4th TanDEM-X Science Team Meeting

Height map generation for hydrology from low incidence TanDEM-X data

XTI_HYDR0388

Damien DESROCHES, Roger FJØRTOFT, Nadine POURTHIE (CNES)
Javier DURO, Patrick ORDOQUI (Altamira-Information)

13 June 2013

Introduction

Two main objectives:

➢ **Compare accuracy of DEM** derived from TanDEM-X data with a reference DEM in the Camargue area in Southern France:

- Reference floodplain DEM of Camargue area: “BDT Rhône” produced by IGN based on airborne **LiDAR** data: 2 meter point spacing and 20 cm height accuracy

- Comparison of **conventional unwrapping method and point-by-point** method based on an approximate reference DEM

➢ Study of **the hydrologic potential** of data

- **Quality of phase** depending on water surfaces conditions
- Potential for extraction of **hydrological parameters** (height, slope, movement)
- Preparation of **JPL/CNES Surface Water and Ocean Topography (SWOT)** mission

TanDEM-X data available in the framework of proposal XTI_HYDR0388:

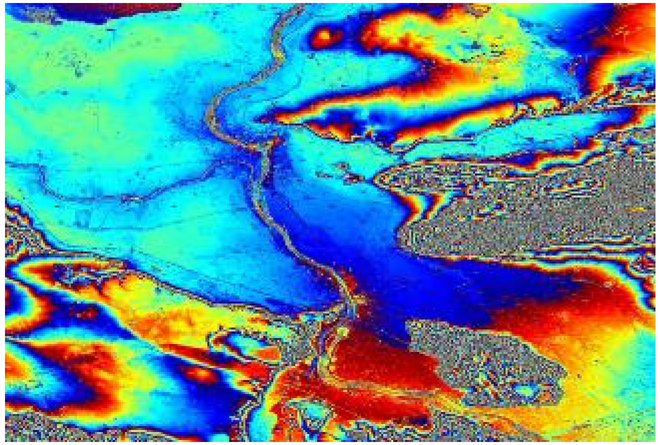
➢ 4 ascending, 8 descending, ~20° incidence, acquired in 2011-2012

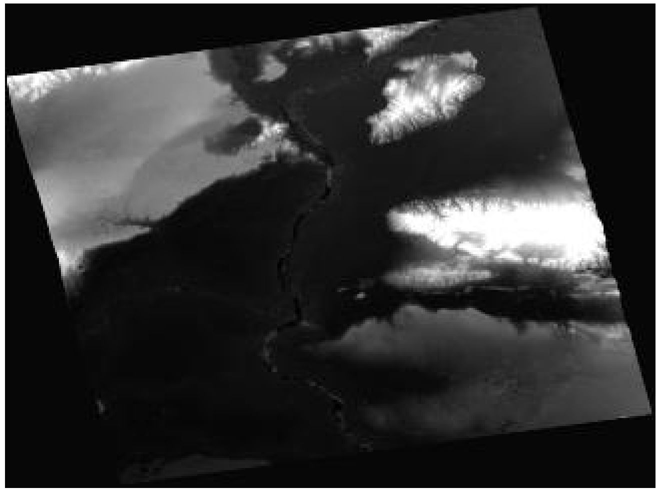
Phase reversal with two methods

- Input data: CoSSC TanDEM-X

- DIAPASON software adapted to bi-static TDX/TSX data (*), classical interferometric approach:
  - Computation of interferometric phase (ref. WGS-84)
  - Phase unwrapping
  - Phase-to-height conversion with ground control points
  - Geocoding

- Point-by-point method:
  - Use of a reference DEM
  - No “horizontal” phase unwrapping
  - No ground control points
  - Very precise knowledge of acquisition parameters necessary


