การเปลี่ยนแปลงสัณฐานท้องน้ำแบบตะกอนทราย ภายใต้การไหลแบบไม่คงที่

MORPHODYNAMIC OF SAND BED EVOLUTION UNDER UNSTEADY FLOW

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Outlines

1. Introduction
2. Governing Equations
3. CIP Method
4. Calibration & Application
5. Conclusion

Alatna River, Alaska

(http://www.terragallria.com)

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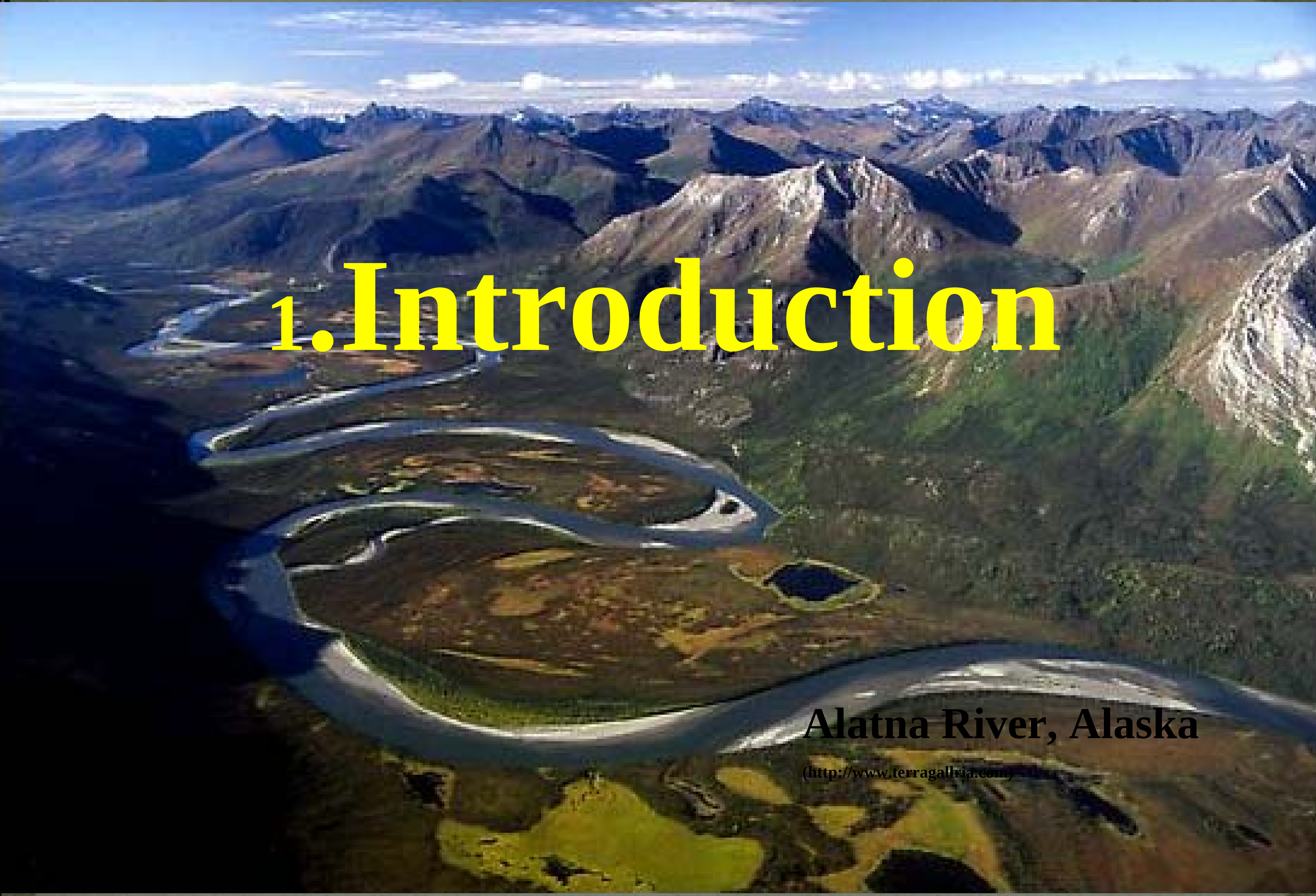

1.Introduction

Alatna River, Alaska

(http://www.terragallria.com)

SAND BED RIVER

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Ping River, Thailand

Kok River, Thailand

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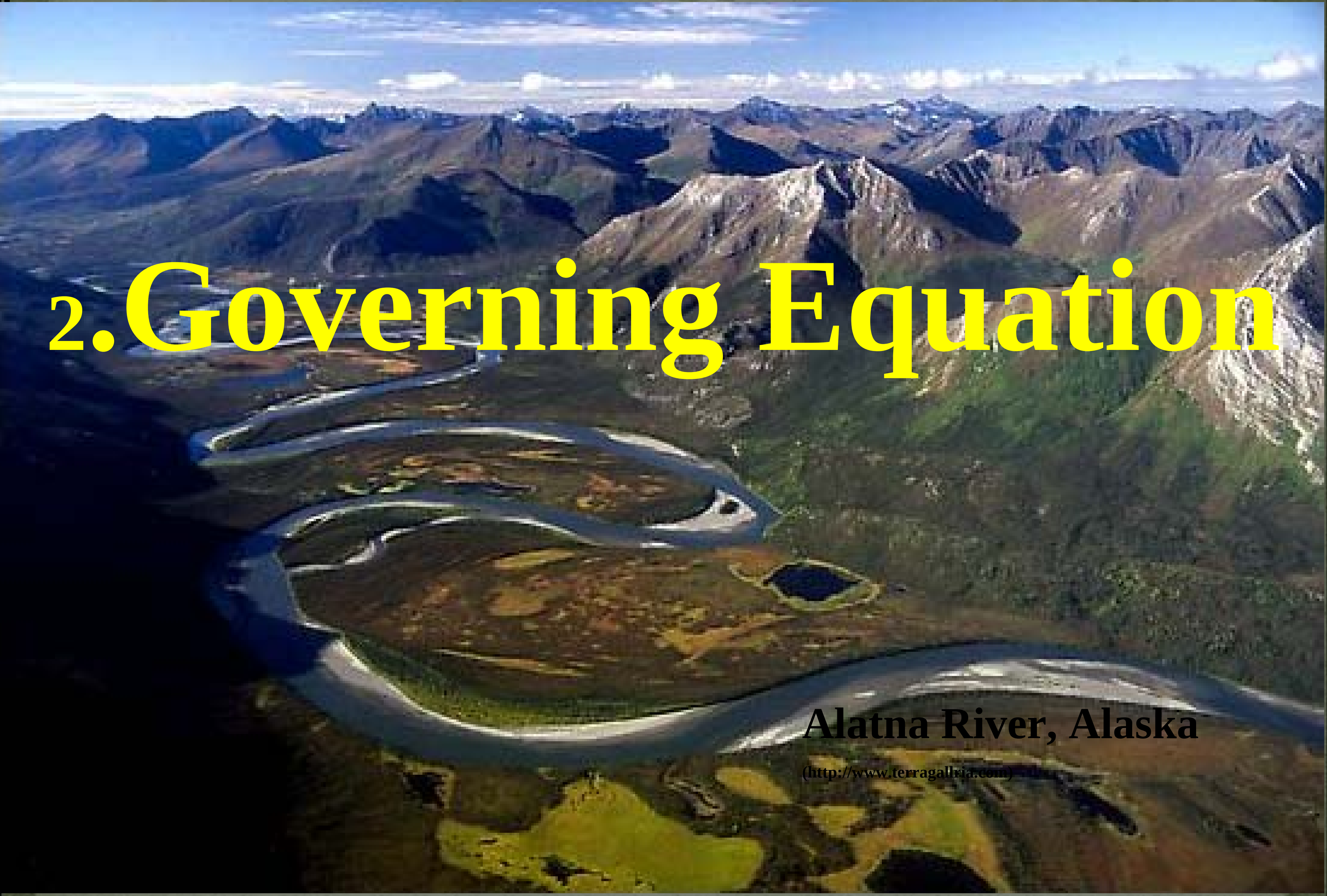
2.Governing Equation



Alatna River, Alaska

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Cartesian coordinate system

Continuity eq.

$$\frac{\partial h}{\partial t}+\frac{\partial(hu)}{\partial x}+\frac{\partial(hv)}{\partial y}=0$$

Momentum eq.

$$\frac{\partial(hu)}{\partial t}+\frac{\partial(hu^2)}{\partial x}+\frac{\partial(huv)}{\partial y}=-gh\frac{\partial H}{\partial x}-\frac{\tau_{bx}}{\rho}+\frac{\partial}{\partial x}\left[\nu\frac{\partial(hu)}{\partial x}\right]+\frac{\partial}{\partial y}\left[\nu\frac{\partial(hu)}{\partial y}\right]$$

$$\frac{\partial(hv)}{\partial t}+\frac{\partial(huv)}{\partial x}+\frac{\partial(hv^2)}{\partial y}=-gh\frac{\partial H}{\partial y}-\frac{\tau_{by}}{\rho}+\frac{\partial}{\partial x}\left[\nu\frac{\partial(hv)}{\partial x}\right]+\frac{\partial}{\partial y}\left[\nu\frac{\partial(hv)}{\partial y}\right]$$

where h= water depth, u, v= average velocity, τ_b=shear stress, ρ=water density, H= water surface elevation (=z_b+h), z_b=bed elevation, ν= eddy viscosity, t=time, and x, y= spatial coordinate in Cartesian coordinate system.

