

Active Sensors – Synthetic Aperture Radar

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Knowledge for Tomorrow



Common active remote sensing systems

- Radar (RAdio Detection And Ranging)
 - long-wavelength microwaves (1-100cm)
 - recording the amount of energy *back-scattered* from the terrain
- Lidar (LIght Detection And Ranging)
 - short-wavelength laser light (e.g., 0.90 μm)
 - recording the light back-scattered from the terrain or atmosphere
- Sonar (SOund Navigation And Ranging)
 - sound waves through a water column
 - recording the amount of energy back-scattered from the water column or the bottom

Synthetic Aperture Radar (SAR) sensors

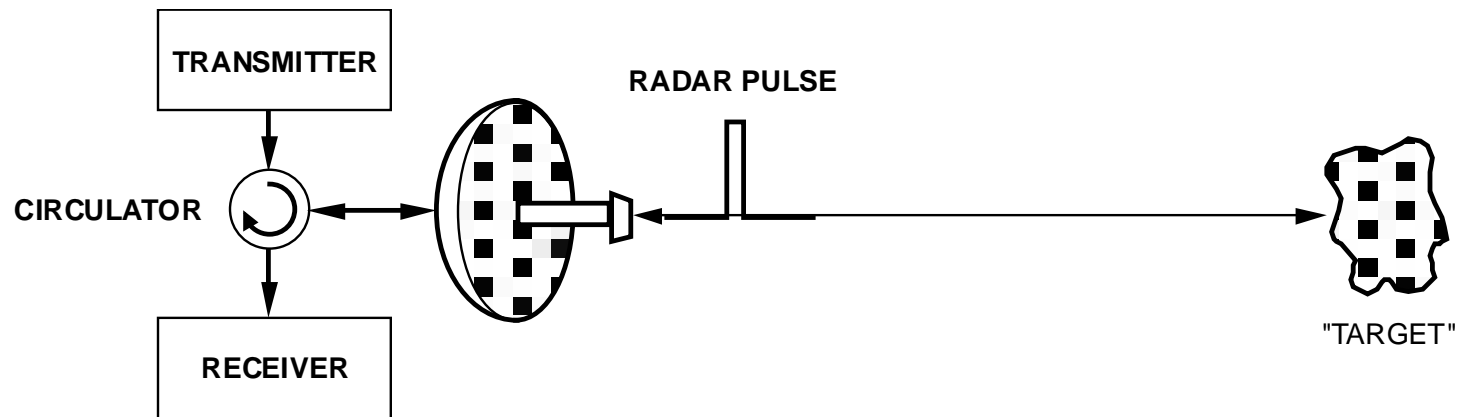


SAR

(Synthetic Aperture Radar)

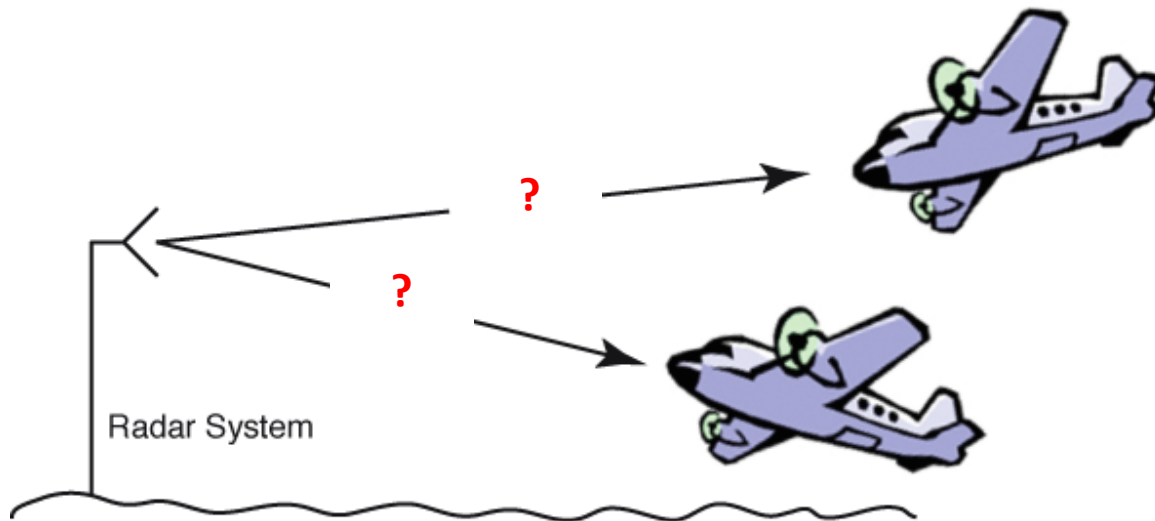


What is Radar?

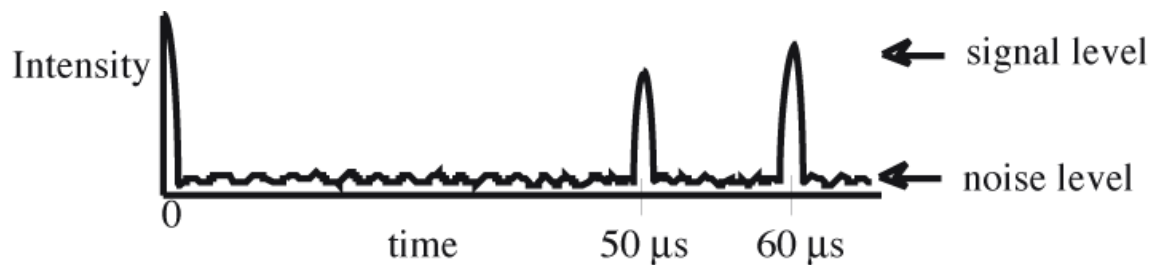


- **RADAR = Radio Detection And Ranging**
- Since radar pulses propagate at the speed of light, the difference to the “target” is proportional to the time it takes between the transmit event and reception of the radar echo

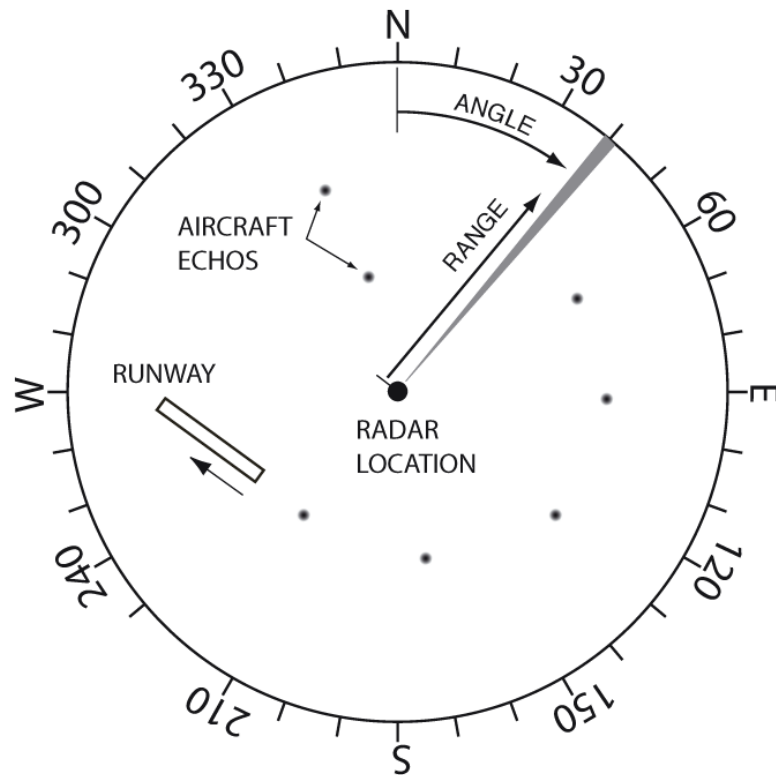
Ranging: Distance Measurement



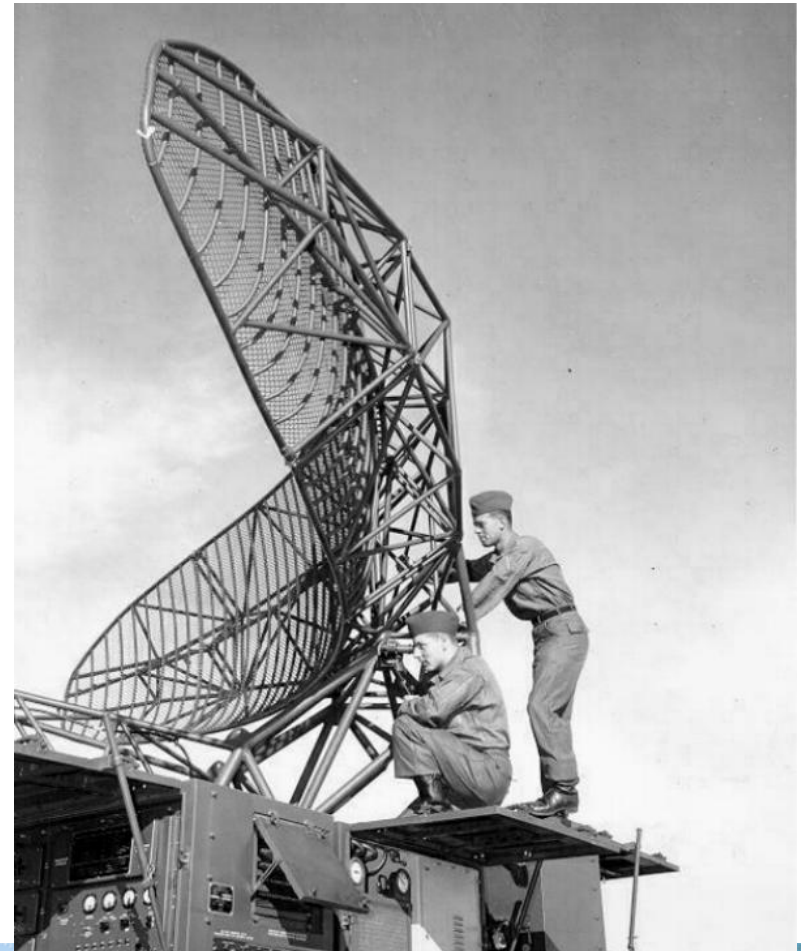
$c = \text{speed of light}$
 $= 3.00 \times 10^8 \text{ m/s}$



