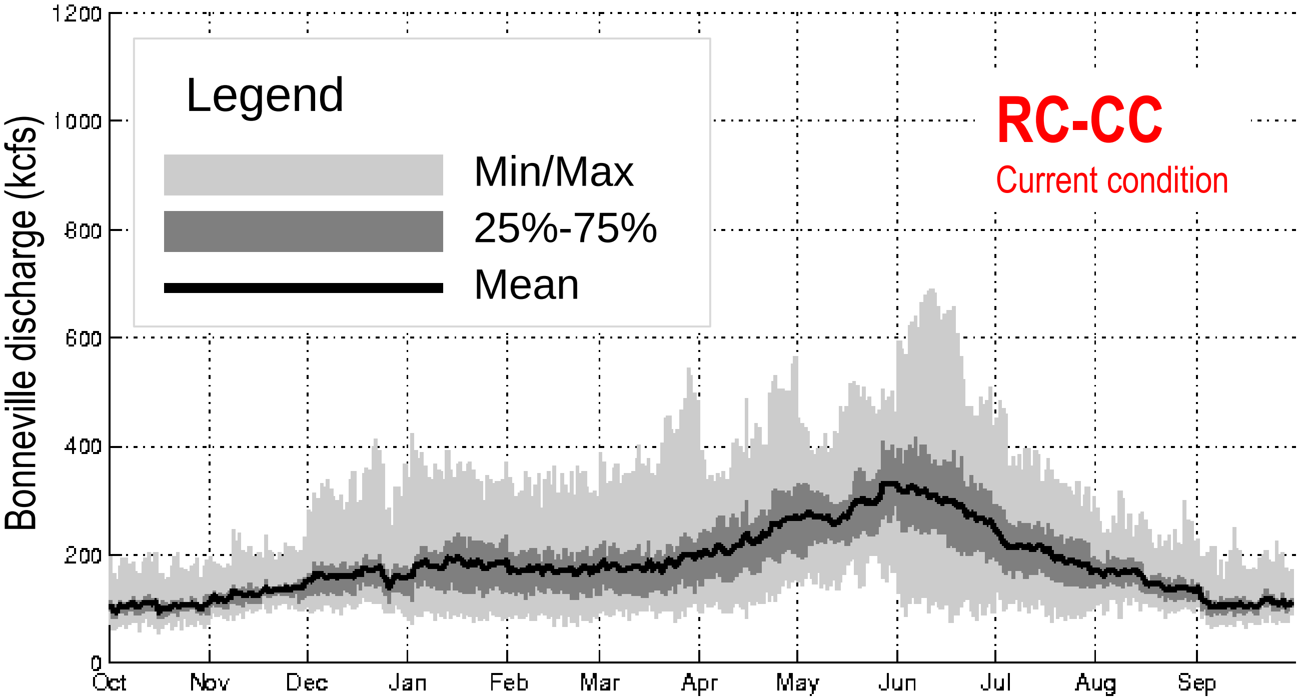
Question	Support slides
Do the alternatives and components lead to significant changes in the estuary?	13 - 21
Are specific alternatives and components distinctive in how they change the estuary?	22 - 26
Are the changes beneficial or harmful to the estuary?	27 - 33
Are any of the changes particularly striking?	34 - 35
What other major lessons have we learned?	36 - 39
Other considerations	53

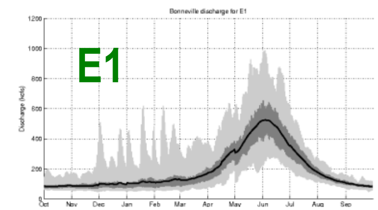
Estuary Domain

Columbia River from Bonneville Dam to the continental shelves of Oregon and Washington

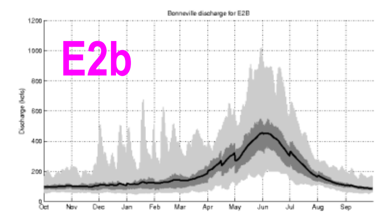


Overview of scenarios (Q_{Bon})

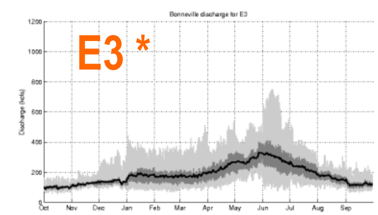




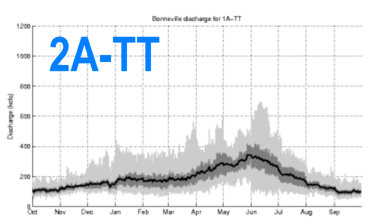
Normative hydrograph



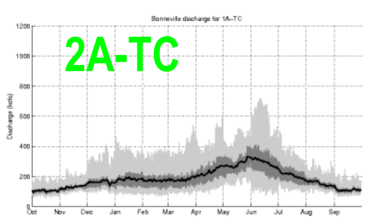
Normative reservoir levels



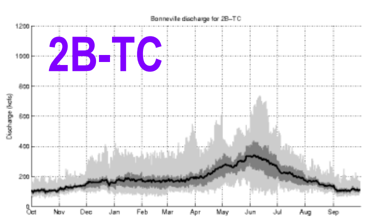
Summer fish migration



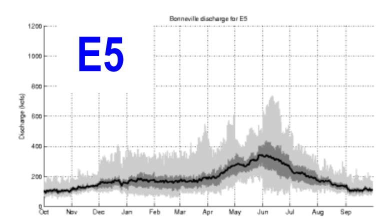
450 Treaty terminates



450 Treaty continues



600 Treaty continues



Dry year strategy

Columbia River Treaty 2014/2024 Review

Bonneville flows: Statistical significance of differences

	River Discharge**	OCT	NOV	DEC	JAN	FEB	MAR	APR 1-15	APR 16-30	MAY	JUN	JUL	AUG 1-15	AUG 16-30	SEP
Flow differences between RC-CC and Iteration 2 alternatives															
2A-TC (450)	High														
	Medium														
	Low														
2A-TT (450)	High														
	Medium														
	Low														
2B - TC (600)	High														
	Medium														
	Low														
Flow differences between RC-CC and Iteration 2 components															
E1 - normative hydrograph	High														
	Medium														
	Low														
E2b - normative reservoir levels	High														
	Medium														
	Low														
2E3 - improve summer fish migration	High														
	Medium														
	Low														
E5 - dry year strategy	High														
	Medium														
	Low														

** Based on percentiles for BON-Q POR - High (95%), Medium (50%), Low (5%)

<u>Alternative/Component flow is</u>:

- Significantly LOWER than RC-CC (strong stat diff)
- Lower than RC-CC (weak stat diff)
- Lower than RC-CC (no stat diff)
- No different than RC-CC
- Significantly HIGHER than RC-CC (strong stat diff)
- Higher than RC-CC (weak stat diff)
- Higher than RC-CC (no stat diff)

Columbia River Treaty 2014/2024 Review

Periods of SELFE simulations

	River Discharge**	OCT	NOV	DEC	JAN	FEB	MAR	APR 1-15	APR 16-30	MAY	JUN	JUL	AUG 1-15	AUG 16-30	SEP
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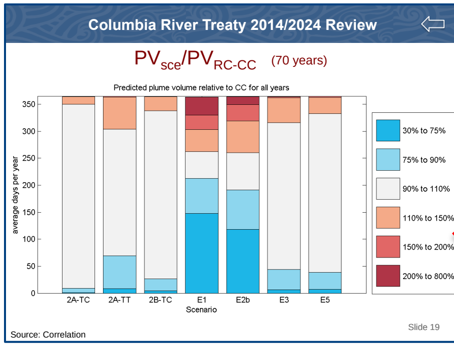
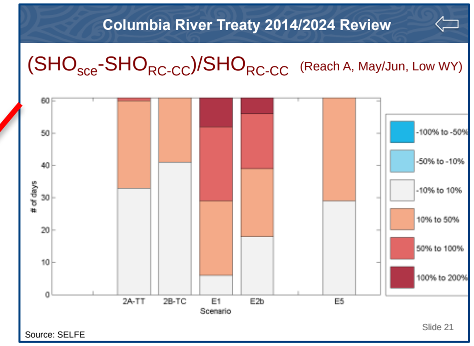
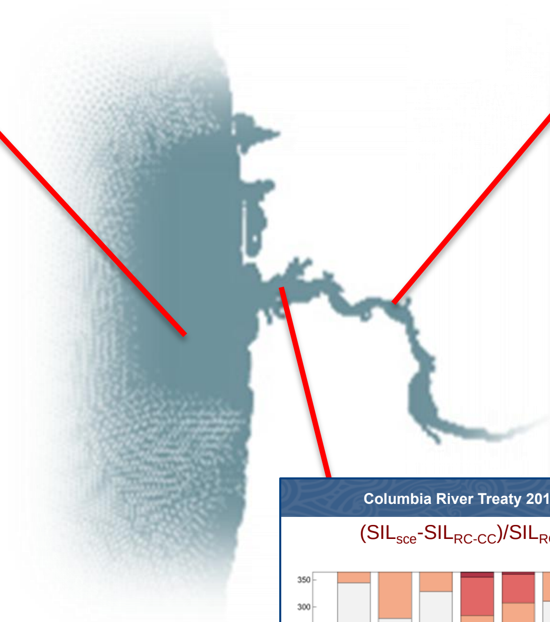
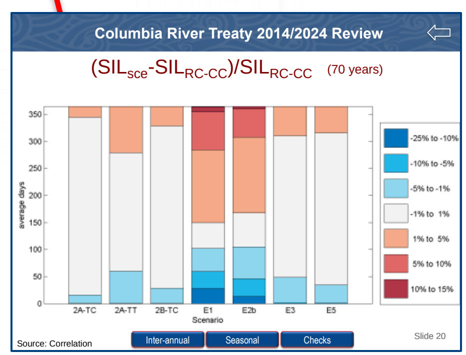


Plume volume
(PV)



Salmon Habitat Opportunity
(SHO)





Salinity Intrusion Length
(SIL)

?

Metrics/Evaluation Criteria

- **Plume Volume (PV, in Km^3)** is a metric for the conditions found by salmon at the time of ocean entry
- Burla et al. 2010 (steelhead) and Miller et al. in press (Fall chinook) showed that smolt-to-adult returns (SAR) for specific salmon stocks correlate positively with plume volumes
  - Larger volumes at time of ocean entry (May, June in particular) are a preferred condition
- Plume volume …
  - Increases with increasing flows, for similar ocean conditions
  - depends on coastal winds, being typically larger for northern winds
- Operational definition: volume of the region of the continental shelf which salinity is below 28 psu

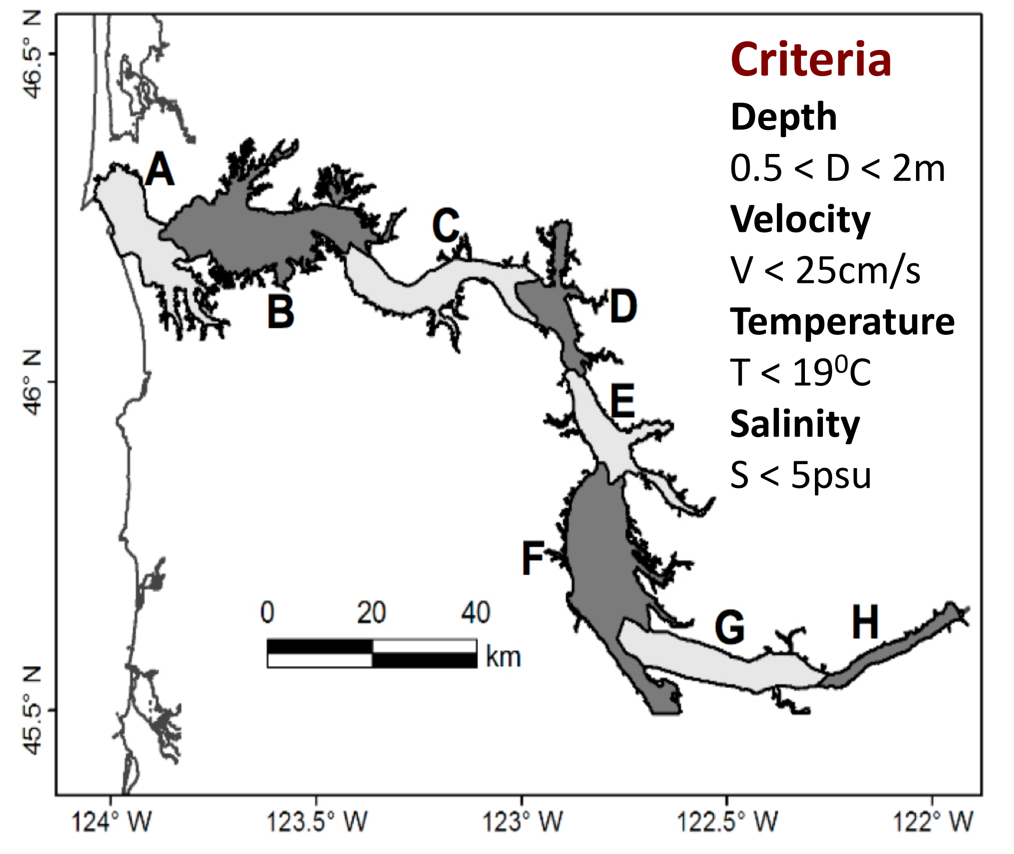
?

Metrics/Evaluation Criteria

- **Salinity Intrusion Length (SIL, in Km)** is a metric for the extent and magnitude of the ocean influences in the estuary – and is an integrative metric for the state of the lower estuary
- SIL varies at tidal, seasonal and inter-annual scales – with Bonneville discharges providing 1st order control over variability (SIL decreases when discharges increase, and vice versa)
- Relative to pre-development flow conditions, Bonneville discharges …
  - reduced the seasonal variability of SIL – and thus of the lower estuary buffer for out-migrating salmon in their way to ocean entry
  - reduced SIL during late spring and summer – which currently means increased potential for estuarine hypoxia and acidification

Metrics/Evaluation Criteria

- **Salmon Habitat Opportunity (SHO, in Km²/d)** metrics measure favorable habitat for subyearling salmon, based on physical factors (Bottom et al. 2005; Burla 2009)
- SHO metrics are computed for each of eight reaches within the Columbia River estuary (reaches A-H)
- Increase of SHO is the preferred condition when change occurs



Use of the estuary by subyearlings …

Hypothesis on salmon use of estuary: Subyearling juvenile Chinook salmon in shallow water habitats

Table adapted from David Teel et al. (NOAA NWFSC) – Draft – Partial – Context Only

Stock	Spring Creek Group Fall		West Cascade Fall		Willamette River Spring		Upper Columbia River Summer/Fall	
	Reach A/B	Reach F/G	Reach A/B	Reach F/G	Reach A/B	Reach F/G	Reach A/B	Reach F/G
Emergent Fry (≤45mm)	JFMAMJ JASOND	JFMAMJ JASOND	JFMAMJ JASOND	JFMAMJ JASOND	JFMAMJ JASOND	JFMAMJ JASOND	JFMAMJ JASOND	JFMAMJ JASOND
Resident Fry (46-65mm)	JFMAMJ JASOND	JFMAMJ JASOND	JFMAMJ JASOND	JFMAMJ JASOND	JFMAMJ JASOND	JFMAMJ JASOND	JFMAMJ JASOND	JFMAMJ JASOND
Subyearling A (66-80mm)	JFMAMJ JASOND	JFMAMJ JASOND	JFMAMJ JASOND	JFMAMJ JASOND	JFMAMJ JASOND	JFMAMJ JASOND	JFMAMJ JASOND	JFMAMJ JASOND
Subyearling B (>81mm)	JFMAMJ JASOND	JFMAMJ JASOND	JFMAMJ JASOND	JFMAMJ JASOND	JFMAMJ JASOND	JFMAMJ JASOND	JFMAMJ JASOND	JFMAMJ JASOND