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Cartesian coordinate system

Sediment transport eq.

$$\frac{\partial z_b}{\partial t} + \frac{1}{1-\lambda}\left[\frac{\partial q_{bx}}{\partial x} + \frac{\partial q_{by}}{\partial y}\right] = 0$$

where z_b=bed elevation, λ=porosity of bed material.

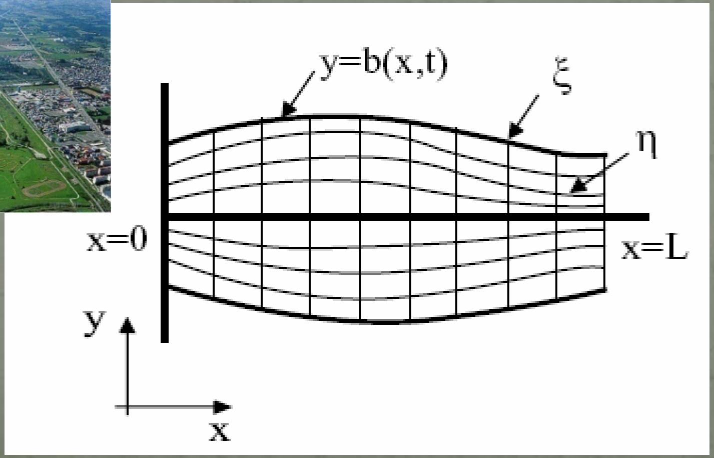
Moving boundary-fitted system

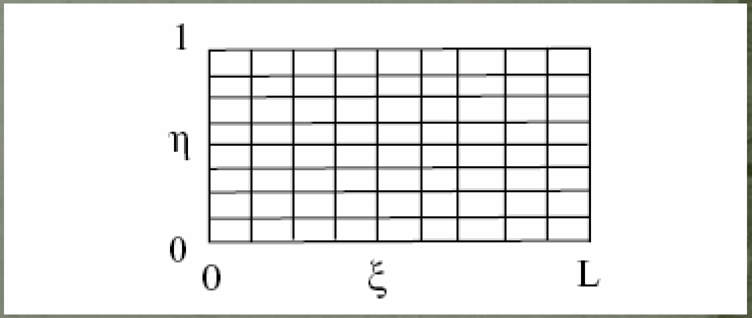
Transformed rule

$$\begin{pmatrix} \frac{\partial}{\partial t} \\ \frac{\partial}{\partial x} \\ \frac{\partial}{\partial y} \end{pmatrix} = \begin{pmatrix} \tau_t & \xi_t & \eta_t \\ \tau_x & \xi_x & \eta_x \\ \tau_y & \xi_y & \eta_y \end{pmatrix} \begin{pmatrix} \frac{\partial}{\partial \tau} \\ \frac{\partial}{\partial \xi} \\ \frac{\partial}{\partial \eta} \end{pmatrix}$$

$$\begin{pmatrix} u \\ v \end{pmatrix} = \frac{1}{J} \begin{pmatrix} \eta_y & -\xi_y \\ -\eta_x & \xi_x \end{pmatrix} \begin{pmatrix} u^{\xi} \\ v^{\eta} \end{pmatrix}$$

where u^{ξ}, v^{η}=average velocity components in the of ξ, η direction, τ=time, and J=Jacobian of coordinate transformed.





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Moving boundary-fitted system

Continuity eq.

$$\frac{\partial}{\partial \tau}\left(\frac{h}{J}\right)+\frac{\partial}{\partial \xi}\left[\left(\xi_t+u^{\xi}\right)\frac{h}{J}\right]+\frac{\partial}{\partial \eta}\left[\left(\eta_t+u^{\eta}\right)\frac{h}{J}\right]=0$$

Momentum eq.

$$\frac{\partial u^{\xi}}{\partial \tau}+\left(\xi_t+u^{\xi}\right)\frac{\partial u^{\xi}}{\partial \xi}+\left(\eta_t+u^{\eta}\right)\frac{\partial u^{\xi}}{\partial \eta}+\alpha_1 u^{\xi}u^{\xi}+\alpha_2 u^{\xi}u^{\eta}+\alpha_3 u^{\eta}u^{\eta}-D_{\xi}$$

$$=-g\left[\left(\xi_x^2+\xi_y^2\right)\frac{\partial H}{\partial \xi}\left(\xi_x\eta_x+\xi_y\eta_y\right)\frac{\partial H}{\partial \eta}\right]-\frac{C_f u^{\xi}}{hJ}\sqrt{\left(\eta_y u^{\xi}+\xi_y u^{\eta}\right)^2+\left(-\eta_x u^{\xi}-\xi_x u^{\eta}\right)^2}$$

$$\frac{\partial u^{\eta}}{\partial \tau}+\left(\xi_t+u^{\xi}\right)\frac{\partial u^{\eta}}{\partial \xi}+\left(\eta_t+u^{\eta}\right)\frac{\partial u^{\eta}}{\partial \eta}+\alpha_4 u^{\xi}u^{\xi}+\alpha_5 u^{\xi}u^{\eta}+\alpha_6 u^{\eta}u^{\eta}-D_{\eta}$$

$$=-g\left[\left(\eta_x^2+\eta_y^2\right)\frac{\partial H}{\partial \eta}\left(\xi_x\eta_x+\xi_y\eta_y\right)\frac{\partial H}{\partial \xi}\right]-\frac{C_f u^{\eta}}{hJ}\sqrt{\left(\eta_y u^{\xi}+\xi_y u^{\eta}\right)^2+\left(-\eta_x u^{\xi}-\xi_x u^{\eta}\right)^2}$$

Moving boundary-fitted system

Sediment transport eq.

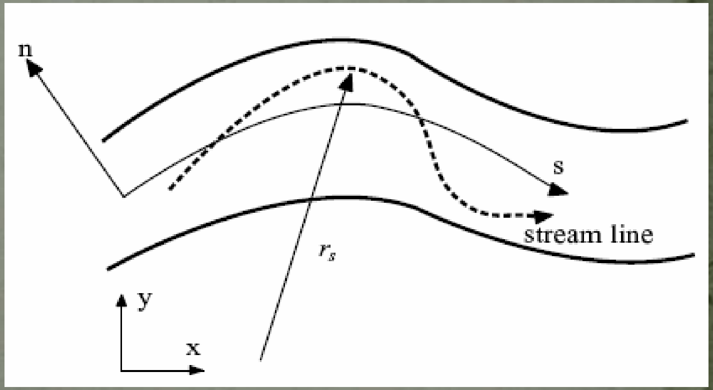
$$\frac{\partial z_b}{\partial t} + \frac{1}{1-\lambda}\left[\frac{\partial q_{bx}}{\partial x} + \frac{\partial q_{by}}{\partial y}\right] = 0$$

$$\frac{\partial}{\partial \tau}\left(\frac{z_b}{J}\right) + \frac{1}{1-\lambda}\left[\frac{\partial}{\partial \xi}\left(\frac{q^{\xi}}{J}\right) + \frac{\partial}{\partial \eta}\left(\frac{q^{\eta}}{J}\right)\right] = 0$$

where q^{ξ}, q^{η}=sediment transport rate components in the ξ, η direction, respectively.

$$q^{\xi} = \left(\xi_x \frac{\partial x}{\partial s} + \xi_y \frac{\partial y}{\partial s}\right) q^s + \left(\xi_x \frac{\partial x}{\partial n} + \xi_y \frac{\partial y}{\partial n}\right) q^n$$

$$q^{\eta} = \left(\eta_x \frac{\partial x}{\partial s} + \eta_y \frac{\partial y}{\partial s}\right) q^s + \left(\eta_x \frac{\partial x}{\partial n} + \eta_y \frac{\partial y}{\partial n}\right) q^n$$