Mapping Multiple Objects: PPI Radar Display

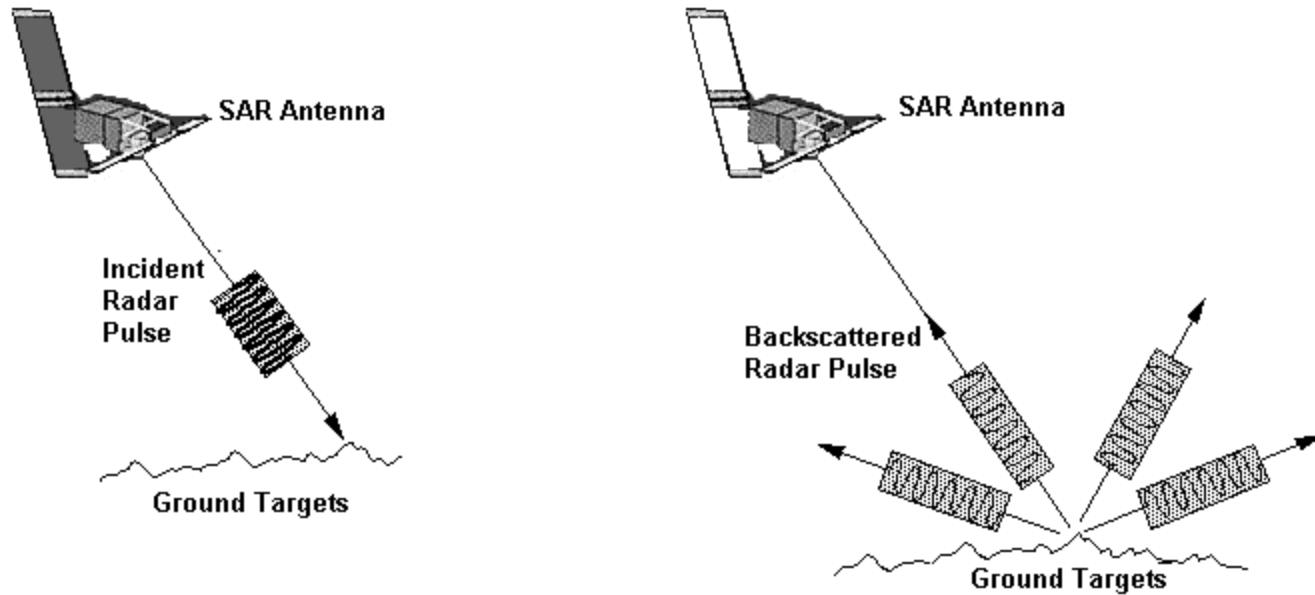


PPI=Plan Position Indicator

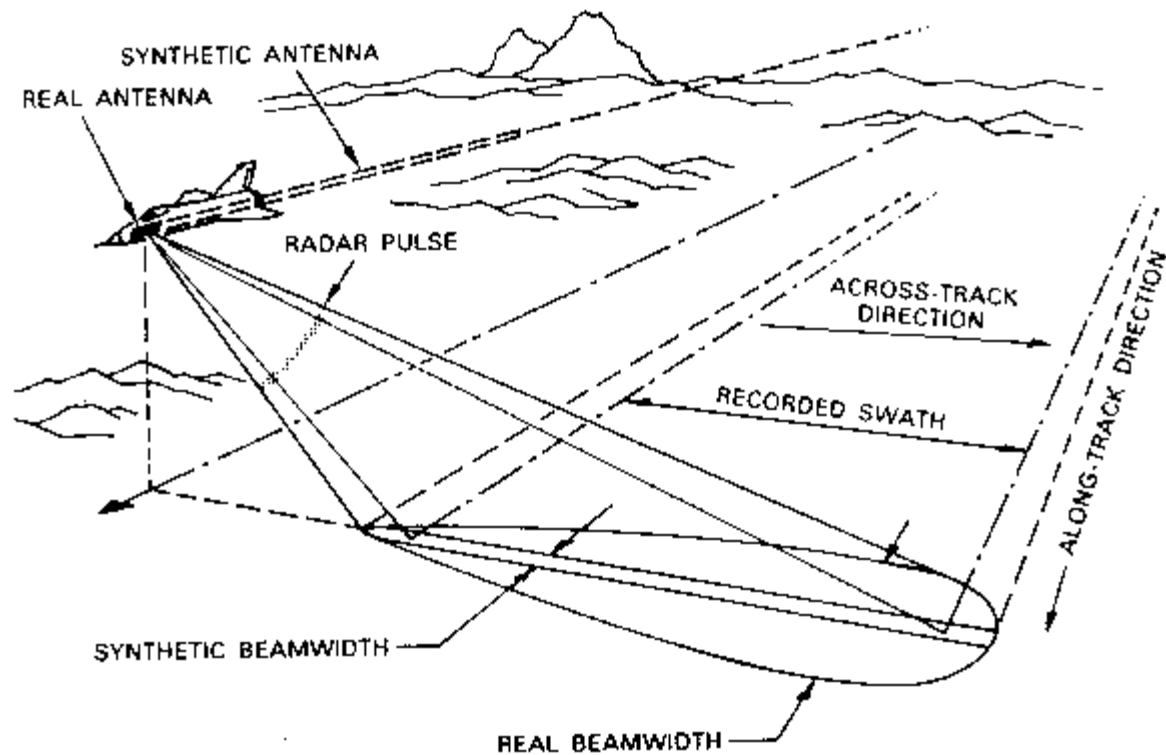


Credit to: Weile Wang

Synthetic Aperture Radar (SAR) sensors



Synthetic Aperture Radar (SAR) sensors



SAR

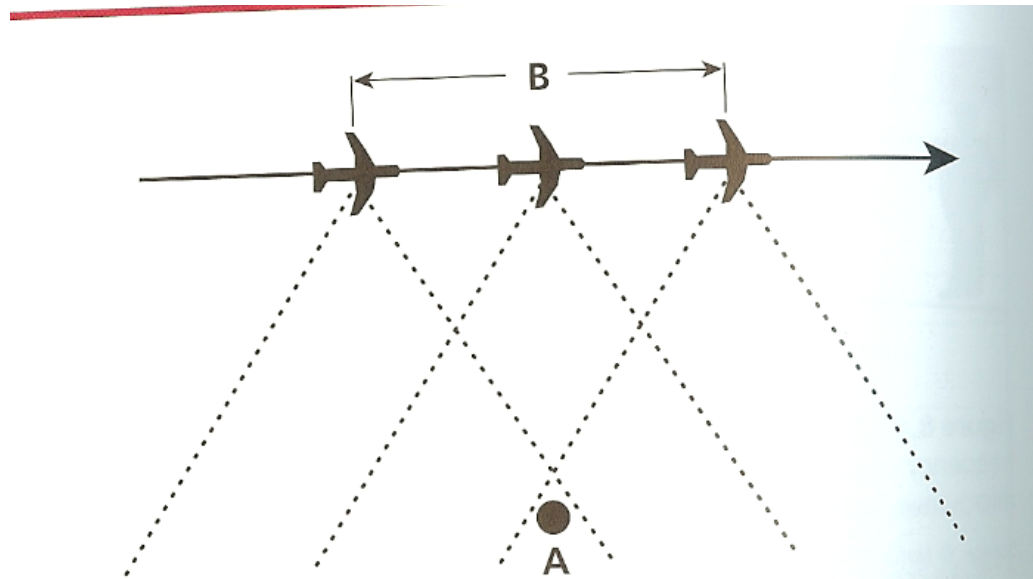
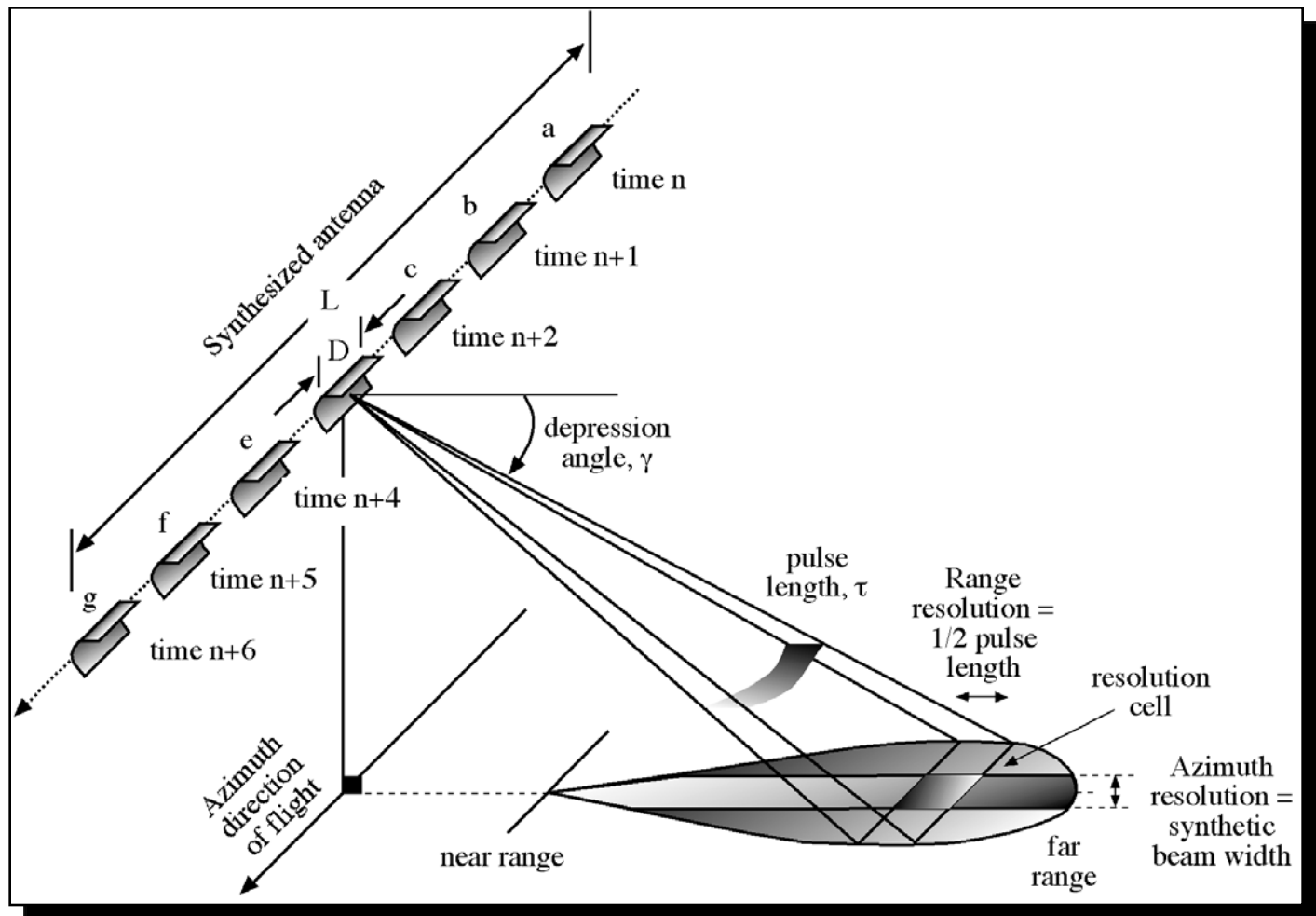


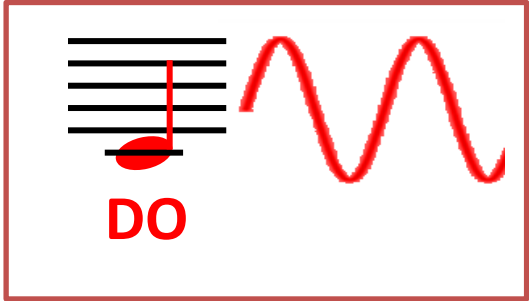
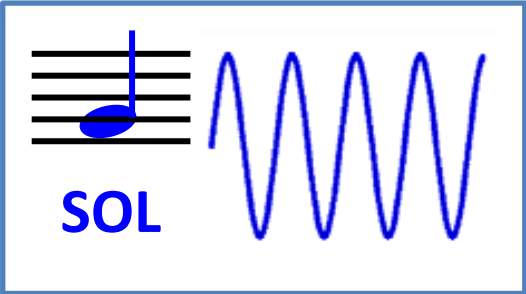
Figure 8.5 Principle of synthetic aperture radar operation. By processing the returns from targets (A) for the entire time they are illuminated by the radar beam, a short antenna can operate as if it was many times longer (B) than its actual length, providing improved spatial resolution.

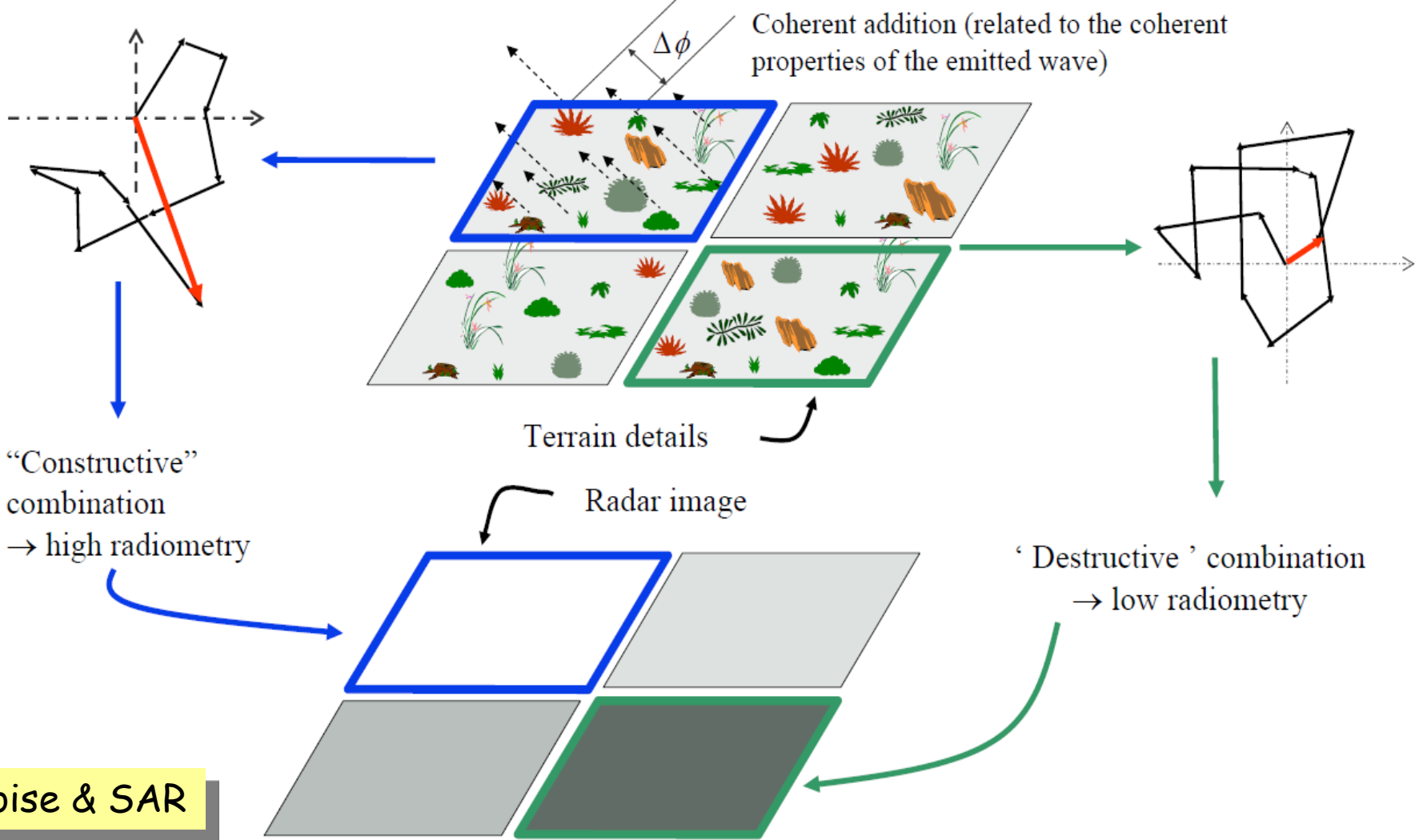
Source: © Natural Resources Canada.

A major advance in radar remote sensing has been the improvement in *azimuth resolution* through the development of *synthetic aperture radar* (SAR) systems. Great improvement in azimuth resolution could be realized if a longer antenna were used. Engineers have developed procedures to *synthesize* a very long antenna electronically. Like a brute force or real aperture radar, a synthetic aperture radar also uses a relatively small antenna (e.g., 1 m) that sends out a relatively broad beam perpendicular to the aircraft. The major difference is that a greater number of **additional beams** are sent toward the object. Doppler principles are then used to monitor the returns from all these additional microwave pulses to *synthesize the azimuth resolution to become one very narrow beam*.



