

TanDEM-X data for early mapping and volume estimation of lava flows:

October 2010 Lava flow of Piton de la Fournaise case study

MG Bato

JL Froger, AJL Harris, N Villanueva, T Souriot

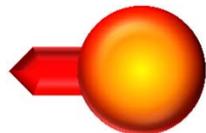
Photo credits: J. Balleydier

5th TerraSAR-X / 4th Tandem-X Science Meeting

10-14 June 2013

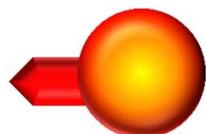
DLR, Germany





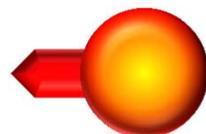
Imaging the Piton de la Fournaise Eruption Through InSAR

- ... The Piton de la Fournaise
- ... InSAR Volcano Monitoring in Piton de la Fournaise
- ... The October 2010 Eruption with TerraSAR-X



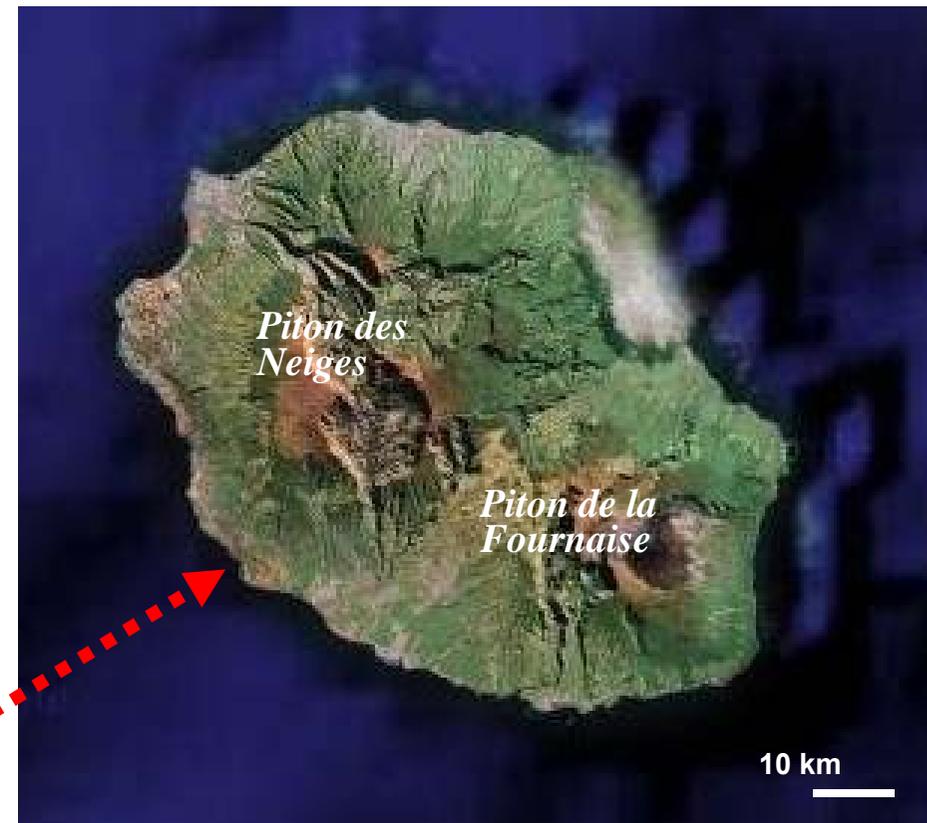
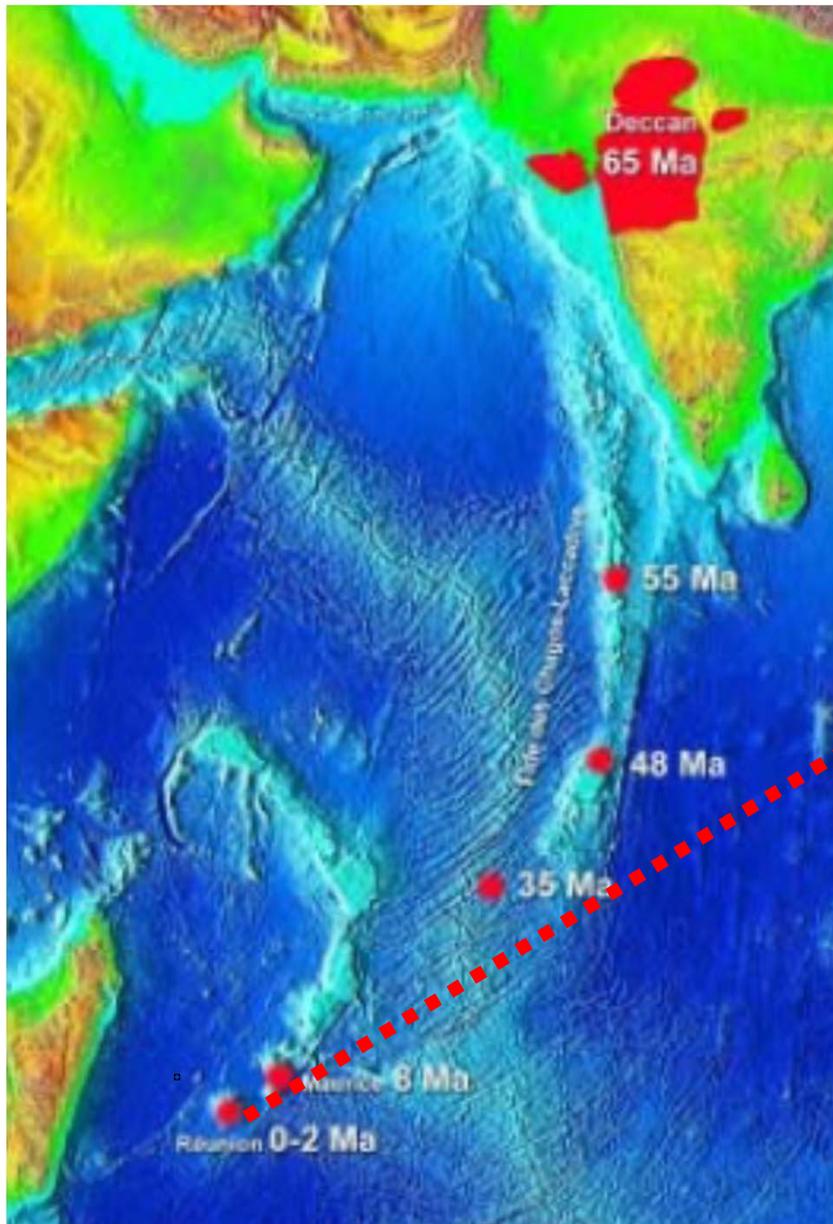
Characterizing the October 2010 Lava Flow using **Cosmo-SkyMed** Data

- ... Image Extraction
- ... Phase Unwrapping
- ... Detrending
- ... The Inversion Model
- ... Conclusion



Characterizing the October 2010 Lava Flow using **Tandem-X** Data

- ... Results
- ... Conclusion

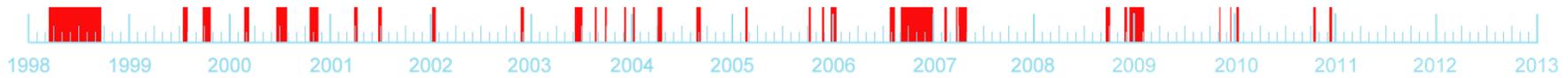


Reunion Island

700 – 800 km east of Madagascar

Deep mantle and constructive plate volcanism

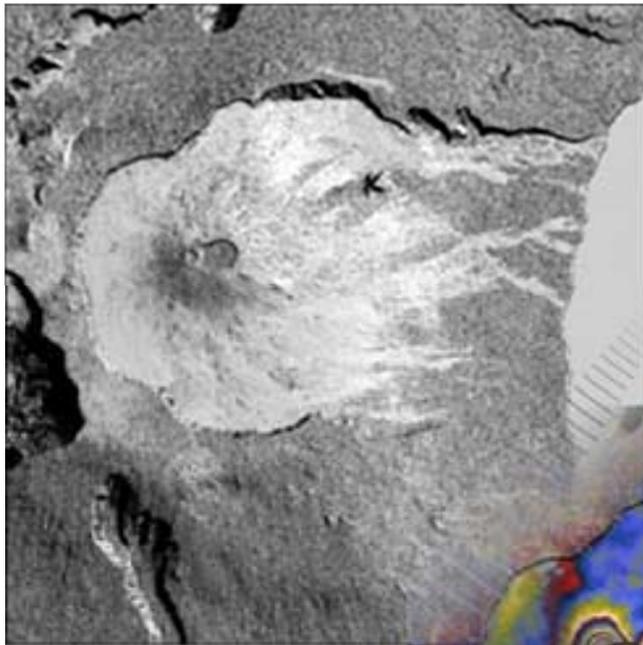
Two basaltic shield volcanoes



RADARSAT-1 database
few images

ENVISAT database (ESA, AOE 746)
(various swaths in ascending and descending passes)

COSMO-SkyMed database (ASI, CSK AO 2080)
(2 ascending & 1 descending swaths)

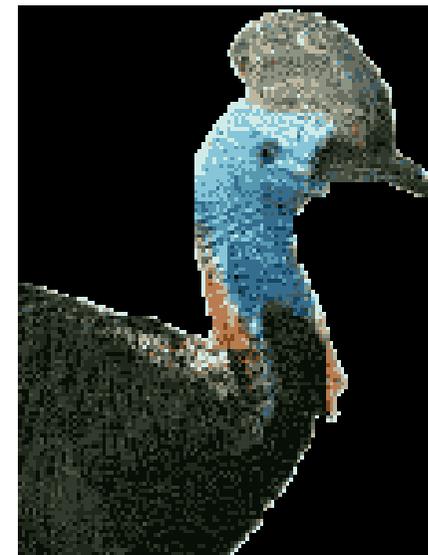
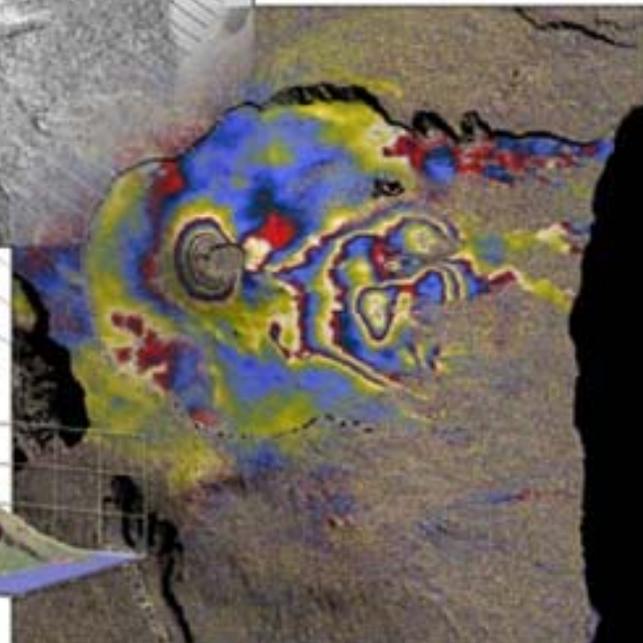
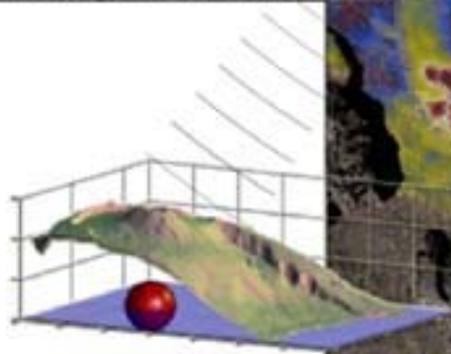


PALSAR database (ESA-JAXA, ALOS ADEN 3622)
(3 swaths in ascending passes)

TerraSAR-X database (CNES-KALIDEOS, DLR LAN 0237)
(1 ascending & 1 descending swaths)

RADARSAT-2 database (CSA-MDA, SOAR 2314)
(2 ascending & 1 descending swaths)

TanDEM-X database



CASOAR

LMV: CASOAR : LIST SELE: x

← → ↻ https://www.obs.univ-bpclermont.fr/casoar/index_liste.php 🔍 ☆ ☰

LIST SELECTOR

Observatoire de Physique
du Globe de Clermont-Ferrand
Laboratoire Magmas et Volcans

User: Bato / OI2
Last connection : 2013-06-28 22:24:23

Folder Selection

- Projects
 - OI2 (Reunion Island)
 - ENVI SAT_A SAR_ILC
 - ENVI SAT_A SAR_INTERF
 - ENVI SAT_MERI S
 - ALD S_PAL SAR_ILC
 - ALD S_PAL SAR_INTERF
 - RADAR SAT_ILC
 - RADAR SAT_INTERF
 - TERRA_SAR_X_ILC
 - TERRA_SAR_X_INTERF
 - DDMMO-SKYMED_ILC
 - DDMMO-SKYMED_INTERF
 - Information

General Selection

TerraSAR X

Select All Select None Beam: All

Mode: Ass. Desc. Droit

Polar: Single Dual Quad Triplex

From: 0 To: 99999

Order by: Date Normal

And by: Orbit Normal

TerraSAR_X : OI2 - 70 input(s)

	Project	Target	Acquiring Date	Receiving Date	Pass	Mission	Product	PolMode	Beam	Orbit
<input type="checkbox"/>	OI2	reunion	2008-12-15	2008-01-21	Des.	T8X1	IM	SINGLE	strip_010	8384
<input type="checkbox"/>	OI2	reunion	2008-12-24	2008-01-21	Des.	T8X1	IM	SINGLE	strip_016	8471
<input type="checkbox"/>	OI2	reunion	2008-01-16	2008-05-02	Des.	T8X1	IM	SINGLE	strip_010	8386
<input type="checkbox"/>	OI2	reunion	2008-02-17	2008-03-02	Des.	T8X1	IM	SINGLE	strip_010	8388
<input type="checkbox"/>	OI2	reunion	2008-03-07	2008-06-10	Asc.	T8X1	IM	SINGLE	strip_005	8687
<input type="checkbox"/>	OI2	reunion	2008-03-22	2008-06-10	Des.	T8X1	IM	SINGLE	strip_010	8787
<input type="checkbox"/>	OI2	reunion	2008-04-09	2008-06-10	Asc.	T8X1	IM	SINGLE	strip_005	10608
<input type="checkbox"/>	OI2	reunion	2008-04-24	2008-06-10	Des.	T8X1	IM	SINGLE	strip_010	10585
<input type="checkbox"/>	OI2	reunion	2008-06-12	2008-06-10	Asc.	T8X1	IM	SINGLE	strip_005	10608
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<input type="checkbox"/>	OI2	reunion	2008-08-01	2008-11-12	Des.	T8X1	IM	SINGLE	strip_010	11211
<input type="checkbox"/>	OI2	reunion	2008-08-03	2008-11-12	Des.	T8X1	IM	SINGLE	strip_010	12212
<input type="checkbox"/>	OI2	reunion	2008-08-21	2008-11-12	Asc.	T8X1	IM	SINGLE	strip_005	12581
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Data provided by CNES/DLR

LMV: CASOAR : reunion_T x

https://www.obs.univ-bpclermont.fr/casoar/visu.php?Type=TerraSAR&Folder=OI2&Data=reunion_TSX1_SMS_D010_08304

reunion_TSX1_SMS_D010_08304

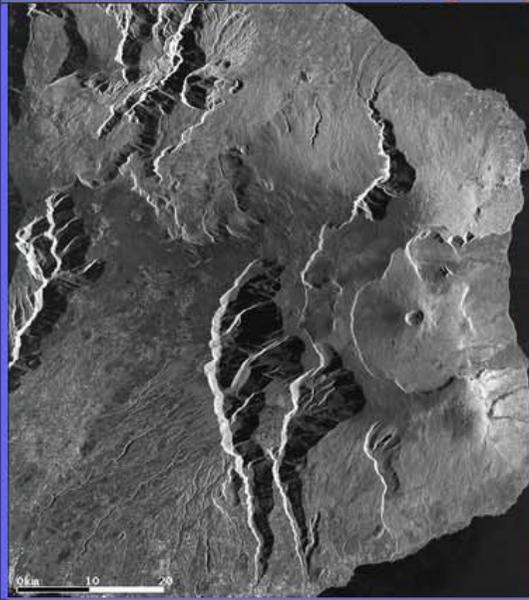
Observatoire de Physique du Globe de Clermont-Ferrand
Laboratoire Magmas et Volcans

[LOGOUT] [LIST SELECTION] [MAP SELECTION] [TABLE SELECTION] [DESIRABLES] [PERSON INFO] [HELP] [CONTACT]

TerraSAR_X : OI2, reunion_TSX1_SMS_D010_08304 - Data provided by CNES/DLR

Projet	OI2	Start	1229129651.320050000 : 15 Dec 2008 8: 42:11.320050
Site	reunion	Stop	1229129658.240090000 : 15 Dec 2008 8: 52:18.240090
Mode	Des.	Longitude	mm
PolMode	HHVHLE	Resolution x / y (m)	8.29999996225 / 1.8374131626
Mission	TSX1	Beam	slrtp_010
Receiving Date	2008-01-21	Line number	17165
Column number	21899	Orbit	3304
Info		Track	8
LatLong point 1	-21.08972717 / 66.8666164	LatLong point 2	-21.03288529 / 66.64282562
LatLong point 2	-21.41048894 / 66.78301747	LatLong point 4	-21.54372661 / 66.47661992

May Jul Sep Nov Jan 2009 Mar May Jul Sep Year




Map Satellite Hybrid

0 km 10 20

POWERED BY Google 10 mi 10 km

Map data ©2013 Google - Terms of Use

LMV: CASOAR: LIST SELE: x

← → ↻ https://www.obs.univ-bpclermont.fr/casoar/index_liste.php

LIST SELECTOR

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Laboratoire Magmas et Volcans

User: Bato / OI2
Last connection: 2013-06-28 22:24:23

Folder Selection [RESET]

- Projects
 - 012 (Reunion Island)
 - ENVI SAT_A SAR_ILC
 - ENVI SAT_A SAR_INTERF
 - ENVI SAT_MERIS
 - ALD_S_PAL SAR_ILC
 - ALD_S_PAL SAR_INTERF
 - RADAR SAT_ILC
 - RADAR SAT_INTERF
 - TERRA_SAR_X_ILC
 - TERRA_SAR_X_INTERF
 - DD SMO-SKYMED_ILC
 - DD SMO-SKYMED_INTERF
 - Information

General Selection [RESET]

TerraSAR-X_INTERF : OI2 - 92 input(s)

Select All | Select None | Orbit Master From: 0

Mode: Asc. Desc. | Orbit Slave From: 99999

Beam: All | Orbit Slave From: 18805

Polarisation: | Orbit Slave To: 99999

Filter: | Alt. Ambi. From: 0

Duration: From: 0 days To: 999999 days

To: 100000 days

Order by: Received | Reverse

And by: Master Orbit | Normal

[Update] [Import] [Export]

Project	Target	Computing Date	Filter	Pass	Beam	Master Orbit Polar	Master Date	Slave Orbit Polar	Slave Date	Alt. Ambi.	Resolution
012	reunion	2012-11-20		Des.	strip_010	2096-M	2010-11-06	27842-SI	2012-08-22	-11.81	7.6
012	reunion	2012-11-20		Des.	strip_010	2096-M	2010-11-06	28172-SI	2012-02-04	-17.49	7.6
012	reunion	2012-11-20		Des.	strip_010	5504-M	2008-12-15	27842-SI	2012-08-22	-114.26	7.6
012	reunion	2012-11-20		Des.	strip_010	5504-M	2008-12-15	18862-SI	2010-10-28	-118.69	7.6
012	reunion	2012-11-20		Des.	strip_010	5504-M	2008-12-15	28172-SI	2012-02-04	66.44	7.6
012	reunion	2012-11-19		Des.	strip_010	7428-M	2011-10-24	28172-SI	2012-02-04	-80.24	7.6
012	reunion	2012-11-19		Des.	strip_010	7428-M	2011-10-24	27842-SI	2012-08-22	-22.06	7.6
012	reunion	2012-11-19		Des.	strip_010	18111-M	2012-04-17	27842-SI	2012-08-22	-8.27	7.6
012	reunion	2012-11-19		Des.	strip_010	18221-SI	2010-08-27	28172-SI	2012-02-04	-77.03	7.6
012	reunion	2012-11-19		Des.	strip_010	18221-SI	2010-08-27	27842-SI	2012-08-22	-26.16	7.6
012	reunion	2012-11-19		Des.	strip_010	18221-SI	2010-08-27	18862-SI	2010-10-28	-26.26	7.6
012	reunion	2012-11-19		Des.	strip_010	17222-SI	2010-07-30	28172-SI	2012-02-04	-63.2	7.6
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012	reunion	2012-11-16		Des.	strip_010	16219-SI	2010-02-20	18862-SI	2010-10-28	267.78	7.6

reunion D 3010
16521 SI
18628 SI

reunion D 3010
17322 SI
26173 SI

reunion D 3010
17322 SI
27842 SI

reunion D 3010
17322 SI
18628 SI

reunion D 3010
17322 SI
26173 SI

reunion D 3010
17322 SI
27842 SI

LMV: CASOAR: LIST SELE x LMV: CASOAR: reunion_T x

https://www.obs.univ-bpclermont.fr/casoar/visu.php?Type=TSarInterf&Folder=OI2&Data=reunion_TDX1_SMS_D010_02095_27843_ext7.5m

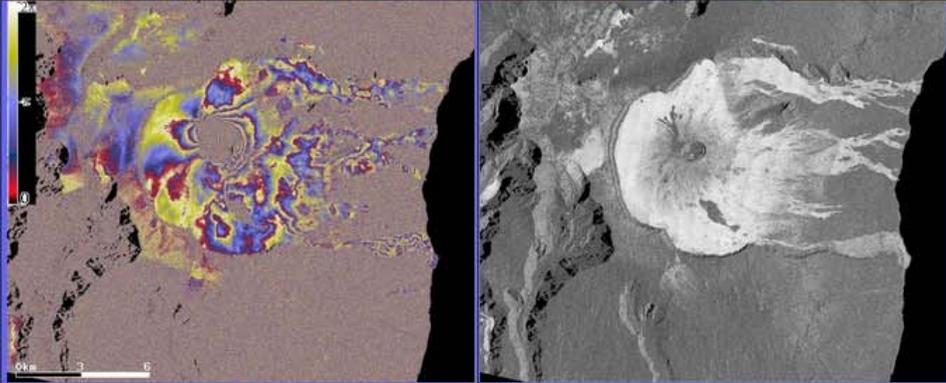
reunion_TDX1_SMS_D010_02095_27843_ext7.5m

Observatoire de Physique du Globe de Clermont-Ferrand
Laboratoire Magmas et Volcans

LOGOUT LIST SELECTION MAP SELECTION TABLE SELECTION DE BRABLE S PERBO INFO HELP CONTACT

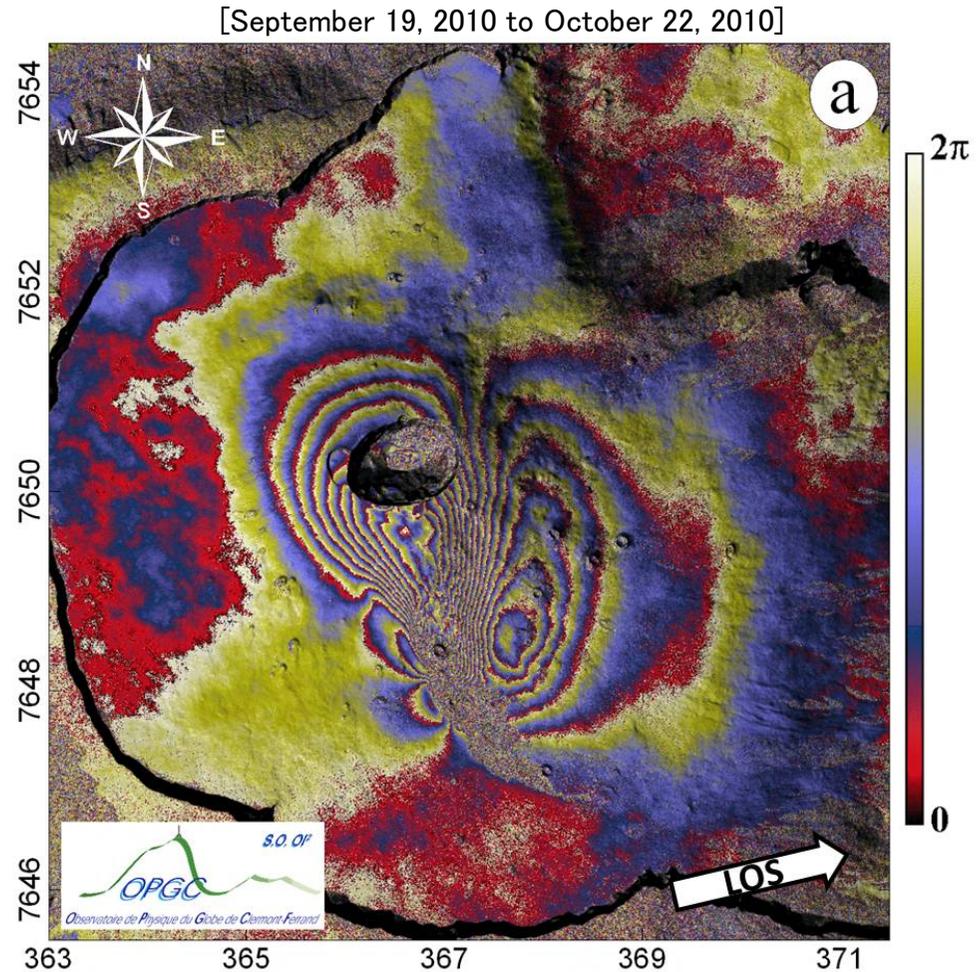
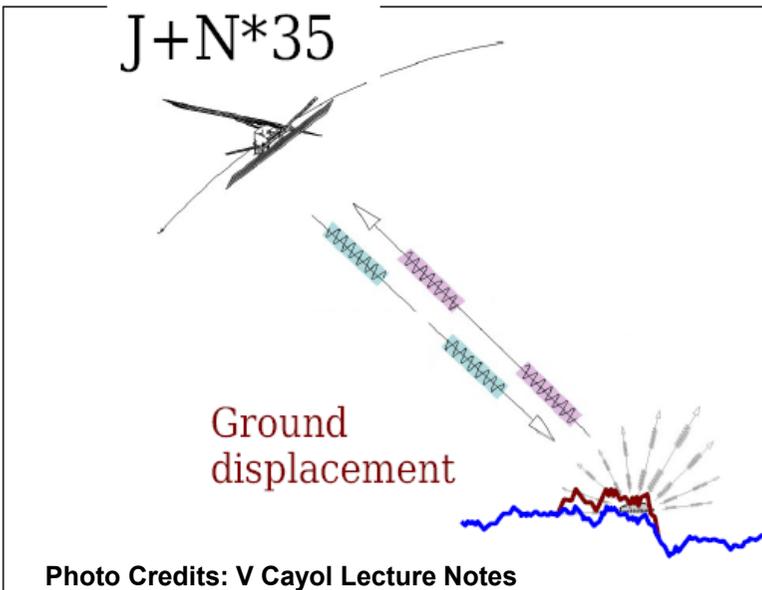
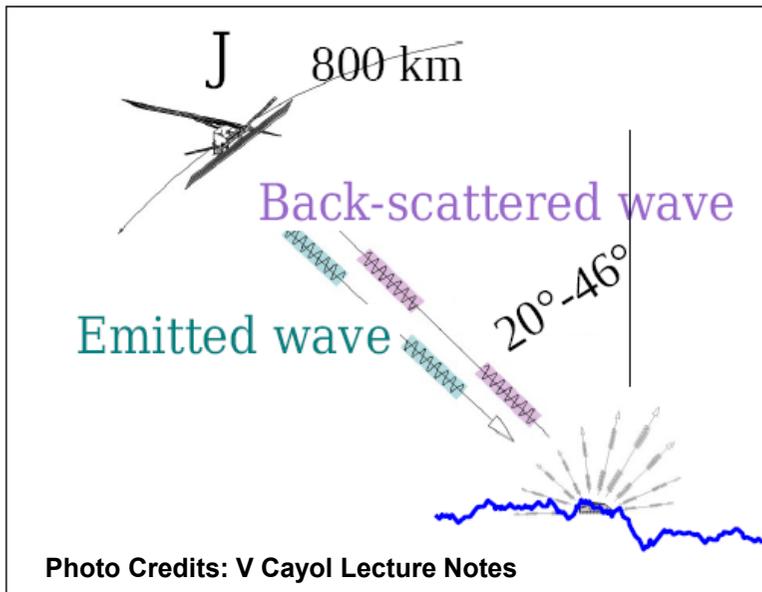
TerraSAR-X_INTERF : OI2_reunion_TDX1_SMS_D010_02095_27843_ext7.5m			
Projet	DOI2	Format	Binaries
Area	INDIAN-OCEAN	Date Of Composition	2010-10-28
Name	MISSION : TDX1_SMS_D010_02095_27843_ext7.5m	Alt. Azim.	-11.91
Filter		DEM	ICM-LEUAC081
Resolution	1.5	File	
Weather orbit / orbit	2009-08	Scan	strip_938
Weather orbit / 1 rev	06 Nov 2010 0:52:24.804000 020950295_020950000	Scene orbit / orbit	27843-01
Lat/Long point 1	23.382817 / 35.822891	Scene orbit / 1 rev	22 Jun 2010 0:52:25.707000 020950295_020950000
Lat/Long point 2	23.33987 / 35.82394	Channel	095 strip
		Lat/Long point 2	23.388811 / 35.82493
		Lat/Long point 4	23.338869 / 35.82393

