Temporal changes in channel migration and the influence of temporal measurement-scale

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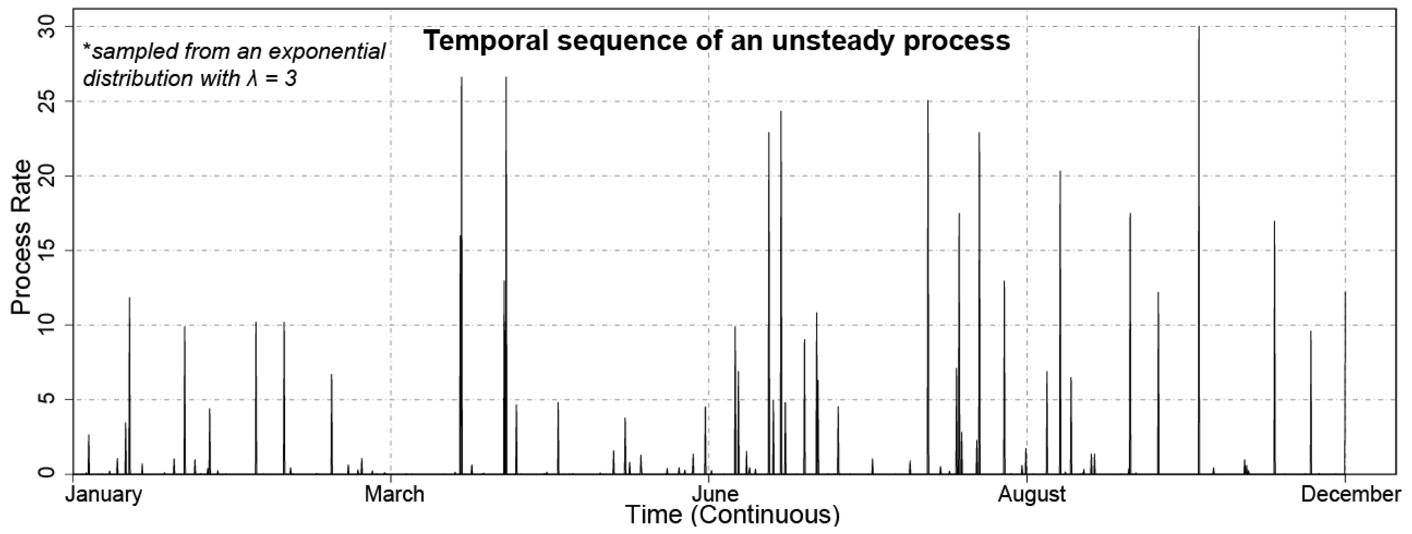
Background

- Historical data in the form of topographic maps and aerial photographs are increasingly scanned and georeferenced into digital format for comparison with contemporary high-resolution topography (HRT) and aerial or satellite photos.
- Comparing historical and contemporary datasets is a common technique to estimate channel migration as well as changes in fluvial morphology and ecological habitats.
- Sadler (1981) and Gardner (1987) demonstrated that measurements of an unsteady process (e.g., sediment accumulation, channel migration) are biased low at longer measurement intervals, often referred to as 'Sadler Effects'.
- At present, no studies that measure channel migration with aerial photograph comparisons account for potential measurement biases arising from different temporal resolutions.



