GLOBEC: Temporal Trends in Ecosystem Variability

Kendra Daly (USF)

&

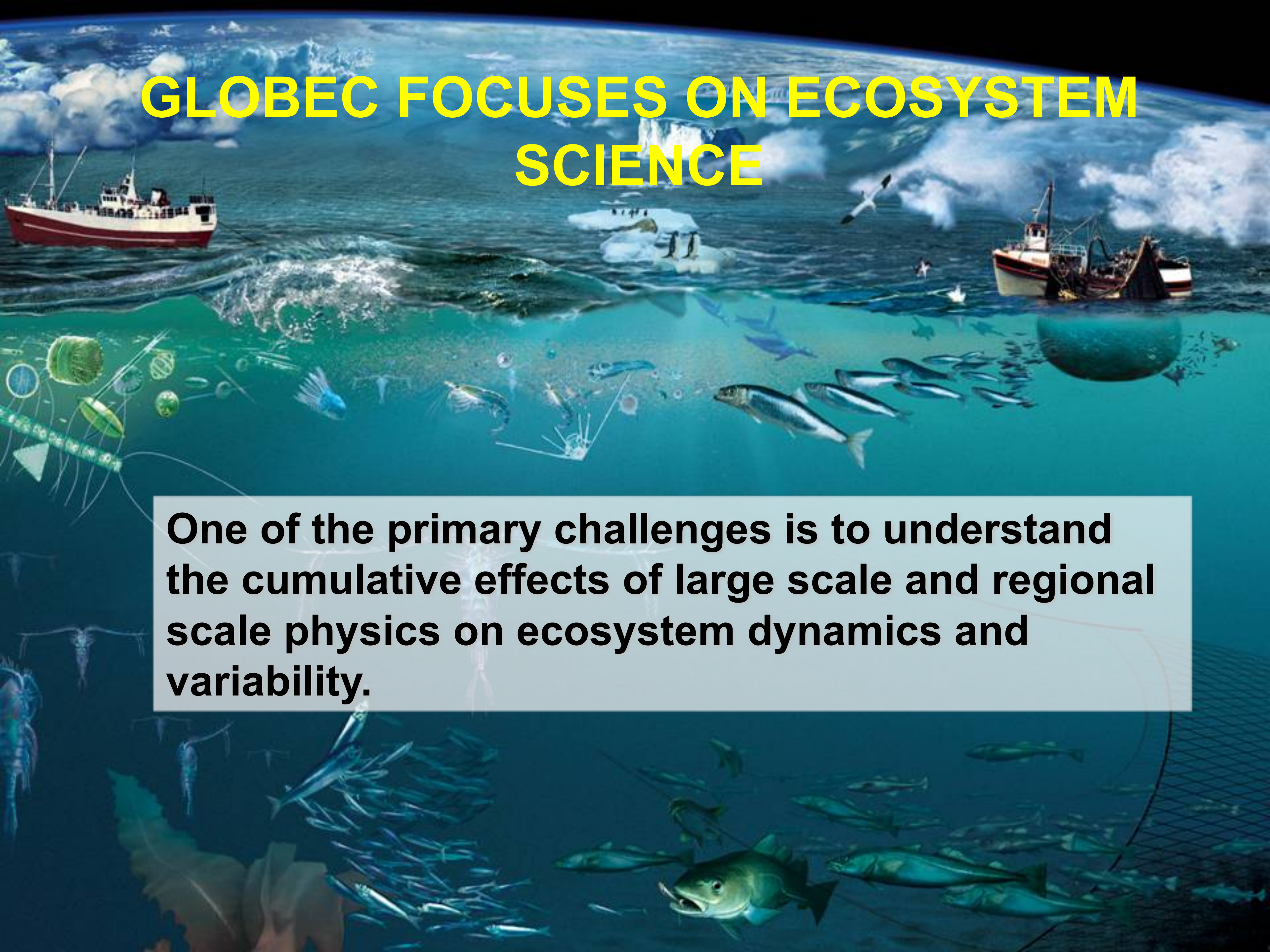
GLOBEC PIs

GOALS:

- **To understand the effects of climate variability on the distribution, abundance, and production of marine animals, including commercially important living marine resources.**

- **To embody this understanding in diagnostic and prognostic ecosystem models, capable of capturing the ecosystem response to major climatic fluctuations.**

GLOBEC
GLOBAL OCEAN ECOSYSTEM DYNAMICS

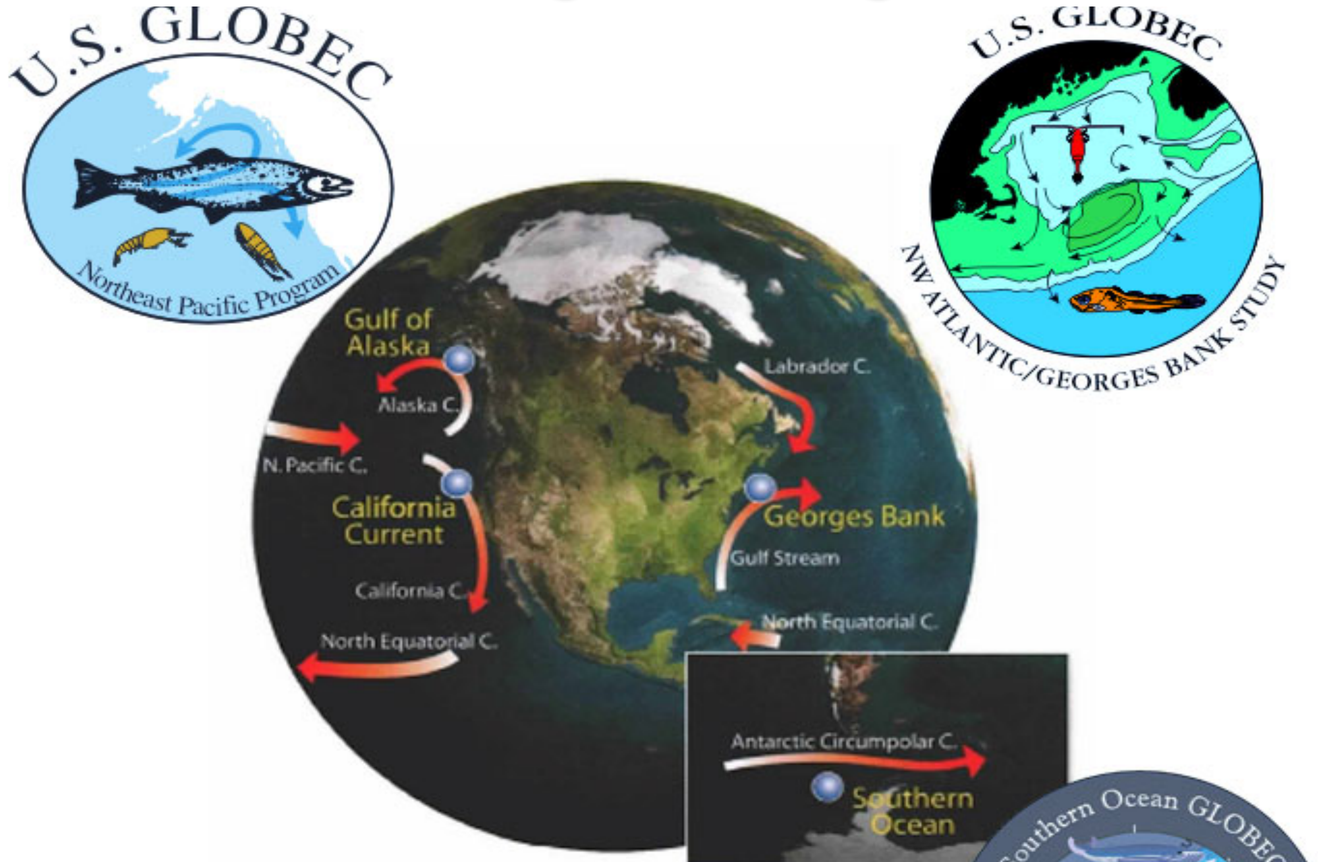


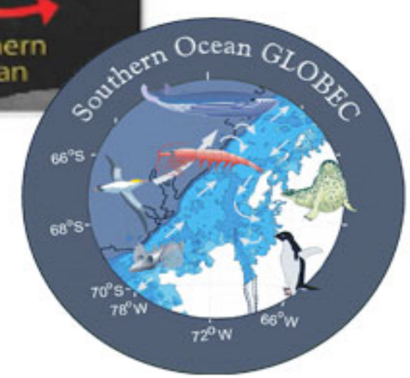
GLOBEC FOCUSES ON ECOSYSTEM SCIENCE

One of the primary challenges is to understand the cumulative effects of large scale and regional scale physics on ecosystem dynamics and variability.