TDX InSAR phase, Camargue area

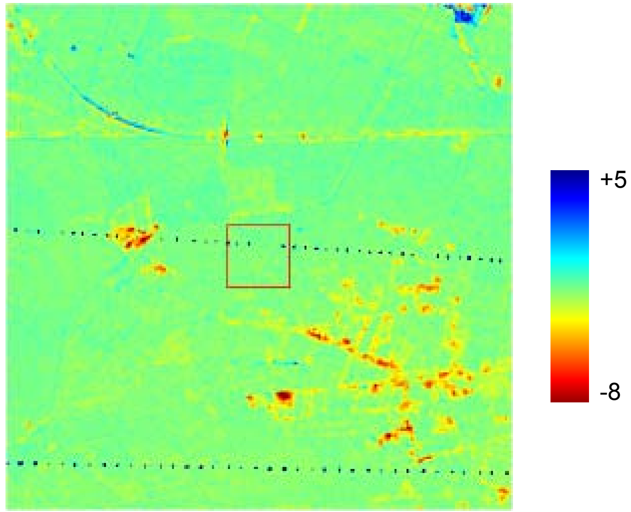

Geocoded heights obtained by DIAPASON processing

(*) Performance analysis of the TanDEM-X DEM generated with DIAPASON software, session 2:SAR Techniques Wednesday, June 12, 2013

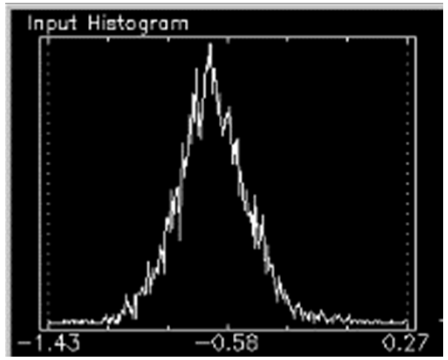
altamira INFORMATION cnes

Comparison between reference DEM and DEM obtained with DIAPASON on TDX data

- Study on an extract of TDX data overlapping the reference DEM
- 7x10 meters ground resolution
- Comparison over flat areas without vegetation or water
- Very high coherence in these areas (~0.8-0.9)
- Global bias of 0.65 m with 0.25 m of standard deviation for the vertical height



Height difference between reference DEM
And DIAPASON TDX DEM



Histogram of the difference between
DIAPASON TDX DEM and reference DEM

altamira INFORMATION cnes

Height computed with point-by-point method

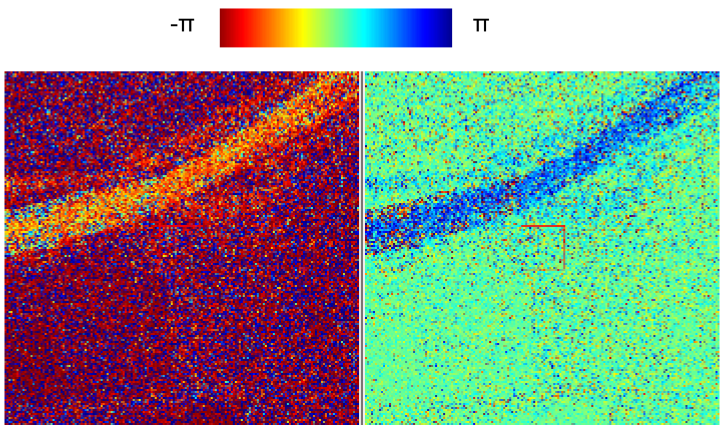
- **Theoretical study made with simulated data** with TDX geometry: perfect synchronization, orbit, and acquisition parameters (but not representative in terms of radiometry)
- Objective: Use of an approximate reference DEM to avoid spatial unwrapping (difference with true height << height of ambiguity)
- Production of a differential interferogram without fringes
- Inversion and geocoding to obtain geolocated heights
- Global bias of 0.0012 m and standard deviation of 0.24m

Reference DEM at 10 m

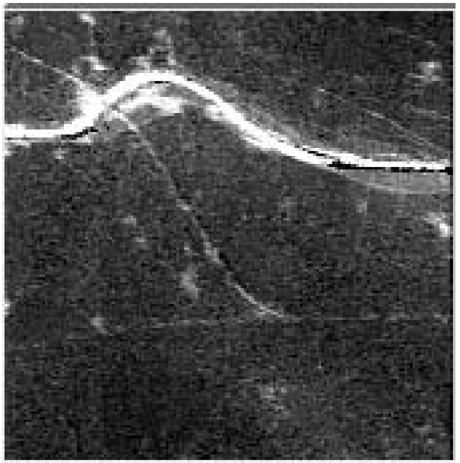
Heights obtained with point-by-point method

