SARCalnet for SAR calibration

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Introduction

- SAR instruments need external calibration targets in order to calibrate imagery and for long term monitoring of image calibration stability
- Currently, most missions design their own external targets, typically a combination of natural and artificial calibration targets
- Like Radcalnet, there is a desire to have an established network of calibration sites that would facilitate collaboration between sensors by using the same calibration references.
- There are three types of external calibration targets used by SAR
  - Natural targets
  - Artificial passive targets
  - Artificial active targets

Types of image calibration

- Radiometric calibration (both natural and artificial targets)
  - Corner reflectors have known brightness
  - Over large radar-bright uniform areas, the antenna pattern can be validated
- Polarimetric (both natural and artificial targets)
  - Phase difference between HH and VV over CRs is well known
  - Channel imbalance between polarimetric channels
  - ”cross talk” corrections
- Geometric (artificial targets)
  - over artificial targets of known position
- Interferometric (ideally artificial targets)
  - Measure phase stability
- Instrument parameters and performance (natural and artificial targets)
  - Impulse response (resolution, ambiguities)
  - Range delays
  - Digital beam forming
  - Pointing
  - Noise level

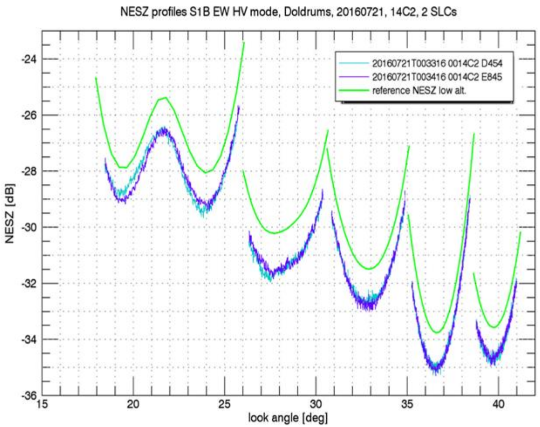
Natural targets

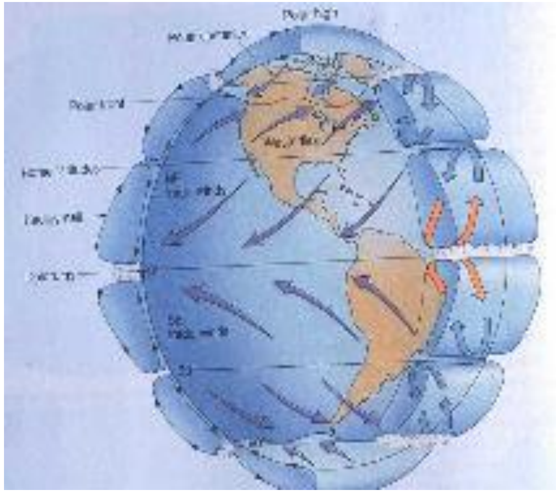
- Typically large, uniform SAR backscatter areas are needed
  - Spanning image swath (up to 250 km)
  - Amazon, Dome C in Antarctica, water bodies, …
  - The uniformity of the area may depend on the frequency band and the polarization
- Sites such as these can be used to monitor SAR image calibration over time
  - The SAR backscatter at these sites may naturally vary with frequency band and polarization
  - Seasonality may need to be considered
- Shapefiles to delineate each natural target area

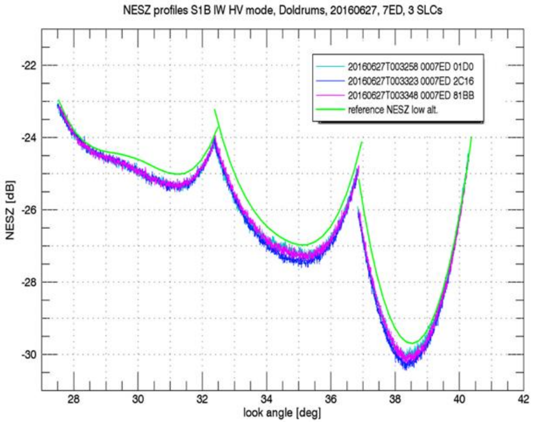
Natural targets

- Could consider including science targets where measurements are regularly made (i.e. soil moisture) that impact the SAR backscatter.
- Could consider including calibration sites used by other sensors (Radcalnet, etc).
- The time history of SAR backscatter measured at different frequency bands and polarizations by different instruments at SARCalnet sites could be hosted on CEOS WGCV SAR webpage
- In providing data from these sites
  - Algorithms for analysis also need to be provided.
  - The imagery should be made freely available if possible in conjunction with reporting results.