Doppler Effect





- One of the main problems of SAR image interpretation
- Optical images are normally affected by additive noise
- SAR images are affected by multiplicative noise (speckle)
- This makes interpretation difficult

SAR & Speckle Noise



SAR sensors

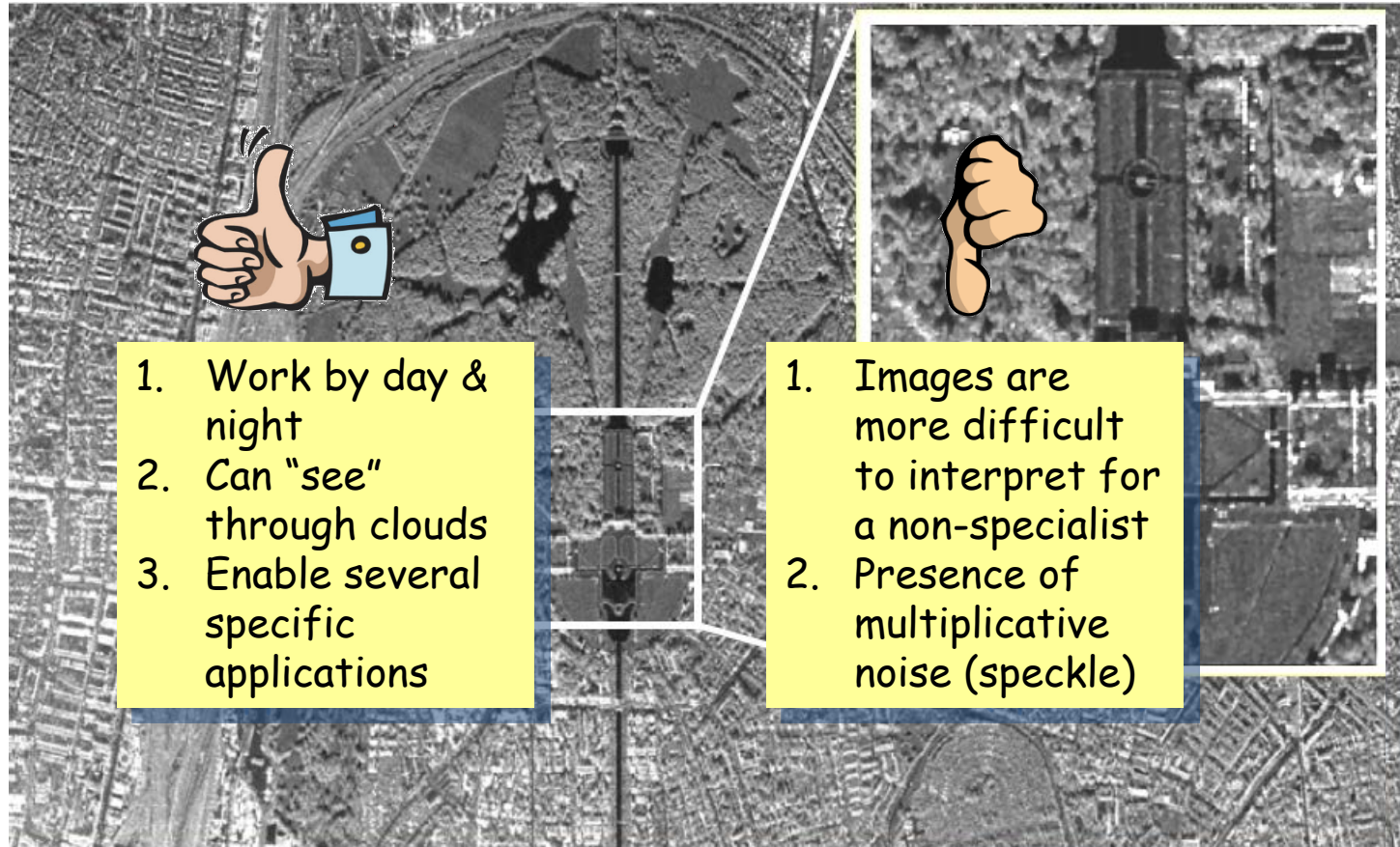
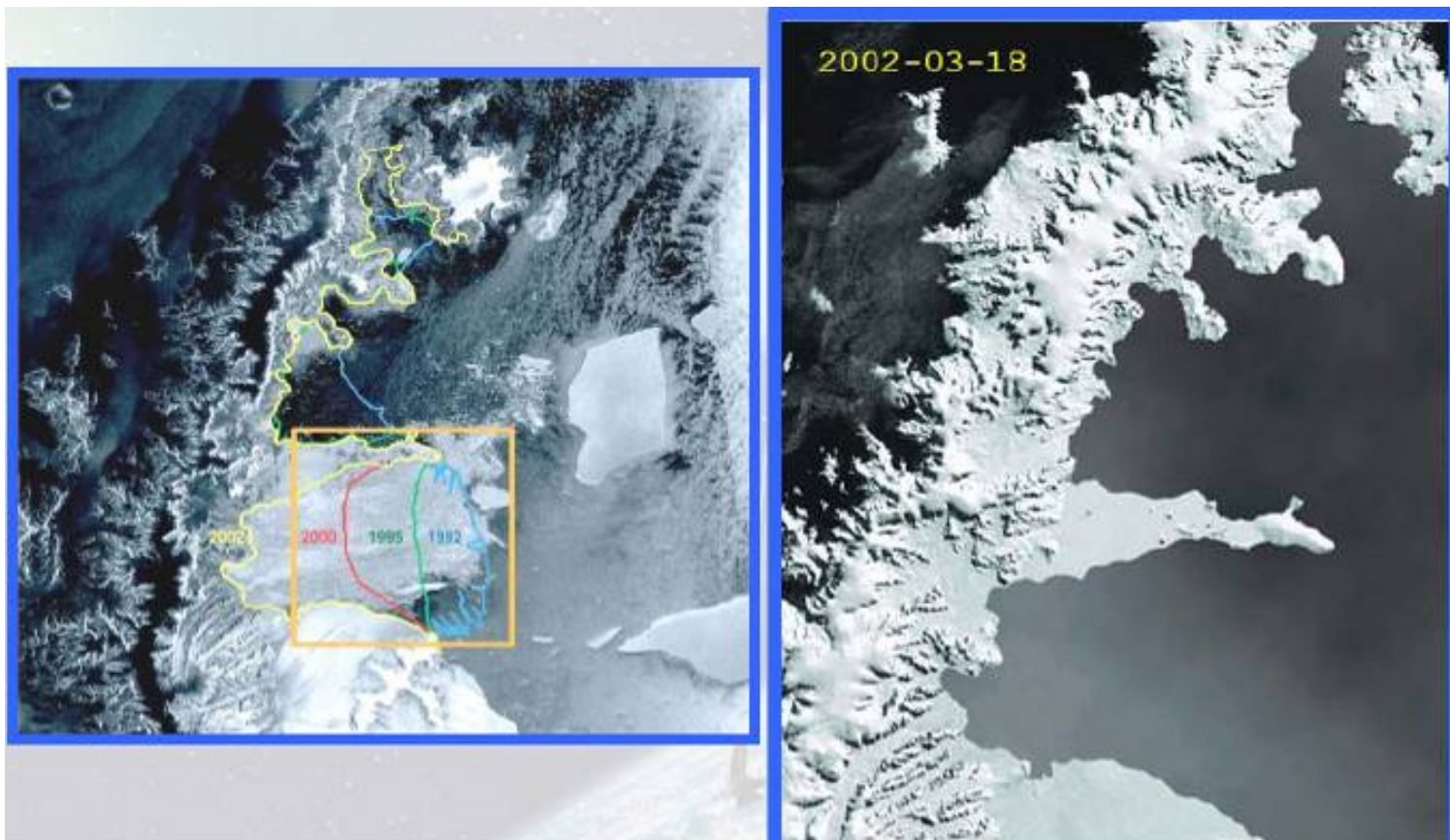


