*INTER**GEO** 2011*

Geodätische Messungen mit TerraSAR-X - Stand der Genauigkeit

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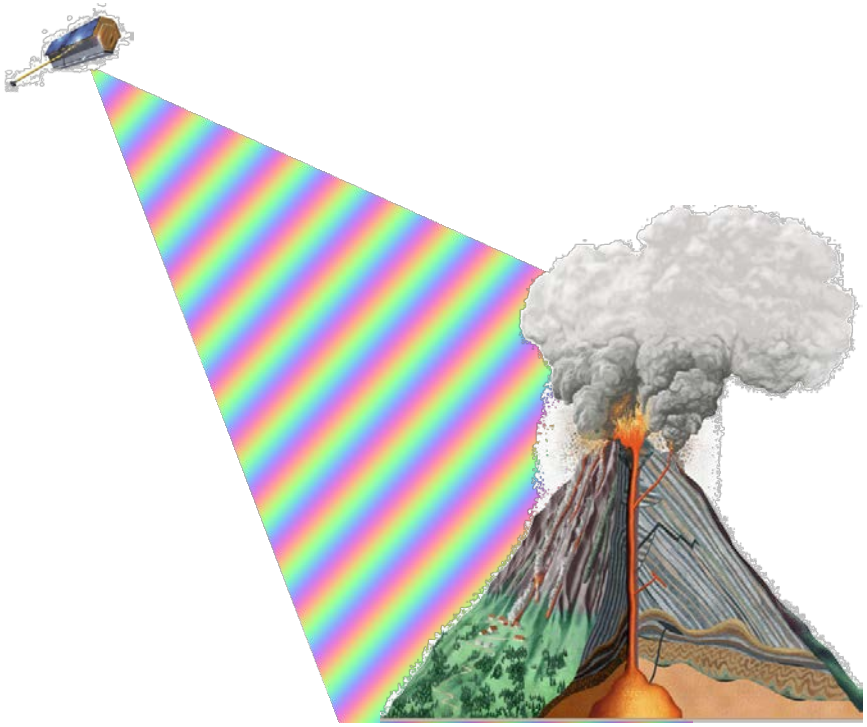
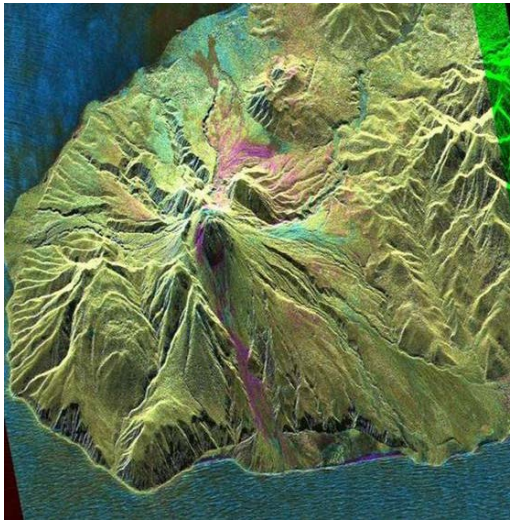
Outline

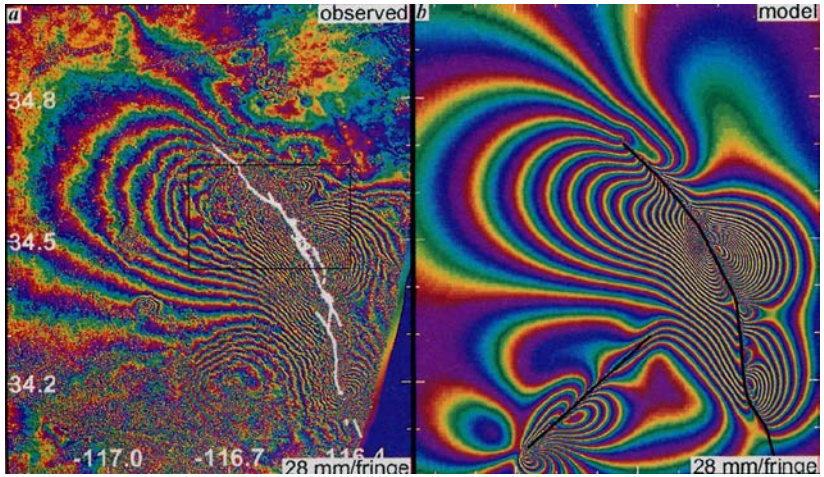
- Goal: Capture earth surface motion globally from space with high accuracy and resolution
- Differences between InSAR and high resolution image correlation techniques (HRIC)
- Error sources & recent correction techniques turning space borne imaging Synthetic Aperture Radar (SAR) systems into geodetic measurement devices
- Examples





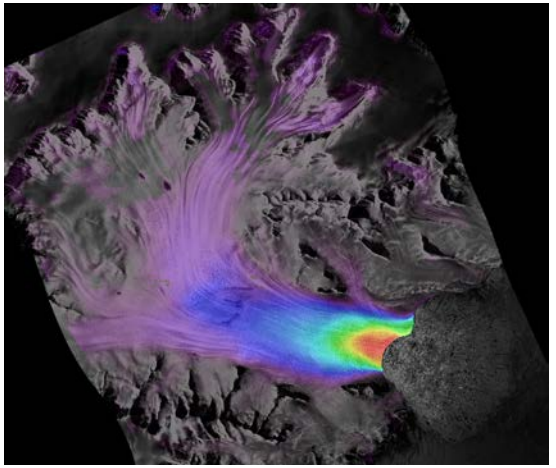
InSAR Versus Image Correlation

InSAR



Massonnet et al., The displacement field of the Landers earthquake mapped by radar interferometry, Nature, V.364, p. 138-142, 1993

Image Correlation



Eineder, Wael Abdel Jaber, Glacier Flow and Topography Measurements with TerraSAR-X and TanDEM-X, IGARSS 2011

- Prinzip:
  - Coherent pixel phase (no contrast needed)
- Properties
  - high spatial resolution (≈ m)
  - high accuracy (≈ $\lambda/10$)
  - 1D, ambiguous, relative

- Prinzip:
  - Inter pixel contrast (needs window/edge)
- Properties
  - lower spatial resolution (≈ m x 10)
  - Lower accuracy (cm)
  - 2D, absolute

Error Source: **Satellite Orbits**

Characteristics: Large scale (smooth) offsets < 5 centimeters

Consequences:

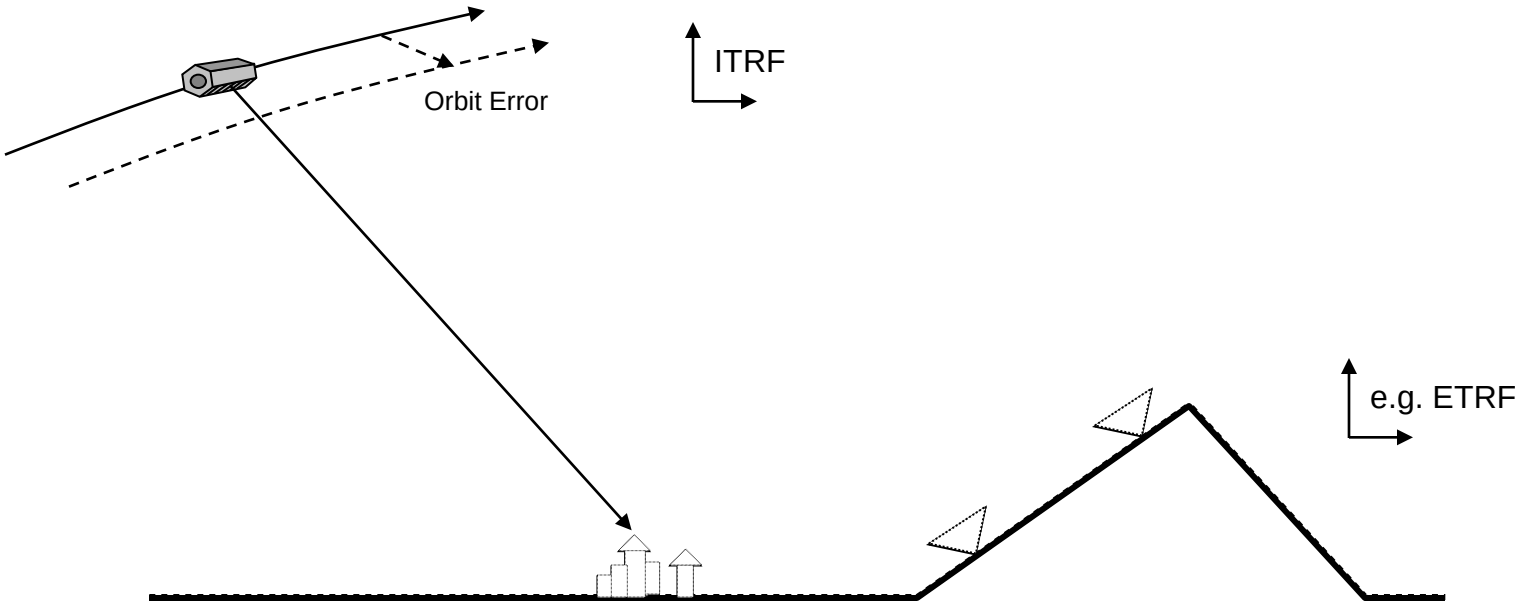
- InSAR:
  - Phase offsets (invisible)
  - Phase ramps → motion error gradients
  - Overall location error (small)
- HRIC:
  - Offsets
  - Ramps (comparatively small)
  - Overall location error (small)

