Wide Area Deformation map generation with TerraSAR-X Data.

The Tohoku Earthquake 2011 Case.

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Deutsches Zentrum
für Luft- und Raumfahrt e.V.
in der Helmholtz-Gemeinschaft

Contents

- The Tohoku earthquake
- Methodology
  - Image correlation technique
  - Solid Earth tides correction
- TerraSAR-X dataset
  - Sendai displacement map
  - Tokyo displacement map
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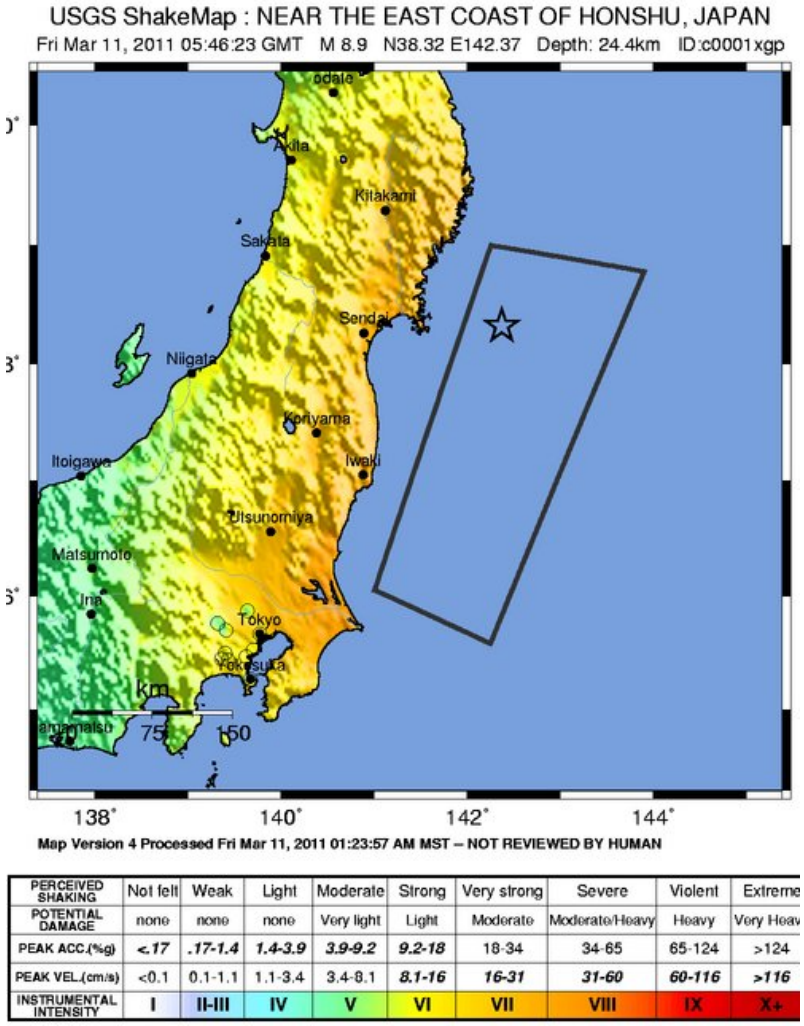
The Tohoku Earthquake

- March 11, 2011 at 05:46 UTC
- 38.322º N 142.369º E 24.4 km depth
- Magnitude: 8.9
- Nearest major city: Sendai

- Tsunami waves were triggered.



PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Moderate/Heavy	Heavy	Very Heav
PEAK ACC.(%g)	*<.17*	*.17-1.4*	*1.4-3.9*	*3.9-9.2*	*9.2-18*	18-34	34-65	65-124	>124
PEAK VEL.(cm/s)	<0.1	0.1-1.1	1.1-3.4	3.4-8.1	*8.1-16*	*16-31*	*31-60*	*60-116*	*>116*
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

Source: USGS

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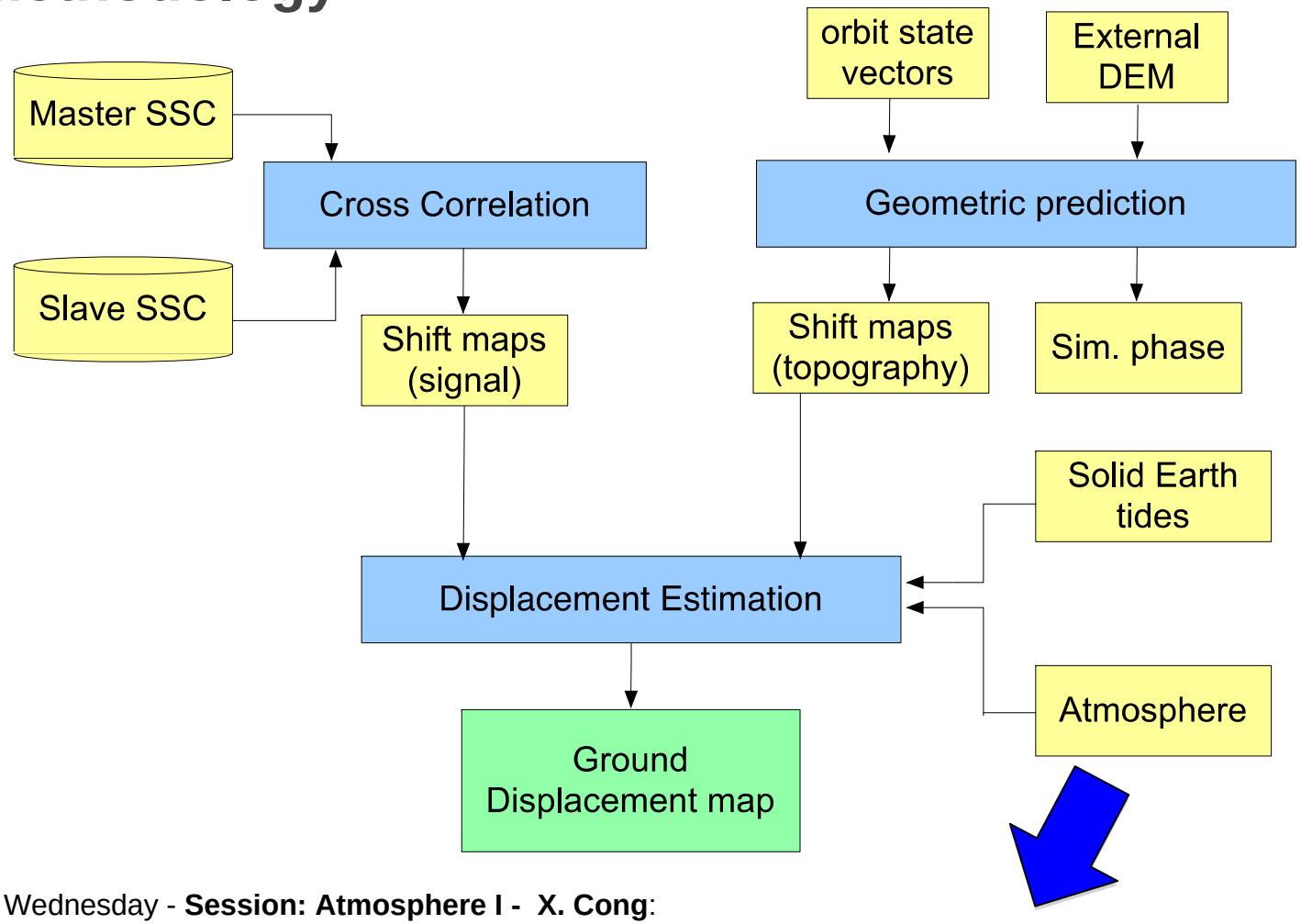
Methodology



