Comparing Modeled Temperature Response

Peter Leinenbach, R10 USEPA

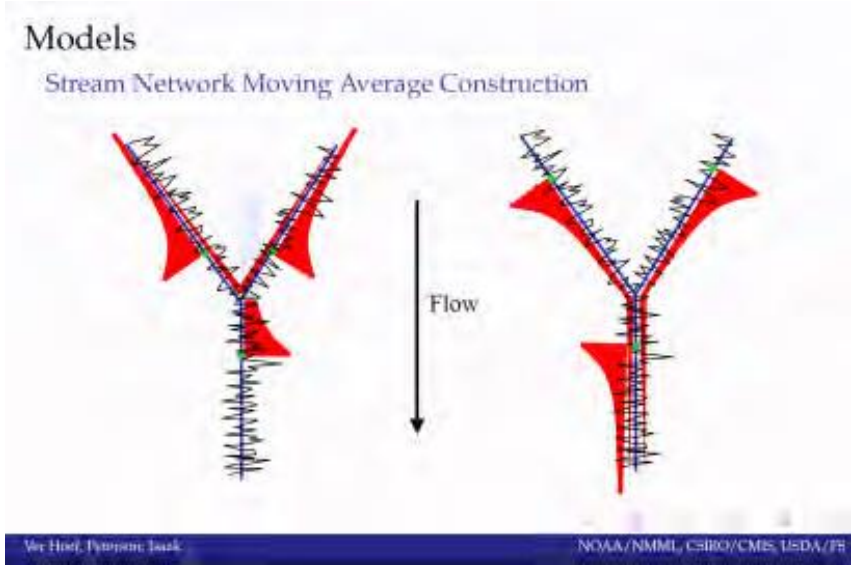
November 4, 2019

1. Middle Fork John Day Basin TMDL (2010)
HeatSource (ODEQ)

2. Wind River Basin TMDL (2001)
Qual2k (USEPA/Tuffs University)

3. South Fork Nooksack Basin TMDL (Present)
Qual2kw (Washington Ecology)

Vs.



Mechanistic Models

SSN Model

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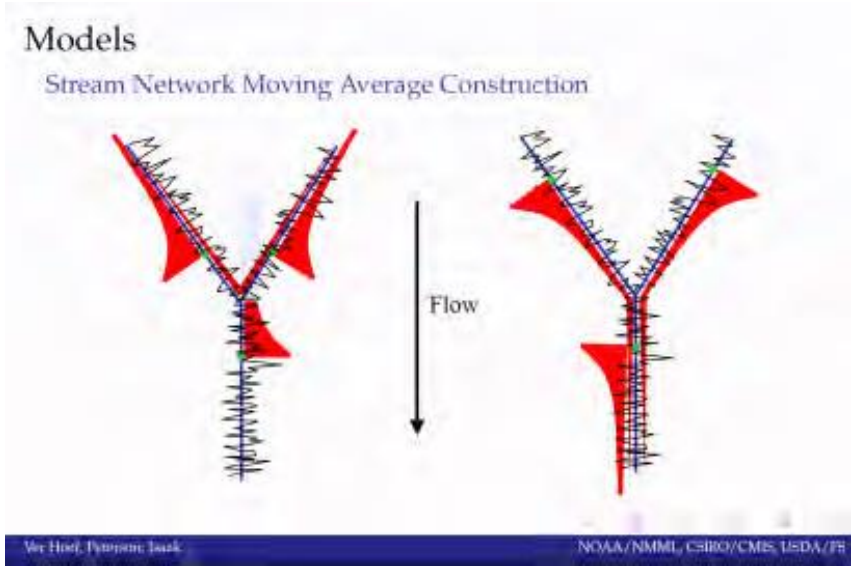

Mechanistic Models

SSN Model

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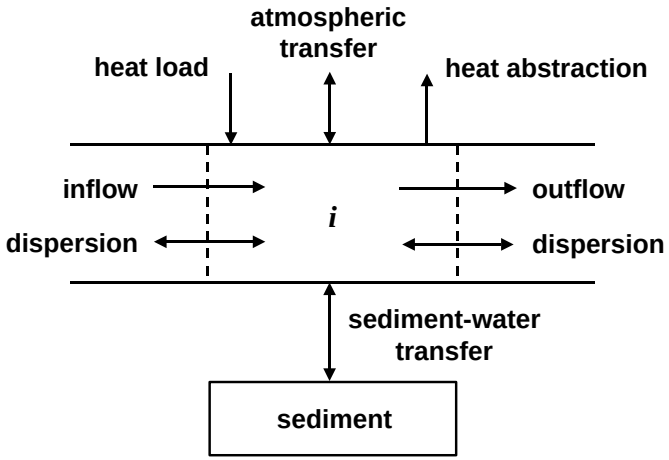
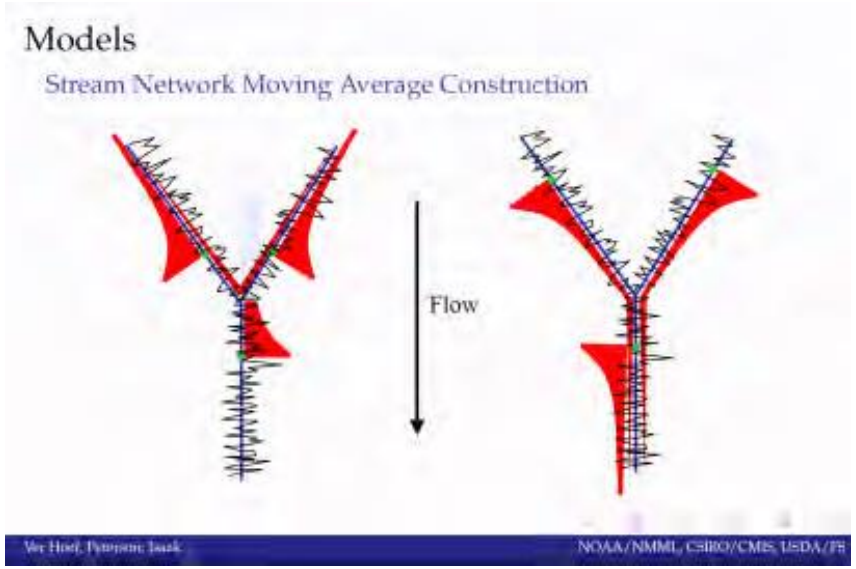


$$\frac{dT_i}{dt} = \frac{Q_{i-1}}{V_i}T_{i-1} - \frac{Q_i}{V_i}T_i - \frac{Q_{ab,i}}{V_i}T_i + \frac{E'_{i-1}}{V_i}(T_{i-1} - T_i) + \frac{E'_i}{V_i}(T_{i+1} - T_i)$$

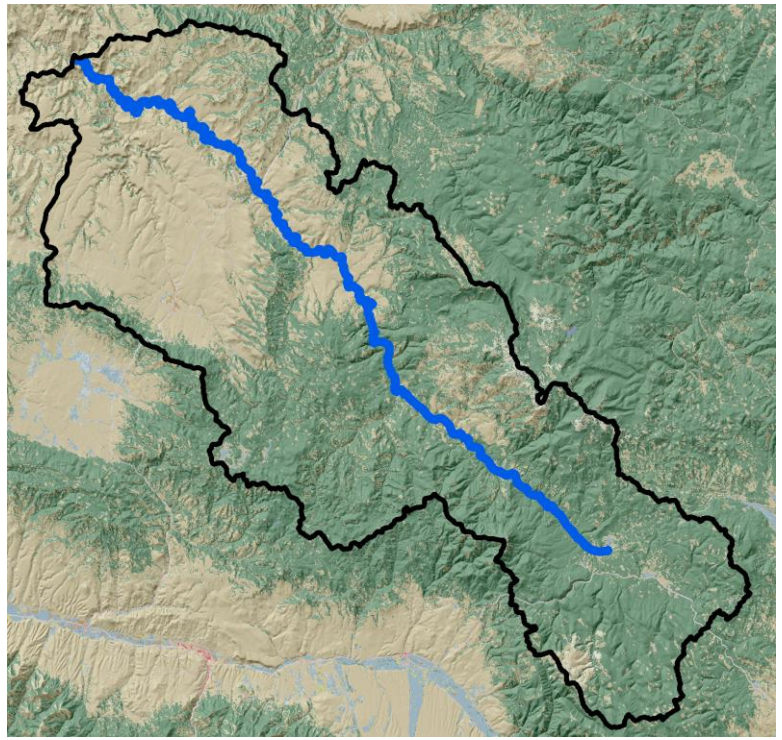
$$+ \frac{W_{h,i}}{\rho_w C_{pw} V_i}\left(\frac{\mathrm{m}^3}{10^6\ \mathrm{cm}^3}\right) + \frac{J_{h,i}}{\rho_w C_{pw} H_i}\left(\frac{\mathrm{m}}{100\ \mathrm{cm}}\right) + \frac{J_{s,i}}{\rho_w C_{pw} H_i}\left(\frac{\mathrm{m}}{100\ \mathrm{cm}}\right)$$

Vs.



Mechanistic Models

SSN Model



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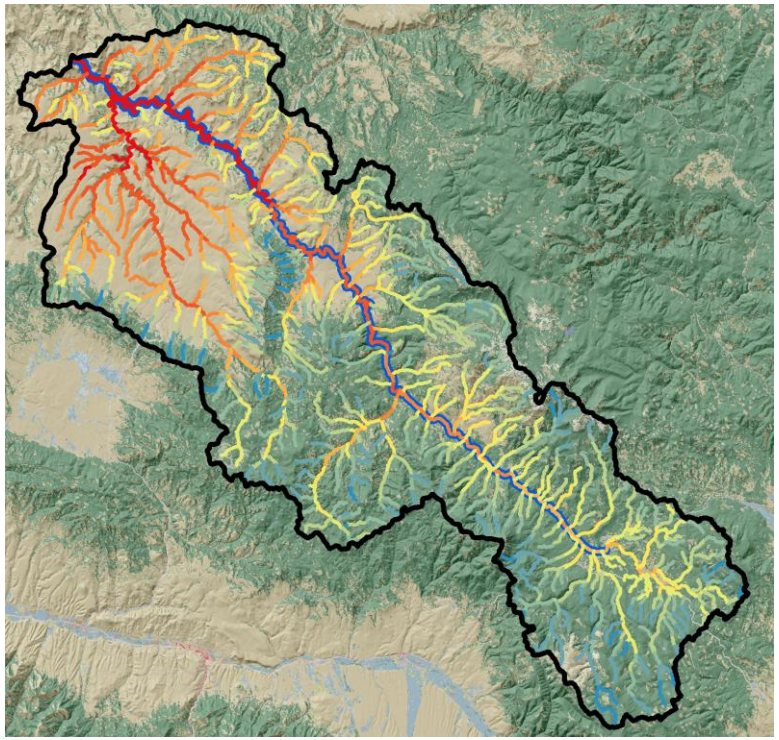


Heat Source Modeling

Simulation Period - May 1 – Oct. 31, 2002

Simulation Extent – 110 KM of the Mainstem

Spatial Resolution – 200m

Time Step – 0.5 minutes

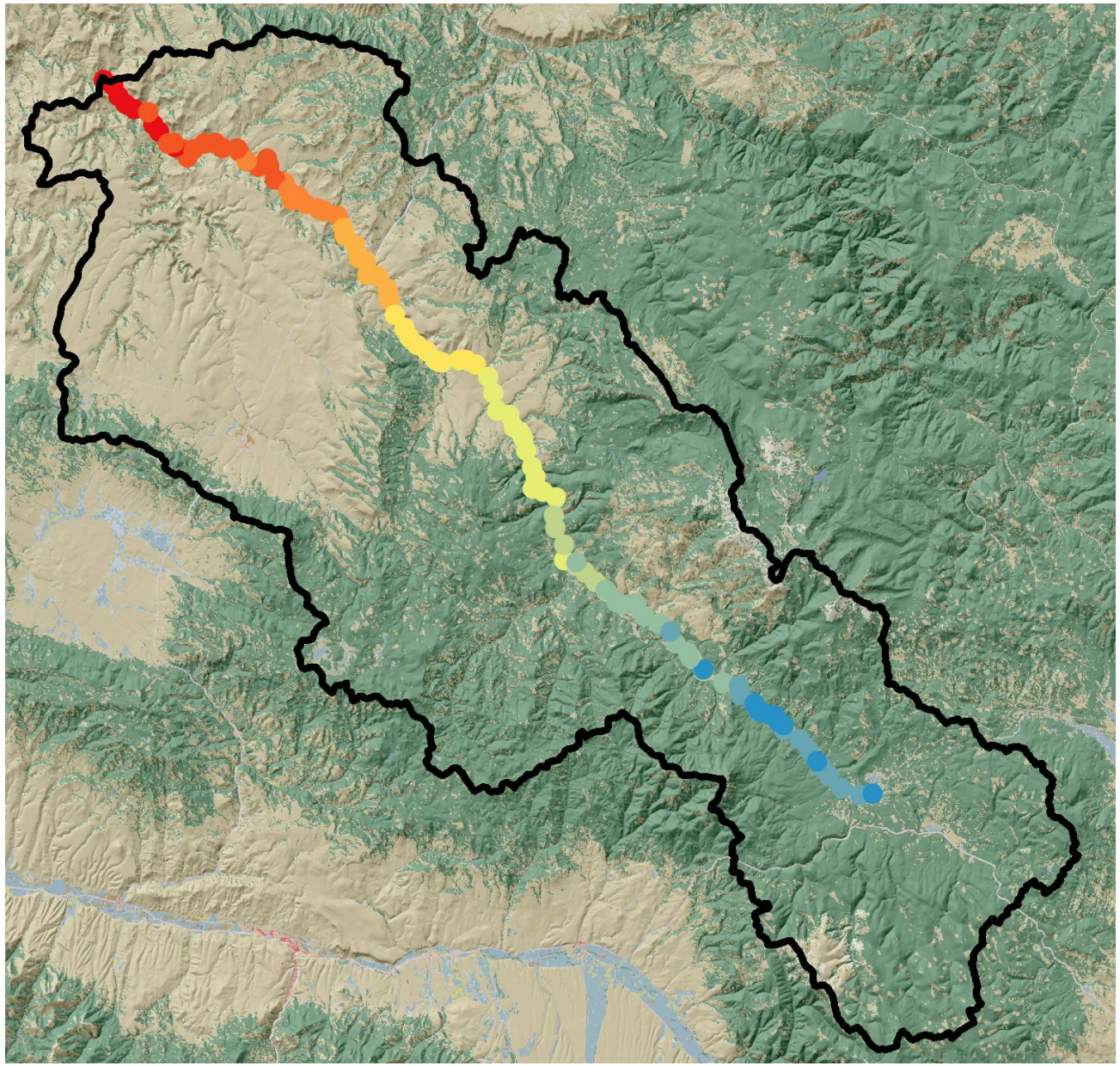
SSN Modeling

Simulation Period – May/Aug/Sept 1990-2015

Simulation Extent – 1:24K Stream Network

Spatial Resolution – ≈ 1 kilometer

Time Step – Monthly



MFJD Model Comparison Reach

- Simulation Extent – 110 KM of the Mainstem

  But Modify Upstream and Tributary Boundary Temperatures

- Spatial Resolution – ≈ 1 kilometer

- Time Step – Monthly & 7DADM (i.e., Weekly)

- Simulation Period – May/Aug/Sept variable years

Middle Fork John Day River Basin

Scenario Description	Time Period	Month	A Current Veg. Shading	B Restored Veg. Shading	C Restored channel width (10-50%)	D Reduced Irrigation H2O use	E Combined Restored Veg/Chan/ Crop Irr
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Scenarios also include the months of May and September

