Quality-guided segmentation for sparse differential interferograms

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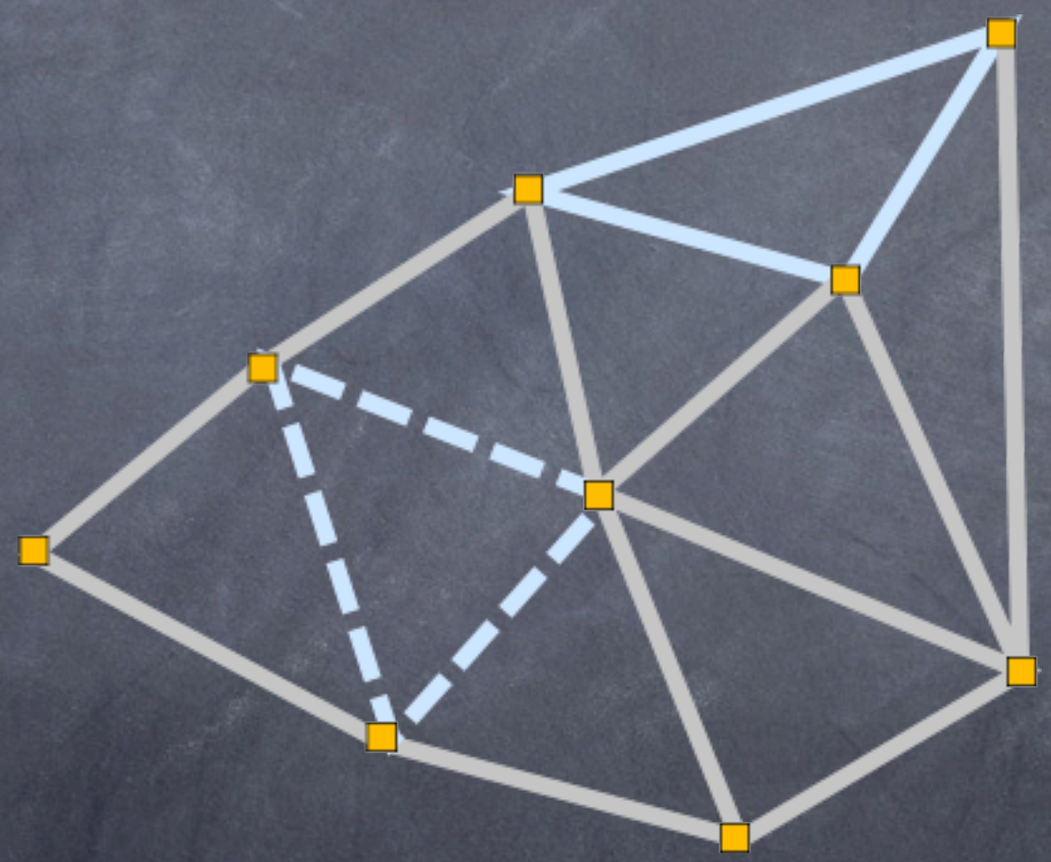
The unwrapping problem

