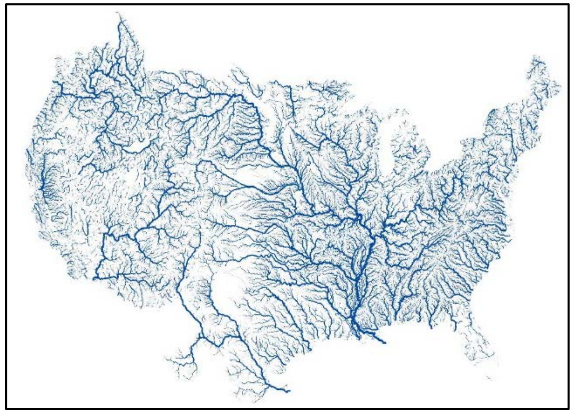
WRF-Hydro GIS Pre-processing Tool Overview



Kevin Sampson

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Outline

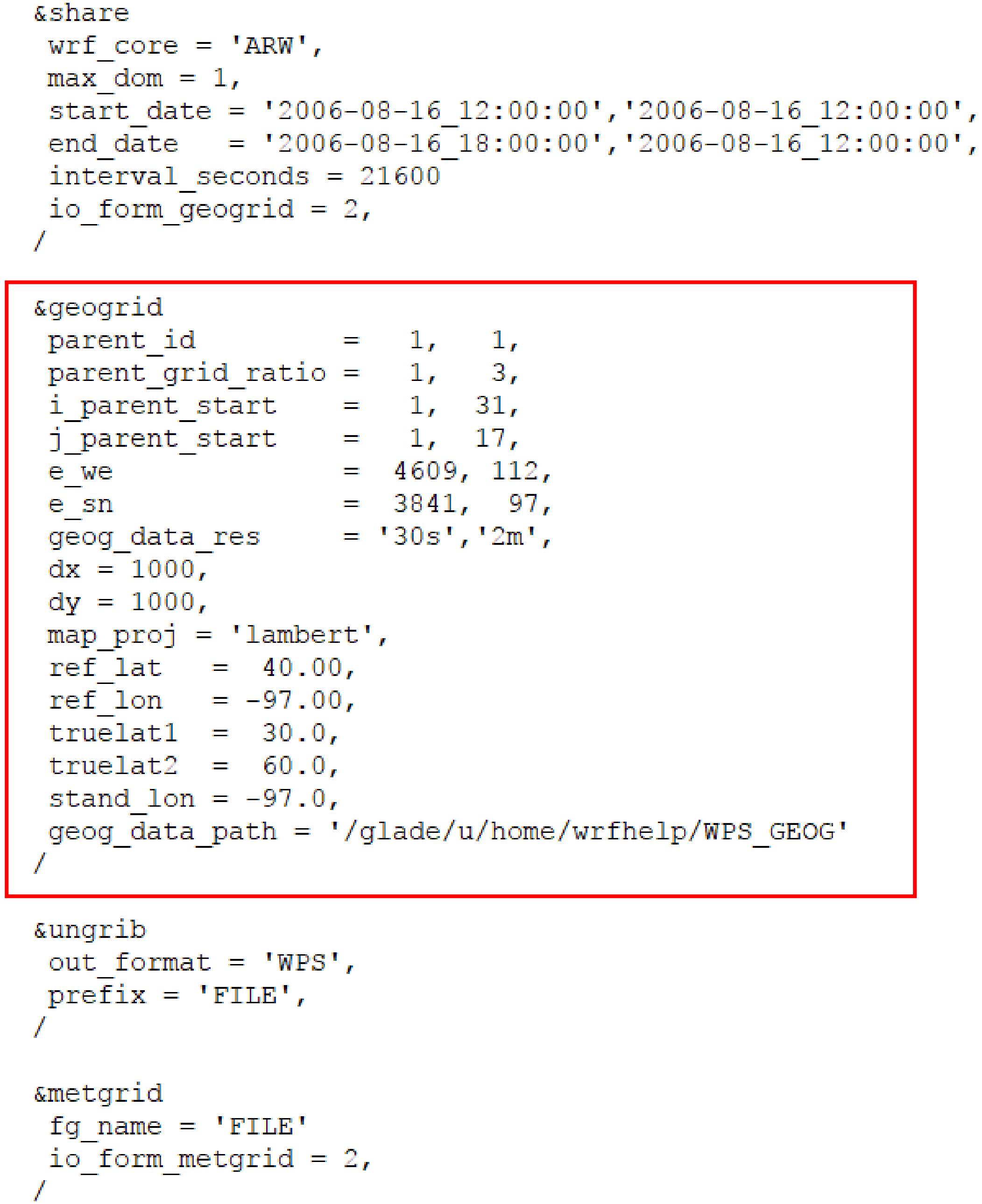
- WRF Pre-processing
- WRF-Hydro ArcGIS Pre-processing tools
- Basic GIS terrain pre-processing for WRF-Hydro
- Demonstration: Generating WRF-Hydro Routing Grids

WRF Pre-Processing System (WPS)

Domain Definition & 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

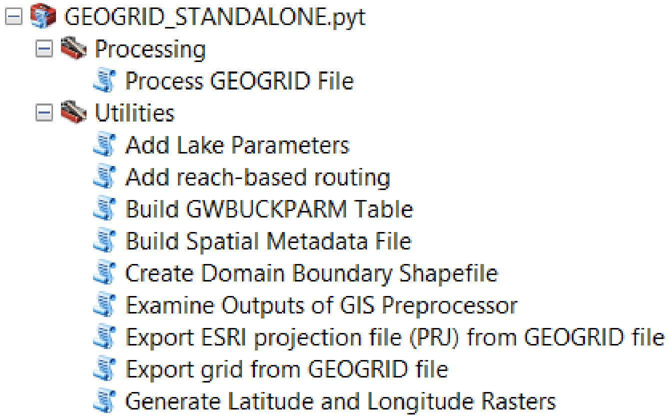


```
&share
 wrf_core = 'ARW',
 max_dom = 1,
 start_date = '2006-08-16_12:00:00','2006-08-16_12:00:00',
 end_date   = '2006-08-16_18:00:00','2006-08-16_12:00:00',
 interval_seconds = 21600
 io_form_geogrid = 2,
/

&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 Toolkit

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



- GEOGRID_STANDALONE.pyt
  - Processing
    - Process GEOGRID File
  - Utilities
    - Add Lake Parameters
    - Add reach-based routing
    - Build GWBUCKPARM Table
    - Build Spatial Metadata File
    - Create Domain Boundary Shapefile
    - Examine Outputs of GIS Preprocessor
    - Export ESRI projection file (PRJ) from GEOGRID file
    - Export grid from GEOGRID file
    - Generate Latitude and Longitude Rasters

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

GitHub 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+
    - has been minimally tested with ArcGIS 10.4, 10.5, and 10.6.
    - 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)

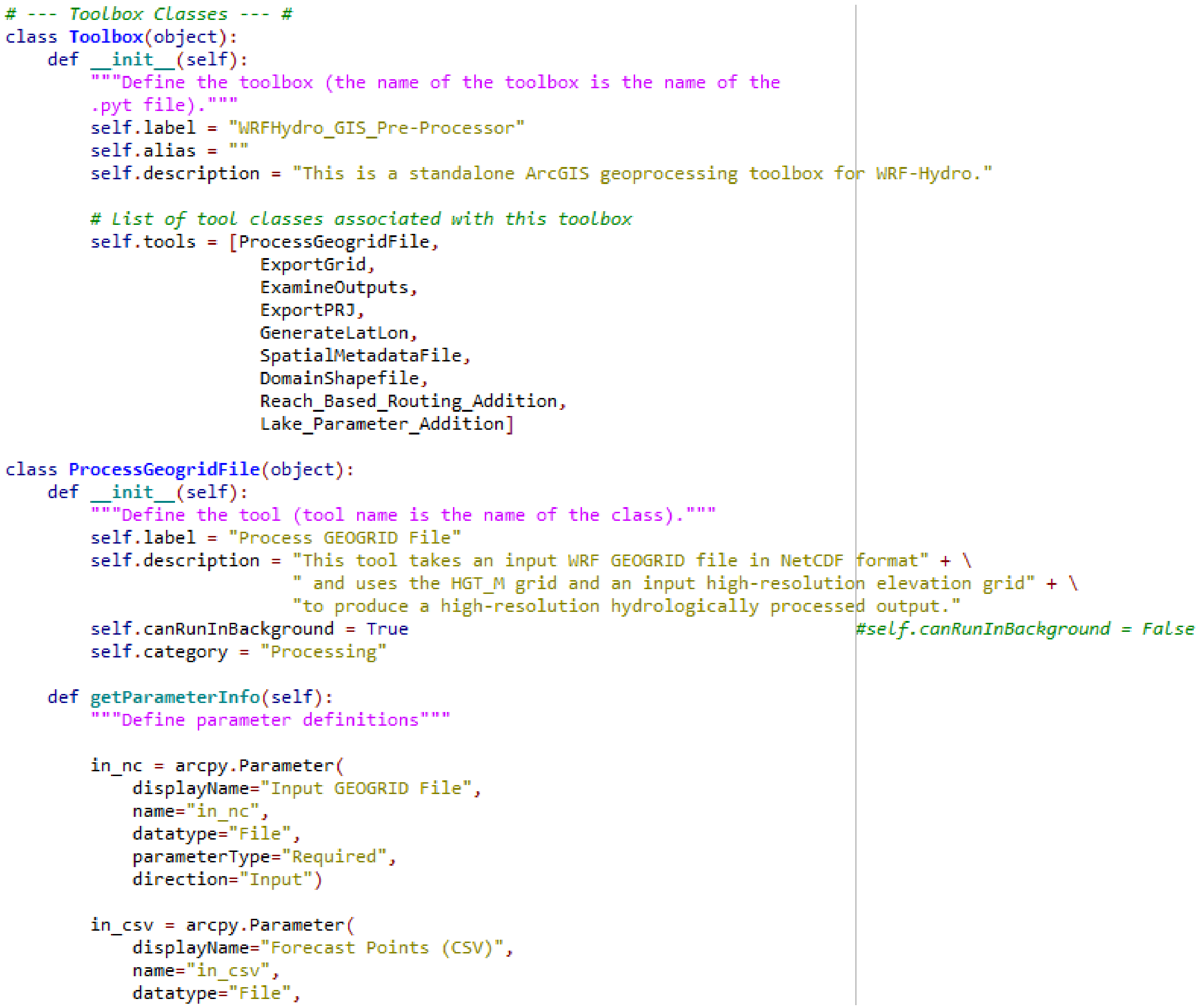
- PYT file is the toolbox script containing multiple toolsets
  - Functions called from separate script (`wrf_hydro_functions.py`)
- Parameter handling and validation

<u>Advantages</u>

Easy to modify
Portable
Many tools organized

Python Toolboxes (.pyt)

- Toolboxes wrapped in Python script…

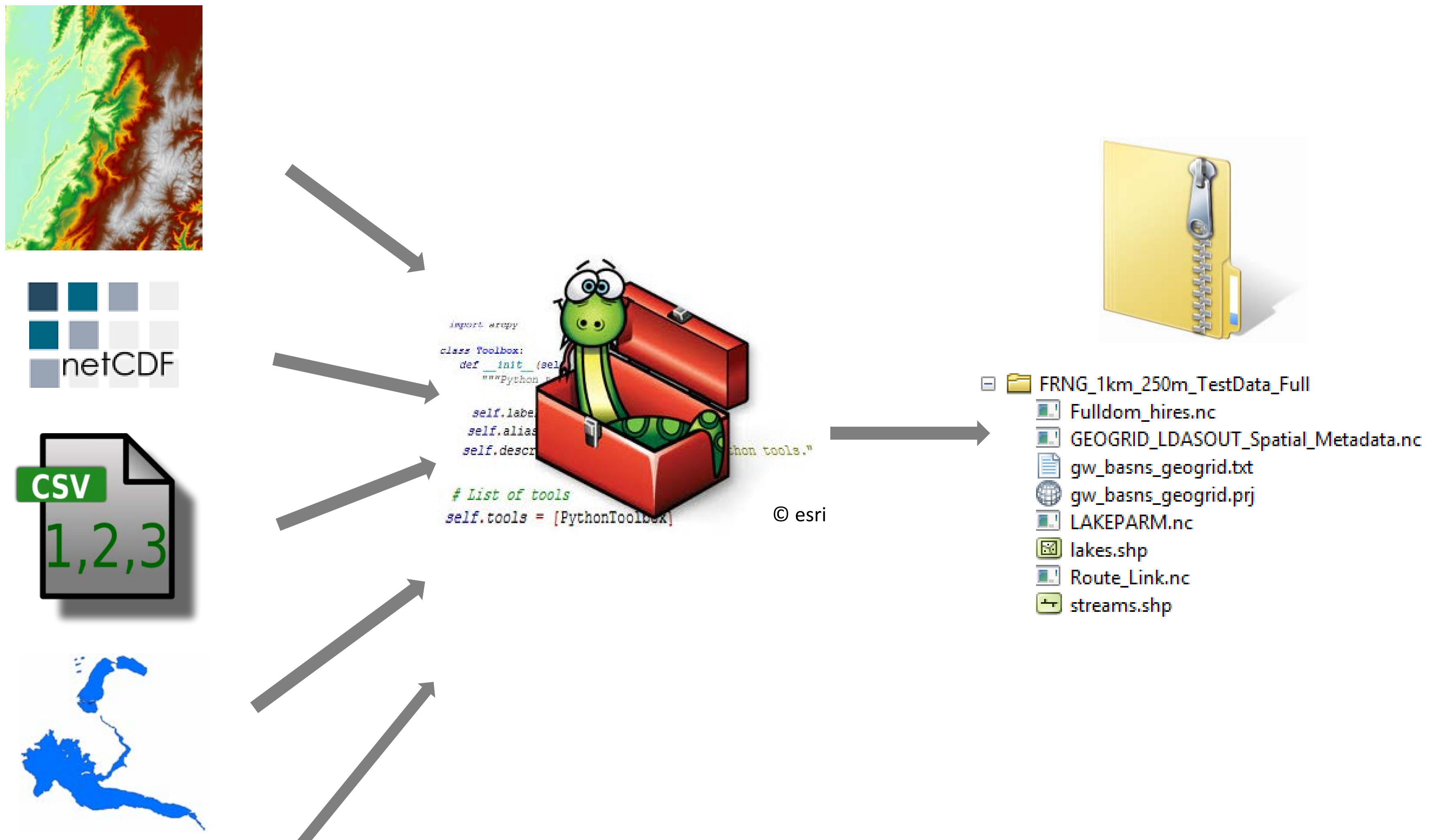


```
# --- Toolbox Classes --- #
class Toolbox(object):
    def __init__(self):
        """Define the toolbox (the name of the toolbox is the name of the
        .pyt file)."""
        self.label = "WRFHydro_GIS_Pre-Processor"
        self.alias = ""
        self.description = "This is a standalone ArcGIS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

Preprocessor

Inputs

Outputs

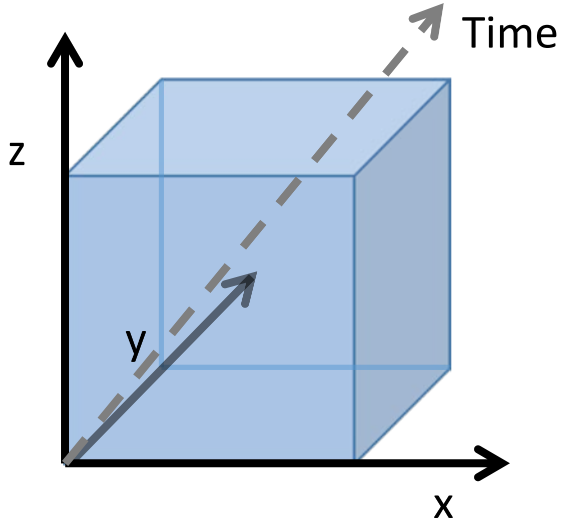


FRNG_1km_250m_TestData_Full
- Fulldom_hires.nc
- GEOGRID_LDASOUT_Spatial_Metadata.nc
- gw_basns_geogrid.txt
- gw_basns_geogrid.prj
- LAKEPARM.nc
- lakes.shp
- Route_Link.nc
- streams.shp

