GTWS meeting 2022

May 17, 2022(Tue) 12:20～12:40

Air-sea gas exchange in a seagrass ecosystem

Photo from NOAA’s HP

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Seagrass's role in Global carbon cycle

		Burial Tg C y^{-1}
Vegetated habitats		
	Mangroves	23.6
	Salt Marsh	60.4
	Seagrass	27.4
Total vegetated habitats		111.4
Depositional areas		98.9
Total coastal burial		210.3
Deep sea burial		6.0
Total oceanic burial		216.3

(Duarte et al., 2005)

Seagrass buries 27.4 Tg C $year^{-1}$, ~10 % of total ocean burial

Calculation of CO_2 flux across air and sea

$$CO_2 \text{ flux} = k \cdot ([CO_{2sea}] - [CO_{2air}])$$

k: gas transfer velocity

$[CO_{2sea}]$, $[CO_{2air}]$: CO_2 conc.

- Gas transfer velocity (k) is hard to measure.

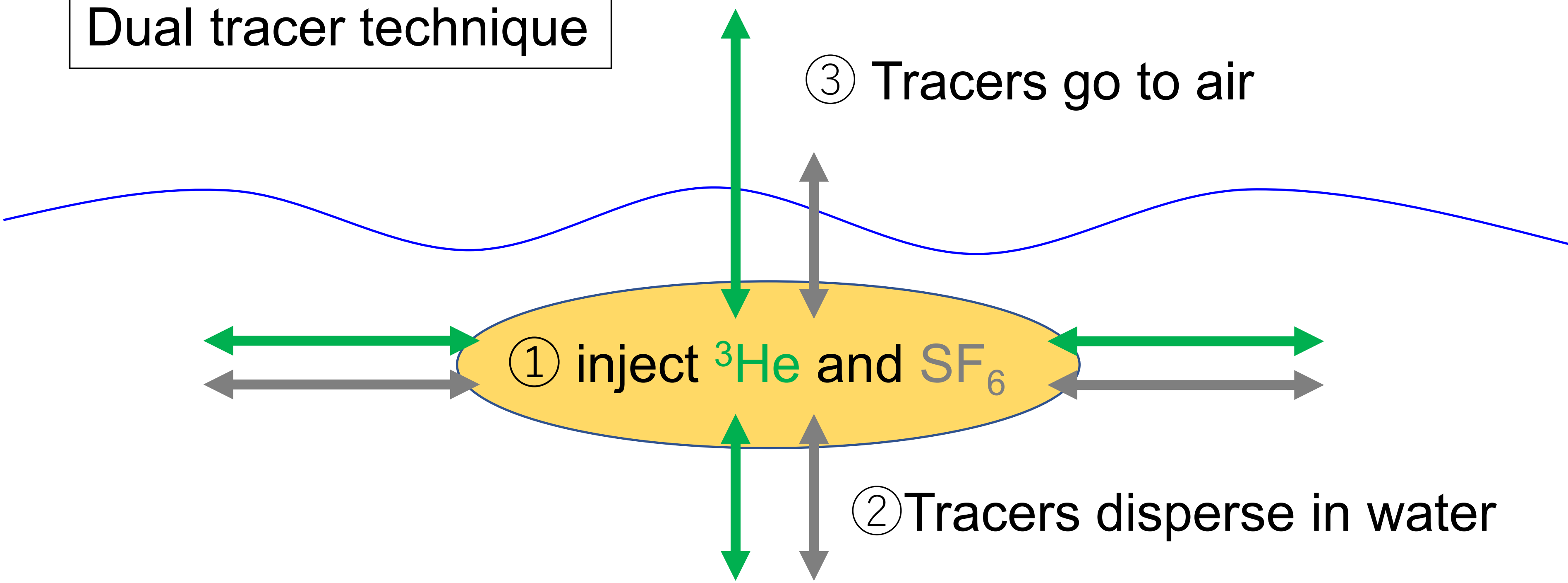
- In <u>offshore</u> region, k well parameterized by wind (u)

  $k = 0.251 \times u_{10m}^2$ for CO_2 at 20 ℃ (e.g., Wanninkhof, 2014)

- In <u>shallow</u> region, other parameters, such as current speed, important as well (e.g., Ho et al., 2016).

Methods How measure the gas transfer velocity (k)?

Dual tracer technique

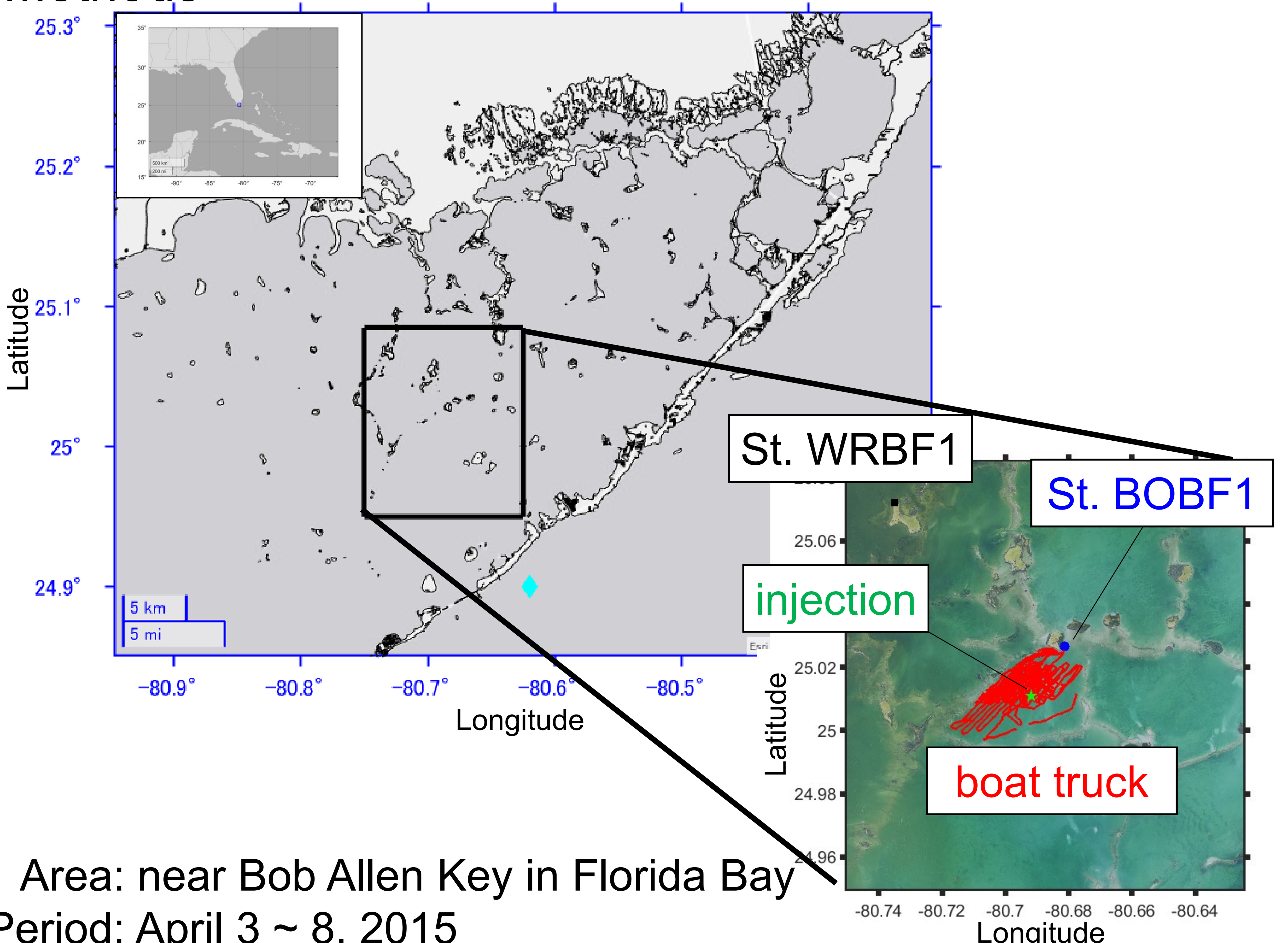


$$\underline{k(600)} = -h\frac{d}{dt}\left(\ln({}^3He_{exc}/SF_6)/1-\left(Sc_{SF_6}/Sc_{{}^3He}\right)^{-\frac{1}{2}}\right)\left(600/Sc_{{}^3He}\right)^{-\frac{1}{2}}$$

