Analyzing and Contextualizing CMIP6 Data in Observations

Jonathan Tran, SEAS '24, jtran800@seas.upenn.edu
Dr. Irina Marinov, SAS Earth and Environmental Science
Class of 1971 Robert J. Holtz Fund

Introduction:

This summer, my research was focused on trying to better understand our oceans by analyzing various metrics such as phytoplankton biomass, salinity, and several different nutrients. Phytoplankton are critical to our global climate as they account for nearly 50% of the total photosynthesis on Earth. My research aims to explore their relationship with our changing climate.

Methods:

My research this summer has largely consisted of computational analyses (Python) of General Circulation Models (GCM) data. I have been working on a variety of projects involving Coupled Model Intercomparison Project Phase 6 (CMIP6) ensemble data. For one such project, I am analyzing differences in present (1991-2010) GCM output under historical scenario and future GCM projections (2081-2100) under ssp585 scenario at three locations: ocean station PAPA (45 50N, 140 150W) , NABE (45 50N, 25 35W) , and one other Atlantic ocean site (45 50N, 13 18W) . I choose these sites because they are where NASA's EXPORTS projects are focused (https://oceanexports.org/).

Global Circulation Models	Variables
CESM2, CESM2-WACCM, GFDL-CM4, GFDL-ESM4, IPSL-CM6A-LR, GISS-E2-1-G, GISS-E2-1-G-CC, MIROC-ES2L, NorCPM1, NorESM1-2-HR, NorESM1-2-LR, UKESM1-0-LL, CNRM-ESM2-1, ACCESS-ESM1-5, CanESM5-CanOE, CanESM5, EC-Earth3	Biomass, Chlorophyll, Diatom, Zooplankton, Primary Production, Export Production at 100m, Air-sea CO2 flux, SpCO2, Iron, Nitrate, Silica, Sea Surface Temperature

