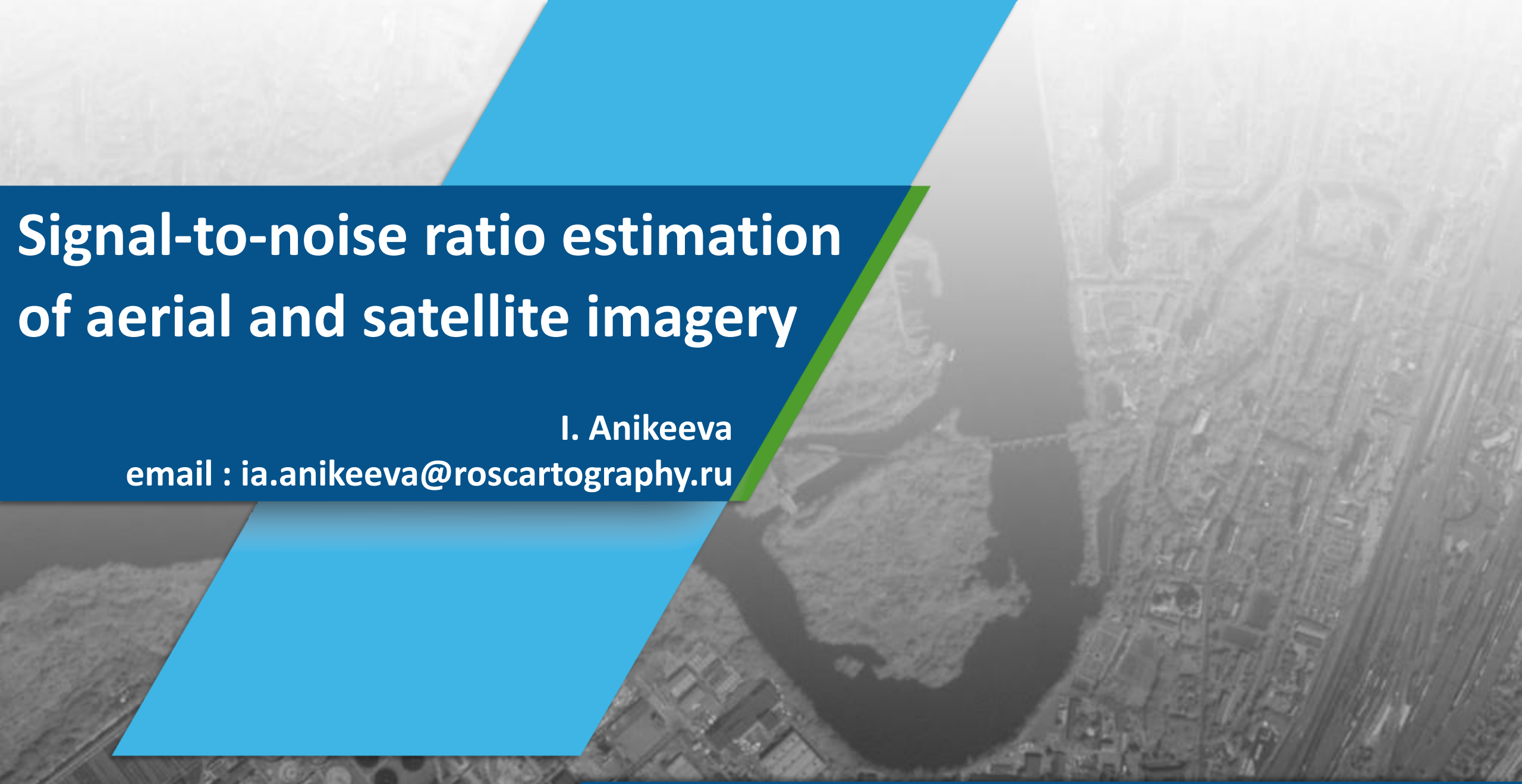
Signal-to-noise ratio estimation of aerial and satellite imagery

