Coastal Ocean Acidification and Increasing Total Alkalinity in the NW Mediterranean Sea

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Coastal ocean acidification and increasing total alkalinity in the northwestern Mediterranean Sea

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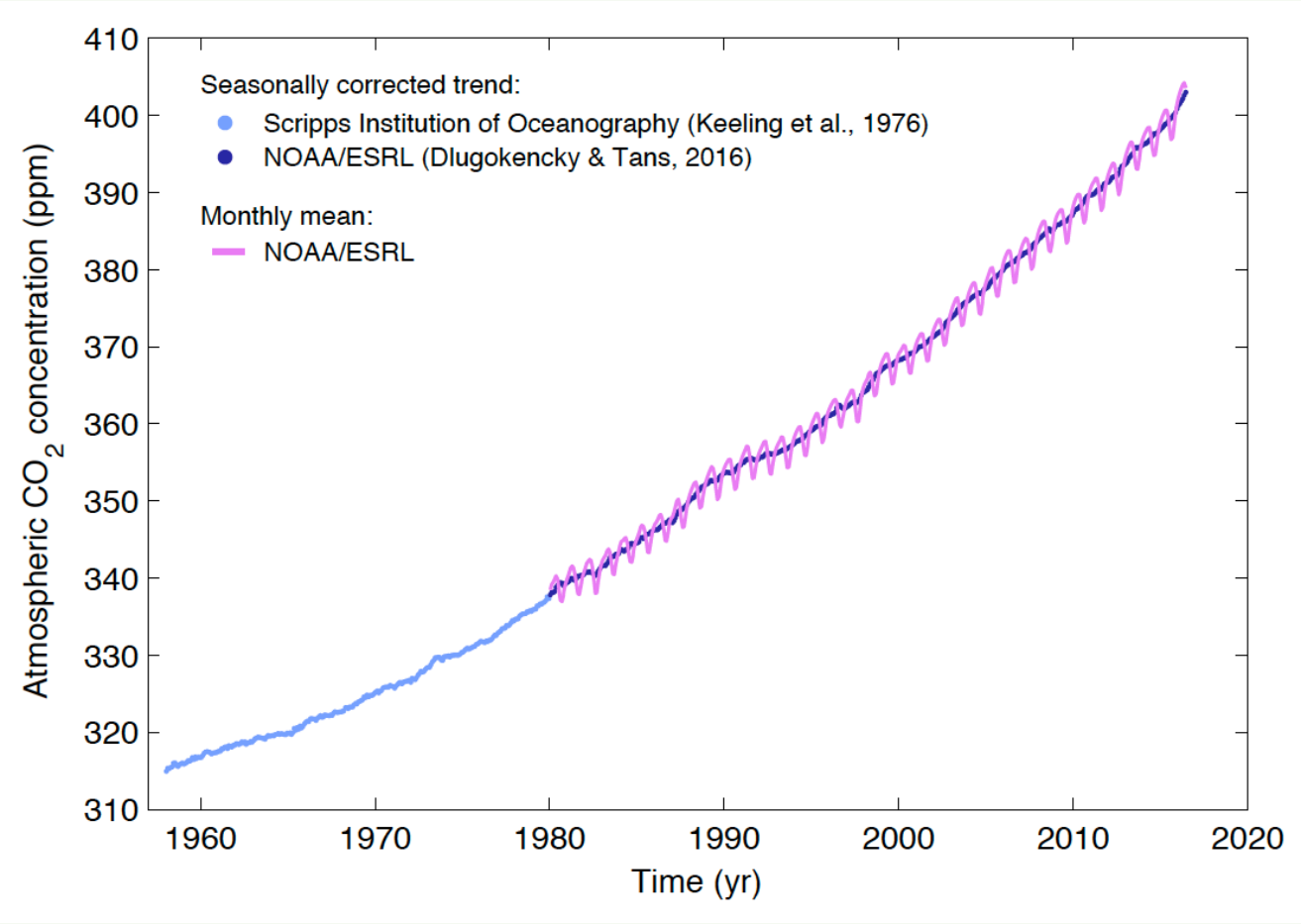
Atmospheric CO_2 increase



