Modeling global patterns in the transfer of energy between primary producers and mesozooplankton in a global circulation model

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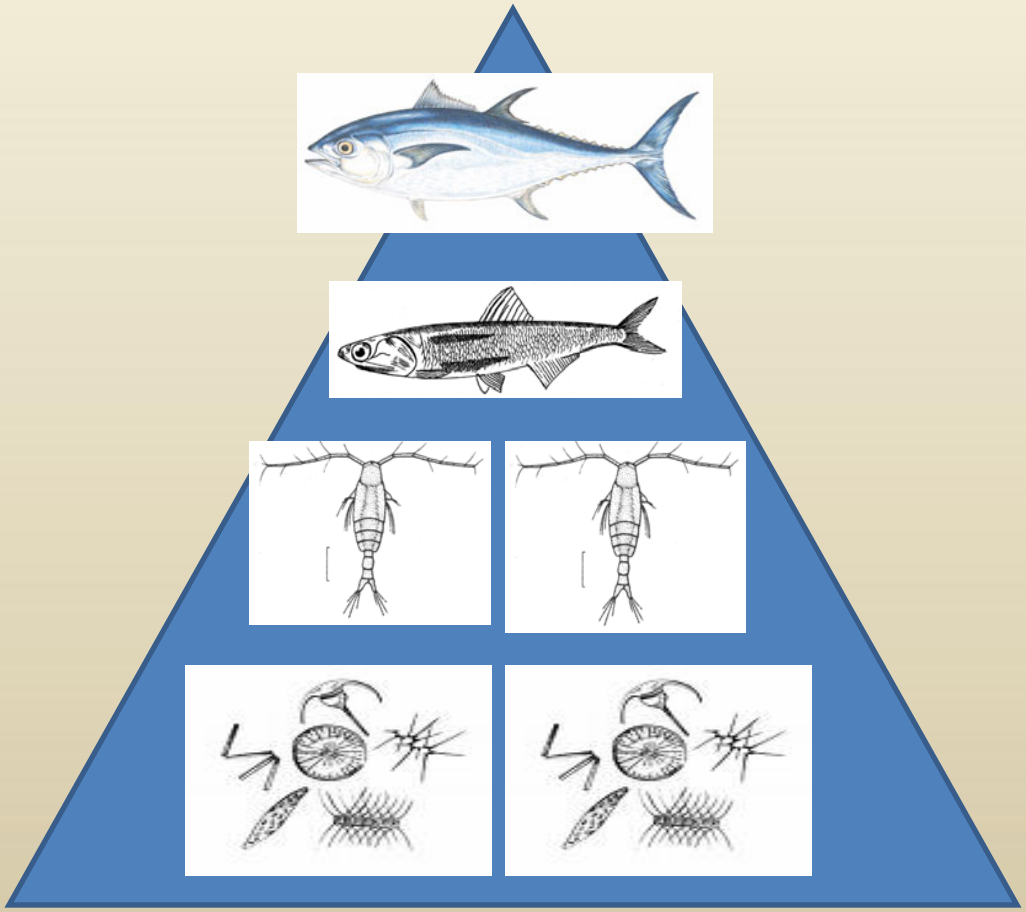
How will climate change impact global fisheries production?

"We have low confidence in predictions of future fisheries production because of uncertainty over future global aquatic net primary production and the transfer of that production through the food chain to human consumption."

