COA 690/790 GIS in Marine Science

Lecture 8
Raster Analysis

Wei Wu
March 27, 2017

Add xy data as a way to add sampling data
In the lab, we will talk about viewing spatial information using ArcCatalog, or “define projection”

Raster Analysis

Raster cells store data (nominal, ordinal, interval/ratio)
Complex constructs built from raster data
- Connected cells can be formed in to networks
- Related cells can be grouped into neighborhoods or regions

Examples:
Predict fate of pollutants in the atmosphere
The spread of disease
Animal migrations
Crop yields
EPA - hazard analysis of urban superfund sites
Local to global scale forest growth analysis

Map algebra

Cell by Cell combination of raster data layers

- Each number represents a value at a raster cell location
- Simple operations can be applied to each number
- Raster layers may be combined through operations
- Addition, subtraction and multiplication
- Entails operations applied to one or more raster data layers.

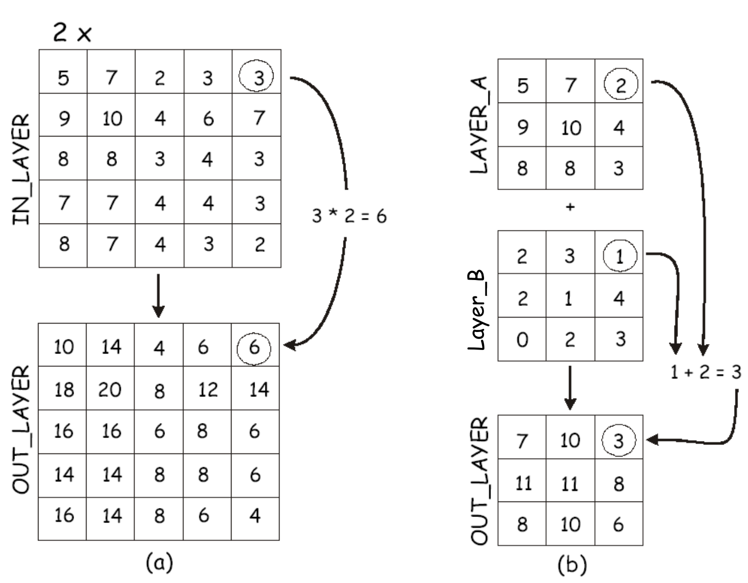


Figure 11-1: An example of raster operations. On the left side (a) each input cell is multiplied by the value 2, and the result written stored in the corresponding output location. The right side (b) of the figure illustrates layer addition.

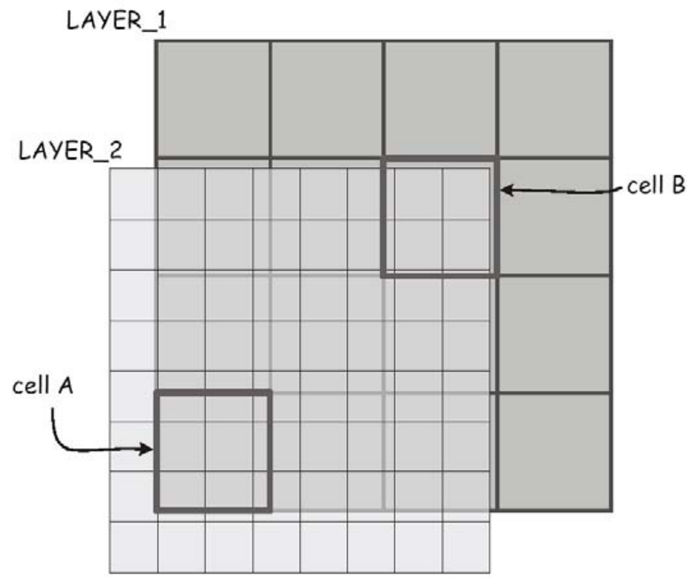
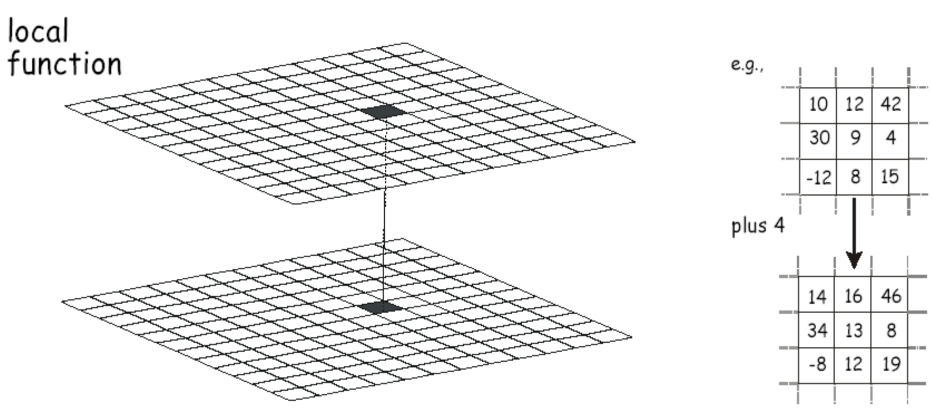
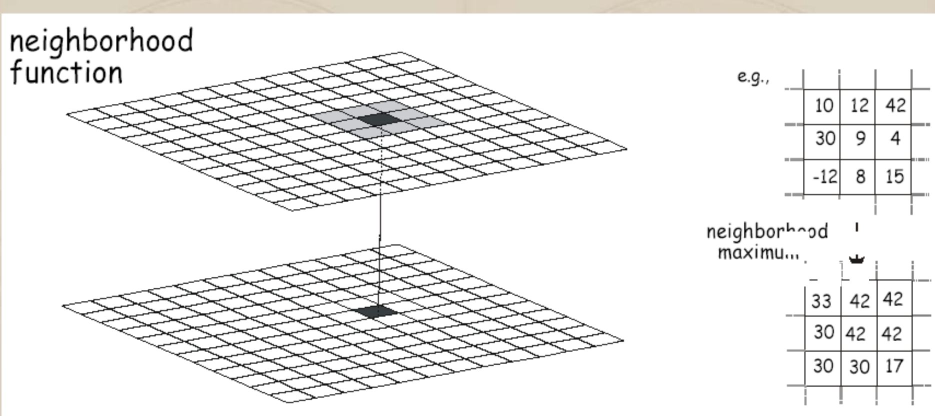


