Application of TanDEM-X data to volcanic flow hazard assessment: example from Merapi Volcano, Central Java, Indonesia

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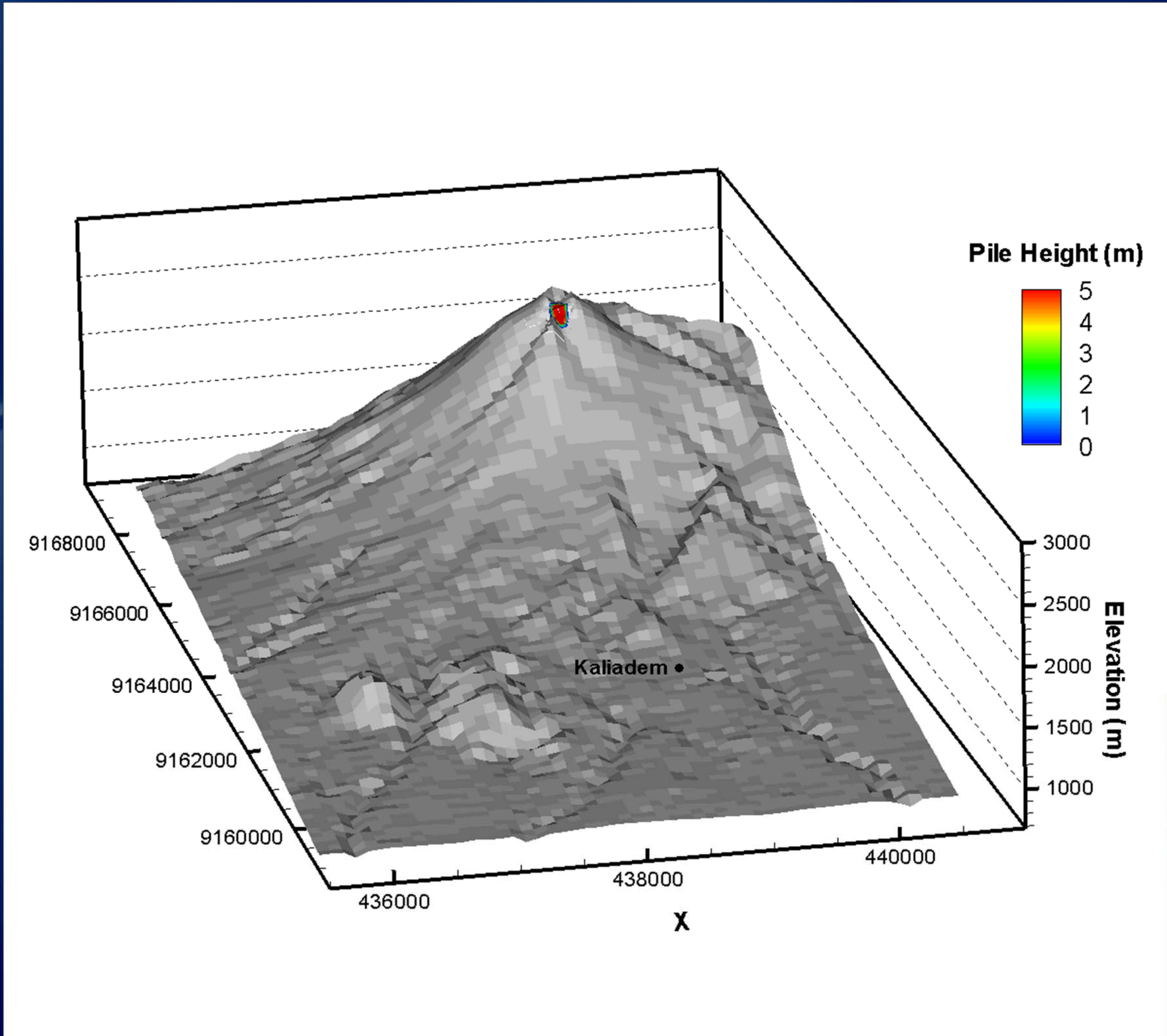
NSF National Science Foundation WHERE DISCOVERIES BEGIN
TANDEM

Motivations

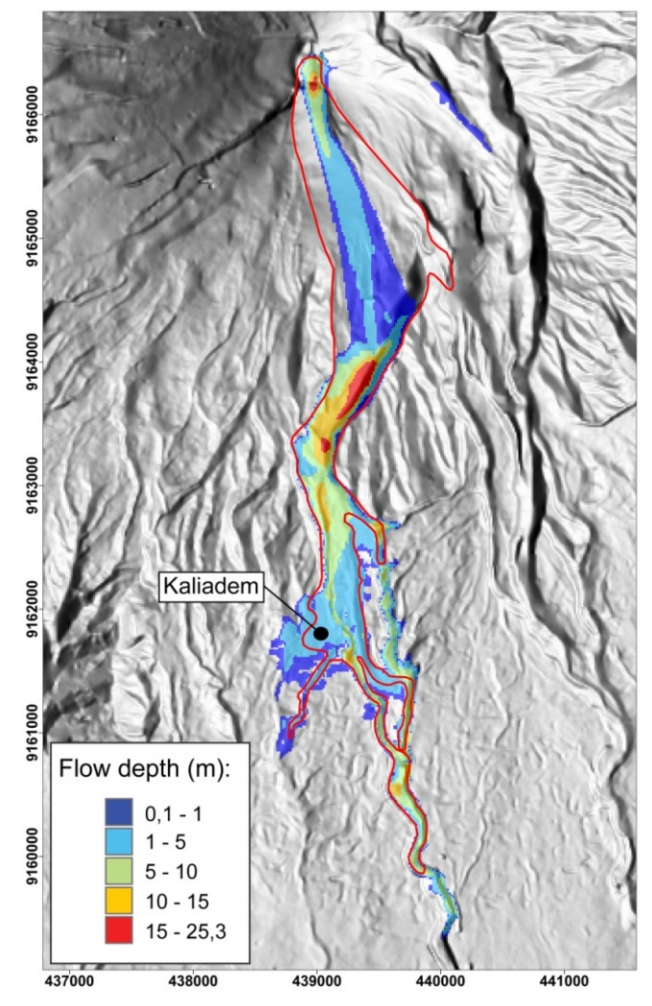
➡ TanDEM-X data can generate accurate numerical topography and/or capture rapid topographic changes associated with the emplacement/removal of volcanic deposits over short periods.

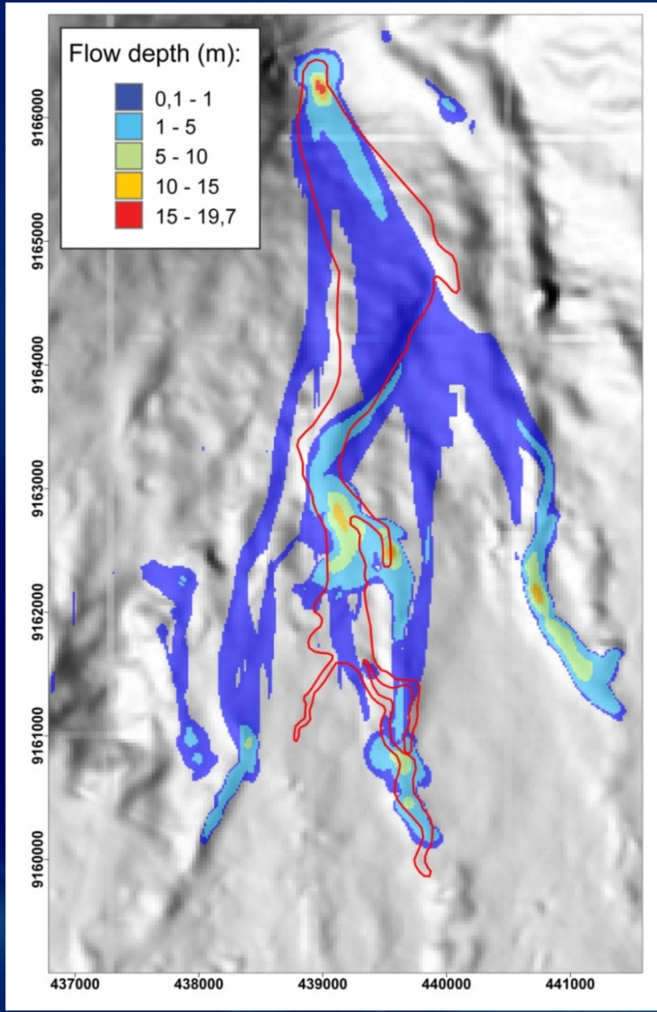
↳ tremendous potential to help us better understand the dynamics of hazardous volcanic flows…
+ define hazard zonations for key areas at risk from future volcanic activity!

