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Update on Leakage detection

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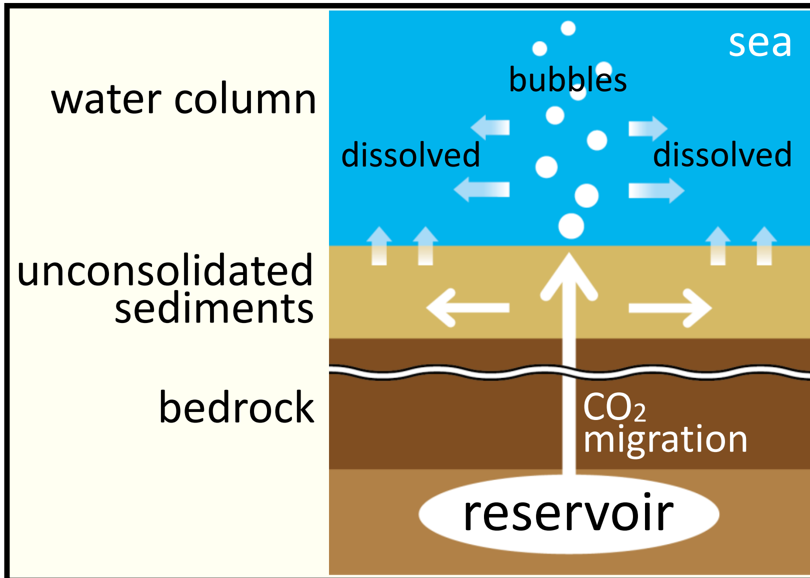
Detecting anomalies



←Some CO_2 is emitted in the form of bubbles, and dissolves in seawater within a few meters rise

←Some CO_2 dissolves in pore water in sediments and is emitted in a dissolve state

Signals of potential CO_2 leakage

- Increase in CO_2 concentration or partial pressure of CO_2 (pCO_2) in seawater near the sea bottom
- CO_2 bubbles in the water column

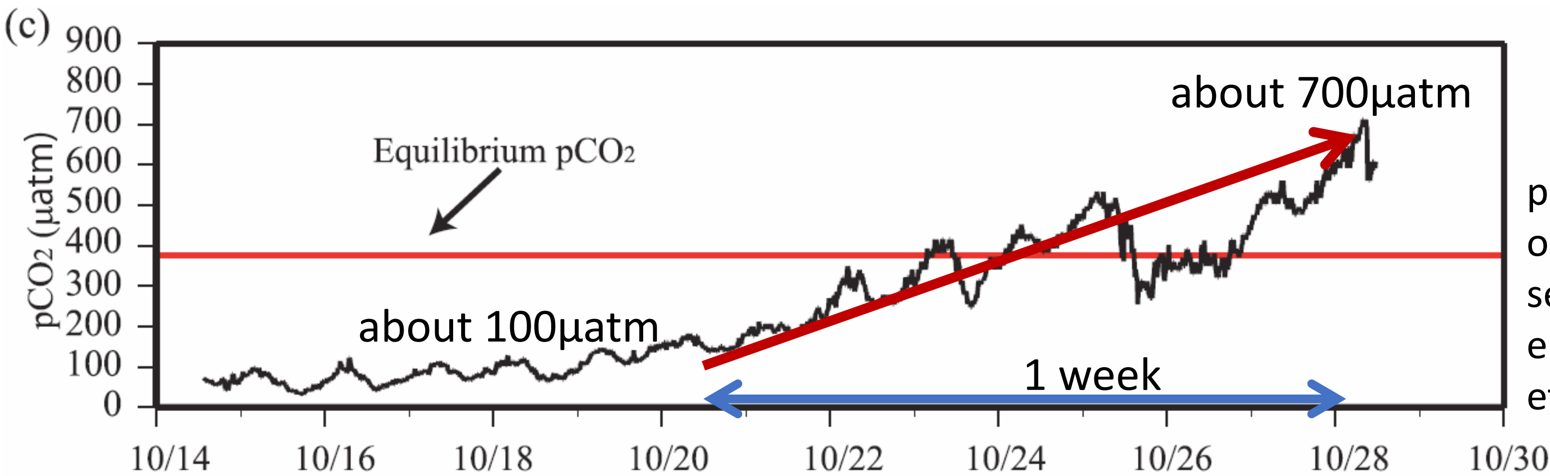
Detecting anomalously high pCO_2

Suspected signs of CO_2 leakage

✓Anomalously high pCO_2

✓Rapid increase in pCO_2

But these are also seen in the natural variability



pCO2 variation observed near the sea surface in a semi-enclosed bay by Fujii et al. (2011)

