# TerraSAR-X SAR Payload Data Processing
# A Commissioning Phase Perspective

## Vancouver, ASAR 2007

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# Payload Ground Segment Workflows

## SAR Data Workflow

Downlink

RAW Datatakes

Decrypted Datatakes

Auxiliary Products
Orbit, Attitude, IOCS Aux

NSG Receiving Station

Decryption

Processing System TMSP

L0 Archive Products

L1b Products

L1b Request

EOWEB

Order Control

Production Control

Product Library Archive

L1b

Product Delivery

MOS Mission Planning

## Request Workflow

# Smooth Transition into CP Operation

## *Pre-launch End-to-End Testing*

- from EOWEB order to delivery of generated L1b product
- including all PGS workflows
- including space, ground and commercial service segment
- hundreds of data takes from all modes recorded and processed

## *Successful Launch*

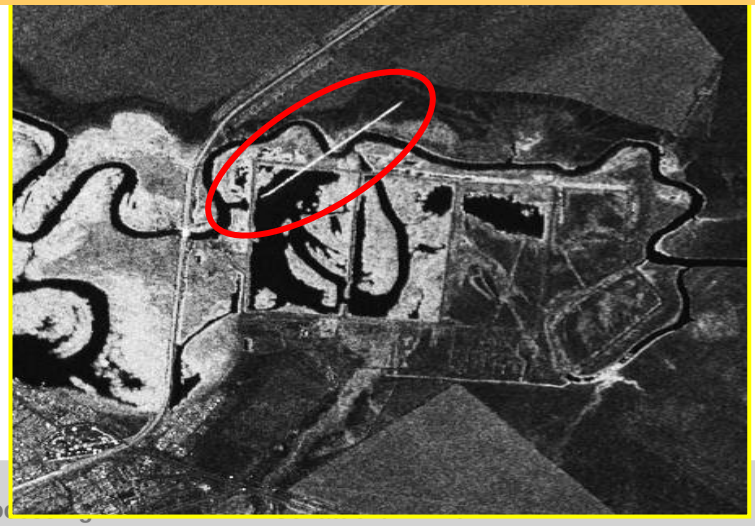
- from Baikonur on June 15th, 2007, 02:11 UTC

## *First Imaging Data Take: Novopetrovskiy, Russia, June 19th*

- acquisition start / stop : 15:03:19.782 - 15:03:31.552 UTC
- downlink to Neustrelitz ground station at 15:03:57 UTC
- after data reception and successfull decryption:
  operational PGS processing system switched on at 15:15 UTC
- successful processing in first run without any manual interaction
- quicklook printout delivered to control room team at 16:00 UTC

- First TerraSAR-X image processed on June 19th !
- SM, HH pol, beam 19, 51º incidence
- Novopetrovskiy/Russia near Volgograd

***1st product generated using the operational PGS systems and workflows !***



# Neustrelitz Ground Station NSG

- DLR‘s multi-mission satellite receiving station
- used for TerraSAR-X S- and X-band data reception
- various redundant reception components connected by matrix
  - 7.3 m X-/S-band antenna
  - demodulators
  - MDA manufactured Direct Archive Systems
    - recording of 300 MBit/s serial data stream
    - frame synchronization, Reed-Solomon correction, ISP reconstruction, data take reconstruction
- station control software performs setup, signal routing, control, reporting
- thus: fully automatised and multi-mission harmonized reception chain including planning, station setup, monitoring and control, reporting
- now in daily use for TerraSAR-X
- successful frame corrections for 5º elevation angle region (BER between 10E-4 and 10E-6)

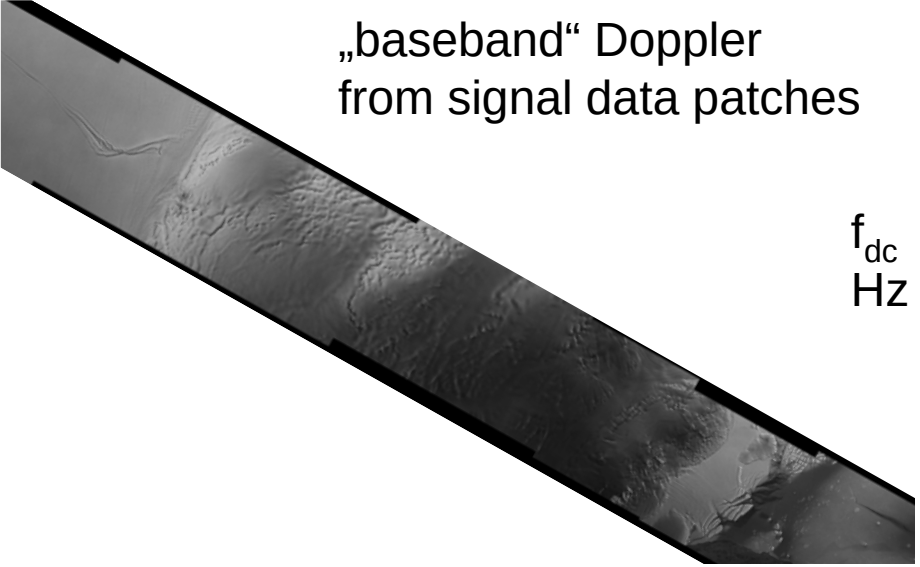
# The TerraSAR Multi-Mode SAR Processor TMSP

- generates in its data-driven L0 screening scenario archive L0 products with
  - decrypted data take files in instrument source packet format
  - extracted noise data and calibration pulses in ISP format
  - comprehensive SAR parameter annotation including e.g.Doppler information
  - quicklook information (different resolutions)
- generates in its request-driven L1b processing scenario all L1b basic product variants (including geocoded products)
  - from data takes just downlinked, but already screened: future order
  - from L0 products archived earlier: catalogue order
- generates in its request-driven NRT processing scenario L1b basic products
  - without previous screening
  - based on predicted and reference attitude information
  - direct delivery on a FTP pickup point

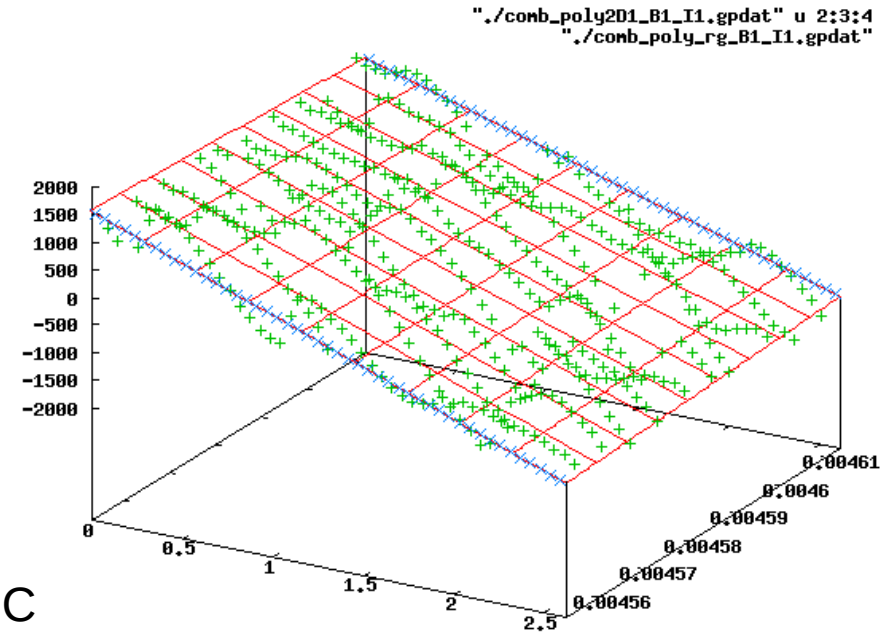
# TMSP Design High-Lights

- SAR focussing kernel: „one fits all“ approach
  - one module for StripMap, SpotLight and ScanSAR modes
  - DLR hybrid algorithm based on (Extended) Chirp and Azimuth Scaling, SPECAN and subaperture processing (phase-preserving for all imaging modes)
- consistent usage of digital elevation model throughout processing chain
  - 10 arcsec reference DEM
  - geolocation information
  - velocity parameter (B-parameter)
  - radiometric corrections (projected antenna pattern)
- geometric Doppler determination based on attitude info, DEM, beam-pointing info and orbit info
- fusion of geometric and signal Doppler estimates
  - only signal baseband Doppler centroid estimator needed
  - refinement with geometric estimates (PRF ambiguity)

