ピクセルオフセット解析における誤差
Errors in Pixel Offset Analysis

奥山 哲（産総研）
Satoshi Okuyama (AIST)

Pixel Offset Analysis

Pixel Offset Analysis (Offset Tracking, Image Matching, etc.)

Coregistrate two Images at densely distributed tie-points and estimate the surface displacement as misfit of the global coregistration function.

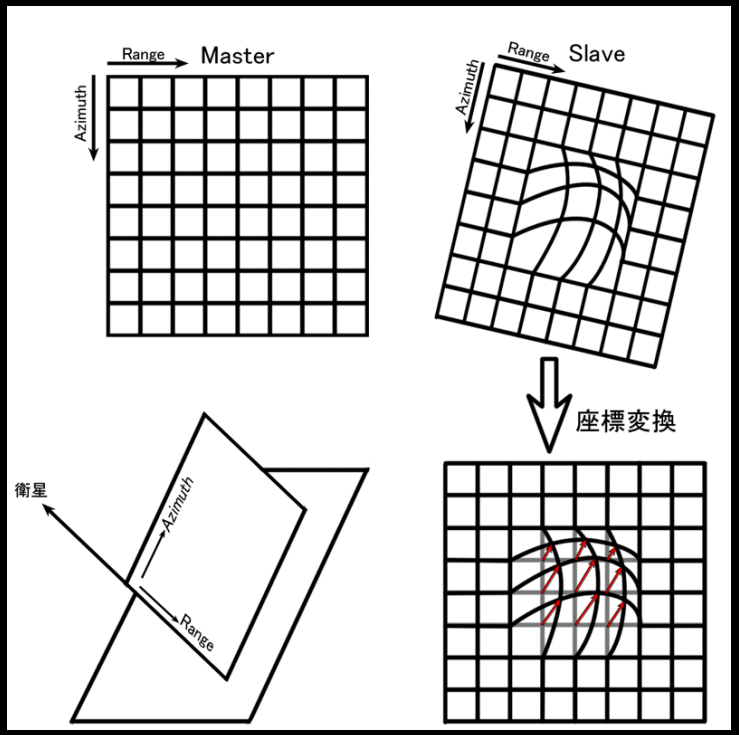
Each offset is calculated as image shift which maximizes the image correlation of small image patches

Compared to InSAR, Pixel Offset Analysis can

- ○ detect large displacement
  InSAR: ~2m / POA: ~(window size)/2
- ○ detect azimuth component of the dis-placement, as well as range

but

- × is less sensitive to the displacement
  InSAR:2~3cm / POA:40cm
- × has lower spatial resolution
  InSAR:18m / POA：~1km



Strategy

Target: Iwate-Miyagi Nairiku (Inland) Earthquake (M7.2, 2008)
Data: 6 PALSAR amplitude image pairs
Method: Calculate EW, NS and UD components of the surface displacement by applying weighted least-square adjustment to estimated range and azimuth offsets

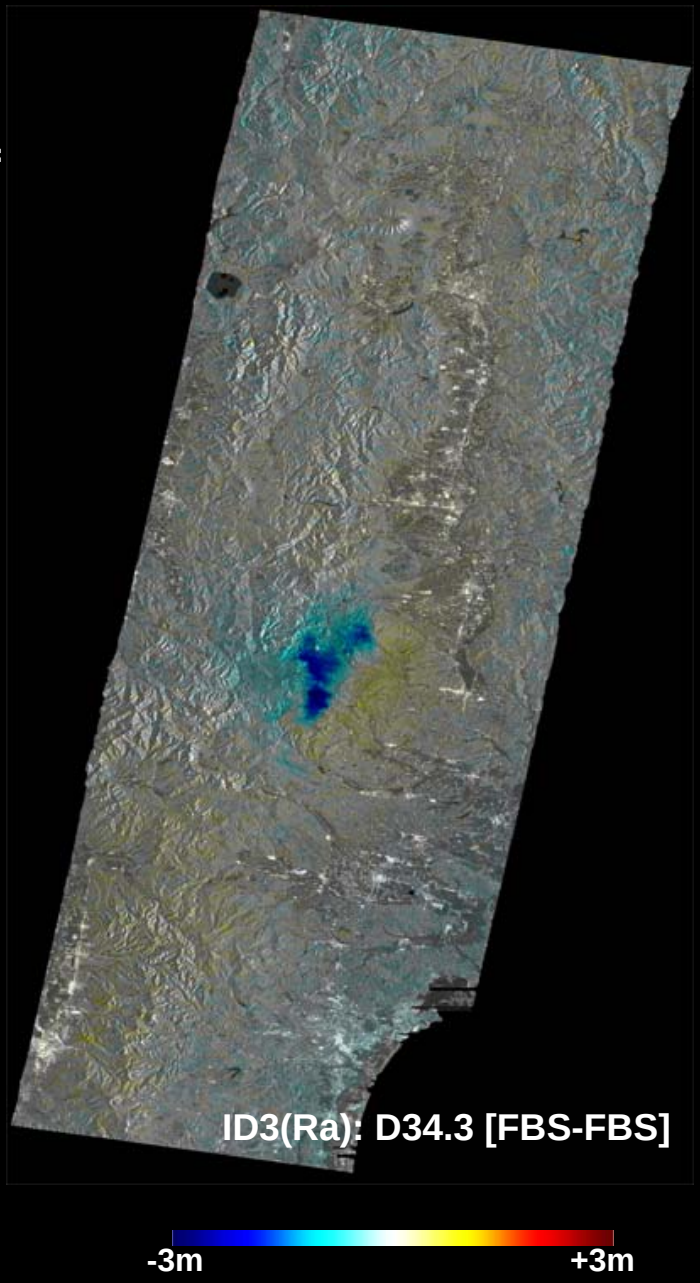
ID	Master Obs. Date [Mode]	Slave Obs. Date [Mode]	Path No. [Off-Nadir]	Bperp
1	2006/06/19 [FBD]	2008/06/24 [FBS]	053 [41.5]	301m
2	2006/07/06 [FBD]	2008/07/11 [FBS]	054 [41.5]	291m
3	2007/08/29 [FBS]	2008/07/16 [FBS]	057 [34.3]	-788m
4	2006/08/02 [FBS]	2008/06/22 [FBS]	061 [21.5]	389m
5	2007/06/21 [FBS]	2008/06/23 [FBS]	402 [34.3]	-335m
6	2007/02/03 [FBS]	2009/02/08 [FBS]	402 [34.3]	-1083m