Research Objectives

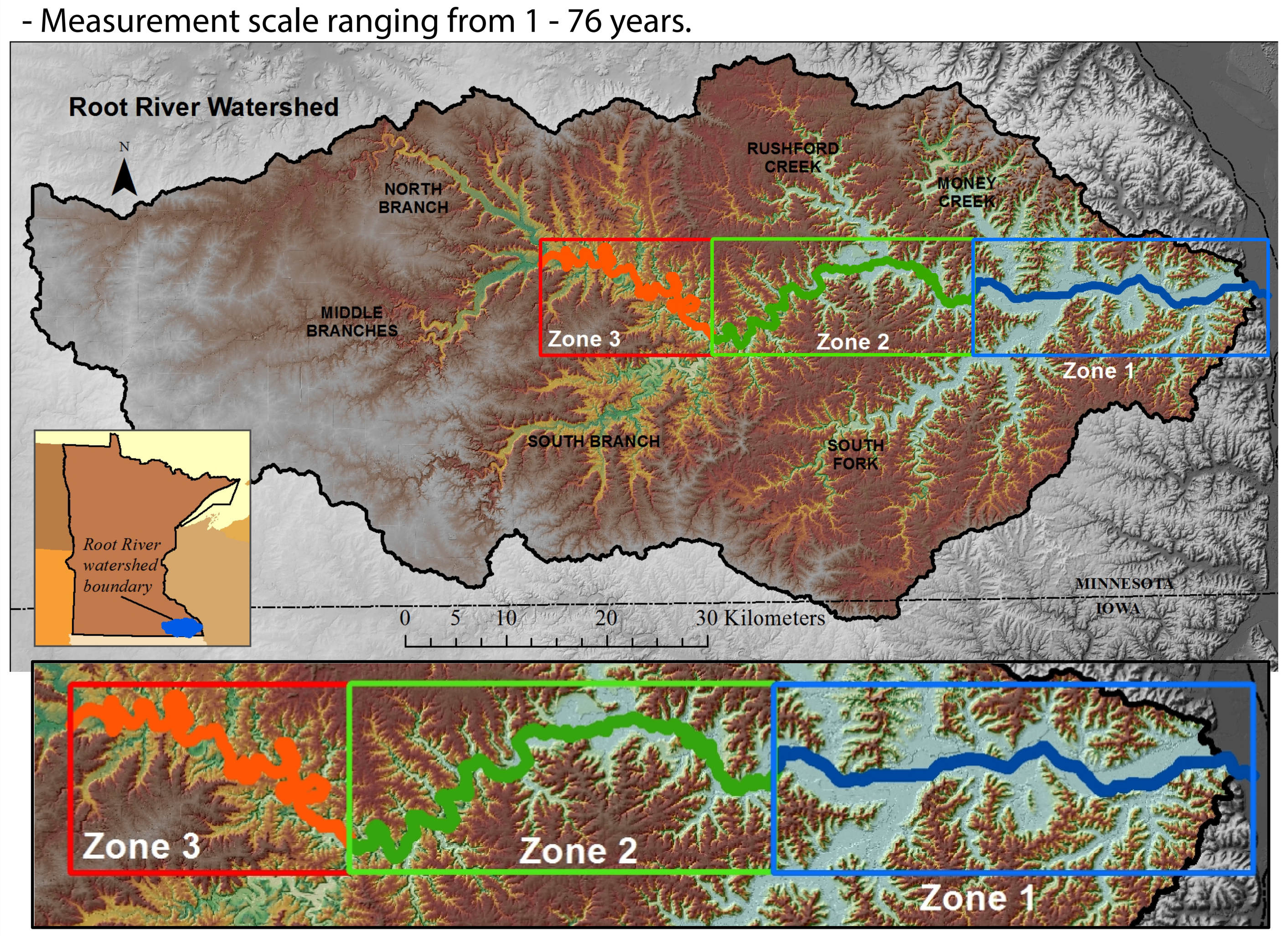
- Quantify the magnitude of measurement-scale effects (e.g., 'Sadler effects') for measurements of channel migration.
- Assess whether measurement-scale effects change in different geormophic contexts (e.g., detect changes in biases based on degree of channel confinement, slope).
- Compare measurement-scale effects for multiple sets of photos within similar geomorphic environments.
- Adjust/correct channel migration measurements for measurement-scale effects and compare to unadjusted results.
- Measure where significant migration occurs above the level of detection (LOD) from a nonuniform error raster+ based on methods from Lea & Legleiter (2016).
- Determine whether increased discharge has driven similar changes in lateral migration.

Research Questions

- How does temporal measurement scale influence estimates of channel migration rate?
- If measurements of migration are biased, can they be corrected/adjusted based on their temporal measurement scale (Δt between photos)?
- Are measurement-scale biases dependent on geomorphic context and/or the unique set of aerial photographs?
- Does an optimal temporal scale(s) exist at which measurements accurately capture the magnitude and variability in channel migration?
- Has increased discharge along the Root River led to similar changes in channel migration over the past 75 years?

