Impact of climate change on the flood risks in the Mekong River basin:
- prediction of future flooding extent using a continental-scale hydrodynamics model

EGU2011-5123

Dai YAMAZAKI[1], Yadu POKHREL[1], Hyungjun KIM[1,2], Shinjiro KANAE[3], and Taikan OKI[1]

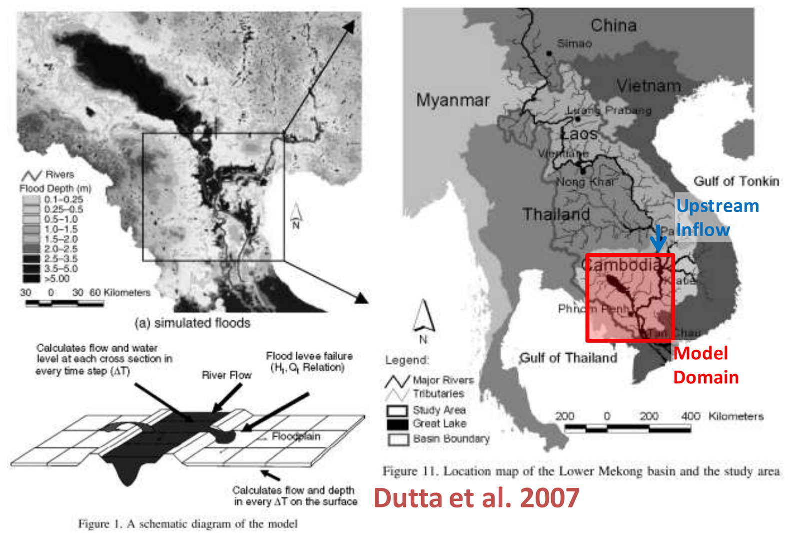
[1] The University of Tokyo, Japan, [2] Tokyo Institute of Technology, Japan, [3] UC Irvine, USA
(*Correspondence to Dai YAMAZAKI: yamadai@rainbow.iis.u-tokyo.ac.jp)

(1) INTRODUCTION

Seasonal flooding of the Mekong River has benefits on agriculture and fisheries, while an extreme flooding causes huge damages on the economics and lives of the riparian population.

Thus the prediction of flooding extent under the changing climate is helpful for the water resources management of the Mekong River, yet the model-based assessment of future flooding extent is still facing various kinds of difficulties.

One difficulty for modeling is the complex hydrodynamics of flooded water on floodplains in the lower Mekong including the substantial backflow from the meinstem of the Mekong River to the Tonle-Sap Lake.

