Tidal Resuspension of Microphytobenthos: Flood-ebb and Spring-neap Variations

part of the study on the ‘Biomass and Productivity of Microphytobenthos on the Tidal Flat of Saga Prefecture, Japan’ (April 2002 - March 2003)

Nov 10, 2006, KORDI

Khim, Jong Seong

Lab. of Marine Benthic Ecology
School of Earth & Environmental Sciences
College of Natural Sciences
Seoul National University

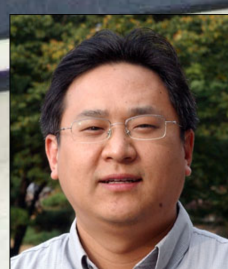
Report on the 'Biomass and Productivity of Microphytobenthos on the Tidal Flat of Saga Prefecture, Japan'

(April 2002 - March 2003)

Seoul National University
SOARING TOWARDS TO THE FUTURE

佐賀大学
Saga university

Prof. Koh, C-H



Dr. Khim, JS

Prof. Araki, H

Prof. Yamanishi, H

Prof. Koga, K

Research Topics

- ECOLOGY -

Topic-1

Hourly, monthly, and seasonal changes in chlorophyll *a* on surface and in depth of sediment

ECSS (in press)

Topic-1a

Chlorophyll *a* as an indicator of resuspension at flood and ebb: concentration

Topic-1b

Material flux in terms of chlorophyll *a* from onshore to offshore: flux

MEPS (2006)

- TAXONOMY -

Topic-2

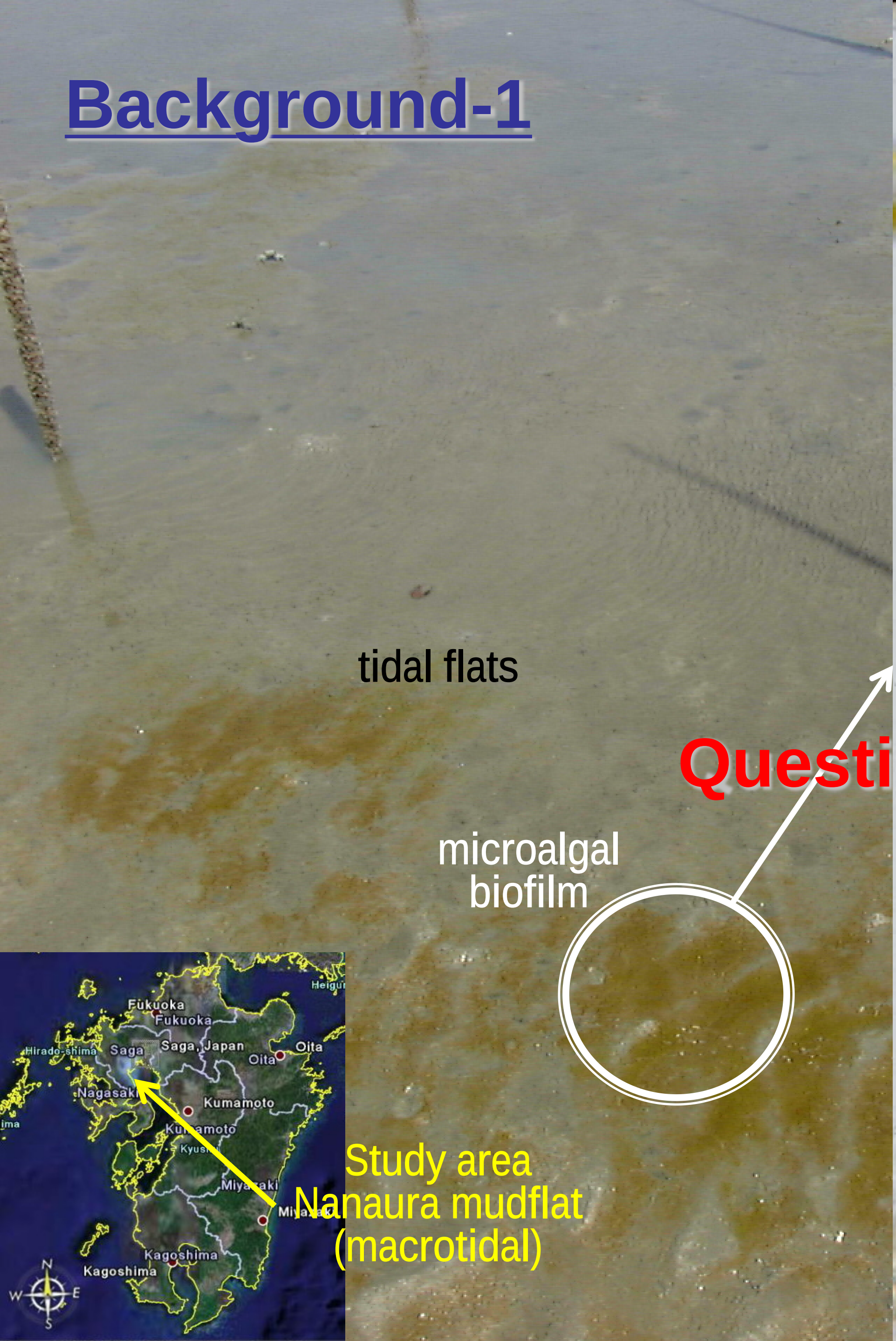
Taxonomical identification of microphytobenthos in sediment and in suspended materials

Diatom Research (submitted)

Content

1. Background
2. Objectives
3. Methods
4. Results
5. Discussion
6. Remark

Background-1



Questioning!

Background-2

Well known

- **General features in the aspect of**

1) Physics - Resuspension and redistribution of microphytobenthos (MPB)
2) Geology - Erosion, sedimentation, and transport of sediment particles (SPM)
3) Ecology - Resuspended MPB may contribute total water column production

in tidal flat ecosystem

Not well known

- **Specific features of**

1) Behavior of MPB and SPM resuspension in terms of tidal cycles (flood-ebb and spring-neap)
2) Relationship between MPB and SPM during resuspension

in terms of ‘concentration’ and/or ‘flux’

Objectives

We aimed to find

- **General features**

1) To examine the resuspension of MPB and SPM during tidal cycles
2) To find the key factors affecting the tidal resuspension of MPB
3) To estimate a portion of benthic-derived MPB in water column

in terms of 'concentration' (earlier Topic-1a)