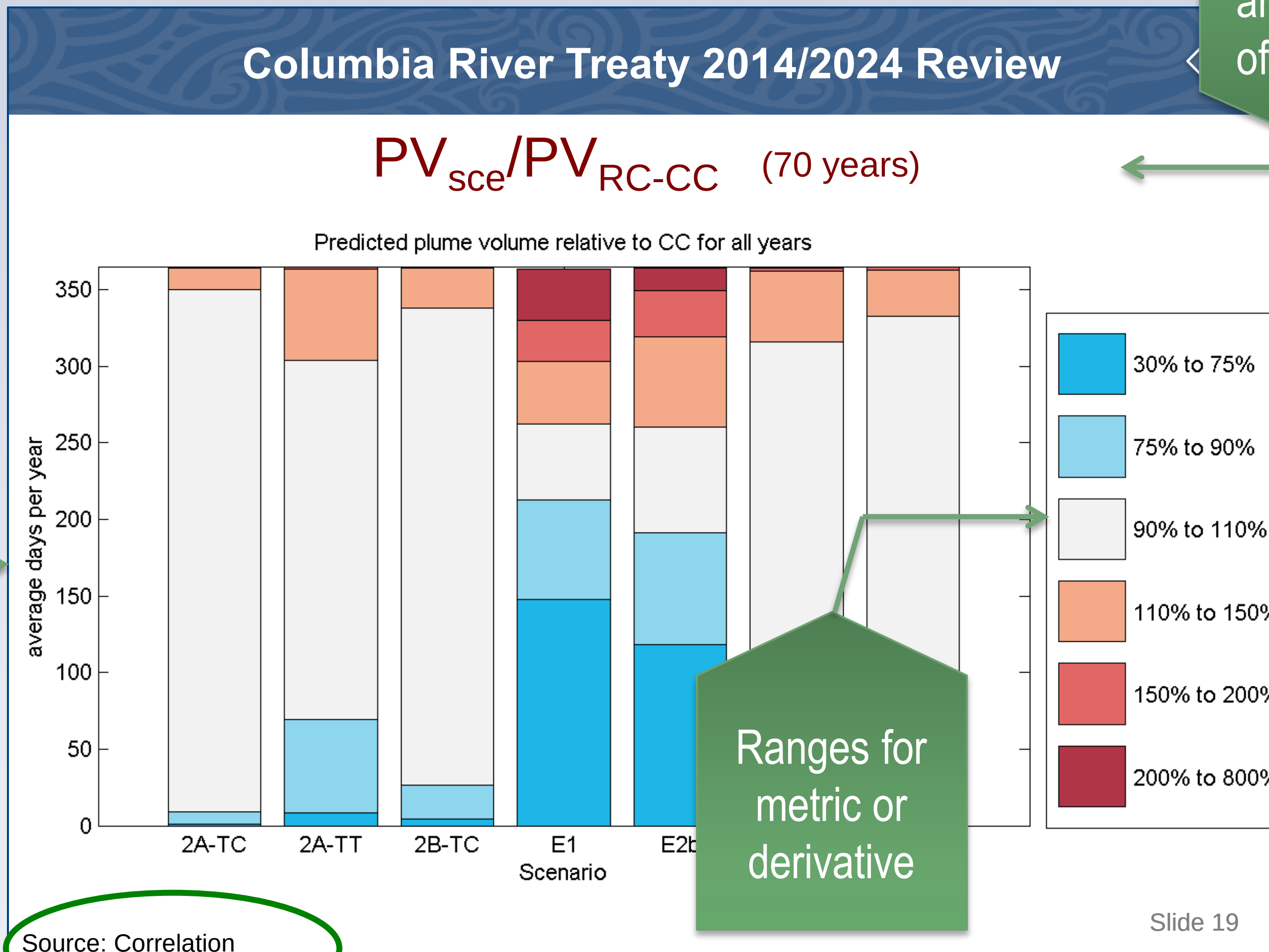
Of note:
- The estuary is used by subyearlings year-round
- Different stocks use different reaches of the estuary at different times of the year
- All stocks above (except WR S) are present in May and/or June

JFMAMJJASOND
- **Black: present**
- **Red: peak month**
- **Blue: near-peak month**
- **Gray: not present or no data**

Explanation of plot

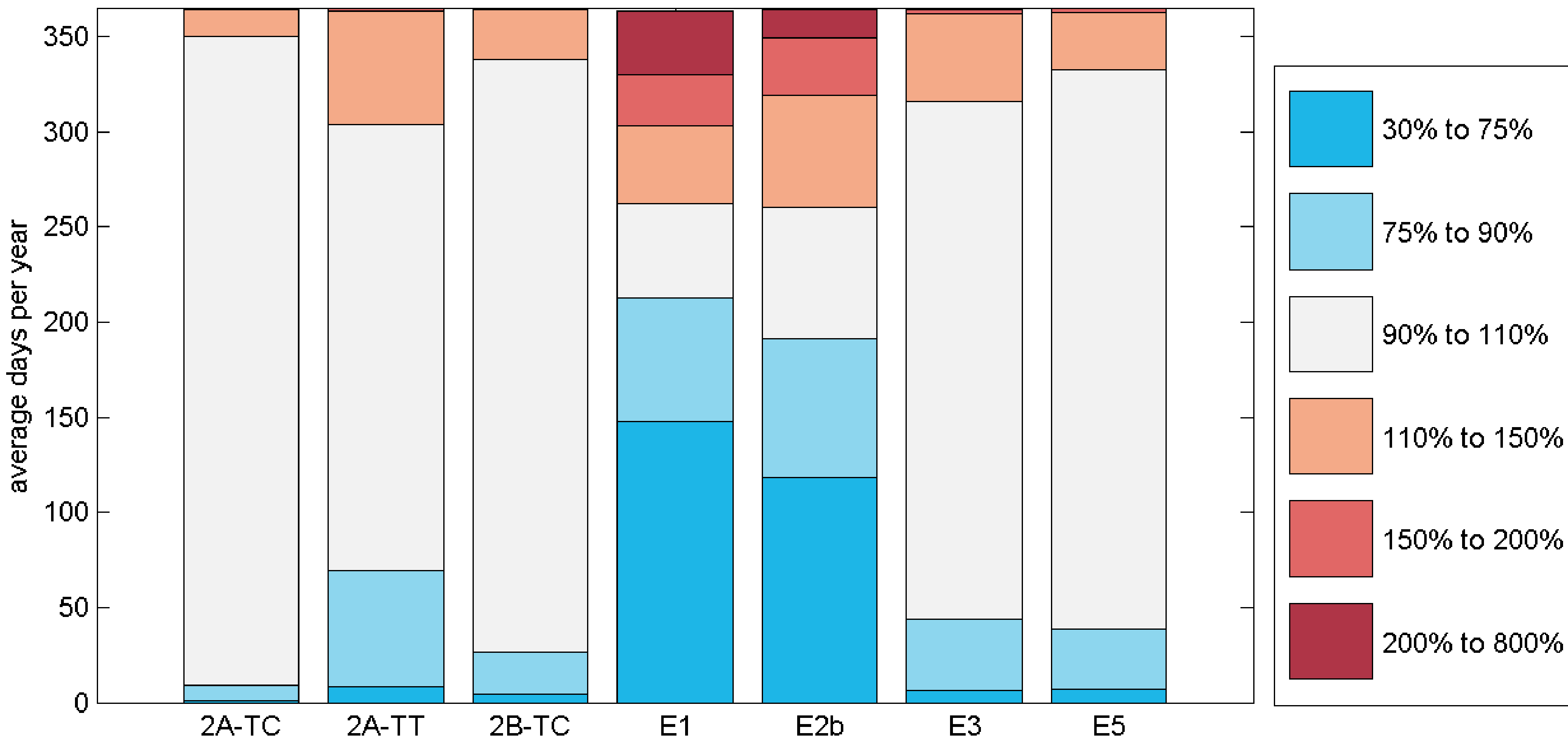
Metric or derivative and (period of analysis)

Number of days (or average days per year) that fall within the range



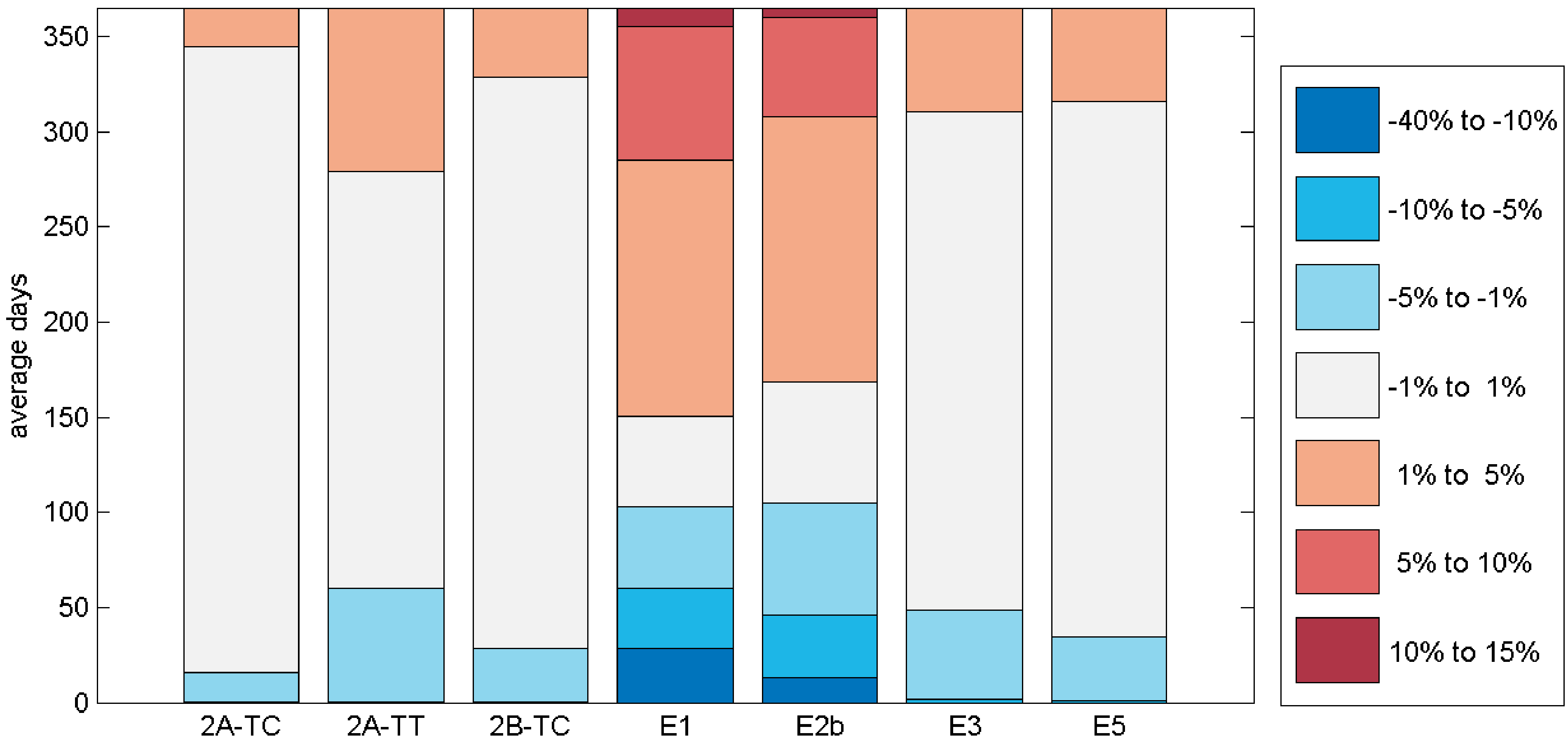
Ranges for metric or derivative

$PV_{sce}/PV_{RC\text{-}CC}$ (70 years)



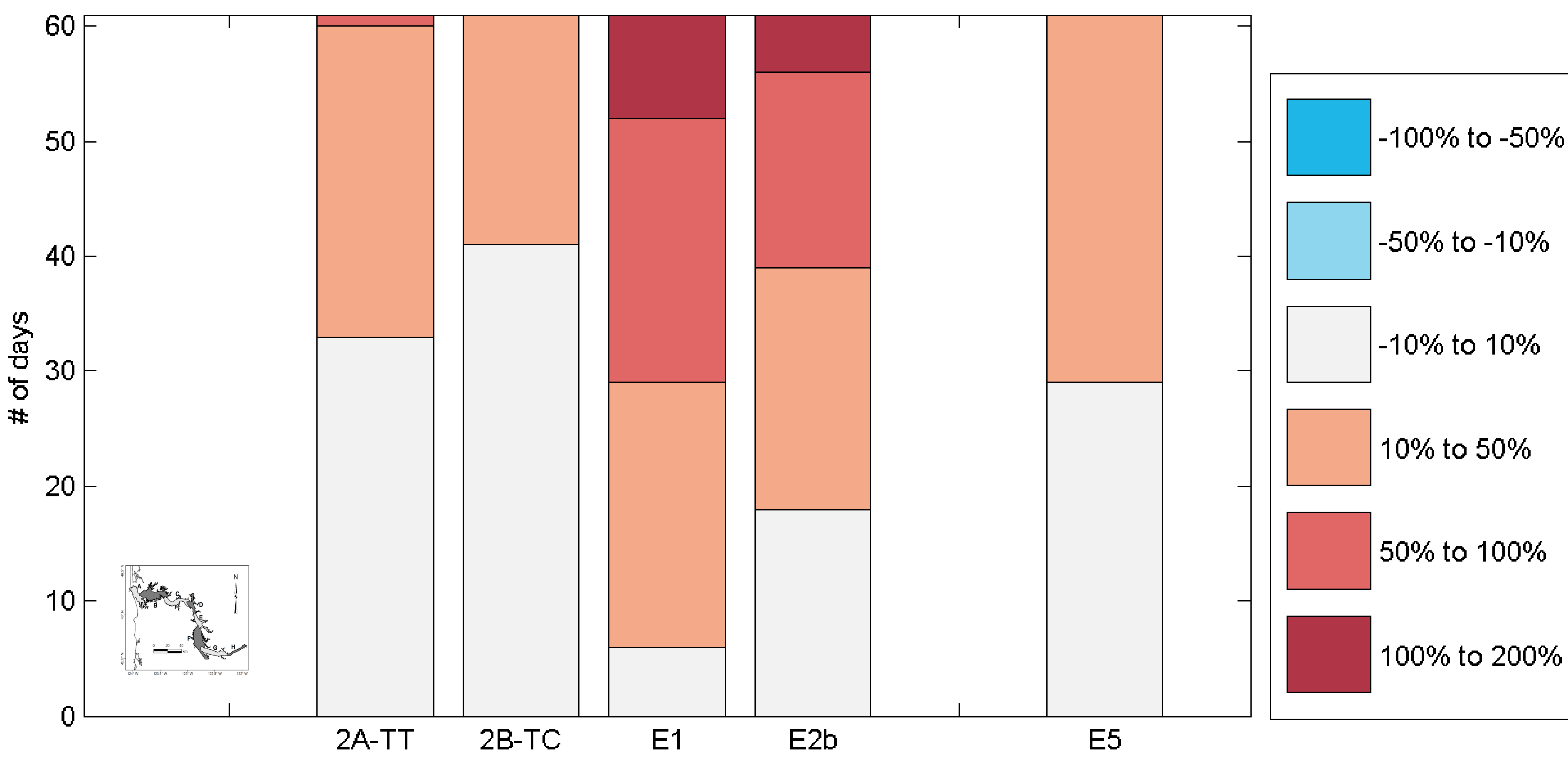
Source: Correlation

$(SIL_{sce}-SIL_{RC\text{-}CC})/SIL_{RC\text{-}CC}$ (70 years)