CO_2 distribution (1750 – 2015)

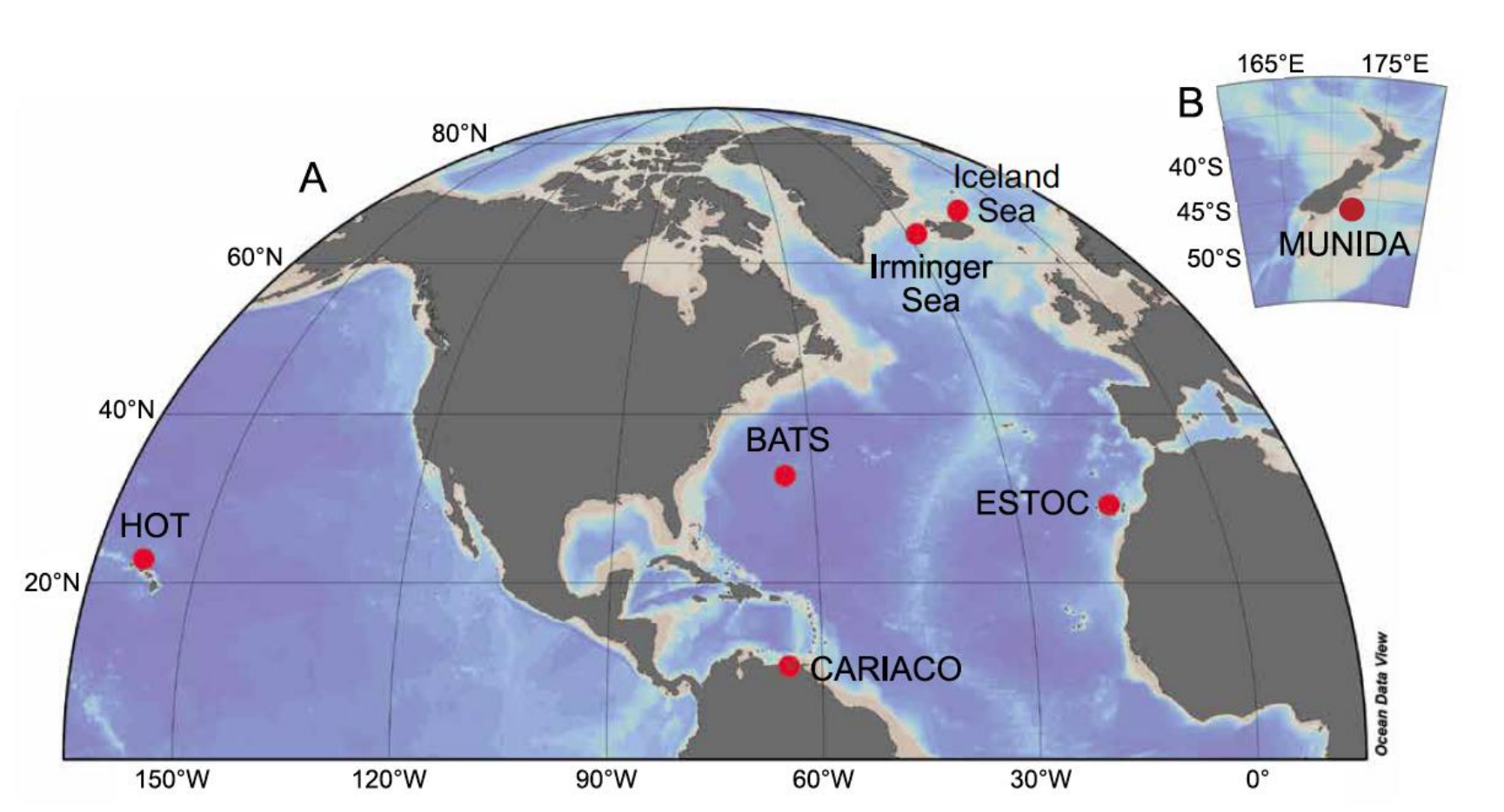
43 % atmosphere

28 % terrestrial sink

29 % ocean sink

Le Quéré et al., *Earth Syst. Sci. Data* 2016

Ocean Acidification time-series as of 2014



Bates et el., 2014

Estimations of Ocean Acidification in the Mediterranean

1. **Models**

   Palmiéri et al., 2015, Krasakopoulou et al., 2011; Touratier and Goyet, 2011; Touratier et al., 2016, Howes et al., 2015

