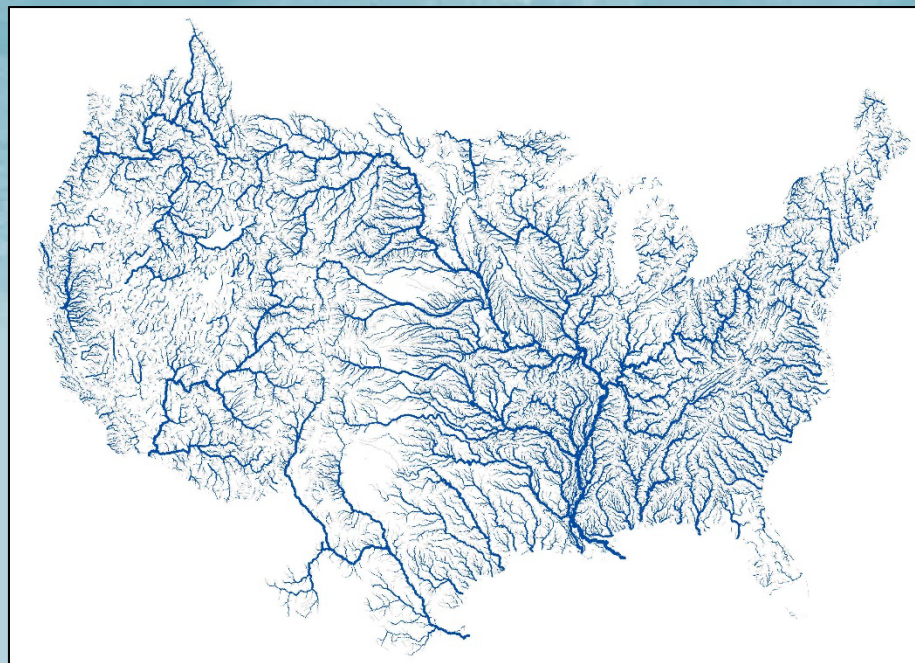


Overview of the WRF-Hydro GIS Pre-processing Tool

Presented by:
Kevin Sampson, GISP
NCAR WRF-Hydro Dev. Team



Outline

- WRF Pre-processing
- WRF-Hydro ArcGIS Pre-processing tools
- Basic GIS terrain pre-processing for WRF-Hydro
- Demonstration: Generating WRF-Hydro Routing Grids

WRF Pre-processing System (WPS)

Domain definition and static input data

WRF Pre-processing System (WPS)

- http://www2.mmm.ucar.edu/wrf/users/docs/user_guide/users_guide_chap3.html

Suite of programs and data to prepare real world simulations

geogrid.exe

- Defines model domains
- Interpolates static geographical data to the model grids

GEOGRID file (geo_em*.nc)

- Coordinate system information contained in global attributes
- Static 2D and 3D gridded variables

WPS namelist for NWM

```
&share
wrf_core = 'ARW',
max_dom = 1,
start_date = '2006-08-16_12:00:00','2006-08-16_12:00:00',
end_date   = '2006-08-16_18:00:00','2006-08-16_12:00:00',
interval_seconds = 21600
io_form_geogrid = 2,
/

&geogrid
parent_id          = 1, 1,
parent_grid_ratio = 1, 3,
i_parent_start     = 1, 31,
j_parent_start     = 1, 17,
e_we              = 4609, 112,
e_sn              = 3841, 97,
geog_data_res     = '30s','2m',
dx = 1000,
dy = 1000,
map_proj = 'lambert',
ref_lat  = 40.00,
ref_lon  = -97.00,
truelat1 = 30.0,
truelat2 = 60.0,
stand_lon = -97.0,
geog_data_path = '/glade/u/home/wrfhelp/WPS_GEOG'
/

&ungrib
out_format = 'WPS',
prefix = 'FILE',
/

&metgrid
fg_name = 'FILE'
io_form_metgrid = 2,
/
```

WRF-Hydro ArcGIS Pre-processing Tools

WRF-Hydro GIS tools

Pre-processing tools, written in Python, using ArcGIS python API (`arcpy`)

Variety of WRF-Hydro configuration options supported

Fast, efficient method for producing the 'routing stack' necessary to run WRF-Hydro

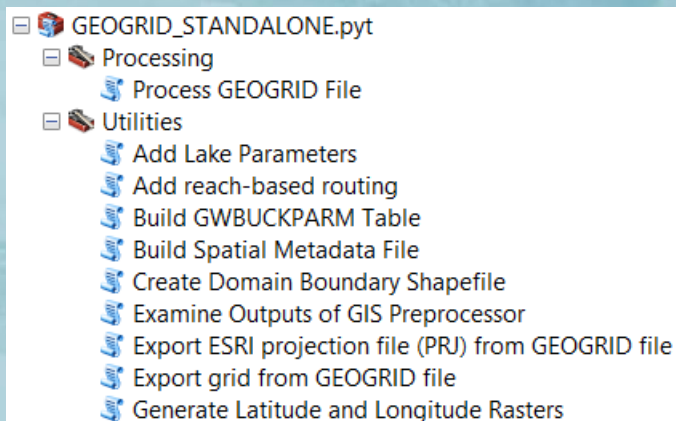
Consistent processing methodology between domains, regions, datasets

Provides WRF-Hydro with a complete set of hydrologically processed routing grids and spatial metadata

Removes the heavy GIS burden from modelers



https://github.com/NCAR/wrf_hydro_arcgis_preprocessor



WRF-Hydro & ArcGIS

Desktop GIS Application Suite

Site-licenses available at most US academic institutions

Ecosystem of compatible hydrology tools

- Spatial Analyst
- ArcHydro
- TauDEM

Extensible using Python API (arcpy)

Handles everything from projections, to analysis, to mapmaking in one library

netCDF4-Python included as of 10.3



Requirements

- ArcGIS for Desktop
 - Version 10.3.1+ (minimum 10.2.1)
 - DO NOT USE ArcGIS 10.4, 10.5
 - Basic, Standard, or Advanced license levels
 - Spatial Analyst extension required
 - Python 2.7.8, NumPy 1.7.1
 - Both installed with ArcGIS Desktop 'complete' installation

Python Toolboxes

Python script wrapped to act as an ArcGIS Toolbox



Toolbox
Script (.pyt)



Function
Script (.py)

PYT file is the toolbox script containing multiple toolsets

- Functions called from separate script (`wrf_hydro_functions.py`)

Parameter handling and validation

Advantages

Easy to modify

Portable

Many tools organized

Python Toolbox (.pyt)

Toolboxes wrapped in Python script...

```
# --- Toolbox Classes --- #
class Toolbox(object):
    def __init__(self):
        """Define the toolbox (the name of the toolbox is the name of the
        .pyt file)."""
        self.label = "WRFHydro_GIS_Pre-Processor"
        self.alias = ""
        self.description = "This is a standalone ArcGIS geoprocessing toolbox for WRF-Hydro."

        # List of tool classes associated with this toolbox
        self.tools = [ProcessGeogridFile,
                      ExportGrid,
                      ExamineOutputs,
                      ExportPRJ,
                      GenerateLatLon,
                      SpatialMetadataFile,
                      DomainShapefile,
                      Reach_Based_Routing_Addition,
                      Lake_Parameter_Addition]

class ProcessGeogridFile(object):
    def __init__(self):
        """Define the tool (tool name is the name of the class)."""
        self.label = "Process GEOGRID File"
        self.description = "This tool takes an input WRF GEOGRID file in NetCDF format + \
                            " and uses the HGT_M grid and an input high-resolution elevation grid" + \
                            " to produce a high-resolution hydrologically processed output."
        self.canRunInBackground = True
        self.category = "Processing"

    def getParameterInfo(self):
        """Define parameter definitions"""

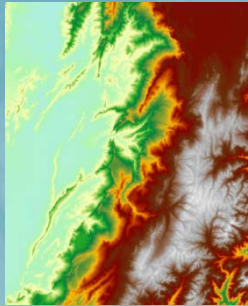
        in_nc = arcpy.Parameter(
            displayName="Input GEOGRID File",
            name="in_nc",
            datatype="File",
            parameterType="Required",
            direction="Input")

        in_csv = arcpy.Parameter(
            displayName="Forecast Points (CSV)",
            name="in_csv",
            datatype="File",
            direction="Input")
```


Pre-processor

Outputs

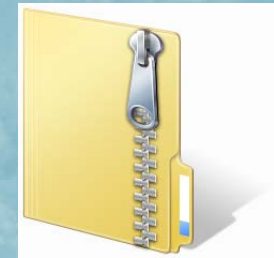
Inputs



Other parameters

```
import arcpy  
  
class Toolbox:  
    def __init__(self):  
        """Python  
        self.label  
        self.alias  
        self.description  
        """  
  
        # List of tools  
        self.tools = [PythonToolbox]
```

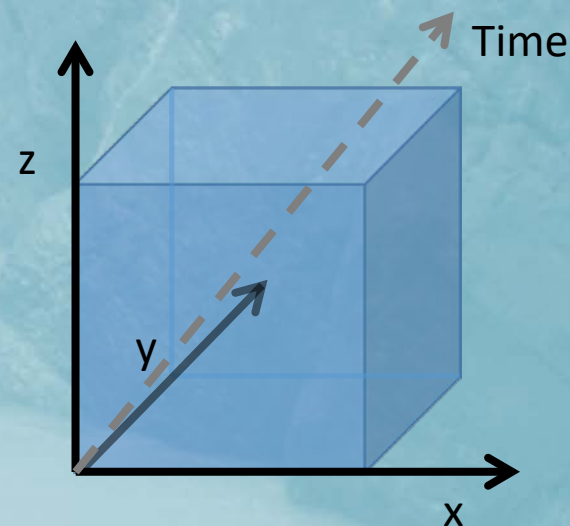
© esri



- FRNG_1km_250m_TestData_Full
 - Fulldom_hires.nc
 - GEOGRID_LDASOUT_Spatial_Metadata.nc
 - gw_basns_geogrid.txt
 - gw_basns_geogrid.prj
 - LAKEPARAM.nc
 - lakes.shp
 - Route_Link.nc
 - streams.shp

netCDF file format

- network Common Data Form
 - “.nc” extension
- Self describing
 - Includes information about the data coordinate system
- Machine independent
 - Usable in many operating systems
- Used extensively in Atmospheric Science
- Multidimensional
 - x,y,z,t



Fulldom File (Routing Grids)

netCDF WRF-Hydro input file

Full high-resolution domain file (Fulldom_hires.nc)

Stores all routing grids as 2-dimensional variables

Stores CF-compliant spatial metadata

- grid_mapping
- Projection information
- Coordinate System variable
- ArcGIS-compliant projection information

Easy to import into GIS Applications (ArcGIS, QGIS)

Ingested directly by WRF-Hydro

A Note on CF Metadata

Climate and Forecast Conventions for netCDF data

- Like a standard
- Current version 1.7
- <http://cfconventions.org/latest.html>

CF conventions for just about any type of data

- Gridded
- Point
- Profile
- timeSeries

CF-compliant netCDF files make them much easier to use in client applications

- Panoply, ArcGIS, QGIS

Process GEOGRID File

Process GEOGRID File

Input GEOGRID File

Forecast Points (CSV) (optional)

Mask CHANNELGRID variable to forecast basins? (optional)

Create reach-based routing (RouteLink) files? (optional)

Create lake parameter (LAKEPARM) file? (optional)

Reservoirs Shapefile or Feature Class (optional)

Input Elevation Raster

Regridding (nest) Factor

Number of routing grid cells to define stream

Output ZIP File

Parameter Values

OVROUGHRTFAC Value

RETDEPRTFAC Value

Process GEOGRID File

This tool takes an input WRF GEOGRID file in NetCDF format and uses the HGT_M grid and an input high-resolution elevation grid to produce a high-resolution hydrologically processed output.

