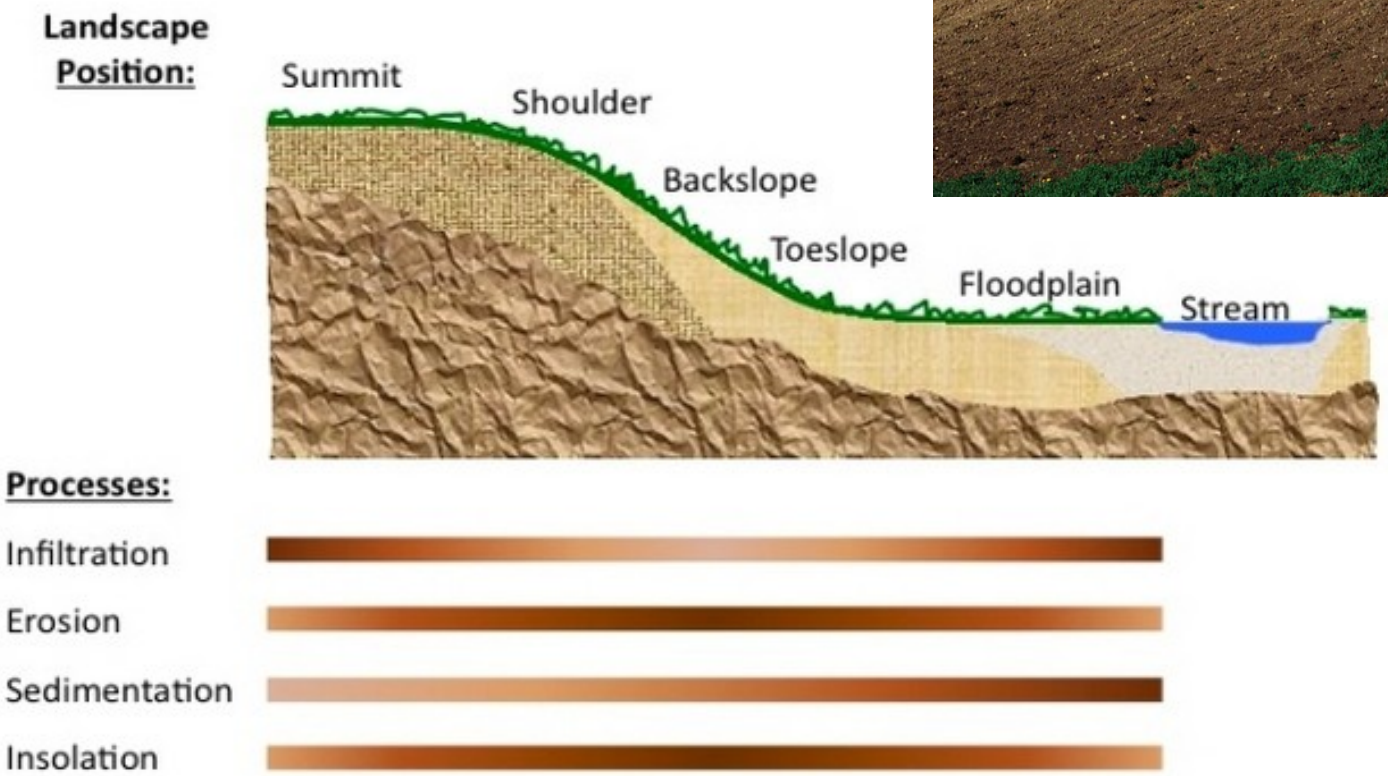
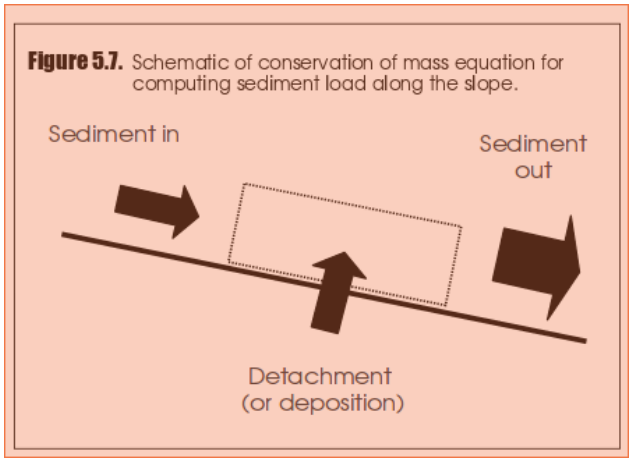
Modelowanie procesów

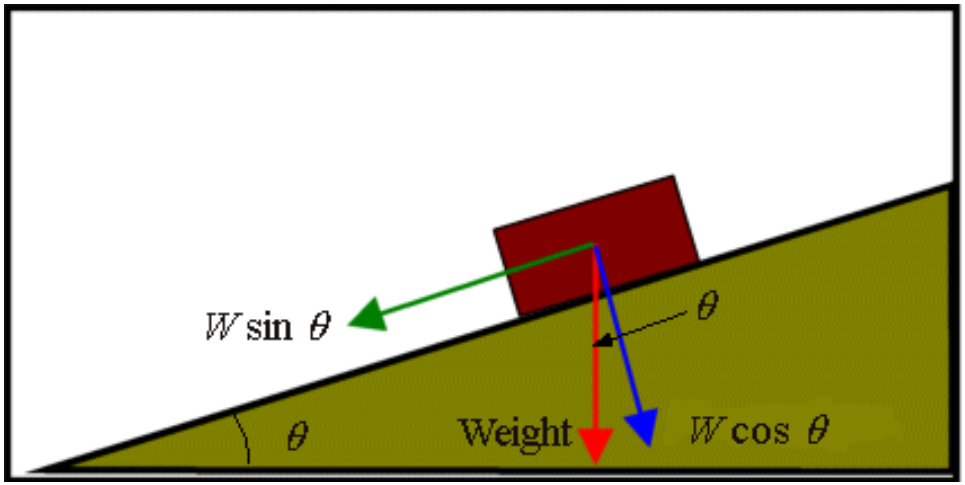
Spływ powierzchniowy

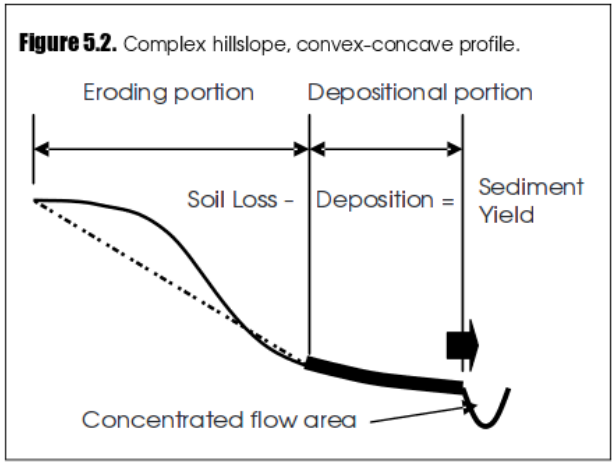


Co wpływa na procesy stokowe?

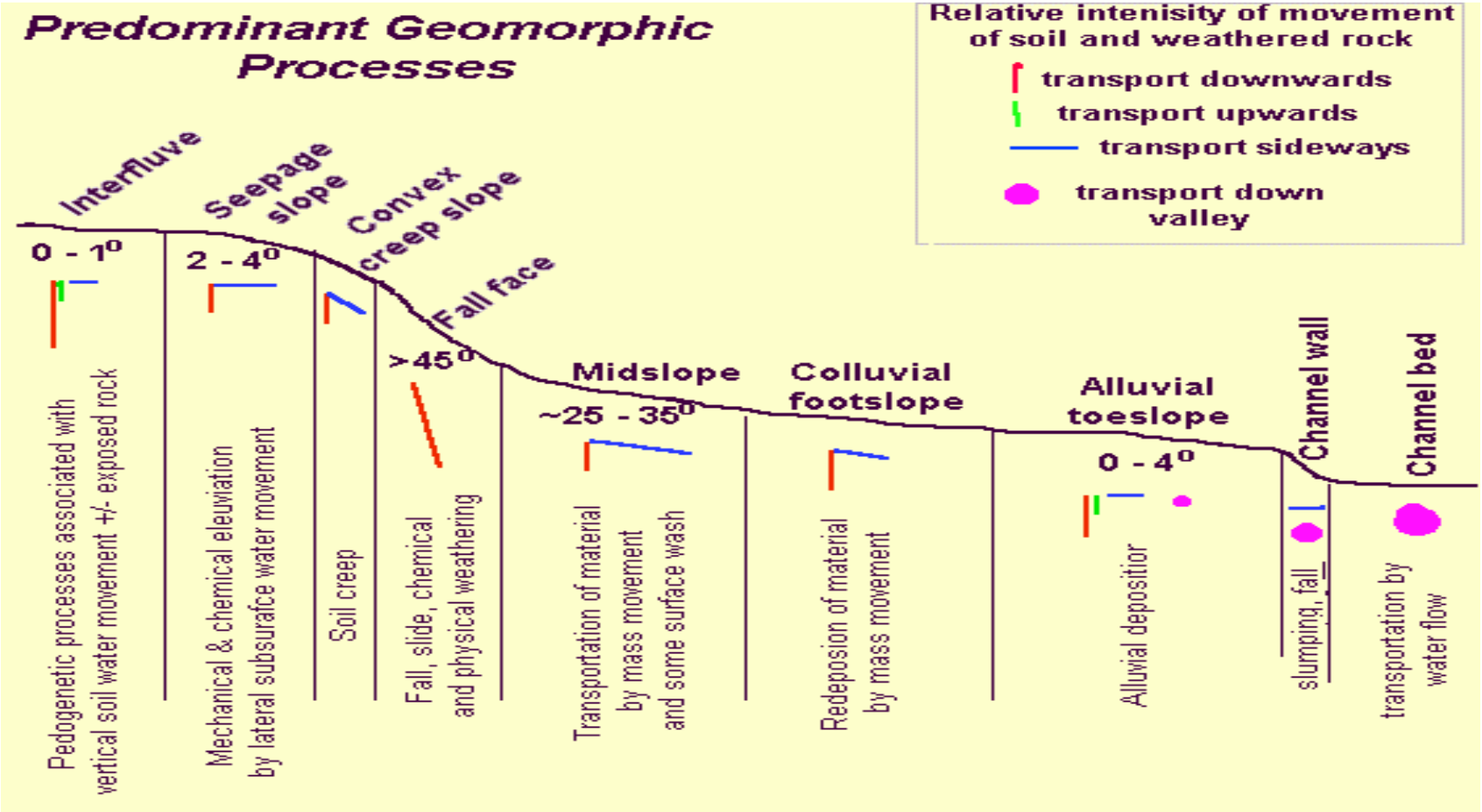
siły działające na stoku



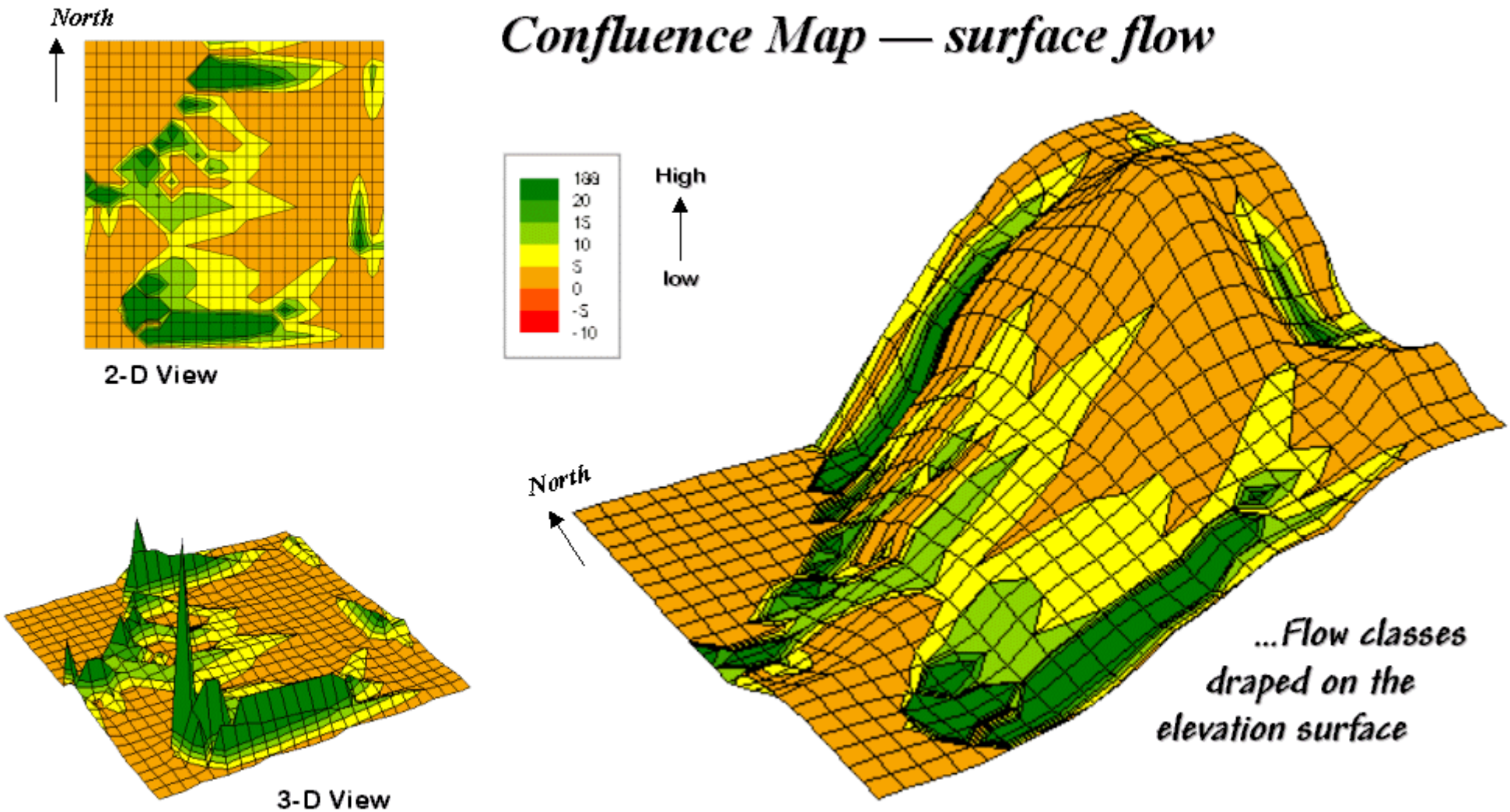




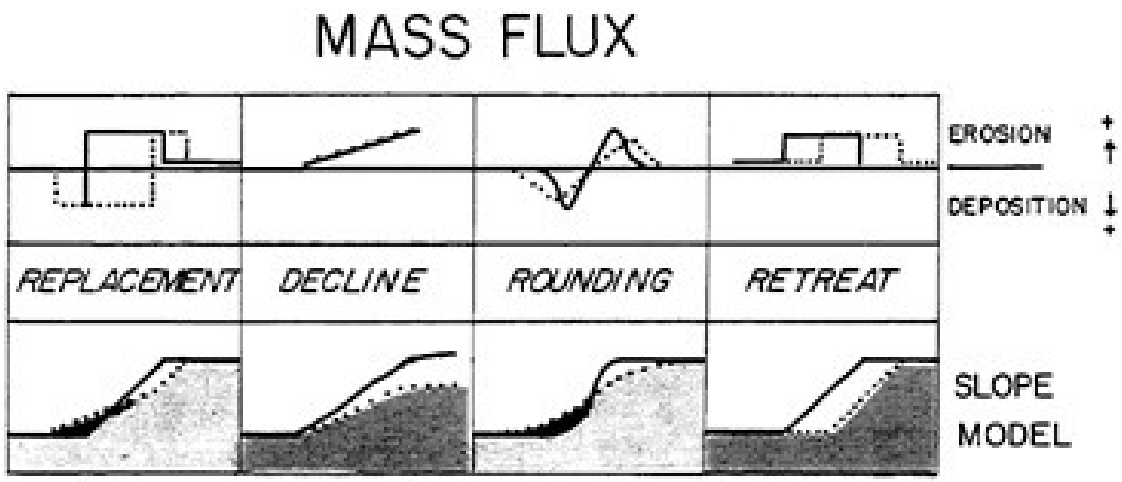
Modelowanie procesów stokowych

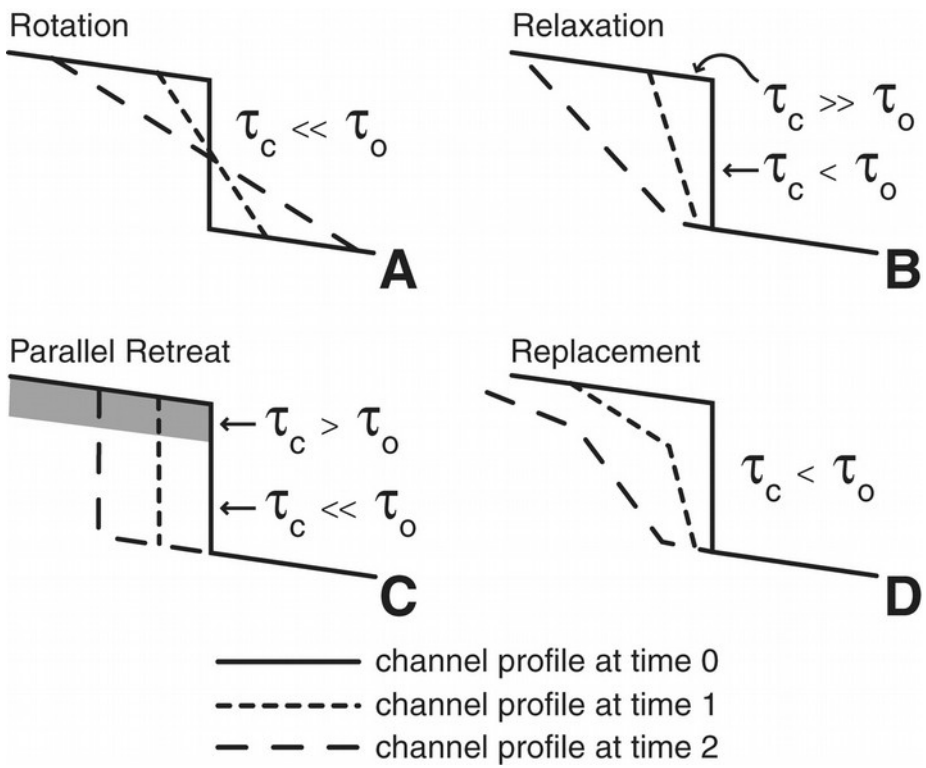


Procesy stokowe

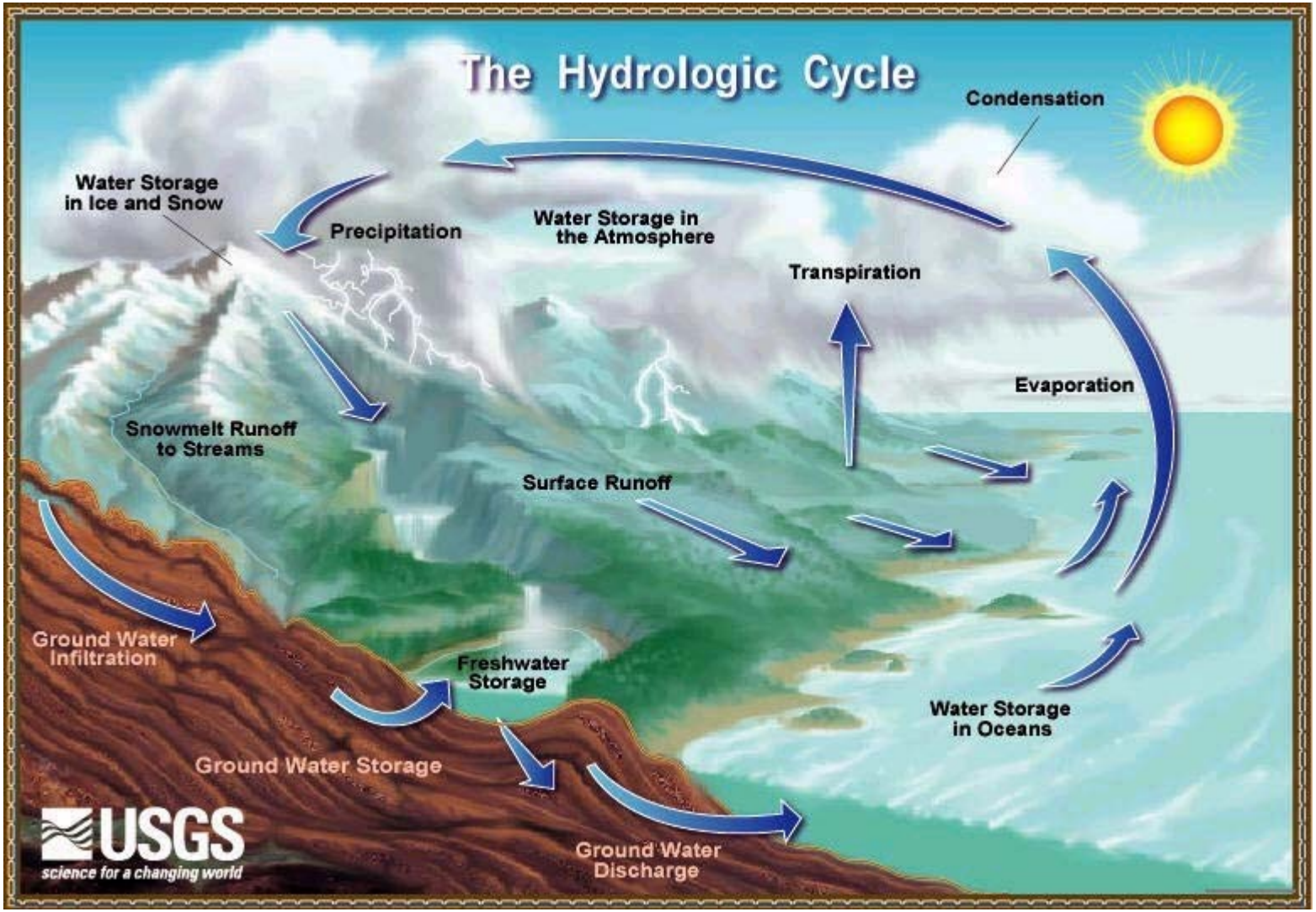


Ewolucja stoków

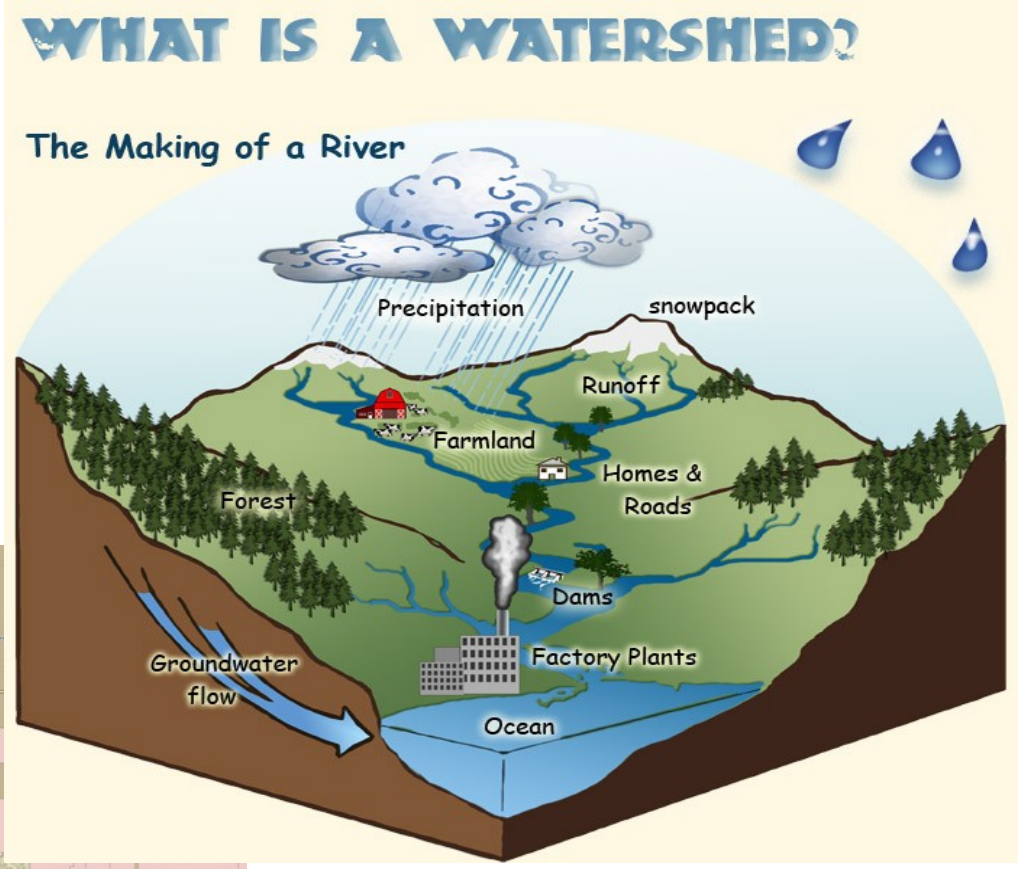


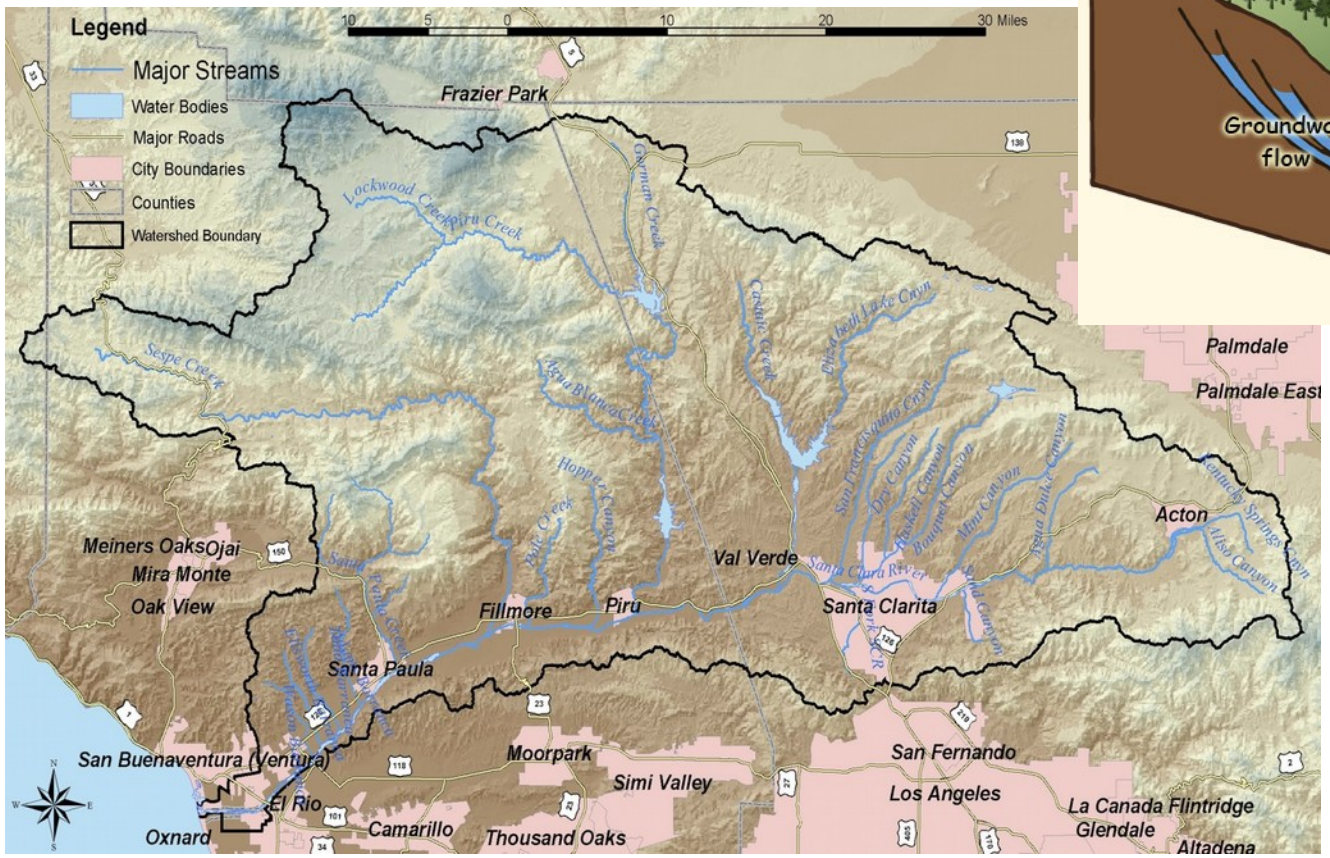


Obieg wody w przyrodzie

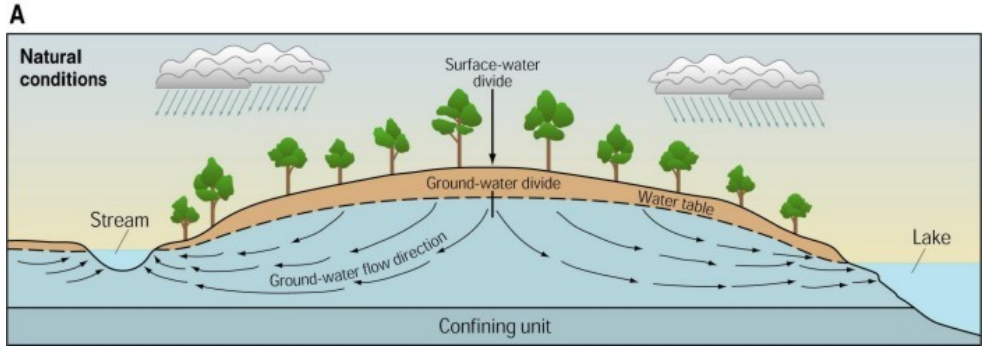


Co to jest zlewnia?





Wododziały


A
Natural conditions
Surface-water divide
Ground-water divide
Water table
Stream
Lake
Ground-water flow direction
Confining unit

Modelowanie procesów w zlewni

Przygotowanie DEM

Modelowanie struktury odpływu

Modelowanie wododziałów

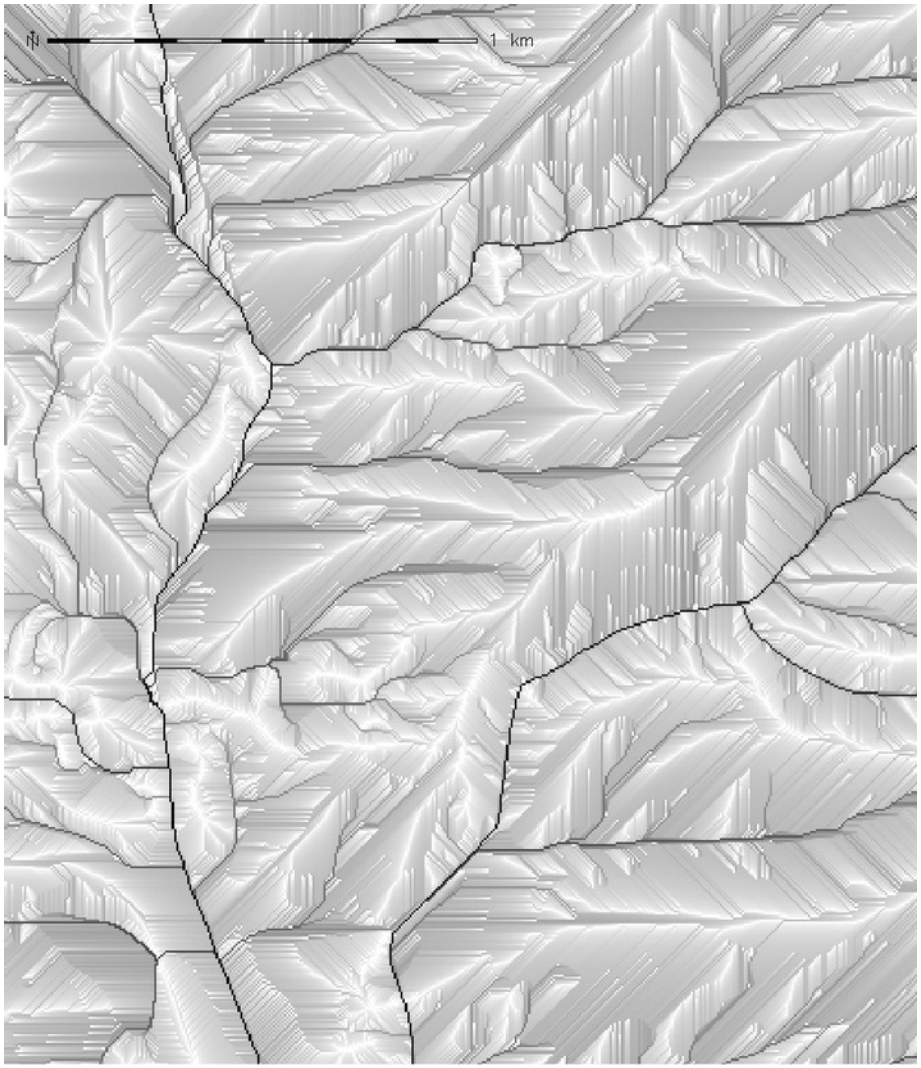
Podział na system korytowy i stokowy

Analiza hortonowska systemu koryt

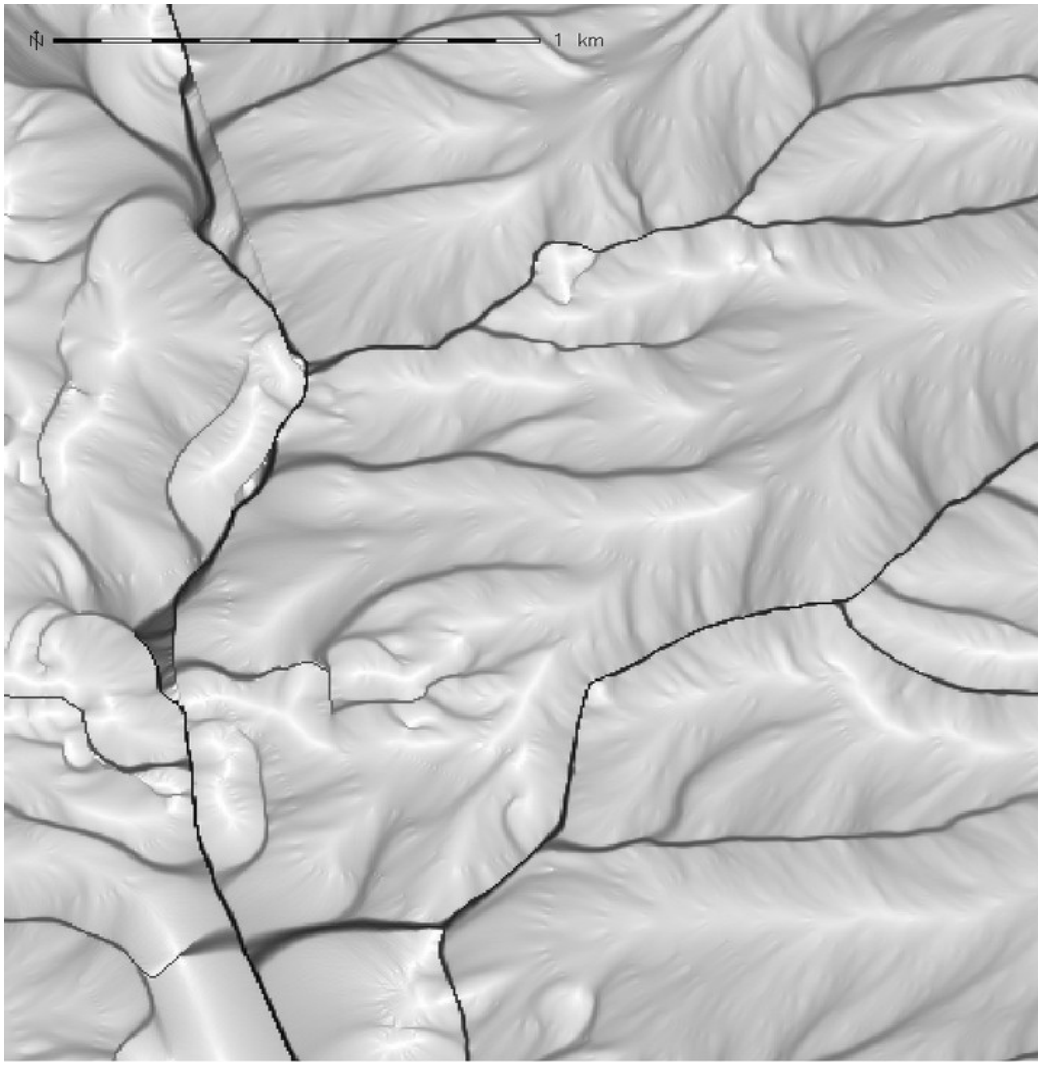
Analiza systemu stokowego

Modelowanie czasowo-przestrzene

Jak modelować spływ powierzchniowy

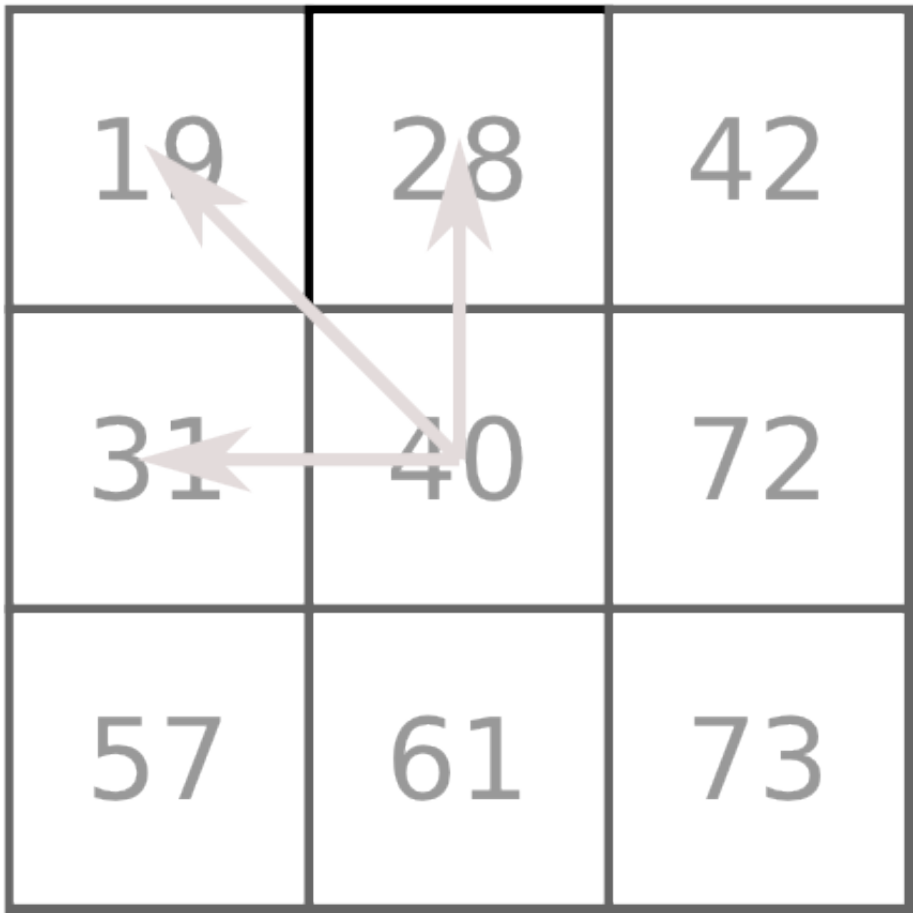


Single Flow direction



Multiple Flow direction

Kierunek spływu na modelu wysokościowym



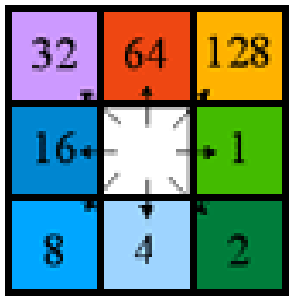
Definicja

78	72	69	71	58	49
74	67	56	49	46	50
69	53	44	37	38	48
64	58	55	22	31	24
68	61	47	21	16	19
74	53	34	12	11	12

