The STUN algorithm for Persistent Scatterer Interferometry

1. **Theory**
2. **PSIC4 Processing**
3. **Conclusions**

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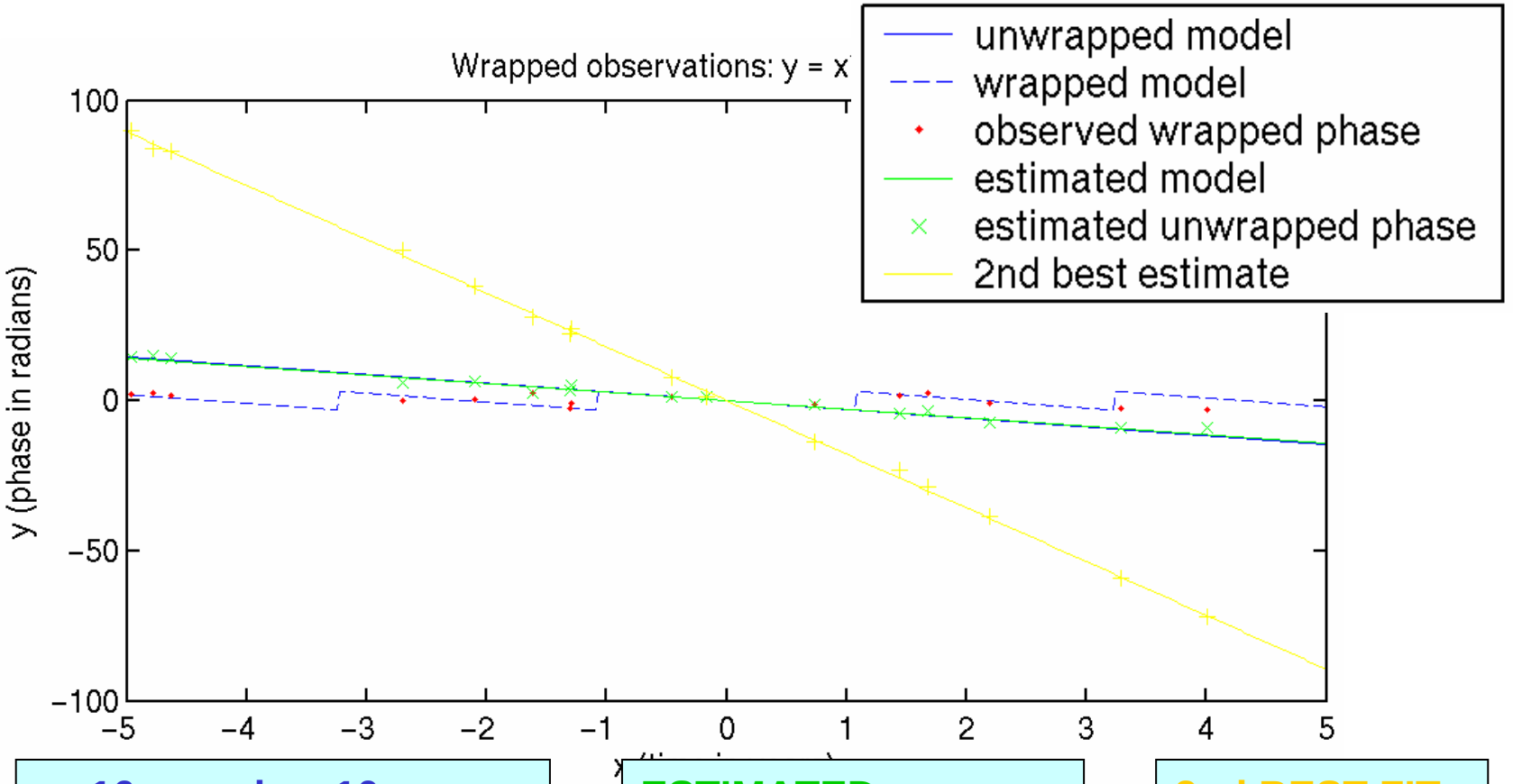
STUN Algorithm

- **Spatio-Temporal Unwrapping Network (STUN)**
  - **1D temporal + 2D spatial phase unwrapping**
- **Goal:**
  - **Unwrap the phase in a single-master stack**
  - **Optimal estimation of displacement parameters**
- **Key Features:**
  - **Integer Least-Squares (ILS): estimator**
  - **Variance Component Estimation (VCE): weights**
  - **Alternative Hypothesis Tests: robust**

STUN Processing Steps

- **Point selection:**
  - **~4 PS/km^2 in reference network**
  - **~200 PS/km^2 for estimation**
  - **Discard ~99%**
- **Reference Network Computation**
  - **Optional interferogram trend correction**
- **Tie more points to network**
- **Explicit phase unwrapping**
  - **Sparse grid Minimal Cost Flow (MCF)**
- **Optional Atmospheric Correction**
  - **Kriging Interpolation**
- **Final Estimation**

Integer-Least Squares (ex. 1)



- **16 samples, 10 years**
- **Noise σ = 69.2 [deg]**
- **Signal = -2.92 [rad/y]**

ESTIMATED:

67.7 [deg] (γ=0.55)

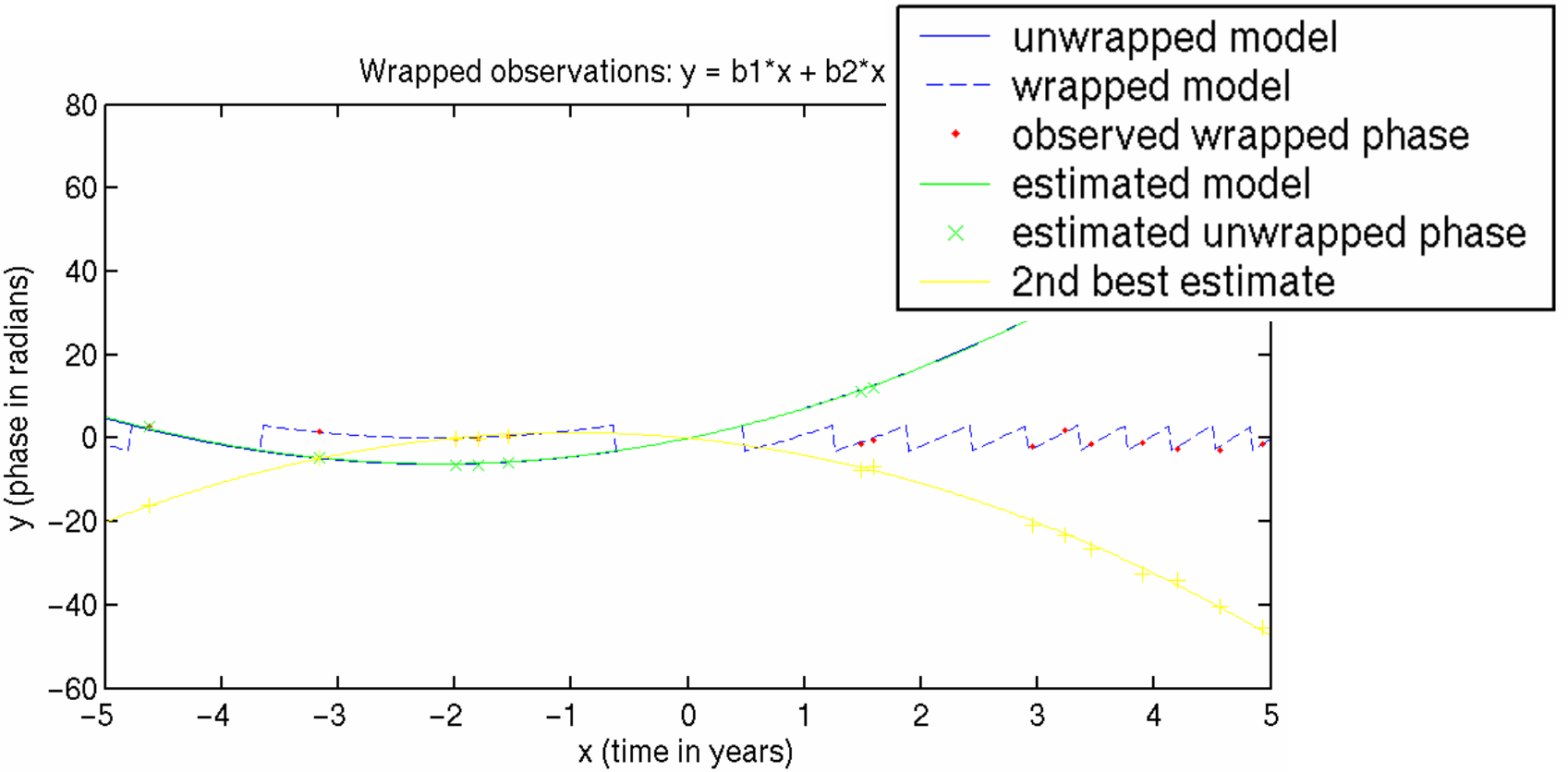
-2.83 [rad/y]

2nd BEST FIT:

(γ=0.41)

-17.9 [rad/y]

Integer Least-Squares (ex. 2)



- **14 samples**
- **σ = 32.3**
- **b1=5.79 b2=1.35**

ESTIMATED:

27.1 [deg] (γ=0.91)

5.75 1.35

2nd BEST FIT:

(γ=0.77)