Figure 11-2: Incompatible cell sizes and boundaries confound multi-layer raster operations. This figure illustrates ambiguities in selecting input cell values from LAYER_2 in combination with LAYER_1. Multiple full and partial cells may contribute values for an operation applied to cell A. A portion of cell B is undefined in LAYER_2. These ambiguities are best resolved by

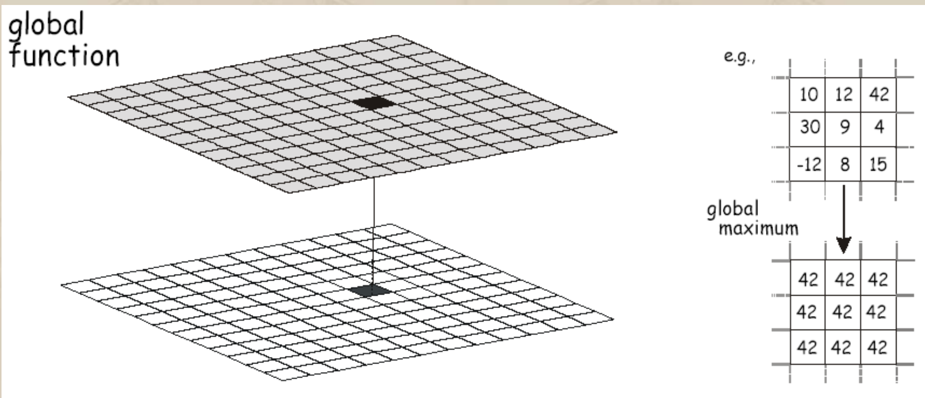
Scope: Local operations



Scope: Neighborhood operations



Scope: Global operation



Local Functions

Function	Description
Add, subtract, multiply, and divide	cell-by-cell combination with the arithmetic operation
ABS	Absolute value of each cell
EXP, EXP10, LN, LN10	Applies base e and base 10 exponentiation and logarithms
SIN, COS, TAN, ASIN, ACOS, ATAN	Apply trigonometric functions on a cell-by-cell basis
INT, TRUNC	Truncate cell values, output integer portion
MODULUS	Assigns the decimal portion of each cell
ROUND	Rounds a cell value up or down to nearest integer value
SQRT, ROOT	Calculates the square root or specifies other root of each cell value
POWER	Raises each cell to a defined power

Logical Operations
AND

Non-zero values are “true”, zero values are “false”
N = null values

Input

1	3	1	1
0	N	2	-1
1	2	5	0
0	1	N	N

AND

0	1	0	9
0	5	2	5
0	2	N	2
0	-3	4	8

=

Output

0	1	0	1
0	N	1	1
0	1	N	0
0	1	N	N

Logical Operations
OR

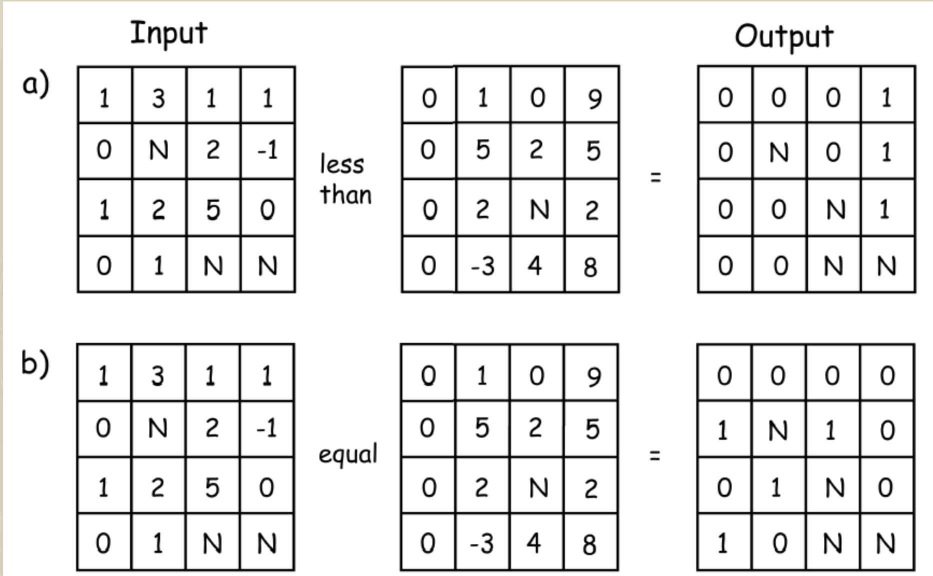
Non-zero values are “true”, zero values are “false”
N = null values