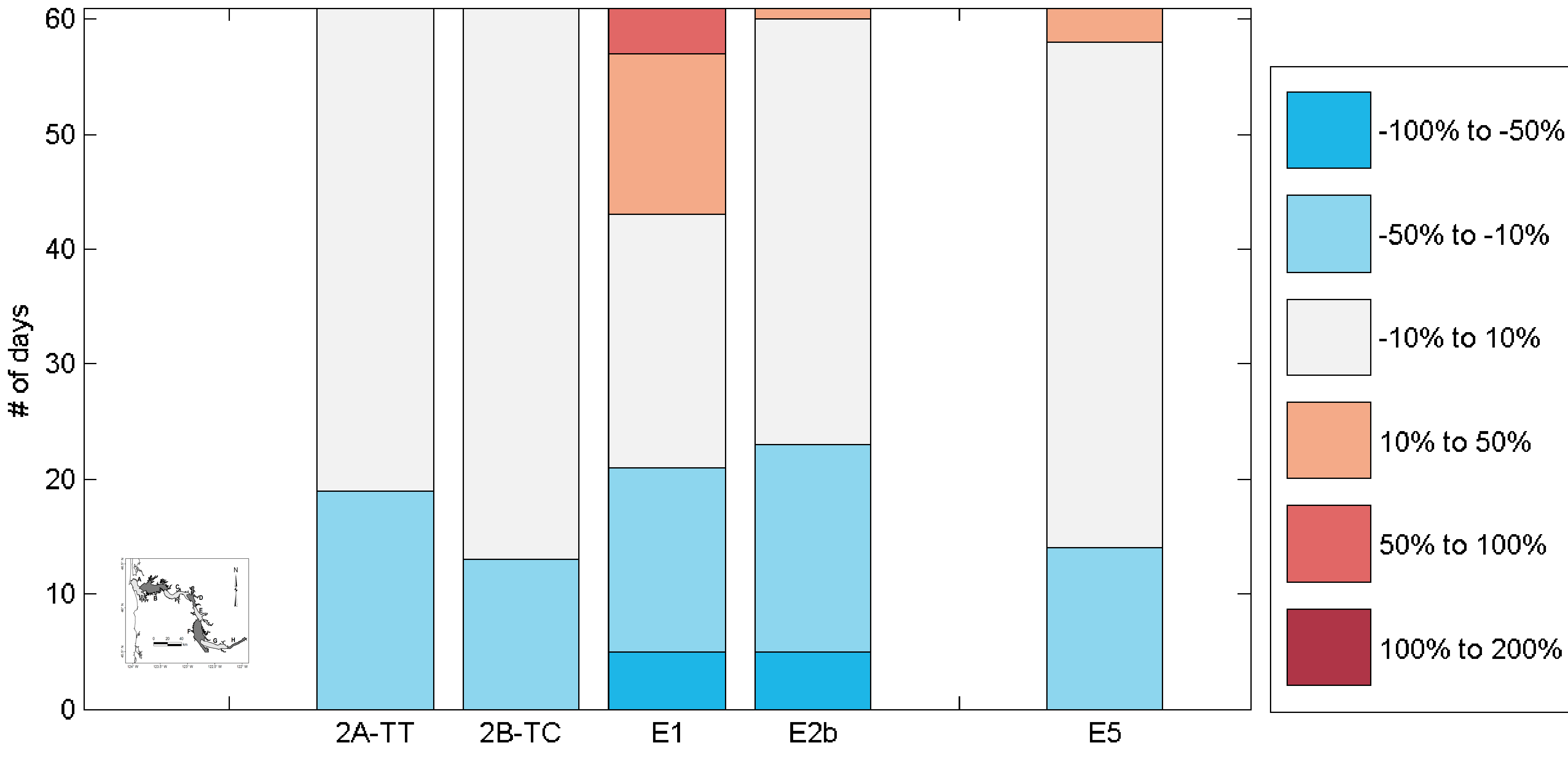
Source: Correlation

$(SHO_{sce}-SHO_{RC\text{-}CC})/SHO_{RC\text{-}CC}$ (Reach A, May/Jun, Low WY)



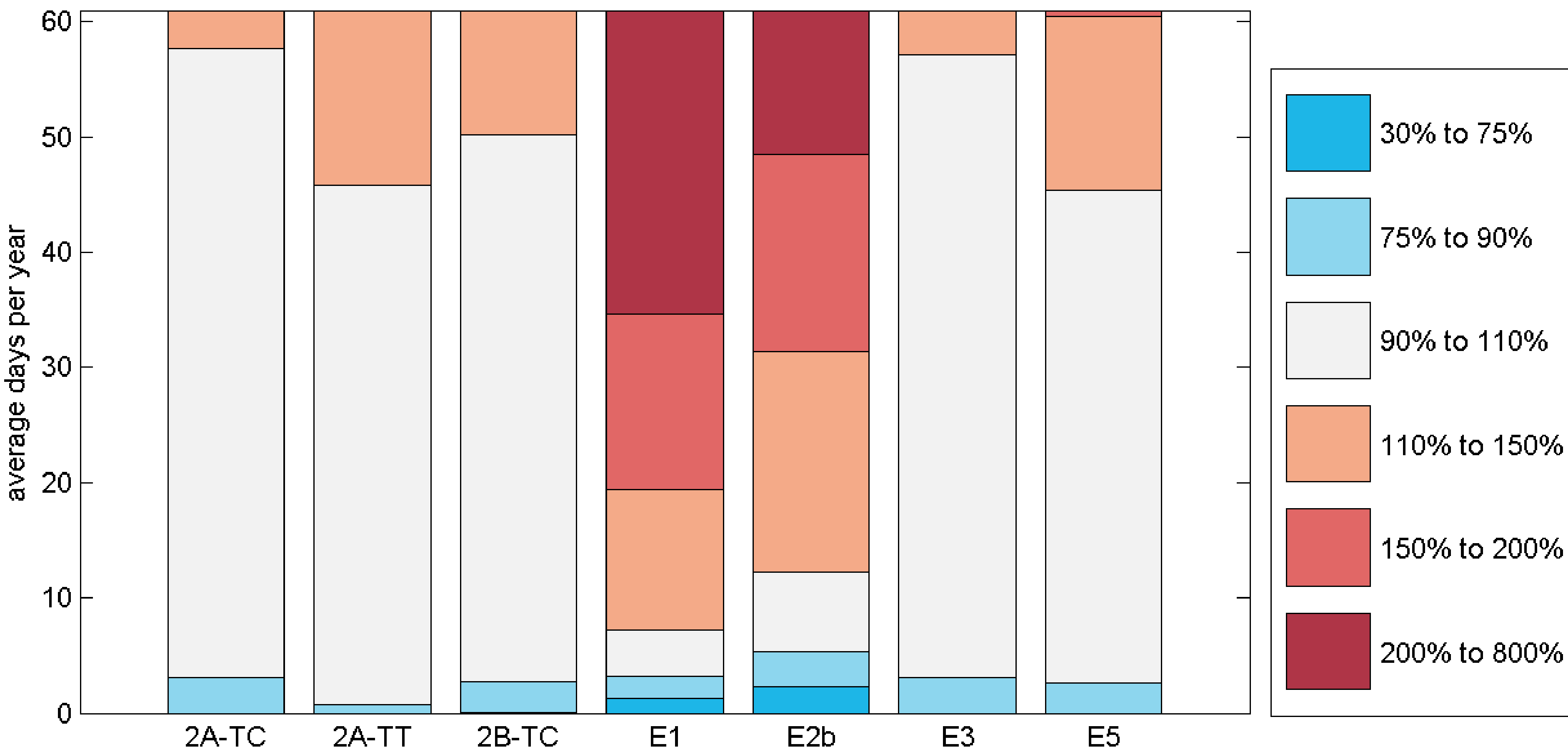
Source: SELFE

$(SHO_{sce}-SHO_{RC-CC})/SHO_{RC-CC}$ (Reach F, May/Jun, Low WY)



Source: SELFE

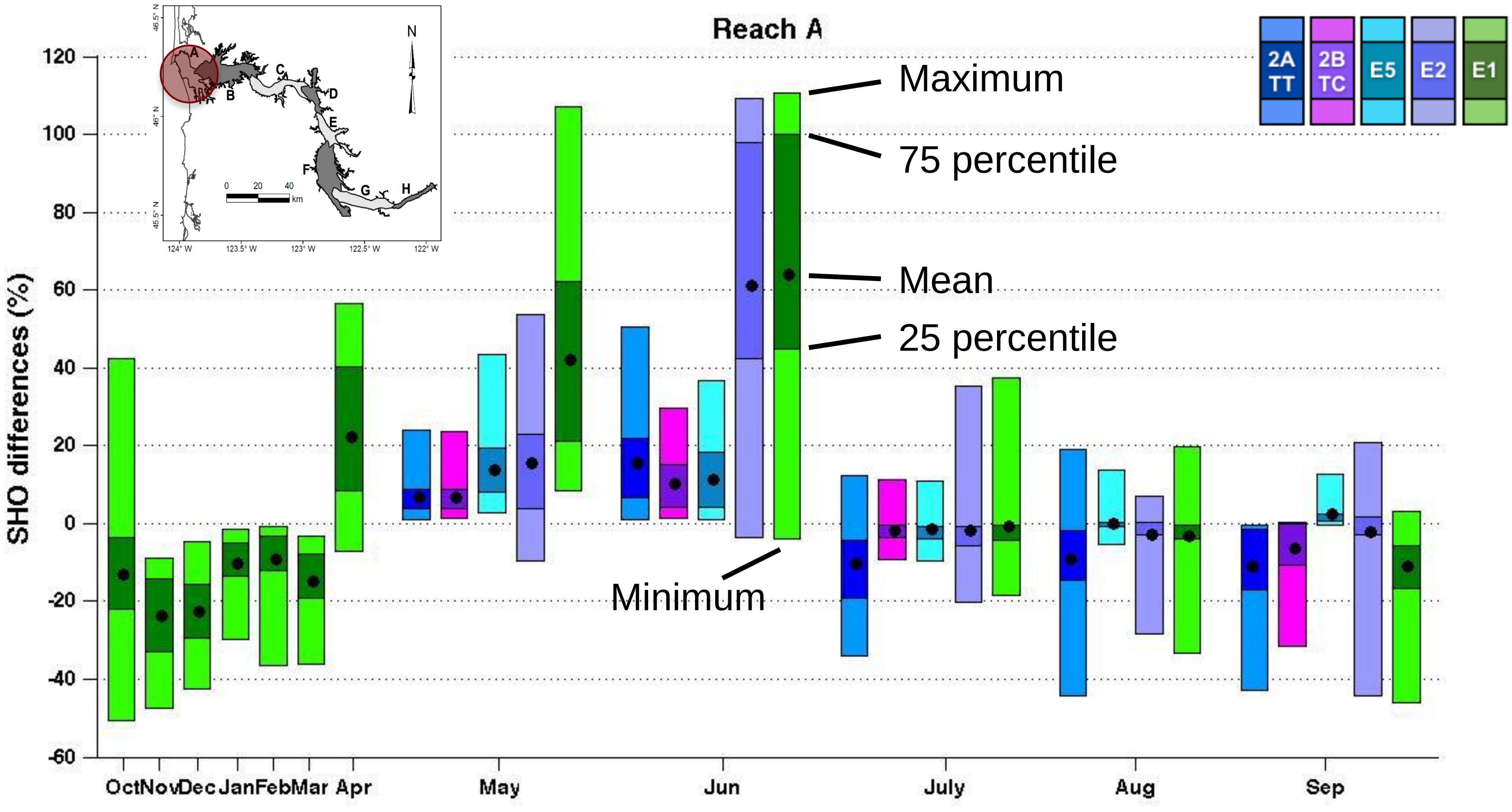
$PV_{sce}/PV_{RC\text{-}CC}$ (May/Jun, 70 years)