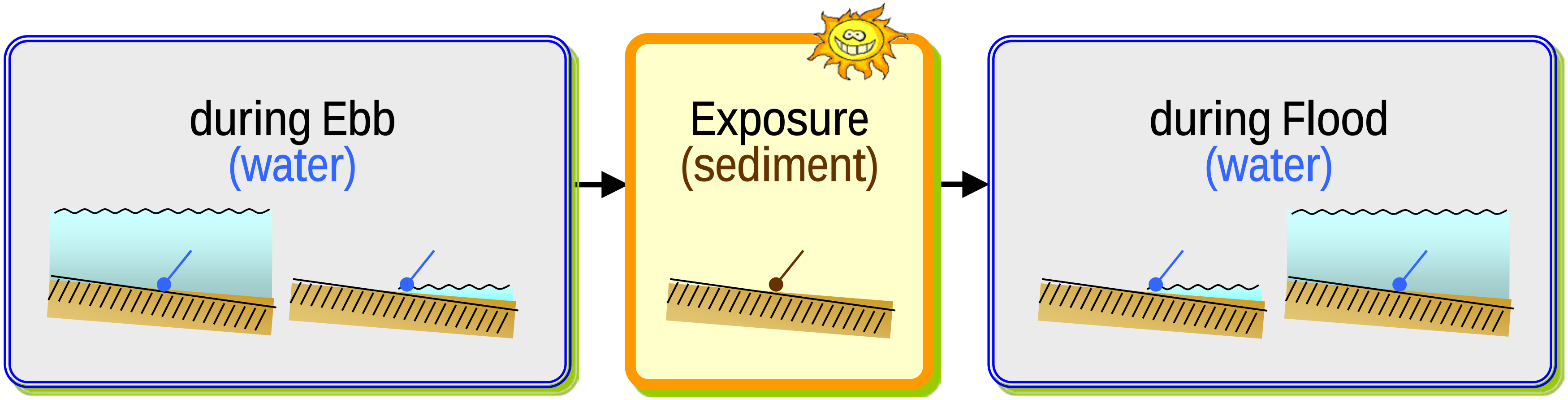
- **Further, Detailed behaviors**

4) To describe the behaviors of MPB and SPM resuspension

in a viewpoint of 'flux' (earlier Topic-1b)

Method-1

Sampling design (at fixed site) and Data sets



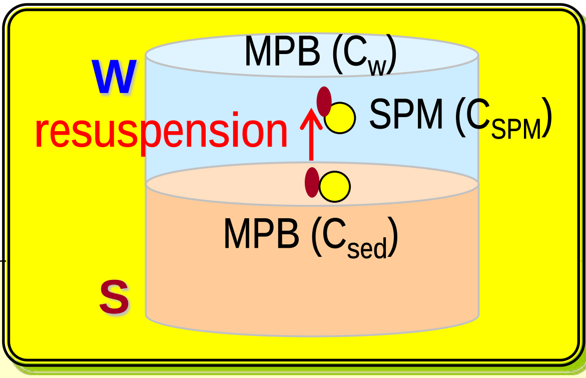
- **Data Set 1** (Resuspension)

- Seawater (1301 records)
- Mar-Apr 2003 (28 tidal periods)
- Mooring records of
1) Chl *a*, 2) SPM, 3) CV, 4) WD
plus 5) Wind during flood-ebb

- **Data Set 2** (Benthic biomass)

- Sediment (n=40)
- Mar 2003 (13 exposure periods)
- Manual measurement of
1) Chl *a*, 2) Pheo-pigments
during exposure

Method-2



Calculations

- **Chl *a* (at time t)**

  $C_w(t)$ (water: mg m^{-3} = µg l^{-1}) $C_{sed}(t)$ (sediment: mg m^{-2})

- **Chl *a*, depth-integrated (h=water depth)**

  $C_{w\text{-}d}(t) = C_w(t) \times h(t)$ (mg m^{-2})

- **Chl *a* flux, depth-integrated**

  $F_{w\text{-}d}(t) = C_{w\text{-}d}(t) \times CV(t) \times Dir(t)$ (mg m^{-1} s^{-1})

- **Baseline Chl *a*, depth-integrated**

  $C_{w\text{-}d}(t) = a \times C_{SPM\text{-}d}(t) + b$, where $b = C_{w\text{-}base\text{-}d}(t)$ (mg m^{-2})

- **Resuspended Chl *a*, depth-integrated**

  $C_{w\text{-}resus\text{-}d}(t) = C_{w\text{-}d}(t) - C_{w\text{-}base\text{-}d}(t)$ (mg m^{-2})

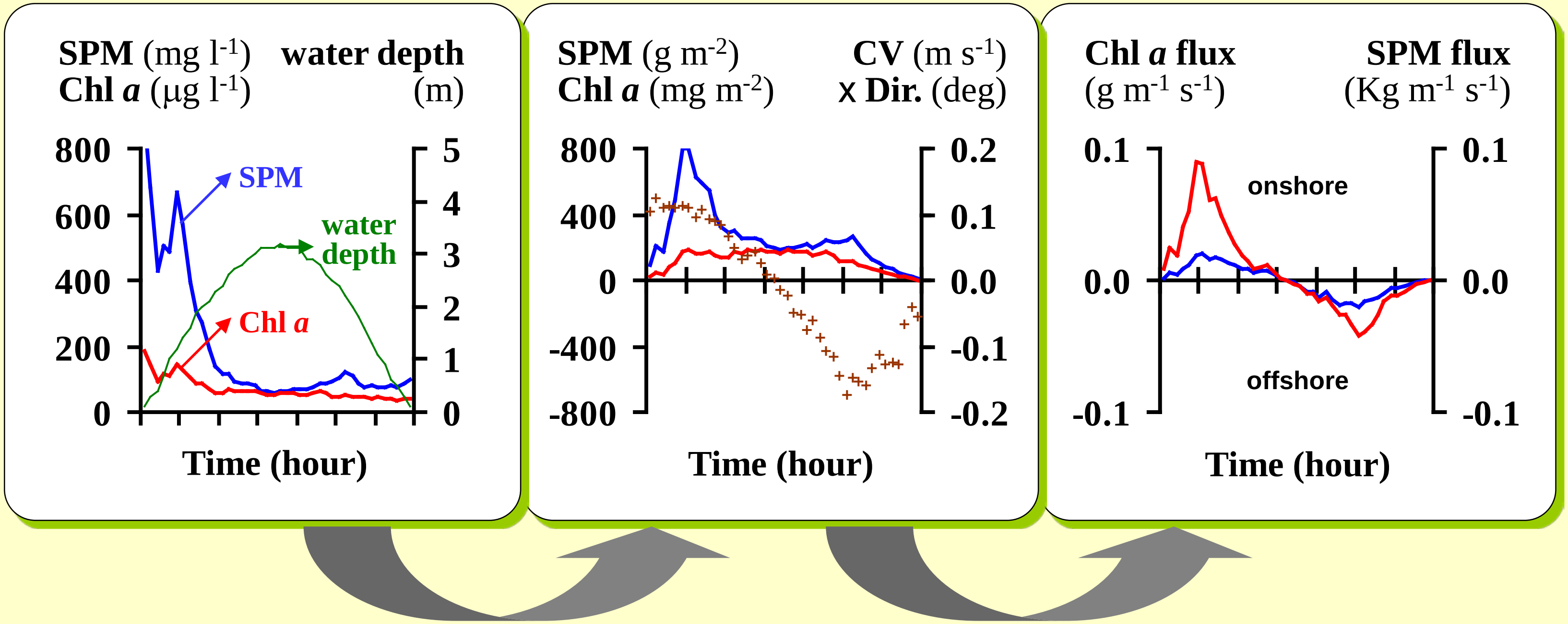
- **Resuspended Chl *a* vs. Sediment Chl *a***

  $C_{w\text{-}resus\text{-}d}(t) / C_{sed}(t)$ (ratio)

Method-3

Example of Calculations: for one flood-ebb cycle

$C_w(t)$ $C_{w\text{-}d}(t)$ $F_{w\text{-}d}(t)$



step-1
(concentration)

step-2
(depth-integrated conc.)

step-3
(flux)

