WRF-Hydro Hydrological Modeling Extension Package & Version 2 Updates

Overview and Project Update: June 24, 2014

D. Gochis, W. Yu, D. Yates, M. Clark, A. Wood, K. Sampson, K. Ikeda, **R. Rasmussen**

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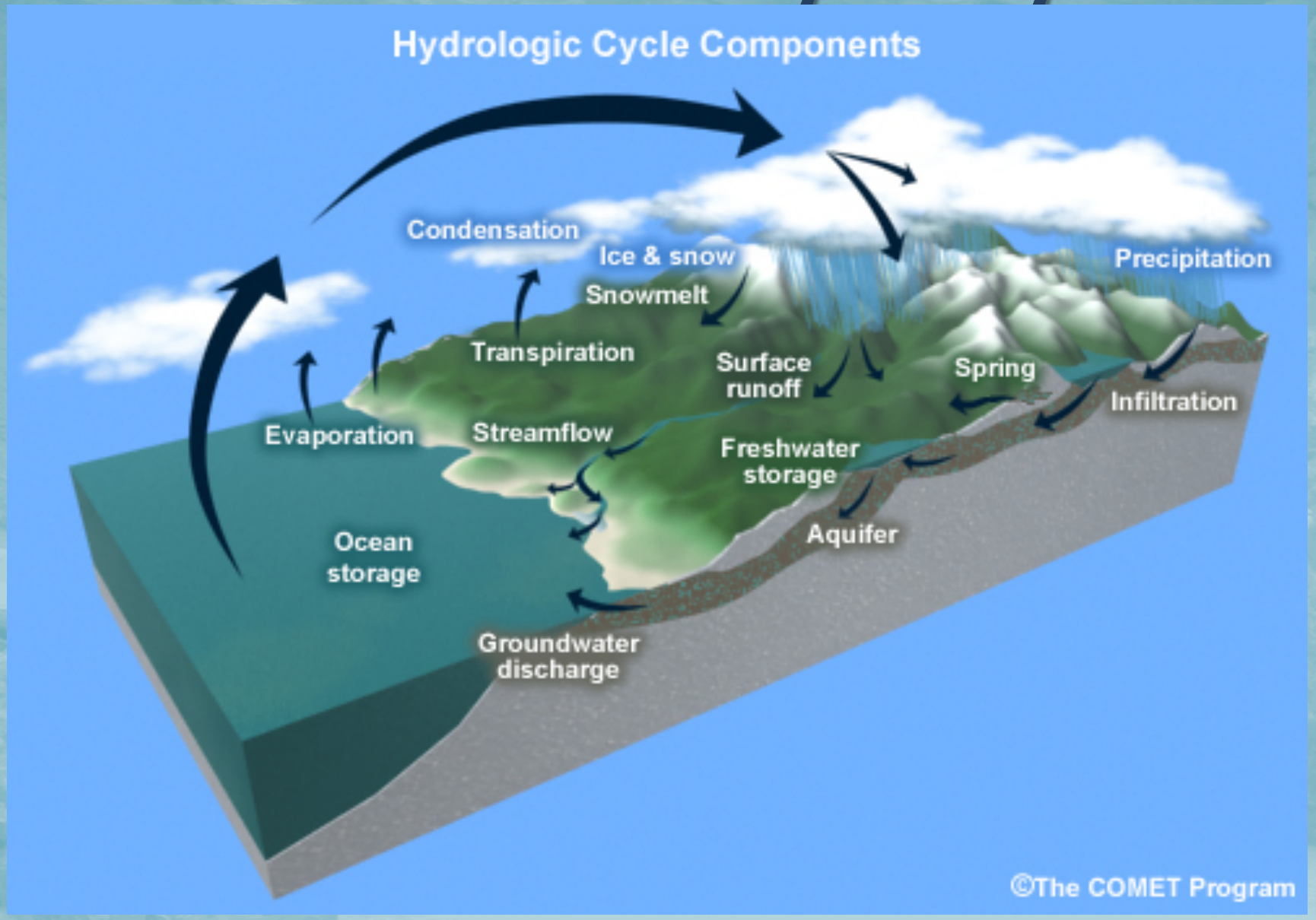
Presentation Outline:

1. Motivation for WRF-Hydro
2. Description of WRF-Hydro
3. Prediction Applications
4. Recent and ongoing enhancements

What is the WRF-Hydro System?



Initiative of the NCAR Water System Program

Initial release to the community April 2013

Version 2.0 released April 2014

What is the WRF-Hydro System?

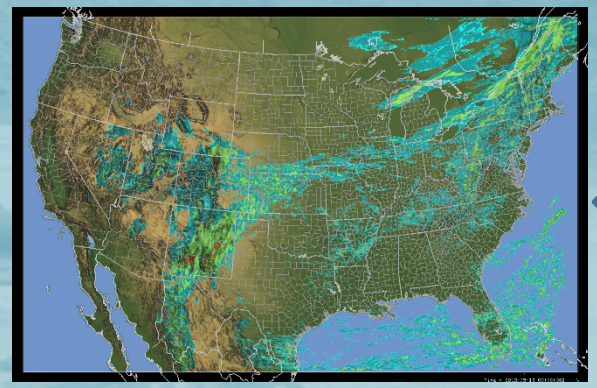
WRF-Hydro is a community-based system designed to couple *multi-scale* process models of the atmosphere and terrestrial hydrology

Seeks to provide:

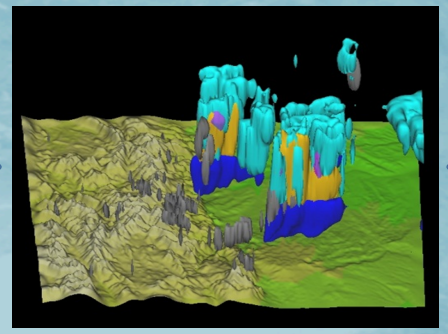
1. An *'Earth Systems-oriented'* capability to perform coupled and uncoupled *multi-physics, multi-scale, spatially-continuous* hydrometeorological simulations and predictions
2. Fully utilize high-performance computing platforms
3. Leverage existing and emerging standards in data formats and pre-/post-processing workflows
4. A consistent extensible, portable and scalable environment for hydrometeorological prediction, hypothesis testing, sensitivity analysis, data assimilation and observation impact research

Motivation for WRF-Hydro:

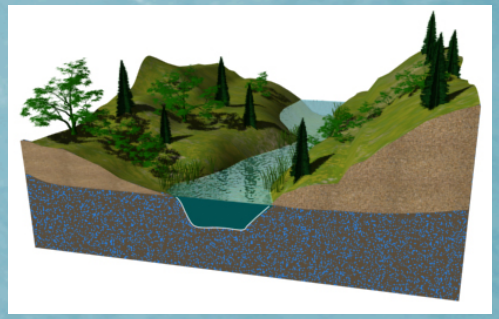
- Scientific Needs:
  - Based on community support requests it was evident that there was a need integrated modeling capabilities for complete predictions of the water cycle…climate impacts
  - Need multi-scale framework…bridge atmosphere-hydro application scales….



1-10's km



100's m - 1's km

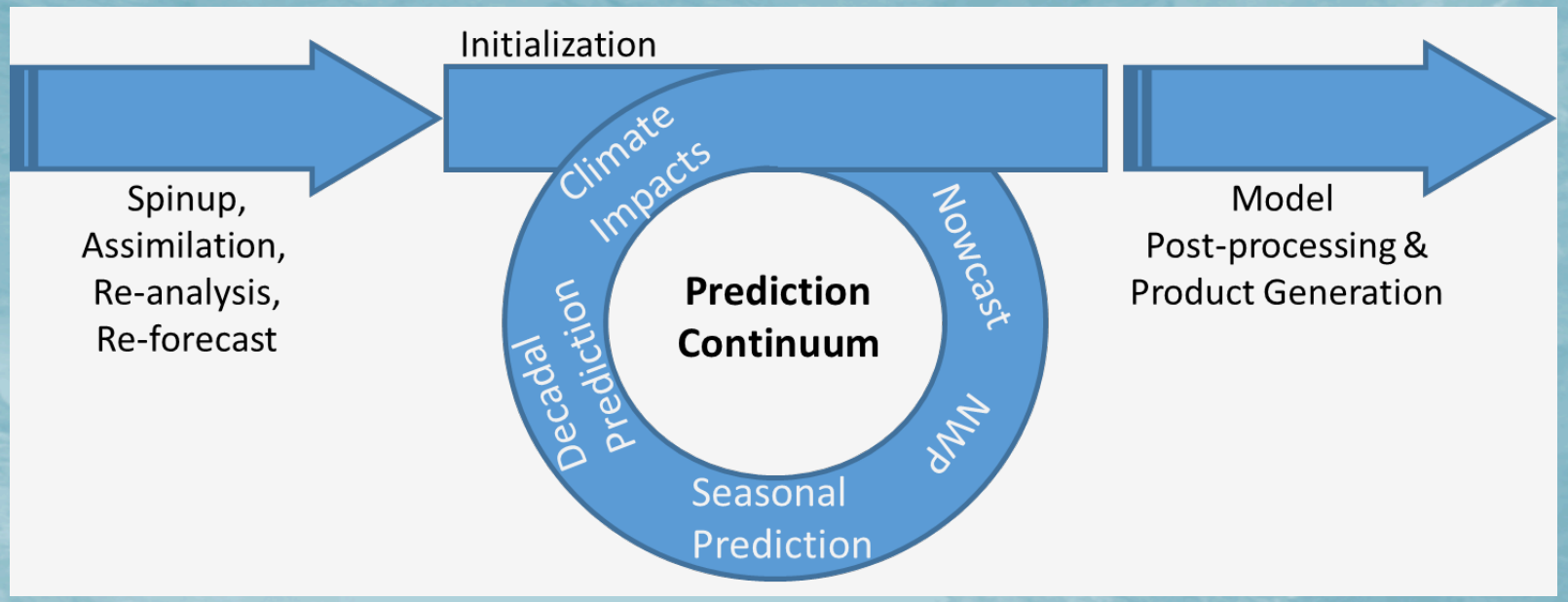


1-10's m

  - Need extensible, multi-physics framework…foster experimentation and expose process uncertainty…

Motivation for WRF-Hydro:

- Prediction System Needs:
  - Need rapid pathway to operational deployment…Seamless hydrometeorological modeling tools for continuum prediction:

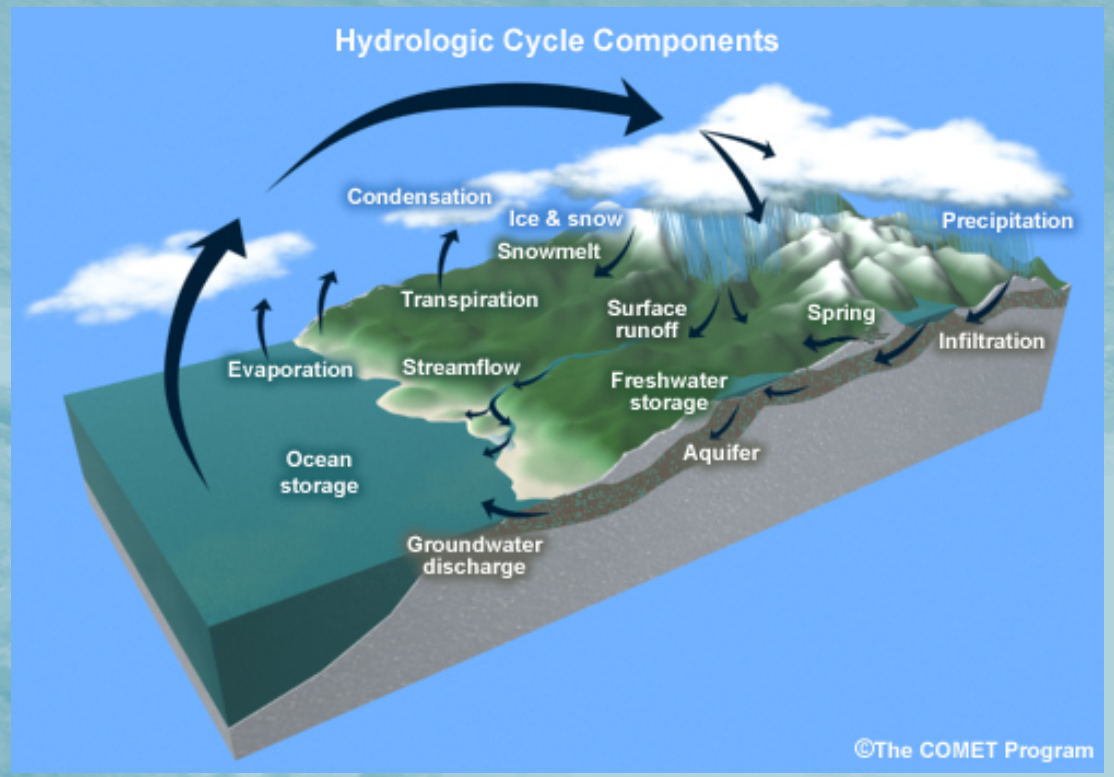


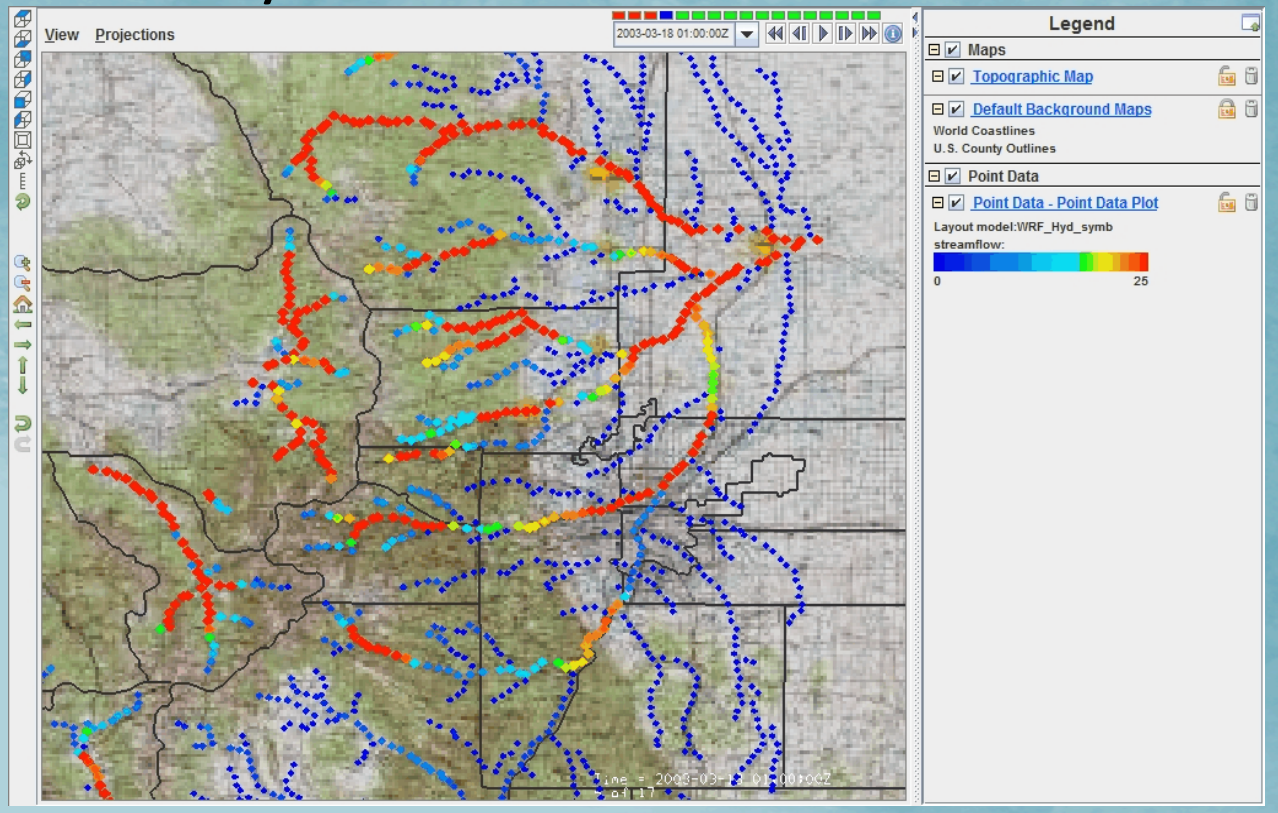
  - Linkage to ensemble forecasting methodologies…
  - Utilization of HPC (on both local and distributed/cloud architectures…)

