

Variability in oceanic CO₂ 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 (pCO₂)**. 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.

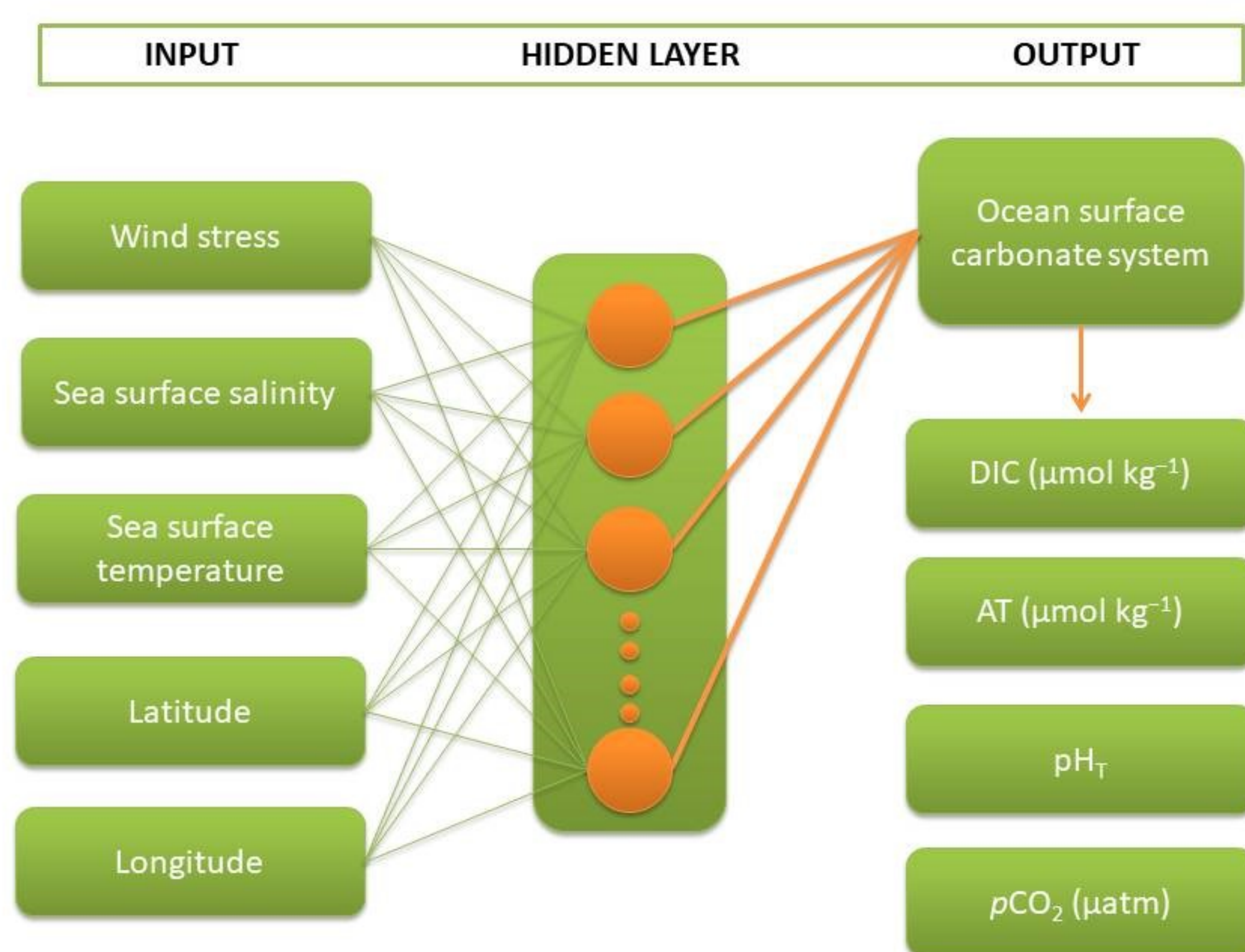


CENTRO INTERDIPARTIMENTALE DI RICERCA PER LE SCIENZE AMBIENTALI



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 pCO₂. 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.