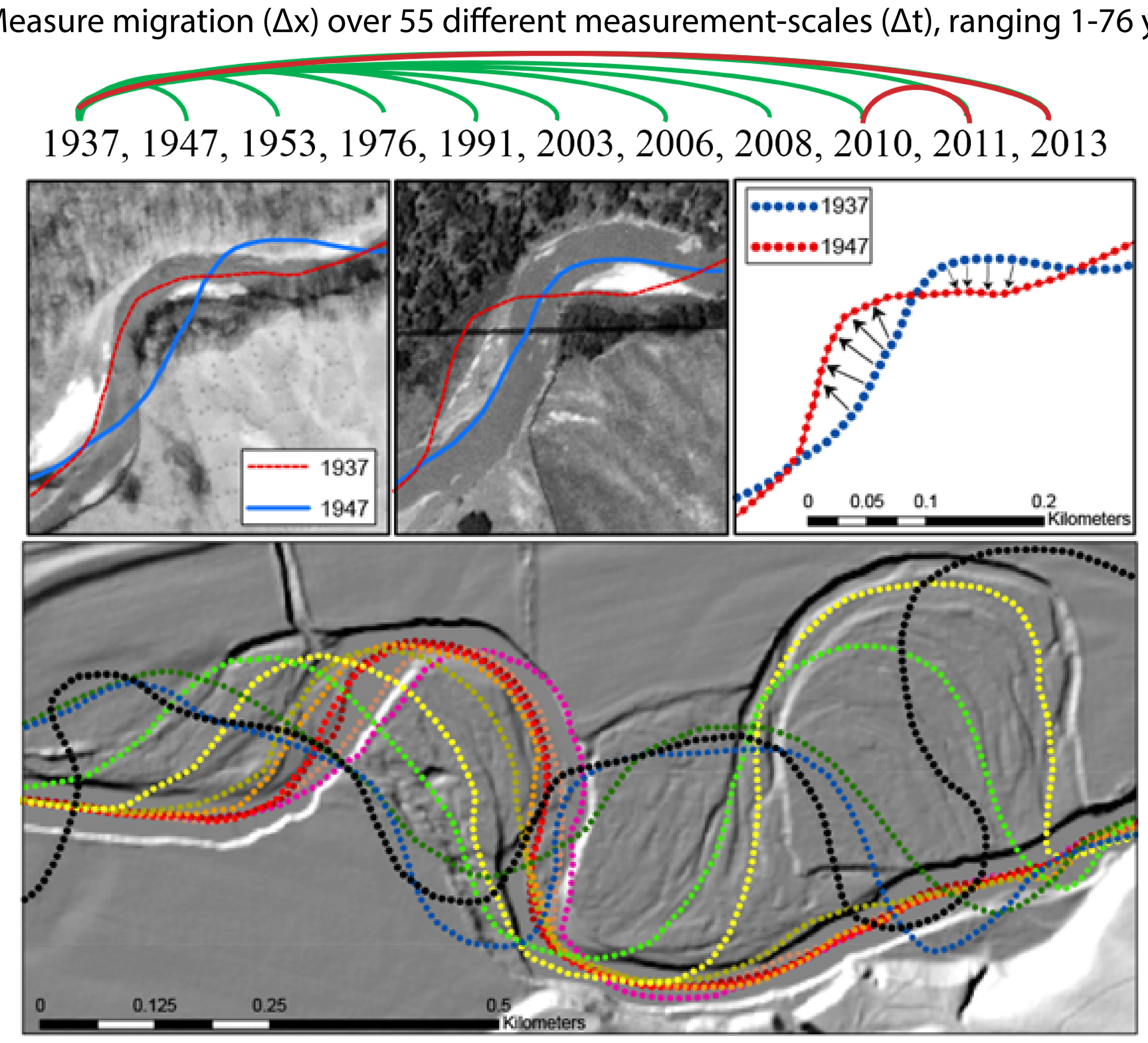
Study Site and Data

- Root River, Minnesota, 4,300 km^2
- Three distinct geomorphic zones, based on confinement and slope.
- Aerial photograph sequence (1937-2013) covering 120-km of river.
- Measurement scale ranging from 1 - 76 years.

