Remote Sensing & Photogrammetry L6

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Image processing

1. Visual interpretation of single spectral band
    - Readout of DN and coordinates: x,y
2. Image enhancement
    - Histogram calculation
    - Linear histogram streatching
    - Image comparison before and after *stretching*
    - Different parameters of linear *stretching*
    - Histogram saturation and equalization
3. Visualization of multispectral bands
    - RGB
    - FCC

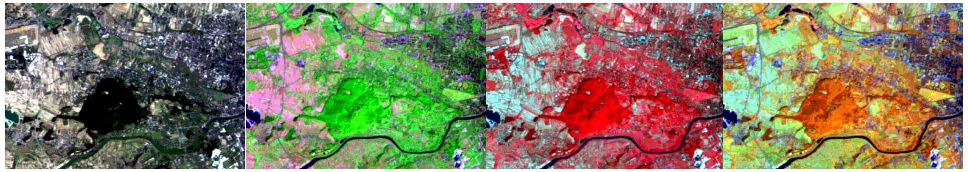

Image processing

4. Multi bands operation
   - Ratio – Vegetation Index (VI)
   - Normalized ratio – Normalized Vegetation Index (NDVI)
   - Multi chanel statistics
   - Principal Componemt Analysis (PCA) (presented live – Lecture 5)
   - Map algebra
   - Image fusion

COR MATRX	lan1lw	lan2lw	lan3lw	lan4lw	lan5lw	lan7lw
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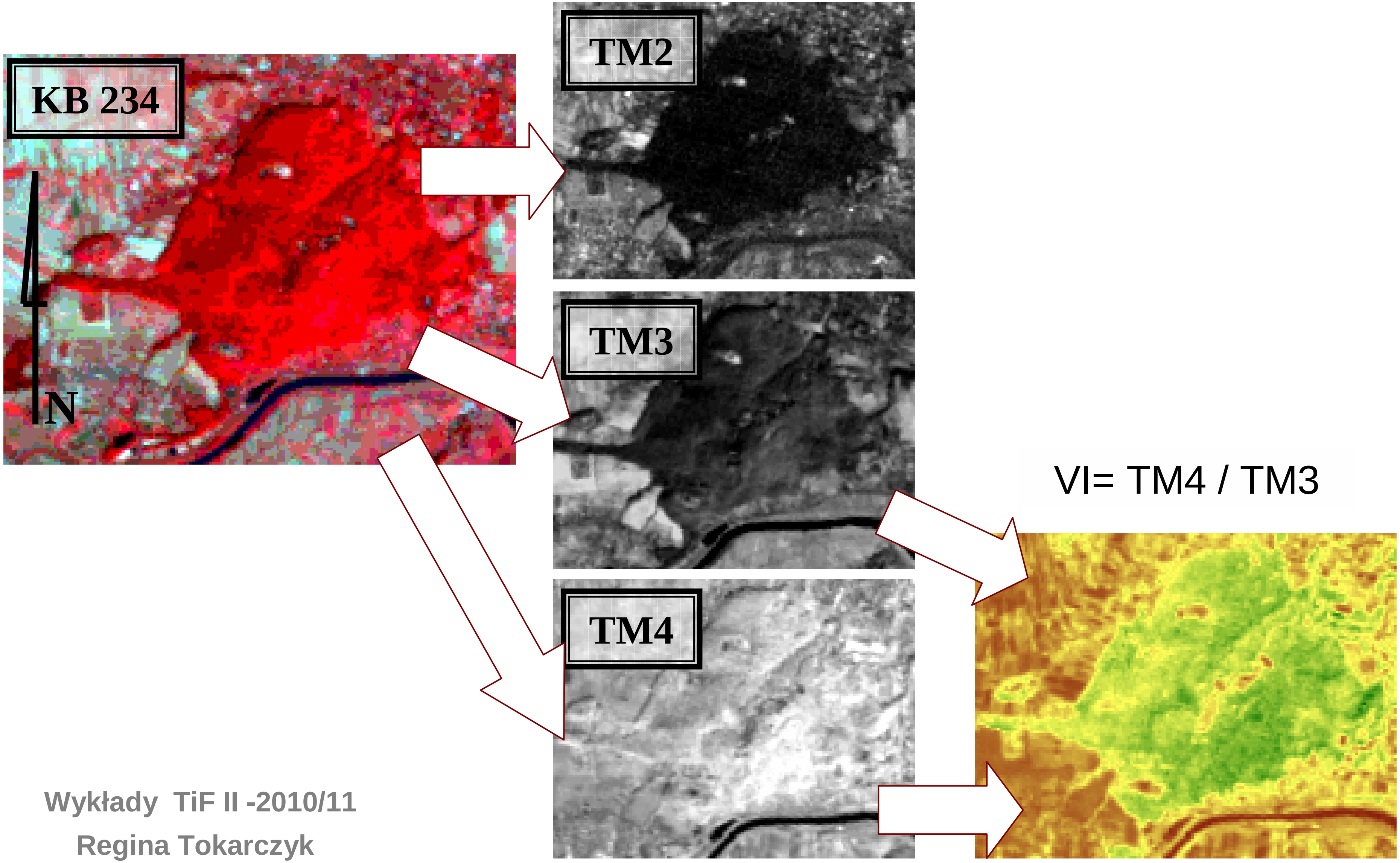
5. Image classification
   - Density slicing
   - piece-wise linear stretchning
   - Mulispectral image classification
     - Sampling
     - Different algorithms
     - Classification accuracy assesement
     - Post classification operation