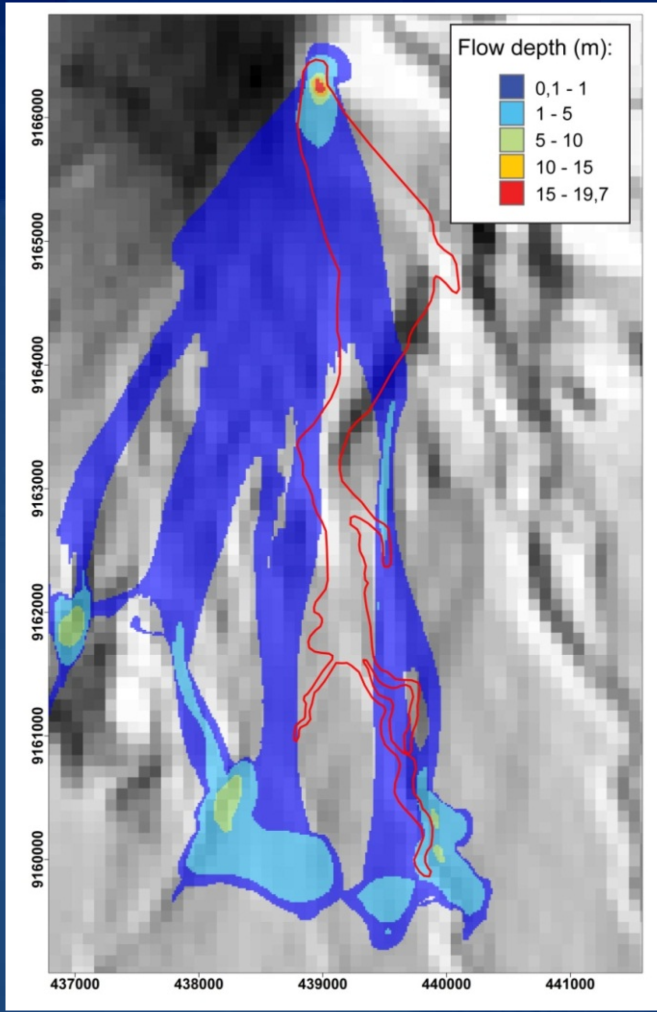
Flow simulation at Merapi volcano



Effects of DEM quality on numerical models







Local DEM

15 m spatial resolution
± 9 m vertical accuracy

ASTER GDEM

~30 m spatial resolution
± 11 m vertical accuracy

SRTM WRS-2

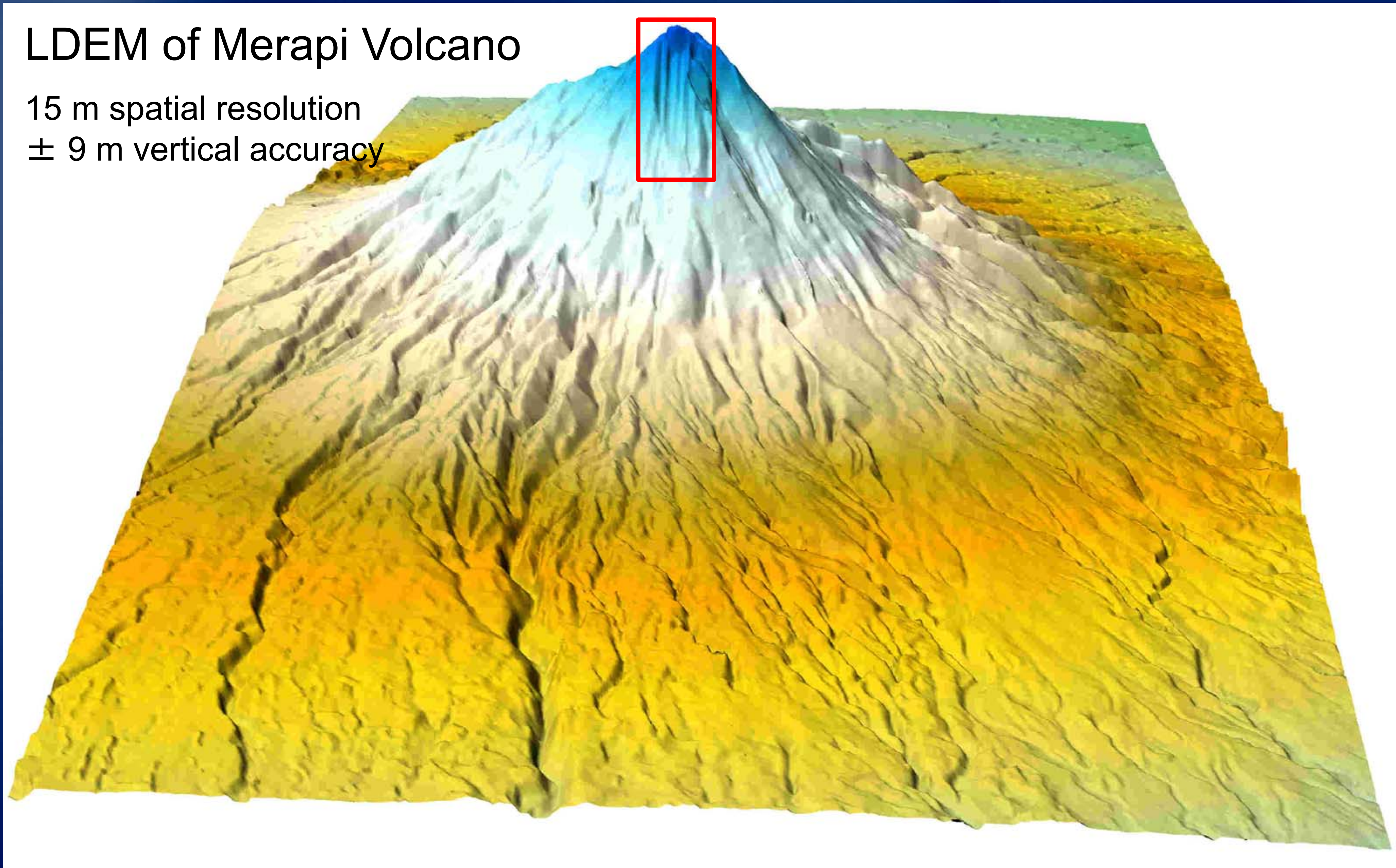
90 m spatial resolution
± 10 m vertical accuracy