Elevation surface

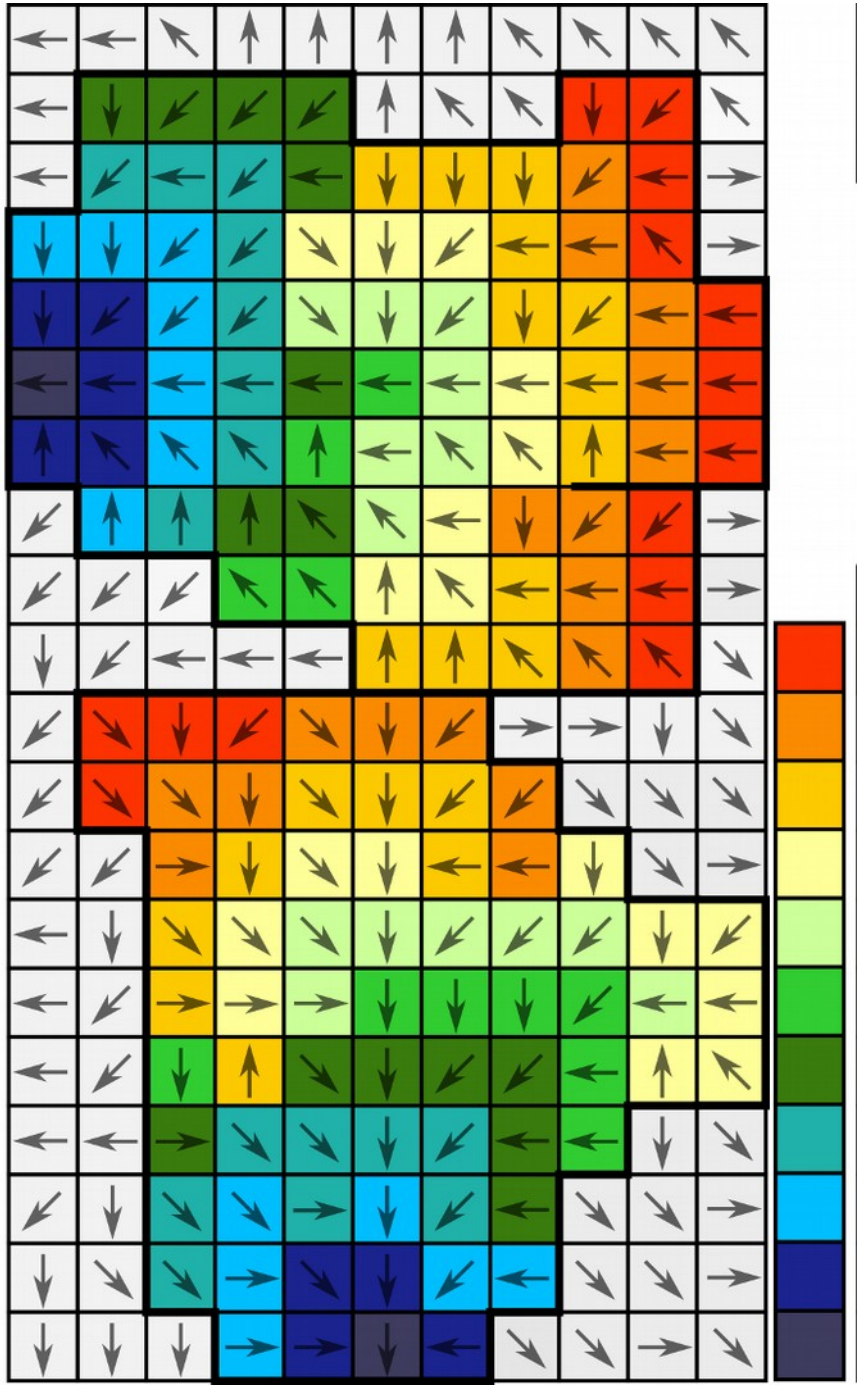
2	2	2	4	4	8
2	2	2	4	4	8
1	1	2	4	8	4
128	128	1	2	4	8
2	2	1	4	4	4
1	1	1	1	4	16

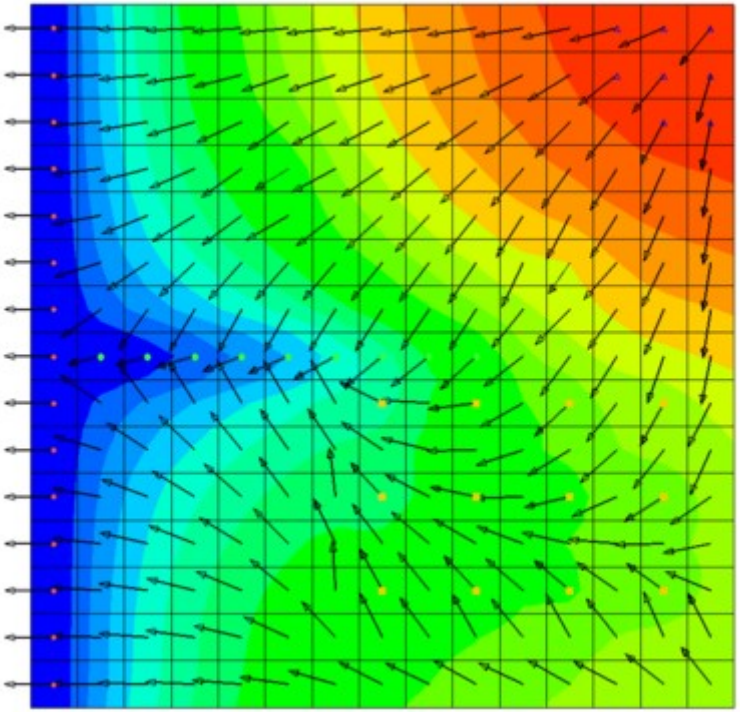
Flow direction

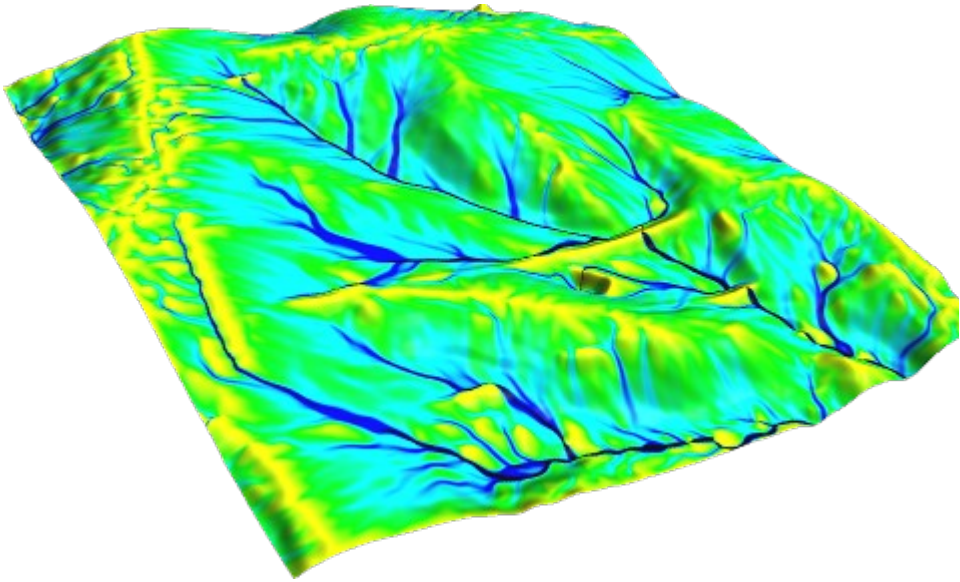


Direction coding

Akumulacja spływu

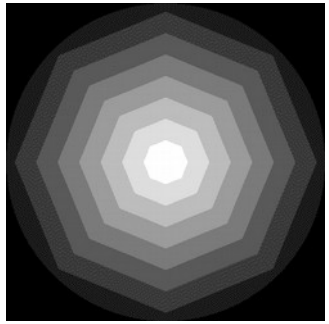


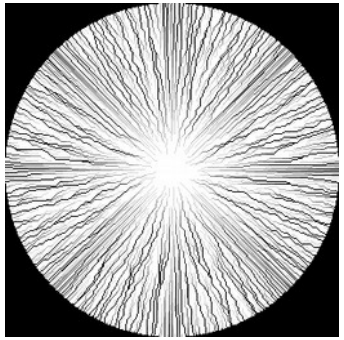




Metody wyznaczania

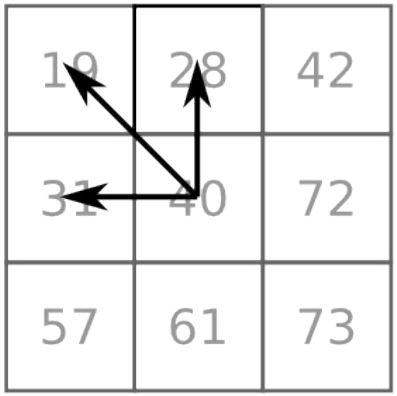
D8





Rho8

A



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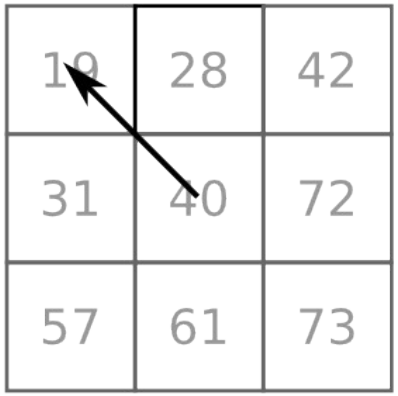

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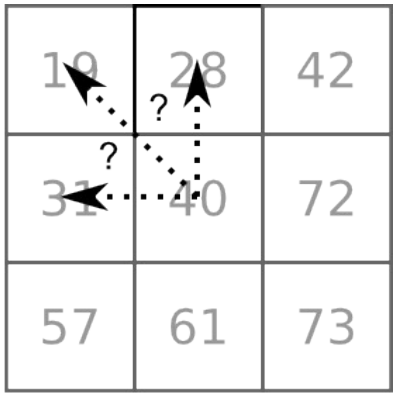

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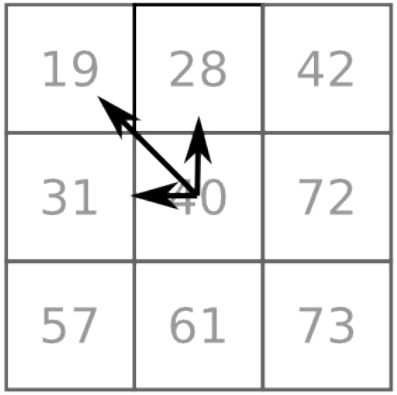
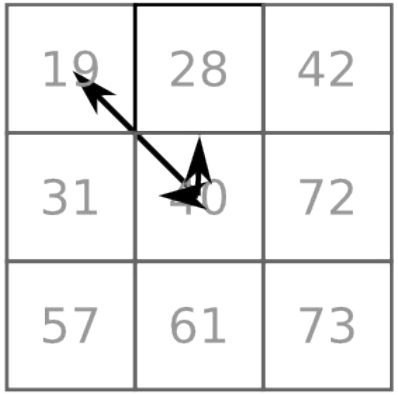
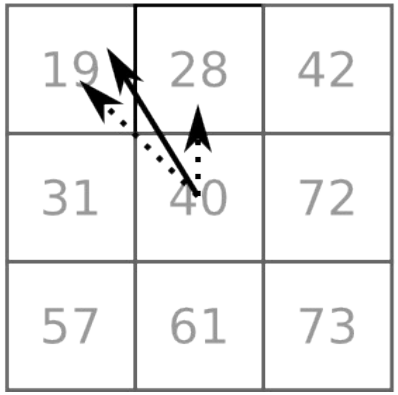
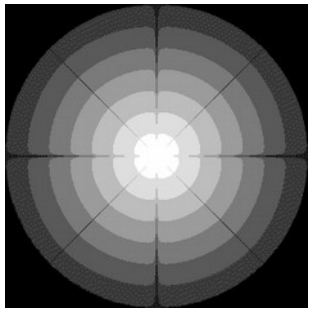