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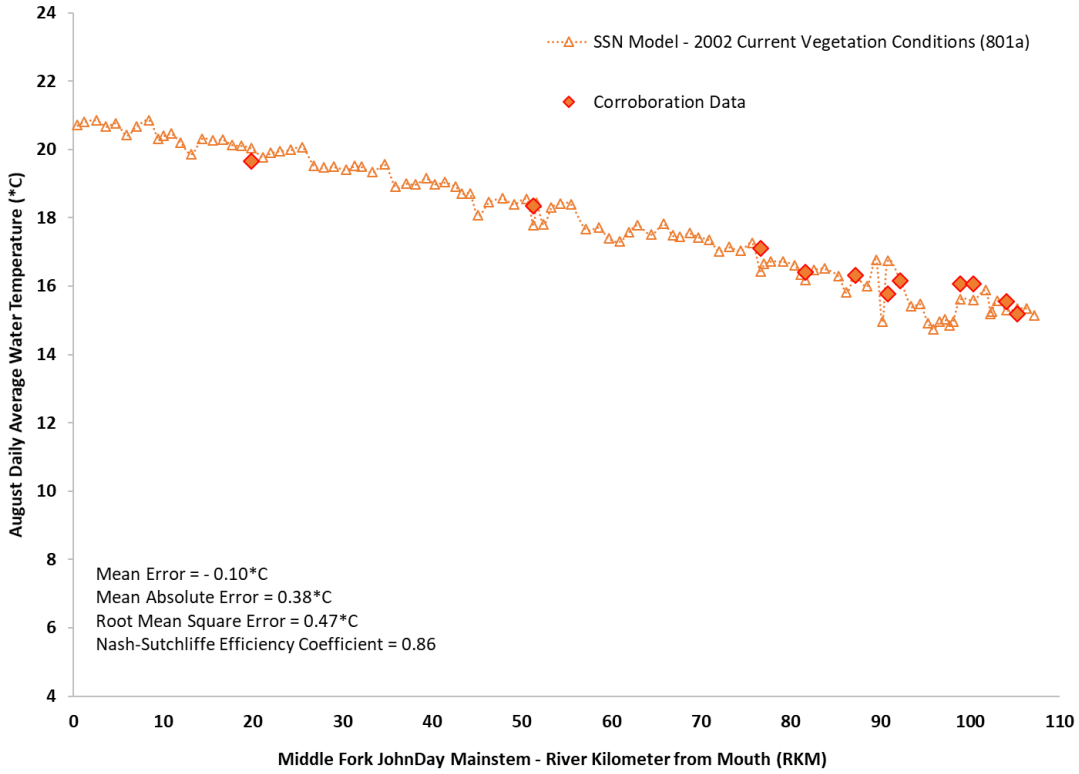
Scenarios also include the months of May and September

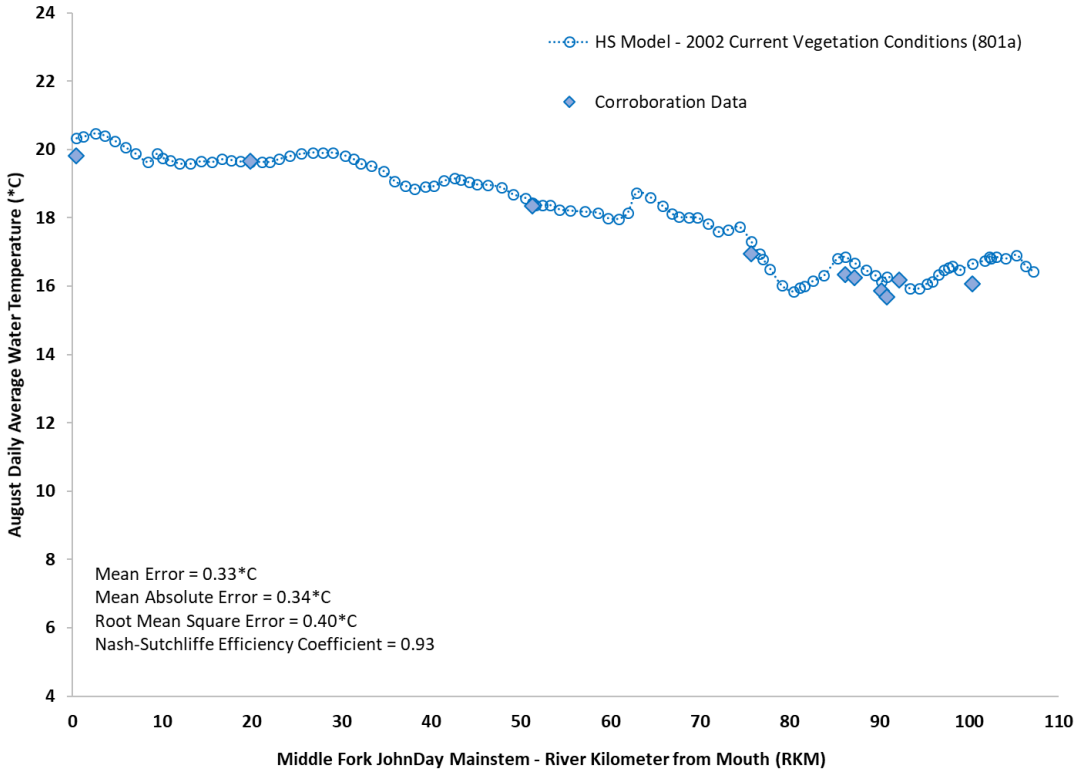
Middle Fork John Day River Basin

		A	B
	Time Period	Current Veg. Shading	Restored Veg. Shading
801	2002	801A	801B
802	1990-2015	802A	802B

Scenarios also include the months of May and September

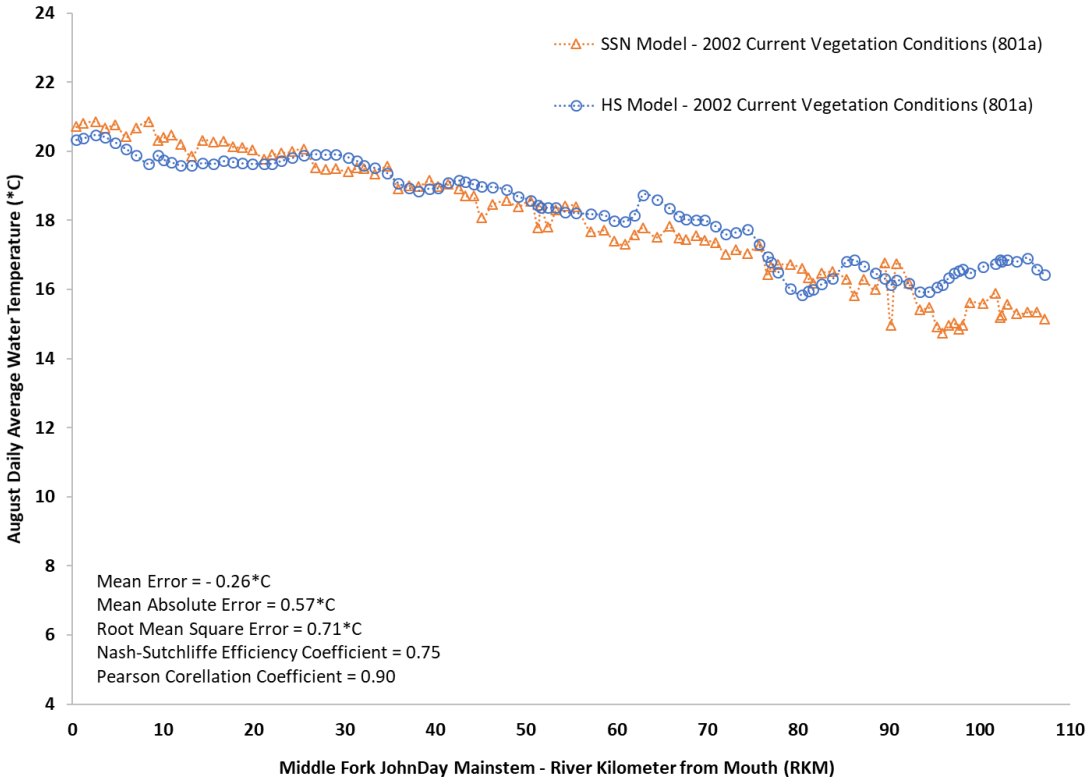
Scenario 801a – August Calibrated “Baseline” Models

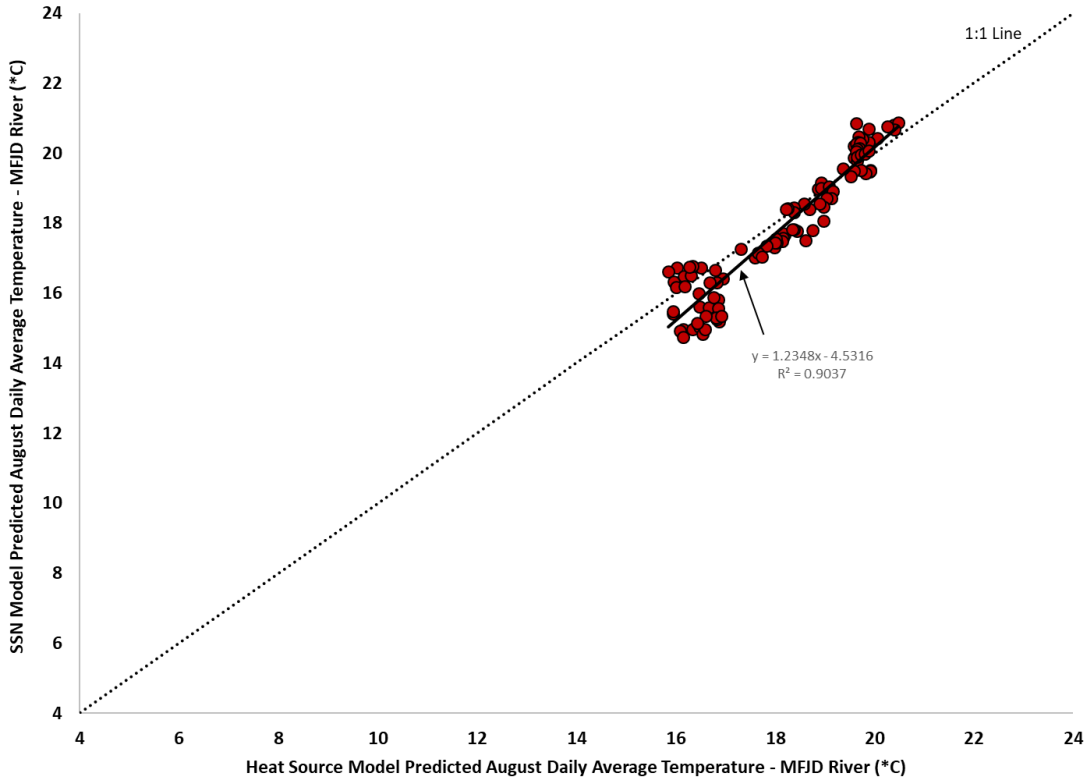




Current Vegetation in the Year 2002 (i.e., Heat Source Model calibrated year)

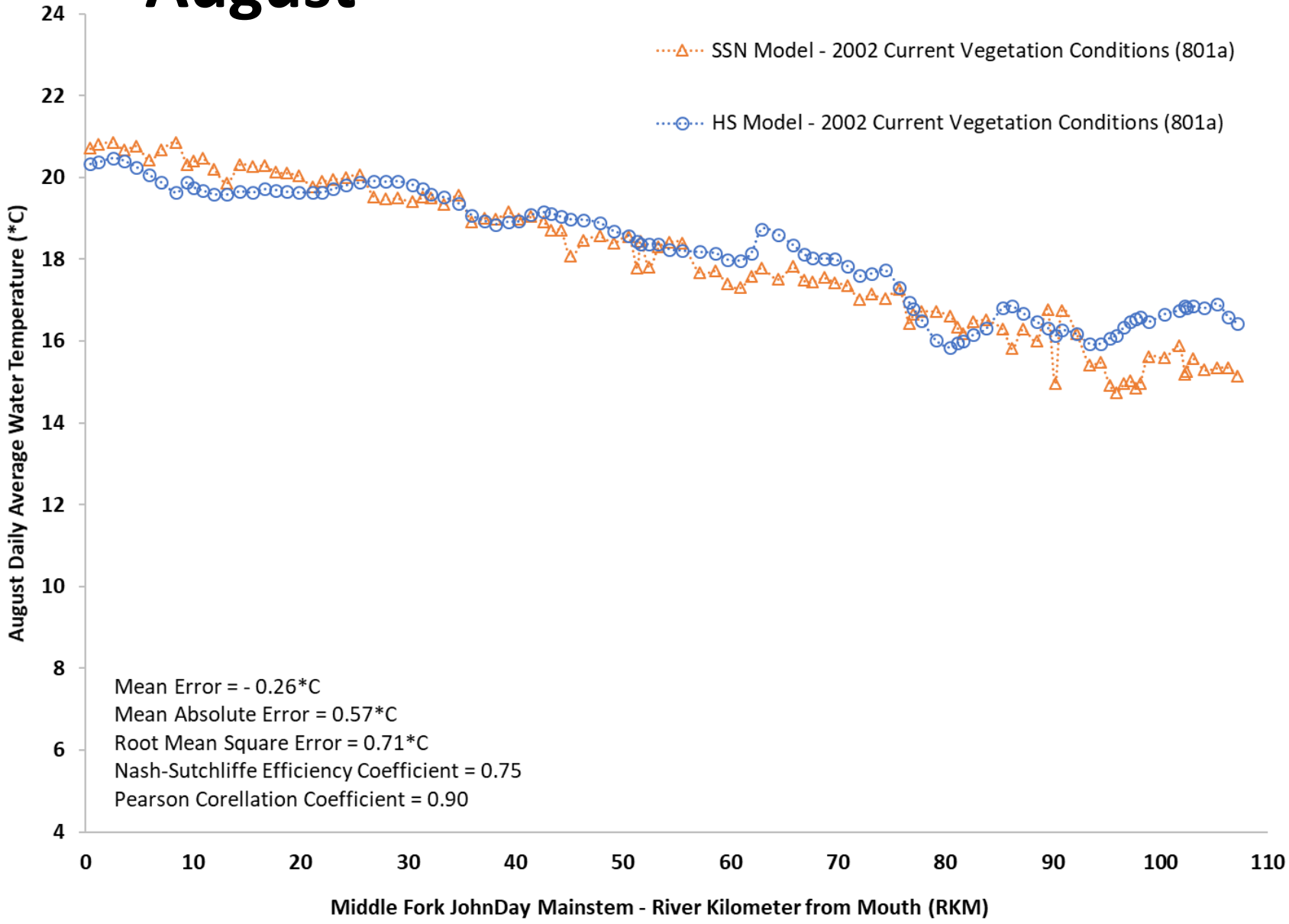
Scenario 801a – August Calibrated “Baseline” Models Comparison





Assuming Mechanistic Model Results Are The “Truth”

August

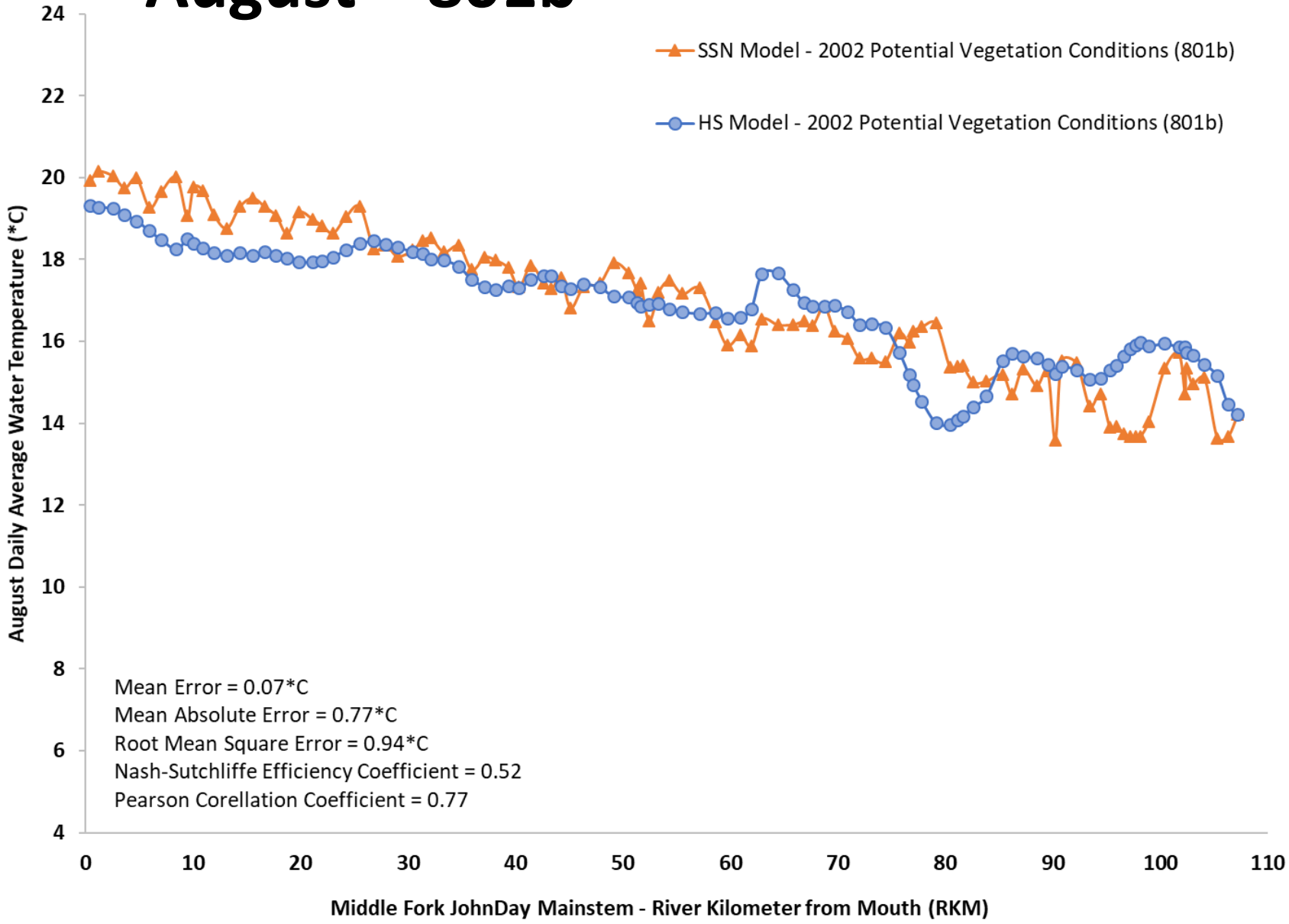


		A	B
	Time Period	Current Veg. Shading	Restored Veg. Shading
801	2002	801A	801B
802	1990-2015	802A	802B

