The combined effects of land use and climate change on river and stream salinity in the lower Colorado River Basin

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Lower Colorado River Science Symposium
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River & stream salinity

- Varies over four orders of magnitude, specific electrical conductivity (EC) from < 10 to > 12,000 µS/cm
- Human activities can increase salinity, to greater than seawater (> 54,000 µS/cm)

Photo: Kalfka et al. 2001

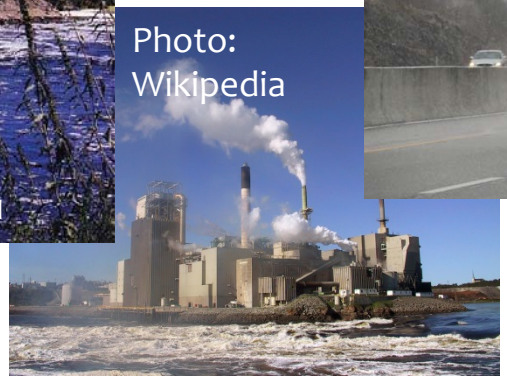


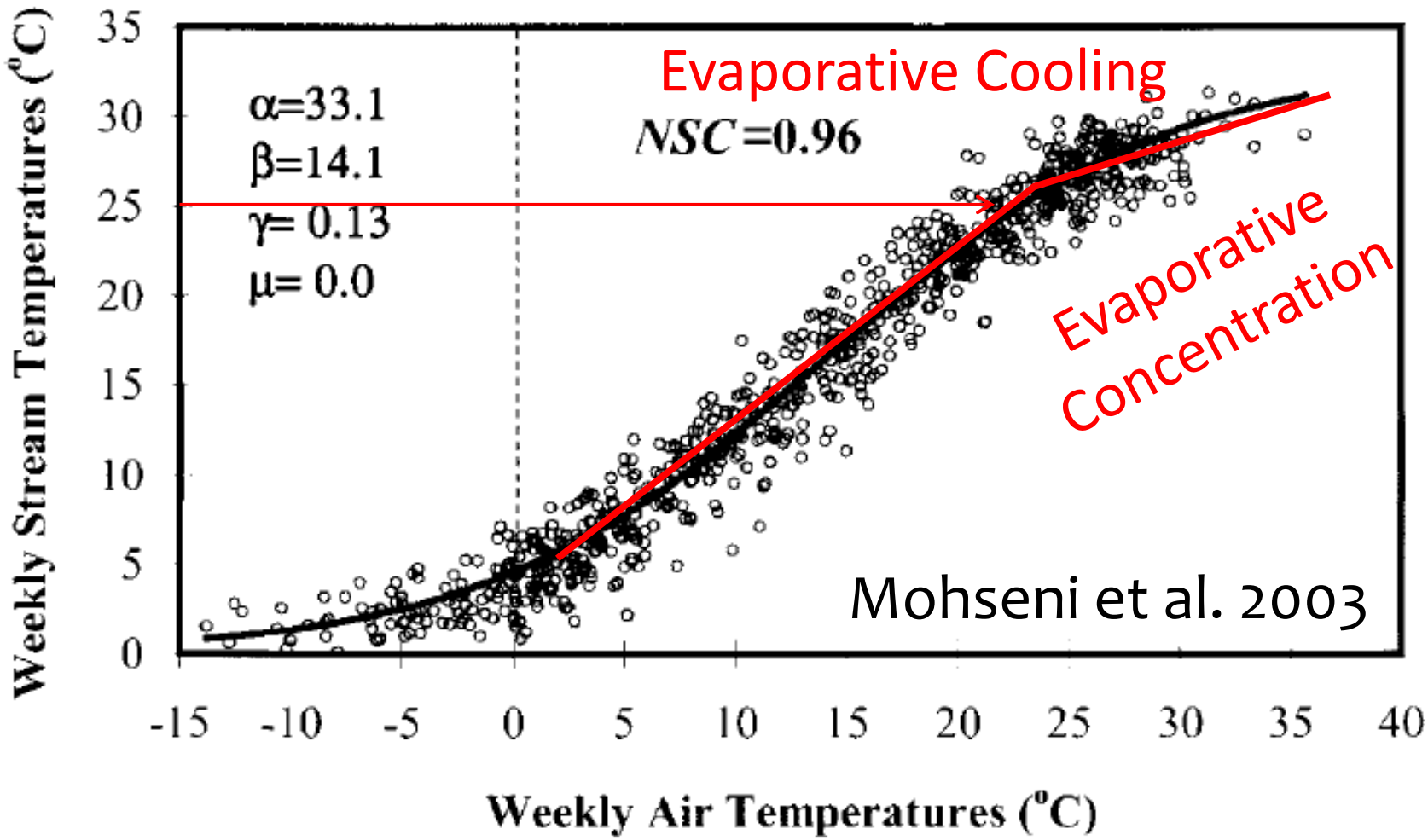
Photo: Wikipedia

Photo: PBS

Photo: Simon Fraser University

Photo: Wikipedia

Effects of Climate Change on Stream Temperature

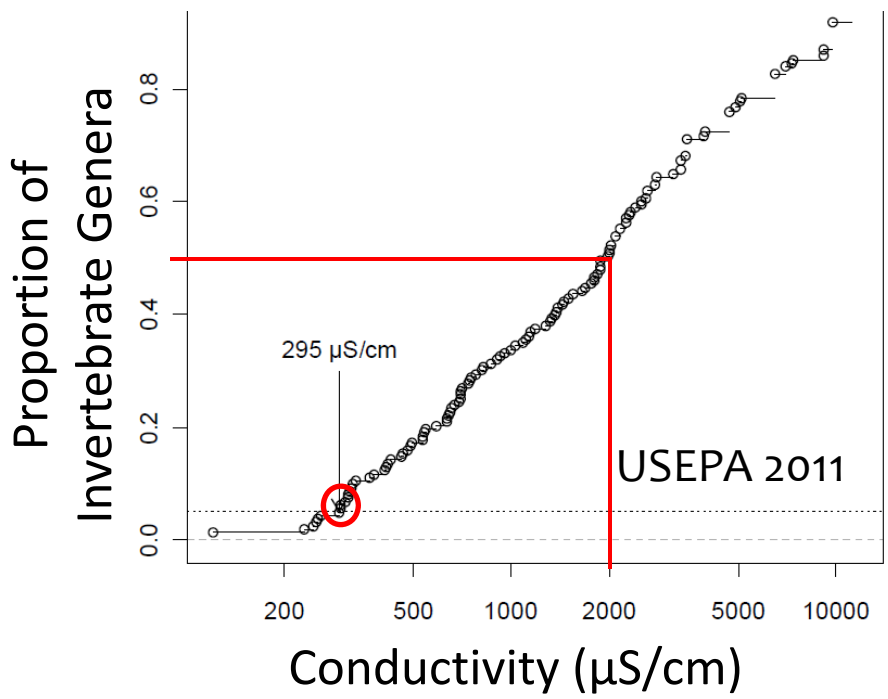


River & stream salinity

Ecosystem impairment

Loss of low salinity habitat :

- ↓ freshwater biodiversity
- Alters ecosystems function



Loss of water resources

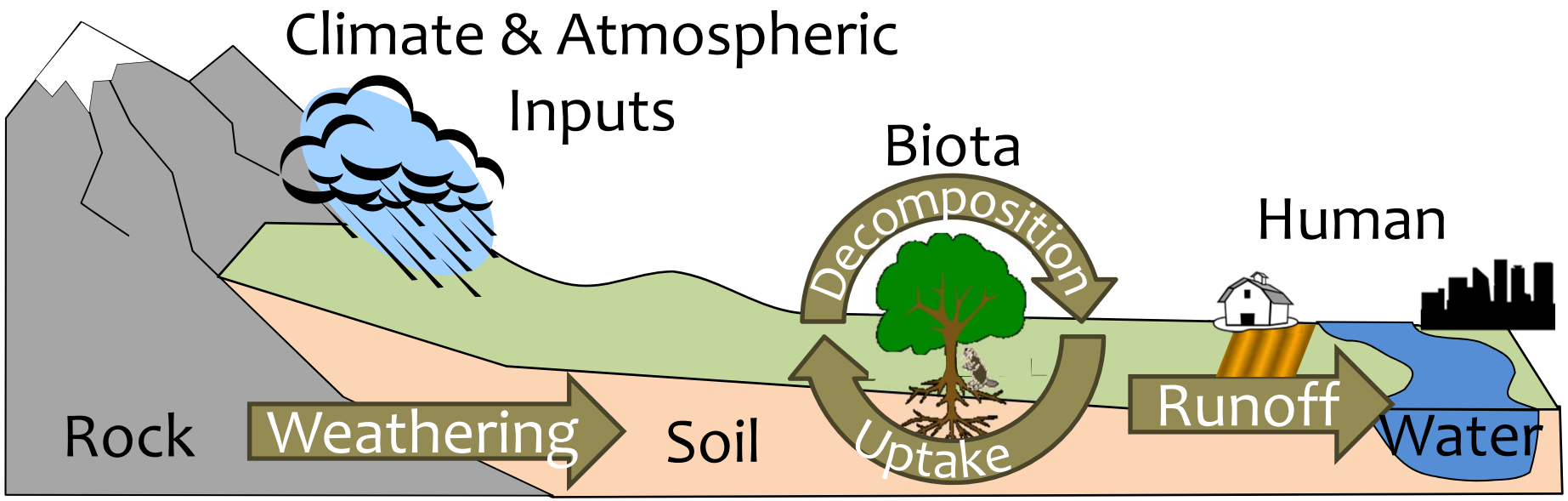
>3,000 µS/cm unsuitable:

- Irrigation
- Industry
- human consumption

To effectively address this challenge, we need to know:

- How much has salinity in streams already been altered by human activities?
- How much more alteration is likely with increasing development and climate change?

