

# Processes controlling air-sea exchange of carbon dioxide, Kaneohe Bay, Oahu, Hawaii

Kathryn E. Fagan, Fred T. Mackenzie,  
Daniel W. Sadler, and Justin Dilg

# Outline

- Introduction
- Study Site
- Methods
- General Trends
- Time Series Data
  - Response to Storms
- Spatial Influence of Bay CO<sub>2</sub>
- Conclusions

# Introduction

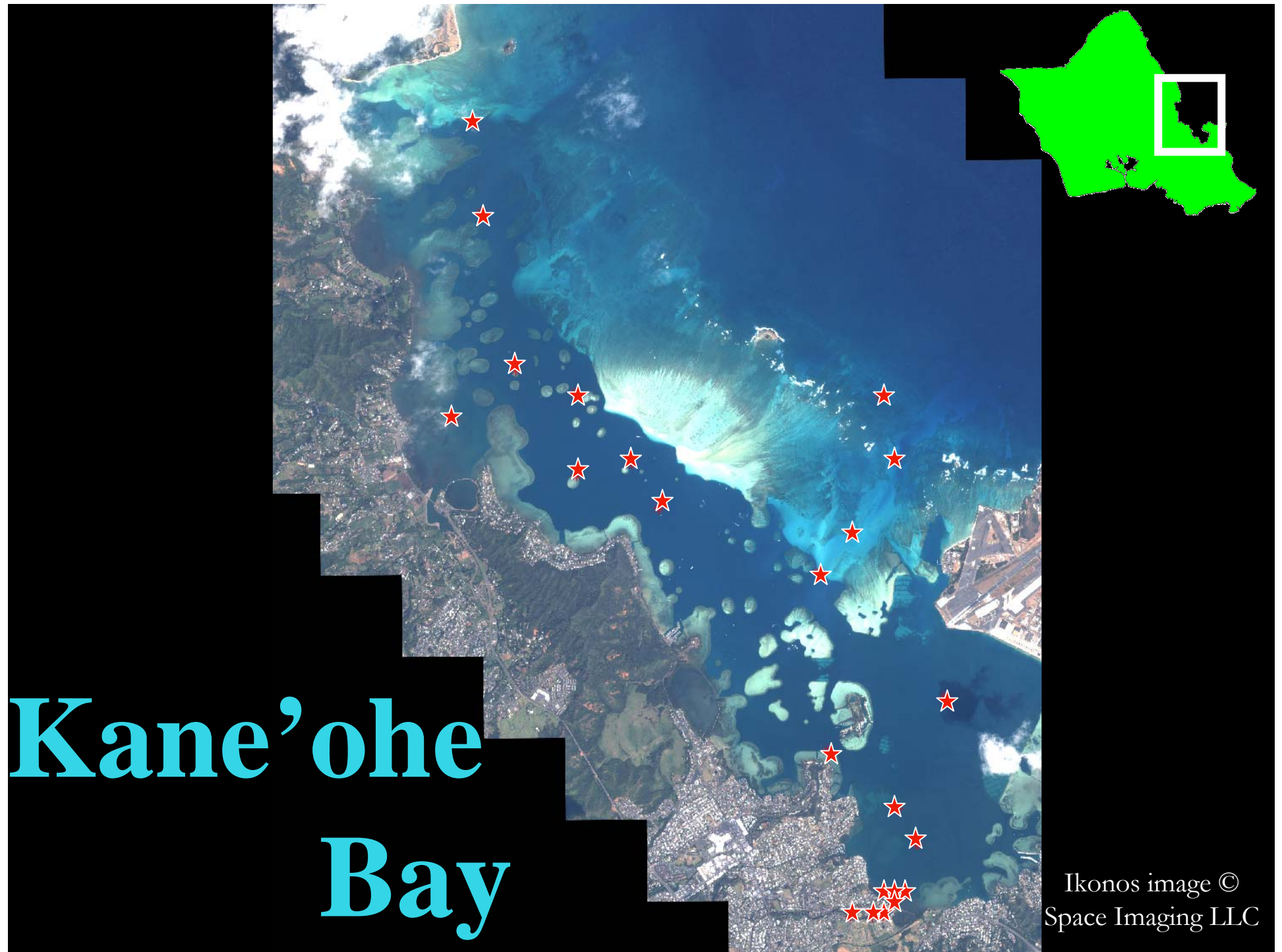
- Much work has been done on the open ocean CO<sub>2</sub> system, including long-term time series studies
  - HOT and BATS
- Comparatively little work has been done on coastal ocean CO<sub>2</sub>, especially time series work

