A new method for the determination of flow directions and upslope areas in grid digital elevation models.

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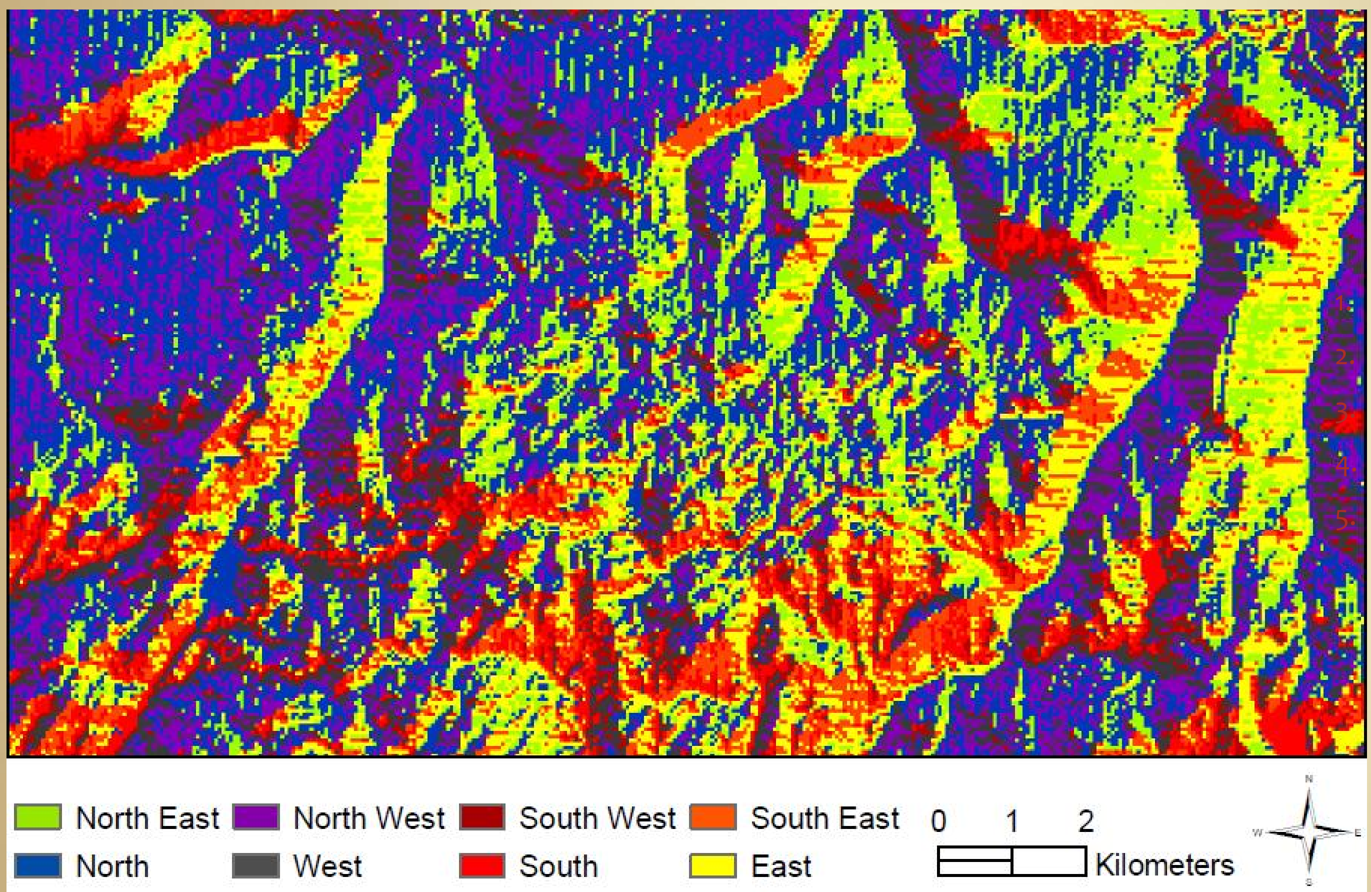
Accurate Water Flow Models

1. Avoid or Minimize dispersion
   - The water moves as one unit through the network
2. Avoid a grid bias
   - Water can move in any direction
3. Precisely resolve flow directions
   - The selection process is repeatable
   - Water flow direction is accurate
4. Can be stored in a simple, efficient grid structure
   - Values can be stored and recalled quickly and easily
5. Are robust
   - Ridges, Saddles, Pits and Flat areas are handled appropriately and without exceptions in the code.

