Data I/O Requirements :

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WRF-Hydro Input Data:

I/O Philosophy :

1. Single, consistent data format for I/O (helps minimize coding conventions)
2. Convenient and ubiquitous (compatible with many graphical analysis and visualization tools)
3. Multiscale, multi-data type
4. Meta-data capable
5. Efficient in terms of overall data storage

Not surprisingly, we adopted netcdf as our primary format
However, we also utilize a few flat ASCII files where necessary

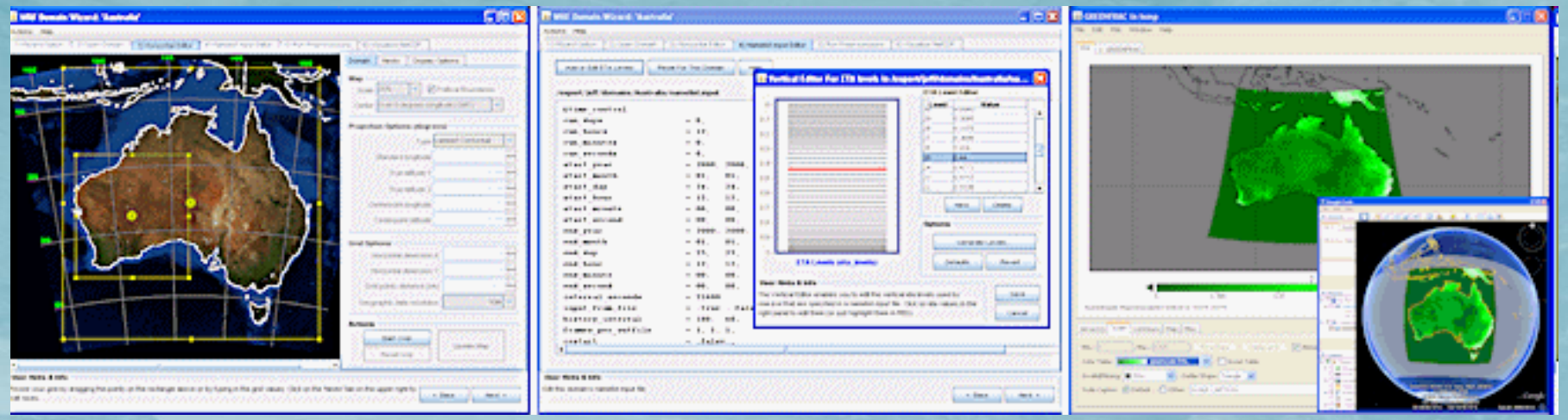
∴ One needs to put/read netcdf files and netcdf library and include directories
∴ These MUST BE PROPERLY INSTALLED AND LINKED TO
(see http://www.unidata.ucar.edu/software/netcdf/)
If WRF is already installed and compiled, then this is take care of

General Requirements:

- Input files needed:
  - Standard WRF-Noah/NoahMP LSM grids (geogrid.exe))
  - ‘wrfinput’ file for initial conditions (real.exe or utility script)
  - One new netcdf file containing high resolution gridded routing information (‘routing grid’)
    - Topography, flowdirection, channel network, observation points, watersheds, stream order, calibration parameters
  - 1-3 new ASCII parameter tables depending on activated options (e.g. lake model, baseflow model, reach routing model)

Inputs:

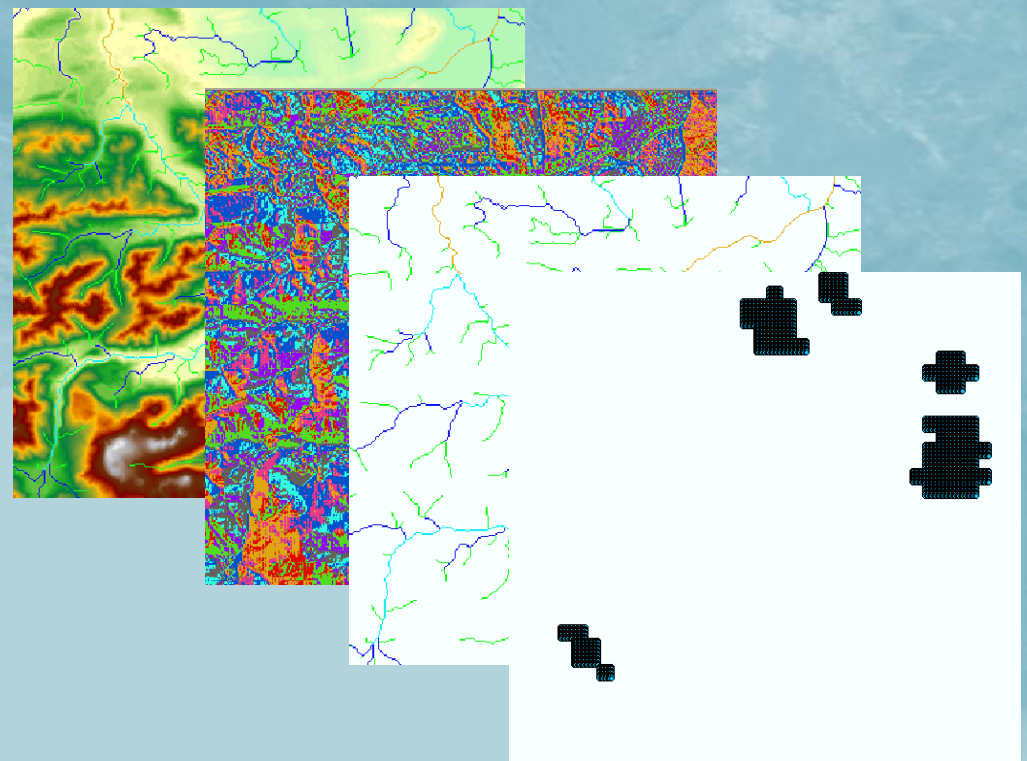
1. Geogrid/LSM grid:
   a) LSM/geogrid data: Using WPS &/or Domain Wizard



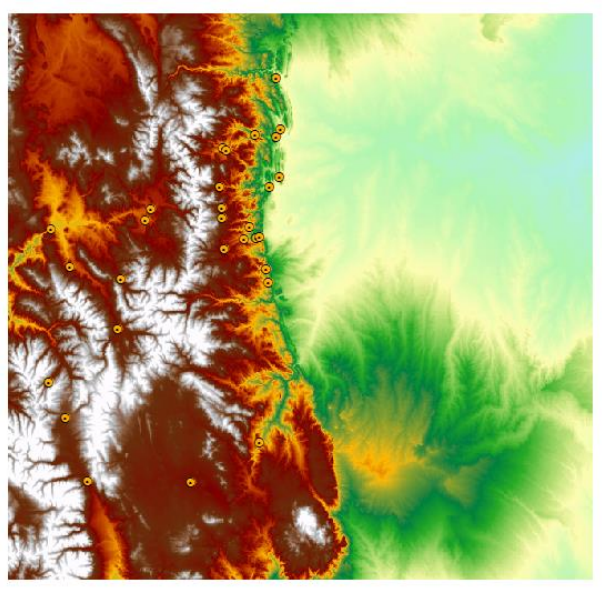
   b) Fields used by WRF-Hydro: soil type, vegetation type, lake mask, green vegetation fraction/LAI, lat/lon, lower soil temperature…(see IDV…)

Inputs:

1. Routing Grid:
   a) High-resolution terrain routing grids: These data are on a fine-resolution terrain grid (~<100m) and are typically created within a GIS such as ArcGIS or manually…(with a little work)… details will be discussed this afternoon…
   b) Necessary variables are:
      - LATITUDE
      - LONGITUDE
      - TOPGRAPHY
      - FLOWDIRECTION
      - CHANNELGRID
      - STREAMORDER
      - LAKEGRID
      - frxst_pts
      - gw_basns
      - calibration fields