Location/Region	Net CO <sub>2</sub> Flux (gCm <sup>-2</sup> yr <sup>-1</sup> )	Reference
Hog Reef flat, Bermuda	-14.4	Bates et al. 2001
New Jersey	+5.2 to +10.1	Boehme et al. 1998
Galician Coast	+7.9 to +14	Borges and Frankignoulle 2001
Scheldt Estuarine Plume	-13.2 to -22.8	Borges and Frankignoulle 2002
South Atlantic Bight	-30	Cai et al. 2003
Mid Atlantic Bight	+12	DeGrandpre et al. 2002
Gulf of Calvi	-28	Frankignoulle 1988
Gulf of Biscay	+21 to +34.6	Frankignoulle and Borges 2001
European estuaries	-438 to -3330	Frankignoulle et al. 1998
Moorea, French Polynesia	-6.6	Gattuso et al. 1993
Northern Arabian Sea	-5.5	Goyet et al. 1998
Cape Perpetua	+87.6	Hales et al. 2003
North Sea	+16.2	Kempe and Pegler 1991
Baltic Sea	+10.8	Thomas and Schneider 1999
East China Sea	+35	Tsunogai et al. 1999
East China Sea	+14.4 to +33.6	Wang et al. 2000

*from Andersson and Mackenzie 2004*

# Study Site

- No time series studies have been performed in coastal zones of the tropical/subtropical Pacific
- Kaneohe Bay, Oahu, HI
  - Windward (Eastern) side of Oahu
  - Largest bay in Hawaii
  - Large barrier reef
  - Numerous patch reefs
  - Multiple riverine inputs



# Kaneohe Bay

Ikonos image ©  
Space Imaging LLC

# Methods

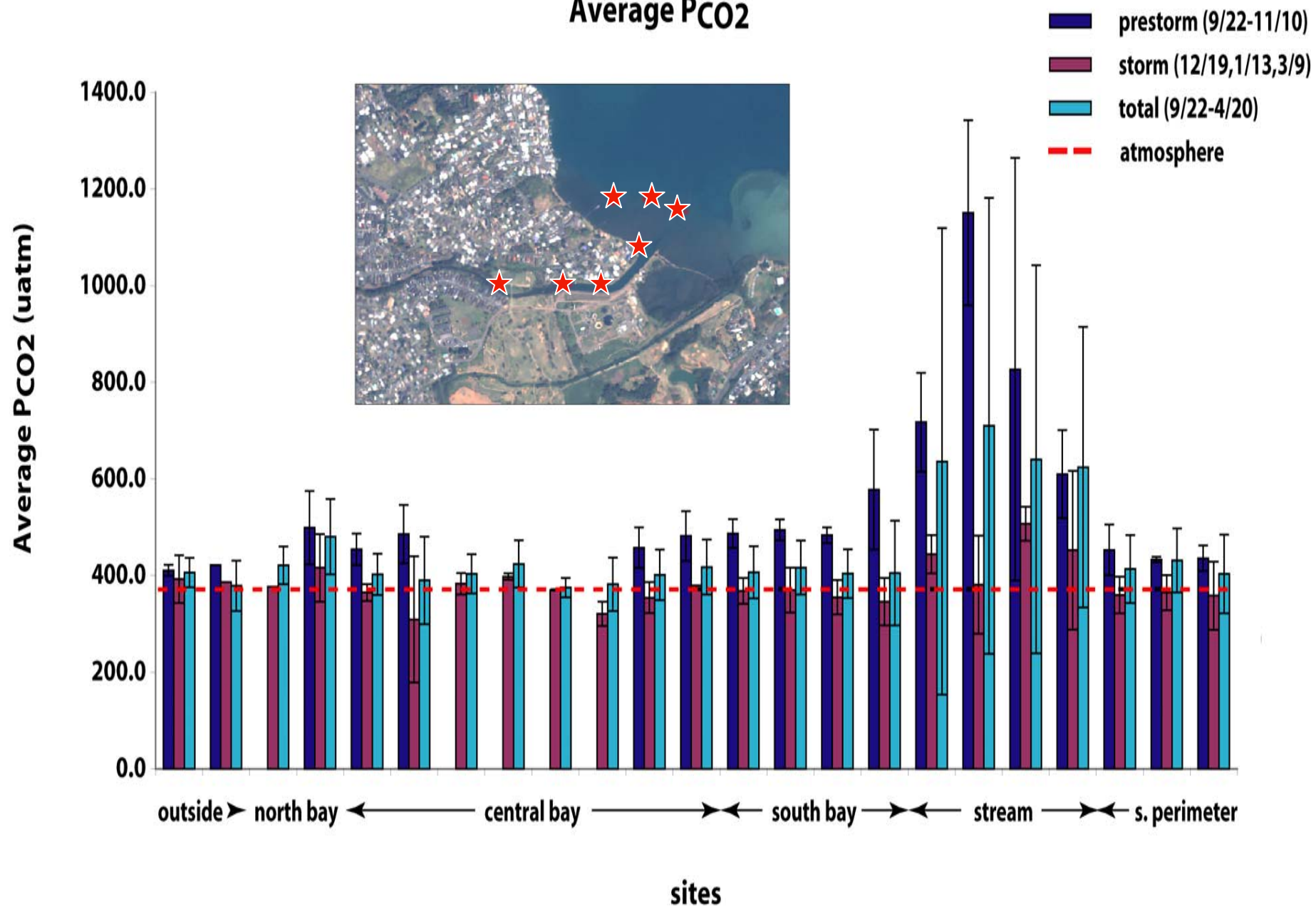
- 23 sample sites
- Bimonthly sampling since September 2003
- Total Alkalinity and Dissolved Inorganic Carbon analysis
  - HOT program equipment and methods
- $P_{\text{CO}_2}$  calculated using constants from Mehrbach et al. (1973) refit by Dickson and Millero (1987)



