Automated artifact-free seafloor surface reconstruction with two-step ODETLAP (Ph.D. Showcase)

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The problem

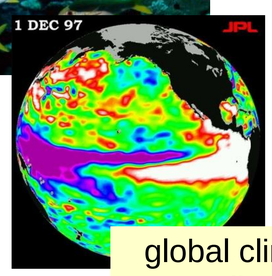
Automated reconstruction of high-resolution, artifact-free seafloor surface from multibeam bathymetry (MBB) data.

Broader Impact

tsunami hazard assessment

habitat management

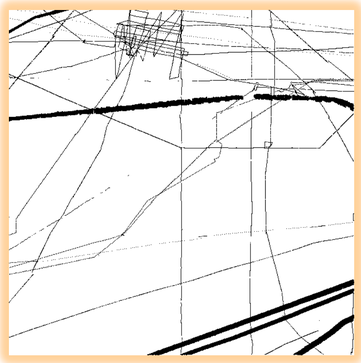
pipeline route planning



global climate prediction

Why this is hard

- MBB data is very unevenly spaced:
  - Dense along the ship tracklines, but then
  - Nonexistent for a long distance sideways.
- Current reconstruction methods often:
  - Produce artifacts (e.g., abrupt slopes, acquisition footprint),
- Current post-processing smoothing often:
  - Require human monitoring
  - Remove terrain features besides artifacts



ODETLAP

$$\begin{bmatrix} 1 & & & & & & & & \\ & 1 & & & & & & & \\ & & \ddots & & & & & & \\ & & & 1 & & & & & \\ r_{11}\mathrm{X} & & & & & & & & \\ r_{12}\mathrm{X} & & & & & & & & \\ \vdots & & & -1\ -1\ 4\ -1\ -1 & & & & \\ \vdots & & & -1\ -1\ 4\ -1\ -1 & & & & \\ & & & -1\ -1\ 4\ -1\ -1 & & & & \\ & & & & \ddots & & & & \\ r_{nn}\mathrm{X} & & & & & & & & \end{bmatrix} \begin{bmatrix} z_{11} \\ z_{12} \\ \vdots \\ \\ \\ \\ \\ \\ z_{nn} \end{bmatrix} = \begin{bmatrix} h_1 \\ h_2 \\ \vdots \\ h_k \\ 0 \\ 0 \\ \\ 0 \\ 0 \\ 0 \\ \\ 0 \\ 0 \end{bmatrix}$$

$\mathbf{A}$ $\mathbf{z}$ $\mathbf{b}$

k equations, each equates the reconstructed height of a known-height position to the respective measured value
$z_{ij} = h_{ij}$

n^2 equations, each equates the reconstructed height of a position to its neighborhood average
$z_{ij} = (z_{i,j-1}+z_{i,j+1}+z_{i-1,j}+z_{i+1,j})/4$

Accuracy-biased (r = 1) on partial grid superior accuracy

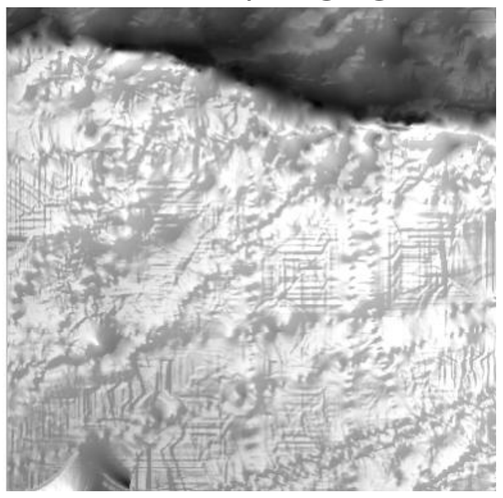
Error	ODETLAP	Natural Neighbor
Area1	24m	31m
Area2	18m	20m
Area3	15m	17m

