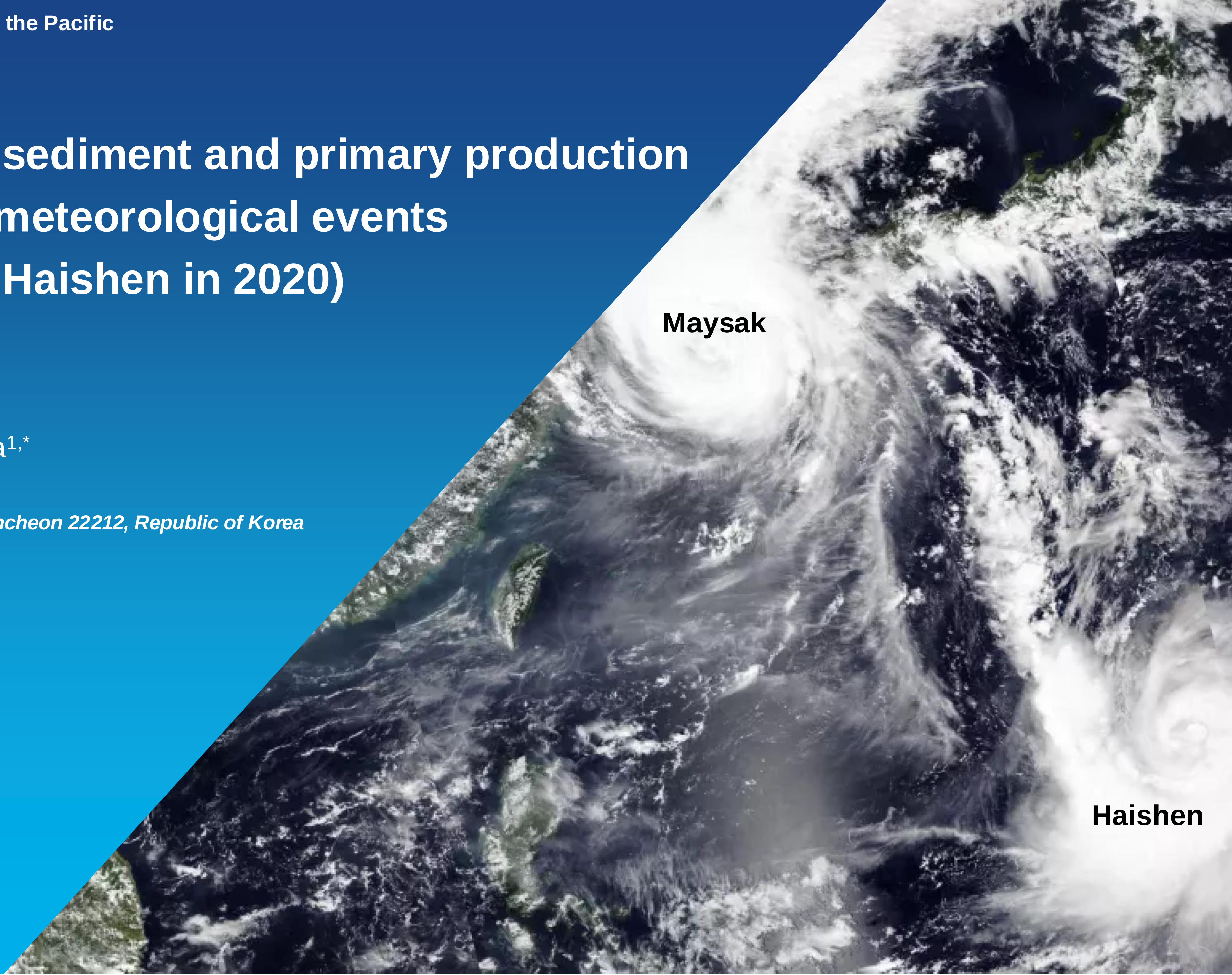
Disturbance in benthic sediment and primary production in tidal flat by extreme meteorological events (typhoons Maysak and Haishen in 2020)



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I Introduction

II Materials and methods

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V Conclusions

Marine environments in Korea

- One of the largest tidal range around the world
- High concentration of suspended sediments
- Tidal flats and estuaries

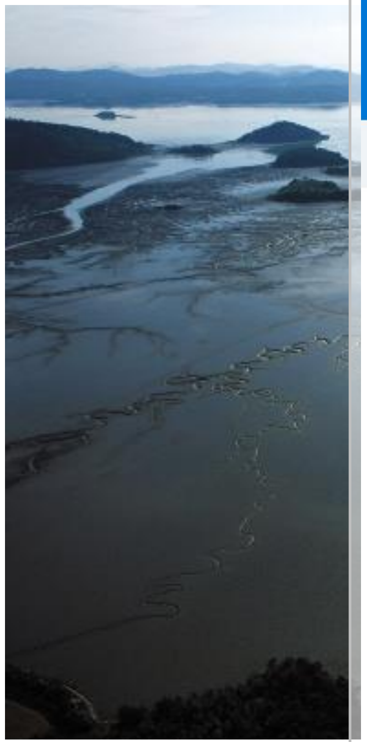
- Deep water depth
- Relatively uniform coastline
- Sand beaches

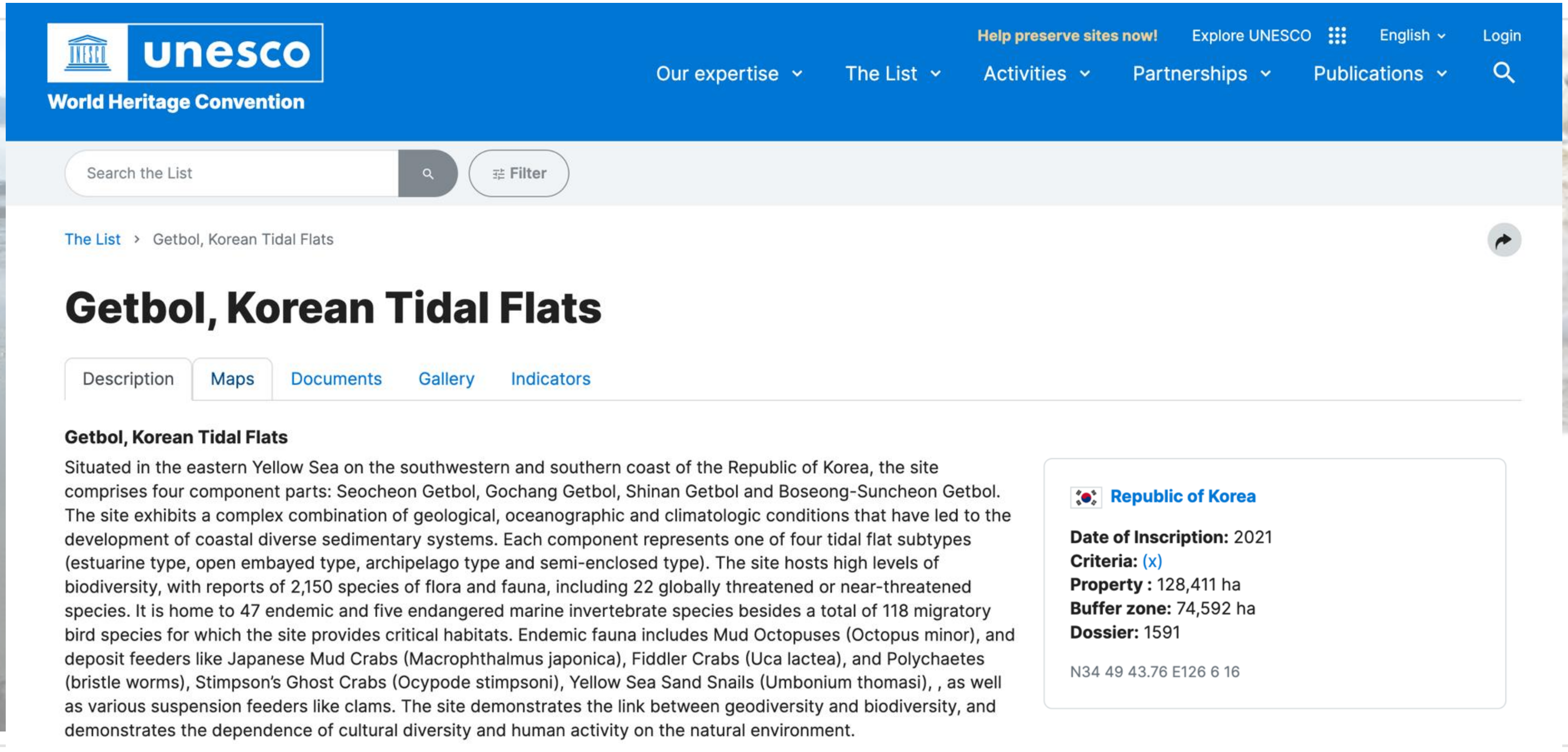
- 60% of islands of Korea are located
- High biodiversity and productivity

Tidal flats in Korea: Getbol

- Tidal flats in Korea show one of the most distinctive features around the world
- **"Mega-tidal range"** and **"high suspended sediment concentration (SSC)"** developed extensive tidal flats
- The tidal flats in Korea are important to both nature and human communities

Tidal flats in Korea: Getbol





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Getbol, Korean Tidal Flats

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Getbol, Korean Tidal Flats

Situated in the eastern Yellow Sea on the southwestern and southern coast of the Republic of Korea, the site comprises four component parts: Seocheon Getbol, Gochang Getbol, Shinan Getbol and Boseong-Suncheon Getbol. The site exhibits a complex combination of geological, oceanographic and climatologic conditions that have led to the development of coastal diverse sedimentary systems. Each component represents one of four tidal flat subtypes (estuarine type, open embayed type, archipelago type and semi-enclosed type). The site hosts high levels of biodiversity, with reports of 2,150 species of flora and fauna, including 22 globally threatened or near-threatened species. It is home to 47 endemic and five endangered marine invertebrate species besides a total of 118 migratory bird species for which the site provides critical habitats. Endemic fauna includes Mud Octopuses (Octopus minor), and deposit feeders like Japanese Mud Crabs (Macrophthalmus japonica), Fiddler Crabs (Uca lactea), and Polychaetes (bristle worms), Stimpson's Ghost Crabs (Ocypode stimpsoni), Yellow Sea Sand Snails (Umbonium thomasi), , as well as various suspension feeders like clams. The site demonstrates the link between geodiversity and biodiversity, and demonstrates the dependence of cultural diversity and human activity on the natural environment.

