The automatic extraction of flood protection parameters for global river models

Yoshiaki Tanaka and Dai Yamazaki

The University of Tokyo

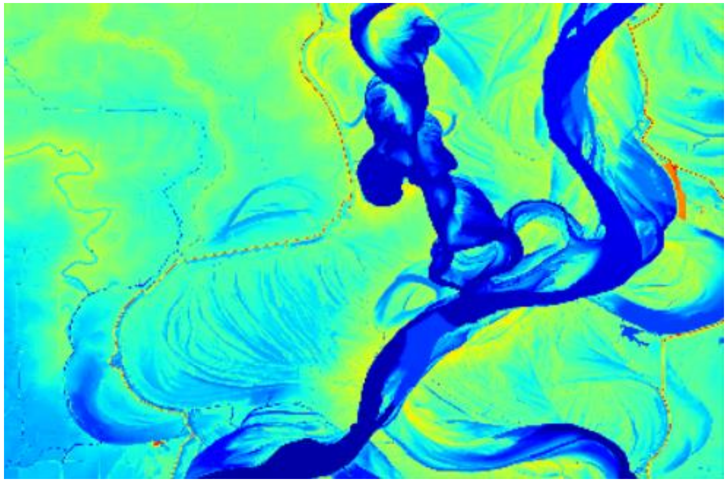
東京大学
THE UNIVERSITY OF TOKYO

Levee consideration in the global flood risk assessment

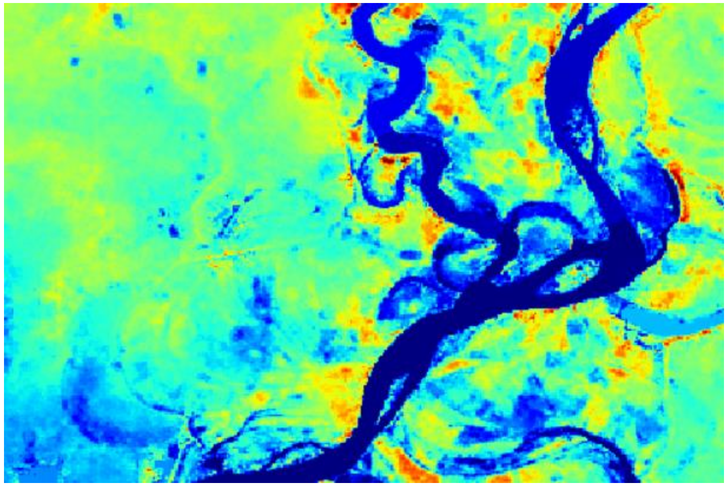
- Levee implementation has been a significant problem in global flood risk assessment Ward et al. (2015)

Causes

- There are few governmental information about flood protection facilities Moel et al. (2015) Wood et al. (2018)
- It is difficult that deriving flood protection facilities from global dataset because of the temporal/spatial resolution



DEM provided by USGS (1/3sec)

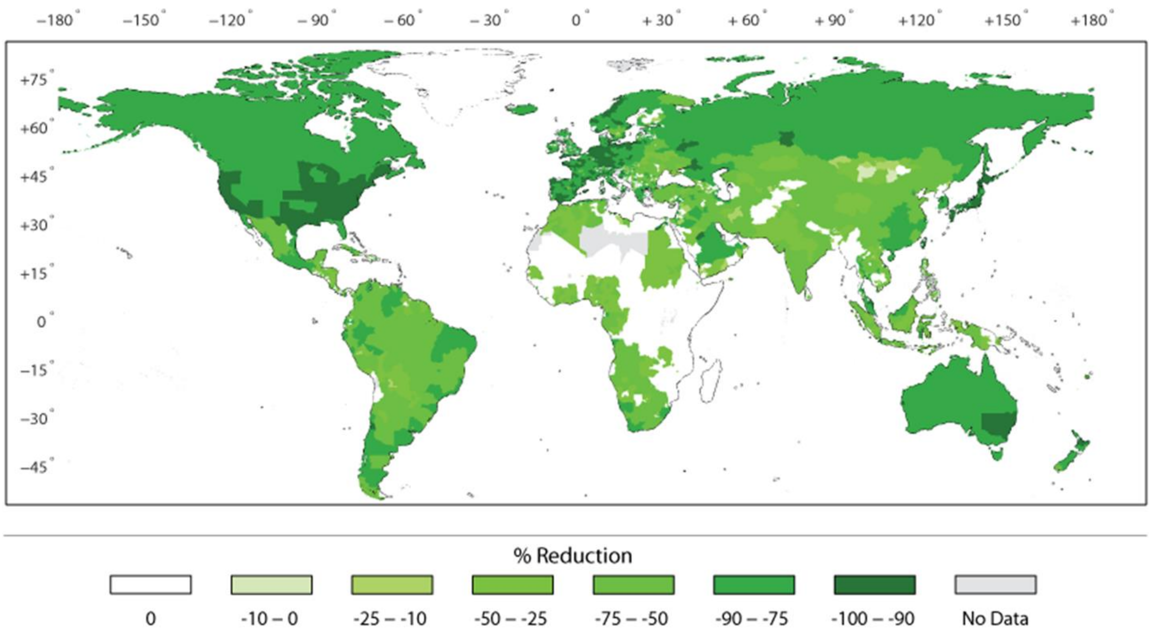


MERIT DEM (3sec)