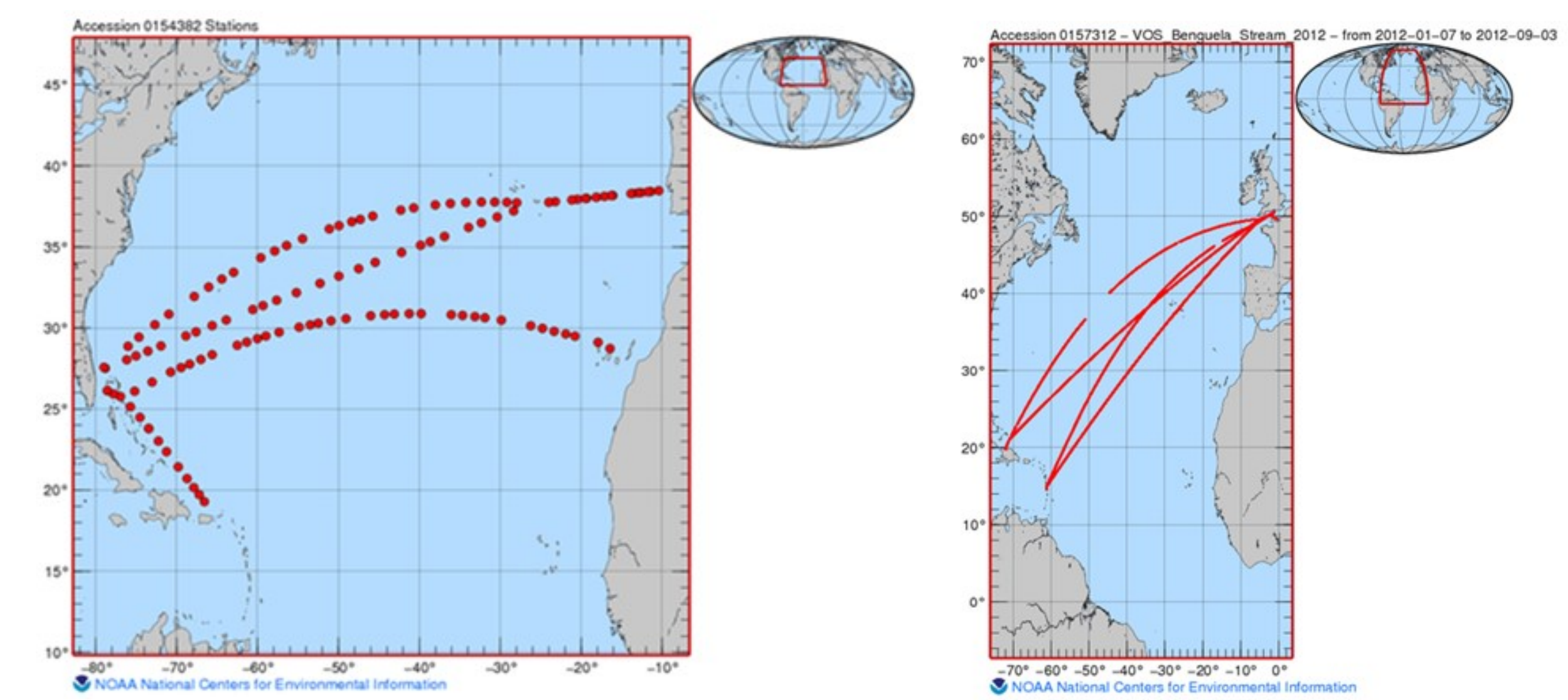
Schematic representation of the backpropagation neural-network algorithm that retrieves the parameters of the carbonate system in seawater (DIC, TA, pH and pCO₂). The input variables are remote sensed wind stress, sea surface salinity, sea surface temperature and their geolocation.
Eq. 1: DIC, TA, pH, pCO₂ = f(wind stress, SSS, SST, Latitude, Longitude) Eq. 2: DIC, TA, pH, pCO₂ = 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 pCO₂ 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 pCO₂ values were calculated using the CO₂SY program on the basis of the other carbonate system values.



