SUPPLEMENTAL MATERIALS

Assessing agreement among alternative climate change projections to inform conservation recommendations in the contiguous United States

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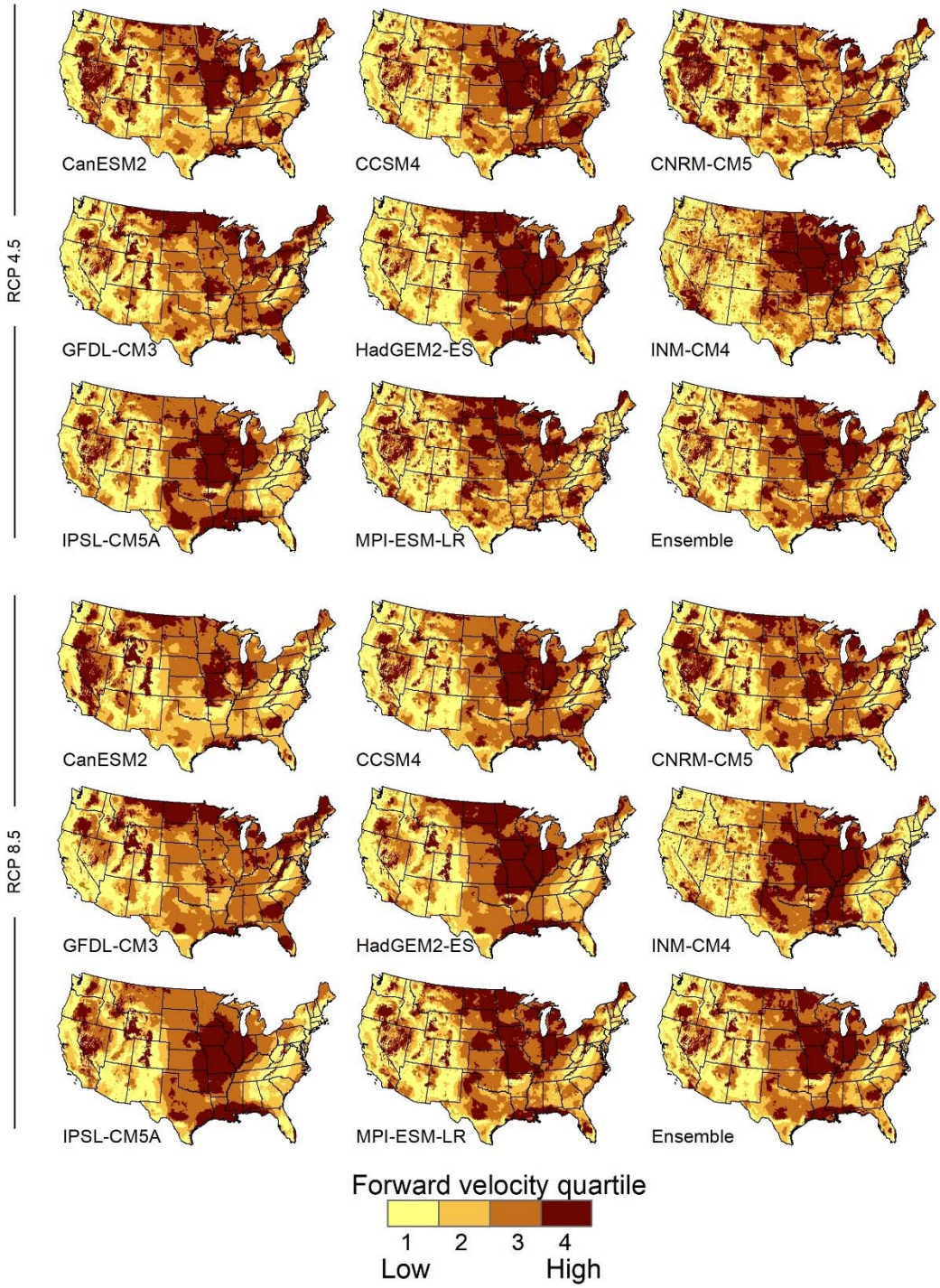
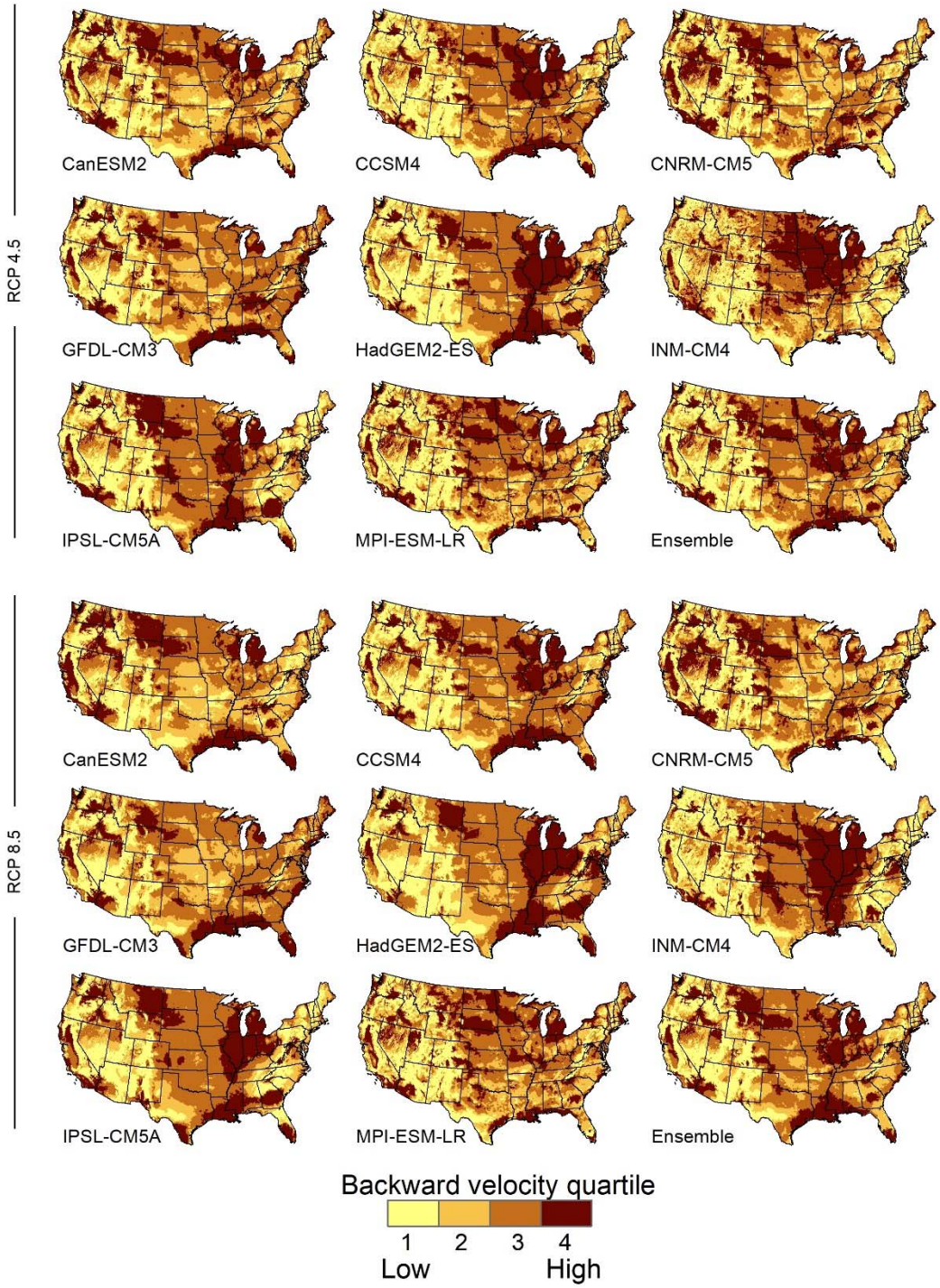
Supplemental Table 1. CMIP5 general circulation models (GCMs) used to evaluate agreement among simulations. The first eight were used as individual simulations with RCP 4.5 and 8.5. In addition to a multi-model ensemble was calculated based on the first eight and the last seven GCMs listed.

Use	GCM	Source
Focal simulations	CanESM2	Canadian Centre for Climate, Canada
	CCSM4	National Center for Atmospheric Research, USA
	CNRM-CM5	Centre National de Recherches Meteorologiques, France
	GFDL-CM3	Geophysical Fluid Dynamics Laboratory, USA
	HadGEM2-ES	Met Office Hadley Centre, UK
	INM-CM4	Institute for Numerical Mathematics, Russia
	IPSL-CM5A-MR	Institute Pierre-Simon Laplace, France
	MPI-ESM-LR	Max Planck Institute for Meteorology, Germany
For Ensemble only	ACCESS1.0	Commonwealth Scientific and Industrial Research Organization, Australia
	MIROC5	Atmosphere and Ocean Research Institute, Japan
	CSIROMk3.6	Commonwealth Scientific and Industrial Research, Australia
	MRI-CGCM3	Meteorological Research Institute, Japan
	MIROC-ESM	Japan Agency for Marine-Earth Science and Technology, Japan
	CESM1-CAM5	National Center for Atmospheric Research, USA
	GISS-E2R	NASA Goddard Institute for Space Studies, USA