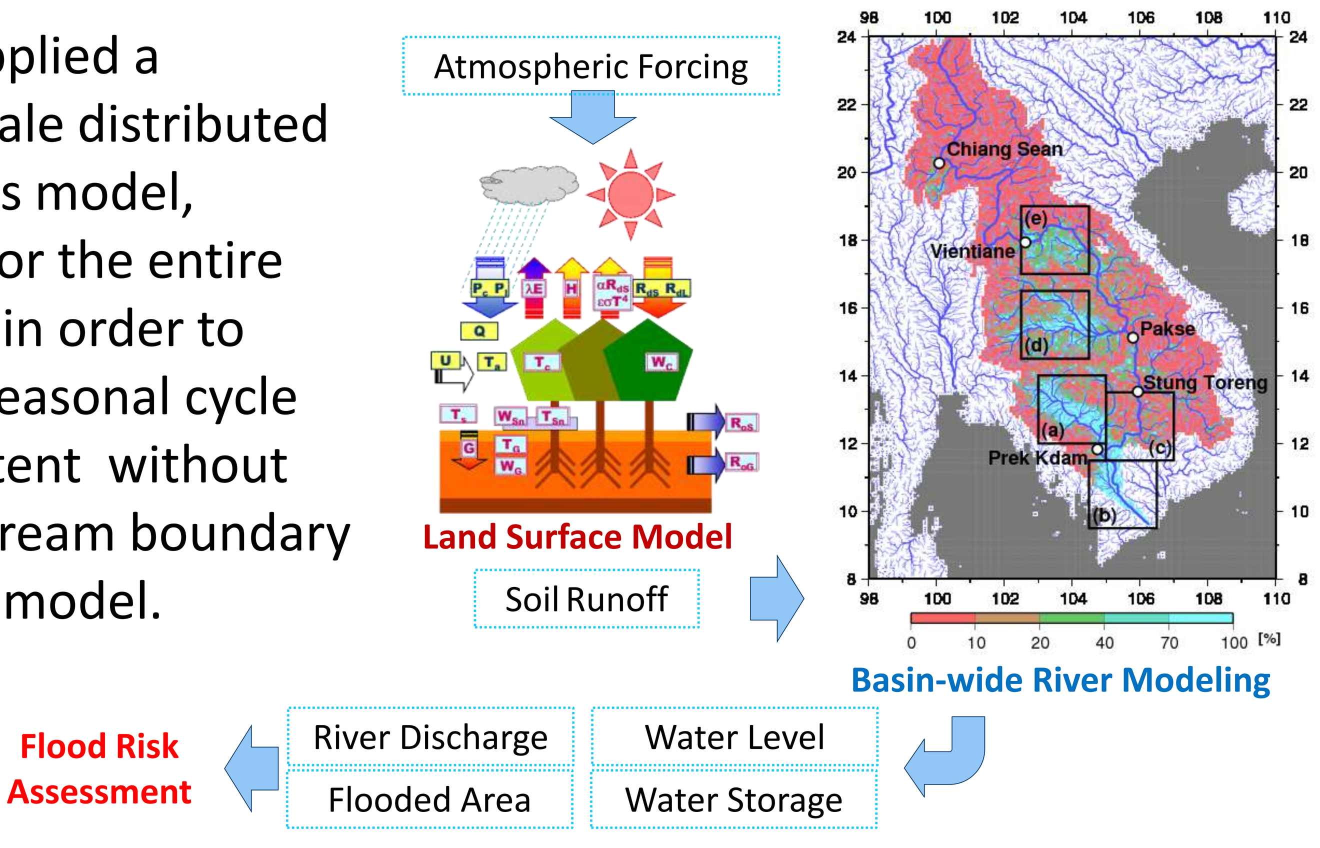


Regional inundation models with detailed topography cannot be applied to future conditions because boundary inflows are not available

Regional hydrodynamics models with high-resolution topography information have been used for representing such complex flows on floodplains, but regional models are not suitable for climate change studies because they require upstream boundary inflows which are not available for future predictions.

Research Framework

Instead, we applied a continental-scale distributed hydrodynamics model, CaMa-Flood, for the entire Mekong River in order to simulate the seasonal cycle of flooding extent without using the upstream boundary Inflows to the model.

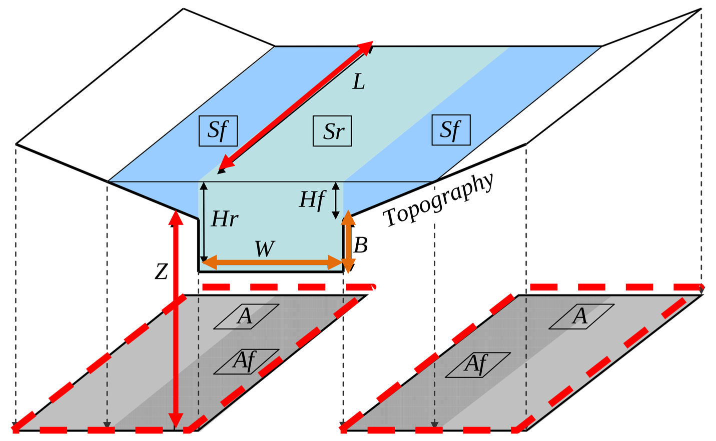


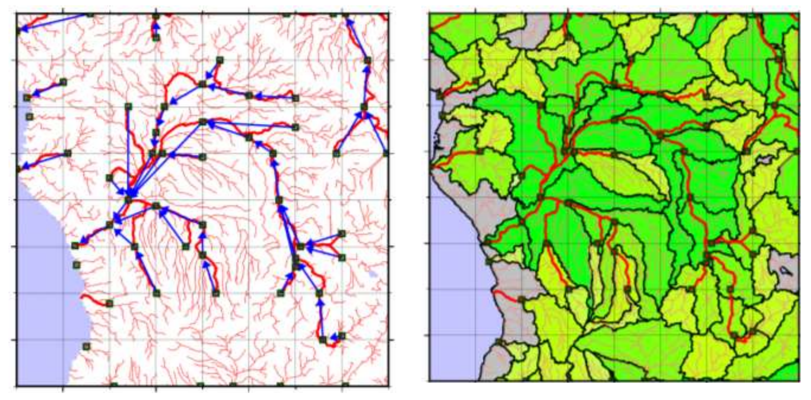
ACKNOWLEDGEMENT

The corresponding author is supported by "the grant-in-aid for JSPS researcher" by JSPS. A part of this research is funded by "Innovative Program of Climate Change Projection for the 21st Century (KAKUSHIN Program)" by MEXT, Japan.