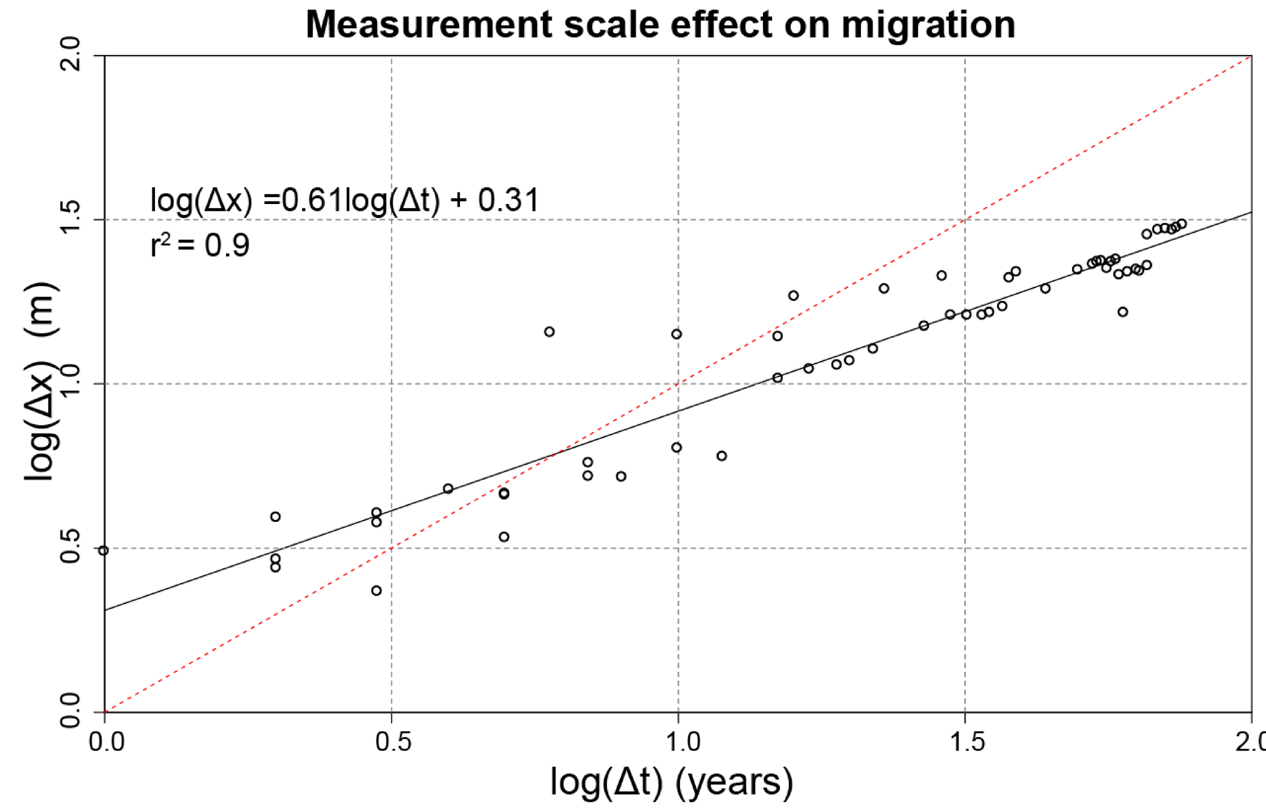


Methods

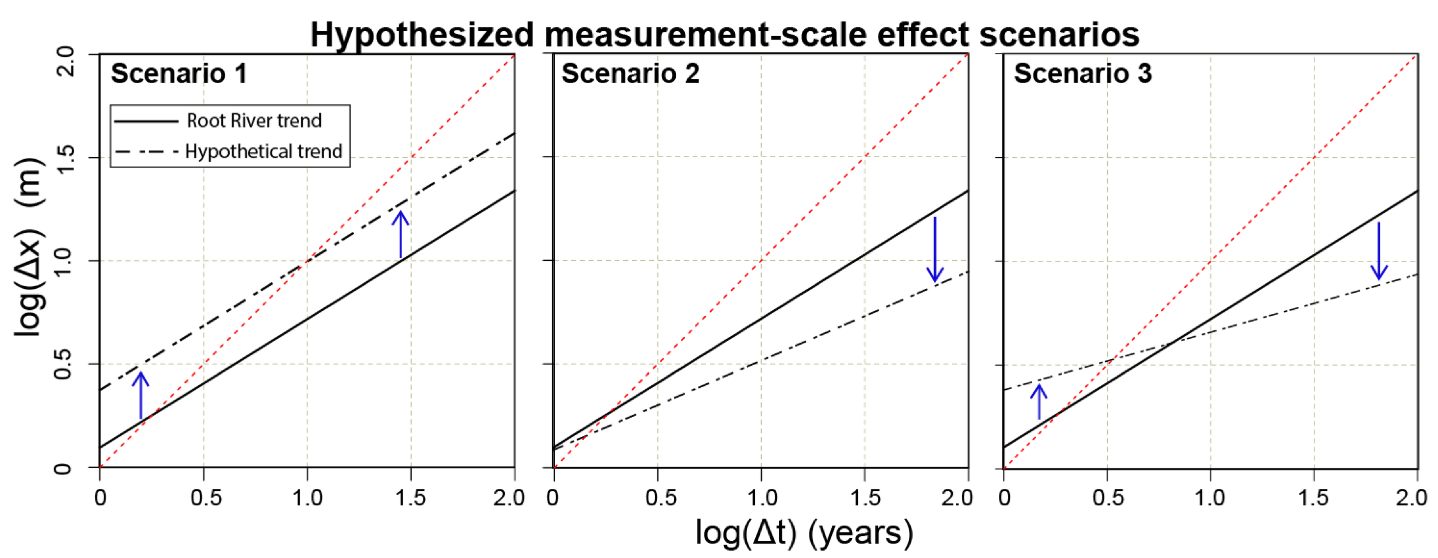
1. Measure migration (Δx) over 55 different measurement-scales (Δt), ranging 1-76 years.



