River Modeling as Big as Texas



Cédric H. David David R. Maidment, Zong-Liang Yang

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Atmospheric modeling

- Equations of fluid mechanics and thermodynamics of the atmosphere commonly solved everyday by computer models
- Temperature, pressure, winds, precipitation, etc. are available
- For past, present and future
- Dynamic maps



Animation of precipitation over the U.S.

Models and datasets available cover the entire U.S.

Land surface modeling





Noah land surface model (first version in 1999), serves as the land model for operational weather prediction in North America

> Bottom boundary conditions for atmospheric models Models and datasets also cover the entire U.S.

NHDPlus – River and Catchment Network for the Nation

Region 12 = Texas Gulf Coast Hydrologic Region

465,000 km²



Entire dataset

Integration of the National Hydrography Dataset, National Elevation Dataset and National Land Cover Dataset completed by EPA in 2006

"Blue line" rivers available for the entire U.S.

USGS National Water **Information System**

20,000+gauges available for the **United States**

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> > 1/1/2000

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1/1/2004

60 40





773 gages total in Region 12 248 with full daily data for 2000/01/01 - 2007/12/31and on reaches with known direction

Integrated River Modeling



Atmospheric Model or Dataset



Land Surface Model



"Blue Line" River Network -High-Performance Computing River Network Model

River model

- **RAPID** (Routing • **Application for Parallel** computation of Discharge)
- Computes flow and • optimizes model parameters
- Model code, input data and • animations are available online
- Can run on supercomputers







uses a matrix version of the Muskingum method, and has an automated parameter estimation procedure that allows to finding optimal model parameters based on available gage measurements. This model uses the Fortran programming language and can be run on personal computers, as well as on massively-parallel supercomputers, with actual parallel speedup, RAPID has the ability to run and/or optimize model parameters on any subbasin included in its computing domain. If major man-made infrastructures are present on the river network, RAPID allows to easily substitute upstream flow by gage measurements luring both computation of river flow and optimization of parameters. Detailed information on RAPID can be found in the related publications

Development history

Designing, developing and testing RAPID were a large part of my Ph. D. work at the Center for Research in Water Resources at the University of Texas at Austin. The development of this model started in September 2007 as I joined the Center for Geosciences at Ecole des Mines de Paris (Mines Paristech), France for a 6-month visit. RAPID was originally developed as a Substitute for the river rooting is chosen of SIM-France, the operational hydro-meteorological model used by Meteo France (the Substitute for the river rooting is chosen of SIM-France, the operational hydro-meteorological model used by Meteo France (the French weather service). The code has since then been adapted to run on the NHDPIn dataset that provides a "blue description of the river networks in the USA. For the current NHDPIns services of APID, several land surface models can be used to compute inflow to the river network

Code

The source code for RAPID can be downloaded <u>hare</u>. Input data including network connectivity, lateral inflow from the land surface (computed with Noah-MP) and gage measurements (from USGS NWIS) for a 4-year run (between 2004-01 and 2007 12) in the Guadalpue and San Antoini River Basin in Texas can be downloaded <u>large</u>. Input data corresponding to the river network of SIM-France is available <u>here</u> for 10 years between 1995-08 and 2005-07.

Documents

A succinct guide on how to compile and run RAPID for the test-case provided is available here. Some information on the data model used for inputs in RAPID can be found here. Explanations on the input and output files used in RAPID are available here. A guide on how to downlaced USGS NWIS observations and format them for RAPID is here.

In the following animations of stream flow, the thickness of river reaches varies with the magnitude of flow rate going through them. One can see the flow waves propagating downstream. All these animations were prepared using 3-hourly outputs from RAPID. They can be played directly from this webpage (full-screen mode available) or downloaded in avi, flw and mp4 formats. The latter can be uploaded to and played on Flores.

This first animation is of the San Antonio and Guadalupe Basins in Texas, USA, over four months (between 2007-06-01 and 2007-09-30). 3-bourly surface and subsurface runoff was produced by the Noah-MP land surface model using a combination of NARR and NEXRAD for atmospheric forcing. RAPID was run at a 15-munute time step. Download an<u>i</u>, <u>fit</u> or <u>mp3</u>.



http://www.geo.utexas.edu/scientist/david/rapid.htm

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Existing RAPID applications



David et al. (2011a), Journal of Hydrometeorology



David et al., in preparation



Guadalupe – San Antonio Streamflow map



Guadalupe – San Antonio Animation



NHDPlus rivers, Noah-MP land surface model, atmospheric forcing from 10 NEXRAD and North American Regional Reanalysis

Texas Gulf Hydrologic Region River flow in 8 major Rivers

River flow produced using 5 different runoff datasets into RAPID





Texas Gulf Hydrologic Region Synoptic hydrology



River flow computations and observations plotted together (24 November 2004)

Texas Gulf Hydrologic Region Animation



NHDPlus rivers, Noah-MP land surface model, atmospheric forcing from 13 North American Land Data Assimilation Sytem

RAPID in France



Operational System: Runs every day at the French Weather Service (Meteo France)



Includes Groundwater Modeling

Groundwater influence varies with time and space



 80% of flow is from groundwater at low flow, 25 % at high flow



Rousset et al., 2007

Seine River at Paris

 Infiltration from rivers to aquifers is important as well Real-time integrated atmosphere/surface/groundwater modeling is great but...







Groundwater is important in Texas too!



Near real-time river flow is doable in Texas as well

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Runoff from the North American Land Data Assimilation System (NLDAS) is available in near real-time

February 7th data available on February 11th (~4-day lag)

ftp://hydro1.sci.gsfc.nasa.gov/data/s4pa/NLDAS/NLDAS_MOS0125_H.002/

Summary

 Today's models of the atmosphere, land surface and rivers can be integrated into Texas-scale river modeling

- This can be made into a near real-time tool
- Some modeling of aquifers would be beneficial

What's next?

- Texas groundwater?
- Real-time RAPID
- Dam treatment
- Divergence data
- Suggestions?





Mississippi Animation



RAPID run by Ahmad Tavakoly

Thank you!

Questions?



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TEXAN'S MAP	XAS

Area of Texas: 261,231.71 mi² (i.e. 261,231.71 x 1.609344² = 676,587.02 km²) (from http://quickfacts.census.gov/qfd/states/48000.html)

Area of France: 643,801 km² (from <u>https://www.cia.gov/library/publications/the-world-factbook/geos/fr.html</u>)

Difference: 1 - 643,801 / 676,587.02 = 0.048 = 4.8%