Macroinvertebrate Thermal Tolerance Index (MTTI)

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April 1, 2022

Background

- Goal: Develop an index to represent thermal tolerances at the <u>assemblage-level</u>

- What it is not: Inferring, or predicting stream temperature
  - There are better methods available, with less error in predictions

- What it is: Realized thermal niche, for an assemblage
  - If every taxon had a vote, what would the temperature be?
  - A single numerical value, on the same scale as state Water Quality Standards

Building the dataset

- Geographic Area: all of Oregon and Washington
- Temperature: NorWeST modeled summer maximum temperature
    - MWMT = maximum weekly maximum temperature
    - Similar to OR and WA temperature water quality standards
    - 1993-2011 average MWMT vs Annual MWMT
- Bug data: local, state, federal, tribal
- Sites associated with NorWeST flowlines and MWMT (modeled temp)
    - Removed duplicates and non-wadeable sites
    - Calibration (CAL) = 3658 unique sites
    - Validation (VAL) = 603 unique sites
        - Independent sites from CAL
        - But on the same stream segments as CAL sites

Taxonomy

- Started with 786 taxonomic names
- Operational Taxonomic Units: 332 unique taxa
  - No ambiguous taxa allowed
  - Explored multiple taxonomic scales, but highest resolution performed best
  - For each taxonomic group, we examined WA optima
    - Minimal differences: roll all children taxa (e.g., species) into parent (e.g., genus)
    - Differing thermal sensitivities: keep lowest level IDs for that group (e.g., species retained, while genus dropped)