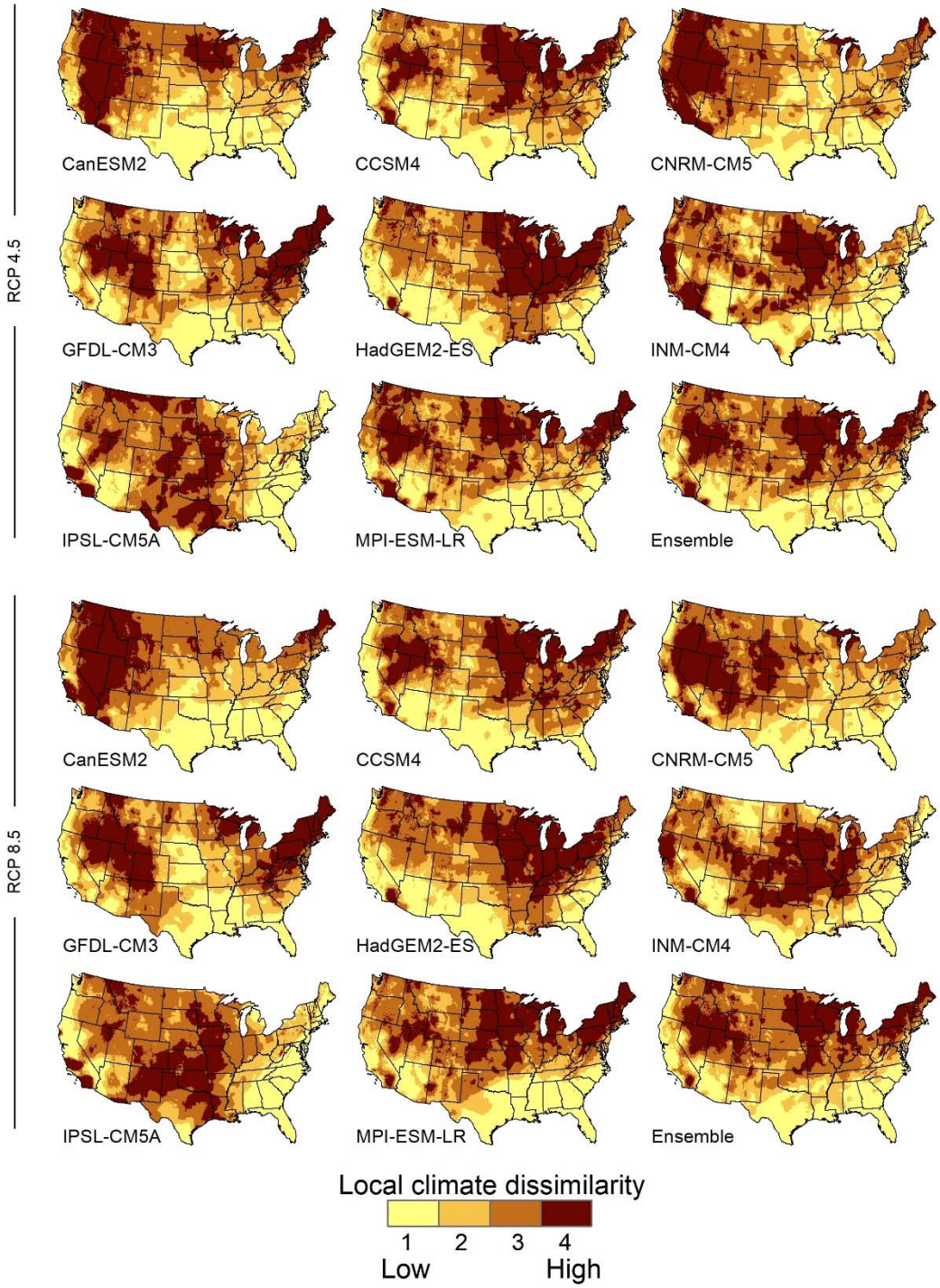
Supplemental Figure 1. Quartiles of all 18 alternative climate projections and scenario outputs for the forward climate velocity. Top nine map panels represent RCP 4.5; bottom 9 maps represent RCP 8.5.



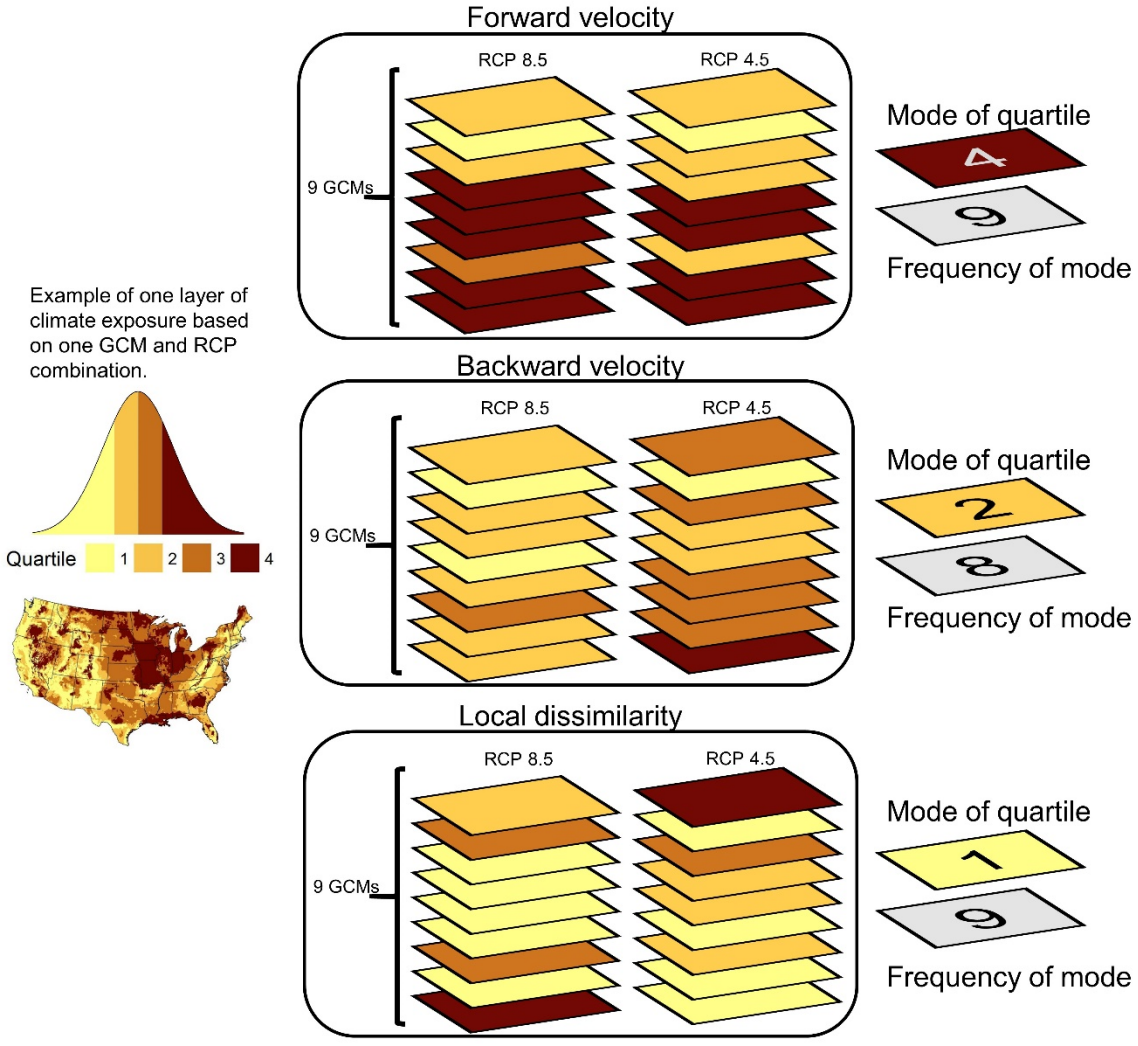
Supplemental Figure 2. Quartiles of all 18 alternative climate projections and scenario outputs for the backward climate velocity. Top nine map panels represent RCP 4.5; bottom 9 maps represent RCP 8.5.



Supplemental Figure 3. Quartiles of all 18 alternative climate projections and scenario outputs for the local climate dissimilarity. Top nine map panels represent RCP 4.5; bottom 9 maps represent RCP 8.5.



Supplemental Figure 4. Simplified depiction of methods used to assess simulation agreement. Each square represents one hypothetical example grid cell location. Three mapped climate metrics for the contiguous U.S. (forward velocity, backwards velocity, local climate dissimilarity) were classified into quartiles and assigned integer values 1 (lower quartile) to 4 (upper quartile). Within each climate exposure metric, classified quartile maps representing estimates from 18 different future climate simulations (9 general circulation models × 2 representative concentration pathways) were stacked. The mode of quartile and frequency of mode were calculated and used to produce maps of simulation agreement for each climate metric.

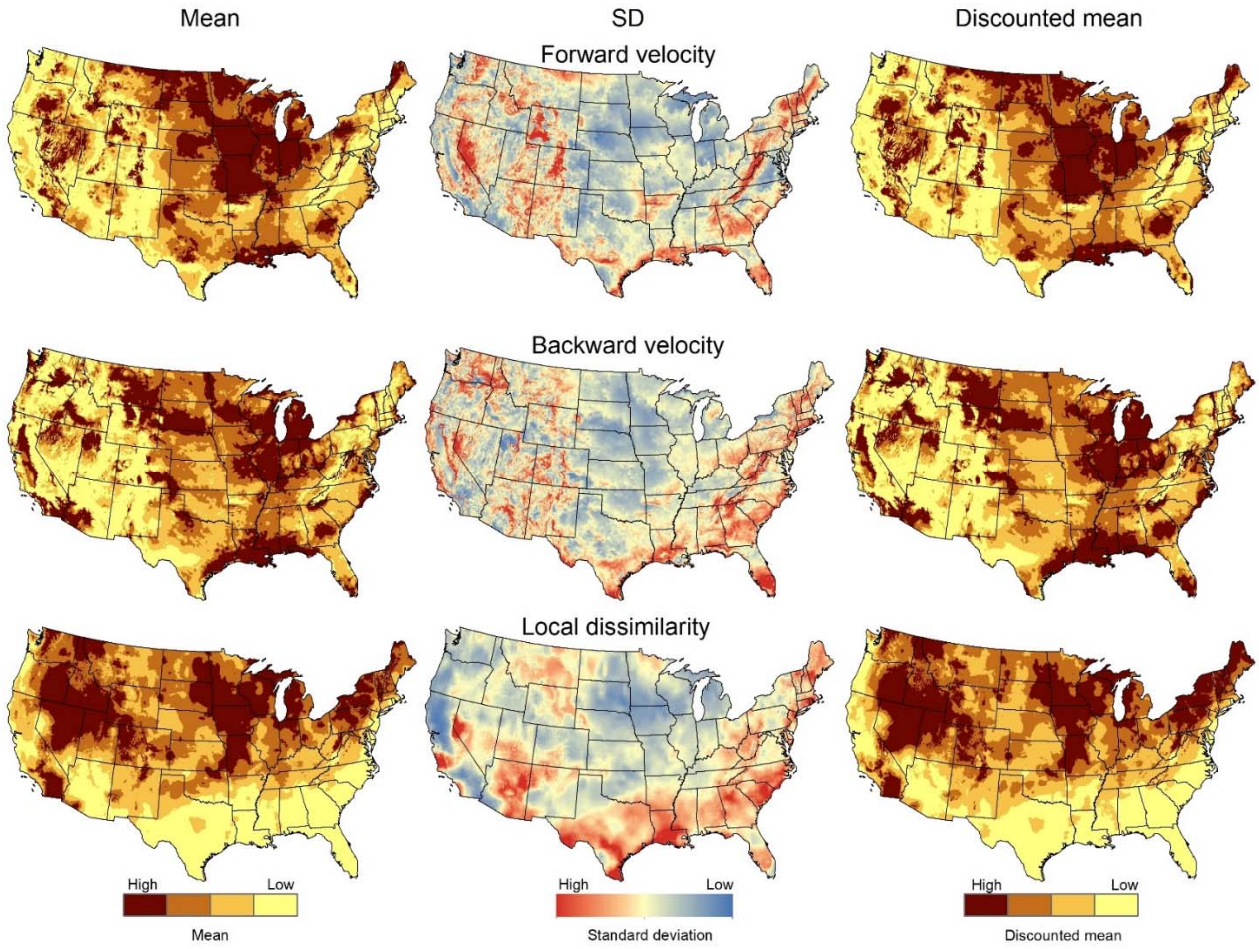


Supplemental Figure 5.