Apr Jul Oct Jan Apr Jul Oct Jan Apr Jul Oct Jan Feb March Year
2010 2011 2013



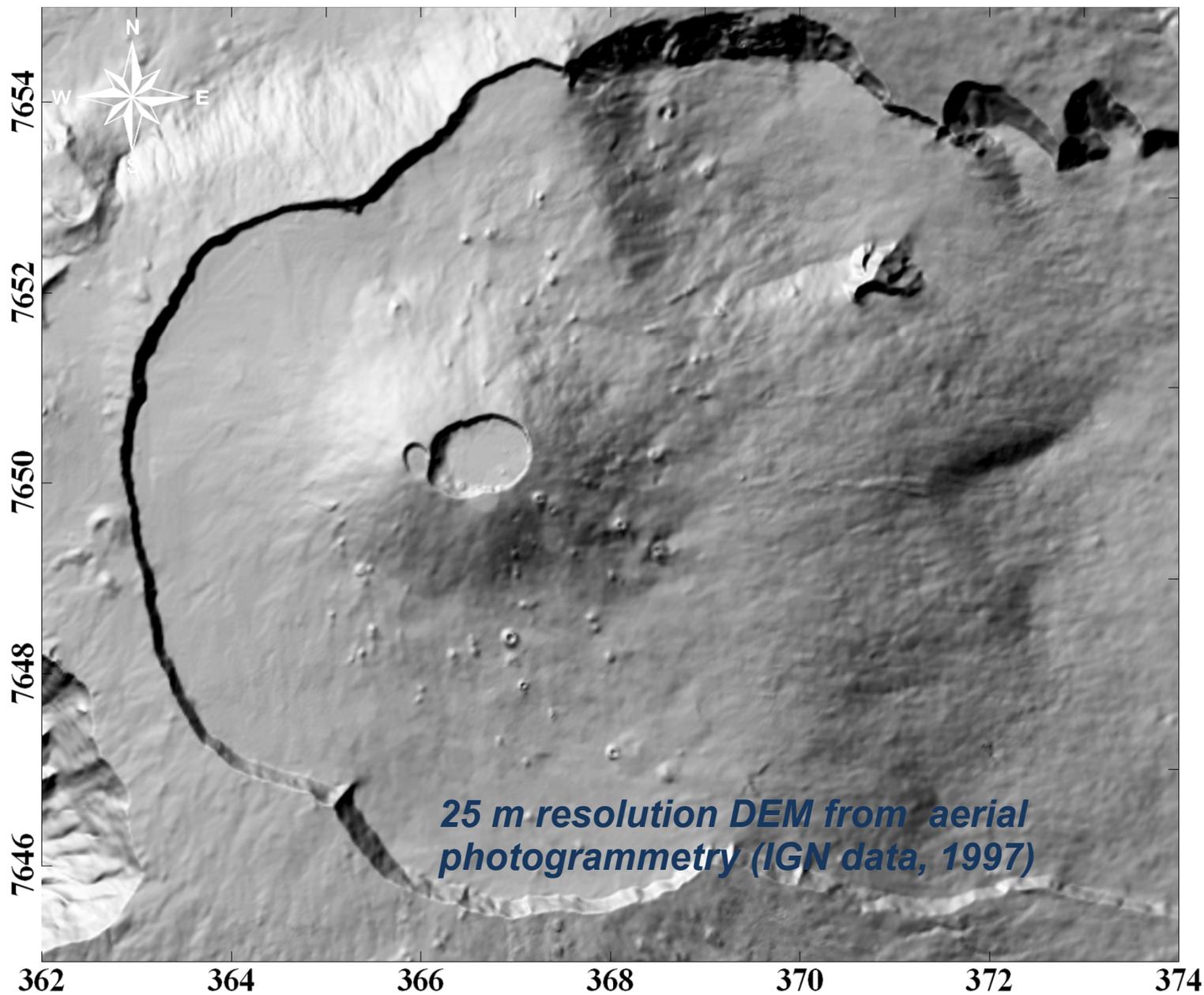
Map Satellite Hybrid

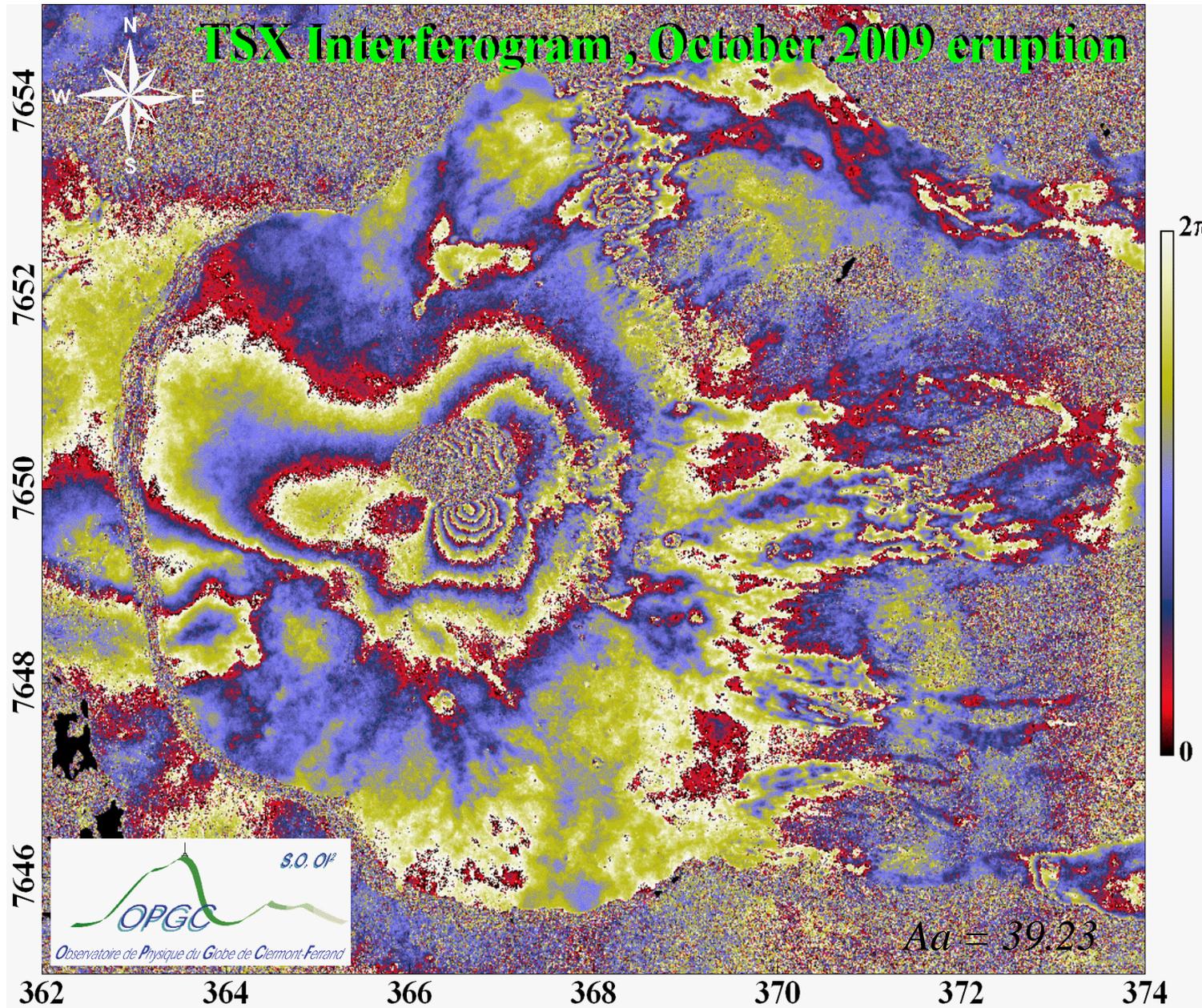


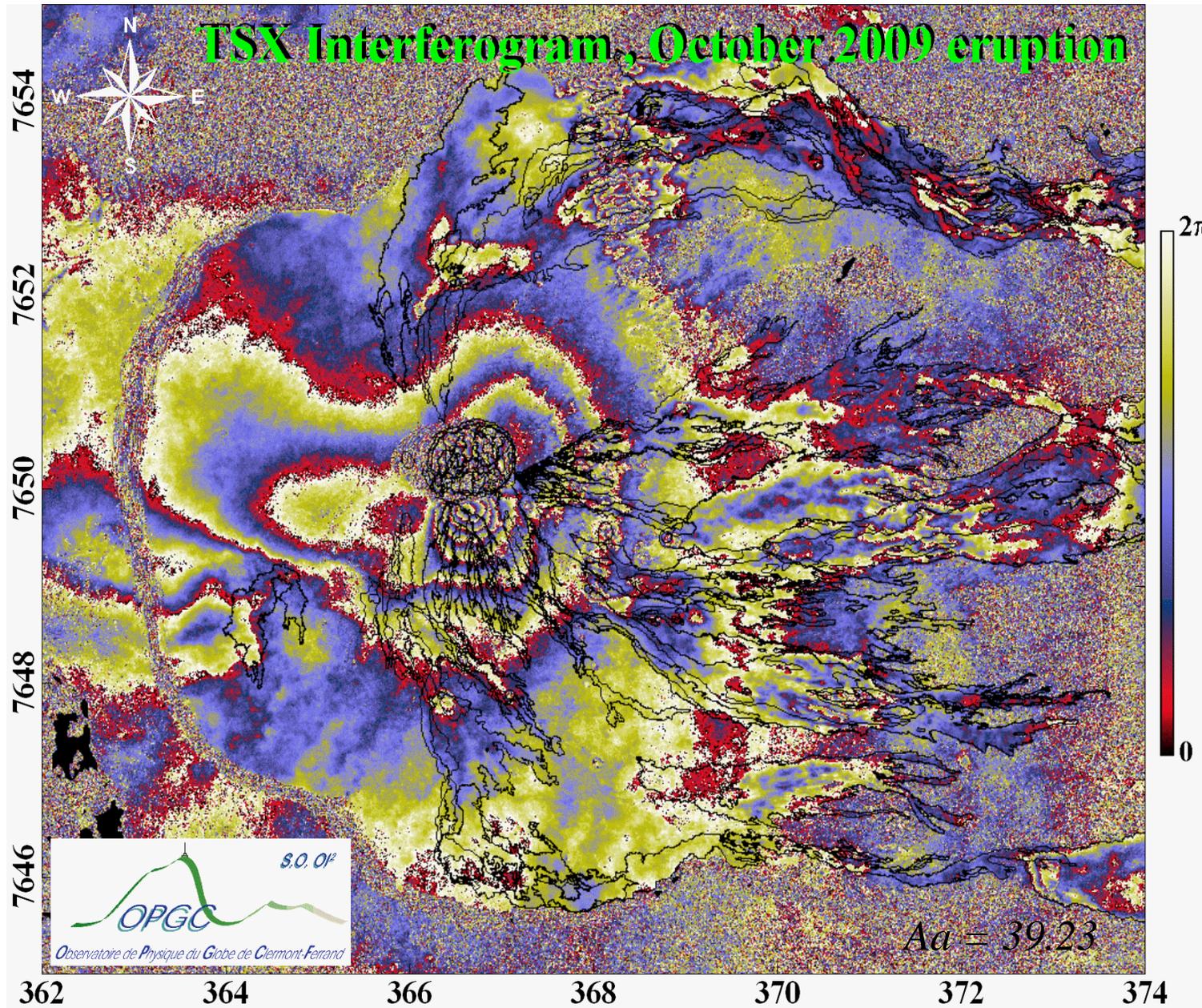


1 fringe = $\lambda / 2$ ($\lambda_{TSX} \approx 3\text{cm}$)

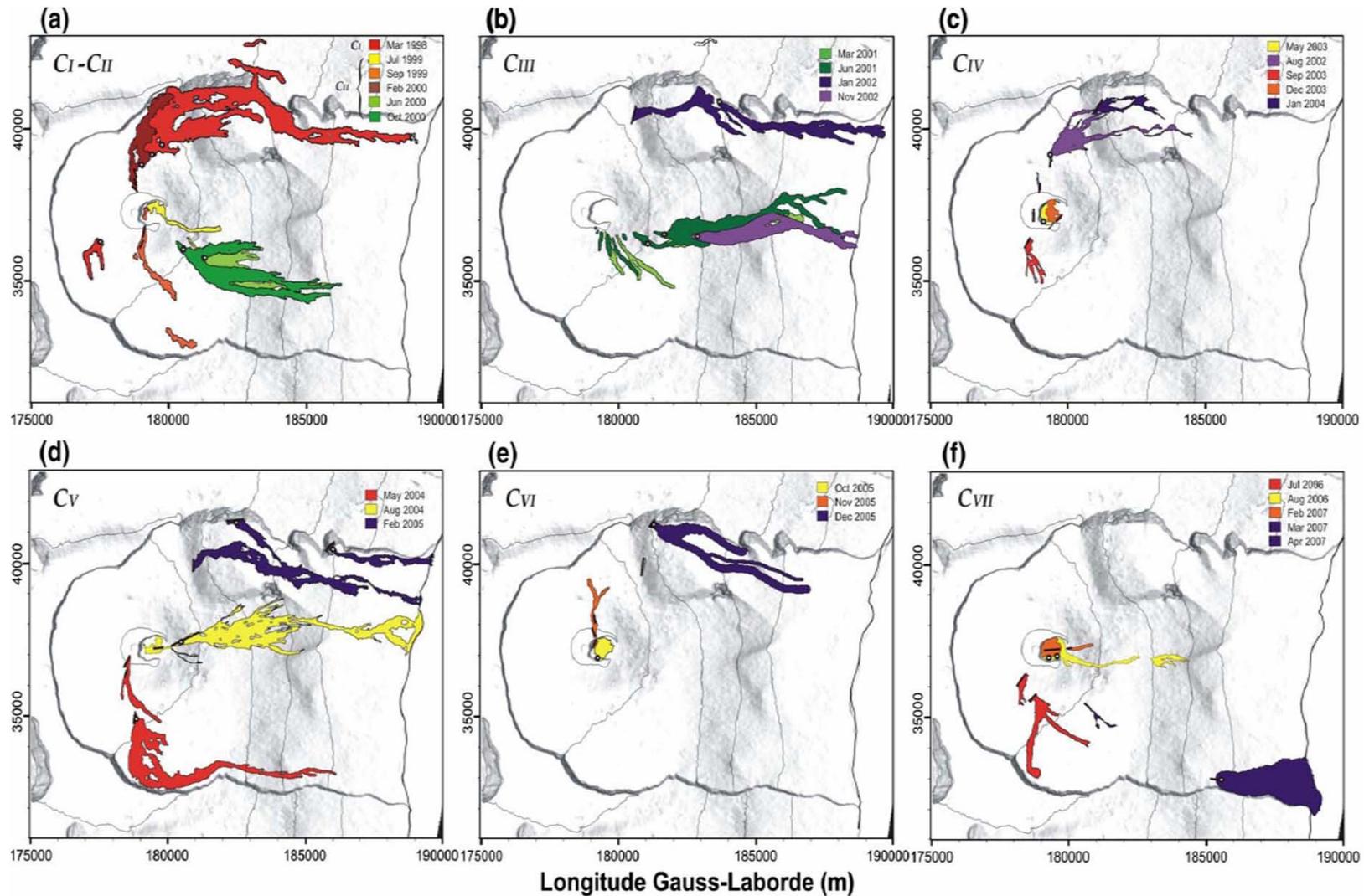
$$\Delta\phi = \phi_{topo} + \phi_{orb} + \phi_{disp} + \phi_{atm} + \phi_{noise}$$

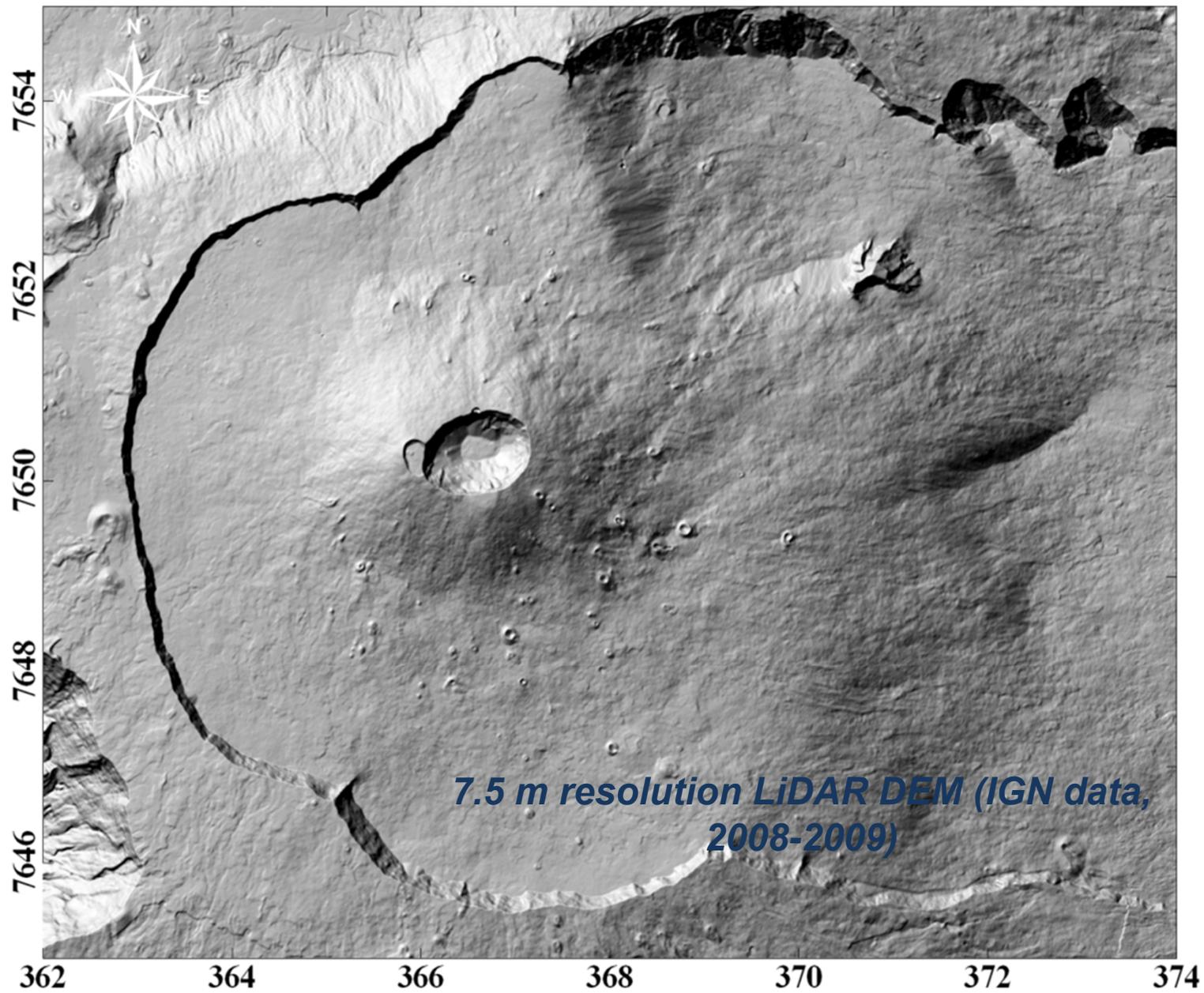


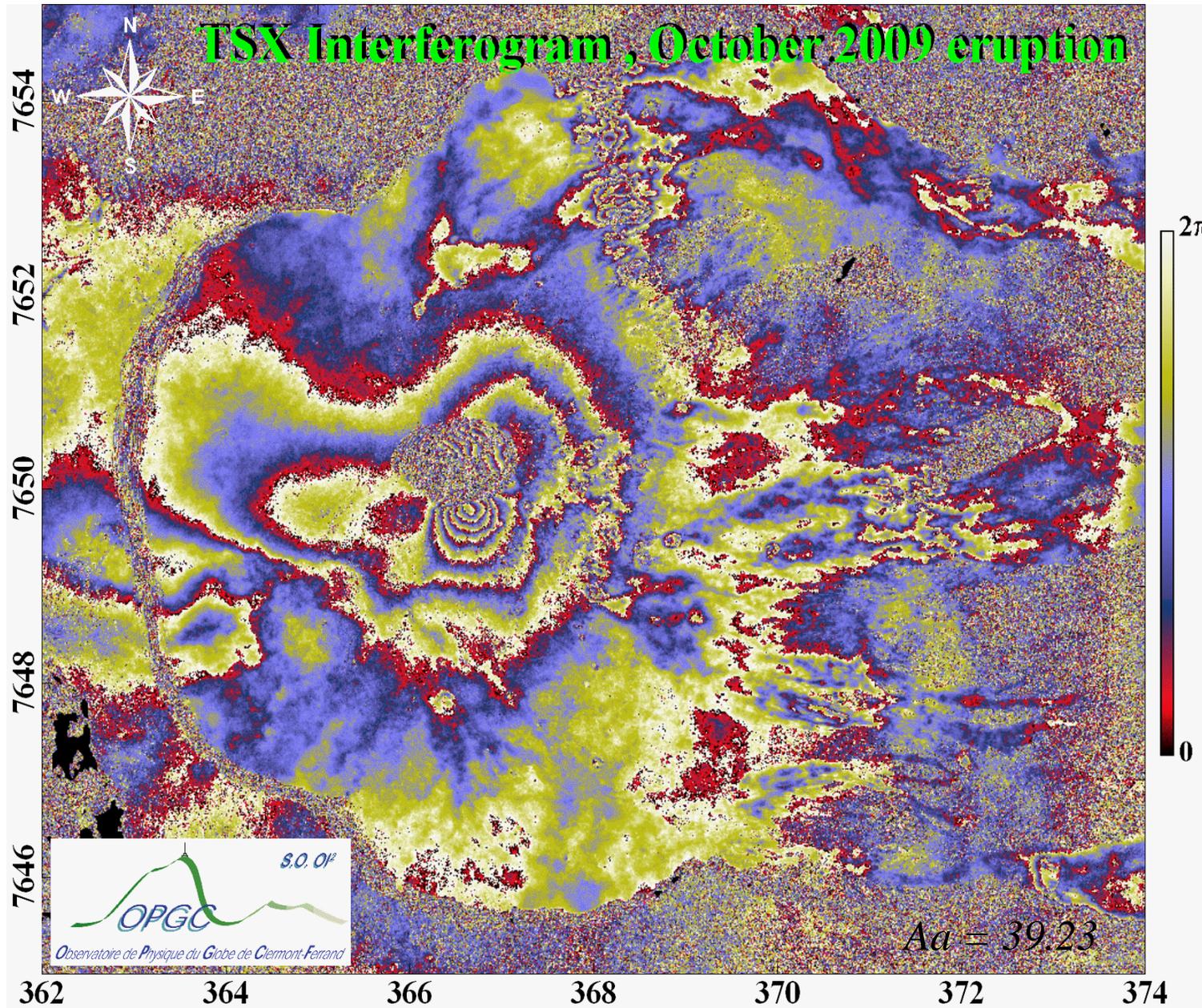


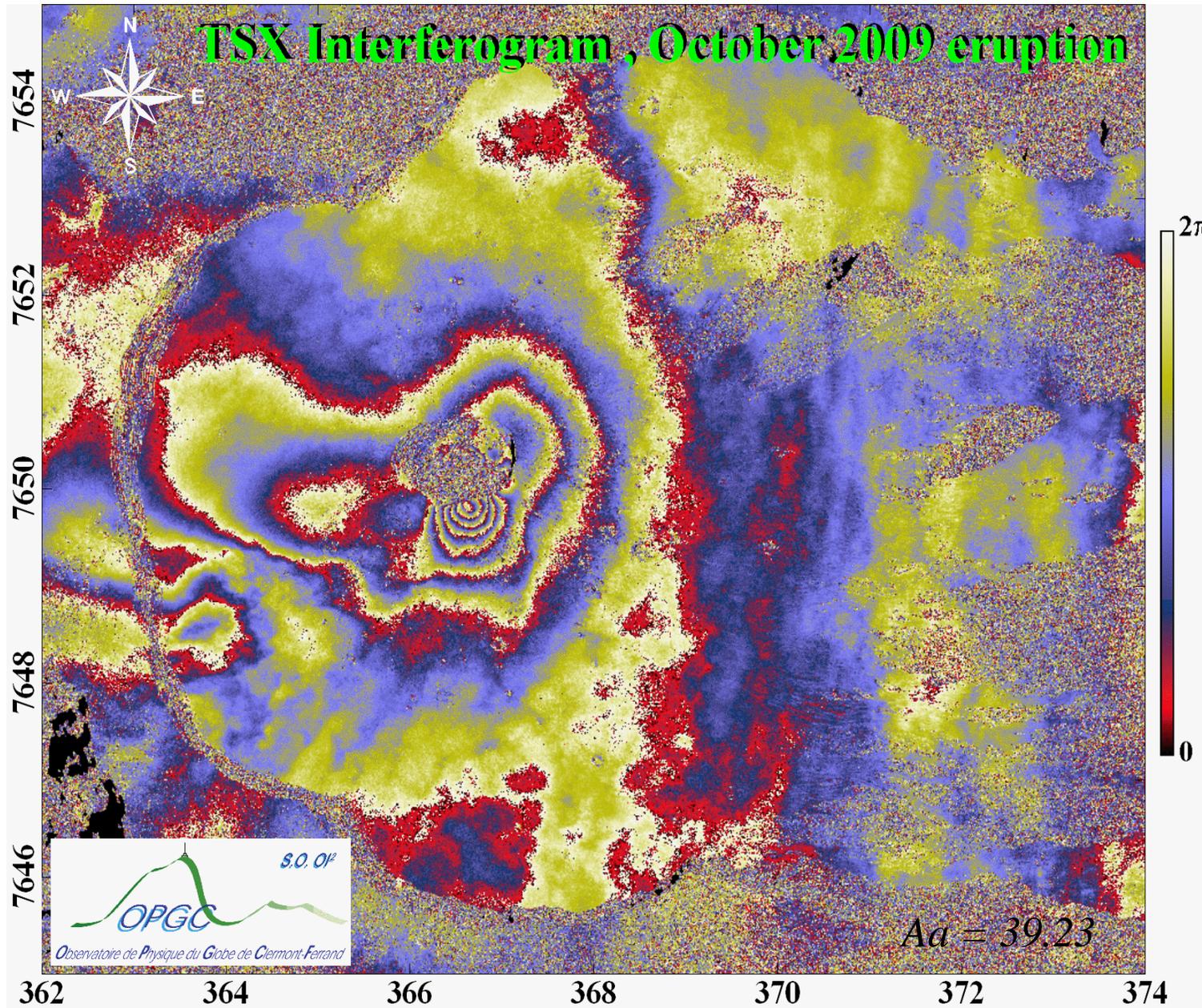


Since 1998, the Piton de la Fournaise topography has changed significantly due to lava flows emplacement (34 eruptions).

