University of Guelph

CENTRE FOR HYDROGEOMATICS

An integral image approach to performing multi-scale topographic position analysis

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Relative topographic position (TP) and landscape ruggedness

Used for landform, soils, veg. and habitat mapping.

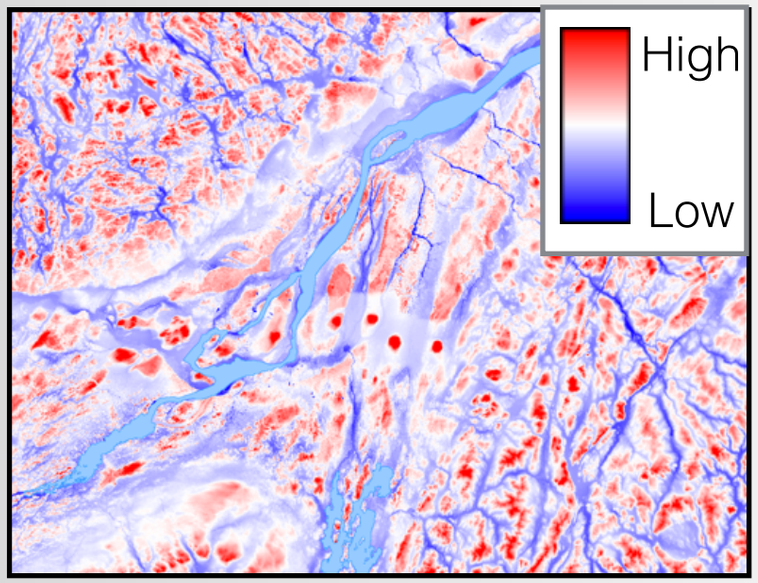
Ruggedness (roughness) measures:

- Local relief; Std. dev. of elevation

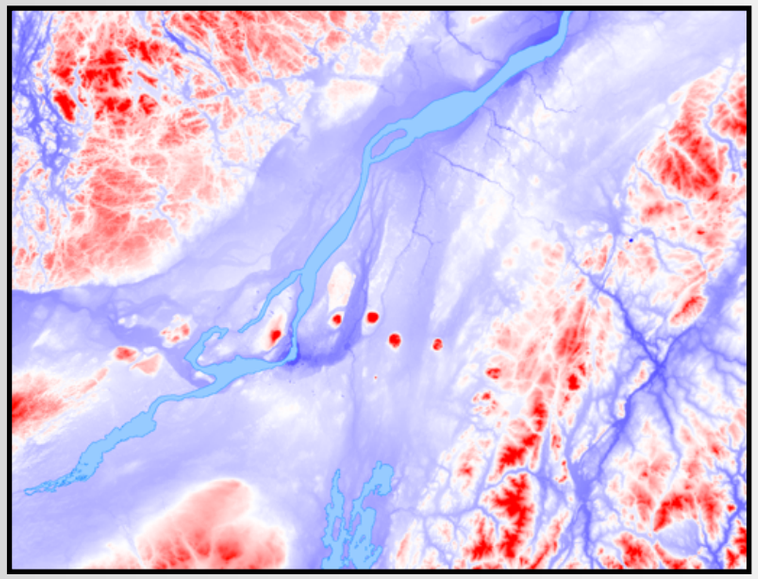
Topographic position measures:

- Difference from mean elevation
- Deviation from mean elevation (*DEV*)
- Elevation percentile

They are inherently scale-dependent.