2. For each geomorphic zone, test for significant changes over time using Mann-Whitney and Kolmogorov-Smirnov tests.
3. For each of three geomorphic zones, assess for measurement-scale effects as outlined in Gardner (1987). Plot log(Δx) vs. log(Δt) and compare to a 1:1 line. If the values deviate from 1:1 line, it indicates a measurement-scale bias exists.



2. Test for significant differences in linear regression slopes and intercepts. Differences indicate that measurement-scale effects are dependent on geomorphic context.



3. Adjust rates based on measurement scale biases and determine where significant changes occur above the level of detection. Sources of error include digitizing (assumed to be constant across the photo) and georeferencing (spatially discontinuous).
4. Re-test for significant differences in migration rates over time.

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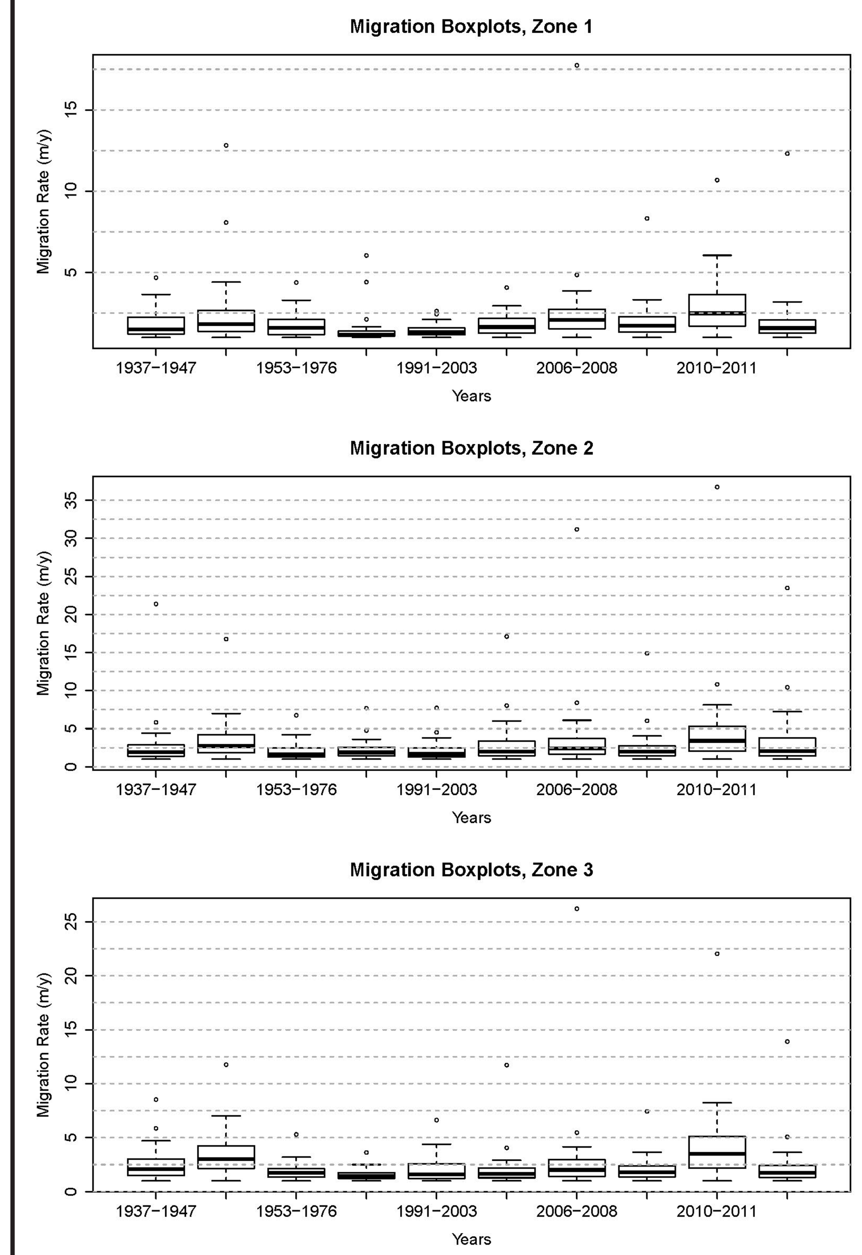
Current results (in progress)