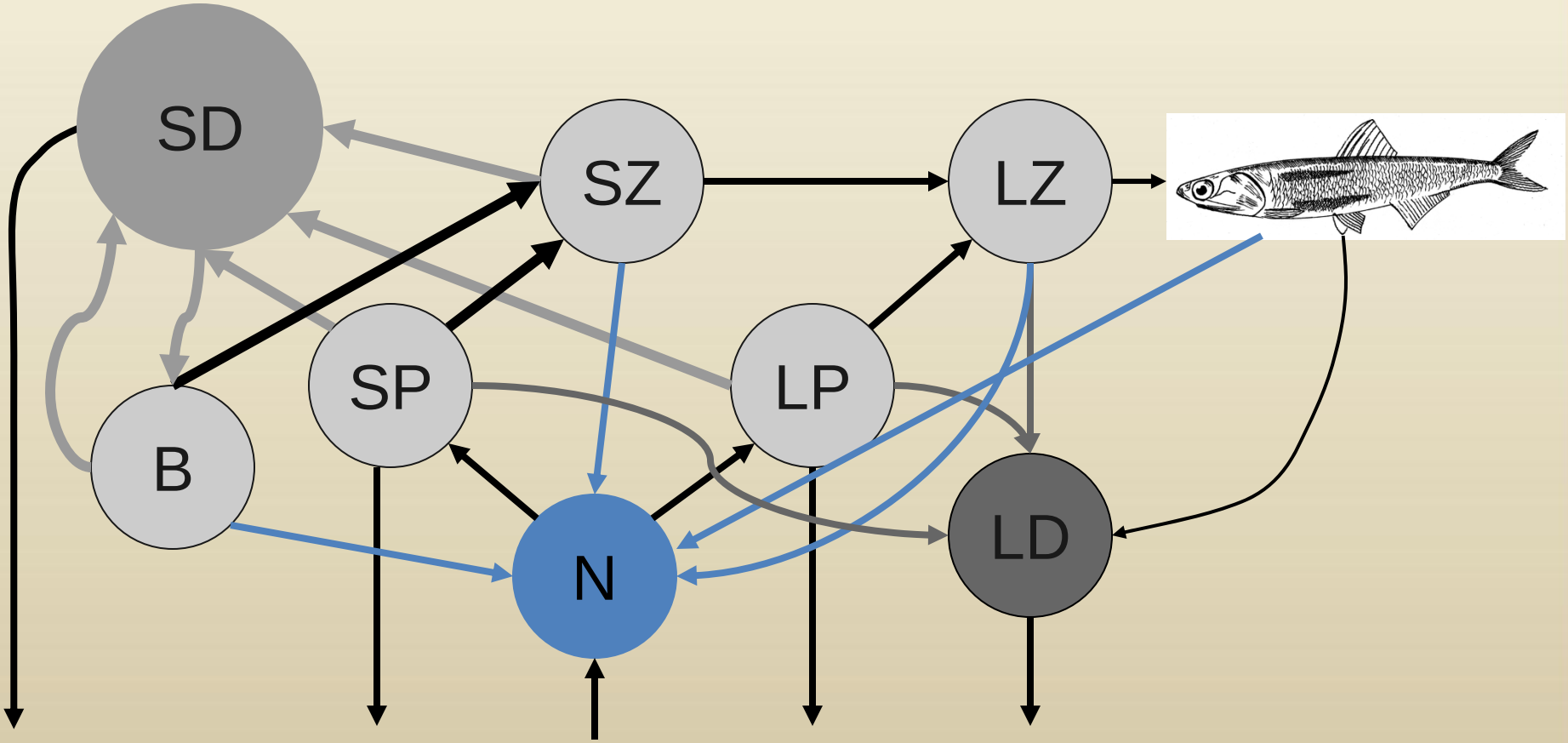
-K.M. Brander, 2007, Global fish production and climate change, PNAS, 104(50), 19709-19714

Old view: a simple food chain

- phytoplankton provide the base of the food chain
- mesozooplankton link plankton and fisheries
- energy decays with each trophic step



New view: a complex foodweb



Does model capture global z-ratio patterns?

Specify model forcing:

- Euphotic zone depth
- Euphotic zone temperature
- Nutrient flux into euphotic zone