Mechanistic Model Input Changes

None (Calibrated “Baseline” Models)

August – 801b



		A	B
	Time Period	Current Veg. Shading	Restored Veg. Shading
801	2002	801A	801B
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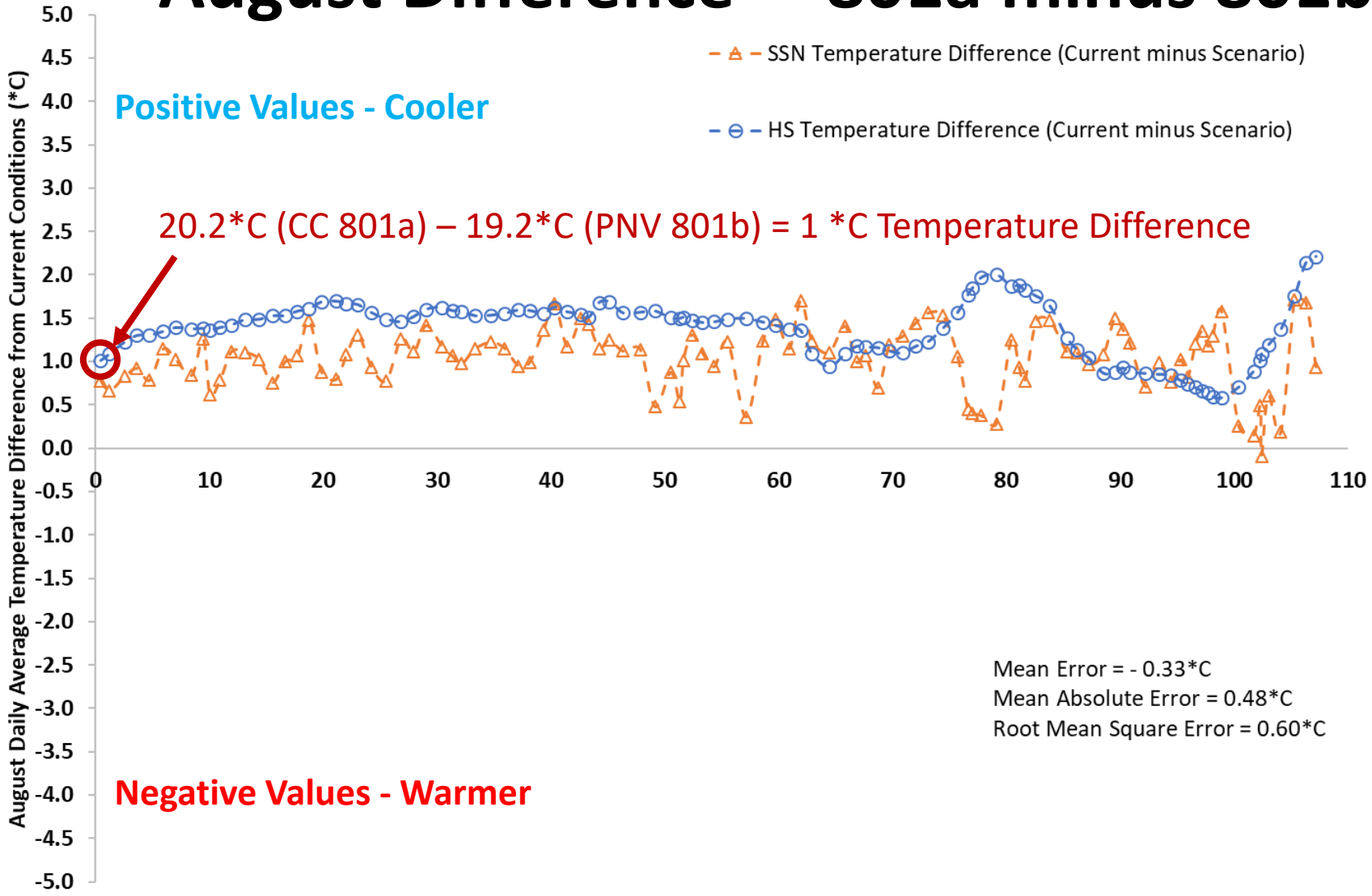
Mechanistic Model Input Changes

August Shade ↑ by 20% (Units)

August Difference – 801a minus 801b



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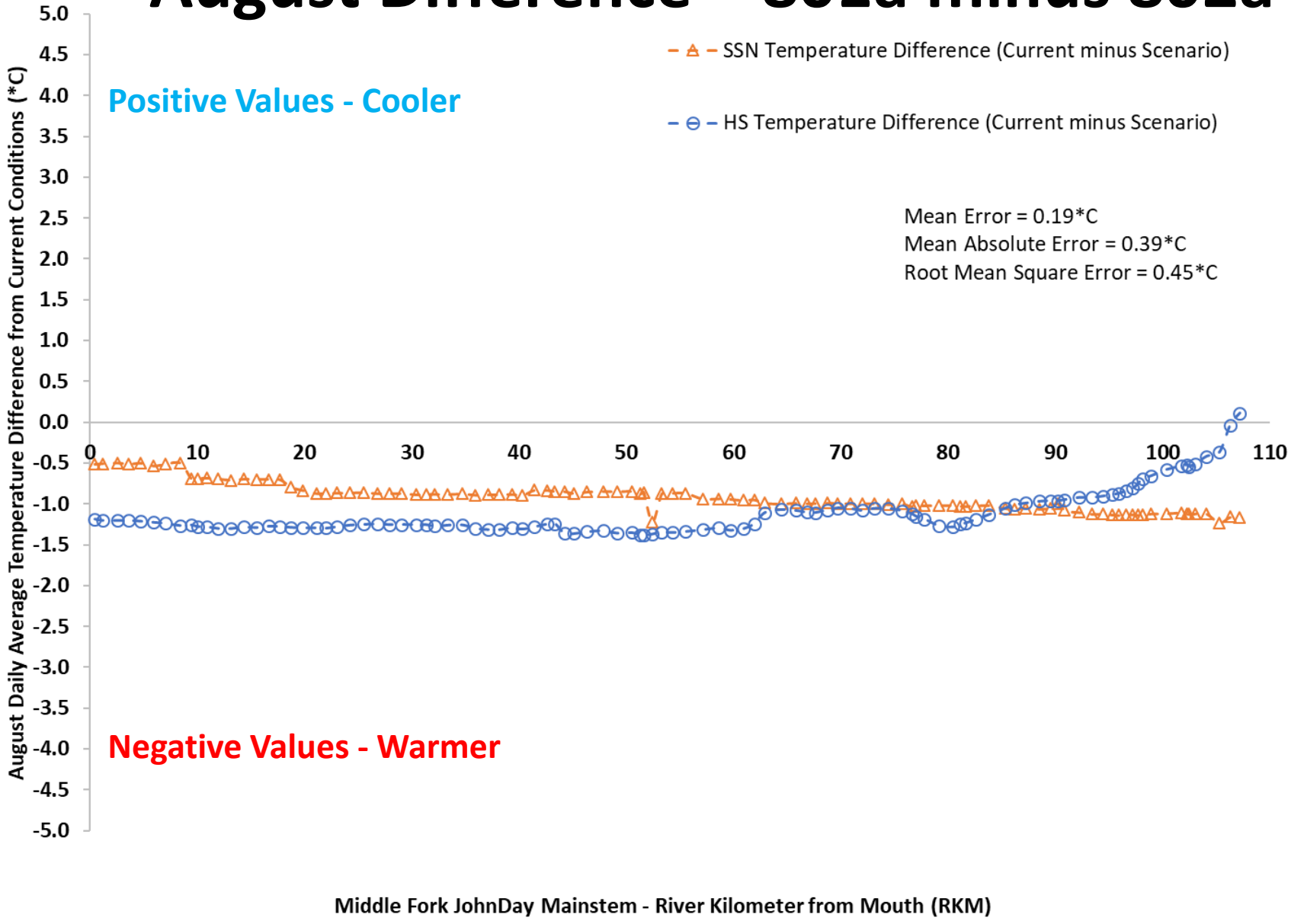
Mechanistic Model Input Changes

August Shade ↑ by 20% (Units)

August Difference – 801a minus 802a



		A	B
	Time Period	Current Veg. Shading	Restored Veg. Shading
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802	1990-2015	802A	802B

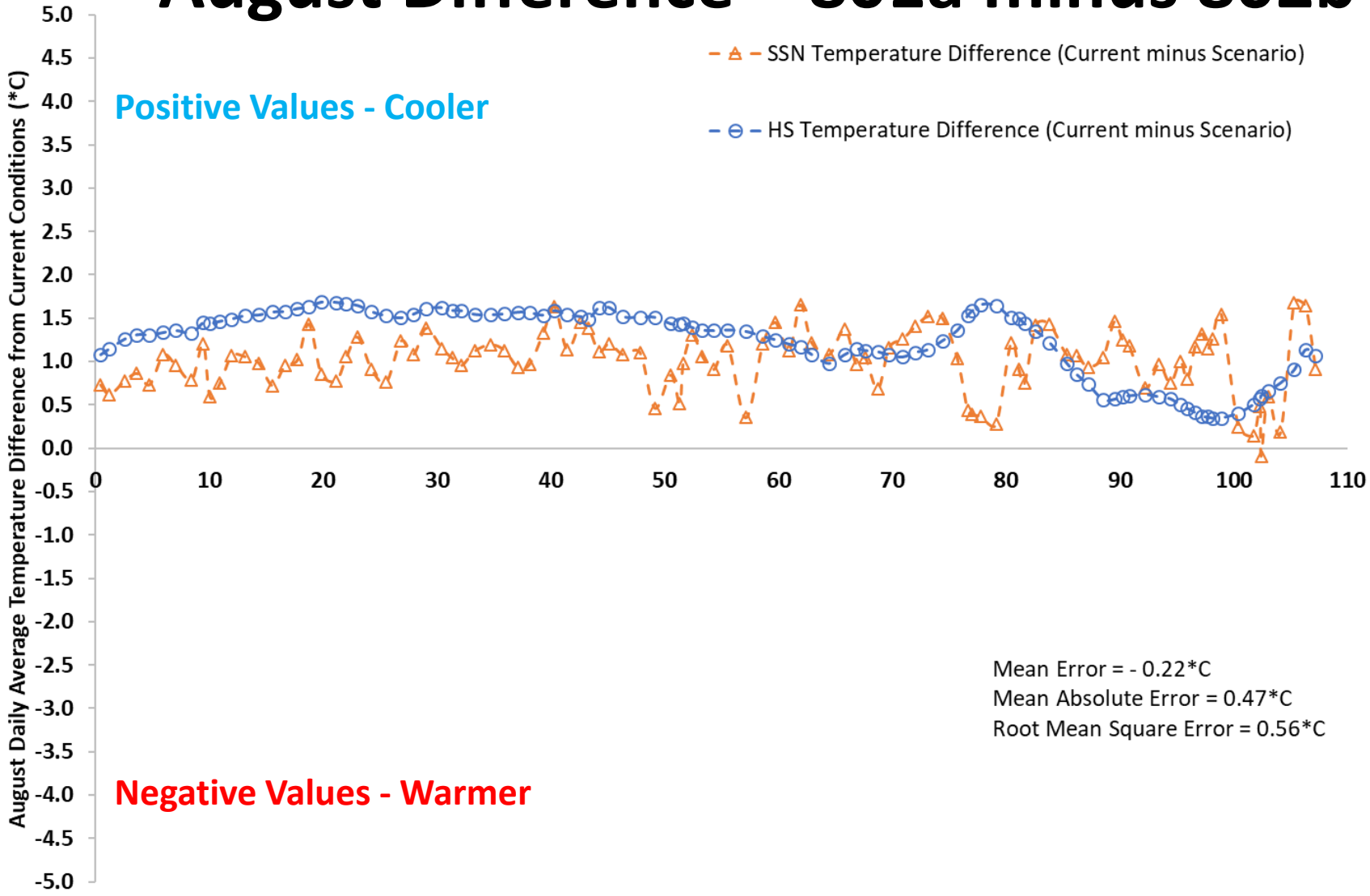
Mechanistic Model Input Changes

August Air Temperature ↑ by 2.2*C

August Stream Flows ↑ 20%

SW/GW withdrawals ↓ by 45%

August Difference – 801a minus 802b



Mean Error = - 0.22*C
Mean Absolute Error = 0.47*C
Root Mean Square Error = 0.56*C

		A	B
	Time Period	Current Veg. Shading	Restored Veg. Shading
801	2002	801A	801B
802	1990-2015	802A	802B

Mechanistic Model Input Changes

August Shade ↑ by 20% (Units)

August Air Temperature ↑ by 2.2*C

August Stream Flows ↑ 20%

SW/GW withdrawals ↓ by 45%

August – Model Comparison Summary

801a

Mean Error = - 0.26*C
Mean Absolute Error = 0.57*C
Root Mean Square Error = 0.71*C
Nash-Sutchliffe Efficiency Coefficient = 0.75
Pearson Correlation Coefficient = 0.90

801b

Mean Error = 0.07*C
Mean Absolute Error = 0.77*C
Root Mean Square Error = 0.94*C
Nash-Sutchliffe Efficiency Coefficient = 0.52
Pearson Correlation Coefficient = 0.77

Difference - 801a minus 801b
Mean Error = - 0.33*C
Mean Absolute Error = 0.48*C
Root Mean Square Error = 0.60*C

802a

Mean Error = - 0.45*C
Mean Absolute Error = 0.52*C
Root Mean Square Error = 0.63*C
Nash-Sutchliffe Efficiency Coefficient = 0.85
Pearson Correlation Coefficient = 0.93

Difference - 801a minus 802a
Mean Error = 0.19*C
Mean Absolute Error = 0.39*C
Root Mean Square Error = 0.45*C

802b

Mean Error = - 0.14*C
Mean Absolute Error = 0.59*C
Root Mean Square Error = 0.76*C
Nash-Sutchliffe Efficiency Coefficient = 0.70
Pearson Correlation Coefficient = 0.81

Difference - 801a minus 802b
Mean Error = - 0.22*C
Mean Absolute Error = 0.47*C
Root Mean Square Error = 0.56*C

		A	B
	Time Period	Current Veg. Shading	Restored Veg. Shading
801	2002	801A	801B
802	1990-2015	802A	802B

Mechanistic Model Input Changes

August Shade ↑ by 20% (Units)

August Air Temperature ↑ by 2.2*C

August Stream Flows ↑ 20%

SW/GW withdrawals ↓ by 45%

Recall This Slide

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814 7Q10	2080s	August	814A	814B	814C1(2,3,4,5)	814D	814E

Scenarios also include the months of May and September

September – Model Comparison Summary

		A	B
	Time Period	Current Veg. Shading	Restored Veg. Shading
801	2002	801A	801B
802	1990-2015	802A	802B

901a

Mean Error = 0.33*C
Mean Absolute Error = 0.81*C
Root Mean Square Error = 0.93*C
Nash-Sutchliffe Efficiency Coefficient = 0.24
Pearson Correlation Coefficient = 0.67

901b

Mean Error = 0.81*C
Mean Absolute Error = 1.23*C
Root Mean Square Error = 1.39*C
Nash-Sutchliffe Efficiency Coefficient = - 1.34
Pearson Correlation Coefficient = 0.45

Difference - 901a minus 901b
Mean Error = - 0.51*C
Mean Absolute Error = 0.63*C
Root Mean Square Error = 0.72*C

