INTERACTION AND MERGENCE OF CUSPATE FORELANDS FORMED AT END OF MULTIPLE SANDY ISLANDS UNDER WAVES

Shiho MIYAHARA — **Coastal Engineering Laboratory Co., Ltd.**

Takaaki UDA — **Public Works Research Center**

Masumi SERIZAWA — **Coastal Engineering Laboratory Co., Ltd.**

INTRODUCTION

- When waves are incident from two opposite directions in a shallow sea, a land-tied island or a cuspate foreland may develop.

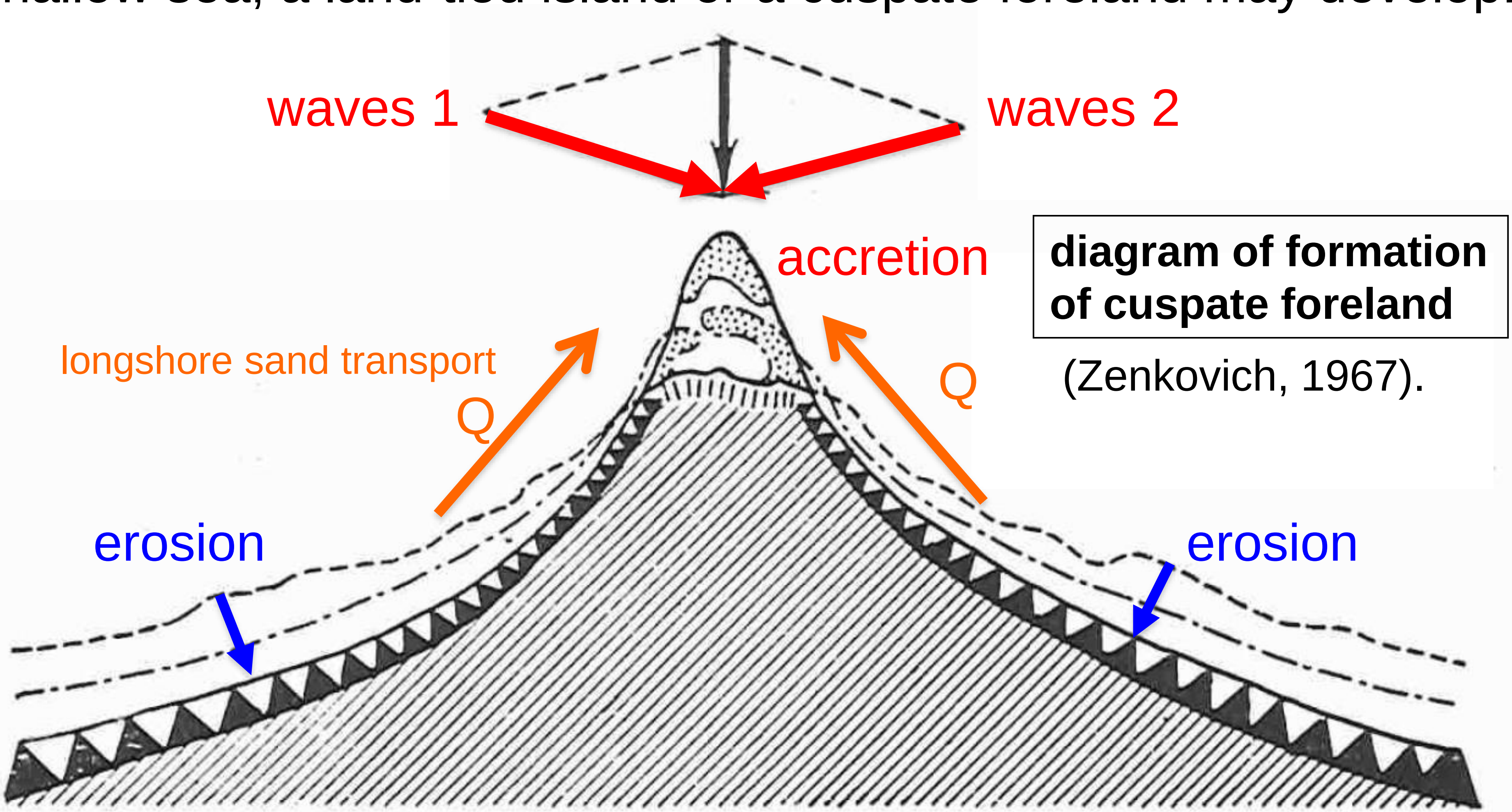
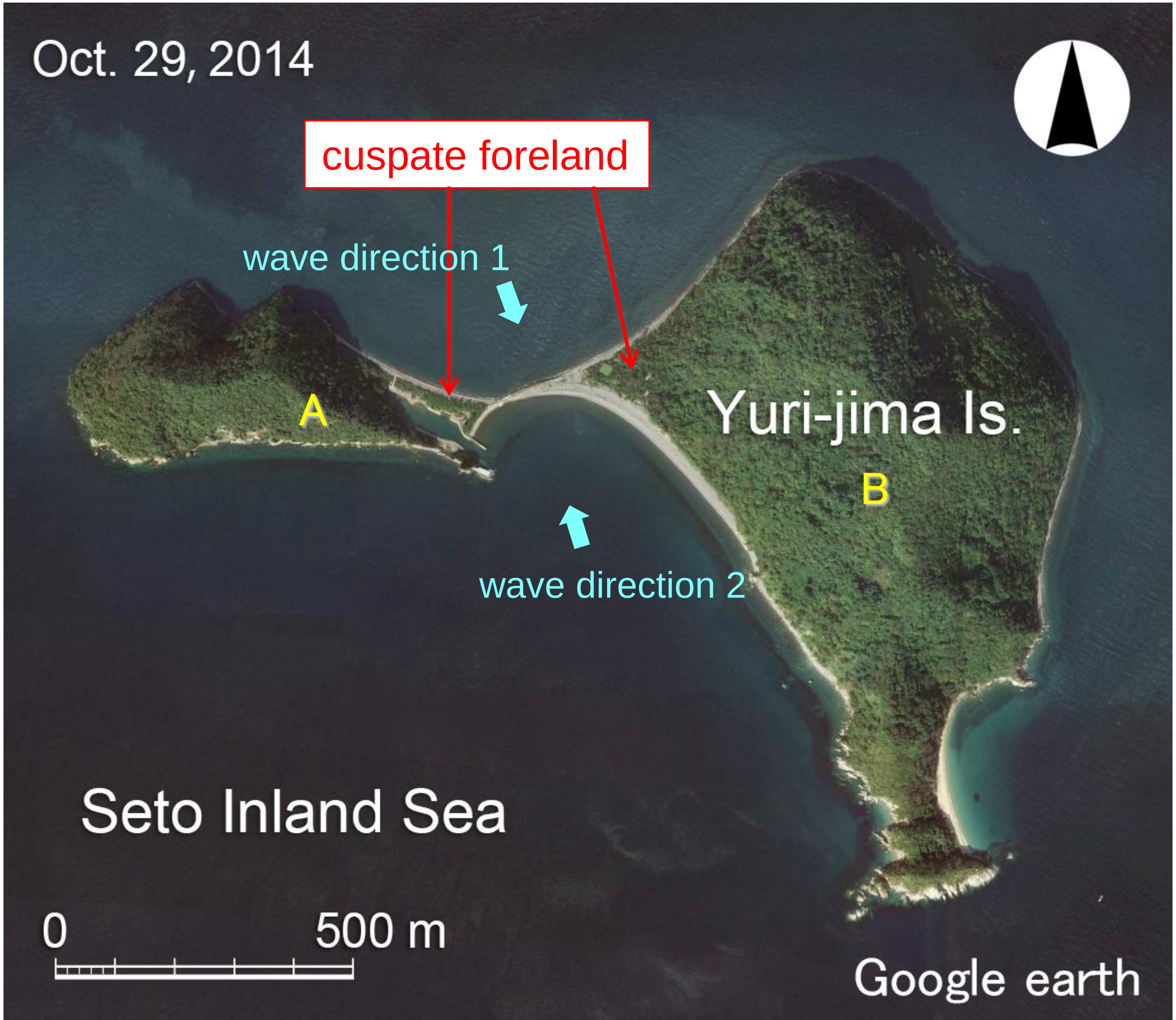


FIG. 205. Diagram of the formation of symmetrical accumulations.

Zenkovich(1967)

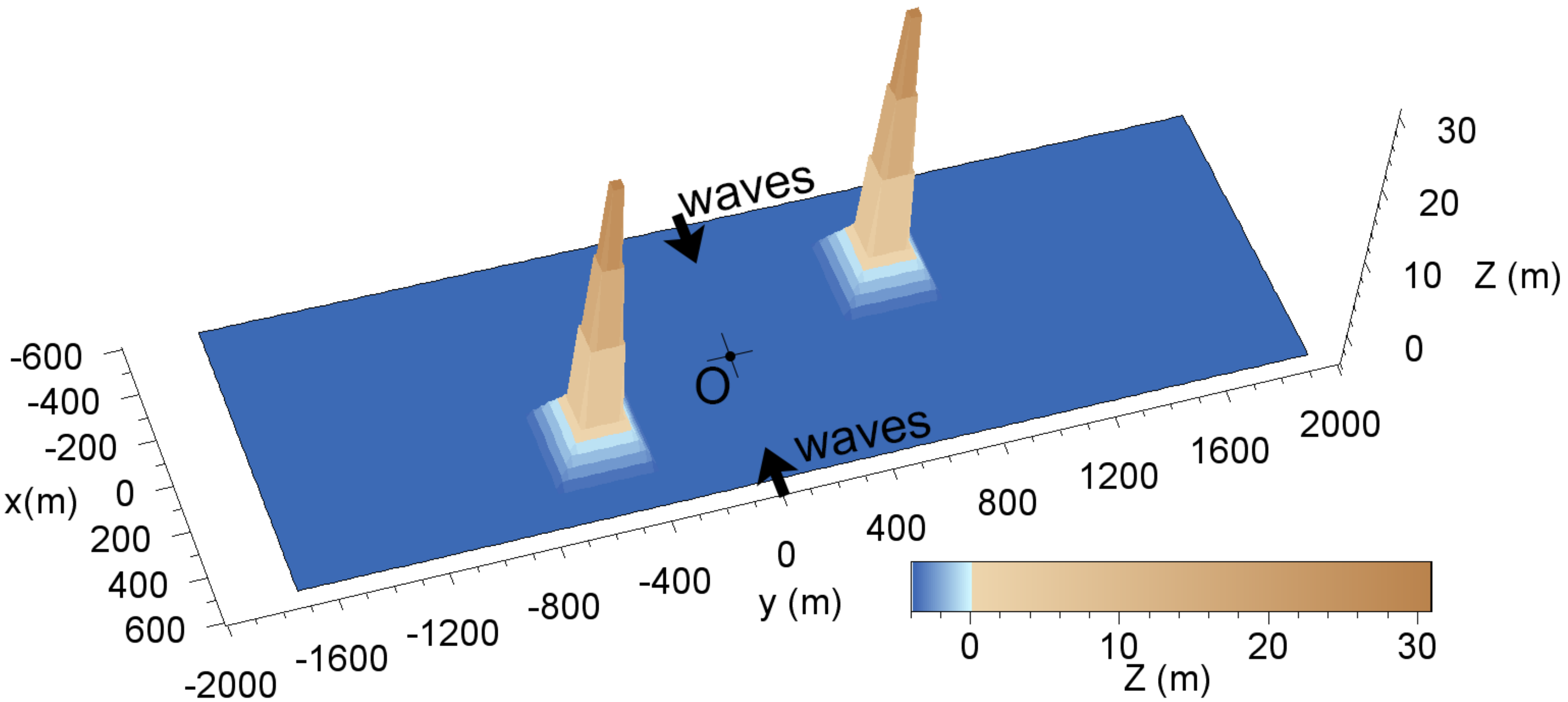
INTRODUCTION

- There are many cases of multiple islands deforming while interacting with each other.



INTRODUCTION

- In this study, we investigated beach changes associated with the interaction and mergence of the cuspate forelands formed at the end of two sandy islands using the BG model (a model for predicting three-dimensional beach changes based on Bagnold's concept).



Examples of
Cuspate forelands extending from islands and connected with each other

Satellite image of islands facing the Yellow Sea in southwestern Korea

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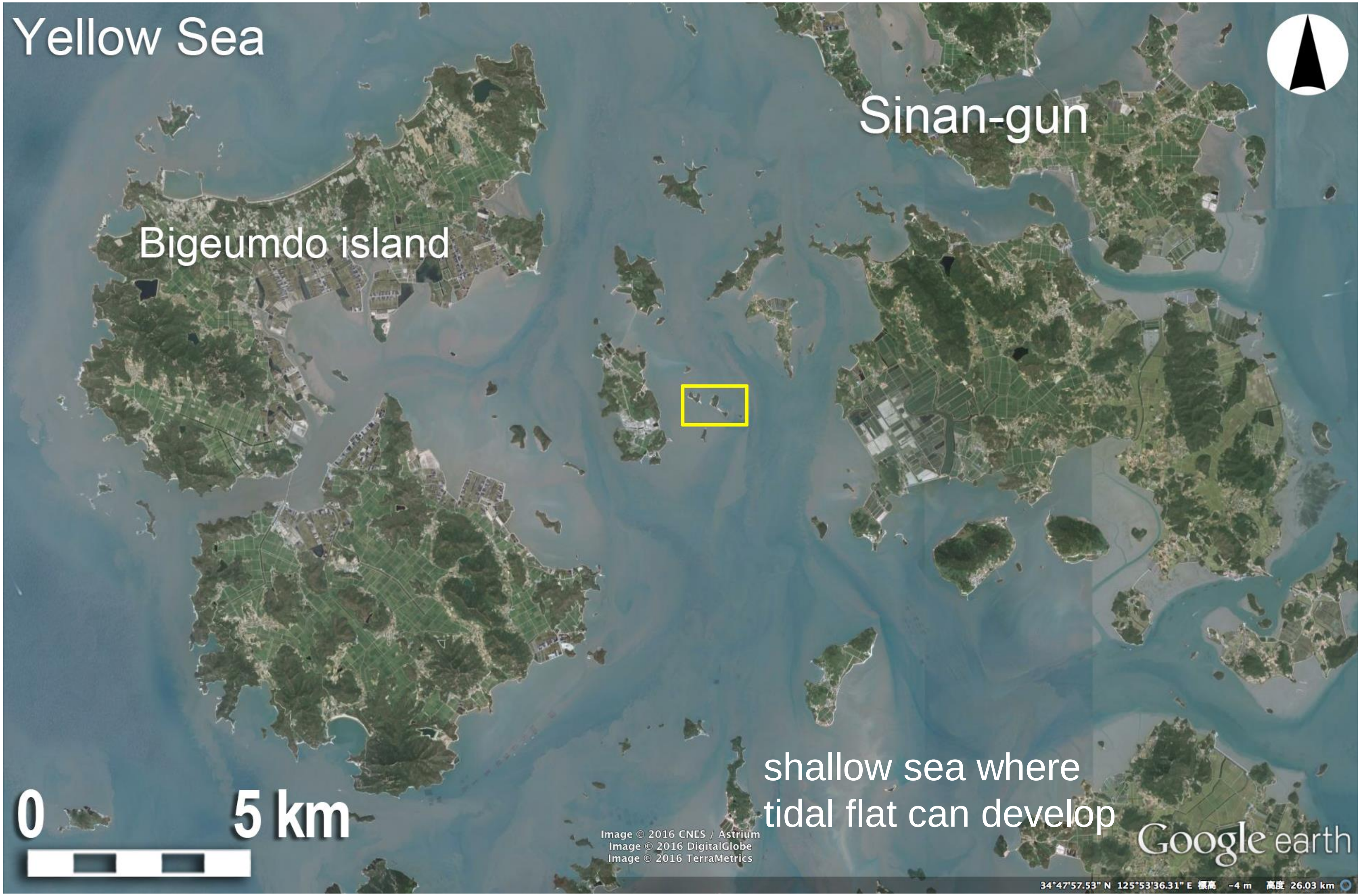
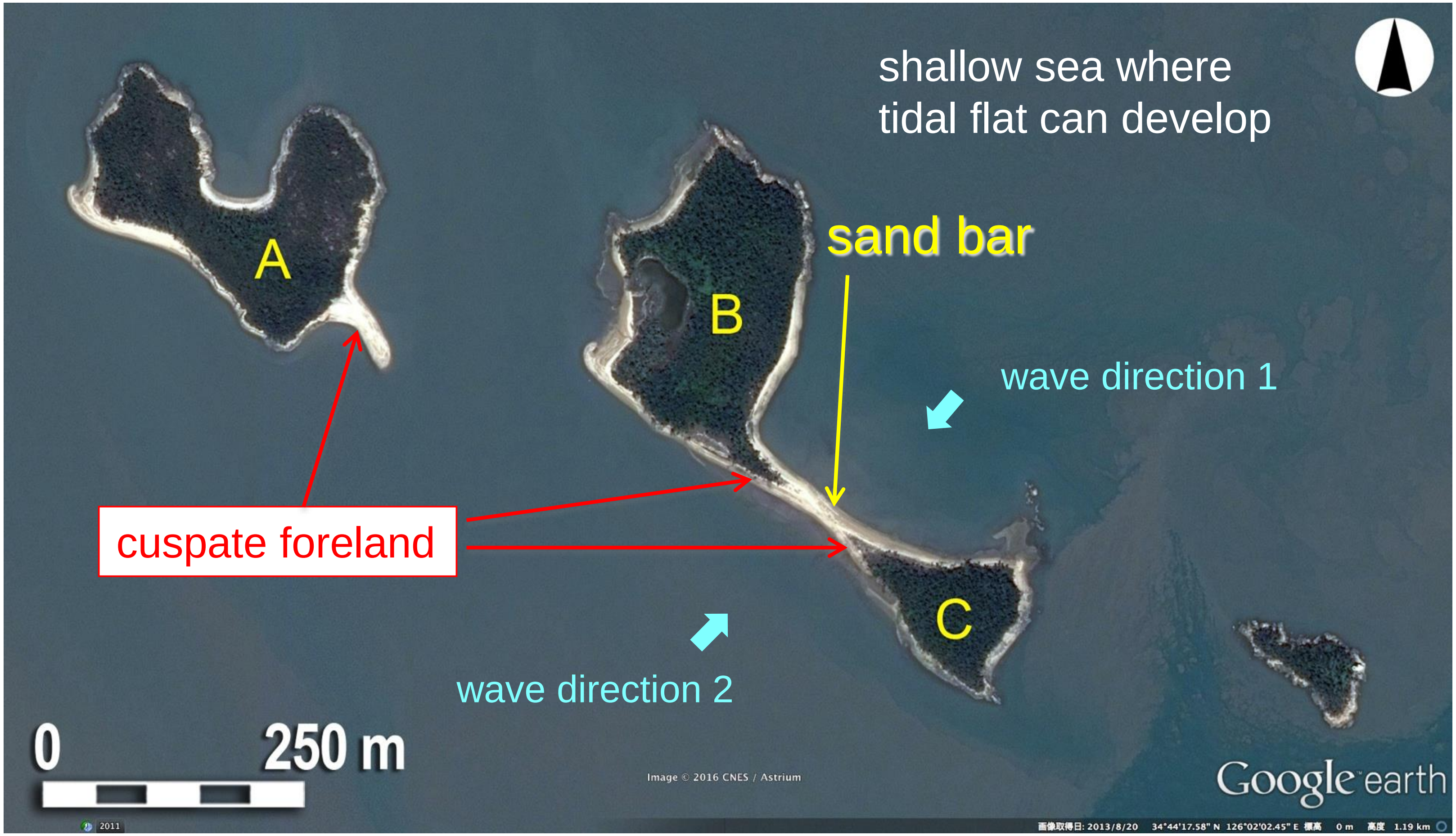
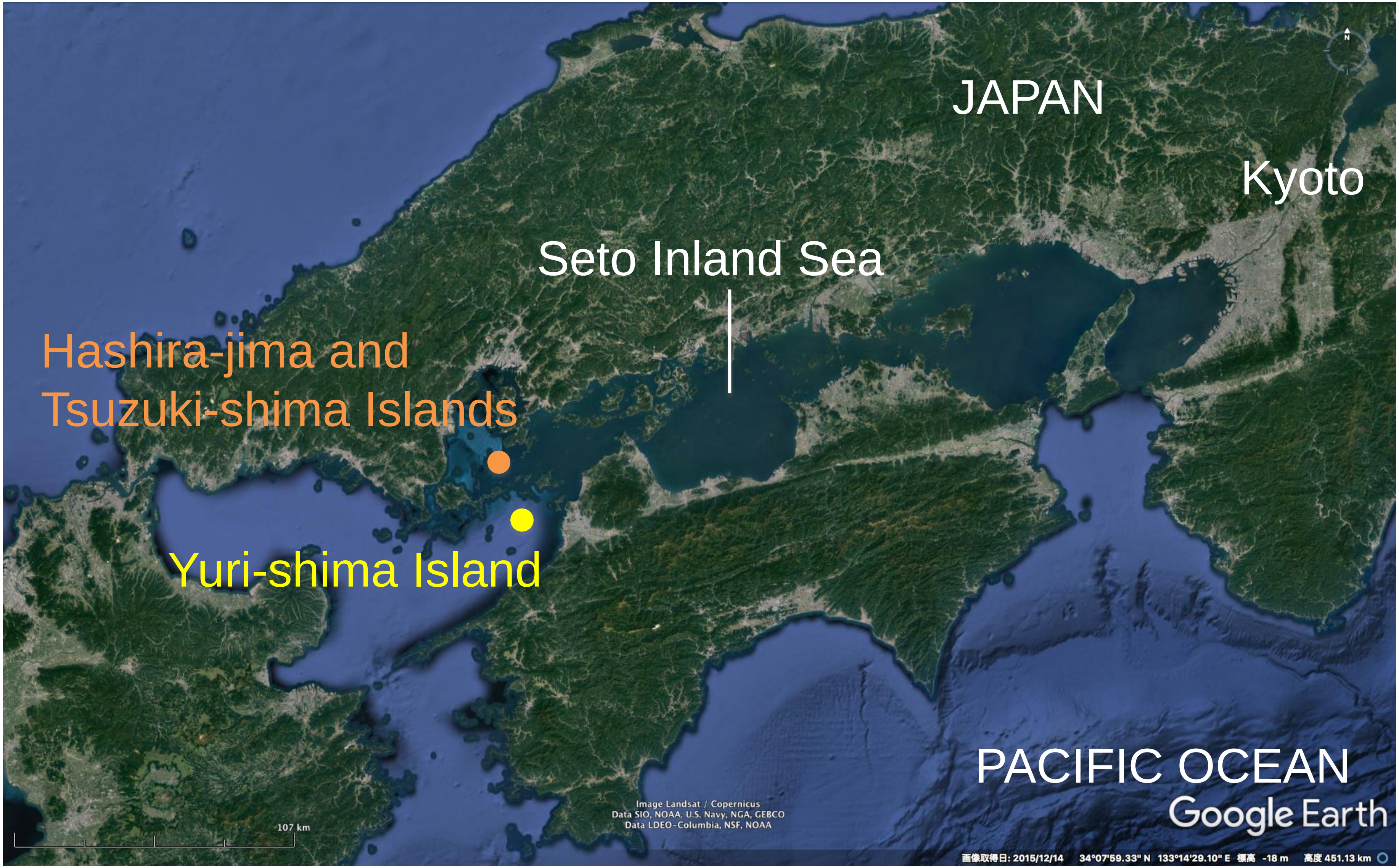