-2.72 -1.35

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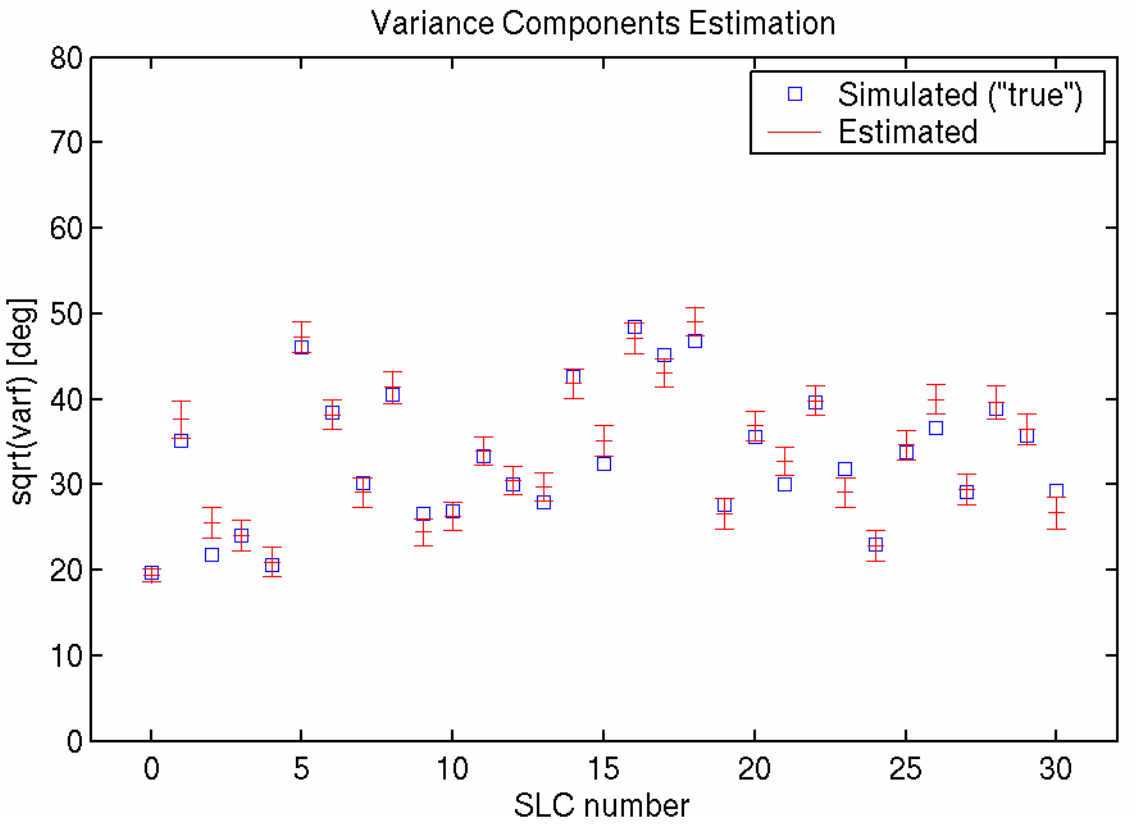
Integer Least-Squares

- **Readily extendible for more parameters:**
  - **Search of ambiguities solution space**
  - **Efficient search strategy exist (GPS application)**
  - **No increase in computation time**
- **Weighted least-squares:**
  - **Stochastic model for double-difference phase observations**
  - **Variance Component Estimation (VCE)**
- **Software available at Delft University of Technology**
  - **http://enterprise.lr.tudelft.nl/mgp/**

Variance Component Estimation (ex. 1)



- 31 SLC images
- 30 interferograms

- 400 PS points
- 200 arcs (double-differences)

Variance Component Estimation

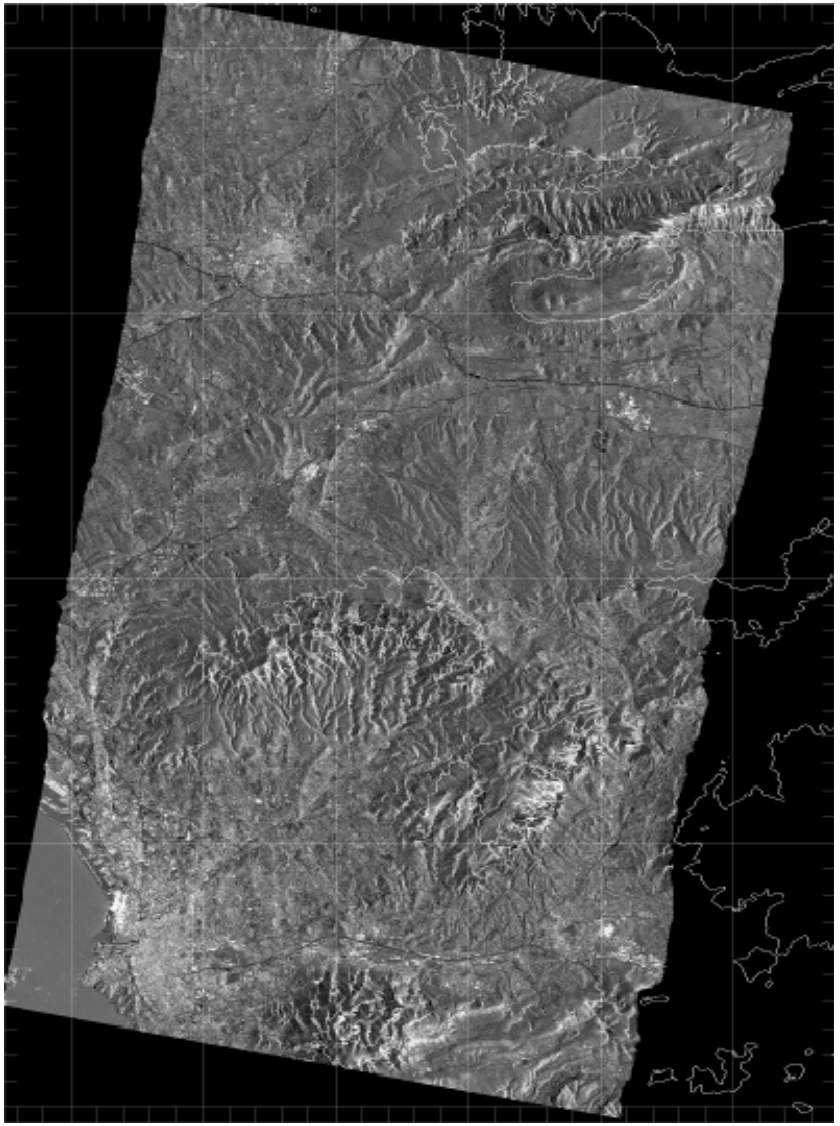
- **“Weights” of the SLC scenes**
  - **Improves quality of estimated parameters**
  - **Reduces number of incorrectly estimated ambiguities**
  - **Automatically detect incorrectly processed interferograms**
  - **Realistic quality description of estimates**
- **Iterative estimation procedure**
- **See paper for equations**

- **Real data application**

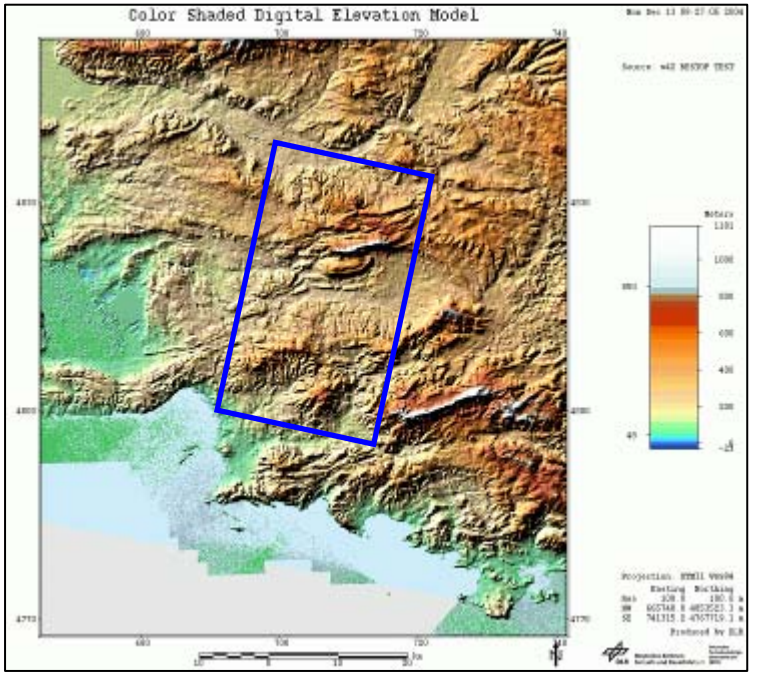
PSIC4 Study

- **Initiated by ESA at *FRINGE 2003***
- **“Cross-Comparison of Persistent Scattering Processing Techniques”**
- **Marseille, France**