Other parameters

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



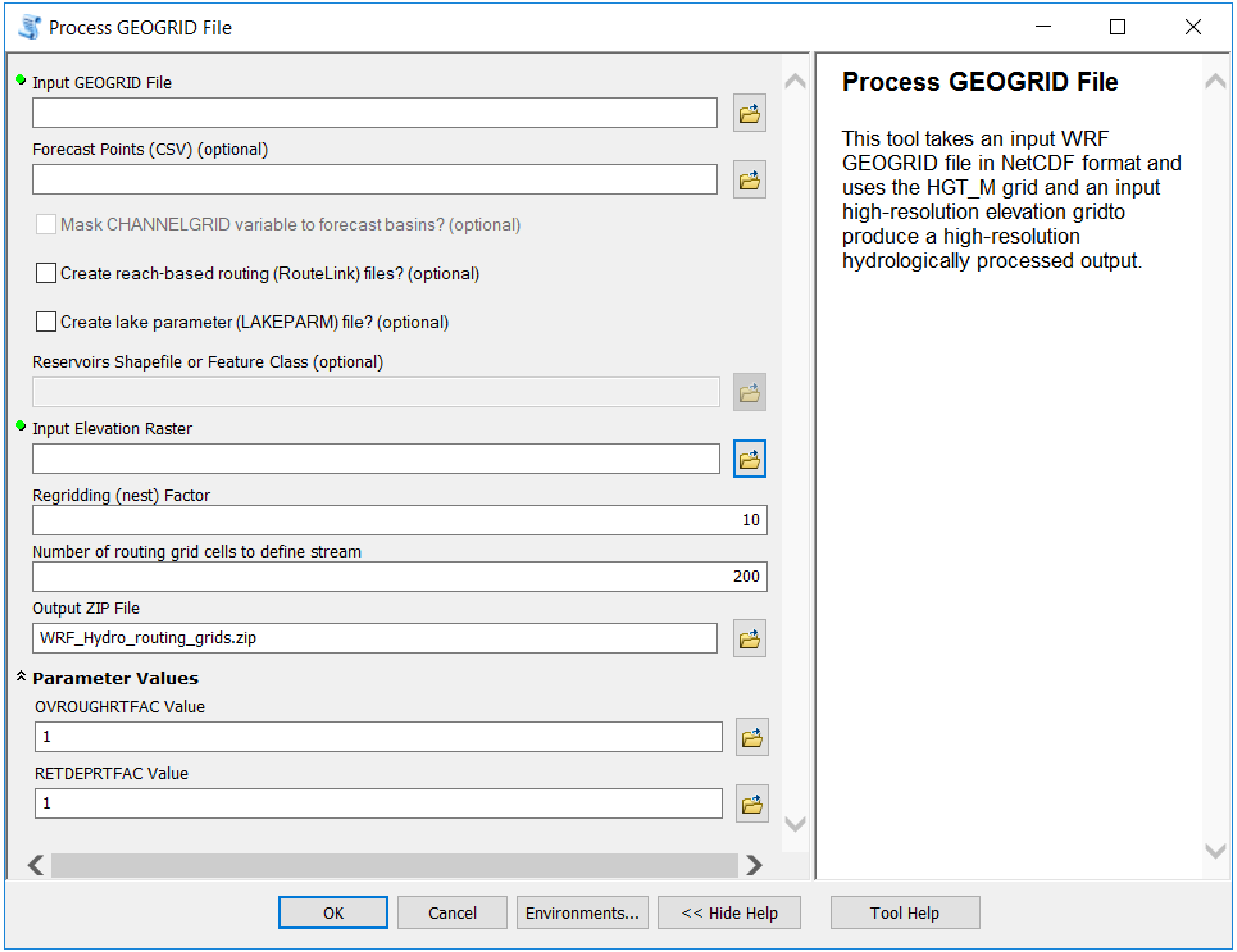
Fulldom File (Routing Grids)

- 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: 10

Number of routing grid cells to define stream: 200

Output ZIP File: WRF_Hydro_routing_grids.zip

Parameter Values

OVROUGHRTFAC Value: 1

RETDEPRTFAC Value: 1

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 gridto produce a high-resolution hydrologically processed output.

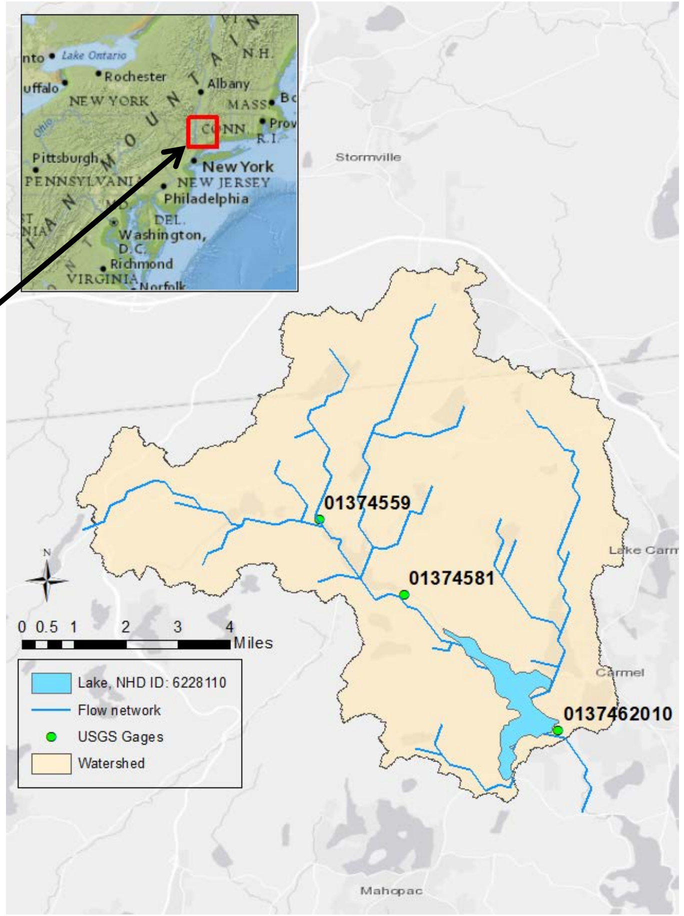
Inputs

- 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)
  - OVROUGHRTFAC – 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



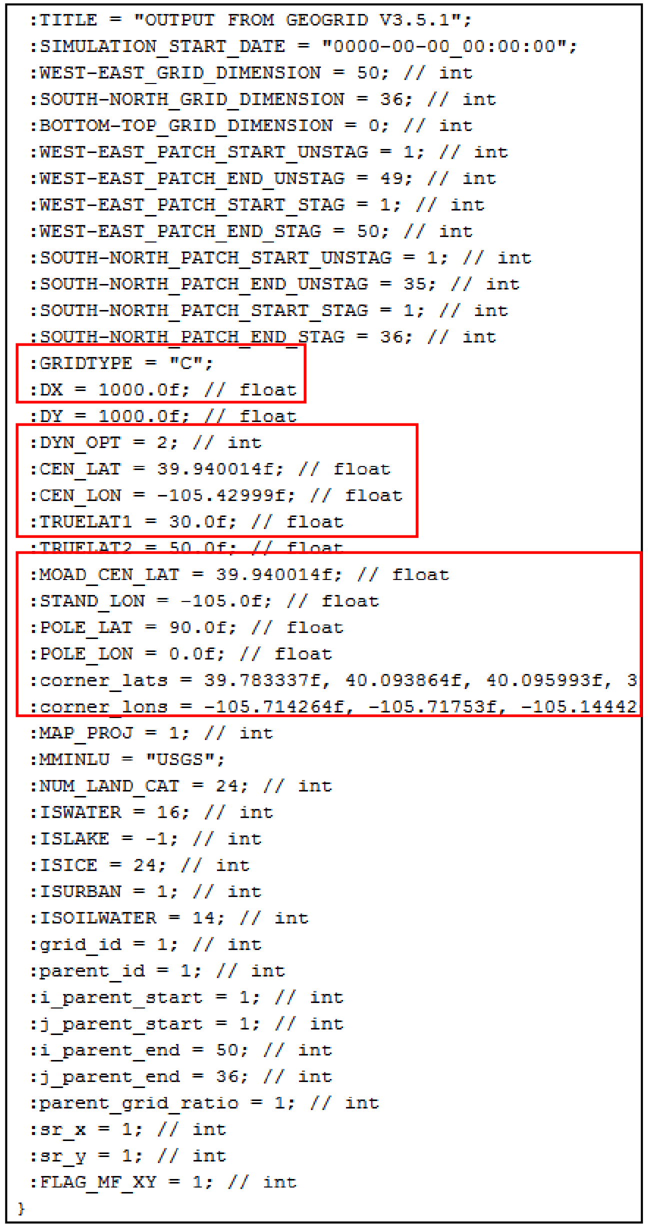
Input: WRF Geogrid File

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)

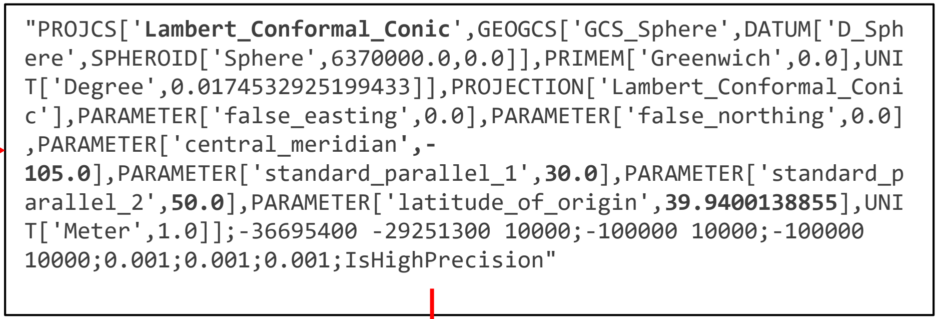
GEOGRID: Projected Coordinate System

Front_Range_geo_em.d02.nc



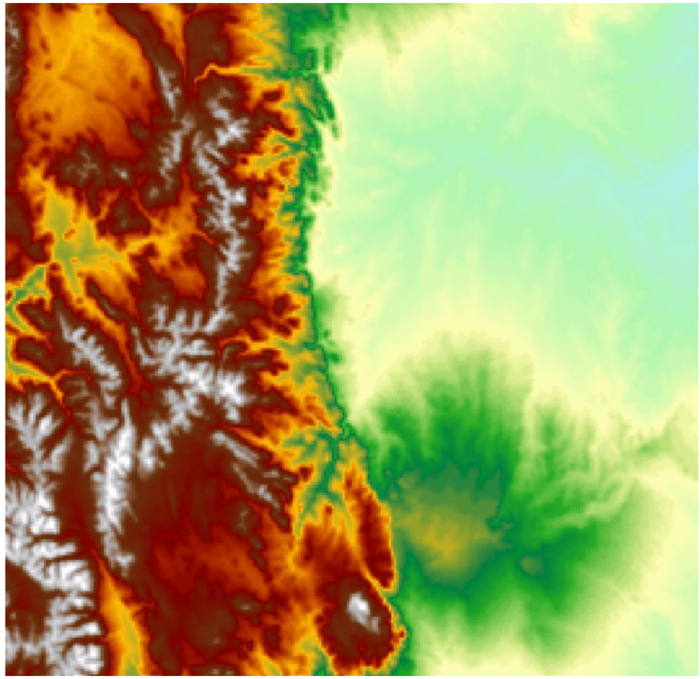
```
:TITLE = "OUTPUT FROM GEOGRID V3.5.1";
:SIMULATION_START_DATE = "0000-00-00_00:00:00";
:WEST-EAST_GRID_DIMENSION = 50; // int
:SOUTH-NORTH_GRID_DIMENSION = 36; // int
:BOTTOM-TOP_GRID_DIMENSION = 0; // int
:WEST-EAST_PATCH_START_UNSTAG = 1; // int
:WEST-EAST_PATCH_END_UNSTAG = 49; // int
:WEST-EAST_PATCH_START_STAG = 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"
```

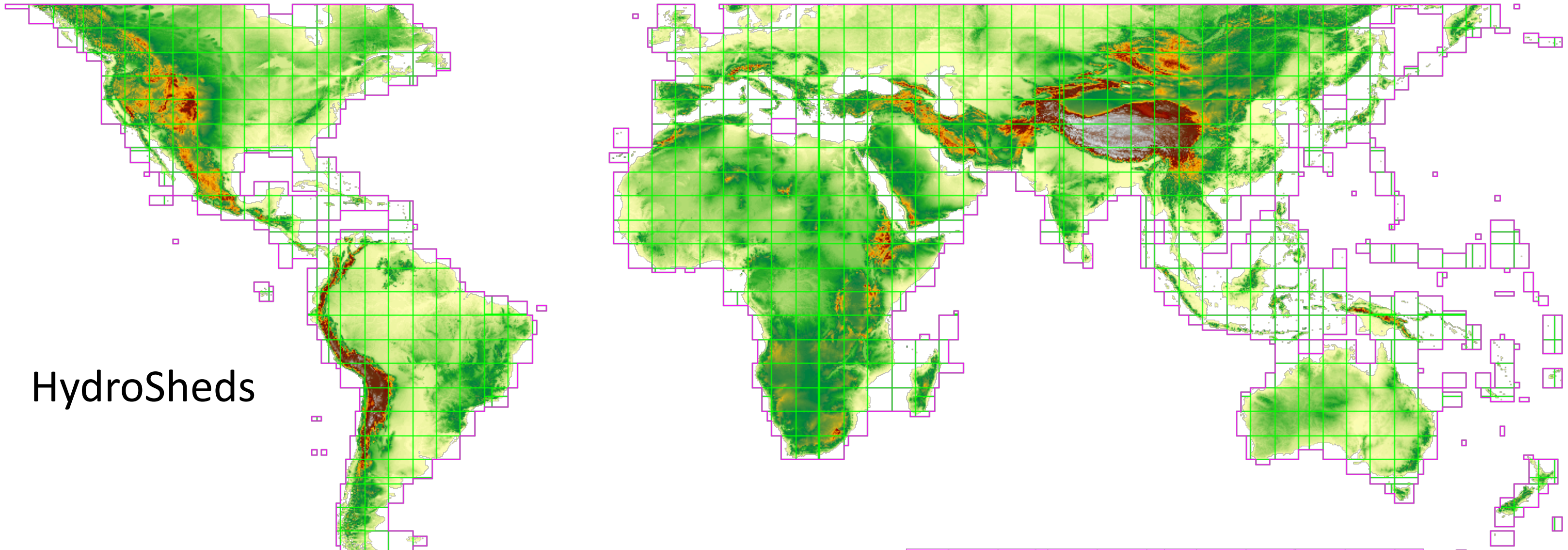
geo_em.d01.boulder_creek_1km.prj



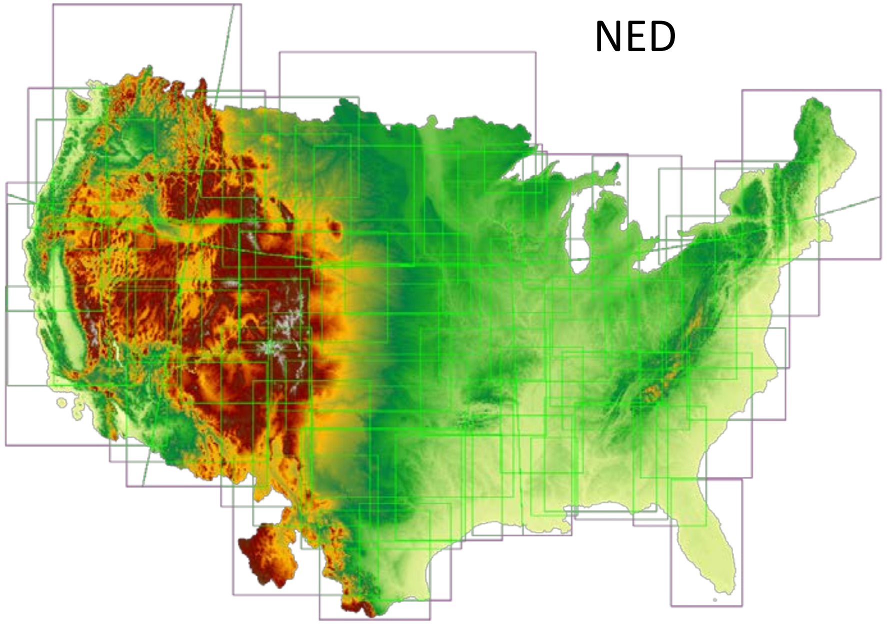
Input Eleveation Raster

- 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 by hydrologically corrected
    - Not necessary but helps with channel placement, hydro enforcement, etc.