Compensation:

- InSAR:
  - Offset control point (anyway)
  - Ramp control points → loss of information
- HRIC:
  - Offset & ramp control points → loss of information

Error Source: **Reference Frames and Earth Tides**

Characteristics: Shifts up to ±20 centimeters



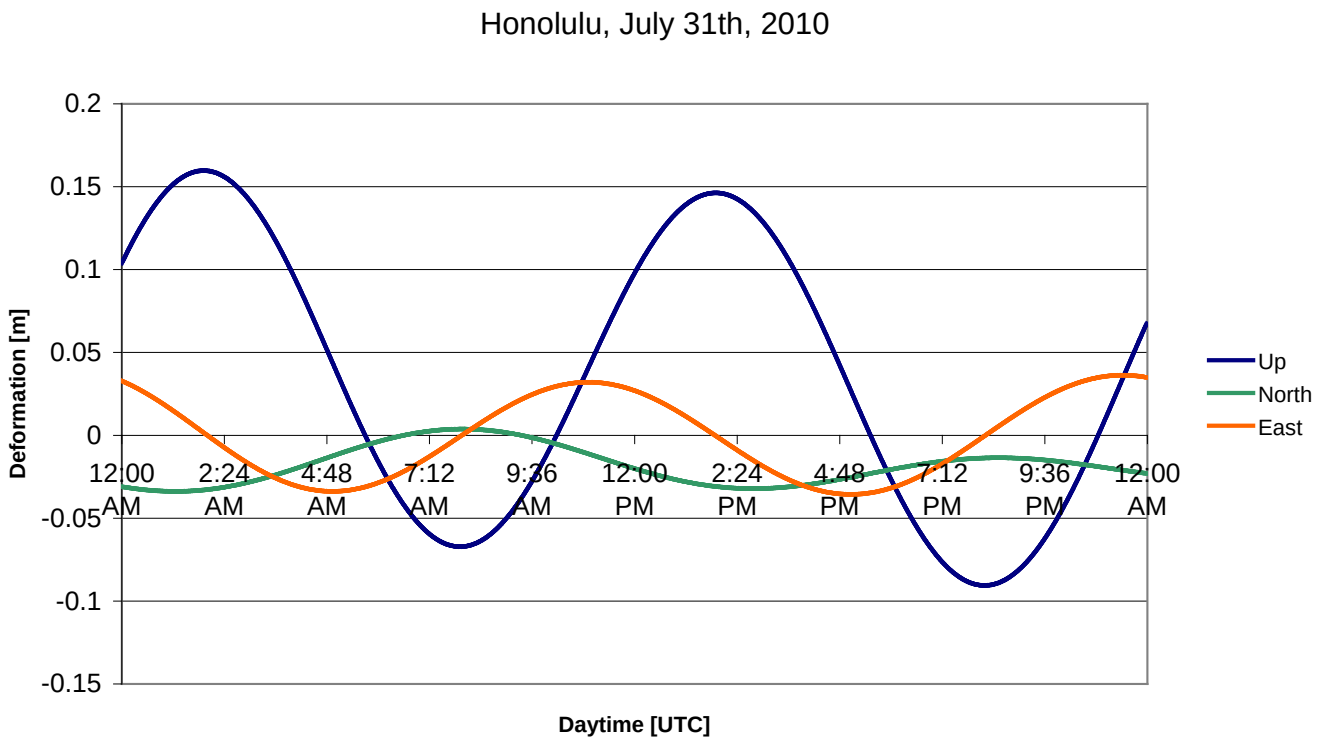
Consequences:

- InSAR:
  - Invisible phase offsets
- HRIC:
  - Offsets (visible)
  - Overall location error (small)

Error Source: **Earth Tides**

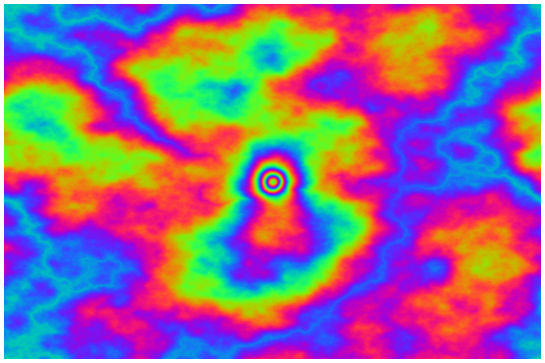
Compensation:

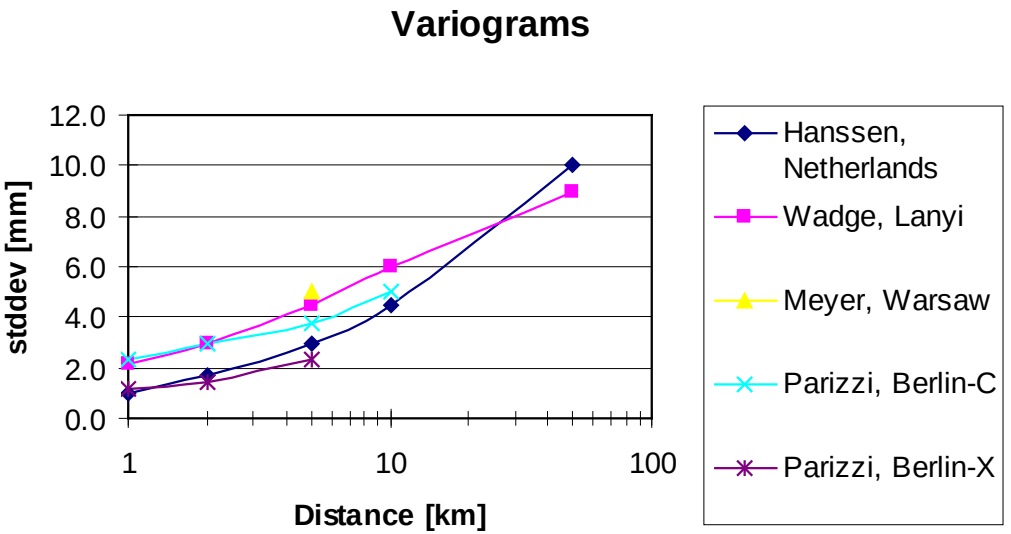
- InSAR: unnecessary because local relative measurement
- HRIC: Use of model



Error Source: **Atmosphere**

Characteristics: Distance dependent turbulences from mm up to ±15 cm





Consequences:

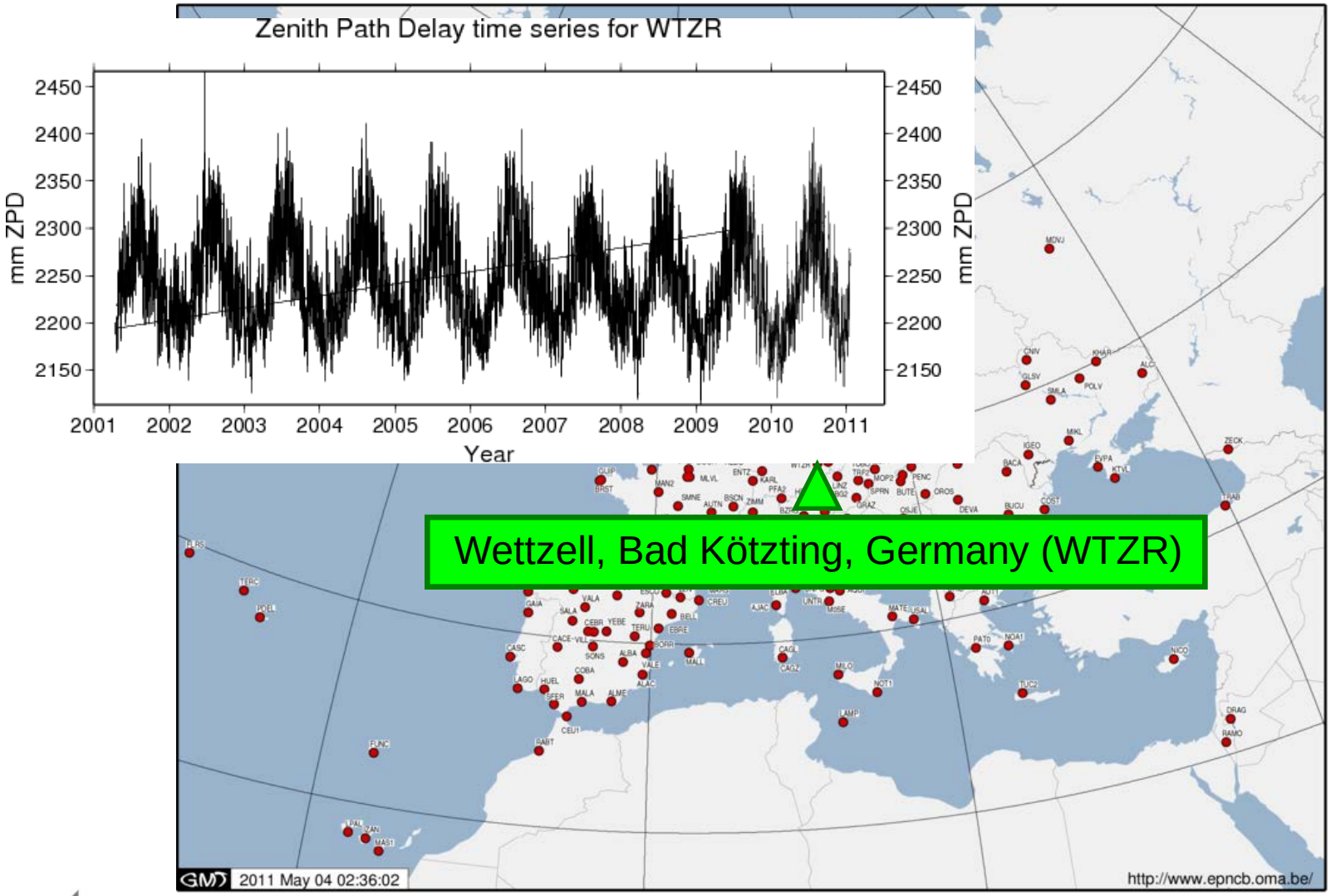
- InSAR:
  - Phase offsets (invisible)
  - Phase patterns → dangerous motion errors
- HRIC:
  - Offsets (visible)
  - Motion patterns (comparatively small)
  - Overall location error (small)

Error Source: **Atmosphere**

Compensation:

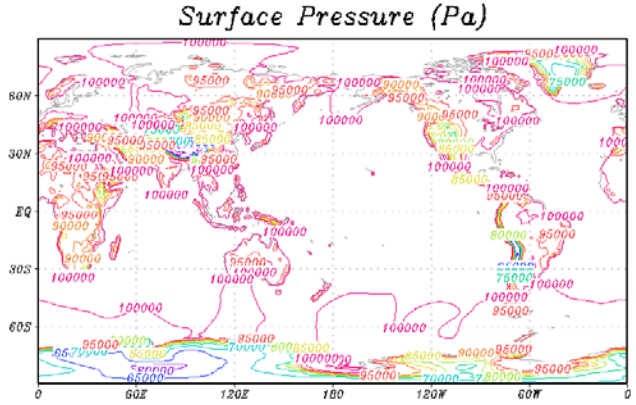
- InSAR: (Goal: mm/year)
  - 1. Temporal averaging → **Persistent Scatterer Interferometry** (state of the art, expensive)
  - 2. High resolution weather (H_2O) modelling (future, not yet operational)
- HRIC: (Goal: cm/year)
  - 1. Large area compensation by **GPS** Trop. Zen. Delay or
  - 2. or **low resolution weather model** (new!) or
  - 3. high resolution weather model (future, not yet operational)

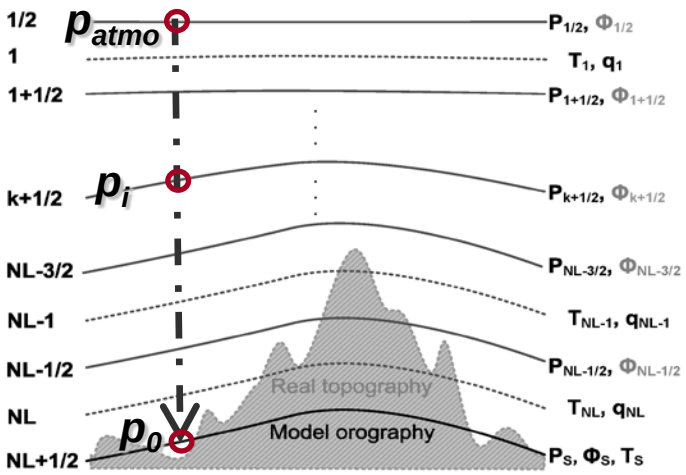
ZDP from EUREF Permanent GPS Network

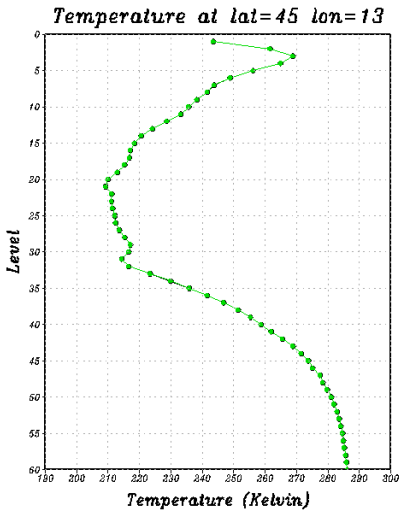


Path Delay from Numerical Weather Model Data

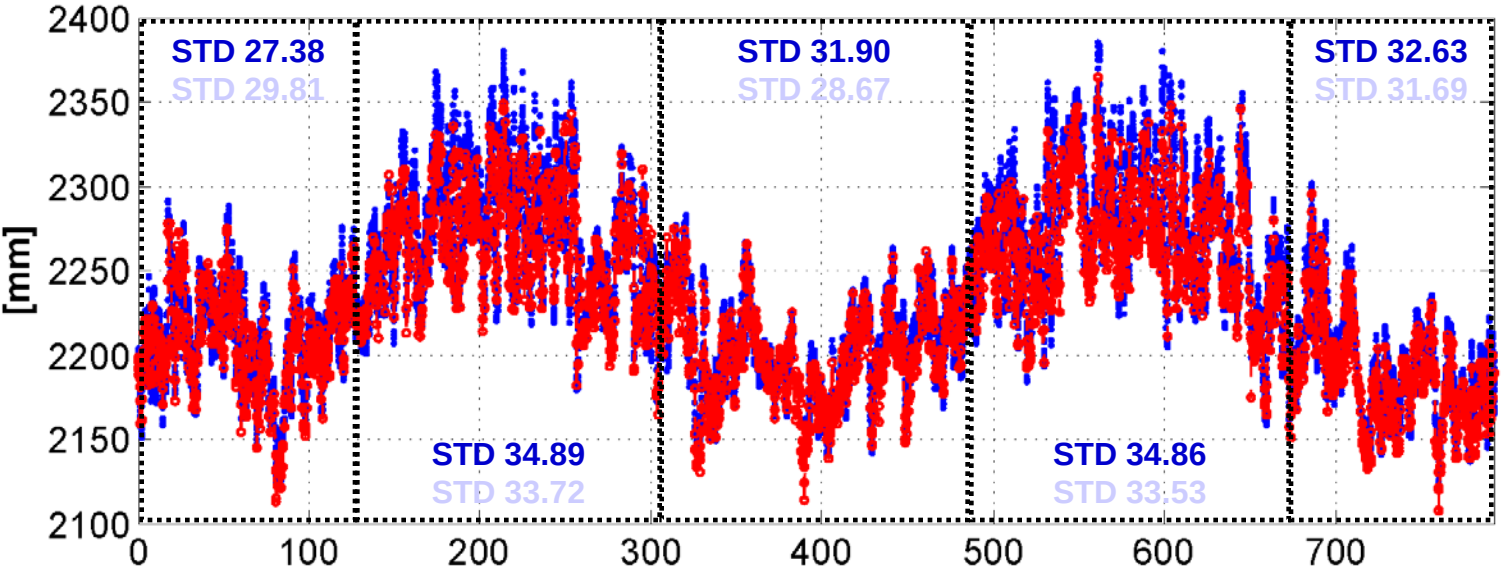
- ERA-Interim reanalysis from European Centre for Medium-Range Weather Forecasts (ECMWF)
- Horizontal resolution: full T255 spectral truncation (grid size ~80 km)
- Available on 0h, 06h, 12h and 18h, since 1989 to current – 3 months