Results obtained on TDX data with point-by-point method

- **Test on real TDX data**: 5 x 5 km extract
- Bias on differential interferogram phase due to inaccuracies in parameters and data processing → Histogram calibration over flat areas
- Results over land surfaces:
  - 1.5 m of offset with the reference = ~0.08 rad in differential interferogram (Hambig ~100 m)
  - Accurate knowledge of image annotations (or GCPs for accurate phase calibration)
- Results over water areas:
  - Contribution of water motion in range direction
  - Phase composed by topographic and velocity components
  - Phase value cannot be directly used to get heights



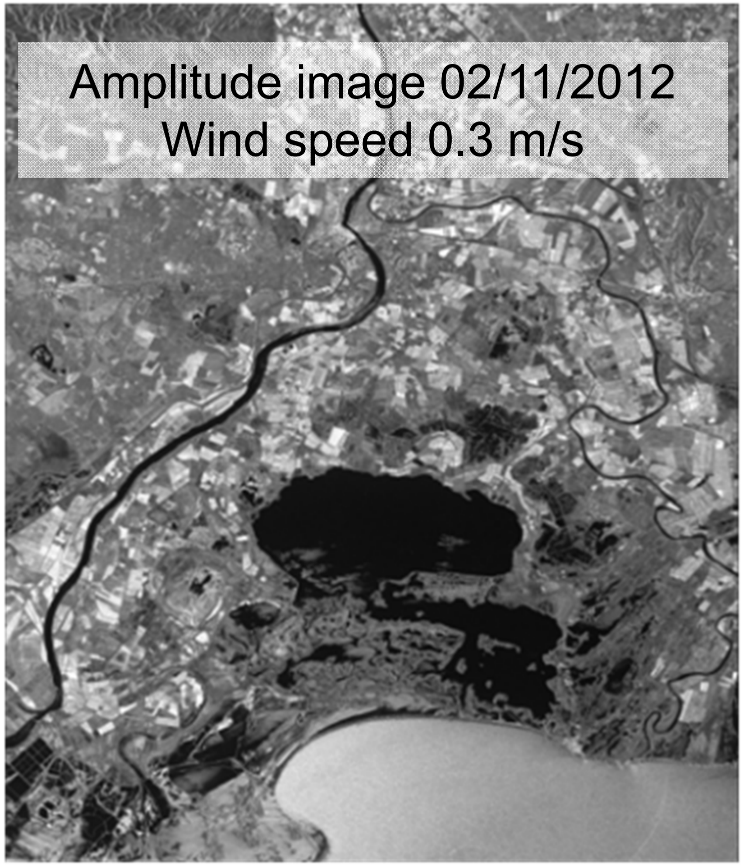
Differential interferogram before and after bias correction