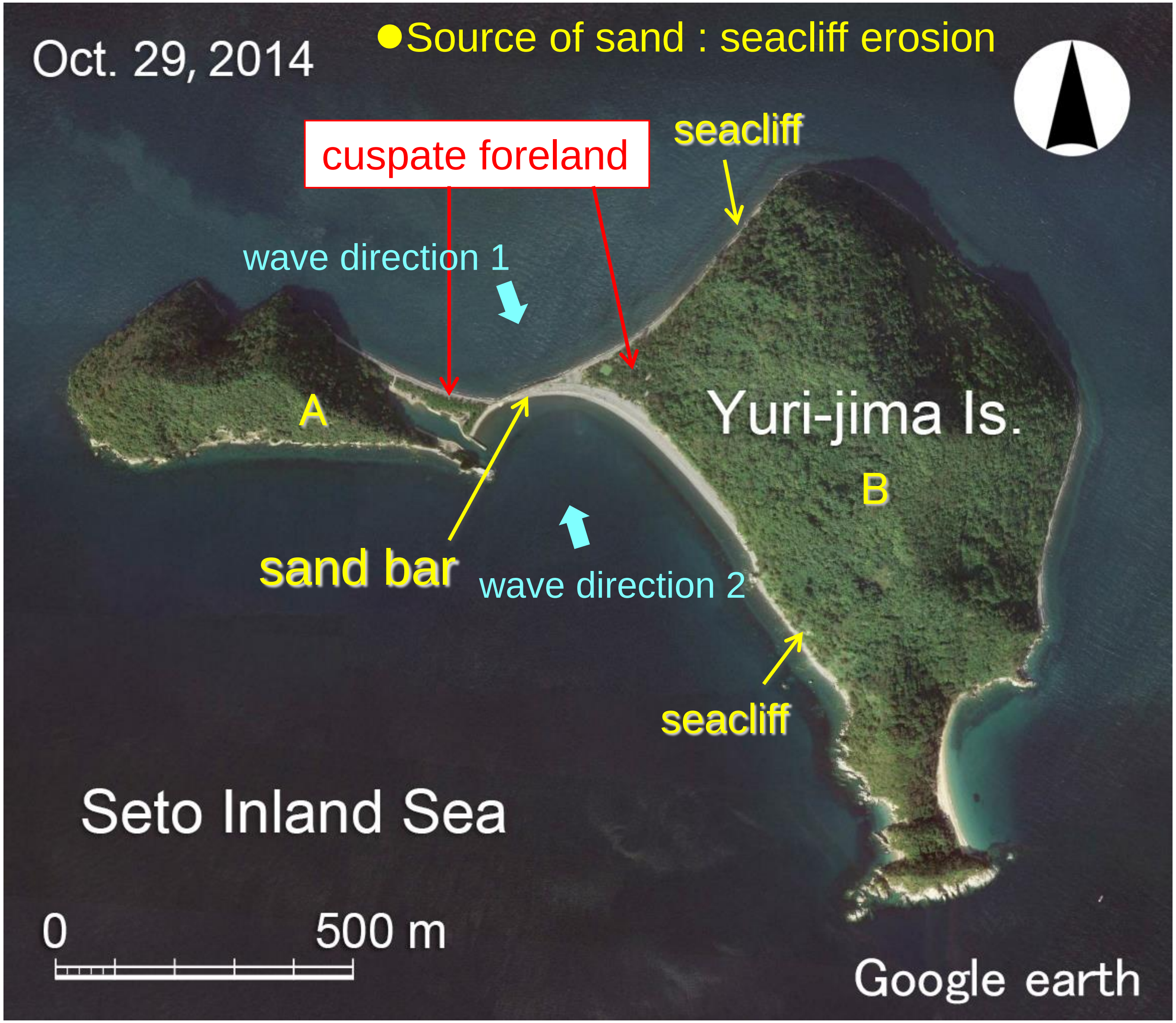
Cuspate forelands extending from islands and connected with each other



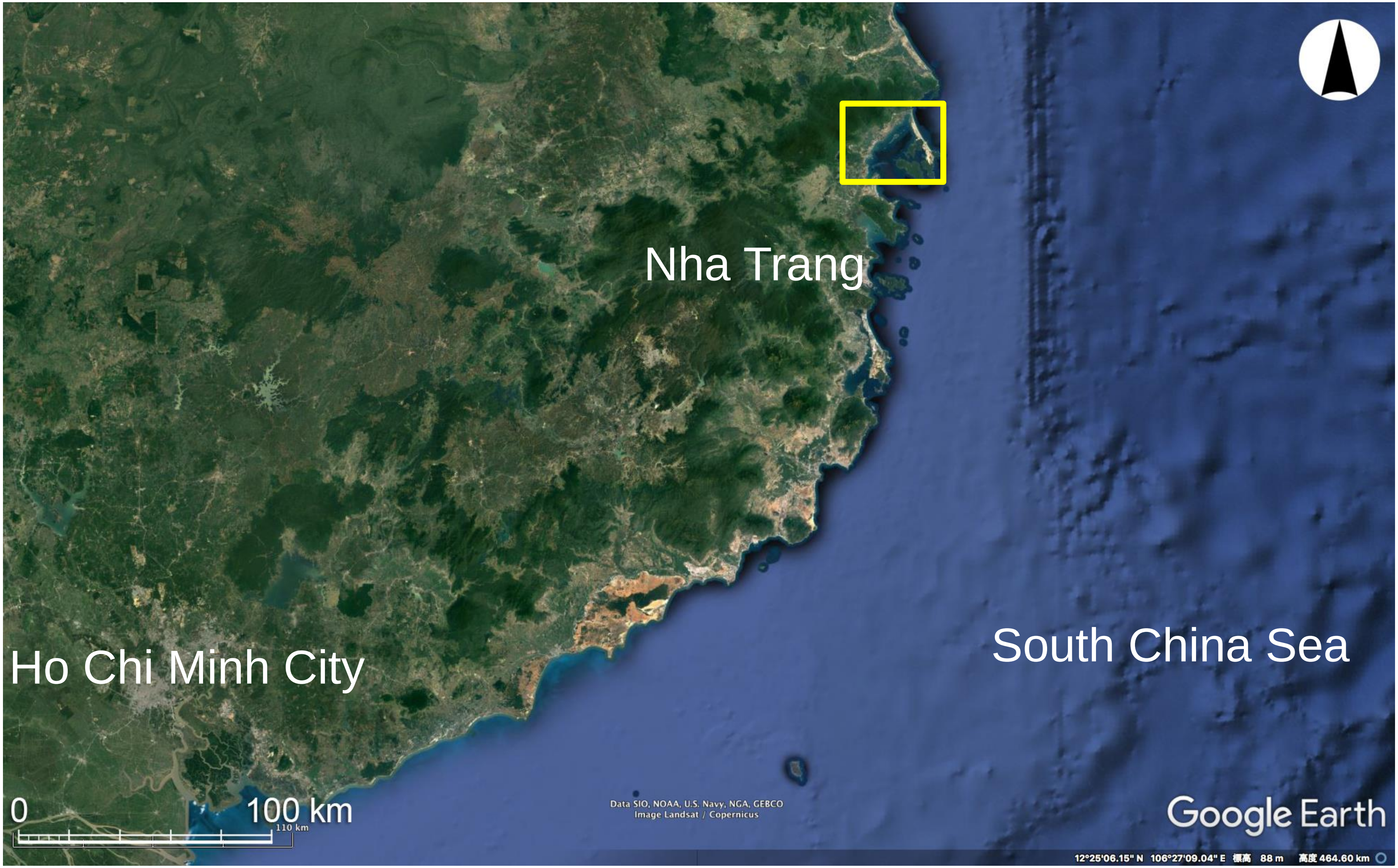
Seto Inland Sea, Japan



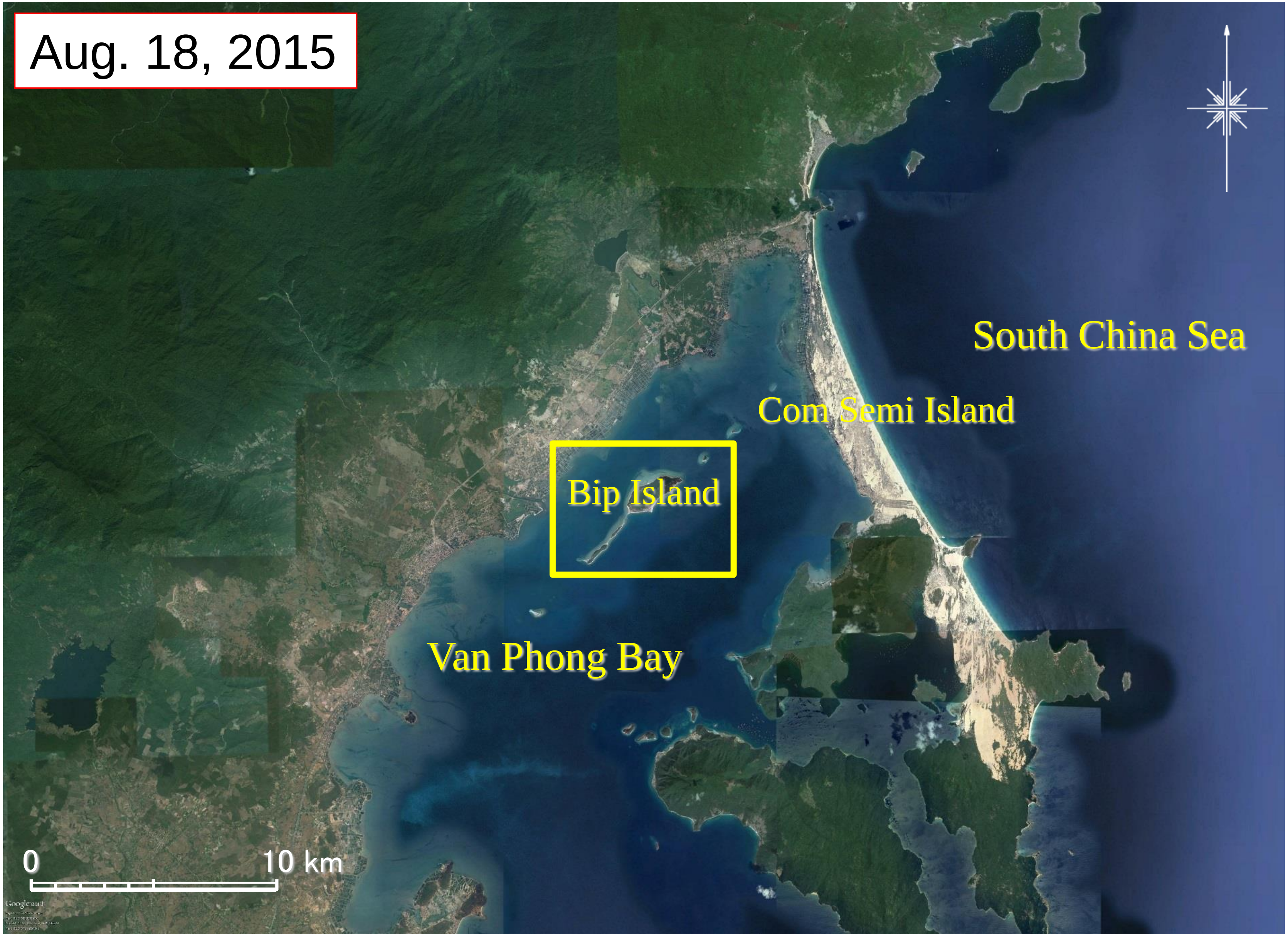
Cuspate foreland on Yuri-shima Island in the Seto Inland Sea, Japan