As a complement to the quadrant-based categorization described, we also applied an approach, distribution discounting, that reduces or discounts the estimated exposure of a site based on the level of uncertainty (e.g., the standard deviation between metrics based on alternative future climate projections) shown by metrics measured at that site[1,2]. Resultant conservation priority areas will then be located preferentially in areas of high agreement between alternative future projections. Because we were interested in assessing uncertainty of the three climate metrics when they were expressed as a conservation target (i.e., with positive values in areas of low climate exposure), we used a refugia index based on -1 times the log transform of the raw metrics[3]. We followed Carroll et al. (2010)[3] in discounting the mean value of the metric across the 18 future projections by one-half of the standard deviation of the metric between future projections. A range of discounting coefficients have been used (e.g., 1.0 rather than 0.5 as used here[2]), corresponding to differing levels of risk aversion.

Although regional patterns of uncertainty differed between the three metrics (with Pearson's correlations of 0.38-0.46), all metrics showed highest uncertainty in the southeastern US and intermountain West. Standard deviation was moderately correlated with mean values for climate dissimilarity (Pearson's correlation = 0.62) but not for either forward or backward velocity (Pearson's correlation = 0.18 and 0.25, respectively). The standard deviation and frequency of climate modes, two estimates of simulation agreement, were not strongly correlated for any metric (forward velocity: $r = -0.08$; backward velocity: $r = -0.15$; local dissimilarity: $r = -0.13$; although p-values were < 0.0001 for each correlation). Though areas with higher standard deviation among simulations were also characterized by lower frequency of climate modes.

Because the relative uncertainty of environmental dissimilarity values was correlated with mean values, use of distribution discounting spread priorities more broadly as compared to priorities based on undiscounted mean values. Patterns of uncertainty for forward and backward velocity were more complex, but generally lowered priorities in the intermountain West and southeastern US. Discounted means could be used as a substitute for the ensemble or median or mean values in bivariate mapping efforts.



Supplemental Figure 6.

We summarized patterns of predicted climate change through the continuous US by EPA level 3 ecoregions[5]. We calculated the mean value of the three multivariate exposure metrics

(forward velocity, backward velocity, and local climate dissimilarity) for all 18 climate projections (based on the combinations of GCM and RCP alternatives). We also calculated the predicted degree of change in the 11 climate variables used in the principal components analysis (see list below) that served as the basis for calculating the multivariate exposure metrics. For temperature variables, we calculated the arithmetic difference between future predictions and current observations. For precipitation and number of day variables, we calculated the percent change between current and future values.

After calculating the mean values for each variable within each ecoregion, we plotted the data using box and whisker plots to summarize variability among ecoregions and alternative climate projections. The variability depicted by the box and whisker plots represent alternative predictions based on the 18 projections. We rank ordered these plots by the median value among the 18 simulation alternatives.

Code	Variable
MAT	mean annual temperature (°C)
MWMT	mean temperature of the warmest month (°C)
MCMT	mean temperature of the coldest month (°C)
TD	difference between MCMT and MWMT, as a measure of continentality (°C)
MAP	mean annual precipitation (mm)
MSP	mean summer (May to Sep) precipitation (mm)
MWP	mean winter (Oct to Apr) precipitation (mm)
DD5	degree-days above 5°C (growing degree days)
NFFD	the number of frost-free days
Eref	Hargreave's reference evaporation
CMD	Hargreave's climatic moisture index.