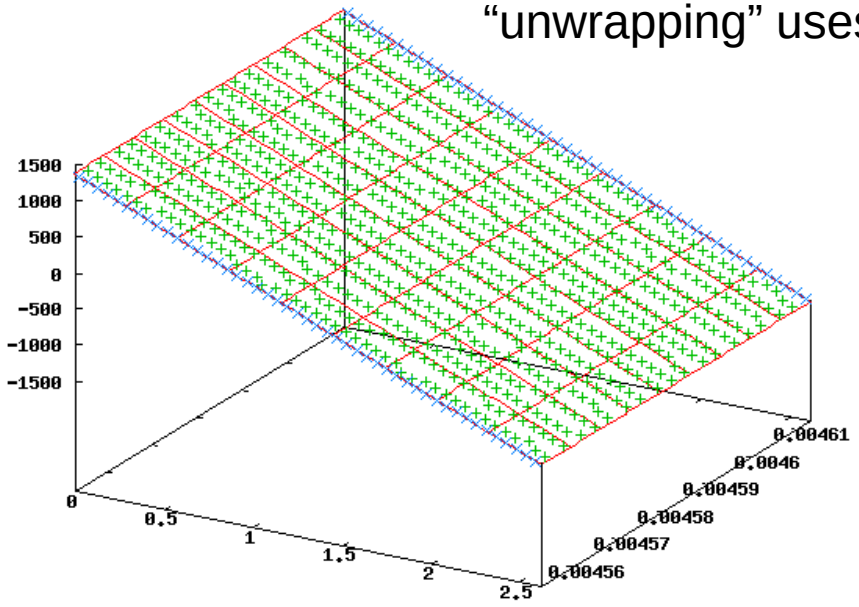
„baseband“ Doppler
from signal data patches

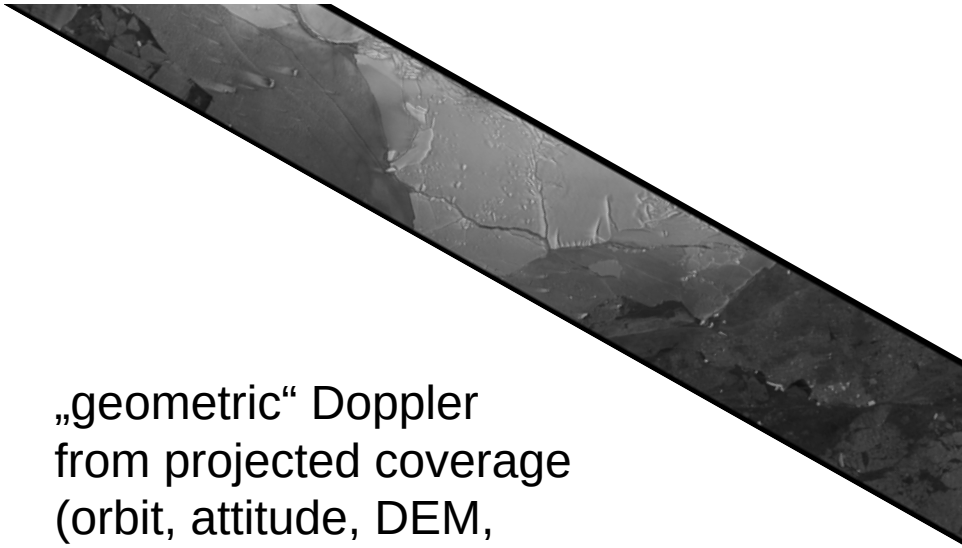


$f_{dc}$
Hz



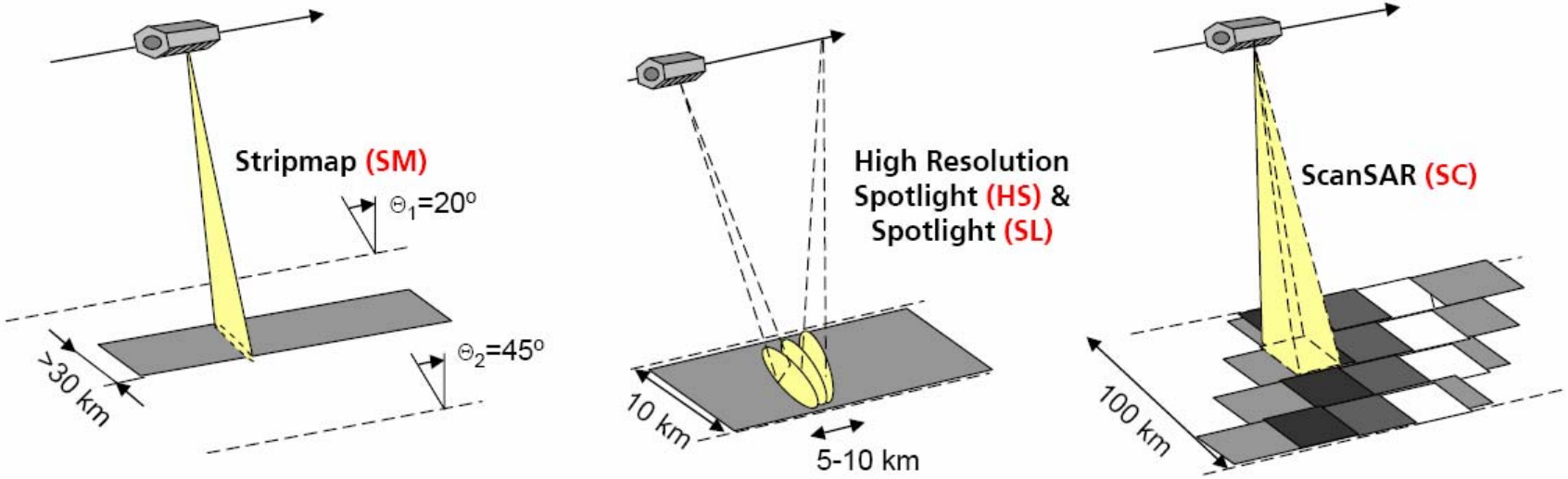

Spotlight baseband DC
“unwrapping” uses geometry



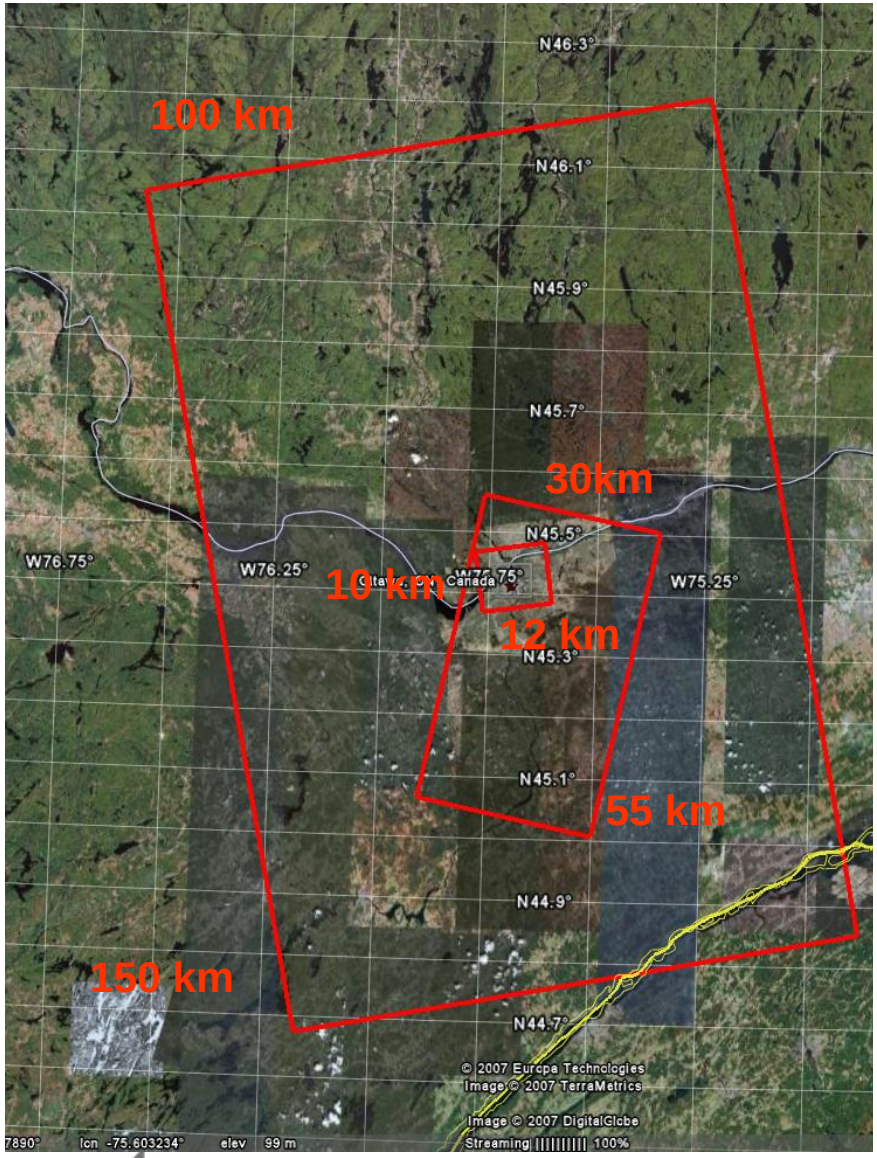
„geometric“ Doppler
from projected coverage
(orbit, attitude, DEM,
beam squint angles)