I. Anikeeva
email : ia.anikeeva@roscartography.ru



Seoul, Korea, 2019/X

DIGITAL NOISE –
FACTOR THAT REDUCES VISUAL QUALITY OF IMAGES

Digital noise on image

randomly arranged pixels that differ significantly in brightness or color from the average brightness or color of neighboring pixels

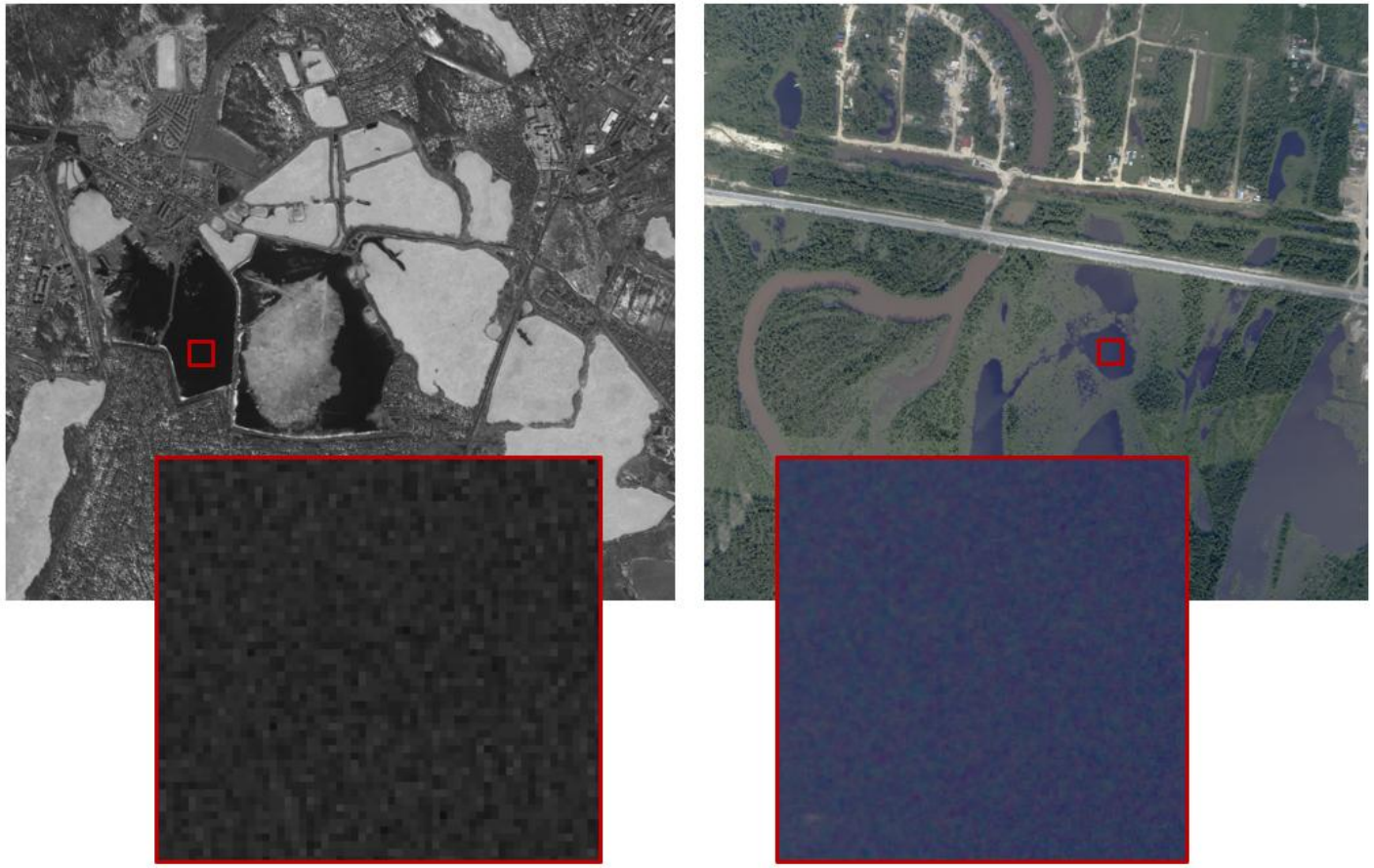
CAUSES OF RANDOM NOISE IN THE IMAGE

1. **shooting camera specs**
   - ✓pixel size,
   - ✓Photosensitivity of matrix,
   - ✓temperature etc.,
2. **shooting options:**
   - ✓exposure value.