Sentinel-1 Noise Equivalent Sigma Zero (NESZ) Measured over the doldrums



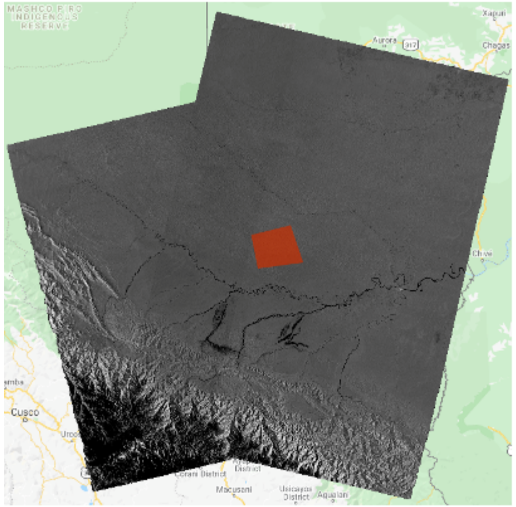




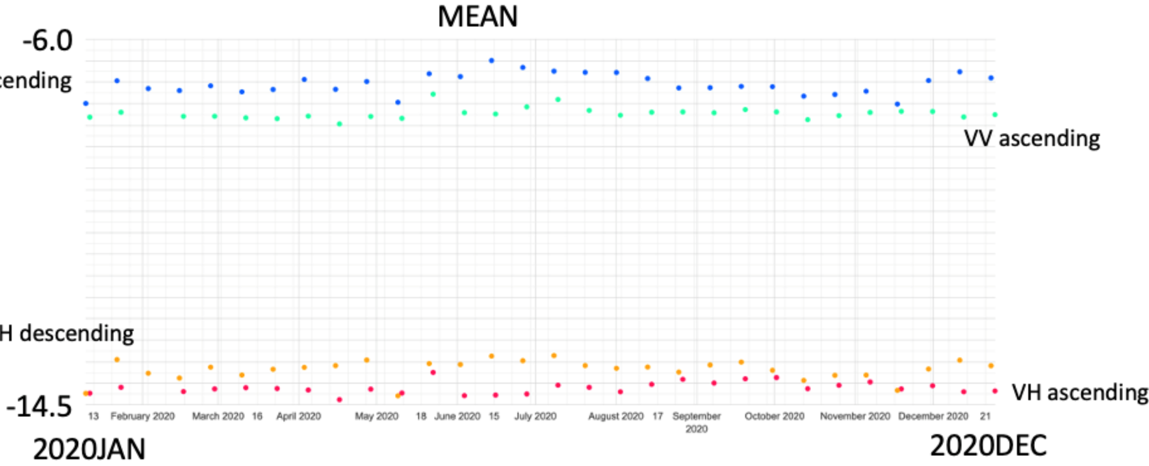
SAR modes	Measured NESZ [dB]
IW	-27.8
EW	-32.2
SM	-25.3

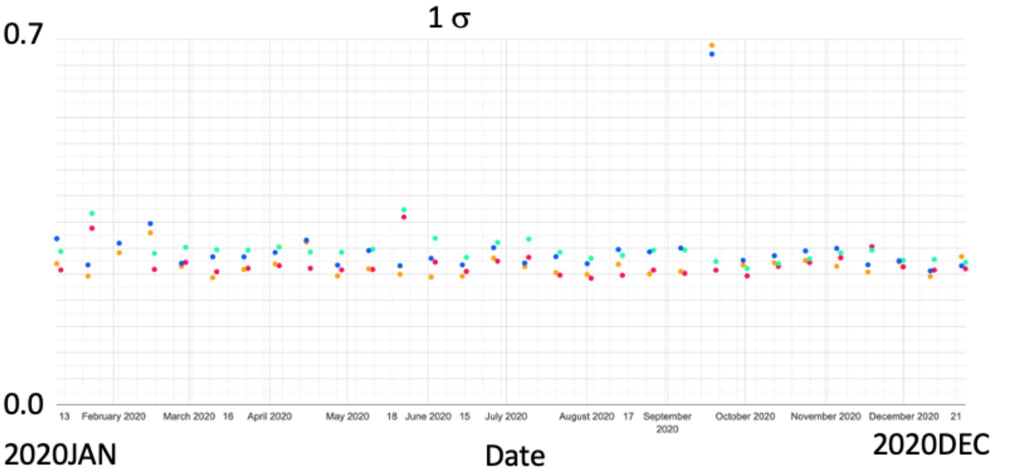
Incidence Angle effects: Ascending vs Descending orbits

Sentinel-1



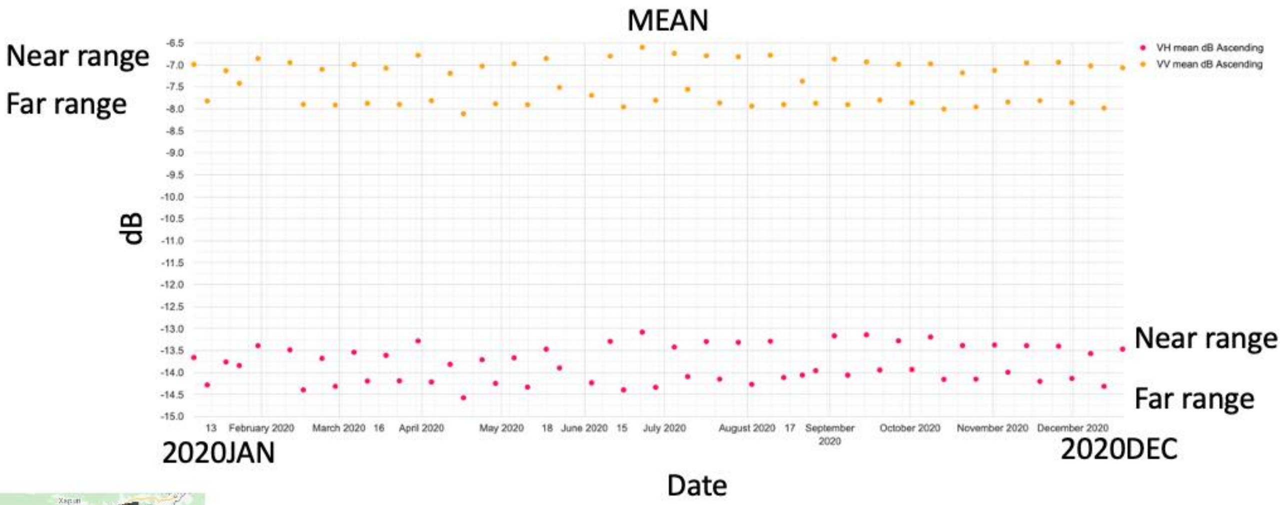
Using script on Google Earth Engine
- draw polygon or use shapefile
- select time interval
- convert values to linear power
- filter ascending/descending
- find mean and standard deviation
- report results in dB