- **FBD images are oversampled in range direction befor offset estimation for FBD-FBS pairs**
- **Correlation window size: 256x256[pixel]**
- **Stereoscopic effect is corrected using SRTM DEM**

Error Evaluation

Evaluate the error by calculating Std. Dev. of the offsets

ID		Mode	Std. Dev.
1	Az	FBD-FBS	65cm
	Ra		40cm
2	Az	FBD-FBS	39cm
	Ra		37cm
3	Az	FBS-FBS	22cm
	Ra		20cm
4	Az	FBS-FBS	69cm
	Ra		64cm
5	Az	FBS-FBS	68cm
	Ra		46cm
6	Az	FBS-FBS	72cm
	Ra		32cm



Calculation of the three-dimensional displacement

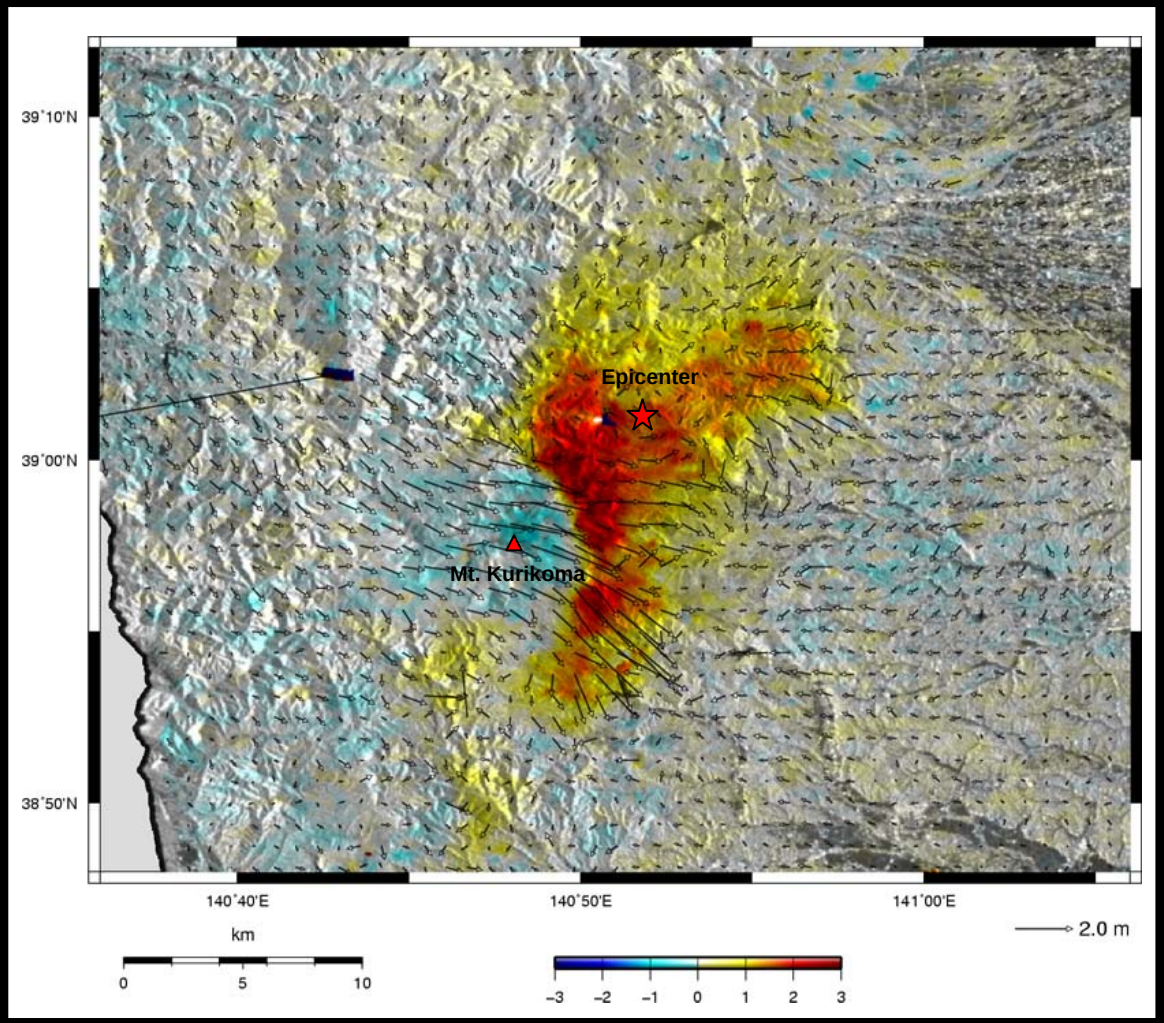
Assumptions

- **All the pairs observe same deformation**
- **Range/Azimuth offset errors follow a normal distribution**
- **The error is constant over the scene**