1	3	1	1		0	1	0	9		1	1	1	1
0	N	2	-1	OR	0	5	2	5	=	0	N	1	1
1	2	5	0		0	2	N	2		1	1	N	1
0	1	N	N		0	-3	4	8		0	1	N	N

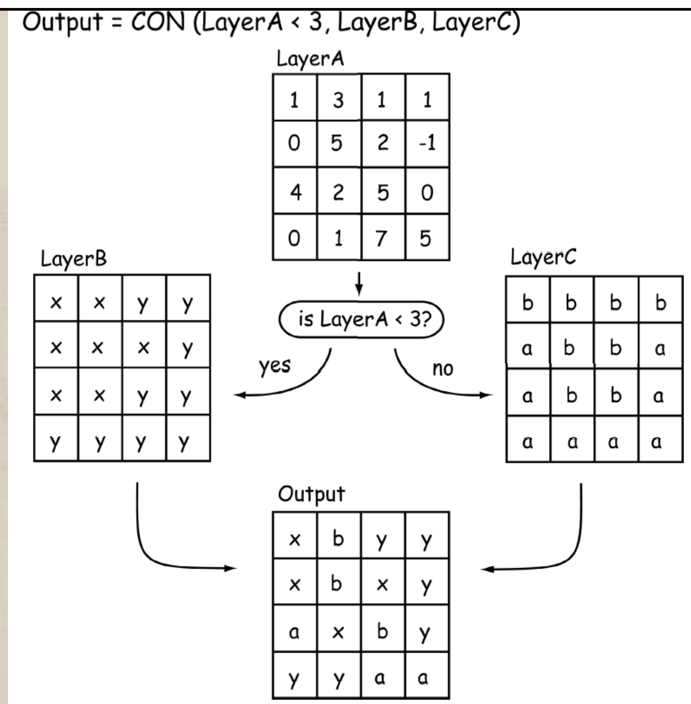
Logical Operations
NOT

	1	3	1	1		0	0	0	0
NOT	0	N	2	-1	=	1	N	0	0
	1	2	5	0		0	0	0	1
	0	1	N	N		1	0	N	N

More Local Functions – logical comparisons

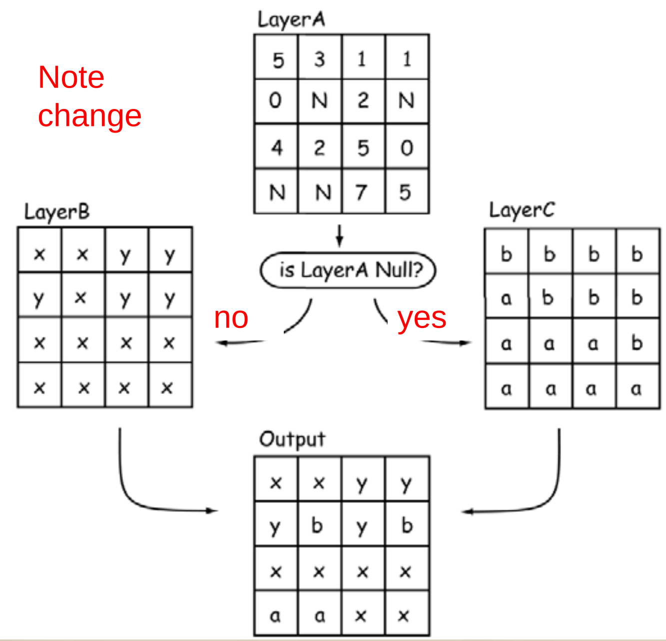


Conditional Function



Nested Functions

Output = CON(ISNULL(LayerA), LayerC, Layer B)