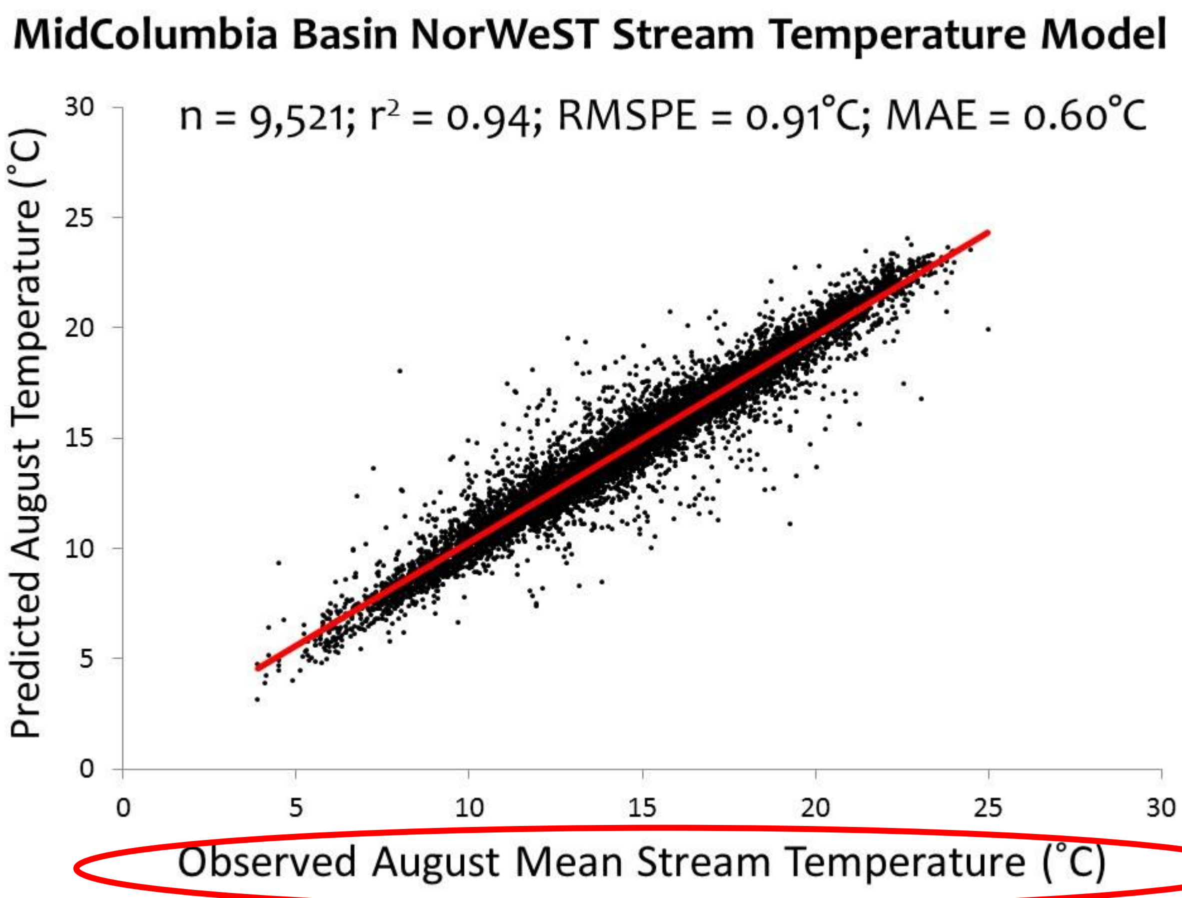
OTU Example: Baetis

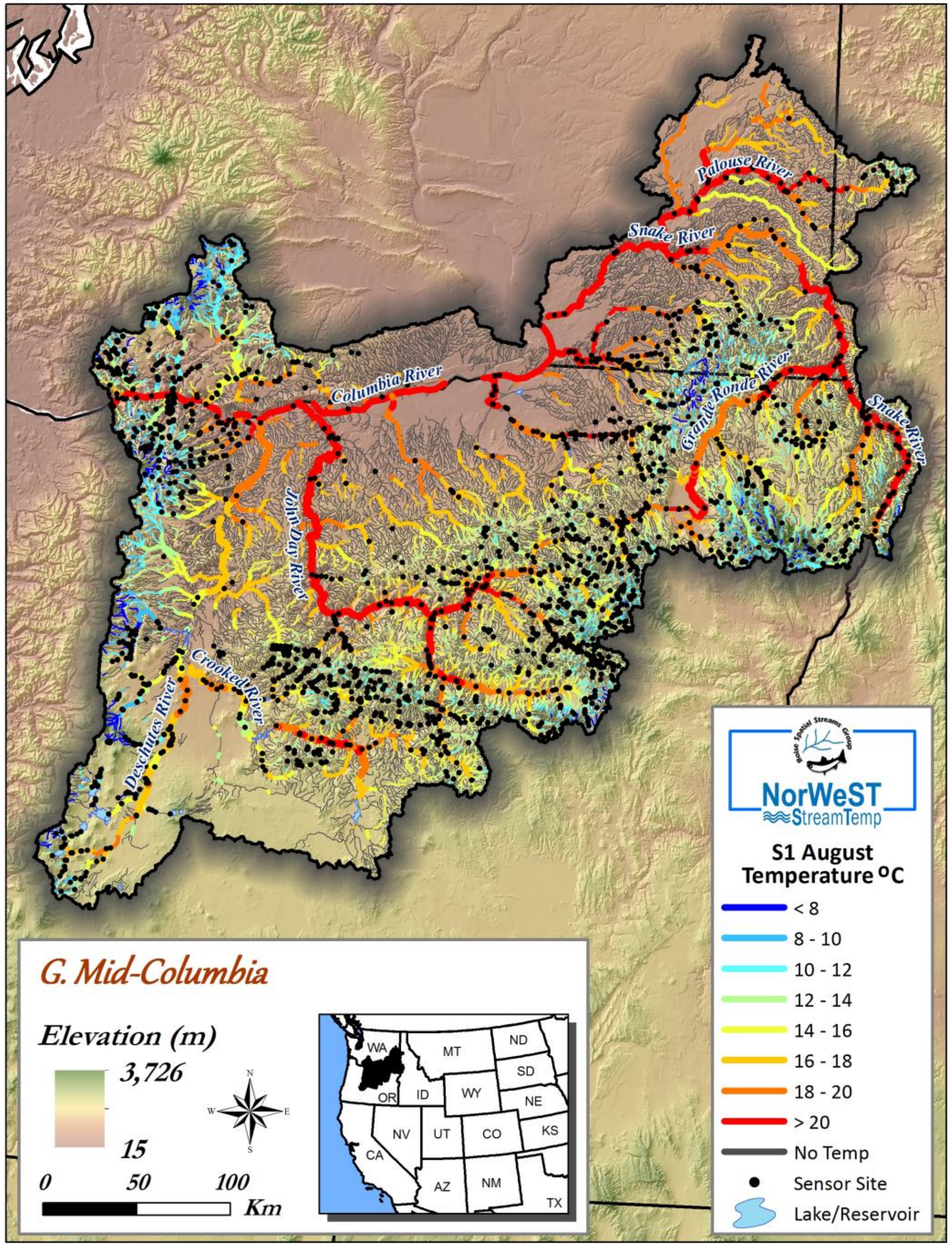
Bio_ALL_TaxaID_v2	ct_CAL	ct_VAL	ct_NOT	MTTI_OTU_highres_v2	WAopt_nOcc_30plus
Baetidae	480	83	484	666	17.42
Baetis	1711	359	1410	666	17.06
Baetis alius	38	3	28	Baetis alius	15.91
Baetis bicaudatus complex	165	16	193	Baetis bicaudatus complex	12.33
Baetis flavistriga complex	76	11	45	Baetis flavistriga complex	19.89
Baetis notos	47	6	29	Baetis notos	22.09
Baetis piscatoris complex	42		38	Baetis piscatoris complex	14.53
Baetis rhodani group	38	3	42	Baetis rhodani group	15.48
Baetis tricaudatus complex	1964	250	2366	Baetis tricaudatus complex	18.32

OTU example: Orthocladius

Bio_ALL_TaxaID_v2	ct_CAL	ct_VAL	ct_NOT	MTTI_OTU_highres_v2	WAopt_nOcc_30plus
Orthocladiinae	1898	290	1809	666	17.86
Orthocladius	640	111	614	Orthocladius	17.09
Orthocladius (Euorthocladius)	6		8	Orthocladius	
Orthocladius (Mesorthocladius)	1			Orthocladius	
Orthocladius (Orthocladius)	1			Orthocladius	
Orthocladius (Symposiocladius)	201	16	154	Orthocladius (Symposiocladius)	17.26
Orthocladius complex	507	70	298	Orthocladius complex	20.92

Modeling a model???





Both figures from NorWeST website: https://www.fs.fed.us/rm/boise/AWAE/projects/NorWeST.html

