CEOS WGCV SAR Virtual Workshop 2020

DLR Geometric Calibration Targets: Status Update and Ongoing Research

C. Gisinger, U. Balss, M. Eineder

German Aerospace Center (DLR)

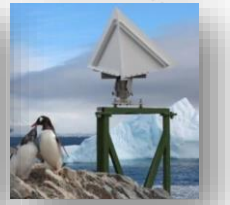
Overview on DLR Calibration Targets

- Passive corner reflectors for ongoing geometrical cal/val activities with TerraSAR-X and Sentinel-1
- Active low cost C-band transponder for application evaluation with Sentinel-1

Metsähovi (Oct. 2013):
1 CR (1.5 m) – **D**
Local ties (< 5 mm)

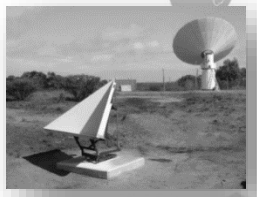
Wettzell (Jul. 2011, Oct. 2013):
1 CR (1.5 m) - **A**, 1 CR (1.5 m) – **D**
Local ties (< 5 mm)

DLR OP (Jan. 2020):
2 ECR– **A/D; 11 CR** (1.5 m)
DGPS 2cm



GARS O'Higgins (March 2012):
1 CR (0.7 m) - **A,** 1 CR (0.7 m) – **D**
Local ties (< 5 mm)

Yarragadee (Aug. 2018):
1 CR (1.5m) – **A, 1 CR** (1.5m) – **D**
Local ties (< 2 cm)



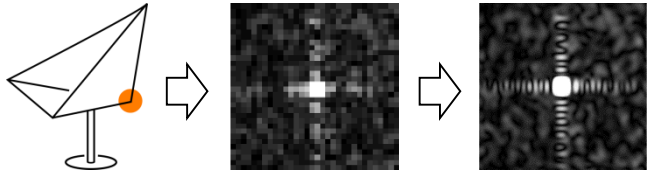
Australian Government
Geoscience Australia

SAR Geolocation Analysis in a Nutshell

Corner reflectors or transponders as reference targets with known coordinates

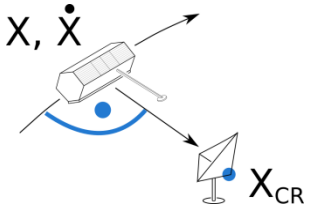
1 SAR image: point target analysis

- Get $t_{Azimuth}$, τ_{Range} at sub-pixel level
- Accuracy proportional to SCR



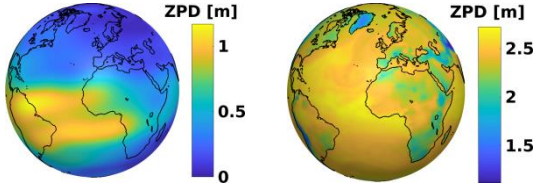
2 Range-Doppler equations: reference timings

- Compute $t_{Azimuth}$, τ_{Range} w.r.t. 0-Doppler geometry
- Known CR coordinates + geodynamics & orbit



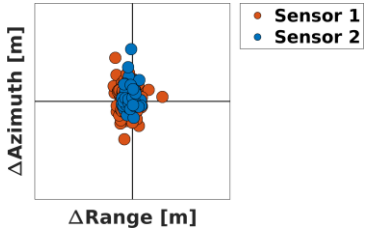
3 Atmospheric path delays in slant range

- Ionosphere: GNSS Tot. Electron Content
- Troposphere: ECMWF integration or GNSS-based



4 Comparison: Absolute Location Error

- For each product: $\Delta t_{Azimuth}$ and $\Delta\tau_{Range}$
- Conversion to units of length with v_{beam} and c