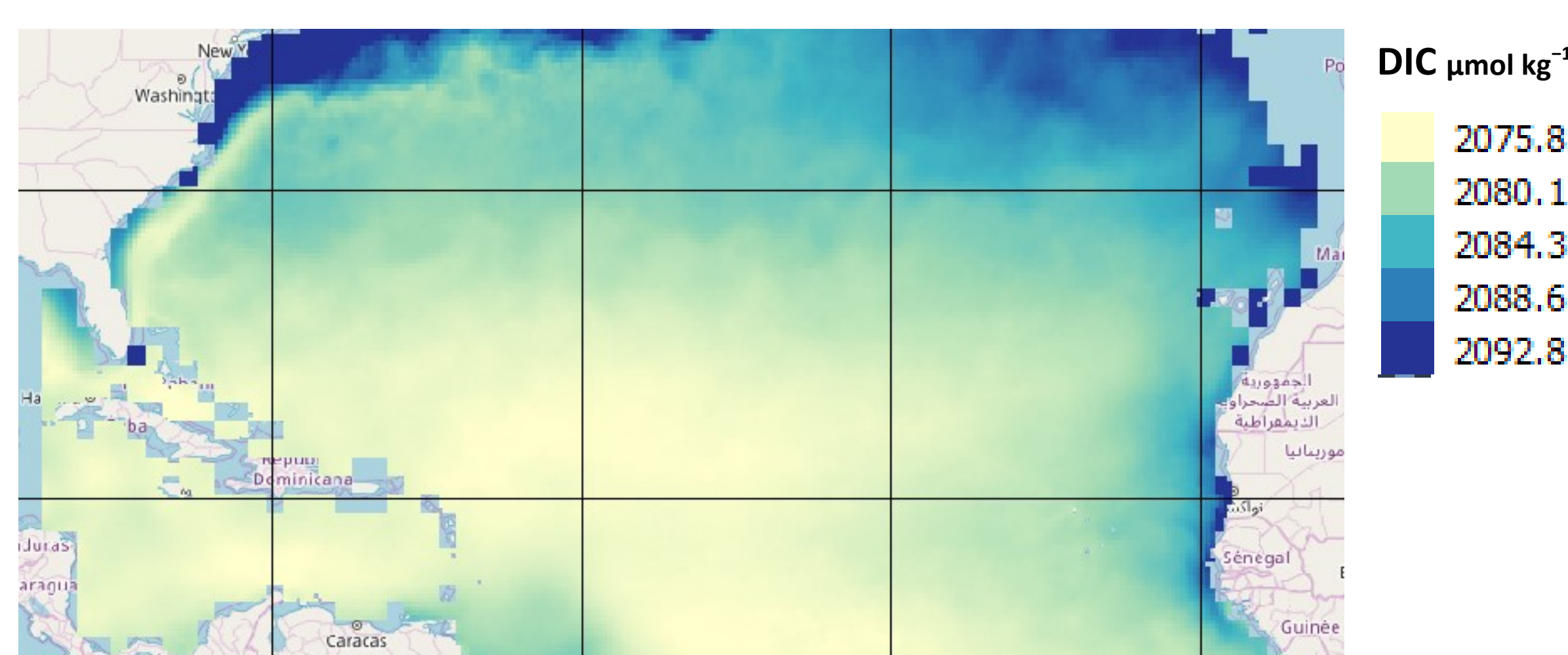
Cruise data used for the training and validation of the MLP neural network.

