WRF-Hydro System: Physics Components

October 17-19, 2017


National Center for Atmospheric Research
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 v4.0 Physics Components:

- Goal...
WRF-Hydro v4.0 Physics Components:

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

Noah LSM v3.5 & Noah-MP

CLM v4.5
WRF-Hydro v4.0 Physics Components:

- Multi-scale aggregation/disaggregation:

100m Terrain

1 km Terrain

Current 'Regridding'

100 m

1 km

Implementing ESMF Regridders

Terrain slope (0-45 deg)
WRF-Hydro v4.0 Physics Components:

- Multi-scale aggregation/disaggregation:
WRF-Hydro v4.0 Physics Components:

- **Surface routing:**
  - Infiltration excess available for hydraulic routing

- **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

Adapted from: Julian et al, 1995 – CASC2D, GSSHA
WRF-Hydro v4.0 Physics Components:

- Subsurface routing:
  - 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

Adapted from:
Wigmosta et. al, 1994
WRF-Hydro v4.0 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
Noah, NoahMP Column Physics:

Noah-MP contains several options for land surface processes:

1. Dynamic vegetation/vegetation coverage (4 options)
2. Canopy stomatal resistance (2 options)
3. Canopy radiation geometry (3 options)
4. Soil moisture factor for stomatal resistance (3 options)
5. Runoff and groundwater (4 options)
6. Surface layer exchange coefficients (4 options)
7. Supercooled soil liquid water/ice fraction (2 options)
8. Frozen soil permeability options (2 options)
9. Snow surface albedo (2 options)
10. Rain/snow partitioning (3 options)
11. Lower soil boundary condition (2 options)
12. Snow/soil diffusion solution (2 options)

Total of ~50,000 permutations can be used as multi-physics ensemble members
Runoff and Routing Physics:

- Overland Flow
- Lateral Subsurface Flow
- Simplified Baseflow Parameterization
- Channel Hydraulics
- Simple Water Management
WRF-Hydro Physics Development Activities:

LSM:
- Implementation of variable soil thickness and extended soil thickness (number of layers and layer thickness)
- Improvements in rain/snow partitioning and linkage to PBL profiles
- Continued snow model upgrade testing... albedo specification, snow depletion curve, density, wind redistribution....alpine glacier implementation

Routing:
- Channel loss parameterization for semi-arid/arid region applications
- Groundwater model coupling:
  - Fersch et al. 2-d groundwater model with 2-way surface coupling planned to be released spring 2017
  - PARFLOW
  - Coupling to Miguez-Macho/Fan subsurface flow scheme
- Ponded water/overland flow thermodynamic accounting (evaporation and ice)
- 2-way channel-overland flow coupling
- Reach-based dynamic wave formulation
WRF-Hydro Parameter Estimation: Channel geometry

Channel Hydraulics:

- Reach/vector-based:

  \[ W = e^i A^a O^b Q^c \]

Channel Parameter Update:

- V1.0 used literature values of channel bottom width and roughness specified as function of Strahler order
- V1.1 implemented a multi-variate regression model to estimate channel bottom width as functions of: (slope tested but didn’t pass...)
  - channel flow (Q)
  - Stream order (O)
  - contributing area (A)
- Utilized USGS cross-section data to develop regression parameters

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Transition to channels...
WRF-Hydro v4.0 Physics Components:

- **Channel routing**: Gridded vs. Reach-based

- **Solution Methods**:
  - Gridded: 1-d diffusive wave: fully-unsteady, explicit, finite-difference
  - Reach: Muskingum, Muskingum-Cunge *(much faster)*

- **Parameters**:
  - A priori function of Strahler order
  - Trapezoidal channel (bottom width, side slope)
NHDPlus Reach Channel Network:
WRF-Hydro v4.0 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 v4.0 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
Defined in GIS Pre-processing, integrated with channel hydrograph

Specified spillway characteristics (length, height)

- Level Pool Scheme:
- 3 ‘passive’ discharge mechanisms:
  - Orifice flow
  - Spillway flow
  - Direct Pass-through

- Development:
  - Basic thermodynamics (CLM/WRF lake model)
  - Full lake accounting
    - Evaporation
    - Ice formation
    - Inflows/outflows
    - Simple management
  - Coupling to FVCOM (GLERL)
Implementing lakes and reservoirs in WRF-Hydro

1. Visualization of lake impacts
**WRF-Hydro Architecture Description:**

- **Model physics components:**
  - Rectilinear regridding
  - ESMF regridding
  - Downscaling

- **Multi-scale components:**
  - Rectilinear regridding
  - ESMF regridding
  - Downscaling
Architecture Description: Basic Concepts

• 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
Thank you!

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

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