D8



Avoid dispersion
Avoid a grid bias
Precisely resolve flow
Efficient grid structure
Robust

Other Models

- Multiple Flow Direction Methods (MS)
  - Assign flow to lower neighbors based on proportion of slope
  - Problems with dispersion (1) and storage (4)
- Pixels as Planes (Lea's)
  - Plane is fit to pixel corners, water flows down the plane's slope
  - Not robust (5)
- Digital Elevation Model Networks (DEMON)
  - Similar to Lea's but water is not assumed to start from the middle of a pixel
  - Not Robust (5)

D∞

- Single flow direction for each cell
- Flow is allowed to be in 360 degrees
- Some dispersion occurs but it is minimal

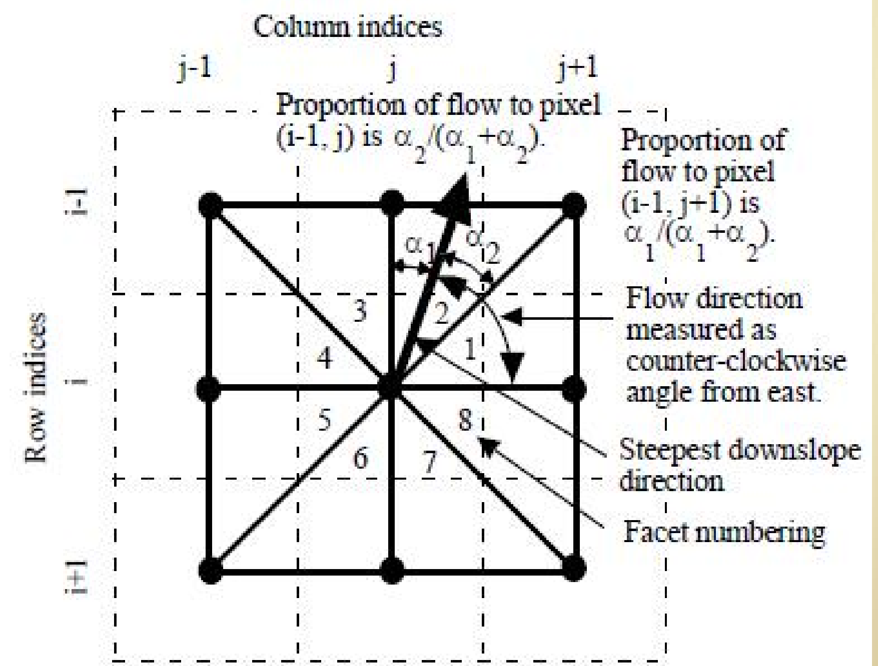
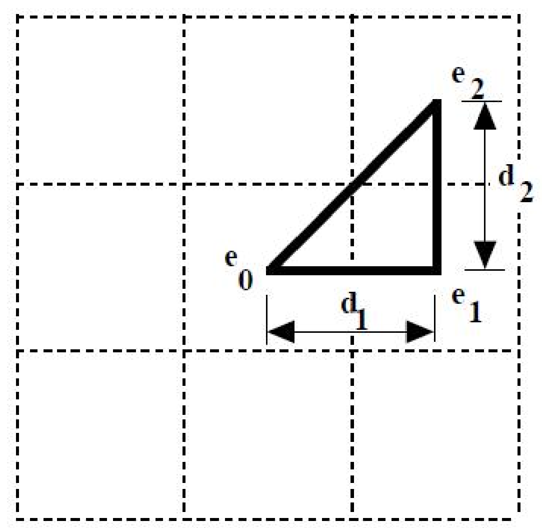