Vegetation index

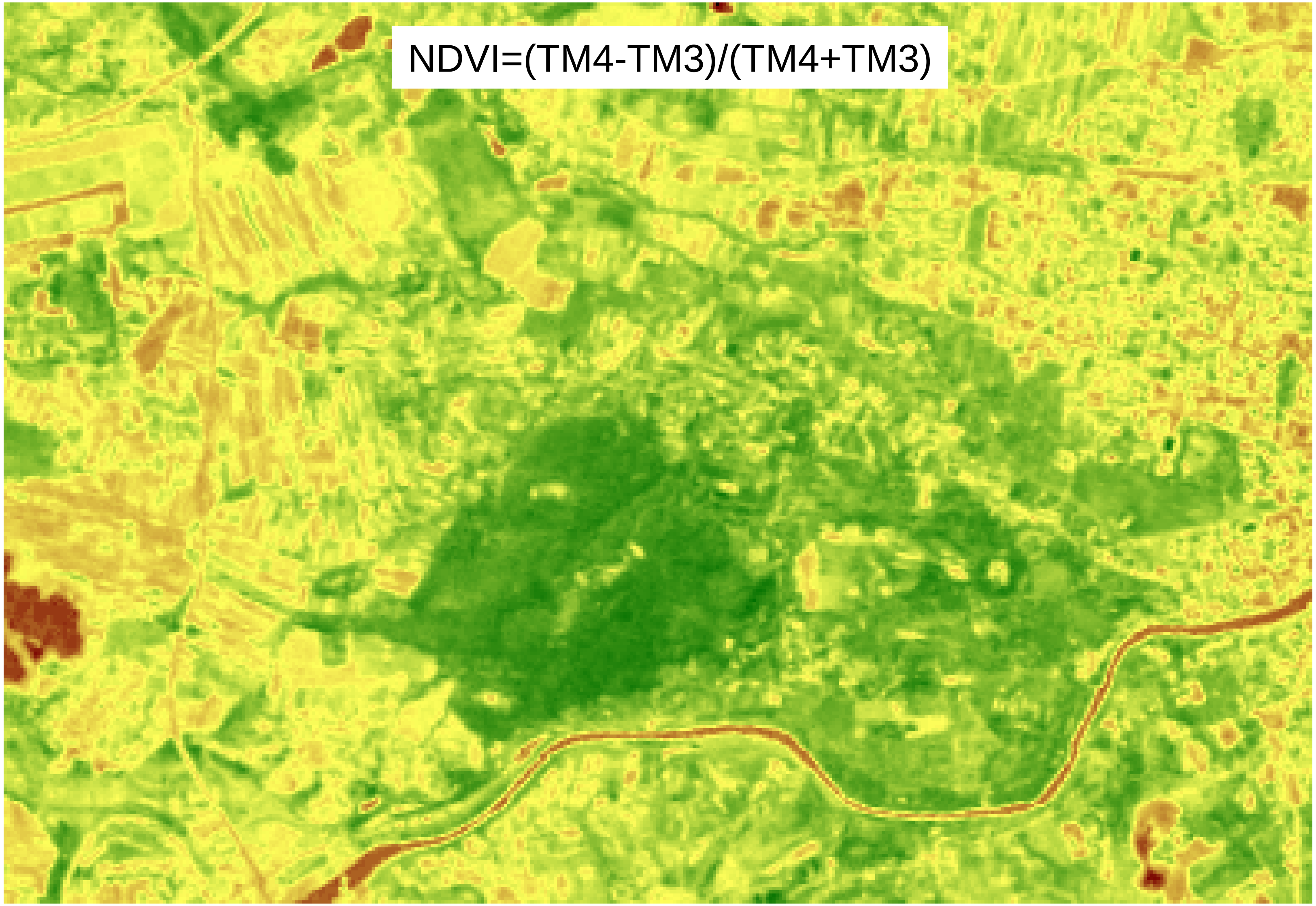
Ratio Vegetation Index VI=NIR/RED

NDVI Normalized Difference Vegetation Index

NDVI=(NIR-RED)/(NIR+RED)



NDVI – Normalized Differential Vegetation Index



Normalized Burn Ratio

- Normalized Burn Ratio

NBR = (TM4 - TM7) / (TM4 + TM7)

- Normalized Difference Burn Ratio (NDBR)

$NDBR = NBR_{pre} – NBR_{post}$

SI radiometry units

Quantity	Symbol[nb 1]	SI unit	Symbol	Dimension	Notes
Radiant energy	Q_e[nb 2]	joule	J	$M \cdot L^2 \cdot T^{-2}$	energy
Radiant flux	Φ_e[nb 2]	watt	W	$M \cdot L^2 \cdot T^{-3}$	radiant energy per unit time, also called *radiant power*.
Spectral power	$\Phi_{e\lambda}$[nb 2][nb 3]	watt per metre	$W \cdot m^{-1}$	$M \cdot L \cdot T^{-3}$	radiant power per wavelength.
Radiant intensity	I_e	watt per steradian	$W \cdot sr^{-1}$	$M \cdot L^2 \cdot T^{-3}$	power per unit solid angle.
Spectral intensity	$I_{e\lambda}$[nb 3]	watt per steradian per metre	$W \cdot sr^{-1} \cdot m^{-1}$	$M \cdot L \cdot T^{-3}$	radiant intensity per wavelength.
Radiance	L_e	watt per steradian per square metre	$W \cdot sr^{-1} \cdot m^{-2}$	$M \cdot T^{-3}$	power per unit solid angle per unit *projected* source area. confusingly called "intensity" in some other fields of study.
Spectral radiance	$L_{e\lambda}$[nb 3] or $L_{e\nu}$[nb 4]	watt per steradian per metre^3 *or* watt per steradian per square metre per hertz	$W \cdot sr^{-1} \cdot m^{-3}$ *or* $W \cdot sr^{-1} \cdot m^{-2} \cdot Hz^{-1}$	$M \cdot L^{-1} \cdot T^{-3}$ *or* $M \cdot T^{-2}$	commonly measured in $W \cdot sr^{-1} \cdot m^{-2} \cdot nm^{-1}$ with surface area and either wavelength or frequency.
Irradiance	E_e[nb 2]	watt per square metre	$W \cdot m^{-2}$	$M \cdot T^{-3}$	power incident on a surface, also called *radiant flux density*. sometimes confusingly called "intensity" as well.
Spectral irradiance	$E_{e\lambda}$[nb 3] or $E_{e\nu}$[nb 4]	watt per metre^3 *or* watt per square metre per hertz	$W \cdot m^{-3}$ *or* $W \cdot m^{-2} \cdot Hz^{-1}$	$M \cdot L^{-1} \cdot T^{-3}$ *or* $M \cdot T^{-2}$	commonly measured in $W \cdot m^{-2} \cdot nm^{-1}$ or $10^{-22} W \cdot m^{-2} \cdot Hz^{-1}$, known as solar flux unit.[nb 5]
Radiant exitance / Radiant emittance	M_e[nb 2]	watt per square metre	$W \cdot m^{-2}$	$M \cdot T^{-3}$	power emitted from a surface.
Spectral radiant exitance / Spectral radiant emittance	$M_{e\lambda}$[nb 3] or $M_{e\nu}$[nb 4]	watt per metre^3 *or* watt per square metre per hertz	$W \cdot m^{-3}$ *or* $W \cdot m^{-2} \cdot Hz^{-1}$	$M \cdot L^{-1} \cdot T^{-3}$ *or* $M \cdot T^{-2}$	power emitted from a surface per wavelength or frequency.

Irradiance

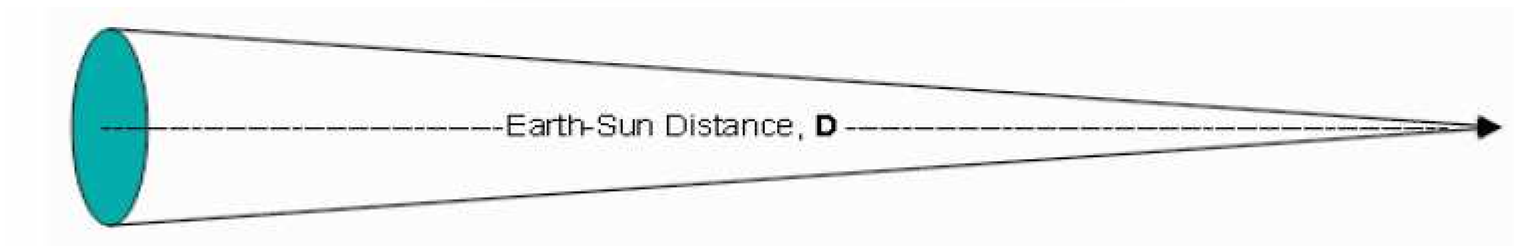
Irradinace – ratio of incidient radiant flux on elementar unit flux stosunek strumienia padającego w elementarnej jednostce czasu na element powierzchni odbiornika do wielkości tej powierzchni dla wąskiego przedziału spektralnego p.e.m. (emitancja spektralna)

$$E = dQ/dt/dA = \Phi/dA \ \ W/m^2$$

Constant on the top of atmosphere : mean value 1366,1 $W/(m^2)$ – solar constant

$$E_\lambda = dQ\ /dt/dA/\ \text{kąt bryłowy}\ \ W/(m^2\ sr\ \mu m)$$

Table 9.1 Solar Spectral Irradiances (watts/m²/nm)	
band 1	1969.000
band 2	1840.000
band 3	1551.000
band 4	1044.000
band 5	225.700
band 7	82.07
band 8	1368.000



Albedo

Albedo (reflectance coefficient) = Energy reflected from the Earth/ Energy incident on the Earth = $Q_{\rho\lambda}/Q_{\lambda}=L_{\lambda}/E_{\lambda}$

(in all EM range)

Albedo depends on:
-Enegry incident (solar zenith angle) – on horizontal and sloping surfaces
-Reflecting object surface (color, charakter, roughness, wetness)