09:20-09:40. Wednesday - **Session: Atmosphere I - X. Cong**:
Validation of Centimeter-Level SAR Geolocation Accuracy after Correction for Atmospheric Delay using ECMWF Weather Data

Image correlation technique

- Cross-Correlation using complex image or intensities
- Performed in frequency domain
- Patches Size: 128x128 pixels (~190x250 m)
- Distance between patches: 64 pixels (~100m)

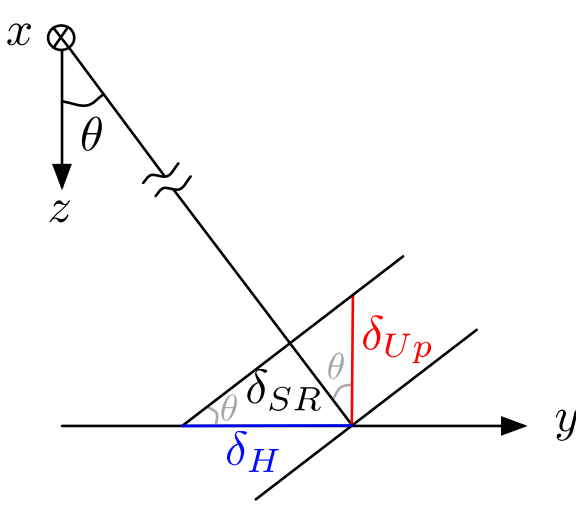
} 50% patches overlap

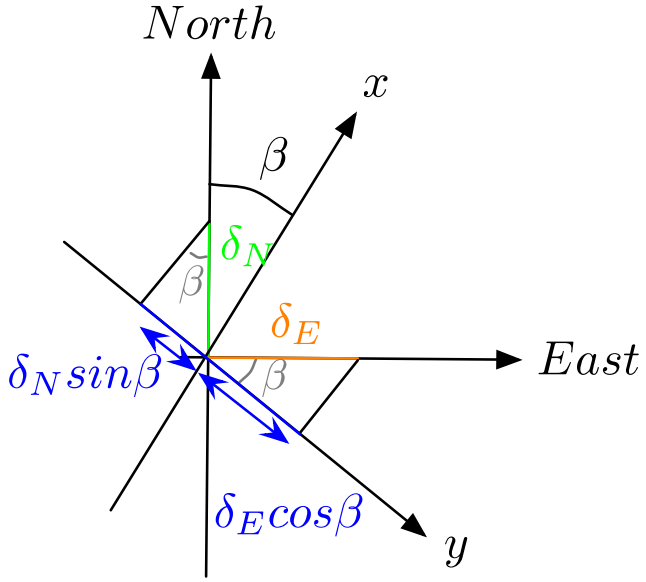
Topography Compensation

- Estimation of shift due to parallax effect and topography
  - TerraSAR-X satellite orbit state vectors accuracy < 5 cm.
  - External DEM: 3'' SRTM.

Solid Earth Tide Correction

Deformation of the Earth due to gravitational forces of Sun and Moon.





$$\delta_{ground} = -\delta_{Up} cos\theta + \delta_{East} sin\theta cos\beta - \delta_{North} sin\theta sin\beta$$

M. Eineder, C. Minet, P. Steinberger, X. Cong, T. Fritz. Imaging Geodesy-Toward Centimeter-Level Ranging Accuracy with TerraSAR-X. IEEE Transactions on Geoscience and Remote Sensing, Vol 49, No 2. February 2011

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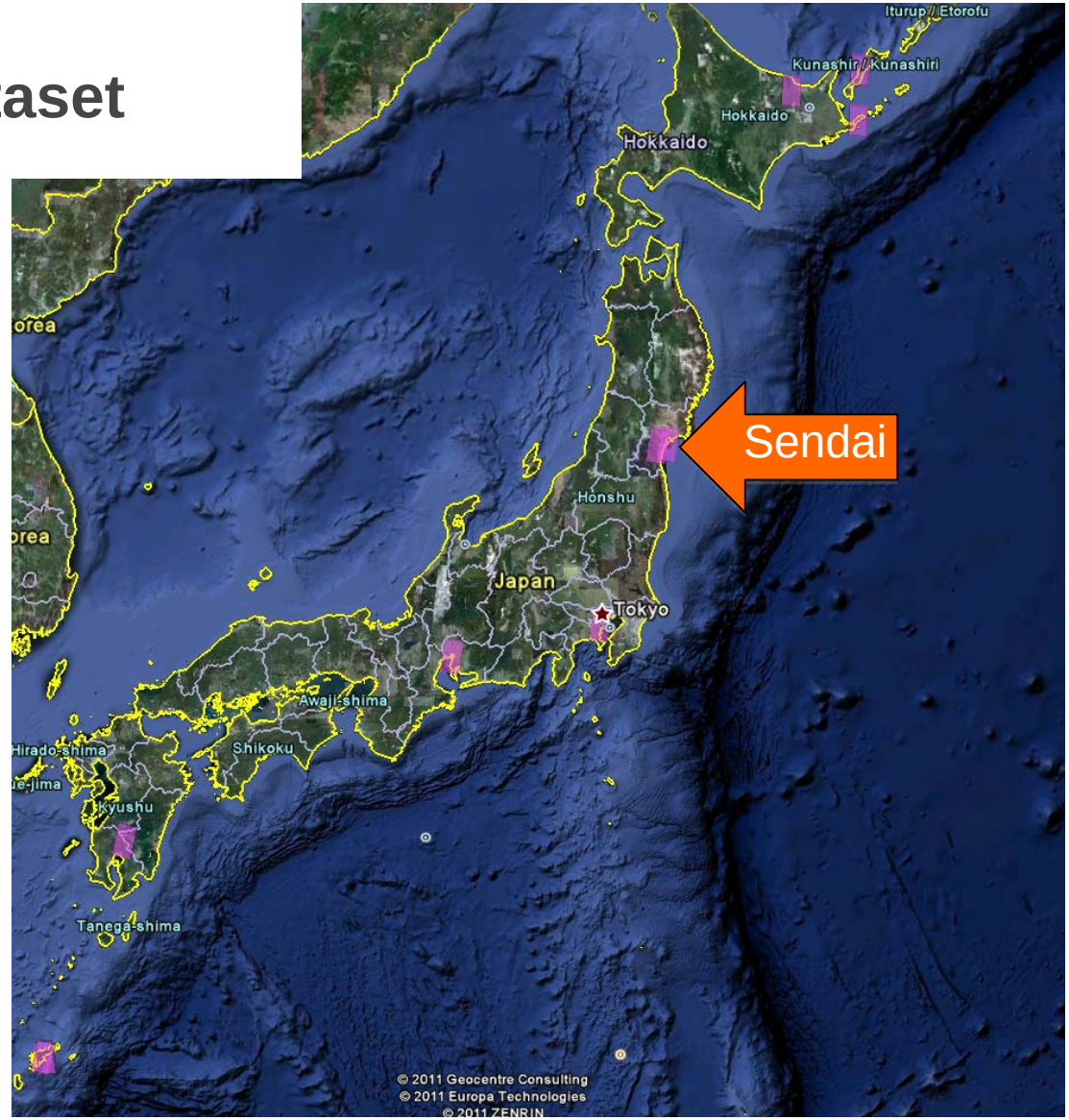
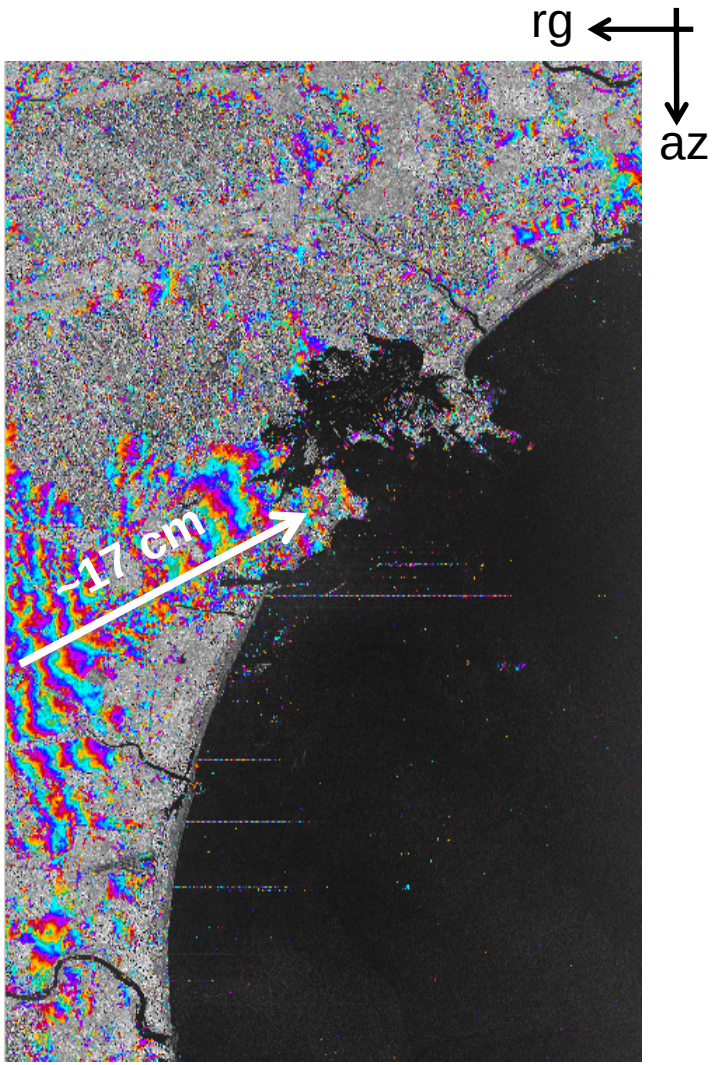
TerraSAR-X Dataset