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

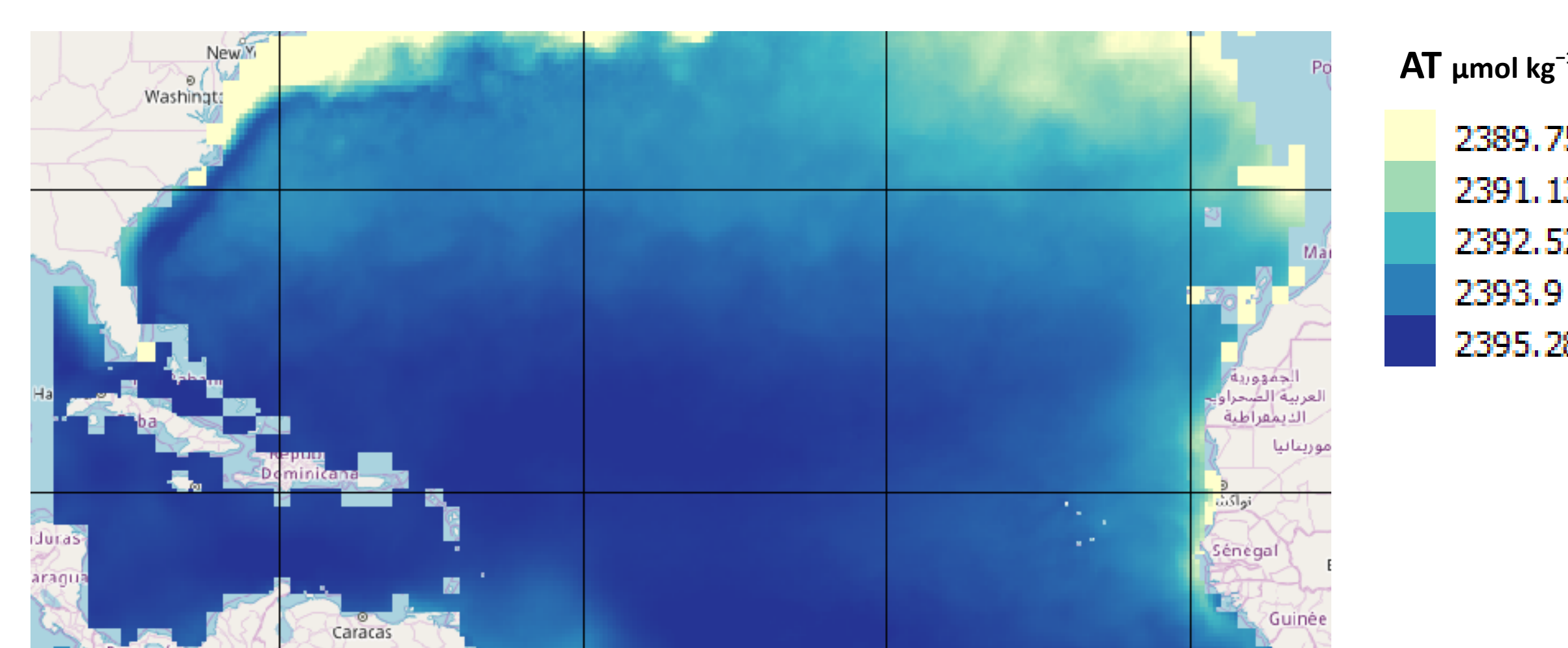
RIGHT: NCEI 0157312; pCO₂; Sampling period: 2012-04-28 to 2012-05-06

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
Apr 28 – May 26, 2015	1020000-1400000	35	0.99
Mar 07-08, 2015	1-19	19	0.78
Apr 16-24, 2016	10000-174000	36	0.98
Oct 30 – Nov 06, 2016	610000-1920000	35	0.97