Two threshold methods

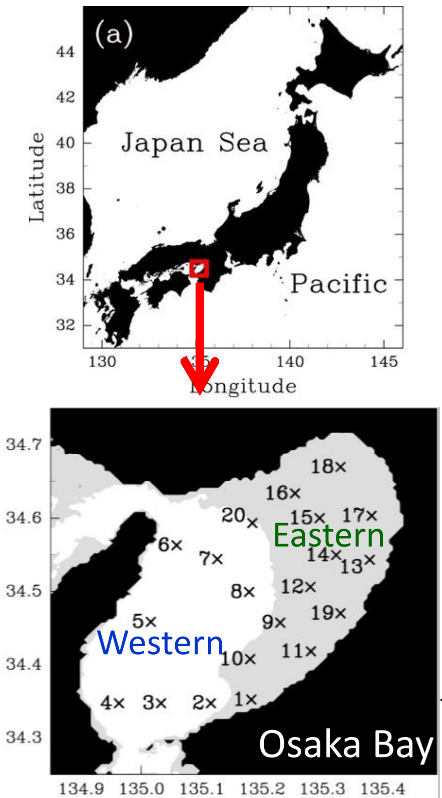
- Seasonal threshold
  - a seasonally fixed value of pCO_2
- Covariance threshold
  - the upper limit of a prediction interval of a linear regression of pCO_2 on DO (DO: Dissolved Oxygen)

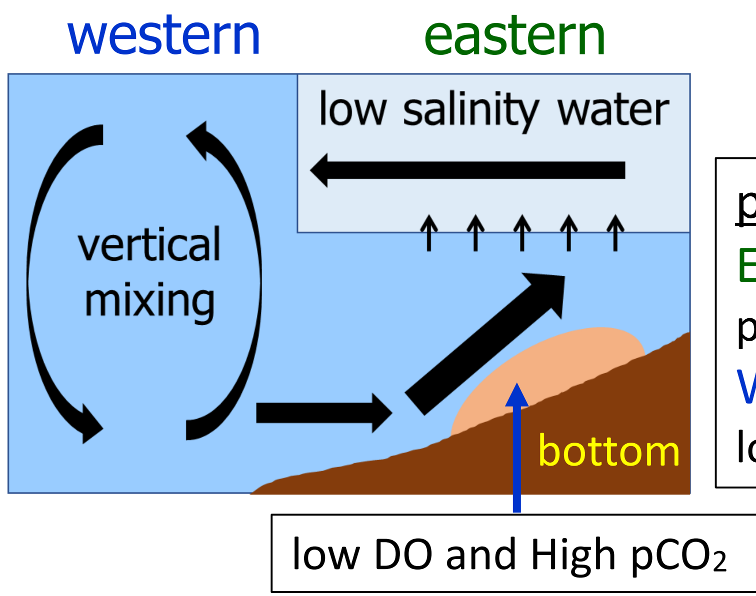
Which is the better of the two?

Case study: Osaka Bay

semi-enclosed bay in Japan

Eastern bay: prone to be stratified throughout the year
Western bay: prone to be vertically mixed