Objectives

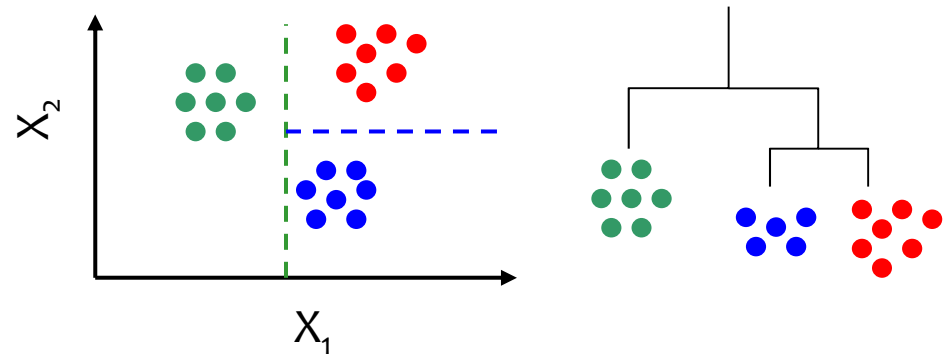


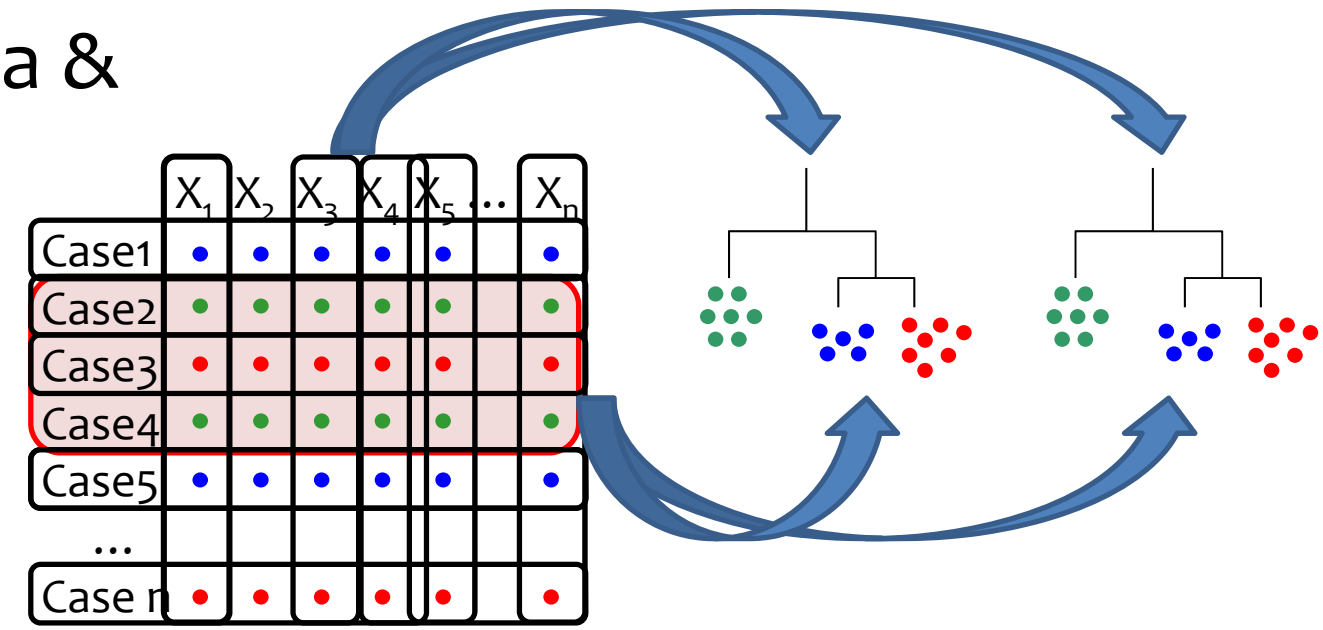
1. Model natural background: Natural EC = f(geology, climate, …)
2. Compare to current salinity: Observed – Natural = EC Alteration
3. Model salinity alteration: EC Alteration = f(urban, ag, mining, …)
4. Predict salinity in 2100: f(future urban, ag, mining, …) = Future EC

Developing Water Chemistry Models

Random Forest (RF) Modeling

- Recursive partitioning creates regression trees (CART)
- Trees built on random subsets of data & predictors
- Unused data used to evaluate

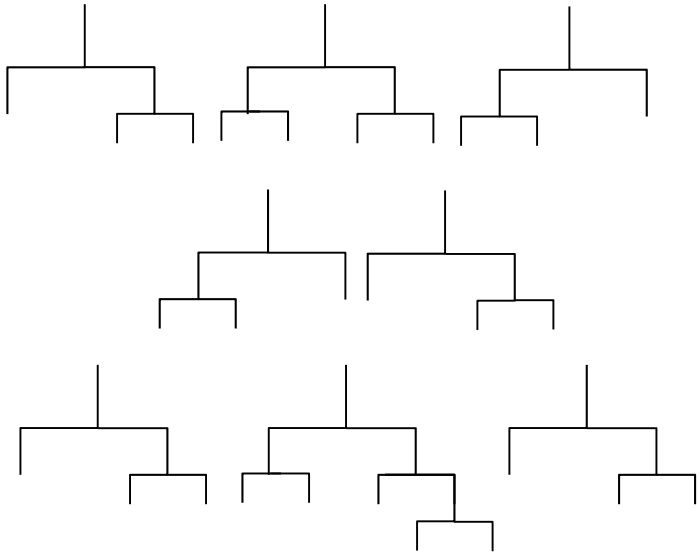




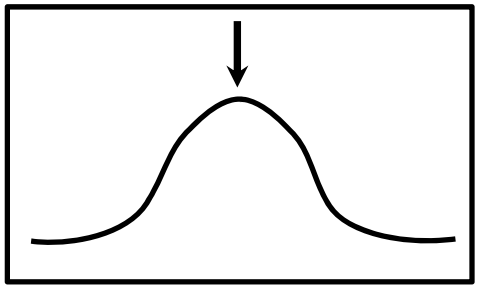
Developing Water Chemistry Models

Random Forest (RF) Modeling

- Build 1000s of trees
- Predicts outcomes by averaging across trees

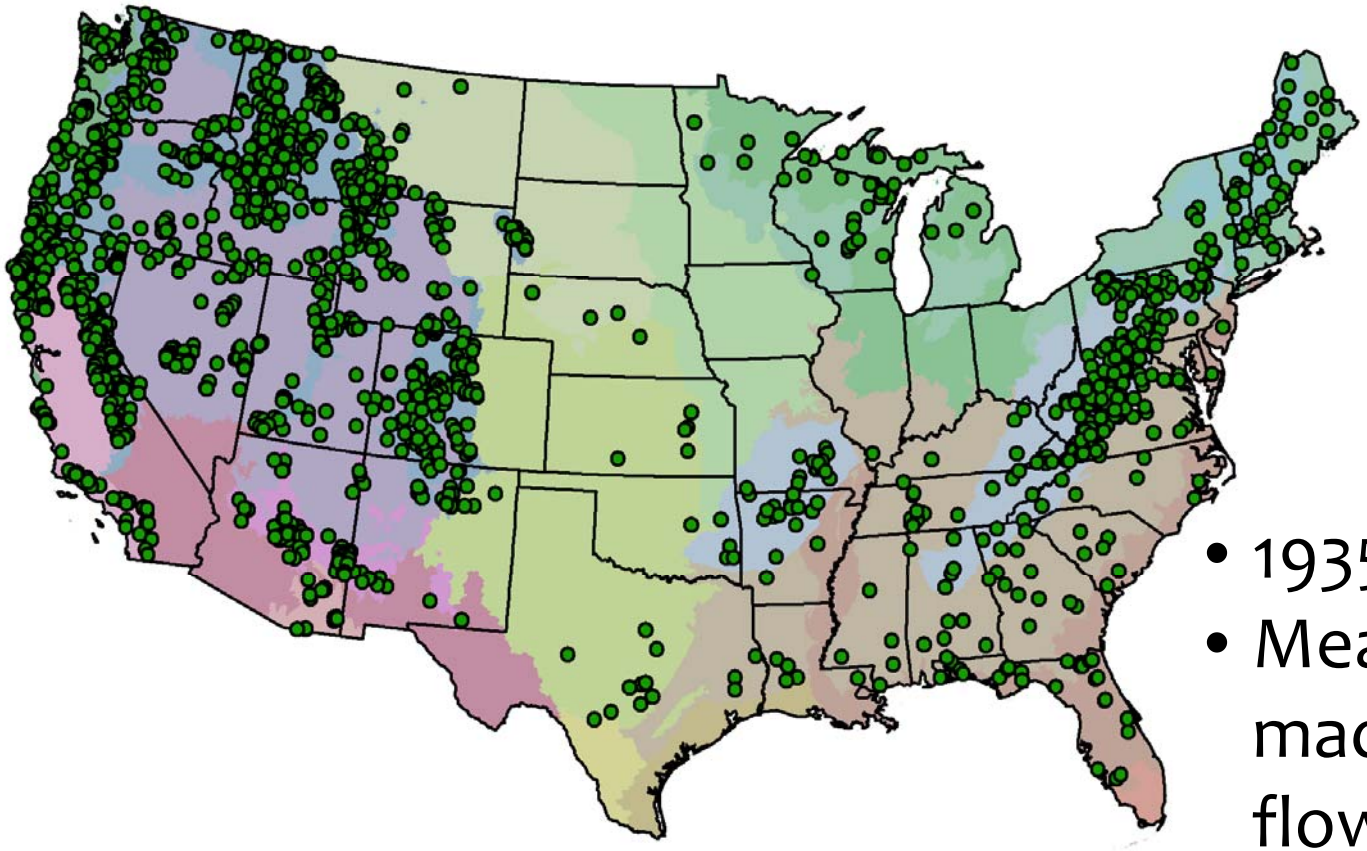


- Advantages:
  - Does not overfit
  - Effectively models non-linear data
  - Incorporates interactions
  - But cannot extrapolate!