EXAMPLES OF RANDOM NOISE ON AERIAL AND SATELLITE IMAGES

- The effect of noise on the visual quality of aerial and satellite imagery is obvious.
- Noise level indicator when evaluating the quality of images is not estimsted

Examples of random noise



A part of an image obtained by Canopus-V spacecraft

A part of an image obtained by aerial camers DMC II

Roscartography

METHODS FOR EVALUATING THE NOISE LEVEL ON IMAGES

- Signal to Noise amplitude rating – contrast ratio of signal and noise:

$$S/N_{amp} = \frac{C_{signal}}{C_{noise}}$$

- Noise power rating – square contrast ratio

$$S/N_{pow} = \left(S/N_{amp}\right)^2 = \left(\frac{C_{signal}}{C_{noise}}\right)^2$$

where: C_{signal} and C_{noise} – values of signal and noise contrasts, respectively

METHODS FOR EVALUATING THE NOISE LEVEL ON IMAGES

- The standard deviations (RMS) ratio of signal and noise:

$$S/N_{RMS} = \frac{\sigma_{signal}}{\sigma_{noise}}$$

- The dispersion ratio of signal and noise :

$$S/N_{disp} = \frac{{\sigma_{signal}}^2}{{\sigma_{noise}}^2}$$

where σ_{signal} and σ_{noise} – the RMS of signal and noise respectively.

- **The Db noise level is measured using the logarithm of the signal-to-noise ratio:**

$$S/N_{Db} = 10 \cdot lg\left(S/N_{pow}\right) = 20 \cdot lg(S/N_{RMS})$$

METHODS FOR EVALUATING THE NOISE LEVEL ON IMAGES

- An algorithm for estimating the noise level of a digital image based on harmonic analysis (proposed by E. Lapshenkov).

  The essence of method is the image noise RMS determination σ based on harmonic analysis.

  The RMS of signal is determined:

$$\sigma_{signal} = \sqrt{\sigma_{total}{}^2 - \sigma_{noise}{}^2}\ ^*$$

where σ_{total} – RMS of pixel values, calculated by the image.

Signal-to –noise ratio is determined:

$$S/N_{RMS} = \frac{\sigma_{signal}}{\sigma_{noise}}$$

* the signal is assumed to be uncorrelated with noise

NORMALIZED SIGNAL-TO-NOISE RATIO ESTIMATION

The *lack* of image signal-to-noise ratio formulas is their **difficult interpretability**.

To obtain an interpreted indicator, the value of the signal-to-noise ratio should be normalized.

Normalized signal-to-noise ratio estimation:

$$S/N_{norm} = \frac{\sigma_{signal}}{(\sigma_{niose} + 1) \cdot \sigma_{signal}} = \frac{1}{\sigma_{noise} + 1}$$

the normalized signal-to-noise ratio varies from 0 to 1:

✓ $S/N_{norm} \rightarrow 1$, the effect of noise on image quality is not significant,

✓ $S/N_{norm} \rightarrow 0$, noise affects image quality.