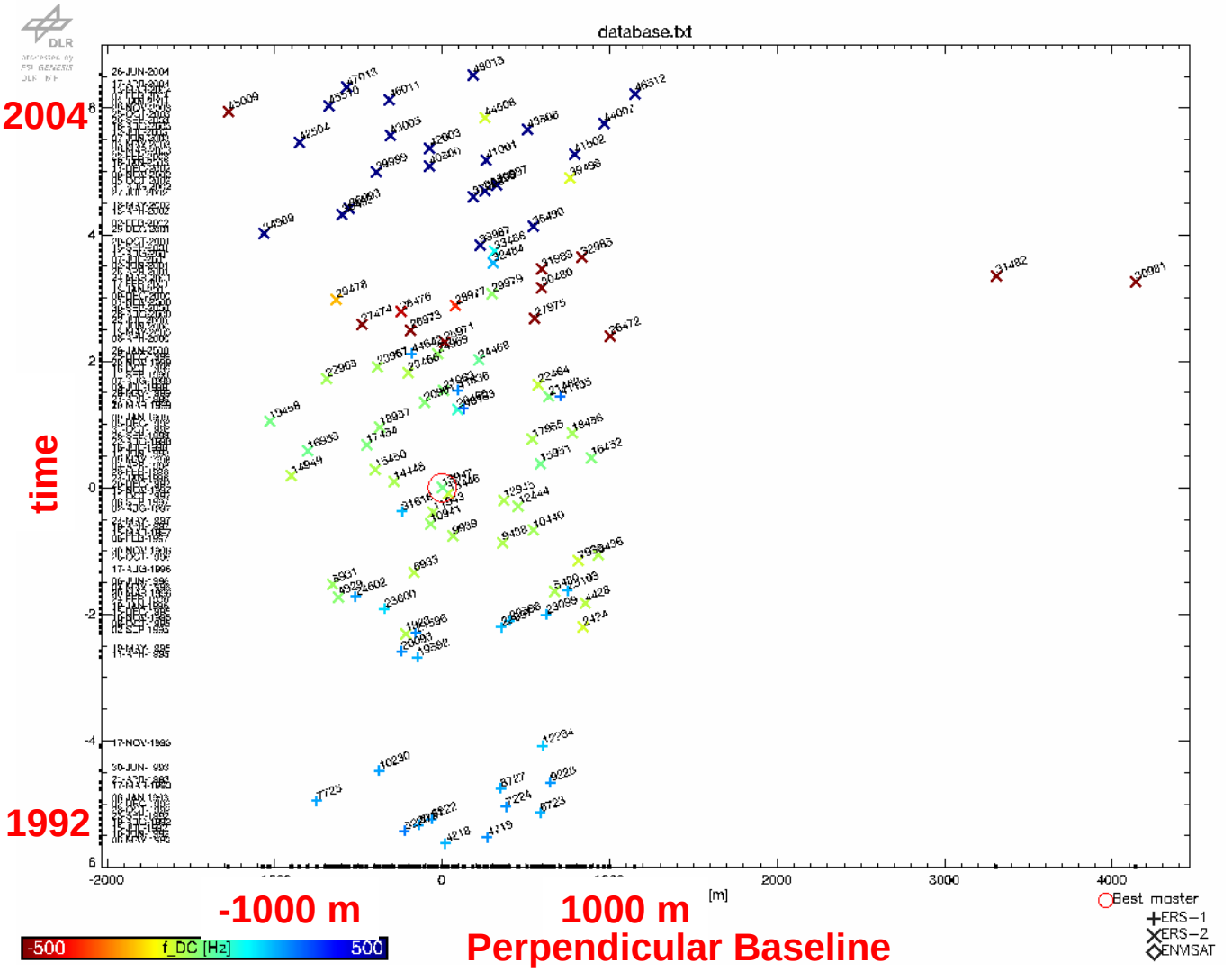
Processed Area



- **25 x 40 km²**
- **Rural area**
- **Mountainous: 0-1000 m**
- **Subsidence due to mining**

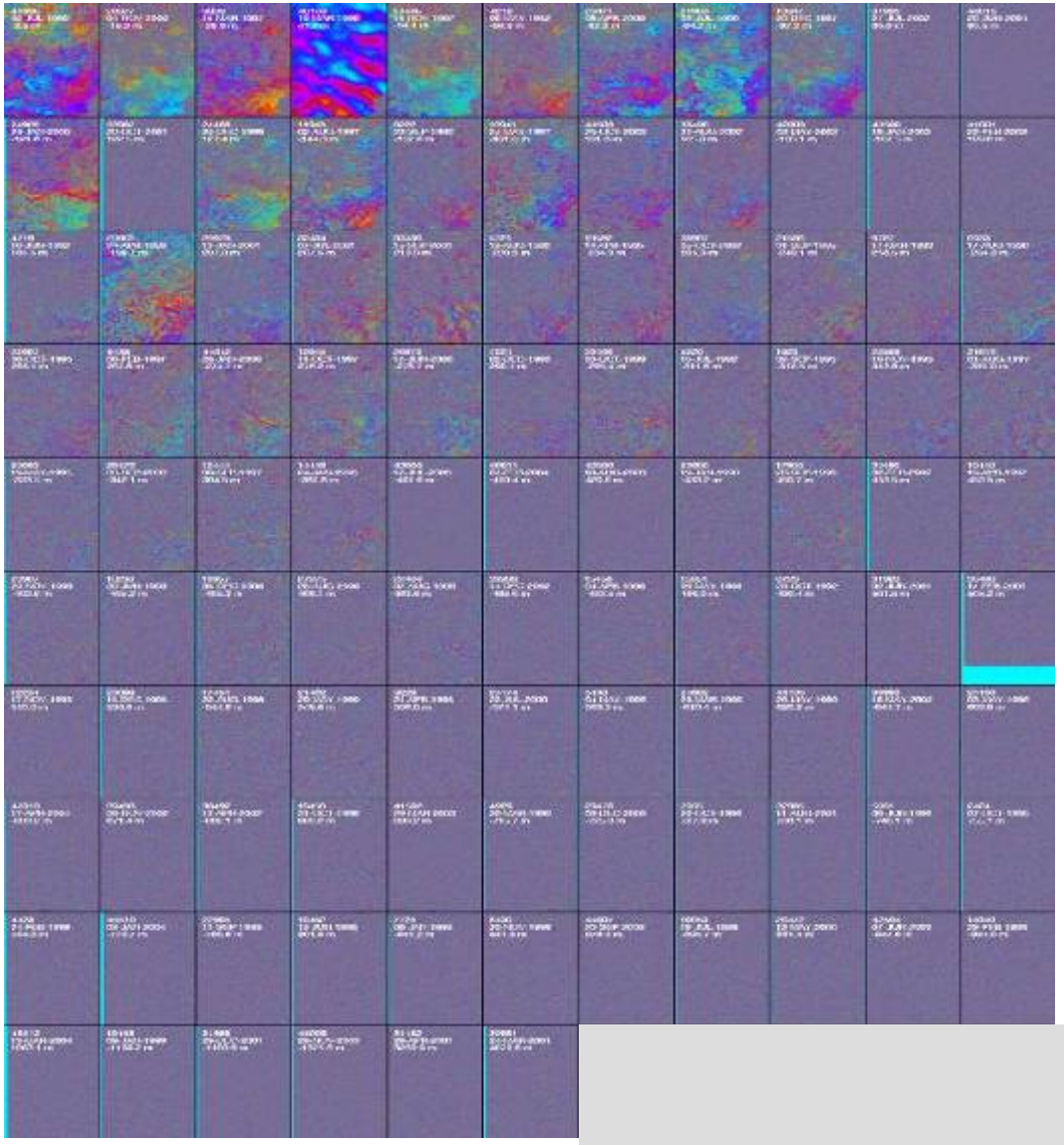


Baseline Distribution



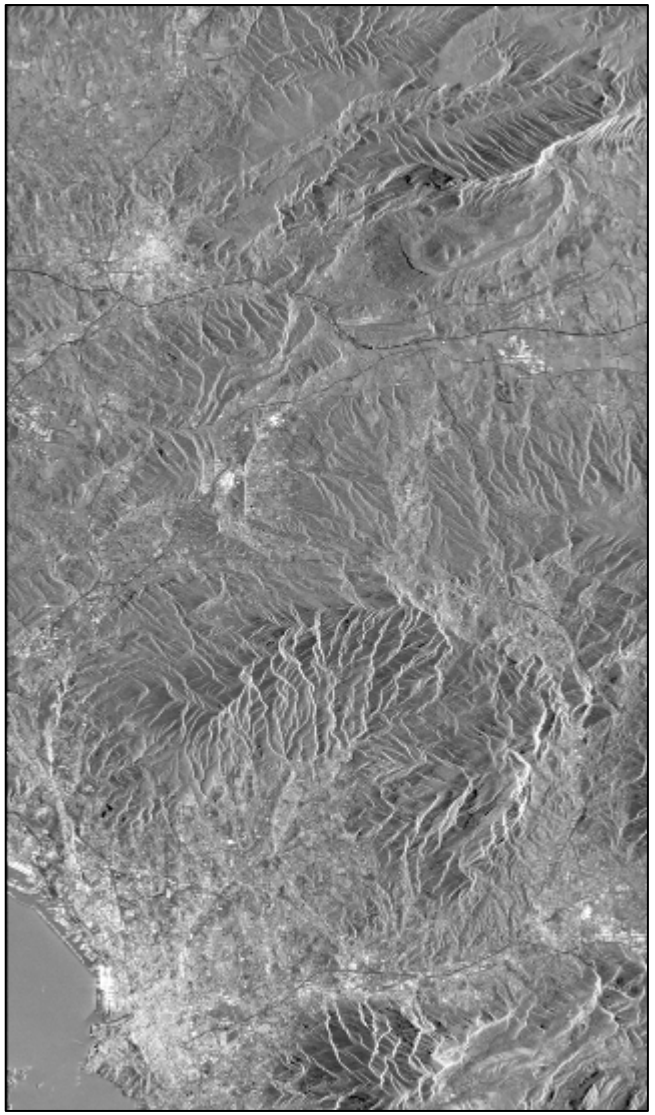
- **80 SLC selected**
- **No extreme Doppler/ large Baseline**