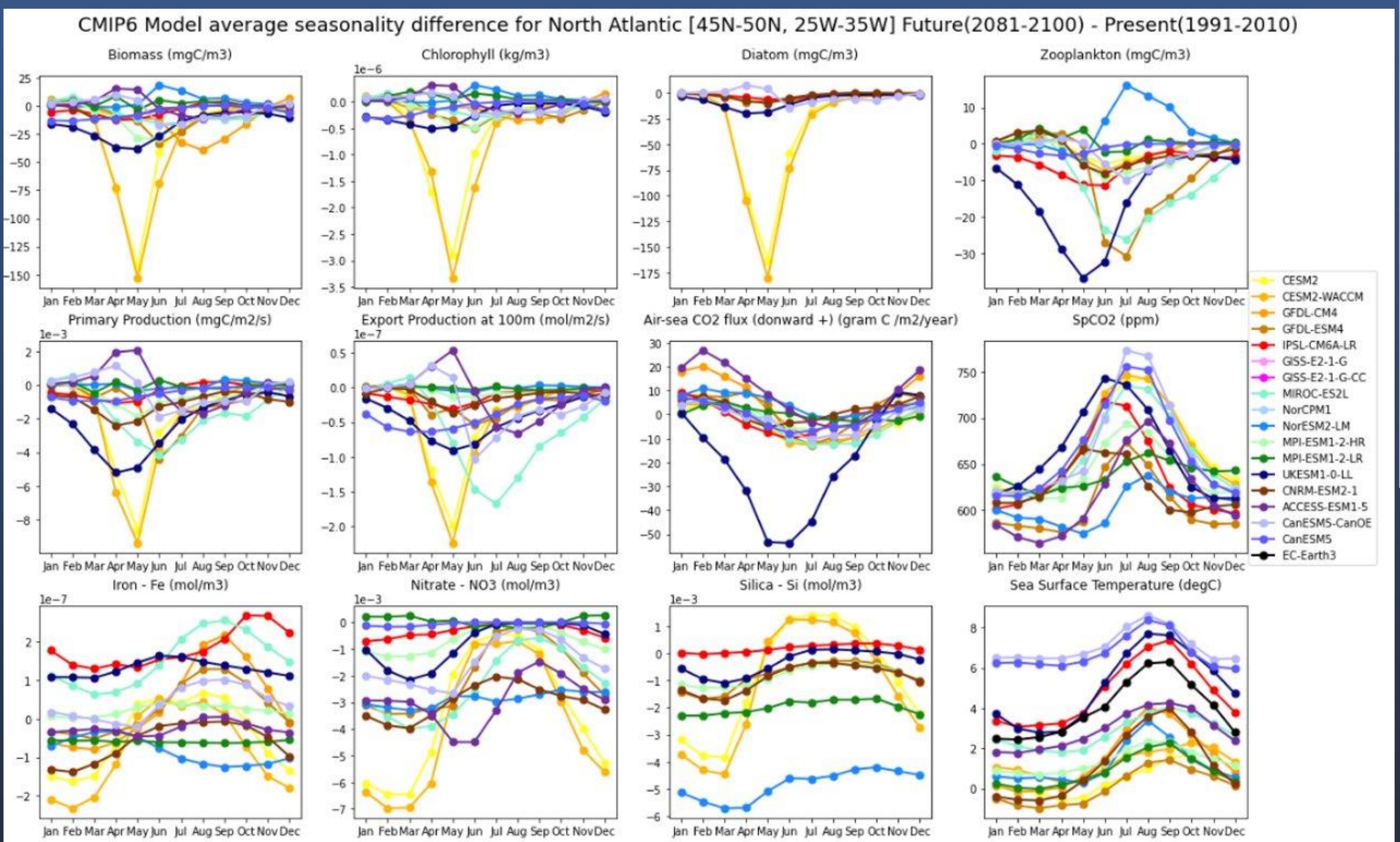

Figure 1. These plots show the average seasonal difference in twelve variables from 1991-2010 to 2081-2100.