Flow coverage match: **72.3%**

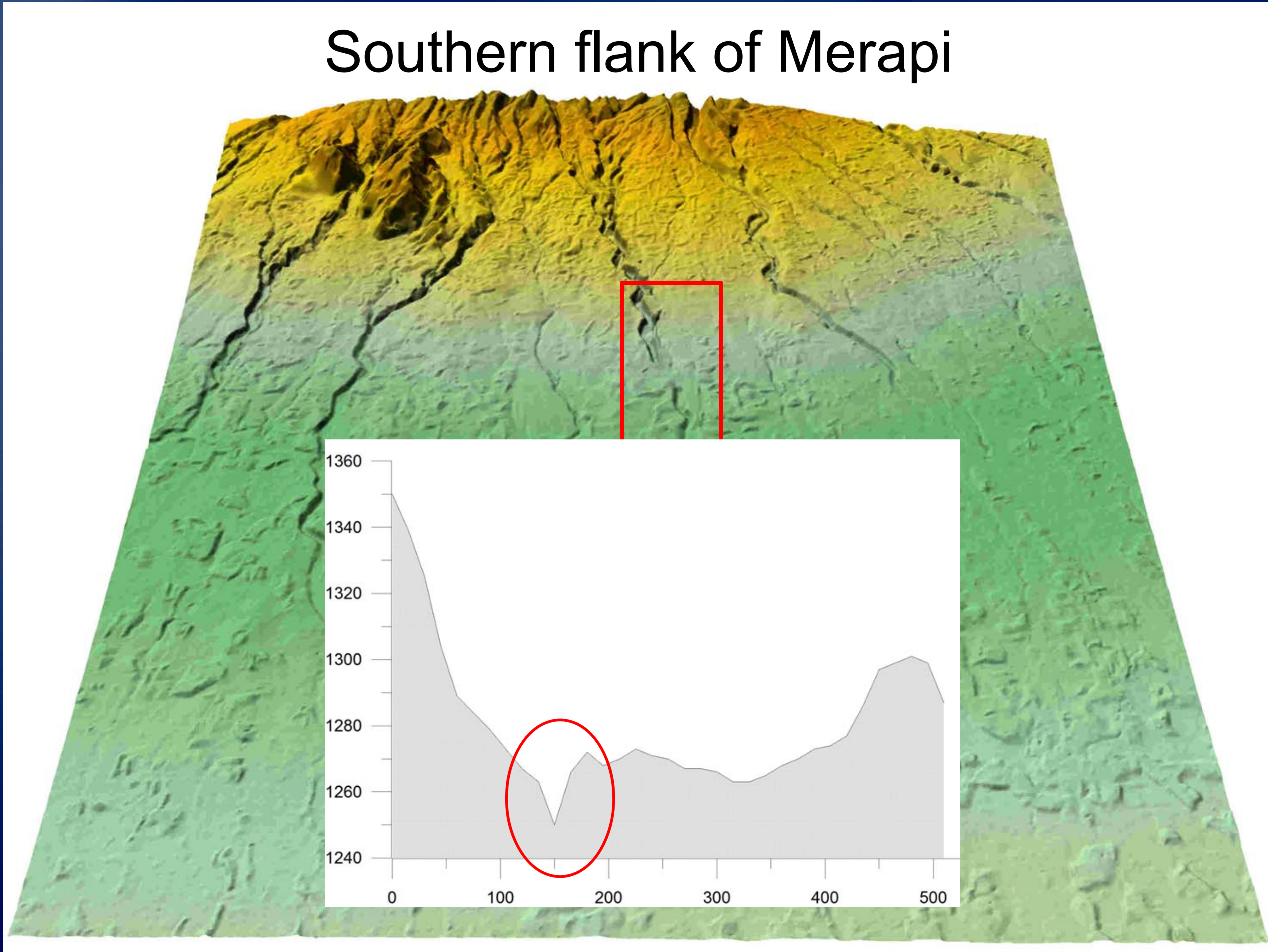
Flow coverage match: **25.6%**

Flow coverage match: **7%**

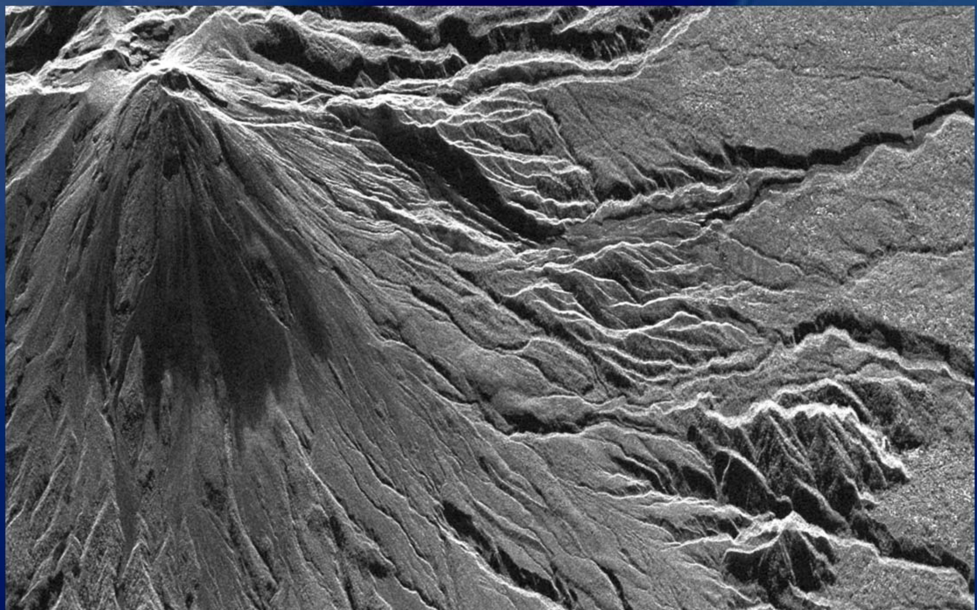
Current DEM errors and anomalies



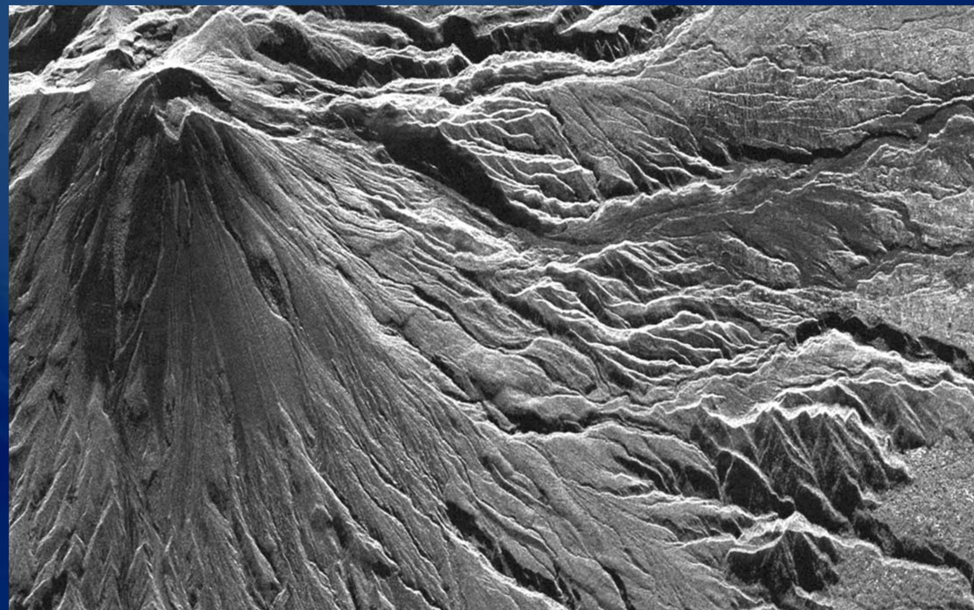
Current DEM errors and anomalies



Merapi Volcano (Indonesia)