2. DESCRIPTION OF THE WRF-HYDRO SYSTEM

Water Cycle Modeling and Prediction components within the WRF-Hydro System:

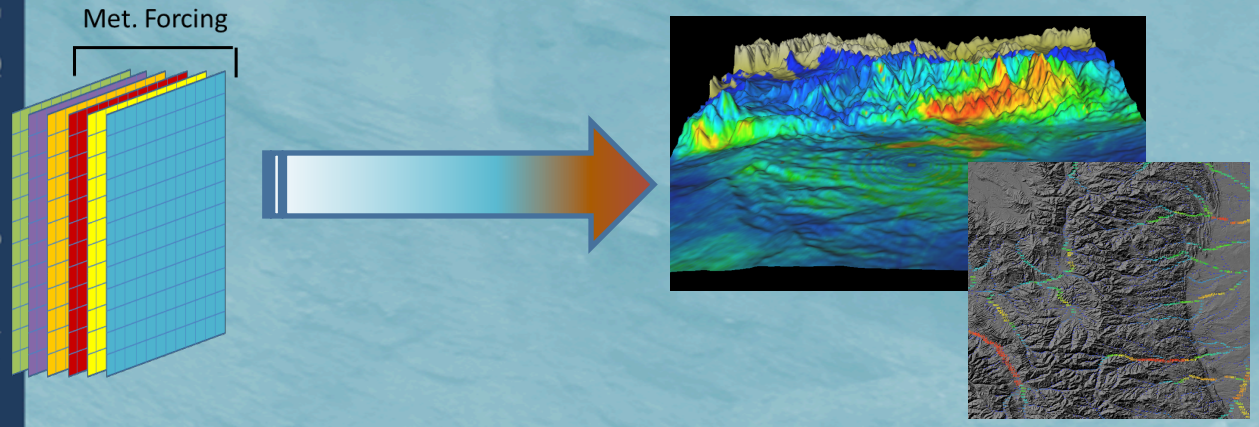
- Modeling of the major water cycle components possible when couple WRF to hydrological components in WRF-Hydro



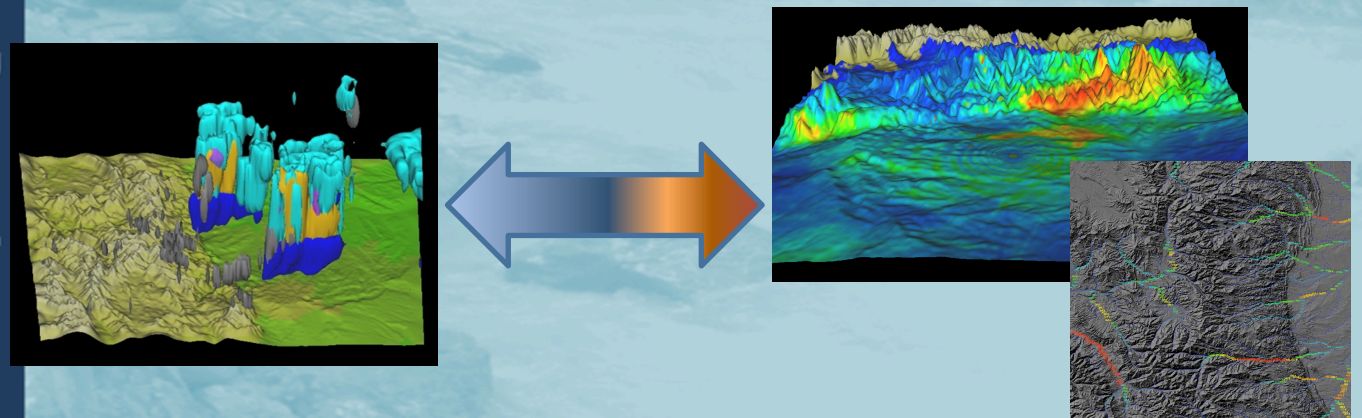


WRF-Hydro Modes of Operation:

One-way ('uncoupled') →

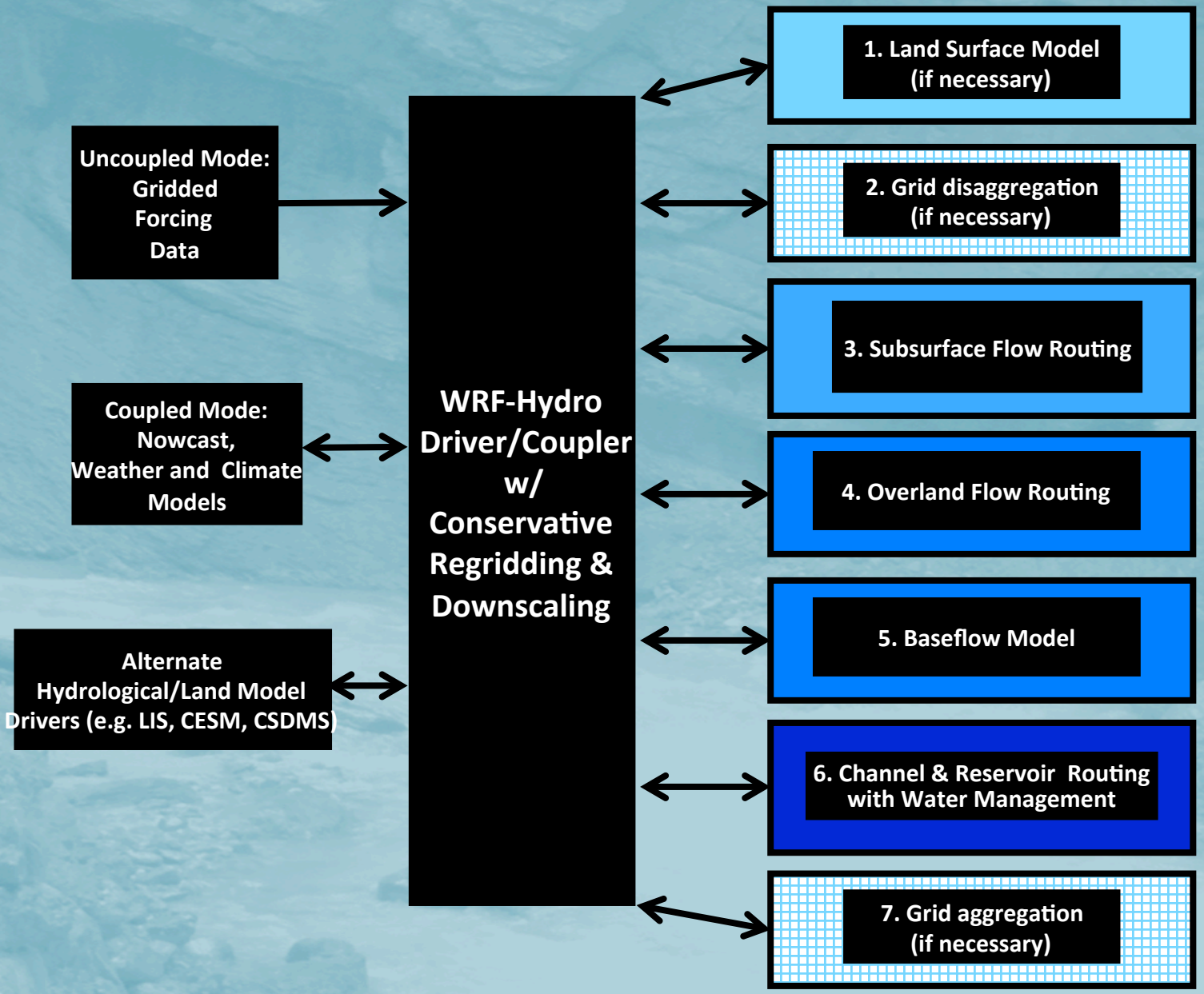


Two-way ('coupled') ↔



- Modes of operation..1-way vs. 2-way
- Model forcing and feedback components:
  - Forcings: T, Press, Precip., wind, radiation, humidity, BGC-scalars
  - Feedbacks: Sensible, latent, momentum, radiation, BGC-scalars

WRF-Hydro Architecture Description:



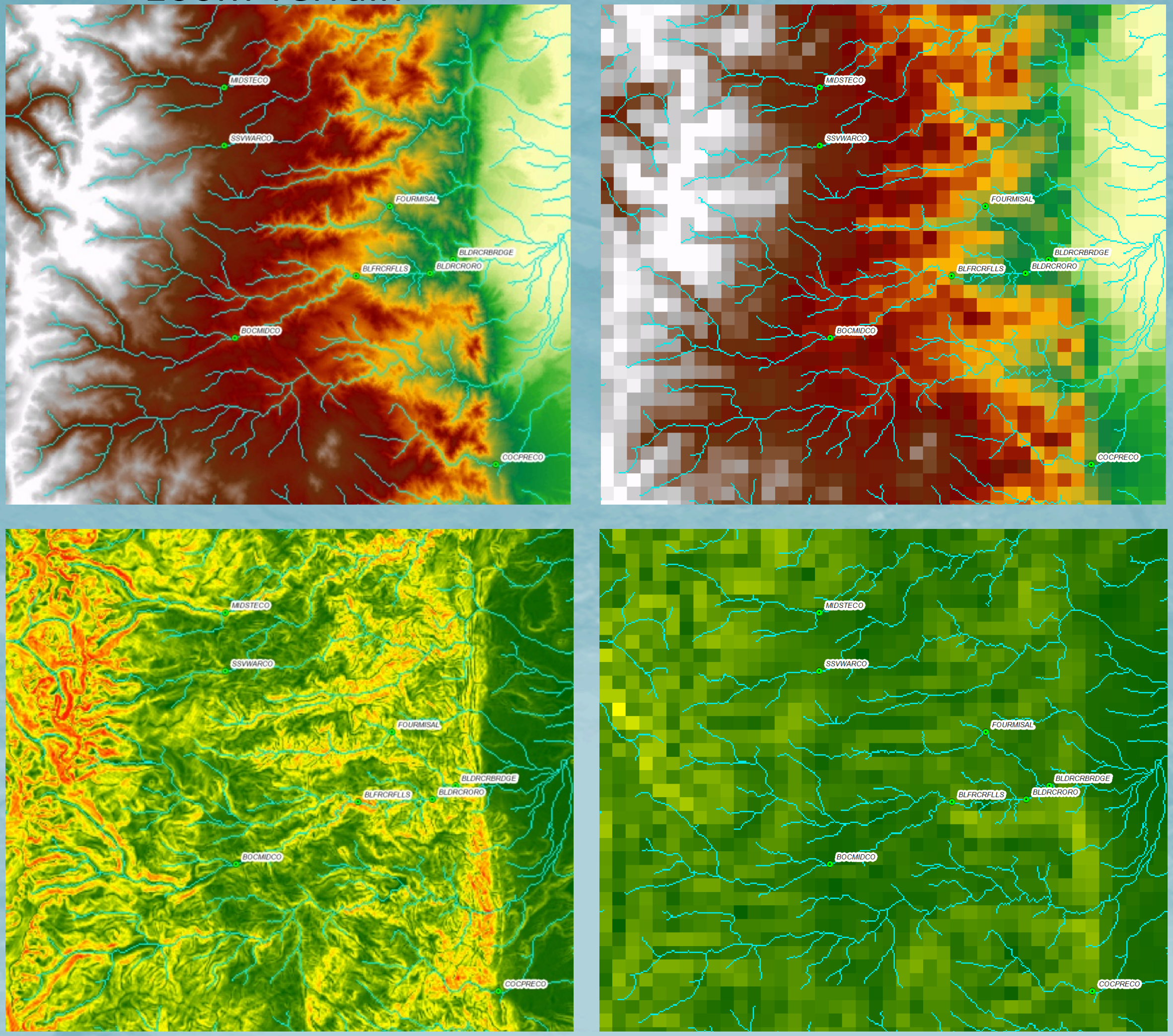
- Plug compatible model physics components….
- Multi-scale components….
  - Rectilinear regridding
  - ESMF regridding
  - Downscaling

WRF-Hydro v2.0 Physics Components:

- Multi-scale aggregation/disaggregation:

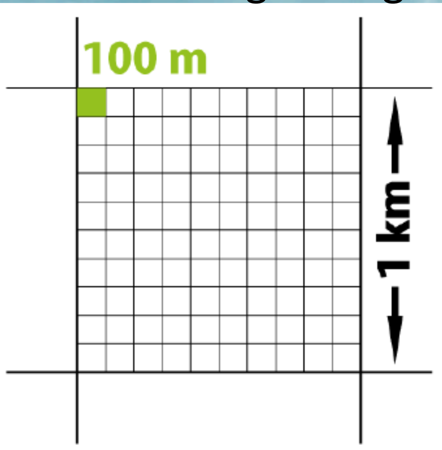
100m Terrain

1 km Terrain

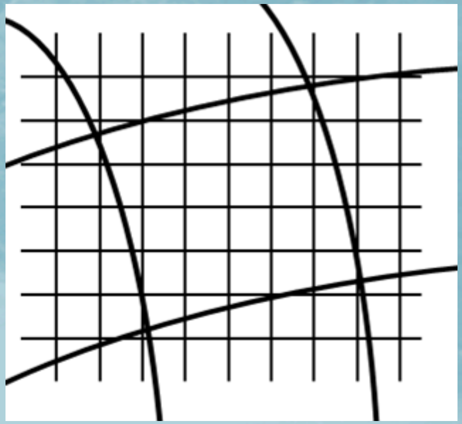


Terrain slope (0-45 deg)