# General Trends



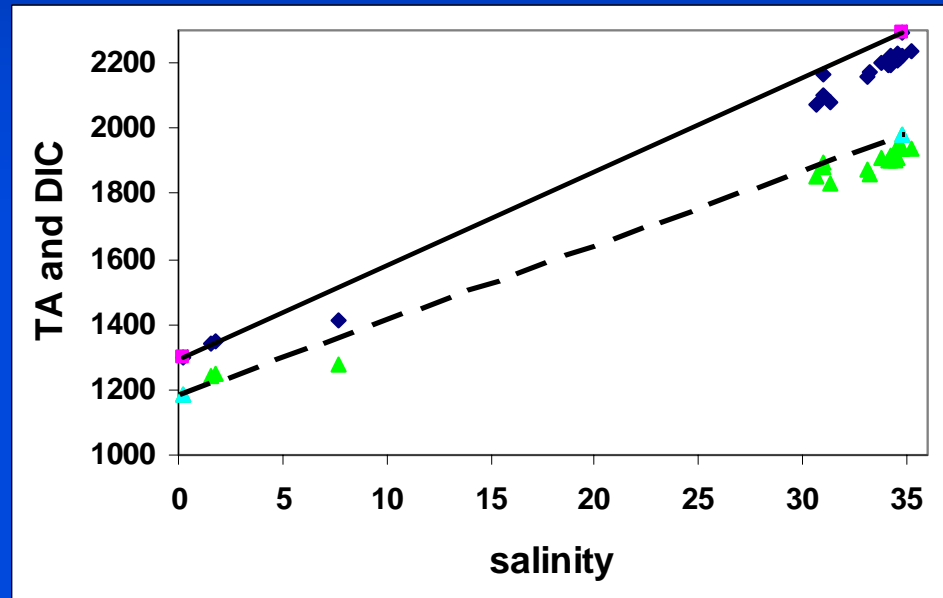
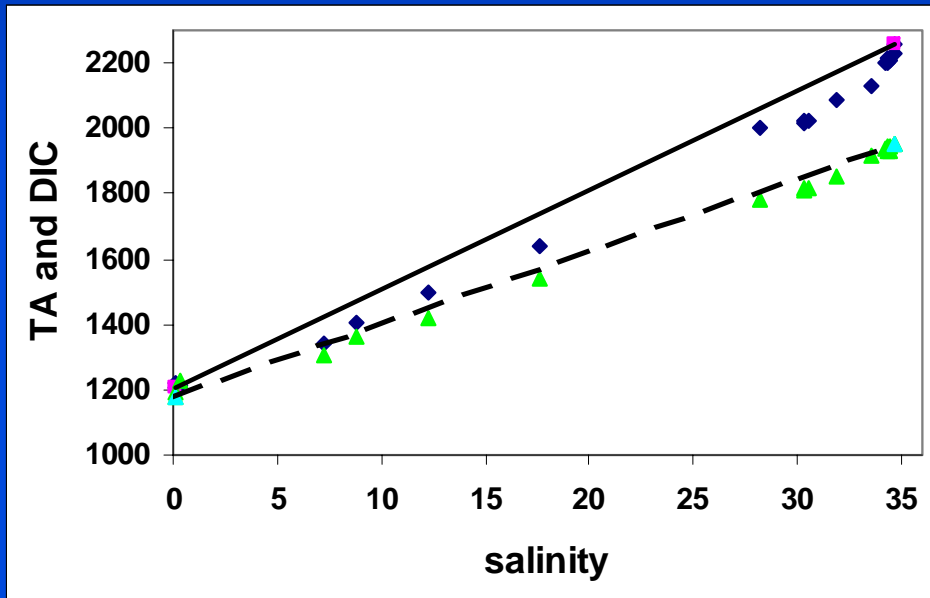
## Average PCO2



# Kaneohe Bay Trends

- $P_{\text{CO}_2}$ s above atmospheric for all sites
  - Calcification
- Highest  $P_{\text{CO}_2}$ s found in stream waters
  - Remineralization of terrestrial organic matter
  - Spatially small influence on bay
- Lowest  $P_{\text{CO}_2}$ s found just outside barrier reef
  - How far until sink?
- Bay sites within  $P_{\text{CO}_2}$  range of  $\sim 425 - 575 \mu\text{atm}$