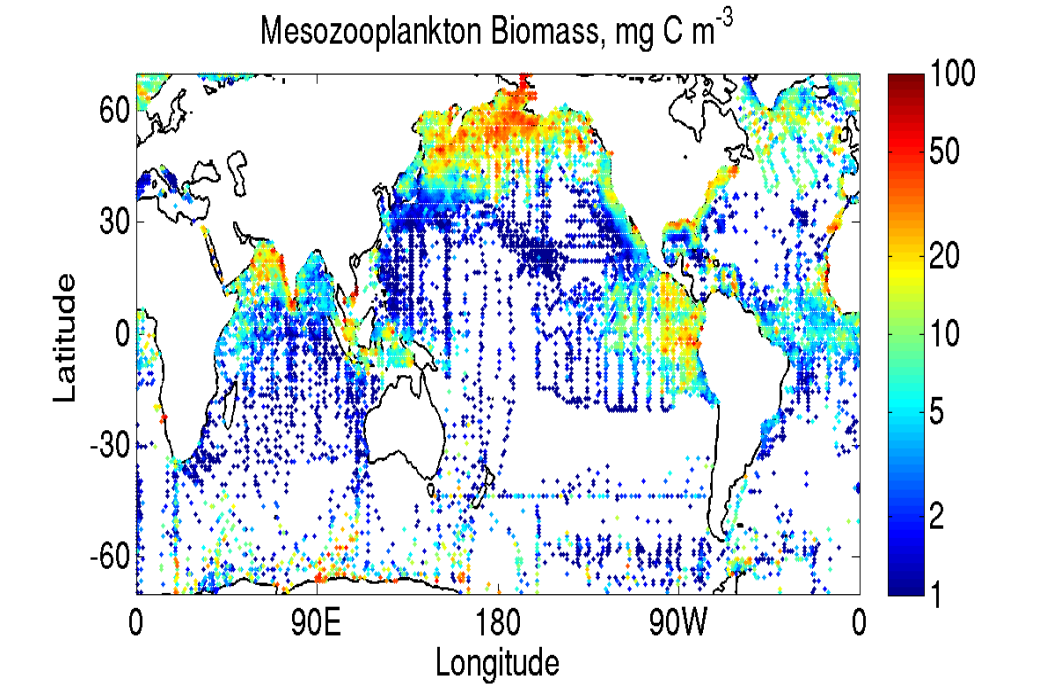
Solve for equilibrium solutions and compare estimates of primary prod., mesozooplankton prod. and the z-ratio with:

- Calibration dataset: 72 z-ratio estimates
- Extended global z-ratio dataset: > 6000 z-ratio estimates

Stock, CA, Dunne, JP. 2010. Controls on the ratio of mesozooplankton production to primary production in marine ecosystem. Deep-sea Research, Part I, 57, 59-112

An extended set of global z-ratio estimates

mesozooplankton biomass (mg C m^{-3})

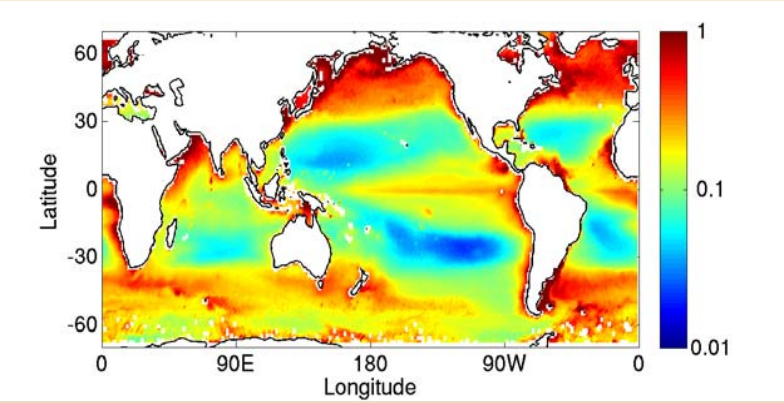


$$z = \frac{\mu_{LZ} \times LZ}{PP}$$

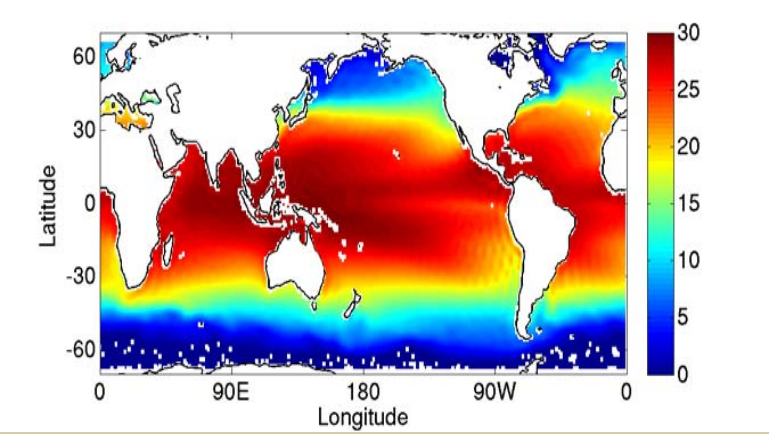
Global average from many net tows
NOAA/NMFS COPEPOD database (O'Brien, 2005)