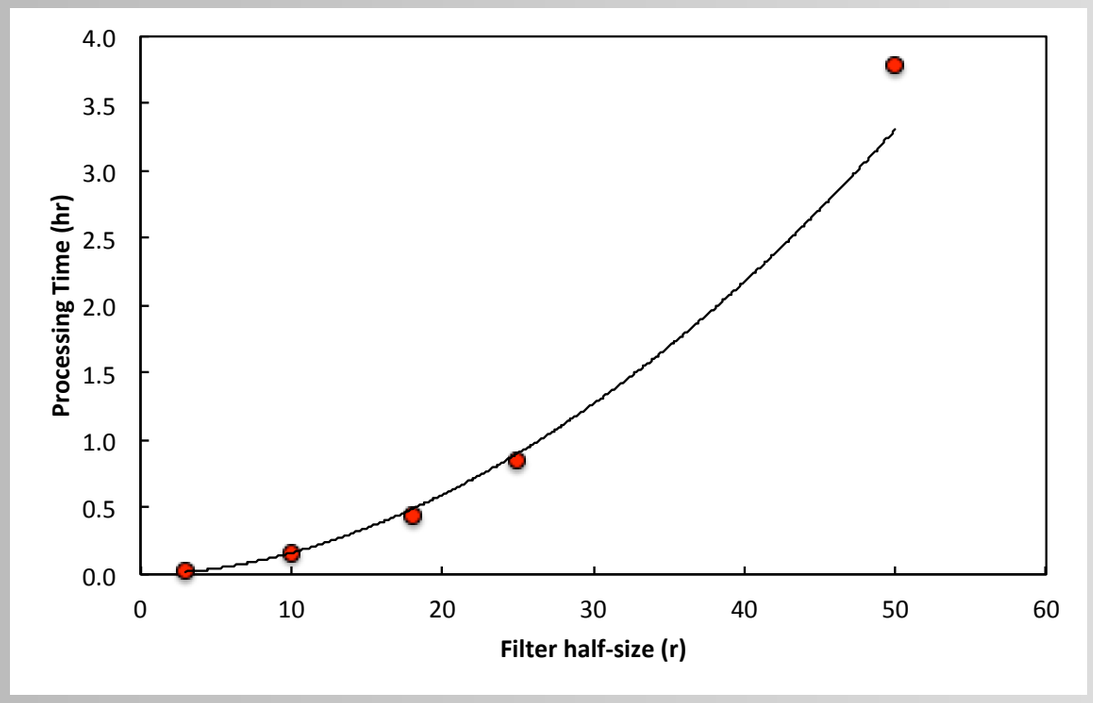
DEV calculated with 100 x 100 filter



DEV calculated with 500 x 500 filter

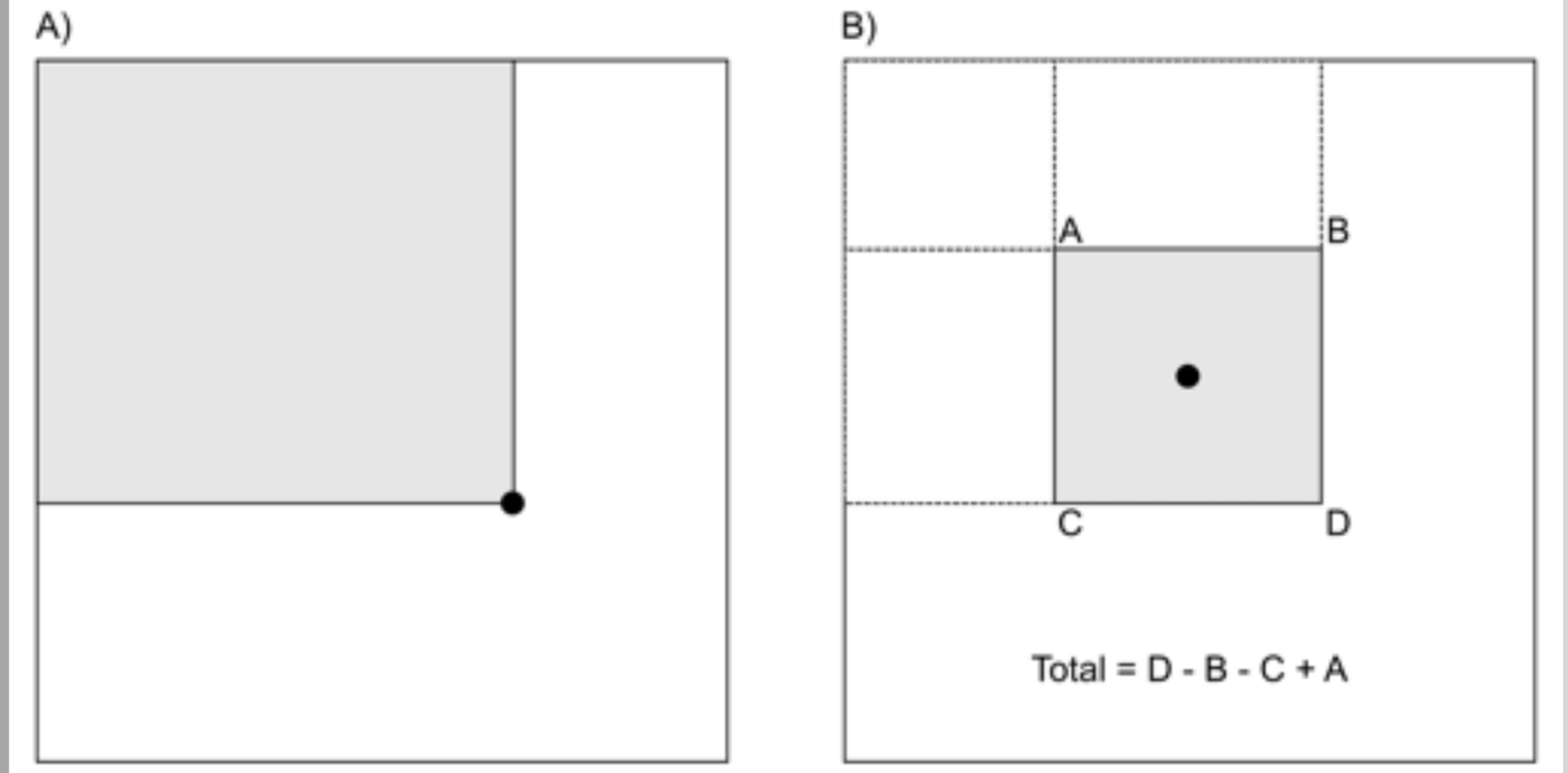
Multi-scaled analysis of TP/ ruggedness offers substantial value

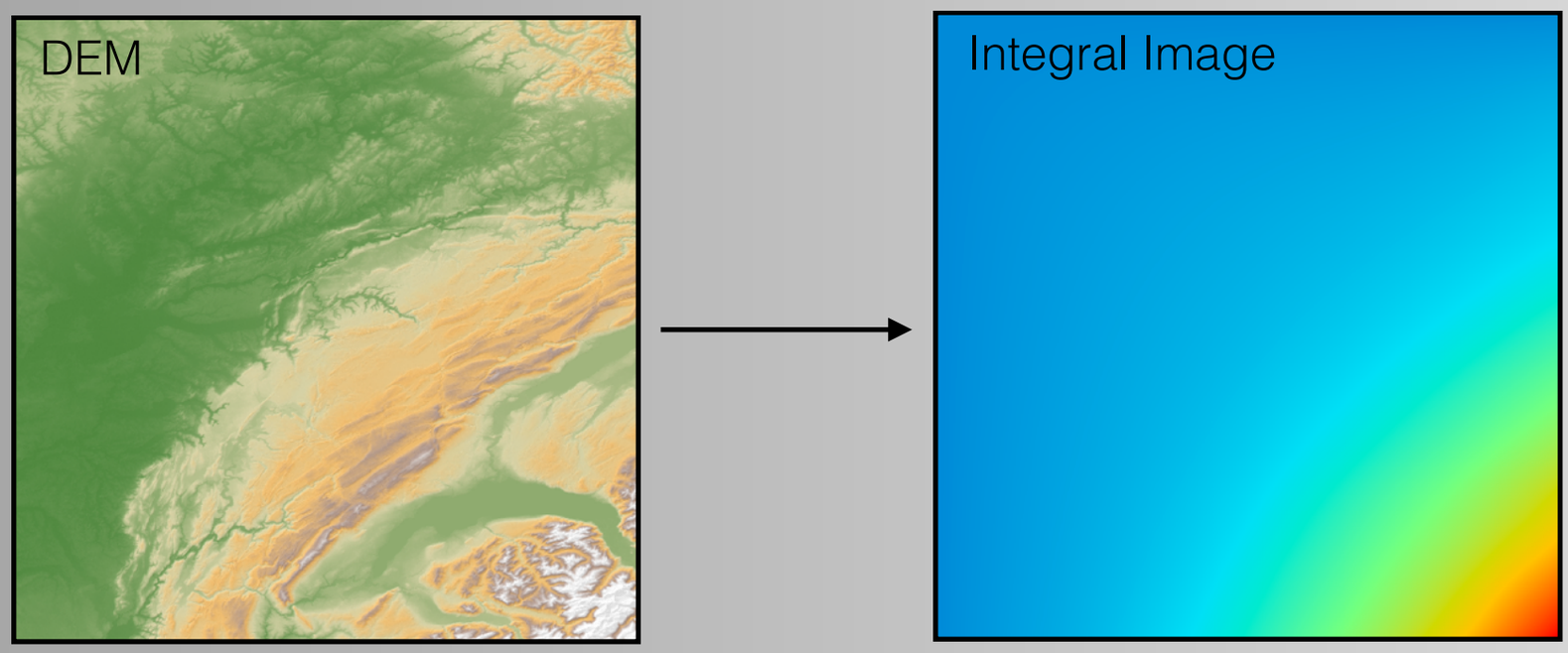
- The inefficiency of the roving window filter approach makes multi-scaled analyses and applications with massive DEMs very challenging.



- Past work has relied on degrading grid resolution.