2. **Partially reconstructed time-series**

   Marcellin Yao et al., 2016

3. **Comparative study periods**

   Luchetta et al., 2010; Meier et al., 2014

4. **Sensors, short study period**

   Flecha et al., 2015

None are based on long time-series with consistent sampling

Coastal time-series are missing globally

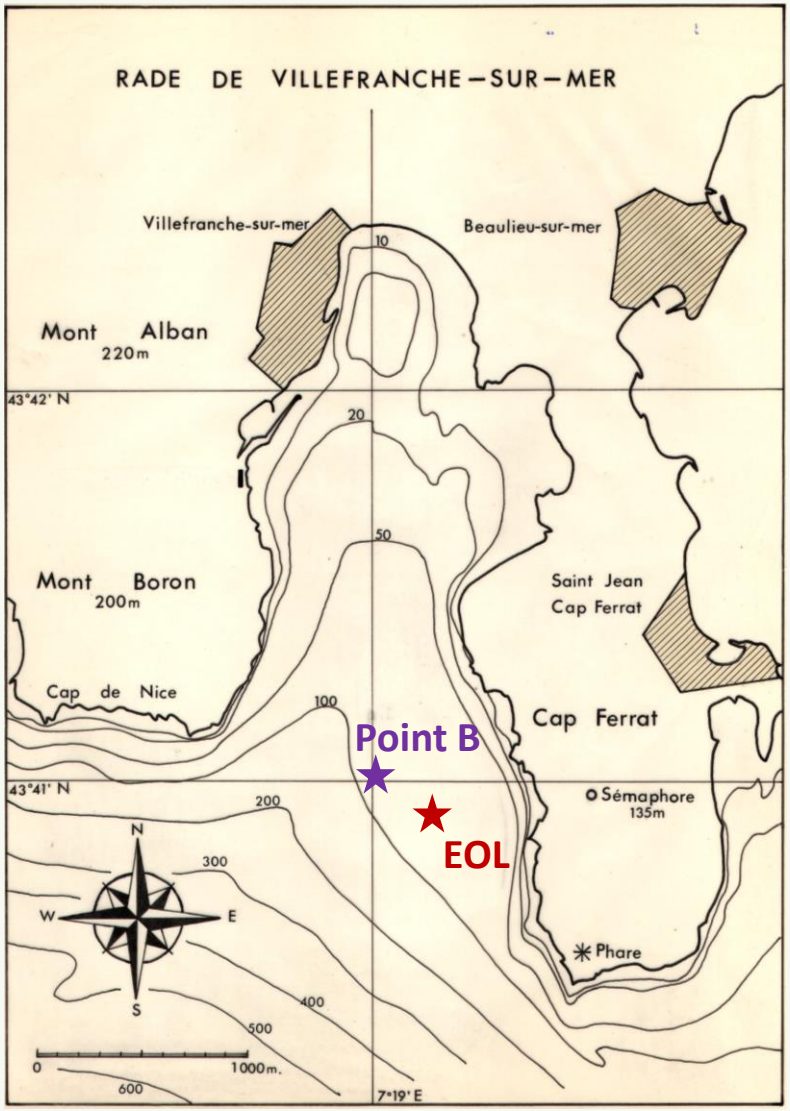
Samping – 2007-2015

Weekly Sampling

- Depth: 1 and 50 m
- Parameters: C_T, A_T, Salinity, Temperature
- SeaFET deployments in 2014

