Development of a prototype flash-flood prediction system for the Colorado Front Rang using the coupled WRF/Noah-Distributed Hydrometeorological Prediction System

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8th Annual WRF User’s Workshop, June 14, 2007
Critical needs and challenges for improved flash flood prediction

- USGS/FEMA Reports: Significant annual losses of life and property
- Spatial and temporal scale of flood generation processes *and* impacts necessitate very highly-resolved systems
- Regions of complex terrain can be particularly vulnerable due rapid collection and transport of flood waters in catchments
- The (growing) urban landscape also imparts significant challenges to traditional watershed modeling approaches
- Many events exhibit low predictability thus necessitating probabilistic approaches

*Photo courtesy: Cornerstones Community Partnerships*
The hydrologically-enhanced Noah-distributed Land Surface Model

(Gochis and Chen, 2003, NCAR Tech Note)

Dynamical Routing Methodologies

Explicit diffusive wave overland flow

Groundwater discharge, reservoir routing &

Explicit channel routing

North Pacolet Streamflow Verification

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Coupled and Uncoupled Modeling Strategy:

Precipitation Forcing:

- Nowcasts
- Gauges: ALERT +
- WRF (1 km)

Assimilated land/stream conditions:

- HRLDAS / Noah-distributed

Streamflow Forecast:

- 0-2 hr ‘warnings’
- 2-24 hr ‘risk’

Disseminate products:

- UDFCD
- NWS, OHD

Optional post-processing:

Add’tl Met. Forcing: EDAS, NAM

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Current applications and deployments:

Walnut River Basin, KS, USA 
(land-atmosphere coupling)

Santee River Basin, SC, USA 
(land-falling Tropical storms)

American River Basin, CA, USA 
(snowmelt hydrology)

North American monsoon, Mex. 
(monsoon hydrology)

Romanian operational hydrologic modeling

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Coupled WRF-Hydro Flash Flood Forecasting in the Colorado Front Range:

- **WRF Model Options**
  - No convection parameterization
  - Purdue/Lin 6-class microphysics
  - RRTM LW, Dudhia SW
  - Yonsei PBL, M-O sfc lyr
  - Noah land surface model w/ and w/out coupled Noah-distributed routing
  - Various initialization times

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Coupled WRF-Hydro Flash Flood Forecasting in the Colorado Front Range:

- Noah-distributed specifications:
  - 1 km Noah grid w/ 100m explicit terrain routing
  - NHDPlus 100m terrain
  - Trained stream network delineation based on NHDPlus ‘blue-lines’
  - STATSGO 1km soils
  - USGS 1km land cover

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Case Study: 1997 Ft. Collins Flood Event (see Peterson et al. 1997 BAMS)

- July 28-29, 1997
- Max. accumulations > 10 in. (250 mm) in 6 hrs.
- 5 fatalities
- Over $200M in damages
- Warm season quasi-stationary convective event

Case Study: 1997 Ft. Collins Flood Event

1 hr rain rates: Jul. 29, 1997 0100Z

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Case Study: 1997 Ft. Collins Flood Event

Mesoscale Analysis

Observed Analysis

“Denver Cyclone”

1 km WRF-no routing:
Init. July 27 12z

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Case Study: 1997 Ft. Collins Flood Event

Mesoscale Analysis

Observed Analysis

"Denver Cyclone"

1 km WRF-w/ routing:
Init. July 27 12z

Gochis et al., 8th Annual WRF User’s Workshop, June 14, 2007
Case Study: 1997 Ft. Collins Flood Event

Mesoscale Analysis

1 km WRF-w/out routing:
Init. July 27 12z

1 km WRF-w/ routing:
Init. July 27 12z

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Mesoscale Analysis

1 km WRF-w/out routing:
Init. July 27 12z

1 km WRF-w/ routing:
Init. July 27 12z

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Mesoscale Analysis

1 km WRF-w/out routing:
Init. July 27 12z

1 km WRF-w/routing:
Init. July 27 12z

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Case Study: 1997 Ft. Collins Flood Event

Accumulated Precipitation

1 km WRF-no routing:
Init. July 27 12z

1 km WRF-with routing:
Init. July 27 12z

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Case Study: 1997 Ft. Collins Flood Event

1 km WRF-w/out routing:
Init. July 27 12z

1 km WRF-w/ routing:
Init. July 27 12z

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Case Study: 1997 Ft. Collins Flood Event

1 km WRF-w/out routing: Init. July 27 12z

Gochis et al., 8th Annual WRF User’s Workshop, June 14, 2007
Case Study: 1997 Ft. Collins Flood Event  Mesoscale Analysis

1 km WRF-w/out routing:
Init. July 27 12z

1 km WRF-w/ routing:
Init. July 27 12z

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Case Study: 1997 Ft. Collins Flood Event
Hydrological Model Results

1 km WRF-w routing:
Terrain Heights (m)

1 km WRF-w routing:
Init. July 15 0z - Top Layer
Surface water Depth (mm)