⇧

k for CO_2 at 20 ℃, fresh water

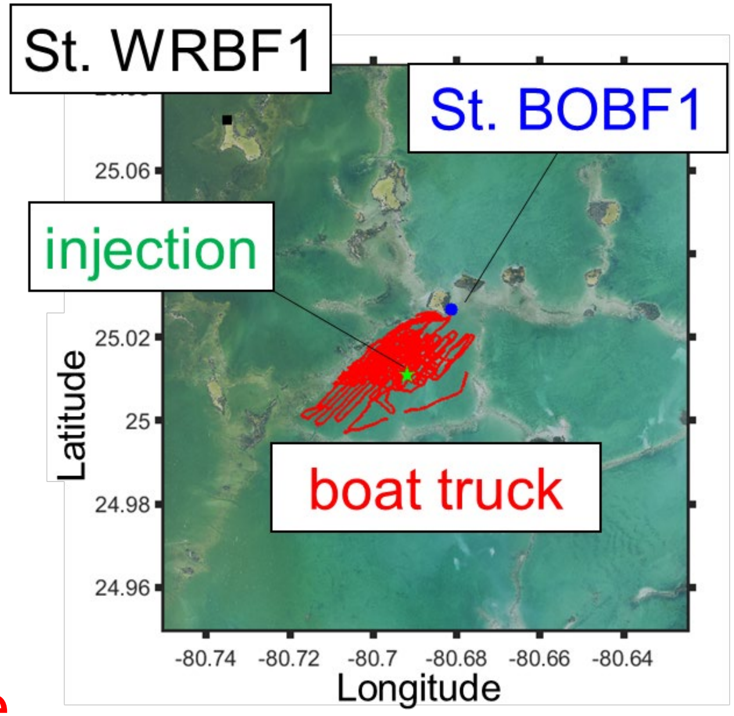
Methods



Area: near Bob Allen Key in Florida Bay

Period: April 3 ~ 8, 2015

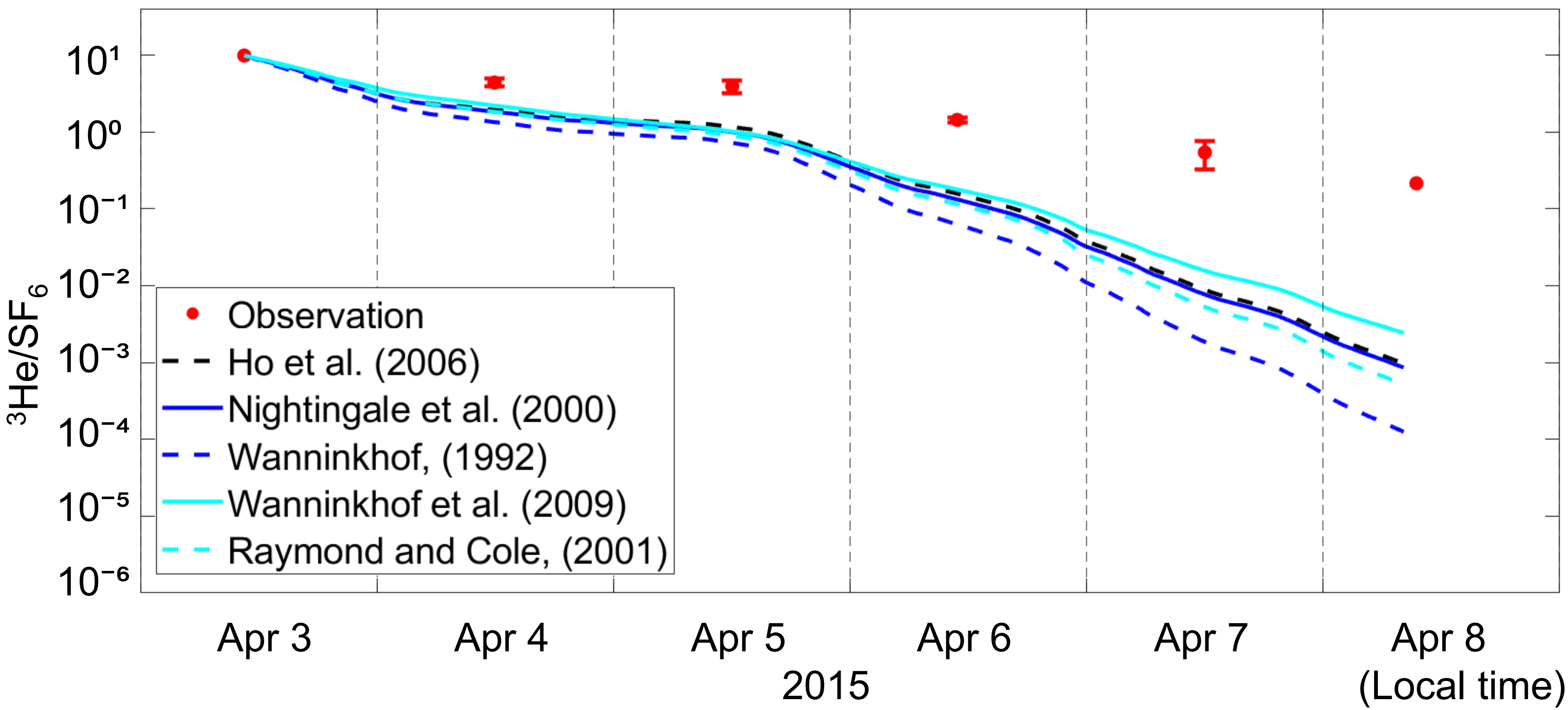
Methods



boat → water sample

parameters	method
^{3}He conc.	He isotope mass spectrometer (Ludin et al., 1998)
SF_6 conc.	gas chromatograph equipped with an electron capture detector (GC/ECD) (Wanninkhof et al., 1987)
Air, water pCO_2	non-dispersive infrared (NDIR; LI-COR 840A) analyzer (Ho et al., 1997; Pierrot et al., 2009)