Raw Data

All-In-One

(start from this figure)

mooring sensor

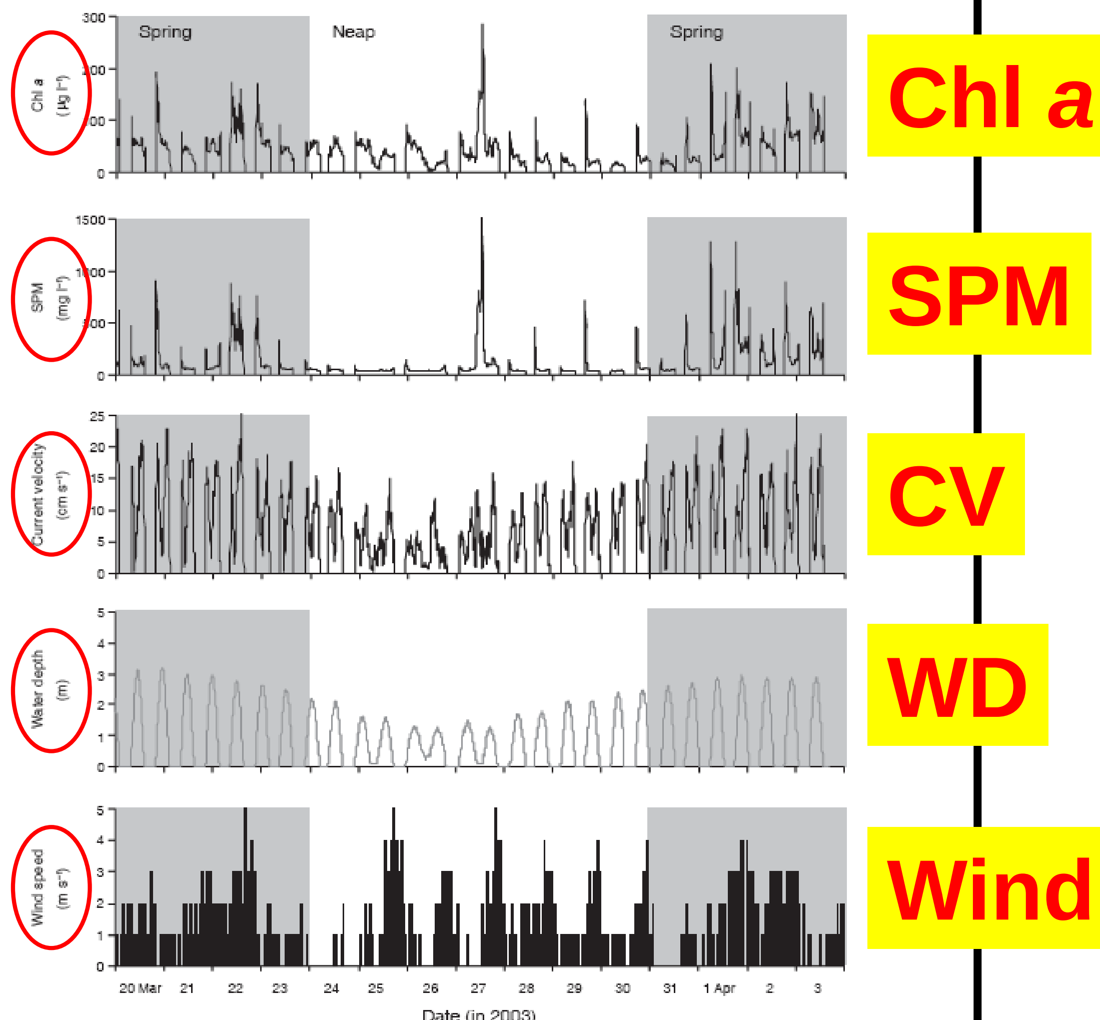


Fig. 3. Temporal changes in chl *a* and suspended particulate matter (SPM) concentrations in seawater measured at Stn A from the upper intertidal flat over 28 tidal cycles (mooring records). Corresponding current velocity, water depth, and wind speed are presented as well. Shaded sections indicate data for spring-tide, while open sections represent data for neap-tide periods