E



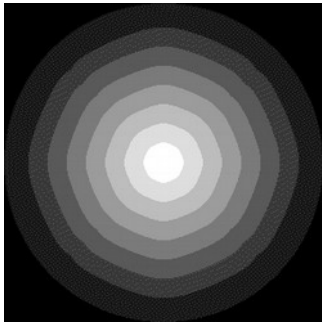
F



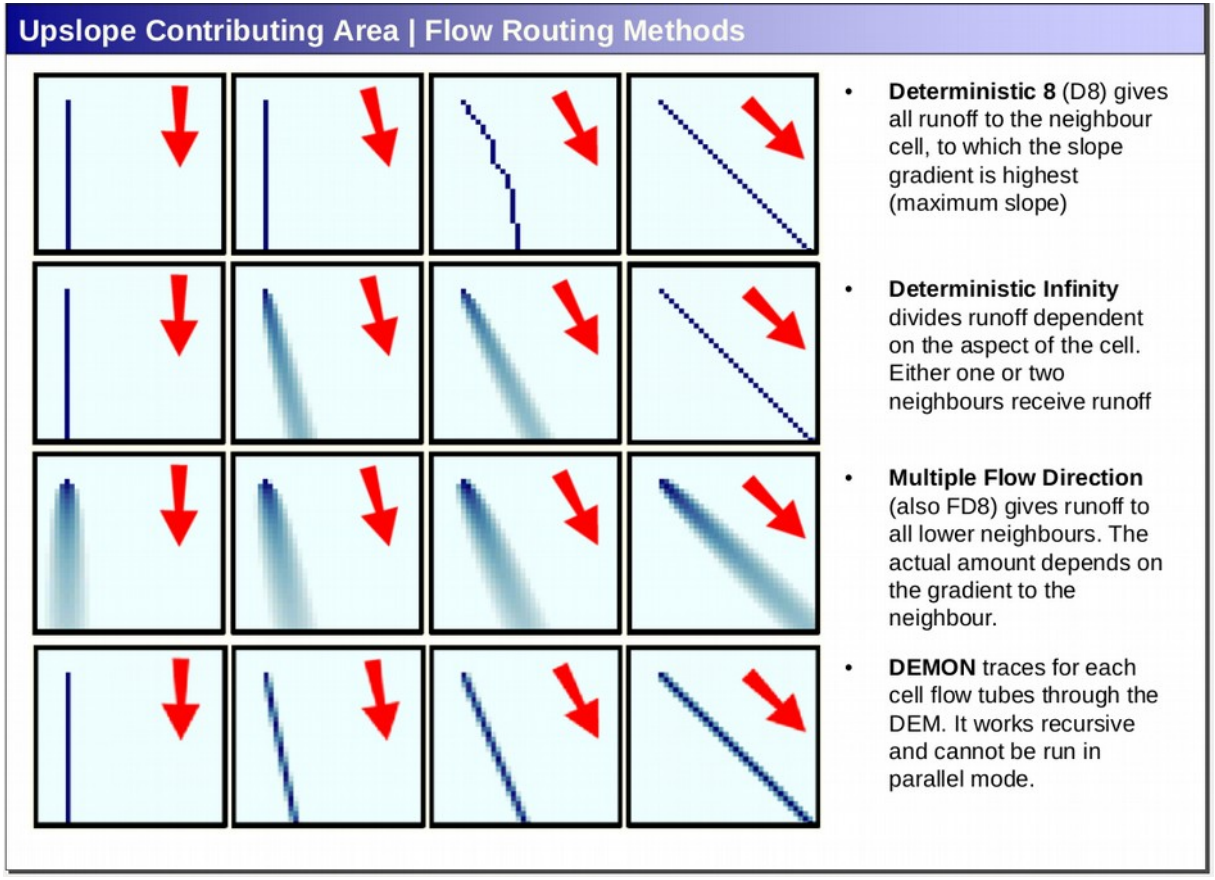


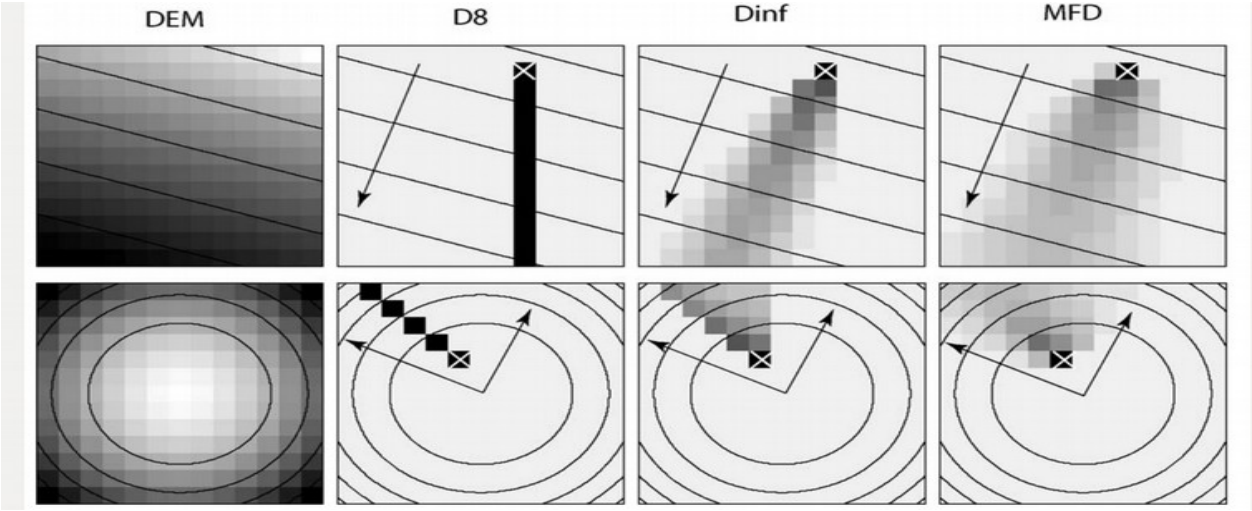
MD8

Dinf

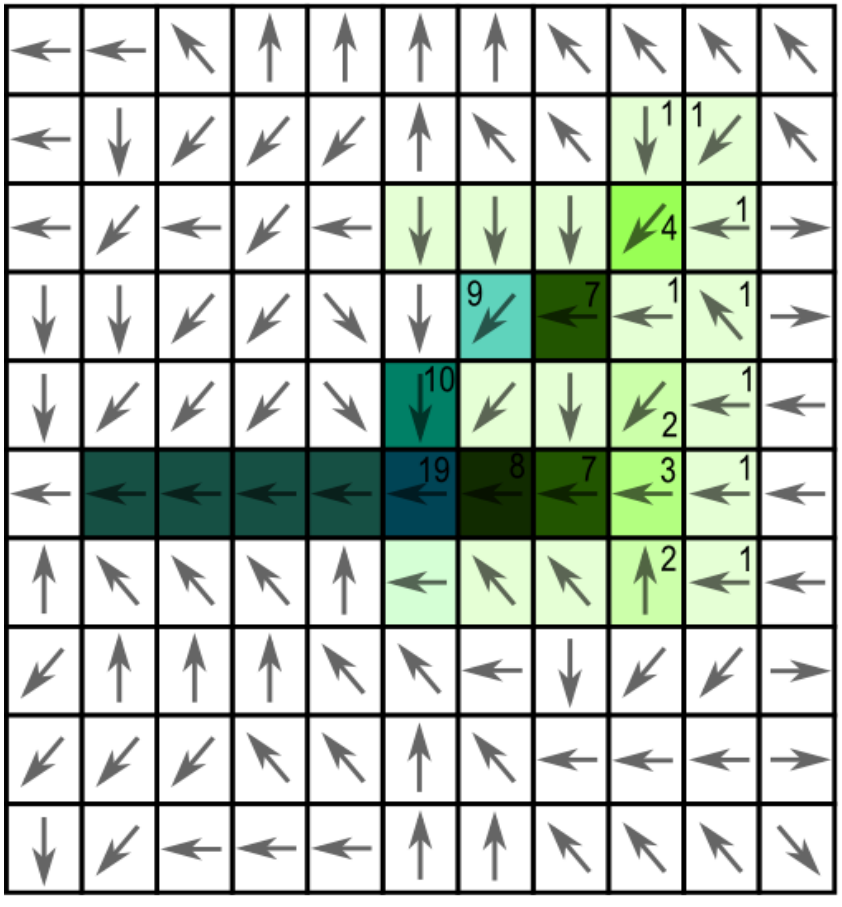


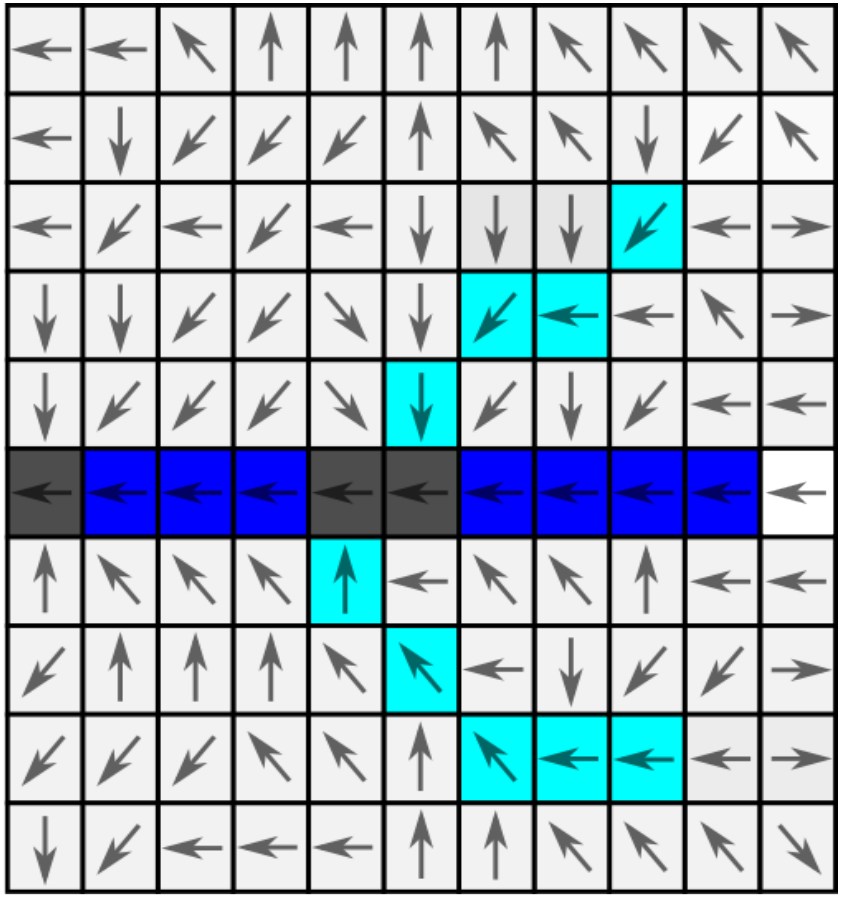
Sposób odwzorowania

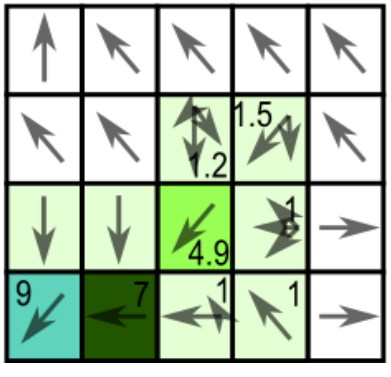




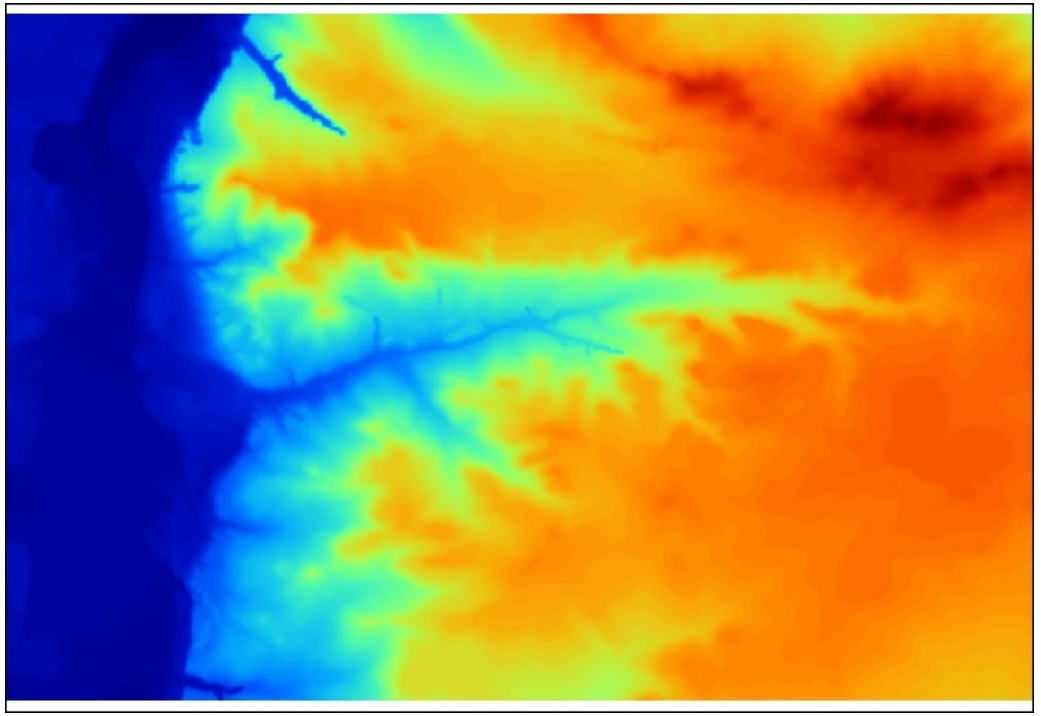
Akumulacja spływu

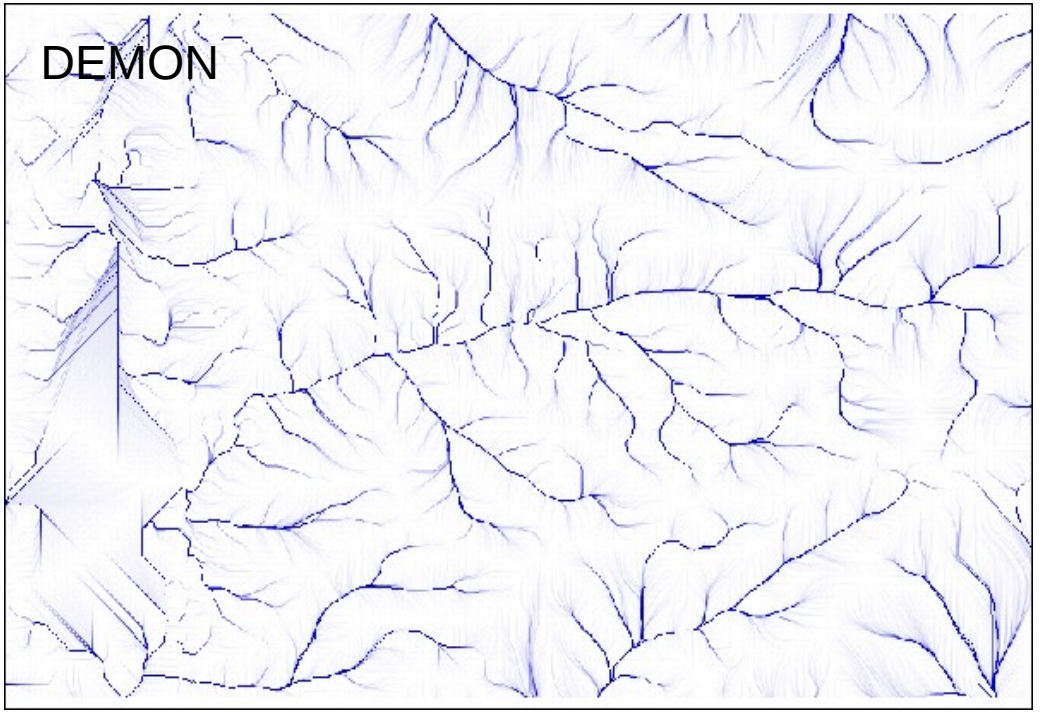


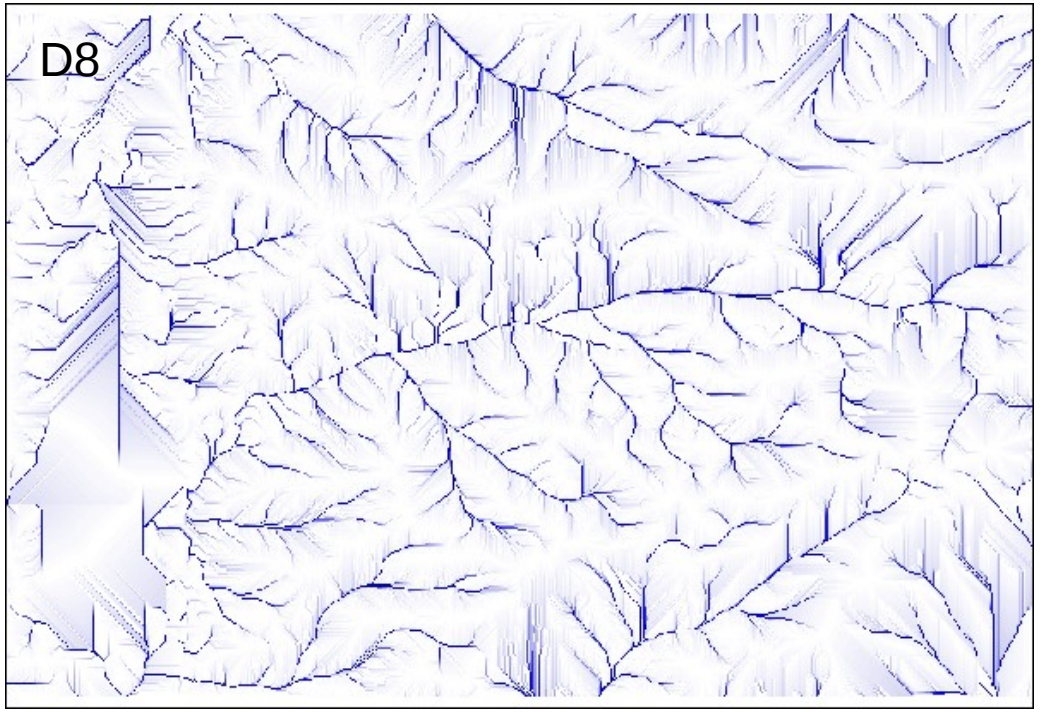


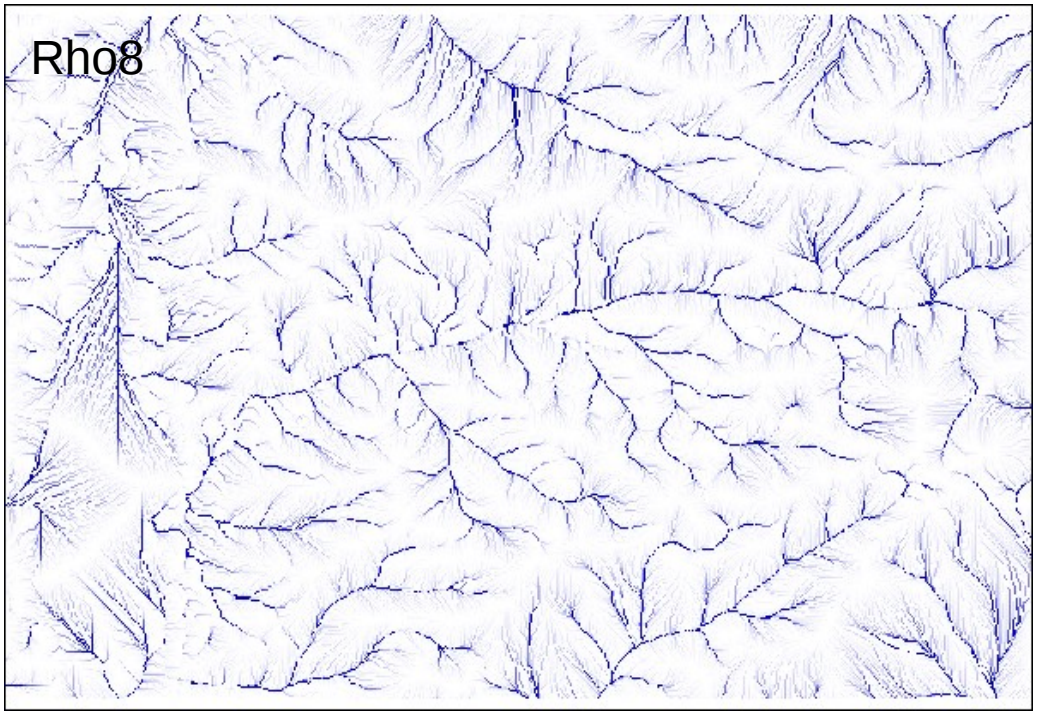


Przykład: różne metody

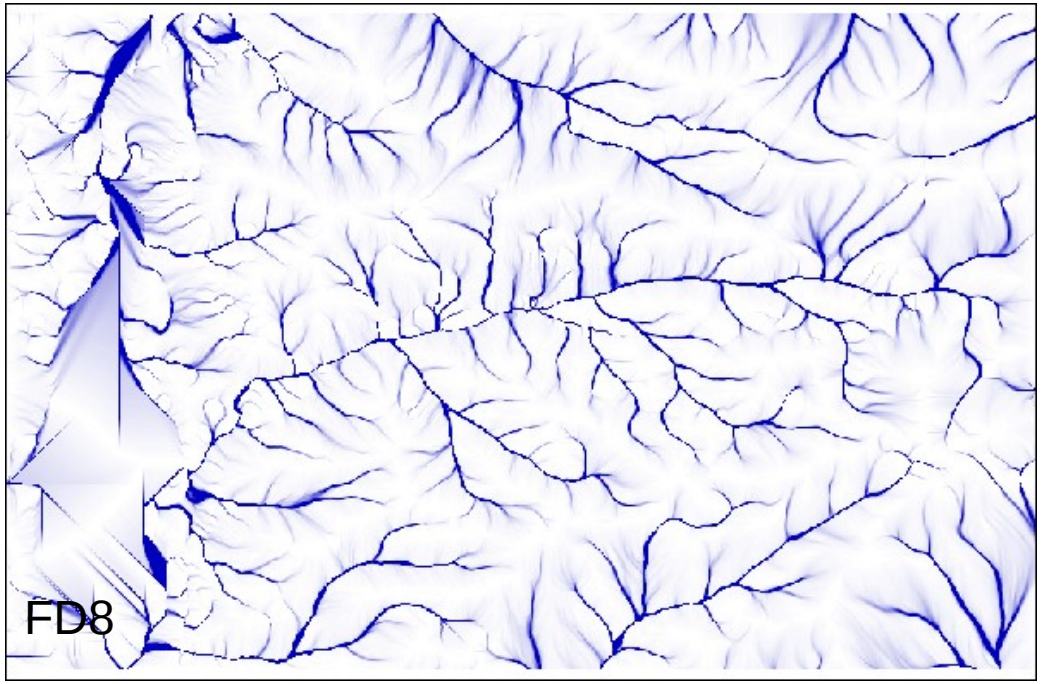


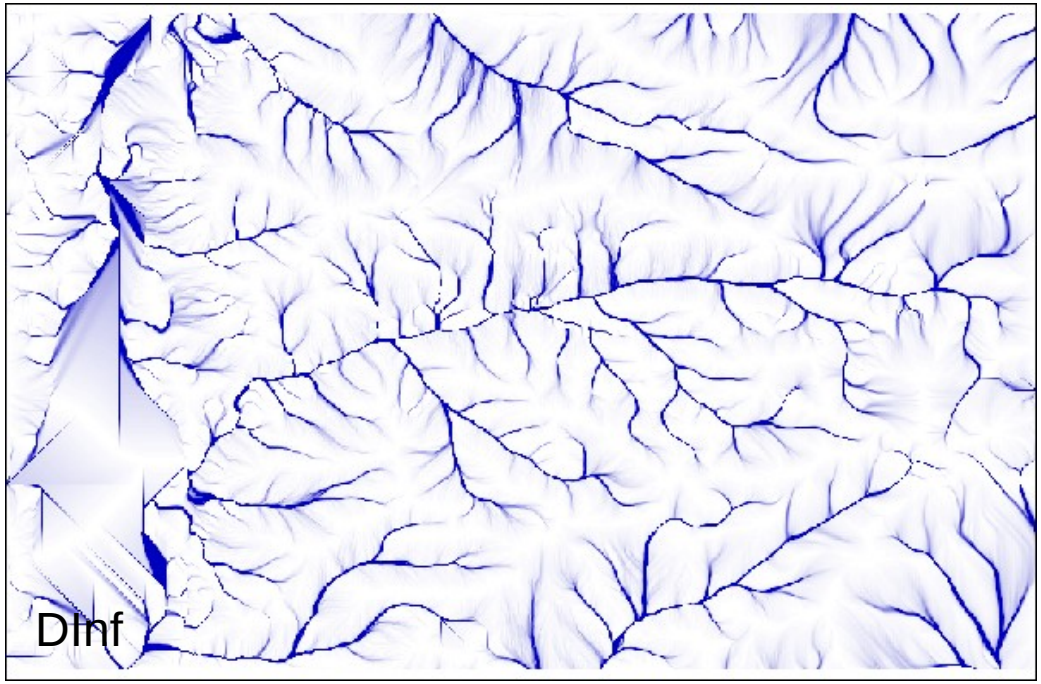


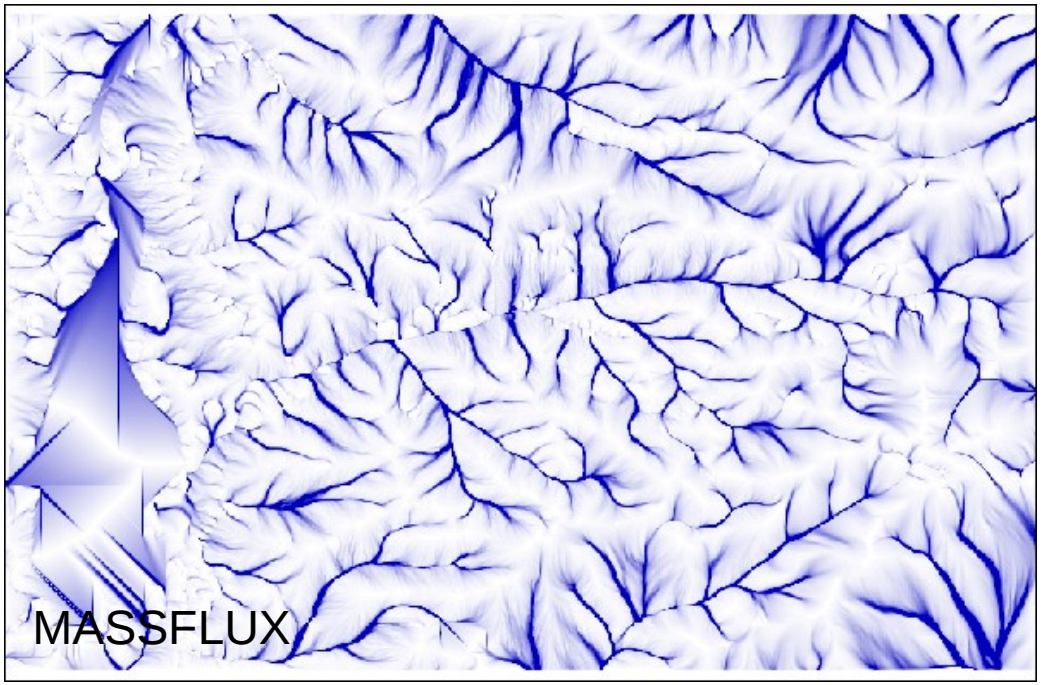




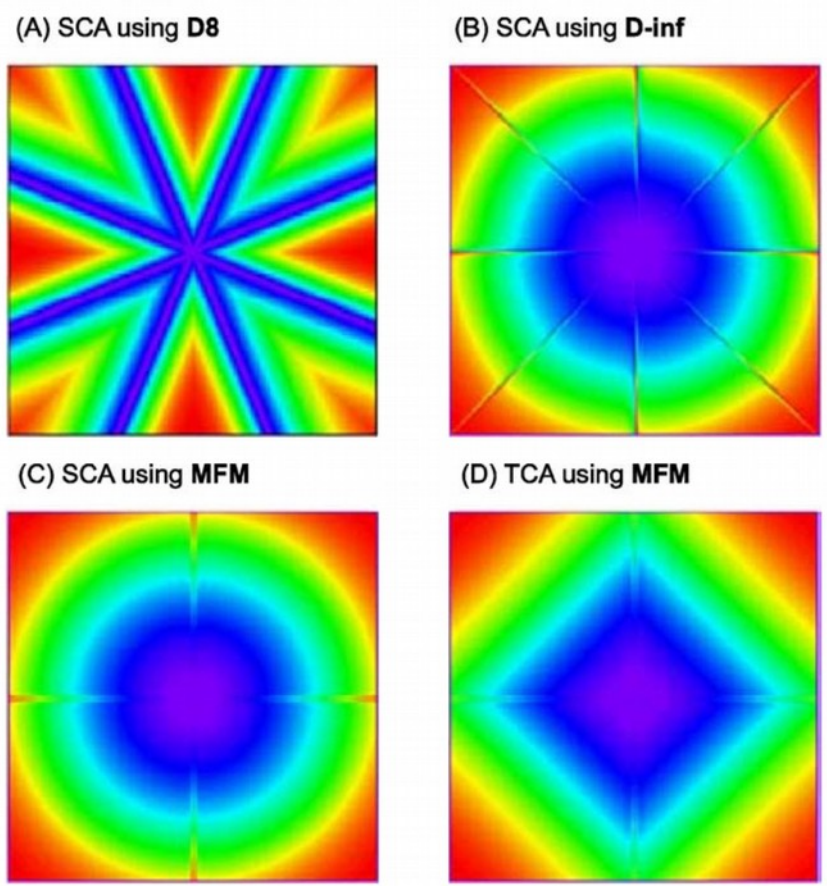
Różne metody





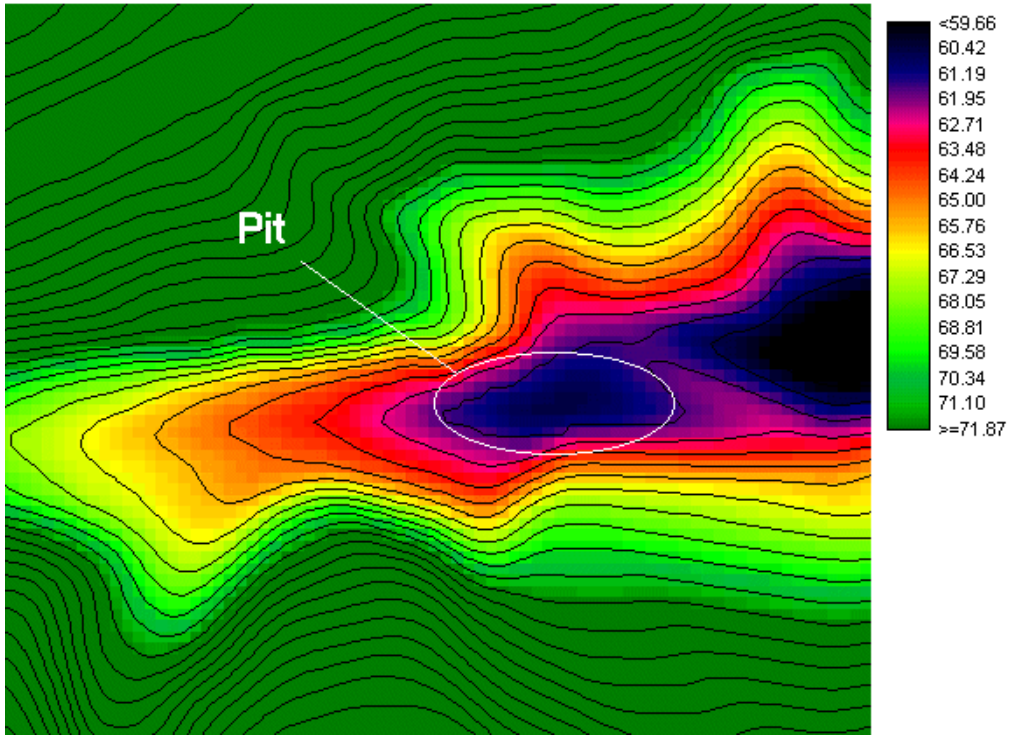


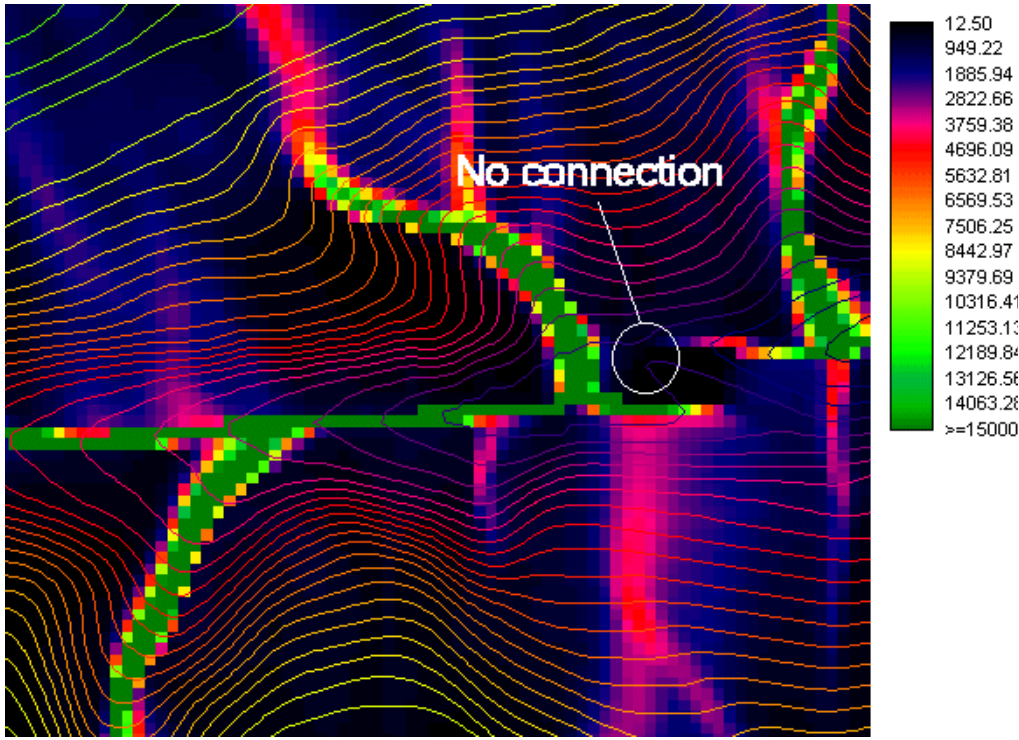
SCA I TCA



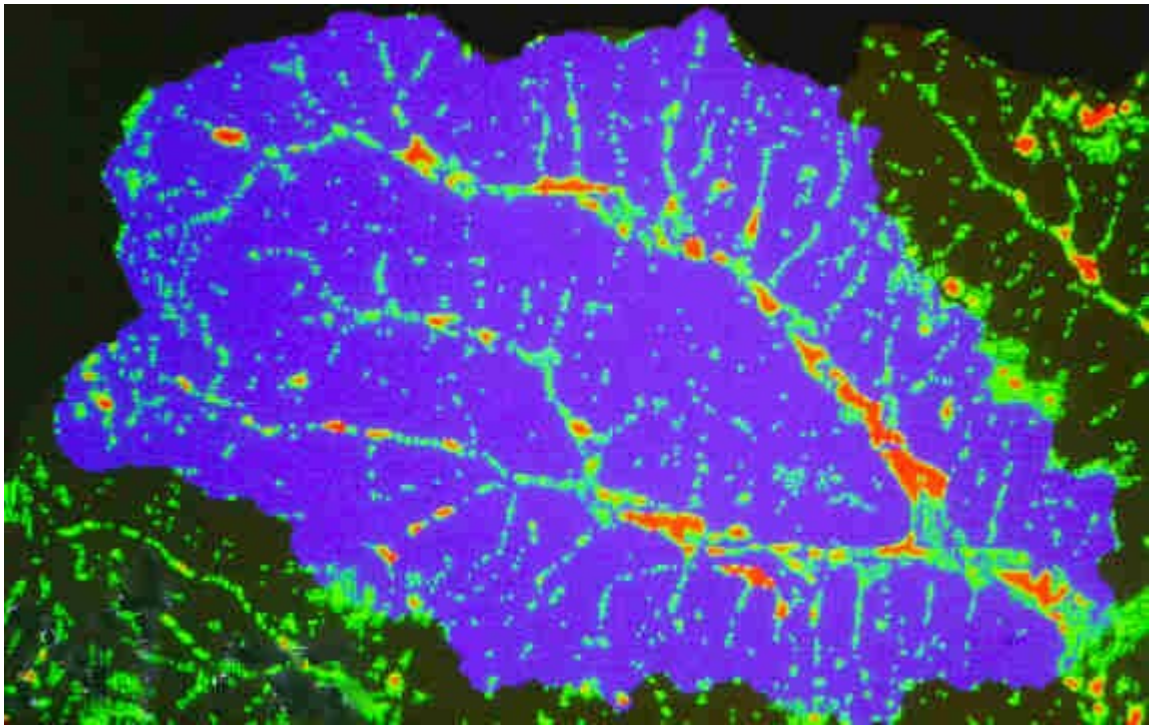
- SCA – Specific catchment area = TCA/flow width
- TCA Total cathcment area

Spływ a depresje (sinks) w DEM



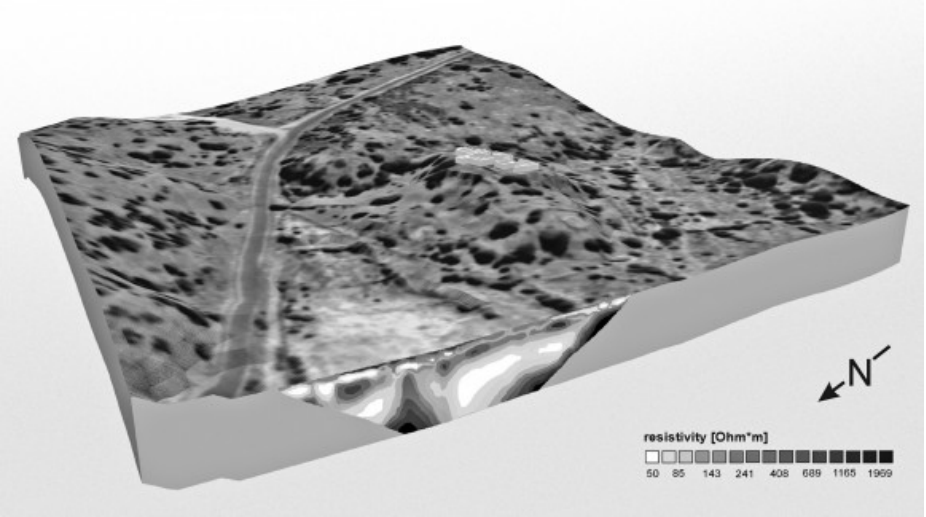


Skąd się biorą depresje?



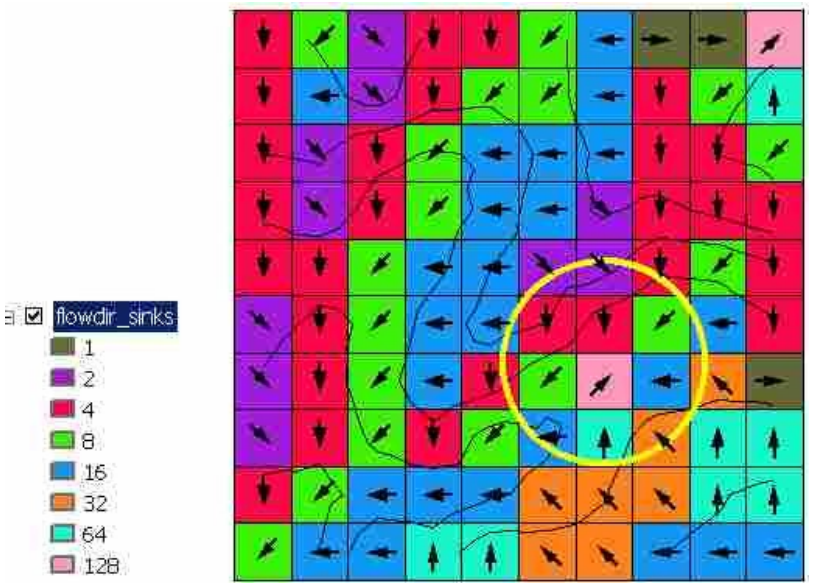
Dojrzała zlewnia - artefakty interpolacji

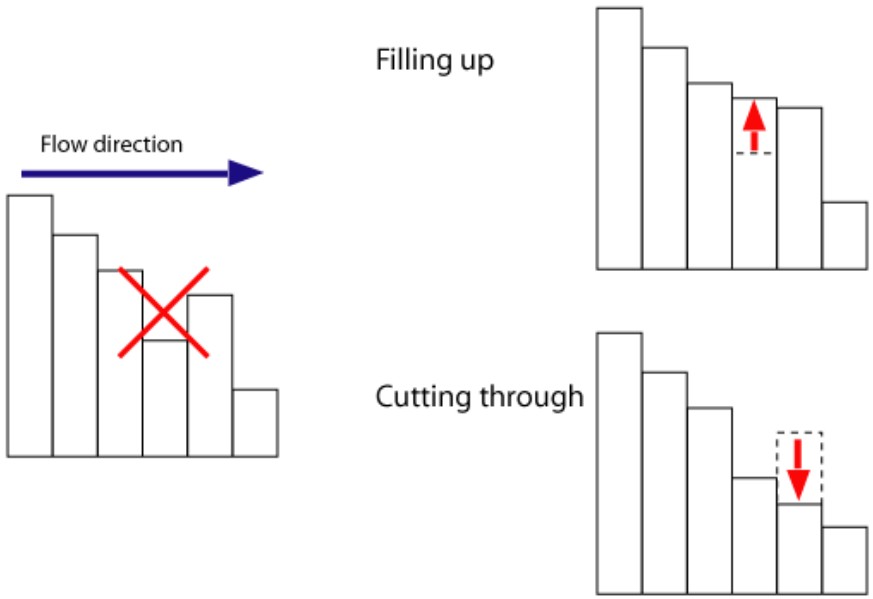
Obszar krasowy - naturalne depresje



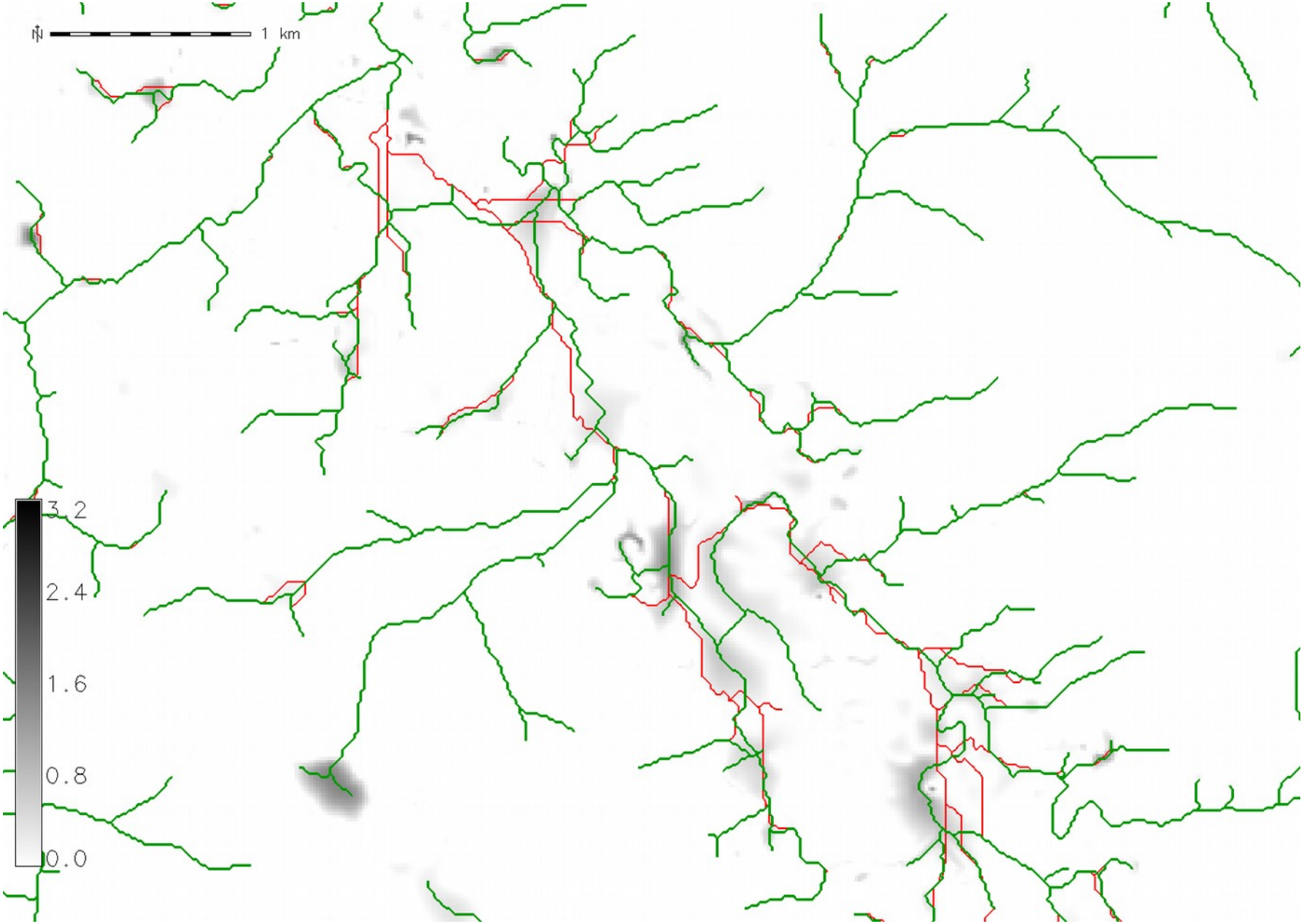
Preprocessing

- Wypełnianie zagłębień
- Przełamywanie zagłębień
- Metody kombinowane

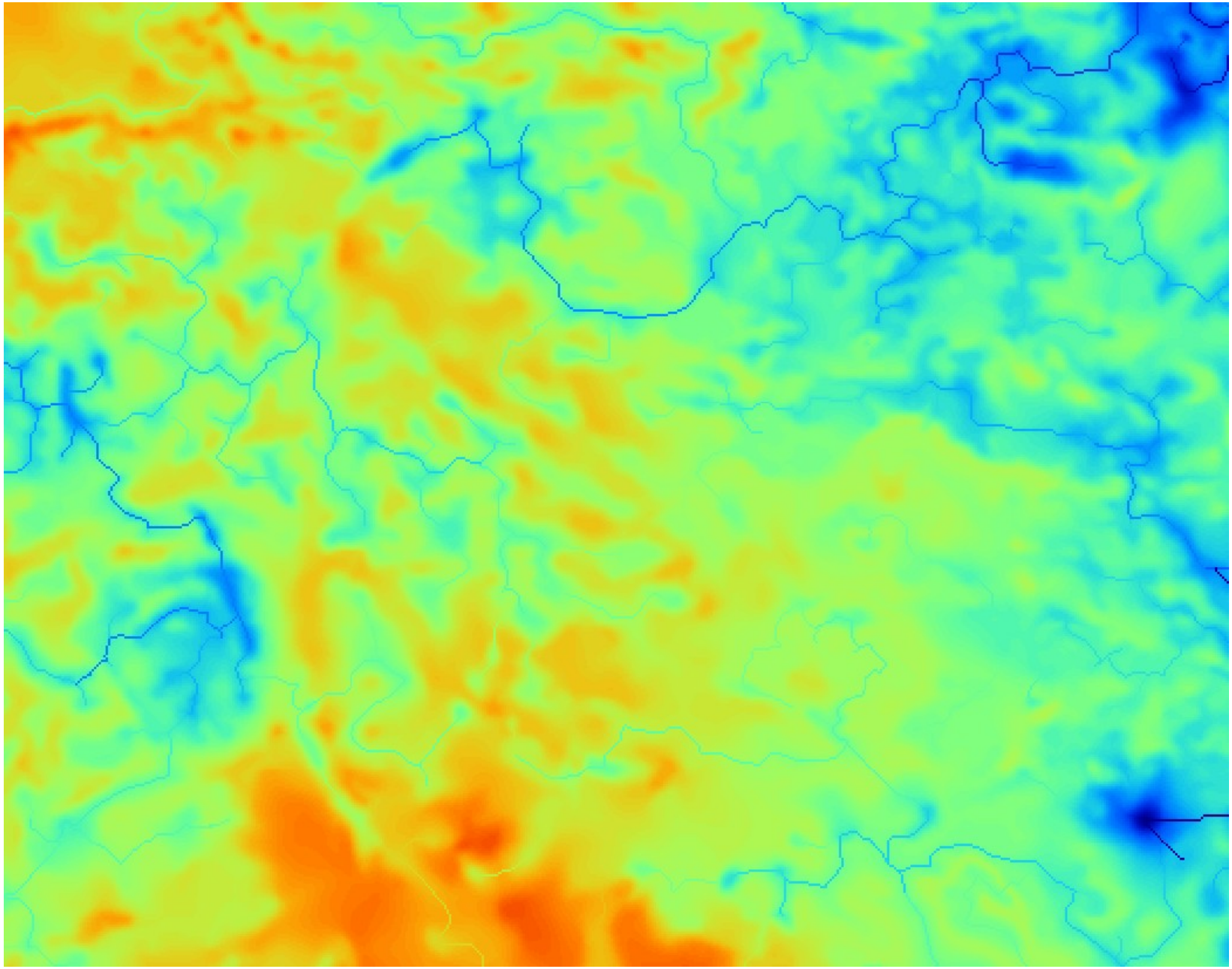




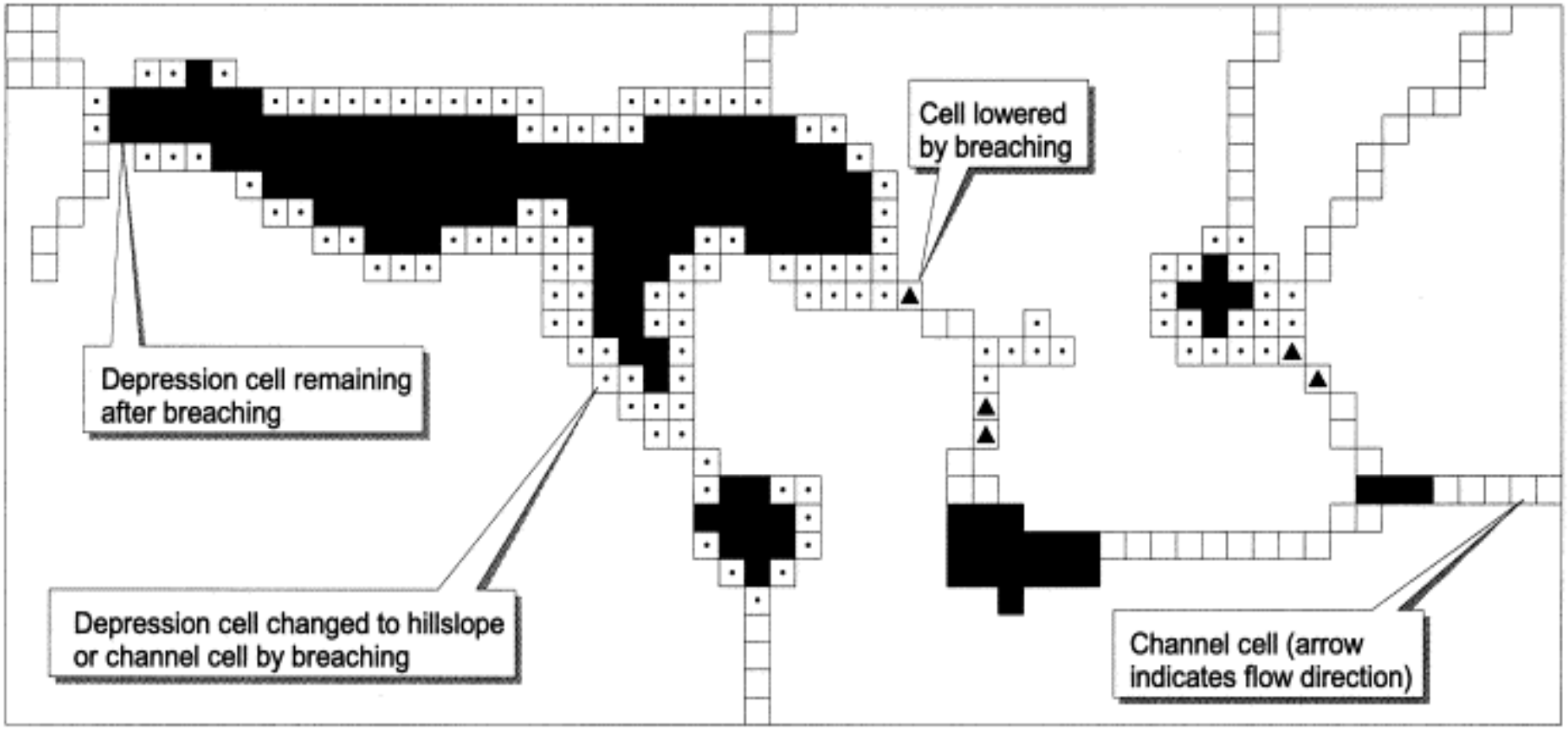
Wypełnianie depresji



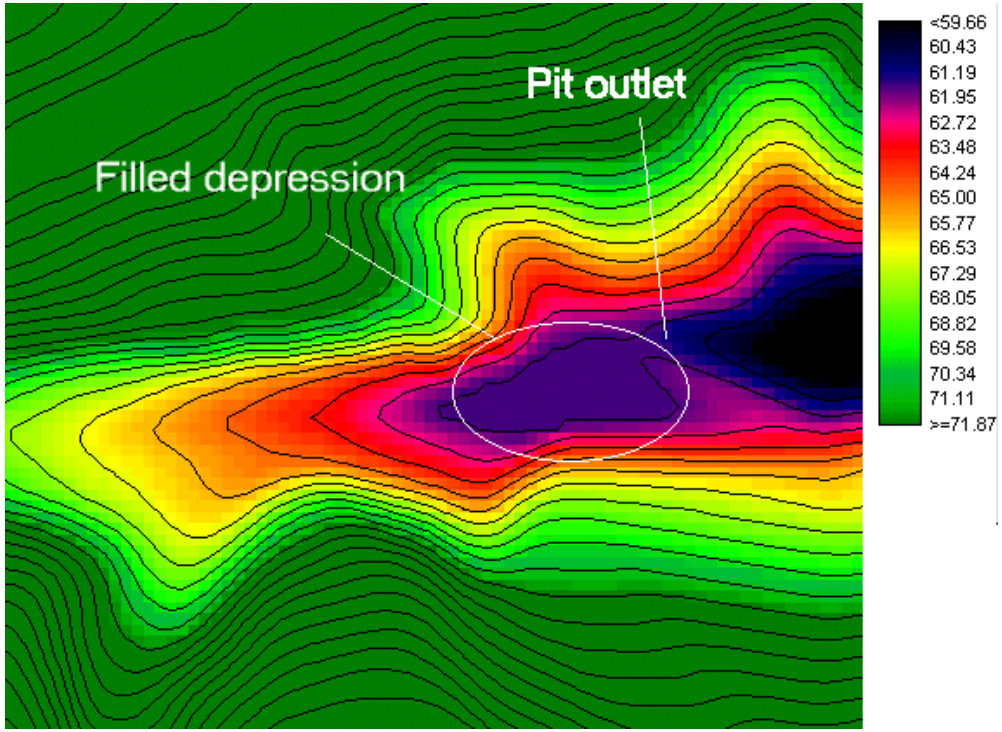
Przełamywanie depresji

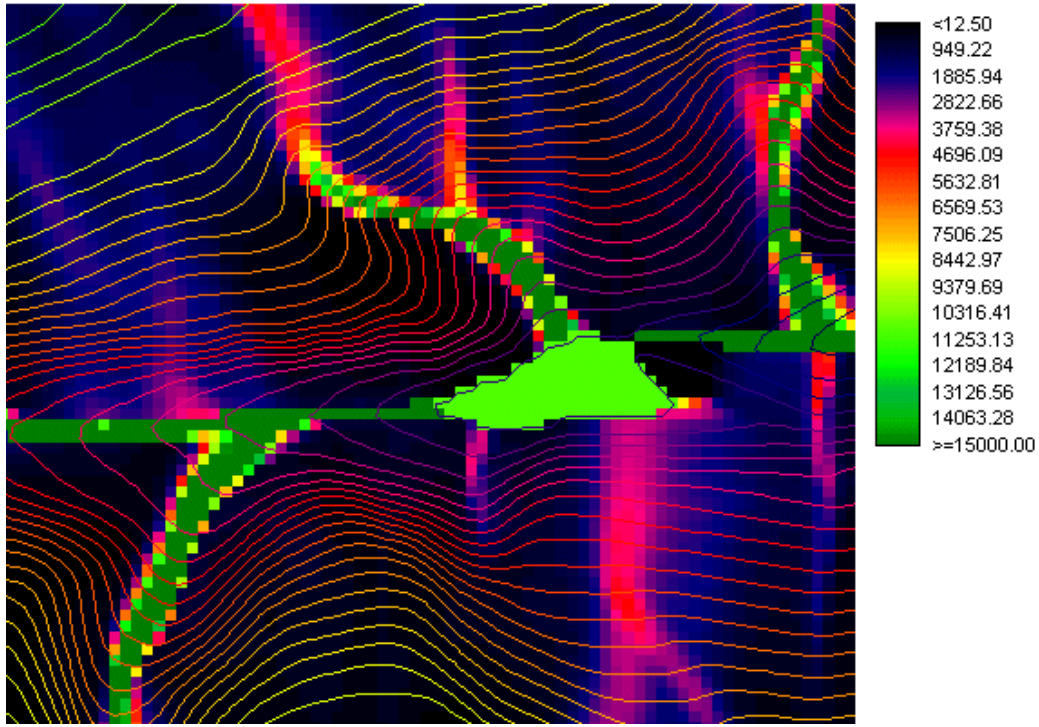


Proces przełamywania



Po korekcie...


Pit outlet
Filled depression
<59.66
60.43
61.19
61.95
62.72
63.48
64.24
65.00
65.77
66.53
67.29
68.05
68.82
69.58
70.34
71.11
>=71.87


<12.50
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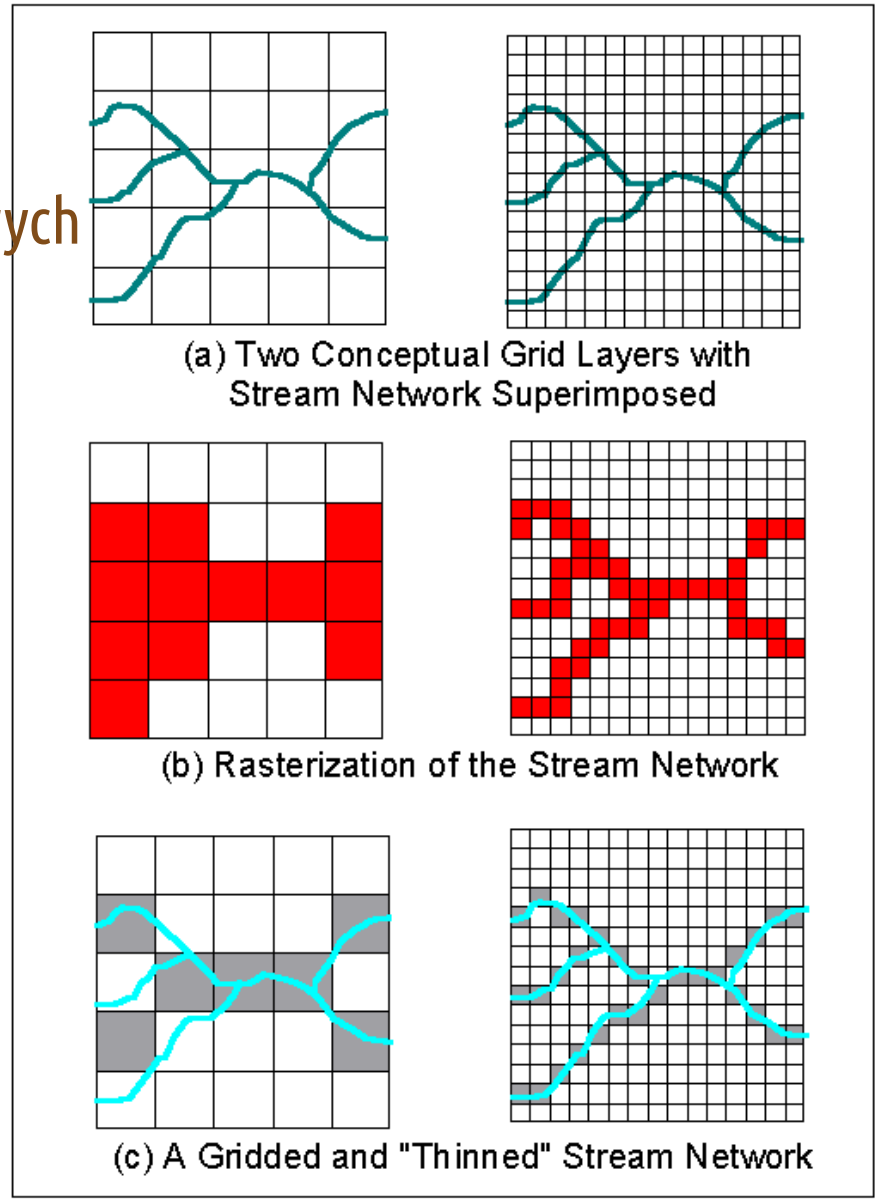
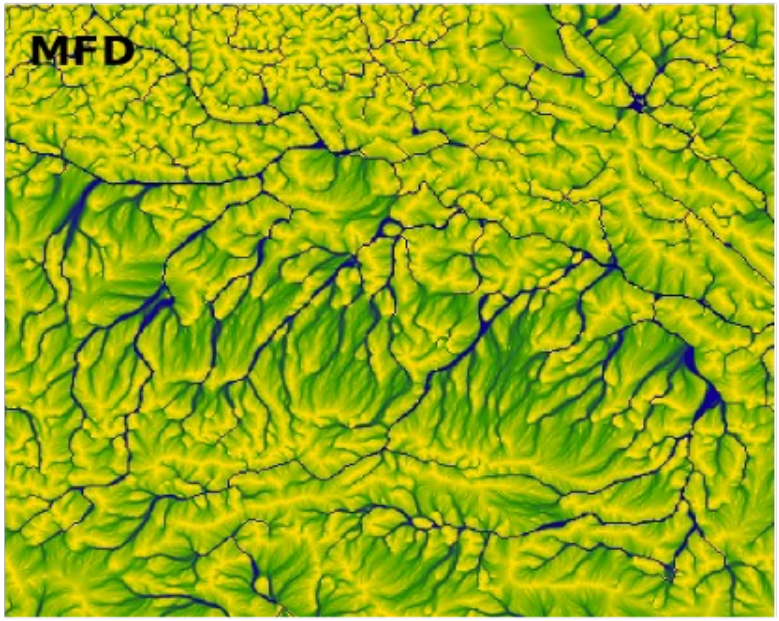
12189.84
13126.56
14063.28
>=15000.00

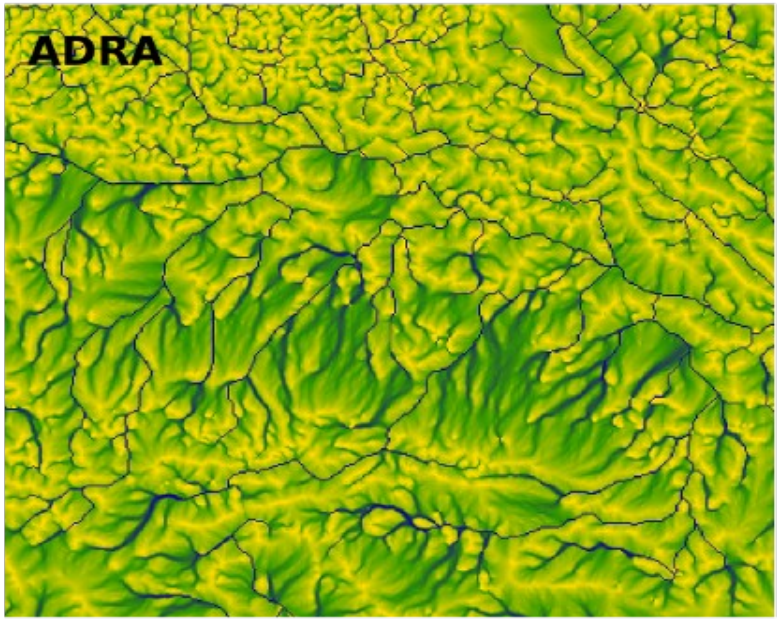
Ekstrakcja strumieni

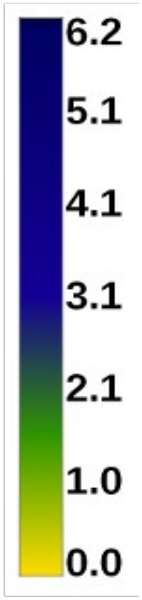
- Progowanie
- Wartości krytyczne krzywizn (Taudem)
- Modelowanie sieci przy pomocy dodatkowych parametrów
- Modelowanie sieci przy pomocy rozpoznawania dolin