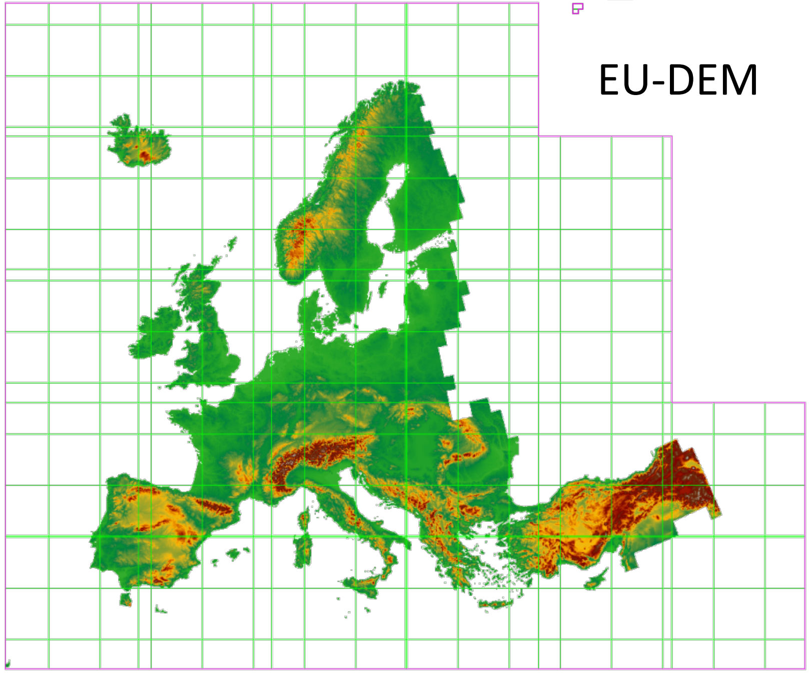
Input Elevation Mosaics



HydroSheds



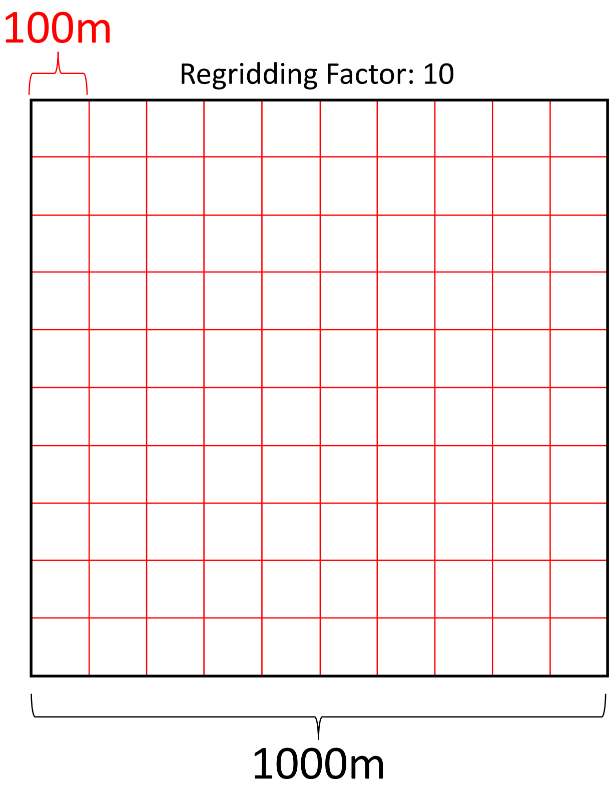
NED



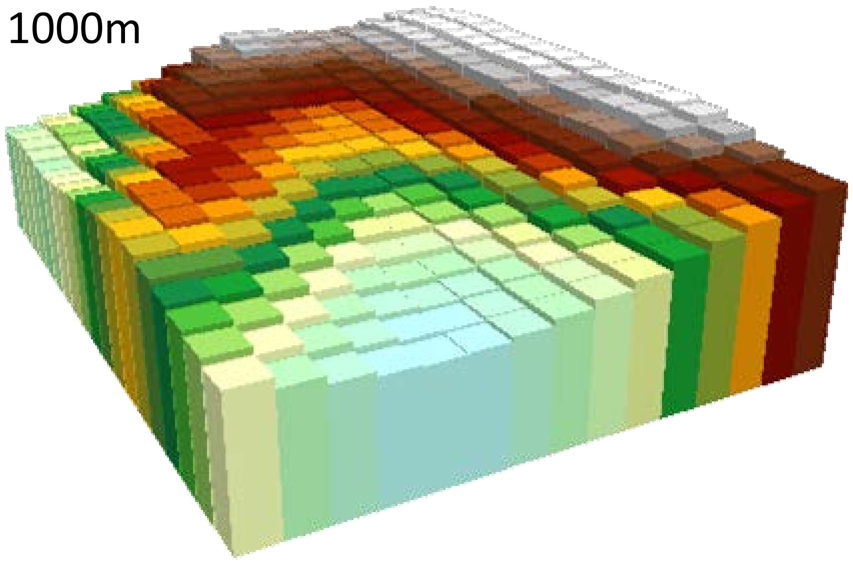
EU-DEM

Input Regriddng Factor

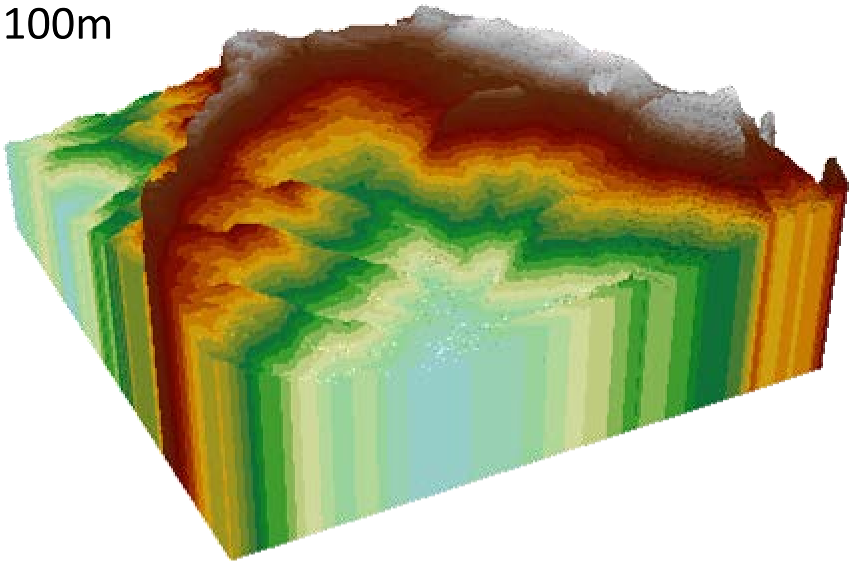
$$\frac{\text{GEOGRID Resolution}}{\text{Regridding Factor}} = \text{Routing Resolution}$$



1000m

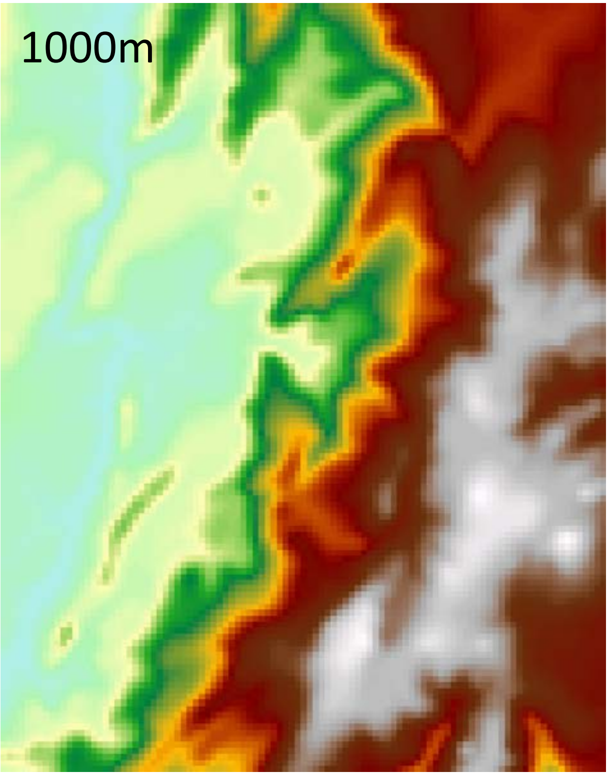


100m

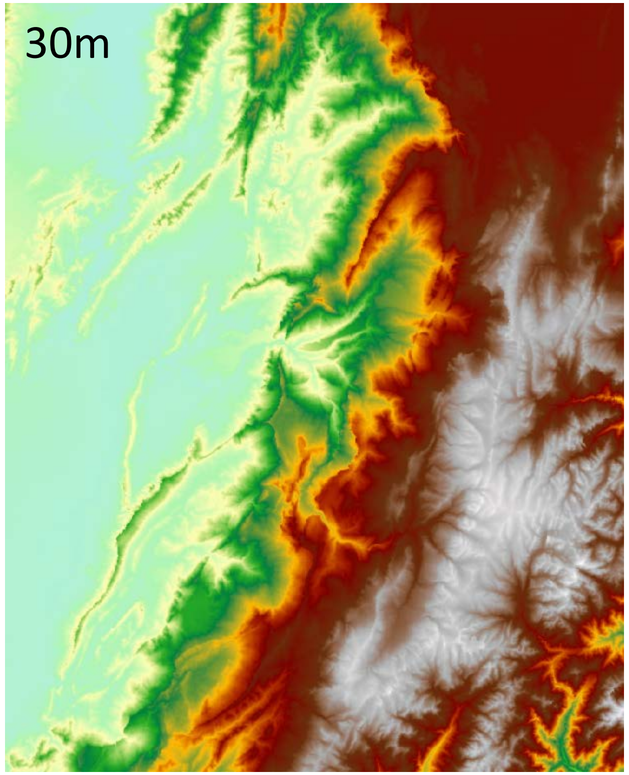


Raster Resolution for Terrain Processing

Model Resolution

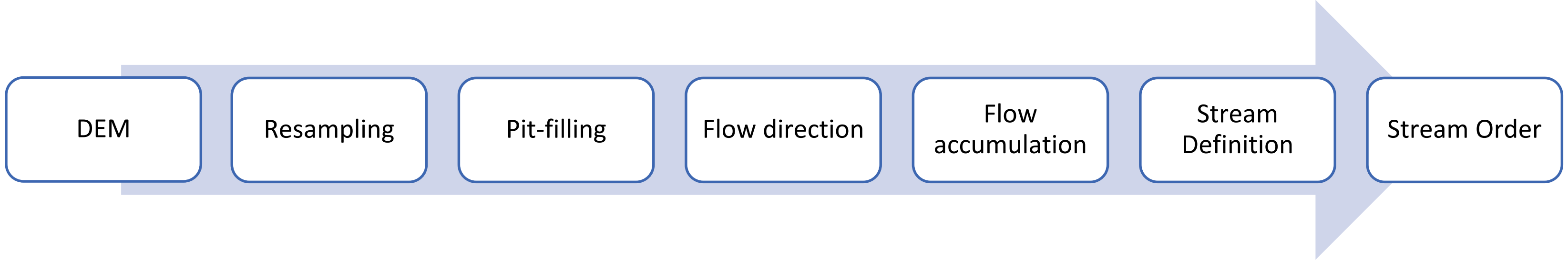


High Resolution



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



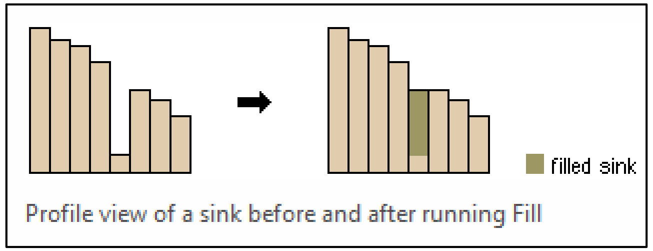
Basic workflow for terrain pre-processing of WRF-Hydro routing grids.

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 centes.
- 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.

Process: Pit Filling

Spatial Analyst “Fill“ Tool



Profile view of a sink before and after running Fill

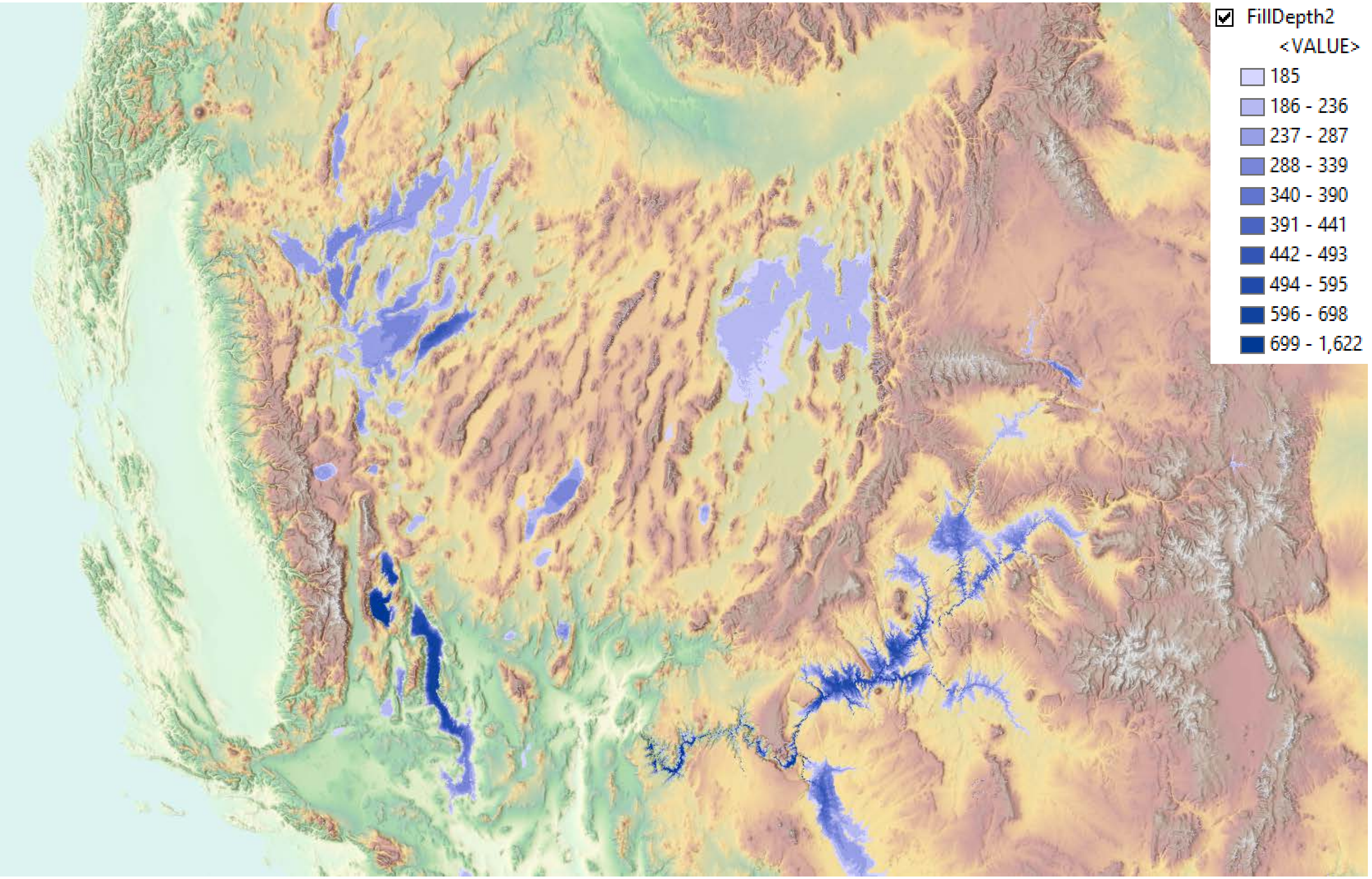
© Esri: http://desktop.arcgis.com/en/arcmap/latest/tools/spatial-analyst-toolbox/how-fill-works.htm

- 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.