Integral image transform

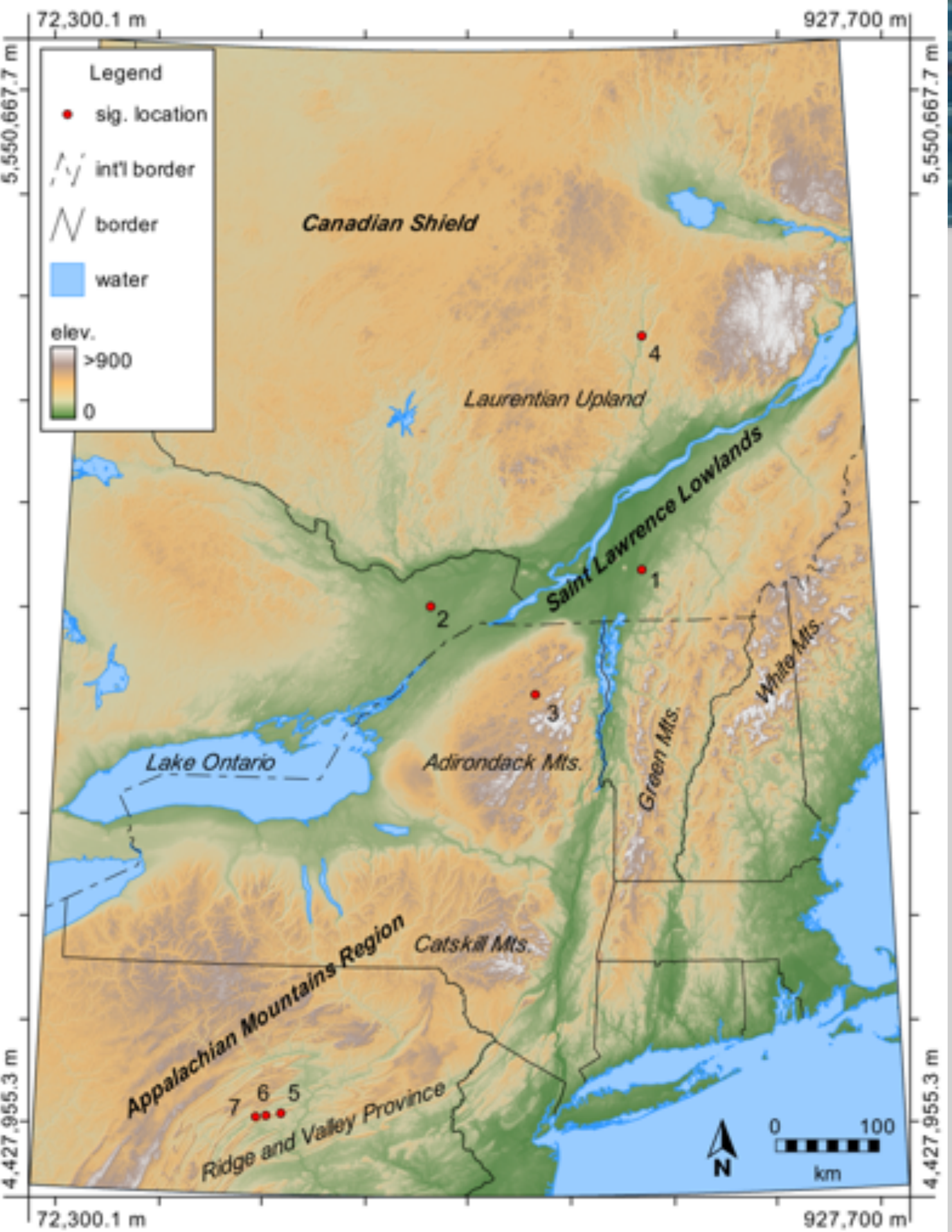




Developed by Crow (1984) and now widely used in comp. vision.

Efficiently calculate window sum, mean, variance, etc.

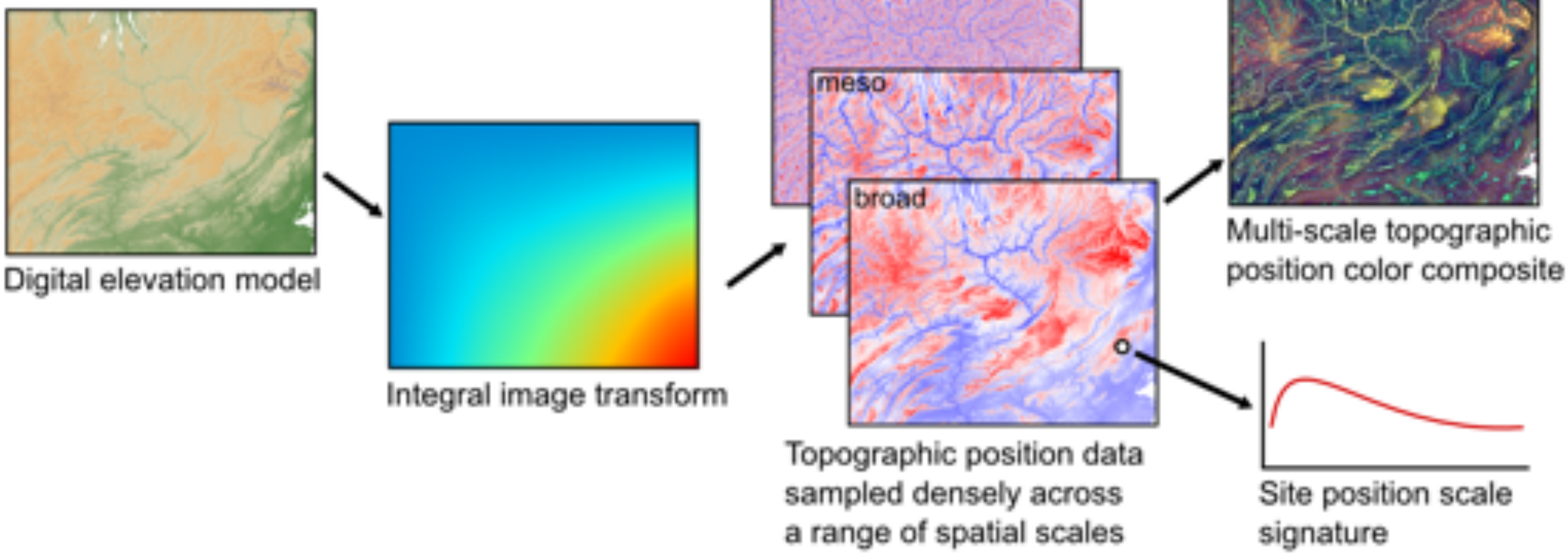
Calculations are independent of roving window size.



