Open-Source Hydrology Using GRASS GIS

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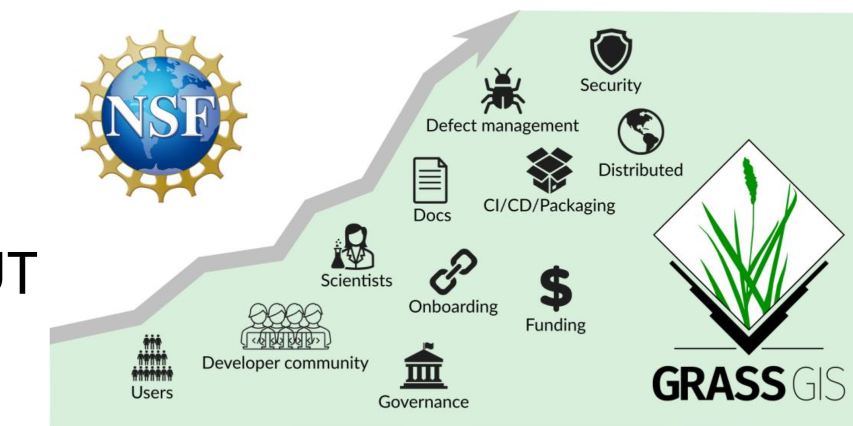
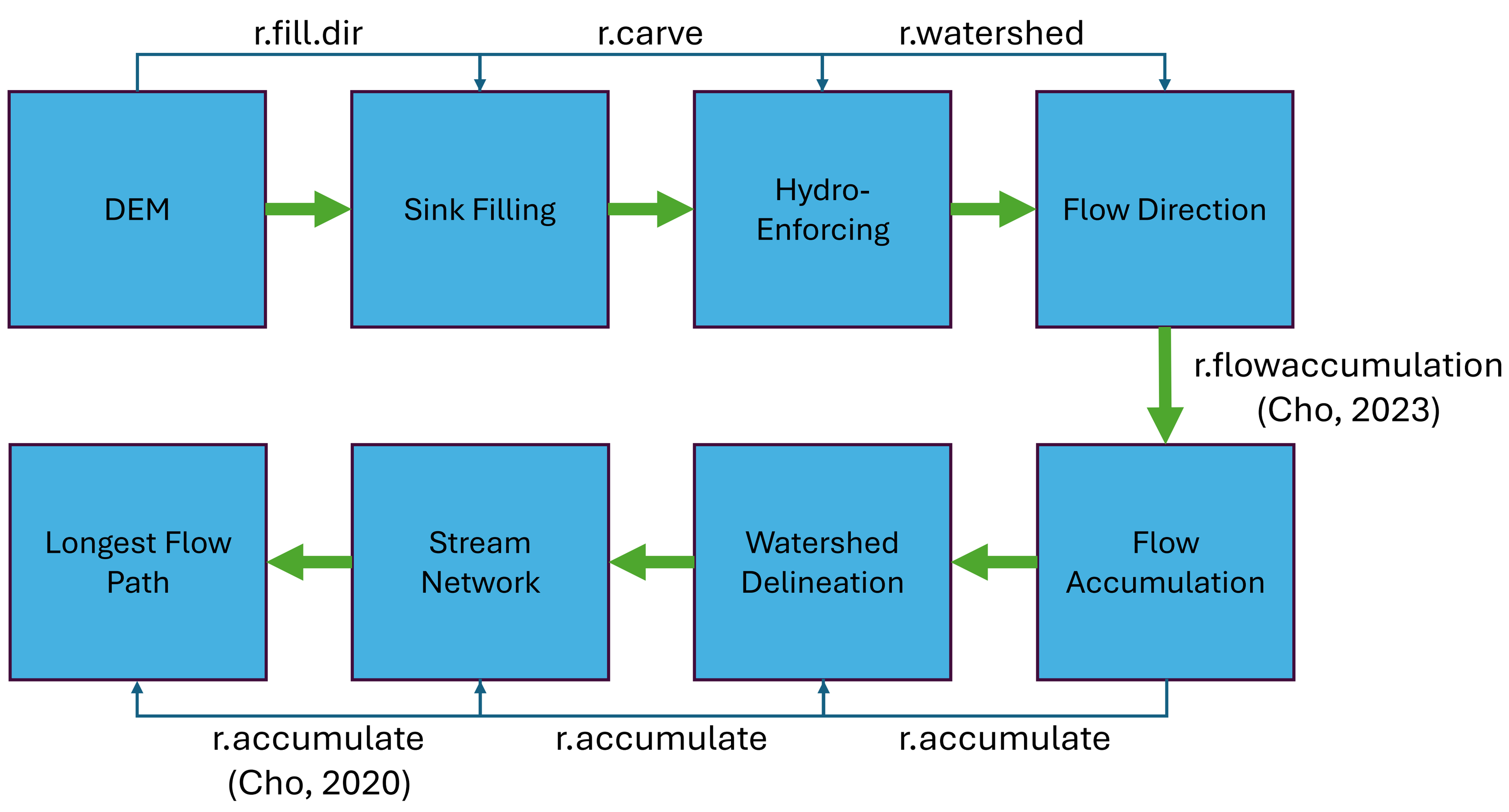