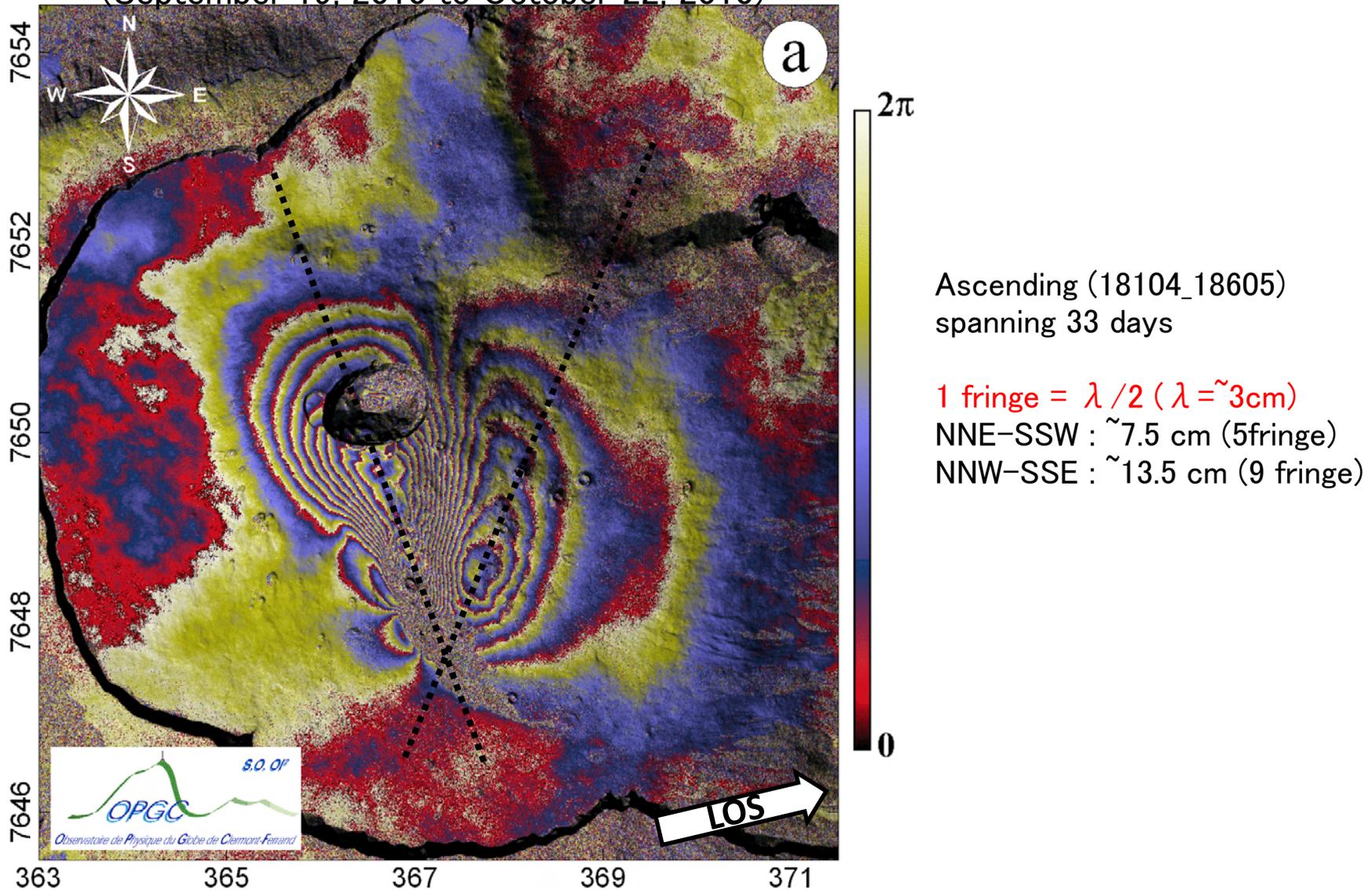




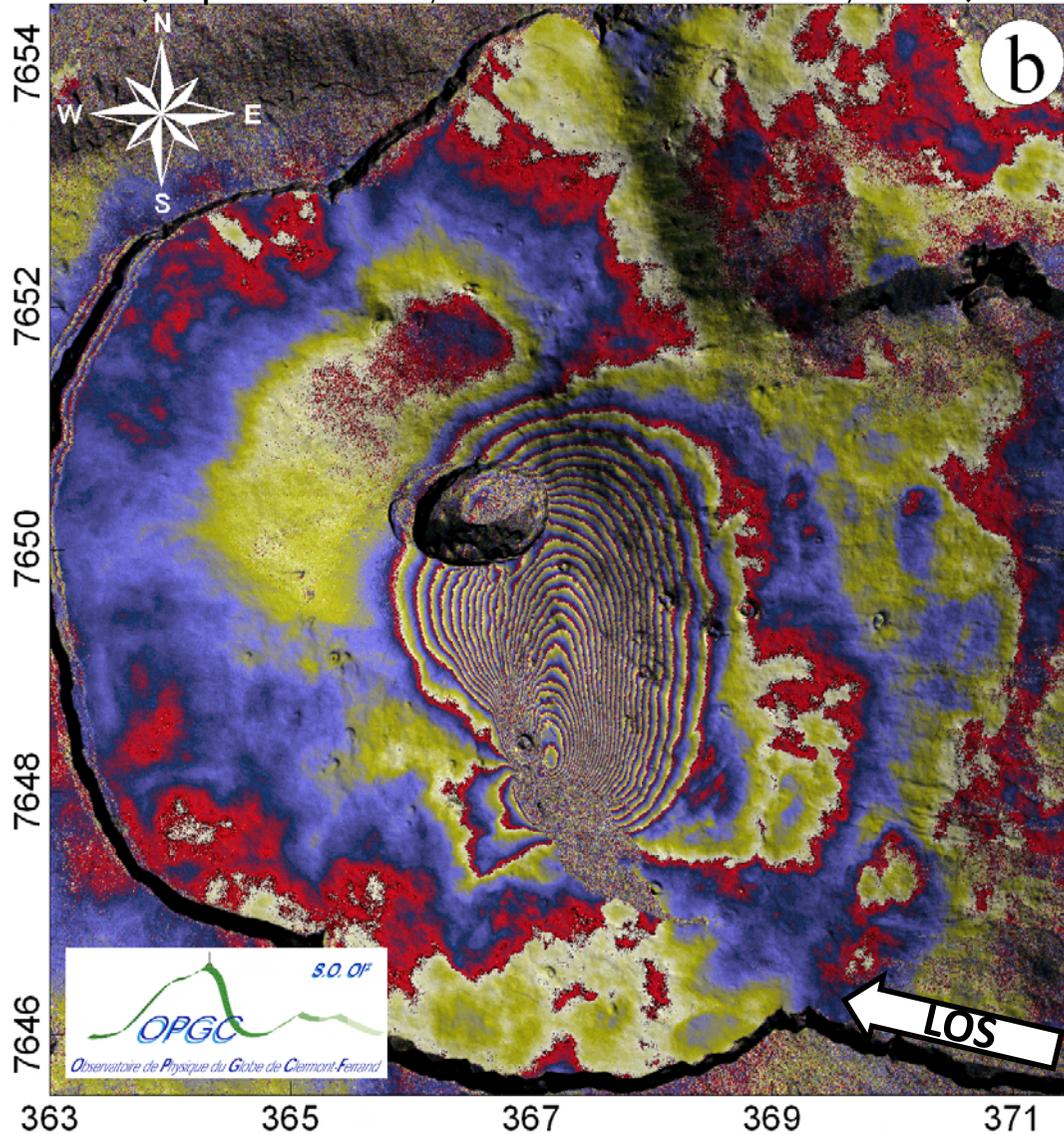




(TSX)October 2010 Eruption (September 19, 2010 to October 22, 2010)

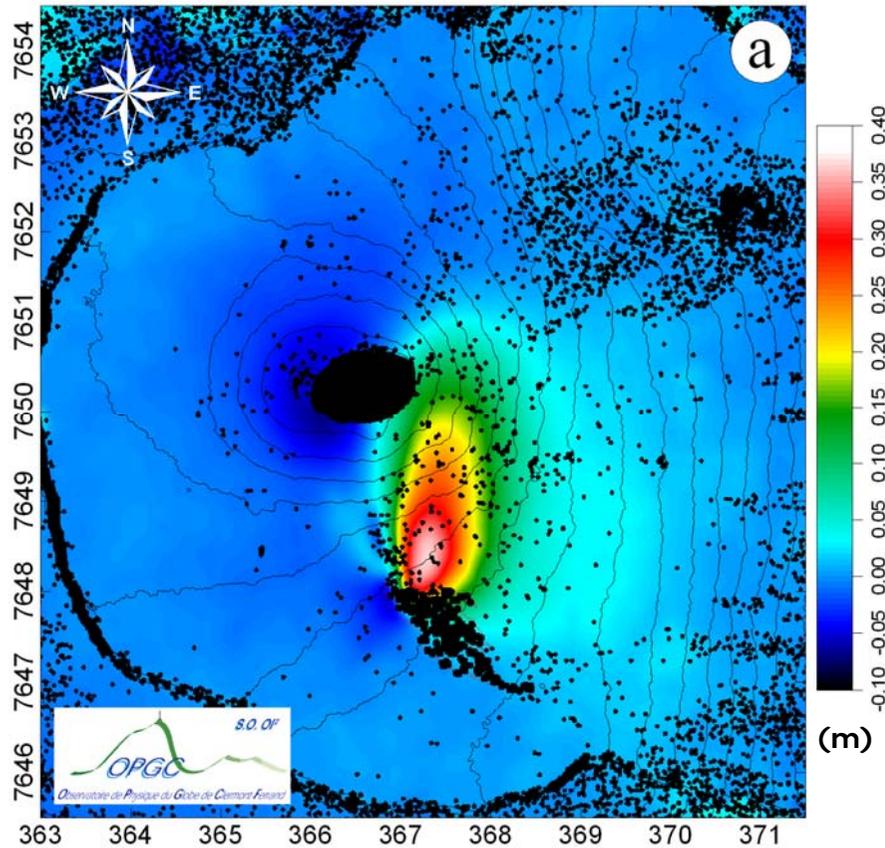


(TSX)October 2010 Eruption (September 01, 2010 to October 26, 2010)

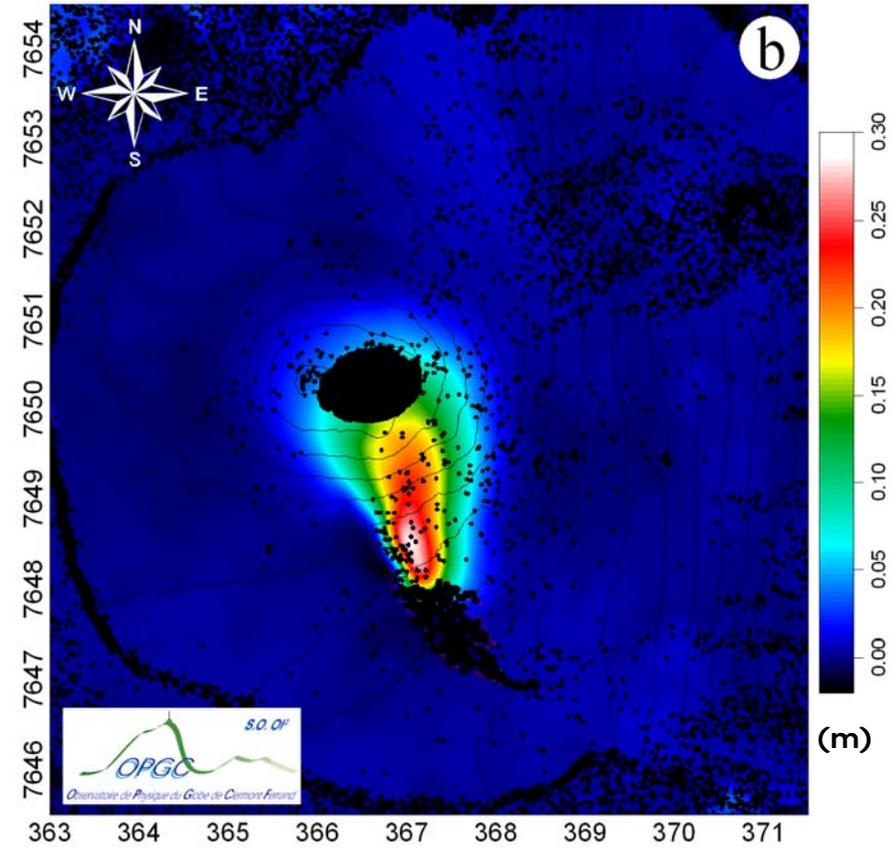


Descending (18104_18605)
spanning 55 days

1 fringe = $\lambda / 2$ ($\lambda \approx 3\text{cm}$)
NS : $\sim 42\text{ cm}$ (27-28 fringes)
Y-B-R

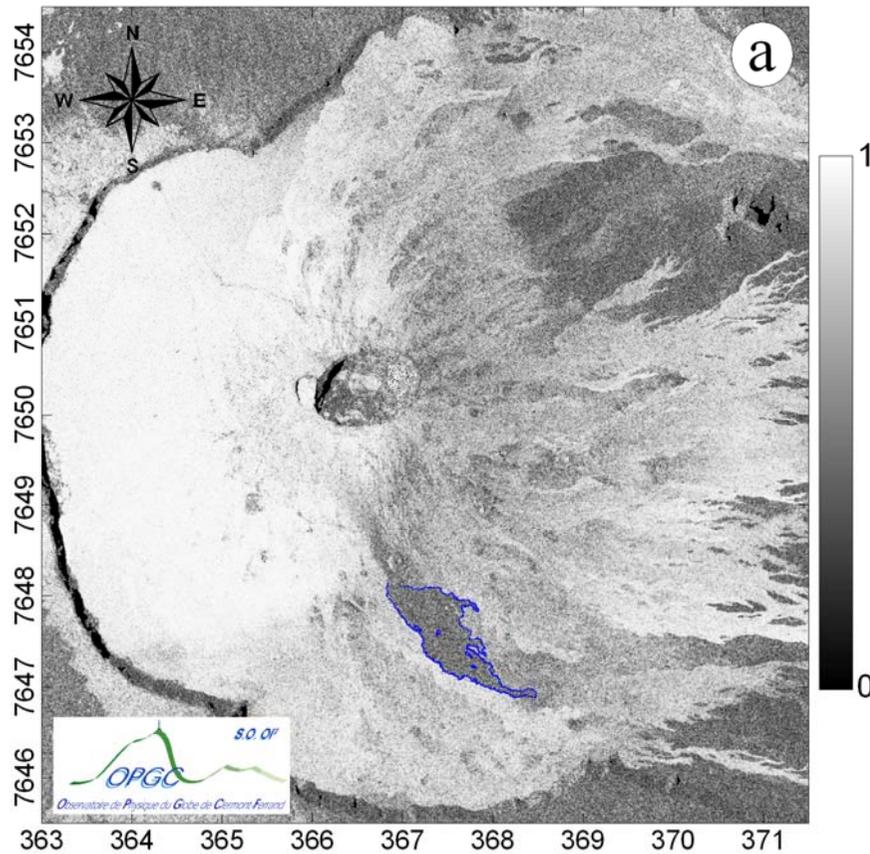


Maximum EW (Horizontal)
displacement: 40 cm



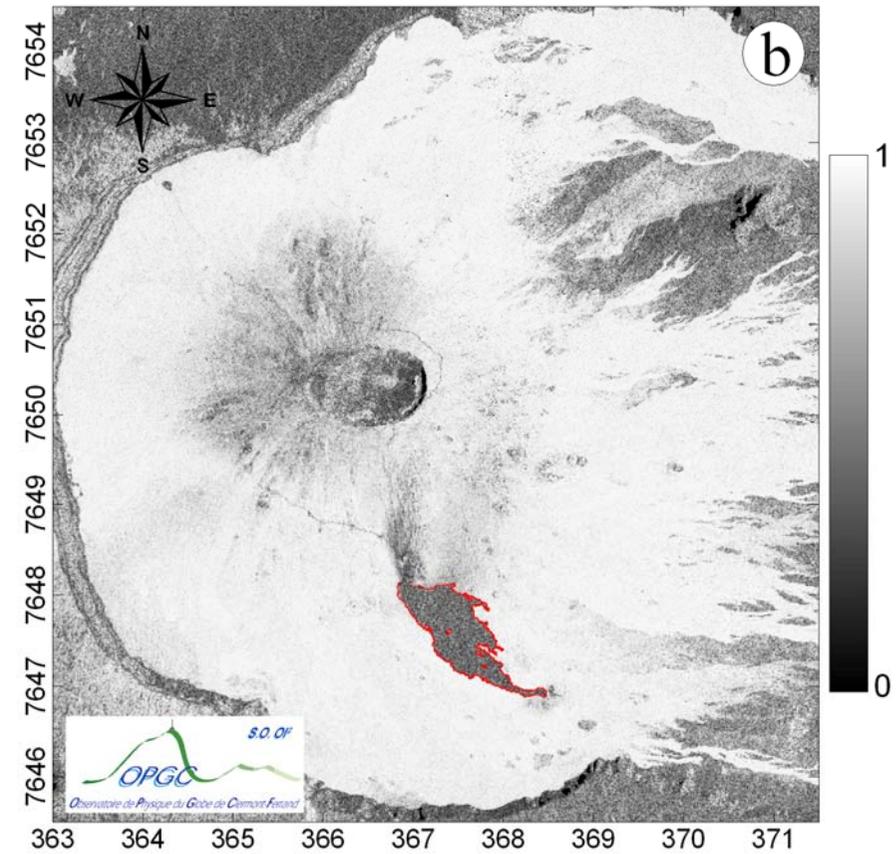
Maximum UD (Vertical)
displacement: 30 cm

Propagation of a dike through the surface!!



Ascending (18104_18605), 33days
(September 19, 2010 to October 22, 2010)

Area: 0.71 km²

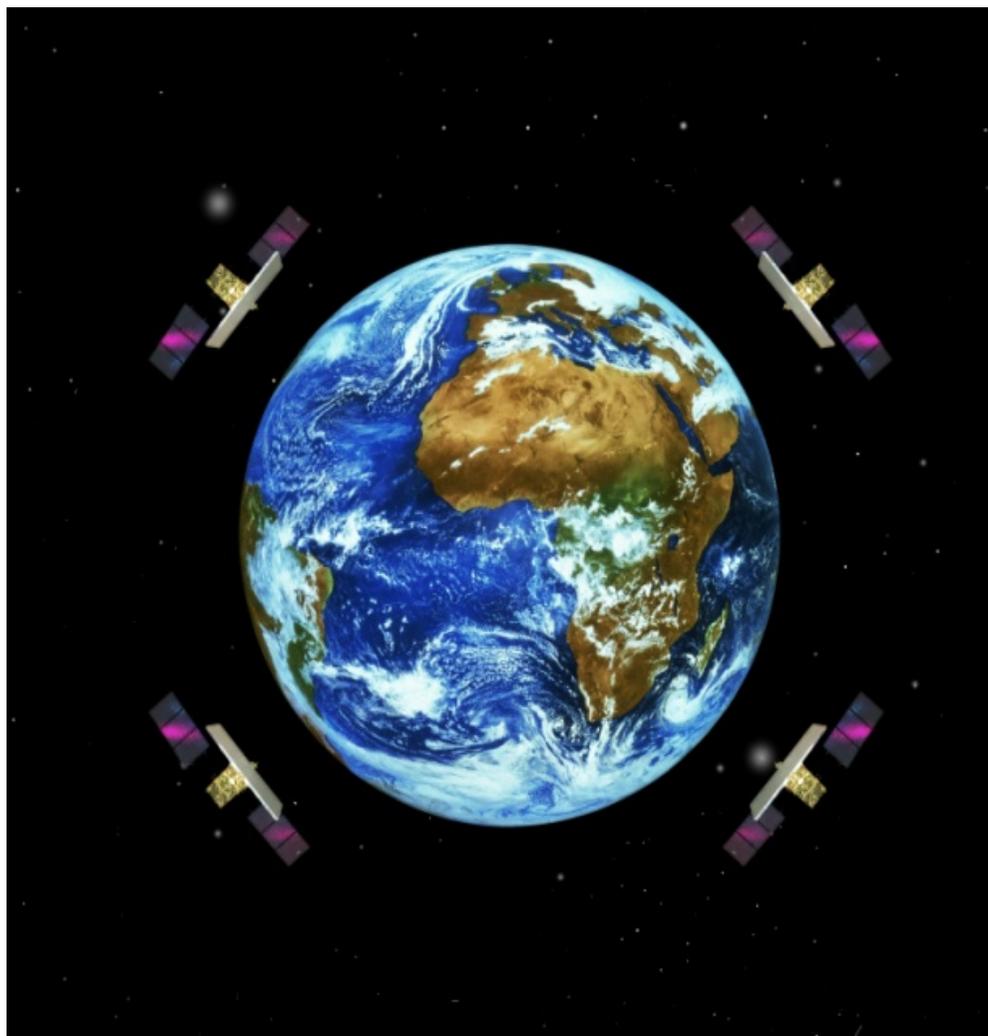


Descending (18104_18605), 55 days
(September 01, 2010 to October 26, 2010)

Area: 0.75 km²

The coherence quantifies the degree of correlation or the stability of the phases between the 2 acquisitions.

What about the post emplacement behavior?

