Melbourne Waterway Research-Practice Partnership

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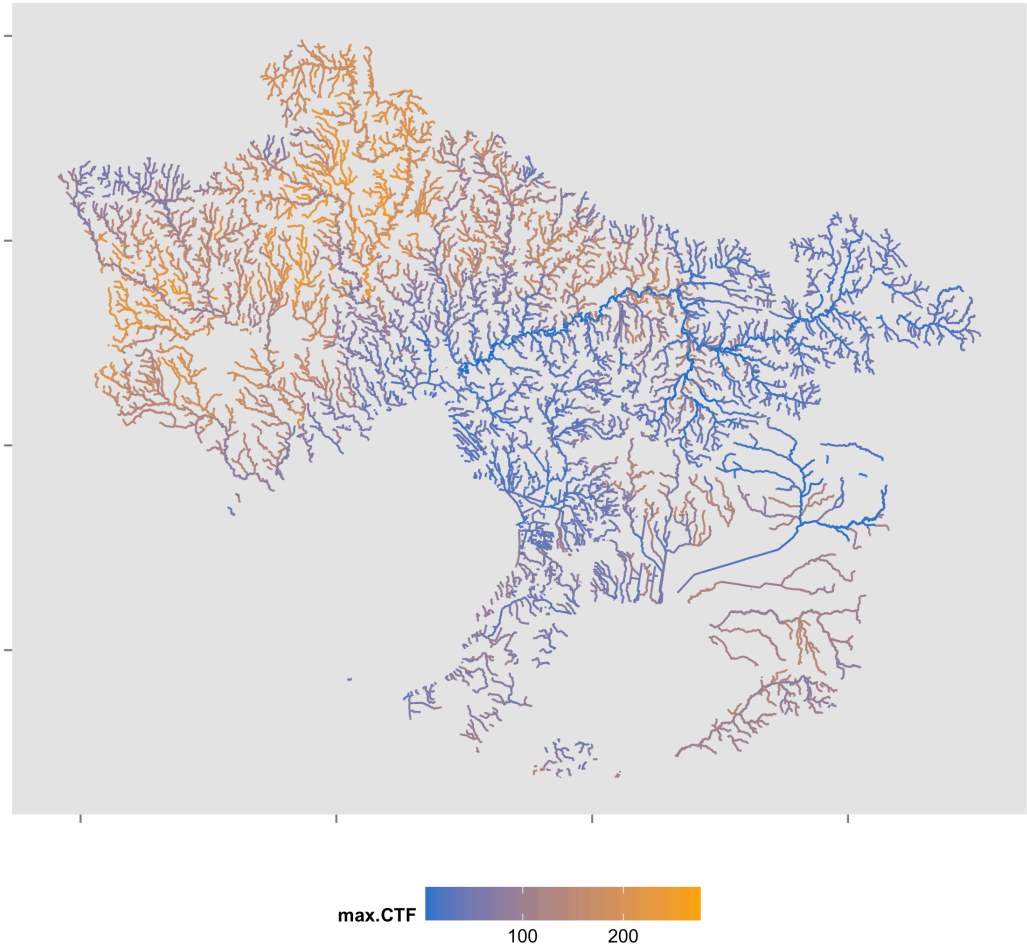
Determination of hydrologic characteristics of un-gauged stream reaches of the Merri Creek Catchment

MWSPP Project 1.4: Refining hydrologic prediction in un-gauged subcatchments

Nick Bond and Matthew Burns



Griffith UNIVERSITY

THE UNIVERSITY OF MELBOURNE

WATERWAY ECOSYSTEM RESEARCH GROUP

Melbourne Water

Draft Report

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Reviewed by: (date, affiliation)

Cover photo: Map showing predicted patterns of flow intermittency (low [blue] – high [fawn]) across the Melbourne Region.

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Exec summary

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Introduction

There is a frequent need for hydrologic information in ungauged catchments, and a range of methods have been developed, which vary in resolution and complexity. The most sophisticated approaches involve development of site-specific rainfall runoff models calibrated against similar gauged catchments, often coupled with re-scaling methods to account for differences in catchment area. An alternative approach is to extrapolate hydrologic indices describing runoff time-series characteristics, rather than transposing the actual time-series. This approach is potentially more robust due to the reduction in temporal complexity, and can be carried out using relatively sophisticated predictive modelling approaches, such as machine learning (e.g. Random Forests, Boosted regression trees), which have high predictive power relative to traditional modelling approaches (Breiman, 2001; Elith, Leathwick, & Hastie, 2008).

This report summarises the results for Merri Creek from an effort to predict hydrologic indices for ungauged catchment right across the Melbourne Water region.

The work encompassed five main steps.

1. Compile hydrologic information from the gauging network.
2. Calculate a suite of hydrologic indices describing various aspects of the flow regime
3. Generate predictive models relating hydrologic indices to catchment and climate characteristics
4. Assess model performance
5. Extrapolate indices to the remainder of the river network

The stream flow statistics that were considered include a range of indices describing 4 main components of the flow regime (base flows, cease-to-flow characteristics, variability, high flows and low flows; Table 1).

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Table 1. Summary statistics calculated for each stream flow gauge and extrapolated to ungauged catchments.

Flow category	flow statistic	Description
Baseflow	MDF	Mean daily flow
Baseflow	Q50	Median daily flow
Baseflow	mean.bf	Mean daily baseflow
Baseflow	mean.bfi	mean baseflow index (Mean daily baseflow/MDF)
CTF	p.CTF	Overall percentage of time with cease-to-flow (CTF)
CTF	avg.CTF	median duration of CTF spells (days)
CTF	med.CTF	Mean duration of CTF spells (days)
CTF	min.CTF	min CTF spell length (days)
CTF	max.CTF	max CTF spell (days)
Variability	ann.cv	coefficient of variation (CV) of annual flows
Variability	daily.cv	coefficient of variation (CV) of daily flows
High Flows	high.spell.threshold	Q10; flow (Ml/day) exceeded 10% of the time
High Flows	spell.freq	Average number of annual occurrences of flows exceeding Q10.
High Flows	avg.high.spell.duration	Mean duration of events exceeding the 10th percentile
High Flows	avg.spell.peak	Average maximum of flow of events exceeding the 10th percentile
High Flows	avg.rise	The average rate of rise (Ml/day) on days exceeding Q10
High Flows	avg.fall	The average rate of fall (Ml/day) on days exceeding Q10
Low Flows	low.spell.threshold	Q90; flow (Ml/day) exceeded 90% of the time
Low Flows	avg.low.spell.duration	Average duration of events below Q90
Low Flows	max.low.duration	Max duration of events below Q90
LowFlows	low.spell.freq	Average number of annual occurrences of flows below Q90.

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Methods

Summary statistics for 113 gauges (figure 1) within the Melbourne Water catchment area were calculated using the hydrostats package (Bond, 2014) within the R statistical environment (R Core Team, 2014). Environmental attributes used in the predictive models (Table 2) were acquired from the WERG research group databases and the national geofabric environmental layers (see J. L. Stein, Stein, & Nix, 2002 for a description). Random Forest models (Breiman, 2001) were then used to predict each of the hydrologic indices, and subsequently used to extrapolate these predictions to the entire river network.

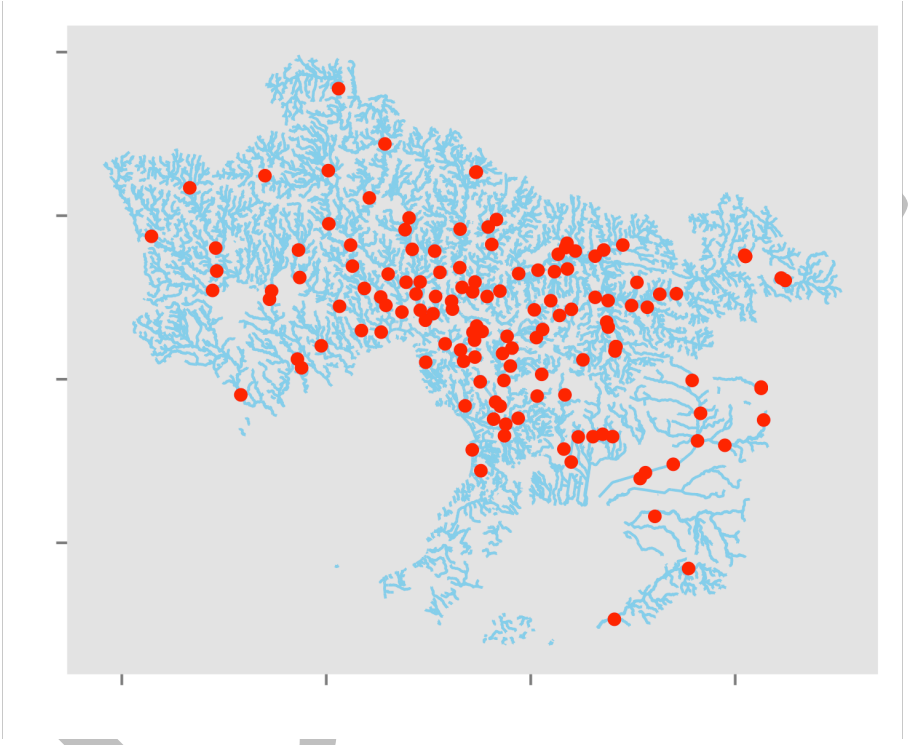

Figure 1. Location of the 113 streamflow gauges used in the modeling.

