Particle Export and Plankton Spatio-Temporal Variability

Exploring mesoscale and interannual variability during NASA EXPORTS cruise with a coupled biogeochemical Earth-system model.

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Intro & Motivation

Fig. 1

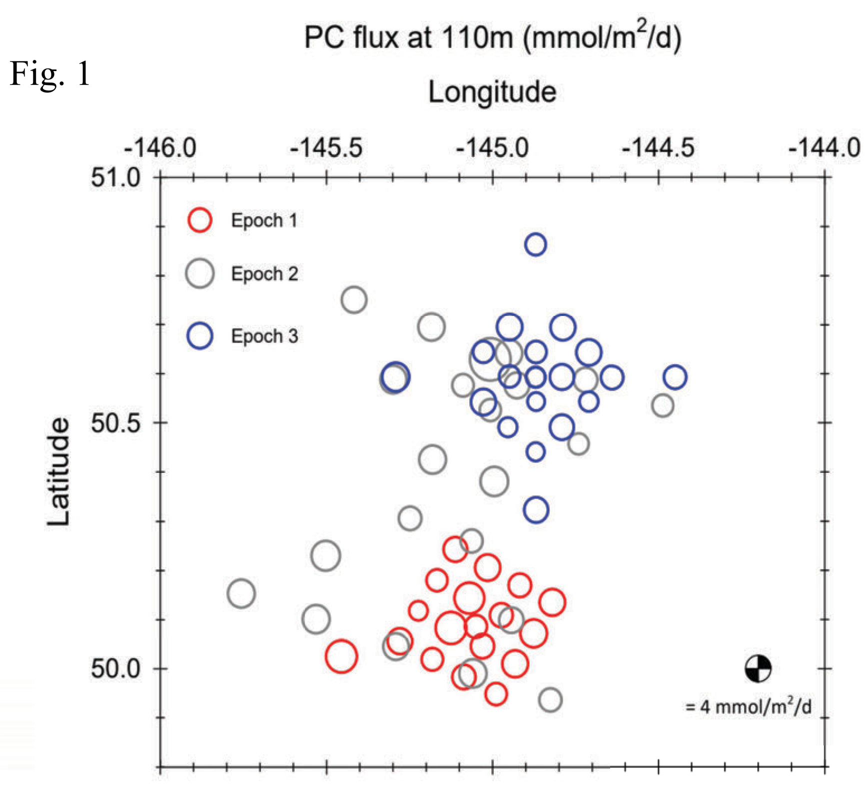


Fig. 1: Sampling grid from Sally Ride during EXPORTS cruise. Color denotes epoch, size denotes particle flux.

During the EXPORTS cruise we measured total thorium flux as a tracer of carbon export. We are exploring whether our model, a fully coupled Earth-system model (ESM2.6), contains the variability observed during the cruise and aim to examine/quantify the processes driving it.

Research Question:

Q. Can we understand the contributions of spatial/temporal variability in the observations, and in particular mesoscale, seasonal & interannual variability?

From cruise data (Fig. 1) we can see spatial variability on the order of 2mmol/100km. Using the Earth system model with coupled biogeochemistry, (Fig. 2) we see comparable spatial variability in the 2°x2° box near Ocean Station Papa. Further we see significant interannual variability of comparable magnitude between the two model years.