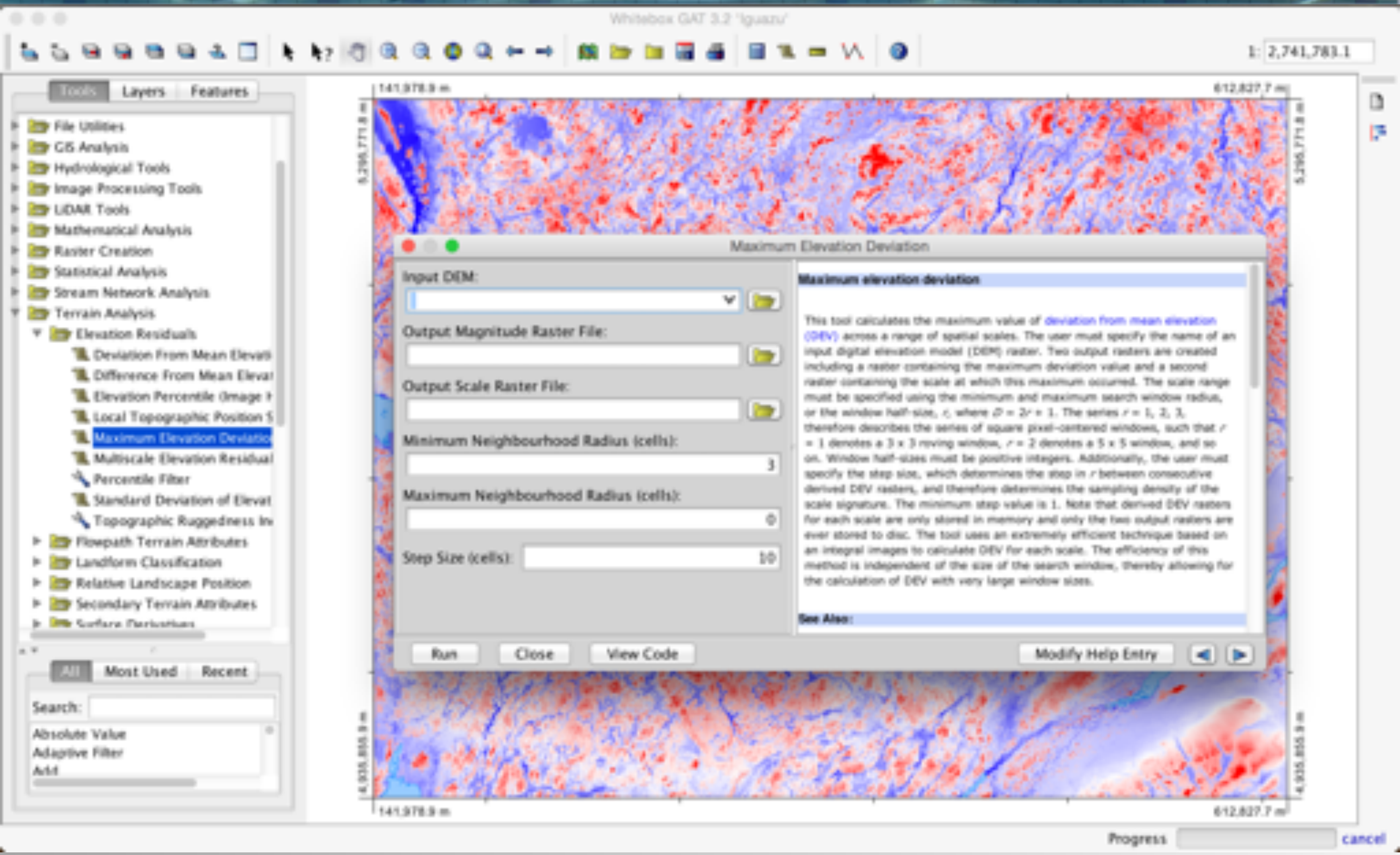
Case study

An extensive area of heterogeneous geomorphology and geology.

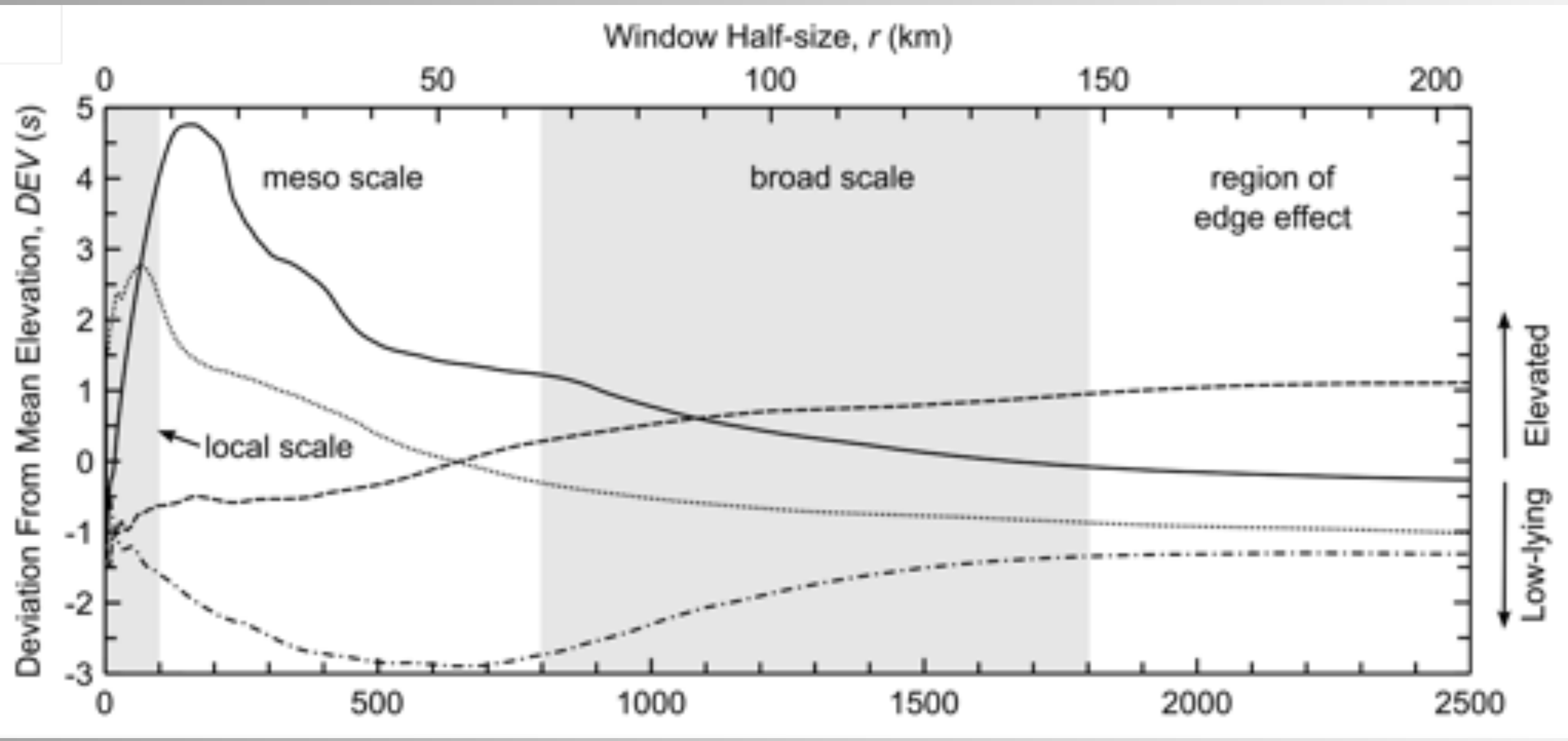
A 13,692 × 10,413 rows by columns (142M grid cells; 544 MB) raster derived from SRTM DEM data.


Digital elevation model
Integral image transform
local
meso
broad
Topographic position data
sampled densely across
a range of spatial scales
Multi-scale topographic
position color composite
Site position scale
signature

Several open-source tools have been created to implement the multi-scale analysis



Scale signatures



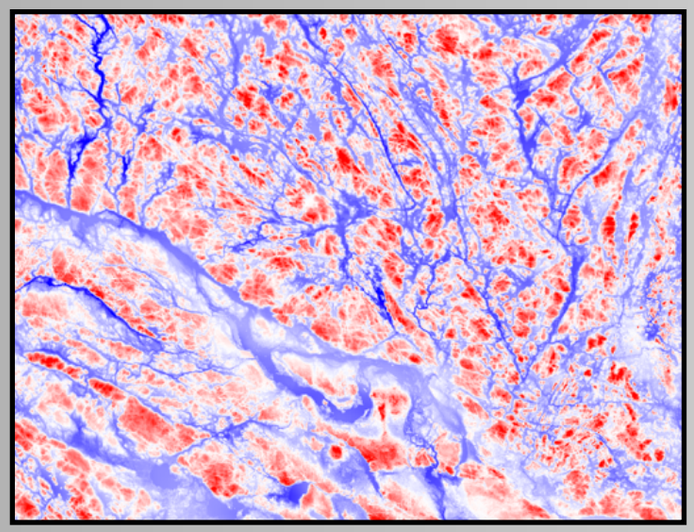
DEV_{max} and r_{max}

- Sample TP across a range of scales and identify the maximally deviated value (DEV_{max}) and window size (r_{max}) at which it occurs for each raster grid cell.