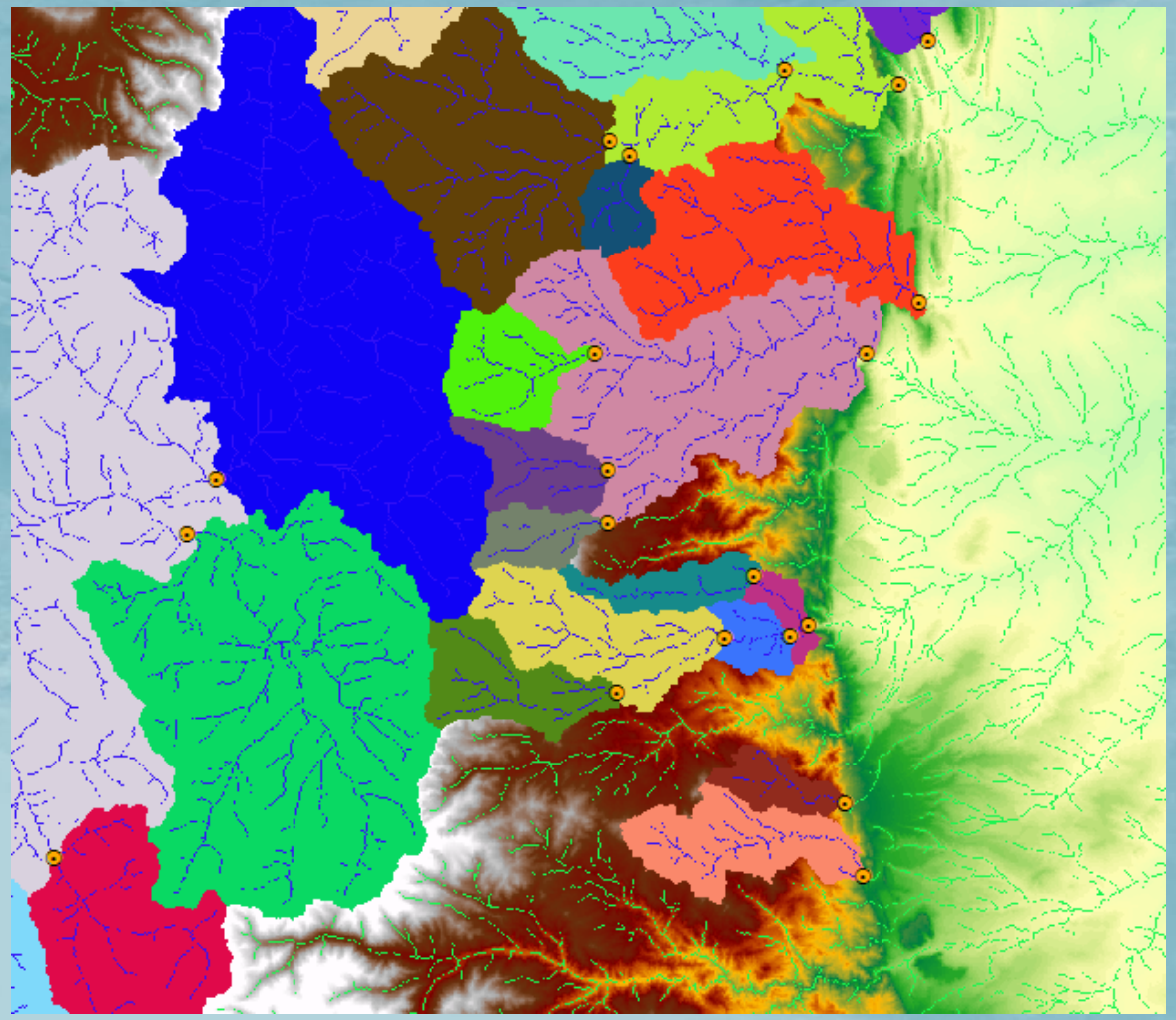


WRF-Hydro 'Hydro-Grid' ArcGIS: Tool Output



Import:
geogrid terrain

Create:
Hydrological
routing grids

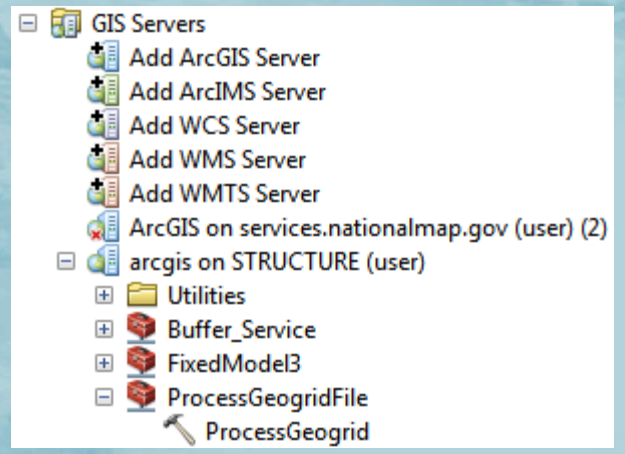


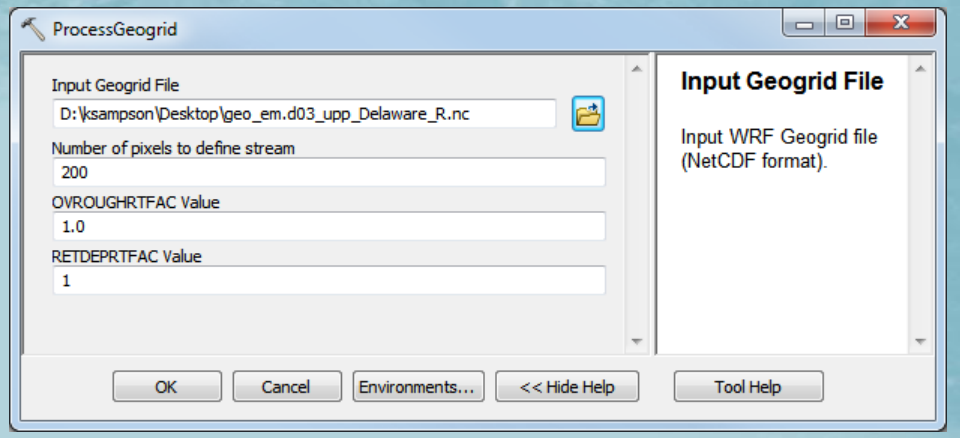
WRF-Hydro 'Hydro-Grid' ArcGIS: Tool Access: K. Sampson - developer

- Esri ArcCatalog or ArcMap applications
  - Add a user connection to the ArcGIS Server
  - Run the tool just like any other ArcGIS tool
  - Inputs:

    WRF geogrid file (NetCDF format)

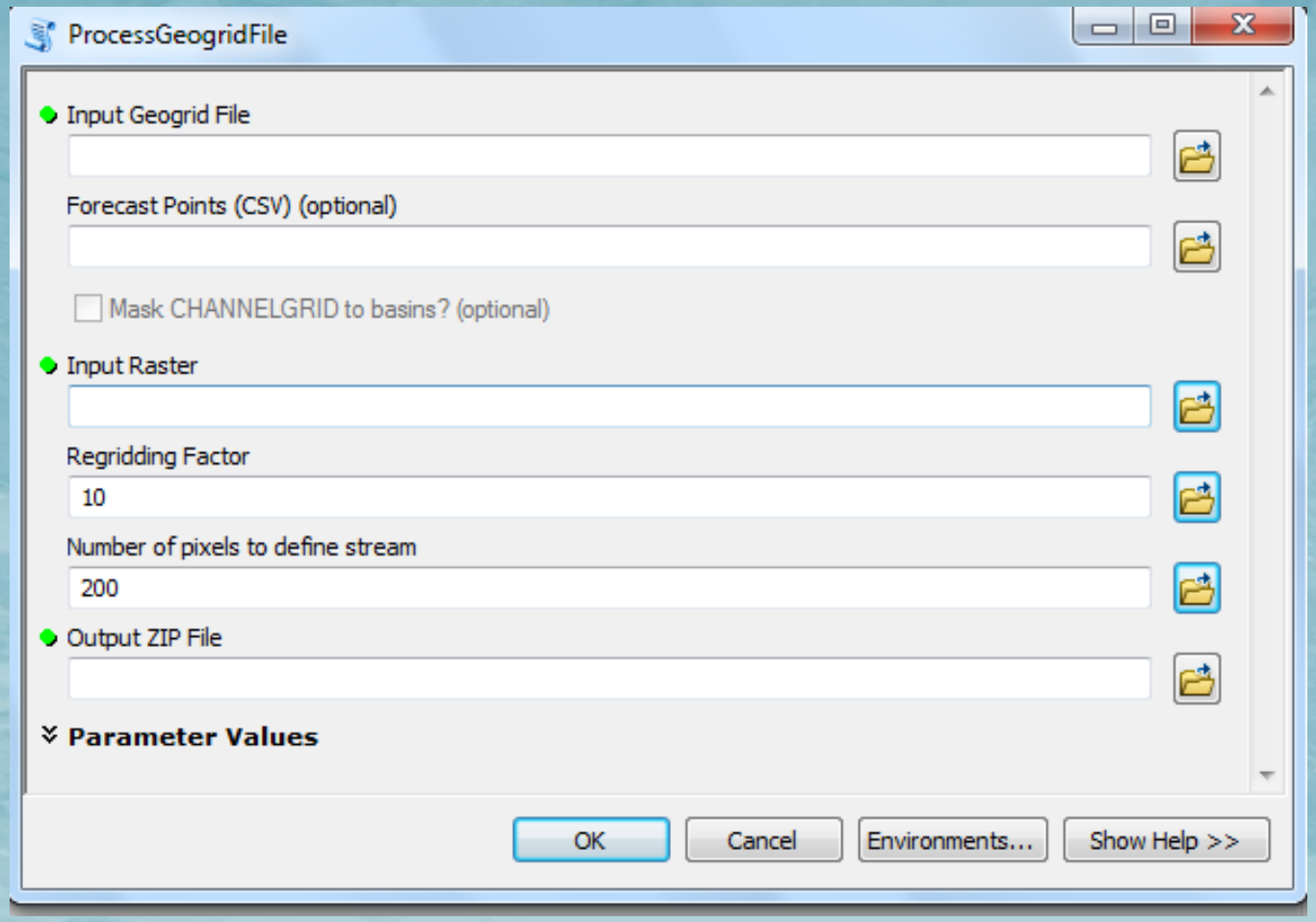
    Additional parameters (defaults pre-set)





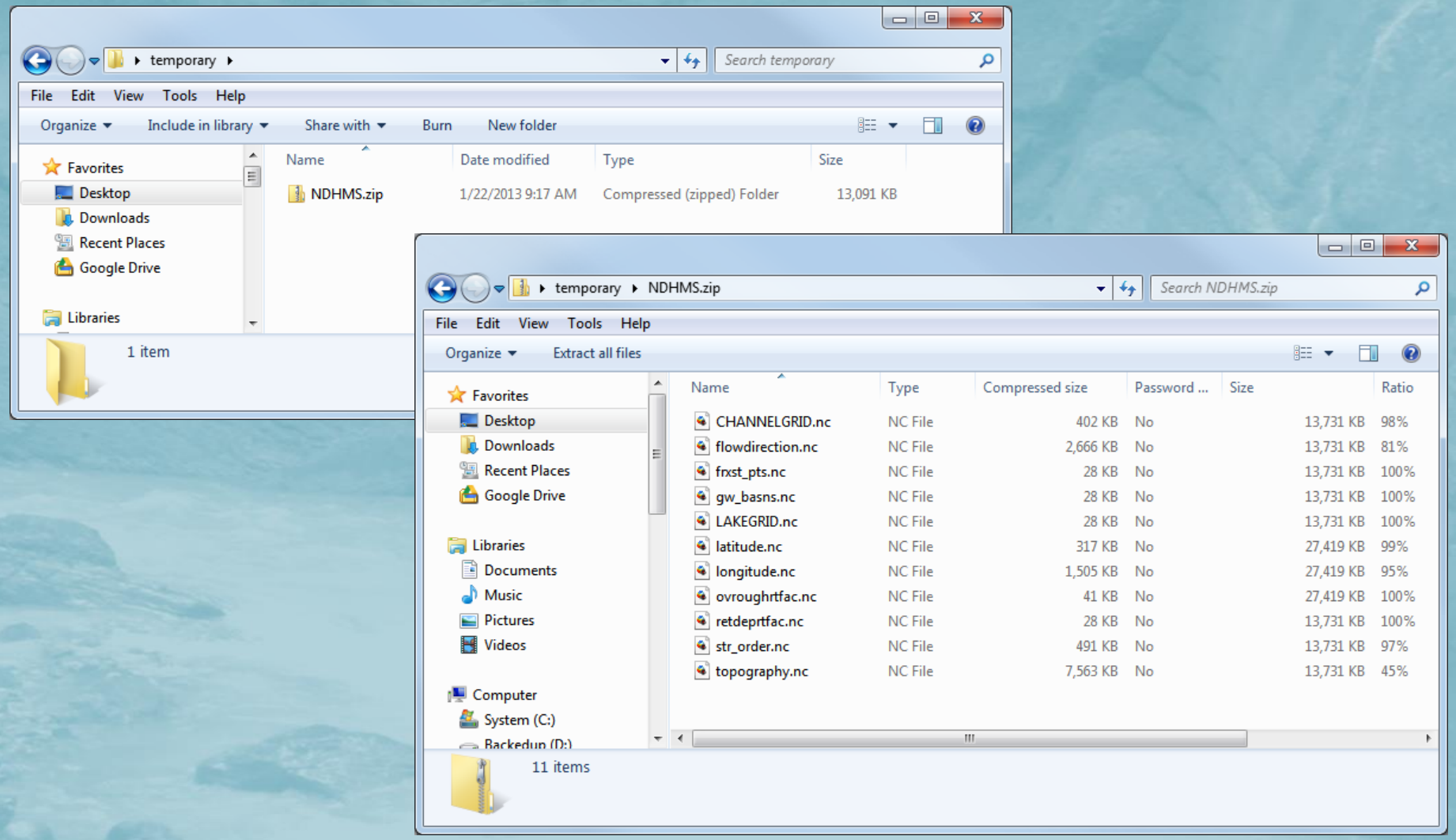
Tool Execution

ArcGIS Stand-alone Tool Dialog Box:



1-10 min.
to complete

WRF-Hydro 'Hydro-Grid' Web Service: Tool Output



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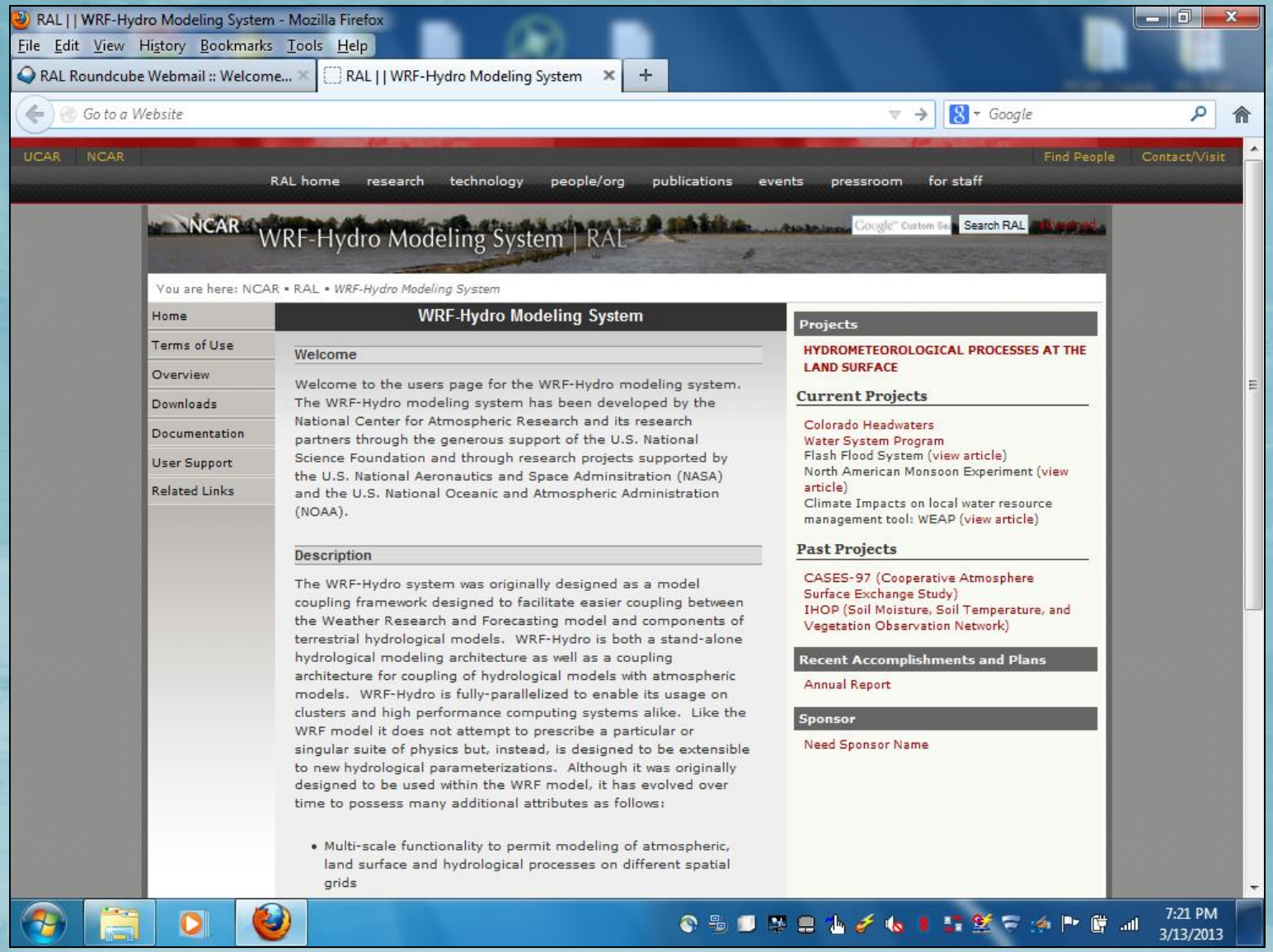
WRF-Hydro 'Hydro-Grid' ArcGIS tool:



Inputs: Model State Initialization

1. Initialization fields:
   - Total soil moisture content, soil liquid water content
   - Soil temperature
   - Canopy water content

*For WRF-Hydro routing grids, either 'cold-start' or from restart files (groundwater level, surface water ponding, routing grid soil moisture…)

2. File creation options:
   a) wrfinput file...created from WRF real.exe OR simple 'user-specified' script (mandatory but values may be over-written by restart files)
   b) Restart files…created from previous runs of WRF and/or WRF-Hydro

Lakes and Reservoirs in WRF-Hydro

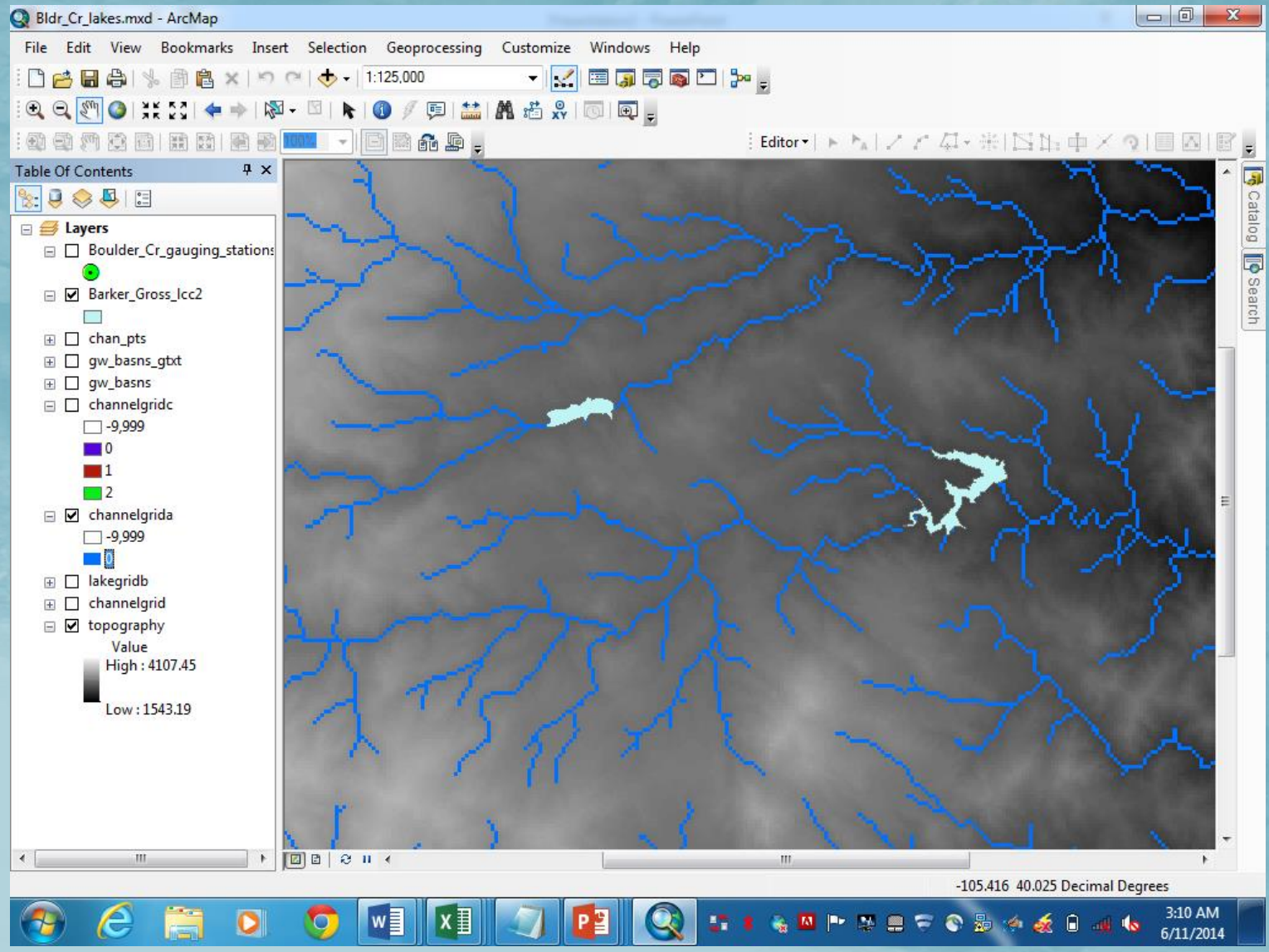
Outline: Implementing lakes and reservoirs in WRF-Hydro

- On-channel reservoirs
- Level-pool storage
- Multiple discharge modes
  - Orifice flow
  - Spillway flow
  - Rule curve
  - Mgt. Schedule

This procedure will help isolate problems which may otherwise be difficult and/or time-consuming to diagnose in many implementations:

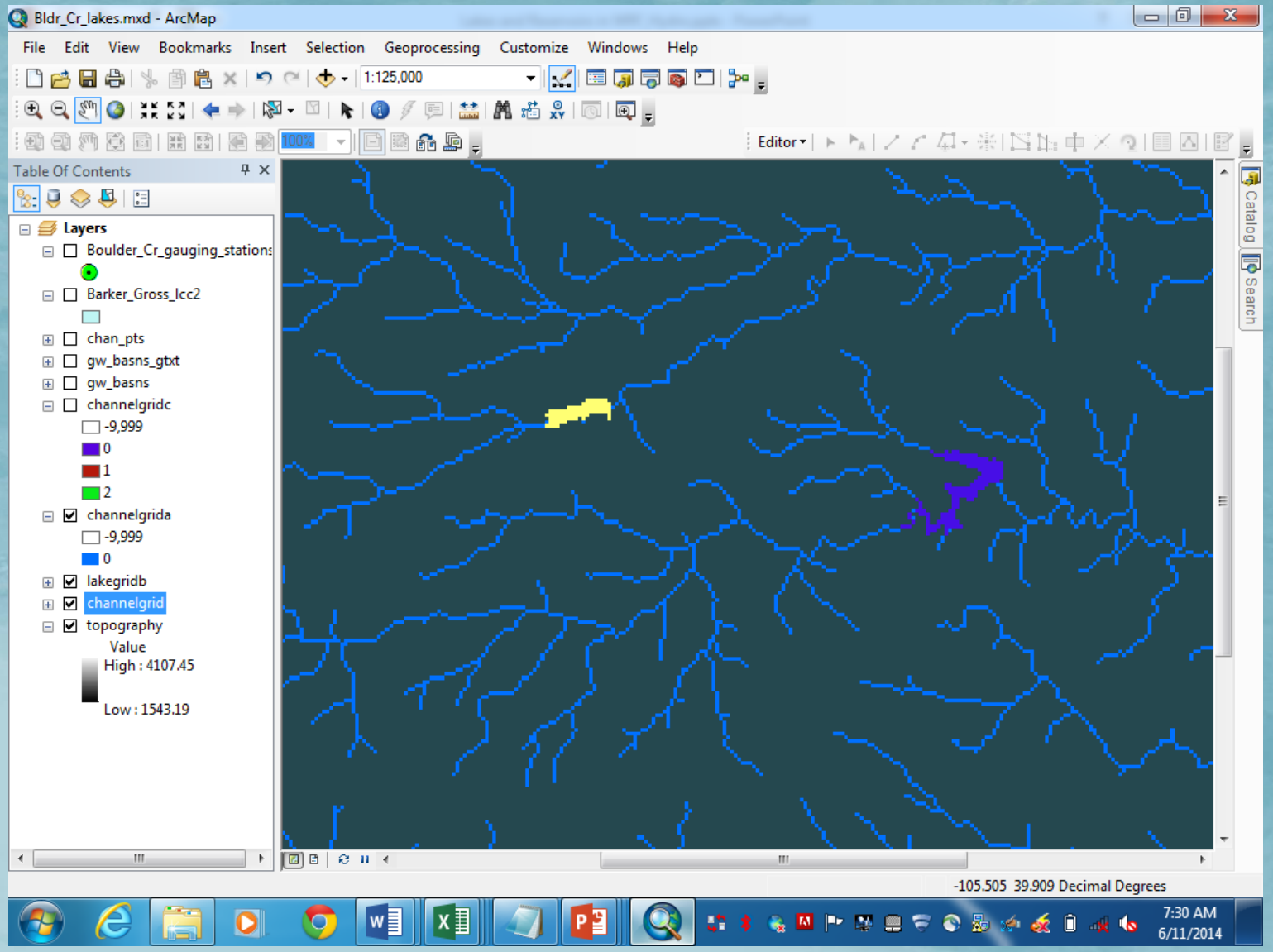
Implementing lakes and reservoirs in WRF-Hydro