Response Data

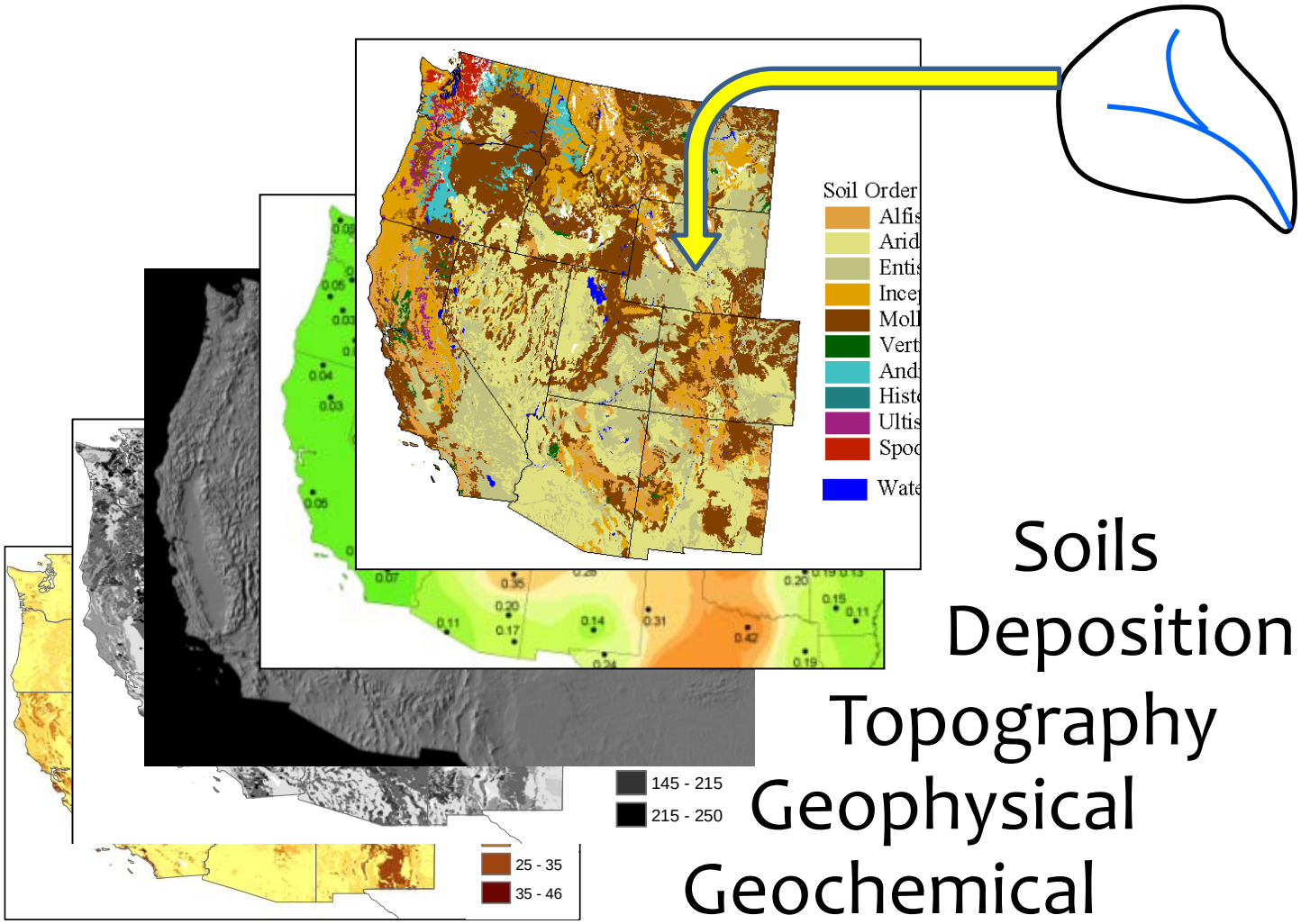
Models based on in situ EC measurements at minimally impacted sites by multiple agencies



- 1935 sites
- Measurements made at “base-flow”

Predictor Data

Watershed averages of 24 **static** predictors



Soils
Deposition
Topography
Geophysical
Geochemical

Predictor Data

Watershed averages of 12 **dynamic** predictors from published climate & land use projections

- IPCC A2 mid-high emission scenario
- Current (2010) and end of century (2100)

Climate

- From Hawkins et al. 2013
- Climate model: NCAR Community Climate System Model v3.0

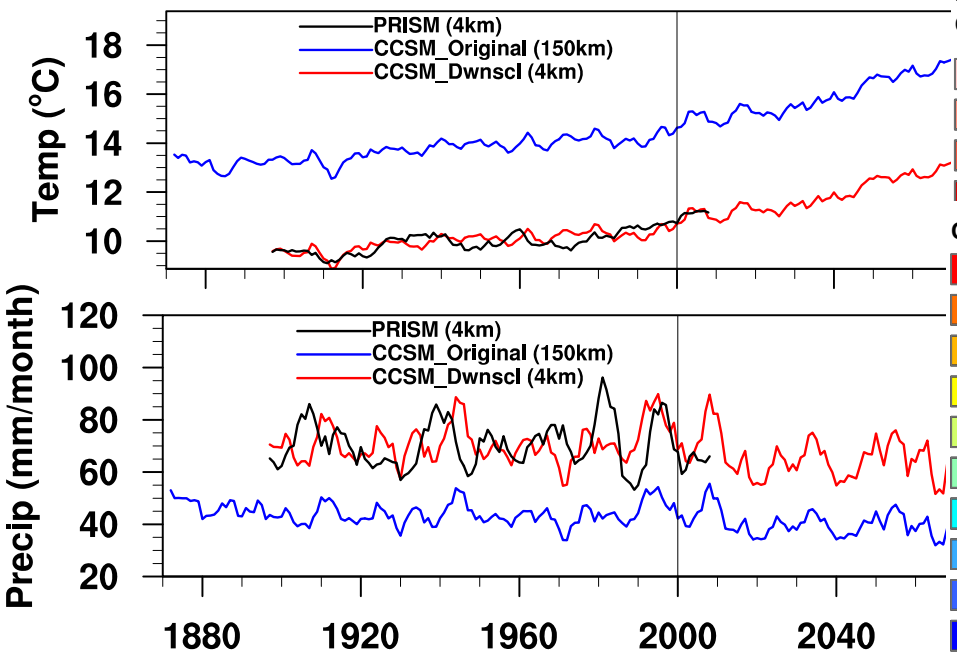
Land use / Land cover

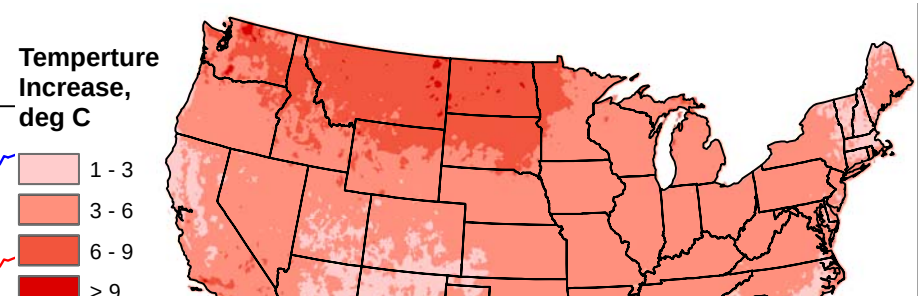
- From Sohl et al. 2014
- USGS FORE-SCE model

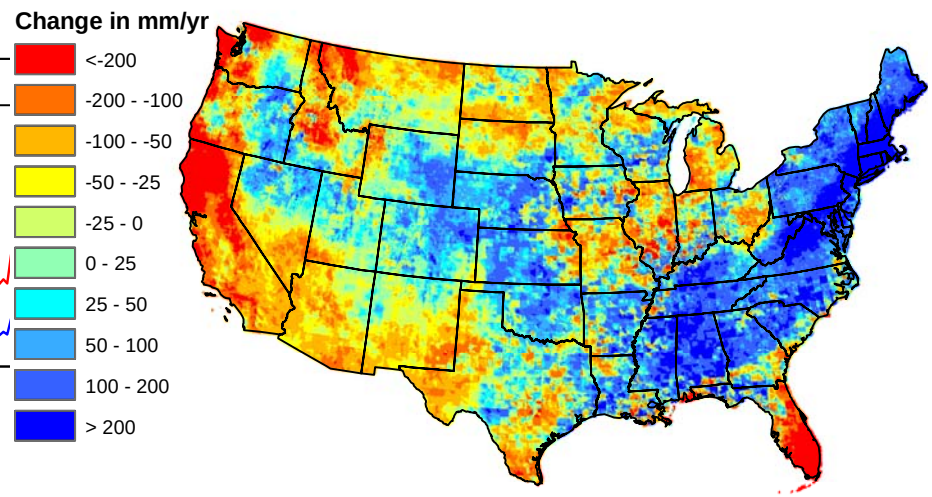
Predictor Data

Climate

- Dynamically downscaled (WRF Regional Climate Model)
- Statistically downscaled (PRISM Climate Data)
- Corrects GCM biases, incorporates topography



