EGU2011-2786

Improvement of streamflow prediction skill in large catchments:

- The effect of floodplain parameterization using a spaceborne DEM

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EGU General Assembly 2011

HS6.4 Catchment hydrology and remote sensing: parameter retrieval and integration with models

5th April, 2011

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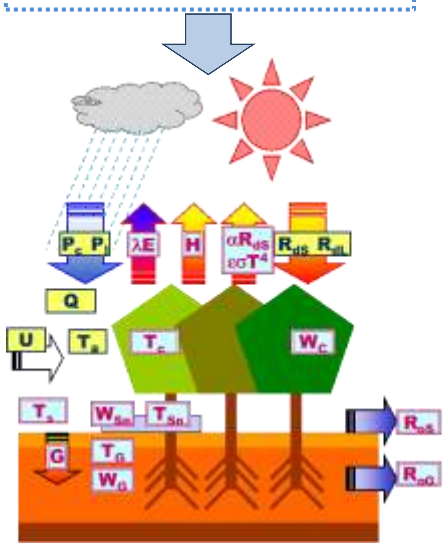
Background: Large-scale River Model

Streamflow prediction is important for both water resources management and flood control. Varieties of hydrodynamics models have been developed for improving the streamflow prediction skill in large catchments.

Research Framework

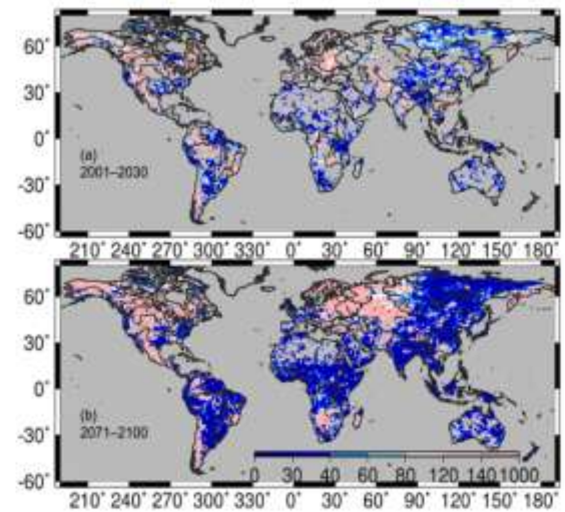
Atmospheric Forcing



Land Surface Model

Soil Runoff

River Routing Model



Flood Forecast &

Water Resources Management

River Discharge (Streamflow)

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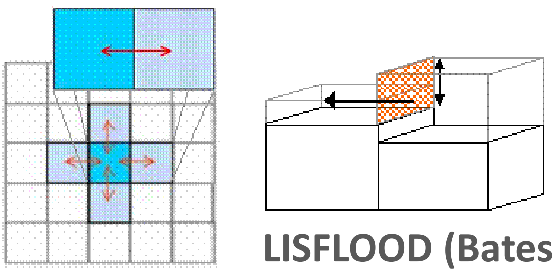
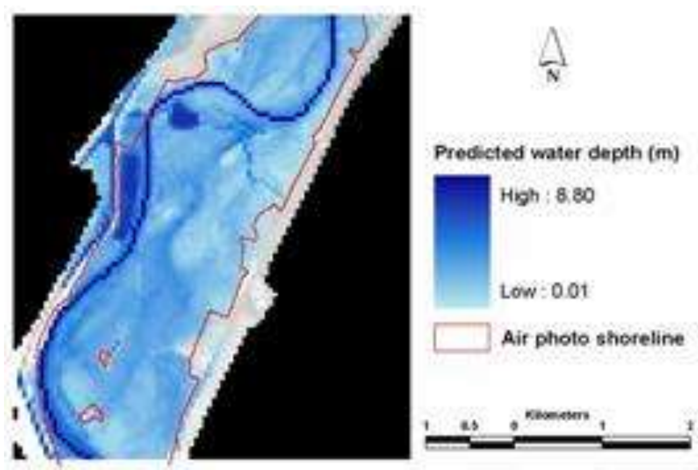
Problem: Scale-difference

However, streamflow prediction in large catchments is still difficult because the movement of water during flood events is regulated by much smaller-scale topography than the grid resolution of typical hydrodynamics models applied to large catchments.



LISFLOOD (Bates & DeRoo, 2000)



Small-scale flooding can be modeled by considering detailed topography.

Photo: Flooding in Mekong River

How can we model the complex hydrodynamics of large-scale flooding?

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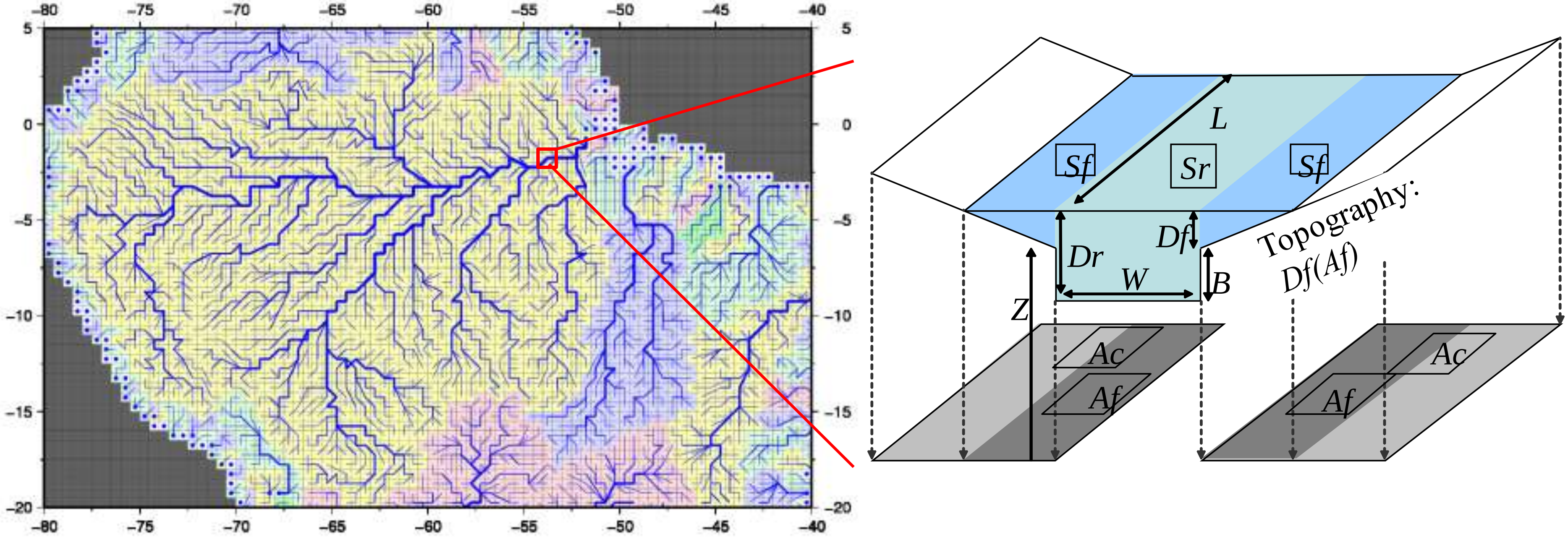
Concept of New Model

CaMa-Flood (**Ca**tchment-based **Ma**cro-scale **Flood**plain model)

- Distributed river routing model using River Network Map
- Input: LSM Runoff, Output : Water storage (Prognostic)
  River discharge, Water level, Inundated area (Diagnosed)
- River and floodplain storage with sub-grid topographic parameters.
  > Explicit representation of water stage in a single grid-box (25km size)



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Concept of New Model

CaMa-Flood (Catchment-based Macro-scale Floodplain model)

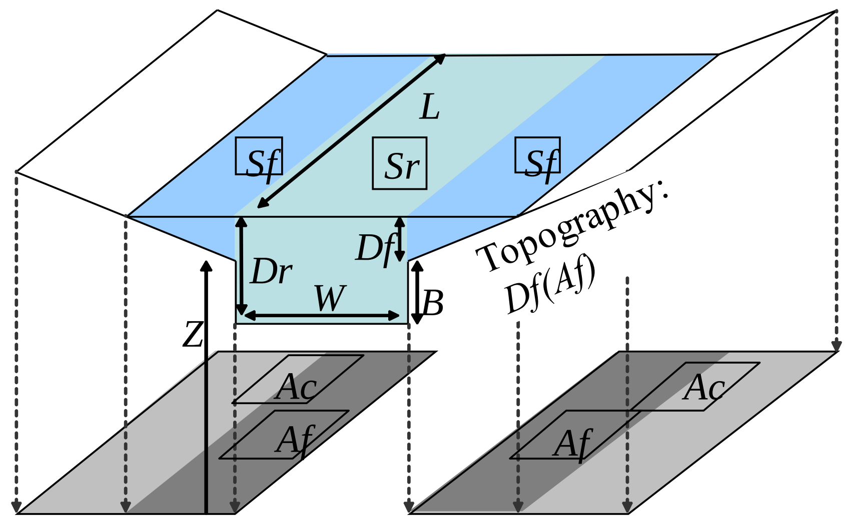
- Distributed river routing model
- Input: LSM Runoff, Output : Water storage (Prognostic)
  Discharge, Water level, Inundated area (Diagnosed)
- River and floodplain storage with sub-grid topographic parameters.
  > Explicit representation of water stage in a single grid-box (25km size)
- Discharge calculation using diffusive wave equation along river network map

Diffusive Wave Eq.

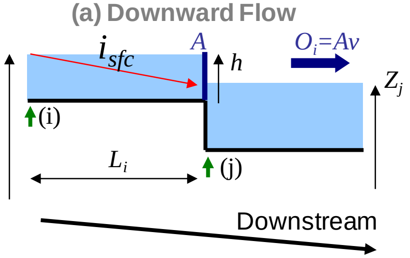
$$\frac{\partial D}{\partial x} + \frac{\partial Z}{\partial x} + i_f = 0$$

Manning Roughness

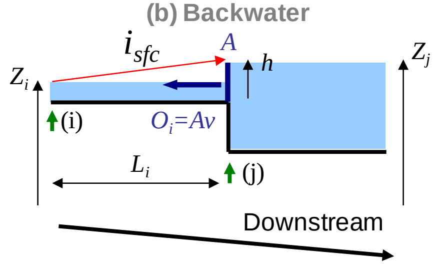
$$i_f = n^2 v^2 D^{-\frac{4}{3}}$$



(a) Downward Flow



(b) Backwater



Key: How can we realistically determine the sub-grid topographic parameters?