Current 'Regridding'



Implementing ESMF Regridders (v2.1)



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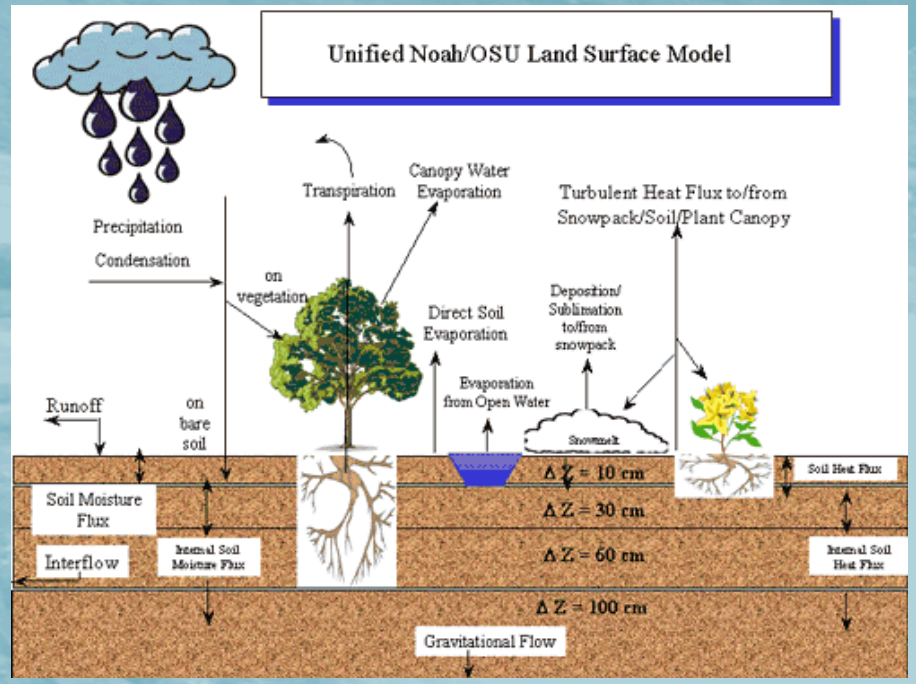
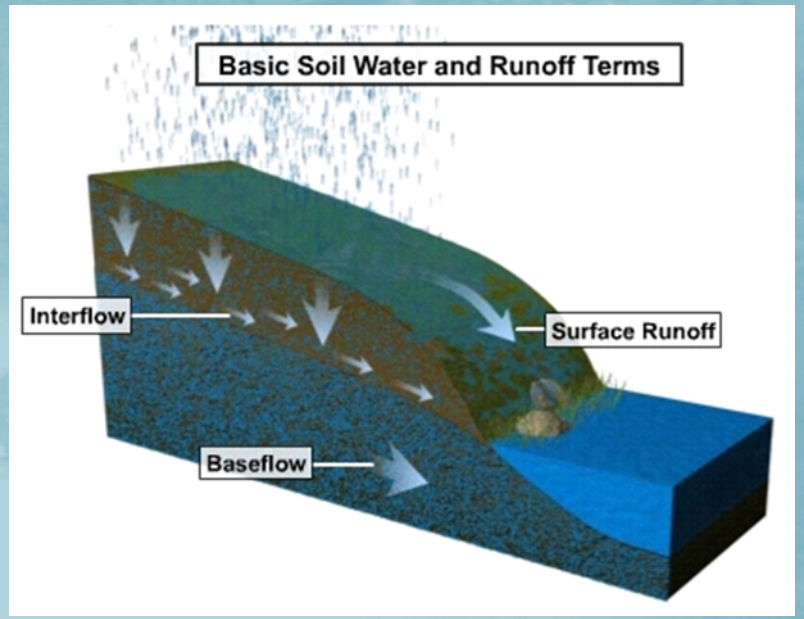
WRF-Hydro v2.0 Physics Components:

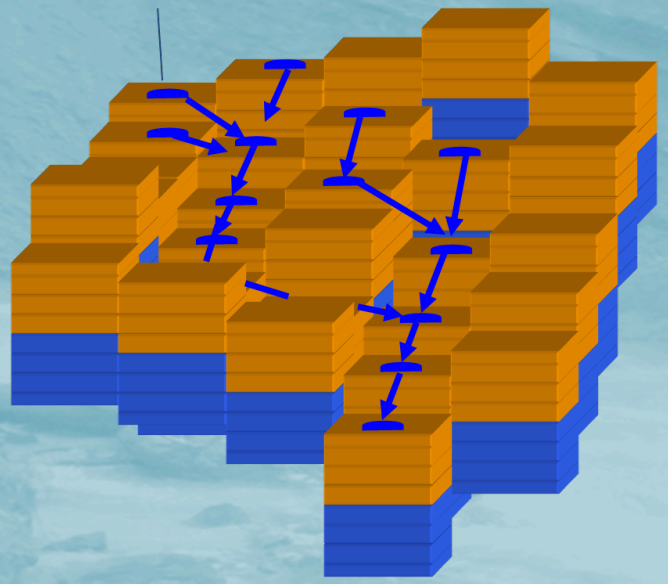
- WRF-coupled and offline Noah and Noah-MP now supported as of April, 2014
- CLM coupling supported through CESM architecture (in progress)
- NOAA SAC-HTET in progress



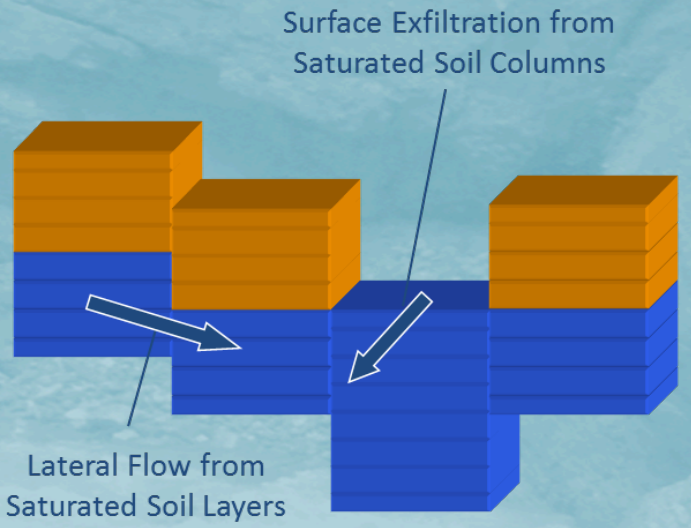


Version 2.0 Release Routing Physics:

- physics-based runoff processes

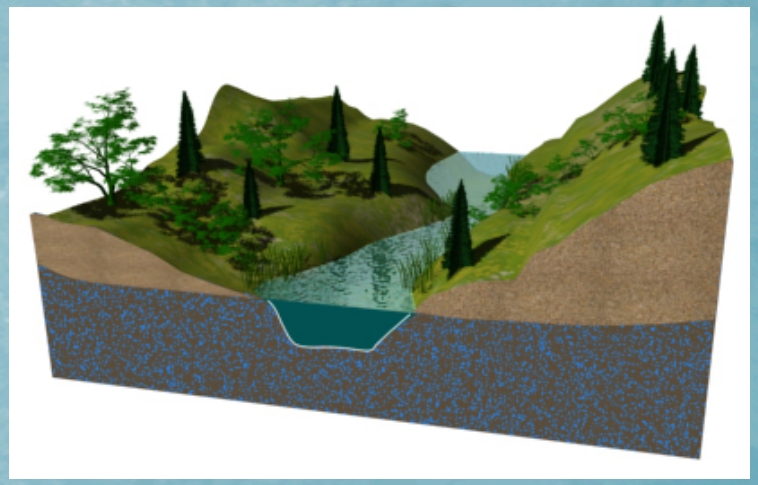


Overland Flow -
Diffusive wave (2-d and 1-d)



Groundwater Flow –
Boussinesq flow

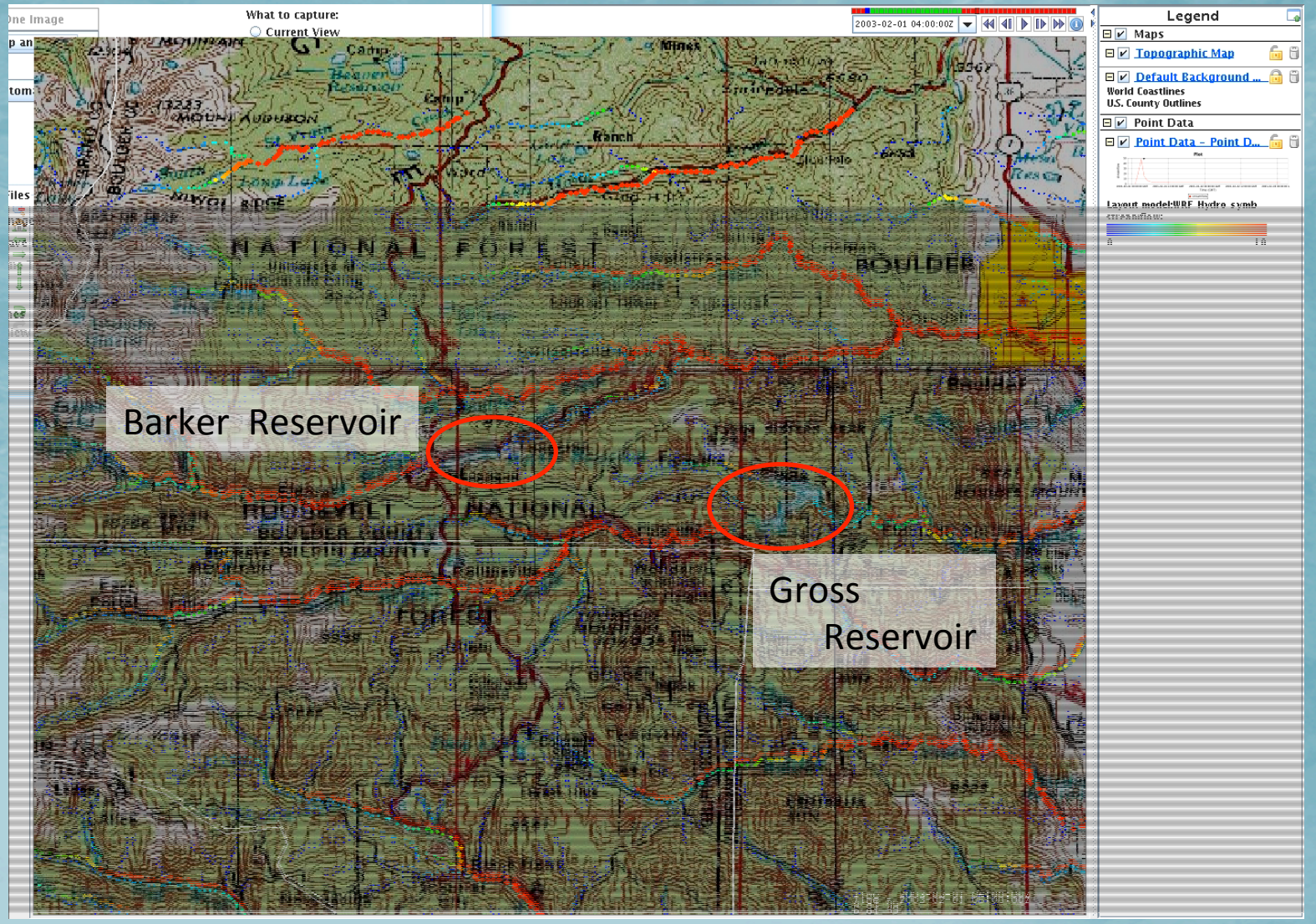
HMS groundwater model
in progress



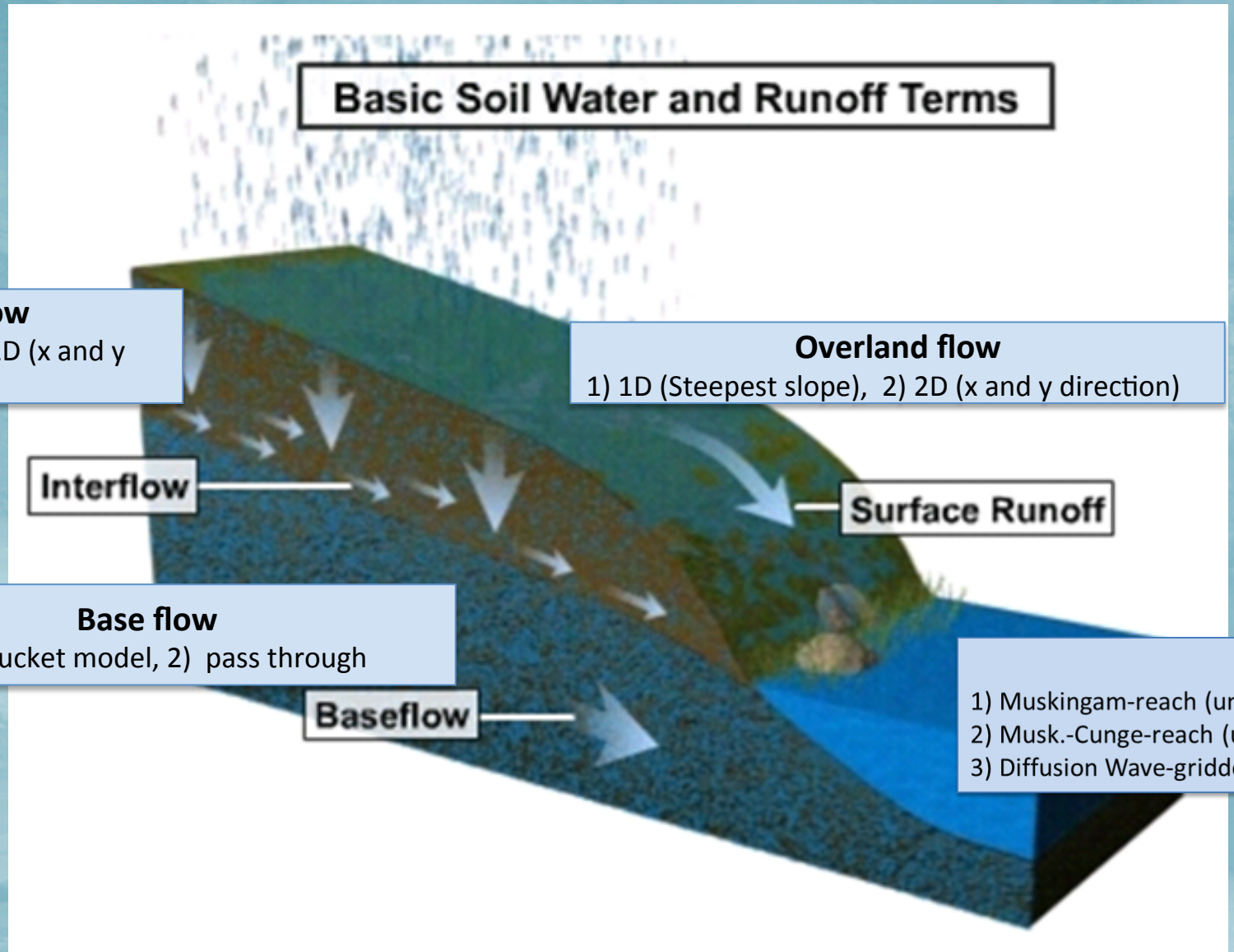
Channel Flow –
Gridded diffusive wave
Reach-based Muskingam
methods (RAPID) in progress