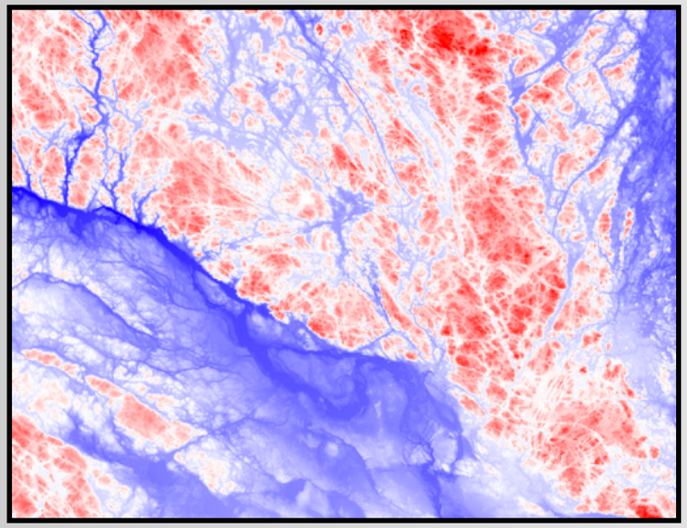
- Each grid cell's TP is recorded at an optimal scale based on its unique scale signature.

- Effectively allows each cell to self-identify with the feature that it most associates with.