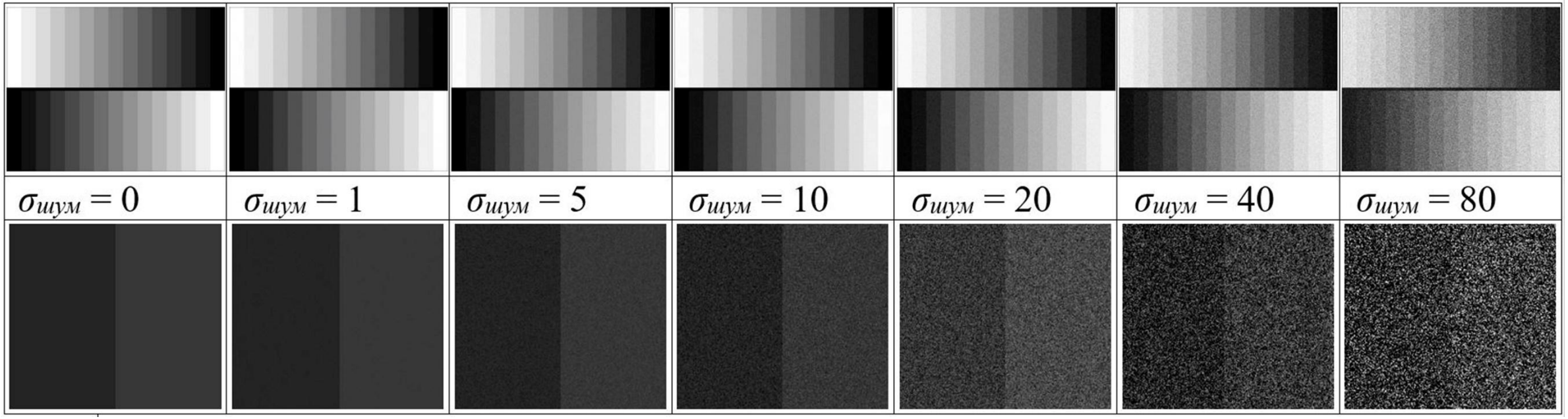
BASIC CHECK OF NOISE LEVEL ASSESSMENT ALGORITHM BASED ON HARMONIC ANALYSIS

The test images sampling

Images were obtained by adding the random noise of levels:

σ_{noise-} = 1, 2, 3, 4, 5, 10, 20, 40, 80

to the artificially created original gray wedge image with null noise level



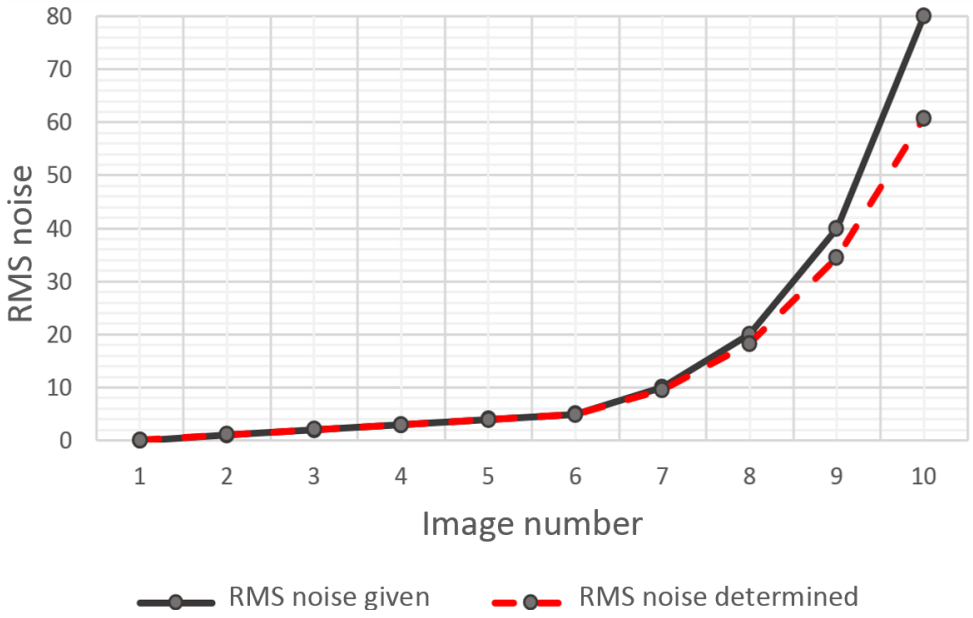
BASIC CHECK OF NOISE LEVEL ASSESSMENT ALGORITHM BASED ON HARMONIC ANALYSIS

The results of test images sampling noise estimation $\sigma_{noise\text{-}}$ based on harmonic analysis

