

# Interferometric Processing of TerraSAR-X Spotlight and TanDEM-X images Using an Open-Source Platform

**Michael Jendryke**, Mingsheng Liao, Timo Balz, Lu Zhang

LIESMARS, Wuhan University, China



# Outline

- Open Source Software
- TanDEM-X processing
  - Modifications (Orbit, File format conver., Ref. phase)
  - Interferograms and ~~(Phase-unwrapping)~~
- Spotlight interferometry
  - Resampling
  - Linear Doppler-drift
- Conclusion

# Open Source Software - DORIS

**DORIS**

**TU Delft**  
Delft University of Technology

- Home
- Introduction
- Status
- Literature
- Download
- Brain Pool
- Links

The Delft Institute of Earth Observation and Space Systems of Delft University of Technology has developed an Interferometric Synthetic Aperture Radar (InSAR) processor named Doris (Delft object-oriented radar interferometric software). The Doris software can be downloaded *freely* from this site for non-commercial applications ([conditions](#)).

Interferometric products and endproducts such as Digital Elevation Models and displacement maps can be generated with this software from Single Look Complex data. Data from the satellites ERS, ENVISAT (first ENVISAT interferogram, 54kB, DEM, 107kB, and perspective view, 177kB), JERS (first JERS interferogram), and RADARSAT (first RADARSAT interferogram) can be processed with the Doris software.

**Introduction** - 24 December 2008  
Introduction to interferometric processing with the Doris software.

**Status** - 24 December 2008  
What's the current status of these pages and the Doris software.

**Literature** - 24 December 2008  
Online publications and InSAR references  
[FRINGE 2009 presentation](#)  
[BAM Earthquake processing overview](#)  
[Searchable InSAR literature](#) (bibtex file with ~2100 entries).

**Download** - 13 March 2012  
Access to the Doris software  
[User manual](#) (html - v4.02.)  
[User manual](#) (pdf - v4.02 changelog)  
[User manual](#) (pdf in Chinese - v3.16)

**Brain Pool** - 17 February 2010  
Experienced users help answer questions from new users and processing strategies are discussed. We encourage you to join this list when you are using the Doris software. Users of other software packages are also welcome to join this list, in order to have as broad a platform as possible.  
Join the [email list](#)  
[FAQ for Doris](#) (Yahoo! group, member of aforementioned list to automatically collect all emails in a searchable archive).

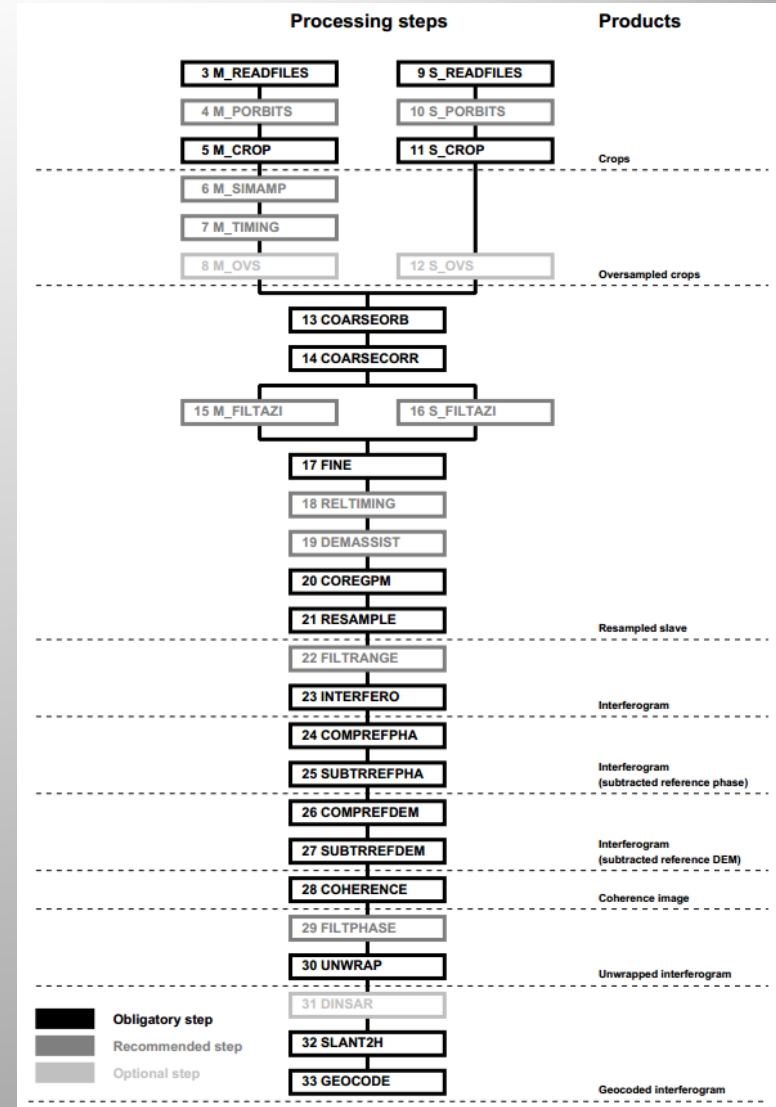
**Links** - 24 December 2008  
Interesting links.

Google

WWW  Doris pages

This page is maintained by [TUDelft - MGP Radar Group](#), mail to: [doris\\_users@tudelft.nl](mailto:doris_users@tudelft.nl)

Disclaimer: These pages contain links to sites outside DUT. We do not take responsibility for the contents of those sites.



DORIS offers a complete InSAR processing chain from SLC to coherence images for common SAR sensors

June 2013 - Michael Jendryke (5. TerraSAR-X / 4. TanDEM-X Science Team Meeting)

# Open Source Software - DORIS

```
michael@michael-VirtualBox: ~
File Edit View Search Terminal Help
20130606-15:10:41 5 michael@michael-VirtualBox:~$
/home/michael/GeoTools/DEVELOPMENT/doris_v4.06beta/trunk/bin/doris

INFO      : @(#)Doris InSAR software, $Revision: 4.06.2 $, $Author: TUDelft $

***      **      *      *      *
* *      * *      * *      * *
* *      * *      * *      * *
* *      * *      * *      * *
***      **      * *      * *

Program: "/home/michael/GeoTools/DEVELOPMENT/doris_v4.06beta/trunk/bin/doris" version 4.06-beta2 (28-12-2011)
        build      Fri Sep 21 05:37:40 2012
Interferometric processor for SAR SLC data.

(c) 1999-2012 Delft University of Technology, the Netherlands.

SYNOPSIS:
/home/michael/GeoTools/DEVELOPMENT/doris_v4.06beta/trunk/bin/doris infile | -h [searchterm] | -v | -c | -q

infile:      input file for /home/michael/GeoTools/DEVELOPMENT/doris_v4.06beta/trunk/bin/doris
-h [term]:   call "helpdoris" (script with searchable help)
-c:          return copyright notice.
-q:          return random quote (not so random).
-v:          return version number.

LIBRARIES (used): fftw-3.3.2

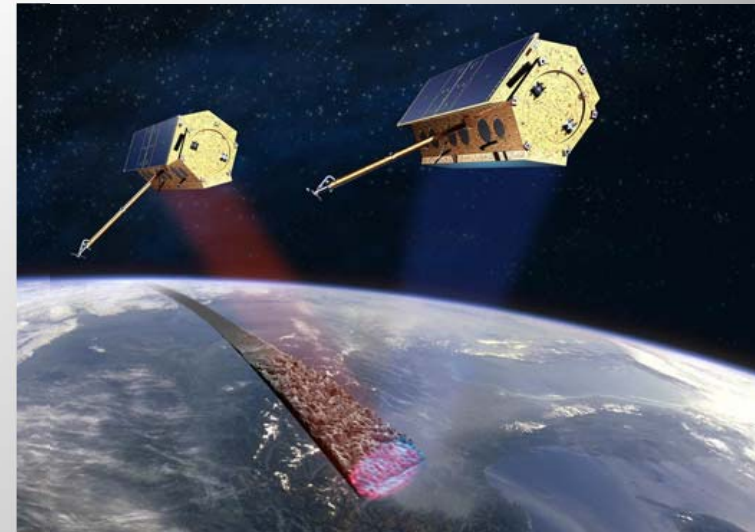
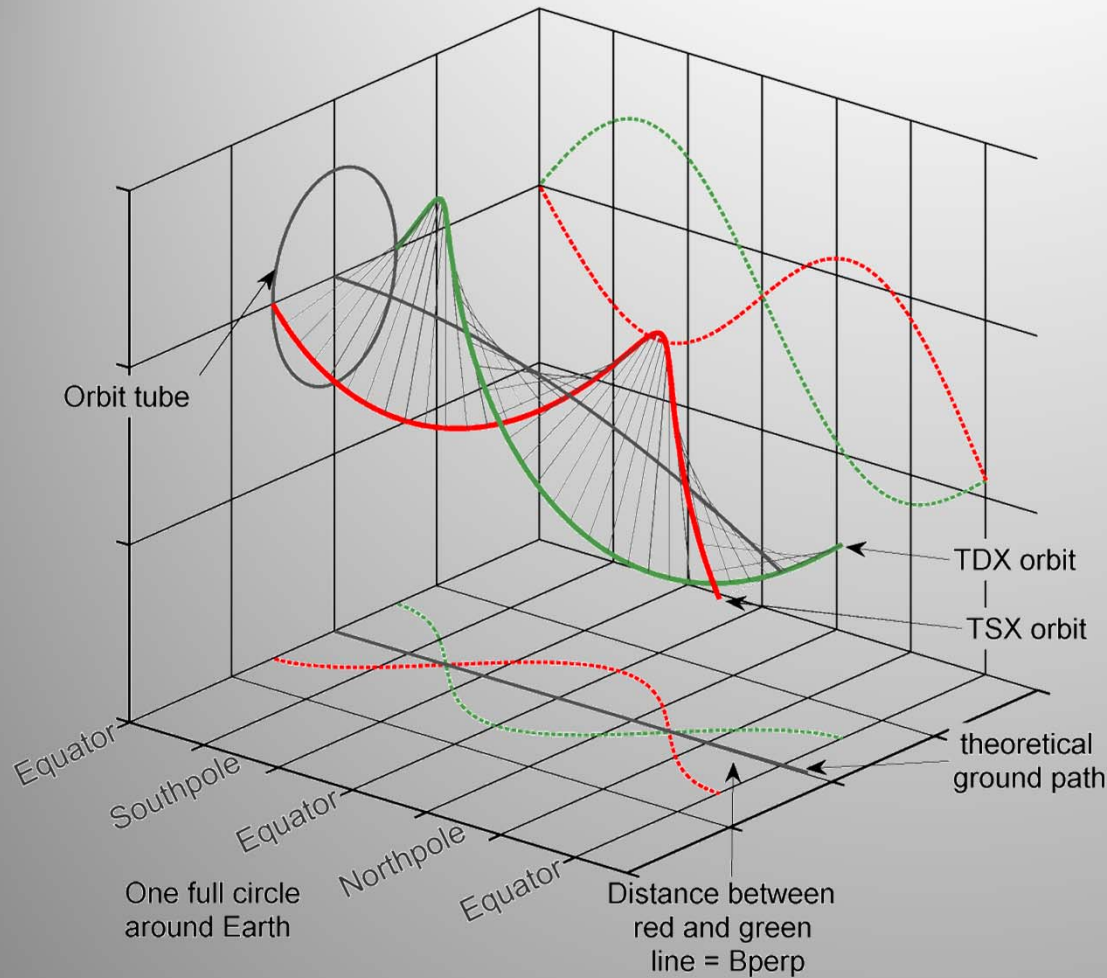
Compiled on DATE: Apr  9 2013 at: 14:00:06
20130606-15:11:10 6 michael@michael-VirtualBox:~$
```

Written in C/C++, command line based, phase unwrapping with SNAPHU



# TanDEM-X processing - Modifications

TanDEM-X orbit helix of TSX and TDX



- Baseline
- File format conversion
- Reference phase

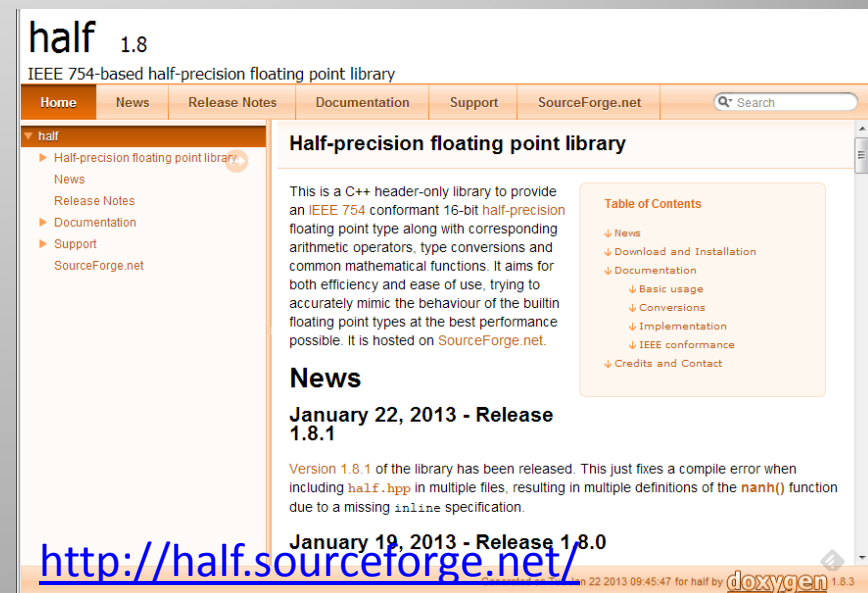
TanDEM-X = Bi-Static, is not supported by DORIS. Minor code changes are necessary.

