Improved Hydrometeorological Forecasting through Physically-based Distributed Models

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OUTLINE

Abstract

As one of the first steps for a successful forecasting process of the distributed hydrologic response in watersheds, an extensive search for appropriate and high quality input information must be performed. The tools to address the proposed scientific objectives are physically-based models which require fine-scale information in order to reach an integrated and complete knowledge of the watershed dynamics. This report synthesizes the selection and information collection processes for the five experimental watersheds in the Colorado Front Range. Basins selection was based on criteria such as high resolution hydro-meteorological information availability, location of important flooding events and water supply regions and ongoing meteorological modeling efforts that are part of the current project. The final section will address some information requirements and next steps in the modeling project.

1. Data Collection and Selection of the Experimental Basins

Hydrometeorological modeling will be initially performed over five pre-selected watersheds within the Colorado Front Range with good availability of topographic, landcover, soils and hydroclimatic data. The following describes our efforts in terms of data collection for the distributed modeling efforts.

1.1 Brief Description of Basins

The selected watersheds are located in Larimer County, 40 km north of Boulder, Colorado. All of them are sub-basins of the Big Thompson watershed. Eastward of Loveland, CO, the Big Thompson River flows to the South Platte River. Some basin characteristics are listed in Table 1:

Table 1. Area and elevation ranges for the five selected watersheds

Basin	Area (km^2)	Elevations range (m)
Buckhorn creek	345.09	[1585, 3242]
North Fork Big Thompson River	206.00	[1944,4080]
Big Thompson River at Moraine	106.27	[2441,3915]
Big Thompson River at Estes	361.95	[2289, 4338]
Fish Creek at Estes	39.92	[2294, 3454]

Figure 1 presents a 10 m resolution USGS Digital Elevation Model, water divides, main streams, roads, railroads, dams and urban centers near the study area. Two of the chosen basins are nested, which will allow us to study the scale-variation of the hydrologic response. Complementarily, Figure 2 shows the slope distribution in the zone. Maximum slopes reach 61%.

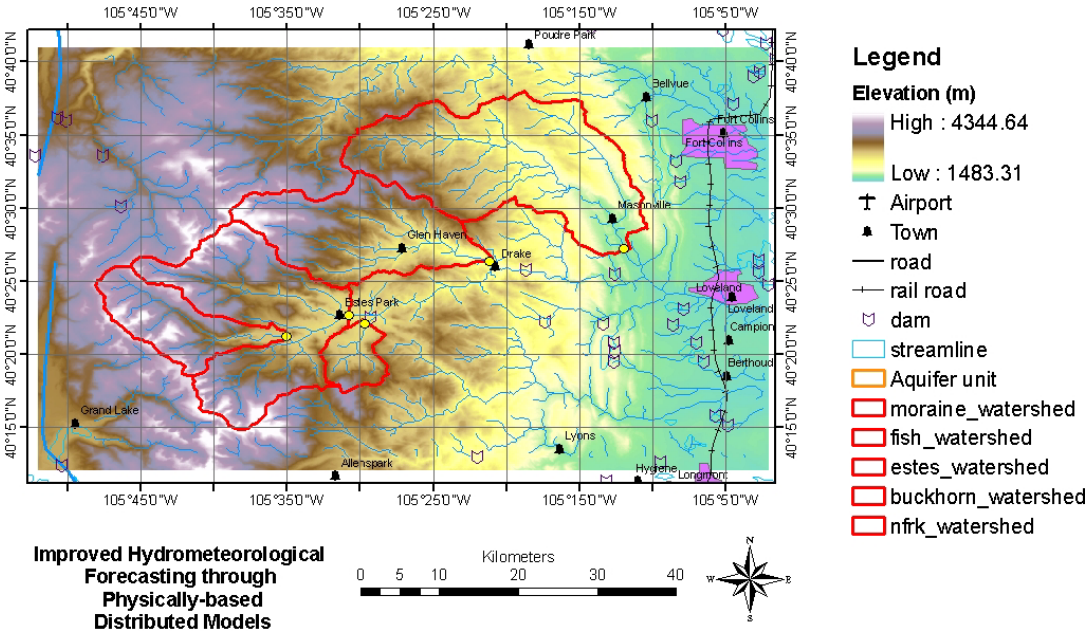

Figure 1. DEM, stream lines, water divides and other main features in the study area.