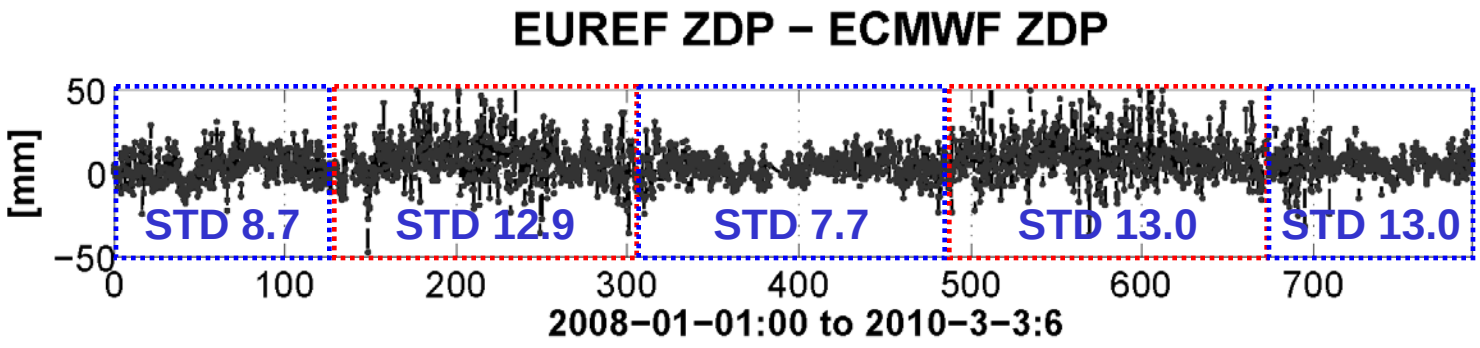


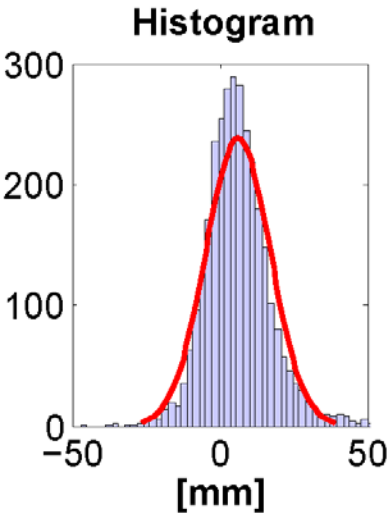




Comparison GPS ZDP with ECMWF

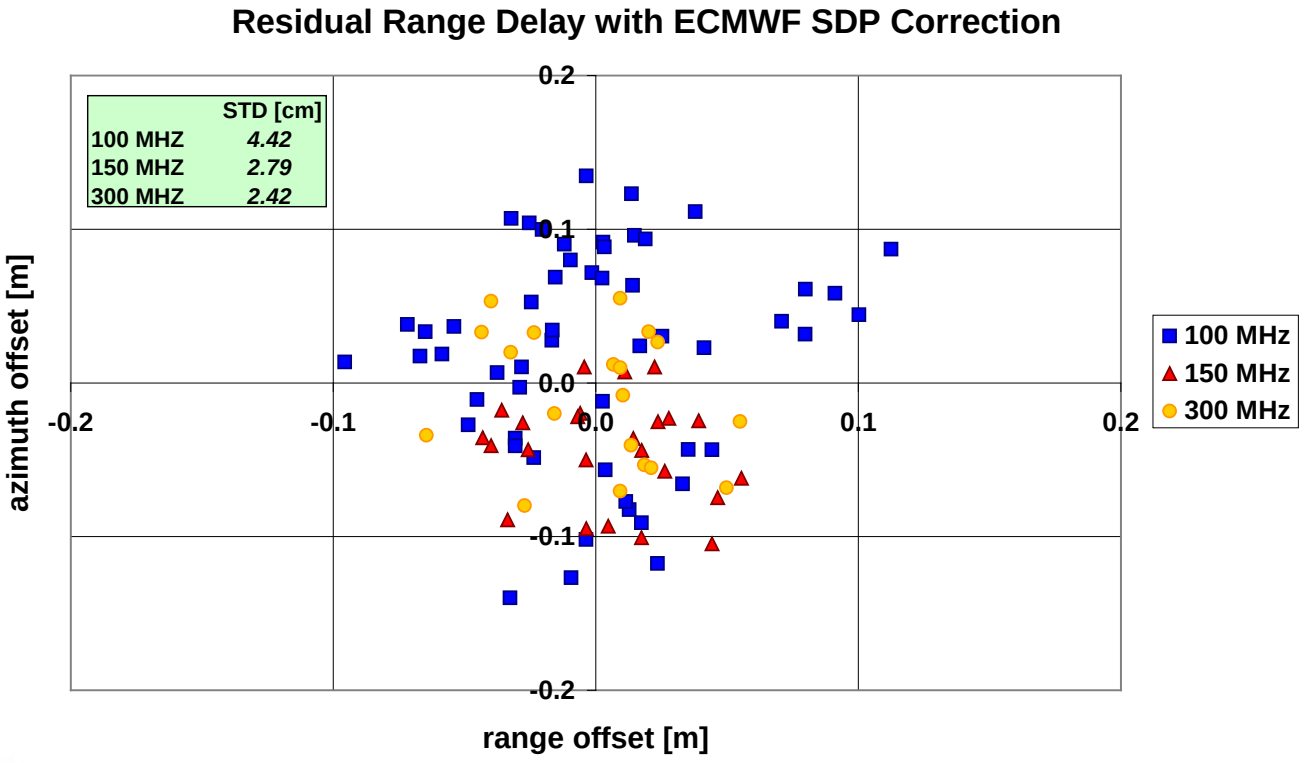






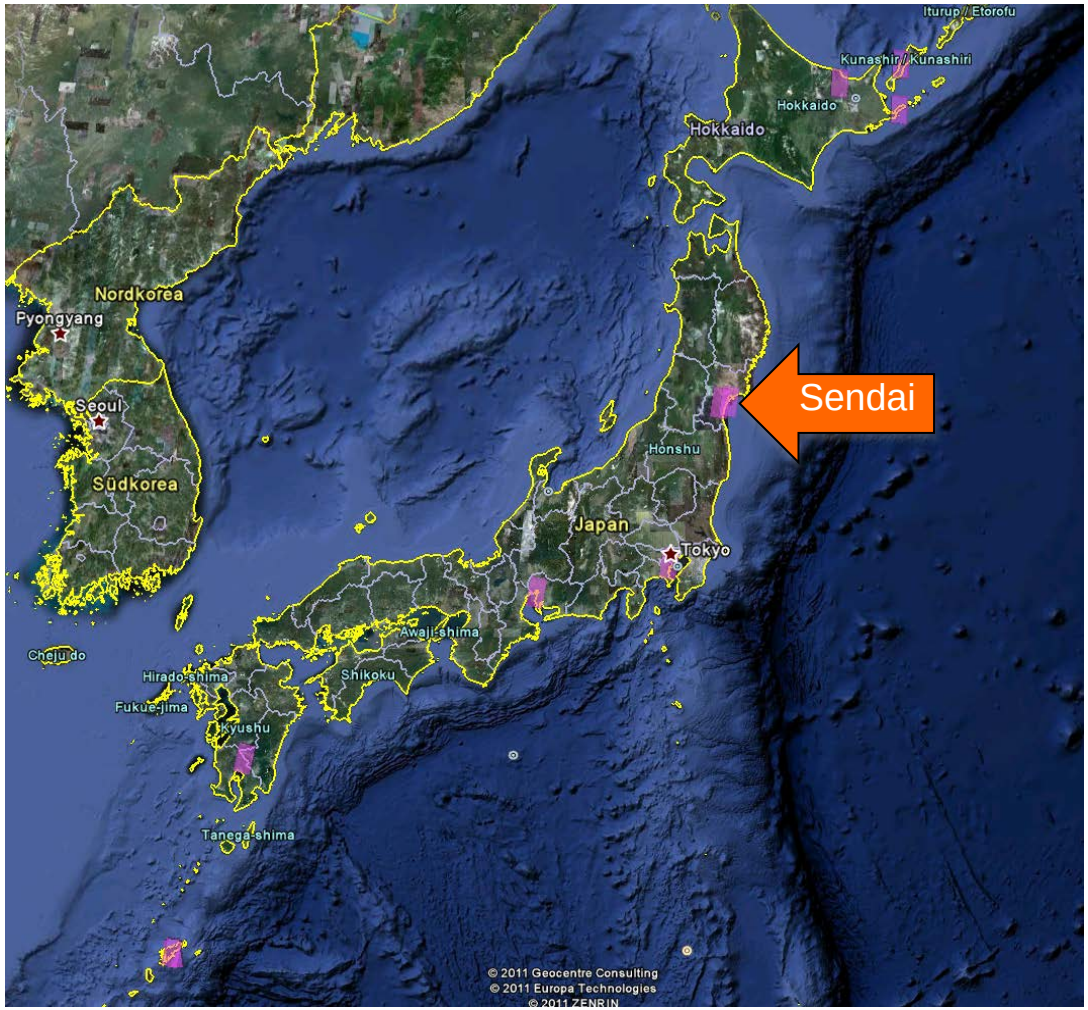
Summary: Current Status in HRICT Accuracy

- Monitoring of 6 corner reflectors with known position and 22 TerraSAR-X acquisitions (100 MHz, 150 MHz and 300 MHz)
- Ascending & descending orbits, incidence angle from: 21° to 58°
