# Determination of mechanical discontinuities at Merapi summit from kinematic GPS

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# Plan

- Introduction
- Deformations modeling
- Methodology: rapid static + kinematic
- First results: Dec. 1999 - March 2000
- Conclusions & perspectives

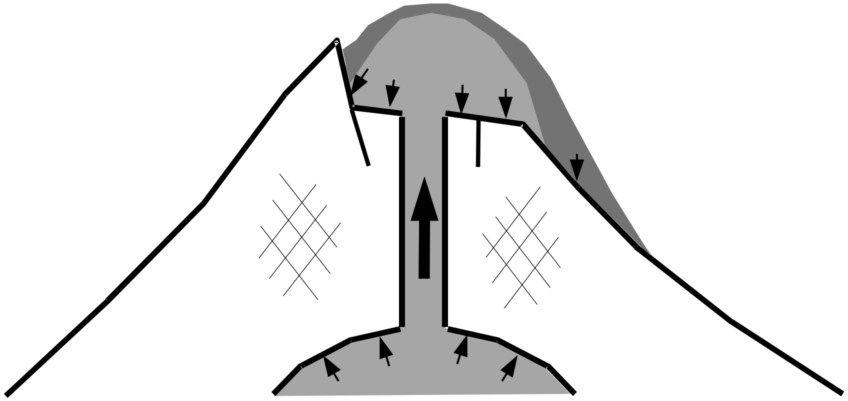
# Introduction

- Eruption:
  - Magnitude?
  - Direction?
- Rock slope problem:
  - Localization?
  - Volume?
- Type of source:
  - Magmatic?
  - Phreatic?

*Prediction = monitoring + interpretative model*

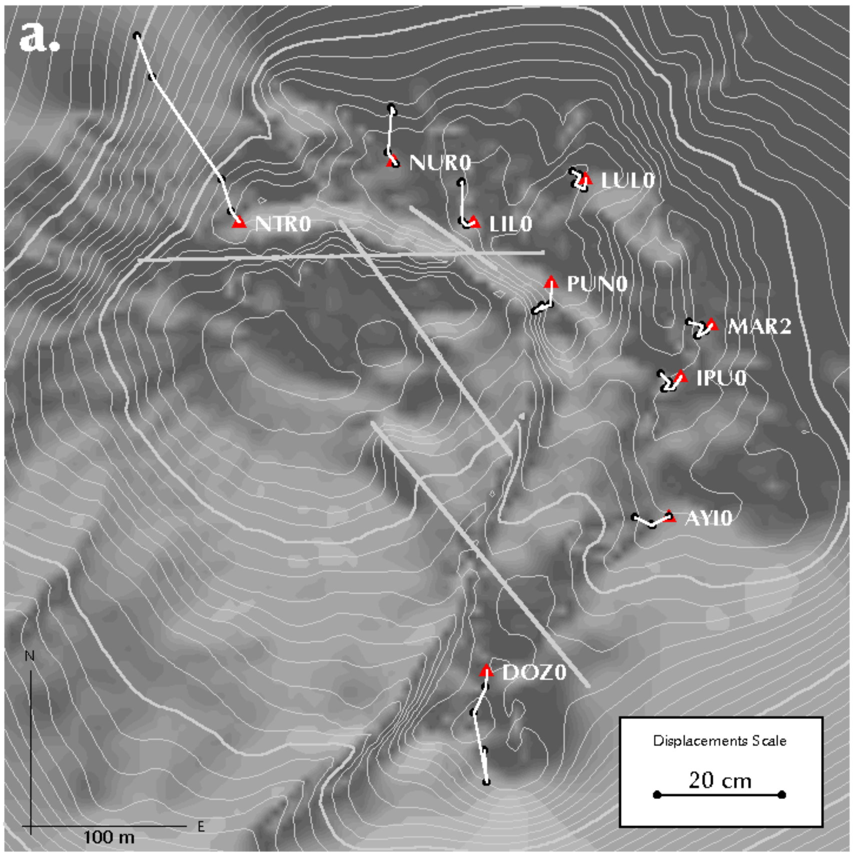
# Deformation modeling (1)