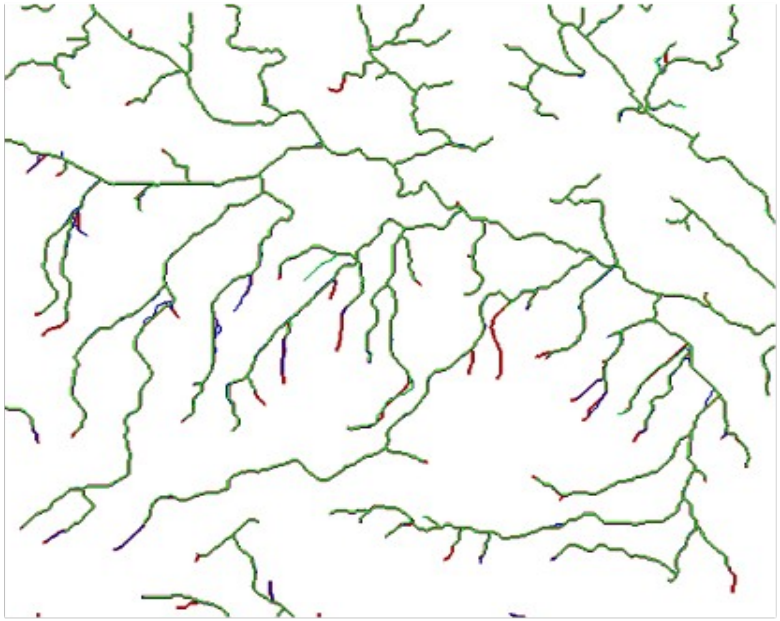


Metody modelowania sieci przez progowanie







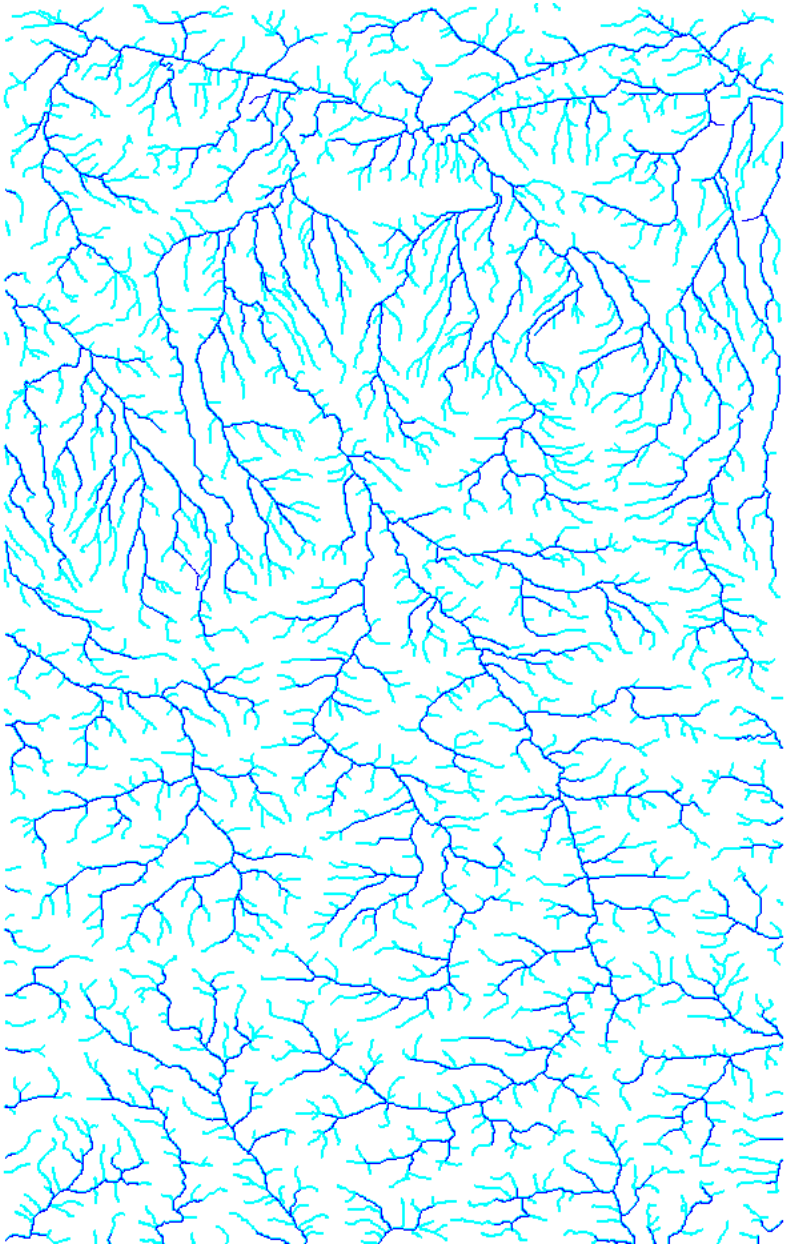


ADRA

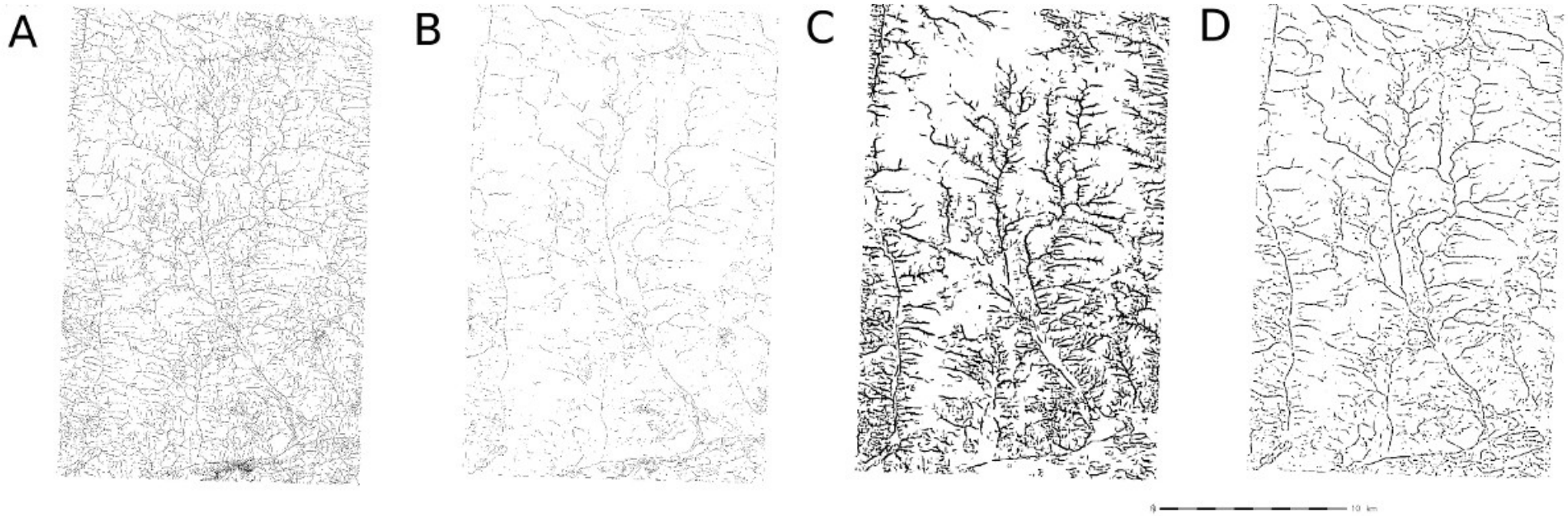
MFD

DEMON

Różne wartości

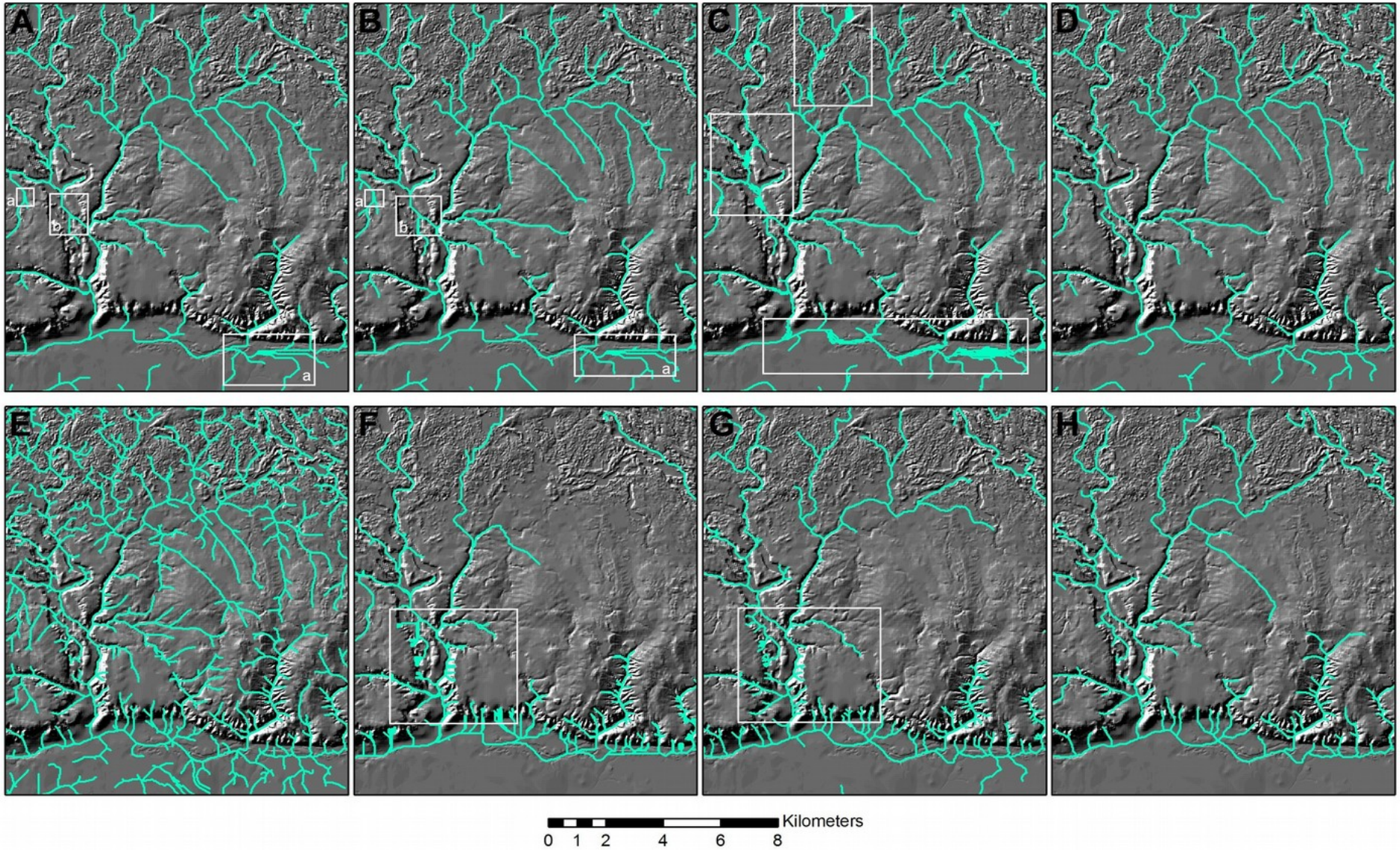


Rozpoznawanie dolin

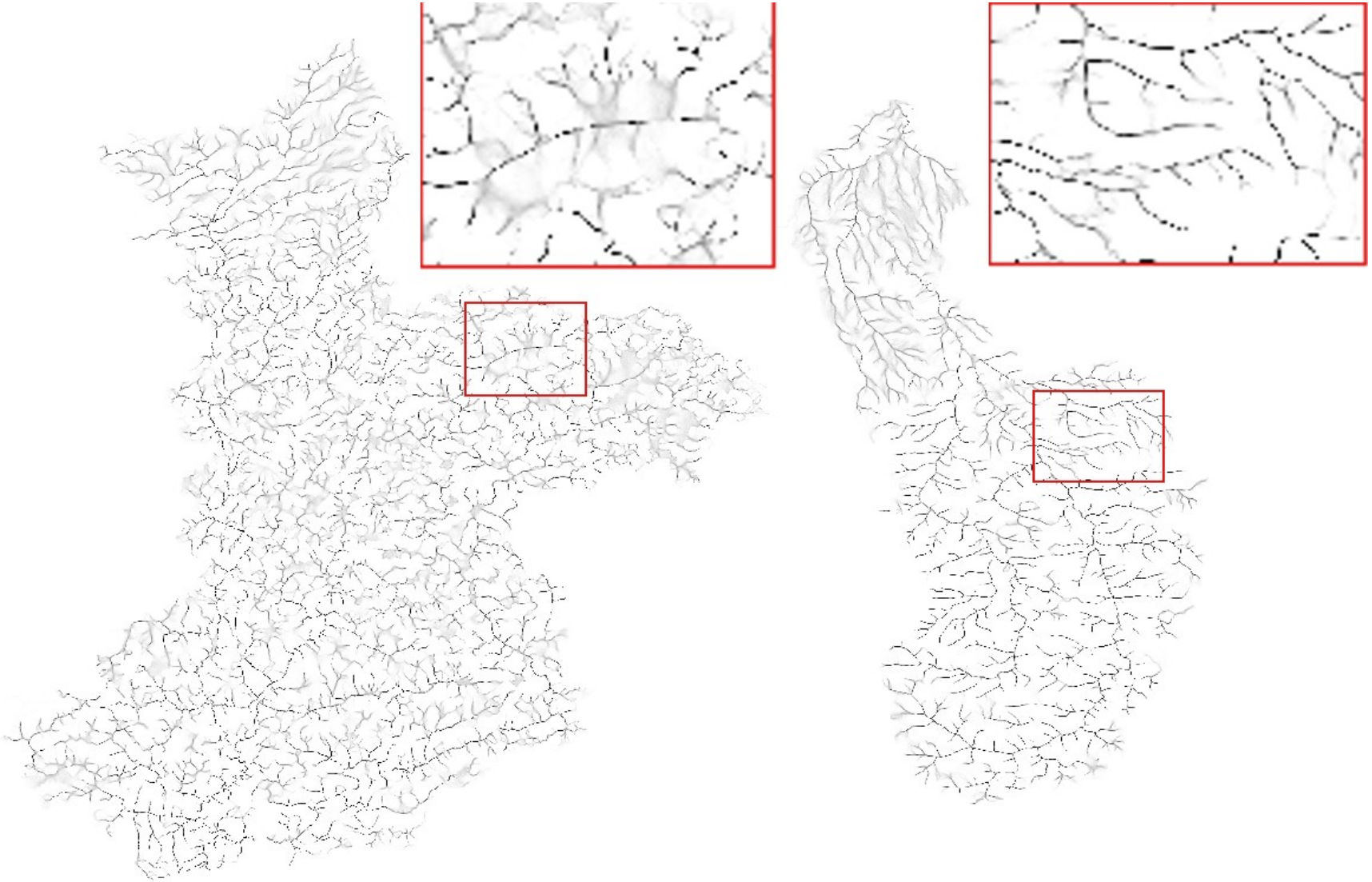


A) algorytm Peukera, Douglasa (1975); B) metoda dolnego kwartylu (Lindsay 2006); C) metoda wyróżniania cieków (Wolf 1992, w impelmentacji Wooda 1995); D) wskaźnik konwergencji (Koethe, Lehmeier, 1996)

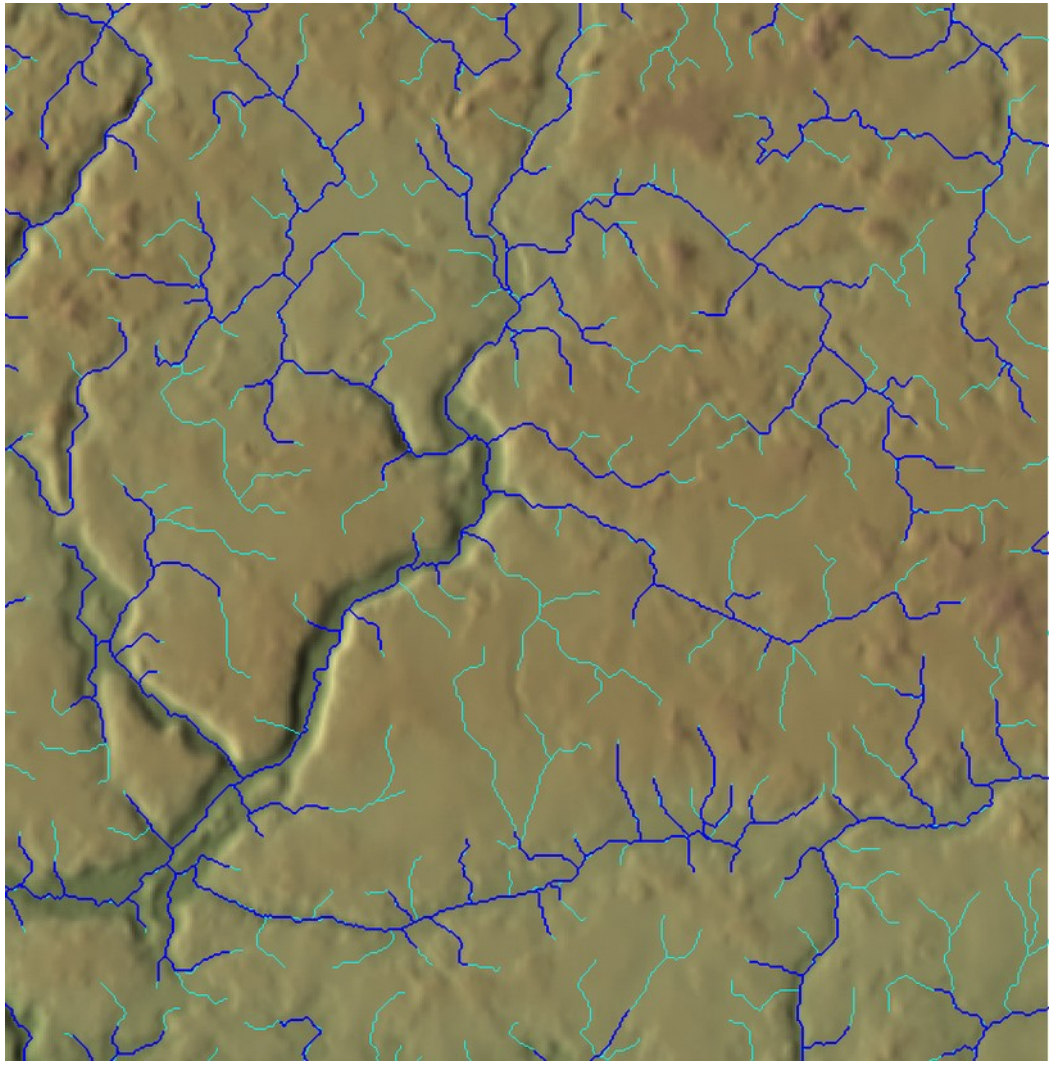
Różne metody - porówanie

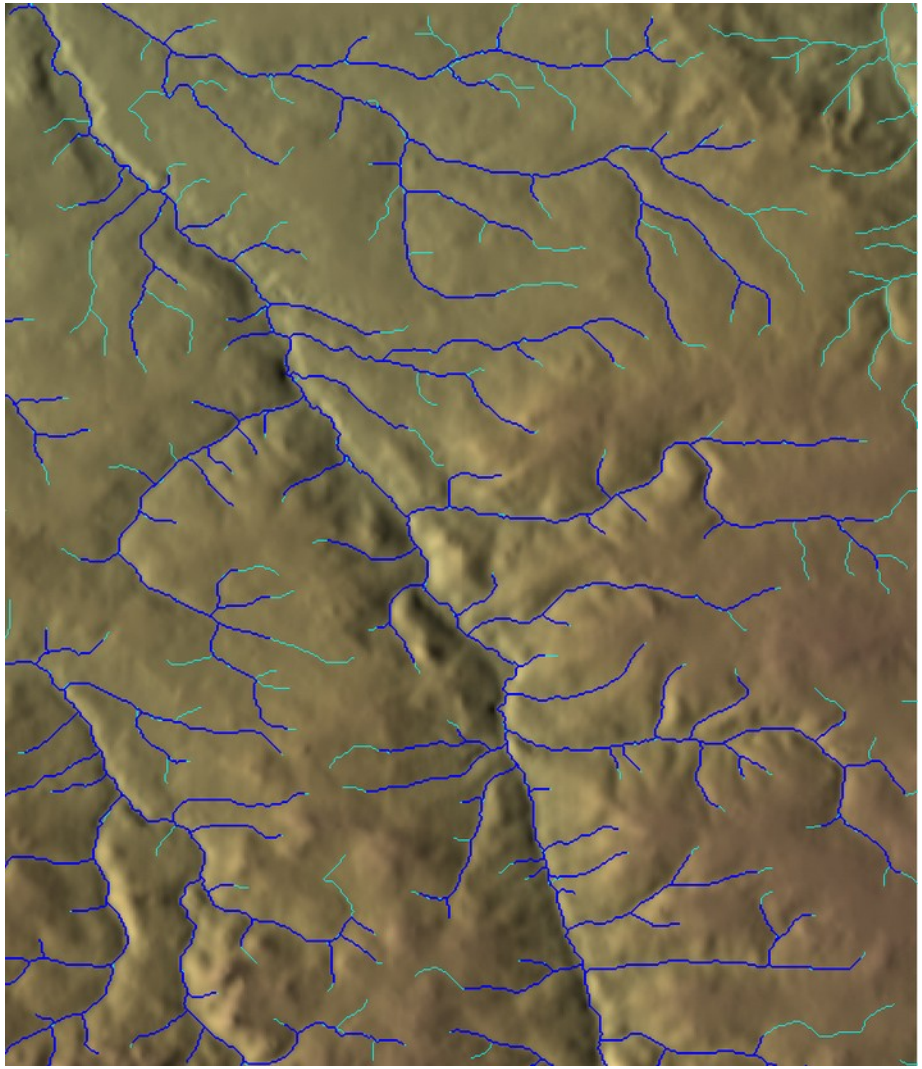


Modelowanie symulacyjne

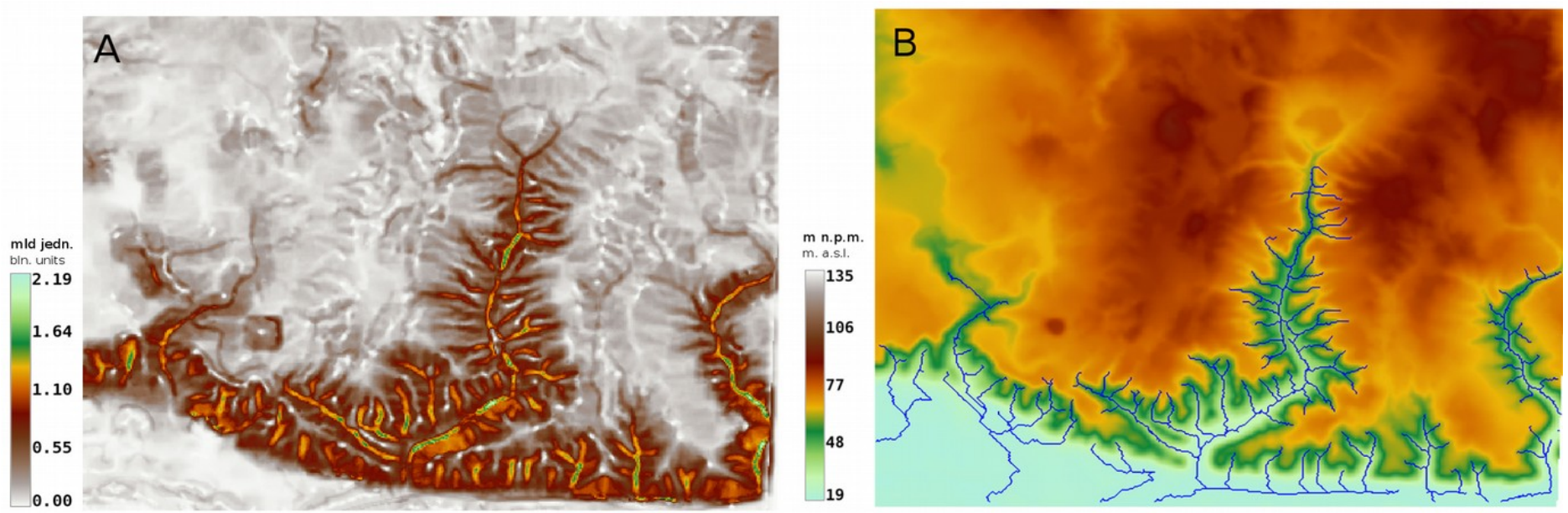


Modelowanie symulacyjne

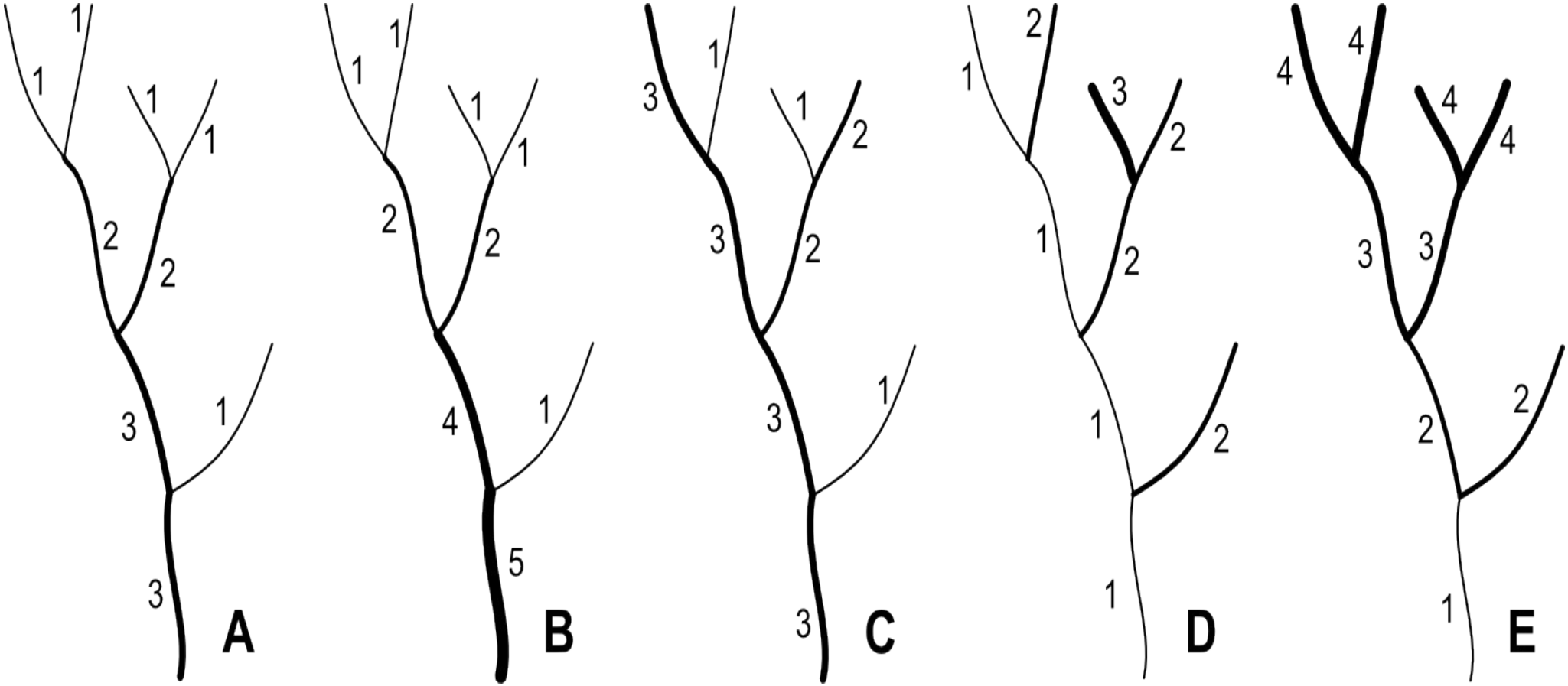




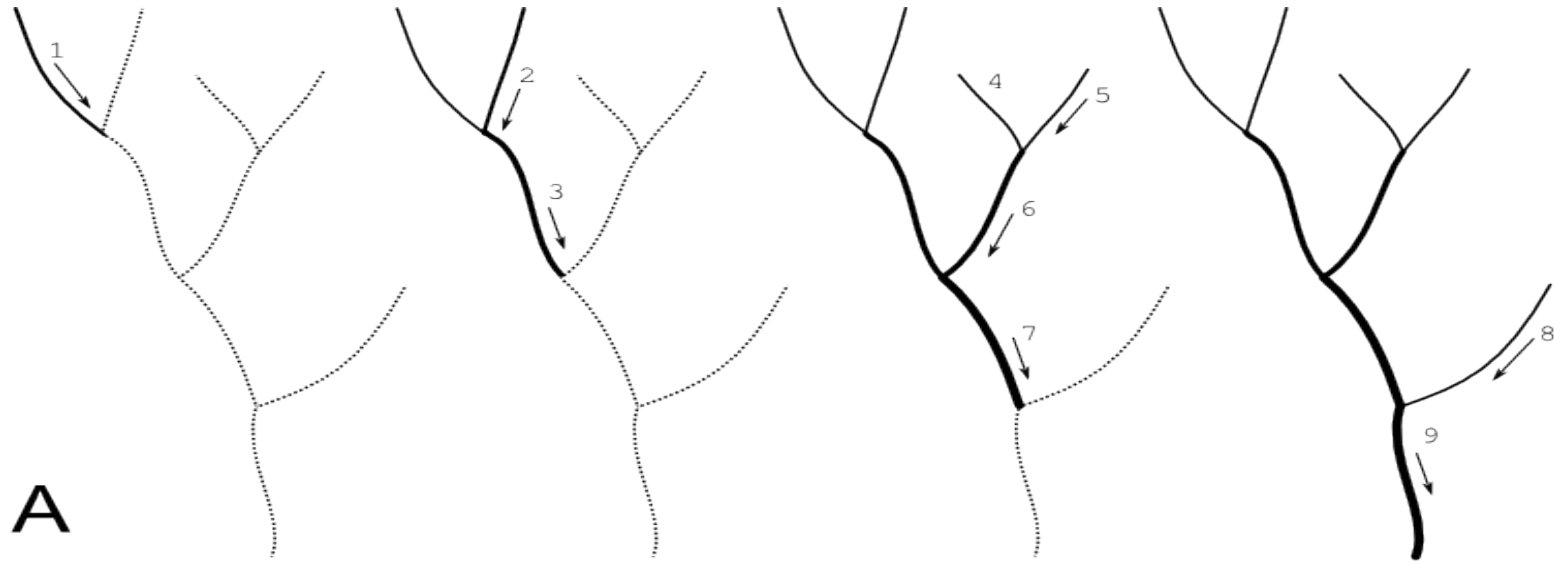
Złożone medoty modelowania

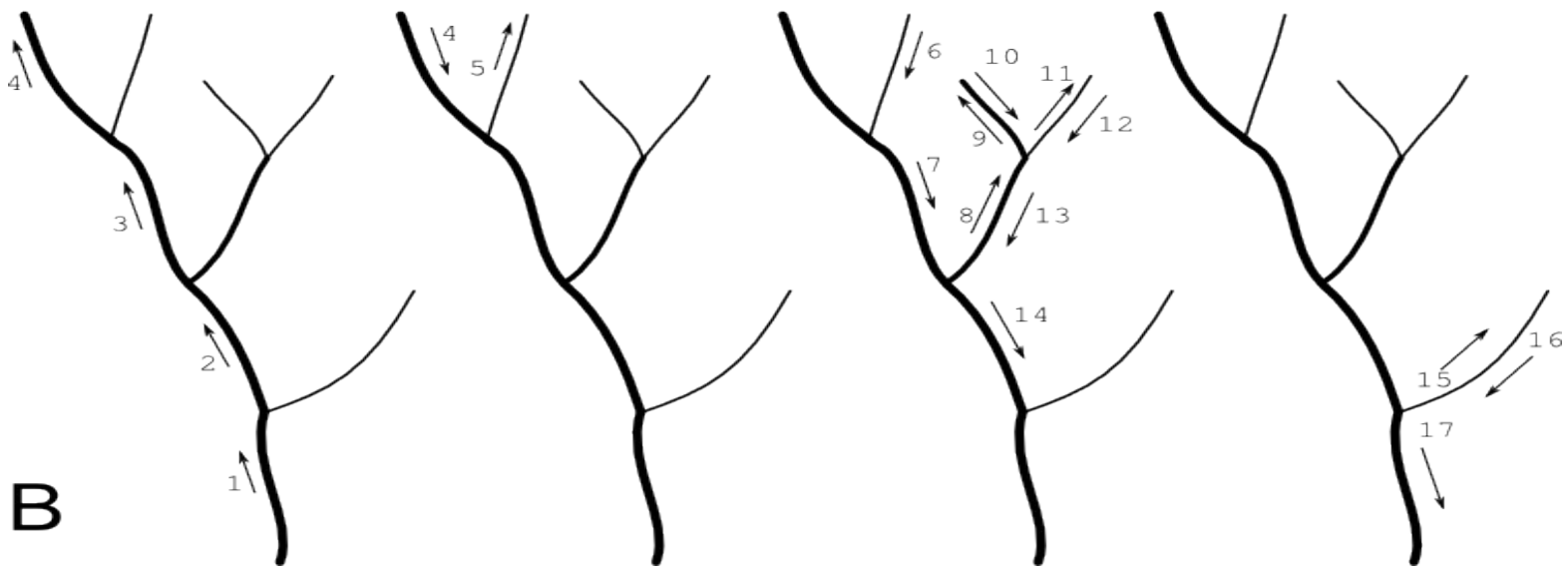


Porządkowanie sieci

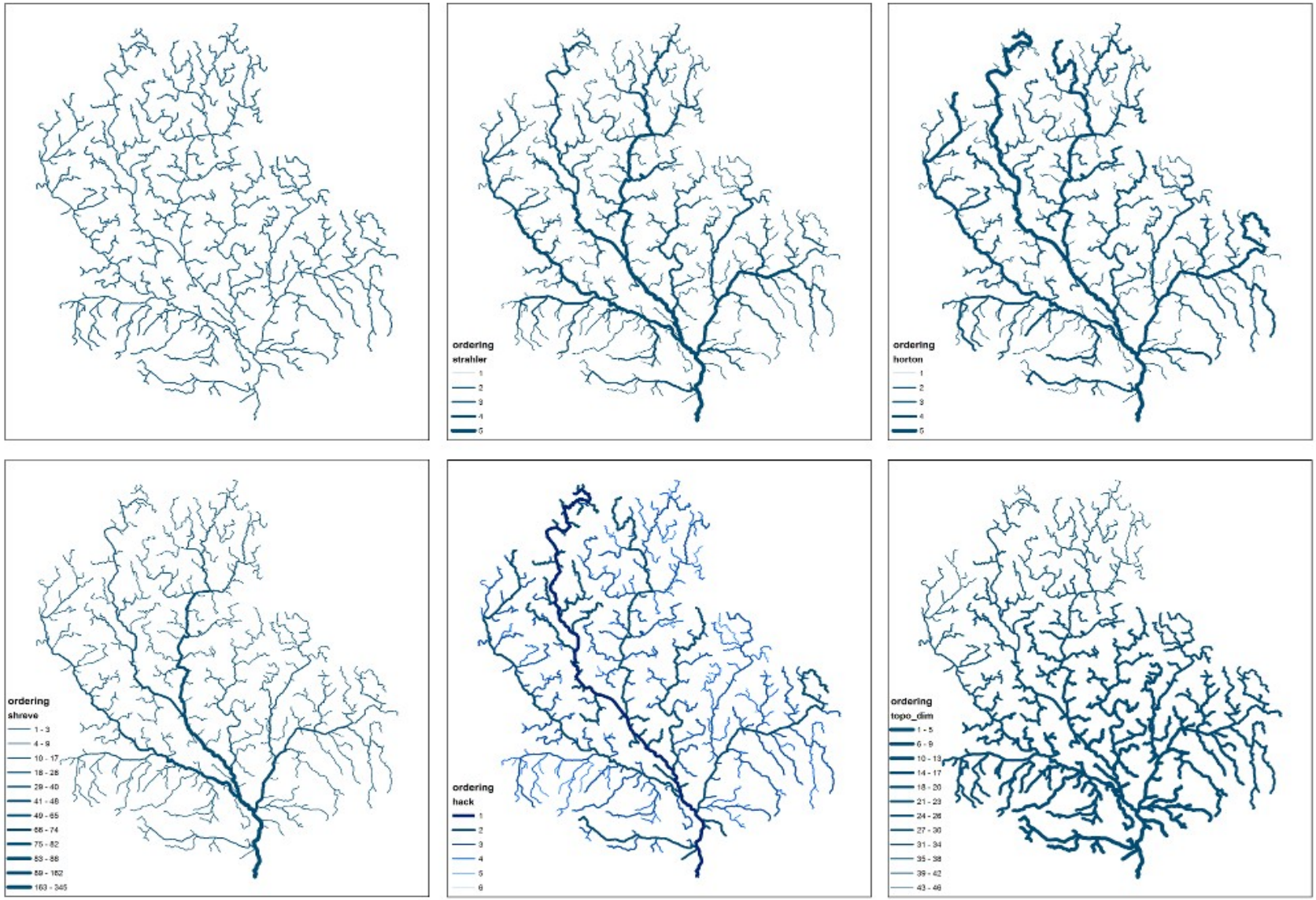


Algorytmy porządkowania

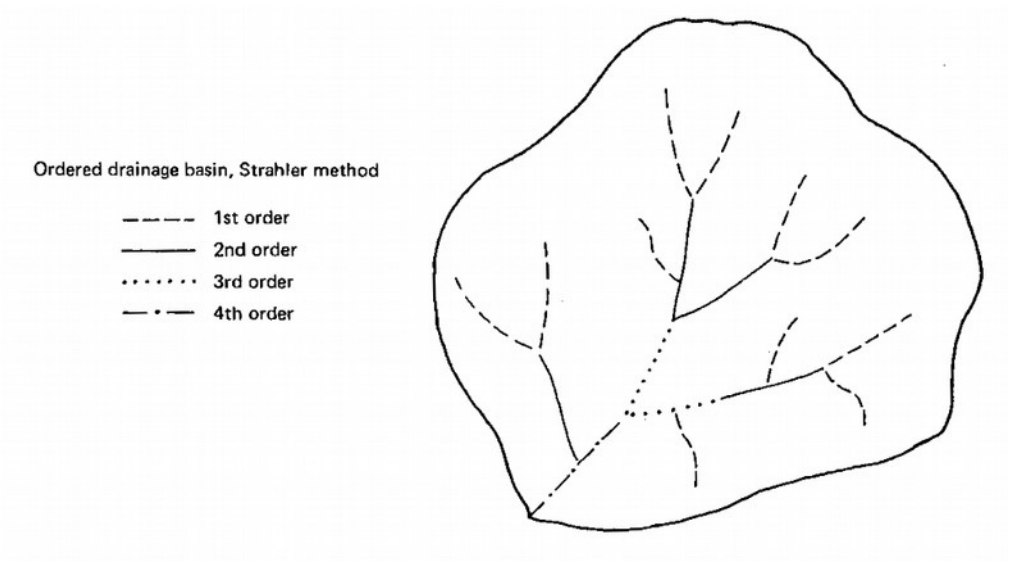




Wyniki porządkowania różnymi metodami



Prawa Hortona



Law of stream numbers	$N_u = R_b^{s-u}$
Law of mean stream lengths	$\overline{L}_u = \overline{L}_1 R_L^{u-1}$
Law of basin areas	$\overline{A}_u = \overline{A}_1 R_a^{u-1}$
Law of total stream lengths	$\Sigma L_u = \overline{L}_1 R_b^{s-u} R_L^{u-1}$
Law of stream gradients	$\overline{S}_u = \overline{S}_1 R_s^{s-u}$

N_u is number of streams of order u

R_b is bifurcation ratio

s is highest order of the basin

$\overline{L}_u$ is mean stream length of order u

R_L is stream length ratio

$\overline{A}_u$ is mean area of basin of order u

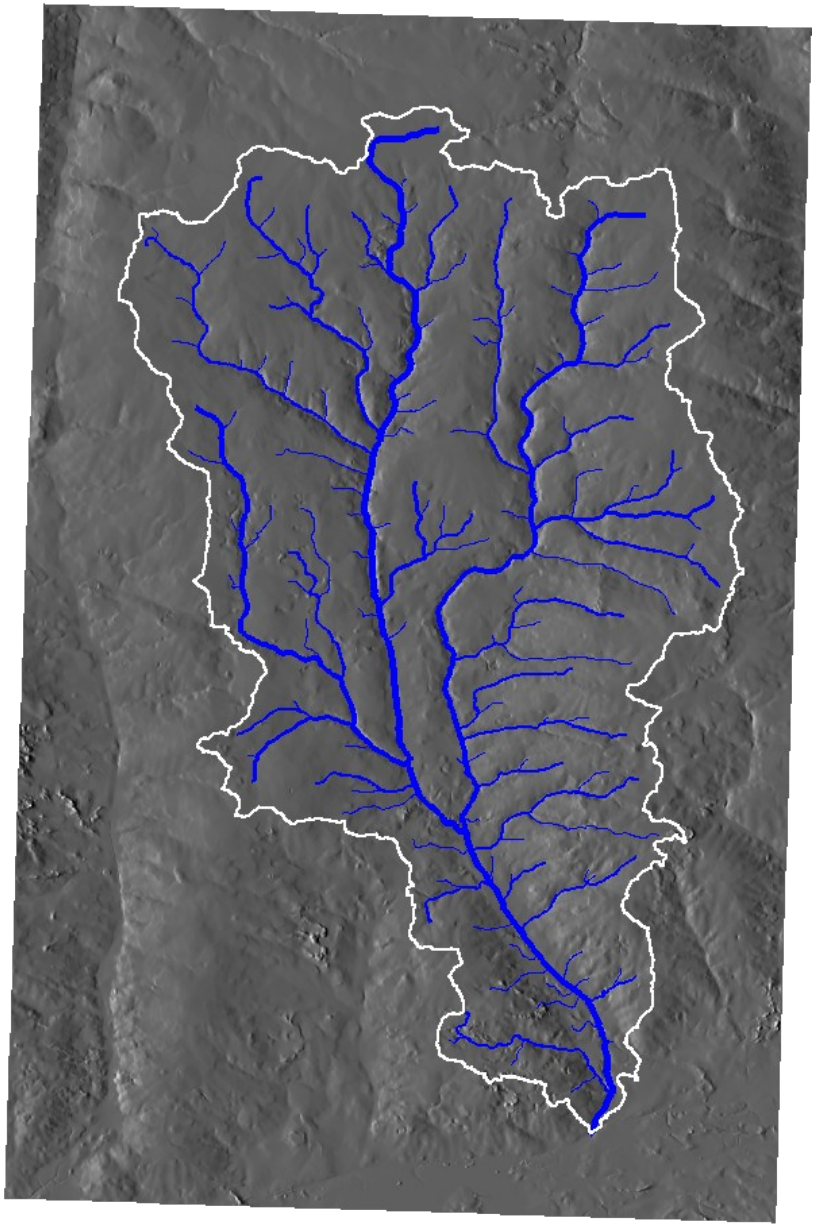
R_a is basin area ratio

ΣL_u is total stream lengths in a basin of order u

$\overline{S}_u$ is mean gradient of stream of order u

R_s is stream gradient ratio

Analiza Hortonowska



Max order (num)	Tot.N.str. (num)	Tot.str.len. (km)	Tot.area. (km2)	Dr.dens. (km/km2)	Str.freq. (num/km2)
5	132	221.0480	164.9546	1.3401	0.8002