- Compensation of solid Earth tides, tropospheric delay and continental drifts

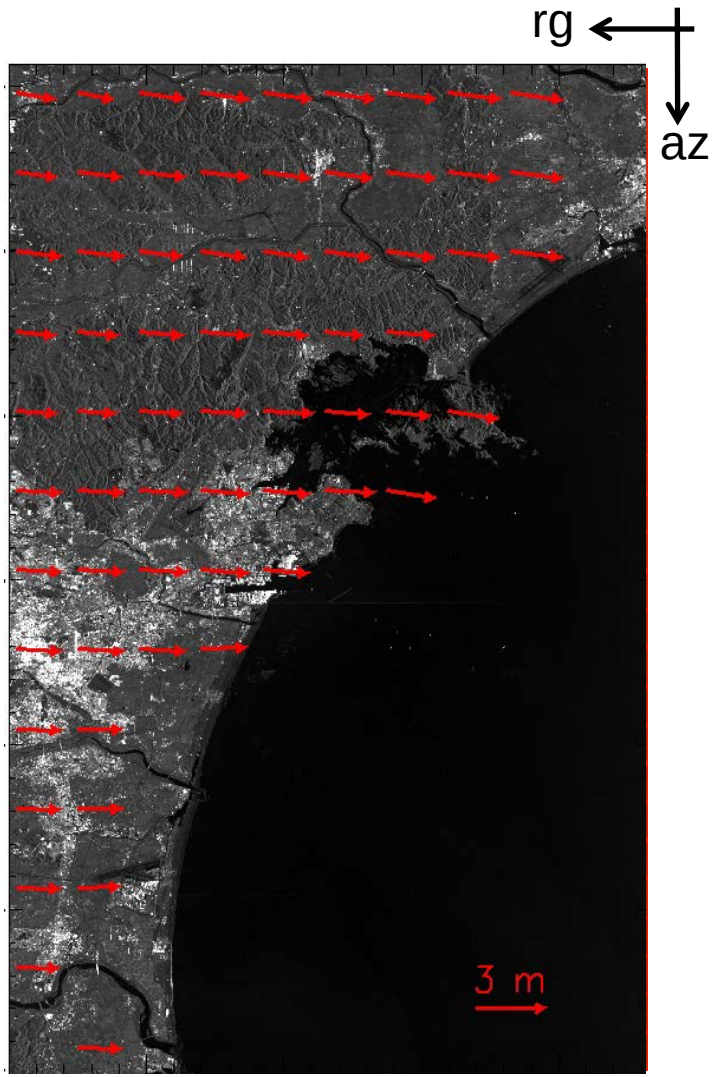


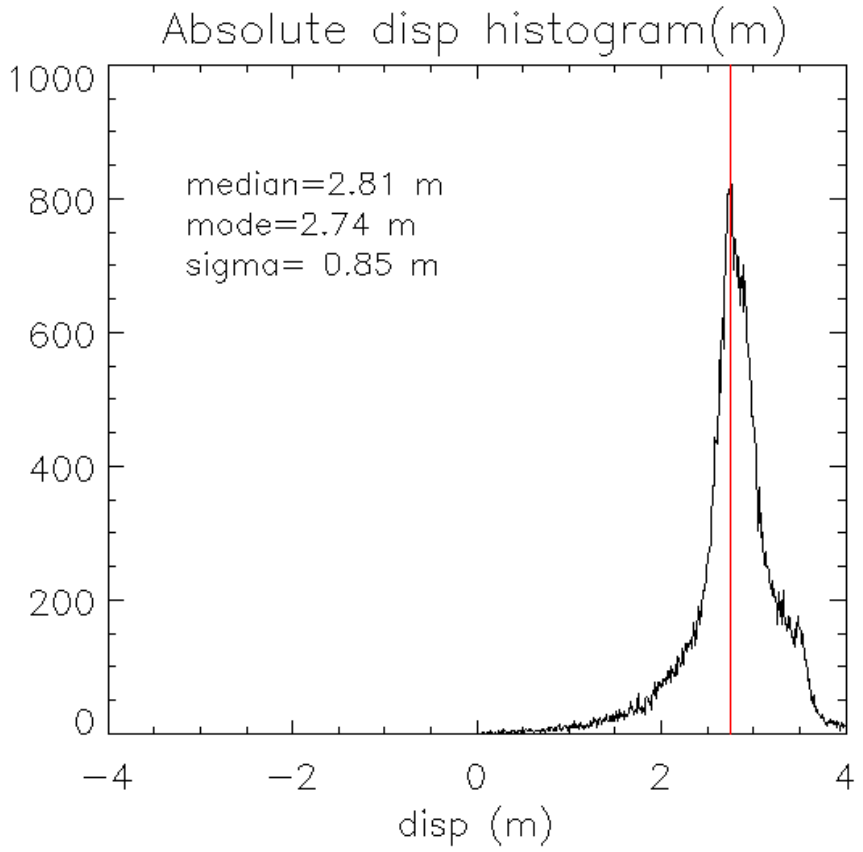
Example 1: Tohoku Earthquake 2011

- 9 descending co-seismic image pairs spread over the archipelago
- stripmap mode (30 x 50 km)
- single acquisitions
  → not possible to derive 3D vectors
  → hor. projection on ground