t_{az}

τ_{rg}

$-$

t_{az}

τ_{rg}

$-$

Δ_{ion}

Δ_{tro}

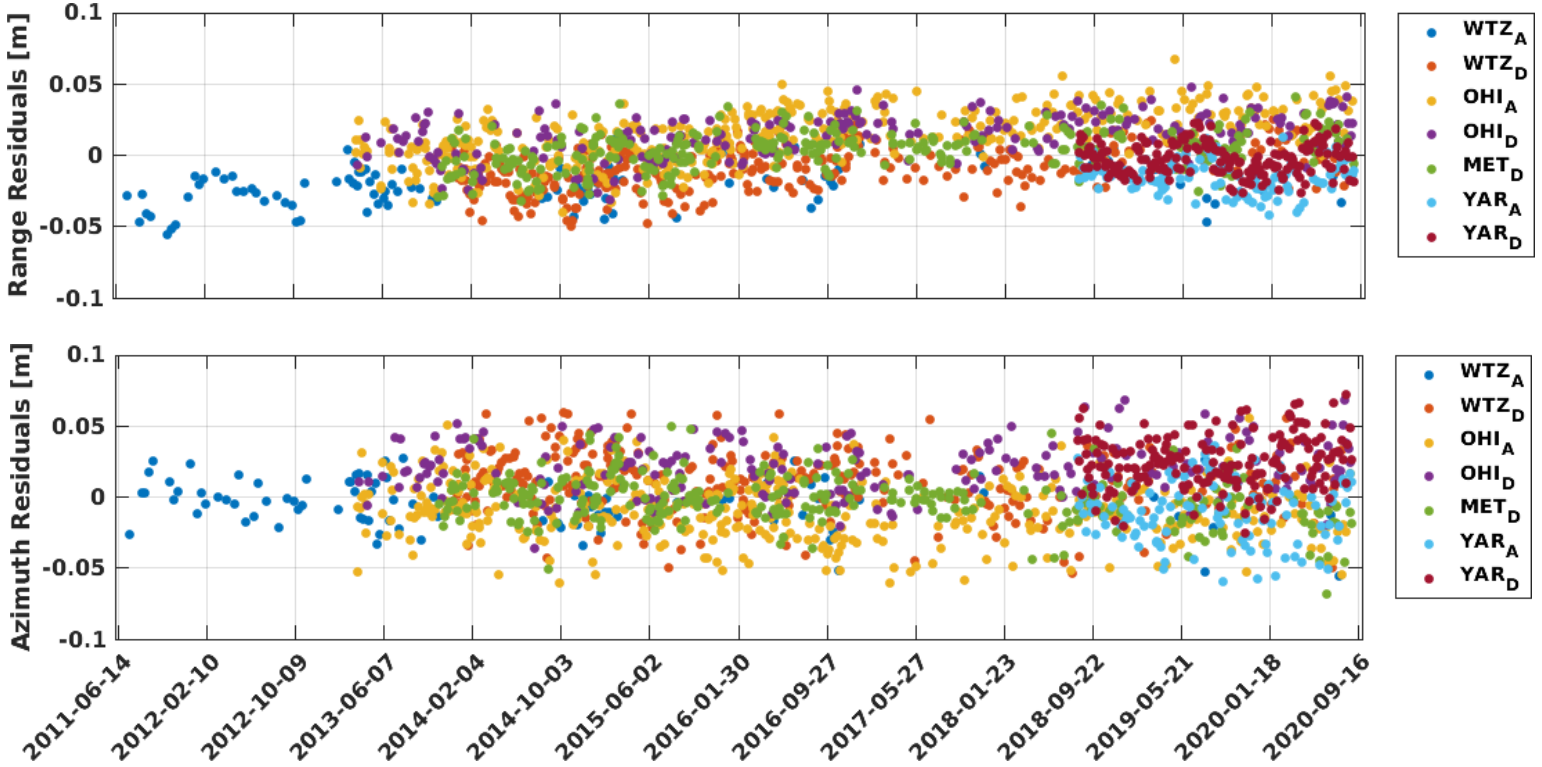
$=$

Δ_{az}

Δ_{rg}

Monitoring of TerraSAR-X and TanDEM-X Geometric System Performance

- Analysis of geolocation error: high-resolution spotlight & staring spotlight products and precise science orbit
- TSX & TDX data series with multiple pass geometries since CR installations: 2011 – ongoing
- Total of 1732 products, outliers removed (snow, water, random errors): less than 10 %



