

# Data I/O Requirements :

# 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

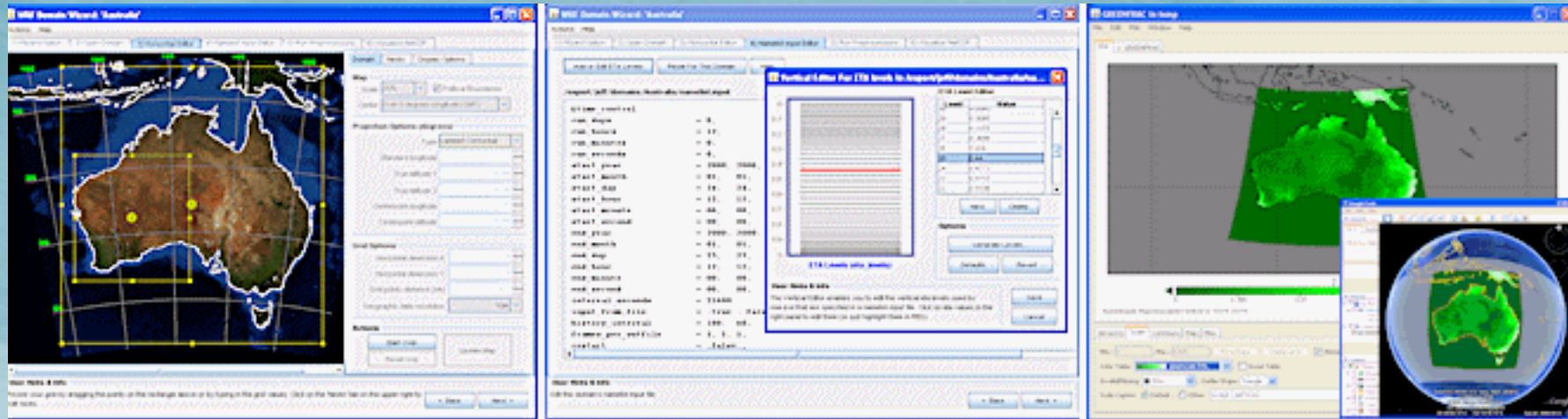
# General Requirements:

- 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...)

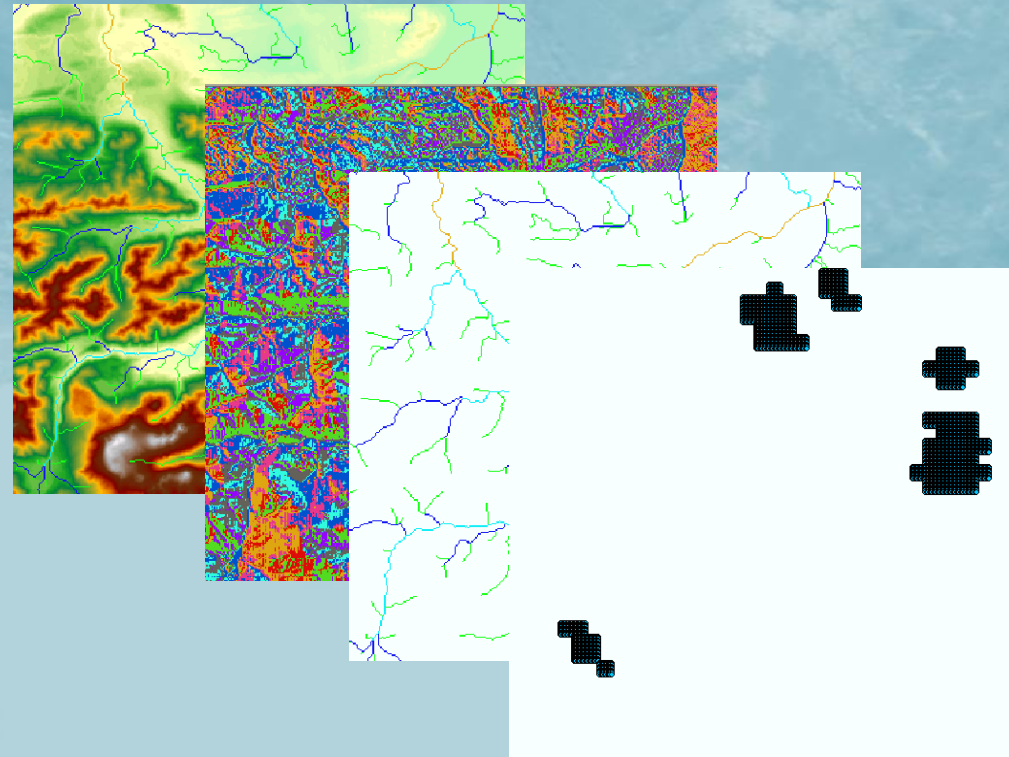
# Inputs:

## 1. Routing Grid:

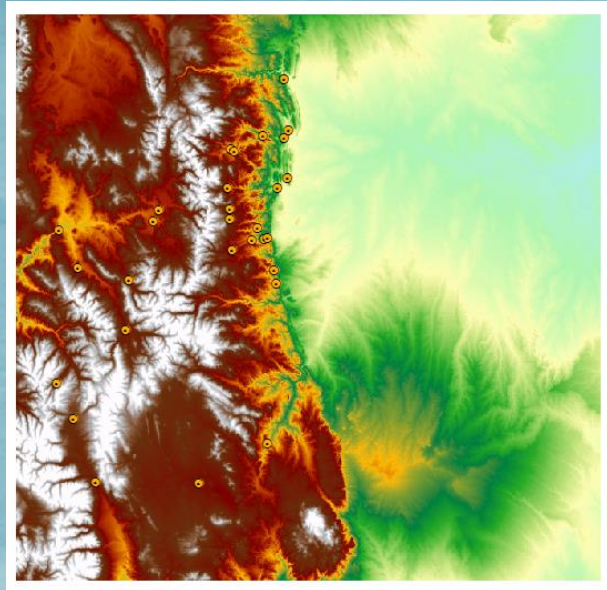
a) High-resolution terrain routing grids: These data are on a fine-resolution terrain grid ( $\sim < 100\text{m}$ ) and are typically created within a GIS such as ArcGIS or manually... (with a little work)... details will be discussed this afternoon...

b) Necessary variables are:

- LATITUDE
- LONGITUDE
- TOPGRAPHY
- FLOWDIRECTION
- CHANNELGRID
- STREAMORDER
- LAKEGRID
- frxst\_pts
- gw\_basns
- calibration fields



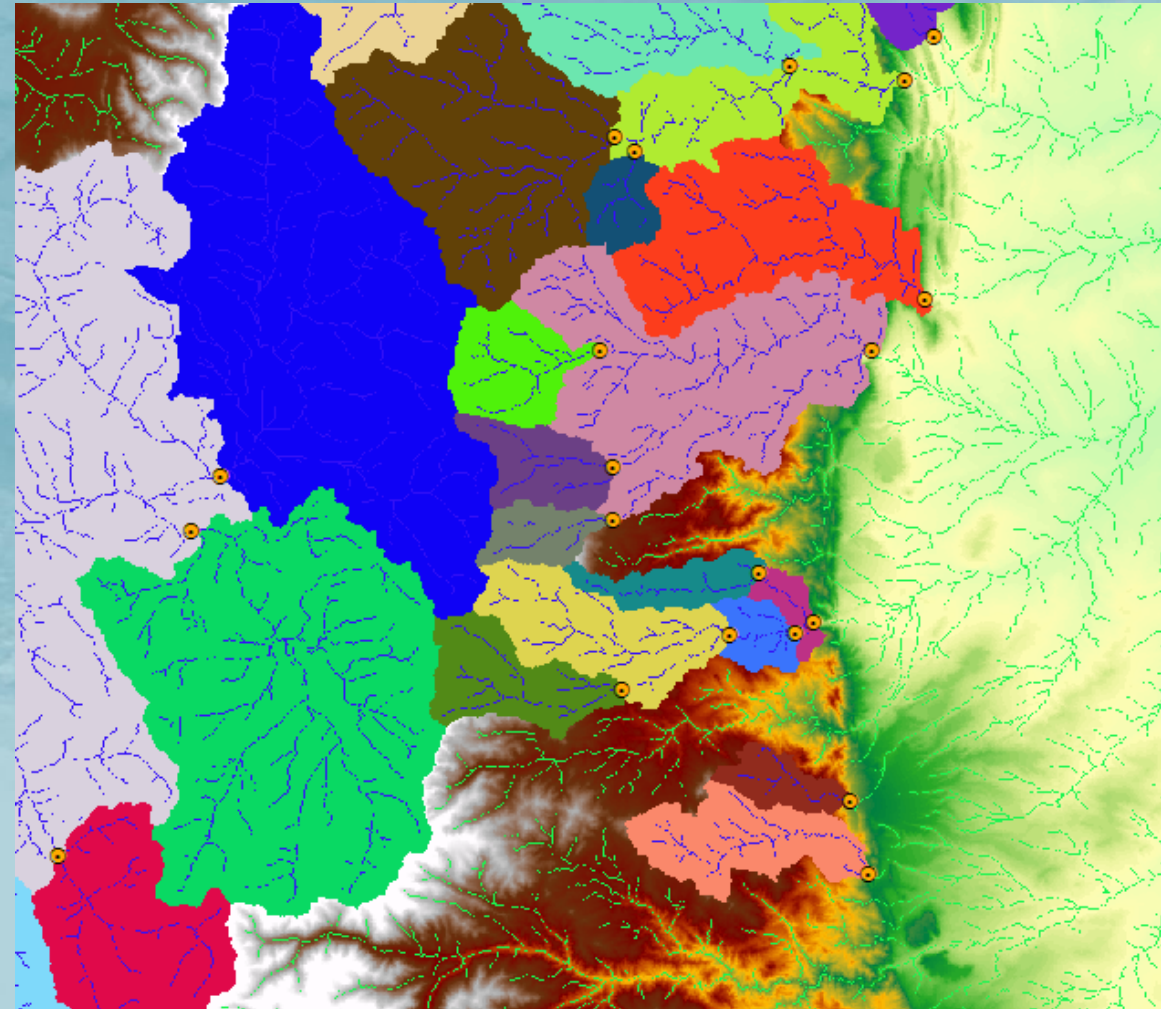
# WRF-Hydro 'Hydro-Grid' ArcGIS: Tool Output