# Conservative Mixing Lines



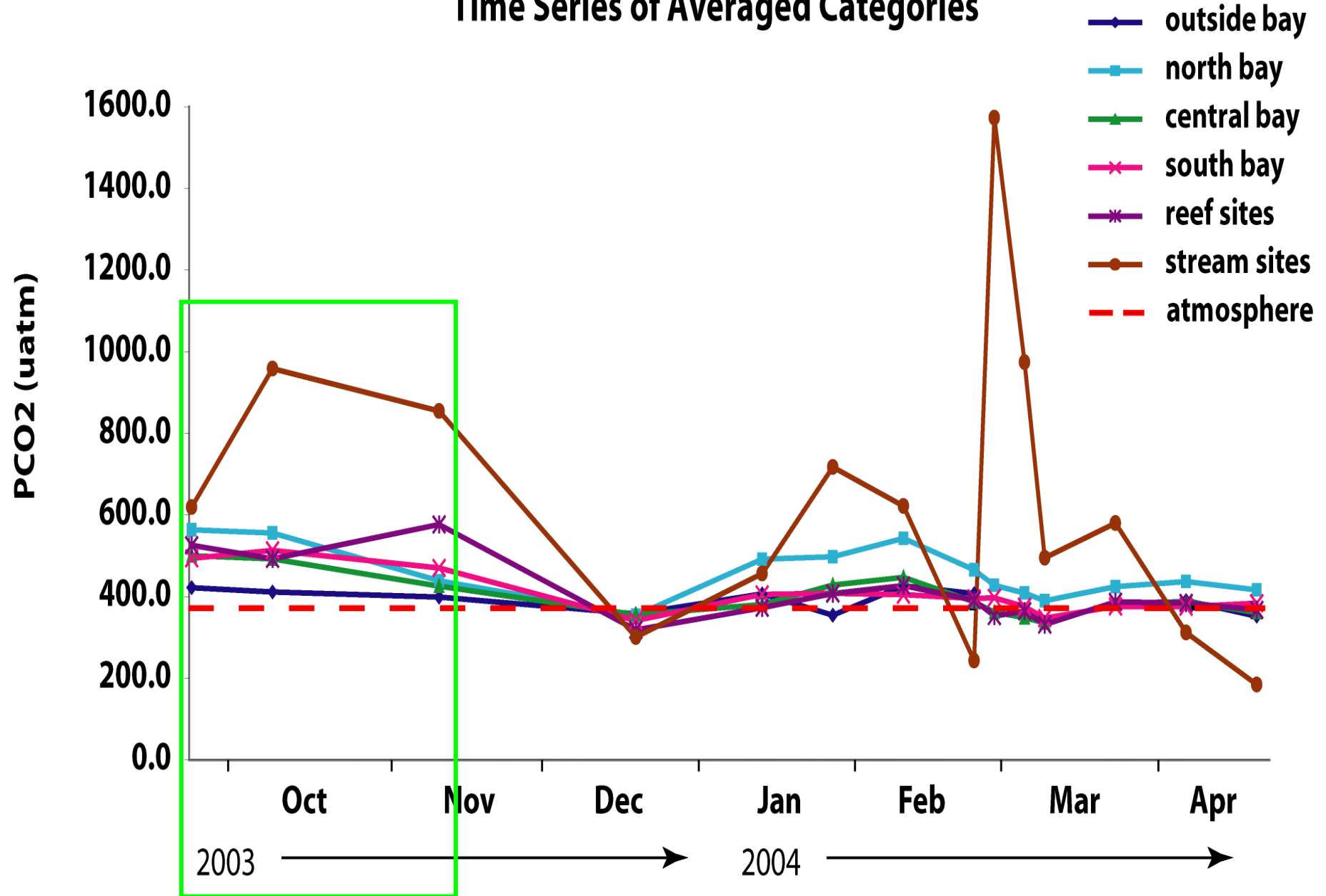
Total Alkalinity



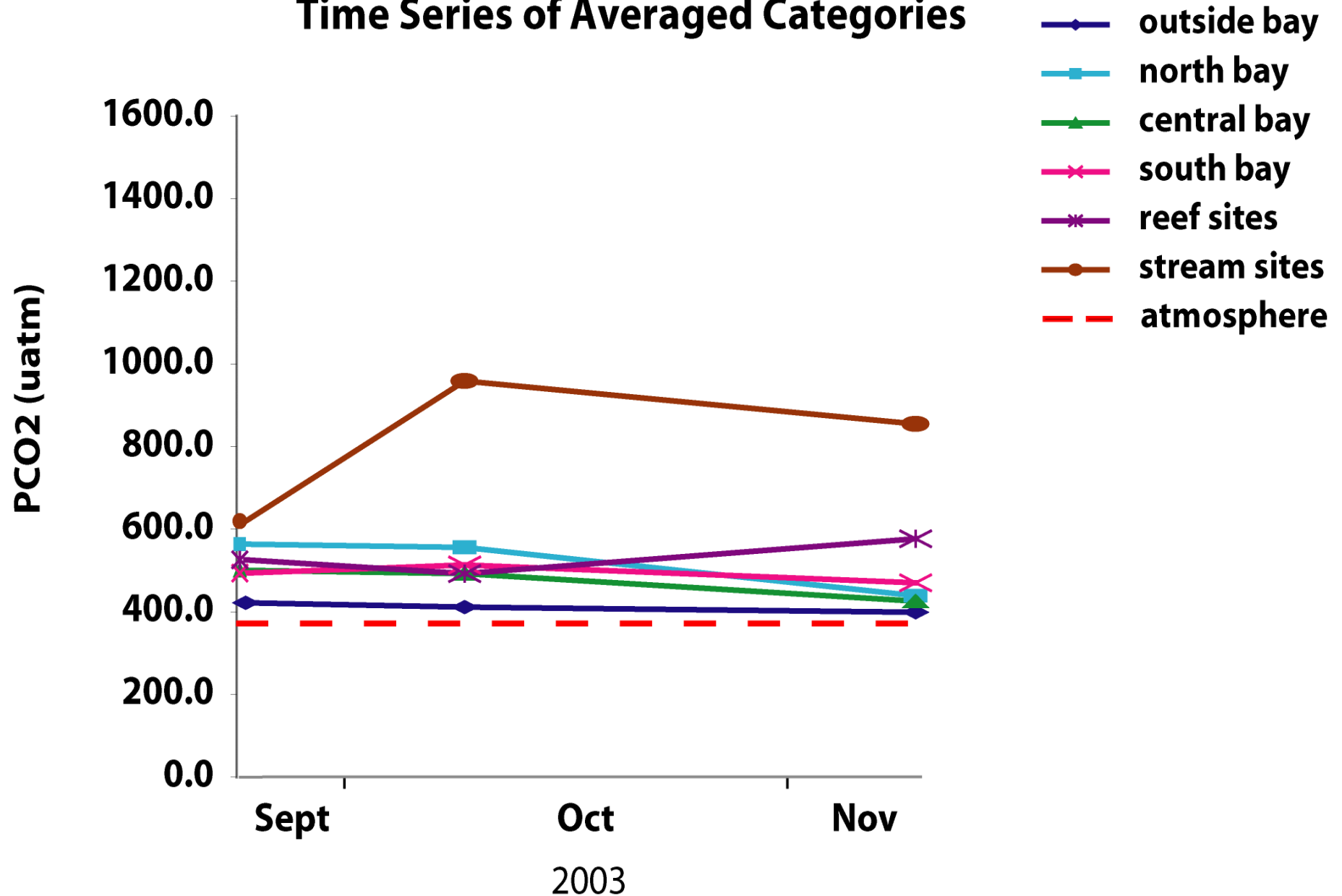