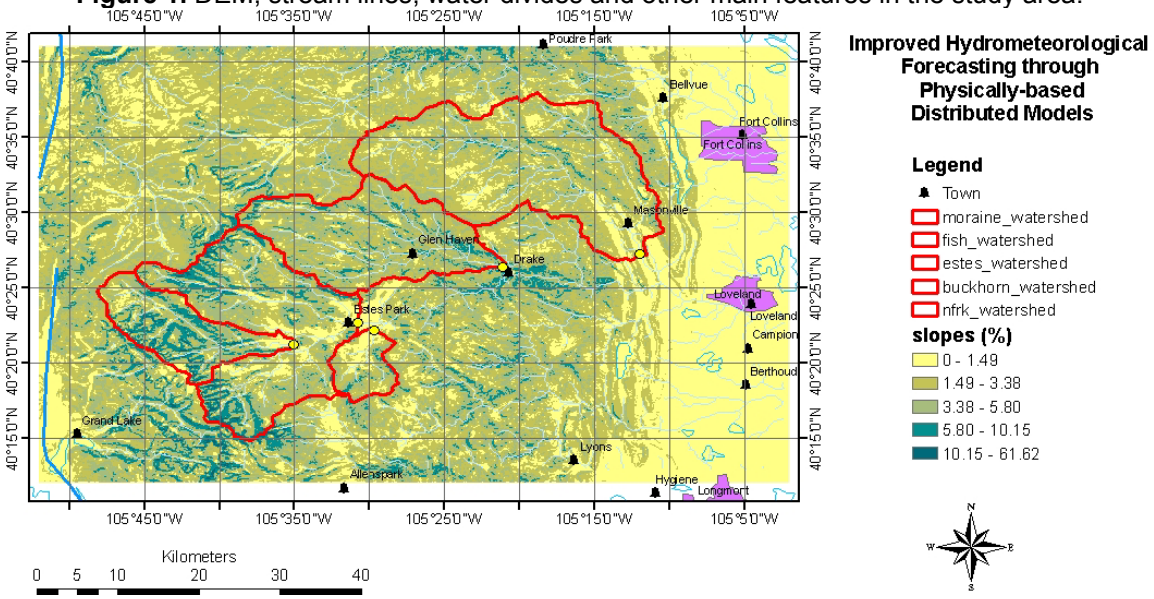

Figure 2. Slope distribution and water divides in the study area.

1.2 Soils and Land cover

Soil characteristics were downloaded from the Soil Survey Geographic (SSURGO) Database. Seven different vector layers from this database have been collected. The complete mosaic is shown in Figure 3. Since some information is still in process of collection, the SSURGO, the data gaps will be filled using the USDA STATSGO database (missing area is pink region between Big Thompson and Fish Creek basins).