Apply least-square adjustment using $1/\sigma^2$ as weight

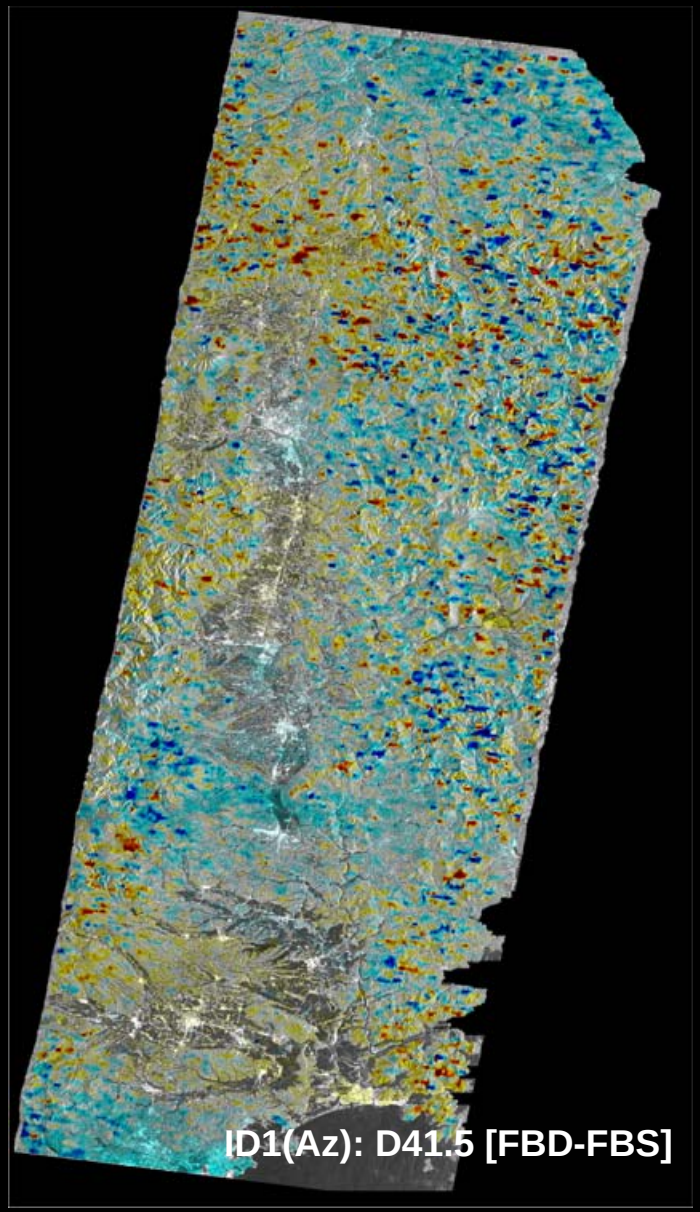
Three-Dimensional coseismic displacement map

Horizontal Displacement Vector (arrows) + Vertical Displacement (color)



Error Evaluation

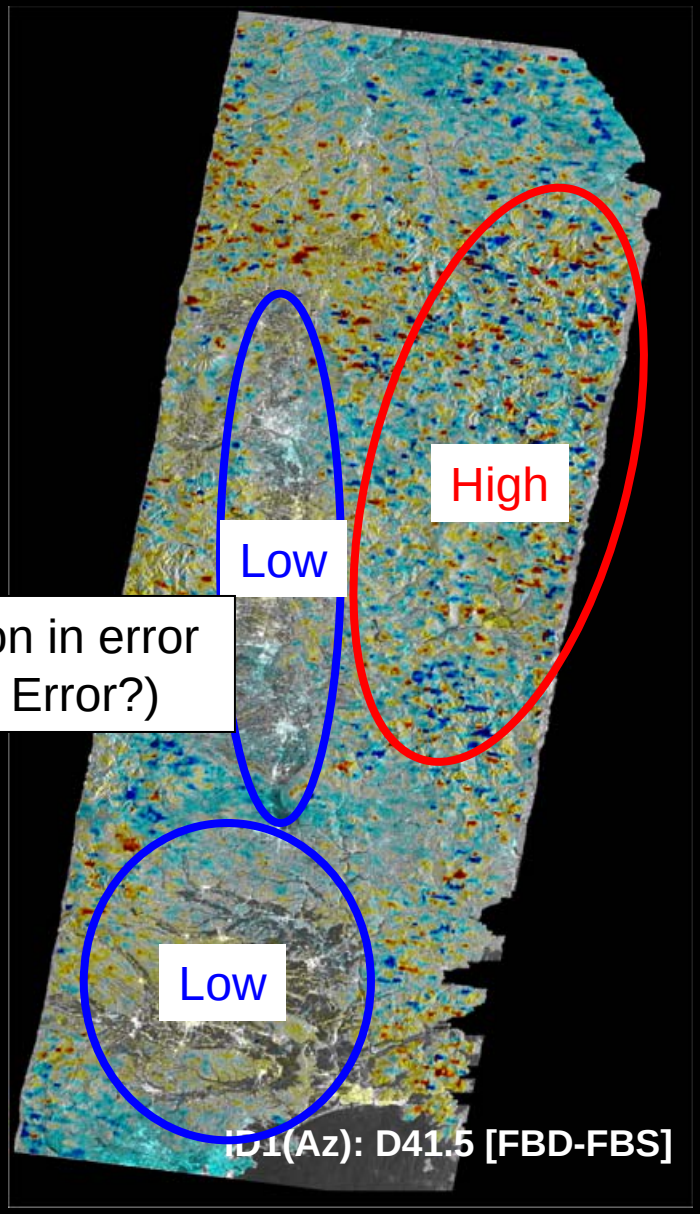
ID		Mode	Std. Dev.
1	Az	FBD-FBS	65cm
	Ra		40cm
2	Az	FBD-FBS	39cm
	Ra		37cm
3	Az	FBS-FBS	22cm
	Ra		20cm
4	Az	FBS-FBS	69cm
	Ra		64cm
5	Az	FBS-FBS	68cm
	Ra		46cm
6	Az	FBS-FBS	72cm
	Ra		32cm



Error Evaluation

ID		Mode	Std. Dev.
1	Az	FBD-FBS	65cm
	Ra		40cm
2	Az	FBD-FBS	39cm
	Ra		
3	Az	FBS-FBS	
	Ra		20cm
4	Az	FBS-FBS	69cm
	Ra		64cm
5	Az	FBS-FBS	68cm
	Ra		46cm
6	Az	FBS-FBS	72cm
	Ra		32cm

There is spatial variation in error
(Mountainous = High Error?)