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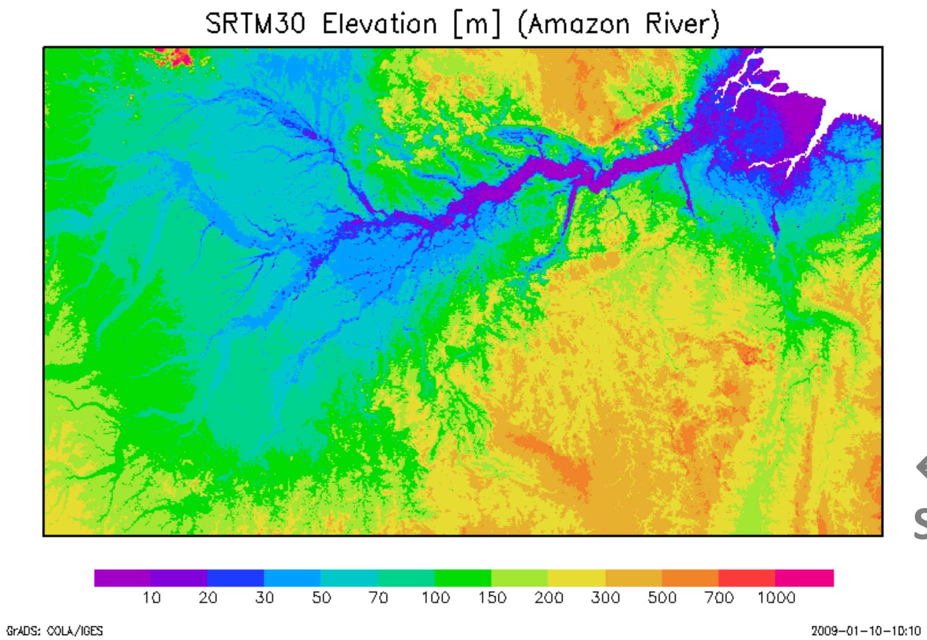
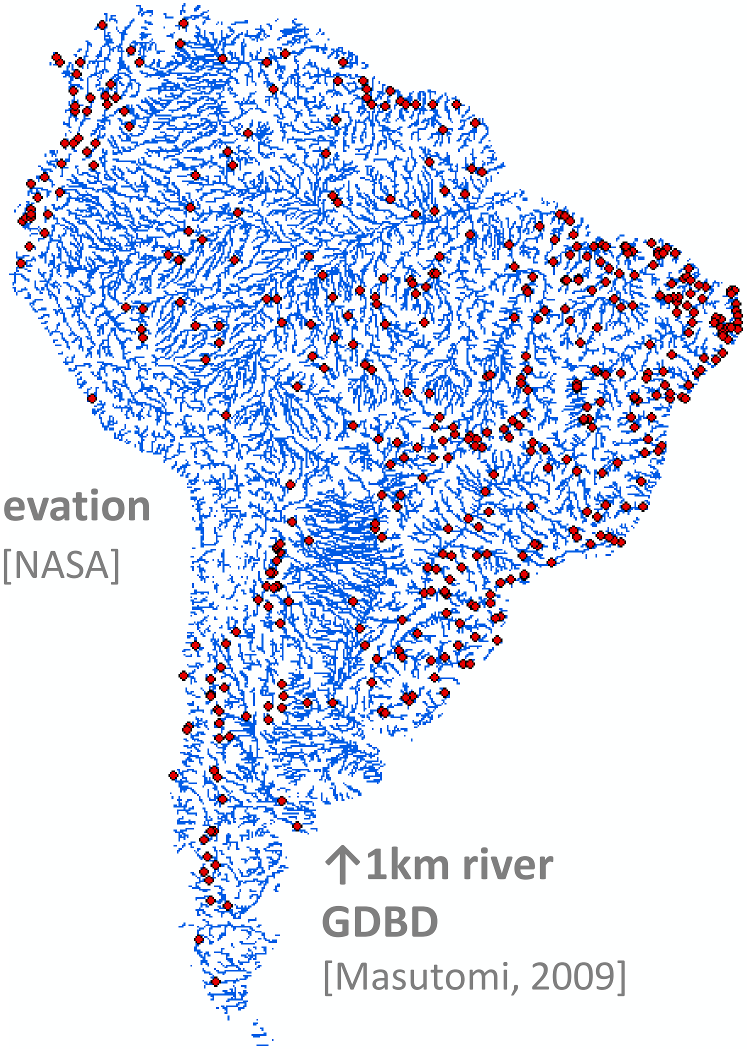
Sub-grid Topographic Parameters

Generated from a Spaceborne DEM and Flow Direction Map.



←1km elevation
SRTM30 [NASA]



↑1km river
GDBD
[Masutomi, 2009]

Algorithm: **FLOW**
(**F**lexible **L**ocation **of** **W**aterways method)

Input: Fine-resolution (1 km) datasets
SRTM30 DEM & GDBD Flow Direction Map

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Sub-grid Topographic Parameters

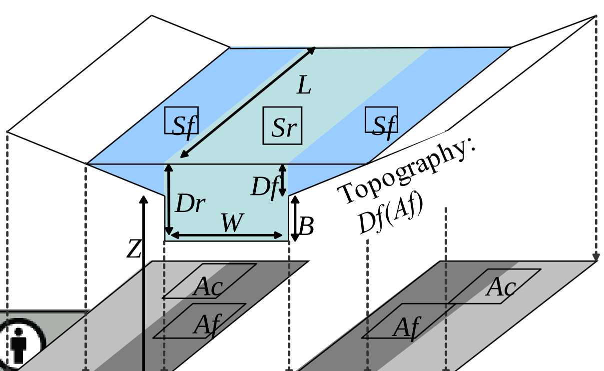
FLOW (Flexible Location of Waterways method)

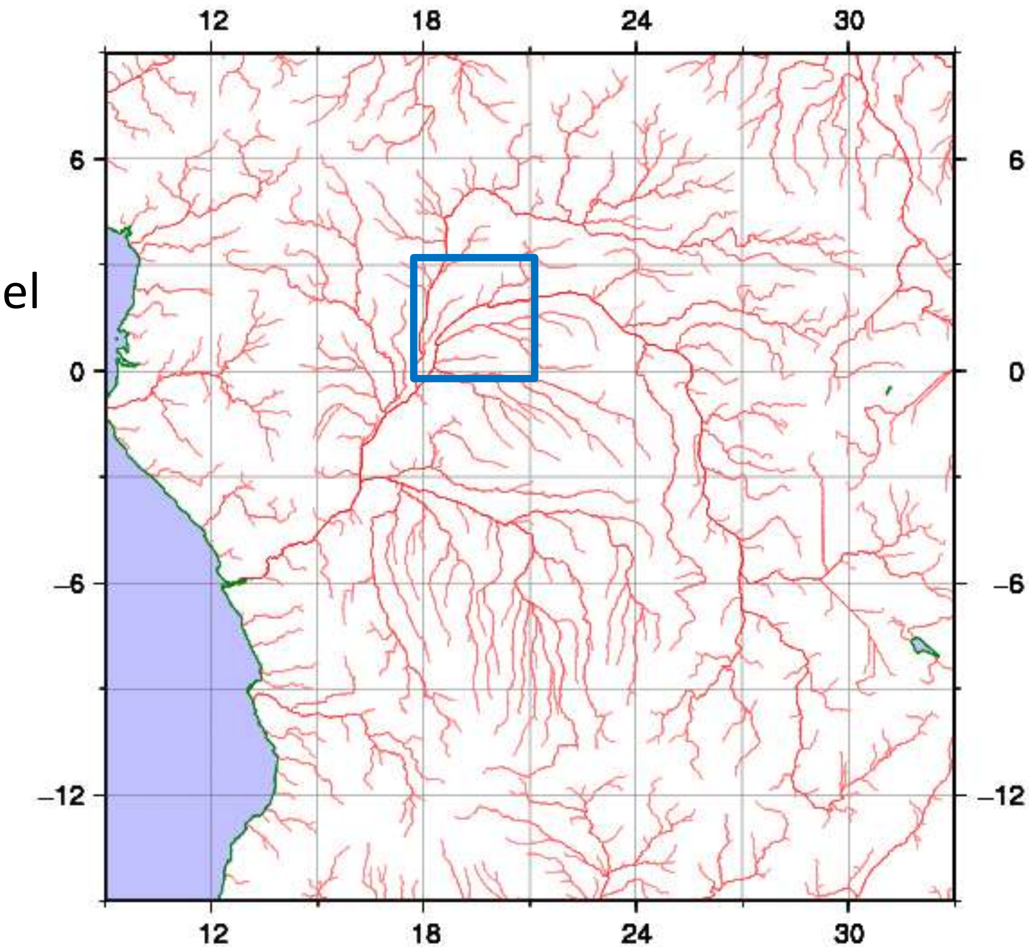
Blue (and grey) cells:

Grid-box of Large-Scale Model

Red pixels:

1-km flow direction map





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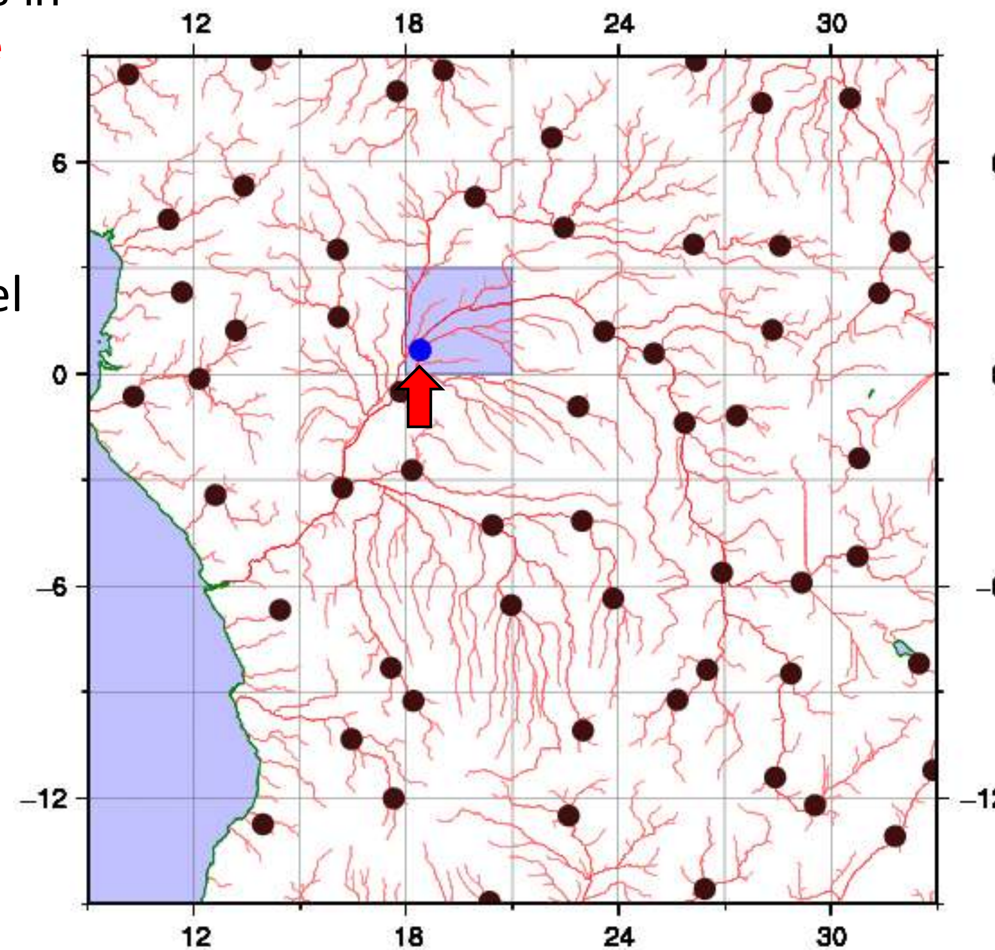
Sub-grid Topographic Parameters

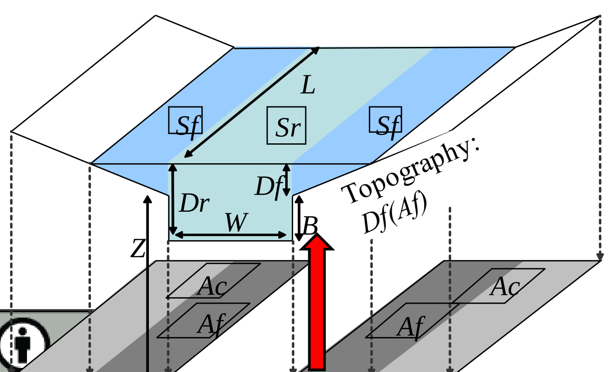
FLOW (**F**lexible **L**ocation **o**f **W**aterways method)

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

Blue (and grey) cells:
Grid-box of Large-Scale Model

Red pixels:
1-km flow direction map





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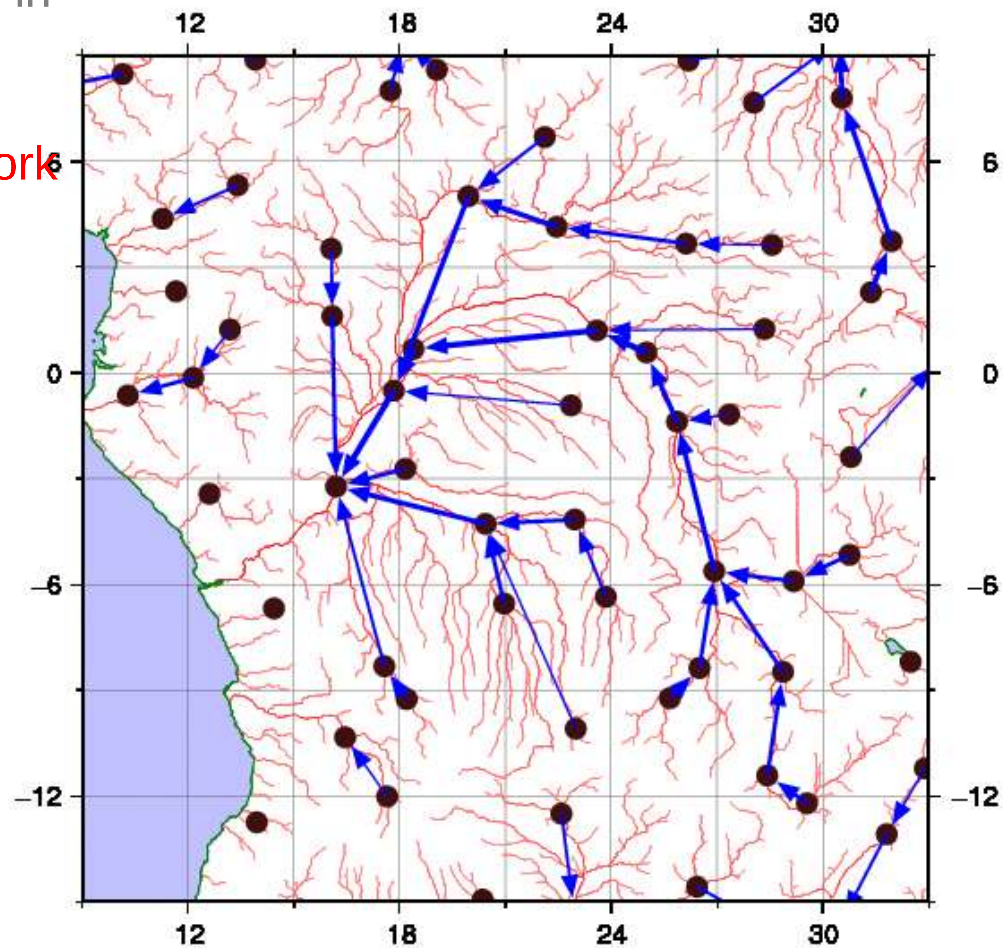
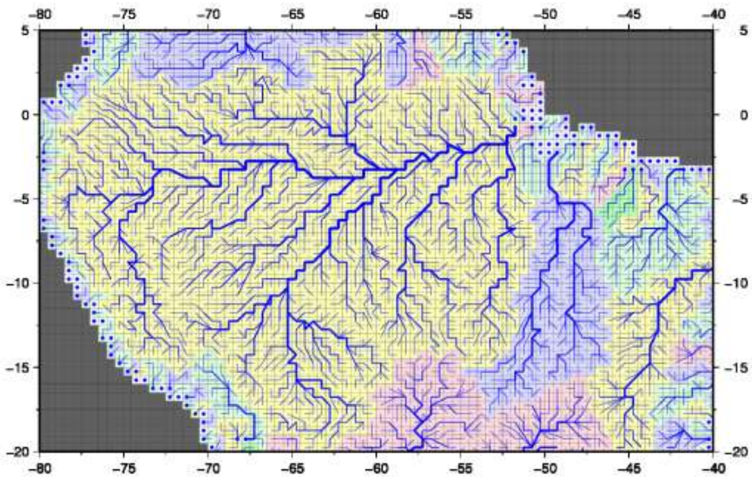
Sub-grid Topographic Parameters

FLOW (**F**lexible **L**ocation **o**f **W**aterways method)

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

2) Decide downstream cell by tracking GDBD path from outlet pixel >River network





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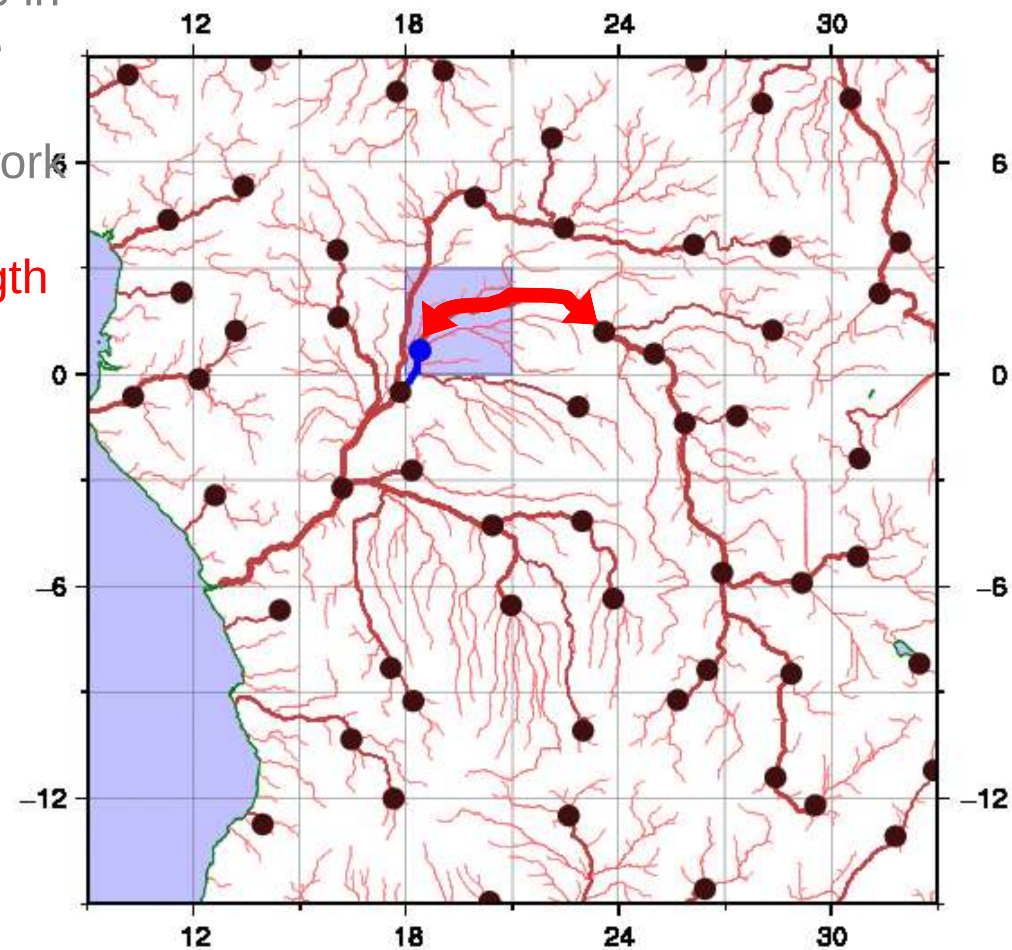
Sub-grid Topographic Parameters