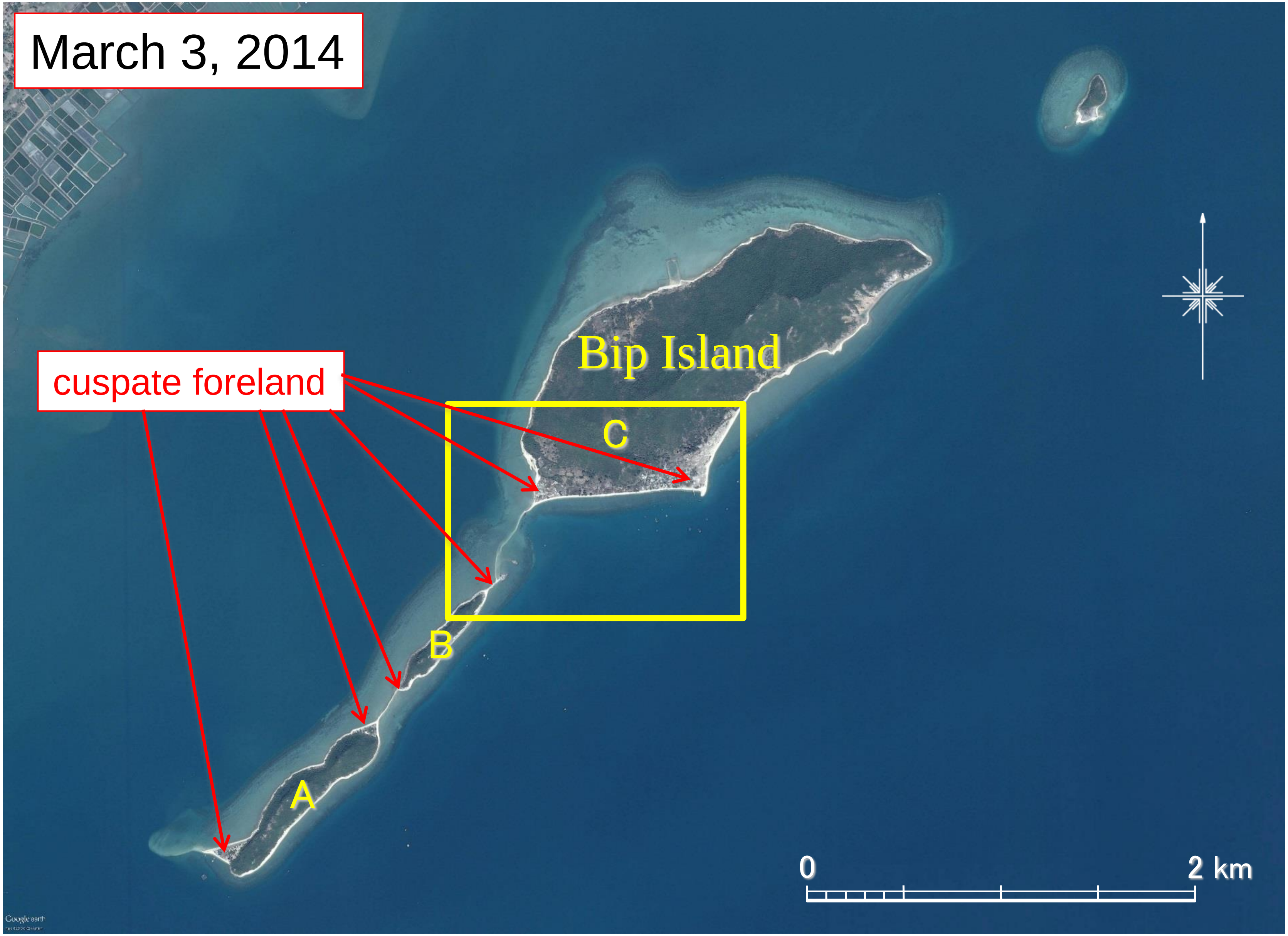
Bip Island, Van Phong Bay, Vietnam



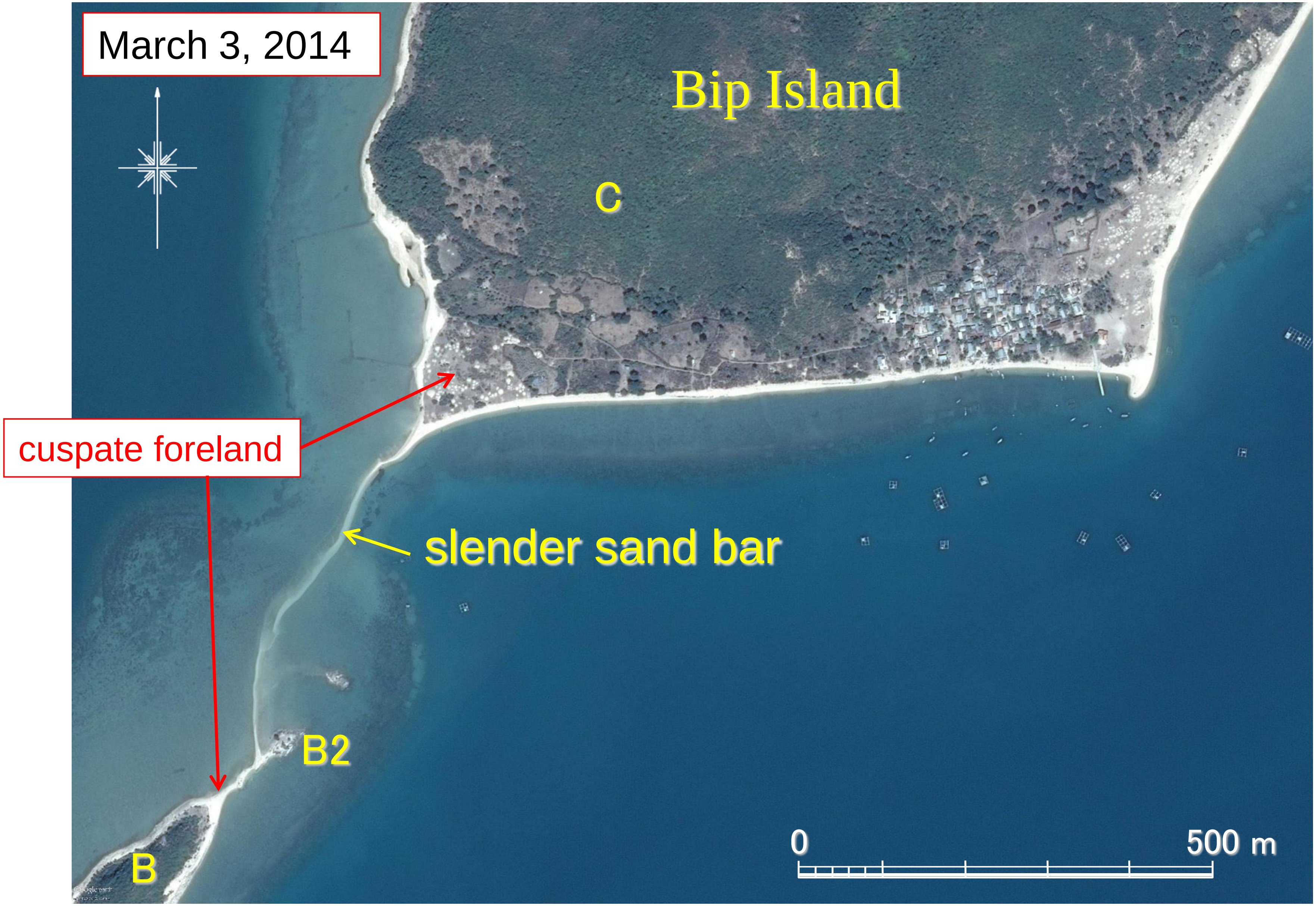
Bip Island, Van Phong Bay, Vietnam



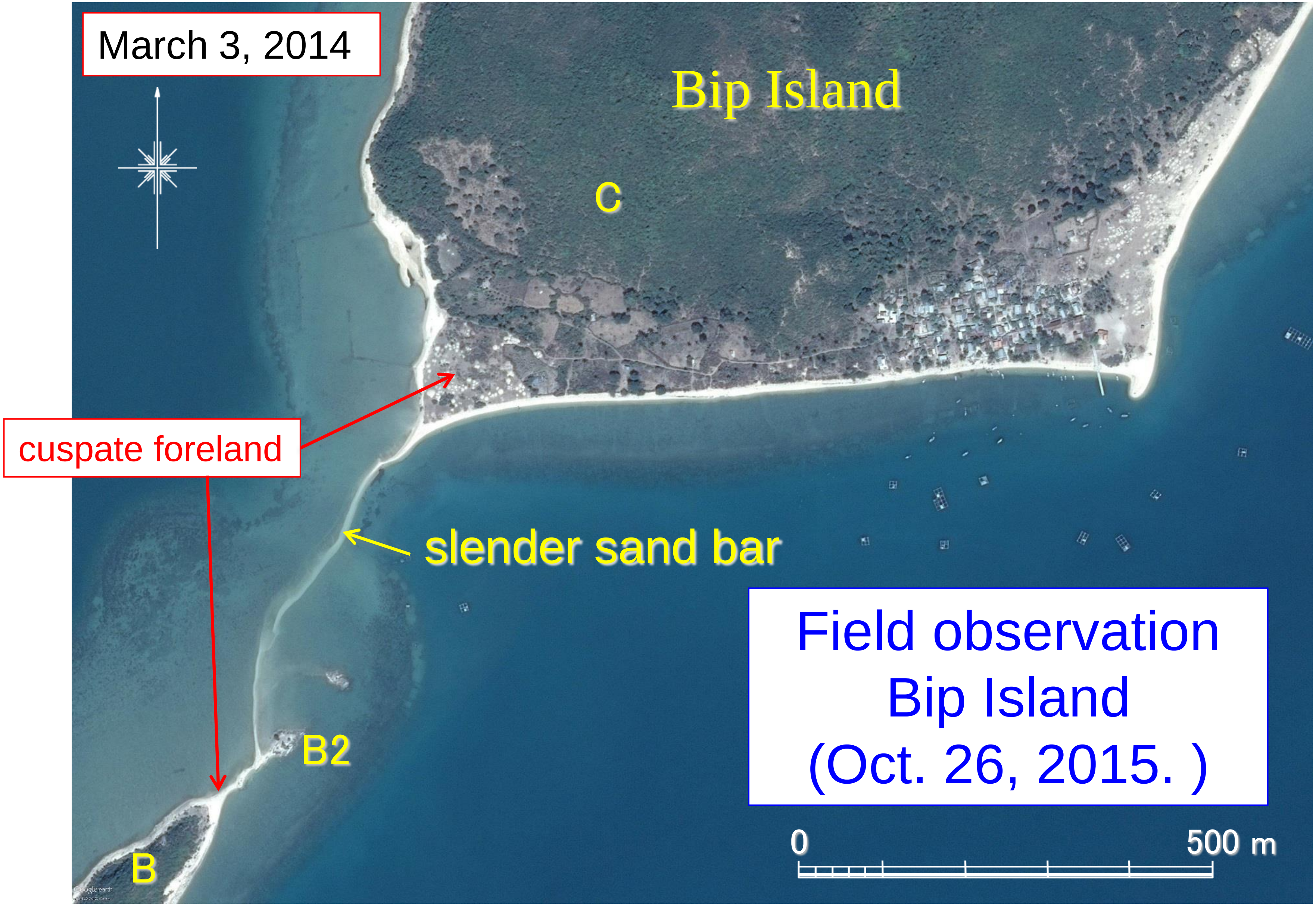
Bip Island, Van Phong Bay, Vietnam



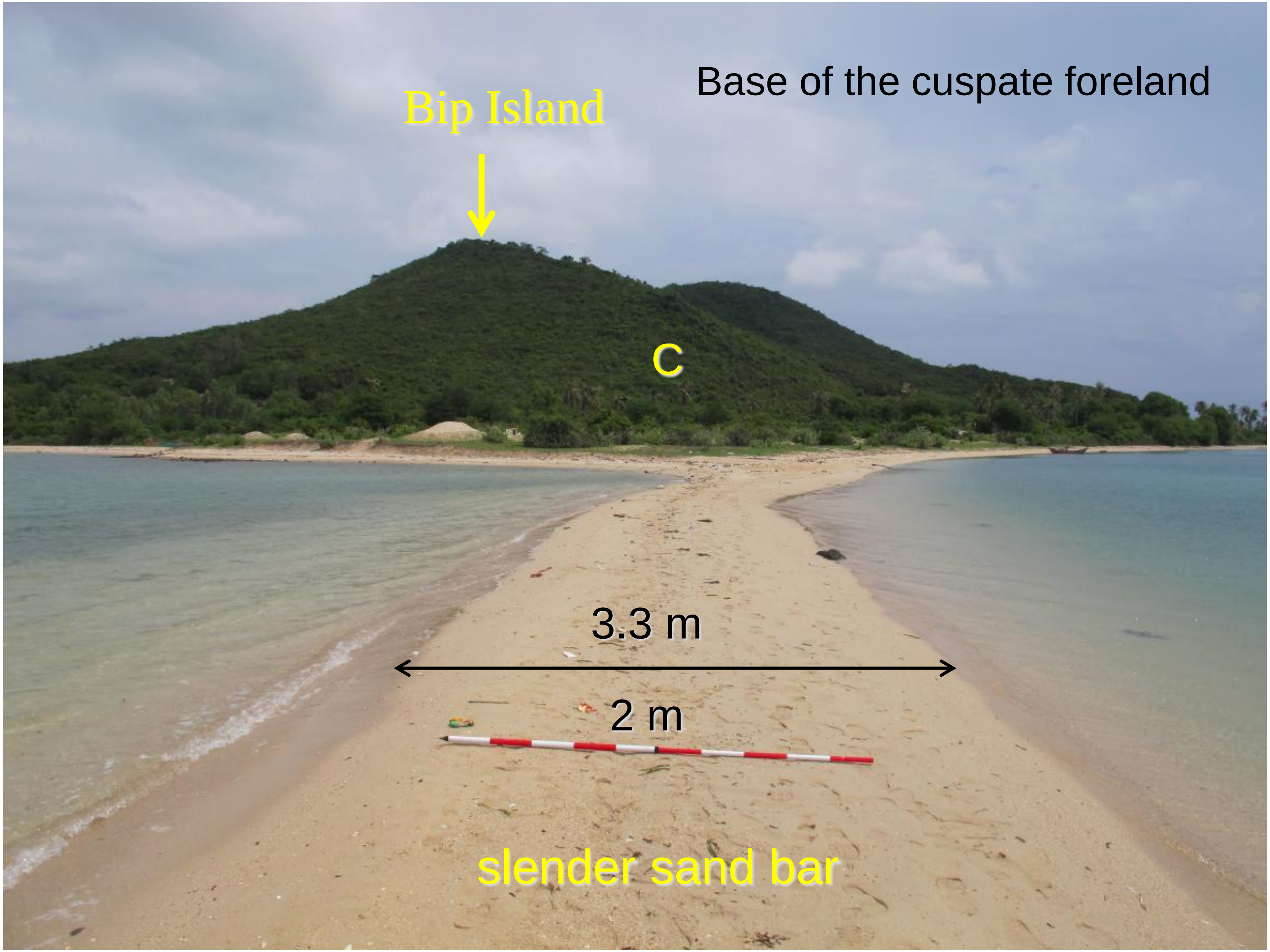
Bip Island, Van Phong Bay, Vietnam



Bip Island, Van Phong Bay, Vietnam



Field observation (Oct. 26, 2015.)



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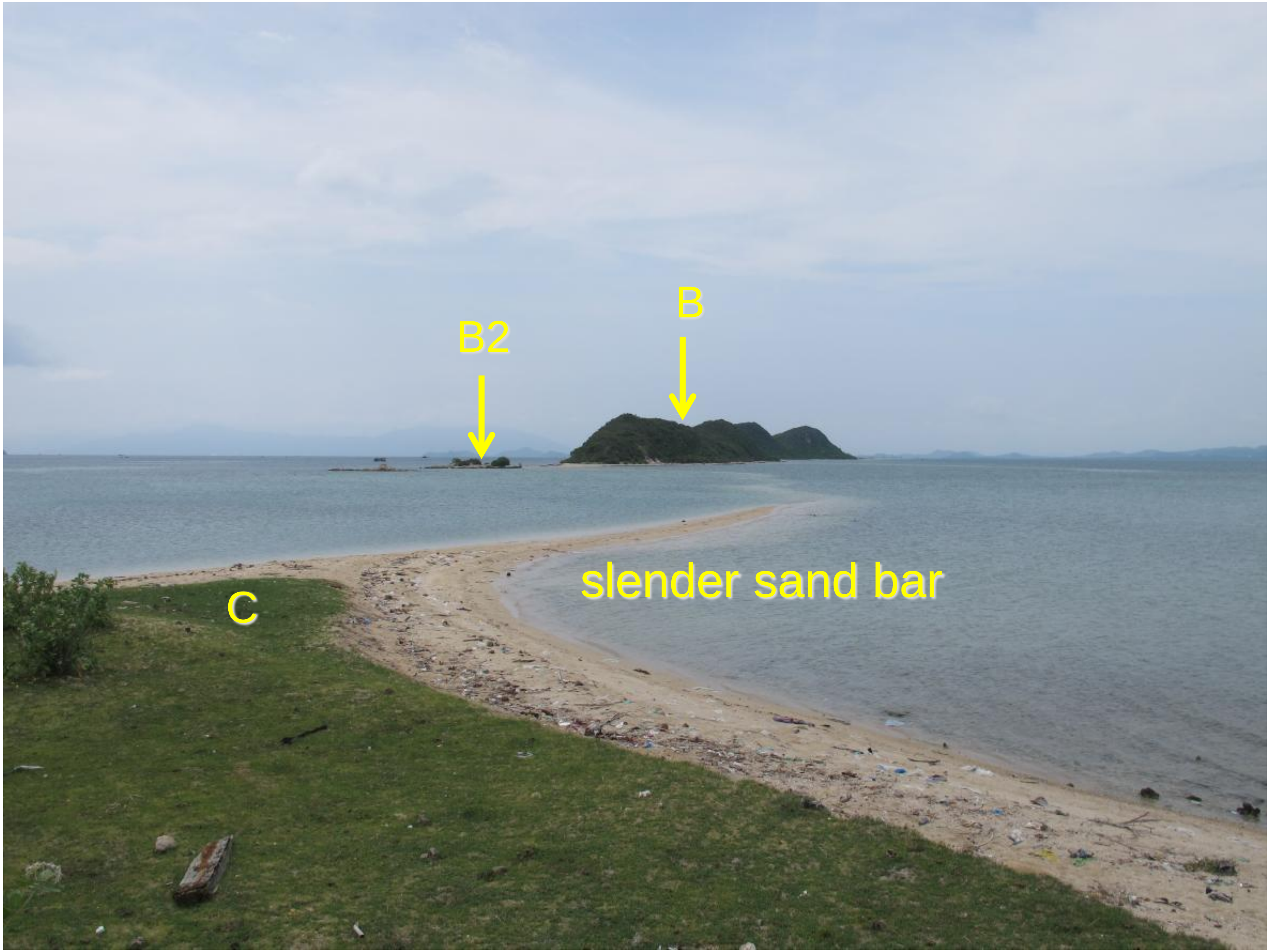

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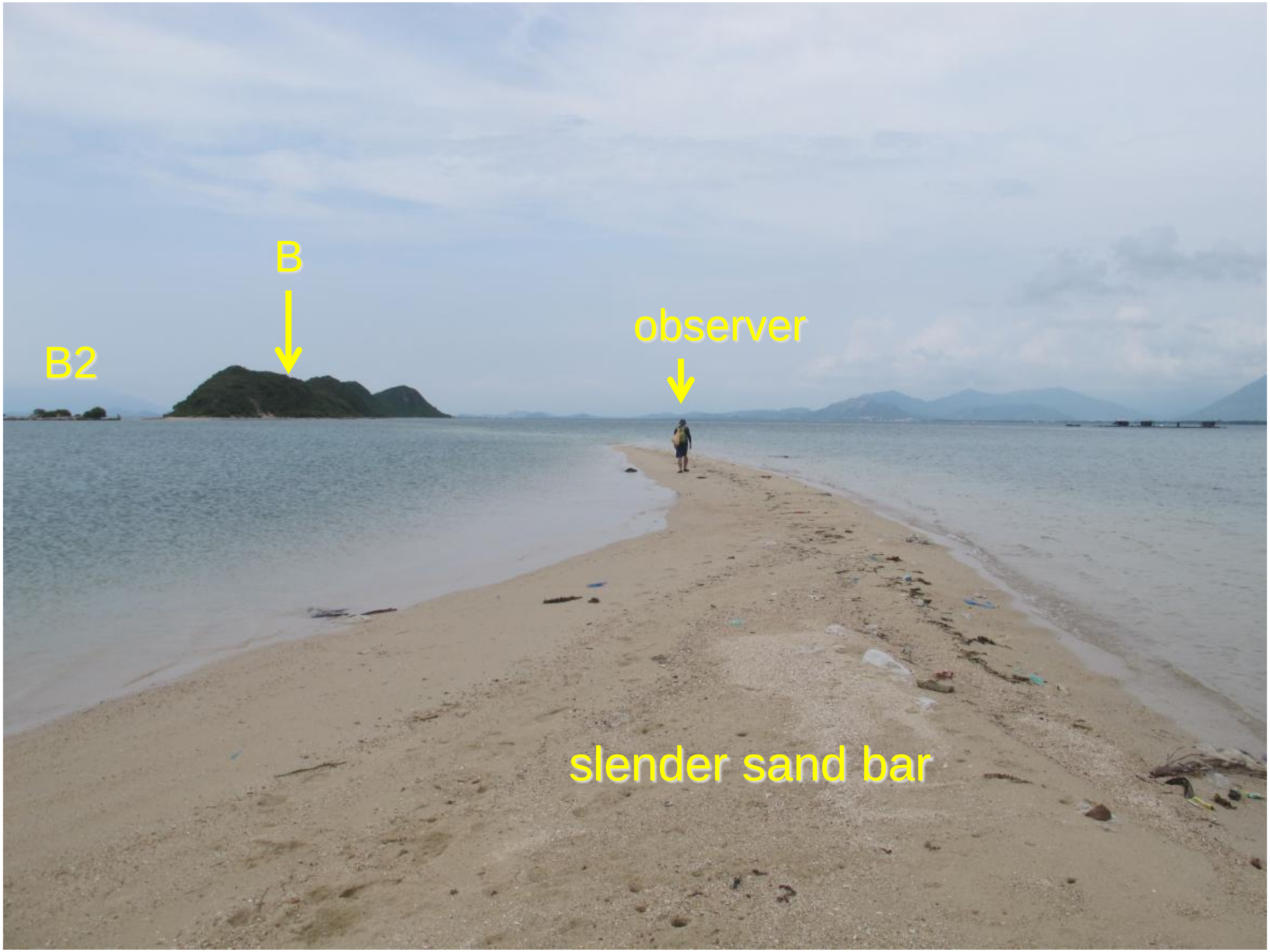

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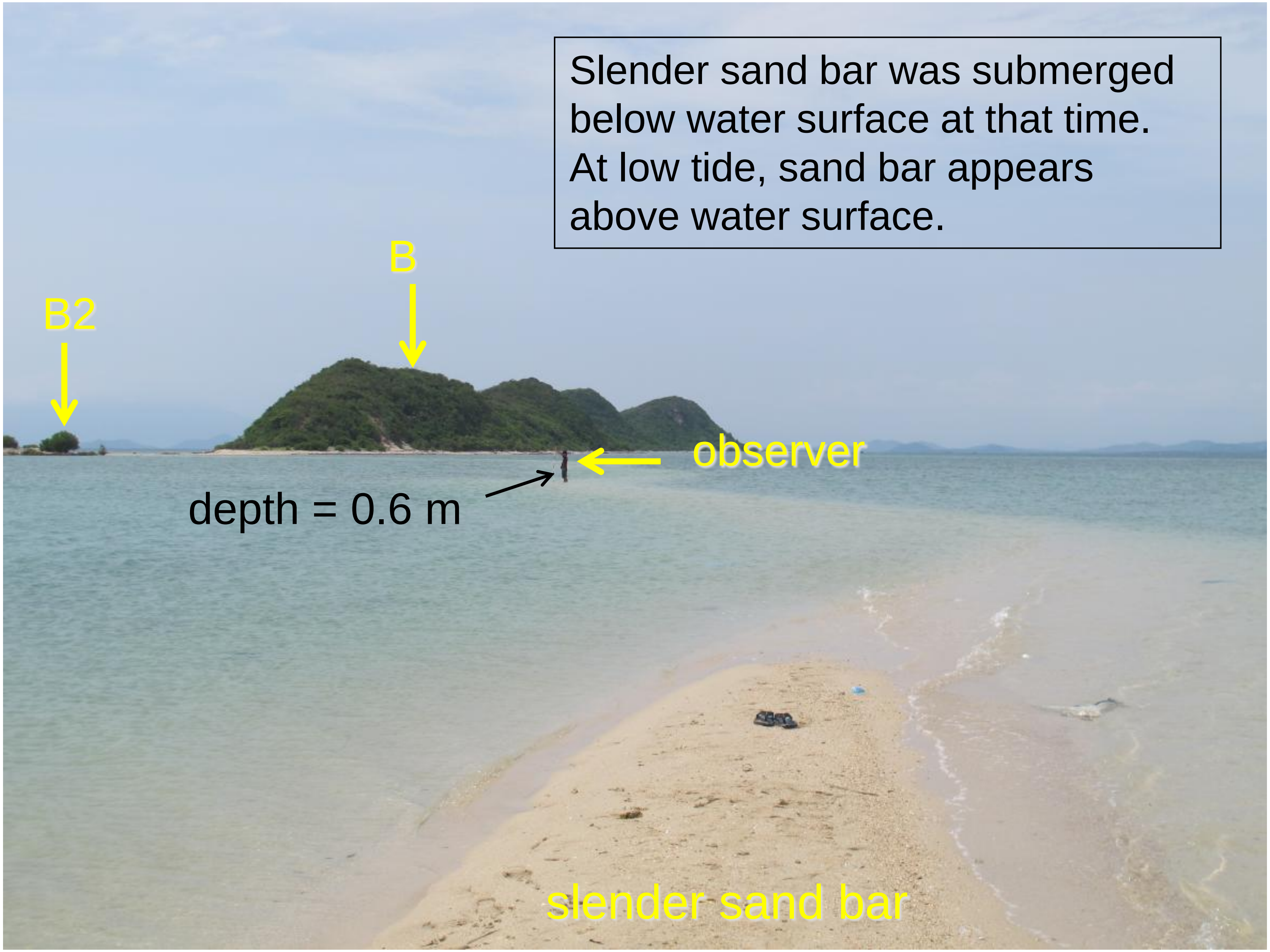


Calculation of connection of two islands.

BG Model (Model for predicting beach changes based on BaGnold's concept)

Serizawa et al. (2015)

Serizawa et al. (2015)

BG Model (Model for predicting beach changes based on BaGnold's concept)

The sand transport equation

- •equilibrium slope : Inman and Bagnold(1963)
- •energetic approach : Bagnold(1963)

$$\vec{q} = C_0 \frac{P}{\tan\beta_c} \left\{ \begin{array}{l} K_n \left(\tan\beta_c \vec{e_w} - |\cos\alpha| \overrightarrow{\nabla Z} \right) \\ + \left\{ (K_s - K_n)\sin\alpha - \boxed{\frac{K_2}{\tan\beta} \frac{\partial H}{\partial s}} \right\} \tan\beta \, \vec{e_s} \end{array} \right\}$$

$$(-h_c \le Z \le h_R) \quad \ldots(1)$$

Ozasa and Brampton (1980)

$P =$ wave energy dissipation by breaking

$$= K\sqrt{g/h}\left[1 - (G/g)^2\right]E \quad \ldots(2)$$

P is calculated by using the results of wave field.

Calculation model of plane wave field:

energy balance equation (Mase, 2001) with dissipation term due to wave breaking (Dally *et al.,* 1984).

$\vec{q} = (q_x, q_y)$: the net sand transport flux

$Z = (x, y, t)$: the seabed elevation

n s: the coordinates of cross-shore and longshore directions,

$\vec{e_n}$: the unit vector normal to the contour lines (shoreward).

$\vec{e_s}$: parallel to a contour line

$\overrightarrow{\nabla Z} = \tan\beta \, \vec{e_n} = (\partial Z/\partial x, \partial Z/\partial y)$: the gradient vector of Z.

$\vec{e_w}$: the unit vector of wave direction

θ_w : the angle between the x-axis and the wave direction

$\tan\beta \, \vec{e_s} = (-\partial Z/\partial y, \partial Z/\partial x)$

$\alpha = \theta_w - \theta_n$: the angle between the wave direction and the normal to the contour line

$\tan\beta = \left|\overrightarrow{\nabla Z}\right|$: the seabed slope

$\tan\beta_c$: equilibrium slope

K_s : coefficients of longshore sand transport

K_n : cross-shore sand transport

h_c : the depth of closure

h_R : the berm height

H : the wave height at a local point

$C_0 = 1/\{(\rho_s - \rho)g(1-p)\}$

Physical meaning of BG model

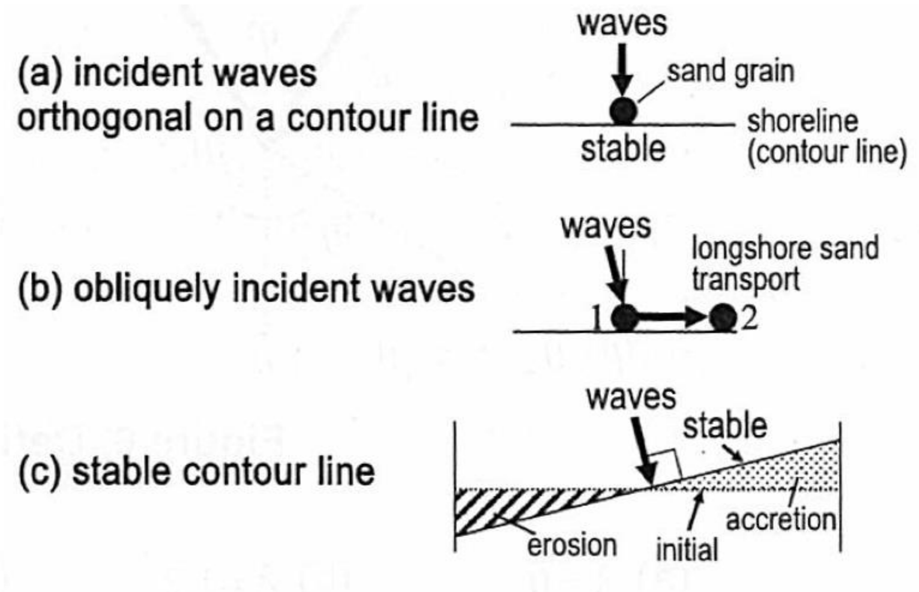


Fig. Stabilization mechanism of contour lines based on wave directions and longshore sand transport.

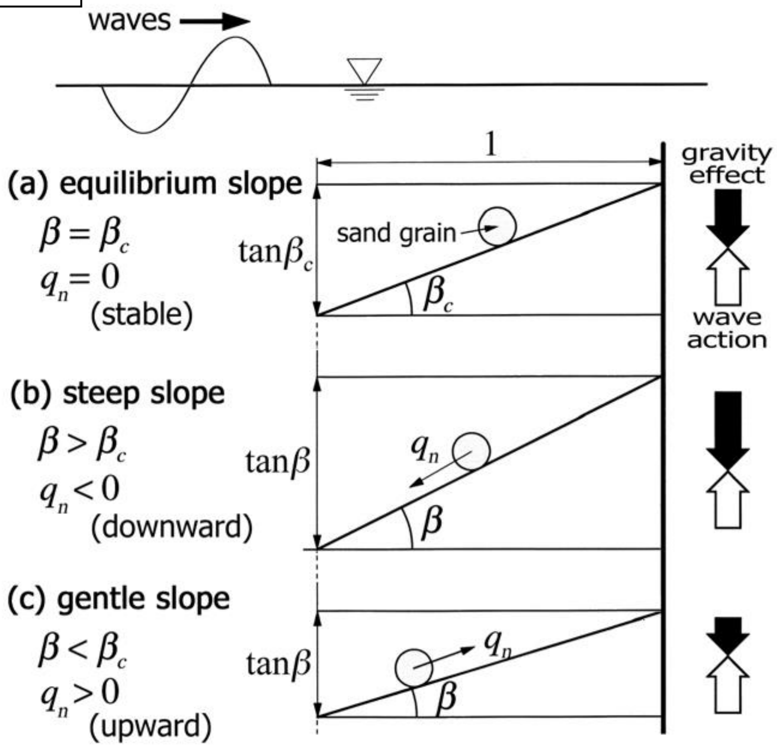
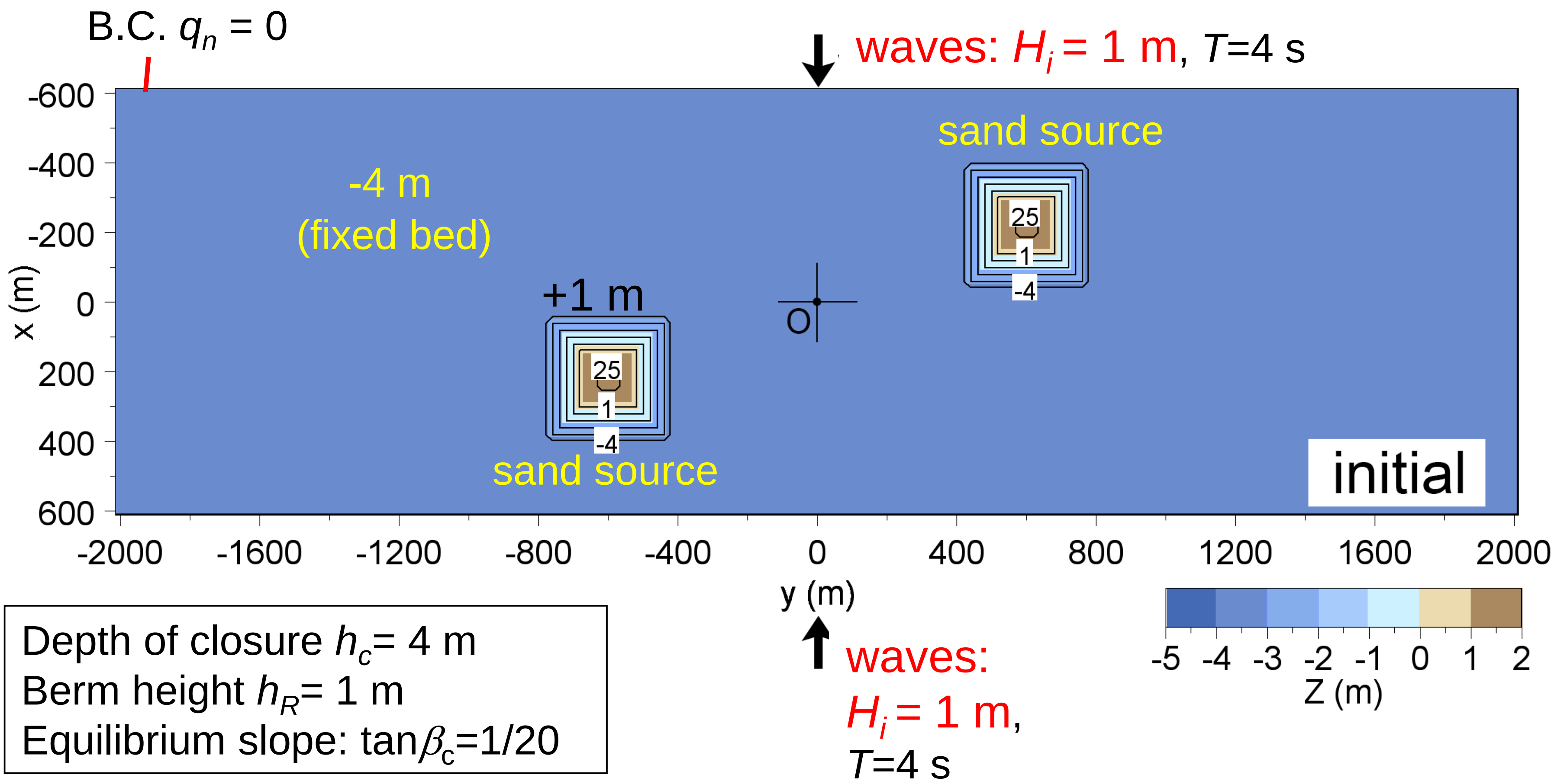


Fig. Stabilization mechanism of beach profile based on equilibrium between gravity effect and wave action.