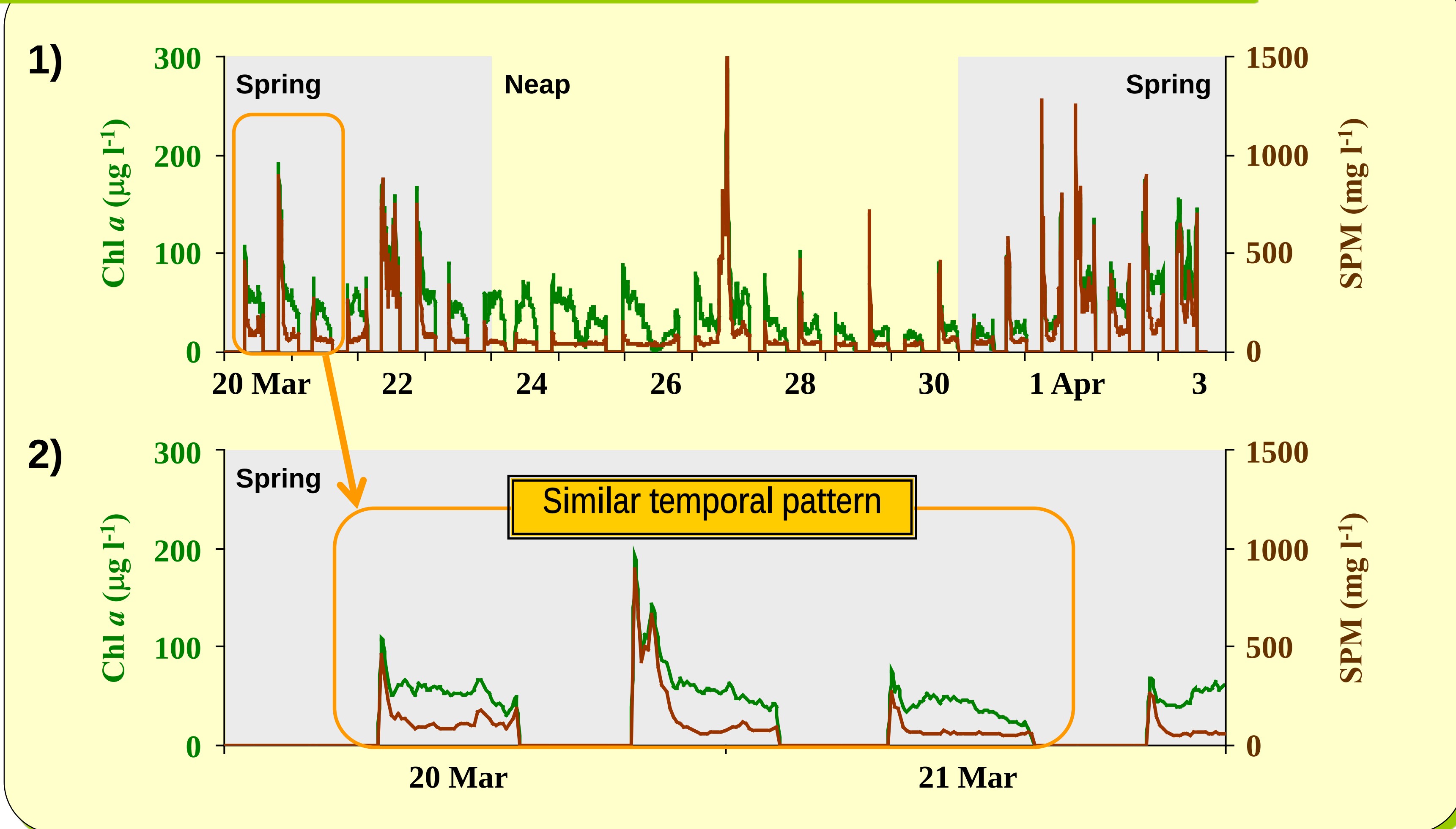
Results-1-5

in terms of

Concentration

Result-1

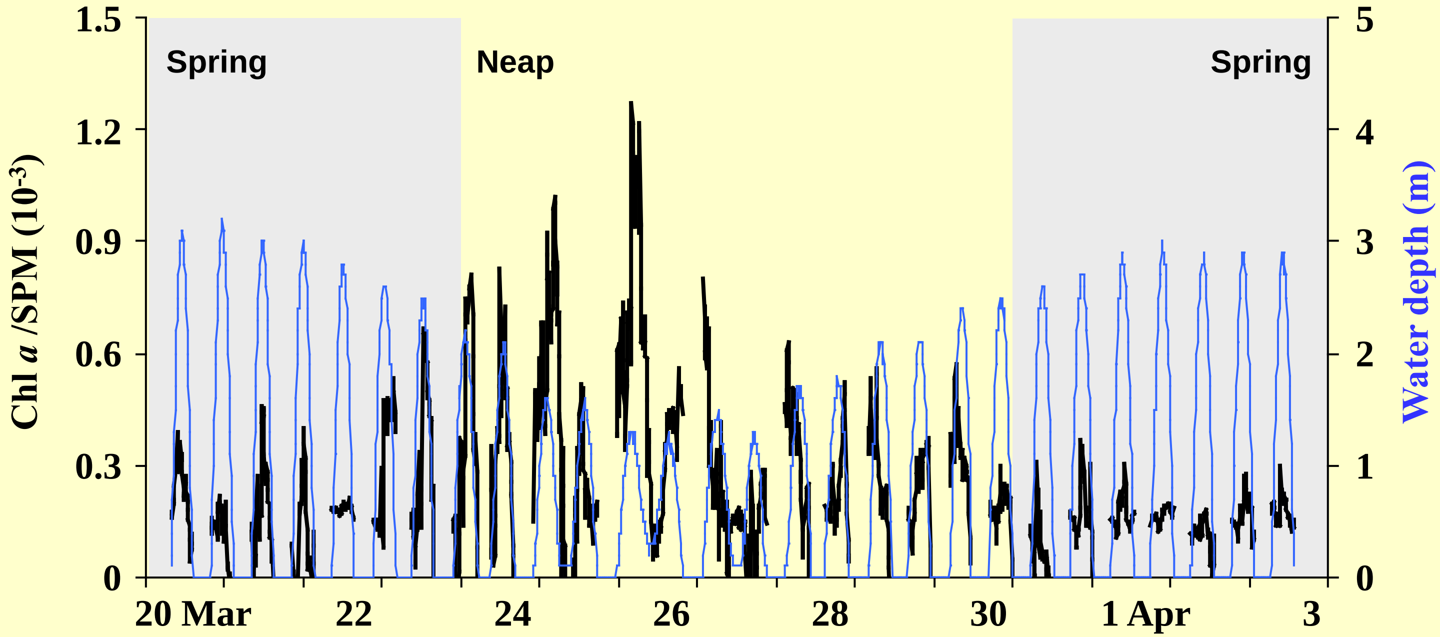
We found: 1) spring > neap concentration, 2) flood peak



Result-2

We found: 3) characteristics of Chl *a*/SPM ratio

3)

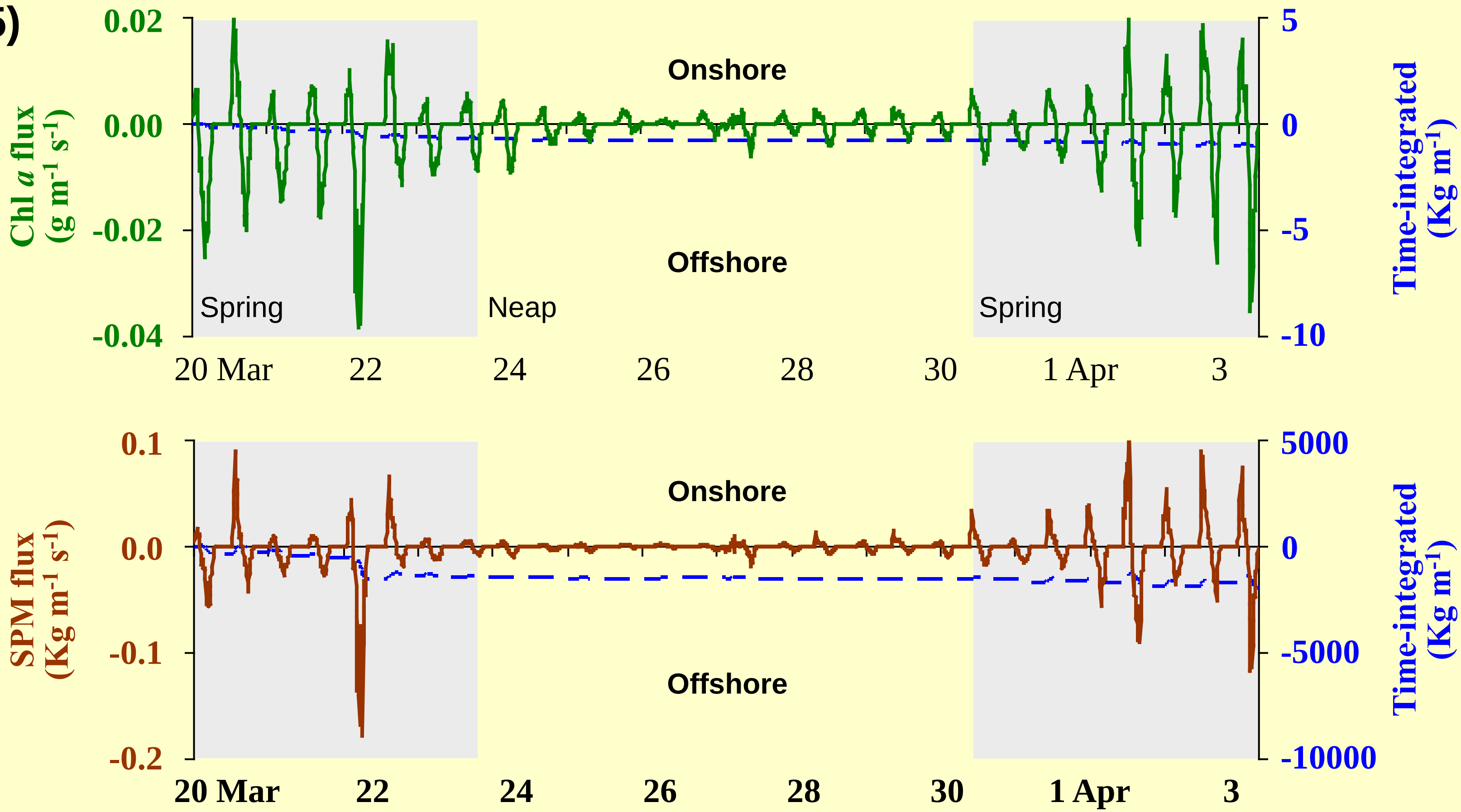


1) Chl *a*/SPM peaked during slack water when current velocity was low
2) Chl *a*/SPM greater during neap tide when current velocity was low