Smoothing-biased (r >> 1) on full grid Smoothing with minimal error

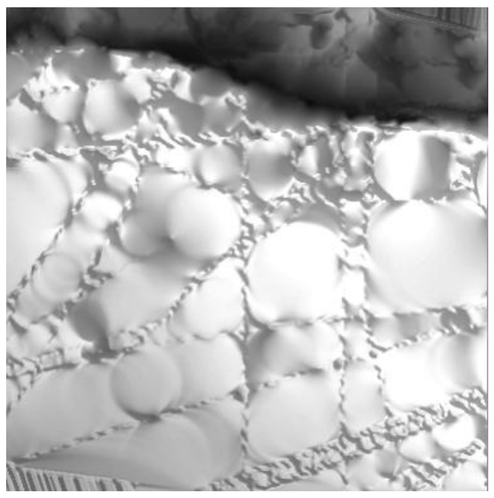
Error	ODETLAP	Mean filter
Area1	130m	297m
Area2	75m	178m
Area3	214m	360m

Conventional scheme

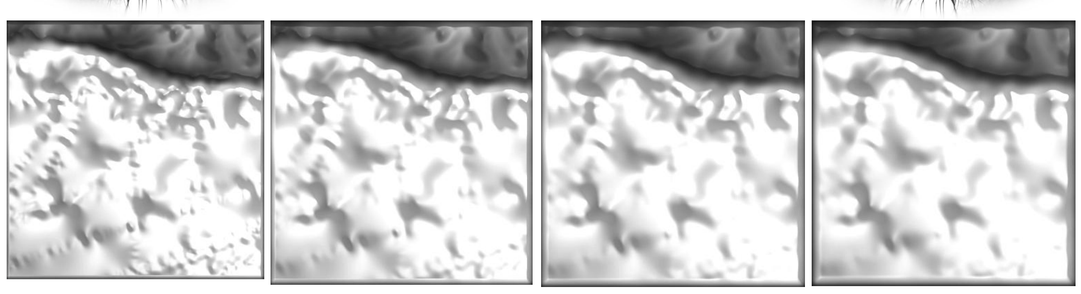
Ordinary Kriging



Natural Neighbor



Human inspection for minimum-error artifact-free terrain



↑ number of filtering

Partial depths

↓

Preliminary terrain reconstruction

↓

Preliminary reconstructed surface

↓

↑smooth factor ↓ Coeff. of variation c_v

↓

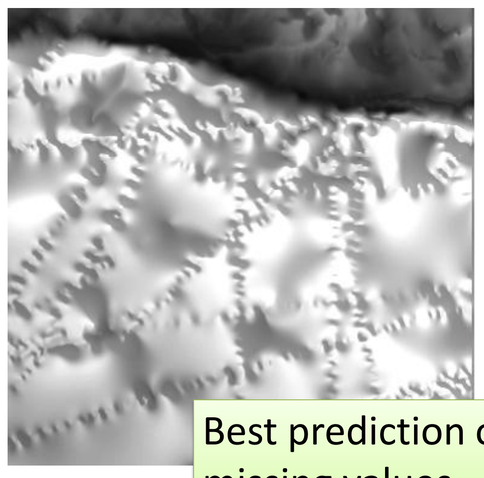
Smoothing-centric ODETLAP

↓

Final reconstructed surface