New Strategy

0. Offset estimation program implemented by GAMMA provides SNR (some kind of quality measure) for each offset estimate

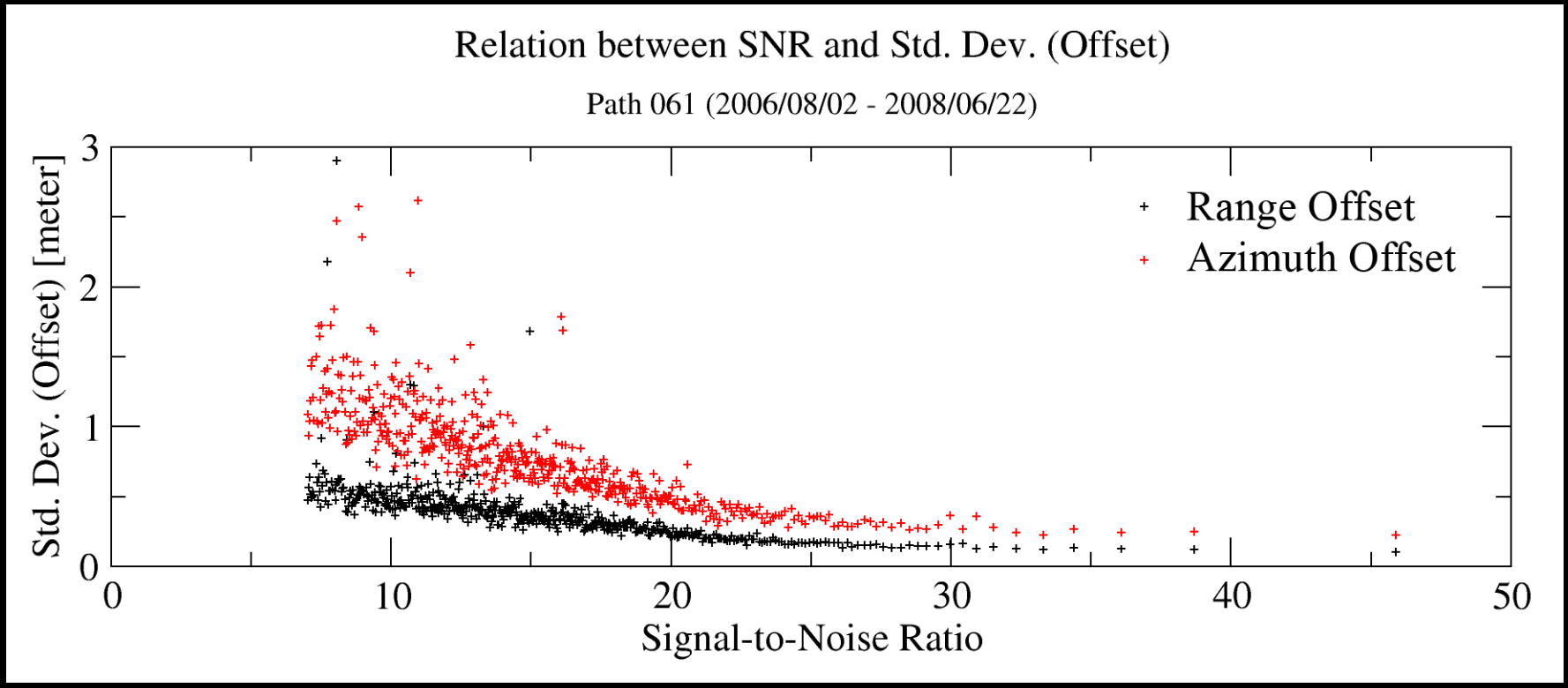
1. Sort offset estimates by SNR

2. Distribute offset estimates into bins so that each bin contains 100 offset estimates

3. Calculate Std. Dev. for each bins assuming that offset estimates of same SNR are under same condition

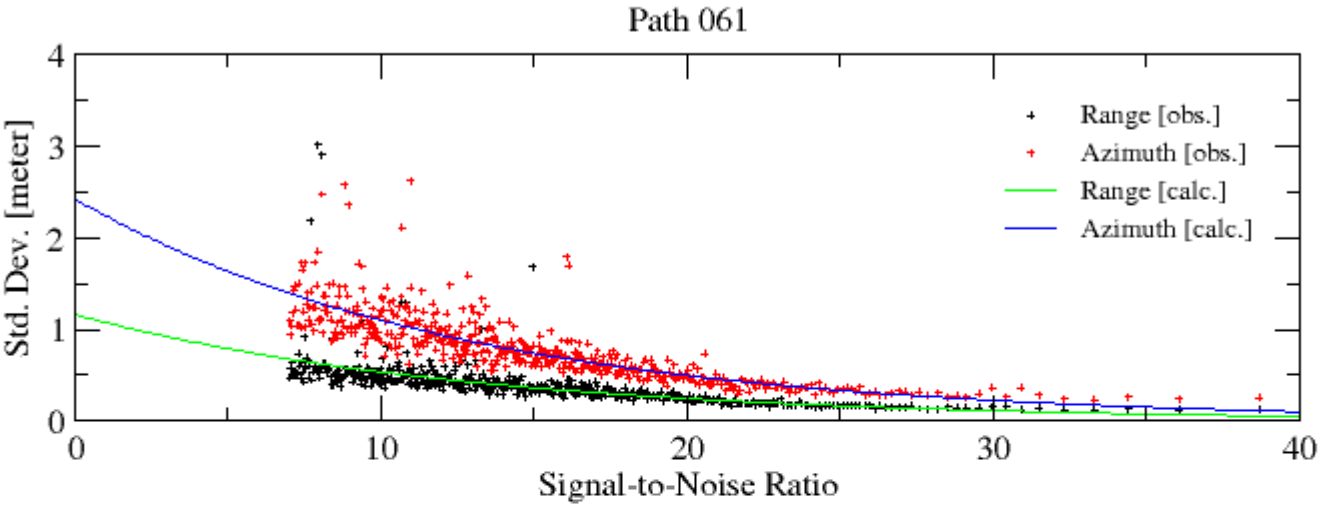
4. Check if any relation is seen between SNR and Std. Dev. of each bins