# TanDEM-X processing - Modifications

## Considerations regarding TanDEM-X CoSSC images

1. Perpendicular baseline and effective baseline
2. Half precision float data format (convert from 16bit to 32bit float (to process in DORIS))
3. Calculating the correct reference phase (Range traveling time)

C++ header file to convert half-precision floating point



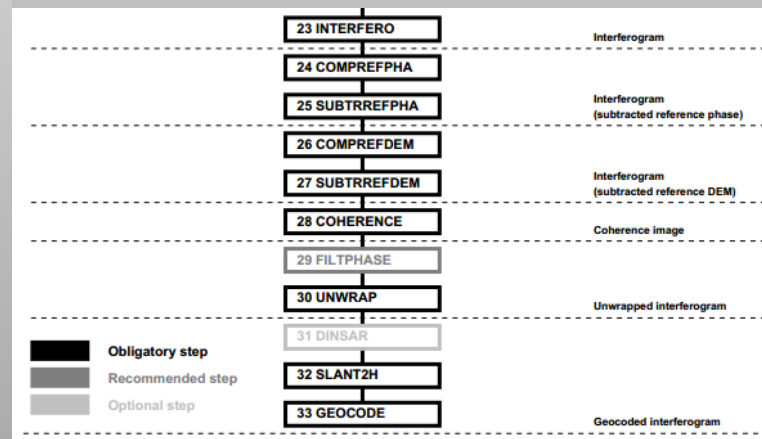
The screenshot shows the SourceForge page for the 'half' library. The page title is 'half 1.8 IEEE 754-based half-precision floating point library'. The navigation menu includes Home, News, Release Notes, Documentation, Support, and SourceForge.net. The main content area is titled 'Half-precision floating point library' and contains a description of the library, a 'Table of Contents' with links to News, Download and Installation, Documentation, Basic usage, Conversions, Implementation, IEEE conformance, and Credits and Contact, and a 'News' section. The news section lists two releases: 'January 22, 2013 - Release 1.8.1' and 'January 19, 2013 - Release 1.8.0'. A blue URL <http://half.sourceforge.net/> is overlaid on the bottom of the screenshot. The footer of the page indicates it was generated by doxygen 1.8.3 on 22 2013 09:45:47.

# TanDEM-X processing - Modifications

Changes in DORIS include:

- Files to be changed
  - *bk\_baseline.hh*
  - *products.c*
  - *referencephase.c*
- Modifications of the SNAPHU inputfile (not finished)

CoSSC file: Start from Interferogram formation





# TanDEM-X processing – Three Gorges (example)

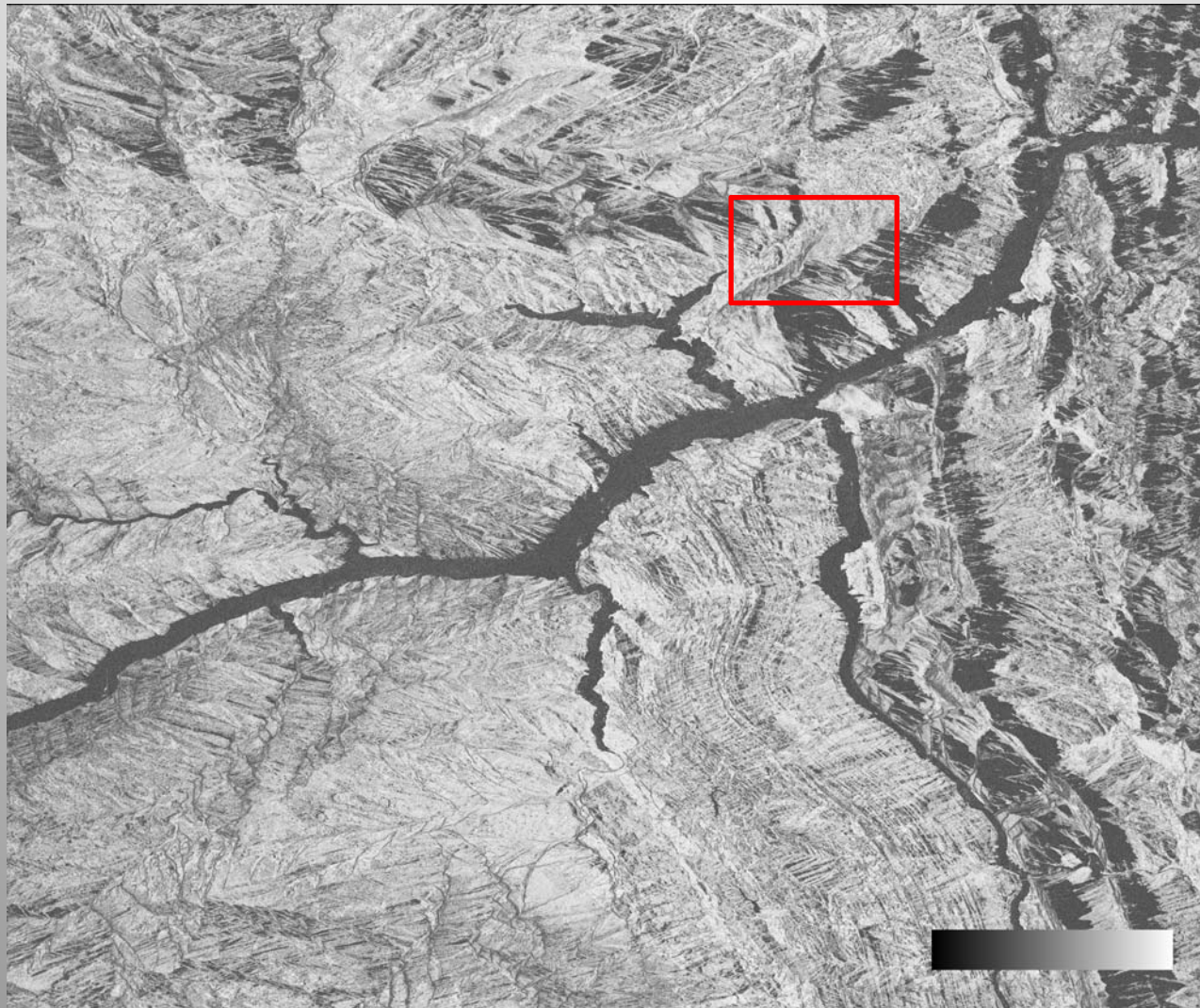


<http://img.shanghaifocus.com/image/yangtze-river-cruise/Blog/three-gorges-1.jpg>

Steep terrain, vegetation and atmospheric effects (water vapor)

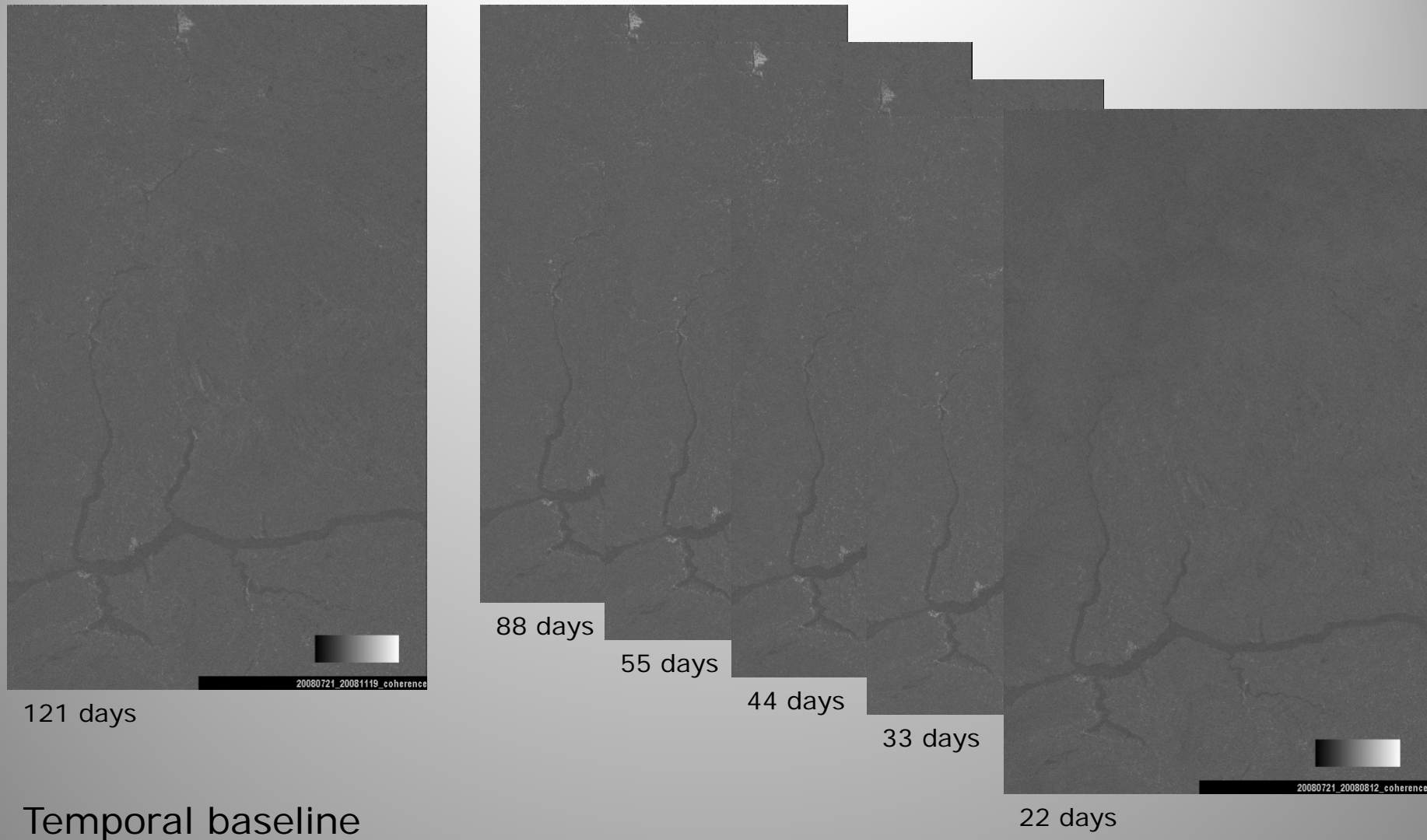


# TanDEM-X processing – Three Gorges (example)



Coherence image: full scene of TanDEM-X image over Three Gorges area.

# TanDEM-X processing – Three Gorges (example)



Coherence of TerraSAR-X Stripmap repeat-pass images over the same area.