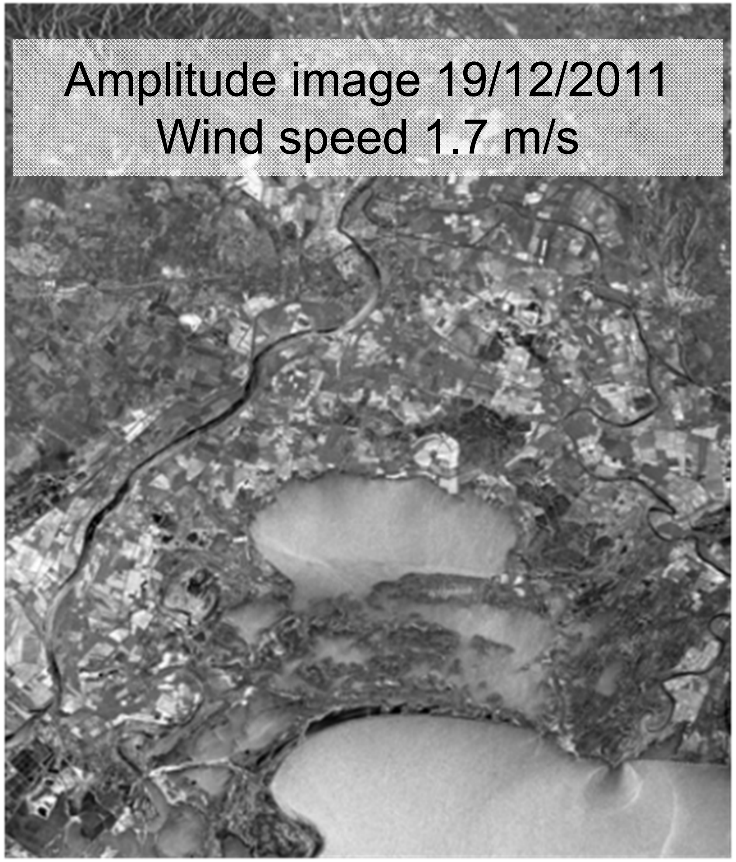


Heights obtained through point-by-point processing

Analysis of TDX InSAR phase over water areas

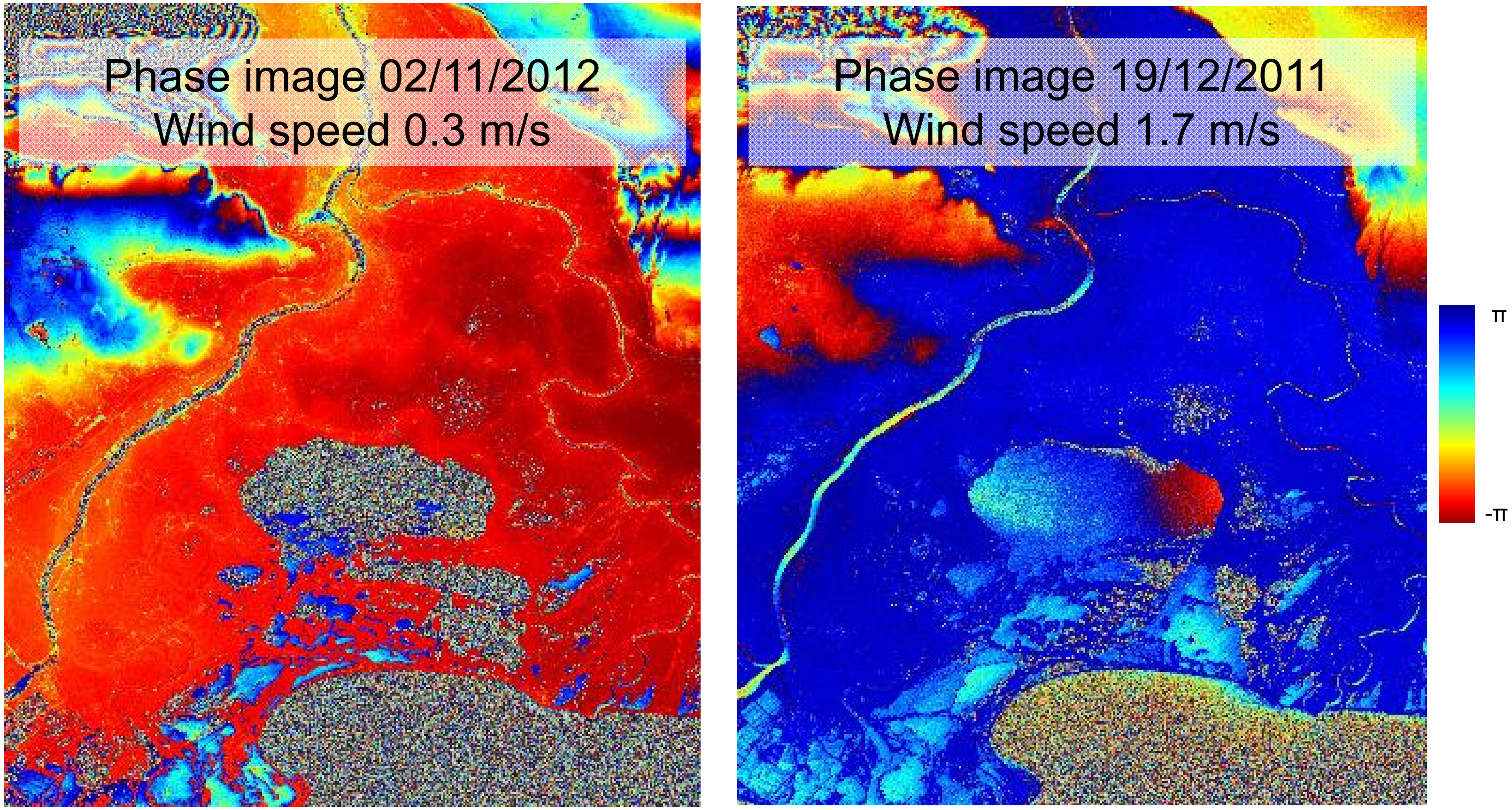
- Influence of the meteorological conditions on the bi-static interferogram
  higher wind → + water roughness → + backscattering → + coherence?