Fig. 2 Monthly Mean Carbon Export In ESM2.6

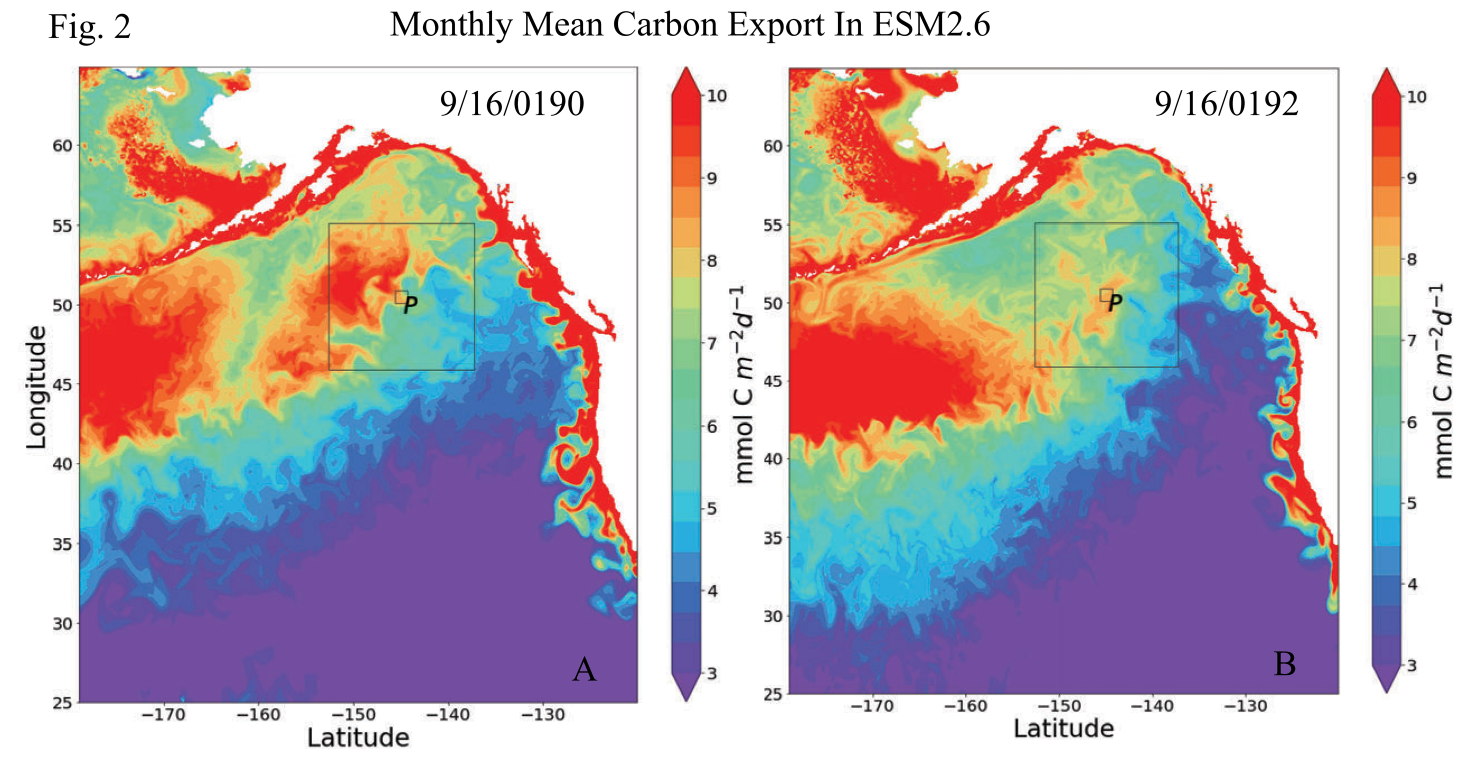


Fig. 2: September monthly mean export of model years 190 (2.A) and 192 (2.B) shown side by side to demonstrate the changes in spatial variability on interannual time scales. In both figures Ocean Station Papa is labeled with a P, the smaller box is a 2x2 degree box containing the EXPORTS cruise sampling sites. The larger box is a 10x10 degree box used during analysis.