Image acquired over Munich, Germany

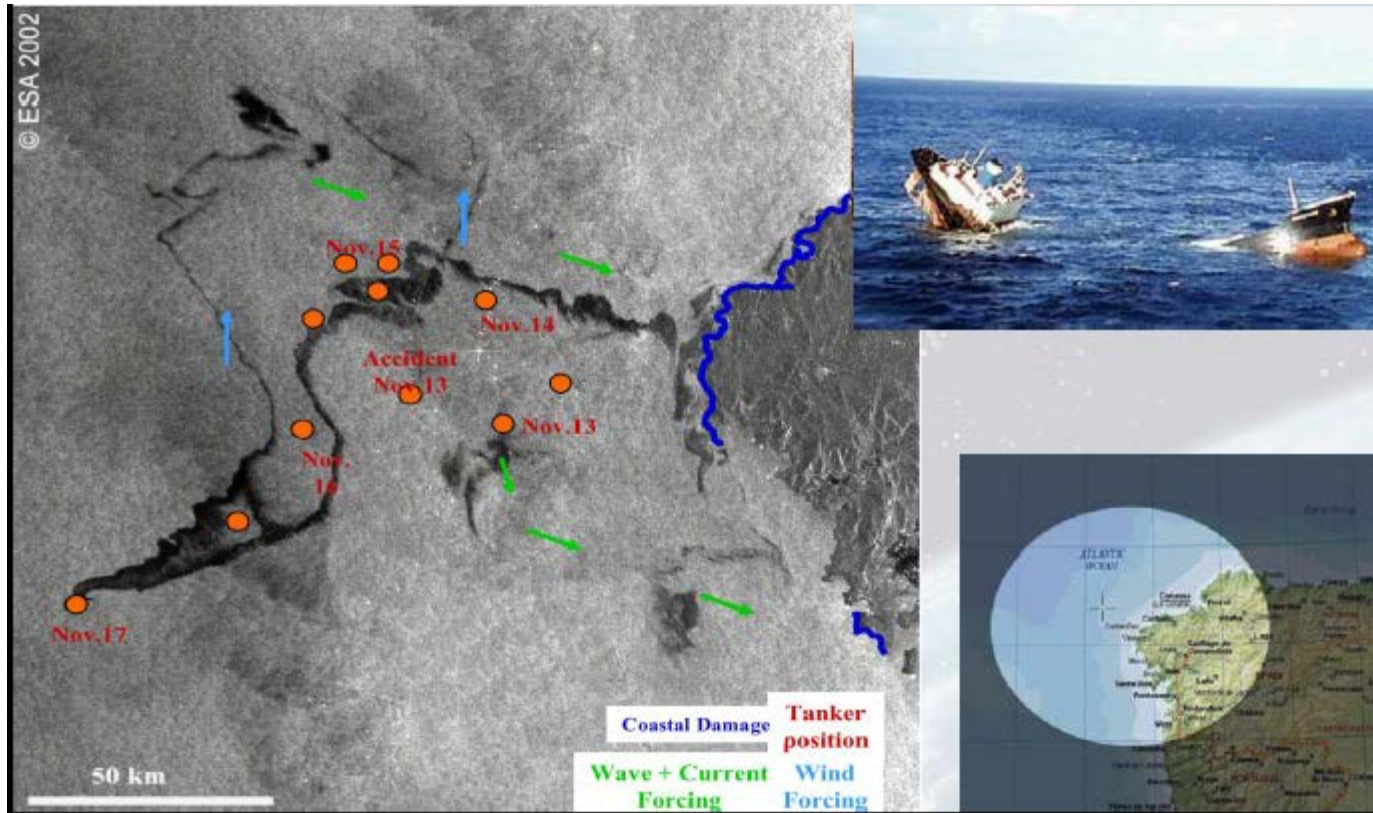


Sample SAR applications



Ice melting monitoring

Sample SAR applications



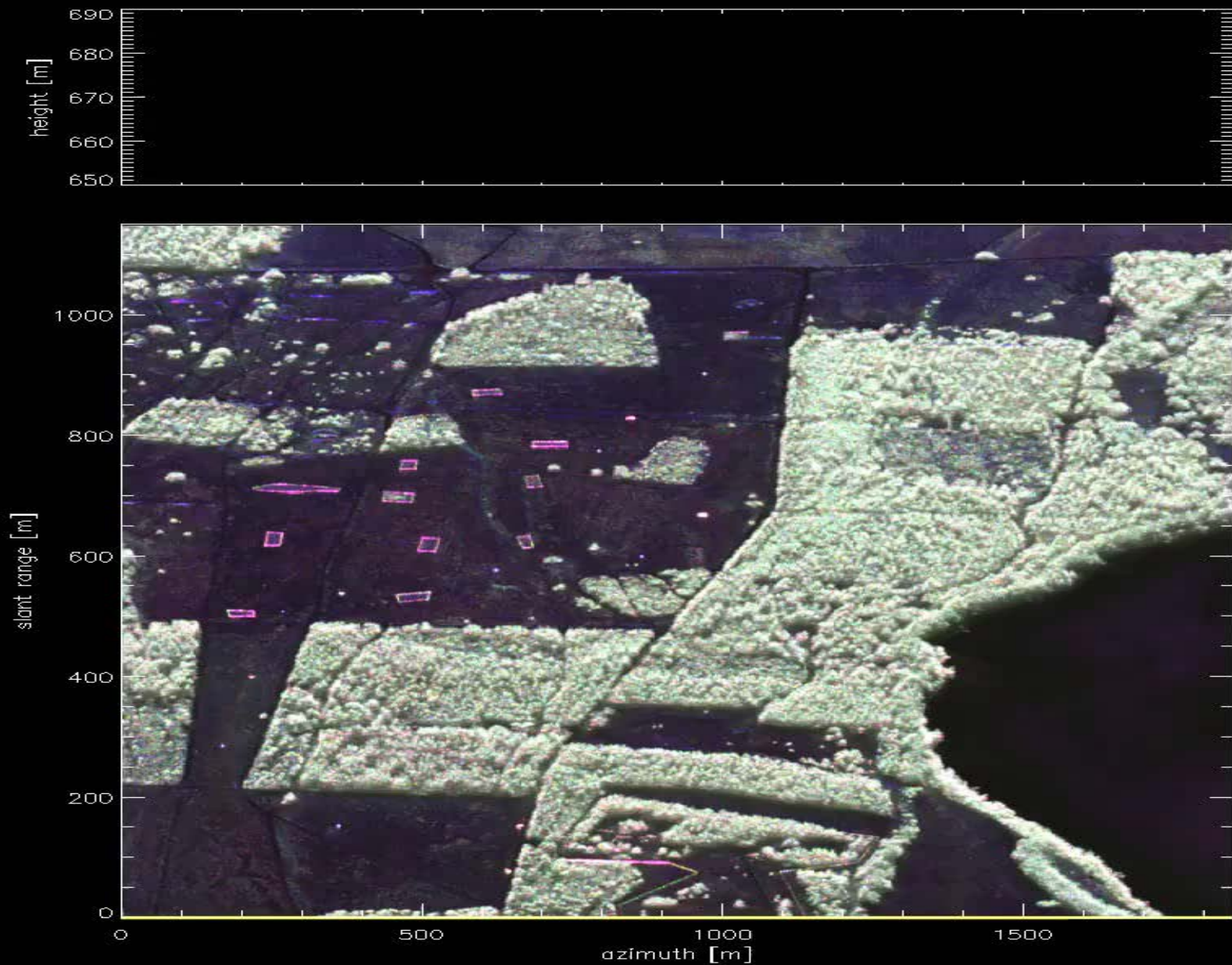
Oil spill detection

Sample SAR applications



Deforestation monitoring

Polarimetric SAR Tomography



TERRA SAR X TANDEM





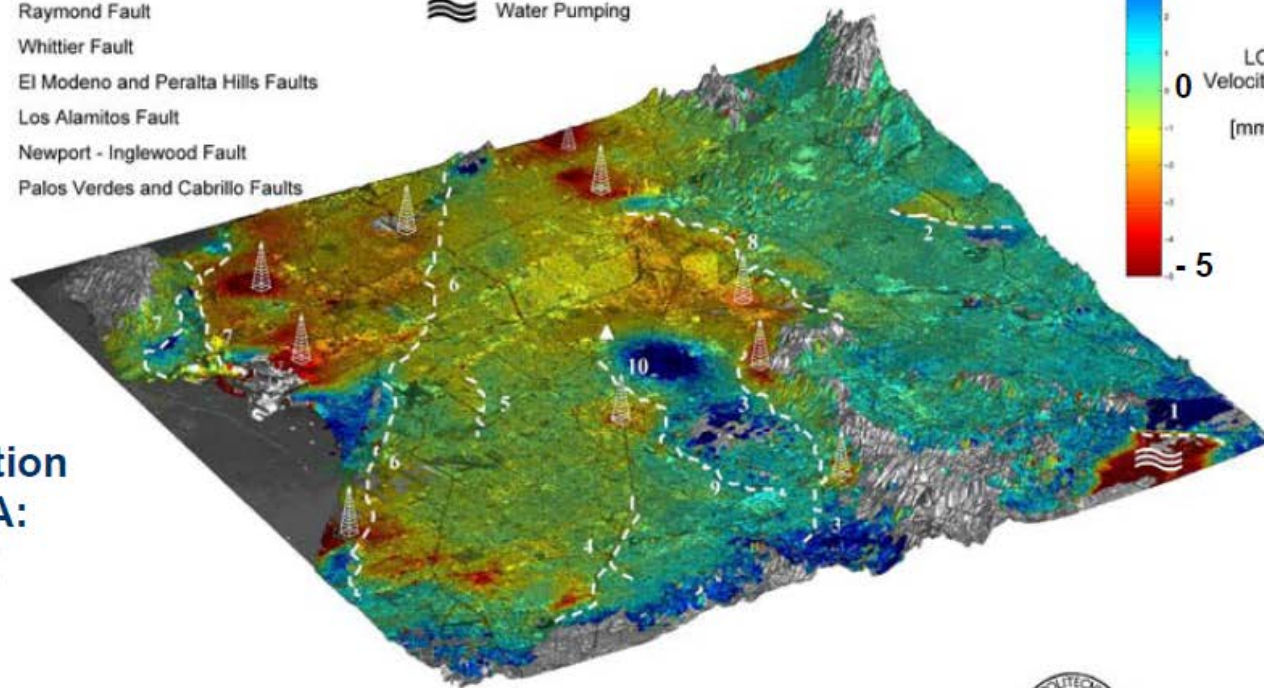
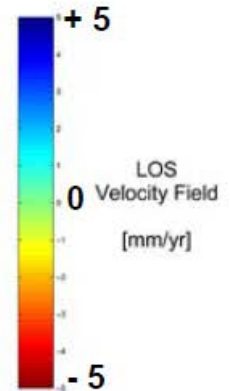
Sample SAR applications

Seismic Faults in Los Angeles Basin:

1. San Jose Fault
2. Raymond Fault
3. Whittier Fault
4. El Modeno and Peralta Hills Faults
5. Los Alamitos Fault
6. Newport - Inglewood Fault
7. Palos Verdes and Cabrillo Faults

Subsidence Phenomena:

-  Oil & Gas Fields
-  Water Pumping



Terrain motion
in L.A., USA:
1992 - 2002

ERS-1/2, C-band



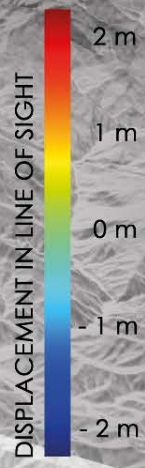
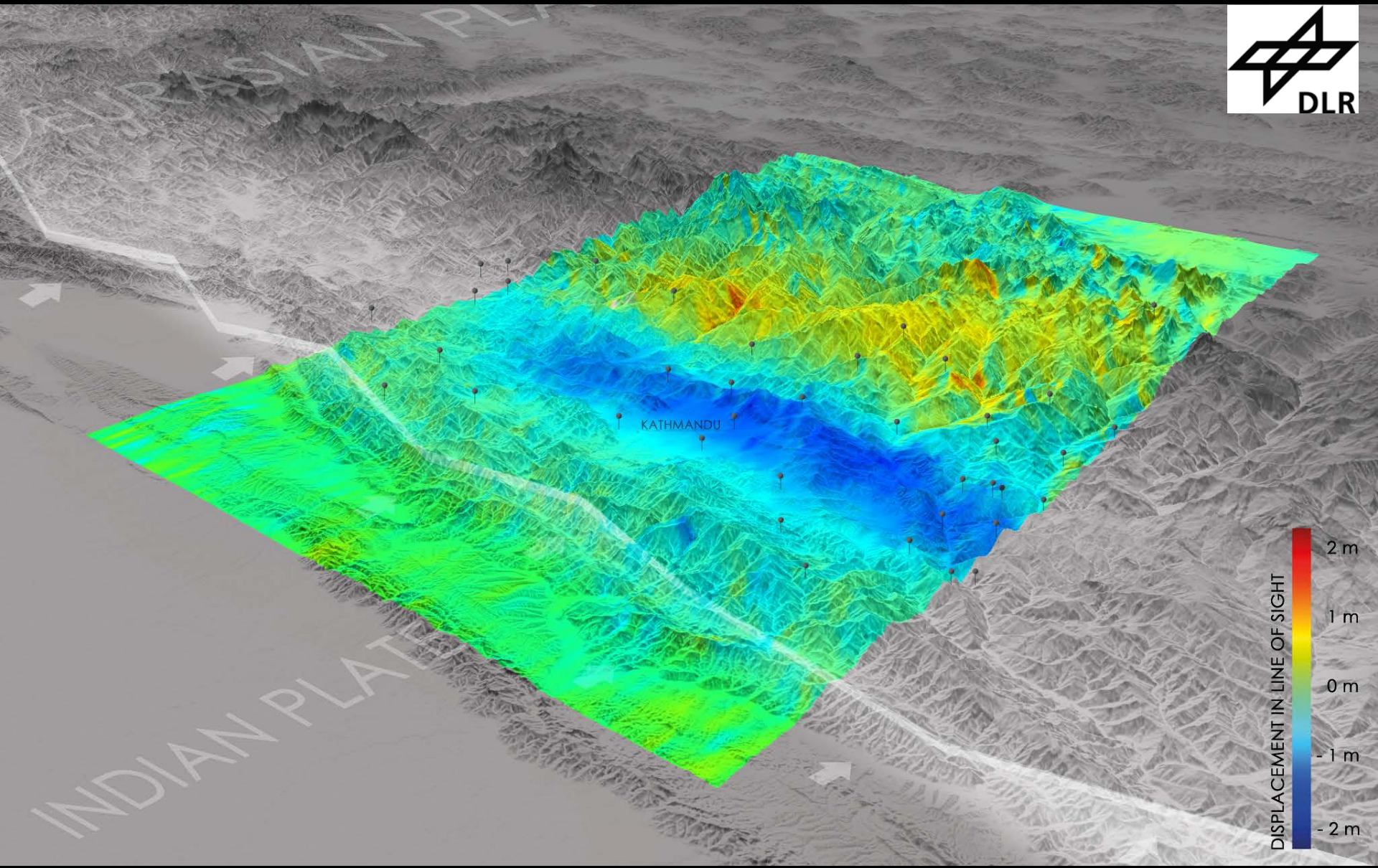
T.R.E.



Interferometry



Adapted from A. Moreira



TanDEM-X DEM (Kamtschatka)

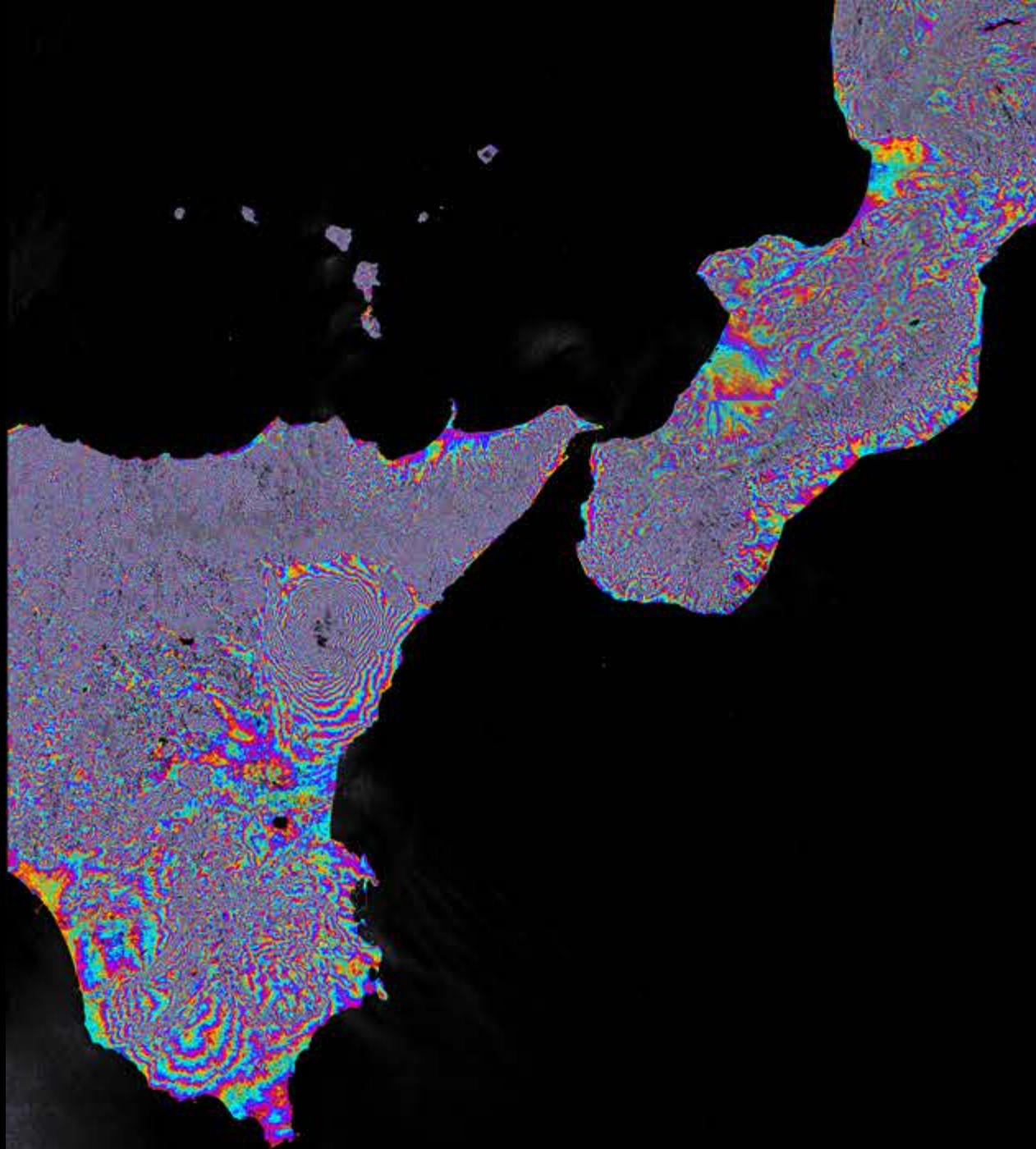


Sentinel-1 Data Take SAR Interferometry 1200 Km

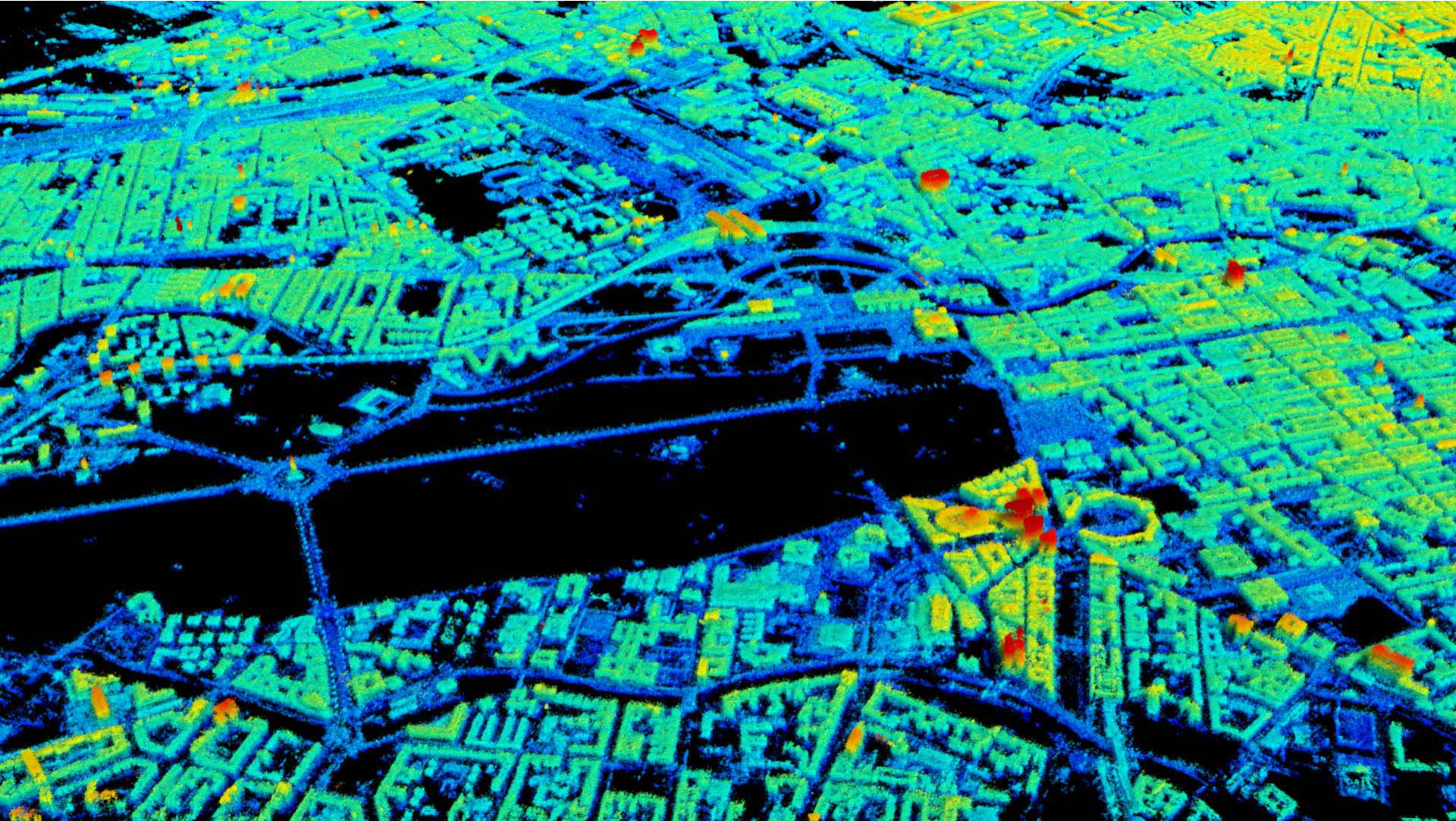
EOC – IMF supported
ESA in verification of
Sentinel-1
interferometric
capabilities