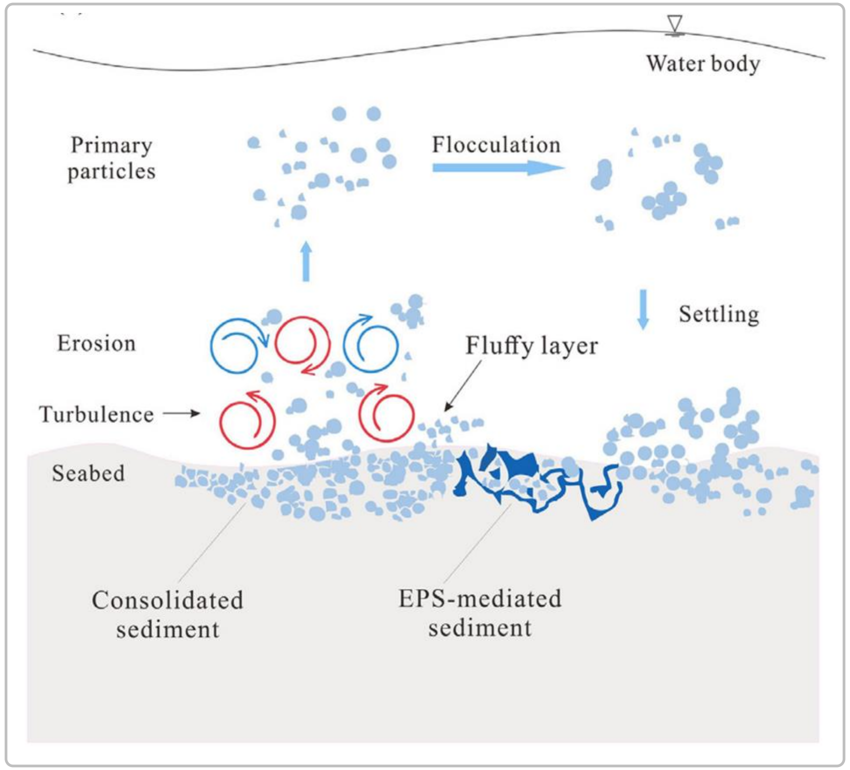
Republic of Korea

Date of Inscription: 2021
Criteria: (x)
Property : 128,411 ha
Buffer zone: 74,592 ha
Dossier: 1591

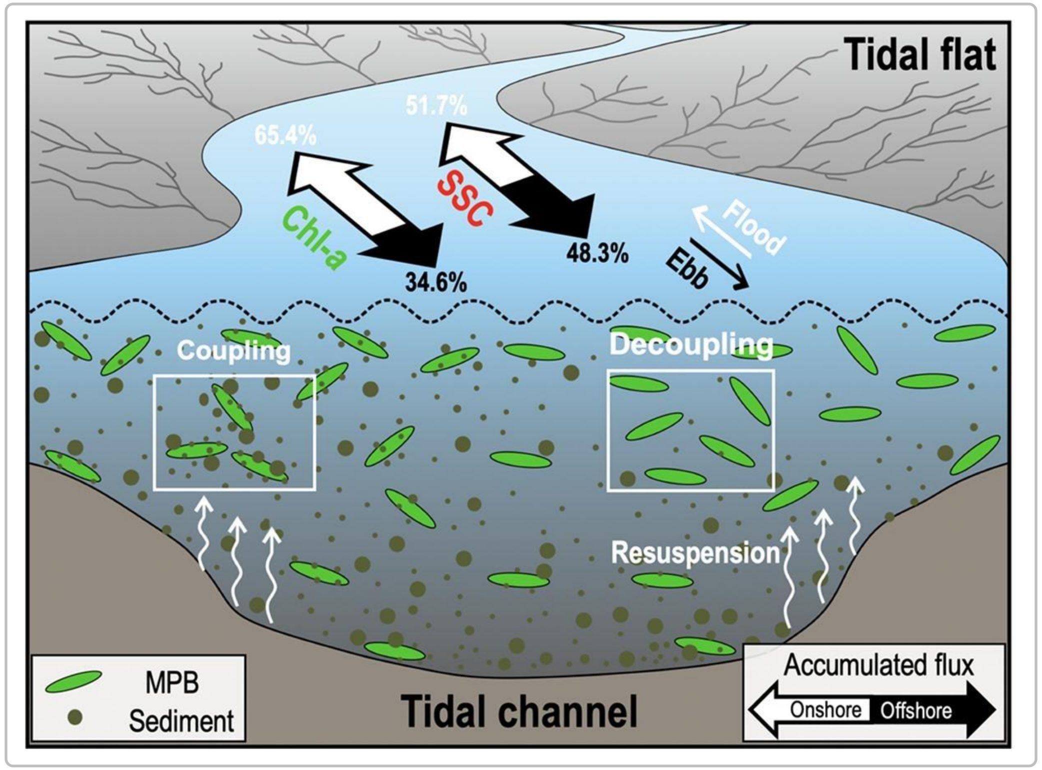
N34 49 43.76 E126 6 16

- Tidal flats in Korea show one of the most distinctive features around the world
- **"Mega-tidal range"** and **"high suspended sediment concentration (SSC)"** developed extensive tidal flats
- The tidal flats in Korea are important to both nature and human communities

Sediment dynamics in tidal flat



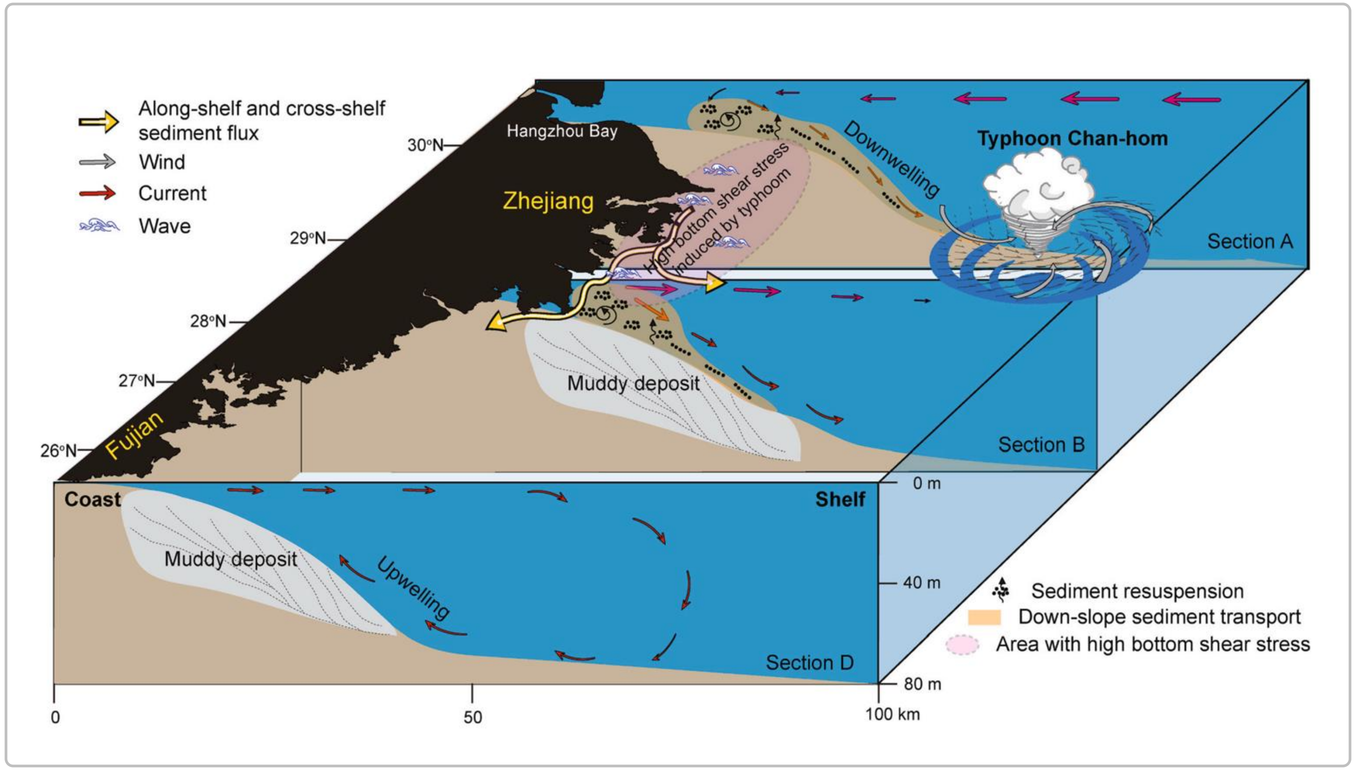
Li et al. (2021)



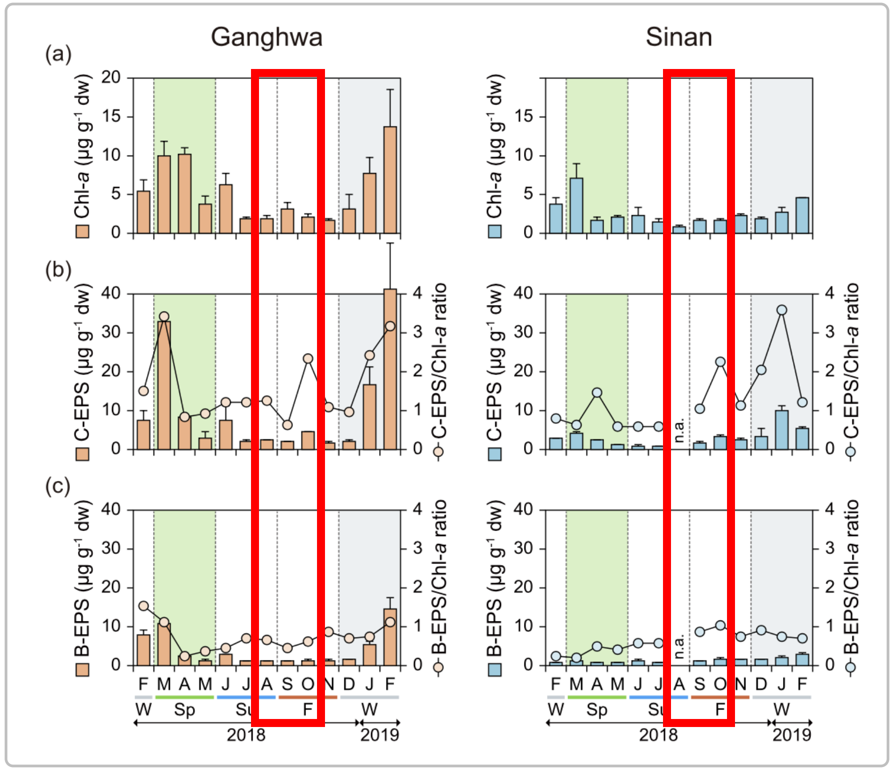
Ha et al. (2020)

- **The erodibility of benthic sediment** is spatially different by sedimentary characteristics (e.g., grain size)
- The benthic sediment of tidal flat is vulnerable to be eroded because of shallow depth
- The **phytoplankton** could be resuspended under various conditions (e.g., tide and wind)

Typhoon and tidal flat



Gong et al. (2021)