Dissolved Inorganic Carbon

# Time Series

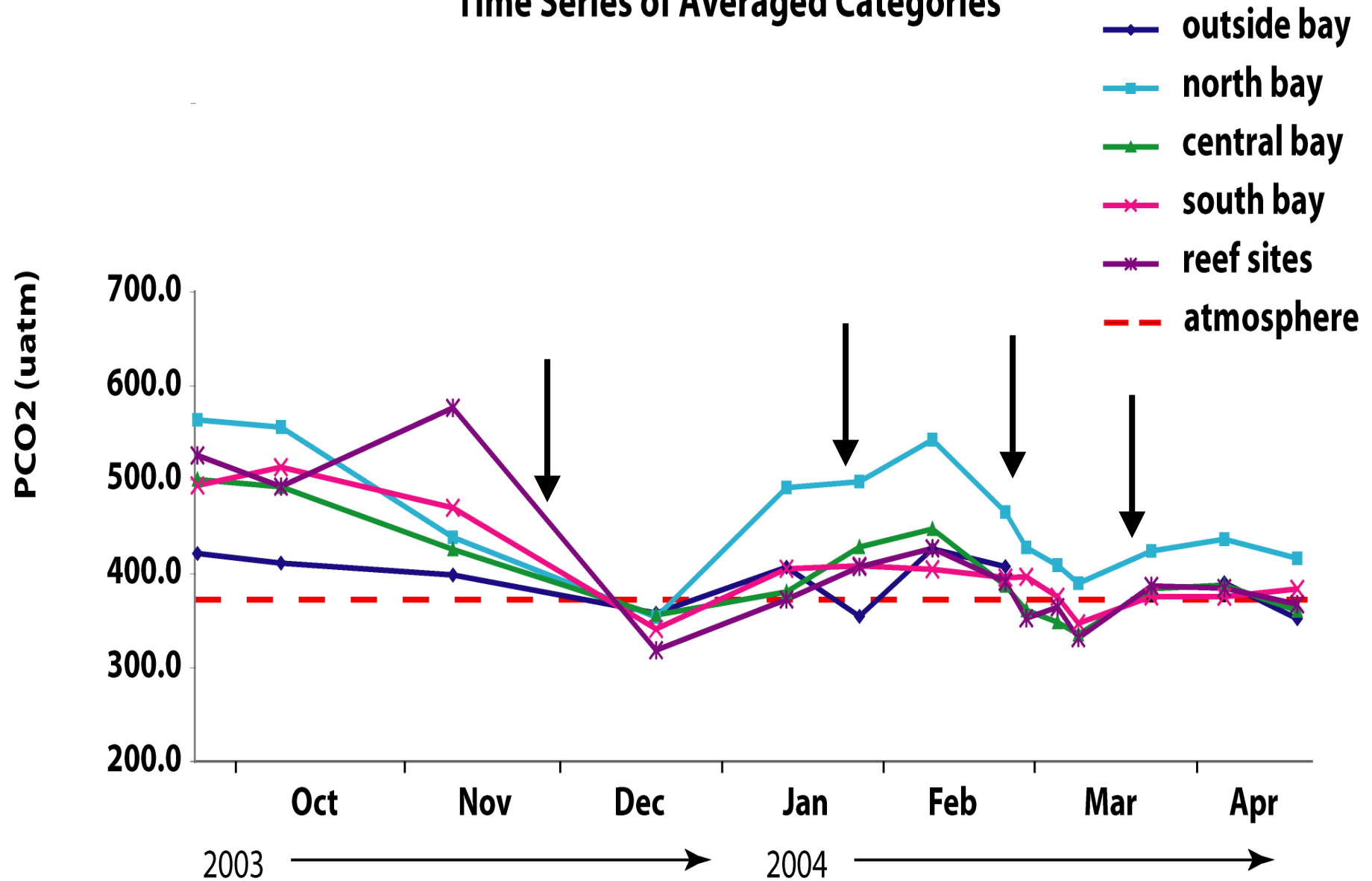
# Time Series of