Overlay in Raster

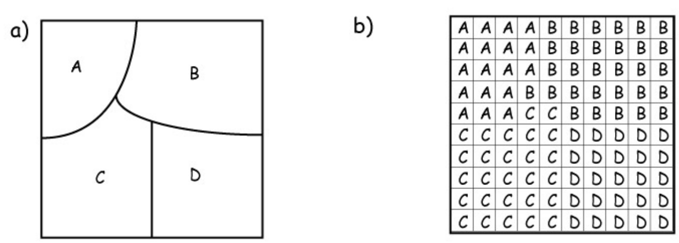
Union and Clip

Cell by Cell Addition or Multiplication

Attribute combinations corresponding to unique cell combinations

A Problem with Raster Analysis

- Too many cells
- Typically, one-to-one relationship between spatial object and attribute table
- Rasters have multiple cells per feature
- Attribute tables grow to be unwieldy



one to one

ID	type	area
1	A	16.8
2	B	22.2
3	C	18.4
4	D	20.7

one to one

ID	type	area
1	A	0.8
2	A	0.8
3	A	0.8
4	A	0.8
5	B	0.8
6	B	0.8
7	B	0.8
100	D	0.8

one to many

ID	type	area
1	A	16.8
2	B	22.2
3	C	18.4
4	D	20.7

Raster overlay as addition

Geographic data

Layer A

10	10	20
30	40	30
20	20	30

\+

Layer B

2	3	5
2	7	1
2	1	0

=

Output Layer

12	13	25
32	47	31
22	21	30

Attribute data

Layer A

ID	Type	Spec
10	A	22b
20	B	19c
30	C	22b
40	D	3b

\+

Layer B

ID	Cover
0	Urban
1	Forest
2	Urban
3	Farm
5	Farm
7	Water

=

Output Layer

ID	Type	Spec	Cover
12	A	22b	Urban
13	A	22b	Farm
25	B	19c	Farm
32	C	22b	Urban
47	D	3b	Water
31	C	22b	Forest
22	B	19c	Urban
21	B	19c	Forest
30	C	22b	Urban

Raster Overlay

Output layer **DOES NOT** have unique records

Geographic data

Layer A

1	1	2
3	4	3
2	1	3

\+

Layer B

2	3	5
2	7	1
2	1	0

=

Output Layer

3	4	7
5	11	4
4	2	3

Attribute data

Layer A

ID	Type	Spec
1	A	22b
2	B	19c
3	C	22b
4	D	3b

\+

Layer B

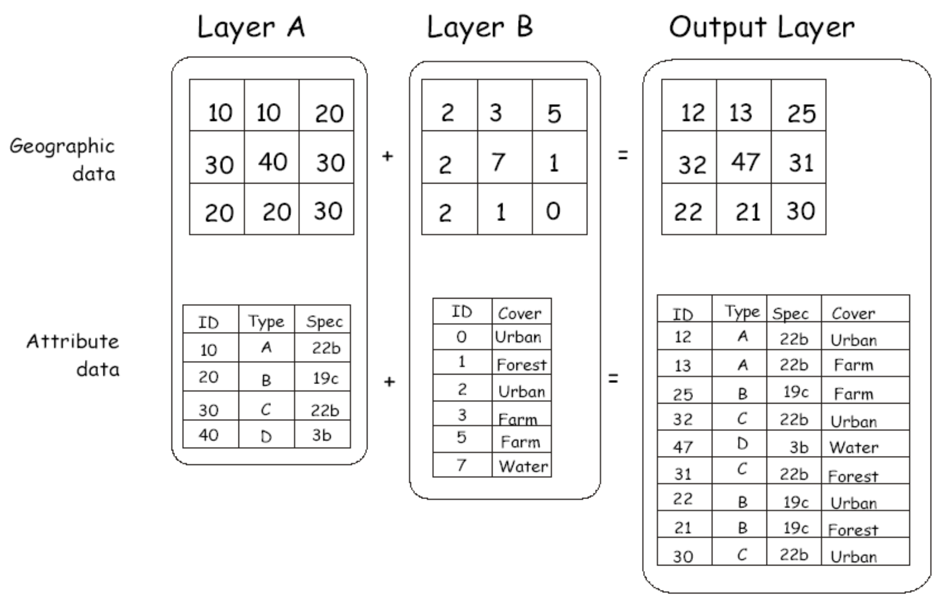
ID	Cover
0	Urban
1	Forest
2	Urban
3	Farm
5	Farm
7	Water

=

Output Layer

ID	Type	Spec	Cover
2	A	22b	Forest
3	?	?	?
4	?	?	?
5	C	22b	Urban
7	B	19c	Farm
11	D	3b	Water

What to do? First multiply Layer A by 10



ID	Type	Spec
10	A	22b
20	B	19c
30	C	22b
40	D	3b

+

ID	Cover
0	Urban
1	Forest
2	Urban
3	Farm
5	Farm
7	Water

=

ID	Type	Spec	Cover
12	A	22b	Urban
13	A	22b	Farm
25	B	19c	Farm
32	C	22b	Urban
47	D	3b	Water
31	C	22b	Forest
22	B	19c	Urban
21	B	19c	Forest
30	C	22b	Urban

Neighborhood Operations

Moving Windows

(Windows can be any size; often odd to provide a center)