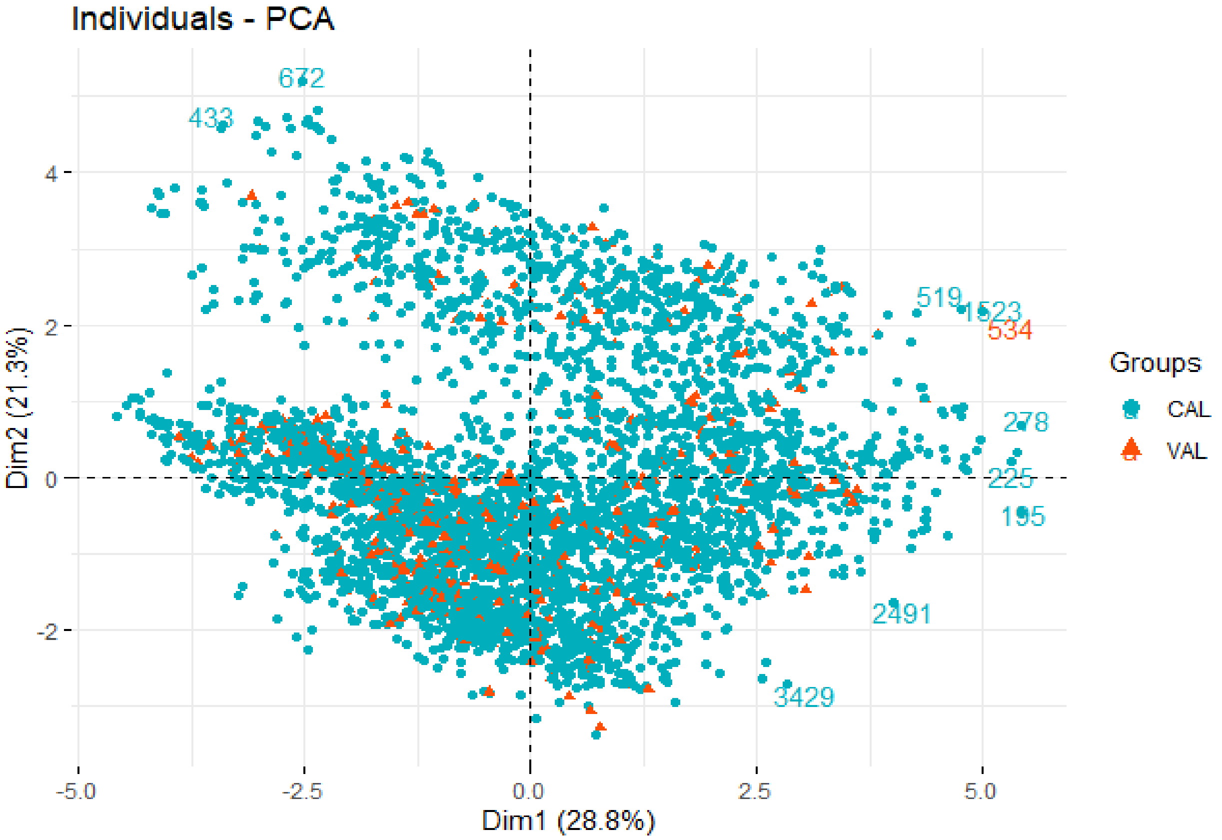
Data sources

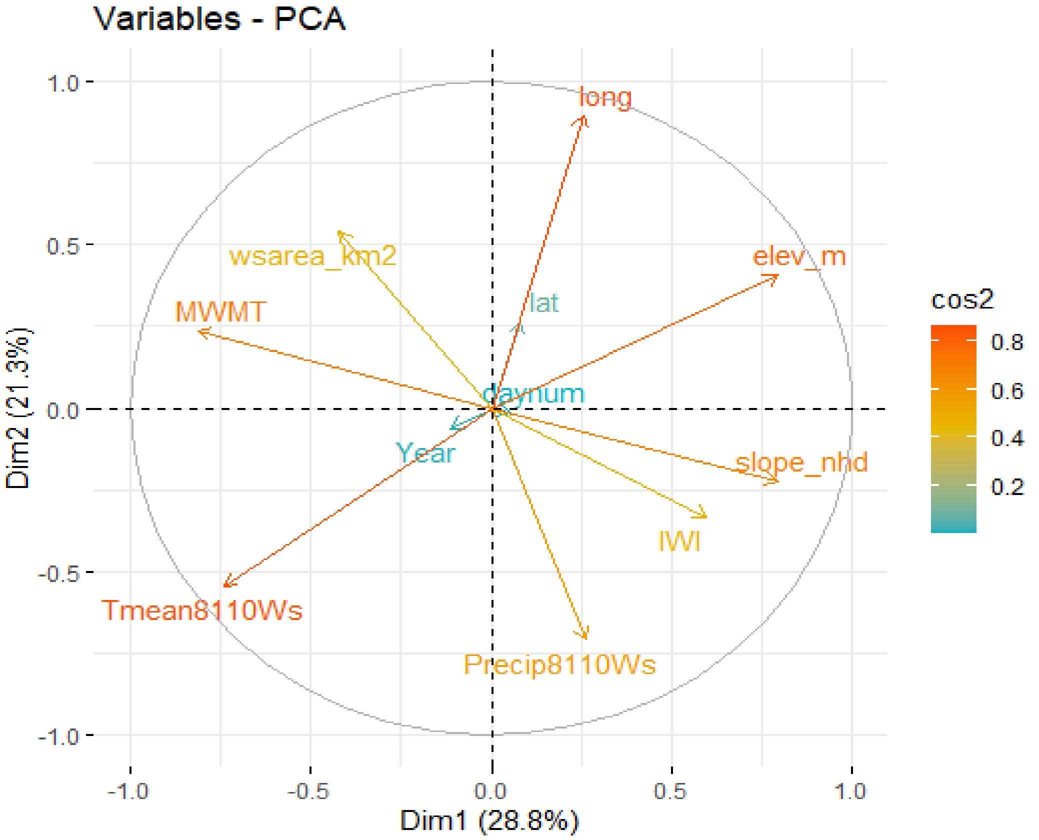
Level III Ecoregion	state	CAL	VAL	%CAL	%VAL
Coast Range	both	906	134	25	22
Cascades	both	785	104	21	17
Puget Lowlands	WA	518	166	14	28
North Cascades	WA	337	26	9	4
Blue Mountains	both	281	77	8	13
Klamath Mountains	both	213	35	6	6
Columbia Plateau	both	182	12	5	2
Willamette Valley	OR	169	22	5	4
East Cascades	both	146	22	4	4
Northern Rockies	WA	86	4	2	1
Northern Basin and Range	OR	34	1	1	0
Snake River Plains	OR	1	0	0	0
TOTAL		**3658**	**603**		

Source Type	%
Tribal	< 1
Federal	44
State	43
Local (county, city)	12

Are CAL and VAL similar populations?

- Principal Components Analysis
  - Spatial, temporal, climate, size, disturbance