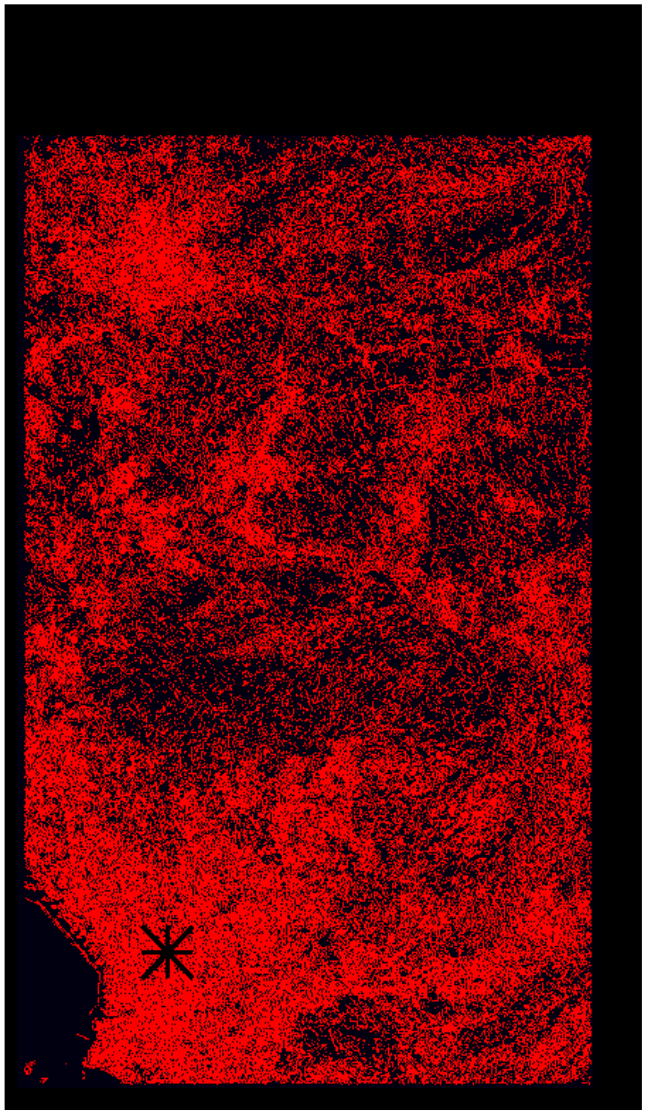
Processed Interferograms



- Differential Interferograms
  - SRTM DEM
- Single Master
  - 20460
  - ERS-2
  - March 1999
- Coregistration
  - Geometry
  - Point Targets
- Sorted according to perpendicular baseline

Selected Points





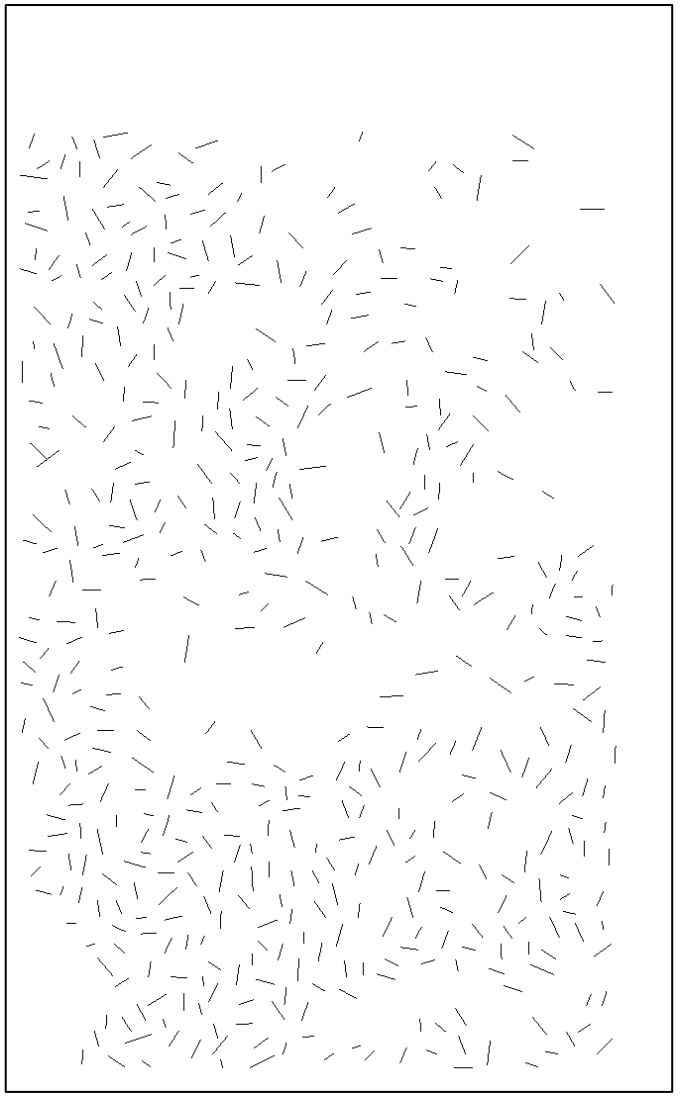
Area:

- **rg: 2400**
- **az: 20000**
- **~50 million pixels**

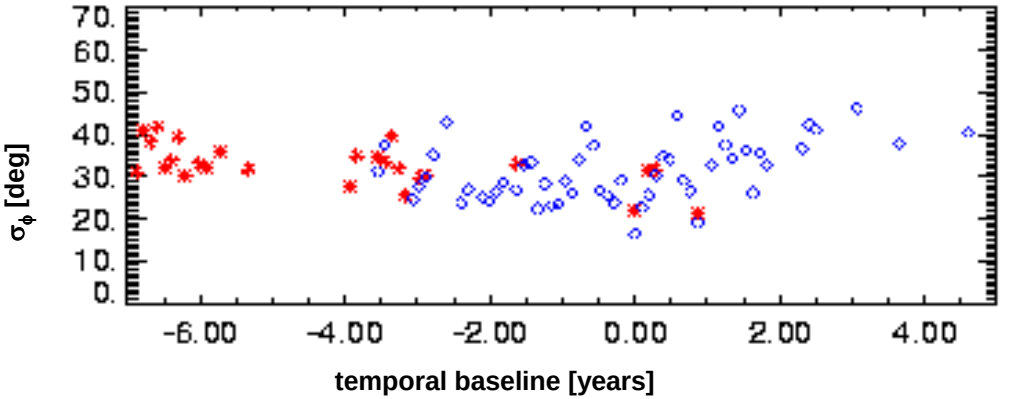
Points:

- **SCR > 1.5**
- **~200,000 PS**
- **Phase data extracted at sub-pixel peak positions**