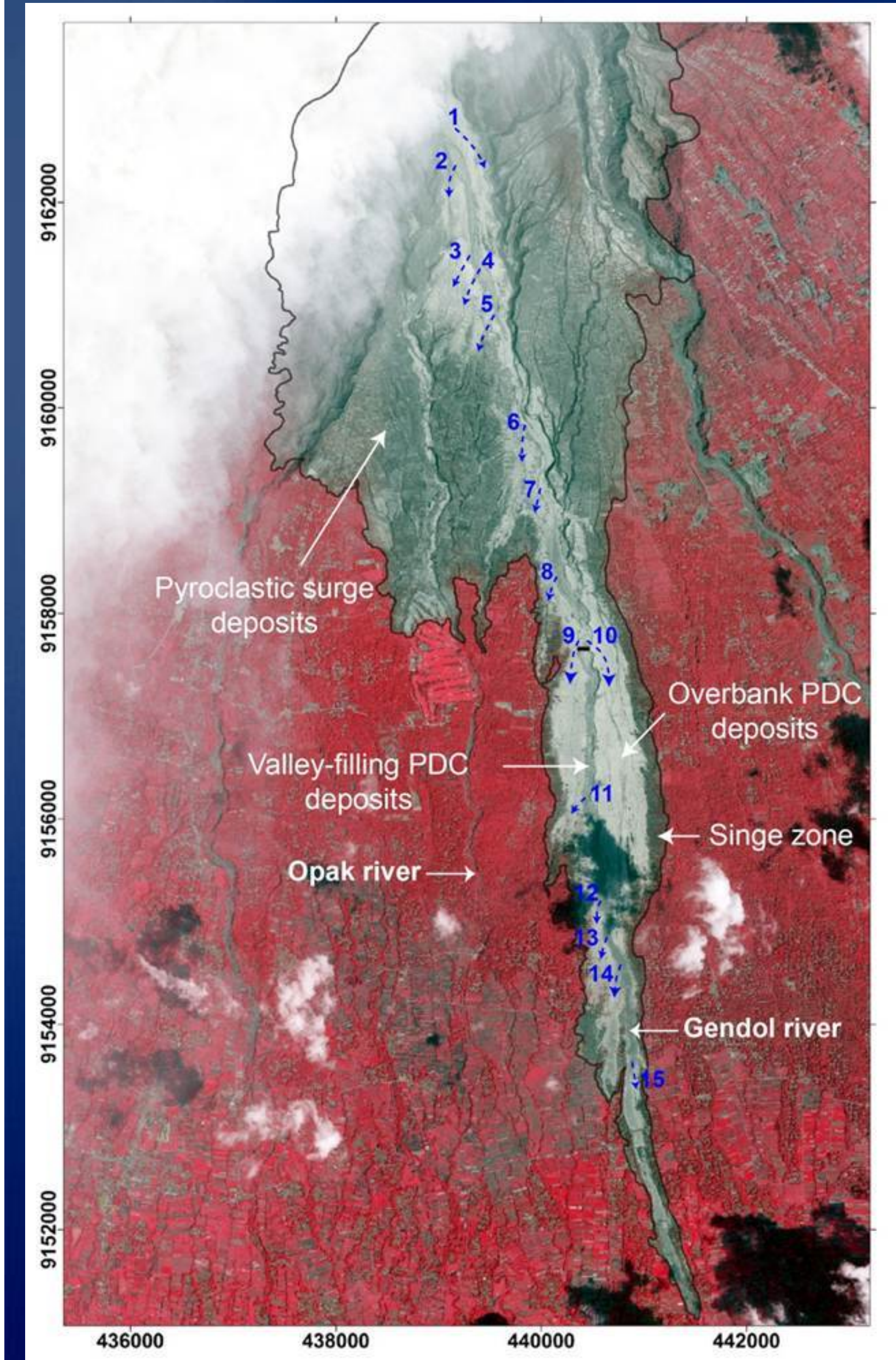


26 Oct. 2010



6 Nov. 2010

Areas and Volumes of the 2010 PDCs



Eruptive phase	Flow type	Area (m²)	Volume (m³)	$A/V^{2/3}$	A/L^2
Phase 1	Channeled Gendol	486200	3889600	19.7	0.0085
	Overbank, PDC overspill	388700	1554900	29.0	0.1
	Surges	5 922 600	592 250	839.8	0.191
Phase 2	Channeled & overbank	600 900	4 206 300	23.1	0.0065
Phase 3	Channeled Opak	226 200	678 600	29.3	0.003
	Channeled Gendol	1 307 000	8 873 500	30.5	0.005
	Surges	16 016 300	3 203 300	737.0	0.21
	Overbank 1, re-channeled	693 400	2 773 550	35.1	0.12
	Overbank 2, re-channeled	671 700	2 149 550	40.3	0.18
	Overbank 3, PDC-overspill	143 000	143 000	52.3	-
	Overbank 4, re-channeled	33 100	99 400	15.4	0.03
	Overbank 5, re-channeled	83 600	250 800	21.0	0.045
	Overbank 6, re-channeled	303 300	909 900	32.3	0.077
	Overbank 7, PDC-overspill	340 400	680 800	43.9	-
	Overbank 8, re-channeled	80 850	242 600	20.8	0.083
	Overbank 9, PDC-overspill	382 000	1 222 400	33.4	-
	Overbank 10, PDC-overspill	990 800	1 981 550	62.8	-
	Overbank 11, re-channeled	91 550	247 650	21.7	0.272
	Overbank 12, re-channeled	209 700	629 100	28.6	0.14
	Overbank 13, re-channeled	117 400	352 200	23.5	0.226
	Overbank 14, re-channeled	159 300	796 610	18.5	0.096
	Overbank 15, PDC-overspill	92 000	184 000	28.4	-
Phase 4	Channeled	336 500	336 500	69.5	0.0095
	Total channeled	**1 533 300**	**18 233 200**		
	Total overbank	**4 780 900**	**14 245 000**		
	Total surges	**16 016 300**	**3 795 500**		
	Total	**22 330 500**	**36 273 700**		

Objectives

Generation of up to date high-resolution DEMs of Merapi :

- existing TanDEM-X acquisitions taken during the 1st global coverage before and after the 2010 eruption

➡ testing and validation of the benchmark TanDEMs + sensitivity of standard volcanic flow models to various qualities of numerical topographies

➡ calculation of the volumes + progressive erosion of the 2010 deposits and geometry of the drainage system on the southern flank → potential for lahar generation (coll. SEDIMER project)

↳ demonstrate the utility of TanDEM data products for volcanic flow hazard assessment

Selected Acquisitions

	15/10/2010	03/09/2011	24/10/2011
Mode	Stripmap	Stripmap	Stripmap
Orbit	Descending	Ascending	Descending
Eff. Baseline	162.5 m	115.1 m	76.1 m
Height of Ambiguity	36.4 m	37.8 m	79.1 m
Incidence Angle	37.1°	28.8°	37.3°
Polarization	HH/HH	HH/HH	HH/HH
Average coherence	0.68	0.69	0.79

Methodology

- Data processing using open-source ADORE-DORIS package

http://code.google.com/p/adore-doris/

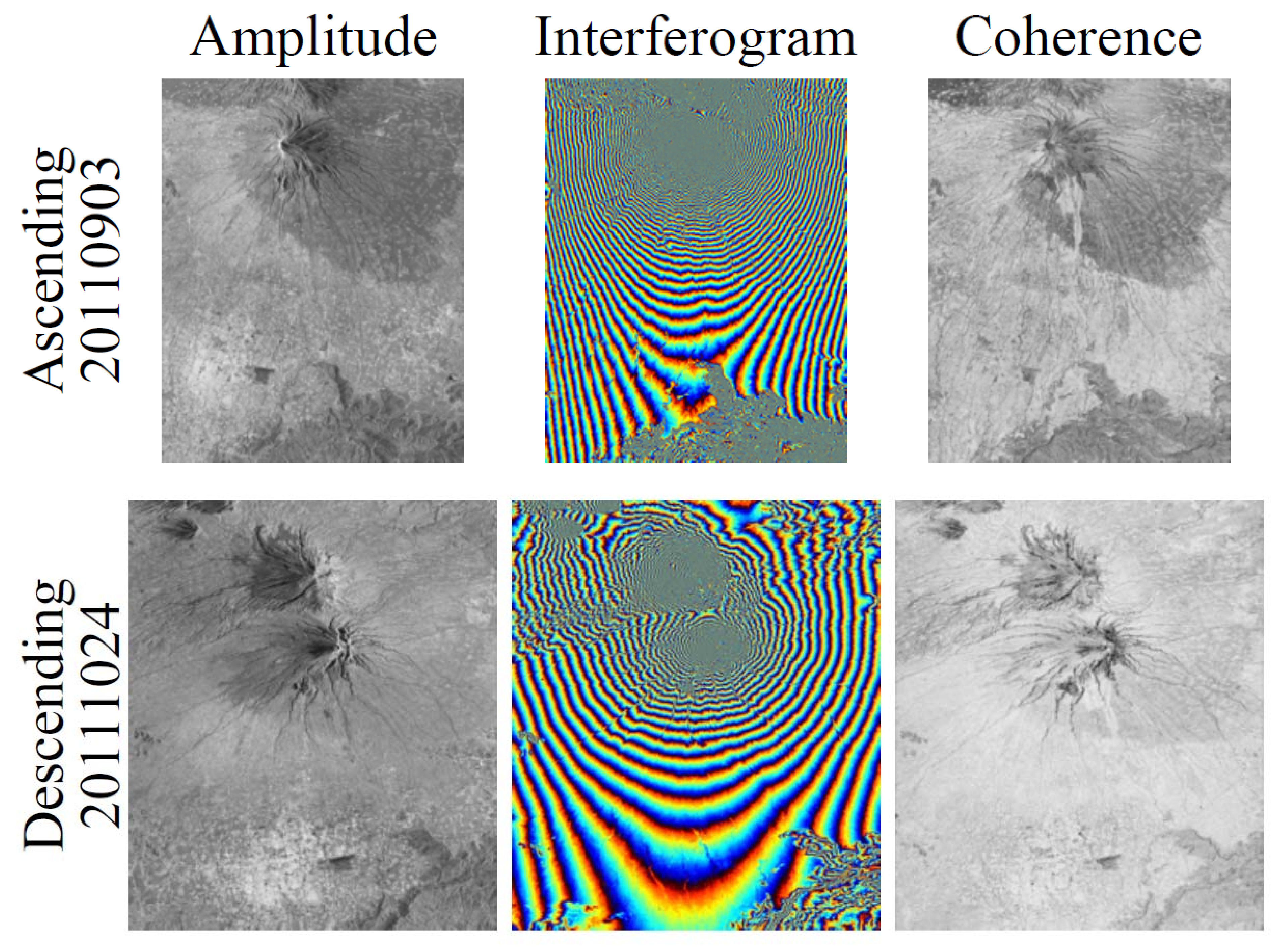
✓ Main Goals:

- Generate high-quality interferograms with ease
- Generate single-master-stack or short-baselines stack interferograms with ease
- Streamline (speed-up) setting-up DORIS input parameters

✓ Current Features:

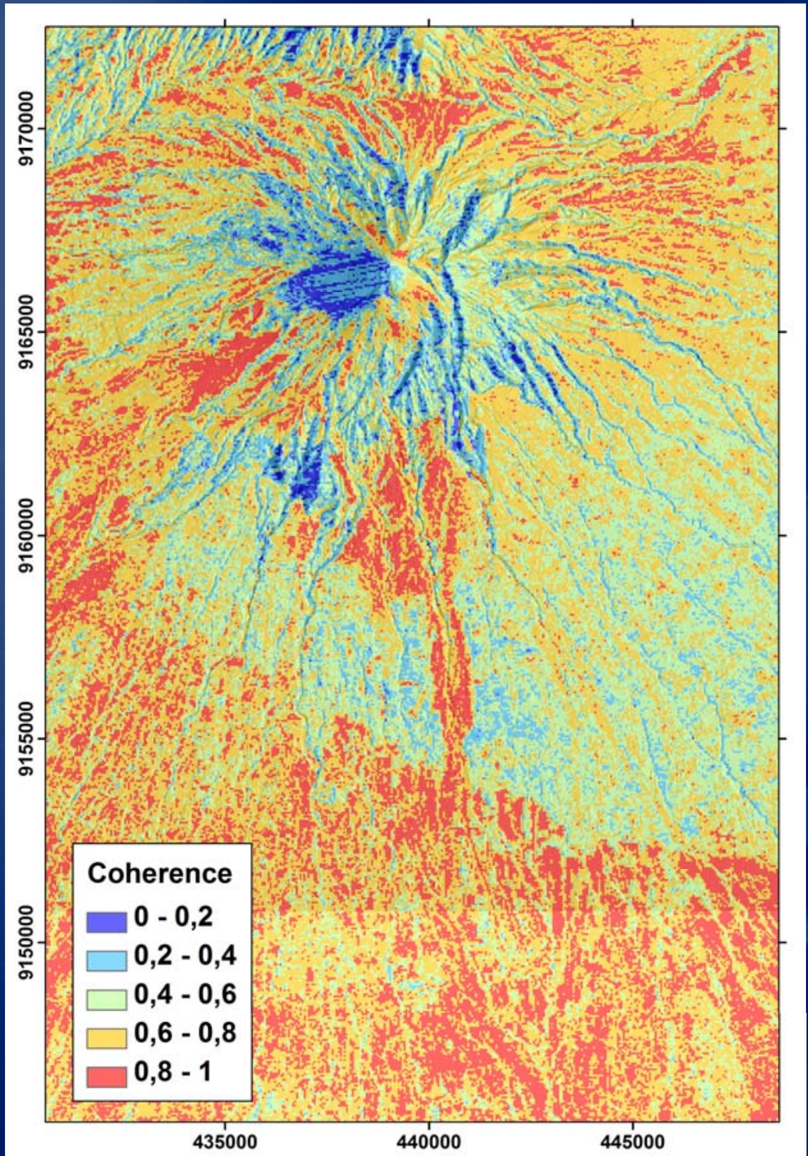
- Automatic generation of DORIS input files with default parameters
- Interactive mode to quickly generate interferograms
- A method to save/load/edit to easily modify project settings
- Interface for cpxfiddle (to generate raster images)
- Interface to check project status
- Interface to generate SRTM DEM
- Interface to load ArcGIS stitched DEM
- Export DORIS results to Envi, ArcGIS
- Script to load DORIS results into Python environment…