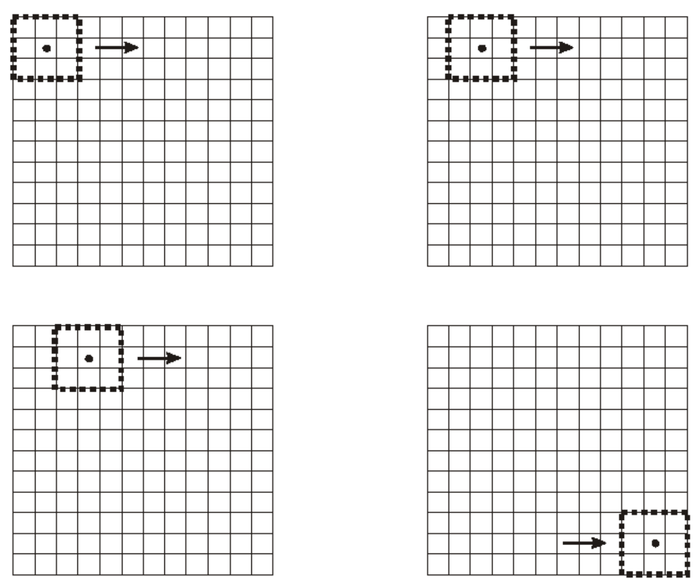
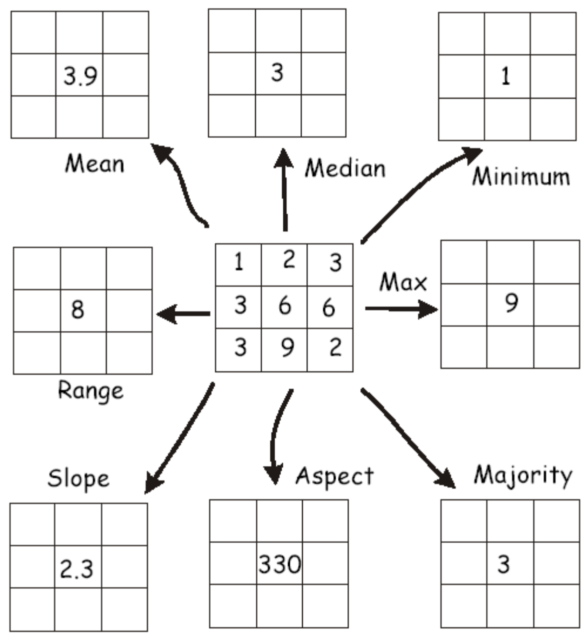
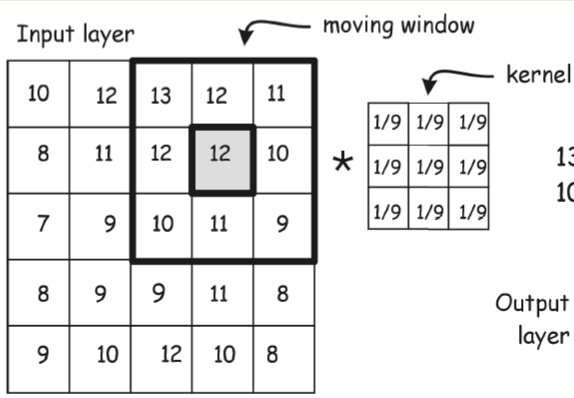


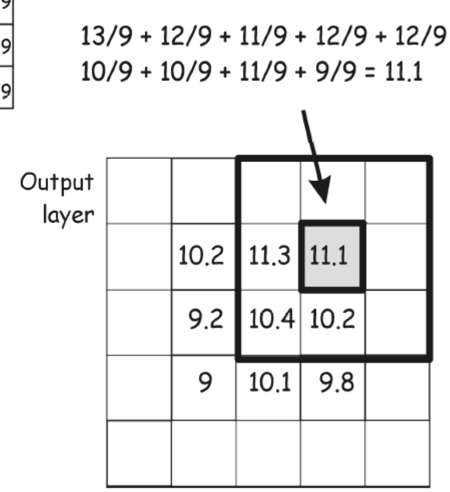
Figure 11-4: The concept of a moving window in raster neighborhood operations. Here a 3 by 3 window is swept from left to right and from top to bottom across a raster layer. The window at each location defines the input cells used in the raster operation.