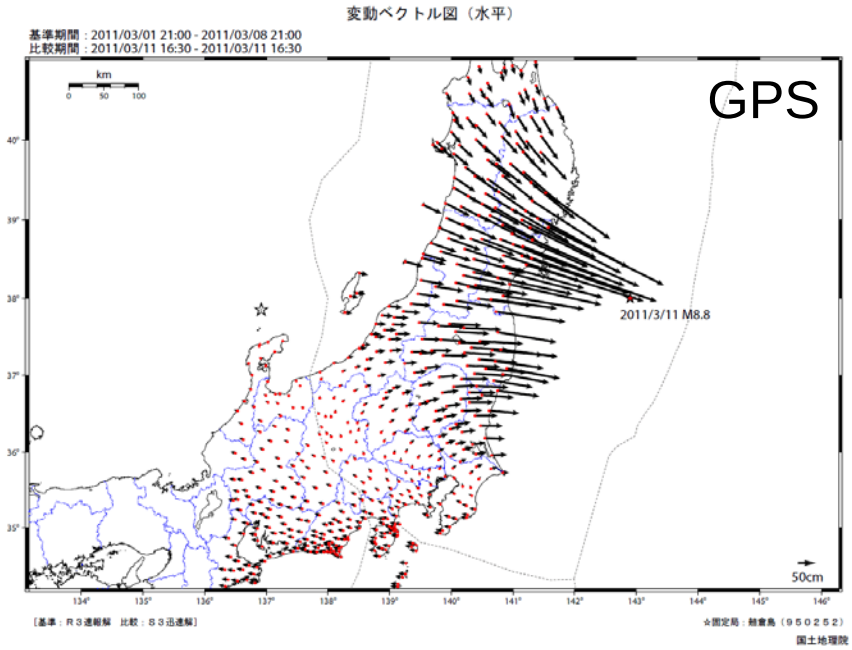


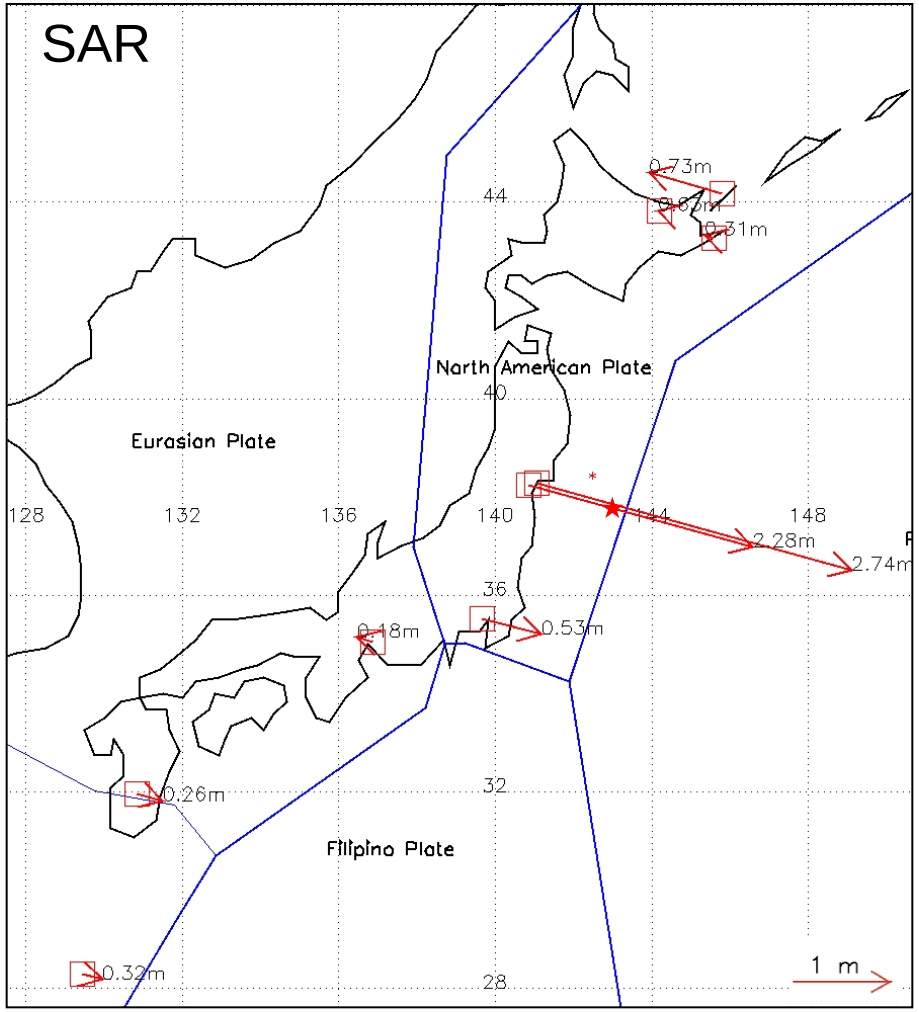
Co-seismic HRIC Displacement Map at Sendai





Co-seismic Displacements from GPS and from SAR



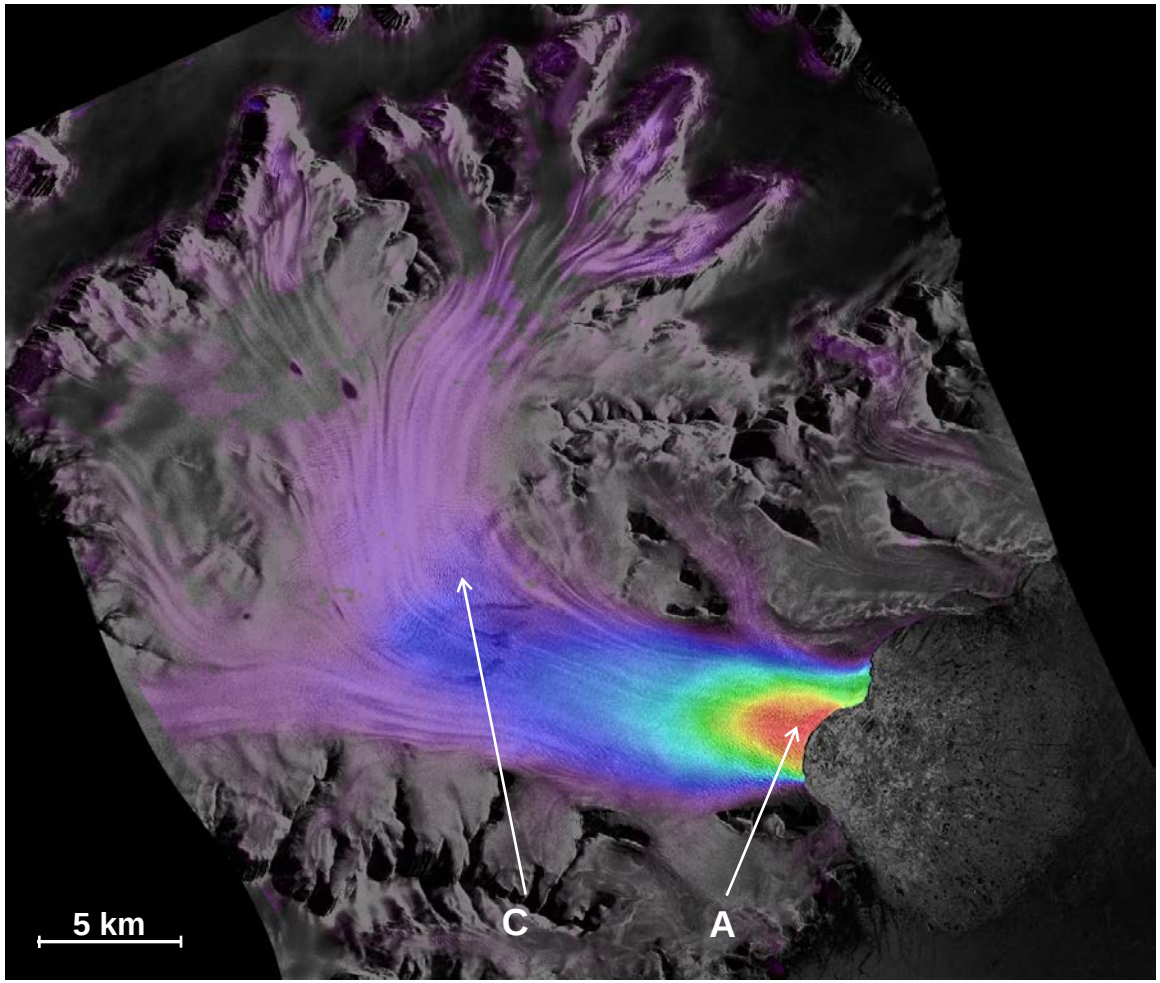


Acknowledgement: Co-seismic displacement from GPS by GEONET. Prof. Hashimoto.
http://supersites.earthobservations.org/sendai.php