Analysis of TDX InSAR phase over water areas

- Influence of the meteorological conditions on the bi-static interferogram
  higher wind → + water roughness → + backscattering → + coherence?

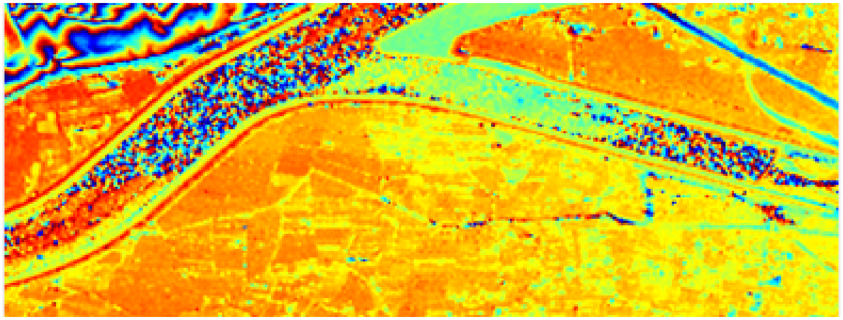


InSAR phase over water surfaces can be exploited in certain meteorological conditions (providing sufficiently high backscattering and coherence)

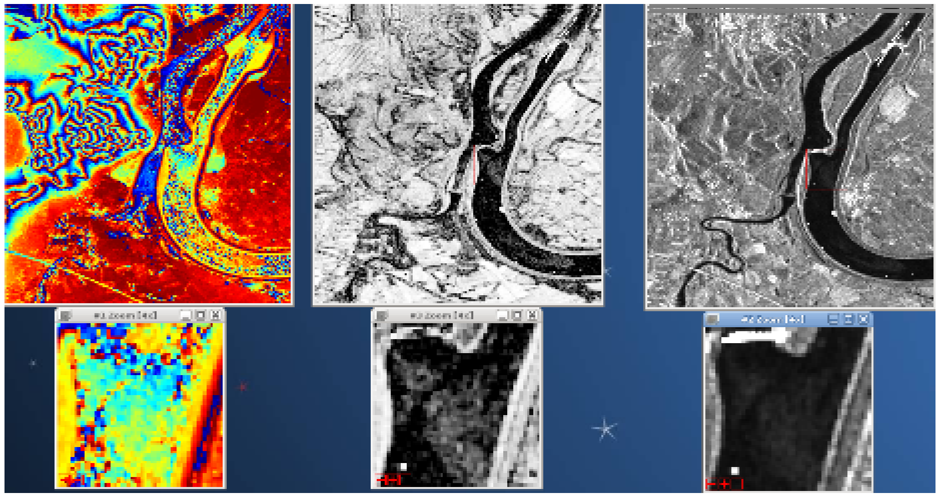
altamira INFORMATION
cnes

Analysis of TDX InSAR phase over water areas

➢ Some river areas **without wind** have coherent InSAR phase, e.g. confluent areas, near dams (small-scale motion, whirlpools...) → **is the phase meaningful?**




Zoom on a coherent area of the river, at a river junction




Zoom on a coherent area of the river, near a dam

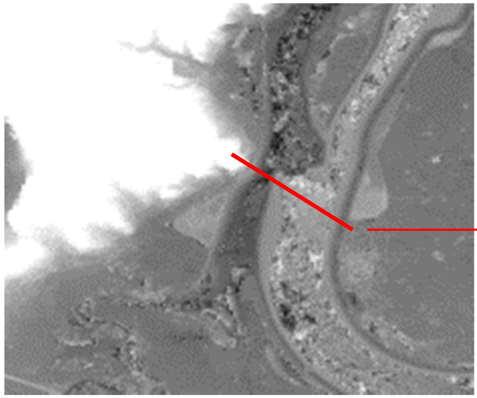
altamira INFORMATION

cnes

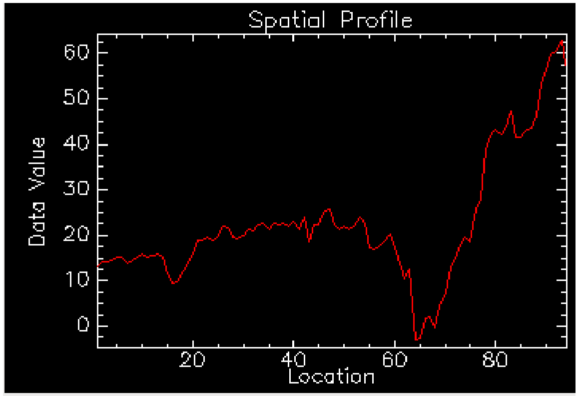
Analysis of TDX InSAR heights over water areas