GRASS GIS is an Open-Source GIS developed by a team of scientists and software developers. It consists of close to a thousand modules (527 binaries and 447 scripts on my personal build) for raster and vector analysis, rendering, and modeling. Our team was recently awarded an NSF POSE grant.

Hydrologic Parameters

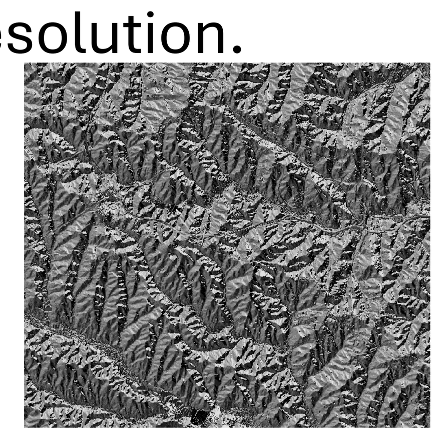
A typical hydrologic analysis requires the following workflow for basic parameters:



Because r.watershed uses a least-cost algorithm, it does not require sink filling. In this presentation, we will skip sink filling and hydro-enforcing for simplicity. We will use the NC dataset from https://grass.osgeo.org/sampledata/north_carolina/nc_spm_08_grass7.zip.

First, we restrict the computational region and resolution.