Averaged Categories



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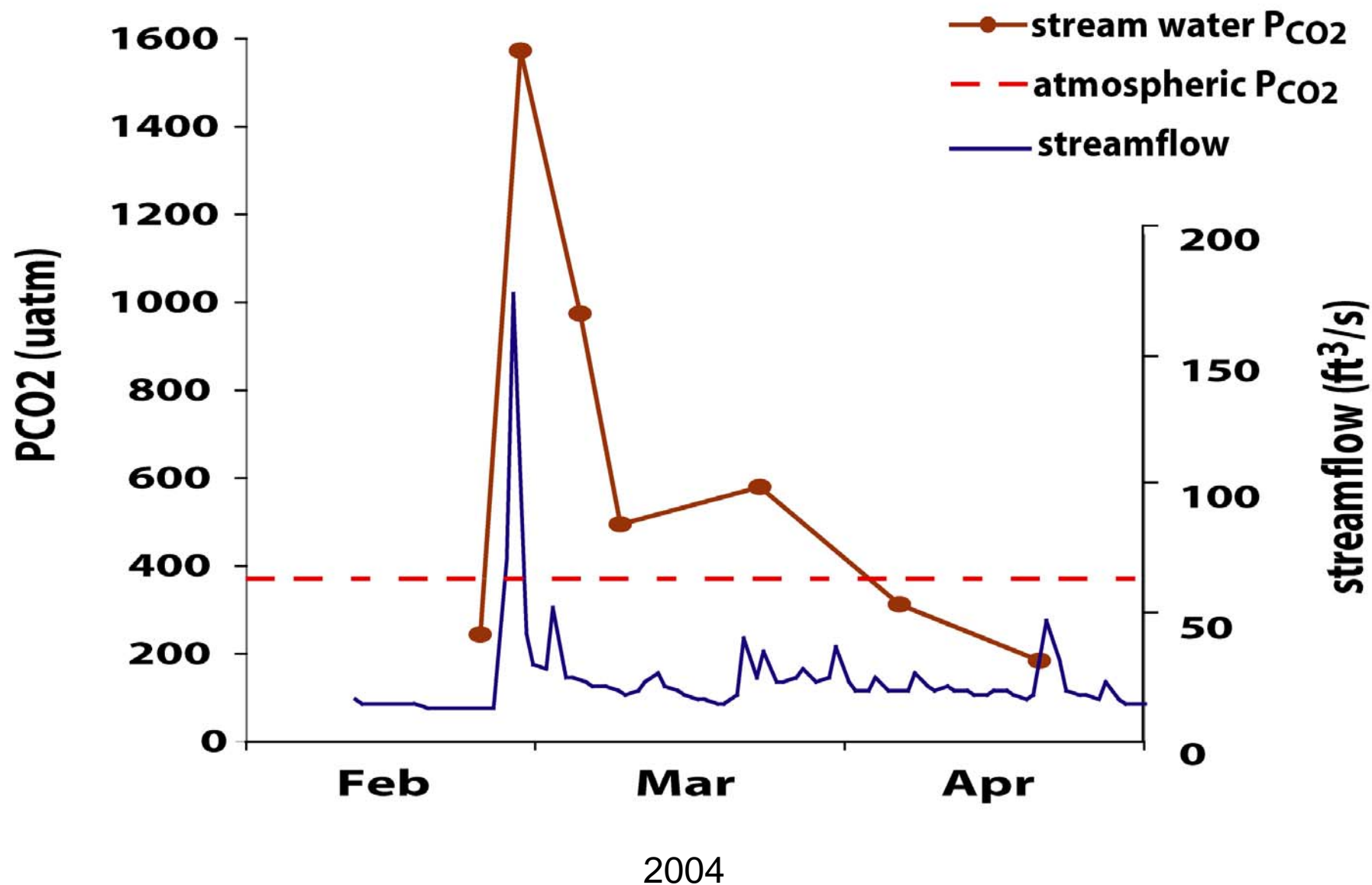