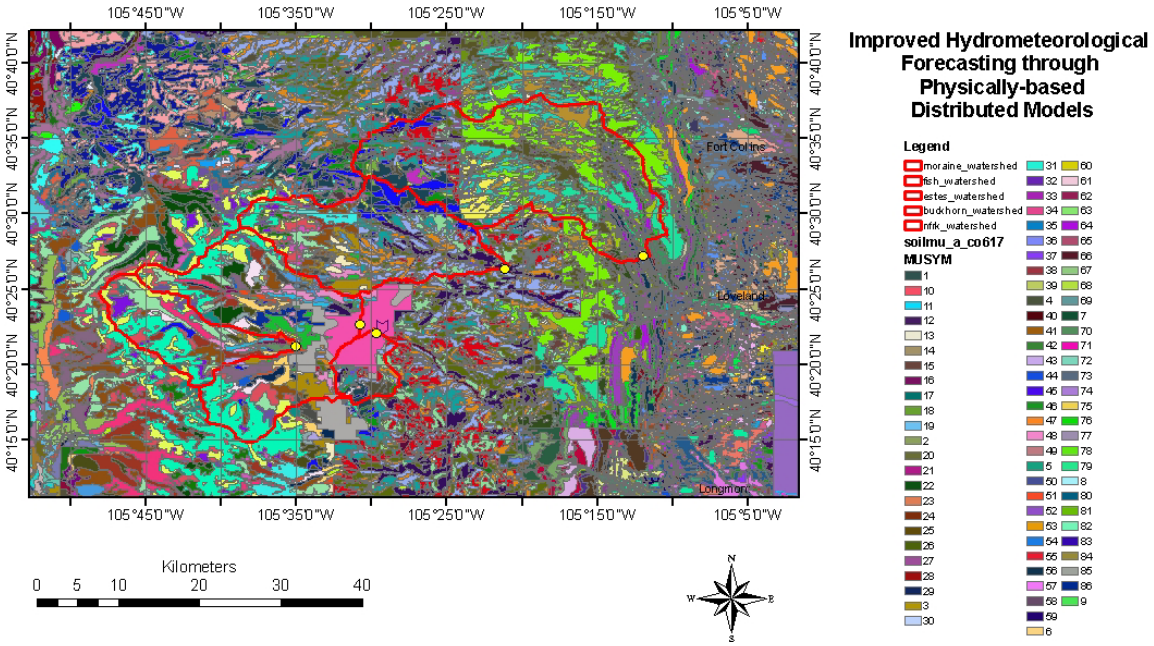

Figure 3. SSURGO soils map for the study area.

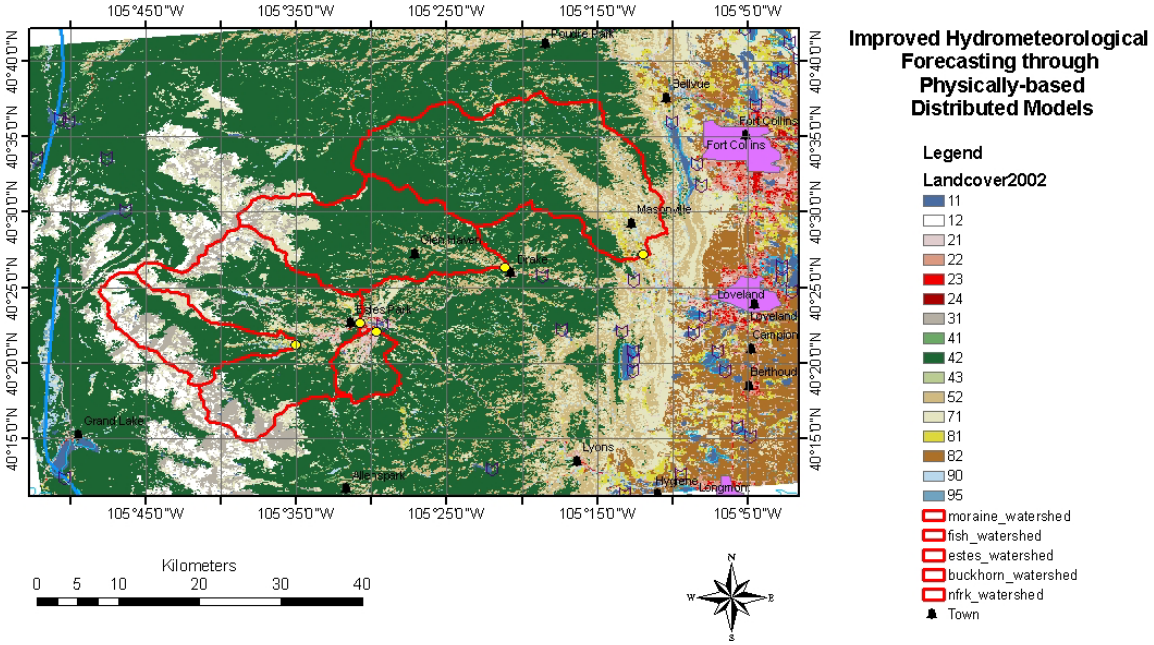

Figure 4. NLCD 2001 landcover map for the study area.

We collected a 30 m pixel resolution landcover map from the USGS seamless National Land Cover Data (NLCD), versions of 1992 and 2001. Figure 4 shows distributed information of land surface coverage types.