Version 2.0 Release Routing Physics:

- Reservoir and water management impacts:
  - On-channel reservoirs
  - Level-pool storage
  - Multiple discharge modes
    - Orifice flow
    - Spillway flow
    - Rule curve
    - Mgt. Schedule



Processes in WRF-Hydro



Subsurface flow
1) 1D (Steepest slope), 2) 2D (x and y direction)

Overland flow
1) 1D (Steepest slope), 2) 2D (x and y direction)

Base flow
1) Explicit bucket model, 2) pass through

Channel Routing
1) Muskingam-reach (under development),
2) Musk.-Cunge-reach (under development),
3) Diffusion Wave-gridded

WRF-Hydro Offline Physical Process Options

Land model option from compiling command

- Noah
- NoahMP

forcing data option from "namelist.hrldas"

- HRLDAS
- HRLDAS + Specified precipitation
- Idealized
- WRF output
- WRF output + specified precipitation

Hydrology physical process option from "hydro.namelist"

- terrain adjustment of incoming solar radiation
- **Subsurface flow**
  1) 1D (Steepest slope), 2) 2D (x and y direction)
- **Overland flow**
  1) 1D (Steepest slope), 2) 2D (x and y direction)
- **Base flow**
  1) Explicit bucket model, 2) pass through
- **Channel Routing**
  1) Muskingam-reach (under development),
  2) Musk.-Cunge-reach (under development),
  3) Diffusion Wave-gridded

WRF-Hydro Fully Coupled Physical Process Options

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Land model option from WRF "namelist.input"

- **Noah**
- **NoahMP**

Hydrology physical process option from "hydro.namelist"

terrain adjustment of incoming solar radiation
Note: choose either from WRF or here

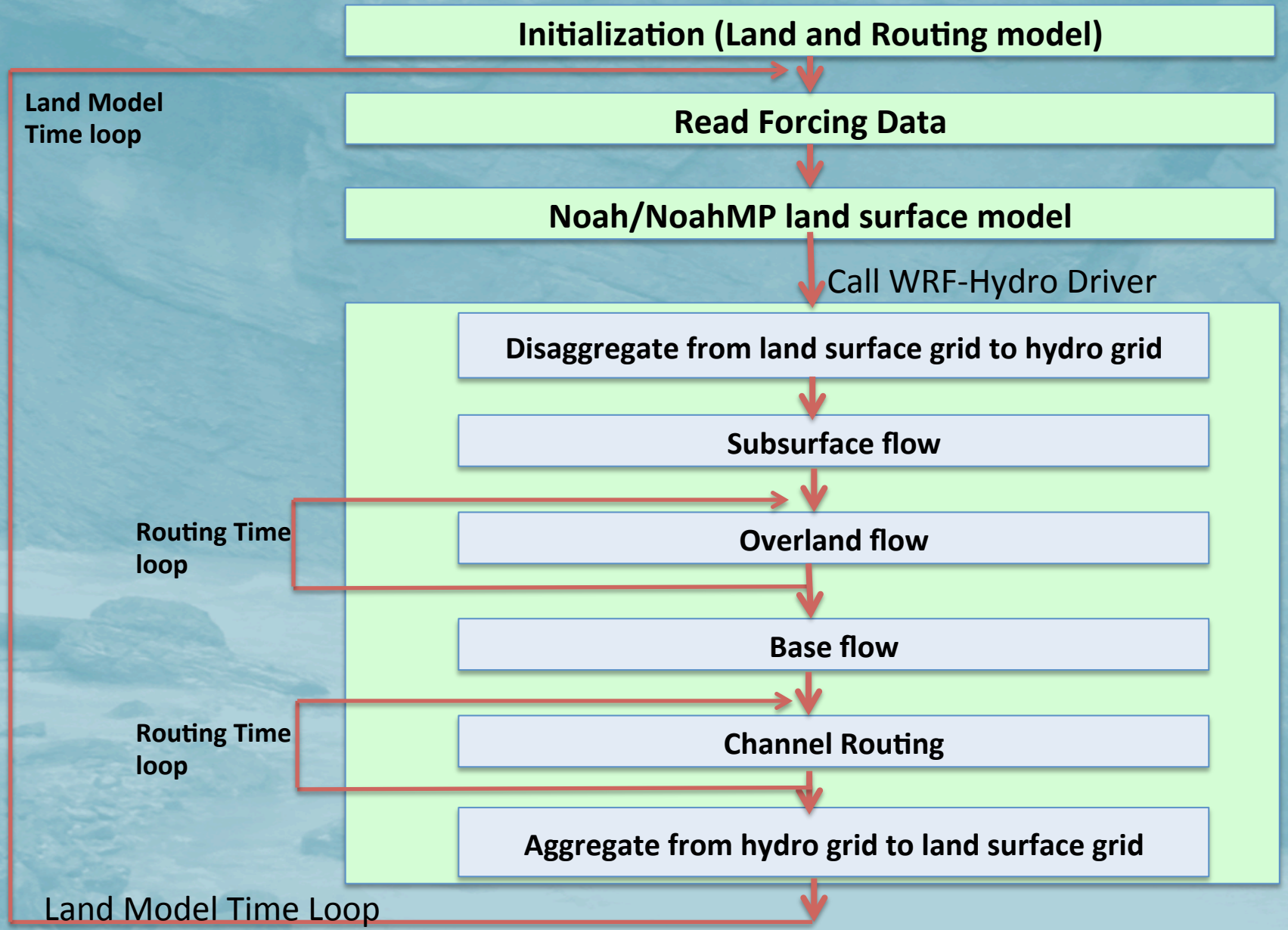
Subsurface flow
1) 1D (Steepest slope), 2) 2D (x and y direction)

Overland flow
1) 1D (Steepest slope), 2) 2D (x and y direction)

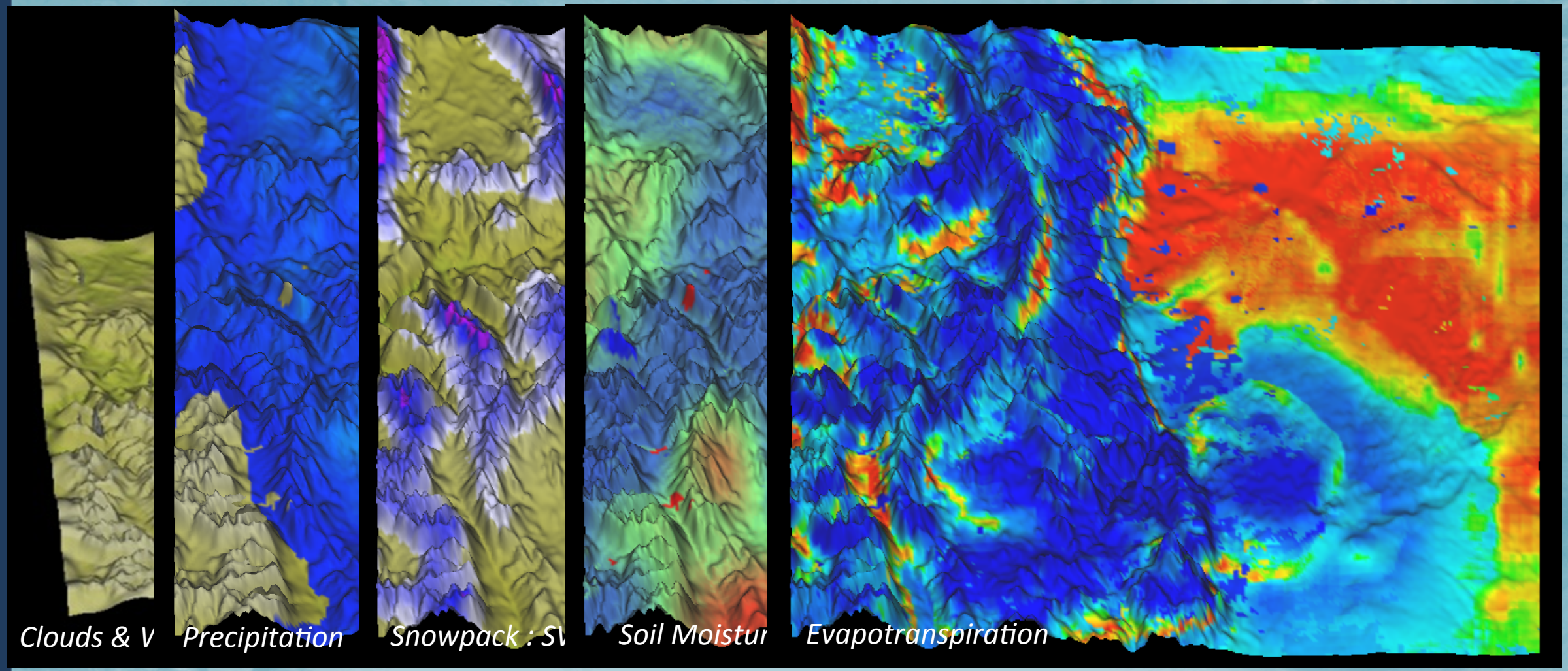
Base flow
1) Explicit bucket model, 2) pass through

Channel Routing
1) Muskingam-reach (under development),
2) Musk.-Cunge-reach (under development),
3) Diffusion Wave-gridded

Flow Chart

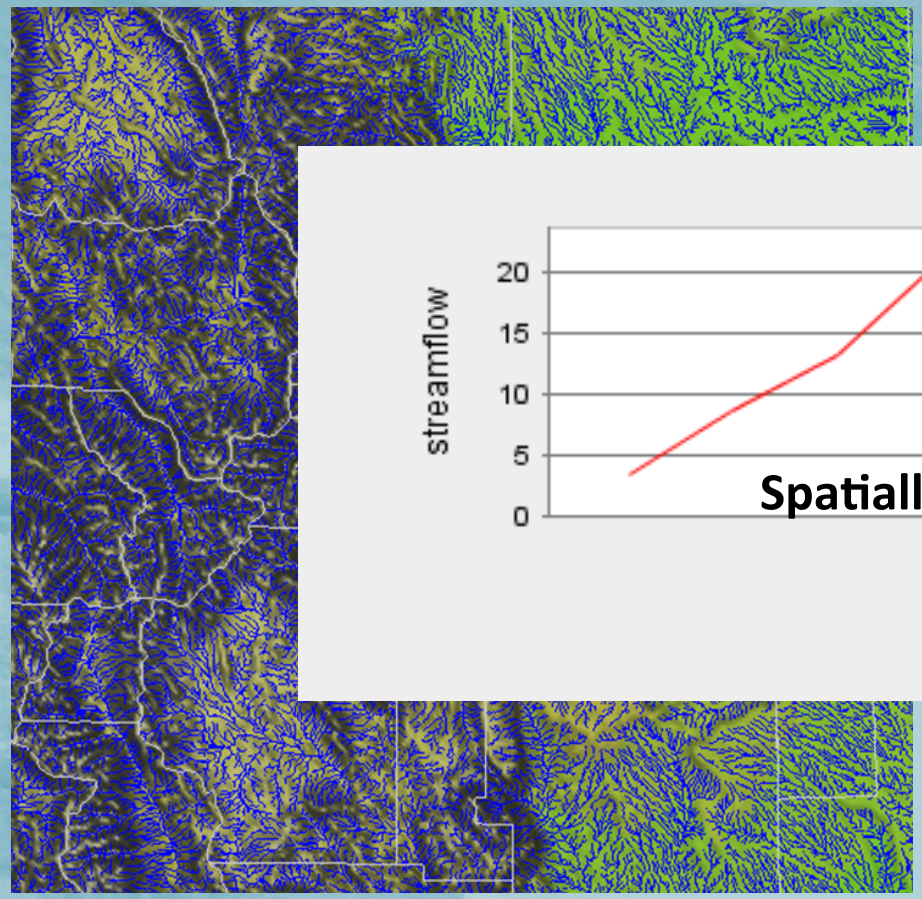


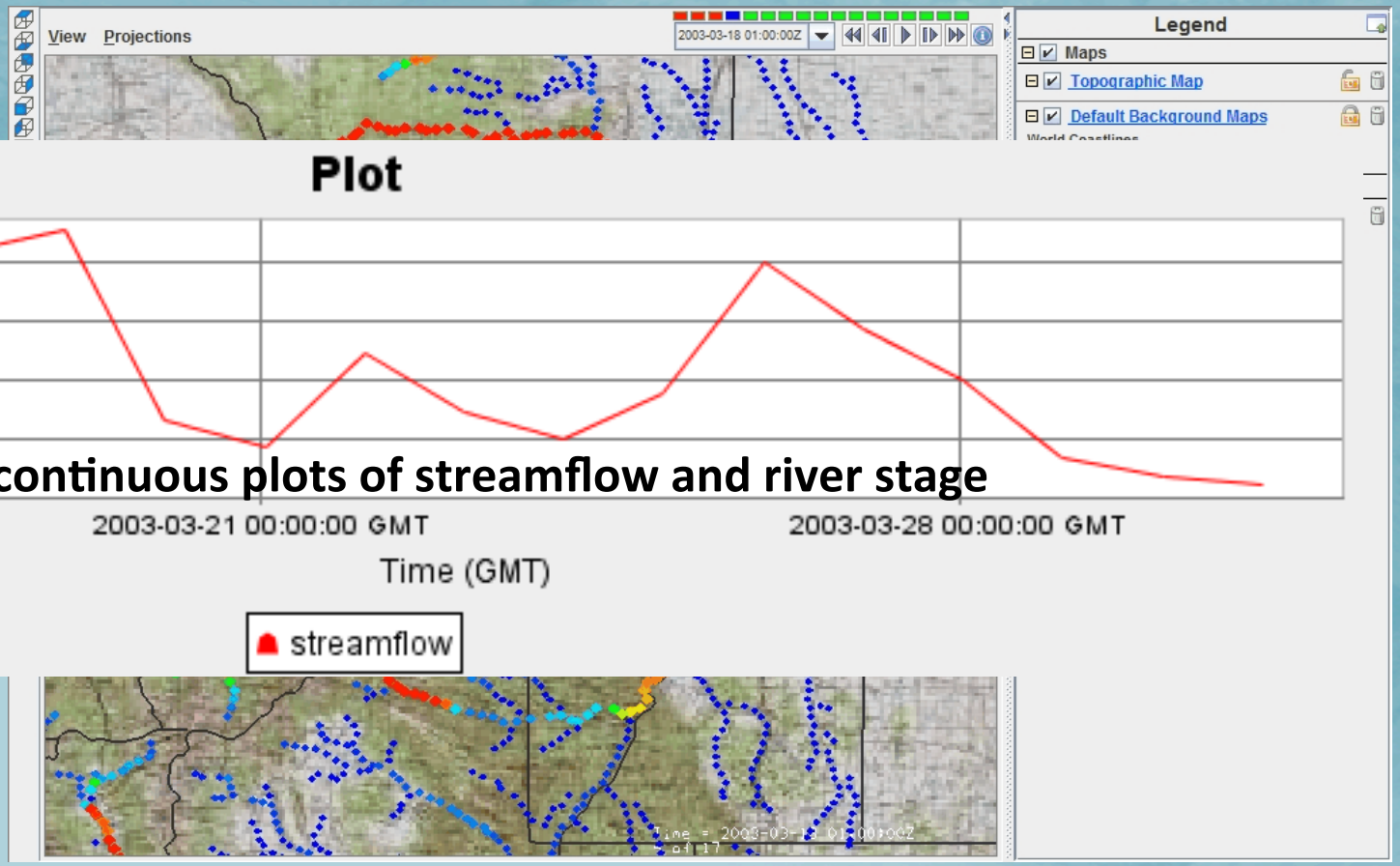
Output products: Forecasts of water cycle components