- 9 Descending co-seismic pairs spread over the archipelago.
- Stripmap mode (30 x 50 km)
- Different looking angles
- Large temporal baselines (2 – 6 months)
- Not crossed orbits -> Not possible to derive 3D deformation maps -> projection on ground
- Processed with Science Orbits



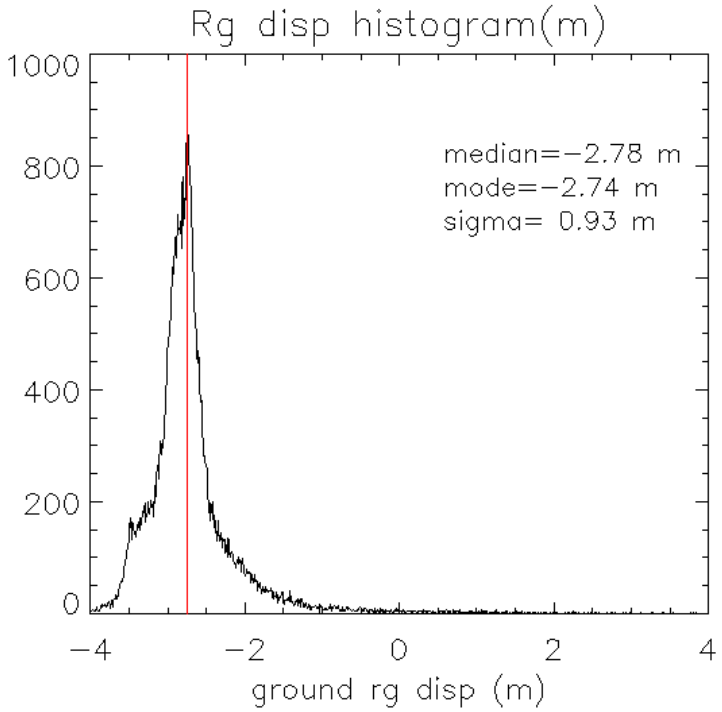
Sendai: dInSAR

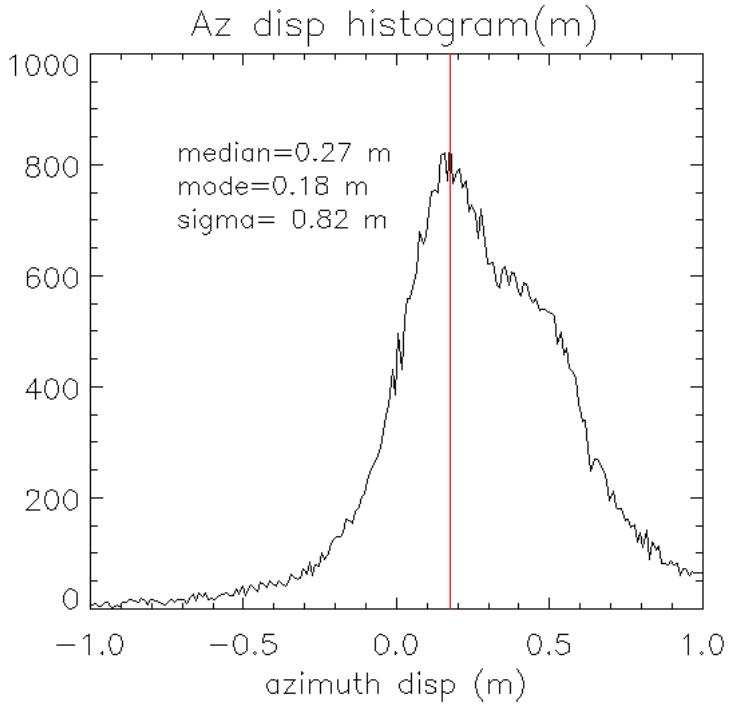
- Descending orbit
- Look angle: 37.3º
- Co-seismic pair:
  - 23.11.2010
  - 12.03.2011
- Eff. Baseline: 48.05 m
- ML: 11 x 11 pixels