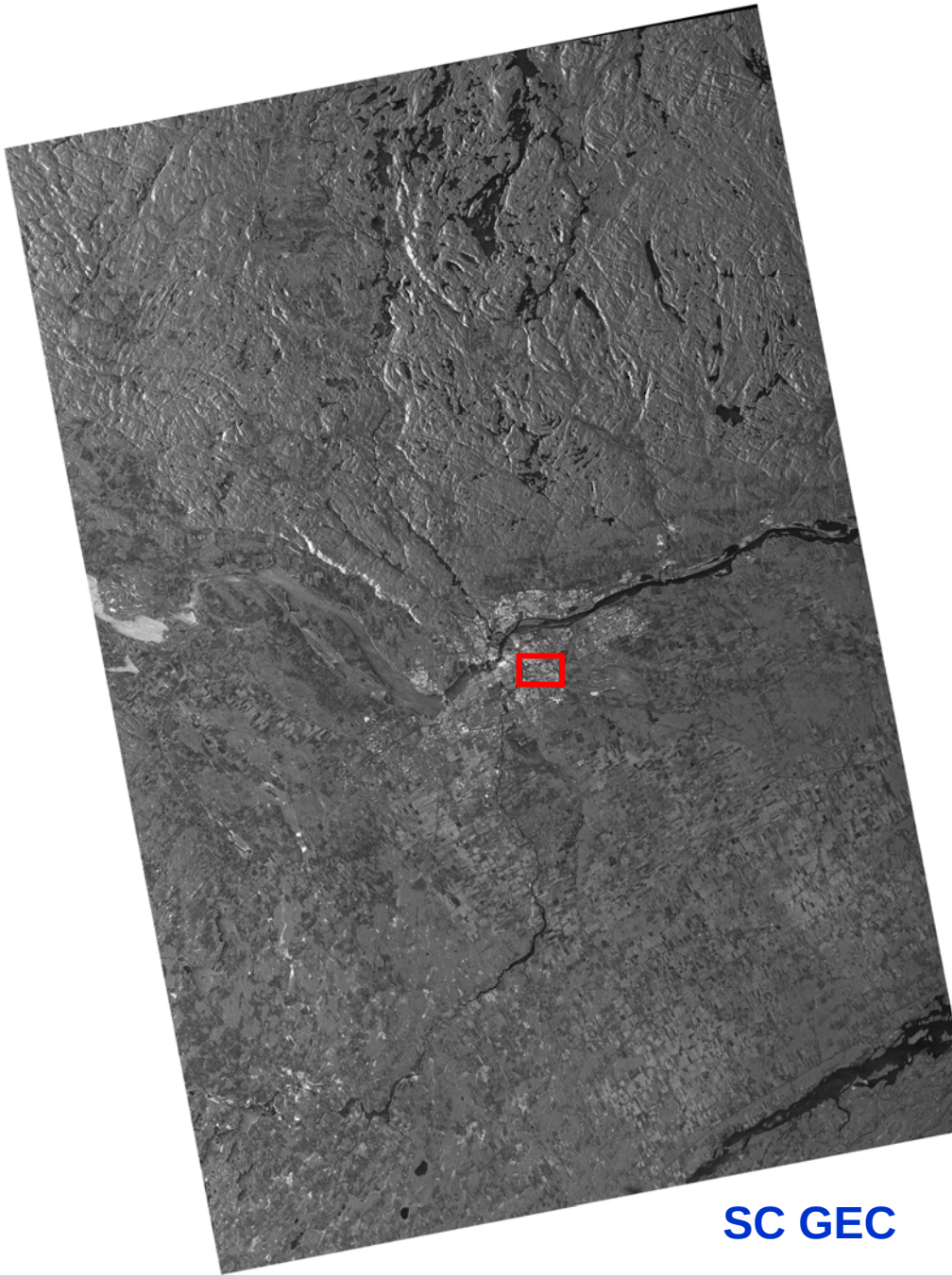
# Imaging Modes



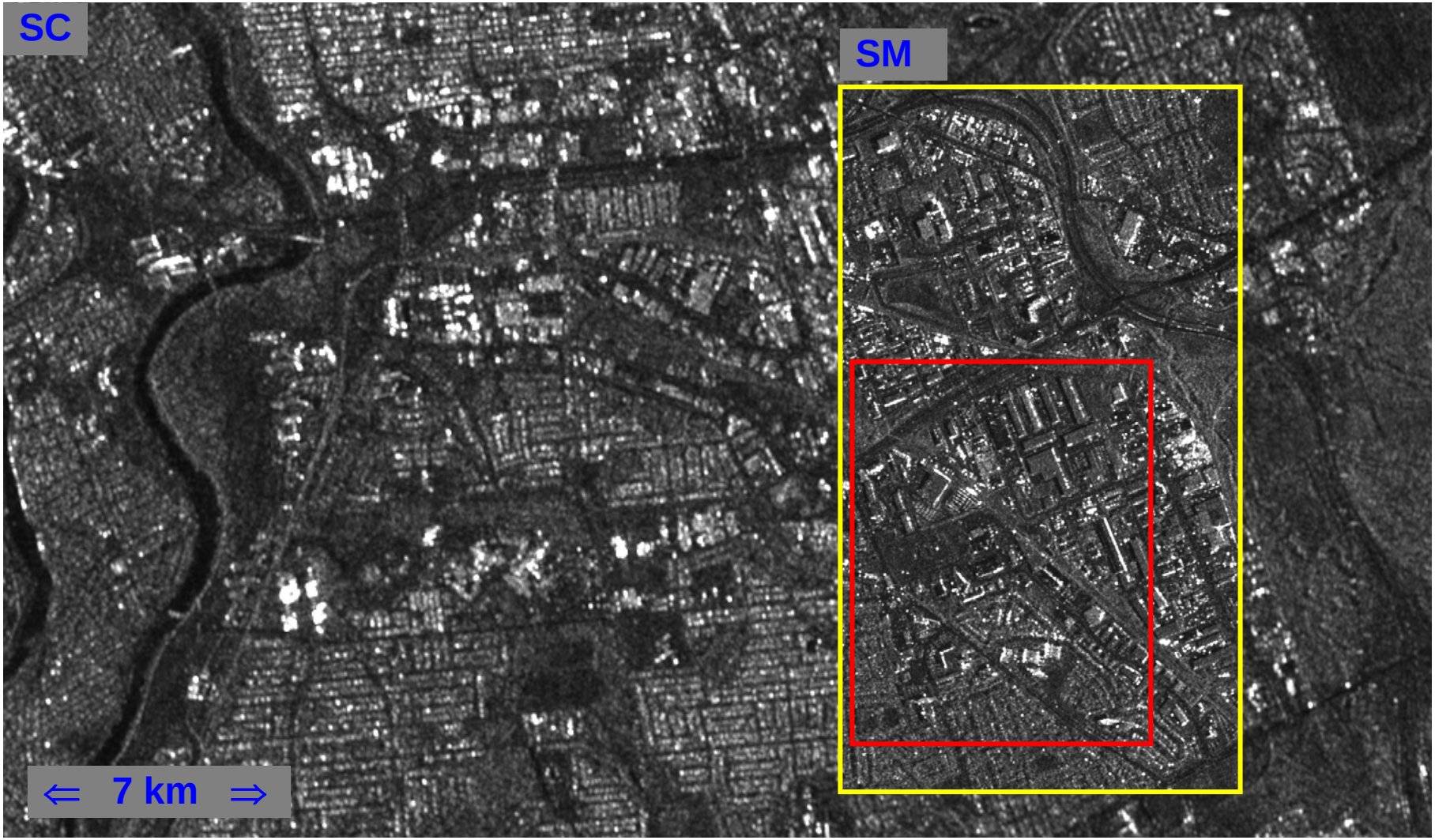

| | **Stripmap** | **Spotlight** (HS & SL) | **ScanSAR** |
|---|---|---|---|
| *swath width* | 30 km (single & twin pol.)<br>15 km (dual & quad pol.) | 10 km @ *150 MHz chirp BW*<br>azimuth: 5 / 10 km (HS / SL) | 100 km |
| *full performance incidence angle range* | 20° - 45° | 20° - 55° | 20° - 45° |
| *azimuth resolution* | 3 m (single pol.)<br>6 m (**dual pol.**) | 1 m / 2 m (HS , single / **dual pol.**)<br>2 m / 4 m (SL , single / **dual pol.**) | 17 m<br>(1 look, 4 beams) |
| *ground range resolution @ 150 MHz chirp BW* | 1.7 m - 3.5 m (@ 45°.. 20°) | 1.5 m - 3.5 m (@ 55°..20°) | 1.7 m - 3.5 m (@ 45°.. 20°) |