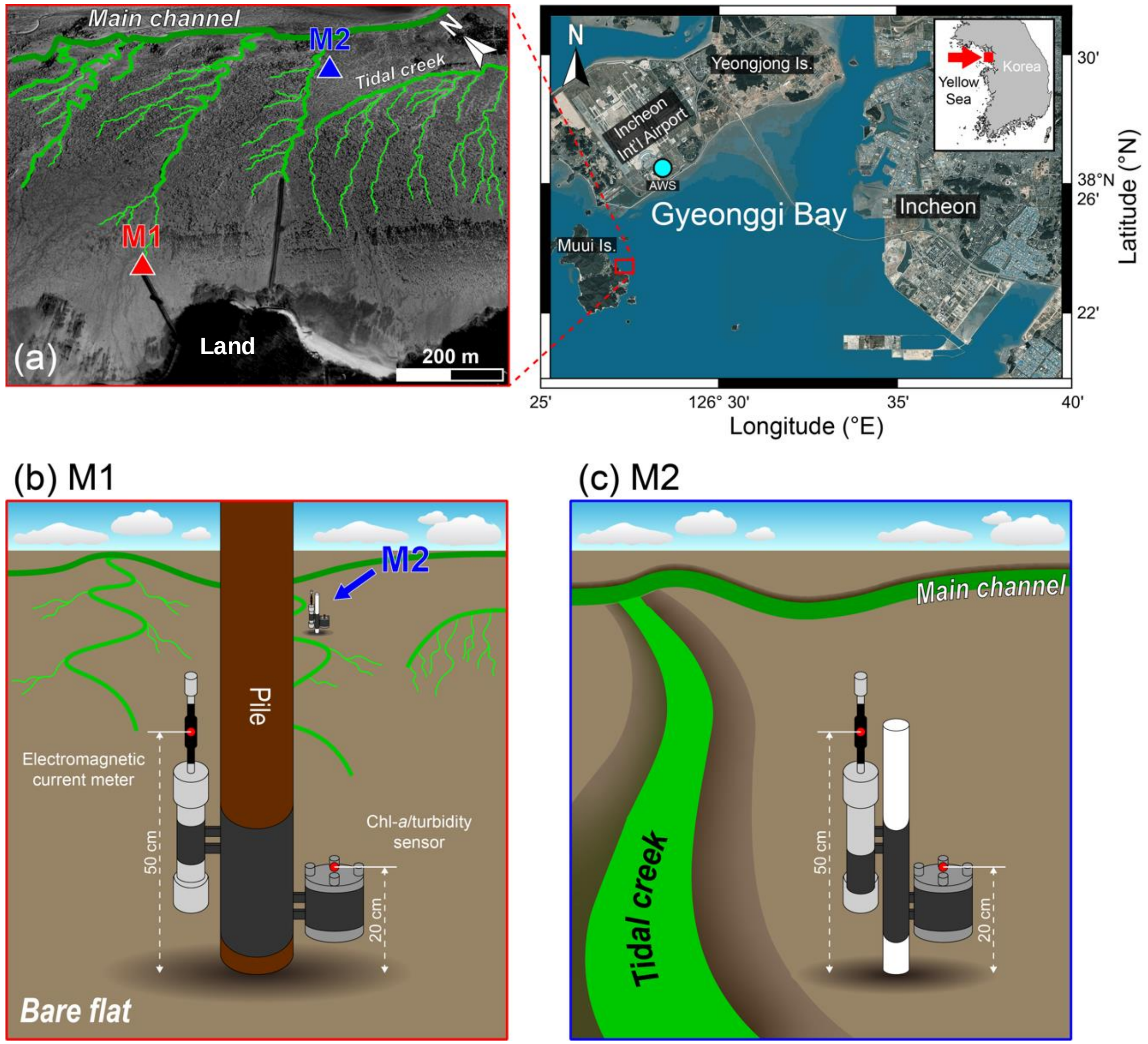
Modified from Kim et al. (2021)

- Strong typhoons usually occur from **late summer to early fall** In Korea
- **The productivity of the tidal flat** is comparatively **low** during the period (late summer to early fall)
- Typhoons could affect resuspension of benthic sediment and phytoplankton

Main objectives

- **To investigate the effect of typhoons on the resuspension of benthic sediment**
- **To reveal the reason of Chl-*a* variation during and after the typhoons**

Study area and hydrodynamic data

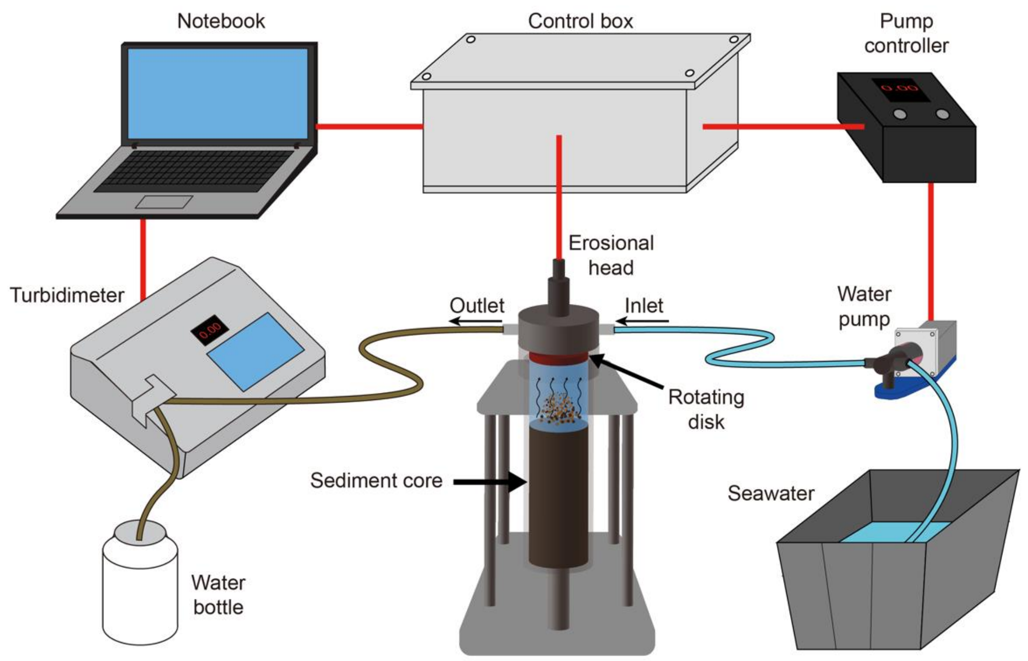


- **Tidal range: ~9 m**
- **M1: upper flat (water depth: ~3.34 m)**
- **M2: lower flat (water depth: ~5.74 m)**
- M2 was located near **the tidal creek**

Mooring period: September 1~23, 2020

Mooring systems			
	Sampling rate	Sampling point	parameters
Electromagnetic current meter	2 Hz	0.5 m above the bed	Current velocity
Chl-*a*/Turbidity sensor	2 Hz	0.2 m above the bed	Turbidity, Chlorophyll-*a*
Meteorological data: Incheon Airport AWS			
	Sampling rate	Sampling point	parameters
Wind	1 hour	10 m above the bed	Speed, direction
Precipitation	1 hour	10 m above the bed	-

Sediment erodibility: Gust erosion microcosm system (GEMS)



$$\boldsymbol{E(m,t) = M(m)[\tau_b(t) - \tau_{ce}(m)]e^{-\lambda t}}$$

Sanford and Maa (2001)

- E : Erosion rate (mg m^{-2} s^{-1})
- m : Eroded mass (mg m^{-2})
- t : Elapsed time (s)
- M : Erosion constant (g m^{-2} s^{-1} Pa^{-1})
- τ_b : Bed shear stress (Pa)
- τ_{ce} : Critical shear stress for erosion (Pa)
- λ : Sediment depletion rate (s^{-1})

- 4 sediment cores were collected for GEMS experiments during the mooring period (September 11 and 14)
- 7 steps of artificial bed shear stresses (0.01–0.6 Pa) were applied on the surface sediment
- Turbidity (NTU) was converted into erosion rate (E, mg m-2 s-1) using the collected water samples