Interferometric phase after topography compensation

Sendai: Cross-correlarion results





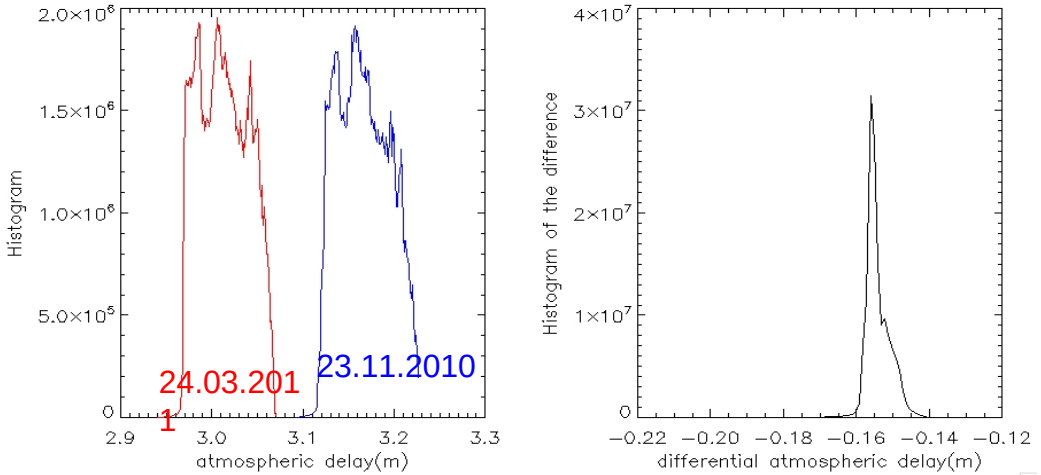
Avg Correlation coef ~ 0.4

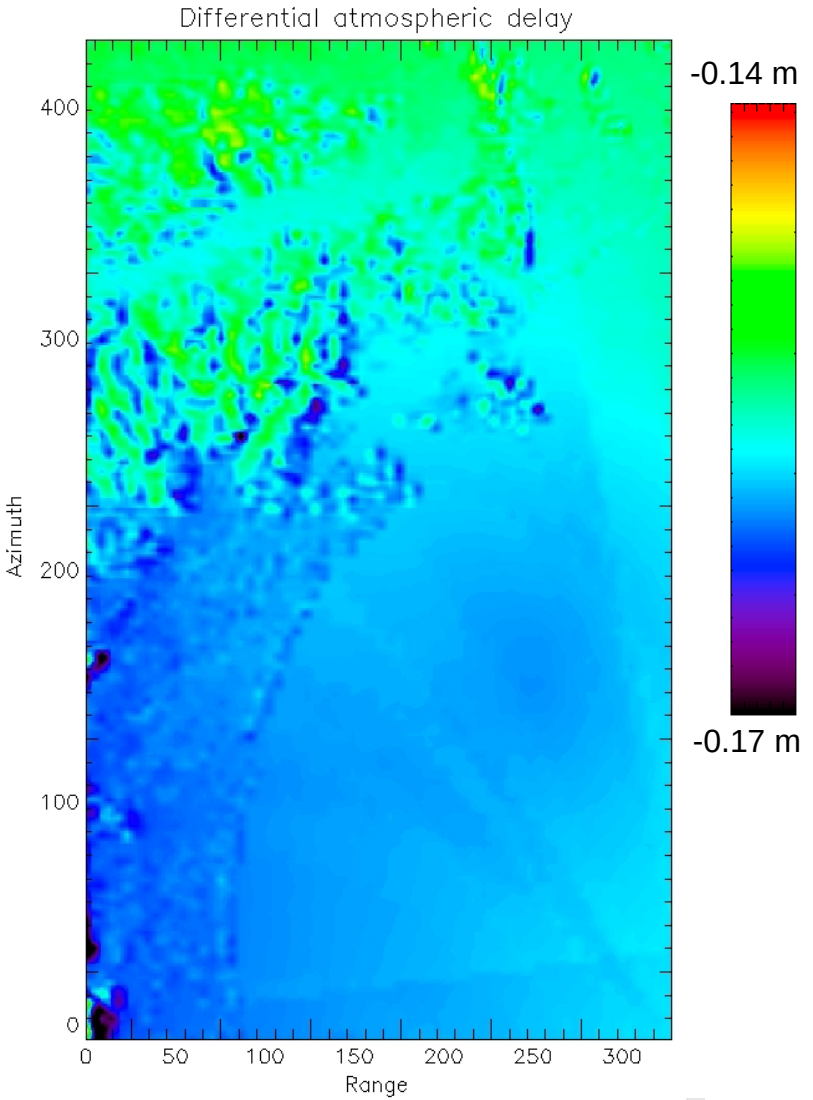
- Range displacement projected on ground

  Approximation: vertical displacements are smaller (~ 6x) than horizontal (from co-seismic GPS measurements)

Sendai: Corrections

Differential atmospheric delay correction





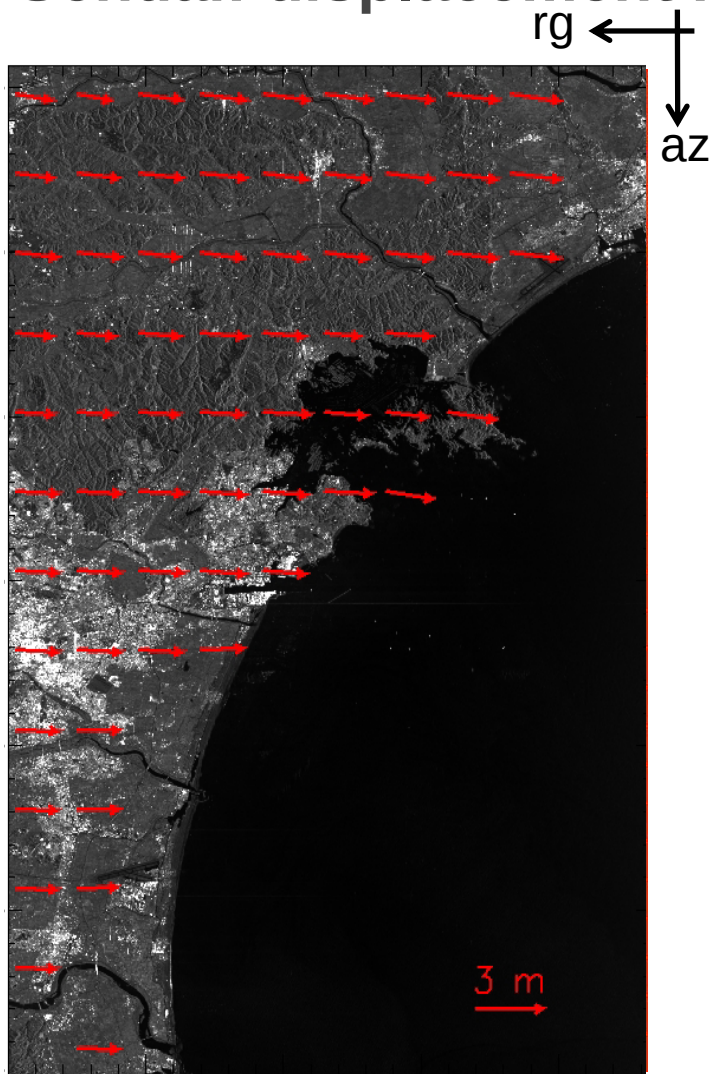
Atmospheric delay mean correction ~ -15.4 cm (slant range)

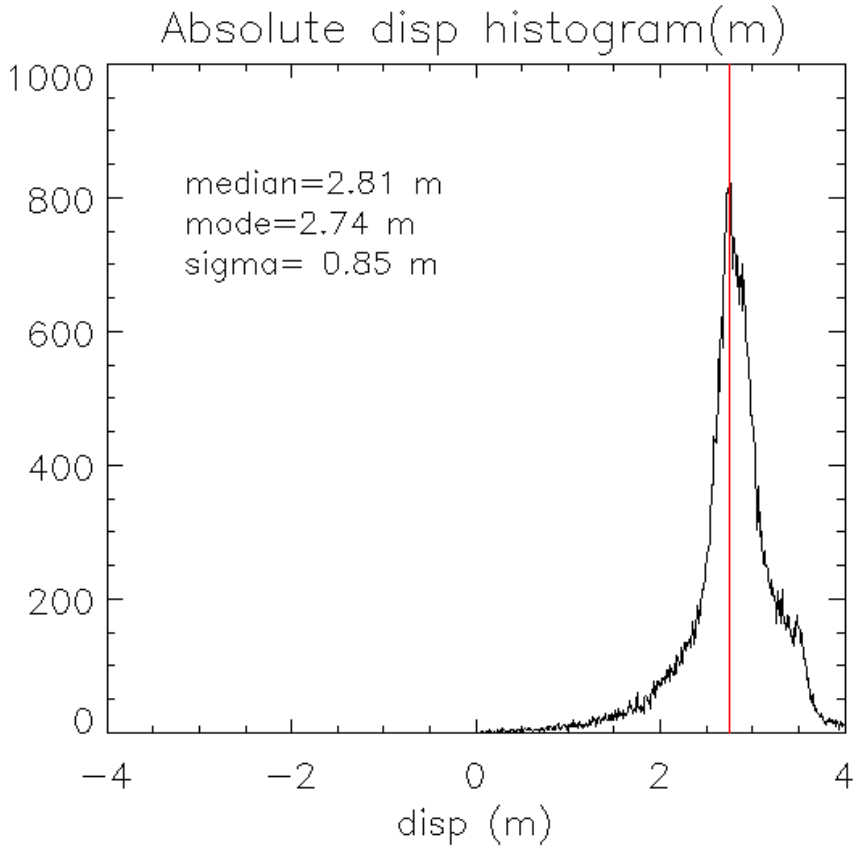
Solid Earth Tide correction

	North	East	Up
23.11.2010	-0.88 cm	2.09 cm	-11,98 cm
24.03.2011	-3.64 cm	-0.35 cm	-7.485 cm
Difference	-2.76 cm	-2.44 cm	4.50 cm