Levee consideration in the global flood risk assessment

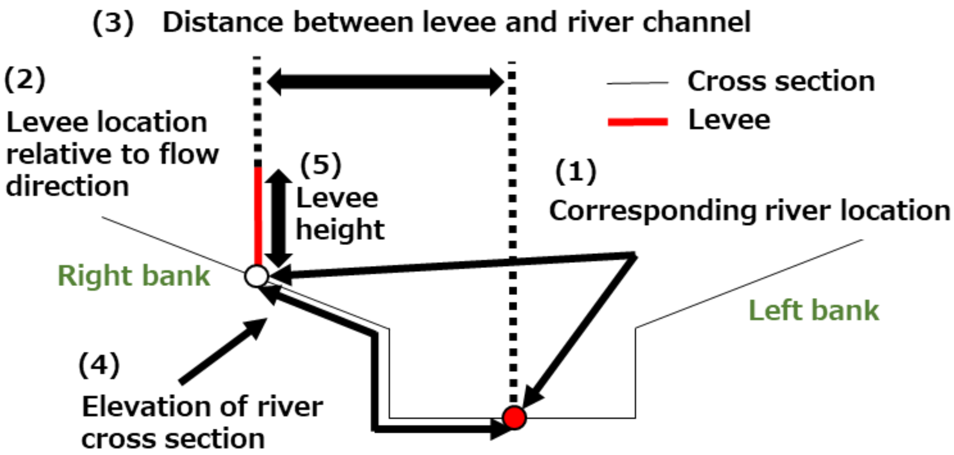
- Only global flood protection data - FLOPROS
  Scussolni et al. (2016)
  - They estimated the flood protection standard by literature research and model estimation
  - The flood protection level in each subnational area is represented as a return period defended by flood protection facilities
- Flood protection has the significant impact on risk assessment
  - In previous research, current flood standard mitigates 91% of damage estimated without flood protection

Ward et al. (2017)



The need for flood protection parameters

- Global flood models such as CaMa-Flood are 1D hydraulic models
  Yamazaki et al. (2011)
- Their river cross section is simplified for use in global calculation
  Therefore It is difficult to use the river cross section elevation to implement levee in global river models
- Flood protection parameters (figure below) can be used to achieve this
- We developed a new algorithm for the automatic extraction of these flood protection parameters and applied it in contiguous U.S.

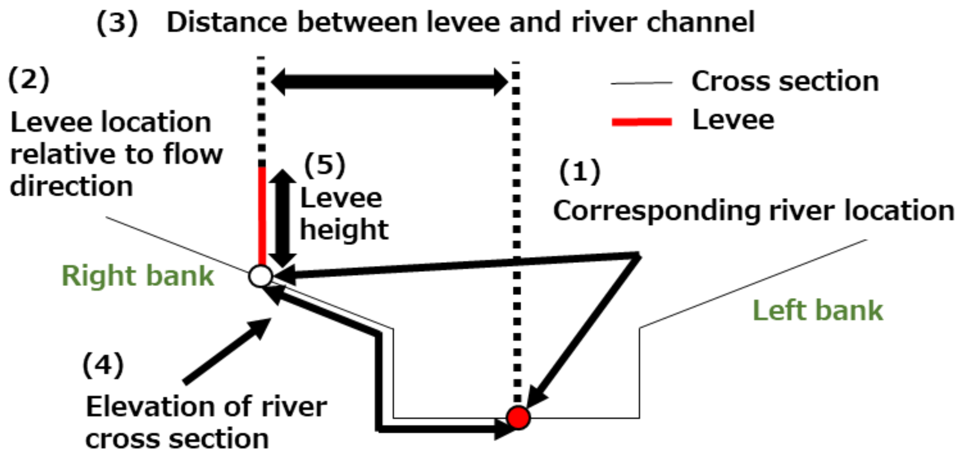


River cross section in CaMa-Flood
(Right levee is added)

The need for flood protection parameters

- Global flood models such as CaMa-Flood are 1D hydraulic models
  Yamazaki et al. (2011)
- Their river cross section is simplified for use in global calculation
  Therefore It is difficult to use the river cross section elevation and levee location data to implement levee in global river models
- Flood protection parameters (figure below) can be used to achieve this
- We developed a new algorithm for the automatic extraction of these flood protection parameters and applied it in contiguous U.S.