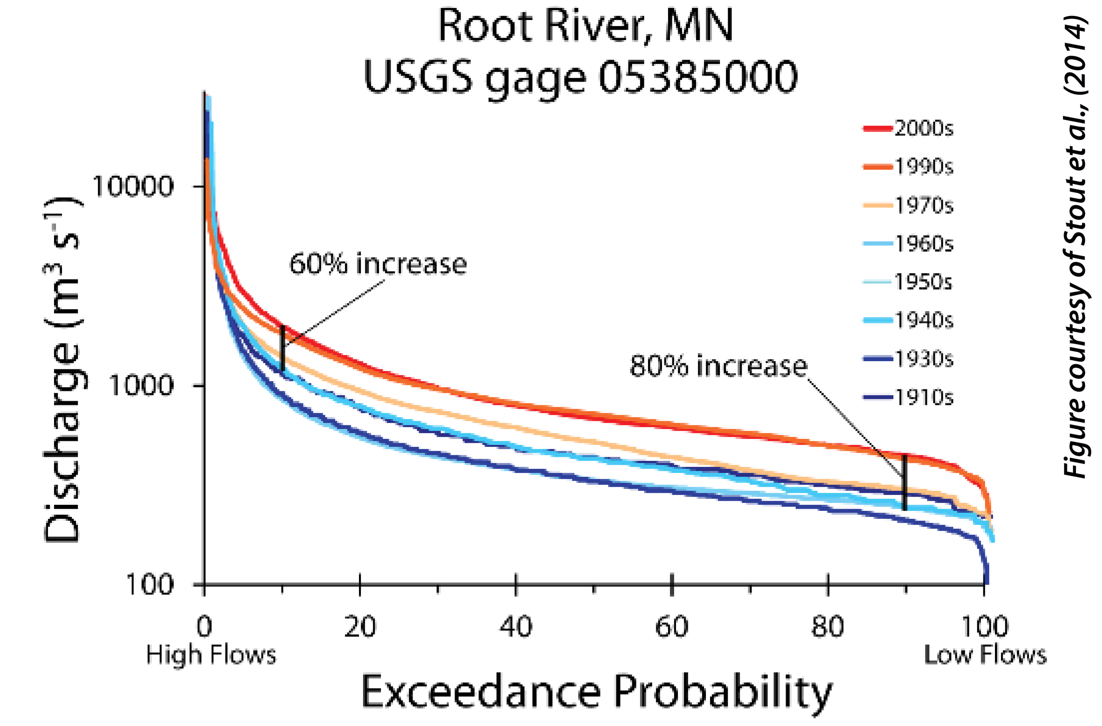
Testing for significant changes over time.

Significant changes were only found in 45% of comparisons between pre- and post-2000 rates of channel migration across the three geomorphic zones.

-This is a significant because:

a. Root River flows have increased 60-80% since 1990 (Stout et al.,2012).
b. Discharge-TSS relationships along the Root are the highest found in Minnesota.
c. Fingerprinting results suggest sediment flux is primarily (~60%) derived from floodplains and near-channel sources.