An extended set oft global z-ratio estimates:

chlorophyll



SST



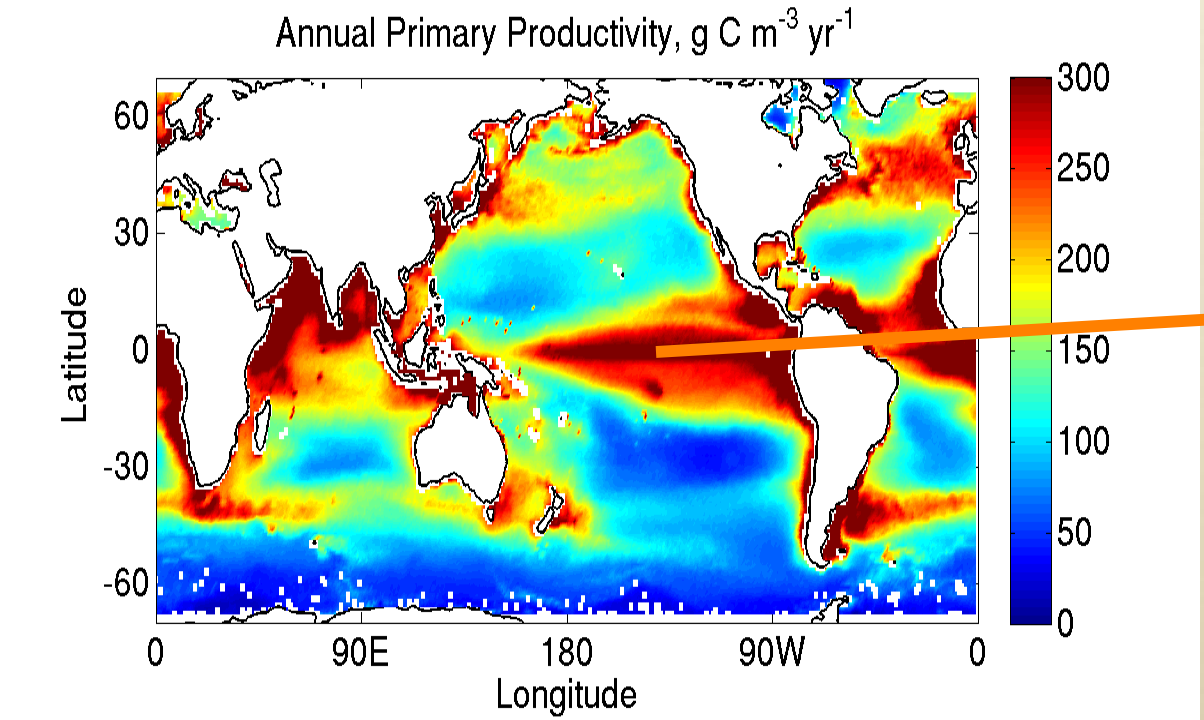
$$\mu_{LZ} = f(chl, sst, W = 10 \mu gC)$$

$$z = \frac{\mu_{LZ} \times LZ}{PP}$$

Hirst and Bunker, 2003. Growth of marine planktonic copepods: Global rates and patterns. Limnol. Oceanogr. 48(5), 1988-2010.