**Time Series of Averaged Categories**





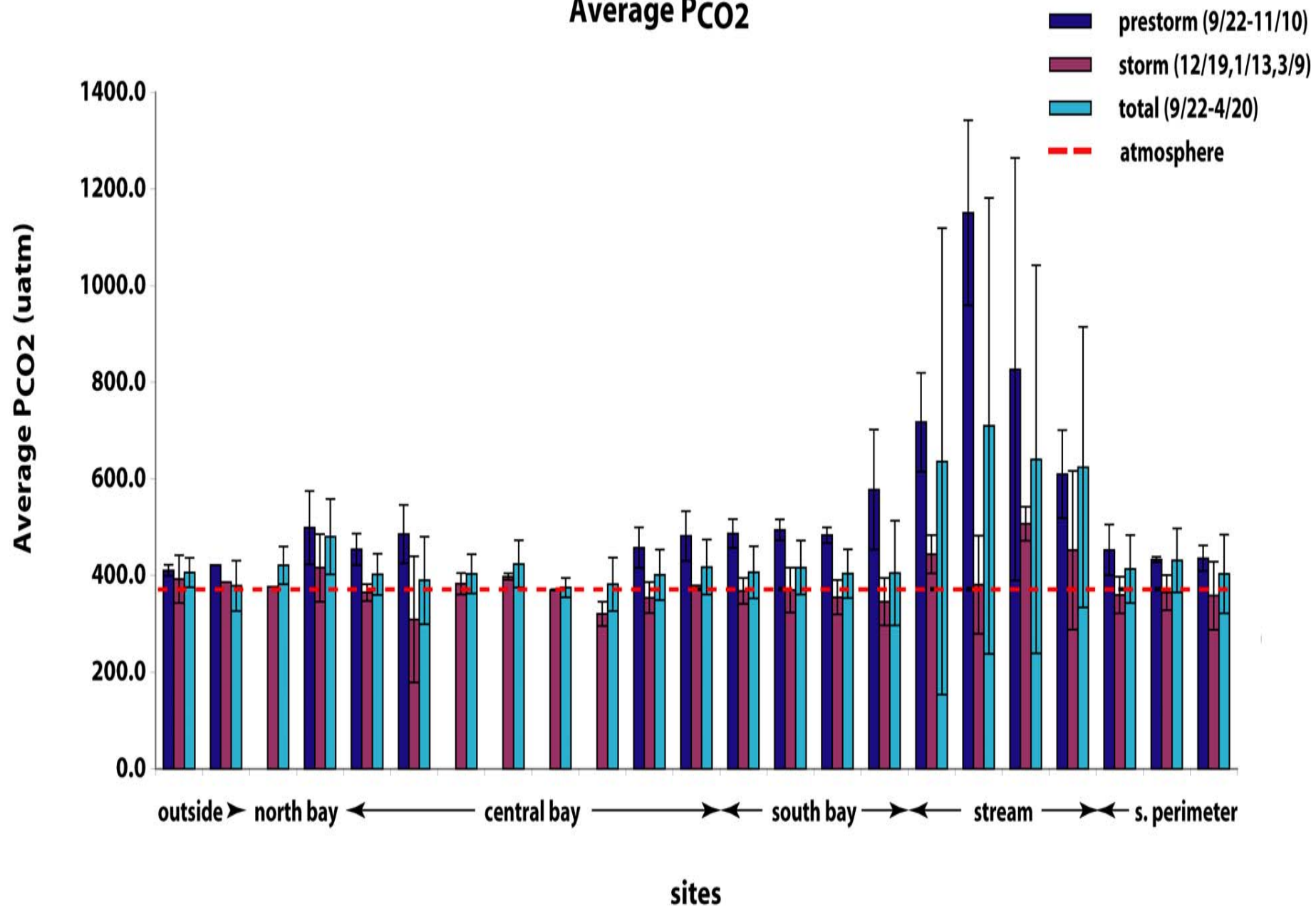
## Stream Water Time Series



# Storm Response

- Storm induced increased river runoff flushes out soil/groundwater
  - Extremely high  $P_{\text{CO}_2}$  water in river
  - Complicating factors
  - Nutrient loading of bay waters
- Photosynthesis stimulated by excess nutrients draws down  $\text{CO}_2$  to at or below atmospheric level throughout bay
  - Response time days to a week  
(*Ringuet and Mackenzie, in press*)