pCO_2 and DO near the bottom

Eastern: often low DO and high pCO_2 during summer

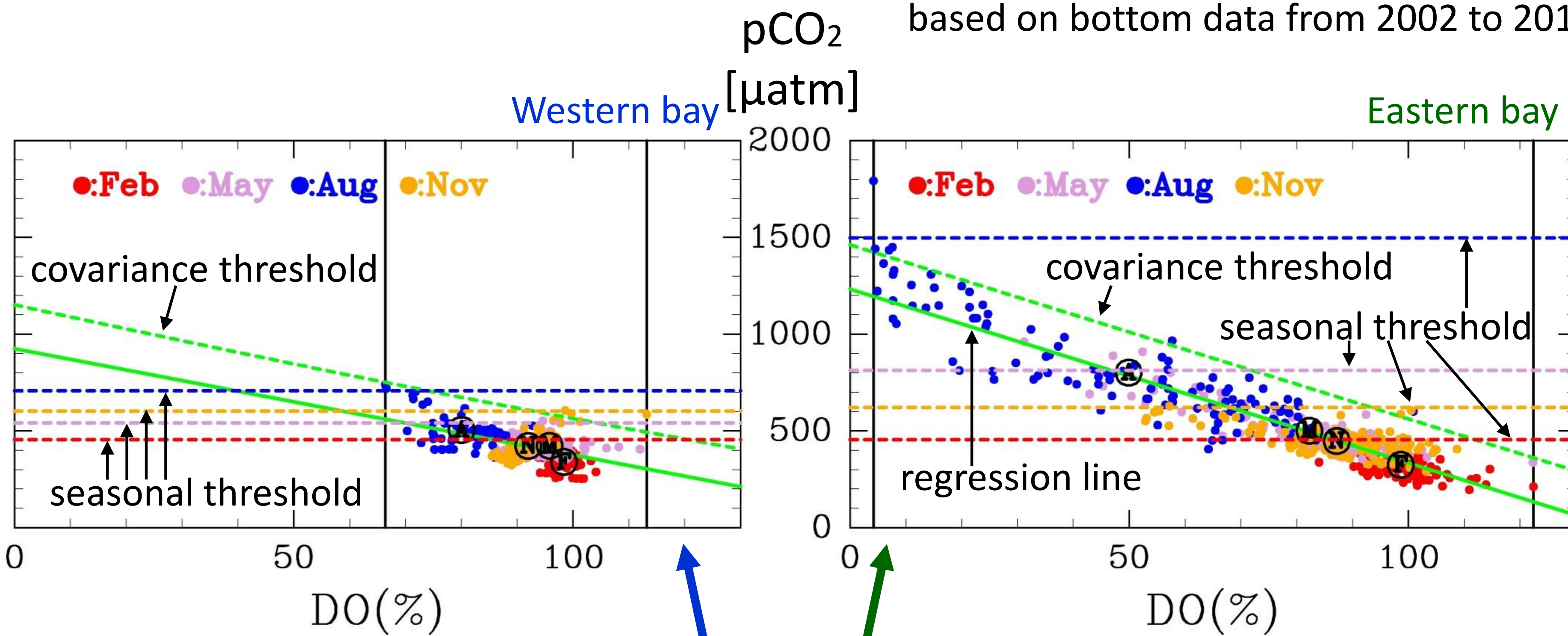
Western: relatively high DO and low pCO_2 throughout the year

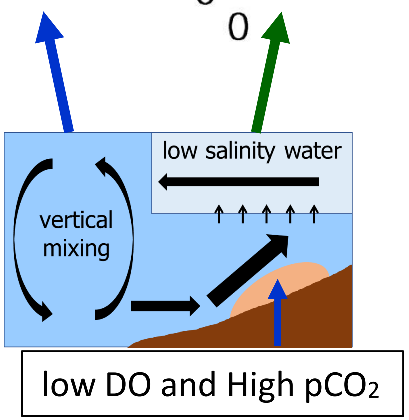
Observation stations

- ✓ temperature, salinity, DO, pH etc.
- ✓ 4 times a year

Thresholds in Osaka Bay

based on bottom data from 2002 to 2010





covariance threshold
the upper limit of 99% prediction interval of the straight line regression

seasonal threshold
average + 2.57 σ
(σ: standard deviation)

What is a good threshold?

- A threshold that rarely overlooks CO_2 leakage is **good**.

false-negatives

- A threshold that often misjudges natural phenomena as leakage is **bad**.

