Continental scale hydrologic-hydraulic model inter-comparison

MGB model
Mississippi basin
Preliminary results

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**Modelo de Grandes Bacias** (MGB-IPH) [Collischonn et al., 2007; Paiva et al., 2011; Pontes et al., 2015]

Coupled Hydrology – Hydraulic model for large basins

**Catchment Flow Routing**
- Surface, subsurface and groundwater runoff are routed using linear reservoirs

**River network routing:**

*Continuity equation*

\[
\frac{\partial A}{\partial t} + \frac{\partial Q}{\partial x} = 0
\]

*Muskingum-Cunge*

*Inertial model (Bates et al., 2010)*

*Momentum equation*

\[
\frac{\partial Q}{\partial t} + \frac{\partial (Q^2/A)}{\partial x} + gA \frac{\partial h}{\partial x} = gAS_0 - gAS_f
\]
Several model applications in South American rivers:

• Flood forecasting and optimal reservoir operation

• Climate change studies

• Land use and land cover changes

• Coupling with SIAQUA-IPH water quality model

• Coupling with sediment transport model

• Use in water management studies

• Coupling with remote sensing data
Ex.: Amazon application  (Paiva et al., 2013 WRR)

Remote sensing

Model

5763 catchments

Nash and Sutcliffe at gauges

ENS = 0.89, ENSlog = 0.89, DI = -11 days, ΔV = -5 %
Niger River Basin

Inner Delta

Niger Inland Delta:

• ~30-50% of inflow waters (~Kemacina + Douna gauges) evaporate until Dire gauge

• Coupled hydrologic and hydrodynamic modeling

Diré gauge, downstream of Inland Delta

Fleischmann et al., in preparation
MGB coupling with river altimetry data

- Use altimetry for model validation (e.g. Paiva et al., 2013 WRR)
- Model calibration using altimetry (e.g. Getirana et al.,)
- Model / Altimetry based rating curves (Paris et al., 2016 WRR)
- Data assimilation (Paiva et al., 2013 HESS)
Ex.: Data Assimilation ENVISAT altimetry

Paiva et al. 2013. HESS

- Ensemble Kalman filter improved water level estimates
- Improvement at daily basis, even though altimetry data has ~35-day temporal resolution

![Amazon Basin](image)

**Δrms**
- Blue: < -30%
- Turquoise: -30% - -10%
- Green: -10% - 10%
- Orange: 10% - 30%
- Red: > 30%
- Black: Assimilation

**Assimilation**
- Envisat
- EnKF
- Open-loop

**Validation**
- Gauge 15630000, lon = -63.02° lat = -7.51°
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Model River network

- Hydrosheeds flow direction and flow accumulation maps
- Minimum upstream drainage area
- Geoprocessing using IPH Hydro Tools
Model Catchments

- Segmentation using Hydrosheds flow direction and flow accumulation maps
- ~16,000 Catchments with river reaches of 10 km.
- Geoprocessing using IPH Hydro Tools
- Hydrosheds DEM
- Catchments with river reaches of 10 km.
- Full hydrosheds river network (thin black lines)
Runoff fields

Surface runoff NASA NLDAS2 VIC 1/8° 1h
Subsurface runoff NASA NLDAS2 VIC 1/8° 1h

Spatial variability of Surface and Subsurface Runoff
Model parameters

Computational Reach length = ~ 10 km

Bankful Width (Andreadis et al. dataset)
Bankful Depth (Andreadis et al. dataset)
Manning’s coefficient: 0.03

Bed elevation = SRTM Elevation – Bankful Depth

Floodplain topography – Extracted from SRTM HydroSHEDS 15 arcsec

Surface and baseflow routing parameters:
Time of concentration (Kirpich formula using slope and length of major tributary)
CS = 10
CB = 10 days
First results: HD model, default W and H

Mississipi River at Thebes

Volume errors
No reservoir simulation

Missouri River at Hermann

Mississippi River at Grafton

Mississippi River at Thebes

Red River at Spring Bank

Attenuated and delayed hydrograph

Ohio River at Metropolis
Simulations using larger Bankful Depth (H95)

- **Missouri River at Hermann**
  - Obs
  - Calc

- **Ohio River at Metropolis**
  - Obs
  - Calc

- **Mississippi River at Grafton**
  - Obs
  - Calc

- **Mississippi River at Thebes**
  - Obs
  - Calc

- **Red River at Spring Bank**
  - Obs
  - Calc

Improved timing
Simulations using larger Bankful Width (W95)

Missouri River at Hermann

Ohio River at Metropolis

Mississippi River at Grafton

Mississippi River at Thebes

Red River at Spring Bank

Improved timing
Maximum flooded areas

H, W default  

H95, W default  

H95, W95  

Different parameters change flooding and hydrograph timing
Simulations using Muskingum Cunge Routing (No floodplain or backwater)

Missouri River at Hermann

Ohio River at Metropolis

Mississippi River at Grafton

Mississippi River at Thebes

Red River at Spring Bank

Needs backwater effect and/or inundation?
Simulations using larger Bankful Depth (H95)

Ohio River at Metropolis

Missouri River at Hermann

Mississippi River at Grafton

Mississippi River at Thebes

Red River at Spring Bank
Simulations using Baseflow Routing (Linear reservoir)
CB = 10 days

Missouri River at Hermann

Ohio River at Metropolis

Mississippi River at Grafton

Mississippi River at Thebes

Red River at Spring Bank

Baseflow routing smooth hydrograph
Simulations using Surface (CS=10) and Baseflow Routing (CB =10days)

Surface runoff routing attenuates spiky hydrographs
Summary

- Large volume errors
  - Cause may be input runoff or reservoirs

- River geometry input parameters play important role on flooding timing of hydrographs

- Catchment routing smoothes spiky hydrographs

- Backwater and flooding may be important in some rivers
Some MGB References:


SORRIBAS, MINO VIANA; PAIVA, RODRIGO C. D.; MELACK, JOHN M.; BRAVO, JUAN MARTIN; JONES, CHARLES; CARVALHO, LEILA; BEIGHLEY, EDWARD; FORSBERG, BRUCE; COSTA, MARCOS HEIL. Projections of climate change effects on discharge and inundation in the Amazon basin. Climatic Change (online), v. x, p. 1.


Paiva et al., 2011. Large scale hydrologic and hydrodynamic modelling using limited data and a GIS based approach. JoH.