Stream ratios with standard deviations:

Bif.rt.	Len.rt.	Area.rt.	Slo.rt.	Grd.rt.
3.5521	0.4406	0.2670	1.3256	1.3333
1.9357	0.1963	0.1264	0.1159	0.1308

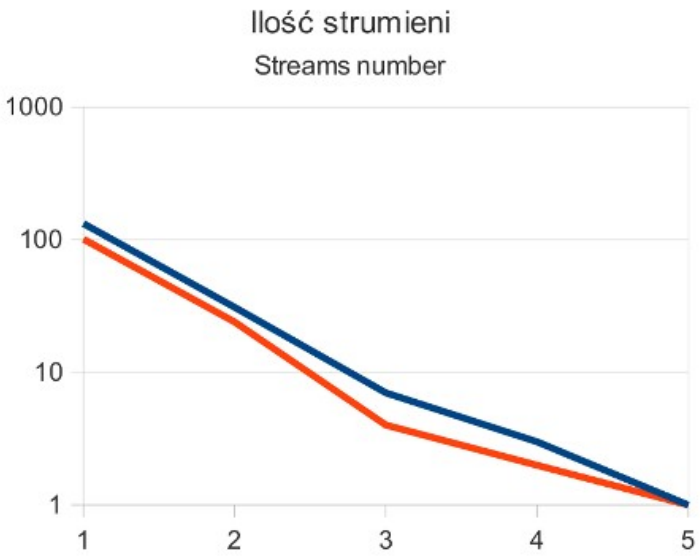
Order num	Avg.len (km)	Avg.ar (km2)	Avg.sl (m/m)	Avg.grad. (m/m)	Avg.el.dif (m)
1	0.7290	0.6266	0.0057	0.0052	3.7318
2	3.0786	3.3145	0.0047	0.0045	13.0892
3	4.6074	7.3515	0.0033	0.0031	14.4862
4	14.2227	41.0462	0.0023	0.0022	31.8169
5	26.6540	164.9546	0.0019	0.0017	44.8757

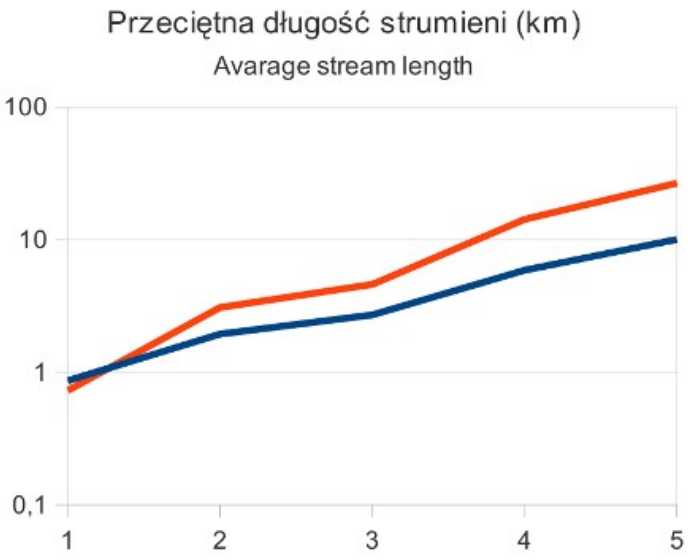
Order num	Std.len (km)	Std.ar (km2)	Std.sl (m/m)	Std.grad. (m/m)	Std.el.dif (m)
1	0.6095	0.4073	0.0029	0.0029	3.3777
2	1.7363	2.4620	0.0016	0.0016	6.2790
3	2.1018	3.0561	0.0005	0.0005	6.6818
4	4.8135	29.3210	0.0001	0.0001	12.4632
5	0.0000	0.0000	0.0000	0.0000	0.0000

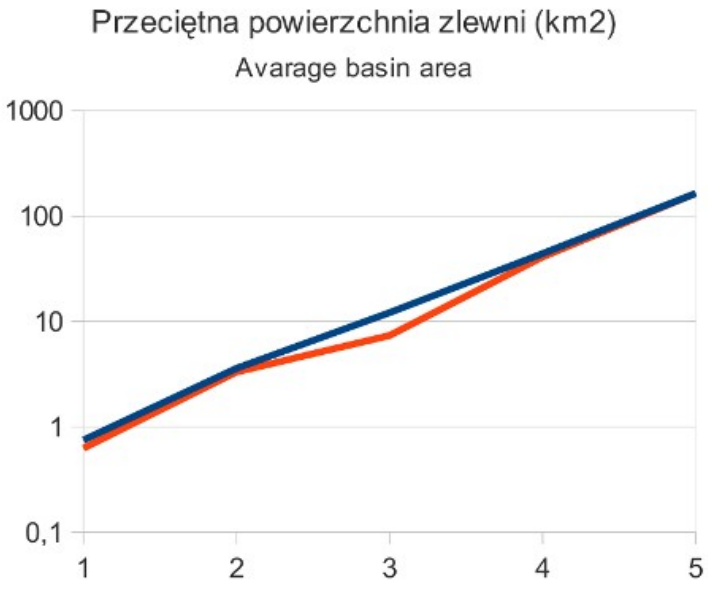
Order	N.streams	Tot.len (km)	Tot.area (km2)
1	101	73.6323	63.2840
2	24	73.8869	79.5482
3	4	18.4294	29.4061
4	2	28.4454	82.0925
5	1	26.6540	164.9546

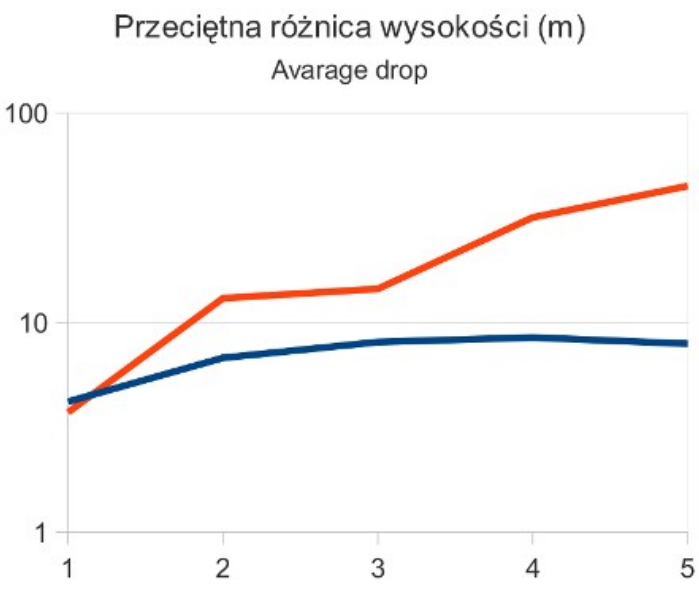
Order	Bif.rt.	Len.rt.	Area.rt.	Slo.rt.	Grd.rt.	d.dens.	str.freq.
1	4.2083	0.2368	0.1890	1.2050	1.1559	1.1635	1.5960
2	6.0000	0.6682	0.4509	1.4334	1.4484	0.9288	0.3017
3	2.0000	0.3239	0.1791	1.4159	1.4128	0.6267	0.1360
4	2.0000	0.5336	0.2488	1.2480	1.3160	0.3465	0.0244
5	0.0000	0.0000	0.0000	0.0000	0.0000	0.1616	0.0061

Analiza hortonowska cd.

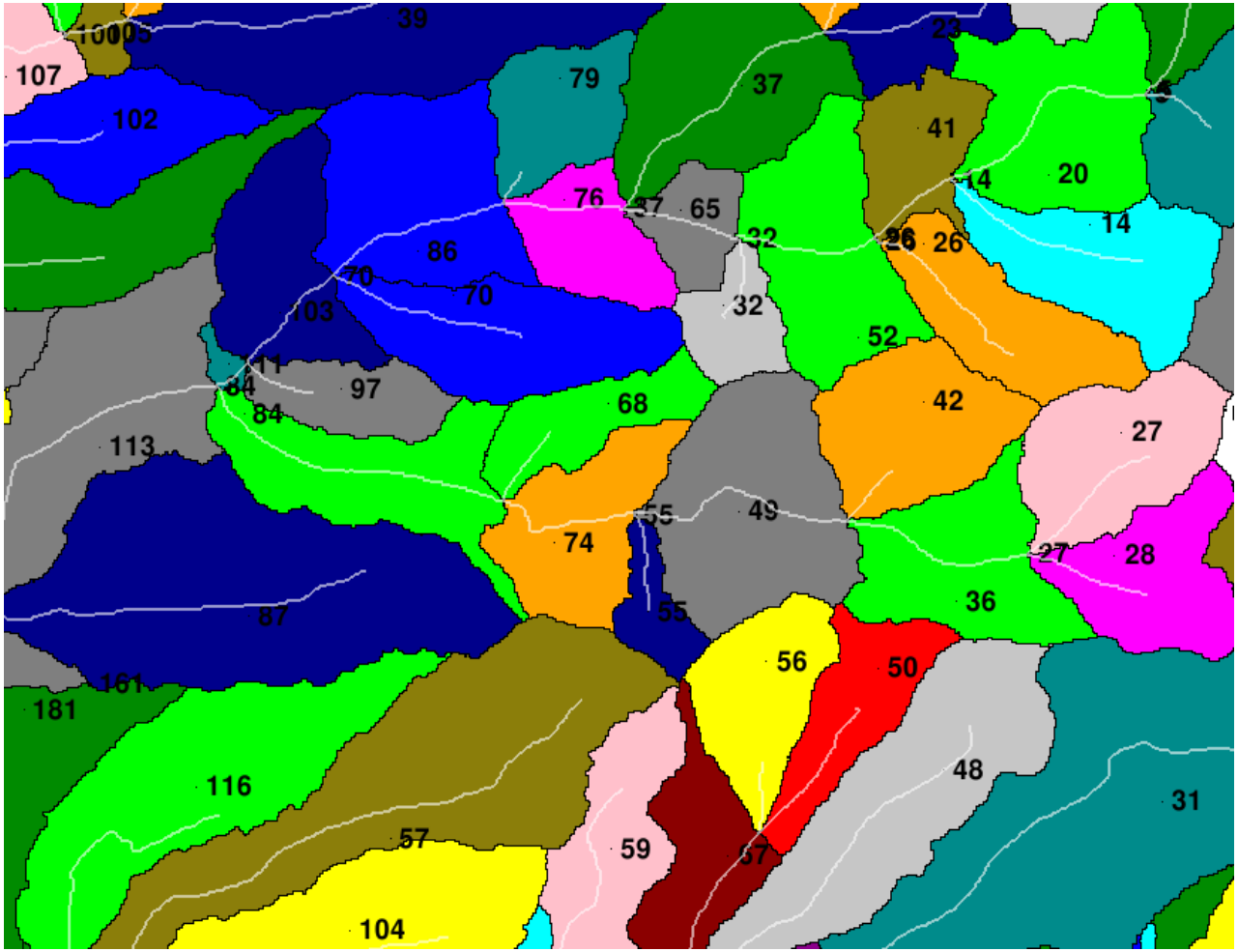




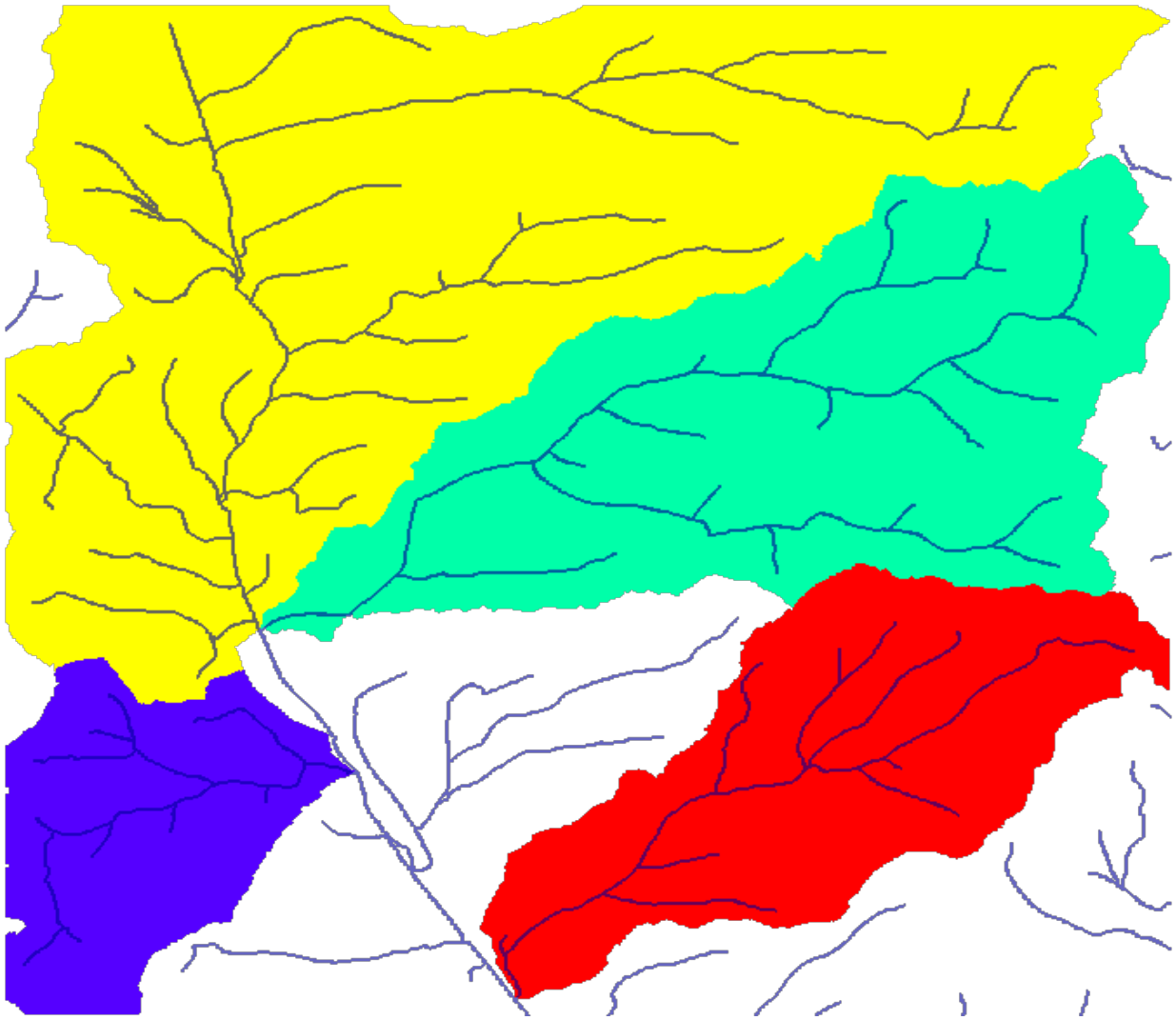




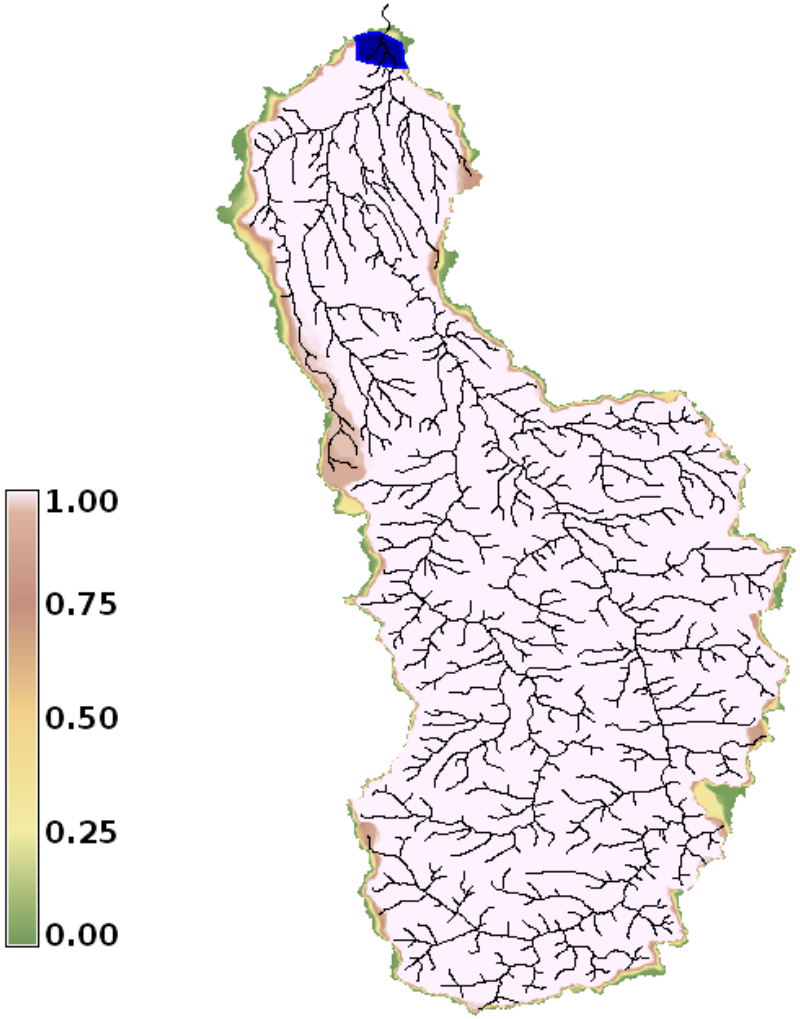
Zlewnie komplementarne

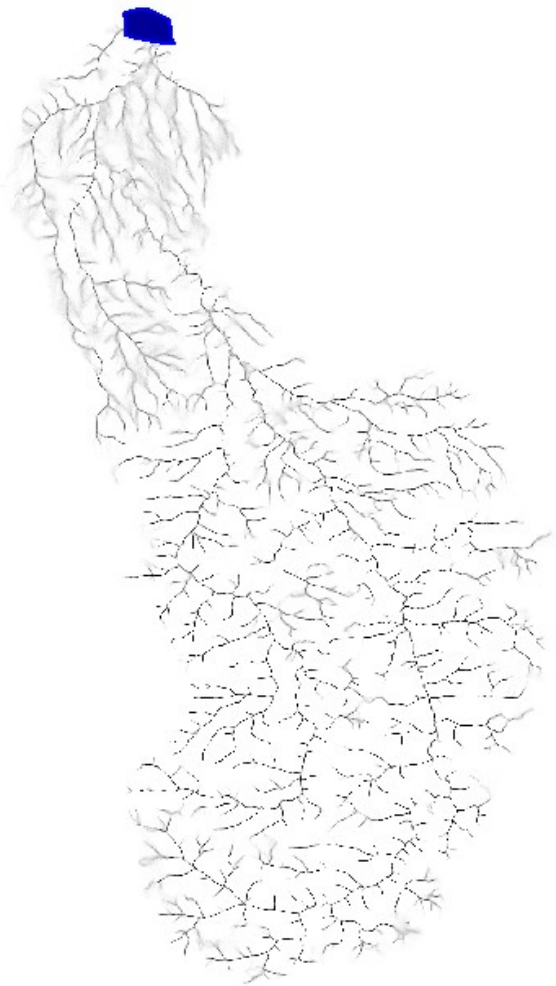


Zlewnie modelowane wg kryteriów użytkownika

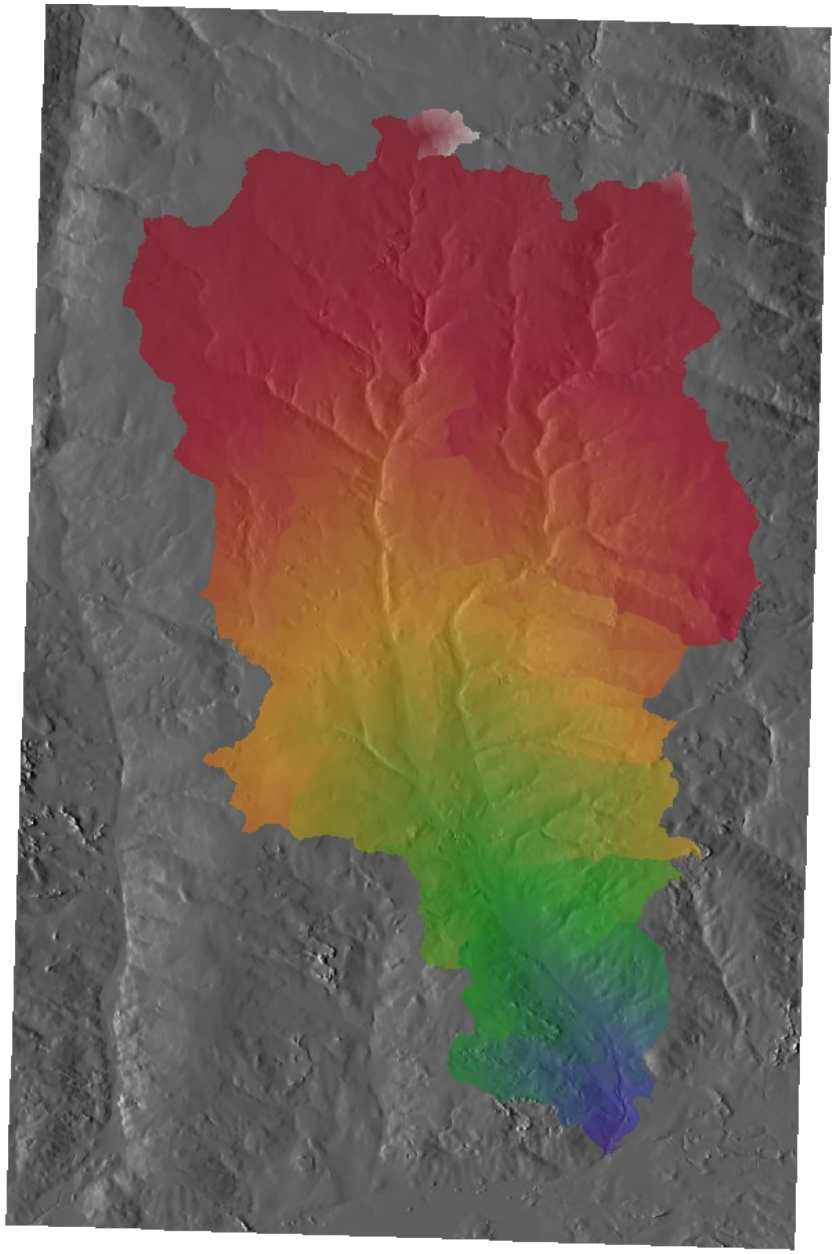


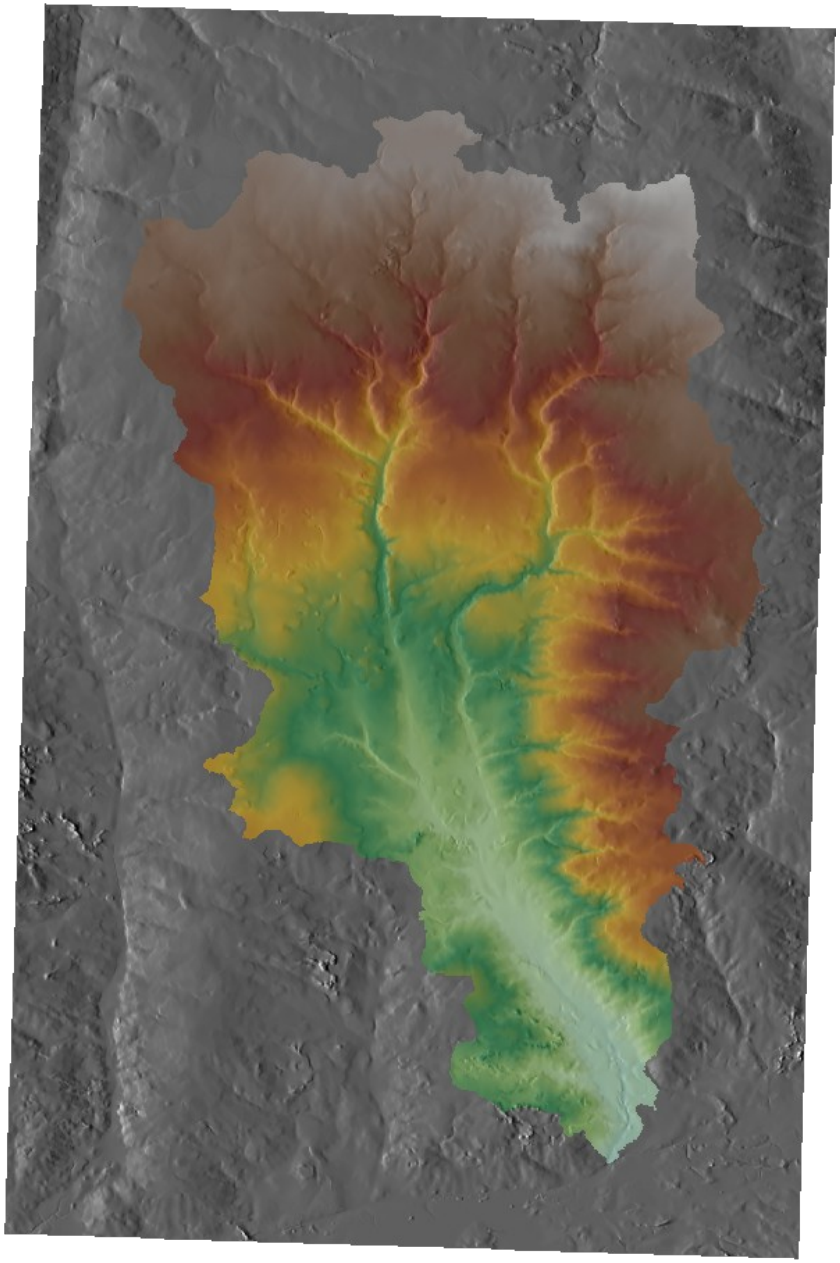
Metody probablilistyczne



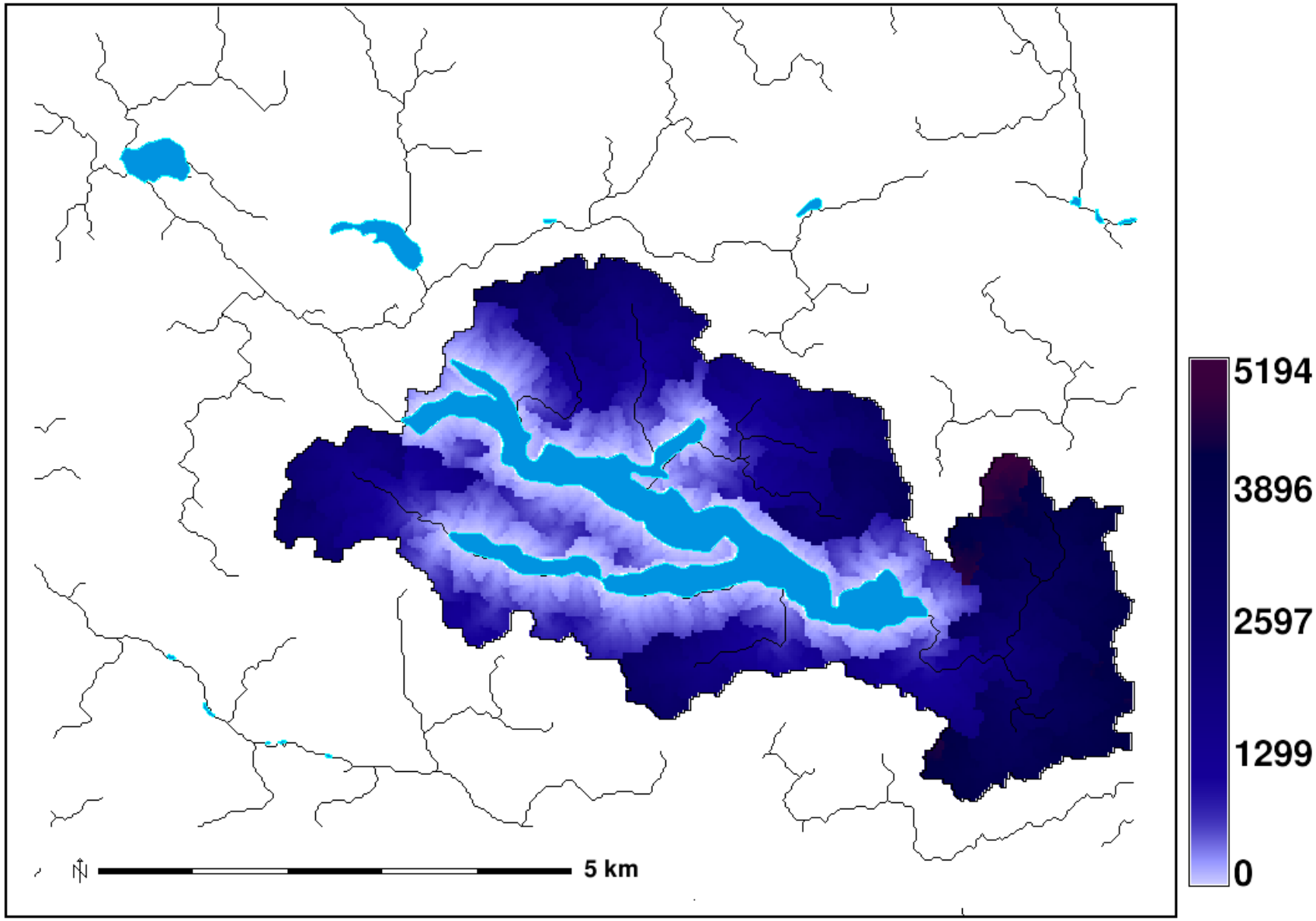


Analiza relacji względem ujścia zlewni

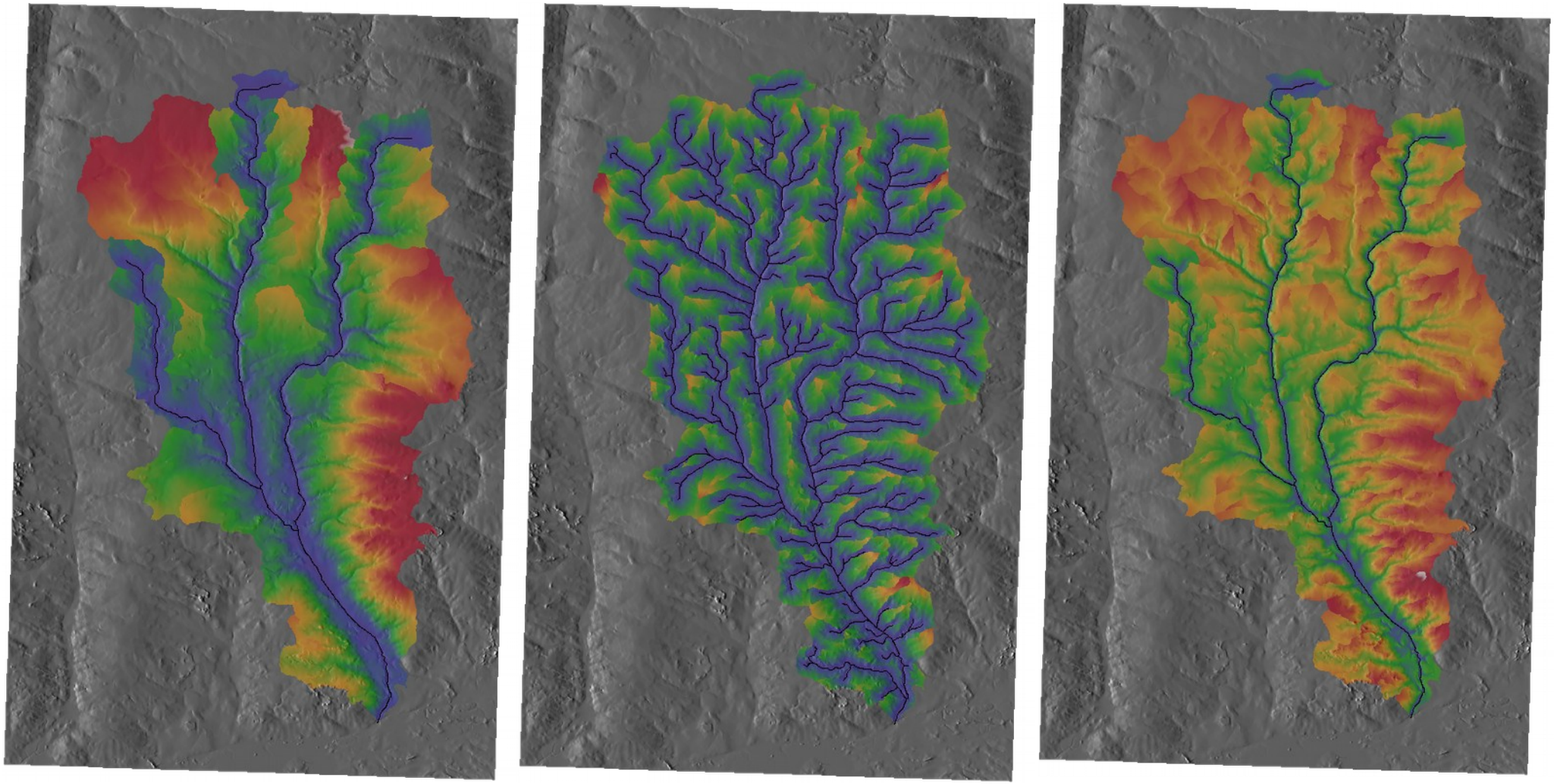




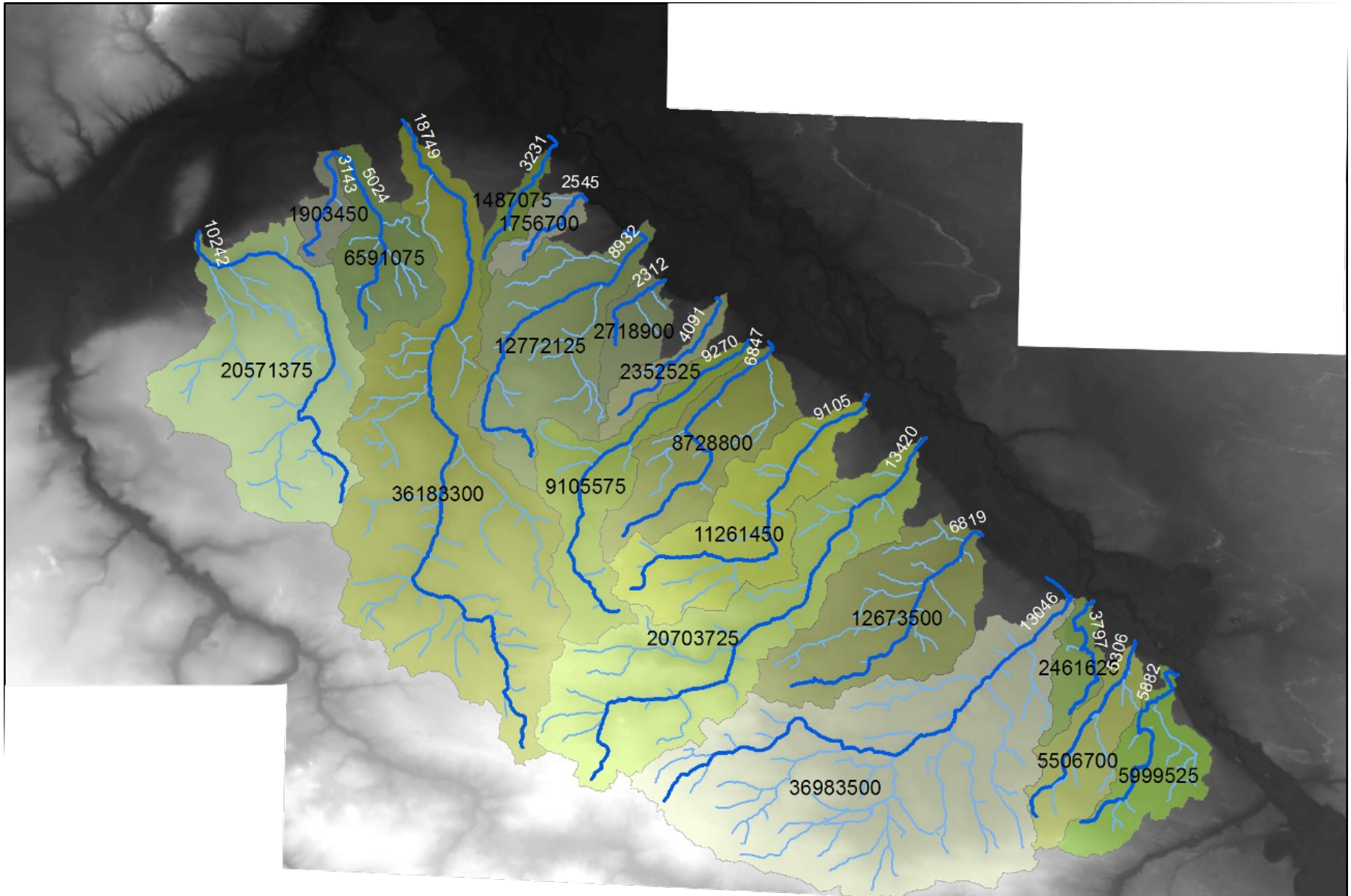
hydrologiczna odległość od zbiornika jeziornego



