WRF-Hydro: A hydrological modeling extension package for the Weather Research and Forecasting System

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WRF-Hydro Component Overview

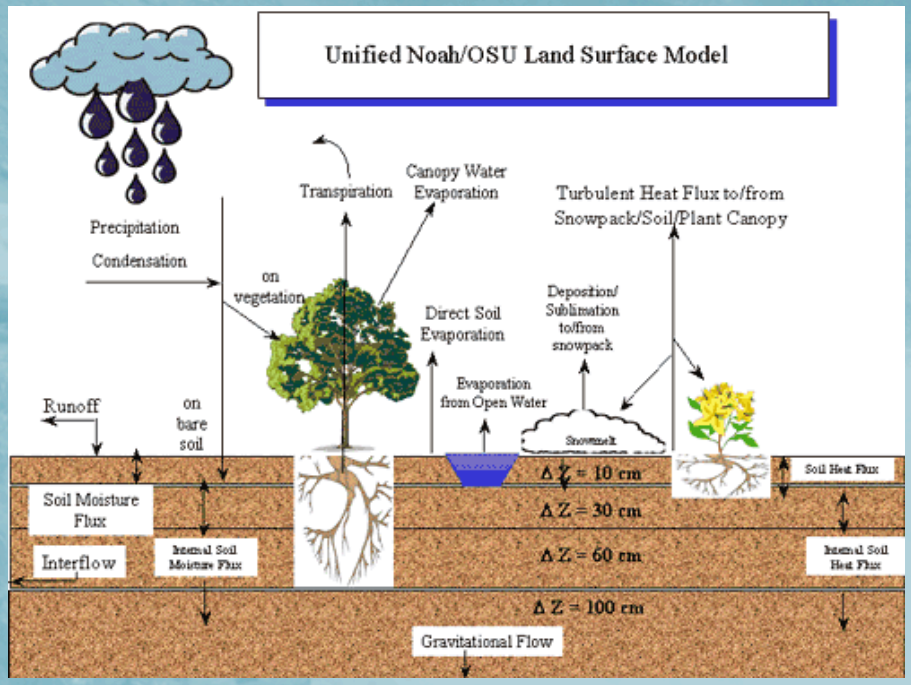
May 2015

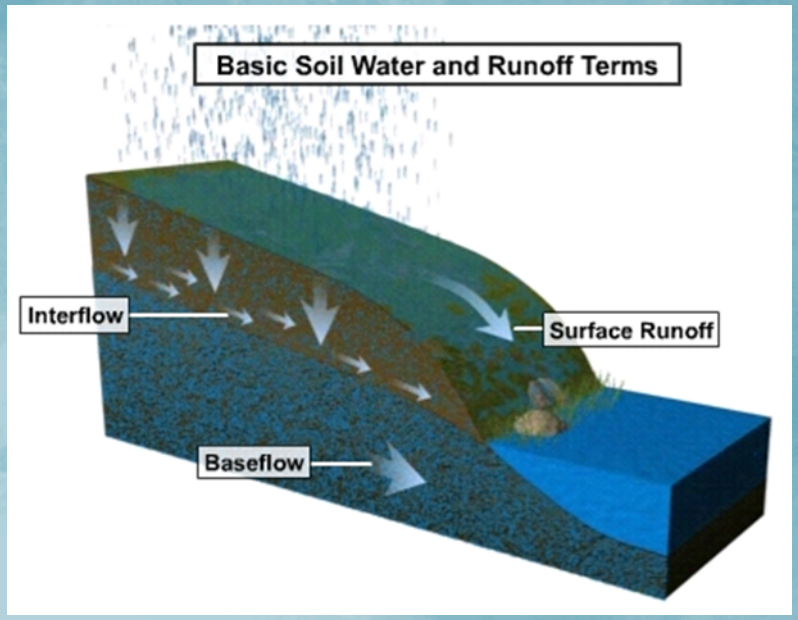
Outline:

- Basic Concepts
- Conceptualization of WRF-Hydro
- Model Architecture & Requirements

Basic Concepts:

- Linking the column structure of land surface models with the 'distributed' structure of hydrological models in a flexible, HPC architecture….





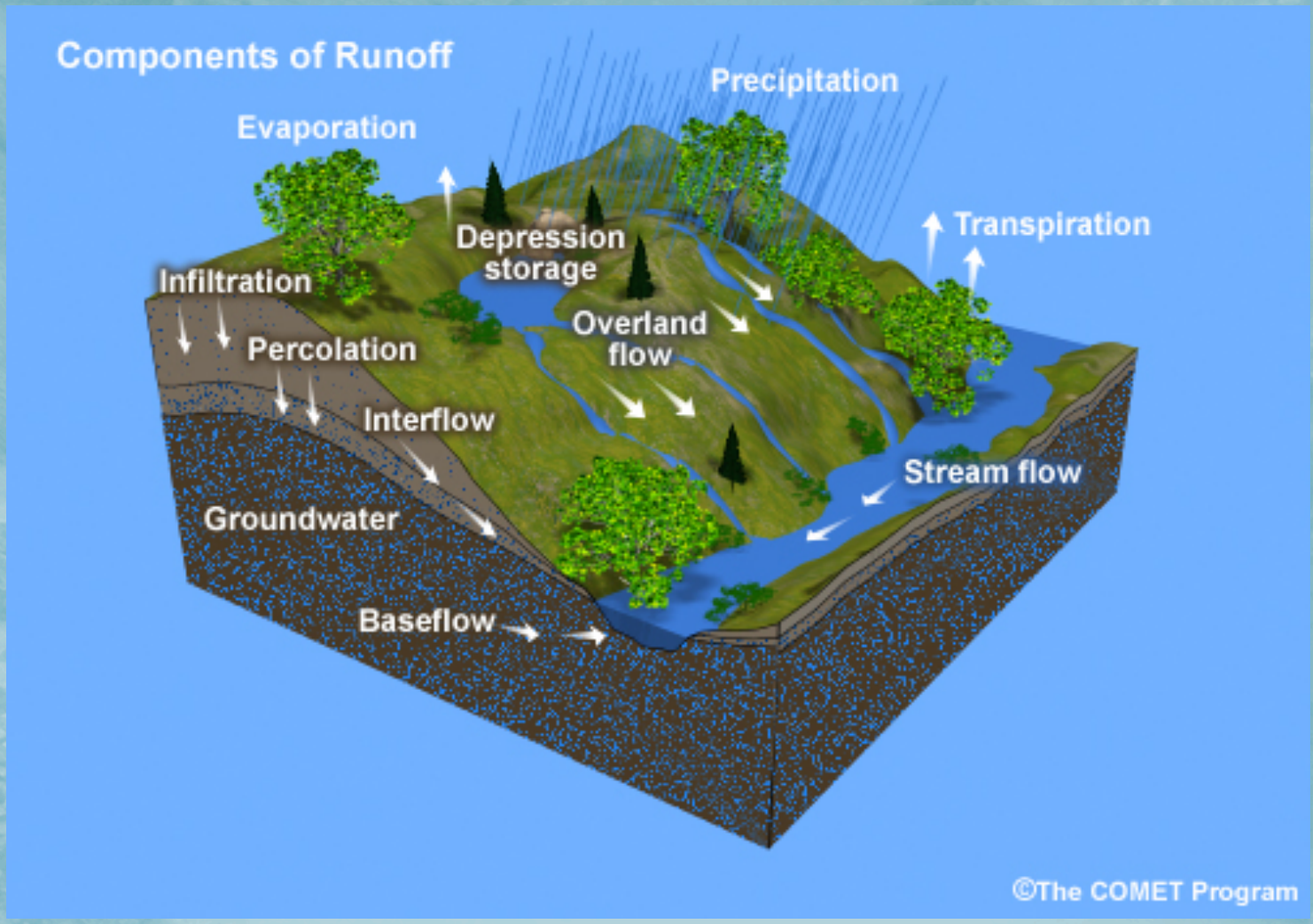
Conceptualization of WRF-Hydro:

- Atmospheric coupling perspective and serving the WRF research and forecasting and CESM communities

- Oriented towards existing NCAR-supported community models, but expanding:
  - Not fully genericized coupling which has pros/cons associated…
  - Also aimed at cluster & HPC architectures

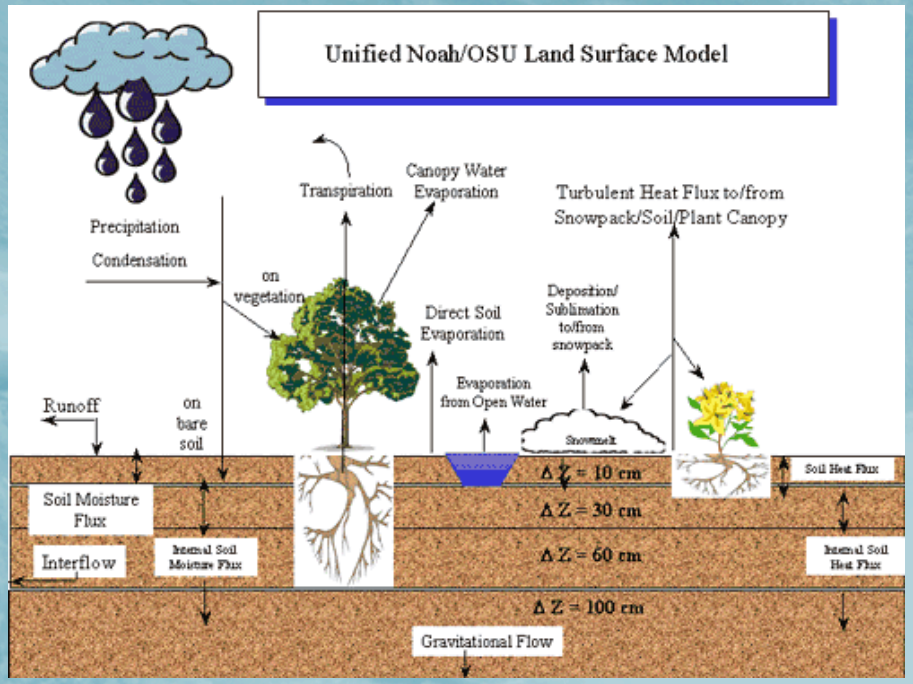
WRF-Hydro v3.0 Physics Components:

- Goal…

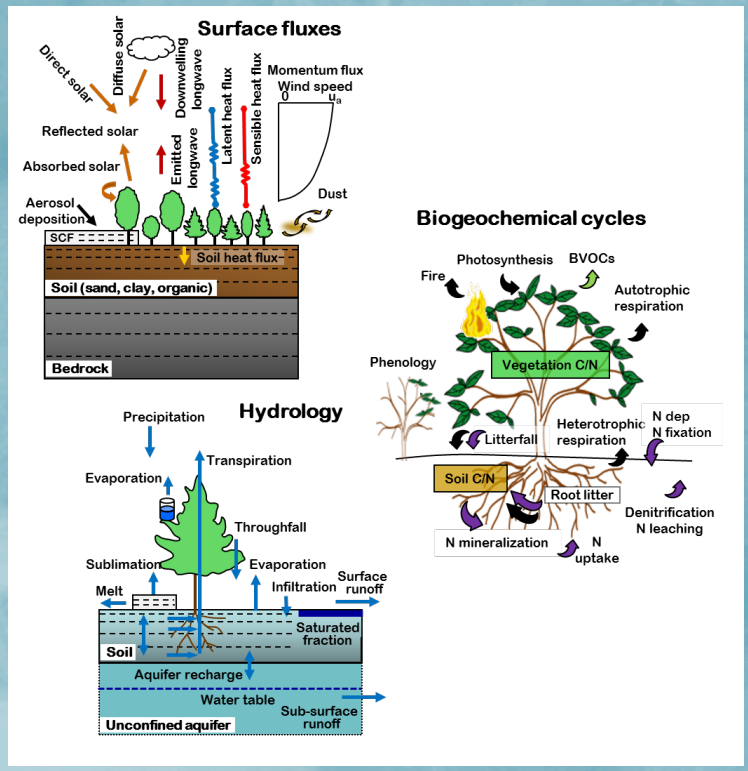


WRF-Hydro v3.0 Physics Components:

- Current Land Surface Models:
  - Column physics & land-atmosphere exchange



Noah LSM v3.5 & Noah-MP

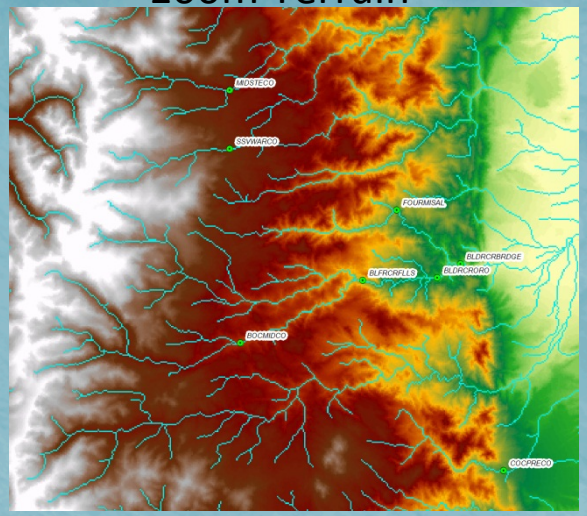


CLM v4.5

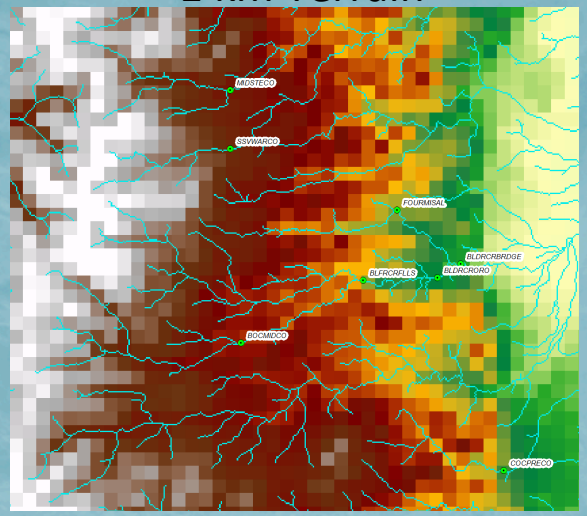
WRF-Hydro v3.0 Physics Components:

- Multi-scale aggregation/disaggregation:

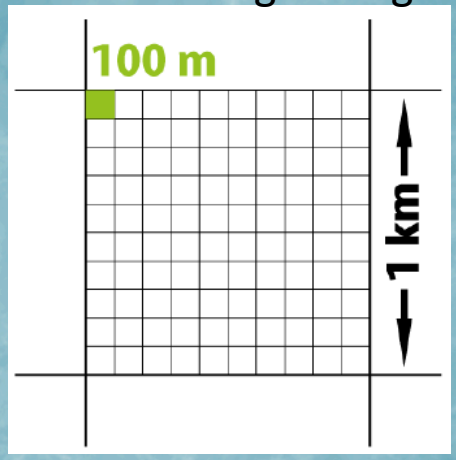
100m Terrain

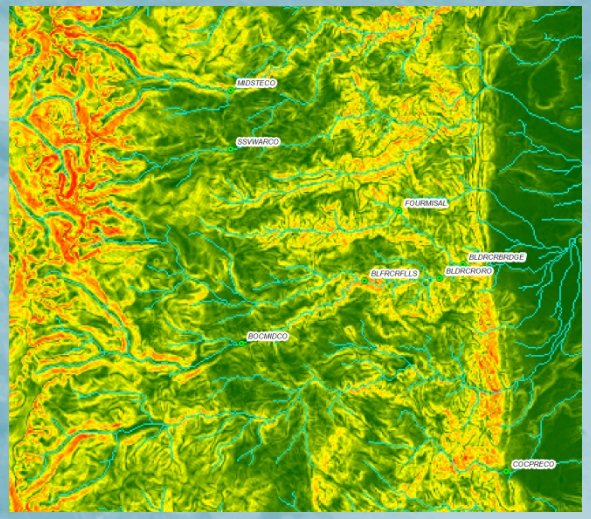


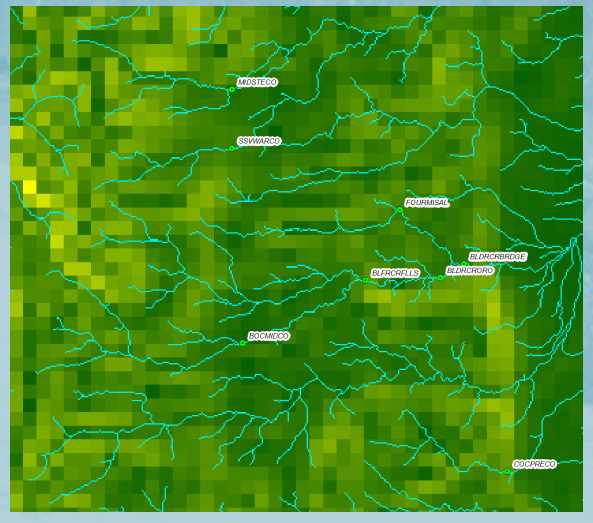
1 km Terrain



Current 'Regridding'