Lambert's law:

Energy incident on the Earth = Energy incident on the Earth (vertical) * cos (Vo)

- Vo – local zenith angle

Example albedo:

- Soil 5-10%
- Conifer forest 15-20%
- Grass 20-25%
- Snow: fresh 75-95%, old 50-60%
- antopological materials (5-20% asphalt, 10-35% concrete, 20-35% stone, 10-35% tile

Map algebra - radiance

- Radiance (luminance) calculation:

$$L_{\lambda} = gain \cdot DN + offset = ((L_{\max} - L_{\min})/255) \cdot DN + L_{\min}$$

- L_{λ} – spectral radinace recorded by sensor
- L_{min} – minimal radiance of detectors in PAN: – 5.00
- L_{max} – maximal radiance of detectors in PAN: 244.00
- DN – of channel 8, PAN

Map algebra - albedo

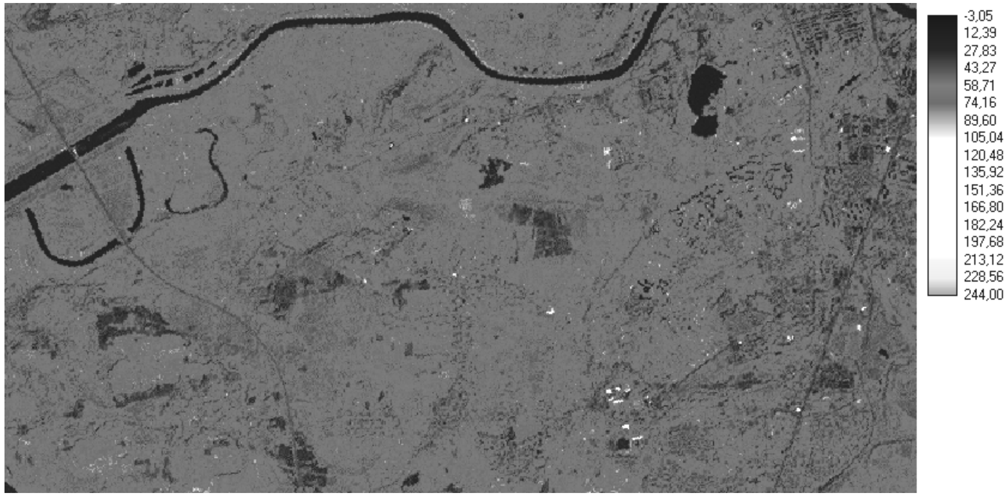
Albedo

$$\rho = \frac{\pi \cdot L_{\lambda} \cdot d^{2}}{ESUN_{\lambda} \cdot \cos \theta_{S}}$$

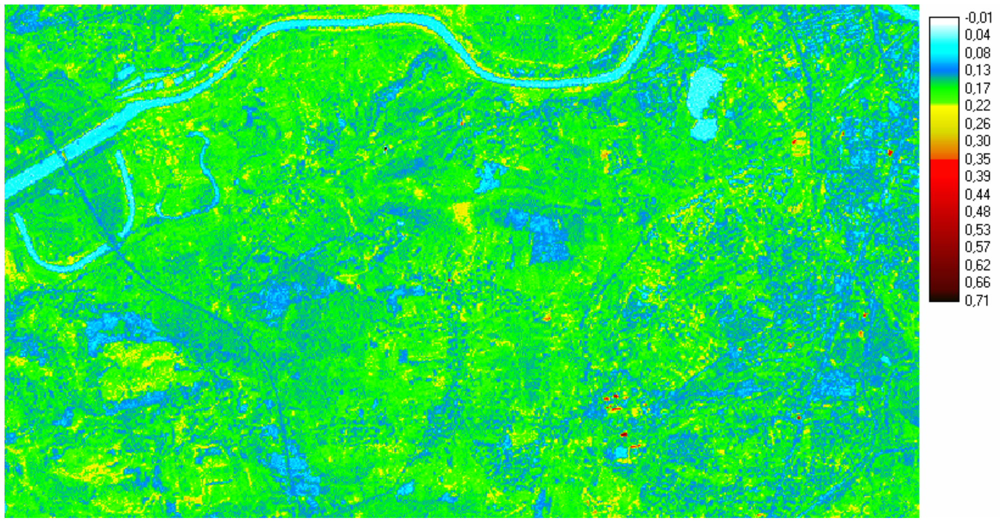
where:
ρ– albedo
L_λ – spectral radiance recorded by sensor
d – distance between Earth and Sun in astronomical units for given day of the year
$ESUN_\lambda$ – mean irradinace = 1368.00
θ_S – Sun zenith angle

Map algebra - albedo

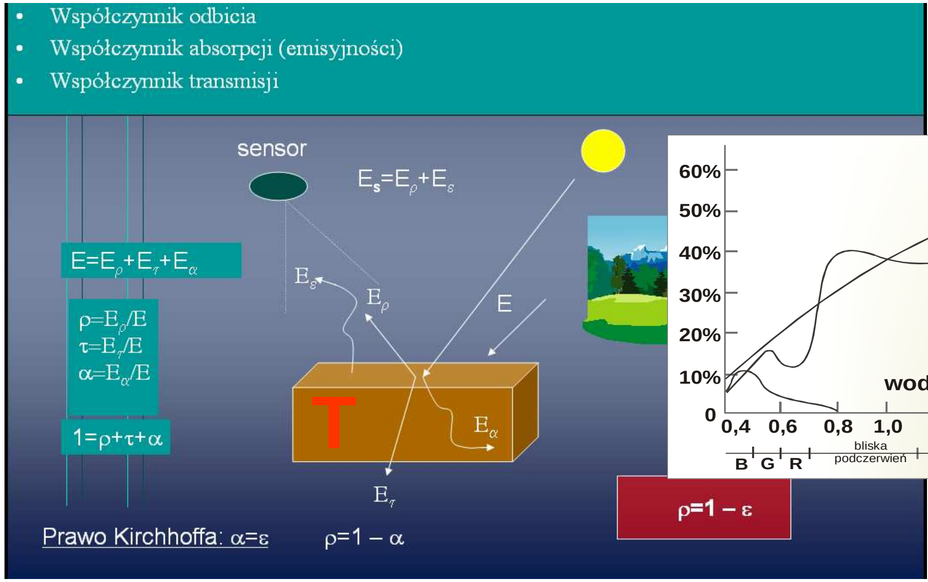
DN
PAN
Band 8
Landsat ETM+



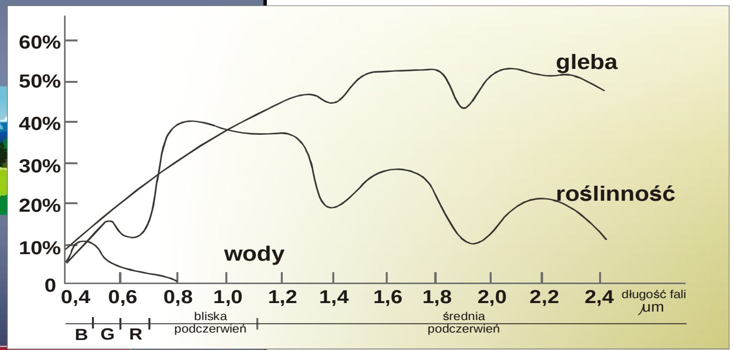
Albedo
(0.52 –0.90 µm)