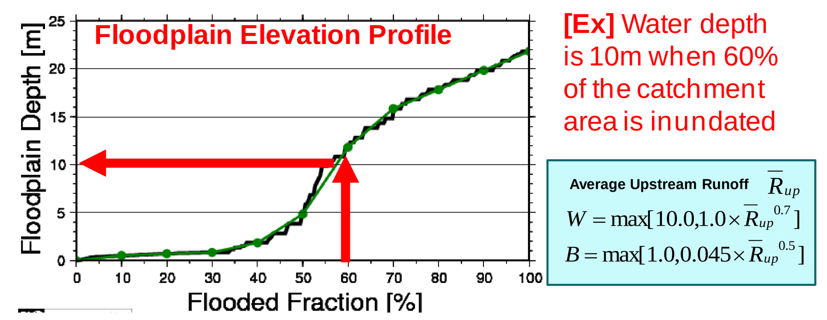
(2) MODEL DESCRIPTION

CaMa-Flood is a global-scale distributed river routing model, which receives runoff from a land surface model and predicts water storage and river discharge at each grid-box.
Even though the spatial resolution of the model is coarse (8 km), CaMa-Flood explicitly predicts the variations of the flooding extent within a single grid-box by allocating a river channel reservoir and a floodplain reservoir with sub-grid topographic parameters.





Red Parameters:
from 90-m resolution HydroSHEDS
with DEM modification [Yamazaki et al. (submitted to JH)]
Orange Parameters:
from empirical equations



Geometry of the river channel and floodplain reservoirs, which determines the relation between water storage and flooding extent, is objectively parameterized from the flow direction map and the DEM from the 90-m resolution HydroSHEDS (FLOW method).

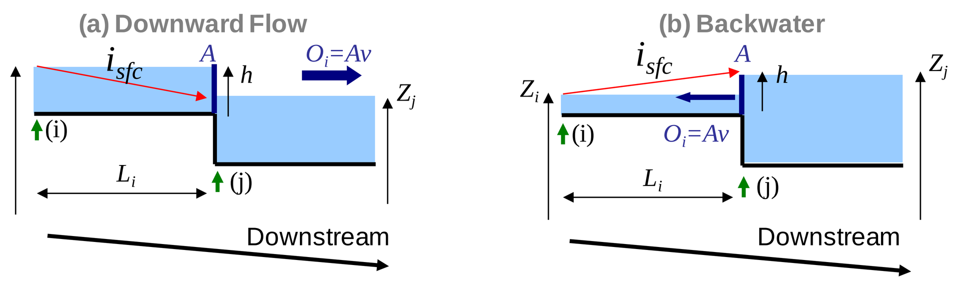
$$\frac{1}{g}\frac{\partial v}{\partial t} + \frac{v}{g}\frac{\partial v}{\partial x} + \frac{\partial h}{\partial x} + i_0 - i_f = 0 \qquad i_f = n^2 v^2 h^{-\frac{4}{3}}$$

Dynamic / Diffusive / Kinematic — Manning's roughness

St. Venant Momentum Equation

$$S_i(t+\Delta t) = S_i(t) + \sum_j^{upstream} Q_j \Delta t - Q_i \Delta t + A_i R_i \Delta t$$

