Establishing Thermal Reference Conditions: Development of Stream Temperature Models in Support of Biological Monitoring and Assessment in the Western USA

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Background:

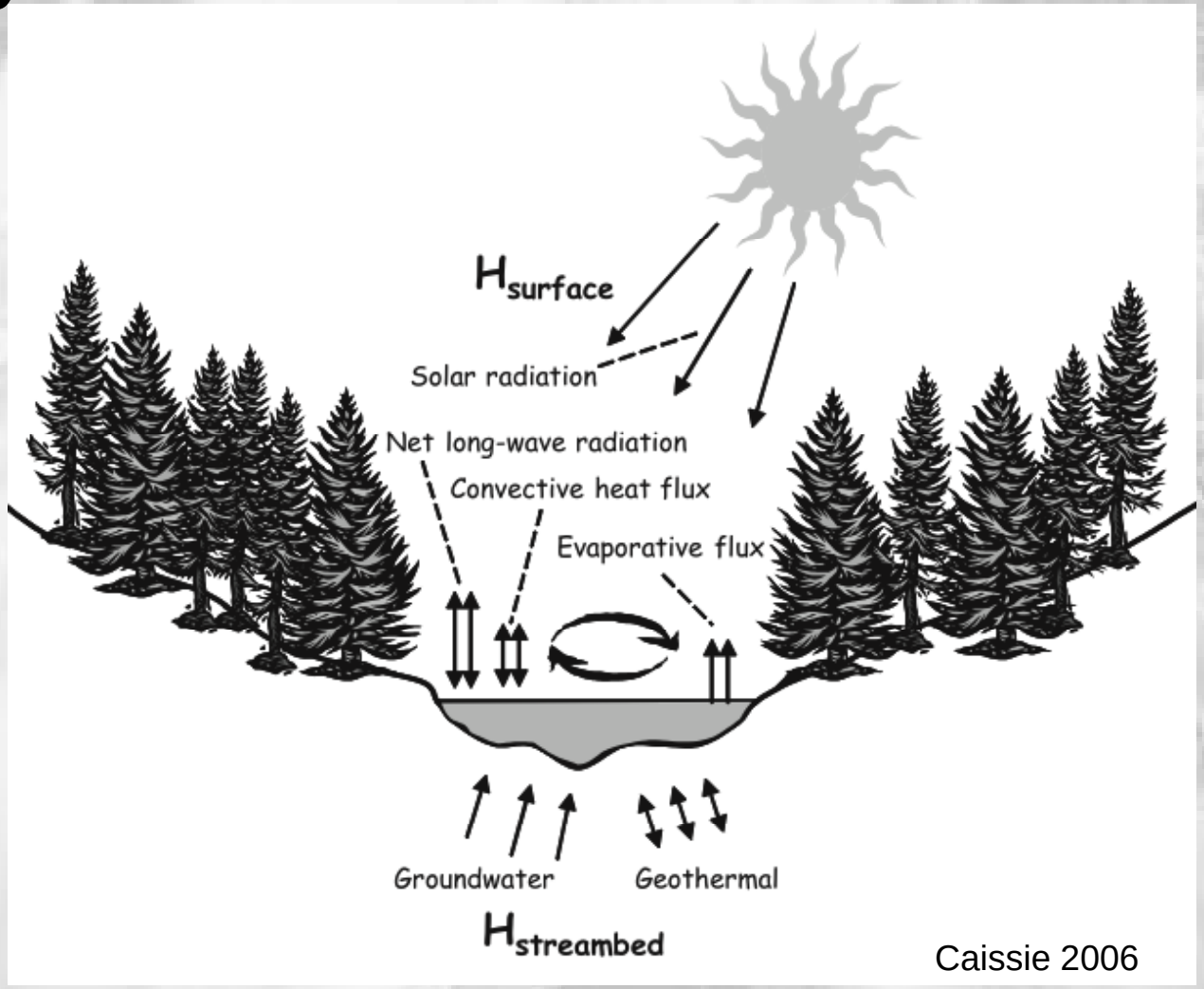
- Stream temperature affects almost all aspects of stream ecosystems.
- Critical need to set meaningful water temperature standards – Need to establish baseline.
- Currently cannot predict well the **natural** thermal condition at unmeasured streams across the USA.

Modeling is needed to:

- Account for spatial heterogeneity.
- Better estimate ‘range of natural variation’.
- Predict biota with a variable that is known to affect taxonomic distributions.

Three common temperature modeling techniques:

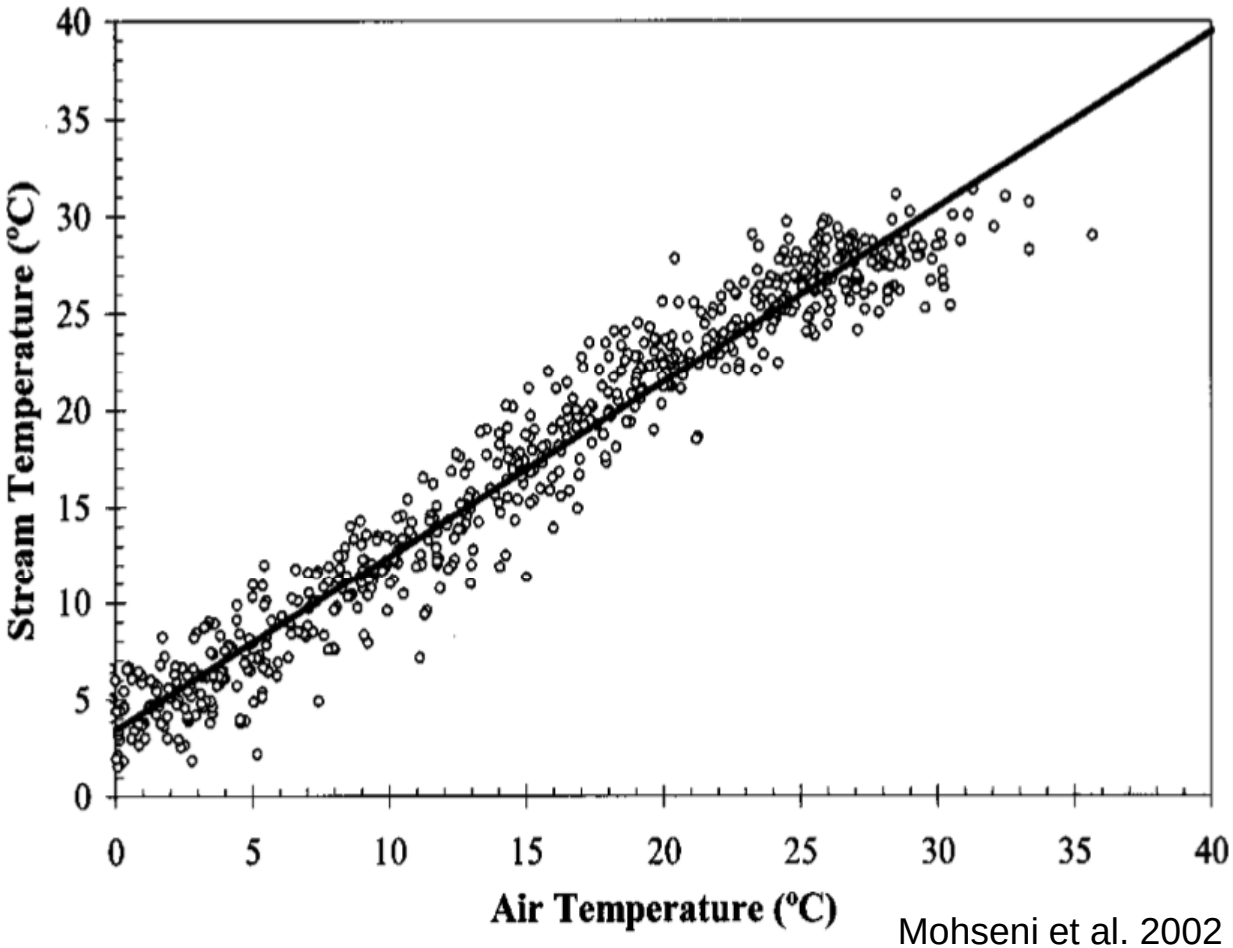
1. Physical models



Caissie 2006

Three common temperature modeling techniques:

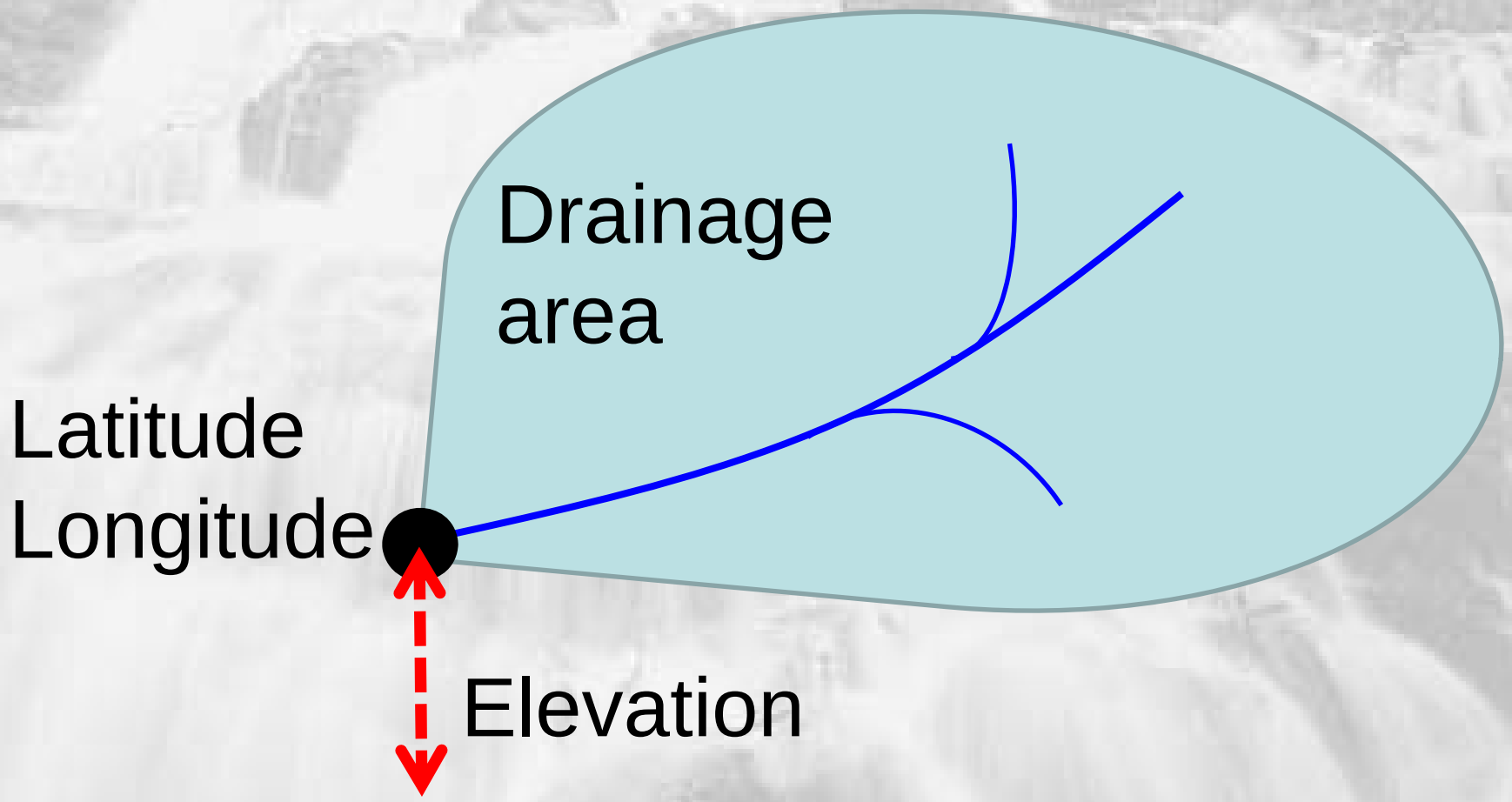
2. Empirical models



Mohseni et al. 2002

Three common temperature modeling techniques:

3. Simple geography-based models



Three common temperature modeling techniques:

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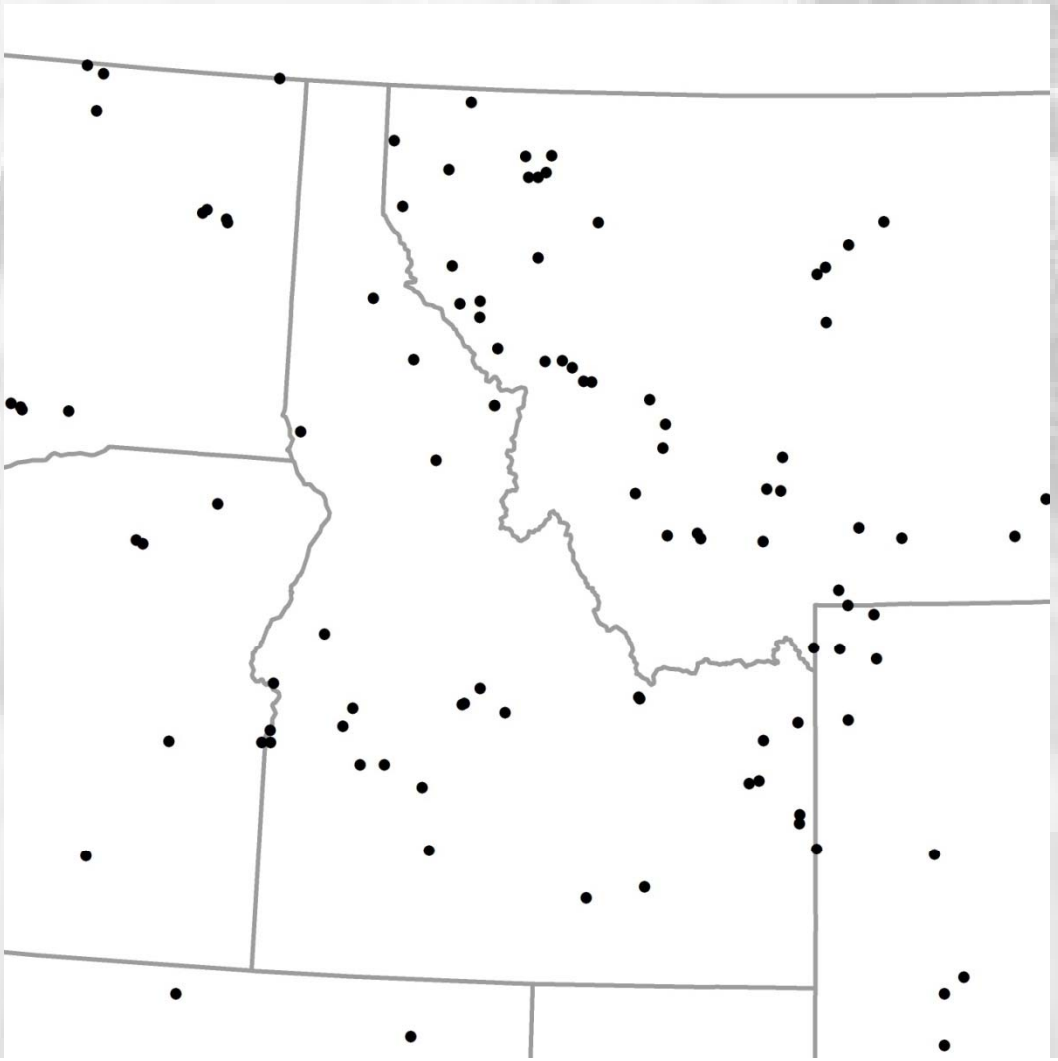
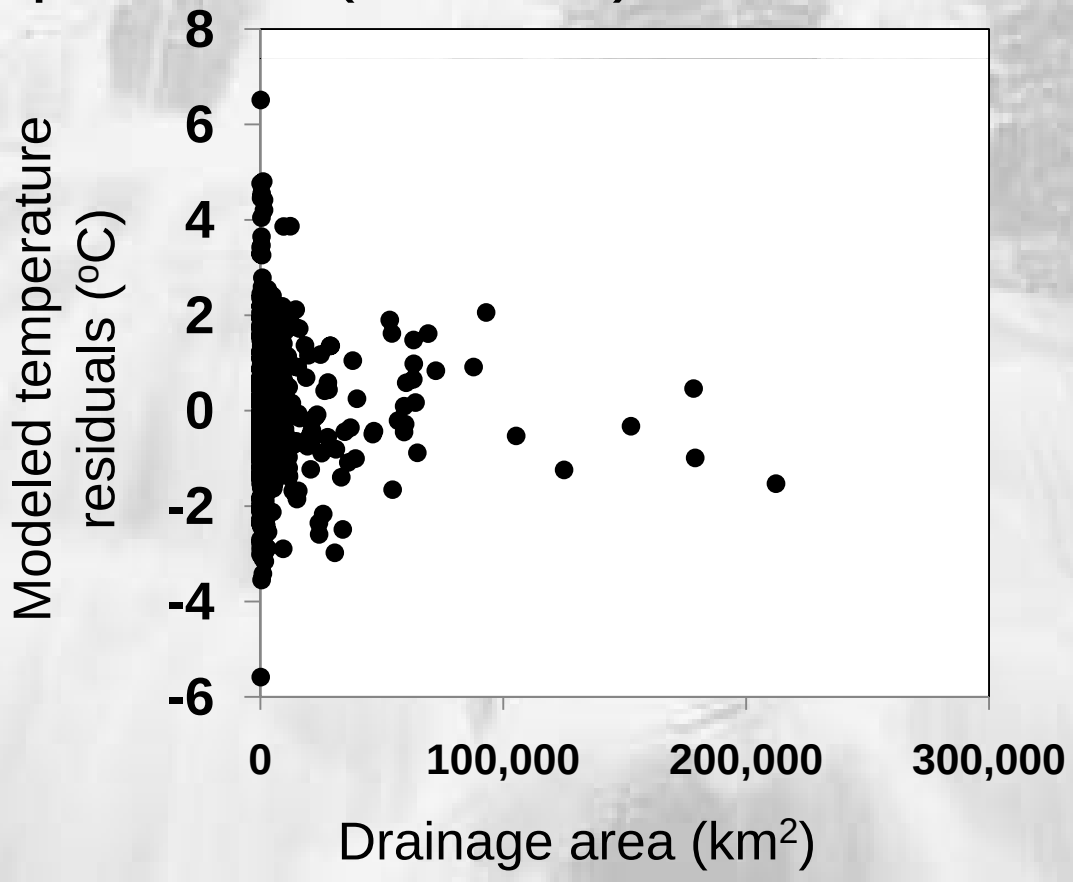