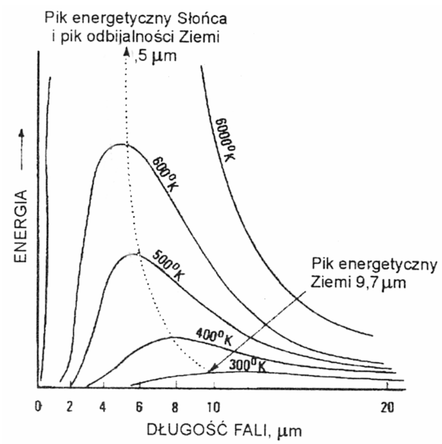


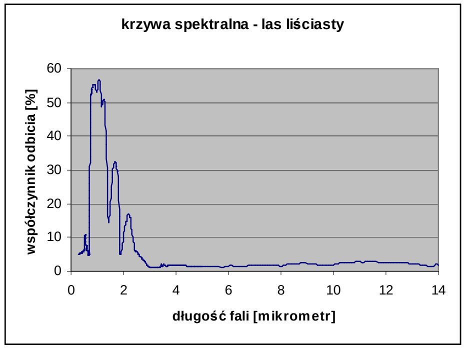
VIR, SWIR, TIR

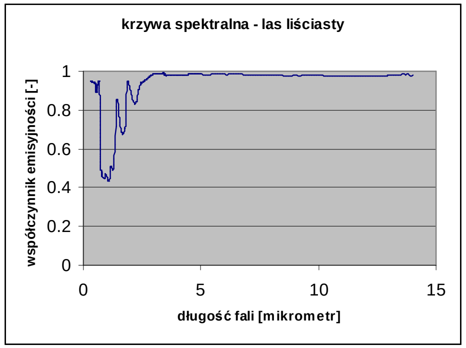


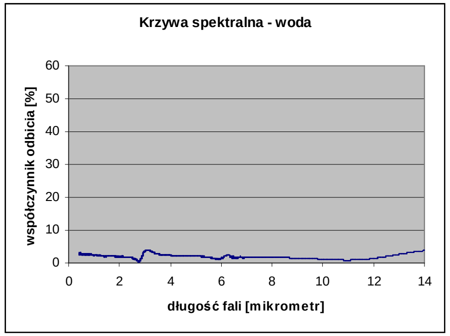
Spectral curves

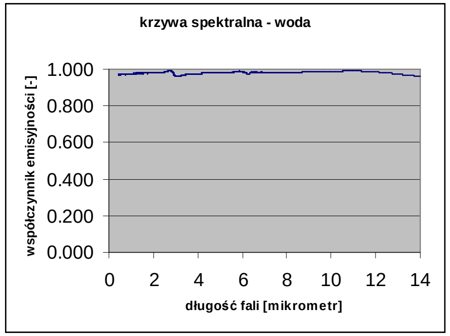












$$E_\rho(\lambda) = \rho(\lambda)\, E(\lambda)$$

$$E_s(\lambda) = \varepsilon(\lambda)\, B(\lambda, T_s) + (1-\varepsilon(\lambda))\, E(\lambda)$$

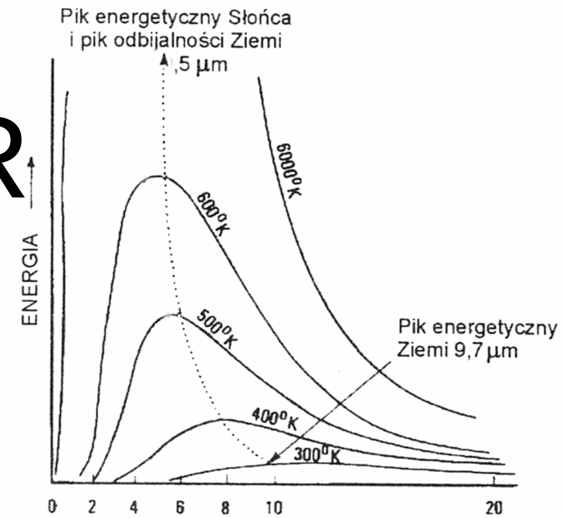
EM laws TIR

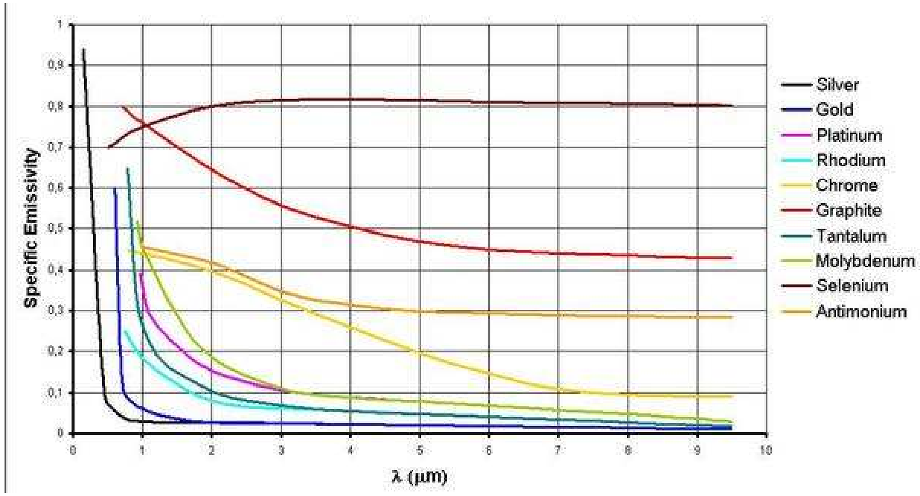
$$M_\lambda = \frac{c_1}{\lambda^5 * [\exp(c_2/\lambda T) - 1]}$$