1.3 Weather and Streamflow Stations

Time series of 29 meteorological stations in the area have been collected from different sources. Almost all of them have precipitation, snow water equivalent (SWE) and temperature values and a few have wind speed and cloudiness. Table 2 and Figure 5 summarize the main features of weather station data.

Table 2. Available weather stations near the study watersheds.

Nro	LAT	LON	ELEV	START	TR	STNUM**	NRCSID	SITENAME
1	40.3100	-105.6400	9500	1/20/2000	1 h	5003	BLKC2	Bear Lake
2	40.2000	-105.5667	8600	1/20/2000	1 h	5018	05J18S	Copeland Lake
3	40.4100	-105.8200	10700	1/20/2000	1 h	5037	05J10S	Lake Irene
4	40.3058	-105.5379	8920	11/17/2004	1 h		CO045	Lily Lake
5	40.4000	-105.8500	9030	1/20/2000	1 h	5057	PHTC2	Phantom Valley
6	40.4300	-105.7300	10700	1/20/2000	1 h	5081	WPRC2	Willow Park
7	40.1803	-105.4775	8241	3/10/2004	1 h	50183	AR365	KM6GE Allenspark
8	40.3447	-105.0997	5161	9/10/2003	15 min		AP542	WMOF Berthoud
9	40.2995	-105.0825	5023	10/29/2003	15 min		AR167	KI0IO-2
10	40.2210	-105.3690	6500	5/16/2002	10 min		BTRC2	Button Rock
11	40.6647	-105.2233	5220	3/23/2007	15 min		FTCC2	Cache la Poudre RVR
12	40.6000	-105.1400	5150	5/15/2002	5 min		CSUF	CSU Foothills campus
13	40.5761	-105.0858	5003	5/16/2002	10 min		FORC2	CSU Campus
14	40.4333	-105.3383	6170	3/13/2007	30 min		DKEC2	North Fork Big Thompson
15	40.3833	-105.4833	7700	1/1/2005	10 min		CW3065	CW3065 Estes Park
16	40.3667	-105.5500	7820	4/3/2001	10 min		ESPC2	Estes Park
17	40.5255	-105.1287	5279	4/28/2004	20 min		C2056	CW2056 Fort Collins
18	40.6405	-105.1052	5003	6/20/2007	15 min		C8229	CW8229 Fort Collins
19	40.5763	-105.0217	4920	4/13/2006	15 min		C5699	CW5699 Ft Collins
20	40.6006	-105.1708		3/23/2007	10 min		HR5C2	Horsetooth reservoir
21	40.3750	-105.0980	5039	11/17/2004	30 min		C0108	Taft Ave Loveland
22	40.3508	-105.1713	5320	11/16/2005	30 min		C4671	CW4671 Loveland
23	40.4537	-105.0667	5020	11/11/2004	10 min		C2749	CW2749
24	40.5708	-105.2269	6160	6/11/2004	1 h		RSOC2	Redstone
25	40.7981	-105.5722	8214	1/1/1997	1 h		RFRC2	Redfeather
26	40.7100	-106.0100	9020	2/26/2003	1 h		RAWC2	Rawah
27	40.7022	-105.7106	7700	3/23/2007	15 min		RUTC2	Rustic9WSW
28	40.5300	-105.8900	10120	1/20/2000	1 h		JWRC2	Joe Wright
29	40.4000	-105.9600	10280	2/26/2003	1 h		NEVC2	Never Summer