σ_{total}	80.08		Values obtained by the method based on harmonic analysis				Method error
Estimated values							
$\sigma_{noise\text{-}}$	S/N_{RMS}	S/N_{norm}	$\sigma'_{noise\text{-}}$	σ'_{signal}	S/N'_{RMS}	S/N'_{norm}	$\sigma'_{noise\text{-}}/\sigma_{noise\text{-}}$
0	-	1.00	0.04	80.08	2002.00	0.96	0.96
1	80.08	0.50	1.13	79.99	70.79	0.47	0.94
2	40.04	0.33	2.04	79.89	39.16	0.33	0.99
3	26.69	0.25	2.98	79.79	26.78	0.25	1.01
4	20.02	0.20	3.89	79.70	20.49	0.20	1.02
5	16.02	0.17	4.85	79.60	16.41	0.17	1.03
10	8.01	0.09	9.52	79.10	8.31	0.10	1.05
20	4.00	0.05	18.27	77.85	4.26	0.05	1.09
40	2.00	0.02	34.50	74.26	2.15	0.03	1.15
80	1.00	0.01	60.75	64.82	1.07	0.02	1.31

RMS S/N'_{norm} 0.011

RMS noise graphs given and calculated based on harmonic analysis

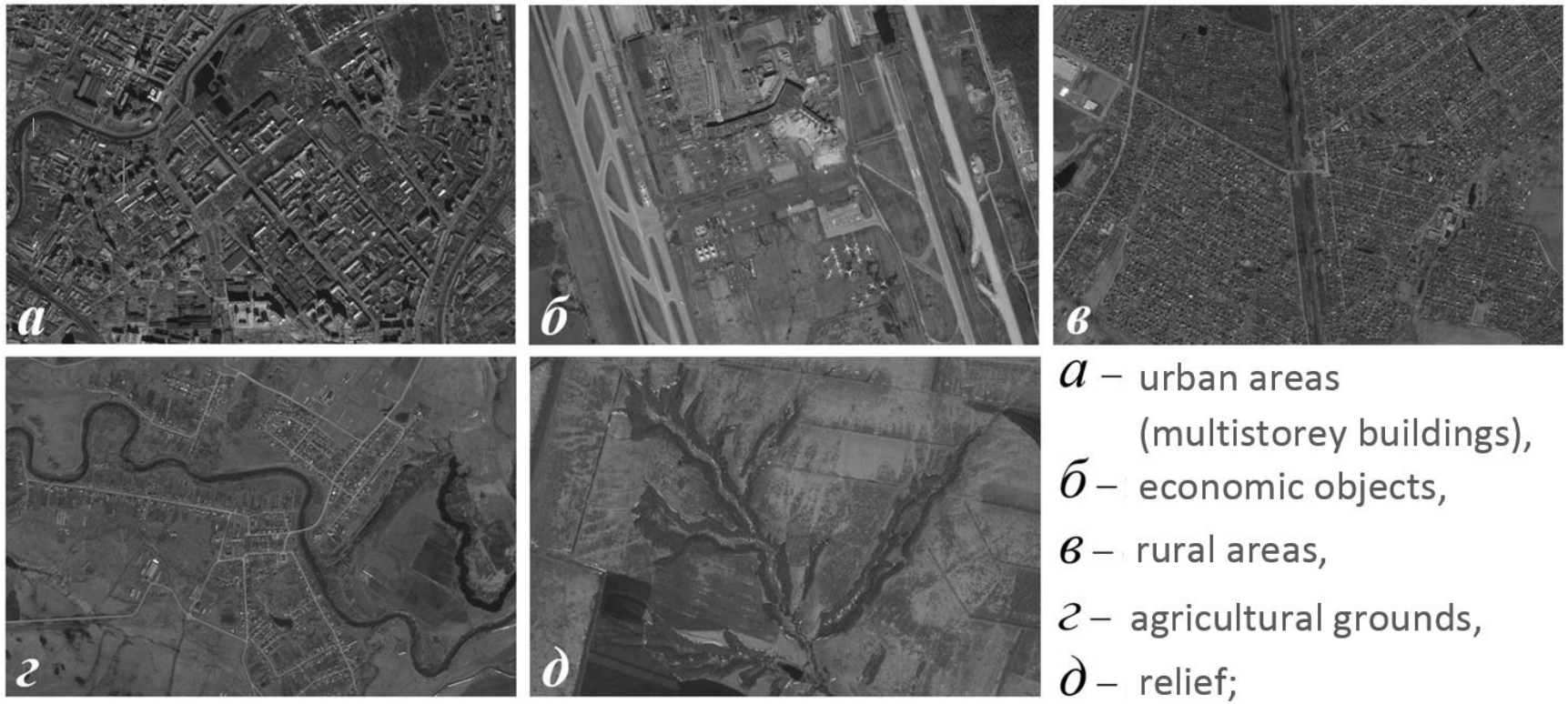


Roscartography

CHECK THE NOISE LEVEL ASSESSMENT ALGORITHM BASED ON HARMONIC ANALYSIS

A sample of satellite images parts with a different type of underlying surface to study the method for estimating noise levels based on harmonic analysis accuracy:

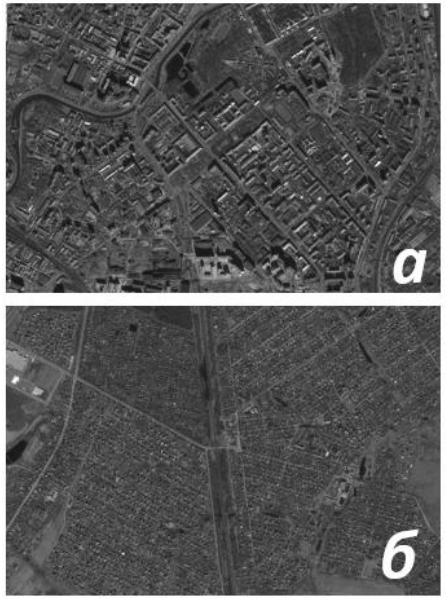
- urban areas (multistorey buildings),
- economic objects,
- rural areas,
- agricultural grounds,
- relief.

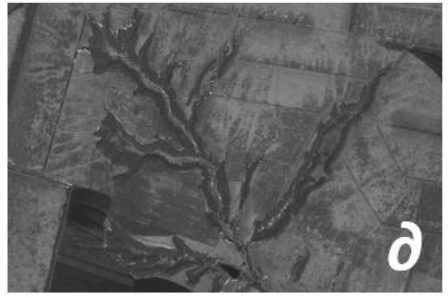


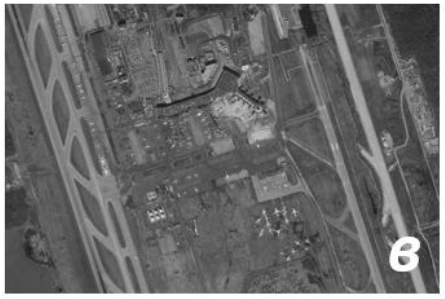
Images obtained by Canopus-V spacecraft №6

CHECK THE NOISE LEVEL ASSESSMENT ALGORITHM BASED ON HARMONIC ANALYSIS

Noise level σ_{noise-} and signal-to-noise ratios of satellite image samples based on harmonic analysis