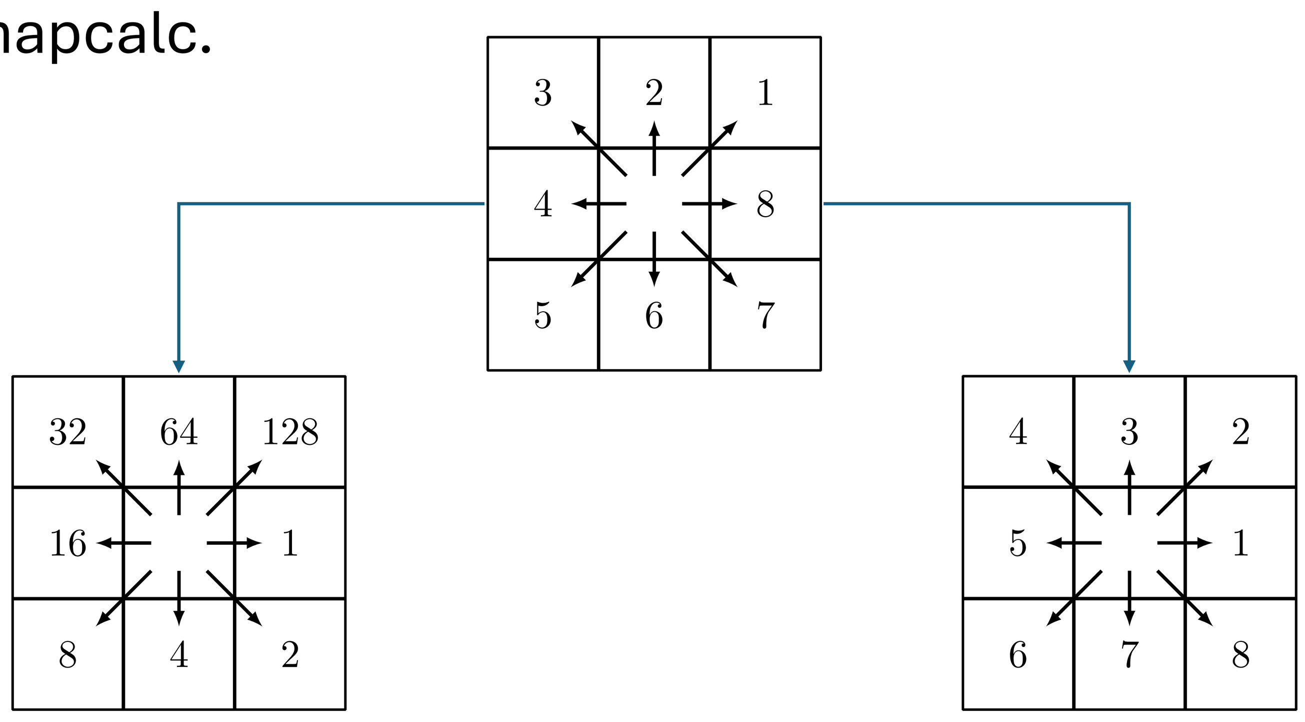
```
g.region -a rast=elevation
```



Calculate the flow direction raster.

```
r.watershed -s elev=elevation drain=drain
```

This is the encoding of the GRASS drainage format, but it can be translated to more common ArcGIS and TauDEM encodings using r.mapcalc.

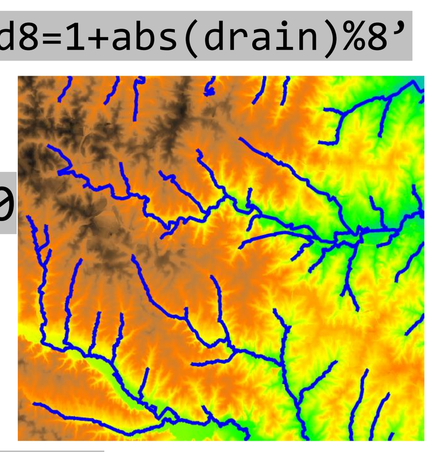



```
r.mapcalc ex='fdr=2^(8-abs(drain))'
```

```
r.mapcalc ex='d8=1+abs(drain)%8'
```

Generate the stream network.

```
r.accumulate drain stream=streams thresh=10000
```



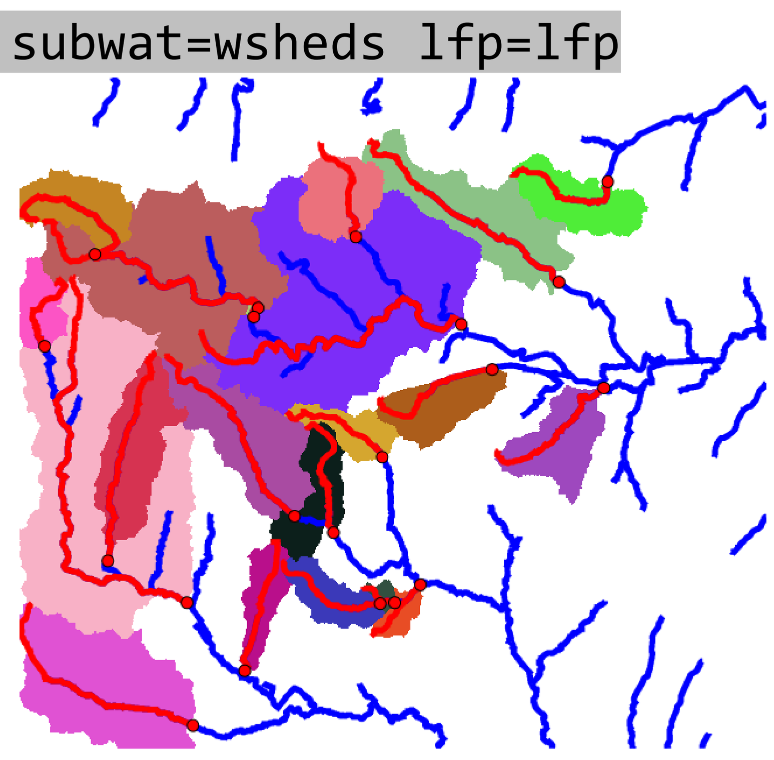
Generate random outlets.

```
v.to.rast streams output=streams use=val
r.random streams npoints=20 vector=outlets seed=1
```

Delineate watersheds and longest flow paths for the 20 random outlets in one command.

```
r.accumulate drain outlet=outlets subwat=wsheds lfp=lfp
```

In this Figure, blue is the stream Network and red is the longest flow path for each watershed.