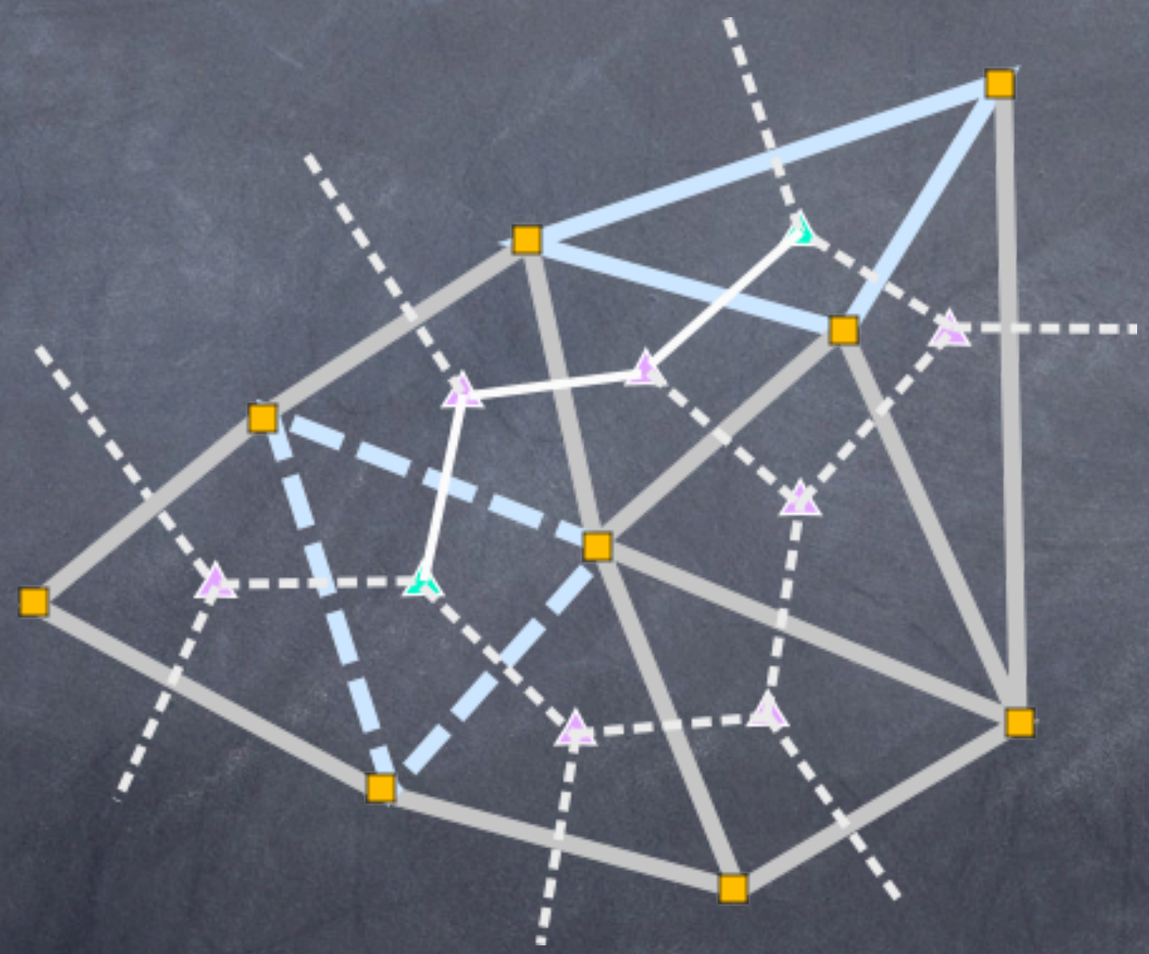
- Measured phase ambiguous to interval $[0, 2\pi)$
- Formulated in terms of residues and branch cuts leads to many algorithms for placing cuts
- Powerful and flexible approach:

  Minimum cost flow (MCF)

The minimum cost flow formulation



The minimum cost flow formulation



The problem with good interferograms

- Cost of obtaining MCF solution grows rapidly in number of node points, even in interferograms of good quality
- Hence, a problem which should be easy becomes computationally untractable
- Solution is to divide problem into smaller pieces
- Problem is how?

Blind segmentation (Tiling)