Bank deformation

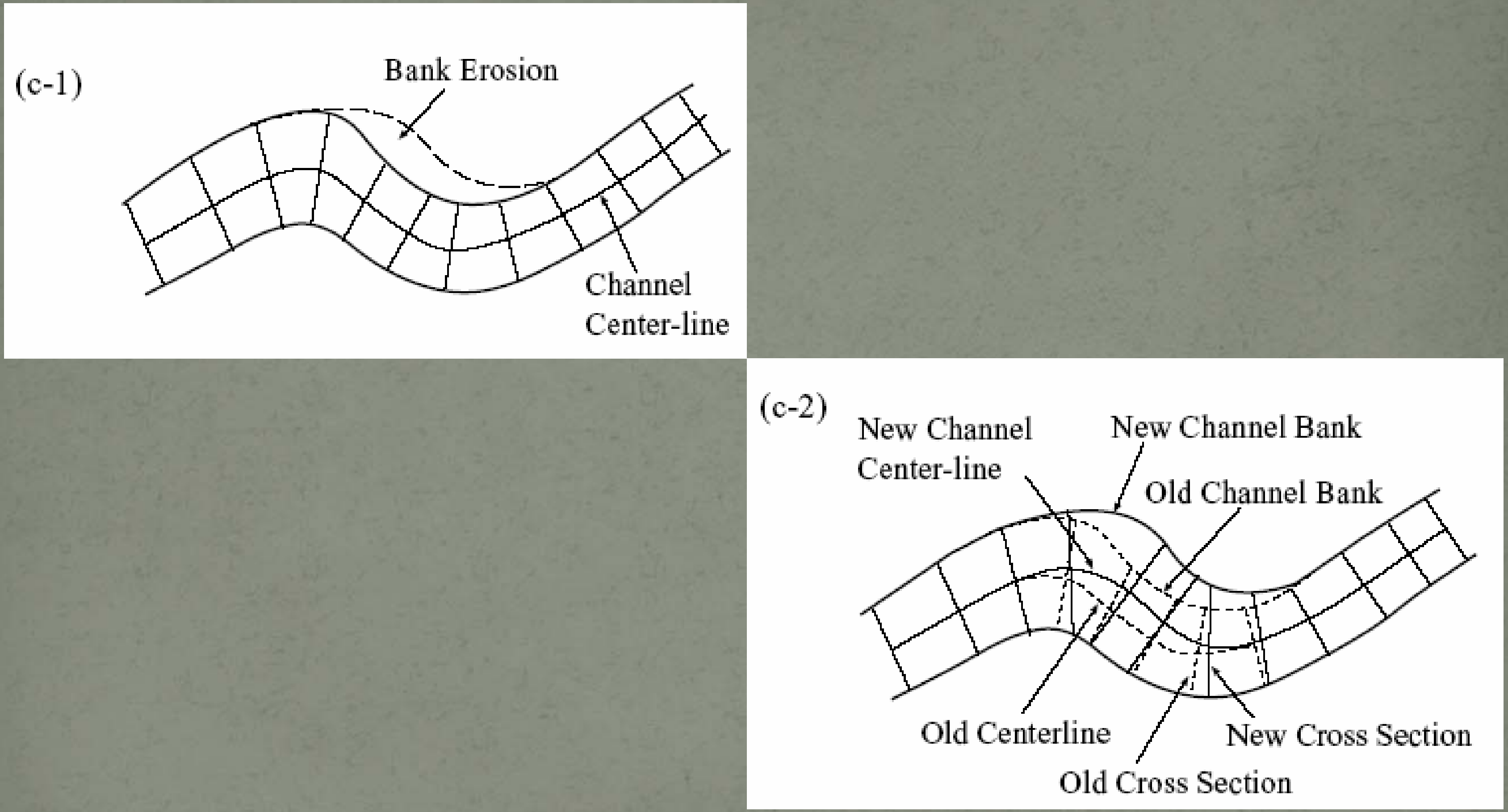
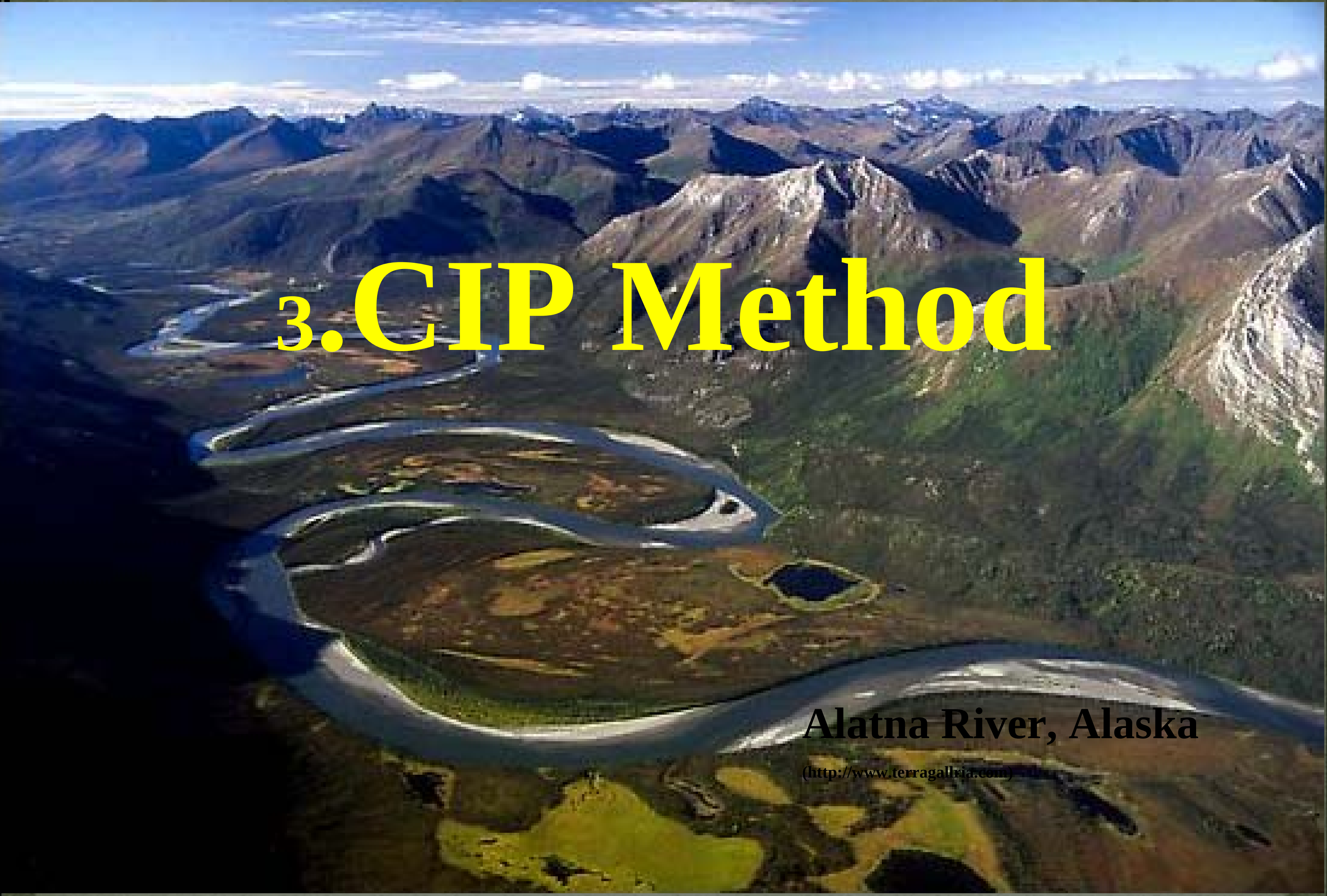


Fig. (c) bank deformation and renewal of the computational grid.

3.CIP Method



Alatna River, Alaska

(http://www.terragallria.com)

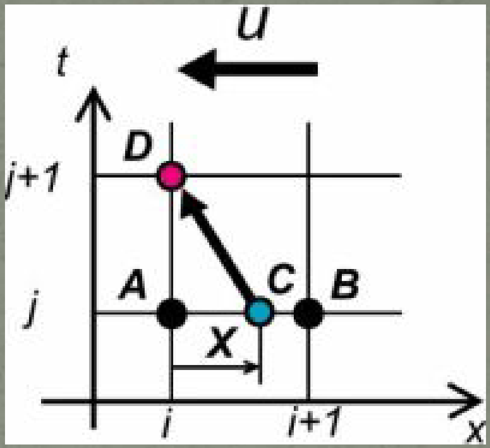
CIP method (Yabe et al., 1990)

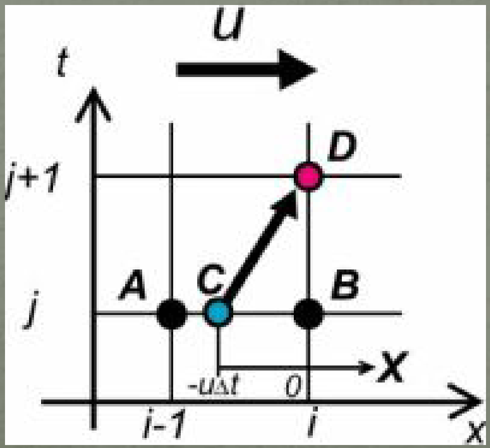
C=Cubic, I=Interpolated, P=Psuedoparticle

$$\frac{\partial h}{\partial t} + u\frac{\partial f}{\partial x} = G$$

Advection phase: $$\frac{\partial h}{\partial t} + u\frac{\partial f}{\partial x} = 0$$

Diffusion phase: $$\frac{\partial h}{\partial t} = G$$





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4. Calibration & Application

Alatna River, Alaska

(http://www.terragallria.com)