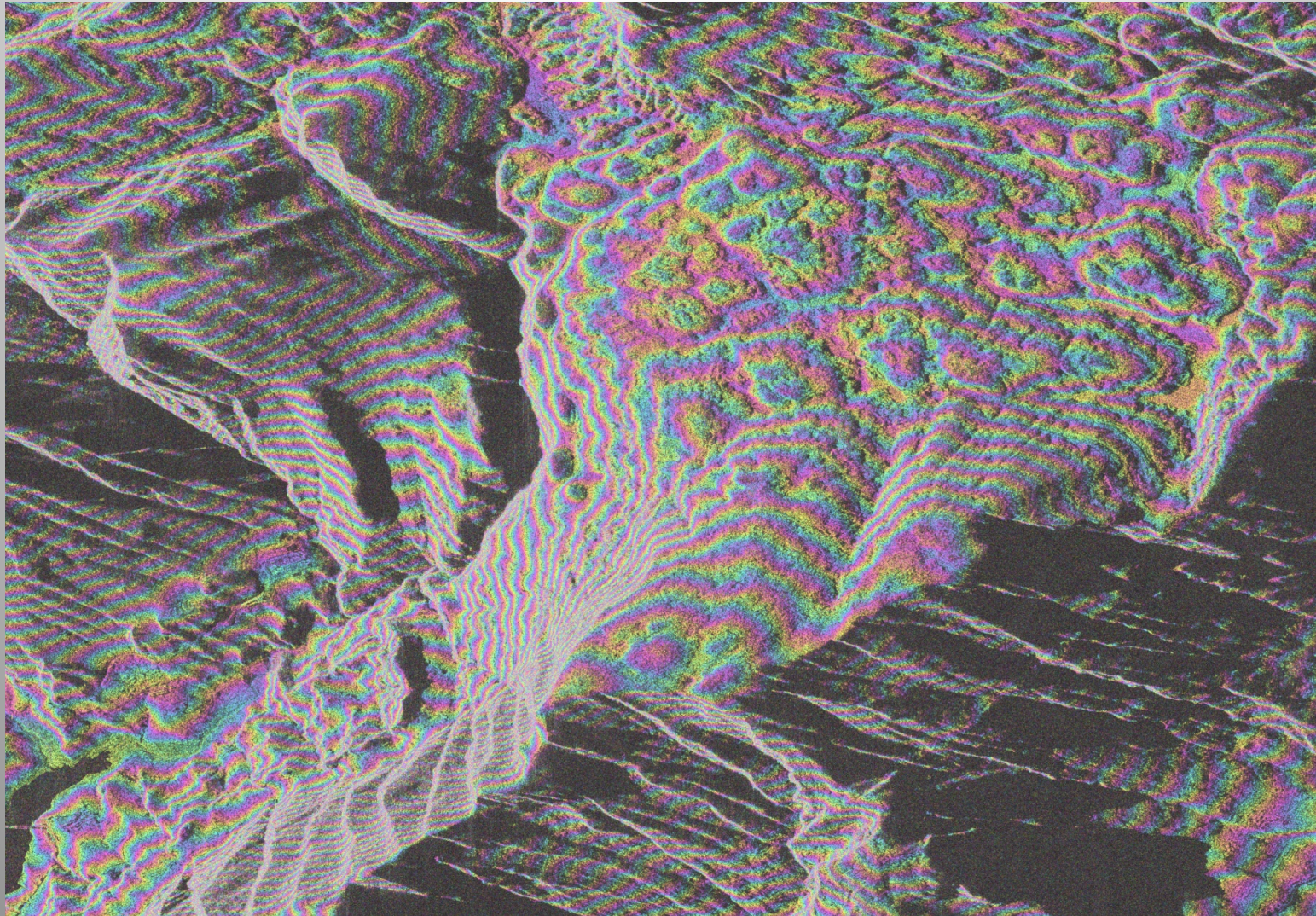
# TanDEM-X processing – Three Gorges (example)



Direct comparison of TSX and TDM coherence images



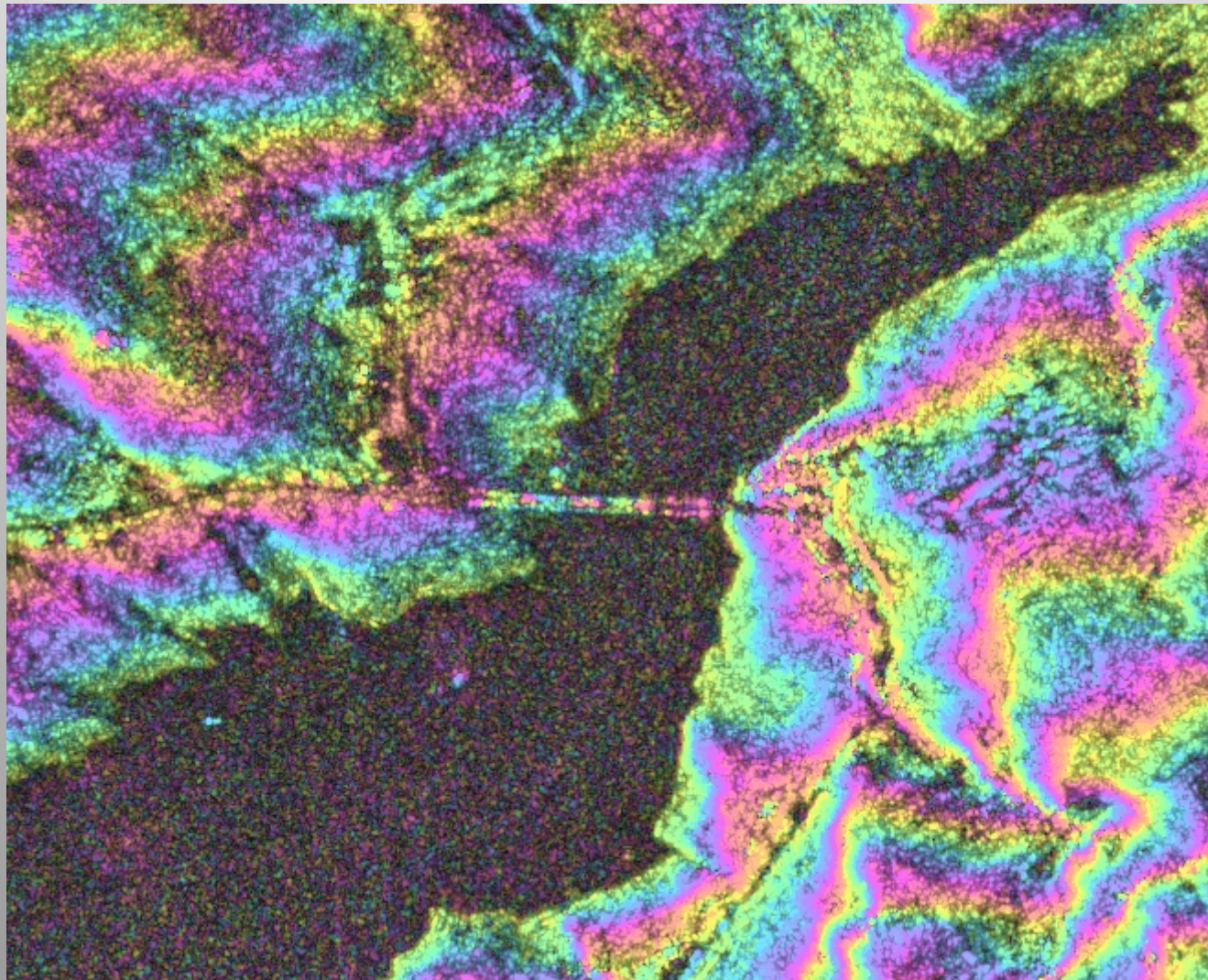
# TanDEM-X processing – Three Gorges (example)