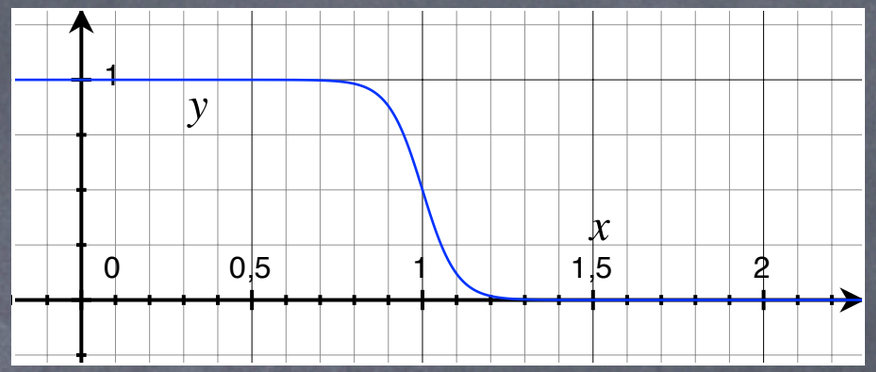
- Pieces can be isolated unnecessarily
- Does not identify easily unwrapped regions

Quality-guided segmentation

- Goal: create segments that unwrap easily
- Define quality of **edges** based on
  - proximity (defined by atmospheric correlation length)
  - coherence
  - $\nabla\varphi$ (DEM-corrected) close to zero
  - avoid layover zones (quality = 0)

Proximity

$$\frac{1}{2}\left(1 - \tanh\left(\frac{d_{ij} - L}{D}\right)\right)$$



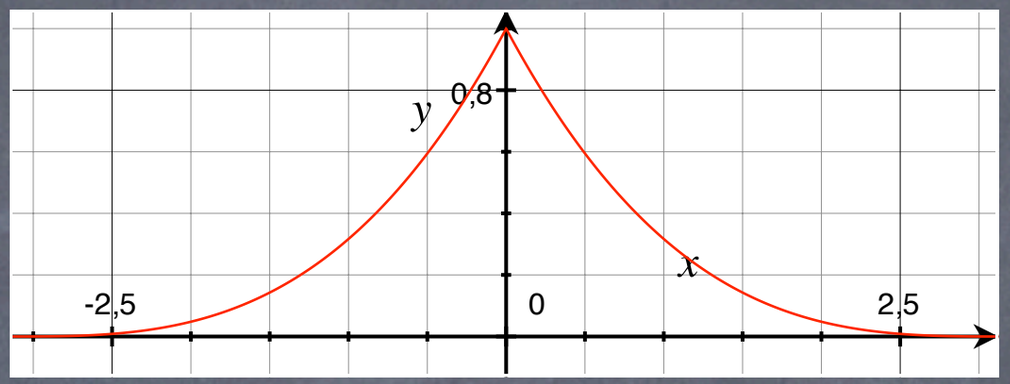
- Atmospheric correlation length defines upper limit on acceptable edge length (parameter L)
- Parameter D determines sharpness of transition from acceptable to unacceptable

Coherence

- Quality of edge limited by minimum of coherence at endpoints

Phase gradient

$$\left(1 - \frac{|\nabla\phi|}{\pi}\right)^n$$



- Edges with phase differences approaching ±π are considered of poor quality
- Parameter n (=3) determines sharpness of peak
- Assumes (rudimentary) DEM correction

Layover

- When either endpoint of an edge is a layover pixel, the quality of the edge is set to zero
  - Segments never grow into (or across) layover regions
  - in growth phase, segments never collide across layover regions
  - Segments can be completely isolated by layover

Quality-guided segmentation

- Seed point: highest coherence amongst unsegmented points
- Pick highest-quality edge from any point in segment, add endpoint to segment
- add all high-quality edges from endpoint for further consideration
- Upper and lower limits on segment size
- Stop when ~10% of points are unsegmented