1. After deriving channel network without reservoirs, overlay lake polygons on top of channel grid



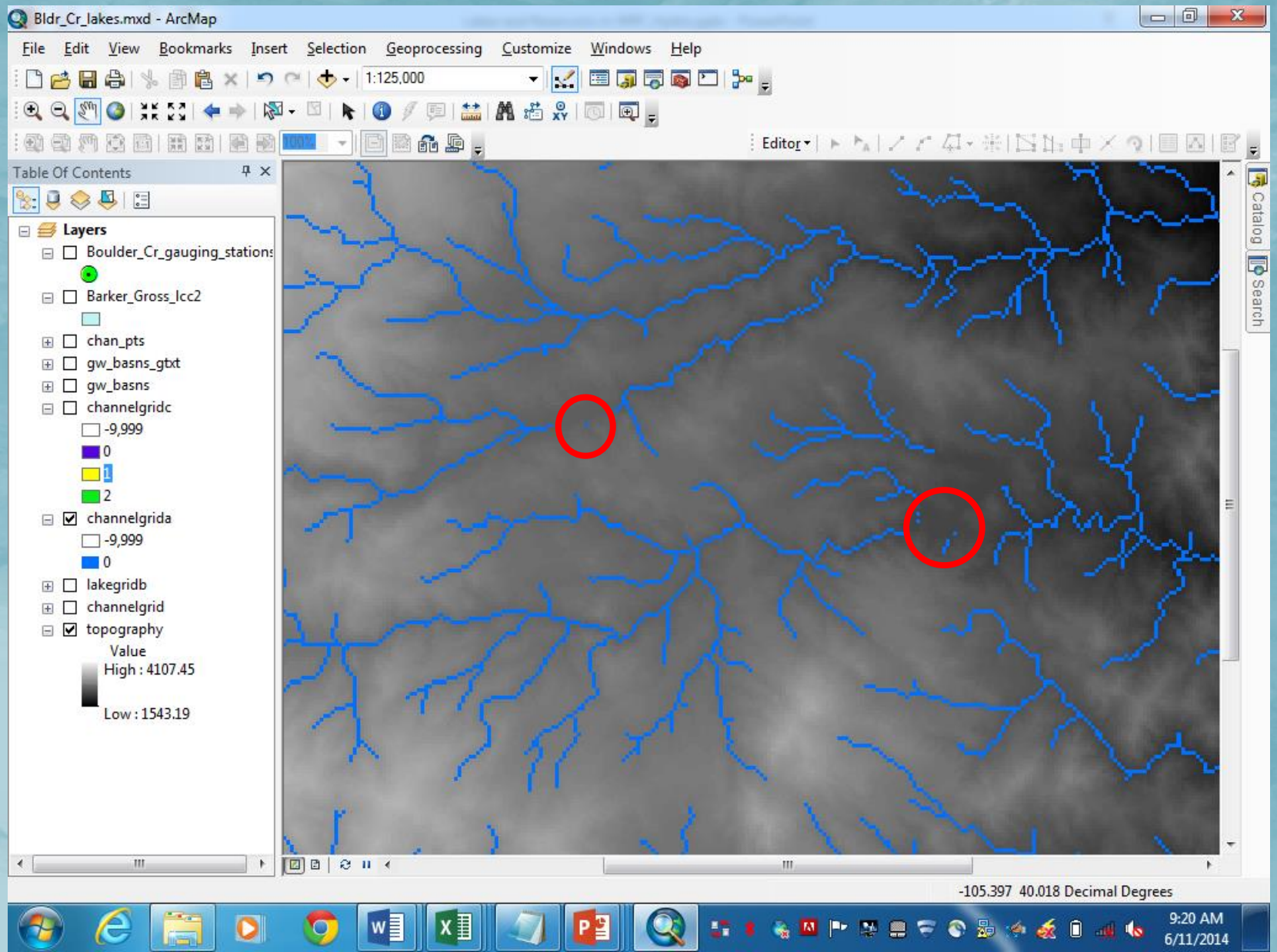
Implementing lakes and reservoirs in WRF-Hydro

1. Convert lake polygon into grid at the same resolution and projection as the channel grid



Implementing lakes and reservoirs in WRF-Hydro

1. Using lake grids as masks, then remove channel grid points ‘underneath’ lakes
2. If channel artifacts exist (see red circles), users will need to remove those by directing editing of grids or conversion to points



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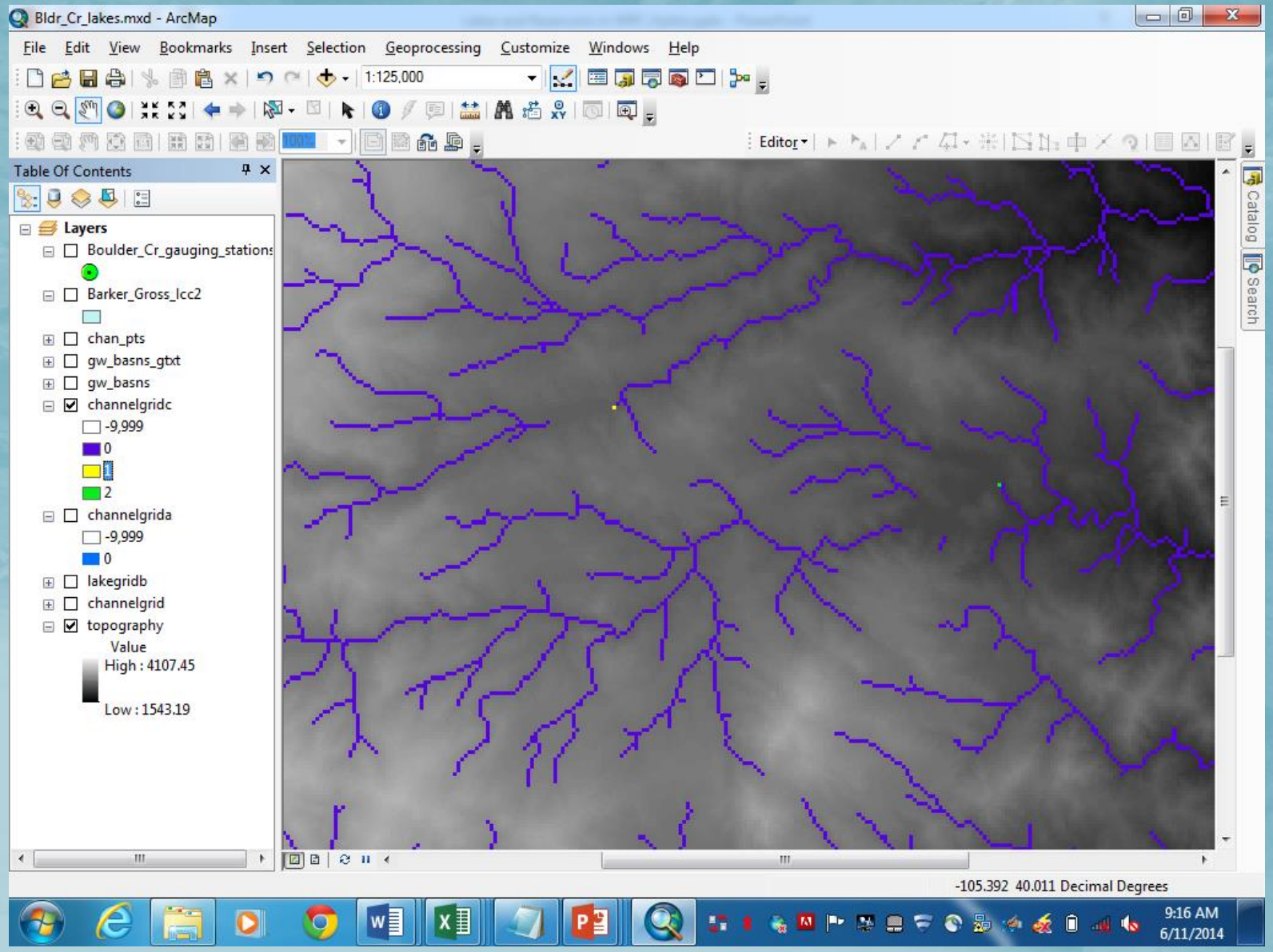
Implementing lakes and reservoirs in WRF-Hydro

1. Need to change value of selected channel grid elements to specify where reservoir discharge is input into channel
2. Channel grid at reservoir discharge location has same index value as reservoir