Calculation results

Calculation results of connection of two islands under wave incidence from two directions

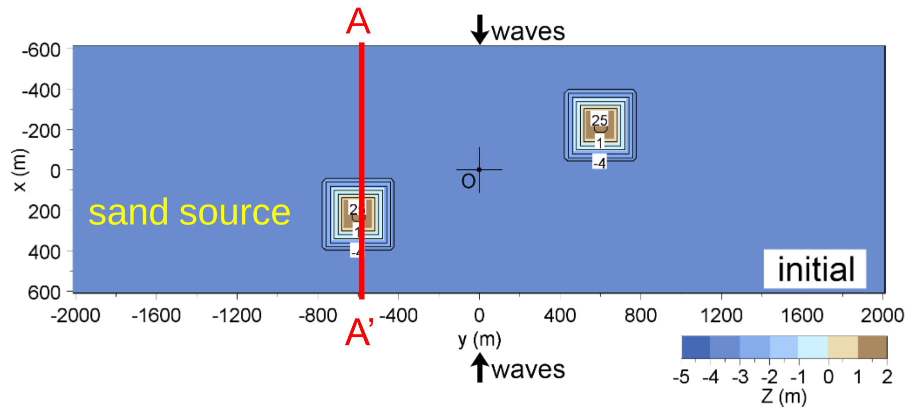
Initial bathymetry

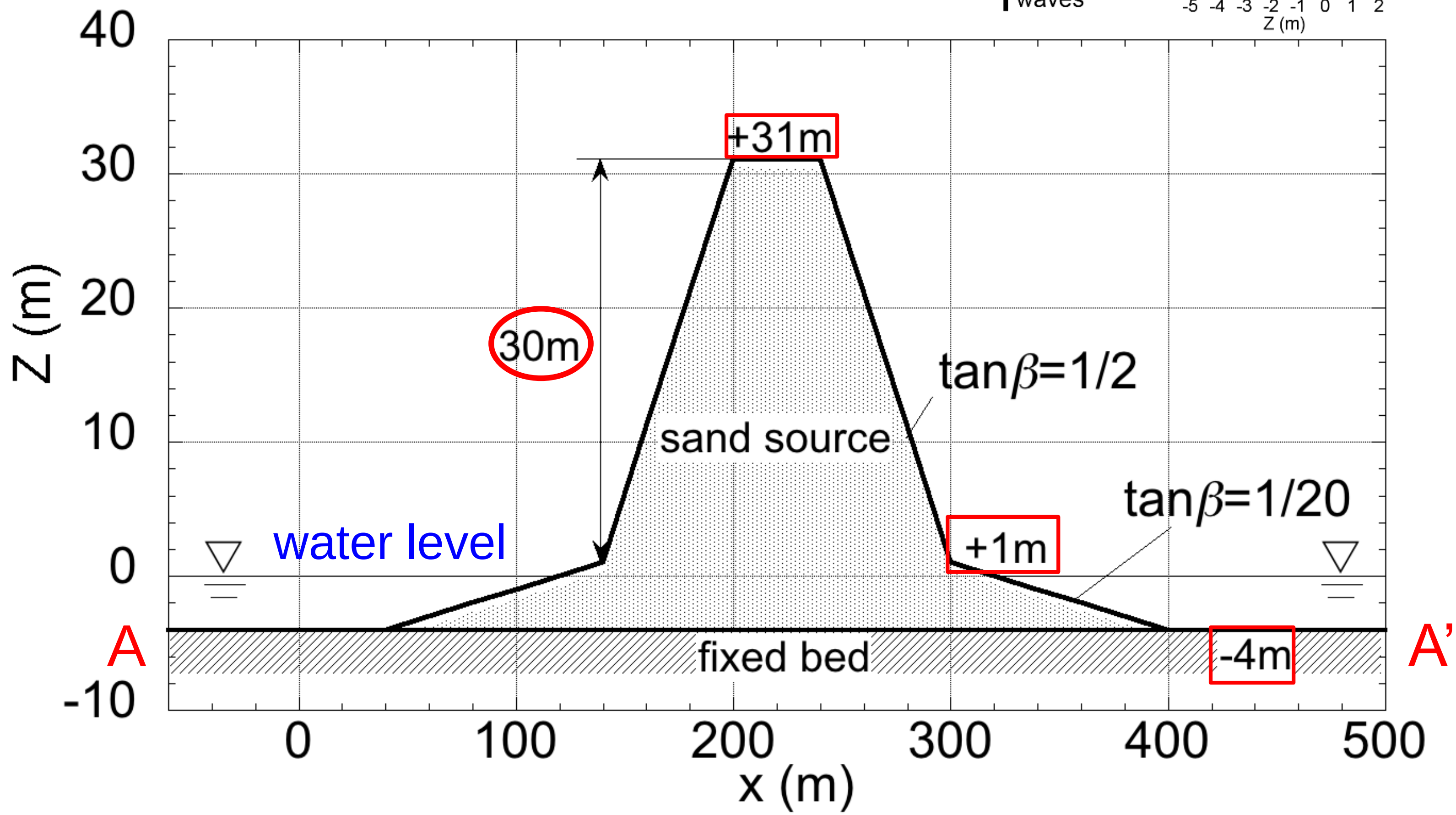


Depth of closure h_c= 4 m
Berm height h_R= 1 m
Equilibrium slope: $\tan\beta_c$=1/20

Cross section of sandy islands

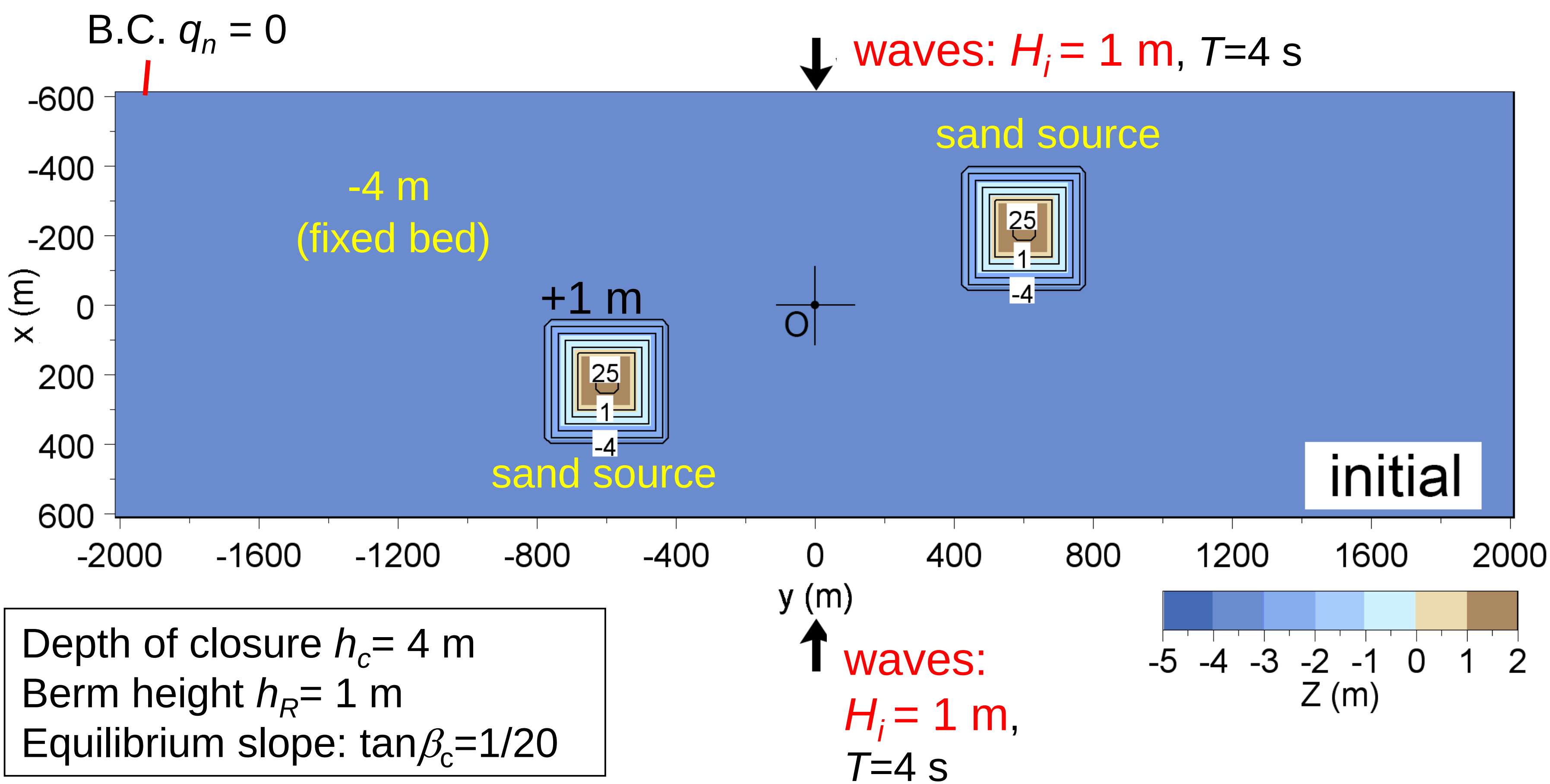
The reason for setting the high tower as the sand source was that a sufficient amount of sand for the elongation of the sand bar could be supplied.





Calculation results of connection of two islands under wave incidence from two directions

Initial bathymetry

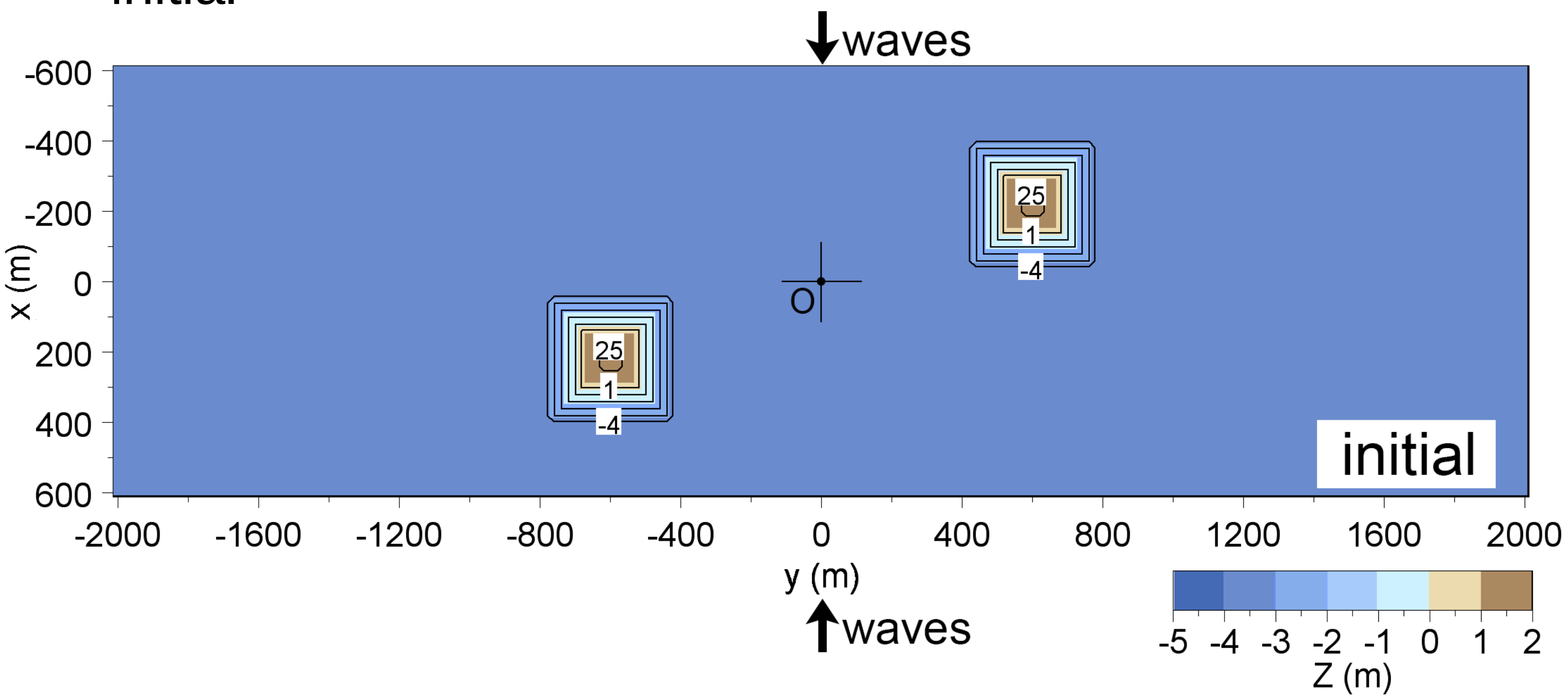


Depth of closure h_c= 4 m
Berm height h_R= 1 m
Equilibrium slope: $\tan\beta_c$=1/20

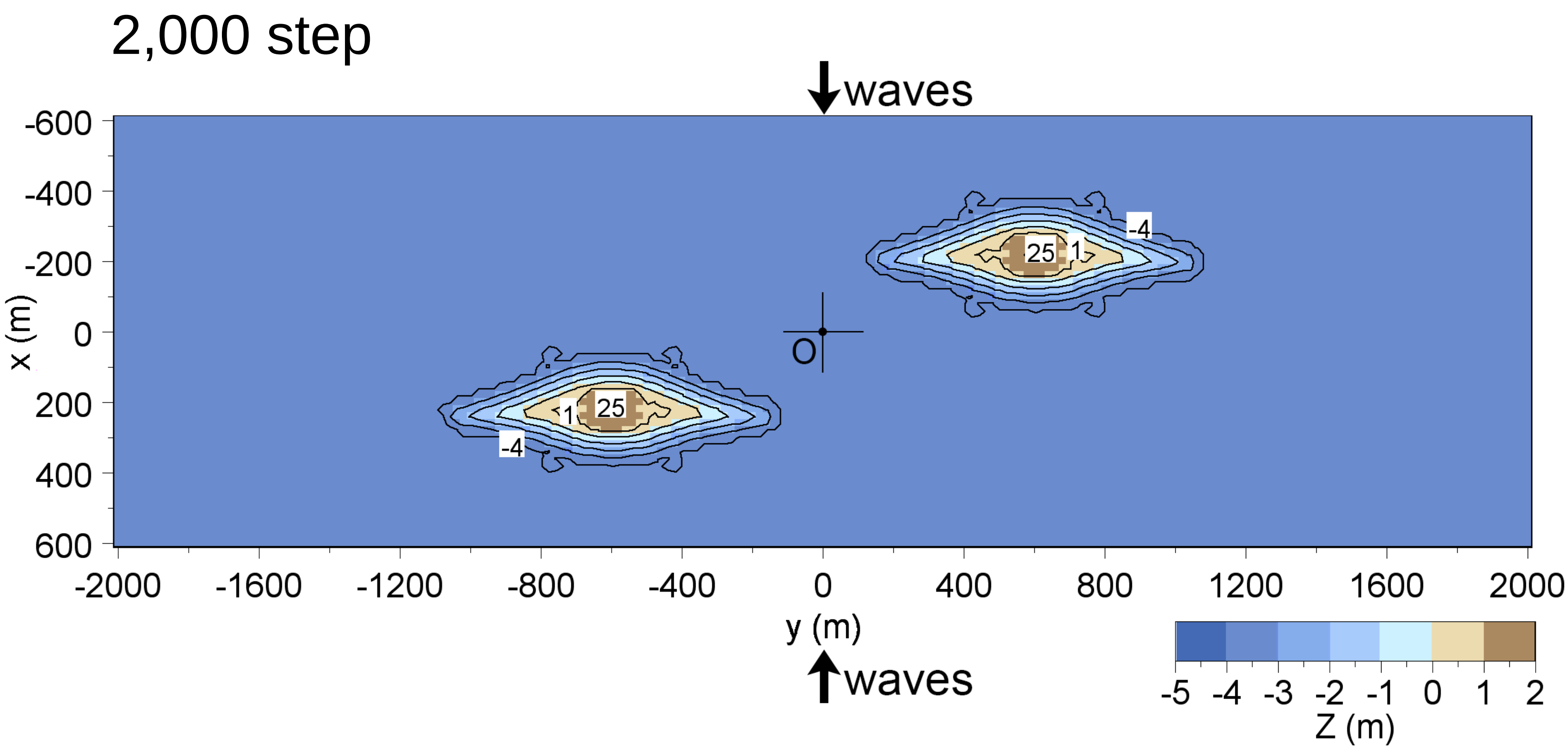
Regarding the wave incidence from two directions, the wave direction was selected every 10 steps of the calculation of beach changes using random numbers.

Calculation results of connection of two islands

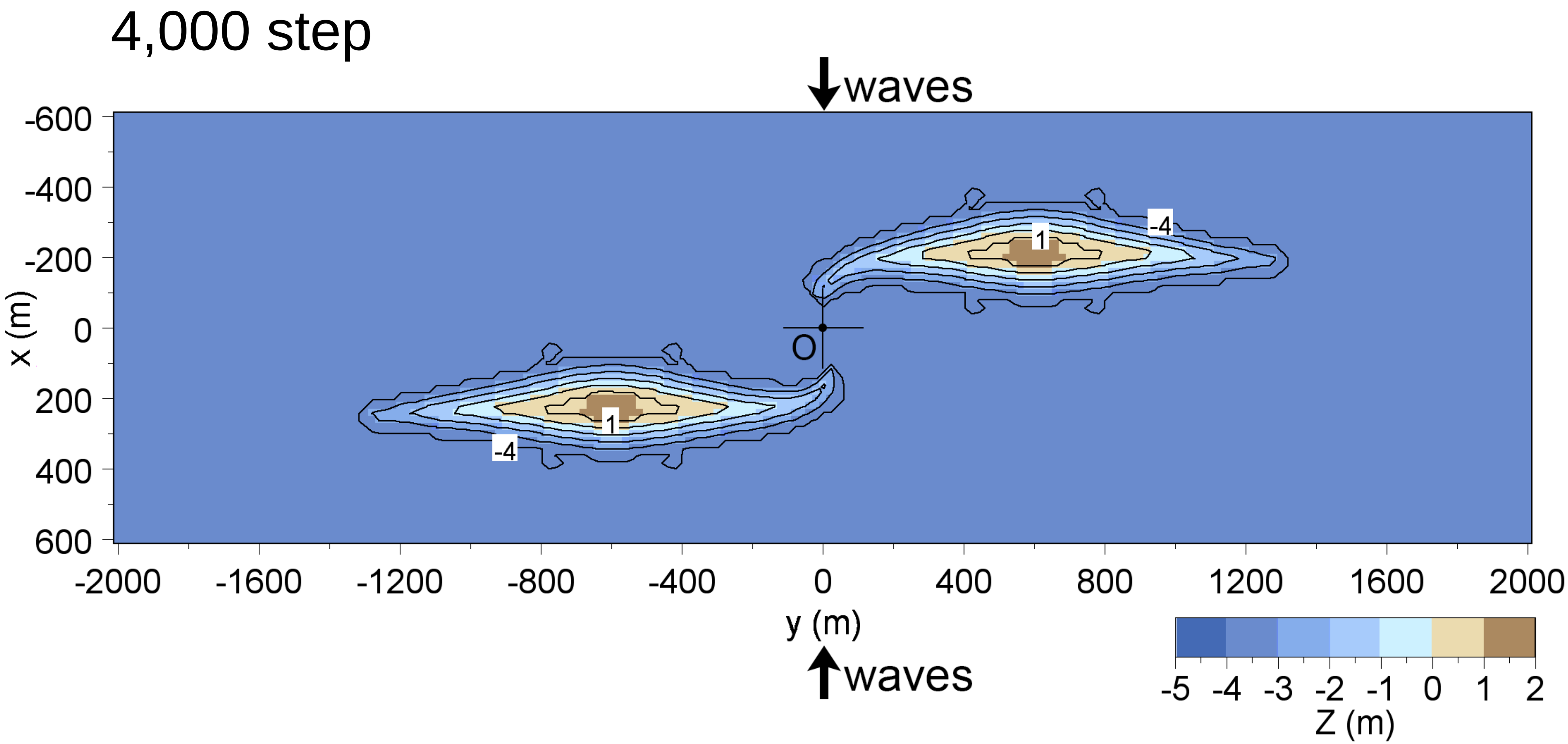
initial



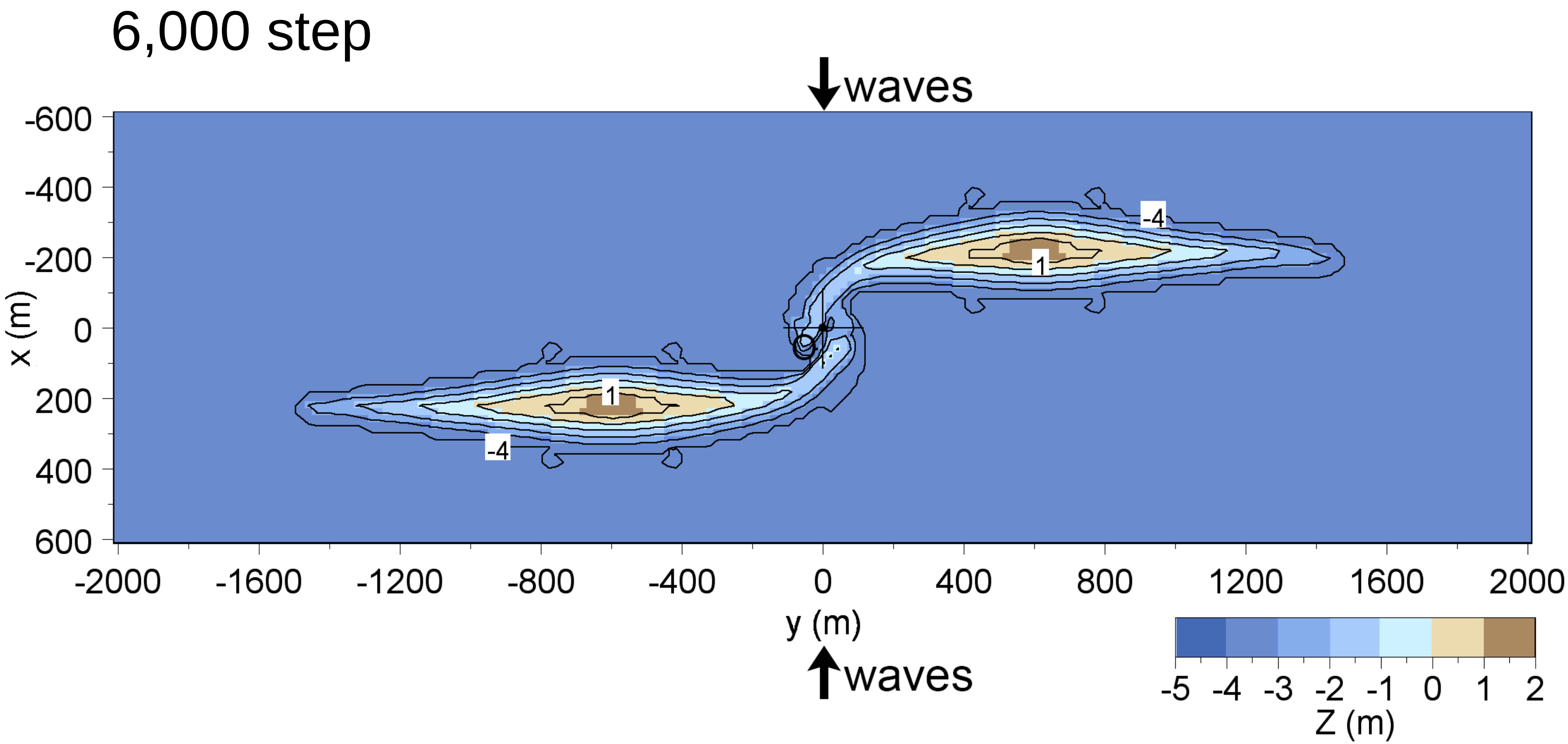
Calculation results of connection of two islands