Central Irregular Plains
Wyoming Basin
Ozark Highlands
Boston Mountains
Western Corn Belt Plains
Central Corn Belt Plains
Eastern Corn Belt Plains
Central Basin and Range
Driftless Area
Northwestern Glaciated Plains
Southern Michigan/Northern Indiana Drift Plains
Interior River Valleys and Hills
Northern Lakes and Forests
Northern Minnesota Wetlands
North Central Appalachians
Northern Glaciated Plains
North Central Hardwood Forests
Lake Agassiz Plain
Erie Drift Plain
Southeastern Wisconsin Till Plains
Edwards Plateau
Mississippi Valley Loess Plains
Southeastern Plains
Nebraska Sand Hills
Southern Florida Coastal Plain
Huron/Erie Lake Plains
Mississippi Alluvial Plain
Northern Basin and Range
Southern Coastal Plain
Interior Plateau
Middle Rockies
Flint Hills
Southern Rockies
Northern Allegheny Plateau
Central Great Plains
Western Gulf Coastal Plain
Mojave Basin and Range
Cross Timbers
Northwestern Great Plains
Middle Atlantic Coastal Plain
Northeastern Highlands
South Central Plains
Acadian Plains and Hills
Blue Mountains
High Plains
Eastern Great Lakes Lowlands
Texas Blackland Prairies
Central Appalachians
Western Allegheny Plateau
Wasatch and Uinta Mountains
Ouachita Mountains
East Central Texas Plains
Eastern Cascades Slopes and Foothills
Arizona/New Mexico Plateau
Columbia Plateau
Sonoran Basin and Range
Canadian Rockies
Piedmont
Southwestern Appalachians
Southwestern Tablelands
Snake River Plain
Atlantic Coastal Pine Barrens
Blue Ridge
Southern Texas Plains
Central California Valley
Ridge and Valley
Arkansas Valley
Idaho Batholith
Colorado Plateaus
Chihuahuan Deserts
Willamette Valley
Northern Rockies
Sierra Nevada
Arizona/New Mexico Mountains
Central California Foothills and Coastal Mountains
Northern Piedmont
Puget Lowland
Northeastern Coastal Zone
Southern California/Northern Baja Coast
North Cascades
Madrean Archipelago
Coast Range
Southern California Mountains
Cascades
Klamath Mountains/California High North Coast Range
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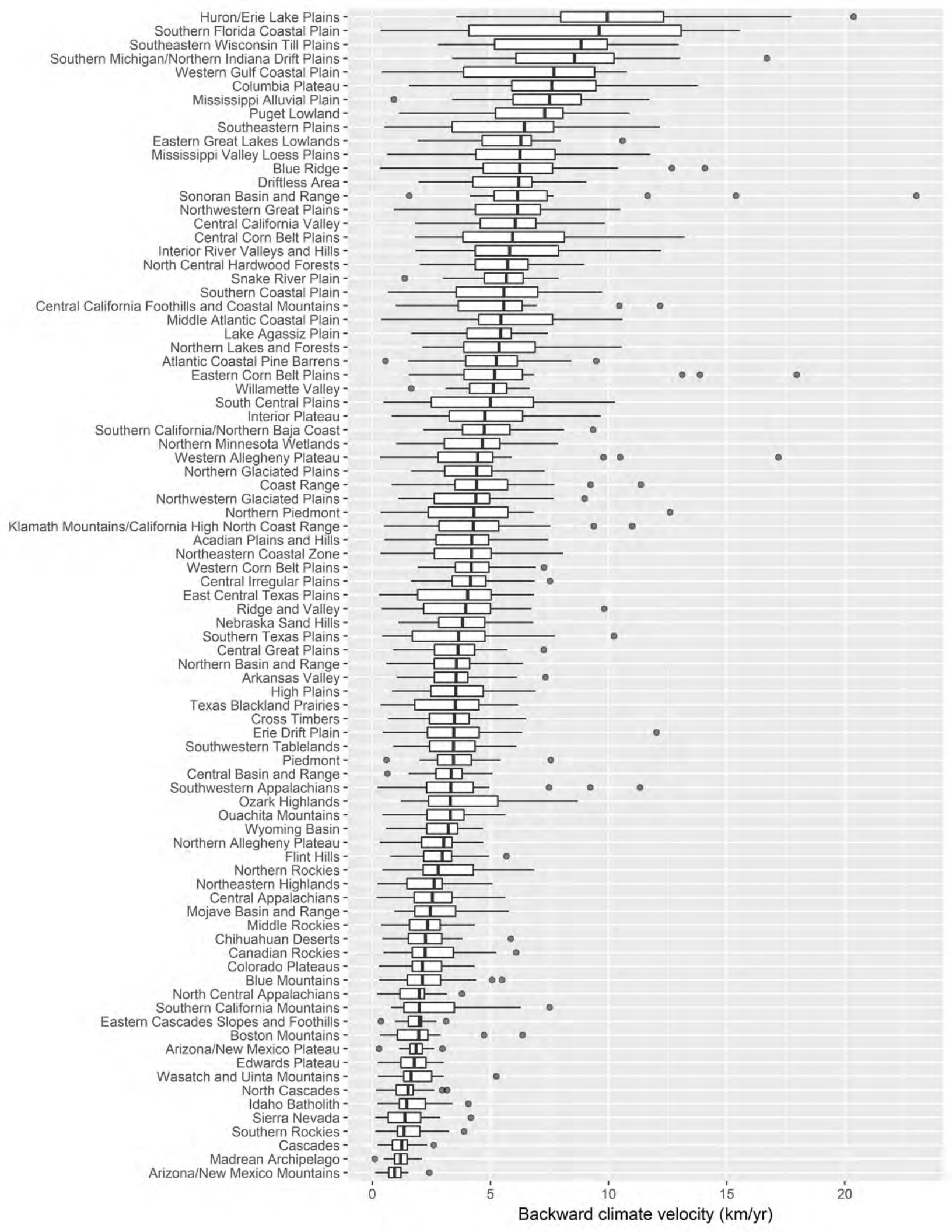
Forward climate velocity (km/yr)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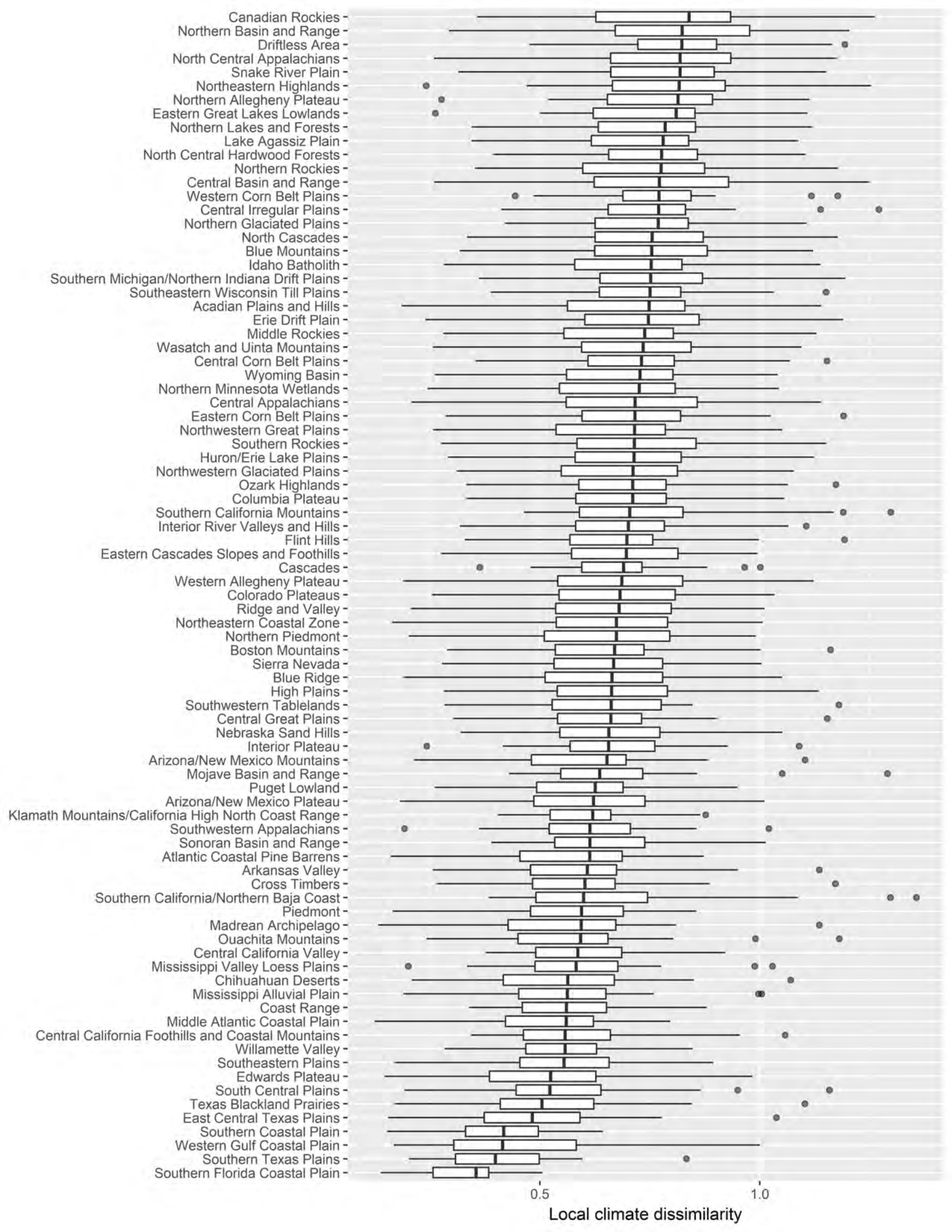
Backward climate velocity (km/yr)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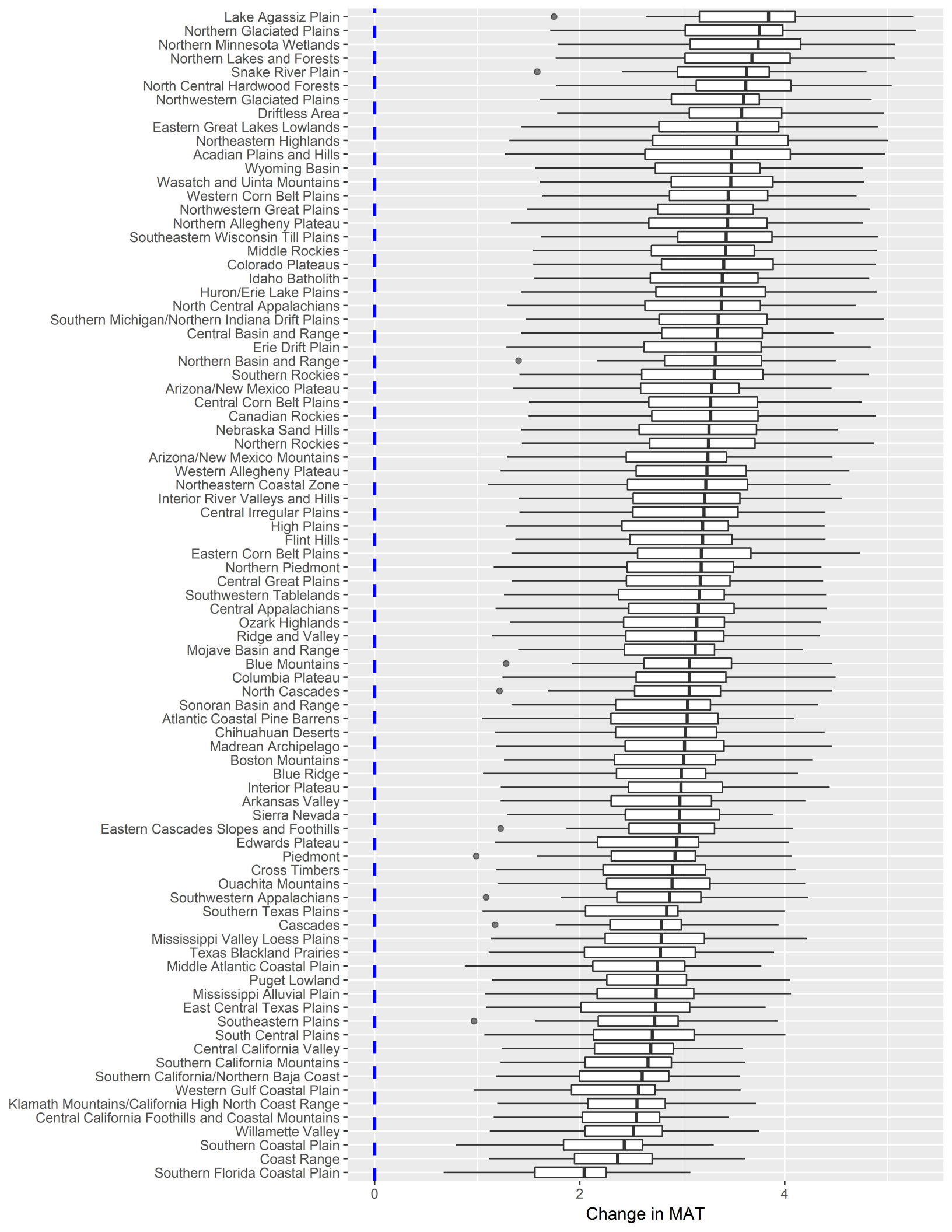
Local climate dissimilarity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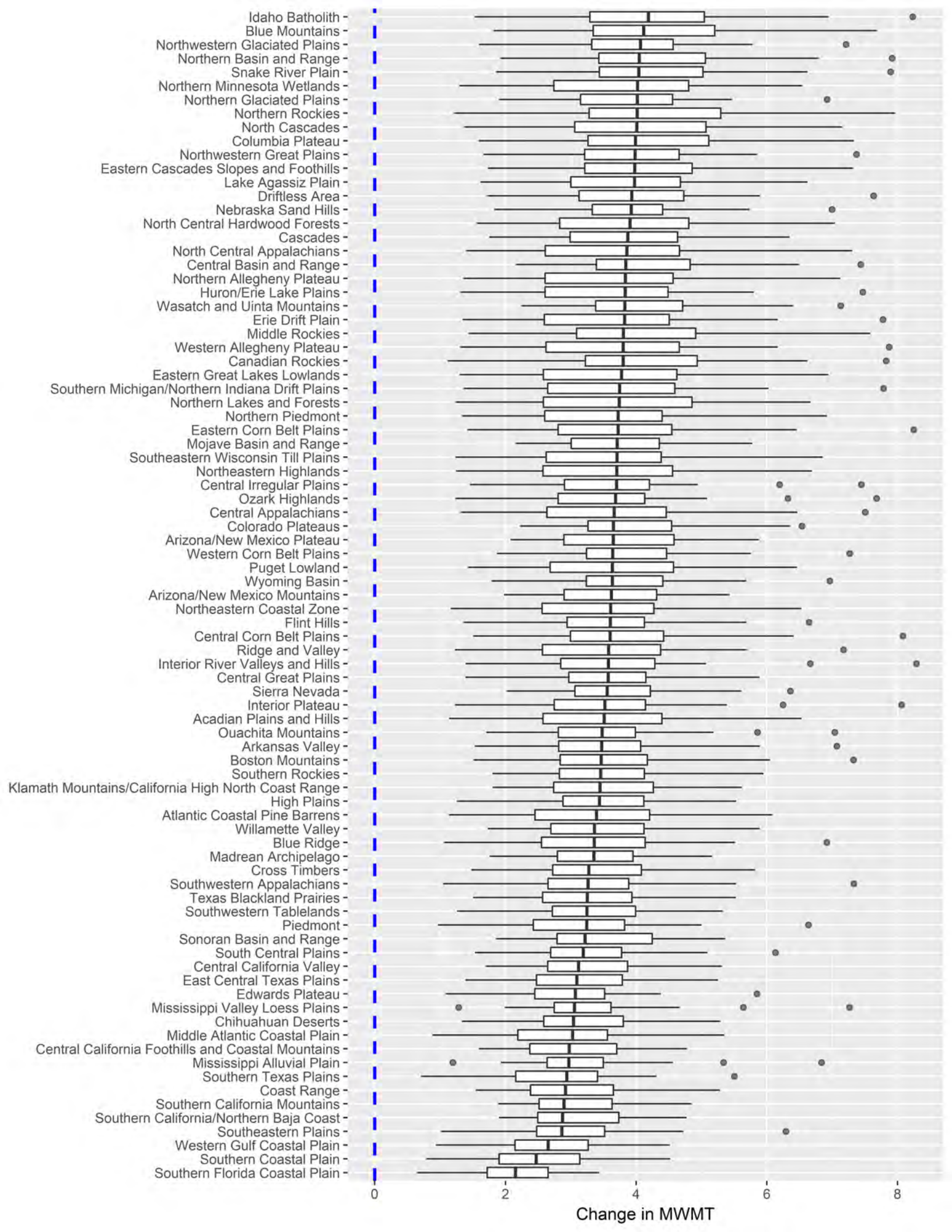
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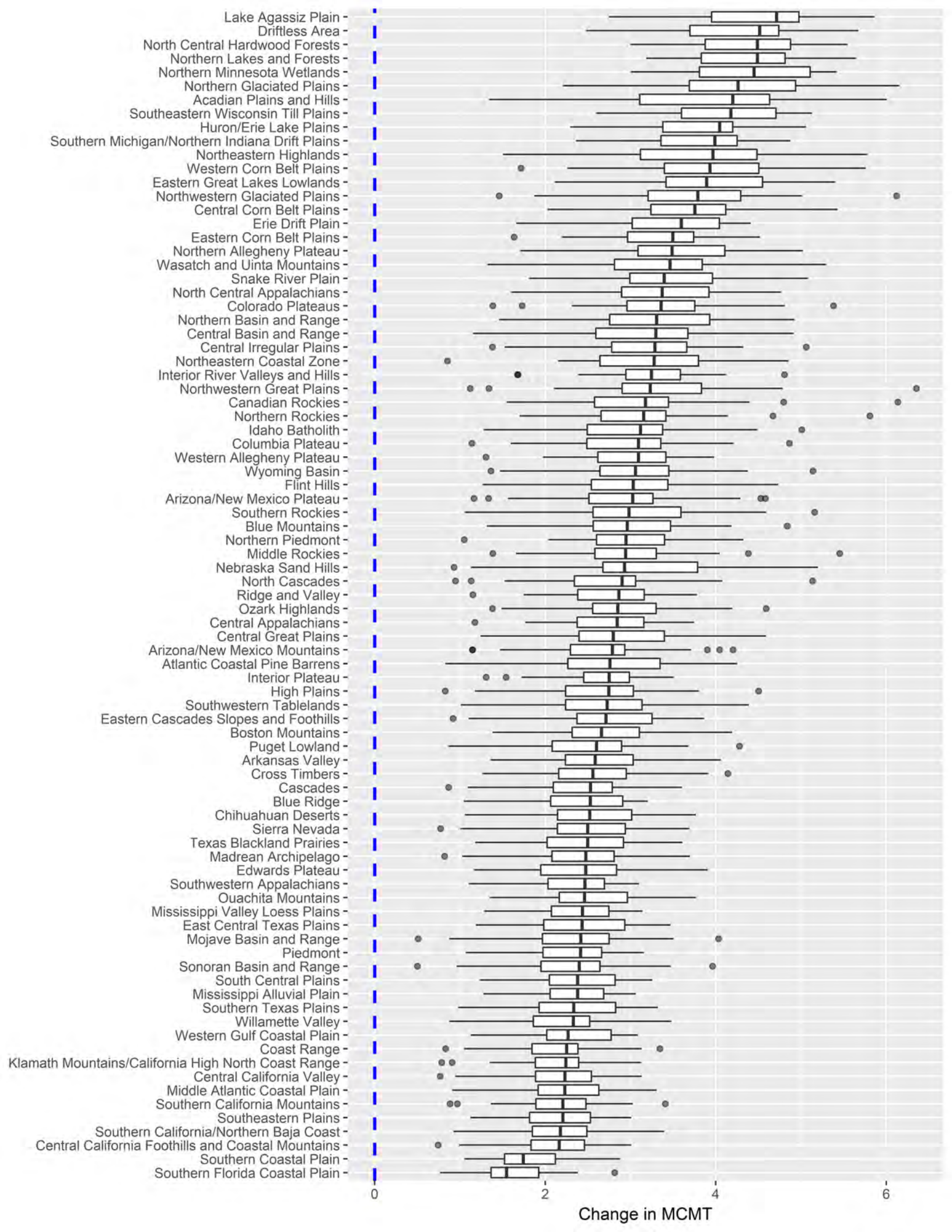
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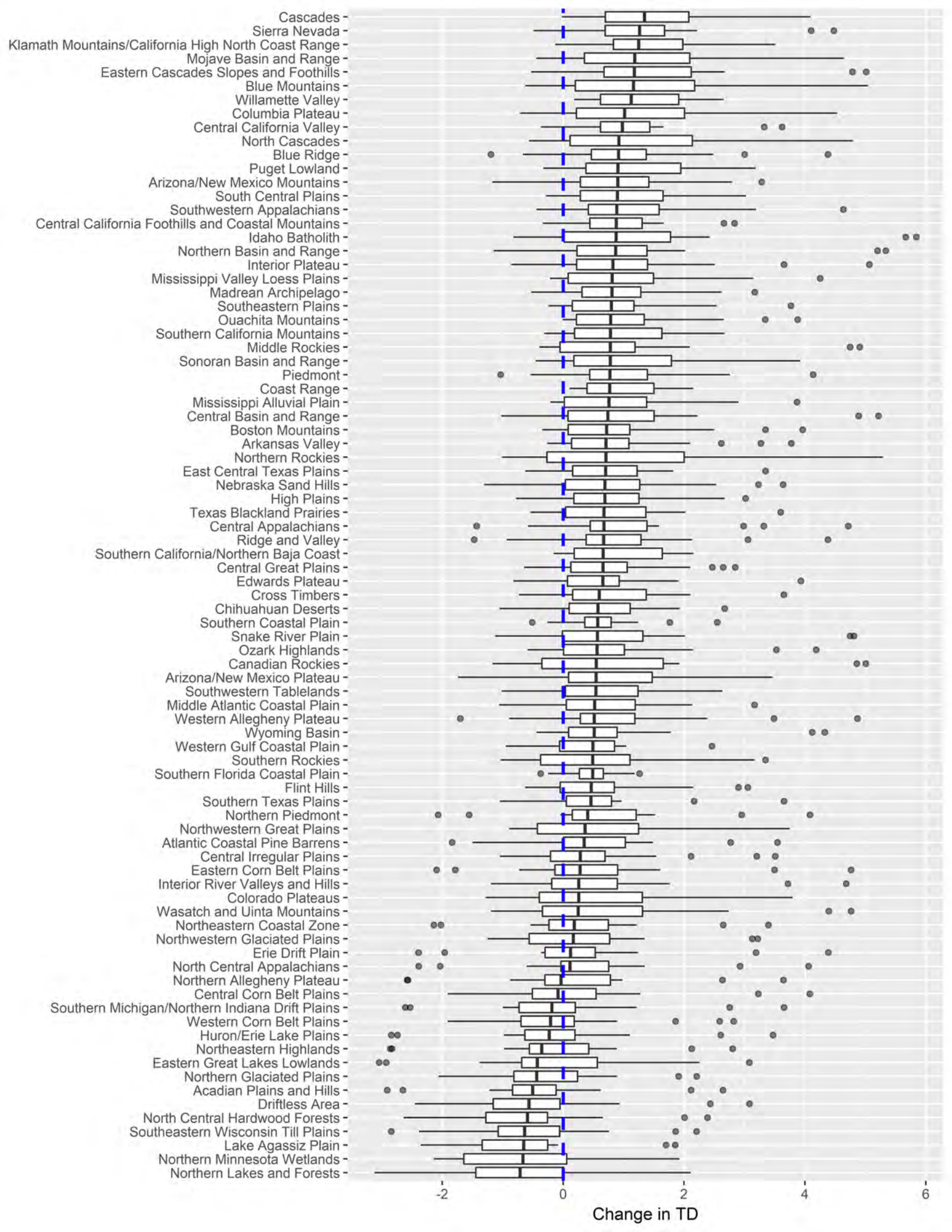
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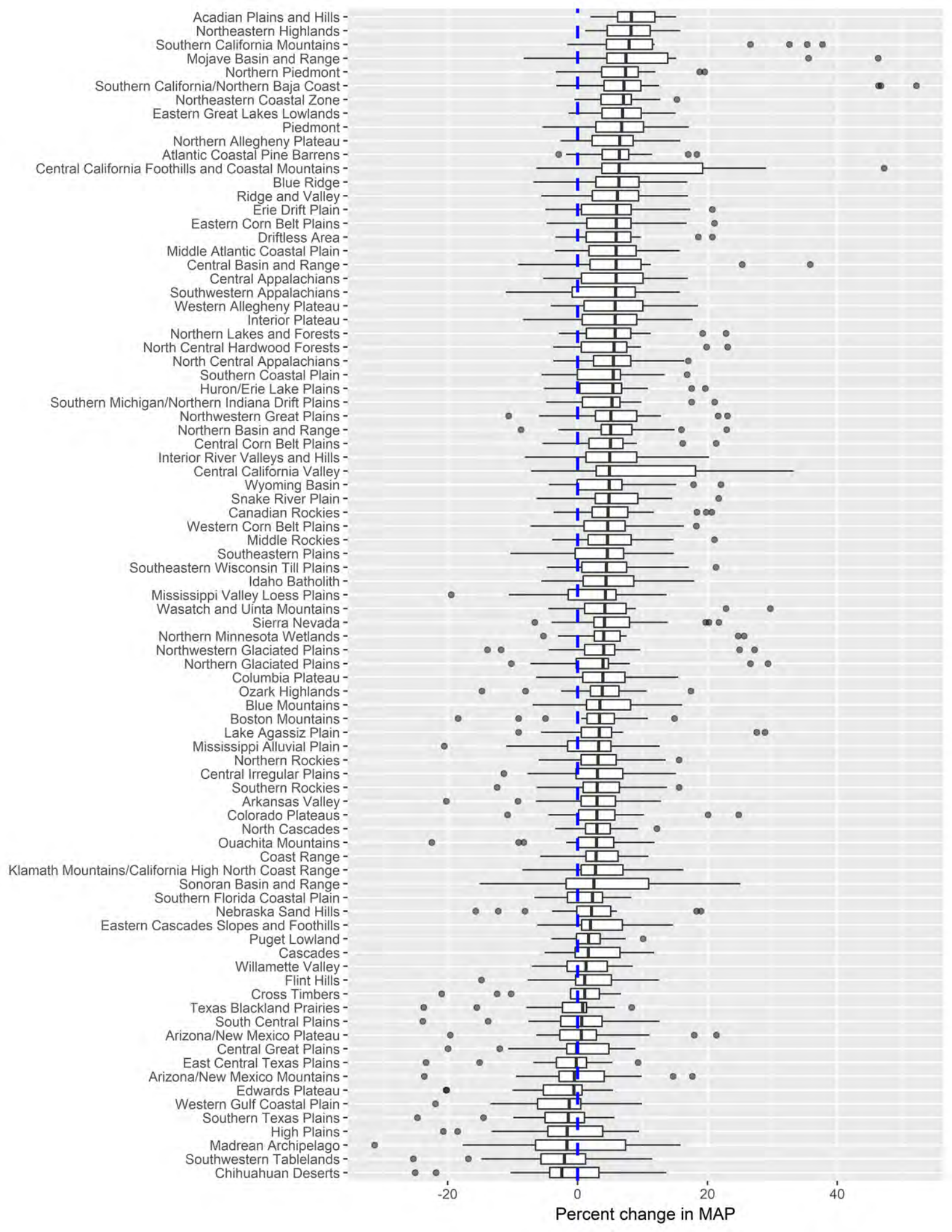
Change in TD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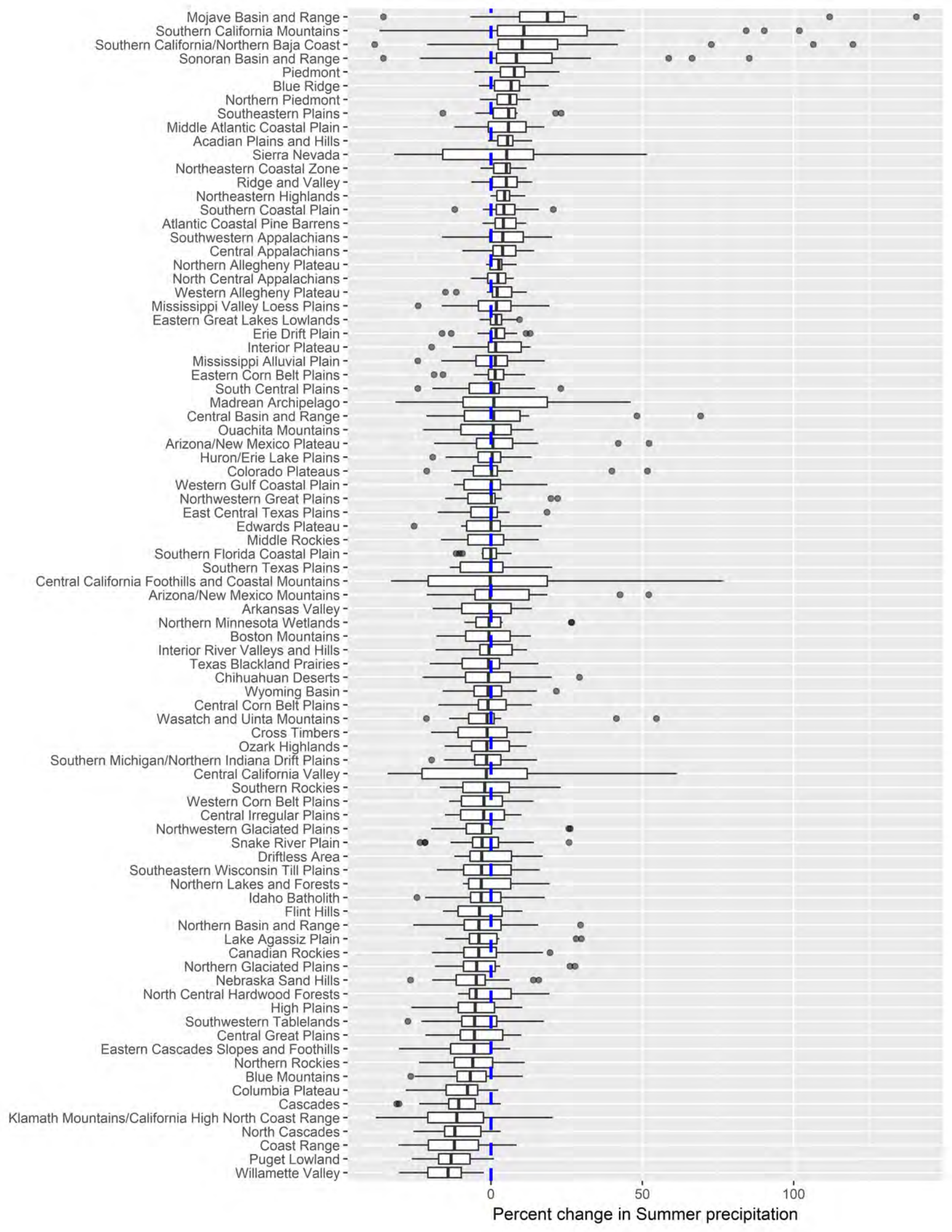
Percent change in MAP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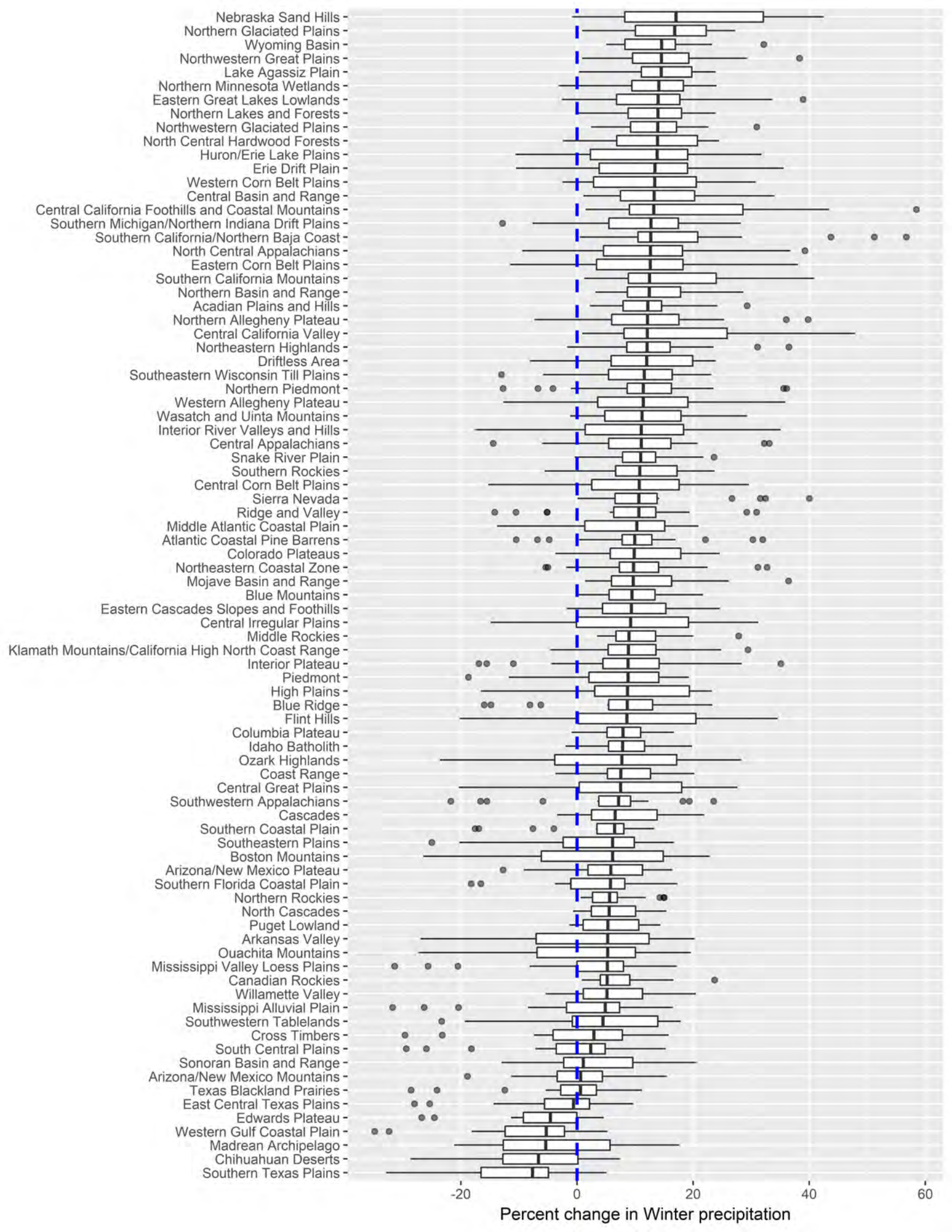
Northern Piedmont
Southeastern Plains
Middle Atlantic Coastal Plain
Acadian Plains and Hills
Sierra Nevada
Northeastern Coastal Zone
Ridge and Valley
Northeastern Highlands
Southern Coastal Plain
Atlantic Coastal Pine Barrens
Southwestern Appalachians
Central Appalachians
Northern Allegheny Plateau
North Central Appalachians
Western Allegheny Plateau
Mississippi Valley Loess Plains
Eastern Great Lakes Lowlands
Erie Drift Plain
Interior Plateau
Mississippi Alluvial Plain
Eastern Corn Belt Plains
South Central Plains
Madrean Archipelago
Central Basin and Range
Ouachita Mountains
Arizona/New Mexico Plateau
Huron/Erie Lake Plains
Colorado Plateaus
Western Gulf Coastal Plain
Northwestern Great Plains
East Central Texas Plains
Edwards Plateau
Middle Rockies
Southern Florida Coastal Plain
Southern Texas Plains
Central California Foothills and Coastal Mountains
Arizona/New Mexico Mountains
Arkansas Valley
Northern Minnesota Wetlands
Boston Mountains
Interior River Valleys and Hills
Texas Blackland Prairies
Chihuahuan Deserts
Wyoming Basin
Central Corn Belt Plains
Wasatch and Uinta Mountains
Cross Timbers
Ozark Highlands
Southern Michigan/Northern Indiana Drift Plains
Central California Valley
Southern Rockies
Western Corn Belt Plains
Central Irregular Plains
Northwestern Glaciated Plains
Snake River Plain
Driftless Area
Southeastern Wisconsin Till Plains
Northern Lakes and Forests
Idaho Batholith
Flint Hills
Northern Basin and Range
Lake Agassiz Plain
Canadian Rockies
Northern Glaciated Plains
Nebraska Sand Hills
North Central Hardwood Forests
High Plains
Southwestern Tablelands
Central Great Plains
Eastern Cascades Slopes and Foothills
Northern Rockies
Blue Mountains
Columbia Plateau
Cascades
Klamath Mountains/California High North Coast Range
North Cascades
Coast Range
Puget Lowland
Willamette Valley
0
50
100
Percent change in Summer precipitation