Method and Model Evaluation

Fig. 3 COBALT Food Web

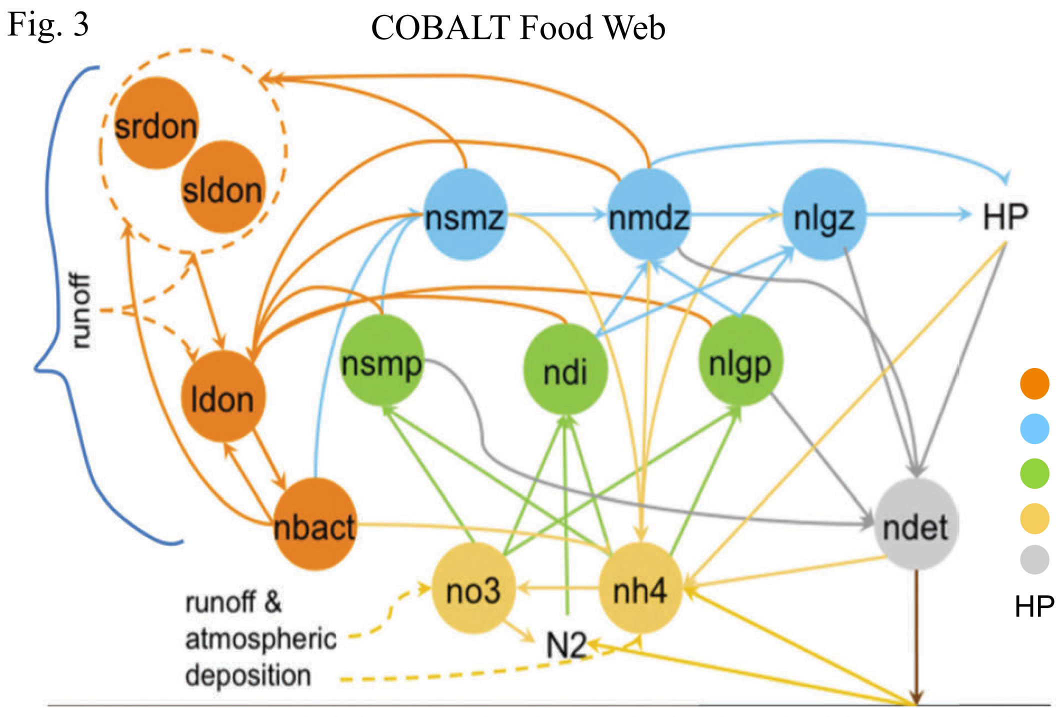


Fig. 3: Schematic of ecological food web in the COBALT model

GFDL Earth System Model (ESM2.6)

- Ocean-Atmosphere-Land Coupled Model -1/10th degree ocean, ½ degree atmosphere
- Present-day greenhouse forcing, 141 year spin up
- Outputs: ~30 years monthly mean data, 2 years daily data for MLD, SST & NO3
- Couple to biogeochemical model of intermediate complexity, COBALT

COBALT (Carbon, Ocean Biogeochemistry and Lower Tropics)

Food Web Description (shown Fig. 3)

- 33 biogeochemical tracers
- 3 phytoplankton, 3 zooplankton, sinking detritus and 3 labilities of DOM

Two model years (191, 192) daily data sets are sampled (Figs. 4,5), with location and frequencies from R/V Sally Ride of the EXPORTS cruise (Fig.1) using a linear interpolation between model points in both space and time. Data sets used for comparison are the Extended Reconstructed Sea Surface Temperature (ERSST) and the Argo MLD climatology product from UCSD.

SST:

- Model interannual variability similar to that seen in the ERSST data and of similar scale to daily spatial variability, which captures variability seen in Sally Ride data.
- 2018 was anomalously warm and thus shifted closer to the model mean.
- In model year 191, variability caused by warm pool moving across the 2°x2° box from mid-September to mid-August.

MLD:

- Daily variability in the model is significantly greater than that of the monthly mean data, indicating successful representation of mesoscale variability but does not capture the sub- mesoscale variability observed in Sally Ride data.