902a

Mean Error = 0.13*C
Mean Absolute Error = 0.59*C
Root Mean Square Error = 0.71*C
Nash-Sutchliffe Efficiency Coefficient = 0.60
Pearson Correlation Coefficient = 0.78

Difference - 901a minus 902a
Mean Error = 0.22*C
Mean Absolute Error = 0.31*C
Root Mean Square Error = 0.34*C

902b

Mean Error = 0.56*C
Mean Absolute Error = 1.06*C
Root Mean Square Error = 1.20*C
Nash-Sutchliffe Efficiency Coefficient = - 0.82
Pearson Correlation Coefficient = 0.50

Difference - 901a minus 902b
Mean Error = - 0.53*C
Mean Absolute Error = 0.64*C
Root Mean Square Error = 0.73*C

Model Input Changes –

September Shade ↑ by 24% (Units)

Sept. Air Temperature ↑ by 0.5*C

September Stream Flows ↑ 12%

SW/GW withdrawals ↓ by 45%

May – Model Comparison Summary

501a

Mean Error = 0.38*C
Mean Absolute Error = 1.55*C
Root Mean Square Error = 2.05*C
Nash-Sutchliffe Efficiency Coefficient = - 1.61
Pearson Correlation Coefficient = 0.91

501b

Mean Error = 0.04*C
Mean Absolute Error = 1.03*C
Root Mean Square Error = 1.33*C
Nash-Sutchliffe Efficiency Coefficient = 0.13
Pearson Correlation Coefficient = 0.88

Difference - 501a minus 501b
Mean Error = 0.47*C
Mean Absolute Error = 0.89*C
Root Mean Square Error = 1.11*C

502a

Mean Error = - 0.37*C
Mean Absolute Error = 1.22*C
Root Mean Square Error = 1.43*C
Nash-Sutchliffe Efficiency Coefficient = 0.17
Pearson Correlation Coefficient = 0.87

Difference - 501a minus 502a
Mean Error = 1.09*C
Mean Absolute Error = 1.28*C
Root Mean Square Error = 1.79*C

502b

Mean Error = - 0.86*C
Mean Absolute Error = 1.22*C
Root Mean Square Error = 1.31*C
Nash-Sutchliffe Efficiency Coefficient = 0.24
Pearson Correlation Coefficient = 0.84

Difference - 501a minus 502b
Mean Error = 0.06*C
Mean Absolute Error = 0.76*C
Root Mean Square Error = 0.94*C

		A	B
	Time Period	Current Veg. Shading	Restored Veg. Shading
801	2002	801A	801B
802	1990-2015	802A	802B

Model Input Changes –

May Shade ↑ by 19% (Units)

May Air Temperature ↑ by 1.2*C

May Stream Flows ↑ 11%

SW/GW withdrawals ↓ by 45%

Scenario 501a – May Calibrated “Baseline” Models Comparison

501a

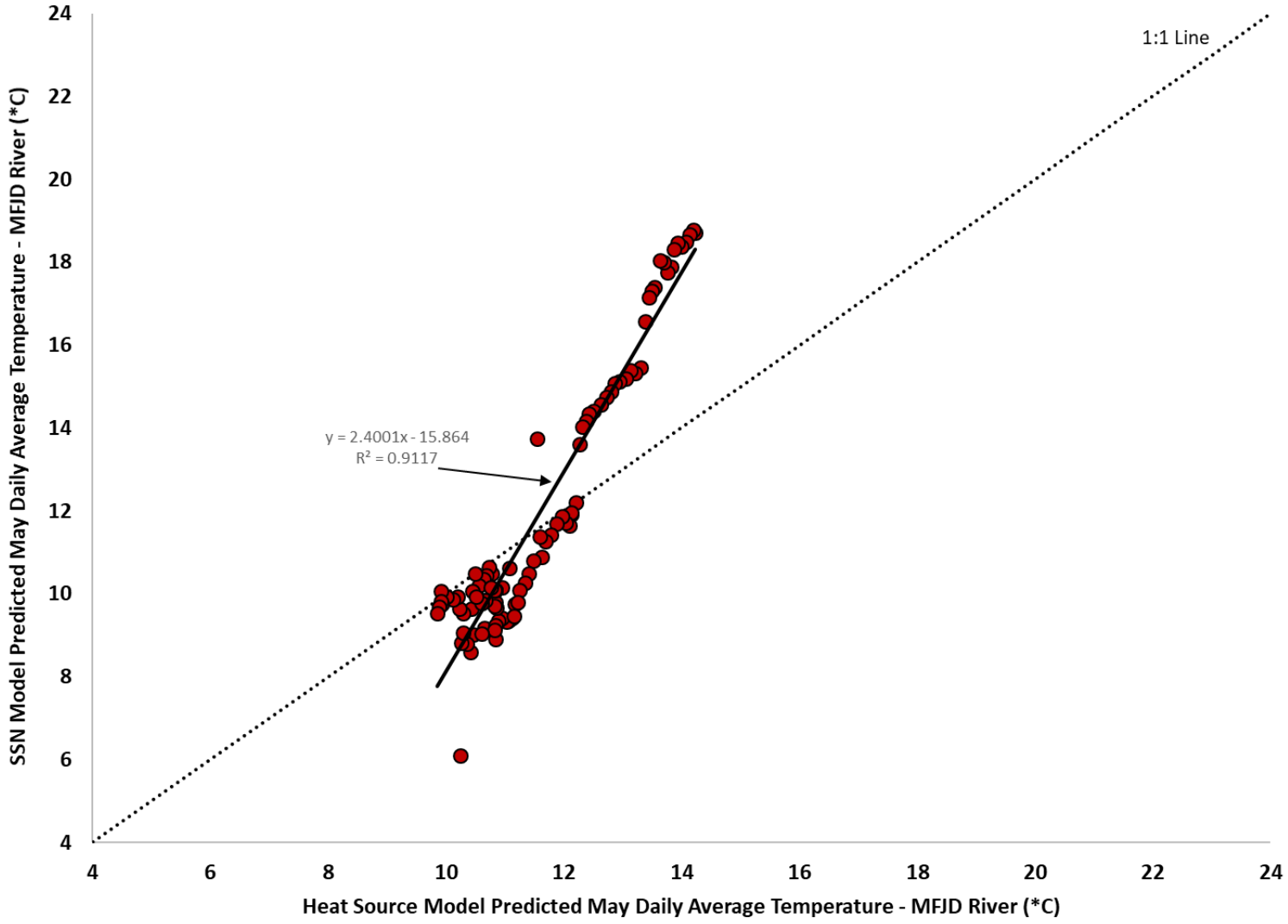
Mean Error = 0.38*C

Mean Absolute Error = 1.55*C

Root Mean Square Error = 2.05*C

Nash-Sutchliffe Efficiency Coefficient = - 1.61

Pearson Correlation Coefficient = 0.91



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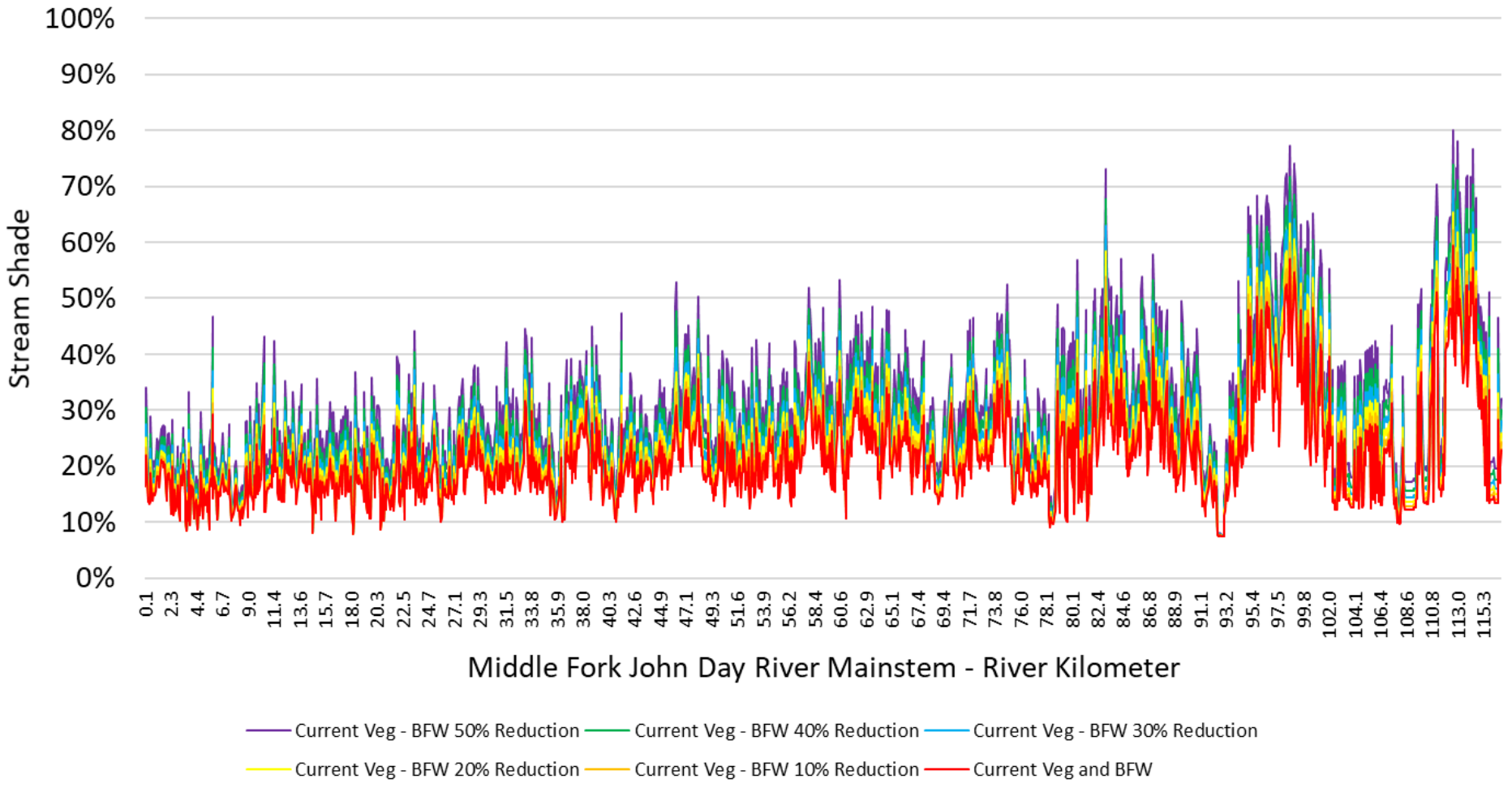
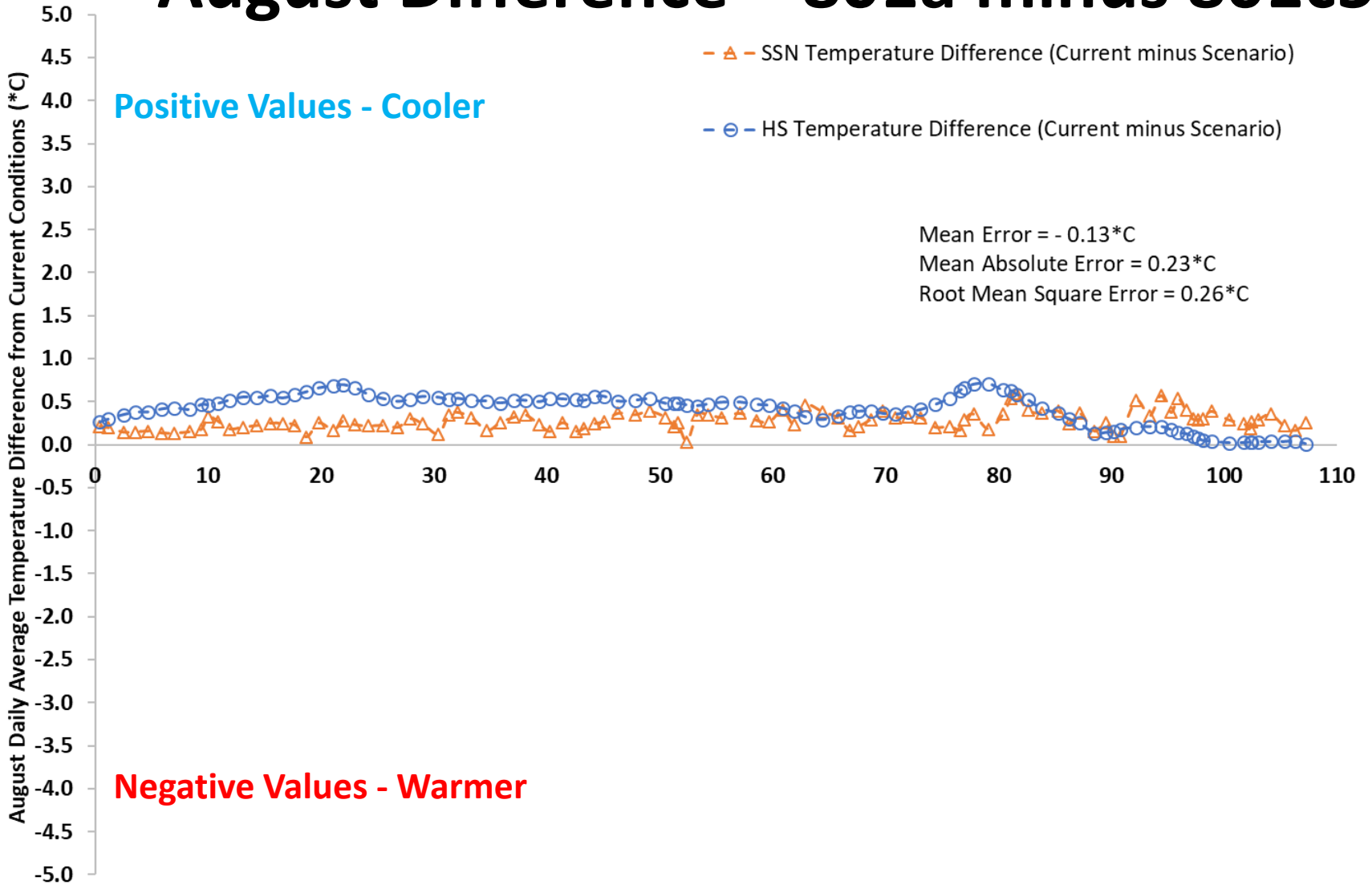
Scenarios also include the months of May and September

SSN Input – 801c Scenarios

C
Restored channel width (10-50%)
801C1(2,3,4,5)



August Difference – 801a minus 801c5 (i.e., 50%)