Nebraska Sand Hills
Northern Glaciated Plains
Wyoming Basin
Northwestern Great Plains
Lake Agassiz Plain
Northern Minnesota Wetlands
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Northern Lakes and Forests
Northwestern Glaciated Plains
North Central Hardwood Forests
Huron/Erie Lake Plains
Erie Drift Plain
Western Corn Belt Plains
Central Basin and Range
Central California Foothills and Coastal Mountains
Southern Michigan/Northern Indiana Drift Plains
Southern California/Northern Baja Coast
North Central Appalachians
Eastern Corn Belt Plains
Southern California Mountains
Northern Basin and Range
Acadian Plains and Hills
Northern Allegheny Plateau
Central California Valley
Northeastern Highlands
Driftless Area
Southeastern Wisconsin Till Plains
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Interior River Valleys and Hills
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Ridge and Valley
Middle Atlantic Coastal Plain
Atlantic Coastal Pine Barrens
Colorado Plateaus
Northeastern Coastal Zone
Mojave Basin and Range
Blue Mountains
Eastern Cascades Slopes and Foothills
Central Irregular Plains
Middle Rockies
Klamath Mountains/California High North Coast Range
Interior Plateau
Piedmont
High Plains
Blue Ridge
Flint Hills
Columbia Plateau
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Ozark Highlands
Coast Range
Central Great Plains
Southwestern Appalachians
Cascades
Southern Coastal Plain
Southeastern Plains
Boston Mountains
Arizona/New Mexico Plateau
Southern Florida Coastal Plain
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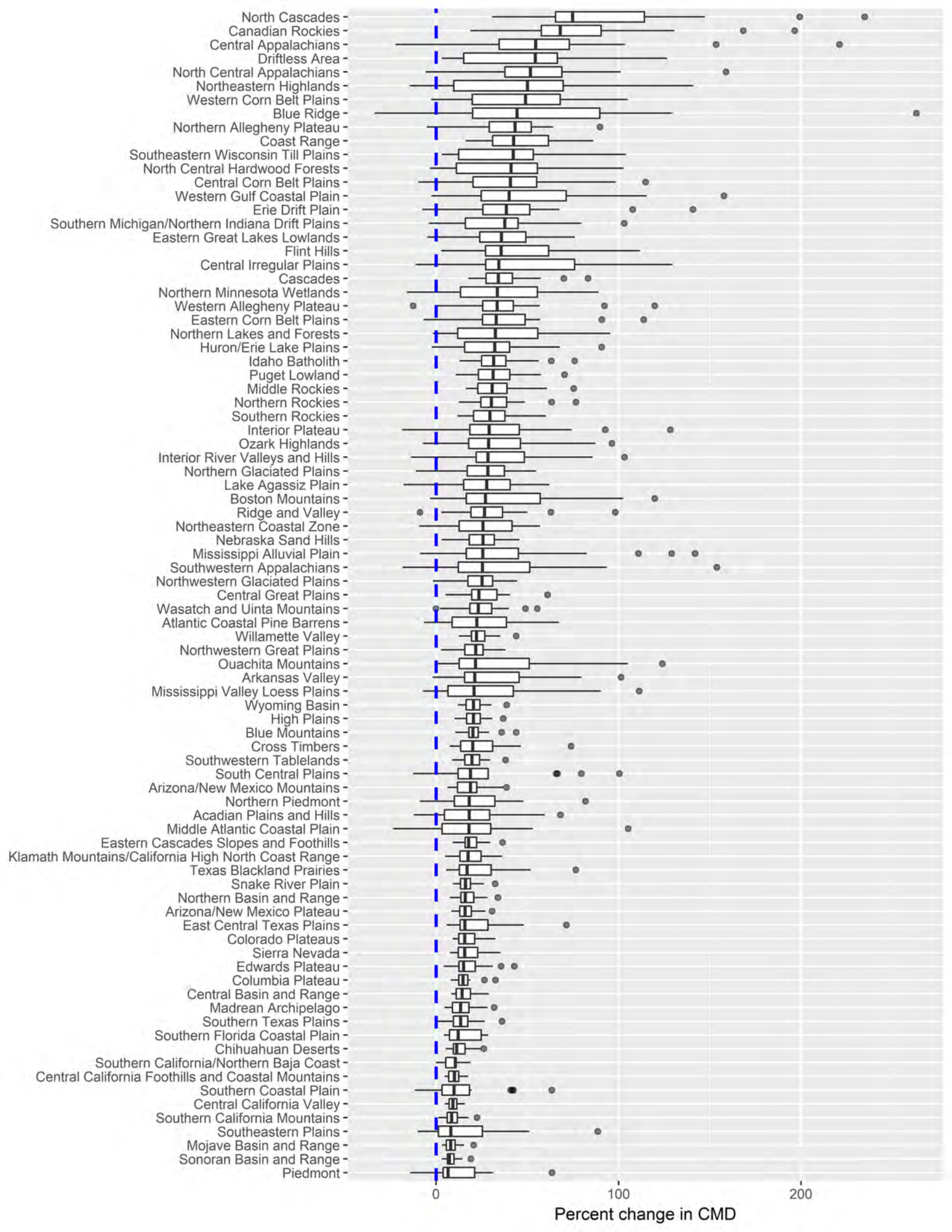
North Cascades
Puget Lowland
Arkansas Valley
Ouachita Mountains
Mississippi Valley Loess Plains
Canadian Rockies
Willamette Valley
Mississippi Alluvial Plain
Southwestern Tablelands
Cross Timbers
South Central Plains
Sonoran Basin and Range
Arizona/New Mexico Mountains
Texas Blackland Prairies
East Central Texas Plains
Edwards Plateau
Western Gulf Coastal Plain
Madrean Archipelago
Chihuahuan Deserts
Southern Texas Plains
-20
0
20
40
60
Percent change in Winter precipitation