Three common temperature modeling techniques:

3. Simple geography-based models

– Accounts for ~75% in mean annual stream temperature (XTEMP)

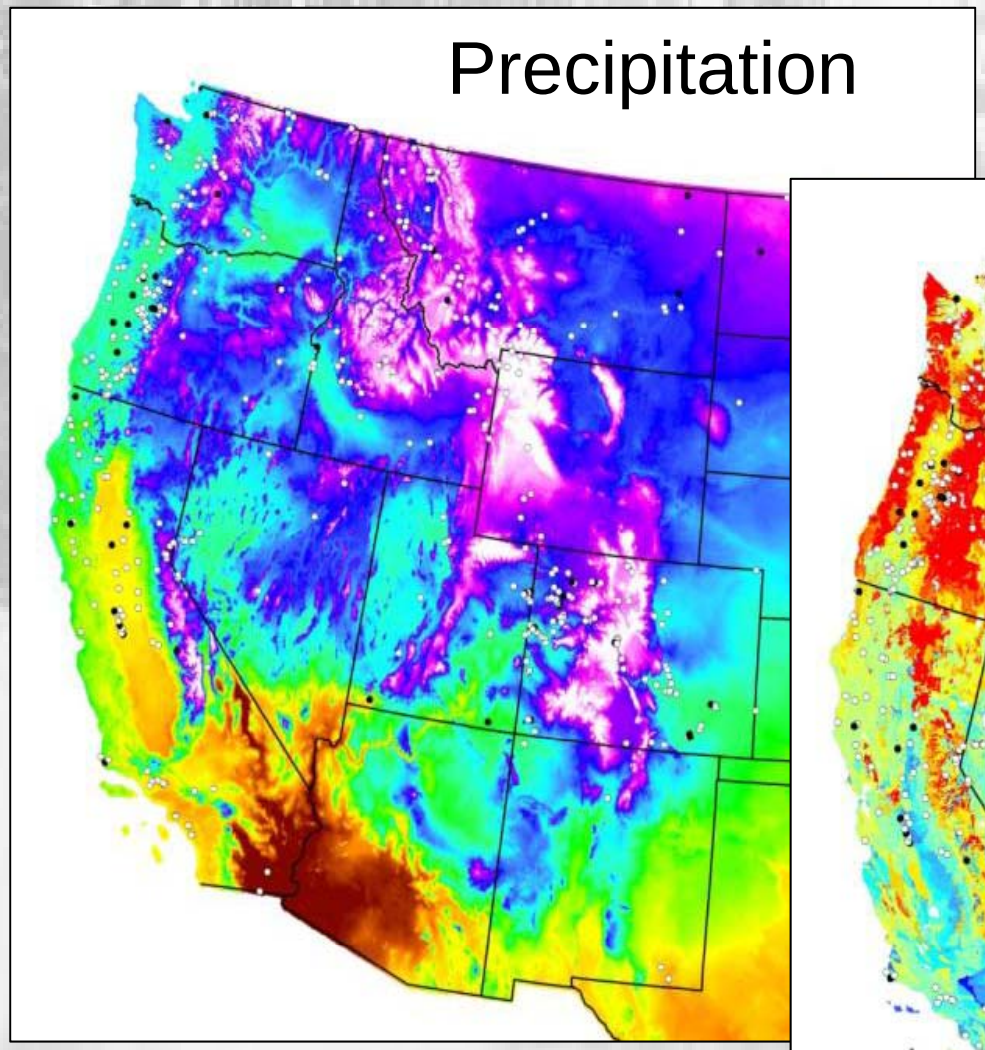


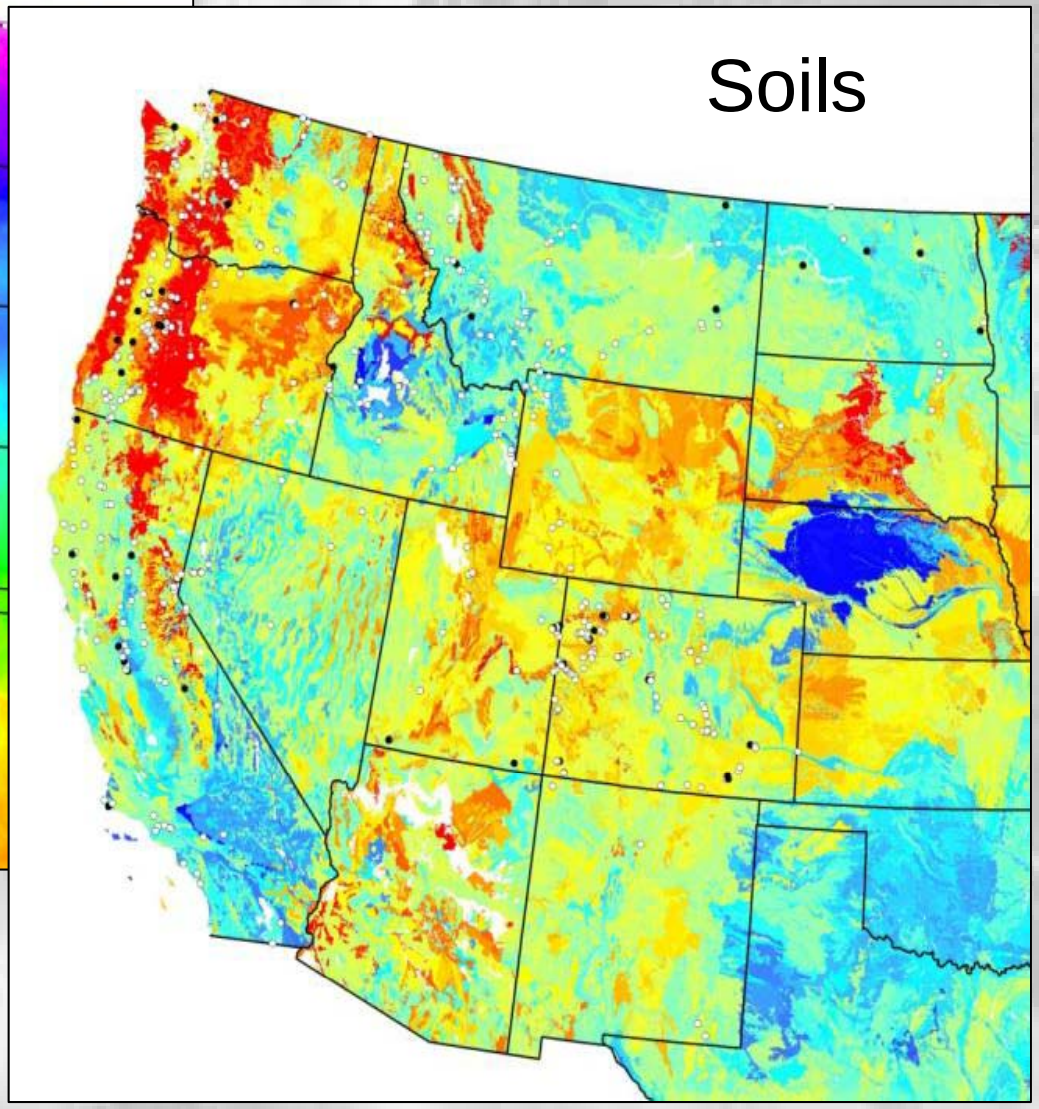
Outline of talk:

- Simple west-wide temperature model with easily obtained GIS predictors.
- Does temperature modeling improve predictions of biota?
- Current and future work to improve upon regional temperature models.

Improve empirical site-specific stream temperature models by adding simple GIS variables

- Latitude, Longitude
- Elevation
- Watershed size
- Climate (PRISM)
- Soils (STATSGO)
- Geology
- Catchment shape

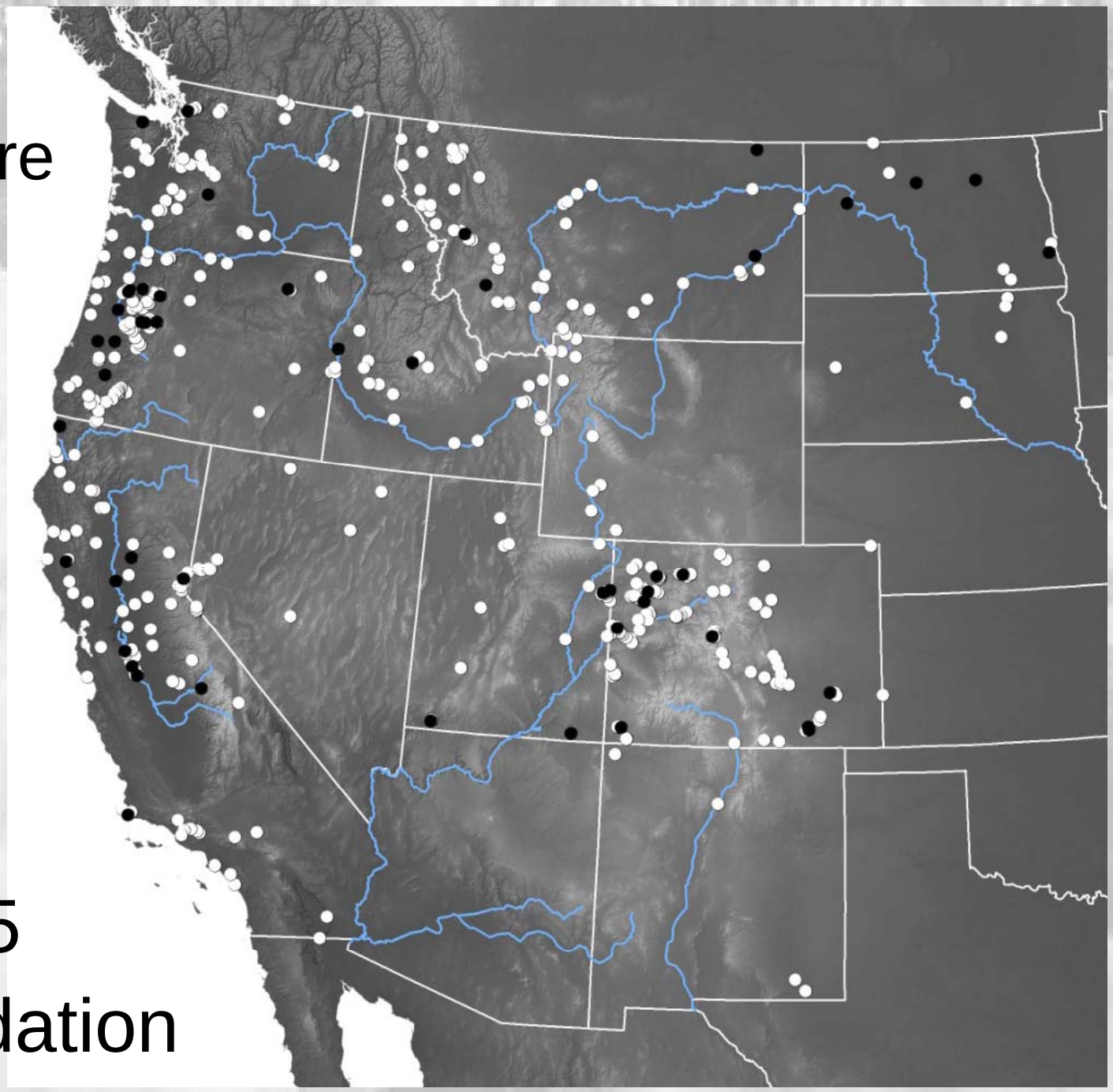

Precipitation


Soils

Approach and results to date

- Initial set of 455 stream sites in the western USA.