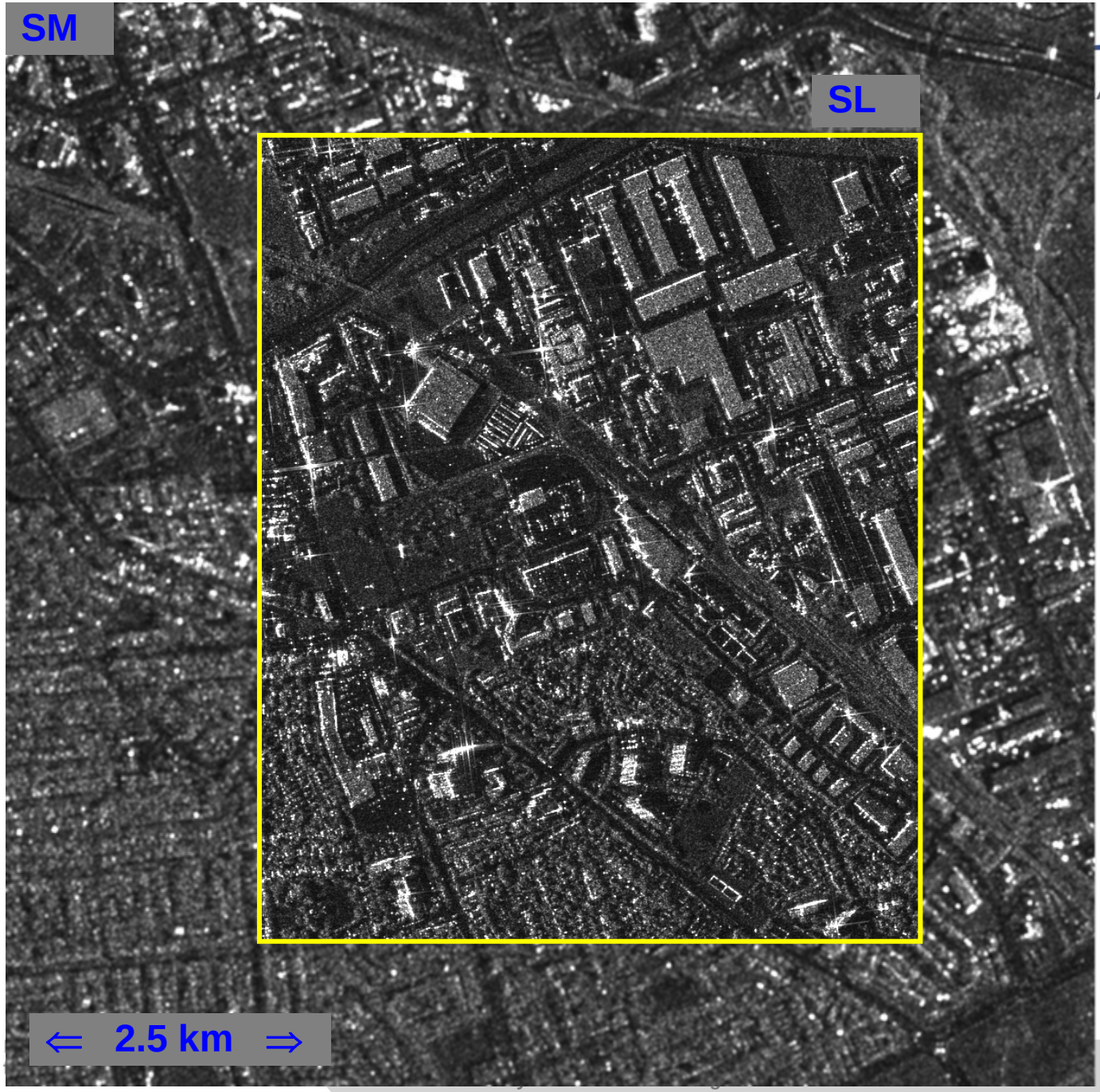
# Ottawa – SC vs. SM vs.