Calculate

- pH
- pCO_2
- Aragonite Sat. State



Results – Part I

Temperature

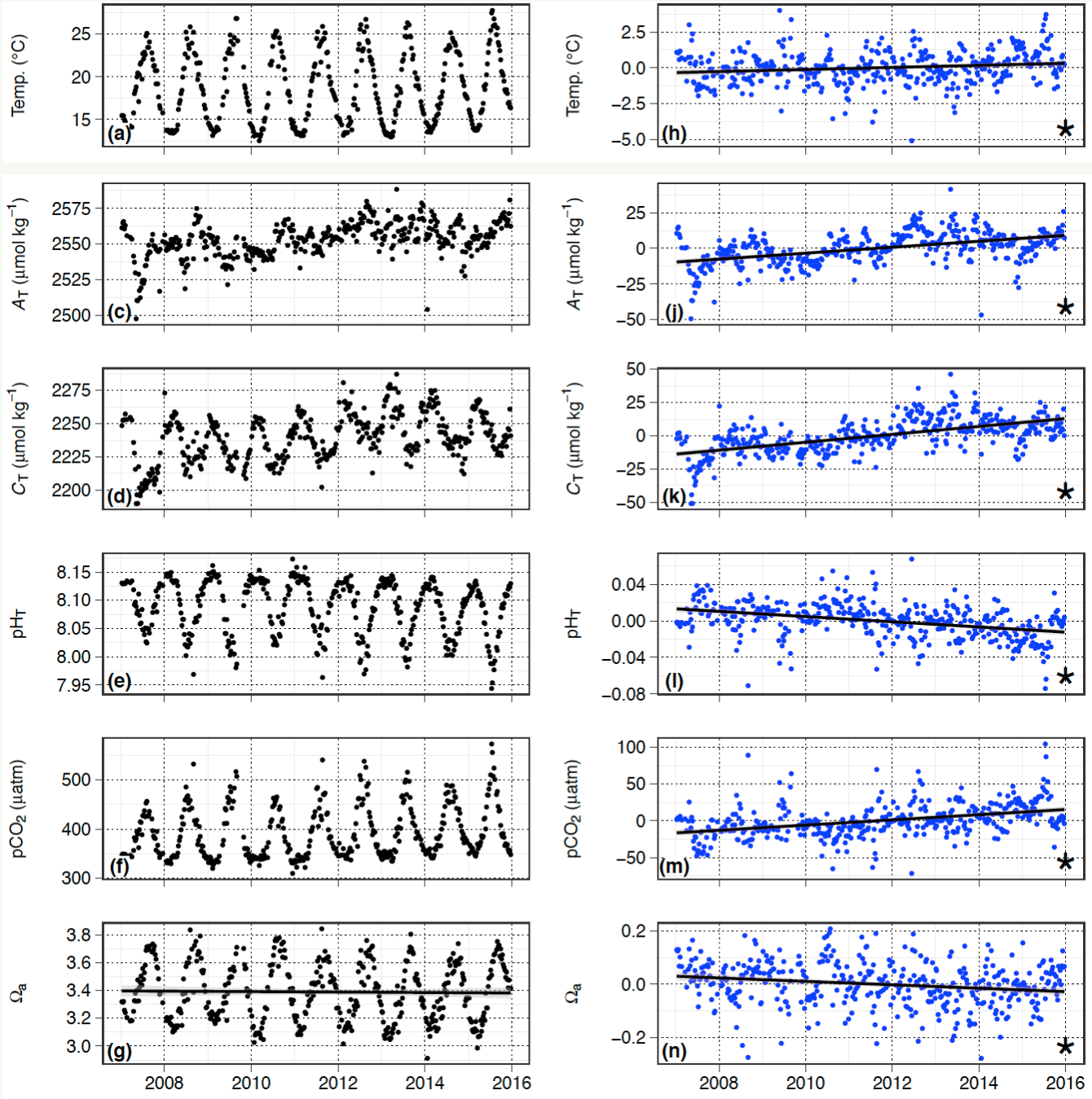
Total Alkalinity

Total Dissolved Inorganic Carbon

pH

pCO_2

Arag. Sat. State



Results – Part I

1 meter depth

Increase in alkalinity	2.08 µmol kg^{-1} yr^{-1}
Warming	0.072 ^{o}C yr^{-1}
Acidification	-0.0028 units pH_T yr^{-1}
$pCO_{2\ sw}$	3.53 µatm pCO_2 yr^{-1}
$pCO_{2\ atm}$	2.08 ppm yr^{-1}