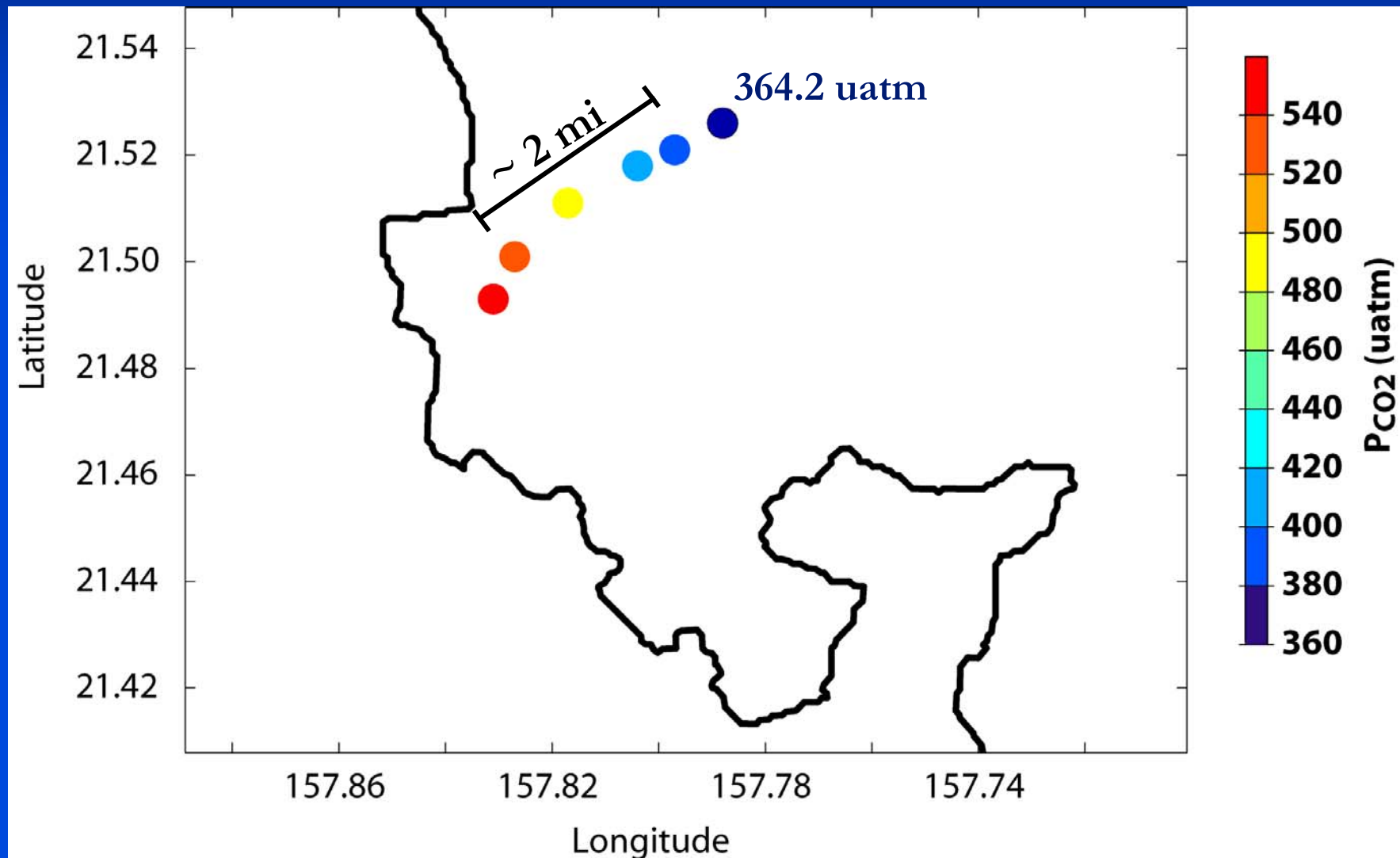
## Average PCO<sub>2</sub>



# Summary

- Kaneohe Bay is a source of CO<sub>2</sub> to the atmosphere
  - Calcification
  - Remineralization
- Storm derived nutrient loading stimulates drawdown of CO<sub>2</sub> by photosynthesis
  - Initial increase in P<sub>CO2</sub> of stream waters
- Despite significant effects of storms, Kaneohe Bay remains a **net source**
  - Estuaries are critical in determining whether coastal ocean is a net source or net sink

# Transect Data



# Conclusions

- Kaneohe Bay is a net source of CO<sub>2</sub> to the atmosphere
  - Dominated by calcification
  - Drawdown following storm derived nutrient loading
  - Source extends beyond bay 'boundary'
- Estuaries are a critical part of determining role of coastal ocean in global inorganic carbon cycle
  - Not yet possible
- Characterization of subtropical estuaries is an important component



A tropical sunset scene with palm trees and a body of water. The sky is a mix of orange, pink, and blue, with the sun low on the horizon. Palm trees are silhouetted against the sky, and their reflections are visible in the water. In the background, there are some buildings and a distant mountain range.

**Thank You**