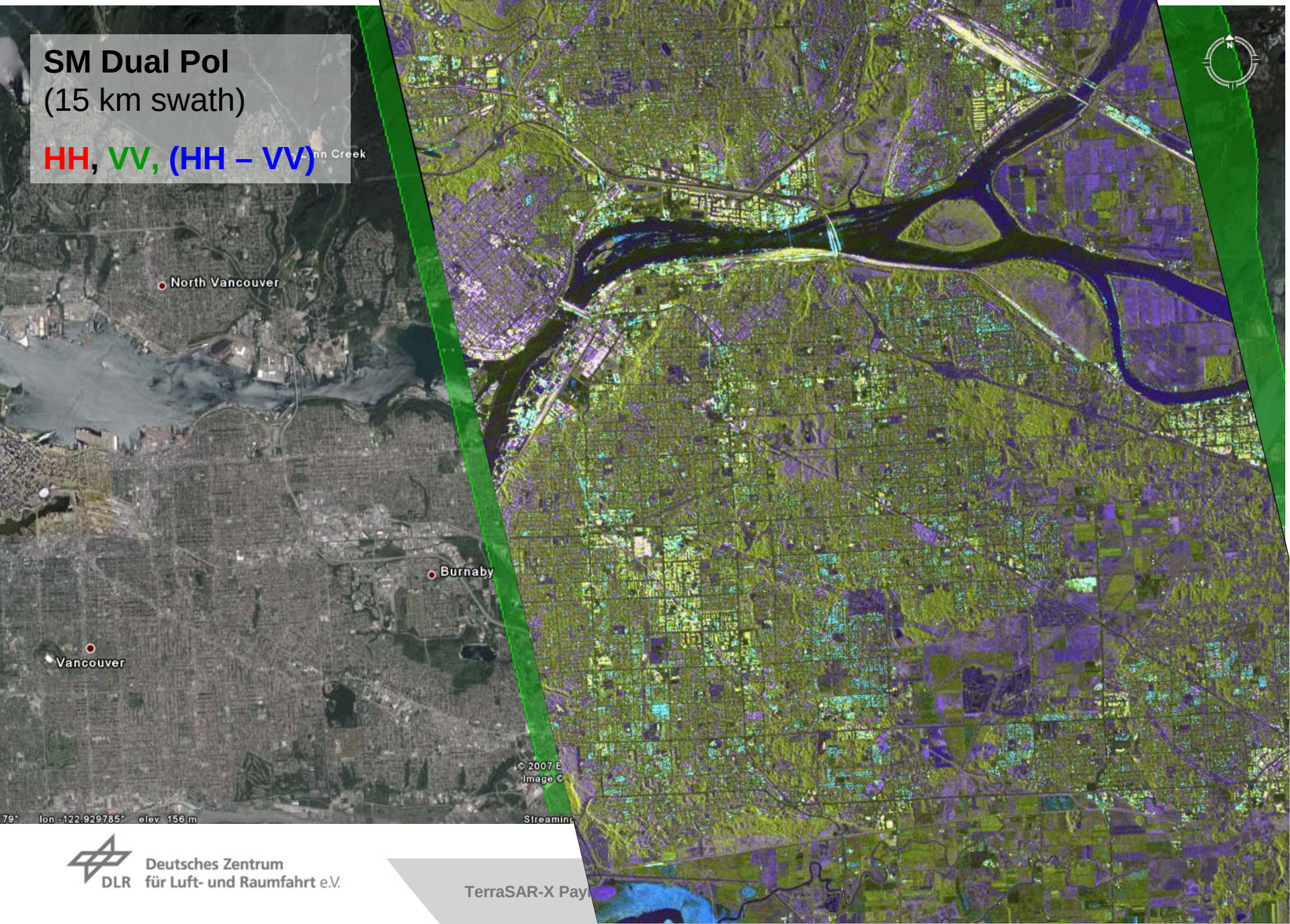


SC GEC


SC
SM
⇐ 7 km ⇒

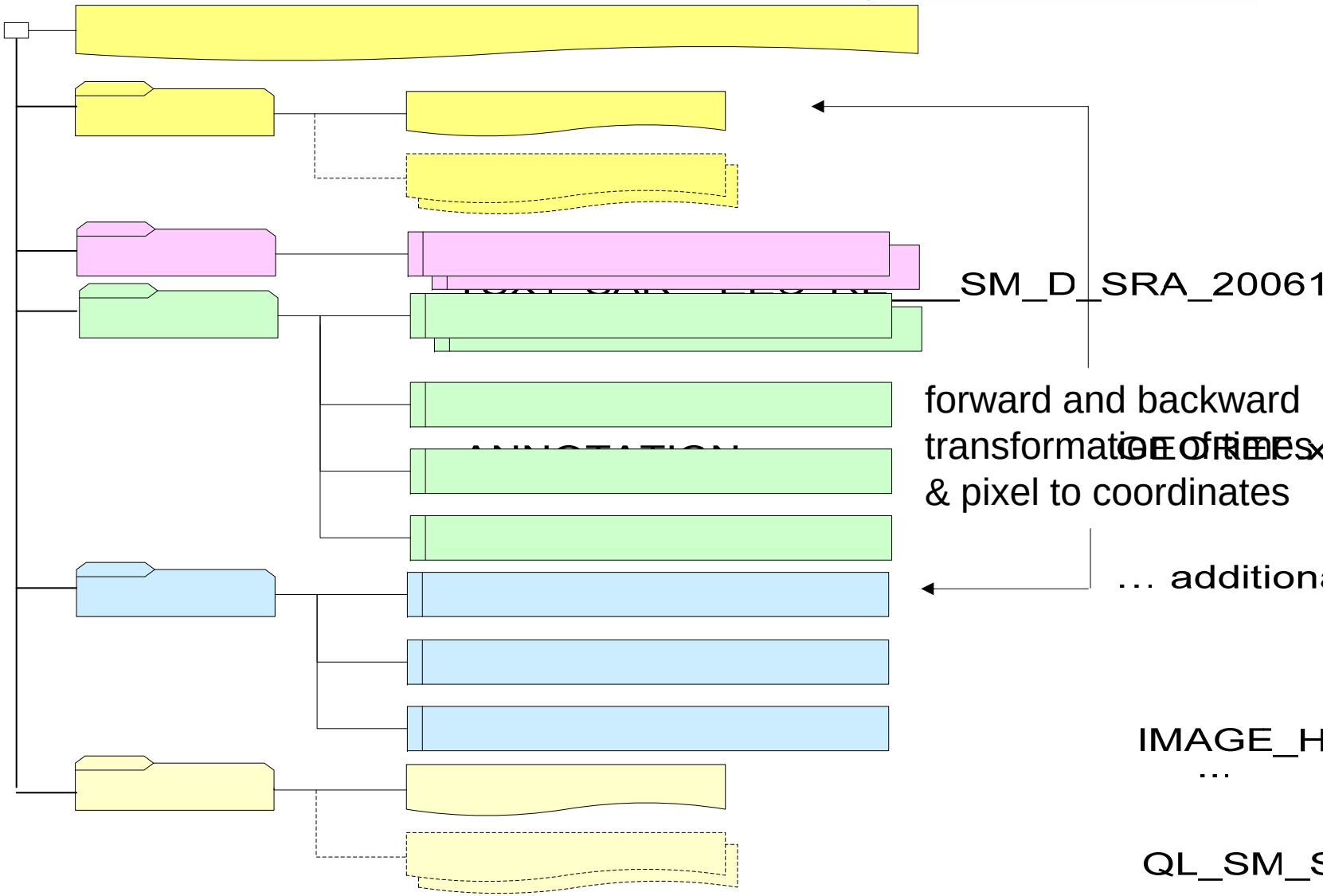

SM
SL
⇐ 2.5 km ⇒


SM Dual Pol
(15 km swath)
HH, VV, (HH – VV)
North Vancouver
Burnaby
Vancouver
lon -122.929785°
elev 156 m

# Basic Product Portfolio

- SSC: single look complex in slant range geometry
  - equidistant spacing in azimuth and in slant range
  - complex representation
- MGD: multi look ground range detected
  - homogenous ground spacing
  - no interpolation artifacts due to image rotation.
  - geo-referenced, but no precise geometry
- GEC: geocoded ellipsoid corrected
  - UTM / UPS projection, WGS84 reference, average height used
- EEC: enhanced ellipsoid corrected
  - UTM / UPS projection, WGS84 reference, “coarse” DEM considered (e.g. SRTM, DTED-1 and -2)
  - pixel localization accuracy down to meter level (depends on DEM availability / quality for r.o.i.)

# Level 1b Product Structure



# L1B SAR Processing: Stripmap Single Polarisation

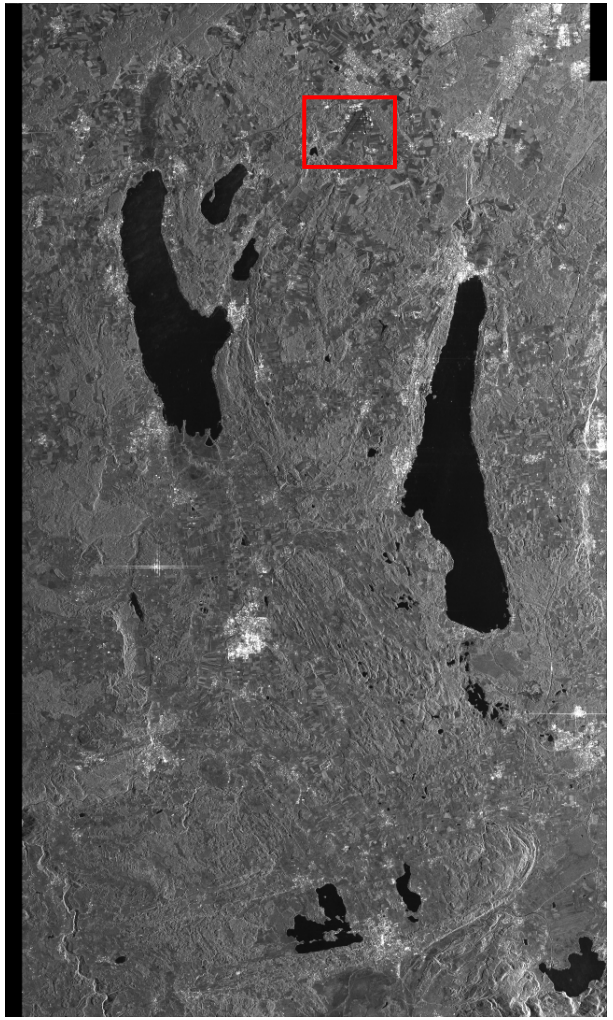
*Acquisition*

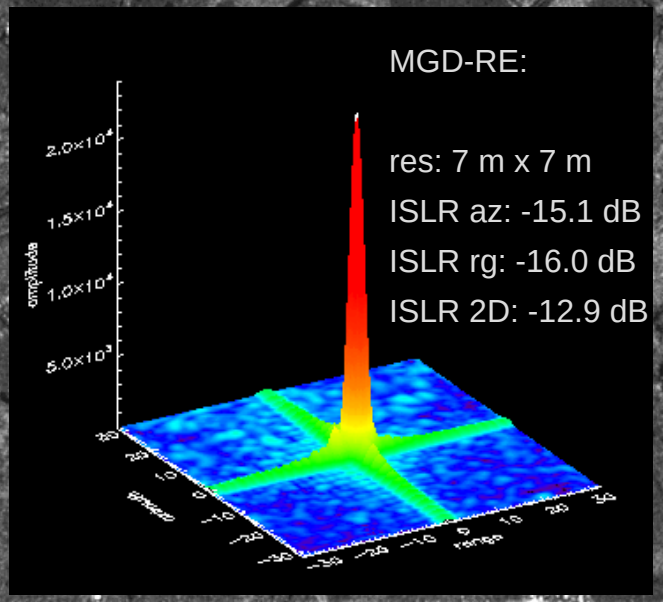
- Oberpfaffenhofen, Fünf-Seen-Land
- Stripmap (HH)
- Incidence angle: 39.5° .. 42.5 °
- 100 MHz bandwidth

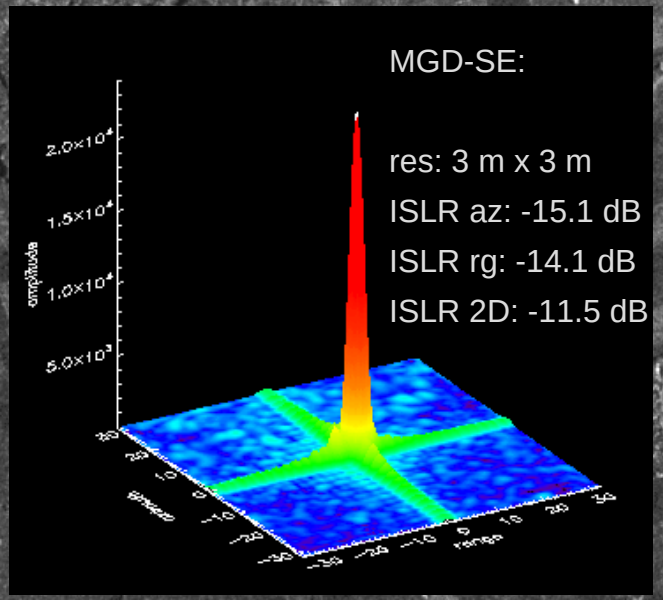
*Level 1b processing of detected products: quadratic resolution in RE & SE variants*

