# Noise Pulses for Assessment and Monitoring of the ICEYE SAR Fleet


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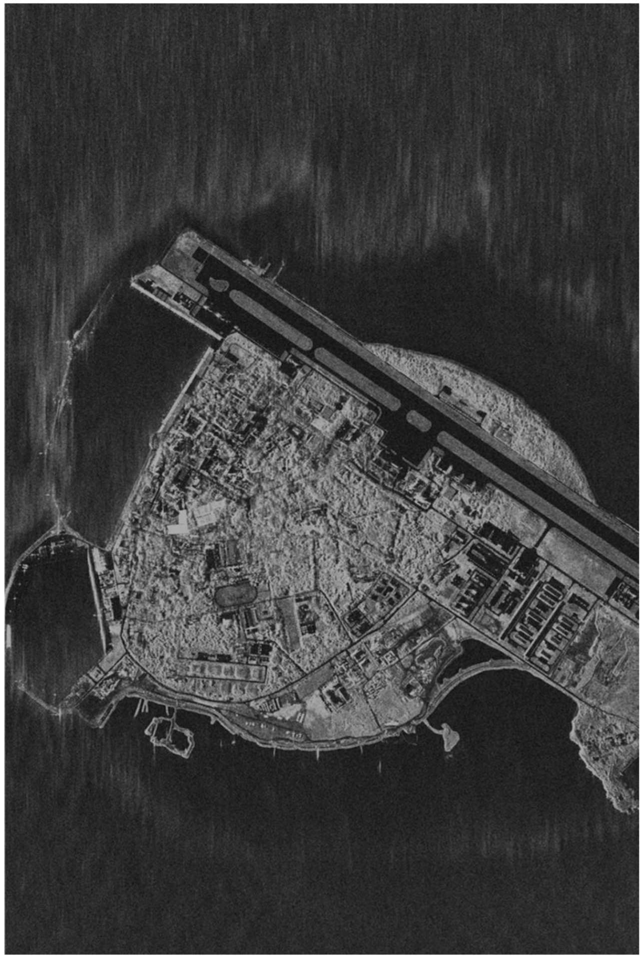
# NESZ concept



The NESZ (Noise-Equivalent Sigma Zero) is related to the system sensitivity to low radar backscatter areas. The NESZ corresponds to the scattering coefficient for which the Signal-to-Noise Ratio (SNR) is equal to one.

NESZ is how 'low-observable' an object can be and be just indistinguishable from the background noise in an image.

$$NESZ = \frac{(4\pi)^2 R^4 L_{feed}^2 FkTB_{rec}}{P_t G A_e \delta x_{az} \delta x_{grg} \tau B_{rec} N_{pulses}}$$



# NESZ concept

- The main driver for NESZ is the transmitted power, the antenna gain and the signal bandwidth.

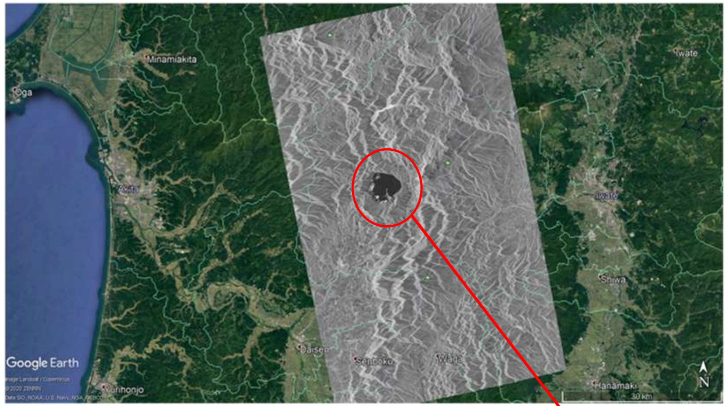
$$NESZ = \frac{(4\pi)^2 R^4 L_{feed}^2 FkTB_{rec}}{P_t G A_e \delta x_{az} \delta x_{grg} \tau B_{rec} N_{pulses}}$$