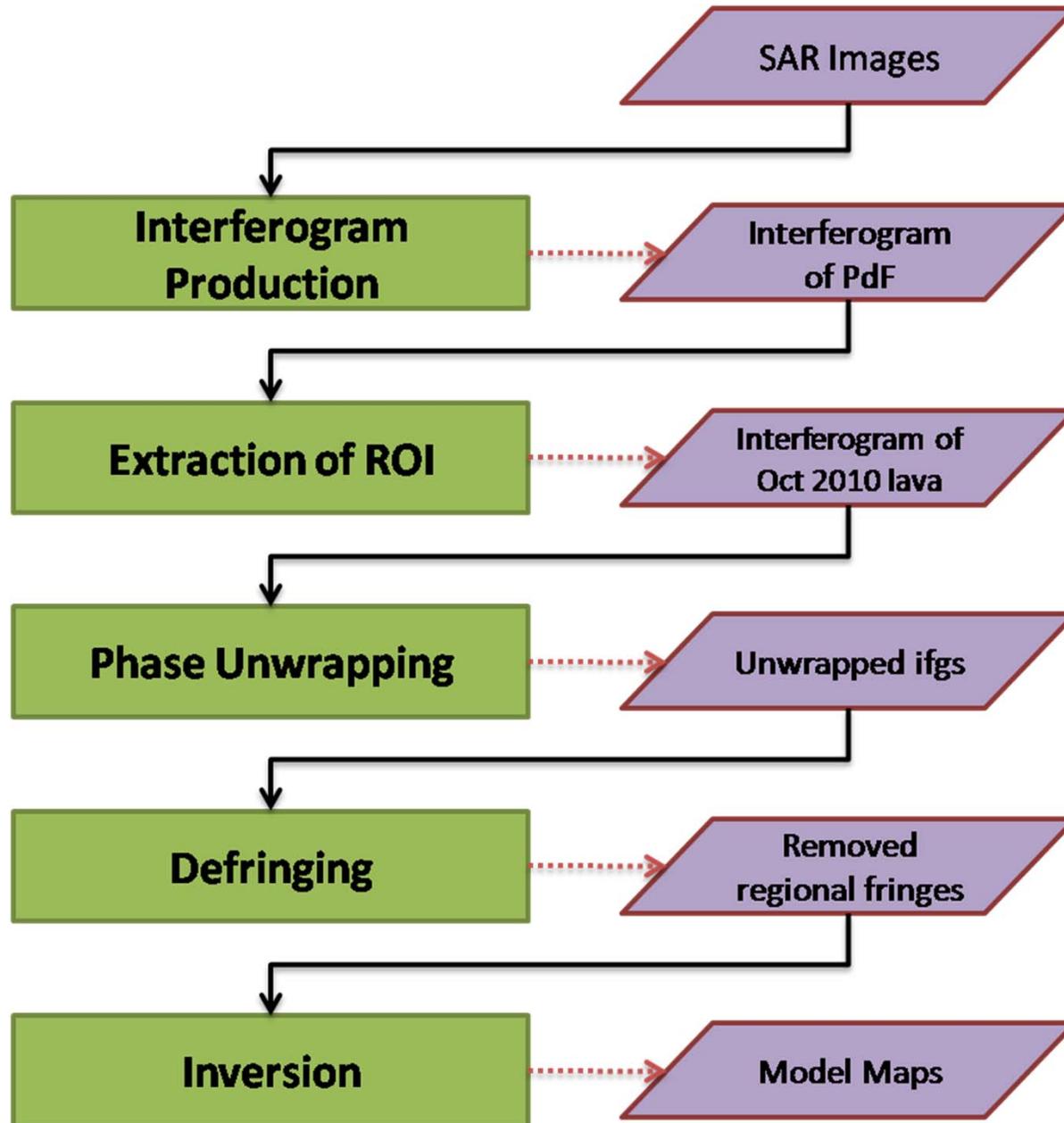


**Cosmo SkyMed Satellite System
(CSK) $\lambda = \sim 3\text{cm}$**

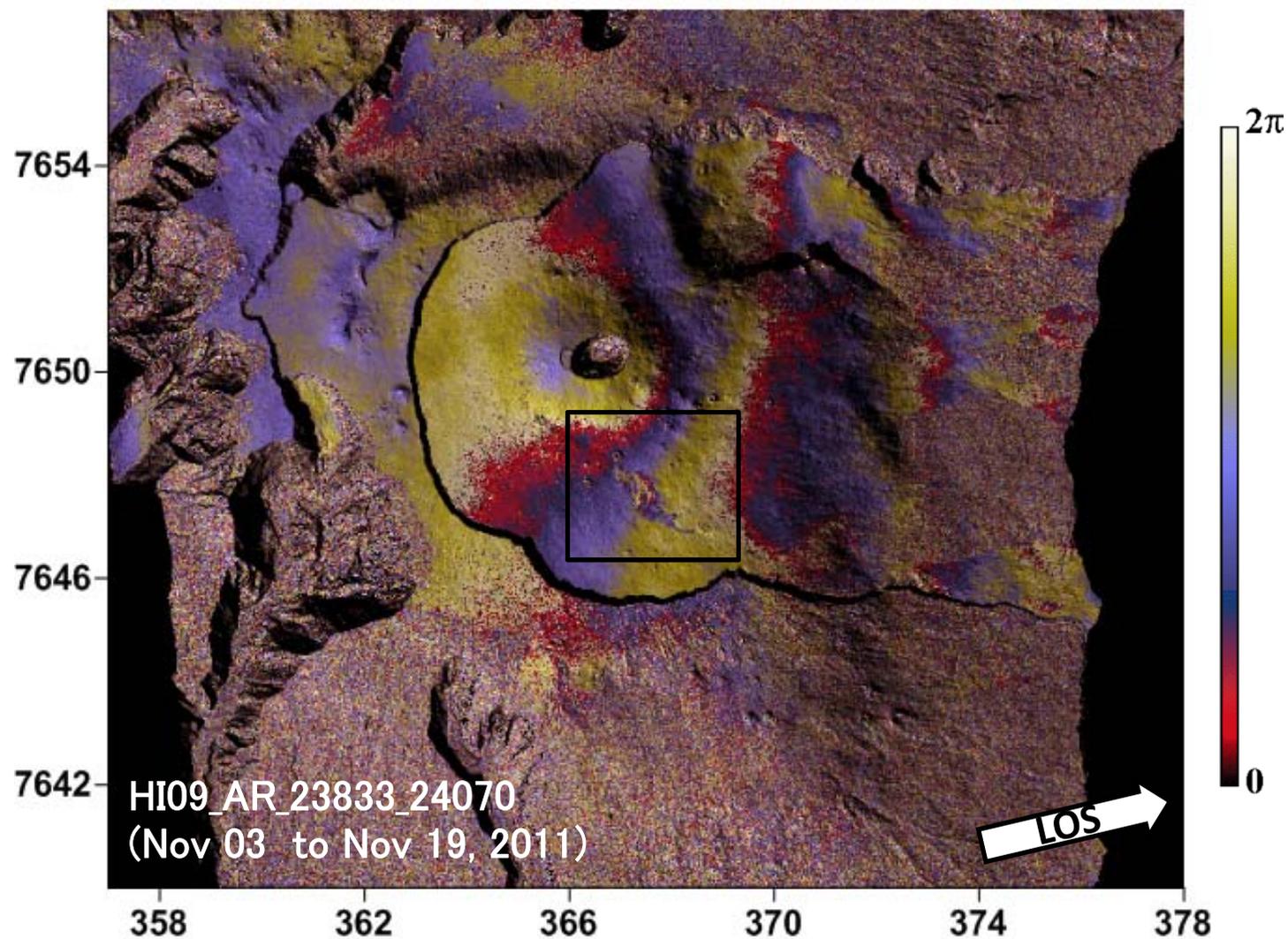
54 SAR Images from CSK
(April 09, 2011 to January 01, 2012)

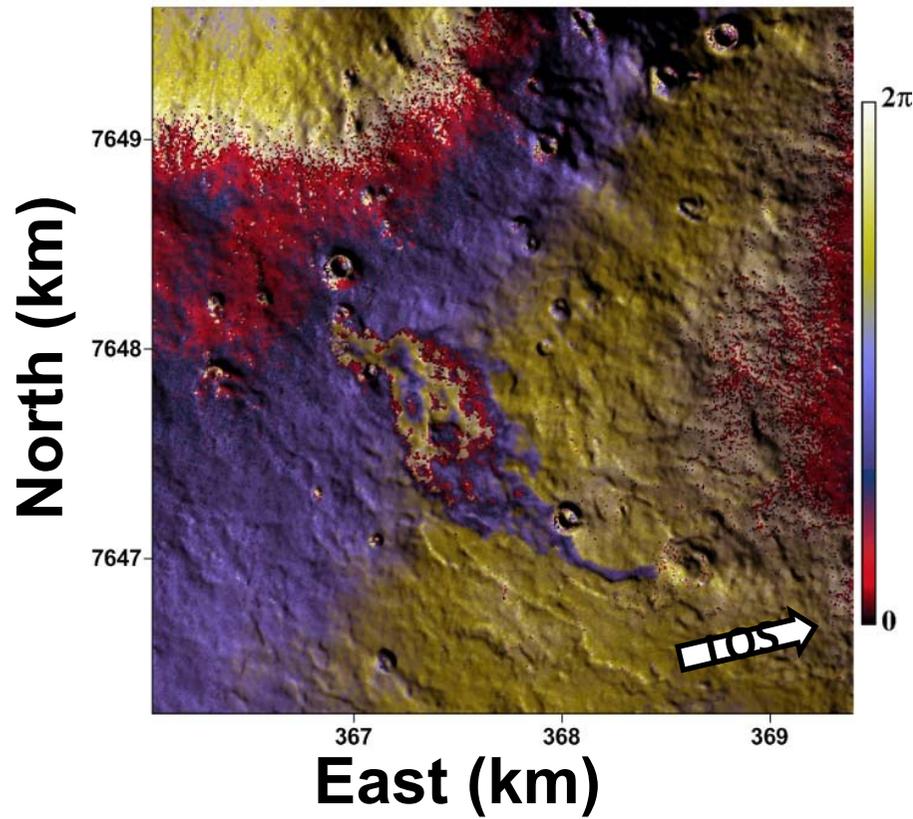
Orbits the Earth every 16 days, covering
237 revolutions per cycle.

435 Interferograms are calculated.



Extracting Region of Interest (ROI)



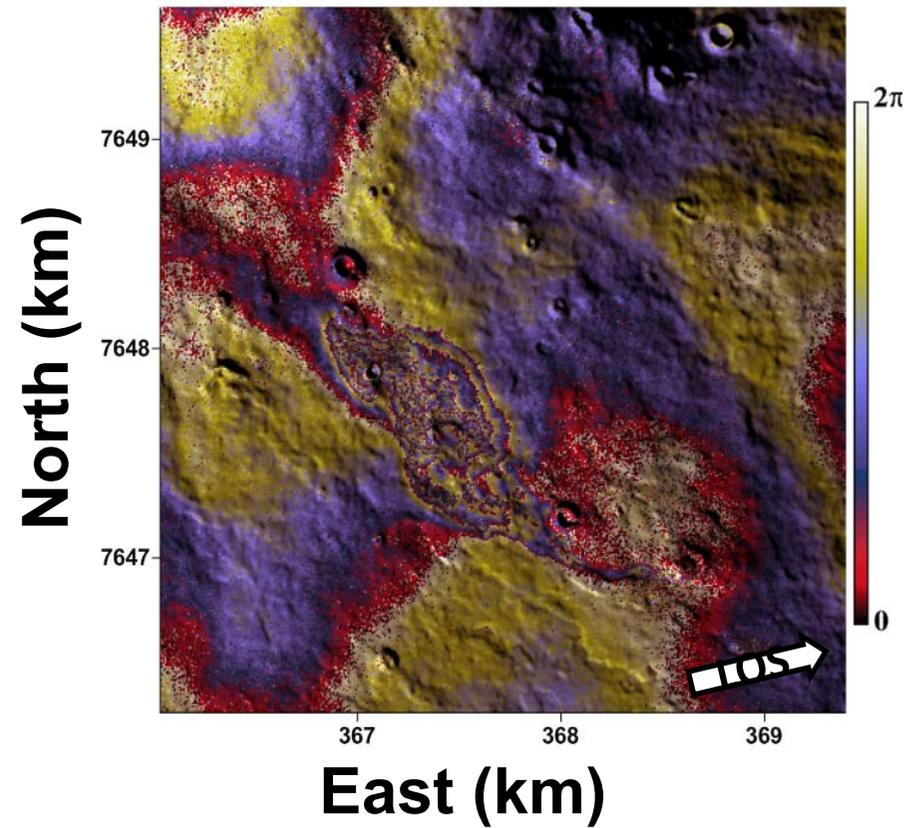


HI09_AR_23833_24070

(November 03 to November 19, 2011)

Duration: 16 days

|AA |: 10.64



HI15_AR_20204_23522

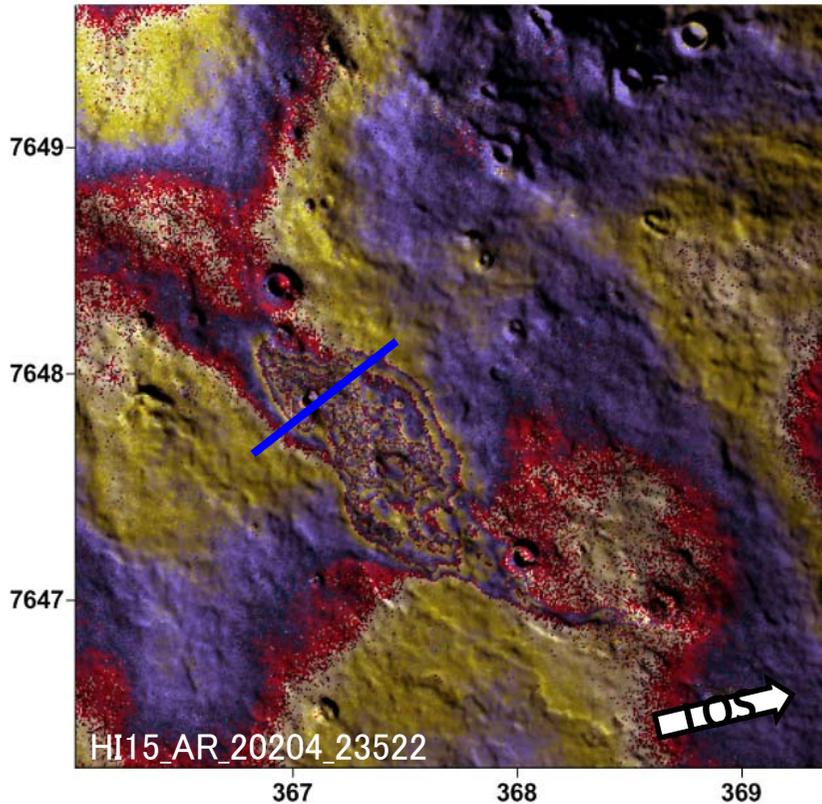
(March 03 to October 13, 2011)

Duration: 224 days

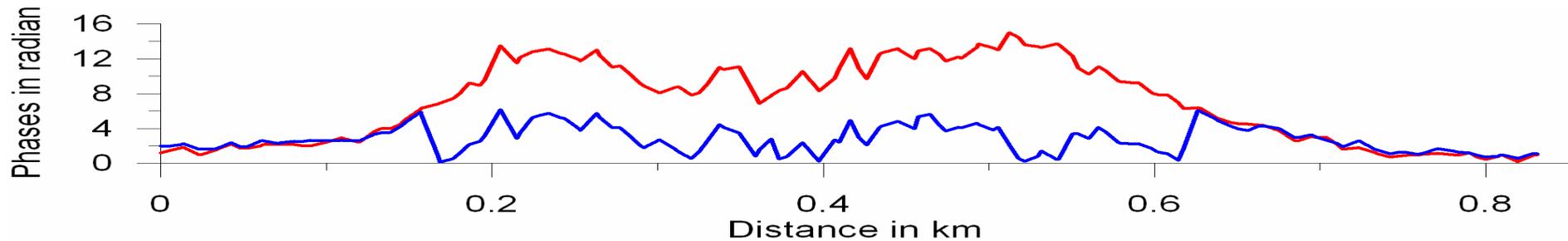
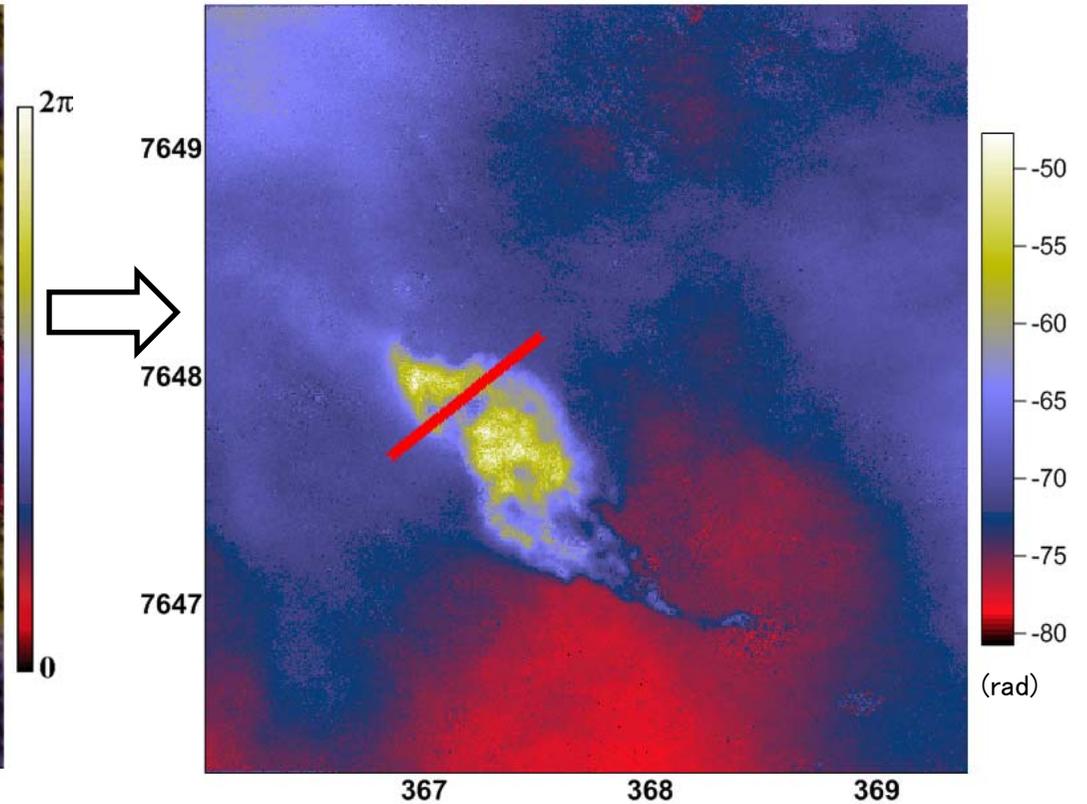
|AA |: 223.59

Phase Unwrapping

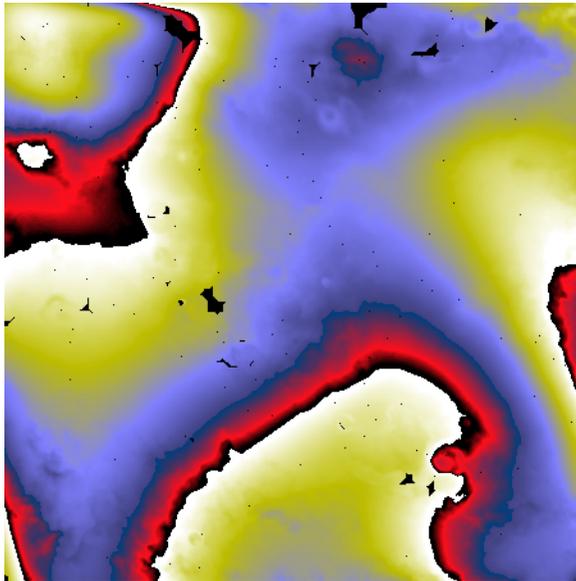
Wrapped Phase



Unwrapped Phase

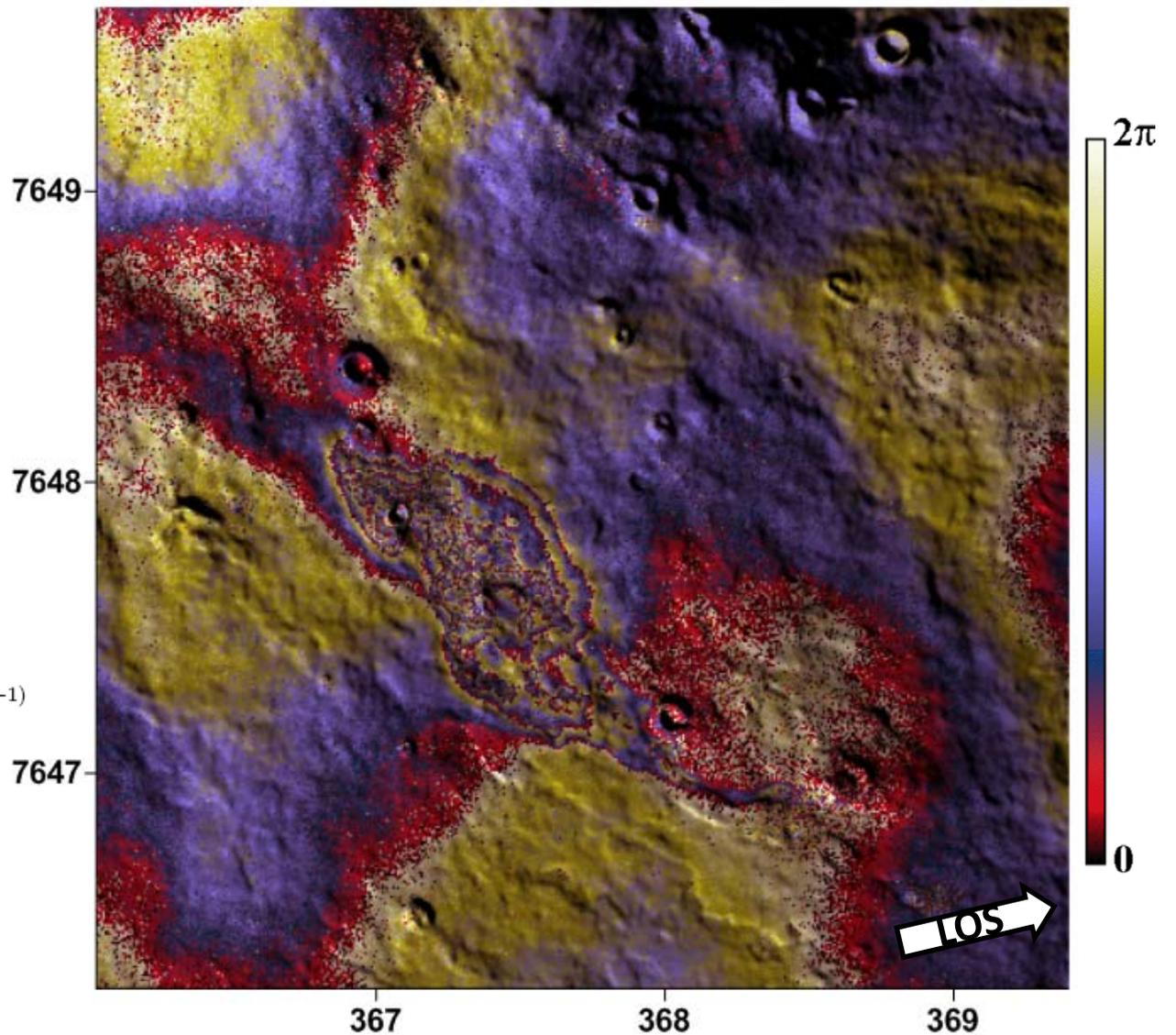


Detrending



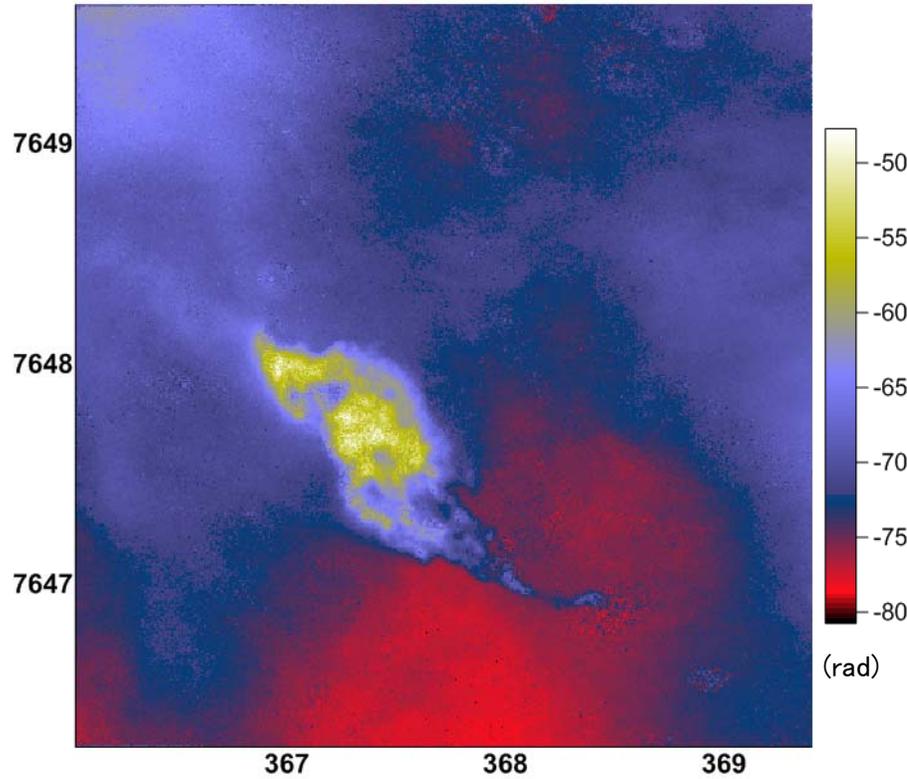
6 degree surface polynomial
(HI15_AR_20204_23522)

$$\phi(X, Y, Z) = \sum_{i=1}^q \sum_{j=1}^p \sum_{k=1}^r P_{ijk} X^{(i-1)} Y^{(j-1)} Z^{(k-1)}$$