Result change in $^3He/SF_6$ with time



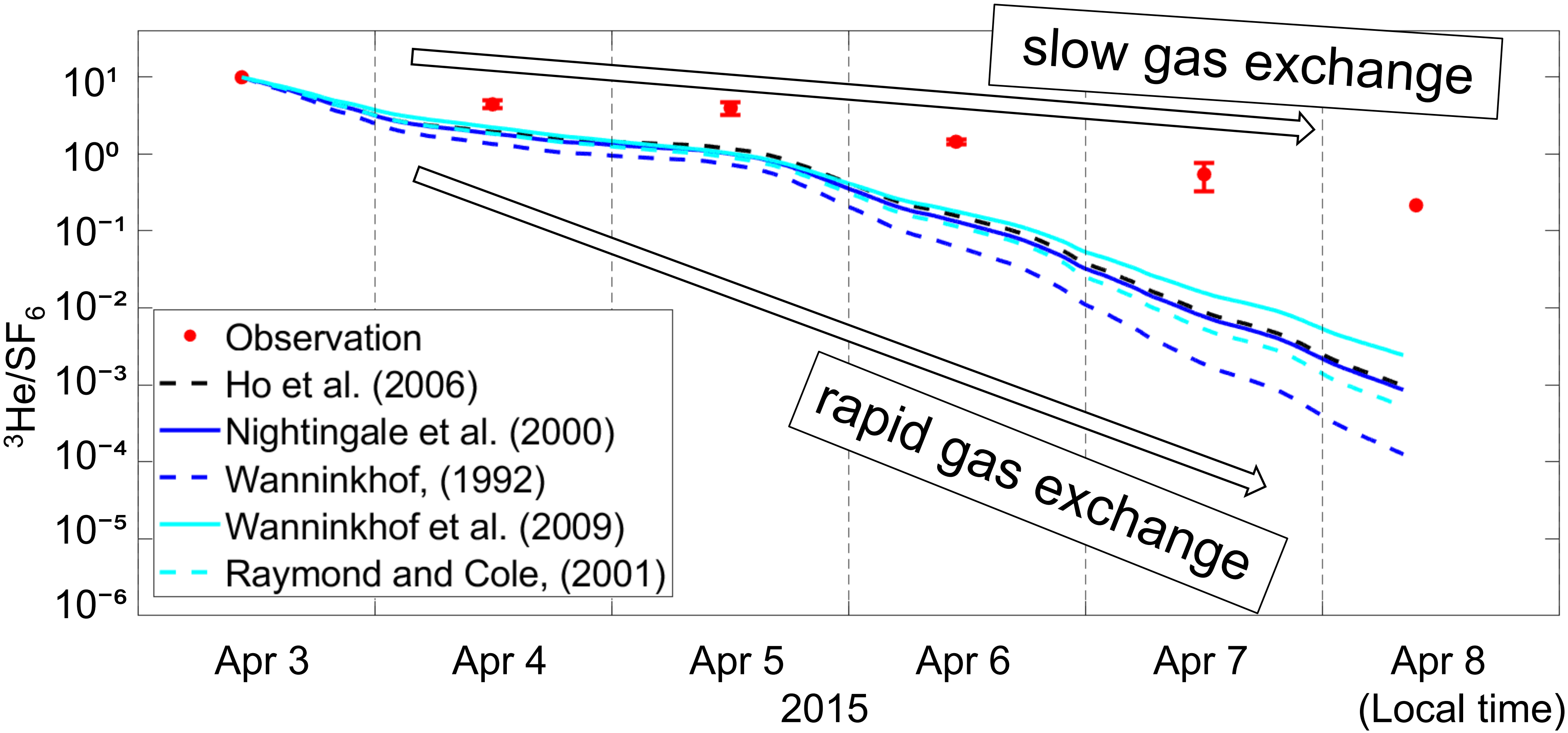
$$k(600) = -h\frac{d}{dt}\left(\ln({}^3He_{exc}/SF_6)/1-\left(Sc_{SF_6}/Sc_{{}^3He}\right)^{-\frac{1}{2}}\right)\left(600/Sc_{{}^3He}\right)^{-\frac{1}{2}}$$

$\underline{k(600)}$ = 4.7 ± 1.8 cm hr^{-1}, lower than other coastal & offshore at same u_{10m}

(Ho and Wanninkhof, 2016)

⇧ k for CO_2 at 20 ℃, fresh water

Result change in $^3He/SF_6$ with time



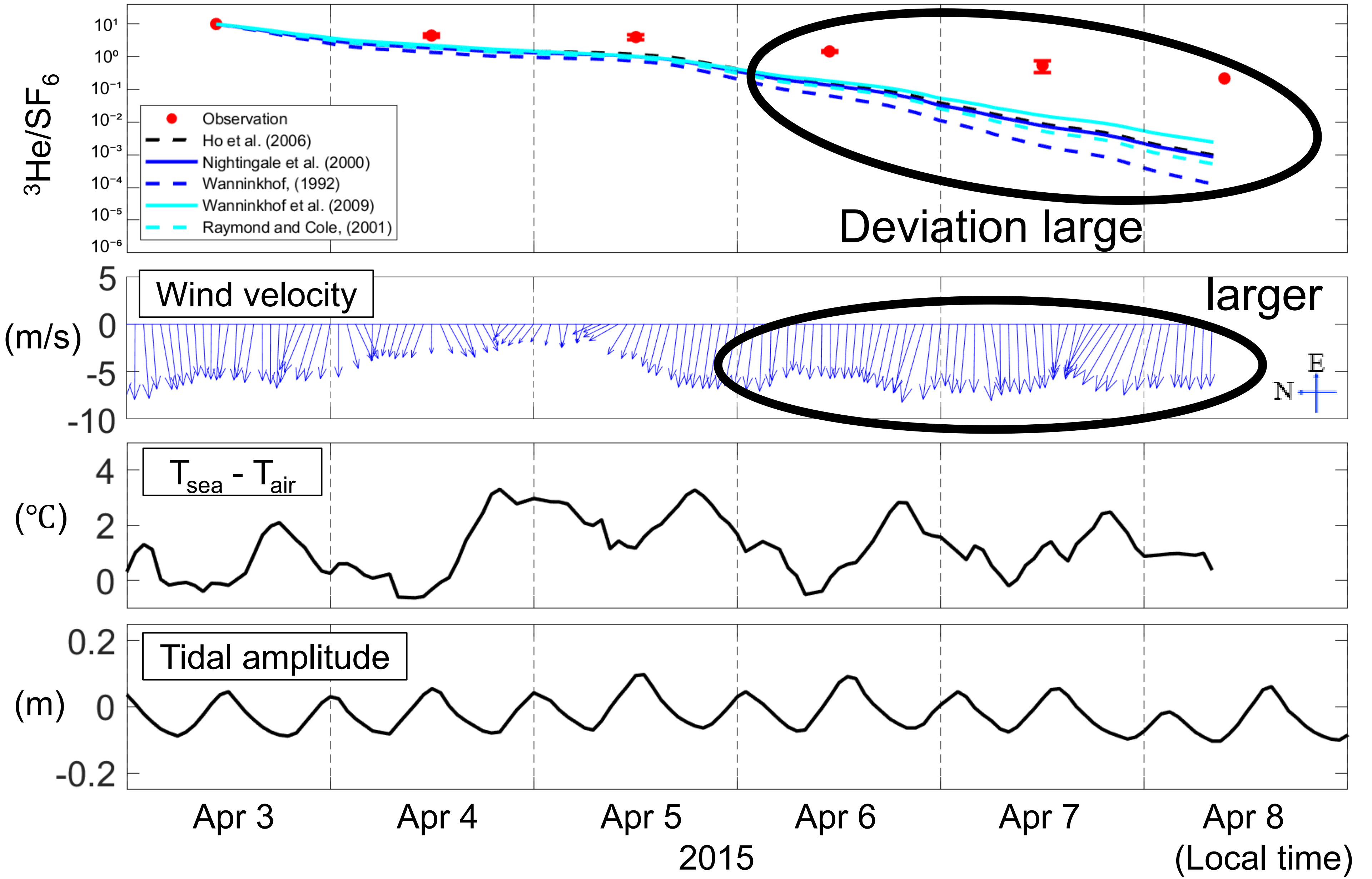
$$k(600) = -h\frac{d}{dt}\left(\ln\left({}^3He_{exc}/SF_6\right)/1 - \left(Sc_{SF_6}/Sc_{{}^3He}\right)^{-\frac{1}{2}}\right)\left(600/Sc_{{}^3He}\right)^{-\frac{1}{2}}$$