Western temperature modeling



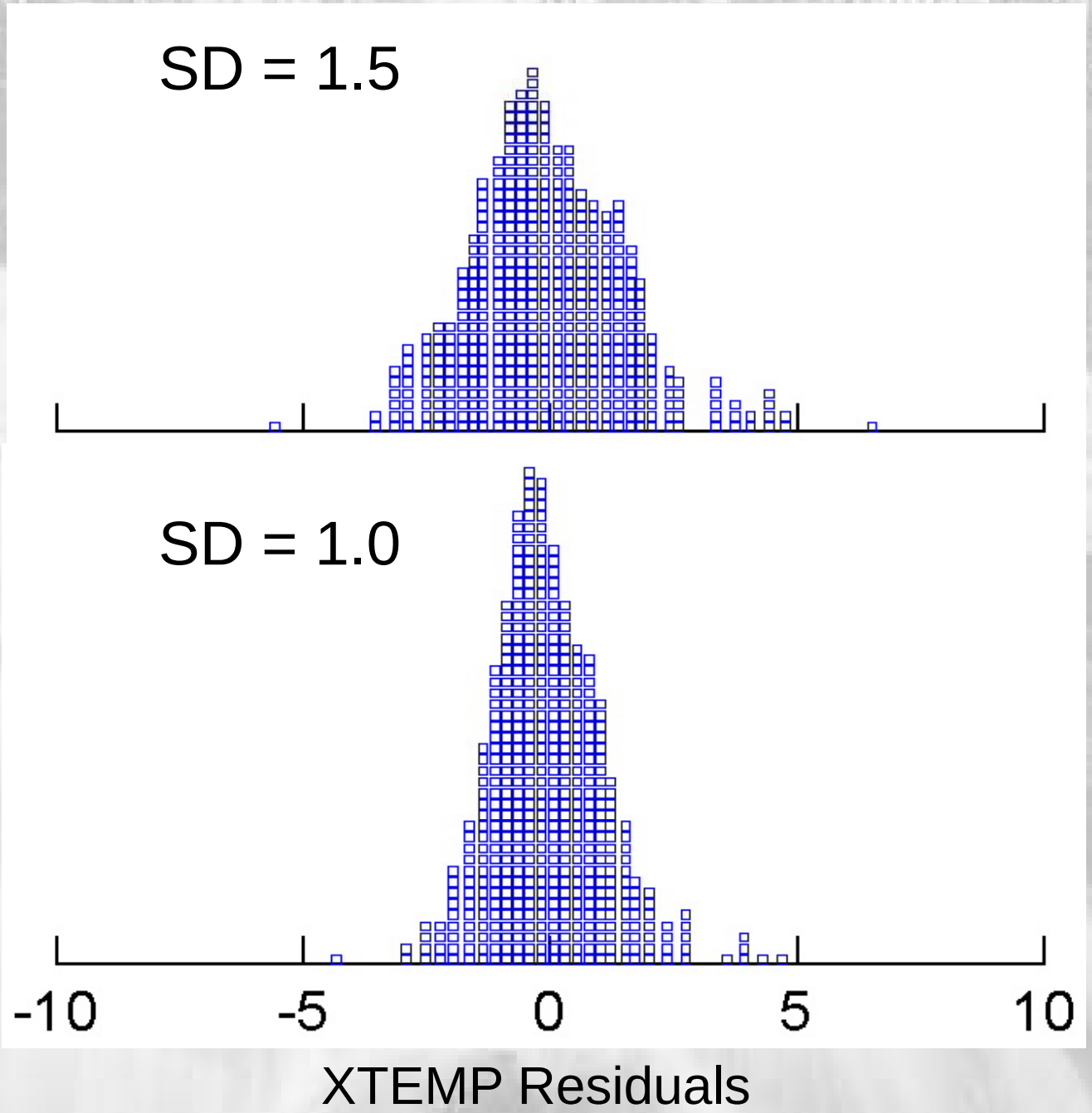
- N = 455
- 50 validation

Approach and results to date

- Initial set of 455 stream sites in the western USA.
- Created 3 sets of models:
  - MLR based on geography/physiography
  - MLR based on climate and watershed attributes
  - Random Forest models based on climate and watershed attributes

Modeling XTEMP (MLR)

Model	Predictors	R^2	RMSE
Geography	elevation latitude WS area longitude	0.75	1.3^o
Climate-WS	elevation **mean air temperature** latitude WS area **# of frost-free days** others	0.86	1.0^o


Geography model
SD = 1.5
Climate-WS model
SD = 1.0
-10
-5
0
5
10
XTEMP Residuals

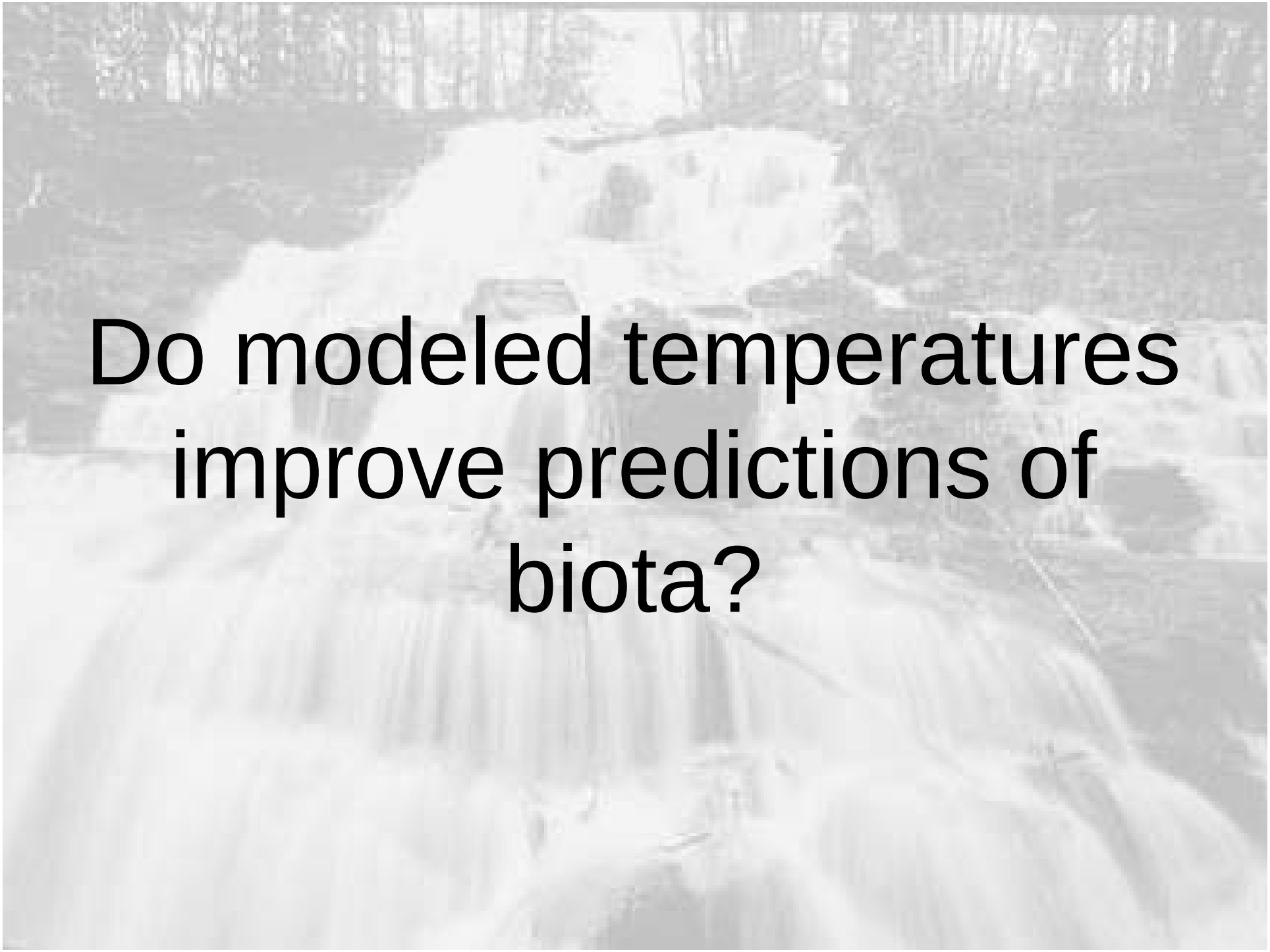
Variable	Predictors	R^2	RMSE
XTEMP	elevation mean air temperature Latitude # of frost-free days WS area	0.86	1.0^{o}
SUMMER	maximum air temperature length of growing season latitude soil bulk density WS area	0.73	2.2^{o}
WINTER	mean air temperature minimum air temperature soil permeability % granitic geology depth to water table	0.75	1.7^{o}

R^2

Model	XYEAR	SUMMER	WINTER
Linear	0.86	0.73	0.75
RF	0.97	0.95	0.96
Difference	0.11	0.22	0.21