TanDEM-X phase fringes

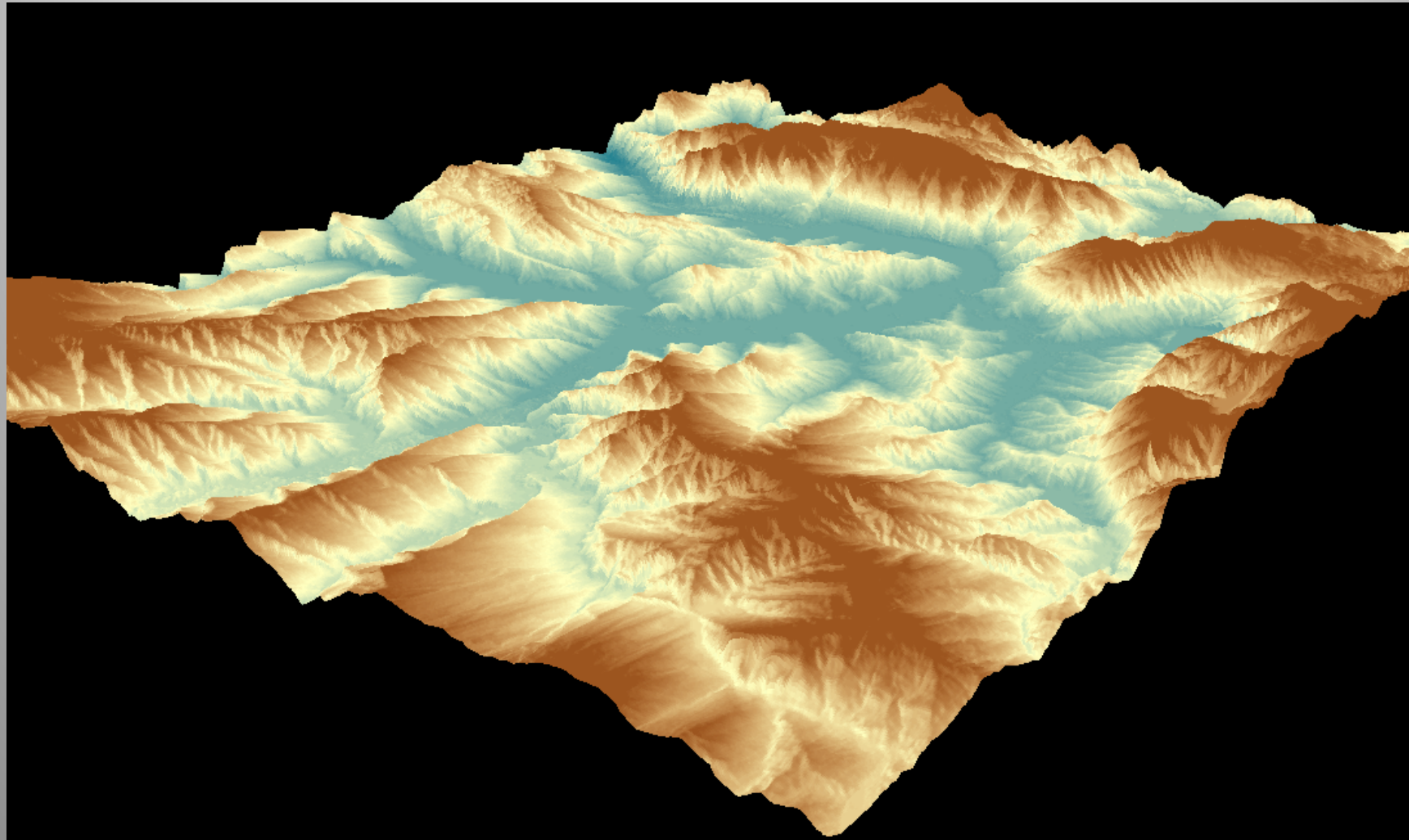


# TanDEM-X processing – Three Gorges (example)



TanDEM-X phase fringes - filtered

# ~~TanDEM-X processing~~ ~~TanDEM-X DEM~~

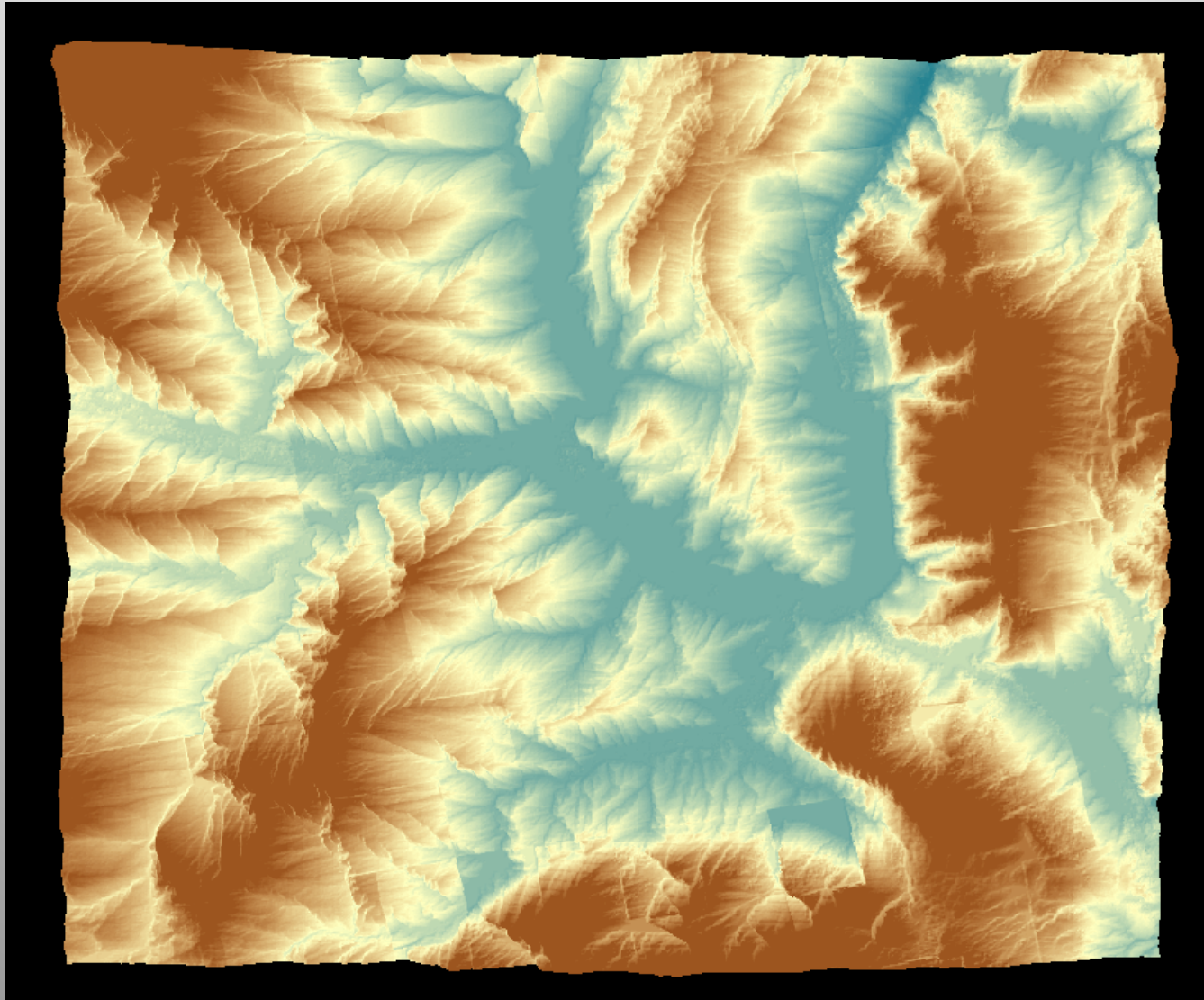


DEM comparison: SRTM vs. TanDEM-X – Phase  
unwrapping with SNAPHU

June 2013 - Michael Jendryke (5. TerraSAR-X / 4. TanDEM-X Science Team Meeting)



# ~~TanDEM-X processing~~ ~~TanDEM-X DEM~~

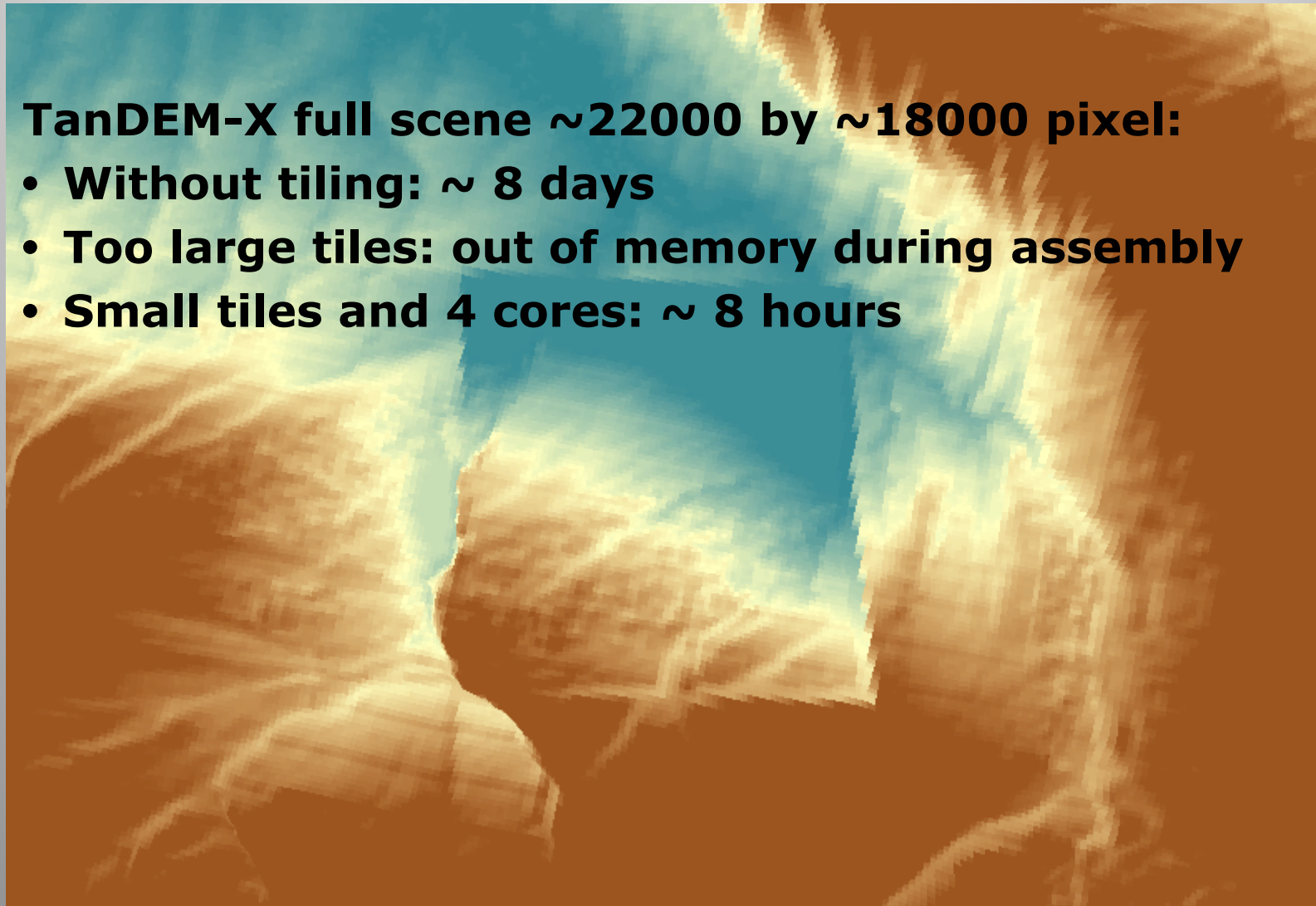


DEM comparison: SRTM vs. TanDEM-X

# ~~TanDEM-X processing~~ ~~TanDEM-X DEM~~

TanDEM-X full scene  $\sim 22000$  by  $\sim 18000$  pixel:

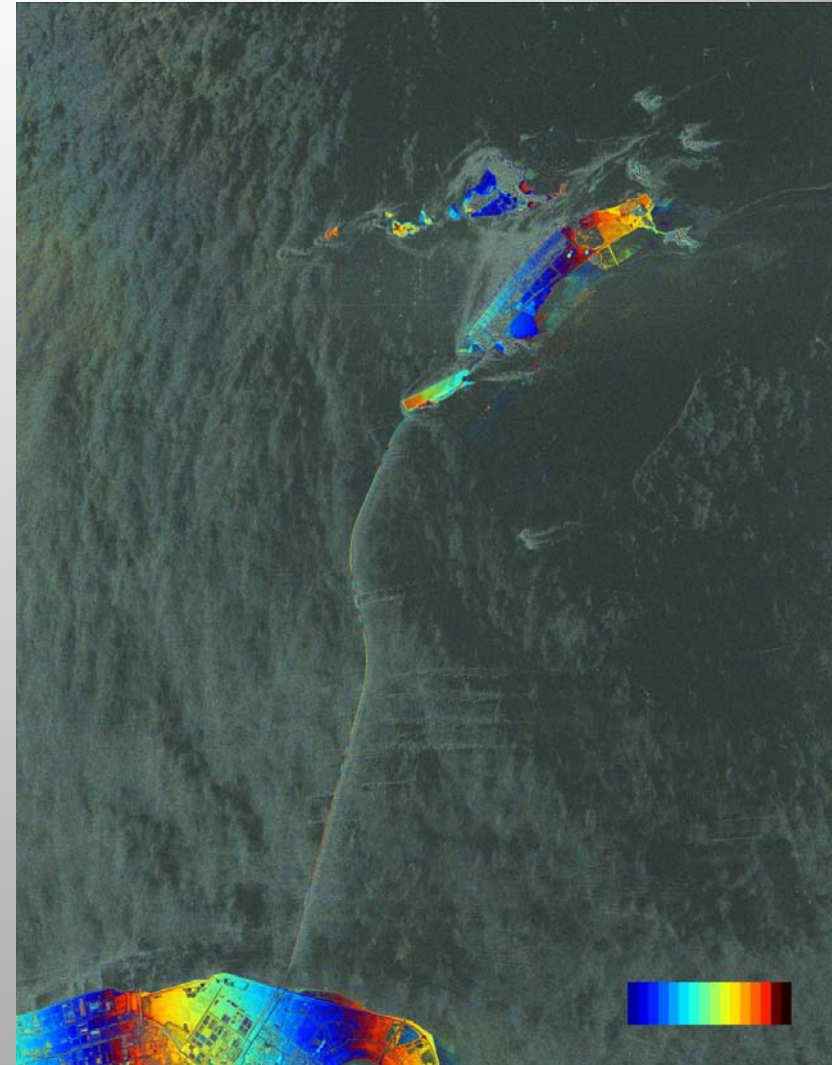
- Without tiling:  $\sim 8$  days
- Too large tiles: out of memory during assembly
- Small tiles and 4 cores:  $\sim 8$  hours



TanDEM-X DEM, Tiling in SNAPHU = **Problems!?**



# TanDEM-X processing – Shanghai (example)



Eastern Ocean Bridge, Shanghai , China



# TanDEM-X processing – Shanghai (example)



[http://www.halcrow.com/PageFiles/642/Eastern\\_Ocean\\_Bridge\\_Shanghai.jpg](http://www.halcrow.com/PageFiles/642/Eastern_Ocean_Bridge_Shanghai.jpg)