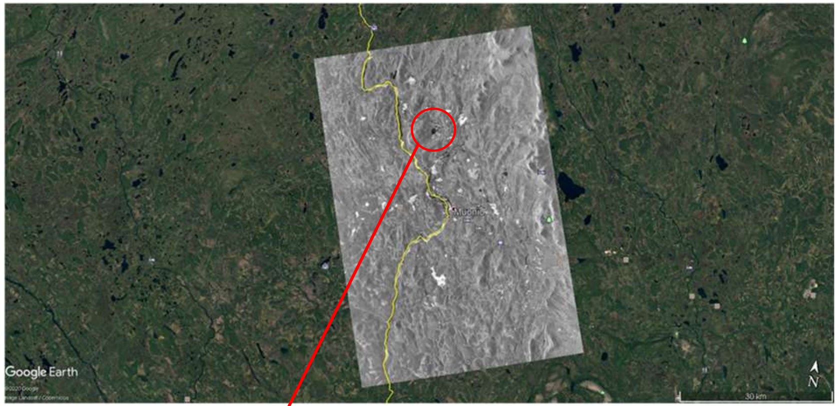
Observations:

- The noise increases increasing the bandwidth of the transmitted signal.
- The increased bandwidth increases also the range resolution, and this results in a worse NESZ for higher bandwidth.
- The NESZ dependence on the azimuth resolution is negligible as a reduction in $\delta x_{az}$ is countered proportionally by an increase in number of pulses $N_{pulses}$

# NESZ calculation

- The NESZ can be computed from the knowledge of the radar parameters and of the antenna characteristics.
- In many cases NESZ can be estimated directly from the dark regions of the image with very low backscattering, like water surfaces.




Meteorological conditions and surfactants contribute to the backscattering. Not all the images are suitable for the NESZ estimation

# NESZ calculation with noise pulses



- Noise Pulses, also called "rank echoes", are recorded during the traveling time of the first transmitted pulses of each burst or acquisition [1].
- The mean power of the noise data can be computed by using these pulses to extract a noise floor of the SAR image.
- For this purpose, the noise data of the pulses is processed by focusing, and a complex image of the noise is acquired

NESZ calculation for each image allows to verify if the parameter is in line with the requirements, to monitor the health of the instrument and to assess the performance of the SAR system

ICEYE implemented an automatic methodology to calculate the NESZ for each acquisition within the theoretical calculation

[1] Riccardo Piantanida, "Sentinel-1 Level 1 Detailed Algorithm Definition", ESA Repost, 17/11/2022

# NESZ Calculation



- The noise data of the pulses is processed by focusing, and a complex image of the noise is acquired
- Applying the calibration, is possible to estimate the NESZ

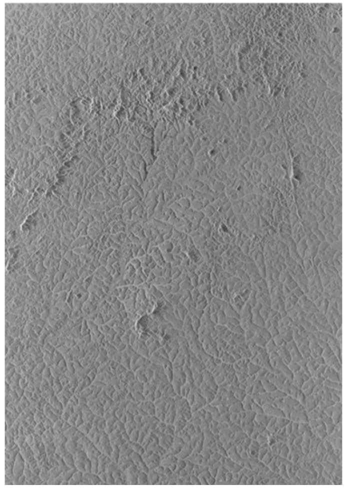
## Calibration Factor Estimation

$$SNR = \frac{1}{K(R)} \frac{\sigma_0}{P_N}$$

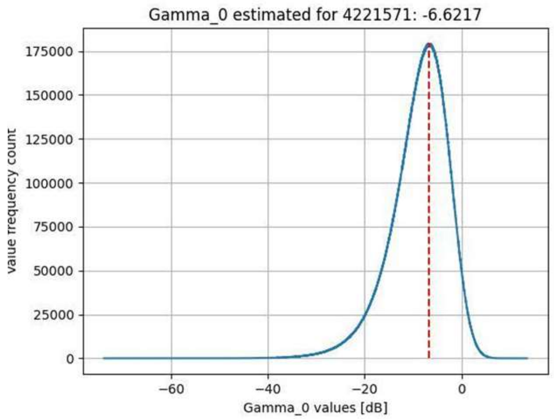
Backscattering Coefficient ($\sigma_0$)

Calibration Factor ($K(R)$)

Noise Power ($P_N$)