US GLOBEC: 1991-2011

Three Regional Programs

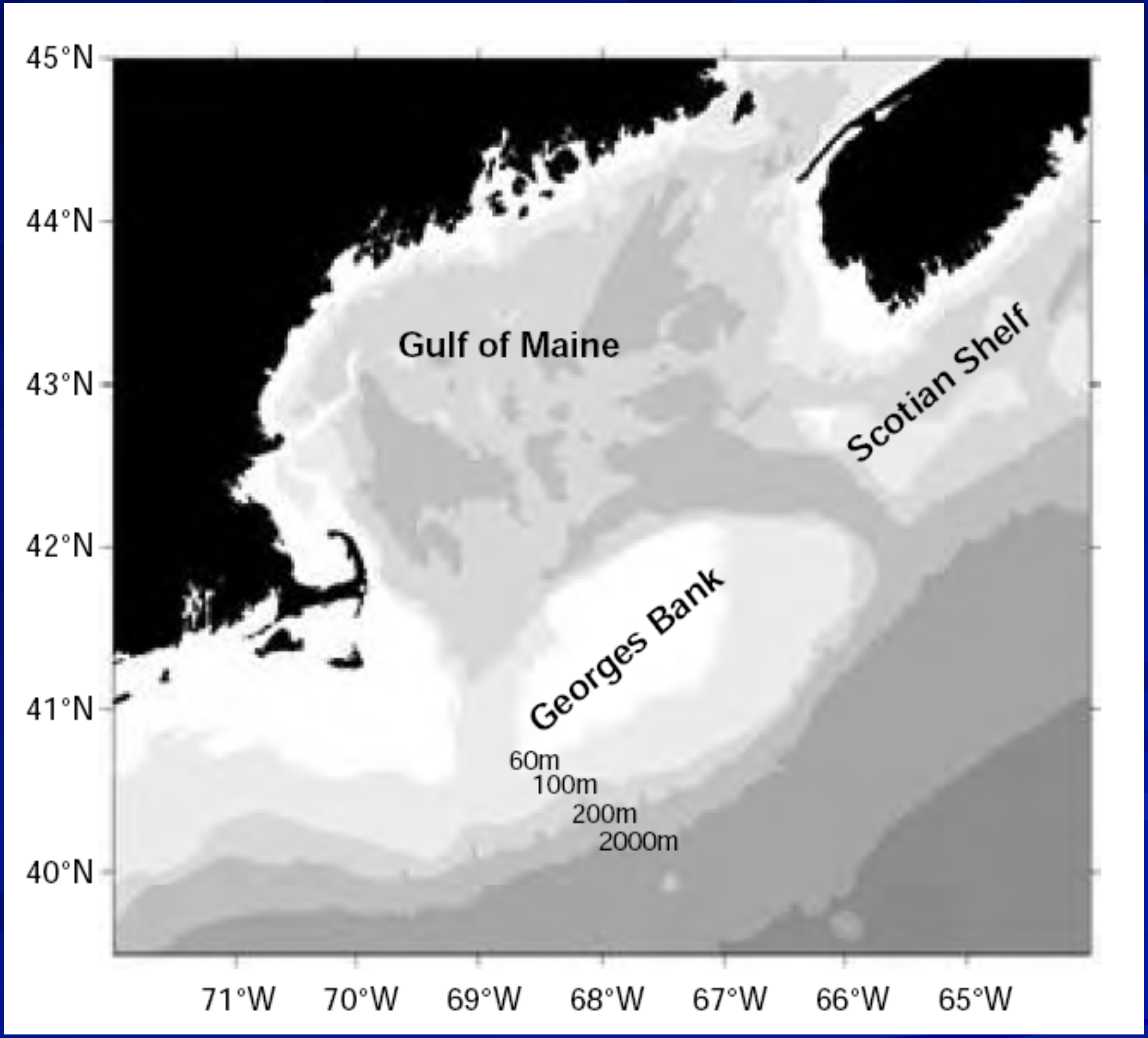




Climate variability examined through
- **Retrospective data analyses**
- **Field process studies**
- **Synthesis & modeling**

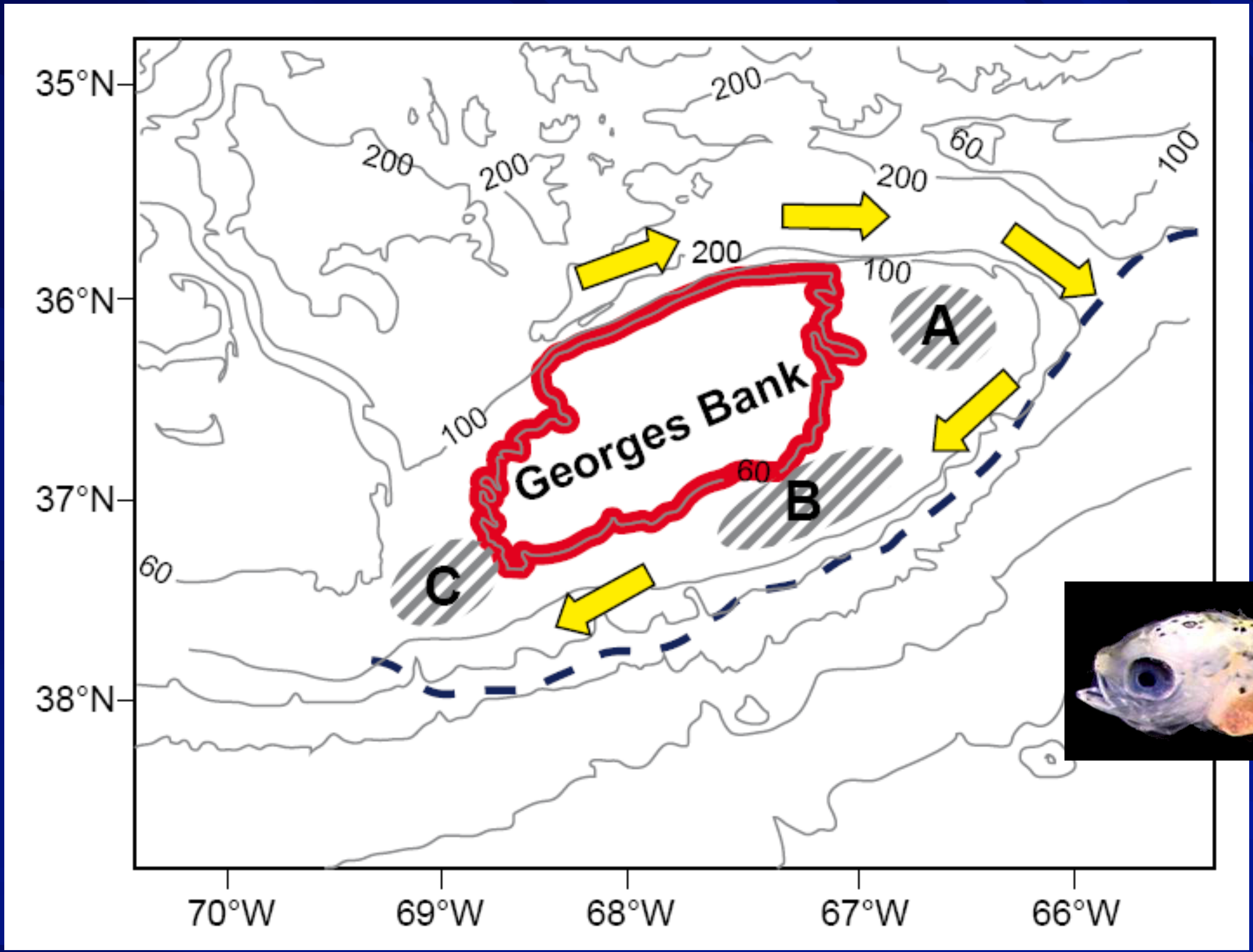
Georges Bank Program

US GLOBEC Northwest Atlantic Program: Georges Bank Study Area



J. Manning (NMFS)

Georges Bank Program: 1995 - 1999



Calanoid copepods

Cod & hake eggs & larvae

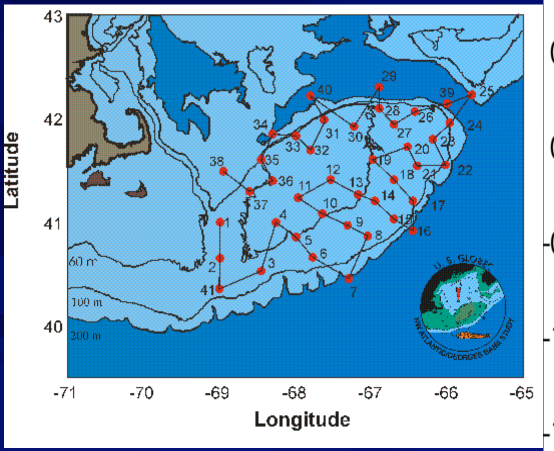
Physical processes: circulation, stratification, exchange of water over the bank

A: eggs, B: larvae, C: pelagic juveniles

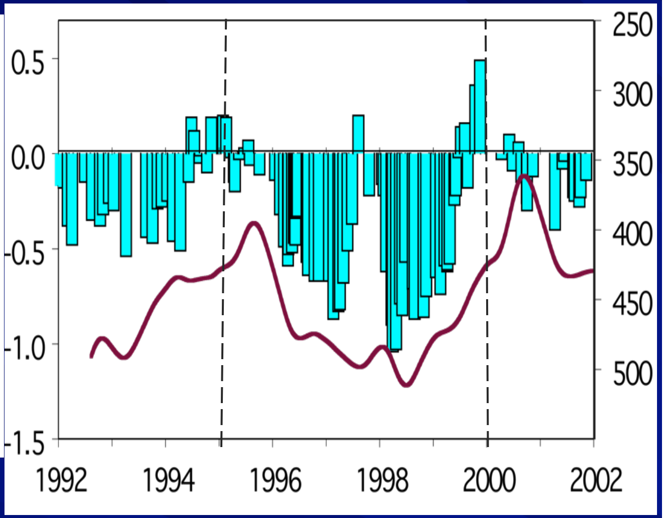
Lough and Manning (2001)