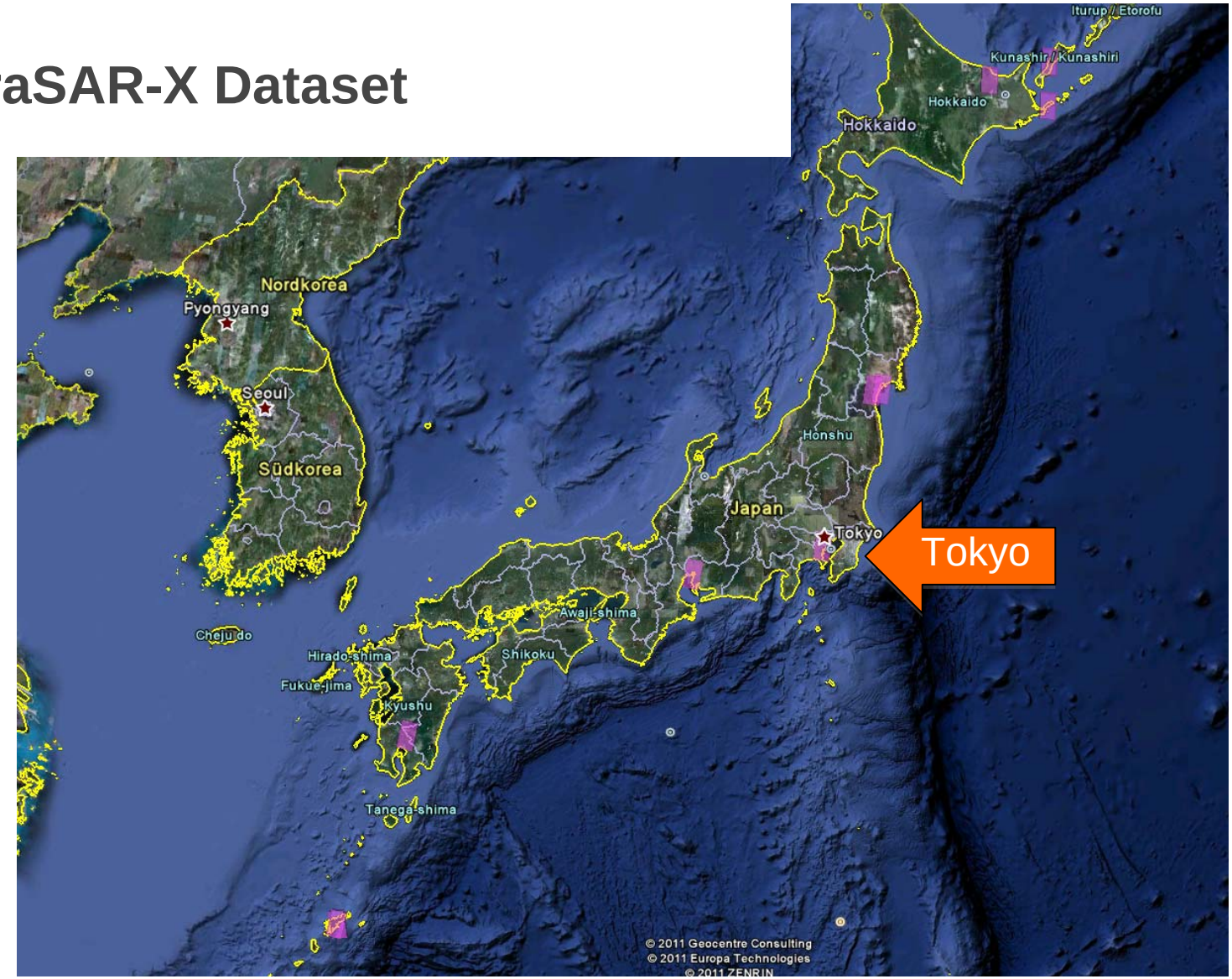
SET mean correction ~ - 2.5 cm (slant range)