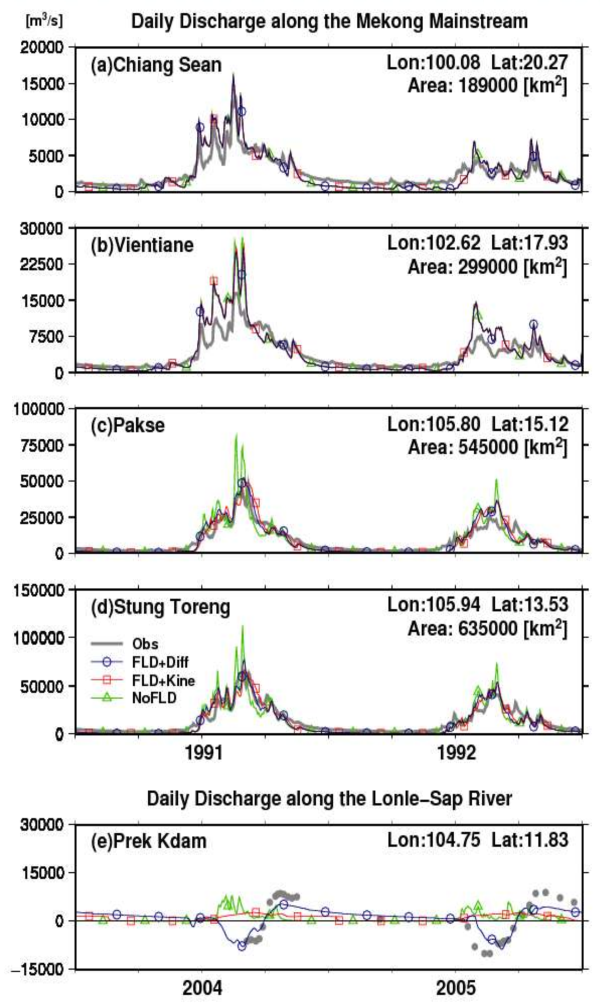
Mass conservation equation

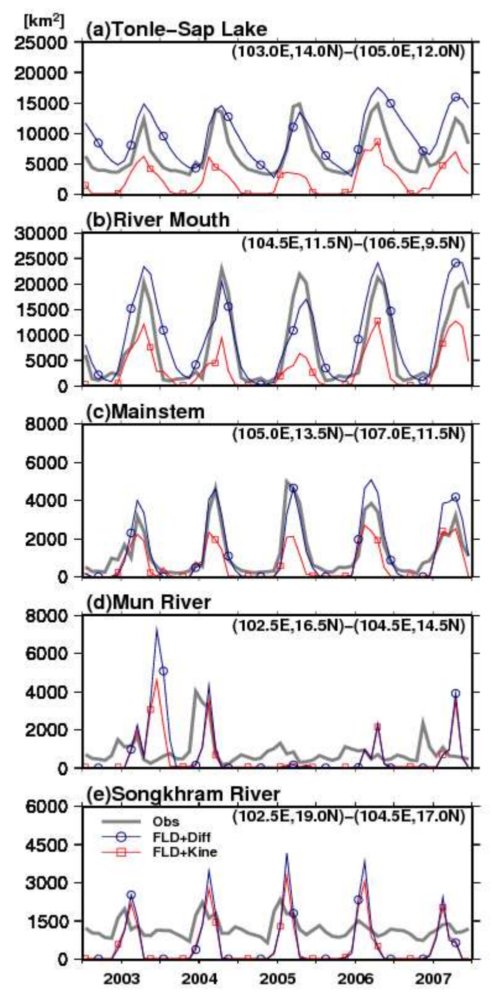


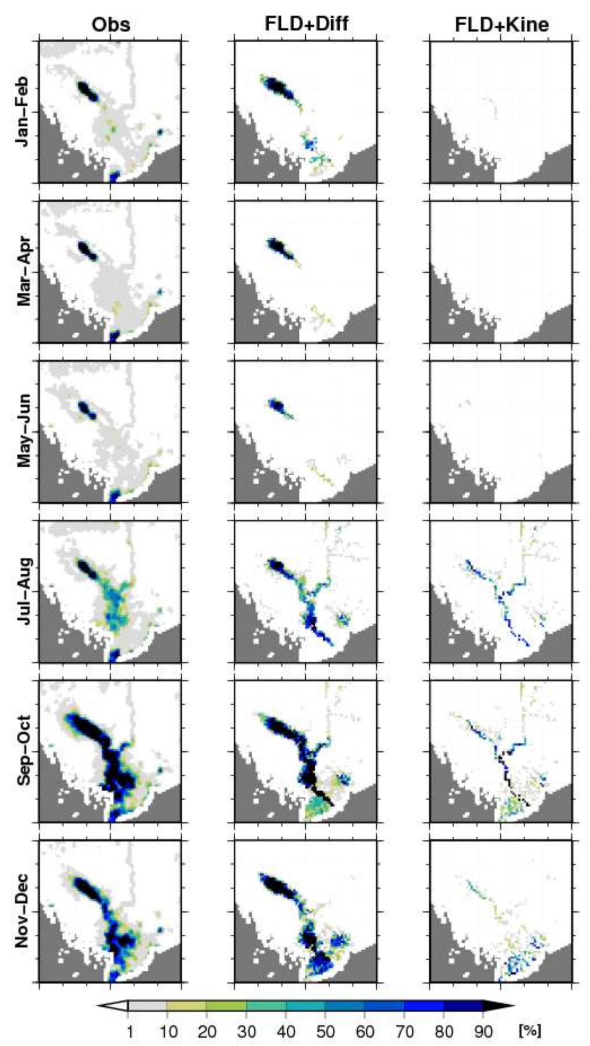
River discharge is calculated along the prescribed river network using a diffusive wave equation, so that backwater effect is considered. Total water storage of each grid-box at next time step is predicted by a mass conservation equation.

(3) VALIDATION