Import:  
geogrid terrain



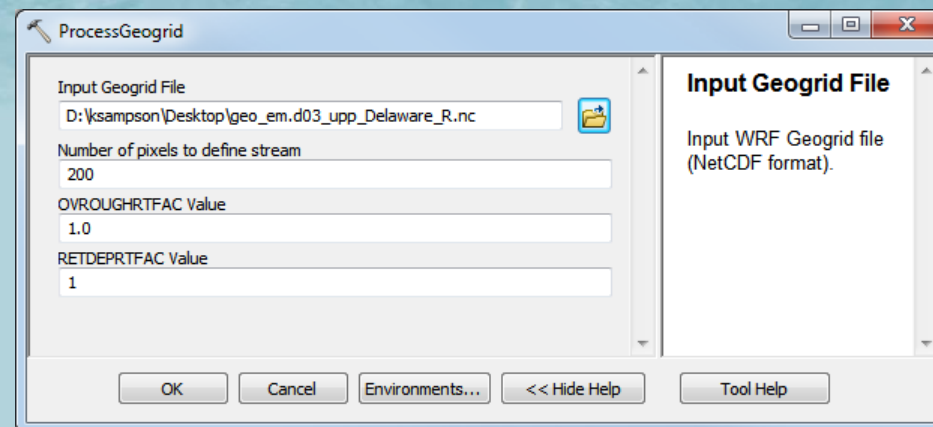
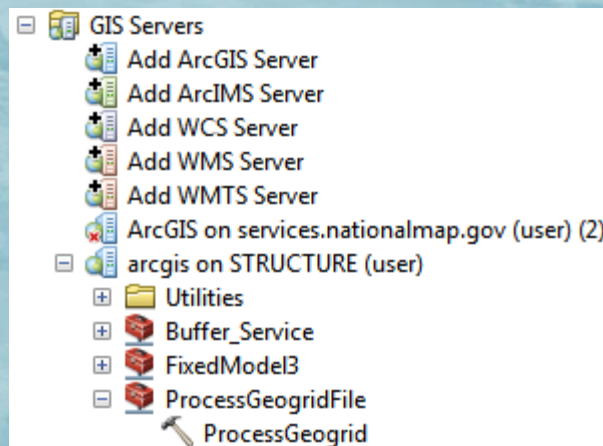
Create:  
Hydrological  
routing grids



# 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:

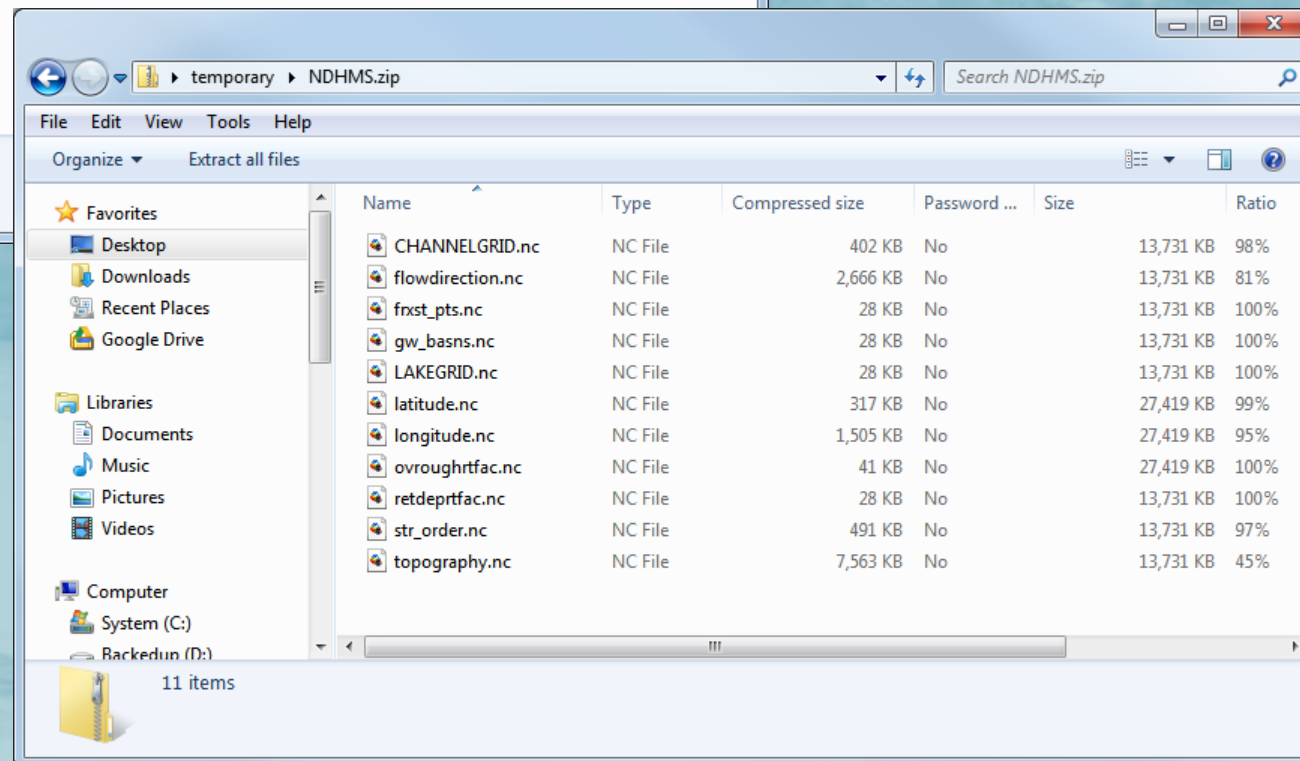
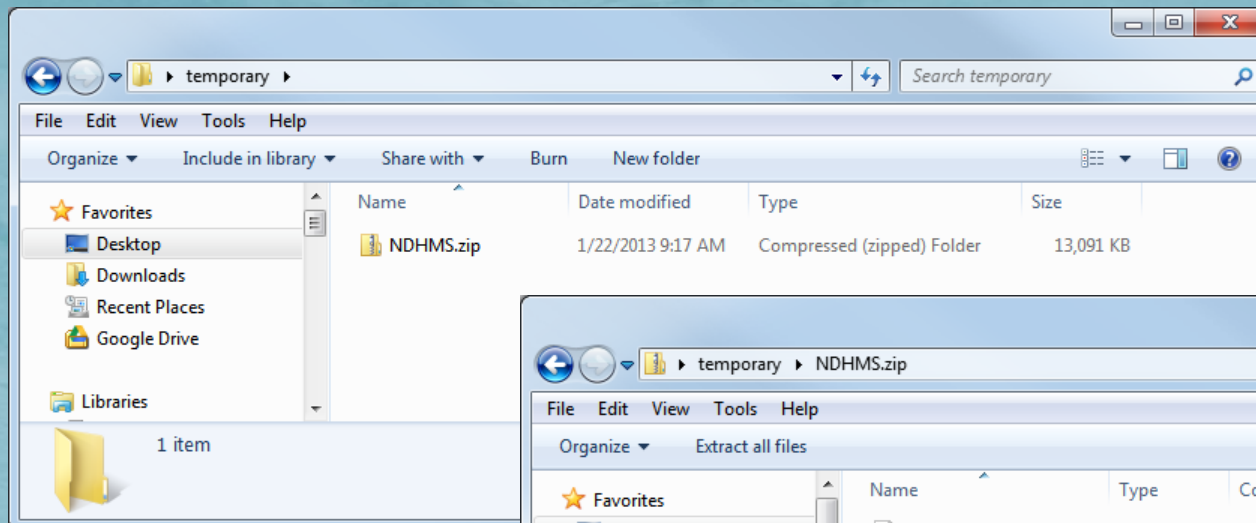
The screenshot shows a dialog box titled "ProcessGeogridFile" with the following fields and options:

- Input Geogrid File**: A text input field with a folder icon to its right.
- Forecast Points (CSV) (optional)**: A text input field with a folder icon to its right.
- Mask CHANNELGRID to basins? (optional)**: An unchecked checkbox.
- Input Raster**: A text input field with a folder icon to its right.
- Regridding Factor**: A text input field containing the value "10" with a folder icon to its right.
- Number of pixels to define stream**: A text input field containing the value "200" with a folder icon to its right.
- Output ZIP File**: A text input field with a folder icon to its right.
- Parameter Values**: A collapsed section indicated by a downward-pointing chevron.