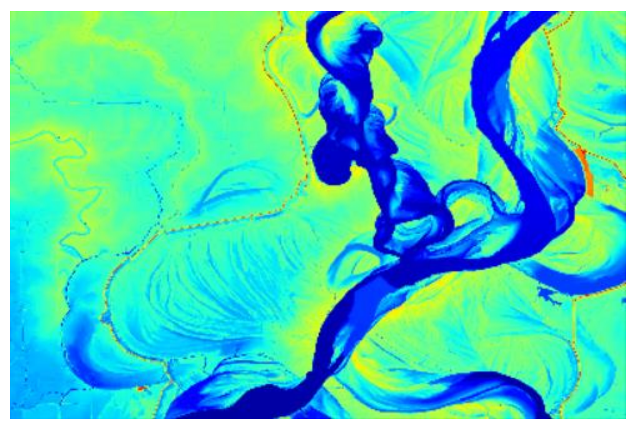
There is the levee location data and hi-res DEM

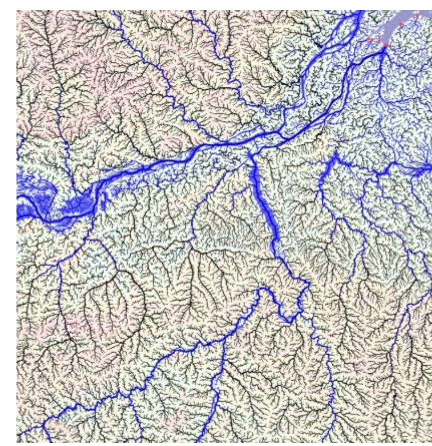


River cross section in CaMa-Flood
(Right levee is added)

Input data

- National Levee Database (NLD) https://levees.sec.usace.army.mil/#/
  - The comprehensive levee database in U.S. provided by USACE
  - Levee location data was used
  - Original shape files were changed to raster format (1/3sec)
- High resolution DEM
  - 3D Elevation Program (3DEP) provided by USGS was used
  - The finest seamless DEM in U.S. (1/3sec)
- Hydrography data Yamazaki et al. (2019) in print
  - MERIT Hydro was used (3sec)
  - I used the flow direction (D8) and the upper drainage area





The extraction of flood protection parameters

[1] Determine pixels on river channel

River pixels which have upper drainage area over the threshold are chosen

[2] Find the corresponding river pixel for each levee pixel

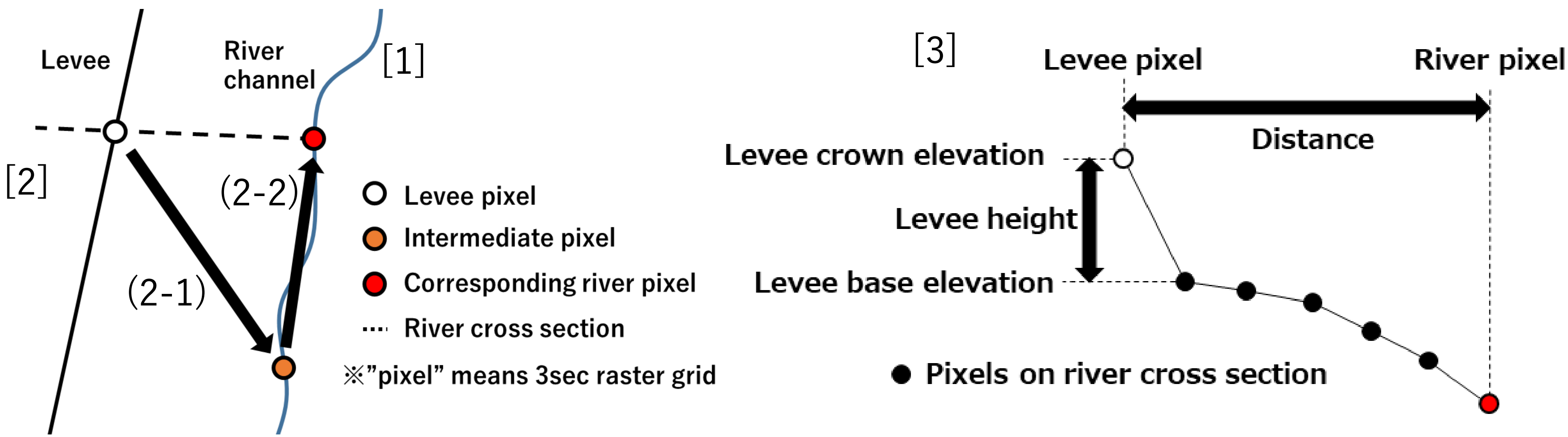
(2-1) Follow flow direction to river pixels