Published parameterizations decrease <u>rapidly</u> than observation

⇕

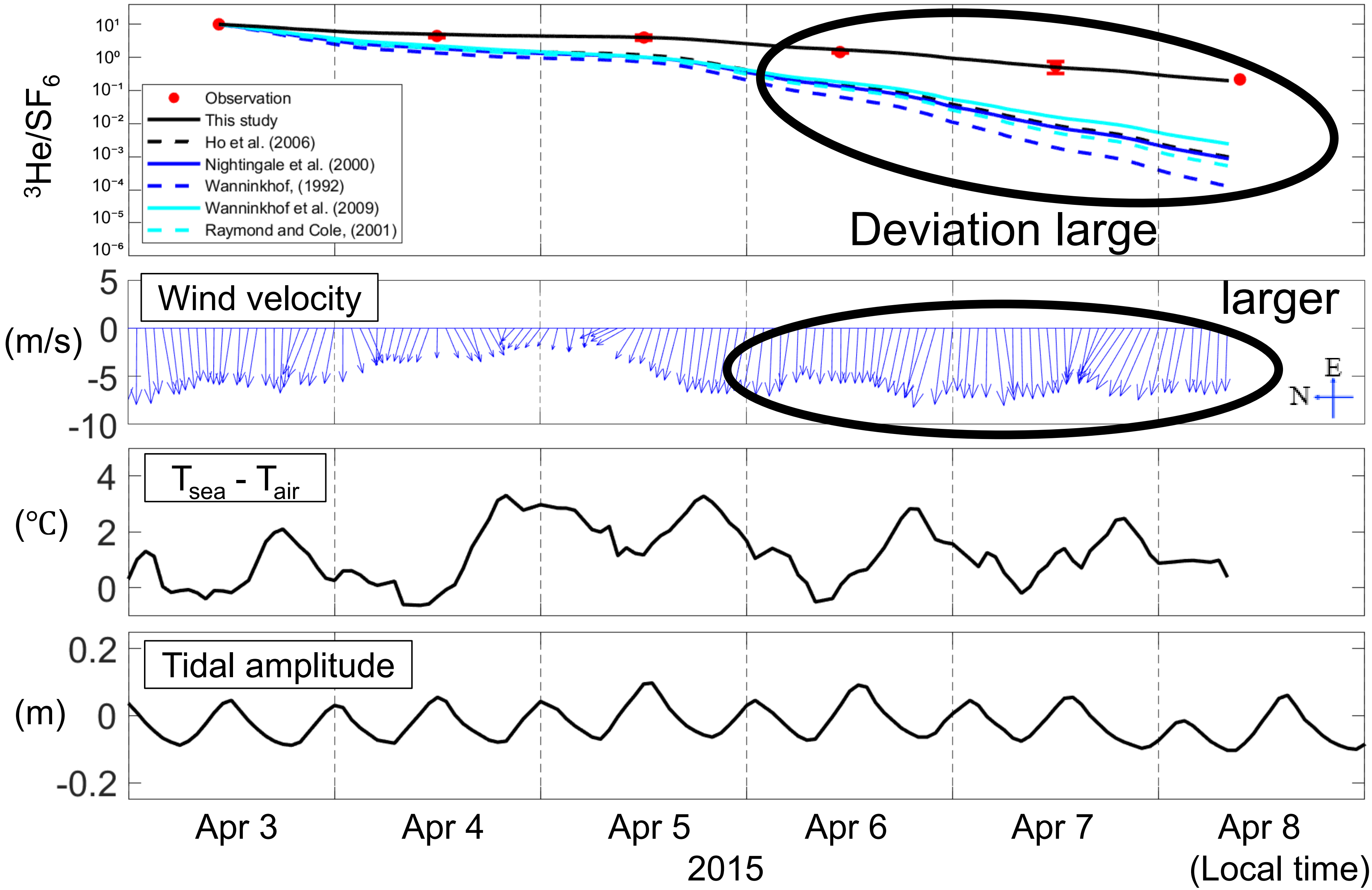
They overestimate gas transfer velocity (*k*)

Why lower air-sea gas exchange ?



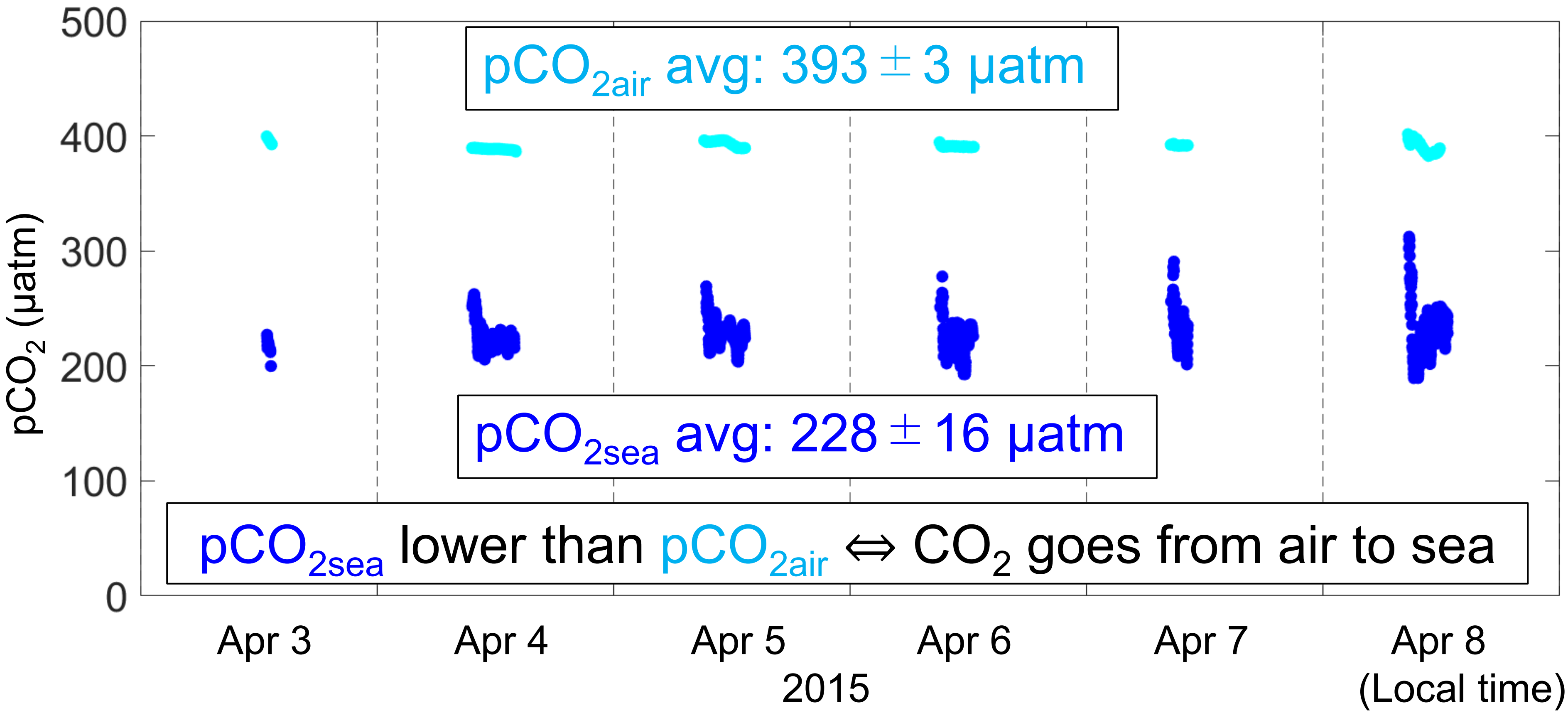
- Wind is dominant factor
- Lower *k* ⇐ fetch limitation or wave attenuation by seagrasses

Why lower air-sea gas exchange ?



New parameterization, $k(600) = 0.122 \cdot u_{10}^2$ fits well.

Measured pCO_2 and CO_2 flux



Values are consistent with Zhang et al. 2014

CO_2 flux $= k \cdot ([CO_{2sea}] - [CO_{2air}]) = -4.3 \pm 2.6$ mmol m^{-2} day^{-1}

Annual CO_2 flux

Zhang et al. 2014 measured pCO_2

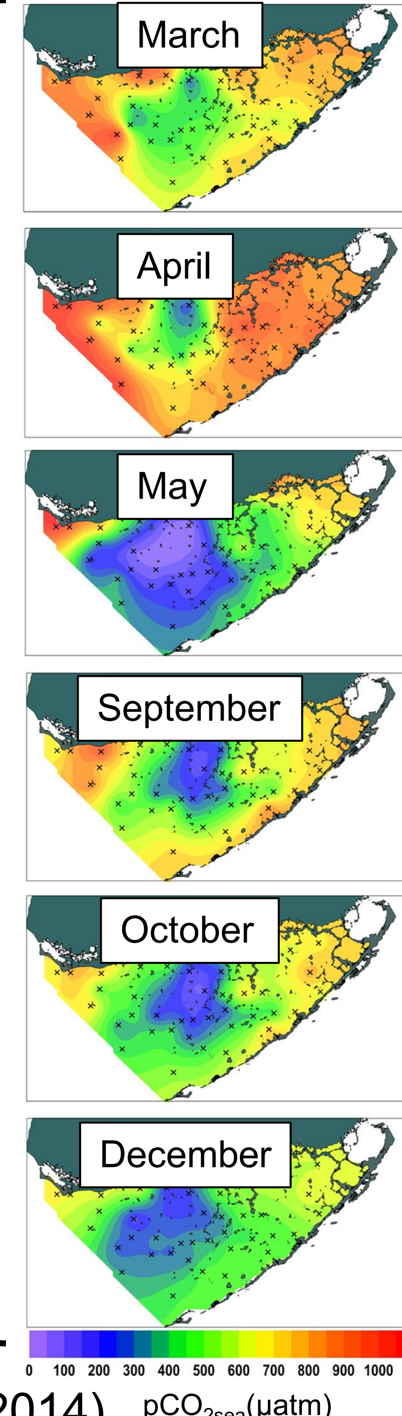
They applied $k(660) = 0.31 \cdot u_{10}^2$ (Wanninkhof, 1992)