Source: Correlation

$(SHO_{sce}-SHO_{RC\text{-}CC})/SHO_{RC\text{-}CC}$

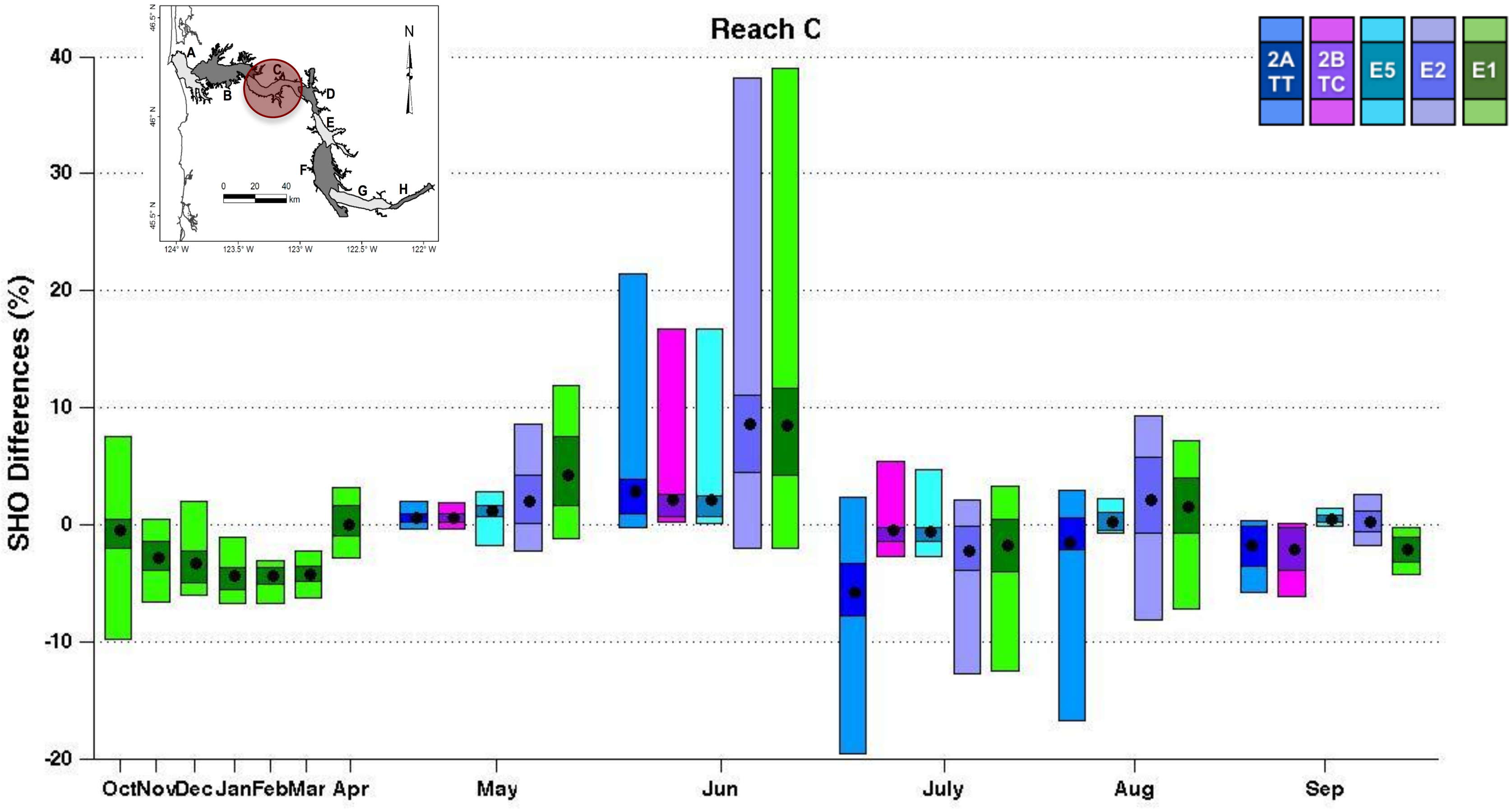
Reach A – All criteria – Low WY



Source: SELFE

$(SHO_{sce}\text{-}SHO_{RC\text{-}CC})/SHO_{RC\text{-}CC}$

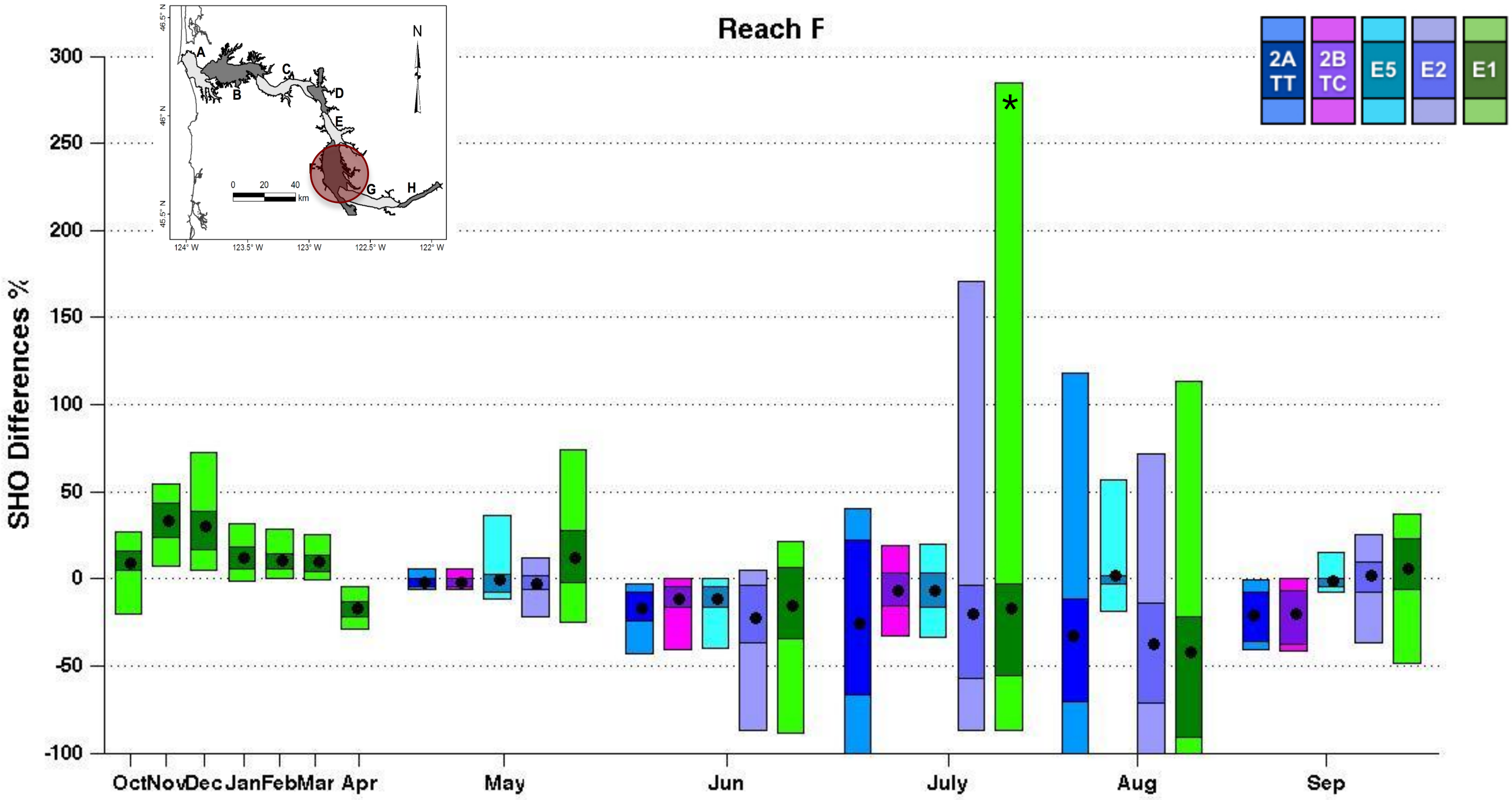
Reach C – All criteria – Low WY



Source: SELFE

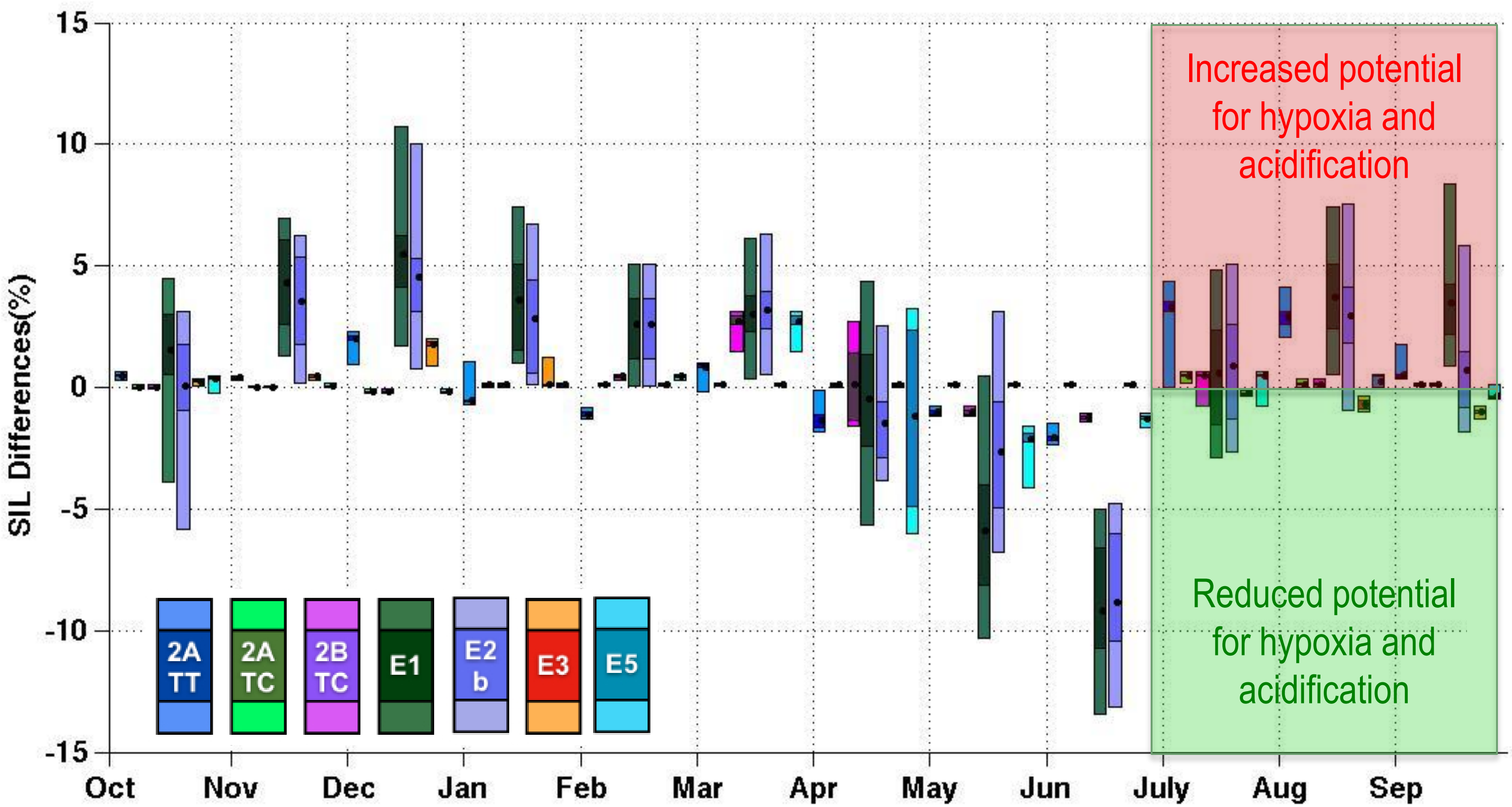
$(SHO_{sce}-SHO_{RC-CC})/SHO_{RC-CC}$

Reach F – All criteria – Low WY



Source: SELFE

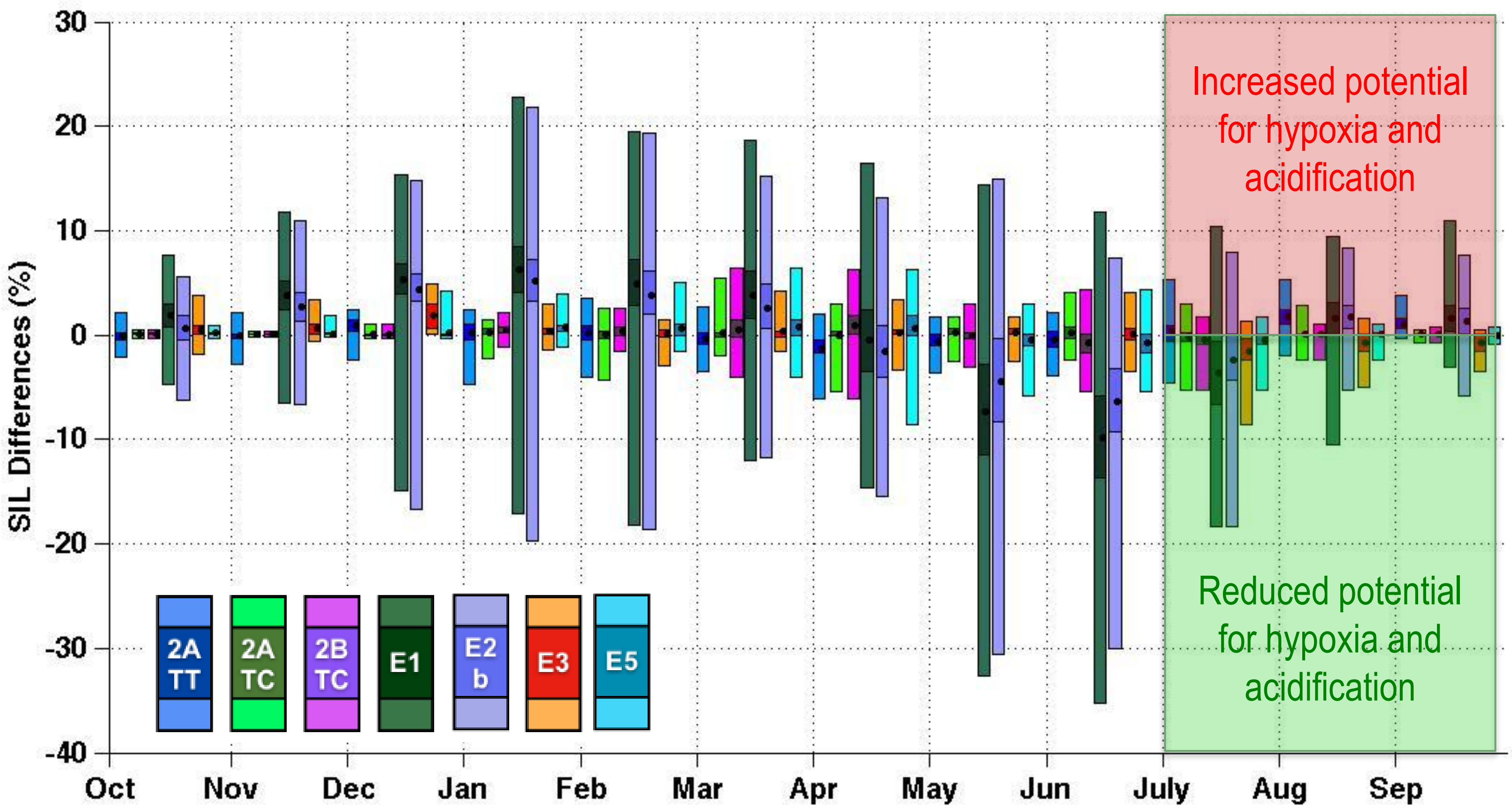
$(SIL_{sce}-SIL_{RC-CC})/SIL_{RC-CC}$ (Low WY)



Low WY | 70y Zoom | 70 y | Jul-Sep

Source: Correlation

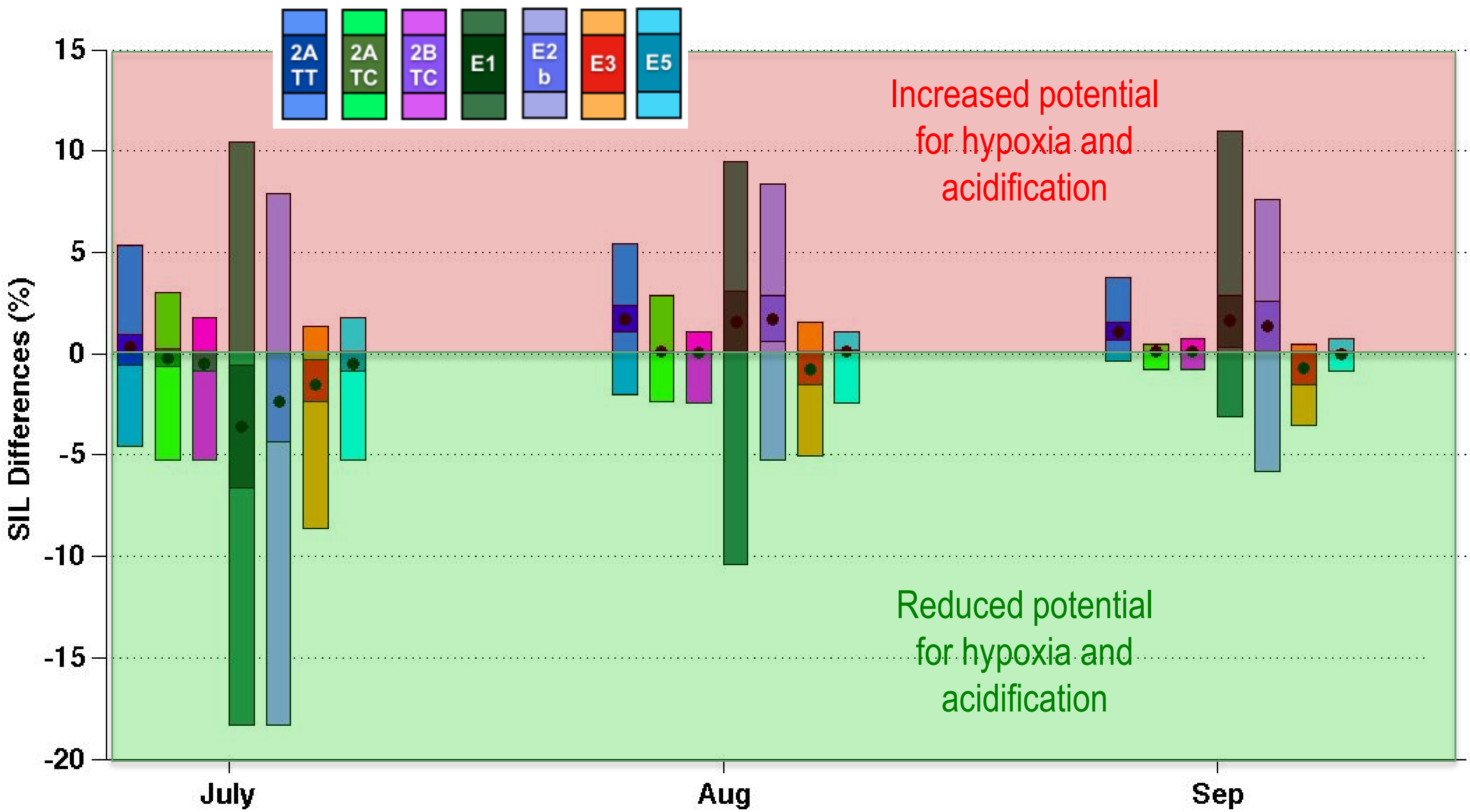
$(SIL_{sce}-SIL_{RC\text{-}CC})/SIL_{RC\text{-}CC}$ (70 years)



Source: Correlation

Low WY | 70y Zoom | 70 y | Jul-Sep

$(SIL_{sce}-SIL_{RC-CC})/SIL_{RC-CC}$ (Jul-Sep, 70 years)