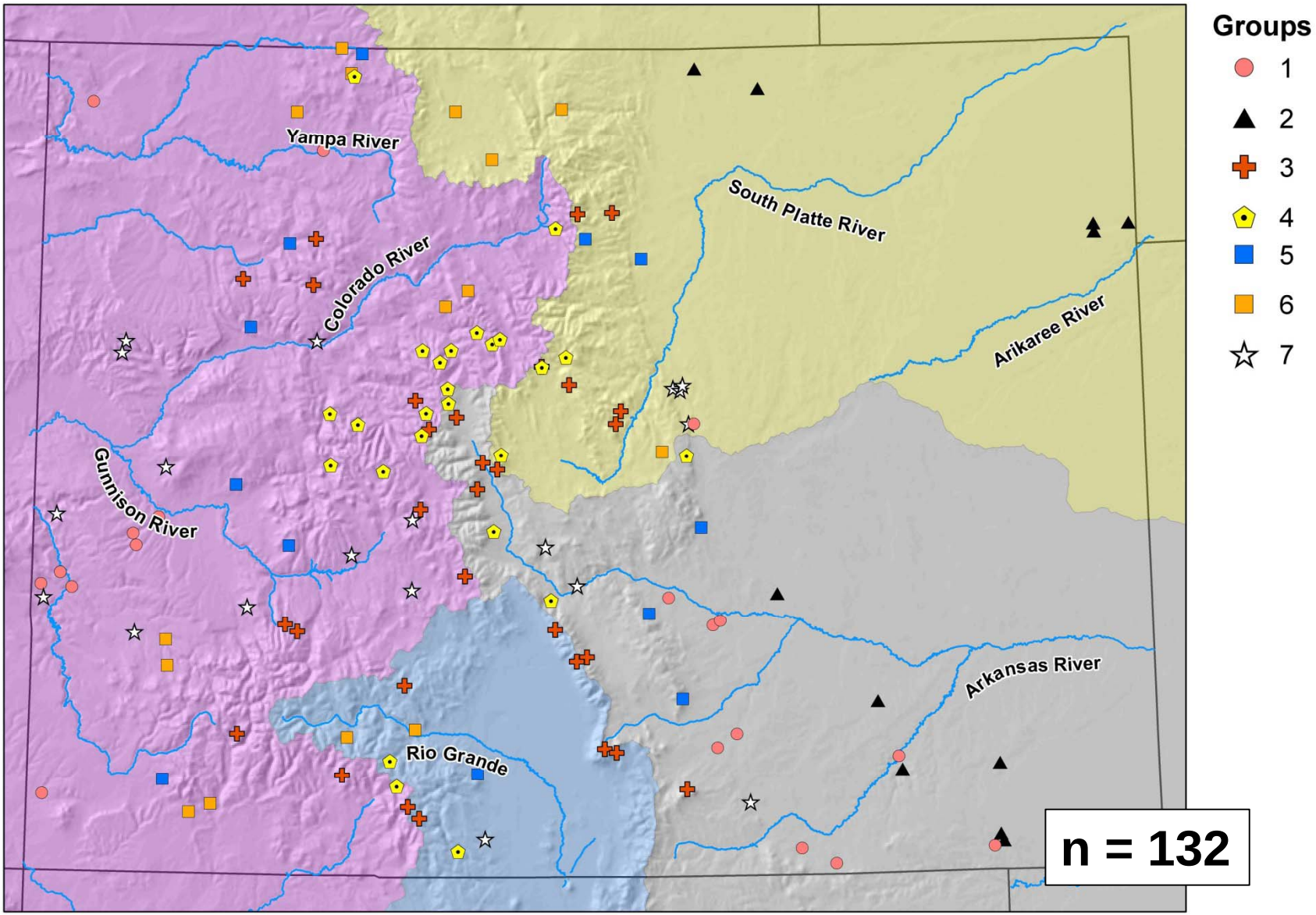
RMSE

Model	XYEAR	SUMMER	WINTER
Linear	1.0°	2.2°	1.7°
RF	0.8°	2.0°	1.3°



Do modeled temperatures improve predictions of biota?

7 classes of CO reference sites



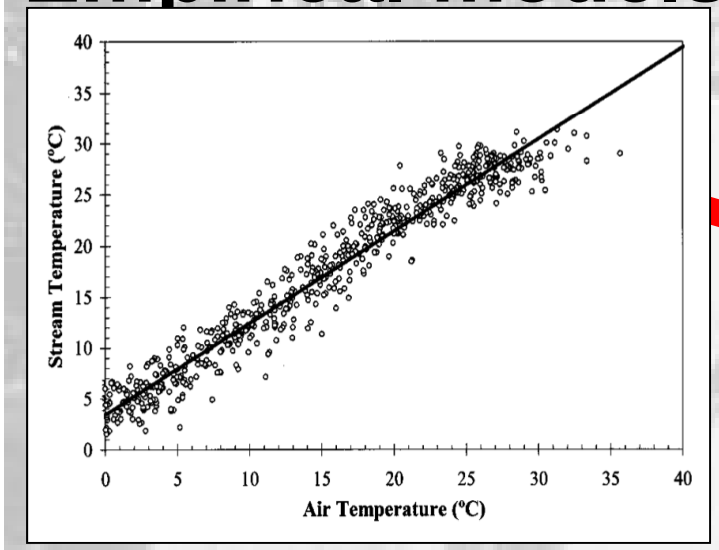
How well did 2 RIVPACS-type models predict invertebrate composition in Colorado reference streams?

Model	Predictors
Both	Day of year Long-term precipitation Previous year precipitation Local topographic relief
Geography	Latitude Elevation WS area
Predicted Temperature	SUMMER WINTER

	Model 1	**Model 2**	
Groups	**%correct**	**%correct**	**Change**
1	47	47	0
2	73	82	+9
3	73	73	0
4	**64**	**80**	**+16**
5	**8**	**33**	**+25**
6	**33**	**60**	**+27**
7	53	53	0
Avg.	**54**	**63**	**9**