** Stations with this code belong to the SNOTEL observation network.

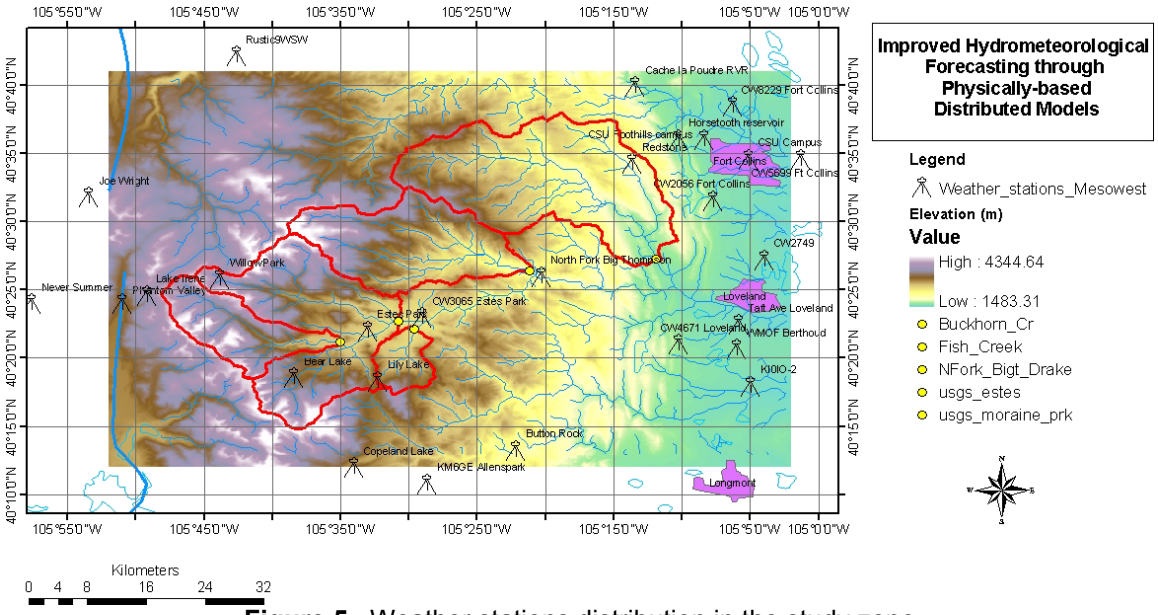

Figure 5. Weather stations distribution in the study zone

Streamflow stations, shown in Figure 5, have discharge data available on a daily basis. We are currently working on obtaining the hourly and 15-minute discharge and stage observations for these locations.

1.4 NEXRAD radar data collection and processing

In addition to surface meteorological and hydrological stations, Level II NEXRAD data has been obtained from the archive of the National Climatic Data Center (NCDC) and is being processed using the NCAR Research Applications Laboratory (RAL) Thunderstorm Initiation, Tracking and ANalysis system (TITAN). The operational NWS/NEXRAD radars to be used in this project include Cheyenne (KCYS), Denver (KFTG) and Pueblo (KPUX).

We have collected and processed data from the majority of the 2004 summer season (Jun 1 – Sep 1) to facilitate initial model implementation, testing and calibration. Several heavy precipitation events resulting in pulsed outflow from the aforementioned sub-basins of the Big Thompson River were observed during this time period. Functionality of TITAN and additional NCAR/RAL radar processing tools include:

- Removal of beam blockage, ground clutter and anomalous propagation signals from Level II NEXRAD radar data.
- Application user-specified functions for radar reflectivity-rain rate (Z-R) relationships.
- Hail, bright band and light rain thresholding.
- Merging of multiple radars, with differing rainfall estimation parameters into a single QPE product.

- Identification and extrapolation in time and space of user-specified thunderstorm objects for generating very short term (0-60 min quantitative precipitation forecasts).

In addition to the above products, controlled adjustment of TITAN model parameters permits the development of ensemble QPEs and QPFs in a computationally efficient framework. Work on developing and enhancing these products for flash flood prediction research will continue over the next year.

1.5 Numerical Weather Prediction

Since project initiation, work has also proceeded on development and implementation of the Weather Research and Forecasting (WRF) model for Colorado Front Range Flash Flood Prediction. A nested modeling domain with an outer grid of 4 km and an inner grid of 1 km has been constructed over the aforementioned test basins. One first order model enhancement has already been made to the WRF model which accounts for the impact of terrain slope and aspect on surface insolation, a functionality previously not available in the version 2.2 of WRF. Initial simulations designed to test of the fidelity of the WRF model to adequately simulate severe weather events in this region showed that while positional errors in WRF simulated storm events were significant, the model could capture the relative timing and general intensity gradients of such events at a range of lead times occurring from 12-36 hrs. It requires note though, that the magnitude of rainfall intensity structures produced by the WRF simulations, as currently setup, are significantly biased low compared to those rain rates observed by processed Stage II NEXRAD data described above. This low bias in WRF rainfall intensity suggests that, to a first order, a bias correction methodology will be required in order to utilize WRF QPF products in hydrological simulation. Work on more clearly defining this bias structure and a methodology to account for it is currently underway.