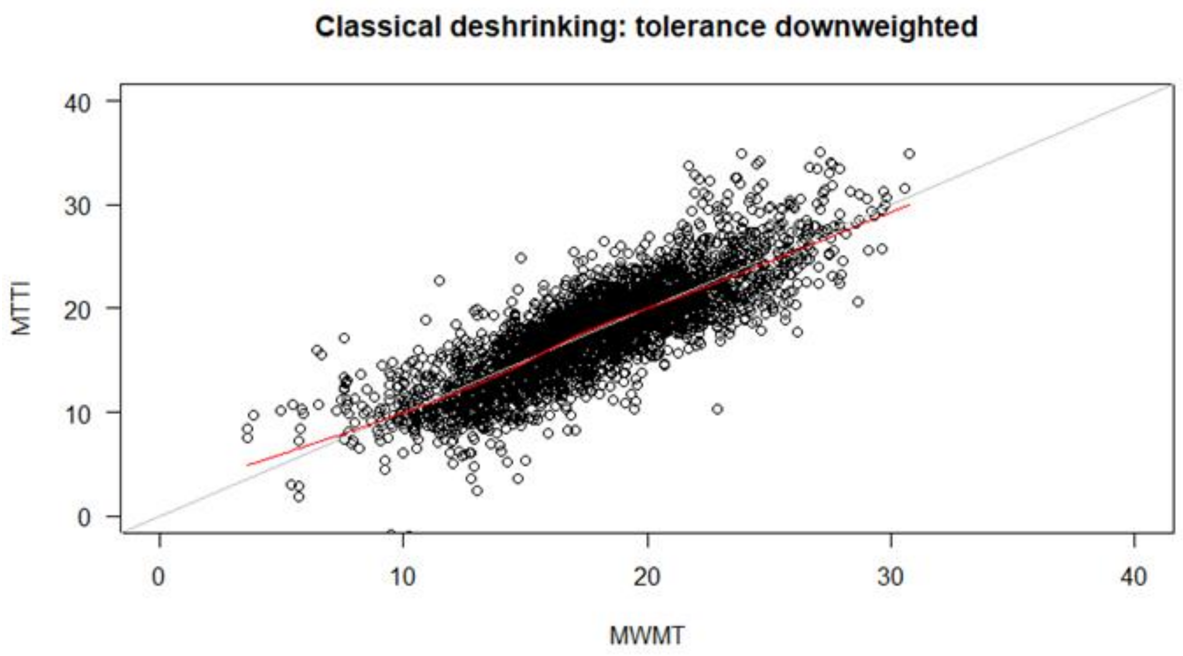


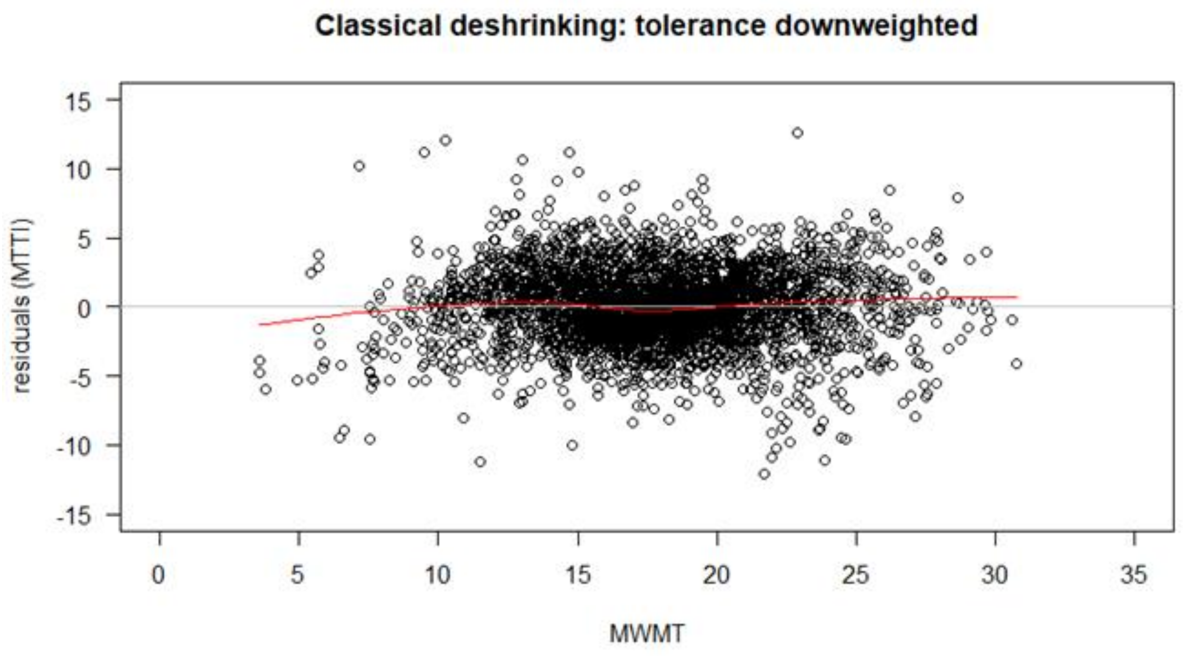
Statistical Methods: Weighted Averaging (WA)

- Paleolimnology: predict past conditions, based on taxa found in sediments
  - We use the same methods, but we apply them differently
- Developed in R, 'rioja' package
- First step: calculate thermal **optima** for all **taxa**
  - Across all sites where a taxon is present
  - Abundances are weighted by temperatures
  - $\Sigma_{sites}((RA \ * TEMPmwmt)/RA)$
  - All taxa have an optimum
    - Even the eurythermal taxa
- Second step: calculate the assemblage-level thermal response (MTTI) for a **site**
  - Across all taxa, within a site
  - Taxa abundances are weighted by their respective thermal optima
  - $\Sigma_{taxa}((RA \ * OPTIMAmwmt)/RA)$
- Tolerance down-weighting, deshrinking
- Taxonomy: Highest resolution model

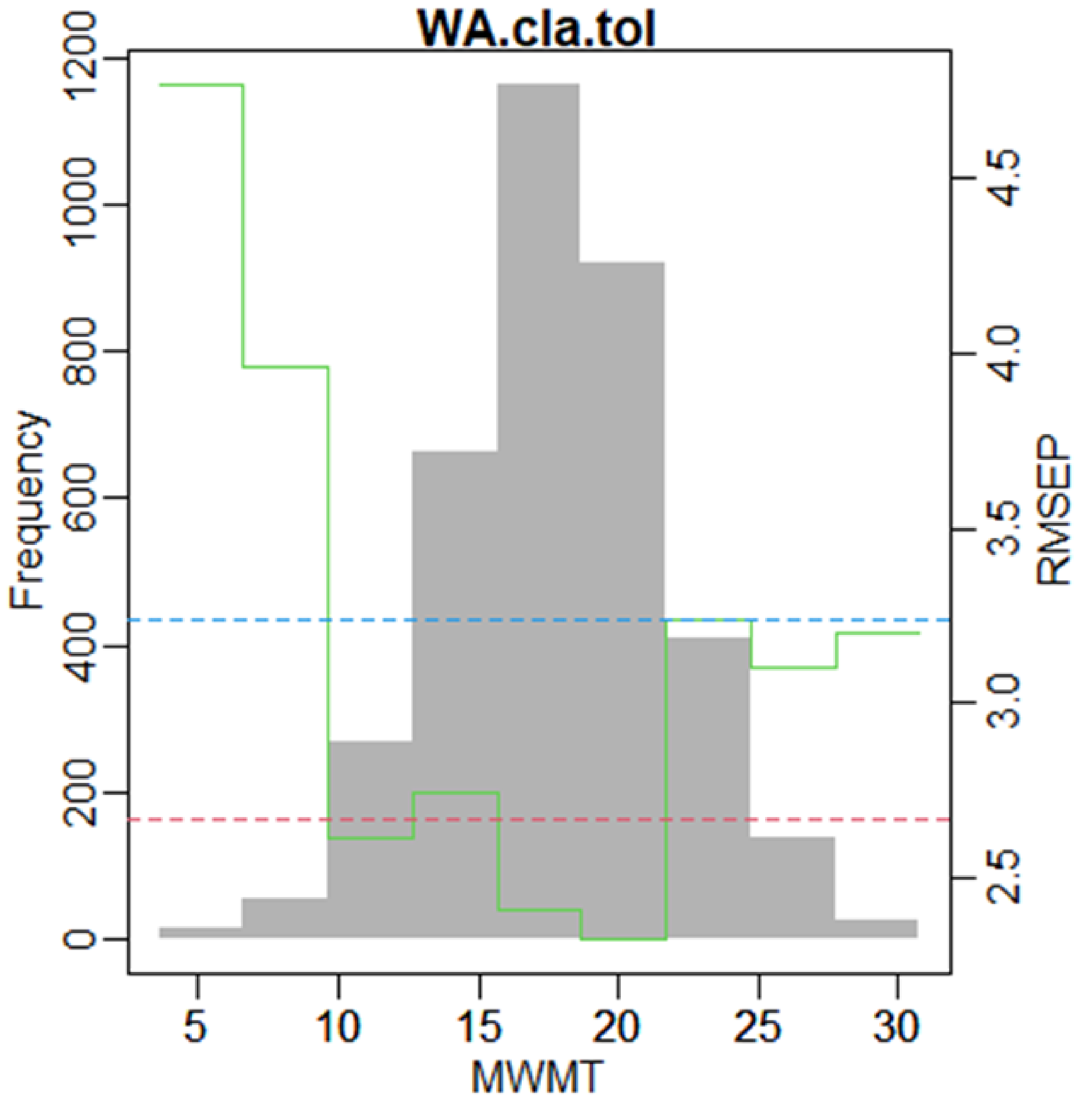
Modeling Results

	Calibration		Validation
	Classical deskrinking, tolerance downweighted	Cross validation: bootstrapped (n = 1000)	Classical deskrinking, tolerance downweighted
RMSE	2.7	2.7	2.4
R2	0.69	0.67	0.66
Max.Bias	2.6	2.8	