Annual CO_2 flux = **3,930** ± 910 mmol m^{-2} yr^{-1}

Recalculate by $k(600) = 0.122 \cdot u_{10}^2$

Annual CO_2 flux = **1,500** ± 350 mmol m^{-2} yr^{-1}

1,500 / **3,930** = 38%



(Zhang et al., 2014)

Summary

- Gas transfer velocity (k) lower than other coastal & open oceans at same wind speed
- Specific parameterization for *k* is needed for inland ecosystems
- New parameterization, $k(600) = 0.122u_{10}^{2}$, fitted air-sea gas exchange well.
- CO_2 flux during observation = -4.3 $\pm$ 2.6 mmol m^{-2} day^{-1}

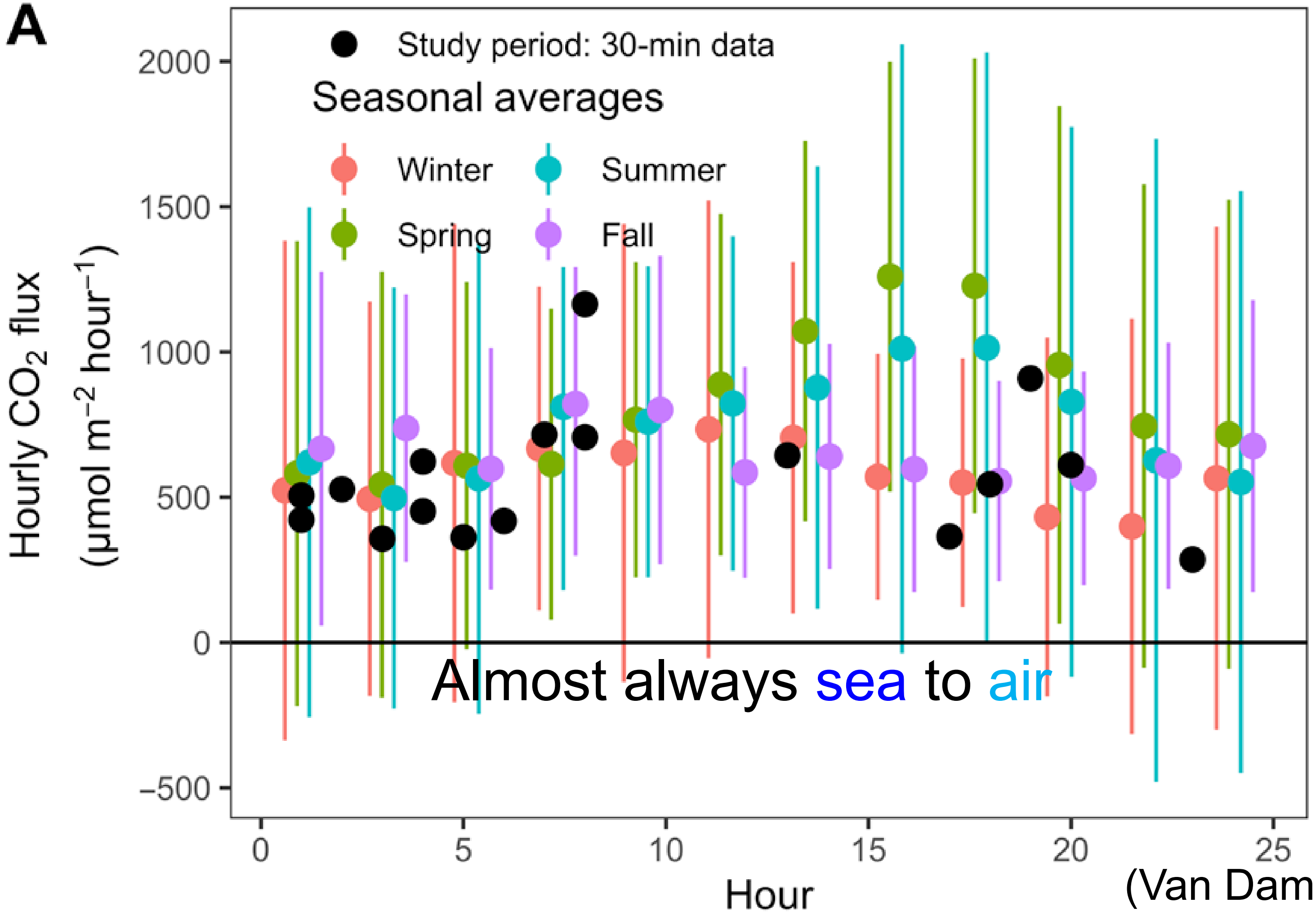
  Recalculated annual CO_2 flux = 1,500 $\pm$ 35 mmol m^{-2} yr^{-1}

$$\text{cvRMSE} = \frac{\sqrt{\frac{1}{N}\sum_{n=1}^{N}\left(R_{mod}^{n} - R_{obs}^{n}\right)^2}}{\overline{R_{obs}}}$$

References	Parameterization	Mean k(600) (cm h^{-1})	cvRMSE
This study	$k(600) = 0.122u_{10}^2$	5.4 ± 2.9	8.6%
Ho et al. (2006)	$k(600)=0.266u_{10}^2$	11.7 ± 6.4	84.4%
Nightingale et al. (2000)	$k(600)=0.333u_{10} + 0.222u_{10}^2$	11.8 ± 6.0	88.4%
Wanninkhof (1992)	$k(660)=0.31u_{10}^2$	14.2 ± 7.8	99.4%
Wanninkhof et al. (2009)	$k(660)=3+0.1u_{10} + 0.064u_{10}^2 + 0.011u_{10}^3$	10.5 ± 4.5	83.1%
Raymond and Cole (2001)	$k(600)=1.58e^{0.3u_{10}}$	12.4 ± 6.6	90.0%