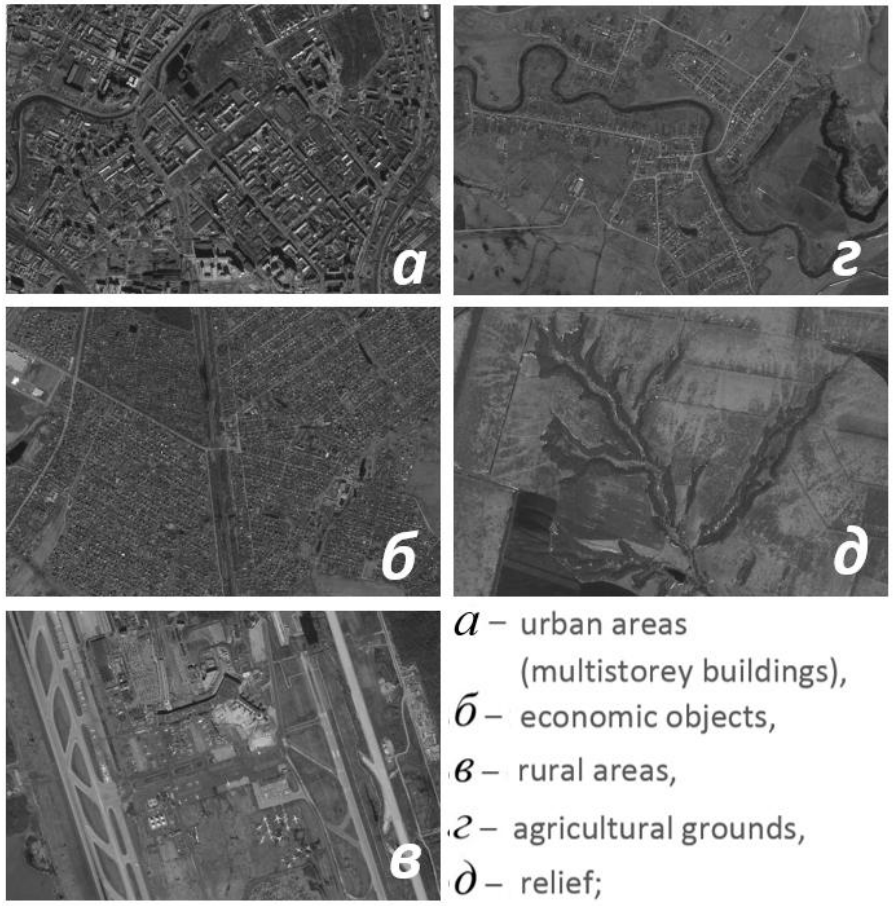


а – urban areas (multistorey buildings),
б – economic objects,
в – rural areas,
г – agricultural grounds,
д – relief;

Image		*а*	*б*	*в*	*г*	*д*
σ_{total}		29.33	27.4	21.75	17.83	20.88
$\Sigma_{noise\ origin}$		1.77	1.41	1.76	1.45	1.40
$S/N_{norm\ origin}$		0.56	0.71	0.57	0.69	0.71
Estimated values		Values obtained by the method based on harmonic analysis				
σ_{noise-}	S/N_{norm}	σ_{noise-}	σ_{noise-}	σ_{noise-}	σ_{noise-}	σ_{noise-}
0	1.00	0	0	0	0	0
1	0.50	1.34	1.29	1.32	1.30	1.34
2	0.33	2.37	2.34	2.44	2.38	2.38
3	0.25	3.46	3.37	3.48	3.38	3.39
4	0.20	4.50	4.40	4.50	4.49	4.40
5	0.17	5.55	5.44	5.55	5.48	5.48
10	0.09	10.70	10.50	10.80	10.55	10.55
20	0.05	20.72	20.48	20.95	20.60	20.42
40	0.02	38.44	39.40	38.99	39.37	39.13
80	0.01	65.63	68.01	66.40	66.80	68.09

CHECK THE NOISE LEVEL ASSESSMENT ALGORITHM BASED ON HARMONIC ANALYSIS

Noise level σ_{noise-} and signal-to-noise ratios of satellite image samples based on harmonic analysis



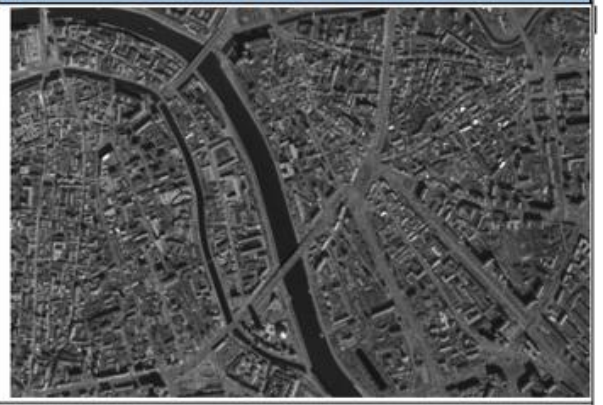
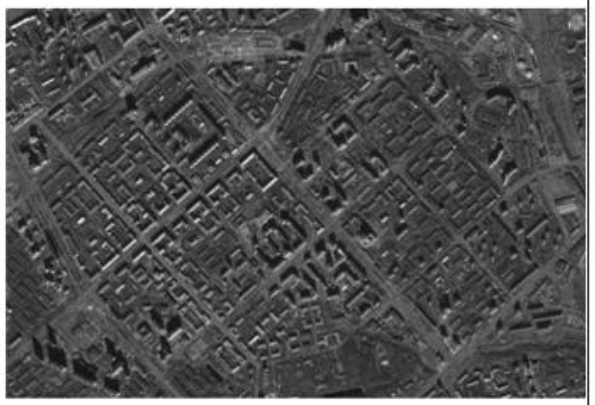
а – urban areas (multistorey buildings),
б – economic objects,
в – rural areas,
г – agricultural grounds,
д – relief;