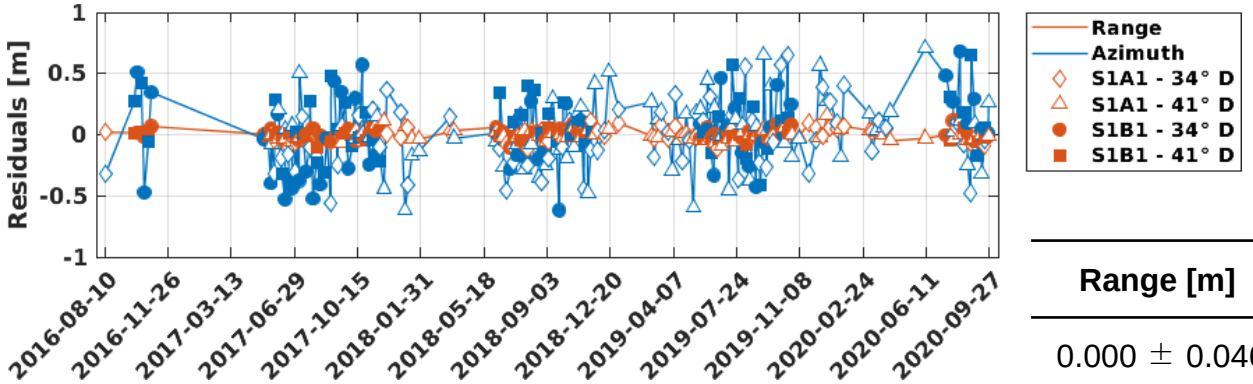
	Range [mm]	Azimuth [mm]
WTZ_A	-23.0 ± 13.7	-4.3 ± 16.8
WTZ_D	-9.6 ± 15.4	10.2 ± 22.4
OHI_A	13.6 ± 18.3	-9.9 ± 20.9
OHI_D	13.7 ± 14.9	20.8 ± 18.4
MET_D*	3.6 ± 13.6	-1.8 ± 17.2
YAR_A	-15.4 ± 11.0	-10.7 ± 21.3
YAR_D	-2.9 ± 10.9	24.7 ± 18.6
Total	**1.2 ± 19.1**	**4.0 ± 23.6**

* Rg / Az calibration site

Analysis of Sentinel-1

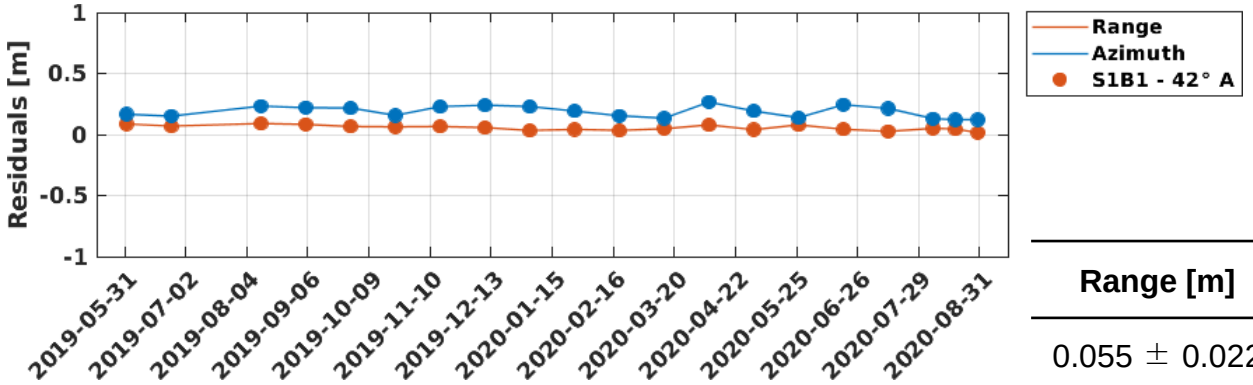
- Sentinel-1 geolocation tests as part of current ESA project S1-ETAD: Extended Time Annotation Dataset