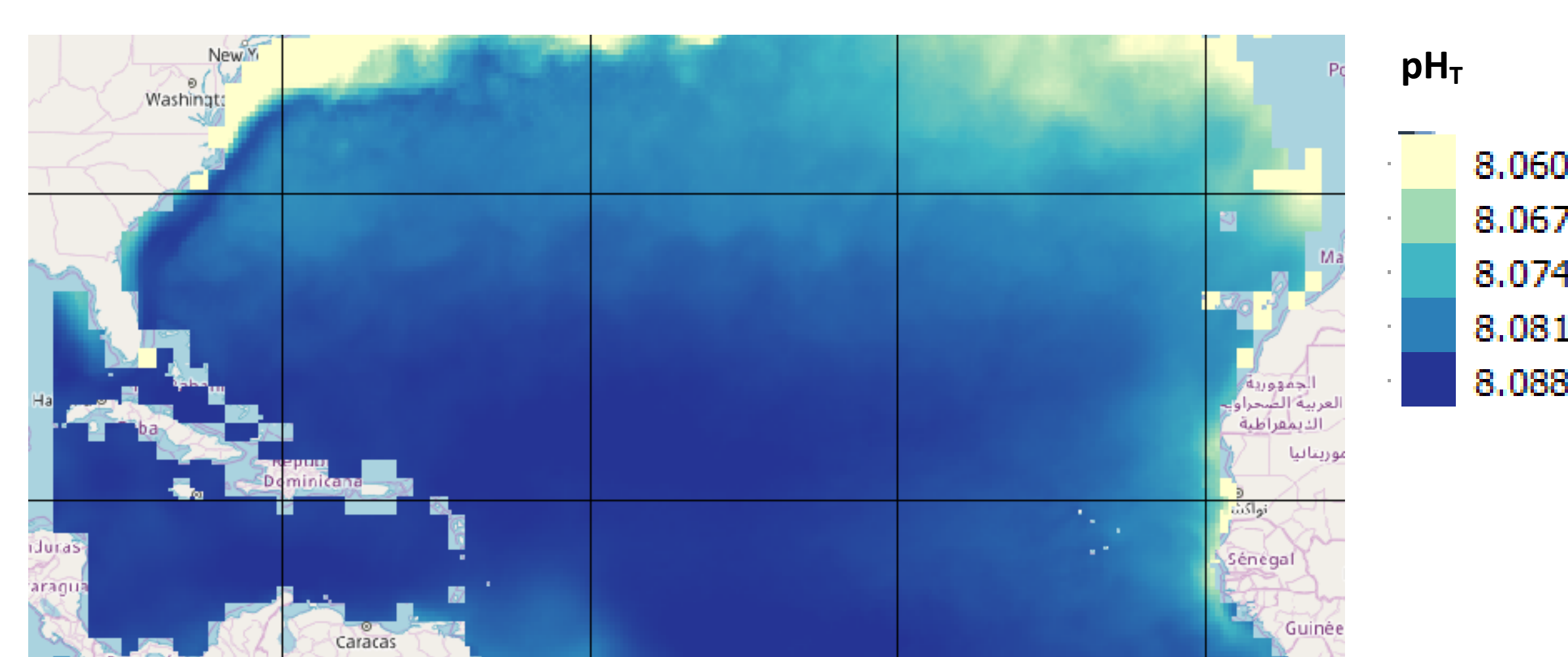
Retrieval of CO₂ parameters



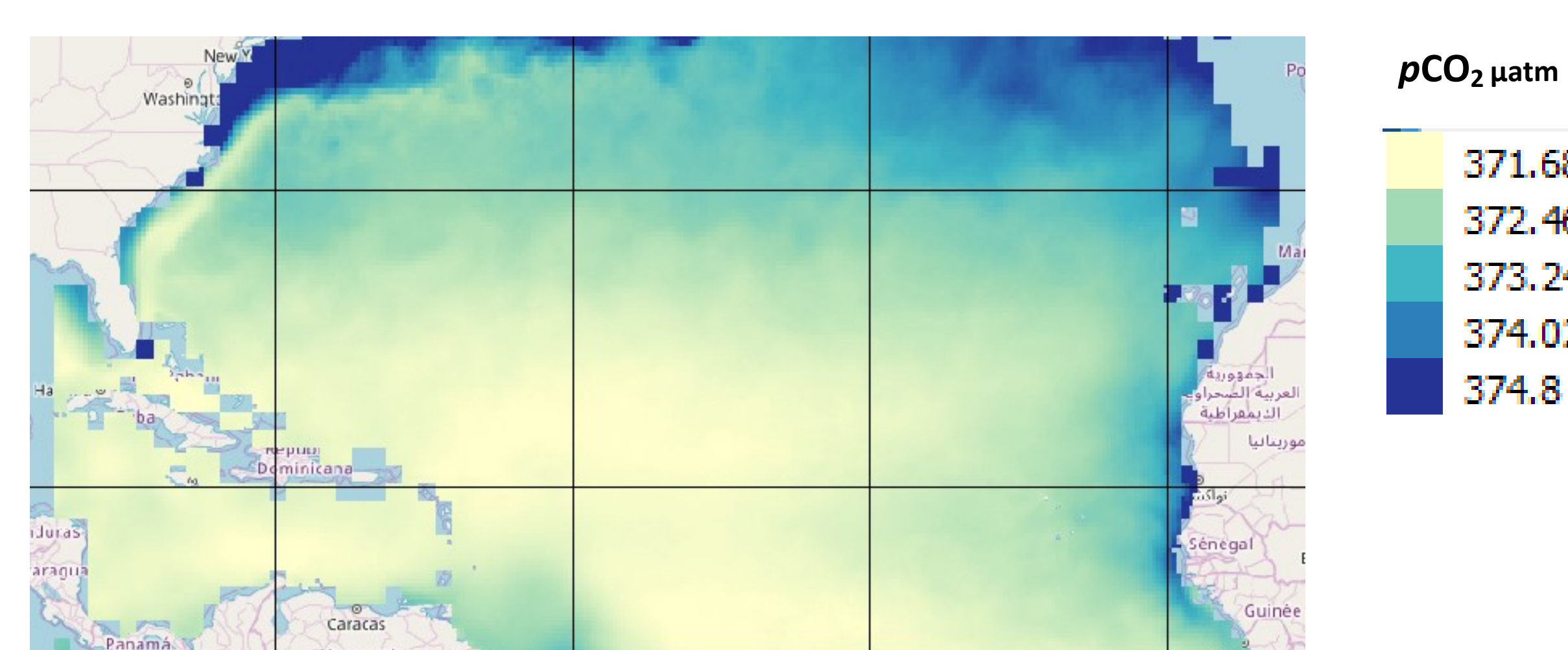
Average Spring 2016 DIC (μmol kg⁻¹) for the northern Atlantic ocean predicted from the monthly wind stress, SSS and SST using neural network at a resolution of 0.25° x 0.25° resolution.