(2-2) Choose the river pixel which has the shortest distance to levee

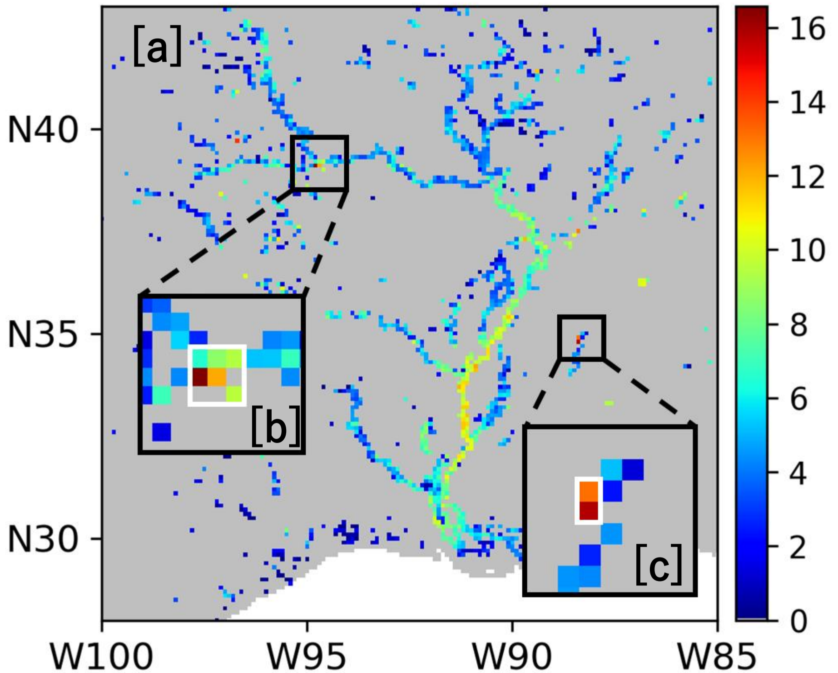
[3] Calculate parameters

[4] Choose parameters for each river pixel

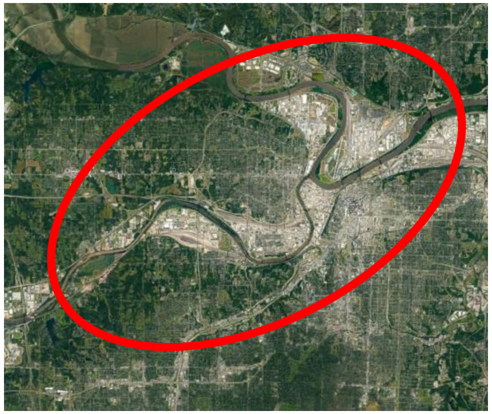
If a river pixel is linked to multiple levee pixels, the pixel with the shortest distance is chosen



Local variability of extracted parameters



[b] Around Kansas City
[c] Around Burnsville
(in white rectangle)

