Variability in oceanic CO_2 parameters in the North Atlantic Subtropical Gyre: a neural network approach.

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Aim of the study

Using artificial neural network to derive the variability of the ocean carbonate system during Spring 2016 over the area of study from monthly satellite-derived wind stress (ASCAT), sea surface salinity (SMOS) and sea surface temperature (OISST) fields over the oceans. The predicted variables were dissolved inorganic carbon (DIC), total alkalinity (AT), pH_T and partial pressure of ocean surface carbon dioxide (pCO_2). Using this approach the components of the seawater carbonate system for springtime 2016 were predicted at high resolution (0.25° x 0.25°) and used to compare against published observations going back since 1988 for the North Atlantic Subtropical Gyre.

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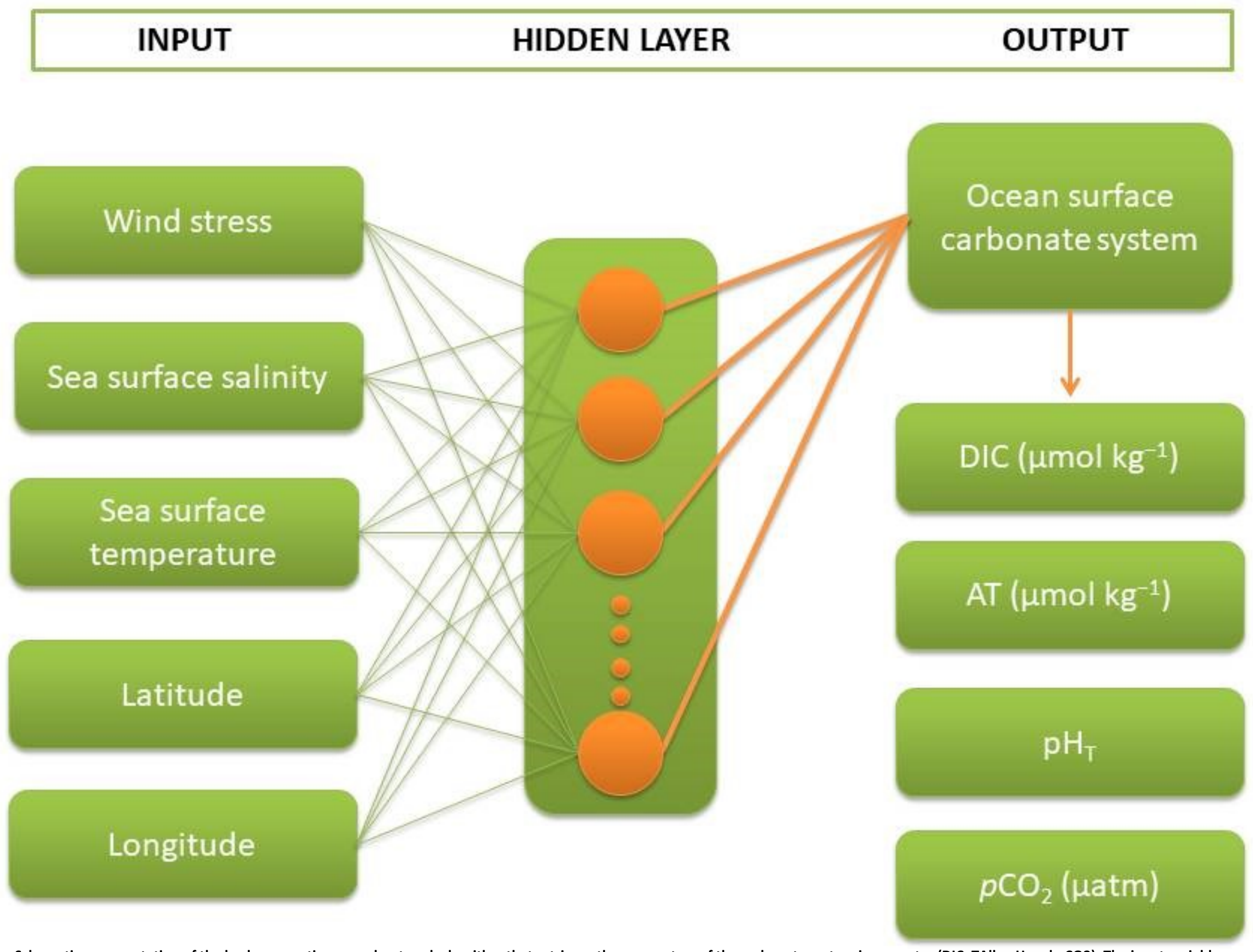
Methodology & validation

Using a Multi-Layered Perceptron neural network, we developed and fine-tuned a method to predict the ocean carbonate system at the sea surface from independent oceanic surface properties. 2 MLPs (referred to as BPN-5' and BPN-3') were trained and validated using concurrent in situ values of DIC, AT, pH_T and pCO_2. While BPN-3' contained only wind stress on the ocean surface, sea surface salinity and sea surface temperature, BPN-5' was also trained with latitude and longitude (in degrees) of the collocated values. After validating the results with in situ data, BPN-3' MLP produced an overall lower BIAS and RMSE.