Amazon Forest Image

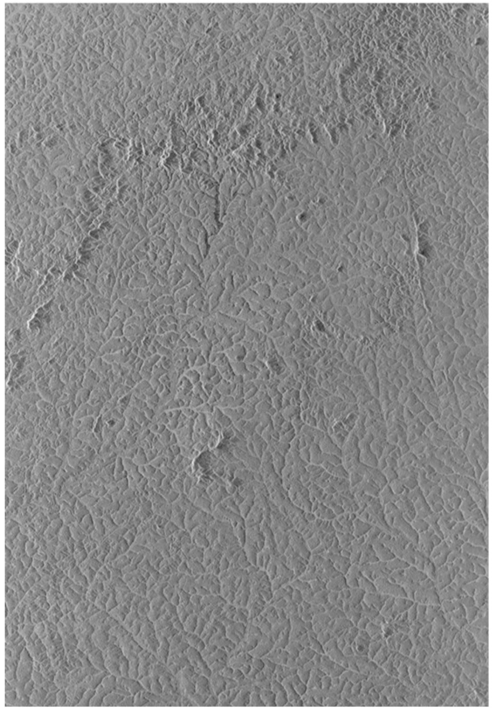


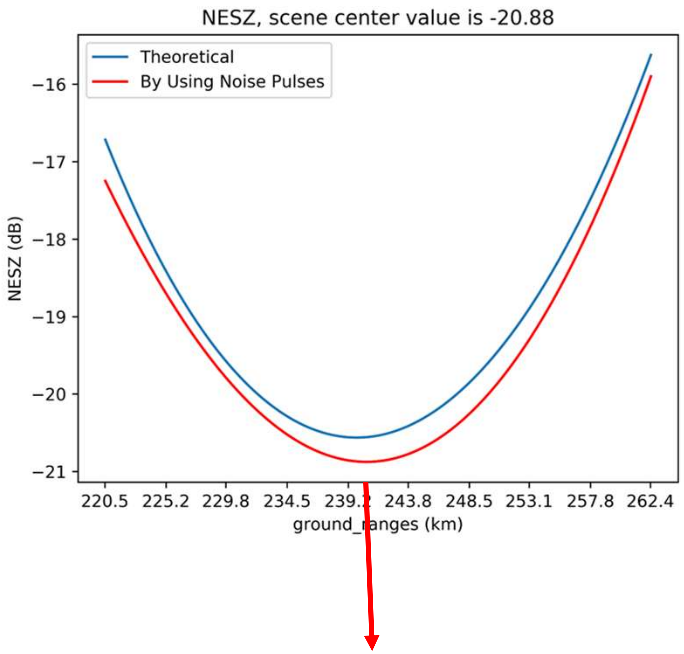

$$\gamma^0(\theta) = K \frac{|DN|^2}{G^2(\theta)} \tan(\alpha)$$

$$K(R) = \frac{(4\pi)^2 R^4 L_{feed}^2}{P_t G_r G^2(\phi) \delta x_{az} \delta x_{grg} N^2} \Rightarrow NESZ = K(R) P_N$$