Methods: Tarboton et al (1991)

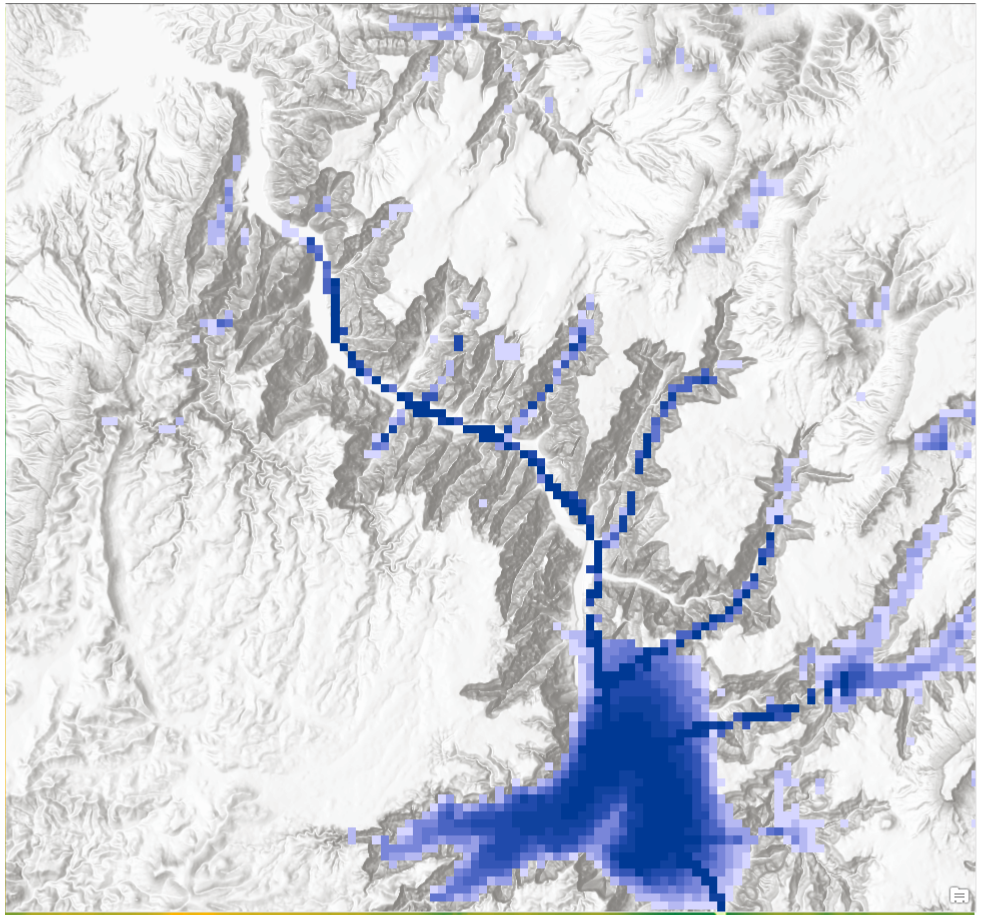
Pit Filling Issues

- …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.

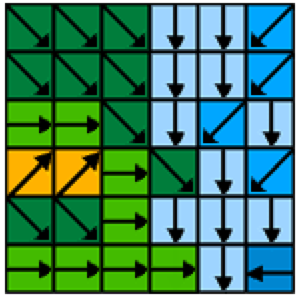


Flow Direction & Flow Accumulation

- D8 Flow Direction

32	64	128
16		1
8	4	2

- Flow Accumulation

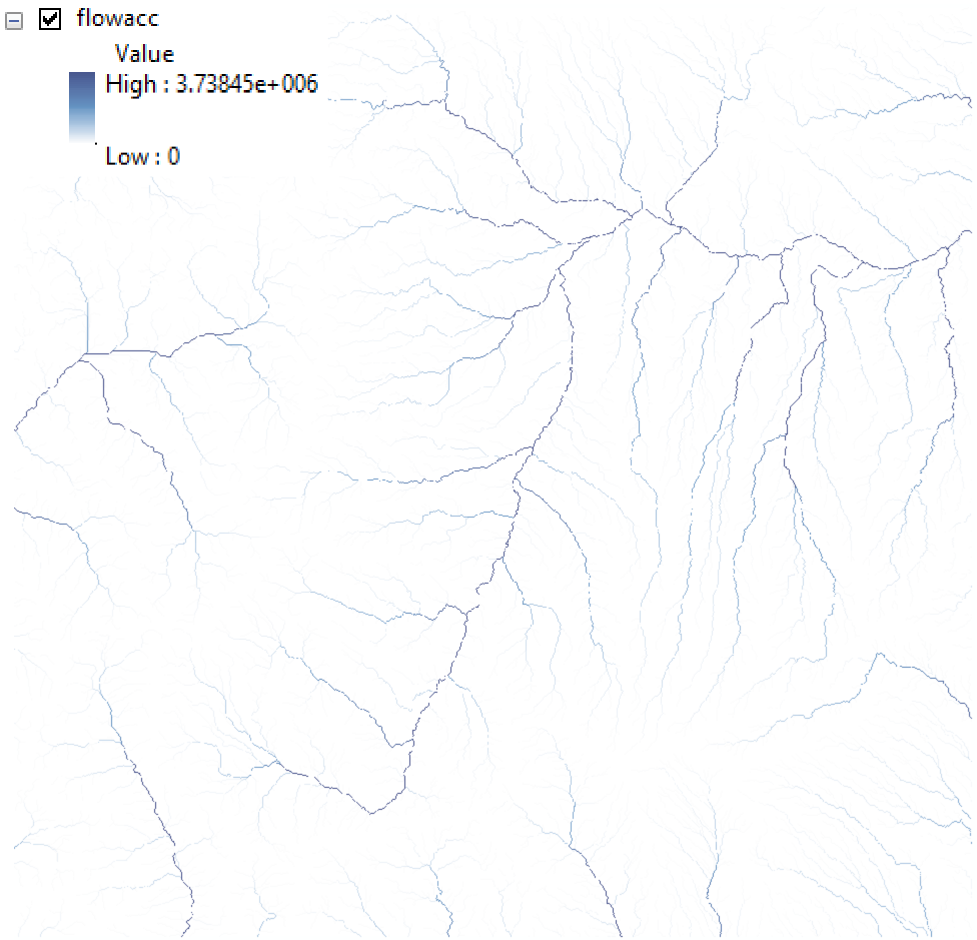


Flow direction

0	0	0	0	0	0
0	1	1	2	2	0
0	3	7	5	4	0
0	0	0	20	0	1
0	0	0	1	24	0
0	2	4	7	35	1

Flow accumulation

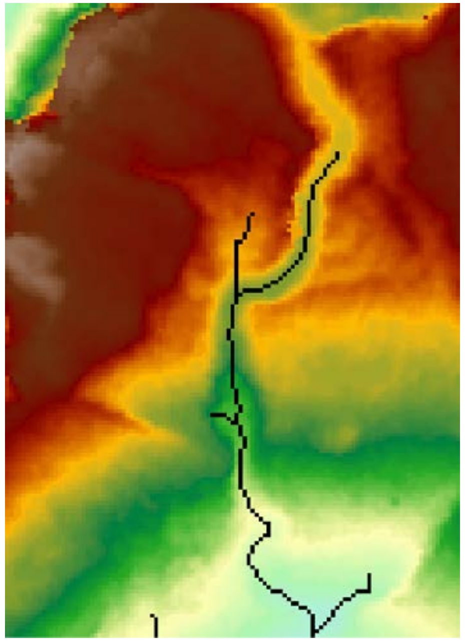
© Esri: http://desktop.arcgis.com/en/arcmap/latest/tools/spatial-analyst-toolbox/how-flow-accumulation-works.htm



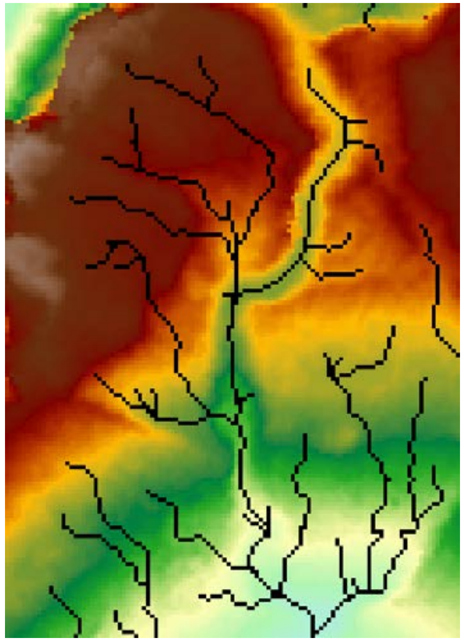
Methods: Jenson and Domingue (1988)

Stream Definition

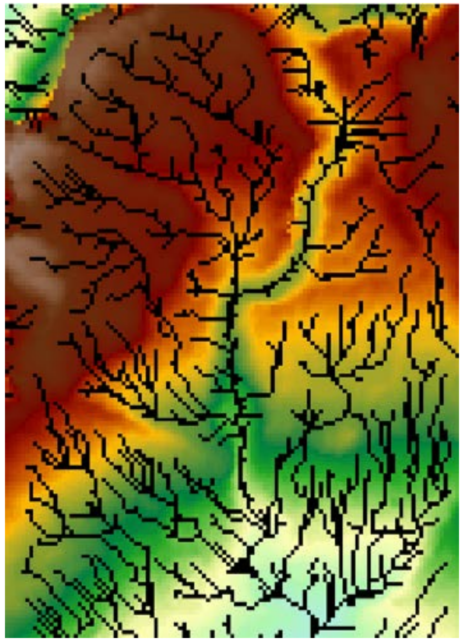
- Input Parameter: Number of pixels to define stream
  - Yields a minimum ‘basin’ size
  - Given in pixels (unitless), on the routing grid
  - Affects density of generated channel network



$1km^2$



$0.1km^2$

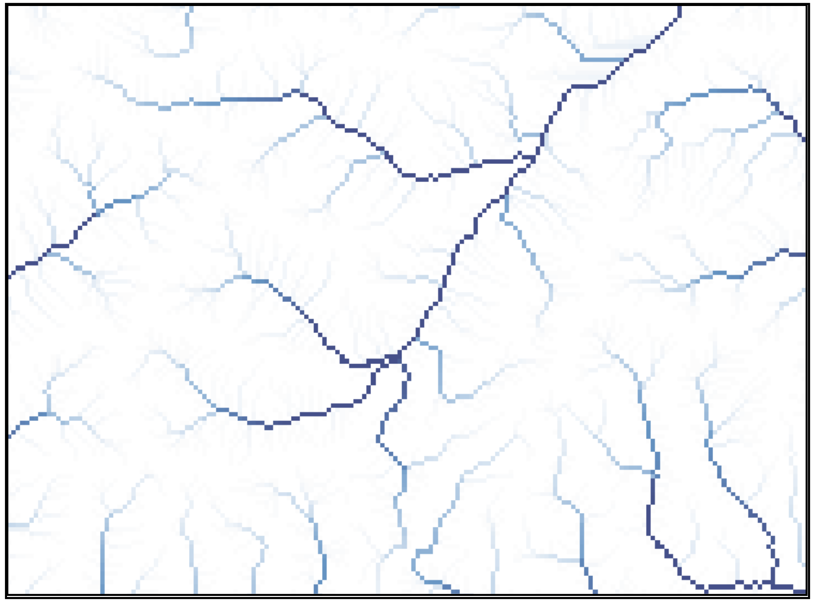


$0.01km^2$

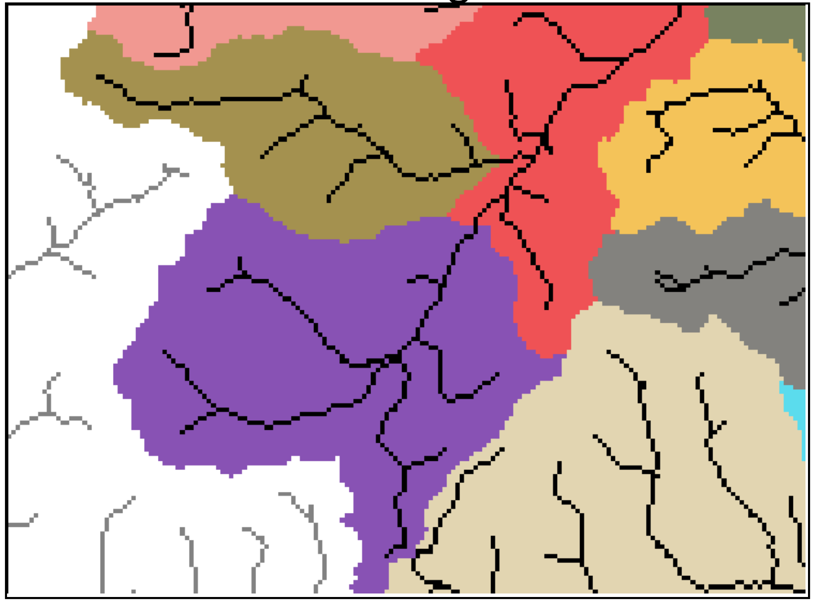
An analytic method for determining an appropriate threshold value for stream network delineation is presented in Tarboton et al. (1991)

Stream Definition

Flow Accumulation

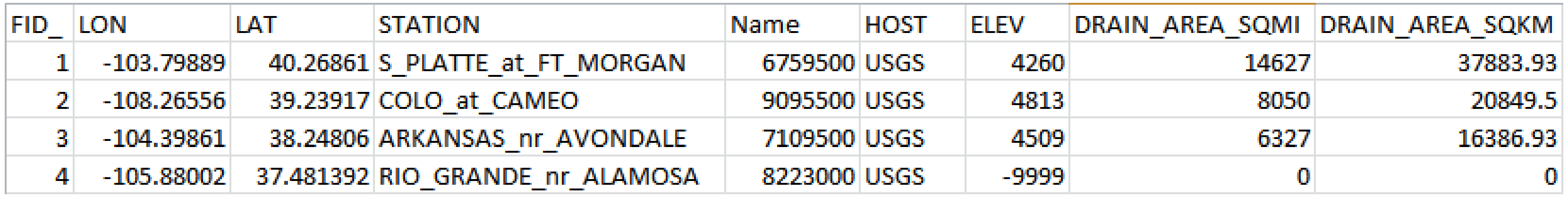


Channelgrid



- 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, Notepad, 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

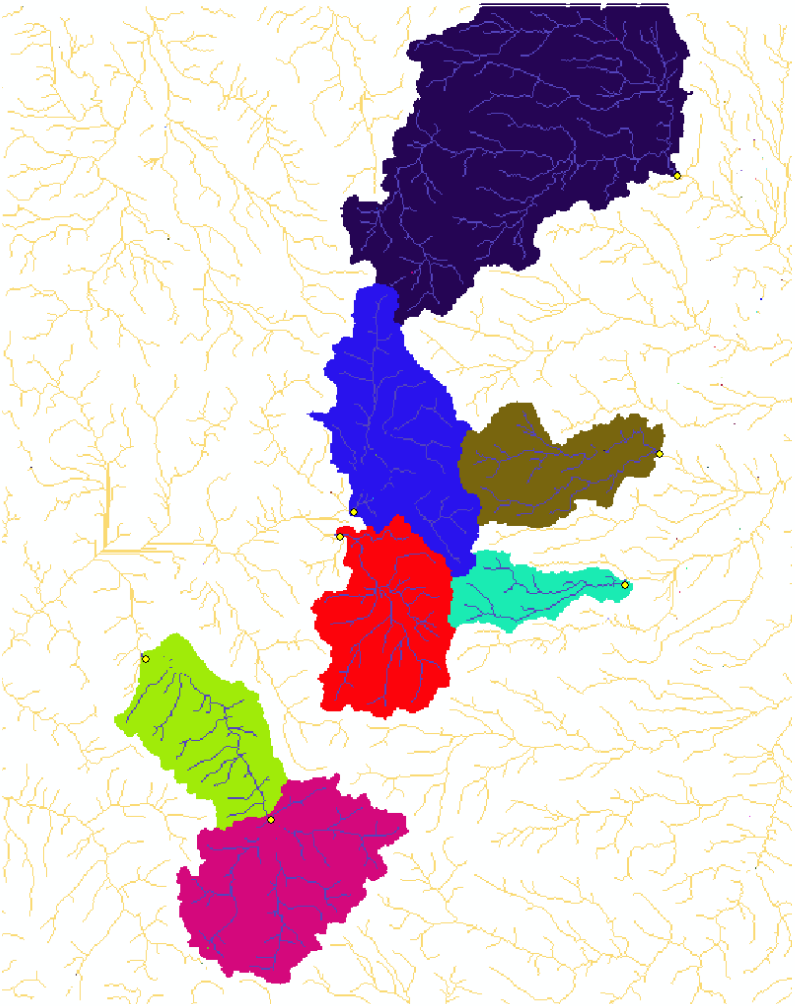
- Snap points to streams
- ‘Walk’ down channel network a specified distance
  - Default = 3 pixel widths (global variable)
- Delineate basin using **Watershed** Spatial Analyst tool