Model errors across the temperature gradient



RMSEP of each bin

Average RMSEP of all bins

Model average RMSEP

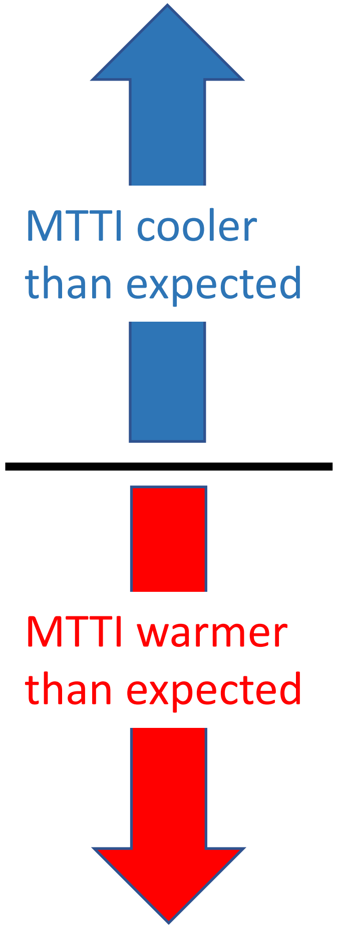
How do these results compare to previous efforts?

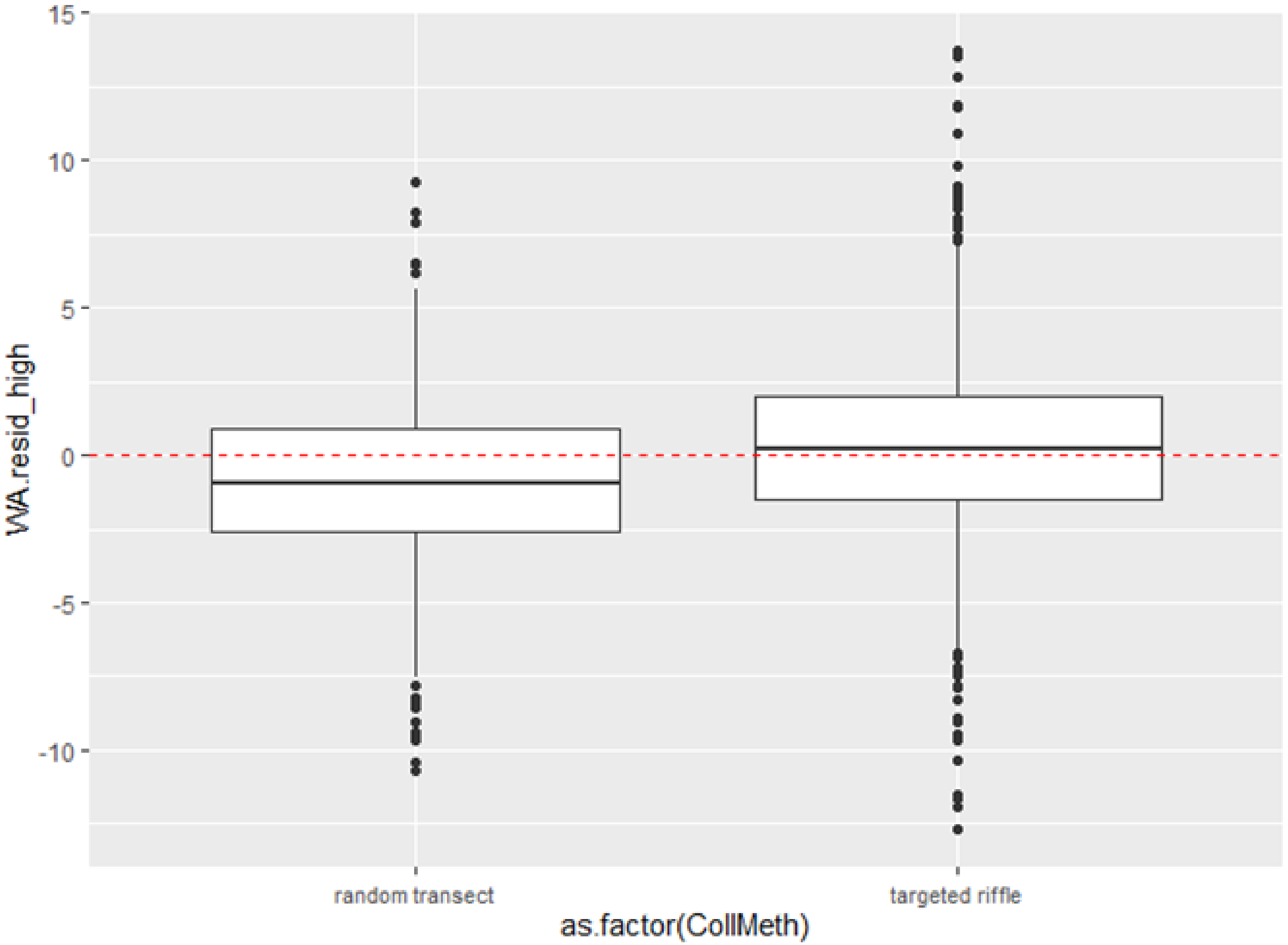
- Huff, Hubler, Pan, Drake (2006): Oregon, statewide
  - Weighted averaging, inverse deshrinking
  - 7-day average maximum temperature (OR WQS, equivalent to MWMT)

Model	Temperature source	Taxa (n)	CAL (n)	VAL (n)	Cross Validation			Independent Validation		
					RMSE	r^2	Max Bias	RMSE	r^2	Max Bias
Huff et al 2006	Field	235*	328	50	2.1	0.73	3.7	2.7	0.66	3.2
MTTI	Modeled stream network	332	3685	603	2.7	0.67	2.8	2.4	0.66	

* No restrictions on number of occurrences. Only 87 taxa with 30 or more occurrences.