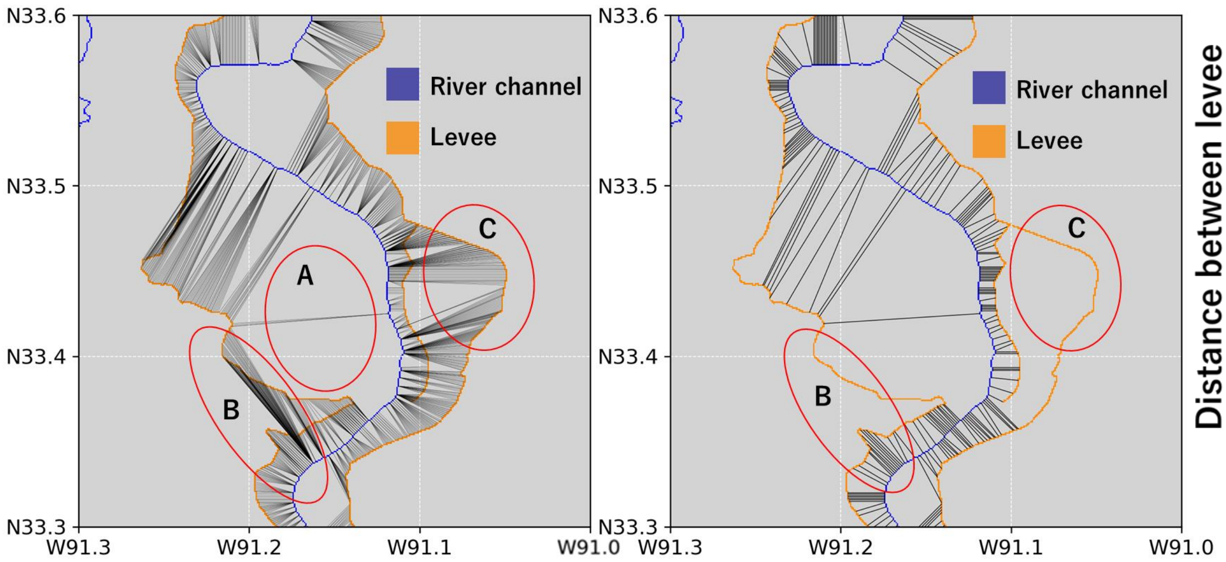


Urban areas compared with neighboring area

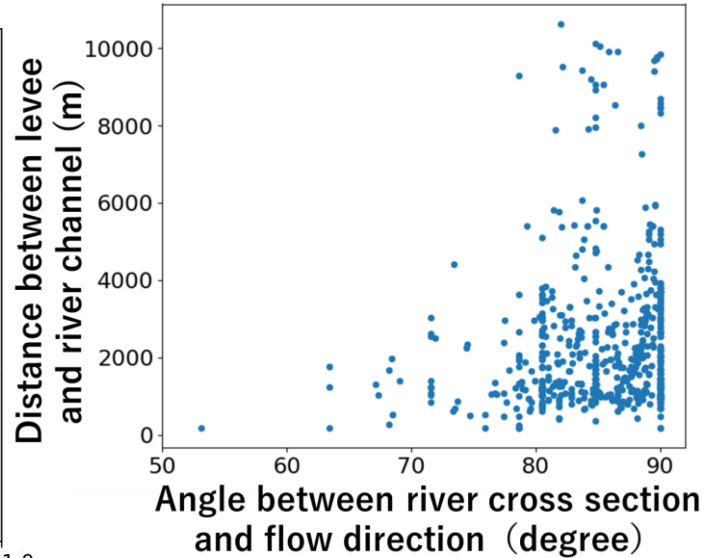
[a] Extracted levee height in Mississippi basin (m), [b][c] Aerial photos in white rectangle

- Median levee height is chosen for each 0.1 degree grid
- Levee height in main channels are higher than ones in tributaries
- In some urban areas ([b],[c]), levee heights are higher than surrounding areas

Linkages between levee and river channel



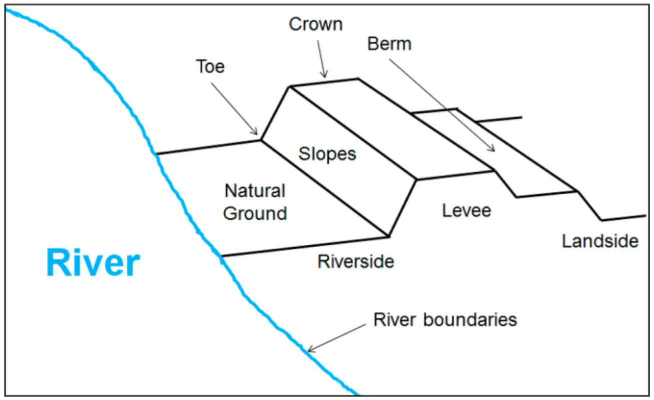
Extracted river cross section (Left: before step[4], Right: after step[4]



Characteristics of river cross sections (N33-34,W91-92)

- Almost all levee pixels (90% throughout the U.S.) are linked to river pixels
- There is at least one corresponding river pixel in 0.1 degree grid (A)
- Many erroneous linkages are removed in choosing a parameter for each river pixel (B)
- If there is a two-line levee, inside one is chosen (C)
- Most extracted river cross sections are nearly orthogonal to flow directions (median angle: 80.5 degree)

Validation of the levee crown elevation



From: Yunjae(2014)

- The input DEM should represent the levee shape, especially the levee crown elevation
- In some levees, NLD has the levee crown elevation data
- The table below shows the accuracy bias in the DEM
- The areas with small errors have higher levee heights
- The resolution of DEM (10m in equator) is slightly shorter than crown width

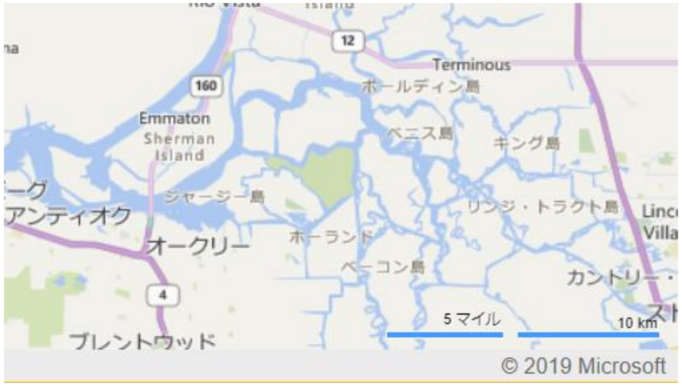
Comparison of levee crown elevation between ground survey (NLDE) and extracted parameter (EE)