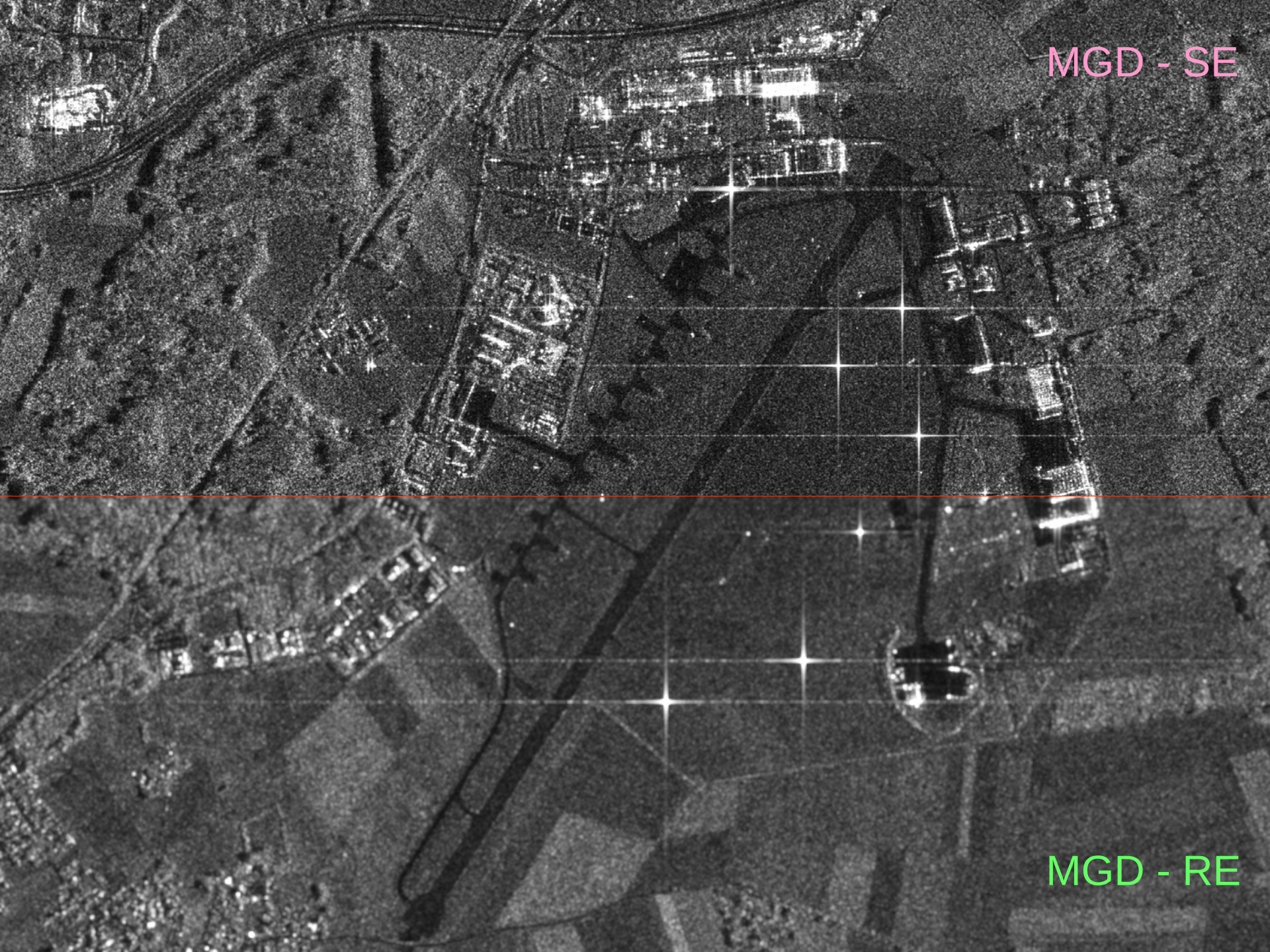
- MGD-**RE** ***(Radiometrically Enhanced)***:
  - 56 km x 30 km (az, rg)
  - **7 m** resolution, 3.25 m spacing
  - 2.3 (az) x 3.5 (rg) looks
  - 17360 lines x 10306 samples (**358 MB**)

- MGD-**SE** ***(Spatially Enhanced)***:
  - 56 km x 30 km (az, rg)
  - **3 m** resolution, 1.25 m spacing
  - 1 (az) x 1.5 (rg) looks
  - 45136 lines x 26796 samples (**2419 MB**)




MGD-RE:
res: 7 m x 7 m
ISLR az: -15.1 dB
ISLR rg: -16.0 dB
ISLR 2D: -12.9 dB
amplitude
azimuth
range


MGD-SE:
res: 3 m x 3 m
ISLR az: -15.1 dB
ISLR rg: -14.1 dB
ISLR 2D: -11.5 dB
amplitude
azimuth
range


MGD - SE
MGD - RE

# Early Checks of Product Annotation and Processing Accuracy

*Multitemporal Stripmap Image*

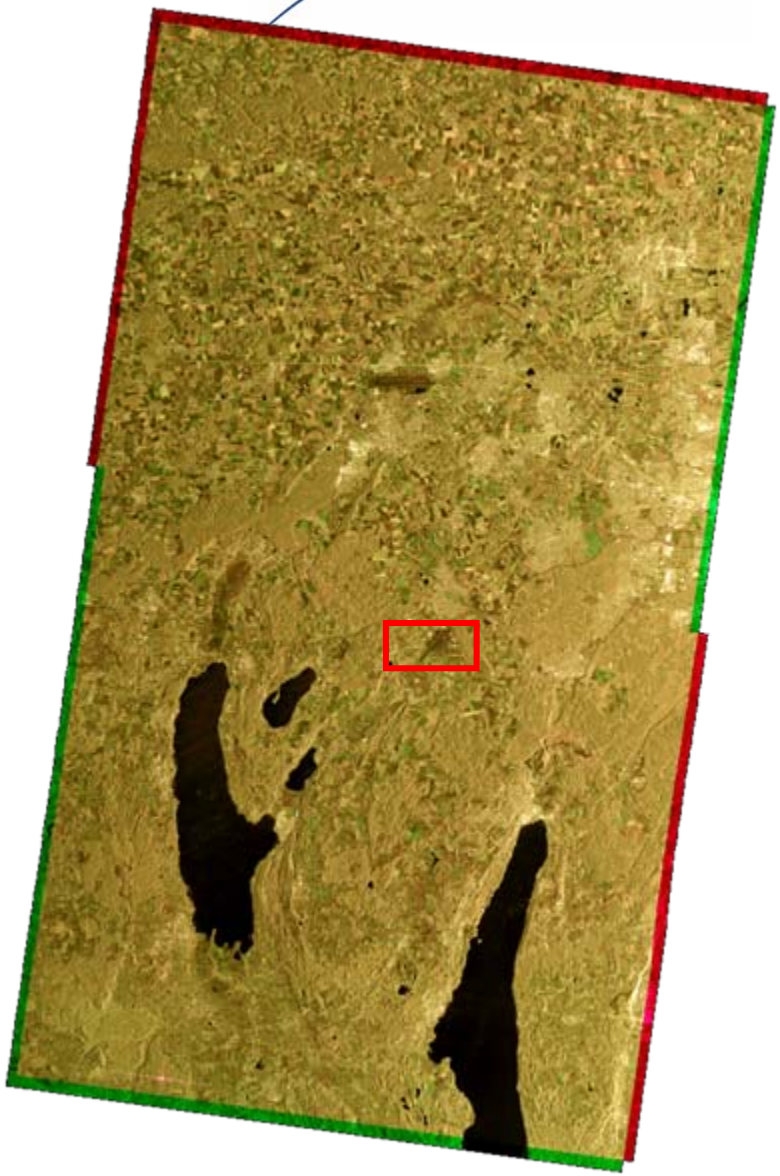
- Overlay based on annotated coordinates only
- No additional co-registration

*Acquisition(s)*

- **June 26** and **July 7** (blue: Δ).
- Stripmap (HH)
- Incid. angle: 39.5° .. 42.5 °
- 100 MHz bandwidth