Positive Values - Cooler

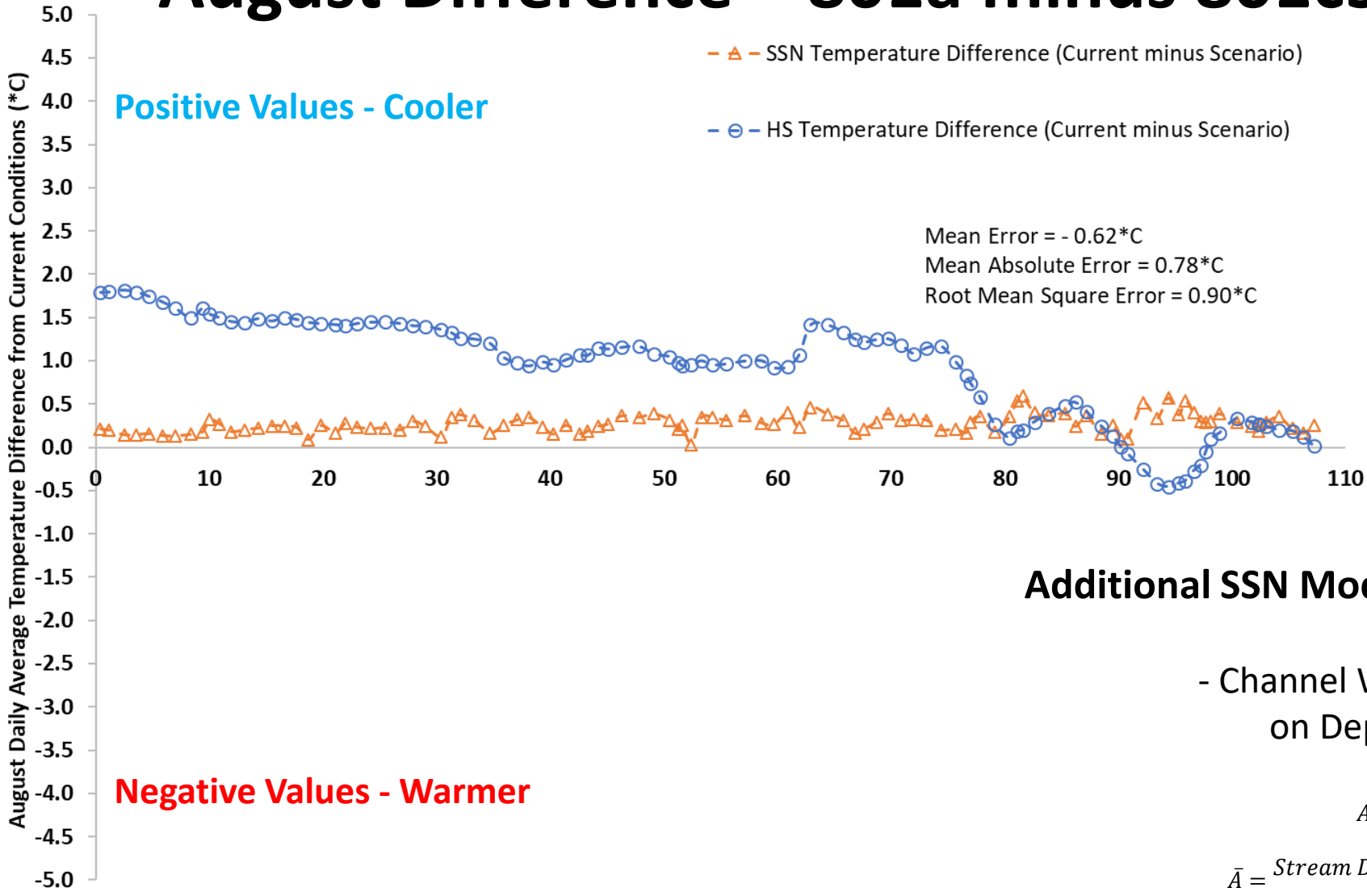
Negative Values - Warmer

C
Restored channel width (10-50%)
801C1(2,3,4,5)

Mechanistic Model Input Changes

August Shade ↑ by 9% (Units)

August Difference – 801a minus 801c5 (i.e., 50%)



C
Restored channel width (10-50%)
801C1(2,3,4,5)

Mechanistic Model Input Changes

August Shade ↑ by 9% (Units)

Channel Width Reduced by 50%

Additional SSN Model Input Covariates are Needed

- Channel Width Modification Effect on Depth (and/or Velocity)

$$Average\ Depth\ (m) = \bar{A}/\bar{B}$$

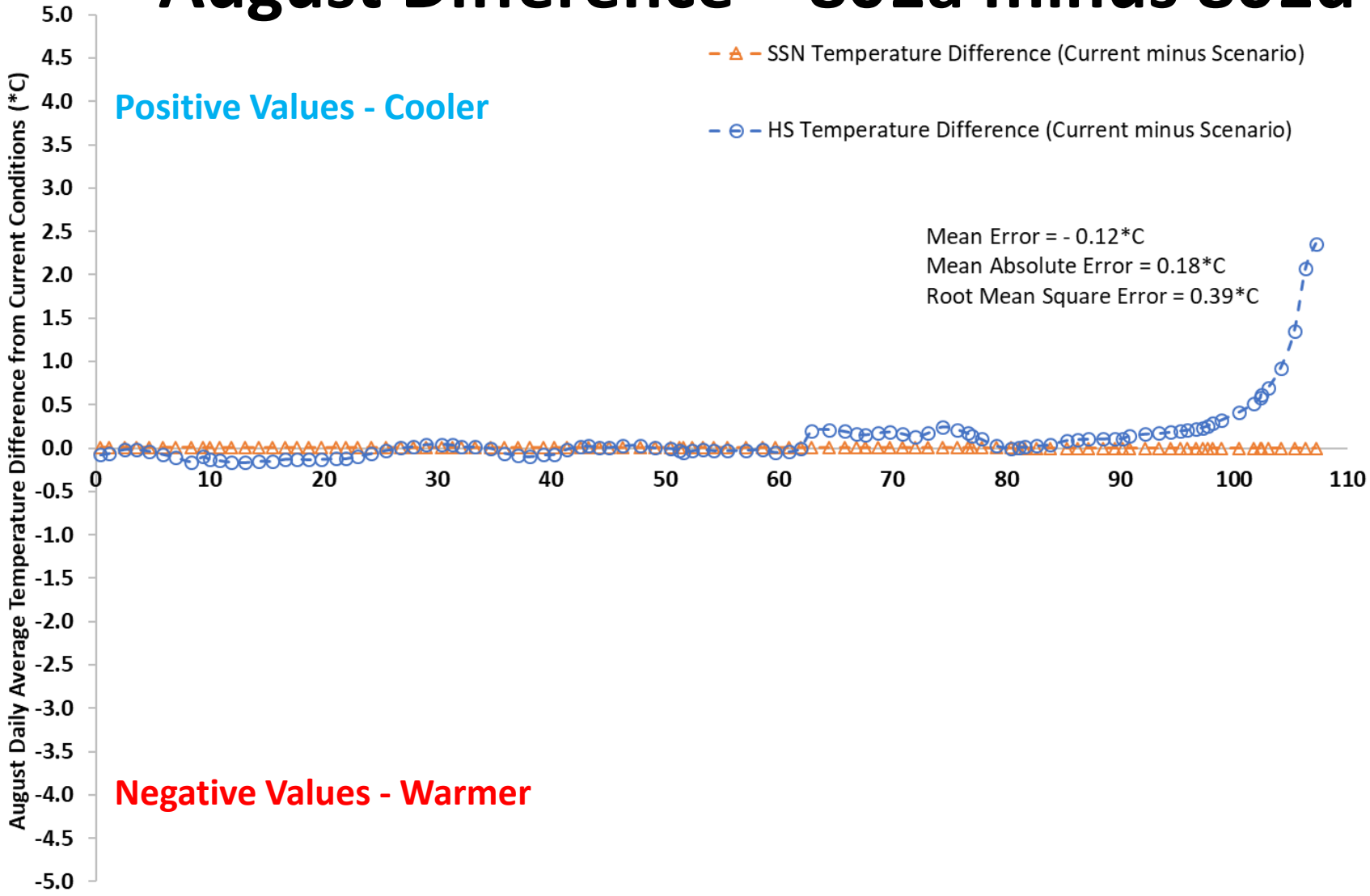
$$\bar{A} = Stream\ Discharge\ (cms)/Stream\ Velocity\ (mps)$$

Recall this slide

Scenario Description	Time Period	Month	A Current Veg. Shading	B Restored Veg. Shading	C Restored channel width (10-50%)	D Reduced Irrigation H2O use	E Combined Restored Veg/Chan/ Crop Irr
801 Mechanistic Model Calibration Year*	2002	August	801A	801B	801C1(2,3,4,5)	801D	801E
802 Historical Record	1990-2015	August	802A	802B	802C1(2,3,4,5)	802D	802E
803 Low PDSI (dry year)*	2007	August	803A	803B	803C1(2,3,4,5)	803D	803E
804 High PDSI (wet year)*	1993	August	804A	804B	804C1(2,3,4,5)	804D	804E
805 Low Water Temperature Year*	2006	August	805A	805B	805C1(2,3,4,5)	805D	805E
806 High Water Temperature Year*	2001	August	806A	806B	806C1(2,3,4,5)	806D	806E
807 Mean Monthly Discharge**	2040s	August	807A	807B	807C1(2,3,4,5)	807D	807E
808 Mean Monthly Discharge	2080s	August	808A	808B	808C1(2,3,4,5)	808D	808E
809 7Q2	1990-2015	August	809A	809B	809C1(2,3,4,5)	809D	809E
810 7Q2	2040s	August	810A	810B	810C1(2,3,4,5)	810D	810E
811 7Q2	2080s	August	811A	811B	811C1(2,3,4,5)	811D	811E
812 7Q10	1990-2015	August	812A	812B	812C1(2,3,4,5)	812D	812E
813 7Q10	2040s	August	813A	813B	813C1(2,3,4,5)	813D	813E
814 7Q10	2080s	August	814A	814B	814C1(2,3,4,5)	814D	814E

Scenarios also include the months of May and September

August Difference – 801a minus 801d



Positive Values - Cooler

Negative Values - Warmer

D

Reduced Irrigation H2O use

801D

Mechanistic Model Input Changes

SW/GW withdrawals ↓ by 100%

Recall this slide

Scenario Description	Time Period	Month	A Current Veg. Shading	B Restored Veg. Shading	C Restored channel width (10-50%)	D Reduced Irrigation H2O use	E Combined Restored Veg/Chan/ Crop Irr
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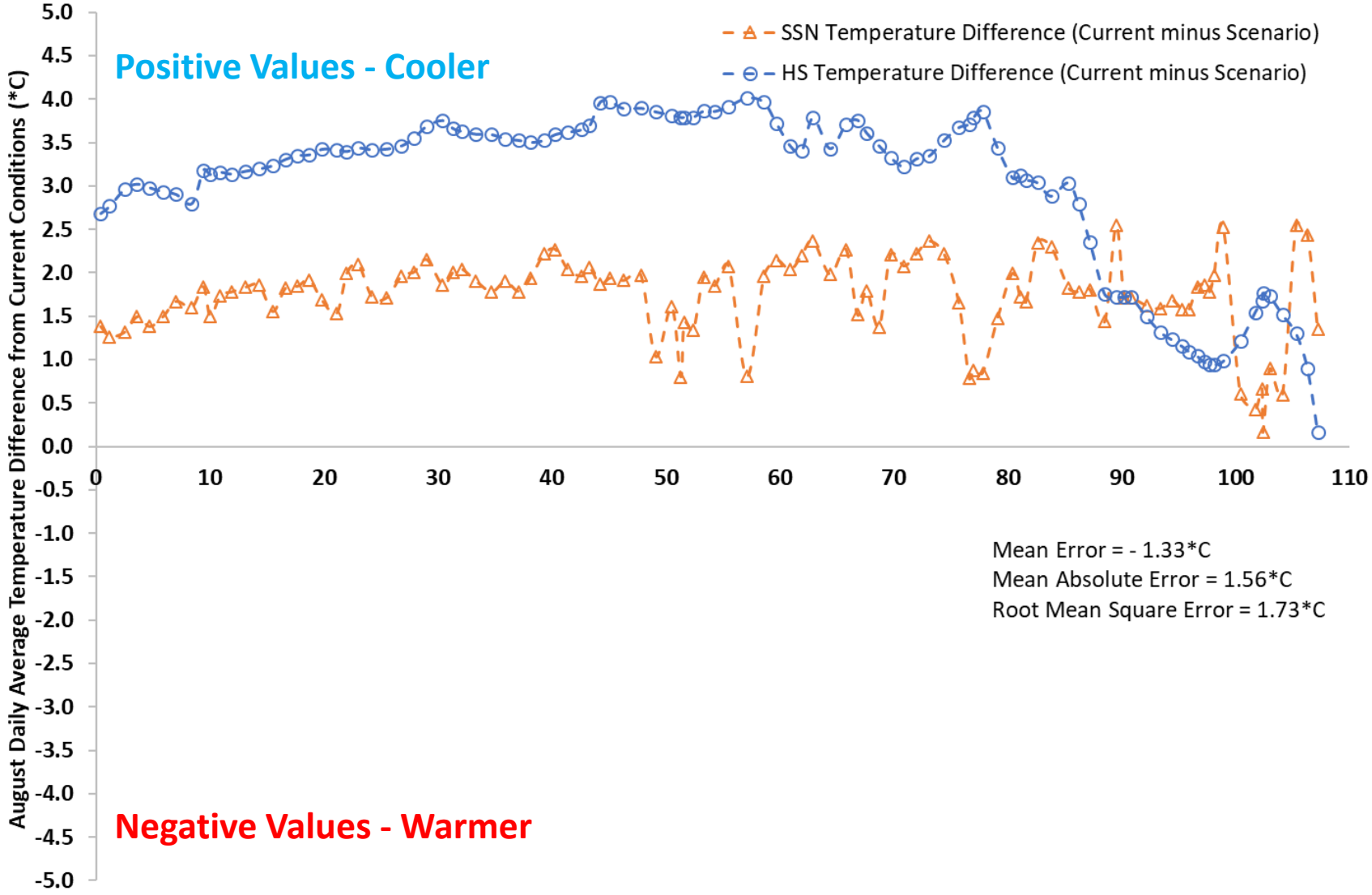
808 Mean Monthly Discharge	2080s	August	808A	808B	808C1(2,3,4,5)	808D	808E
809 7Q2	1990-2015	August	809A	809B	809C1(2,3,4,5)	809D	809E
810 7Q2	2040s	August	810A	810B	810C1(2,3,4,5)	810D	810E
811 7Q2	2080s	August	811A	811B	811C1(2,3,4,5)	811D	811E
812 7Q10	1990-2015	August	812A	812B	812C1(2,3,4,5)	812D	812E
813 7Q10	2040s	August	813A	813B	813C1(2,3,4,5)	813D	813E
814 7Q10	2080s	August	814A	814B	814C1(2,3,4,5)	814D	814E

Scenarios also include the months of May and September

August Difference – 801a minus 801e

E
Combined Restored Veg/Chan/ Crop Irr
801E



Mean Error = - 1.33*C
Mean Absolute Error = 1.56*C
Root Mean Square Error = 1.73*C

Mechanistic Model Input Changes

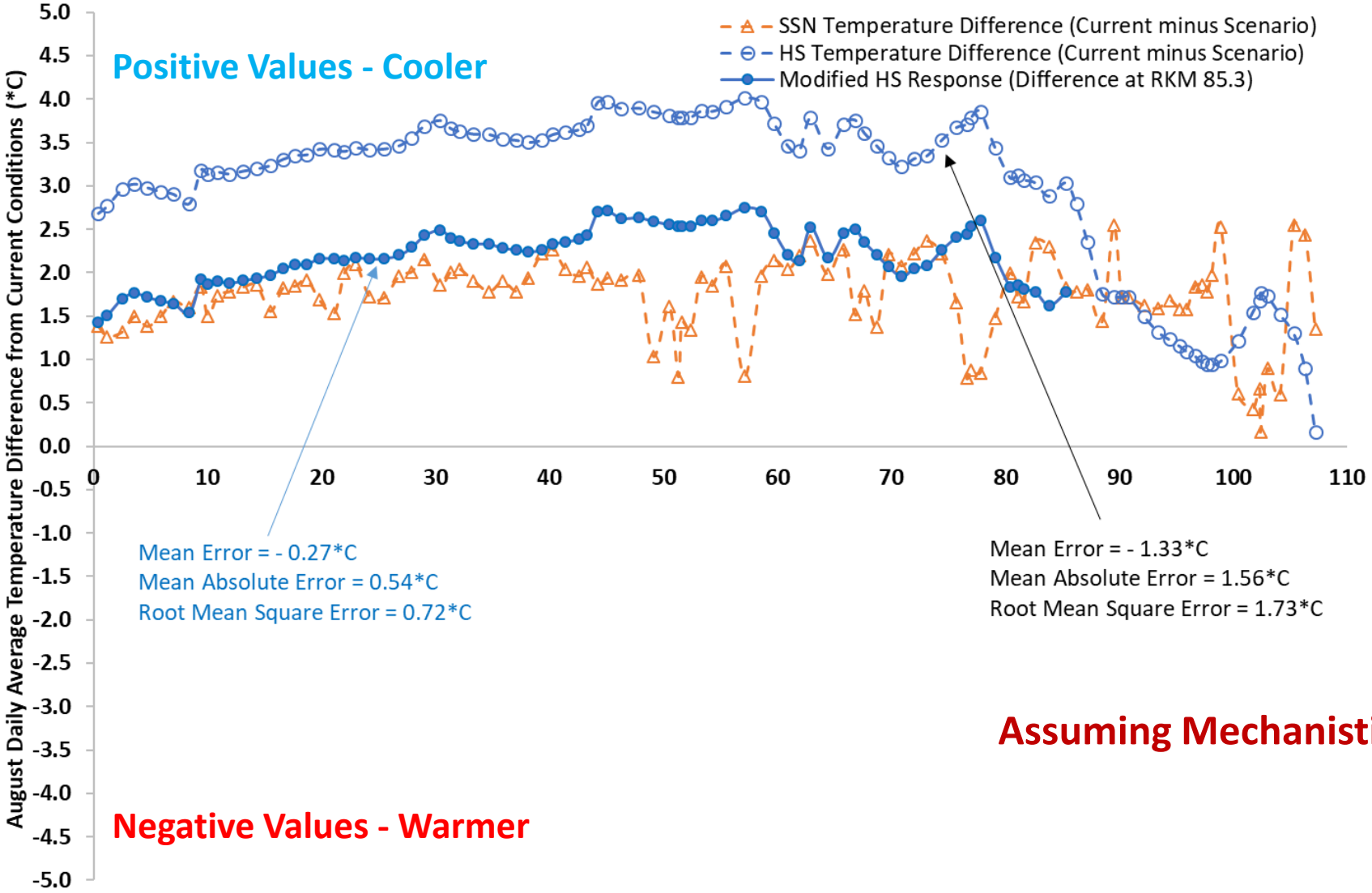
Shade ↑ by 42% (Units)