OK Cancel Environments... << Hide Help Tool Help

Inputs

Required:

- WRF GEOGRID file (.nc)
- High-resolution Elevation
 - Elevation file (Esri GRID, GeoTIFF, etc.)
 - Mosaic Dataset

Parameters

- Regridding Factor – nesting relationship of routing:land grids
- Minimum basin size (in routing grid cells)
- OVRUGHRTFAC – constant
- RETDEPRTFAC – constant
- LKSATFAC – constant

Optional:

- Station Locations (.csv)
- Lake Polygons (polygon feature class or .shp)

Model Domain

- Area of interest
- Defines model domain
 - Size
 - Location
 - Horizontal resolution
- Defined by GEOGRID file
 - Example:



geo_em.d03.nc



Input: WRF GEOGRID File

The purpose of the GEOGRID file is to define the simulation domain and interpolate various static geographical datasets to the model grid.

GEOGRID is used in the WRF-Hydro GIS Pre-processor to define the domain's coordinate reference system, extent, resolution, and certain 2D variables:

- HGT_M (elevation)
- LU_INDEX (landuse)

Currently supported GEOGRID coordinate systems

- MAP_PROJ = 1 (Lambert Conformal Conic)
- MAP_PROJ = 3 (Mercator)
- MAP_PROJ = 6 (Cylindrical Equidistant but NOT w/ rotated pole)
- MAP_PROJ = 2 (Polar Stereographic)

GEOGRID: Projected Coordinate System

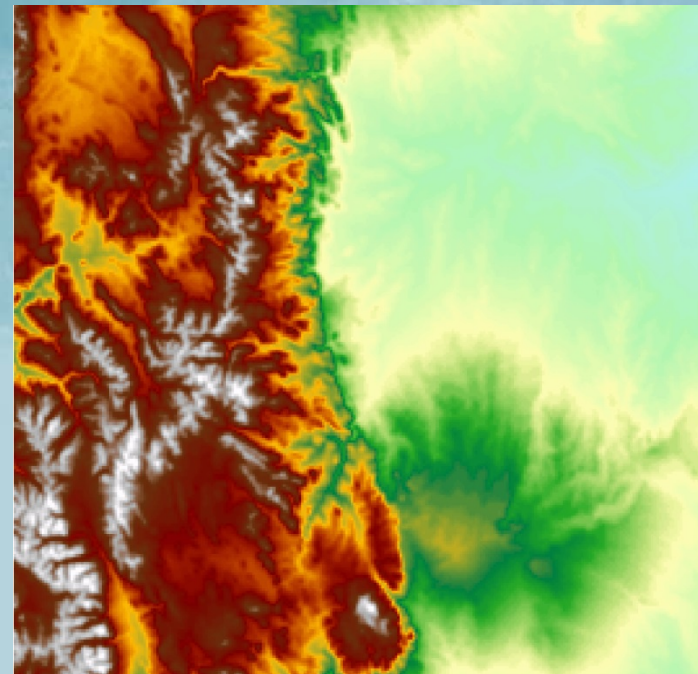
Front_Range_geo_em.d02.nc

```
:TITLE = "OUTPUT FROM GEOGRID V3.5.1";
:SIMULATION_START_DATE = "0000-00-00 00:00:00";
:WEST-EAST_GRID_DIMENSION = 50; // int
:SOUTH-NORTH_GRID_DIMENSION = 36; // int
:BOTTOM-TOP_GRID_DIMENSION = 0; // int
:WEST-EAST_PATCH_START_UNSTAG = 1; // int
:WEST-EAST_PATCH_END_UNSTAG = 49; // int
:WEST-EAST_PATCH_START_STAG = 1; // int
:WEST-EAST_PATCH_END_STAG = 50; // int
:SOUTH-NORTH_PATCH_START_UNSTAG = 1; // int
:SOUTH-NORTH_PATCH_END_UNSTAG = 35; // int
:SOUTH-NORTH_PATCH_START_STAG = 1; // int
:SOUTH-NORTH_PATCH_END_STAG = 36; // int
:GRIDTYPE = "C";
:DX = 1000.0f; // float
:DY = 1000.0f; // float
:DYN OPT = 2; // int
:CEN_LAT = 39.940014f; // float
:CEN_LON = -105.42999f; // float
:TRUELAT1 = 30.0f; // float
:TRUELAT2 = 50.0f; // float
:MOAD_CEN_LAT = 39.940014f; // float
:STAND_LON = -105.0f; // float
:POLE_LAT = 90.0f; // float
:POLE_LON = 0.0f; // float
:corner_lats = 39.783337f, 40.093864f, 40.095993f, 3
:corner_lons = -105.714264f, -105.71753f, -105.14442
:MAP_PROJ = 1; // int
:MMINLU = "USGS";
:NUM_LAND_CAT = 24; // int
:ISWATER = 16; // int
:ISLAKE = -1; // int
:ISICE = 24; // int
:ISURBAN = 1; // int
:ISOILWATER = 14; // int
:grid_id = 1; // int
:parent_id = 1; // int
:i_parent_start = 1; // int
:j_parent_start = 1; // int
:i_parent_end = 50; // int
:j_parent_end = 36; // int
:parent_grid_ratio = 1; // int
:sr_x = 1; // int
:sr_y = 1; // int
:FLAG_MF_XY = 1; // int
}
```

WKT

```
"PROJCS['Lambert_Conformal_Conic',GEOGCS['GCS_Sphere',DATUM['D_Sph
ere'],SPHEROID['Sphere',6370000.0,0.0]],PRIMEM['Greenwich',0.0],UNI
T['Degree',0.0174532925199433]],PROJECTION['Lambert_Conformal_Coni
c'],PARAMETER['false_easting',0.0],PARAMETER['false_northing',0.0]
,PARAMETER['central_meridian',-
105.0],PARAMETER['standard_parallel_1',30.0],PARAMETER['standard_p
arallel_2',50.0],PARAMETER['latitude_of_origin',39.9400138855],UNI
T['Meter',1.0]];-36695400 -29251300 10000;-100000 10000;-100000
10000;0.001;0.001;0.001;IsHighPrecision"
```

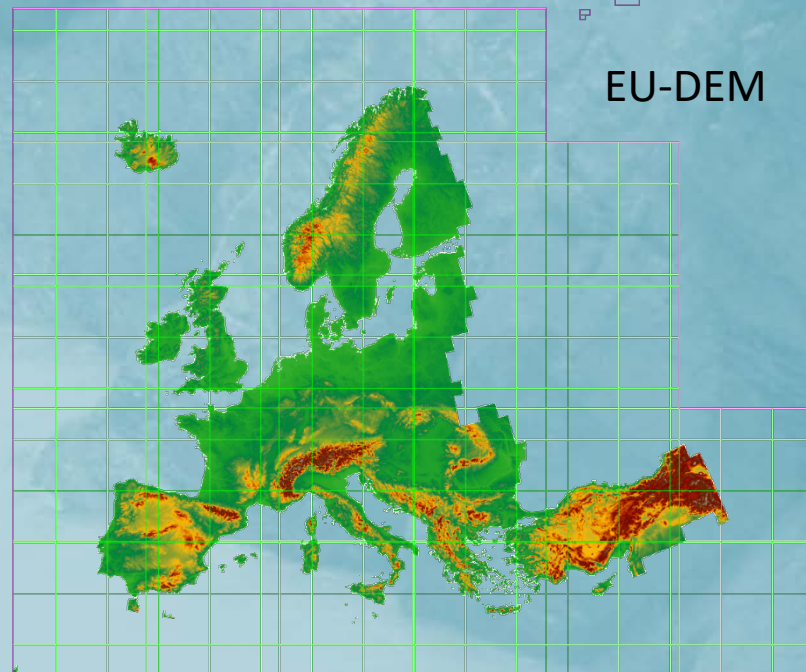
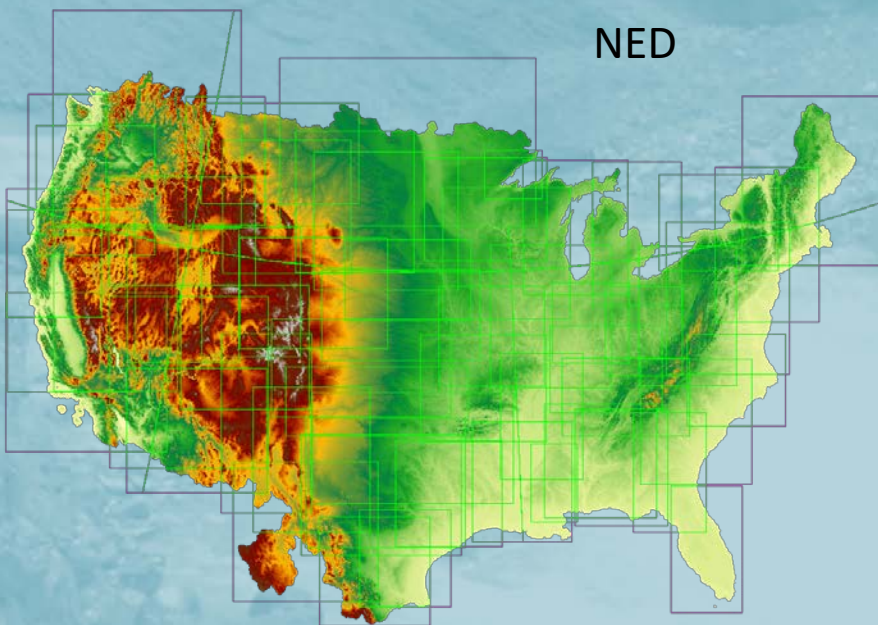
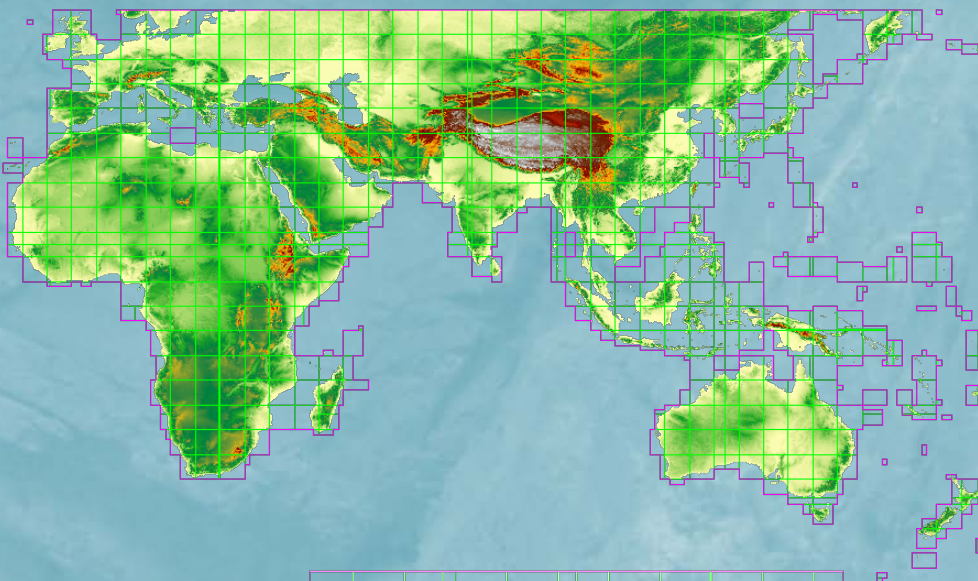
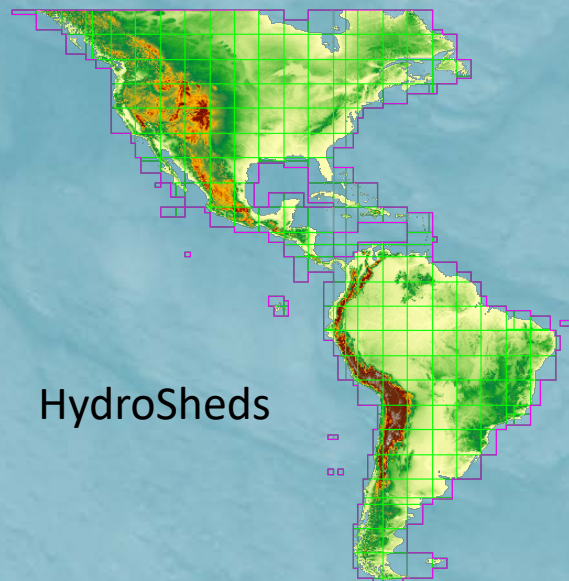
geo_em.d01.boulder_creek_1km.prj