IW data series at MET_D: Geometric S1A & S1B Calibration for ETAD

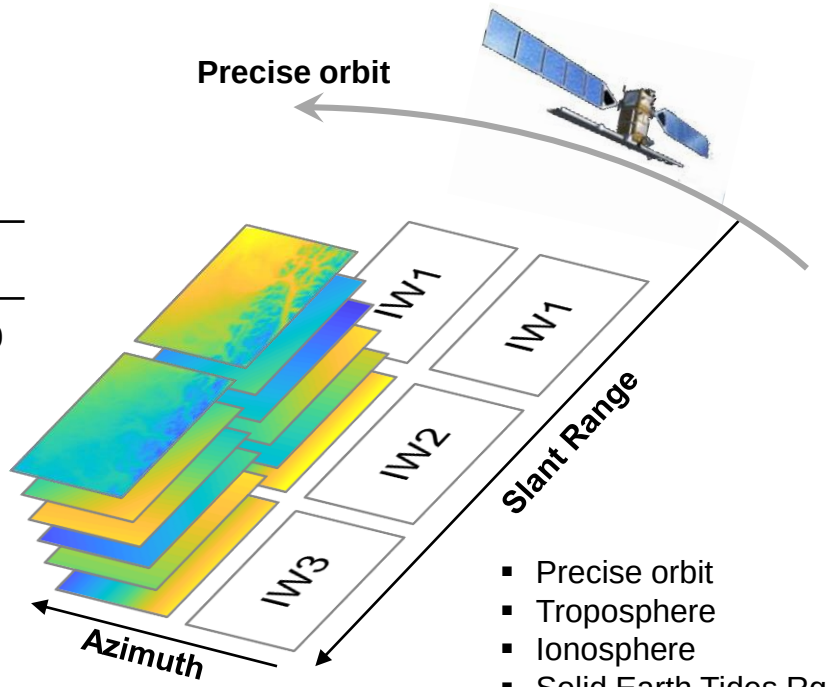


Range [m]	Azimuth [m]
0.000 ± 0.046	0.017 ± 0.280

SM data series at YAR_A: Test of SM Performance*



Range [m]	Azimuth [m]
0.055 ± 0.022	0.187 ± 0.047



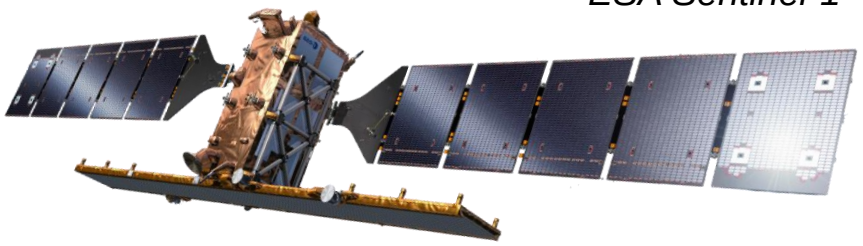
- Precise orbit
- Troposphere
- Ionosphere
- Solid Earth Tides Rg / Az
- System Corrections Rg / Az
- Geometric Calibration

*** not yet ETAD but comparable corrections**

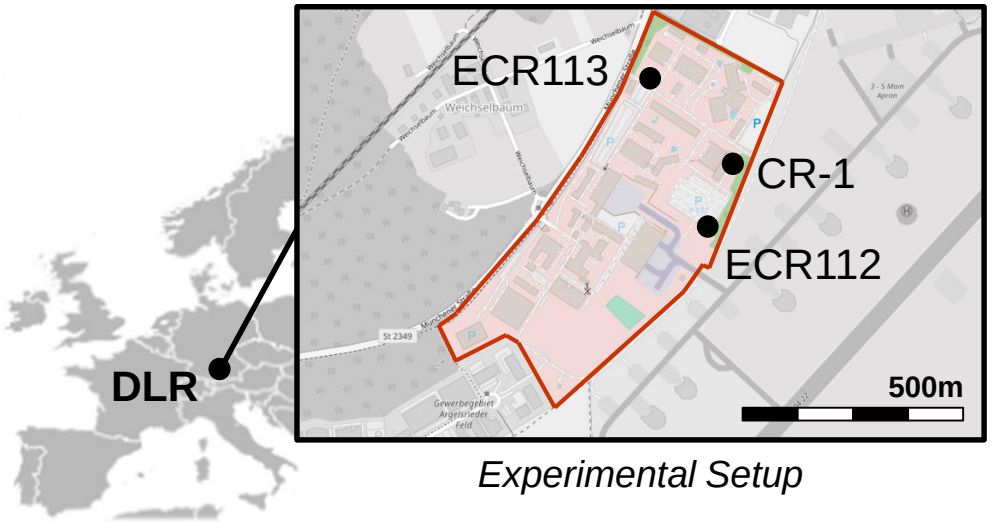
Details on our S-1 processing: *Gisinger et al. 2020, In-Depth Verification of Sentinel-1 and TerraSAR-X Geolocation Accuracy Using the Australian Corner Reflector Array, IEEE TGRS, DOI: 10.1109/TGRS.2019.2961248*