An extended set of global z-ratio estimates

Sattelite-derived primary production

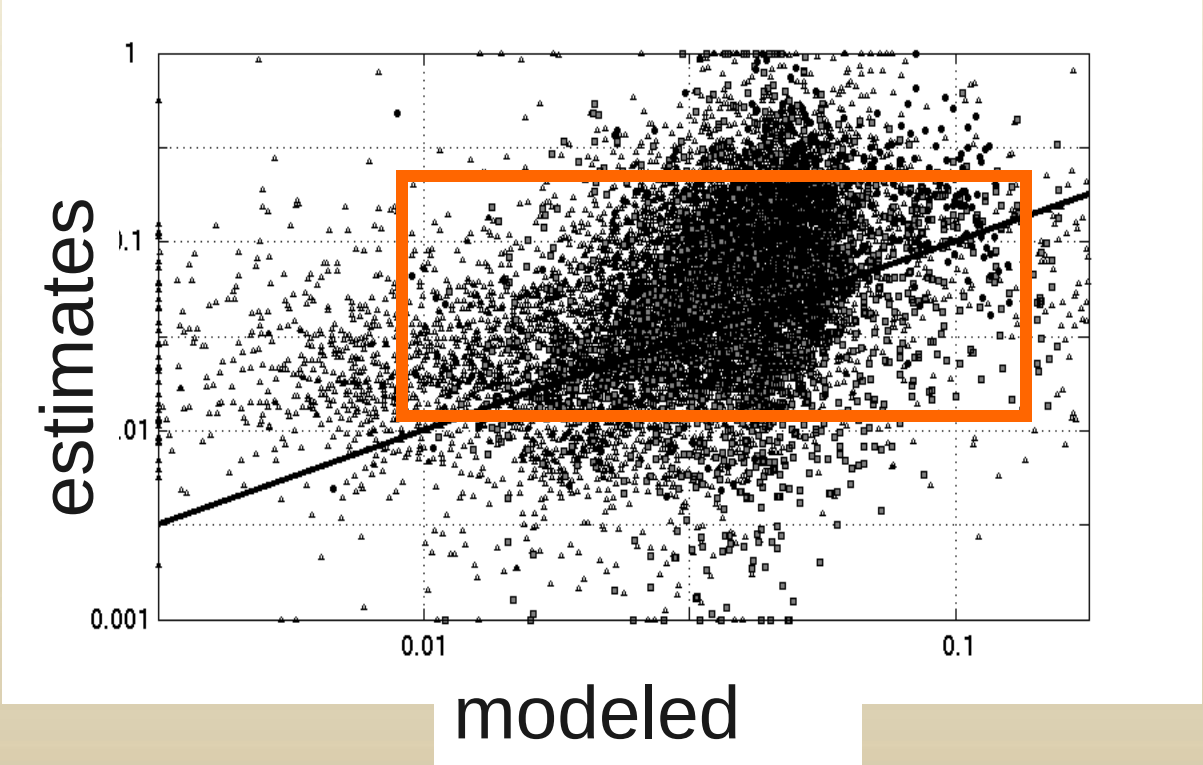


$$z = \frac{\mu_{LZ} \times LZ}{PP}$$

Restrict analysis to 50S-50N, >100m depth

Carr, M.-E., 2002. Estimation of potential productivity in Eastern Boundary Currents using remote sensing. Deep-Sea Research II 49, 59–80.

Model comparison to z-ratio estimates (1)