Result



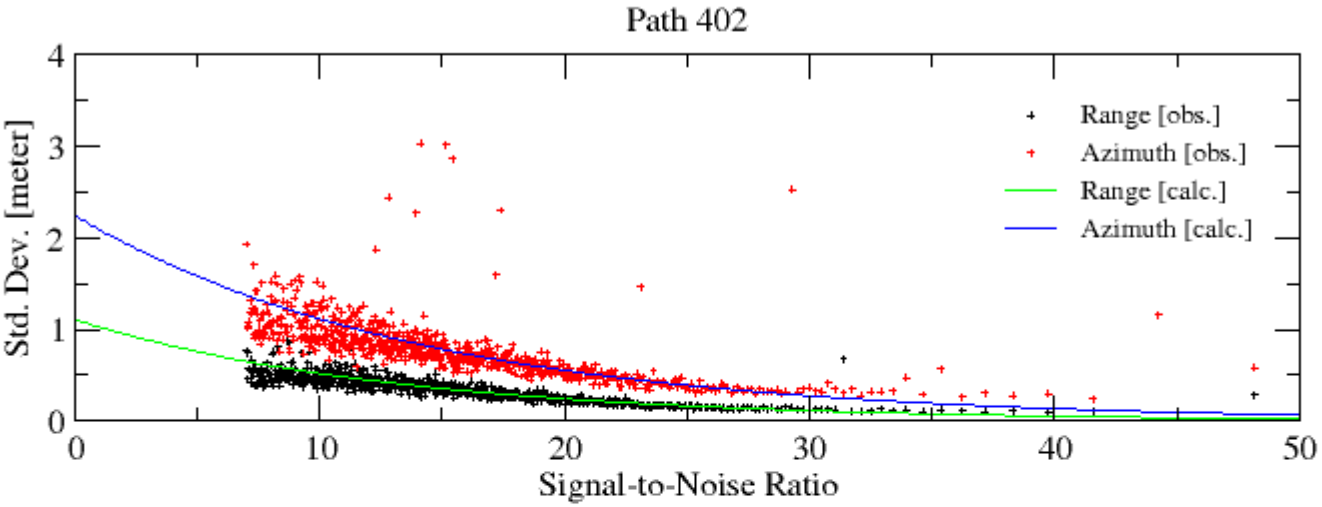
Exponential Function ($y = ae^{bx}$) should explain the data well

Result



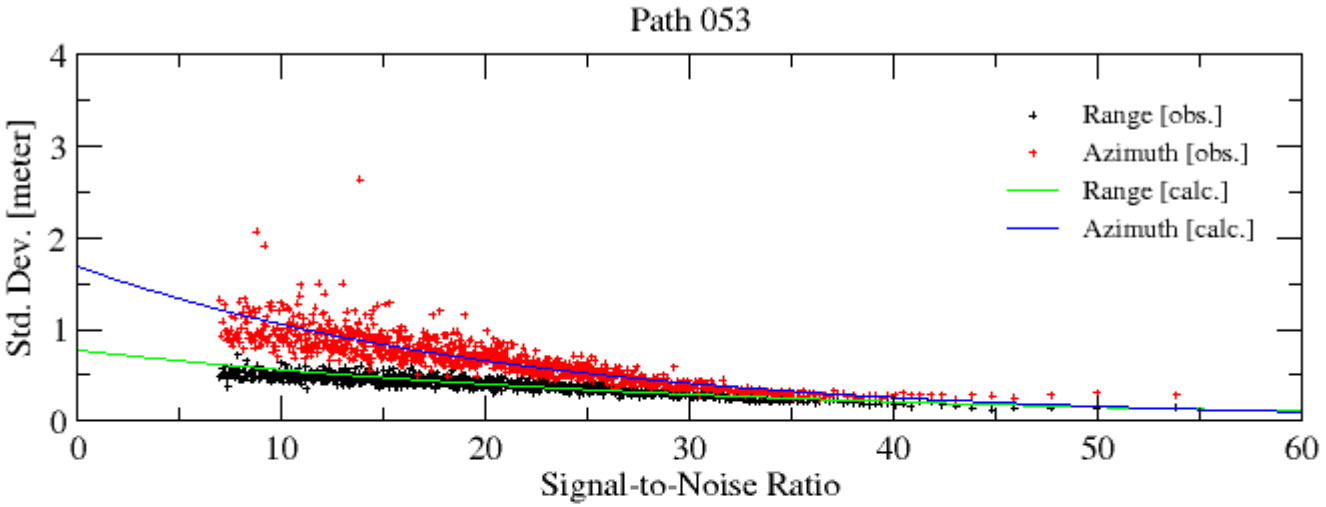
$$\sigma_{offset} = 1.16 \times e^{-0.077(SNR)} \quad \text{(Range)}$$
$$= 2.42 \times e^{-0.079(SNR)} \quad \text{(Azimuth)}$$

Result



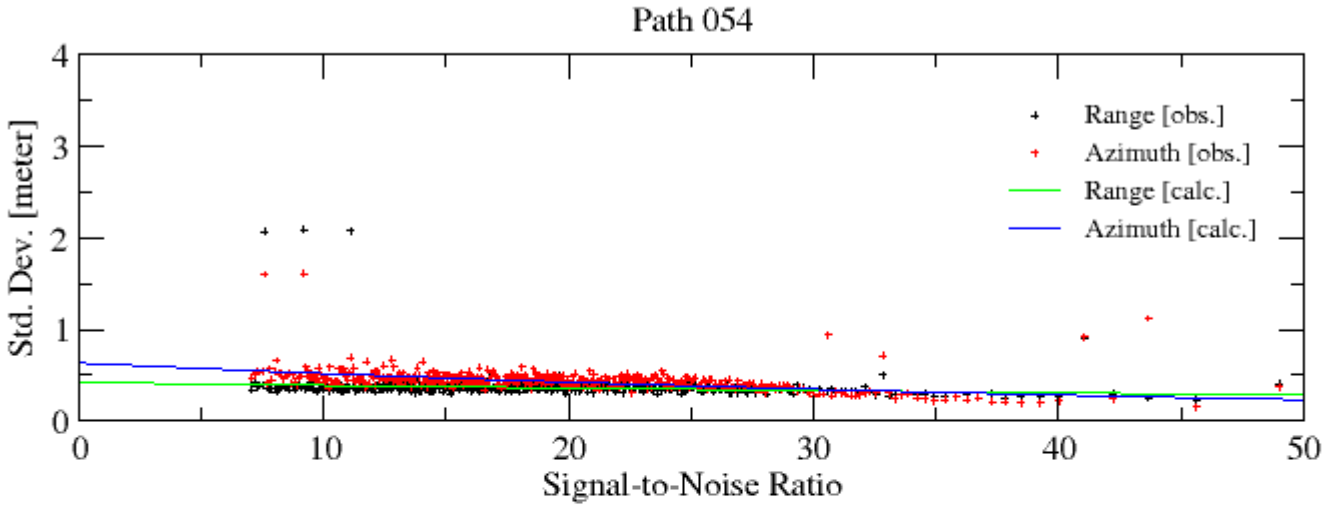
$$\sigma_{offset} = 1.11 \times e^{-0.076(SNR)} \quad \text{(Range)}$$
$$= 2.24 \times e^{-0.070(SNR)} \quad \text{(Azimuth)}$$