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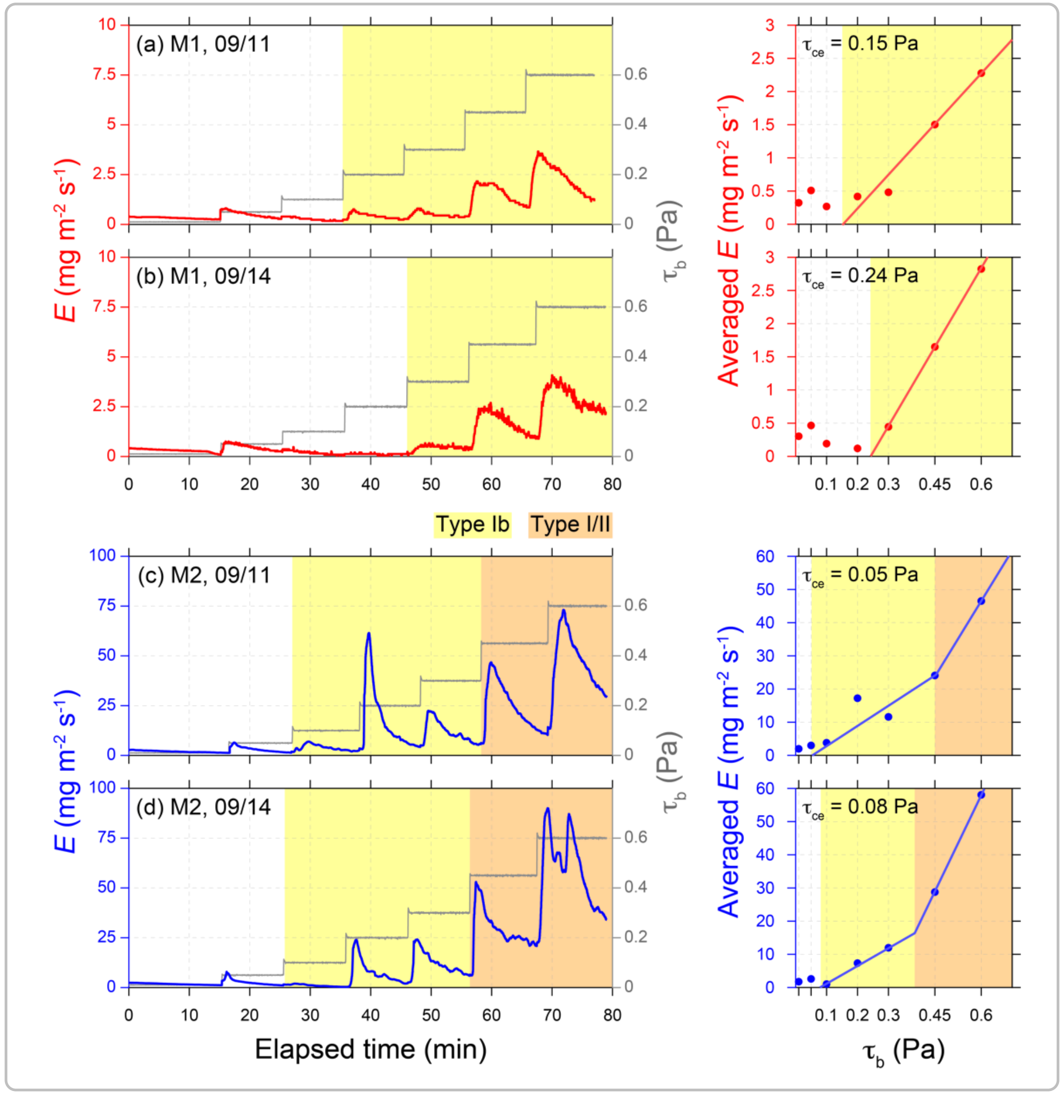
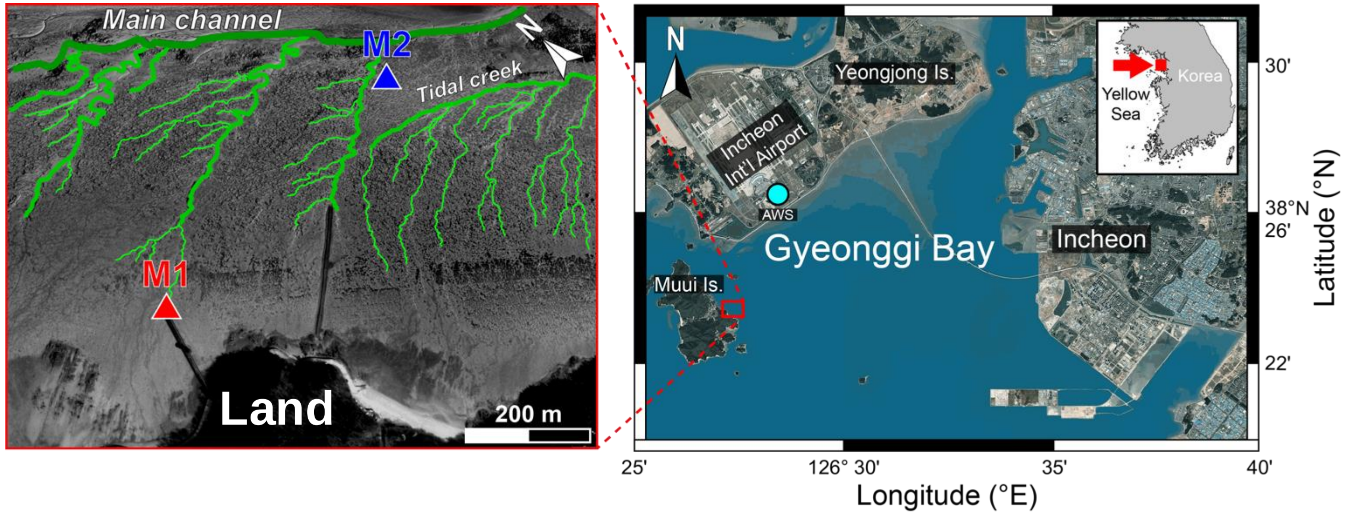
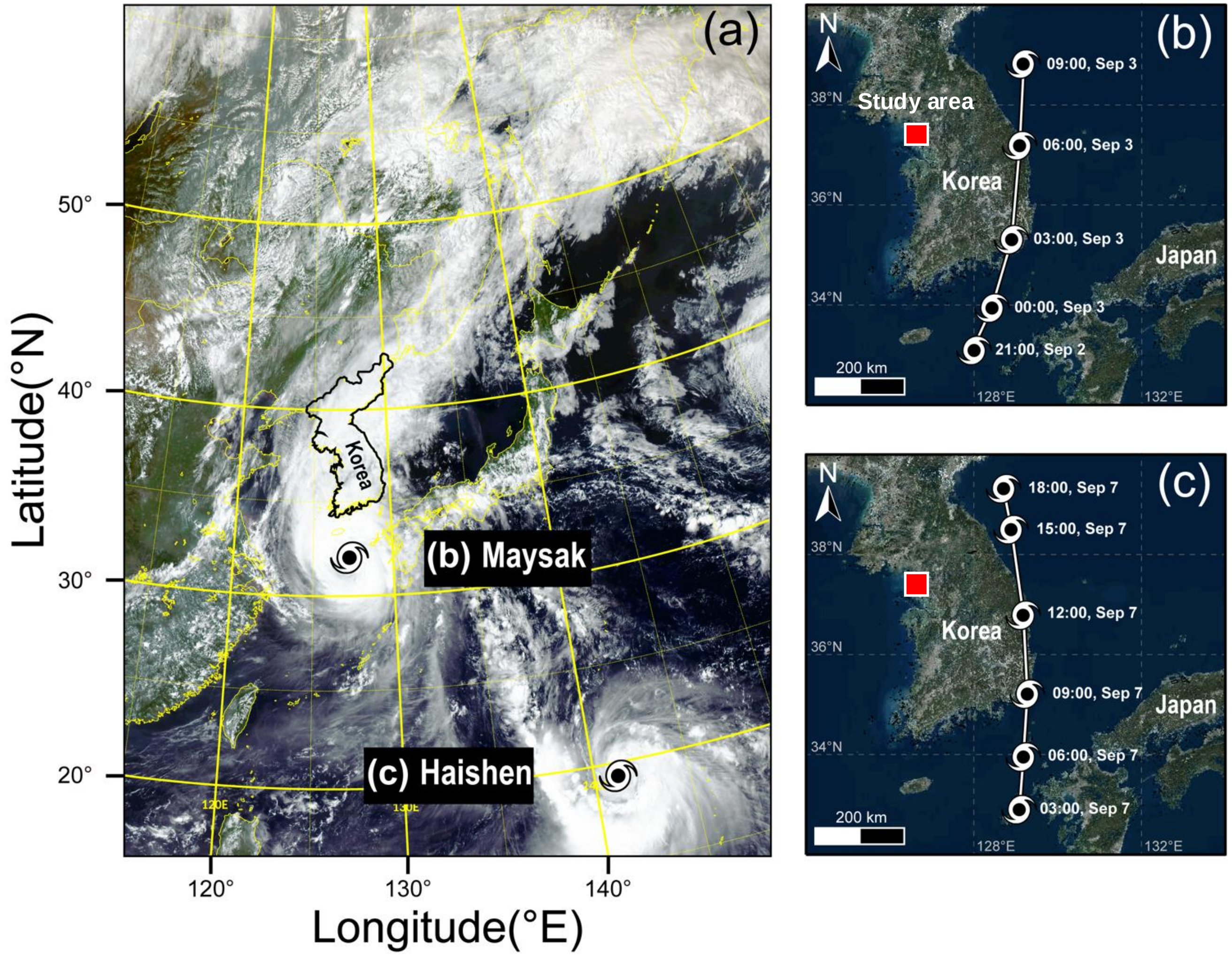
Sediment erodibility





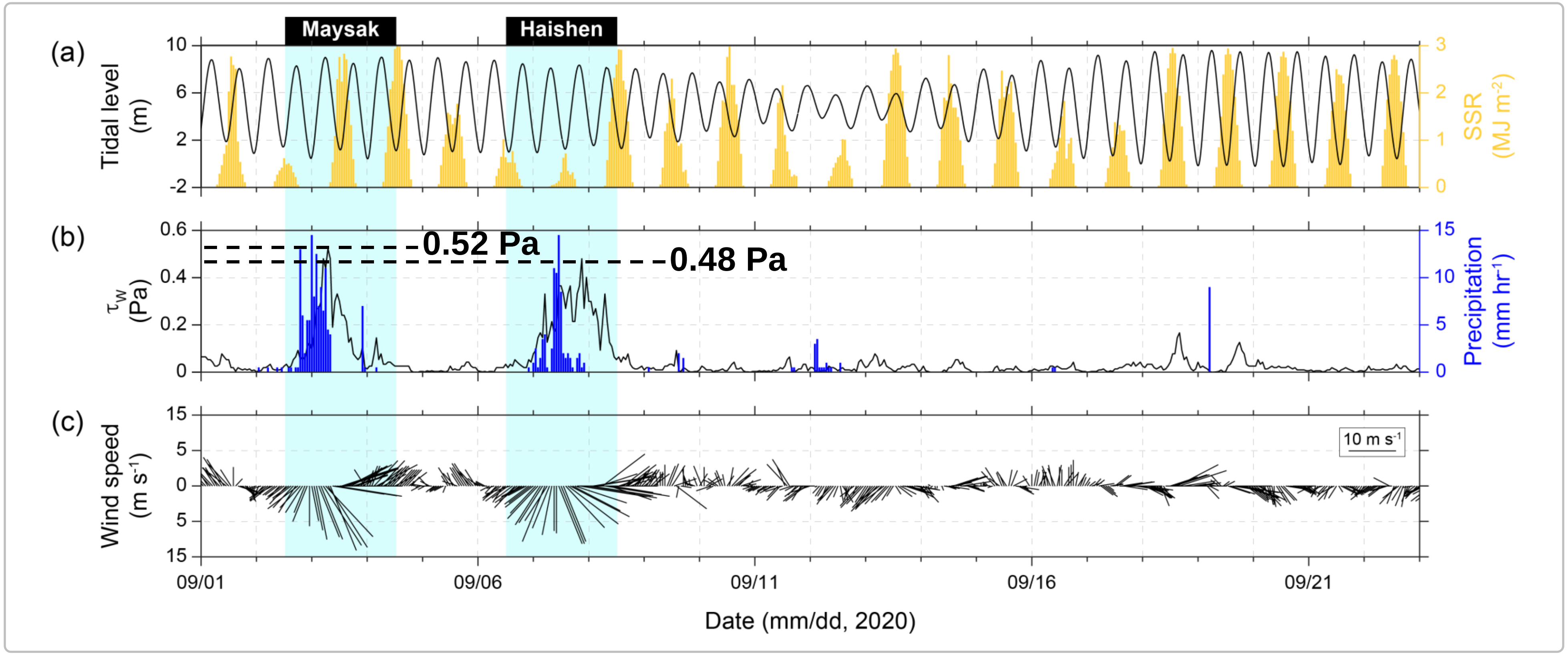
- **M1: upper flat**
  - Low erodibility (E: 0.76–4.08 mg m^{-2} s^{-1})
  - High τ_{ce} (0.15 and 0.24 Pa)
- **M2: lower flat**
  - High erodibility (E: 6.88–89.98 mg m^{-2} s^{-1})
  - Low τ_{ce} (0.05 and 0.08 Pa)

Typhoons “Maysak” and “Haishen”



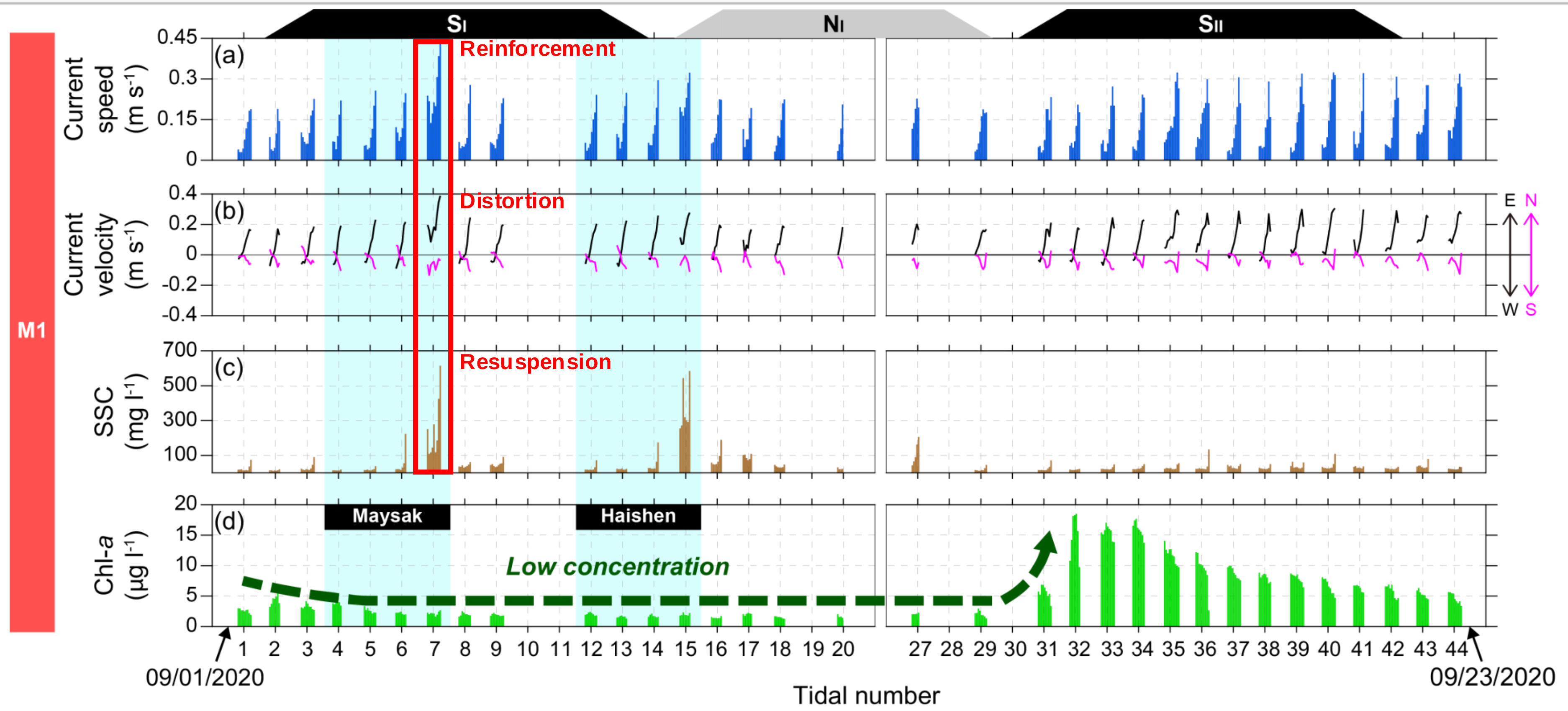
- **The typhoon “Maysak”**
  - ➢Duration: 21:00, 09/02 to 09:00, 09/03
  - ➢Maximum wind speed: 45 m s^{-1}
  - ➢Minimum central pressure: 945 hPa
- **The typhoon “Haishen”**
  - ➢Duration: 03:00, 09/07 to 18:00, 09/07
  - ➢Maximum wind speed: 43 m s^{-1}
  - ➢Minimum central pressure: 950 hPa
- The class of both typhoons was **“5”**, which could be classified as **“very strong typhoon”**