GLOBEC NW Atlantic Program: 1995 - 1999

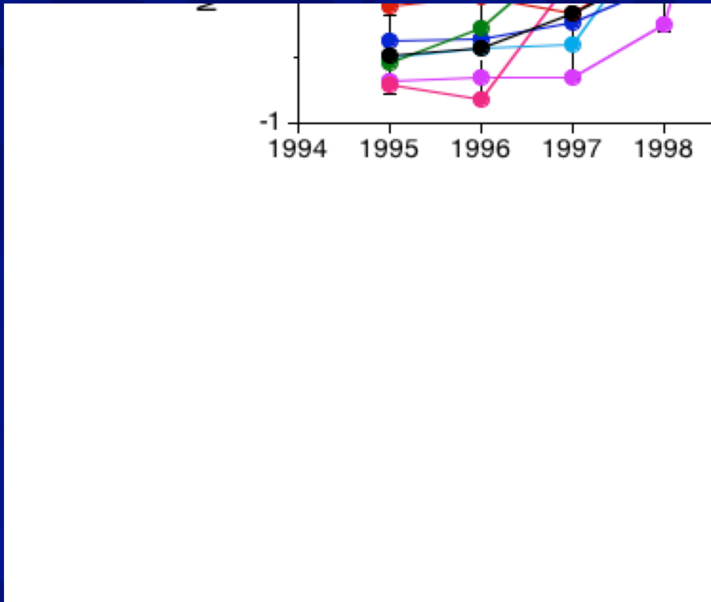
Sampling Grid



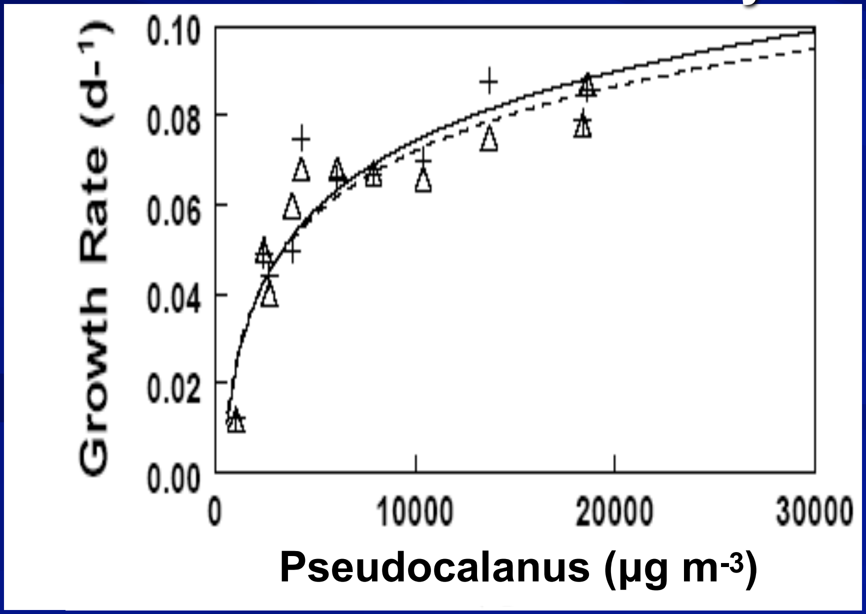
Salinity Anomaly



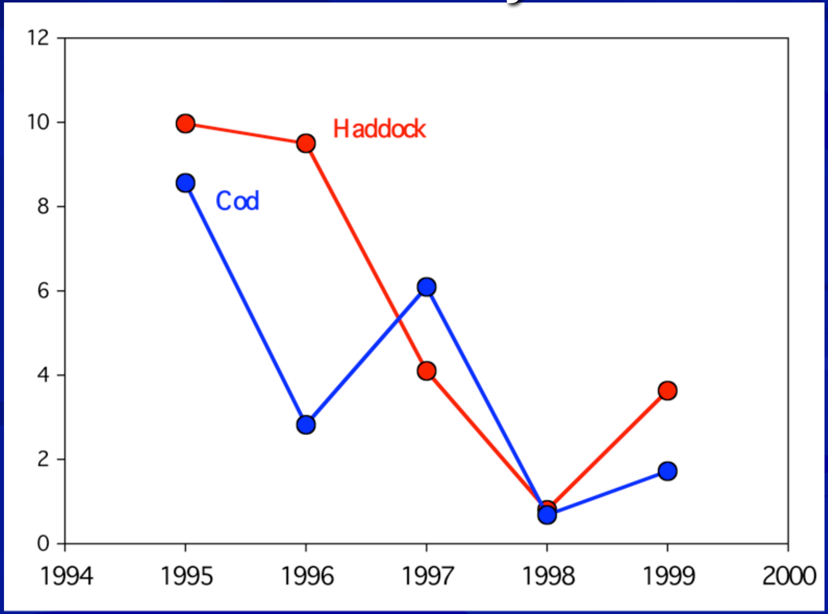
Copepods vs Year



Larval Fish Growth vs Prey



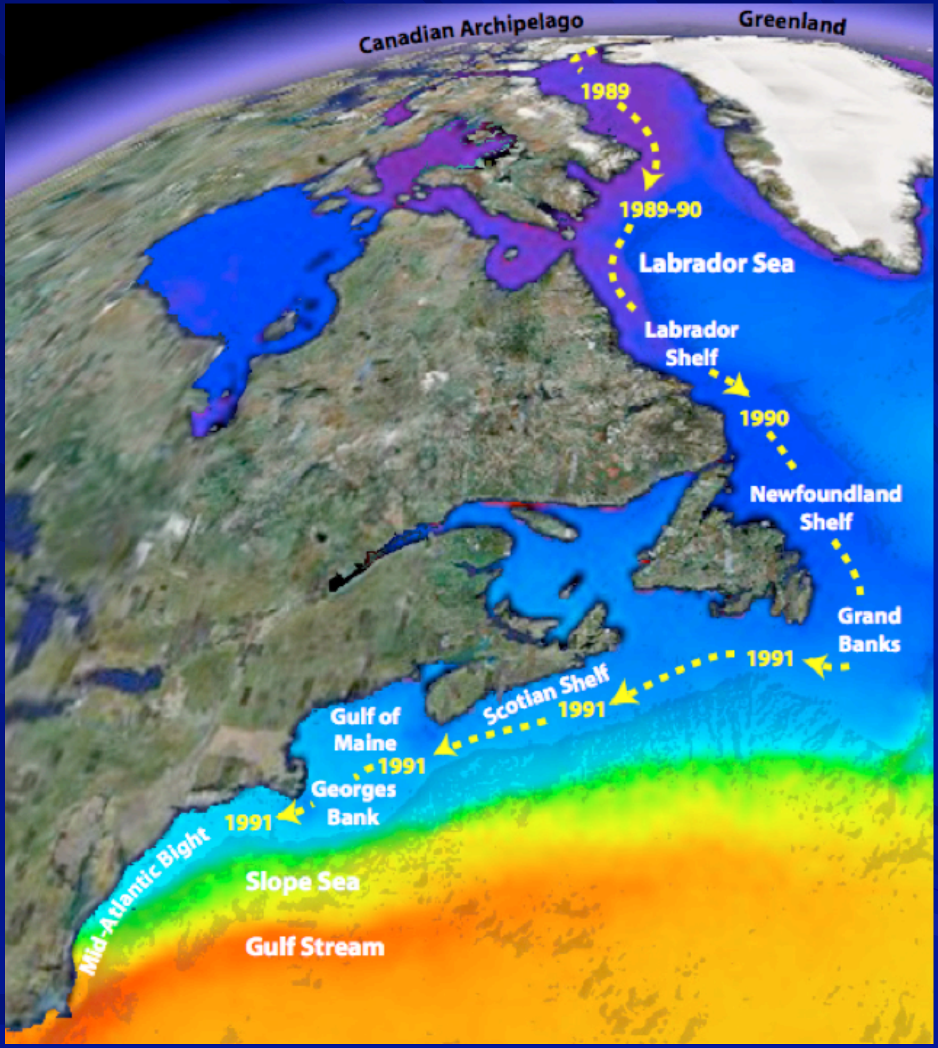
Larval Fish Mortality vs Year



Climate: Georges Bank Freshening During 1990s

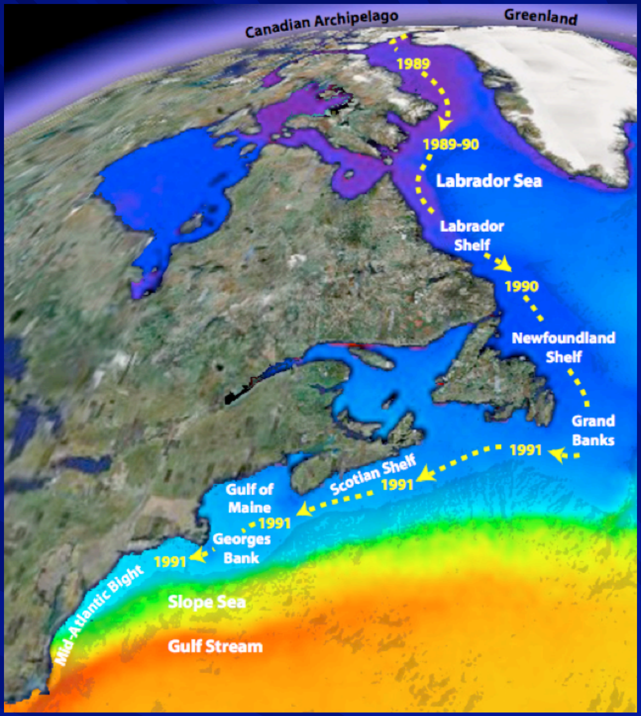
Oxygen isotope ratios (O18/O16) traced low salinity water to the Labrador Sea

(Houghton et al. 2002)



Climate: Georges Bank Freshening During 1990s

Greene and Pershing, 2007. *Science*



Freshwater in early 1990s traced to Arctic

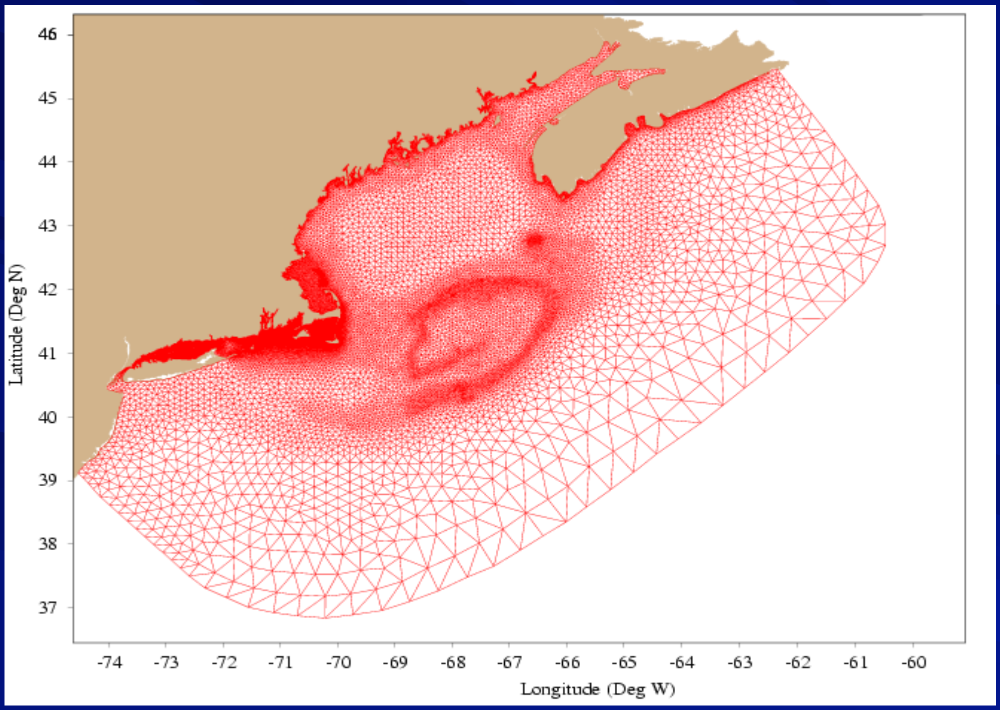
- Arctic Oscillation: positive phase - winds strengthen in Beaufort Gyre, meltwater accumulates locally
- Arctic Oscillation: negative phase– winds reverse, freshwater released from gyre