Result-3

We found: 4) spring > neap flux, 5) predominant offshore transport

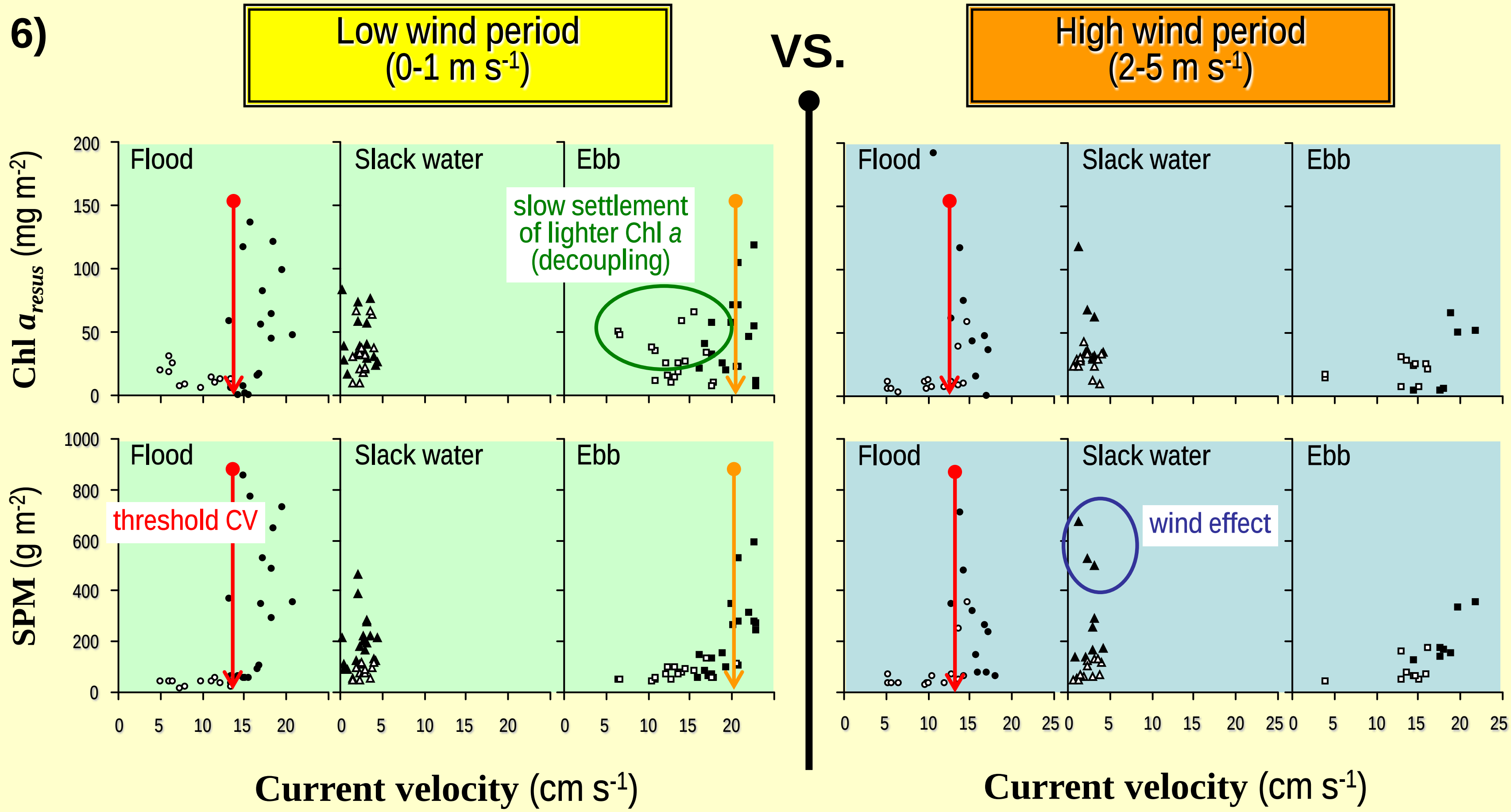
4-5)



Result-4

We found: 6) resuspension influenced by CV and wind speed

6)

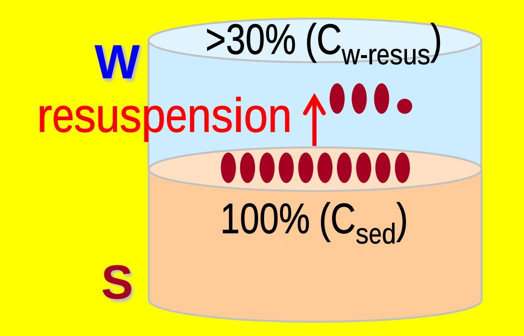


Result-5

We found: 7) resuspended Chl *a* equal to >30% of sediment Chl *a*

7)

Tidal condition	Sampling date	Sediment C_{sed} (mg m^{-2})	Seawater $C_{w\text{-}resus\text{-}f}$ (mg m^{-2})	Seawater $C_{w\text{-}resus\text{-}e}$ (mg m^{-2})	Seawater / Sediment $C_{w\text{-}resus\text{-}f}$ / C_{sed} (ratio)	Seawater / Sediment $C_{w\text{-}resus\text{-}e}$ / C_{sed} (ratio)
Spring	20 Mar	151	58	47	0.37	0.30
	21 Mar	123	53	12	0.35	0.08
	22 Mar	89	14	19	0.12	0.15
	23 Mar	76	55	64	0.61	0.71
	23 Mar	63	16	50	0.22	0.66
Neap	24 Mar	62	15	47	0.23	0.74
	25 Mar	63	28	27	0.46	0.43
	25 Mar	69	9	8	0.14	0.13
	26 Mar	63	22	30	0.31	0.44
	26 Mar	73	16	10	0.22	0.13
	27 Mar	47	11	13	0.24	0.27
Spring	31 Mar	84	31	20	0.37	0.24
Mean ± SD						
Spring period		98 ± 33	38 ± 20	35 ± 21	0.34 ± 0.17	0.36 ± 0.27
Neap period		63 ± 9	17 ± 7	22 ± 15	0.27 ± 0.11	0.36 ± 0.23
Entire period		80 ± 29	27 ± 18	29 ± 19	0.30 ± 0.14	0.36 ± 0.24



Summary-1: Results-1-5

We found

- **Key results were**

1) resuspension found to be clearly associated with flood-ebb and spring-neap tidal characteristics (tidal energy)

2) Peaks of resuspended Chl *a* and SPM consistently observed shortly after the current velocity maximized (early flood, >15 cm s^{-1})

3) Chl *a* and SPM fluxes showed clear spring-neap variations, and time-integrated fluxes denoted predominant offshore transport

4) Much more highly fluctuating, irregular peaks of Chl *a* and SPM occasionally observed when wind speed ≥3 m s^{-1}

5) Daily mean percentage of resuspended Chl *a* in water column relative to benthic Chl *a* estimated to be ca. 10-70% (mean=33%)