Input: Elevation Raster

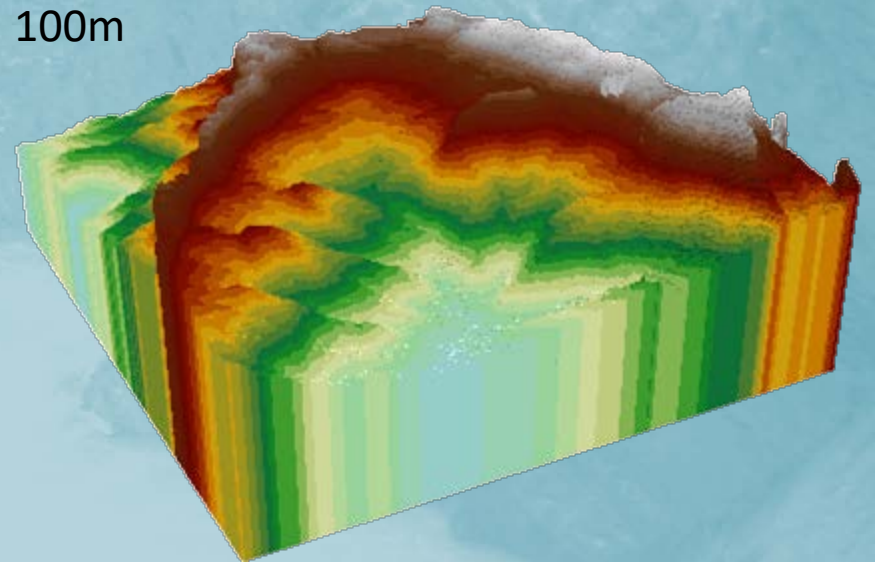
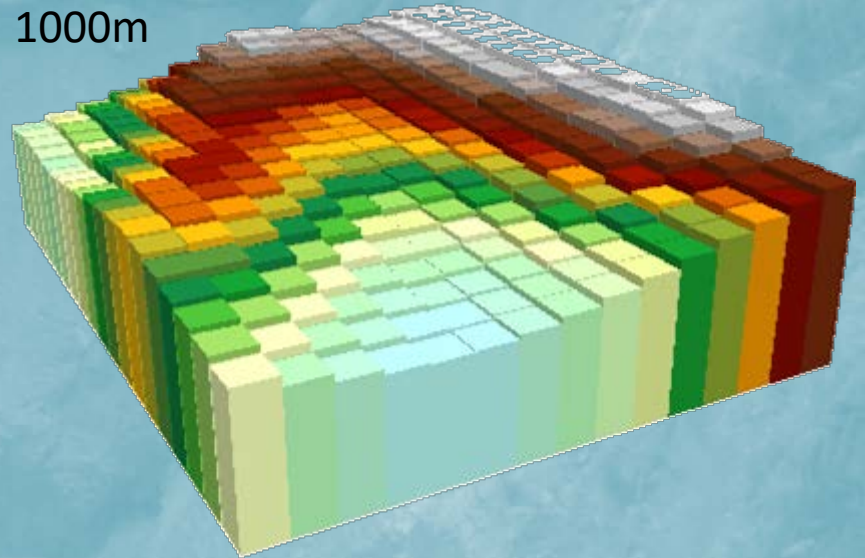
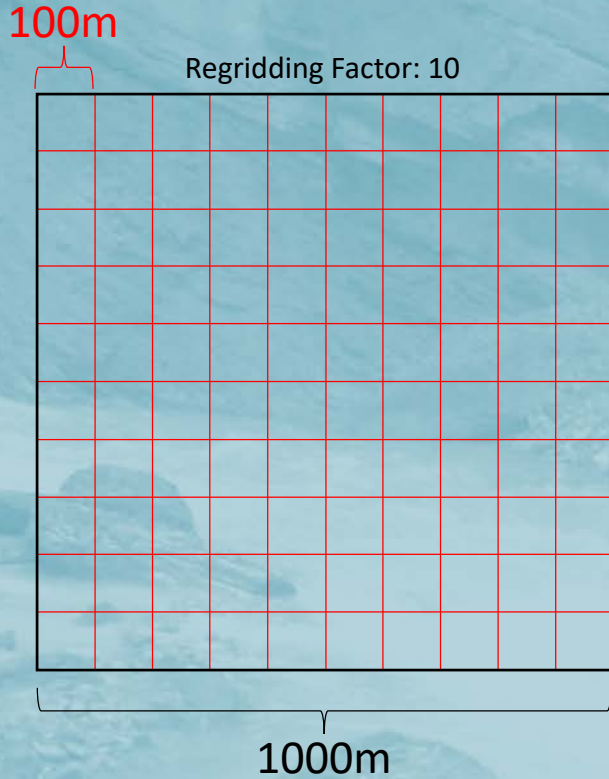
- Must be an ArcGIS-readable raster format
- Must contain valid coordinate reference system
- Must cover entire extent (and more) of your GEOGRID domain
- Elevation units must be converted to meters (m)
- Should be hydrologically corrected
 - Not necessary but helps with channel placement, hydro enforcement, etc.

Input: Elevation Mosaics



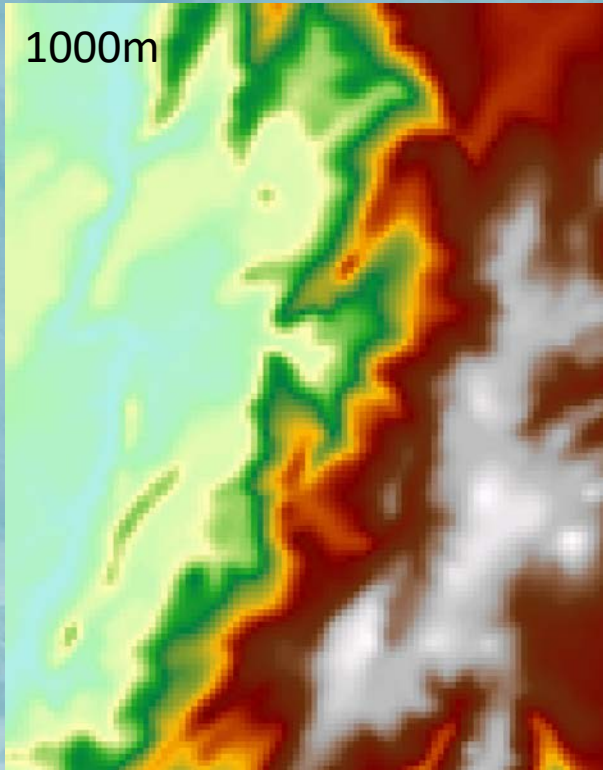
Input: Regridding Factor

$$\frac{\text{GEOGRID Resolution}}{\text{Regridding Factor}} = \text{Routing Resolution}$$

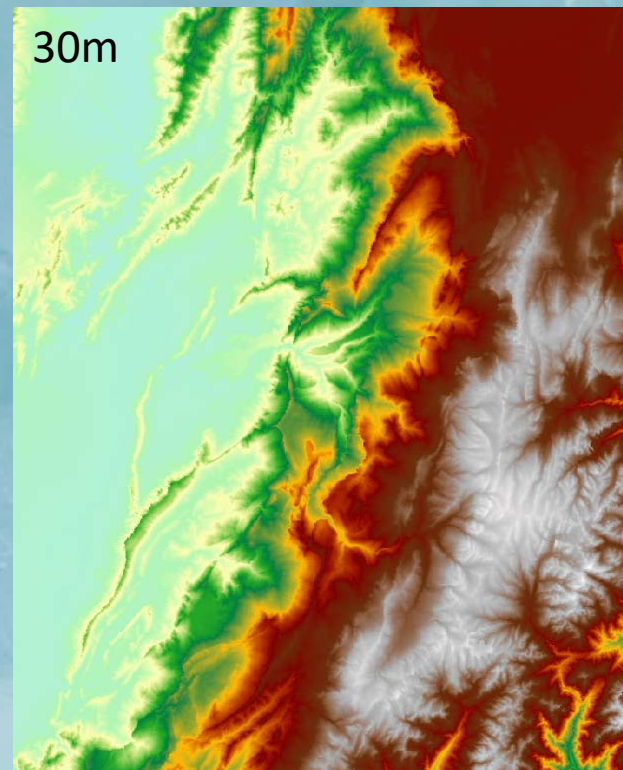


Raster resolution for terrain processing

Model Resolution



High Resolution



Terrain Pre-processing Workflow

Resample high-resolution DEM and land use

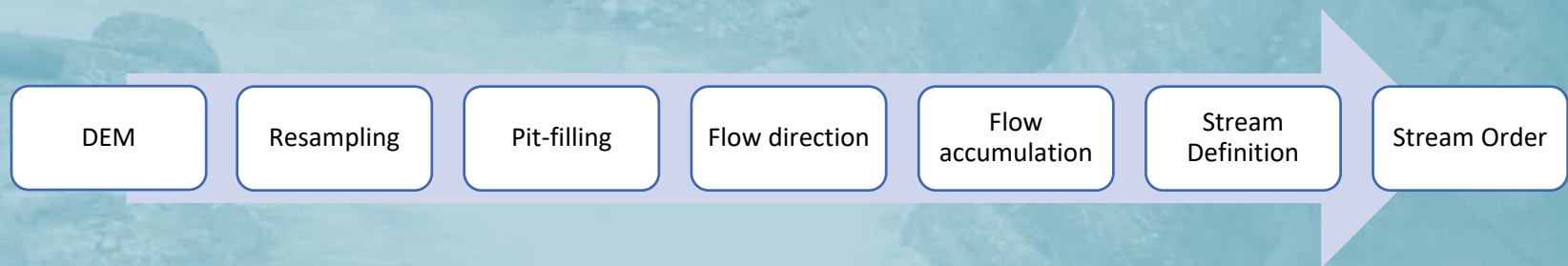
Void-fill the resampled DEM

D8 Flow Direction

Flow Accumulation

Derive CHANNELGRID from flow accumulation raster using threshold of minimum basin size

Derive Strahler stream order from CHANNELGRID



Basic workflow for terrain pre-processing of WRF-Hydro routing grids.

Reproject & Resample Hydro DEM

Project input DEM to model projection and domain

Resample to routing grid resolution

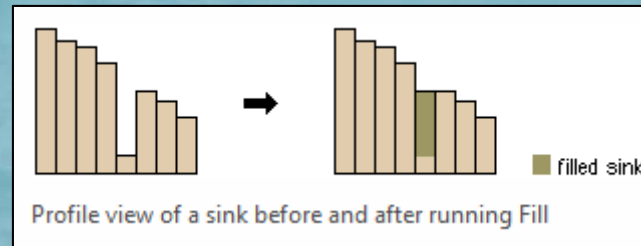
- BILINEAR resampling uses a distance-weighted average of the 4 nearest cell centres.

Re-projection and resampling can 'break' the input HydroDEM.

- Causing artificial 'pits'.
- Filling in 'burned in' areas.

Even though we start with a HydroDEM, we 'break' it, then re-condition it.