Fig. 4 Model Year 191 SST

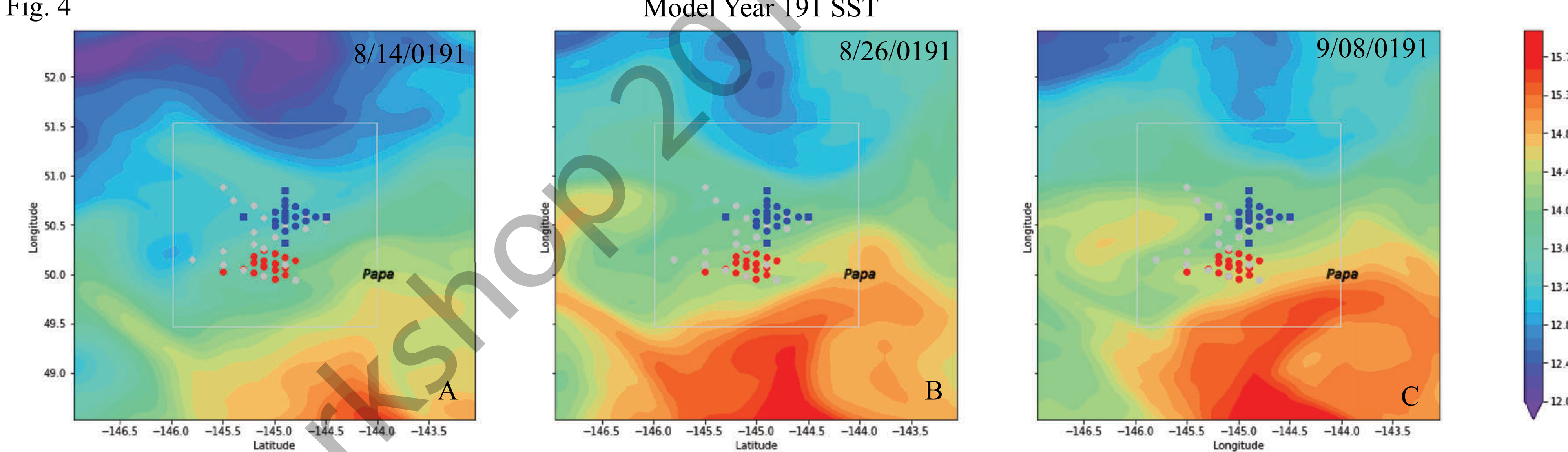


Fig. 5

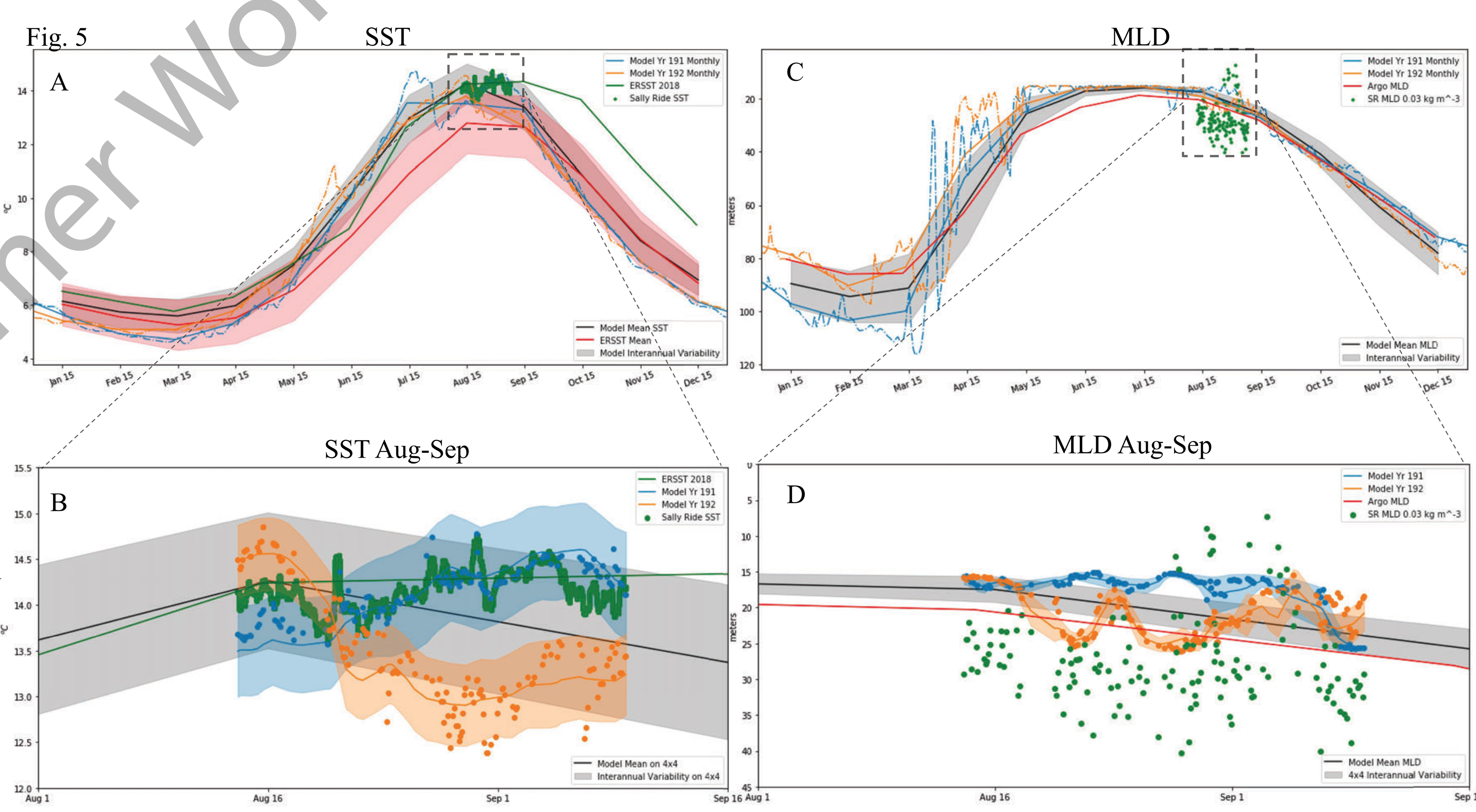
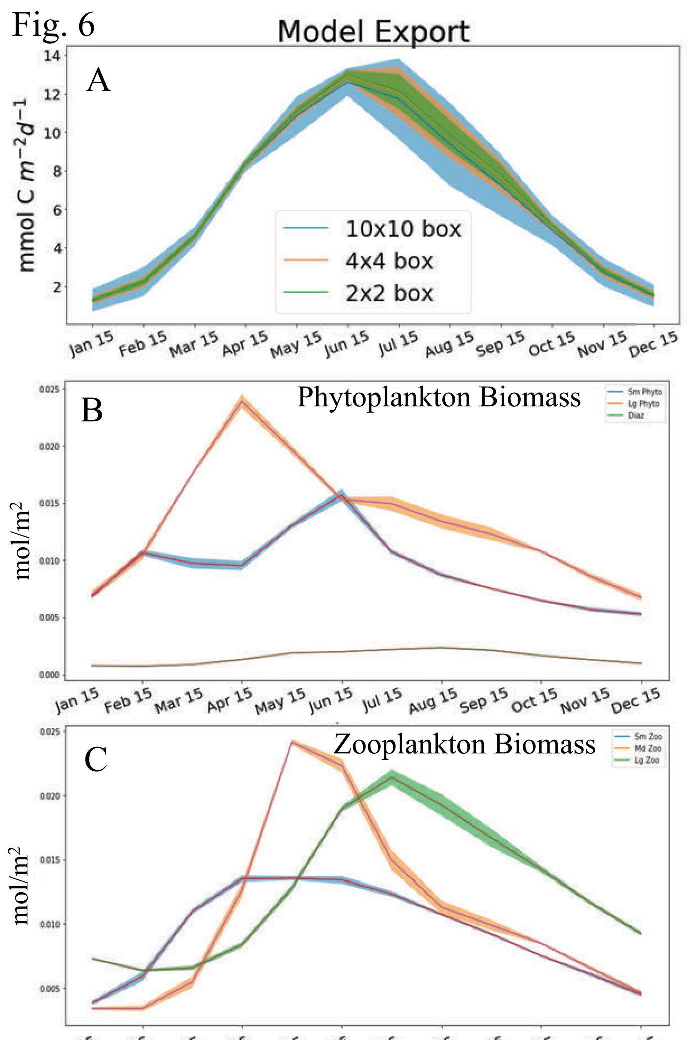