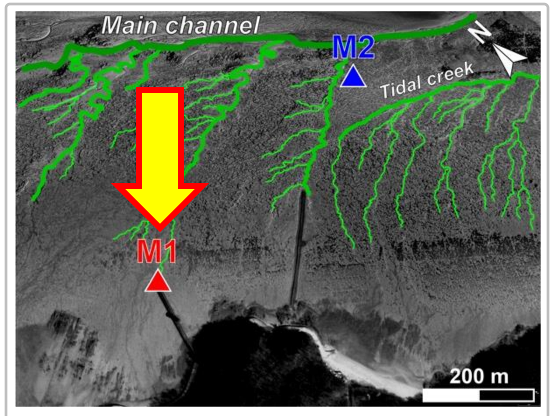
Mooring: Meteorological conditions



- Surface solar radiation (SSR) decreased down to 0.62 MJ m^{-2} during typhoons
- The typhoons increased **wind stress (τ_w) up to 0.52 Pa** and were accompanied with precipitation (>12 mm hr^{-1})
- During the typhoon passage, strong northerly wind (>10 m s^{-1}) occurred

Mooring: M1 (upper flat)

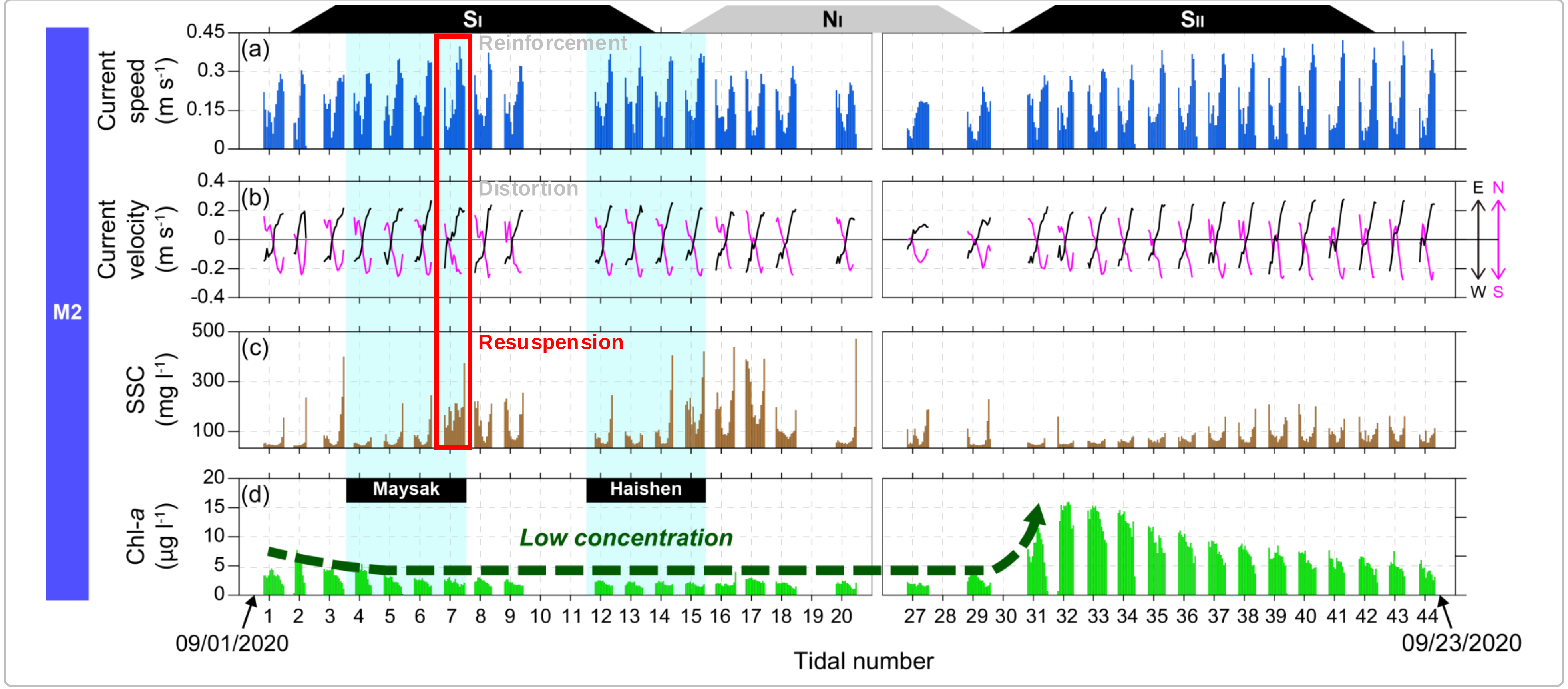


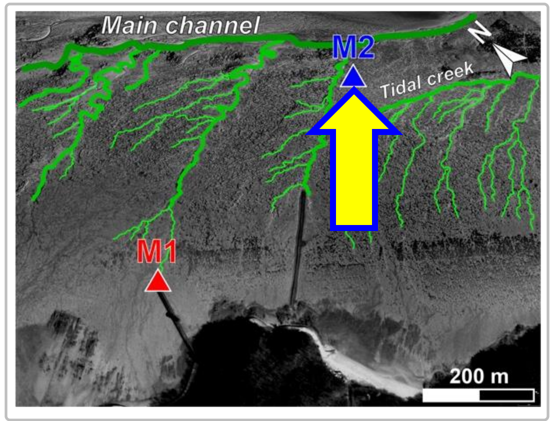


- Current velocity
  - Non-typhoon: ~0.25 m s^{-1}
  - Typhoon: ~0.44 m s^{-1}
- SSC
  - Non-typhoon: ~54.03 mg l^{-1}
  - Typhoon: ~614.07 mg l^{-1}
- Chl-*a*
  - Non-typhoon: ~5.52 µg l^{-1}
  - Typhoon: ~2.67 µg l^{-1}
  - After typhoons: ~18.31 µg l^{-1}

- Current velocity increased up to 0.44 m s^{-1} during the typhoons
- **SSC** rapidly increased (up to 614 mg l^{-1}) and **immediately decreased** during and after the typhoons
- Chl-*a* maintained low during the typhoons and increased up to 19 µg l^{-1} at the early stage of 2nd spring tide

Mooring: M2 (lower flat)



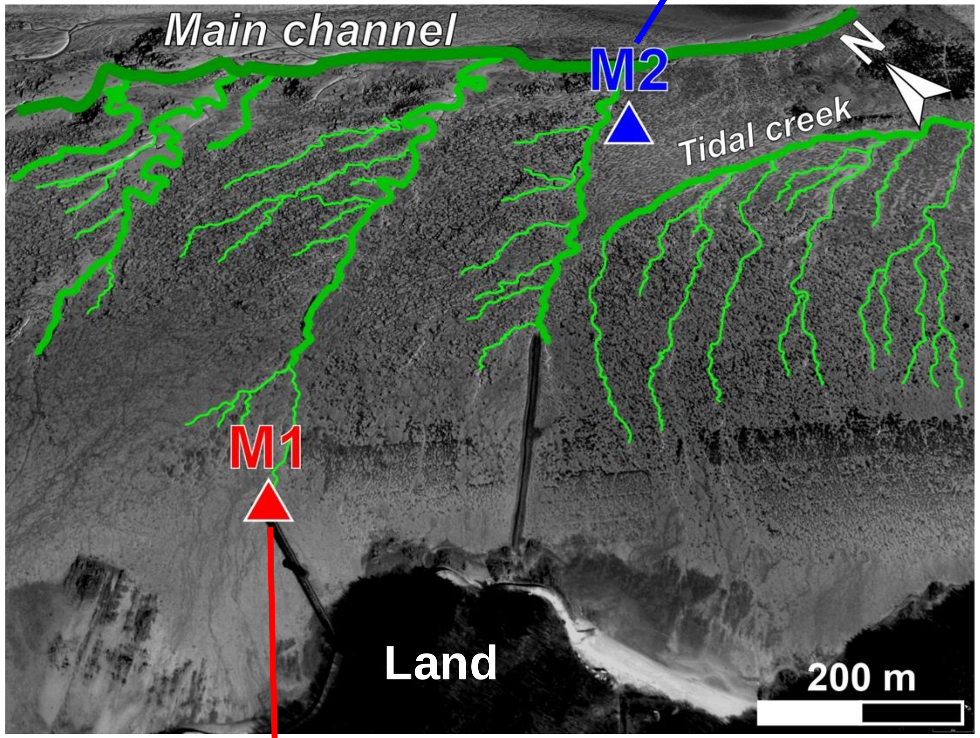


- Current velocity
  - Non-typhoon: ~0.34 m s^{-1}
  - Typhoon: ~0.40 m s^{-1}
- SSC
  - Non-typhoon: ~122.70 mg l^{-1}
  - Typhoon: ~364.11 mg l^{-1}
- Chl-*a*
  - Non-typhoon: ~7.72 µg l^{-1}
  - Typhoon: ~3.03 µg l^{-1}
  - After typhoons: ~15.94 µg l^{-1}

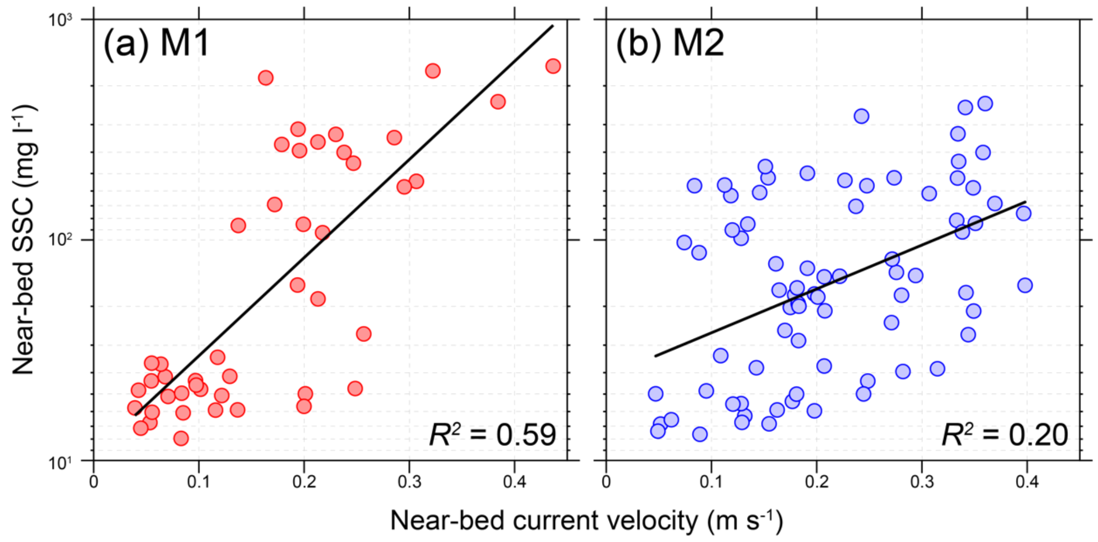
- Current velocity gradually increased up to 0.40 m s^{-1} during the typhoons
- **Increased SSC (~434 mg l^{-1})** during the typhoons **lasted for a longer time** compared to M1
- Chl-*a* maintained low during the typhoons, and it increased up to 16 µg l^{-1} at the early stage of 2^{nd} spring tide

Why high SSC occurred?