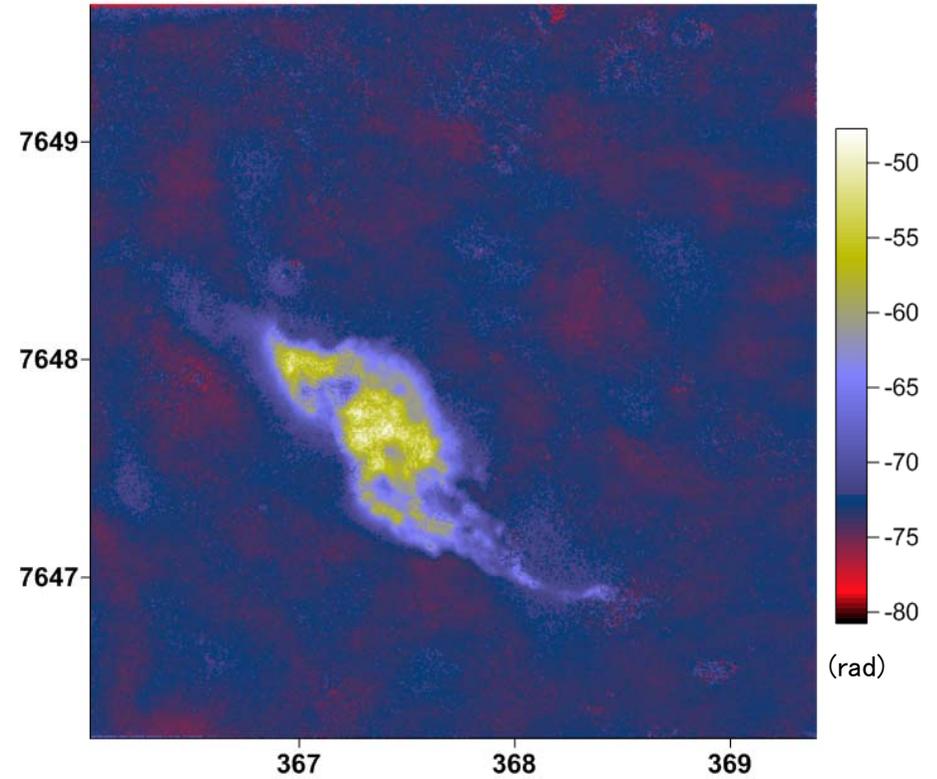
Detrending

Unwrapped Phase



HI15_AR_20204_23522
Duration: 224 days

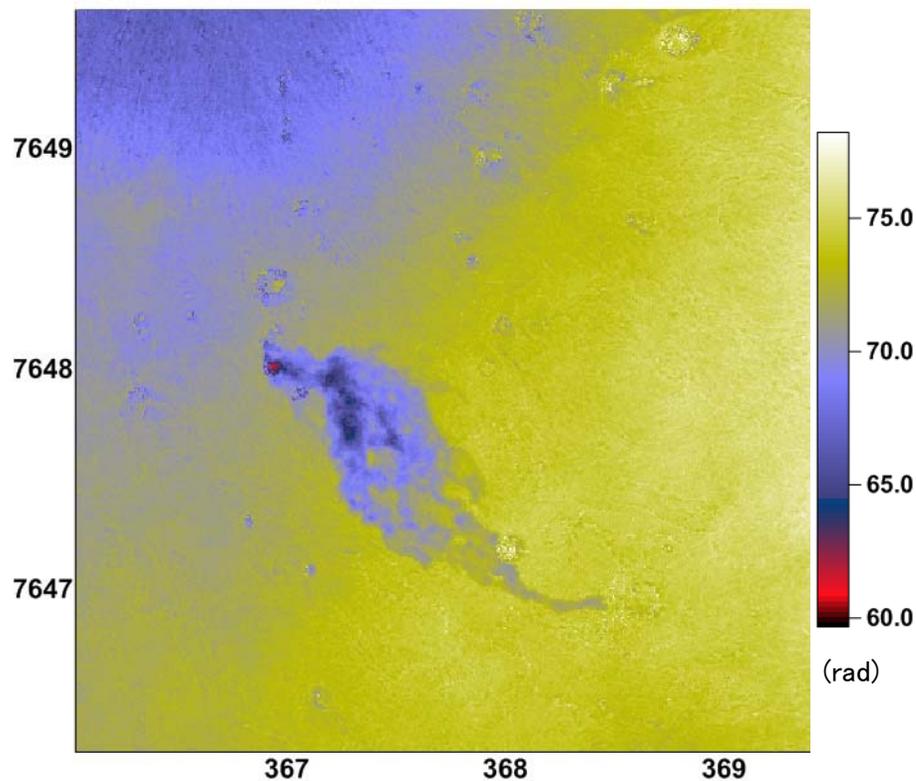
Detrended Unwrapped Phase



(March 03, 2011 to October 13, 2011)
|AA |: 223.59

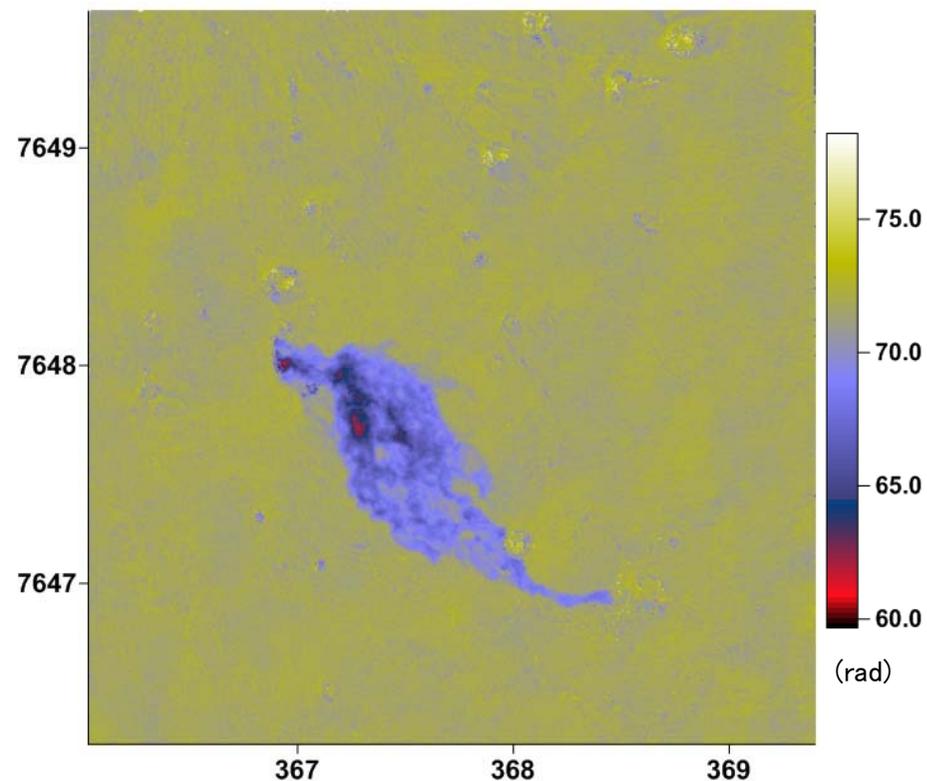
Detrending

Unwrapped Phase



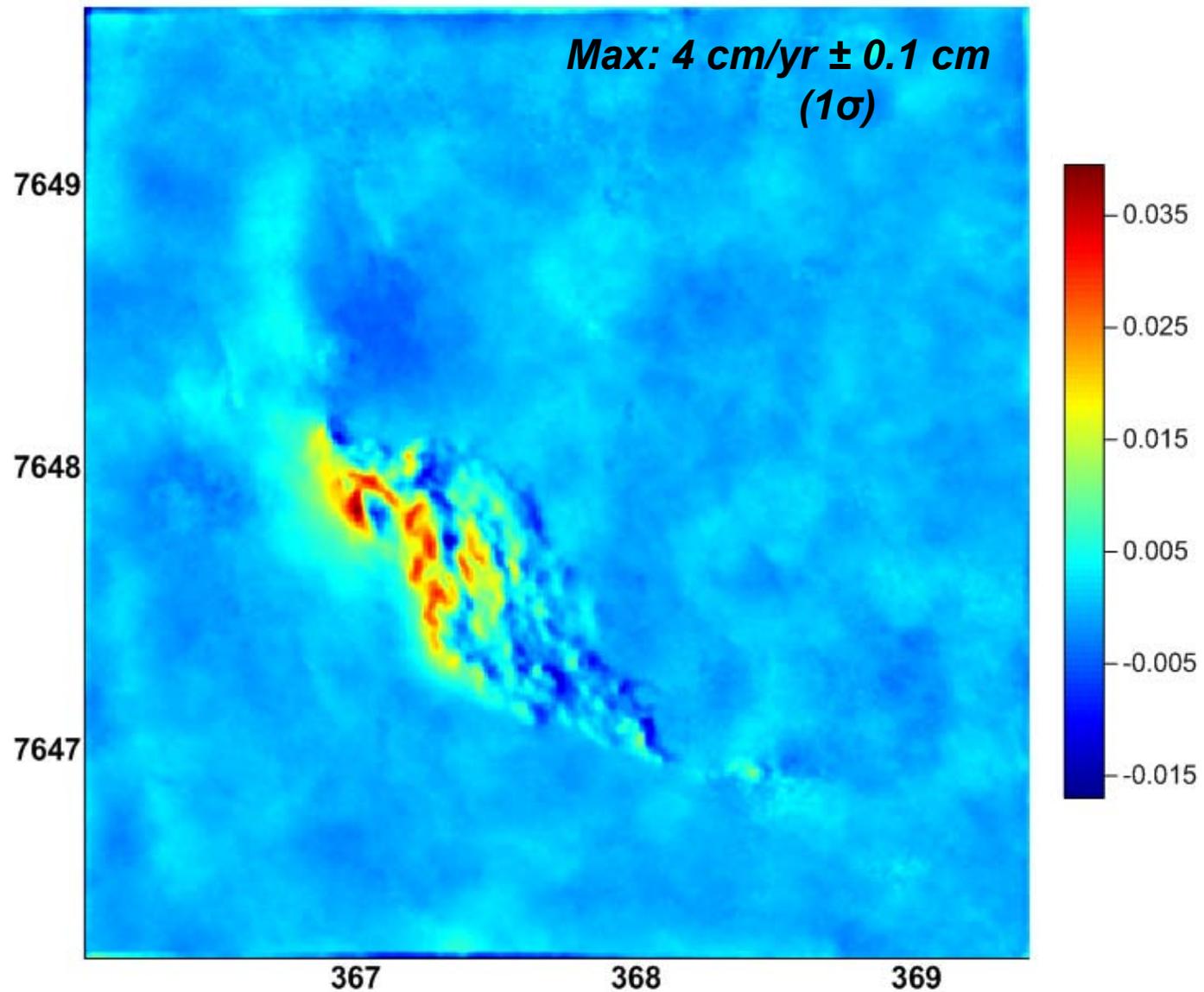
HI09_AR_23833_24070
Duration: 16 days

Detrended Unwrapped Phase

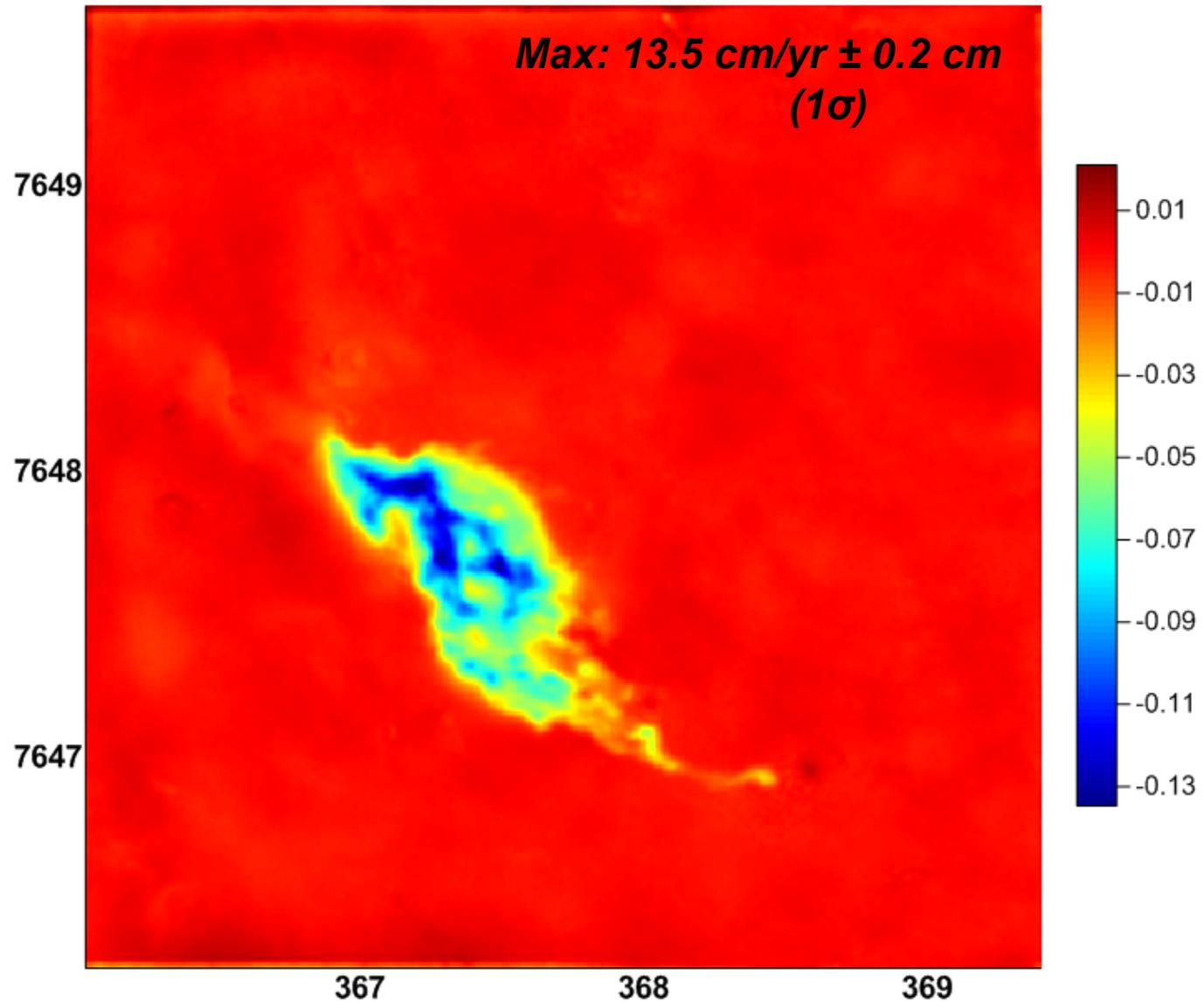


(Nov 03, 2011 to Nov 19, 2011)
|AA |: 10.64

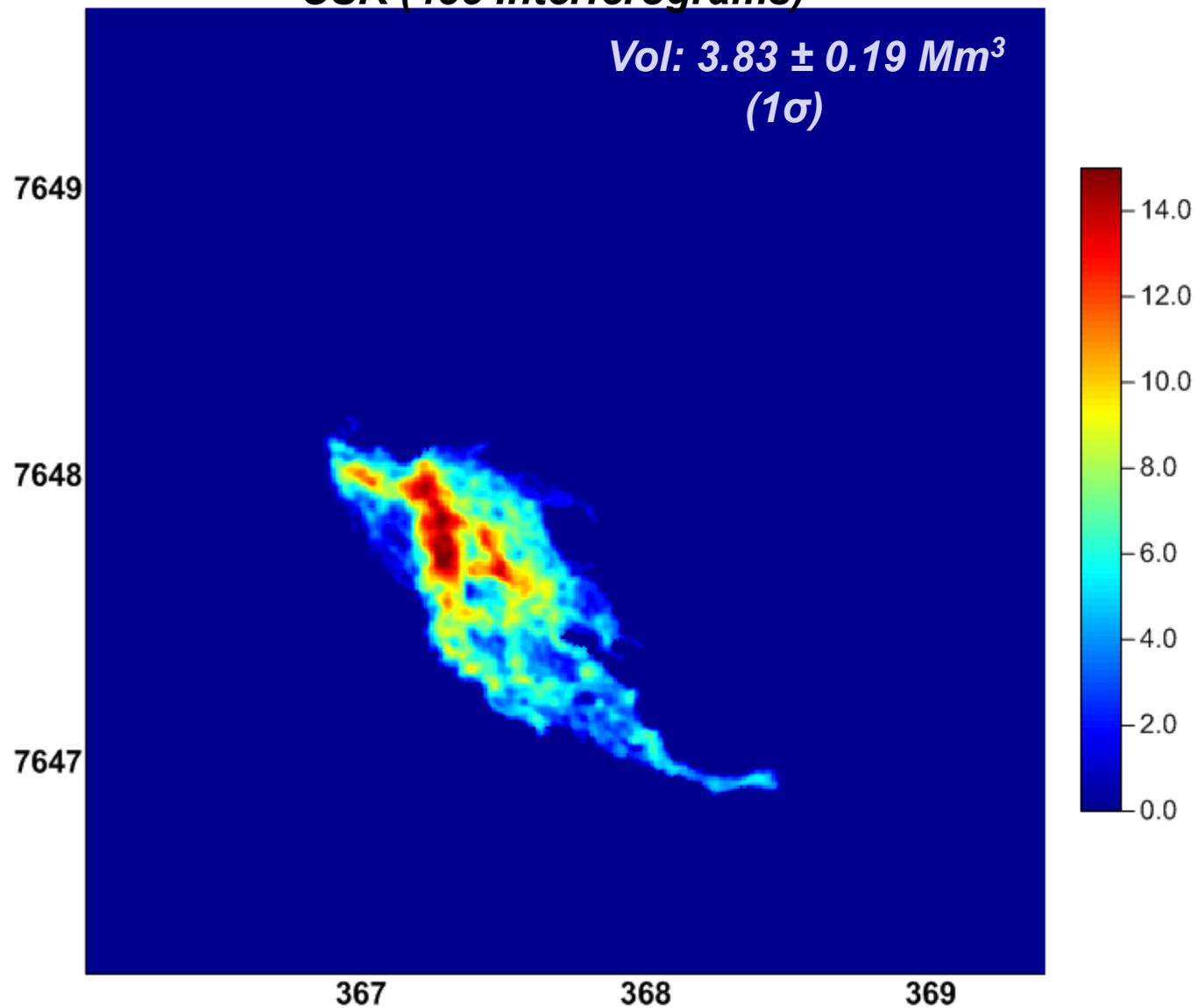
EW Displacement Rate



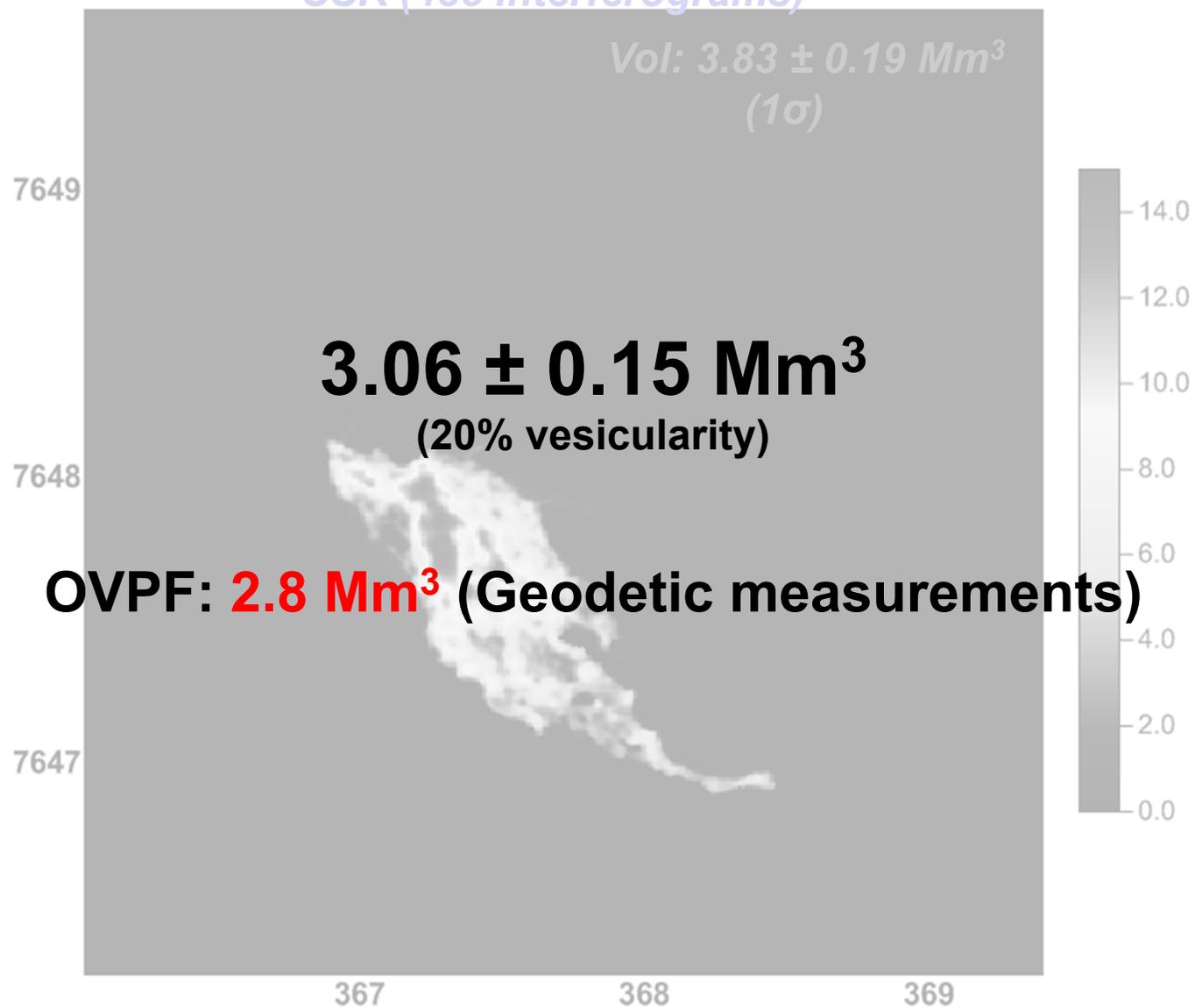
UD Displacement Rate



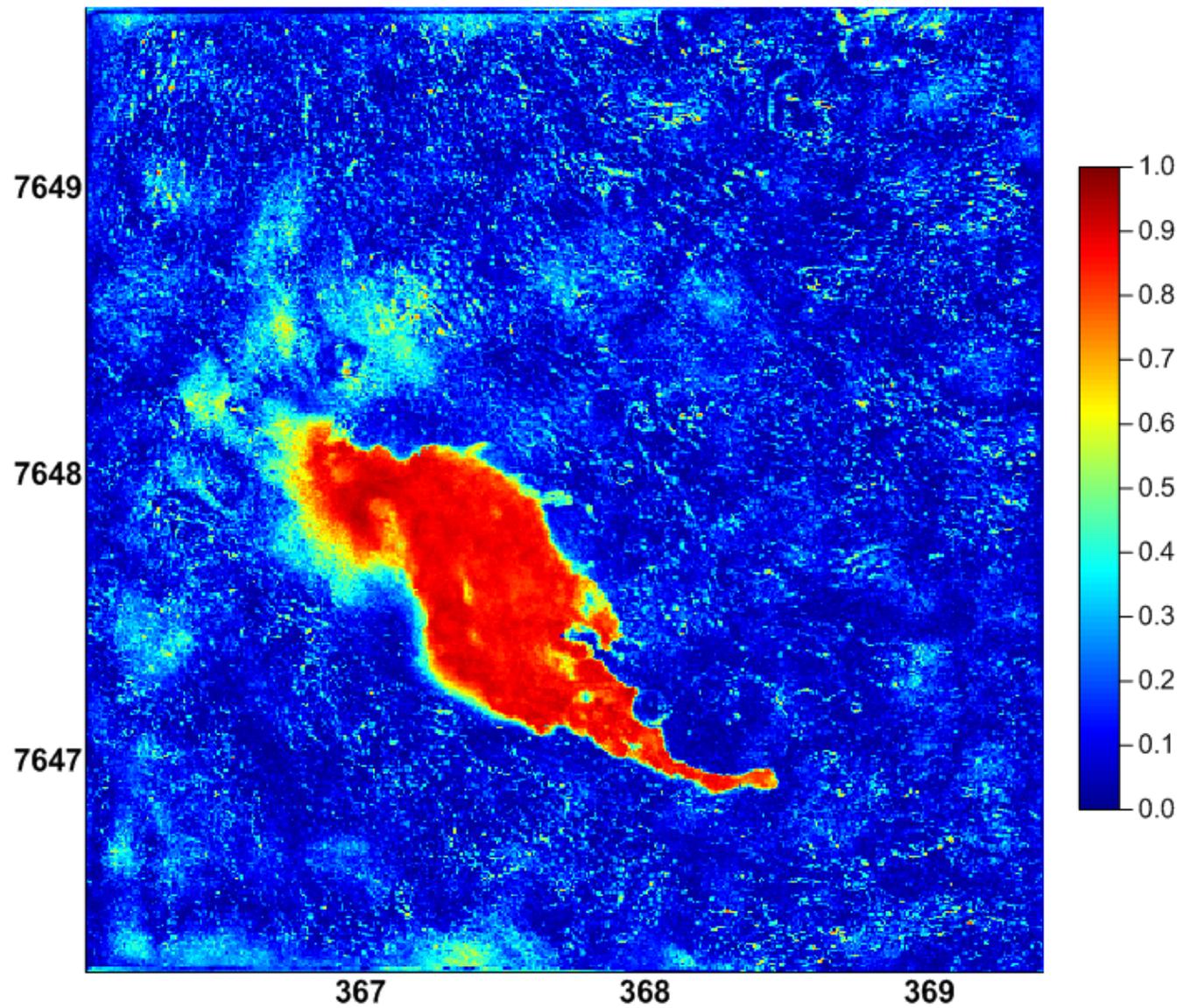
Derived Thickness Map CSK (435 Interferograms)



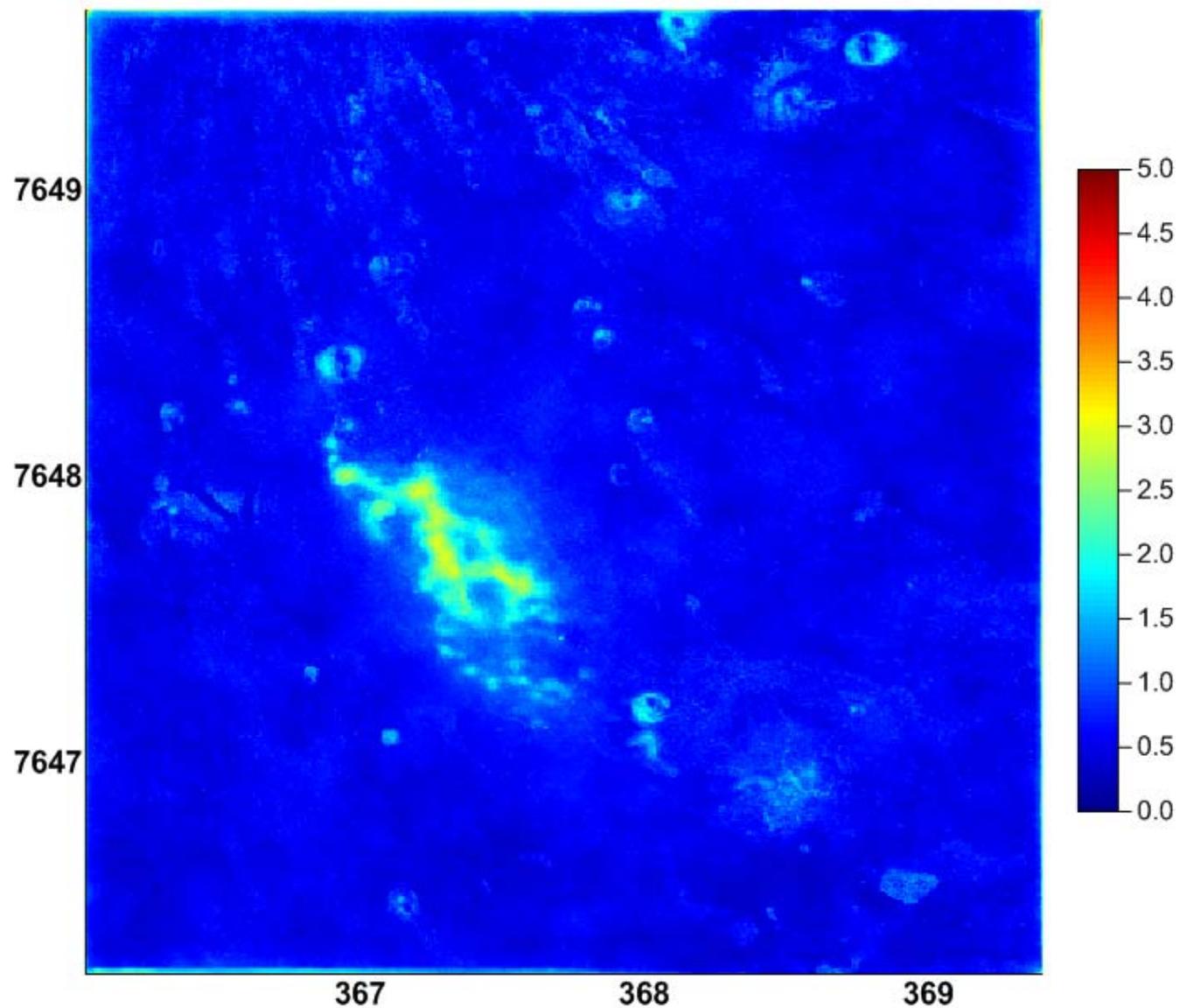
*Derived Thickness Map
CSK (435 Interferograms)*