The simulation under the present climate was performed by running the model with observation-based climate forcing, and results were validated against both discharges from in-situ gauges and flooding extents from satellites.





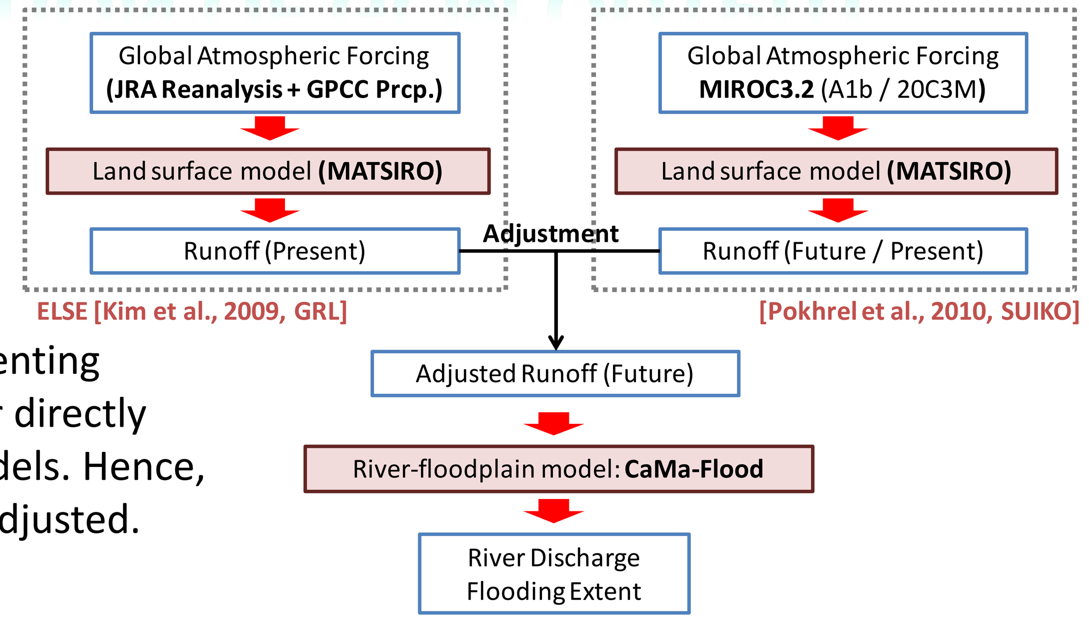


Experiment	Storage	Flow Routing
NoFLD	River Channle Only	Kinematic Wave
FLD+Kine	River Channel + Floodplain	Kinematic Wave
FLD+Diff	River Channel + Floodplain	Diffusive Wave