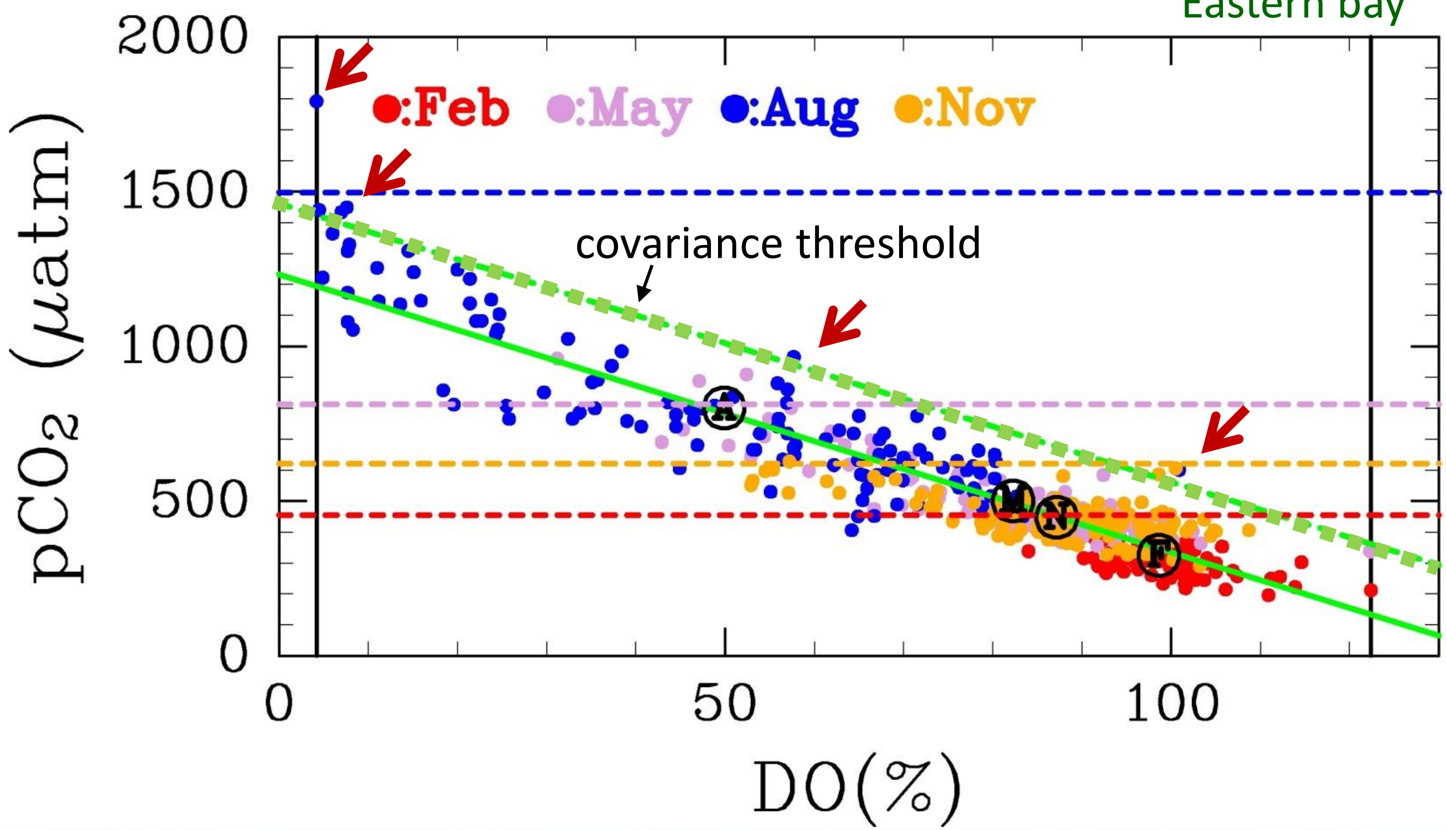
false-positives

We should compare false-negatives of the two thresholds under the same level of the occurrence of false-positives

False-positives

To misjudge natural phenomena as leakage

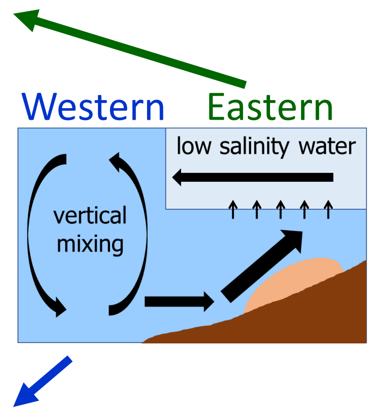
Eastern bay



False-positives

Eastern bay: stratified area

Threshold	Feb	May	Aug	Nov	Total
seasonal	0 (0%)	3 (2.59%)	1 (0.86%)	1 (0.85%)	**5 (1.08%)**
covariance	0 (0%)	0 (0%)	6 (5.17%)	2 (1.71%)	**8 (1.72%)**



Western bay: vertically mixed area

Threshold	Feb	May	Aug	Nov	Total
seasonal	0 (0%)	1 (1.59%)	2 (3.17%)	1 (1.59%)	**4 (1.59%)**
covariance	0 (0%)	0 (0%)	0 (0%)	3 (4.76%)	**3 (1.19%)**