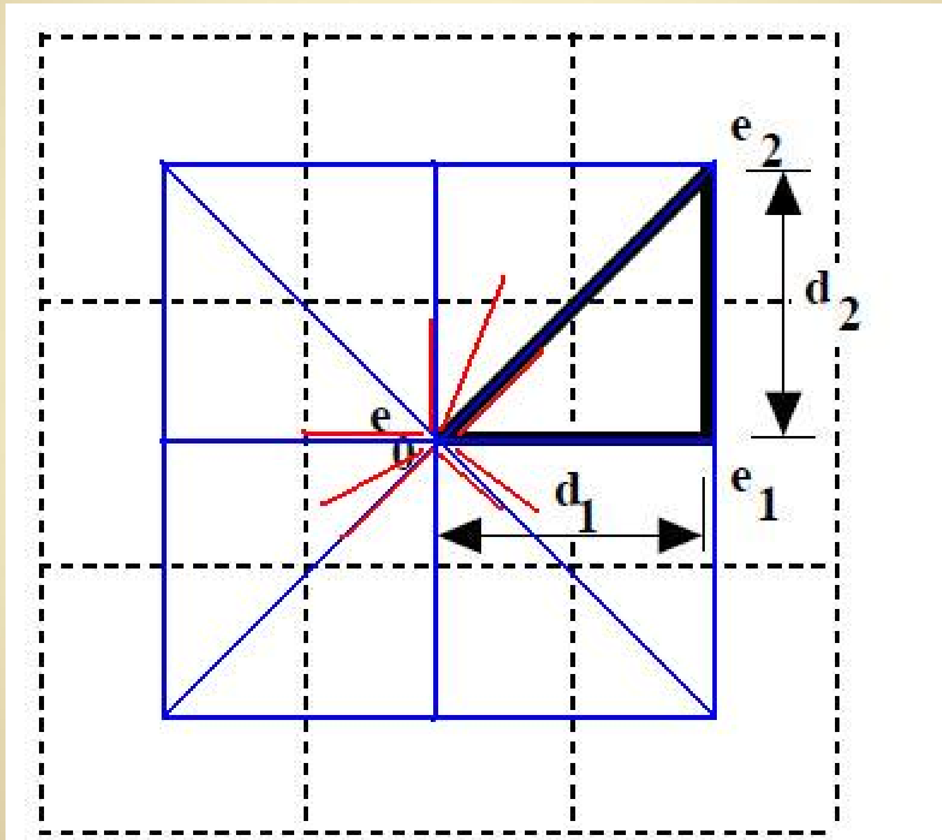
Figure 2. Flow direction defined as steepest downwards slope on planar triangular facets on a block centered grid.