Results – Part II Drivers of pCO_2 changes

sensitivity trend

$$\frac{dpCO_2}{dt} = \frac{\partial pCO_2}{\partial T}\frac{dT}{dt} + \frac{\partial pCO_2}{\partial S}\frac{dS}{dt} + \frac{\partial pCO_2}{\partial A_T}\frac{dA_T}{dt} + \frac{\partial pCO_2}{\partial C_T}\frac{dC_T}{dt}$$

ΔpCO_2 due to warming	ΔpCO_2 due to salinity	ΔpCO_2 due to total alkalinity	ΔpCO_2 due to dissolved inorganic carbon

Partial derivative:

$\frac{\partial pCO_2}{\partial T}\frac{dT}{dt}$ *Calculate changes in pCO_2 due to temperature alone, using constant salinity, A_T and C_T*

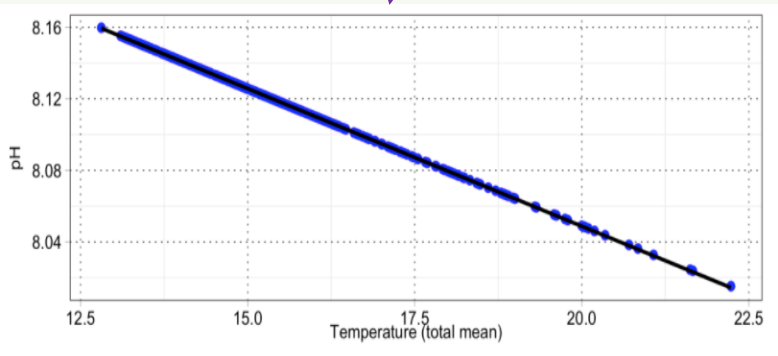
García-Ibáñez et al., 2016

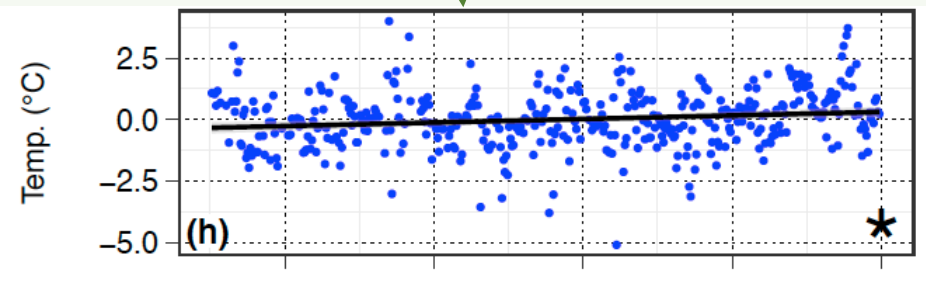
Partial derivatives explained

Sensitivity of pH to temperature

$$\frac{\partial pH_T}{\partial T}\frac{dT}{dt}$$

Trend of temperature





2007 → 2015

Results – Part II Drivers of pCO_2 changes

sensitivity trend

$$\frac{dpCO_2}{dt} = \underbrace{\frac{\partial pCO_2}{\partial T}\frac{dT}{dt}}_{\Delta pCO_2 \text{ due to warming}} + \underbrace{\frac{\partial pCO_2}{\partial S}\frac{dS}{dt}}_{\Delta pCO_2 \text{ due to salinity}} + \underbrace{\frac{\partial pCO_2}{\partial A_T}\frac{dA_T}{dt}}_{\Delta pCO_2 \text{ due to total alkalinity}} + \underbrace{\frac{\partial pCO_2}{\partial C_T}\frac{dC_T}{dt}}_{\Delta pCO_2 \text{ due to dissolved inorganic carbon}}$$

3.53 = 1.19 + -0.02 + -3.08 + 5.14 µatm pCO_2 yr^{-1}

Results – Part II Drivers of pCO_2 changes

sensitivity trend

$$\frac{dpCO_2}{dt} = \frac{\partial pCO_2}{\partial T}\frac{dT}{dt} + \frac{\partial pCO_2}{\partial S}\frac{dS}{dt} + \frac{\partial pCO_2}{\partial A_T}\frac{dA_T}{dt} + \frac{\partial pCO_2}{\partial C_T}\frac{dC_T}{dt}$$