Variance Component Estimation

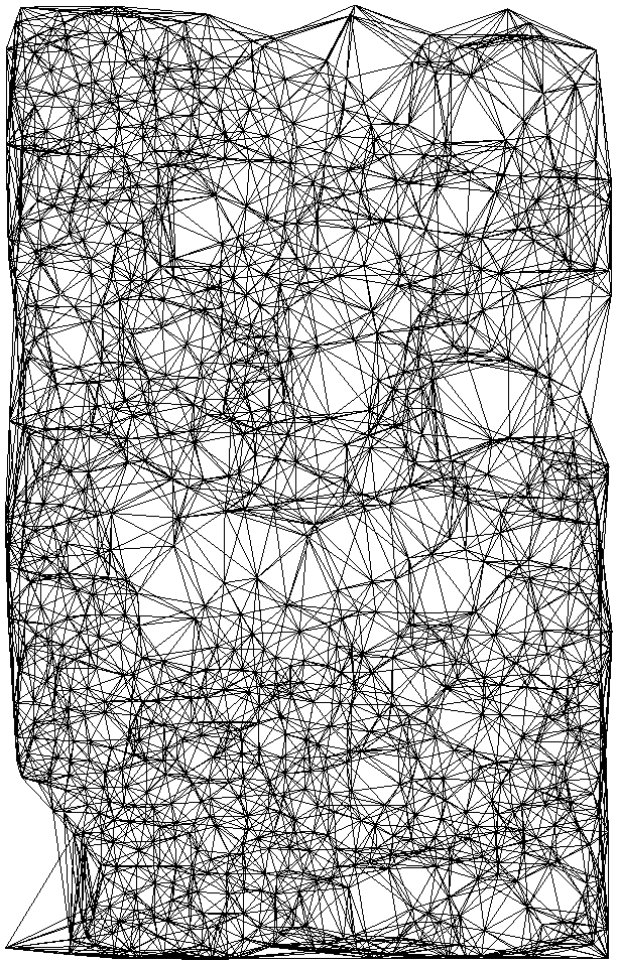


- **Average of estimated components at ~600 independent arcs**



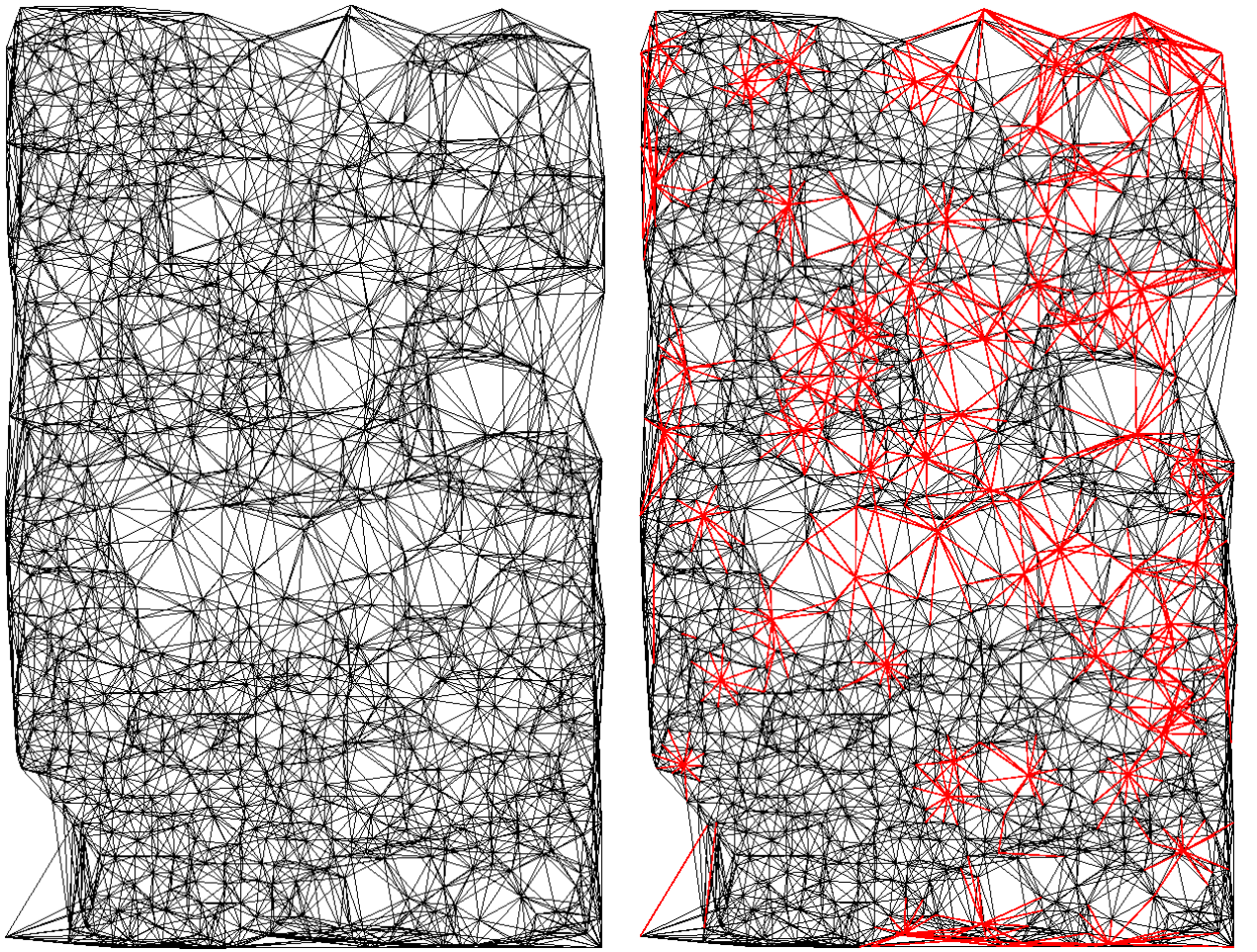
- **SLC sigma ~15 -- 45 [deg]**
- **Accounts for random noise and atmospheric difference signal at arcs of typical length (1250 m)**

Reference Network



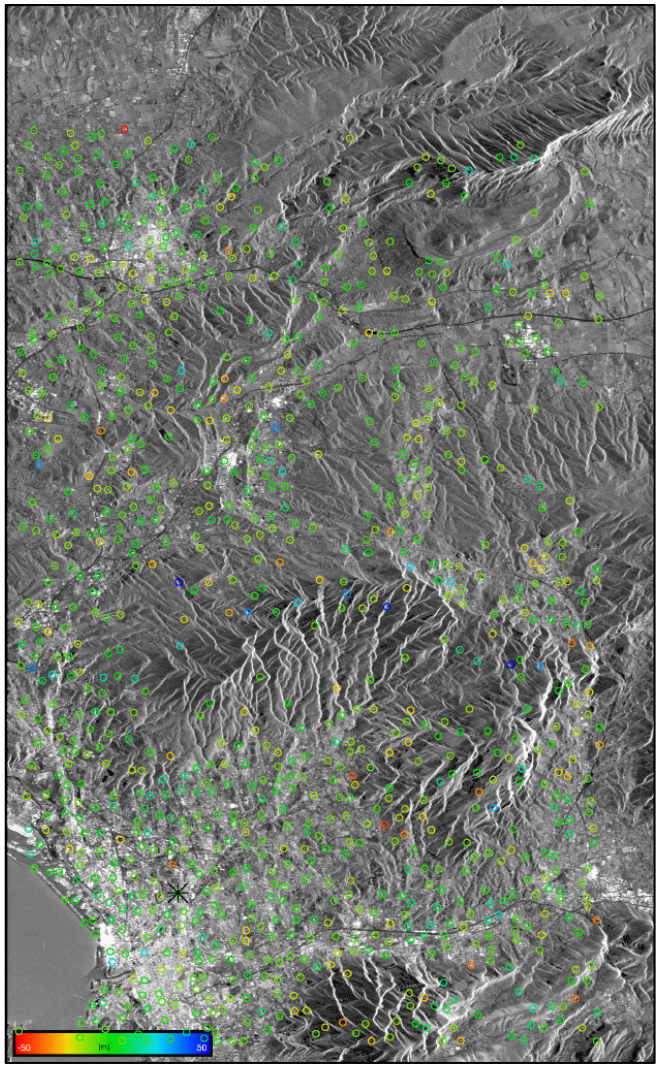
- **Points in reference network selected based on amplitude dispersion index:**
  - **Expected to be temporally coherent**
- **Network constructed**
  - **~10 arcs per point**
- **At all arcs, estimate:**
  - **DEM error differences**
  - **Displacement rate differences**
- **Integer least-squares Estimator**
  - **Weighted**

Parameter Integration

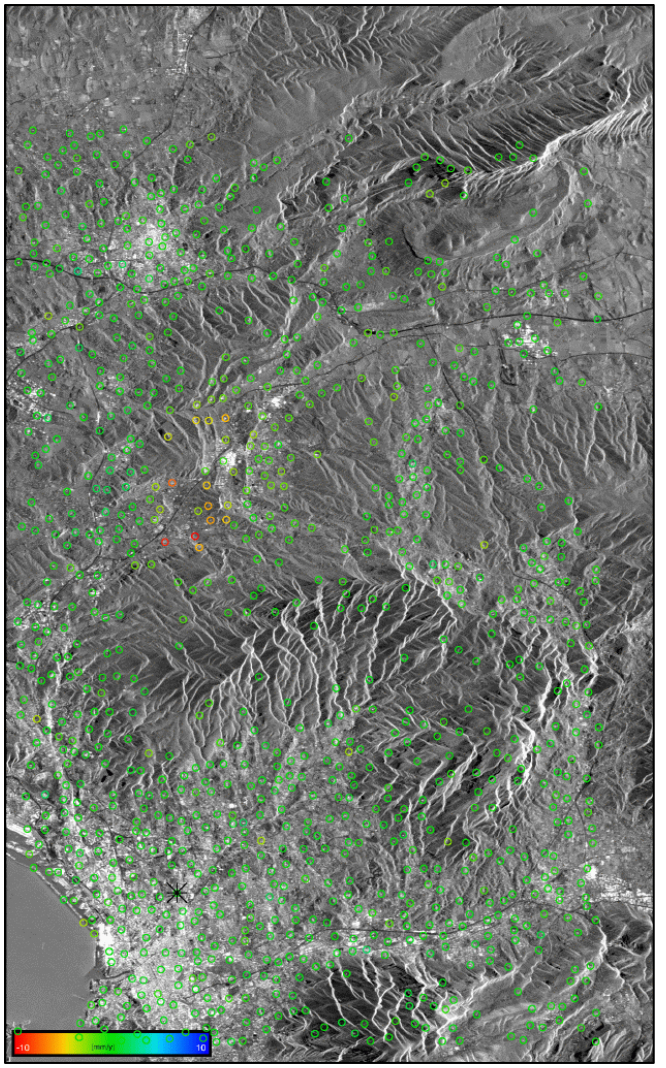


- **Least-squares adjustment of estimates *between* PS points**
- **Yields DEM errors and Displacement rates *at* the PS points**
- **Alternative Hypothesis Tests**
- **Red: rejected arcs**