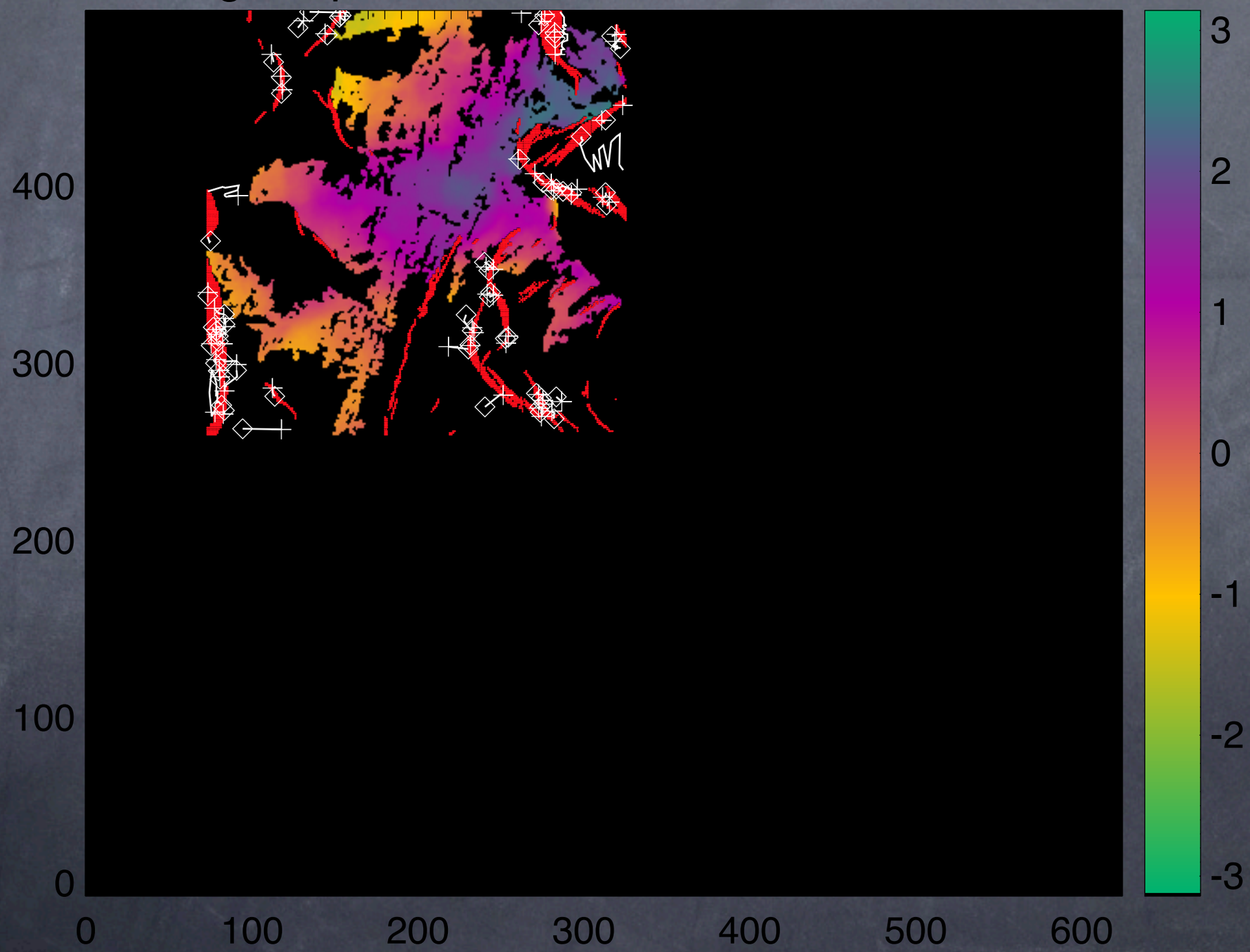
Initial segmentation

Per-segment unwrapping

- After segmentation, each segment is unwrapped separately
- Many small segments can be integrated directly (no residues)
- When residues -> MCF
  - Cost of flow = quality of edge to cut
- Residues often along edges, MCF problem more tractable