# NESZ of a single image



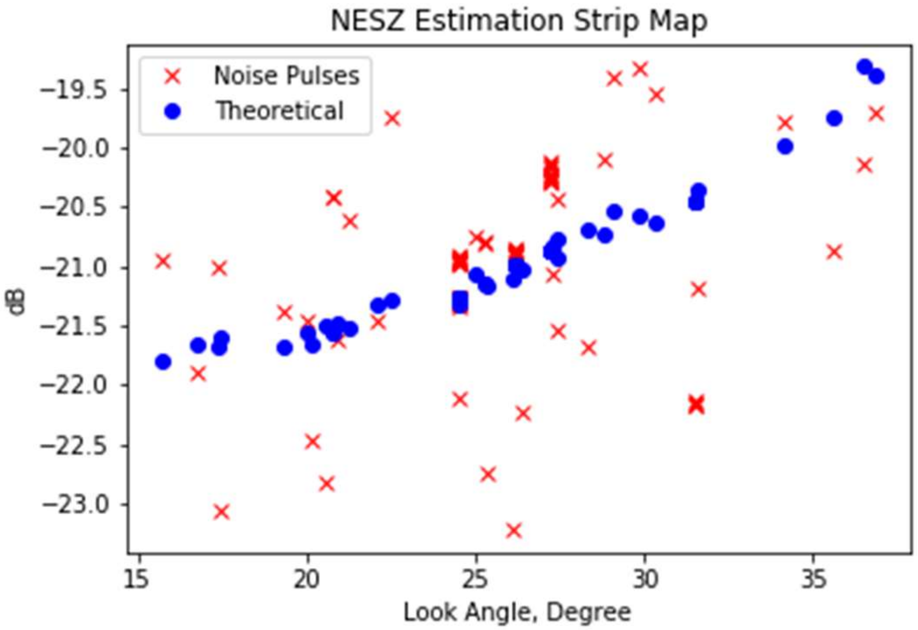




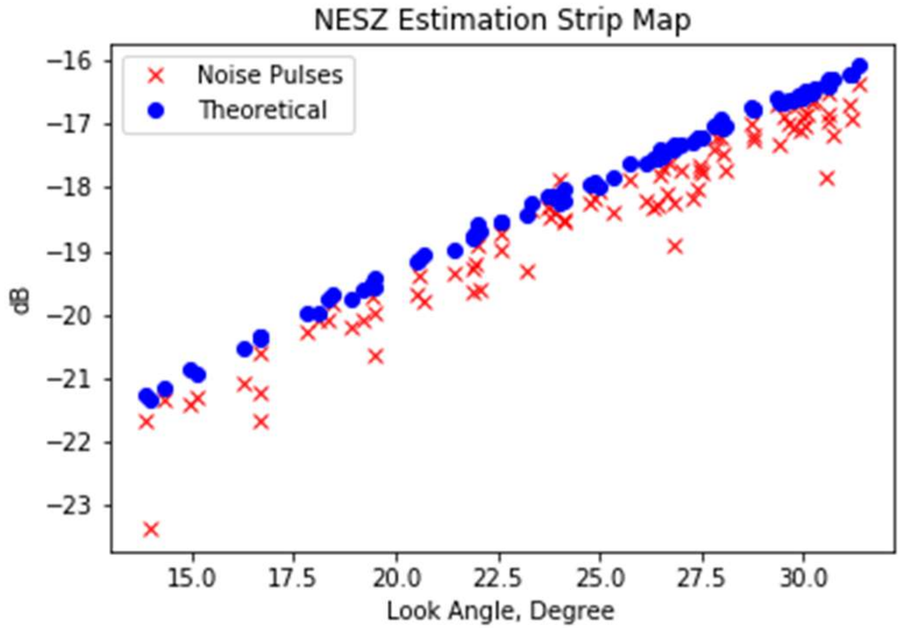

NESZ for scene center is assessed for each image!