Sendai: displacement map



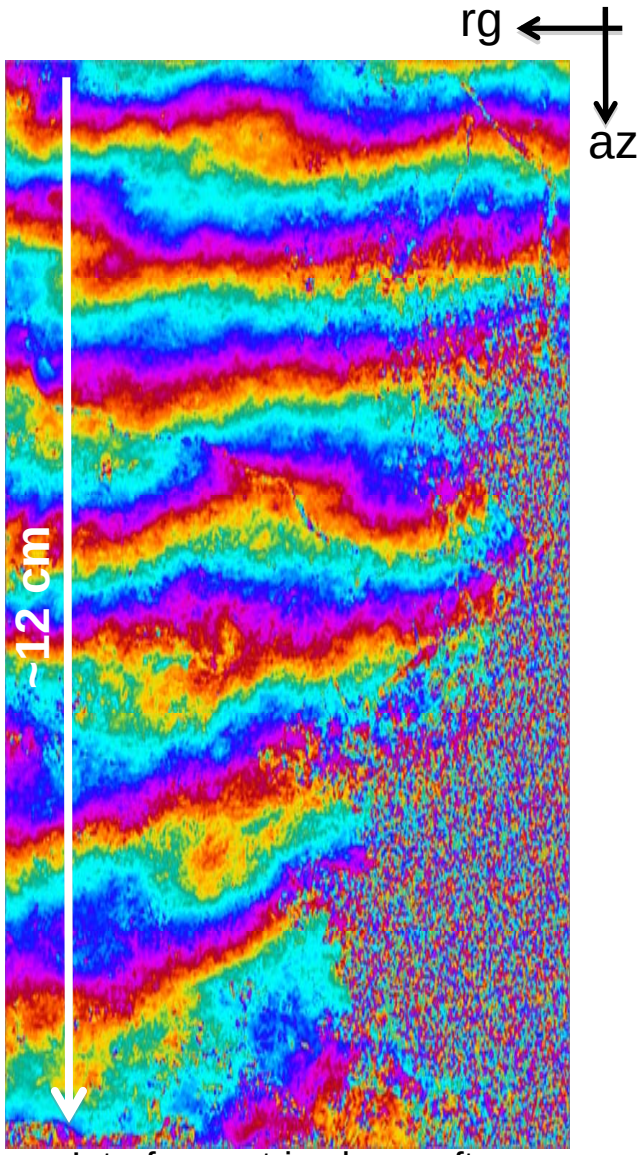


TerraSAR-X Dataset



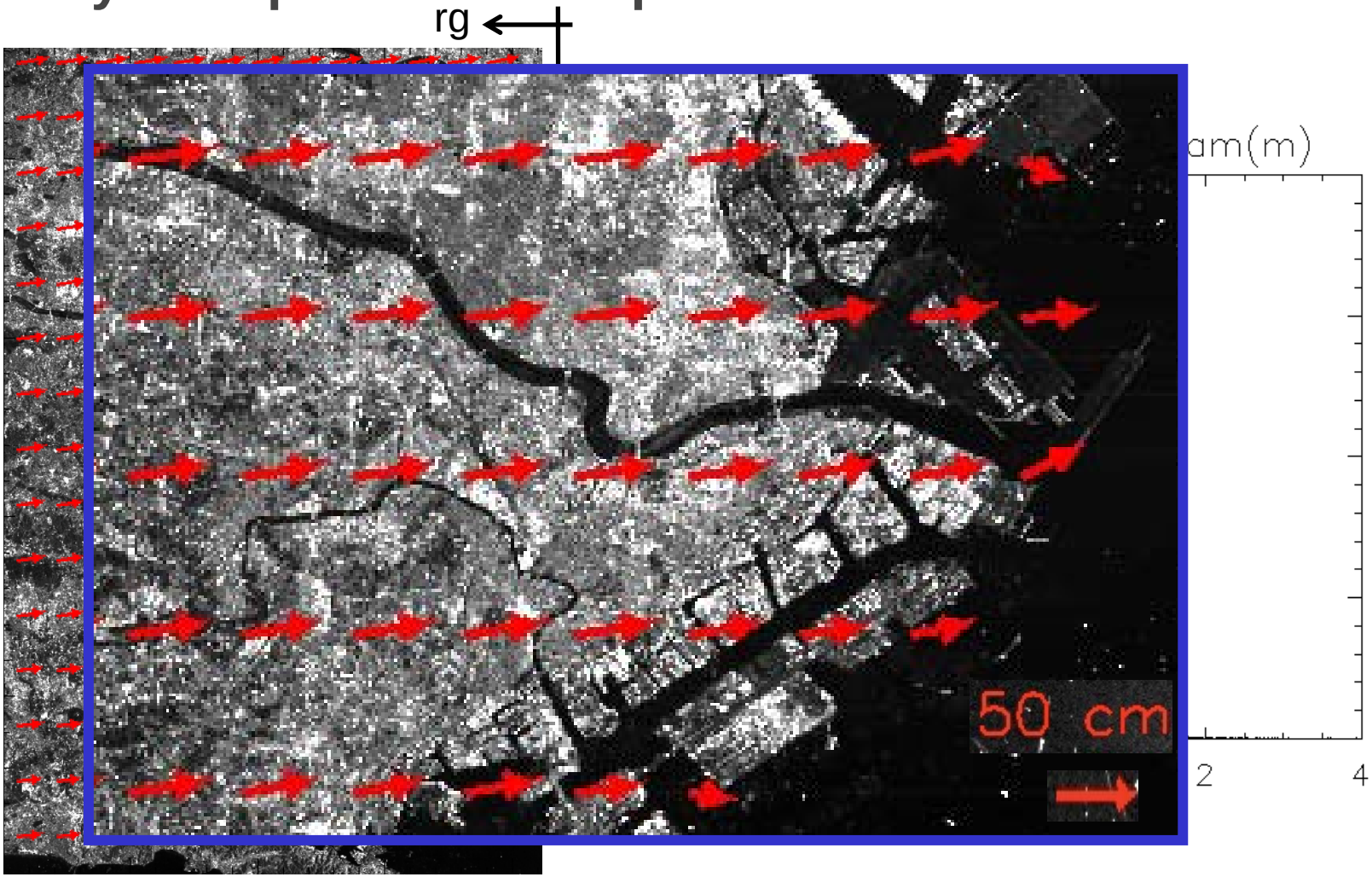
Tokyo: dInSAR

- Descending orbit
- Look angle: 42.8 º
- Co-seismic pair:
  - 16.01.2011
  - 12.03.2011
- Eff. Baseline: 116.36 m
- ML: 11 x 11 pixels