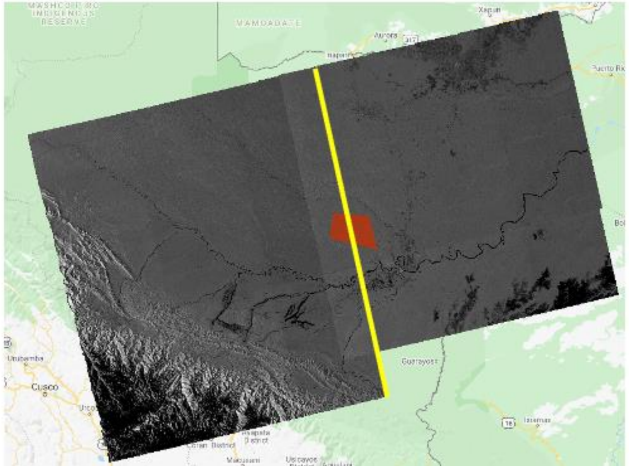




Incidence Angle effect: near/far range overlap

Sentinel-1





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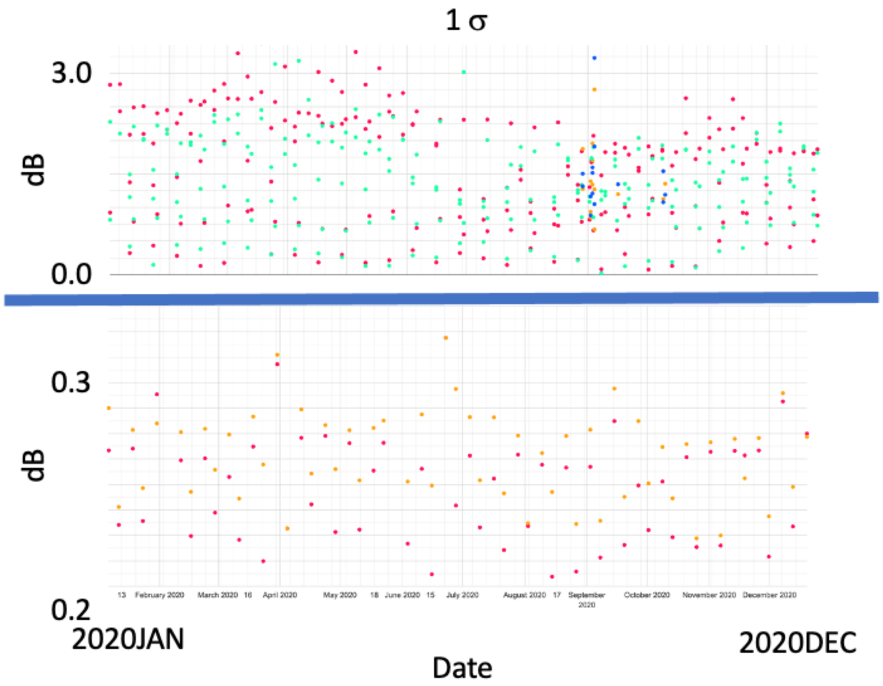
Sentinel-1 scene variability