Research on Low Cost C-Band Transponders

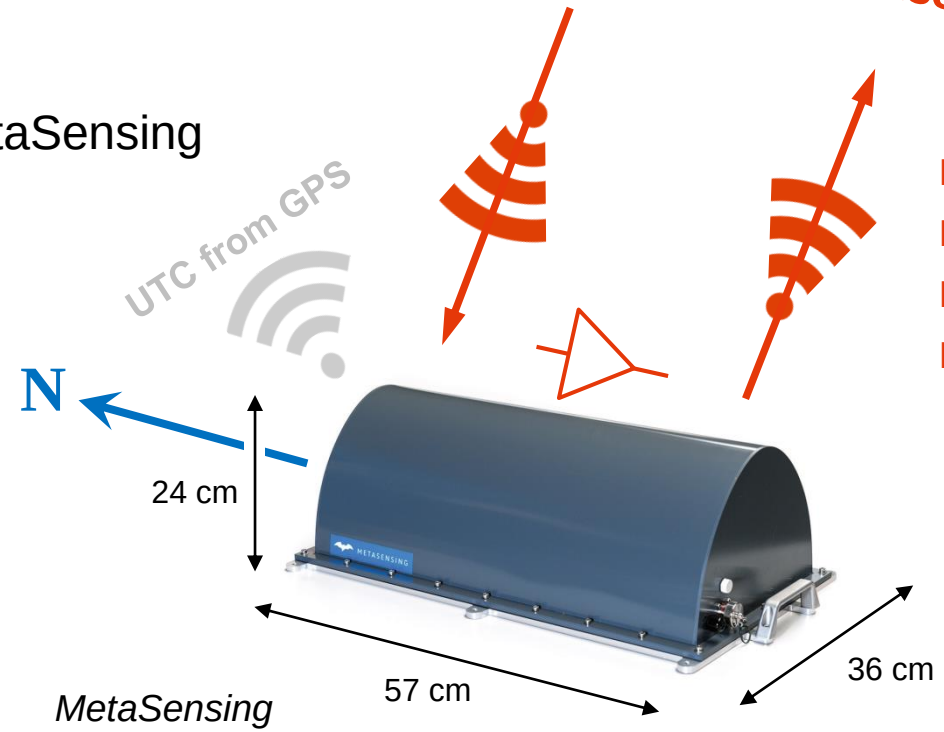
- Active devices **synthesizing 2 passive reflectors**
- **Sufficient brightness** for medium resolution C-band
- Designed for **mm-level phase stability**
- First off-the-shelf transponders (ECRs) by MetaSensing



ESA Sentinel-1



Experimental Setup



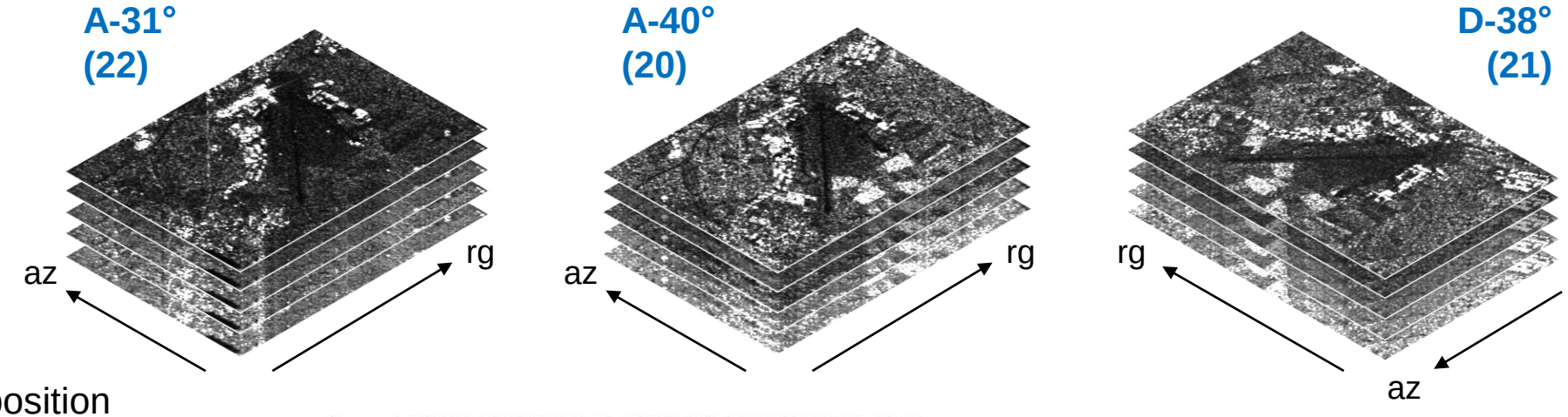
PASS	Asc & Desc
POL	VV or HH
BW	5.4 GHz ± 70 MHz
EIRP	5 dBm ↔ 3.2 mW