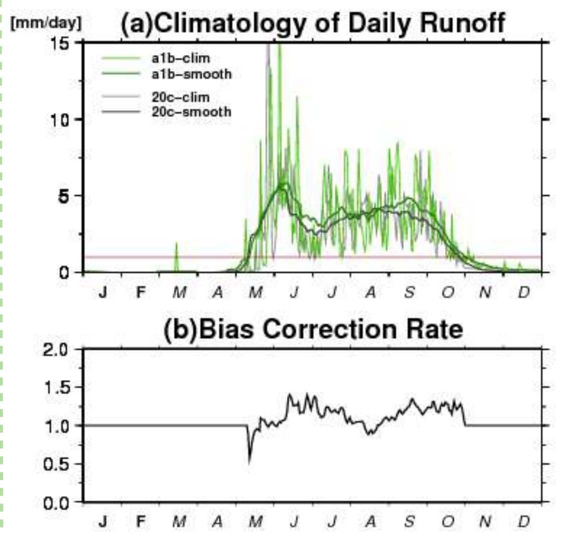
The model well reproduces the daily river discharge in both mountainous reach & lower reach with floodplains including the backflow from the Mekong River to the Tonle-Sap Lake. The flooding extents simulated by the model also well agree to the satellite observations.

(4) BIAS CORRECTION OF GCM OUTPUT

The simulation for a future climate condition is executed using the runoff forcing from a climate change experiment.



GCMs still have difficulties for representing hydrological cycle realistic enough for directly applying them to hydrodynamics models. Hence, the runoff from the GCM should be adjusted.



$$R_{Adjust}^{year(i+100),day(j),grid(k)} = R_{OBS}^{year(i),day(j),grid(k)} \times \frac{\frac{1}{31}\sum_{l=-15}^{15}\frac{1}{21}\sum_{i=1}^{21} R_{GCM:A1B}^{year(i+100),day(j+l),grid(k)}}{\frac{1}{31}\sum_{l=-15}^{15}\frac{1}{21}\sum_{i=1}^{21} R_{GCM:20C3M}^{year(i),day(j+l),grid(k)}}$$

Adjustment performed on every date and every grid

Correction Rate (GCM:future/GCM:present)

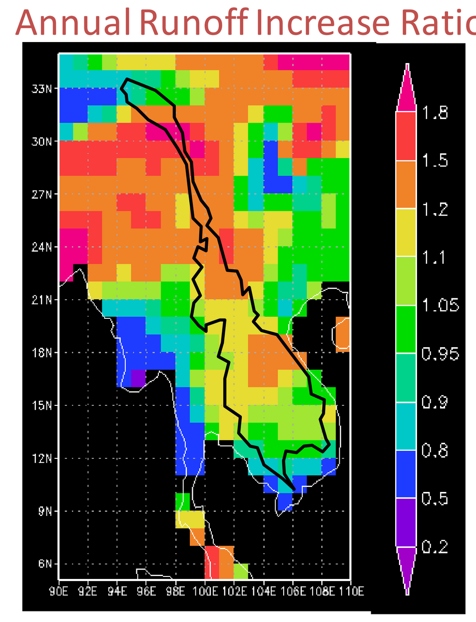
Moving average of daily runoff climatology

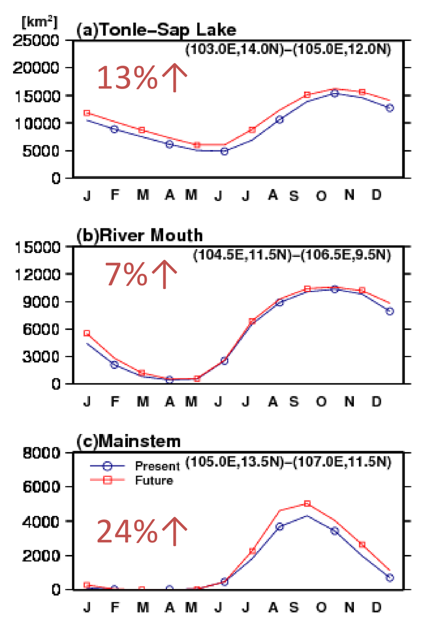
Input runoff should be realistic, so that future runoff is given by applying "runoff change ratio" to the current runoff. The spatially and temporally varied change in future runoff is considered by calculating the "change ratio" for each grid at each date.