Is the MTTI biased? Sampling method



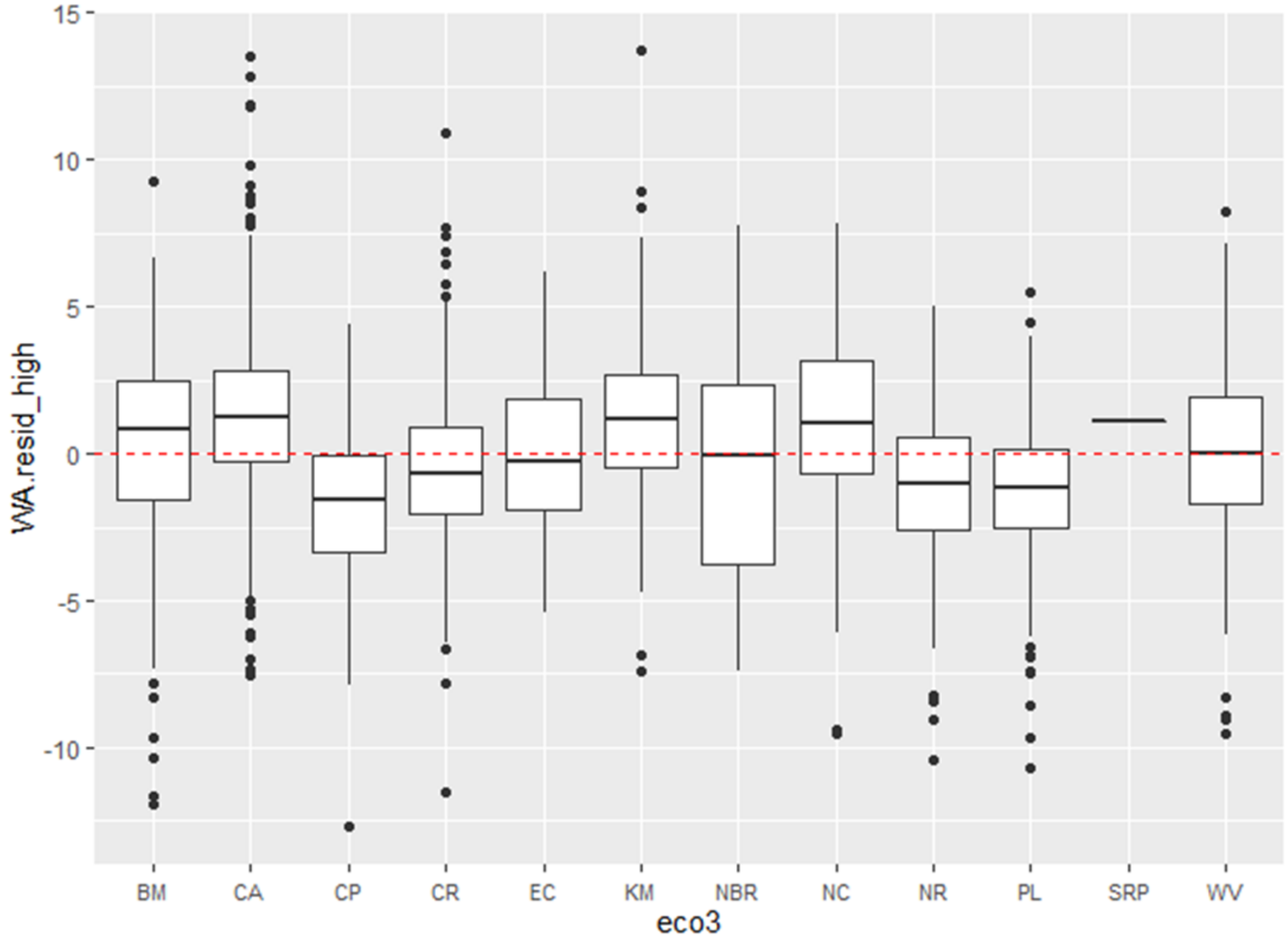


Also: No LAB effect observed

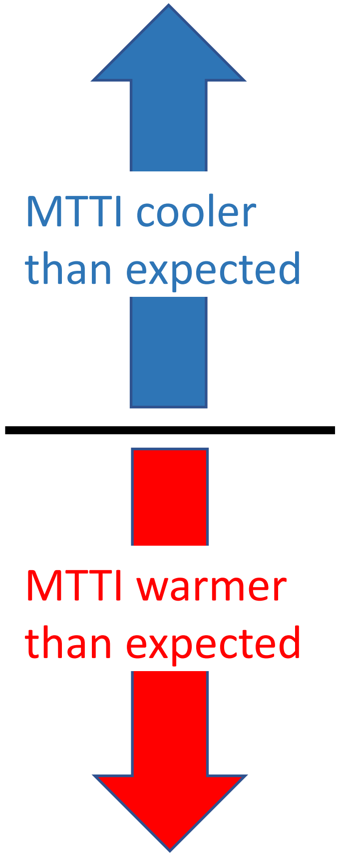
Spatial bias? Ecoregion

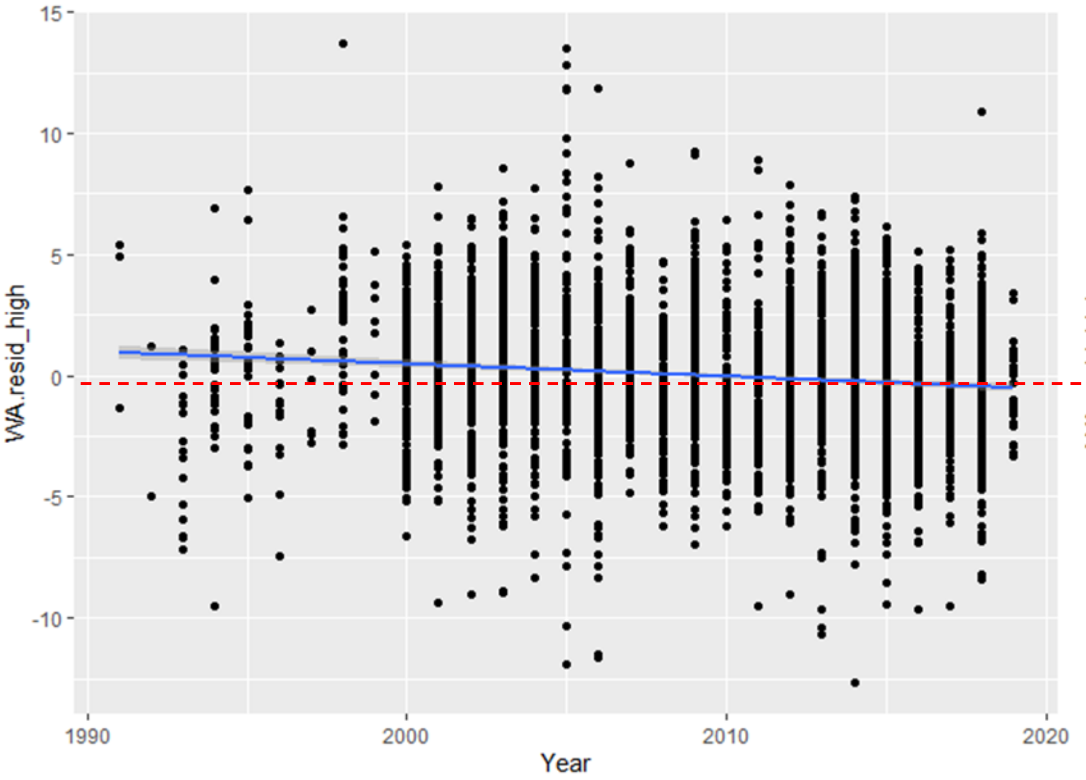
MTTI cooler than expected

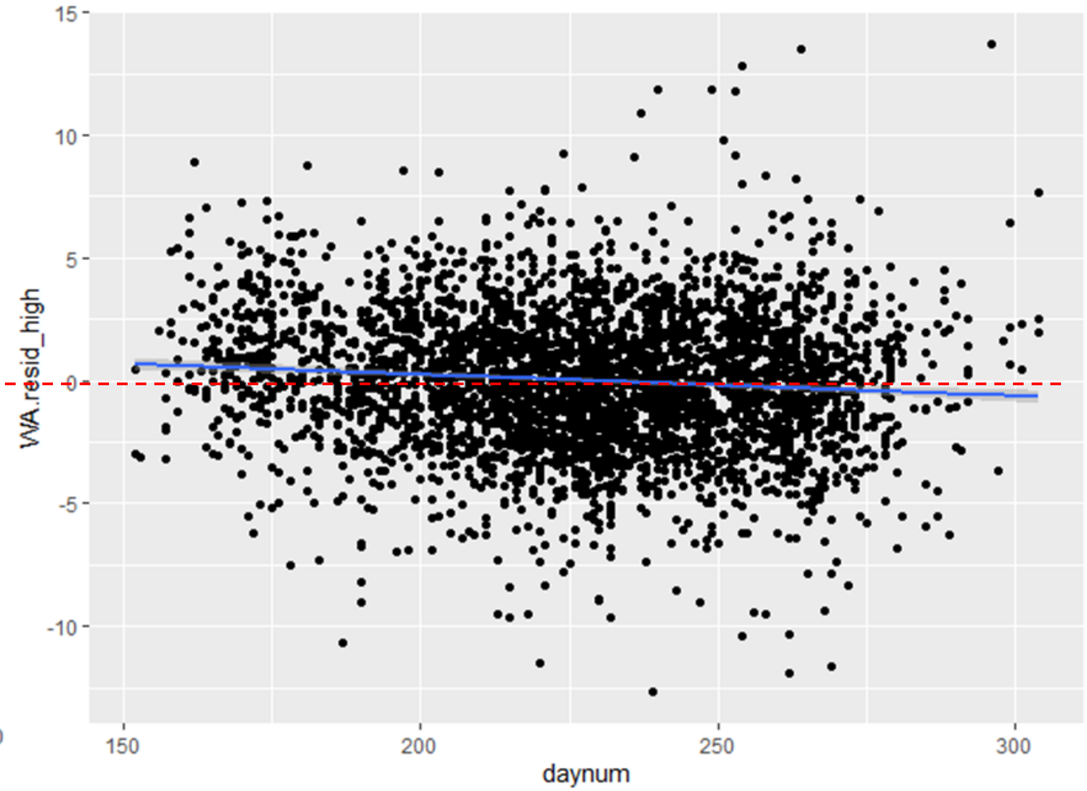
MTTI warmer than expected



Temporal bias? Year, day of year