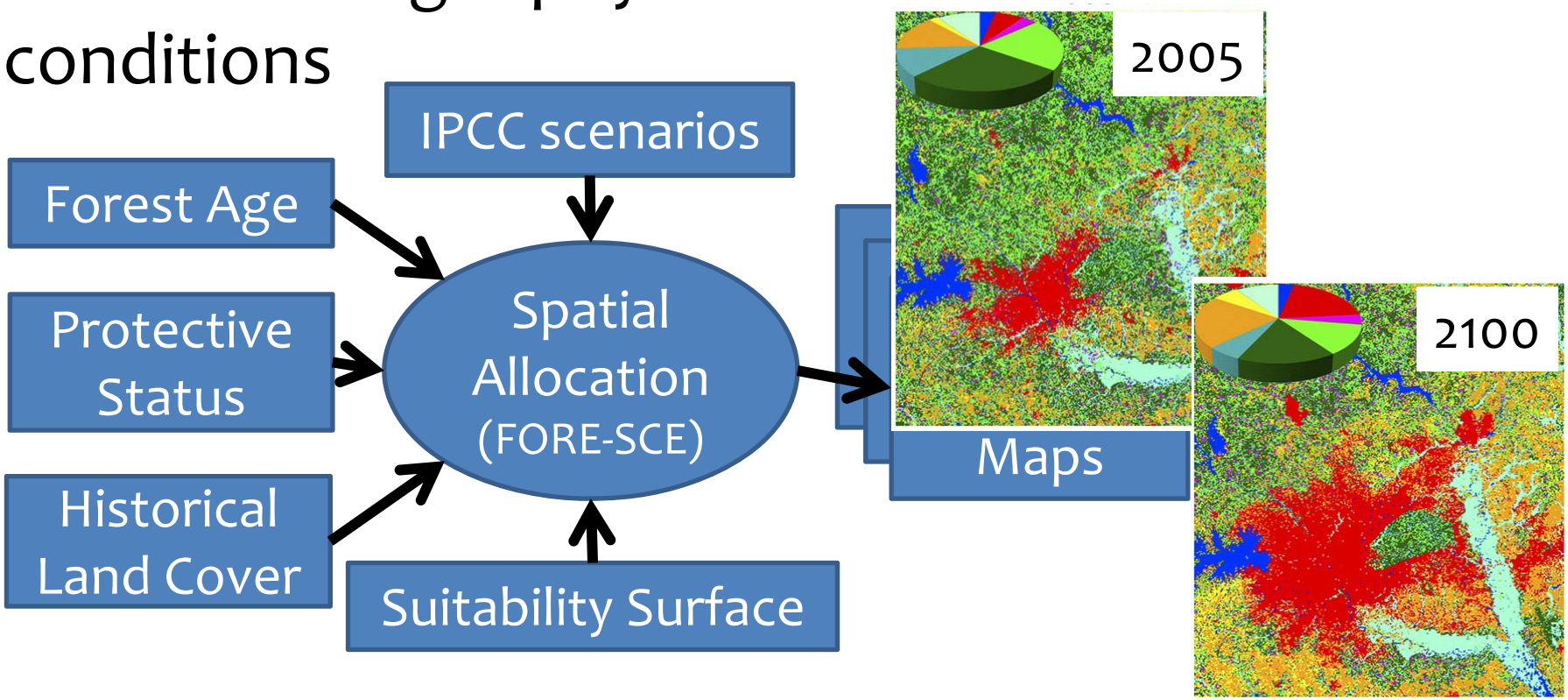




Predictor Data

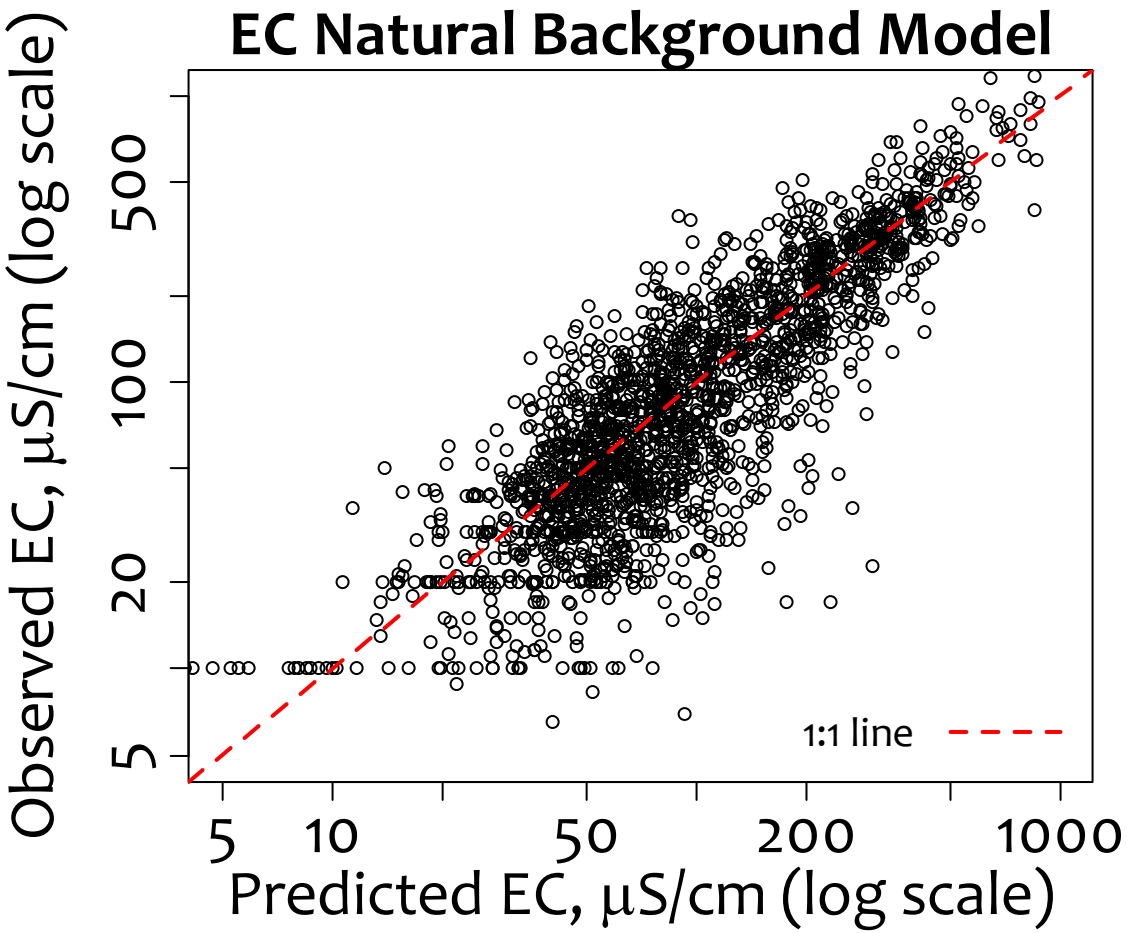
Land use / Land cover

- FORE-SCE model spatially allocates land use change using logistic regression models
- Based on biogeophysical and socioeconomic conditions



Natural Background Salinity Model

Model Performance

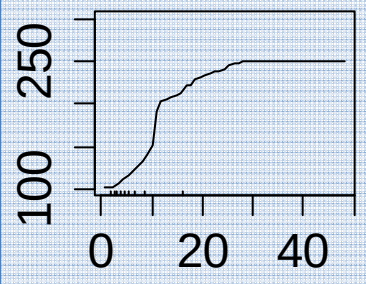
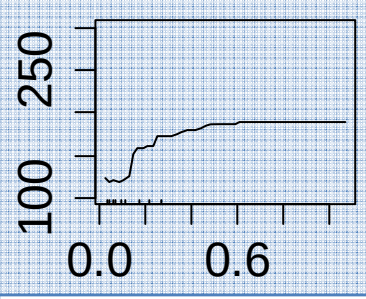
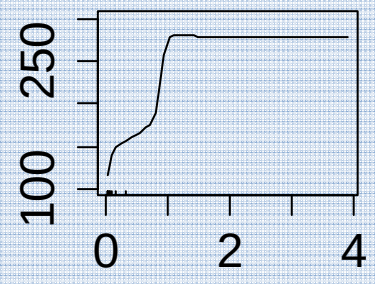
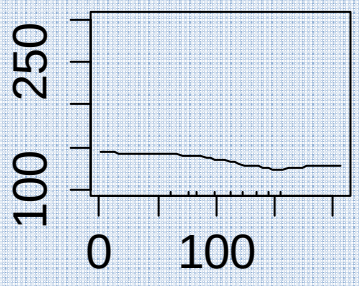


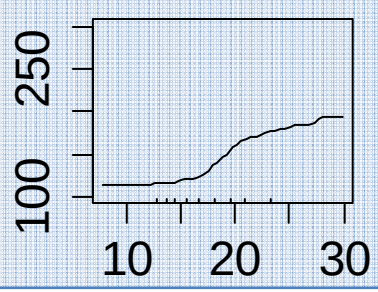
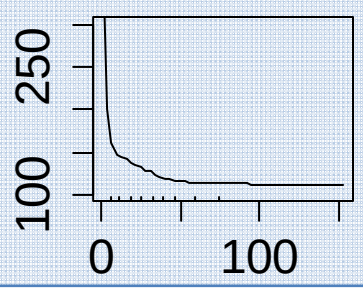
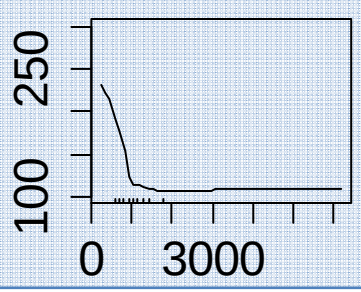
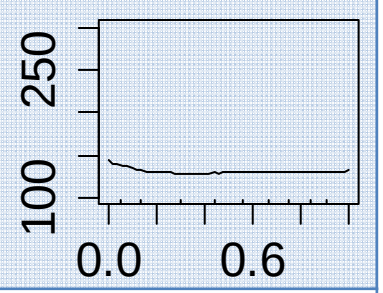
RMSE = 67 µS/cm