Snow Festival, 2004

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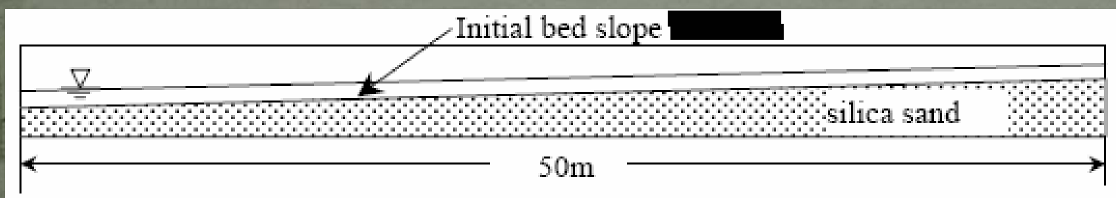
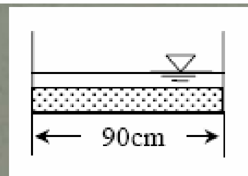
Watanabe et al., 2004

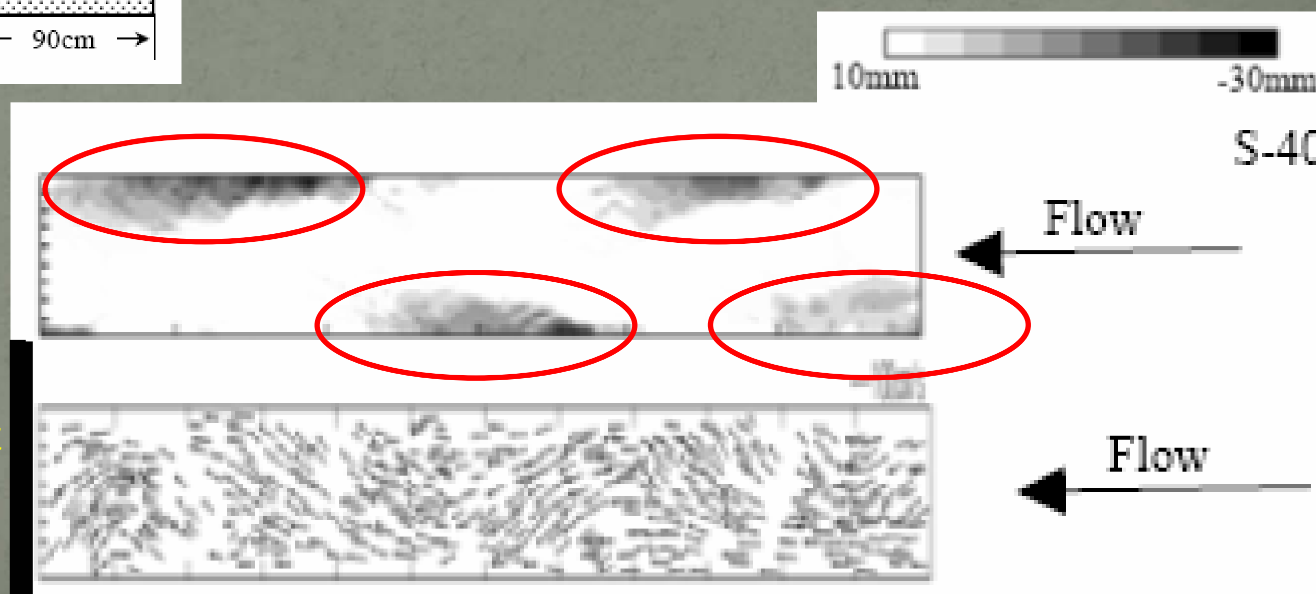
Run S-40

L = 50.0 m, b = 0.90 m, q = 0.76 l/s, i_0 = 1/83, d = 0.75 mm



Experiment





web number

λ = 0.45

non-dimensional height

Z_b = 2.80

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Boundary Condition Test (S-40 no bank erosion)

Periodic boundary | **non-Periodic condition**

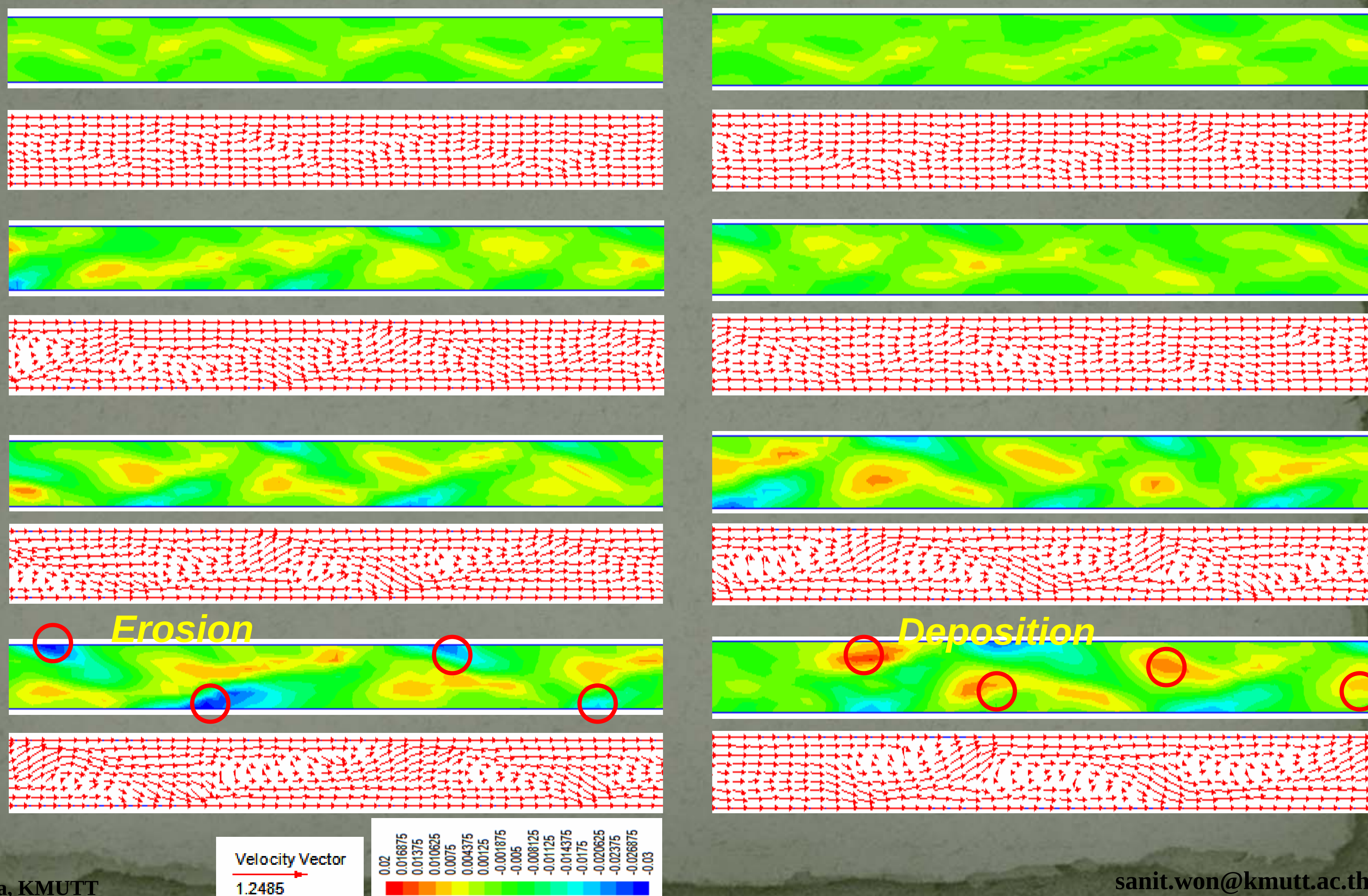
T(hr)