- Writes output file to:

```
frxst_pts
basn_msk
```

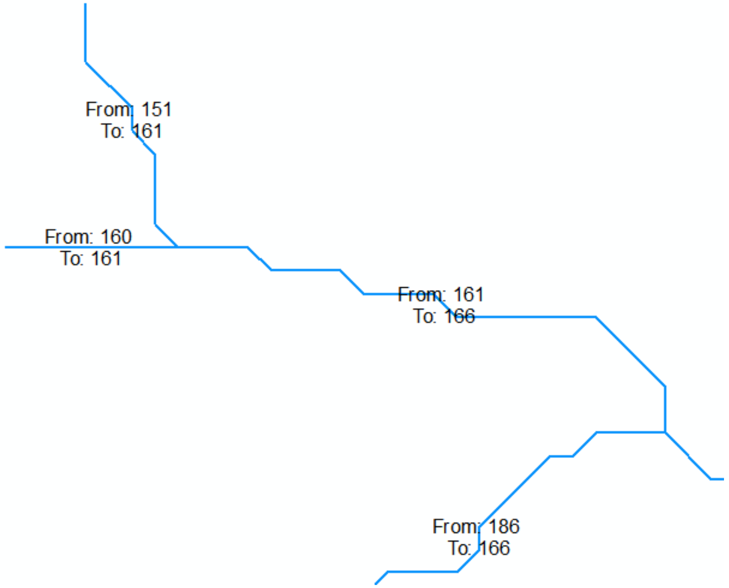
Basin Masking

- 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



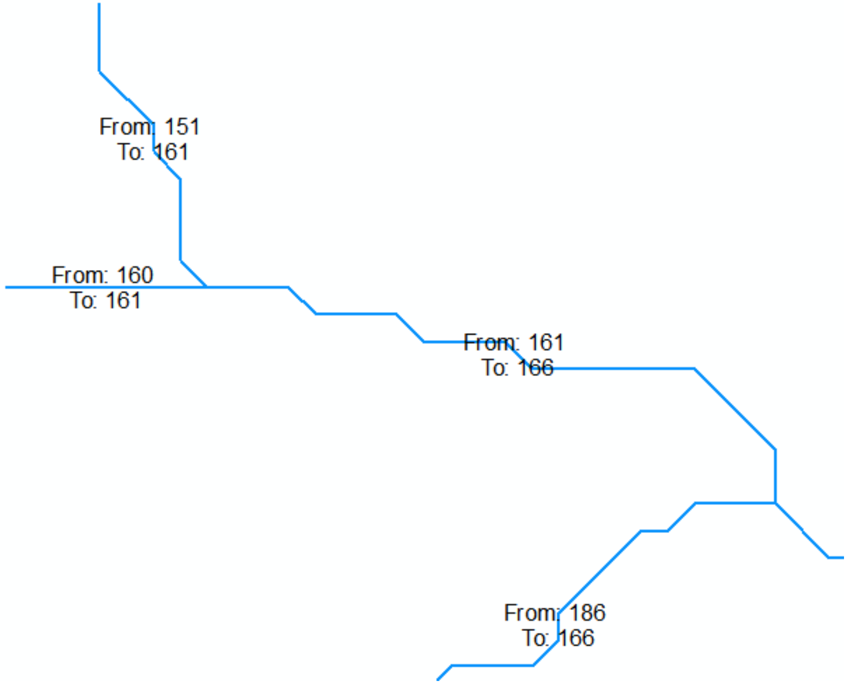
Reach-Based Routing Background

- 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



Process: Reach-Based Routing

- CHANNELGRID raster is converted to a line vector (`streams.shp`)
- Decomposes line geometry to nodes, and gathers elevation, Latitude, and Longitude at each node
- LINKID grid in Fulldom file is created and populated with link ID values
- Constructs a .nc file with necessary parameters for reach-based routing:
  - Length, Slope, Order, Drop, X/Y, etc.
  - Writes output file to `Route_Link.nc`



Reach-Routing Table

- CF-netCDF file containing reach-routing parameters
- Mix of derived attributes and default values

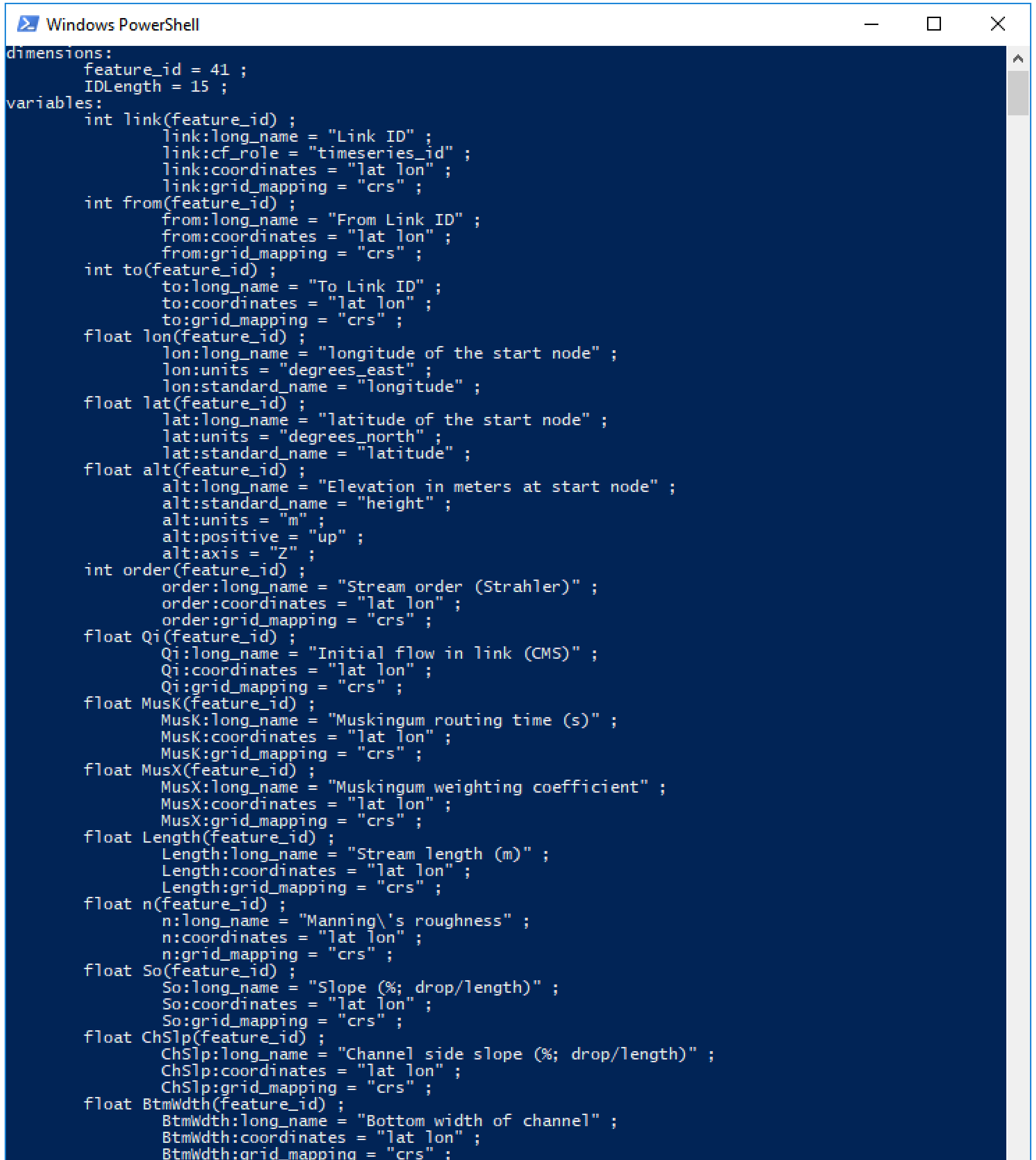
Parameter	Description
link	Link ID
from	From Link ID
to	To Link ID
lon	longitude of the start node
lat	latitude of the start node
alt	Elevation in meters from DEM at start node
order	Stream order (Strahler)
Qi	Initial flow in link (CMS)
MusK	Muskingum routing time (s)
MusX	Muskingum weighting coefficient
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

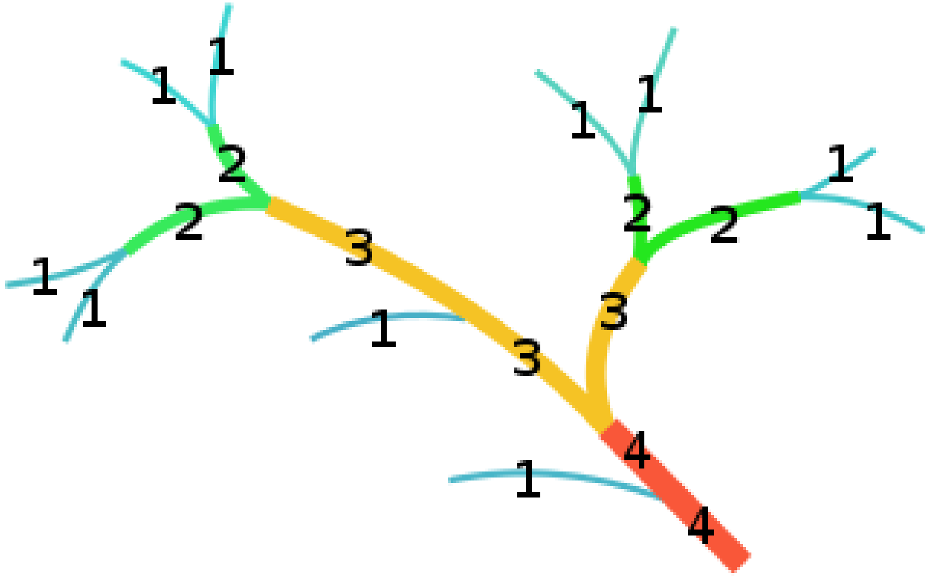
Qi:	0 cms
MusK:	3600 s
MusX:	0.2
n:	0.035
ChSlp:	0.05
BtmWdth:	5 m
Kc:	0 mm/hr



```
dimensions:
        feature_id = 41 ;
        IDLength = 15 ;
variables:
        int link(feature_id) ;
                link:long_name = "Link ID" ;
                link:cf_role = "timeseries_id" ;
                link:coordinates = "lat lon" ;
                link:grid_mapping = "crs" ;
        int from(feature_id) ;
                from:long_name = "From Link ID" ;
                from:coordinates = "lat lon" ;
                from:grid_mapping = "crs" ;
        int to(feature_id) ;
                to:long_name = "To Link ID" ;
                to:coordinates = "lat lon" ;
                to:grid_mapping = "crs" ;
        float lon(feature_id) ;
                lon:long_name = "longitude of the start node" ;
                lon:units = "degrees_east" ;
                lon:standard_name = "longitude" ;
        float lat(feature_id) ;
                lat:long_name = "latitude of the start node" ;
                lat:units = "degrees_north" ;
                lat:standard_name = "latitude" ;
        float alt(feature_id) ;
                alt:long_name = "Elevation in meters at start node" ;
                alt:standard_name = "height" ;
                alt:units = "m" ;
                alt:positive = "up" ;
                alt:axis = "Z" ;
        int order(feature_id) ;
                order:long_name = "Stream order (Strahler)" ;
                order:coordinates = "lat lon" ;
                order:grid_mapping = "crs" ;
        float Qi(feature_id) ;
                Qi:long_name = "Initial flow in link (CMS)" ;
                Qi:coordinates = "lat lon" ;
                Qi:grid_mapping = "crs" ;
        float MusK(feature_id) ;
                MusK:long_name = "Muskingum routing time (s)" ;
                MusK:coordinates = "lat lon" ;
                MusK:grid_mapping = "crs" ;
        float MusX(feature_id) ;
                MusX:long_name = "Muskingum weighting coefficient" ;
                MusX:coordinates = "lat lon" ;
                MusX:grid_mapping = "crs" ;
        float Length(feature_id) ;
                Length:long_name = "Stream length (m)" ;
                Length:coordinates = "lat lon" ;
                Length:grid_mapping = "crs" ;
        float n(feature_id) ;
                n:long_name = "Manning\'s roughness" ;
                n:coordinates = "lat lon" ;
                n:grid_mapping = "crs" ;
        float So(feature_id) ;
                So:long_name = "Slope (%; drop/length)" ;
                So:coordinates = "lat lon" ;
                So:grid_mapping = "crs" ;
        float ChSlp(feature_id) ;
                ChSlp:long_name = "Channel side slope (%; drop/length)" ;
                ChSlp:coordinates = "lat lon" ;
                ChSlp:grid_mapping = "crs" ;
        float BtmWdth(feature_id) ;
                BtmWdth:long_name = "Bottom width of channel" ;
                BtmWdth:coordinates = "lat lon" ;
                BtmWdth:grid_mapping = "crs" ;
```

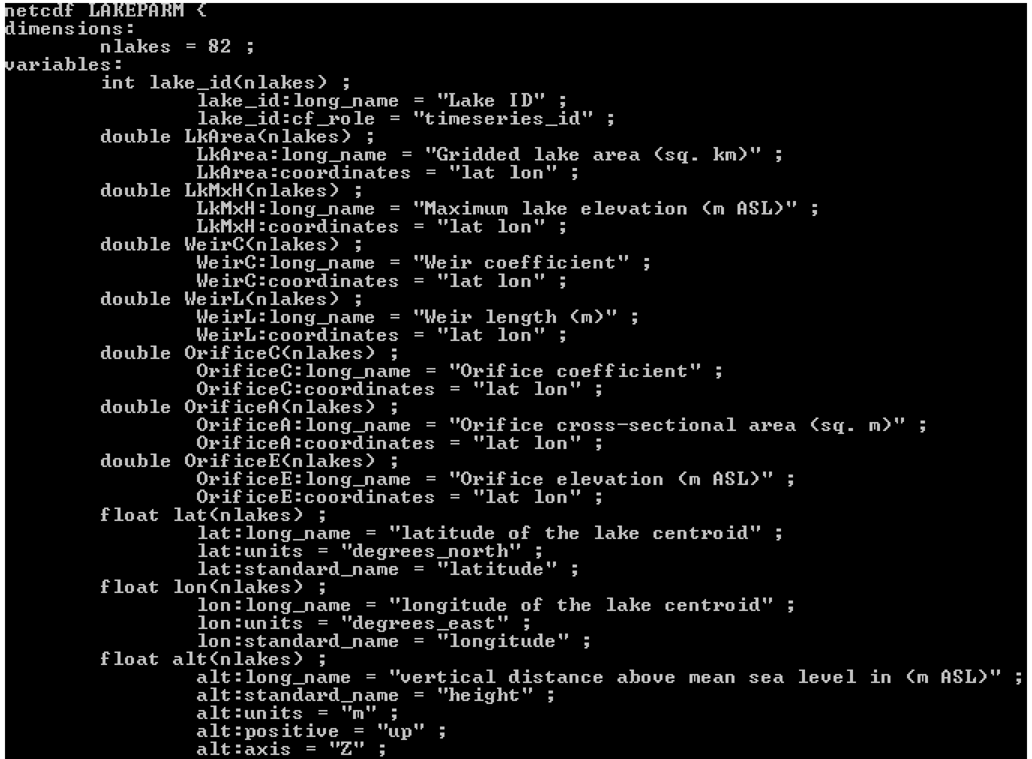
Process: Stream Order

- **Stream Order** Spatial Analyst tool
  - Strahler stream order
  - Writes output file to STREAMORDER variable