Table 2. List of predictors used in the models. Note that future iterations of this work will trial additional predictors, but also that, unlike traditional regression models, Random Forests are robust in the presence of uninformative predictors.

predictors	**Description**
dai9	Upstream catchment connected imperviousness
Catchment.area	Catchment area (km^2)
Igneous.geol	% igneous geology
Att.Forest	Attenuated forest cover
STRCOLDMTHMIN	Stream coldest monthly minimum temperature
STRHOTMTHMAX	Stream hottest monthly maximum temperature
CATANNRAIN	Catchment annual rainfall
RUNMTHCOFV	Coefficient of variation of monthly runoff (surplus rainfall)
RUNSUMMERMEAN	Average summer runoff (surplus rainfall)
CAT_A_KSAT	Soil saturated hydraulic conductivity
CAT_SOLPAWHC	Catchment soil plant available water holding capacity
RUNANNMEAN	Average annual runoff (surplus rainfall)

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Results

Gauge locations within the Merri Creek catchment and their hydrologic characteristics are shown in Figure 2 and Table 3. Note that several of the gauges have a very short period of record, and may not be particularly reliable, whereas the predictions from the modeling draw on the longer period of record available from similar catchments elsewhere in the Melbourne Water region.

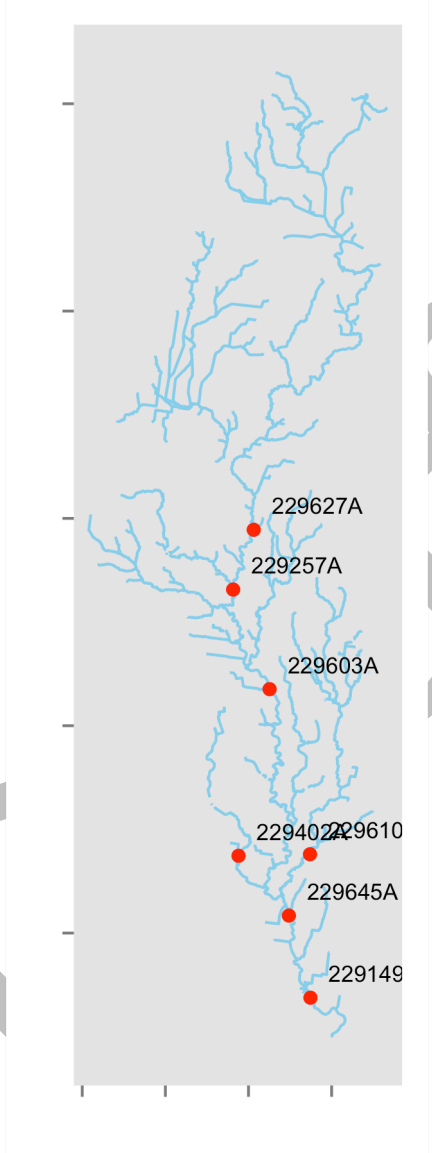

Figure 2. Location of streamflow gauges within the Merri Creek catchment.

Table 3. Summary statistics for the 7 gauges located within the Merri Creek catchment. Note several of the gauges have very short periods of record.

	Gauge						
Statistic	**229149A**	**229257A**	**229402A**	**229603A**	**229610A**	**229627A**	**229645A**
n.years	38.0	5.1	14.0	3.8	36.0	36.0	34.0
MDF	98.0	9.8	4.6	41.0	13.0	23.0	75.0
Q50	24.0	2.4	1.2	13.0	3.6	1.9	25.0
mean.bf	24.0	2.3	1.0	12.0	3.6	3.3	26.0
mean.bfi	0.24	0.23	0.22	0.28	0.27	0.14	0.34
p.CTF	0	8	11	0	8	10	0
avg.CTF	2.0	10.0	7.0	0.0	6.4	7.9	0.0
med.CTF	2	7	4	0	3	4	0
min.CTF	2	2	1	0	1	1	0
max.CTF	2	34	81	0	100	87	0
ann.cv	71	89	31	47	49	110	65
daily.cv	340	260	280	260	300	560	320
high.spell.threshold	190	23	11	92	27	29	160
n.events	480	41	210	35	600	150	380
spell.frequency	8.50	0.73	3.70	0.62	11.00	2.70	6.80
ari	0.120	1.400	0.270	1.600	0.093	0.370	0.150
avg.high.spell.duration	3.7	4.7	3.2	4.3	3.3	9.3	4.1
med.high.spell.duration	2	4	2	3	2	5	2
max.high.spell.duration	54	15	18	18	65	120	52
avg.spell.volume	1200	200	37	570	110	1400	810
avg.spell.peak	510	65	23	220	60	180	360
sd.spell.peak	780	49	30	250	88	350	600
avg.rise	460	37	21	180	63	170	280
avg.fall	360	27	17	110	50	94	220
low.spell.threshold	8.200	0.160	0.061	3.400	0.900	0.110	6.000
avg.low.spell.duration	3.9	9.1	6.8	4.2	5.0	8.0	4.2
max.low.duration	30	28	81	28	110	87	44
low.spell.freq	6.10	0.36	1.40	0.59	4.60	2.90	5.20

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Predictive accuracy varied substantially among the different hydrologic indices (Figure 3), being highest for base flow statistics and lowest for aspects of cease-to-flow. Arguably however all models performed sufficiently well to produce useful statistical summaries for locations where gauging data is not available. Future work will include additional estimation of the range of uncertainty for individual river reaches. The relative importance of different predictors in determining the spatial pattern in each of the different flow indices is summarised in Table 4. Maps illustrating the predicted hydrologic characteristics throughout the Merri Creek catchment are provided at the end of the document.

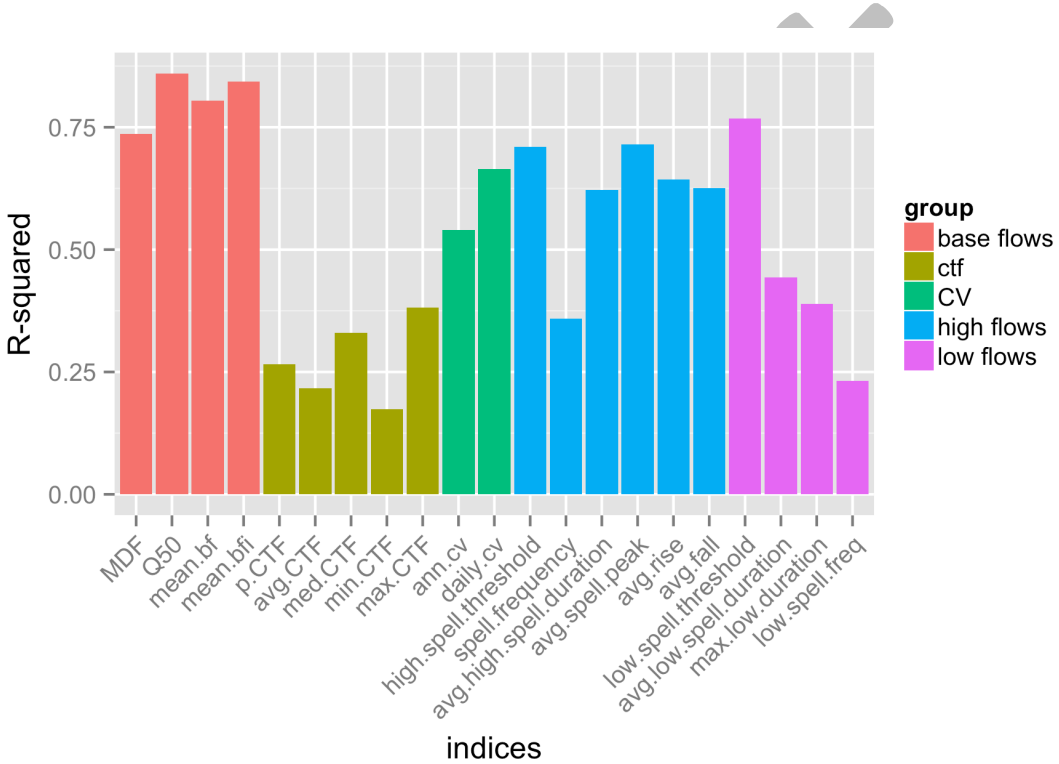

Figure 3. Predictive performance of the models based on 10-fold cross validation.