# NESZ values of an image stack






<300MHz

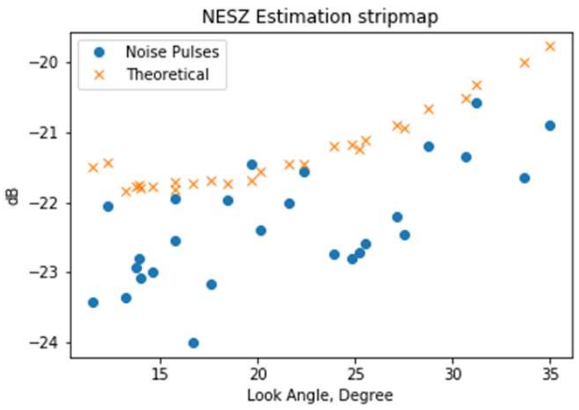


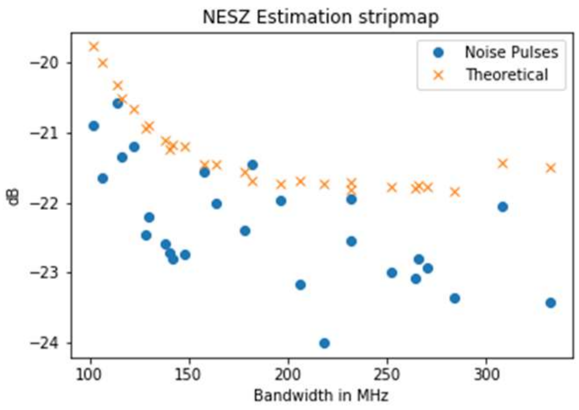

=300MHz

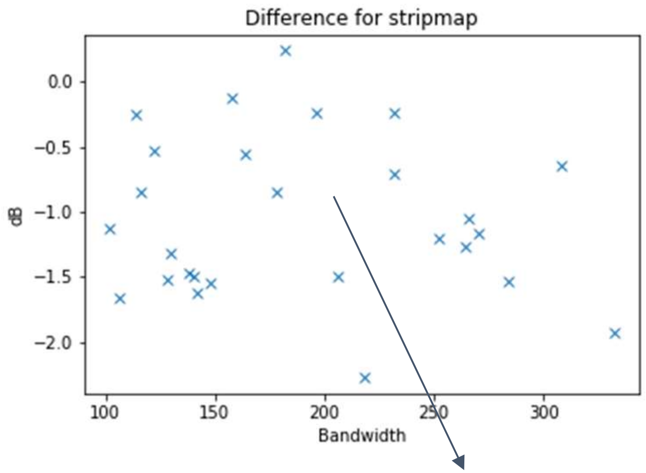
Little difference between the theoretical and measured values!
Some indication on calibration factor - bandwidth relation