- Fluid transport (magma, gas, water)
- Numerical models need boundary conditions:
  - Internal substructure geometry
  - Source parameters



*Why does a volcano deform?*

# Deformation modeling (2)




[*Beauducel et al.*, JGR, 2000]

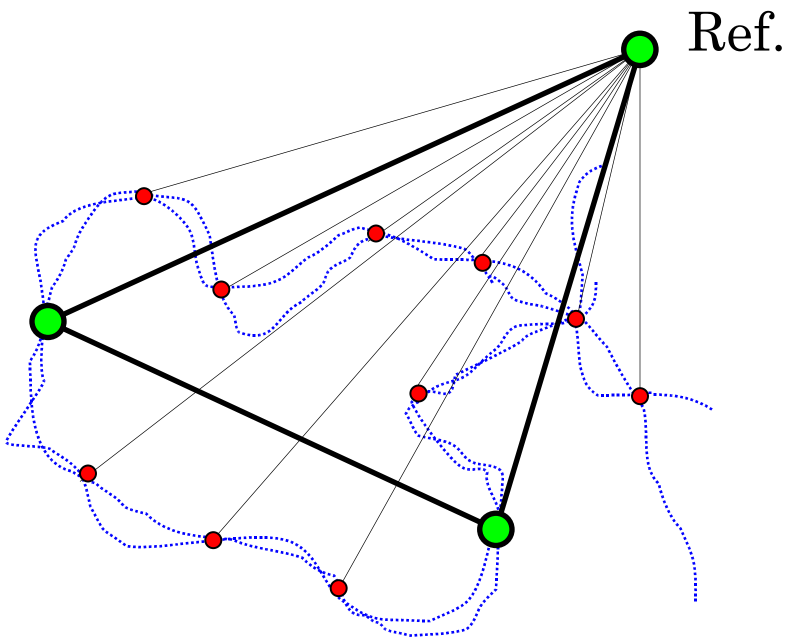
- 3-D mixed boundary elements method:
  - quasi-static elastic
  - discontinuities
- Merapi since 1993:
  - evidence for fractures involvement
  - local not elastic behavior

# Methodology (1)

- Needs for rock slopes monitoring:
  - dense geodetic network
  - brief field campaigns at summit
- Proposed solution:
  - GPS dual-frequency small receivers
  - Very short baselines (< 500 m)
  - Kinematic / rapid static processing
  - Automatic routines for interpretation