Target river（Levee location)	Mean Error	RMSE	Levee Height	Crown Width
Mississippi river (N33-34,W91-92)	0.01	0.29	9.78	7
Missouri river (N38-39,W91-92)	-0.02	0.19	4.41	3
Alameda Creek (N36-37,W121-123)	-0.06	0.37	4.87	5
Rio Grande (N35-36,W106-107)	-2.87	3.02	0.38	5
James Bypas (N36-37,W120-121)	-1.40	1.88	0.32	5

Error: EE-NLDE, **Levee Height:** Median value of extracted ones Unit: m
Crown Width: Extracted from Google Earth aerial image

Limitations in terms of input data

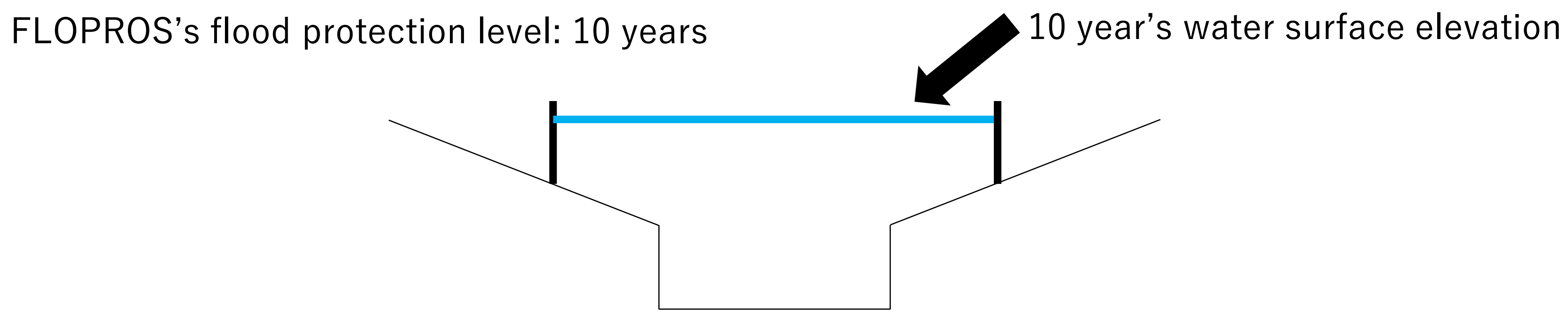
- NLD
  - NLD doesn't cover all levees in the U.S.
- DEM
  - The accuracy is different according to the location
  - It is ideal for the resolution to be shorter than levee crown width
- Hydrography
  - Channel bifurcation is not represented because each pixel is assumed to have only one downstream direction
  - In small rivers, some levee pixels overlap with river pixels



Delta region in San Francisco

How to expand this globally

- This algorithm can be applied in other regions, but both of levee location data and hi-res DEM don't exist widely
- It is possible that global levee height is estimated by using FLOPROS and Global River Model



- Extracted flood parameters can be used as the validation data for the global estimation of levee height

Conclusion

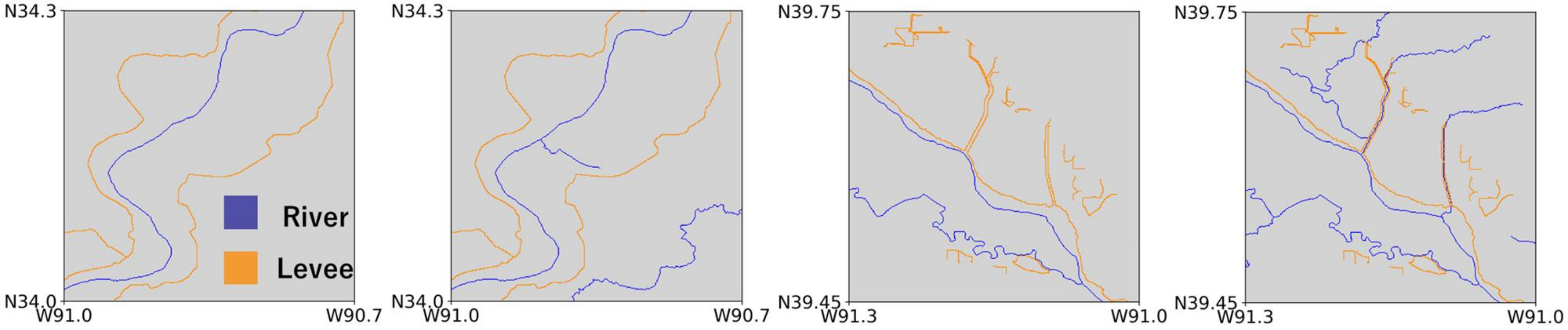
- We developed a new algorithm of the automatic extraction of flood protection parameters for use in global river model
- Extracted parameters represent the variability of these parameters since the hi-res input data is used
- Most extracted river cross sections are nearly orthogonal to flow directions
- The vertical accuracy of parameters changes according to the location
- These parameters can be used as a validation data for global estimation of parameters