Eastern Ocean Bridge, Shanghai

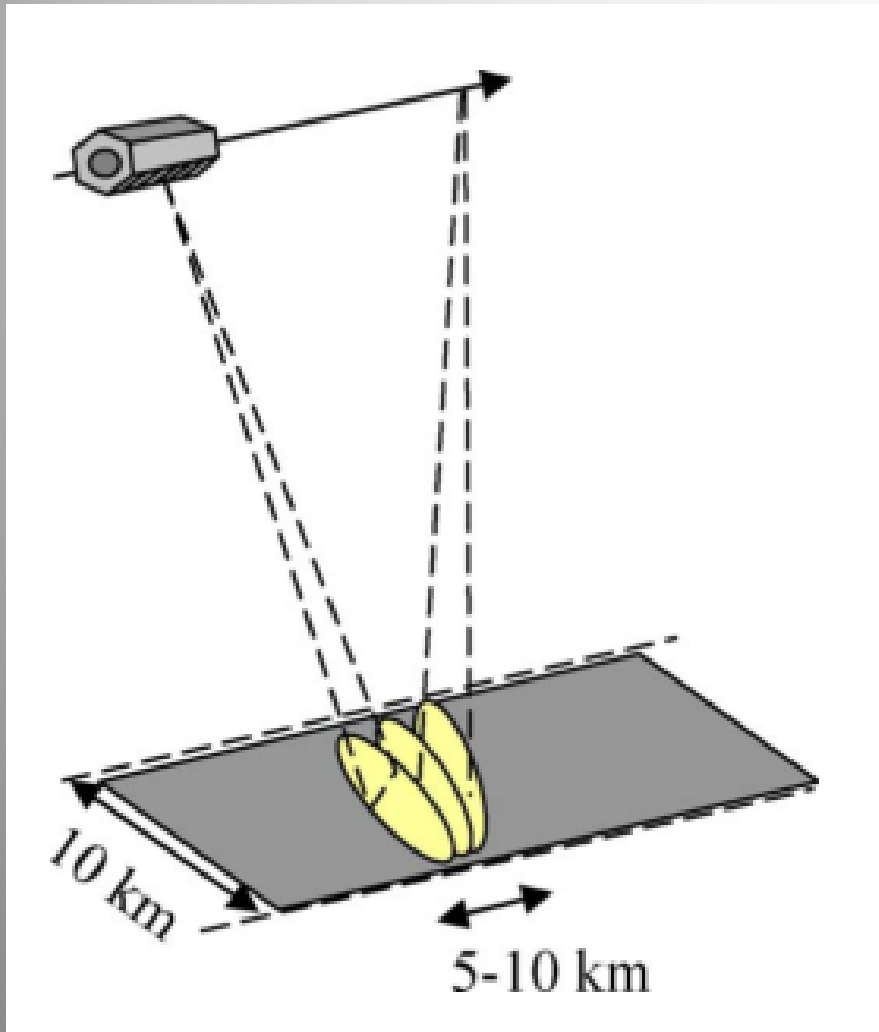
# Spotlight Interferometry – (Recap.)

## Problem

- (HS) Spotlight images  $\neq$  Stripmap images
  - **Linear Doppler shift** (in azimuth)
  - Phase information is not suitable for InSAR after resampling
  - Align image spectrum (of slave to master)
- 
- (Amplitude information is not affected)



# Spotlight Interferometry – (Recap.)



The antenna **beam is gradually steered backwards** while the satellite passes over the area of interest

Sliding spotlight image geometry



# Spotlight Interferometry – Example Lüneburg



Example Spotlight scene from Lüneburg, Germany



# Spotlight Interferometry – using open source sw.

Dataset for testing

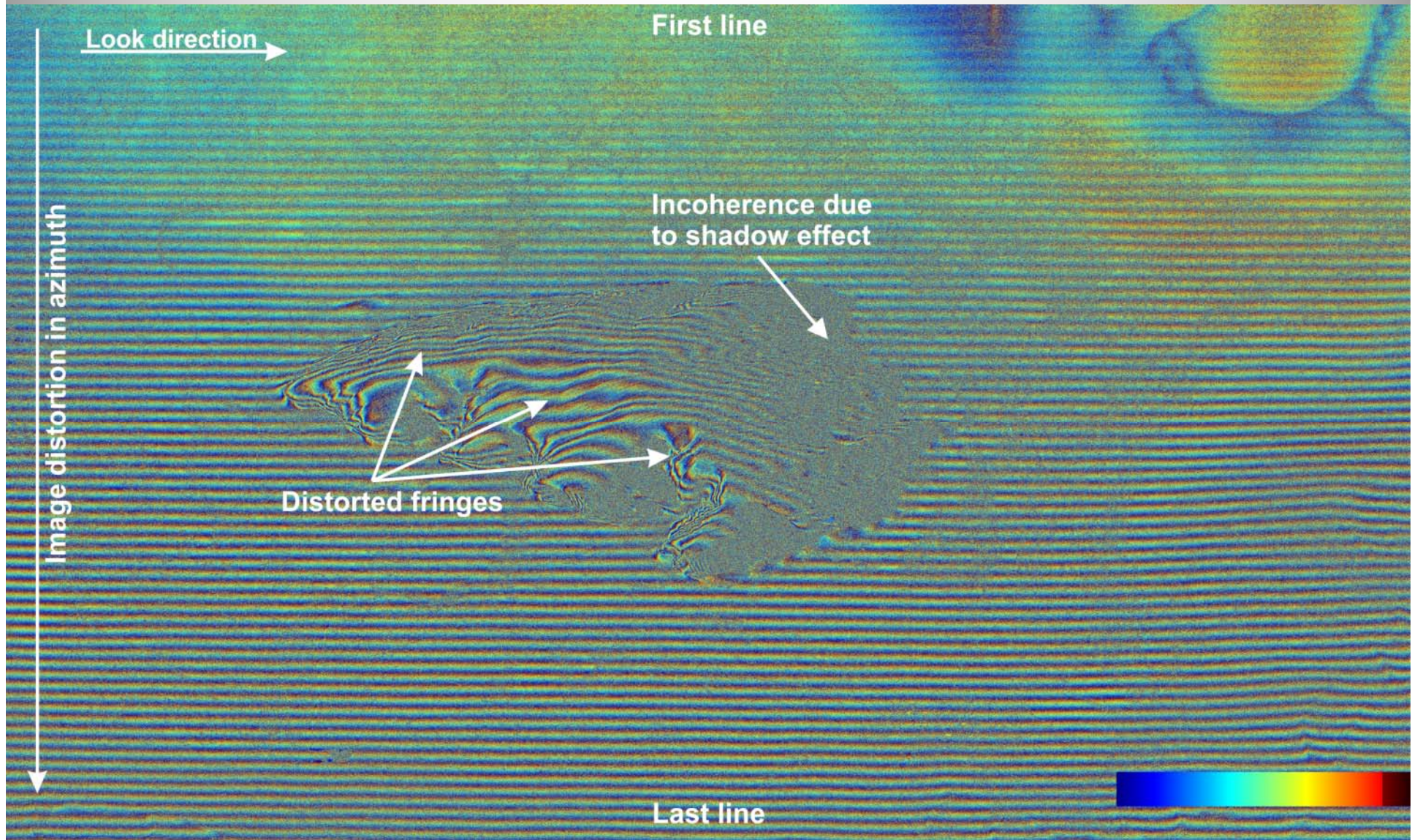


TerraSAR-X Spotlight image (full scene) of Urulu, Australia.  
Image shows the Ayers rock. Sample dataset from Infoterra  
ASTRIUM. © DLR 2009

June 2013 - Michael Jendryke (5. TerraSAR-X / 4. TanDEM-X Science Team Meeting)



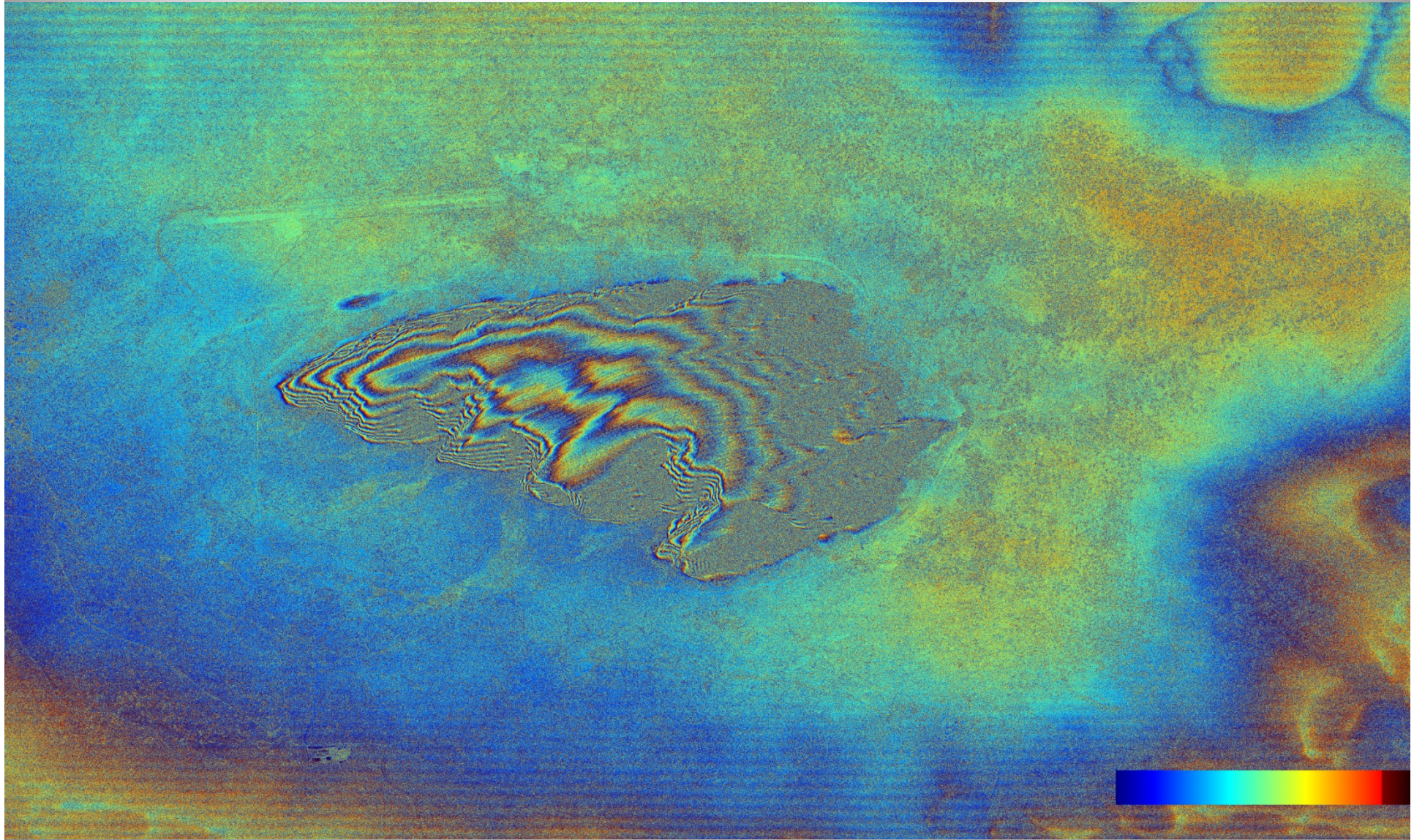
# Spotlight Interferometry – using open source sw.



Wrong Result in DORIS – Doppler Shift in azimuth ON



# Spotlight Interferometry – using open source sw.



Wrong Result in DORIS – Doppler Shift in azimuth OFF



# Spotlight Interferometry – using open source sw.

Our implementation:

Shift the interpolation kernel during the resampling step.