Fig. 4: Snapshots in 4°x4° box of Sea Surface Temperature (SST) in model year 191 with same year-dates as the start (A), midway (B) and end (C) of the EXPORTS cruise. Sampling pattern the same as that seen in fig 1 with color denoting epoch, station Papa labeled, and 2°x2° box outlined in gray.

Fig. 5: Model and data temporal evolution of SST (A,B) and MLD (C,D) in EXPORTS cruise region. Data are from Sally Ride (green symbols) and from ERSST and Argo MLD climatologies (red solid lines) and interannual variability (red envelope is 1 temporal standard deviation in 4°x4° box). Model results are monthly climatology (solid black line) and interannual variability (grey envelope is 1 temporal standard deviation in 4°x4° box), and daily results from 2 individual model years (years 191 in blue and 192 in orange) sampled at the location of the Sally Ride samples (symbols) and averaged over the 2°x2° cruise are (lines and envelope).

Seasonal and Interannual Variability

Fig. 6



Particle Export and Plankton Biomass:

- Simulated export (Fig. 6A) shows a seasonal cycle with variability peaking in late summer to early fall. This trend follows that of plankton biomass (C,D) and is especially evident in the larger size groups.
- The model also shows the expected succession of the phytoplankton groups from large to small, and the reverse order succession for zooplankton, small to large.