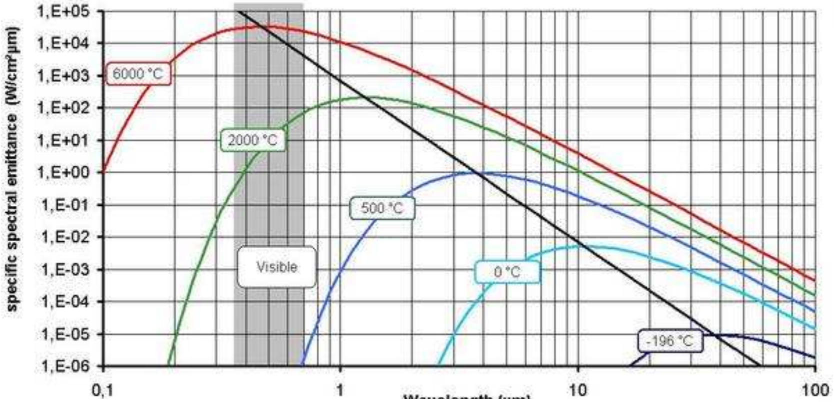
$c_1 = 3{,}74 * 10^{-16}\ W*m^2$

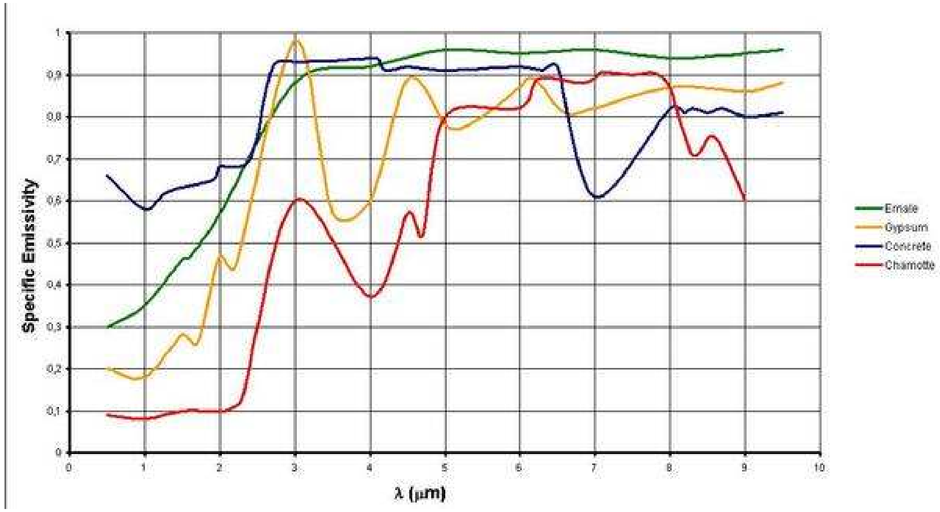
$c_2 = 1{,}44 * 10^{-2}\ K*m$

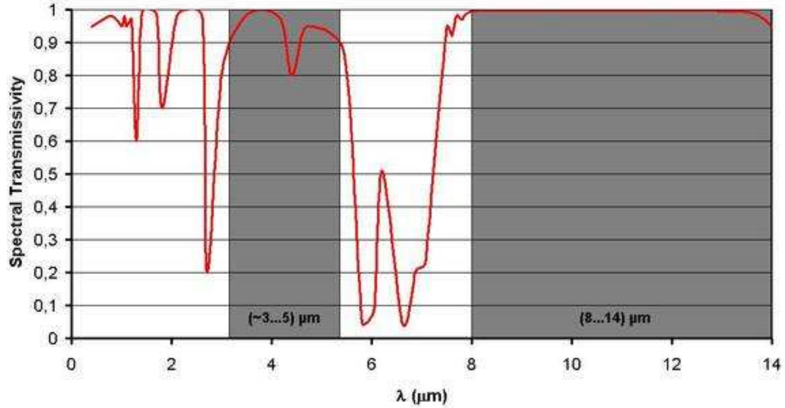
$$\lambda_{max} * T = 2896\ \mu m * K$$









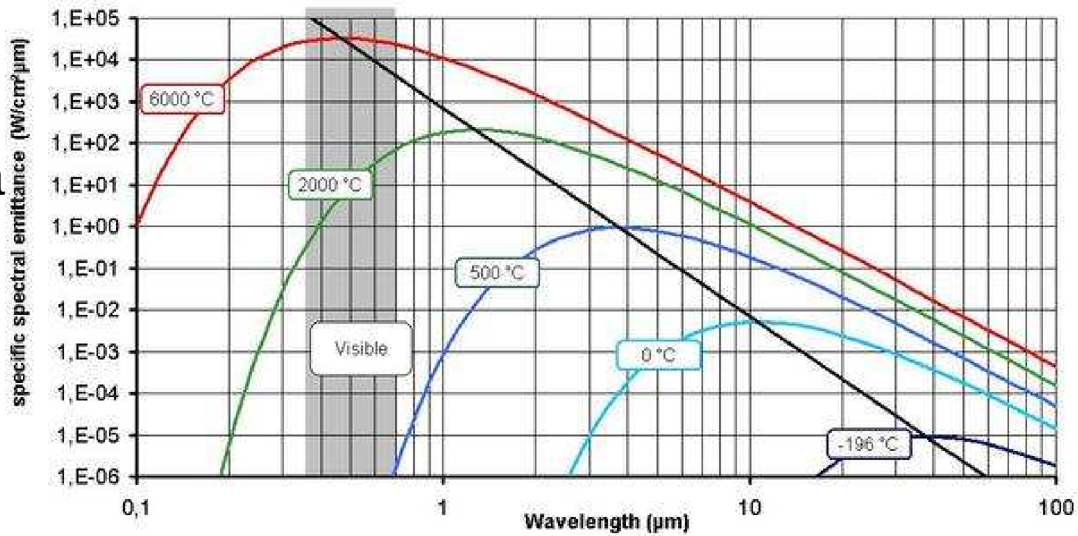


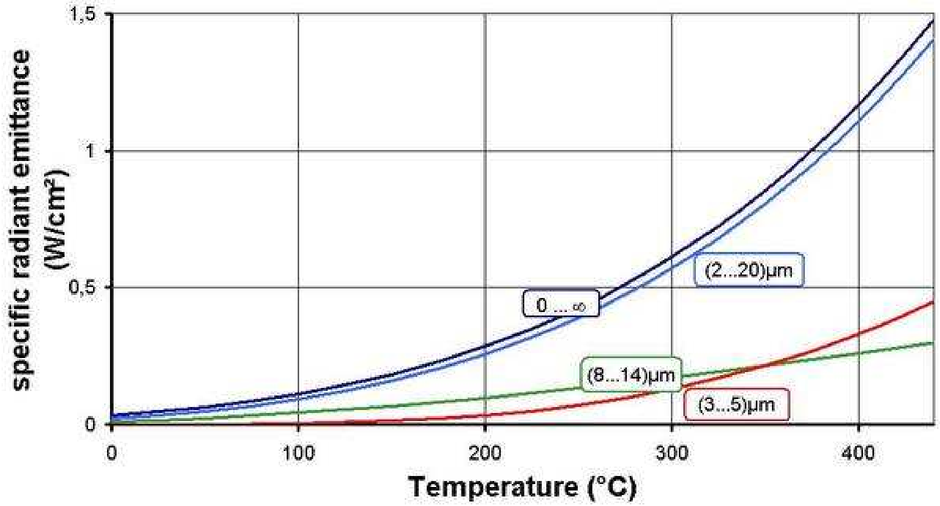
EM laws TIR

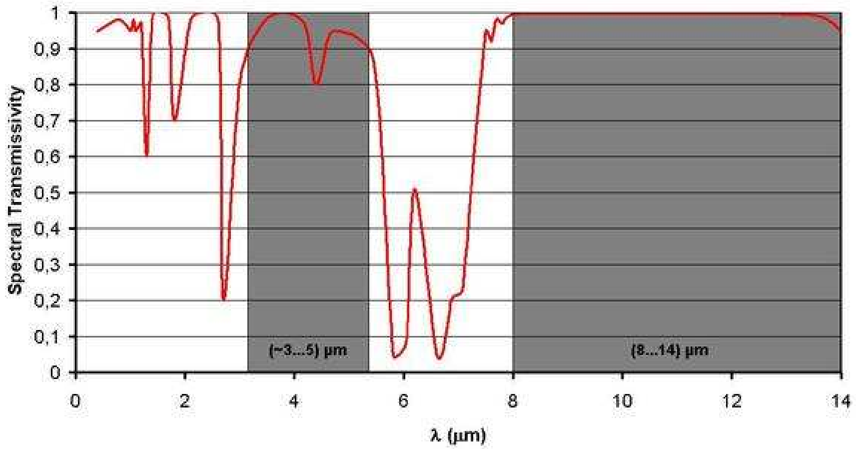
$E = \varepsilon \sigma T^4$

σ - Stefan-Boltzmann consta

$5{,}67 \cdot 10^{-8} W/(m^2 \cdot K)$





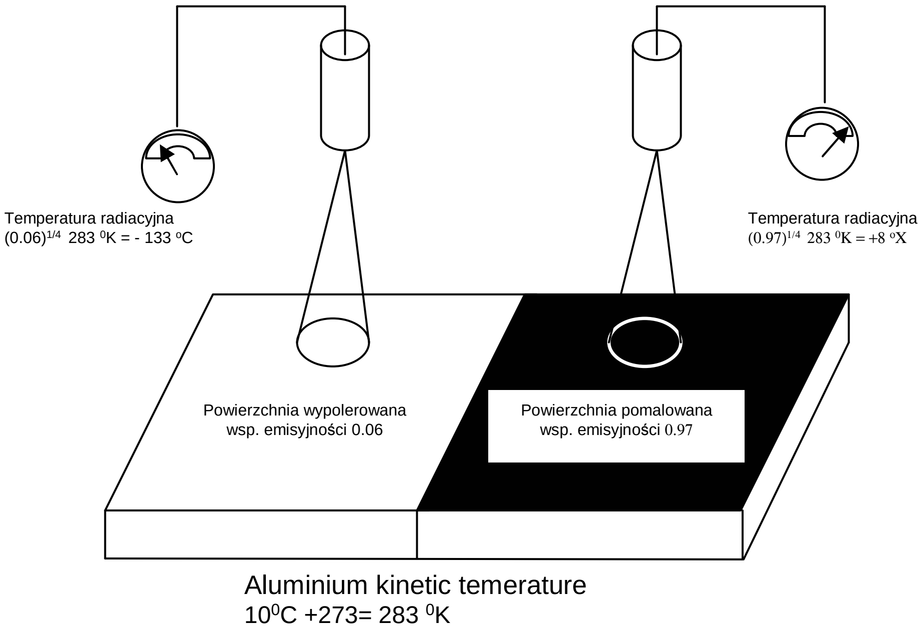


Map algebra - temperature

Radiant temperature

$$T = \sqrt[4]{\varepsilon} \cdot T_{rzecz}$$

$$E = \sigma T^4 = \sigma[(\varepsilon)^{1/4} T_{rzecz}]^4 = \sigma \varepsilon T^4_{rzecz}$$



Radiant temperature

Porównanie temperatury kinetycznej i radiacyjnej typowych obiektów [°C]

obiekt	emisyjność	T.kinetyczna	T. radiacyjna
ciało doskonale cz.	1,00	27,0	27,0
roślinność	0,98	27,0	25,5
gleba wilgotna	0,95	27,0	23,2
gleba sucha	0,92	27,0	20,8

Źródło Kurczyński 2006/ Lillesand, Kiefer, 2000

Map algebra - temperature

Temperature

$$L_\lambda = gain \cdot DN + offset = \left(\left(L_{\max} - L_{\min}\right)/255\right) \cdot DN + L_{\min}$$