R^2 = 0.78

Natural Background Salinity Model

Model Predictors

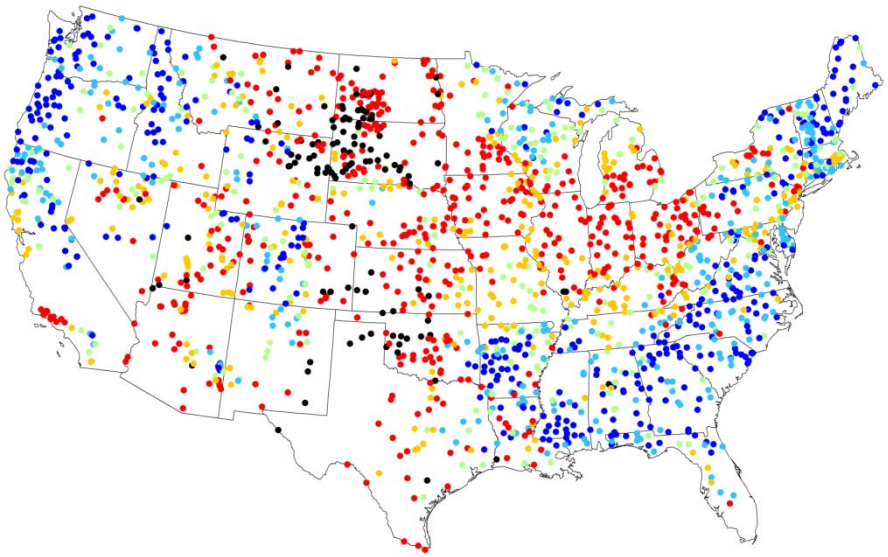
Predictor	Rock % CaO	Atm Ca Dep	Rock % S	Rck Strength
Static Effects				
% MSE ↑	92	53	50	45

Predictor	Max Temp	Min Precip	Yearly Precip	% Conifer
Dynamic Effects				
% MSE ↑	71	60	59	41

Natural Background Salinity

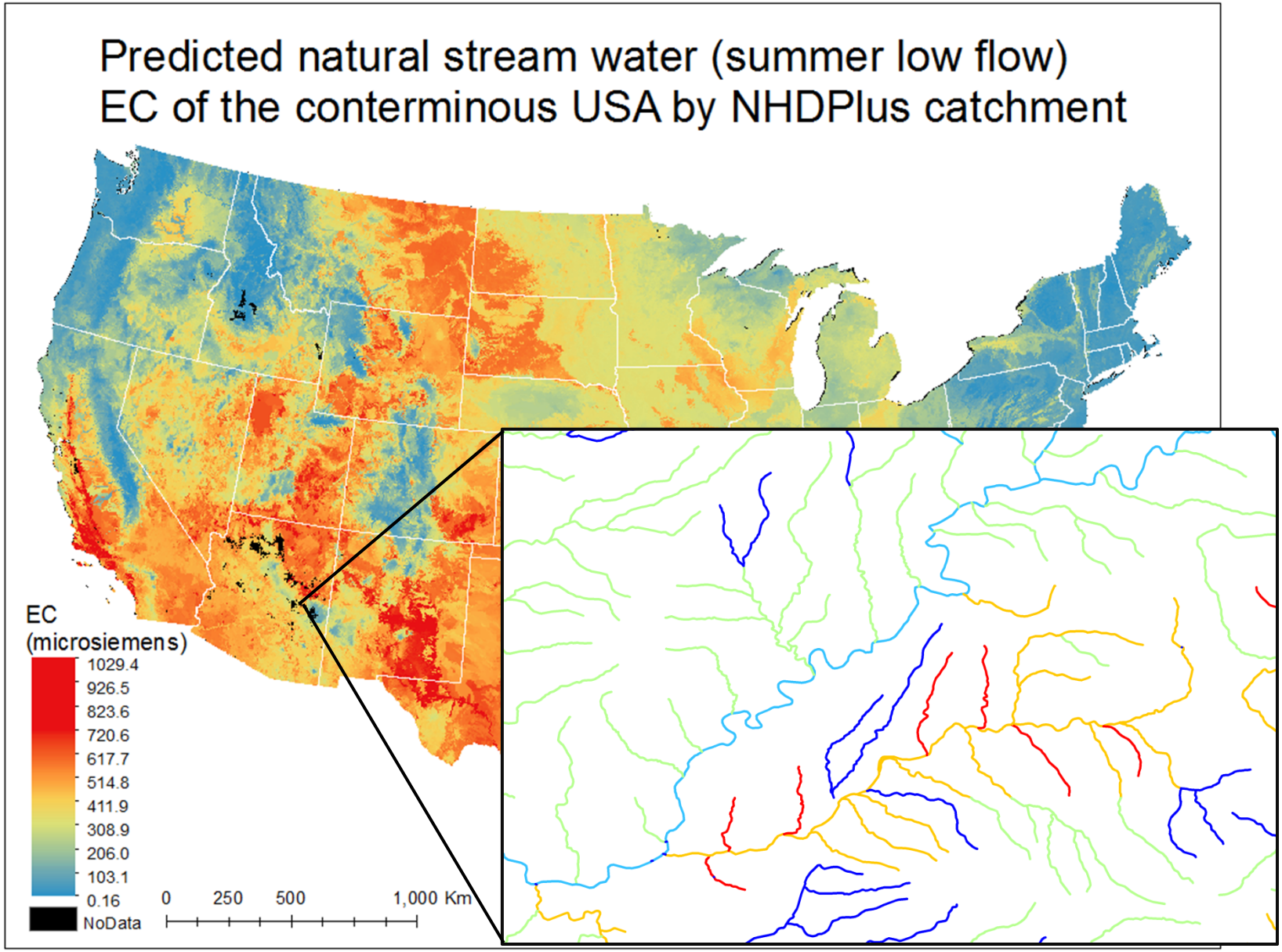
- 2,001 sites, part of the U.S. EPA's National River and Stream Assessment Sites chosen using a probability-based sample design
- Statistically represent U.S. streams

Current Observed EC (µS/cm)



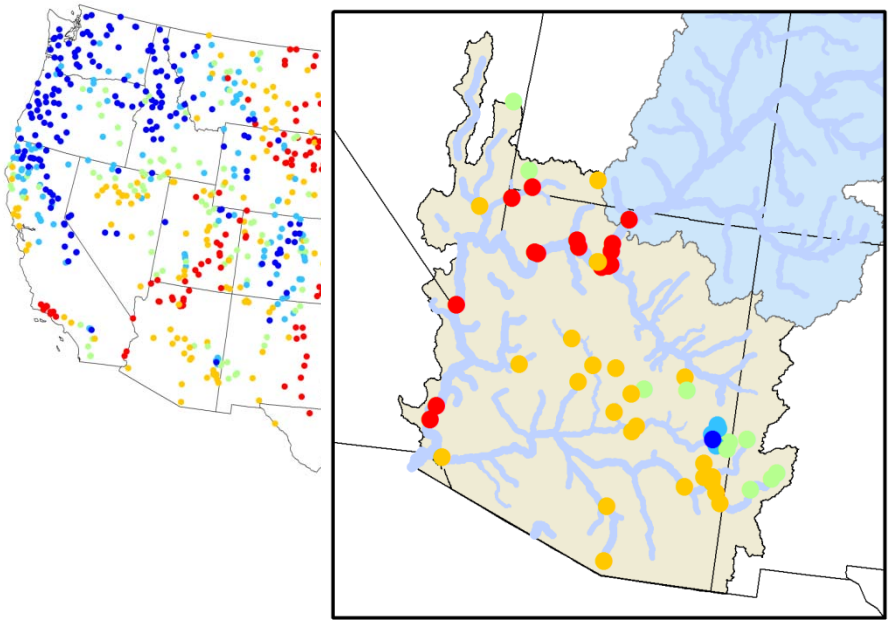
●	< 100	●	200 - 300	●	500 - 2000
●	100 - 200	●	300 - 500	●	> 2000

Natural Background Salinity

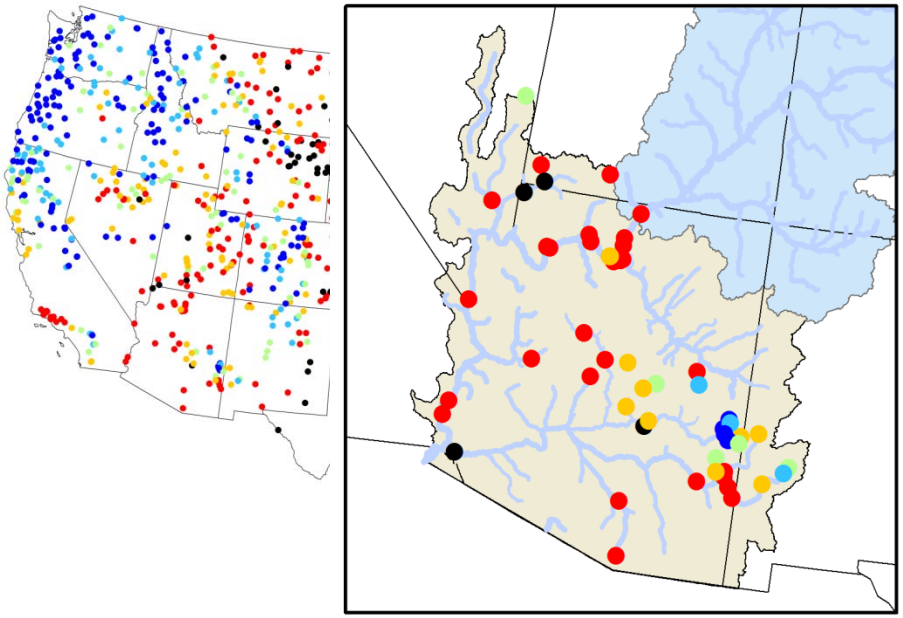


Natural Background Salinity

Predicted Natural Background EC (µS/cm)