Spatial Analyst “Fill” Tool



© Esri: <http://desktop.arcgis.com/en/arcmap/latest/tools/spatial-analyst-toolbox/how-fill-works.htm>

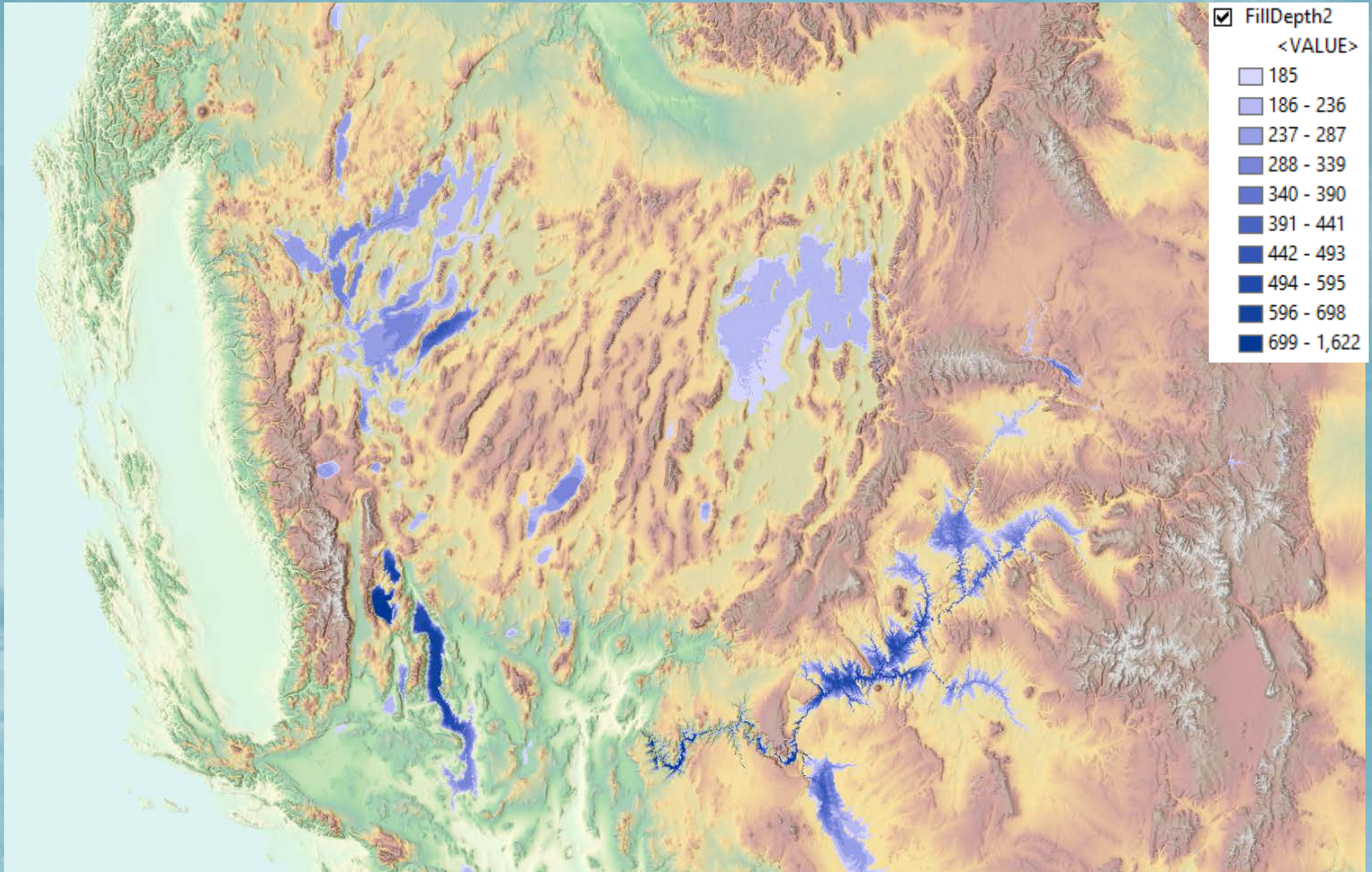
Fill depressions so that water can roll downhill only. This also creates a smoother Dem than you might find in nature.

This simple hydro-enforcement method can resolve most flow issues in a DEM.

Optional z-limit (global variable) to limit fill depth.

Pit-filling issues

- ...some pits are natural, some are not.

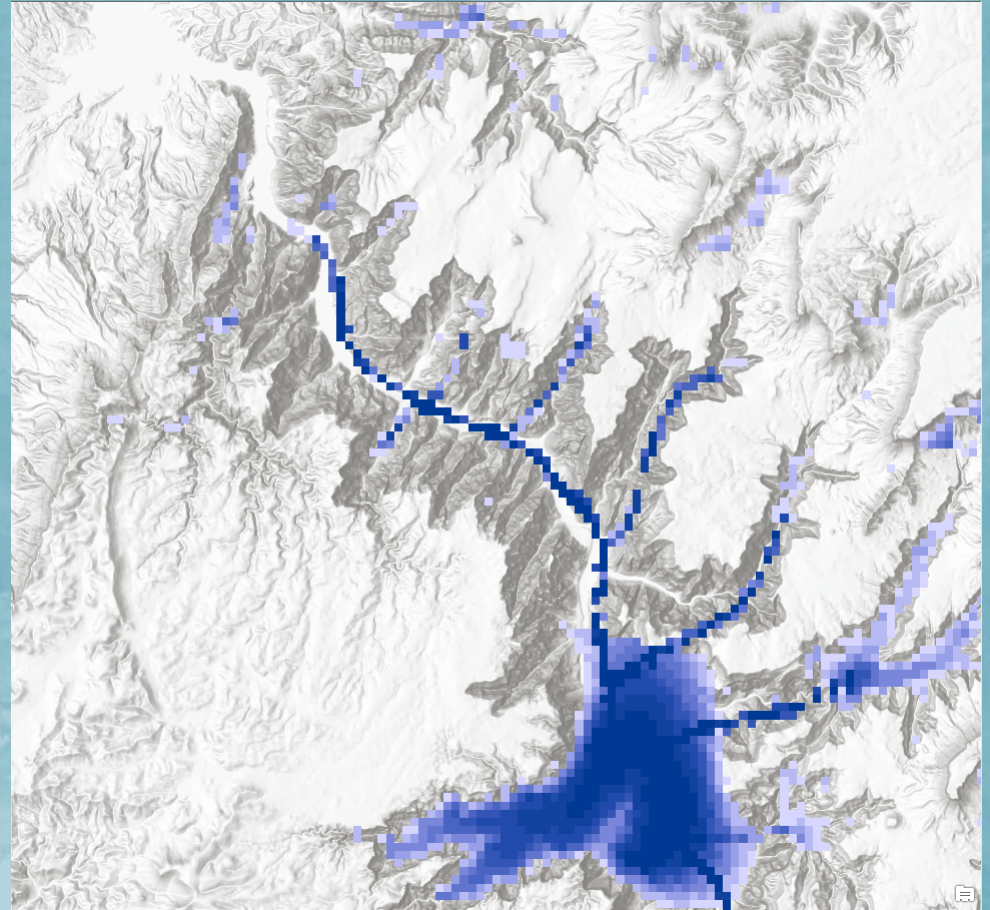


Resampling can break hydrologic connectivity

Coarsening a HydroDEM can break hydrologic connectivity.

Try not to get too much coarser than input HydroDEM, or perform extensive hydro-enforcement on you input DEM first.

Here, a canyon outlet is filled, causing entire valley to fill during pit-filling process.

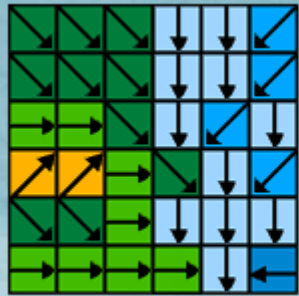


Flow Direction & Flow Accumulation

D8 Flow Direction

32	64	128
16		1
8	4	2

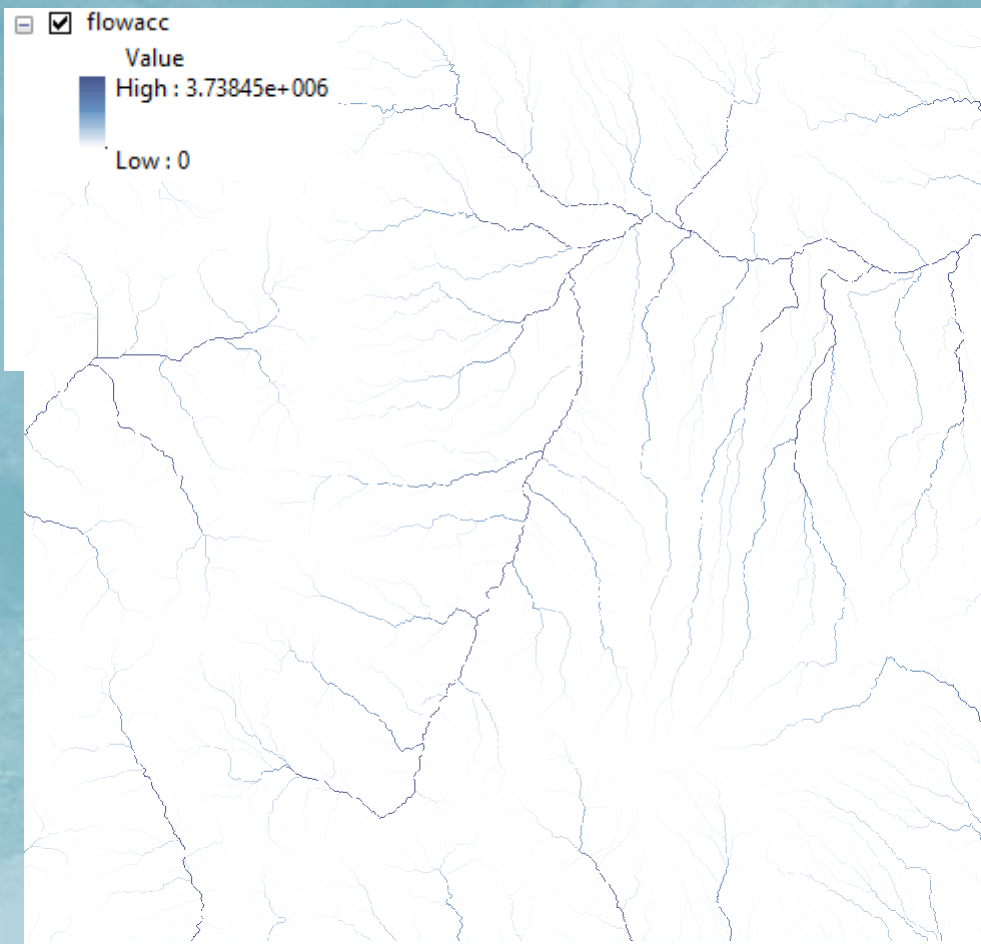
Flow Accumulation



Flow direction



Flow accumulation

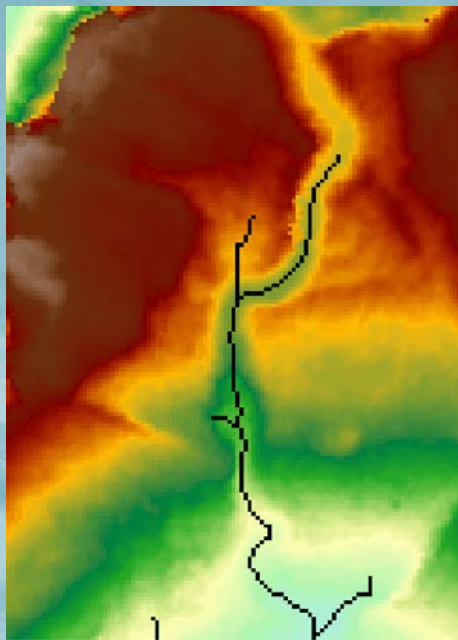


© Esri: <http://desktop.arcgis.com/en/arcmap/latest/tools/spatial-analyst-toolbox/how-flow-accumulation-works.htm>

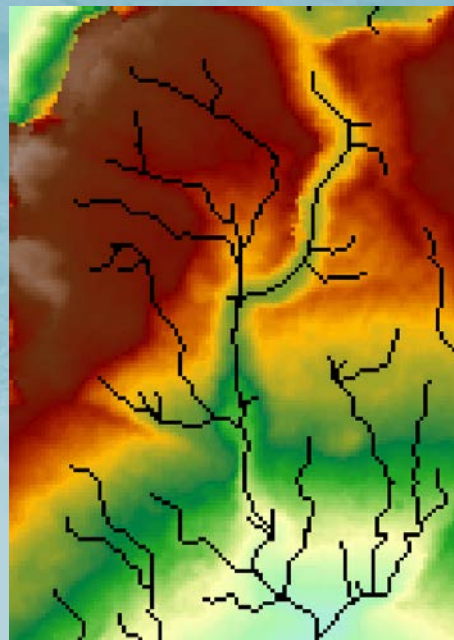
Stream Definition

Input Parameter: Number of pixels to define stream

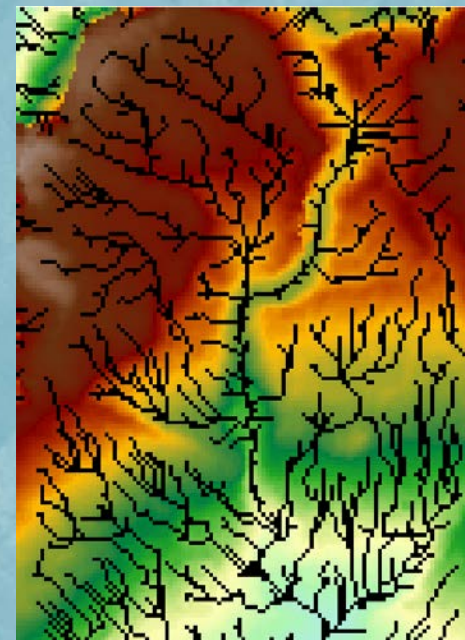
- Yields a minimum 'basin' size
- Given in pixels (unitless), on the routing grid
- Affects density of generated channel network