North Cascades
Canadian Rockies
Central Appalachians
Driftless Area
North Central Appalachians
Northeastern Highlands
Western Corn Belt Plains
Blue Ridge
Northern Allegheny Plateau
Coast Range
Southeastern Wisconsin Till Plains
North Central Hardwood Forests
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Western Gulf Coastal Plain
Erie Drift Plain
Southern Michigan/Northern Indiana Drift Plains
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Cascades
Northern Minnesota Wetlands
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Interior Plateau
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Arkansas Valley
Mississippi Valley Loess Plains
Wyoming Basin
High Plains
Blue Mountains
Cross Timbers
Southwestern Tablelands
South Central Plains
Arizona/New Mexico Mountains
Northern Piedmont
Acadian Plains and Hills
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Arizona/New Mexico Plateau
East Central Texas Plains
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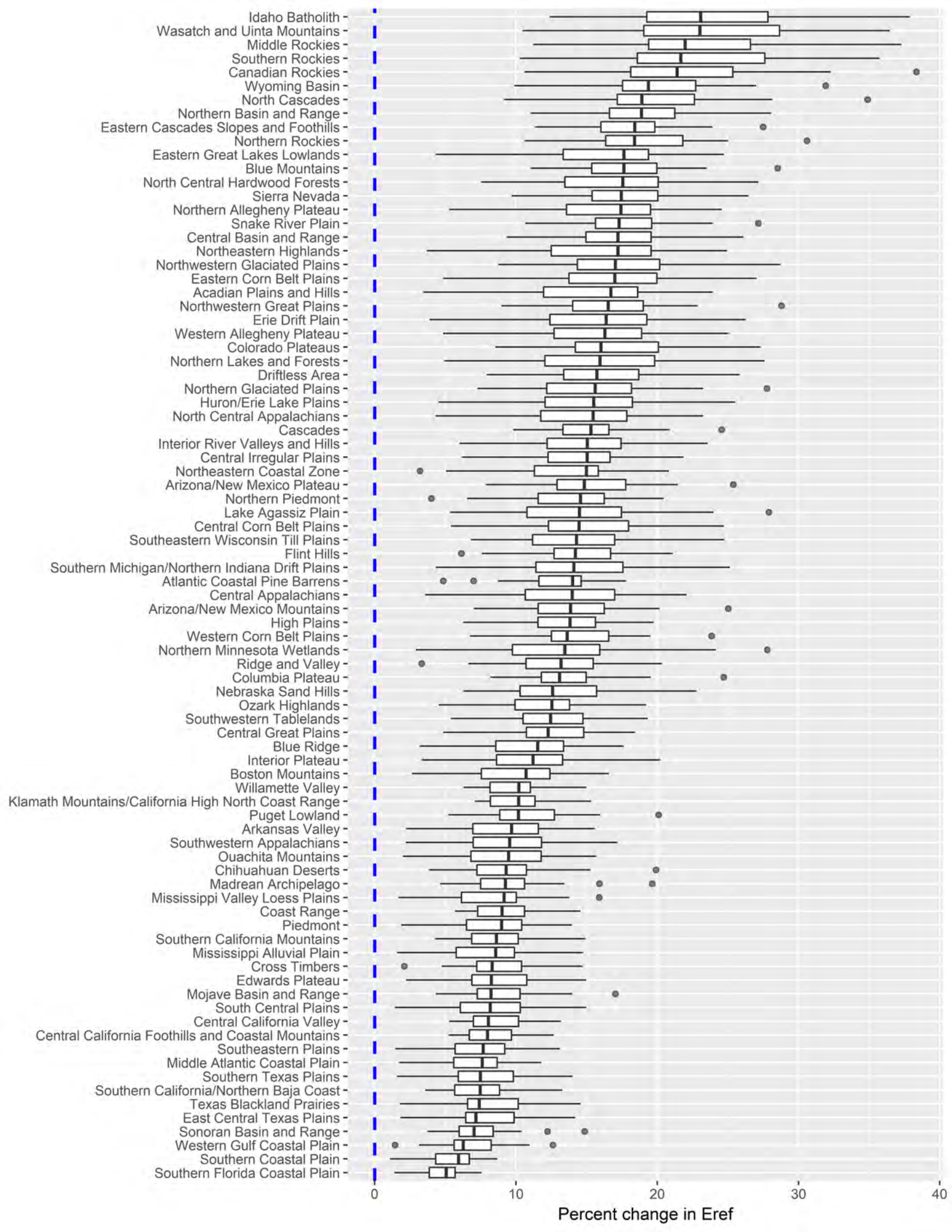
Edwards Plateau
Columbia Plateau
Central Basin and Range
Madrean Archipelago
Southern Texas Plains
Southern Florida Coastal Plain
Chihuahuan Deserts
Southern California/Northern Baja Coast
Central California Foothills and Coastal Mountains
Southern Coastal Plain
Central California Valley
Southern California Mountains
Southeastern Plains
Mojave Basin and Range
Sonoran Basin and Range
Piedmont
0
100
200
Percent change in CMD