US mid-west

Amazon



More variability

More uniform

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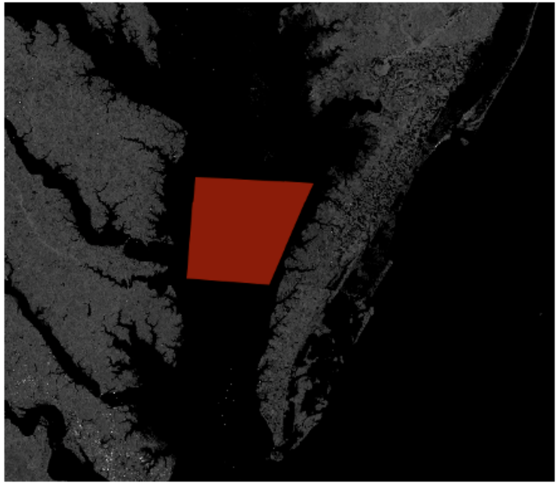
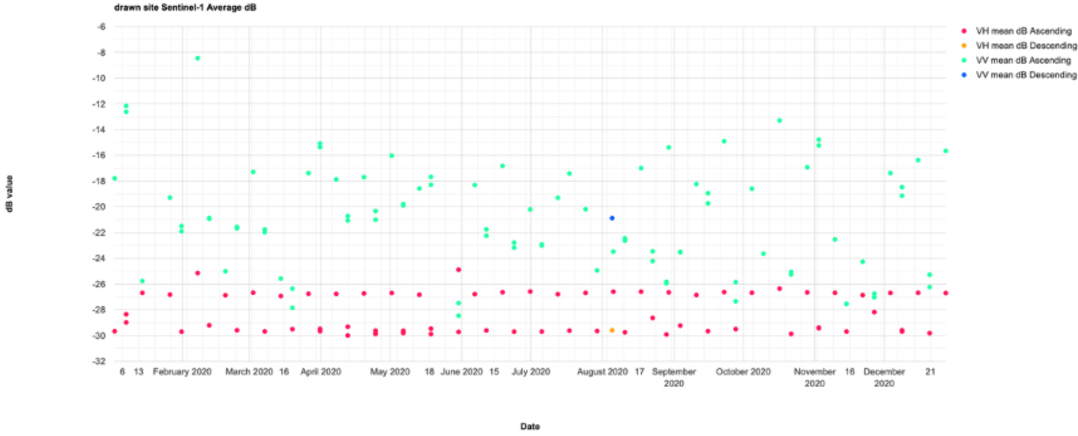
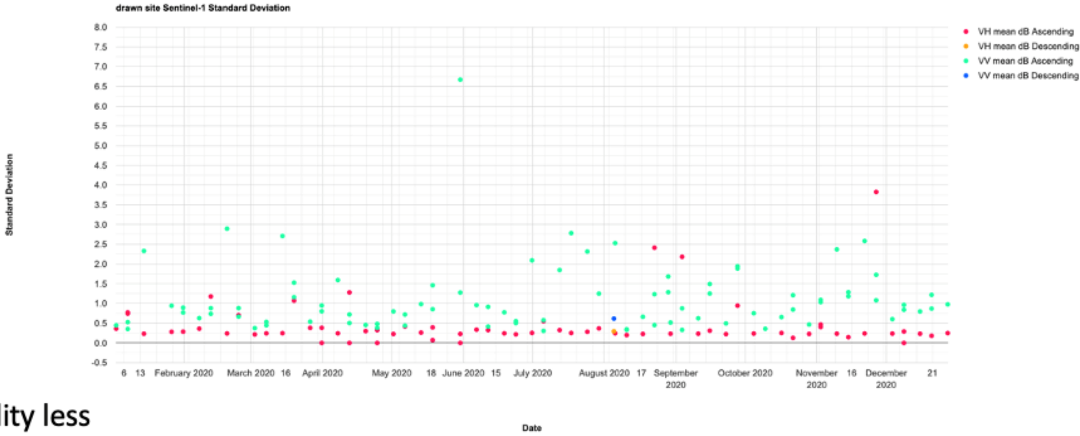
Over Water

Chesapeake Bay







Variability less

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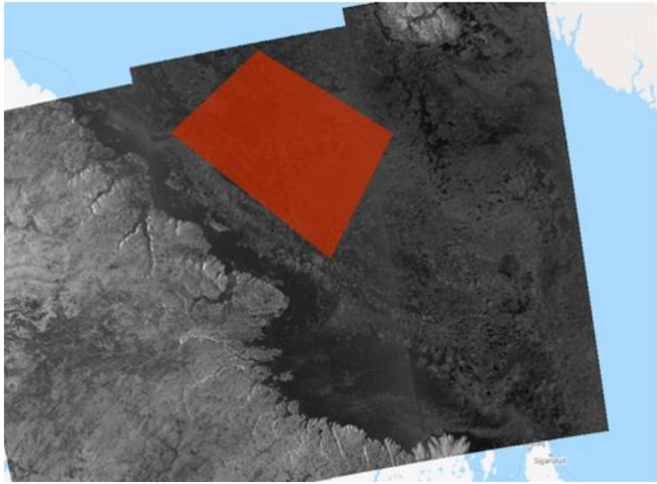
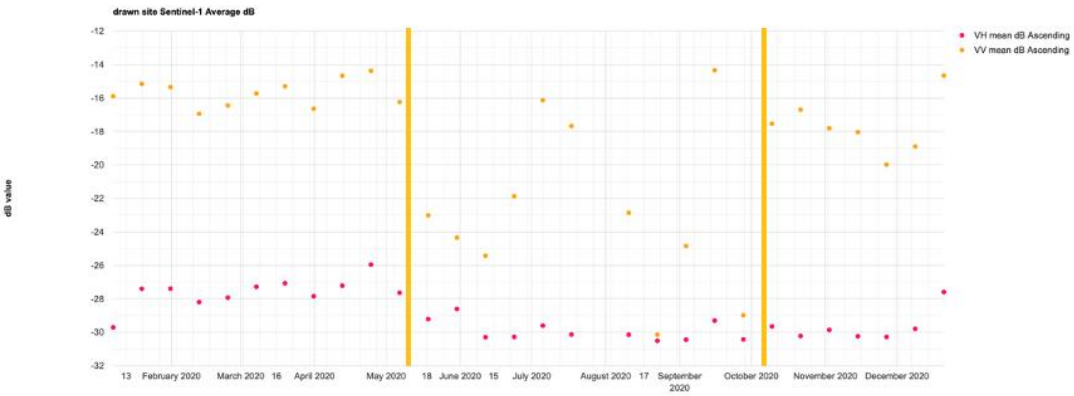
Seasonal dependence