Calculation results of connection of two islands

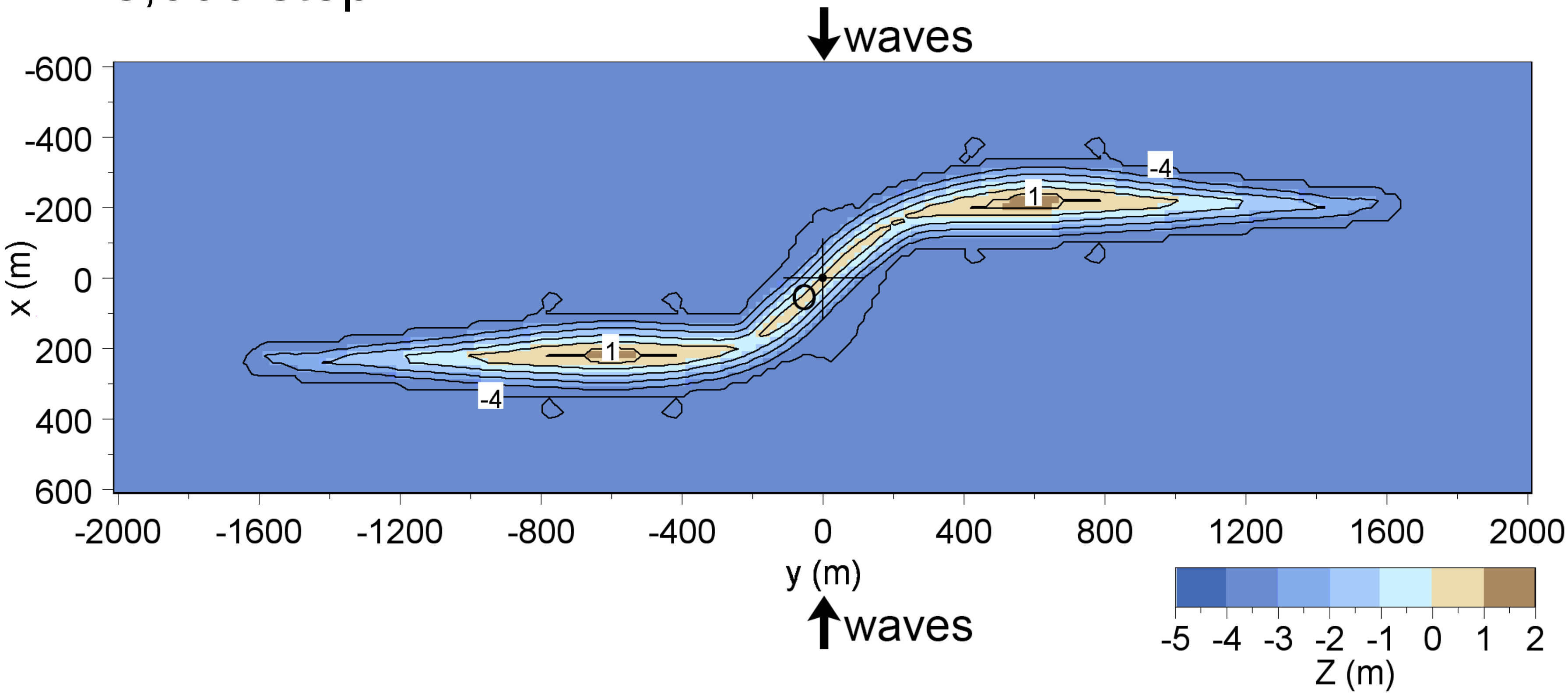


Calculation results of connection of two islands



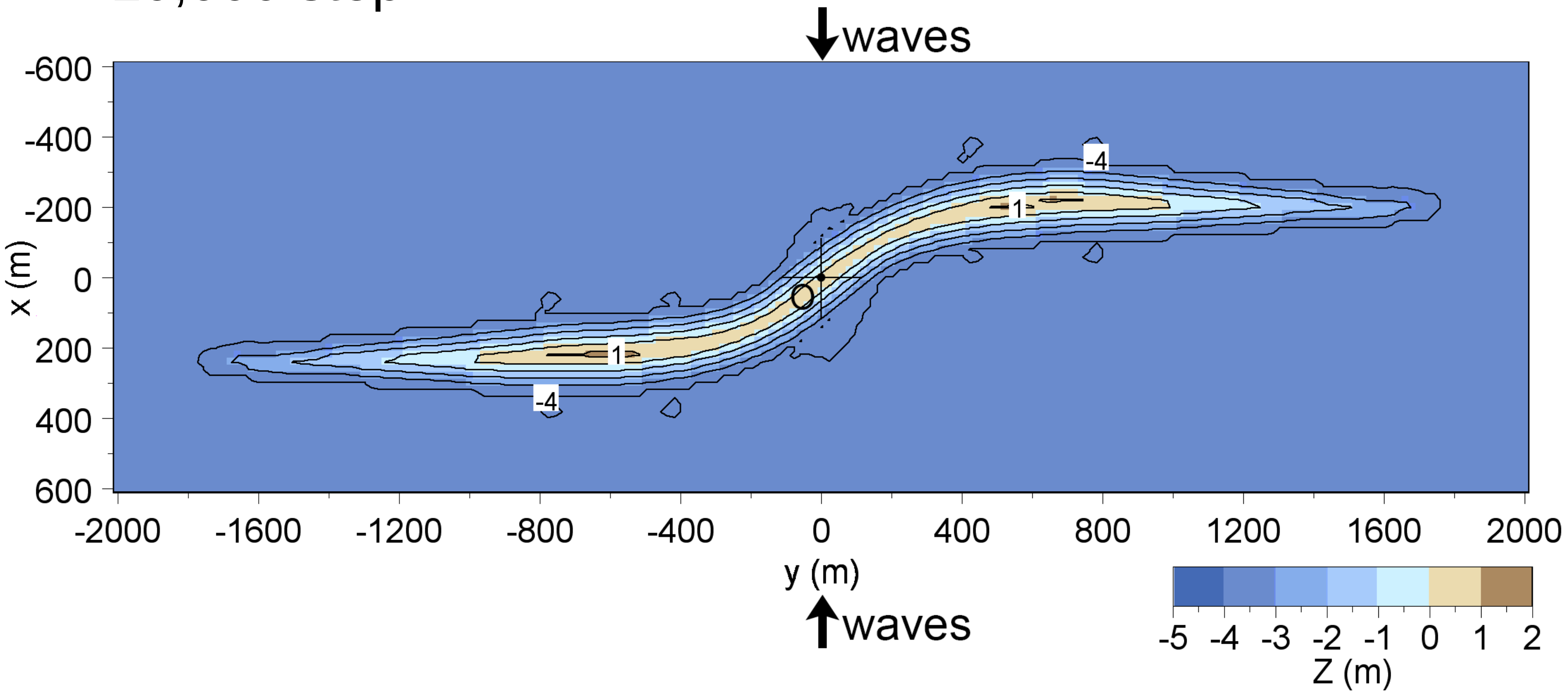
Calculation results of connection of two islands

8,000 step

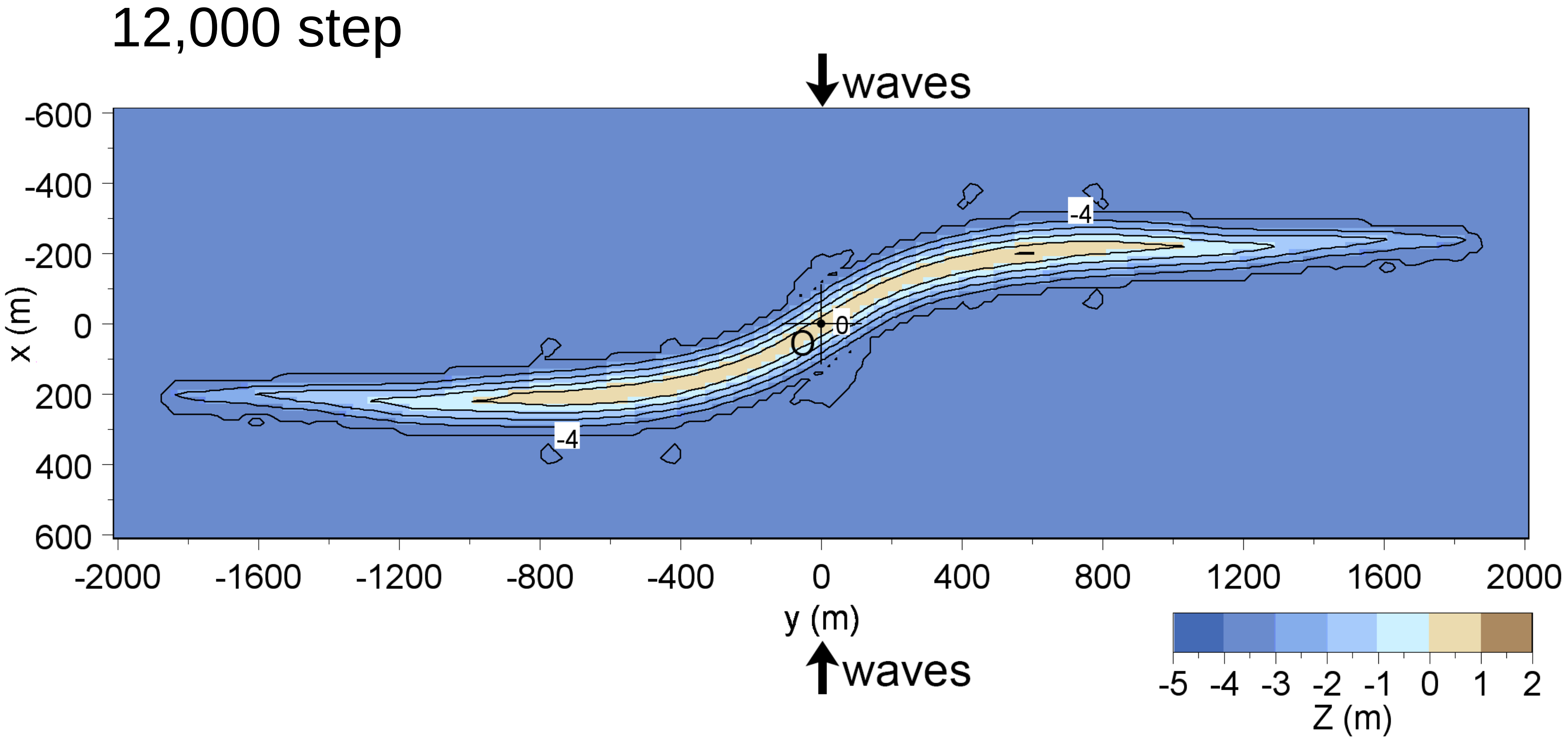


Calculation results of connection of two islands

10,000 step

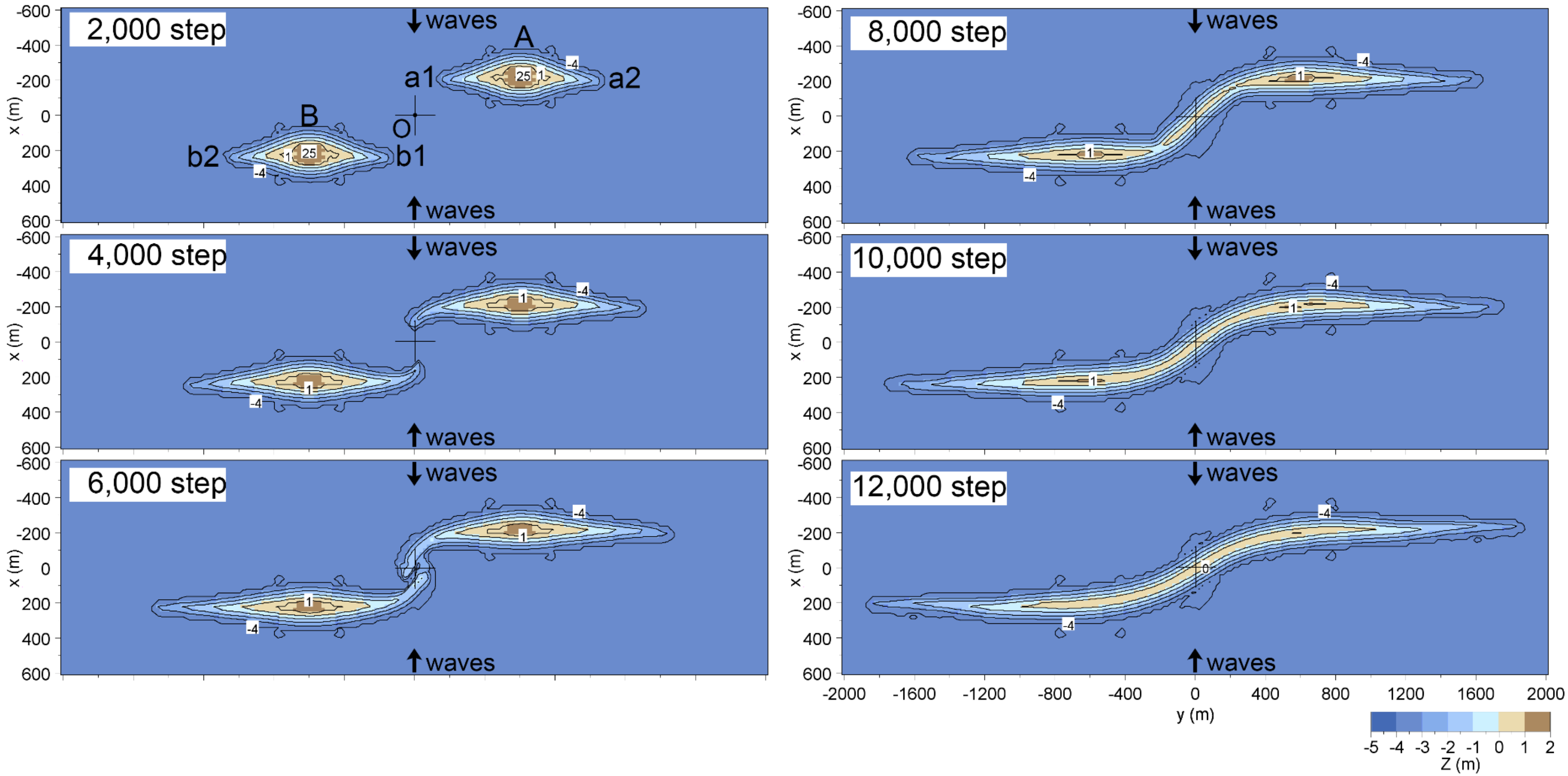


Calculation results of connection of two islands

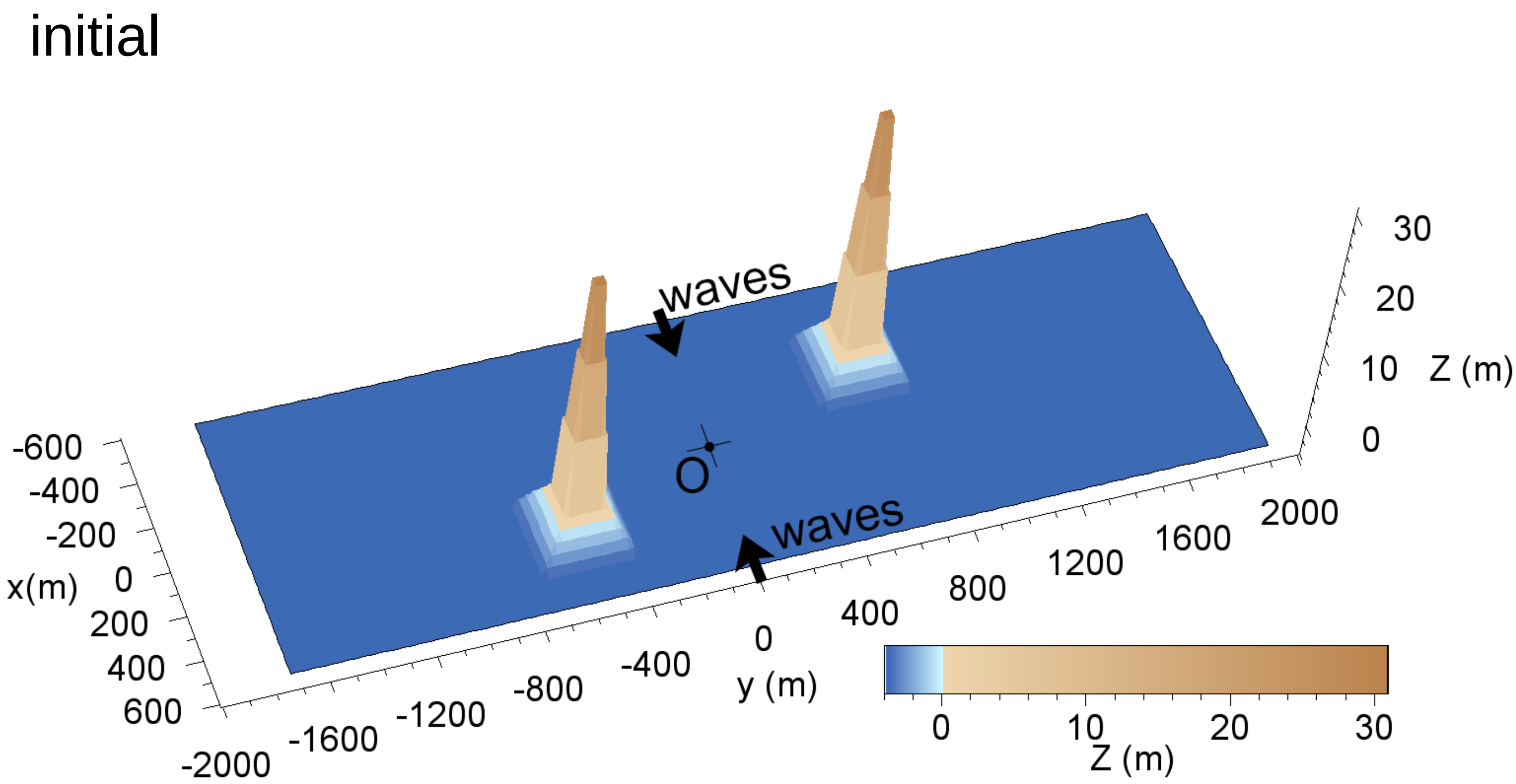


Calculation results of connection of two islands

•cuspate foreland •slender sand bar

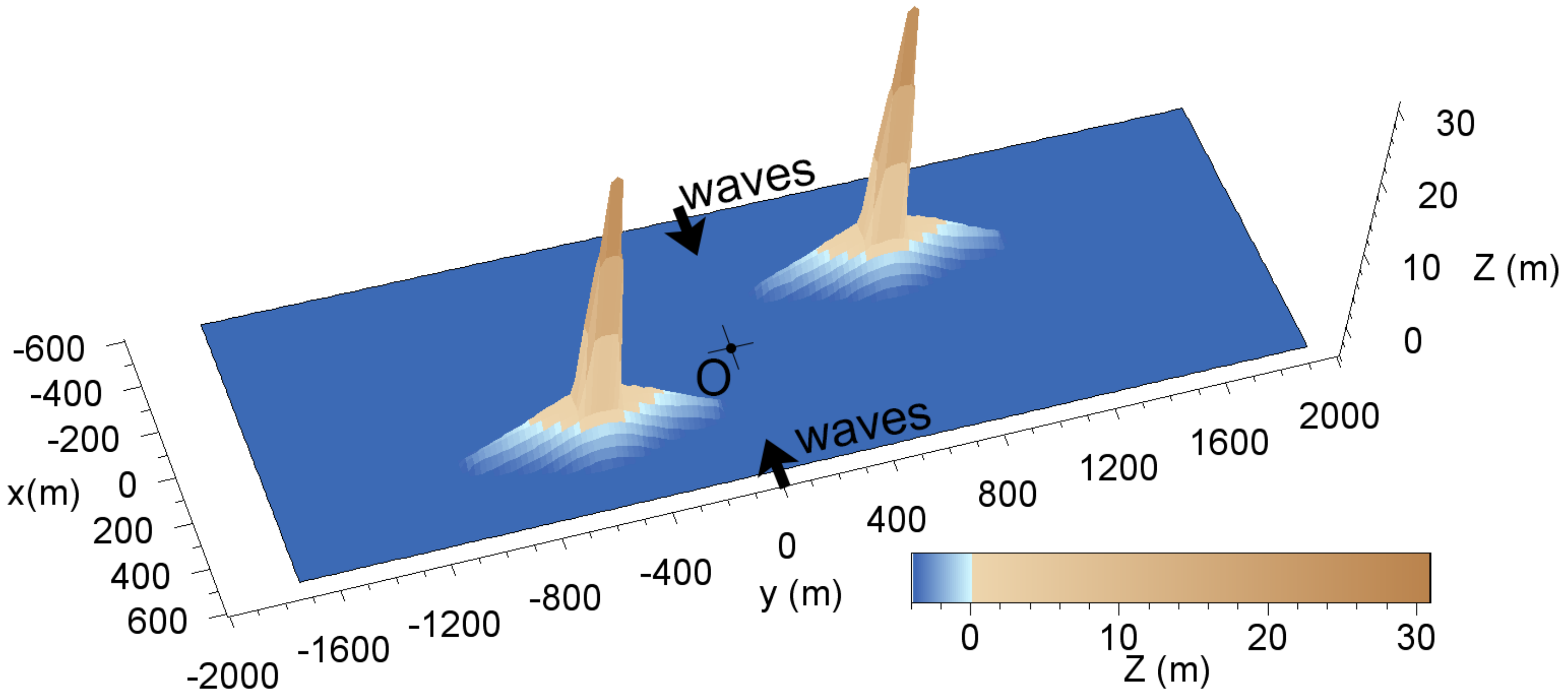


Calculation results (bird's eye view)