		ΔpCO_2 due to warming		ΔpCO_2 due to salinity		ΔpCO_2 due to total alkalinity		ΔpCO_2 due to dissolved inorganic carbon	
3.53	=	1.19	+	-0.02	+	-3.08	+	5.14	µatm pCO_2 yr^{-1}
% contribution		**41 %**		**0 %**		**-115 %**		**174 %**	

Synchronous changes in A_T and C_T

CO_2 → increase in C_T only (produces H^+ and HCO_3^-)

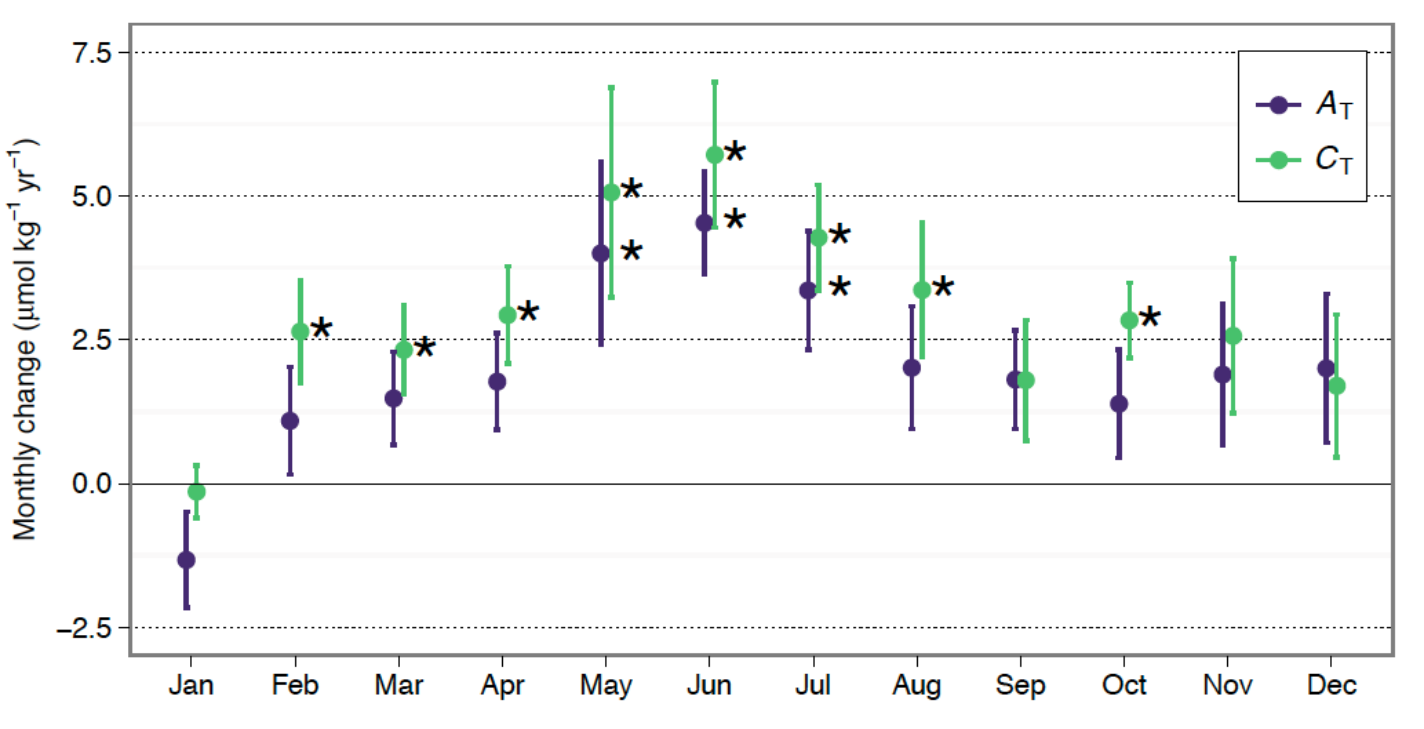
HCO_3^- → increase in C_T and A_T

CO_3^{2-} → increase in C_T and A_T

$A_T = [HCO_3^-]_T + 2[CO_3^{2-}]_T + [B(OH)_4^-]_T + ...$

96 % of A_T at Point B is carbon based

* Due to synchronicity, we assume the increase in A_T is due to increase in HCO_3^- and CO_3^{2-} *



