HESSS2 24th June, 2010 @ IIS U-Tokyo

^{G5.3} Physically-based representation
of floodplain inundation dynamics
in a global river routing model

Dai YAMAZAKI¹, Shinjiro KANAE², Taikan OKI¹ ¹The University of Tokyo ²Tokyo Institute of Technology

Yamazaki et al. (2010), A description of floodplain inundation dynamics based on physical evidence in a global river routing model, *J. Geophys. res*, **13**, in prep.

Dai YAMAZAKI ::: IIS, U-Tokyo ::: yamadai@rainbow.iis.u-tokyo.ac.jp

1. Introduction

Rivers play an important role as a component of the climate system and as a freshwater supplying system for both human beings and ecosystems.

[Observations] In addition to *in-situ* observation of discharge, advancement of satellite remote sensing reveals various information on surface waters.



[Modeling] On the other hand, global river routing models have mainly focused on simulation of river discharge. Prediction of water surface elevation or inundated are is not realistically incorporated in global models.

=> Dynamics of surface waters are regulated by smaller topography than the resolutions of global models.

1. Introduction

[Dataset] Global hydro-geographical dataset at fine-resolution (<1 km) is already provided based on satellite observations.

SRTM:

[NASA]



[Basin-scale] Models for a small basin represent detailed topography on which 2-D inundation dynamics are simulated.

> 2-D Inundation model [Dutta, 2000]



1. Introduction

[Dataset] Global hydro-geographical dataset at fine-resolution (<1 km) is already provided based on satellite observations.

[Global] Global-scale models represents water storage in lakes, wetlands and floodplains *conceptually or statistically*.





We propose a new global river routing model, which incorporate *physically-based representation* of floodplain inundation dynamics: *Catchment-based Macro-scale Floodplain model (CaMa-Flood)*

2. Model Framework: CaMa-Flood

Catchment-based Macro-scale Floodplain model

- > A distributed river routing model
- > Input: LSM runoff, Boundary Condition: Water level at river mouth
 - Output : water storage (Prognostic); discharge, water level, Inundated area (Diagnosed)
- > River and floodplain storage with sub-grid topographic parameters.



2. Model Framework: CaMa-Flood

Catchment-based Macro-scale Floodplain model

- > A distributed river routing model
- > Input: LSM runoff, Boundary Condition: Water level at river mouth
 - Output : water storage (prognostic); discharge, water level, Inundated area (Diagnosed)
- > River and floodplain storage, with sub-grid topographic parameters.
- > Diffusive wave equation, roughness = Manning, along river network.

Realistic description of sub-grid topographic parameter is quite important!



3. Sub-grid topographic parameters: FLOW <u>Flexible Location of Waterways method</u>

←1km elevation

SRTM30

SRTM30 Elevation [m] (Amazon River)



GrADS: COLA/IGES

Fine-resolution (1 km) hydro-topographical datasets
GDBD Flow Direction Map & SRTM30 DEM
<u>FLOW</u> method [Yamazaki, 2009] is used to objectively decide sub-grid topographic parameters from those hydro-topographical datasets.

Yamazaki et al. (2009), Deriving a global river network map and its sub-grid topographic characteristics from a fine-resolution flow direction map, *HESS*, **13**, 2241–2251.

个1km river GDBD

3. Sub-grid topographic parameters: FLOW <u>Flexible Location of Waterways method</u>





<u>Flexible Location of Waterways method</u>

1) Decide "outlet pixel" from GBDB pixels in each CaMa-Flood cell. *>Channel altitude*





<u>Flexible Location of Waterways method</u>

 Decide "outlet pixel" from GBDB pixels in each CaMa-Flood cell. >Channel altitude
Decide downstream cell by tracking GDBD path from outlet pixel >River map





<u>Flexible Location of Waterways method</u>

 Decide "outlet pixel" from GBDB pixels in each CaMa-Flood cell. >Channel altitude
Decide downstream cell by tracking GDBD path from outlet pixel >River network
Calculate channel length considering meandering in 1-km scale >Channel length