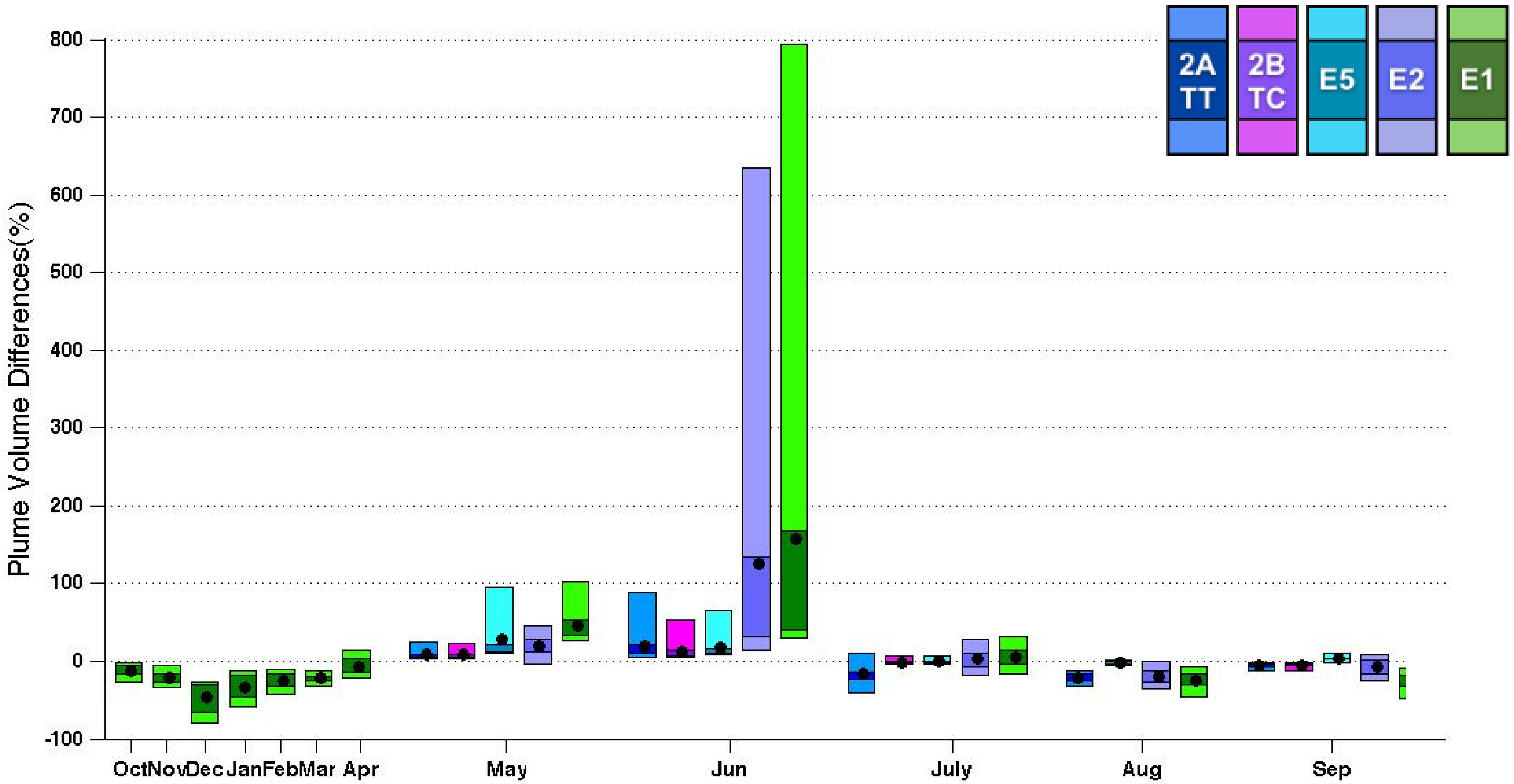


Low WY | 70y Zoom | 70 y | Jul-Sep

Source: Correlation

Seasonal variability: PV change

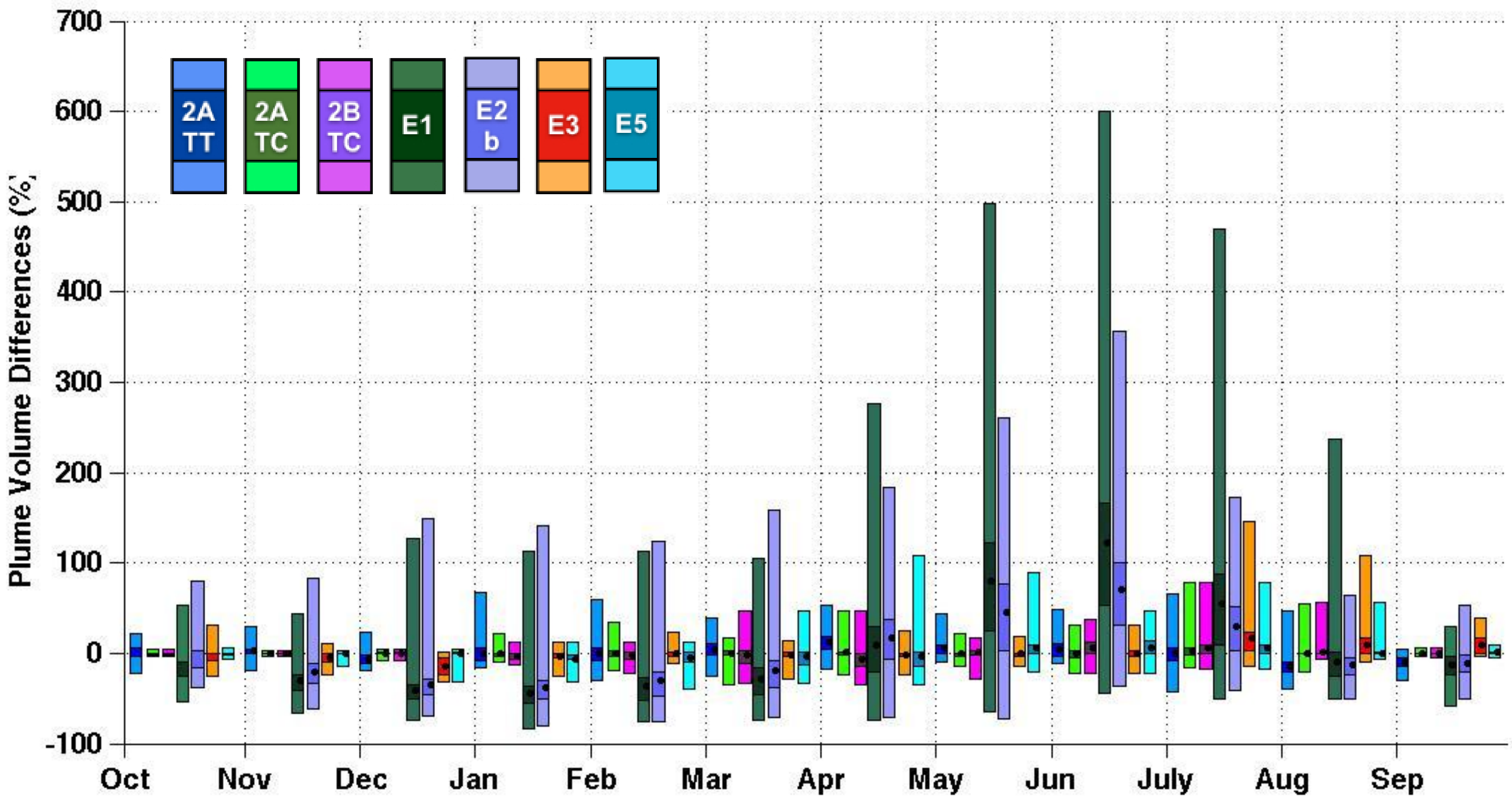
Low-flow WY



Source: SELFE

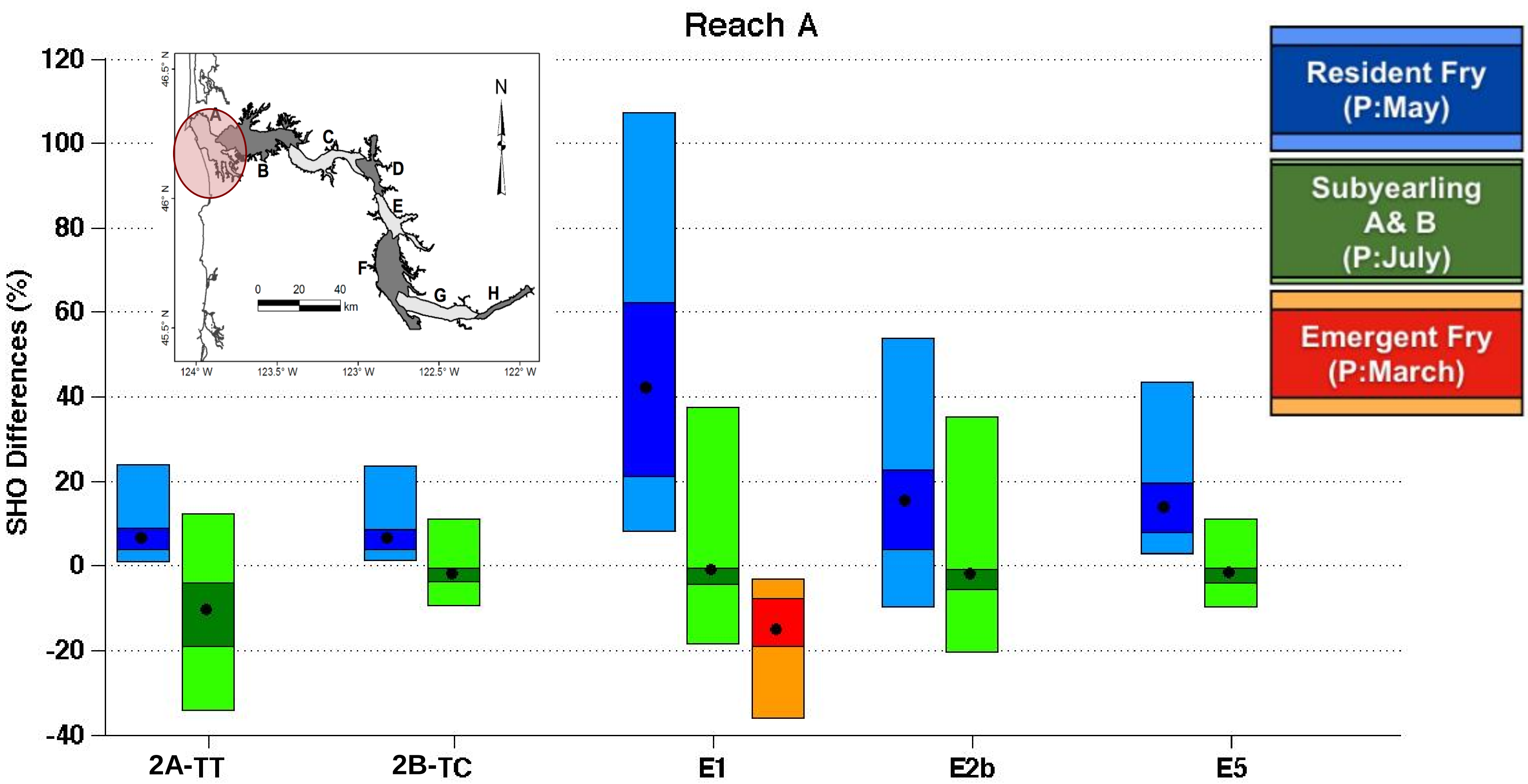
Seasonal variability: PV change

(70 years)



Source: Correlation

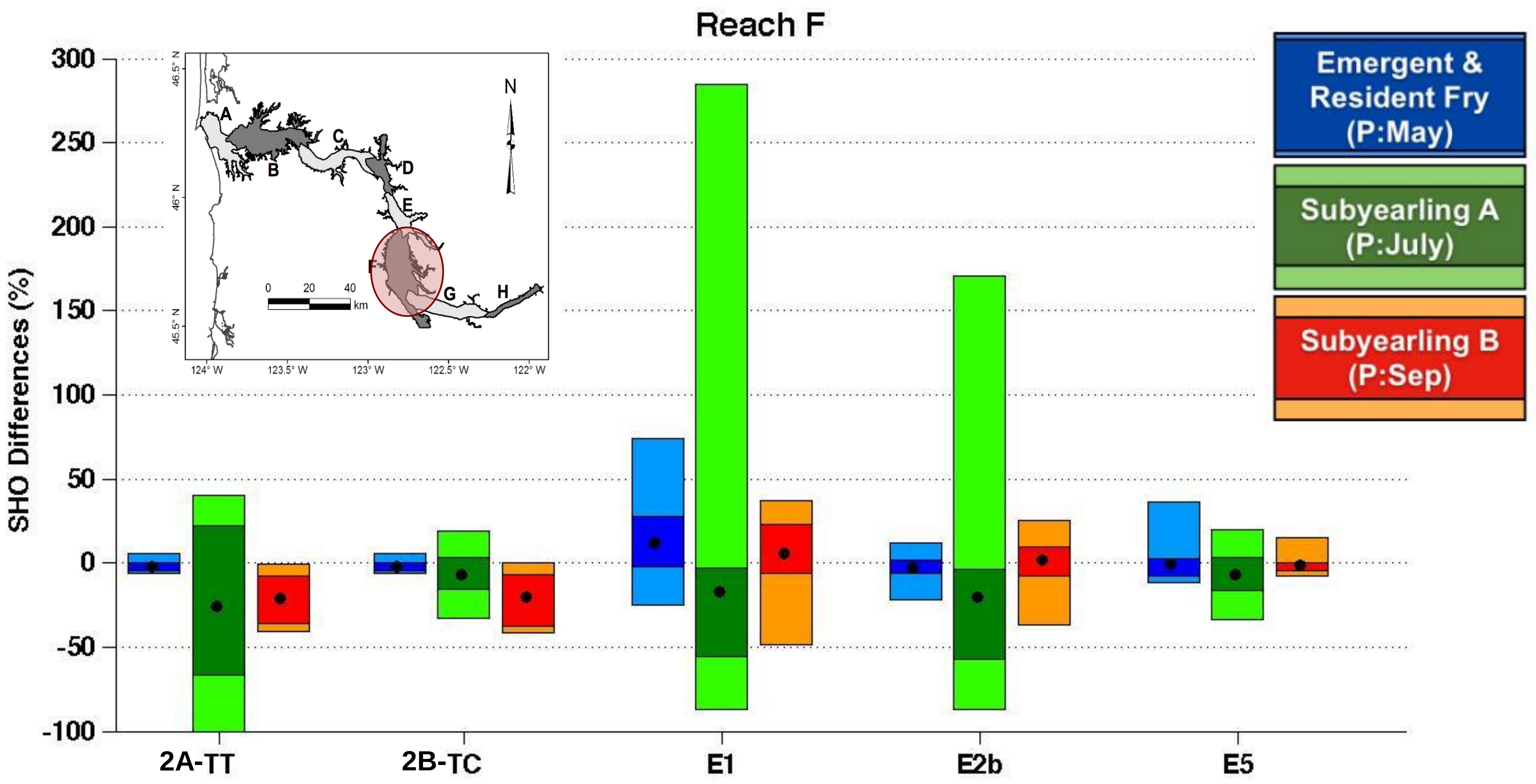
$(SHO_{sce}-SHO_{RC-CC})/SHO_{RC-CC}$ (Low WY)



Stock: West Cascade Fall

Source: SELFE

$(SHO_{sce}-SHO_{RC-CC})/SHO_{RC-CC}$ (Low WY)