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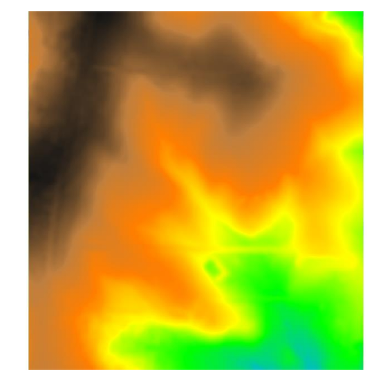
Shallow Water Hydrology

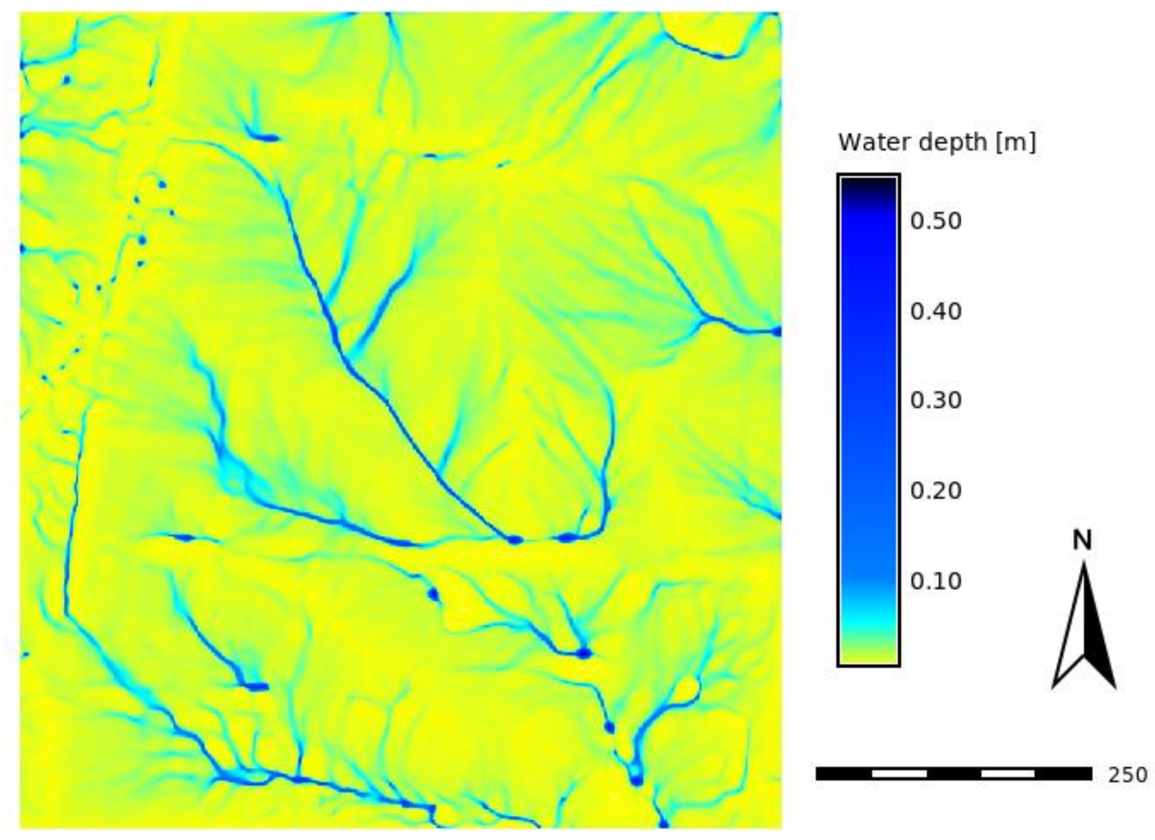
r.sim.water simulates shallow water flow. First, calculate the first-order partial derivative of the 1m elevation raster.



```
g.region rast=elev_lid792_1m
r.slope.aspect elev_lid792_1m dx=dx dy=dy
```

Simulate the shallow water flow.

```
r.sim.water elev_lid792_1m dx=dx dy=dy rain_val=100
  depth=depth_m discharge=discharge_cms nprocs=24
```



Flooding Simulation

r.lake.series creates a space-time raster dataset for flood simulation. It uses cells in a stream raster as flooding seeds, and takes the starting and ending water levels with a step of water level. We start by converting the stream vector to raster.

```
g.region rast=elev_lid792_1m
v.to.rast -d streams output=rural_streams use=val val=1
```

Prepare a shaded relief map.