Datatake (7 slices):

- IW mode
- Vertical Polarization
- Acq. Dates:
 - 09/08/2014
 - 21/08/2014



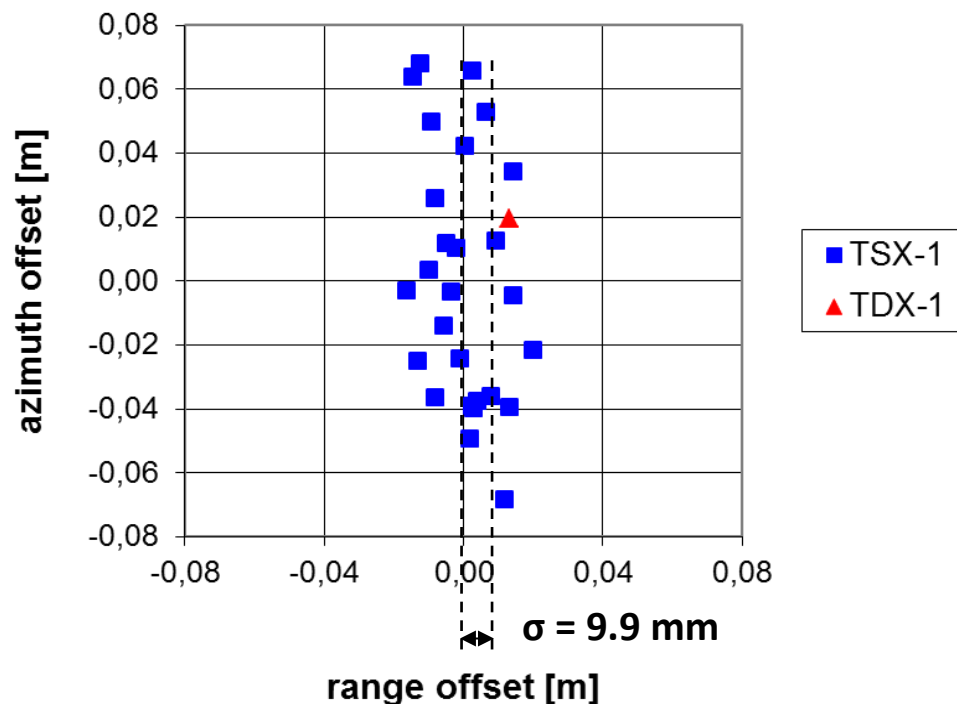
SAR Imaging of Urban Areas



World Record in SAR Geolocation Accuracy

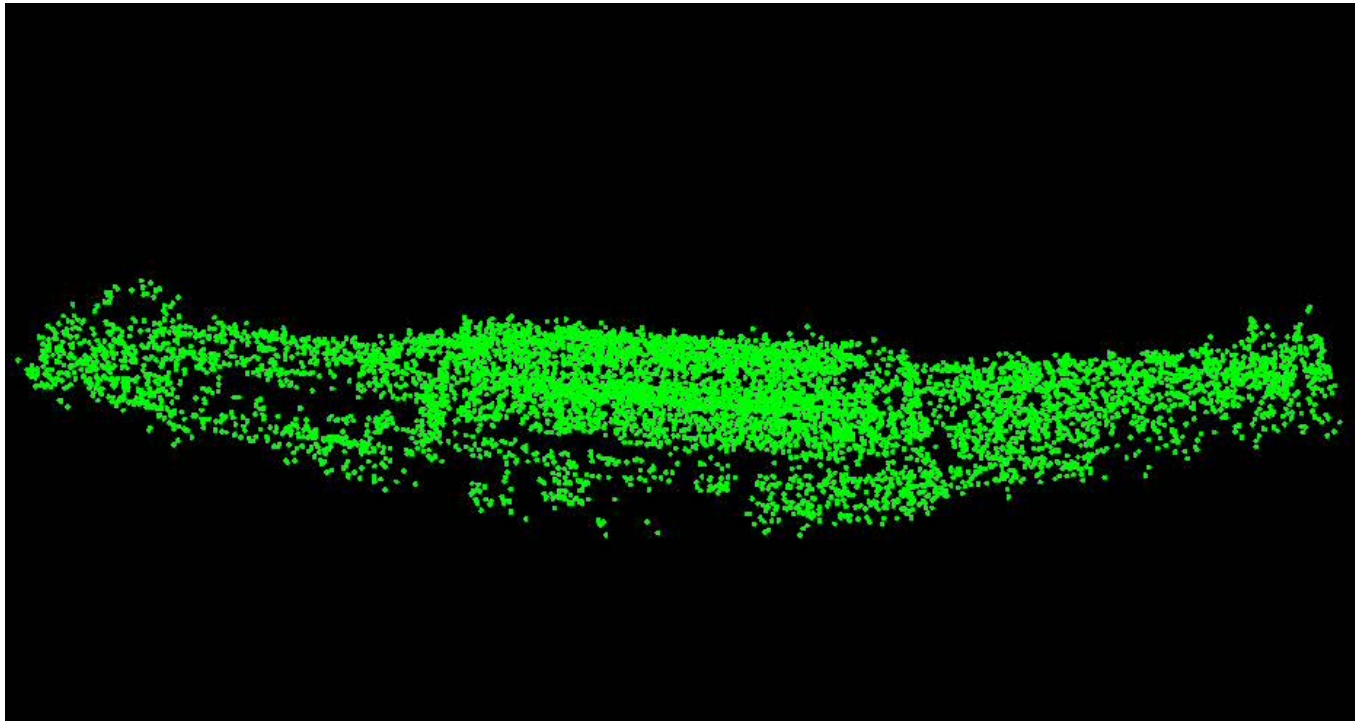
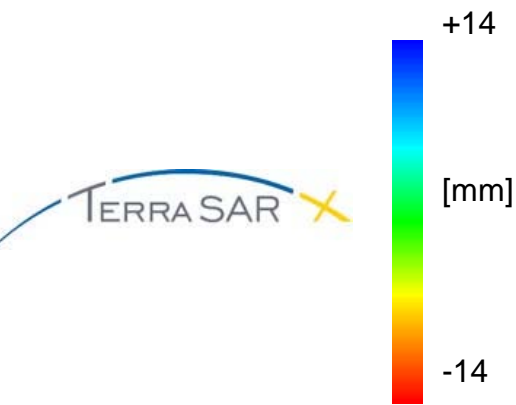
Range Error After Corrections: < 10 mm

CR result of 28 TSX/TDX acquisitions
(residual bias removed)



reference corner reflector, Wettzell





Sample applications



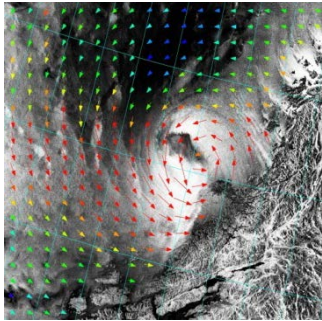
Target Detection
(detection of tanks)



Island Barðarbunga Volcano



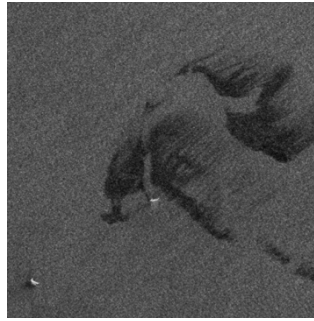
Ocean Surface Parameter from space based SAR



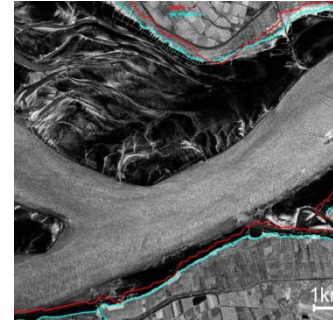
Wind



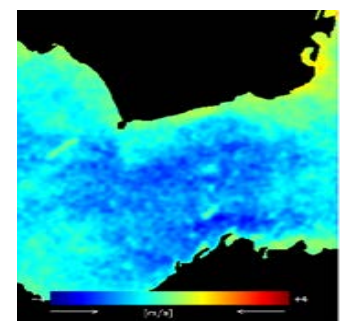
Waves



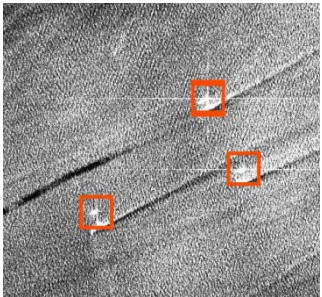
Oil



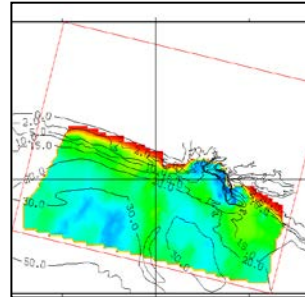
Coast line



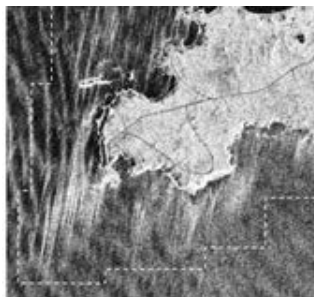
Currents



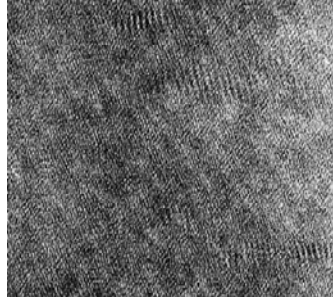
Ships



Bathymetry



Breaking Waves



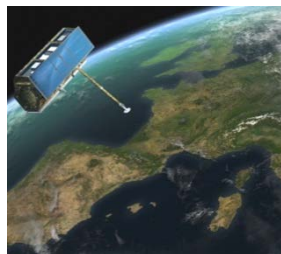
Single waves



Sea Ice



Sentinel-1



TERRA SAR X

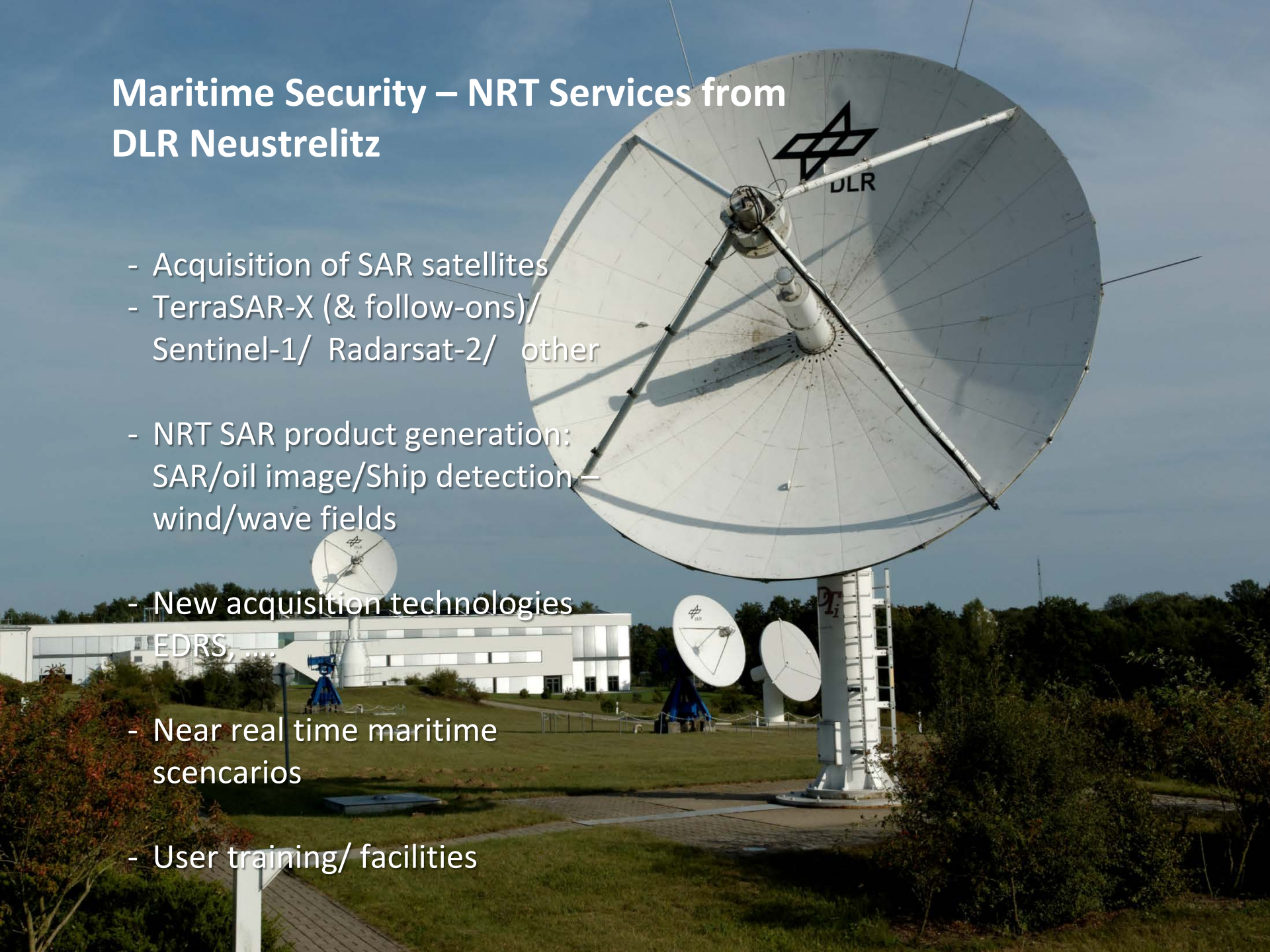


Radarsat-2



Maritime Security – NRT Services from DLR Neustrelitz

- Acquisition of SAR satellites
- TerraSAR-X (& follow-ons)/ Sentinel-1/ Radarsat-2/ other
- NRT SAR product generation: SAR/oil image/Ship detection – wind/wave fields
- New acquisition technologies EDRS,
- Near real time maritime scenarios
- User training/ facilities