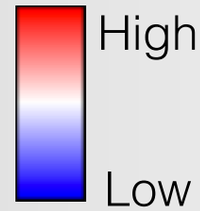
DEV_{max} and r_{max}

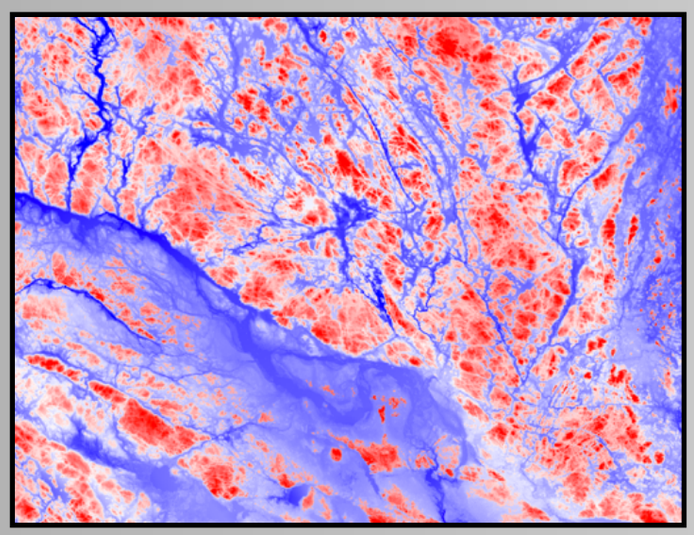


DEV 201 x 201 window

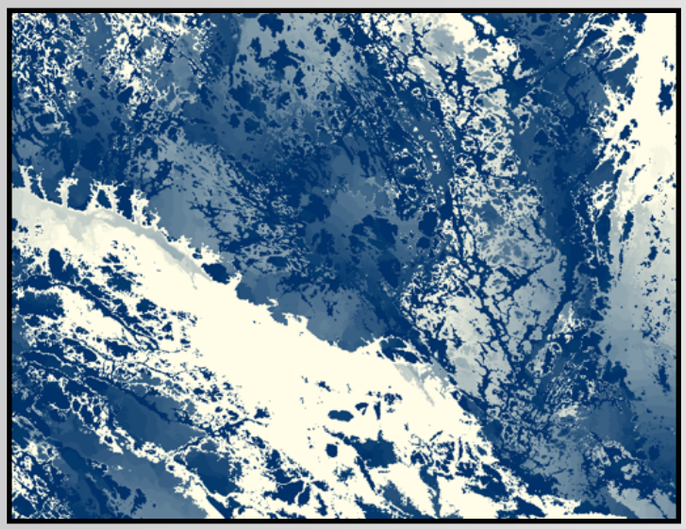


DEV 1501 x 1501 window

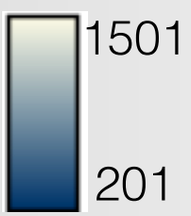


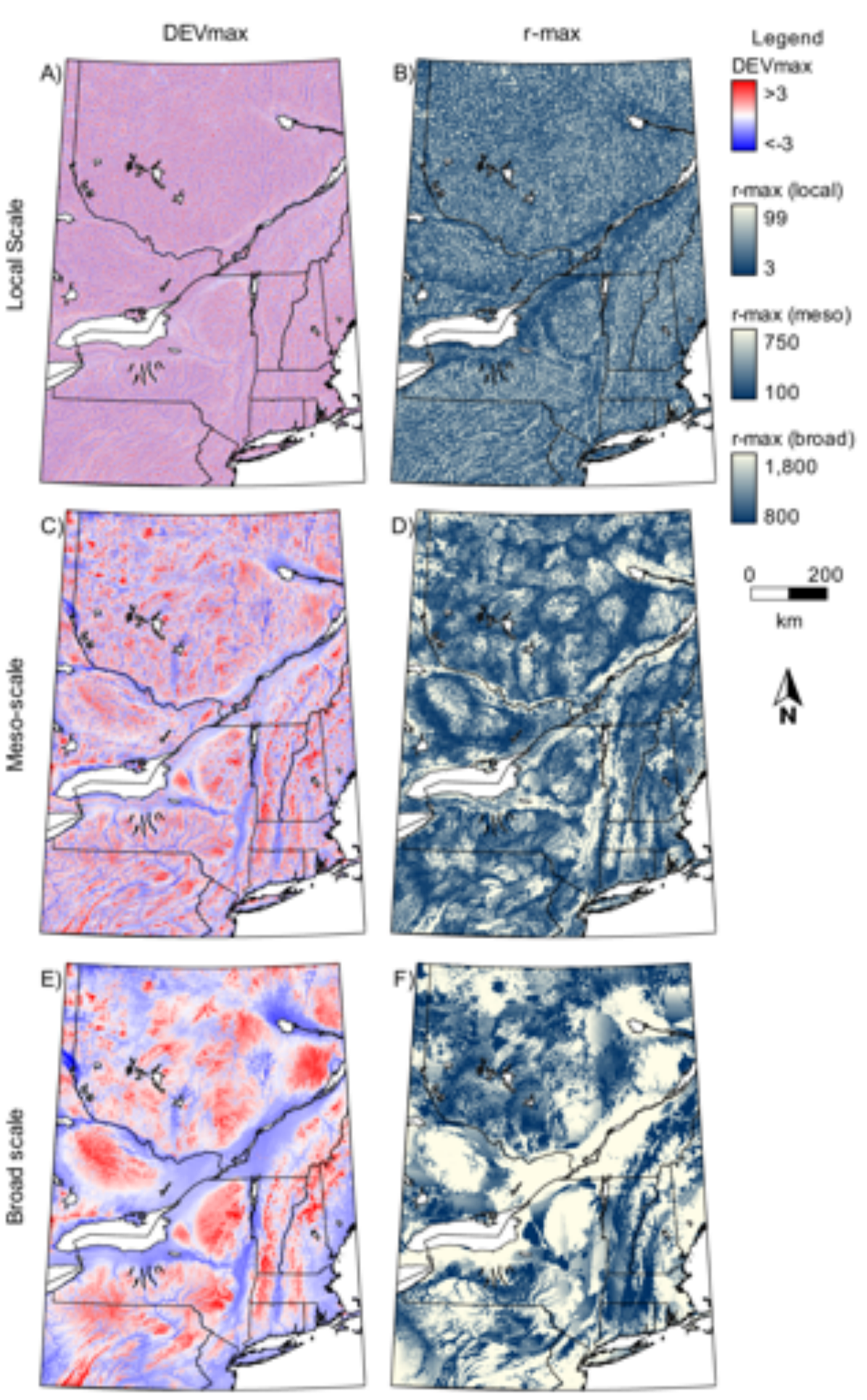


DEV_{max} for windows ranging from 201-1501, step = 10



r_{max} for windows ranging from 201-1501, step = 10

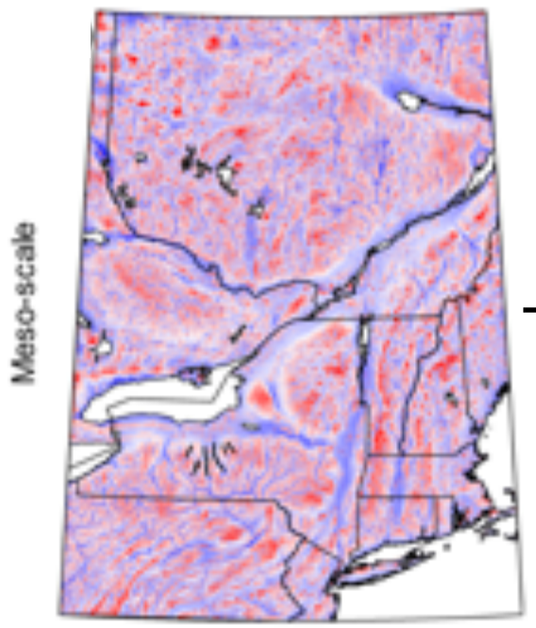


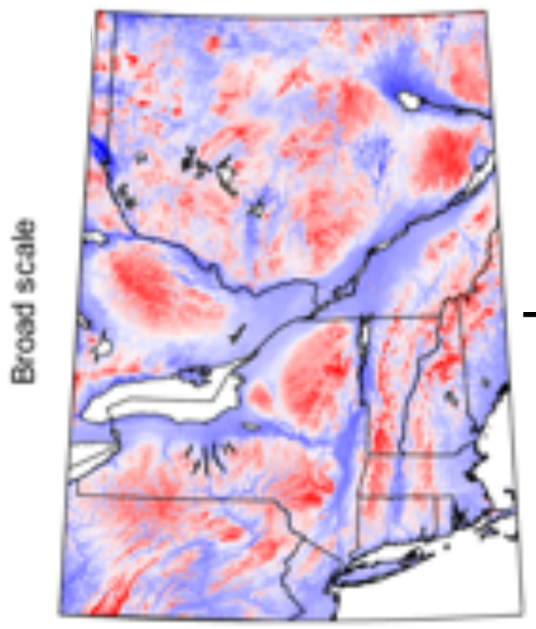


DEV_{max} and r_{max}

- 338 individual *DEV* rasters were calculated to create the three DEV_{max} rasters with window sizes ranging from 7 × 7 to 3601 × 360.

- 28 minutes to process three scales on a 3.0 GHz system compared with estimated 23.3 years using roving window approach.





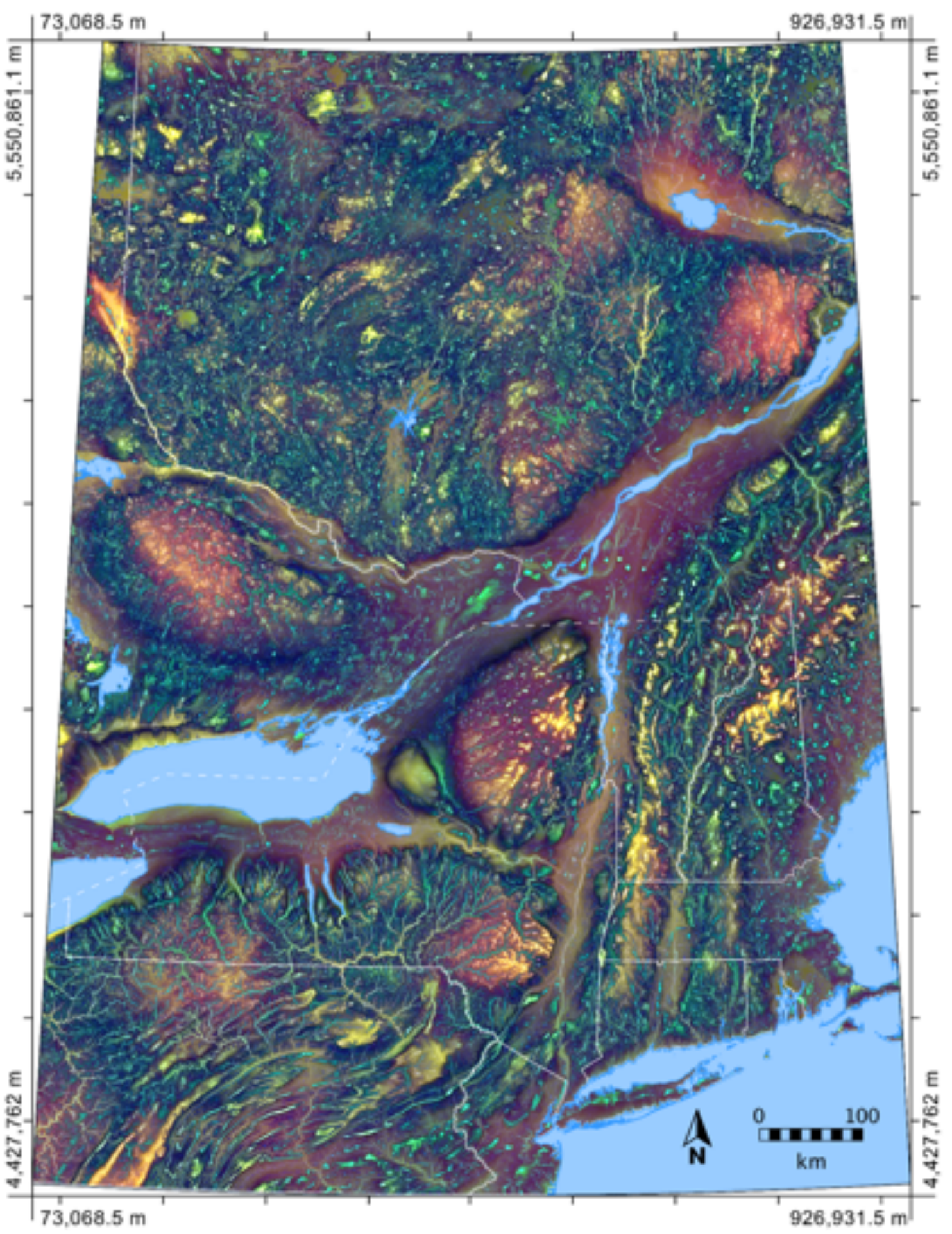
Convert to absolute value, rescale 0-255, and combine into RGB colour composite.