Table 4. The relative importance of individual predictor variables in determining the various runoff characteristics modelled using random forests.

variable	MDF	Q50	mean bf	mean bfi	p CTF	avg CTF	med CTF	min CTF	max CTF	ann cv	daily cv	high spell threshold	spell frequency	avg high spell duration	avg spell peak	avg rise	avg fall	low spell threshold	avg low spell duration	max low duration	low spell freq
dai9	6.16	3.95	5.07	5.23	9.74	8.27	7.33	2.85	12.37	14.15	4.52	4.04	11.62	25.22	4.88	3.95	6.77	3.42	10.33	13.16	8.68
Catchment.area	23.13	29.93	27.37	3.23	4.12	2.72	-0.56	1.64	2.27	7.02	7.89	27.41	5.22	11.92	21.94	37.09	29.8	23.56	4.55	0.82	1.48
Igneous.geol	3.08	3.58	1.72	5.36	3.09	2.39	1.62	1.06	2.42	4.16	3.67	2.31	2.17	-0.13	4.04	3.87	1.68	3.93	7.81	3.09	3.8
Att.Forest	2.64	2.17	2.57	4.58	5.01	4.57	5.33	4.04	5.03	2.94	2.39	2.08	1.16	3.41	2.44	2.32	4.06	2.44	6.05	4.48	2.04
STRCOLDMTHMIN	7.13	4.79	5.44	7.28	8.71	8.09	24.55	0.85	11.79	12.57	11.15	4.9	5.29	4.32	9.34	7.97	12.74	4.91	11.94	8.89	7.02
STRHOTMTHMAX	7.1	5.01	5.12	3.68	3.02	6.25	2.87	1.08	5.85	6.25	10.81	5.11	4.01	0.43	8.02	5.72	8.22	5.25	4.81	6.46	5.1
CATANNRAIN	5.71	5.77	4.68	12.41	7.91	5.33	5.35	4.21	9.87	11.9	19.76	4.11	7.84	2.42	4.58	1.77	5.05	6.34	7.51	8.88	4.83
RUNMTHCOFV	9.72	7.99	9.45	10.42	7.02	6.54	5.56	4.24	7.08	6.76	2.75	7.23	9.92	3.63	8.53	3.96	5.5	10.7	7.54	7.1	5.89
RUNSUMMERMEAN	4.44	3.61	4.33	16.49	5.69	6.77	6.82	4.45	8.61	9.37	17.86	3.25	8.35	9.69	5.31	2.05	1.87	4.41	7.56	8.14	6.63
CAT_A_KSAT	1.89	4.61	3.57	8.59	5.14	3.1	4.88	4.59	7.2	9.32	3.14	3.5	2.18	4.38	3.78	1.04	3.5	3.87	7.01	4.52	0.64
CAT_SOLPAWHC	5.01	4.71	4.44	8.27	3.72	6.92	9.7	4.78	7.01	10.52	2.28	3.55	2.18	1.38	5.78	2.11	0.66	4.52	5.14	5.89	2.51
RUNANNMEAN	4.95	5.65	5.77	10.19	8.37	7.13	5.47	5.38	8.41	6.21	4.89	4.4	8.19	3.18	6.1	2.29	3.2	6.88	7.66	6.09	6.56

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Discussion

This section of the report to include 3 main topics

Summary of drivers of runoff characteristics

Potential applications of the model results

Caveats around the statistics, in particular:

- Scales and sources of uncertainty
- Methodology ignores local factors not captured in spatial database layers
- Does not explicitly consider temporal variation (e.g. wet vs dry years)

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Appendix 1.

Maps showing flow indices across the Merri Creek Catchment.

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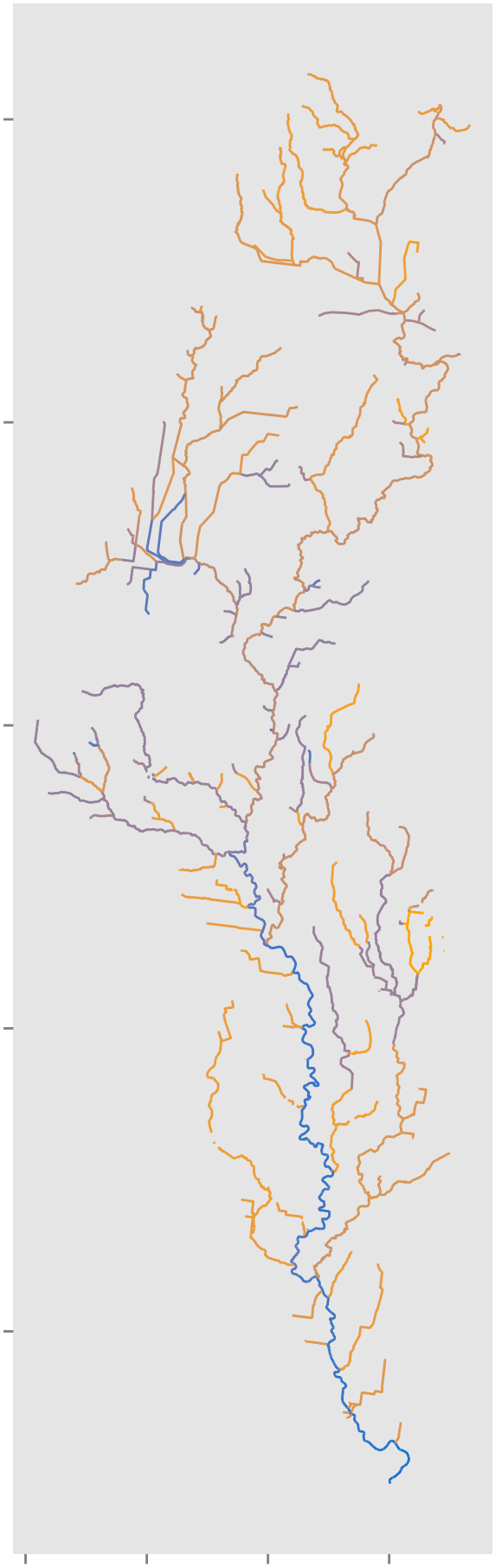

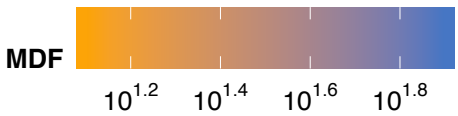
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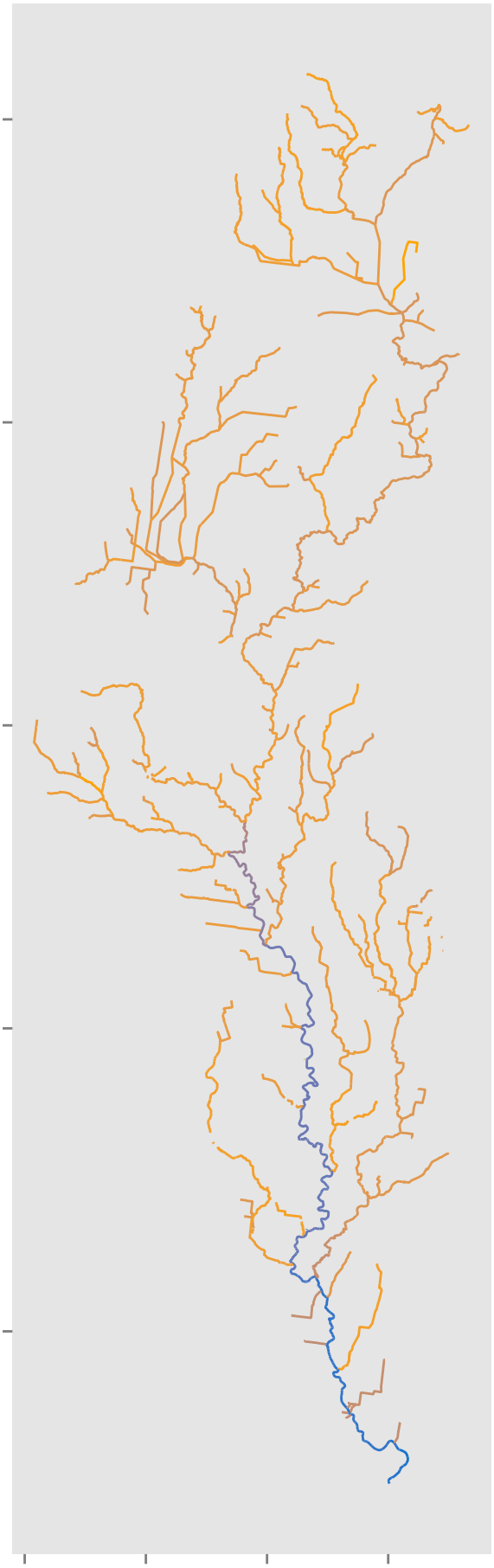