1.6 Summary matrix

The data collection efforts are summarized in the Table 3.

Information	Type	Sources	Additional Information
Digital Elevation Models	NED-raster 1 arc-second (approx. 30m) 1/3 arcsec (approx. 10m) SRTM- raster 1 arc-second (approx. 30m) 3 arcsec (approx. 90m)	USGS Seamless: http://seamless.usgs.gov/website/Seamless/viewer.htm	Projection: Geographic Horizontal Datum: NAD83 - Cont.U.S., HI, PR, & VI Vertical Accuracy: +/- 7 to 15 meters (depends on the source DEM) Projection: Geographic Horizontal Datum: WGS84 Vertical units: meters
Vegetation-landcover	NLCD 1992-raster 1 arc-second (approx. 30m) NLCD 2001-raster 1 arc-second (approx. 30m)	National Land Cover Data (NLCD): http://seamless.usgs.gov/faq/nlcd_faq.php	NLCD 2001 Land Cover Class Definitions. Projection: Geographic Horizontal Datum: NAD83
Soils	Vector polygons belonging to the Counties: Larimer, Weld, Boulder, Jackson, Grand north of Colorado state. Zipfiles: soils_co617, co617, co643, co644, co645, co646, co649, co651.	Soil Survey Geographic (SSURGO) Database: http://www.soils.usda.gov/survey/geography/ssurgo/ U.S. General Soil Map (STATSGO) http://www.soils.usda.gov/survey/geography/ssurgo/	Mapping scales generally range from 1:12,000 to 1:63,360. Coordinate system: Geographic.
Weather time-series	Vector points: coordinates, starting date, data type, time resolution.	Snotel Data and products: http://www.wcc.nrcs.usda.gov/snotel/ Utha University weather observations net: http://www.met.utah.edu/droman/states/CO_state_frame.html Western regional climate center http://www.wrcc.dri.edu/	Projection: Geographic Horizontal Datum: WGS84 Full access to time-series data
Radar data	Raster-study domain STAGEIII: Hourly rainfall data 09/1996-03/2002. MPED: 02/2002 - 09/2005	NOAA Hydrologic data systems group. Archive of river forecast center operational NEXRAD data: http://dipper.nws.noaa.gov/hdsb/data/nexrad/nexrad.html	Projection: Geographic Horizontal Datum: WGS84
Roads, counties, states, towns, dams, railroads, roads, airports, HUS,etc.	Vector layers	US National Atlas: http://nationalatlas.gov/ USGS National Map: http://nmviewogc.cr.usgs.gov/viewer.htm Colorado Geographic Information Portal: http://coloradogis.nsm.du.edu/Portal/ Colorado division of water resources: http://water.state.co.us/	Projection: Geographic Horizontal Datum: WGS84

1.7 Additional required information

There are some gaps in the published information which will need to be filled in from other sources, including state government agencies in the zone. This information can be summarized as:

- Hourly or 15 minutes discharge data at the basin outlets.
- Inventory of pumping wells in the zone. Groundwater elevation maps.
- Geologic profiles and maps of quaternary deposits and bedrock depth.
- Landsat, Quickbird or Ikonos satellite images.
- Complementary climatic data.

1.8 Next steps in the project development

After completing the collection of the additional required information, we will continue with the Model Setup and Design of Forecasting Experiments in the study watersheds. These two next steps are addressed to prepare the terrain, landscape, initial and boundary conditions, as well as, the input precipitation fields for the desired forecasting period. A first experiment will be conducted at the Moraine watershed (106.27 km^2) with the purpose of model calibration and first assessment of the experimental performances. A further step will decide the better set of model parameterization in the coupling processes of QPF and QPE to the hydrologic model.

References

Visited web pages:

http://ucblibraries.colorado.edu/map/links/gis.htm#co
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