Interferometric phase after topography compensation

Tokyo: displacement map



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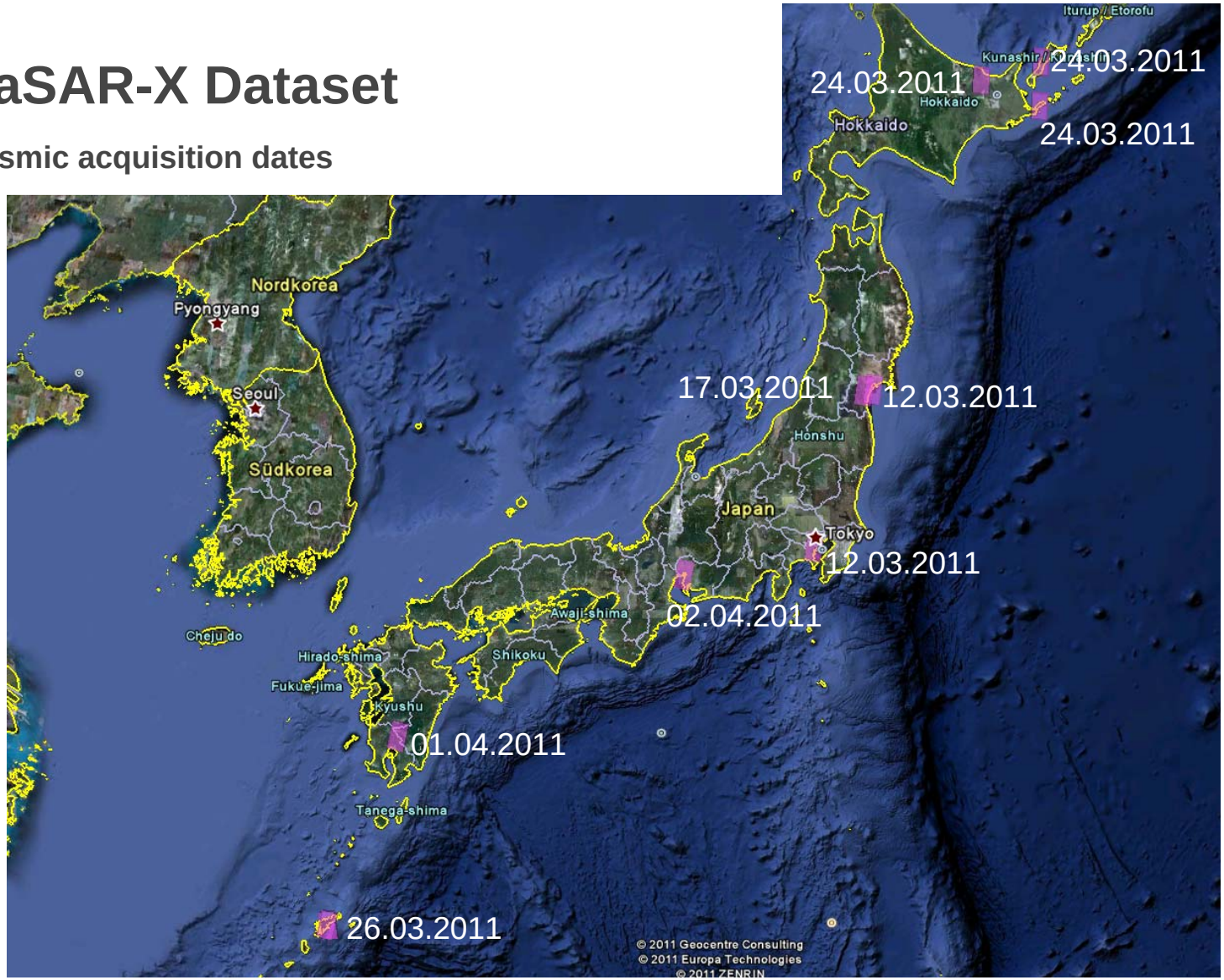
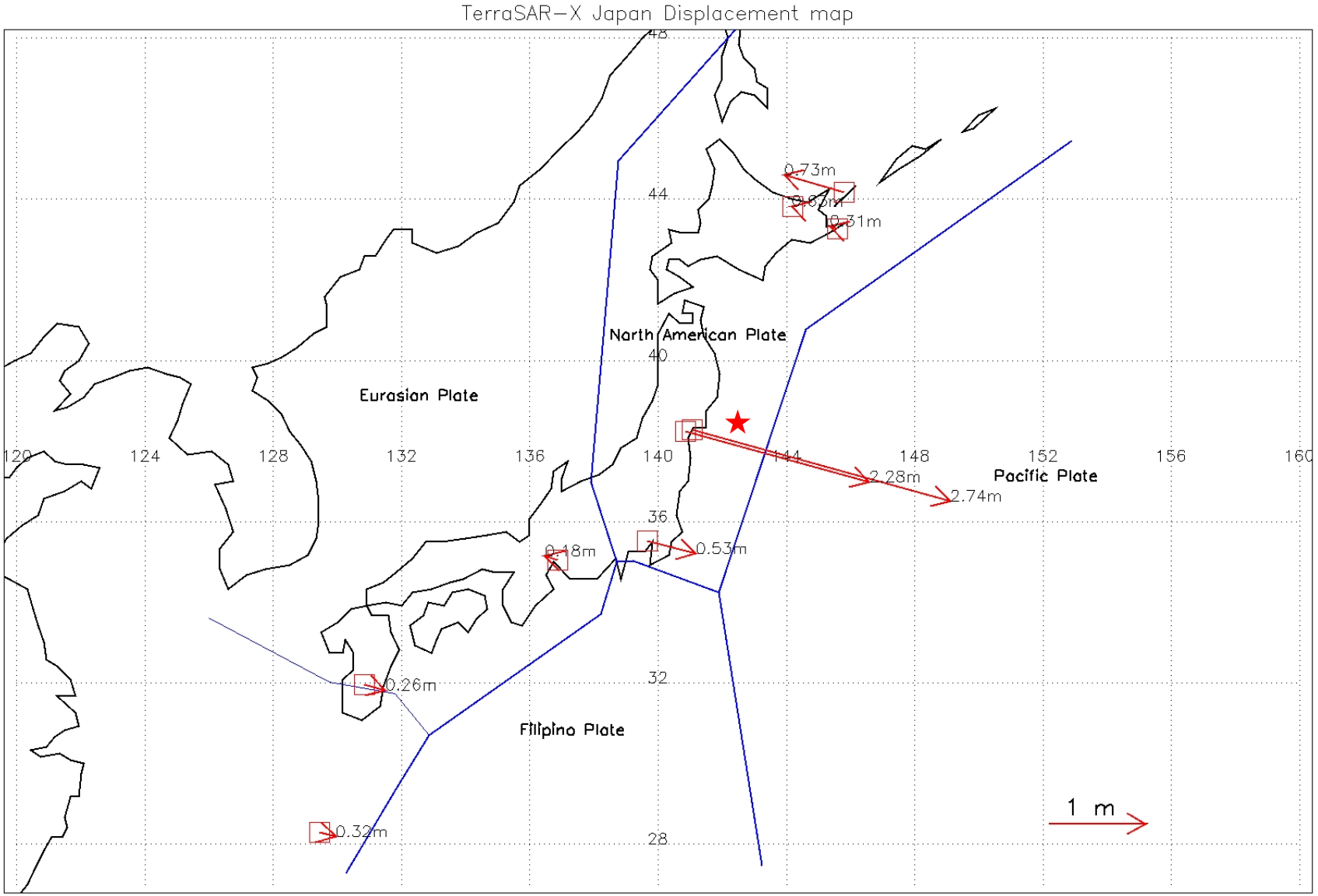
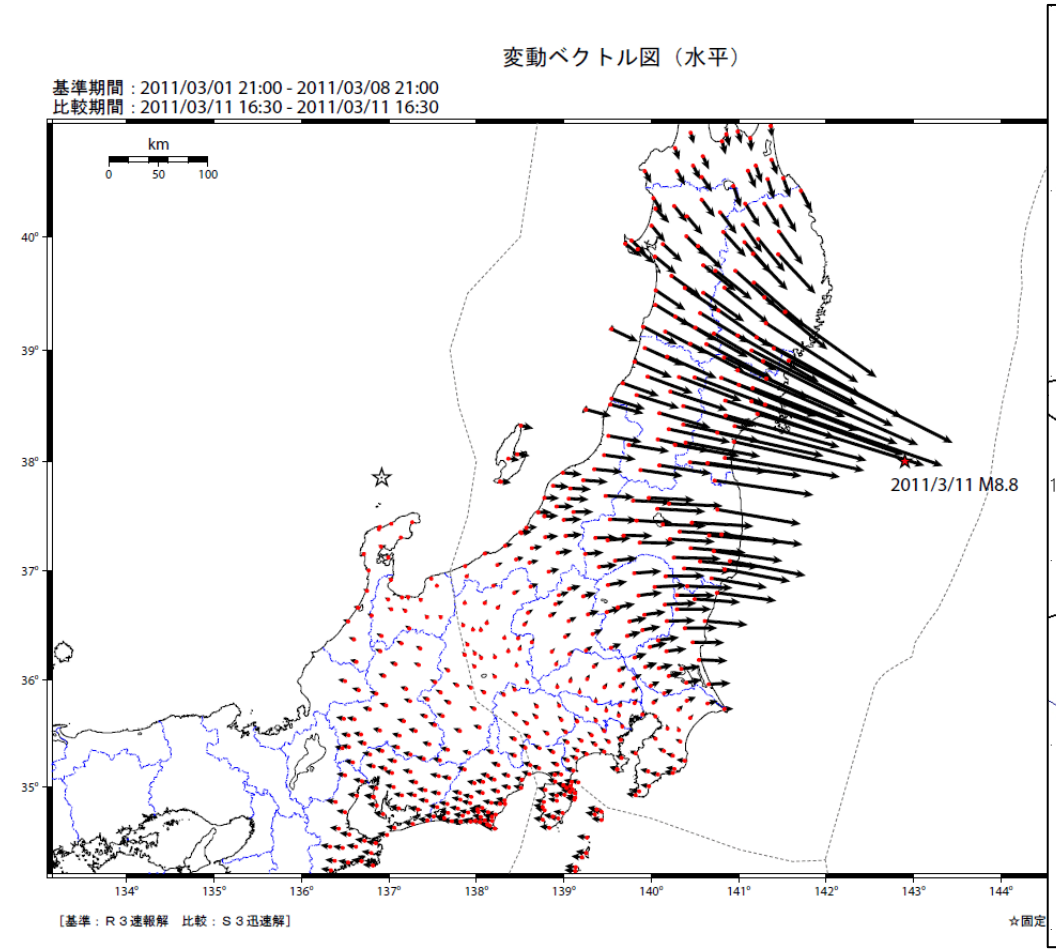
TerraSAR-X Dataset