Oxygen isotope ratios (O18/O16) traced low salinity water to the Labrador Sea (Houghton et al. 2002)

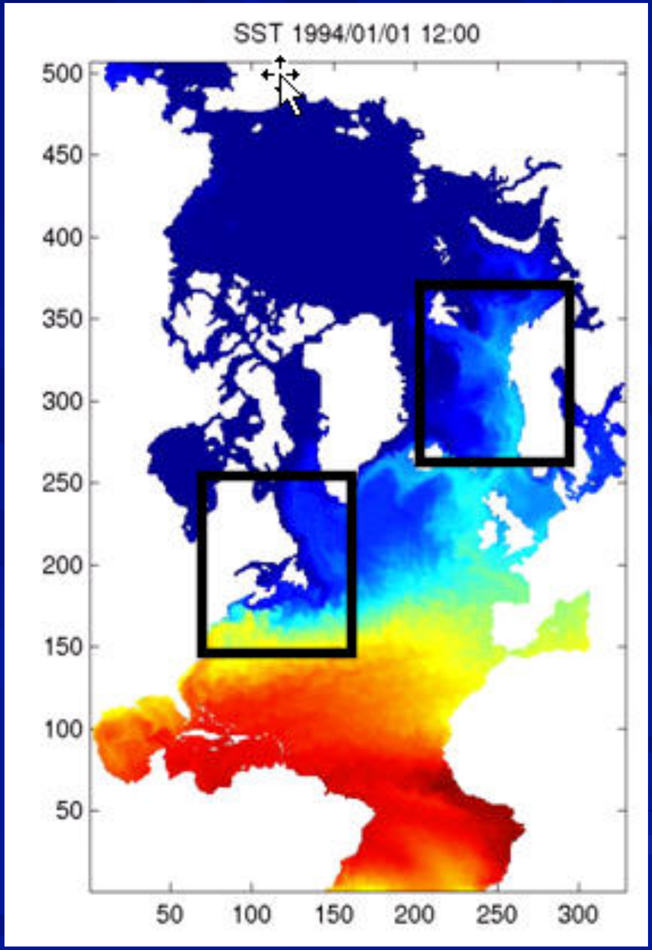
Present Work, Synthesis: Models

Cabell Davis and co-PIs

Regional-Scale Model

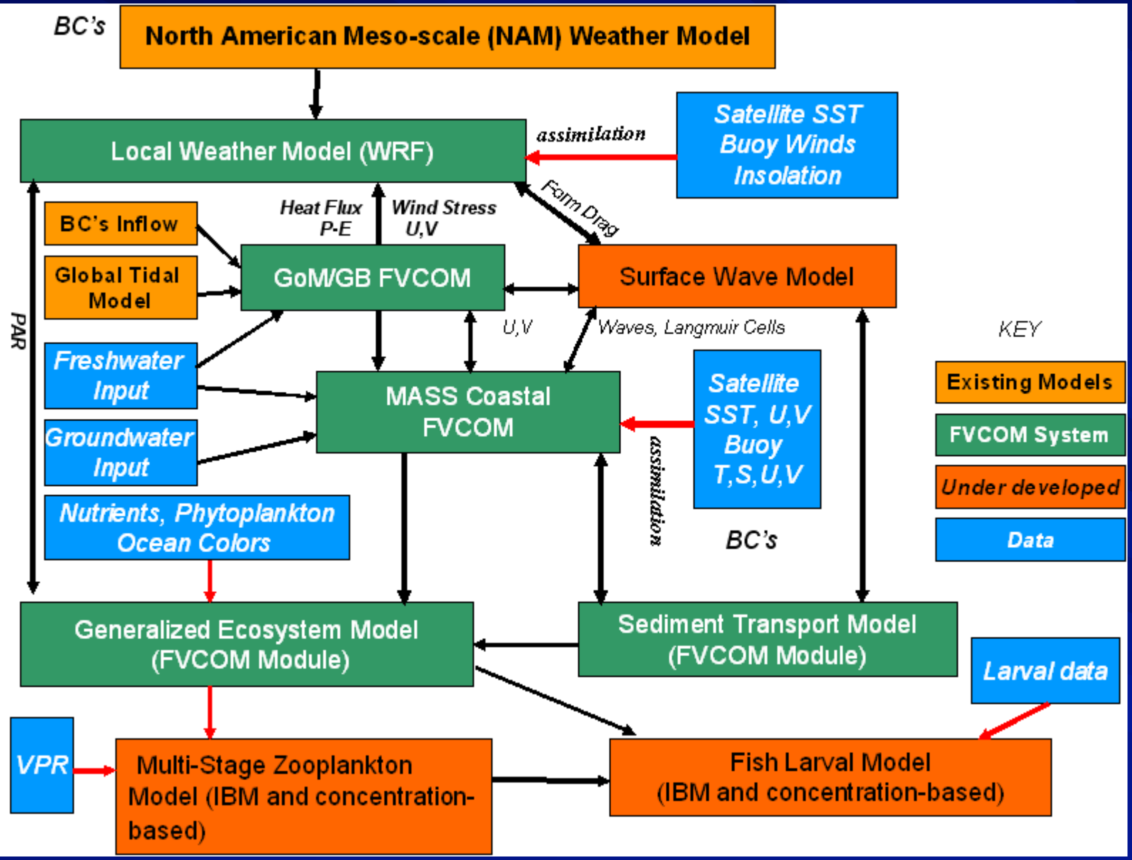


Basin-Scale Model

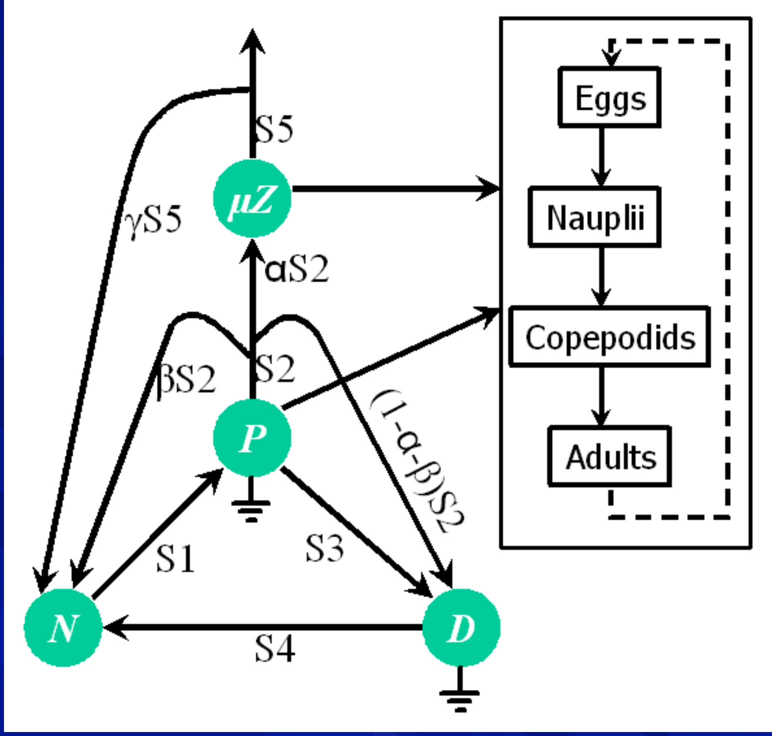


Goal: To understand the underlying mechanisms influencing biological communities over Georges Bank.