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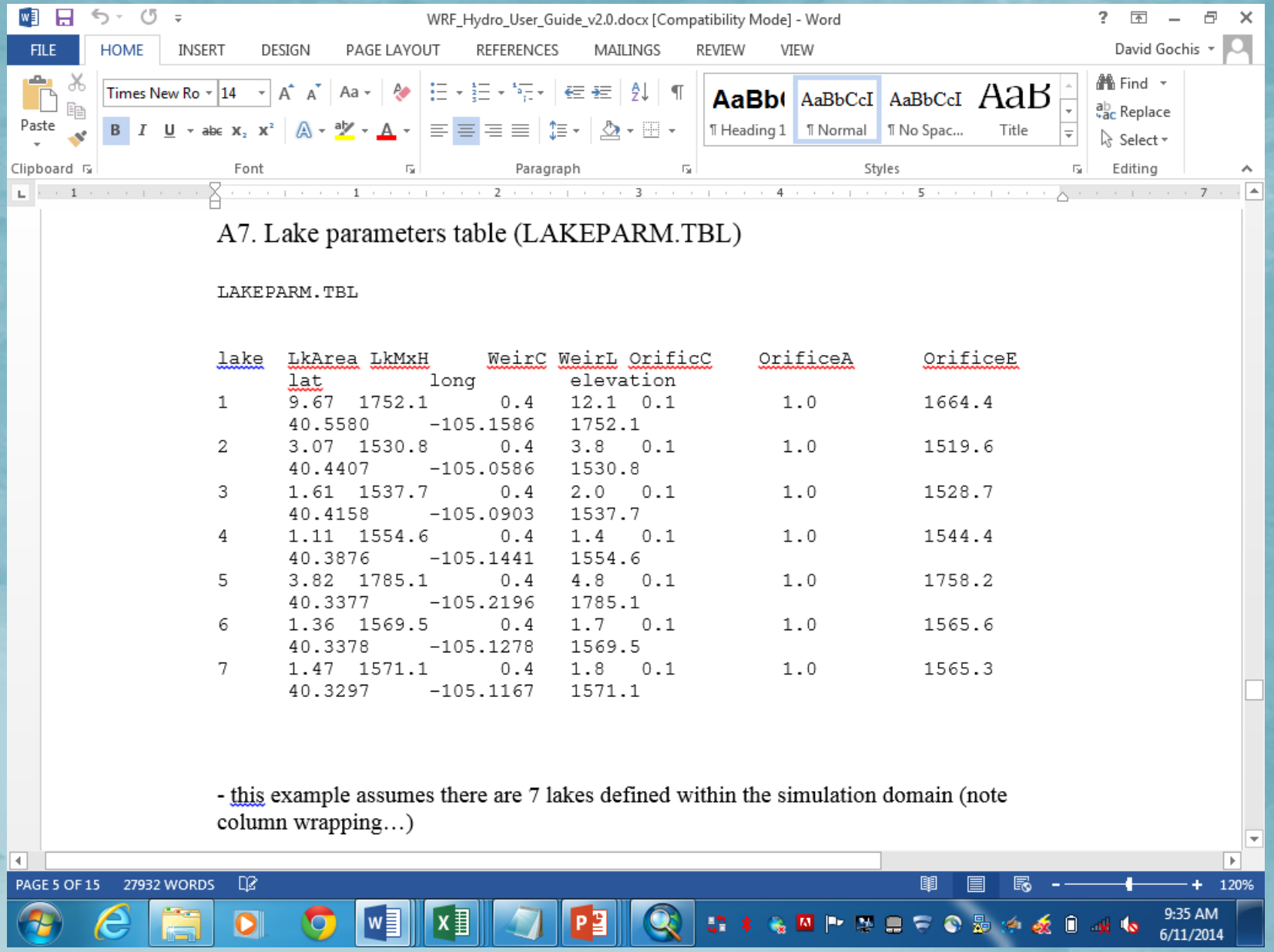
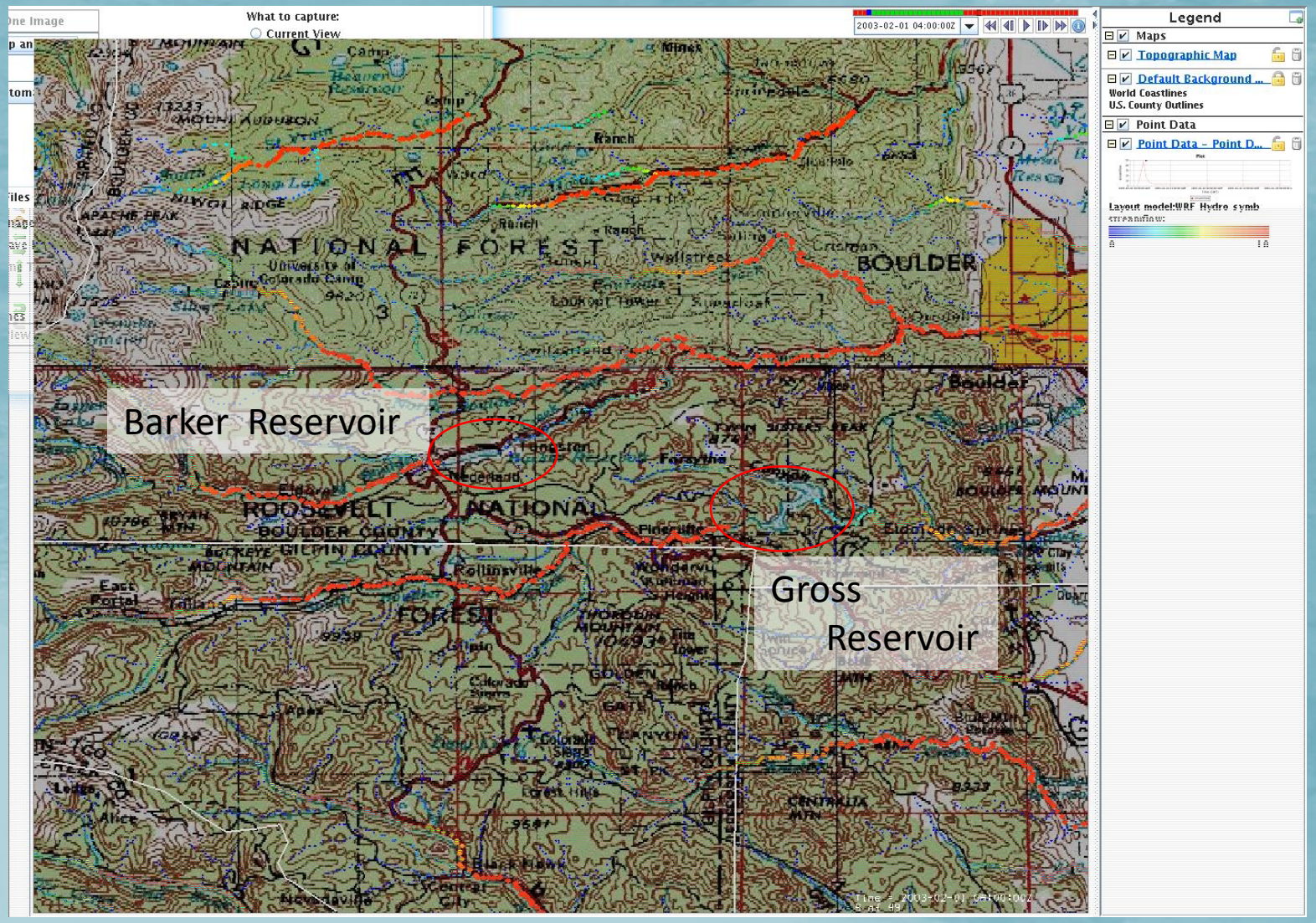
Implementing lakes and reservoirs in WRF-Hydro

1. Parameter Table (LAKEPARM.TBL)



Implementing lakes and reservoirs in WRF-Hydro

1. Visualization of lake impacts



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WRF-Hydro Forcing Data:

Input Forcing Data Requirements:

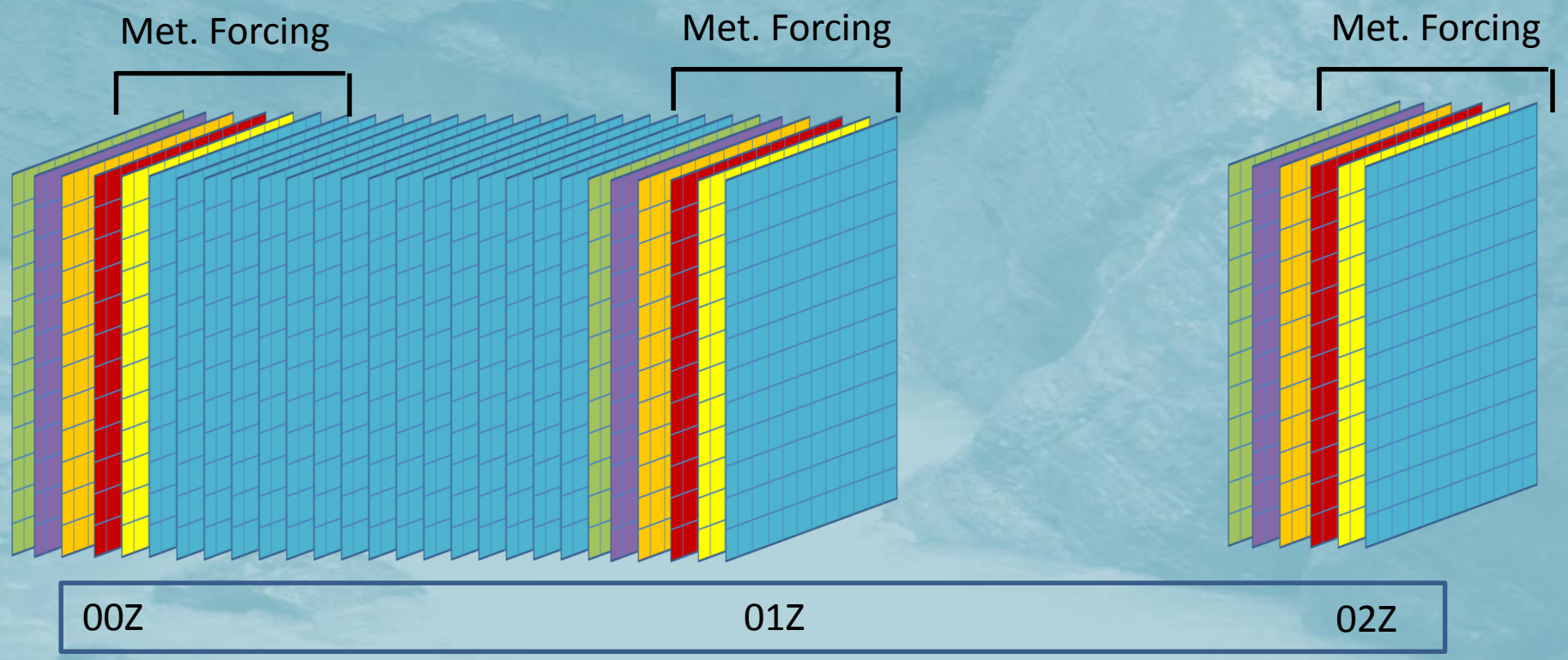
- Forcing Inputs:
  - Temperature (deg K), humidity-mixing ratio (kg/kg), short & longwave radiation (W/m^2), pressure (Pa), wind speed (m/s) and precipitation rate (mm/s)
  - Optional formats of forcing data:
    - Fully-coupled model
    - Existing wrf output files
    - Unified analysis (all met. variables together – Netcdf file, e.g. NLDAS-hourly)
    - Specified precipitation (Netcdf file , precipitation comes from alternate source, e.g. radar, satellite, gauge analysis)

ALL FORCING DATA IS MAPPED TO SAME GRID (based on WRF 'geogrid')

SPECIFIED PRECIPITATION MAY HAVE HIGHER TIME RESOLUTION (e.g. 5min)

Input Forcing Data Requirements:

- Data Requirements:
  - Forcing Input: Forecast Example…



Input Forcing Data Requirements:

- Data Pre-processing Options:
  - Several utilities for formatting and creating 'forcing' data:
    - Using netcdf as the underlying data model…
    - One file per forcing input time…
    - Direct use or simple regrid of existing wrf output
    - ESMF/ncl scripts for conservative regridding of data between structured or unstructured grids, ASCII-netcdf formats, etc.
    - nco-based shell scripts to change variable names, threshold units, re-order grids, etc
    - HRLDAS tools for preparing forcing with topographic adjustment

* BEST PRACTICE: Use as high of time-resolution forcing data as possible! (particularly rainfall)

Input Forcing Data Requirements:

- netcdf forcing input file header…(see documentation Appendix A11)