0.5

1.0

1.5

2.0



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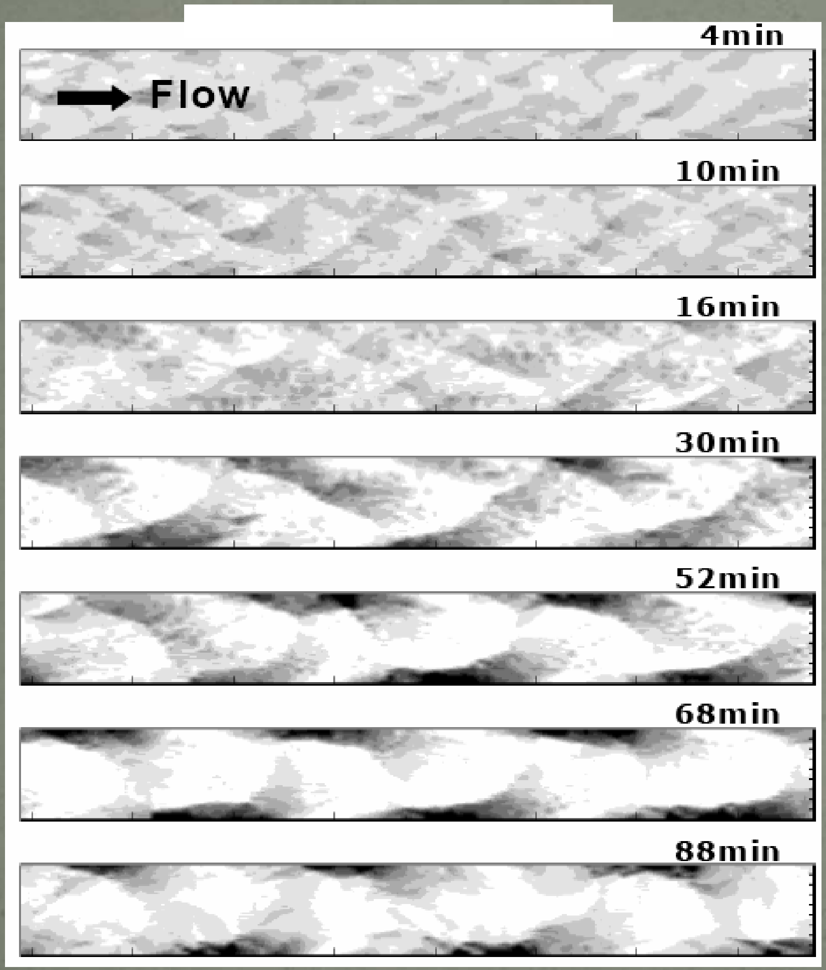
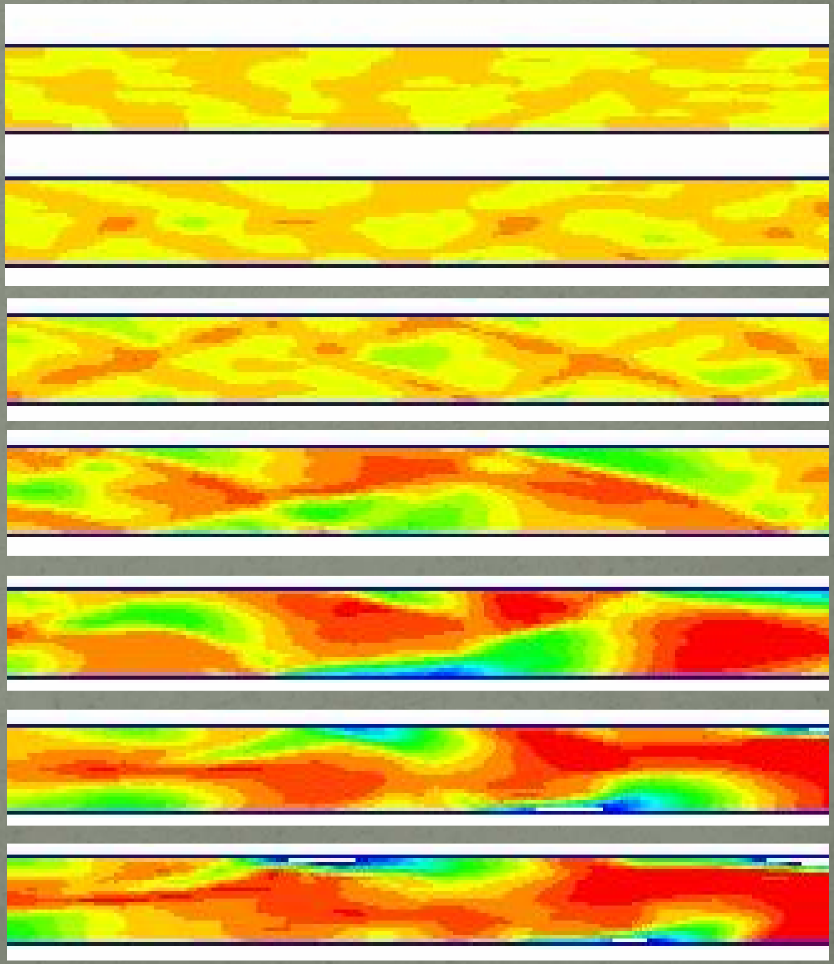
Straight Channel (U-50 no bank erosion)

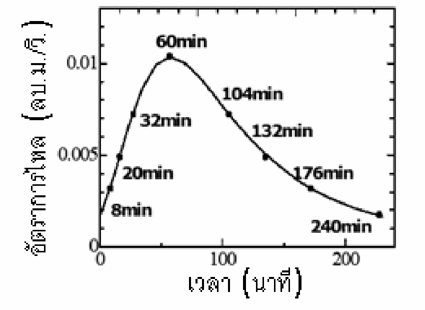
Experiment



Calculated



Straight Channel (U-30 no bank erosion)



T(min)

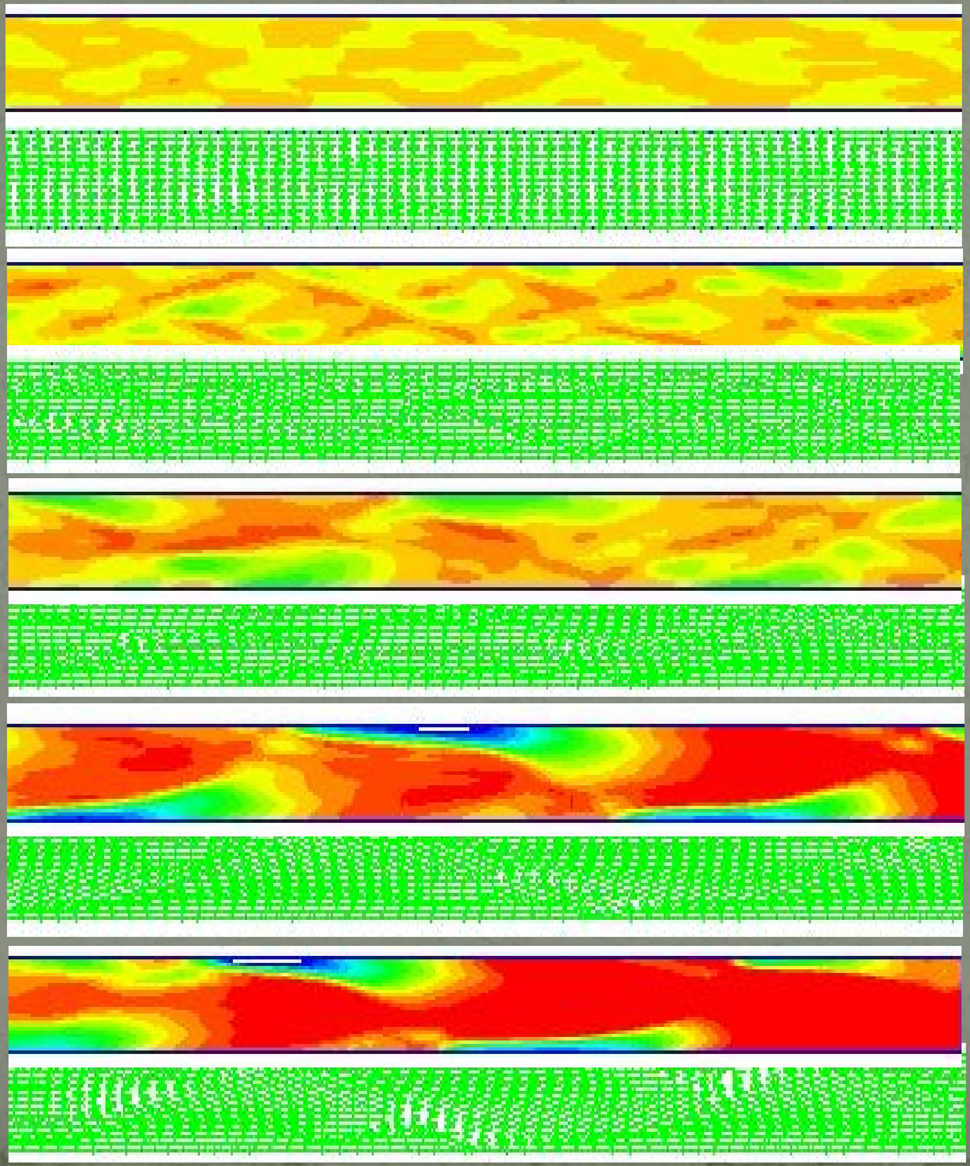
8

20

32

60

90



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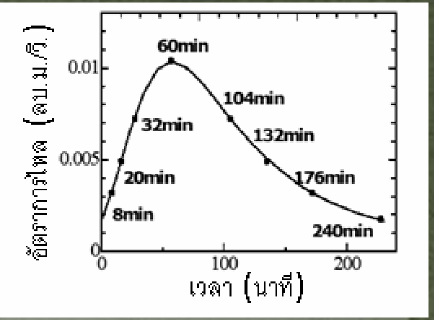


Straight Channel (U-30 with bank erosion)

T(min)