At the bottom of the dialog box are four buttons: "OK", "Cancel", "Environments...", and "Show Help >>".

1-10 min.  
to complete

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



# WRF-Hydro 'Hydro-Grid' ArcGIS tool:

The screenshot shows a Mozilla Firefox browser window displaying the WRF-Hydro Modeling System website. The browser's address bar shows the URL "RAL || WRF-Hydro Modeling System". The website's navigation menu includes links for "RAL home", "research", "technology", "people/org", "publications", "events", "pressroom", and "for staff". The main content area features a header with "NCAR WRF-Hydro Modeling System | RAL" and a search bar. Below the header, a breadcrumb trail reads "You are here: NCAR • RAL • WRF-Hydro Modeling System". A left-hand navigation menu lists "Home", "Terms of Use", "Overview", "Downloads", "Documentation", "User Support", and "Related Links". The main content area is titled "WRF-Hydro Modeling System" and includes a "Welcome" section, a "Description" section, and a "Projects" section. The "Description" section states: "The WRF-Hydro system was originally designed as a model coupling framework designed to facilitate easier coupling between the Weather Research and Forecasting model and components of terrestrial hydrological models. WRF-Hydro is both a stand-alone hydrological modeling architecture as well as a coupling architecture for coupling of hydrological models with atmospheric models. WRF-Hydro is fully-parallelized to enable its usage on clusters and high performance computing systems alike. Like the WRF model it does not attempt to prescribe a particular or singular suite of physics but, instead, is designed to be extensible to new hydrological parameterizations. Although it was originally designed to be used within the WRF model, it has evolved over time to possess many additional attributes as follows:"

- Multi-scale functionality to permit modeling of atmospheric, land surface and hydrological processes on different spatial grids

The "Projects" section is divided into "Current Projects" and "Past Projects". "Current Projects" includes links for "HYDROMETEOROLOGICAL PROCESSES AT THE LAND SURFACE", "Colorado Headwaters Water System Program", "Flash Flood System (view article)", "North American Monsoon Experiment (view article)", and "Climate Impacts on local water resource management tool: WEAP (view article)". "Past Projects" includes links for "CASES-97 (Cooperative Atmosphere Surface Exchange Study)", "IHOP (Soil Moisture, Soil Temperature, and Vegetation Observation Network)", and "Recent Accomplishments and Plans". A "Sponsor" section at the bottom right contains the text "Need Sponsor Name". The browser's taskbar at the bottom shows the system time as 7:21 PM on 3/13/2013.

# 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

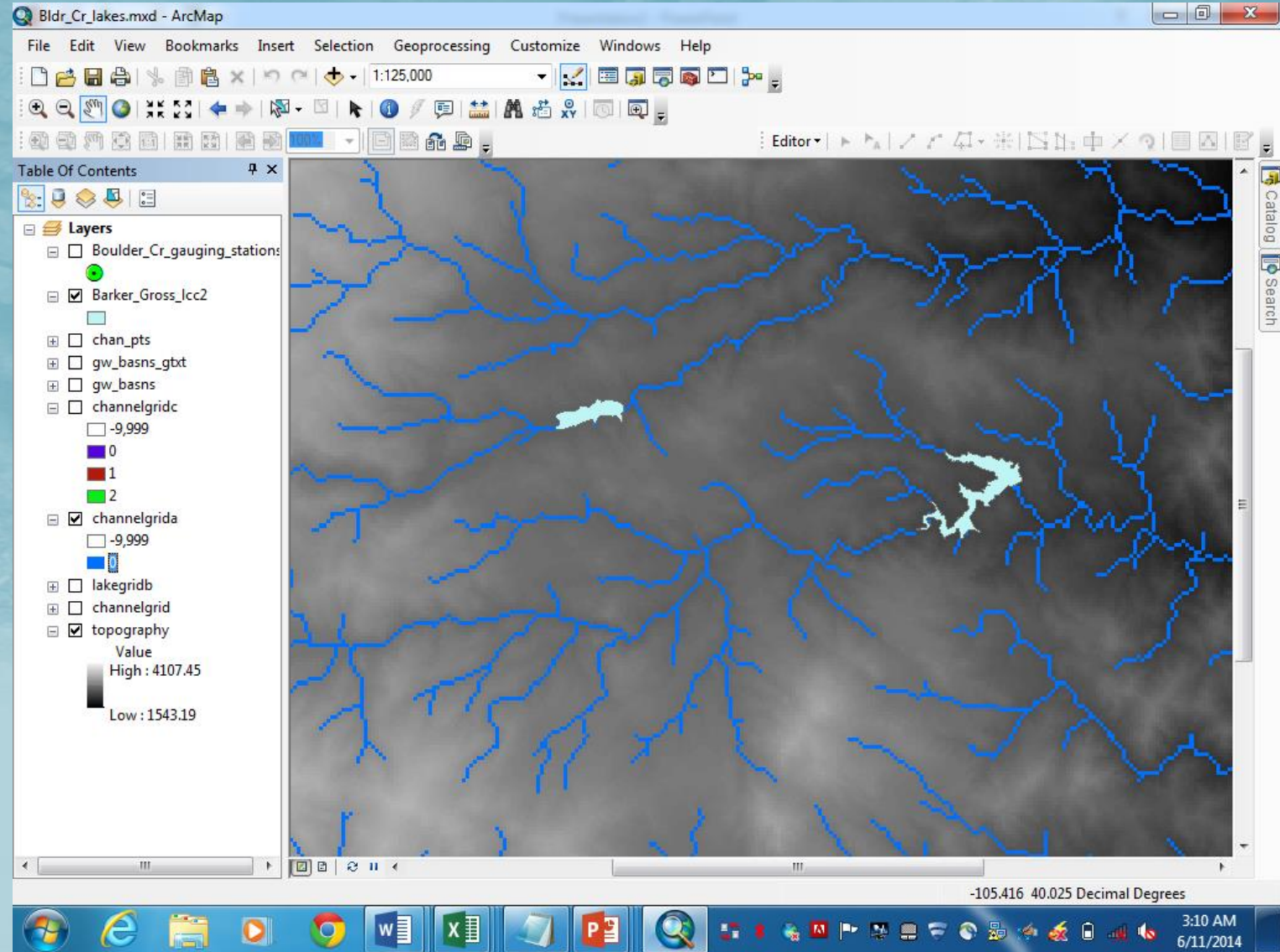
# Outline: Implementing lakes and reservoirs in WRF-Hydro

- 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:

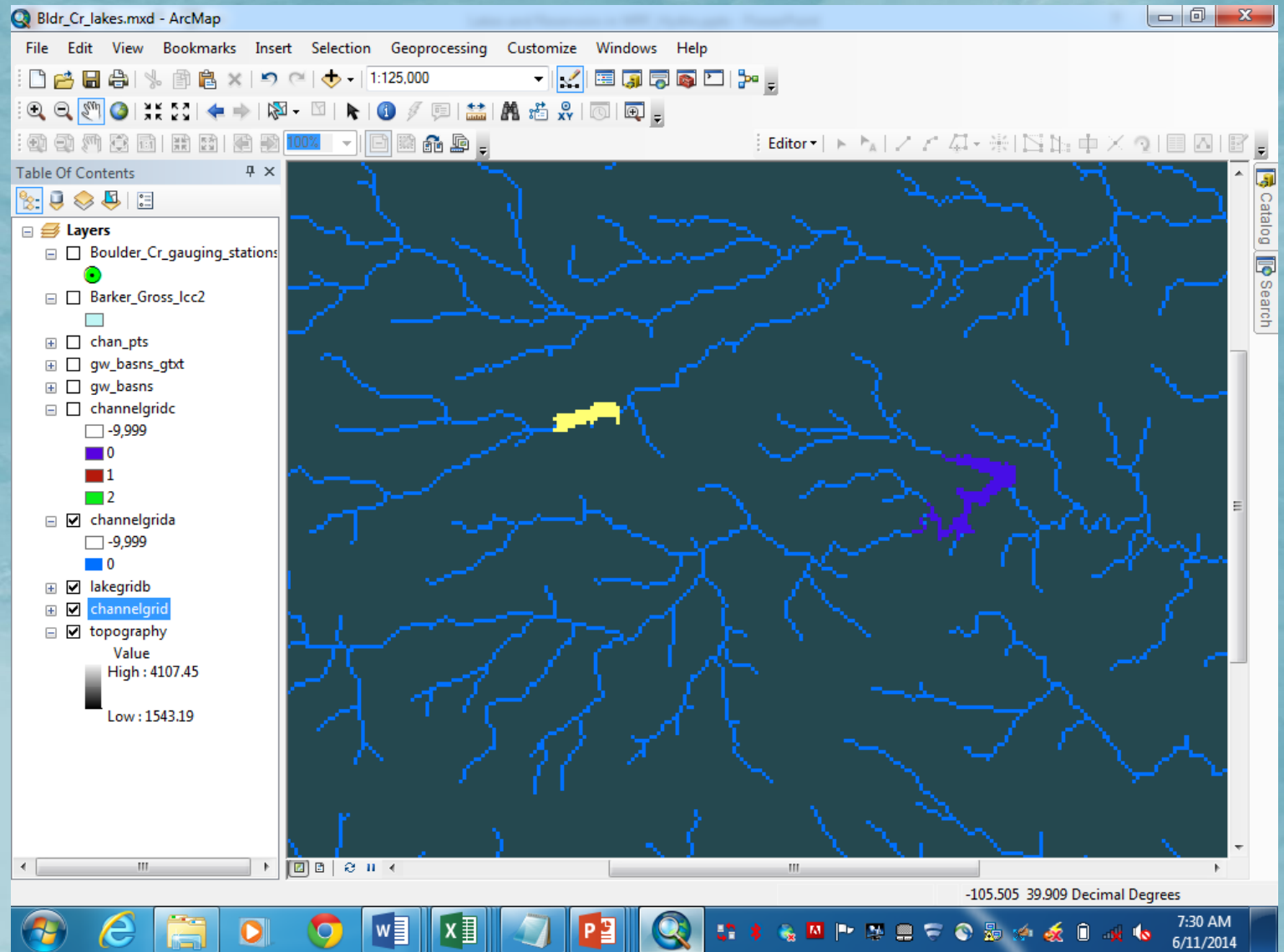
# Implementing lakes and reservoirs in WRF-Hydro