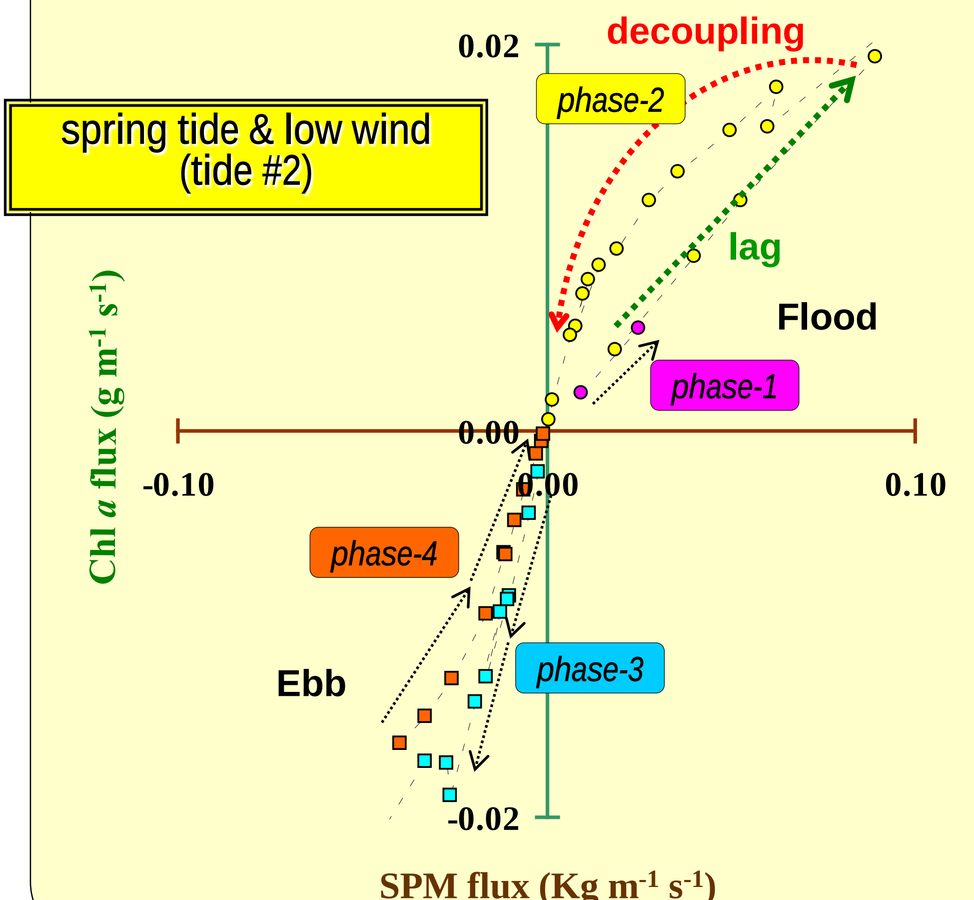
Results-6a-e

in terms of

Flux

Result-6a

We found: flux lag and coupling-decoupling behavior (typical)



Four-tidal phases classified by current velocity (CV)

- Flood tide
  - to maximum (early flood) — *phase-1*
  - **down to ≈zero (mid-**late flood) — *phase-2*
- Ebb tide
  - to minimum (early-mid ebb) — *phase-3*
  - to last period (mid-late ebb) — *phase-4*

Fluxes of Chl *a* and SPM during

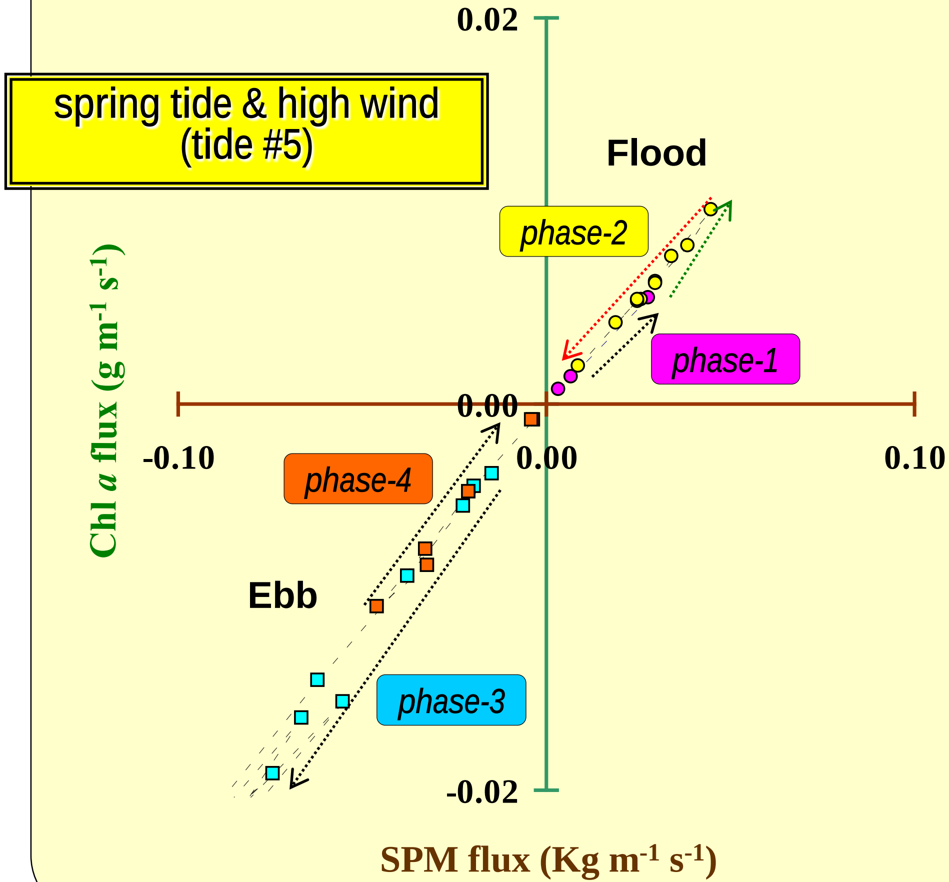
- *phase-1*: increased
- *phase-2*: increased for a time;
  CV reached maximum at phase-1, but flux still increasing for a time (flux-lagged: lag)
  then decreased; flux of Chl *a* segregated from SPM (decoupling)
- *phase-3*: increased
- *phase-4*: decreased

Fluxes of Chl *a* and SPM

high flux in response to high CV

Result-6b

We found: flux lag but lack of decoupling (masking by wind)



Four-tidal phases classified by current velocity (CV)

- Flood tide
  - to maximum (early flood) — *phase-1*
  - **down to ≈zero (mid-**late flood) — *phase-2*
- Ebb tide
  - to minimum (early-mid ebb) — *phase-3*
  - to last period (mid-late ebb) — *phase-4*

Fluxes of Chl *a* and SPM during

- *phase-1*: increased
- *phase-2*: increased for a time (lag), then decreased (but lack of decoupling)
- *phase-3*: increased (but irregular)
- *phase-4*: decreased