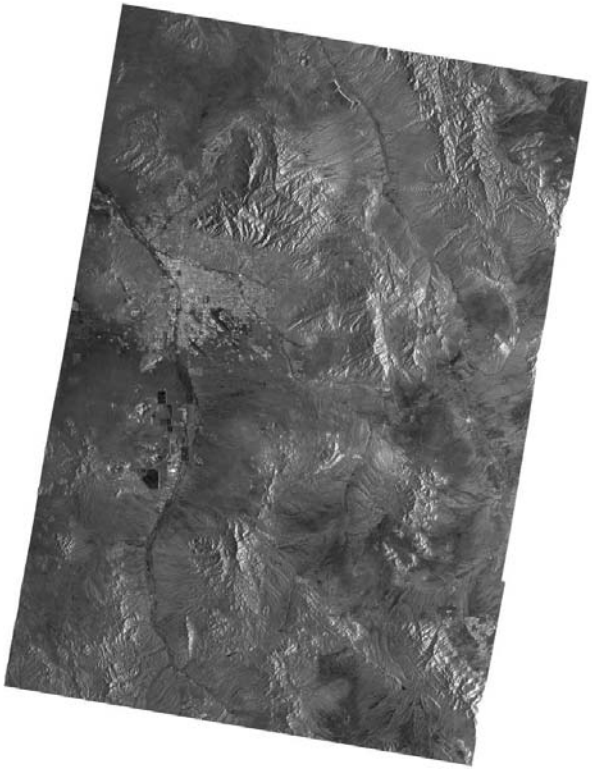
*Processing*

- Enhanced Ellipsoid Corrected (EEC), radiometrically enhanced (RE)
- Resolution 7 m, spacing 3.25 m

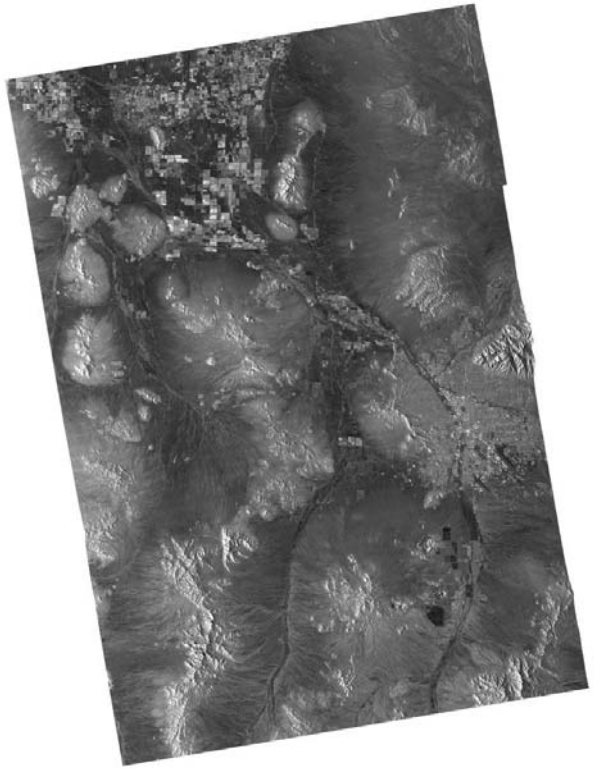


# Geometric (Multiangle) Accuracy
# 3 x ScanSAR Tucson (AZ): EEC RE

descending
scan_003
25º inc
20070701T133311



descending
scan_010
42º inc
20070703T012409



ascending
scan_011
40º inc
20070707T132440

# Multitemporal ScanSAR EEC Image

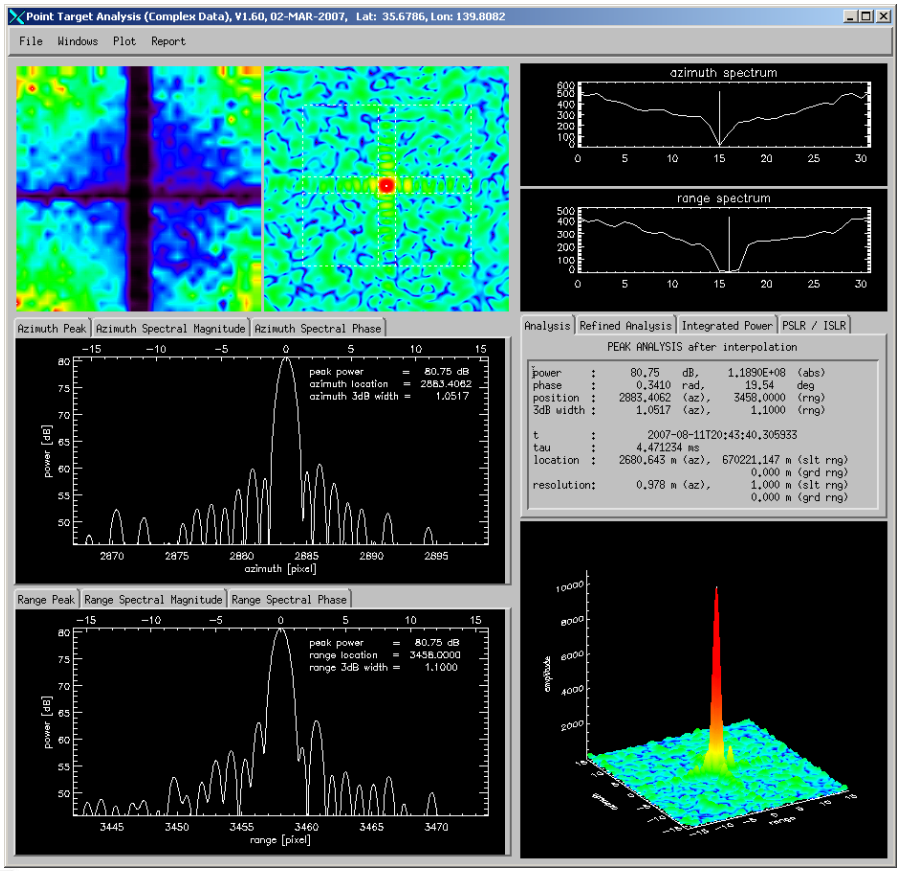
# TMSP „One fits all“ – Also in Infoterra‘s Direct Access Stations

- exclusive usage of TMSP processor also at Direct Access Stations (DAS) of the TSXX commercial service segment
- currently: DAS in Japan in check-out phase
- first successful data reception and processing in cycle 6
- example: **HS** Tokyo acquisition, 150 MHz BW, incidence angle 42º
- PASCO deployed corner reflector
- Results presented from PGS reference processing

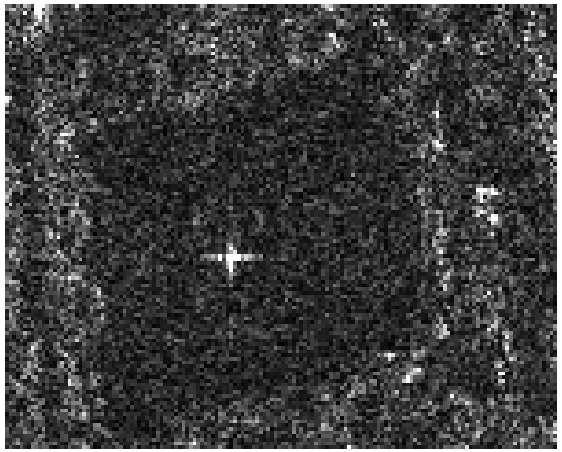

# SSC Corner Reflector Analyis

## PASCO provided GPS location information

| | |
|---|---|
| latitude | 35º 40’ 43.15247” |
| longitude | 139º 48’ 29.17091” |
| height | 38.689 m |







## measured spatial resolution (SSC)

| | |
|---|---|
| slant range | 1.000 m |
| azimuth | 0.9778 m |

# SSC and EEC Corner Location Analysis

- **HS** Data Take from 20070811 processed with science orbit
- **TMSP** uses and annotates **troposheric and ionospheric range delay corrections**
  - annotated 2-way delay for this scene: **6.2178 m**
  - essential for high geometric TerraSAR-X accuracy
- measured vs. predicted **SSC** location
  (based on science orbit, delay correction and GPS coordinates)

| | | |
|---|---|---|
| range pixel | 3458.0000 | 3458.1528 |
| azimuth pixel | 2883.4062 | 2884.6060 |