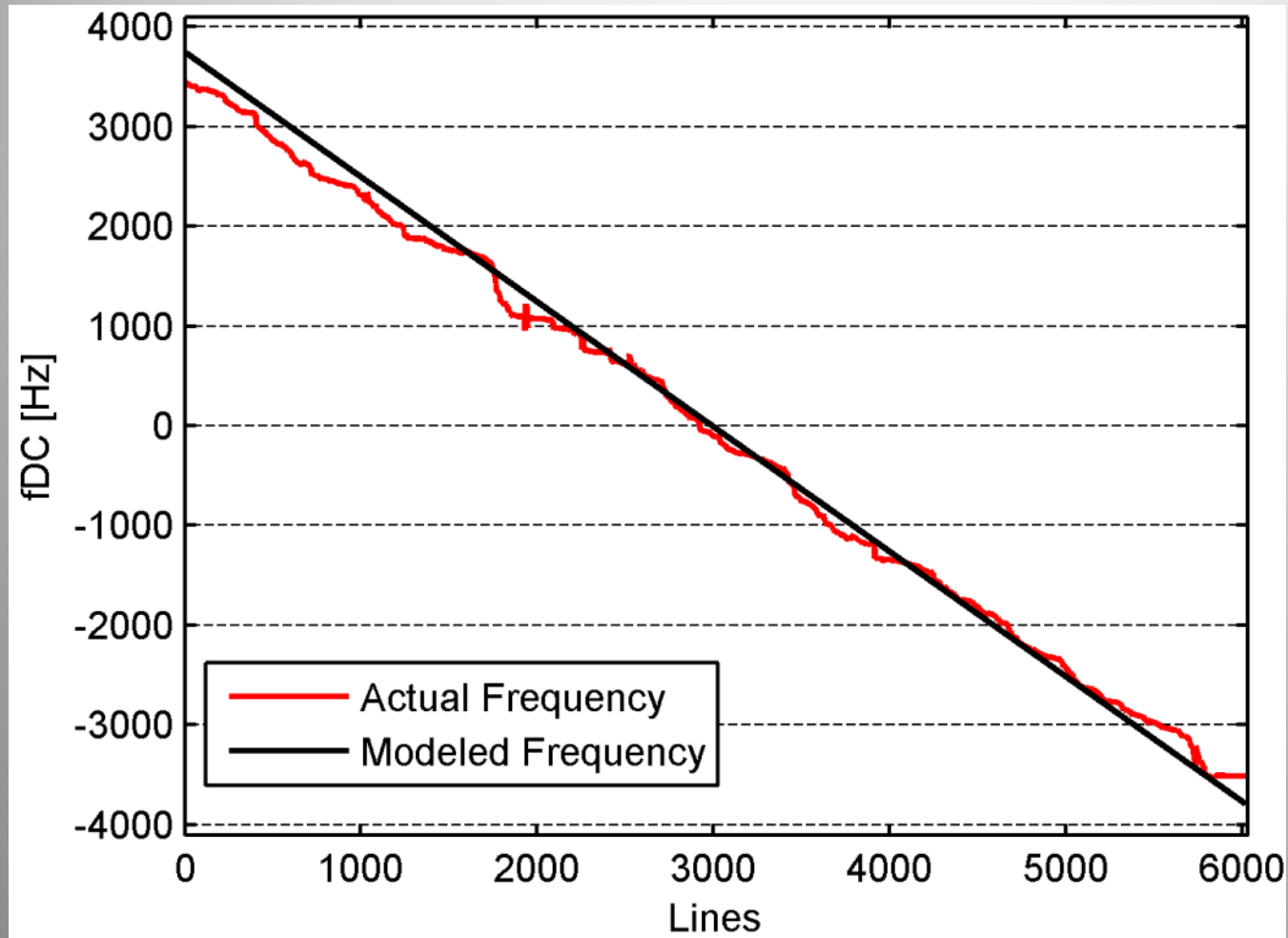
RS\_METHOD

cc6p\_**SP** (*new code*)

RS\_SHIFTAZI

OFF

# Spotlight Interferometry – using open source sw.



**Red line:**

The actual frequency for a single azimuth column.

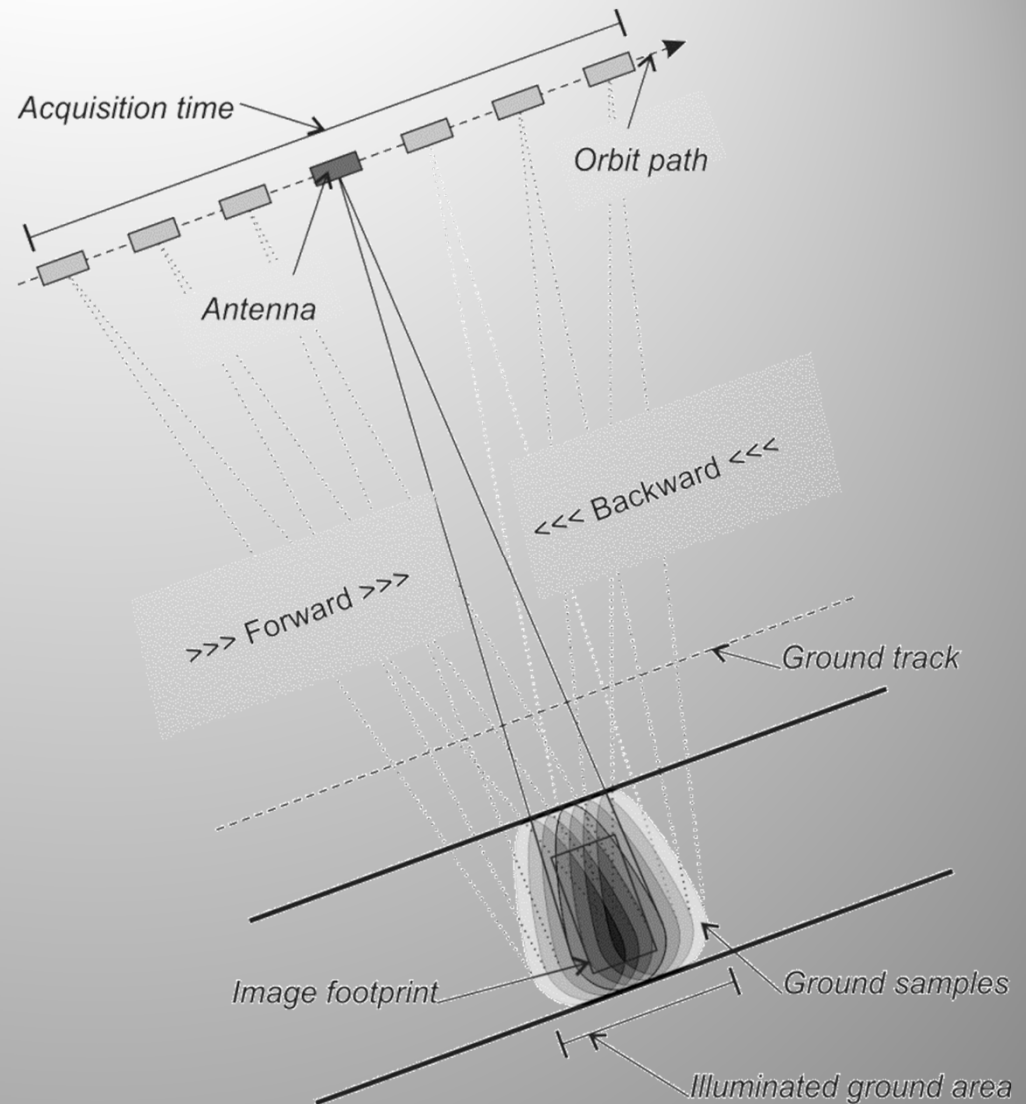
**Black line:**

The modeled frequency.

# Spotlight Interferometry – using open source sw.

This beam steering or beam sweeping technique leads to a **positive Doppler shift** in the upper image lines and a **negative shift** towards the last lines.

Solution: 'Shift interpolation kernel in azimuth during resampling'

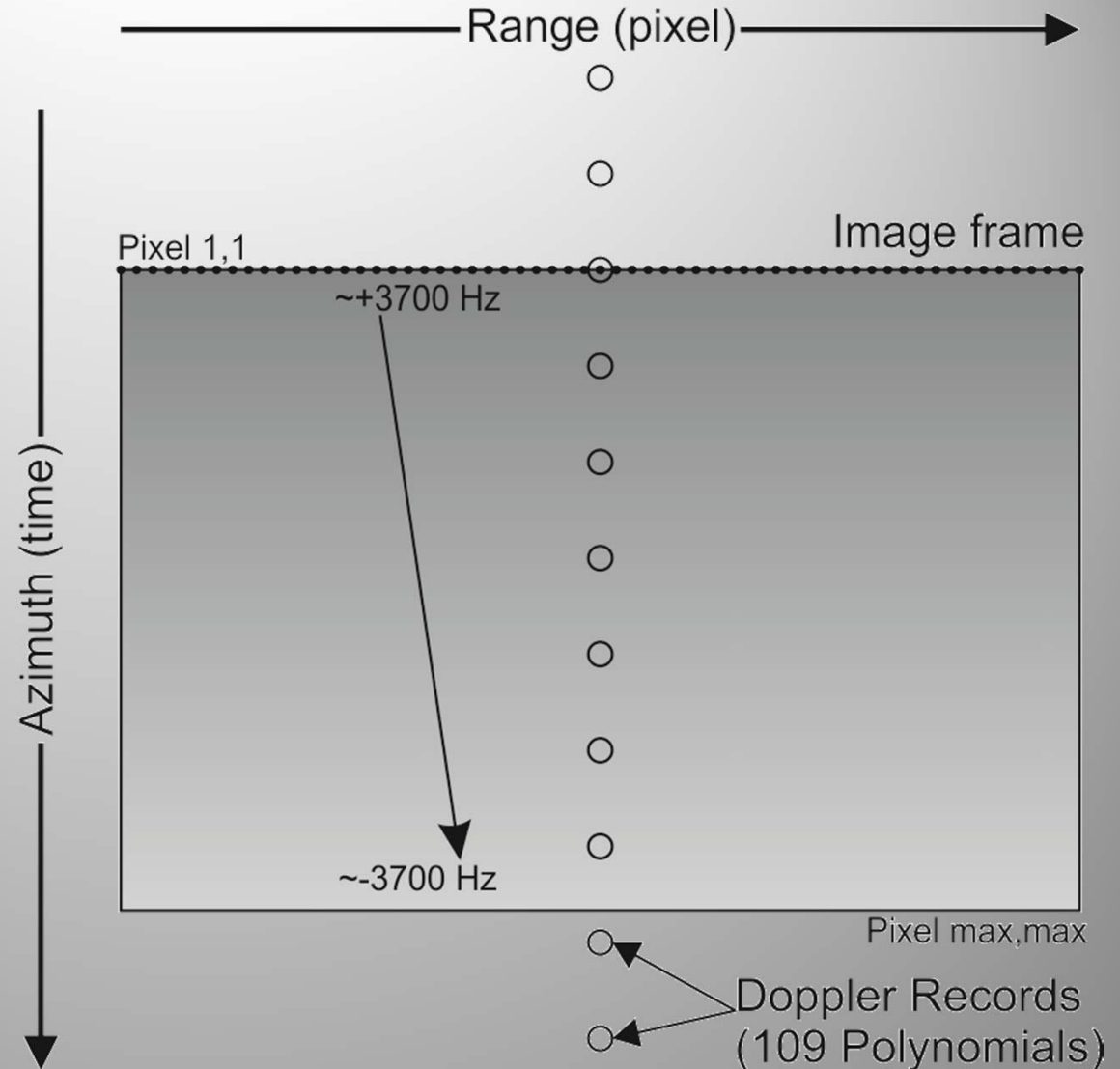


# Spotlight Interferometry – using open source sw.

Metadata contains **Doppler polynomials**.

A **frequency matrix** is created by interpolating these along range time and azimuth.

This matrix is used **to shift the interpolation kernel in azimuth** direction.