Process: Reservoir Routing

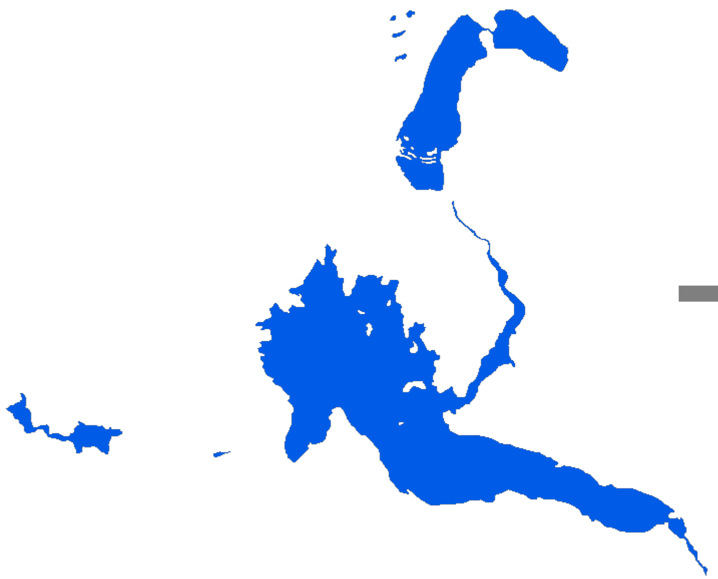
- If the option is selected, a polygon shapefile or feature class is required as input.
- Populates LAKEGRID variable
- Assigns lake ID values to pixels where lakes drain into channel
- Constructs a LAKEPARM.nc file with necessary variables for reach-based routing:
    - Lake area, max elevation, min elevation, base elevation, orifice elevation



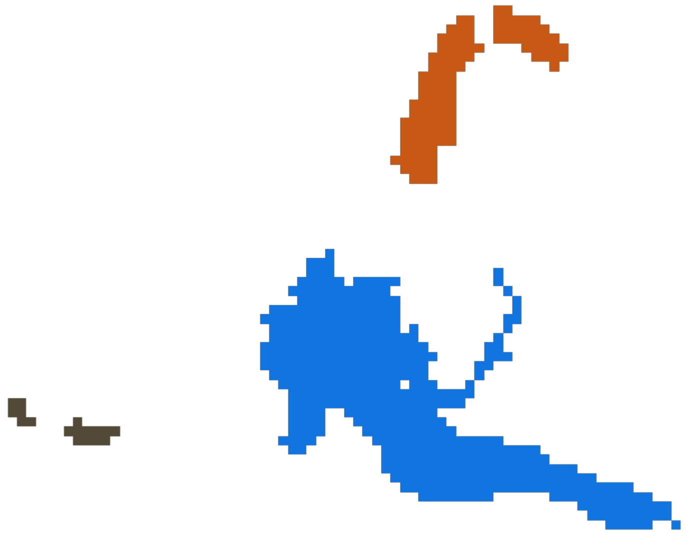
```
netcdf LAKEPARM {
dimensions:
        nlakes = 82 ;
variables:
        int lake_id(nlakes) ;
                lake_id:long_name = "Lake ID" ;
                lake_id:cf_role = "timeseries_id" ;
        double LkArea(nlakes) ;
                LkArea:long_name = "Gridded lake area (sq. km)" ;
                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" ;
                alt:axis = "Z" ;
```

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

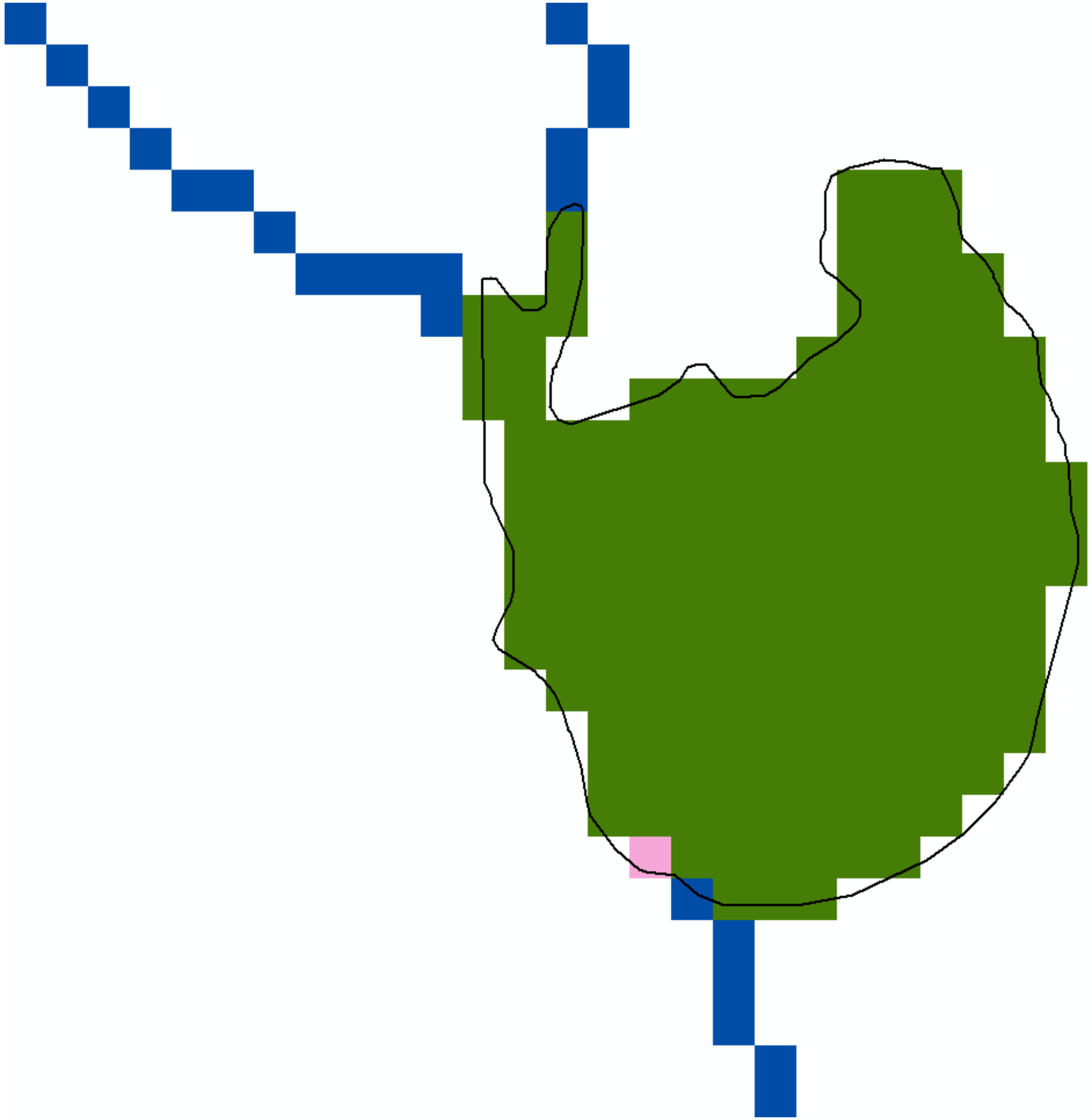


Original polygons



Lakes on the routing grid

Reservoirs & Channels



Lakes/Reservoir Routing in the NWM

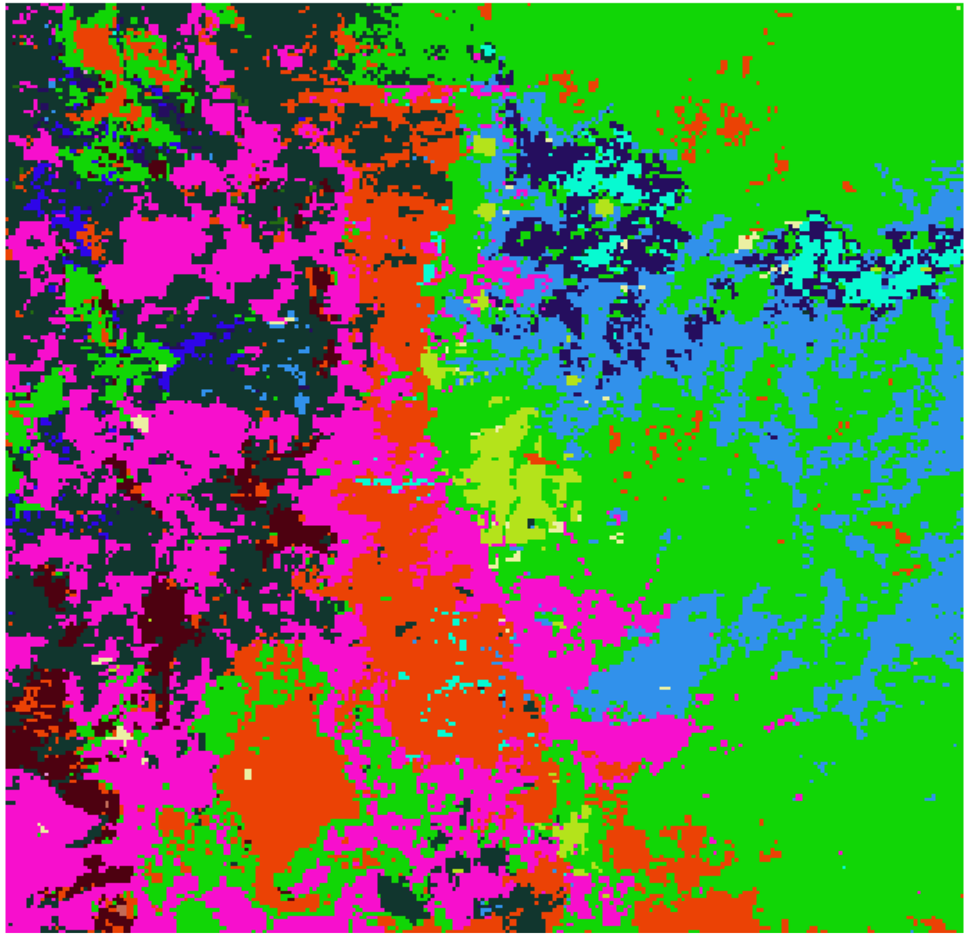
- Lake parameters are stored in the LAKEPARM.nc lake routing table
- Lakes are defined on the routing grid, parameters in the table

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)
Ifd	Initial fractional water depth (% full)
lake_id	Lake ID
lat	latitude of the lake centroid
lon	longitude of the lake centroid

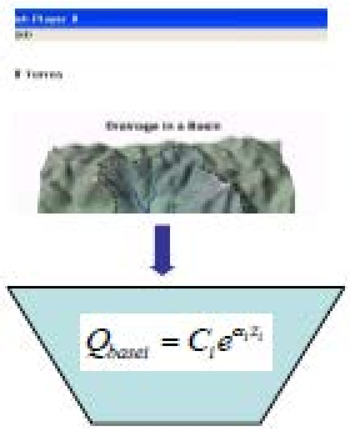
Other Grids

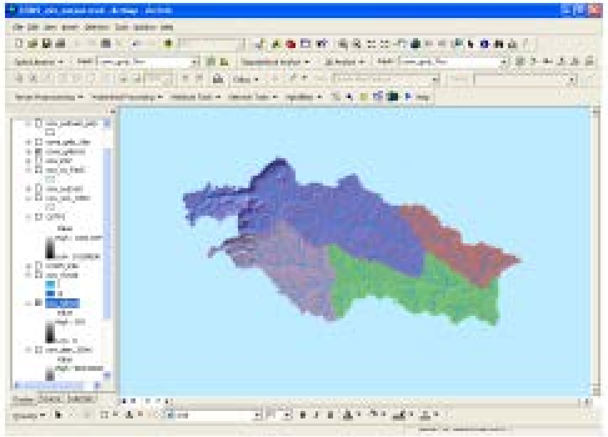
- Landuse
  - GEOGRID LU_INDEX resampled (nearest neighbor) to routing grid
- OVROUGHRTFAC
  - Constant 1.0 (float32)
- RETDEPRTFAC
  - Constant 1.0 (float32)
- LKSATFAC
  - Constant 1000.0 (float32)



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
```

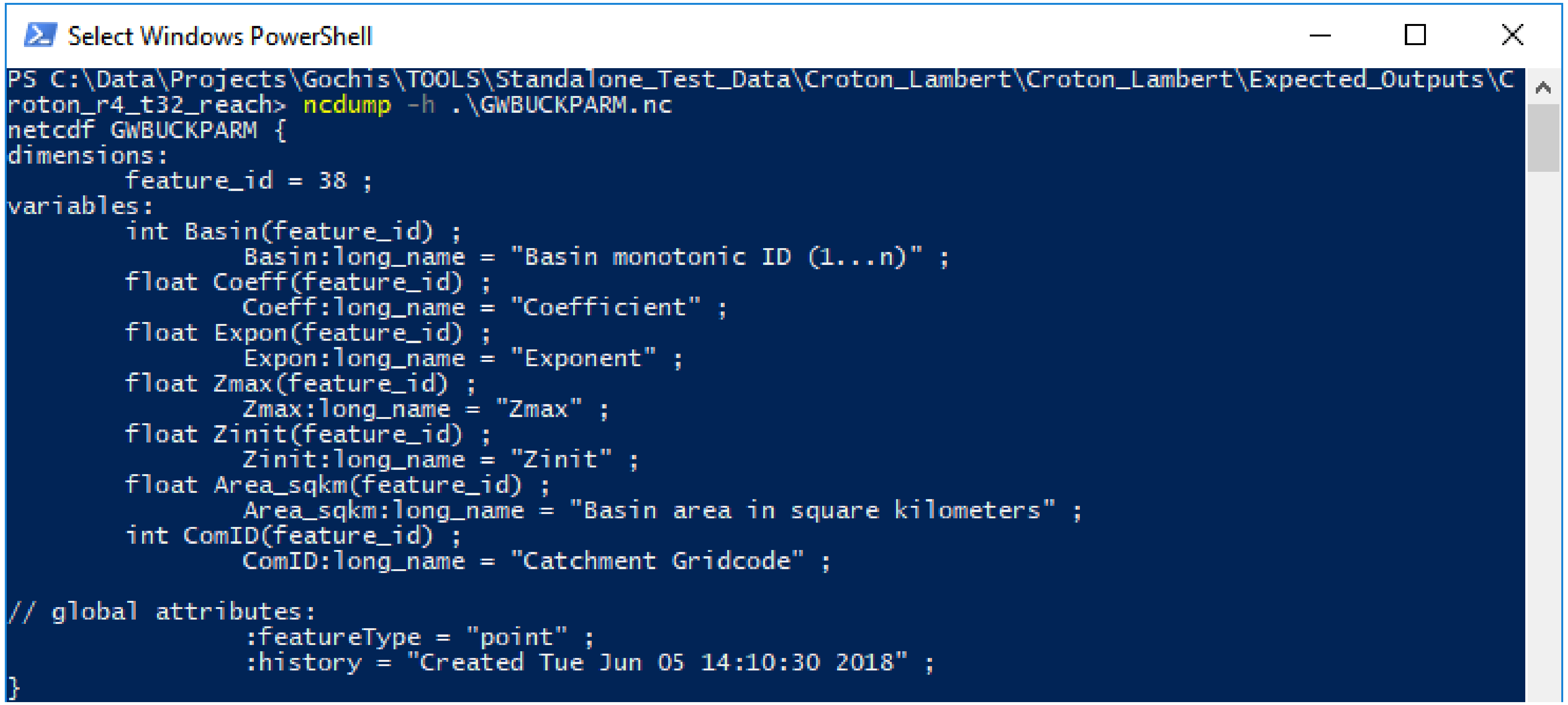
From WRF-Hydro User Guide, Figure 3.7

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

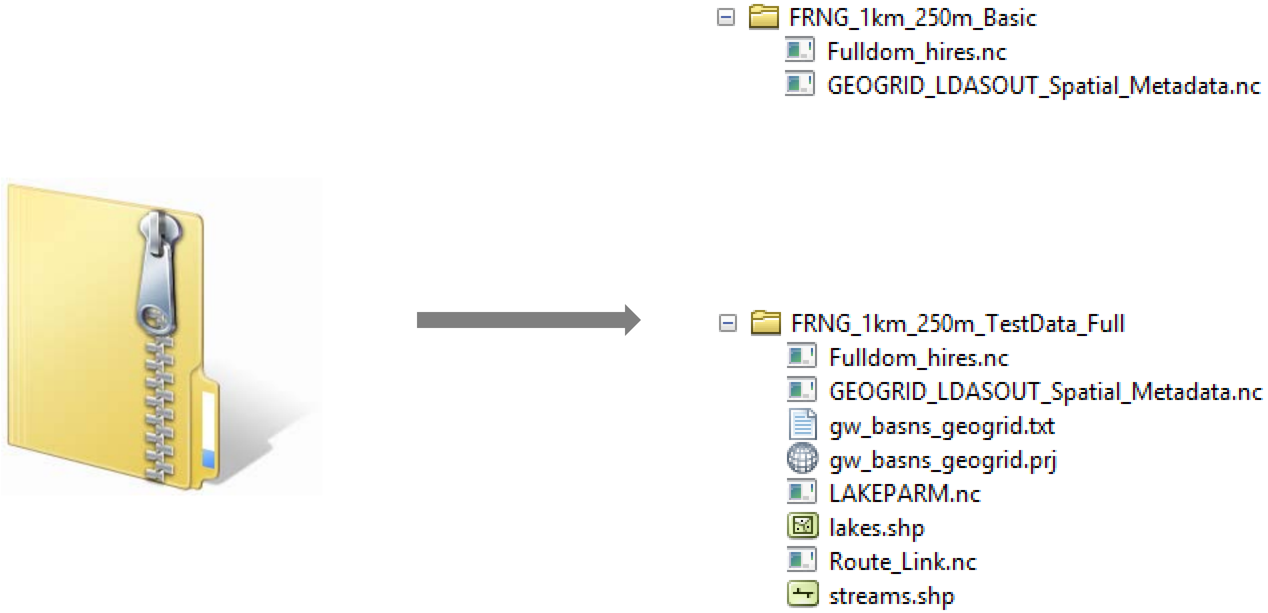
    Polygon Shapefile