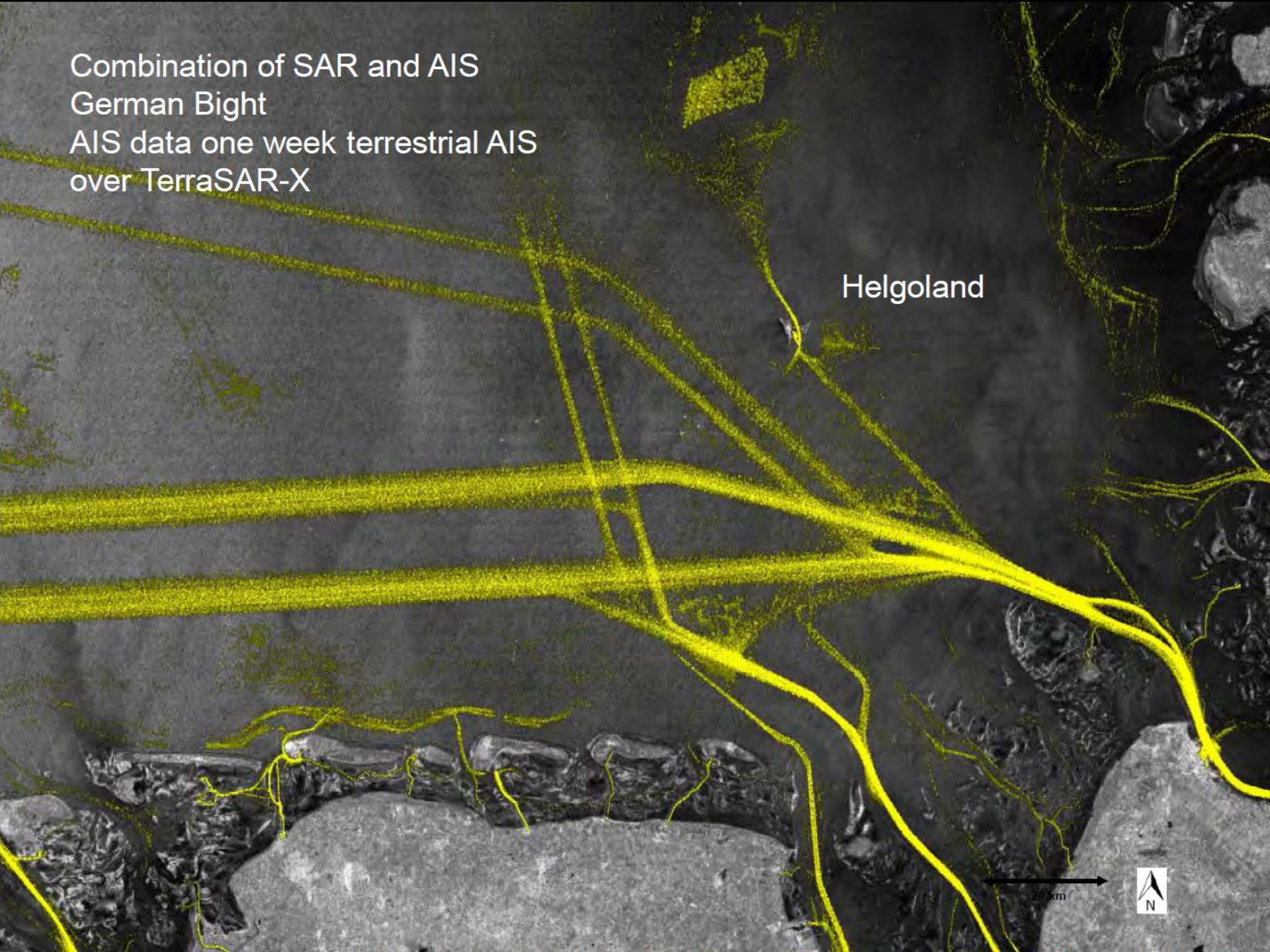


Sentinel-1
Acquired and processed at
DLR Neustrelitz

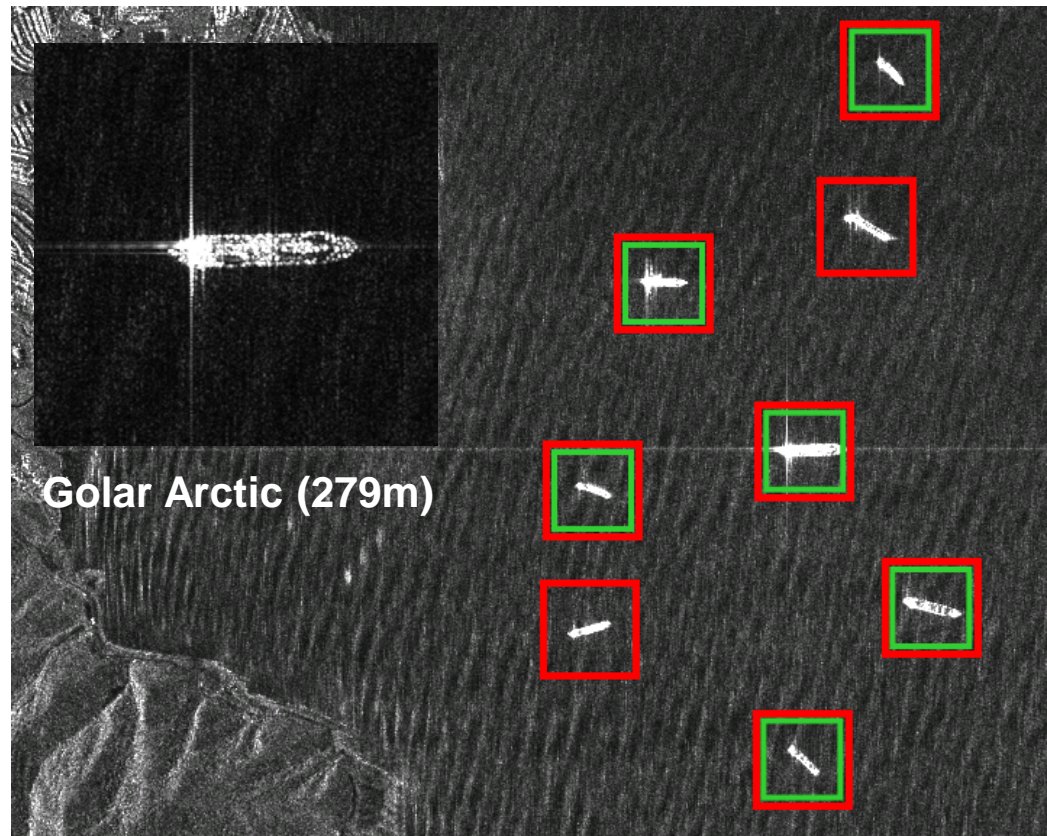
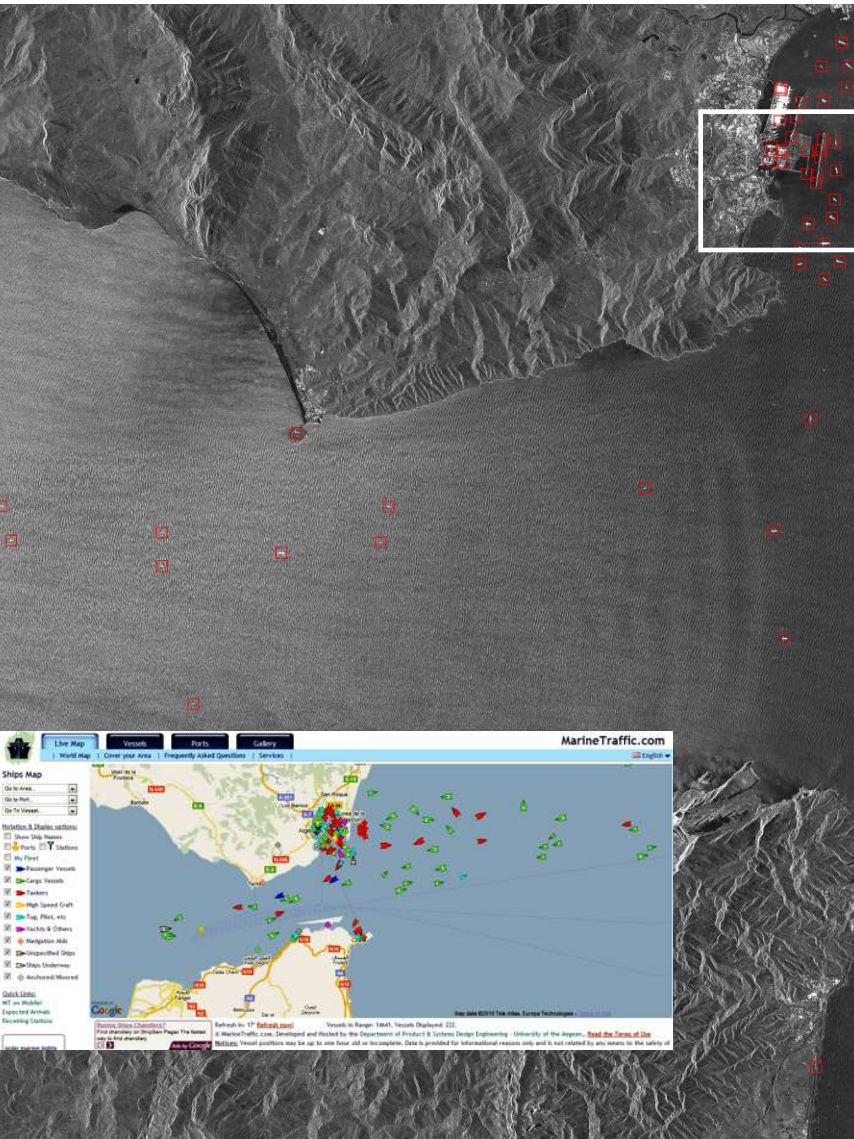


Combination of SAR and AIS
German Bight
AIS data one week terrestrial AIS
over TerraSAR-X

Helgoland



SAR-based ship detection vs. AIS (NRT Processing)