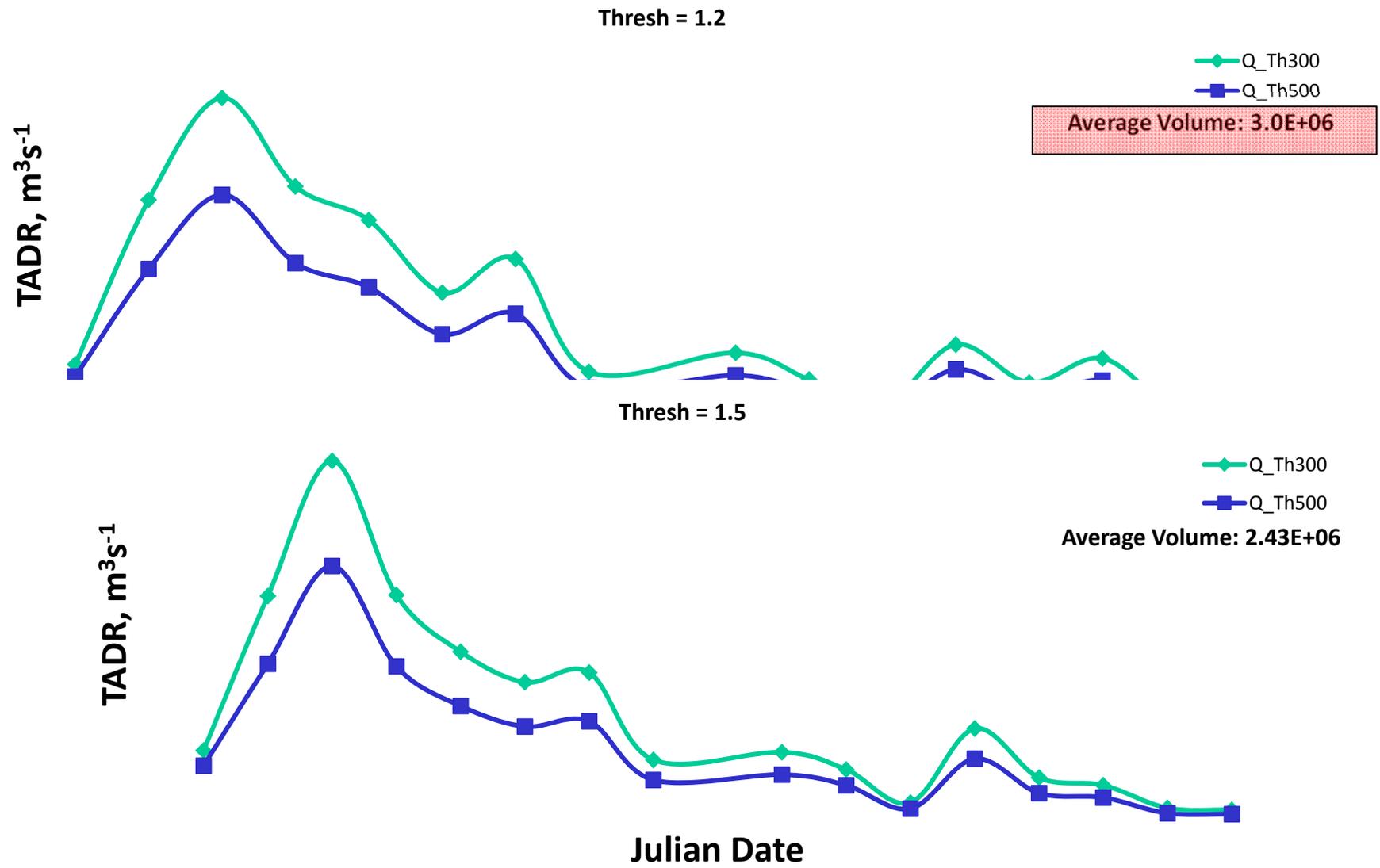


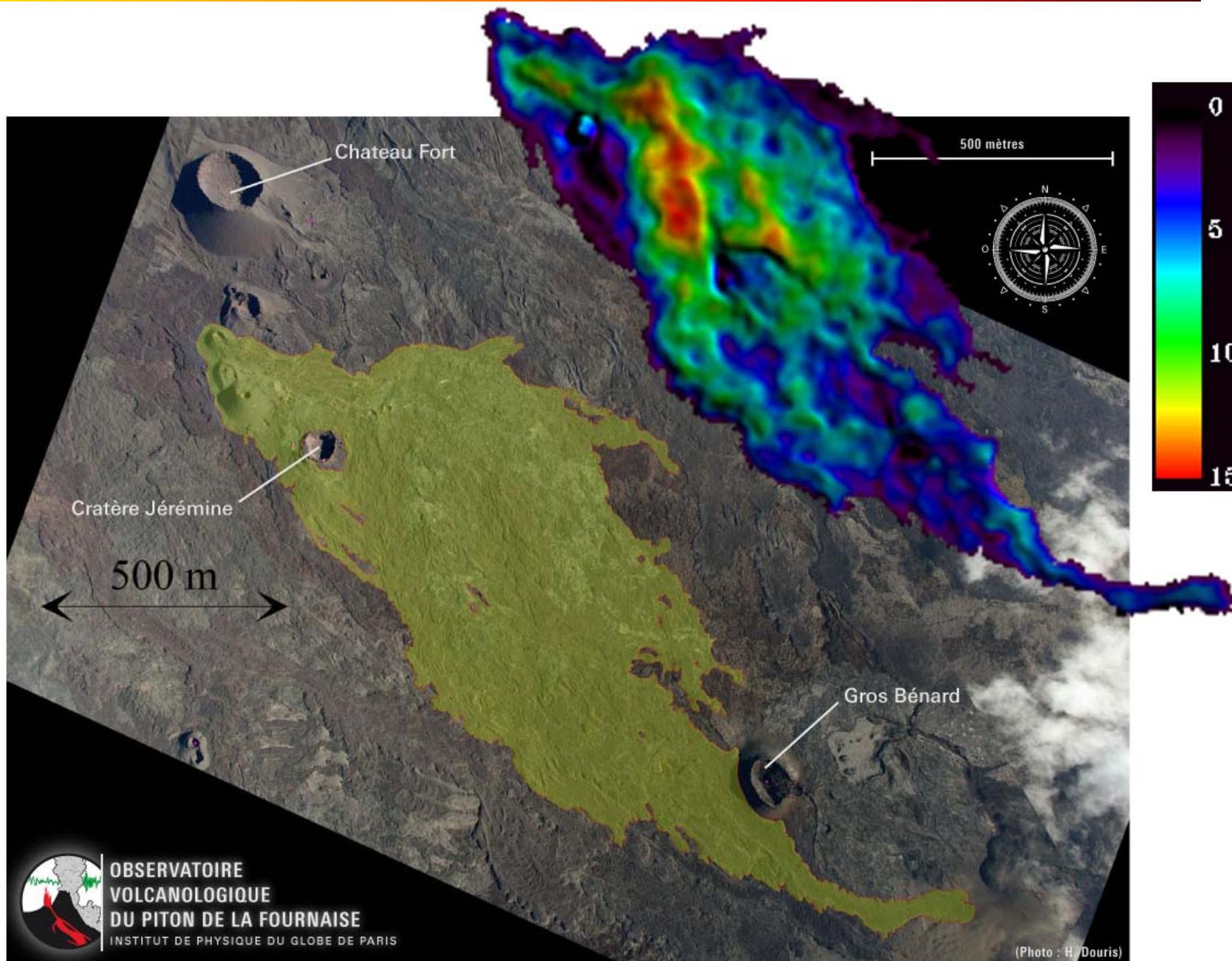
R²Map (Cosmo Skymed, 435 Interferos)

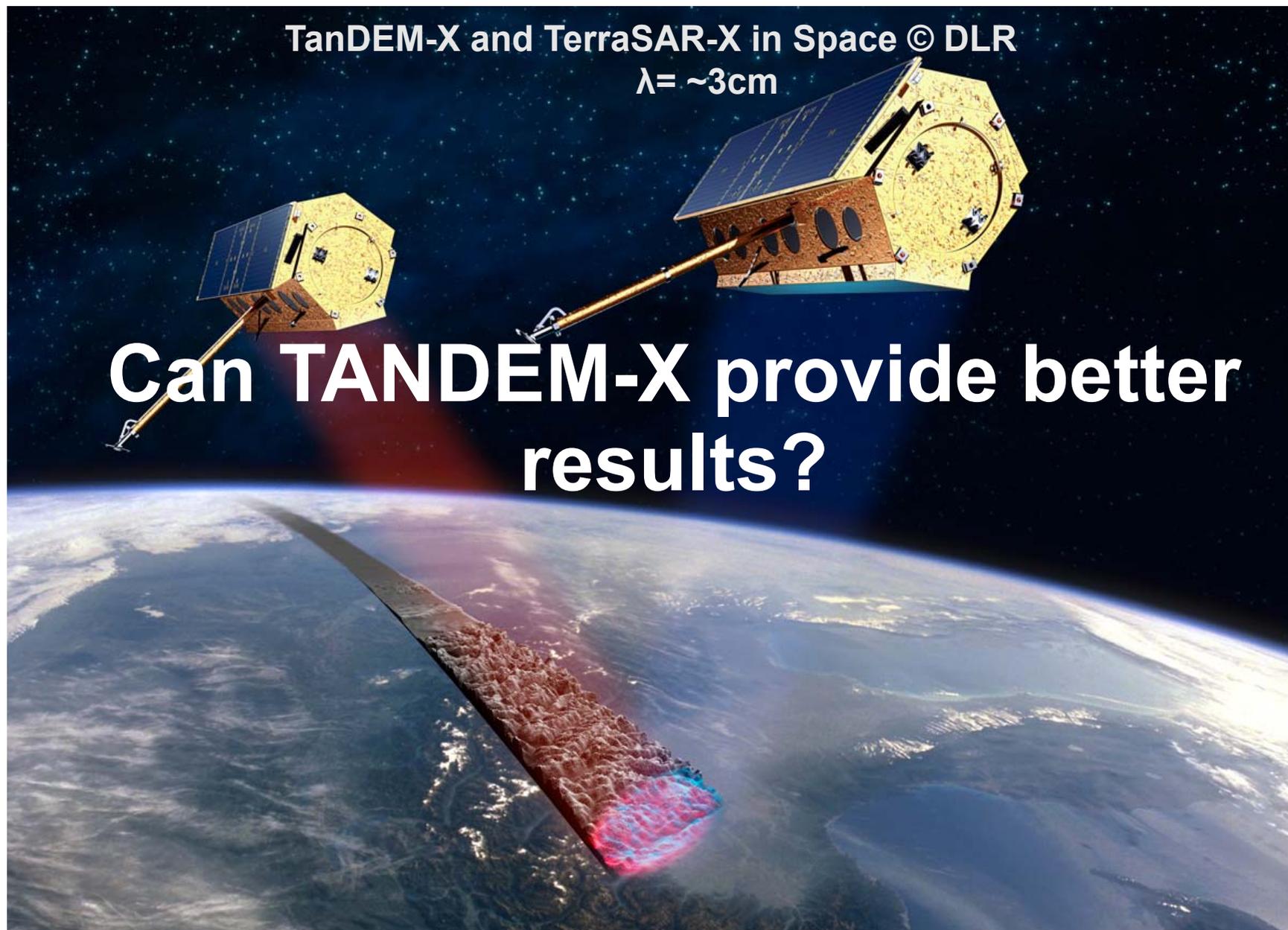


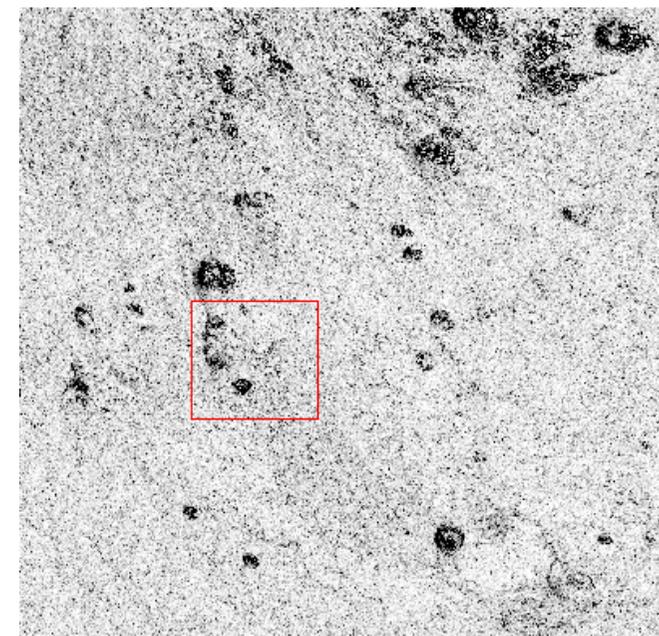
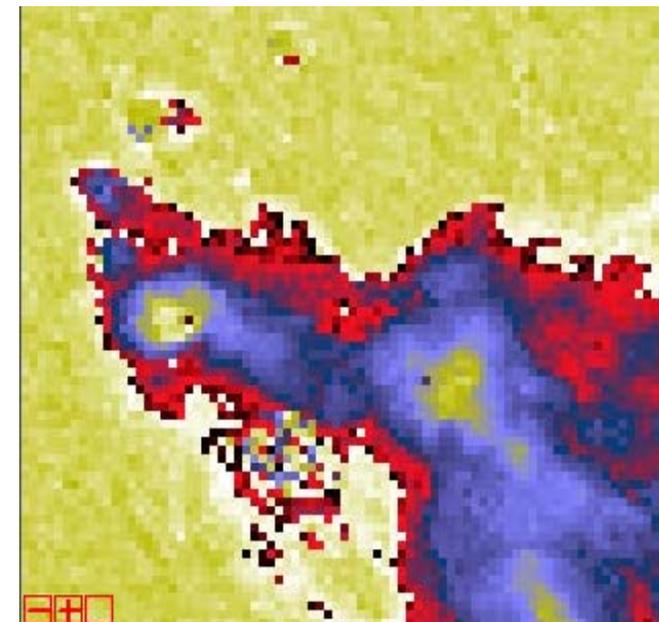
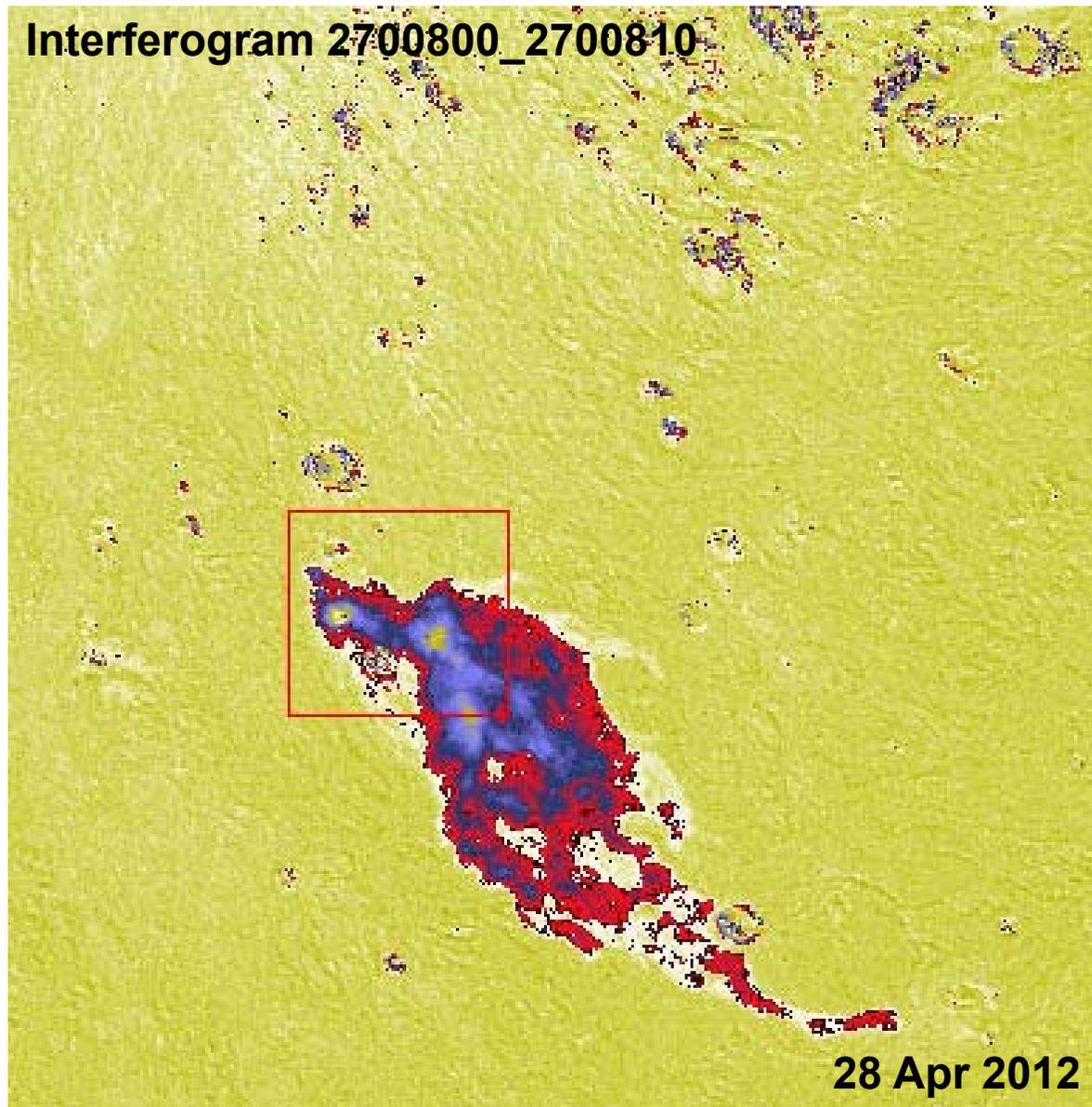
Misfit Map (Cosmo Skymed, 435 Interferos)

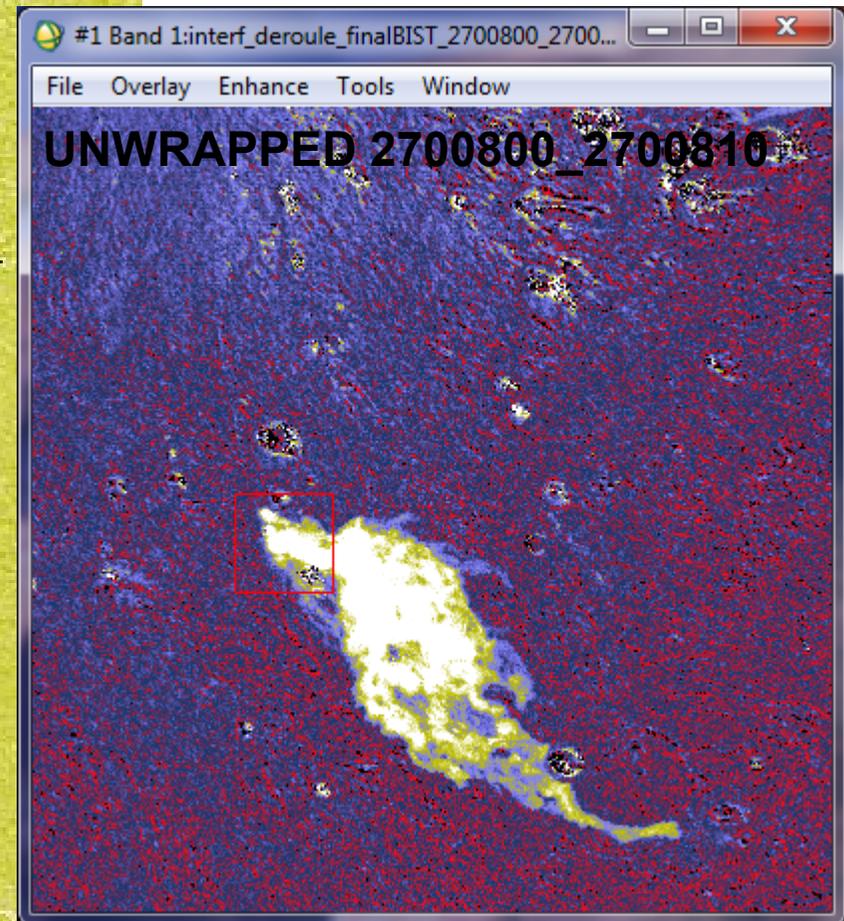
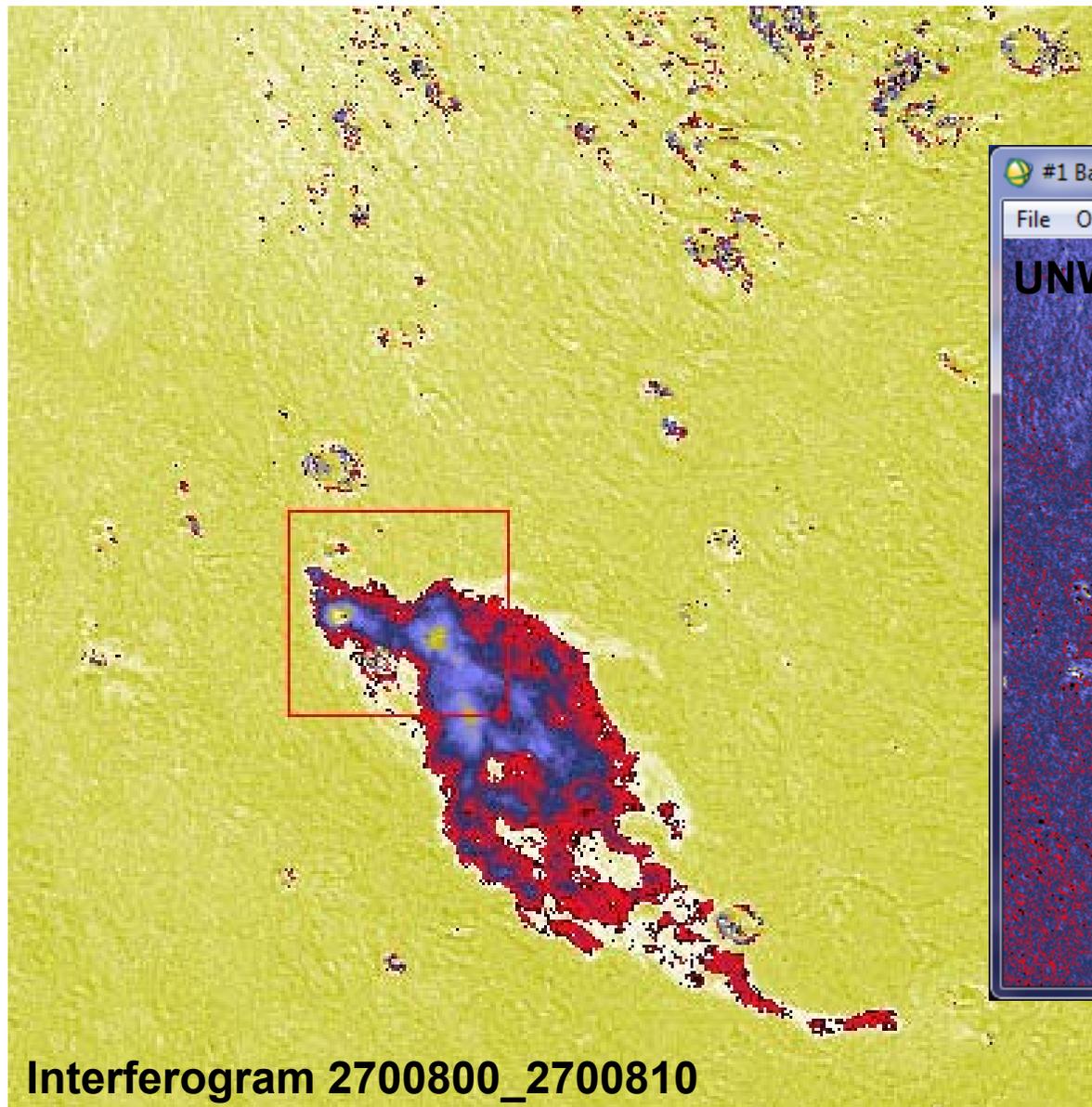


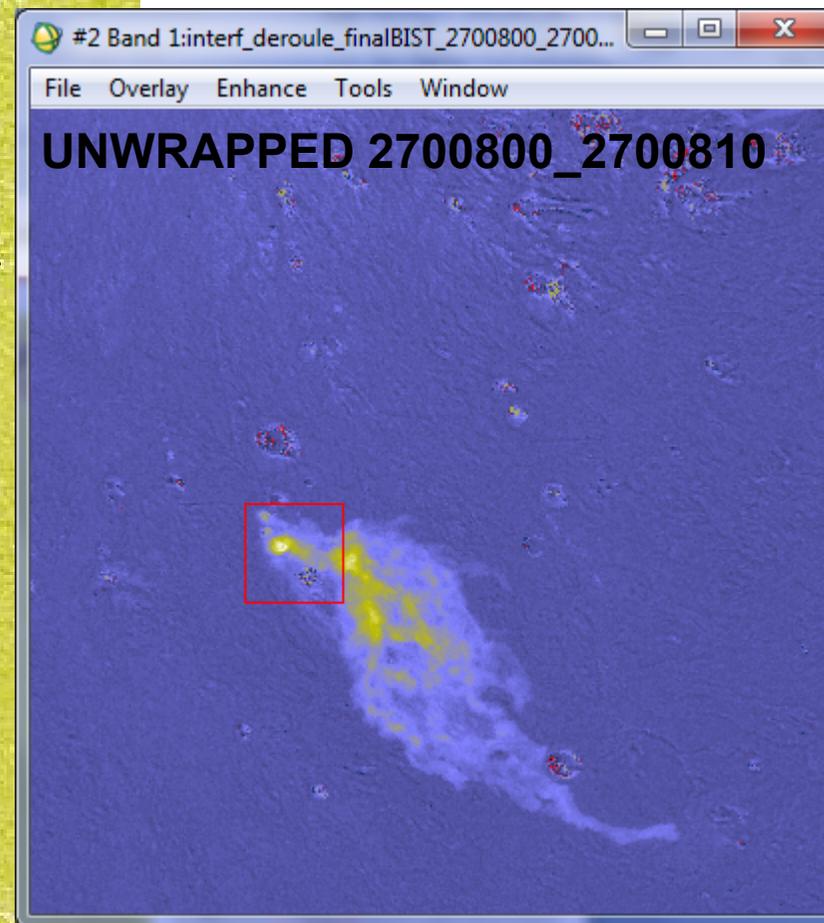
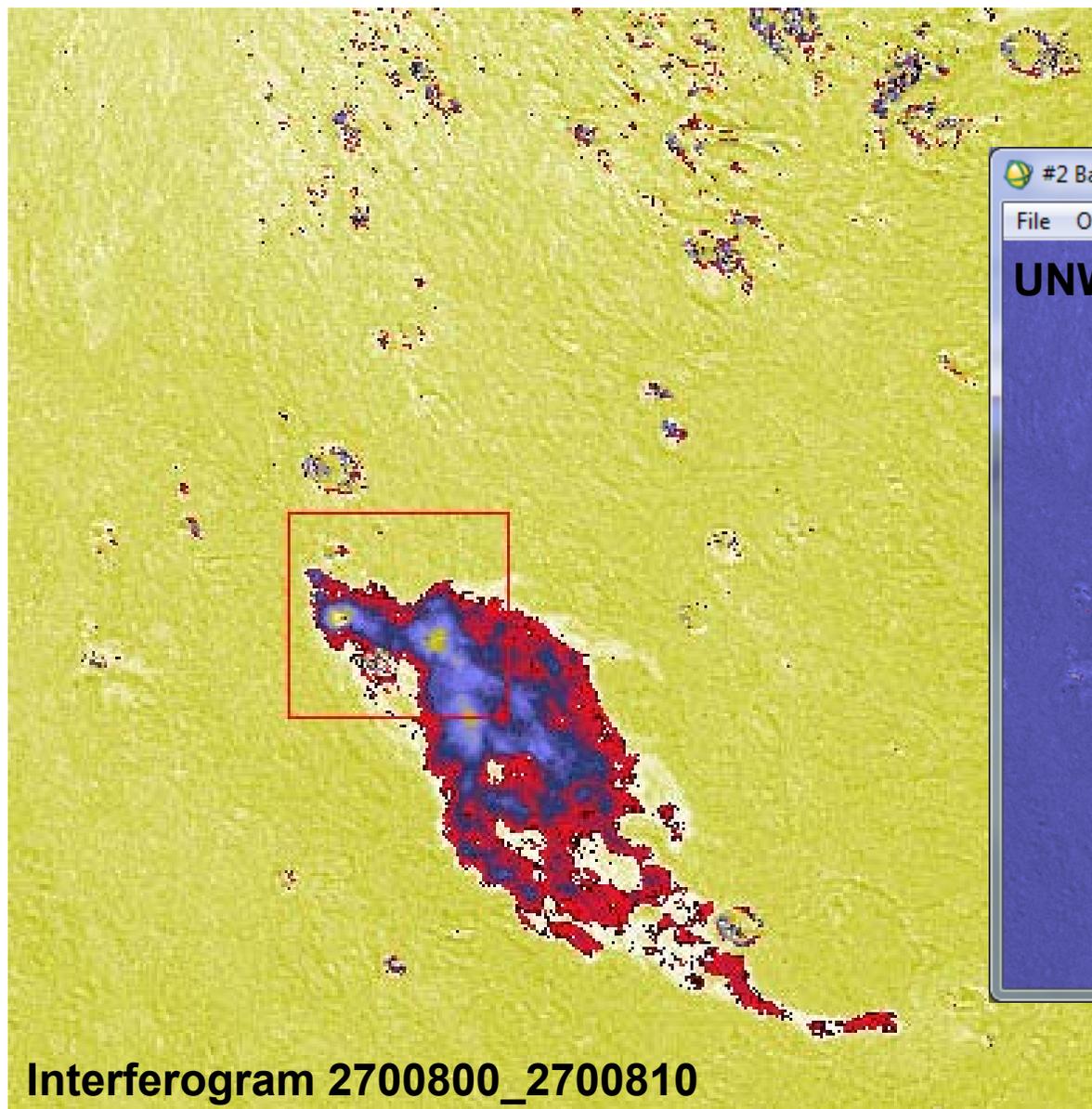