A11. Forcing data netcdf file header

```
netcdf \201111040900 {
dimensions:
        Time = UNLIMITED ; // (1 currently)
        south_north = 475 ;
        west_east = 475 ;
variables:
        float Q2D(Time, south_north, west_east) ;
                Q2D:FieldType = 104 ;
                Q2D:MemoryOrder = "XY " ;
                Q2D:description = "QV at 2 M" ;
                Q2D:units = "kg kg-1" ;
                Q2D:stagger = "" ;
                Q2D:coordinates = "XLONG XLAT" ;
        float T2D(Time, south_north, west_east) ;
                T2D:FieldType = 104 ;
                T2D:MemoryOrder = "XY " ;
                T2D:description = "TEMP at 2 M" ;
                T2D:units = "K" ;
                T2D:stagger = "" ;
                T2D:coordinates = "XLONG XLAT" ;
        float SWDOWN(Time, south_north, west_east) ;
                SWDOWN:FieldType = 104 ;
                SWDOWN:MemoryOrder = "XY " ;
                SWDOWN:description = "DOWNWARD SHORT WAVE FLUX AT
GROUND SURFACE" ;
                SWDOWN:units = "W m-2" ;
                SWDOWN:stagger = "" ;
                SWDOWN:coordinates = "XLONG XLAT" ;
        float LWDOWN(Time, south_north, west_east) ;
```

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WRF-Hydro Output Data:

WRF-Hydro Outputs:

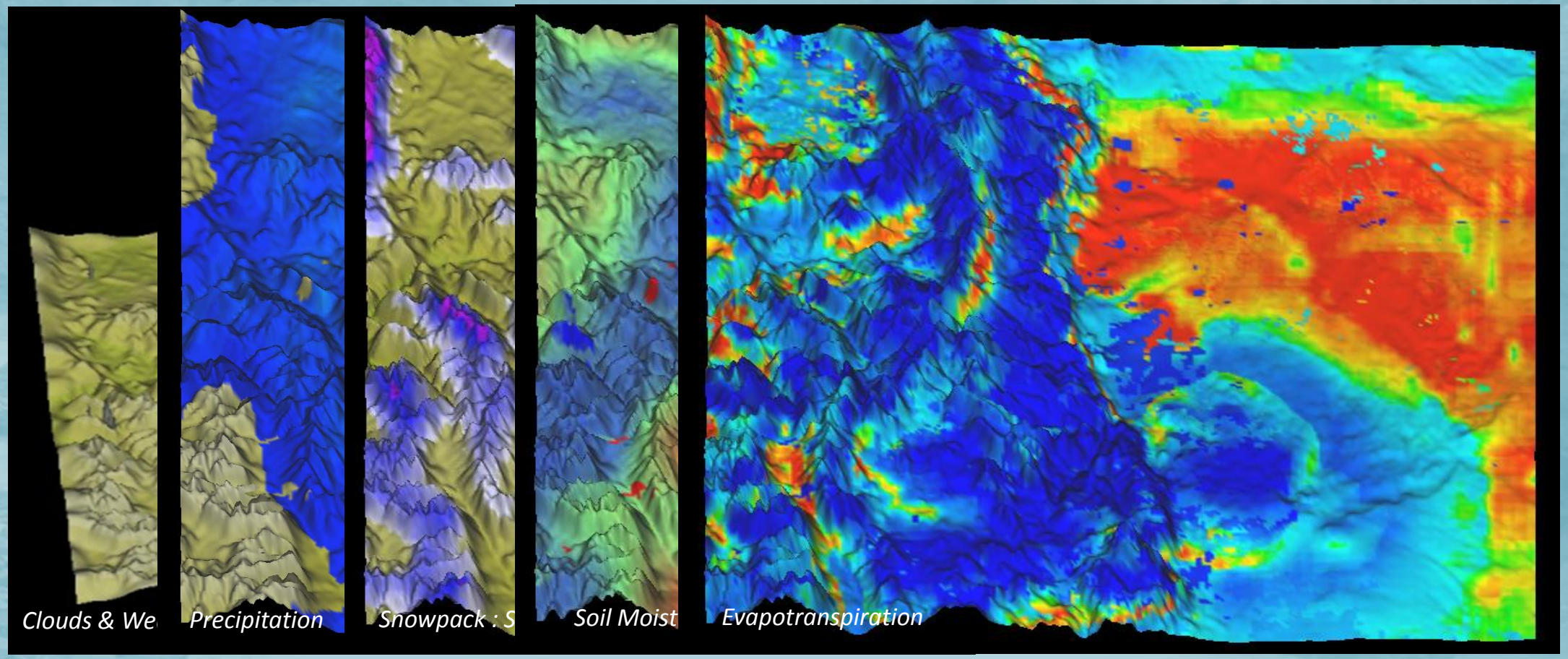
1. Model Outputs:
   a) Standard WRF model output, when run in coupled mode…

   b) LSM gridded output (netcdf)

   c) Routing outputs:
      a) High resolution gridded output (netcdf, not common due to filesize)
      b) Channel-inflow (ascii timeseries)
      c) Station observations (netcdf point file AND ascii timeseries)
      d) Full channel network output (netcdf point file)
      e) Lake/reservoir output (netcdf point file)
      f) Groundwater/baseflow output (3 ascii timeseries files)

WRF-Hydro Outputs:

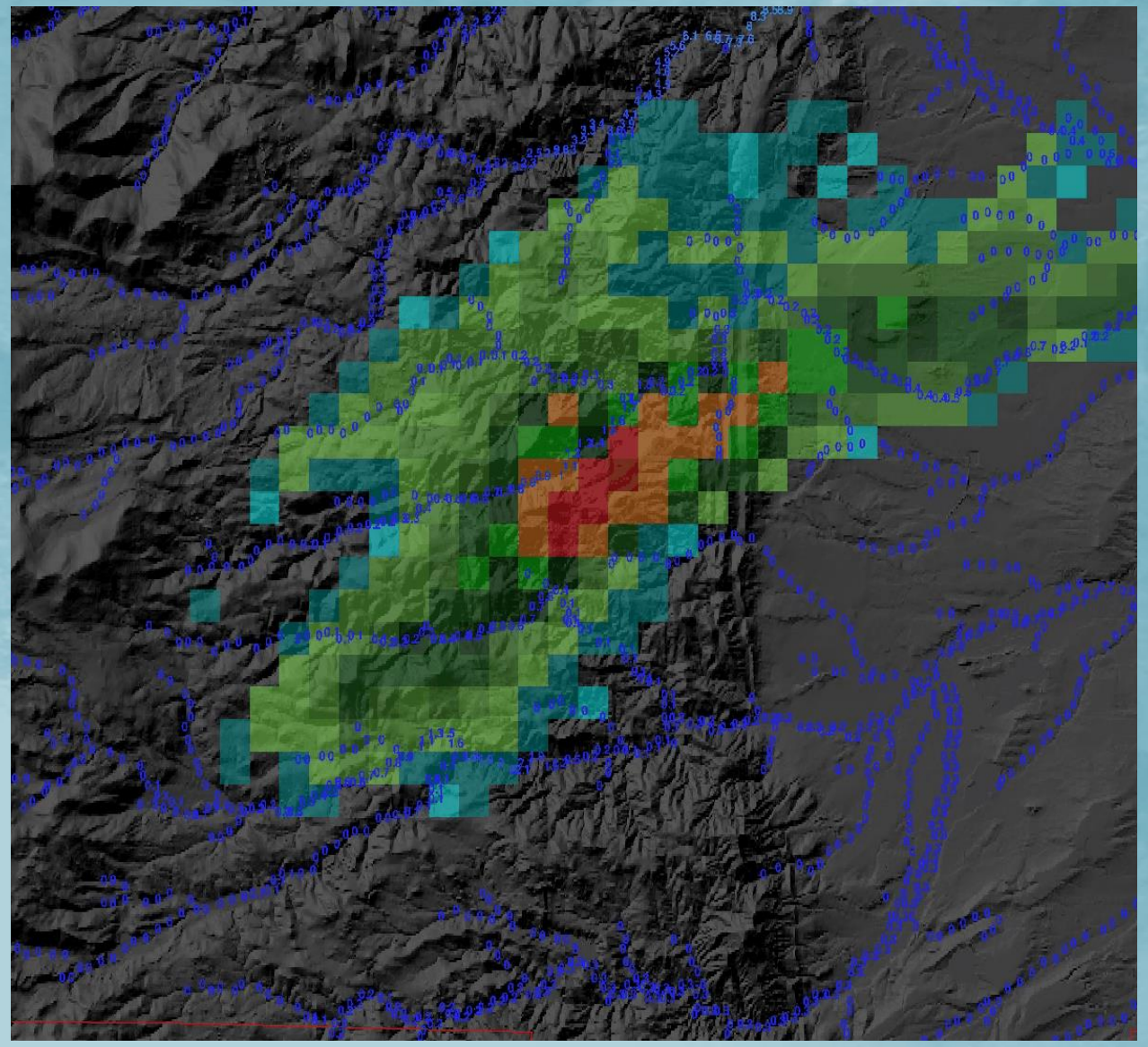
- Standard WRF/LSM outputs: (IDV visualization)



WRF-Hydro Outputs:

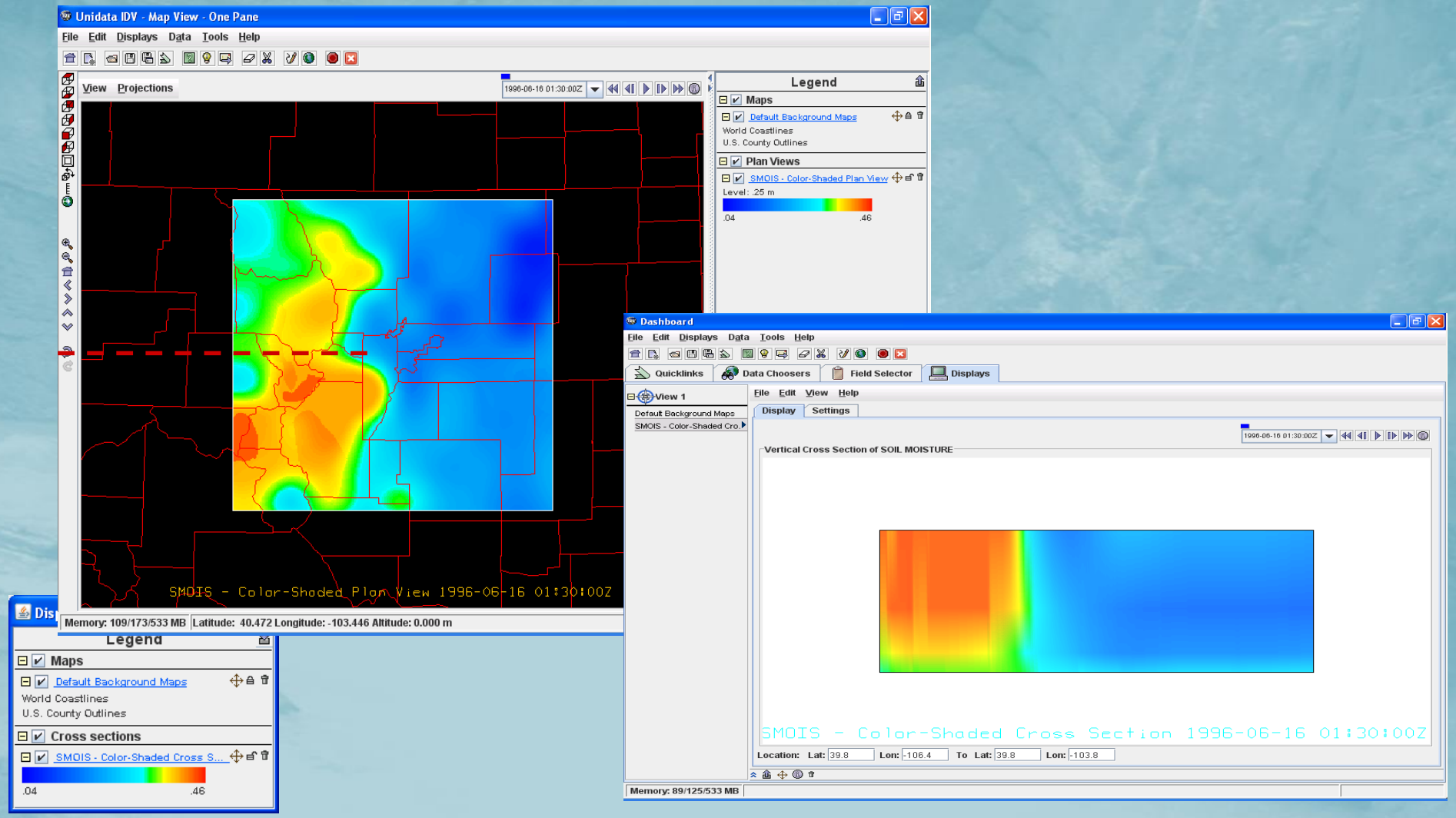
- 'Hydro'-specific data:
  - Ponded water
  - Streamflow
  - Water table depth