Neighborhood Operations



Neighborhood Operations: Mean Function

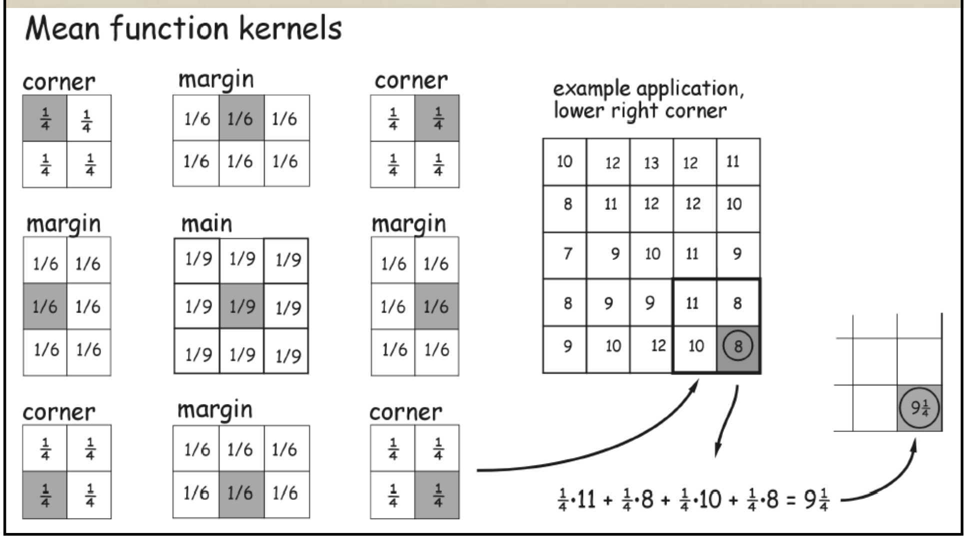




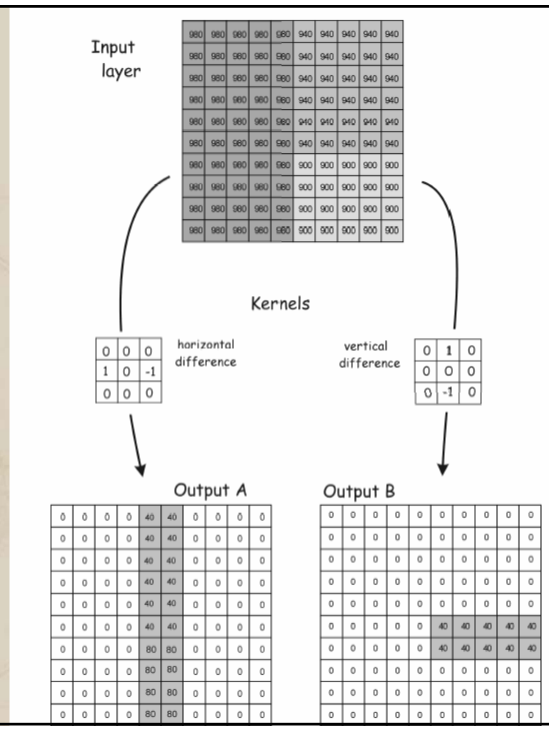
What about the edges?

Neighborhood Operations:

Separate edge kernals can be used



Example:Identifying spatial differences in a raster layer



Raster Analysis

Moving windows and kernels can be used with a mean kernel to reduce the difference between a cell and surrounding cells. *(done by average across a group of cells)*

Raster data may also contain “noise”; values that are large or small relative to their spatial context.
(Noise often requiring correction or smooth(ing))

Know as “high-pass” filters

The identified spikes or pits can then be corrected or removed by editing

Raster Analysis

High pass filters

Return:
- Small values when smoothly changing values.
- Large positive values when centered on a spike
- Large negative values when centered on a pit

Input layer with "noise"

1065	1068	929	864	960	1113	974	896	890	841	759	719	705	696	720	708
1038	963	947	950	999	1021	1011	1015	995	1044	870	773	734	703	676	684
1142	1005	1151	310	1117	1056	1007	1002	902	954	935	913	789	756	724	700
1116	1114	1270	1165	1097	1025	922	917	821	829	860	838	807	810	758	760
1275	1170	1295	1114	1009	942	953	847	835	729	738	797	723	718	694	670
1441	1263	1196	1055	913	869	829	771	736	765	766	688	694	1676	684	698
1348	2900	1056	969	948	951	940	867	818	863	784	732	704	733	776	804
1377	1238	1122	1019	1089	950	956	896	2000	800	760	698	779	867	896	744
1489	1320	1188	1152	1050	942	922	952	815	841	721	780	852	28	845	738
1432	1415	1196	1100	1001	974	924	911	914	756	809	861	898	830	746	710
1412	1474	1240	1100	1001	982	873	835	829	853	931	937	845	706	685	680
1493	1368	1201	1090	1064	970	902	902	958	952	1015	841	782	803	786	711
1437	1407	118	1145	1070	1107	982	1047	1077	1052	954	884	44	940	828	771
1349	1369	1267	1247	1194	1196	1077	1214	1145	999	906	894	1024	1046	923	862
1319	1292	1378	1400	1367	1276	1162	1088	961	930	872	985	1010	1178	1148	1000

kernel for
high-pass filter

$$\frac{1}{9} * \begin{array}{|c|c|c|}\hline -1 & -1 & -1 \\ \hline -1 & 9 & -1 \\ \hline -1 & -1 & -1 \\ \hline \end{array}$$

$$\left(\frac{\begin{array}{l} (-1)*1065 + \\ (-1)*1068 + \\ (-1)*929 + \\ (-1)*1038 + \\ (9)*963 + \\ (-1)*947 + \\ (-1)*1142 + \\ (-1)*1005 + \\ (-1)*1151 \end{array}}{9} \right) \rightarrow \mathbf{35.7}$$