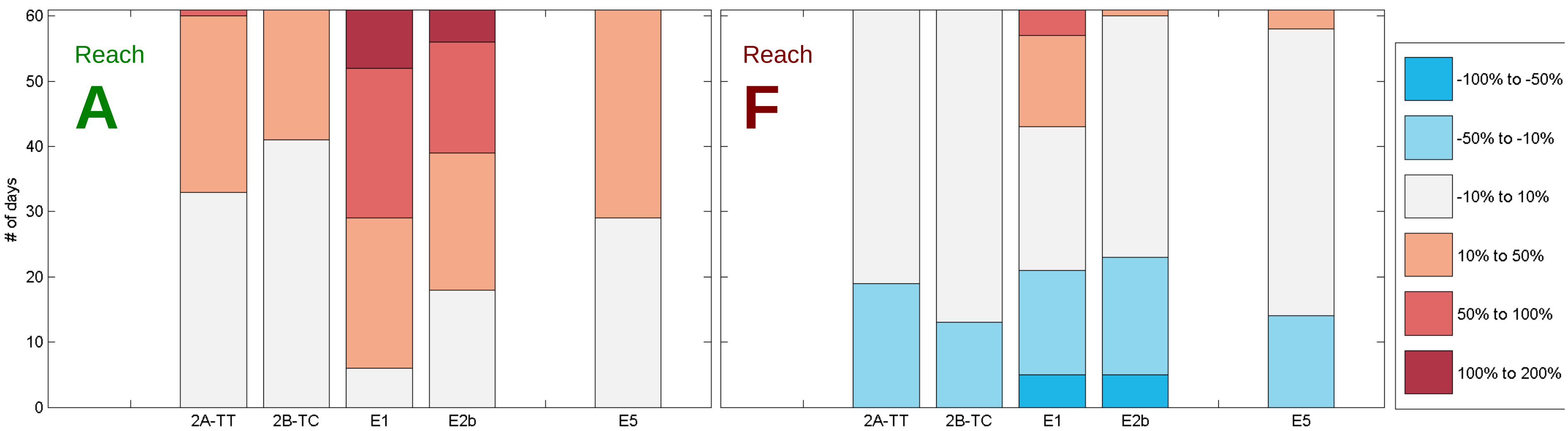


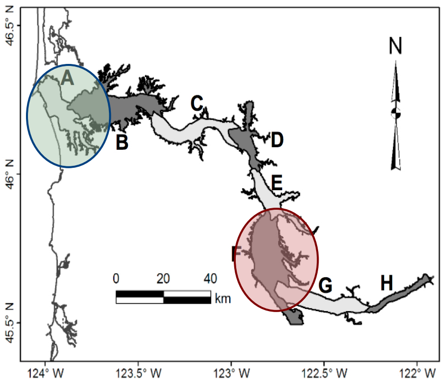
Stock: West Cascade Fall

Source: SELFE

$(SHO_{sce}-SHO_{RC-CC})/SHO_{RC-CC}$

(Reach A vs Reach F, All criteria, May/Jun, Low WY)





Source: SELFE

Results - Sediment Transport

Comparison of Current Condition (RC-CC) vs CRT Scenarios

HIGH FLOW (1997) July 1 – Aug 30

Scenario	Total Reach								Navigation Channel							
	A	B	C	D	E	F	G	H	A	B	C	D	E	F	G	H
2A-TC	0.5	0.7	-0.9	0.5	0.4	2.0	-0.8	0.4	0.2	0.4	0.5	0.5	0.4	0.4	0.5	0.5
2A-TT	0.4	0.6	-0.4	0.4	0.5	-1.0	17.8	2.8	0.2	0.3	0.4	0.4	0.5	0.2	0.4	0.5
2B-TC	In-Progress															
2E1 norm hydro	0.6	0.9	4.9	1.1	1.1	-1.0	103	0.1	0.9	1.8	0.8	1.4	1.1	1.0	1.4	0.5
2E2b norm res	0.5	0.8	0.7	0.7	0.8	2.5	0	0.9	0.3	0.4	0.6	0.9	0.7	0.7	0.9	0.6
2E5 dry year	In-Progress															

Alt/Comp **EROSION** is MUCH HIGHER than RC-CC (>=50%)

Alt/Comp **EROSION** is HIGHER than RC-CC (> 30% & <50%)

Alt/Comp **EROSION** is LESS than RC-CC

Alt/Comp **DEPOSITION** is MUCH HIGHER than RC-CC (>=50%)

Alt/Comp **DEPOSITION** is HIGHER than RC-CC (> 30% & <50%)

Alt/Comp **DEPOSITION** is LESS than RC-CC

+ Alternative/Component MORE erosion/deposition than RC-CC
- Alternative/Component LESS erosion/deposition than RC-CC

Support slides (3rd tier)

Topic	Slides
Statistical significance	41 - 42
Salinity is a good proxy for hypoxia and acidification	43
Plume volumes and SAR	44
Historical discharges (The Dalles)	45
Hydrograph changes (Bonneville) for alternatives and components	46 - 52
Circulation modeling	53-55
Grid for sediment transport modeling	56

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SIL: Statistical significance of differences

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	Low														

** Based on percentiles for SIL POR - High (95%), Medium (50%), Low (5%)

<u>Alternative/Component SIL is</u>:

- Significantly GREATER than RC-CC (strong stat diff)
- Greater than RC-CC (weak stat diff)
- Greater than RC-CC (no stat diff)
- No different than RC-CC
- Significantly SMALLER than RC-CC (strong stat diff)
- Smaller than RC-CC (weak stat diff)
- Smaller than RC-CC (no stat diff)

PV: Statistical significance of differences

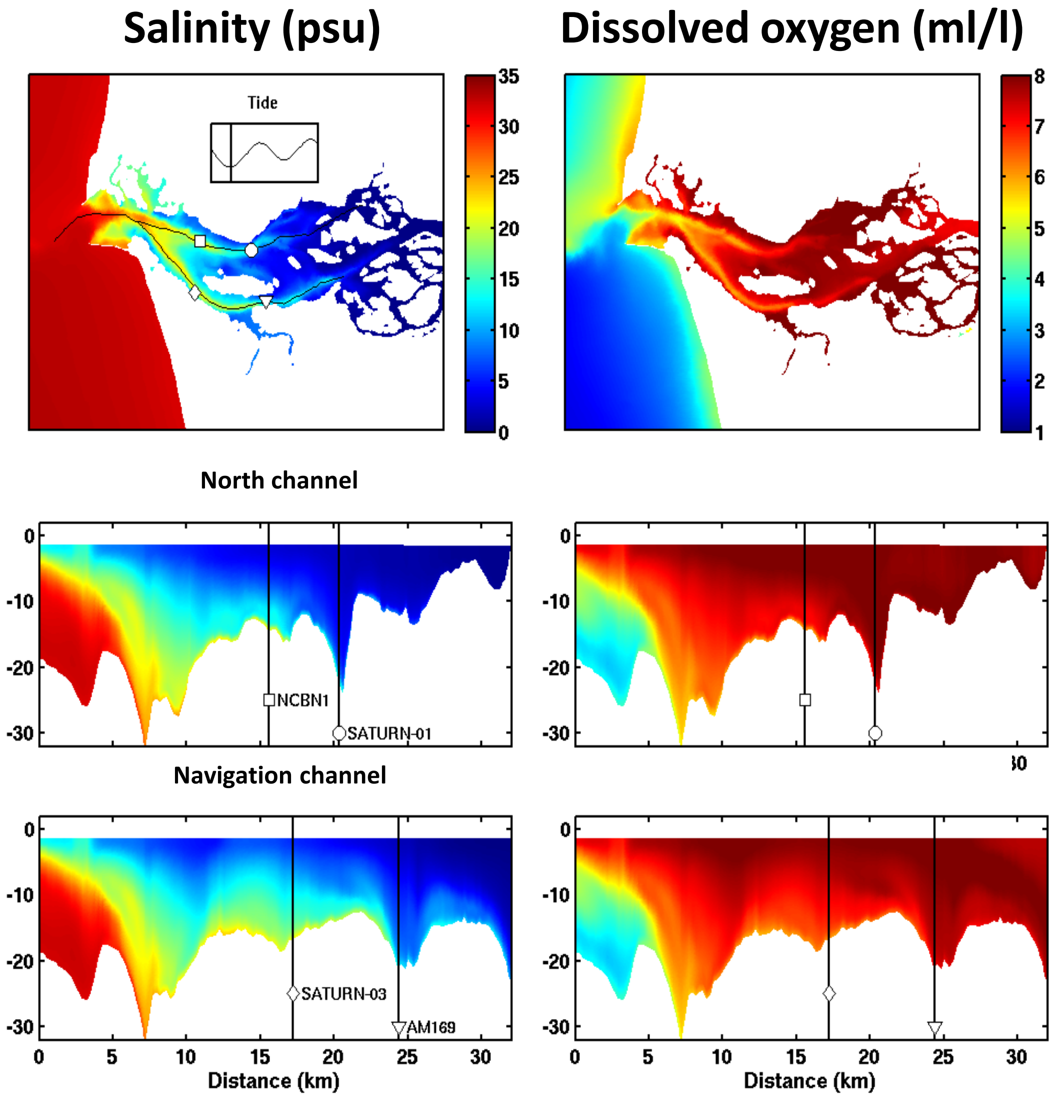
	Plume Volume**	OCT	NOV	DEC	JAN	FEB	MAR	APR 1-15	APR 16-30	MAY	JUN	JUL	AUG 1-15	AUG 16-30	SEP
Plume Volume (PV) differences between RC-CC and Iteration 2 alternatives															
2A-TC (450)	High														
	Medium														
	Low														
2A-TT (450)	High														
	Medium														
	Low														
2B - TC (600)	High														
	Medium														
	Low														
Plume Volume (PV) differences between RC-CC and Iteration 2 components															
E1 - normative hydrograph	High														
	Medium														
	Low														
E2b - normative reservoir levels	High														
	Medium														
	Low														
2E3 - improve summer fish migration	High														
	Medium														
	Low														
E5 - dry year strategy	High														
	Medium														
	Low														

** Based on percentiles for Plume Volume POR - High (95%), Medium (50%, Low (5%)

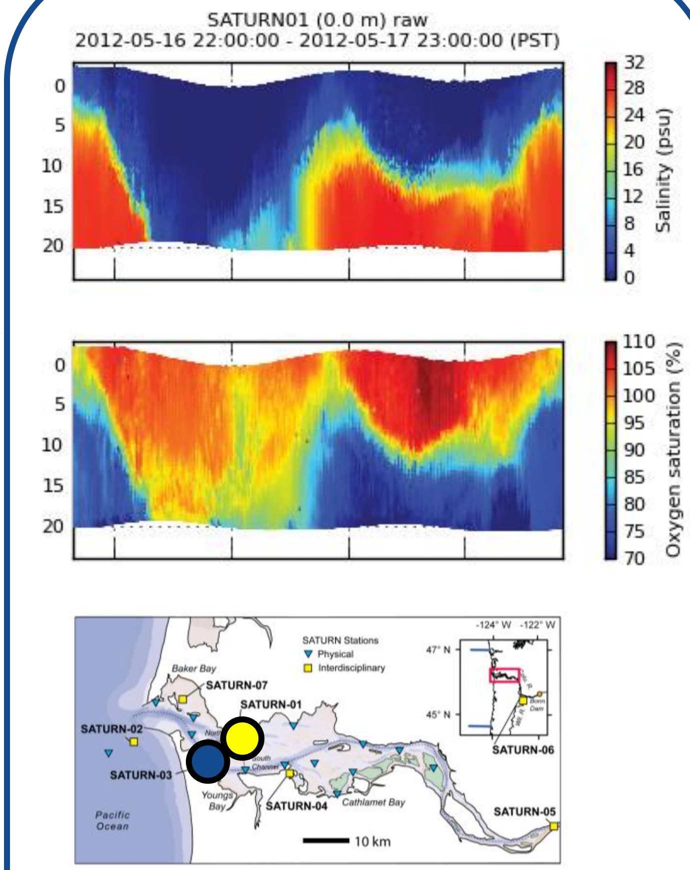
<u>Alternative/Component PV is</u>:

- Significantly SMALLER than RC-CC (strong stat diff)
- Smaller than RC-CC (weak stat diff)
- Smaller than RC-CC (no stat diff)
- No different than RC-CC
- Significantly LARGER than RC-CC (strong stat diff)
- Larger than RC-CC (weak stat diff)
- Larger than RC-CC (no stat diff)

Columbia River Treaty 2014/2024 Review



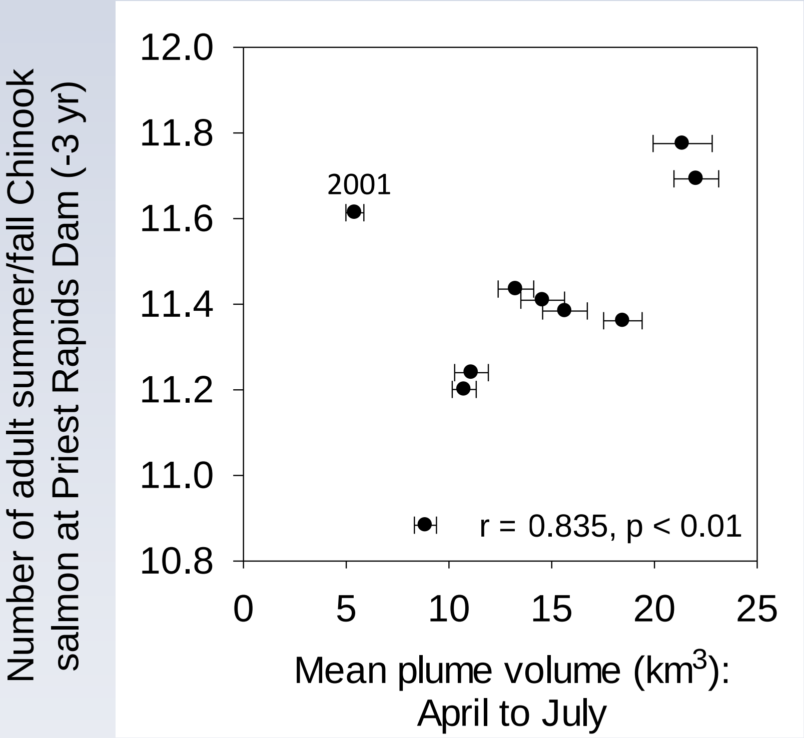
Simulation - August 28, 2010



Observation - May 16, 2012

Columbia River Treaty 2014/2024 Review

What we know: Large plumes at time of ocean entry appear to correlate to larger SAR for specific stocks. Larger plumes are associated with larger river discharges, for similar ocean conditions



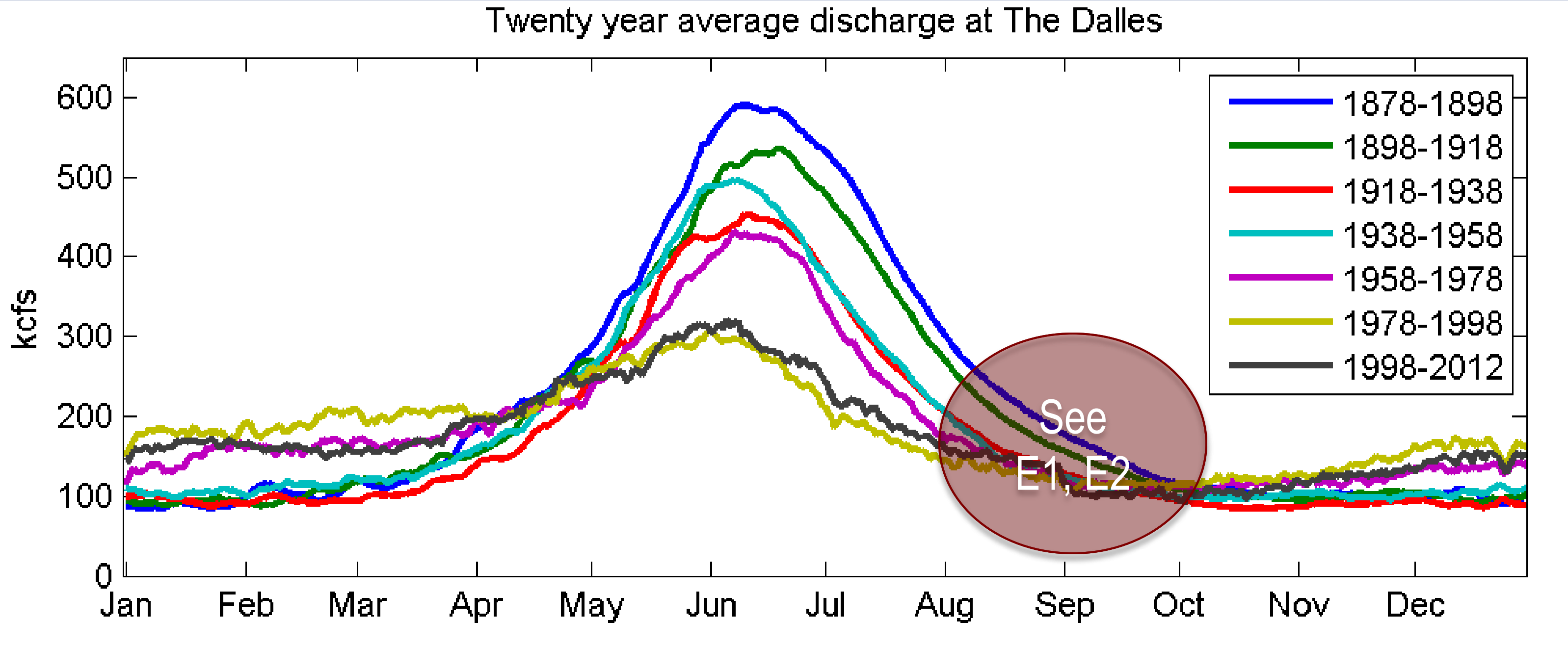
Note: Low-flow 2001 not included in the correlation analysis