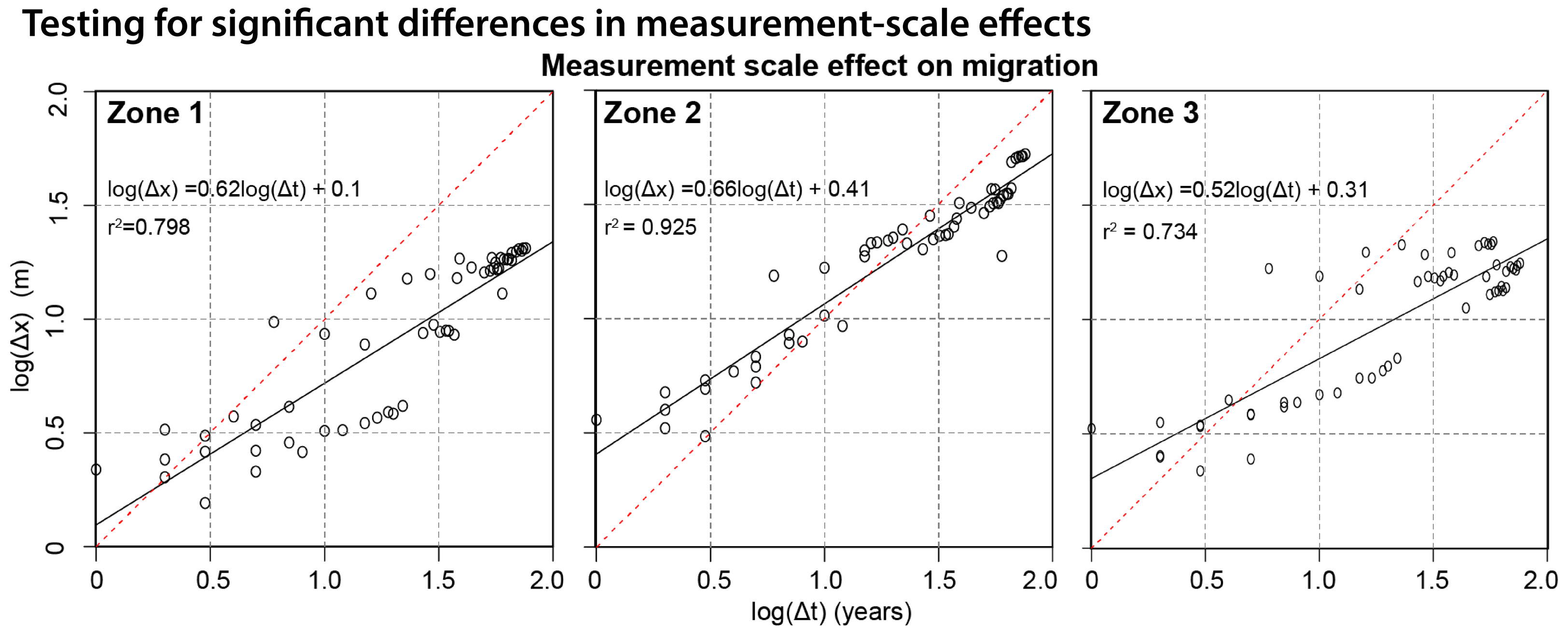
Based on these findings: Decadal increases in flow should drive increased TSS, and therefore, remobilization of floodplain sediment.