$$\left(W \cdot m^{-2} \cdot sr^{-1} \cdot \mu m^{-1}\right)$$

- where:
- L_λ – spectral radiance of the sensor,
- L_{min} – minimum spectral radiance , in thermal band 0.00,
- L_{max} – maximum spectral radiance , in thermal band 17.04
- DN – of thermal band

Map algebra - temperature

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$$c_1 = 3{,}74 * 10^{-16}\ W*m^2$$
$$c_2 = 1{,}44 * 10^{-2}\ K*m$$

$$T = \frac{K_2}{\ln\left(\frac{K_1}{L_\lambda} + 1\right)}$$

gdzie:

L_λ – luminancja spektralna zarejestrowana przez radiometr satelity $\left(W \cdot m^{-2} \cdot sr^{-1} \cdot \mu m^{-1}\right)$

K_1, K_2 - stałe kalibracyjne

$$K_1 = \frac{2 \cdot \pi \cdot c^2 \cdot h}{\lambda^5} = 666.09 \left(\frac{W}{m^2 \cdot sr \cdot \mu m}\right)$$

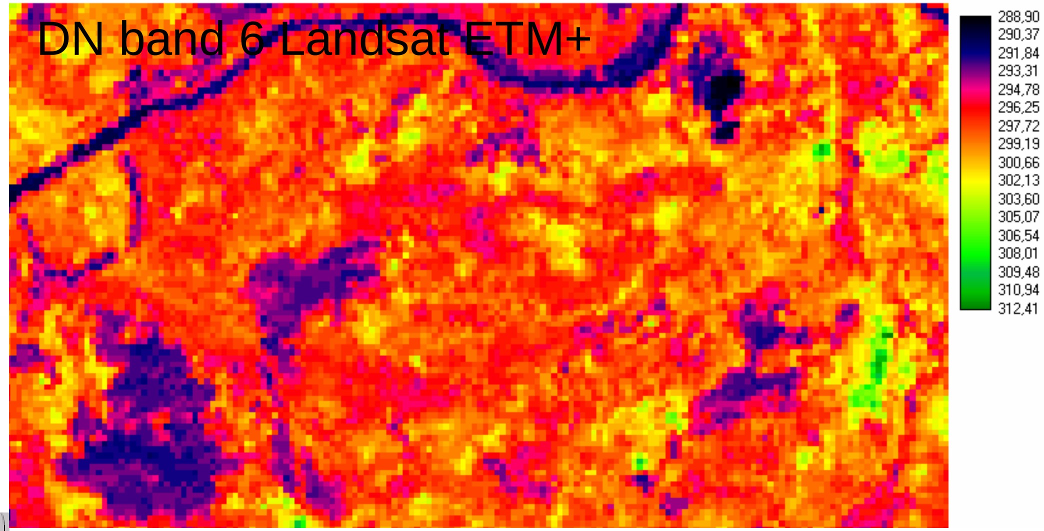
$$K_2 = \frac{h \cdot c}{k \cdot \lambda} = 1282.71\ (K)$$

k – stała Boltzmanna $1{,}380 \cdot 10^{-23} \left(\frac{J}{K}\right)$

h – stała Planka $6{,}626 \cdot 10^{-34}\ (J \cdot s)$

c – prędkość światła $2{,}998 \cdot 10^{8} \left(\frac{m}{s}\right)$

λ – długość fali (m)



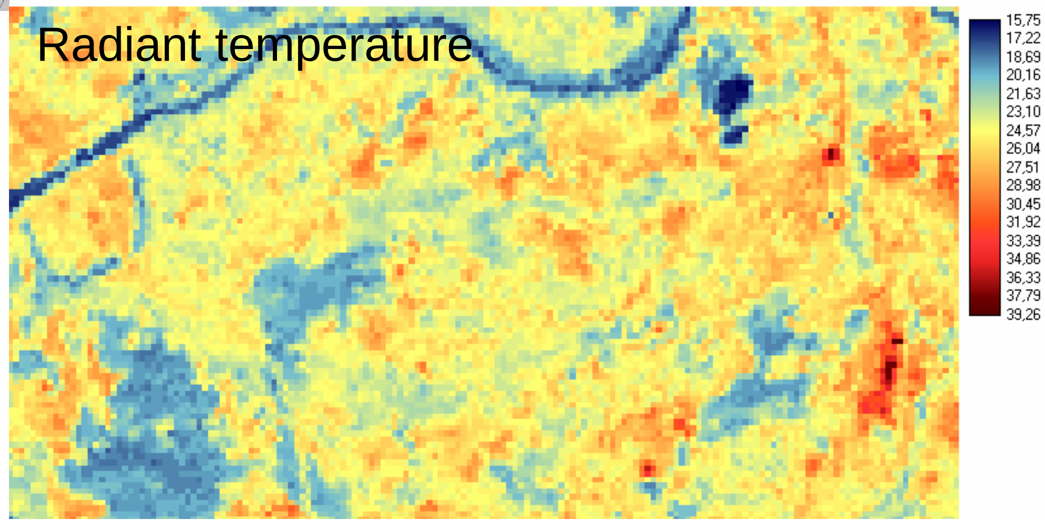


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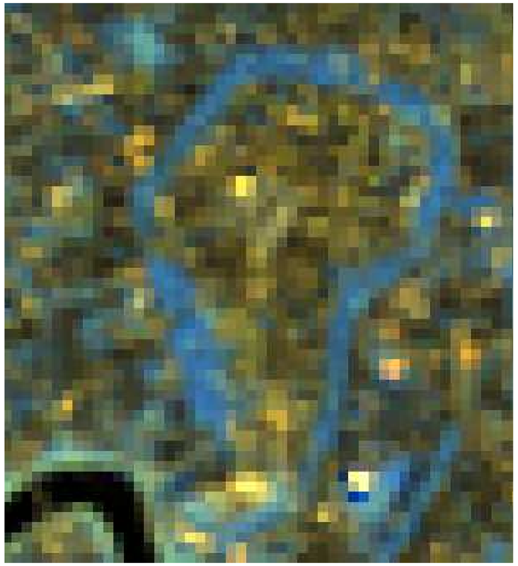
Image fusion