Miller J, Teel D, Baptista A., Morgan, C.A. in press. *Bottom-up and top-down influences during a critical period in the life history of an anadromous fish. Canadian Journal of Fisheries & Aquatic Sciences*

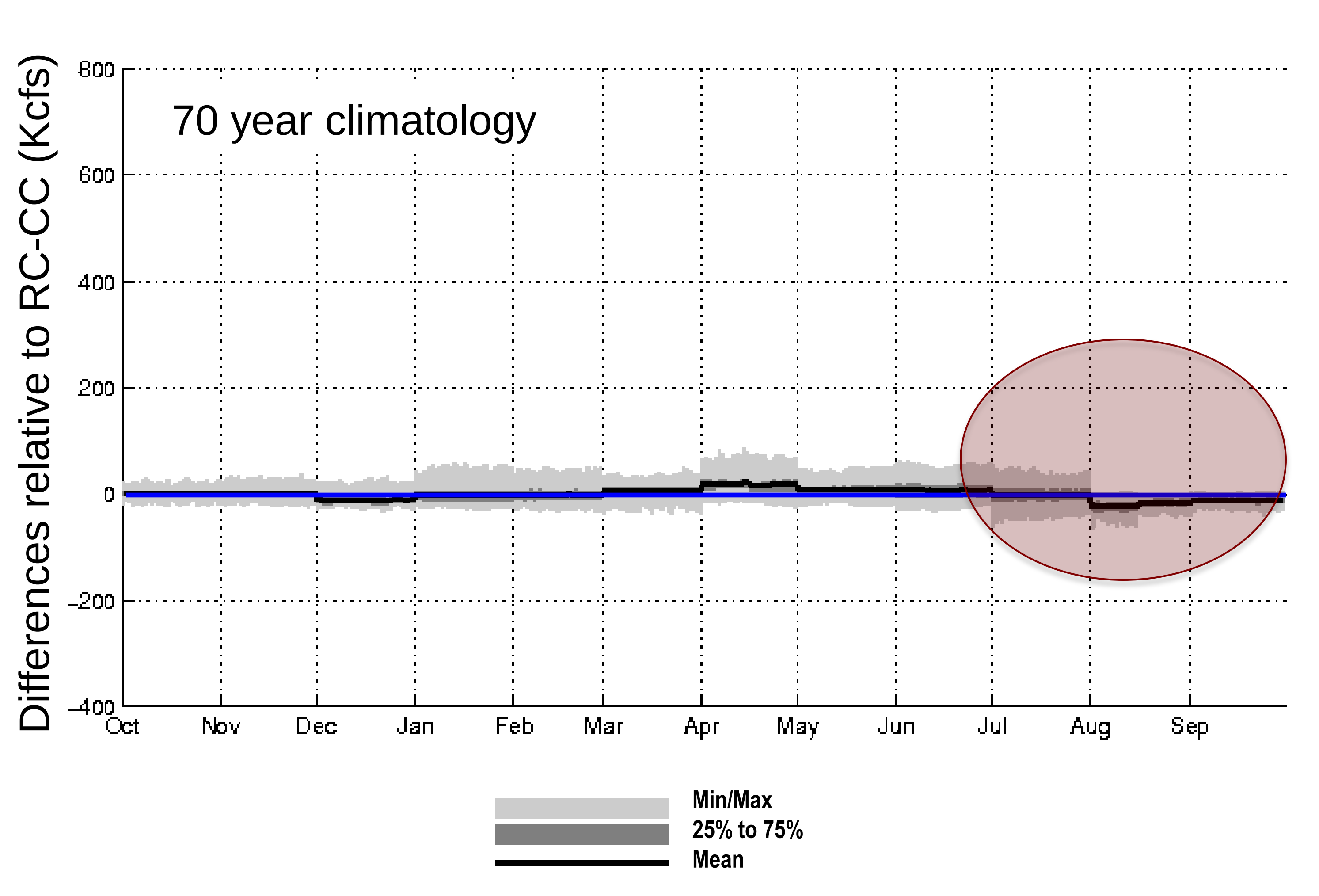
Also: *Burla M, Baptista A, Casillas E, Williams JG, Marsh DM. 2010. The influence of the Columbia River plume on the survival of steelhead (Oncorhynchus mykiss) and Chinook salmon (*Oncorhynchus tshawytscha*): a numerical exploration. Canadian Journal of Fisheries & Aquatic Sciences. 67(10):1671-1684*

Historical discharges

- River discharges have been drastically changed over the last ~1.5 centuries
- Freshet magnitudes and duration have decreased and winter discharges have increased