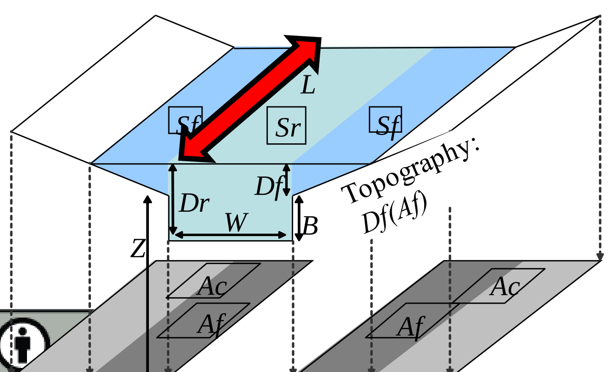
FLOW (**F**lexible **L**ocation **o**f **W**aterways method)

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

2) Decide downstream cell by tracking GDBD path from outlet pixel >River network

3) Calculate channel length considering meandering in 1-km scale >Channel length





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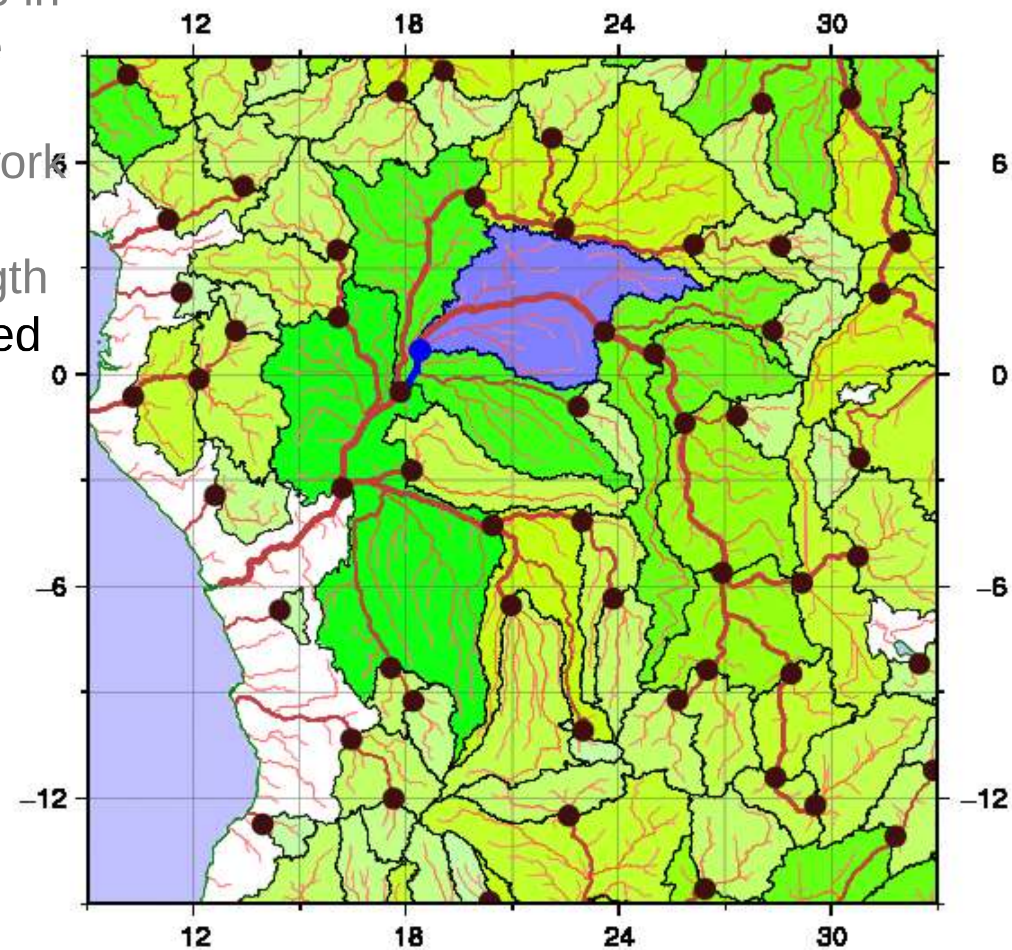
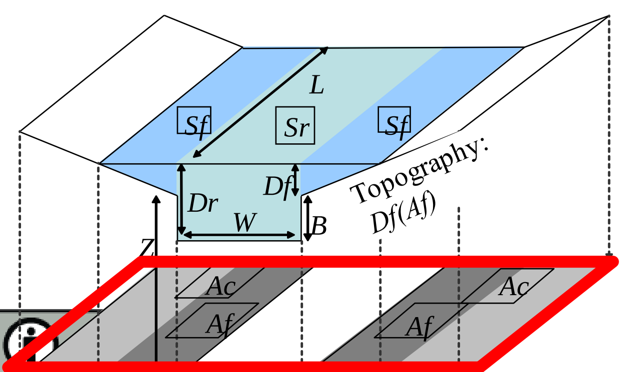
Sub-grid Topographic Parameters

FLOW (Flexible Location of Waterways method)

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





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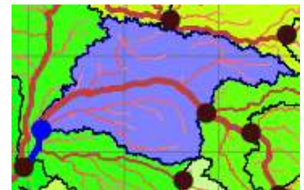
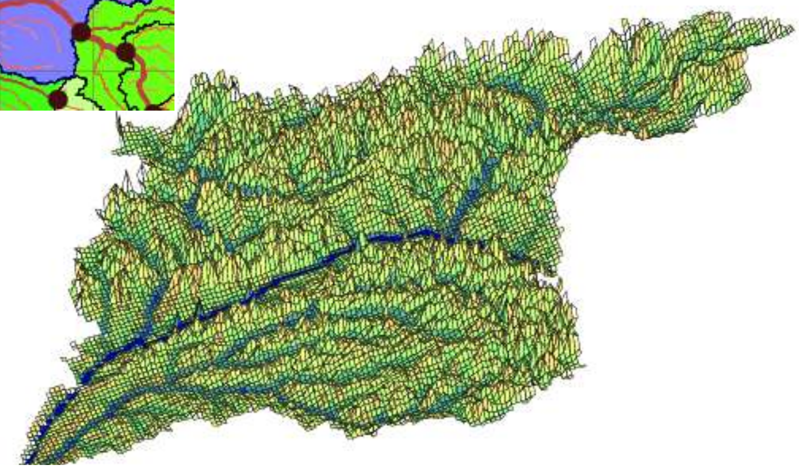
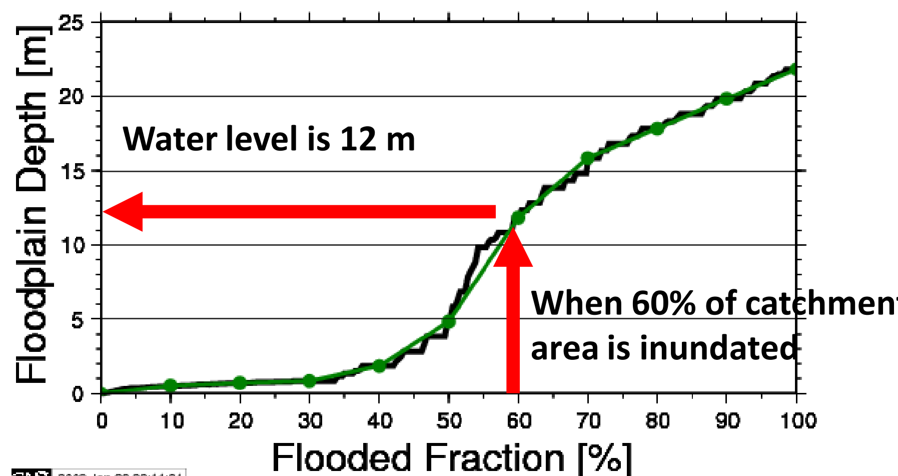
Sub-grid Topographic Parameters

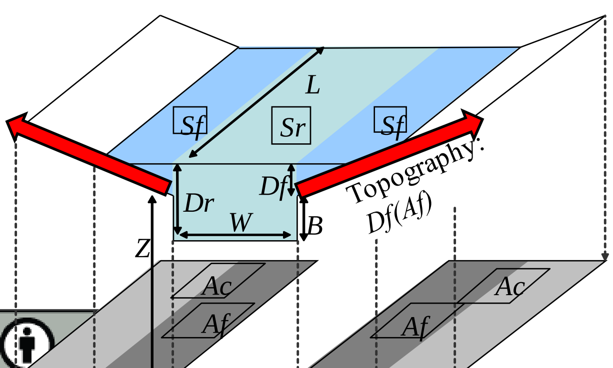
FLOW (Flexible Location of Waterways method)