- Current velocity reinforcement (X)
- Tidal direction distortion (X)

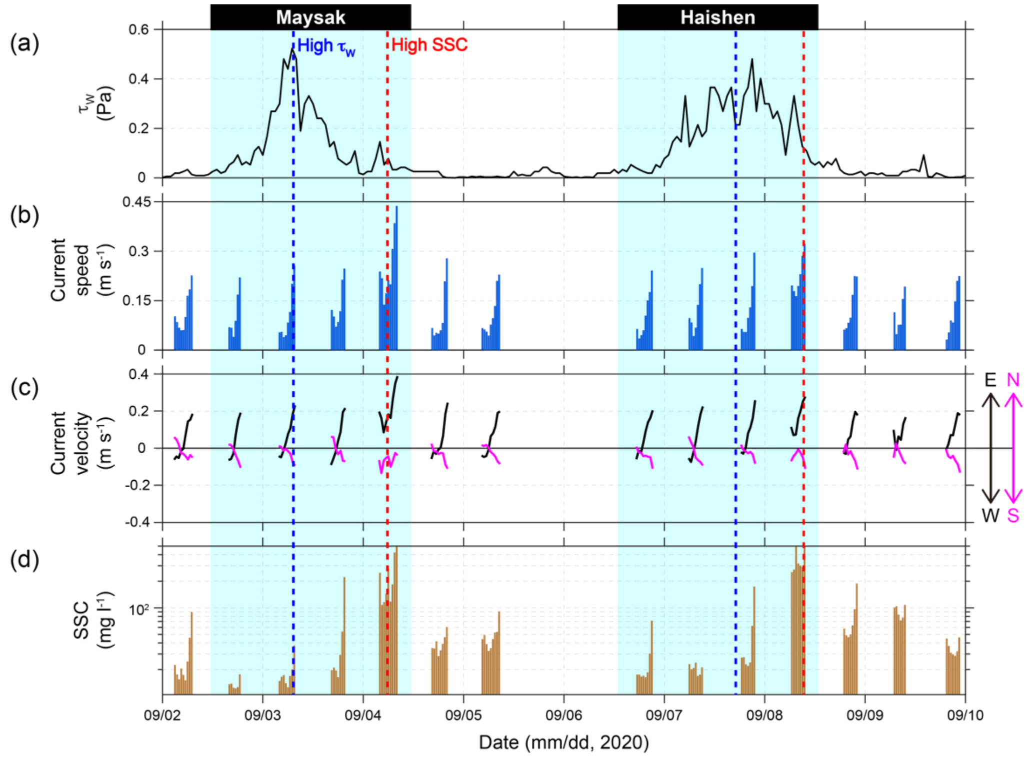


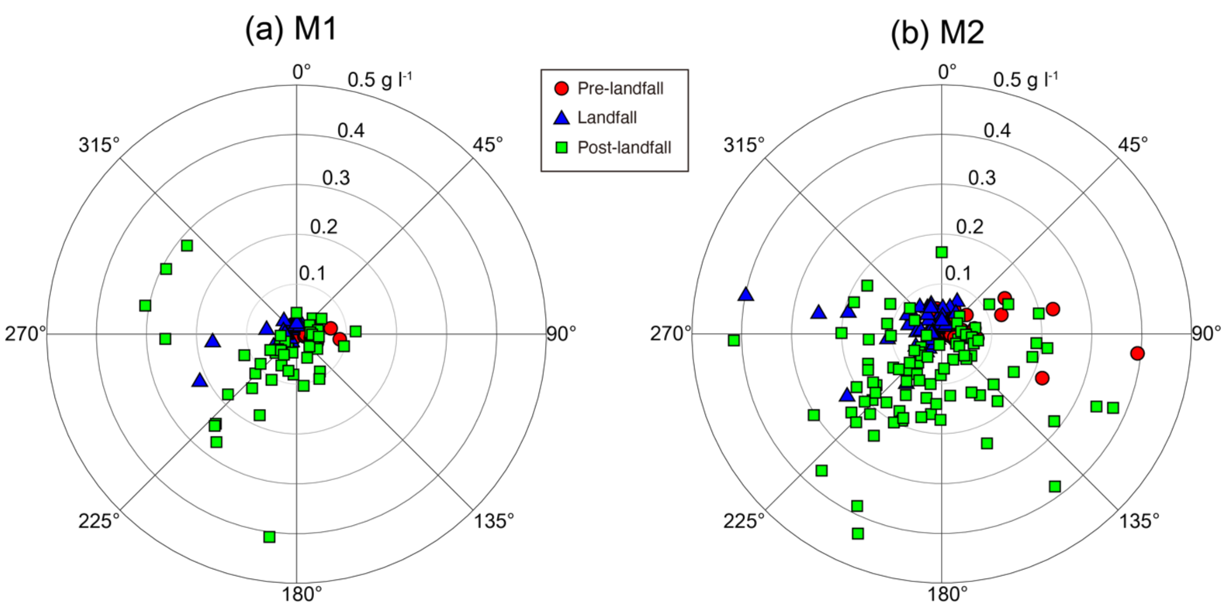
- Current velocity reinforcement (O)
- Tidal direction distortion (O)



- **M1: upper tidal flat**
  - ➢High correlation between current velocity and SSC
  - ➢Direct effect of typhoon on benthic environment
- **M2: lower tidal flat**
  - ➢Low correlation between current velocity and SSC
  - ➢Possible reason for high SSC
    : sediment transport through the tidal creek