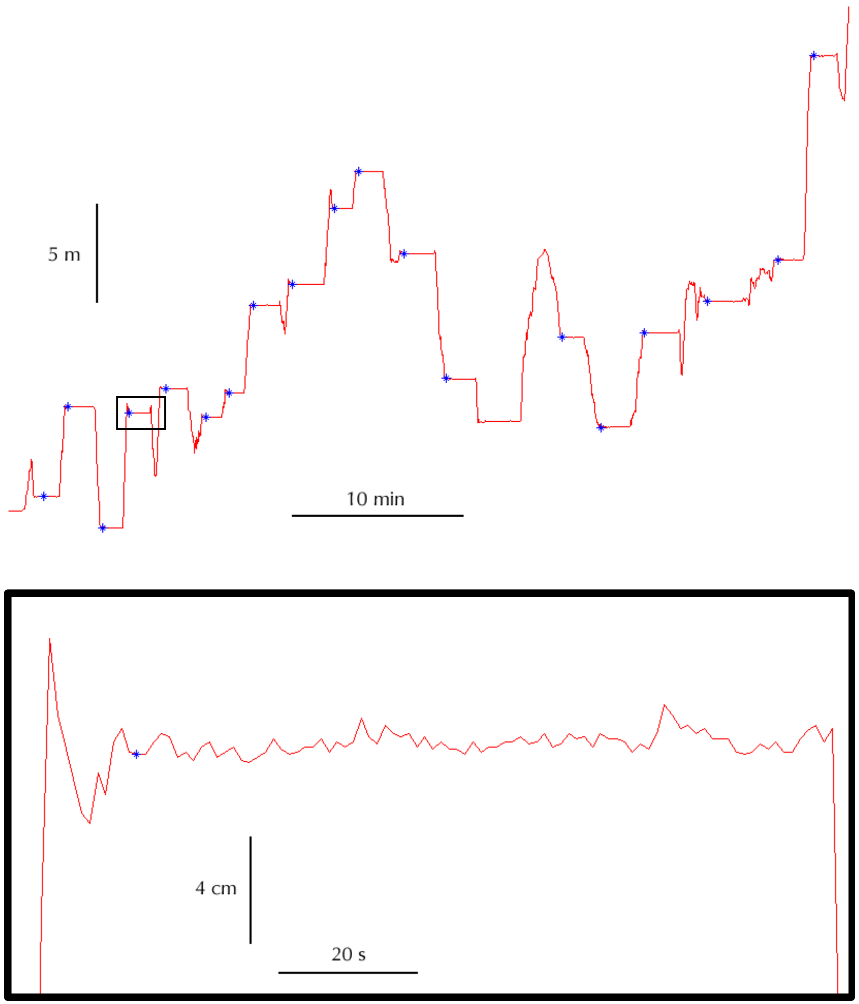
# Methodology (2)

- Kinematic GPS
  - ~ 50 benchmarks
  - 2-min. measur. $\times n$
  - < 5 cm precision
- Rapid Static GPS
  - 7 benchmarks
  - 15-min. measur.
  - < 1 cm precision
- Both 1-s sample rate



# Methodology (3)

- Trajectories:
  - Marks detection
  - Positions extraction (3 components + STD)
  - Automatic naming for new points



# Methodology (4)

- Combination:
  - Rapid static baselines
  - Differential kinematic baselines (from point to point)
- Adjustment:
  - Geocentric referential
  - Least square linear system solving