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







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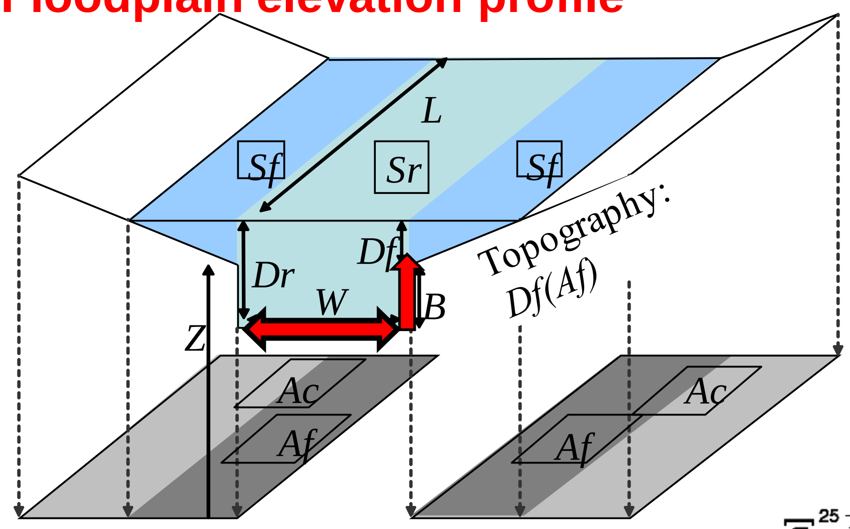
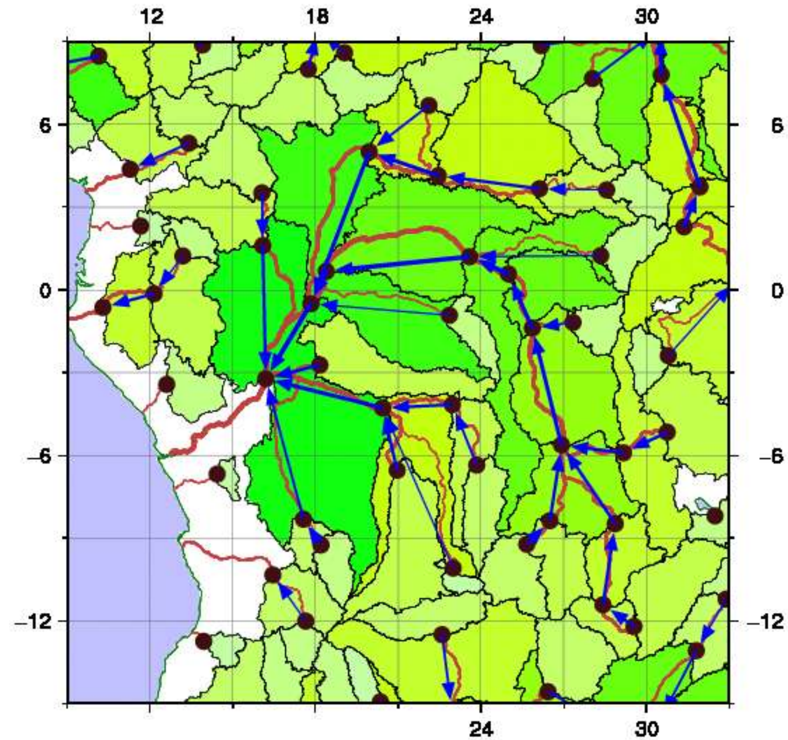
Sub-grid Topographic Parameters

FLOW (Flexible Location of Waterways method)

> Automatically derived from 1-km datasets

Channel elevation・Downstream cell・Channel length・Catchment area・Floodplain elevation profile



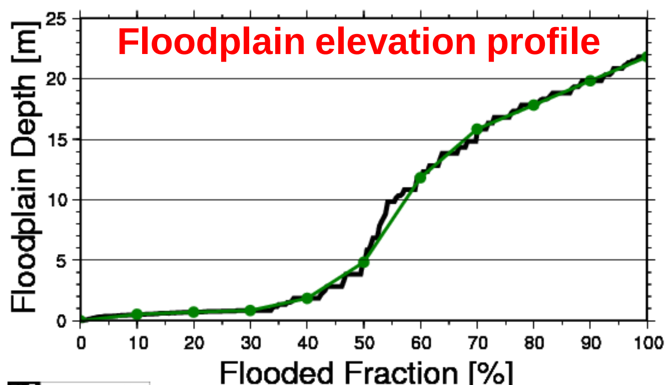


> Empirically estimated from runoff

River width・Bank height

$$W = \max[1.00 \times R_{up}^{0.7}, 10.0]$$

$$B = \max[0.035 \times R_{up}^{0.5}, 1.0]$$



Channel elevation
Downstream cell
Channel length
Catchment area

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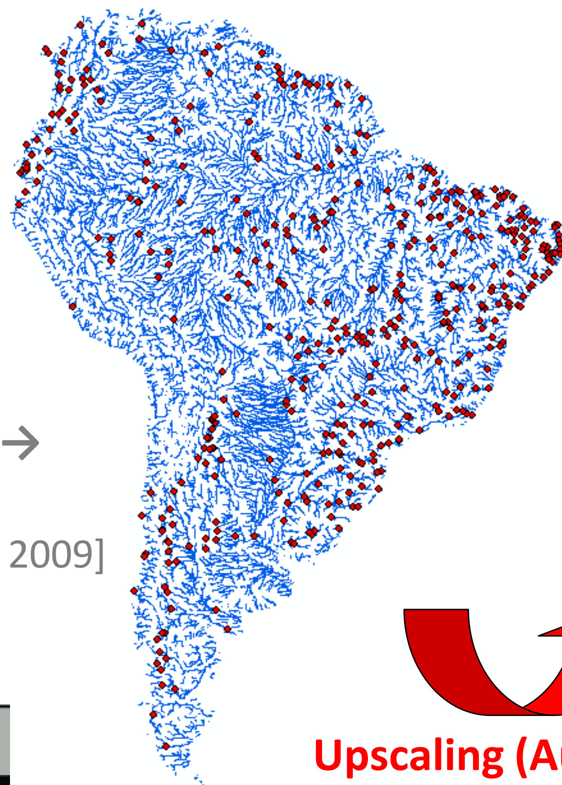
Key: **D8** .vs. **Flexible** River Network

FLOW (**F**lexible **L**ocation **o**f **W**aterways method)

Traditionally, macro-scale river models use **D8 (neighboring cell) River Network**, but it requires **manual editing** of flow directions.

The relation between upscaled grid-boxes and the original fine-resolution datasets is lost by the process of manual editing.

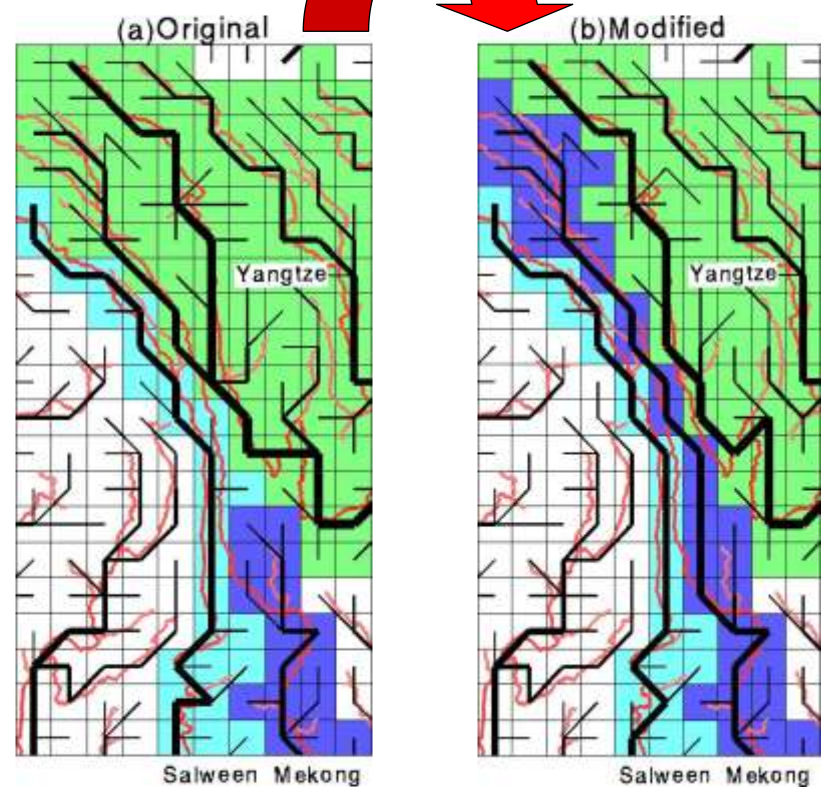
Manual Editing



1km river → GDBD

[Masutomi, 2009]

Upscaling (Automatic)



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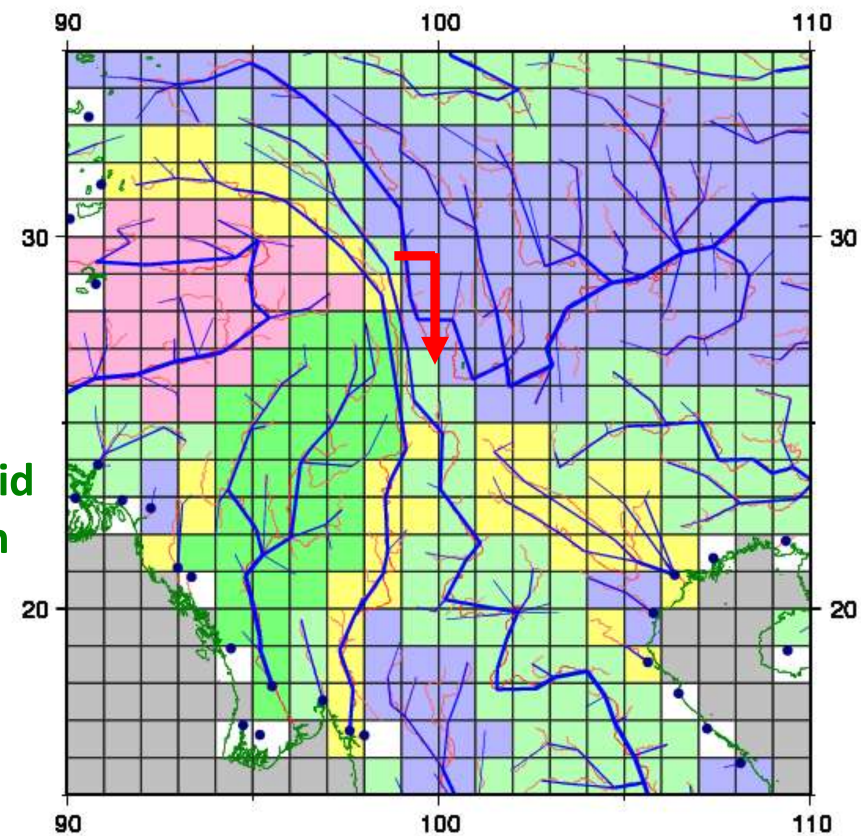
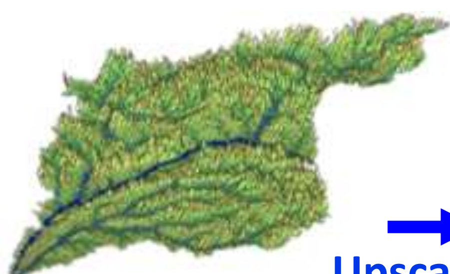
Key: **D8** .vs. **Flexible** River Network