spikes ■ pits □

Ouput layer

$= 35.7 \rightarrow$ 35

	35	142	141	177	105	112	162	156	250	99	59	61	58	43	
	33	292	-657	270	145	121	158	60	147	148	179	85	89	74	
	66	345	235	237	124	61	107	41	76	111	108	102	146	110	
	62	256	114	100	95	161	93	122	23	41	117	-58	-43	-59	
	-35	-7	110	40	37	35	12	14	68	88	28	-59	1039	-69	
	1784	-140	35	79	118	152	-16	-38	37	109	79	-59	-54	-14	
	-74	-83	66	202	83	131	-23	1238	-45	69	18	179	243	281	
	158	125	178	135	68	88	25	-82	-1	20	71	214	-718	227	
	220	86	108	78	119	102	126	159	10	66	108	249	207	165	
	278	135	111	80	125	50	33	42	57	150	161	105	-3	21	
	281	207	207	123	83	46	68	119	99	192	130	115	179	105	
	340	-1004	228	68	167	47	129	158	162	115	166	-758	247	67	
	306	227	253	104	169	69	265	215	121	64	151	248	257	59	

Input Layer with "noise"

kernal for mean filter

$$\frac{1}{9} * \begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{bmatrix}$$

1065	1068	929	864	960	1113	974	896	890	841	759	719	705	696	720	708
1038	963	947	950	999	1021	1011	1015	995	1044	870	773	734	703	676	684
1142	1005	1151	310	1117	1056	1007	1002	902	954	935	913	789	756	724	700
1116	1114	1270	1165	1097	1025	922	917	821	829	860	838	807	810	758	760
1275	1170	1295	1114	1009	942	953	847	835	729	738	797	723	718	694	670
1441	1263	1196	1055	913	869	829	771	736	765	766	688	694	1676	684	698
1348	2900	1056	969	948	951	940	867	818	863	784	732	704	733	776	804
1377	1238	1122	1019	1089	950	956	896	2000	800	760	698	779	867	896	744
1489	1320	1188	1152	1050	942	922	952	815	841	721	780	852	28	845	738
1432	1415	1196	1100	1001	974	924	911	914	756	809	861	898	830	746	710
1412	1474	1240	1100	1001	982	873	835	829	853	931	937	845	706	685	680
1493	1368	1201	1090	1064	970	902	902	958	952	1015	841	782	803	786	711
1437	1407	118	1145	1070	1107	982	1047	1077	1052	954	884	44	940	828	771
1349	1369	1267	1247	1194	1196	1077	1214	1145	999	906	894	1024	1046	923	862
1319	1292	1378	1400	1367	1276	1162	1088	961	930	872	985	1010	1178	1148	1000

$$\left(\frac{\begin{array}{l} (1)*1065 + \\ (1)*1068 + \\ (1)*924 + \\ (1)*1038 + \\ (1)*963) + \\ (1)*947 + \\ (1)*1142 + \\ (1)*1005 + \\ (1)*1151 \end{array}}{9} \right) = 1034$$

Ouput Layer

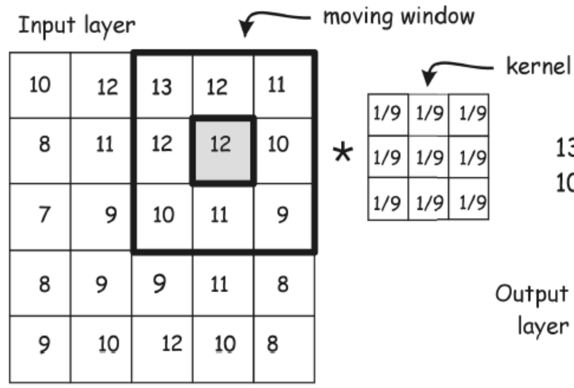
smoothed spike or pit

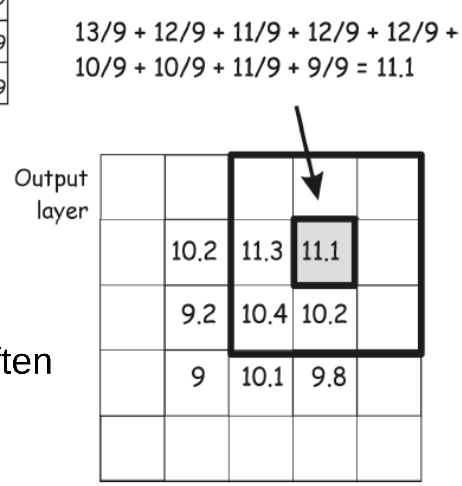
1034	909	914	932	1028	1010	965	948	910	867	799	754	722	707
1082	986	1000	971	1028	997	954	942	912	890	835	791	750	730
1170	1066	1058	981	1014	963	911	870	844	843	822	794	753	732
1237	1182	1123	1021	951	897	847	805	786	778	767	861	840	829
1438	1335	1061	974	928	885	844	803	781	762	736	829	822	828
1437	1313	1040	973	938	892	979	946	921	761	733	841	867	875
1448	1329	1065	1007	972	930	1018	983	933	775	756	685	720	714
1308	1194	1101	1030	978	936	1032	987	935	780	795	732	749	711
1351	1242	1114	1033	963	923	886	856	829	832	848	748	715	663
1359	1242	1110	1031	965	919	894	878	890	883	879	833	786	739
1238	1127	1003	1058	994	955	933	945	957	935	803	753	713	767
1223	1134	1044	1120	1062	1044	1033	1038	1006	944	816	806	797	852
1215	1180	1131	1222	1159	1127	1083	1057	988	941	841	889	904	966