Result



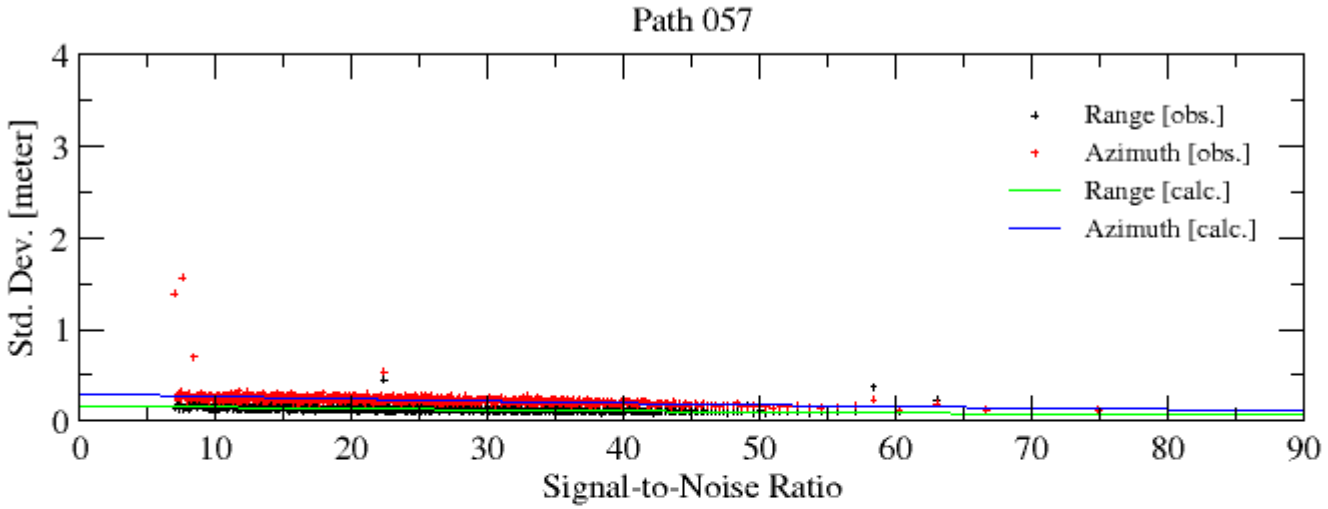
$$\sigma_{offset} = 0.78 \times e^{-0.032(SNR)} \quad \text{(Range)}$$
$$= 1.69 \times e^{-0.047(SNR)} \quad \text{(Azimuth)}$$

Result



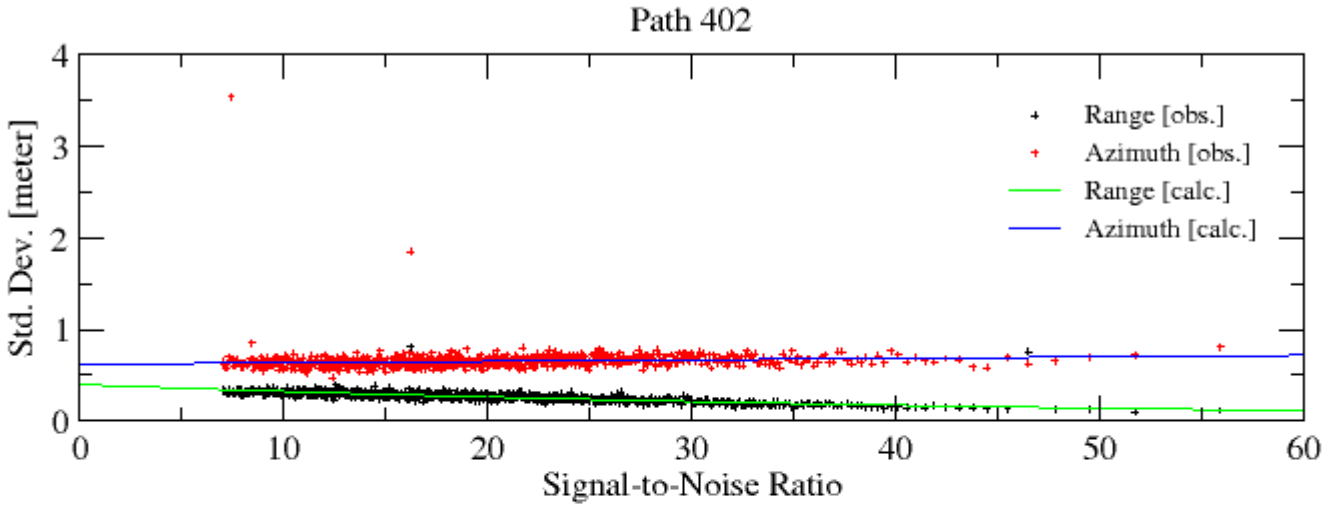
$$\sigma_{offset} = 0.42 \times e^{-0.008(SNR)} \quad \text{(Range)}$$
$$= 0.63 \times e^{-0.020(SNR)} \quad \text{(Azimuth)}$$

Result



$$\sigma_{offset} = 0.17 \times e^{-0.077(SNR)} \quad \text{(Range)}$$
$$= 0.30 \times e^{-0.011(SNR)} \quad \text{(Azimuth)}$$