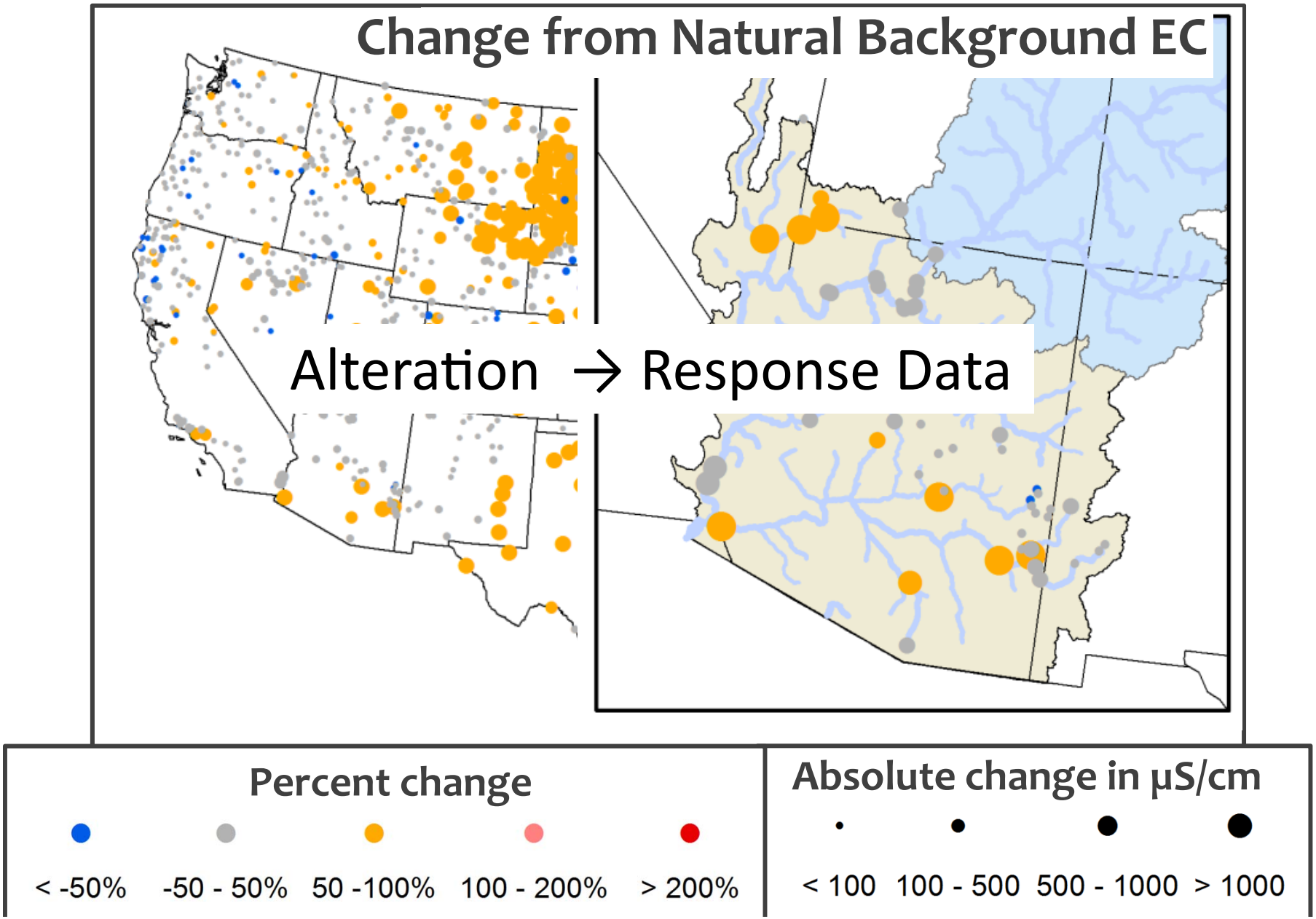


Current Observed EC (µS/cm)



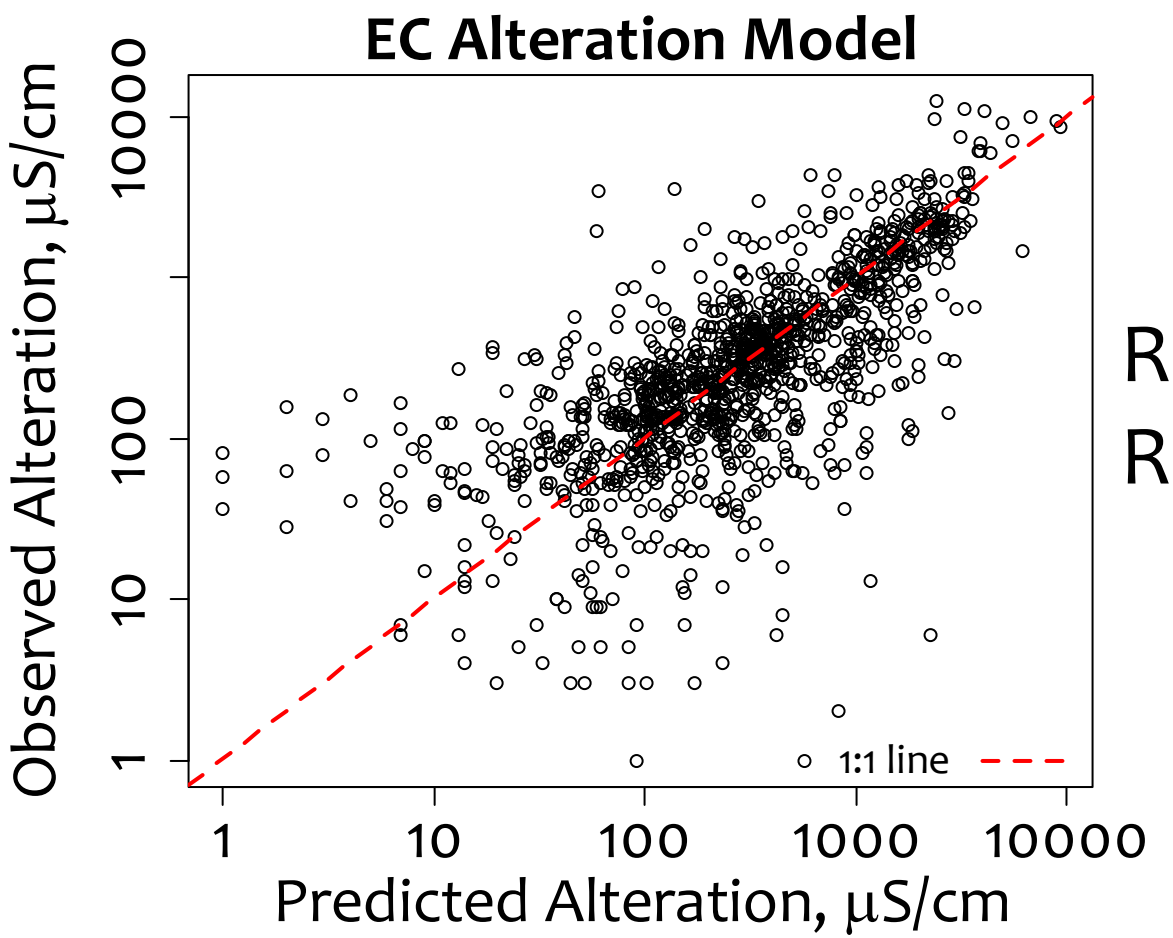
- < 100
- 100 - 200
- 200 - 300
- 300 - 500
- 500 - 2000
- > 2000

Natural Background Salinity



Salinity Alteration Model

Model Performance

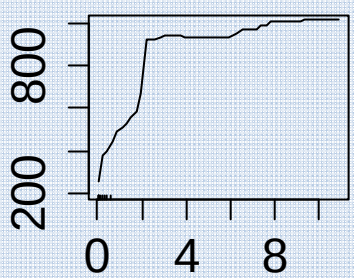
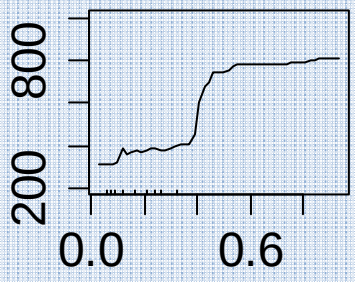
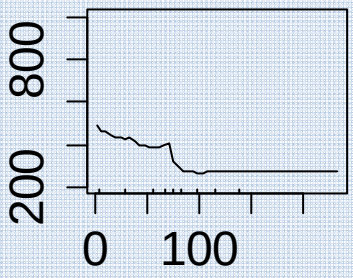
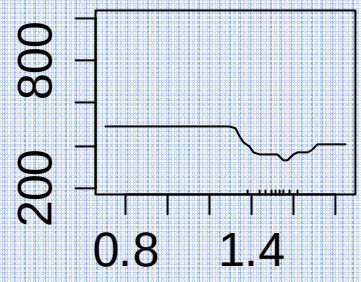