Parameters at Reference Network



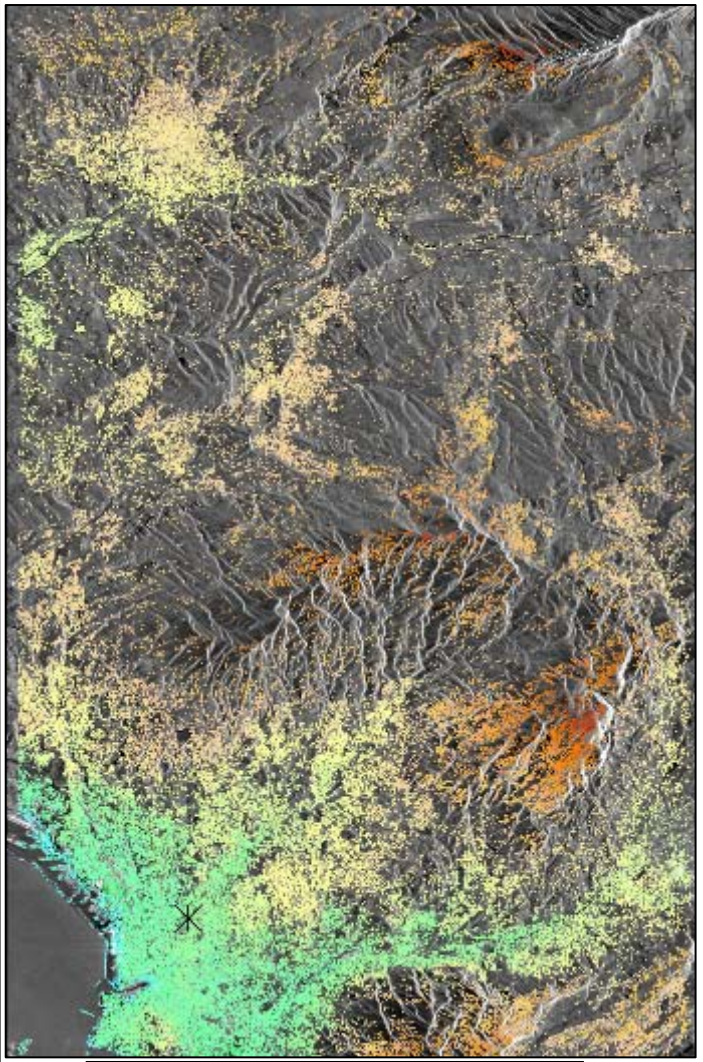
- DEM error



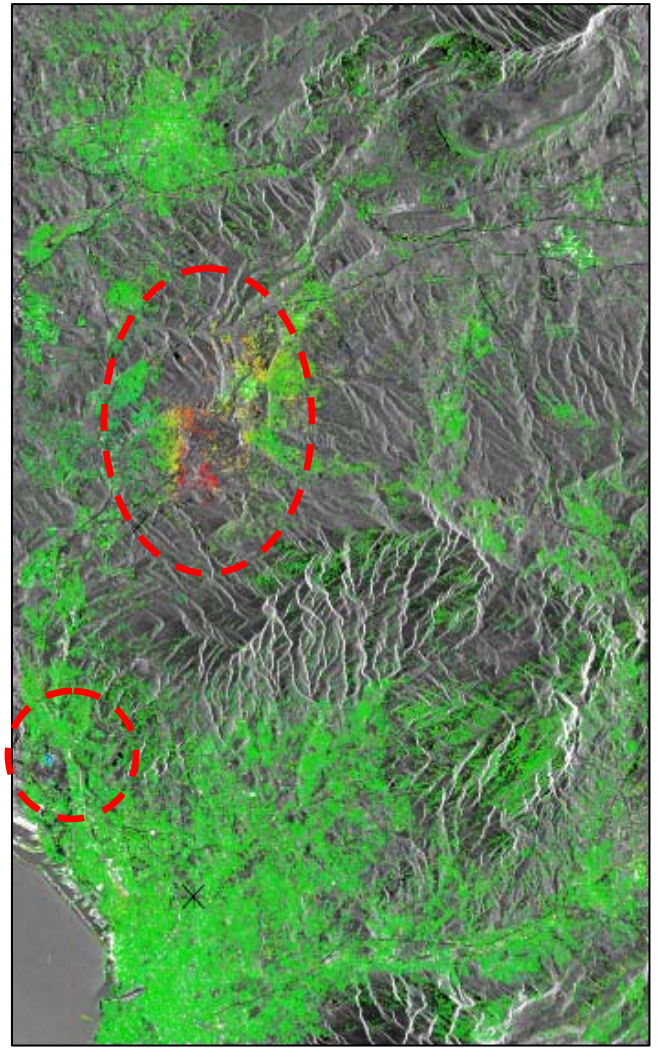
- Displacement Rate

- Reference network
- ~1600 PS

Estimated Parameters at PS



- DEM update



- Displacement Rate

- 60,000 PS accepted
- Subsidence
- -13 mm/y
- Uplift
- +5 mm/y

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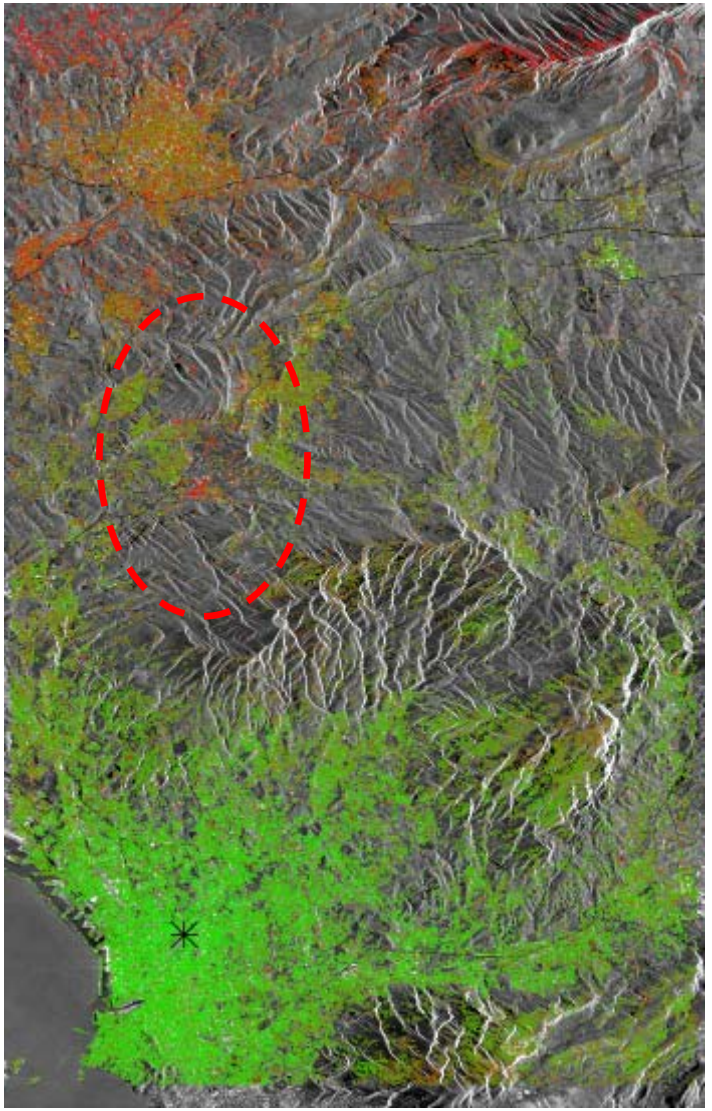
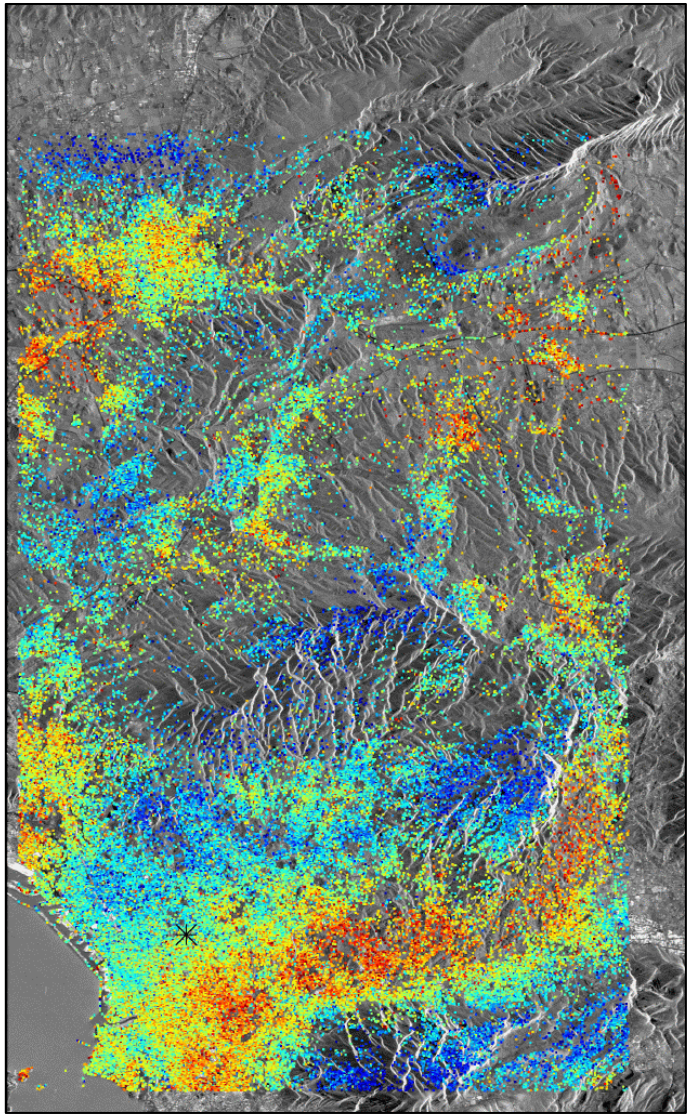
Estimated Quality