Results

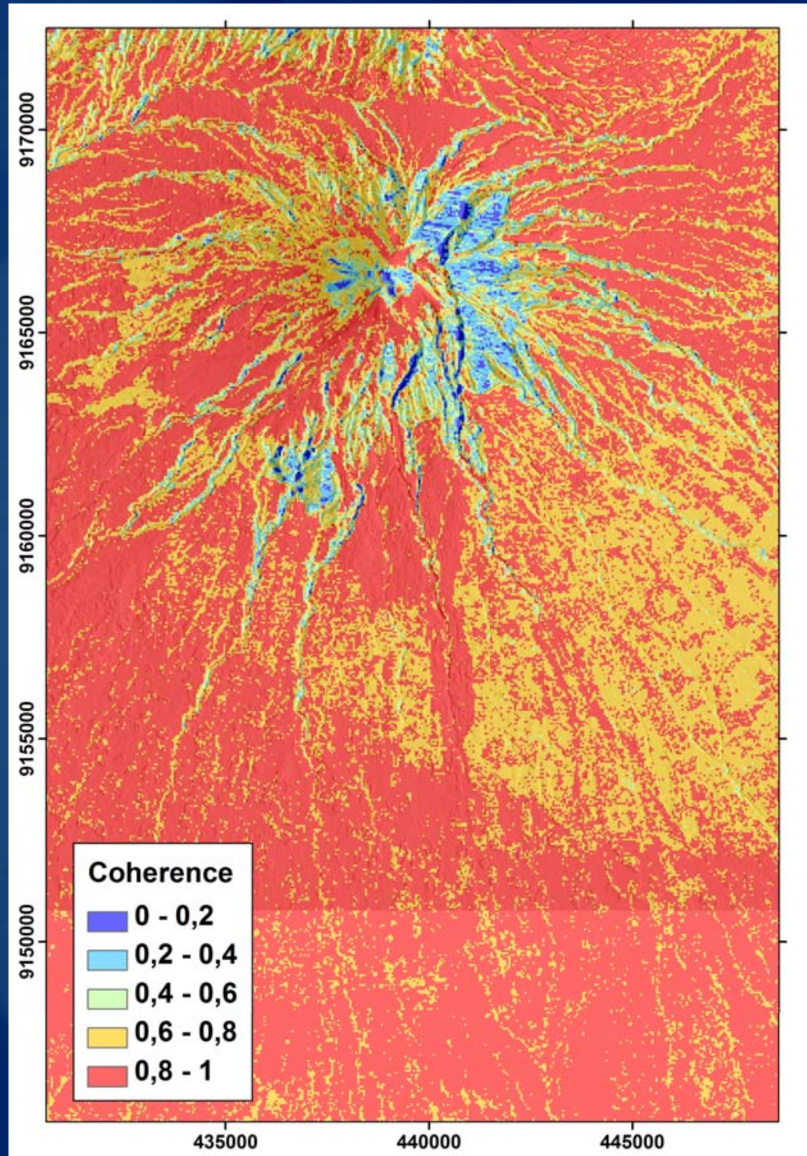

Amplitude
Interferogram
Coherence
Ascending
20110903
Descending
20111024

Results: Coherence

Ascending 03/09/2011

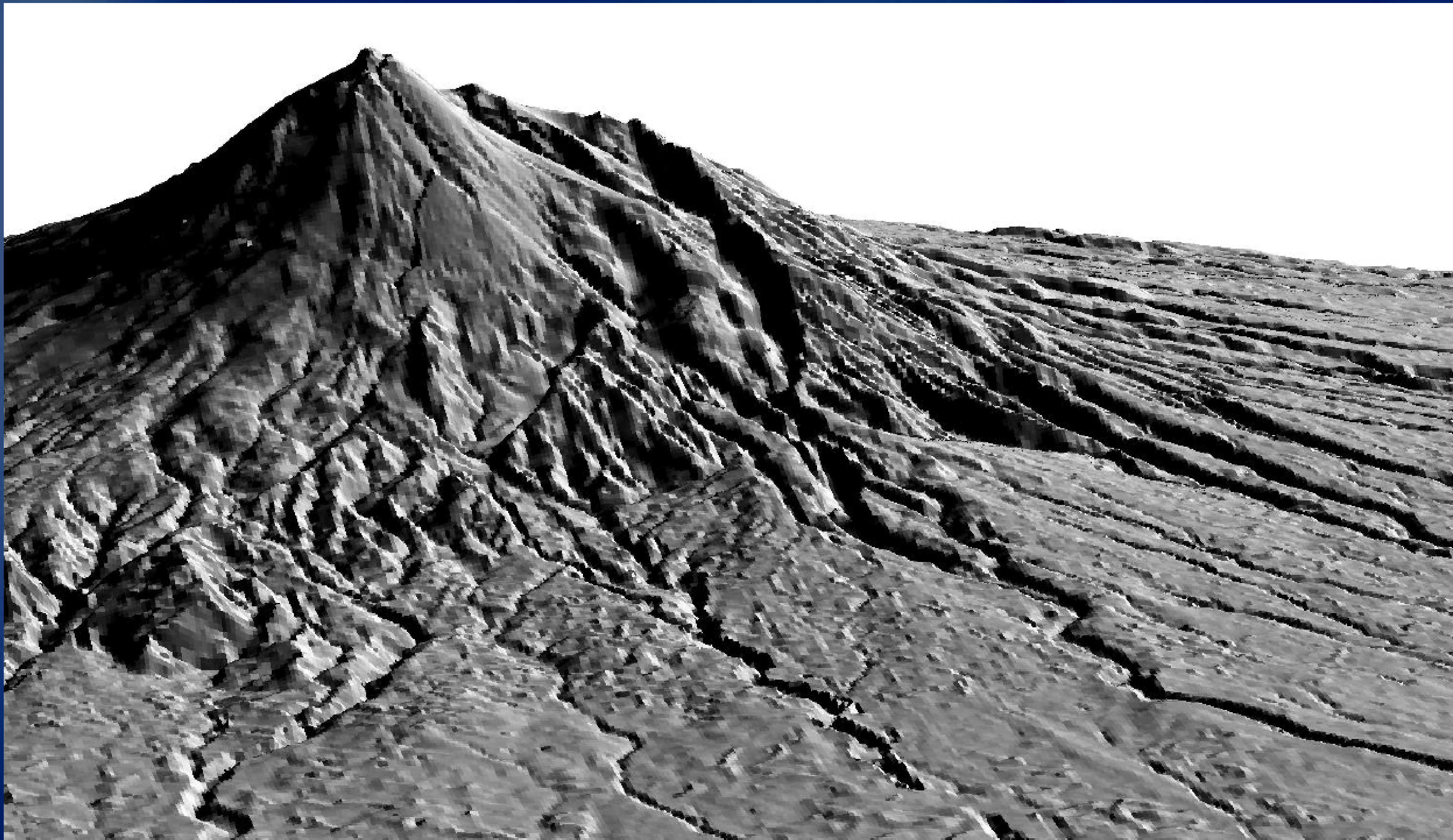


Descending 10/24/2011



- Descending data more coherent than ascending data…
- Loss of coherence in steep and highly vegetated terrains → layover and shadow areas in interferograms → phase unwrapping errors

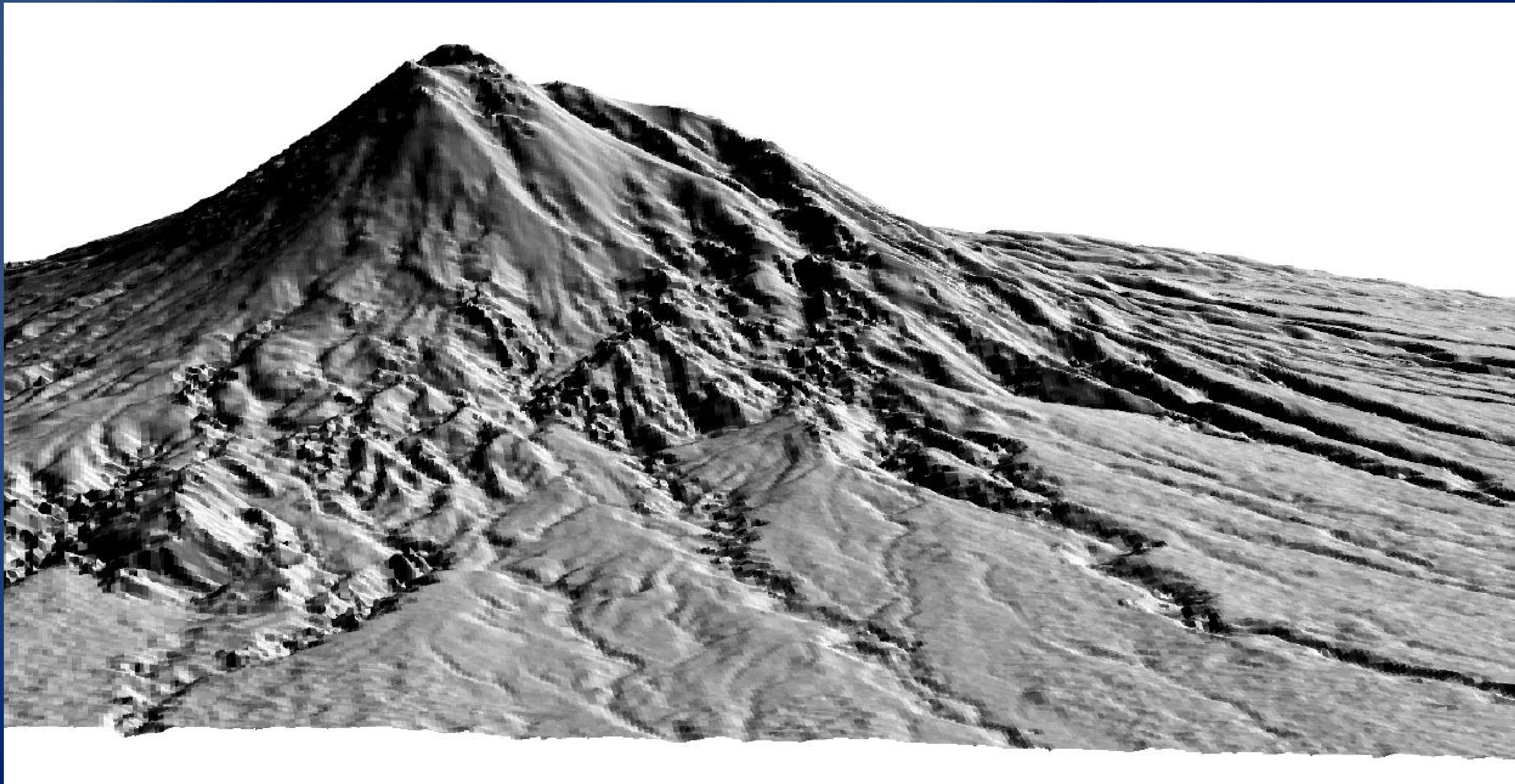
Results: Pre-eruption DEM (reference)