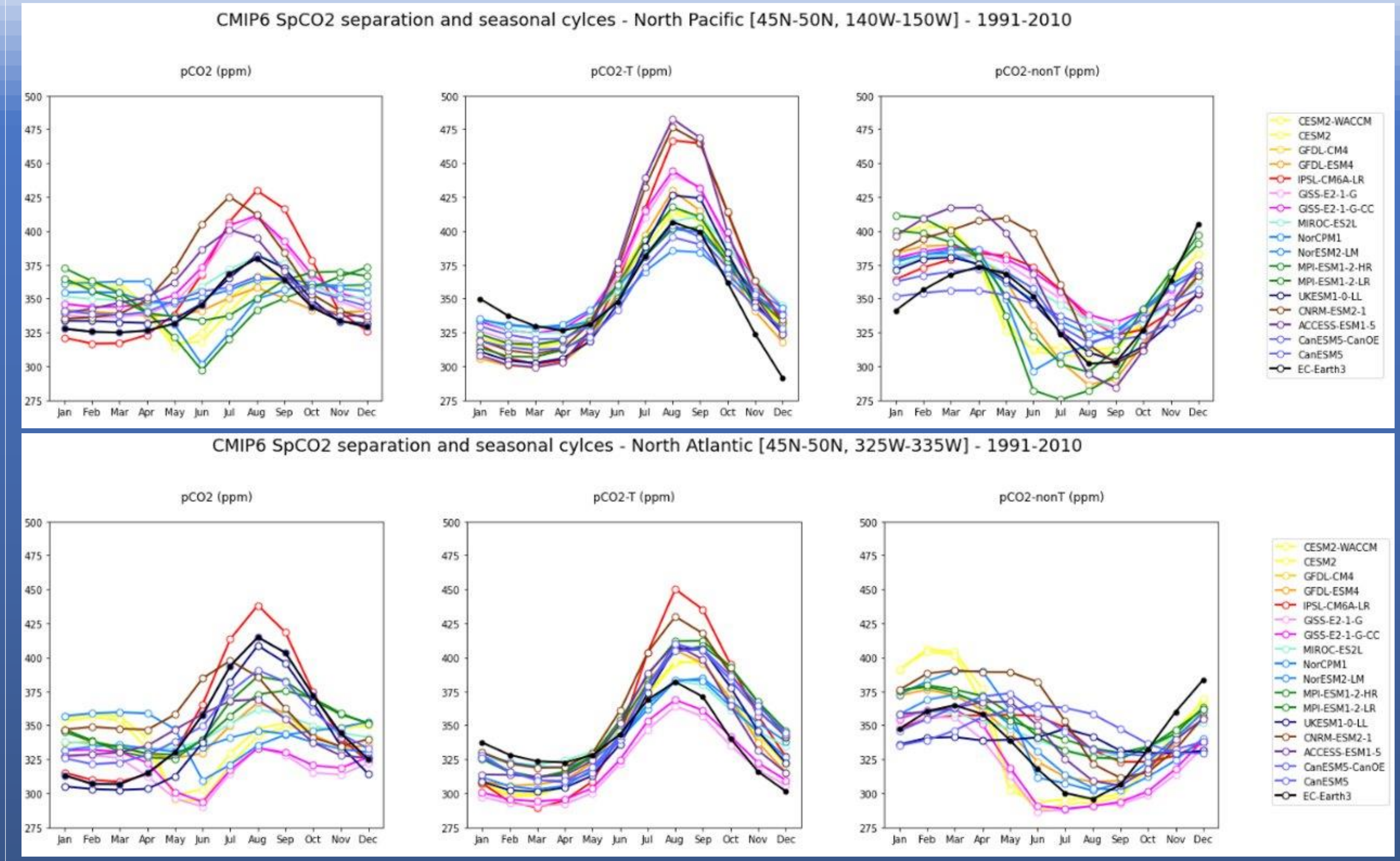

Figure 2. Spco2 separation for two of the three sites (PAPA and NABE) with model data (unfilled circle data points) and observational data (filled circle).

Results and Conclusions:

My analysis confirms the seasonal cycle of phytoplankton (biomass) and zooplankton (figure 1, panels 1 and 4). Zooplankton populations peak in the summer months after phytoplankton bloom in the spring, which is an expected result, as zooplankton graze on phytoplankton. We also compared subpolar Atlantic (above) and the other two boxes. For the CESM2 GCM subpolar box in the North Atlantic, we see that observed nitrate (NO3) is in the middle range of all modeled NO3 (figure 1, panel 10) in winter and spring. In the summer, however, observed NO3 goes to zero, while model NO3 goes to zero in only half of the models. Biological uptake by phytoplankton is too weak in the summer in some models, while, at ocean station PAPA in the subpolar North East Pacific, the opposite trend is observed . In the summer, NO3 is higher than in most models. In most models, phytoplankton growth is too high during the summertime at PAPA. This is explained by phytoplankton not being iron limited enough compared to reality. We can therefore deduce the iron cycle (figure 1, panel 9) is not correct in most models here. Furthermore, we were able to study differences in present and future data. We found that across multiple models, phytoplankton populations and the nutrients they rely on (e.g., nitrate) are projected to decrease. Phytoplankton are responsible for 50% of photosynthesis performed on Earth. Drops in phytoplankton population are important for carbon cycle and might affect climate on a global scale.

Another variable that is that is important to study effects of phyto growth on carbon cycle is surface aqueous partial pressure of carbon dioxide (spco2). To learn more about the seasonal cycles of spco2, I created GCM data plots of the seasonal cycle of spco2 from 1991-2010 (present) to study fluctuations throughout the year . By further breaking down spco2 into its temperature and non temperature components, I was able to understand the driving forces of these seasonal changes, whether that may be temperature or biology. In addition to CMIP6 GCM data I analyzed spco2 observational data (Fay et al., 2021). I combined their spco2 product with temperature data from the World Ocean Atlas (WOA) (figure 2). The culmination of this work are plots that combine model data (from CMIP6) and observations (SeaFlux and WOA). My analysis can be used for GCM validation and shows that the observational data falls within the deviations between models, assuring us that in these cases, the models are relatively accurate. This is important for these plots and future investigations.

Projections like these demonstrate the need to take action to prevent further climate change. In future work, we are interested in studying various ratios such as grazing rate/primary production, biomass/ chl ratios, zoopl /total biomass, and Si/NO3. Understanding the relationship between such variables will ultimately allow us to draw further conclusions on future climate projections.