Idaho Batholith
Wasatch and Uinta Mountains
Middle Rockies
Southern Rockies
Canadian Rockies
Wyoming Basin
North Cascades
Northern Basin and Range
Eastern Cascades Slopes and Foothills
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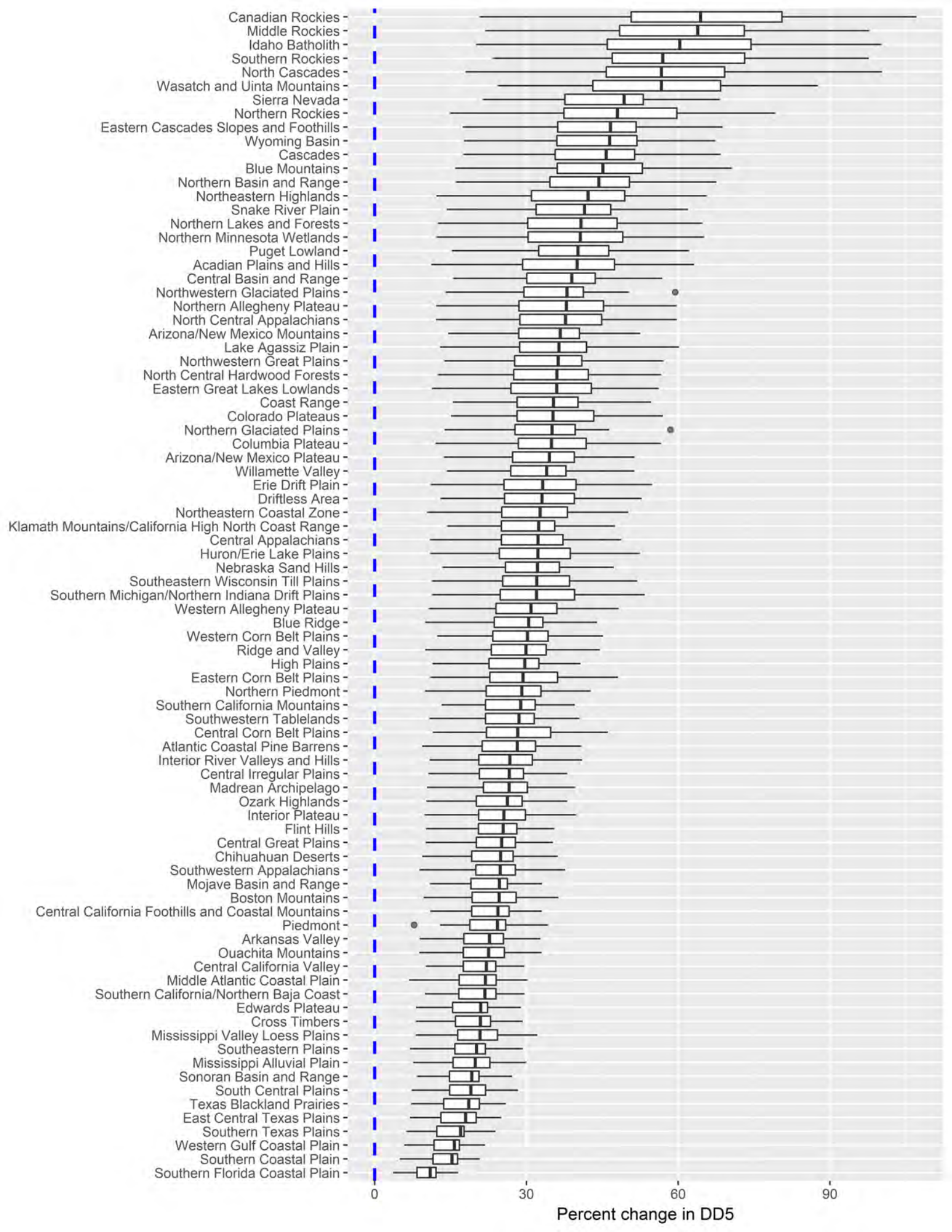
Mojave Basin and Range
South Central Plains
Central California Valley
Central California Foothills and Coastal Mountains
Southeastern Plains
Middle Atlantic Coastal Plain
Southern Texas Plains
Southern California/Northern Baja Coast
Texas Blackland Prairies
East Central Texas Plains
Sonoran Basin and Range
Western Gulf Coastal Plain
Southern Coastal Plain
Southern Florida Coastal Plain
0
10
20
30
40
Percent change in Eref