- Two different approaches: local analysis of TDX DEM or relative phase values
- Problems with phase unwrapping (steep topography at the riverbanks, low coherence areas, wrong reference DEM values over water,…)

- Extract of the computed TDX DEM
- Estimated water surface height = 0.5 m

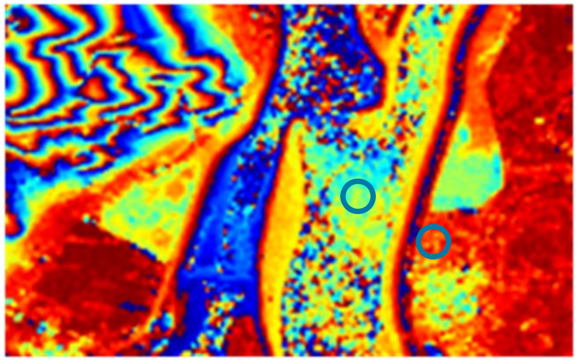


Estimated heights near the Vallabrègues dam



Profile of the height map: the river appears above the banks ➔ subtraction of ambiguity height

- Computing phase difference between river and banks
- Estimated water surface height = 3 m



Interferometric phase near the Vallabrègues dam

Difference of 2.5 m between the two methods

altamira INFORMATION

cnes

River motion contribution to the phase

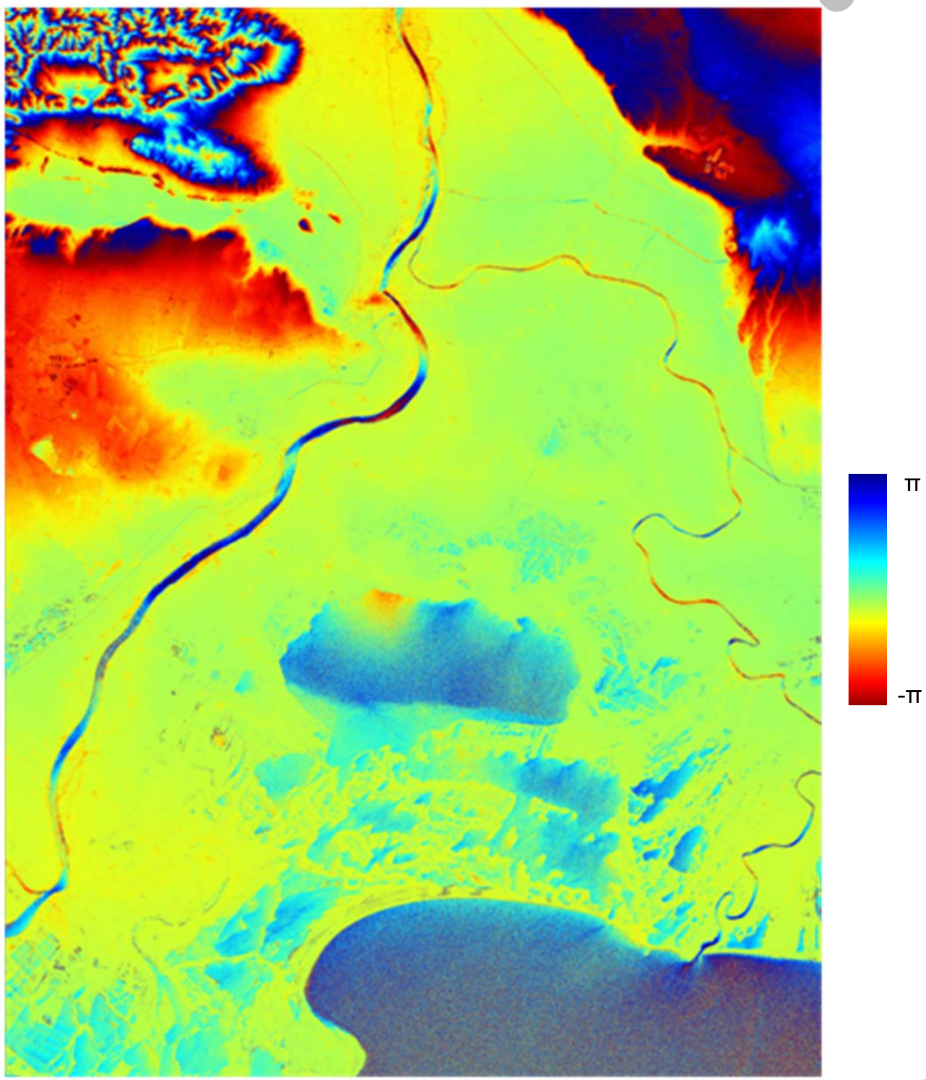
➢ River phase values contain topographic and motion information

