Decadal Trends of Underway pCO_2 from VOS Ships in the Tropical Pacific

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ABSTRACT

As part of a multi-year effort to quantify the flux of CO_2 between the ocean and atmosphere, the Ocean Climate Observation Program of NOAA supports the deployment of underway pCO_2 systems on NOAA research ships and volunteer observing ships (VOS) in the Atlantic, Pacific and Southern Oceans. For the past decade (2004 - present), PMEL has collected underway pCO_2 on 39 transits across the Pacific Ocean from Long Beach to New Zealand, capturing data during various ENSO conditions. Results indicate an increasing decadal trend of higher pCO_2 distributions across the basin, coupled with increased sea surface temperature in the eastern Pacific.

DATA COLLECTION

The equatorial Pacific is a particularly dynamic area exhibiting significant variation in surface CO_2, both interannually due to the effects of ENSO dynamics, and seasonally due to changes in wind strength and upwelling patterns. From February 2004 to the present, PMEL has maintained an underway pCO_2 system on 6 different container ships covering the transect from Long Beach California to New Zealand (Figure 1). Data are quality controlled following a CO_2 community protocol described in Pierrot et al. (2006), and globally via the Surface Ocean Carbon Atlas (SOCAT) (Figure 2). This community effort has resulted in high quality and well documented pCO_2 data across the globe (Bakker et al., 2016).

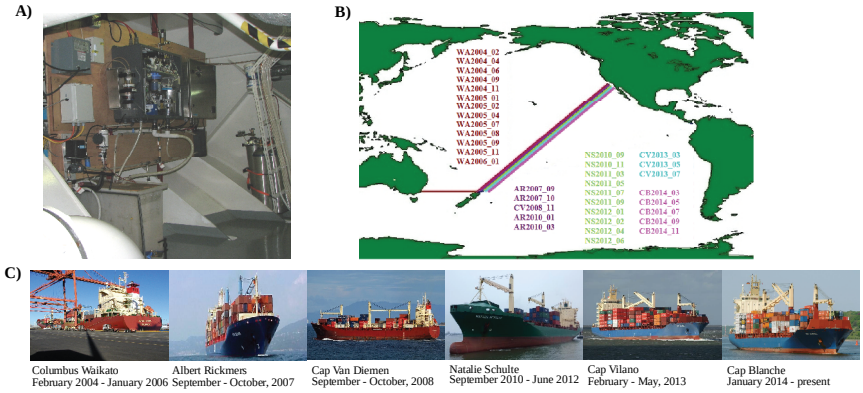

Figure 1. A) PMEL Underway pCO_2 system in the engine room of a container ship. B) 39 Trans-Pacific transects from Long Beach to New Zealand. C) VOS ships hosting PMEL underway pCO_2 equipment.

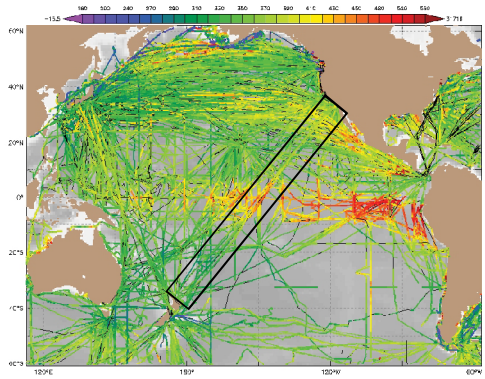

Figure 2. PMEL cruises of underway pCO_2 data in the Surface Ocean Carbon Atlas (SOCAT). Transits from Long Beach to New Zealand are highlighted in the rectangular box.

DECADAL VARIATION OF SUSTAINED HIGH QUALITY pCO_2 MEASUREMENTS

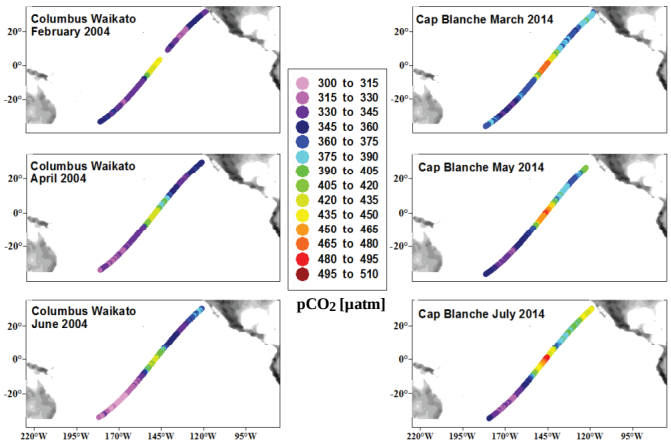

Figure 3. pCO_2 measured from Long Beach to New Zealand transects in 2004 and 2014.