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



# Implementing lakes and reservoirs in WRF-Hydro

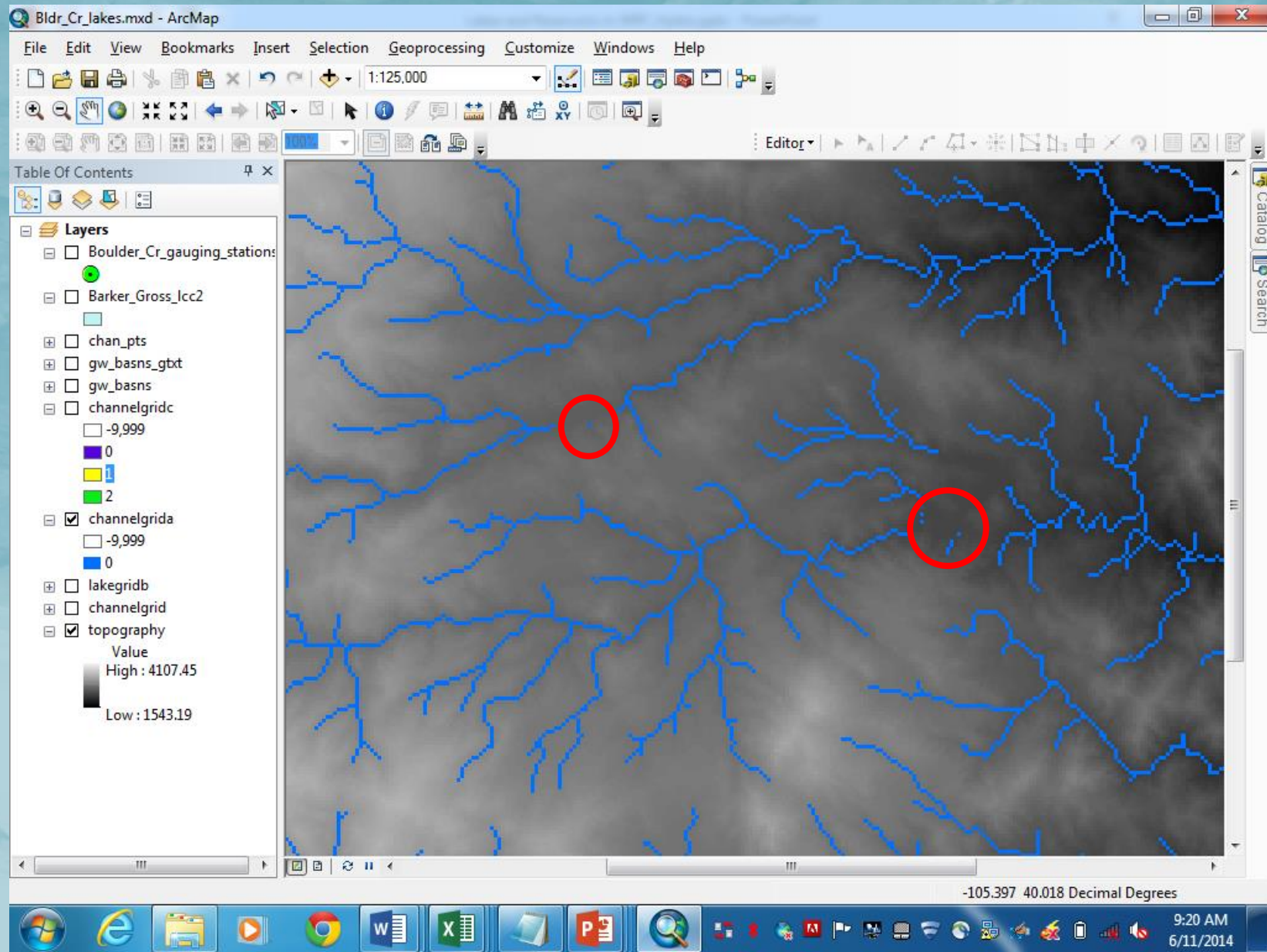
1. Convert lake polygon into grid at the same resolution and projection as the channel grid





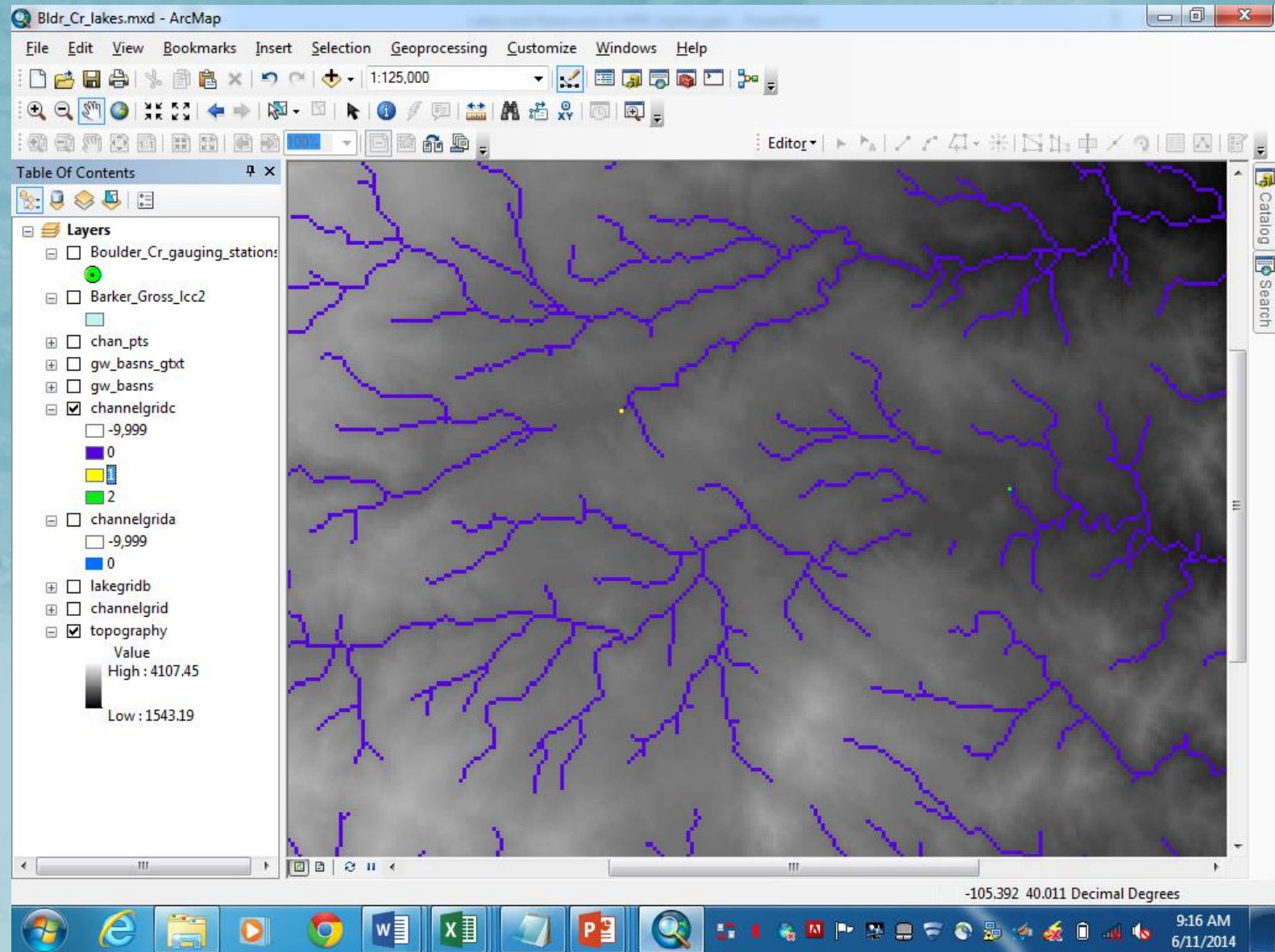
# Implementing lakes and reservoirs in WRF-Hydro

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



# 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



# Implementing lakes and reservoirs in WRF-Hydro

## 1. Parameter Table (LAKEPARAM.TBL)

A7. Lake parameters table (LAKEPARAM.TBL)