Multispectral image
composition
low spatial
resolution

+

PAN
High spatial
resoluion

=

merging, band sharpening …

Image fusion

IHS TRANSFORMATION

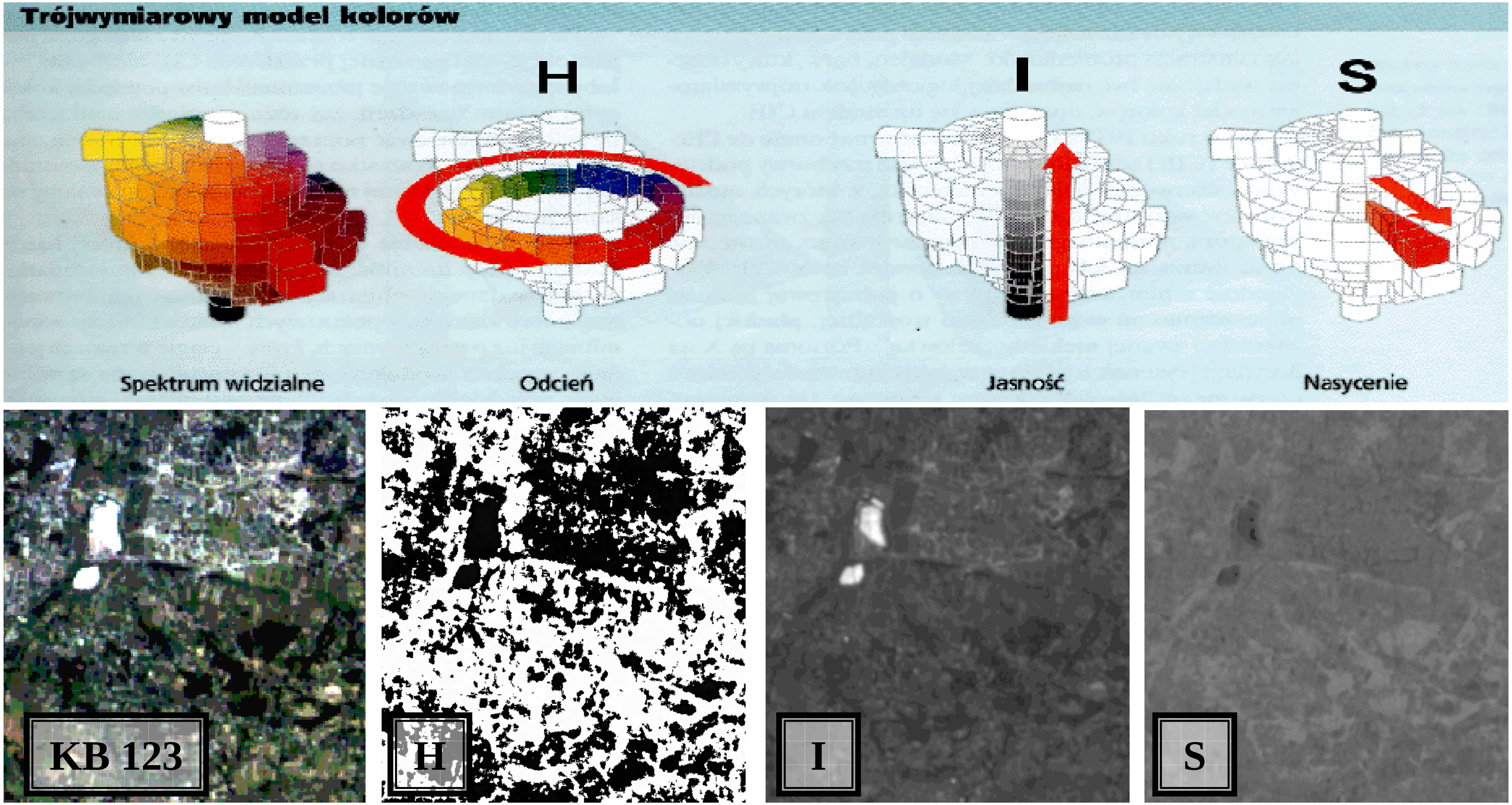


Image fusion

IHS TRANSFORMATION

$$\begin{pmatrix} I \\ \nu_1 \\ \nu_2 \end{pmatrix} = \begin{pmatrix} \frac{1}{\sqrt{3}} & \frac{1}{\sqrt{3}} & \frac{1}{\sqrt{3}} \\ \frac{1}{\sqrt{6}} & \frac{1}{\sqrt{6}} & -\frac{2}{\sqrt{6}} \\ \frac{1}{\sqrt{2}} & -\frac{1}{\sqrt{2}} & 0 \end{pmatrix} * \begin{pmatrix} R \\ G \\ B \end{pmatrix} \quad (a)$$

$$\begin{pmatrix} R \\ G \\ B \end{pmatrix} = \begin{pmatrix} \frac{1}{\sqrt{3}} & \frac{1}{\sqrt{6}} & \frac{1}{\sqrt{2}} \\ \frac{1}{\sqrt{3}} & \frac{1}{\sqrt{6}} & -\frac{1}{\sqrt{2}} \\ \frac{1}{\sqrt{3}} & -\frac{2}{\sqrt{6}} & 0 \end{pmatrix} * \begin{pmatrix} I \\ \nu_1 \\ \nu_2 \end{pmatrix}$$

$$H = \tan^{-1}\left(\frac{\nu_2}{\nu_1}\right) \quad (b) \qquad S = \sqrt{\nu_1^2 + \nu_2^2} \quad (c)$$