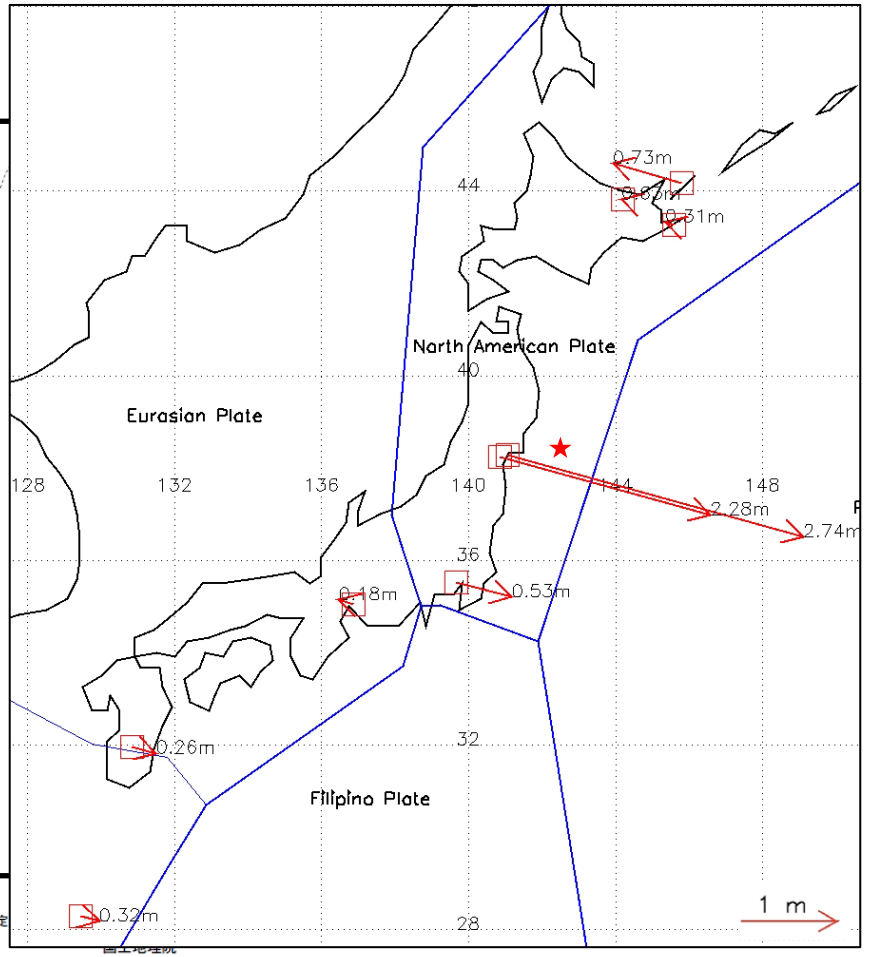
Postseismic acquisition dates




TerraSAR−X Japan Displacement map
North American Plate
Eurasian Plate
Pacific Plate
Filipino Plate
0.73m
0.31m
2.28m
2.74m
0.53m
0.18m
0.26m
0.32m
1 m
48
44
40
36
32
28
120
124
128
132
136
140
144
148
152
156
160

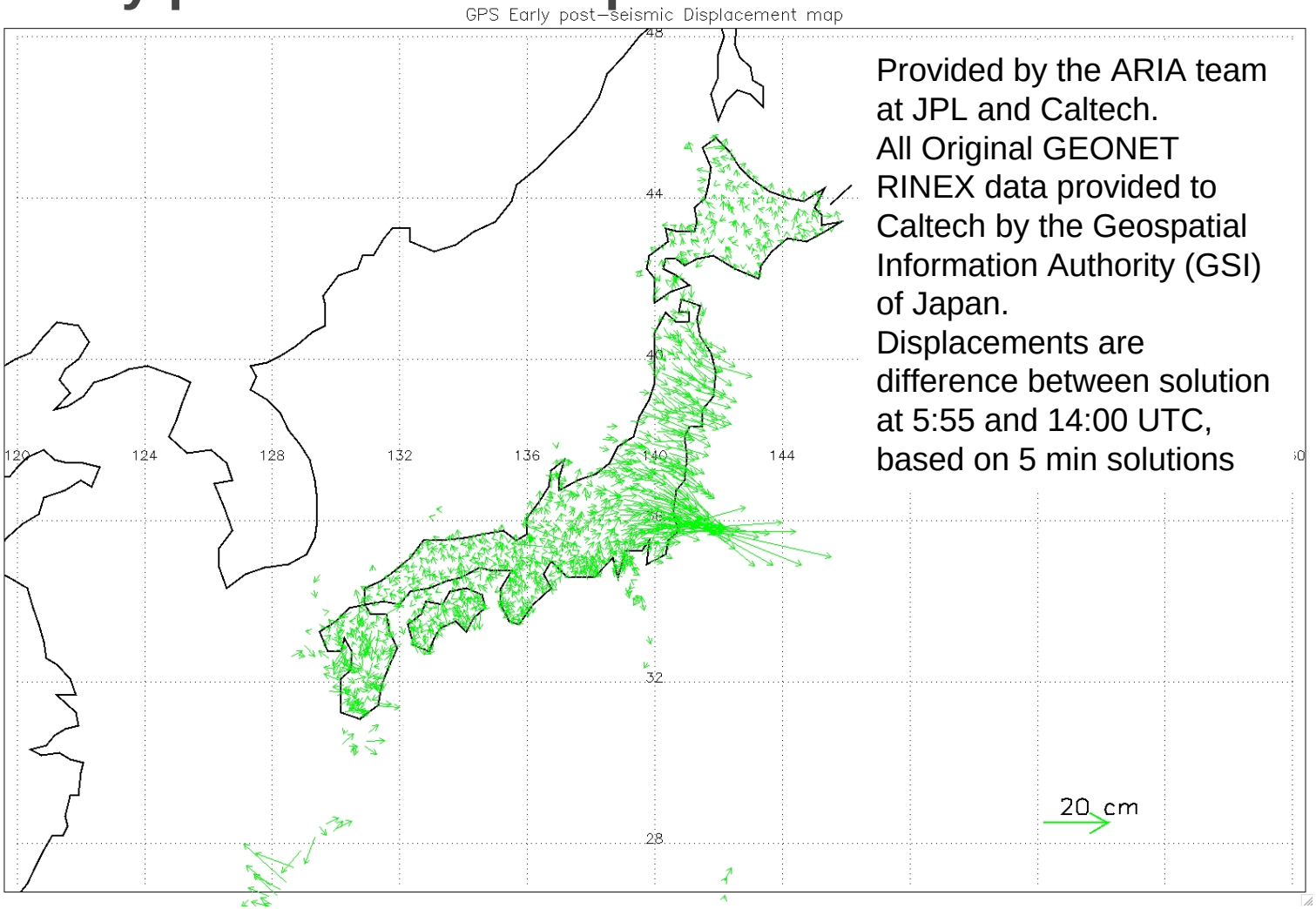
Co-seismic displacement from GPS





Acknowledgement: Co-seismic displacement from GPS by GEONET. Prof. Hashimoto.
http://supersites.earthobservations.org/sendai.php

Early post-seismic displacement from GPS



Provided by the ARIA team at JPL and Caltech.
All Original GEONET RINEX data provided to Caltech by the Geospatial Information Authority (GSI) of Japan.
Displacements are difference between solution at 5:55 and 14:00 UTC, based on 5 min solutions

Summary and Conclusions

- Single TerraSAR-X scenes coverage is too small to study wide area deformation phenomena.
- Use of nine interferometric co-seismic pairs distributed over the Japanese archipelago.
- Heterogeneous dataset (different look angles).
- Large temporal baselines (2 – 6 months).
- Cross-correlation technique used to derive absolute displacements in slant-range and azimuth direction.
- Correction for Solid Earth Tides and atmospheric path delays have been performed.
- Agreement with GPS data.
- If cross-orbit acquisitions had been available, 3D deformation maps could have been generated.

Thank you

Acknowledgements

- Supersite Tohoku http://supersites.earthobservations.org/sendai.php
- Xiao Ying Cong from DLR for the atmospheric path delay compensation.
- Starlab (Spain) for supporting me to assist to FRINGE Conference.