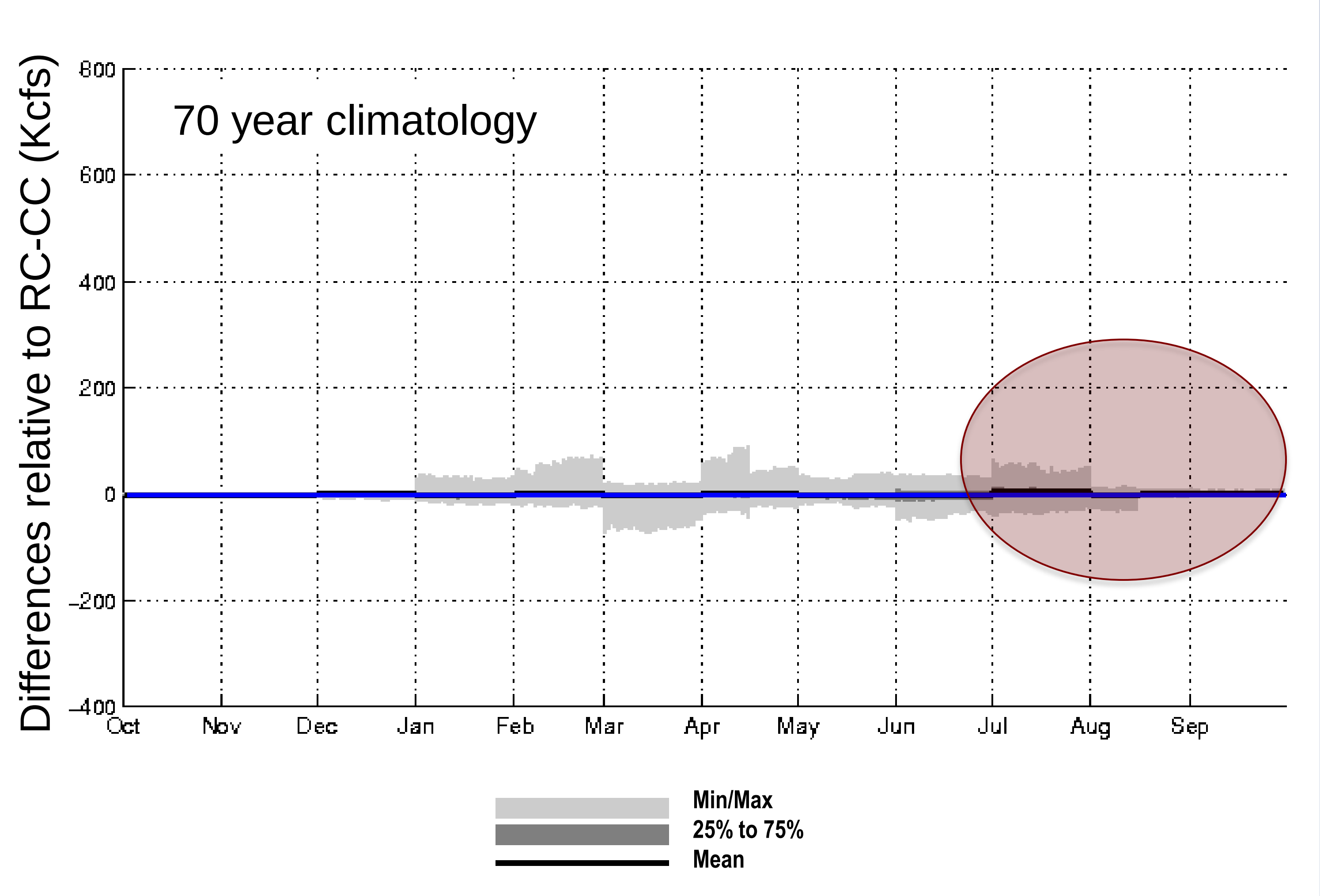


2A-TT: Hydrograph Changes at Bonneville



2A-TT
2A-TC
2B-TC
E1
E2b
E3
E5

2A-TC: Hydrograph Changes at Bonneville



2A-TT

2A-TC

2B-TC

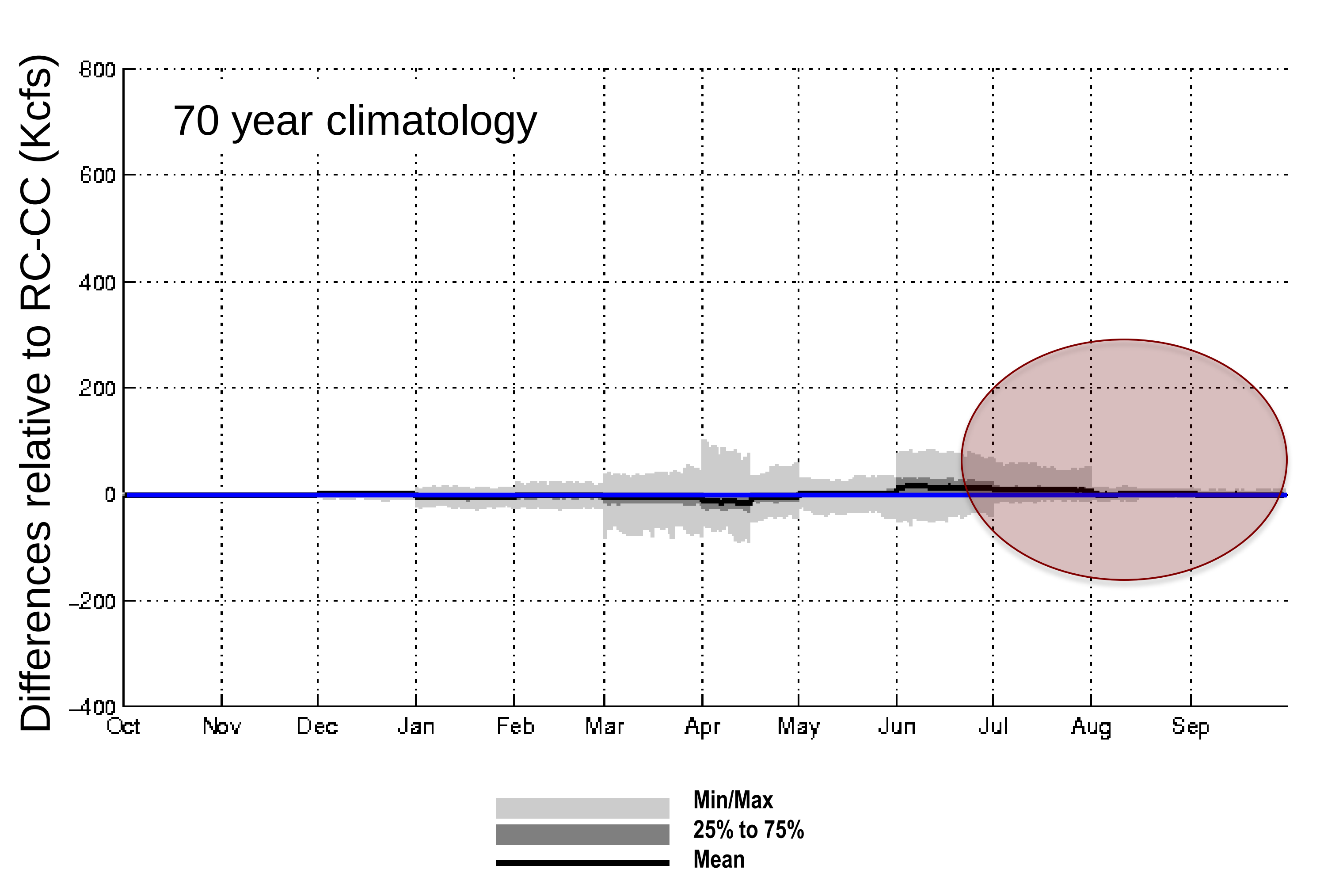
E1

E2b

E3

E5

2B-TC: Hydrograph Changes at Bonneville



2A-TT

2A-TC

2B-TC

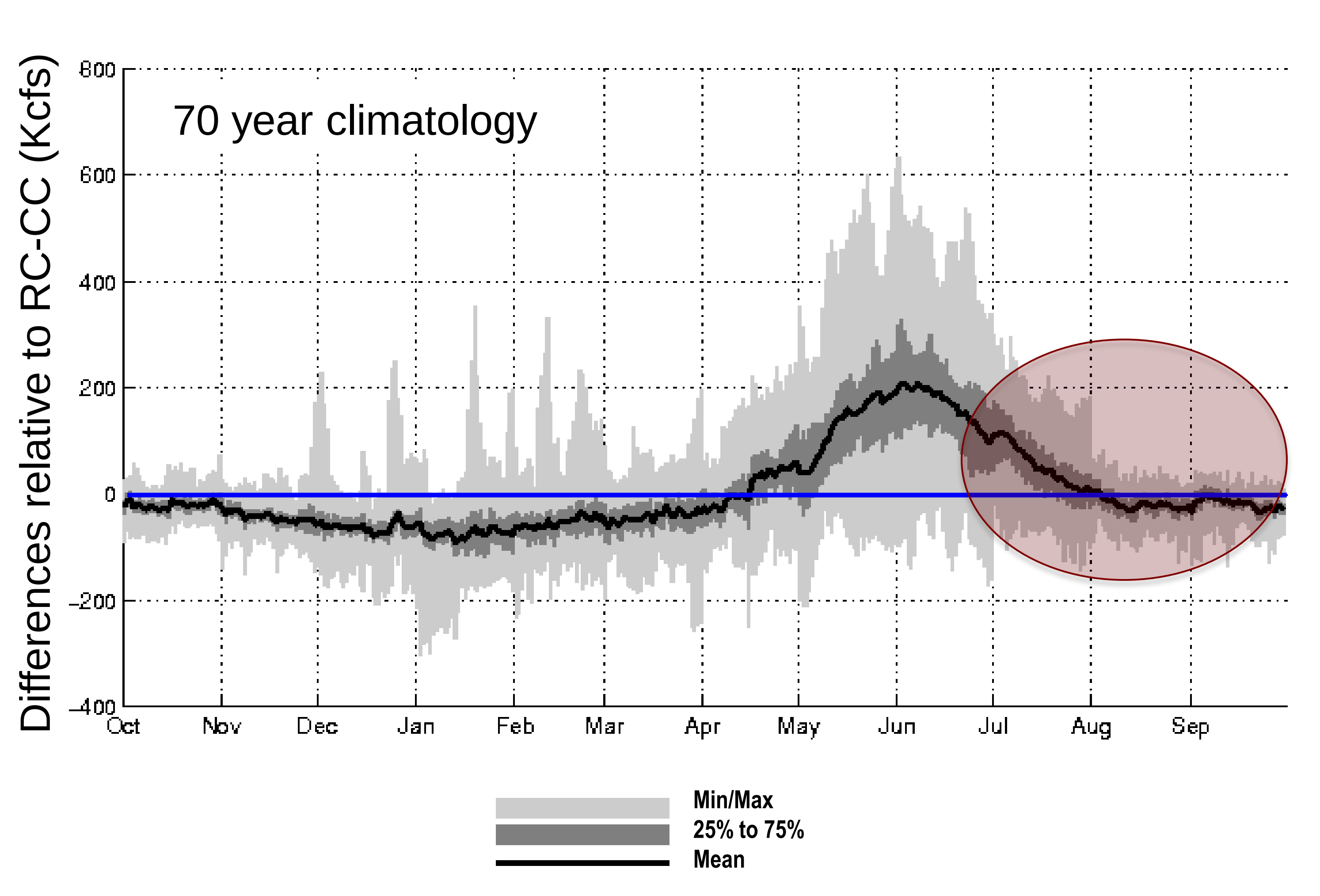
E1

E2b

E3

E5

E1: Hydrograph Changes at Bonneville



2A-TT

2A-TC

2B-TC

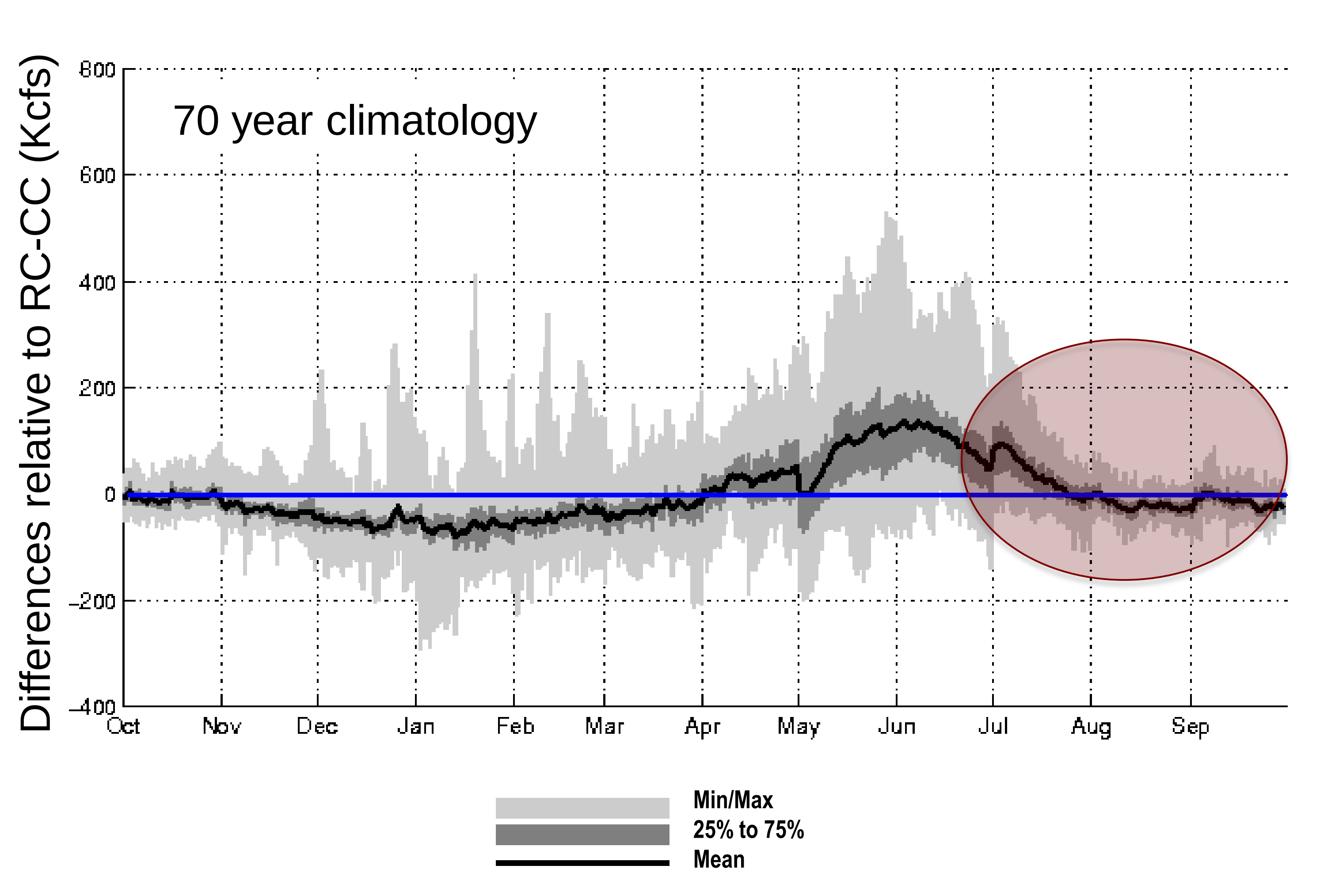
E1

E2b

E3

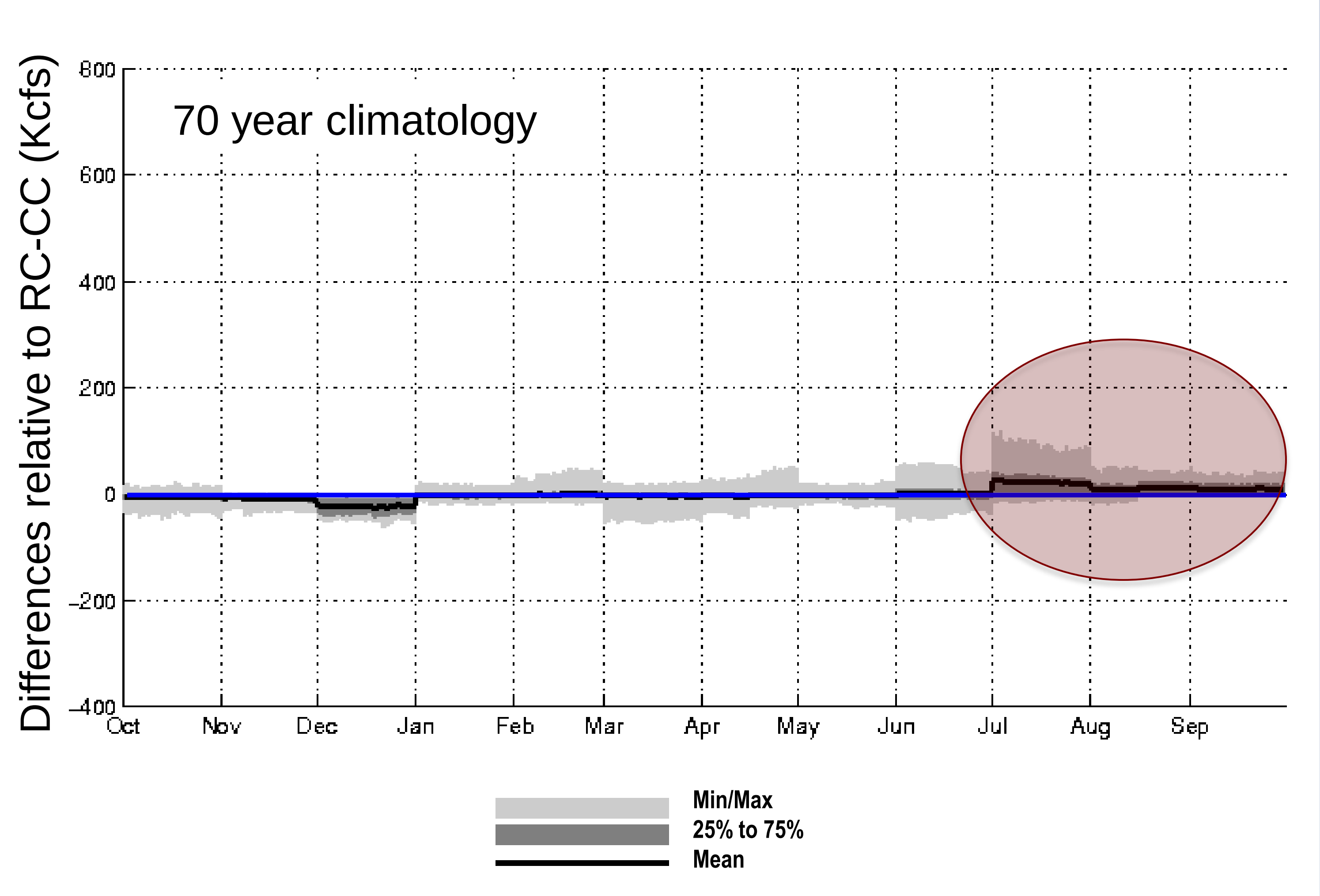
E5

E2b: Hydrograph Changes at Bonneville



2A-TT
2A-TC
2B-TC
E1
E2b
E3
E5

E3: Hydrograph Changes at Bonneville



2A-TT

2A-TC

2B-TC

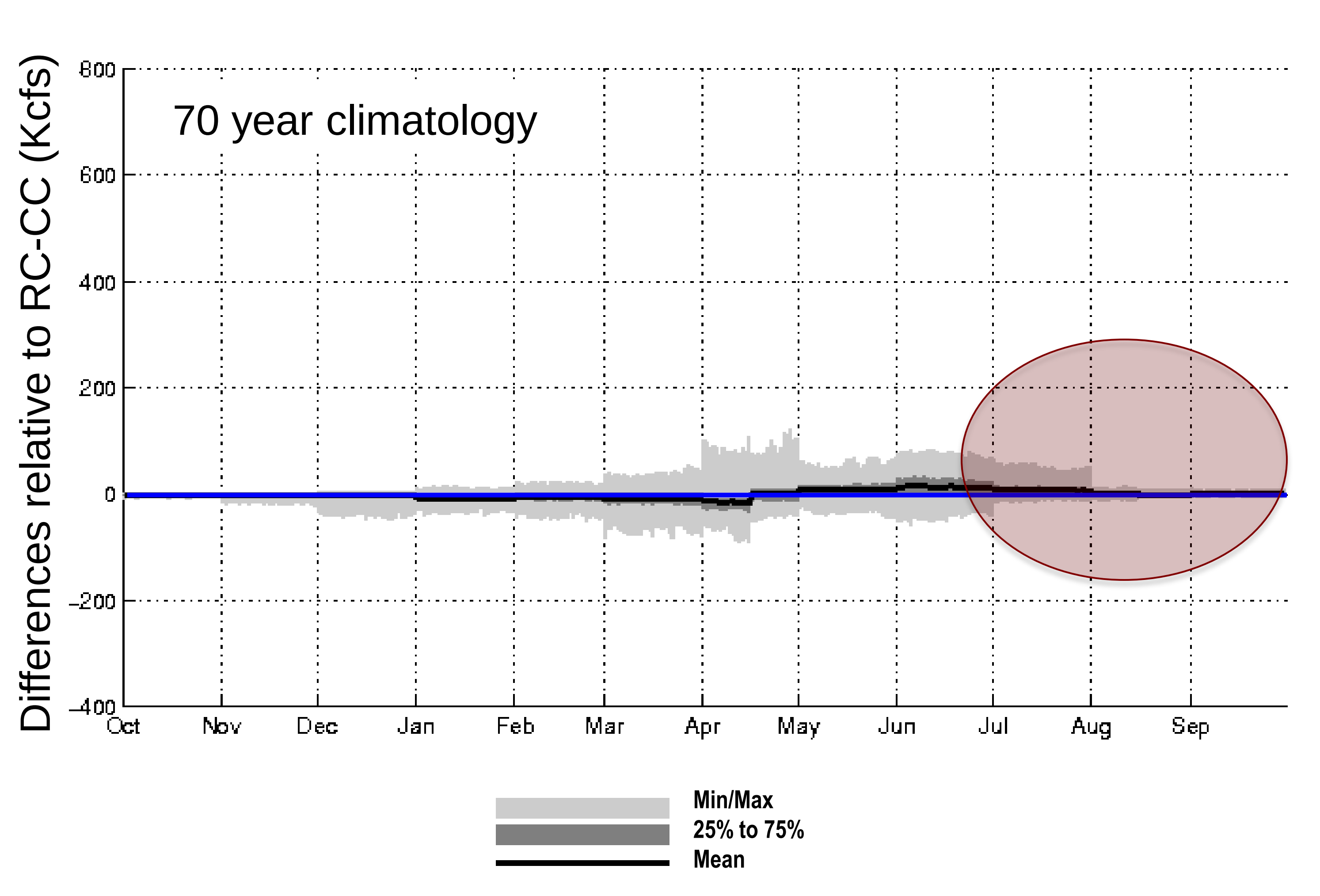
E1

E2b

E3

E5

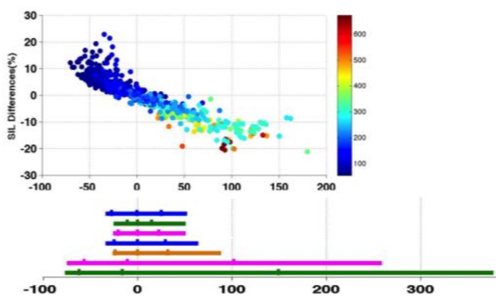
E5: Hydrograph Changes at Bonneville



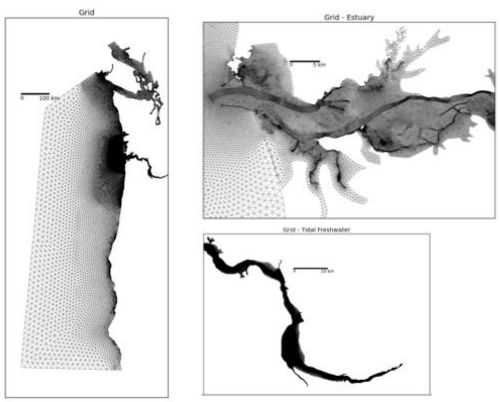
2A-TT
2A-TC
2B-TC
E1
E2b
E3
E5

Overview of Circulation Modeling

- 70 years
- Selected metrics



Metrics



- Selected periods
- All metrics

Correlation analysis

- Based on our prior CR knowledge and on correlations built from limited SELFE simulations
- Offers 1st order screening /predictive capability
- **Trivially fast**
- **Trivial storage requirements**

Circulation simulations

- Use the SELFE 3D circulation model
- High-resolution in space and time
- **Computationally very expensive** (~2 weeks per year and scenario)
- **High storage requirements** (2.6-5.7TB per year & scenario)

Overview of Circulation Modeling

- SELFE inputs
  - Bathymetry
  - **Bonneville Dam discharges (Q_{Bon})** and temperatures*
  - Willamette Falls discharges and temperatures
  - Ocean tides
  - Coastal winds
  - Ocean salinity and temperature
- SELFE outputs
  - Water levels (depths), salinity, temperature, velocity
  - After filtering: SIL, PV, SHO, SWH
  - Also: levels and fluxes for Delft3D

Overview of Circulation Modeling

- Inputs for correlation analysis
  - Target metric from SELFE (current options: SIL, SHO)
  - **Bonneville Dam discharges (Q_{bon})**
  - Willamette Falls discharges
  - Ocean tides
  - Coastal winds
- Outputs of correlation analysis
  - Time series of the metric for WY 1929-1998
  - Skill of correlation

DELFT3D Model Grid