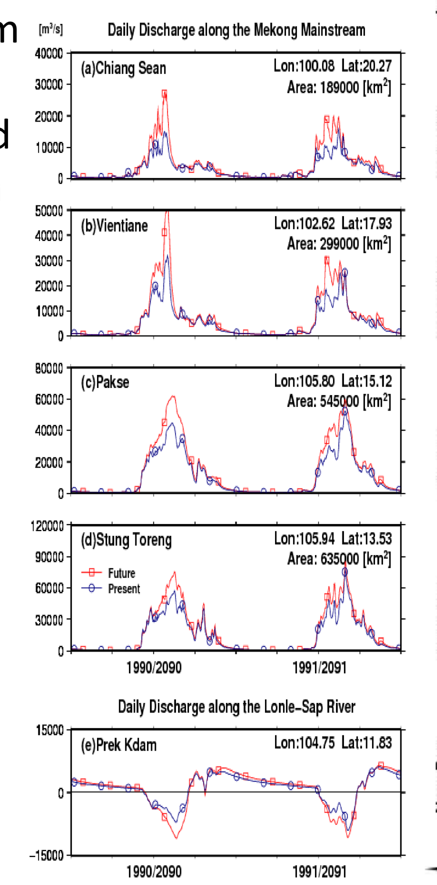
(5) FUTURE PROJECTION

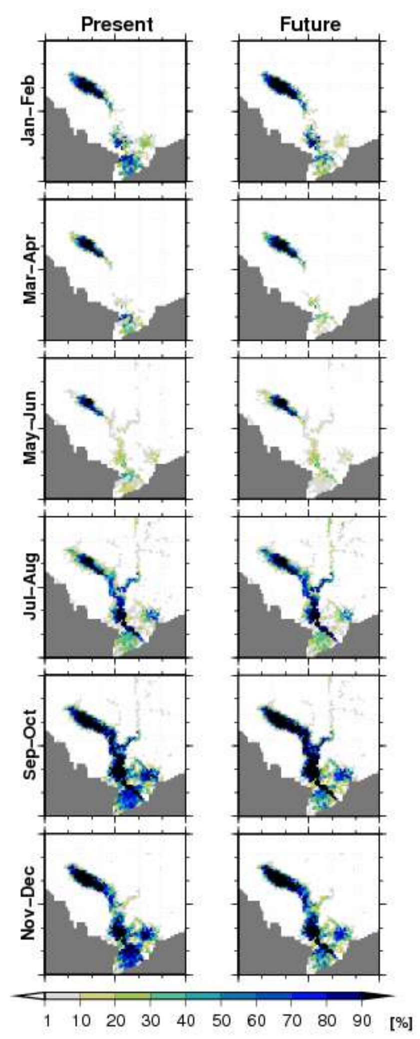
The flooding extents are increased along the mainstem where the increase in upstream runoff is observed. However, the increase in flooding extents is also found around the Tonle-Sap Lake even though the lake basin has no significant increase in upstream runoff.

Annual Runoff Increase Ratio









It is found that the enhanced flooding in the mainstem intensifies the seasonal backflow from the mainstem to the Tonle-Sap Lake, which enhances the flooding extent around the Tonle-Sap Lake without the increase in upstream runoff into the lake basin.

SUMMARY

This study suggested a possibility for the explicit prediction of the flooding extent under the climate change using a continental-scale hydrodynamics model. Though there still exist lots of uncertainties: Errors in DEM (vegetation bias, low accuracy in mountainous region), Model parameter (river width, bank height, etc.), Model structure (no levee, sub-grid hydrodynamics, no dam), Observation uncertainty (especially for rainfall), GCM accuracy and adjustment method

REFERENCES

Kim et al. (2009), Role of rivers in the seasonal variations of terrestrial water storage over global basins, *GRL*
Lehner et al. (2008), New global hydrography derived from spaceborne elevation data, *EOS Trans. AGU*
Mori et al. (2009), Estimation of land surface water coverage (LSWC) with AMSR-E and MODIS. 2nd *Joint Seminar at AIT: Bangkok, Thailand, 2009 Jul.*
Pokhrel et al. (2010), Extreme River Discharge Under Present and Future Climate Conditions Using High-Resolution Climate Model Data, *JSCE*
Yamazaki et al. (2009), Deriving a global river network map and its sub-grid topographic characteristics from a fine-resolution flow direction map, *HESS*
Yamazaki et al. (2011), A physically-based description of floodplain inundation dynamics in a global river routing model, *WRR*

EGU General Assembly 2011, 3-8 April 2011, Vienna, Austria

(NH1.3/HS12.7) Flood risk and uncertainty