Compare CO_2 flux with previous study

CO_2 flux near St. Bob Allen keys in 2019, from eddy covariance

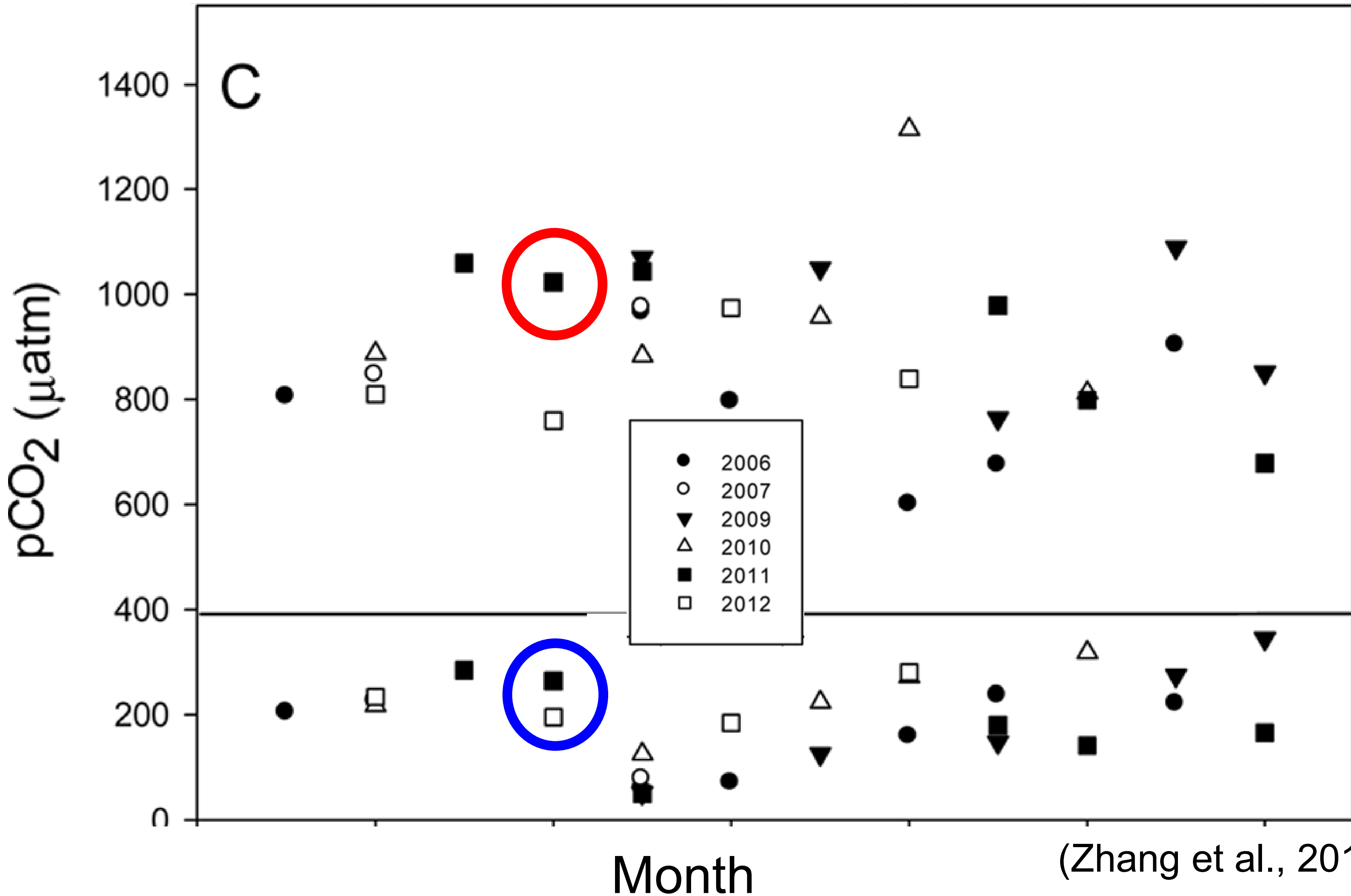


(Van Dam et al., 2021)

Even in Spring, CO_2 from sea to air might be due to scale of bloom.

6.1 mol m^{-2} $year^{-1}$ > 1.50 mol m^{-2} $year^{-1}$ in Zhang et al. 2014

Horizontally max and min pCO2 in Florida bay



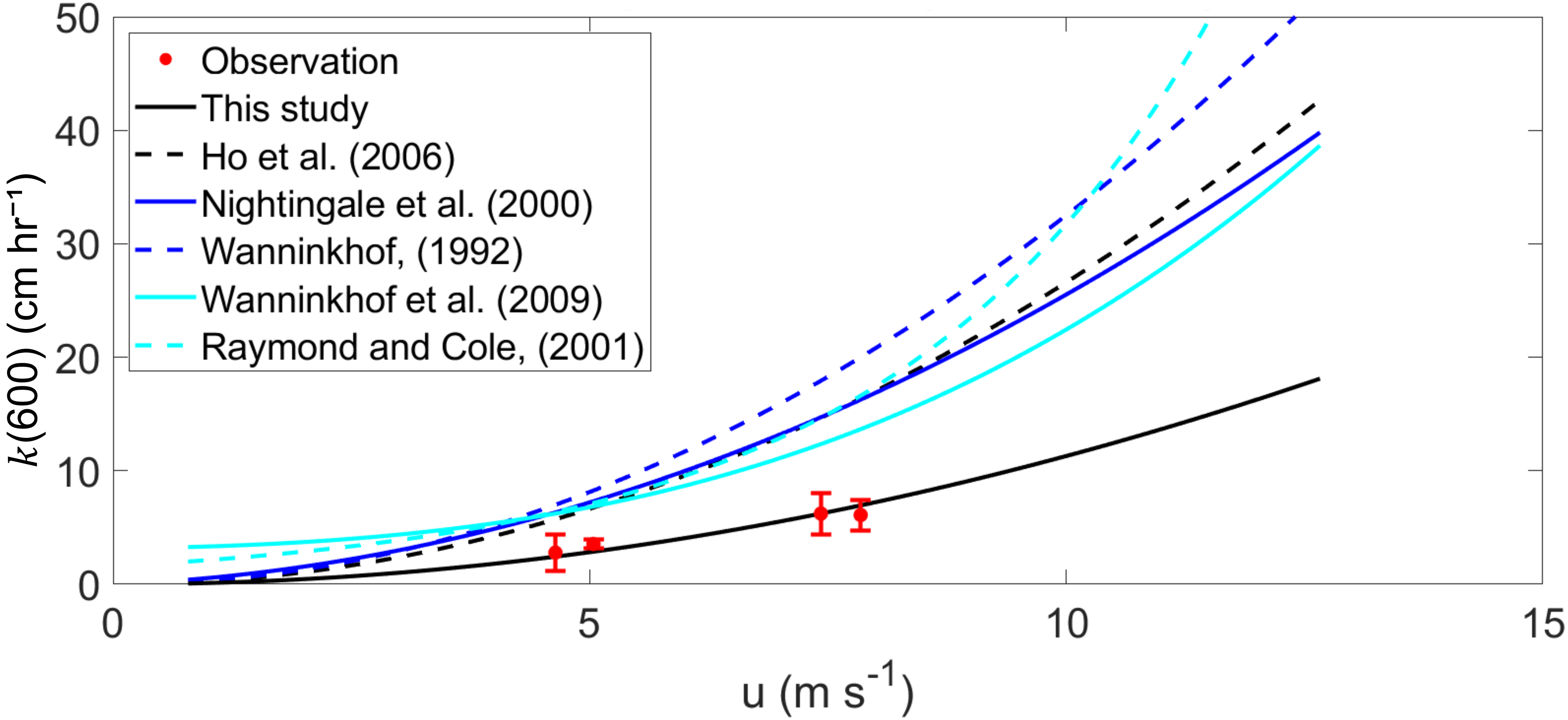
(Zhang et al., 2014)