Per-segment unwrapping

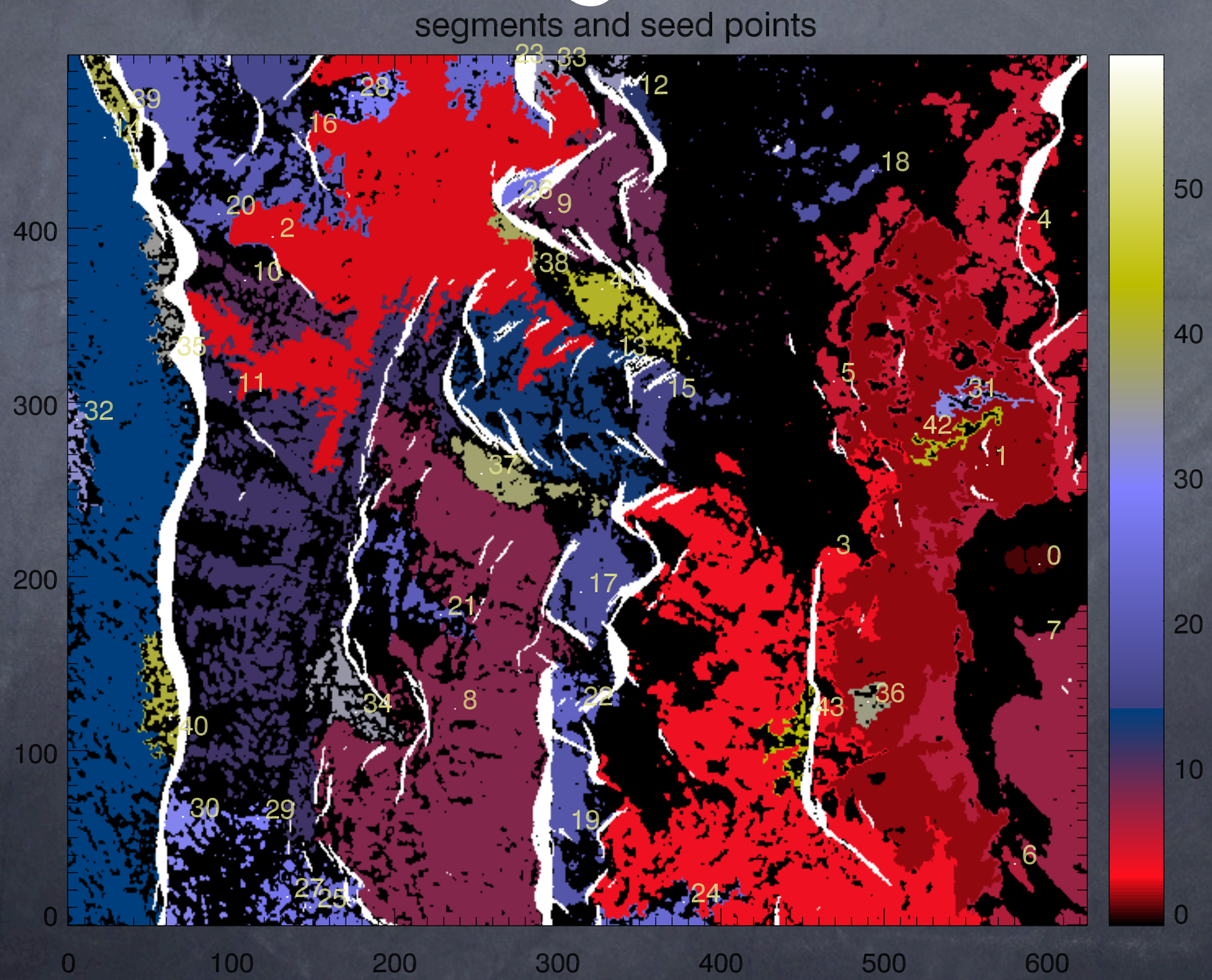
original phase data, residues and branch cuts