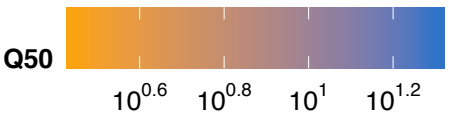
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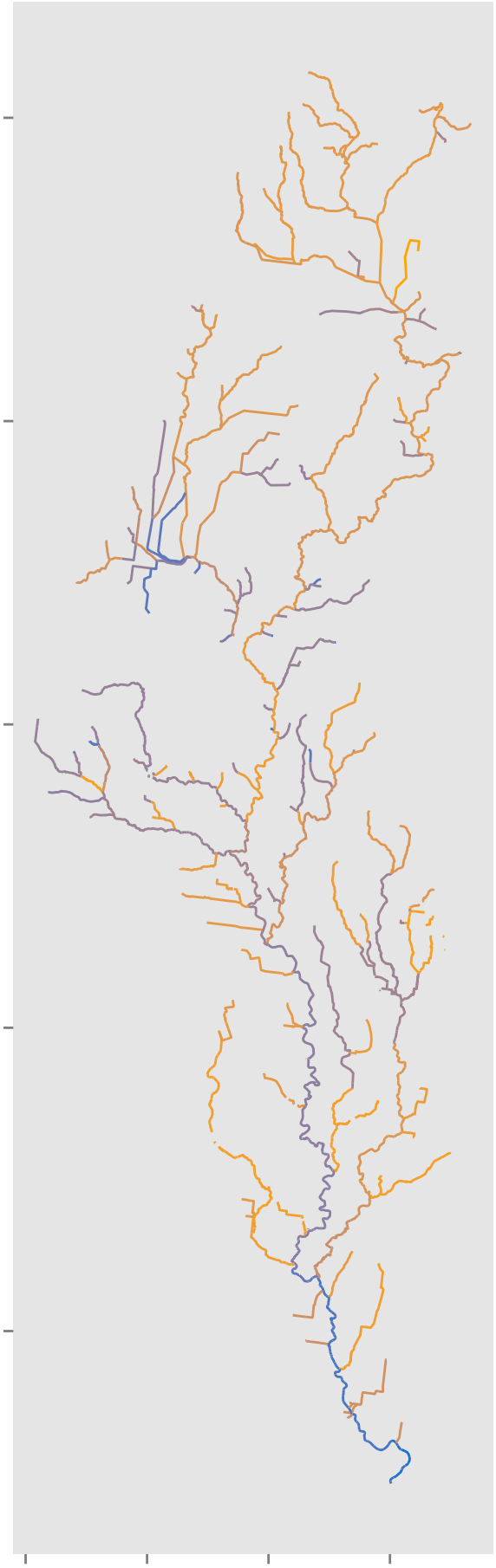

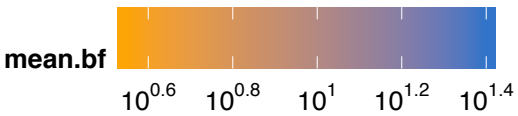
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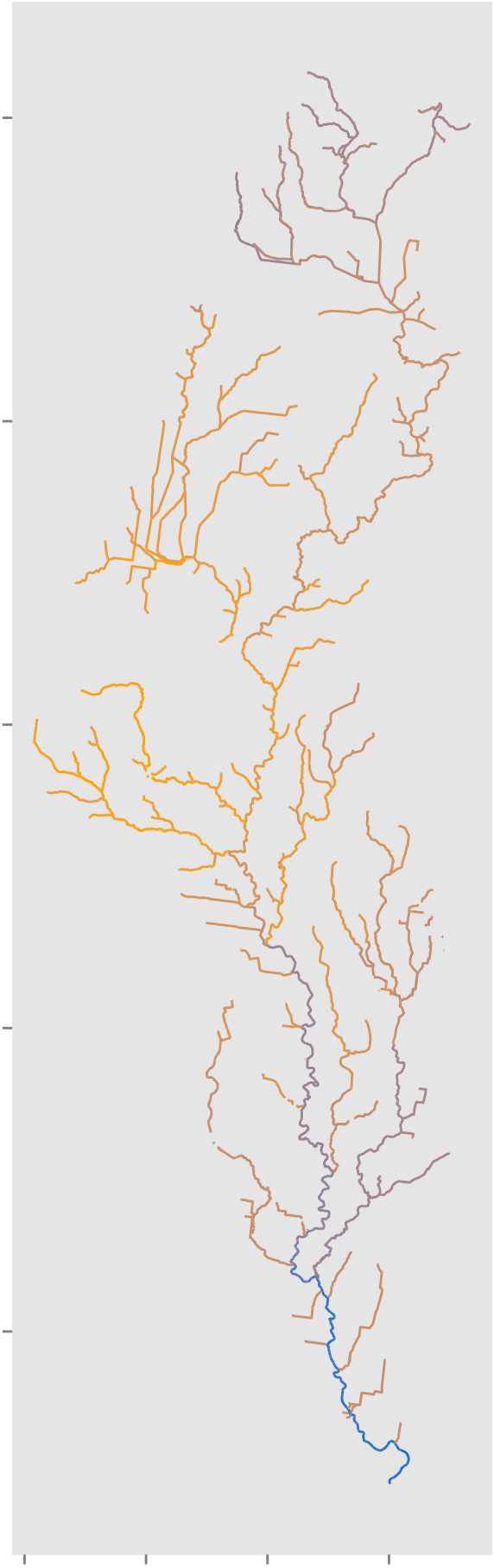

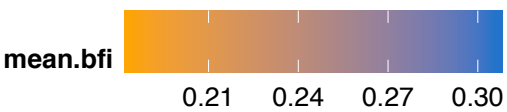
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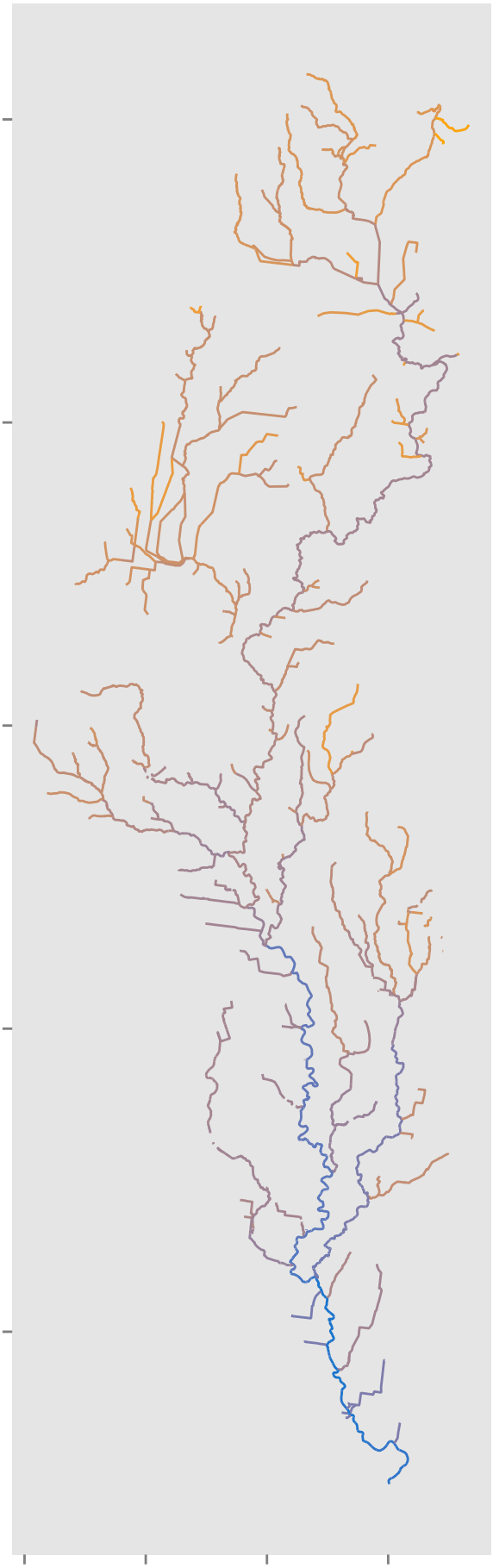