Output products: Forecasts of water cycle components:

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



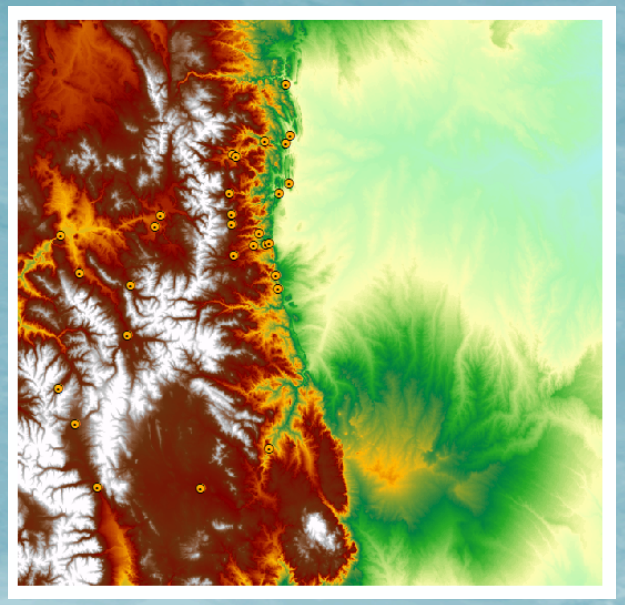


Spatially-continuous plots of streamflow and river stage

WRF-Hydro System: General Attributes

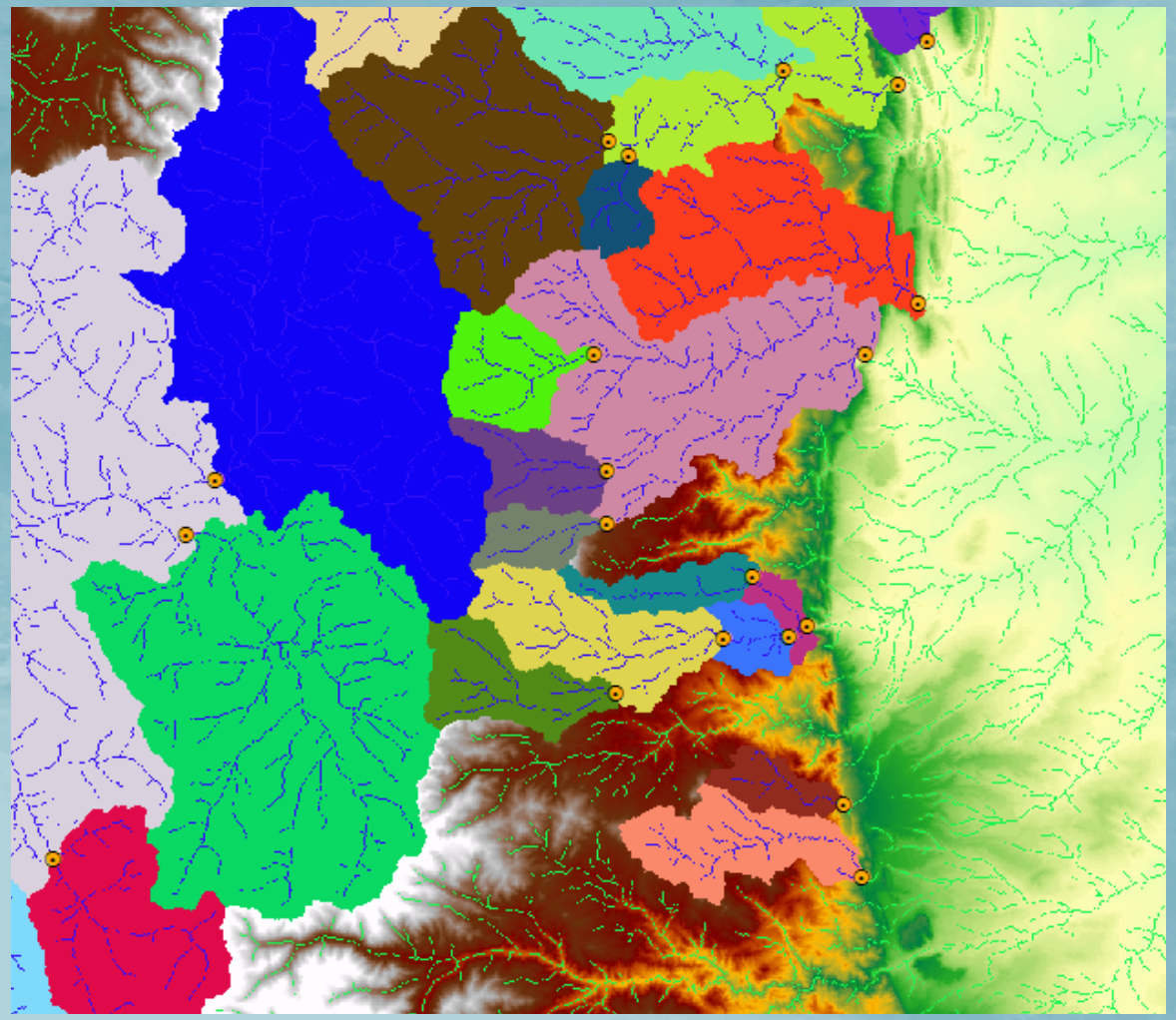
- Runs coupled or uncoupled to WRF
- Open source, community-contributed code
- Readily extensible for multiple physics options
- Multi-scale/multi-resolution
- Supported, documented, multiple test-cases
- Portable/scalable across multiple computing platforms
- Standards based I/O
- Pre-/Post-processing Support
  - ArcGIS pre-processing tool

WRF-Hydro ArcGIS Pre-processing Tool: K. Sampson - developer



Import:
WRF-geogrid terrain

Create:
Hydrological
routing grids



3. PREDICTION APPLICATIONS

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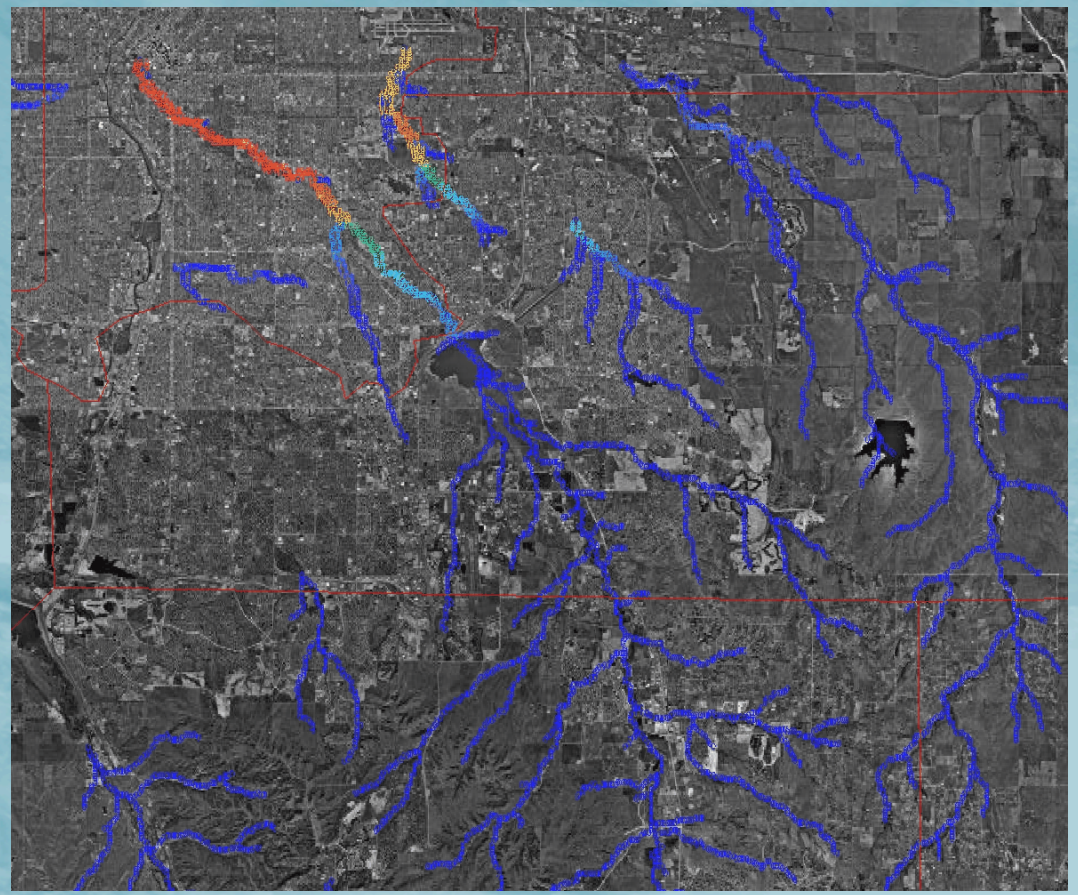
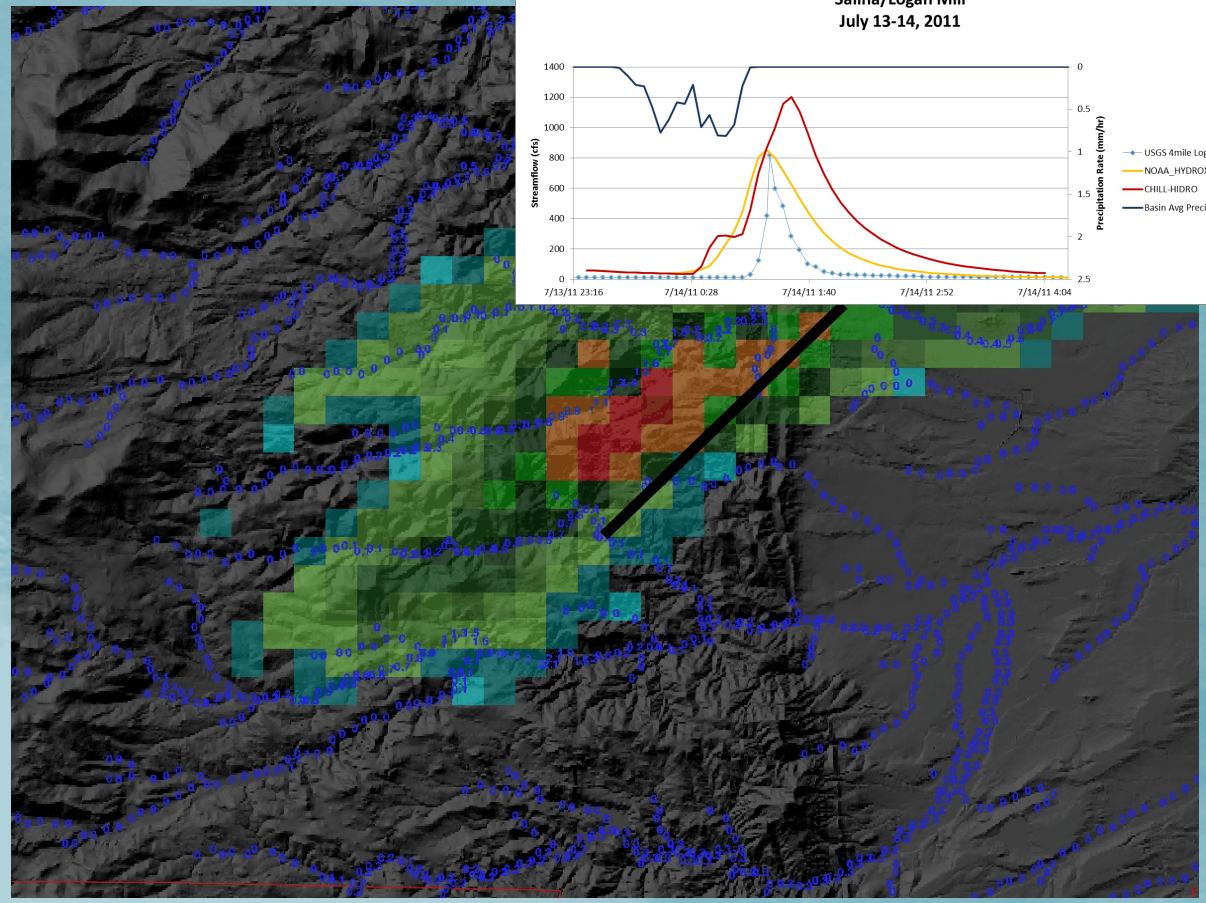
WRF-Hydro Applications: 'Disturbance' Hydrology