<u>Flexible Location of Waterways method</u>

 Decide "outlet pixel" from GBDB pixels in each CaMa-Flood cell. >Channel altitude
Decide downstream cell by tracking GDBD path from outlet pixel >River network
Calculate channel length considering meandering in 1-km scale >Channel length
Calculate group of GDBD pixels drained to the river channel >Catchment Area





Flexible Location of Waterways method

 Decide "outlet pixel" from GBDB pixels in each CaMa-Flood cell. >Channel altitude
Decide downstream cell by tracking GDBD path from outlet pixel >River network
Calculate channel length considering meandering in 1-km scale >Channel length
Calculate group of GDBD pixels drained to the river channel >Catchment Area
CDF of elevation within a catchment is created. >Floodplain Inundation Profile
Water level and inundated area is diagnosed from floodplain water storage.





<u>Flexible Location of Waterways method</u>



Impact of introducing 1) *floodplain reservoir* and 2) *diffusive wave equation* is discussed

> Experimental setting

Experiment	Storage	Flow Routing
NoFLD	River Channle Only	Kinematic Wave
FLD+Kine	River Channel + Floodplain	Kinematic Wave
FLD+Diff	River Channel + Floodplain	Diffusive Wave

> Special Resolution = 15 arc-min (25 km), Time step = 15 min

> LSM runoff [Kim, 2009]: Spatial = 1 deg, Time step = 1 day (Linear interpolation) Climate Forcing (JRA25) + Precipitation (GPCP) \Rightarrow LSM (MATSIRO) \Rightarrow Runoff

> Boundary condition at river mouth: Constant sea elevation.

Validation of daily river discharge:



Validation of daily river discharge:



Flow velocity in May 1993: [Kinematic .vs. Diffusive]



18

Comparison of inundated area against satellite obs. [Prigent, 2007]



General pattern of inundated area is reproduced.

Comparison of inundated area against satellite obs. [Prigent, 2007]





5. Hydrological simulation in Tonle-Sap, Cambodia

Can CaMa-Flood reproduce unique characteristics of Tonle-Sap?

- > Experiment setting: River + Floodplain reservoir + Diffusive Wave Equation
- > Spatial resolution = 5 arc-min (8 km); Time step : 5 min
- > LSM runoff [Kim, 2009]: Spatial = 1 deg; Time step = 1 day (Linear Interpolation) Climate Forcing (JRA25) + Precipitation (GPCP) ⇒ LSM (MATSIRO) ⇒ Runoff

> Boundary condition at mouth: Constant sea level



5. Hydrological simulation in Tonle-Sap, Cambodia

Inundated area compared to MODIS+AMSR observation [Mori, 2009]



Seasonal lake area change is reproduced.



5. Hydrological simulation in Tonle-Sap, Cambodia

Discharge at Tonle-Sap River, which connects Tonle-Sap Lake and Mekong River.



During its flooding phase, the Tonle Sap receives more than 51,000 millionm³ of water from the Mekong River via the Tonle Sap River. [Penny, 2006]



6. Results in major rivers in the world.



Simulated discharge by CaMa-Flood shows good agreement with observation, except for boreal rivers in cold region.

6. Results in major rivers in the world.

Validation of inundated area against satellite observation [Prigent, 2007]



Inundation in floodplains along mainstream of major rivers is reproduced.

While, inundated area is generally underestimated in the global-scale:

> Inundation in small pools due to local depression is not considered.

> Irrigated paddy fields are also not negligible.

Inundated area fraction at annual maximum (1993)

7. Summary

- Physically-based description of inundated area dynamics is achieved in the global river routing model, CaMa-Flood.
 - River networks and topographic parameters are automatically derived from 1-km DEM and flow direction map.
 - Relationship between water storage, water level, inundated area is objectively described.
 - Flow computation by diffusive wave equation is realized.
- Simulation by CaMa-Flood
 - Daily river discharge is well reproduced. Consideration of floodplains reduces overestimation of flood peak discharge.
 - Diffusive wave equation is effective to simulate flow velocity variability in a flat river basins like the Amazon.
 - Inundation in floodplains along mainstreams of major rivers are reproduced.
 - Large-scale backflow in Tonle-Sap River is reproduced by realistic representation of water surface elevation.

Thank You!

Tonle-Sap Lake, Cambodia 3rd Oct 2009