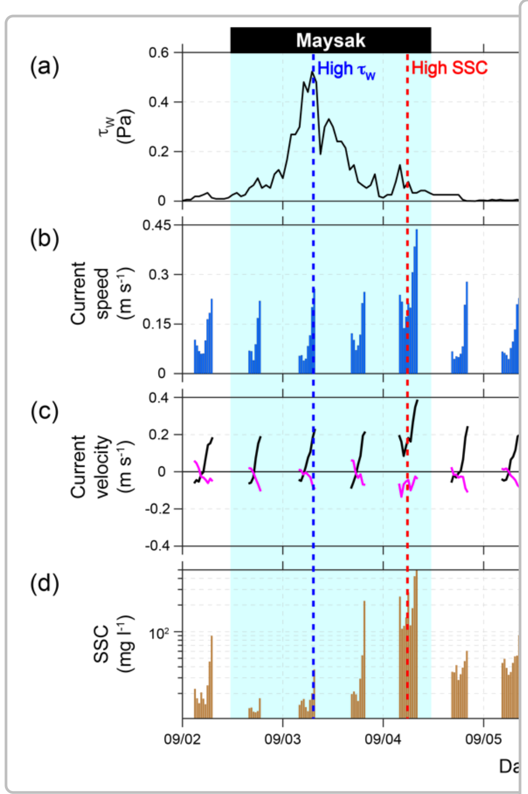
Time lag between τ_w and SSC

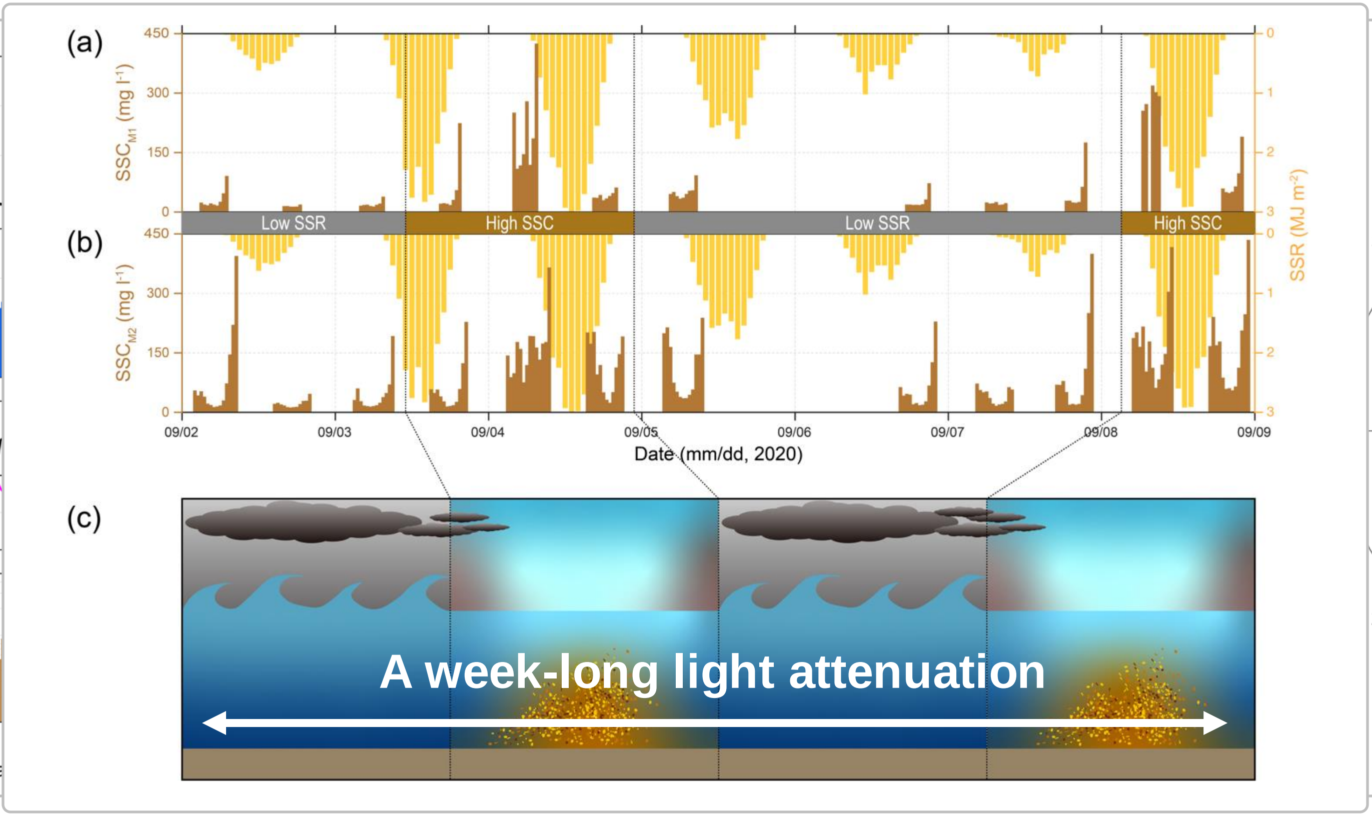


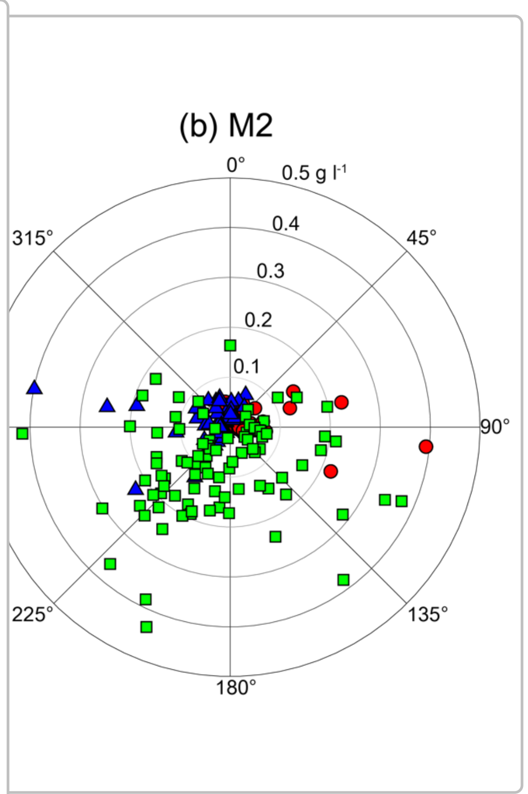


- There was a time lag of ~1 day between maximum τ_w (0.52 Pa) and SSC (614 mg l^{-1})
- During the post-typhoons, the magnitude of current increased up to 0.45 m s^{-1} and its direction severely distorted
- **The westerly** during the post-typhoons **reinforced ebb current**, resulting in the disturbance of benthic environment

Time lag between τ_w and SSC







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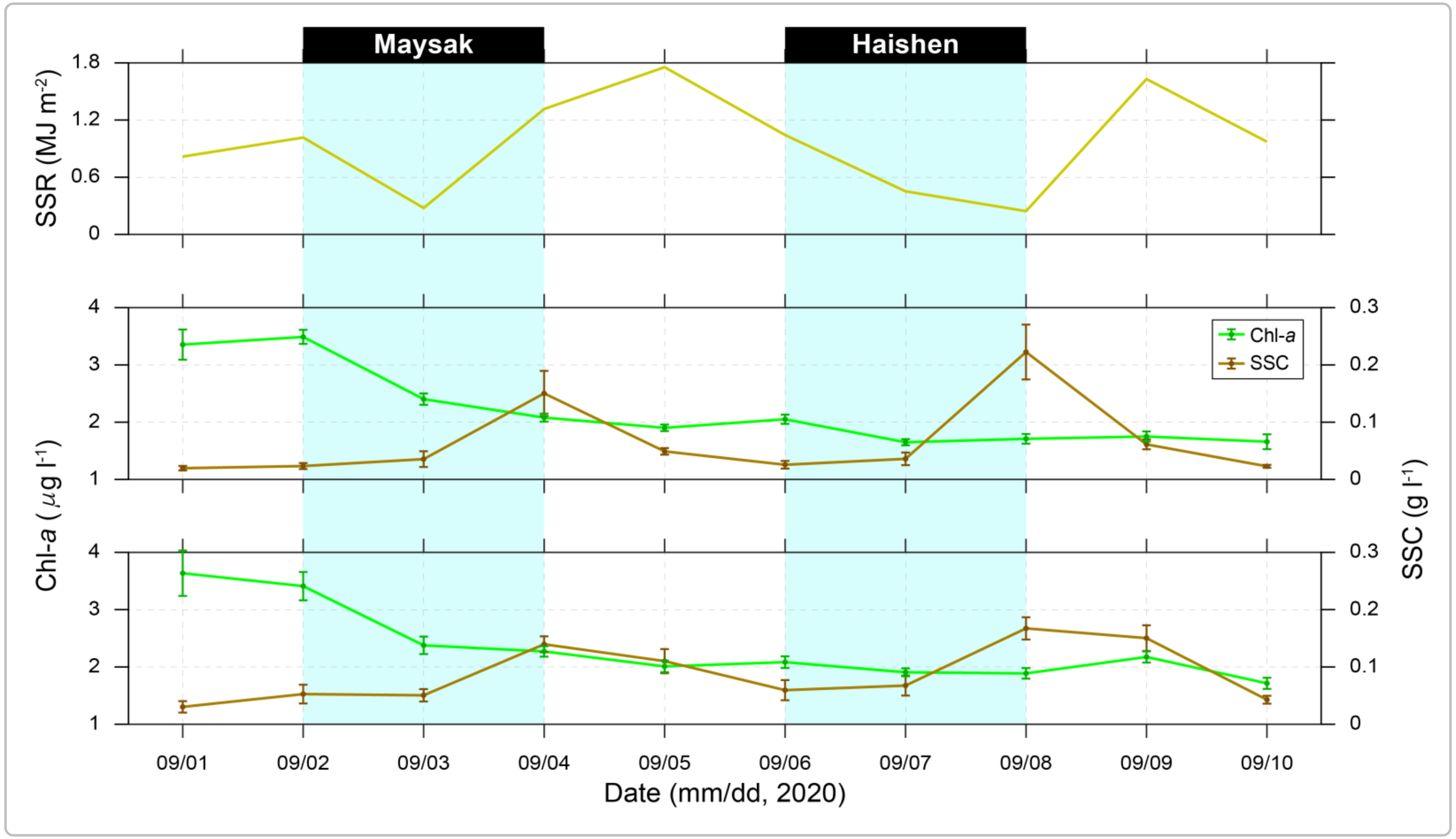
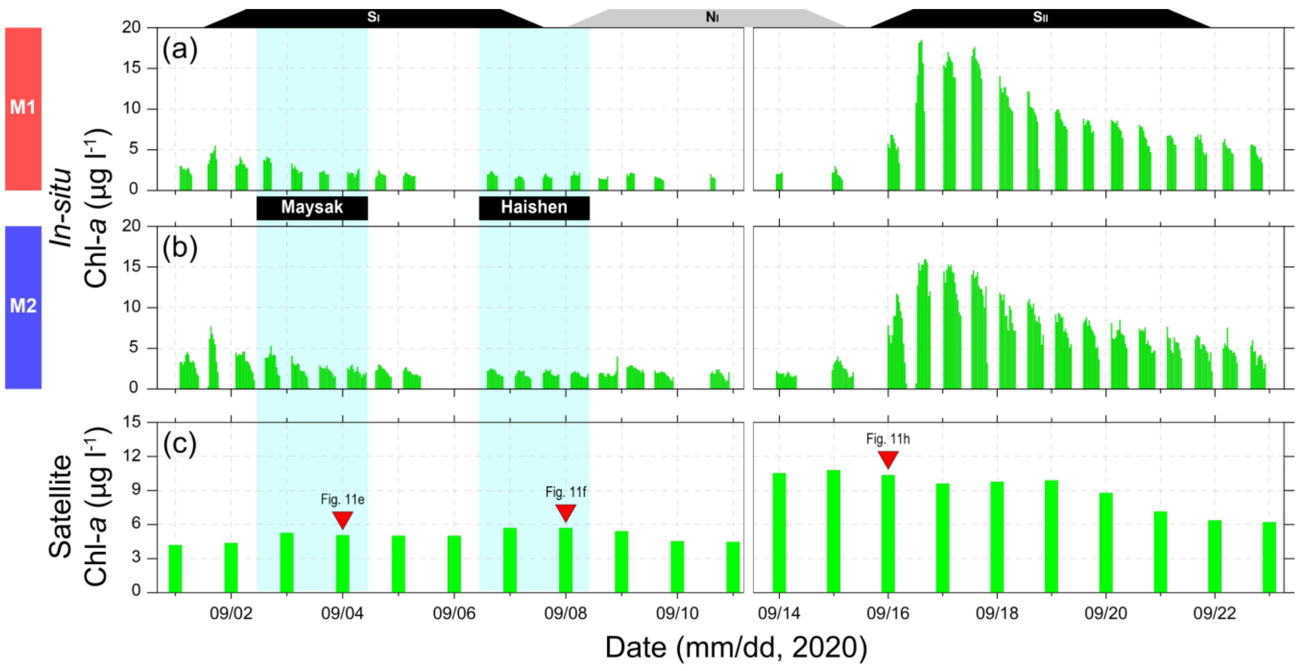
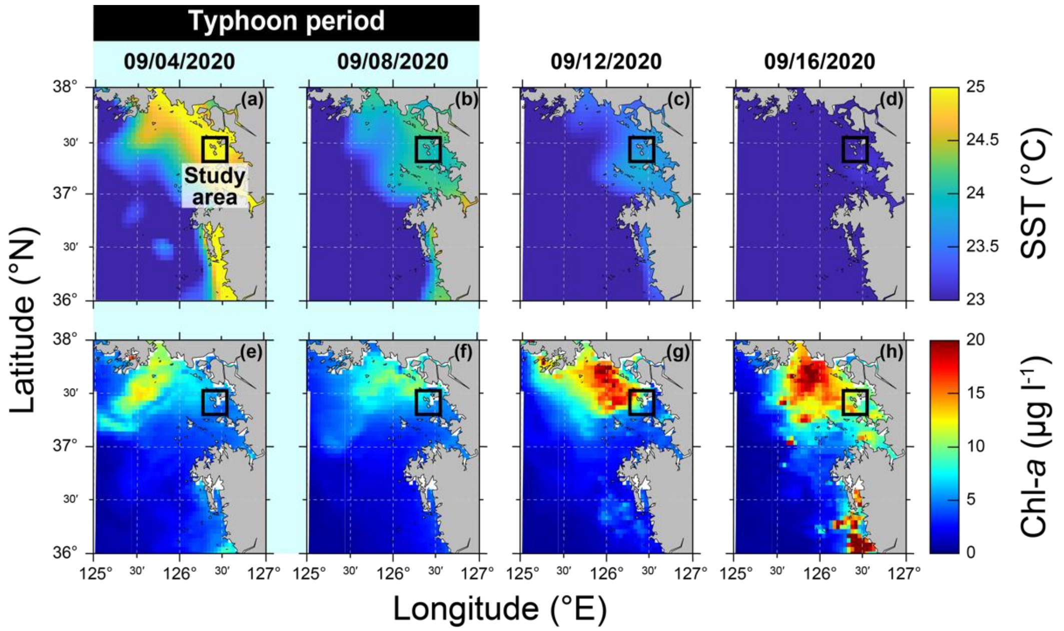
Chl-*a* during the typhoons



- Though SSR increased between the two typhoons, Chl-*a* maintained low because of following high SSC
- The results indicate that **the turbidity of water column is dominant factor which controls Chl-*a* at tidal flat**