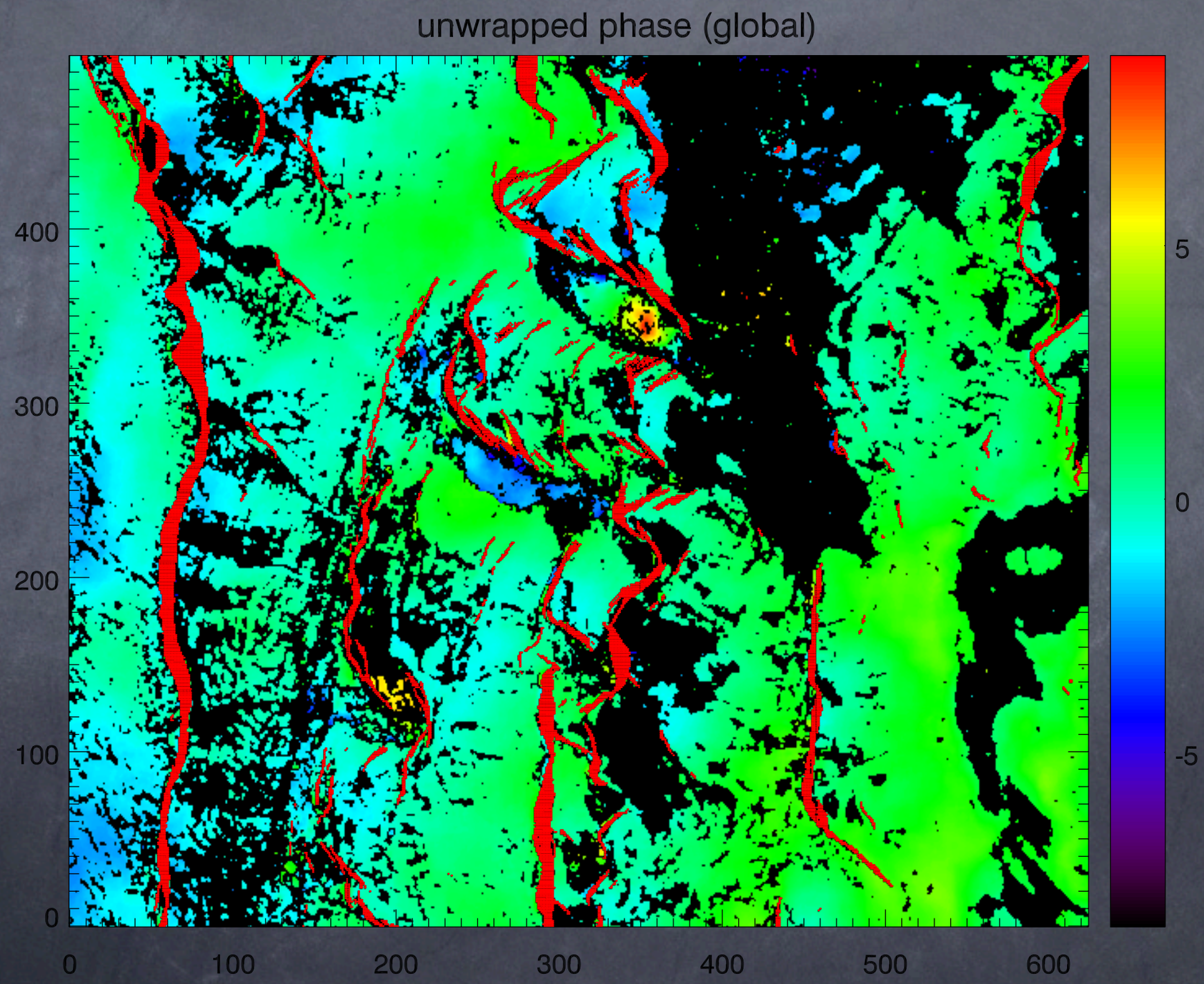
Growth phase

- Grow all segments in order of edge quality
- as segments collide:
  - if wrapping numbers in collisions are consistent, join segments
  - otherwise, defer decision until end
- Results still not consistently satisfactory
- Will consider more sophisticated region growing/collision algorithm

Results (segmentation)



Results (unwrapped phase)



Conclusions

- QGS results in segments that unwrap quickly and consistently yielding very good results
- All operations are essentially local, so the technique is very attractive for large interferograms
- More work needed on stitching of segments
- still, problem size reduced by orders of magnitude