~~SW/GW withdrawals ↓ by 100%~~

Sensitivity Analysis

August Difference – 801a minus 801e

E
Combined Restored Veg/Chan/ Crop Irr
801E



Mechanistic Model Input Changes

Shade ↑ by 42% (Units)

~~SW/GW withdrawals ↓ by 100%~~

Sensitivity Analysis

Assuming Mechanistic Model Results Are The "Truth"

Recall this slide

Scenario Description	Time Period	Month	A Current Veg. Shading	B Restored Veg. Shading	C Restored channel width (10-50%)	D Reduced Irrigation H2O use	E Combined Restored Veg/Chan/ Crop Irr
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805 Low Water Temperature Year*	2006	August	805A	805B	805C1(2,3,4,5)	805D	805E
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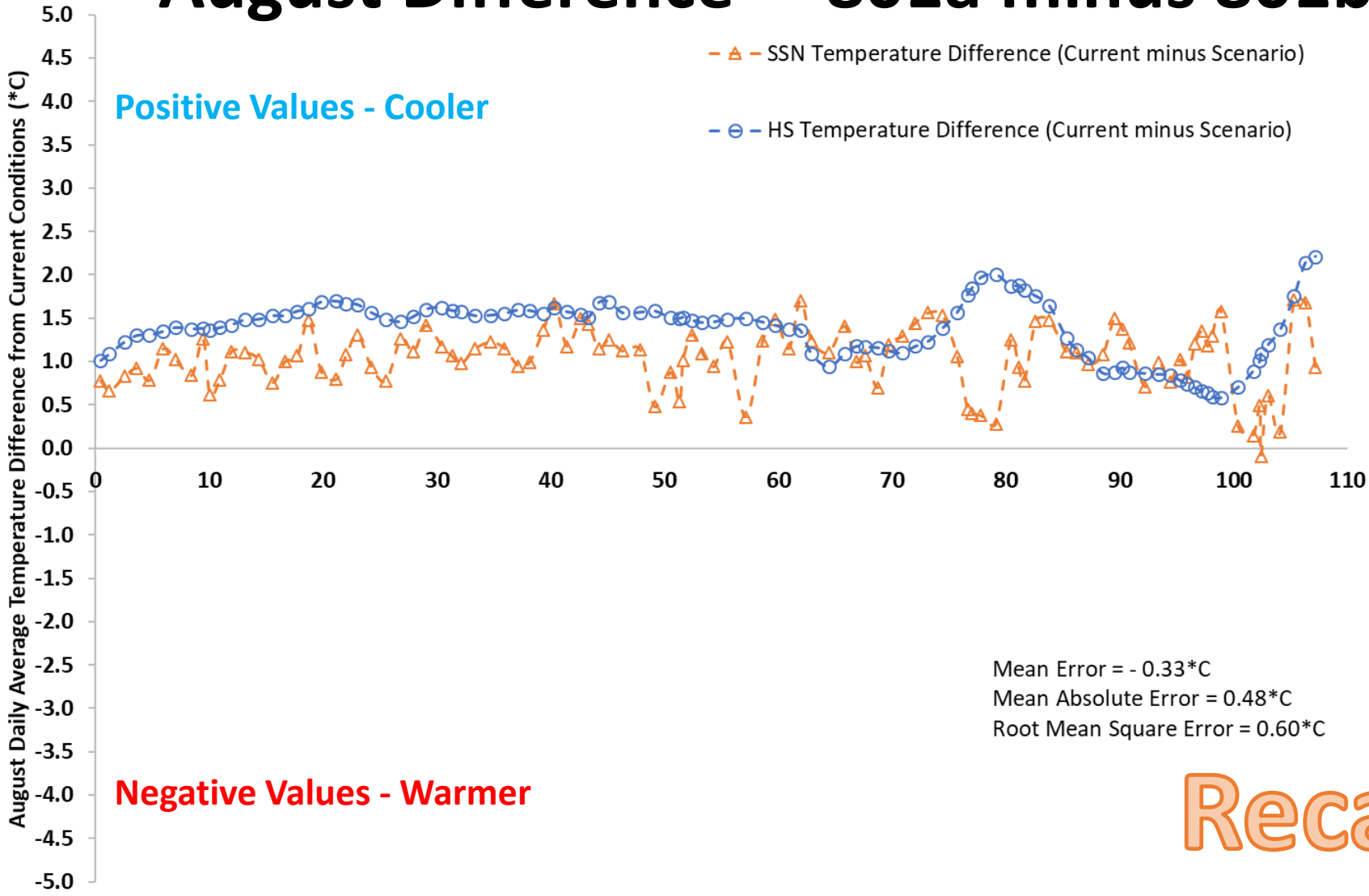
808 Mean Monthly Discharge	2080s	August	808A	808B	808C1(2,3,4,5)	808D	808E
809 7Q2	1990-2015	August	809A	809B	809C1(2,3,4,5)	809D	809E
810 7Q2	2040s	August	810A	810B	810C1(2,3,4,5)	810D	810E
811 7Q2	2080s	August	811A	811B	811C1(2,3,4,5)	811D	811E
812 7Q10	1990-2015	August	812A	812B	812C1(2,3,4,5)	812D	812E
813 7Q10	2040s	August	813A	813B	813C1(2,3,4,5)	813D	813E
814 7Q10	2080s	August	814A	814B	814C1(2,3,4,5)	814D	814E

Evaluating Maximum 7DADM Temperature Metric

August Difference – 801a minus 801b



		A	B
	Time Period	Current Veg. Shading	Restored Veg. Shading
801	2002	801A	801B
802	1990-2015	802A	802B

Mechanistic Model Input Changes

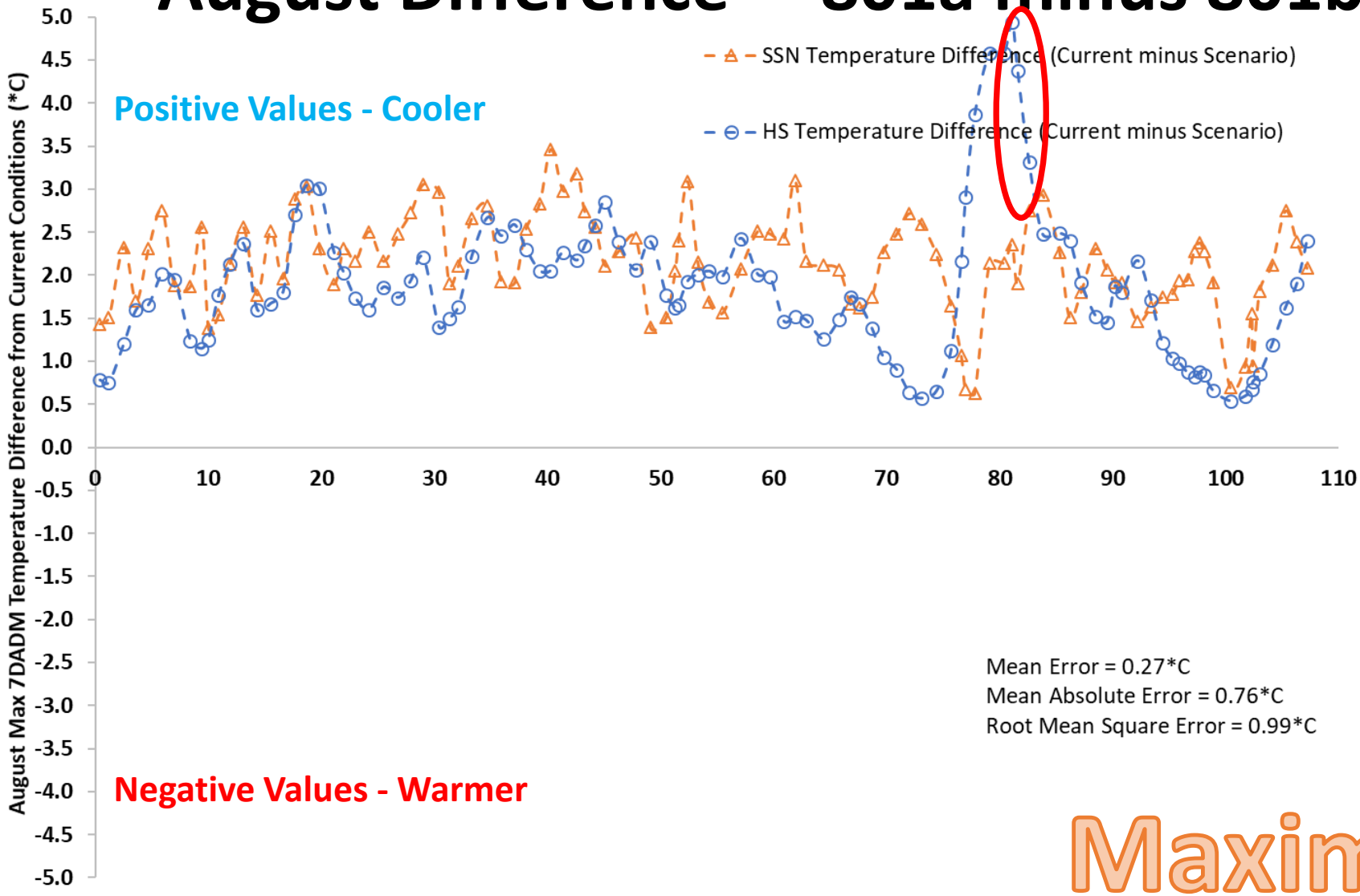
August Shade ↑ by 20% (Units)

Mean Error = - 0.33*C
Mean Absolute Error = 0.48*C
Root Mean Square Error = 0.60*C

Recall This Slide

August Daily Average

August Difference – 801a minus 801b



Positive Values - Cooler

Negative Values - Warmer

Middle Fork JohnDay Mainstem - River Kilometer from Mouth (RKM)

		A	B
	Time Period	Current Veg. Shading	Restored Veg. Shading
801	2002	801A	801B
802	1990-2015	802A	802B

Mechanistic Model Input Changes

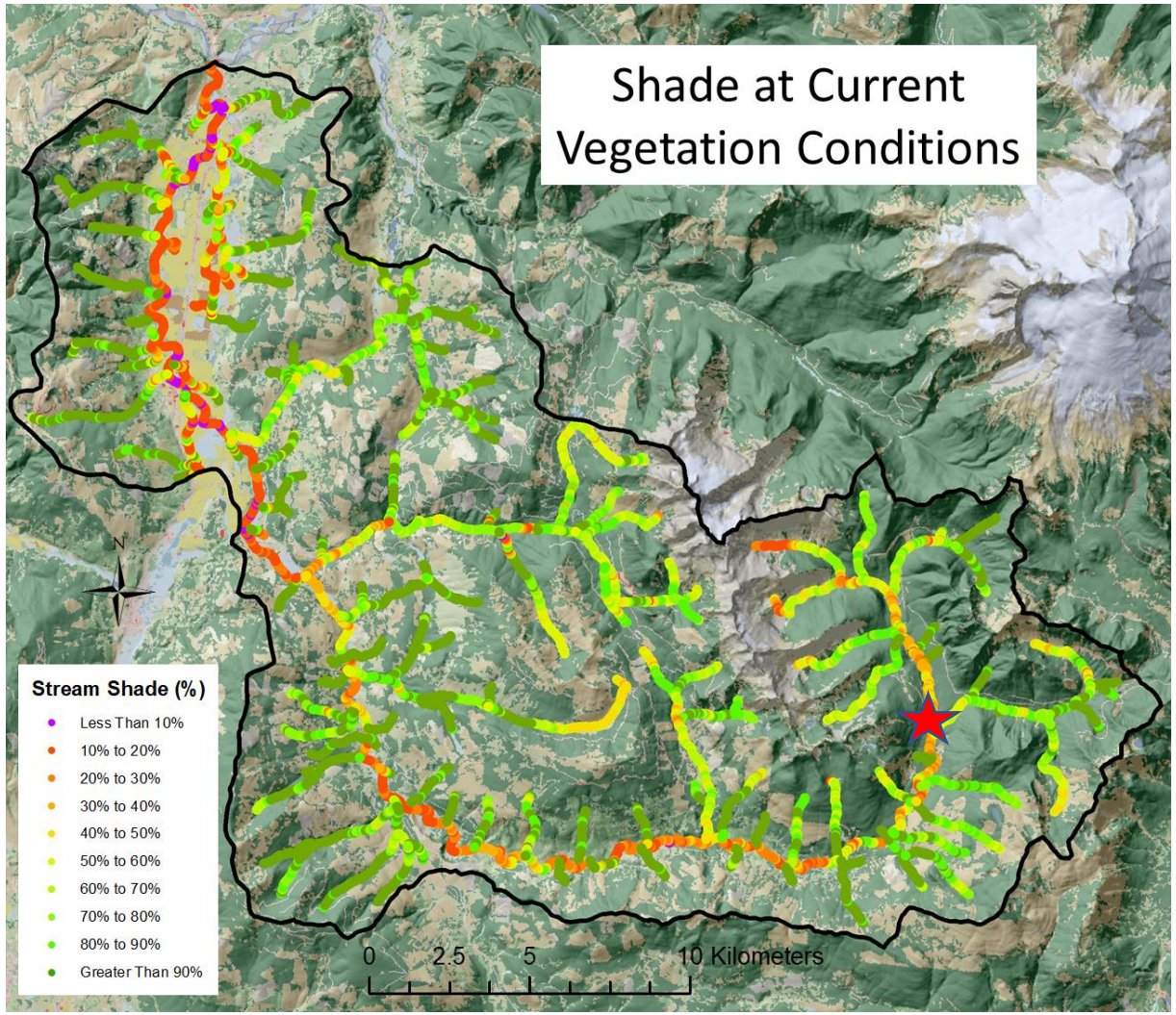
August Shade ↑ by 20% (Units)

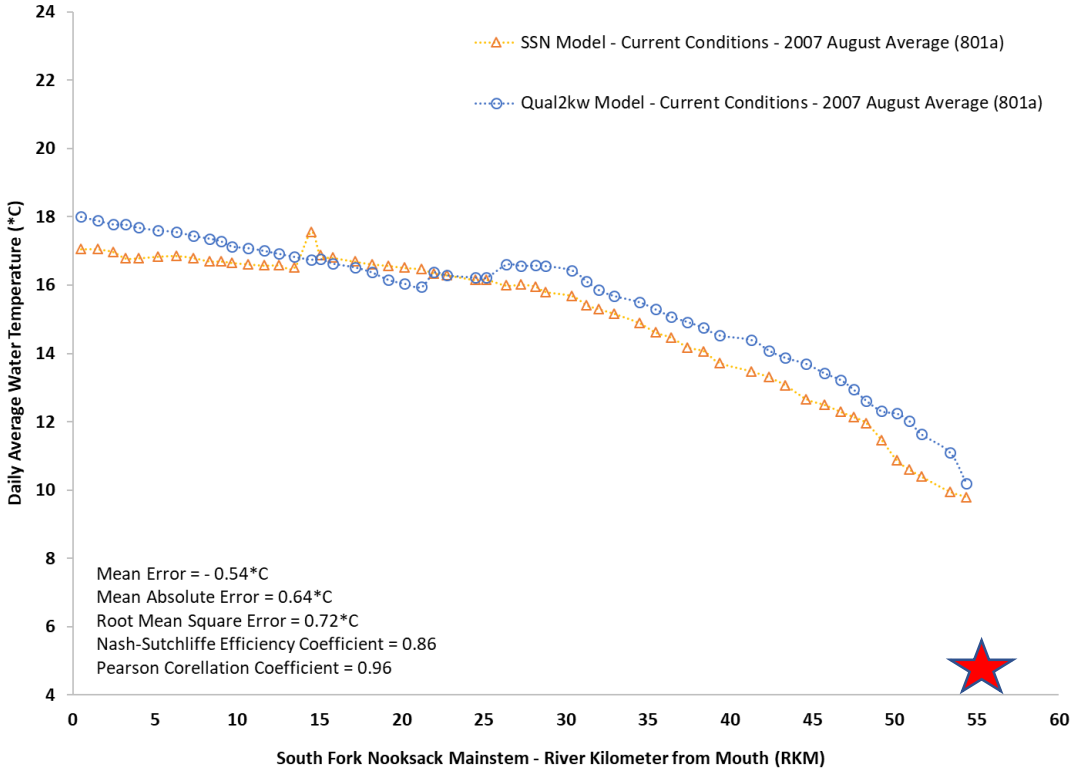
Mean Error = 0.27*C
Mean Absolute Error = 0.76*C
Root Mean Square Error = 0.99*C