Schematic representation of the backpropagation neural-network algorithm that retrieves the parameters of the carbonate system in seawater (DIC, TAlk, pH and pCO2). The input variables are remote sensed wind stress, sea surface salinity, sea surface salinity and their geolocation.

Eq. 1: DIC, TAlk, pH, pCO_2 = *F* (wind stress, SSS, SST, Latitude, Longitude)   Eq 2: DIC, TAlk, pH, pCO_2 = *F* (wind stress, SSS, SST)

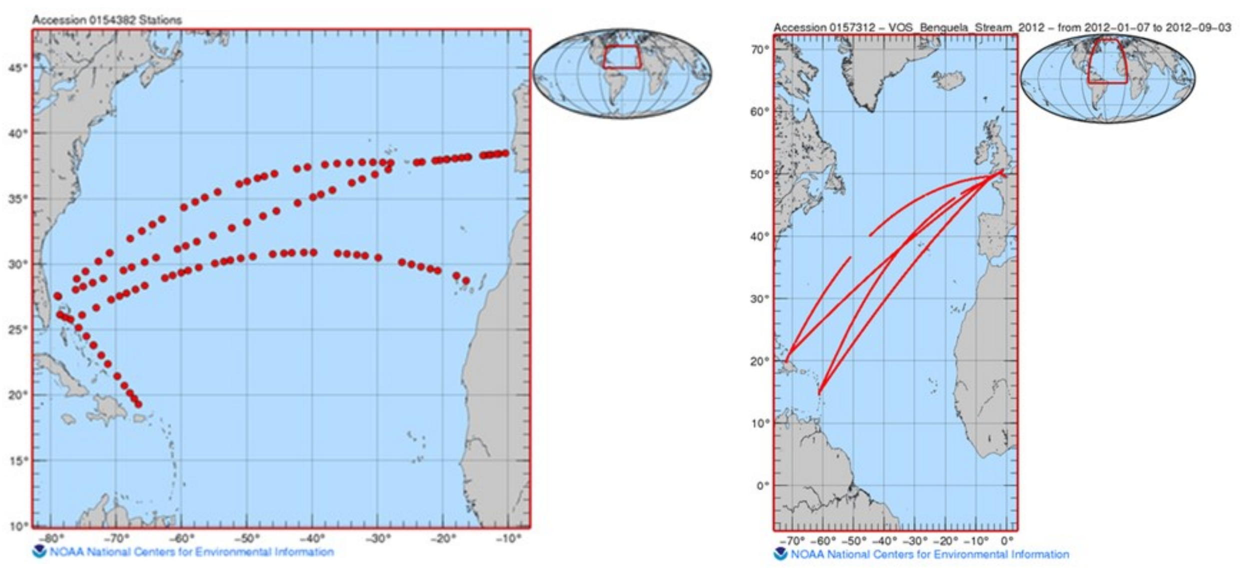
While Eq.1 takes into account all five input parameters, Eq. 2 makes use of only wind stress, sea surface salinity and sea surface temperature as the ANN input parameters to predict the ocean carbonate system variables.

Table 1.	mean ship-measured	mean predicted (MLP)	Average Bias *(observed-predicted)*
DIC µmol kg^{-1}	2049 (σ 16)	2051 (σ 15.94)	-46
AT µmol kg^{-1}	2377 (σ 15)	2381 (σ 15.77)	3.6
pH_T	8.111 (σ 0.011)	8.115 (σ 0.011)	0.077
pCO_2 µatm	404 (σ 9.7)*	377 (σ 7.2)	22

Table 2.	mean ship-measured	mean predicted (MLP)	Average Bias *(observed-predicted)*
DIC µmol kg^{-1}	2090 (σ 25)	2082 (σ 19)	6.7
AT µmol kg^{-1}	2410 (σ 16)	2428 (σ 11)	17
pH_T	8.098 (σ 0.030)	8.117 (σ 0.018)	0.022
pCO_2 µatm	415 (σ 22)*	373 (σ 1.4)	42