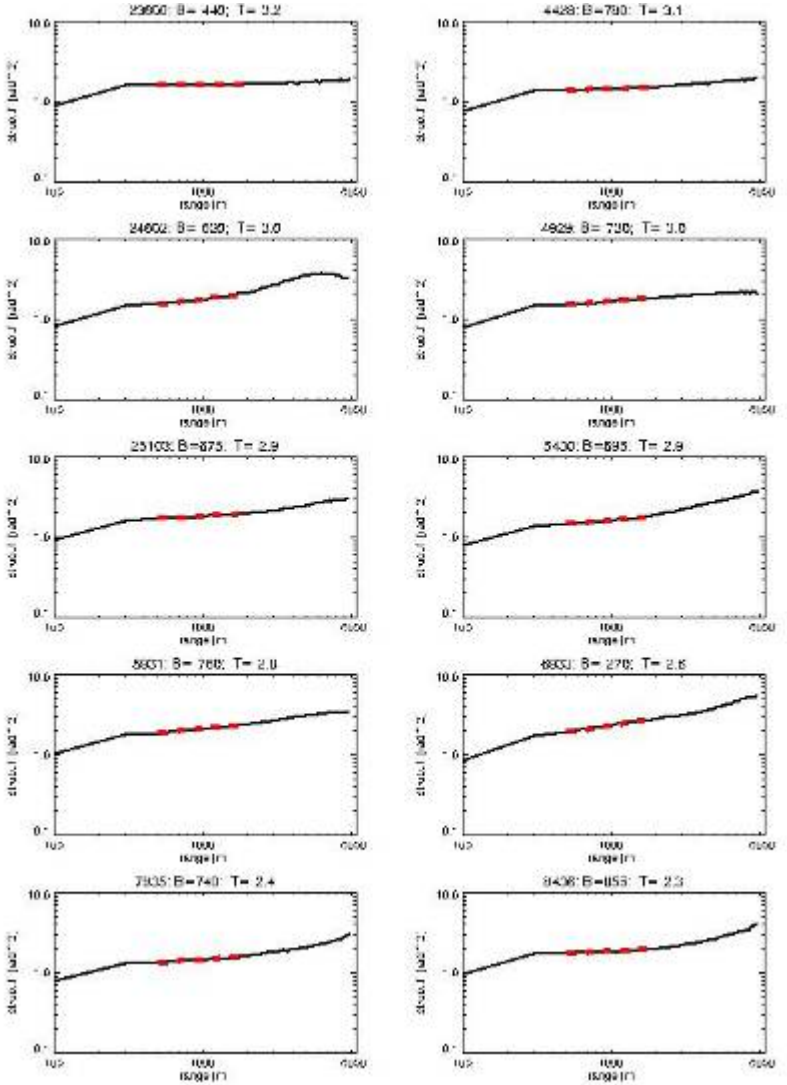
- A posteriori variance factor
- Unwrapped data
  - Not yet corrected for atmospheric signal
- Precision decreases the further away from reference point (asterisk)
- Subsidence area: this factor is locally larger:
  - Functional model not correct?

Residual Phase



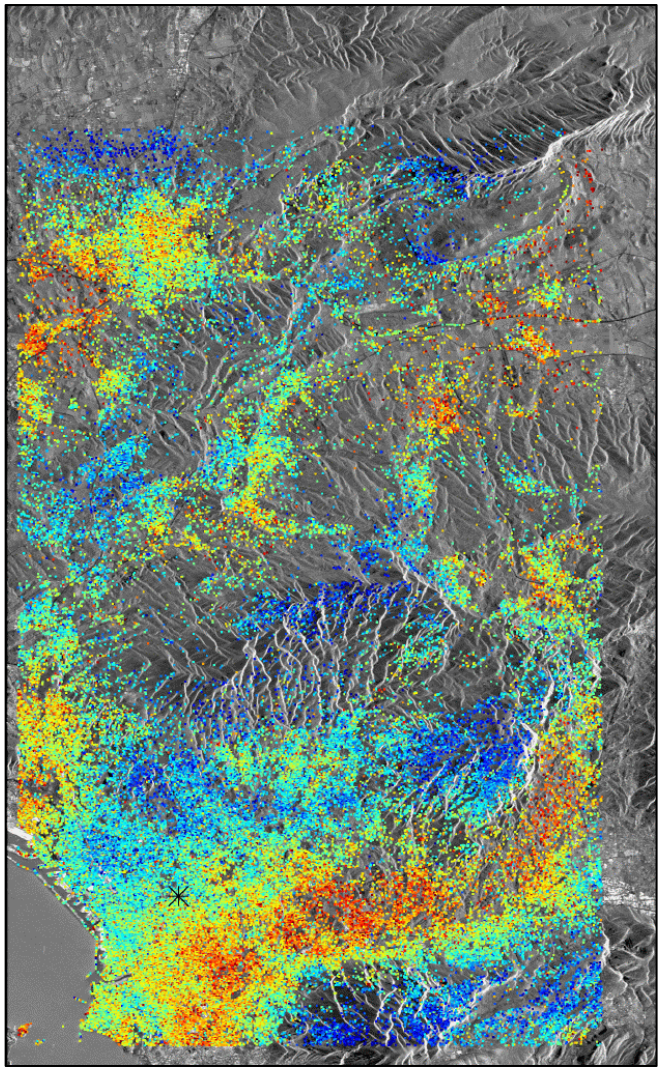
- Residual phase in interferogram
  - DEM error corrected
  - Displacement rate
- This is interpreted as
  - Random noise +
  - Atmospheric signal
- → Kriging Interpolation

Structure Functions

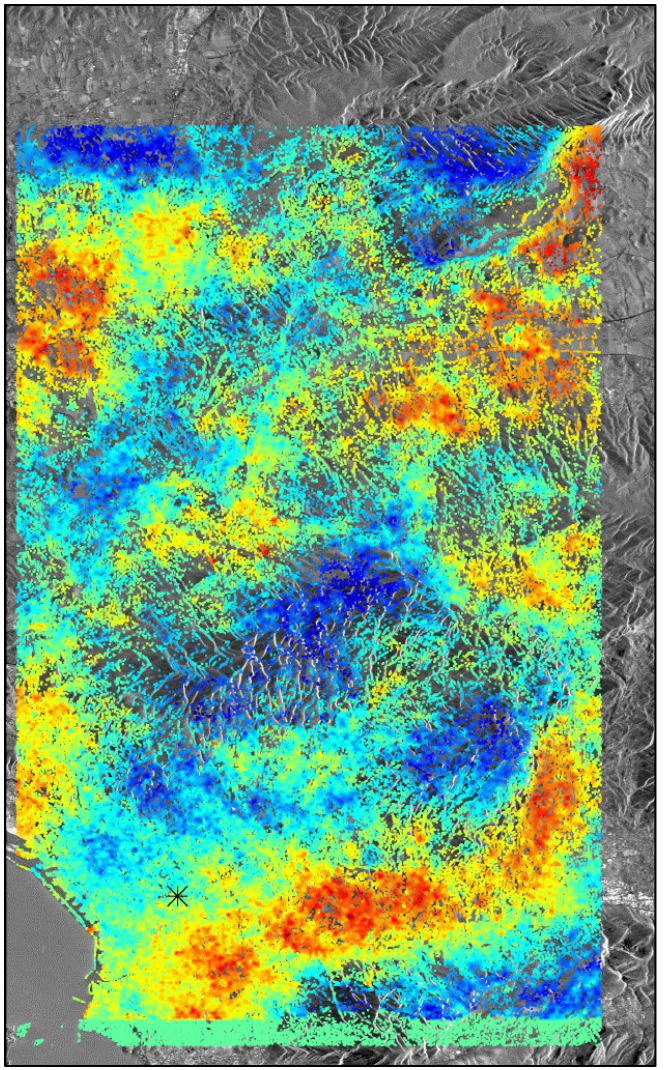


- **Each panel shows the structure function of the residual phase in an interferogram.**
- **Atmospheric signal:**
  - **power-law**
  - **slope in loglog plot**
- **Red: estimated slope**
  - **input for Kriging**