Site-specific model

Empirical models

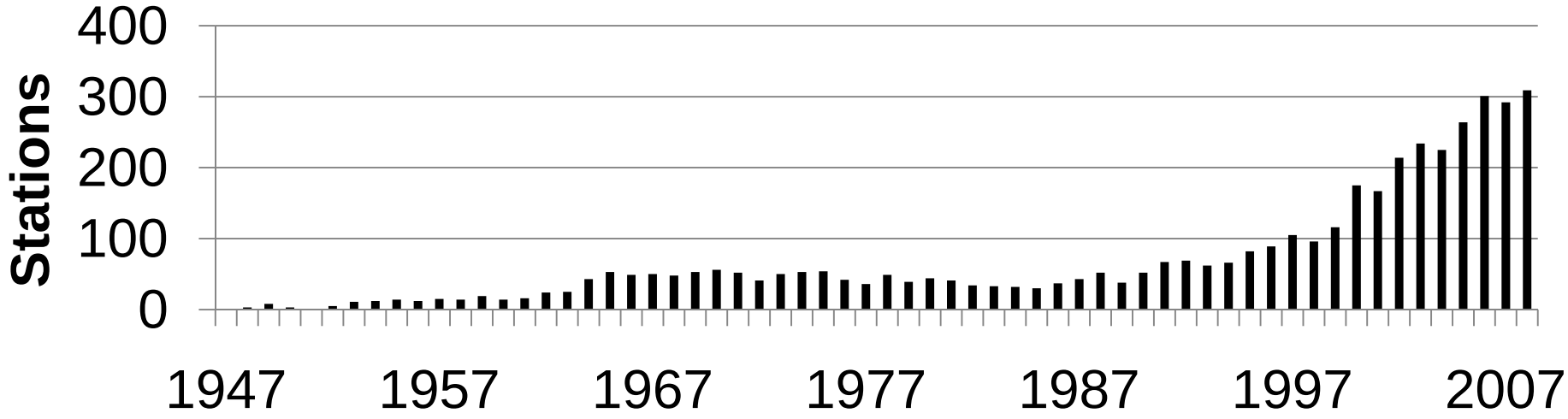


Time-series
air temperatures

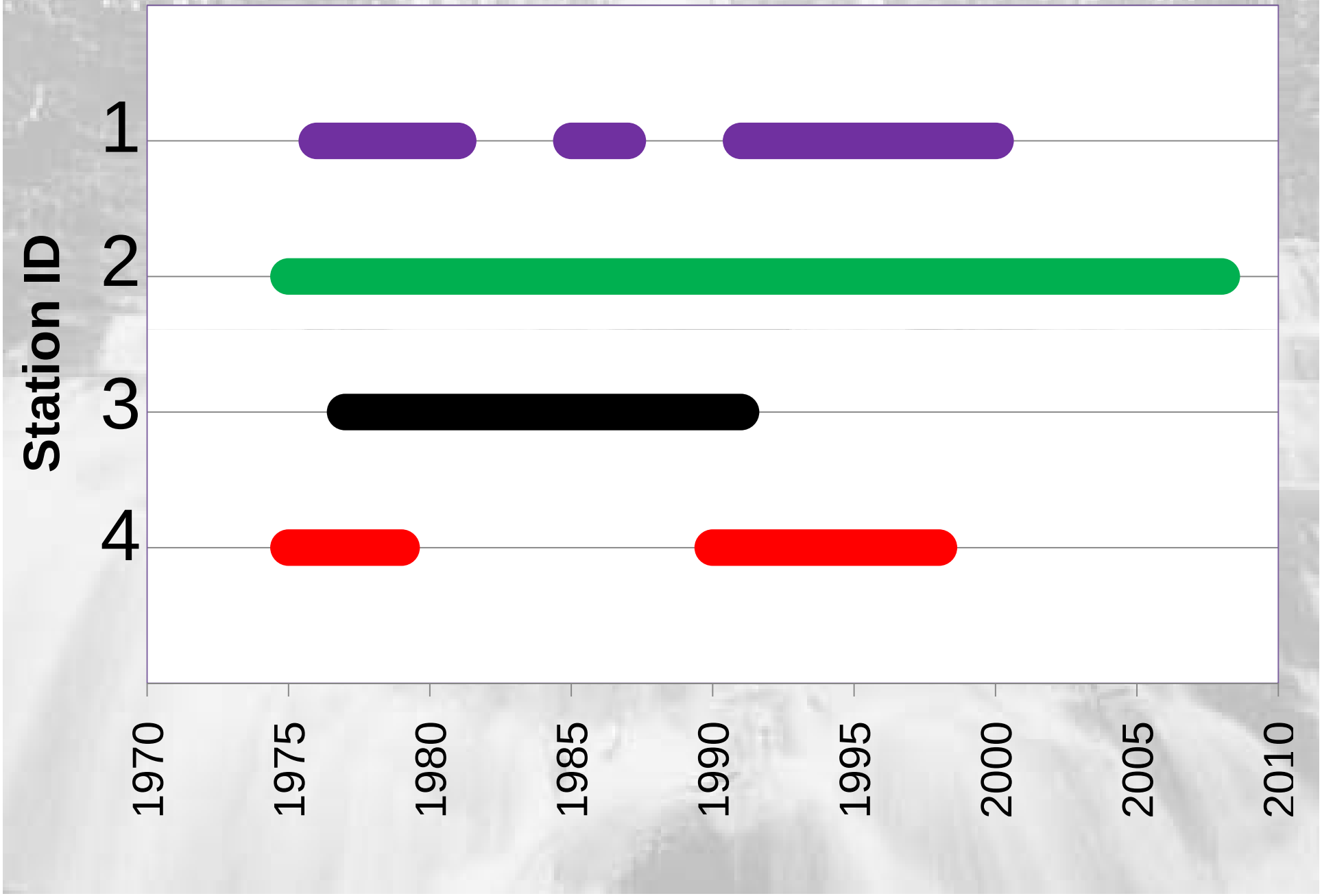
Site-specific
model

Current Work:

- 1,798 candidate stations with temperature data.
- Total period of record = 1947-2008.
- But, records are not evenly distributed across years.

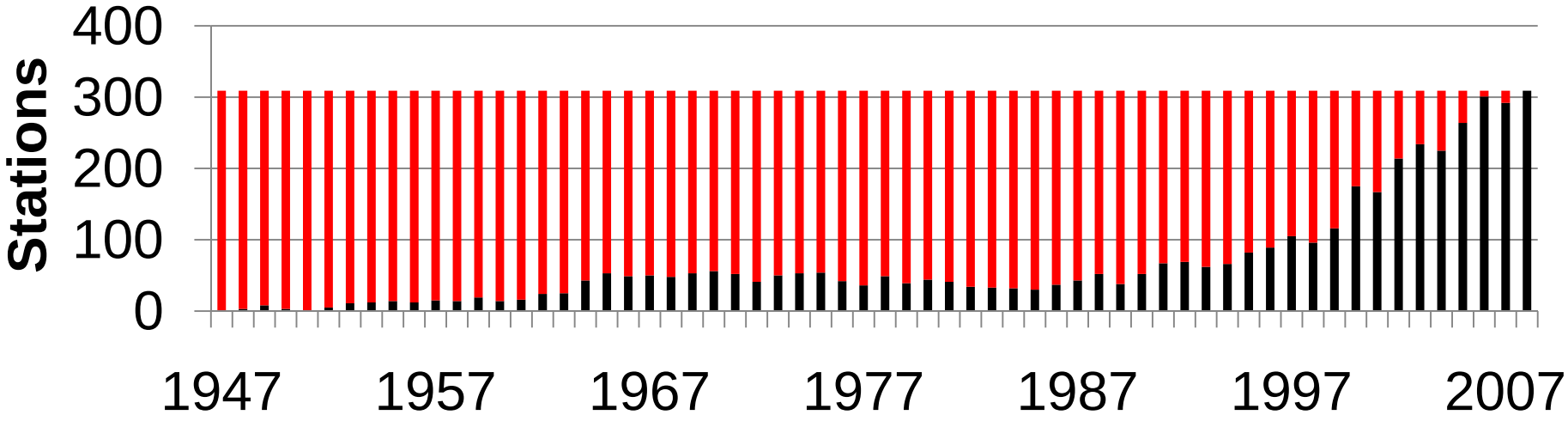


Unbalanced data can create model bias.

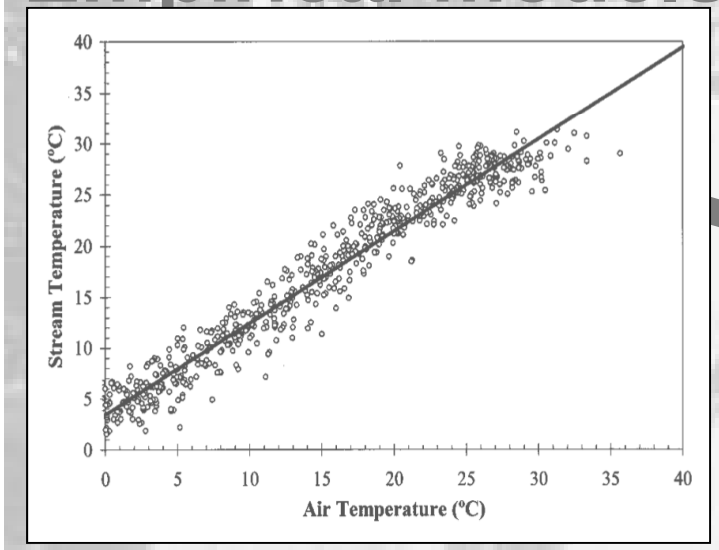


Current Work:

- Working with USU spatial/temporal statistician to balance stream temperature data.
- Match specific months/years of stream data to specific months/years of PRISM climate data.