# Spotlight Interferometry

## Reference

*M. Eineder, N. Adam, R. Bamler, N. Yague-Martinez, and H. Breit, "Spaceborne Spotlight SAR Interferometry With TerraSAR-X," IEEE Transactions on Geoscience and Remote Sensing, vol. 47, no. 5, pp. 1524–1535, May 2009.*

1524

IEEE TRANSACTIONS ON GEOSCIENCE AND REMOTE SENSING, VOL. 47, NO. 5, MAY 2009

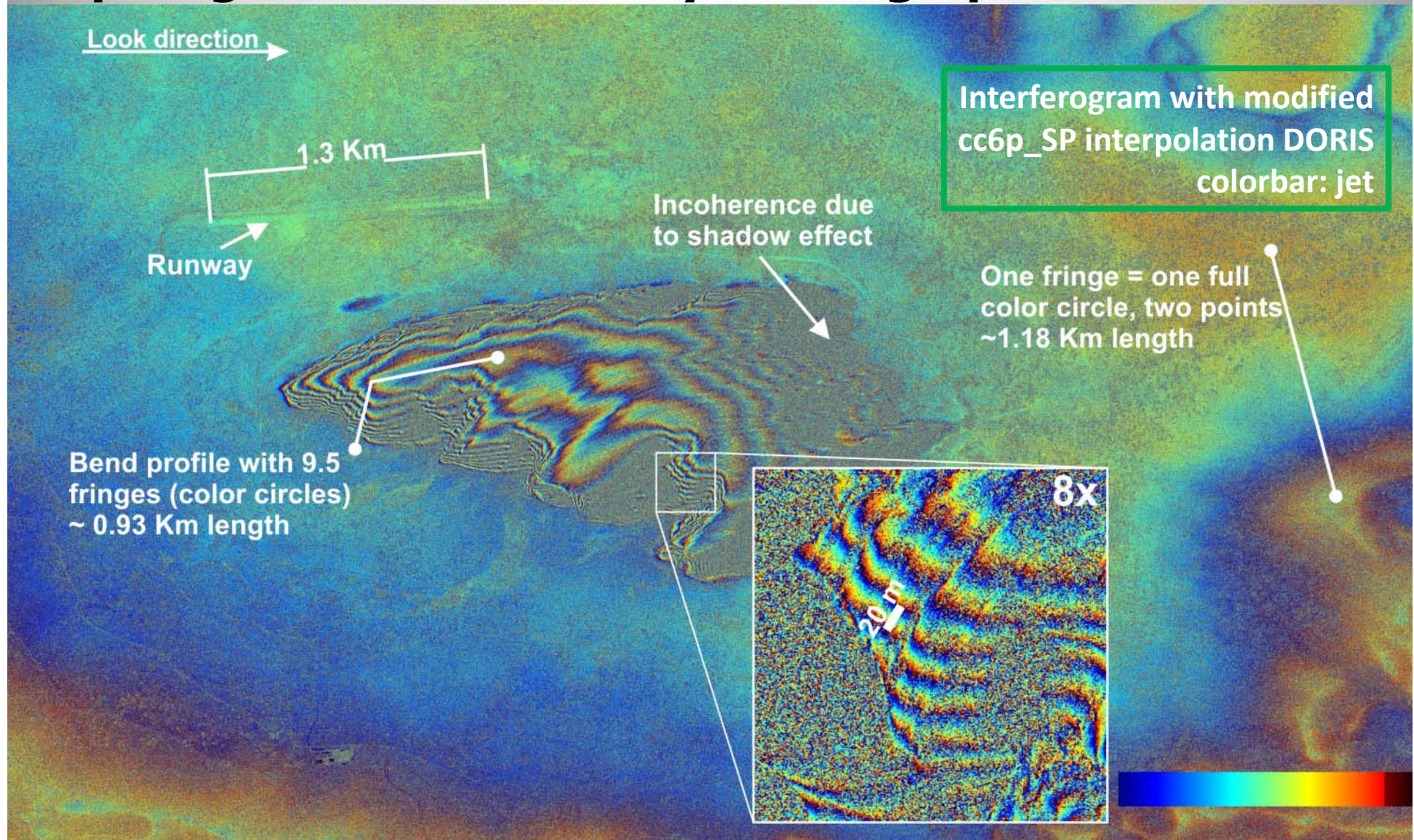
## Spaceborne Spotlight SAR Interferometry With TerraSAR-X

Michael Eineder, *Member, IEEE*, Nico Adam, Richard Bamler, *Fellow, IEEE*,  
Nestor Yague-Martinez, and Helko Breit

The paper covers more adjustments (filtering), which is not yet included.



# Spotlight Interferometry – using open source sw.



Interferogram generated with DORIS using the cc6p\_SP interpolation kernel. Temporal baseline is 11 days and perpendicular baseline is 233.7 m with a height ambiguity of 34 m.



# Spotlight Interferometry – Las Vegas (example)

TerraSAR-X

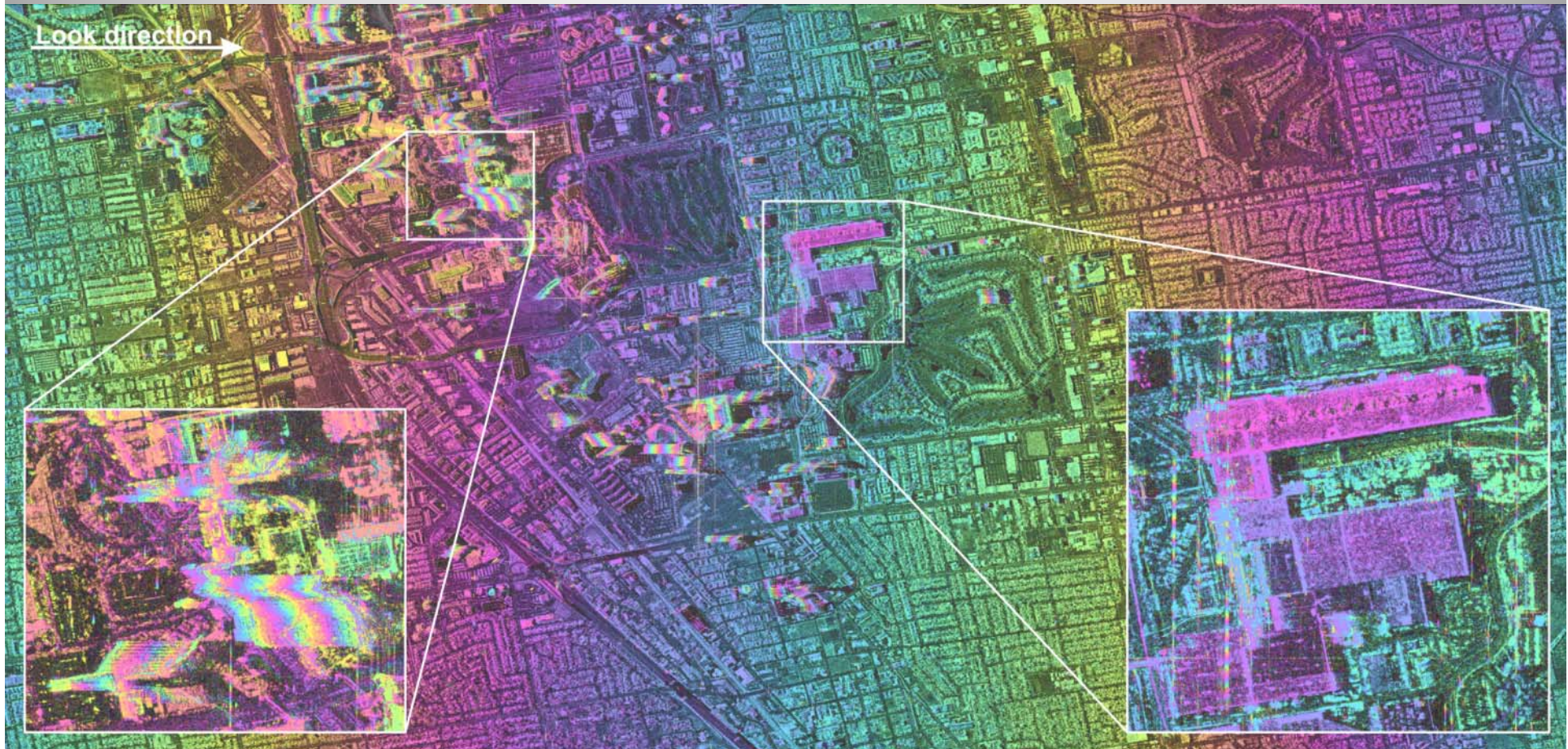


TerraSAR-X flattened interferogram with amplitude image in background. Temporal baseline 110 days, perpendicular baseline: 48.1 m.



# Spotlight Interferometry – Las Vegas (example)

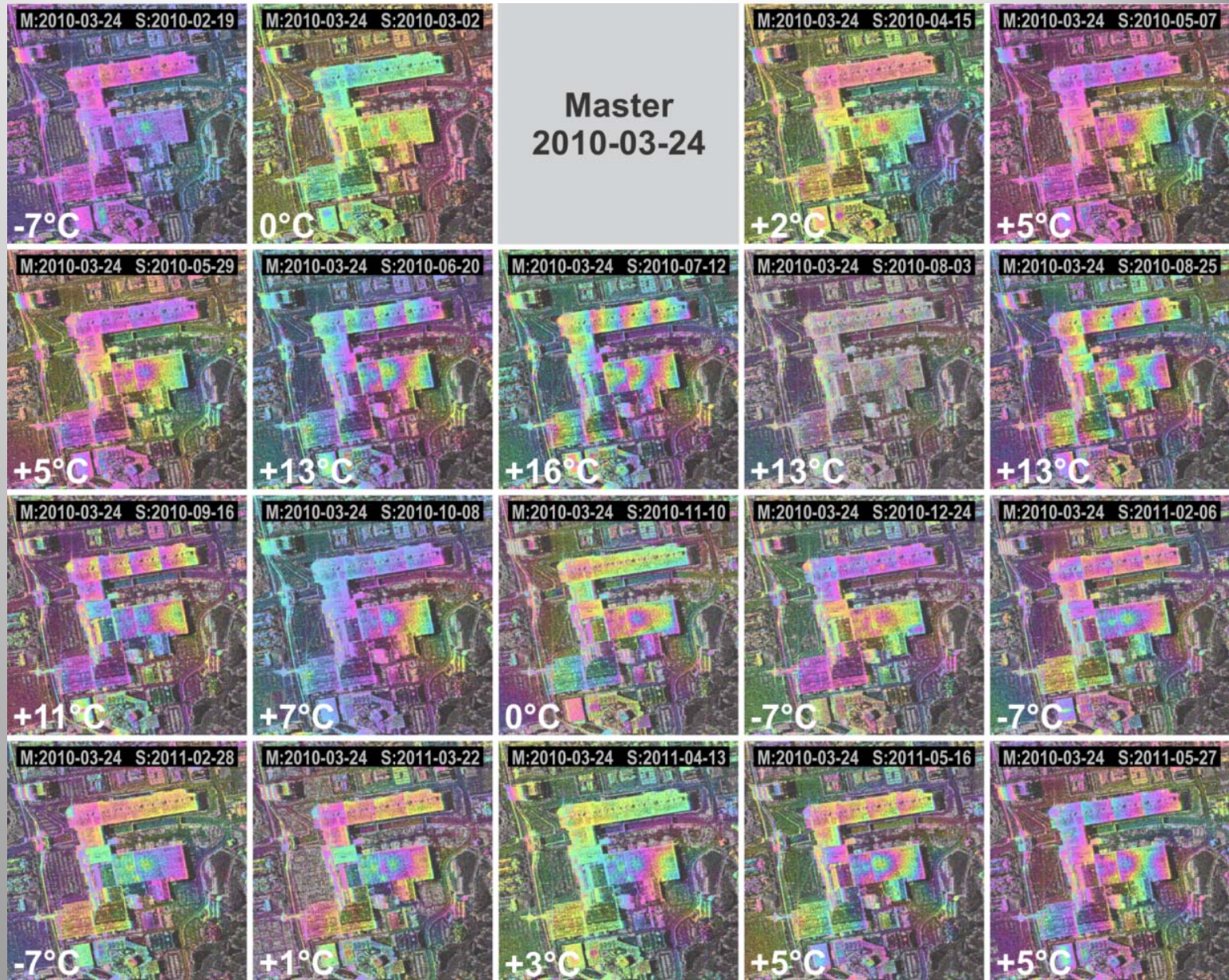
TanDEM-X



TanDEM-X flattened interferogram in radar coordinates with amplitude image in background. Subsets show hotels and the Convention Center in Las Vegas, USA. Temporal baseline 0 days, effective baseline: ~87 m.



# Spotlight Interferometry – Las Vegas (example)



Time series of interferograms showing the convention centre in Las Vegas.



# Spotlight Interferometry – Las Vegas (example)

Bistatic – TanDEM-X



TanDEM-X Coherence image. Temporal baseline 0 days,  
effective baseline: ~87 m.