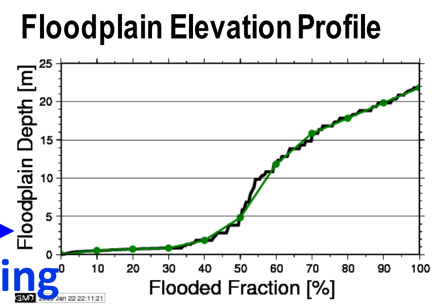
FLOW (**F**lexible **L**ocation **o**f **W**aterways method)

The new model, CaMa-Flood, adopts **Flexible River Network.**
(i.e. The downstream grid does not have to be a neighboring cell)

- No manual editing, High resolution river networks are available
- Sub-grid topographic parameters can be objectively derived from the original datasets.



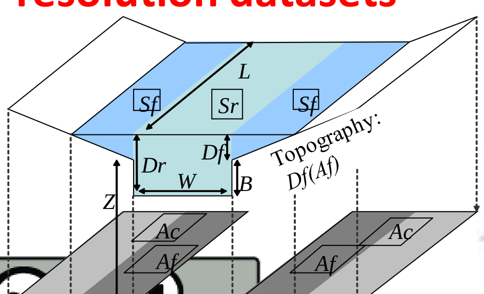


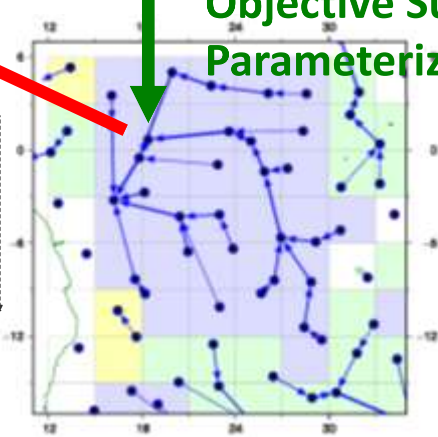


Upscaling

Objective Sub-grid Parameterization

Reference to fine-resolution datasets





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Simulation Setting

CaMa-Flood (**Ca**tchment-based **Ma**cro-scale **Flood**plain model)

In order to discuss the impacts of **1) introducing floodplain storage** and **2) adapting diffusive wave equation**

> Three experiments are performed:

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: 10 min

(Input runoff) Spatial Resolution: 1 deg, Time step: 1 day (Linear interpolation)

Boundary condition at river mouth: Constant sea surface elevation.

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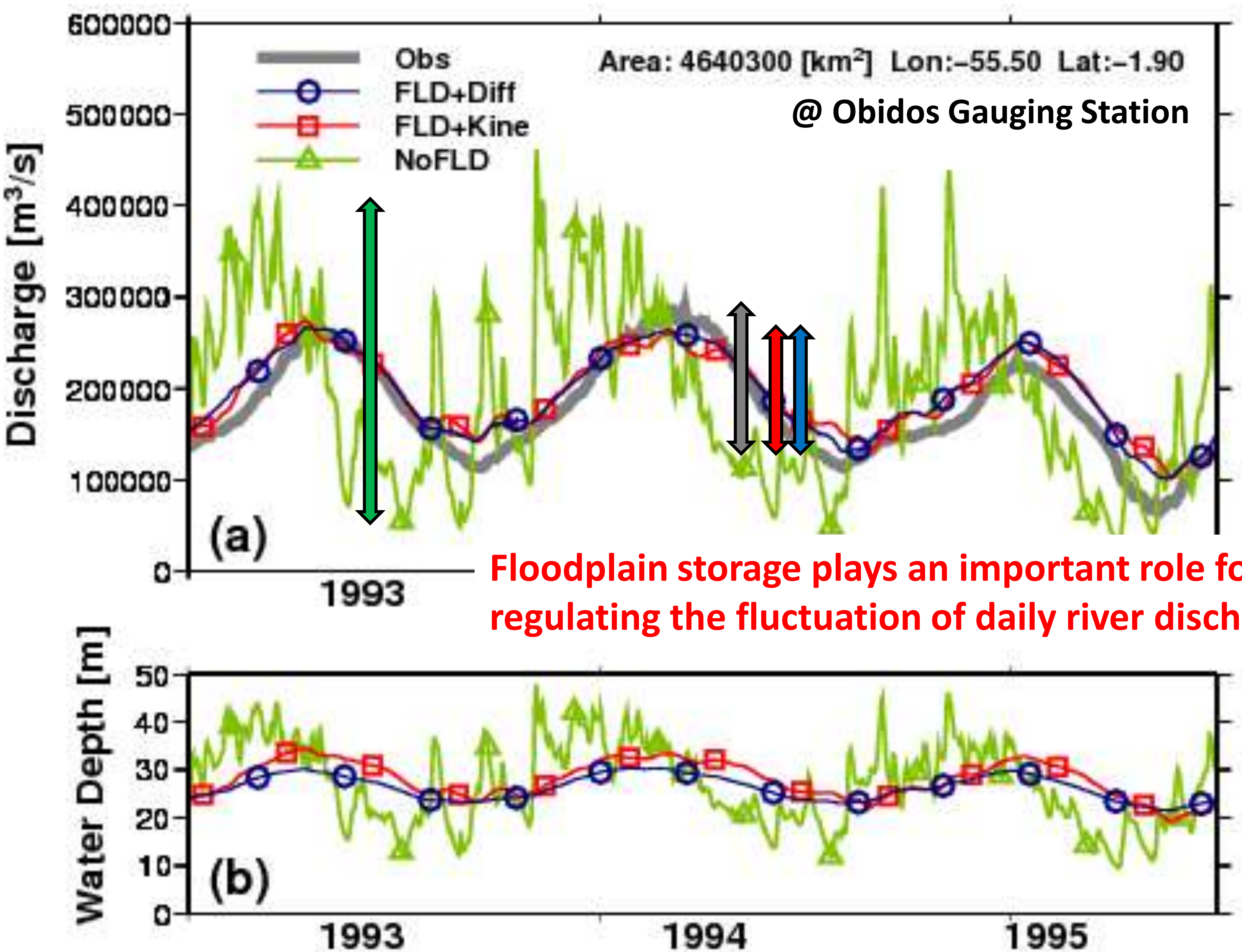
Results (Amazon River)

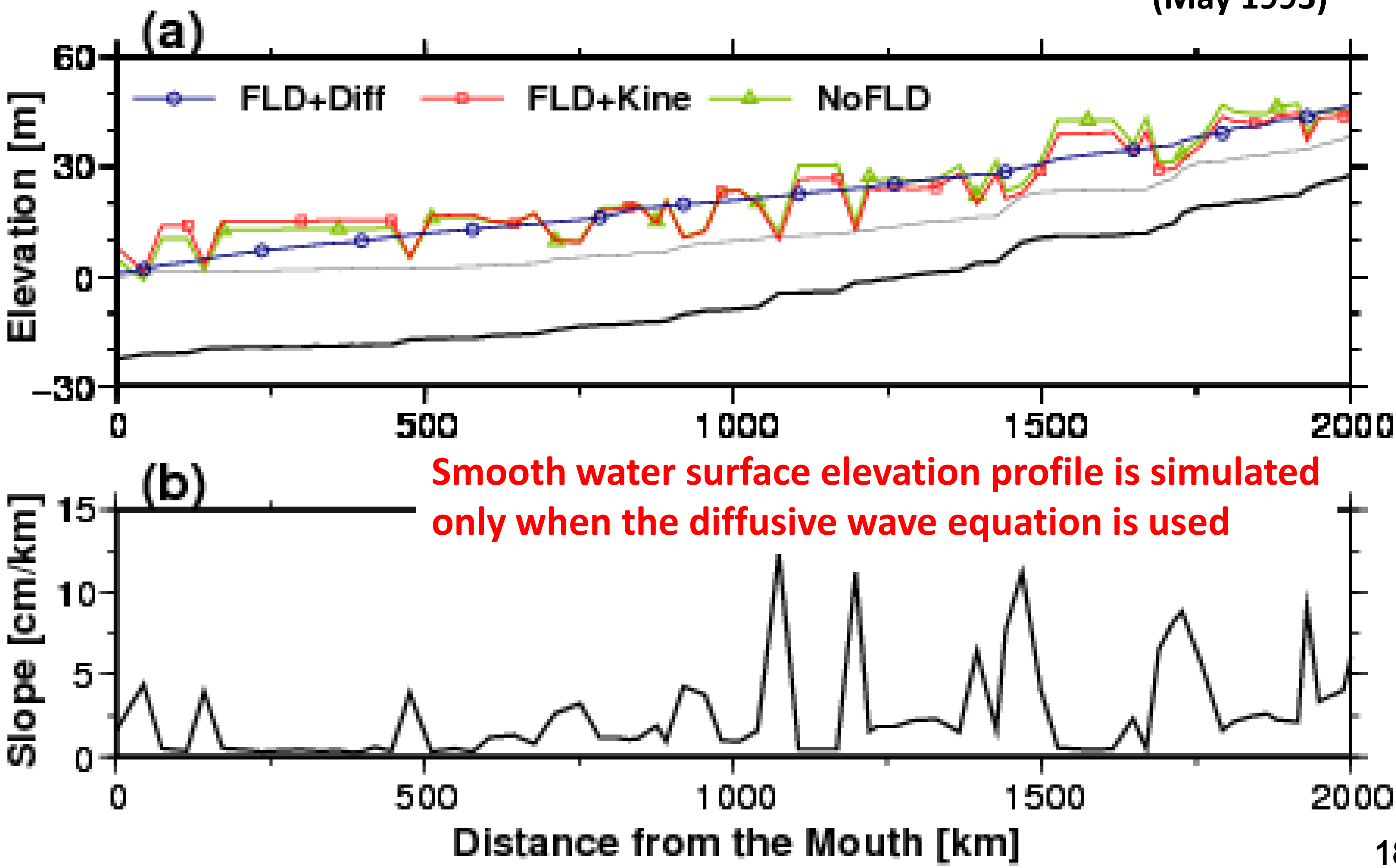


Floodplain storage plays an important role for regulating the fluctuation of daily river discharge