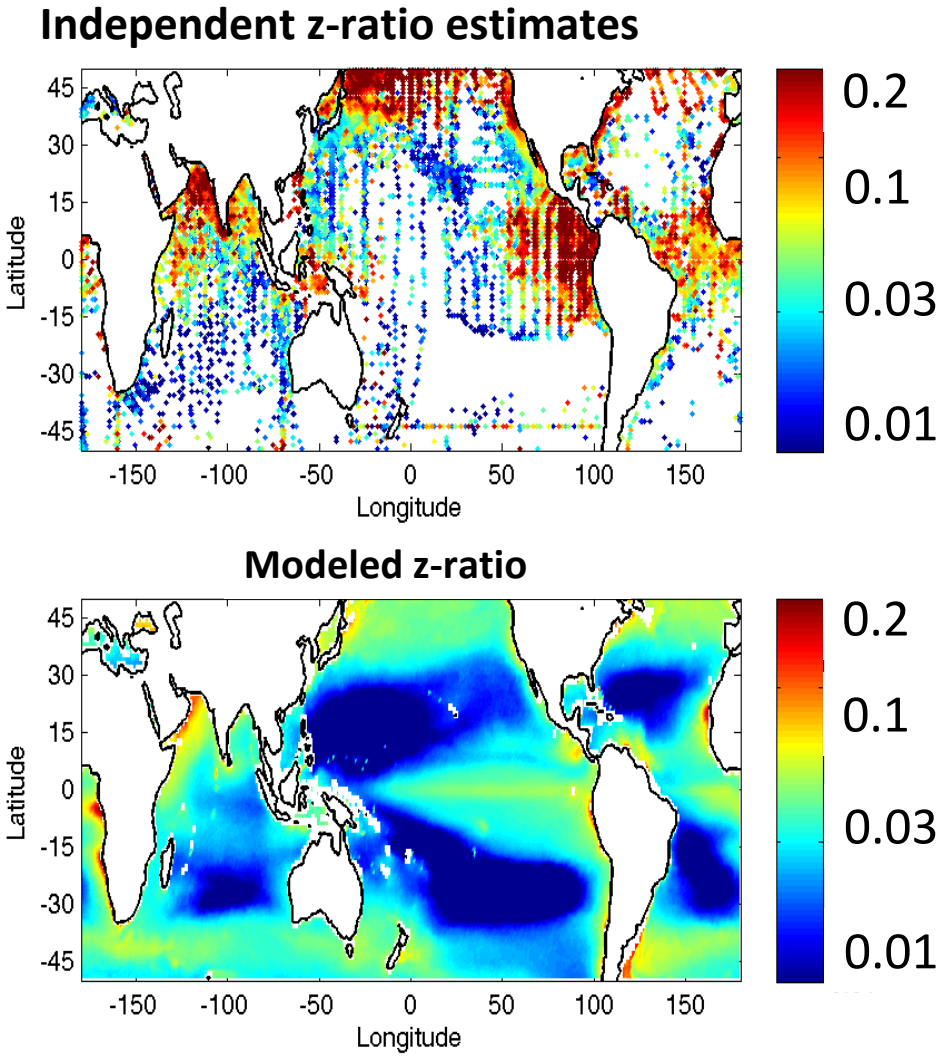


- majority of points between 0.01-0.2
- "low frequency" trend overlain by substantial unexplained variability

correlation = 0.4

Model comparison to z-ratio estimates (2)

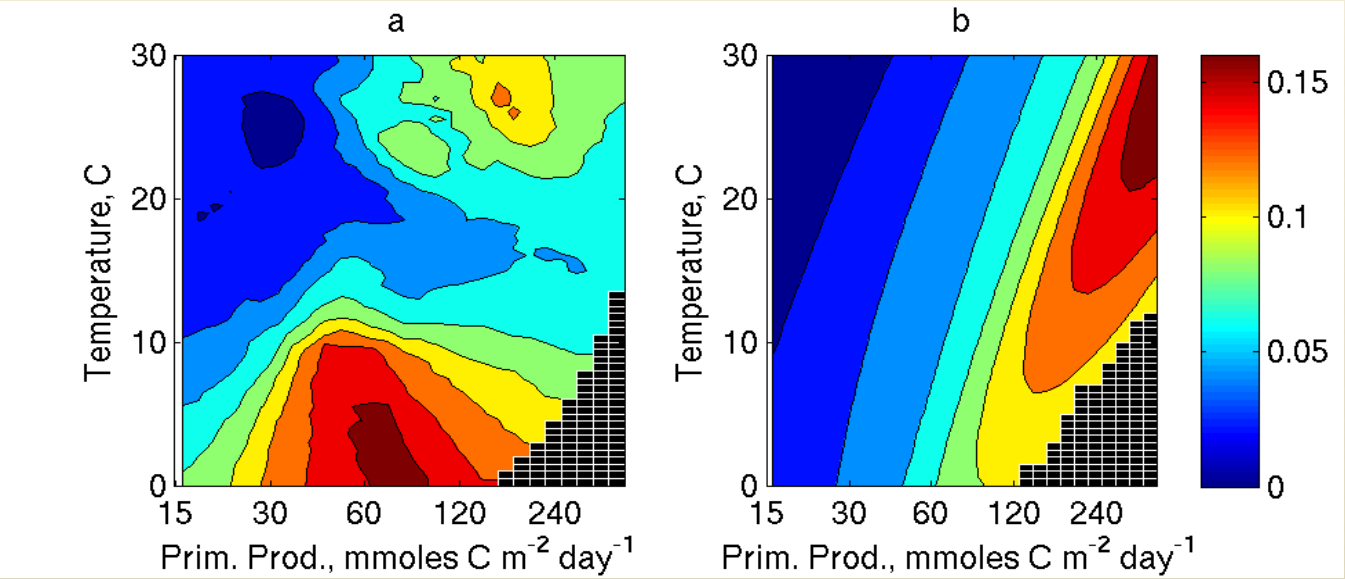
~10-20% of primary production transferred to mesozooplankton production in upwelling systems; ~1-3% in sub-tropical gyres



Model comparison to z-ratio estimates (3)