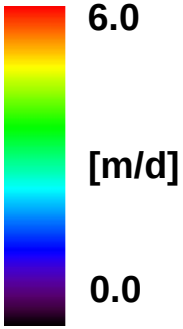
Conclusions

- SAR interferometry is an established method for DEM generation and **relative** subsidence measurements (Persistent Scatterer Interferometry)
  - with ambiguity problems
  - provides only relative measurements
- High resolution image correlation techniques with novel geodetic corrections provide absolute distances with centimeter accuracy and
  - avoid phase ambiguity problems
  - deliver 2D motion vectors
- Goal/potential: reach millimeter accuracy absolute

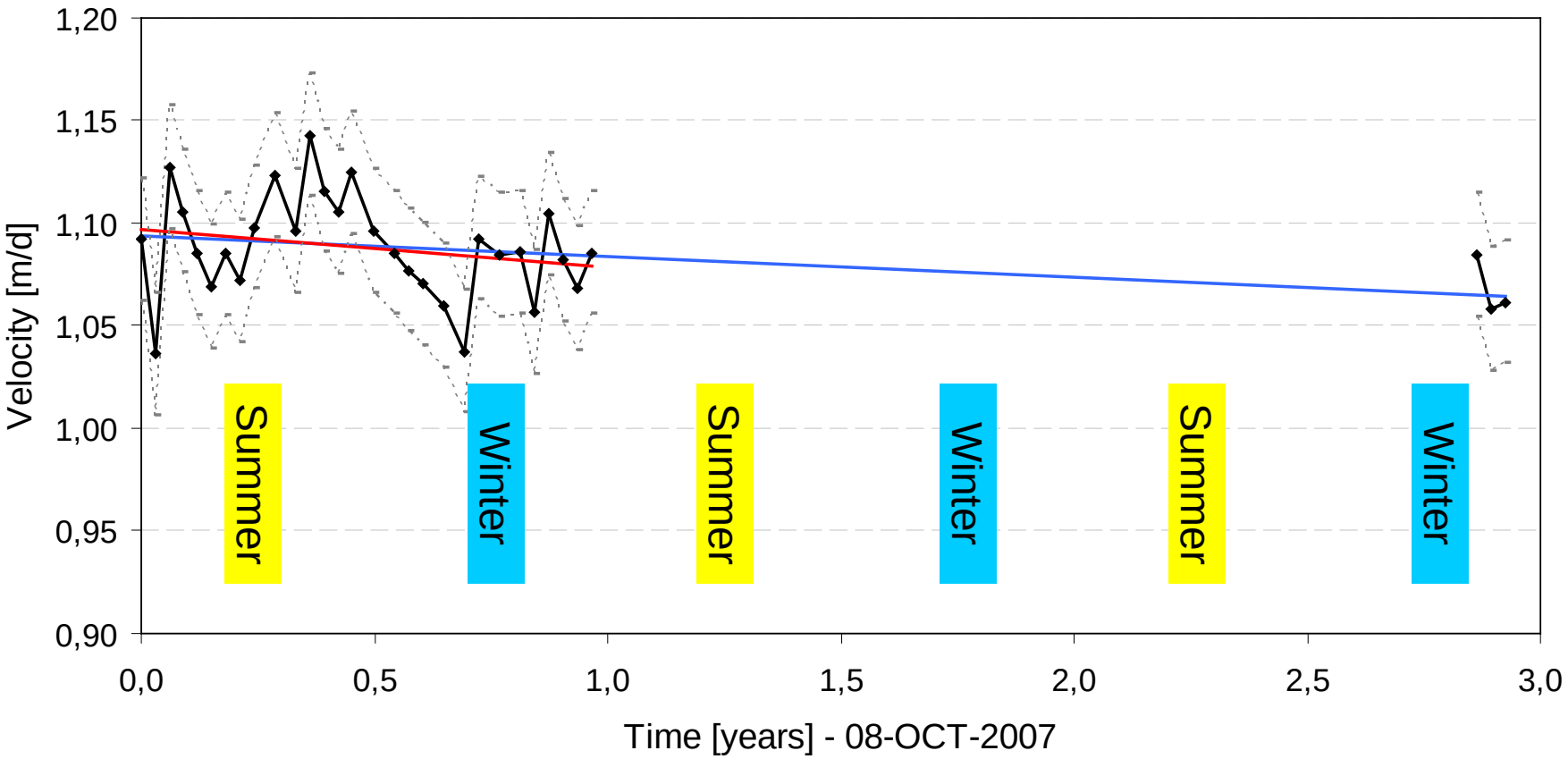
Example 2: Glacier Velocity Measurements



Average Three-Year Velocity Map
Drygalski Glacier, Antarctica



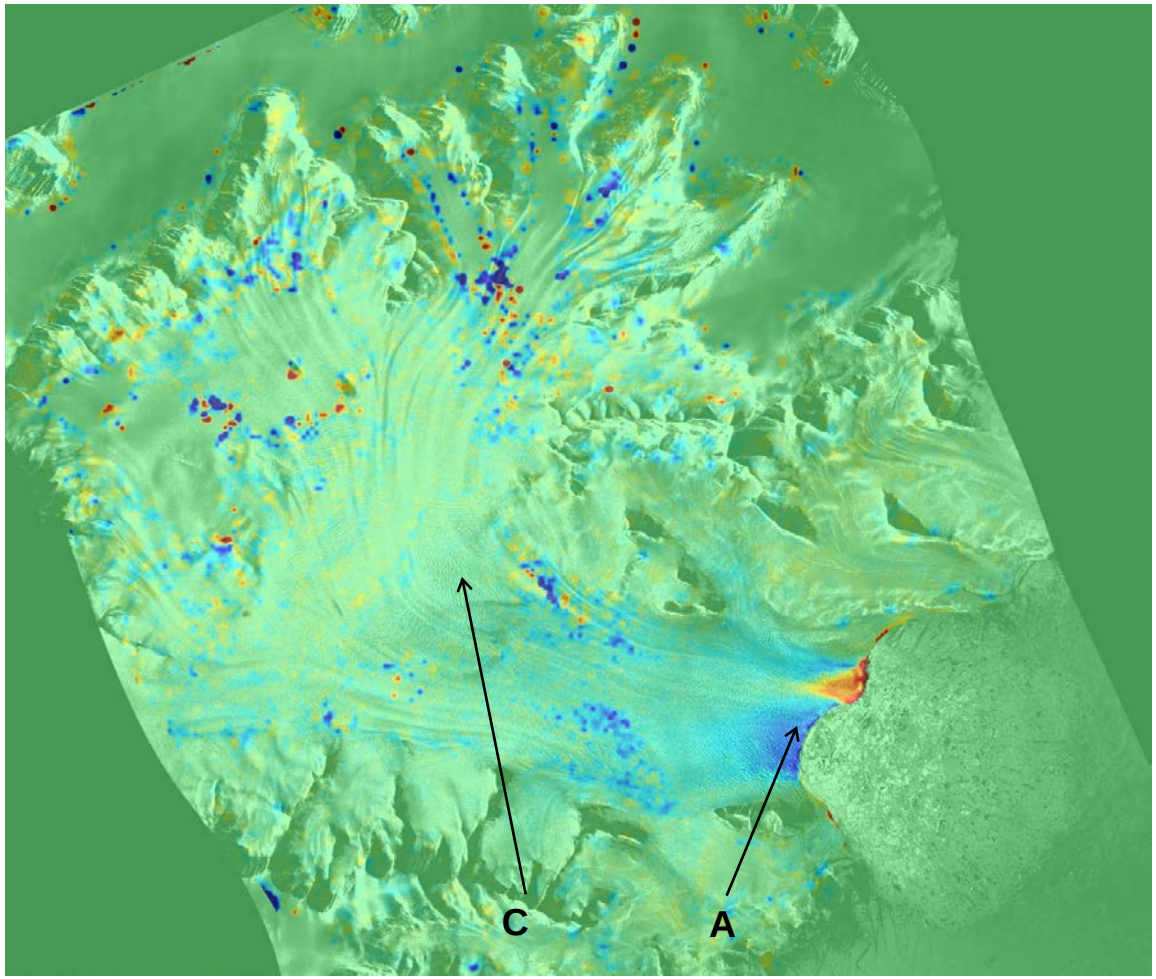
Temporal Velocity Profile at Point C



→ Measurements confirm error margin (residuals stdev. < 2 cm d^{-1})