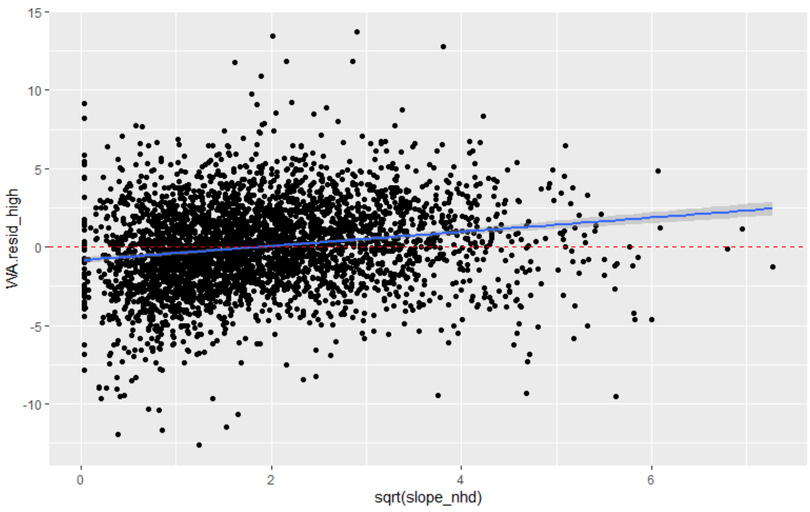


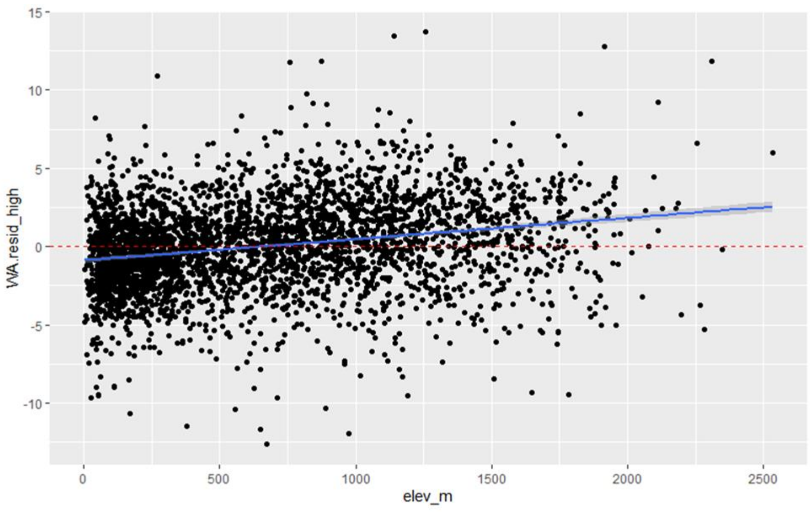


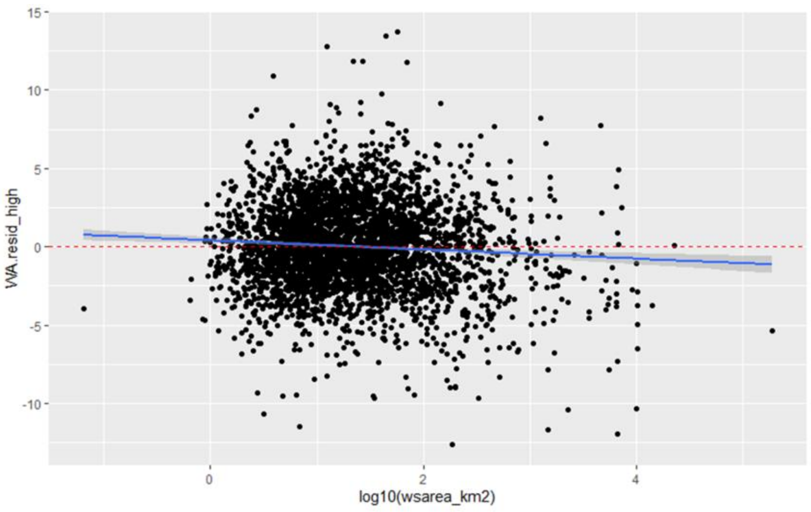


Natural gradients bias? Slope, elevation, size

- Cooler than expected: higher slopes and elevations, smaller watersheds
- Warmer than expected: lower slopes and elevations, larger watersheds