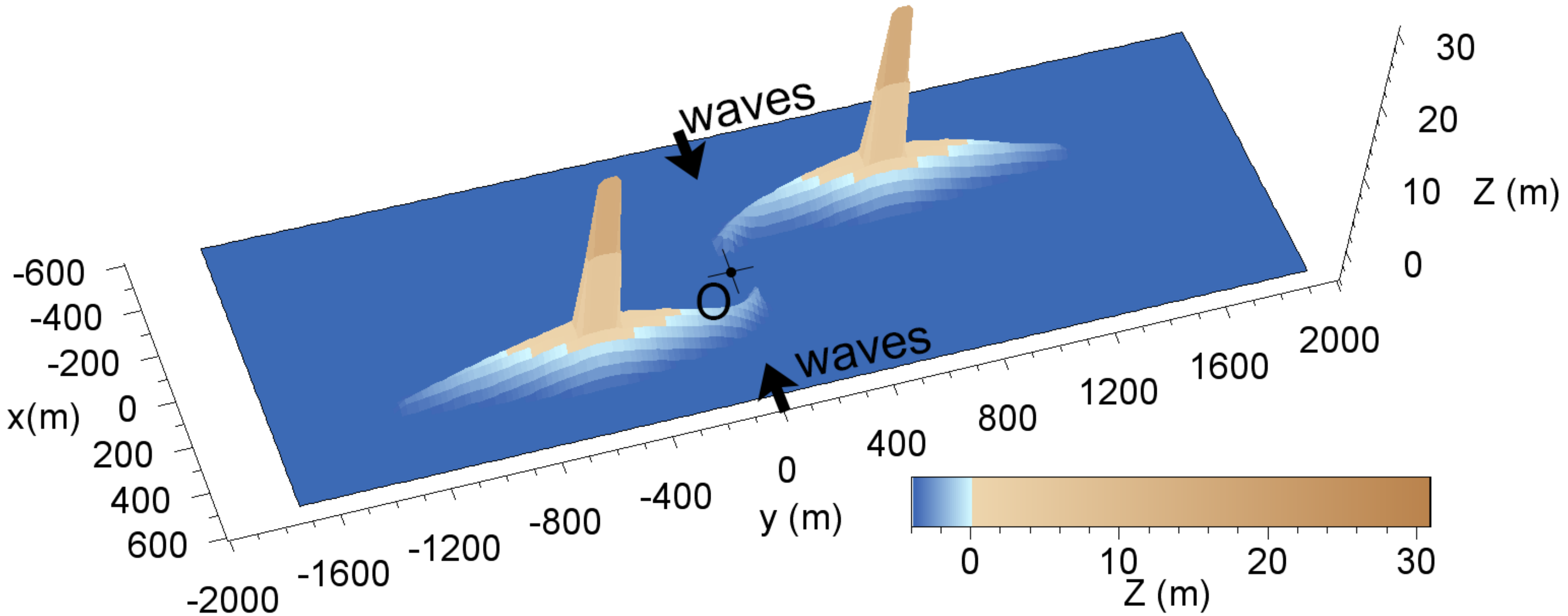
Calculation results (bird's eye view)

2,000 steps



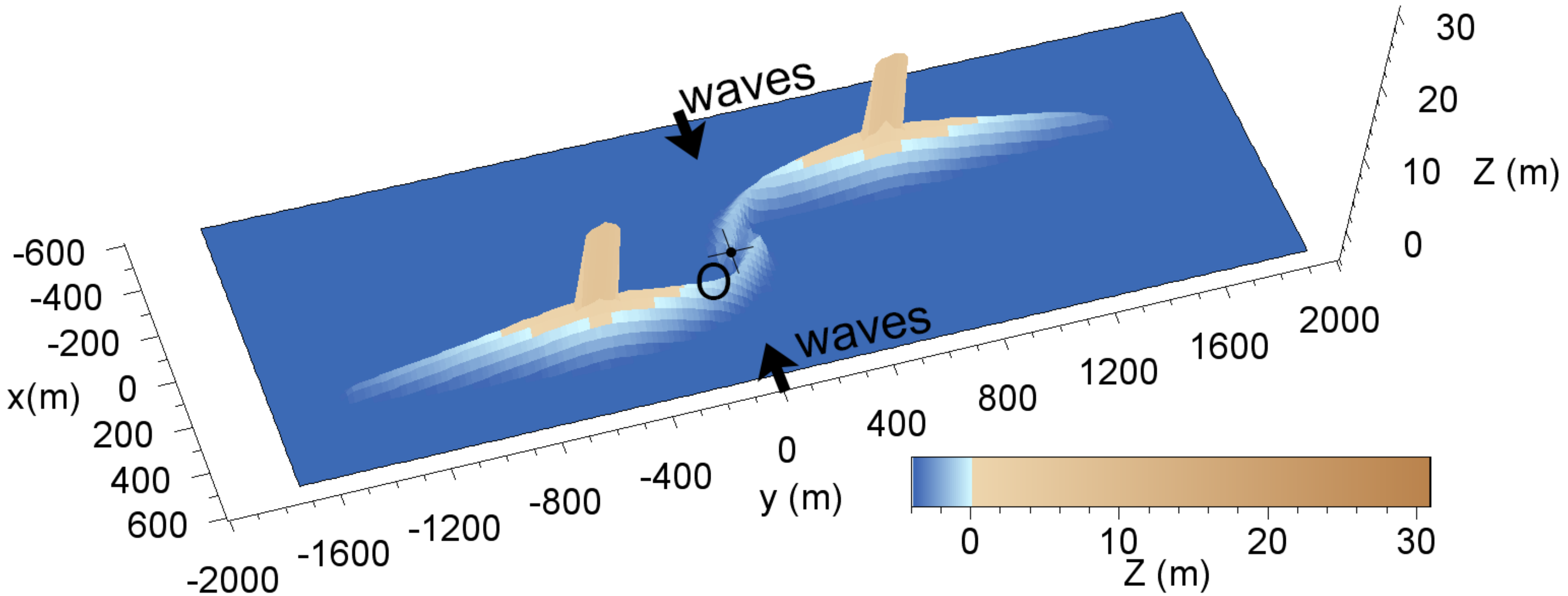
Calculation results (bird's eye view)

4,000 steps



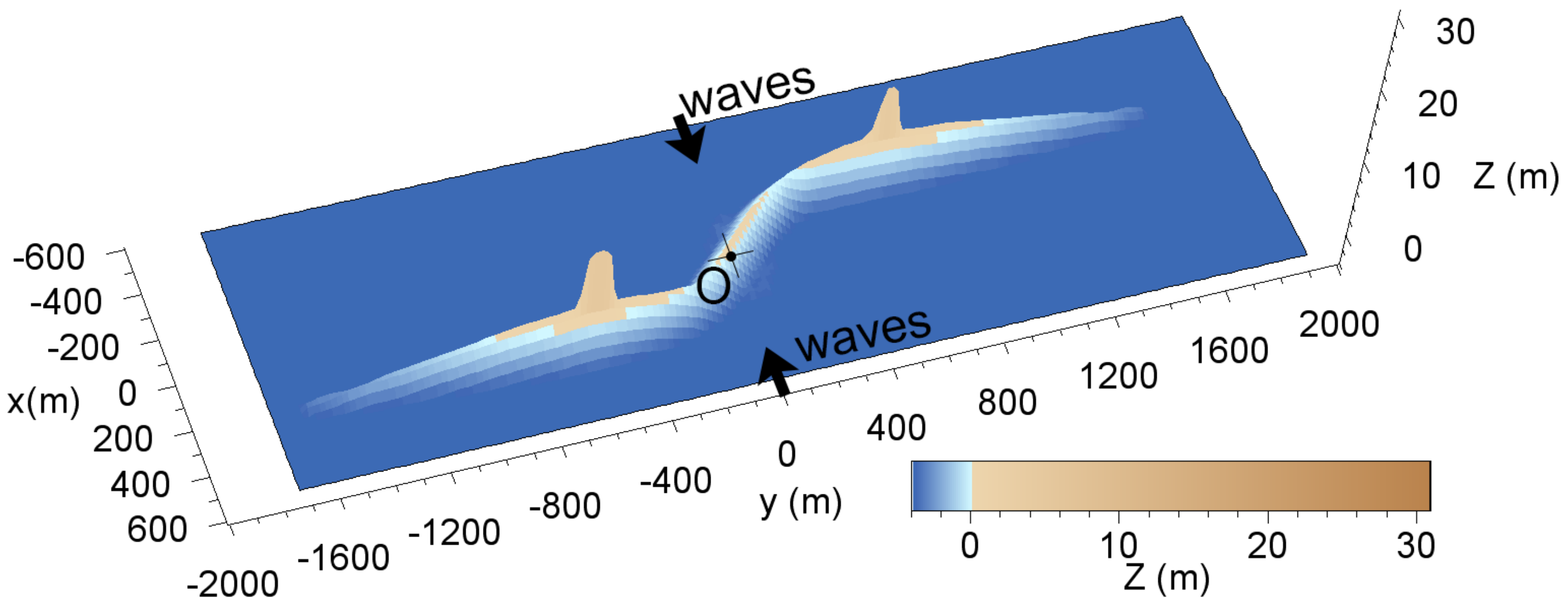
Calculation results (bird's eye view)

6,000 steps



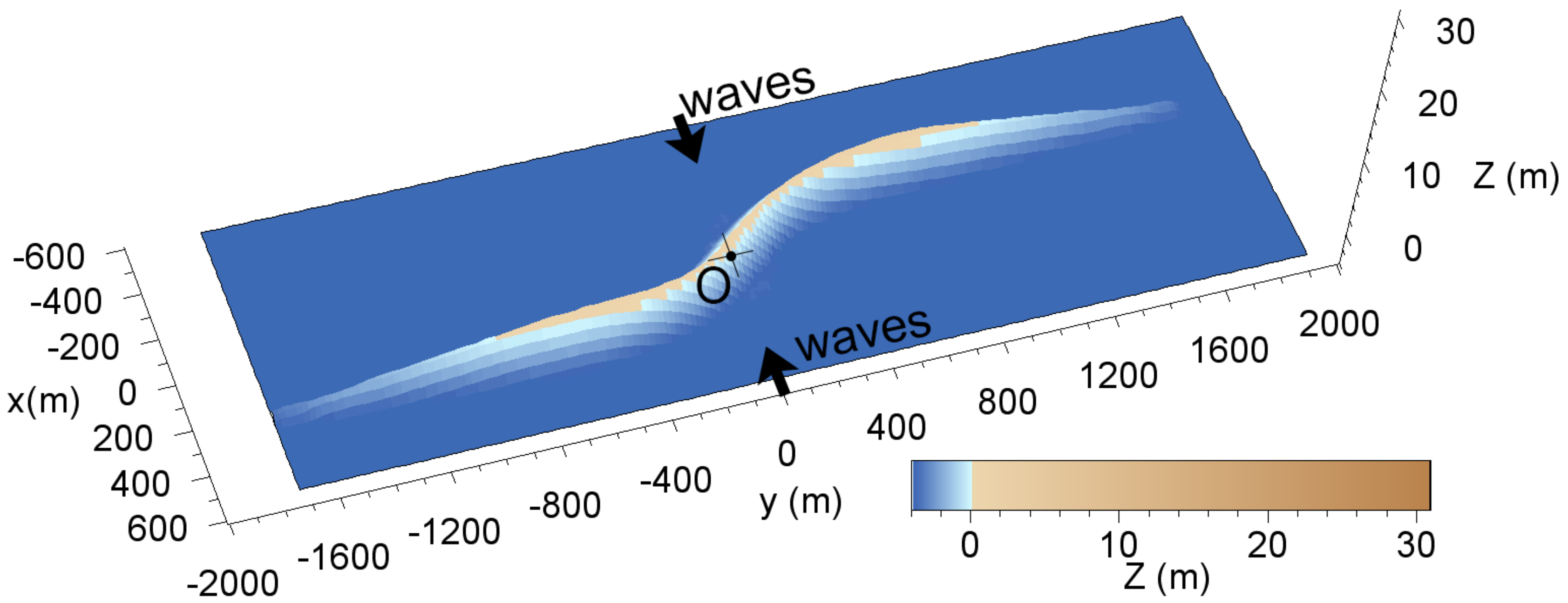
Calculation results (bird's eye view)

8,000 steps



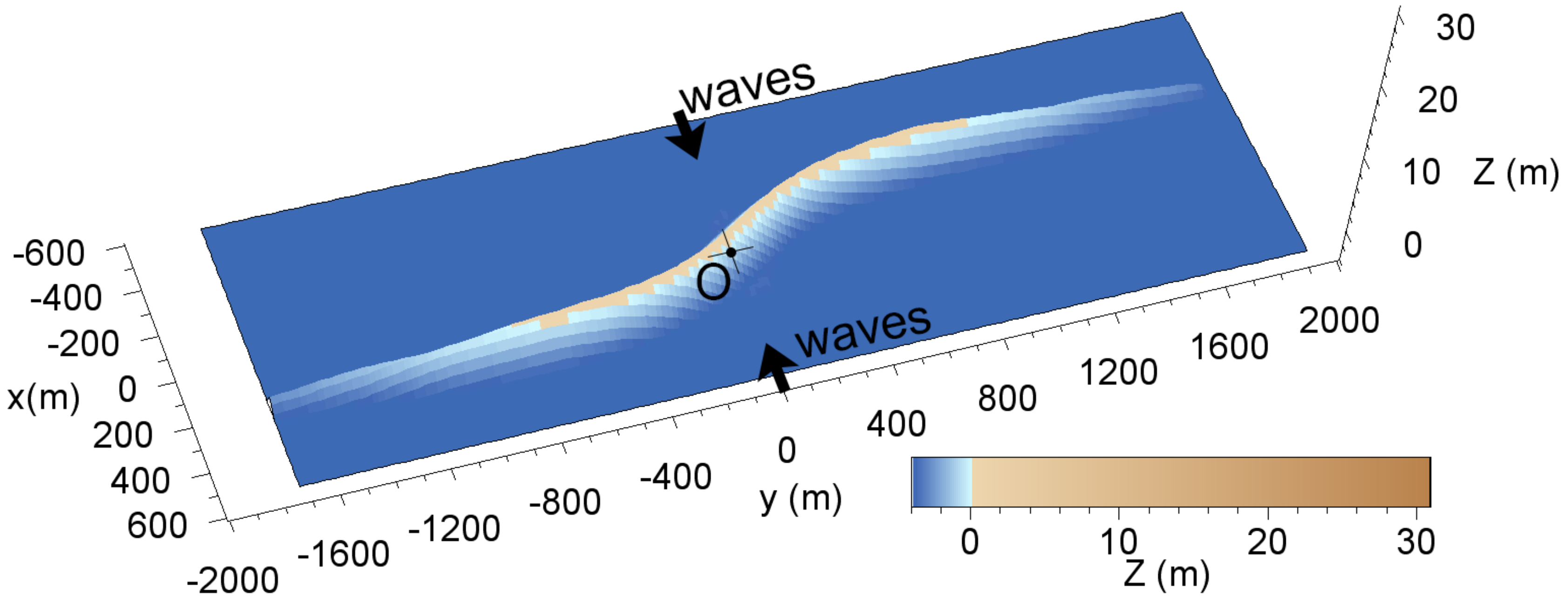
Calculation results (bird's eye view)

10,000 steps

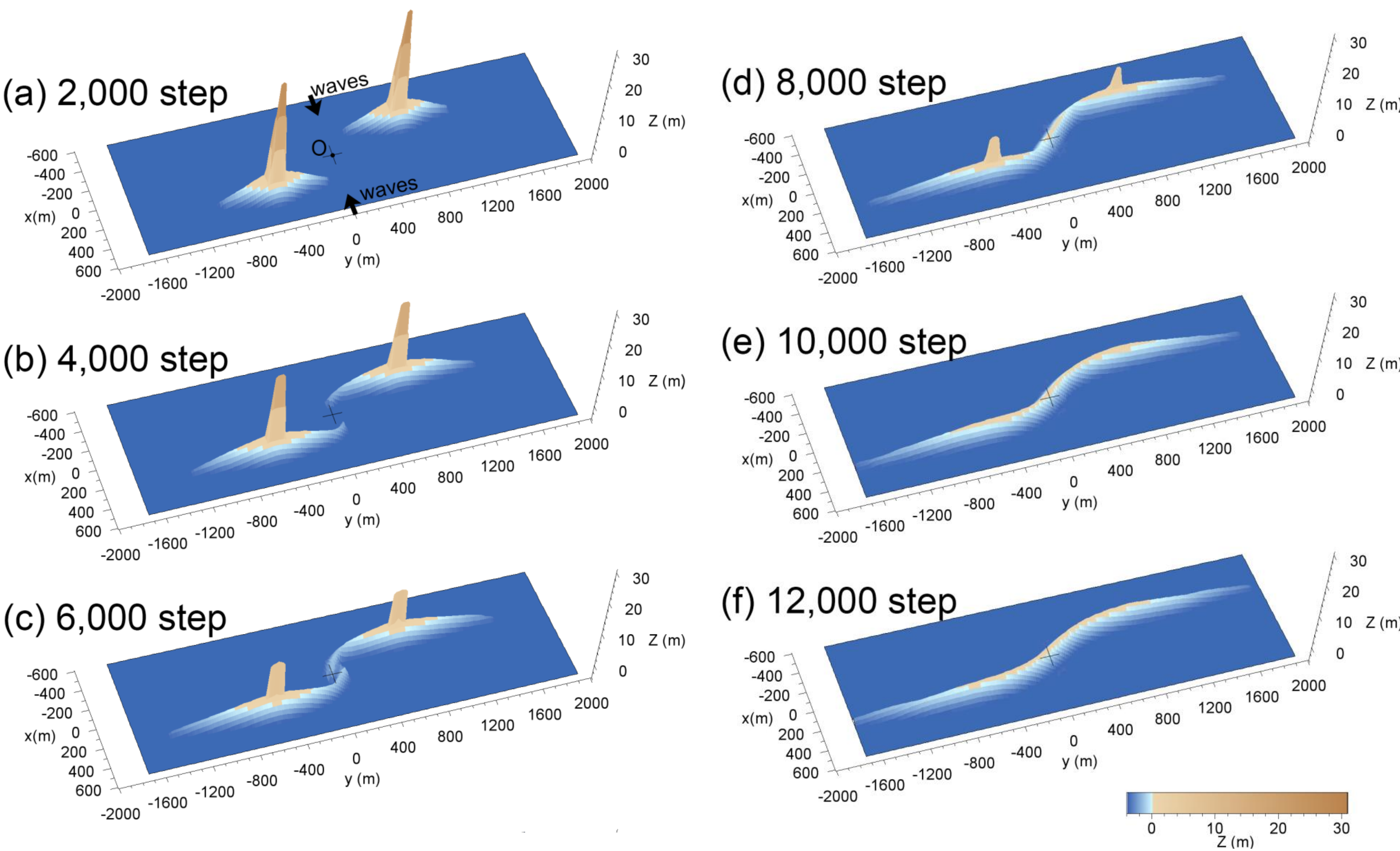


Calculation results (bird's eye view)

12,000 steps



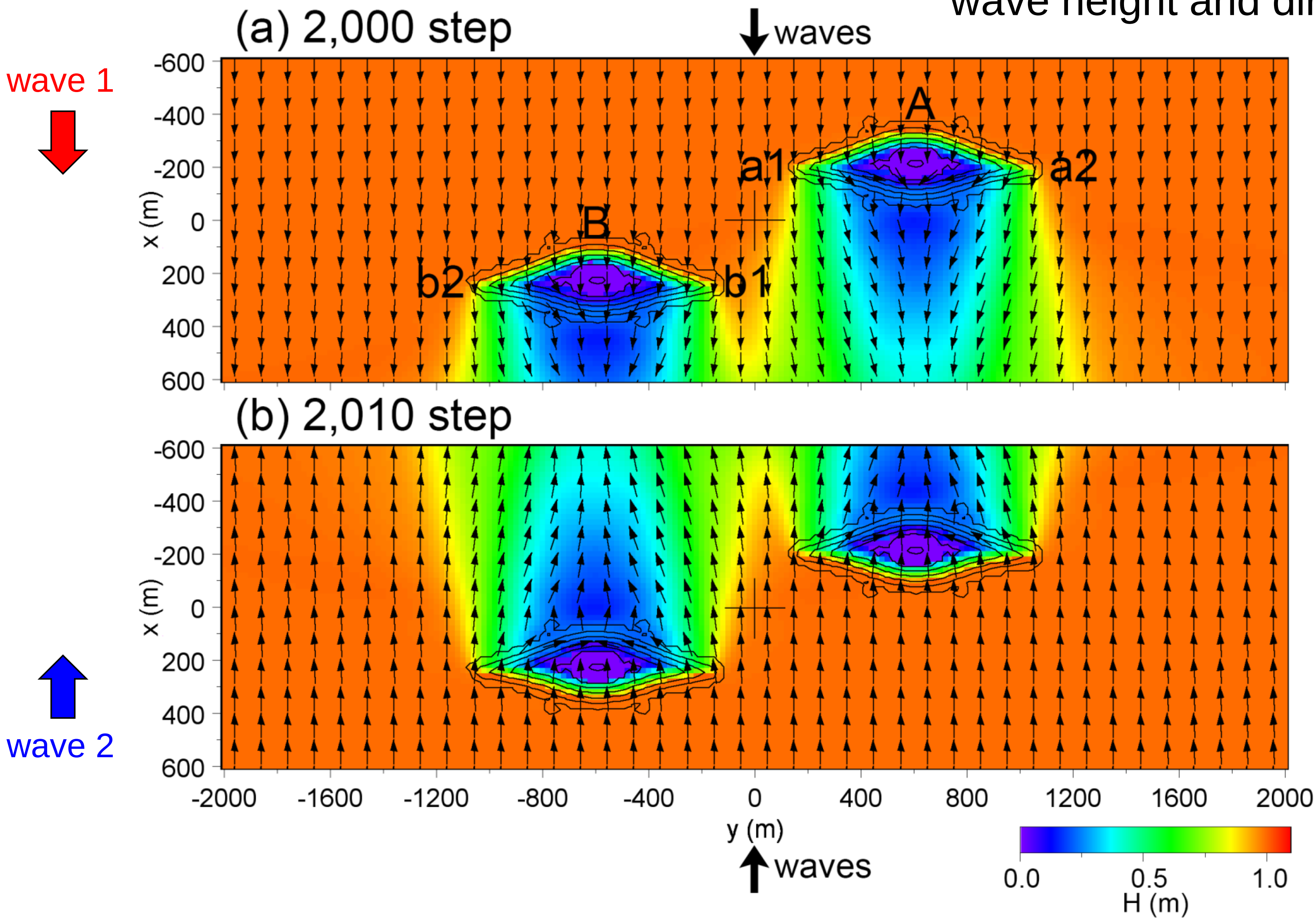
Calculation results (bird's eye view)