Northeast Coastal Ocean Forecast System (NECOFS)

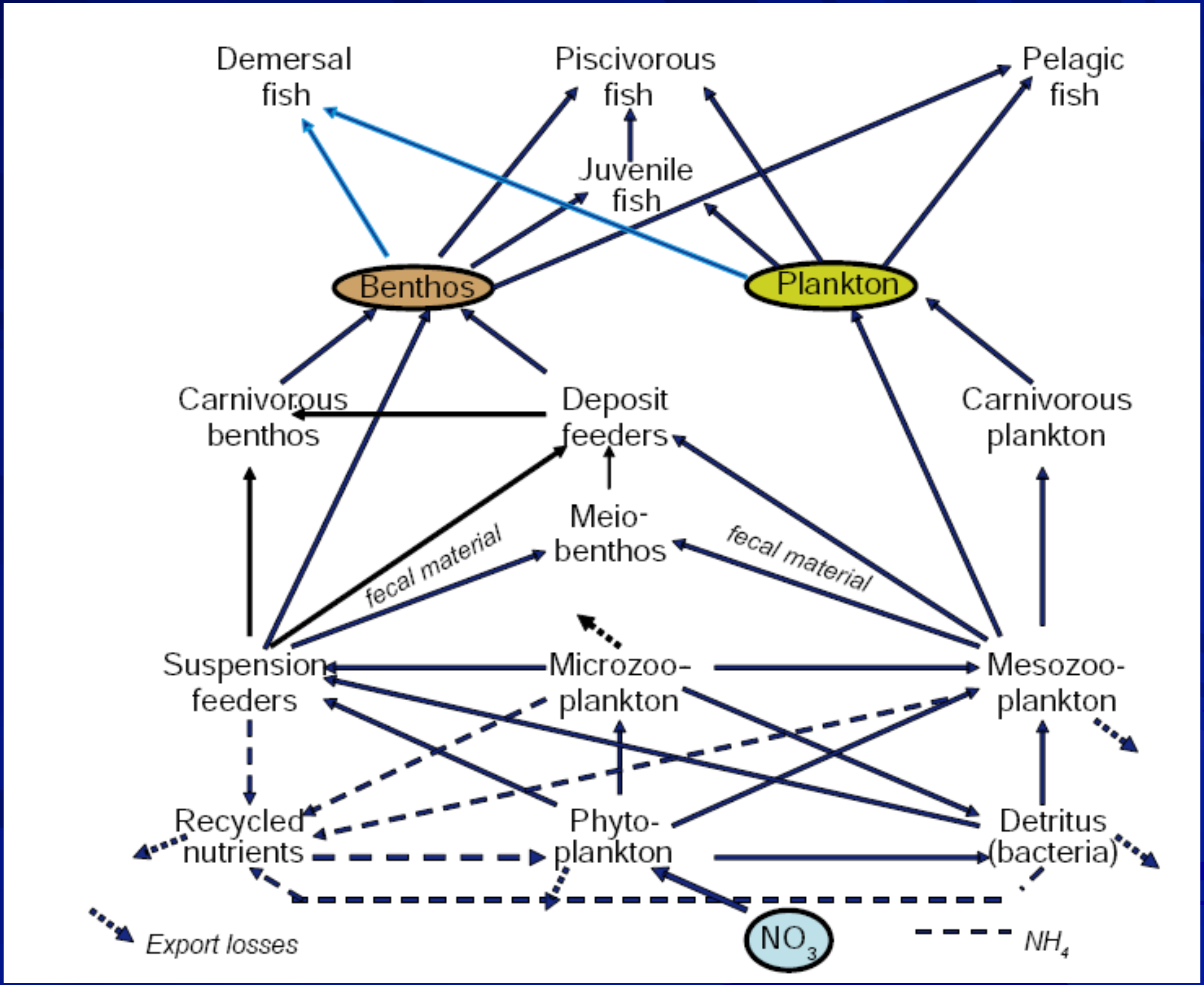


Concentration-based Food-web and Copepod Species Models



Coupling circulation models (FVCOM and ROMS) with lower food web (NPZD) and copepod population dynamics models to study how climate and local forcing impacts system productivity and species composition.

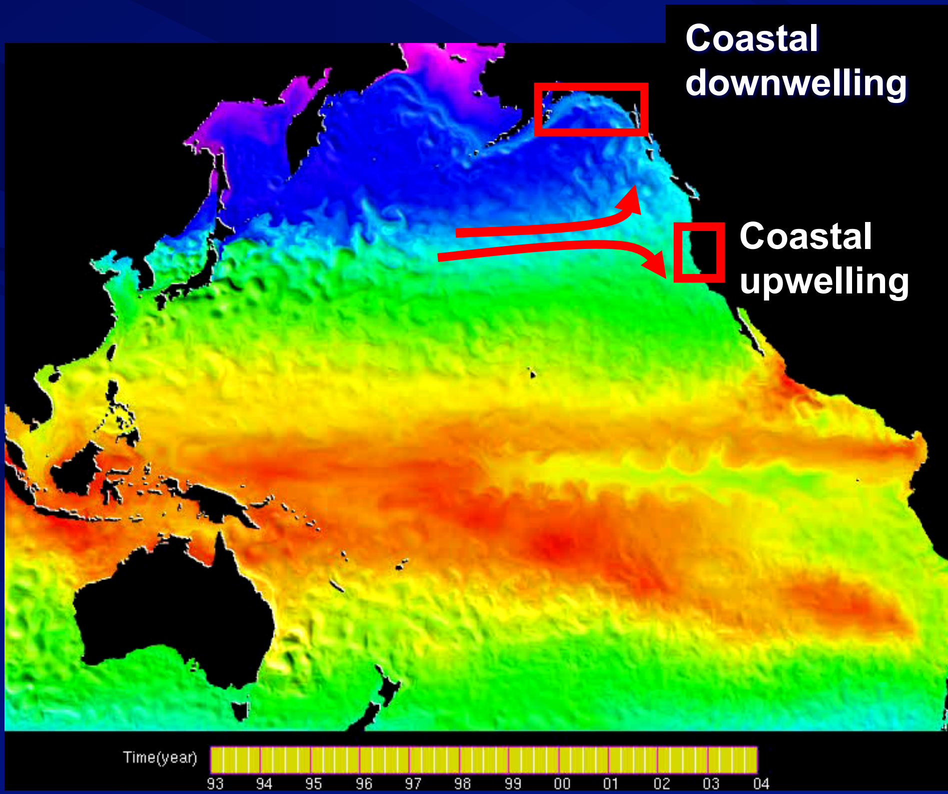
End to End Food Web Model for Georges Bank (Steele et al. 2007)

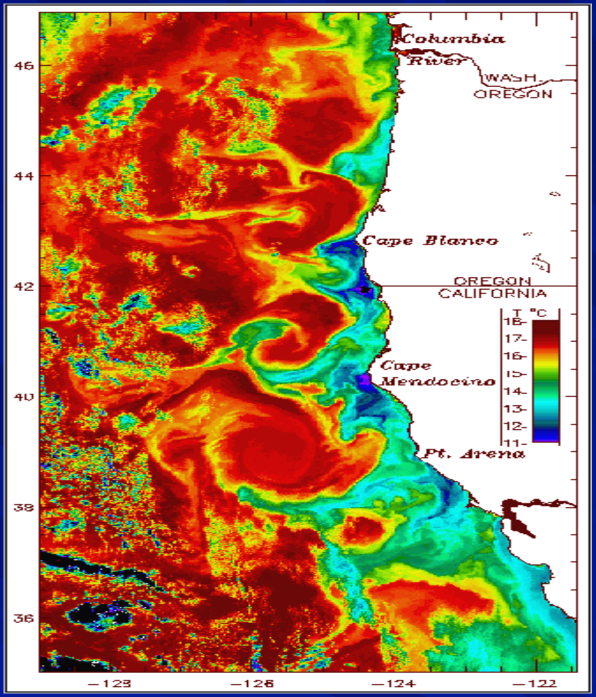


Northeast Pacific GLOBEC Program

Northeast Pacific Field Program: 1997-2005

Productive eastern boundary current



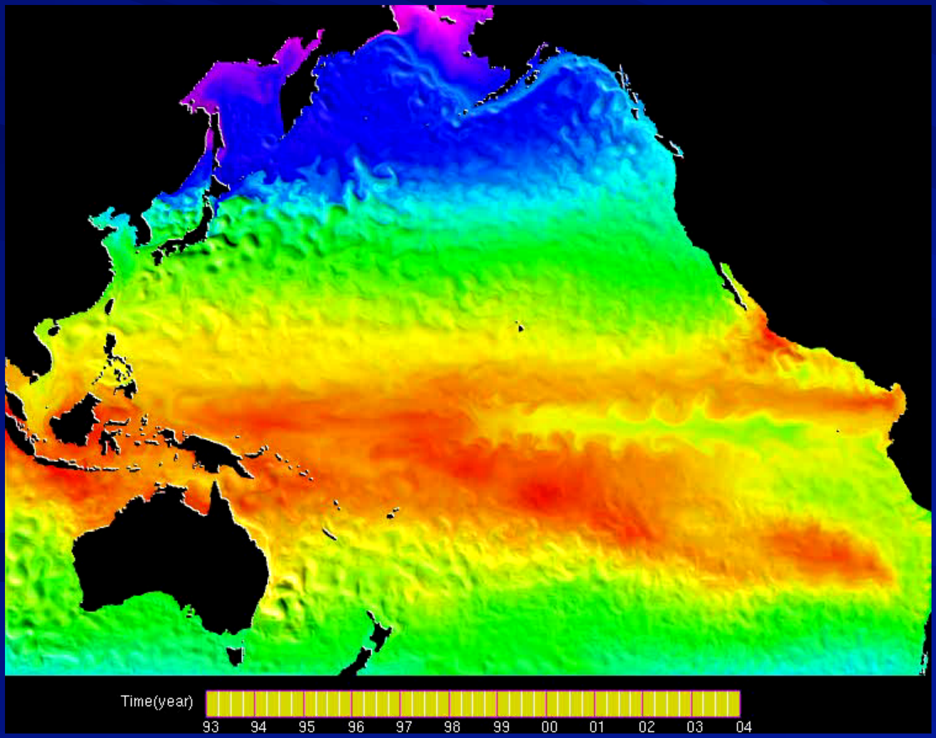


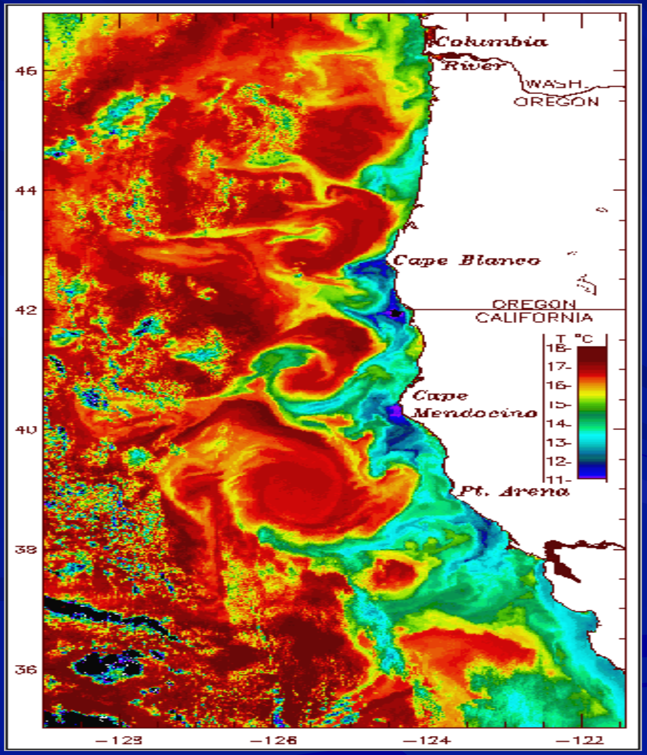
SST plotted in shade relief format

D. Haidvogel (Rutgers) & Y. Chao (JPL)

Basin-Scale and Regional Events During NEP GLOBEC

- 1997-1998 El Niňo (SST, SSH, transport, biological communities)
- 1999 Regime shift of physical properties & biological communities
- 2002 Anomalous cold/fresh water mass in Gulf of Alaska and off coast of Oregon
- 2002-2006 Hypoxia events off coastal Oregon & Washington