LAKEPARAM.TBL

<u>lake</u>	<u>LkArea</u>	<u>LkMxH</u>	<u>WeirC</u>	<u>WeirL</u>	<u>OrificC</u>	<u>OrificeA</u>	<u>OrificeE</u>
	<u>lat</u>	<u>long</u>		<u>elevation</u>			
1	9.67	1752.1	0.4	12.1	0.1	1.0	1664.4
	40.5580	-105.1586		1752.1			
2	3.07	1530.8	0.4	3.8	0.1	1.0	1519.6
	40.4407	-105.0586		1530.8			
3	1.61	1537.7	0.4	2.0	0.1	1.0	1528.7
	40.4158	-105.0903		1537.7			
4	1.11	1554.6	0.4	1.4	0.1	1.0	1544.4
	40.3876	-105.1441		1554.6			
5	3.82	1785.1	0.4	4.8	0.1	1.0	1758.2
	40.3377	-105.2196		1785.1			
6	1.36	1569.5	0.4	1.7	0.1	1.0	1565.6
	40.3378	-105.1278		1569.5			
7	1.47	1571.1	0.4	1.8	0.1	1.0	1565.3
	40.3297	-105.1167		1571.1			

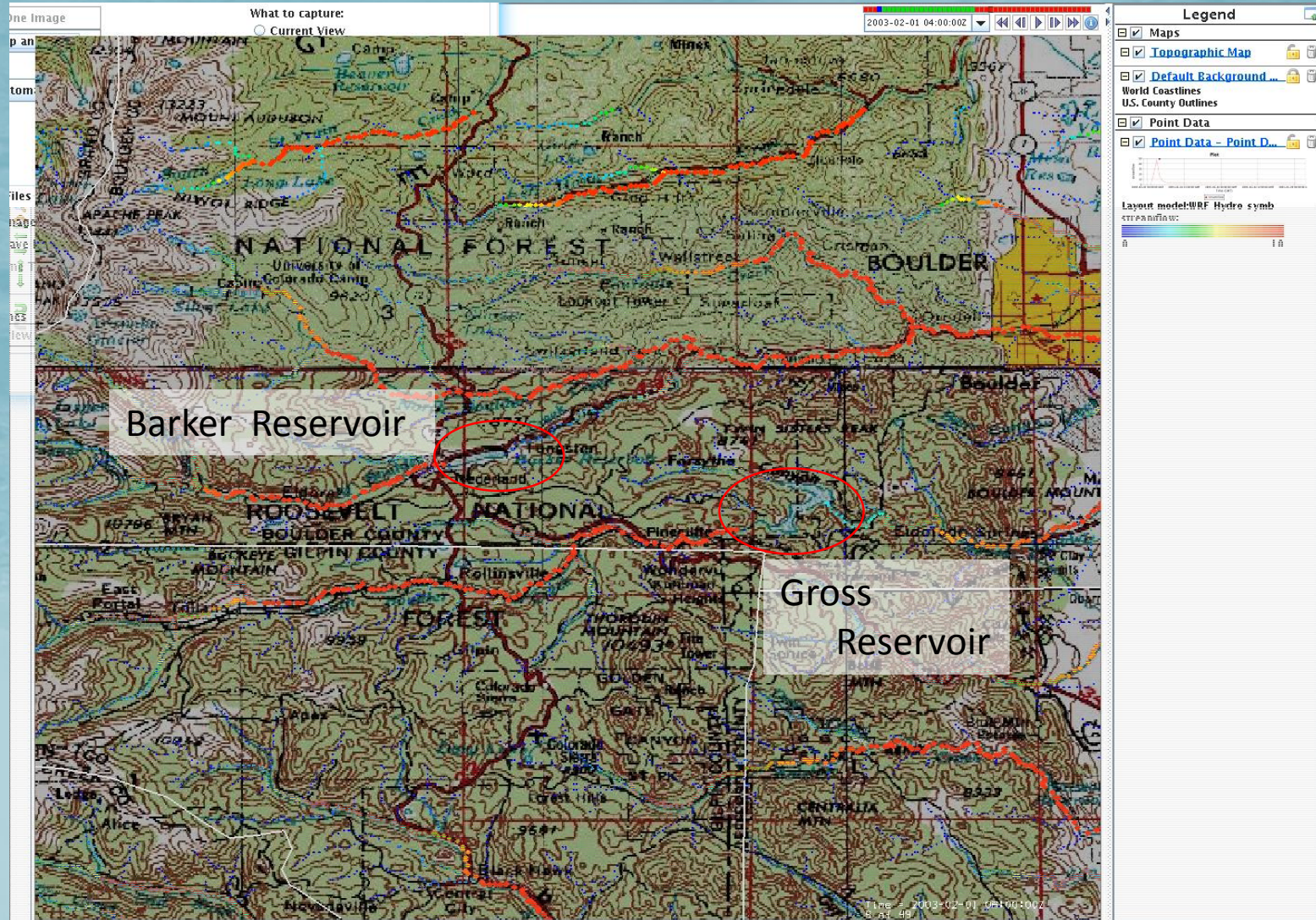
- this example assumes there are 7 lakes defined within the simulation domain (note column wrapping...)