Results – Part II, deconvolution applied to pH

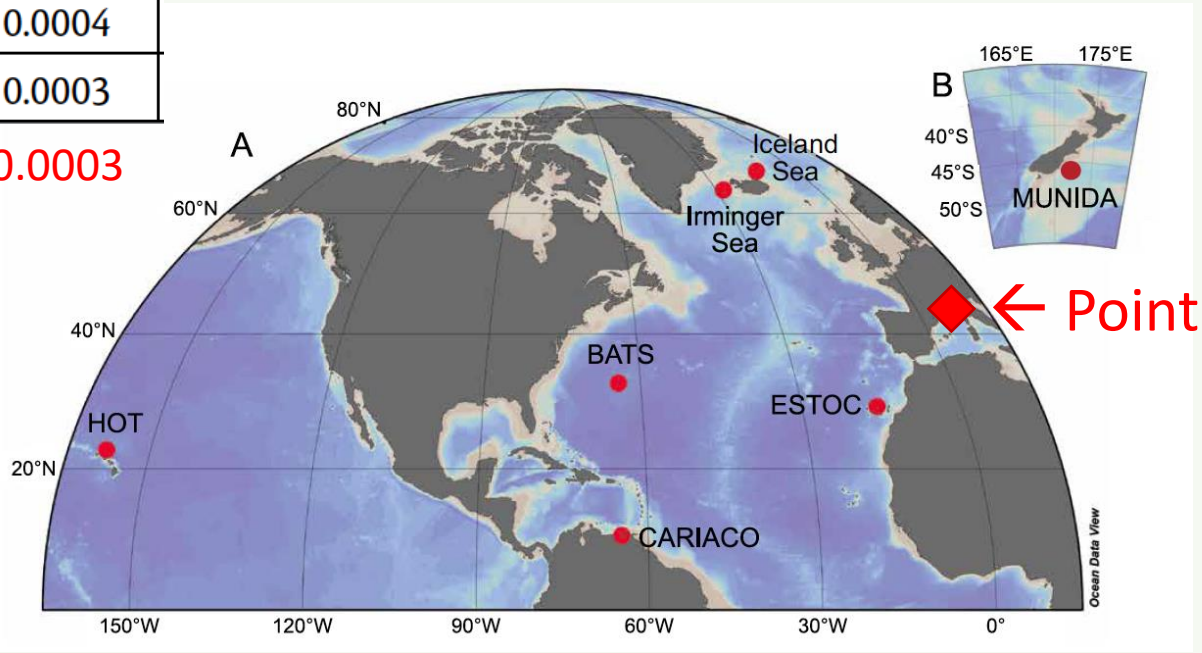
Assuming the A_T and C_T represent changes only due to CO_2 addition, surface ocean acidification(-0.0028 units pH_T yr^{-1}) at Point B is due to:

1. Atmospheric CO_2 forcing — 59 % contribution
2. Warming — 41 % contribution

Good comparison to other time-series

Time-Series Site	pH
Iceland Sea	−0.0014 ± 0.0005
Irminger Sea	−0.0026 ± 0.0006
BATS	−0.0017 ± 0.0001
ESTOC	−0.0018 ± 0.0002
HOT	−0.0016 ± 0.0001
CARIACO	−0.0025 ± 0.0004
Munida	−0.0013 ± 0.0003
Point B	-0.0028 ± 0.0003

Alkalinity change could be unique to the coastal environment



Bates et al., 2014

Summary – Changes at Point B, 2007-2015

	1 m	50 m	units
Warming	0.072	0.088	$^{o}C\ yr^{-1}$
Acidification	-0.0028	-0.0026	$pH_T\ yr^{-1}$
Total Alkalinity	2.08	1.59	$\mu mol\ kg^{-1}\ yr^{-1}$

Merci !