Difference of false-positives between the two thresholds is small

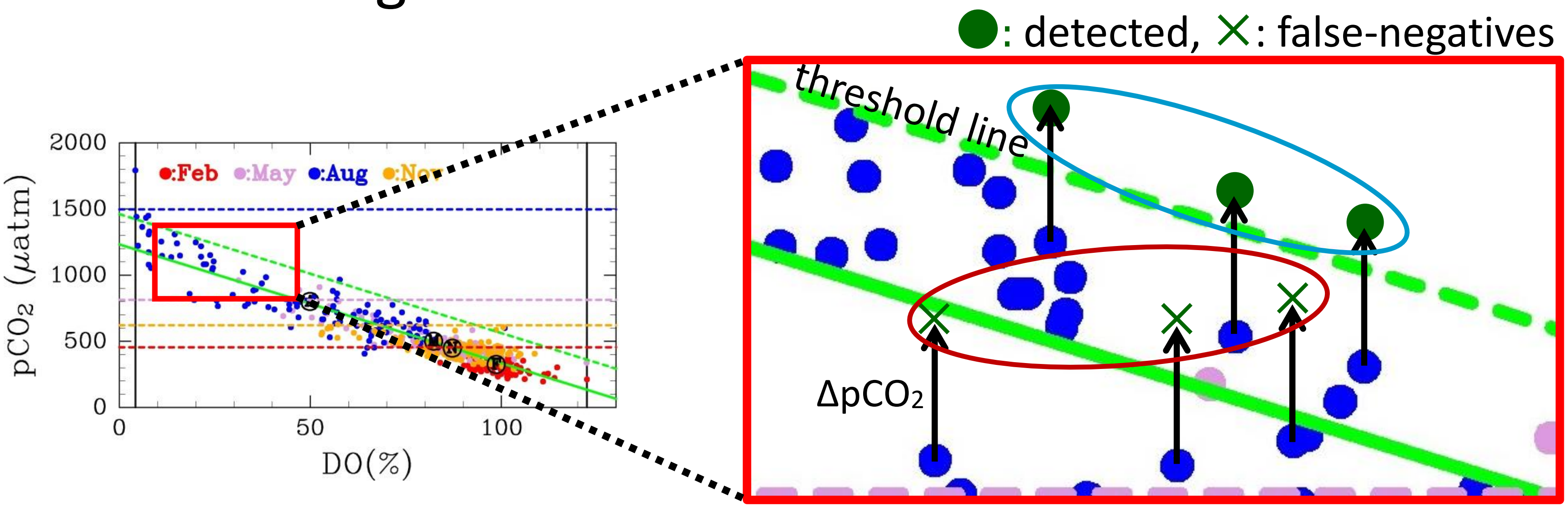
↓

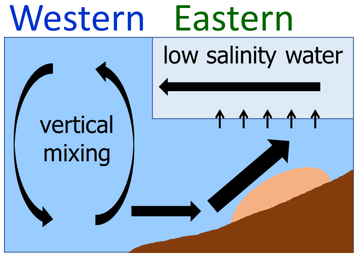
Regarding the level of false-positives as the same, we compared the false-negatives.