1km²



0.1km²

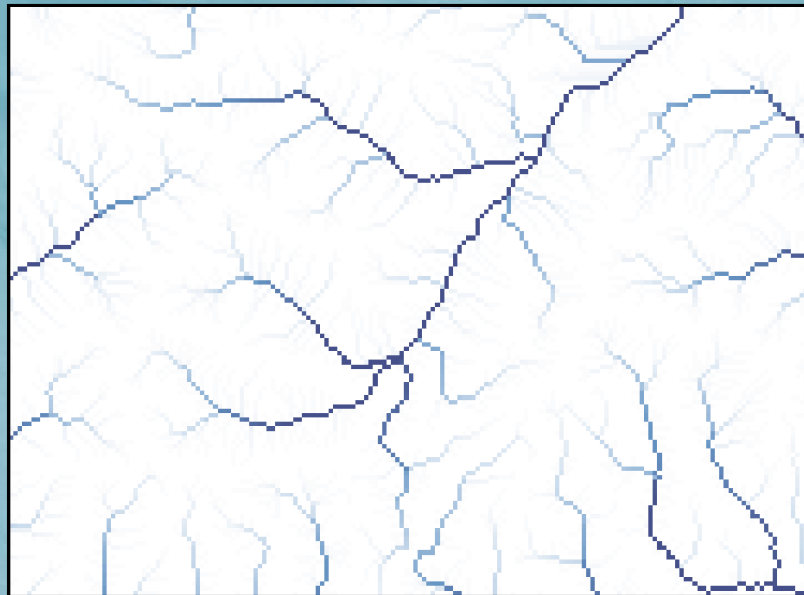


0.01km²

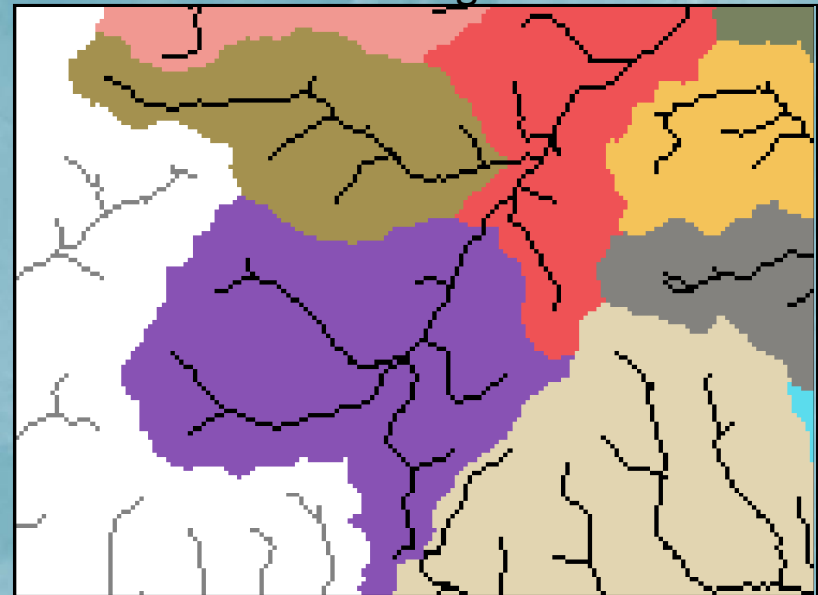
An analytic method for determining an appropriate threshold value for stream network delineation is presented in Tarboton et al. (1991)

Stream Definition

Flow Accumulation



Channelgrid



Use flow accumulation threshold to define channels

Option: use gaged basins as mask to assign CHANNELGRID values

If reach-based routing is selected, **Stream to Feature** used to create vector geometry of streams

- `streams.shp` shapefile written to output directory

Forecast Points

FID_	LON	LAT	STATION	Name	HOST	ELEV	DRAIN_AREA_SQMI	DRAIN_AREA_SQKM
1	-103.79889	40.26861	S_PLATTE_at_FT_MORGAN	6759500	USGS	4260	14627	37883.93
2	-108.26556	39.23917	COLO_at_CAMEO	9095500	USGS	4813	8050	20849.5
3	-104.39861	38.24806	ARKANSAS_nr_AVONDALE	7109500	USGS	4509	6327	16386.93
4	-105.88002	37.481392	RIO_GRANDE_nr_ALAMOSA	8223000	USGS	-9999	0	0

FID,LON,LAT,STATION,Name

15,-105.92833,40.08139,Fraser_at_Granby,9033300

18,-105.9,40.12083,COLO_nr_GRANBY,9019500

20,-106.3333,39.8803,Blue_R_blw_Grn_Mtn,9057500

Create in Excel, Numbers, Word, etc.

Direct output of attribute table from shapefile or feature class

“LON”, “LAT”, “FID” required

If present, basins will be delineated using the points provided

- frxst_basns output variable will be created
- frxst_pts & basin_msk variables will be populated

If masked to basins, CHANNELGRID will have values -1, 0, -9999

Process: Basin Delineation

Snap points to streams

'Walk' down channel network a specified distance

- Default = 3 pixel widths (global variable)

Delineate basin using **Watershed** Spatial Analyst tool



- Writes output file to:

`frxst_pts`

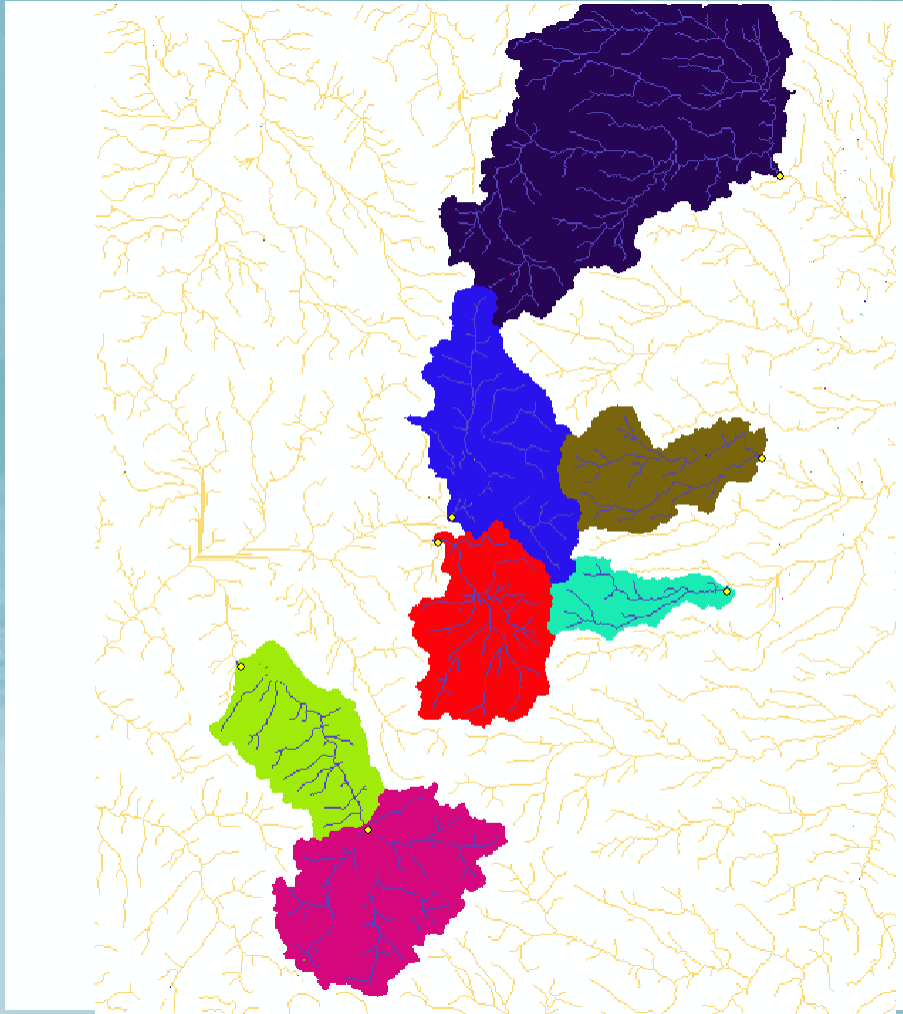
`basn_msk`

Basin Masking

Option to 'turn off' channel networks outside gaged basins.

If gages are provided and the option to mask CHANNELGRID to basins is selected.

- Channel pixels inside gaged basins = 0
- Channels outside = -1



Reach-based routing background

A vector-based approach to routing flow

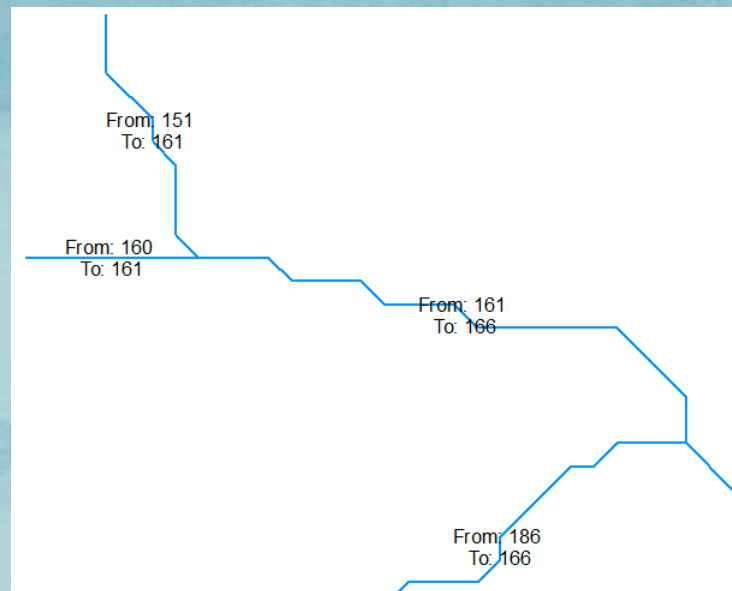
Channel network is comprised of 'links' instead of pixels

Derive the channel network automatically from the

Muskingum-Cunge parameters applied to reaches

With network topology defined, flow can be routed down reaches

Computational efficiency vs. gridded methods



Reach-routing Table

CF-netCDF file containing reach-routing parameters

Mix of derived attributes and default values

Parameter	Description
link	Link ID
from	From Link ID
to	To Link ID
lon	longitude of the start node
lat	latitude of the start node
alt	Elevation in meters from DEM at start node
order	Stream order (Strahler)
Qi	Initial flow in link (CMS)
MusK	Muskingum routing time (s)
MusX	Muskingum weighting coefficient
Length	Stream length (m)
n	Manning's roughness
So	Slope (meters/meter)
ChSlp	Channel side slope
BtmWdth	Bottom width of channel
Kchan	Channel conductivity (mm/hr)
x	X-coordinate in projected coordinate system
y	Y-coordinate in projected coordinate system

Route_Link.nc

netCDF file to store link information.