Maximum 7DADM

South Fork Nooksack River

August 2007

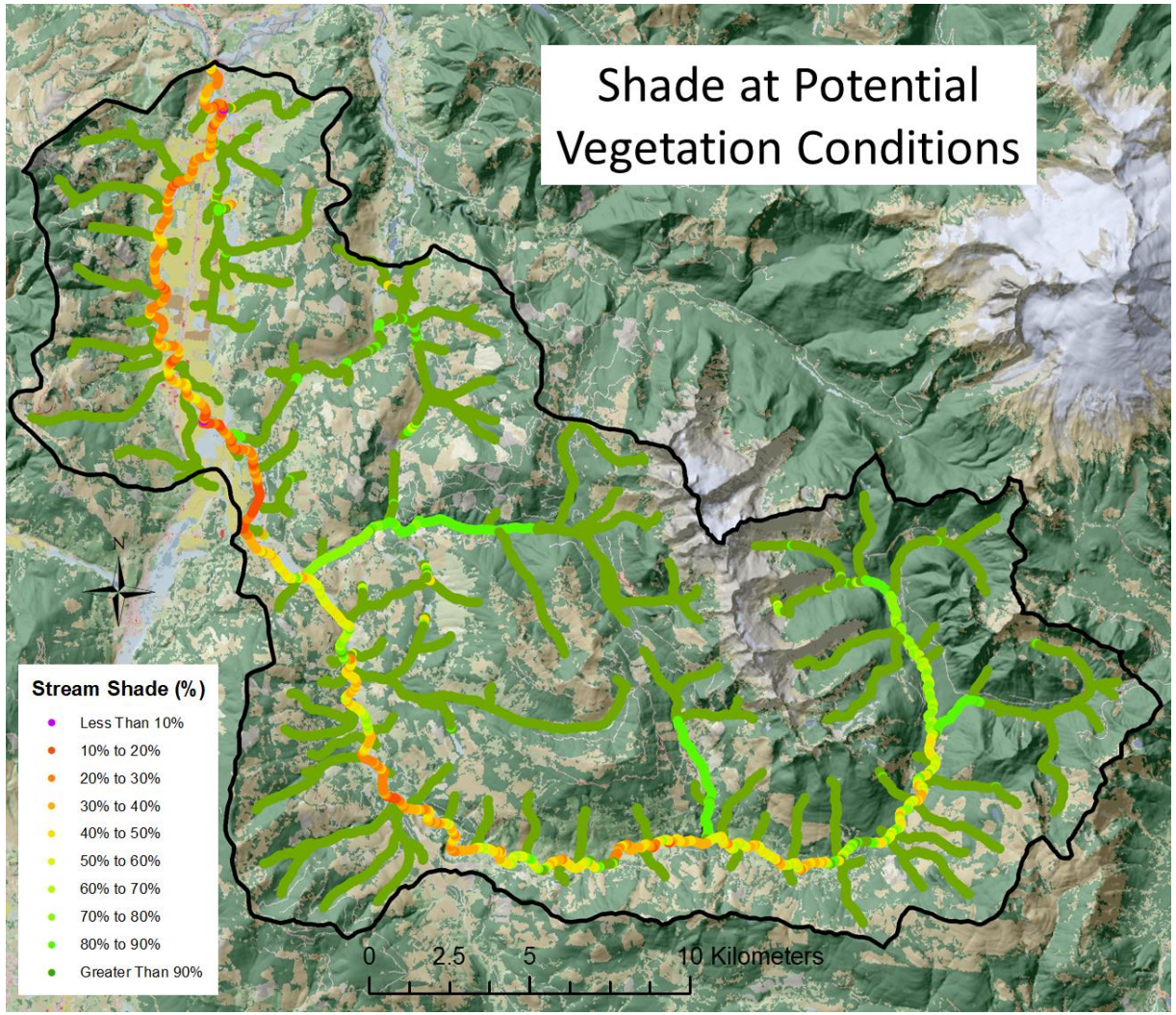


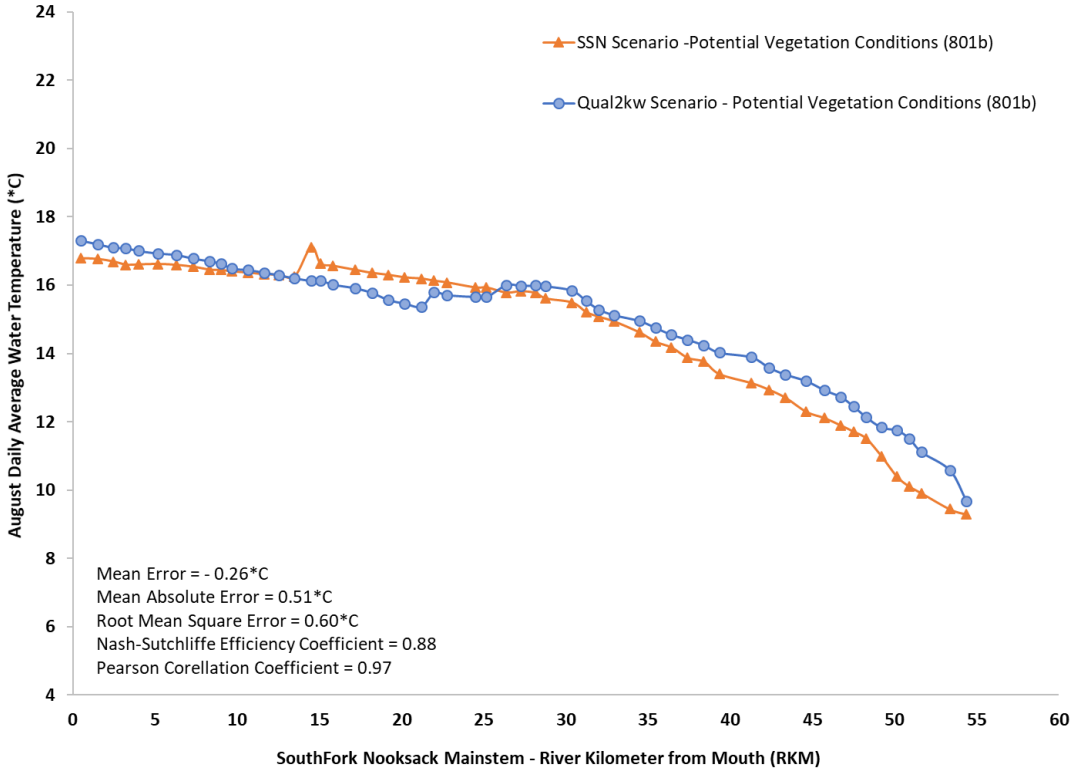


Qual2kw Model vs. SSN Model

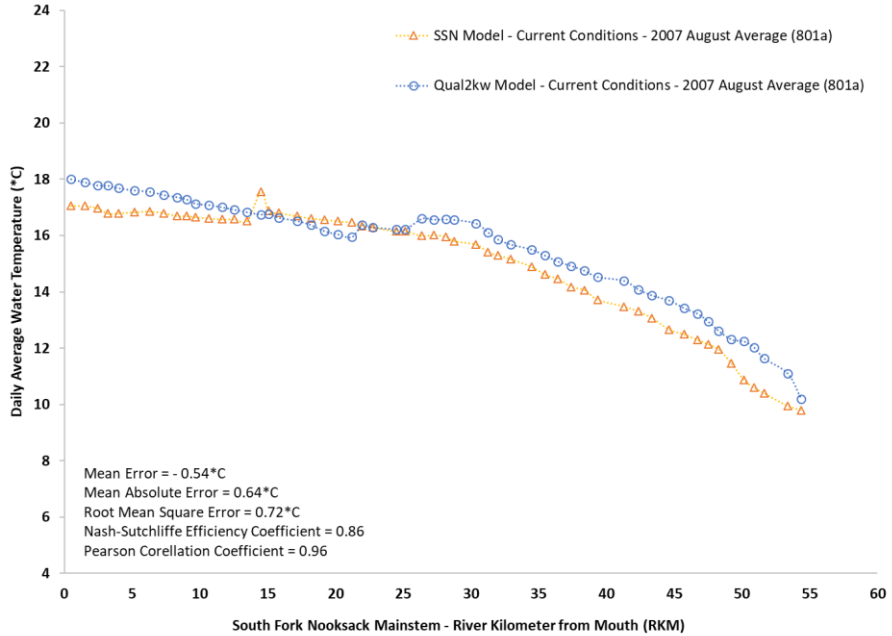
South Fork Nooksack River

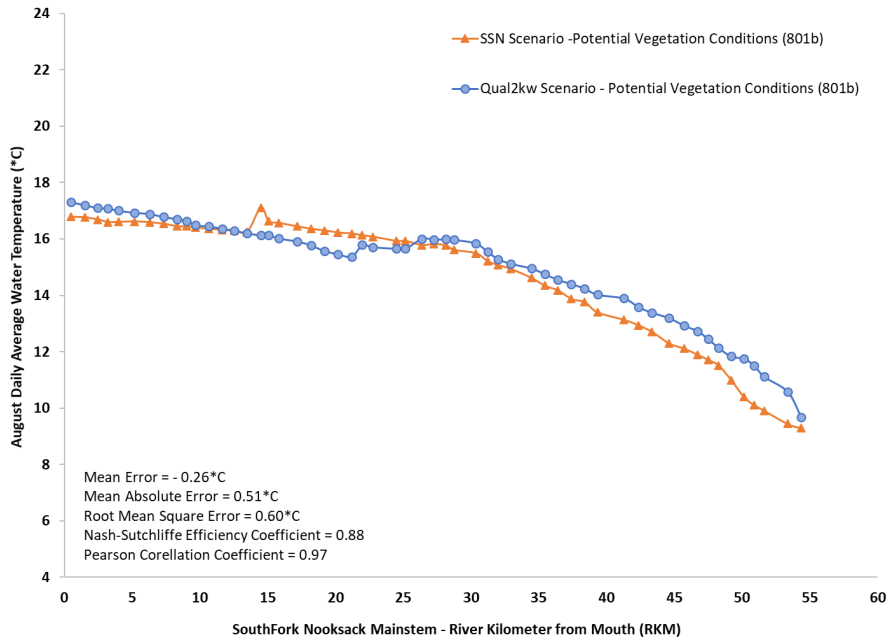
August 2007





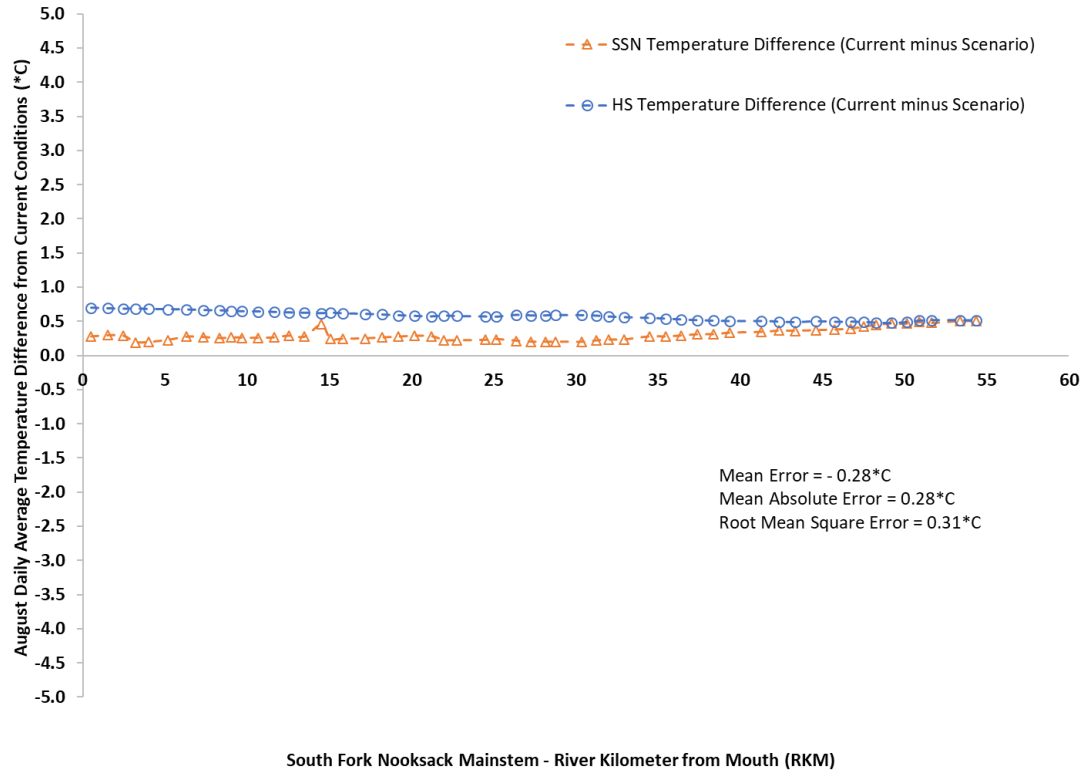
Qual2kw Model vs. SSN Model



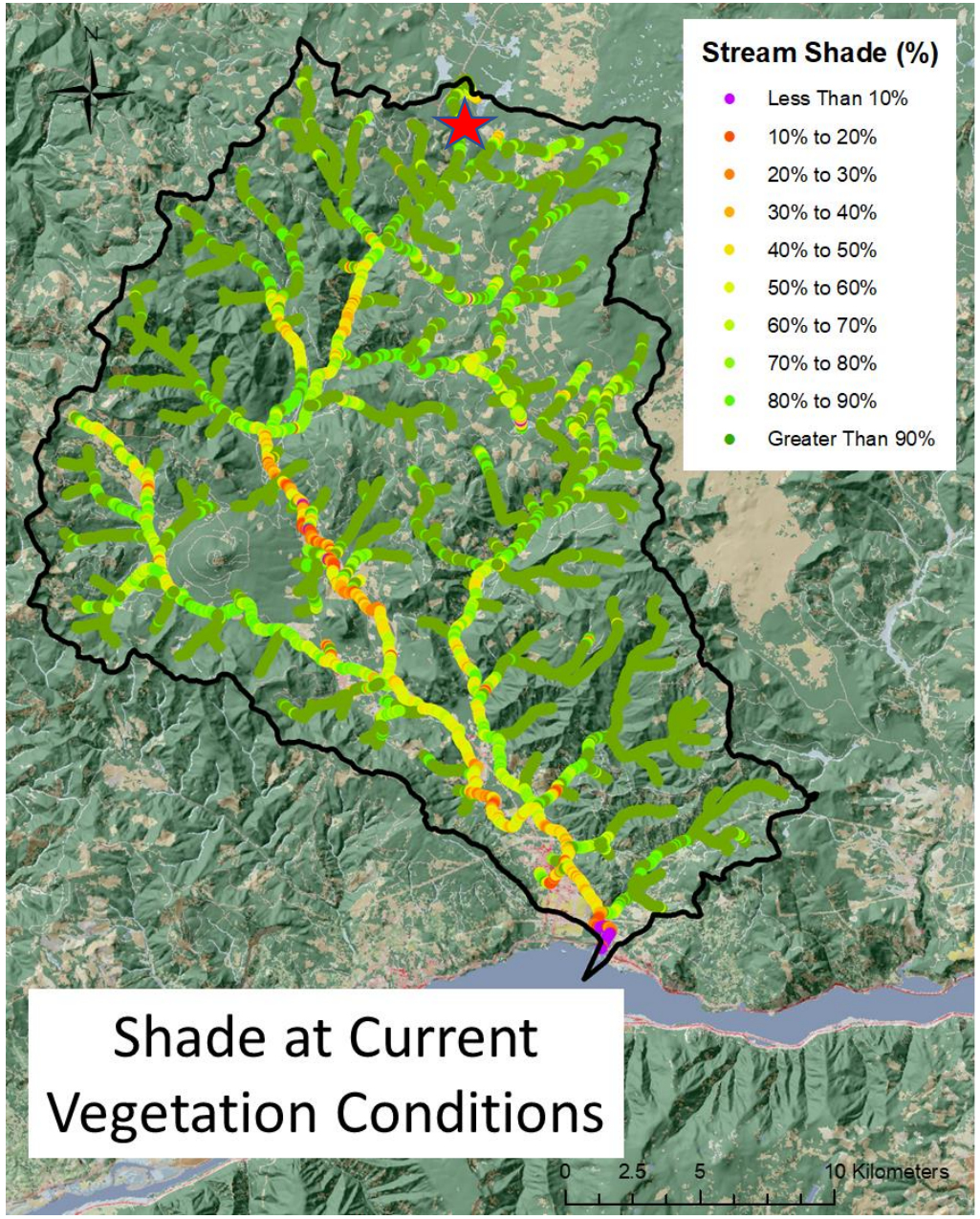


South Fork Nooksack River

August 2007

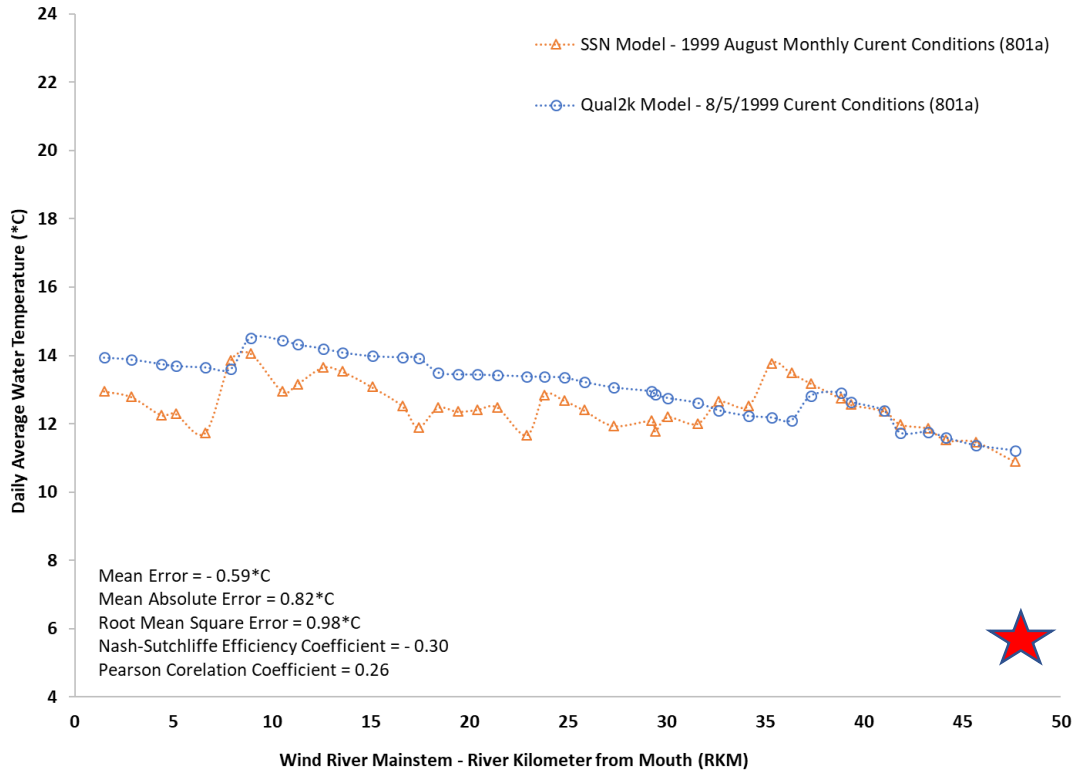


Qual2kw Model vs. SSN Model

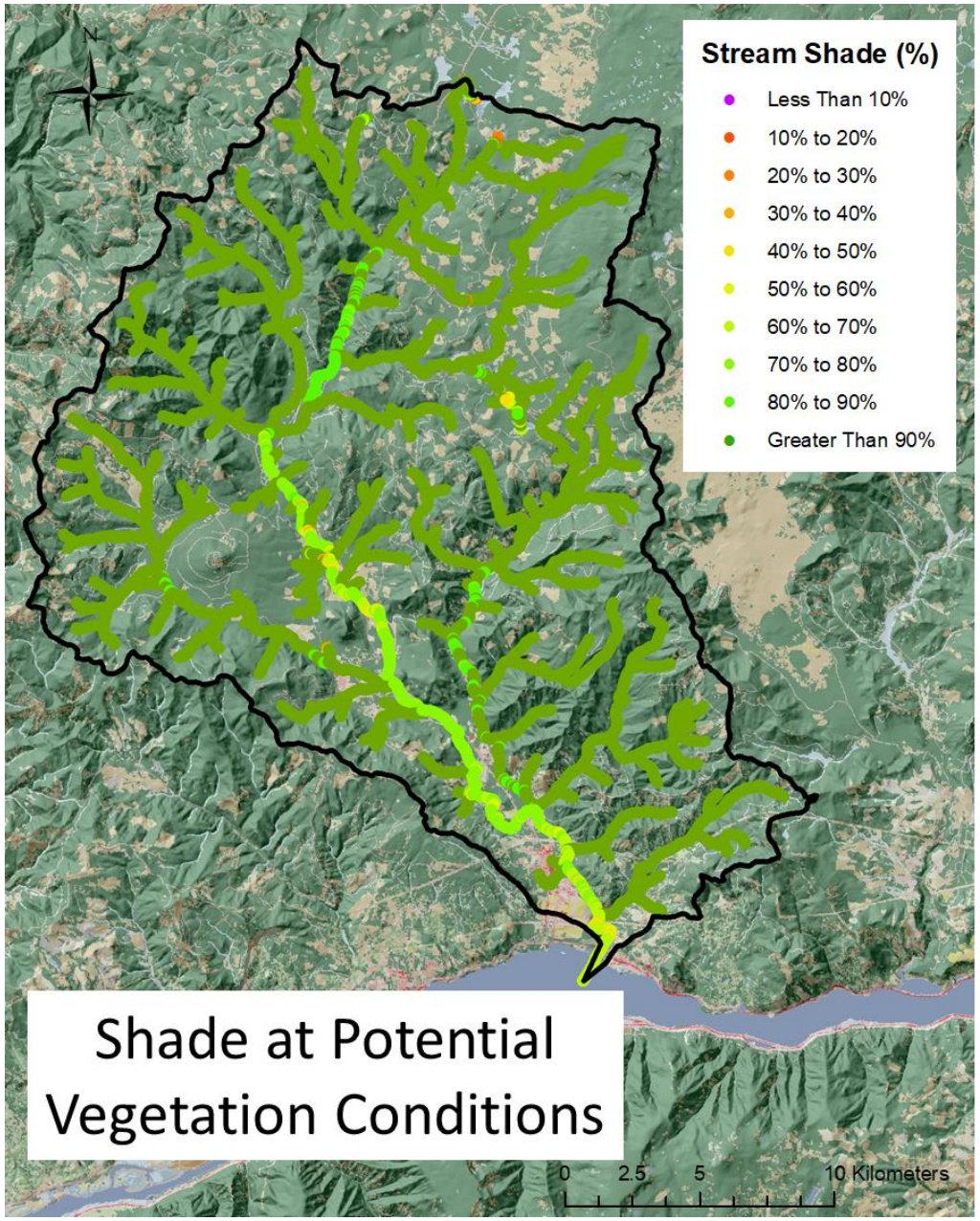


Wind River

August 1999

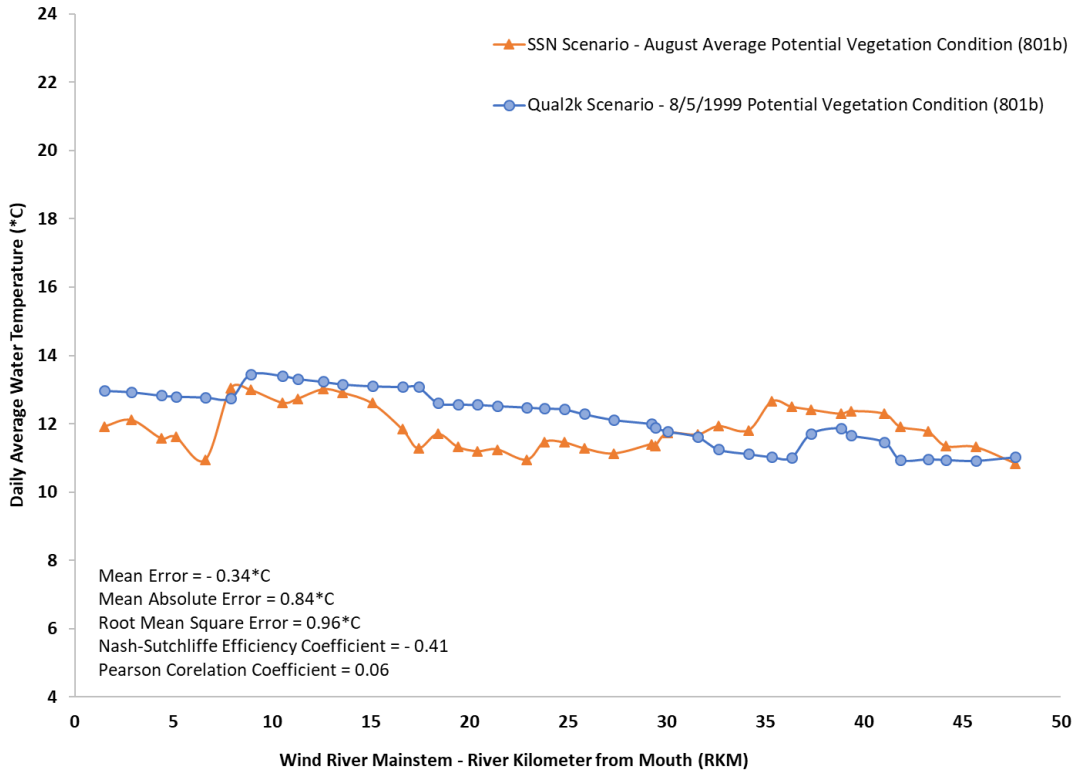


Qual2k Model vs. SSN Model