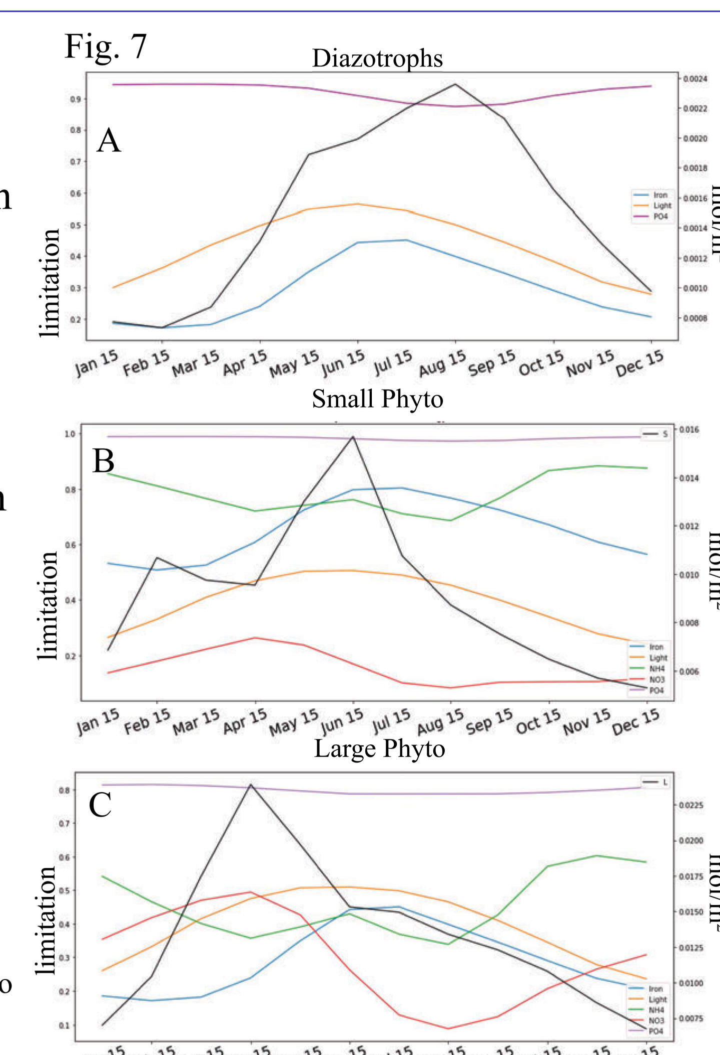
Fig. 6: (A) Model mean climatology of particle export, with shading for interannual variability for three different boxes centered at Station Papa. (B) Phytoplankton climatological biomass by size, smallest (diazotrophs) in green, then blue, then orange. Shading represents interannual variability. (C) Zooplankton biomass climatology, with coloring and shading by size.

Phytoplankton Limitation:

- We connect the phytoplankton succession to their respective limitations, (Fig. 7). We see iron limitation of large phytoplankton in early spring shifts to a nitrate limitation in summer. Small phytoplankton is nitrate limited whereas diazotrophs show only iron limitation.

Fig. 7: (A) Diazotroph biomass in black with light, phosphate and iron limitation in yellow, purple and blue respectively. (B) Small Phyto and (C) Large phyto also have nitrate limitation in red.

Fig. 7



Conclusions

-Model captures mesoscale variability and likely underestimates sub-mesoscale as seen in MLD.

-Simulated exports shows largest interannual variability during late summer period coinciding with cruise timing and increased phytoplankton and zooplankton biomass variability.

Future Plans

- Explore mesoscale variation and eddies to look at spatial variation.
- Look at physical/biological coupling to explain variability in phyto/zooplankton biomass.

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References: [1] Stock C A, Dunne J P and John J G 2014 Global-scale carbon and energy flows through the marine planktonic food web: An analysis with a coupled physical–biological model Prog. Oceanogr. 120 1–28, [2] Boyin Huang, et. al. NOAA Extended Reconstructed Sea Surface Temperature (ERSST), Version 5. NOAA National Centers for Environmental Information. doi:10.7289/V5T72FNM [accessed Feb 2018], [3] Holte, J., et al, An Argo mixed layer climatology and database, Geophys. Res. Lett., 44, 5618–5626,