A pattern of increased pCO_2 distributions across the Pacific basin has emerged from the sustained high quality pCO_2 measurements PMEL has attained from container ships over the past decade. Trans-Pacific pCO_2 measurements from 2004 and 2014 during normal ENSO conditions (3 month running SST anomaly within ± 0.5°C of the climatological mean in the Nino 3.4 region) are shown in Figure 3.

The decadal increase in pCO_2 reaches ~ 36 µatm at the equator (Figure 4 and Table 1). Data collected in the northern hemisphere during 2014 captures the effect of the sustained temperature anomaly known as "the Blob" (Bond et al., 2015, Figure 5).

When the anomalously high pCO_2 values from the Blob are excluded, the mean decadal increase in pCO_2 for the Long Beach to New Zealand track line is 26 µatm (15°N to 35°S), consistent with trends of pCO_2 at stationary moorings in the equatorial Pacific (Sutton et al., 2014). In the region where the transect travels through the Blob (15°N to 35°N), the decadal increase in pCO_2 reaches values up to 49 µatm which constitutes a 47% enrichment in pCO_2 due to the anomalously warm waters relative to the decadal change. This enhanced carbon source may have strong implications for the oceanic carbon budget for the time frame it continues to exist, transitioning the region from a CO_2 sink to a CO_2 source.

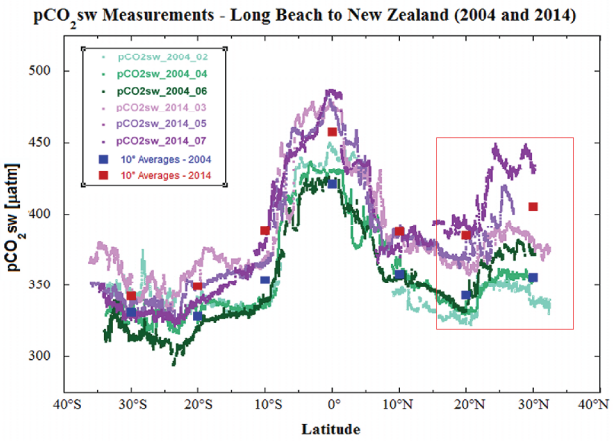

Figure 4. pCO_2 from Long Beach to New Zealand transects in 2004 and 2014 with squares indicating average pCO_2 values for each 10° latitude band. The largest changes in pCO_2 occur near the equator and in the north Pacific north of 15°N, the latter in part due to "the Blob".

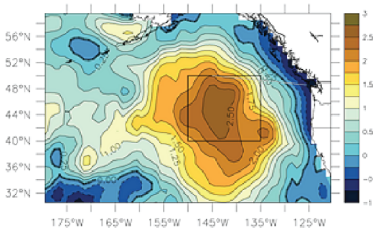

Figure 5. Sea surface temperature anomalies (°C) in NE Pacific Ocean for February 2014. From Bond et al., 2014.

pCO_2sw (µatm)	2004	2014	Decadal Change
35°N - 35°N	355.49 ± 13.63	404.90 ± 24.38	49.42
25°N - 15°N	342.88 ± 12.55	384.45 ± 19.57	41.56
15°N - 5°N	357.80 ± 17.26	387.51 ± 14.87	29.7
5°N - 5°S	420.82 ± 18.14	457.26 ± 18.02	36.44
15°S - 5°S	353.42 ± 30.06	388.21 ± 33.19	34.79
25°S -15°S	328.34 ± 10.90	348.99 ± 14.43	20.64
35°S - 25°S	330.87 ± 14.46	342.18 ± 12.91	11.31

SST (°C)	2004	2014	Decadal Change
35°N - 35°N	17.26 ± 1.64	19.07 ± 1.93	1.81
25°N - 15°N	21.62 ± 1.57	22.90 ± 1.82	1.28
15°N - 5°N	26.55 ± 1.40	27.14 ± 1.01	0.58
5°N - 5°S	27.76 ± 0.83	27.80 ± 0.55	0.03
15°S - 5°S	29.08 ± 0.38	28.64 ± 0.47	-0.4
25°S -15°S	27.46 ± 1.58	26.60 ± 1.96	-0.8
35°S - 25°S	22.02 ± 2.28	21.35 ± 2.39	-0.6

Table 1. 10° averages of pCO_2 and SST measured on trans-Pacific transects in 2004 and 2014.

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