$$\mathbf{AX} = \mathbf{B} + \mathbf{E}$$

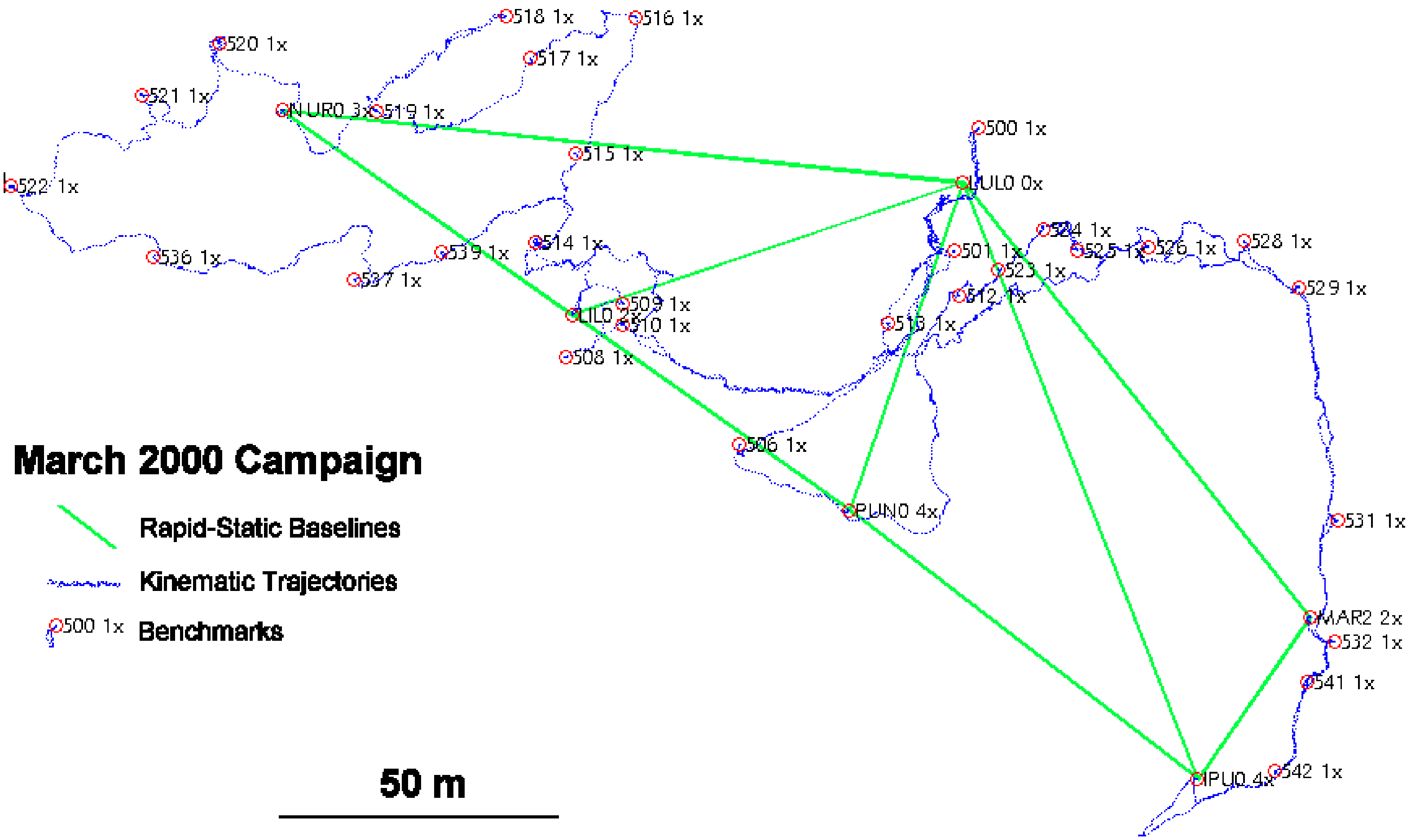
$$\mathbf{X} = (\mathbf{A}^{T}\mathbf{V}^{-1}\mathbf{A}^{T})^{-1}\ \mathbf{A}^{T}\mathbf{V}^{-1}\mathbf{B}$$

$$A = \begin{pmatrix} 1 & 0 & 0 & -1 & \dots \\ 0 & 1 & 0 & 0 & -1 \\ 0 & 0 & 1 & \dots & \dots \\ \dots & \dots & \dots & \dots & \dots \\ \dots & \dots & \dots & \dots & \dots \end{pmatrix} \quad B = \begin{pmatrix} X_{ref} - X_1 \\ Y_{ref} - Y_1 \\ \dots \\ X_{lul} - X_{pun} \\ \dots \end{pmatrix} \quad X = \begin{pmatrix} X_1 \\ Y_1 \\ \dots \\ X_{pun} \\ \dots \end{pmatrix}$$