1 km WRF-w routing:
Init. July 15 0z -
Accum. Stream Inflow (mm)

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Concluding thoughts and future activities:

- Much work remains in analyzing the thermodynamic forcing of convection and precipitation in WRF runs:
  - Inclusion of routing component in Noah-WRF appears to have surprisingly significant effect Jul. 28-29 storm events
  - Early, intense, terrain convection in routing model case produces precipitation regime more like that observed over flooding domain
  - Significant interaction with propagating convection in the Denver area

- Need to complete control/spin-up runs for the hydrological model for Ft. Collins event:
  - Several unresolved issues related to estimation of precip. rates from Stage II radar data
  - Nowcast runs will follow directly
  - Stream/reservoir network over this large region needs to be completed for channel routing

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Romanian Operational Hydrological Modeling:

- DEStuctive WATers Abatement Program
- World Bank funded project to support Romania’s application to EU
- NCAR tasked to provide modeling support to Baron AMS and NASA-LIS team
- Implementation and real-time forecasts began Oct. 1, 2006
**Framework for Hydrometeorological Prediction System Development**

1. Obtain and Process Meteorological Forcing Data
   - Observed Met. Forcing
     - Precipitation
     - Temperature
     - Humidity
     - Radiation
     - Wind
     - Pressure
   - Drive ‘Offline’ Land Surface Model
     - NCAR-HRLDAS/
     - NASA-LIS

2. Land Data Assimilation Cycling

3. Weather and Climate Model Initialization

4. Generation of Coupled Hydrometeorological Forecasts

5. Post-process data within Decision Support Systems

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**Emergency Management Decision Support Systems**
Coupled WRF-Hydro Flash Flood Forecasting in the Colorado Front Range:

4 km and 1 km WRF Domains

100m Topography on 1km Domain

USGS NHDPlus terrain

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Case Study: 1997 Ft. Collins Flood Event

Accumulated Precipitation

Ft. Collins rain gauge locations

Spring Creek radar coverage

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Case Study: 1997 Ft. Collins Flood Event

Accumulated Precipitation

WRF vs. Rain Guages

WRF vs. CHILL

WRF vs. KCYS NEXRAD

1 km WRF-no routing:
Init. July 27 12z

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Case Study: 1997 Ft. Collins Flood Event

Accumulated Precipitation

WRF vs. Rain Guages

Start of radar data

WRF vs. CHILL

WRF vs. KCYS NEXRAD

1 km WRF-with routing: Init. July 27 12z

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Case Study: 1997 Ft. Collins Flood Event

Accumulated Precipitation

WRF vs. Rain Gauges

WRF vs. CHILL

WRF vs. KCYS NEXRAD

1 km WRF-no routing:
Init. July 28 06z

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Case Study: 1997 Ft. Collins Flood Event

Accumulated Precipitation

WRF vs. Rain Guages

WRF vs. CHILL

WRF vs. KCYS NEXRAD

1 km WRF-no routing:
Init. July 28 12z

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Case Study: 1997 Ft. Collins Flood Event

Mesoscale Analysis

Observed Analysis

1 km WRF-no routing:
Init. July 28 12z

These model results are not consistent with rainfall accumulation figures. Are we sure they are correct?

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Case Study: 1997 Ft. Collins Flood Event

Mesoscale Analysis

1 km WRF-w/out routing:
Init. July 27 12z

1 km WRF-w/ routing:
Init. July 27 12z

Gochis et al., 8th Annual WRF User’s Workshop, June 14, 2007
Case Study: 1997 Ft. Collins Flood Event

Mesoscale Analysis

1 km WRF-w/out routing: Init. July 27 12z

1 km WRF-w/ routing: Init. July 27 12z

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Case Study: 1997 Ft. Collins Flood Event

Mesoscale Analysis

1 km WRF-w/out routing:
Init. July 27 12z

1 km WRF-w/ routing:
Init. July 27 12z

Gochis et al., 8th Annual WRF User’s Workshop, June 14, 2007
Case Study: 1997 Ft. Collins Flood Event

Mesoscale Analysis

1 km WRF-w/out routing:
Init. July 27 12z

Latent heat flux at the surface
W/m²

1 km WRF-w/ routing:
Init. July 27 12z

Latent heat flux at the surface
W/m²

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Concluding thoughts and future activities:

- Need to complete control/spin-up runs for the hydrological model for Ft. Collins event:
  - David Yates is working on radar derived precip using MDV, working through some projection issues
  - Several unresolved issues related to estimation of precip. rates from Stage III radar data
  - Nowcast runs will follow directly
  - Stream/reservoir network over this large region needs to be completed

- Much work remains in analyzing the thermodynamic forcing of convection and precipitation in WRF runs:
  - Inclusion of routing component in Noah-WRF appears to have significant effect on low-level circulation and precipitation. Need to determine exactly why.

- Continued benchmarking and case studies of coupled system to proceed this summer
  - Will likely look at May 29th 2007 event which resulted in widespread street flooding in Denver
  - Need to determine computational needs for operational work to initiate during Spring of 2008