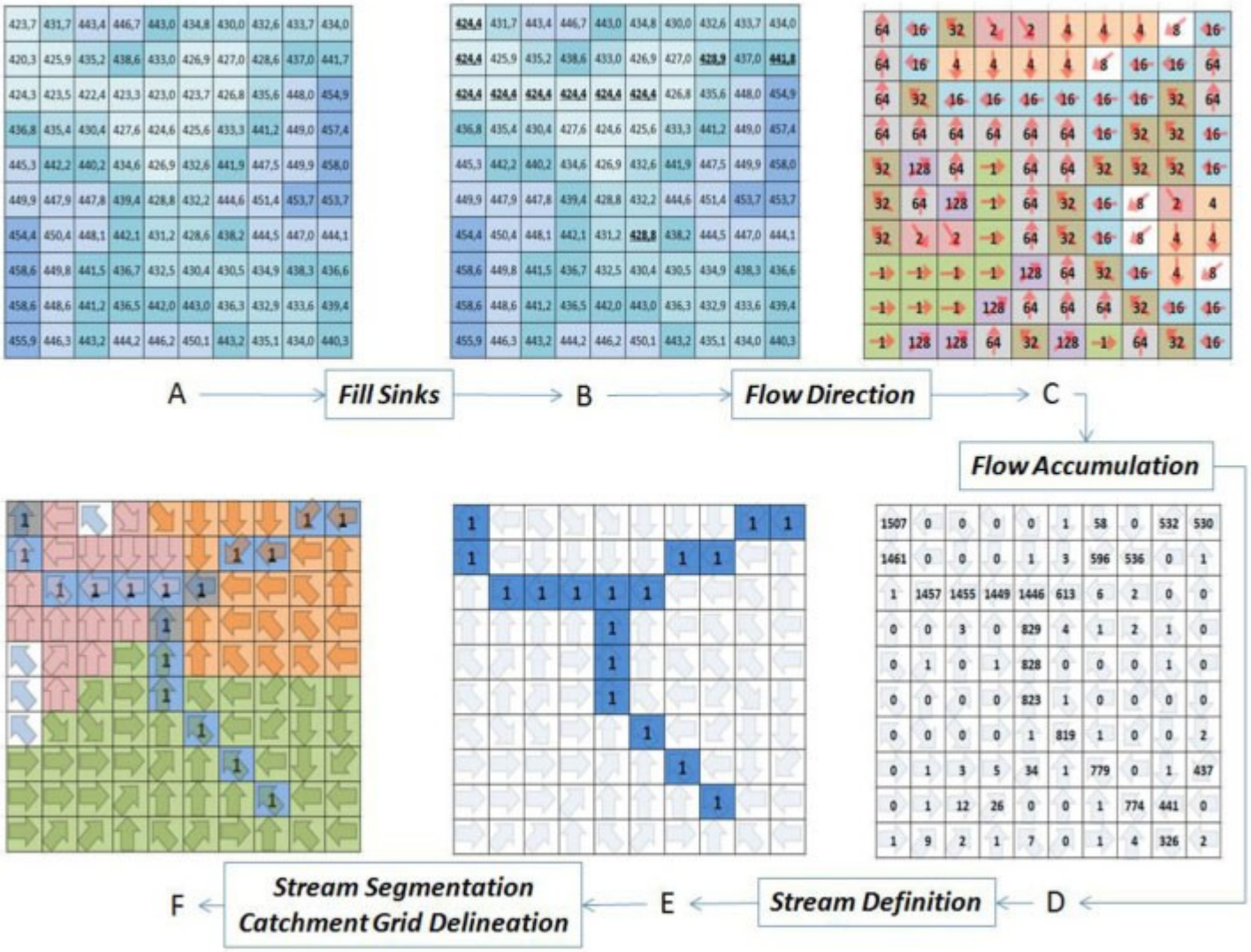
rzędna względem głównych strumieni



analiza długość strumienia - wielkość dorzecza



Pełen proces modelowania drenażu



Computers & Geosciences
Volume 37, Issue 8, August 2011, Pages 1162–1173

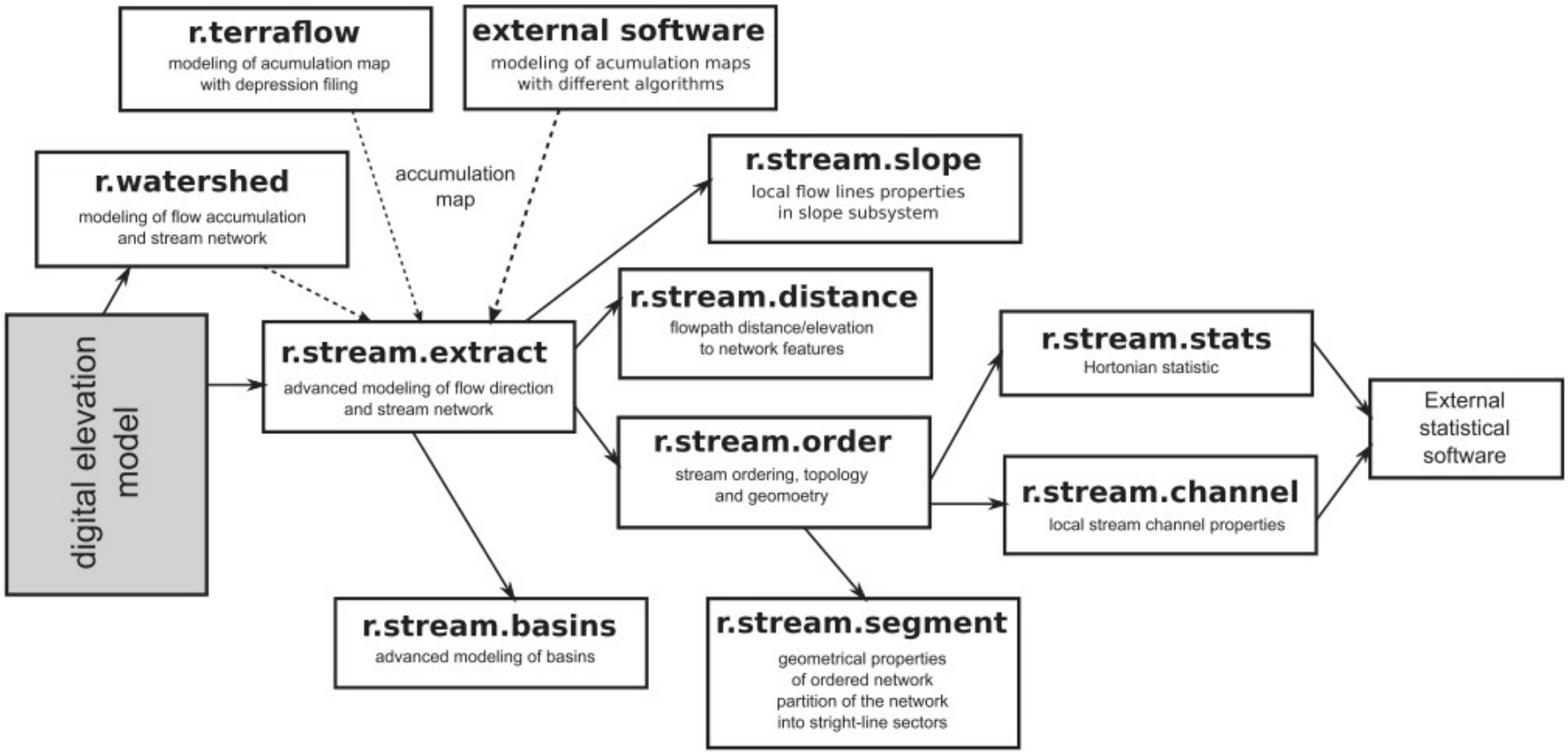
A new GRASS GIS toolkit for Hortonian analysis of drainage networks

Jarosław Jasiewicz[a], Markus Metz[b]

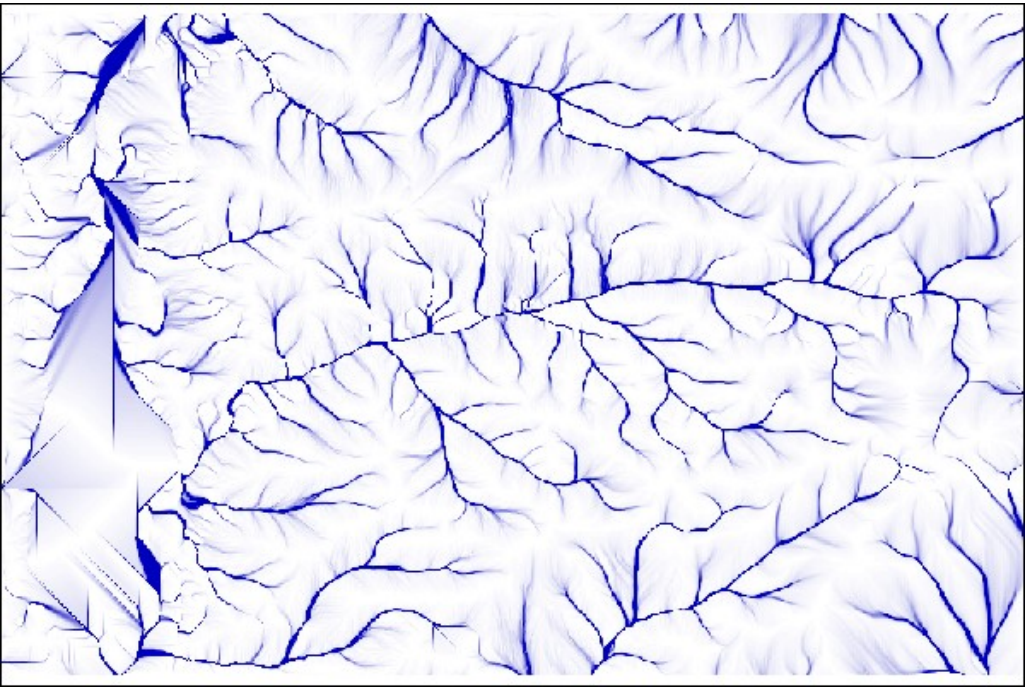
[a] Adam Mickiewicz University, Geoekology and Geoinformation Institute, Dzięgielowa 27 60-081 Poznań, Poland

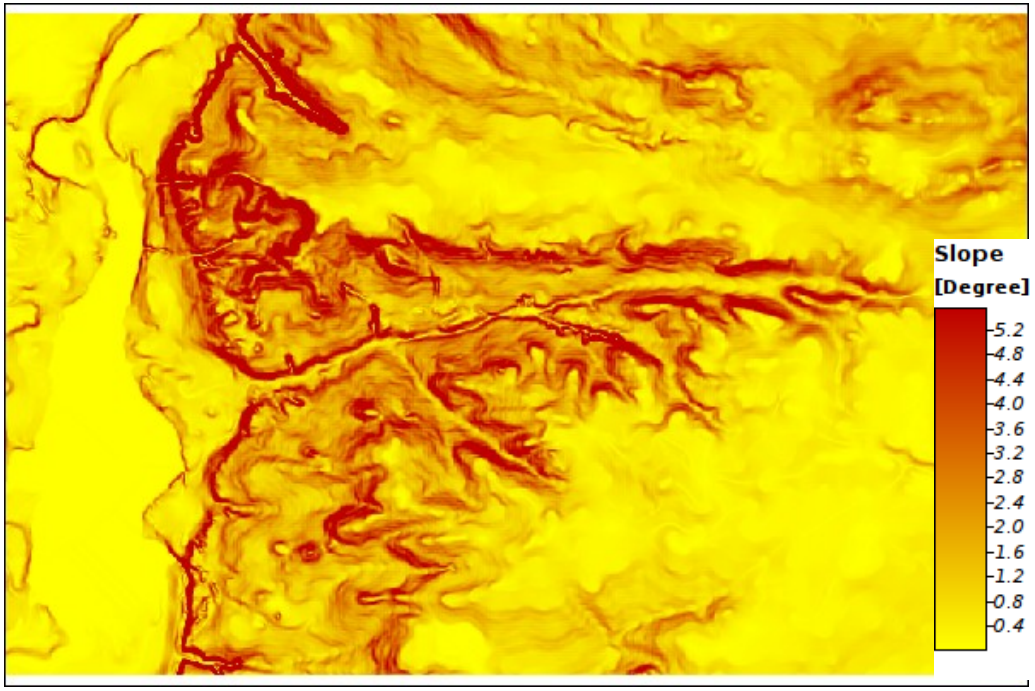
[b] University of Ulm, Institute of Experimental Ecology, Allee 11, 89069 Ulm, Germany

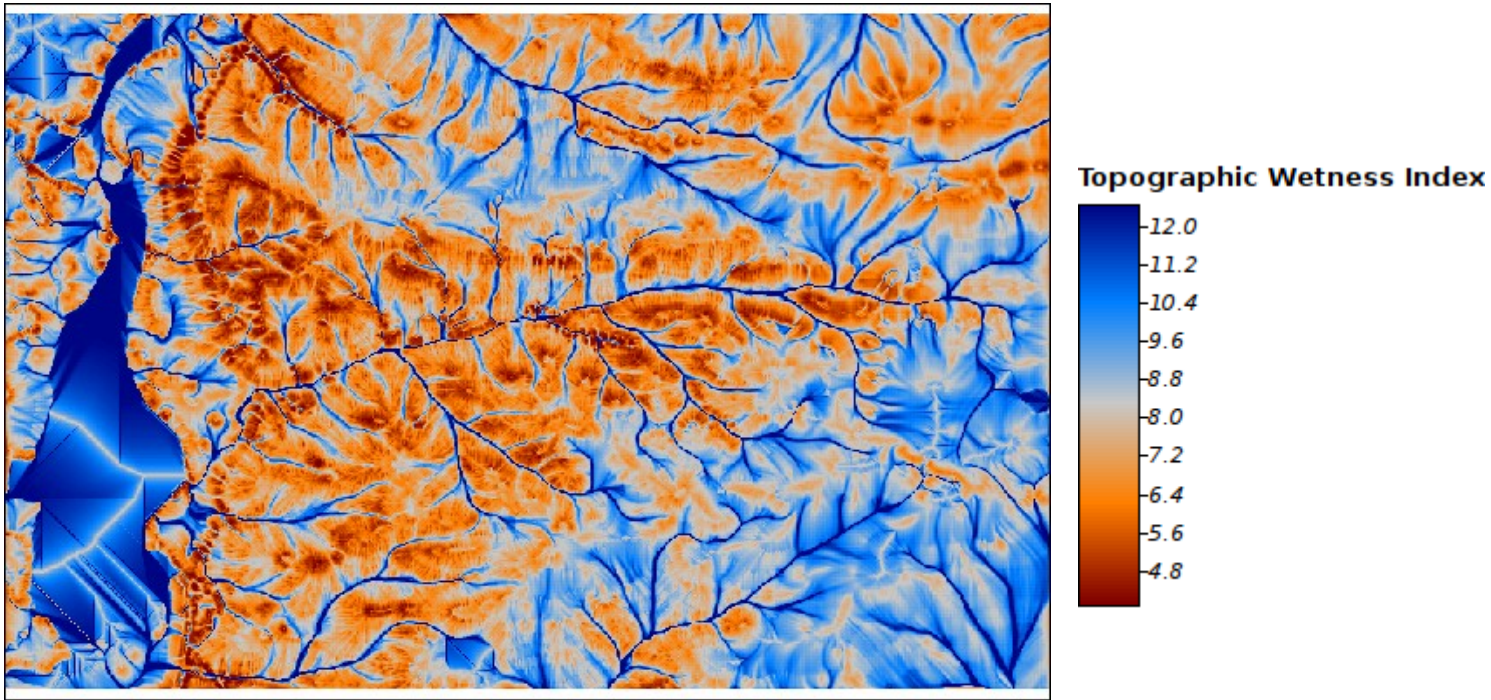
Received 8 March 2010, Revised 24 February 2011, Accepted 2 March 2011, Available online 21 March 2011



Modelowanie procesów erozyjno-denudacyjncych



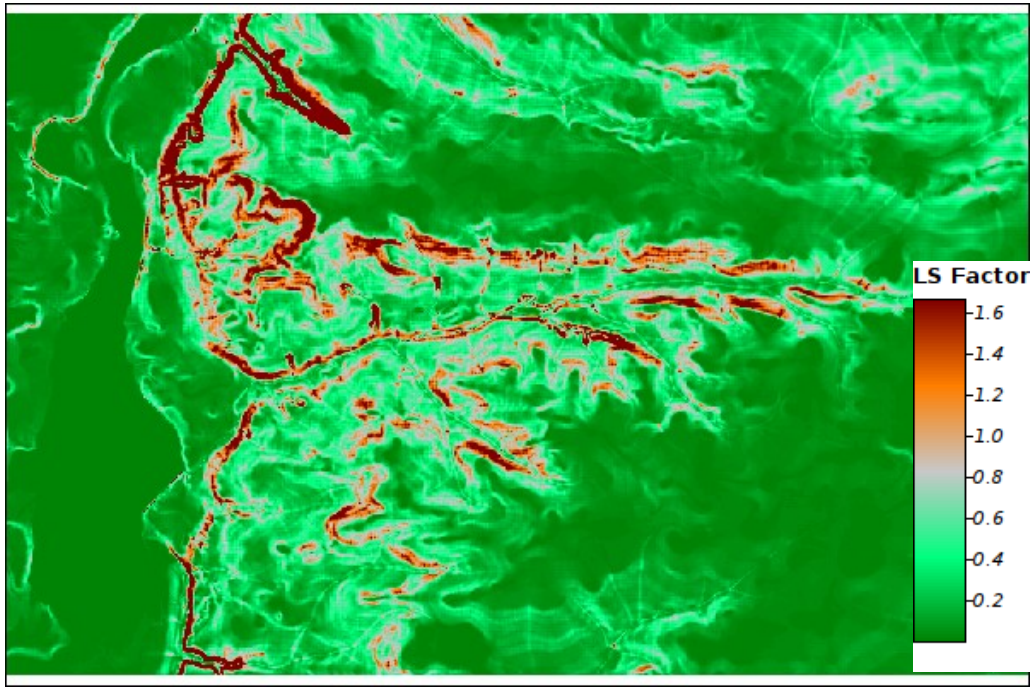




$$\mathrm{TWI} = \ln\left[\frac{A}{\tan(\beta)}\right]$$

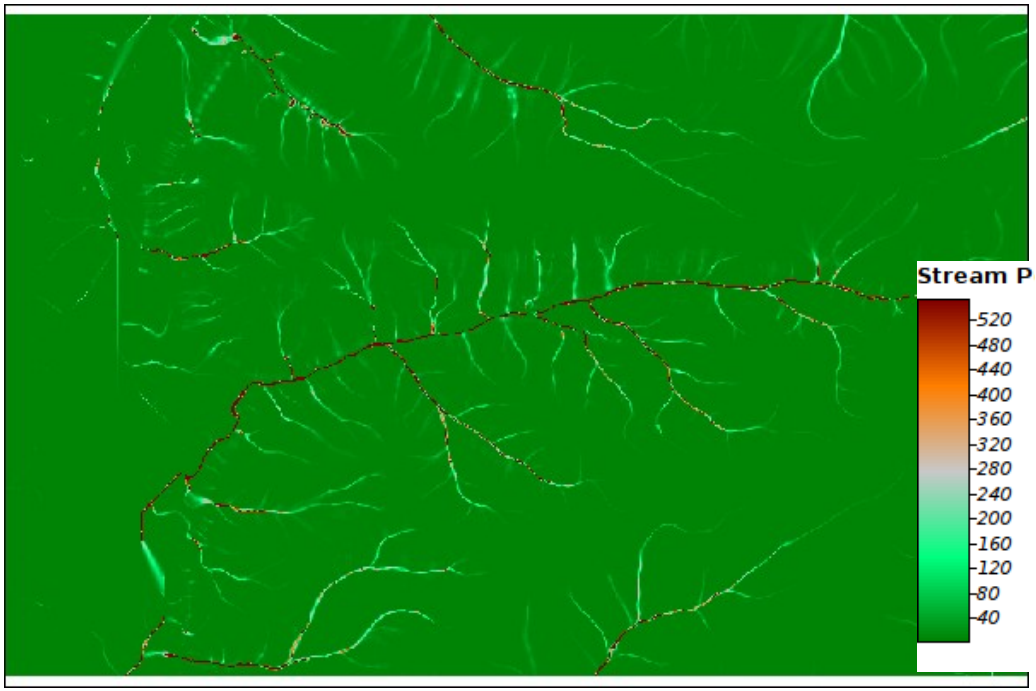
Erozja i transport osadów

Length-Slope Factor



$$LS = \left(\frac{A_s}{22.13}\right)^m \left(\frac{\sin(\theta)}{0.0896}\right)^n$$

Stream Power



$$\mathrm{SPI} = A \cdot \tan(\beta)$$

USLE – universal soil loss equation

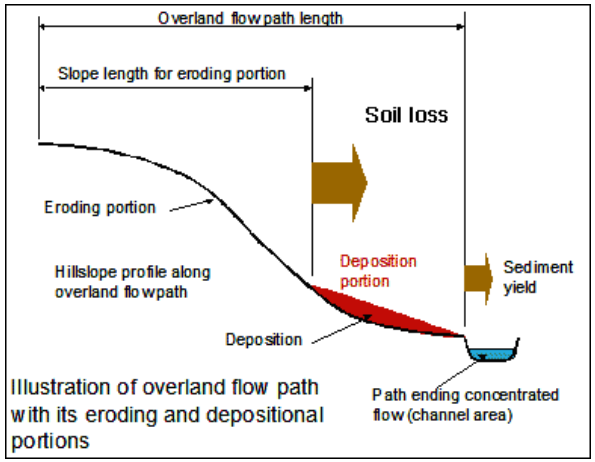
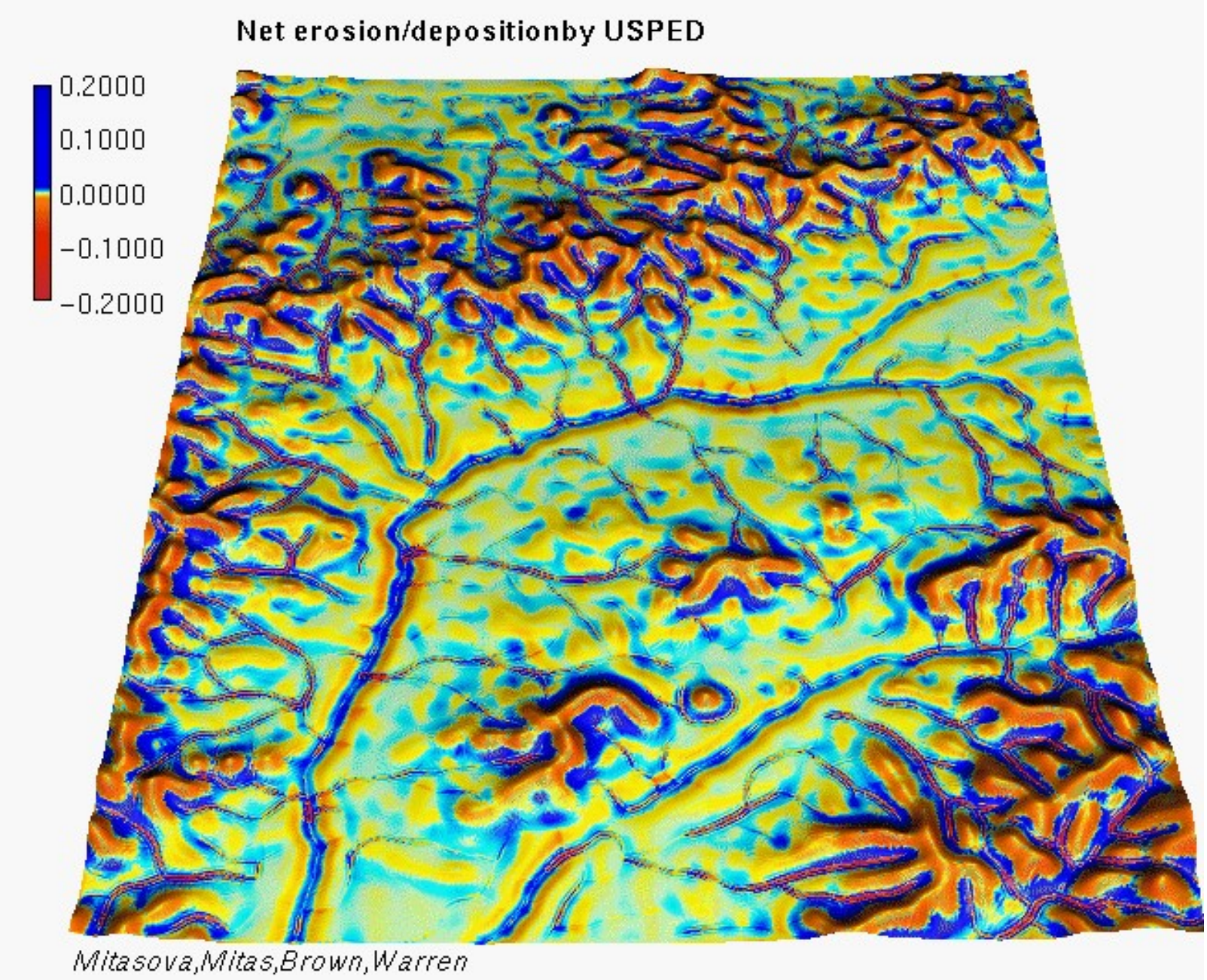
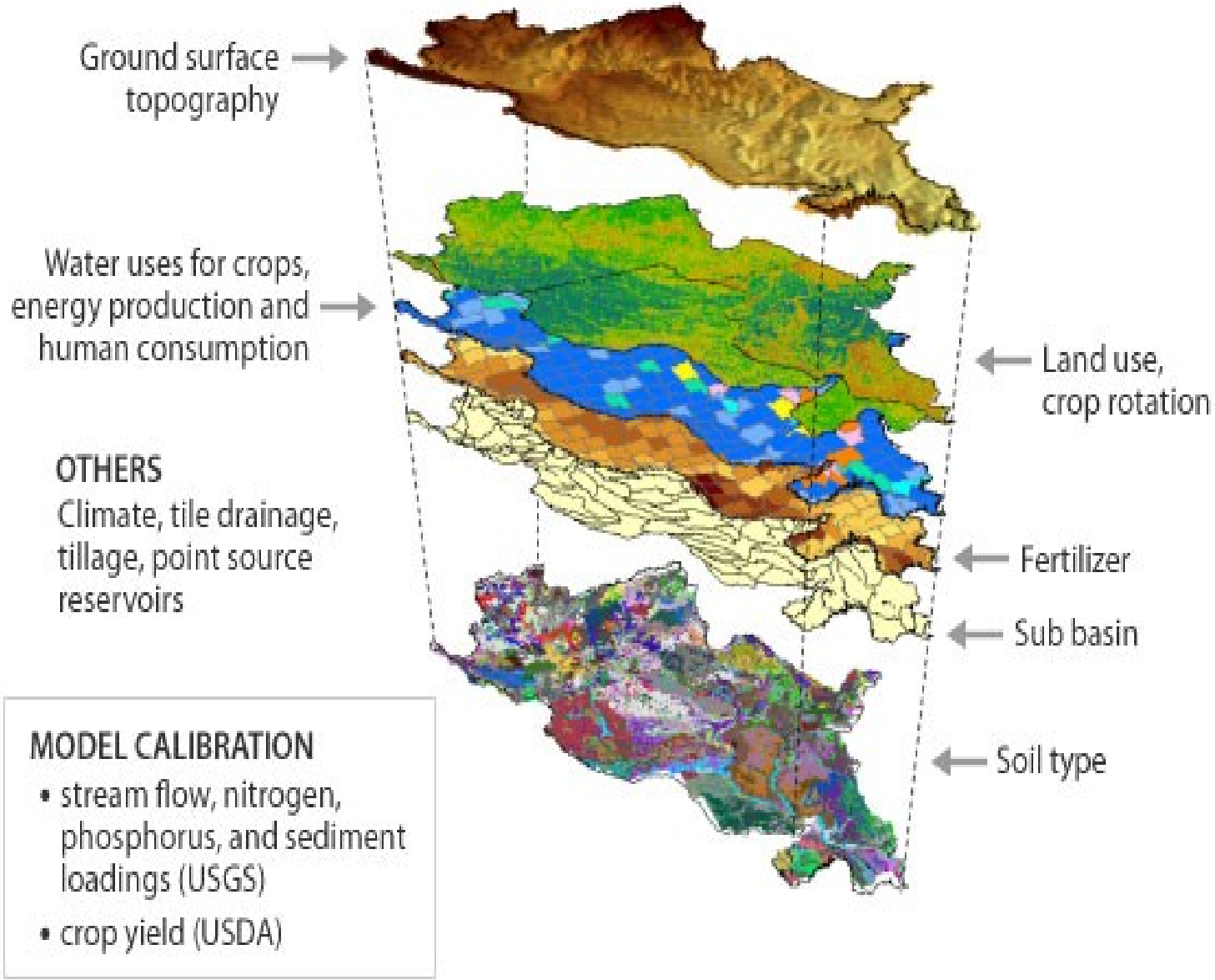