Min pCO_{2water} 200 ~ 1000 µatm

This study's result: pCO_{2water} = 228 µatm ⇐ still in the range

Calculated $\underline{k(600)}$

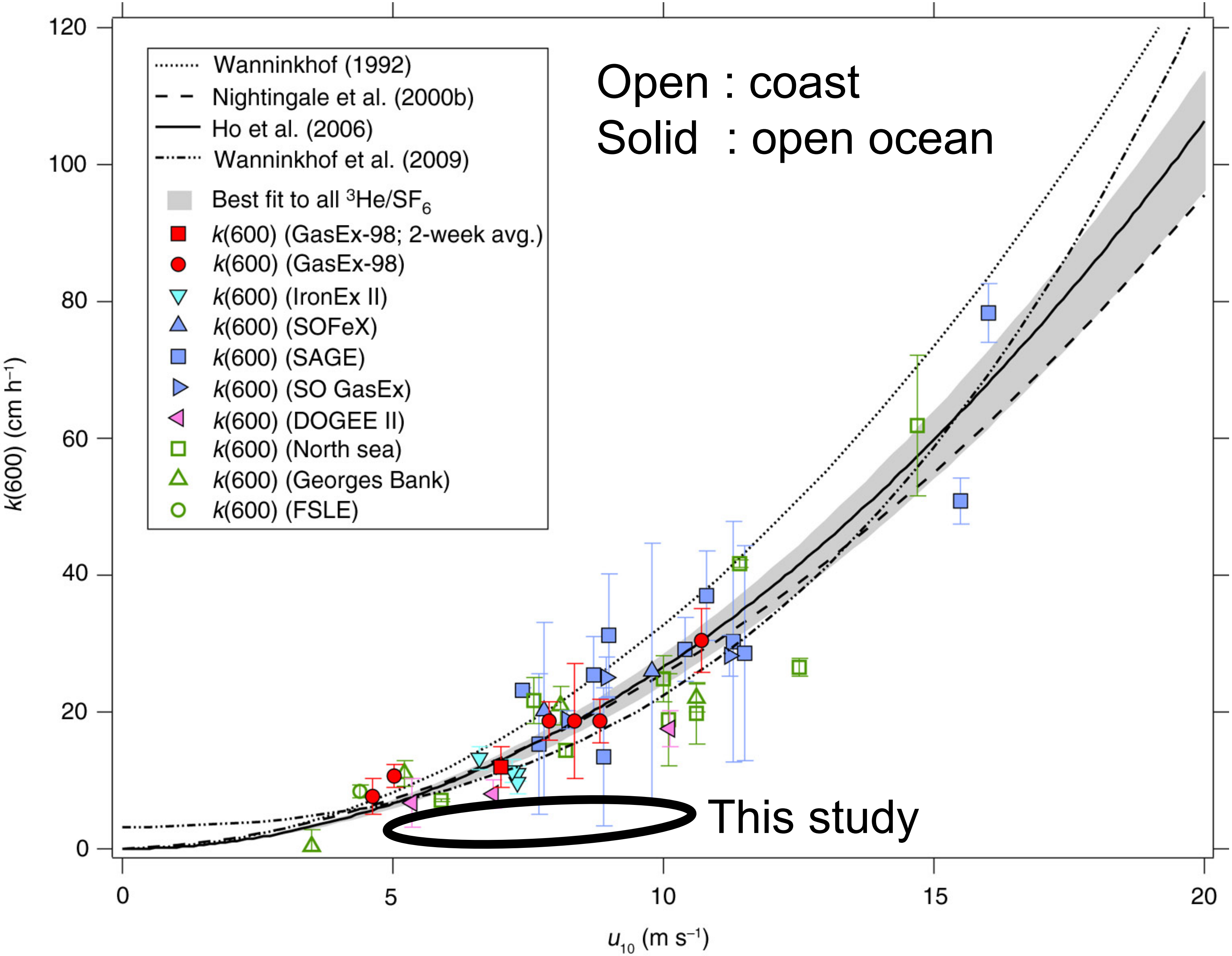
k for CO_2 at 20 ℃



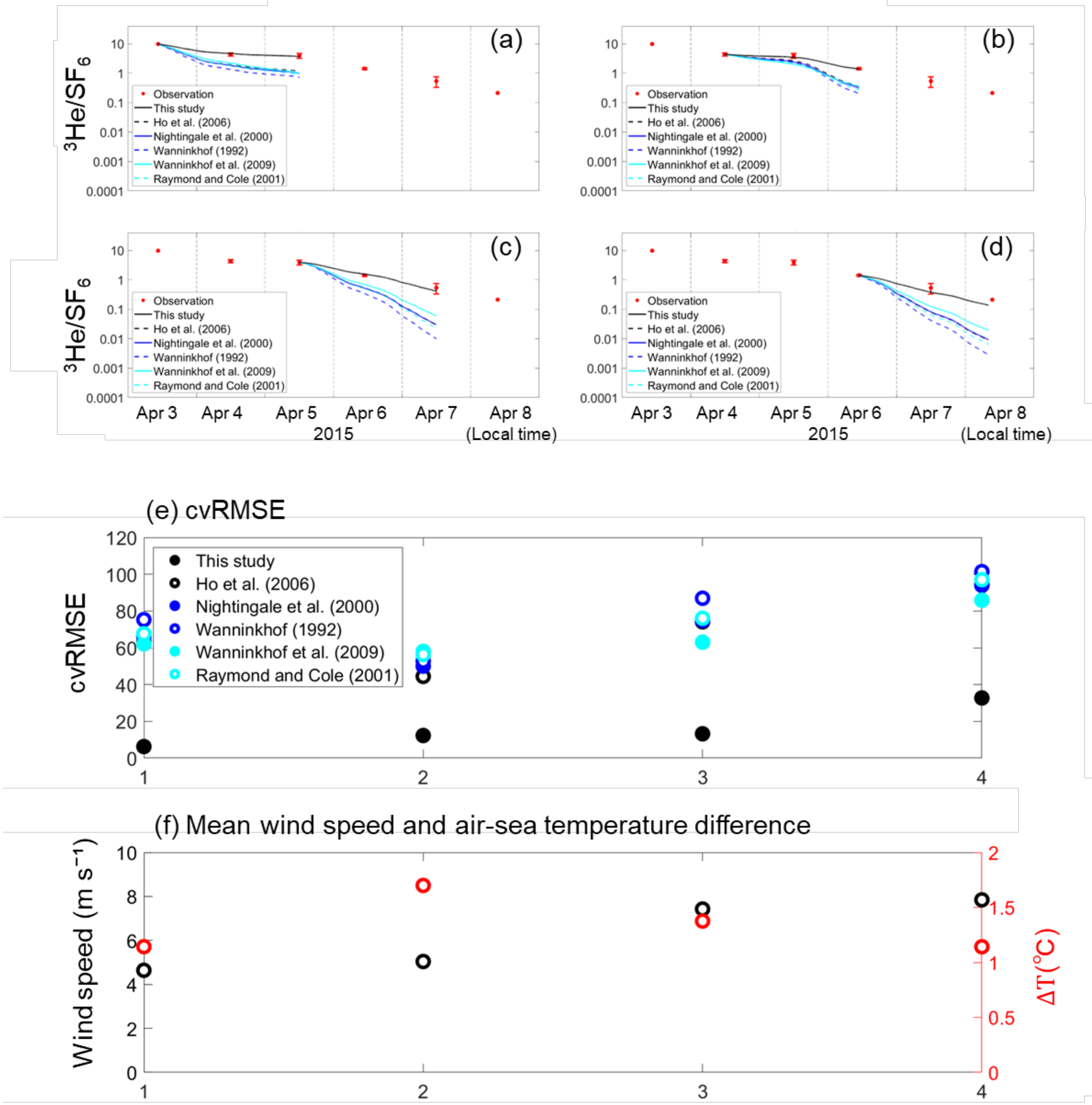
Average $k(600)$ is 4.67 ± 1.76 cm hr^{-1}

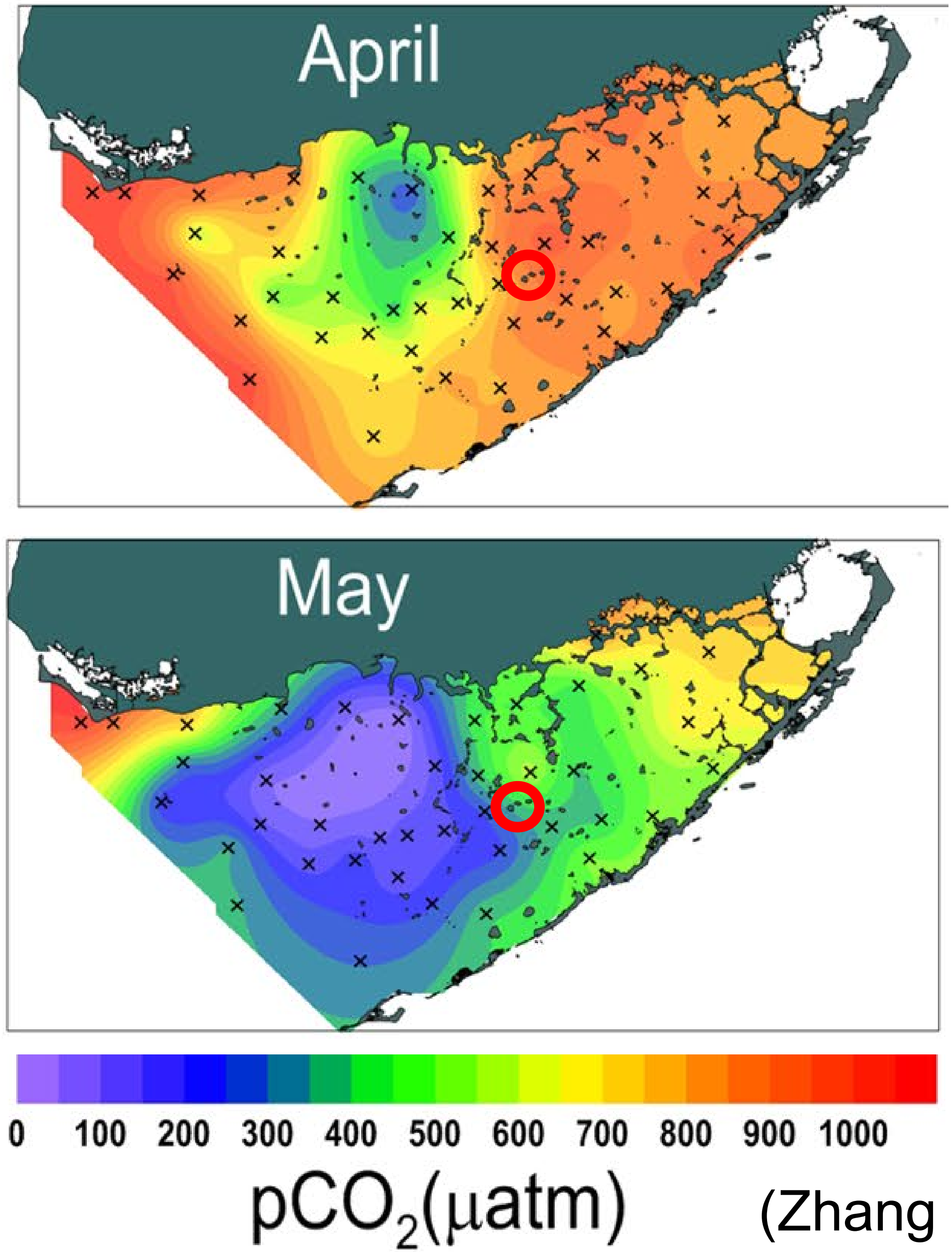
$k(600)$ is lower than previous experiments in coastal & open ocean