```
PS C:\Data\Projects\Gochis\TOOLS\Standalone_Test_Data\Croton_Lambert\Croton_Lambert\Expected_Outputs\C
roton_r4_t32_reach> ncdump -h .\GWBUCKPARM.nc
netcdf GWBUCKPARM {
dimensions:
        feature_id = 38 ;
variables:
        int Basin(feature_id) ;
                Basin:long_name = "Basin monotonic ID (1...n)" ;
        float Coeff(feature_id) ;
                Coeff:long_name = "Coefficient" ;
        float Expon(feature_id) ;
                Expon:long_name = "Exponent" ;
        float Zmax(feature_id) ;
                Zmax:long_name = "Zmax" ;
        float Zinit(feature_id) ;
                Zinit:long_name = "Zinit" ;
        float Area_sqkm(feature_id) ;
                Area_sqkm:long_name = "Basin area in square kilometers" ;
        int ComID(feature_id) ;
                ComID:long_name = "Catchment Gridcode" ;

// global attributes:
                :featureType = "point" ;
                :history = "Created Tue Jun 05 14:10:30 2018" ;
}
```

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



- FRNG_1km_250m_Basic
  - Fulldom_hires.nc
  - GEOGRID_LDASOUT_Spatial_Metadata.nc

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

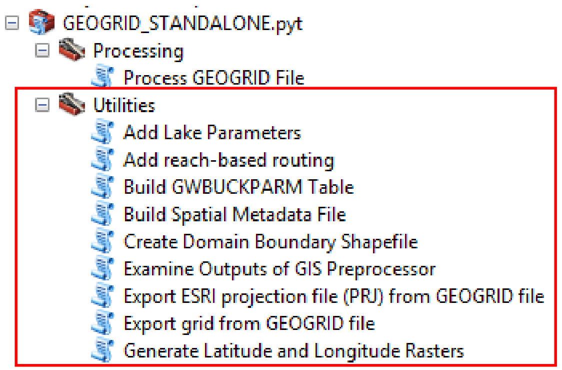
Other Utilities

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

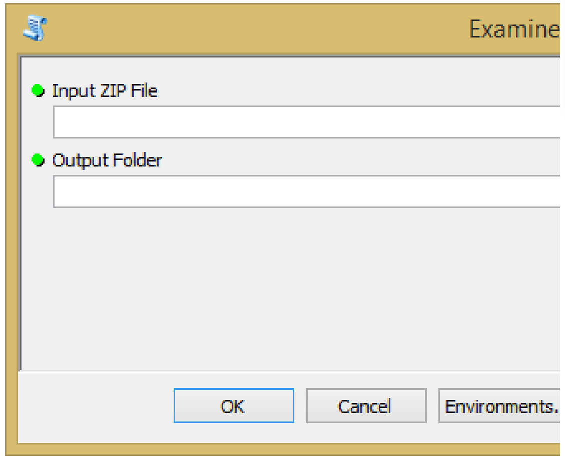
file

ster

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



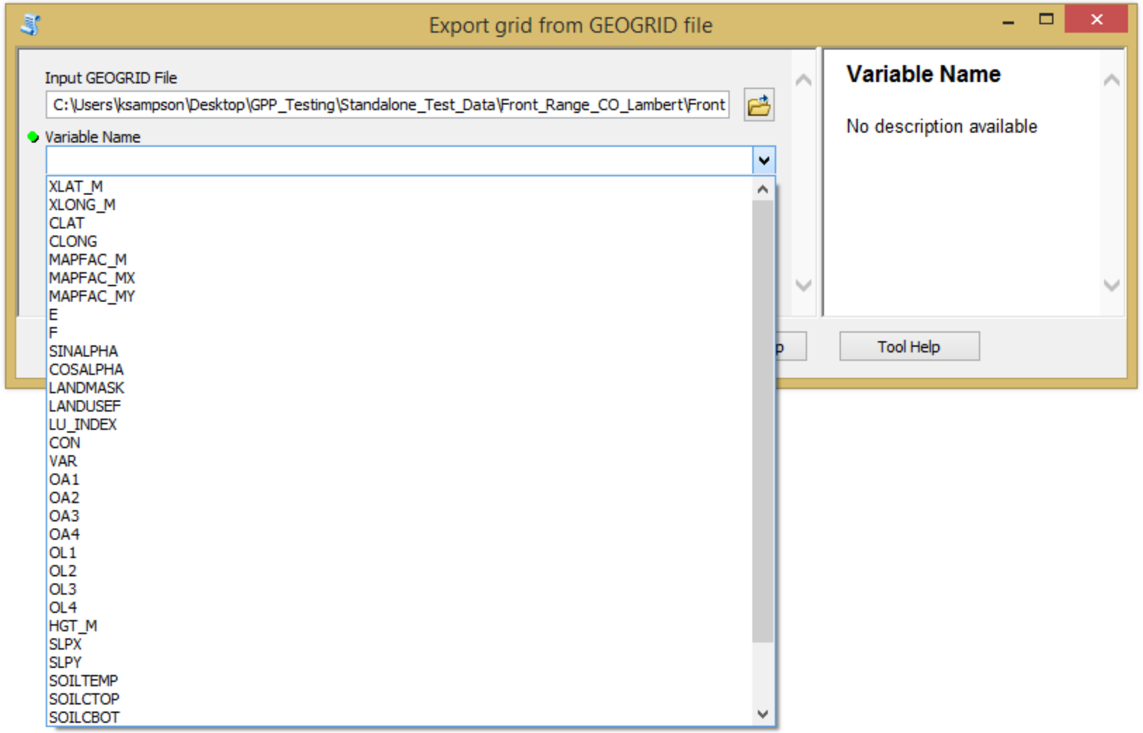
- GEOGRID_STANDALONE.pyt
  - Processing
    - Process GEOGRID File
  - Utilities
    - Add Lake Parameters
    - Add reach-based routing
    - Build GWBUCKPARM Table
    - Build Spatial Metadata File
    - Create Domain Boundary Shapefile
    - Examine Outputs of GIS Preprocessor
    - Export ESRI projection file (PRJ) from GEOGRID file
    - Export grid from GEOGRID file
    - Generate Latitude and Longitude Rasters



Examine

Input ZIP File

Output Folder



Export grid from GEOGRID file

Input GEOGRID File

C:\Users\ksampson\Desktop\GPP_Testing\Standalone_Test_Data\Front_Range_CO_Lambert\Front

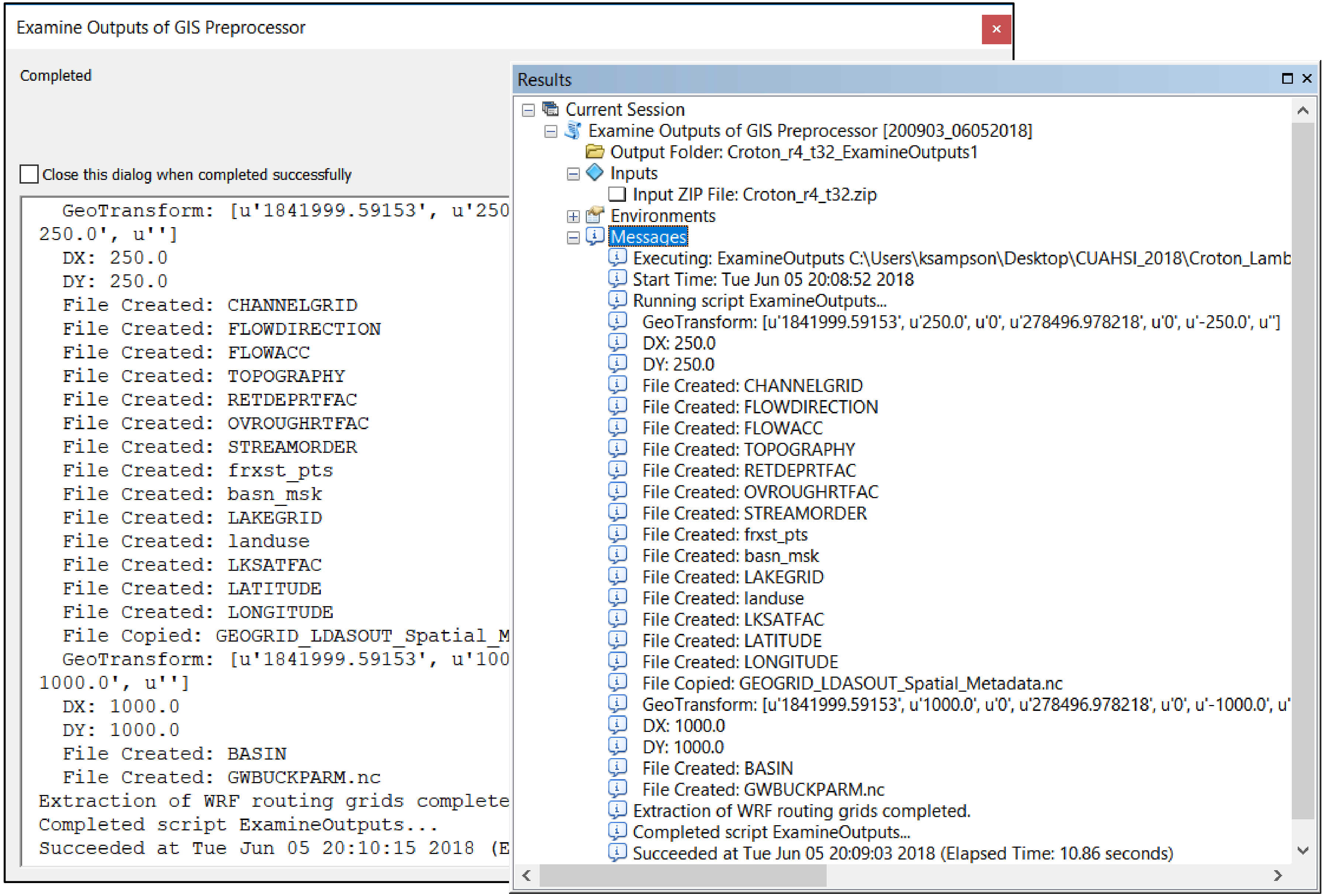
Variable Name

XLAT_M
XLONG_M
CLAT
CLONG
MAPFAC_M
MAPFAC_MX
MAPFAC_MY
E
F
SINALPHA
COSALPHA
LANDMASK
LANDUSEF
LU_INDEX
CON
VAR
OA1
OA2
OA3
OA4
OL1
OL2
OL3
OL4
HGT_M
SLPX
SLPY
SOILTEMP
SOILCTOP
SOILCBOT

Variable Name

No description available

Tool Messages



Examine Outputs of GIS Preprocessor

Completed

☐ Close this dialog when completed successfully

```
  GeoTransform: [u'1841999.59153', u'250
250.0', u'']
  DX: 250.0
  DY: 250.0
  File Created: CHANNELGRID
  File Created: FLOWDIRECTION
  File Created: FLOWACC
  File Created: TOPOGRAPHY
  File Created: RETDEPRTFAC
  File Created: OVROUGHRTFAC
  File Created: STREAMORDER
  File Created: frxst_pts
  File Created: basn_msk
  File Created: LAKEGRID
  File Created: landuse
  File Created: LKSATFAC
  File Created: LATITUDE
  File Created: LONGITUDE
  File Copied: GEOGRID_LDASOUT_Spatial_M
  GeoTransform: [u'1841999.59153', u'100
1000.0', u'']
  DX: 1000.0
  DY: 1000.0
  File Created: BASIN
  File Created: GWBUCKPARM.nc
Extraction of WRF routing grids complete
Completed script ExamineOutputs...
Succeeded at Tue Jun 05 20:10:15 2018 (E
```

Results

```
Current Session
  Examine Outputs of GIS Preprocessor [200903_06052018]
    Output Folder: Croton_r4_t32_ExamineOutputs1
    Inputs
      Input ZIP File: Croton_r4_t32.zip
    Environments
    Messages
      Executing: ExamineOutputs C:\Users\ksampson\Desktop\CUAHSI_2018\Croton_Lamb
      Start Time: Tue Jun 05 20:08:52 2018
      Running script ExamineOutputs...
        GeoTransform: [u'1841999.59153', u'250.0', u'0', u'278496.978218', u'0', u'-250.0', u'']
        DX: 250.0
        DY: 250.0
        File Created: CHANNELGRID
        File Created: FLOWDIRECTION
        File Created: FLOWACC
        File Created: TOPOGRAPHY
        File Created: RETDEPRTFAC
        File Created: OVROUGHRTFAC
        File Created: STREAMORDER
        File Created: frxst_pts
        File Created: basn_msk
        File Created: LAKEGRID
        File Created: landuse
        File Created: LKSATFAC
        File Created: LATITUDE
        File Created: LONGITUDE
        File Copied: GEOGRID_LDASOUT_Spatial_Metadata.nc
        GeoTransform: [u'1841999.59153', u'1000.0', u'0', u'278496.978218', u'0', u'-1000.0', u'
        DX: 1000.0
        DY: 1000.0
        File Created: BASIN
        File Created: GWBUCKPARM.nc
      Extraction of WRF routing grids completed.
      Completed script ExamineOutputs...
      Succeeded at Tue Jun 05 20:09:03 2018 (Elapsed Time: 10.86 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
  - Croton (Lambert Conformal Conic)
- Expected Output provided for comparison
- Required Elevation files (.tif) provided
- Optional stream gages & lakes provided

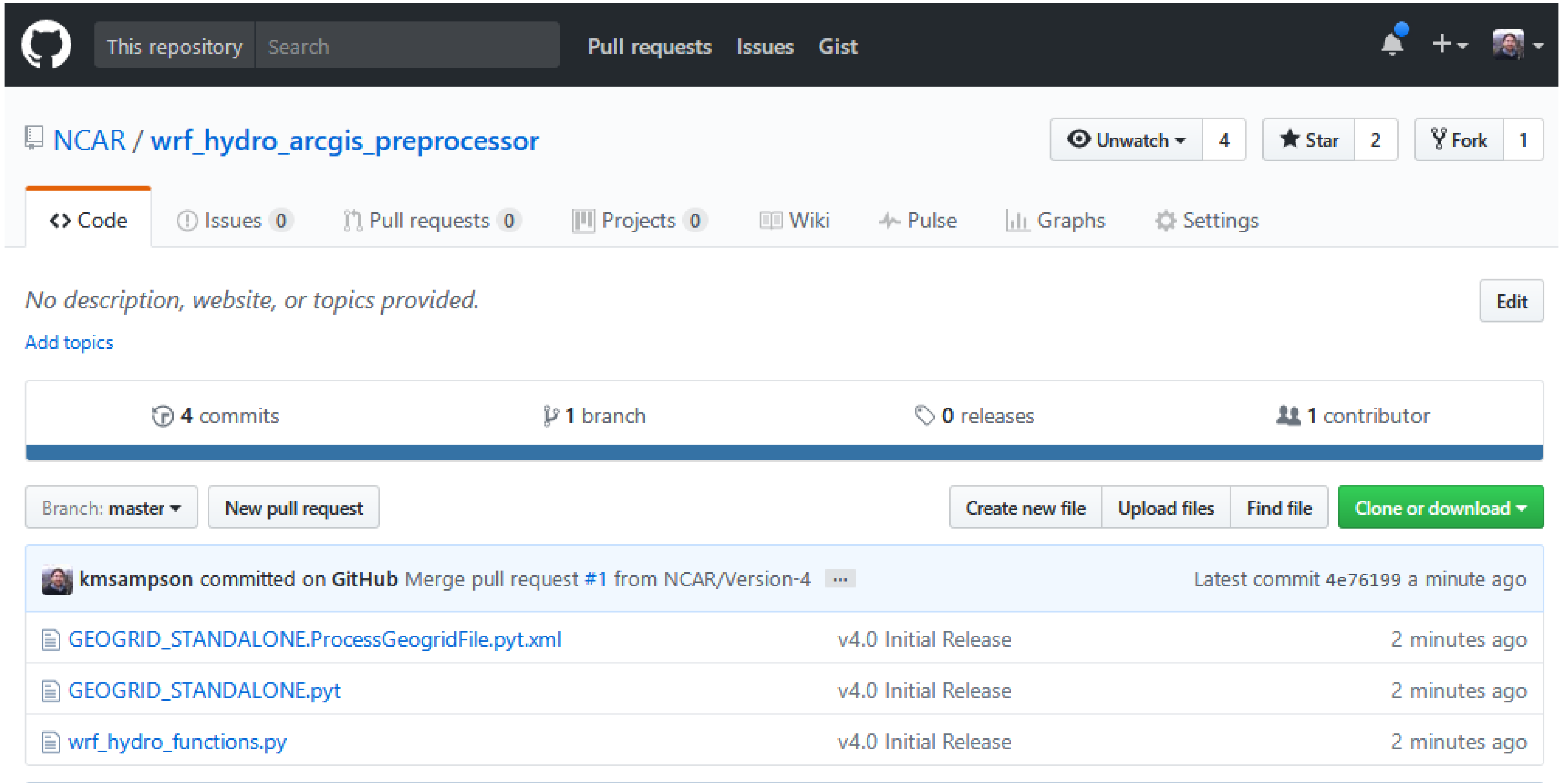
https://ral.ucar.edu/projects/wrf_hydro/pre-processing-tools

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
  - Hydrology tools parallelized in ArcGIS 10.6, not implemented in WRF-Hydro GIS Pre-processor yet
- Windows only GIS platform

GitHub

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



NCAR / wrf_hydro_arcgis_preprocessor

No description, website, or topics provided.