# Monitoring Multiple Satellites





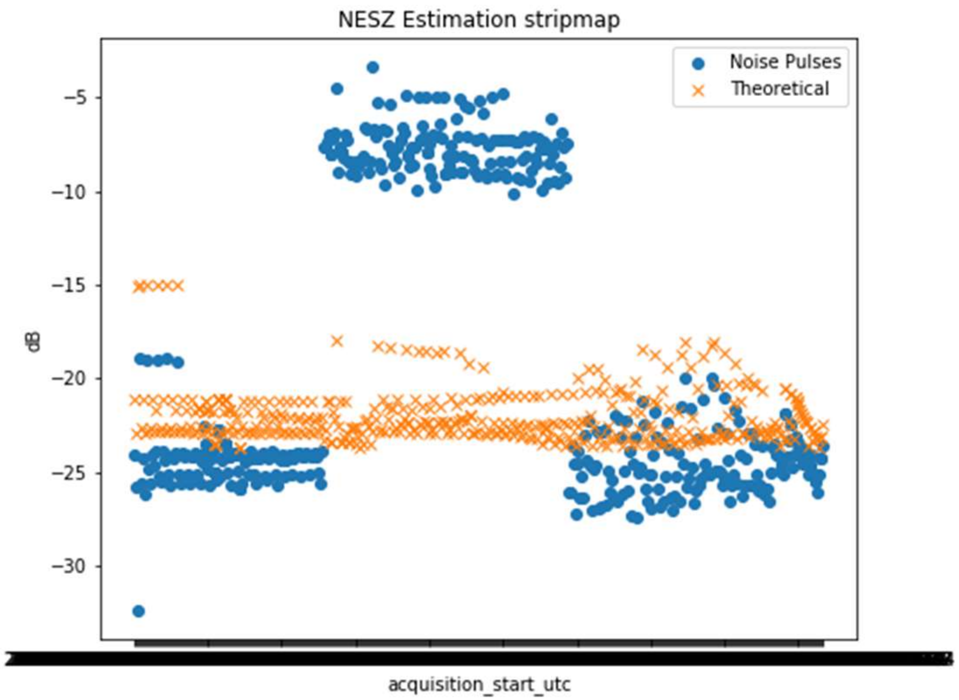



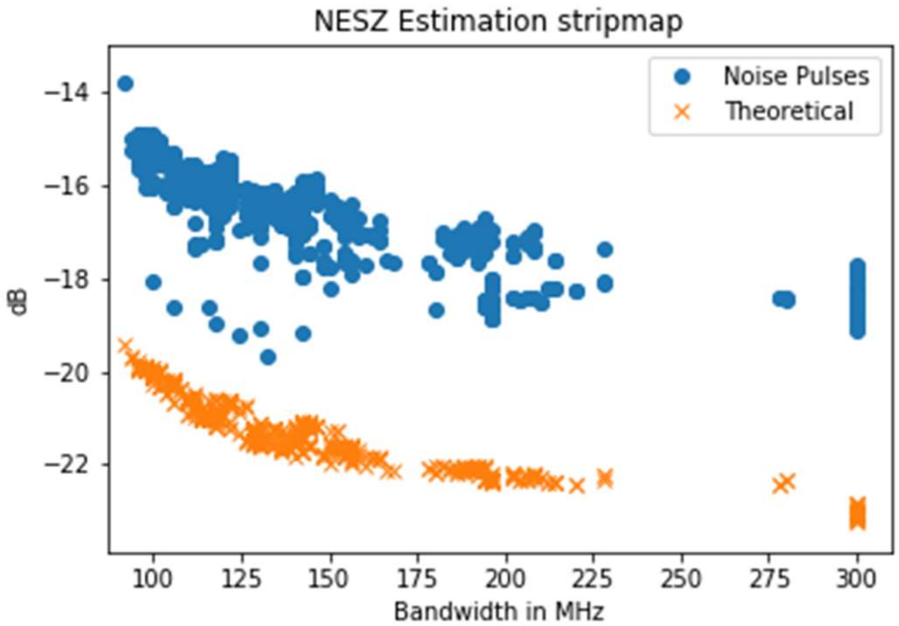

Diff between measured and theoretical, **-1dB**+-1dB

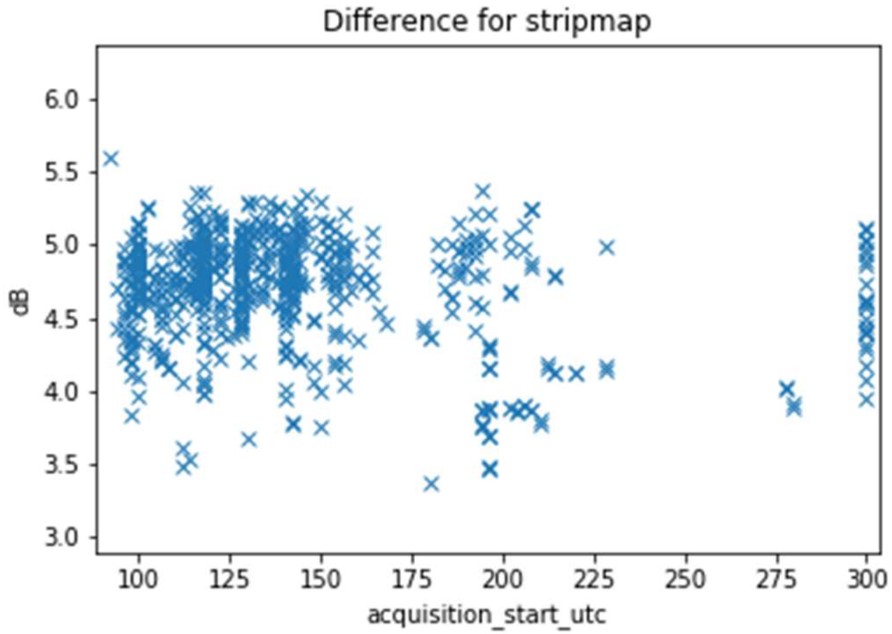
Our tolerance for computation of theoretical NESZ is **1dB** more pessimistic than what is measured

# Anomaly Detection




During a test campaign for electronic steering capabilities, a problem with phase shifters setting resulted in huge antenna gain degradation.




On average a 5dB loss for this satellite! Some of the TRM modules are lost.

# Conclusions



- The NESZ calculation using Noise Pulses allows to estimate the NESZ level for each image
- It provides a good metric about the quality of the single image and about the data quality compliance
- It is useful to monitor the healthy status of the ICEYE fleet
- It is an important tool for anomaly detection.

NESZ calculation for each image is already implemented in the operational chain.

Currently, ICEYE is implementing the automatic analysis of the single satellites to automatically detect anomalies