Canadian Arctic

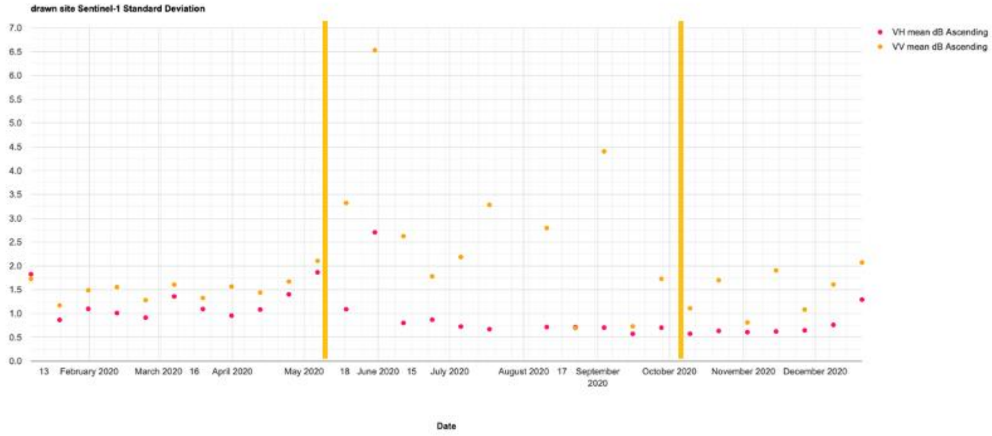




Frozen

Thaw

Frozen



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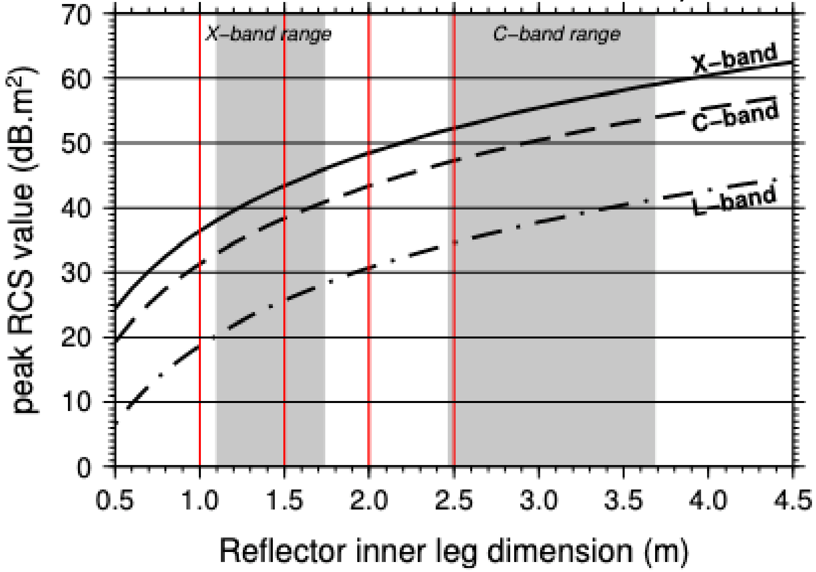
Artificial Passive Targets

- These targets are point targets with known brightness
- Can be used to assess both image radiometric calibration, geolocation accuracy, and resolution
- Frequency bands dictates the size and material (longer wavelengths can utilize perforated materials)
- Typically deployed by a mission during their commissioning/calibration period.
- Persistently maintained arrays can be costly
    - Resurvey costs
    - Other maintenance
    - Land rights

Garthwaite et al, 2013



Artificial Passive Targets

- Characteristics vary with band
  - Size, mounts, materials
- Typical measurements of the reflector
  - Heading, elevation angle, orthogonality, flatness, accuracy of measurements
- Typically oriented parallel to the SAR path
  - Most targets are oriented for right looking, polar orbits, but not all
  - Depending on target type, the orientation may need to be adjusted
- Might not be permanently deployed

JPL 0.7 m corner reflector on Rosamond Lake Bed for Ka-band

AuScope Australian Geophysical Observing System C/X-band 1.5 m

(b)

2.8 m DLR reflector in stowed position

esa

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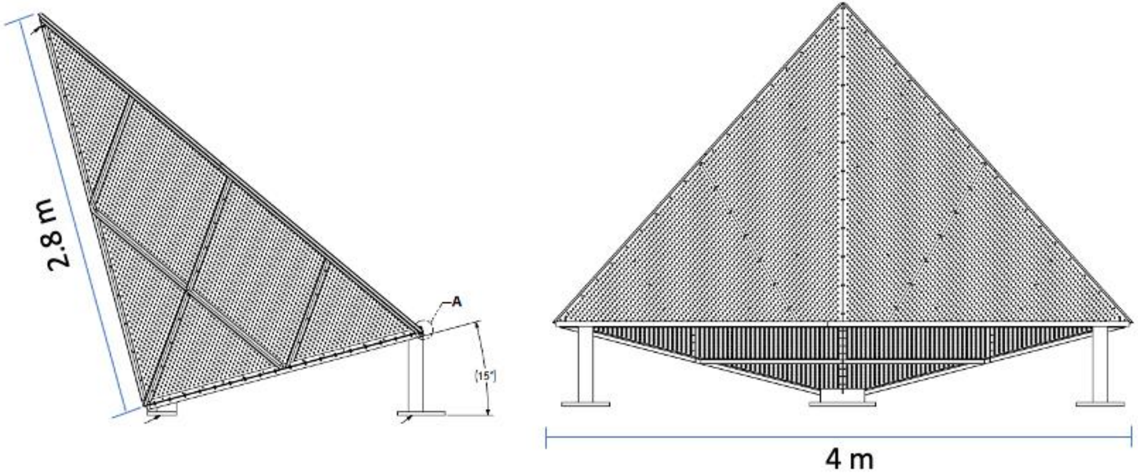
NISAR