New parameterization, $k(600) = 0.122u_{10}^2$ fits well.



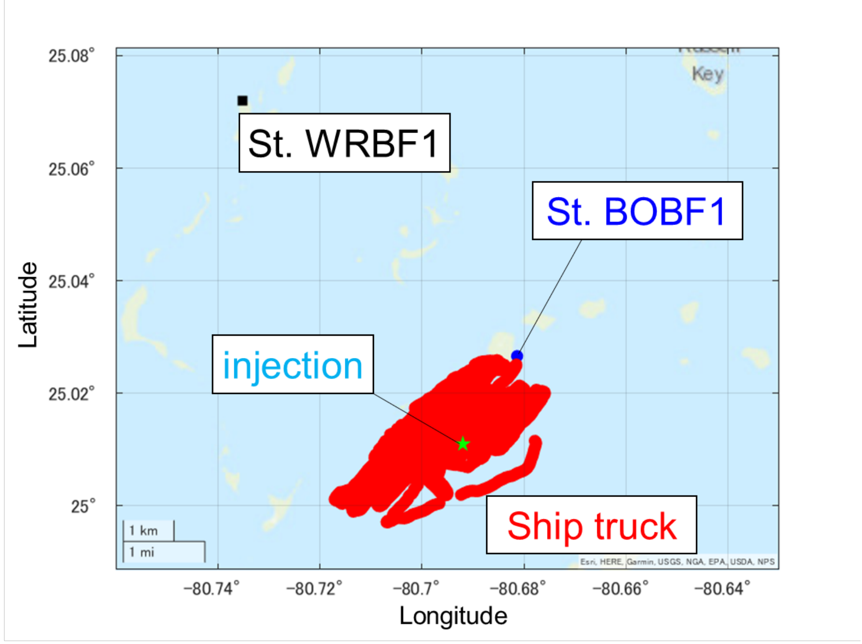
(Ho and Wanninkhof, 2016)


(a)
(b)
(c)
(d)
^{3}He/SF$_6$
Observation
This study
Ho et al. (2006)
Nightingale et al. (2000)
Wanninkhof (1992)
Wanninkhof et al. (2009)
Raymond and Cole (2001)
Apr 3
Apr 4
Apr 5
Apr 6
Apr 7
Apr 8
2015
(Local time)
(e) cvRMSE
cvRMSE
(f) Mean wind speed and air-sea temperature difference
Wind speed (m s^{-1})
ΔT(°C)



(Zhang et al., 2014)

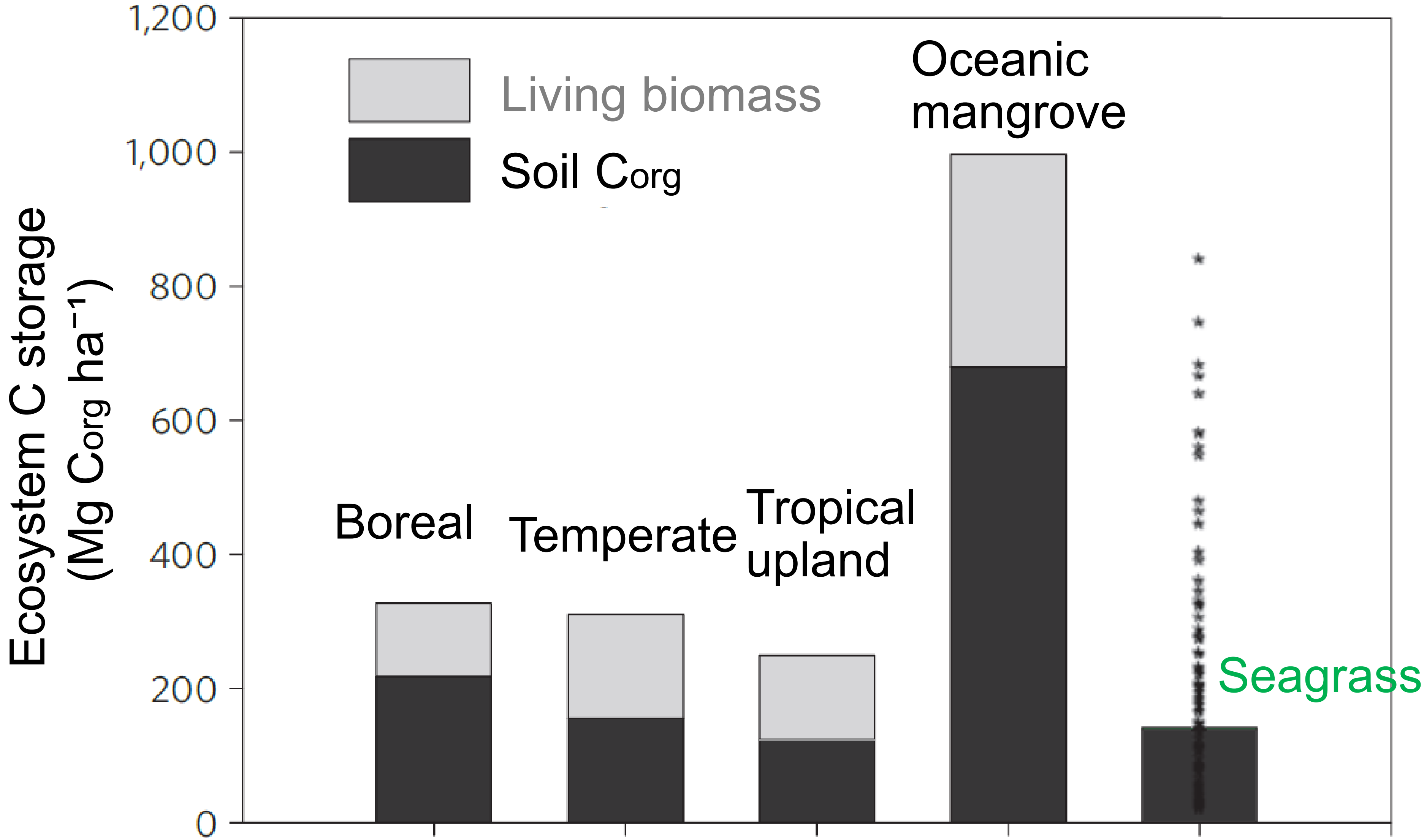
Methods



St. BOBF1 & WRBF 1

parameters	Method
Wind	Sonic anemometer. Converted to 10 m height
Air T	Sonic anemometer
Water T	Taken by Everglades National Park

Seagrass's role in Global carbon cycle



Seagrass stock 139.7 Mg C_{org} ha^{-1}

(Fourqurean et al., 2012)