Mean filter applied

Note edge erosion

Moving windows: Consider the overlap in cell calculations





Neighborhood operations often
Increase spatial covariance

Cost Surface

The minimum cost of reaching cells in a layer **from** one or more sources cells

"travel costs"
Time to school; hospital;
Chance of noxious foreign weed spreading out from an introduction point

•Units can be money, time, etc.

•Distance measure is combined with a fixed cost per unit distance to calculate travel cost

•If multiple source cells, the lowest cost is typically placed in the output cell

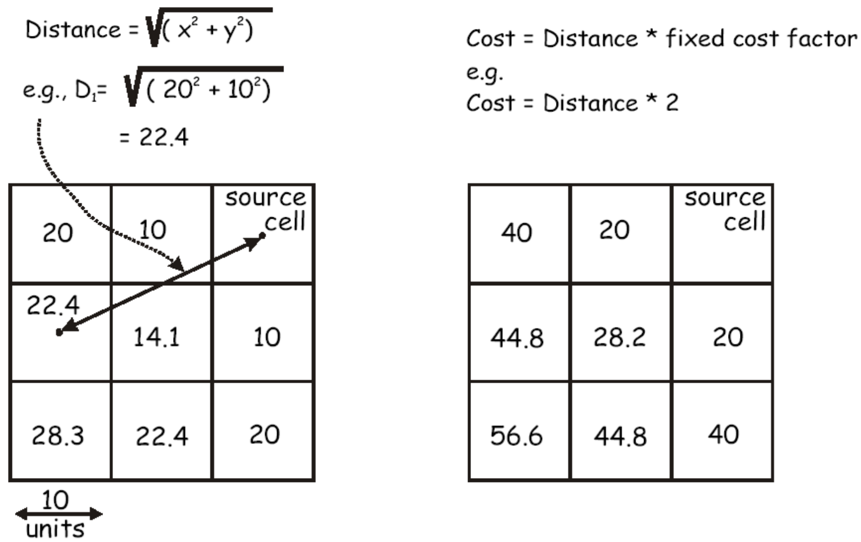


Figure 11-13: A cost surface based on a fixed cost per unit distance. Minimum distance from a set of source cells is multiplied by a fixed cost factor to yield a cost surface.

Friction Surface *(version of a Cost Surface)*

The cell values of a friction surface represent the cost per unit travel distance for crossing each cell – <u>varies from cell to cell</u>

Used to represent areas with variable travel cost.

<u>Notes:</u>
•Barriers can be added.

•Multiple paths are often not allowed

•Cost surfaces are always related to a source cell(s); “from something”

•The center of a cell is always used the distance calculations

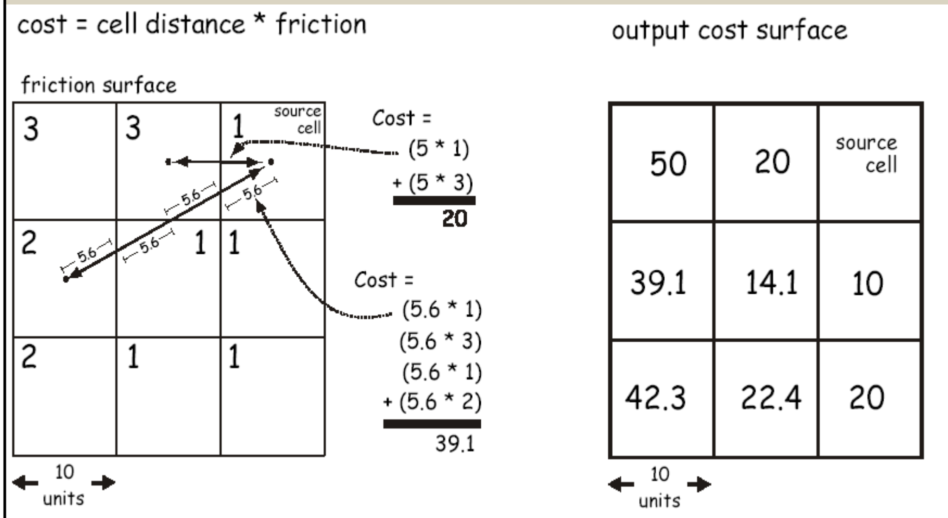


Figure 11-14: A cost surface based on spatially-variable travel costs. A friction surface specifies the spatially varying cost of travelling through raster cells. The distance traversed through each cell is multiplied by the cost in the friction surface. The values are summed for each path to yield a total cost.