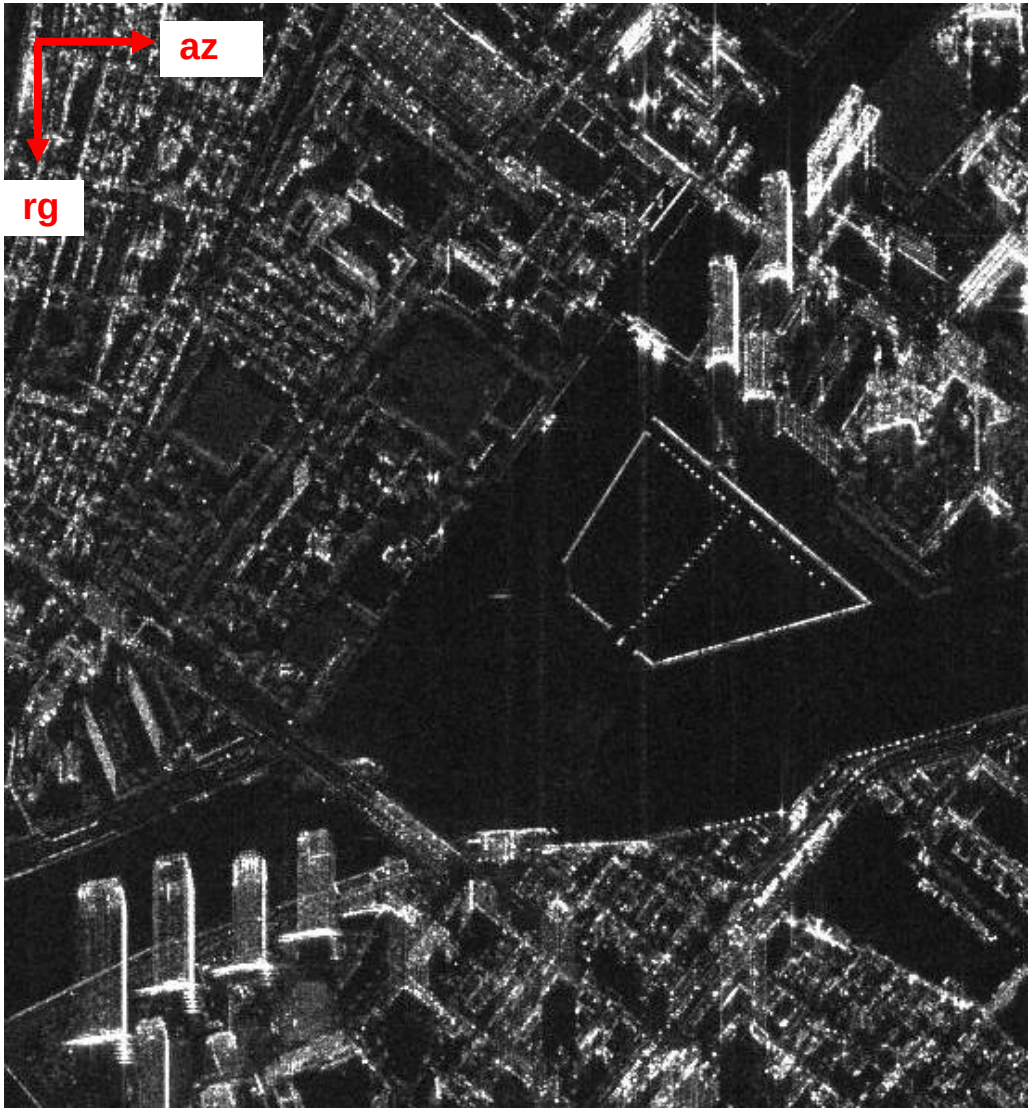
- resulting **SSC** deviations

| | |
|---|---|
| slant range | **0.1390 m** (pixel spacing 0.9094 m) |
| ground range @42.5º | 0.2057 m |
| azimuth | **1.1155 m** (projected spacing 0.9297 m) |

  (@ ground velocity 7039 m/s, systematic shift not yet corrected)
- measured vs. predicted **EEC** location (with SRTM DEM)

| | | | |
|---|---|---|---|
| easting | 392143.148 | 392140.535 | **ΔE = 2.613 m** |
| northing | 3948962.766 | 3948961.865 | **ΔN = 0.901 m** |

# Tokyo River Island

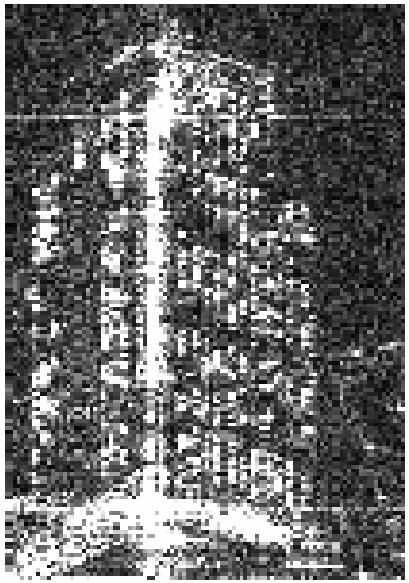


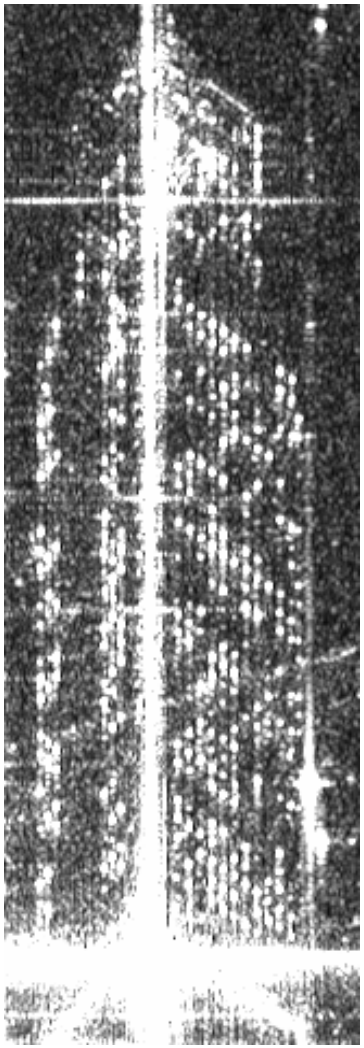


# More Things to Discover in Tokyo Scenes

**St. Luke‘s Tower**

150 MHz BW
2007-08-11





300 MHz BW
2007-09-02

**A Big Wheel**

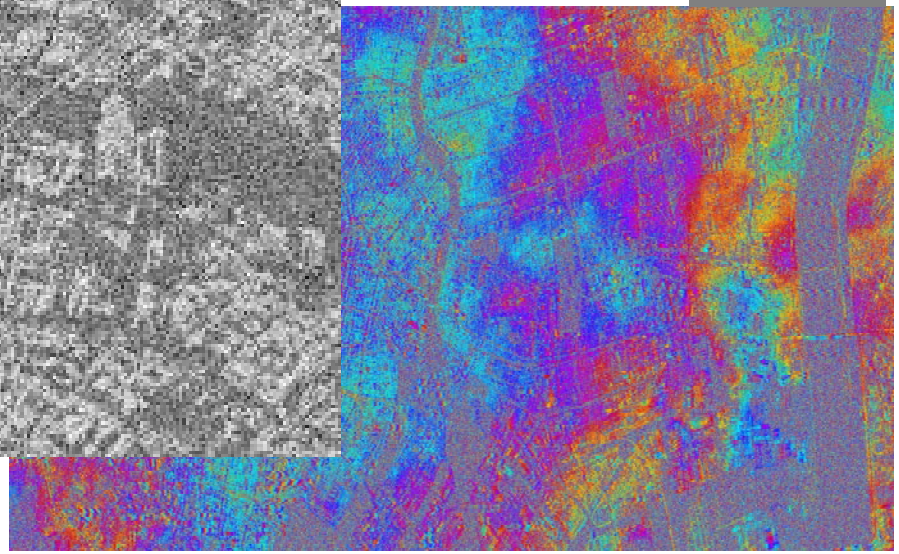
# TerraSAR-X Interferometry

- to support system and processing verification and quality assessment in term stability
- chall metry
- exan 33 days apart) with a 90 m ef
- co-re only remaining cons d

**Coherence**



**Phase**



# PGS CP Status

- PGS system operational for commissioning phase since launch
- System Users (DLR IOCS, DLR PGS, ITD commercial coordinator) submit orders and receive products using the operational PGS user services
- More than 5000 data takes recorded, processed and archived so far
- Operational TMSP
  - qualified for all basic products
  - qualified for experimental complex SC-SSC and twin-pol products
  - processes specific data take variants to support overall system verification and calibration (notch beams, extreme azimuth pointing, PN gating, and more)
- operational qualification of both the system and the products according to commissioning phase schedule (see presentation Mittermayer)


TerraSAR-X not only is a good system,
but also fun to work with