Image		*а*	*б*	*в*	*г*	*д*
Estimated values		Values obtained by the method based on harmonic analysis				
σ_{noise-}	S/N_{norm}	S/N_{norm}	S/N_{norm}	S/N_{norm}	S/N_{norm}	S/N_{norm}
0	1.00	1.00	1.00	1.00	1.00	1.00
1	0.50	0.43	0.44	0.43	0.43	0.43
2	0.33	0.30	0.30	0.29	0.30	0.30
3	0.25	0.22	0.23	0.22	0.23	0.23
4	0.20	0.18	0.19	0.18	0.18	0.19
5	0.17	0.15	0.16	0.15	0.15	0.15
10	0.09	0.09	0.09	0.08	0.09	0.09
20	0.05	0.05	0.05	0.05	0.05	0.05
40	0.02	0.03	0.02	0.03	0.02	0.02
80	0.01	0.02	0.01	0.01	0.01	0.01
СКО S/N'_{norm}		**0.023**	**0.020**	**0.023**	**0.022**	**0.024**

CHECK THE NOISE LEVEL ASSESSMENT ALGORITHM BASED ON HARMONIC ANALYSIS

- The method of estimating the noise level based on harmonic analysis allows us to obtain an estimate of the normalized signal-to-noise ratio with an accuracy (RMS) of no worse than 0.025.
- In this example, panchromatic images were used. When evaluating the noise level of color images, the calculation is performed separately for each color channel.

THE SATTELITE IMAGING NOISE LEVEL ESTIMATION BASED ON HARMONIC ANALYSIS

Canopus-V №3	Canopus-V №4	Canopus-V №5
		
$S/N_{norm} = 0.37$	$S/N_{norm} = 0.30$	$S/N_{norm} = 0.29$
Canopus-V №6	**Resource-P**	**Aist-2D**
		
$S/N_{norm} = 0.35$	$S/N_{norm} = 0.29$	$S/N_{norm} = 0.42$

Roscartography

THE AERIAL IMAGING NOISE LEVEL ESTIMATION BASED ON HARMONIC ANALYSIS

DMC II			RCD 30 Penta			Sony RX		
								
R	G	B	R	G	B	R	G	B
0.42	0.44	0.45	0.40	0.52	0.51	0.28	0.29	0.29
S/N_{norm}			S/N_{norm}			S/N_{norm}		

Roscartography

CONCLUSION

- Digital noise affects a quality of aerial and satellite imagery.
- When assessing the fine quality of aerial and satellite imagery, an evaluation should be made of the noise level in the images.
- To evaluate the signal-to-noise ratio, it is recommended to use the normalized value of the indicator to obtain an interpreted result.
- Evaluation method based on harmonic analysis, proposed by E. Lapshenkov, allows you to get a normalized estimation of the signal-to-noise ratio of an image with the standard deviation not worse than 0.025.
- The considered method and proposed normalized criterion for estimating the signal-to-noise ratio will be normatively fixed in the organization standard of JSC “Roskartography” “Metrological quality of aerial and satellite imagery used for mapping purposes. Fine quality requirements for aerial and satellite imagery”

THANKS FOR YOUR ATTENTION

Roscartography

Moscow, 109316,
Volgogradsky av., 45/1

phone: (499) 177-50-00
fax: (499) 177-59-00
e-mail: info@roscartography.ru