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9:35 AM 6/11/2014

# Implementing lakes and reservoirs in WRF-Hydro

1. Visualization of lake impacts



# WRF-Hydro Forcing Data:

# Input Forcing Data Requirements:

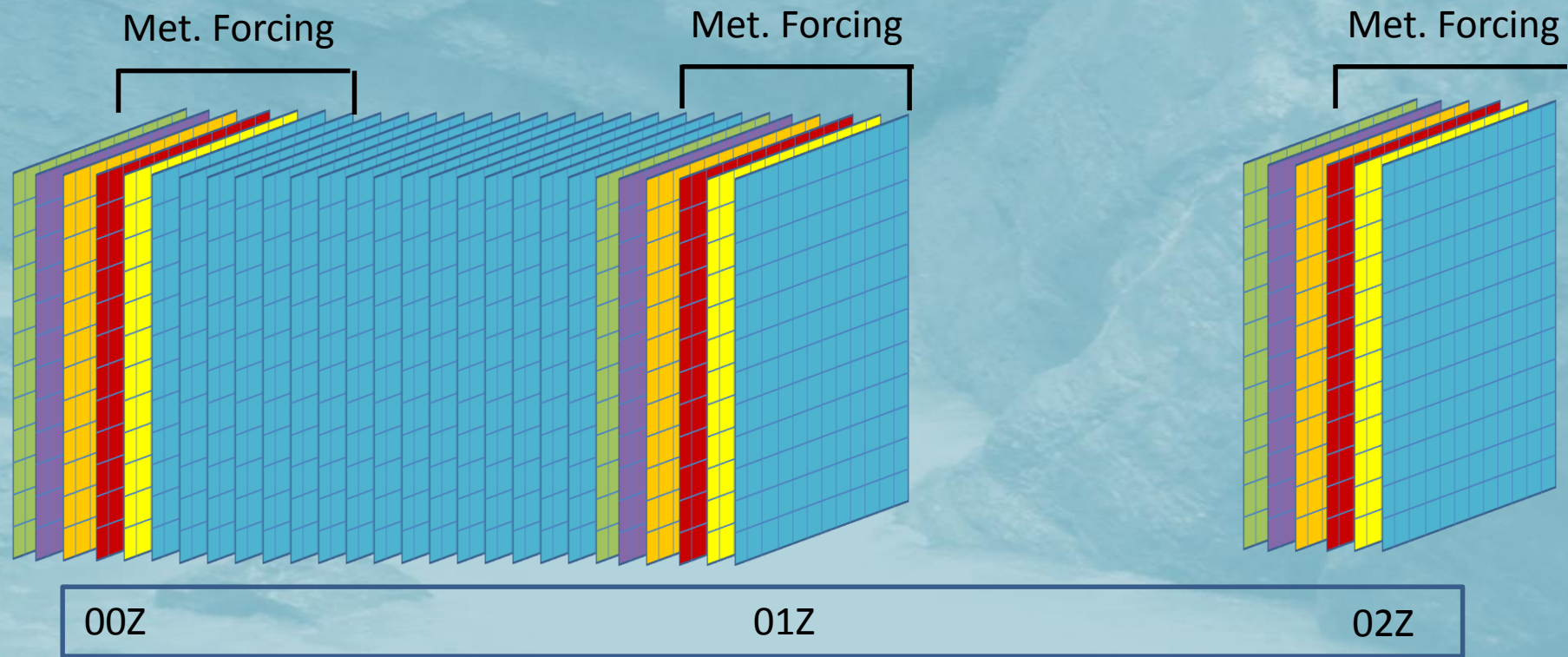
- Forcing Inputs:
  - Temperature (deg K), humidity-mixing ratio (kg/kg), short & longwave radiation ( $W/m^2$ ), pressure (Pa), wind speed (m/s) and precipitation rate (mm/s)
  - Optional formats of forcing data:
    - Fully-coupled model
    - Existing wrf output files
    - Unified analysis (all met. 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);
```