Results (Amazon River)

Monthly averaged water surface elevation along the meinstem

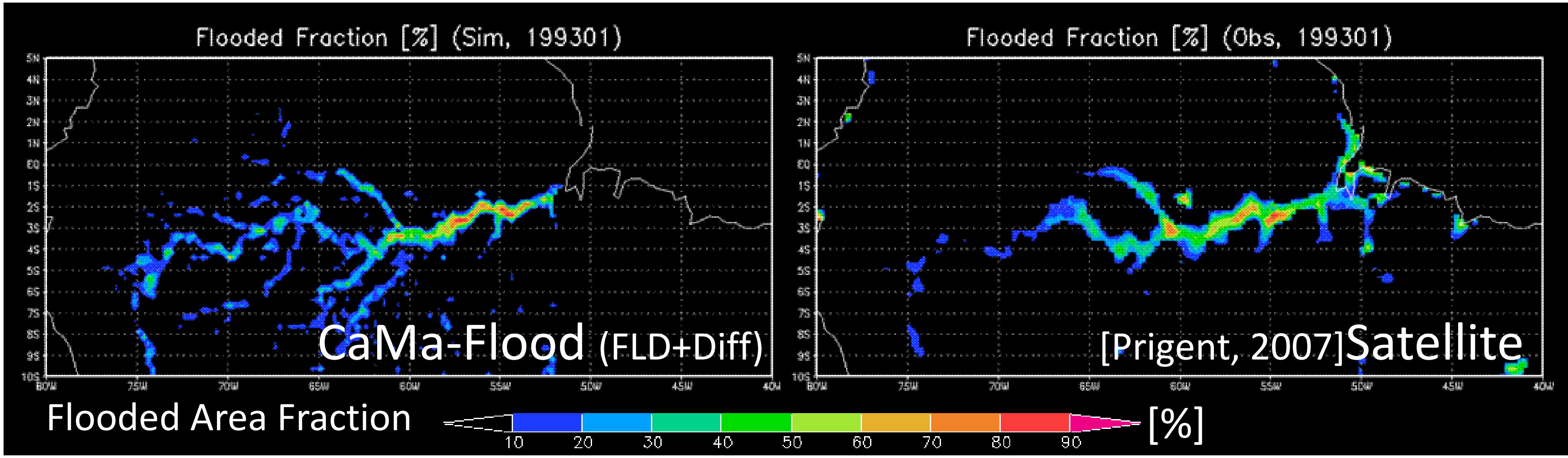
(May 1993)

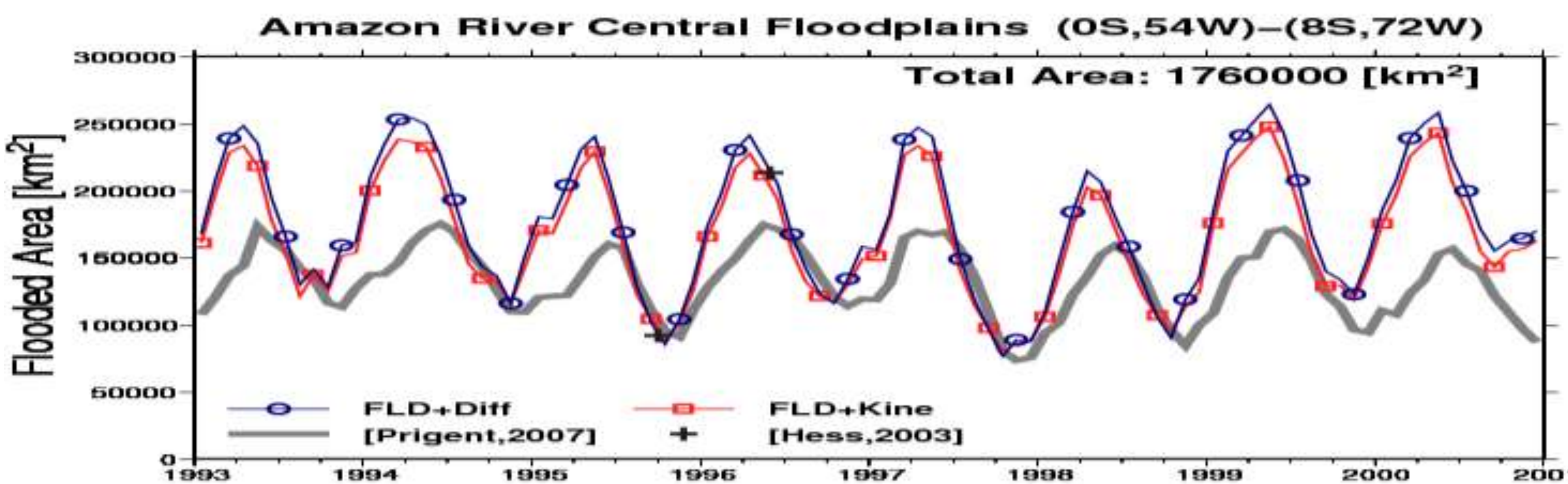


Smooth water surface elevation profile is simulated only when the diffusive wave equation is used

Results (Amazon River)

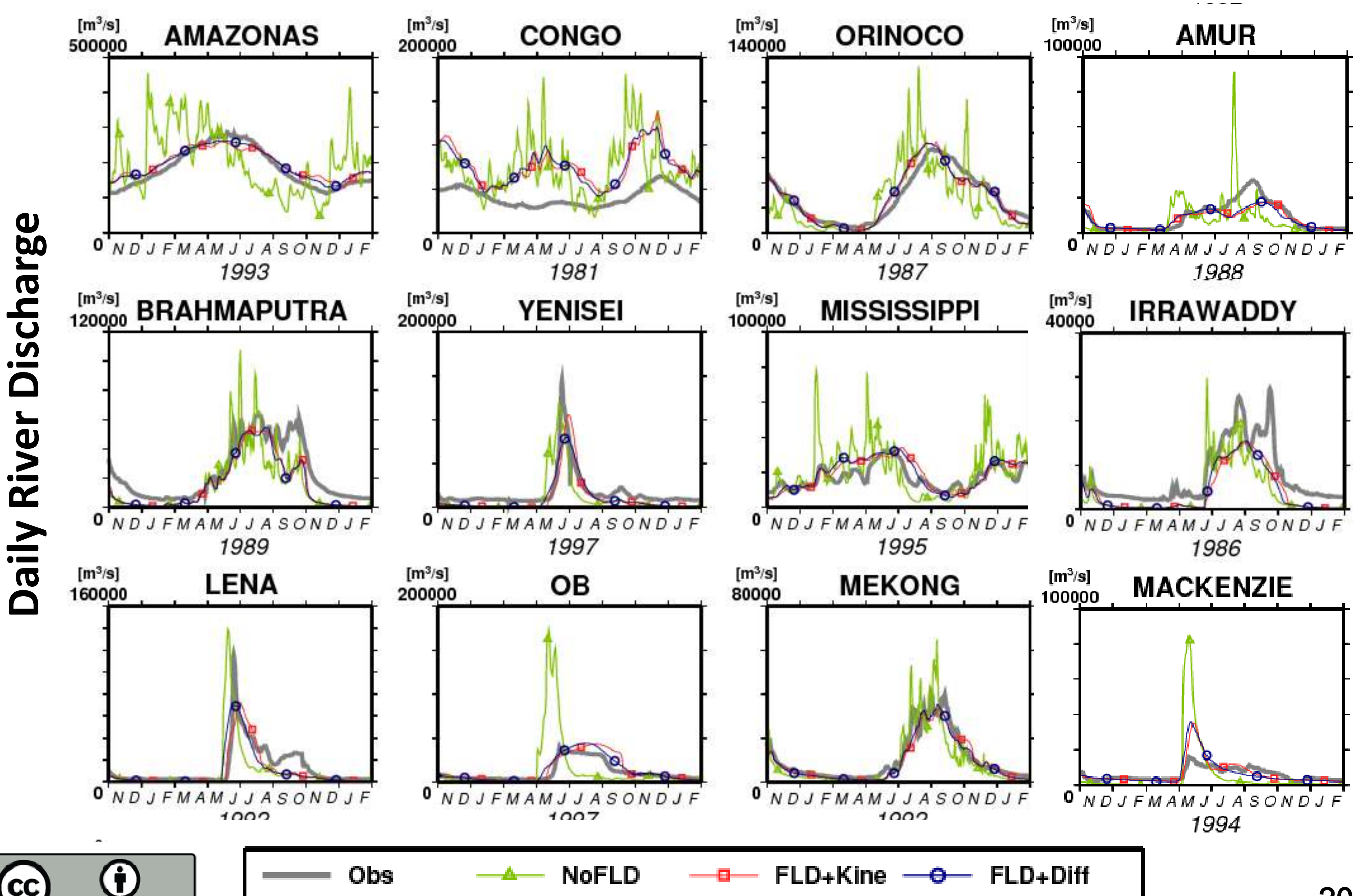
Spatial-temporal distribution of flooded area