Illustration of overland flow path with its eroding and depositional portions

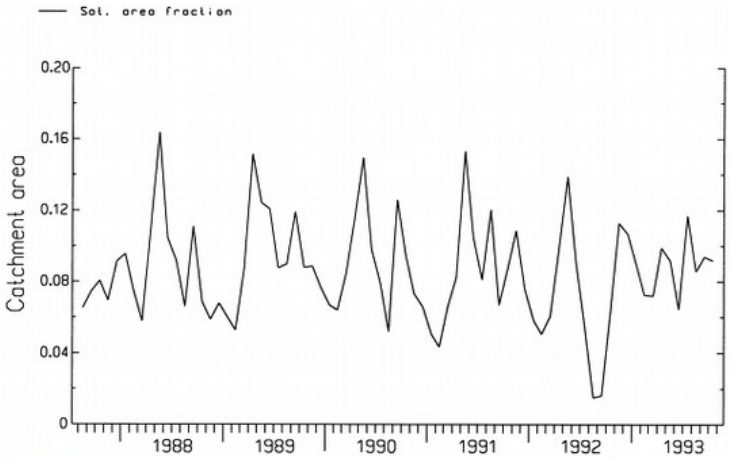
Sieć erozyjno-denudacyjna

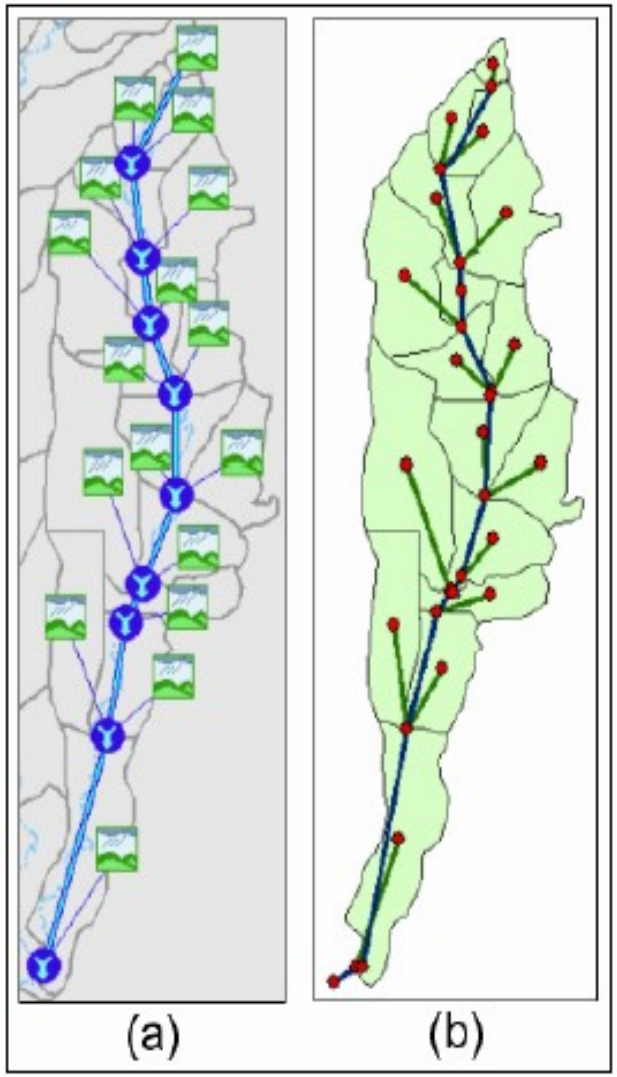


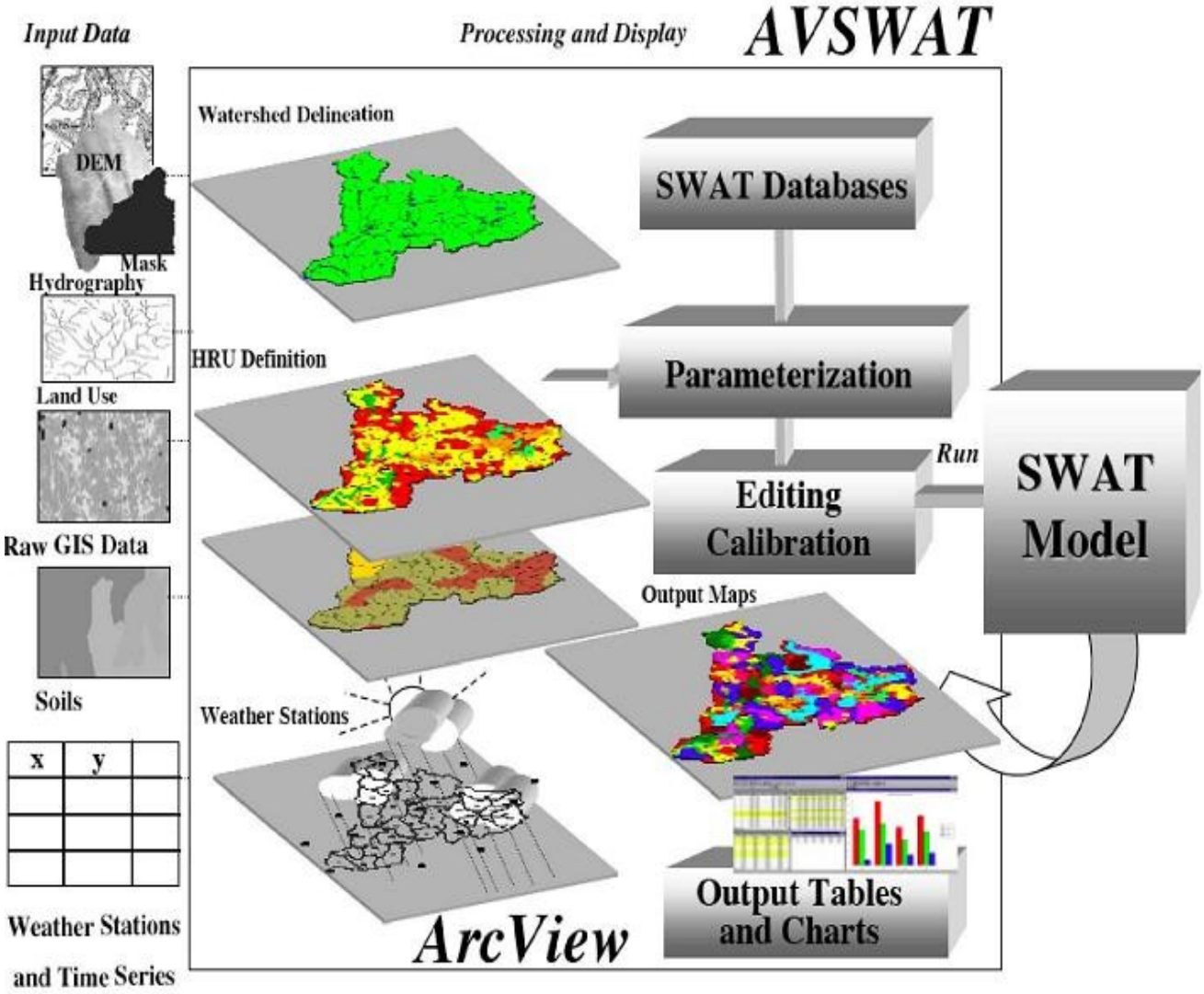
Modelowanie procesów hydrologicznych



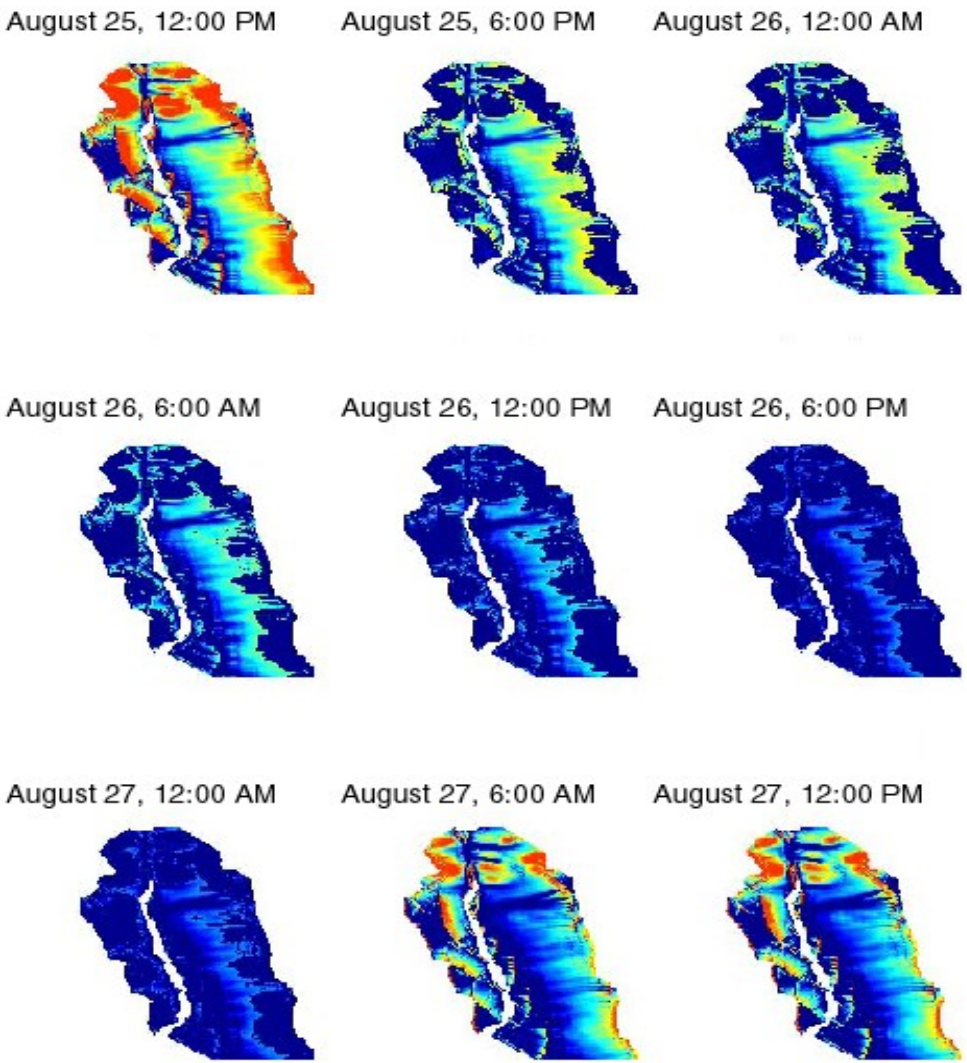
SWAT/TOPMODEL







Symulacje hydrologiczne

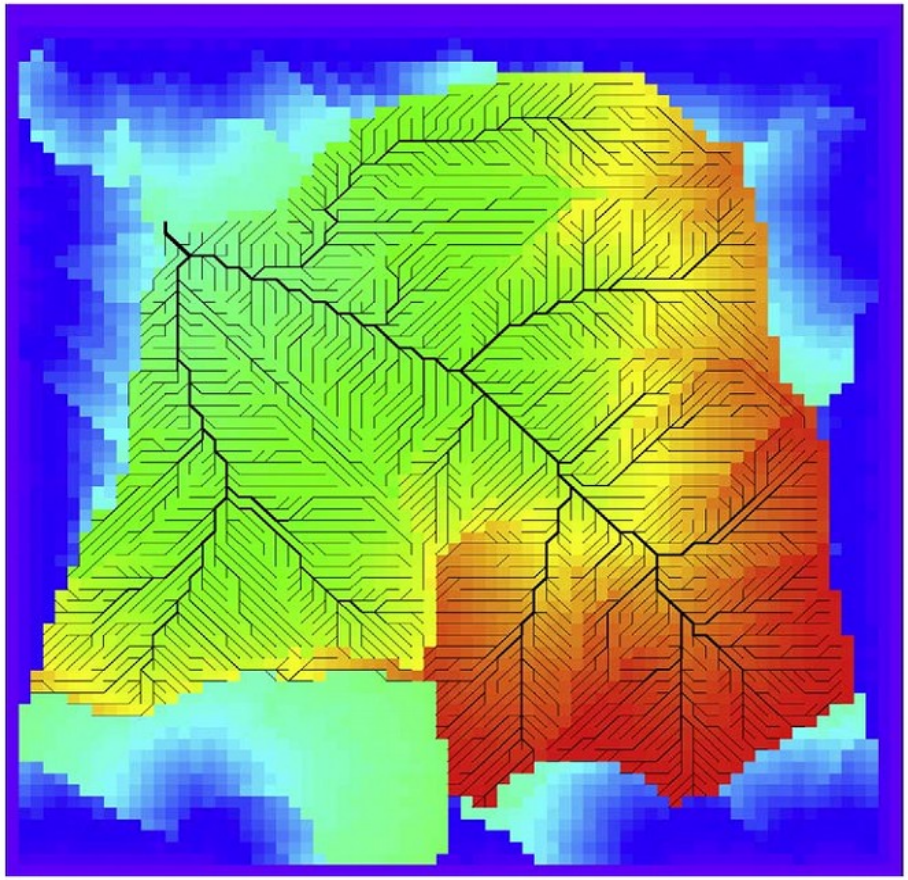


Przestrzenne modelowanie hydrologiczne

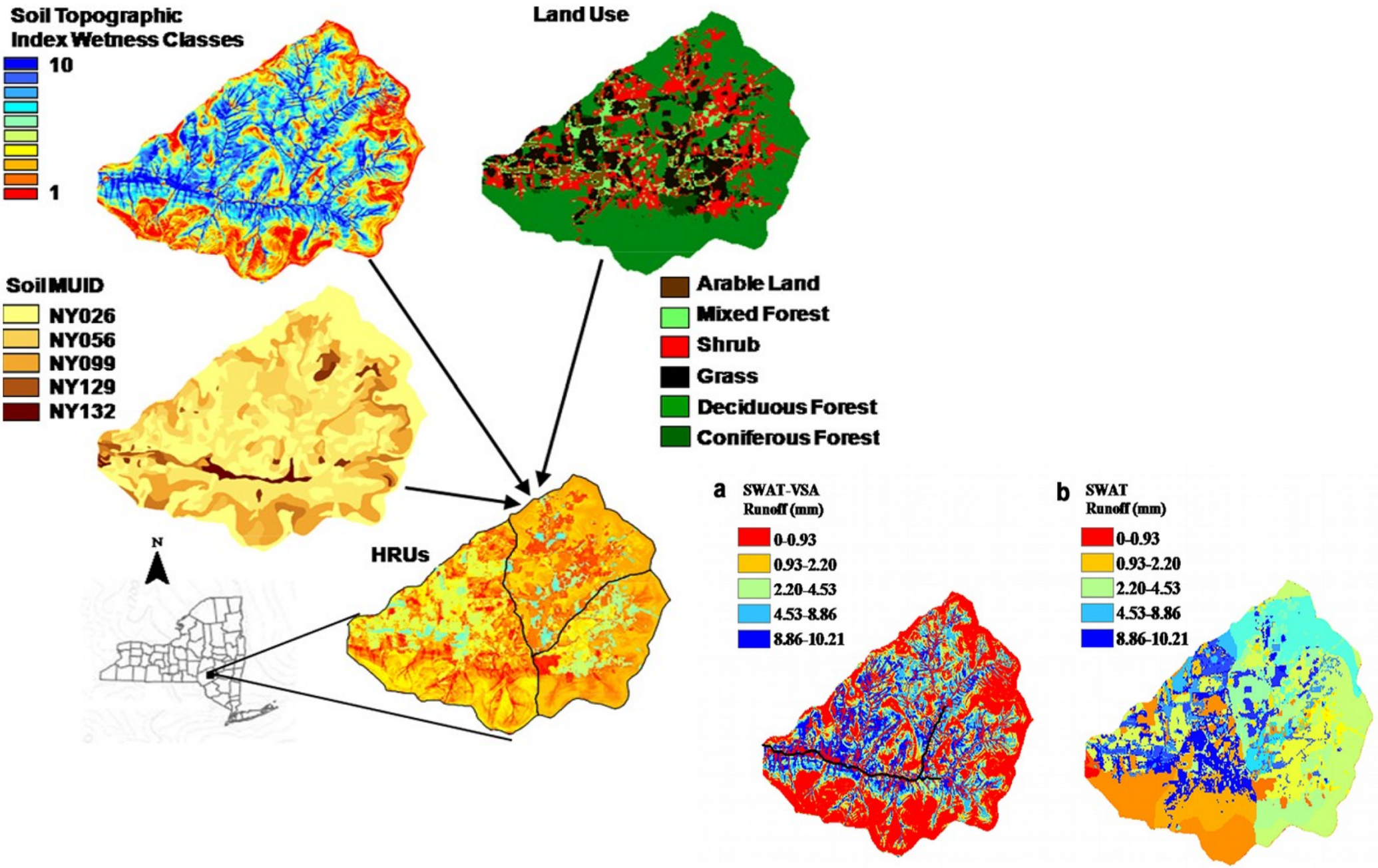
$$R = (P + M + G) - (E + I)$$

R Odpływ
P opad
M topnienie śniegu
G dopływ podziemny
E parowanie
I infitracja

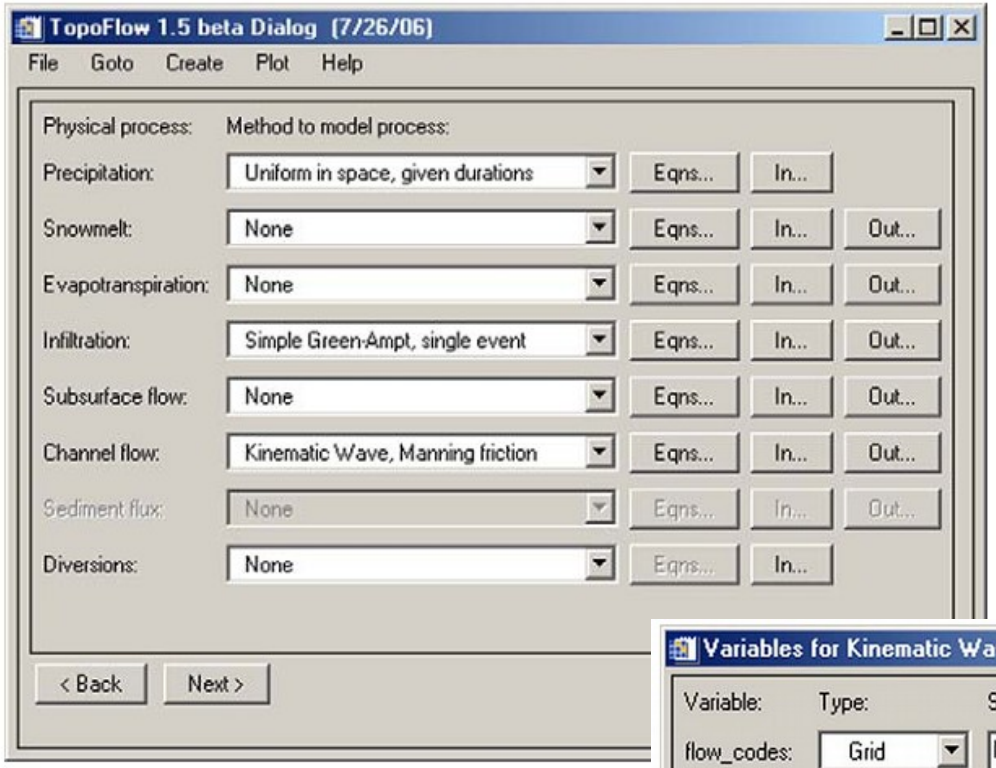
odpływ korytowy (channel flow process)
spływ pozakorytowy (overland flow)

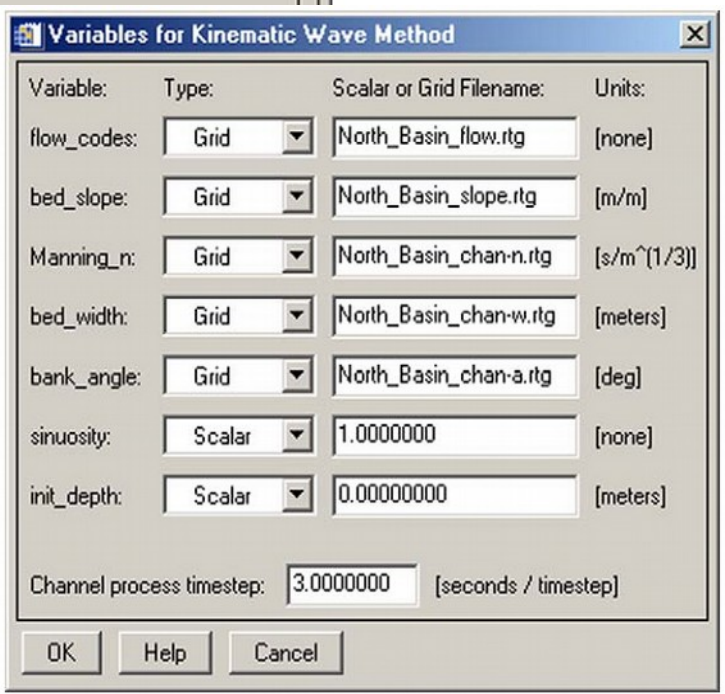


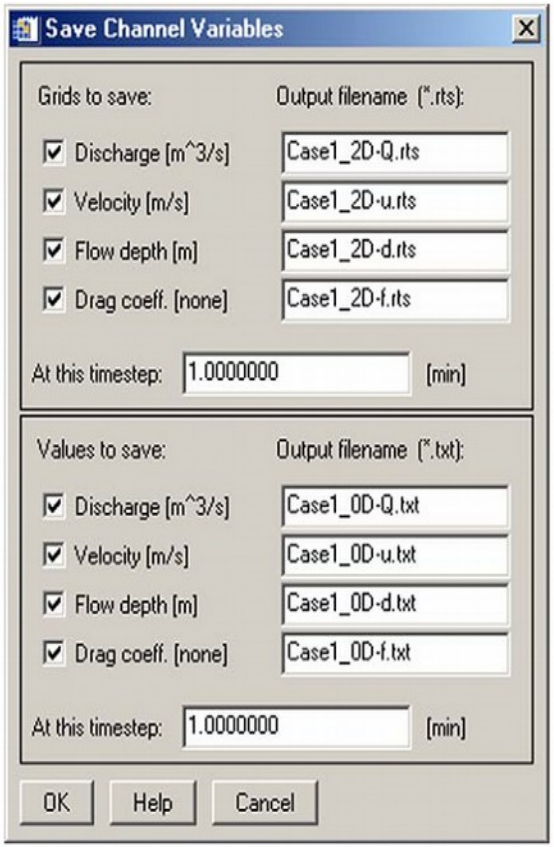
SWAT/TOPMODEL



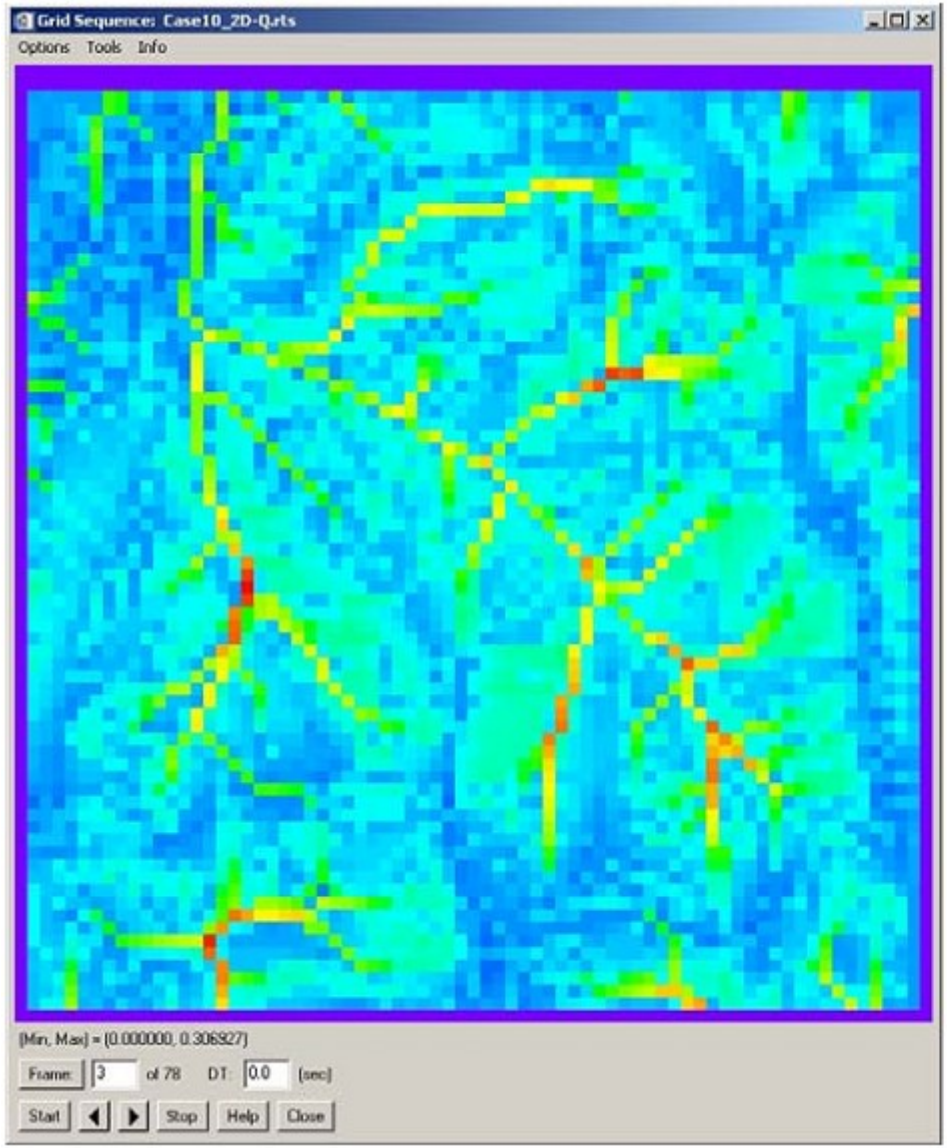
Dane wejściowe

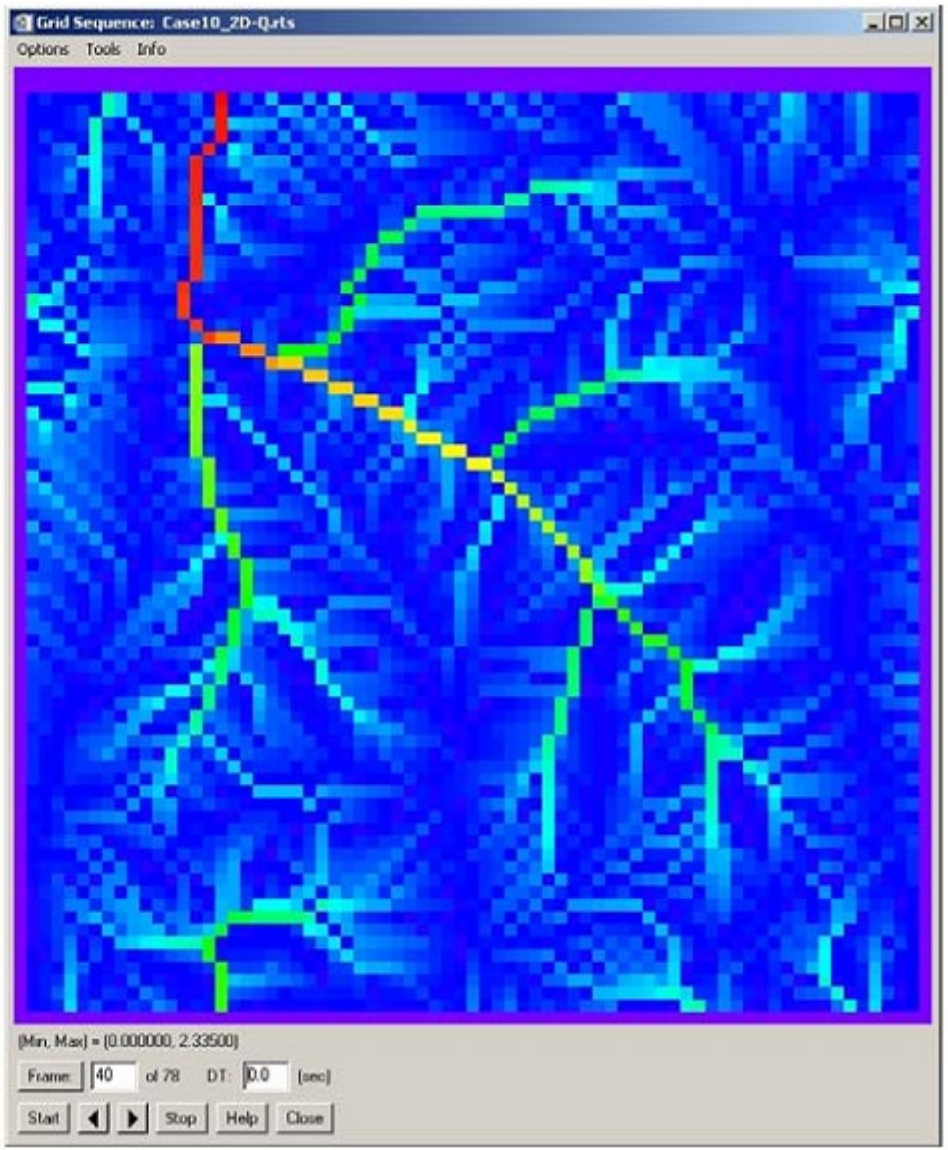




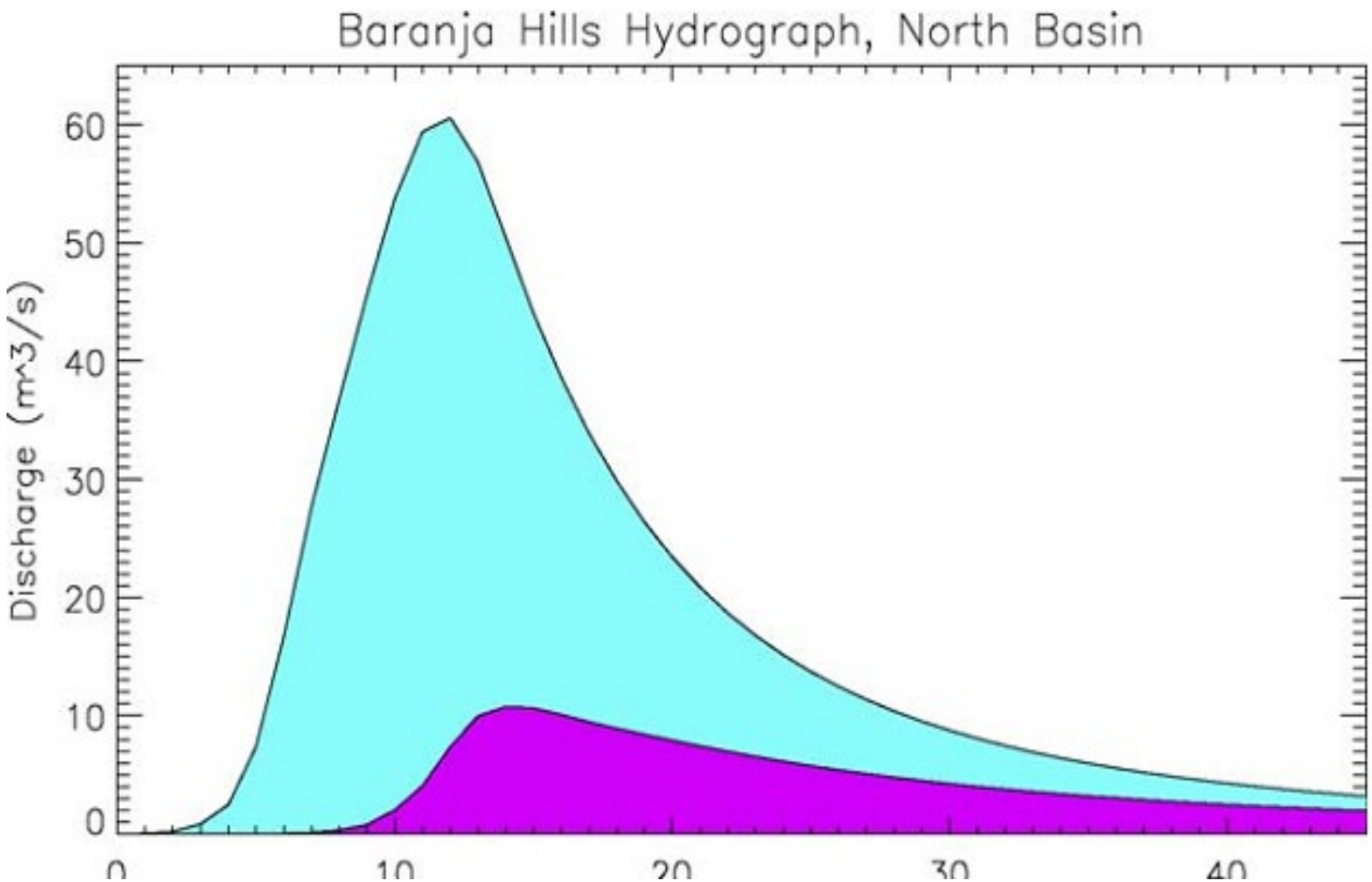


Kroki symulacji

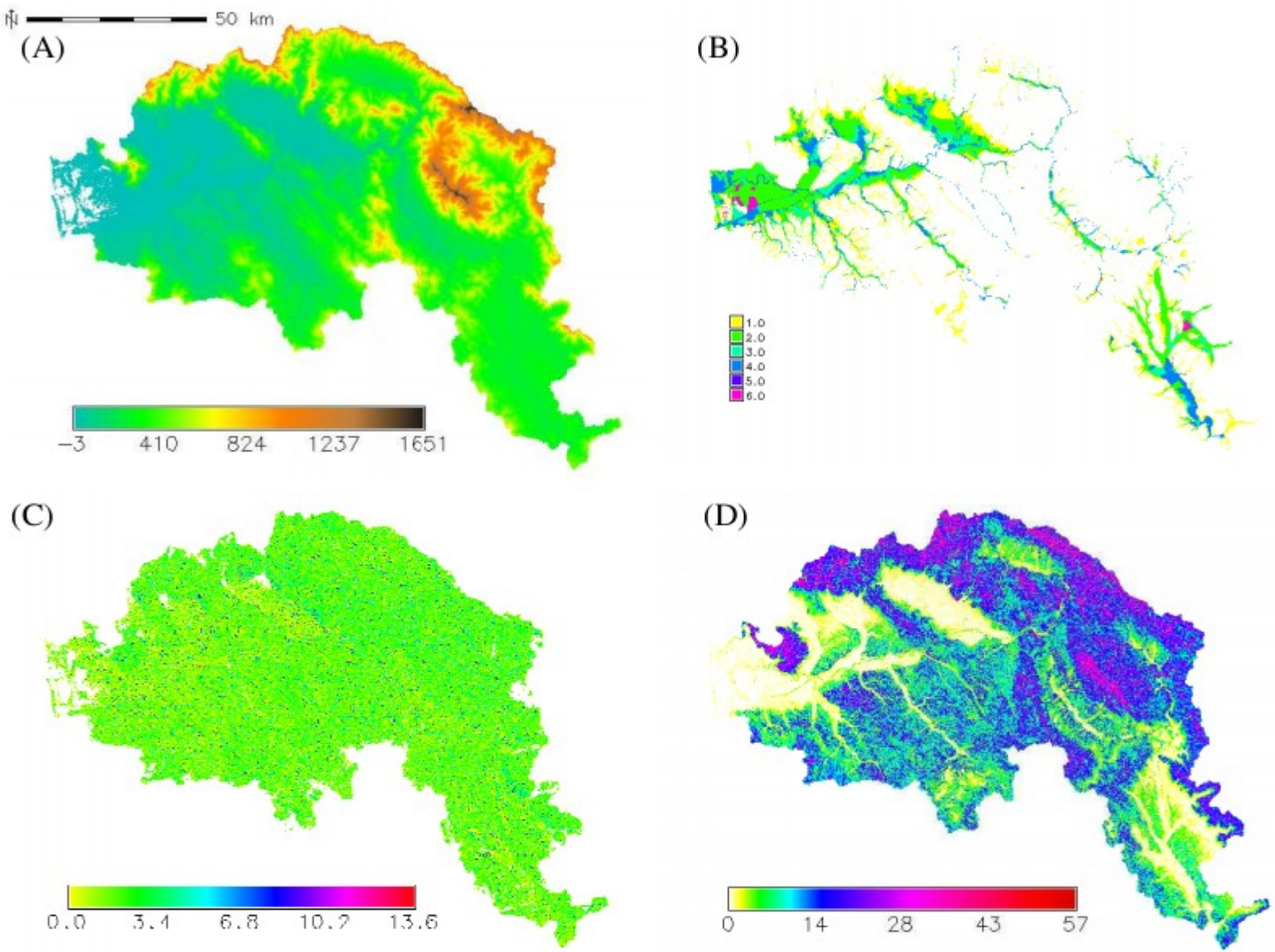




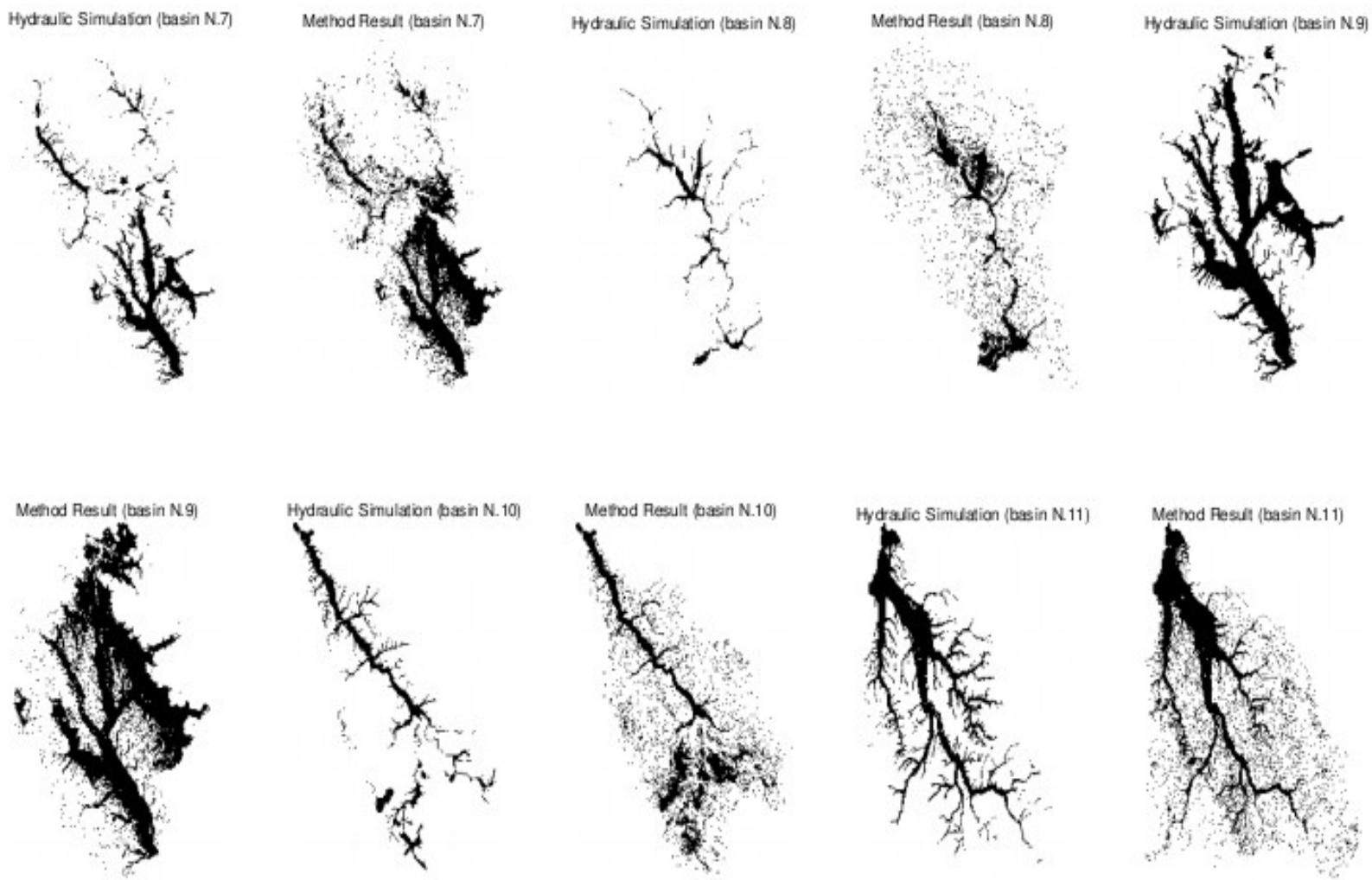
Hydrograf


Baranja Hills Hydrograph, North Basin
Discharge (m^3/s)
60
50
40
30
20
10
0
0
10
20
30
40

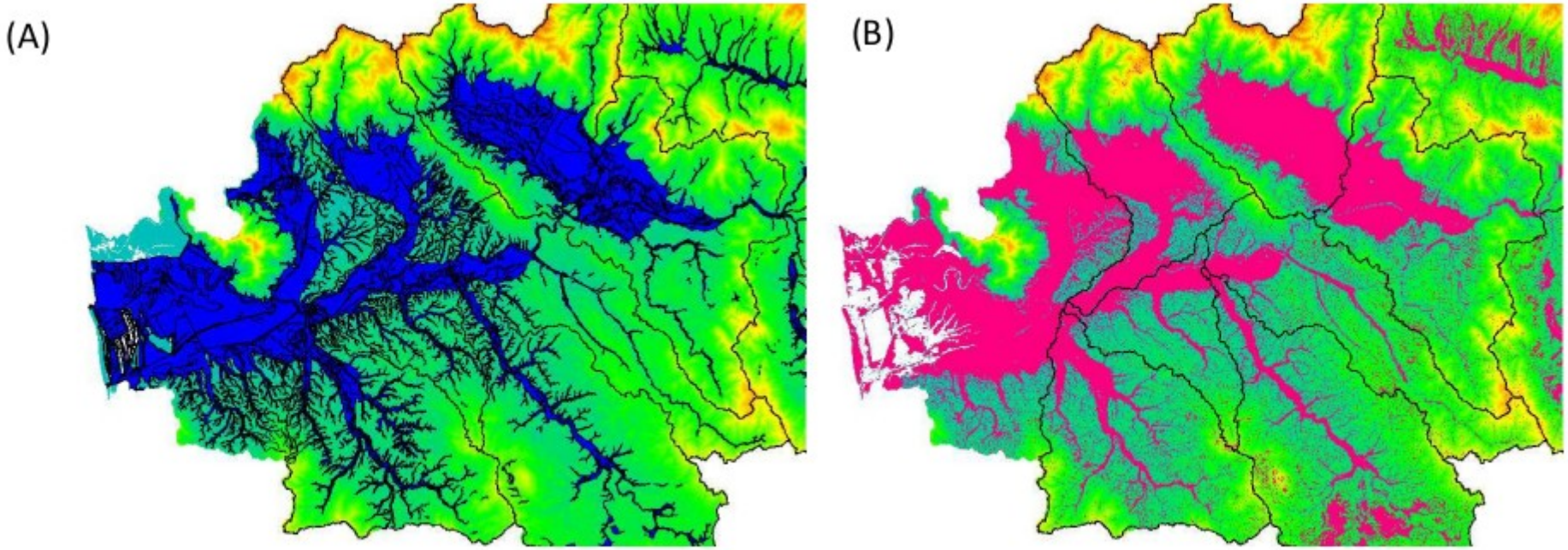
Powodzie


50 km
(A)
−3
410
824
1237
1651
(B)
1.0
2.0
3.0
4.0
5.0
6.0
(C)
0.0
3.4
6.8
10.2
13.6
(D)
0
14
28
43
57

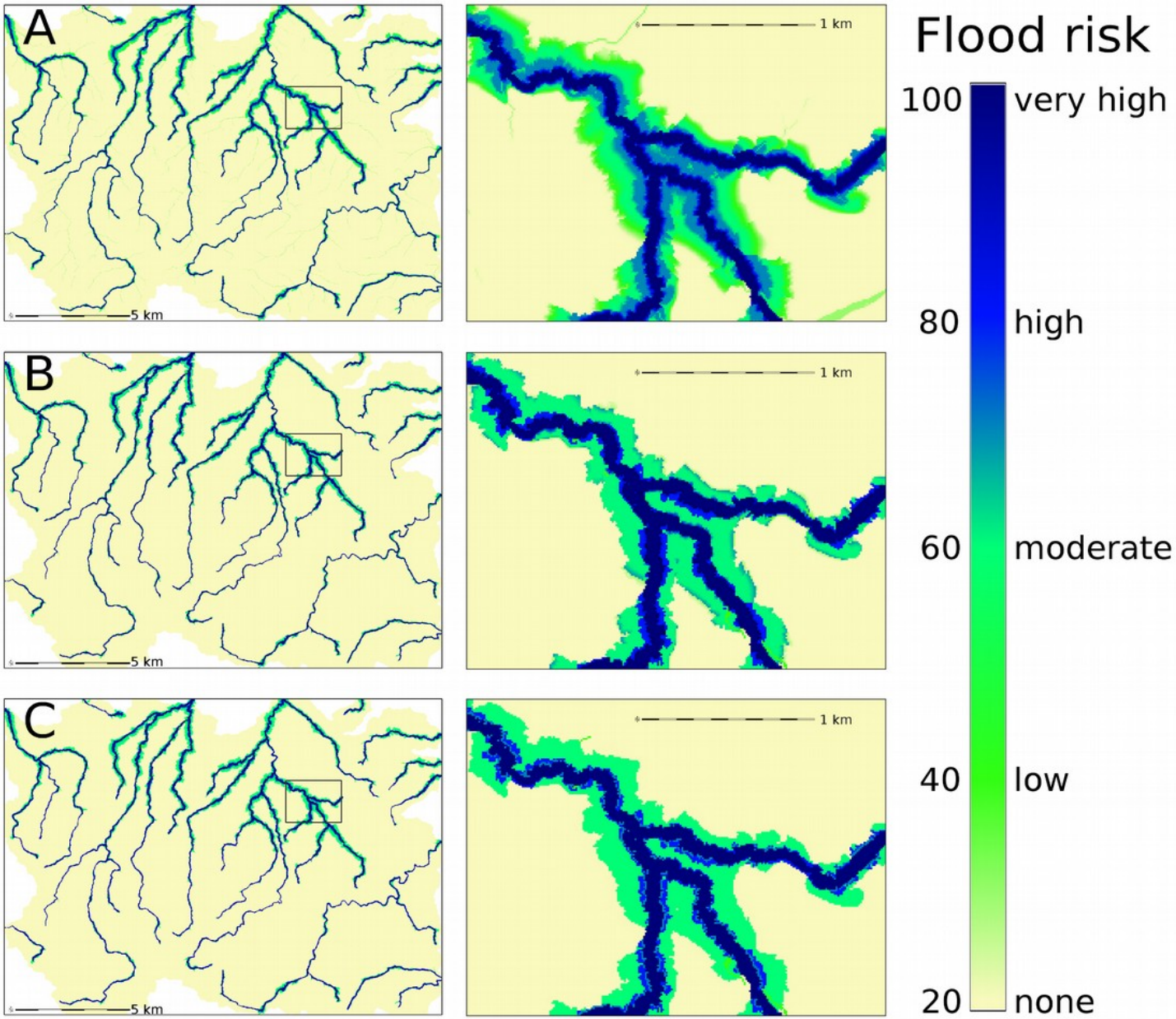
Symulacje hydrauliczne



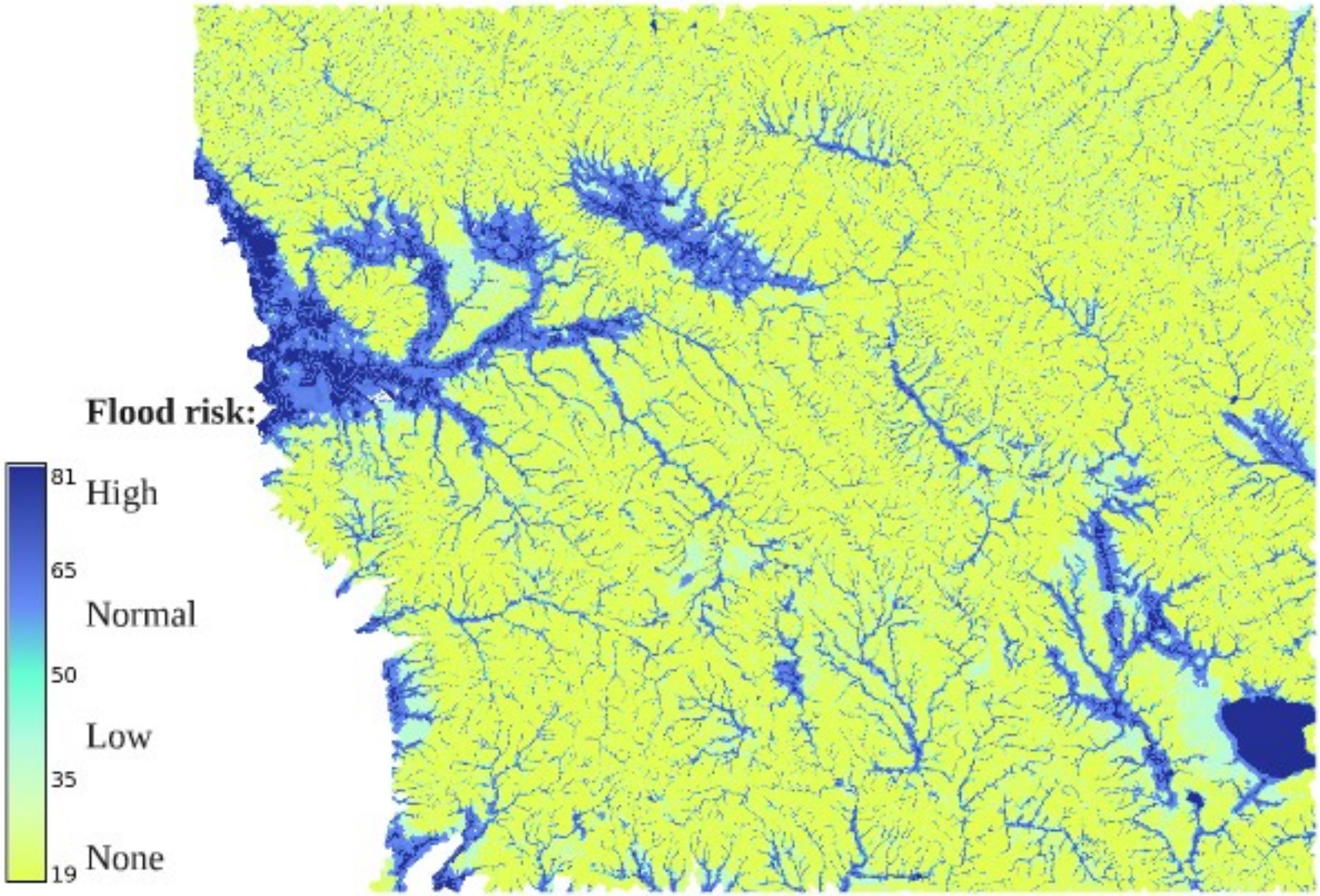
Porówanie danych pomiarowych i symulacji