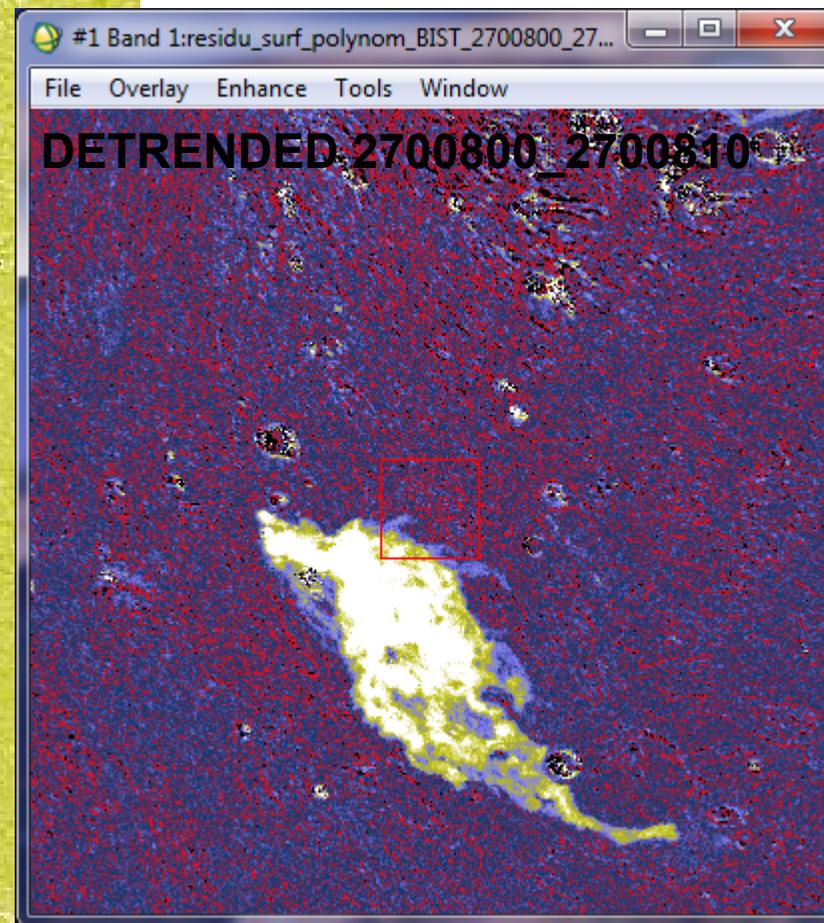
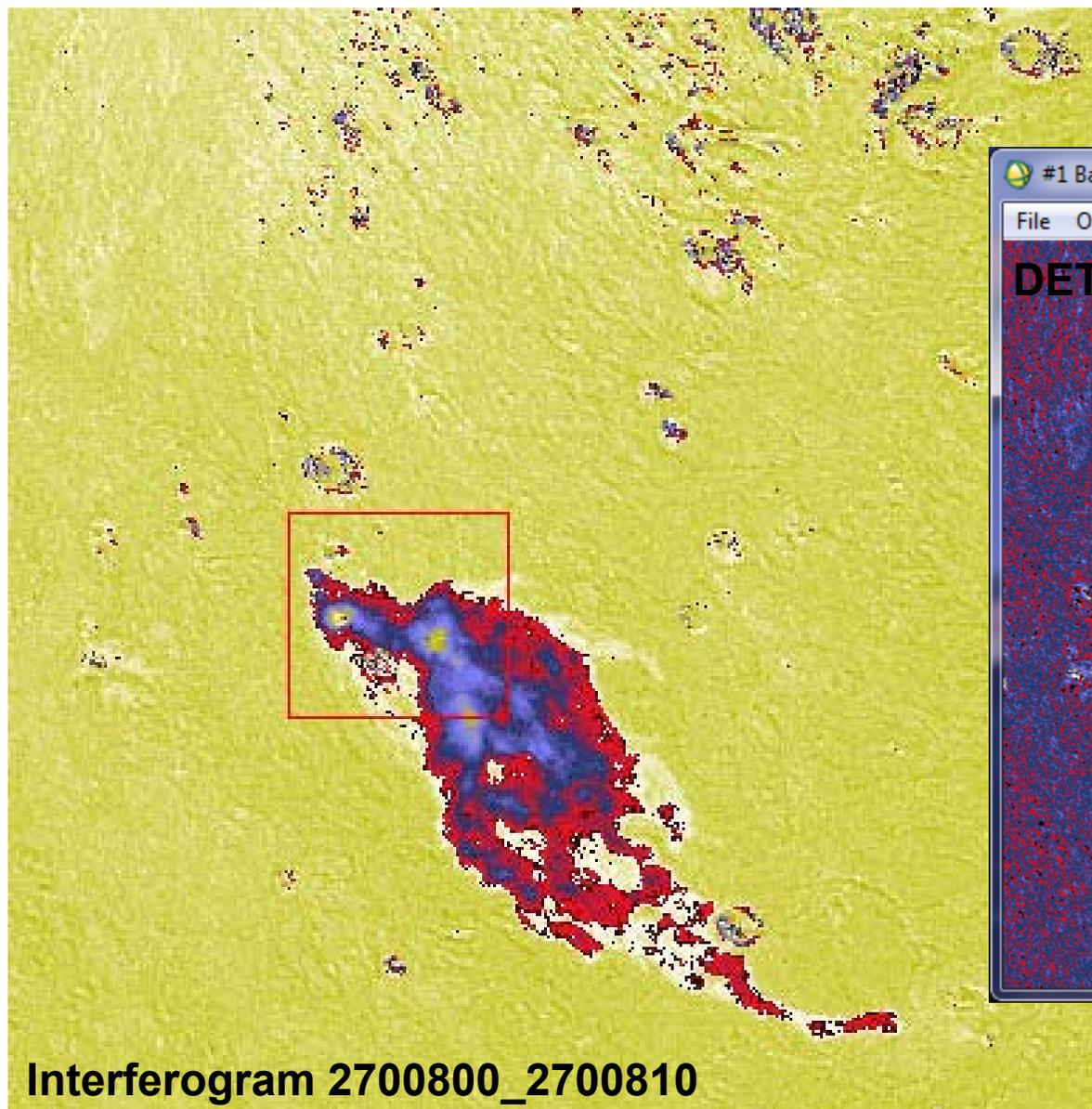


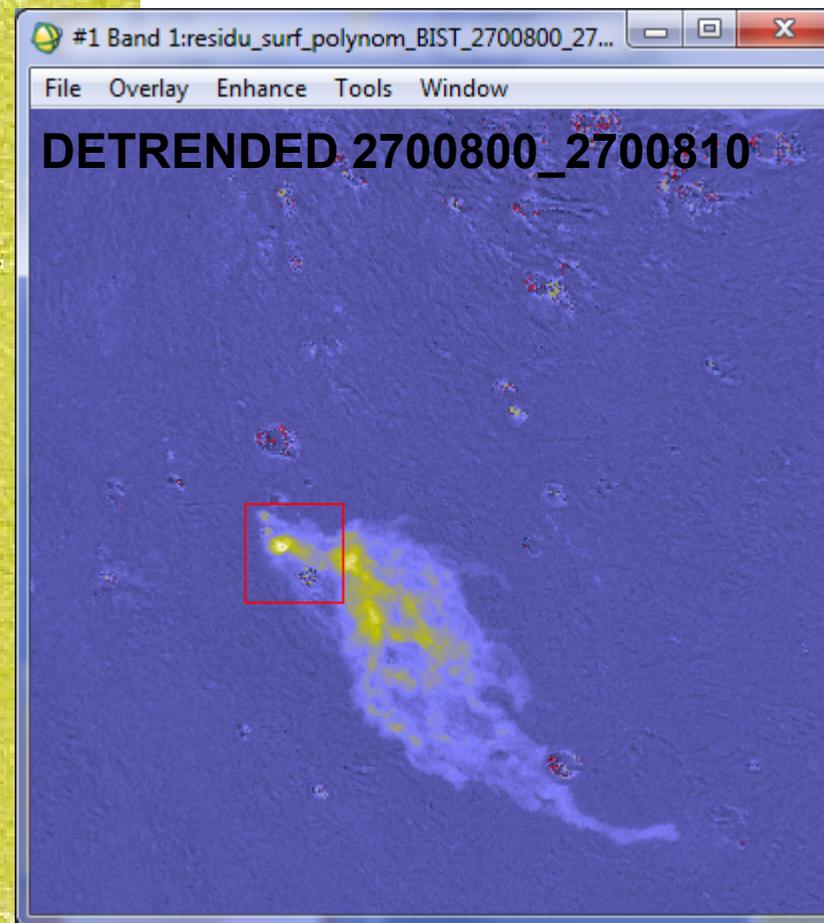
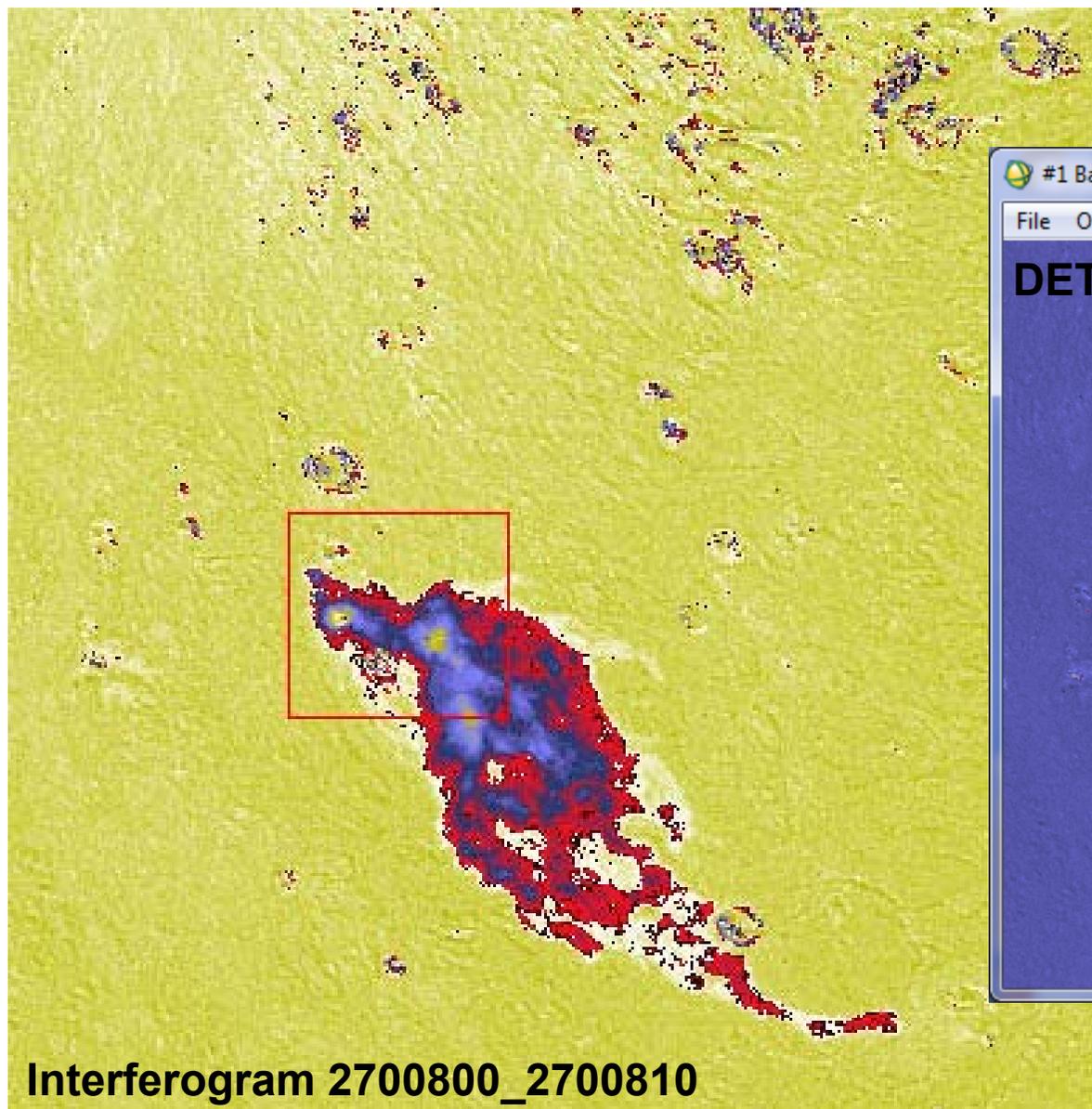






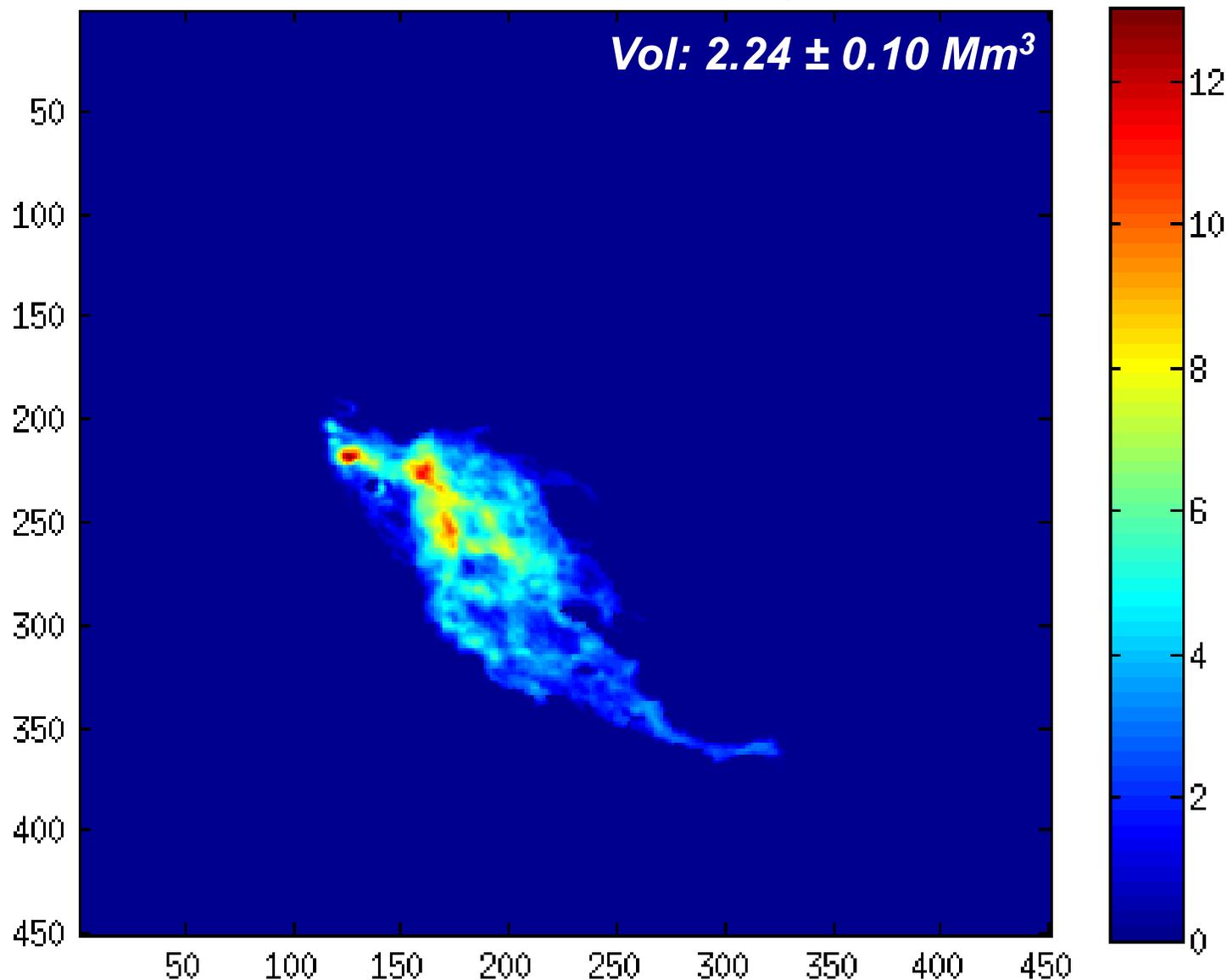






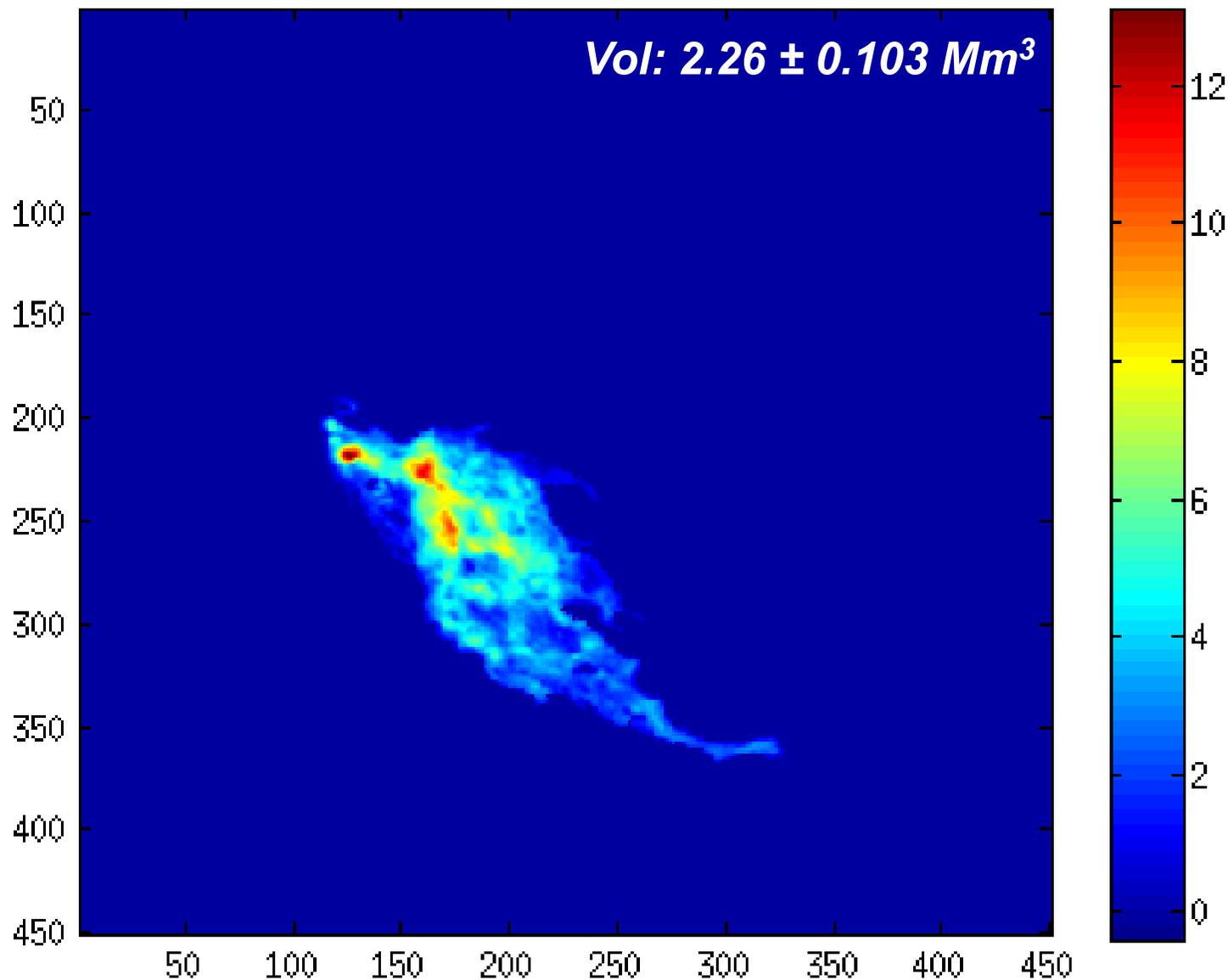
Derived Thickness Map:

TanDEM-X (41 interfero)



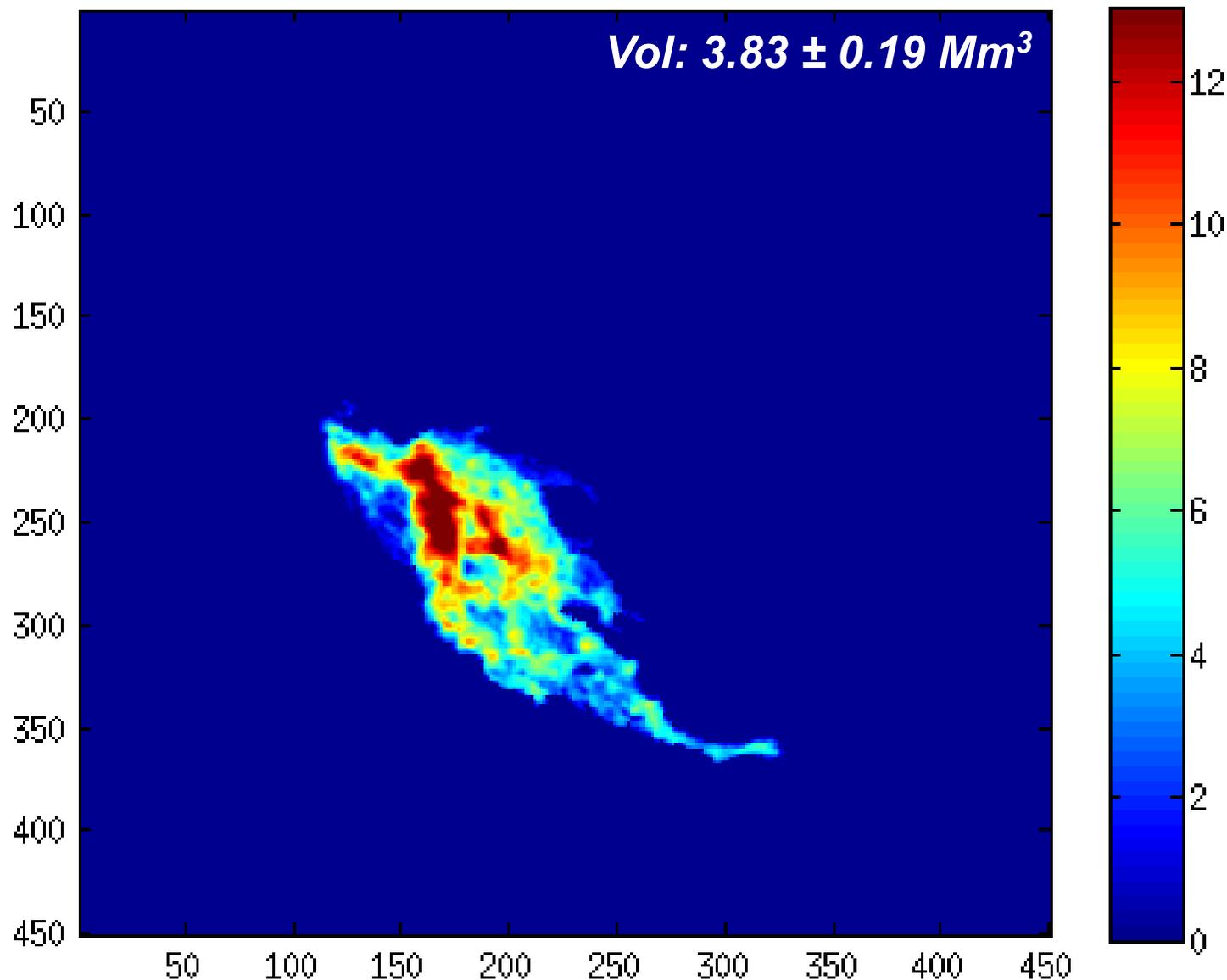
Derived Thickness Map:

TanDEM-X (AA and SNR filtered, 27 interfero)