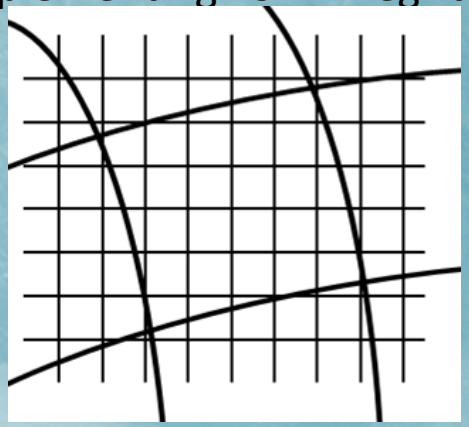






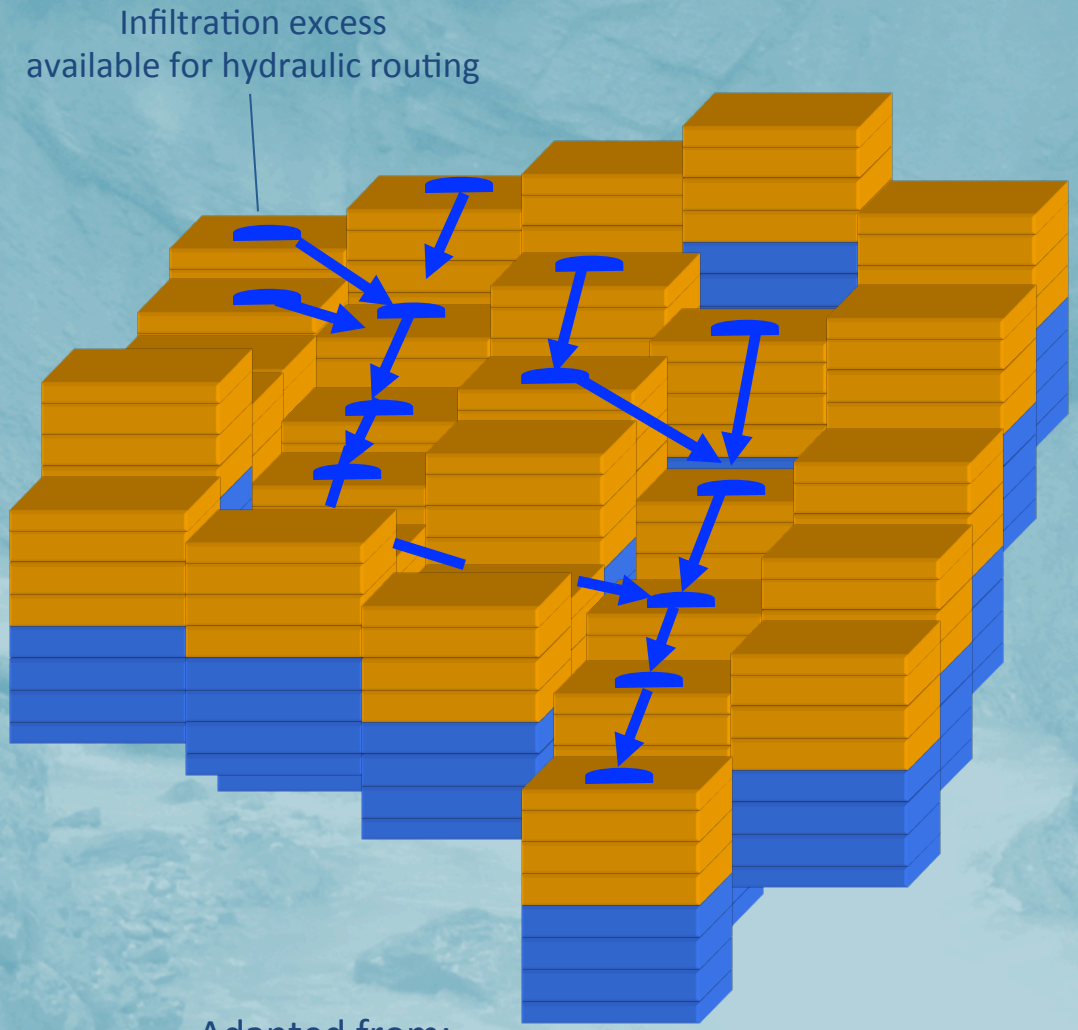
Terrain slope (0-45 deg)

Implementing ESMF Regridders



WRF-Hydro v3.0 Physics Components:

- Surface routing:

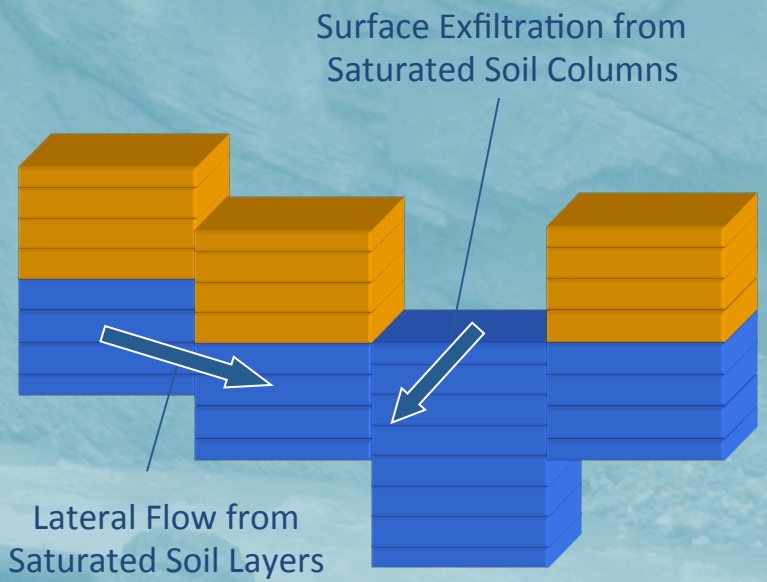


Adapted from:
Julian et al, 1995 – CASC2D, GSSHA

- Pixel-to-pixel routing
  - Steepest descent or 2d
  - Diffusive wave/ backwater permitting
  - Explicit solution
- Ponded water (surface head) is fully-interactive with land model
- Sub-grid variability of ponded water on routing grid is preserved between land model calls

WRF-Hydro v3.0 Physics Components:

- Subsurface routing:



Adapted from:
Wigmosta et. al, 1994

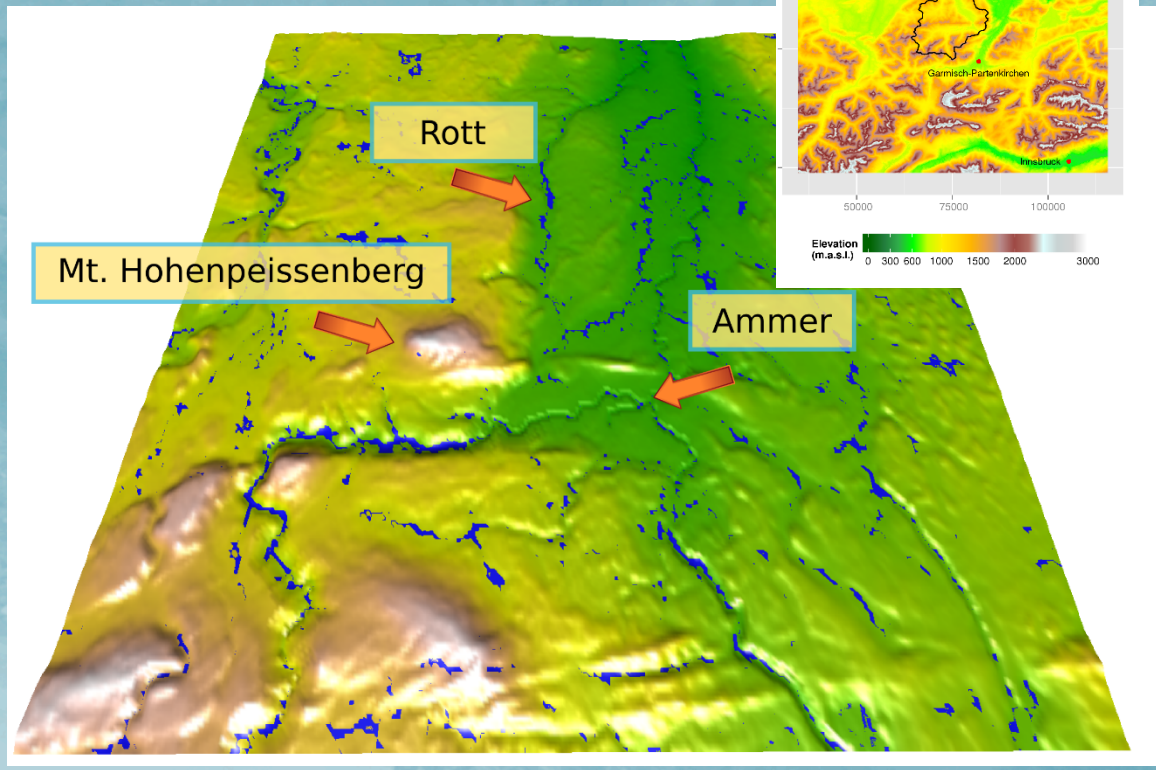
- Quasi steady-state, Boussinesq saturated flow model
- Exfiltration from fully-saturated soil columns
- Anisotropy in vertical and horizontal Ksat
- No 'perched' flow
- Soil depth is uniform