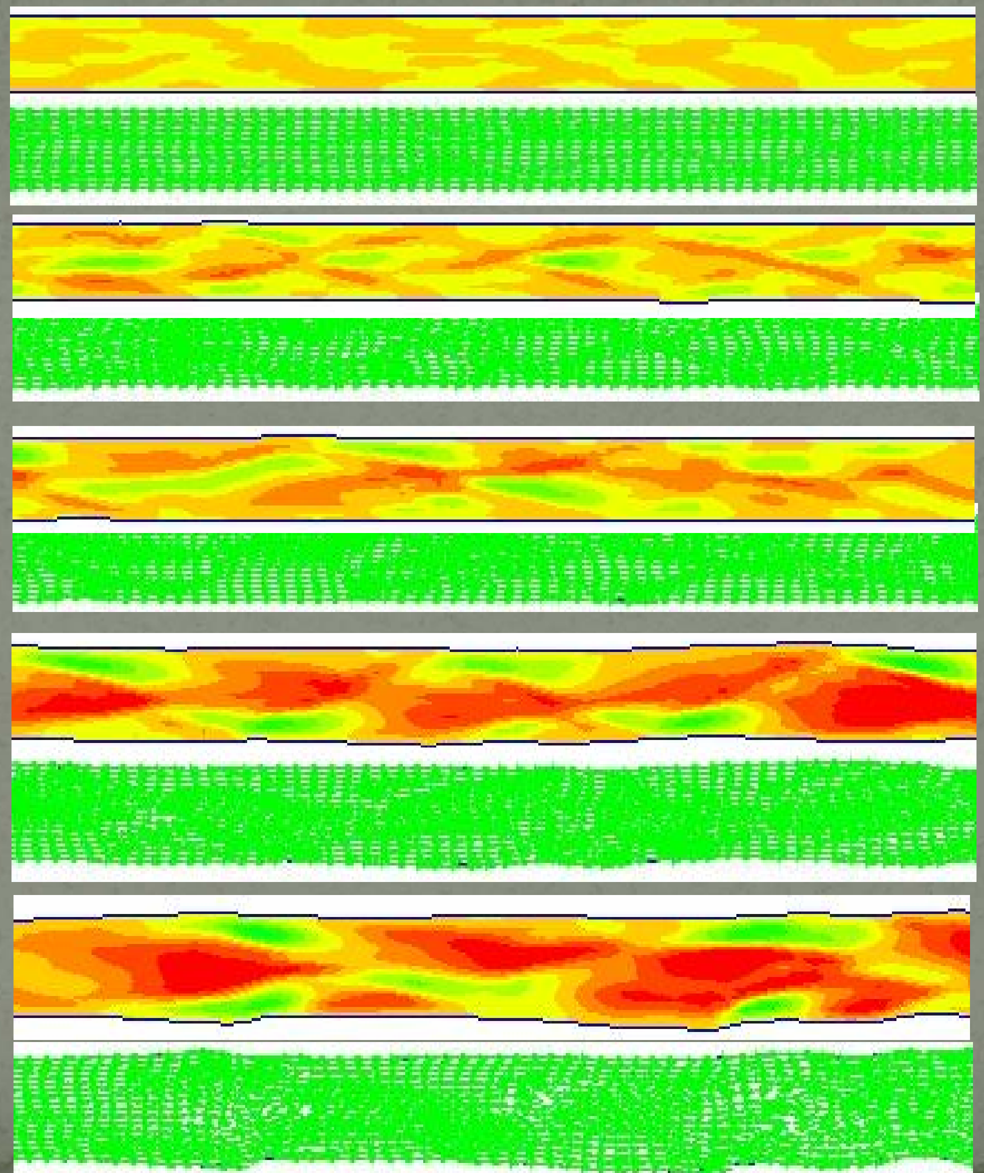
8

20

32

60

90



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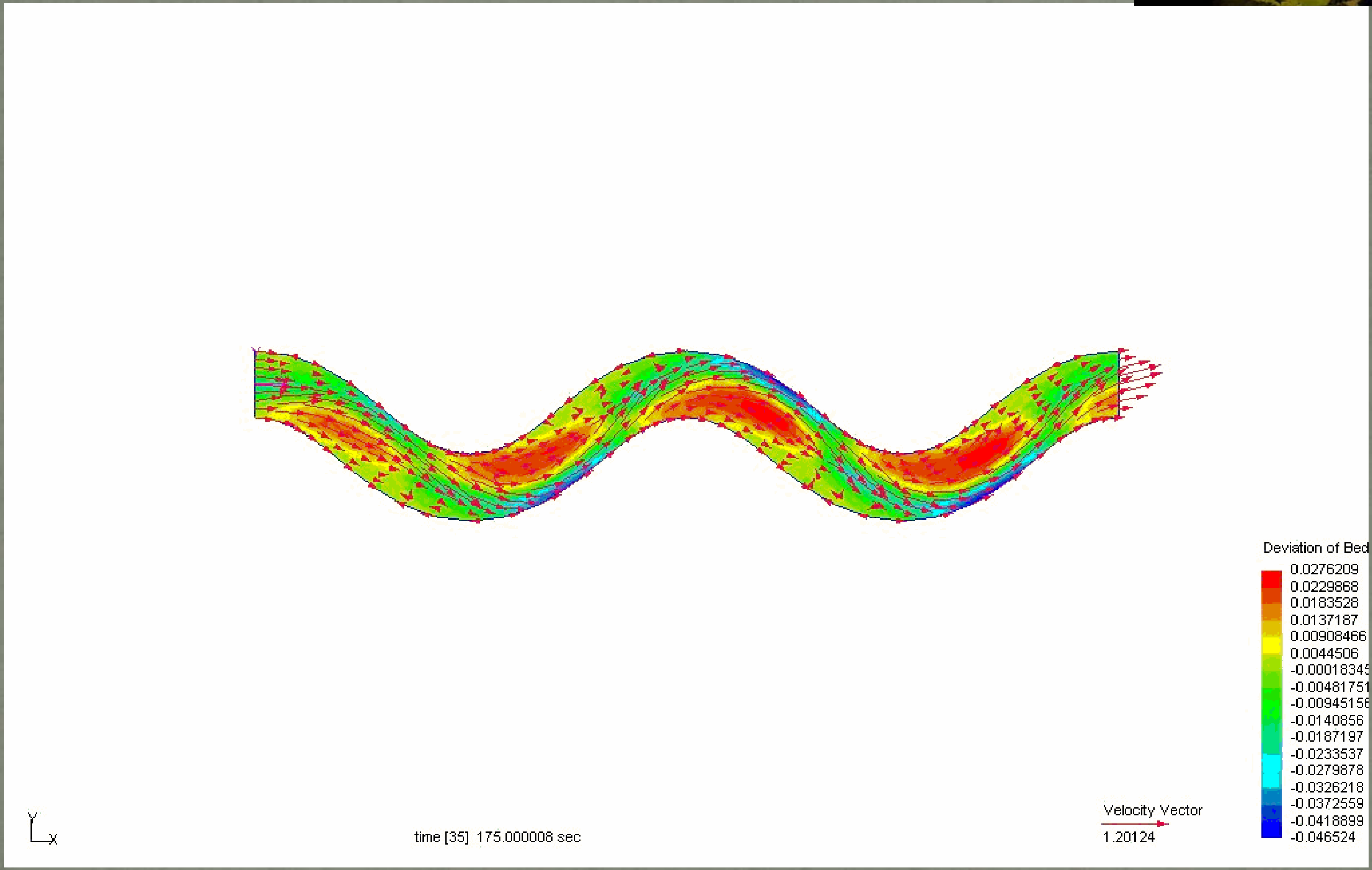
Sine-generated



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Sine-generated & Bank Erosion

Steady flow | **Unsteady flow**

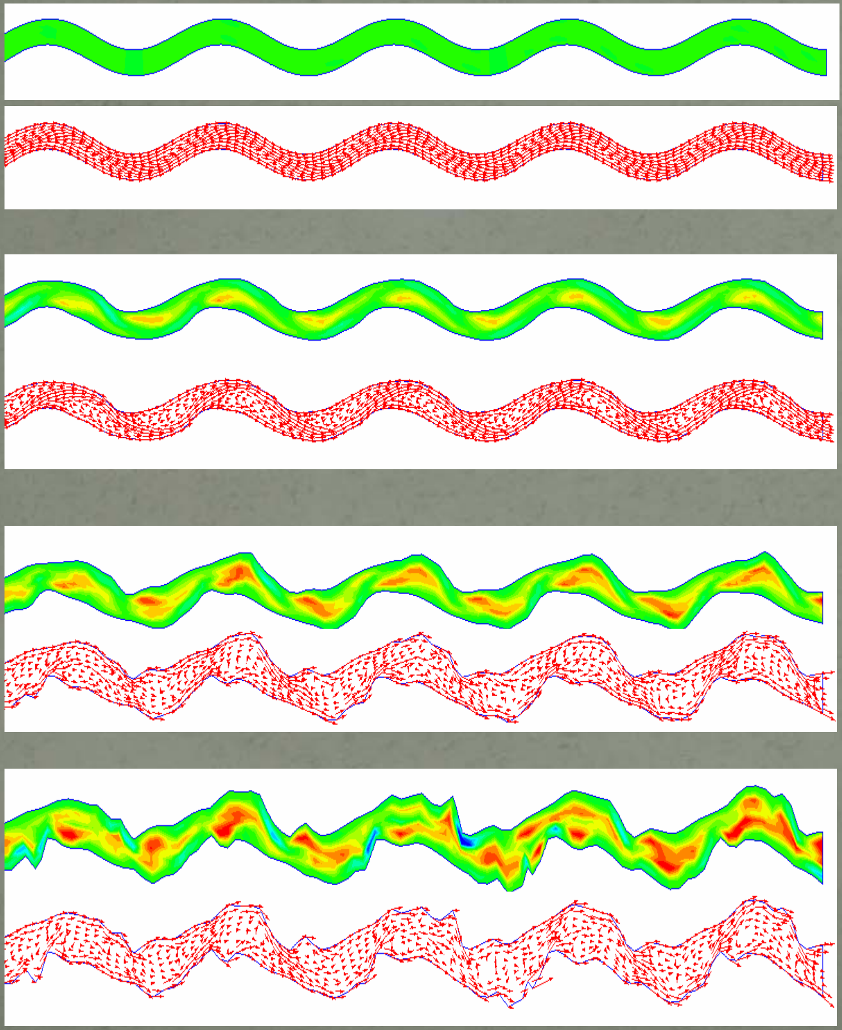
T(hr)