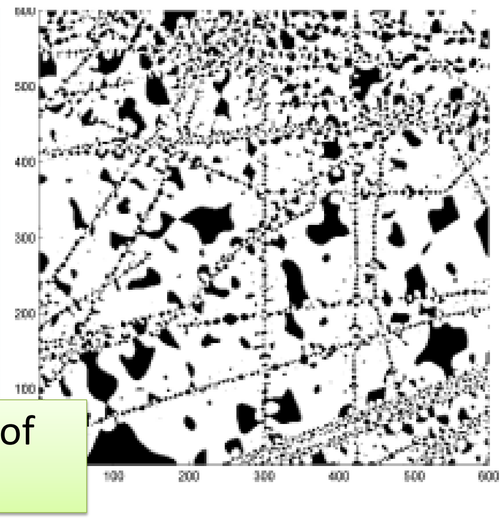
Two-step ODETLAP

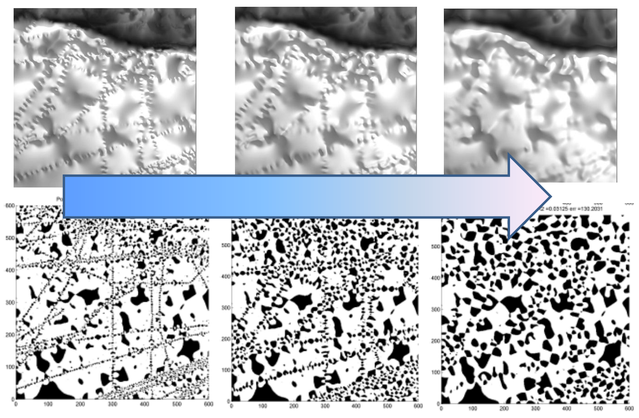
Accuracy-biased ODETLAP



Best prediction of missing values

Patches of Positive Gaussian curvature

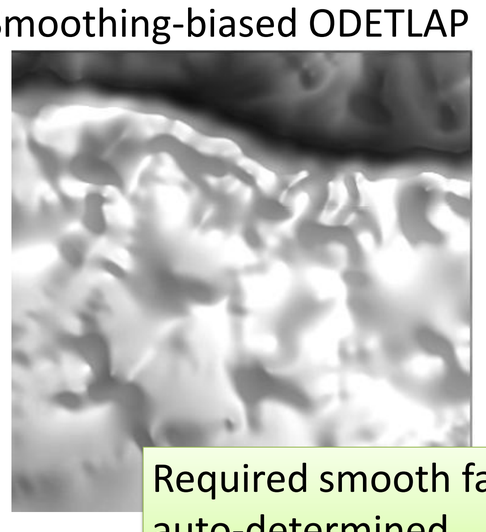




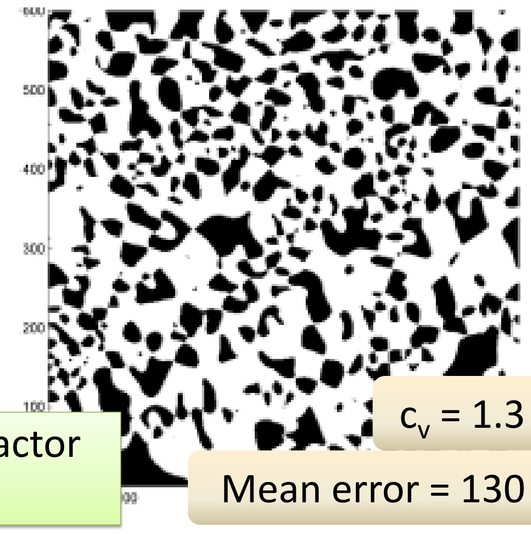
↑smooth factor ↓ Coeff. of variation c_v

Binary search for c_v = 1.3

Smoothing-biased ODETLAP

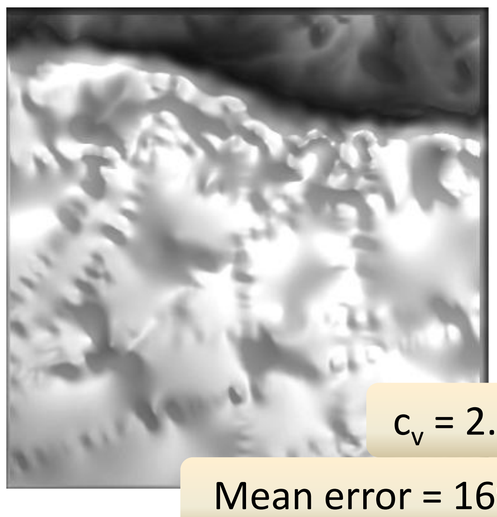


Required smooth factor auto-determined



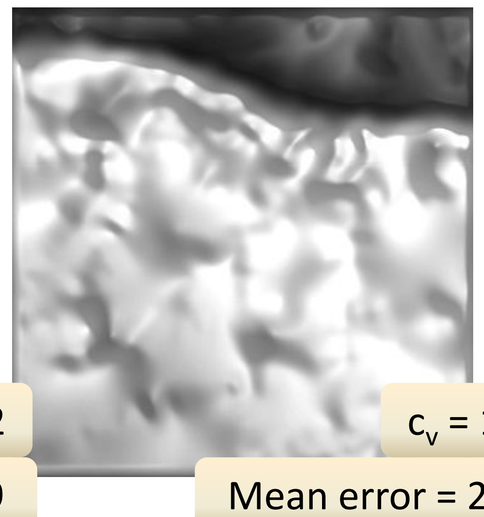
c_v = 1.3

Mean error = 130



c_v = 2.2

Mean error = 169



c_v = 1.3

Mean error = 297