D∞ Equations

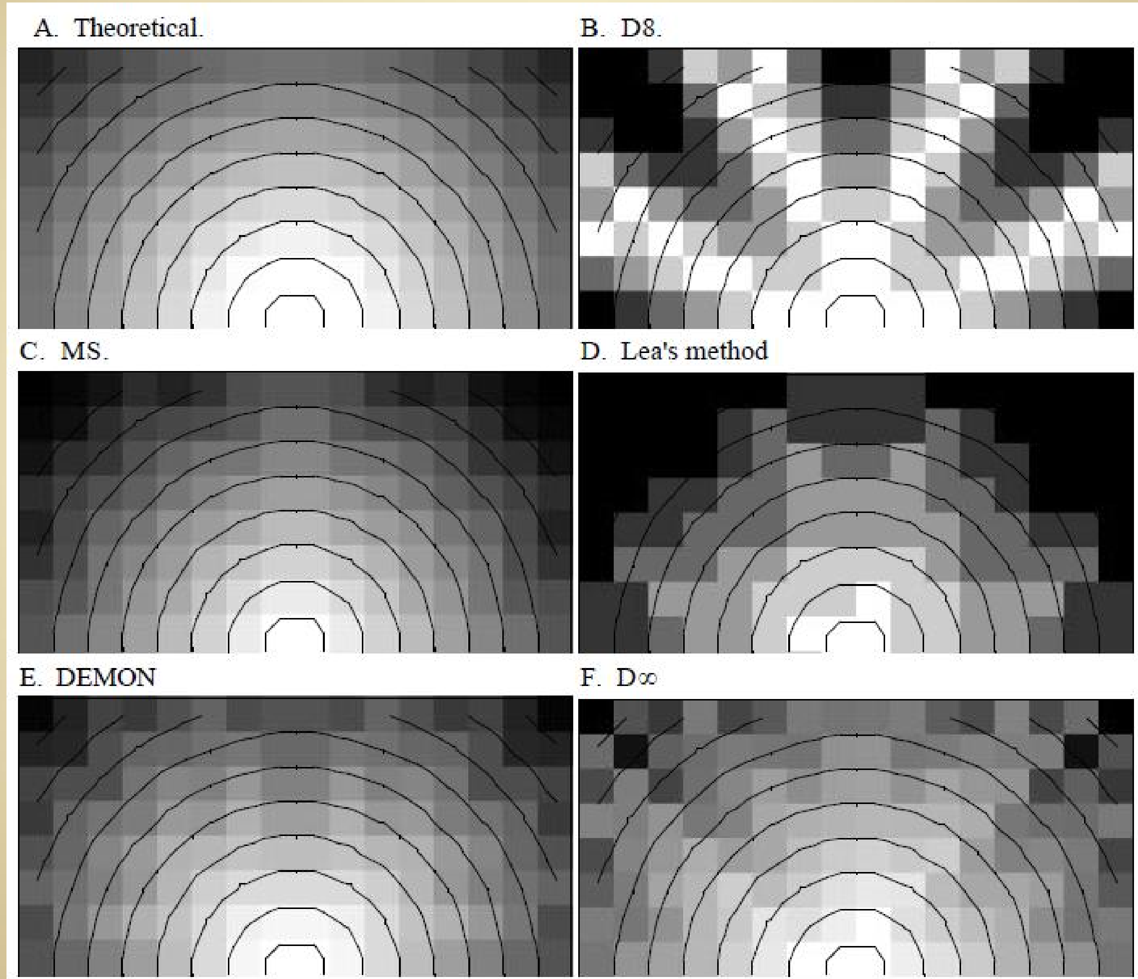
Slope 1	$s_1 = (e_0 - e_1)/d_1$	(1)
Slope 2	$s_2 = (e_1 - e_2)/d_2$	(2)
Direction	$r = \tan^{-1}(s_2/s_1)$	(3)
Magnitude	$s = \sqrt{s_1^2 + s_2^2}$	
Special Cases	if $r < 0$, $r = 0$, $s = s_1$	(4)
	if $r > \tan^{-1}(d_2/d_1)$, $r = \tan^{-1}(d_2/d_1)$, $s = (e_o - e_2)/\sqrt{d_1^2 + d_2^2}$	(5)