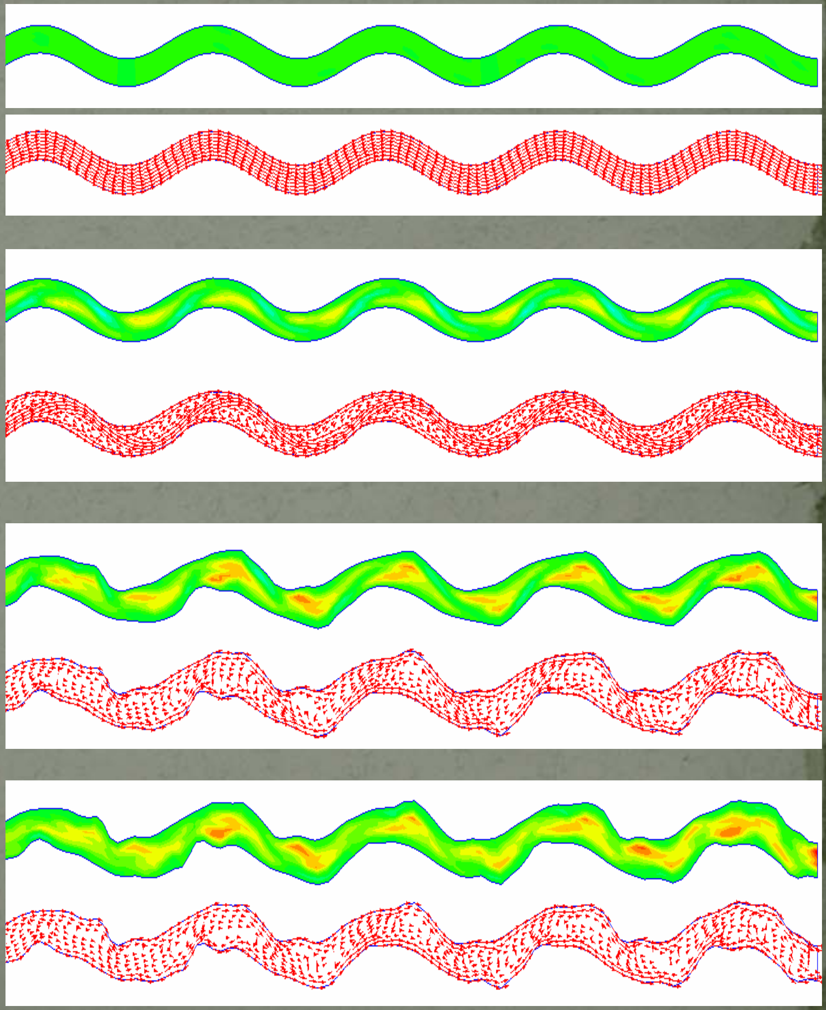
0.5

1.0

1.5

2.0





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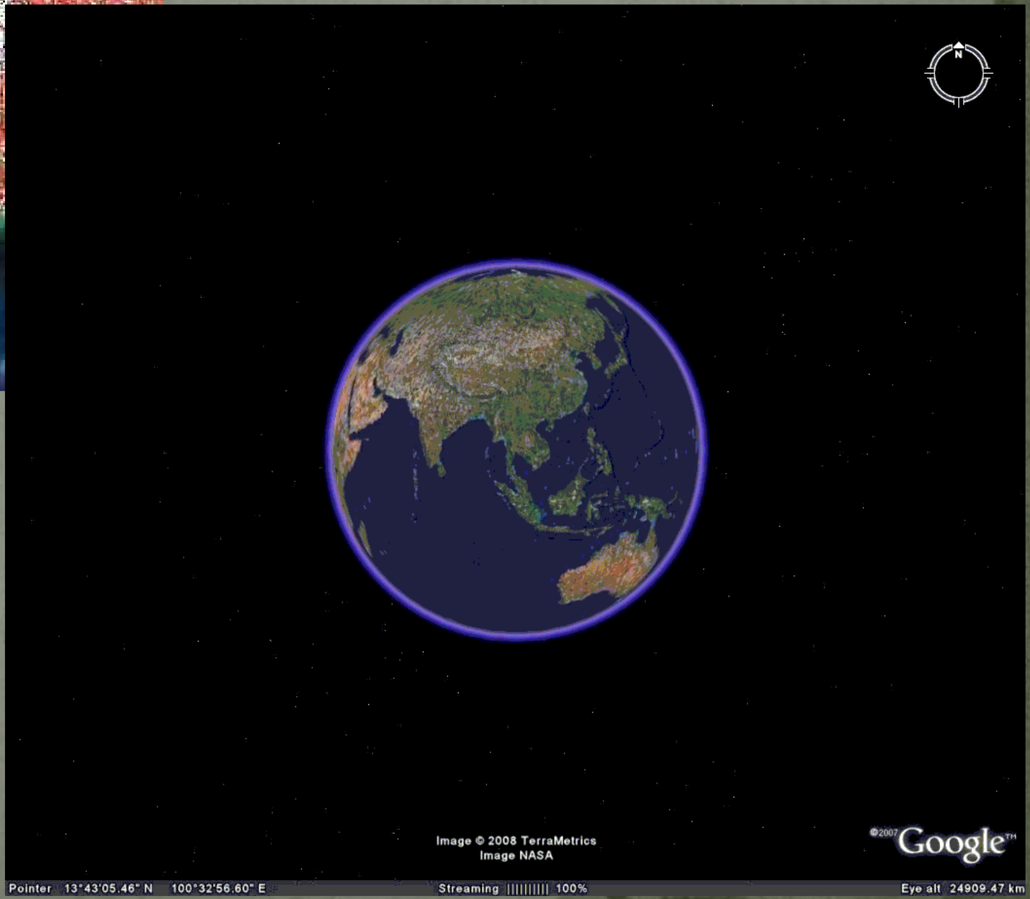
ChaoPhraya River

at Estuary



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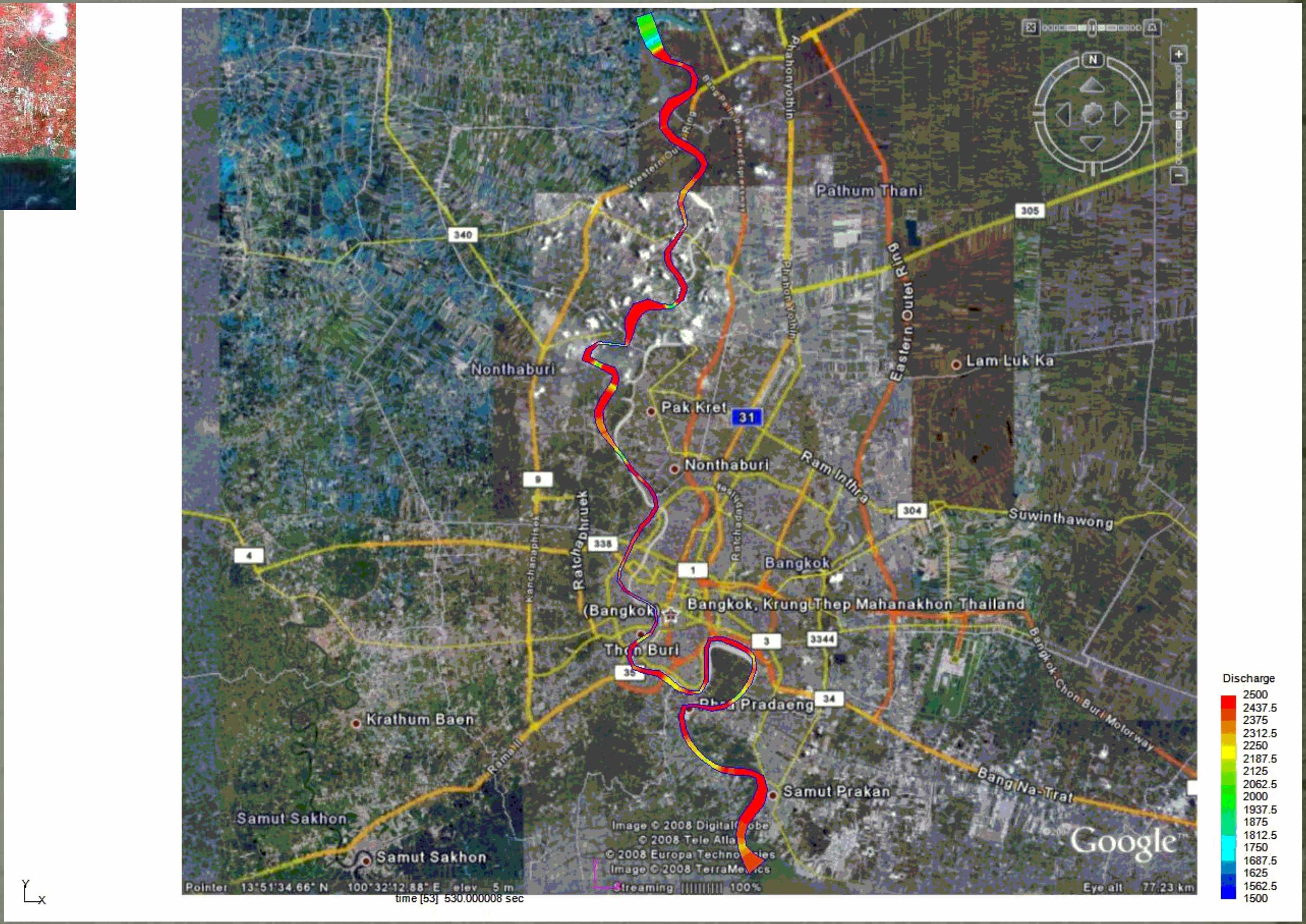
ChaoPhraya River