- 1-Dimension (linkDim)

CF-netCDF 'timeSeries' convention

Defaults

Qi:	0 cms
MusK:	3600 s
MusX:	0.2
n:	0.035
ChSlp:	0.05
BtmWdth:	5 m
Kc:	0 mm/hr

```
netcdf Route_Link {
dimensions:
    linkDim = 5726 ;
variables:
    int link(linkDim) ;
        link:long_name = "Link ID" ;
        link:cf_role = "timeseries_id" ;
    int from(linkDim) ;
        from:long_name = "From Link ID" ;
        from:coordinates = "lat lon" ;
    int to(linkDim) ;
        to:long_name = "To Link ID" ;
        to:coordinates = "lat lon" ;
    float lon(linkDim) ;
        lon:long_name = "longitude of the start node" ;
        lon:units = "degrees_east" ;
        lon:standard_name = "longitude" ;
    float lat(linkDim) ;
        lat:long_name = "latitude of the start node" ;
        lat:units = "degrees_north" ;
        lat:standard_name = "latitude" ;
    float alt(linkDim) ;
        alt:long_name = "Elevation in meters at start node" ;
        alt:standard_name = "height" ;
        alt:units = "m" ;
        alt:positive = "up" ;
        alt:axis = "Z" ;
    int order(linkDim) ;
        order:long_name = "Stream order (Strahler)" ;
        order:coordinates = "lat lon" ;
    float Qi(linkDim) ;
        Qi:long_name = "Initial flow in link (CMS)" ;
        Qi:coordinates = "lat lon" ;
    float MusK(linkDim) ;
        MusK:long_name = "Muskingum routing time (s)" ;
        MusK:coordinates = "lat lon" ;
    float MusX(linkDim) ;
        MusX:long_name = "Muskingum weighting coefficient" ;
        MusX:coordinates = "lat lon" ;
    float Length(linkDim) ;
        Length:long_name = "Stream length (m)" ;
        Length:coordinates = "lat lon" ;
    float n(linkDim) ;
        n:long_name = "Manning\'s roughness" ;
        n:coordinates = "lat lon" ;
    float So(linkDim) ;
        So:long_name = "Slope (%; drop/length)" ;
        So:coordinates = "lat lon" ;
    float ChSlp(linkDim) ;
        ChSlp:long_name = "Channel side slope (%; drop/length)" ;
        ChSlp:coordinates = "lat lon" ;
    float BtmWdth(linkDim) ;
        BtmWdth:long_name = "Bottom width of channel" ;
        BtmWdth:coordinates = "lat lon" ;
    float time ;
        time:standard_name = "time" ;
        time:long_name = "time of measurement" ;
        time:units = "days since 2000-01-01 00:00:00" ;

// global attributes:
    :featureType = "timeSeries" ;
    :history = "Created Mon May 02 14:43:17 2016" ;
}
```

Process: Stream Order

Stream Order Spatial Analyst tool

- Strahler stream order
- Writes output file to STREAMORDER variable



Process: Reservoir Routing

If the option is selected, a polygon shapefile or feature class is required as input.

Populates LAKEGRID variable

Assigns lake ID values to pixels where lakes drain into channel

Constructs a LAKEPARM.nc file with necessary variables for reach-based routing:

- Lake area, max elevation, min elevation, base elevation, orifice elevation

```
netcdf LAKEPARM <
dimensions:
  nlakes = 82 ;
variables:
  int lake_id(nlakes) ;
    lake_id:long_name = "Lake ID" ;
    lake_id:cf_role = "timeseries_id" ;
  double LkArea(nlakes) ;
    LkArea:long_name = "Gridded lake area (sq. km)" ;
    LkArea:coordinates = "lat lon" ;
  double LkMxH(nlakes) ;
    LkMxH:long_name = "Maximum lake elevation (m ASL)" ;
    LkMxH:coordinates = "lat lon" ;
  double WeirC(nlakes) ;
    WeirC:long_name = "Weir coefficient" ;
    WeirC:coordinates = "lat lon" ;
  double WeirL(nlakes) ;
    WeirL:long_name = "Weir length (m)" ;
    WeirL:coordinates = "lat lon" ;
  double OrificeC(nlakes) ;
    OrificeC:long_name = "Orifice coefficient" ;
    OrificeC:coordinates = "lat lon" ;
  double OrificeA(nlakes) ;
    OrificeA:long_name = "Orifice cross-sectional area (sq. m)" ;
    OrificeA:coordinates = "lat lon" ;
  double OrificeE(nlakes) ;
    OrificeE:long_name = "Orifice elevation (m ASL)" ;
    OrificeE:coordinates = "lat lon" ;
  float lat(nlakes) ;
    lat:long_name = "latitude of the lake centroid" ;
    lat:units = "degrees_north" ;
    lat:standard_name = "latitude" ;
  float lon(nlakes) ;
    lon:long_name = "longitude of the lake centroid" ;
    lon:units = "degrees_east" ;
    lon:standard_name = "longitude" ;
  float alt(nlakes) ;
    alt:long_name = "vertical distance above mean sea level in (m ASL)" ;
    alt:standard_name = "height" ;
    alt:units = "m" ;
    alt:positive = "up" ;
```


LAKEGRID / LAKEPARM.nc

Input: Reservoirs shapefile or feature class (polygon)

Polygons are resolved on the model grid if they are large enough

Lake ID is renumbered to 1-n

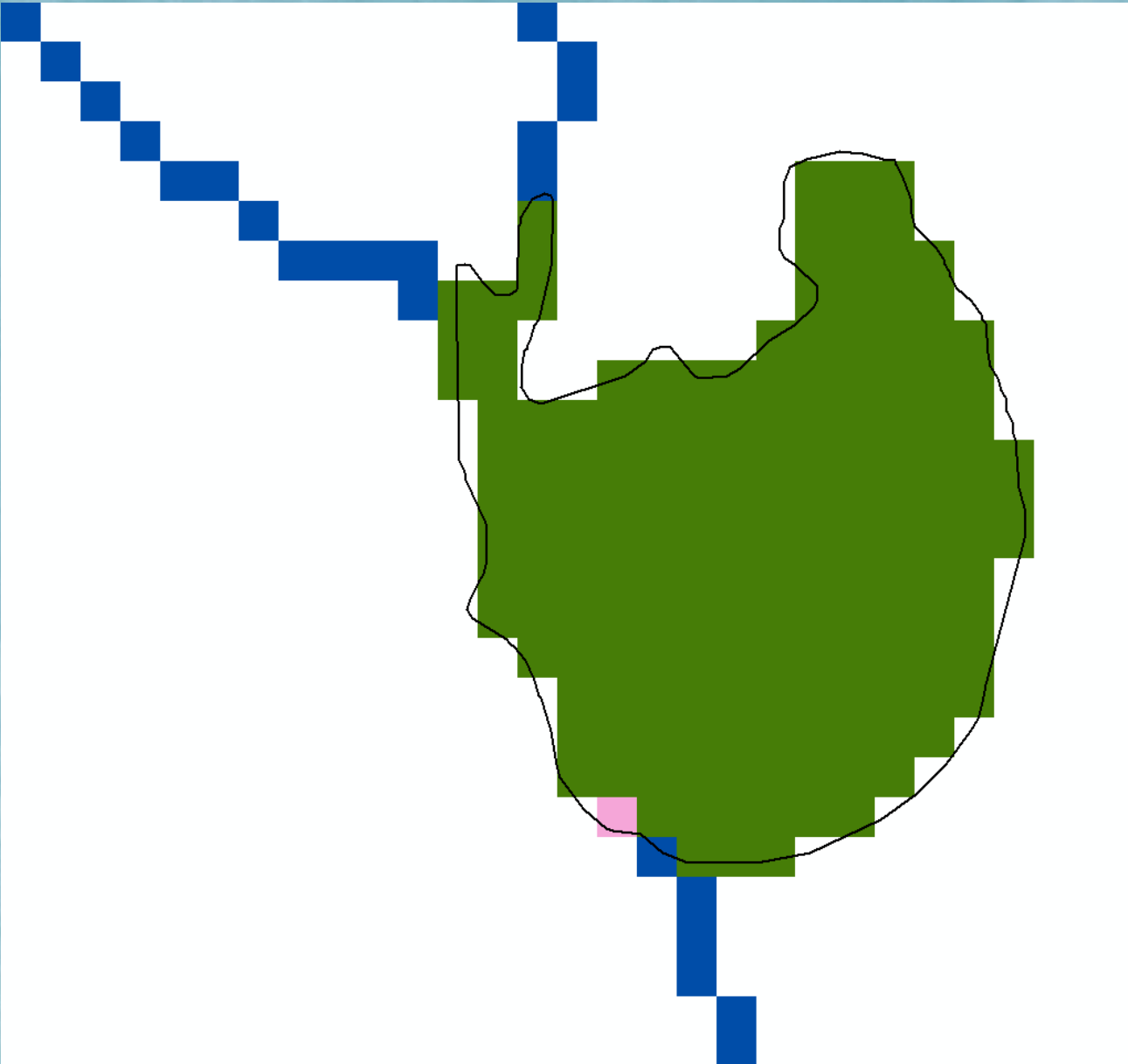


Original polygons



Lakes on the routing grid

Reservoirs and Channels



Lakes/Reservoir routing in the NWM

Lake parameters are stored in the LAKEPARAM.nc lake routing table
Lakes are defined on the routing grid, parameters in the table

Lake Routing Table

Parameter	Description
LkArea	Gridded lake area (sq. km)
LkMxH	Maximum lake elevation (m ASL)
OrificeA	Orifice cross-sectional area (sq. m)
OrificeC	Orifice coefficient
OrificeE	Orifice elevation (m ASL)
WeirC	Weir coefficient
WeirH	Weir Height (m ASL)
WeirL	Weir length (m)
lfd	Initial fractional water depth (% full)
lake_id	Lake ID
lat	latitude of the lake centroid
lon	longitude of the lake centroid

Other Grids

Landuse

- GEOGRID LU_INDEX resampled (nearest neighbor) to routing grid

OVROUGHRTFAC

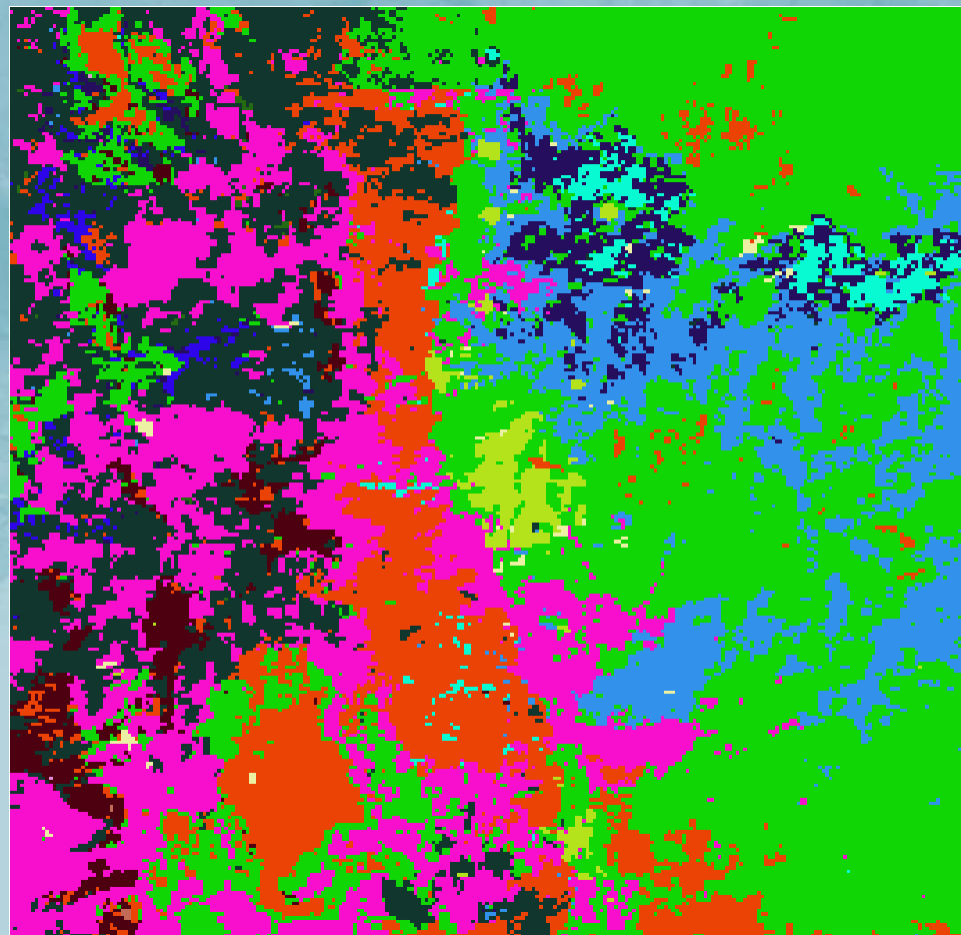
- Constant 1.0 (float32)