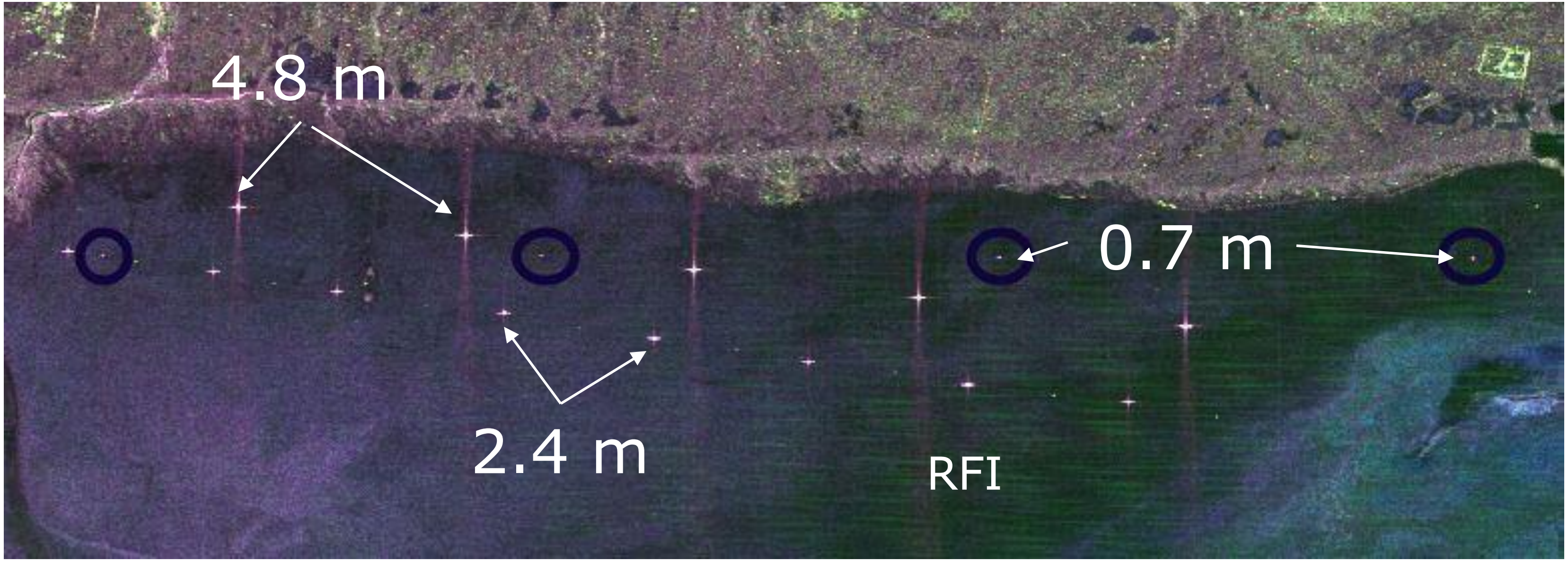
L-band Trihedral Corner Reflectors

2.8 m L-band trihedral reflectors for NISAR



JPL P-band reflector 4.8 m at Rosamond Dry Lake

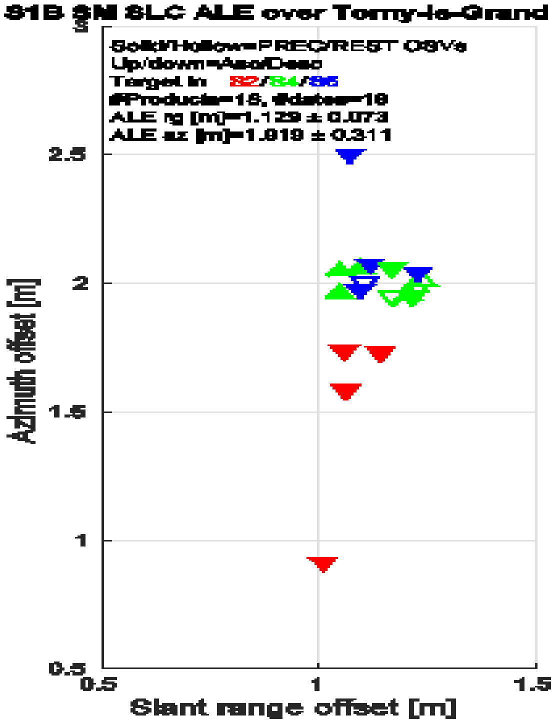
NASA/JPL Rosamond Corner Reflector Array Southern California



L-band UAVSAR image

Sentinel-1

Geolocation of SAR imagery over ***Swiss corner*** **reflector** site by University of Zurich, RSL