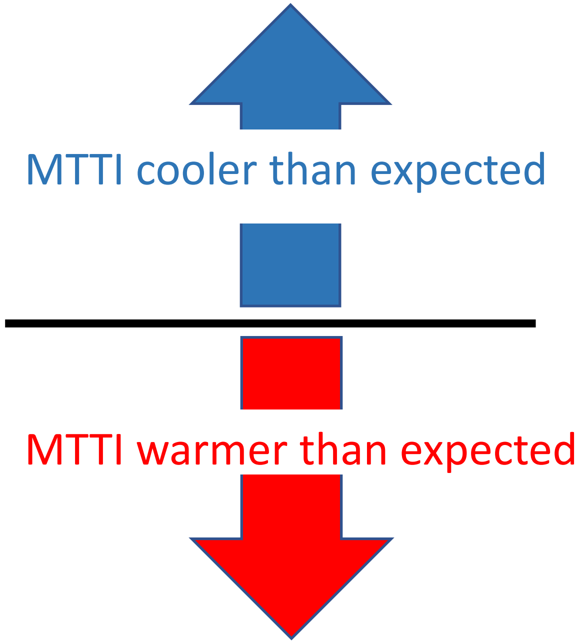


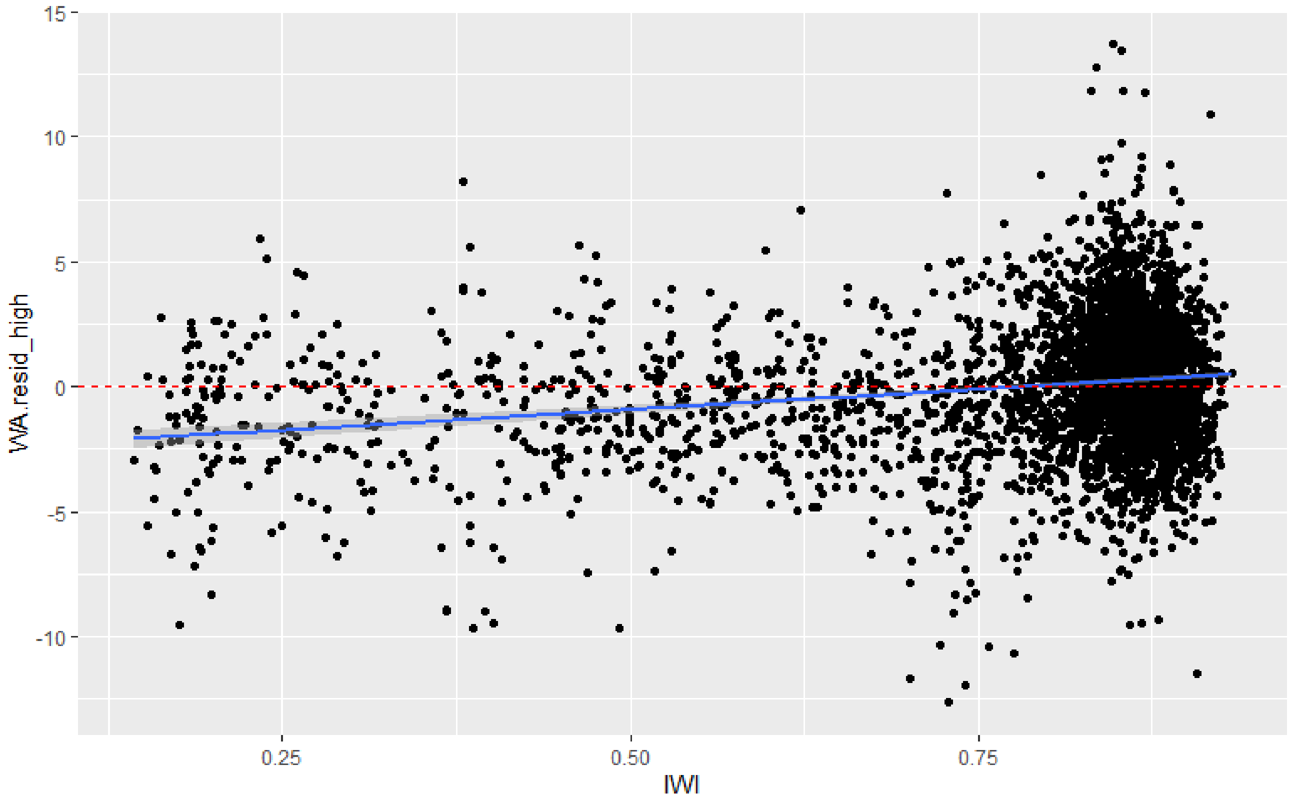




Is the MTTI biased? Disturbance

- IWI = Index of Watershed Integrity (source = StreamCat)
- MTTI warmer than expected at higher levels of disturbance





Other biases?

- ID Laboratory: minor
- Collection entity: minor

- Differences observed more likely due to study areas/monitoring designs
  - E.g., National Park Service – MTTI tended to be cooler than modeled MWMT
  - Higher elevations, higher gradients, lower disturbances?

MTTI: Next Steps

- Incorporate feedback from PNW-BCG workgroup!
- Bias – leave as is
  - Natural gradients to be factored out in setting reference expectations (later work)
- Repeatability
- Case study
  - Restoration project? (hopefully already included in Jen's database)
  - How does MTTI relate to thermal tolerance metrics?
  - Using MTTI (or thermal metrics?) to identify the appropriate Dissolved Oxygen standard in OR
- Validate R-code, input data files
  - Distributable R package
- Peer-reviewed journal article

Other stressors?

- Fine sediment: Macroinvertebrates
  - PNW = Fine Sediment Biotic Index (Relyea et al. 2012, Environmental Management)
  - Oregon = Biological Sediment Tolerance Index (Hubler et al. 2016, Ecological Indicators)
  - Use BCG Thermal database to update the model to cover OR & WA?
    - Are habitat protocols the same?
- Nutrients: Periphyton
  - Nutrient Scientific Technical Exchange Partnership & Support (N-STEPS)
  - Diatom tolerance index used in the National Rivers and Streams Assessment
  - Tetra Tech support (Mike Paul) to apply to data from ecoregions in Oregon and neighboring states
  - TAXONOMY LIMITATIONS!!!!!!!