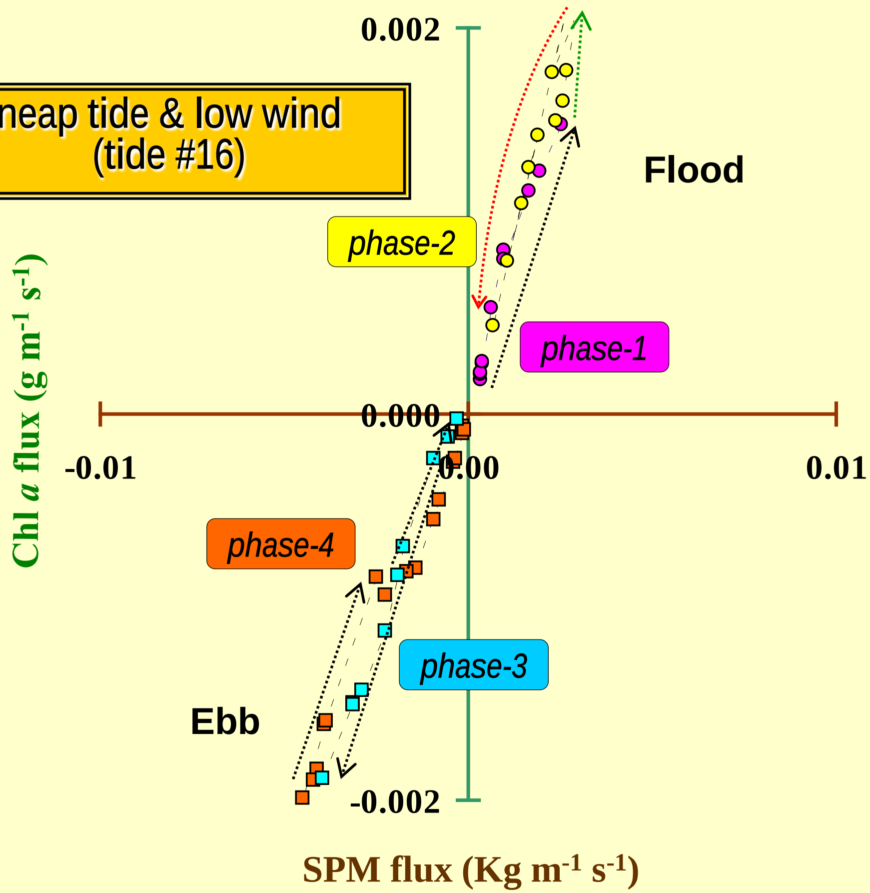
Fluxes of Chl *a* and SPM

high flux in response to high CV

Result-6c

We found: flux lag and weak decoupling (low current velocity)

neap tide & low wind
(tide #16)



Four-tidal phases classified by current velocity (CV)

- Flood tide
  - to maximum (early flood) — *phase-1*
  - **down to ≈zero (mid-**late flood) — *phase-2*
- Ebb tide
  - to minimum (early-mid ebb) — *phase-3*
  - to last period (mid-late ebb) — *phase-4*

Fluxes of Chl *a* and SPM during

- *phase-1*: increased
- *phase-2*: increased for a time (lag), then decreased (weak decoupling)
- *phase-3*: increased
- *phase-4*: decreased

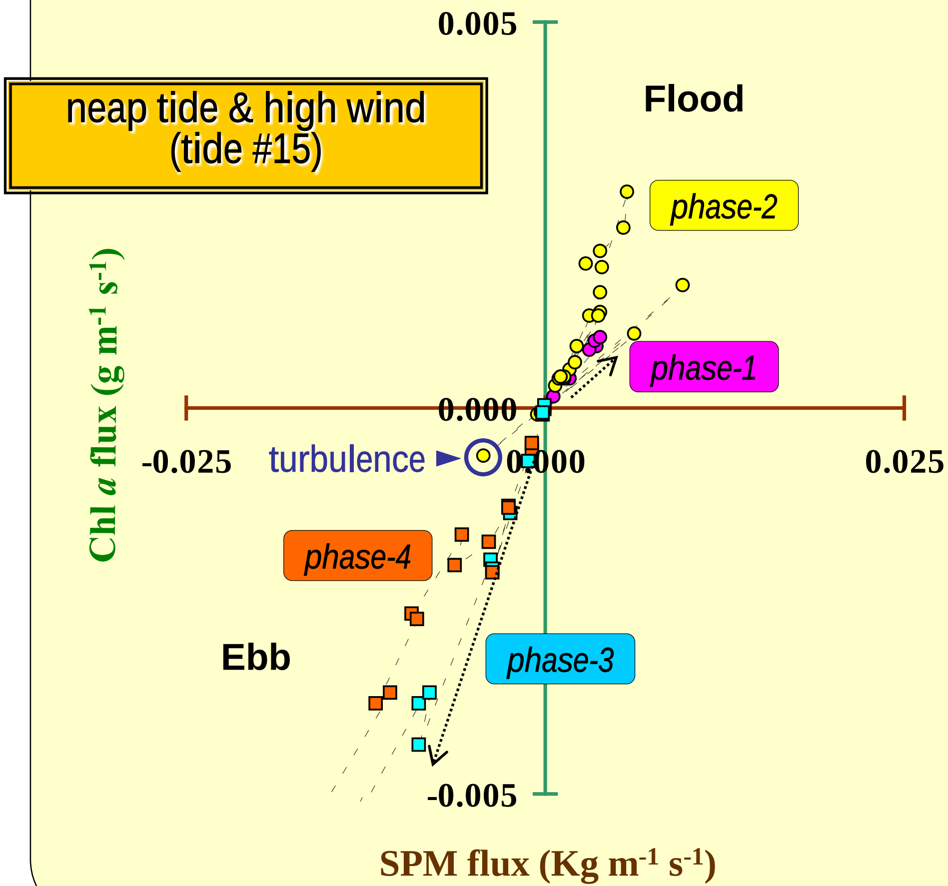
Fluxes of Chl *a* and SPM

low flux in response to low CV

(scale of X-Y is in 1/10 compared to result 4a and 4b)

Result-6d

We found: irregular pattern (high wind effect)



Four-tidal phases classified by current velocity (CV)

- Flood tide
  - to maximum (early flood) — *phase-1*
  - **down to ≈zero (mid-**late flood) — *phase-2*
- Ebb tide
  - to minimum (early-mid ebb) — *phase-3*
  - to last period (mid-late ebb) — *phase-4*

Fluxes of Chl *a* and SPM during

- *phase-1*: increased
- *phase-2*: irregular (high wind effect)
- *phase-3*: increased
- *phase-4*: irregular (high wind effect)