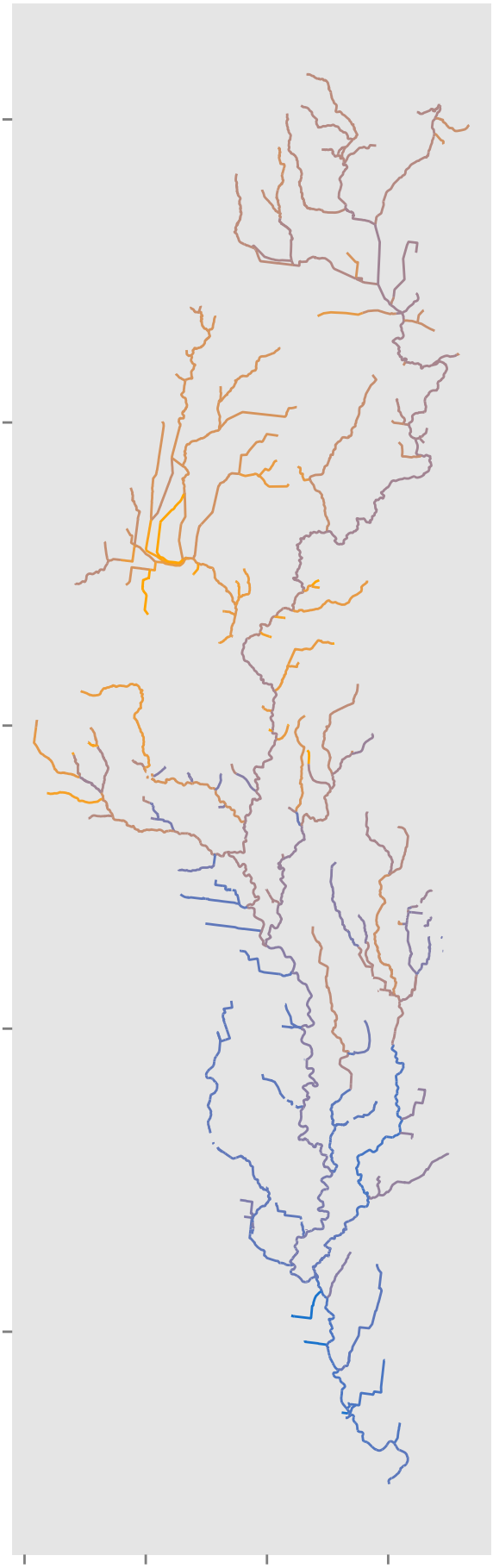

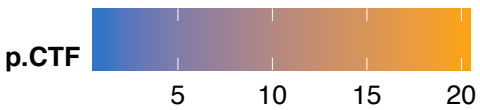
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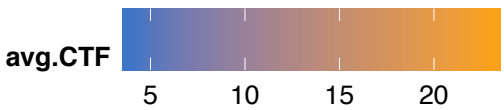
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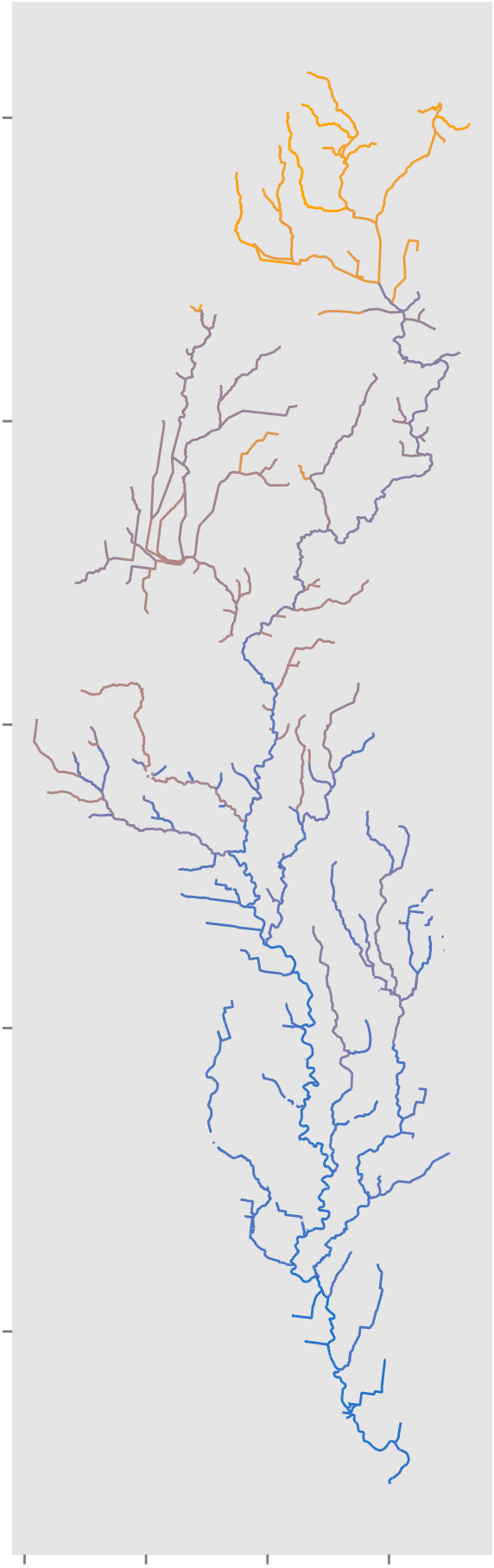

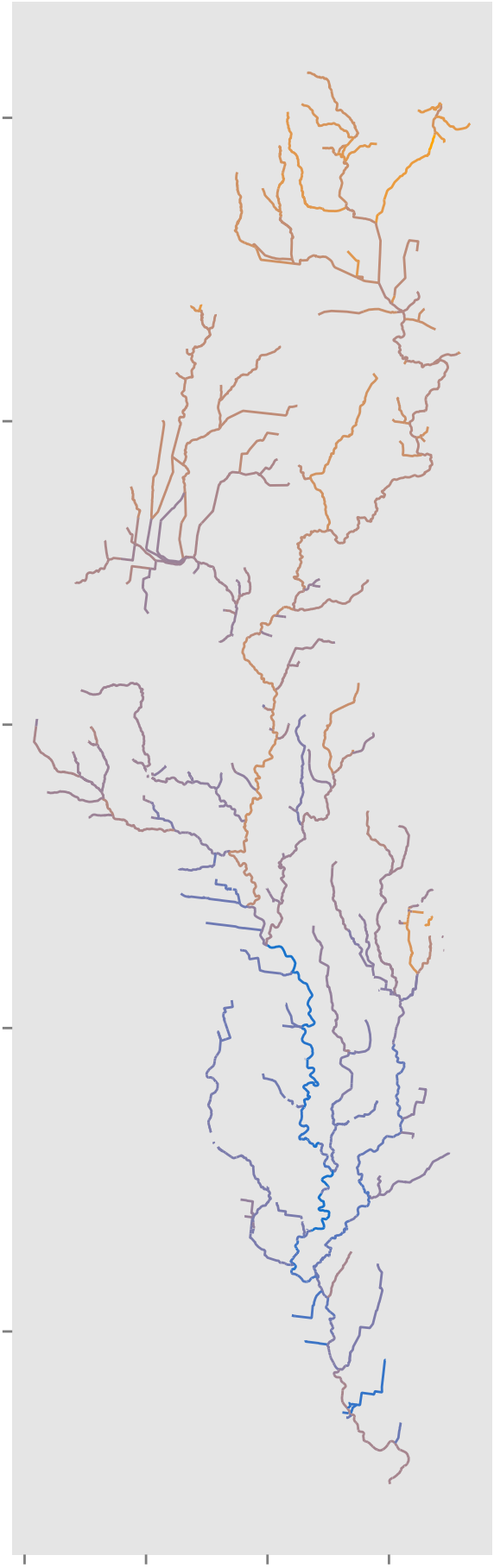

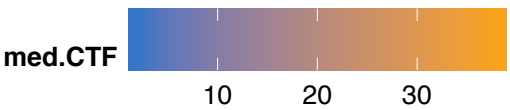
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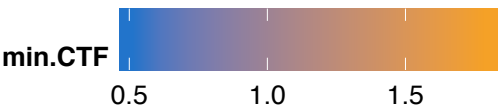
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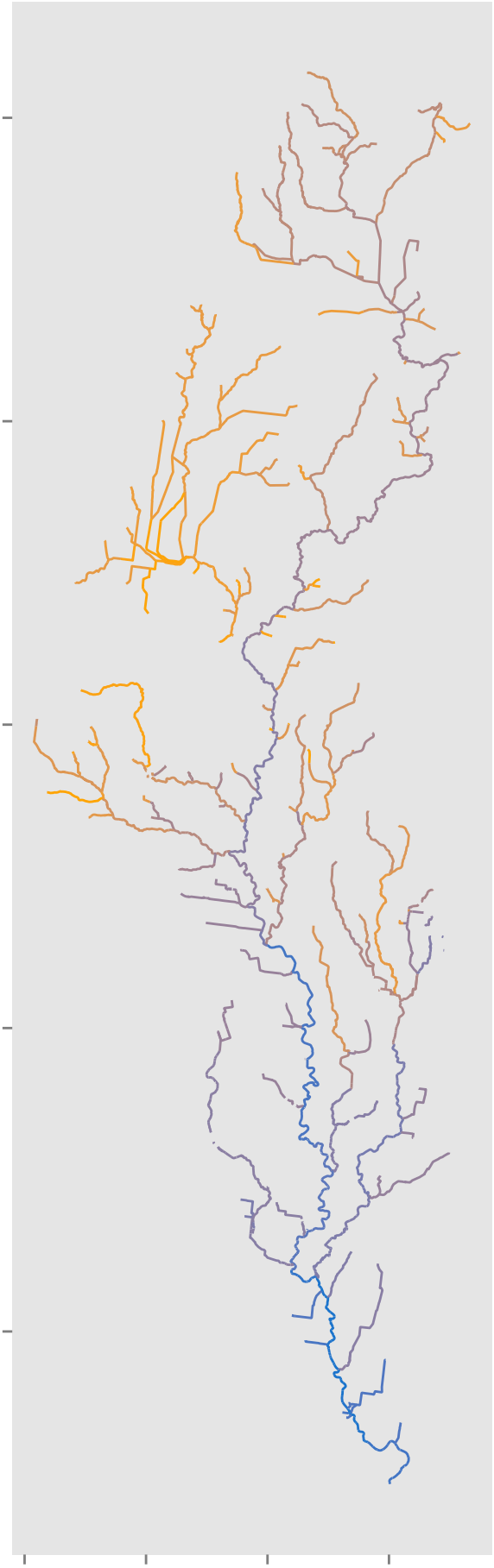