Urban Flooding: South Denver, Colorado-2008

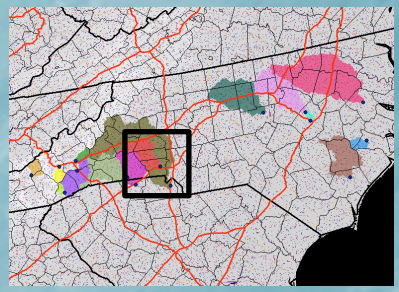


Western U.S. Wildland F



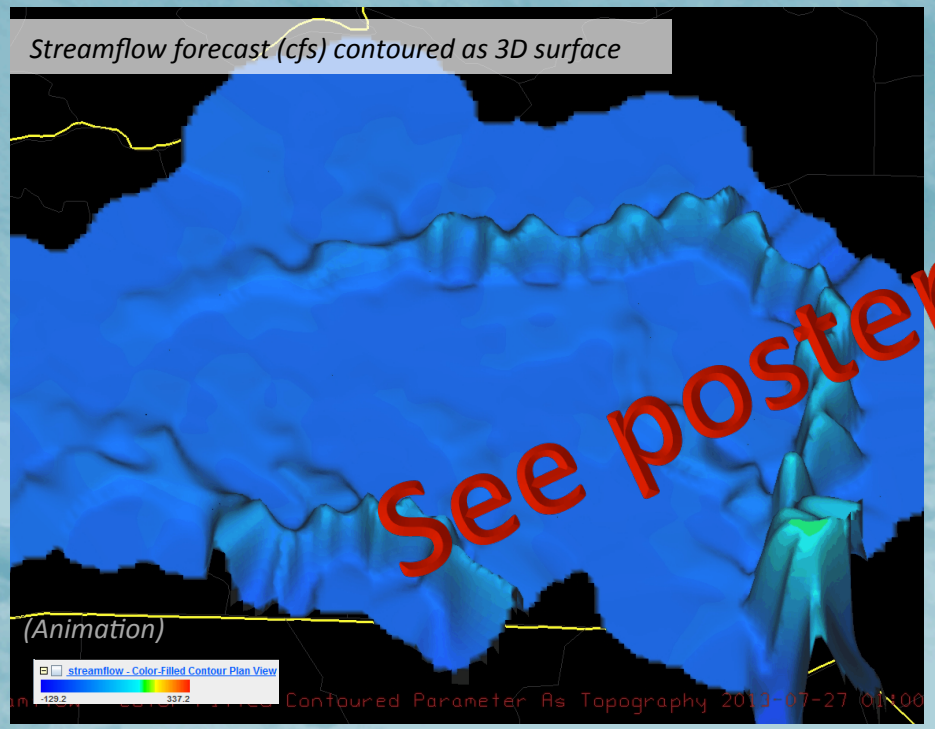
USFS-USGS Burned area severity (BAER) Maps

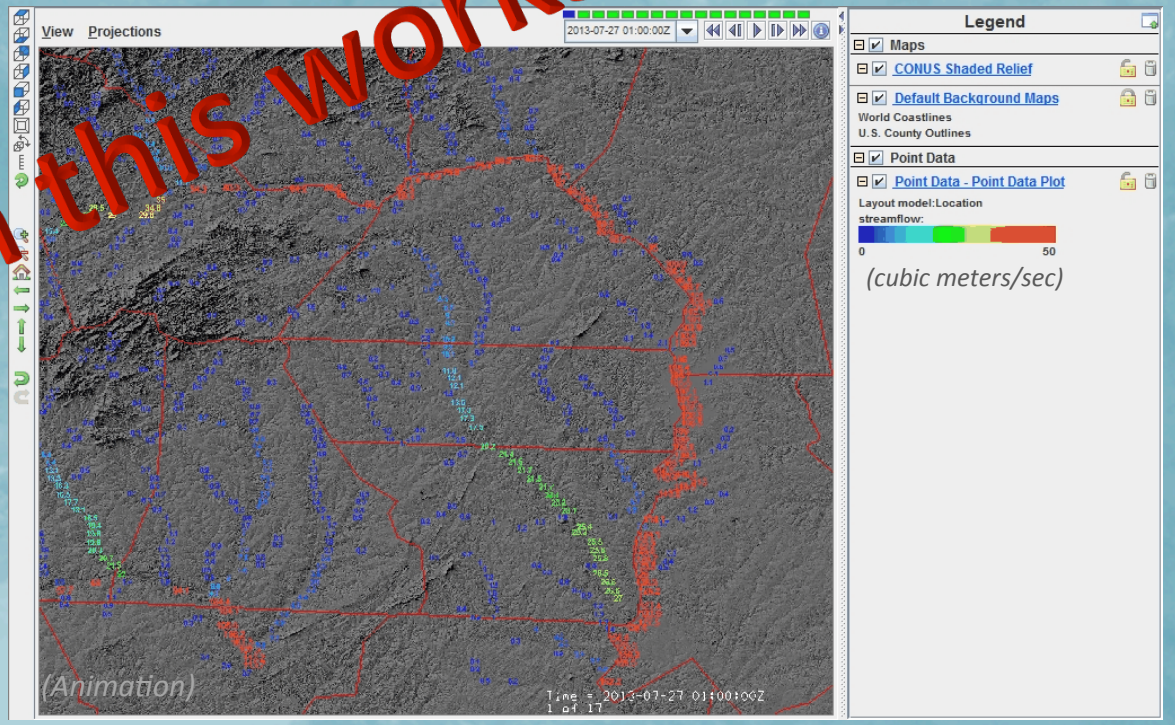
WRF-Hydro Application:
NOAA-HMT SE, 27 July 2013 Flash Flood Case Study



HRRR, ExSREF-driven, calibrated simulation example output: Streamflow forecast

Potential for variety of gridded model output displays (forecasts at specific points also generated)





Streamflow in cubic feet per second, contoured and colorfilled.

Streamflow in cubic meters per second, with actual forecast values color coded and size coded from 0-50 cubic meters per second

Courtesy K. Mahoney, NOAA/ESRL

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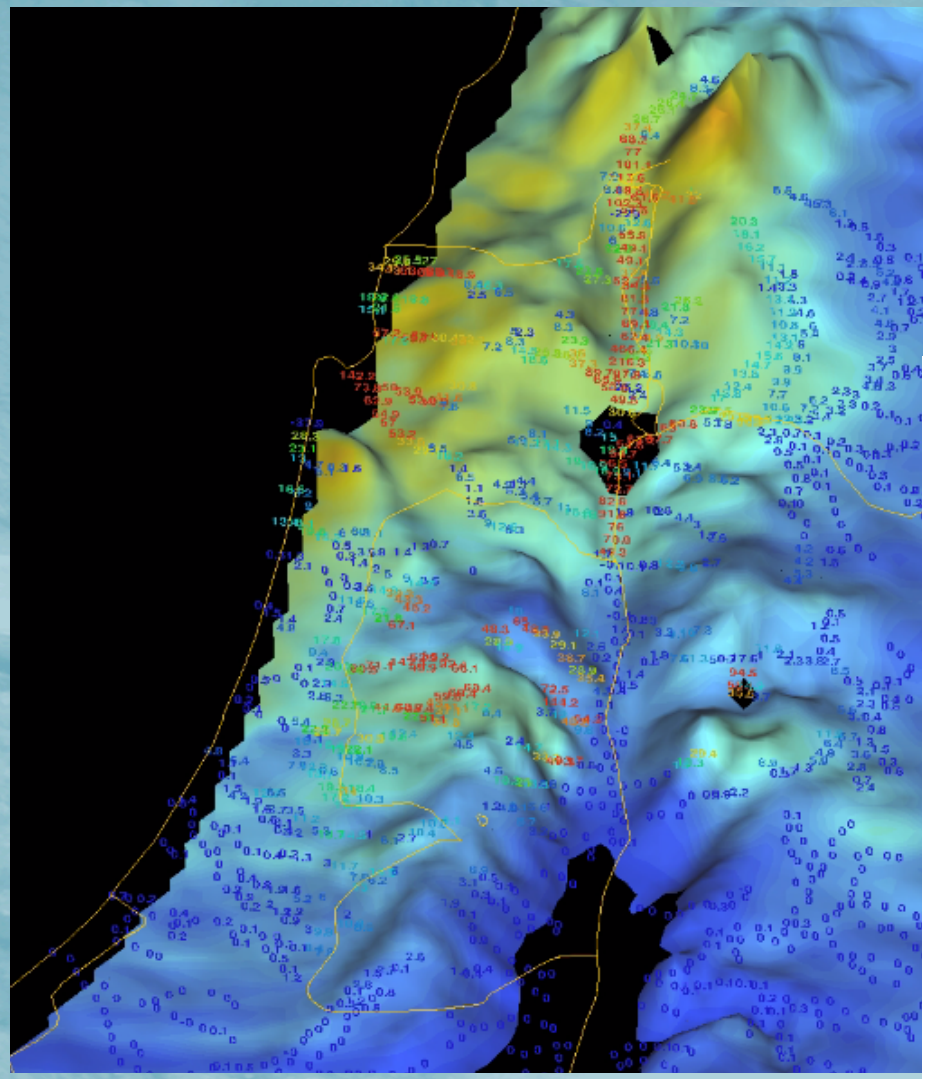
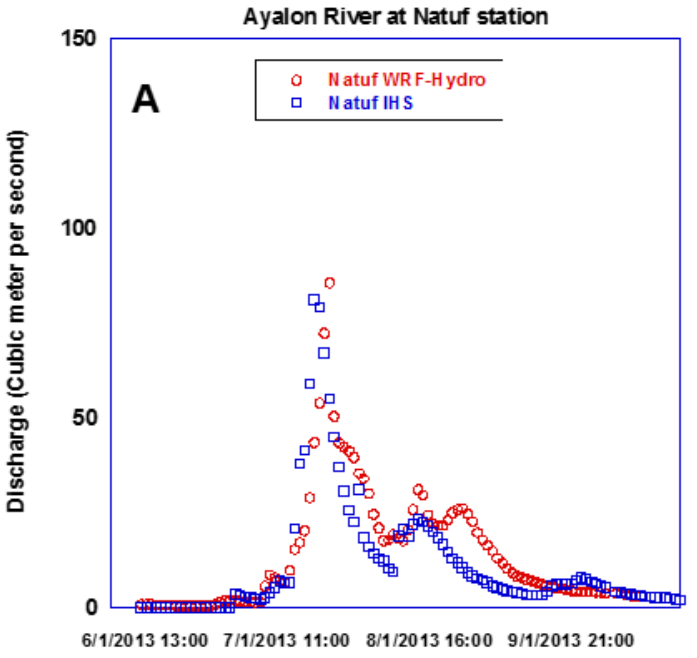
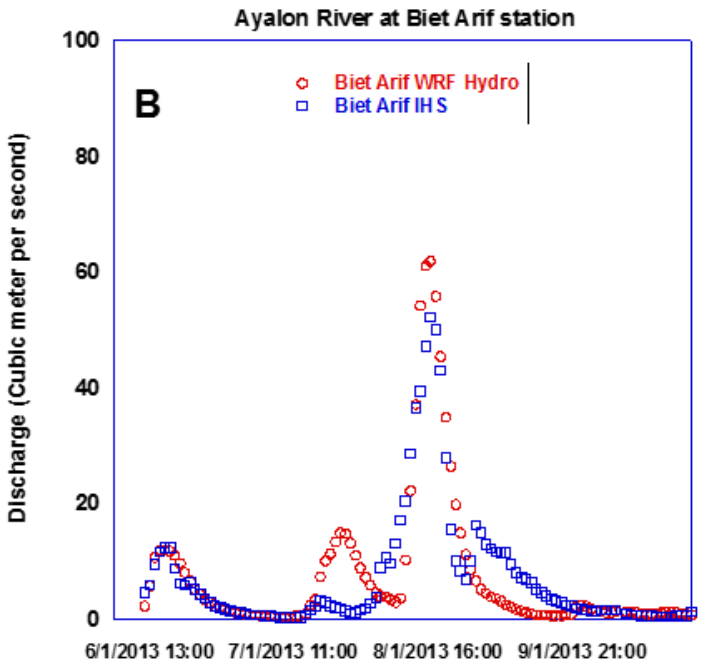
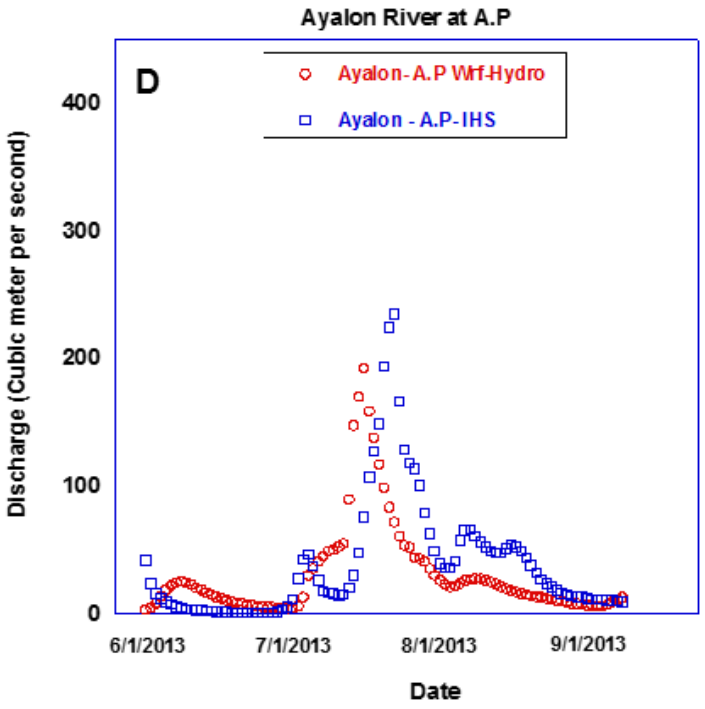
WRF-Hydro Applica

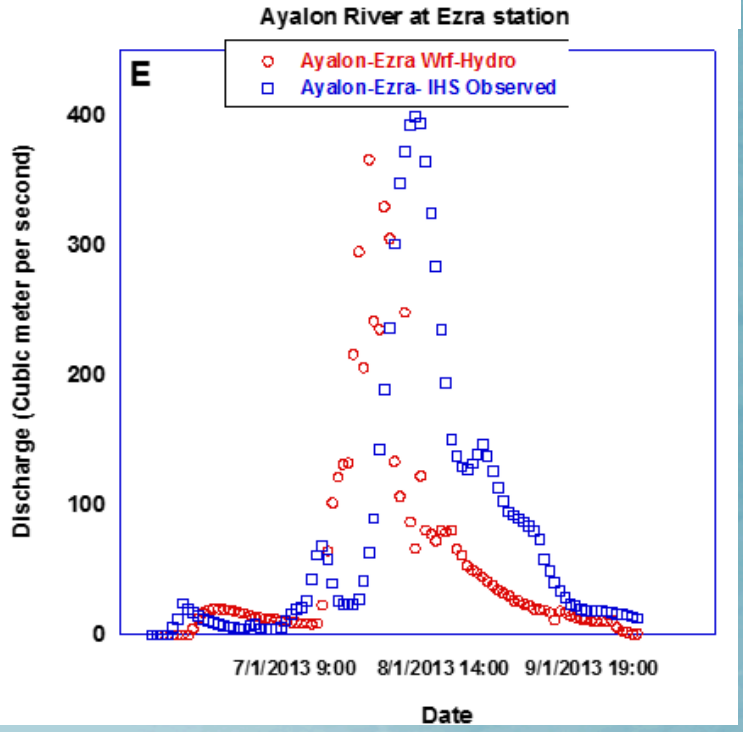
2013-14 operational streamflow prediction a
2 cycles daily, 48hr fully-coupled WRF/WRF-H