June 2013 - Michael Jendryke (5. TerraSAR-X / 4. TanDEM-X Science Team Meeting)



# Spotlight Interferometry – Las Vegas (example)

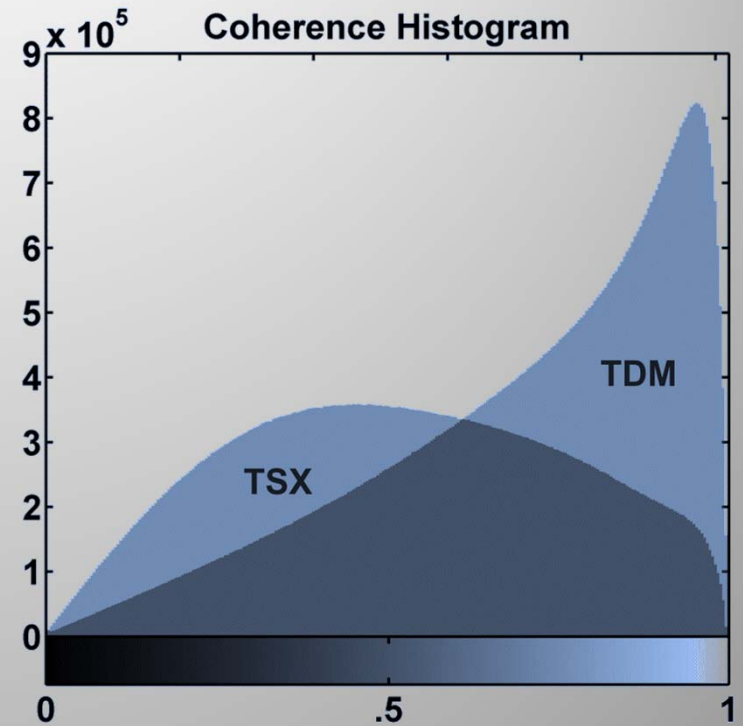


TerraSAR-X Coherence image. Temporal baseline 110 days, perpendicular baseline: 48.1 m.

June 2013 - Michael Jendryke (5. TerraSAR-X / 4. TanDEM-X Science Team Meeting)



# Spotlight Interferometry – Coherence

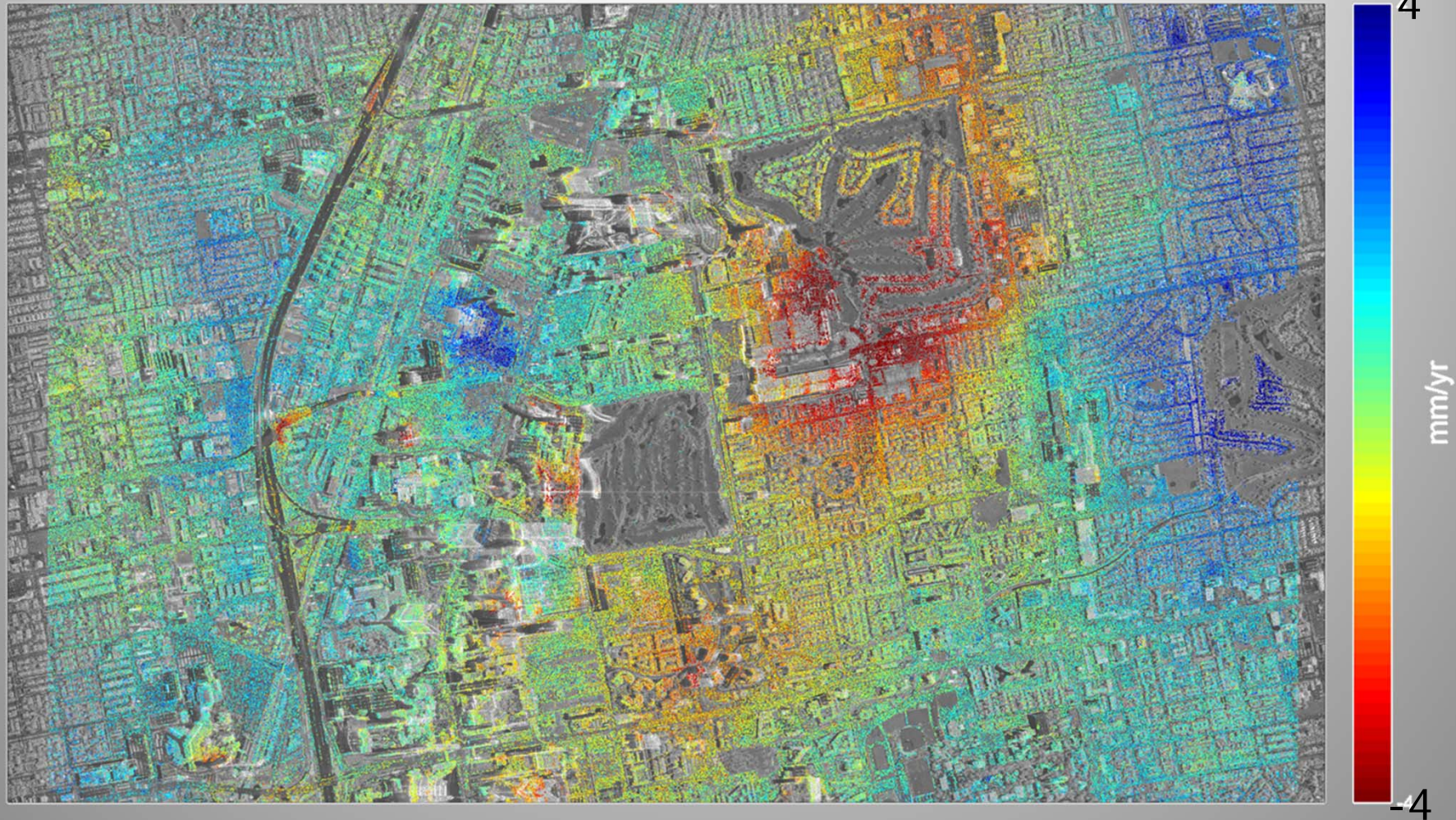


Comparison of TanDEM-X and TerraSAR-X coherence images



# Spotlight Interferometry – PS-InSAR

## Modified version of StaMPS

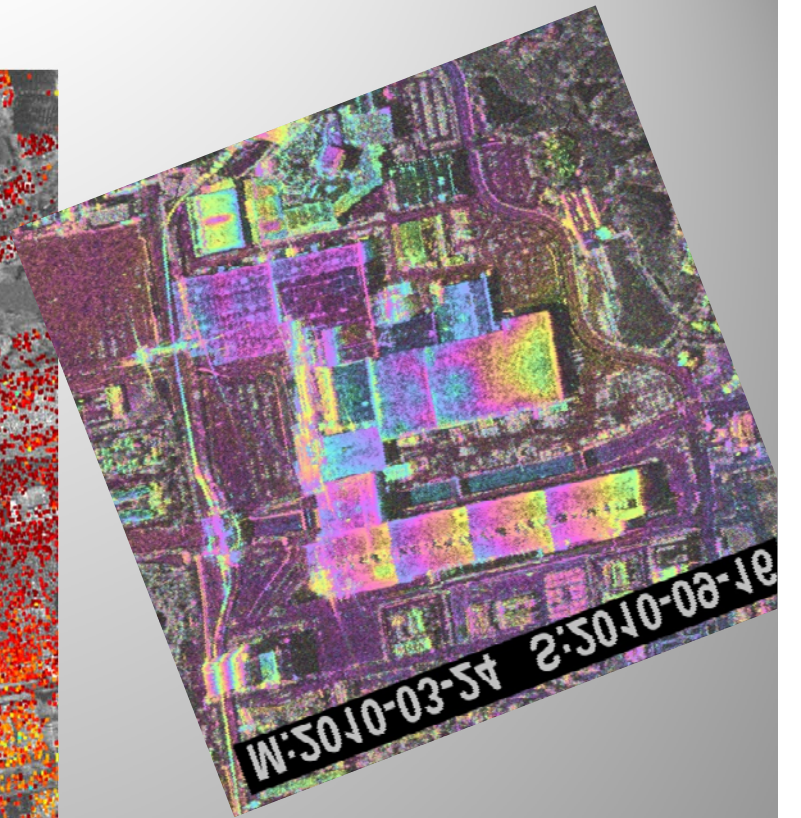
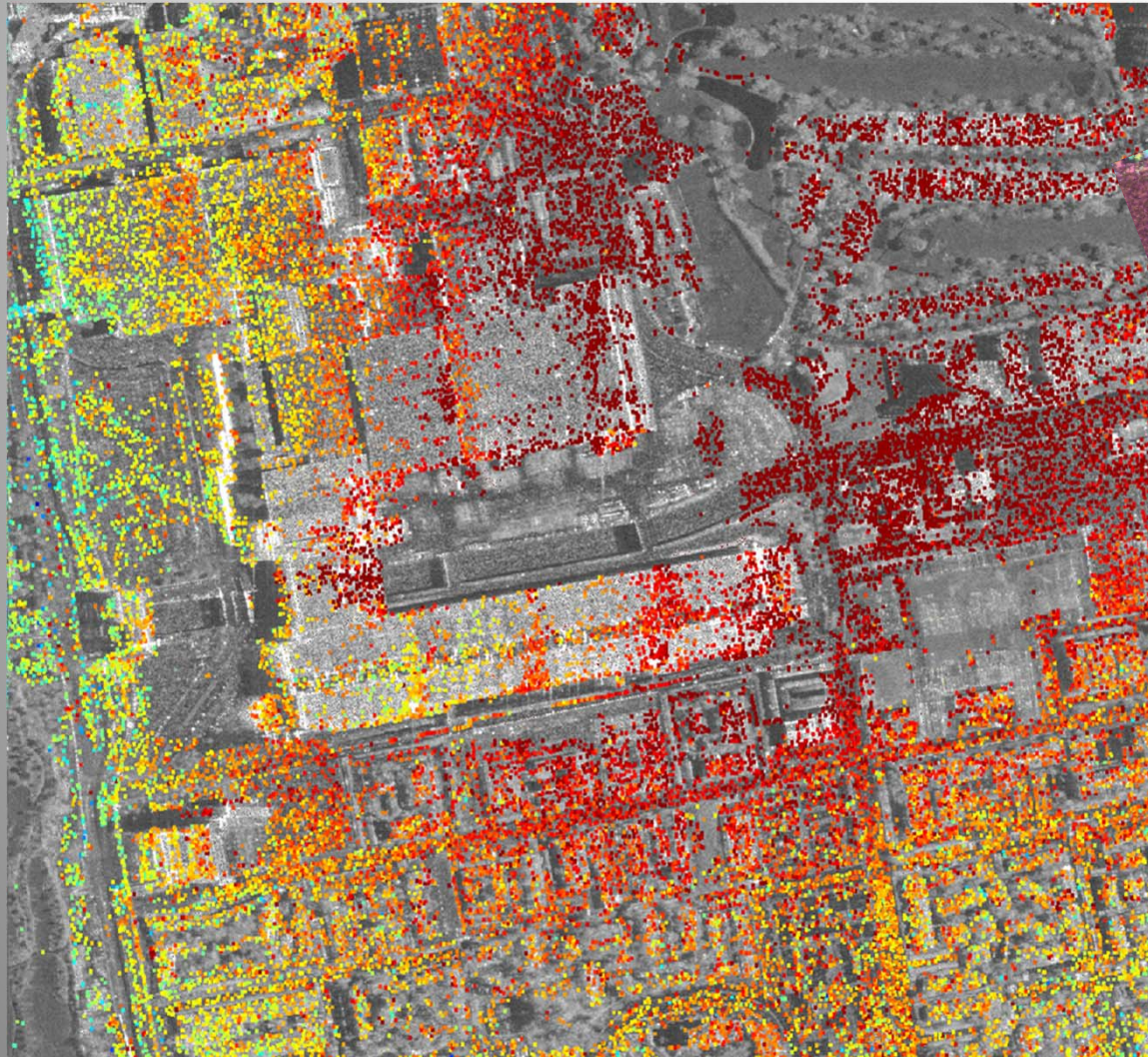


PS-InSAR analysis of Las Vegas using StaMPS.  
Modifications: Corregistration and Resampling Step

June 2013 - Michael Jendryke (5. TerraSAR-X / 4. TanDEM-X Science Team Meeting)



# Spotlight Interferometry



PS-InSAR analysis of Las Vegas, persistent scatter on roof of convention centre.



# Conclusions

Now available:

- Modified DORIS (beta) version for TerraSAR-X **Spotlight** processing
- Modified DORIS (beta) version for TanDEM-X **bistatic** processing ~~and phase unwrapping~~
- Program to convert TanDEM-X data from 16bit to 32bit floating point
- New inputfiles for StaMPS to do PS-InSAR with spotlight images

# Thank You!

Questions?

[michaeljendryke@gmail.com](mailto:michaeljendryke@gmail.com)