Blue Channel

Green Channel

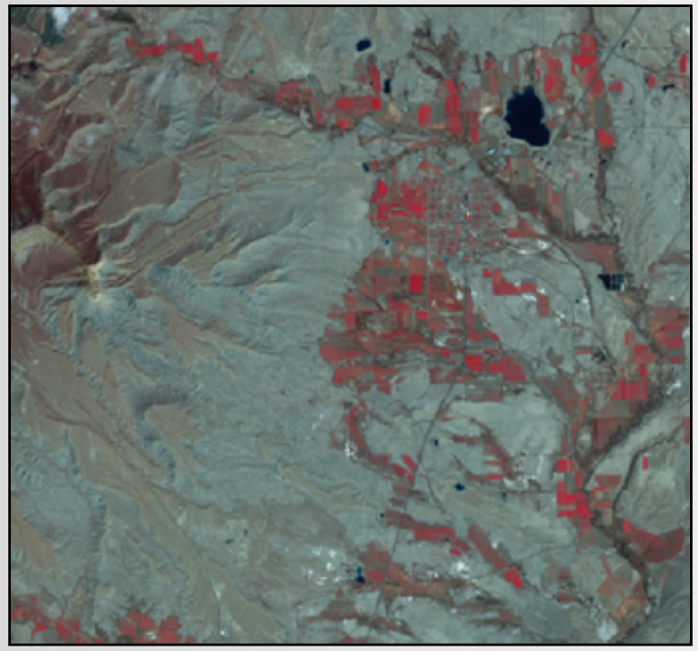
Red Channel

RGB Colour Composite



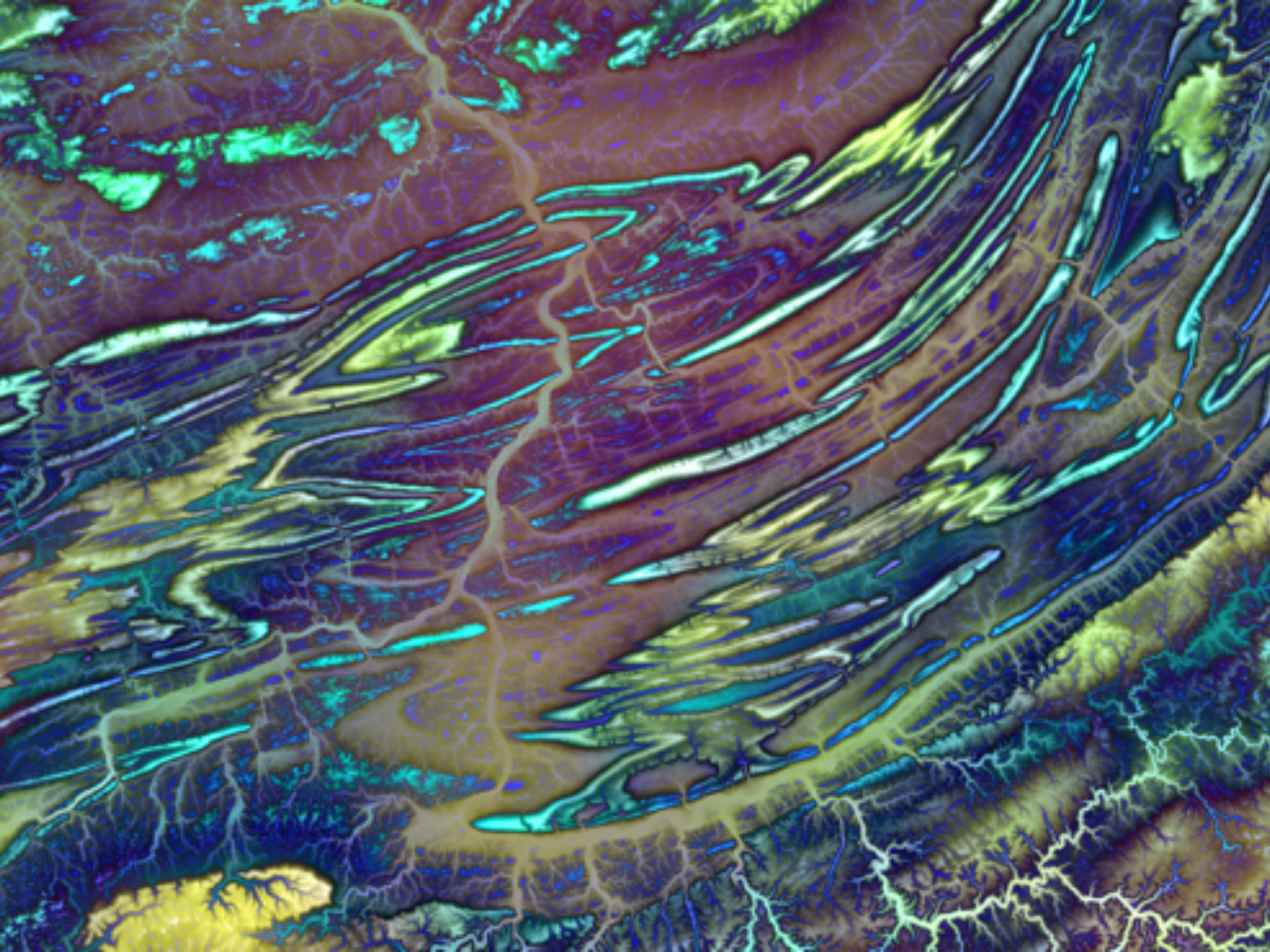
The MTPCC Image

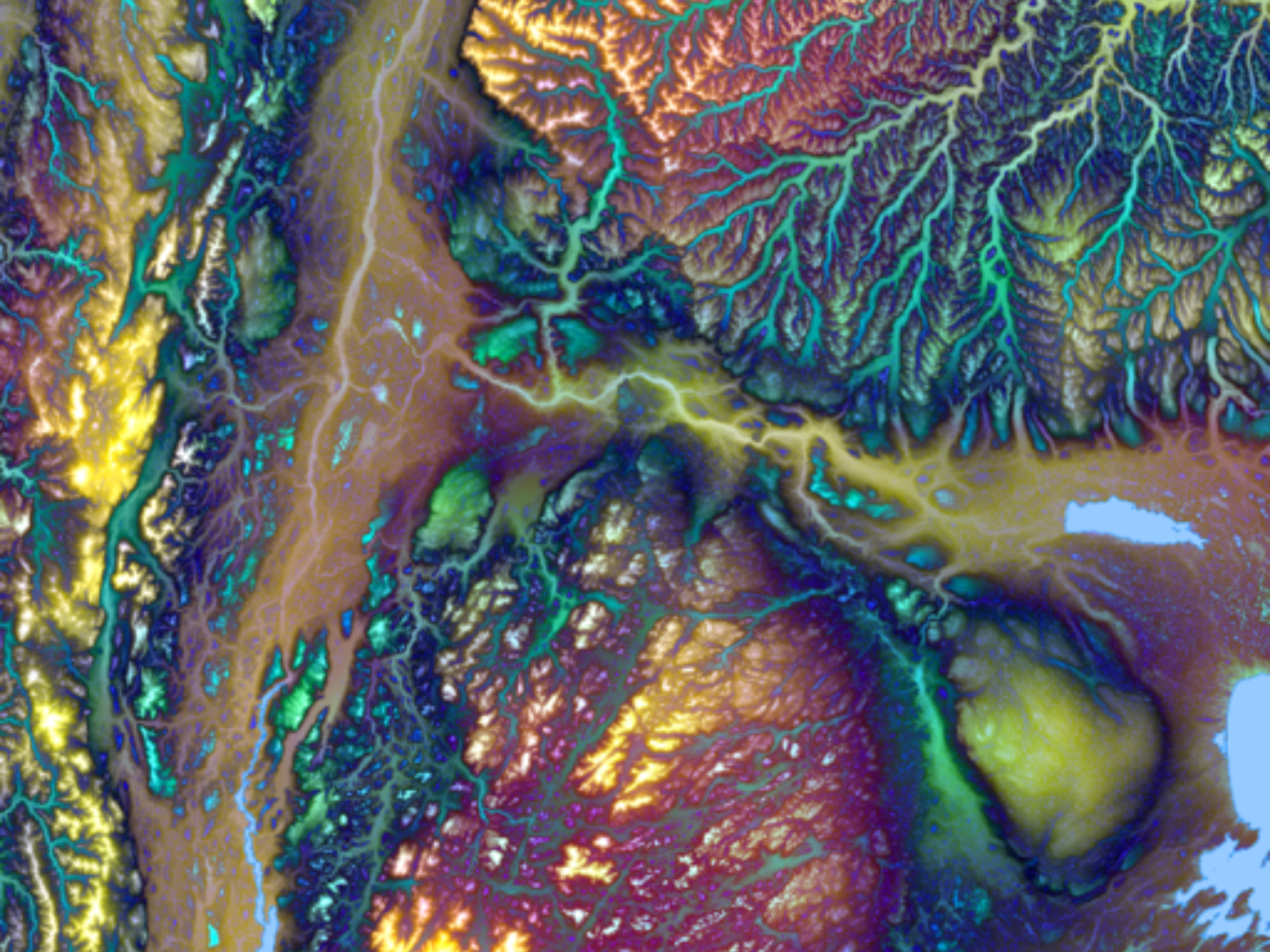
Colour	Multi-scaled TP description
	Deviated (either elevated or low-lying) local-scale TP; average TP at the two larger scales
	Deviated meso-scale position; average TP at both the local and broad-scale range
	Deviated broad-scale position; average TP at both of the shorter scales
	Deviated TP at both the local and meso-scale range; average TP in the broad-scale range
	Deviated TP at the meso- and broad-scale ranges; average TP in the local-scale range
	Deviated TP across a wide range of spatial scales
	Average TP across a wide range of spatial scales

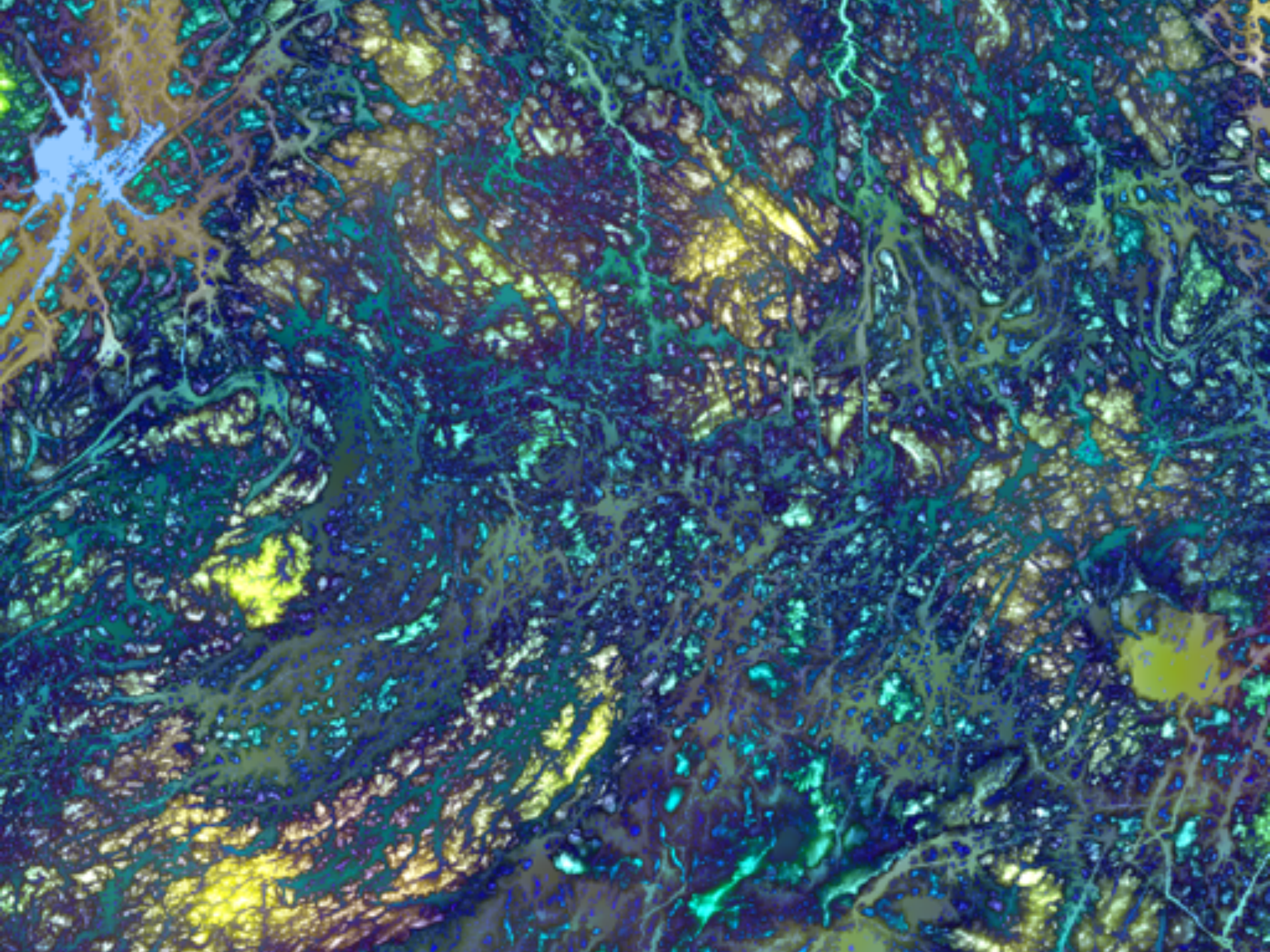


An MTPCC is similar to a colour satellite image created by combining three bands.

A pixel's colour tells you about the site's topographic position across three spatial ranges.







Conclusions

- An integral image approach allows for the efficient computation of TP and ruggedness indices.

- This provides the opportunity to study the multi-scaled properties of TP and ruggedness at resolutions and scales not previously possible using a roving window approach without resorting to degrading data resolution.

- DEV_{max} provides a valuable means of summarizing topographic position information for each pixel at key spatial scales within a wider range of scales.

Conclusions

- The MTPCC image, derived by combining three DEV_{max} rasters into a single colour composite image, provides a convenient means of interpreting the multi-scale properties of locations within the landscape.

- Where from here? Object-based classifications of landscapes; an input to soils and vegetation mapping application; soil moisture modelling.

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