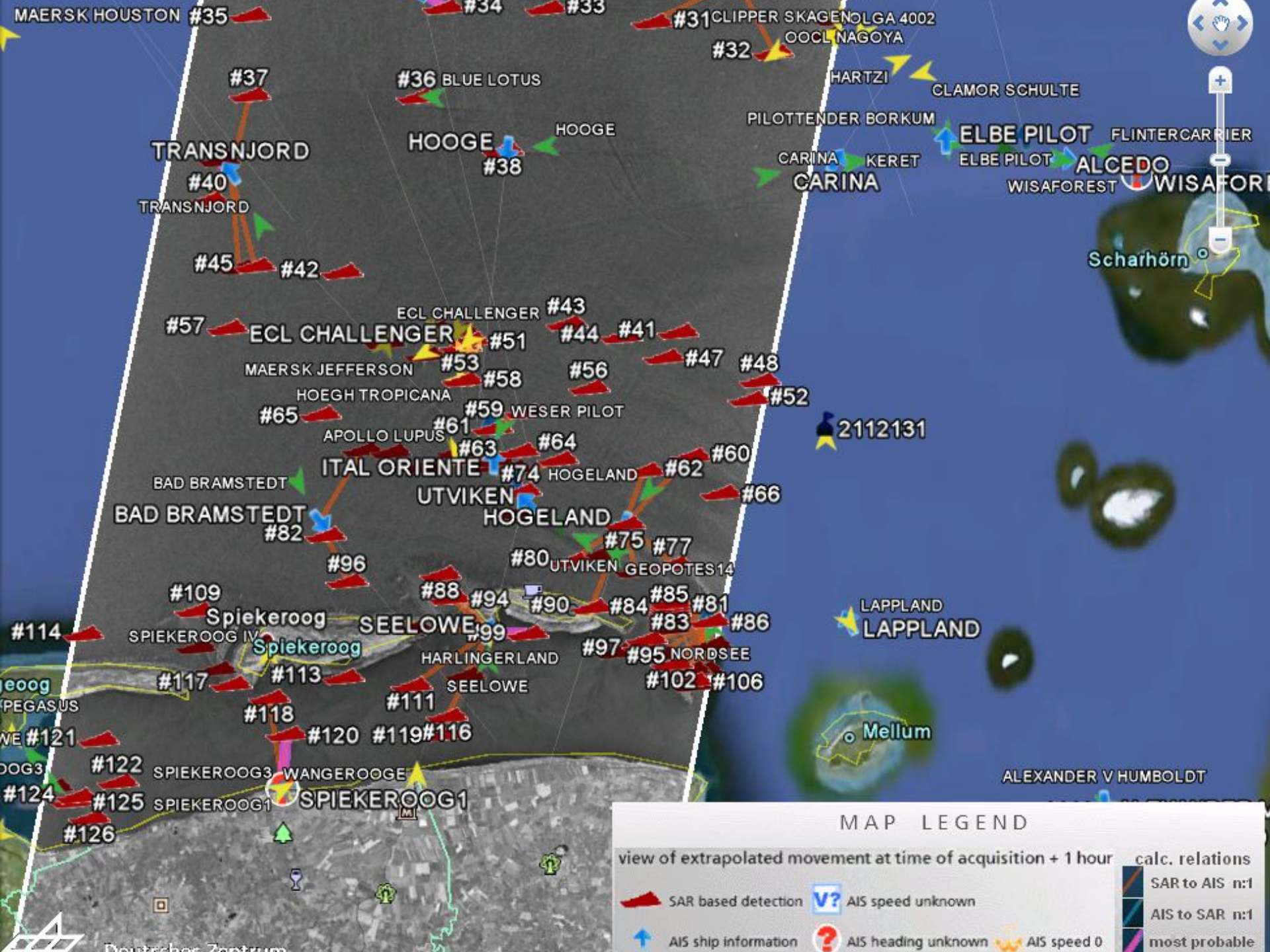


TerraSAR-X











coastal AIS



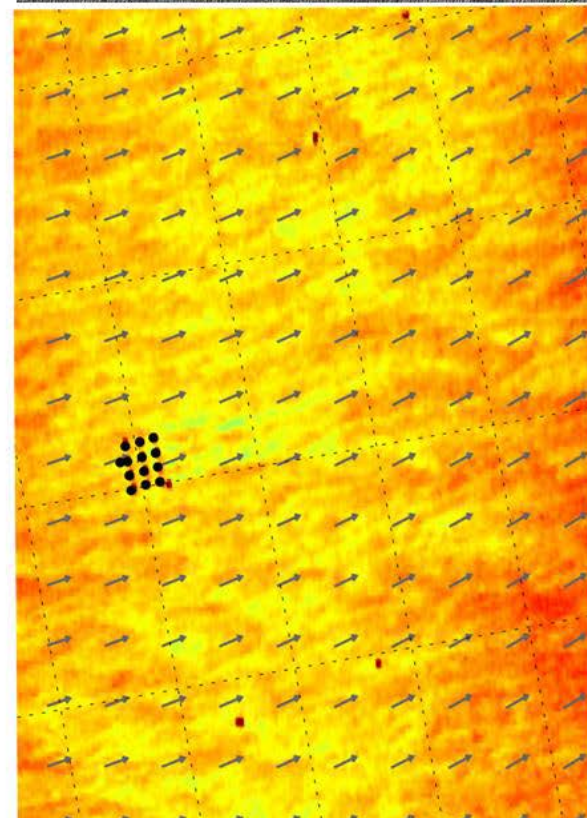
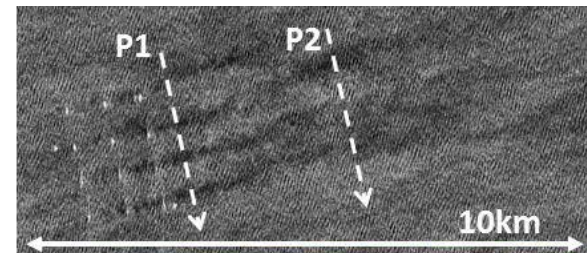
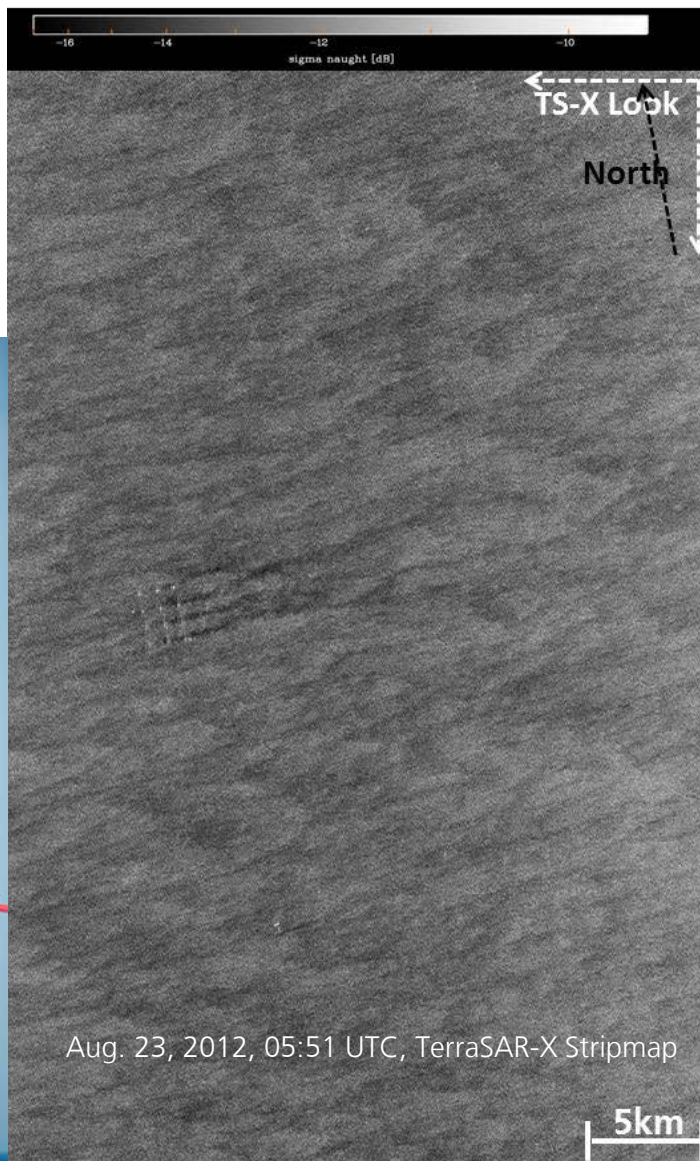


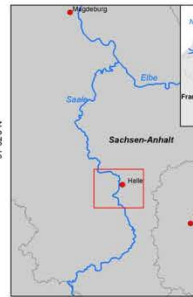
MAP LEGEND

view of extrapolated movement at time of acquisition + 1 hour

 SAR based detection	 AIS speed unknown	 calc. relations SAR to AIS n:1
 AIS ship information	 AIS heading unknown	 AIS to SAR n:1
 AIS speed 0		 most probable

Wind & Waves Measured by Satellite





Legende

	Siedlung
	Wald
	Kritische Infrastruktur
	Ber



nach unserer besten Fähigkeit
 Kenntnisstand realisiert worden.
 Alle geographischen Information
 Einschränkungen hinsichtlich des
 Auflösung, des Aufnahmedatums und
 der Ausgangsdaten. Durch den Produk-
 Haftung für die Inhalte oder deren Nutz-
 Die Krisenprodukte werden regelmä-
 besuchen Sie unsere Webseite (<http://www.zki.dlr.de>)
 die aktuellste Version dieses Produktes