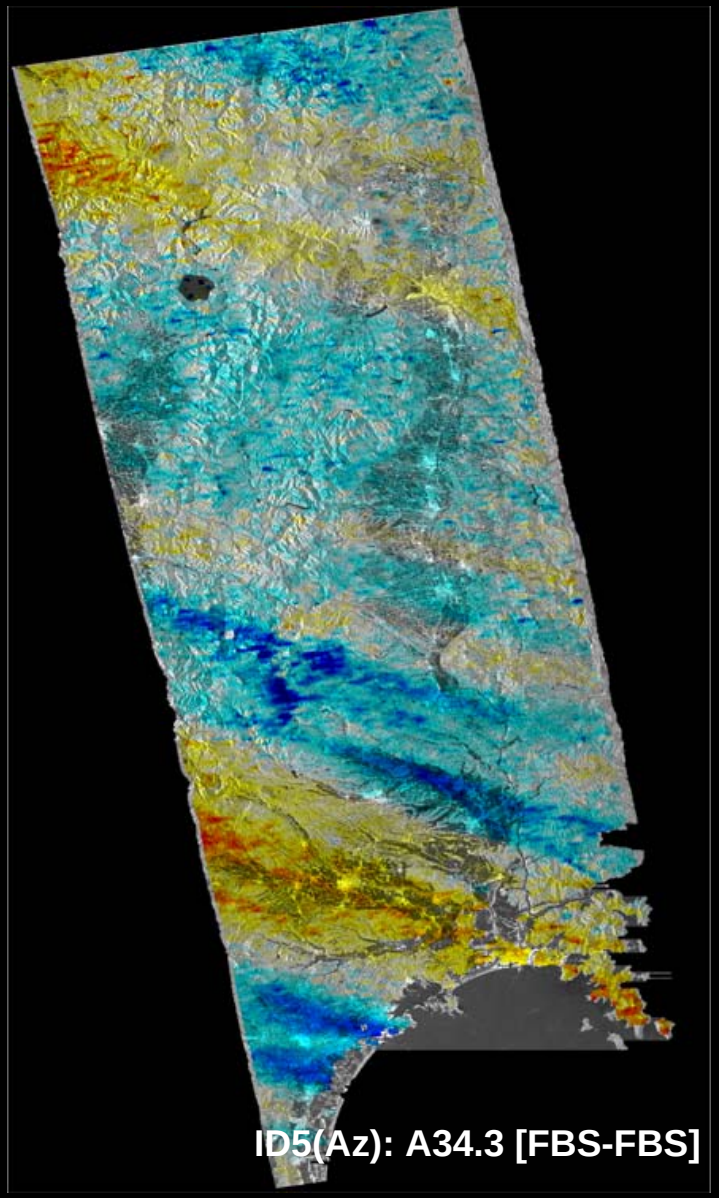
Result



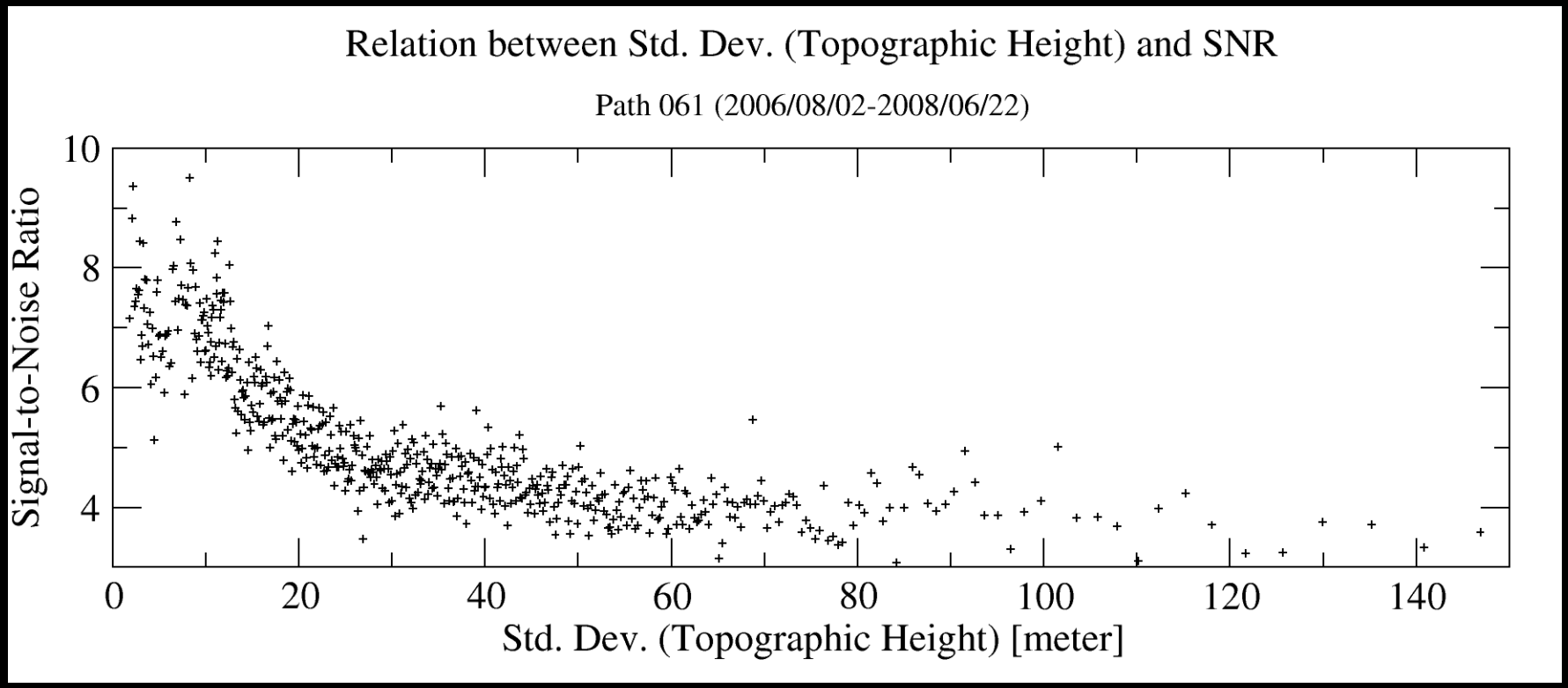
$$\sigma_{offset} = 0.40 \times e^{-0.021(SNR)} \quad \text{(Range)}$$
$$= 0.62 \times e^{0.002(SNR)} \quad \text{(Azimuth)}$$