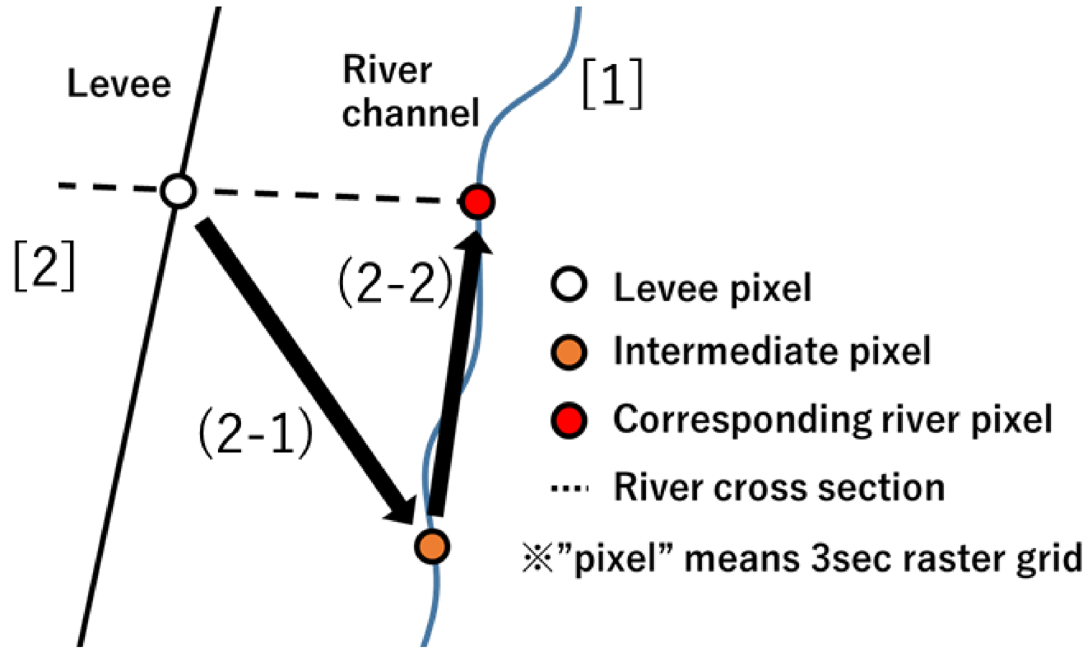
Conclusion

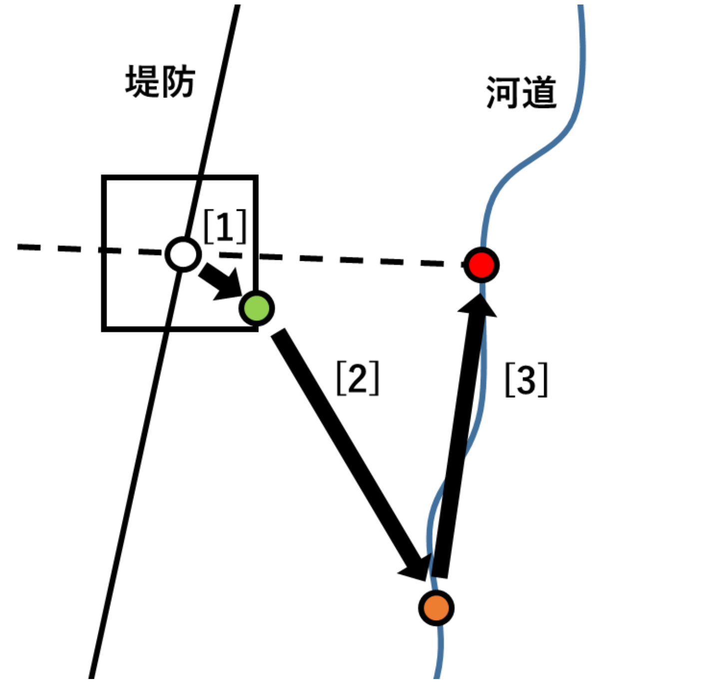
- We developed a new algorithm of the automatic extraction of flood protection parameters for use in global river model
- Extracted parameters represent the variability of these parameters since the hi-res input data is used
- Most extracted river cross sections are nearly orthogonal to flow directions
- The vertical accuracy of parameters changes according to the location
- These parameters can be used as a validation data for global estimation of parameters

Thank you for listening!