Photogrammetry DEM (1982) 15 m spatial resolution

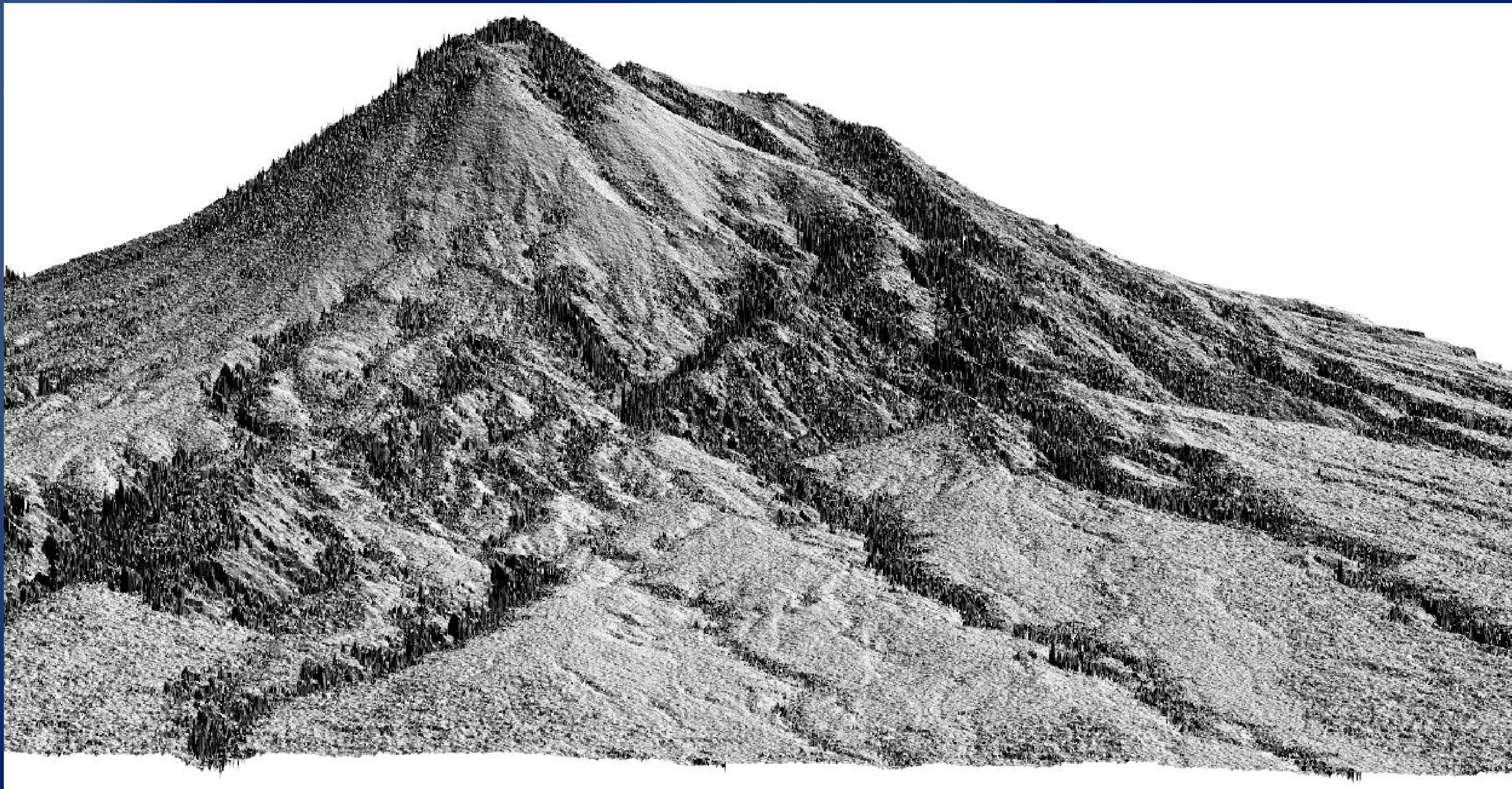
Gerstenecker et al., NHESS, 2005

Results: Post-eruption multi-looked TanDEM



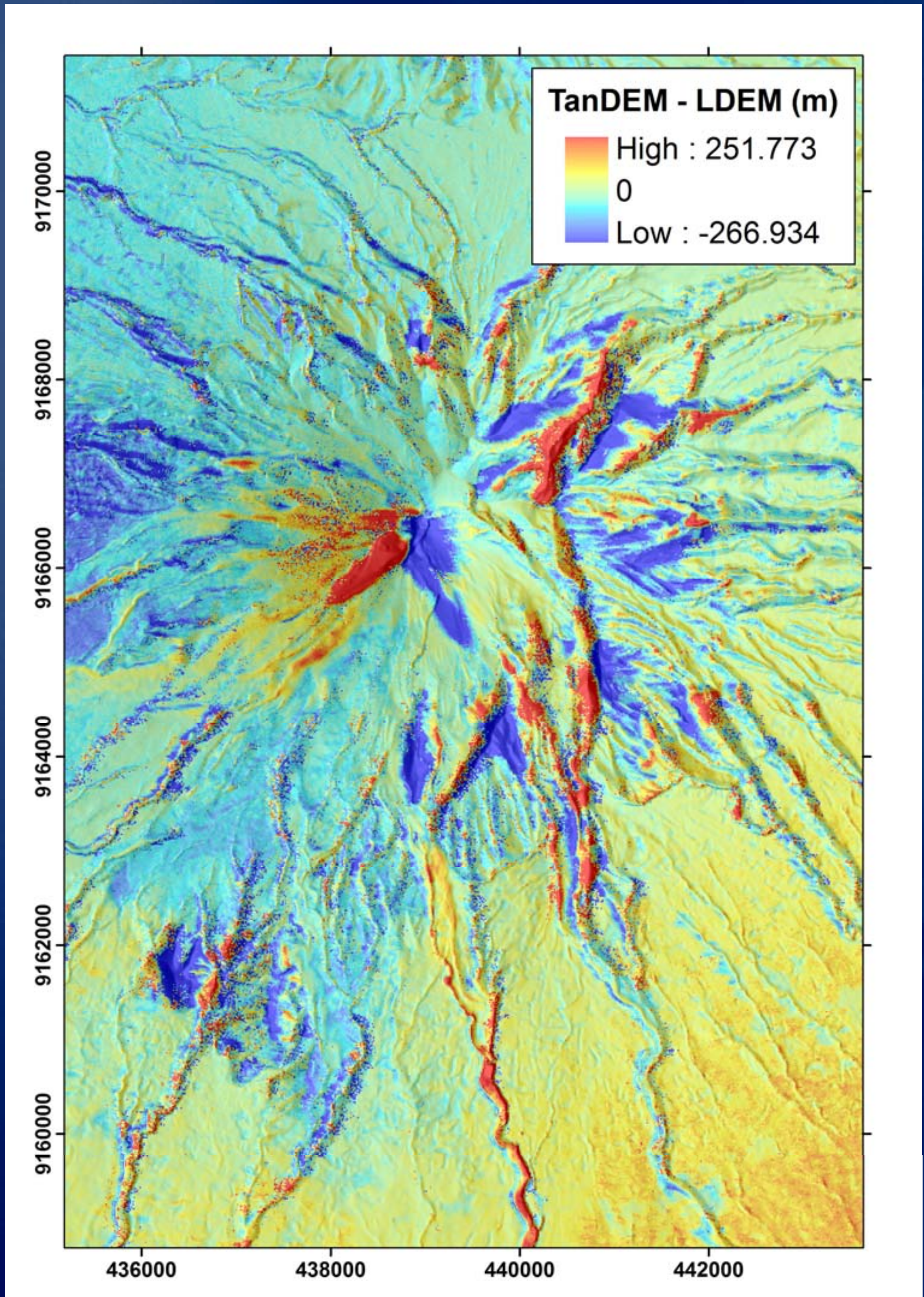
TanDEM-X DEM 20 m spatial resolution
(descending 24/10/2011)