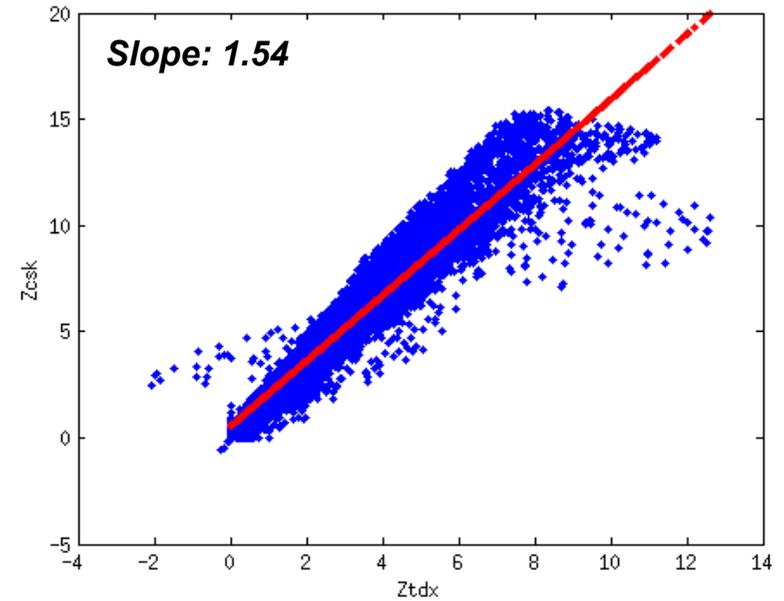
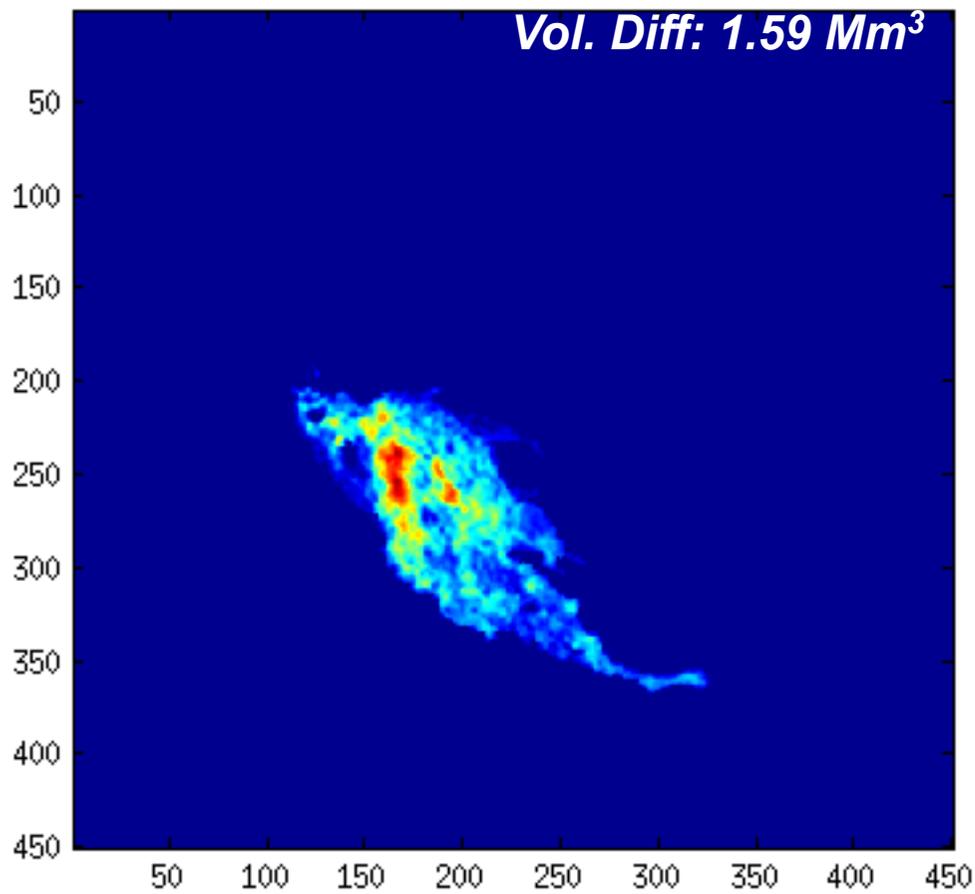
Derived Thickness Map:

Cosmo-SkyMed (435 interfero)



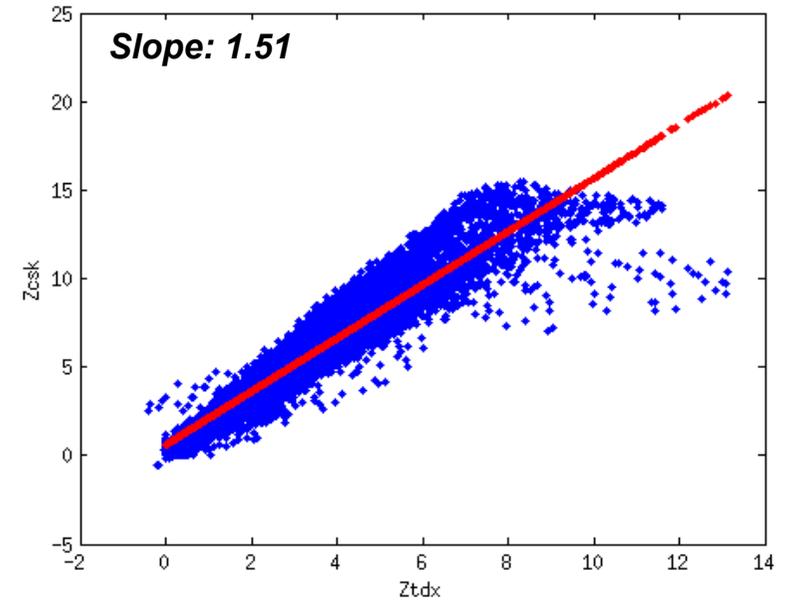
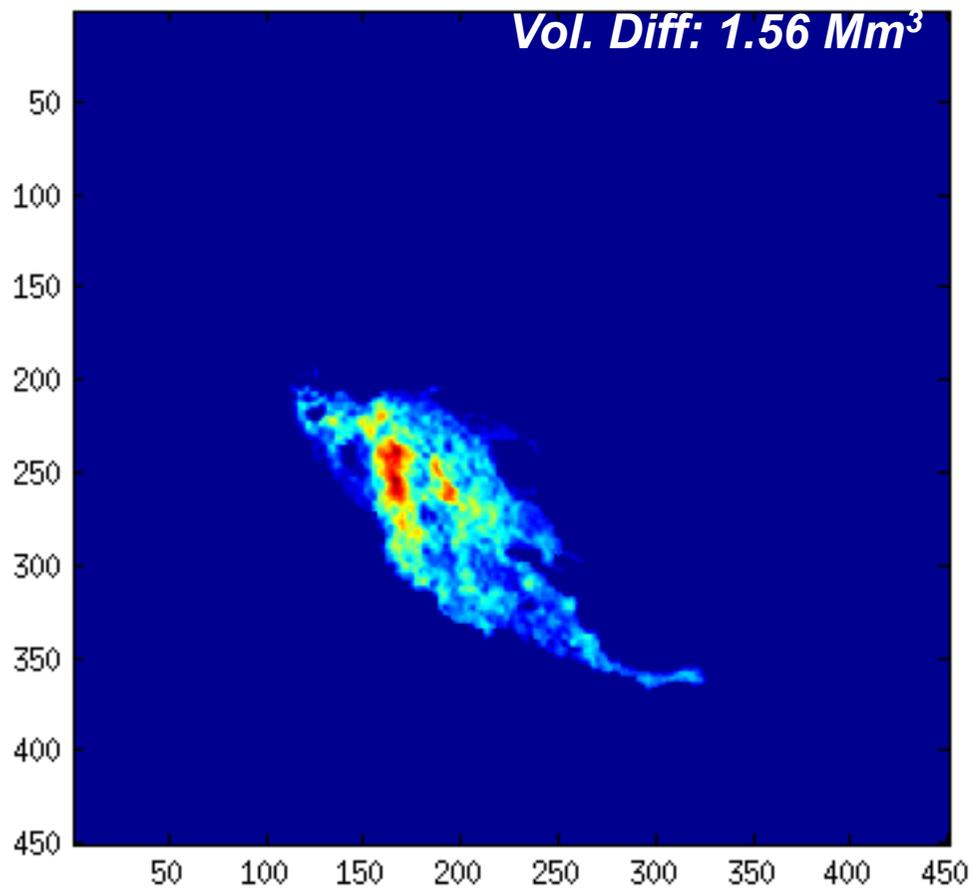
Difference in Thickness

CSK (435 images) vs. TDX (41 images)

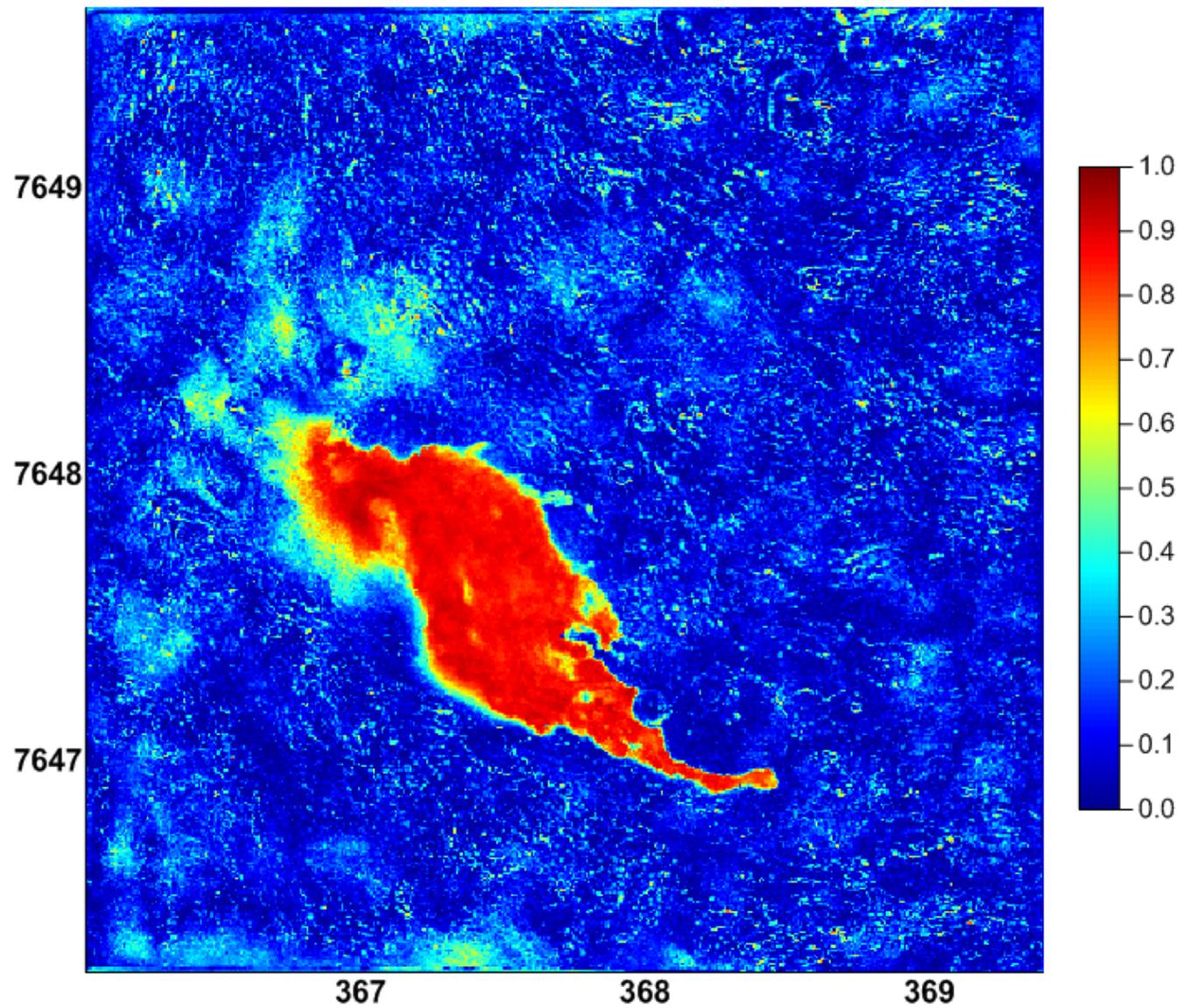


Difference in Thickness

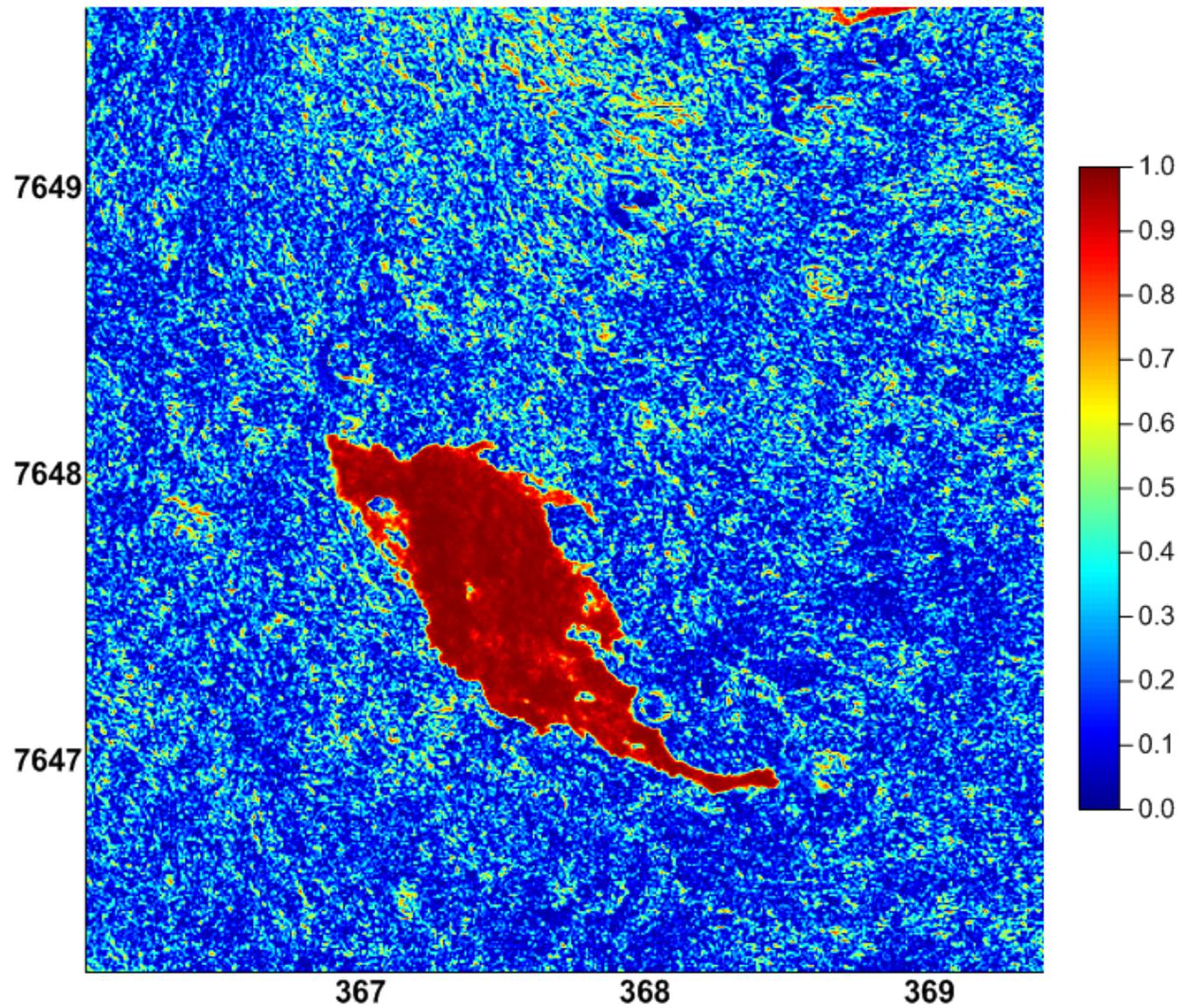
CSK (435 images) vs. TDX (27 images)



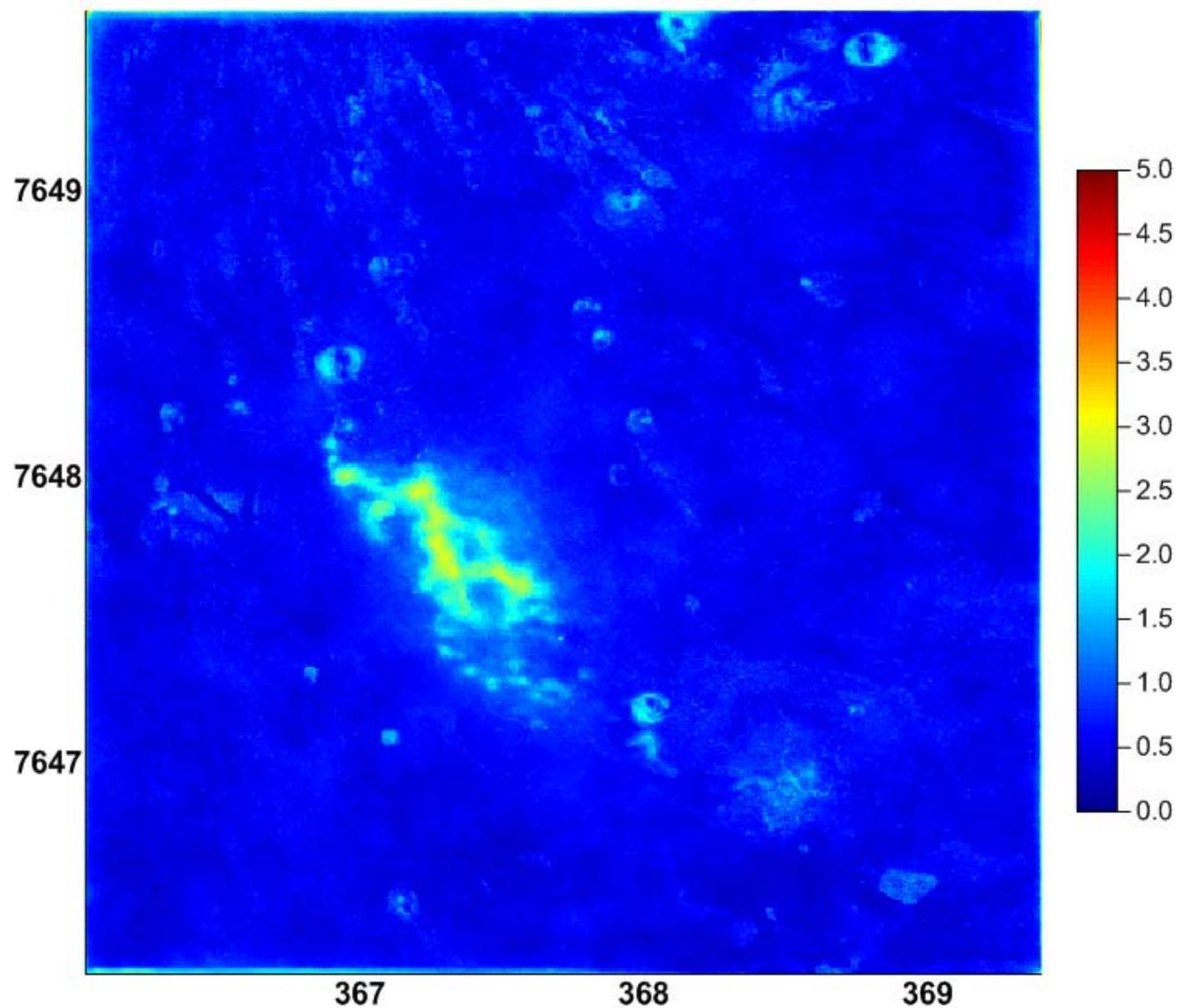
R²Map (Cosmo Skymed, 435 Interferos)



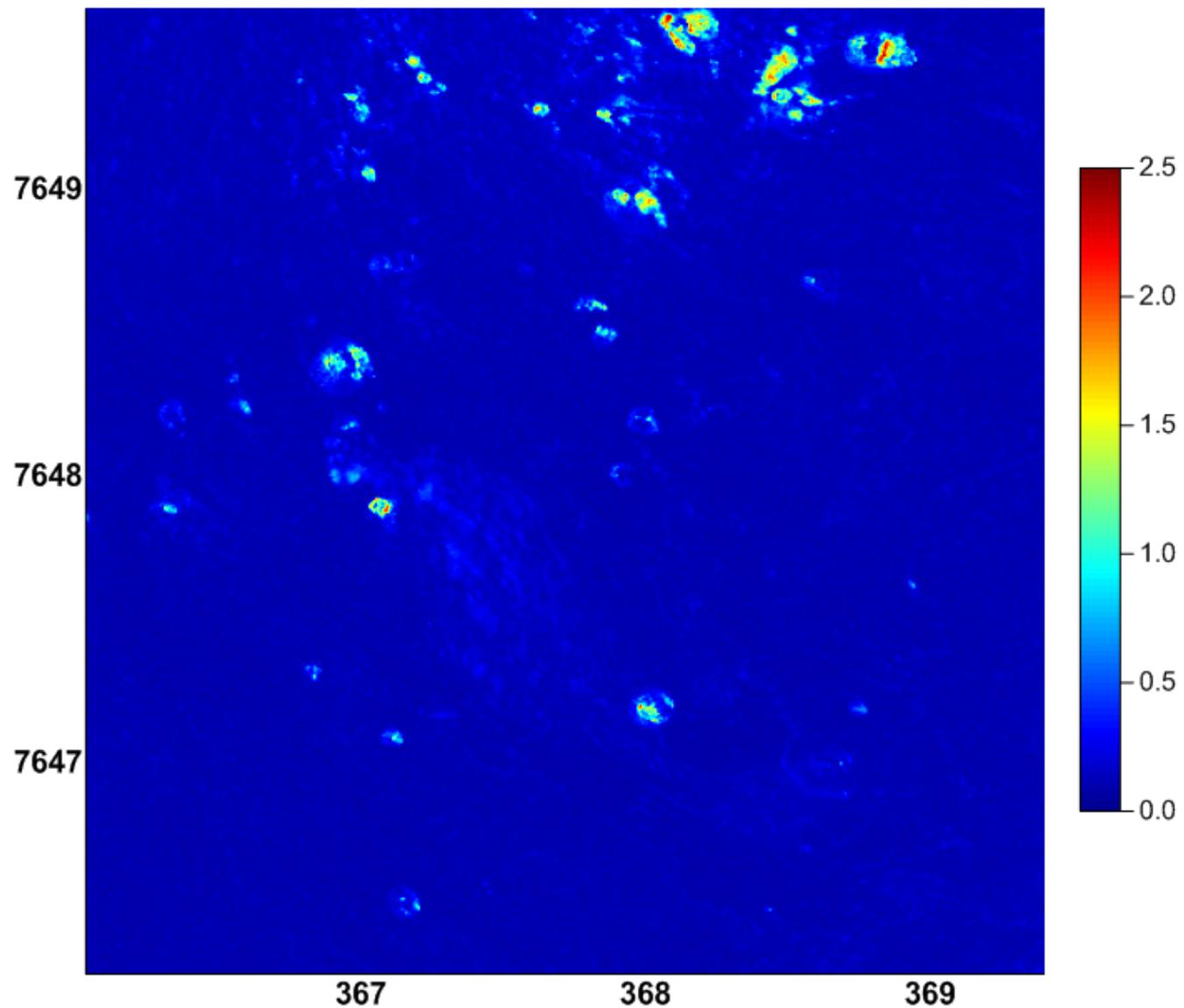
R²Map (Tandem-X, 27 Interferos)

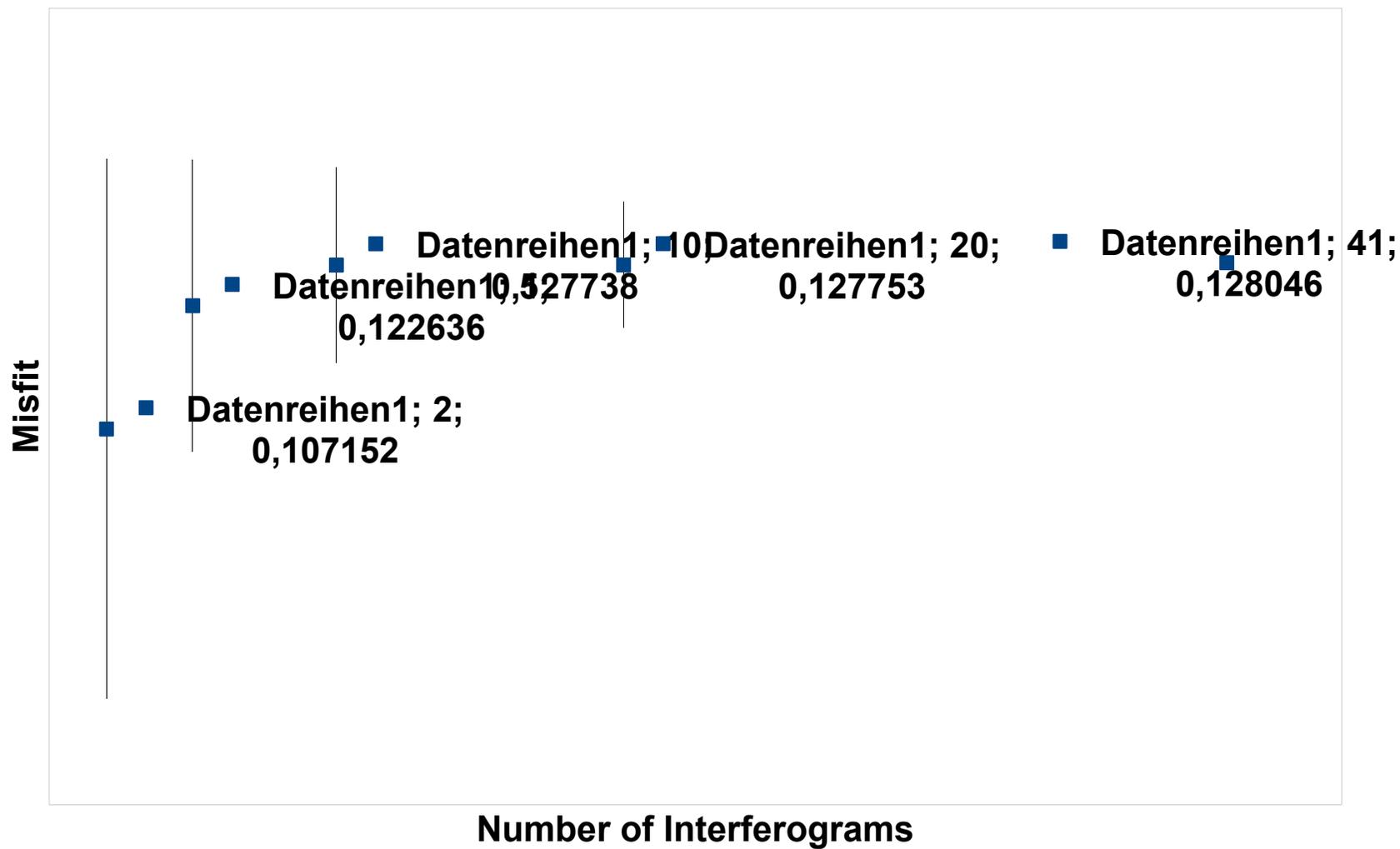


Misfit Map (Cosmo Skymed, 435 Interferos)



Misfit Map (Tandem-X, 27 Interferos)

















Thank you ! 😊