IDV – overlays of accumulated rainfall and streamflow



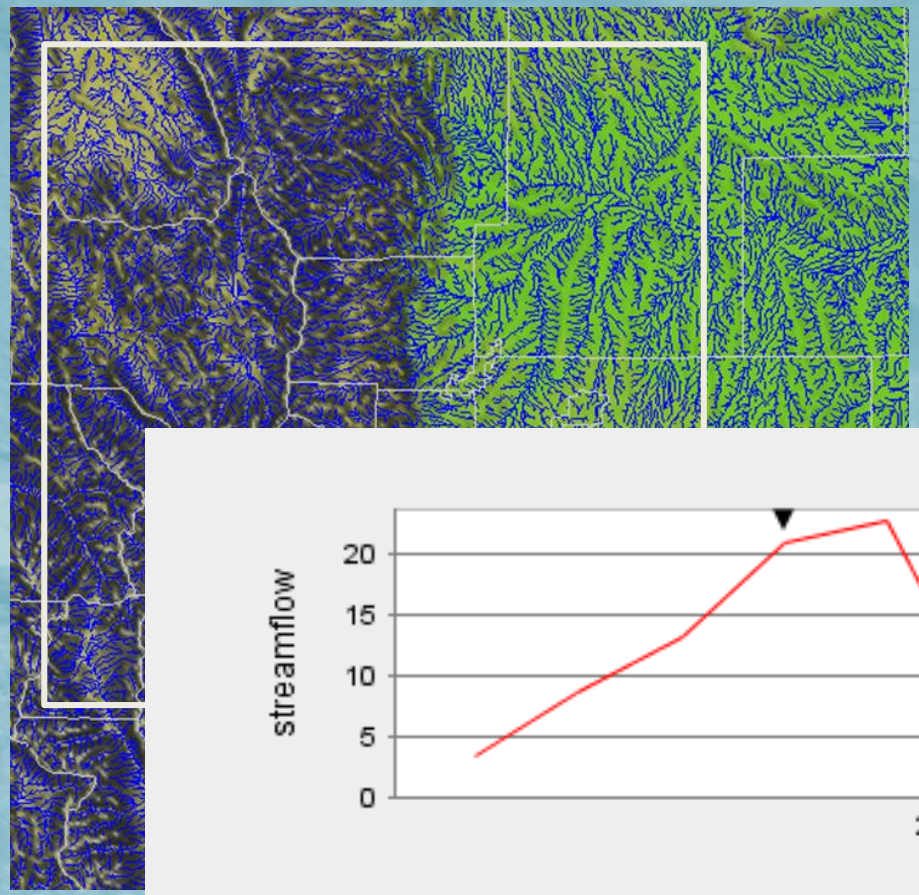
WRF-Hydro output products: IDV

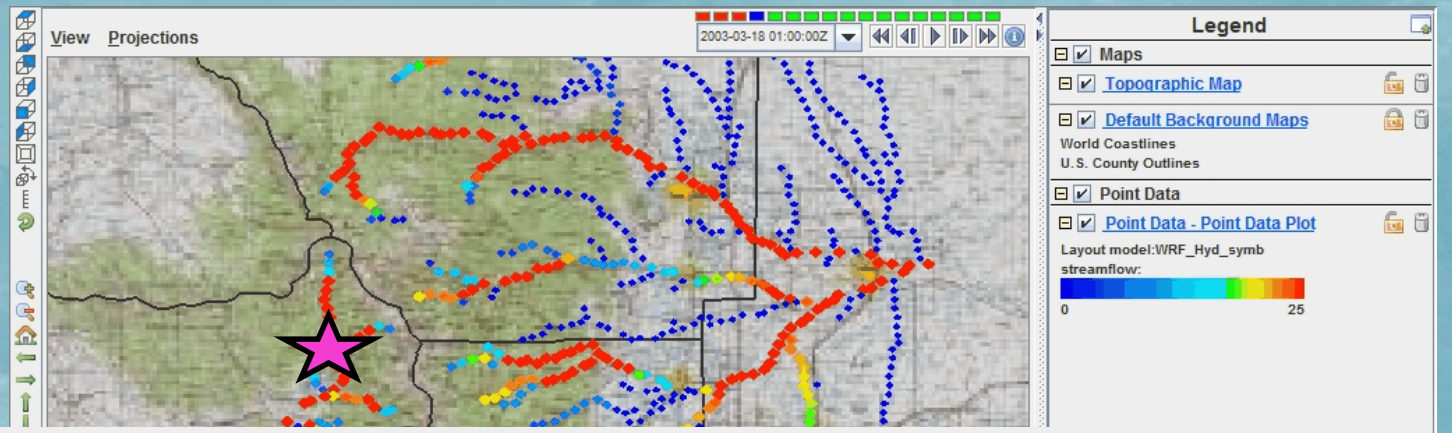
- Soil moisture plan view and vertical cross-section