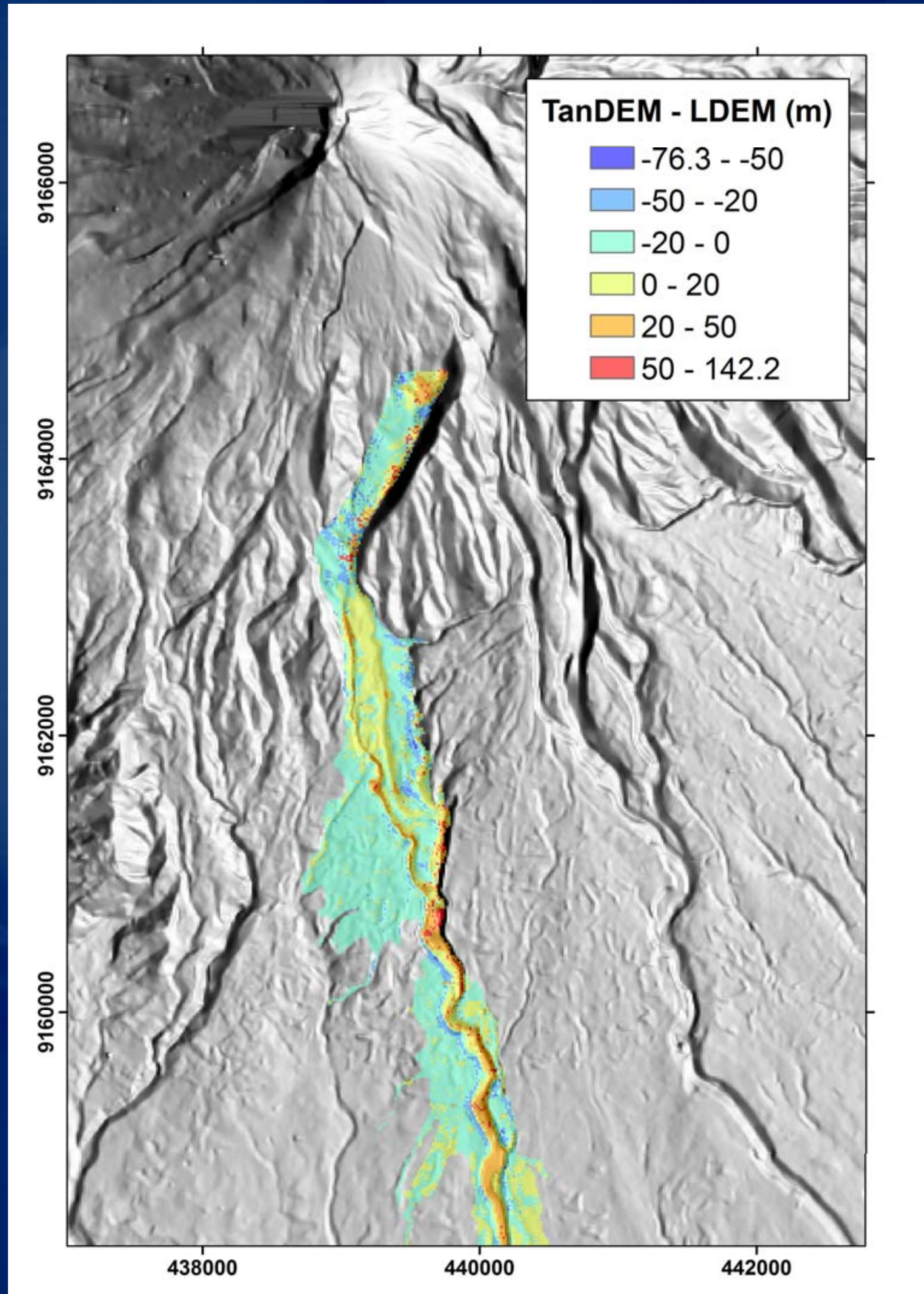
Results: Post-eruption native TanDEM



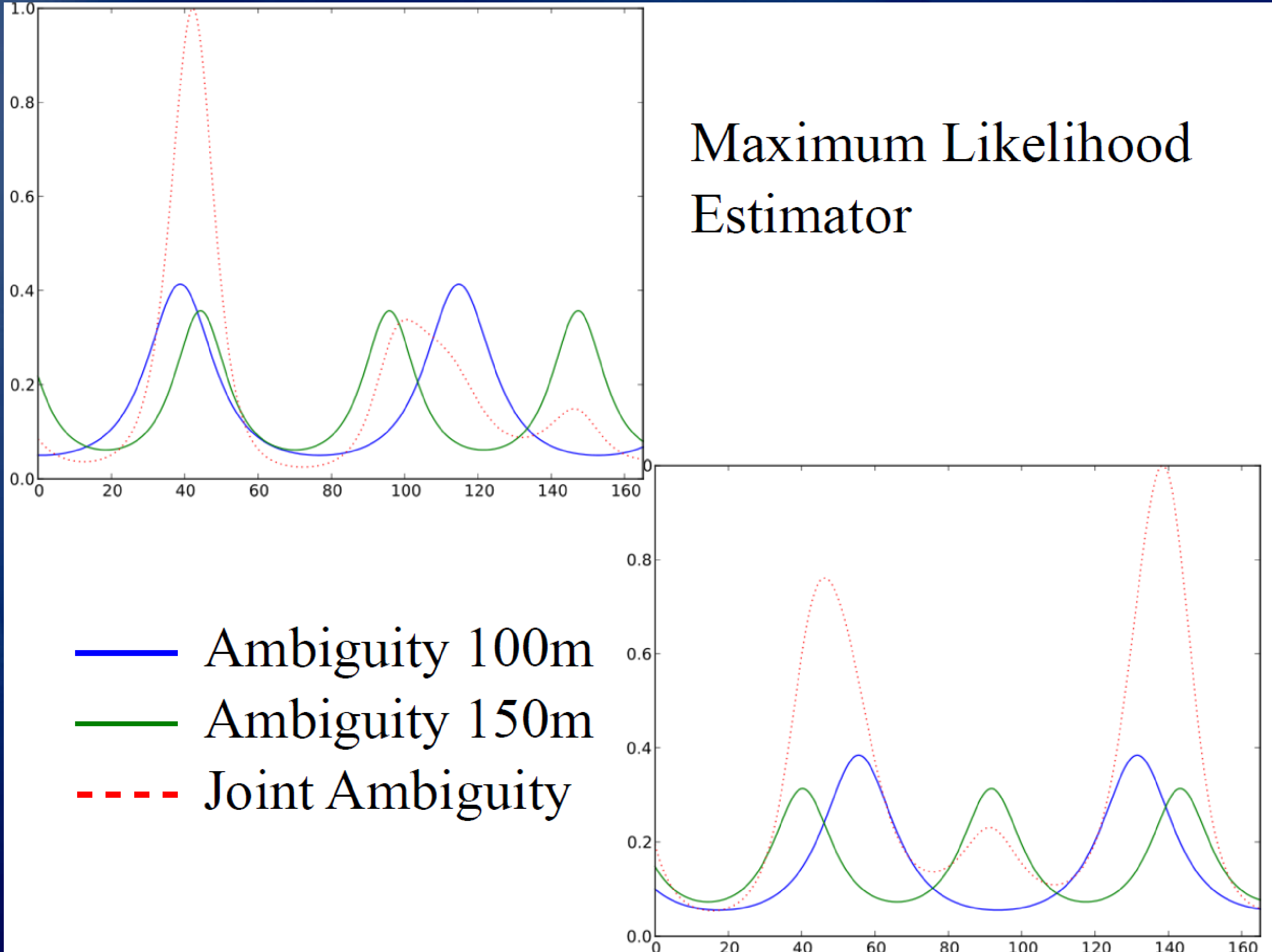
TanDEM-X DEM 3 m spatial resolution
(descending 24/10/2011)

Results: TanDEM - LDEM

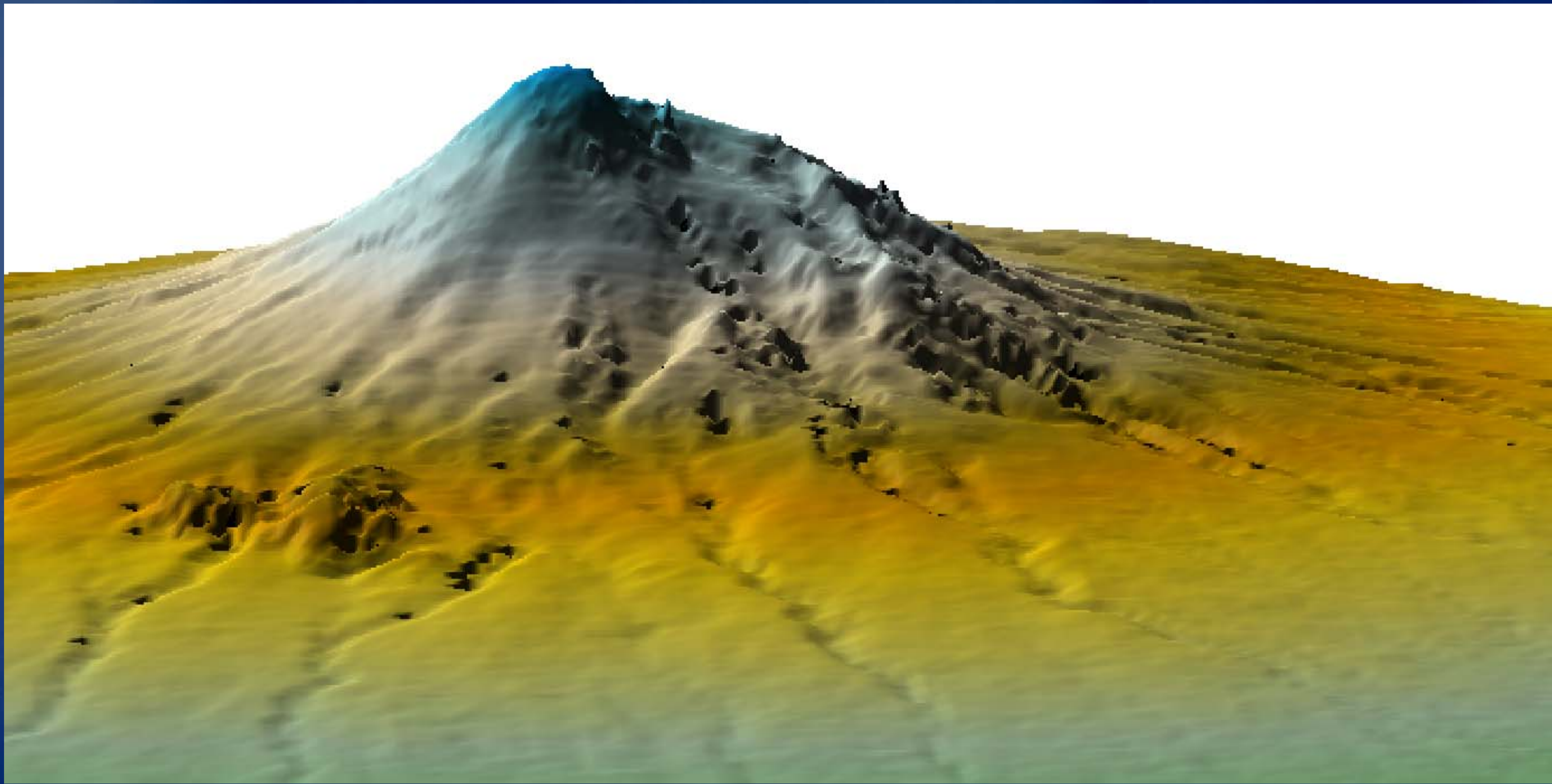




Towards a combined TanDEM…



Towards a combined TanDEM…



Combined MLE TanDEM at 50 m spatial resolution:

- Better estimation of the topography in low valley gradients… but unwrapping errors are still present in steep slopes!

Preliminary conclusions

Application of TanDEM-X data for volcanic flow hazard assessment is possible but challenging:

- Bistastic and CoSSC data format and processing issues… but now we can (almost) deal with it!
- Phase unwrapping at volcanoes are problematic due to: high fringe rate, large radar shadows at the summit (on steep terrains) and inside valleys
- Combining ascending and descending interferograms to improve coverage becomes difficult due to unwrapping errors...

⤷ Use different radar geometries with larger baselines?

⤷ Use radargrammetry and dual baseline PU correction?


Questions?