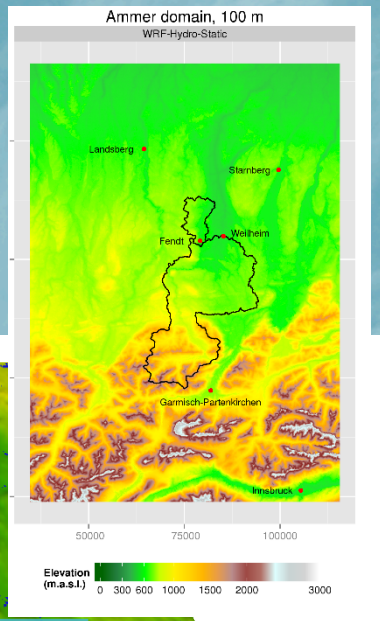
- Critical initialization value: water table depth

WRF-Hydro v3.0 Physics Components

Subsurface routing:

- 2d groundwater model
- Coupled to bottom of LSM soil column through Darcy-flux parameterization
- Independent hydraulic characteristics vs. soil column
- Full coupling to gridded channel model through assumed channel depth and channel head
- Detailed representation of wetlands

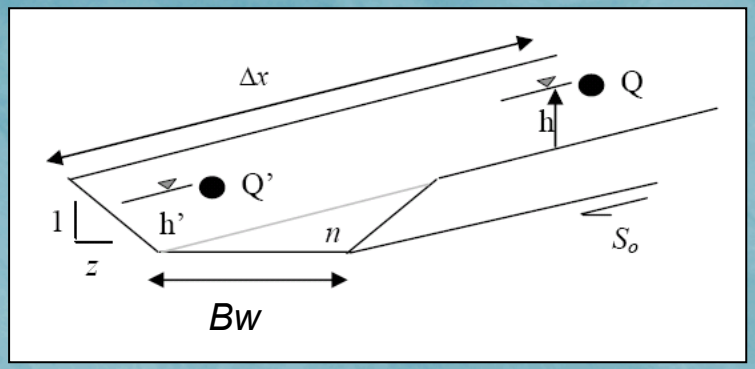


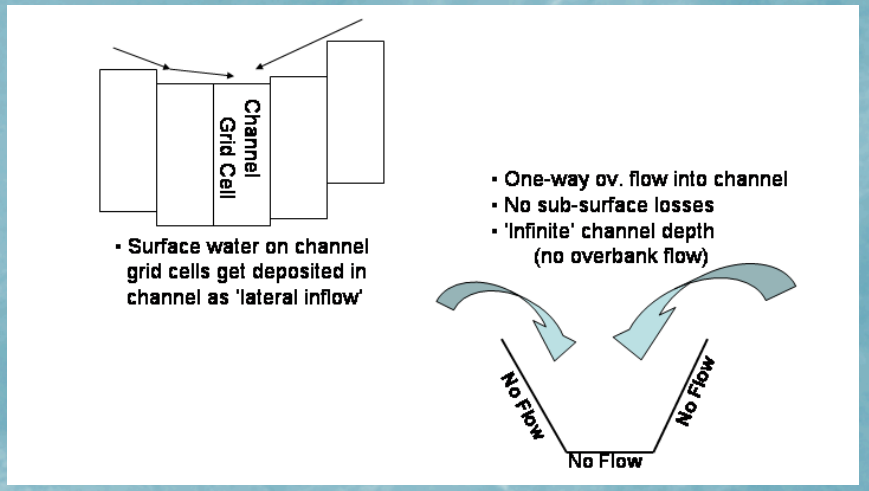


Surface ponded water from coupled groundwater in WRF-Hydro
B. Fersch, KIT, Germany

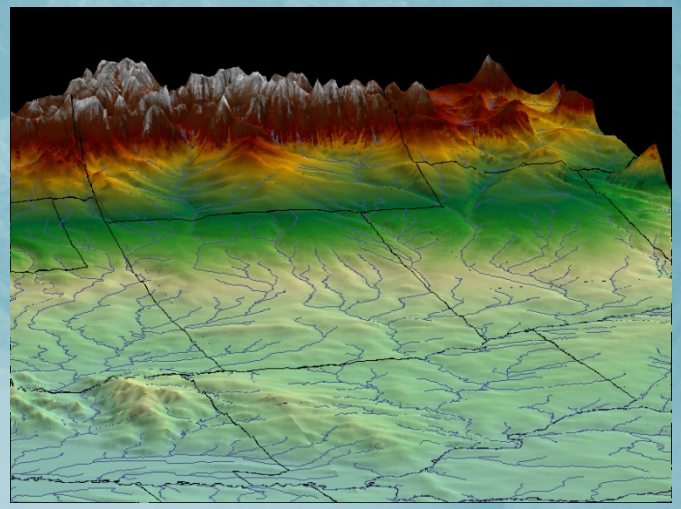
WRF-Hydro v3.0 Physics Components:

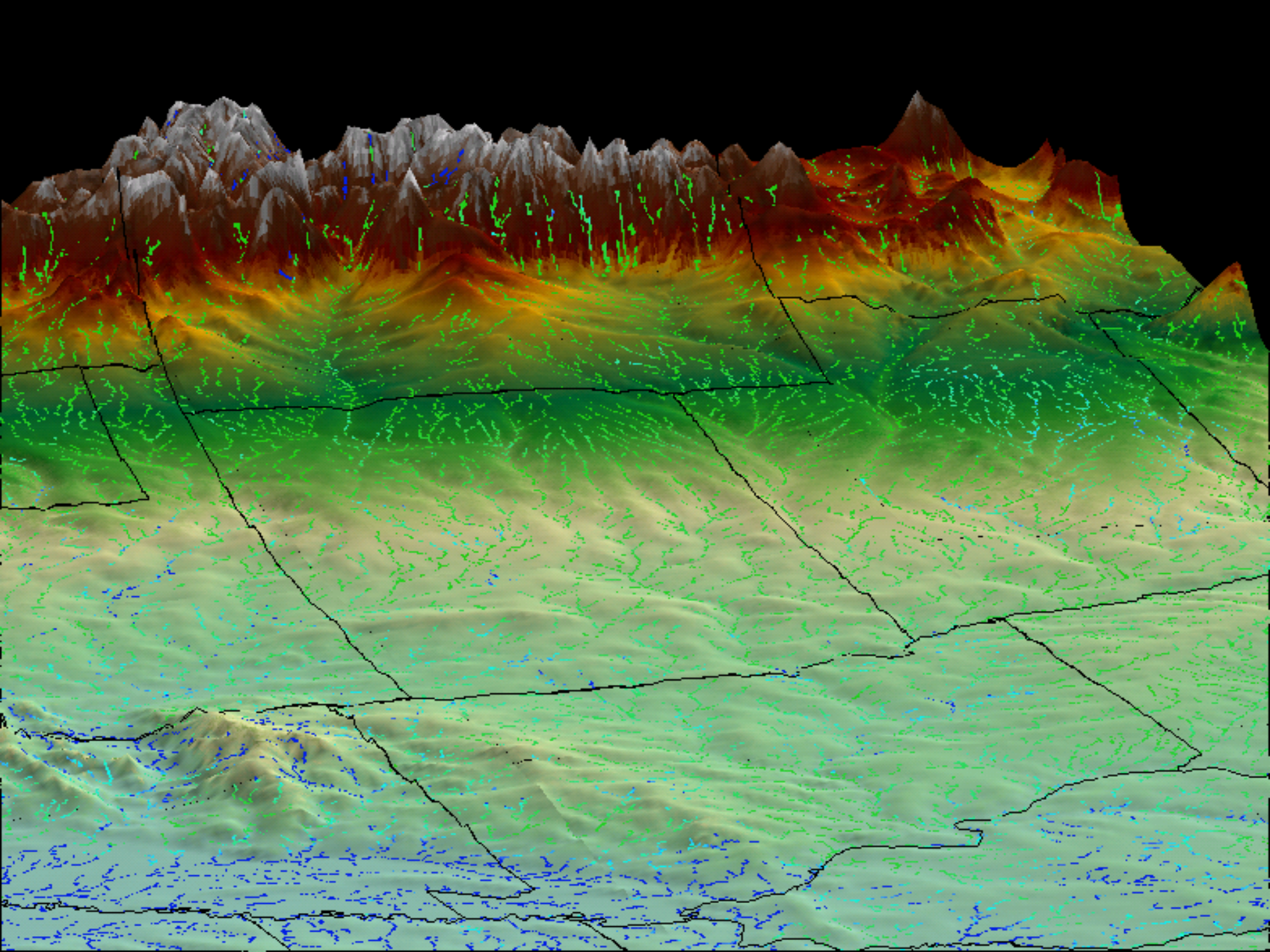
- Channel routing: Gridded vs. Reach-based





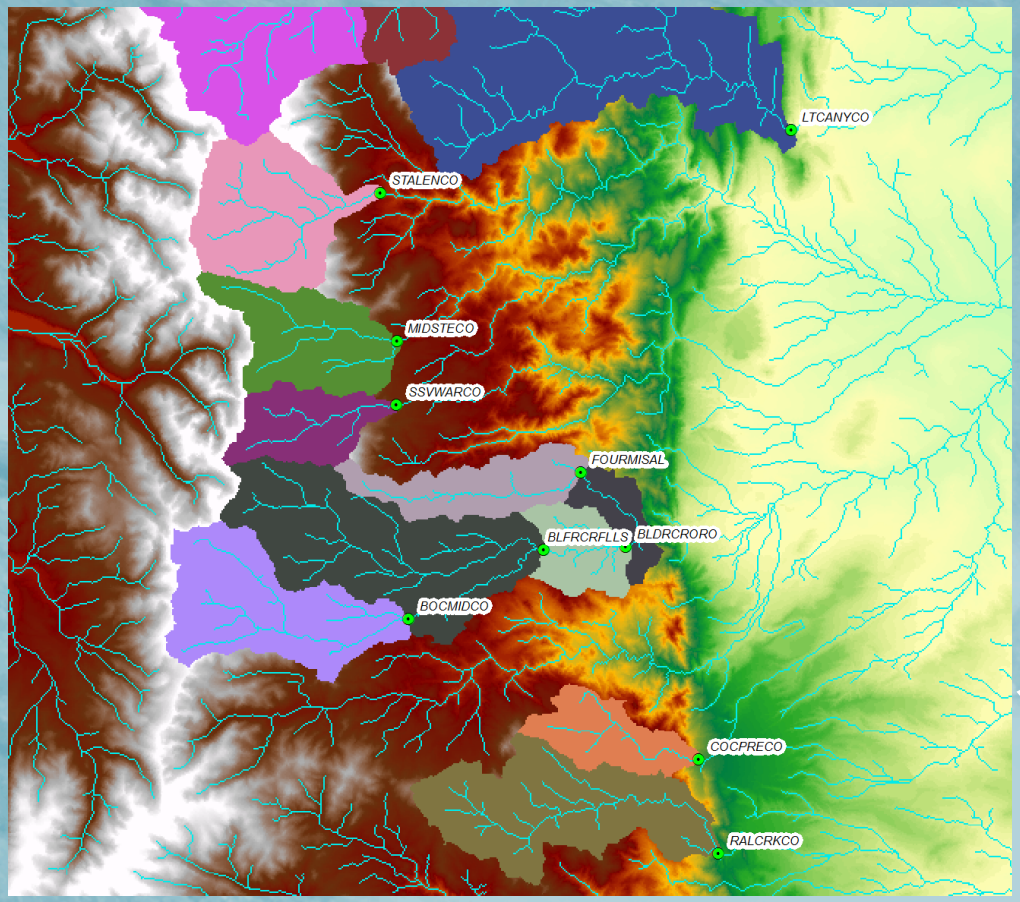
- Solution Methods:
  - Gridded: 1-d diffusive wave: fully-unsteady, explicit, finite-difference
  - Reach: Muskingam, Muskingam-Cunge *(much faster)*
- Parameters:
  - A priori function of Strahler order
  - Trapezoidal channel (bottom width, side slope)