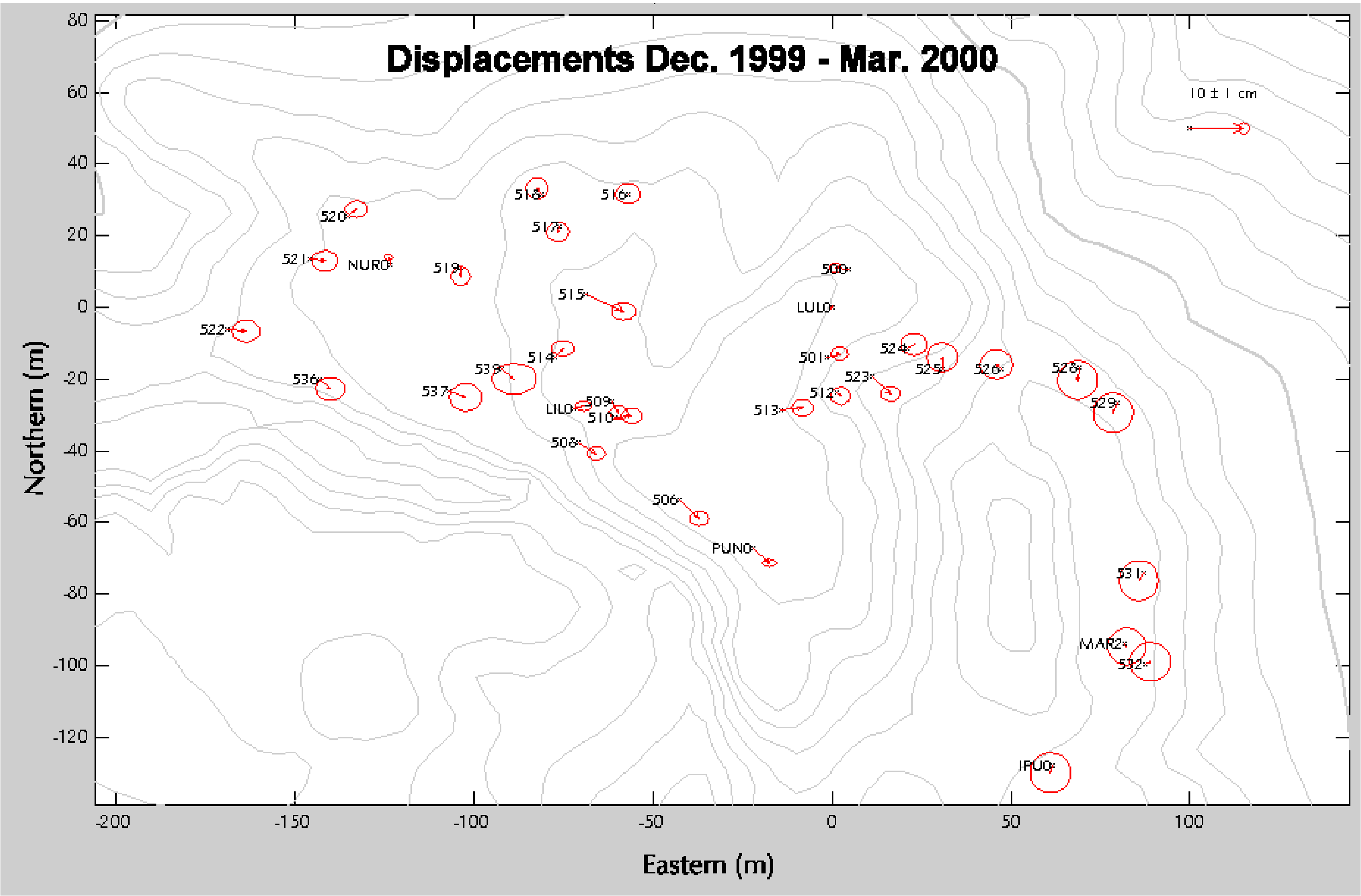
$$V = \begin{pmatrix} \sigma_X^2 & \sigma_{XY} & \sigma_{XZ} & \dots & \dots \\ \dots & \sigma_Y^2 & \sigma_{YZ} & \dots & \dots \\ \dots & \dots & \sigma_Z^2 & \dots & \dots \\ \dots & \dots & \dots & \dots & \dots \end{pmatrix}$$

**A** = partial derivatives
**B** = observations
**V** = covariance matrix
**X** = unknowns

# First results (1)



# First results (2)



# Conclusion & perspectives

- Residues after adjustment < 1.5 cm for the entire network and 3 components
- No significant displacement from Dec. 1999 to March 2000
- Field strategy:
  - $\geq$ 2 trajectories + $\geq$ 3 static baselines
  - Campaigns every 1-2 month (VSI)