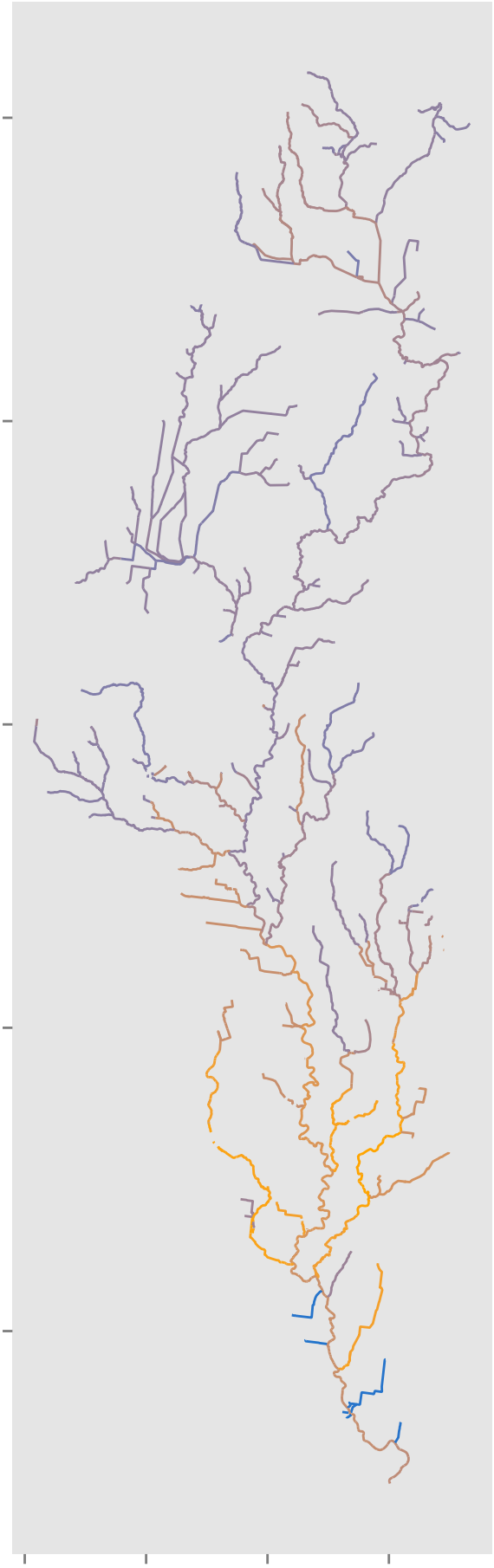

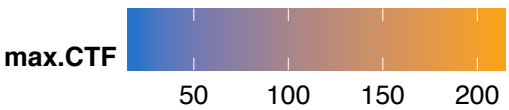
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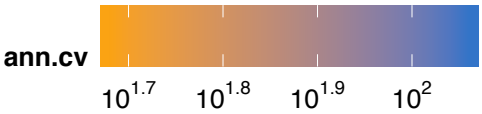
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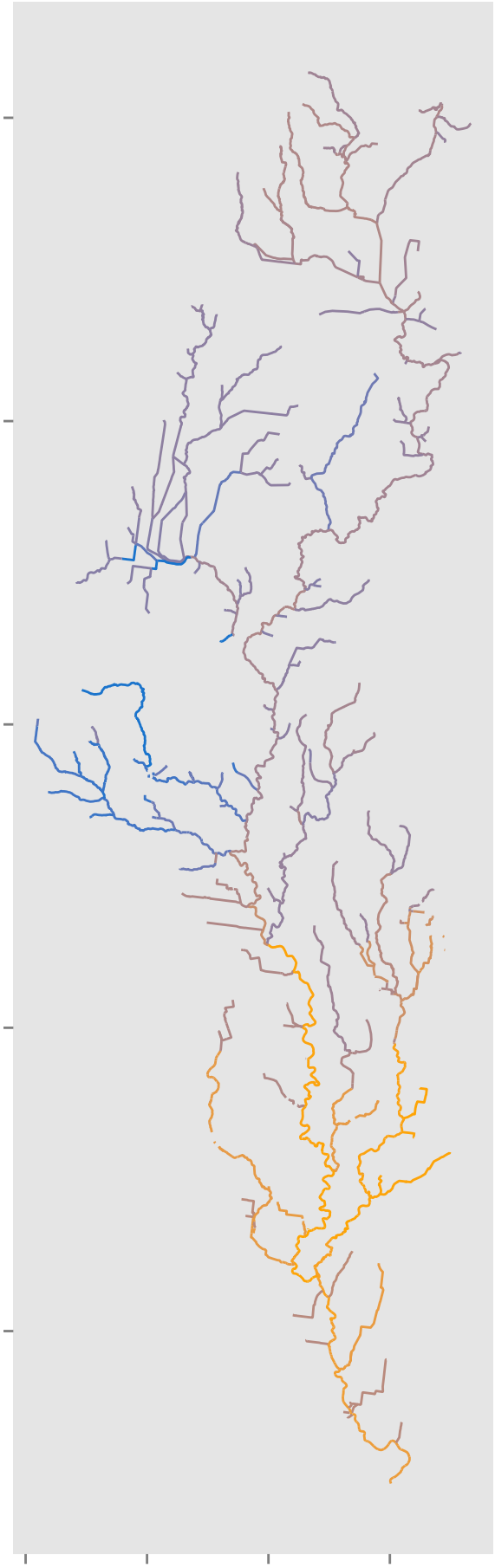