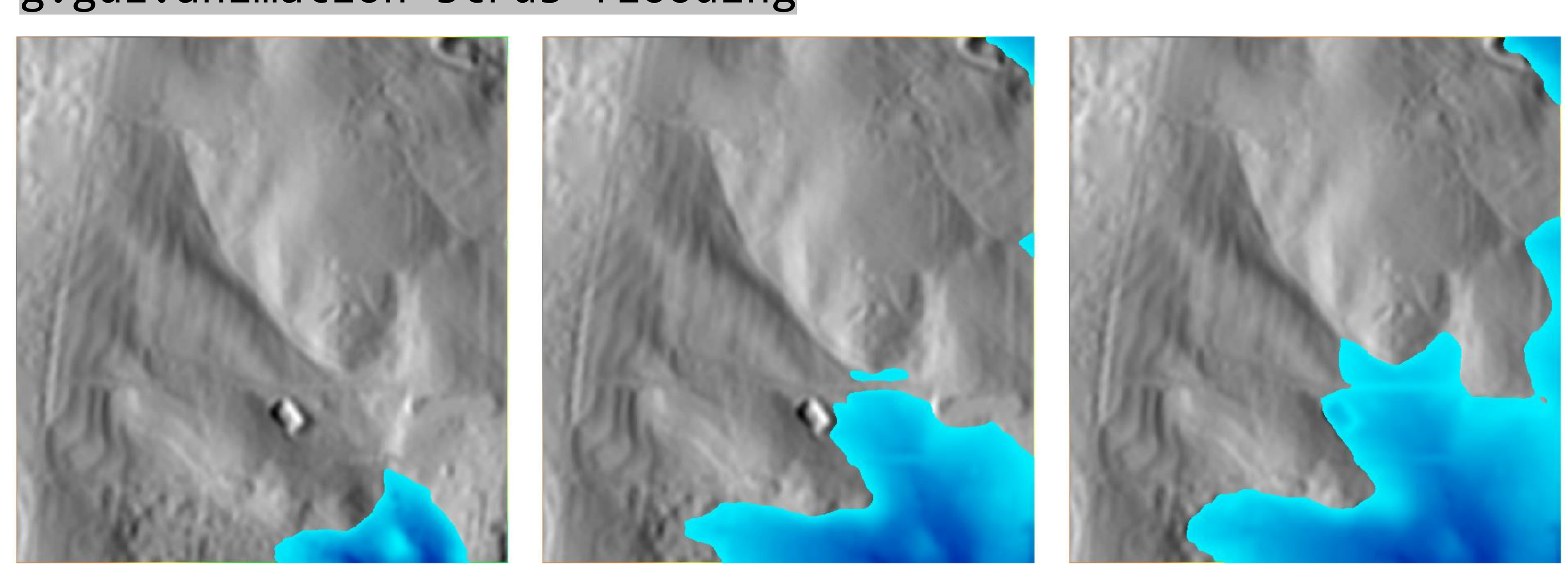
```
r.relief elev_lid792_1m output=elev_lid792_1m_shade
```

Start a flooding scenario.

```
r.lake.series elev_lid792_1m seed=rural_streams
  start_wl=104 end_wl=130 wl_step=0.2 output=flooding
```

Animate the results.

```
g.gui.animation strds=flooding
```



Additional Resources

- https://grasswiki.osgeo.org/wiki/Hydrological_Sciences
- https://workshop.isnew.info/foss4g-2021-r.topmodel/
- https://github.com/HuidaeCho/midas: New GRASS GIS modules for the Memory-Efficient I/O-Improved Drainage Analysis System (MIDAS) will be added.
- NSE POSE: We work on modernization of the build system for better cross-platform support and creation of standardized datasets for different regions.

References

- Cho, H., 2020. *A Recursive Algorithm for Calculating the Longest Flow Path and Its Iterative Implementation.* Environmental Modelling & Software 131, 104774.
- Cho, H., 2023. *Memory-Efficient Flow Accumulation Using a Look-Around Approach and Its OpenMP Parallelization.* Environmental Modelling & Software 167, 105771.

https://clawrim.isnew.info/