Table 3.	mean ship-measured	mean predicted (ANN)	Average Bias *(observed-predicted)*
pCO_2 (µatm)	345 (σ 5.4)*	372 (σ 0.40)	22

Tables 1-3 show validation of MLP-predicted values of DIC, AT, pH_T and pCO_2 against cruise samples taken at sea surface from (1) March 07-08, 2015, off Bahamas and Dominican Republic // (2) October 30-November 6, 2016, North Atlantic Ocean (20°N to 40°N; -80°W to -10°W) // (3) April 28-May 6, 2012 Atlantic Ocean. * *The pCO_2 values were calculated using the CO2SYS program on the basis of the other carbonate system values.*



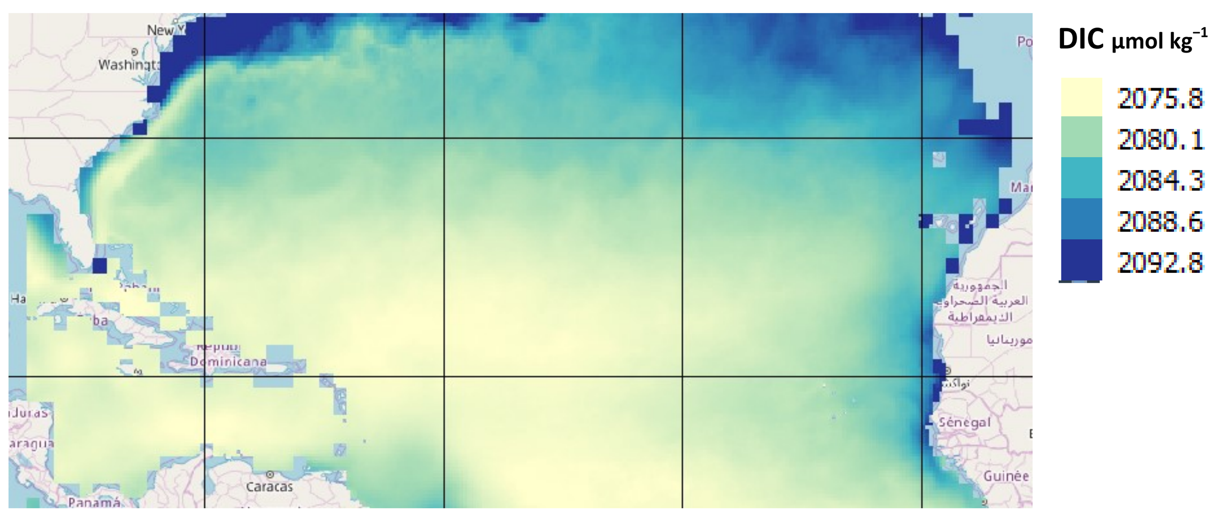
Cruise data used for the training and validation of the MLP neural network.

LEFT: **NCEI 0154382**; DIC, AT and pH_T data; Sampling period: 2015-03-07 to 2016-11-06

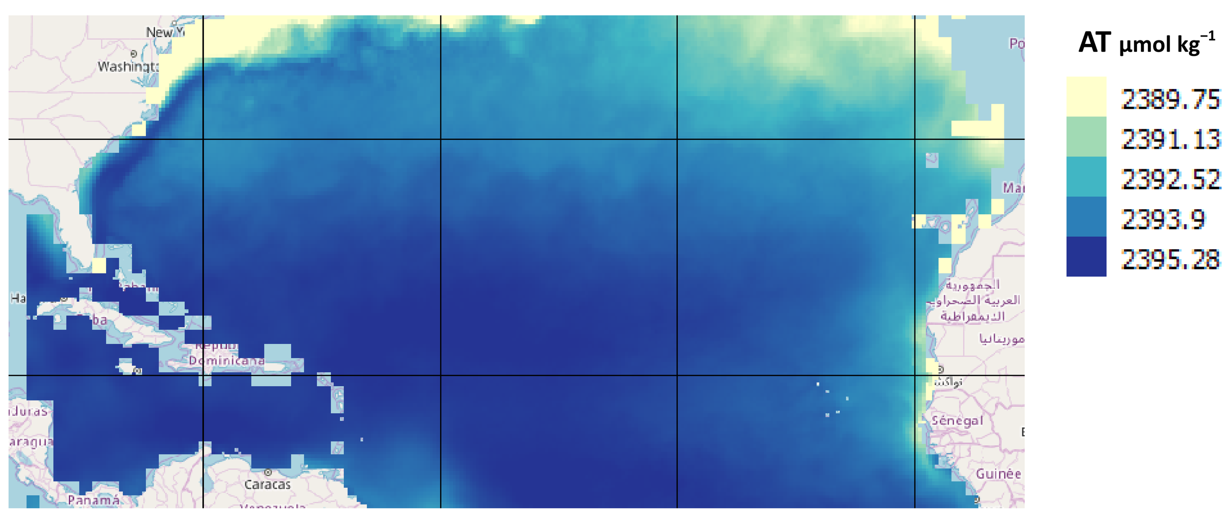
RIGHT: **NCEI 0157312**; pCO_2; Sampling period: 2012-04-28 to 2012-05-06