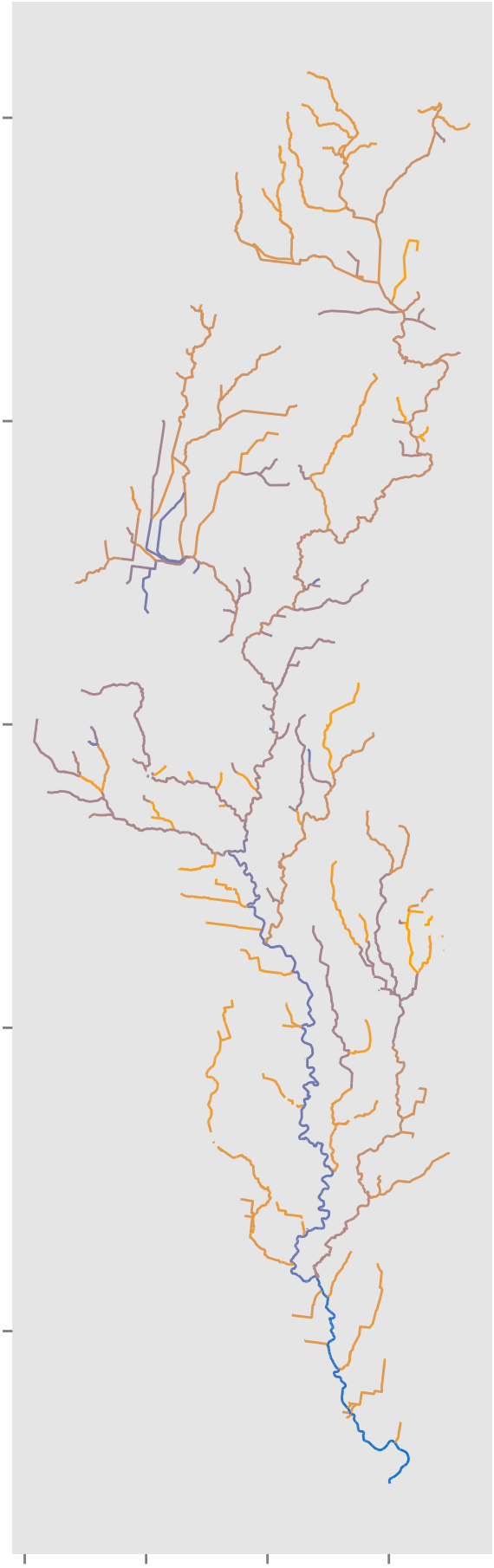
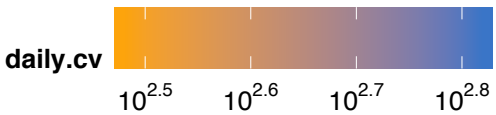
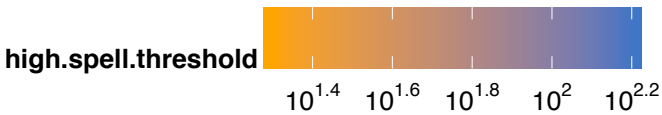
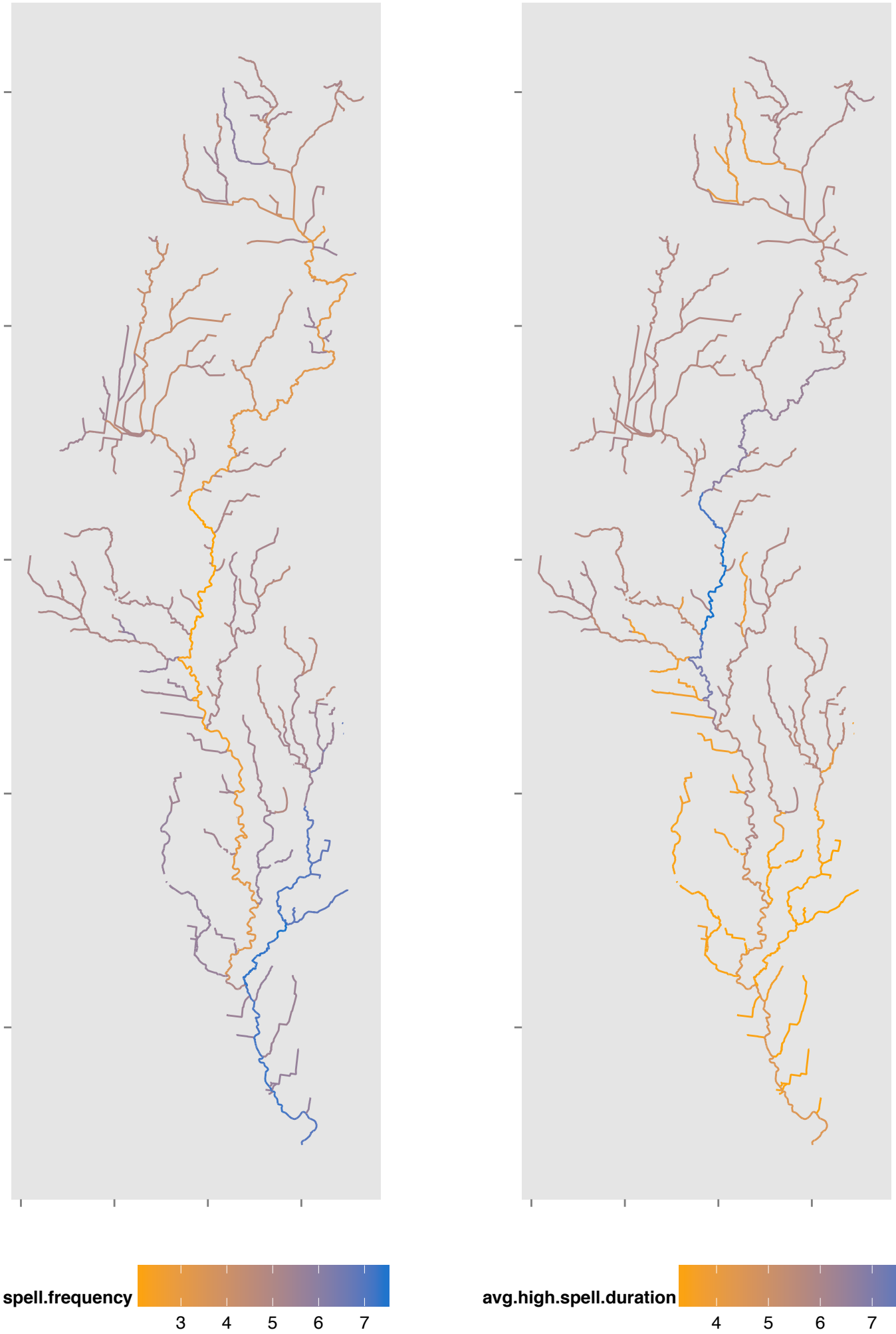
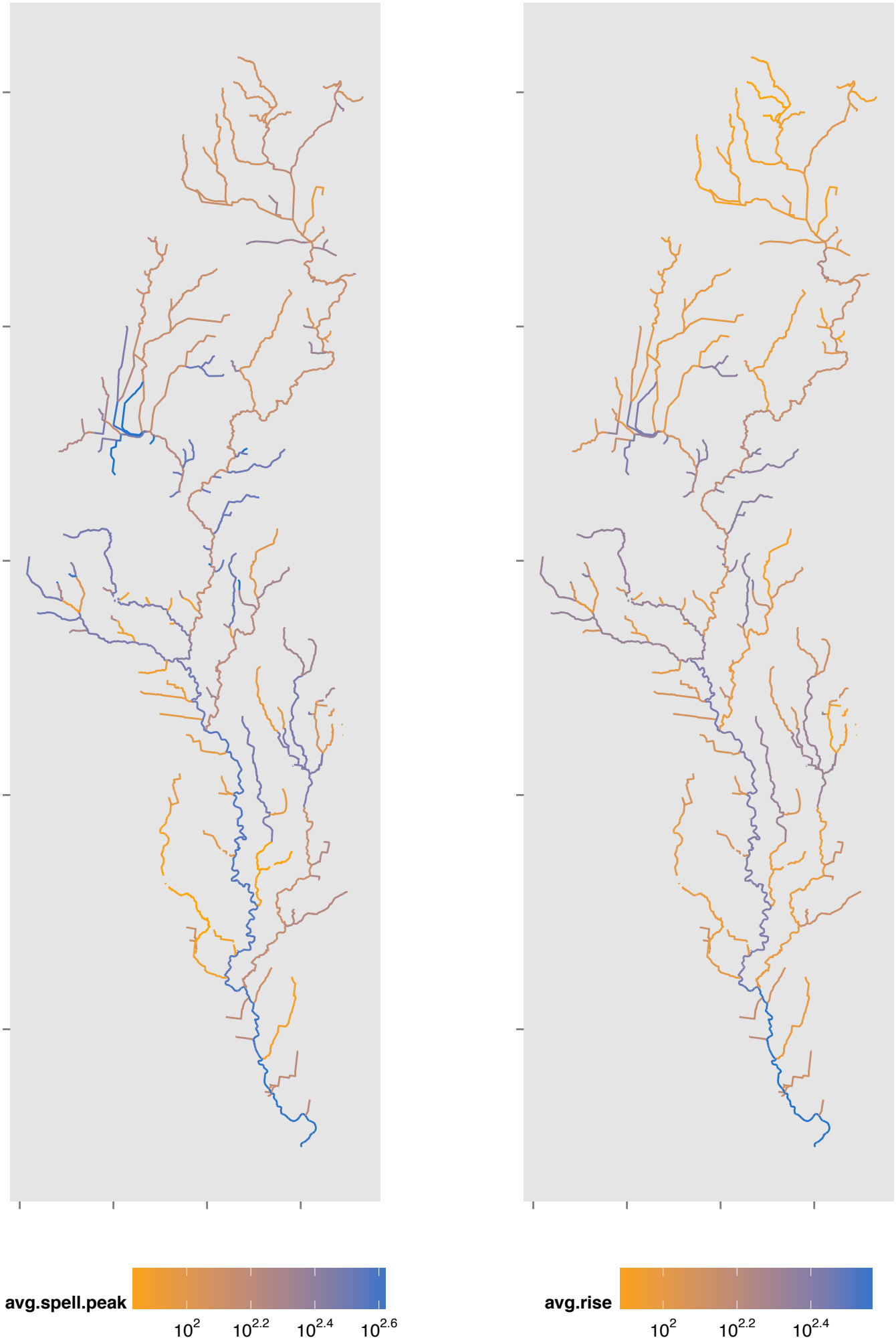