4 commits | 1 branch | 0 releases | 1 contributor

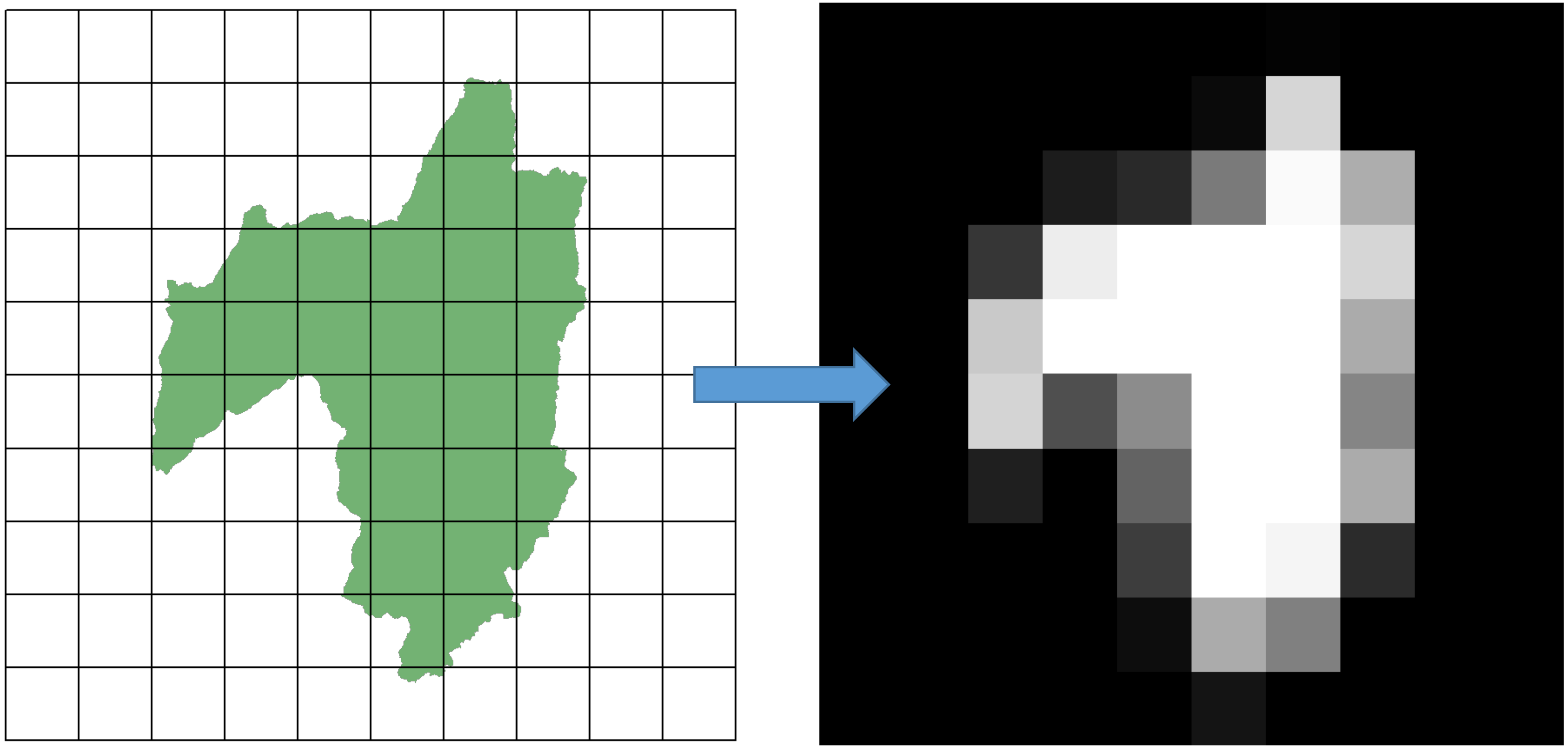
kmsampson committed on GitHub Merge pull request #1 from NCAR/Version-4 … Latest commit 4e76199 a minute ago

GEOGRID_STANDALONE.ProcessGeogridFile.pyt.xml	v4.0 Initial Release	2 minutes ago
GEOGRID_STANDALONE.pyt	v4.0 Initial Release	2 minutes ago
wrf_hydro_functions.py	v4.0 Initial Release	2 minutes ago

Catchments & Grid-to-Basin Mapping

Grid-to-Basin Mapping

fraction of each grid cell in each sub-basin

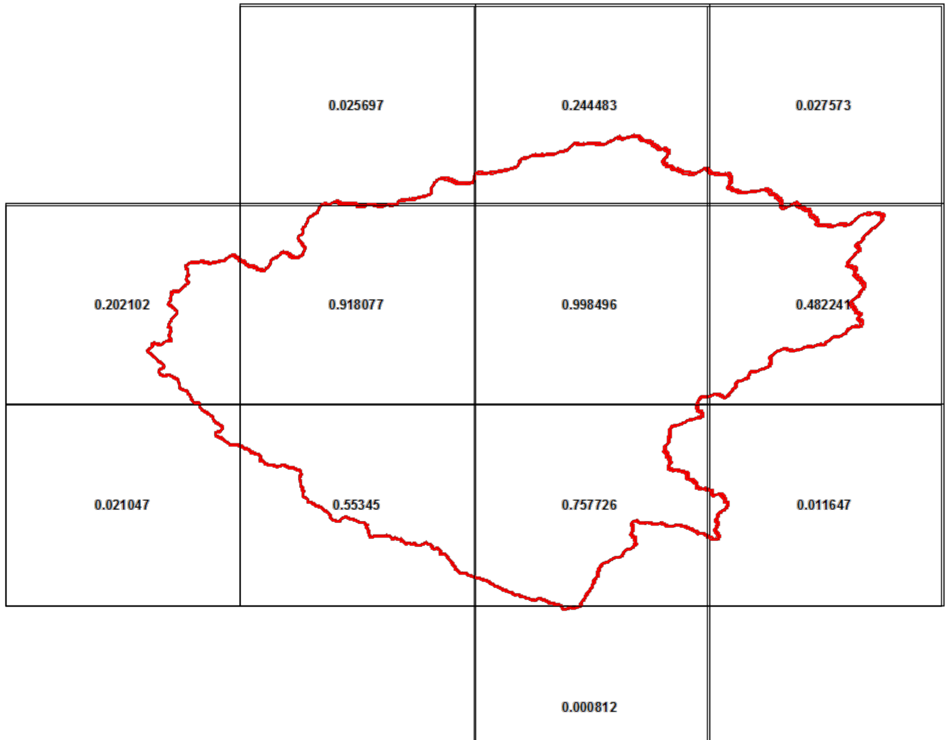


maps gridded meteorological fields to sub-basins within the model domain

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.

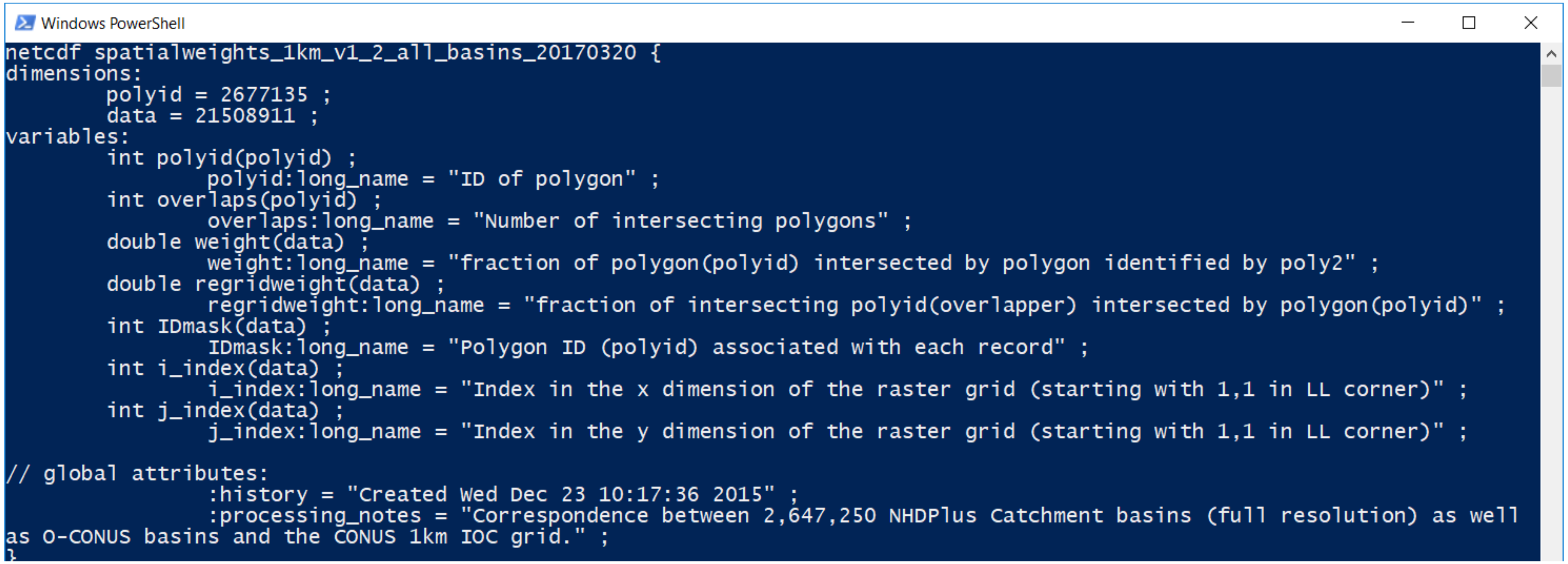
Spatial Weight



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

Custom Correspondence netCDF

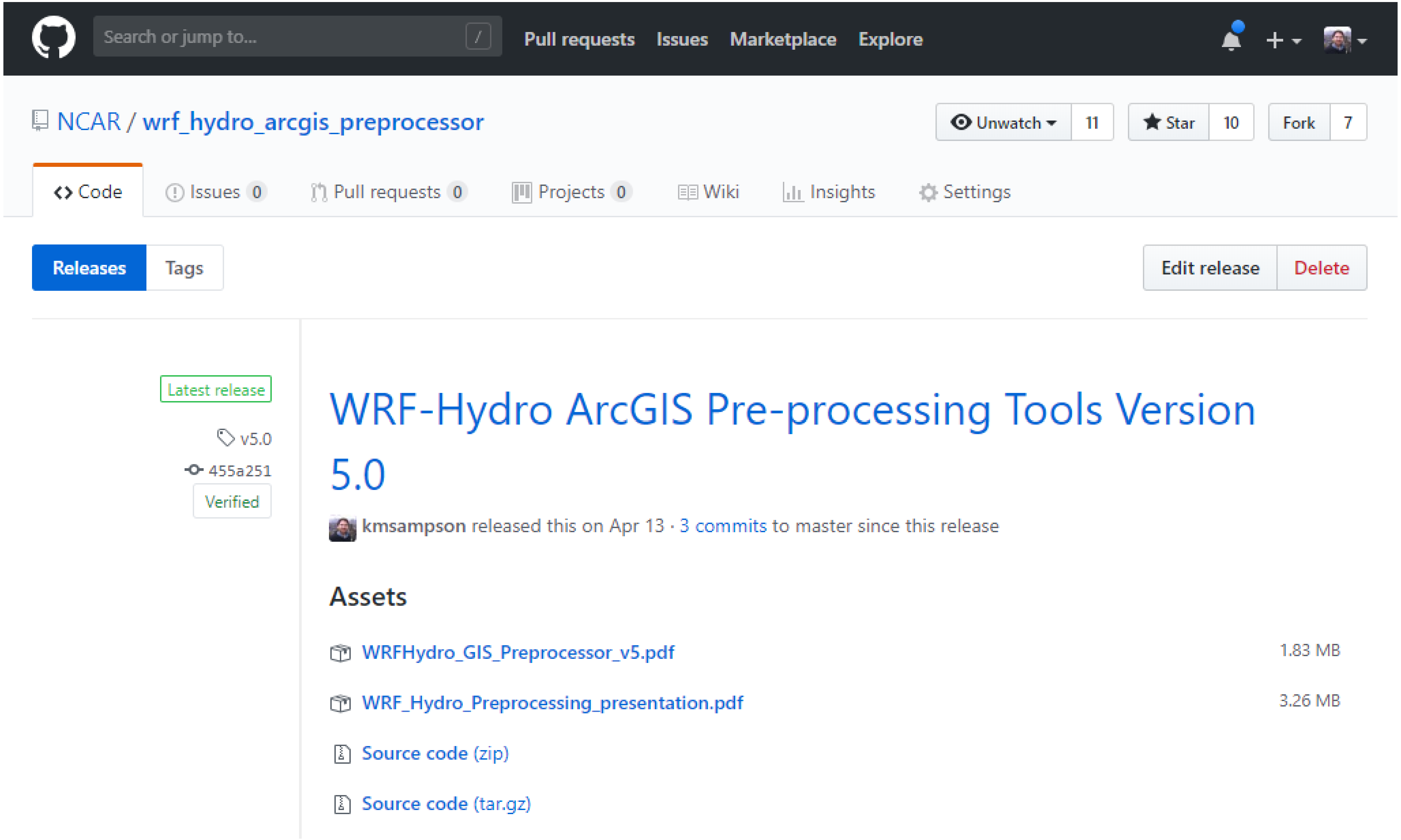
Custom Correspondence netCDF



```
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 NHDPlus Catchment basins (full resolution) as well
as O-CONUS basins and the CONUS 1km IOC grid." ;
}
```

GIS Pre-processing Demonstration

https://github.com/NCAR/wrf_hydro_arcgis_preprocessor/releases/tag/v5.0



WRF-Hydro ArcGIS Pre-processing Tools Version 5.0

kmsampson released this on Apr 13 · 3 commits to master since this release

Assets

WRFHydro_GIS_Preprocessor_v5.pdf	1.83 MB
WRF_Hydro_Preprocessing_presentation.pdf	3.26 MB
Source code (zip)	
Source code (tar.gz)	

WRF-Hydro
MODELING SYSTEM

Thank you

Questions: wrfhydro@ucar.edu

References

- Jenson, S. K., and J. O. Domingue. 1988. "Extracting Topographic Structure from Digital Elevation Data for Geographic Information System Analysis." Photogrammetric Engineering and Remote Sensing 54 (11): 1593–1600.
- Tarboton, D. G., R. L. Bras, and I. Rodriguez–Iturbe. 1991. "On the Extraction of Channel Networks from Digital Elevation Data." Hydrological Processes 5: 81–100.