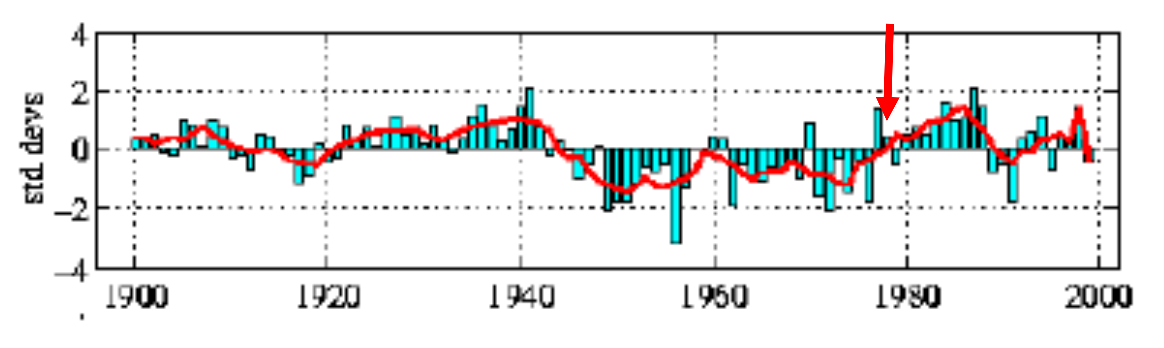


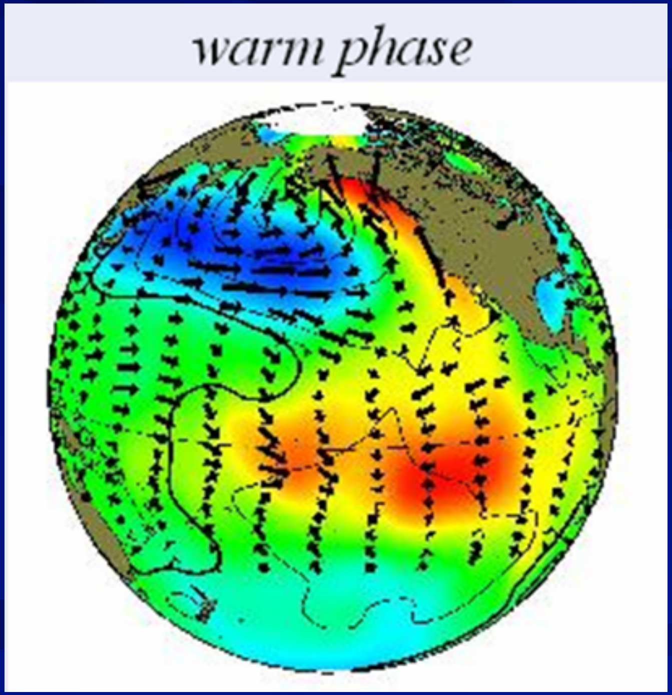


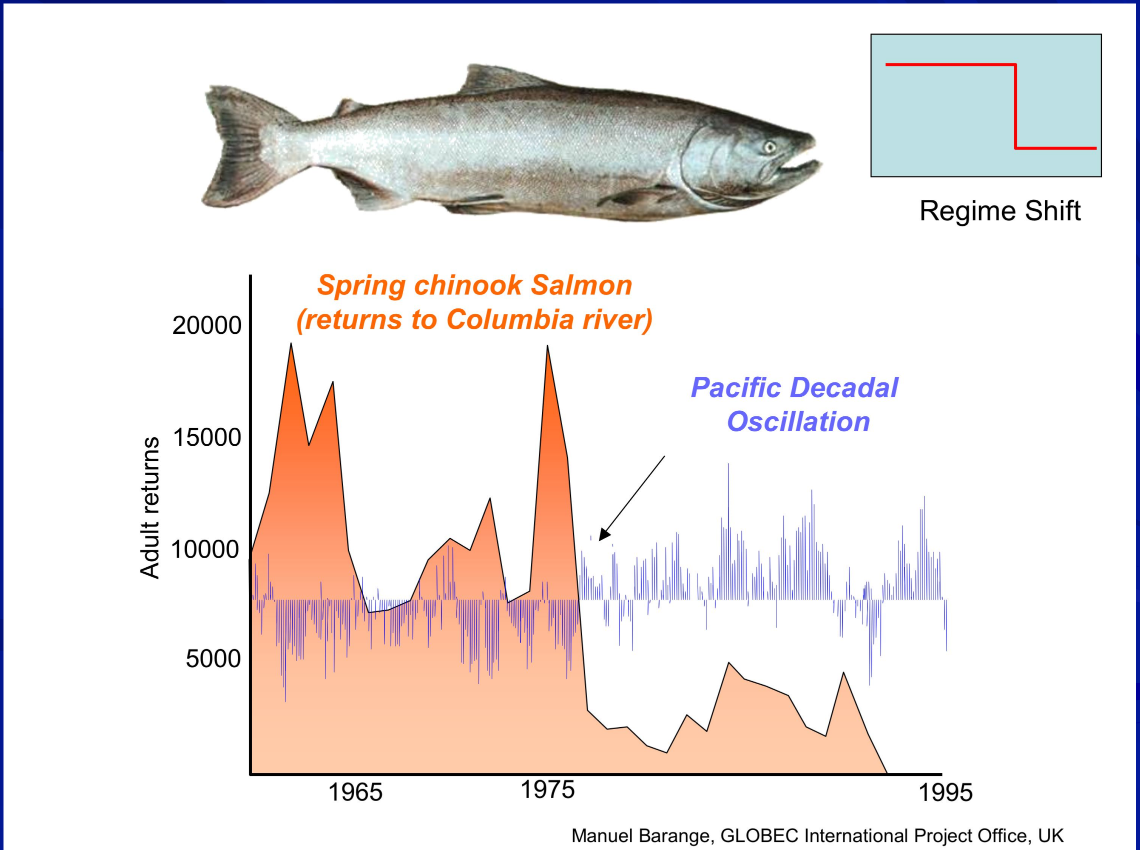
Large-Scale Changes in Atmosphere-Ocean Interactions Influence Marine Ecosystems

During a warm Pacific Decadal Oscillation (PDO), zooplankton and salmon stocks decrease off of Washington and Oregon.

PDO: SST anomalies







Pacific Decadal Oscillation vs Northern & Southern Copepod Anomalies Along Oregon Coast