RETDEPRTFAC

- Constant 1.0 (float32)

LKSATFAC

- Constant 1000.0 (float32)



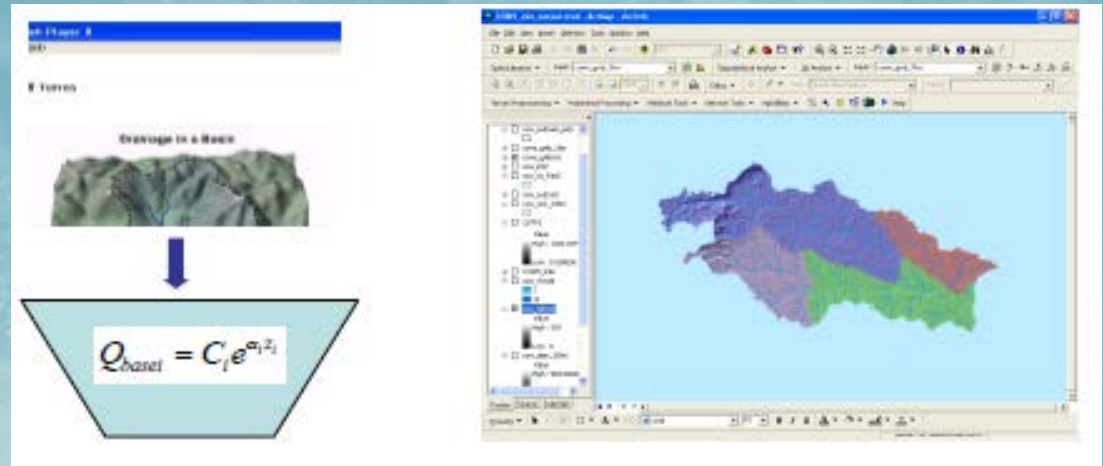
Groundwater Buckets

Conceptualized baseflow

Spatially aggregated drainage from soil profile stored in 'buckets' representative of an aquifer

GWBUCKPARM.nc bucket parameter file

Buckets resolved on the coarse grid, written to a 2D netCDF file
GWBASINS.nc



Basin	Coeff.	Expon.	Zmax	Zinit
1	1.0000	3.000	150.00	10.0000
2	1.0000	3.000	250.00	40.0000
3	1.0000	3.000	150.00	30.0000
4	1.0000	3.000	100.00	20.0000
5	1.0000	3.000	100.00	50.0000

From WRF-Hydro User Guide, Figure 3.7

Groundwater Representation

Groundwater Bucket Parameters

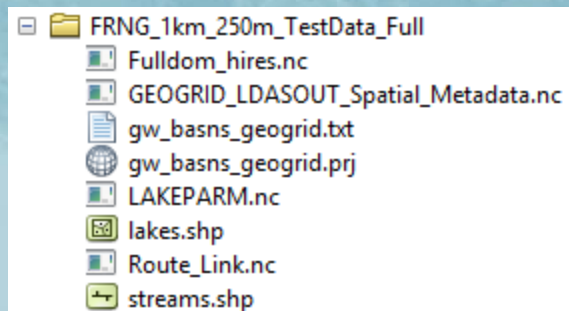
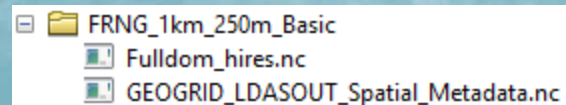
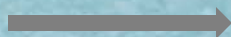
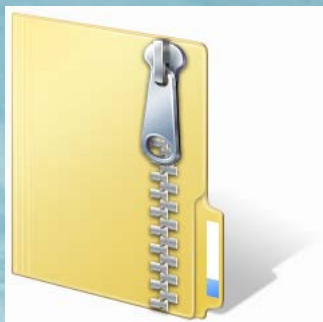
- Built using default groundwater bucket parameters combined with LINKID-based local contributing basins.
- Other methods available to produce groundwater basins from
 - Forecast Points
 - Polygon Shapefile

```
Windows PowerShell
PS C:\Data\Projects\Gochis\NWM_v1_2\GW_BUCKPARAM> ncdump -h .\GWBUCKPARAM_NWM_v1_2_20170320_sorted.nc
netcdf GWBUCKPARAM_NWM_v1_2_20170320_sorted {
dimensions:
  BasinDim = 2677135 ;
variables:
  int Basin(BasinDim) ;
    Basin:long_name = "Basin monotonic ID (1...n)" ;
  float Coeff(BasinDim) ;
    Coeff:long_name = "Coefficient" ;
  float Expon(BasinDim) ;
    Expon:long_name = "Exponent" ;
  float Zmax(BasinDim) ;
    Zmax:long_name = "Zmax" ;
  float Zinit(BasinDim) ;
    Zinit:long_name = "Zinit" ;
  float Area_sqkm(BasinDim) ;
    Area_sqkm:long_name = "Basin area in square kilometers" ;
  int ComID(BasinDim) ;
    ComID:long_name = "NHDCatchment FEATUREID (NHDFlowline ComID)" ;
// global attributes:
  :featureType = "point" ;
  :history = "Created Mon Mar 20 16:35:22 2017" ;
}
```


GIS Pre-processor Outputs

Set of netCDF, shapefile, ASCII & log files

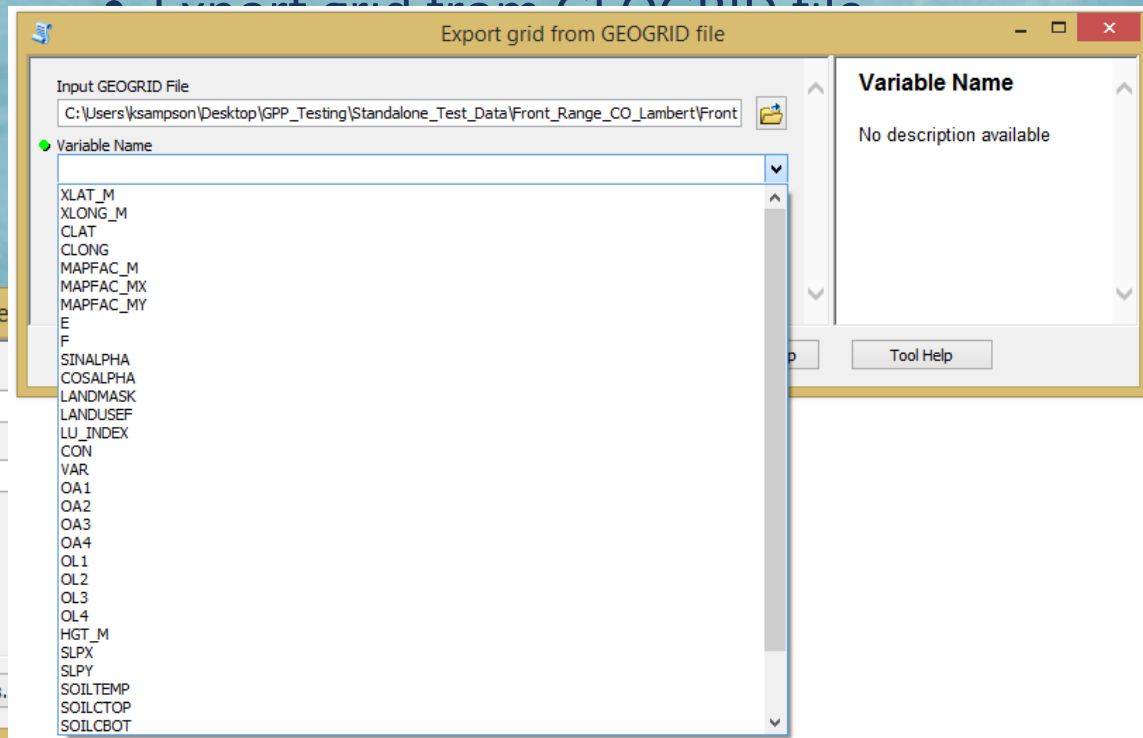
- 2-6 netCDF files
- 0-1 ASCII Raster (.txt)
- 0-2 Shapefiles
- 1 .log file



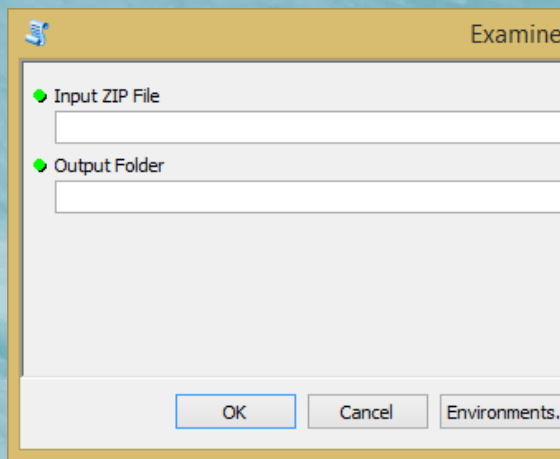
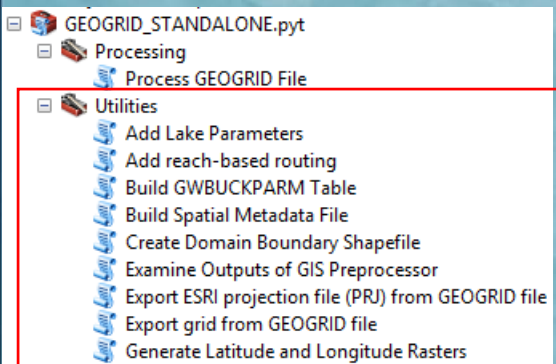
Other Utilities

- Examine Outputs of GIS Preprocessor
 - Extracts .zip output file to individual rasters for viewing in Desktop GIS applications.

Export grid from GEOGRID file



- Creates a polygon shapefile defining the domain boundary from a GEOGRID file
- Build Groundwater Inputs
 - Creates groundwater input files in 3 ways



Tool Messages

ProcessGeogridFile

Completed

Close this dialog when completed successfully

Process: flowdirection.nc completed with
Output File: E:\Projects\Gochis\dom

Process: flowacc.nc completed without er
Output File: E:\Projects\Gochis\dom

Process: Flow Accumulation completed with
Process: retdeprtfac.nc completed witho
Output File: E:\Projects\Gochis\dom

Process: ovroughrtfac.nc completed witho
Output File: E:\Projects\Gochis\dom

Process: str_order.nc completed without
Output File: E:\Projects\Gochis\dom

Routing table will be created...
Stream to features step complete.
Done reading streams layer.
Done building Nodes layer with adjus
Done extracting elevations to points
Done reading elevations.
Done reading Strahler stream orders.
Routing Table:
403 Lines
445 Nodes.
Done writing CSV table to disk.
Routing table created without error.

Process: LINKID.nc completed without err
Output File: E:\Projects\Gochis\dom

Process: frxst_pts.nc completed without
Output File: E:\Projects\Gochis\dom

Process: frxst_pts was empty.

Process: gw_basns.nc completed without e
Output File: E:\Projects\Gochis\dom

Process: gw_basns was empty.