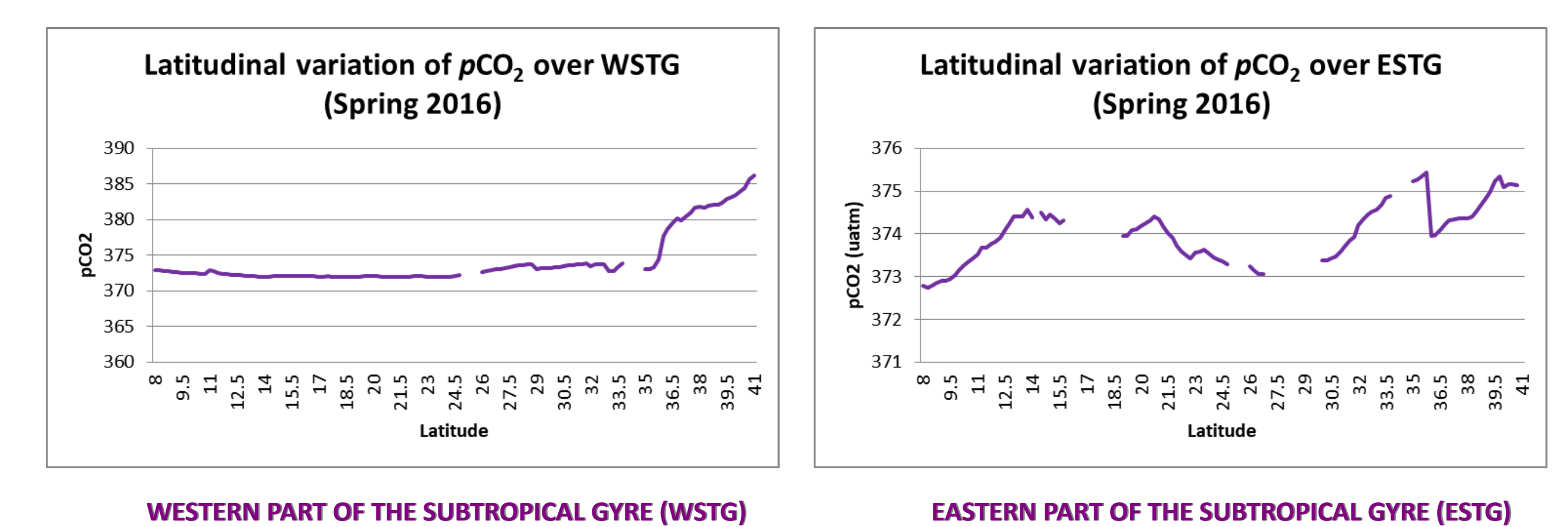
Average Spring 2016 TA (μmol kg⁻¹) for the northern Atlantic ocean predicted from the monthly wind stress, SSS and SST using neural network at a resolution of 0.25° x 0.25° resolution.



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 pCO₂ (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.



General observations

- A general decrease in pCO₂ is evident from north to south.
- Surface pCO₂ 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