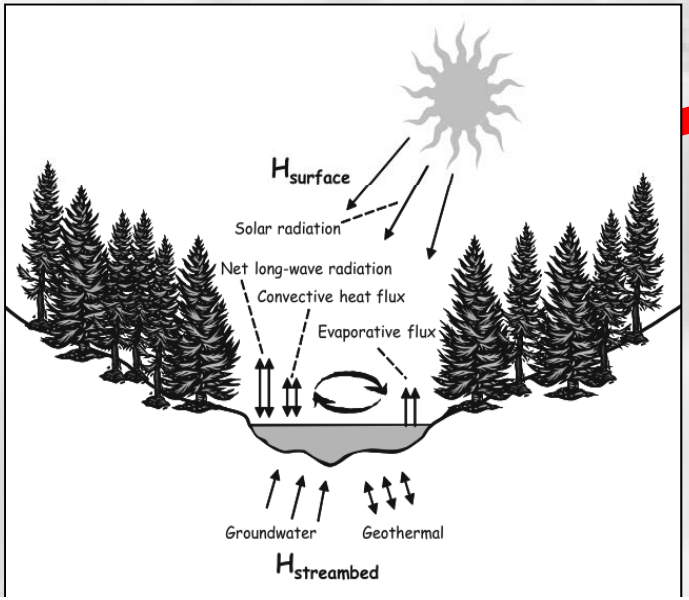
Empirical models



Time-series
air temperatures

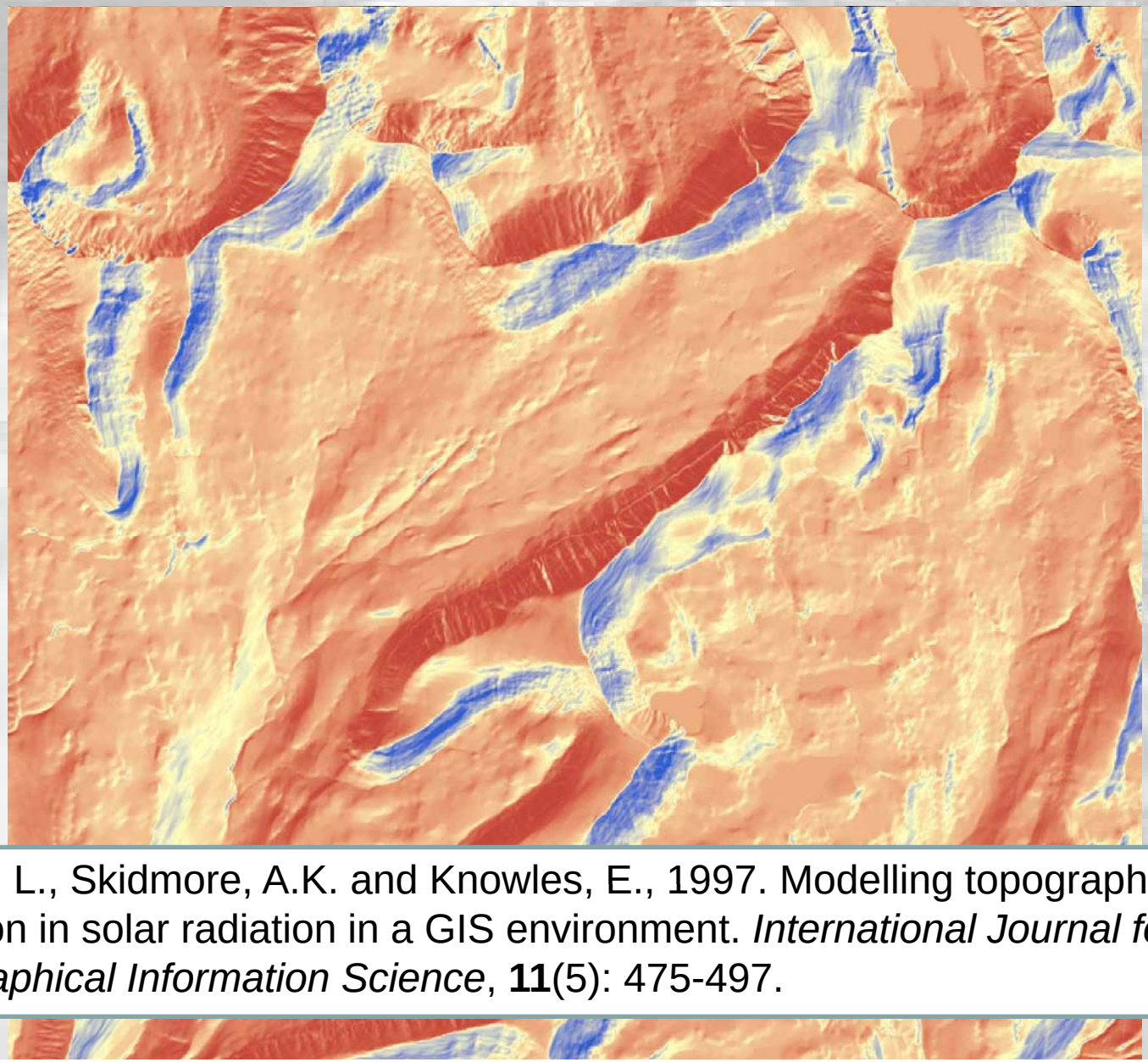
Site-specific model

Physical models



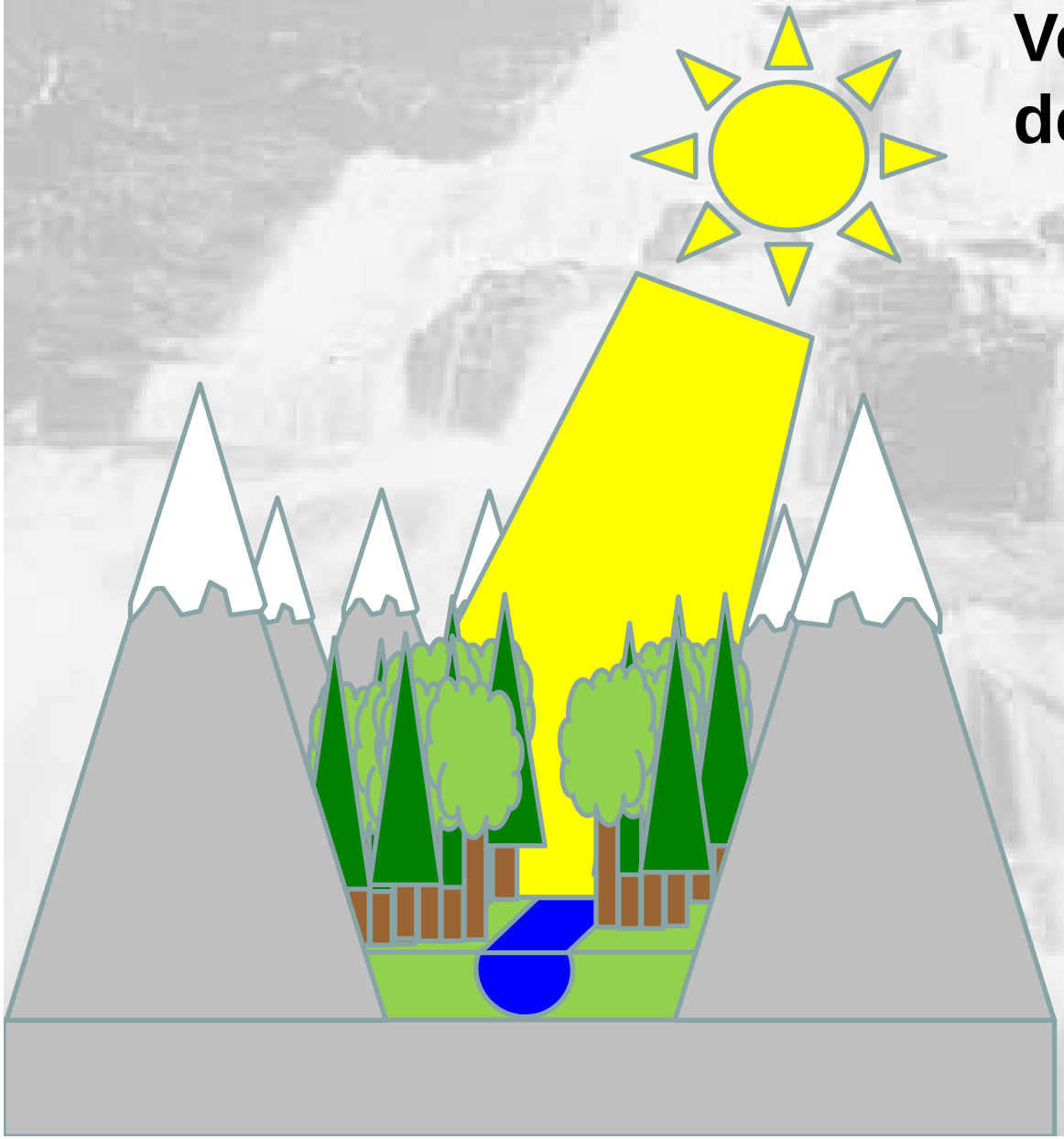
Hydrology (groundwater)
Topography/solar radiation
Stream width
Vegetation cover

Topography/solar radiation



Kumar, L., Skidmore, A.K. and Knowles, E., 1997. Modelling topographic variation in solar radiation in a GIS environment. *International Journal for Geographical Information Science*, **11**(5): 475-497.

Riparian cover



Vegetation height and density –

- USDA LANDFIRE dataset.
- Produced with satellite and GIS data for fire modeling.
- Contains mapped vegetation type, height and density.
- Potential vegetation also included.

Questions?