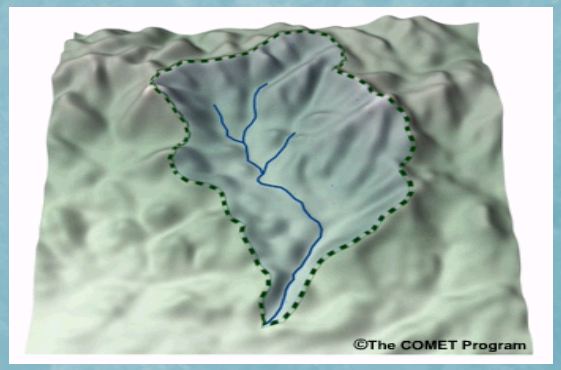


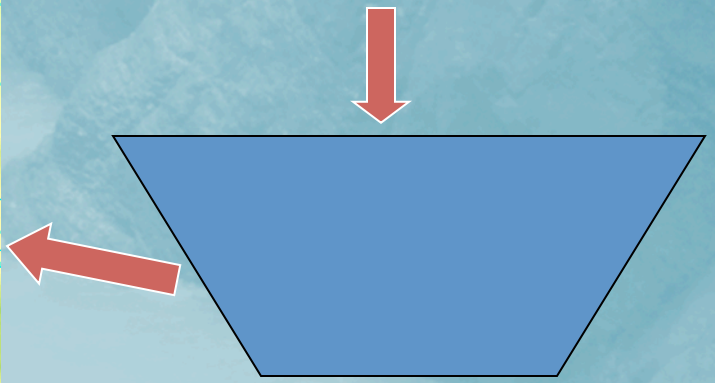


WRF-Hydro v3.0 Physics Components:

- Optional conceptual 'Bucket' models:
  - Used for continuous (vs. event) prediction
  - Simple pass-through or 2-parameter exponential model
  - Bucket discharge gets distributed to channel network

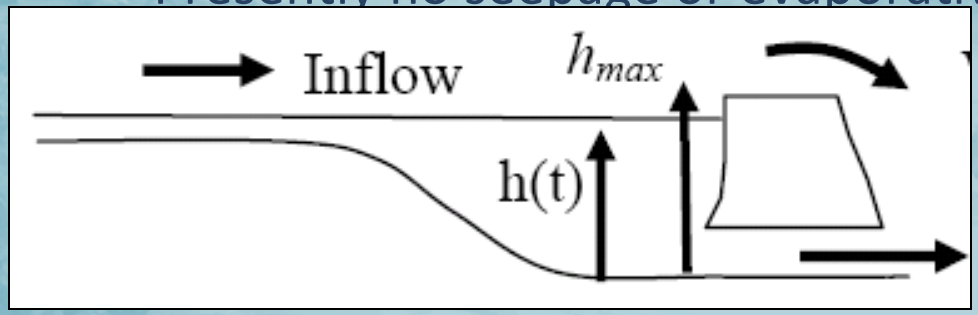






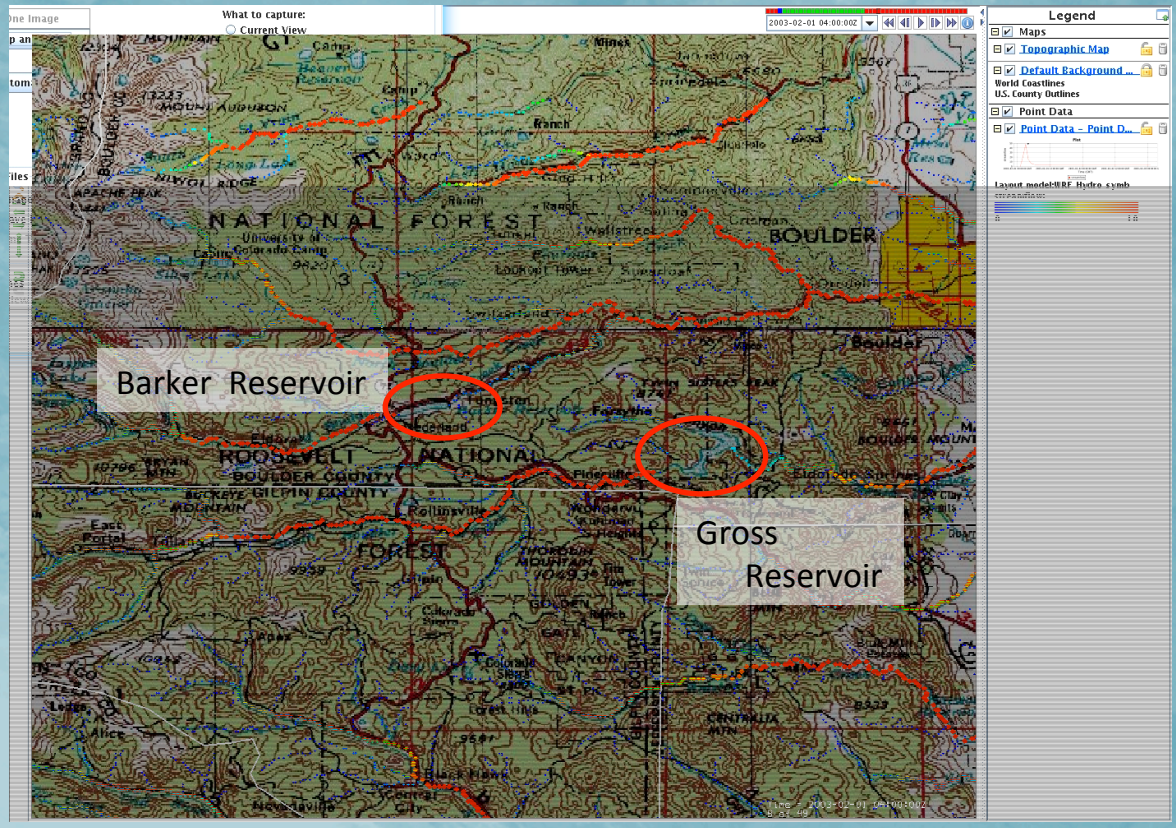
WRF-Hydro v3.0 Physics Components:

- Optional lake/reservoir model:
  - Level-pool routing (i.e. no lagging of wave or gradient in pool elevation)
  - Inflows via channel and overland flow
  - Discharge via orifice and spillway to channel network
  - Parameters: lake and orifice elevations, max. pool elevation, spillway and orifice characteristics; specified via parameter table
  - Active management can be added via an operations table
  - Presently no seepage or evaporative loss functions