Many thanks to Dr. Prigent and Dr. Hess for providing the satellite datasets

Results (World major rivers)



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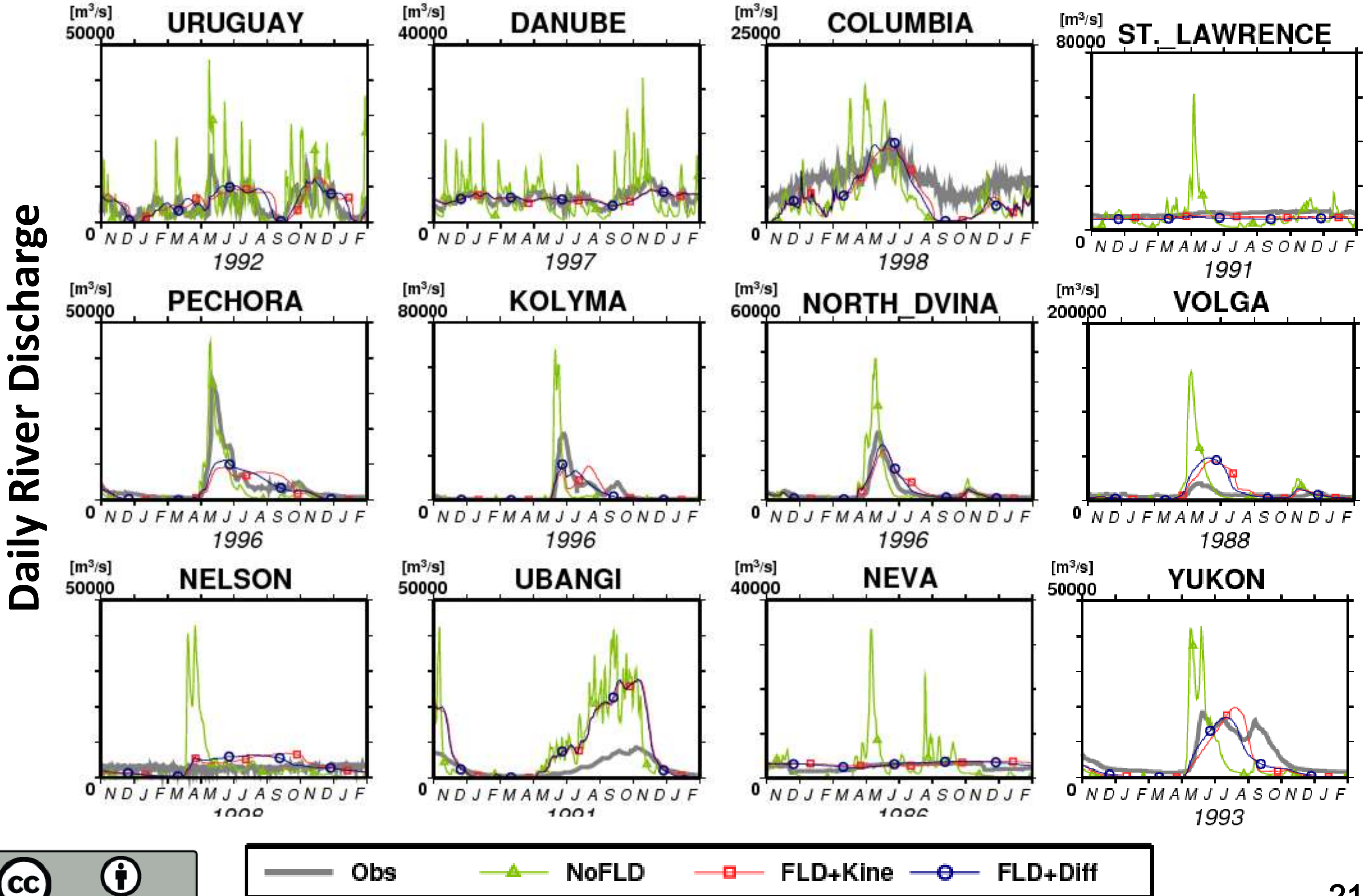

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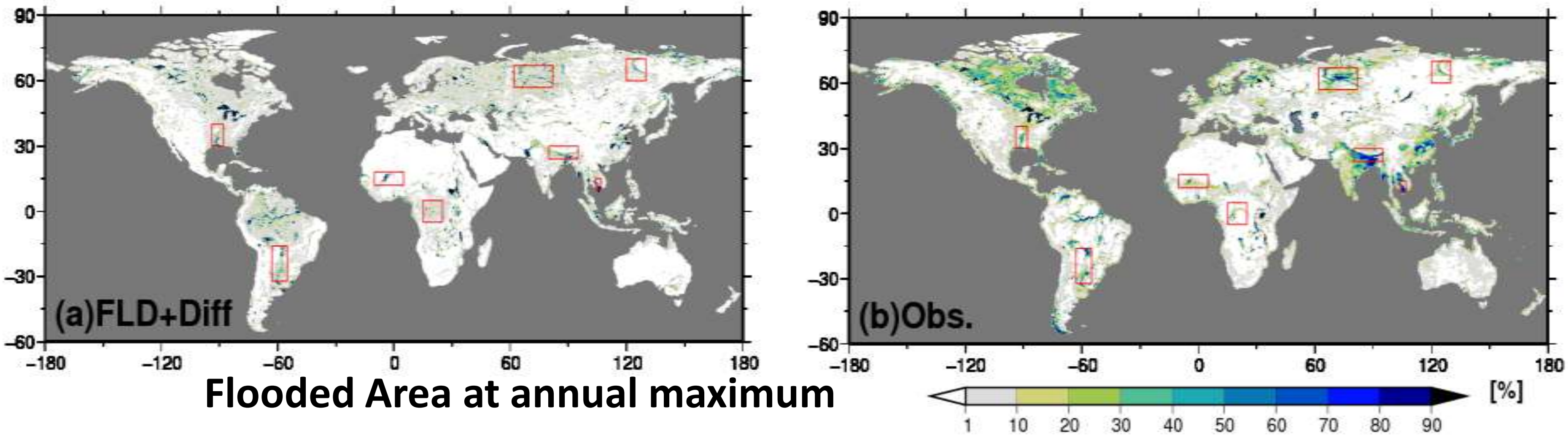
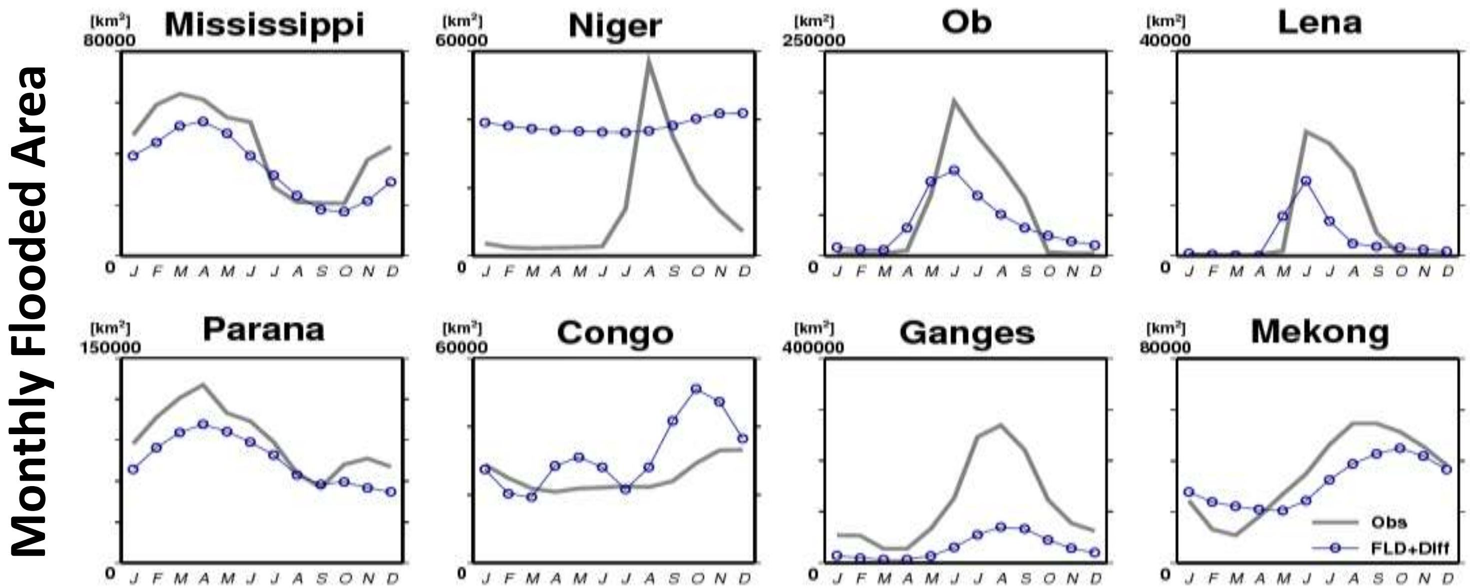


Flooded Area at annual maximum



Flooding from river channels is simulated

Irrigated paddy fields and isolated lakes/wetlands are not represented

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Summary

1) We developed the new river routing model, CaMa-Flood.

- Floodplain inundation is represented as sub-grid process.
- Diffusive wave equation is adopted as a governing equation.

2) Predictability of daily discharge in large catchments are improved.

- Floodplains play important role for regulating daily discharge
- The improvement seems robust because CaMa-Flood also shows reasonable results for flooded area and water surface elevation.

Follow Up

1. Detailed model description and results available in WRR:

   -Dai YAMAZAKI et al: A physically-based description of floodplain inundation dynamics in a global river routing model, *Water Resources Research*, **2011 (published last week)**

2. Poster presentation on Friday

   - Yamazaki et al. (NH1.3/HS12.7 Flood risk and uncertainty)
   - Getirana et al. (HS2.8 – Large scale hydrology: observations and modelling)

3. Source code of CaMa-Flood is available for research purposes

   -Please contact me via e-mail (yamadai@rainbow.iis.u-tokyo.ac.jp) or,

   -Google “Dai Yamazaki” or “CaMa-Flood”