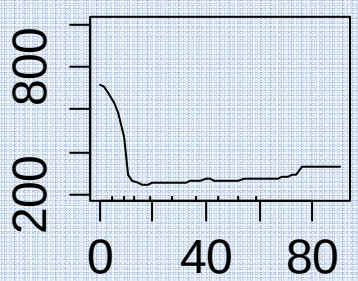
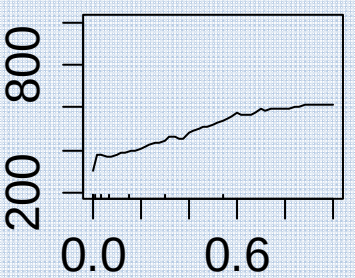
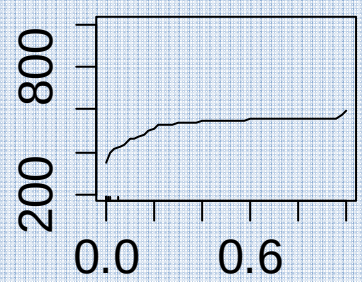
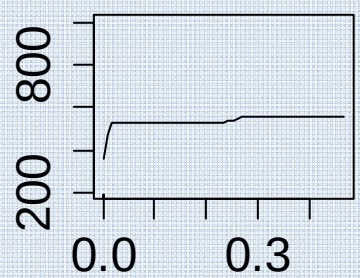
RMSE = 604 µS/cm

R^2 = 0.60

Salinity Alteration Model

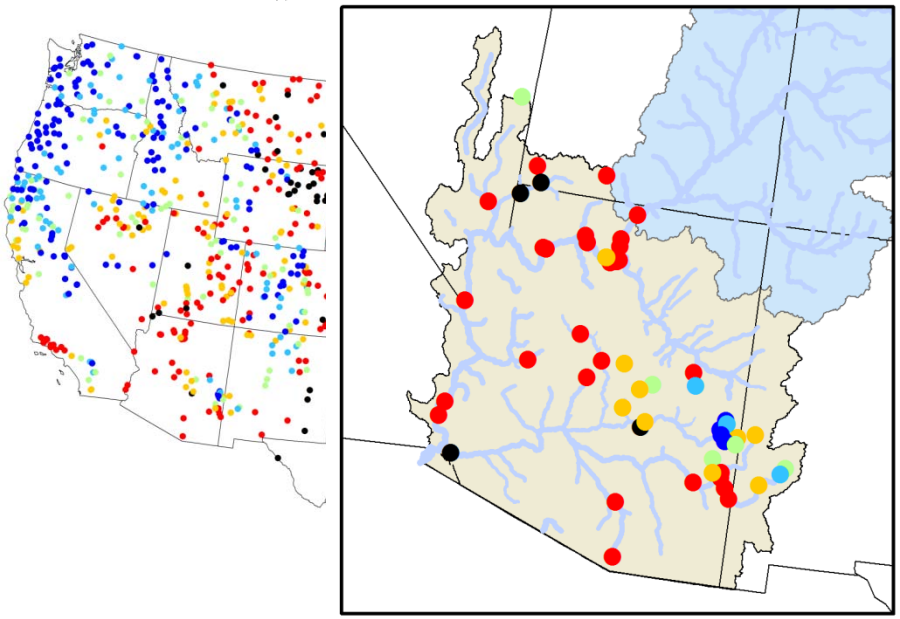
Model Predictors

Predictor	Rock % S	Atm Ca Dep	Rck Strength	Soil Bulk D
Static Effects				
% MSE ↑	37	31	25	23

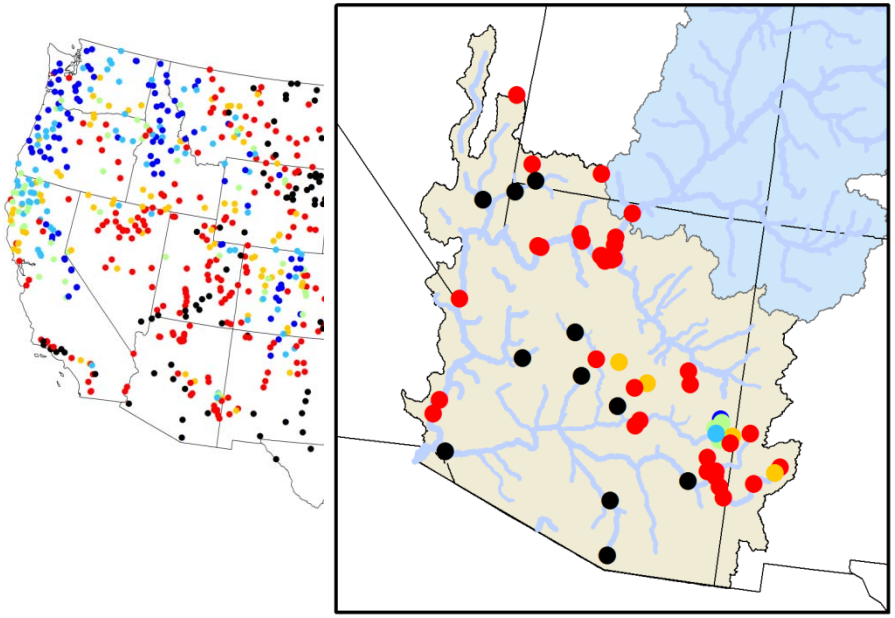
Predictor	Min Precip	% Crops	% Urban	% Mining
Dynamic Effects				
% MSE ↑	38	26	19	12

End of Century Salinity

Current Observed EC (µS/cm)

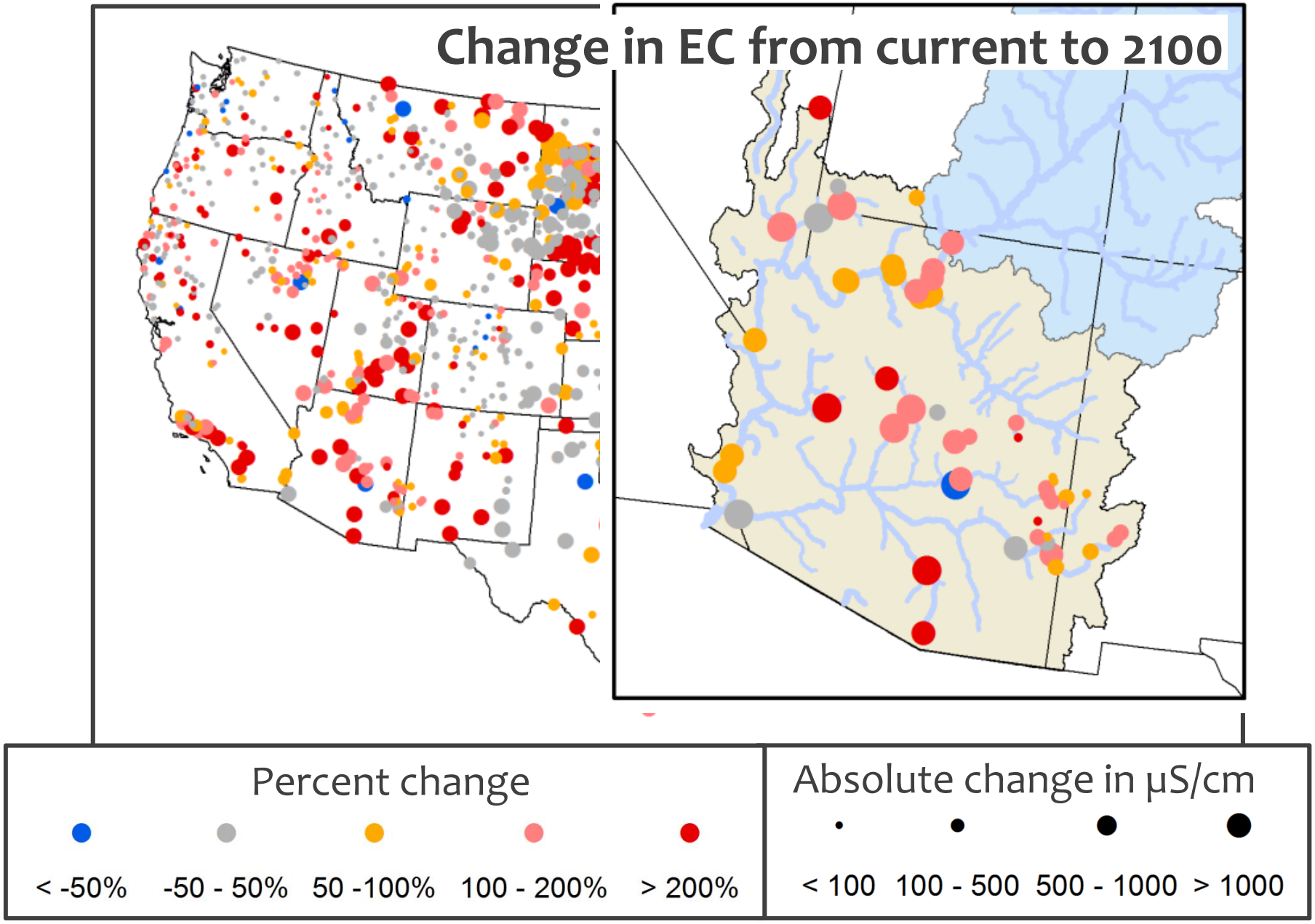


Predicted End of Century EC (µS/cm)