# 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)

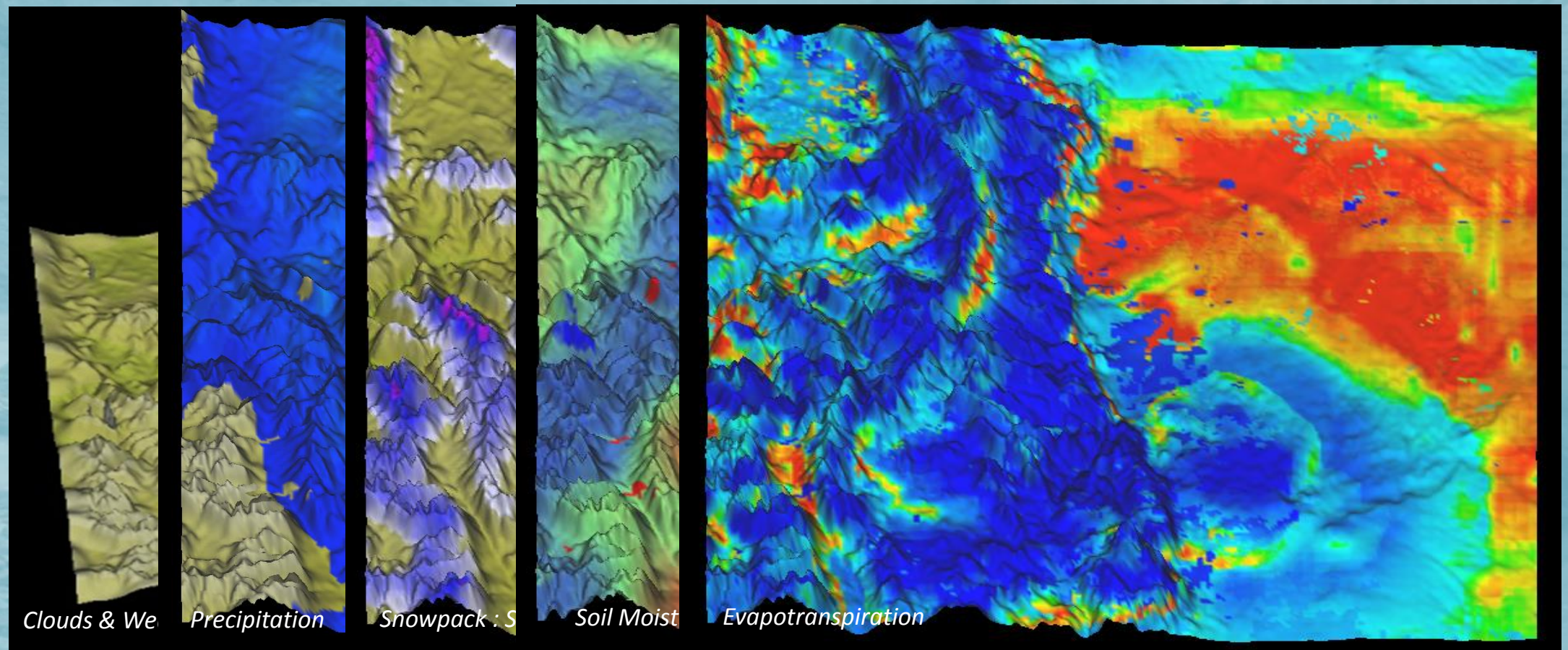
d) Full channel network output (netcdf point file)

e) Lake/reservoir output (netcdf point file)

f) Groundwater/baseflow output (3 ascii timeseries files)

# WRF-Hydro Outputs:

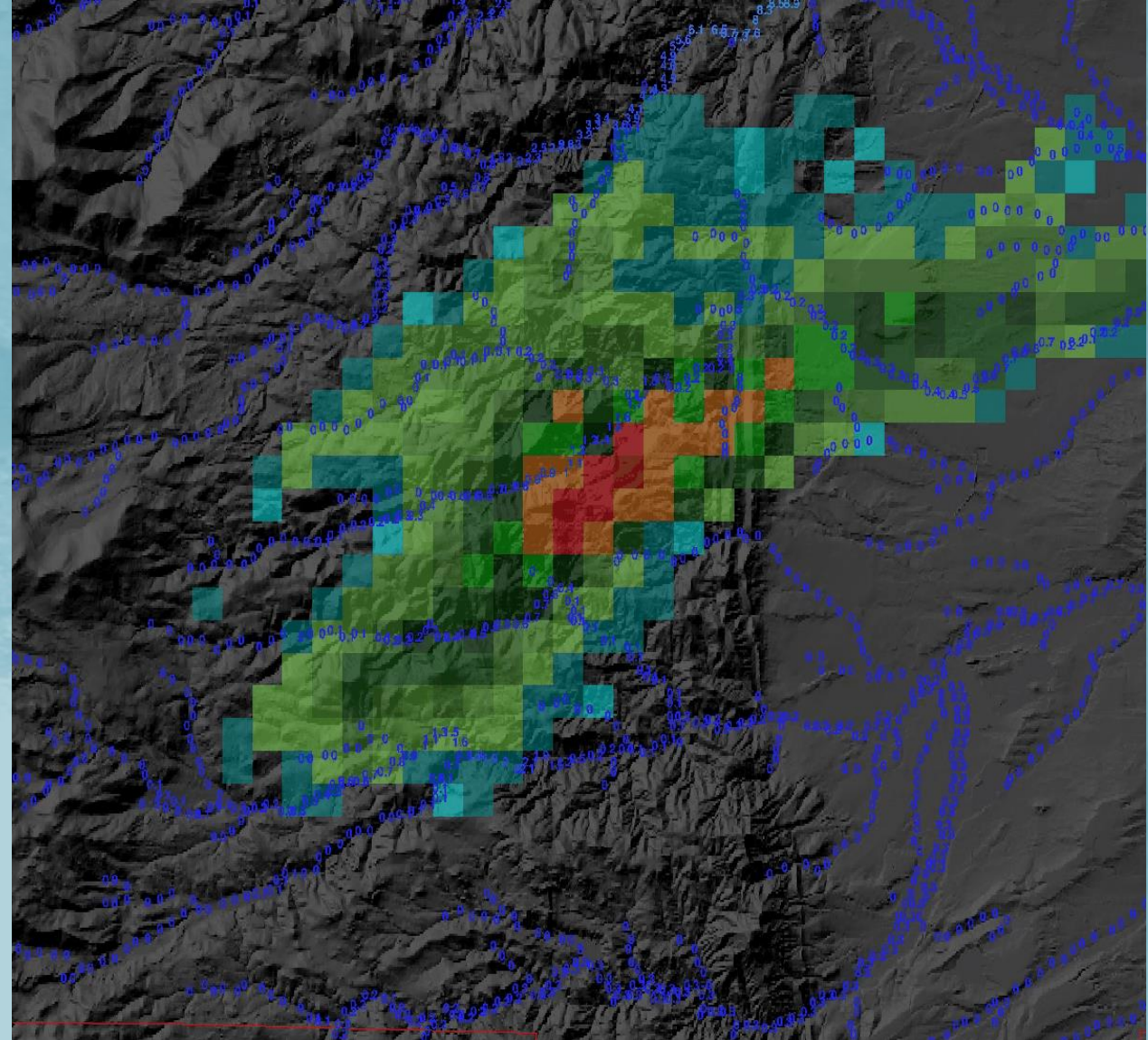
- Standard WRF/LSM outputs: (IDV visualization)



# WRF-Hydro Outputs:

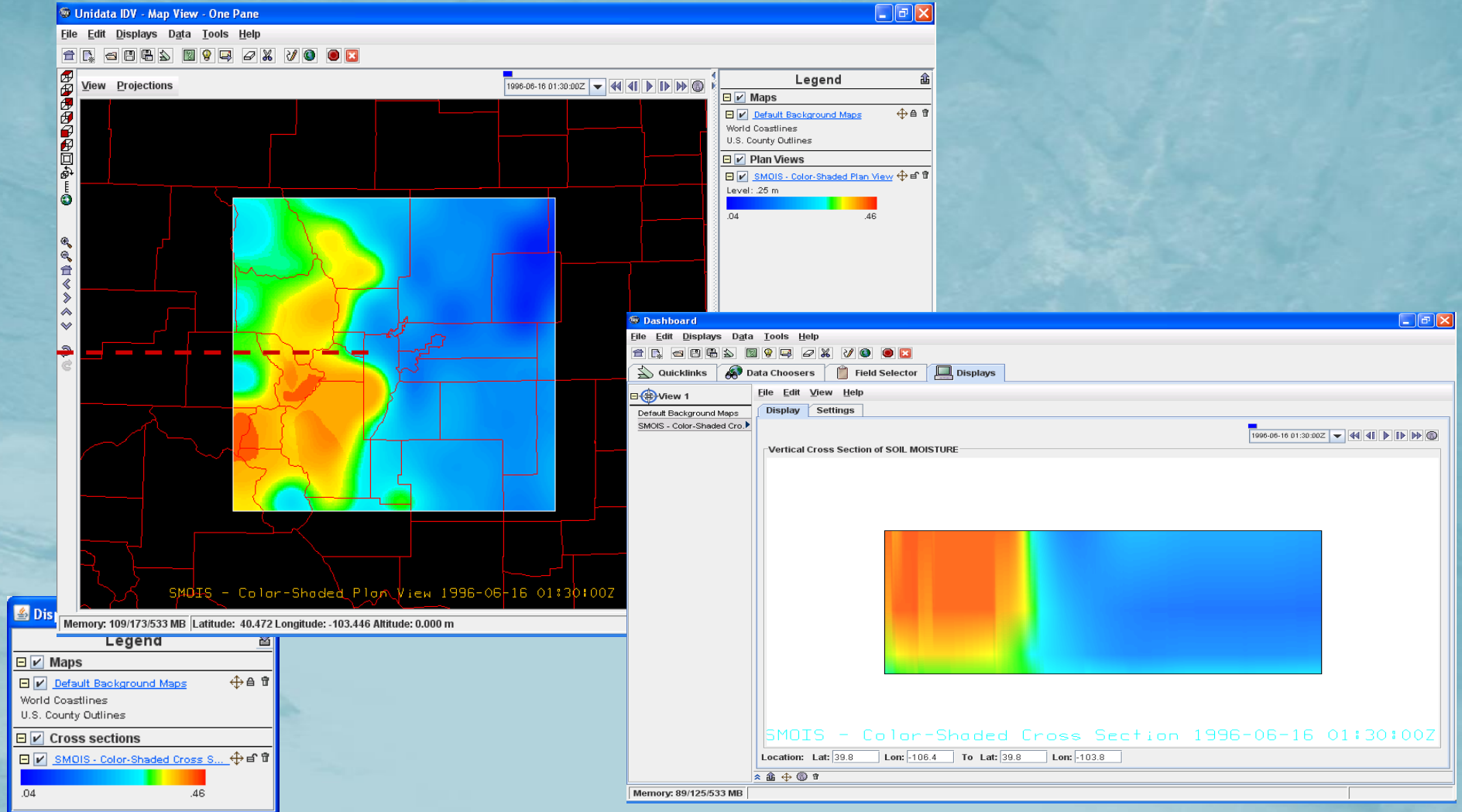
- ‘Hydro’-specific data:
  - Pondered water
  - Streamflow
  - Water table depth

IDV – overlays of accumulated rainfall and streamflow



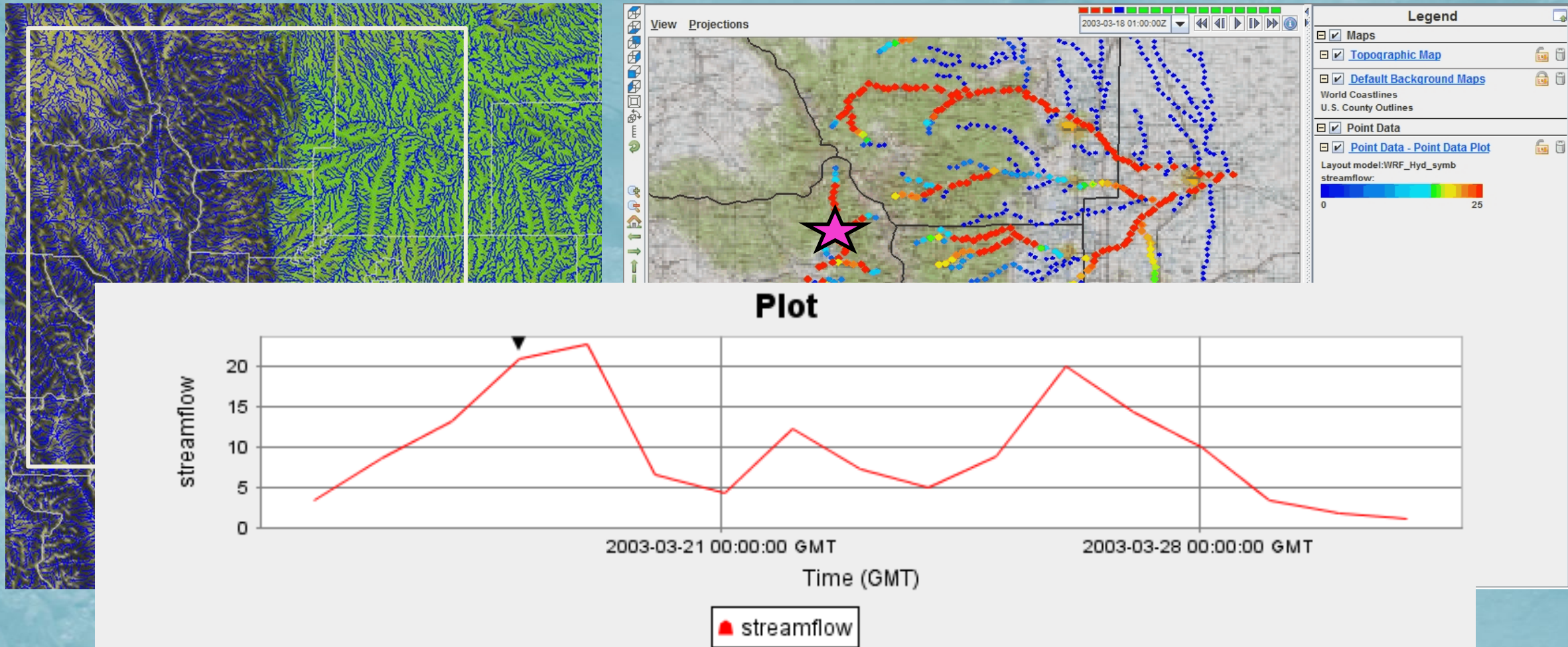