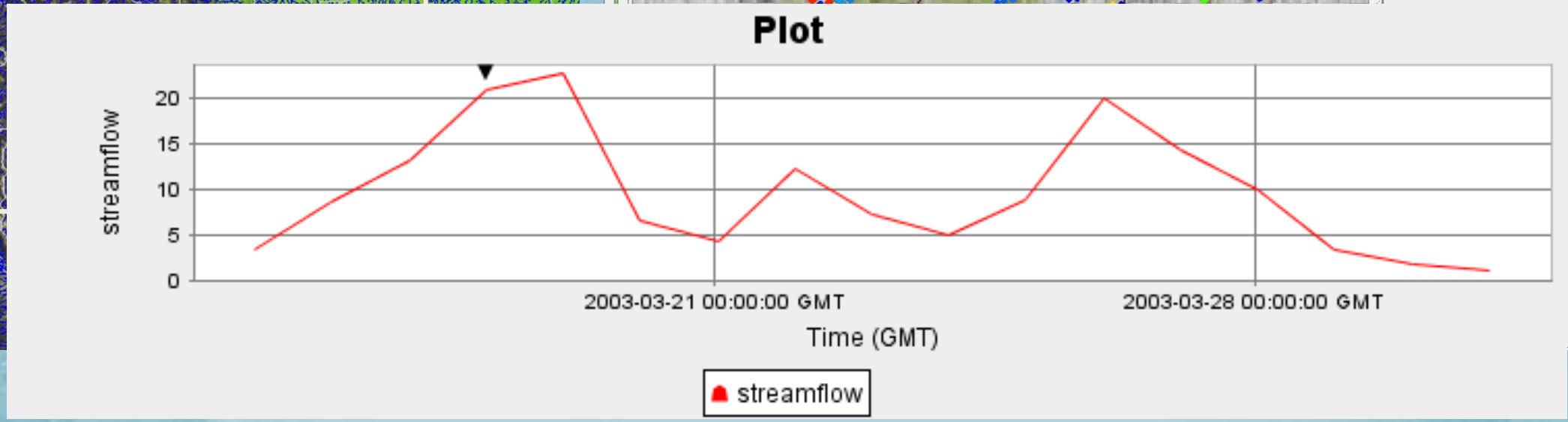


WRF-Hydro output products: Additional examples…IDV

Channel Flows at spatial resolutions of 10s to 100s of meters

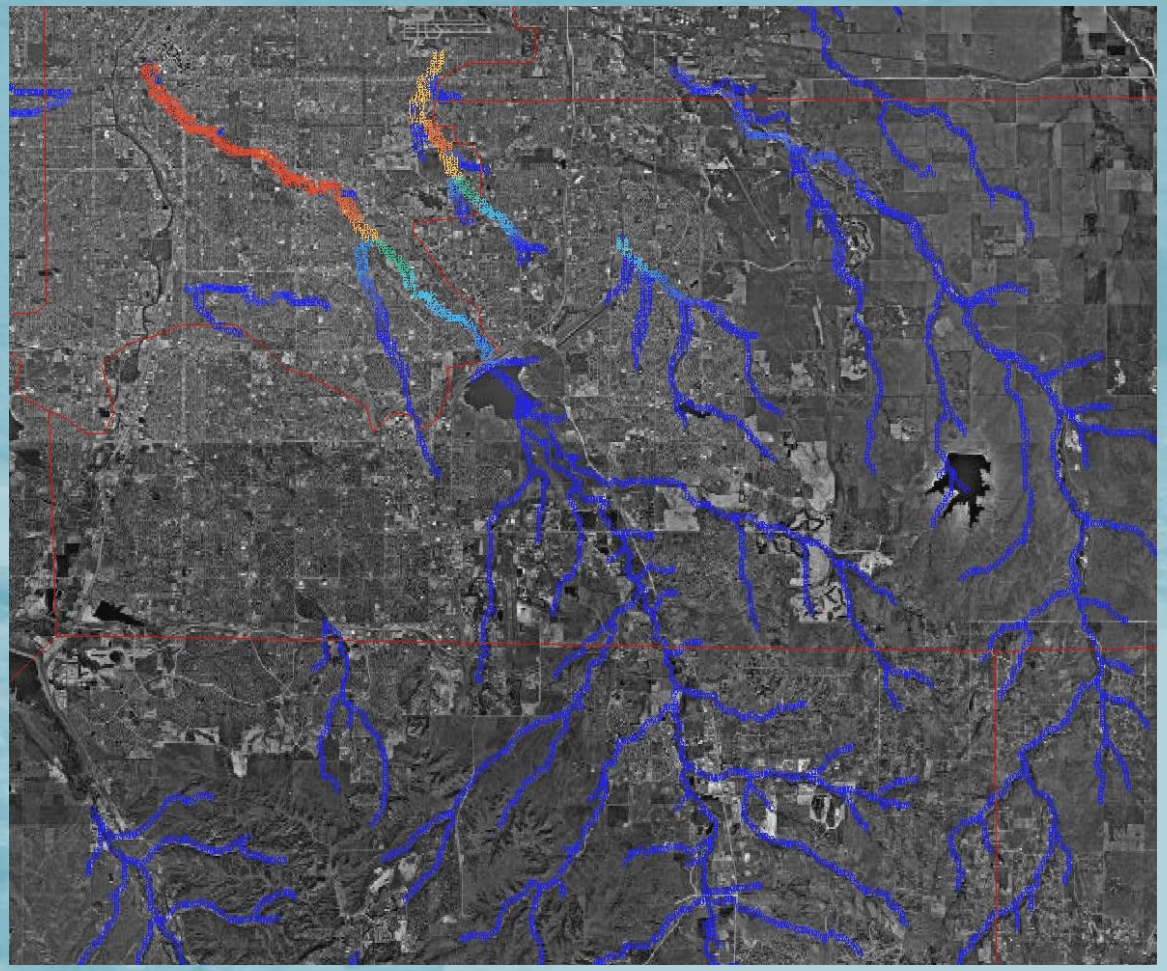




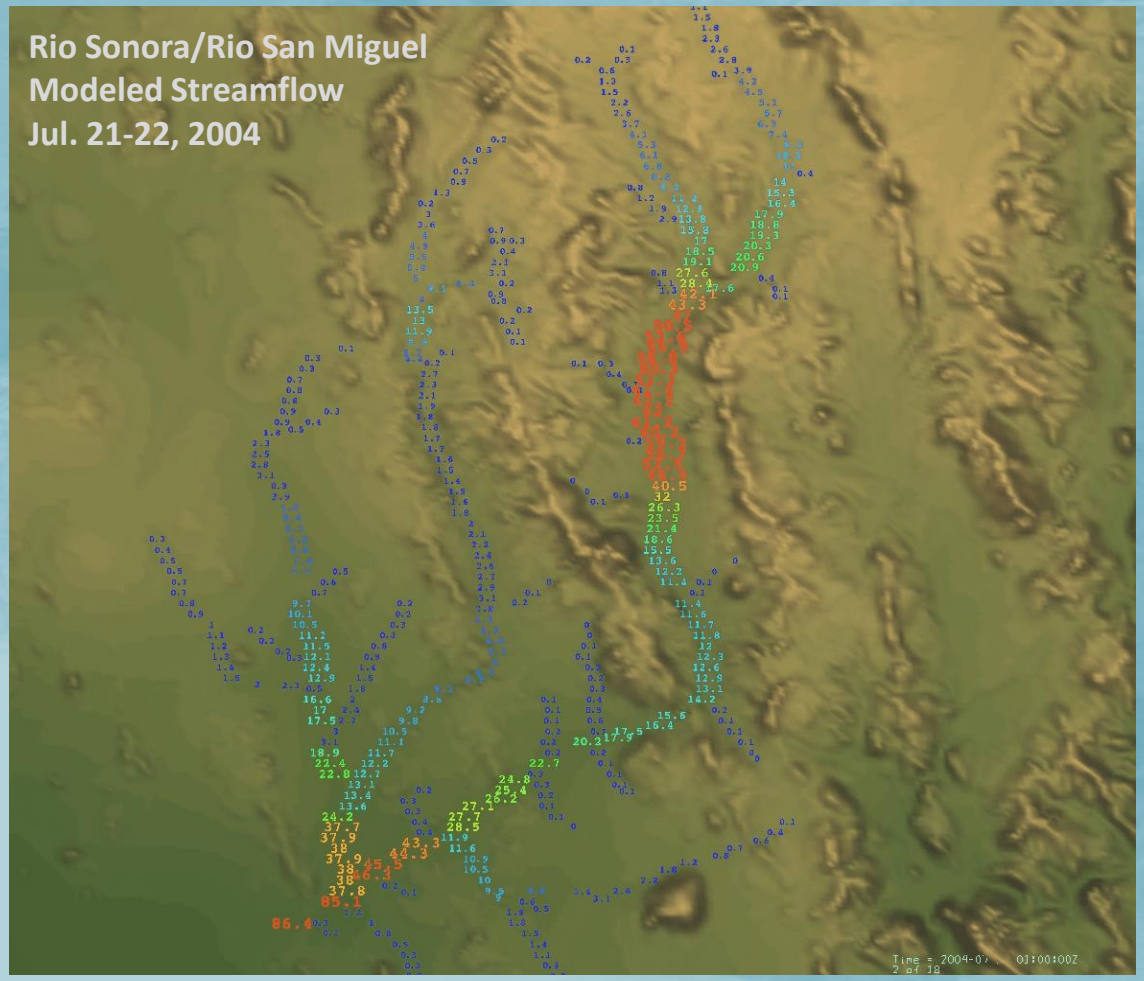


WRF-Hydro output products: Additional examples…IDV

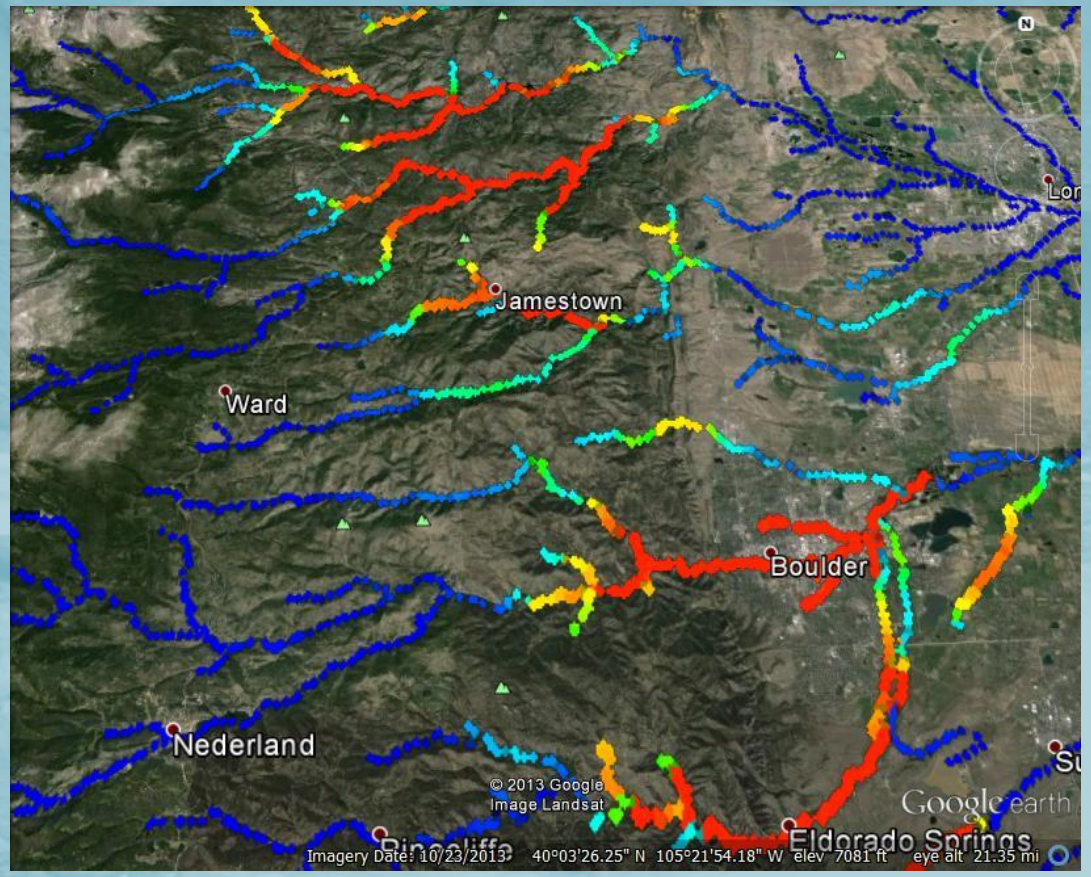
Urban Flooding: Genoa-2011



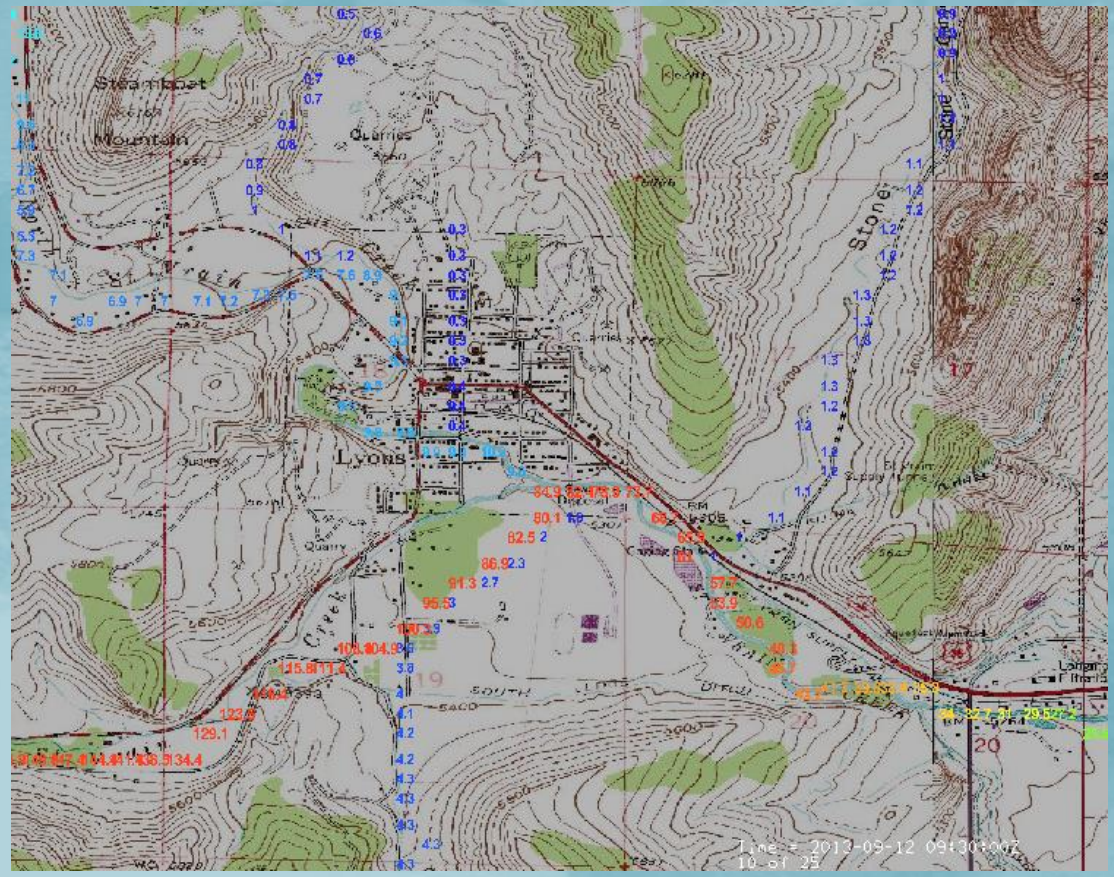
Northwest Mexico



WRF-Hydro output products: Additional examples…



Google Earth (kmz)



GIS map overlays

WRF-Hydro output tools: other options

- ncview, NASA-Panoply: general netcdf file viewers
- ncl (NCAR command language): good all purpose netcdf-based analysis and visualization scripting language
- ArcGIS, qGIS: Good for integrating with other GIS data layers, have scripts to support import and projection definition for ArcGIS
- R : just getting started, building scripting capabilities for streamflow forecast verification and general time-series analysis and some graphing