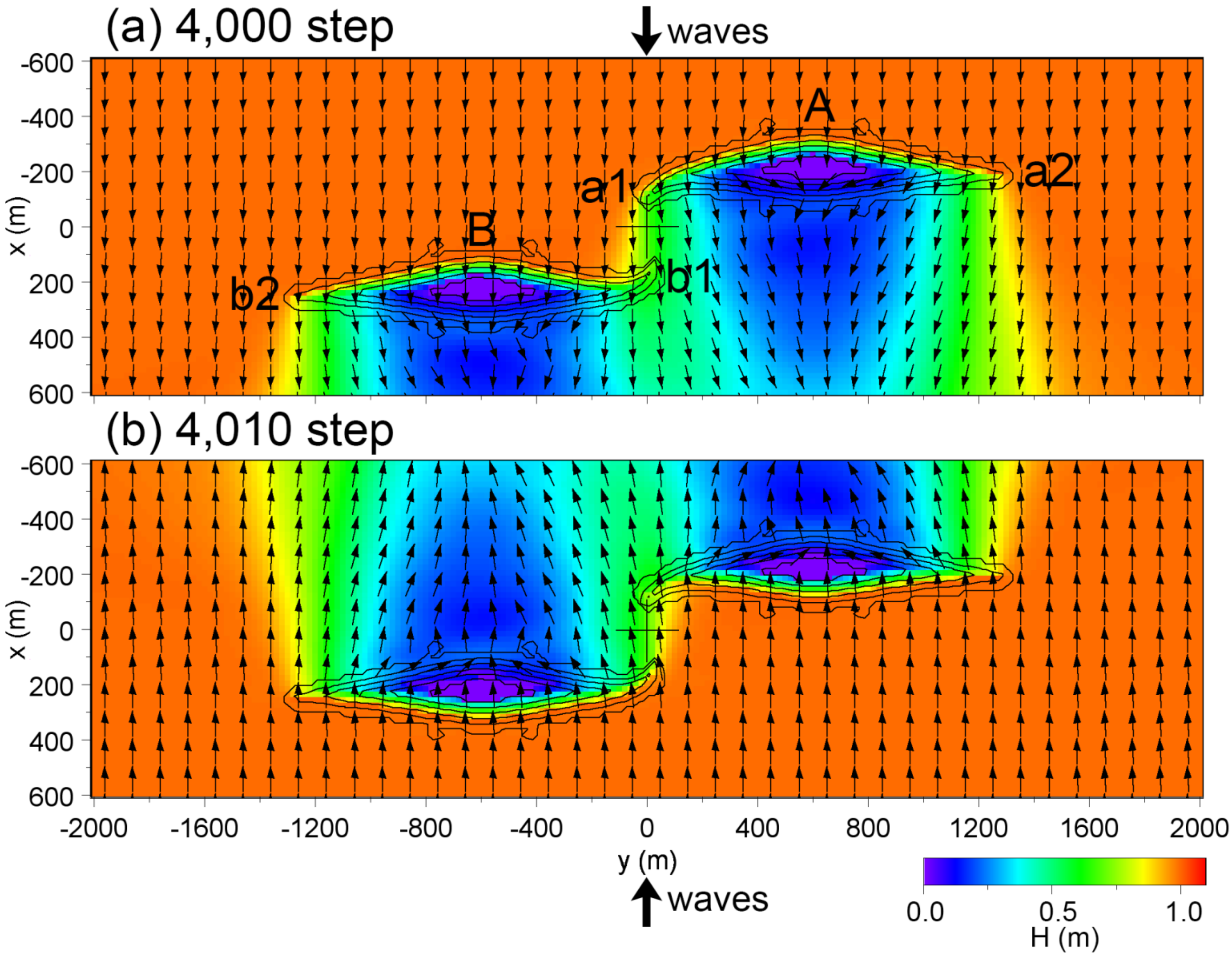
•cuspate foreland •slender sand bar

Wave field

wave height and direction

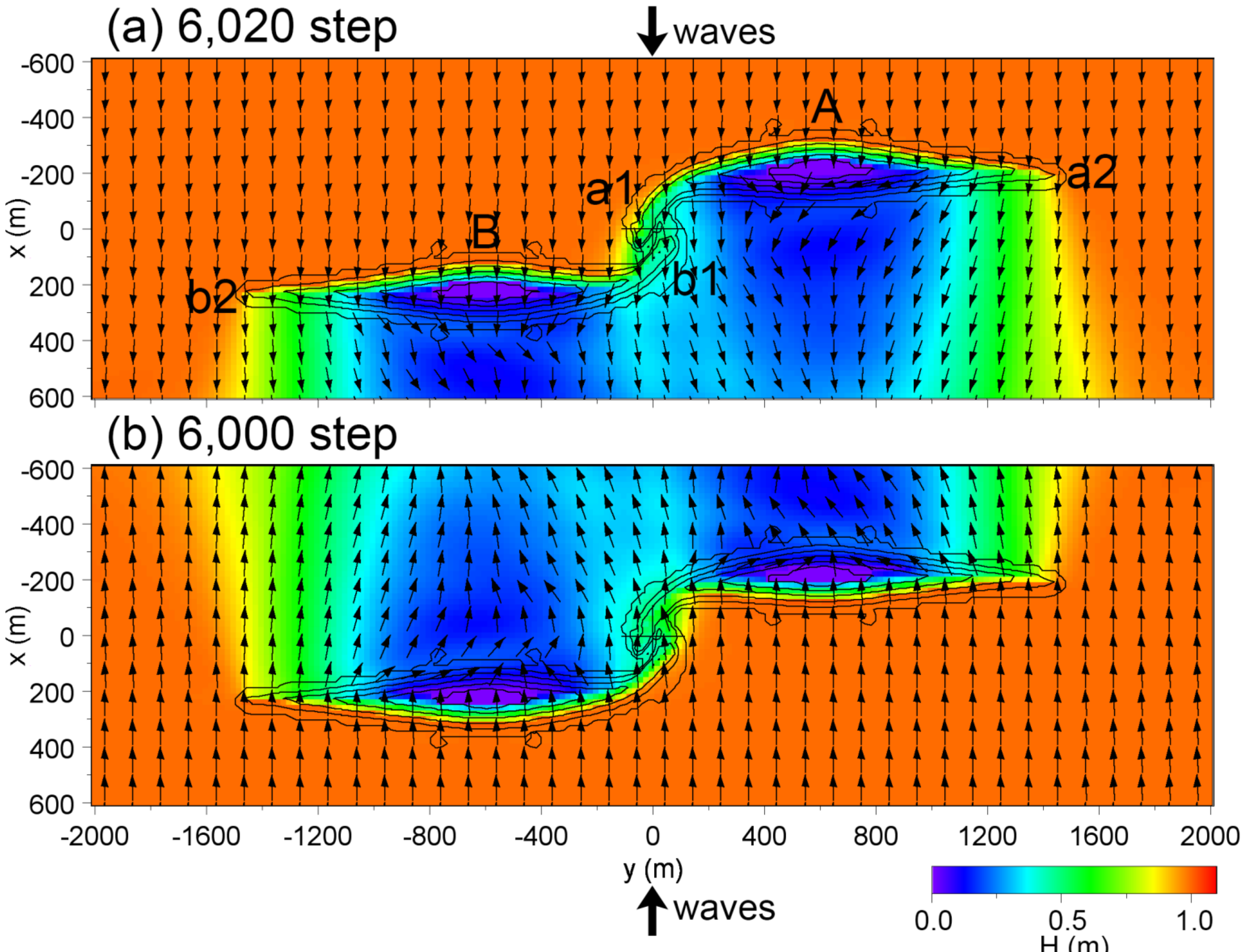


Wave field



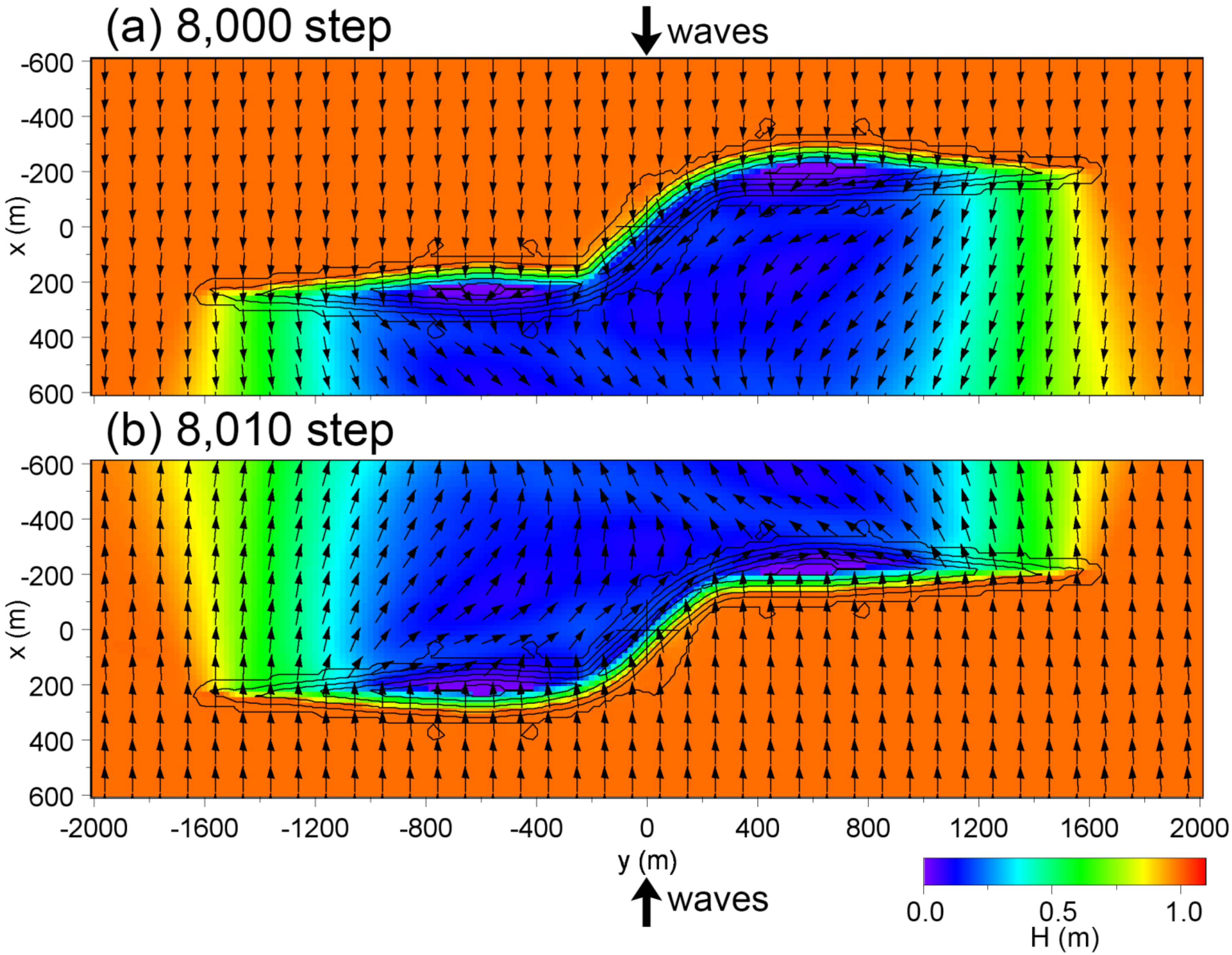
(a) 4,000 step
waves
A
a1
a2
B
b1
b2
x (m)
-600
-400
-200
0
200
400
600
(b) 4,010 step
-600
-400
-200
0
200
400
600
x (m)
-2000
-1600
-1200
-800
-400
0
400
800
1200
1600
2000
y (m)
waves
0.0
0.5
1.0
H (m)

Wave field



(a) 6,020 step
waves
A
a1
a2
B
b1
b2
x (m)
-600
-400
-200
0
200
400
600
(b) 6,000 step
x (m)
-600
-400
-200
0
200
400
600
-2000
-1600
-1200
-800
-400
0
400
800
1200
1600
2000
y (m)
waves
0.0
0.5
1.0
H (m)

Wave field

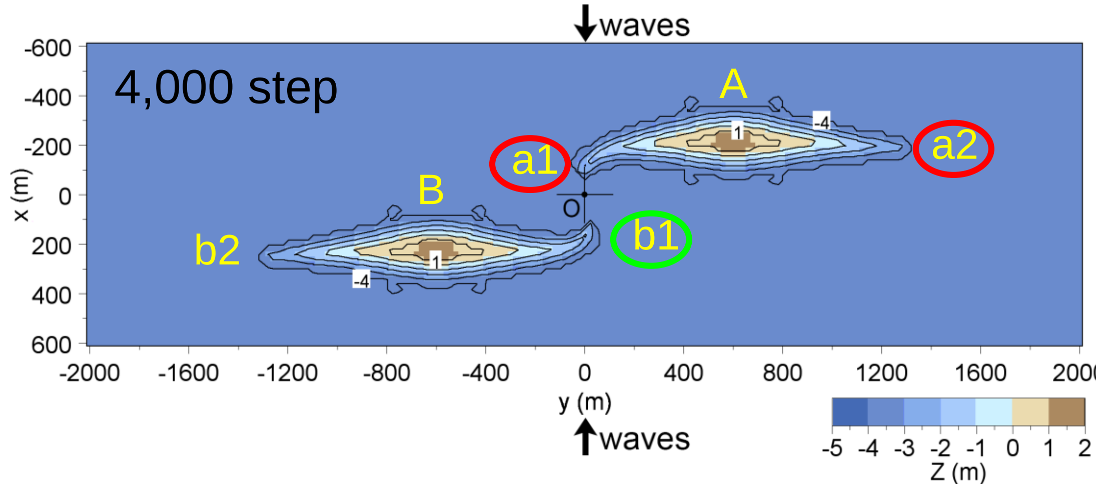


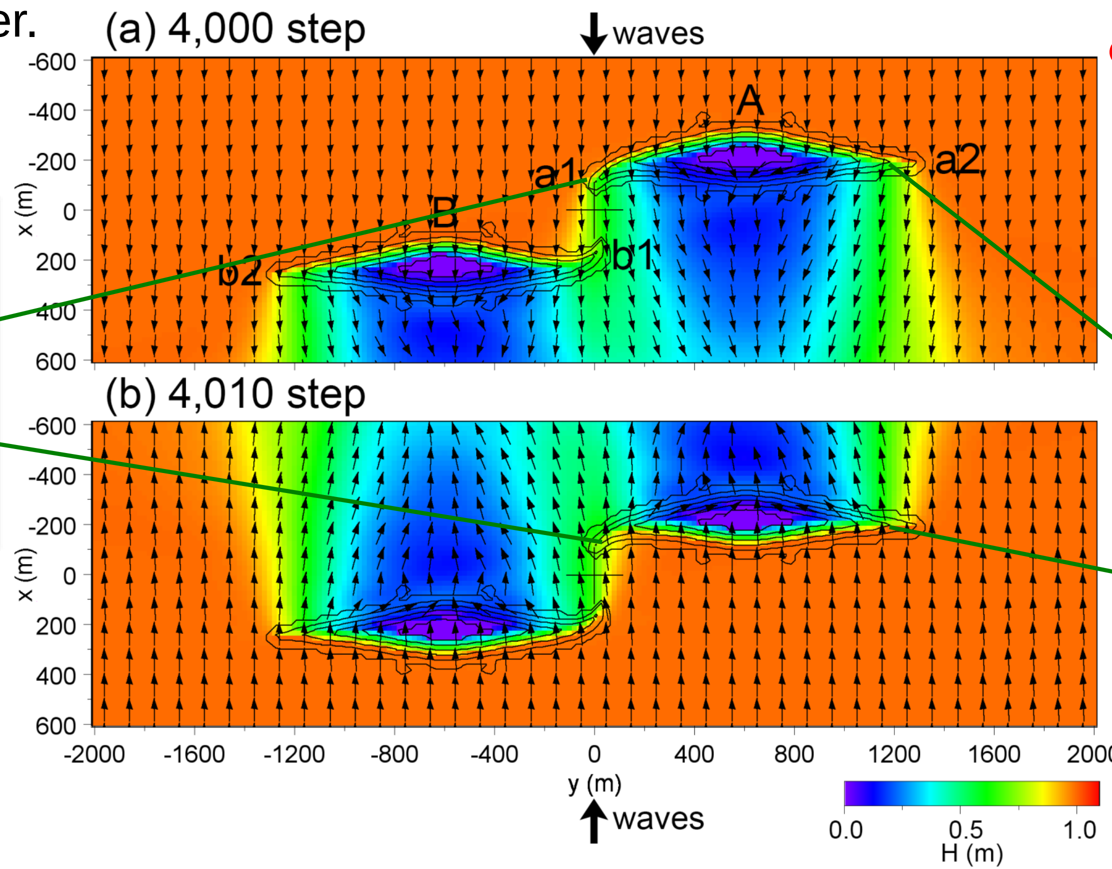
(a) 8,000 step
waves
-600
-400
-200
0
200
400
600
x (m)
(b) 8,010 step
-600
-400
-200
0
200
400
600
x (m)
-2000
-1600
-1200
-800
-400
0
400
800
1200
1600
2000
y (m)
waves
0.0
0.5
1.0
H (m)

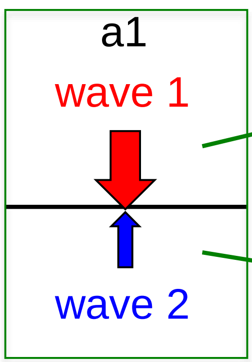
Wave-sheltering effect of one island on the other island

- At a1, action of wave2 is small due to wave-sheltering effect of b1.

  So, a1 moves downward.
- In the same way, b1 moves upward.
- As a result, a1 and b1 connect with each other.

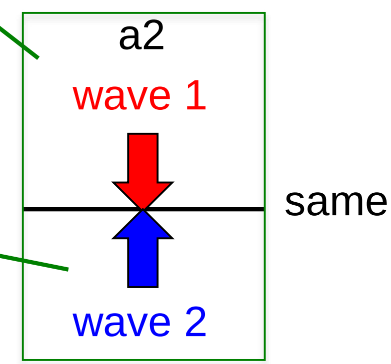






balance of action of 2 waves

- At a2, action of wave2 is same as wave1. So, a2 moves just right beside.