Relative lateral migration rates, by year and by reach

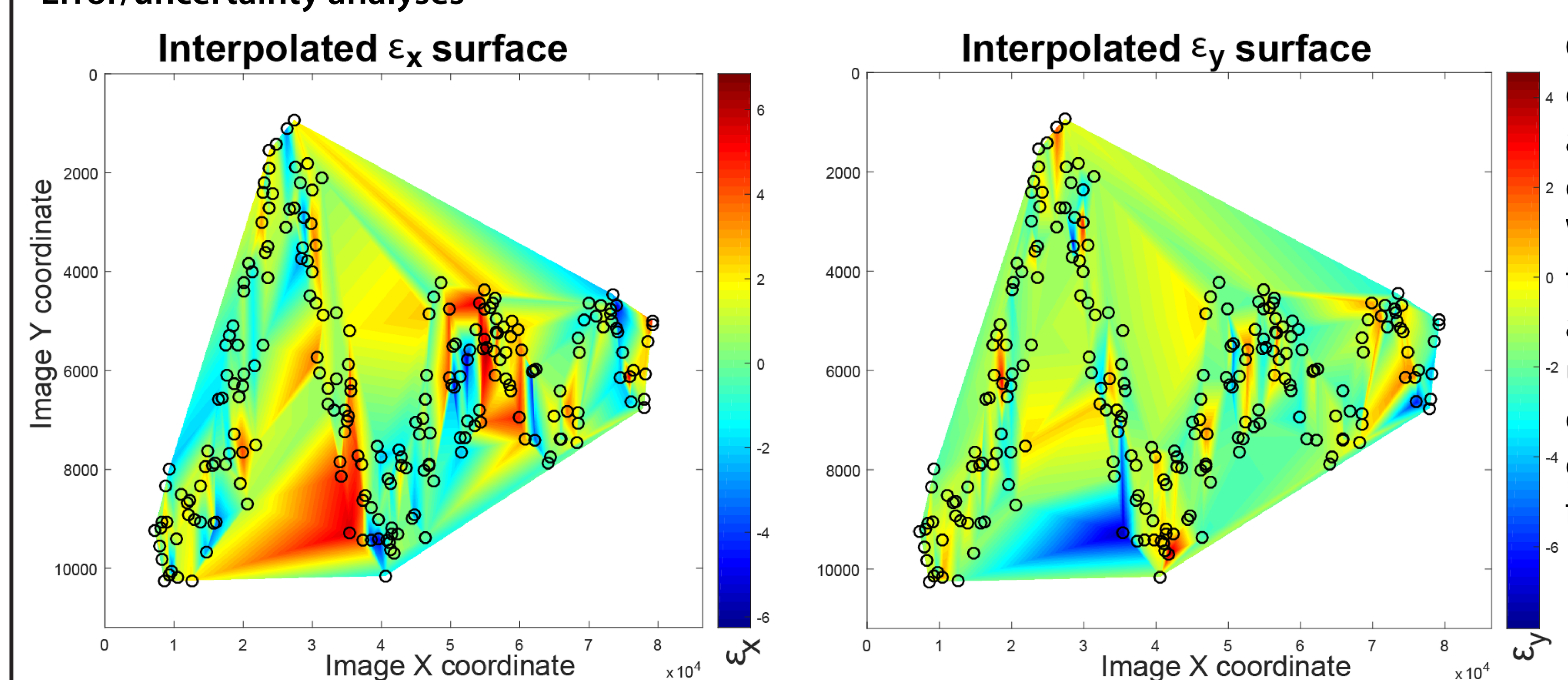
Reach ID	1937_1947	1947_1953	1953_1976	1976_1991	1991_2003	2003_2006	2006_2008	2008_2010	2010_2011	2011_2013	Average (by reach)
1	0.825	0.805	0.495	0.274	0.234	0.225	0.232	0.224	0.230	0.221	0.376
2	0.921	0.721	0.511	0.329	0.281	0.270	0.270	0.257	0.259	0.251	0.407
3	0.772	0.991	0.632	0.386	0.339	0.326	0.322	0.307	0.305	0.297	0.468
4	0.859	0.898	0.659	0.527	0.457	0.462	0.442	0.421	0.427	0.431	0.558
5	2.156	1.747	1.407	1.182	1.417	1.393	1.379	1.338	1.334	1.303	1.466
6	1.405	1.151	1.170	0.694	0.636	0.655	0.643	0.644	0.625	0.632	0.826
7	1.436	1.137	0.597	0.380	0.324	0.321	0.312	0.306	0.297	0.306	0.542
8	1.677	1.645	0.593	0.446	0.391	0.404	0.378	0.378	0.359	0.378	0.665
9	2.436	1.702	0.457	0.390	0.336	0.334	0.327	0.317	0.319	0.319	0.694
10	1.037	0.991	0.393	0.170	0.143	0.136	0.133	0.115	0.143	0.132	0.339
11	1.176	0.917	0.472	0.239	0.208	0.212	0.196	0.190	0.193	0.193	0.400
Average (by year)	1.336	1.155	0.672	0.456	0.433	0.431	0.421	0.409	0.408	0.406	

Testing for significant differences in measurement-scale effects



For each of three geomorphic zones, migration regression slope values were significantly different than the 1:1 line at large Δt values, but not from each other (excluding zones 3 and 2, p~0.004). Respectively, each result indicates that migration measurents are biased, but the bias is largely independent of geomorphic conditions.

Error/uncertainty analyses



Continuous error rasters were generated and are being applied to the data to filter out non-significant values. We recognize this will alter the results, and will re-analyze the data once we uncertainty (due to digitization and georeferencing) has been fully accounted for.