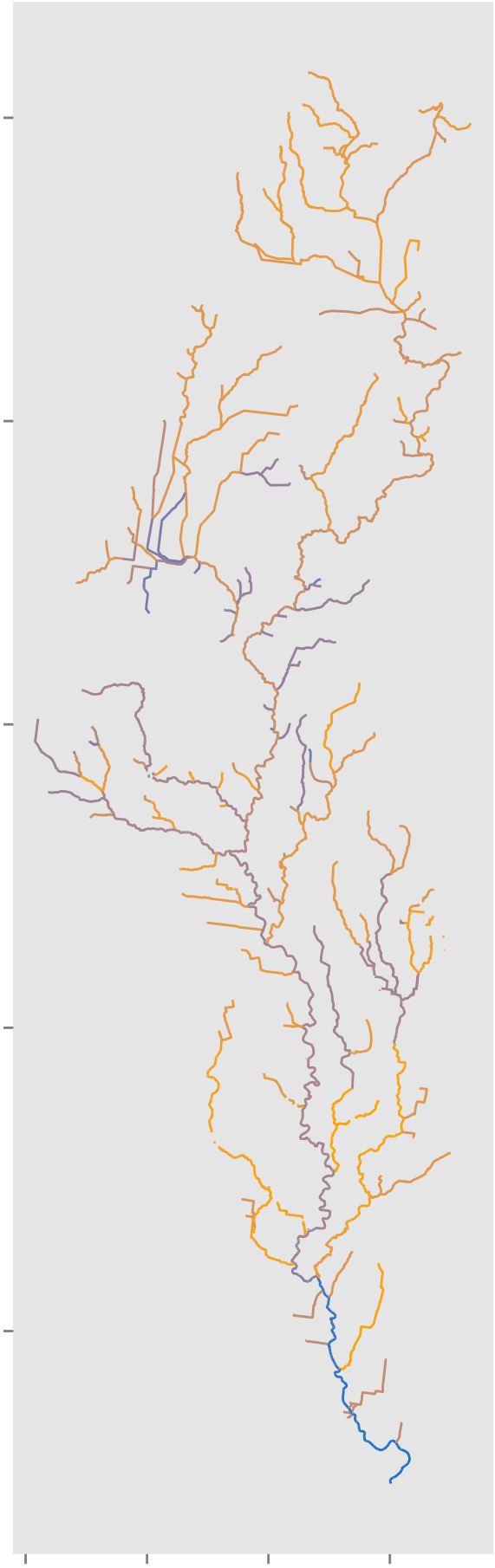


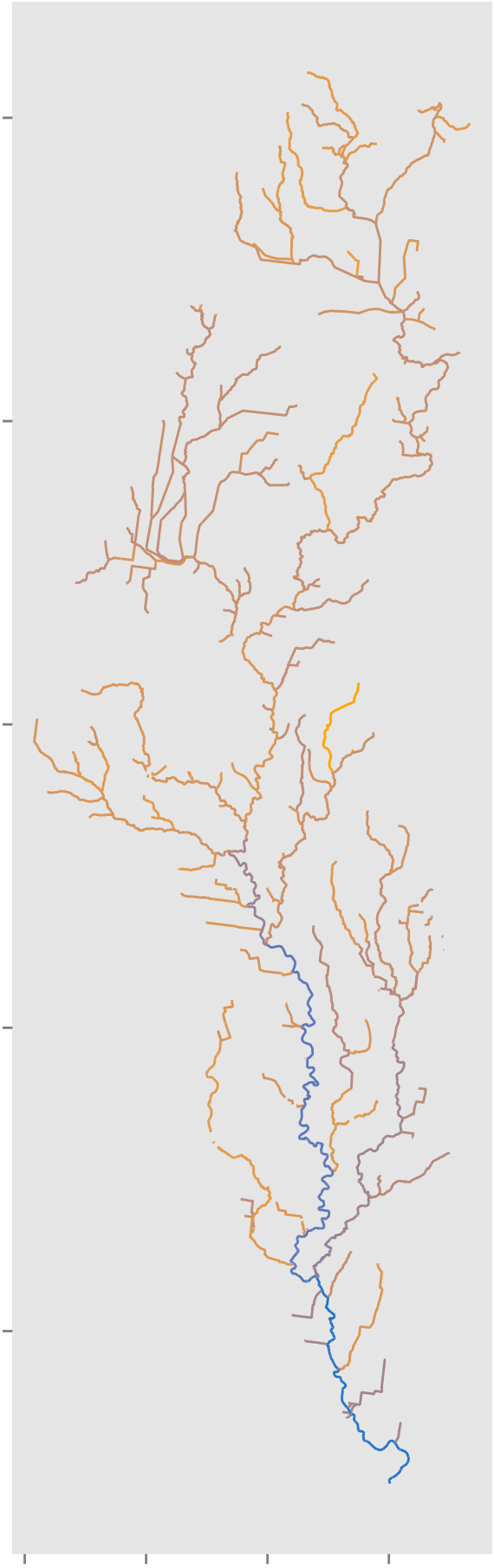

daily.cv
$10^{2.5}$
$10^{2.6}$
$10^{2.7}$
$10^{2.8}$

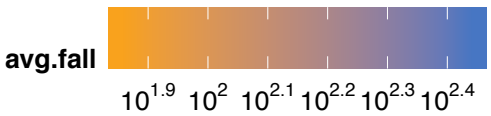

high.spell.threshold
$10^{1.4}$
$10^{1.6}$
$10^{1.8}$
10^{2}
$10^{2.2}$

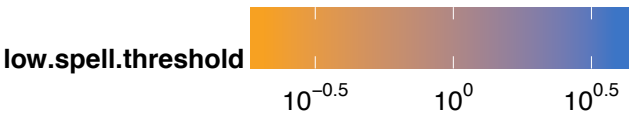

spell.frequency
3
4
5
6
7
avg.high.spell.duration
4
5
6
7
8

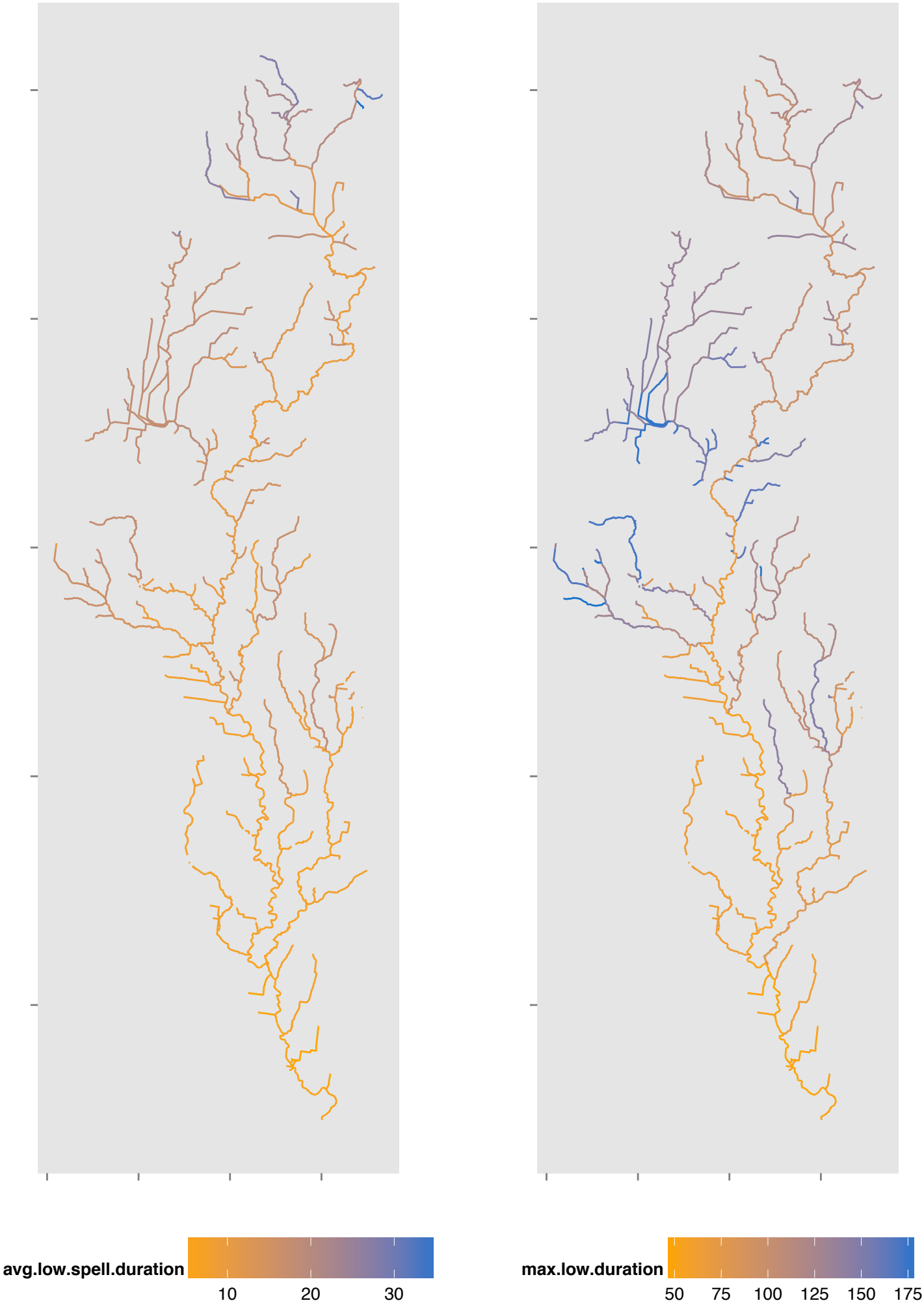

avg.spell.peak
10^2
$10^{2.2}$
$10^{2.4}$
$10^{2.6}$
avg.rise
10^2
$10^{2.2}$
$10^{2.4}$

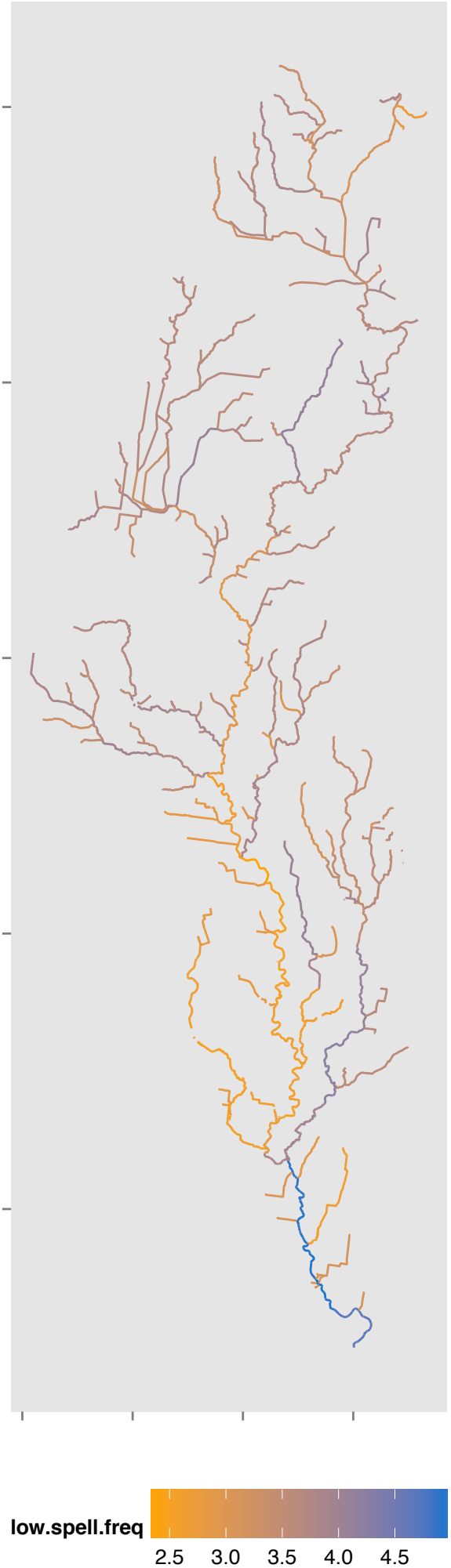





avg.fall
$10^{1.9}$ 10^{2} $10^{2.1}$ $10^{2.2}$ $10^{2.3}$ $10^{2.4}$


low.spell.threshold
$10^{-0.5}$ 10^{0} $10^{0.5}$


avg.low.spell.duration
10
20
30
max.low.duration
50
75
100
125
150
175


low.spell.freq
2.5
3.0
3.5
4.0
4.5