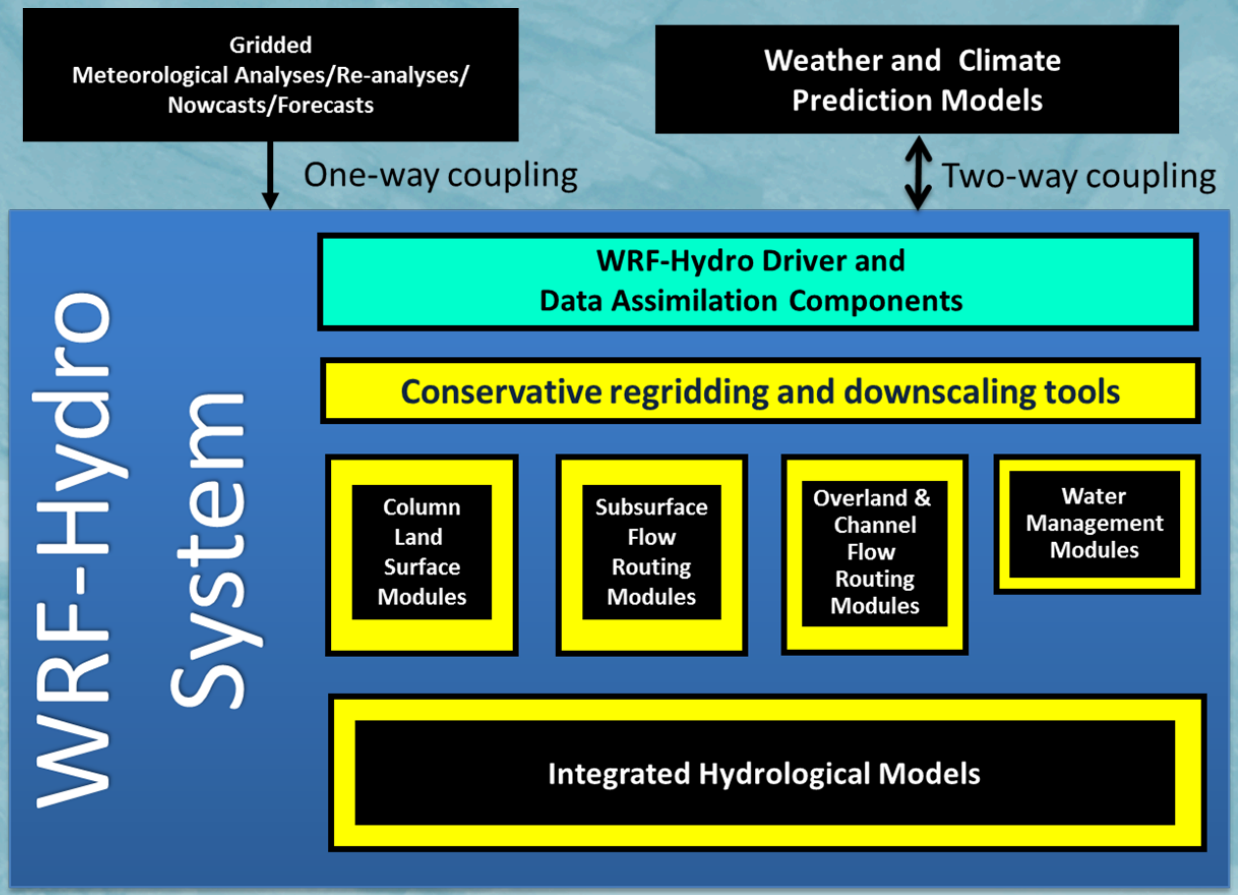


Implementing lakes and reservoirs in WRF-Hydro

1. Visualization of lake impacts



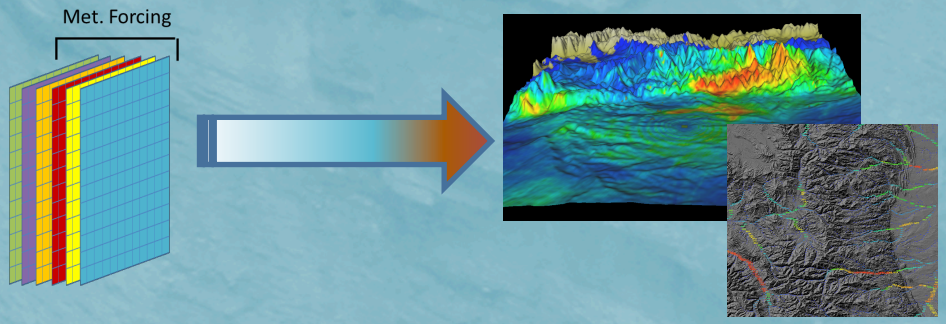
WRF-Hydro Architecture Description:



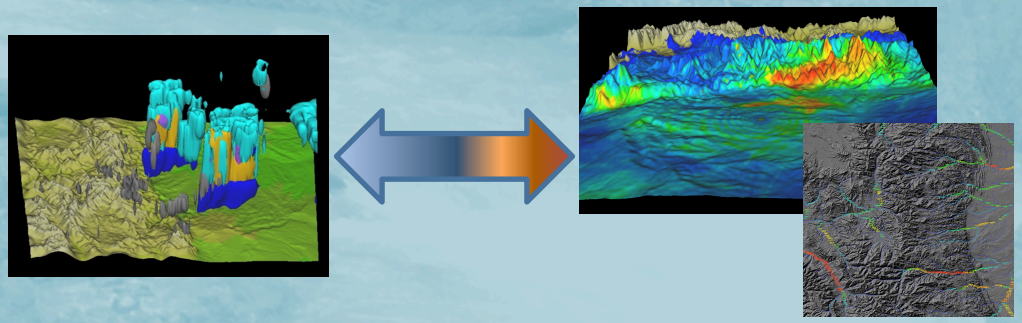
- Model physics components….
- Multi-scale components….
  - Rectilinear regridding
  - ESMF regridding
  - Downscaling

Architecture Description: Basic Concepts

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' Software Features:

- Modularized F90 (and later) and integrated in the WRF ARW & NMM and CESM systems and NASA-LIS
- Coupling options are specified at compilation and WRF-Hydro is compiled as a new library in WRF
- Physics options are switch-activated though a namelist/configuration file
- Options to output sub-grid state and flux fields to standards-based netcdf point and grid files
- Fully-parallelized to HPC systems with 'good' scaling performance
- Ported to Intel, IBM and MacOS systems and a variety of compilers

Wei Yu (RAL) – lead engineer

The National Center for Atmospheric Research

Thank you!

D. Gochis, gochis@ucar.edu, W. Yu, K. Sampson, D. Yates

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

Funding provided by:

NSF, NOAA-OHD, NASA-IDS, DOE-ESM