	StationID range	N	Sea surface Temperature (Pearson correlation R)	Sea Surface Salinity (Pearson correlation R)
Apr 28 – May 6, 2012	n/a	1123	0.99	0.99
Apr 28- May 26, 2015	1020000-1400000	35	0.99	0.69
Mar 07-08, 2015	1-19	19	0.78	0.93
Apr 16-24, 2016	10000-174000	36	0.98	0.90
Oct 30 – Nov 06, 2016	610000-1920000	35	0.97	0.63

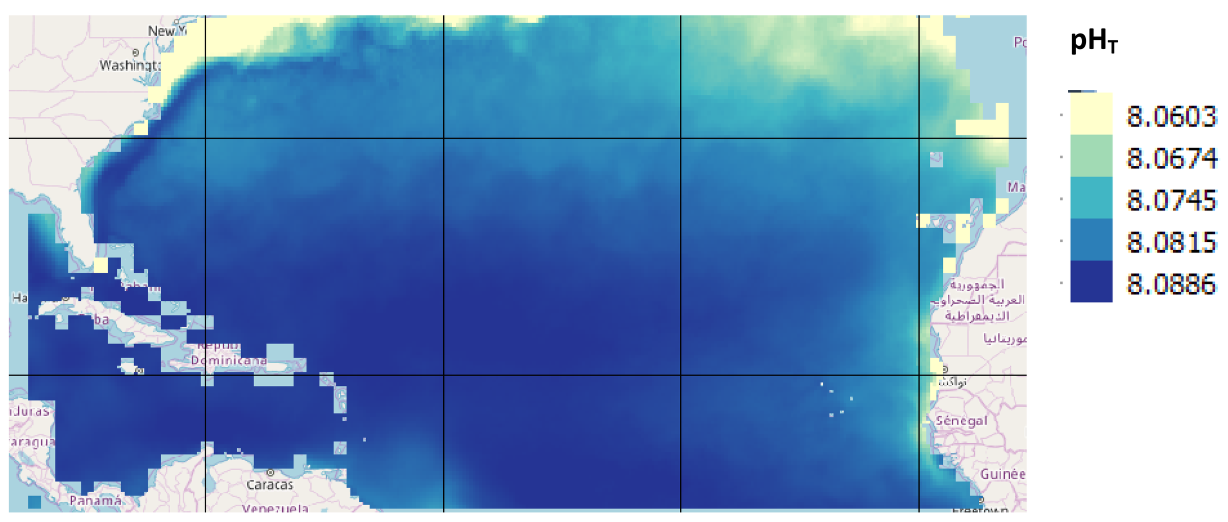
Retrieval of CO_2 parameters



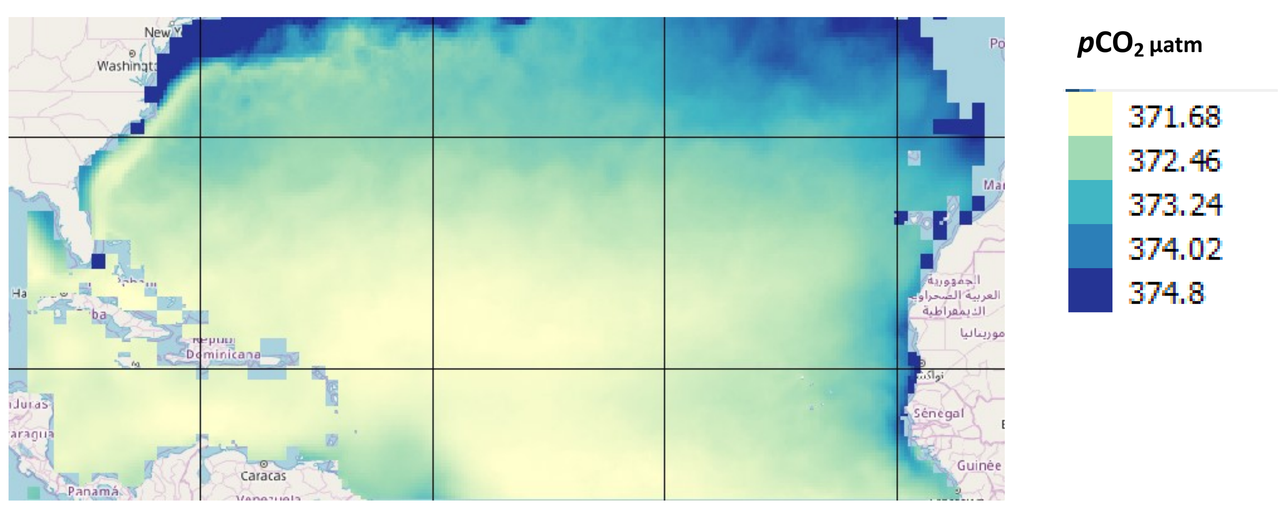
Average Spring 2016 DIC (µmol kg^{-1}) for the northern Atlantic ocean predicted from the monthly wind stress, SSS and SST using neural network at a resolution of 0.25° x 0.25° resolution.



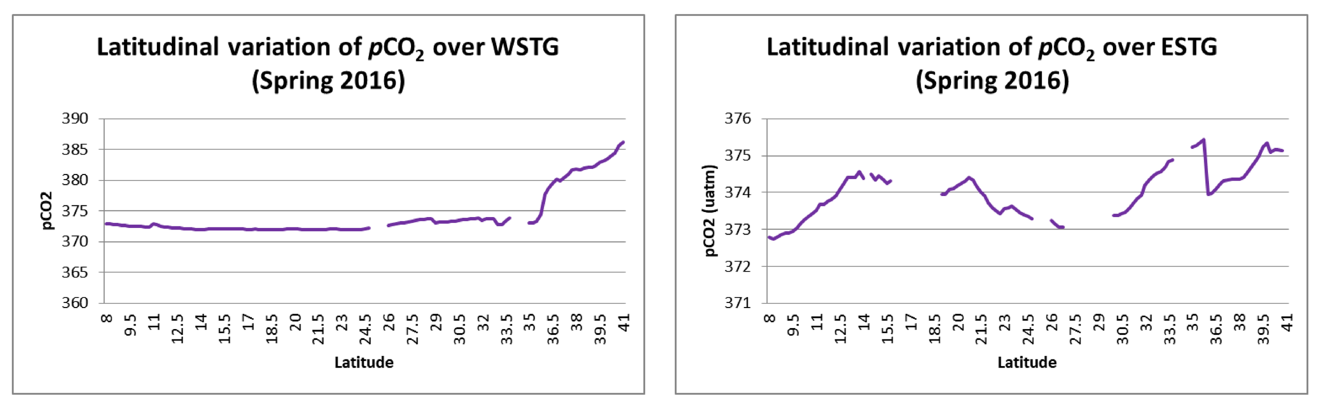
Average Spring 2016 TA (µmol kg^{-1}) for the northern Atlantic ocean predicted from the monthly wind stress, SSS and SST using neural network at a resolution of 0.25° x 0.25° resolution.



Average Spring 2016 pH_T for the northern Atlantic ocean predicted from the monthly wind stress, SSS and SST using neural network at a resolution of 0.25° x 0.25° resolution.



Average Spring 2016 pCO_2 (µatm) for the northern Atlantic ocean predicted from the monthly wind stress, SSS and SST using neural network at a resolution of 0.25° x 0.25° resolution.



WESTERN PART OF THE SUBTROPICAL GYRE (WSTG)   **EASTERN PART OF THE SUBTROPICAL GYRE (ESTG)**

General observations

- A general decrease in pCO_2 is evident from north to south.
- Surface pCO_2 values in both WSTG and ESTG were lower than mean atmospheric values (406.4 ppm) recorded at the NOAA/CMDL sites in the Azores, but higher than the springtime observations over the region, estimated to be 343 ± 8 µatm during Spring 2011 by Burgos et al, (2015) and even down to 310 ± 30 µatm for Spring 1970-2006 (Takahashi et al., 2009)
- The mean DIC (WSTG+ESTG) was 2080 ± 5,
- The mean AT (WSTG+ESTG) was 2394 ± 2
- The mean pH was 8.08 ± 0.01

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