D∞ Assignment of Flow Direction



Upslope Area of an Outward Draining Cone



Influence Map (flow paths) of Outward Draining Cone

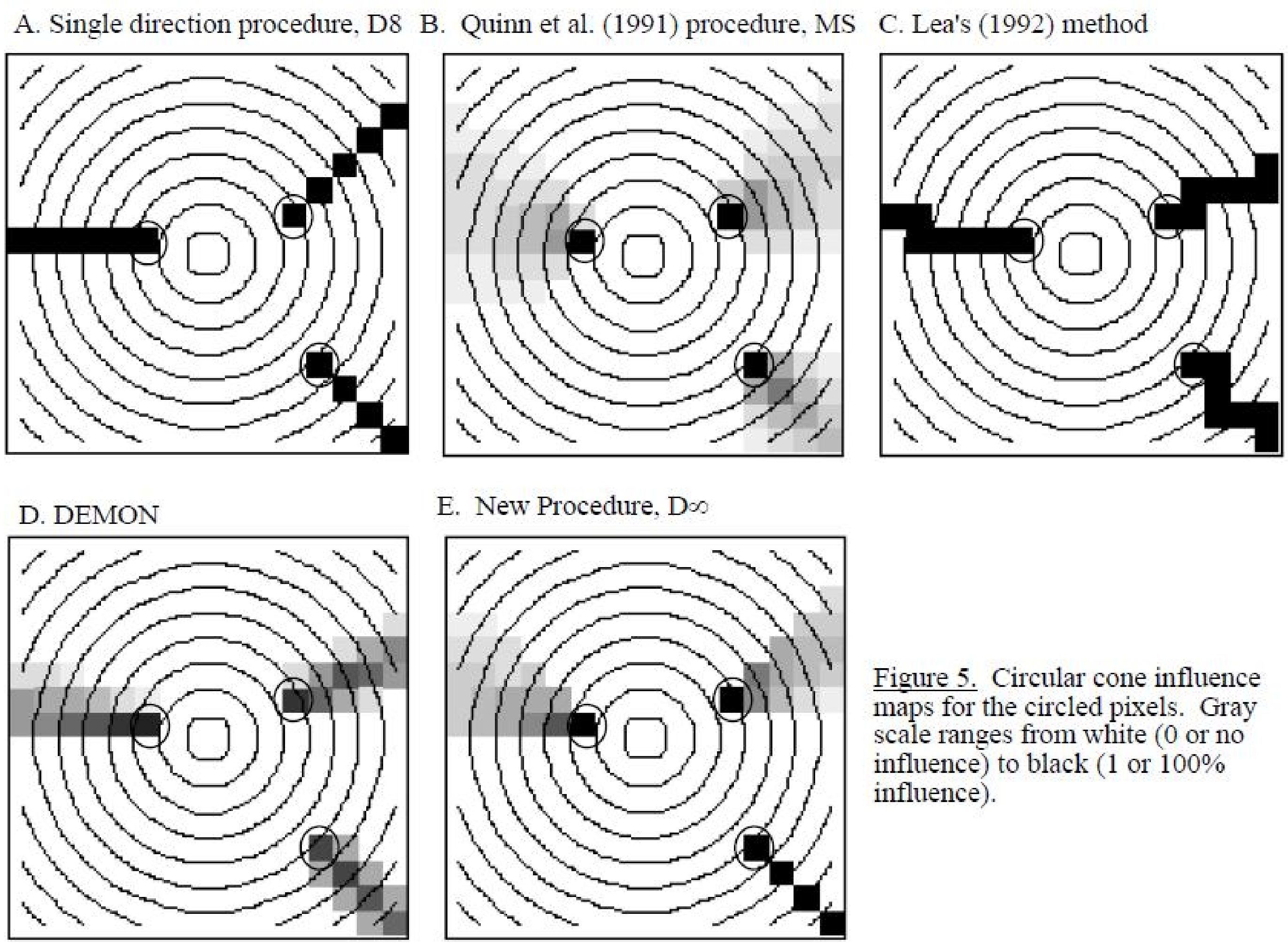
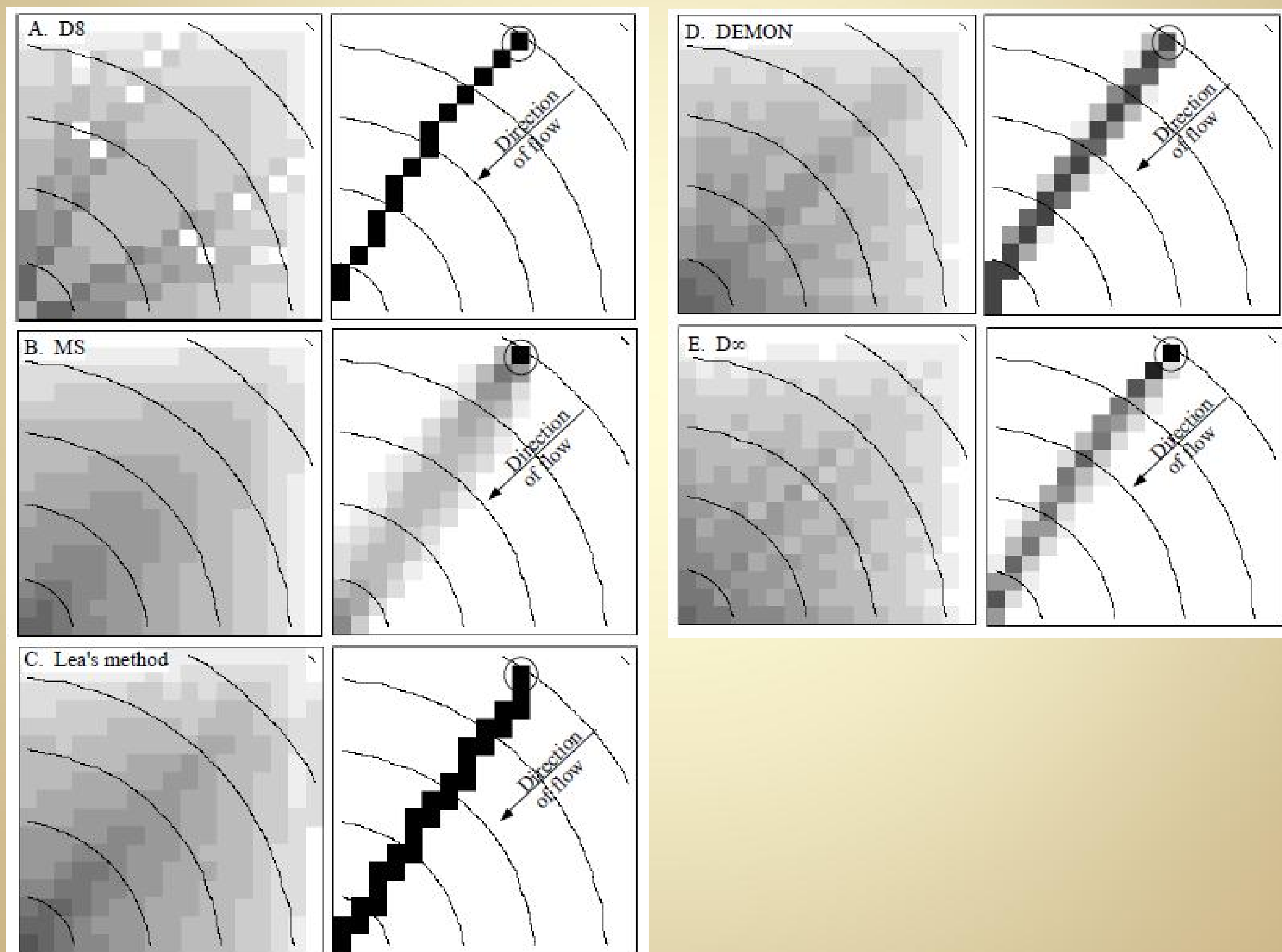
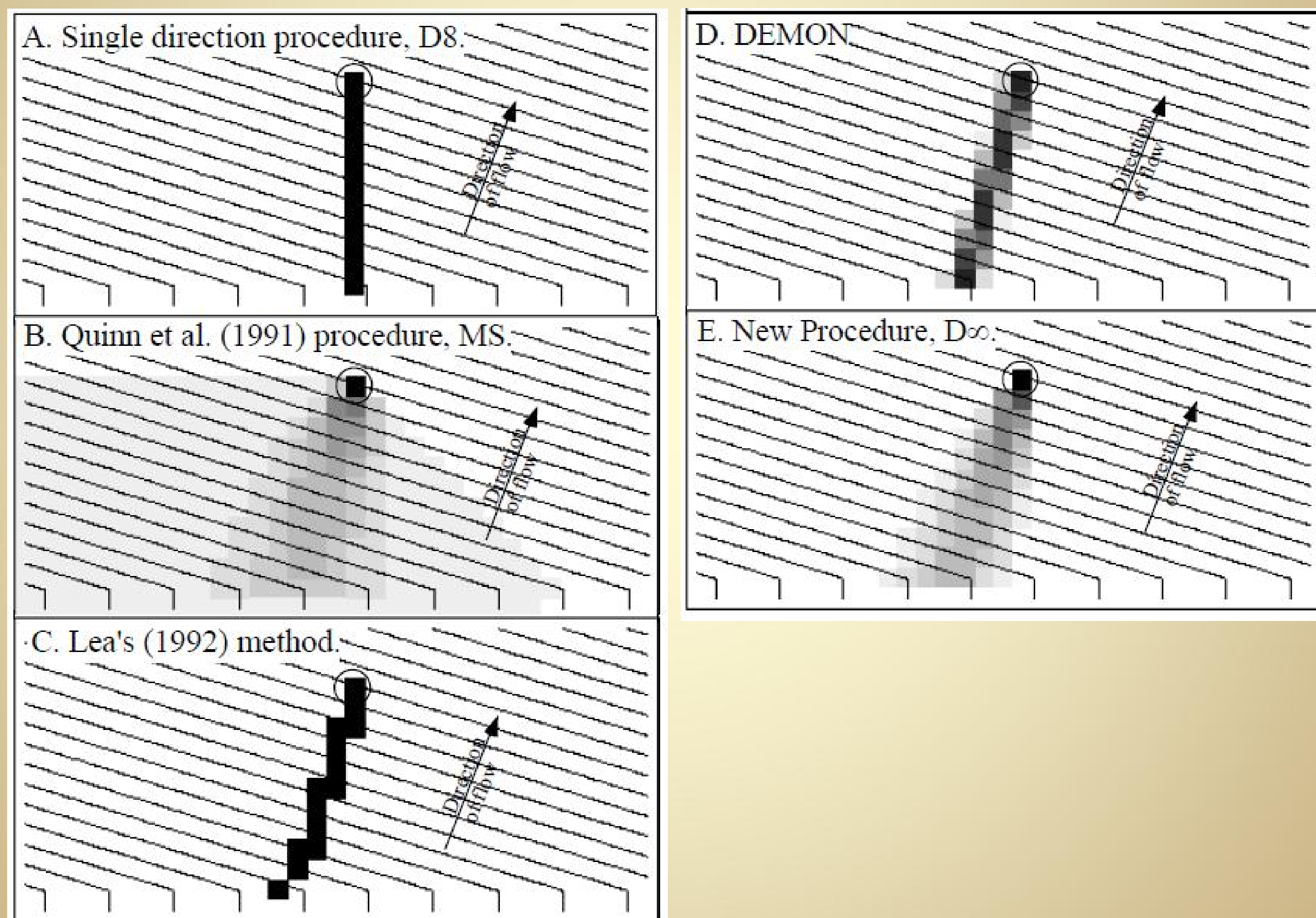


Figure 5. Circular cone influence maps for the circled pixels. Gray scale ranges from white (0 or no influence) to black (1 or 100% influence).

Upslope area and Influence Function of Inward Draining Cone



Dependence Map of a Planar Surface (not aligned with grid)



Comparison of Methods

- D8 – Grid based errors
  - Streaky alignment of flow
- MS – Dispersion based errors
  - Not as sharp/precise as D∞
- Lea's – Overestimates upslope values
  - Not used for real world calculations
- DEMON – Small MSE, best at inward cone
  - Not used for real world calculations- code is inadequate
- D∞ – Small MSE,

Take home messages for real world applications

- Larger research areas will have similar results
- For smaller scale locations the model matters
- Differences more apparent with better resolution
- D∞ is better than D8, MS, Lea’s methods
- D∞ is comparable to DEMON on simple surfaces

The significance of topology for modeling the surface hydrology of fluvial landscapes

Warrick R. Dawes and David Short