➢ In most cases, the river motion contribution is higher than the topographic term

➢ Along-track interferometry (ATI) permits to measure water speed in the range direction:

$$V_{range} = \frac{\lambda V_{sat} \varphi}{4\pi B_{along} \sin\theta}$$

➢ **TDX combines ATI and across-track interferometry in the same acquisition**



TDX interferogram with high water coherence

River motion contribution to the phase

Experimental ATI results for river areas:

- Parallel area of the river used as reference (radial speed = 0 m/s)

- Determination of phase and radial speed in some homogeneous areas

$$V_{rad} = \frac{\lambda V_{sat} \Delta\Phi}{4\pi B_{along} \sin\theta}$$

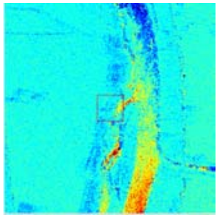
- Estimation of the angle w.r.t. the azimuth axis and computation of river velocity

$$V = \frac{V_{rad}}{\sin(angle)}$$

- Rhone current velocity ~2 m/s

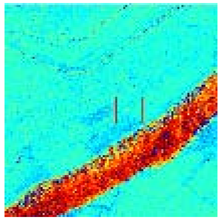
- Precise knowledge of the river velocity in principle allows to extract water surface heights even in a moving area

REFERENCE:



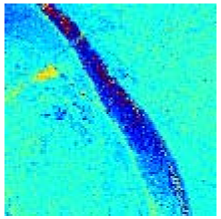
Φ_{ref} = -0.04
$\Delta\Phi$= 0.

V_{rad} = 0 m/s
V = ? m/s



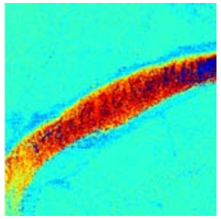
Φ = -1.87
$\Delta\Phi = \Phi_{ref} - \Phi$ = 1.83

V_{rad} = 1.53m/s
Angle=1.13 rad
V = 1.70m/s



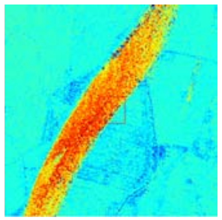
Φ = 1.57
$\Delta\Phi = \Phi_{ref} - \Phi$ = -1.61

V_{rad} = -1.35m/s
Angle = -0.65 rad
V = 2.23m/s



Φ = -1.91
$\Delta\Phi = \Phi_{ref} - \Phi$ = 1.94

V_{rad} = 1.56 m/s
Angle=1.05 rad
V = 1.81m/s



Φ = -1.60
$\Delta\Phi = \Phi_{ref} - \Phi$ = 1.56

V_{rad} = 1.36m/s
Angle=0.63 rad
V = 2.22m/s

Conclusion and outlook

- Excellent TDX DEMs obtained on **land** surfaces with two different methods

  ➔ Potential use as floodplain DEM for hydrological monitoring

- On **water**: sufficient coherence to use phase information only in certain areas and for certain weather conditions

  ➔ Wind-exposed and whirlpool areas (with cm-scale roughness)

- **Water surface phase** depends on both water **height and water motion**
  - Generally dominated by radial water speed for rivers
  - ATI can be used to retrieve river velocity
  - Difficult to extract directly water heights except on motionless water

- TanDEM-X permits to obtain water heights only in some particular areas

- The upcoming JPL/CNES mission SWOT is dedicated to water height measurements: Ka-band interferometry with 10 m across-track baseline (no along-track baseline), operating at low incidences (0.6°-3.9°)