Chl-*a* after the typhoons





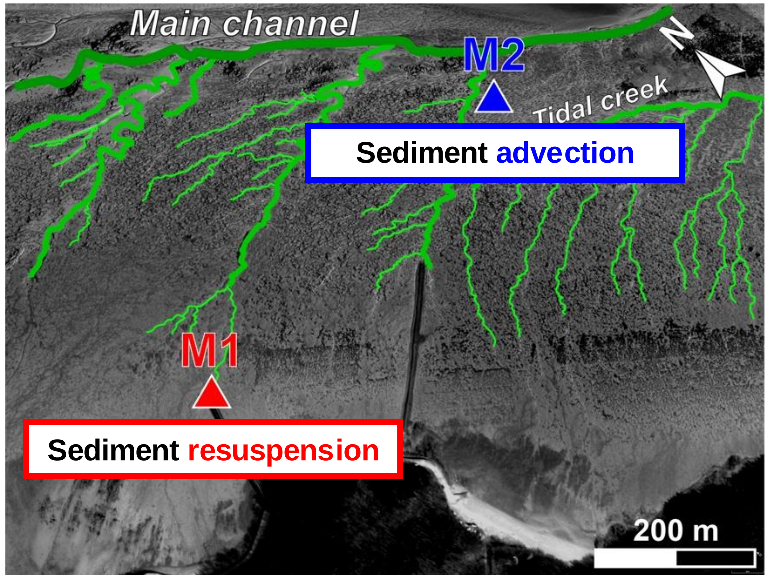
- **Chl-*a* drastically increased (~19 μg l^{-1})** after the two typhoons and neap tide
- Offshore and in-situ Chl-*a* showed similar increase pattern
- Increased Chl-*a*, which is induced by **offshore phytoplankton increase**, was flooded into the tidal flat

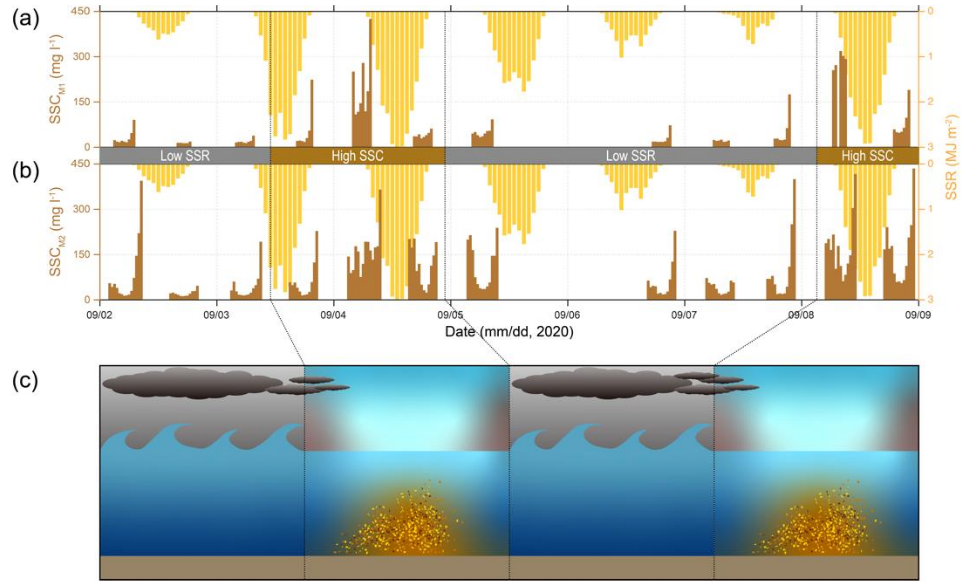
Effect of typhoons on sediment dynamics

- **The consecutive typhoons disturbed benthic sedimentary environment**

  ✓ **The reason of high SSC was spatially different during the typhoons between upper and lower flat**

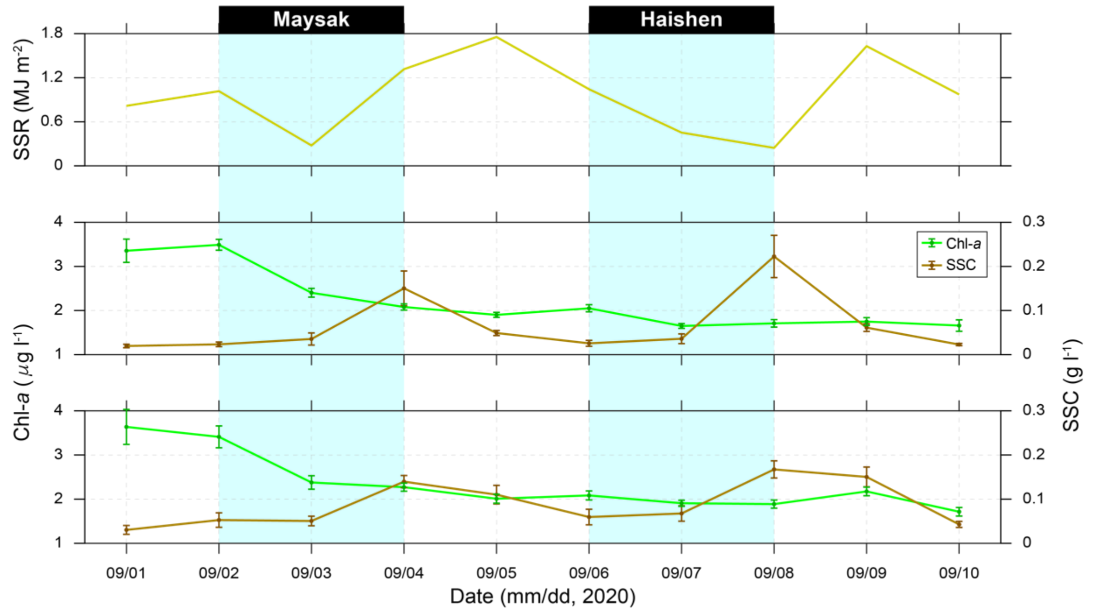
  ✓ **There was a time lag between the typhoon and benthic sediment disturbance resulting in a light attenuation**

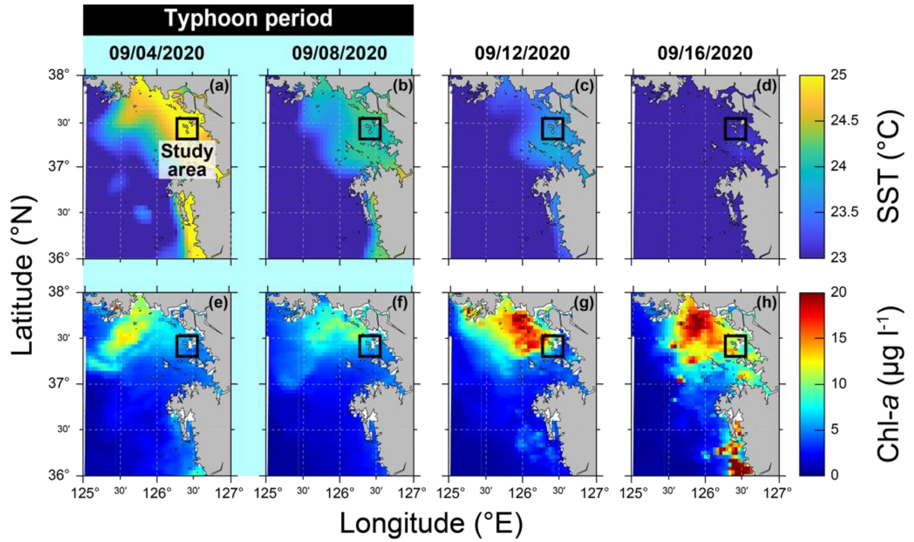




Effect of typhoons on phytoplankton dynamics

- **The mechanisms of Chl-*a* fluctuation during and after the typhoon period**
  - ✓ **During the typhoons, Chl-*a* maintained low because of continuous low surface solar radiation and high turbidity.**
  - ✓ **After the typhoons, offshore Chl-a, increased by typhoon-induced vertical mixing effect, flooded into the tidal flat**





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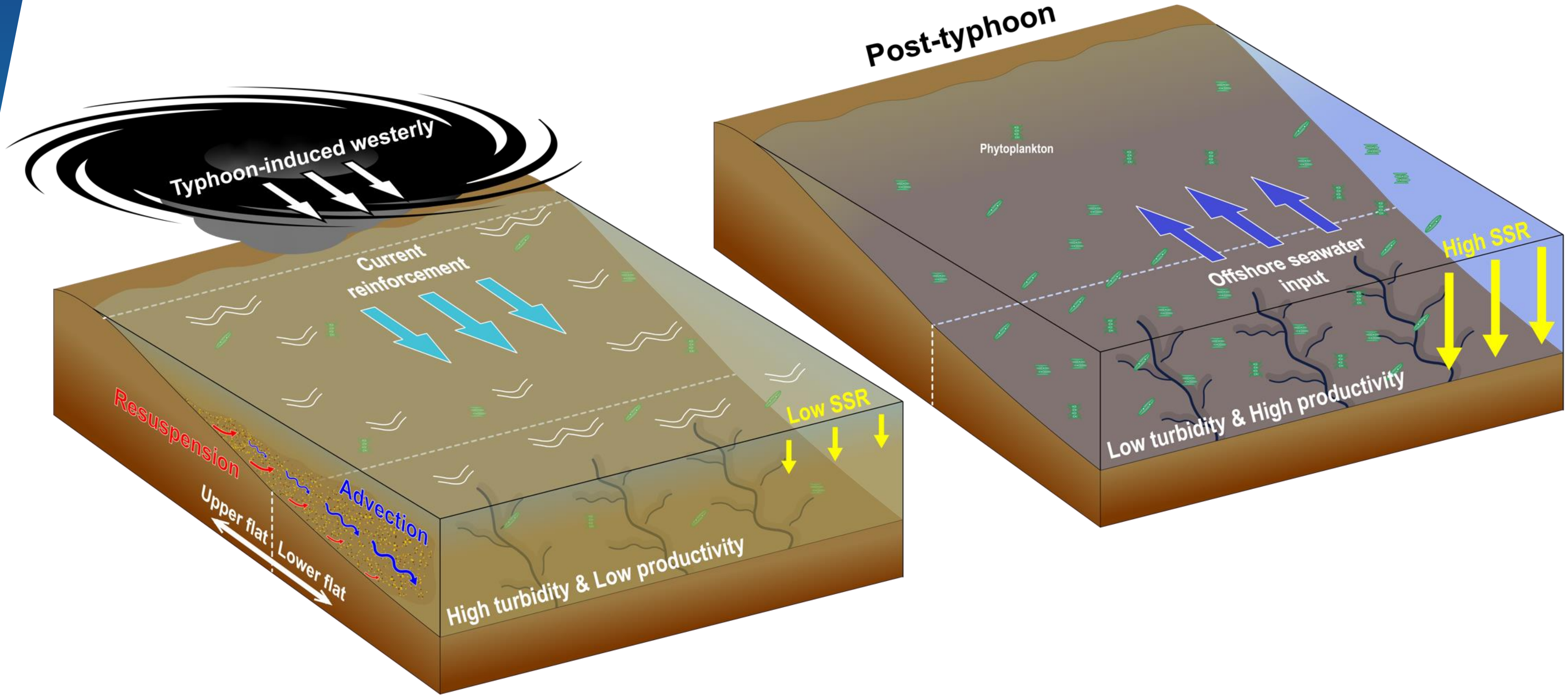

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