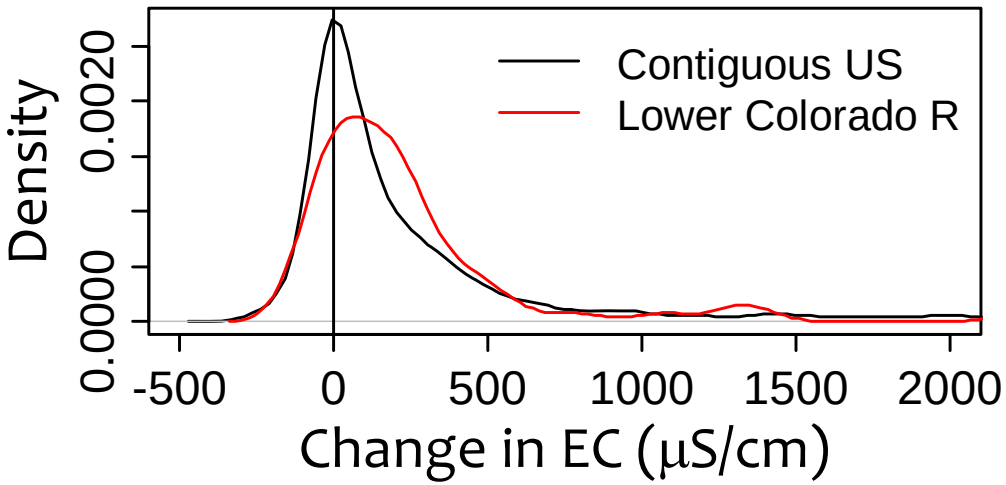
●	< 100	●	200 - 300	●	500 - 2000
●	100 - 200	●	300 - 500	●	> 2000

End of Century Salinity



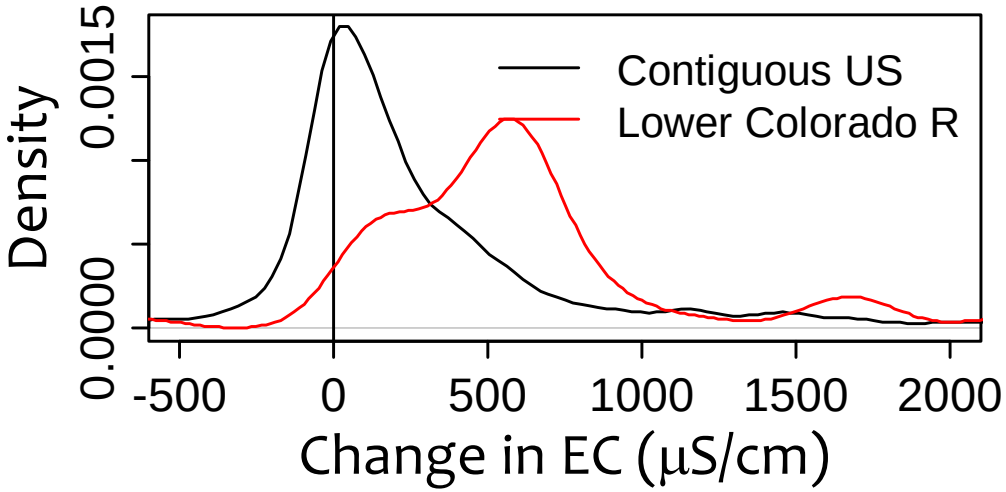
Change in Salinity

Natural Background to Current



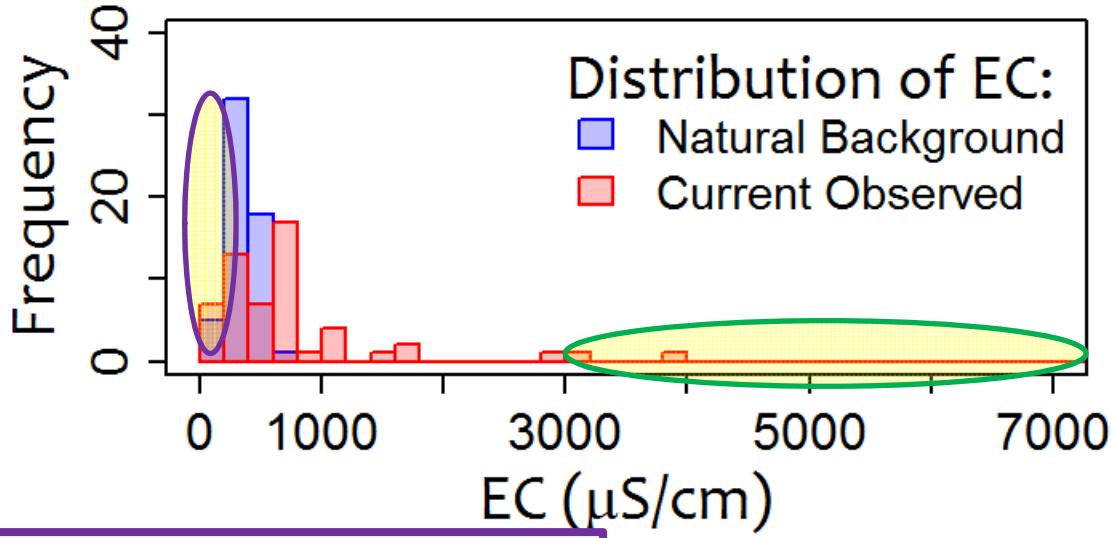
	US	Lower Colorado
Mean	366	523
Median	86	162

Current to End of Century



	US	Lower Colorado
Mean	234	732
Median	124	602

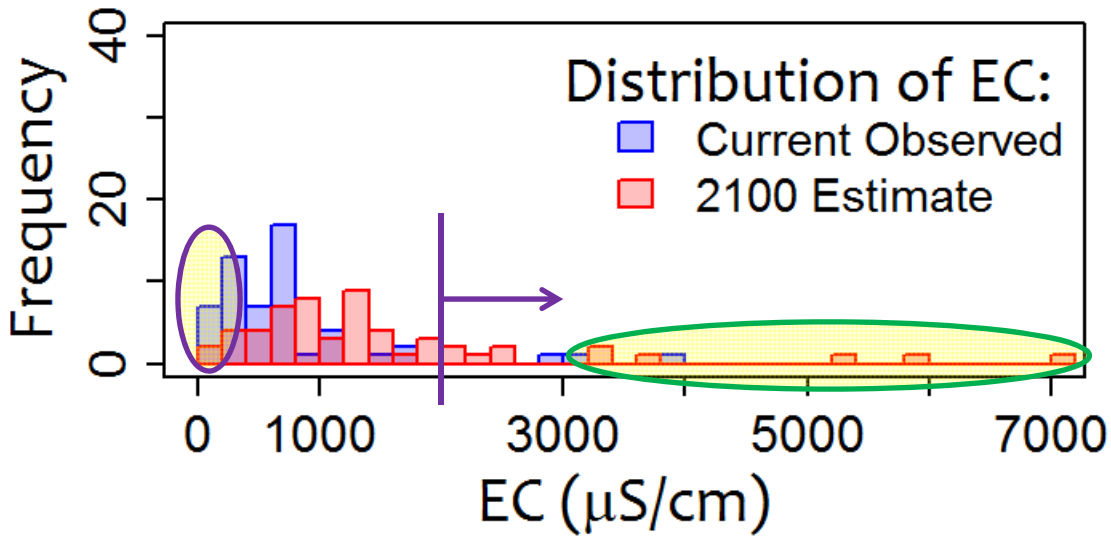
Change in Salinity



EC > 3,000 µS/cm
Human use threshold
Currently - 3% of sites
2100 – 11% of sites

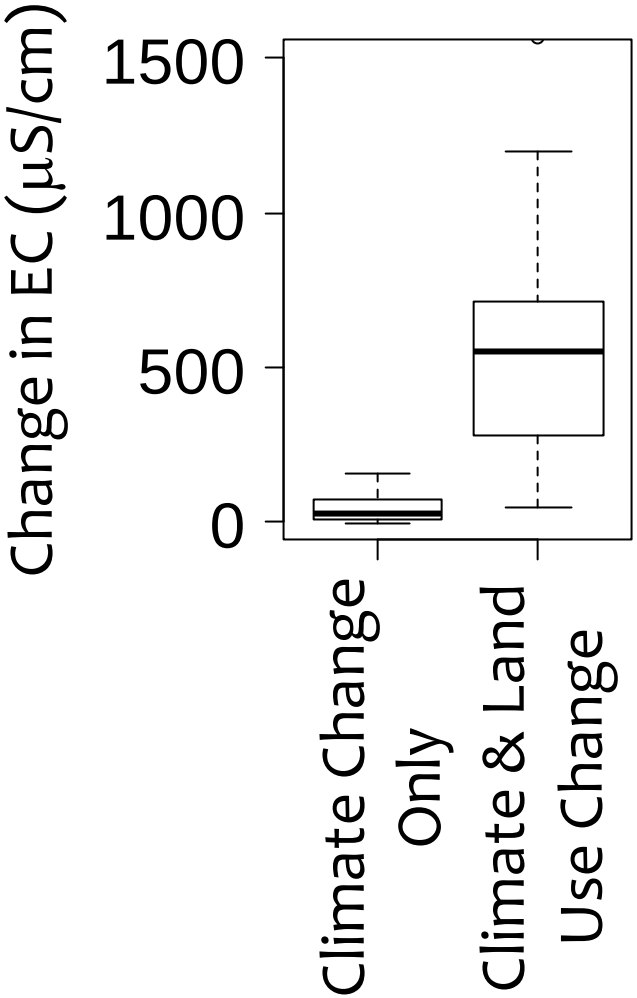
EC < 300 µS/cm
Extirpation Threshold
Currently – 30% of sites
2100 – 9% of sites

18% of sites > 2000 µS/cm
50% Extirpation



Change in Salinity

- We calculated the effects of climate change on salinity separate from the total change
- Climate change accounts for < 10% of changes in salinity in 2100



Conclusions

- Median salinity already increased 162 µS/cm in lower Colorado River Basin
- Future increases in median could be as large as 600 µS/cm
- Climate change only accounts for < 10% of change by itself
- 2/3 of low salinity habitat may be lost by end of century, adding additional pressure to stressed communities

Questions?

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