Kriging Interpolation



- Residual Phase



- Kriging

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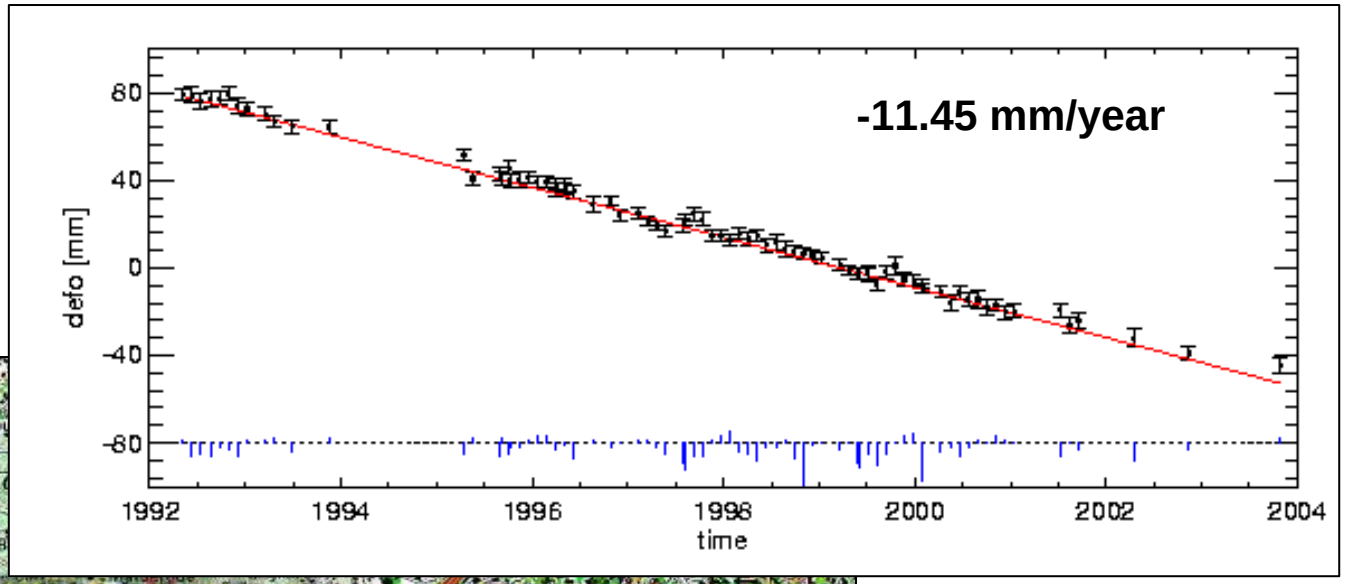
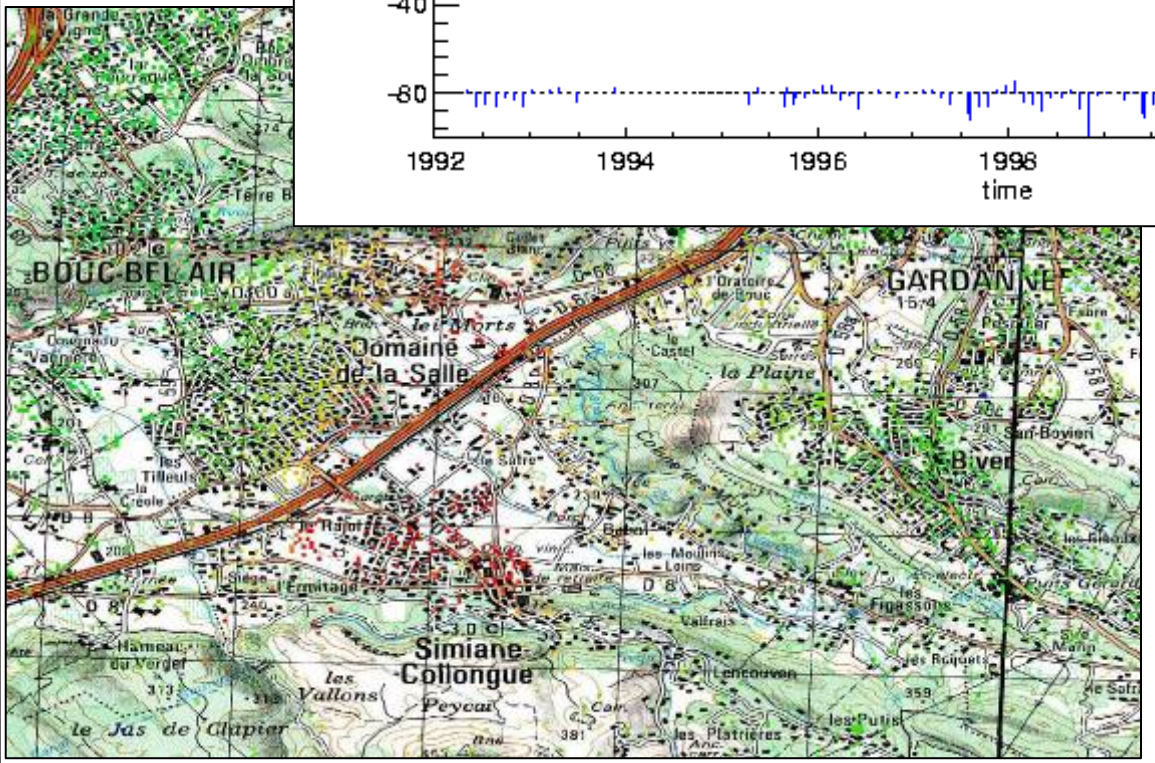
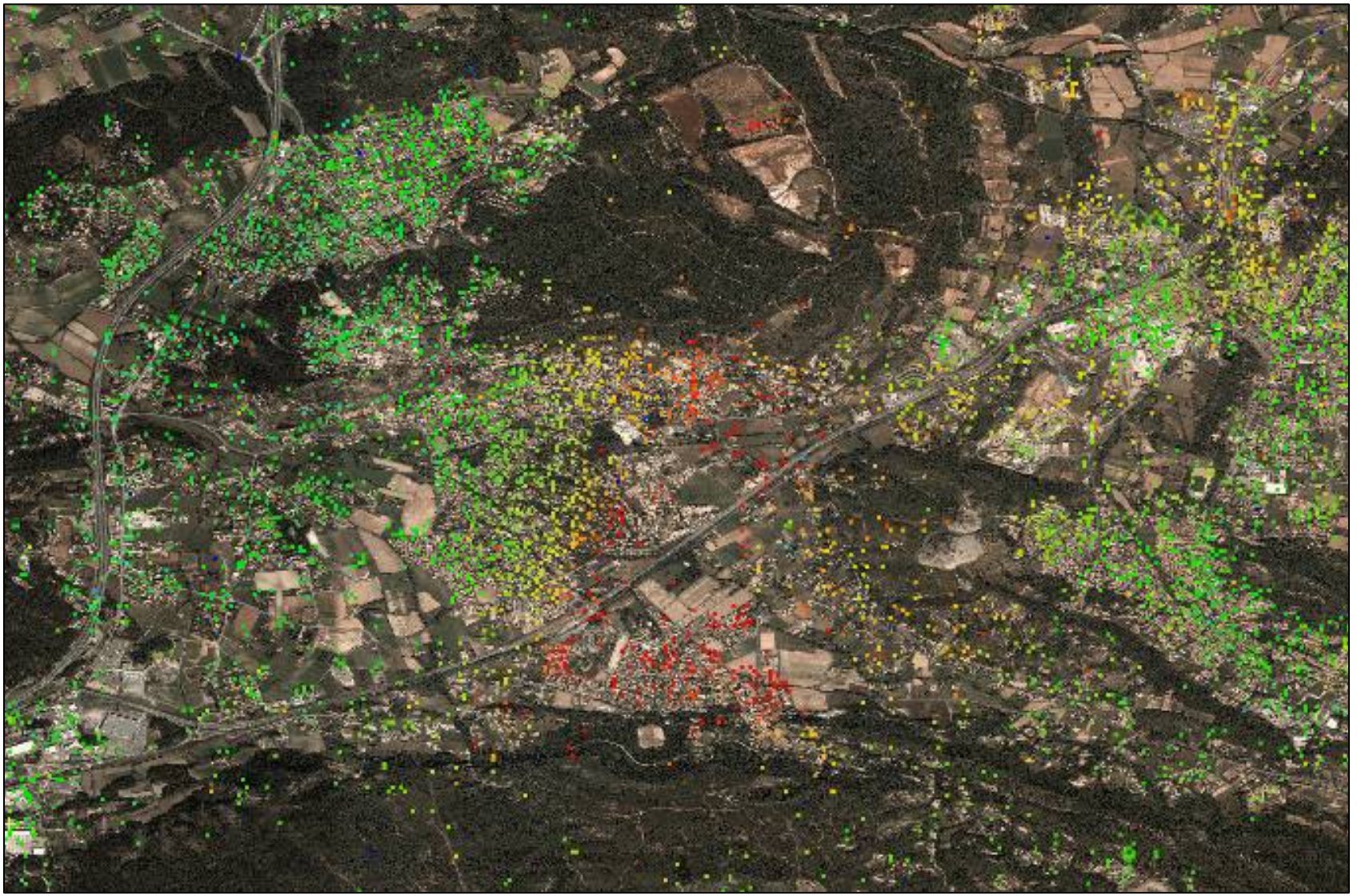
Final Estimation





- **Data corrected for estimated atmospheric signal**

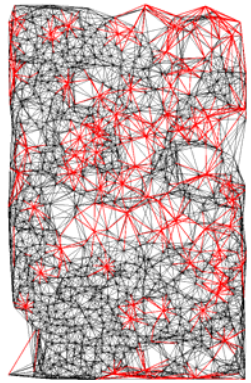
GIS Interface (geoTIFF)

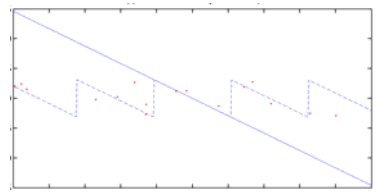


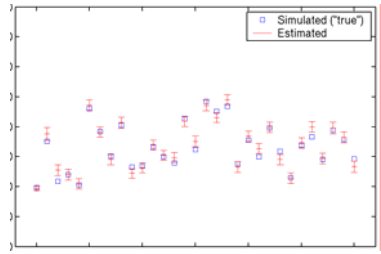
- **Conclusions**

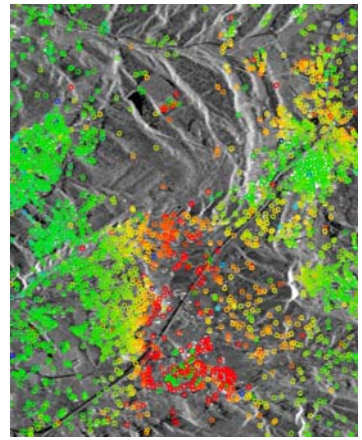
Conclusions

- **STUN = Spatio-Temporal Unwrapping Network**
  - **Integer Least-Squares**
  - **Variance Component Estimation**
  - **Alternative Hypothesis Tests**
- **PSIC4 Processing Report**
  - **Point Selection**
  - **Reference Network**
  - **Unwrapping**
- **Our paper gives more details on theory and displacement models**
- **Visit our Poster:**
  - ***“DLR’s Results of the PSIC4 Study”***









Thank you!