<u>PDO "negative" or cool phase</u>

➢ Northern copepods have high biomass

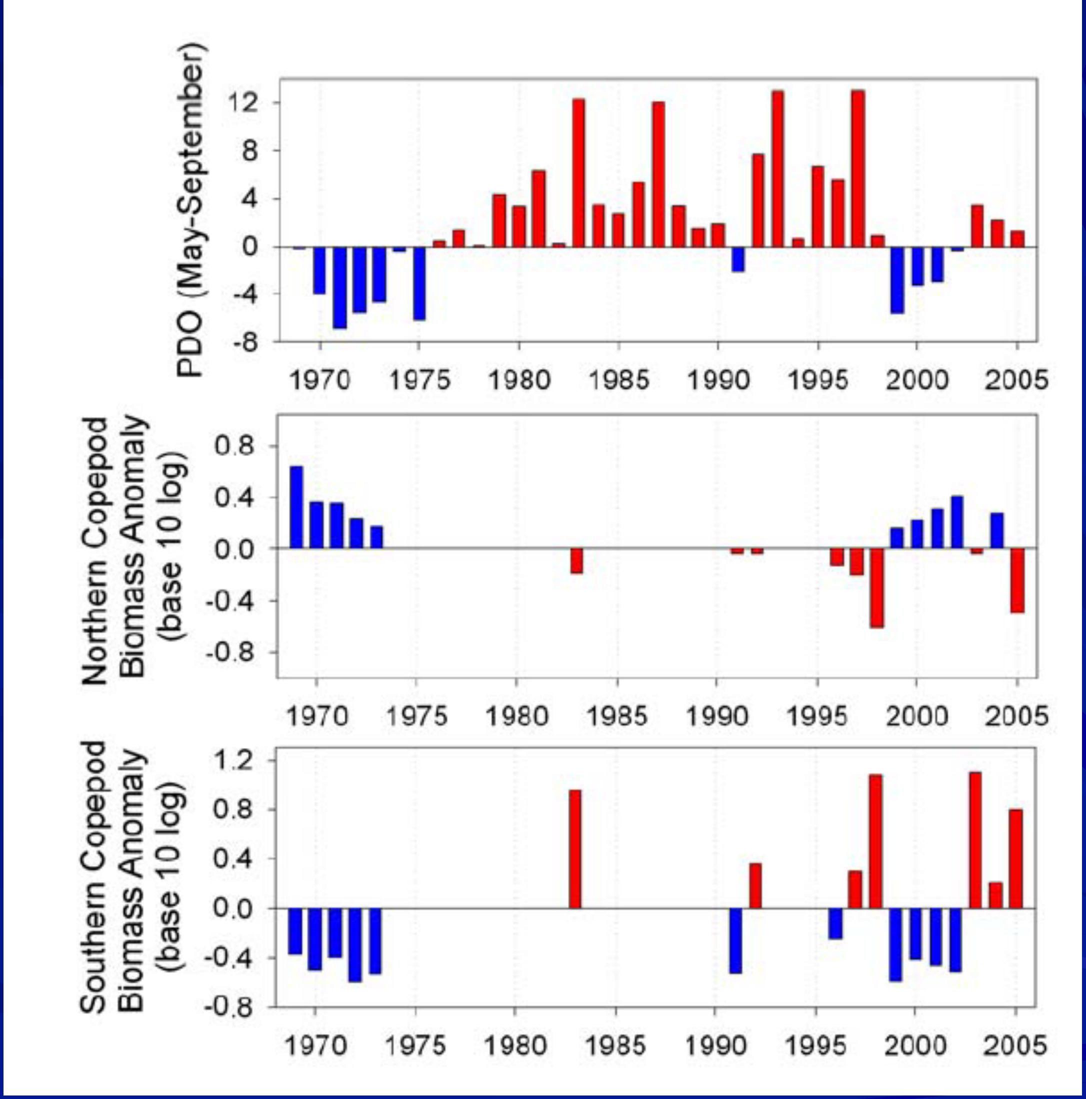
Large individuals with lipids

Southern copepods low biomass

Smaller, less lipid

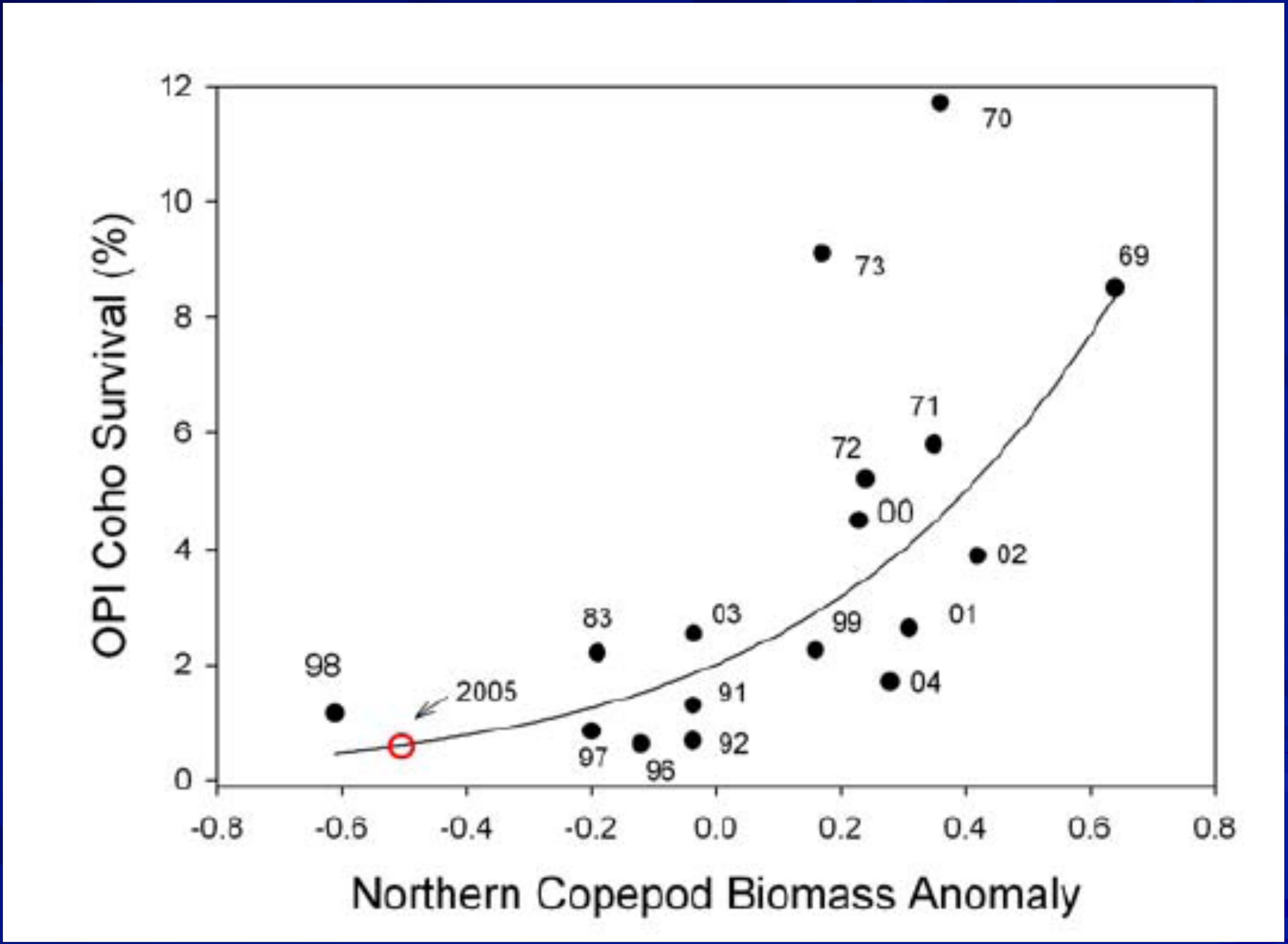
<u>PDO "positive" or warm phase is opposite</u>

Biomass changes are rapid and orders of magnitude differences among years.



B. Peterson (NOAA)

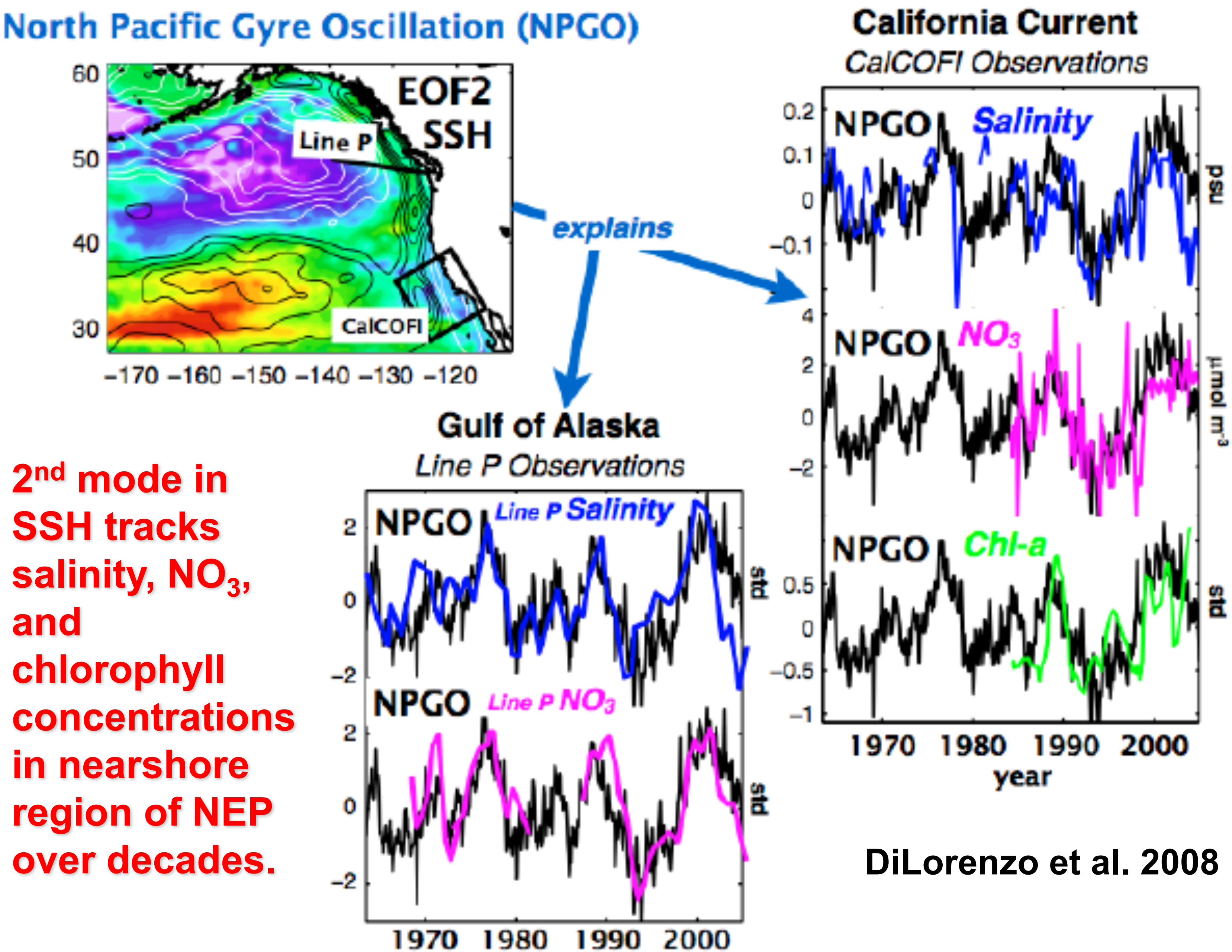
High Coho Salmon Survival Related to Increased Biomass of Northern Copepods