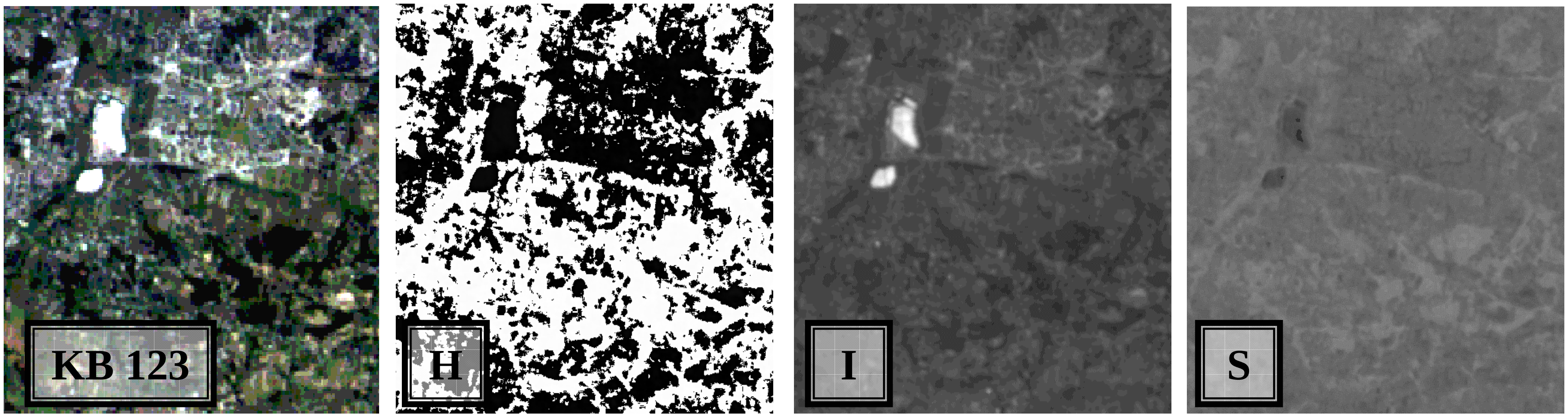


Image fusion

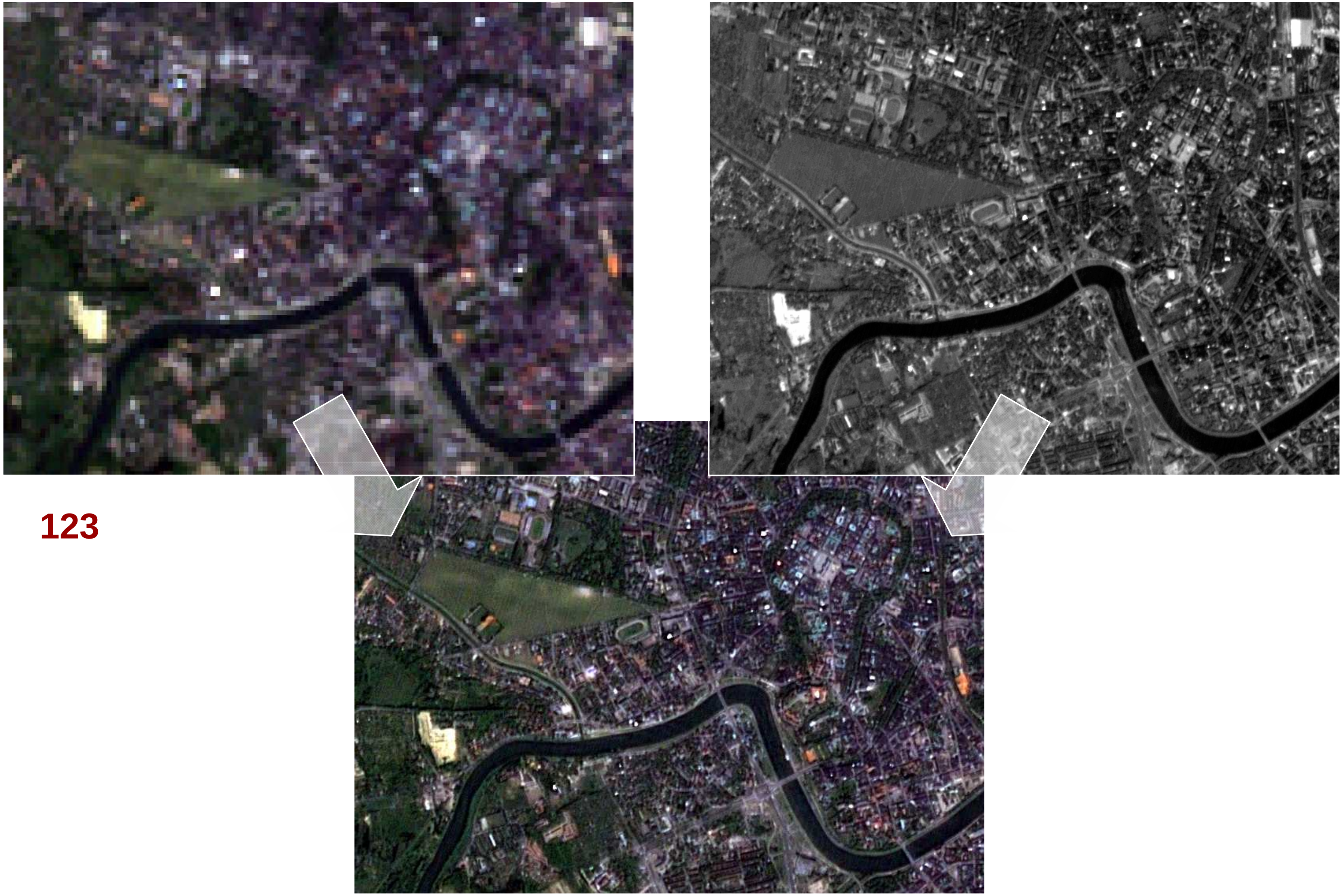


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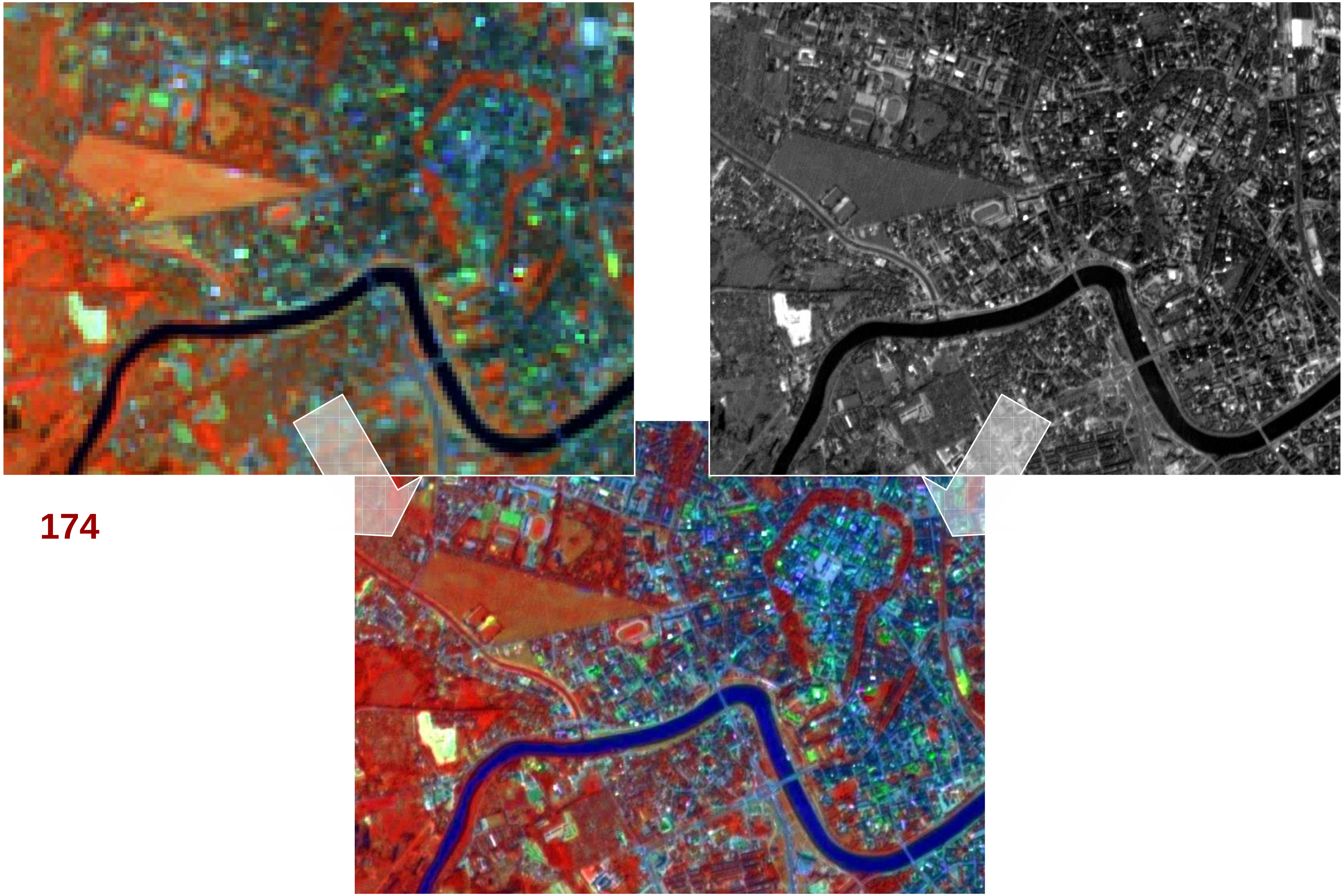
Image fusion



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