An Improved Hydrologic Modeling Framework for Flood Simulations in Connecticut

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Key features for an improved CT hydrologic model:

− Main
  • a fully Distributed Linear Reservoir Routing (DLRR)
  • an energy & water balances coupled scheme for ET and snow process
  • distributed parameters from 1km soil map, 500m land cover maps 1km LAI (Leaf Area Index) product

− Extended
  • multi-site calibration based on multi-objective optimization.
  • flood inundation mapping using 1 meter LiDAR-derived DEM
  • include hydraulic structures for selected towns
Model Overview

- K_{SAT}
- W_{m}
- FC
- Albedo
- Height
- SWmin
- Roughness
- W_{m}
- TAIR
- Rad_{SW}
- Rad_{LW}
- Humidity
- Pressure
- Wind

**Remotely Sensed Products**
- Leaf Area Index

**Hourly Meteorologic Variables**
- Climatology
- Precipitation

**Distributed Variables**
- Land Cover
- Soil Properties
- Vegetation Library
- Impervious Area

**GIS-Terrain**
- Elevation
- Flow direction
- Stream network

**Water Balance**
- Interception
- Evapotranspiration
- Snow Process
- Infiltration

**Energy Balance**
- Atmospheric Layer
- Canopy Layer
- Snow Pack Layer
- Surface Soil Layer
- Deep Soil Layer

**Fully Distributed Routing**
- ET
- Runoff

**Routing parameters**

**USGS (Q)**

**Calibration**
Cell-To-Cell Routing

Fully Distributed Linear Reservoir
Experiment Design

- Connecticut River, CT
- Forcing data
  - NLDAS Reanalysis (14km × 14km, Hourly)
  - Stage IV Precipitation (4km × 4km, Hourly)
  - MODIS LAI (1km × 1km, 8-day)
- Land Cover: Satellite data (MODIS: 500m × 500m)
- Soil Texture Map
  - Soil Grids 1k (1km × 1km, 6 layers, 0-2m depth)
  - http://www.soilgrids.org/
SNOW & SWE (Snow Water Equivalence)

Snowfall

Date: 2002/10/20

SWE of the snow pack on the ground

Date: 2002/10/20

Intercepted snow by canopy

Date: 2002/10/20

Value

High: 2.29

Low: 0

Intercepted snow by canopy

Date: 2002/10/20

Value

1.5069

1.3562

1.2065

1.0548

0.9041

0.7534

0.6027

0.4520

0.3013

0.1507
Hydrologic Statistics

- **NSCE** = \( 1 - \frac{\sum_{t=1}^{T}(X_{obs}^t - X_m^t)^2}{\sum_{t=1}^{T}(X_{obs}^t - \bar{X}_{obs})^2} \) ∈ \([-\infty, 1]\)

- **CC** = \( \frac{\sum_{t=1}^{T}(X_m^t - \bar{X}_m)(X_{obs}^t - \bar{X}_{obs})}{\sqrt{\sum_{t=1}^{T}(X_{obs}^t - \bar{X}_{obs})^2} \sum_{t=1}^{T}(X_{obs}^t - \bar{X}_{obs})^2} \) ∈ \([-1, 1]\)

- **Bias** = \( \frac{\sum_{t=1}^{T}(X_{obs}^t - X_m^t)}{n\bar{X}_{obs}} \times 100\% \)
VIC’s ET Result in CT River

Evapotranspiration

Monthly ET (mm)

Date


Obs
VIC
VICET
CELL-To-CELL Validation

vs. a random 8km by 8km MODIS ET cell

NSCE=0.80
Bias=3.08%
River Discharge

NSCE=0.60  
CC=0.87  
Bias=-5.5%

Tropical Storm Tammy & Subtropical Depression 22
Conclusions

• We have developed a computationally efficient and physically consistent distributed hydrologic model that can be used for hydrologic studies in mid-latitude basins.

• The model was tested in the CT river basin with high simulation accuracy of ET without prior calibration as well as river runoff.

• The model will next be used for evaluating snow process effects on river flooding and to derive flood frequency maps over CT for current and future (end of century) climate conditions.
Cell-to-cell Evaluation vs. MODIS Long-term ET Over CT River

ET & Rain & Intercepted Rain
Soil moisture
Land surface Process

- Energy Balances & SNOW PROCESS (upgraded in v3.0)