Canadian Rockies
Middle Rockies
Idaho Batholith
Southern Rockies
North Cascades
Wasatch and Uinta Mountains
Sierra Nevada
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Eastern Cascades Slopes and Foothills
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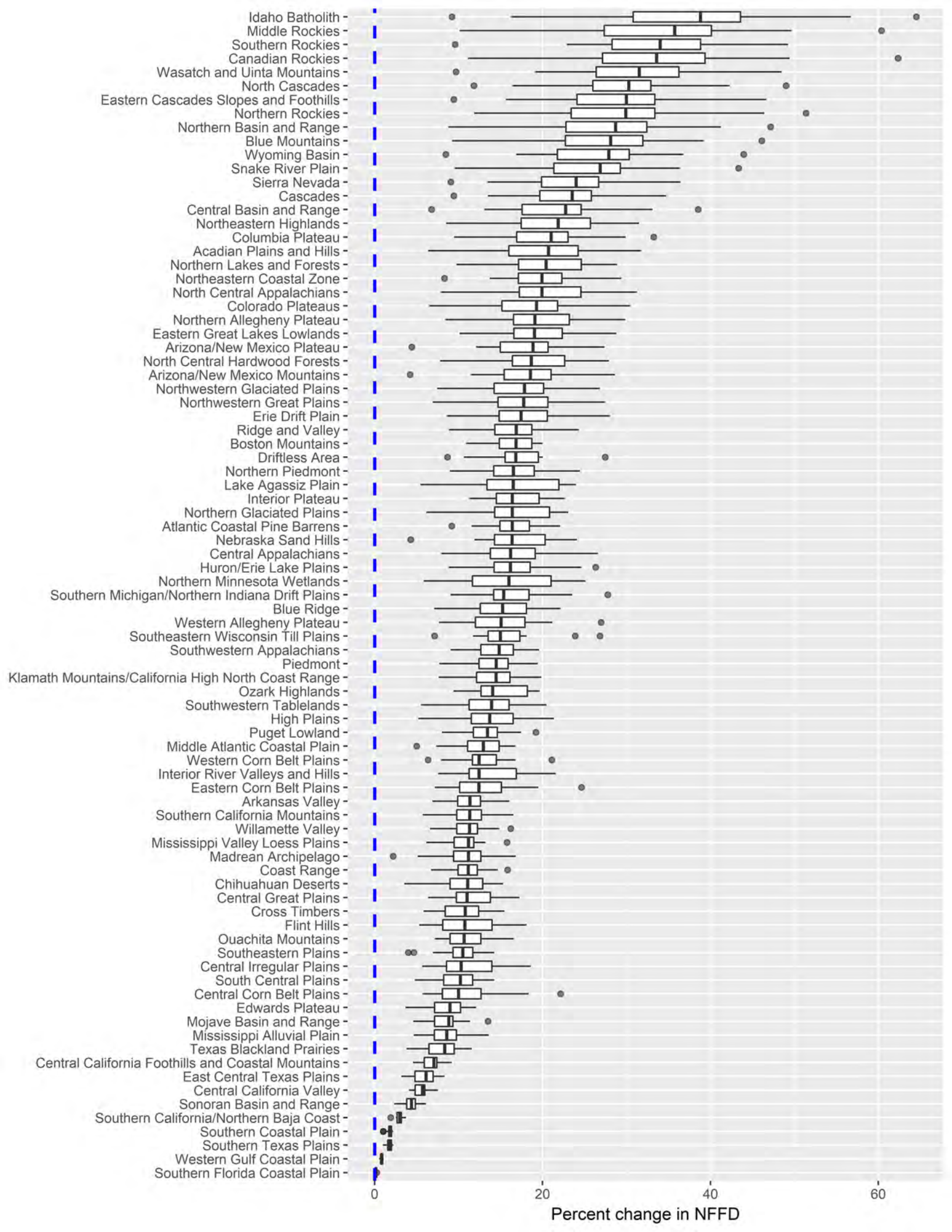
Cross Timbers
Mississippi Valley Loess Plains
Southeastern Plains
Mississippi Alluvial Plain
Sonoran Basin and Range
South Central Plains
Texas Blackland Prairies
East Central Texas Plains
Southern Texas Plains
Western Gulf Coastal Plain
Southern Coastal Plain
Southern Florida Coastal Plain
0
30
60
90
Percent change in DD5


Idaho Batholith
Middle Rockies
Southern Rockies
Canadian Rockies
Wasatch and Uinta Mountains
North Cascades
Eastern Cascades Slopes and Foothills
Northern Rockies
Northern Basin and Range
Blue Mountains
Wyoming Basin
Snake River Plain
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Central California Foothills and Coastal Mountains
East Central Texas Plains
Central California Valley
Sonoran Basin and Range
Southern California/Northern Baja Coast
Southern Coastal Plain
Southern Texas Plains
Western Gulf Coastal Plain
Southern Florida Coastal Plain
0
20
40
60
Percent change in NFFD

References

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