Supplementary slides


N34.3
N34.0
W91.0
W90.7
River
Levee
N34.3
N34.0
W91.0
W90.7
N39.75
N39.45
W91.3
W91.0
N39.75
N39.45
W91.3
W91.0

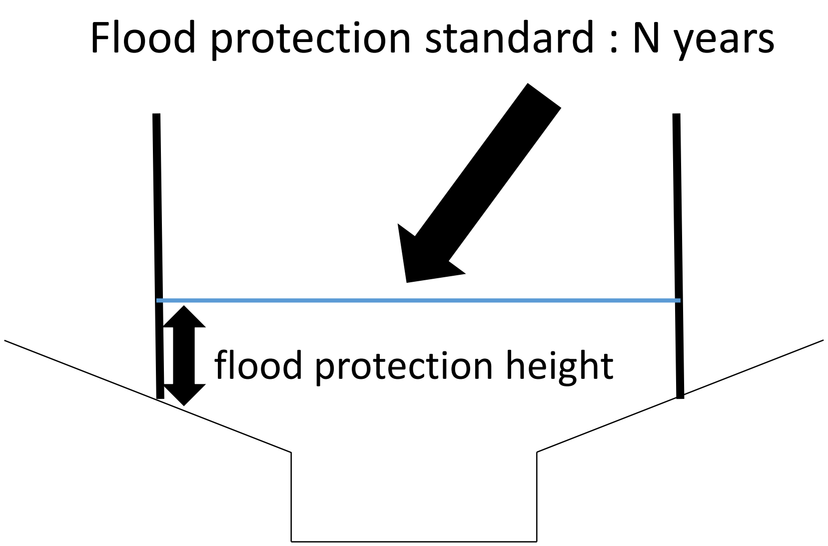

Levee
River channel
[1]
[2]
(2-2)
(2-1)
Levee pixel
Intermediate pixel
Corresponding river pixel
River cross section
※"pixel" means 3sec raster grid


堤防
河道
[1]
[2]
[3]

Outline of calculation

Calculation of the embankment height, using CaMa-Flood and FLOPROS

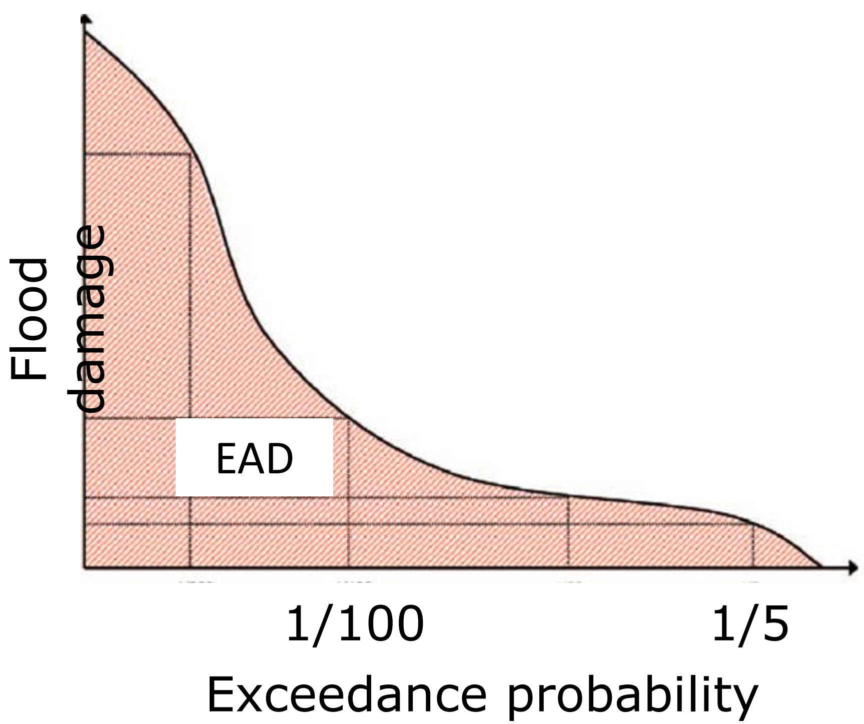
- In advance, construct very high levees in unit catchments that possibly have flood protection
- Calculate simulation for many years and derive N year's river depth



Merit

- derive the levee height without inundation scheme
- don't need iteration
- can consider the continuity of flood protection

Without flood protection



With flood protection