Programmable activation windows, e.g. 6 minutes

MetaSensing Electronic Corner Reflector C-Band (ECR-C)

First ECR Experiments with Sentinel-1 Products

- **Sentinel-1 Interferometric Wide-swath SLC products** with 3.5m x 22.7m resolution (slant range x azimuth)
- Sensors **S1A** & **S1B**
- **3 stacks** with 6 days temporal sampling
- 01/2020 – 05/2020



2D Geolocation Analysis

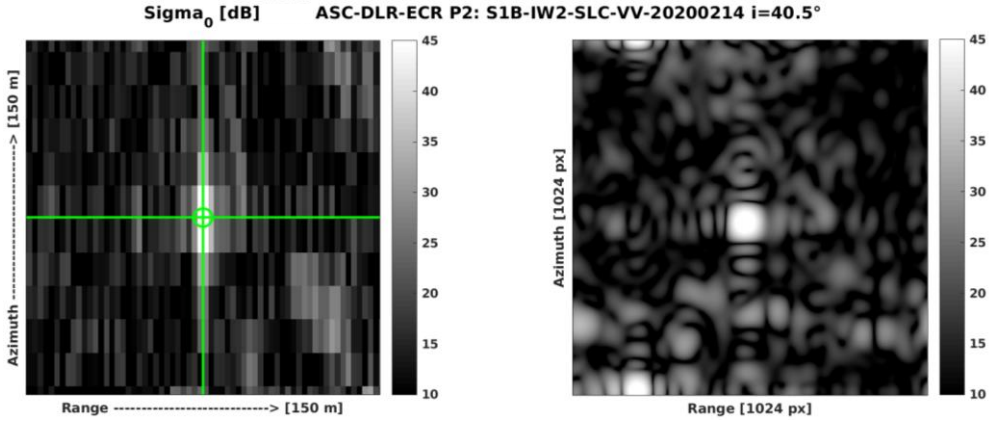
– Comparison with reference position

3D Localization

– Absolute 3D positions from SAR

Analysis of Phase Stability

– Phase differences ECR to CR

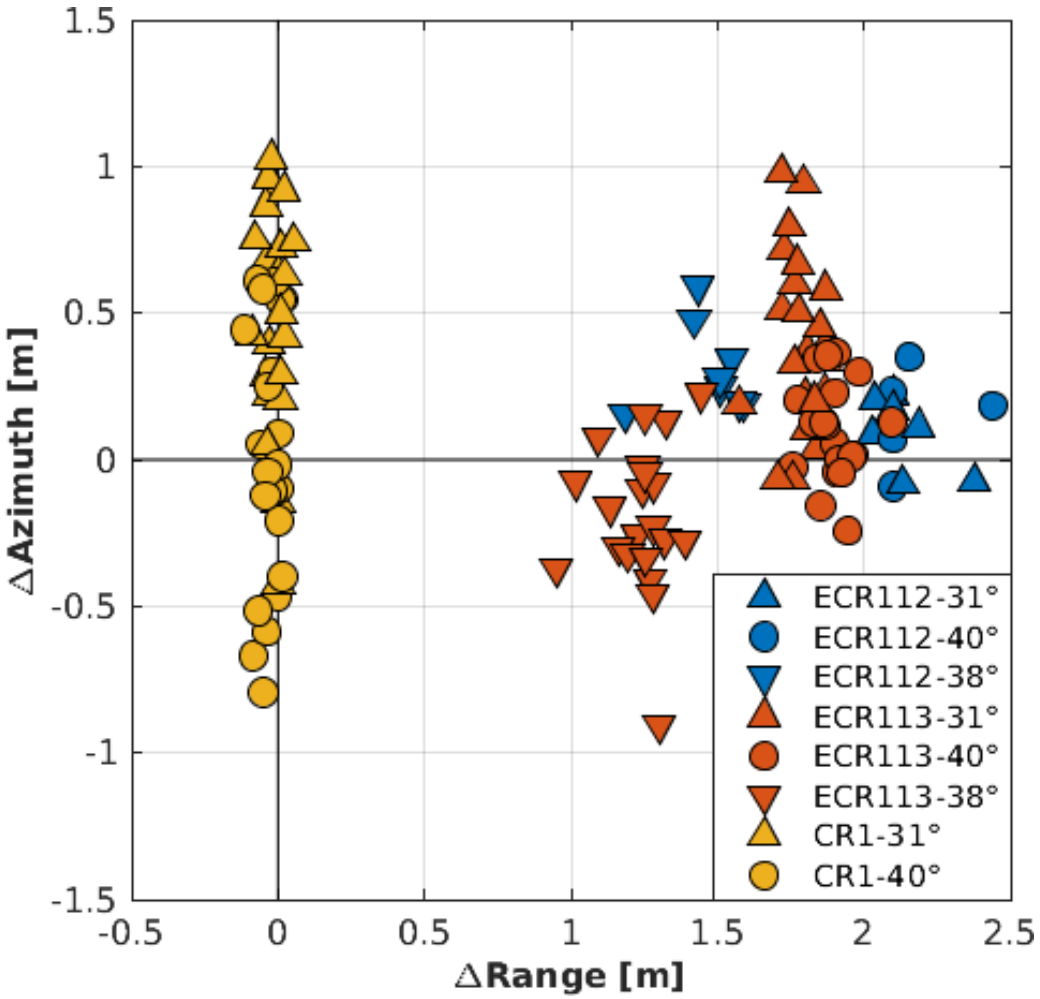


ECR113	42.4 dBm²	RCS
CR-1	37.0 dBm²	RCS

2D Geolocation Results: CR vs ECRs

- SAR rg / az versus rg / az from reference position & orbit[1]
  - Sentinel-1 **precise orbit** ephemerides solution
  - Corrections for **atmospheric path delays**
  - Corrections for **solid Earth** tidal **deformations**
  - Corrections for **Sentinel-1** SAR **processing effects**

	Range [m]	Azimuth [m]
ECR112	1.881 ± 0.365	0.193 ± 0.171
ECR113	1.636 ± 0.303	0.110 ± 0.350
CR-1	-0.020 ± 0.034	0.246 ± 0.472



Conclusions

- Large trihedral CRs are still the preferred choice for SAR geometric cal / val
- Low cost transponders show promising results but delay stability needs to be improved for geometric cal / val
- TerraSAR-X geometric system performance extremely stable throughout mission life time