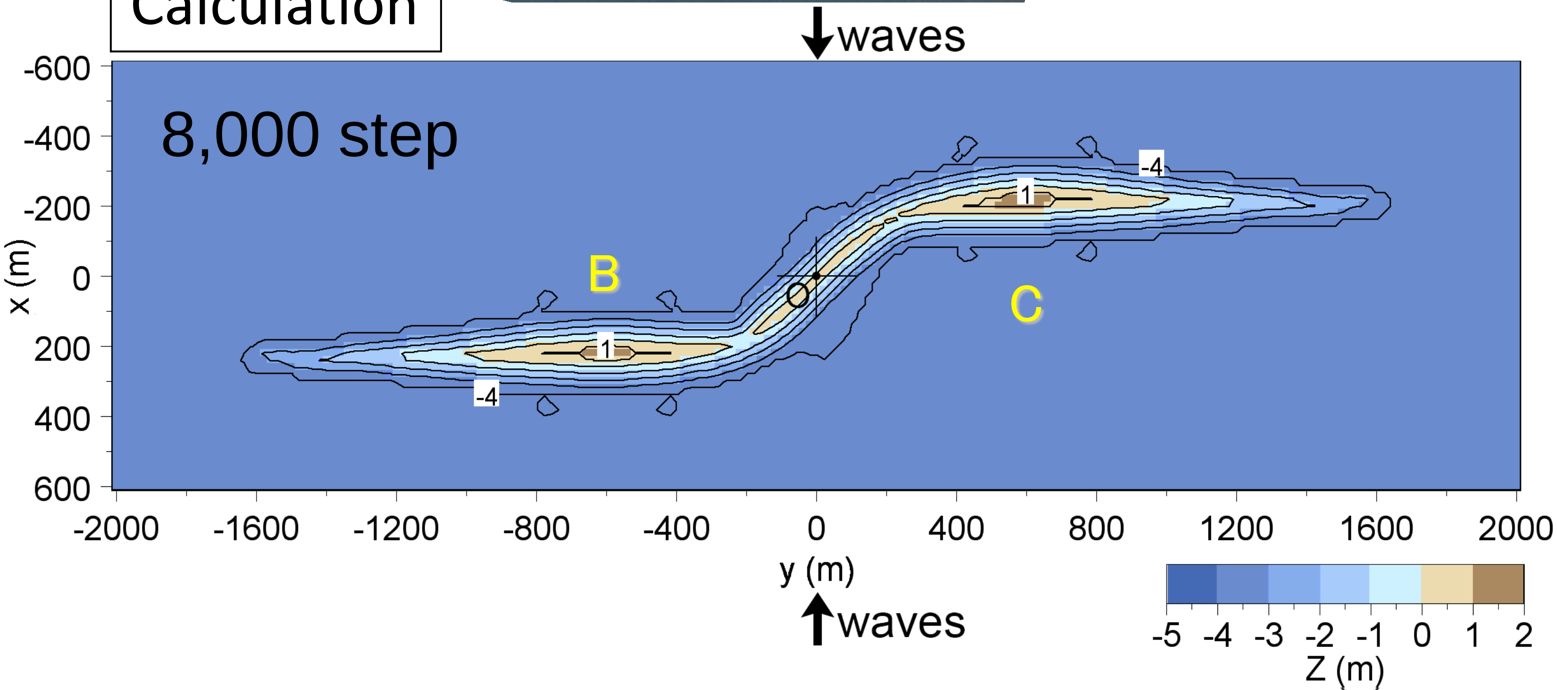


balance of action of 2 waves

Comparison with site observation

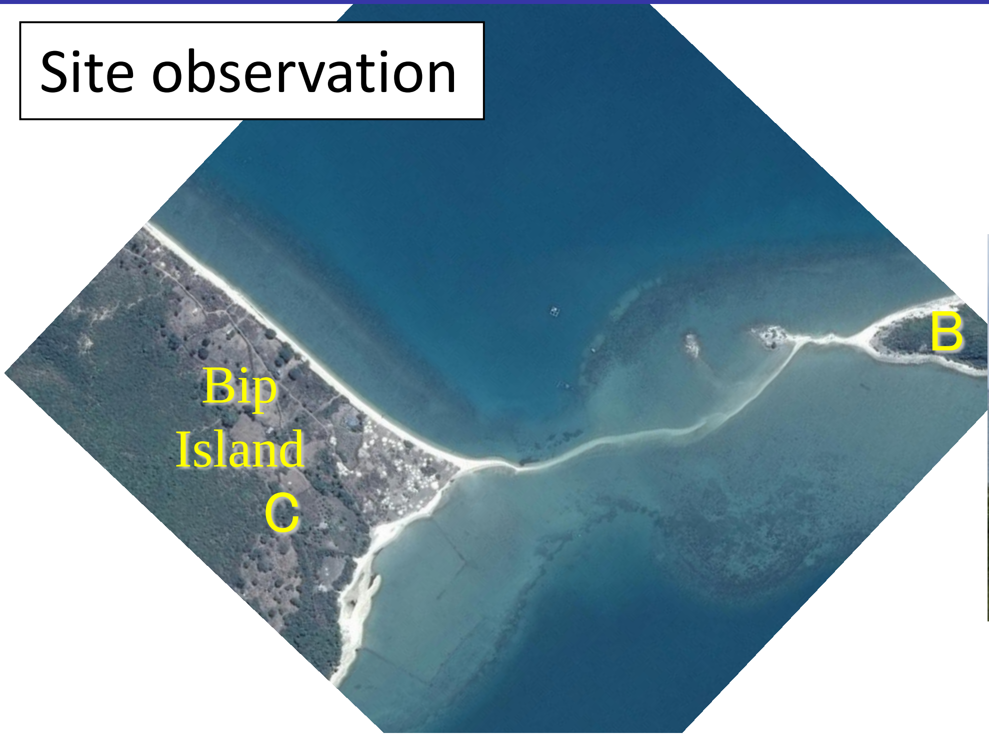
Site observation

Calculation

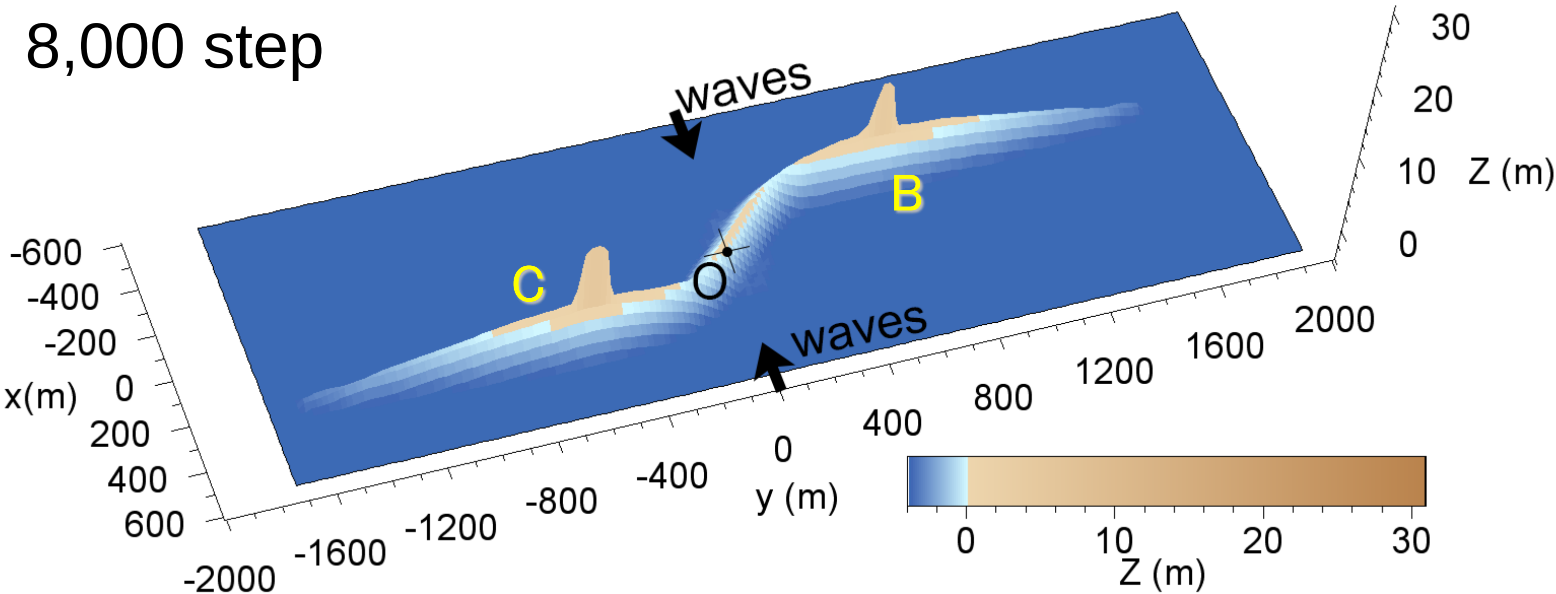


Comparison with site observation

Site observation



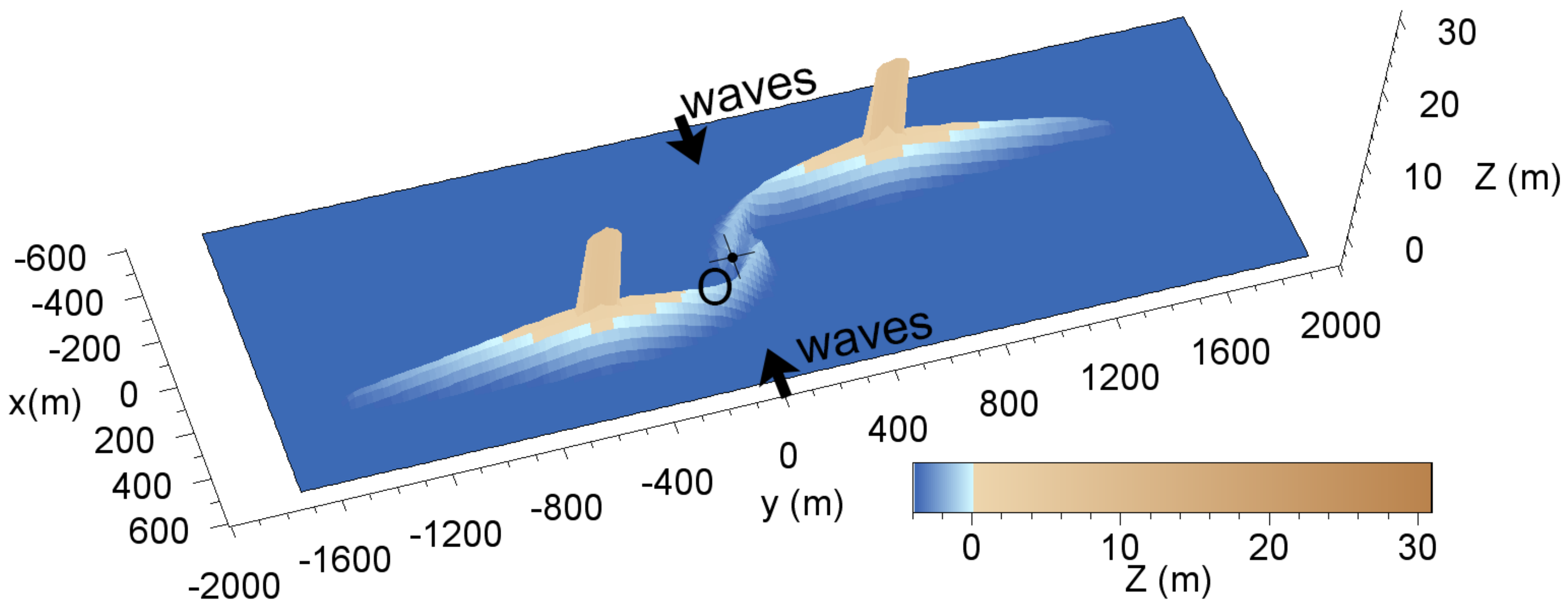
Calculation 8,000 step



CONCLUSION

- The mechanism of beach changes associated with interaction and mergence of multiple islands was successfully explained by the numerical simulation using the BG model .

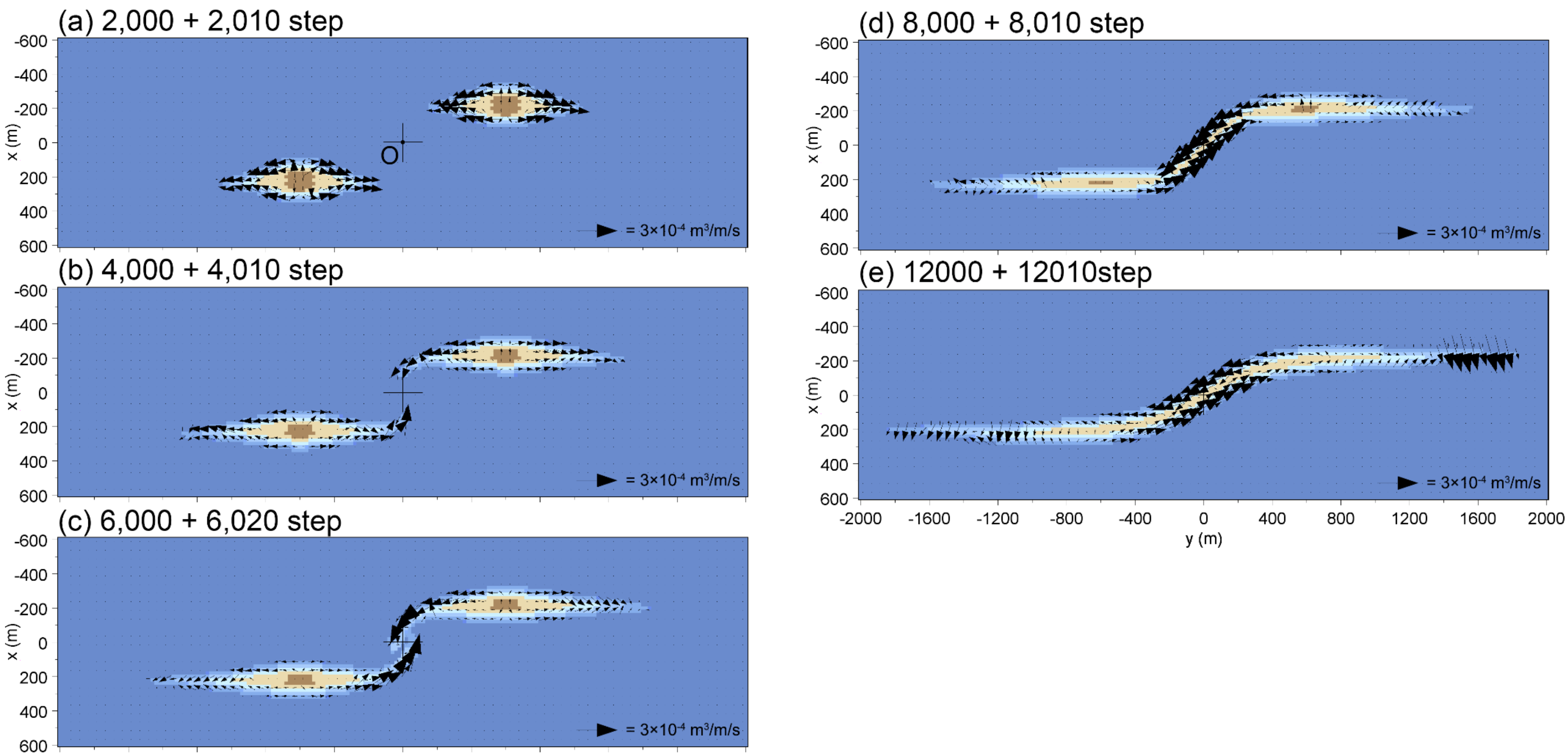
6,000 step



Calculation conditions.

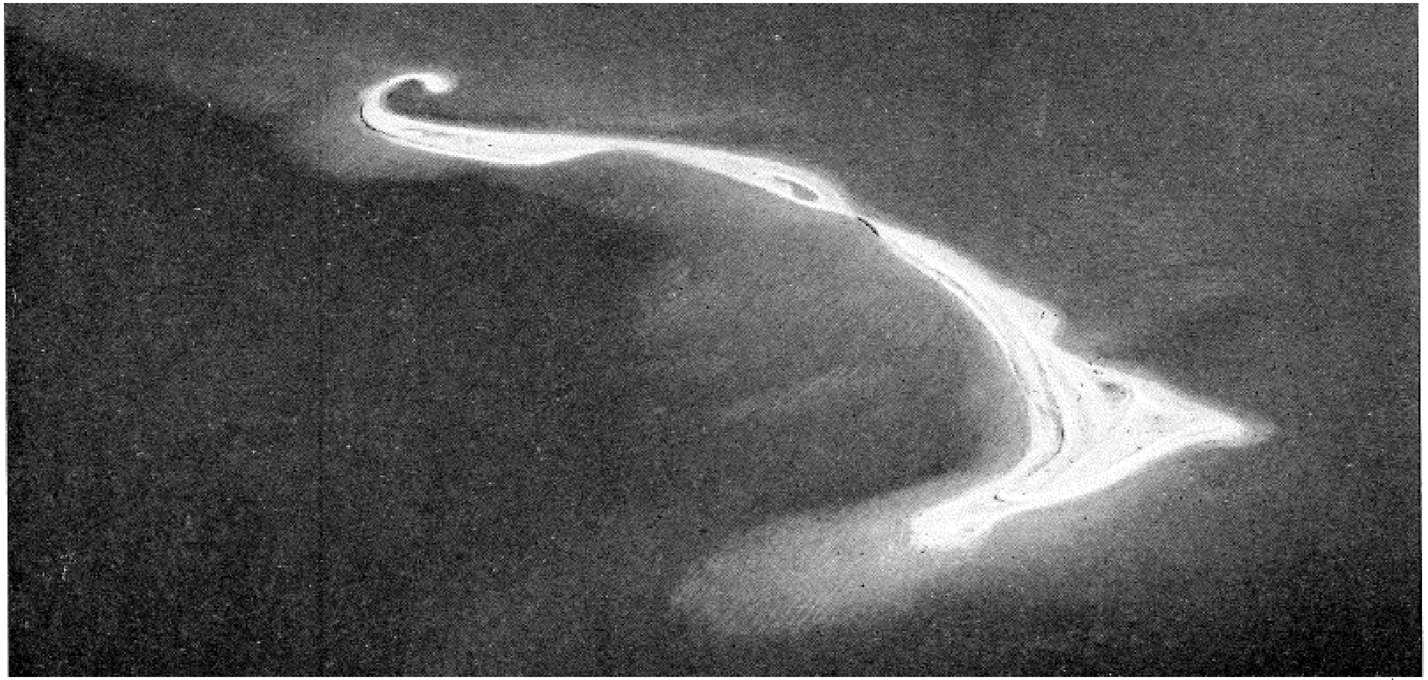
Wave conditions	Incident waves: H_I = 1 m, T = 4 s, wave direction θ_I = 0° and 180° relative to -x axis
Berm height	h_R = 1 m
Depth of closure	h_c = 4 m
Equilibrium slope	$\tan\beta_c$ = 1/20
Coefficients of sand transport	Coefficient of longshore sand transport K_s = 0.2 Coefficient of Ozasa and Brampton[10] term K_2=1.62K_s Coefficient of cross-shore sand transport K_n = K_s
Mesh size	Δx = Δy = 20 m
Time intervals	Δt = 0.5 hr
Duration of calculation	0.7×10^4 hr (1.4×10^4 steps)
Boundary conditions	Shoreward and landward ends: q_x = 0, right and left boundaries: q_y = 0
Calculation of wave field	Energy balance equation[5] • Term of wave dissipation due to wave breaking: Dally et al. [11] model • Wave spectrum of incident waves: directional wave spectrum density obtained by Goda [12] • Total number of frequency components N_F = 1 and number of directional subdivisions N_θ = 8 • Directional spreading parameter S_{max} = 25 • Coefficient of wave breaking K = 0.17 and Γ = 0.3 • Imaginary depth between minimum depth h_0 (0.5 m) and berm height h_R • Wave energy = 0 where $Z \geqq h_R$ • Lower limit of h in terms of wave decay due to breaking: 0.5 m

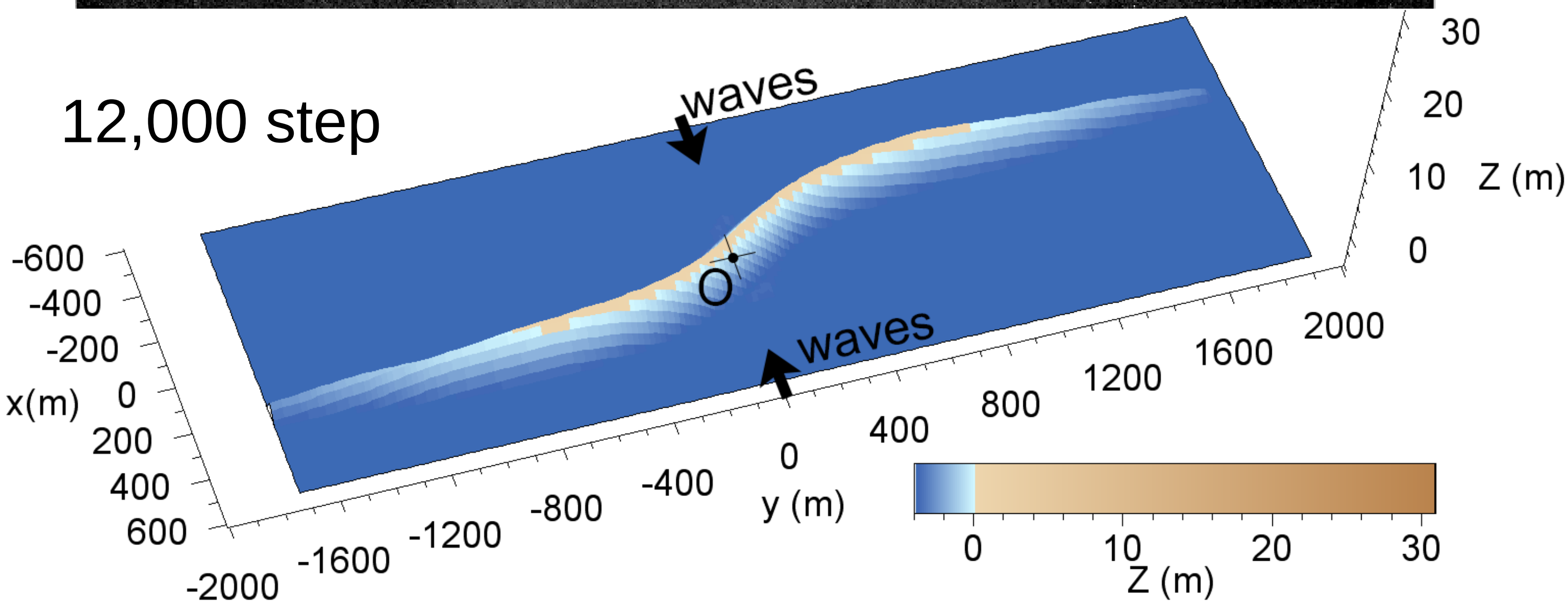
sand flux



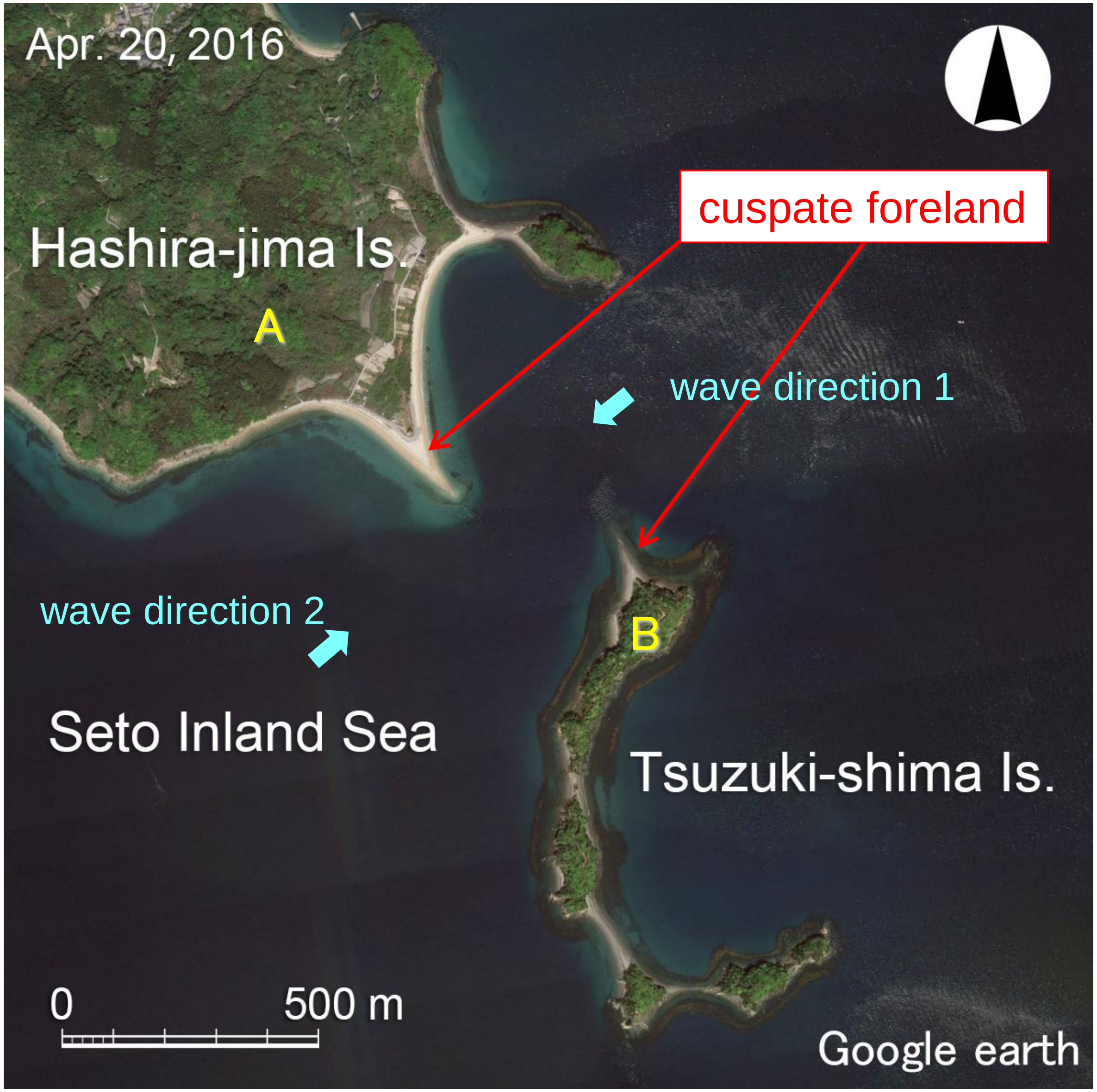
(a) 2,000 + 2,010 step
(b) 4,000 + 4,010 step
(c) 6,000 + 6,020 step
(d) 8,000 + 8,010 step
(e) 12000 + 12010step
x (m)
y (m)
O
= 3×10⁻⁴ m³/m/s
-600
-400
-200
0
200
400
600
-2000
-1600
-1200
-800
-400
0
400
800
1200
1600
2000

浅い海域にできた2つの孤立砂州の連結 (Zenkovich,1967)





Cuspate forelands extending between Hashira-jima and Tsuzuki-shima Islands in the Seto Inland Sea, Japan.



Cuspate foreland on Bijindo Island offshore of Busan in Korea.

Cuspate forelands extending from islands and connected with each other

Cuspate foreland formed at tips of multiple islands in Kara Sea