Erstellungsdatum 06 Juni 2013
 © DLR 2013

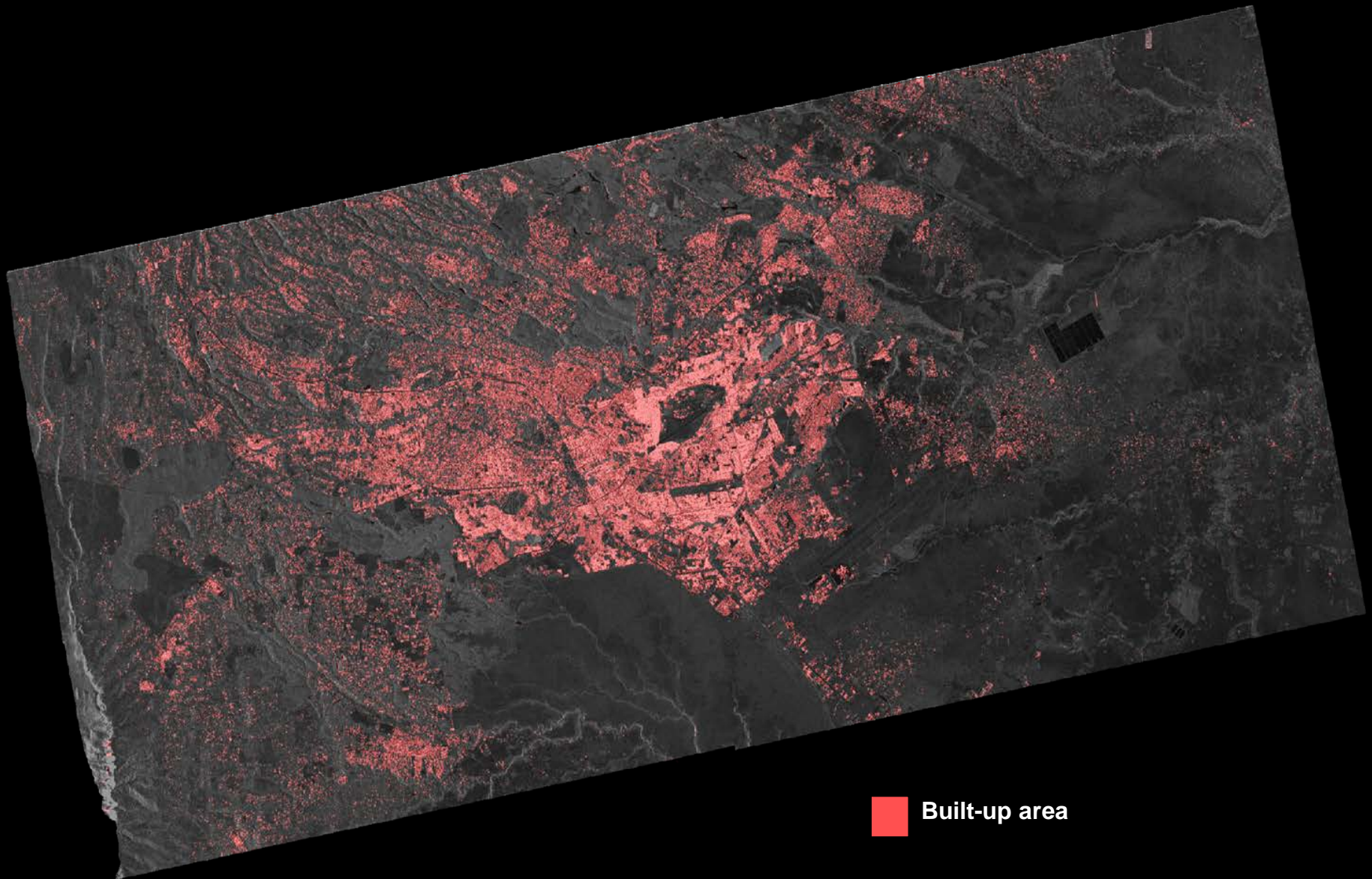
zki@dlr.de
<http://www.zki.dlr.de>



Zentrum für satellitengestützte
 -Notfallkartierung & Katastroph

Deutsches Fernerkundungsdaten
 Deutsches Zentrum für Luft- und R

Global Urban Footprint

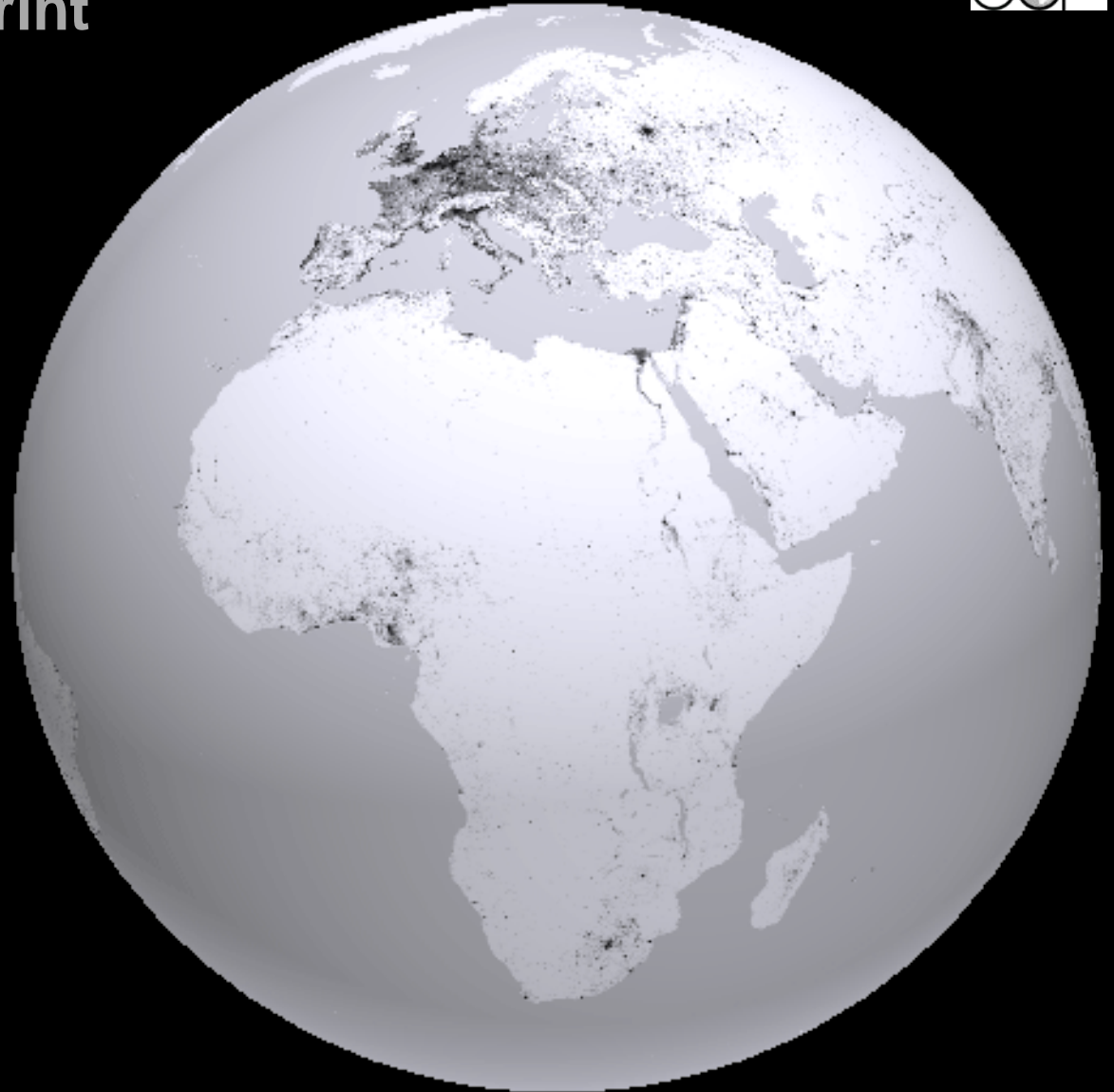


 Built-up area

Global Urban Footprint

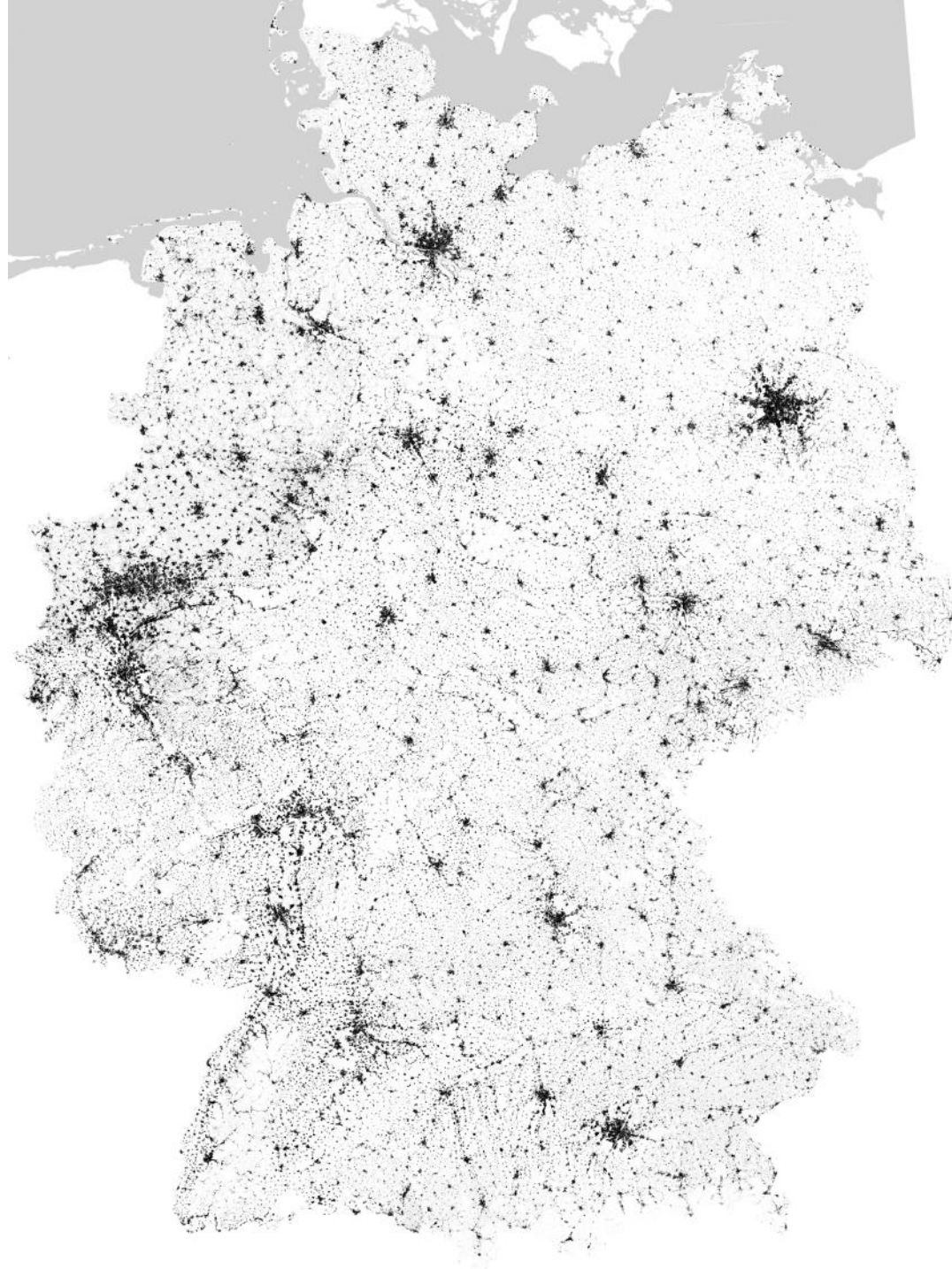


- Binäre Maske aller künstlichen (vertikalen) Strukturen
- Räumliche Auflösung 0.4 arcsec (12.5 m)
- Globale Abdeckung durch ~180.000 TerraSAR-X und TanDEM-X Datensätze (~300 TB).
- SAR Datenerhebung durch TerraSAR-X und TanDEM-X zwischen 2011 und 2013;



**Global
Urban
Footprint
TanDEM-X**

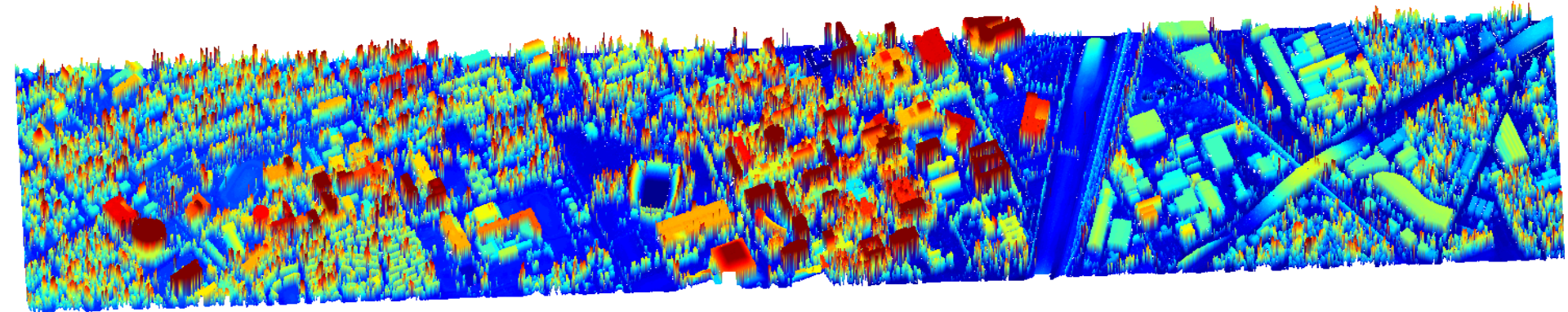
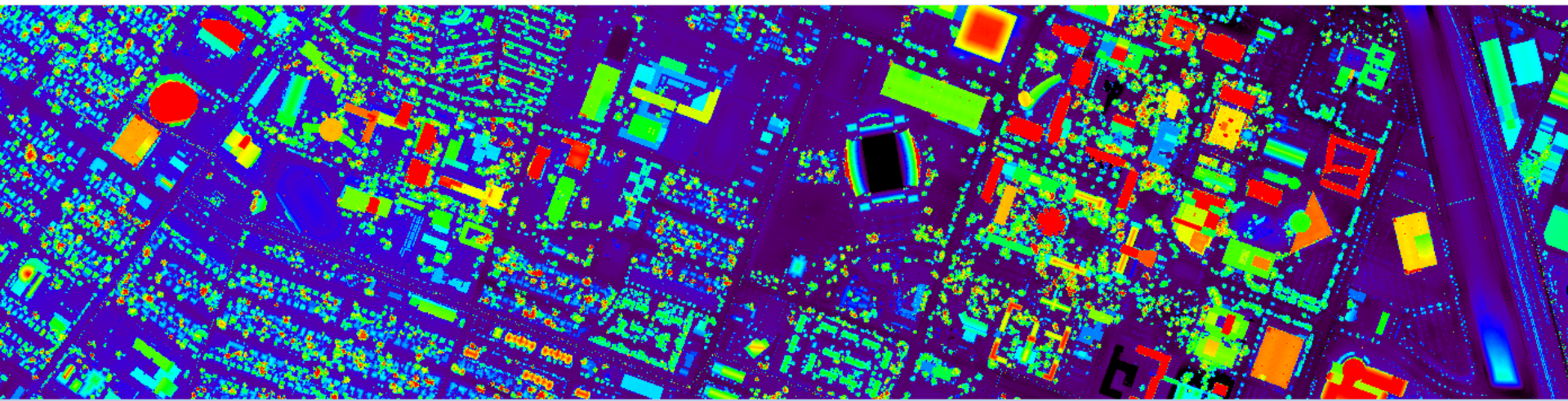
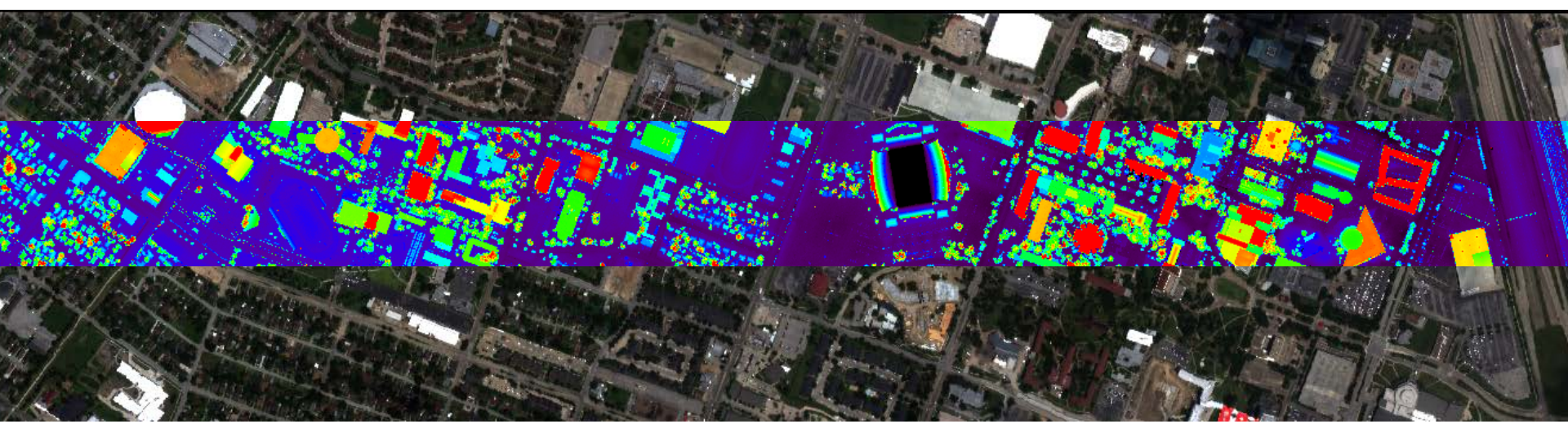
Deutschland



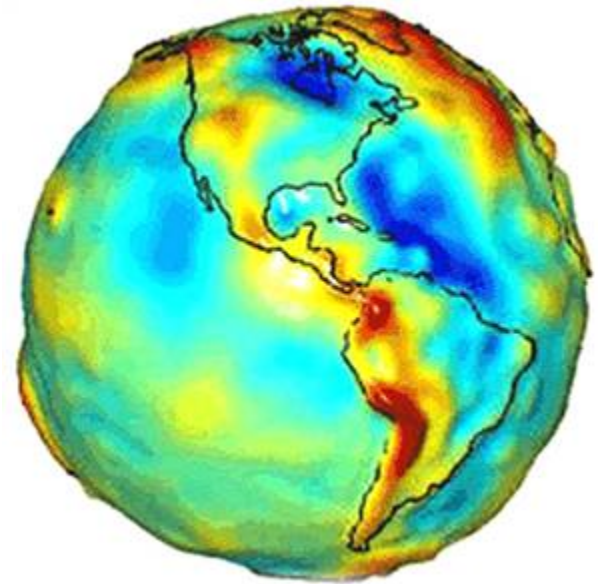
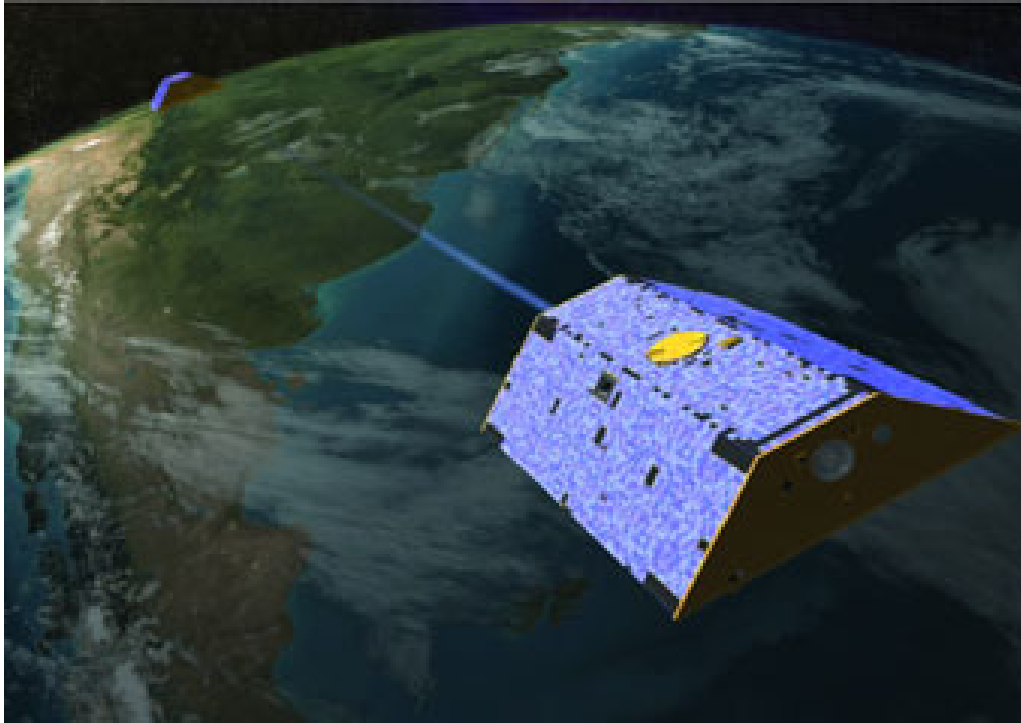
LIDAR

(Light Detection And Ranging)





Another Interesting Sensor: GRACE



GRACE: Gravity Recovery And Climate Experiment



Credit to: Weile Wang