Independent estimates

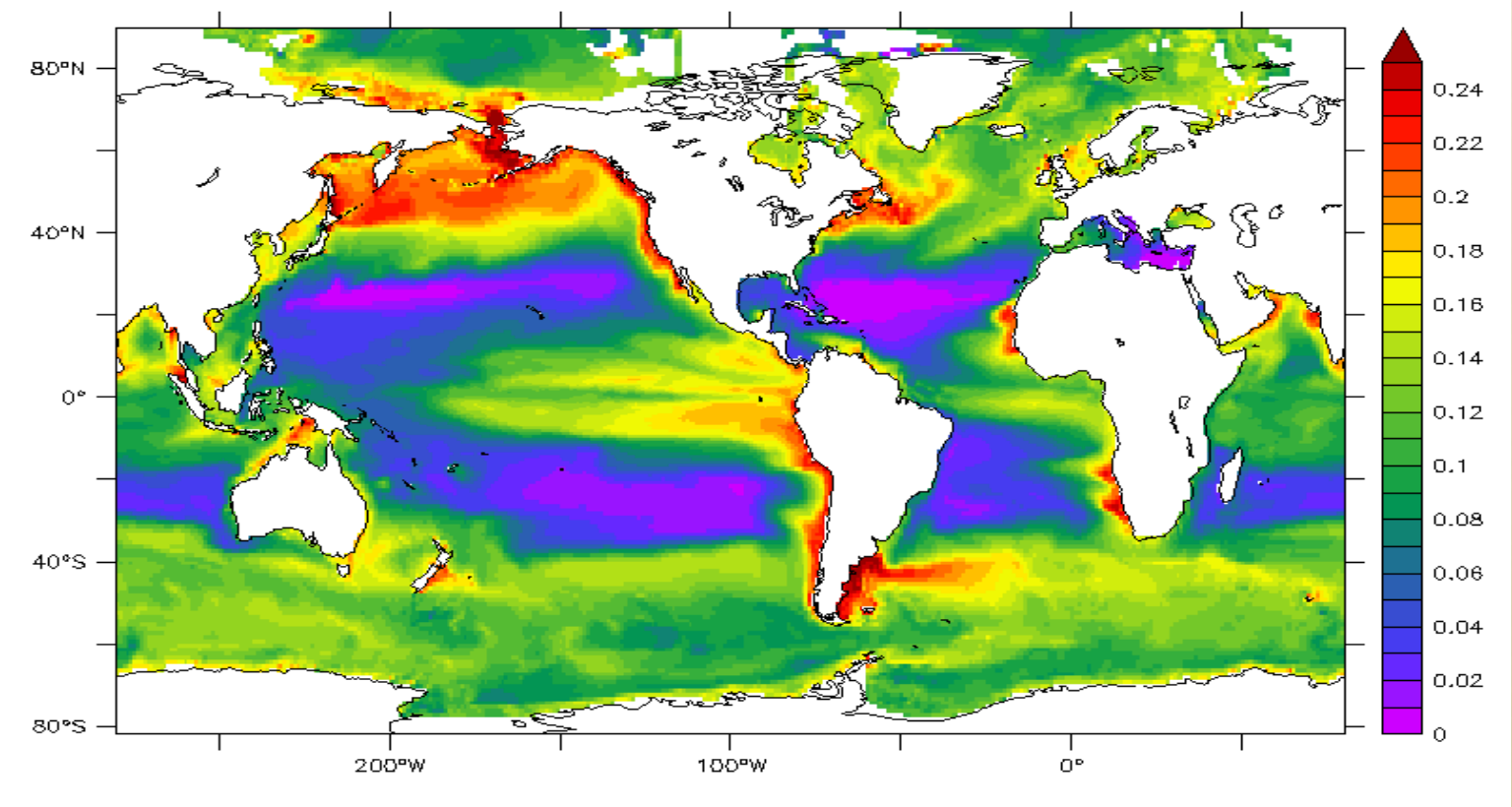
model



Implication: a fractional change in prim. production leads to a larger fractional change in mesozooplankton production

Carbon, Ocean Biogeochemistry & Lower Trophics (COBALT)

Simulated z-ratio patterns in Global Ocean-ice Simulation



Conclusions

- Mesozooplankton production is generally ~1-20% of primary production.
- Z-ratio trends from 1-3% in center of sub-tropical gyres to 10-20% in highly productive ecosystems.
- This trend implies that the mesozooplankton response to a change in PP is "amplified".
- Caveat: large unexplained variation from mesozooplankton patchiness
- Historical ocean-ice simulations underway and may improve model fidelity; projections in the next 1-2 years
- Questions? Charles.Stock@noaa.gov