Process: LAKEGRID.nc completed without e
Output File: E:\Projects\Gochis\dom

Process: CHANNELGRID.nc completed witho
Output File: E:\Projects\Gochis\dom

Process: landuse.nc completed without er
Output File: E:\Projects\Gochis\dom

Step 4 completed without error.
Completed without error.
Completed script ProcessGeogridFile...
Succeeded at Mon Nov 17 20:01:54 2014 (Elaps

Results

Current Session

ExamineOutputs [223032_11162014]

Output Folder: Boulder_Creek_100m_1km_NHDPI1

Inputs

Input ZIP File: Boulder_Creek_100m_1km_NHDPlus_Reservoirs.zip

Environments

Messages

- Executing: ExamineOutputs E:\Projects\Gochis\domains\Boulder_Creek\Boulder_Creek_100m_1km...
- Start Time: Sun Nov 16 22:30:30 2014
- Running script ExamineOutputs...
- Beginning to extract WRF routing grids...
- File Created: E:\Projects\Gochis\domains\Boulder_Creek\Boulder_Creek_100m_1km_NHDPI1\CHAN...
- File Created: E:\Projects\Gochis\domains\Boulder_Creek\Boulder_Creek_100m_1km_NHDPI1\flowa...
- File Created: E:\Projects\Gochis\domains\Boulder_Creek\Boulder_Creek_100m_1km_NHDPI1\flowd...
- File Created: E:\Projects\Gochis\domains\Boulder_Creek\Boulder_Creek_100m_1km_NHDPI1\frxst_p...
- File Created: E:\Projects\Gochis\domains\Boulder_Creek\Boulder_Creek_100m_1km_NHDPI1\gw_ba...
- File Created: E:\Projects\Gochis\domains\Boulder_Creek\Boulder_Creek_100m_1km_NHDPI1\LAKEC...
- File Created: E:\Projects\Gochis\domains\Boulder_Creek\Boulder_Creek_100m_1km_NHDPI1\landu...
- File Created: E:\Projects\Gochis\domains\Boulder_Creek\Boulder_Creek_100m_1km_NHDPI1\latitud...
- File Created: E:\Projects\Gochis\domains\Boulder_Creek\Boulder_Creek_100m_1km_NHDPI1\longit...
- File Created: E:\Projects\Gochis\domains\Boulder_Creek\Boulder_Creek_100m_1km_NHDPI1\ovrou...
- File Created: E:\Projects\Gochis\domains\Boulder_Creek\Boulder_Creek_100m_1km_NHDPI1\retdep...
- File Created: E:\Projects\Gochis\domains\Boulder_Creek\Boulder_Creek_100m_1km_NHDPI1\str_or...
- File Created: E:\Projects\Gochis\domains\Boulder_Creek\Boulder_Creek_100m_1km_NHDPI1\topog...
- Extraction of WRF routing grids completed.
- Completed script ExamineOutputs...
- Succeeded at Sun Nov 16 22:30:32 2014 (Elapsed Time: 2.09 seconds)

Documentation & Test Data

Detailed documentation

- 40+ page PDF
- Describes tool capabilities, requirements, parameters, and GIS methods used in the tool chain.

Small GEOGRID domains for testing tool functionality

- Front Range (Lambert Conformal Conic)
- India (Mercator)

Expected Output provided for comparison

Required Elevation files (.tif) provided

Optional stream gages & lakes provided (Front Range)

https://ral.ucar.edu/projects/wrf_hydro/pre-processing-tools

Bottlenecks / Constraints

Project high-resolution dataset for large areas

- Can be avoided by pre-projecting/resampling high res data before running the GIS pre-processor

Flow Accumulation – slowest part of the process

Not multi-threaded

- Process runs on one core
- Process chain not well suited to parallelization

Windows only GIS platform



- https://github.com/NCAR/wrf_hydro_arcgis_preprocessor.git

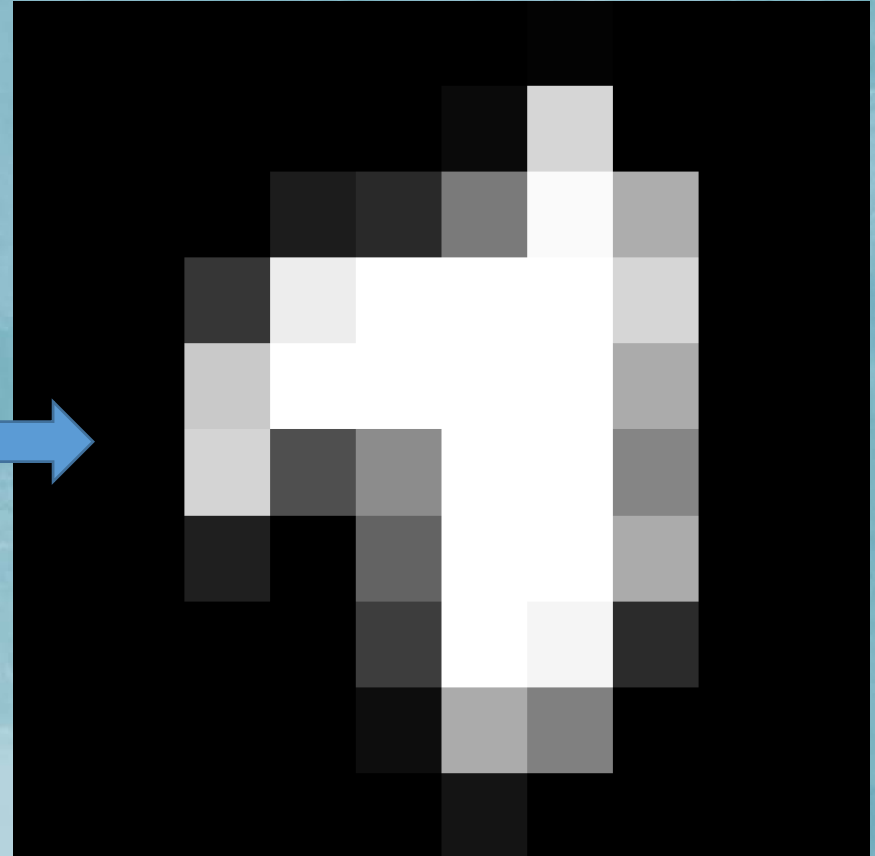
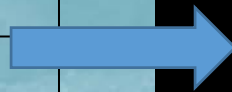
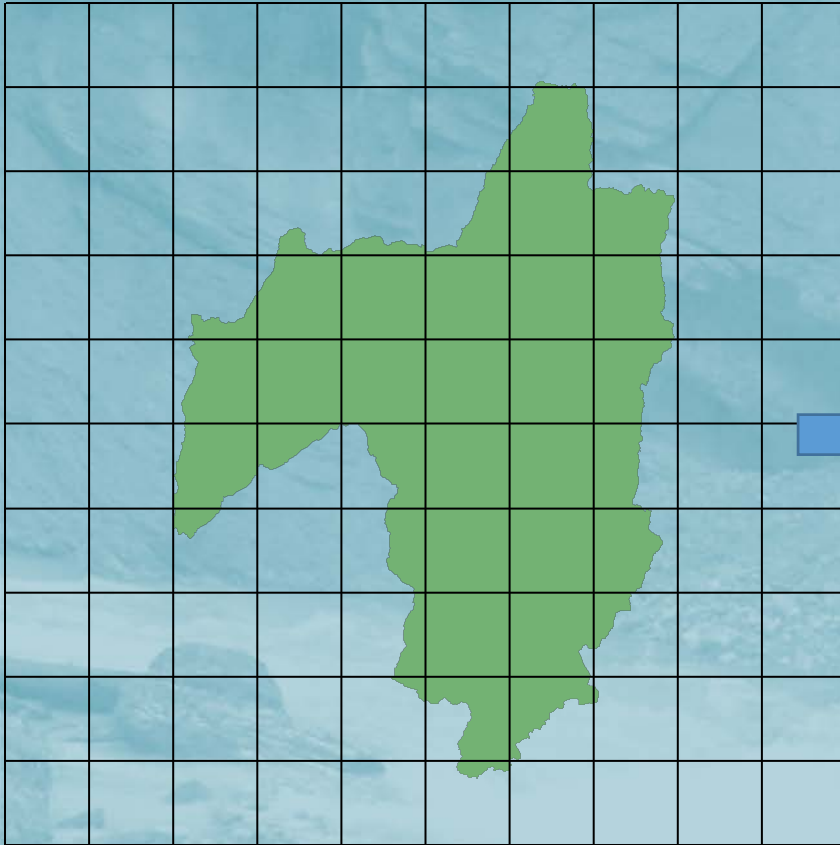
The screenshot shows the GitHub repository page for `NCAR / wrf_hydro_arcgis_preprocessor`. The repository has 4 commits, 1 branch, 0 releases, and 1 contributor. The latest commit was made by `kmsampson` on GitHub, merging pull request #1 from `NCAR/Version-4`, 4e76199, a minute ago. The commit history shows three files: `GEOGRID_STANDALONE.ProcessGeogridFile.pyt.xml`, `GEOGRID_STANDALONE.pyt`, and `wrf_hydro_functions.py`, all from the v4.0 Initial Release, 2 minutes ago.

File	Version	Time
<code>GEOGRID_STANDALONE.ProcessGeogridFile.pyt.xml</code>	v4.0 Initial Release	2 minutes ago
<code>GEOGRID_STANDALONE.pyt</code>	v4.0 Initial Release	2 minutes ago
<code>wrf_hydro_functions.py</code>	v4.0 Initial Release	2 minutes ago

Catchments and Grid-to-Basin Mapping

Grid-to-basin mapping

fraction of each grid cell in each sub-basin



maps gridded meteorological fields to sub-basins within the model domain

Grid-to-basin mapping

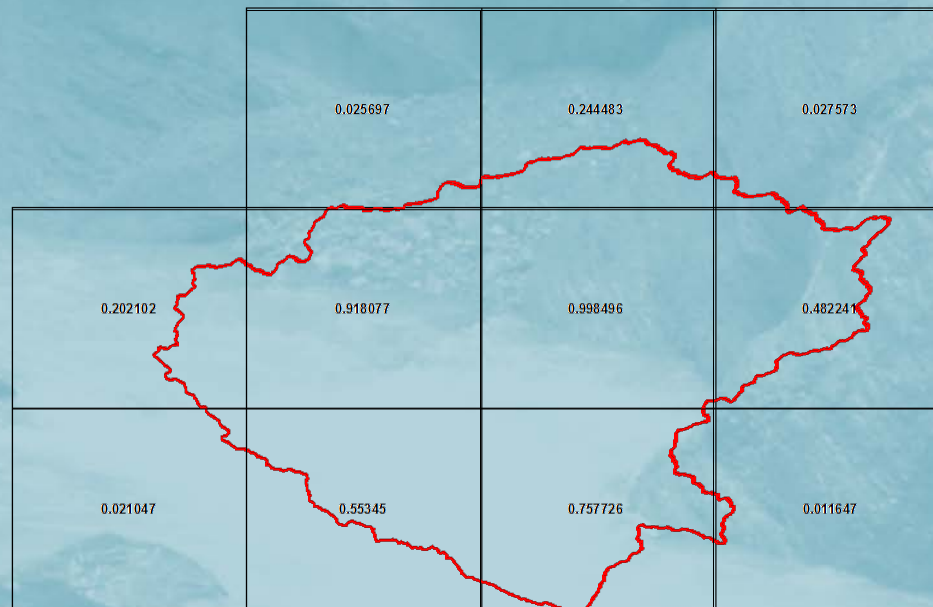
Correspondence between basins and grid must be established

Spatial weights allow conservative remapping of variables between grids and catchments

This method enables the NHD reach-routing scheme by moving overland and subsurface flow into the reach associated with each catchment

Custom, open-source, parallel Python tools for generating the mapping.

Spatial Weight



Intersections:
1km: 21.5M
250m: 172M

Custom Correspondence netCDF

```
Windows PowerShell
netcdf spatialweights_1km_v1_2_all_basins_20170320 {
dimensions:
    polyid = 2677135 ;
    data = 21508911 ;
variables:
    int polyid(polyid) ;
        polyid:long_name = "ID of polygon" ;
    int overlaps(polyid) ;
        overlaps:long_name = "Number of intersecting polygons" ;
    double weight(data) ;
        weight:long_name = "fraction of polygon(polyid) intersected by polygon identified by poly2" ;
    double regridweight(data) ;
        regridweight:long_name = "fraction of intersecting polyid(overlapper) intersected by polygon(polyid)" ;
    int IDmask(data) ;
        IDmask:long_name = "Polygon ID (polyid) associated with each record" ;
    int i_index(data) ;
        i_index:long_name = "Index in the x dimension of the raster grid (starting with 1,1 in LL corner)" ;
    int j_index(data) ;
        j_index:long_name = "Index in the y dimension of the raster grid (starting with 1,1 in LL corner)" ;

// global attributes:
    :history = "Created Wed Dec 23 10:17:36 2015" ;
    :processing_notes = "Correspondence between 2,647,250 NHDPPlus Catchment basins (full resolution) as well
as O-CONUS basins and the CONUS 1km IOC grid." ;
}
```

GIS Pre-processing Demonstration

Thank you

Questions: wrfhydro@ucar.edu