- Sentinel-1 will receive major improvement in geolocation from the ETAD product

- **We can share the CR coordinates of Metsähovi, Wettzell and GARS O'Higgins for the target data base**
  - CRs with highly accurate reference positions due to co-location with ITRF reference sites
  - On-site GNSS-based zenith path delays are the best way to correct the tropospheric delay
- Proposal of data format by Geoscience Australia:

Column name	Unit	Comments
Name	-	Name of Corner Reflector Apex Point
Latitude	degrees	Geodetic latitude in decimal degrees (WGS-84)
Longitude	degrees	Geographic longitude in decimal degrees (WGS-84)
Height	metres	Ellipsoidal height (WGS-84)
Epoch	years	Epoch of XYZ coordinate
X	metres	Geocentric, cartesian coordinate (Earth-centred, Earth-fixed, ITRF2014)
Y	metres	Geocentric, cartesian coordinate (Earth-centred, Earth-fixed, ITRF2014)
Z	metres	Geocentric, cartesian coordinate (Earth-centred, Earth-fixed, ITRF2014)
veloX	metres/yr	Velocity at XYZ location according to ITRF station
veloY	metres/yr	Velocity at XYZ location according to ITRF station
veloZ	metres/yr	Velocity at XYZ location according to ITRF station
Azimuth	degrees	Azimuth of corner reflector boresight vector (0 degree: North, 90 degrees: East)
Elevation	degrees	Elevation of corner reflector boresight vector (0 degree: local horizon, 90 degrees: local zenith)