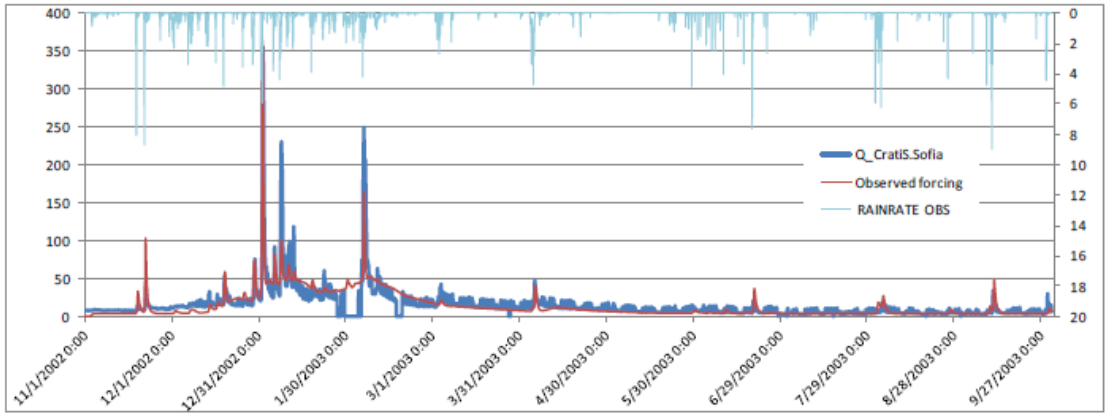




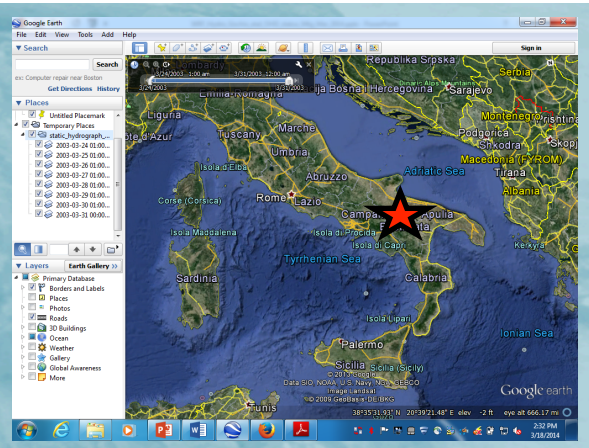
WRF-Hydro Applications:

Automated model calibration work: Calabria, Italy

Performed by: A. Senatore, U. Calabria



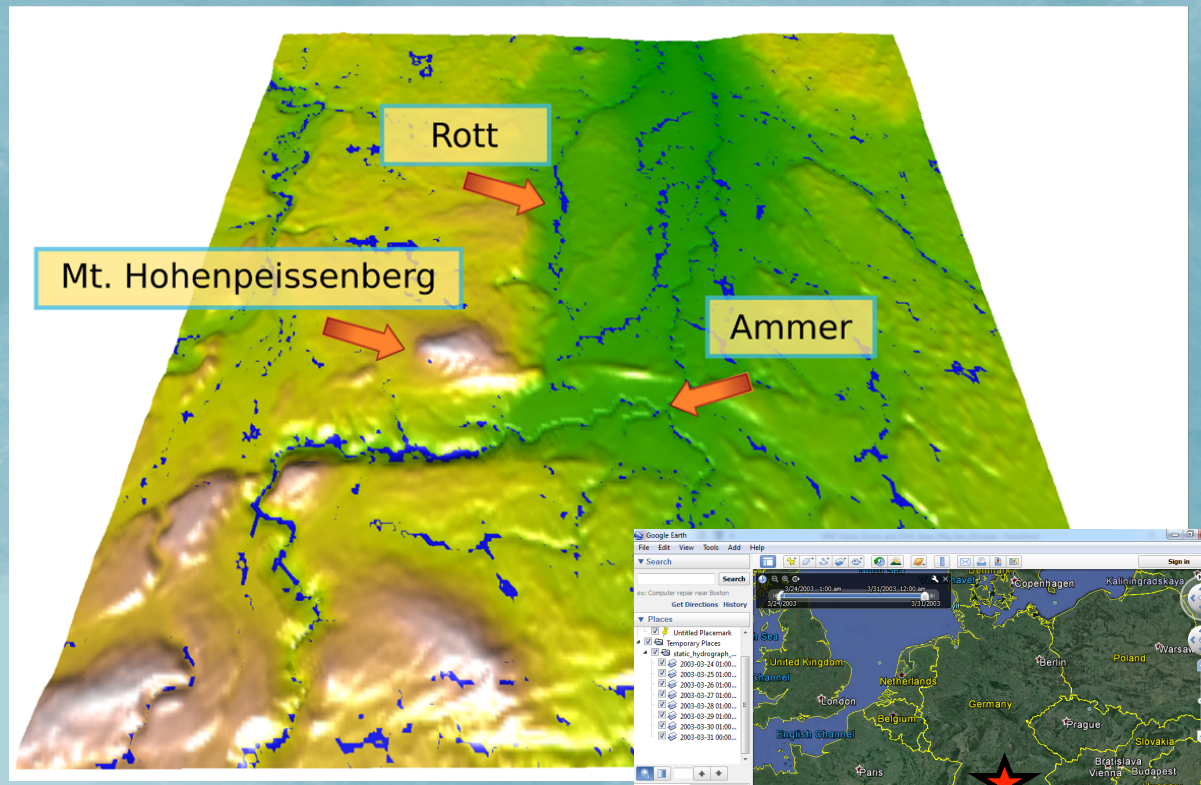
Observed vs simulated streamflow data at the S. Sofia d'Epiro gauge (observed forcing). Nash-Sutcliffe coefficient for the calibration period (2002.12.01-2003.01.05) = **0.930**, for the validation period (2003.01.06-2003.10.1) = **0.720**, overall value = **0.799**.



Validation N-S: 0.74 on hourly flows

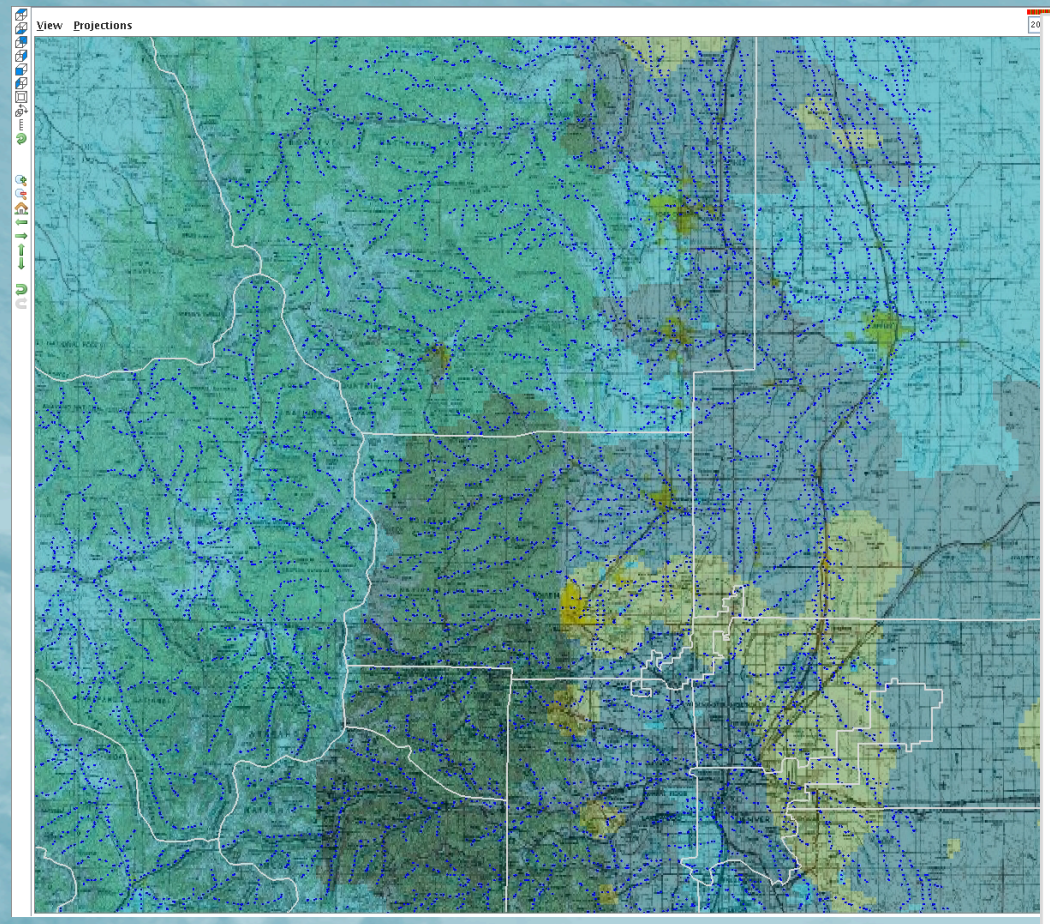
3-d HMS Groundwater Model over southern TERENO Network Bavaria, Germany

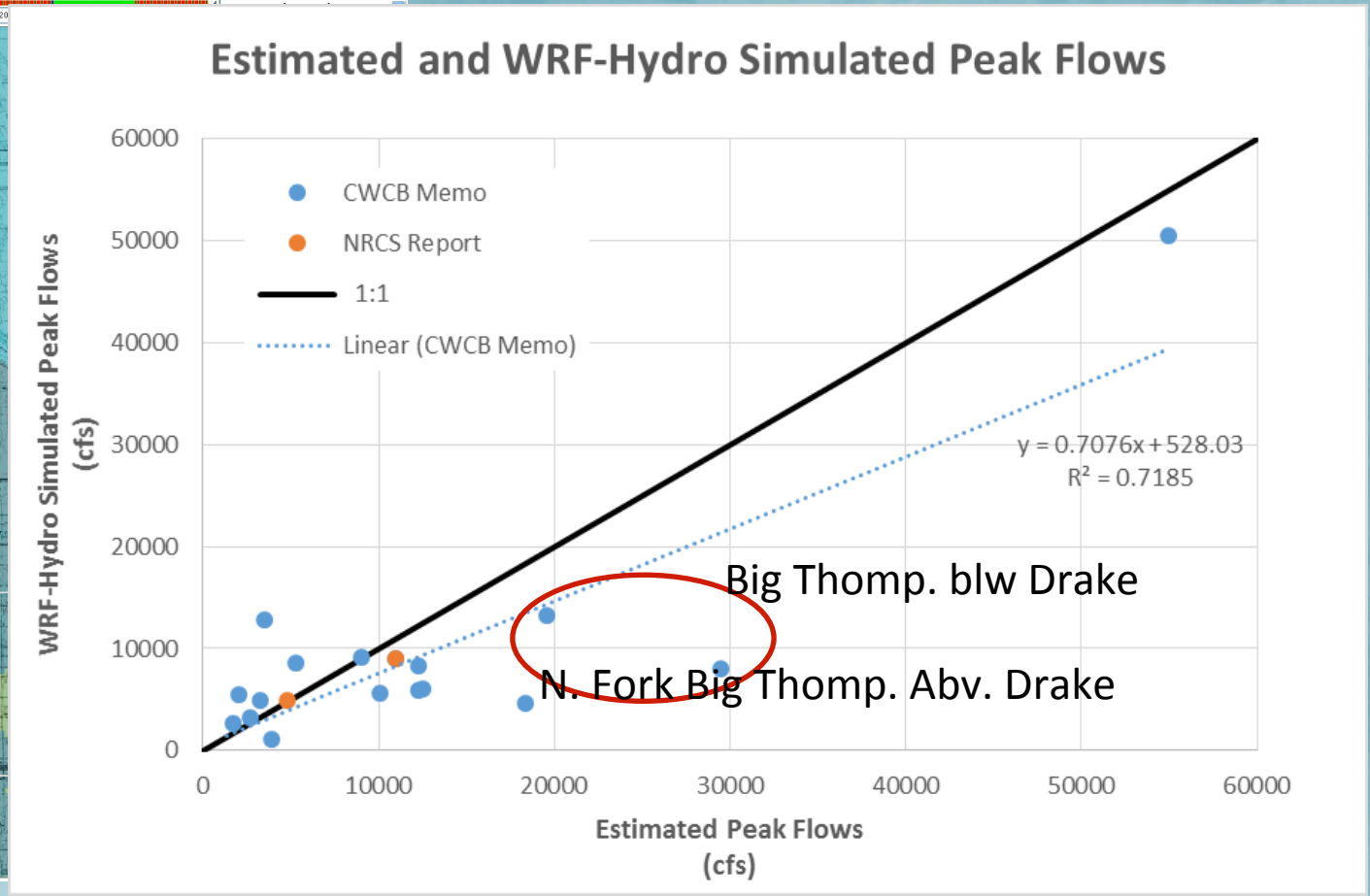
Implemented by B. Fersch, KIT-Garmisch, Germany



WRF-Hydro Applications:

1. Regional Flood Forecasting - Sep. 2013 Front Range





MPE – driven WRF-Hydro, Sep 11-13, 2013

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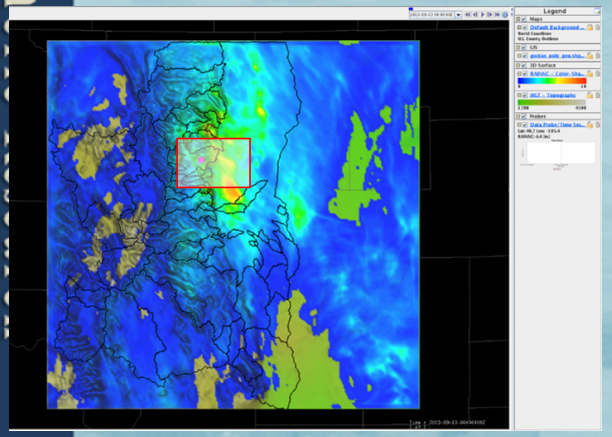
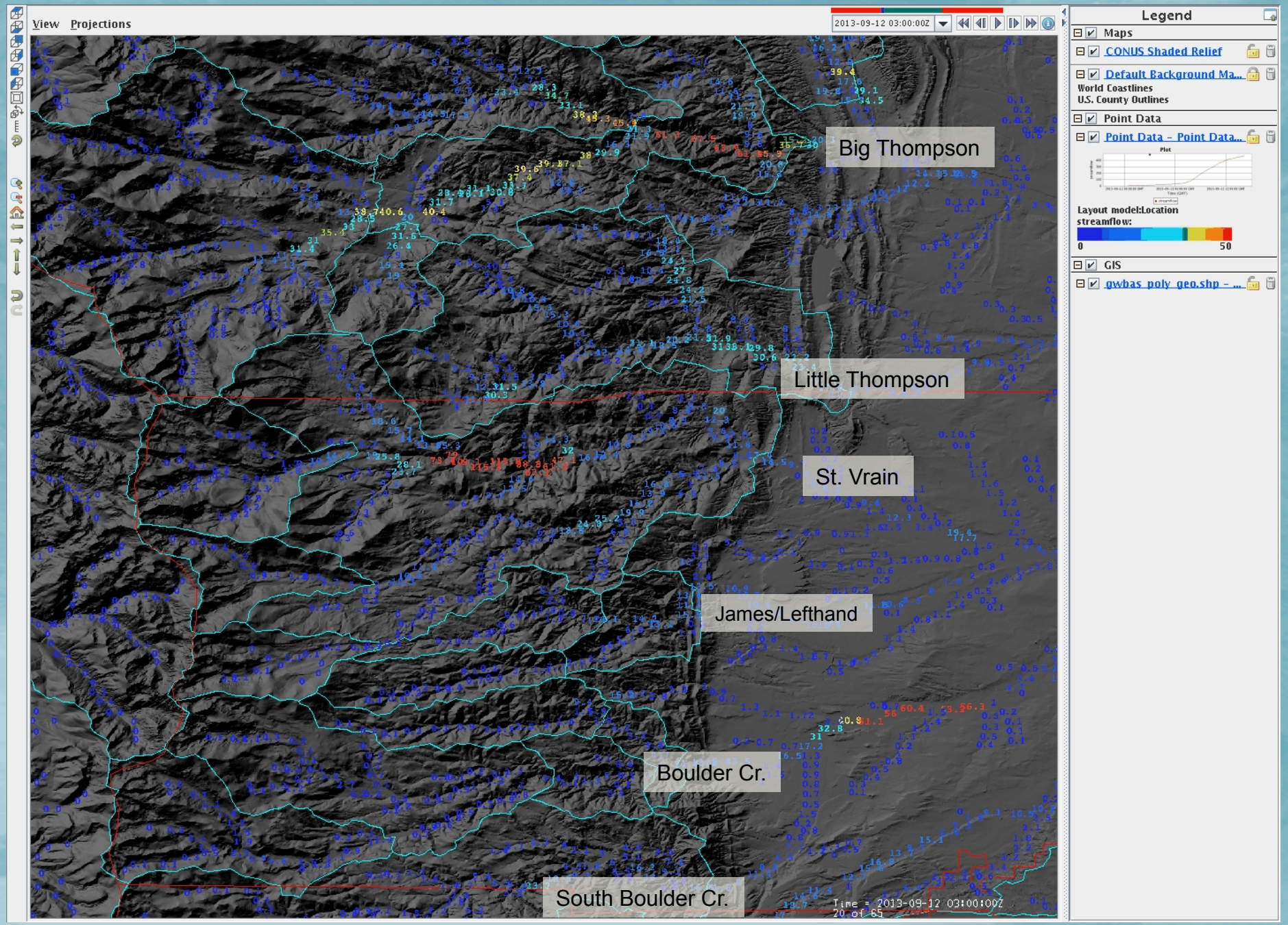
Hindcasted streamflow coupled WRF/ WRF-Hydro model

Initialization: 9/11 00z

Valid: 9/12 07z



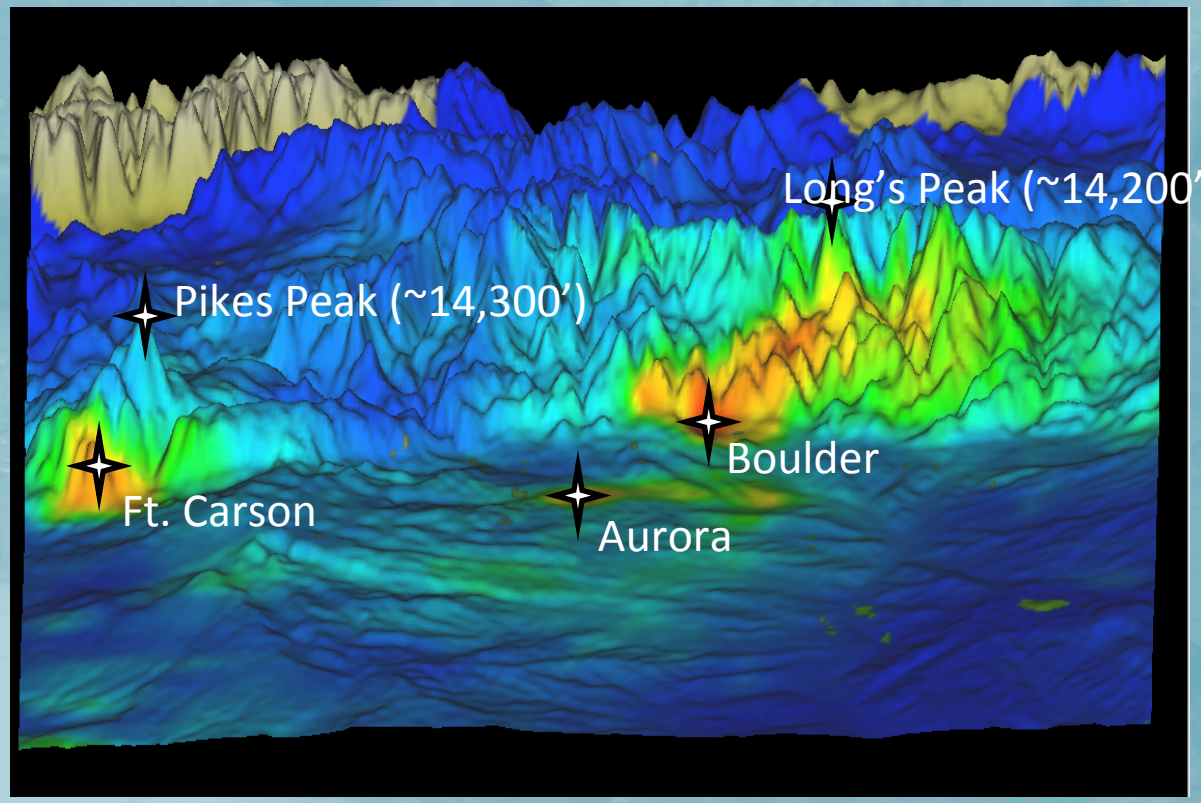
Streamflow in cms



4. RECENT ENHANCEMENTS

Forcing data supported:

- NLDAS, NARR analyses
- QPE products: MPE, StgIV, NCDC-served, dual-pol, Q3/ MRMS
- NOAA QPF products: GFS, NAM, RAP, HRRR, ExREF
- Nowcast (NCAR Trident/ TITAN)
- NOHRSC SNODAS



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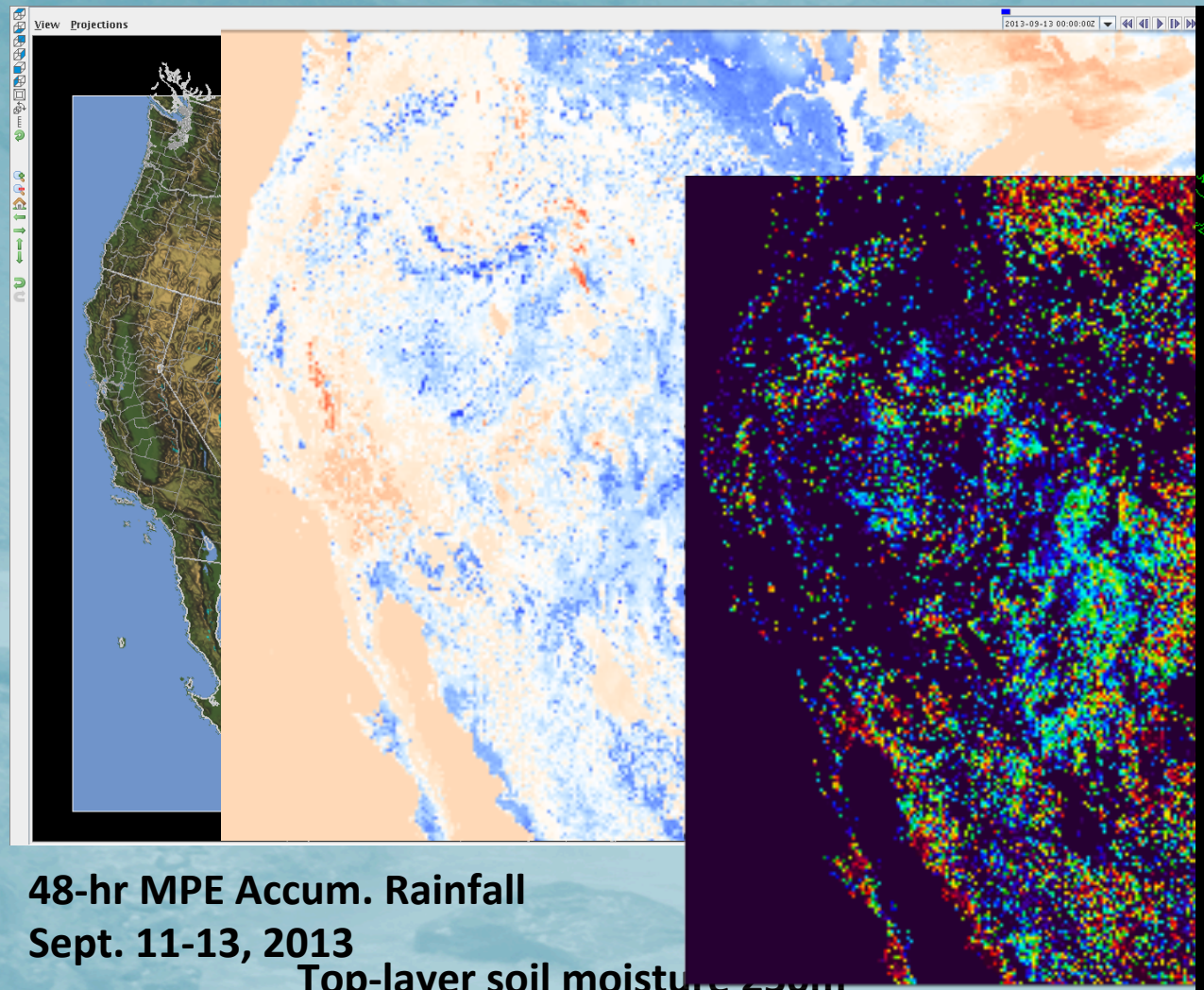
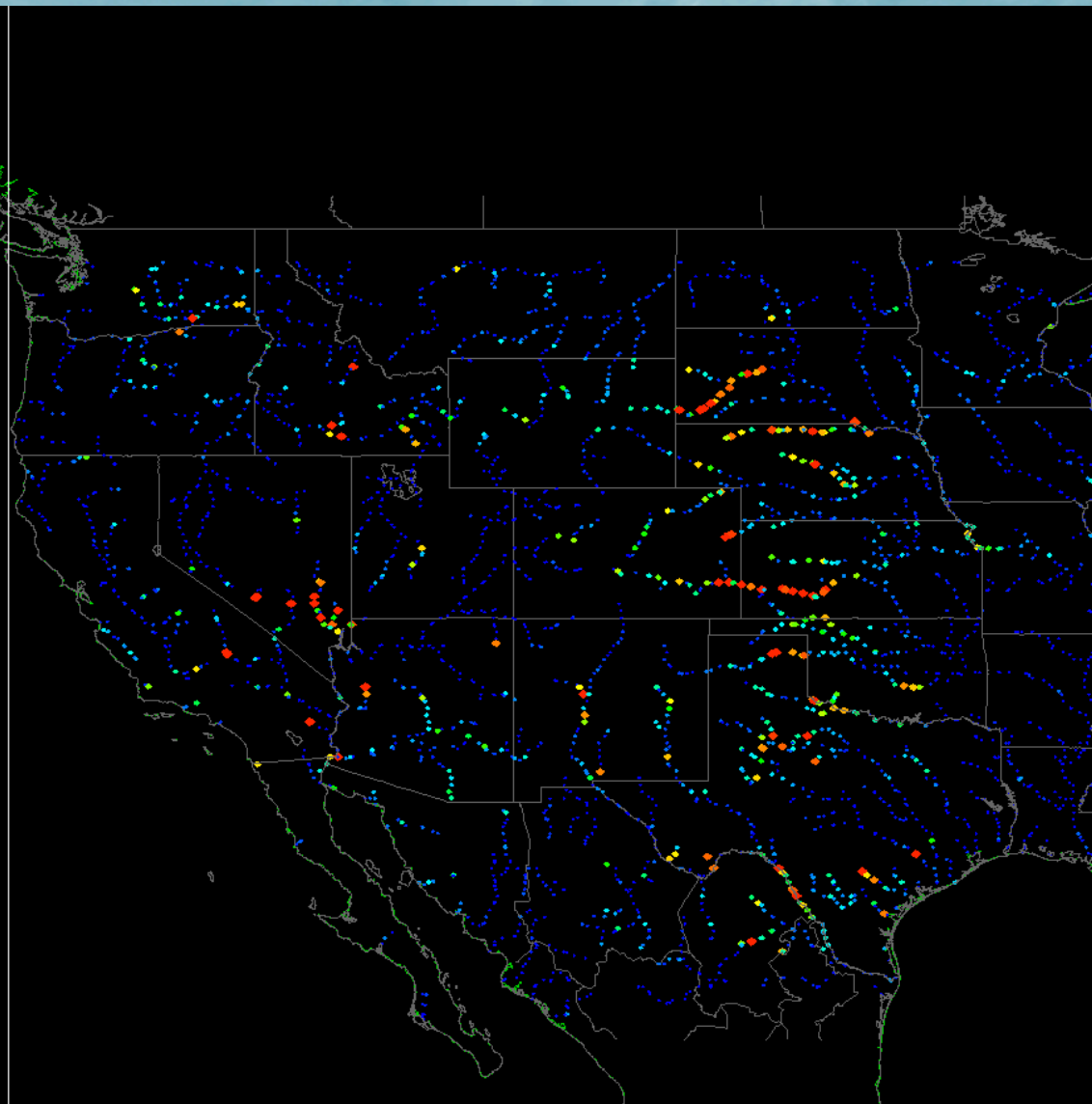
National-scale domain applications: 4km/250m



48-hr MPE Accum. Rainfall
Sept. 11-13, 2013

Top-layer soil moisture 250m



Channel 'inflows' 250m

5. ONGOING ACTIVITIES:

WRF-Hydro Ongoing Activities

- Hydrologic Data Assimilation within WRF-Hydro (in progress):
  1. Interfacing with multi-agency GSI (Gridpoint Statistical Interpolation system) for support of variational methods and WRF-embedded applications
  2. Interfacing with NCAR DART (Data Assimilation Research Testbed) for support of ensemble-based DA methods

WRF-Hydro Ongoing Activities

- **Expanded Support, Documentation & Training:** Remains a fundamental challenge under current project- based support structure… but an area where there is substantial groundwork
  - Full website with downloads, documentation and test cases
  - Creating pdf's of past training seminars
  - Expanding library of pre-/post-processing scripts

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Thank you!

D. Gochis, gochis@ucar.edu

WRF-Hydro: http://www.ral.ucar.edu/projects/wrf_hydro/

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Contributions:

NCAR Internal:

D. Gochis (Project Lead)
W. Yu (Lead Software Engineer)
D. Yates (Water Resources Lead)
A. Wood (Advising Scientist)
M. Clark (Advising Scientist)
J. McCreight (Post-doc)
K. Sampson (GIS Specialist)
K. Ikeda (Data Analyst)
R. Rasmussen (Sr. Advising Scientist)

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Contributors

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