Path 402, Azimuth Offset

ID		Mode	Std. Dev.
1	Az	FBD-FBS	65cm
	Ra		40cm
2	Az	FBD-FBS	39cm
	Ra		37cm
3	Az	FBS-FBS	22cm
	Ra		20cm
4	Az	FBS-FBS	69cm
	Ra		64cm
5	Az	FBS-FBS	68cm
	Ra		46cm
6	Az	FBS-FBS	72cm
	Ra		32cm

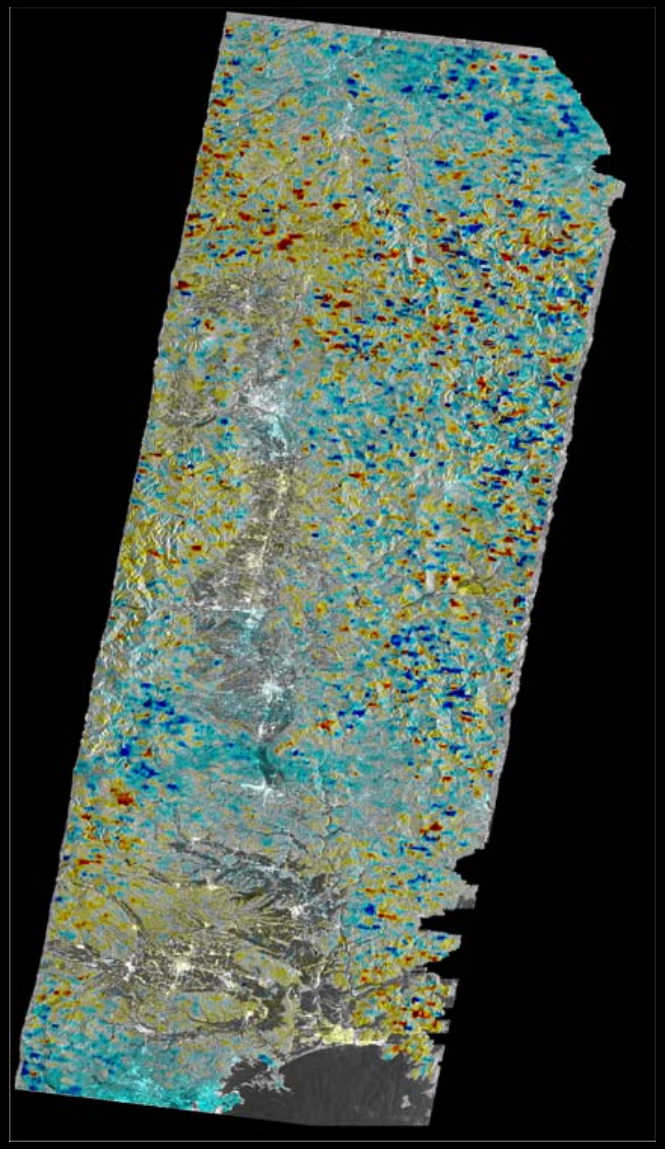


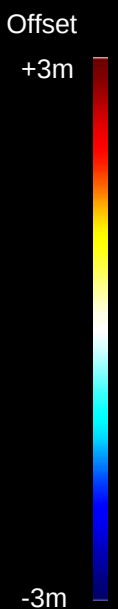
Effect of Topography

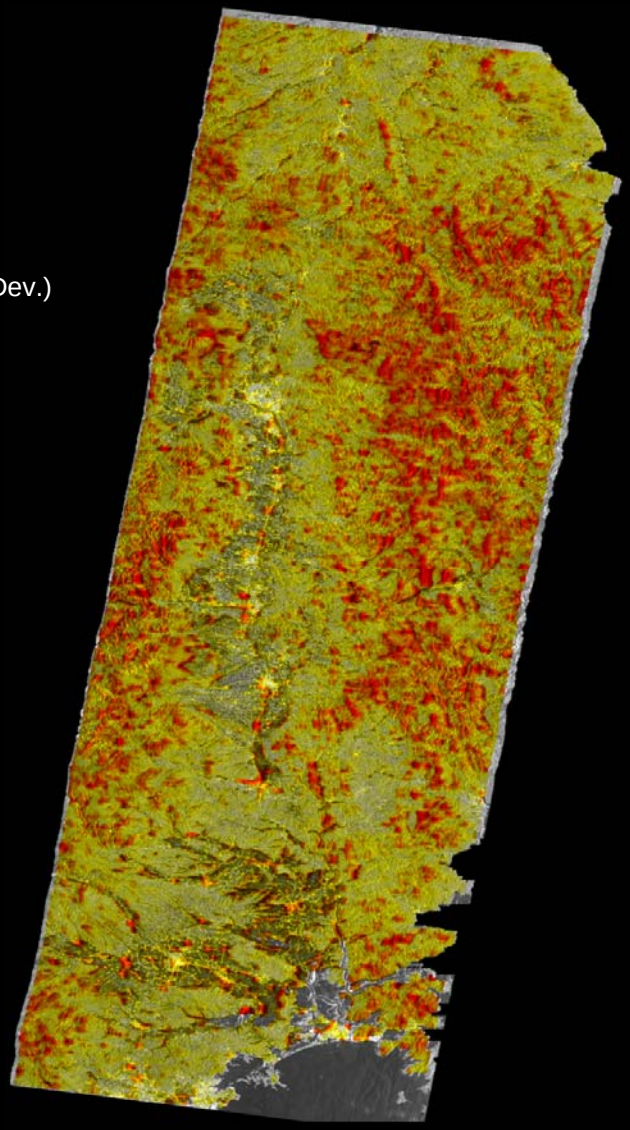


$$SNR = a + b / \sigma_{topo} \qquad (\sigma_{topo} > 10)$$
$$random \qquad (\sigma_{topo} < 10)$$

Offset and Error Map







Summary

The relation between the SNR and offset error is investigated in empirical manner

- σ_{offset} can be well explained as an exponential function of SNR
- SNR is inverse proportional to σ_{topo} when σ_{topo} is greater than 10m