# WRF-Hydro output products: IDV

- Soil moisture plan view and vertical cross-section



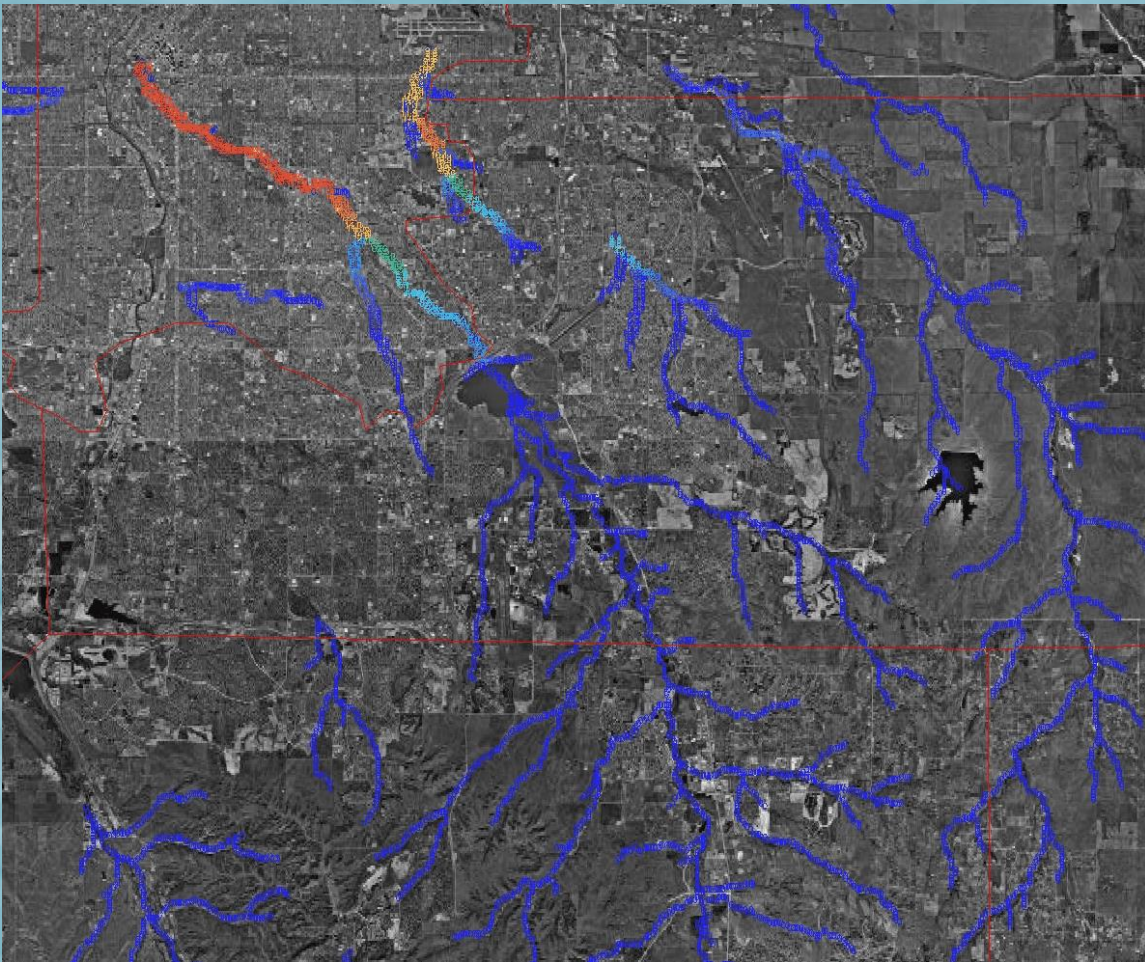
# WRF-Hydro output products: Additional examples...IDV

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



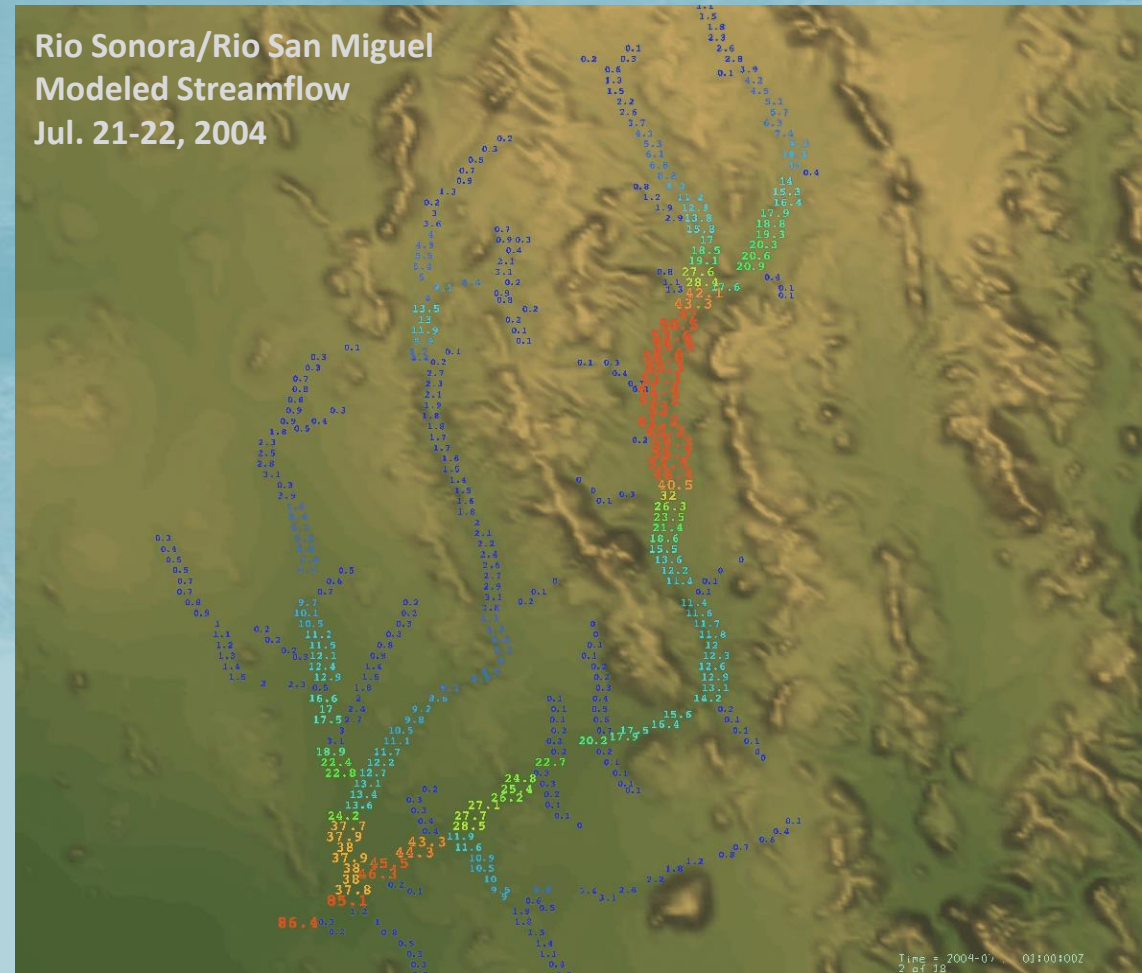
# WRF-Hydro output products: Additional examples...IDV

Urban Flooding: Genoa-2011



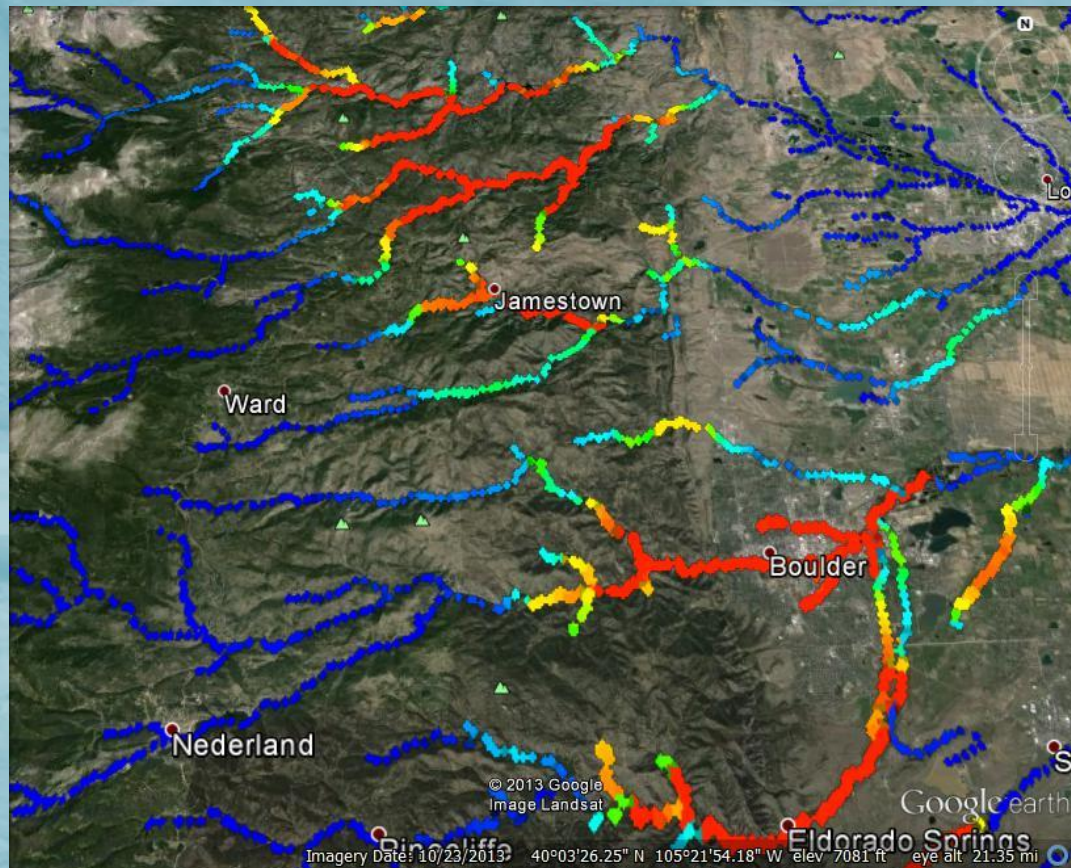
Northwest Mexico

Rio Sonora/Rio San Miguel  
Modeled Streamflow  
Jul. 21-22, 2004

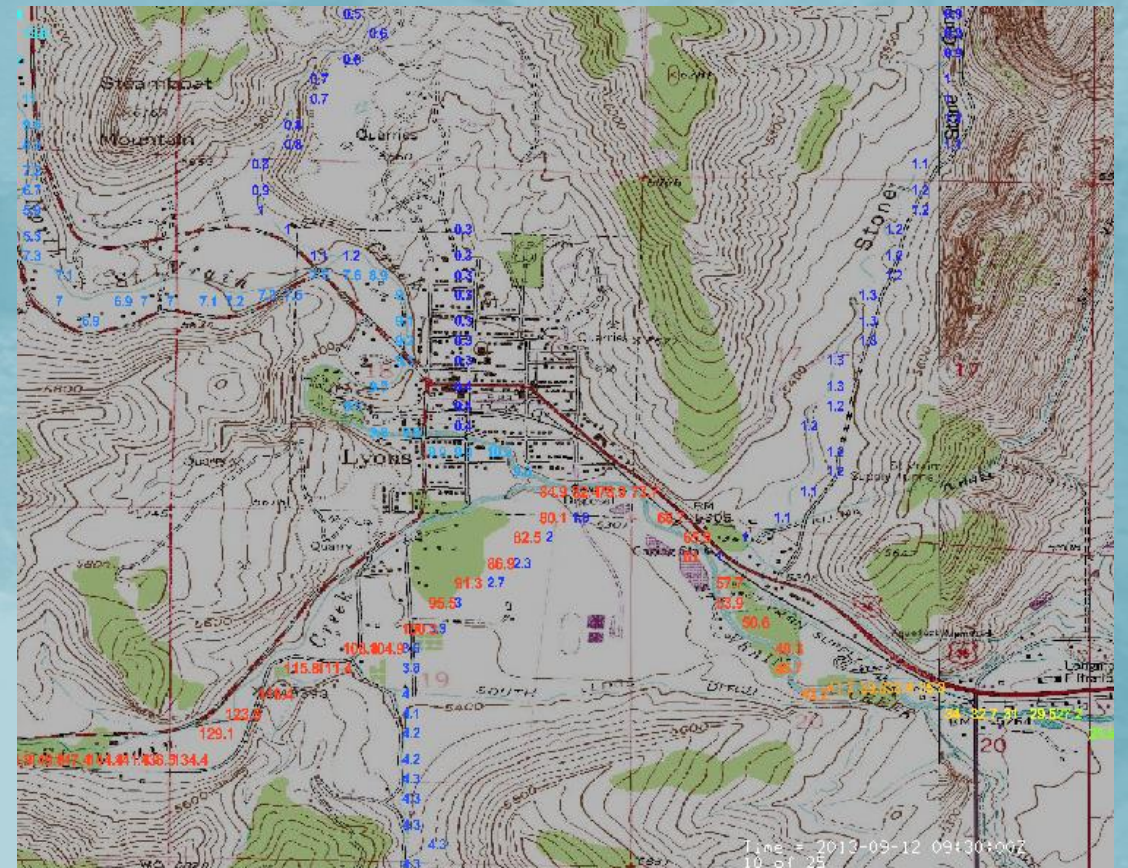




# WRF-Hydro output products: Additional examples...



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