→ slight seasonal variations, maybe decelleration

Glacier Acceleration Measurements



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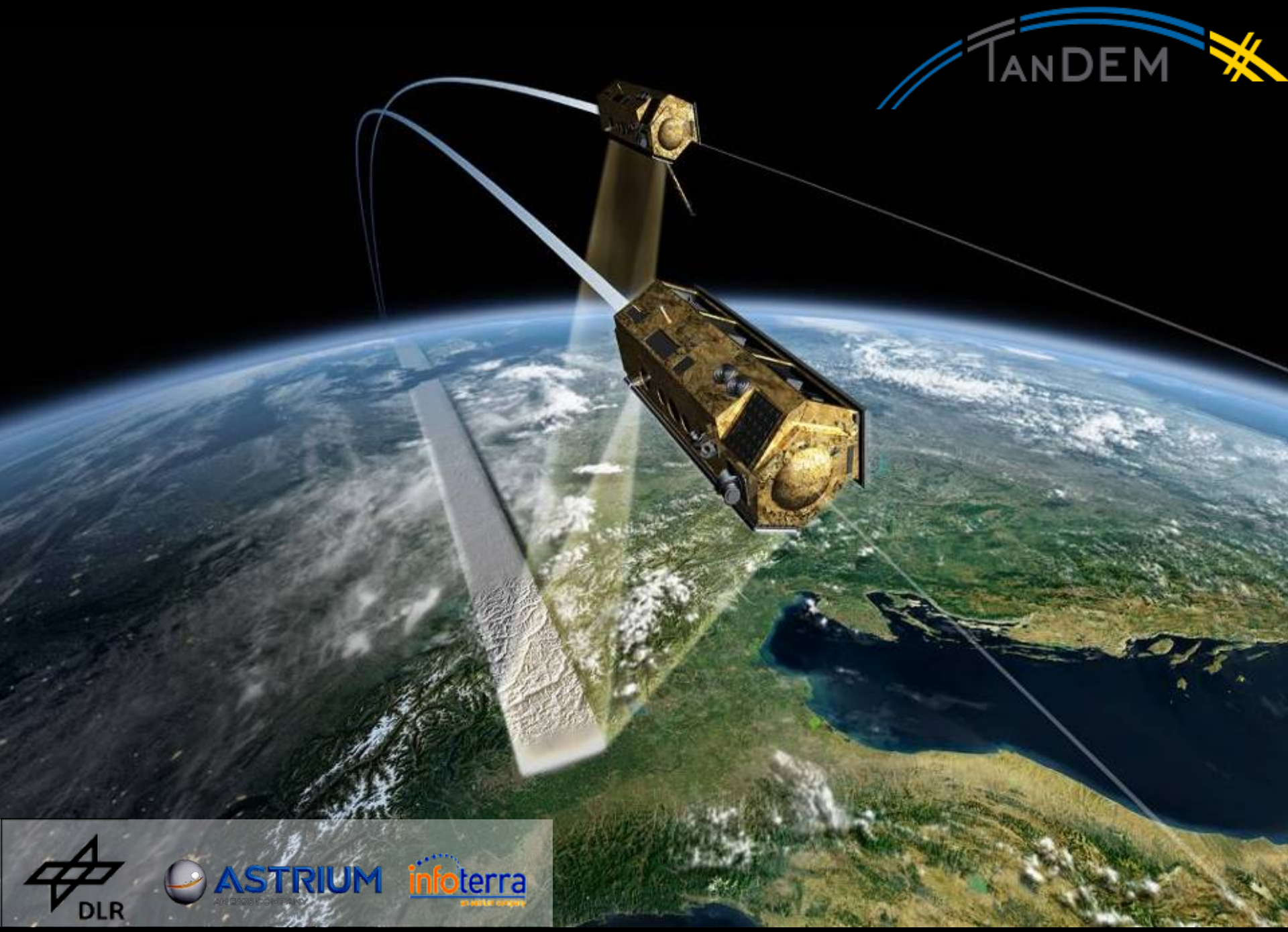
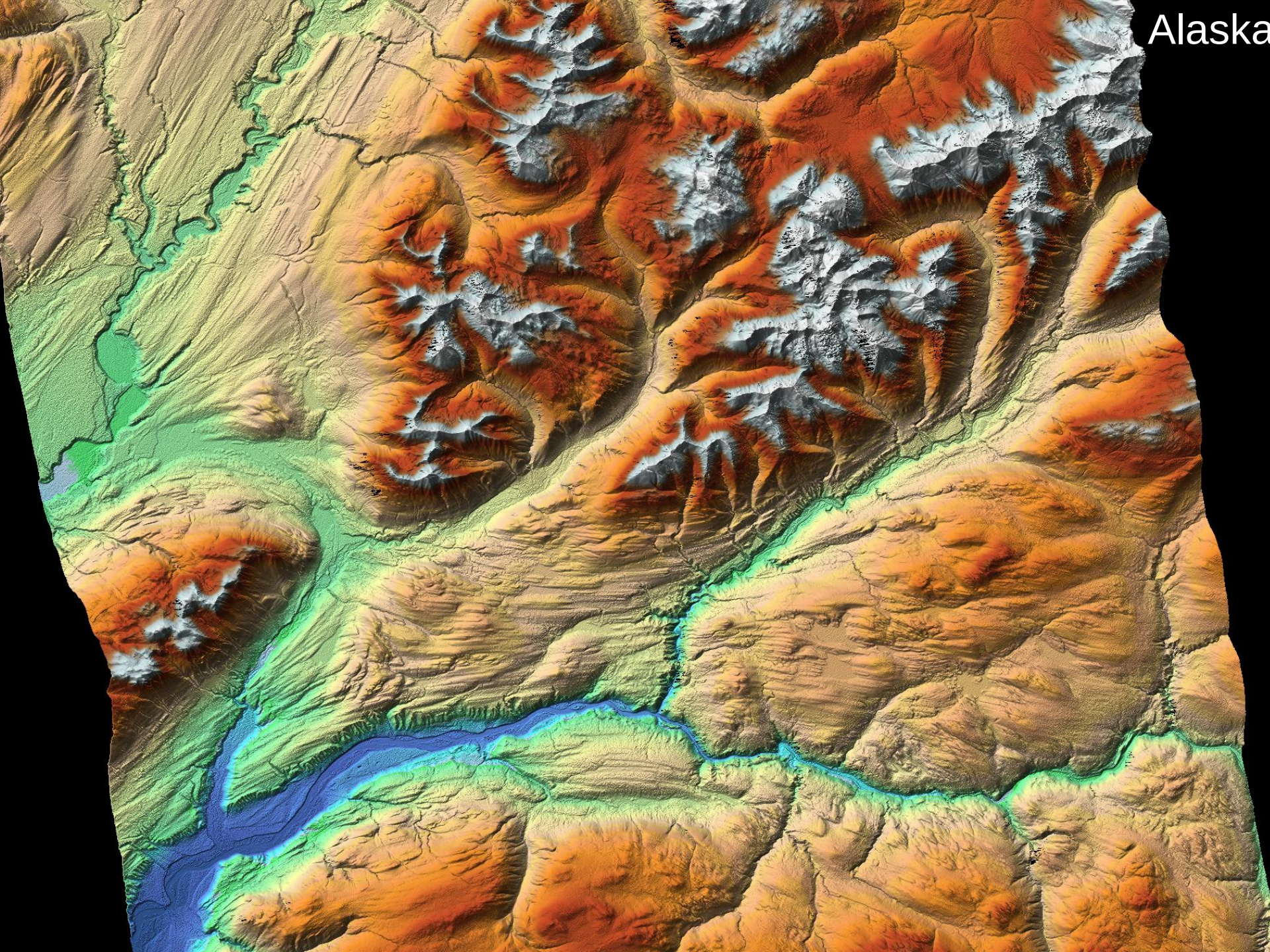

TanDEM
DLR
ASTRIUM
infoterra


Alaska