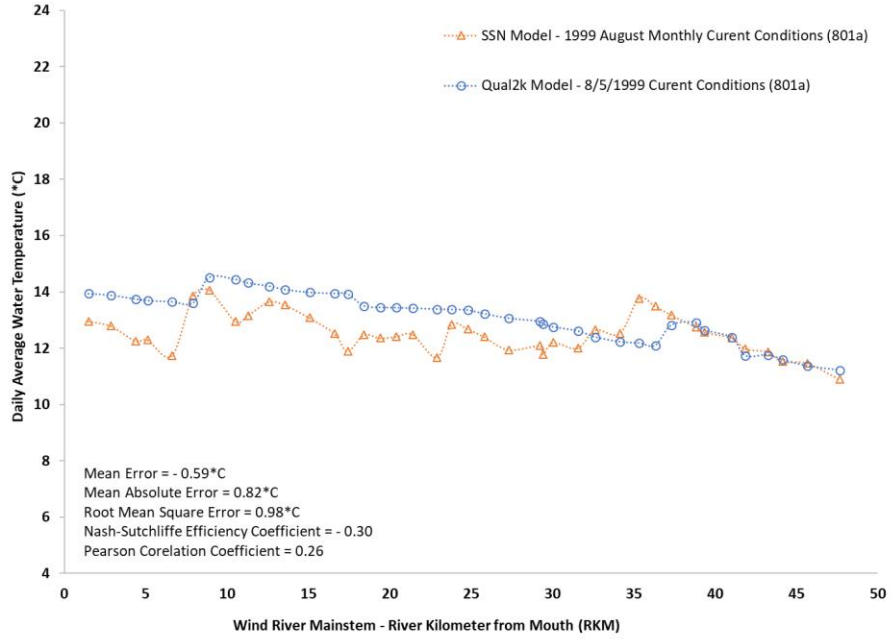


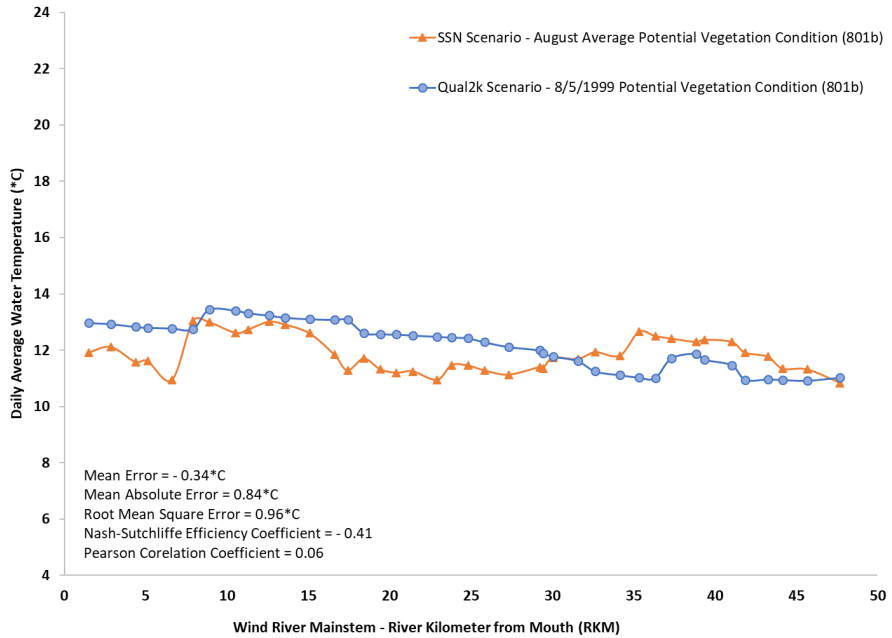
Wind River

August 1999



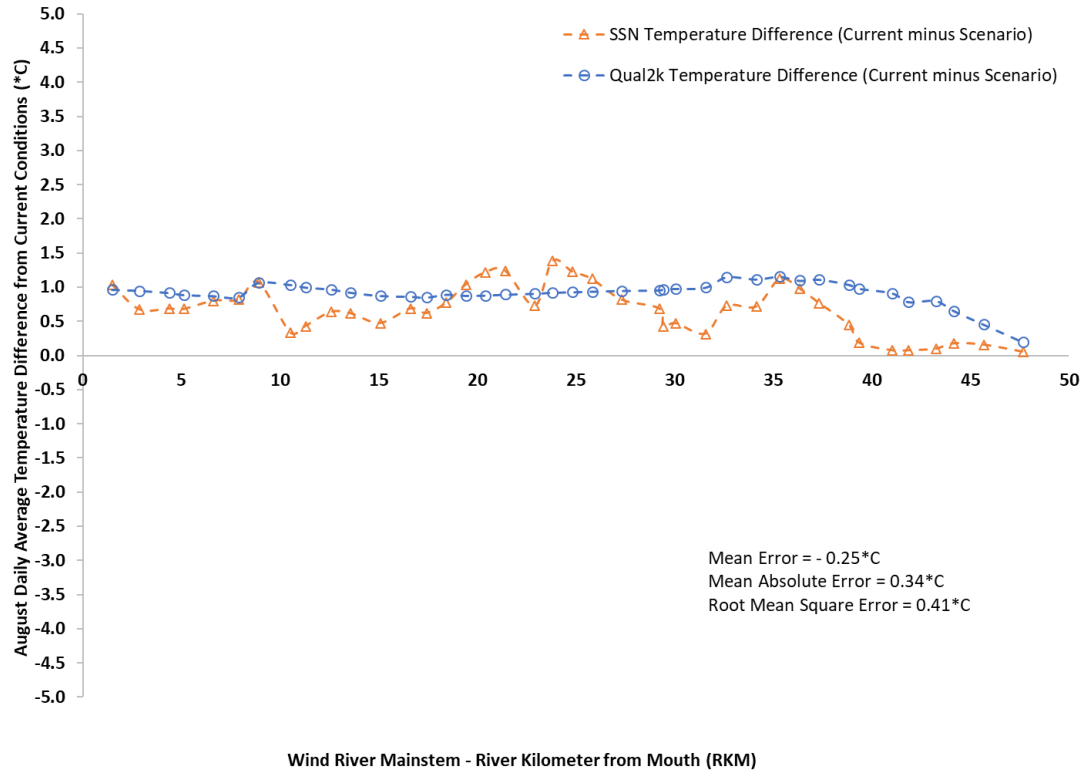
Qual2k Model vs. SSN Model





Wind River

August 1999



Qual2k Model vs. SSN Model

Summary

- Similar temperature response (both Average Monthly and Maximum 7DADM) were observed between the SSN and mechanistic models
  (i.e., HeatSource, Qual2kw, and Qual2k)

- SSN temperature predictions were responsive to utilized input covariate
  (i.e., channel width example)

- Calibration data availability affected both models
  (i.e., May scenario had high error, but high correlation)

Any Questions?