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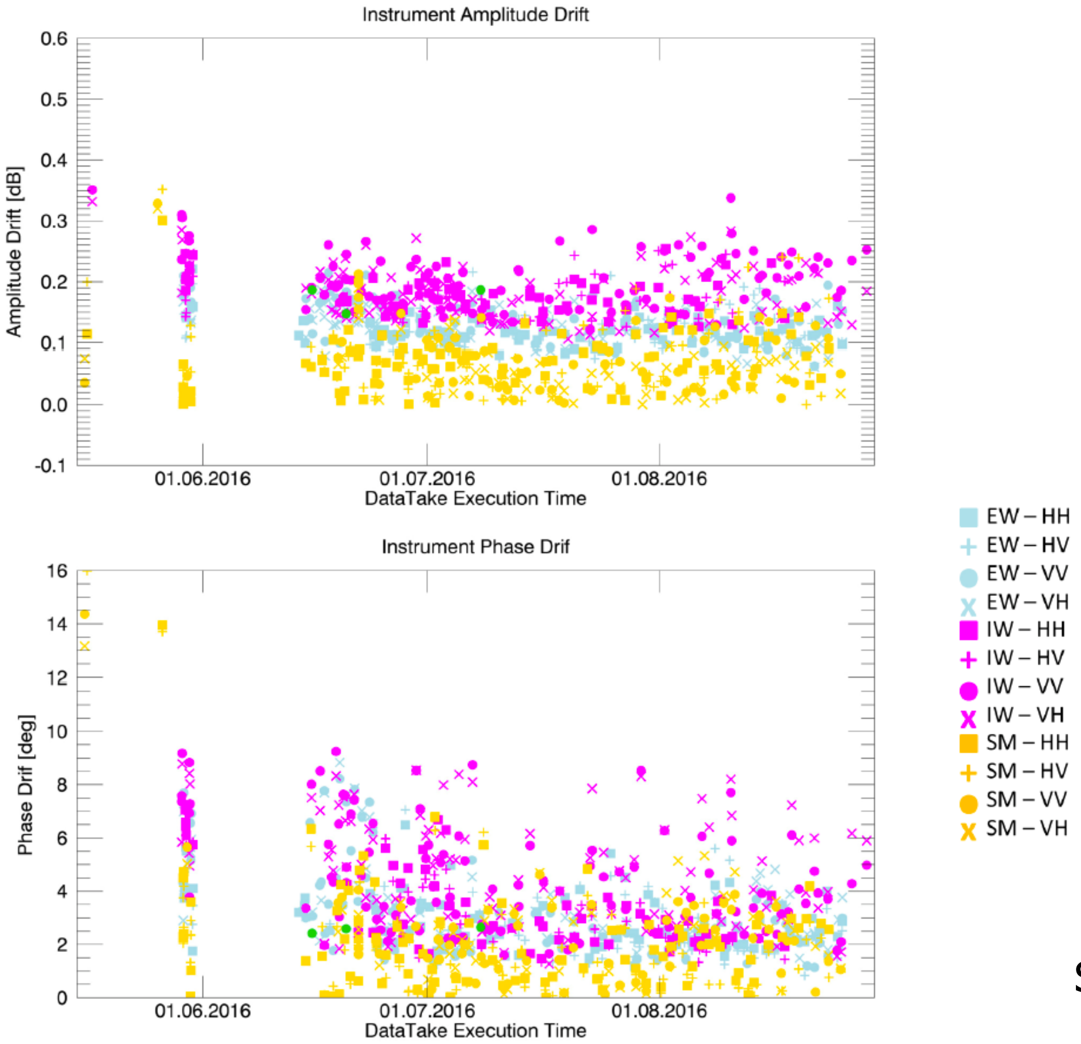
Sentinel-1B