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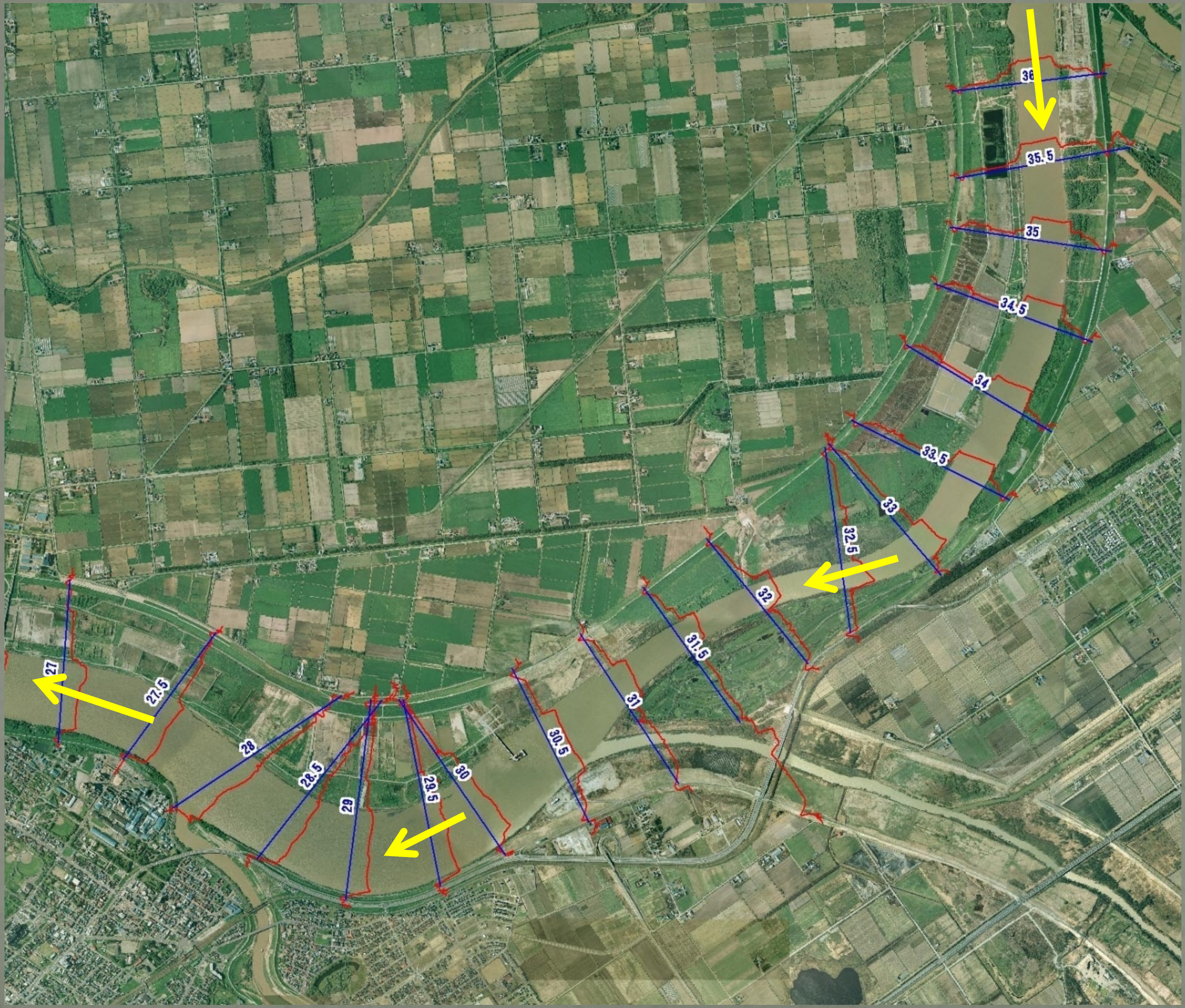
Ishikari River



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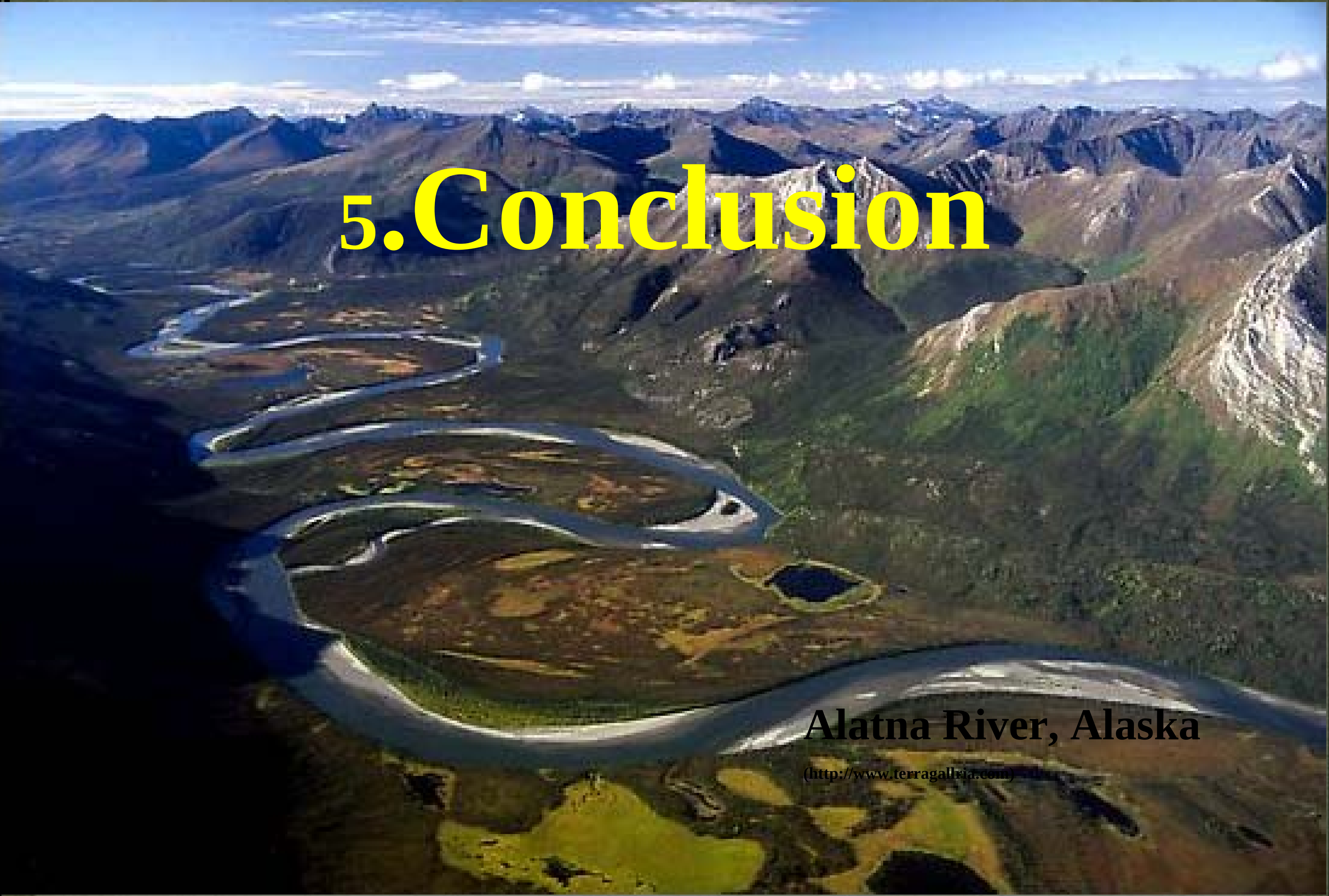
5.Conclusion



Alatna River, Alaska

(http://www.terragallria.com)

Conclusions

- 2-D numerical model is proposed to investigate sand bed evolution in straight and meandering channel.

-CIP method has been proposed for solving water flow.

- Some numerical results compared with experiment data are presented to demonstrate applicability of the model.

- Good performances of simulated results were observed for channel evolutions under unsteady flow conditions, therefore, are indicating that the proposed model is reasonably achieved.

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THE END

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