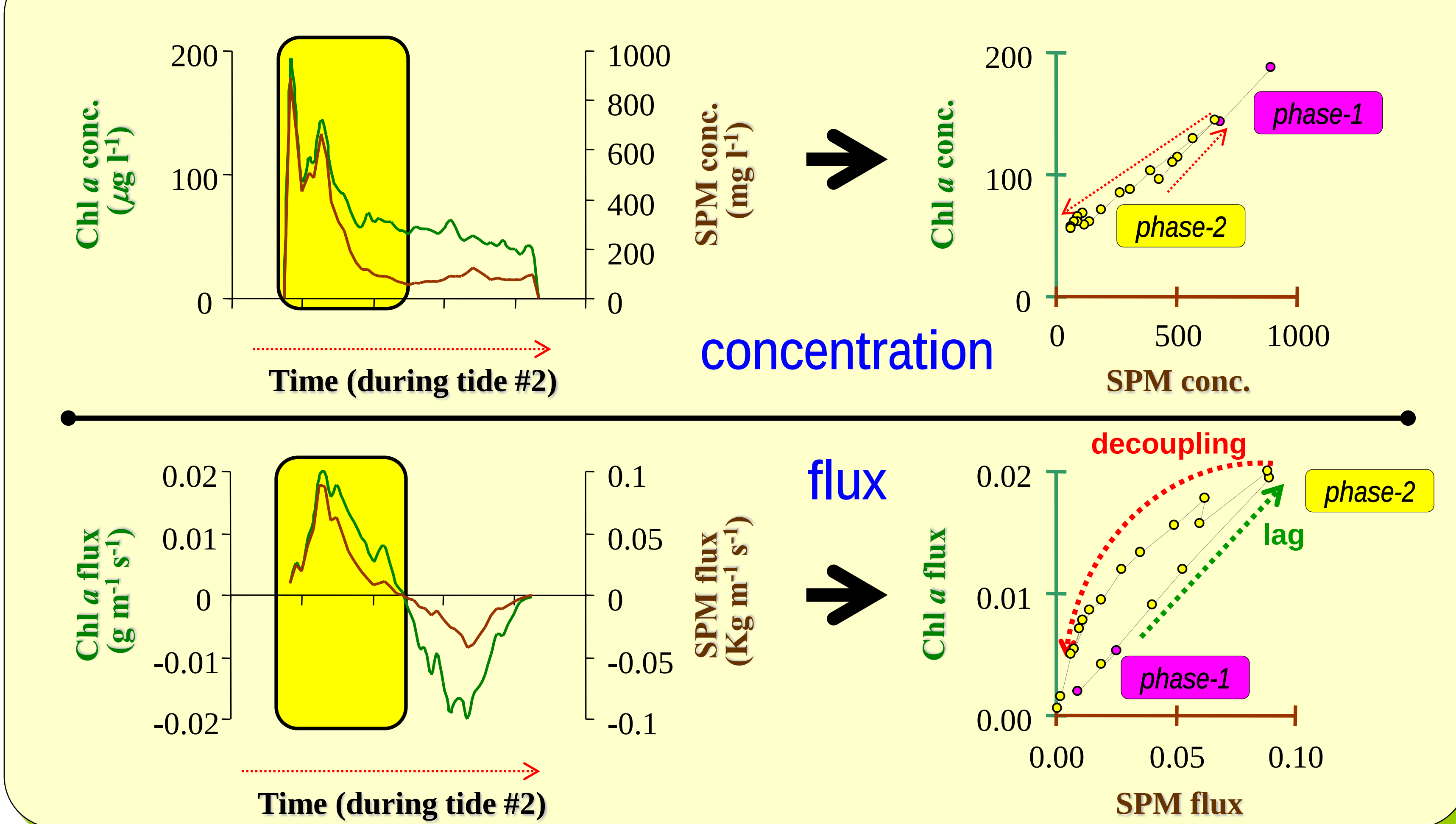
Fluxes of Chl *a* and SPM

moderate flux in response to high wind though under low CV

(scale of X-Y is in 1/4 compared to result 4a and 4b)

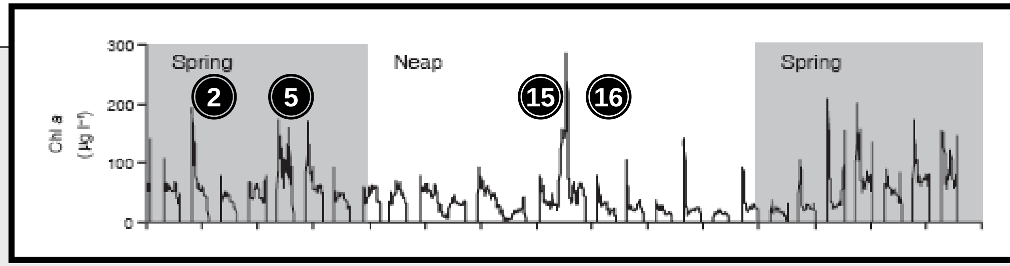
Result-6e

We found: behaviors of Chl *a* and SPM: much clear in 'flux'



Summary-2: Results-6a-e

We further found



- **Key results were**

1) clear patterns of 'lag' and 'decoupling', with high fluxes
(under spring tide & low wind condition; tide # 1, 2, 3, 4, 6, 7, 22, 23, 27, 28**)**

2) 'lag' found, but no 'decoupling', sometime irregular, with high fluxes
(under spring tide & high wind condition; tide # 5, 24, 25, 26**)**

3) 'lag' found and weak 'decoupling', with low fluxes
(under neap tide & low wind condition; tide # 8, 9, 10, 12, 14, 16, 18, 20, 21**)**

4) irregular fluctuation, with moderate fluxes
(under neap tide & high wind condition; tide # 11, 13, 15, 17, 19**)**

Discussion

Discussion-1

Present study indicated: in terms of 'concentration'

- **Tide- and wind-induced resuspension of MPB and SPM**

1) Similar temporal fluctuation of MPB and SPM in water column (influenced by current and wind)

2) Tide-induced resuspension: regular (threshold CV of ca. 15 cm s^{-1})

3) Wind-induced resusepension: irregular, twice more effective than CV (effective wind speed of ca. 3 m s^{-1})

- **Benthic-pelagic coupling**

4) Sediment MPB showed similar temporal distribution with water-column MPB during a full spring to neap tidal cycle

5) Overall contribution of resuspended Chl *a* to total Chl *a* in tidal flat considerable ranging from 9 to 61% (mean=42%)

Discussion-2

Present study revealed: in terms of 'flux'

- **Behavior of MPB and SPM**

1) Fluxes of MPB and SPM broadly reflected tidal energy (in terms of direction and strength) during a full spring to neap tidal cycle

2) Plotting MPB and SPM fluxes over time (namely four-tidal phases) indicated 'lag', 'coupling', 'decoupling', & 'irregular' characteristics of MPB and SPM behaviors in water column during resuspension

3) current velocity primarily controlled MPB and SPM behaviors ('decoupling' pattern & ranges of fluxes)
   higher wind masked regular pattern of MPB and SPM behaviors (viz. current-dependant fluxes)

Remark!

Important note

- **Need to examine more data**

1) Overall, the analysis of Chl *a* and SPM indicated that MPB (viz. Chl *a*) were closely associated with sediment particles (viz. SPM) in water column during a course of tidal resuspension (evidence from the observation and data presented)

2) However, more detailed analyses of each parameter from the plenty of mooring data should be analyzed to further extract and confirm the type of behavior of microphytobenthic Chl *a* together with SPM, in terms of 'flux' as well as 'concentration'

3) Finally, further flora and production study should be performed to clearly demonstrate the structure and function of MPB in tidal flat ecosystem

Thank You !

Acknowledgement

- to Prof. Hayashi and Miss Yahiro in ILT, Saga University
- supported by the Research and Development Program for New Bio-industry Initiatives (2001-03), Japan (Title: Technological development for bottom sediment improvement and benthos restoration in the Ariake Sea)
- supported by the Korean Sea Grant Project (2001-03), Ministry of Maritime Affairs & Fisheries, Korea (Title: An estimation of biomass and production of benthic microalgae in coastal sediment, Korea)