Monitoring amplitude and phase stability



Schwerdt et al, 2017

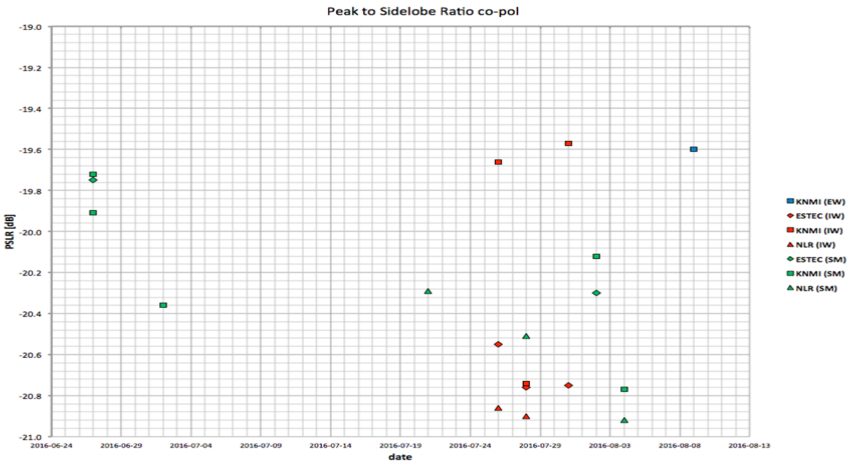
Corner Reflectors

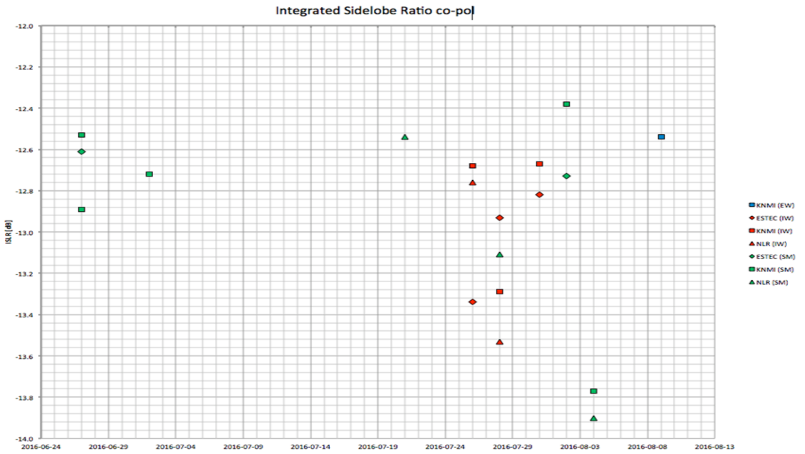
- Typically, when a reflector has been deployed and the agency responsible is open to sharing of the reflector for calibration, the size, position, and orientation is provided.
- But in addition what is needed:
  - The measured RCS for each reflector over time by their SAR, and other SARs.
  - Survey accuracy, date of survey, deployment date, any termination date, or gap in deployent.
  - characterize background SAR backscatter over time for the region, such as by their SAR and others.
- If reflectors are deployed N/S, they may be suitable for both right and left looking observations with only minimal loss to RCS.

Artificial Active targets

- Band specific
- Retransmits the received signal
- Can be polarimetric
- Requires power and needs to be powered on for the satellite overpass
- Must be characterized
  - Stability, antenna pattern, gain
- The costs are higher for these devices, and their availability is more limited than for passive devices.

Impulse Response - using 3 ESA transponders





IRF Parameter	SM	IW	EW
Peak to Sidelobe Ratio (PSLR) [dB]	-23.44 ± 0.79	-23.07 ± 0.93	-24.94 ± 2.74
2-D Integrated Sidelobe Ratio (ISLR) [dB]	-15.69 ± 0.52	-15.75 ± 0.38	-17.85 ± 4.64
Spurious Sidelobe Ratio (SSLR) [dB]	-31.94 ± 0.46	-31.40 ± 0.65	-32.85 ± 3.42
Early Azimuth Ambiguity Ratio [dB]	-26.54 ± 4.34	-31.23 ± 1.31	-33.06 ± 3.65
Late Azimuth Ambiguity Ratio [dB]	-27.45 ± 3.54	-29.32 ± 0.63	-32.25 ± 2.28

Sentinel-1A Absolute Radiometric Accuracy from DLR C-band transponders

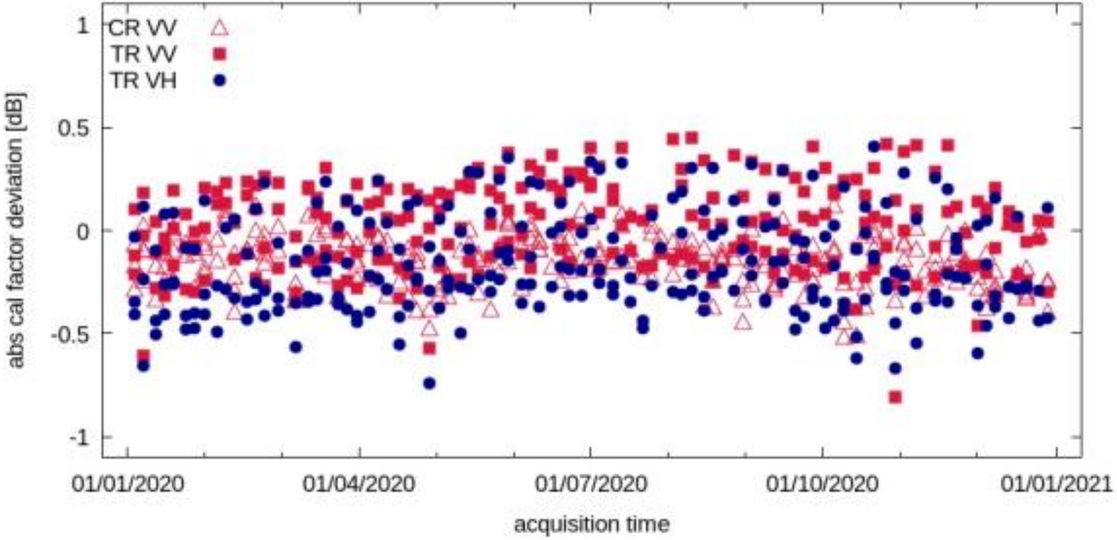


Figure 24: S-1A calibration factor for IW acquisitions in 2020 derived from DLR reference targets; the polarization is depicted by colour: VV in red, VH in blue.

	S-1A IW (VV and VH)	S-1B IW (VV and VH)
Mean value ± standard deviation	-0.10 dB ± 0.21 dB	-0.04 dB ±0.24 dB
Absolute radiometric accuracy (1σ)	0.302 dB	0.325 dB

ESA Transponder

DLR Transponder

JPL L-band PARC from University of Michigan

Conclusions

- There is a demand for well-defined calibration targets for SAR calibration
  - These targets are used to calibrate the data from these missions
  - Currently, in most cases these targets are defined differently for each SAR mission.
- There are three main category of targets
  - Natural Targets
  - Artificial Passive Targets
  - Artificial Active Targets
- "SARcalnet" is in the early stages of formulation by the CEOS WGCV SAR subgroup.
  - It would be an established network of calibration sites that would facilitate collaboration between sensors by using the same calibration references.

Thank you

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