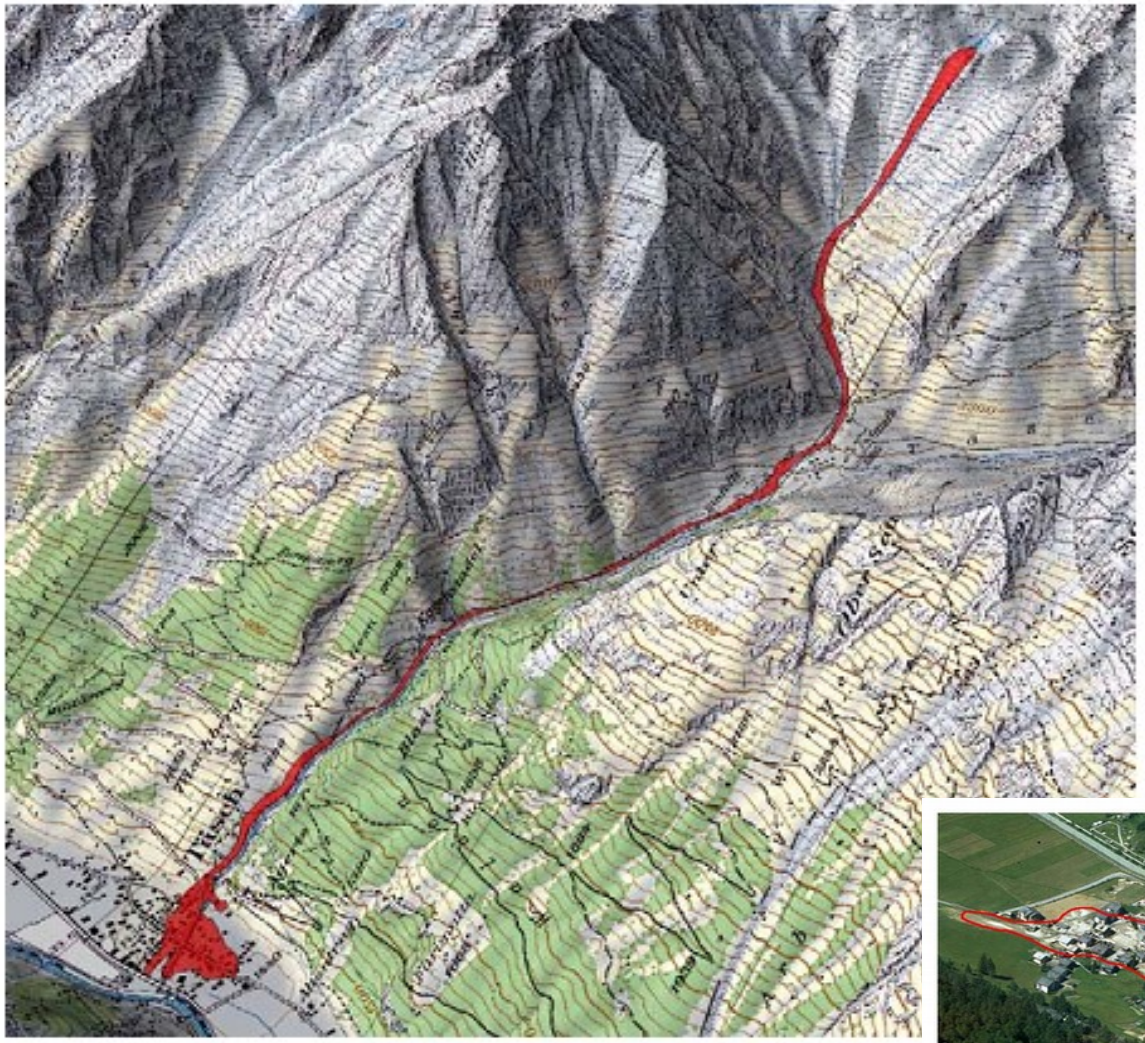
Modelowanie rozmyte

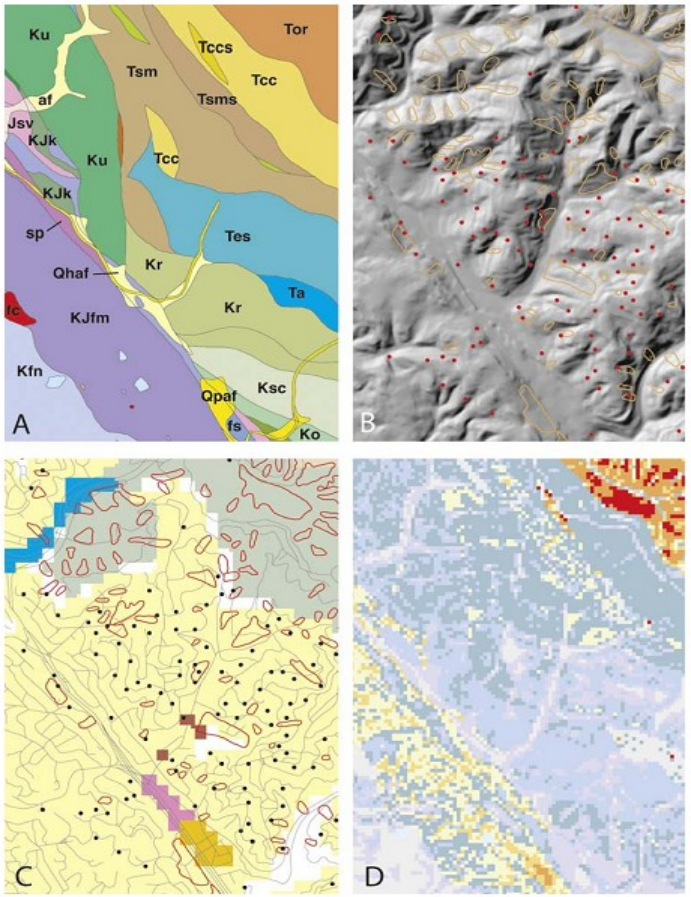


Modelowanie rozmyte stref zagrożeń

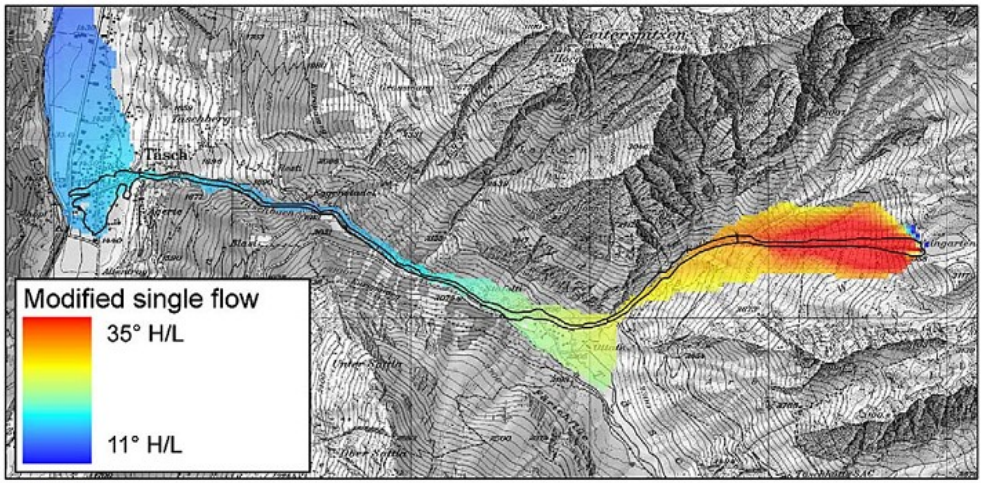


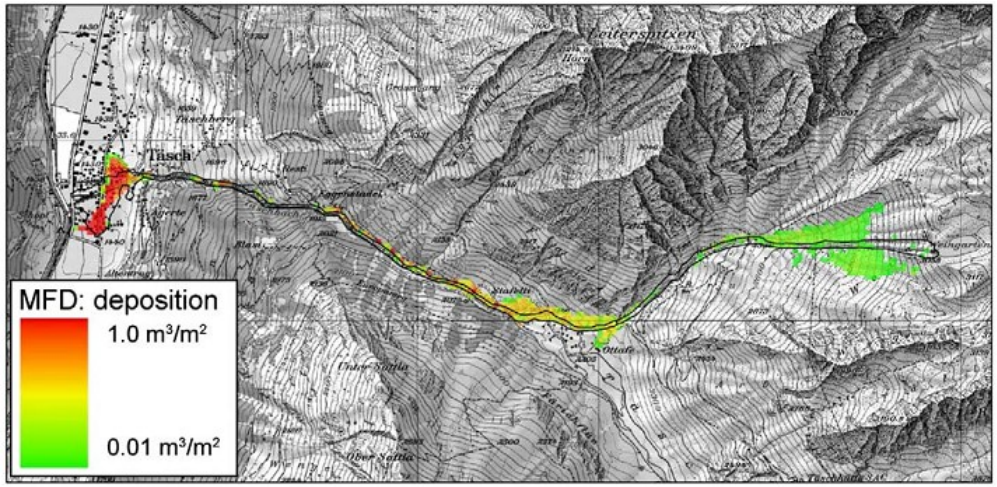
Ruchy masowe i osuwiska

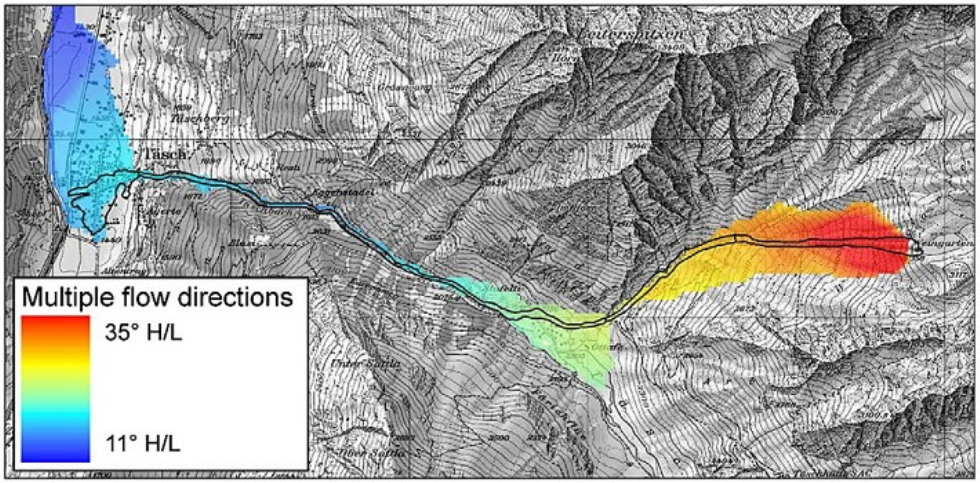


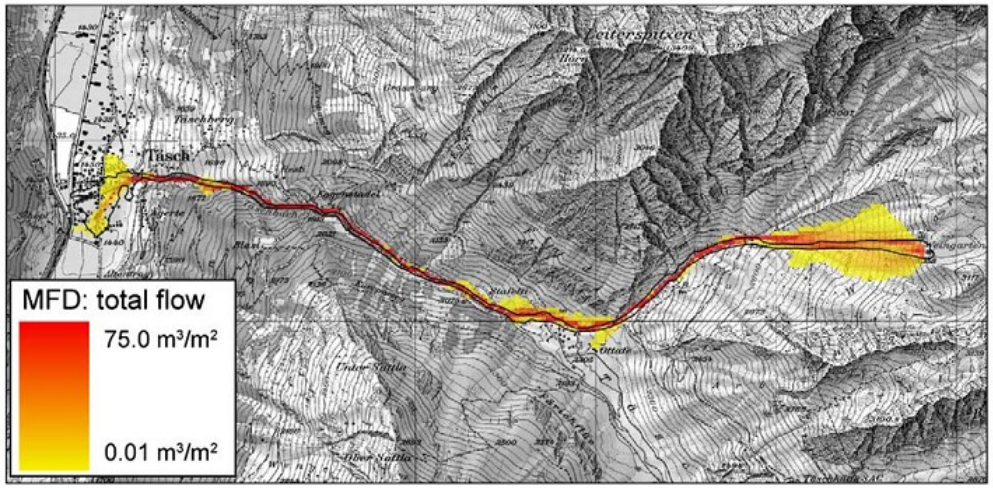


Modelowanie osuwisk





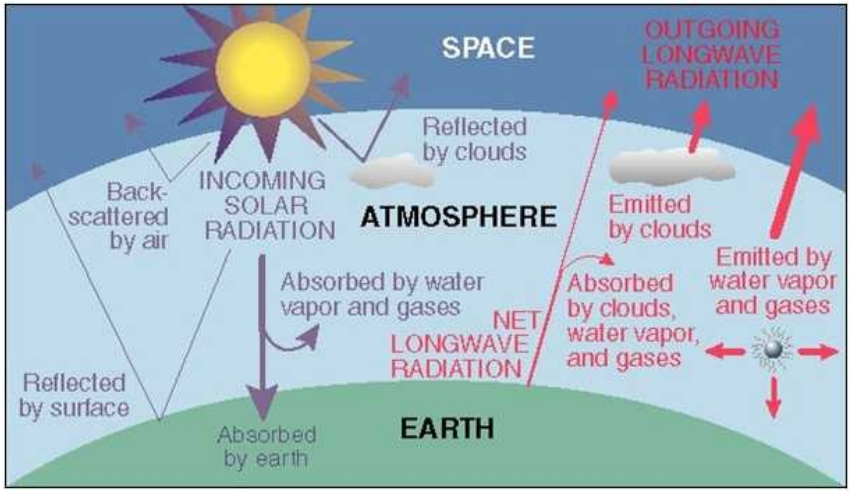




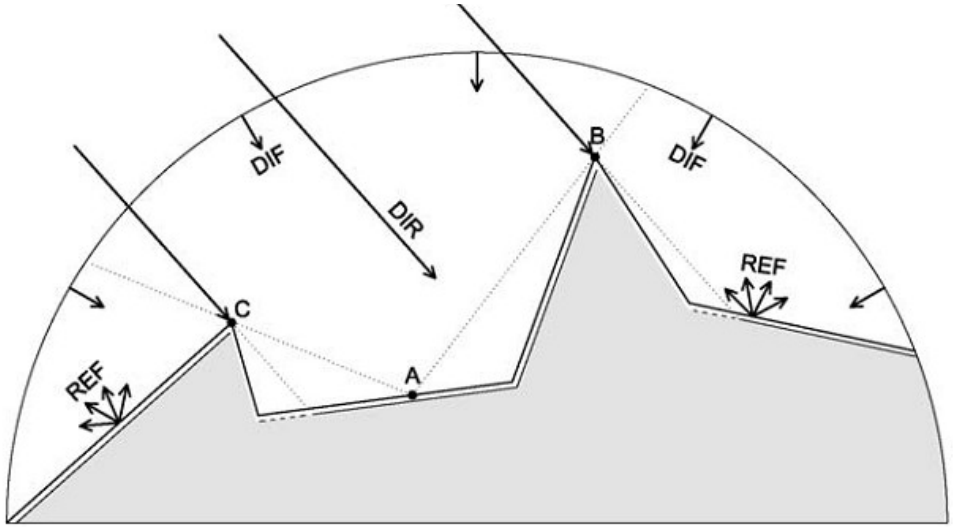
Analizy klimatyczne

- usłonecznienie (solar radiation)
- modelowanie temperatur
- modelowanie opadów
- modelowanie wystawienia na wiatr
- modelowanie przepływu ciepła

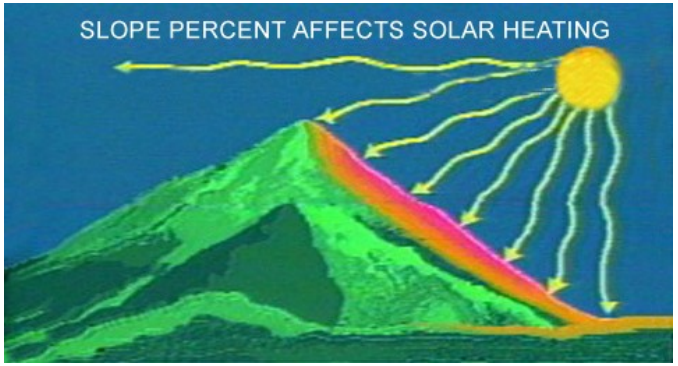
Usłonecznienie

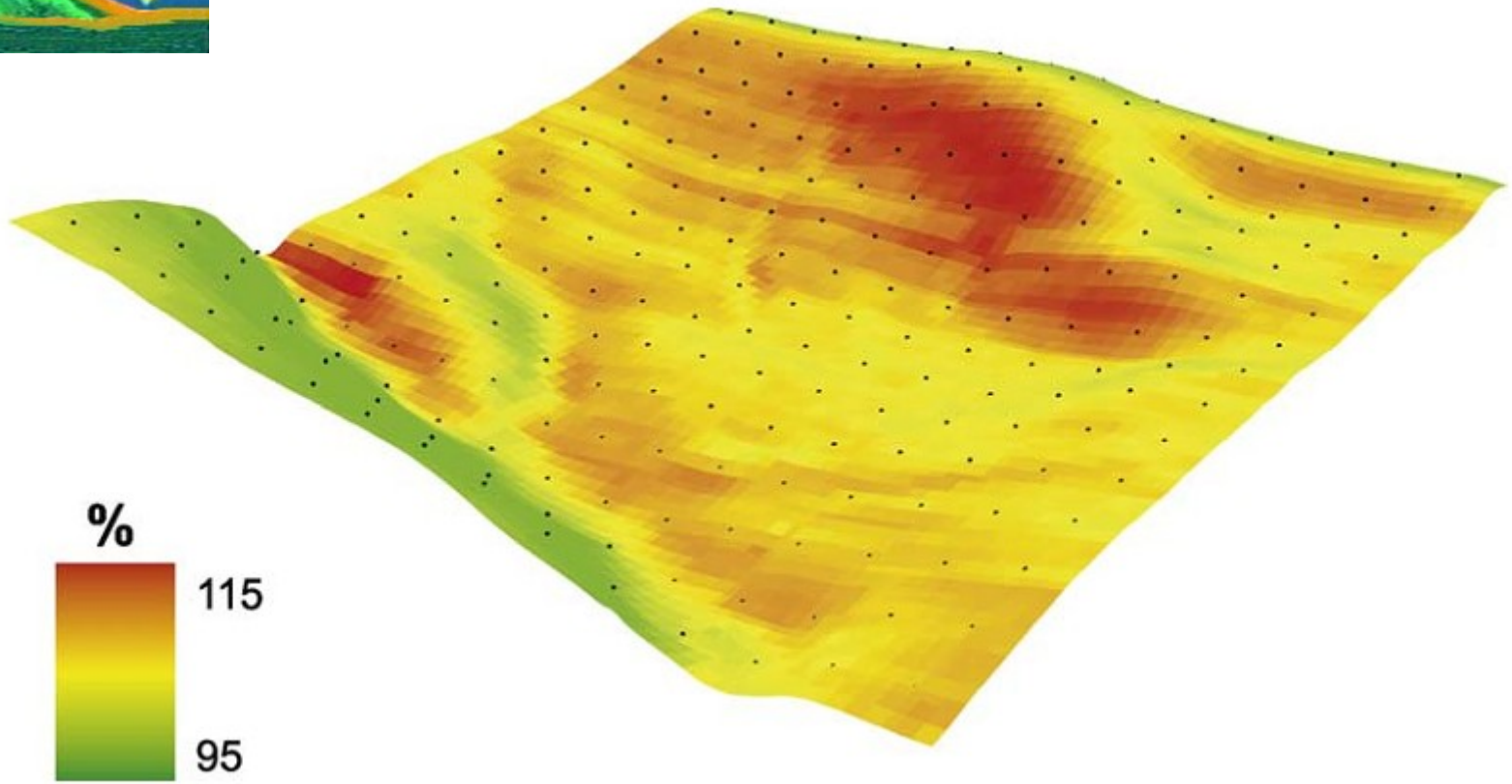


$$S_n^* = \left(S_s^* + S_h^* + S_t\right) \cdot (1 - r)$$



Lokalne usłonecznie

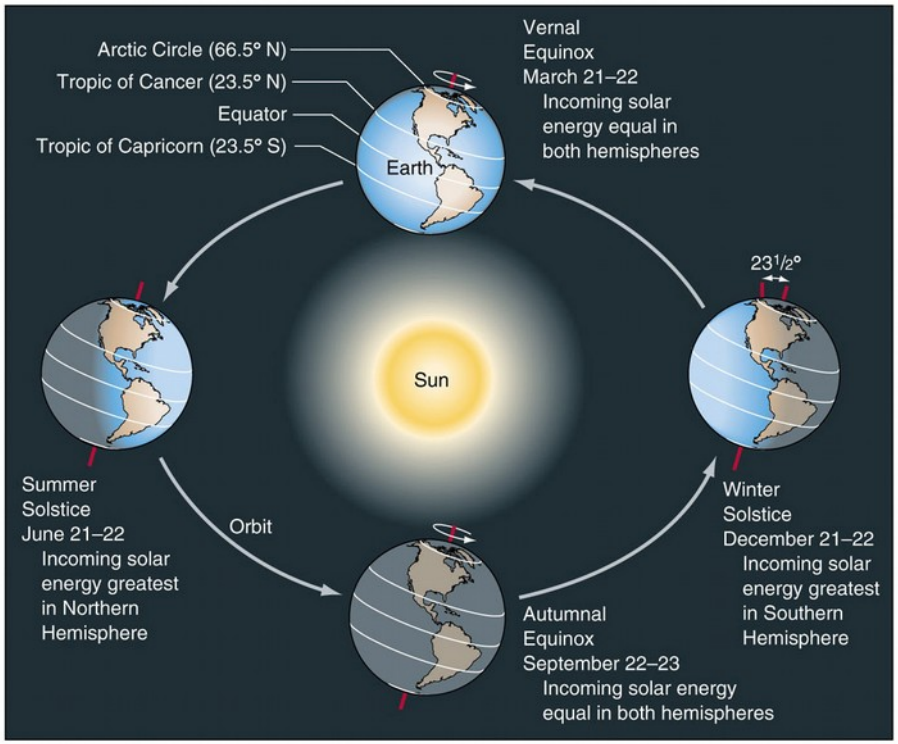


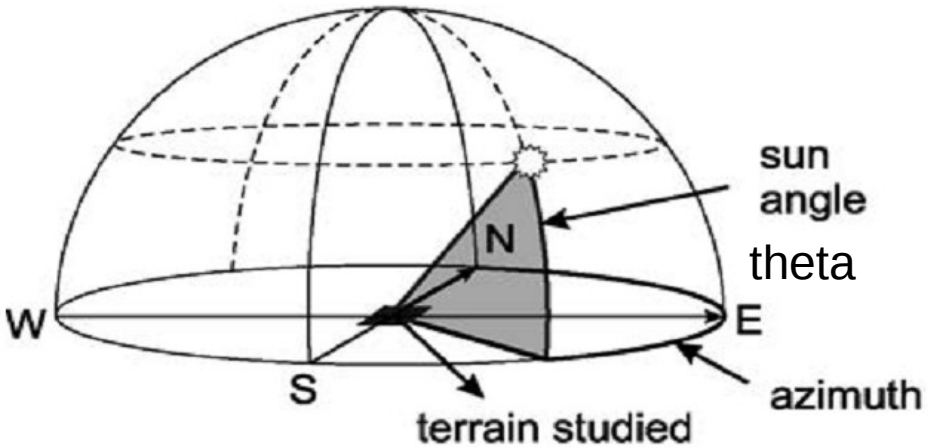


Roczne usłonecznienie

$$\sin\theta = \cos\lambda \cdot \cos\delta \cdot \cos\varpi + \sin\lambda \cdot \sin\delta$$

$$\cos\phi = \frac{\cos\delta \cdot \cos\varpi - \sin\theta \cdot \cos\lambda}{\sin\lambda \cdot \cos\theta}$$

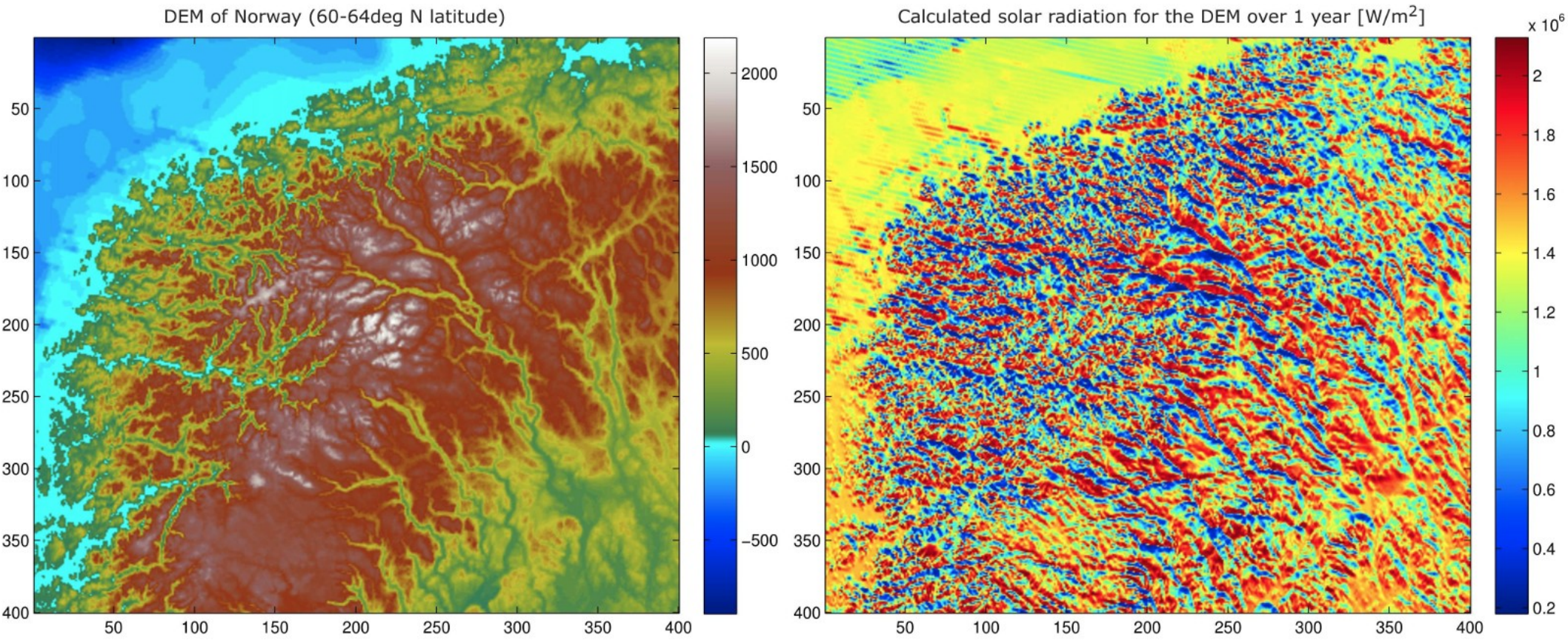




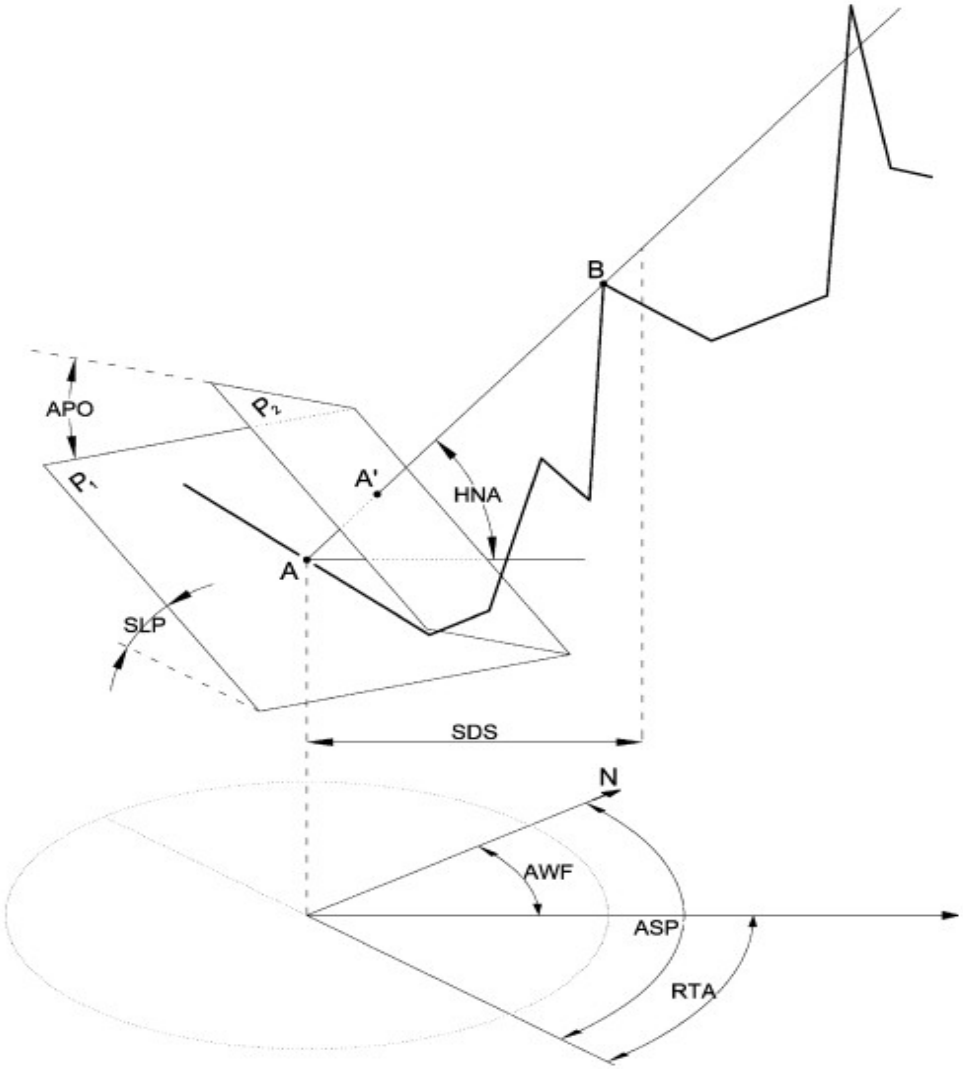
phi

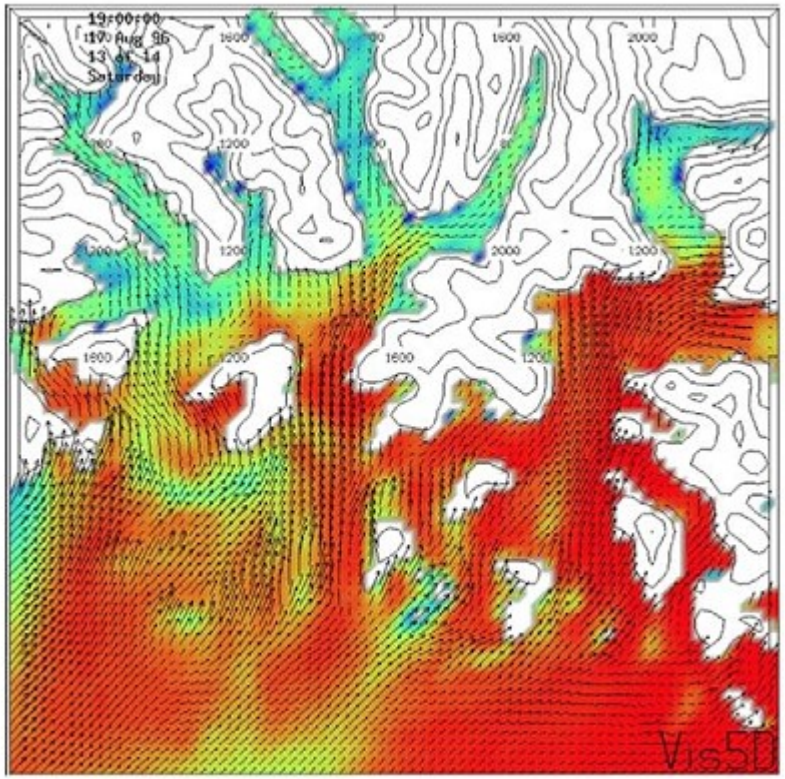
$$\delta = 23.45 \cdot \sin\left(\frac{360^\circ \cdot [284 + J]}{365}\right)$$

$$\varpi = 15^\circ \cdot (12 - t)$$ godzina

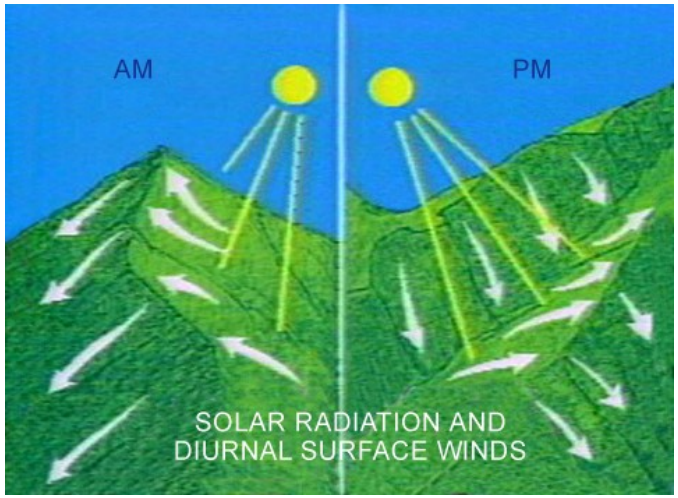

DEM of Norway (60-64deg N latitude)
Calculated solar radiation for the DEM over 1 year [W/m2]
x 10^6
50
100
150
200
250
300
350
400
2000
1500
1000
500
0
−500
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2

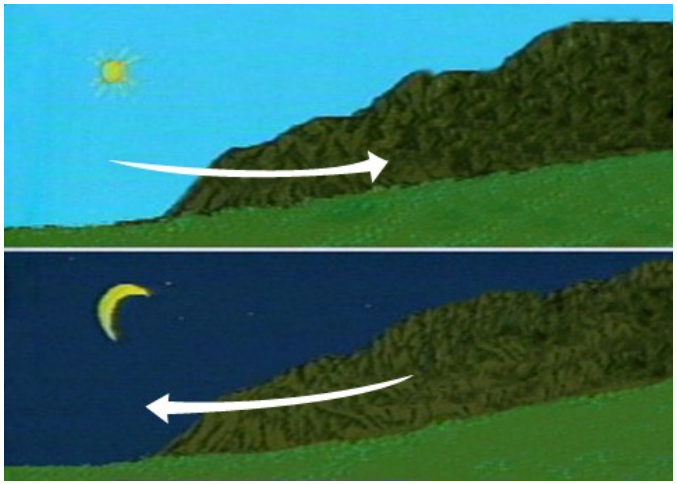
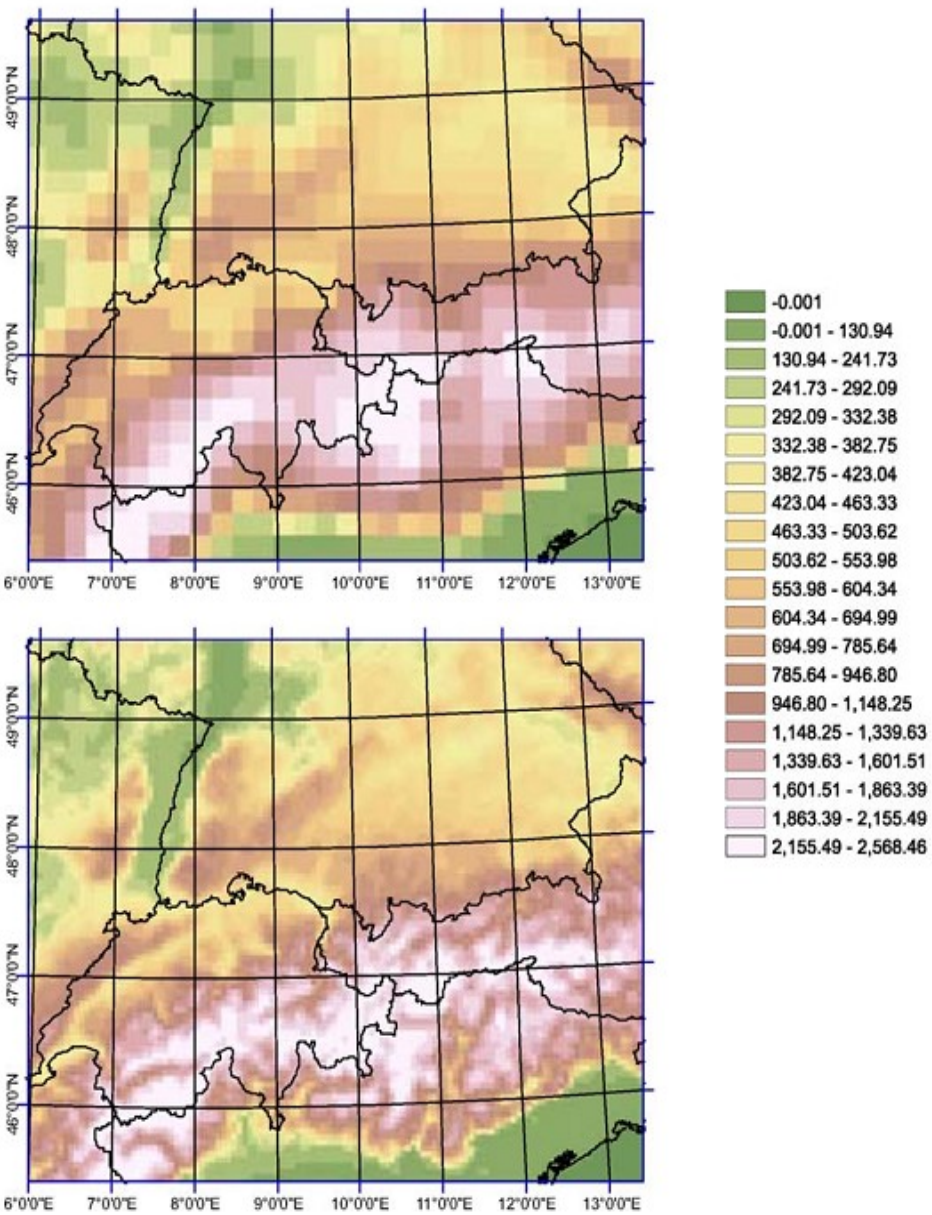
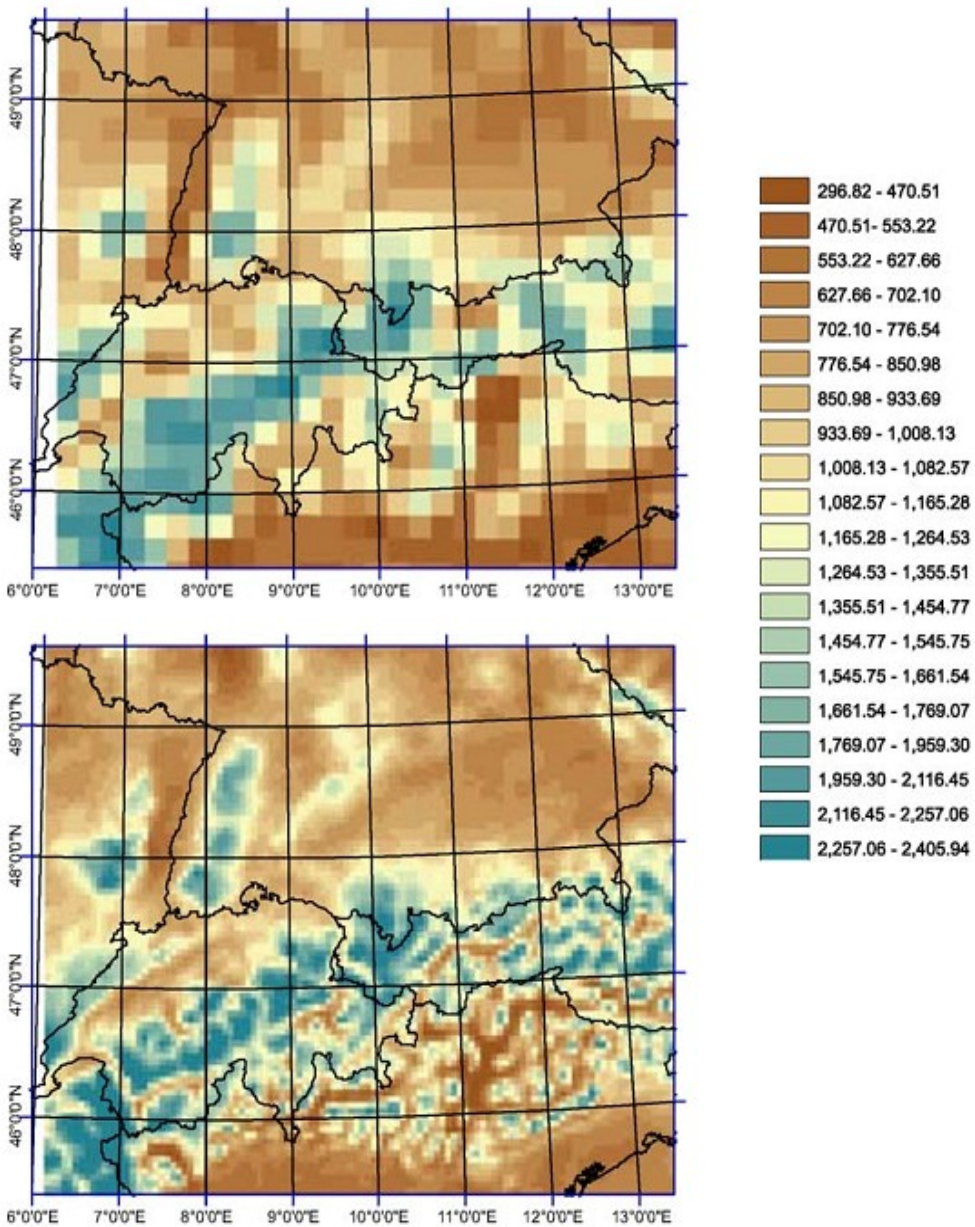
Topograficzna podatność na wiatr





Ukształtowanie terenu a wiatr





Symulacja rozkładu opadów