False-negatives

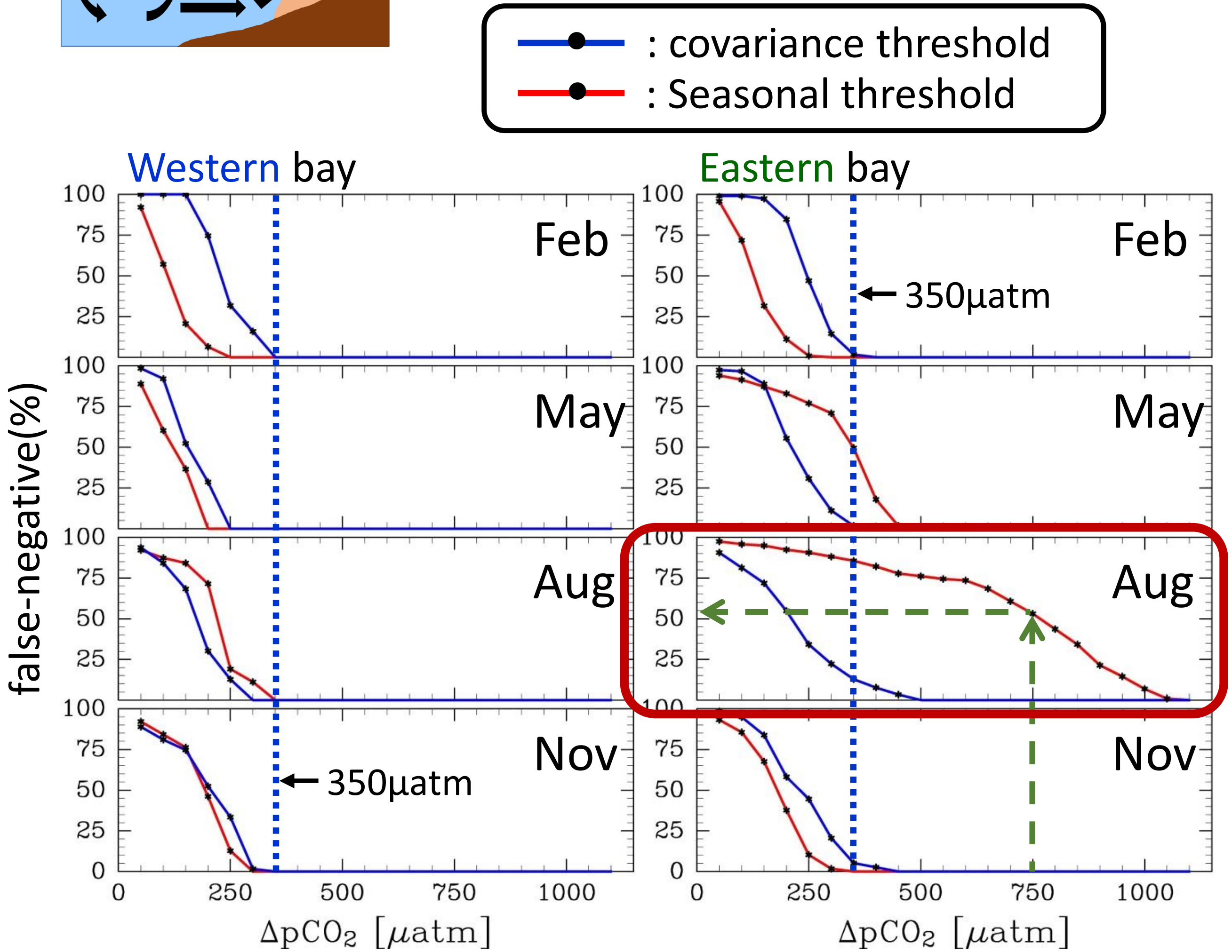
Assumption: CO_2 leakage makes pCO_2 increase by ΔpCO_2 but DO remains unchanged

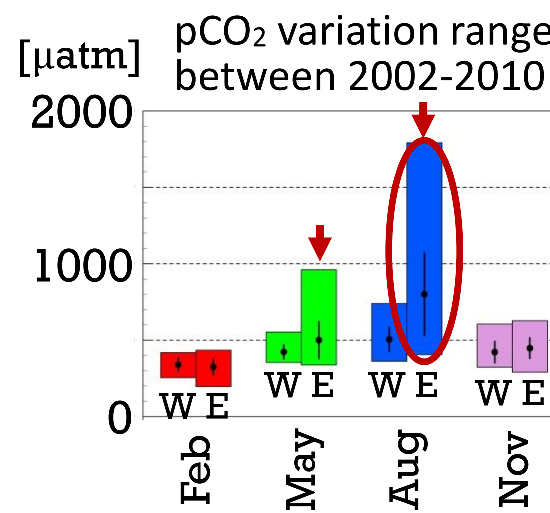
Data are translated upward parallel to the vertical axis due to leakage





False-negatives





Summary

Observing pCO_2 in the sea around the storage sites is an option in marine monitoring to detect CO_2 leakage

- **Seasonal threshold**: good detectability in many cases but useless in some cases
- **Covariance threshold**: not necessarily the better but reasonable detectability in any case

Which threshold to use depends on the season and area;

it is conjectured that

- in areas and seasons with a large variation in pCO_2 the **covariance threshold** is better,
- in areas and seasons with a small variation in pCO_2 the **seasonal threshold** is better.

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The presentation is based on our paper:

Uchimoto, K., Nishimura, M., Kita, J., Xue, Z. (2018). Detecting CO_2 leakage at offshore storage sites using the covariance between the partial pressure of CO_2 and the saturation of dissolved oxygen in seawater. *International Journal of Greenhouse Gas Control*, 72, 130-137.