OPI = Oregon Production Index

B. Peterson (NOAA)

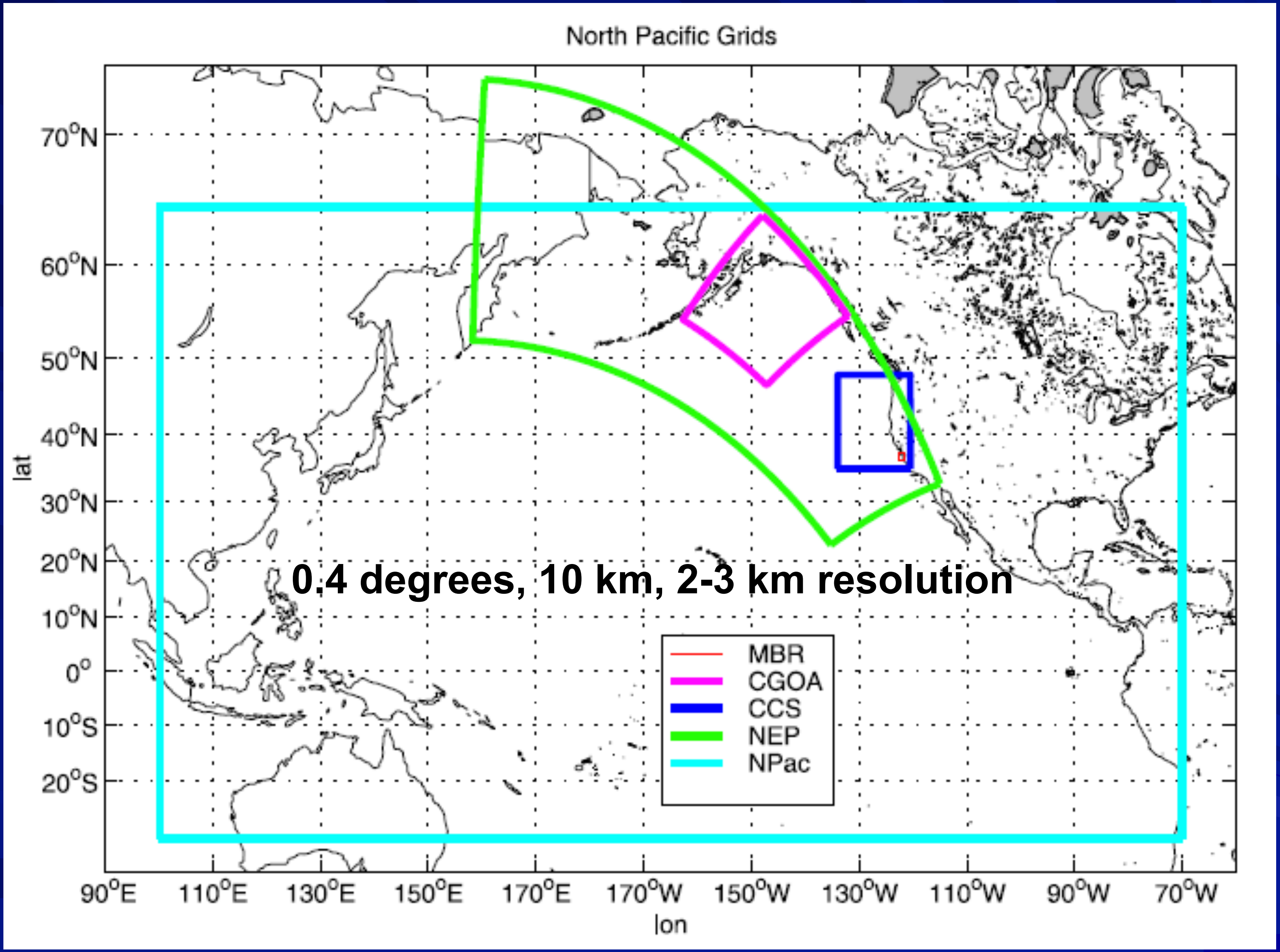
Effects of Large-Scale Processes on Coastal Properties



2nd mode in SSH tracks salinity, NO_3, and chlorophyll concentrations in nearshore region of NEP over decades.

DiLorenzo et al. 2008

Multi-Scale Modeling of the North Pacific Ocean (Curchitser et al. 2005)



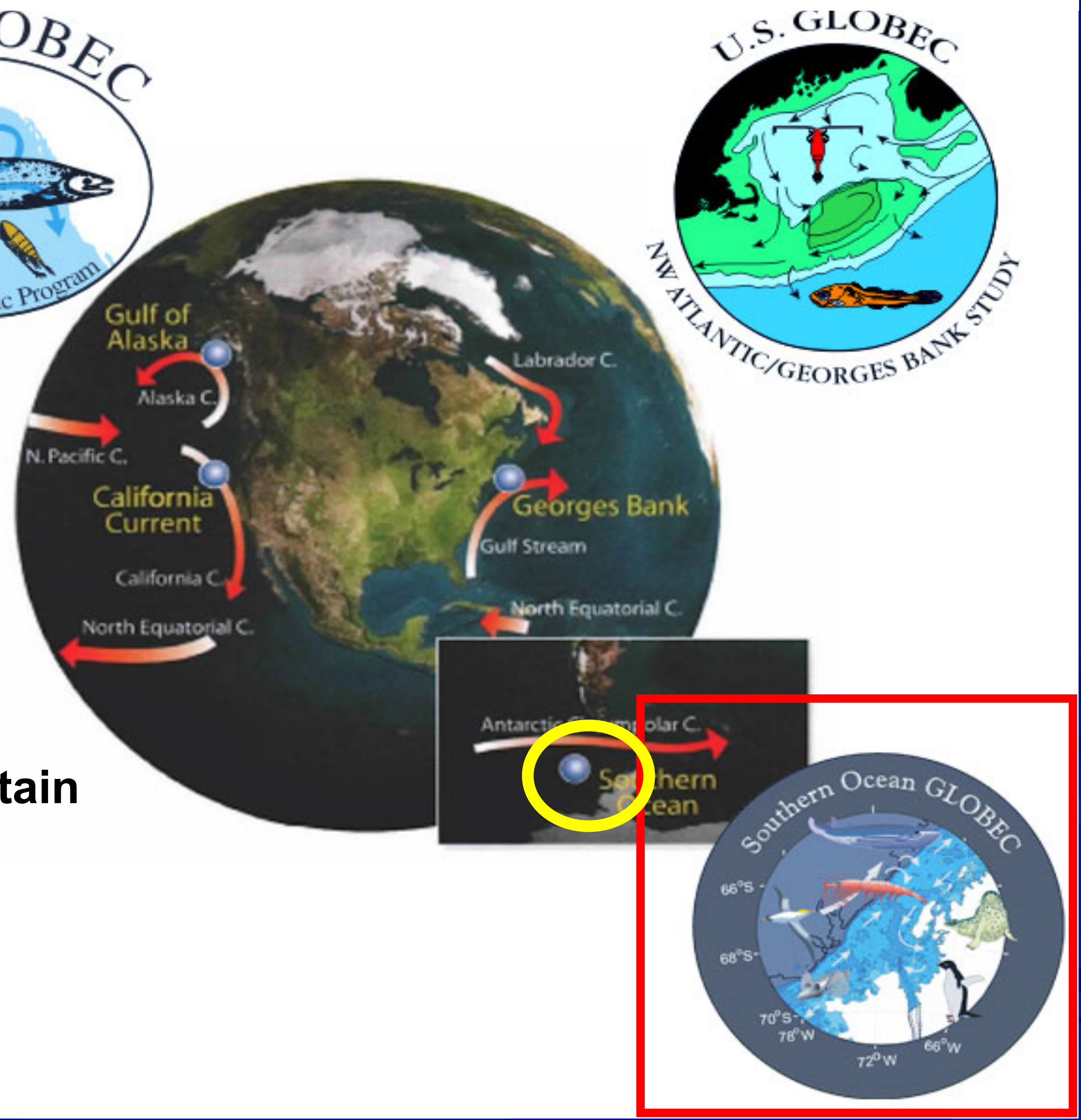
Nested Grids - Regional Ocean Modeling System (ROMS)

2002 Cold Anomaly Field Observations and Model Results

- **Model suggests the origin of the cold water mass was due to enhanced winter mixing in Alaska Gyre during the previous winter; change in density allowed southward transport of water mass**
- **Off Oregon, California Current cooled (1 degree cooler & 0.4 psu fresher than 2001), thermocline deepened, decreased stratification**
- **Upwelling led to increased nutrient supply & biological production on shelf**
- **Decay of sinking phytoplankton led to hypoxia, killing many bottom fish and invertebrates, such as crabs.**

Bottom dwelling fish off of Oregon

US Southern Ocean GLOBEC Program



US

Great Britain

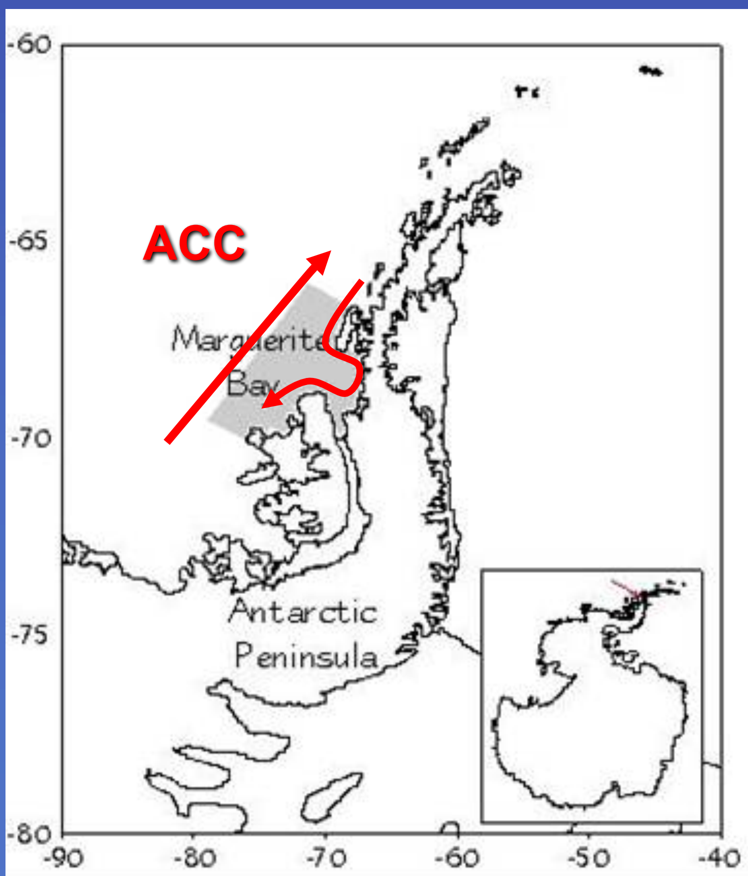
Germany

Australia

Korea

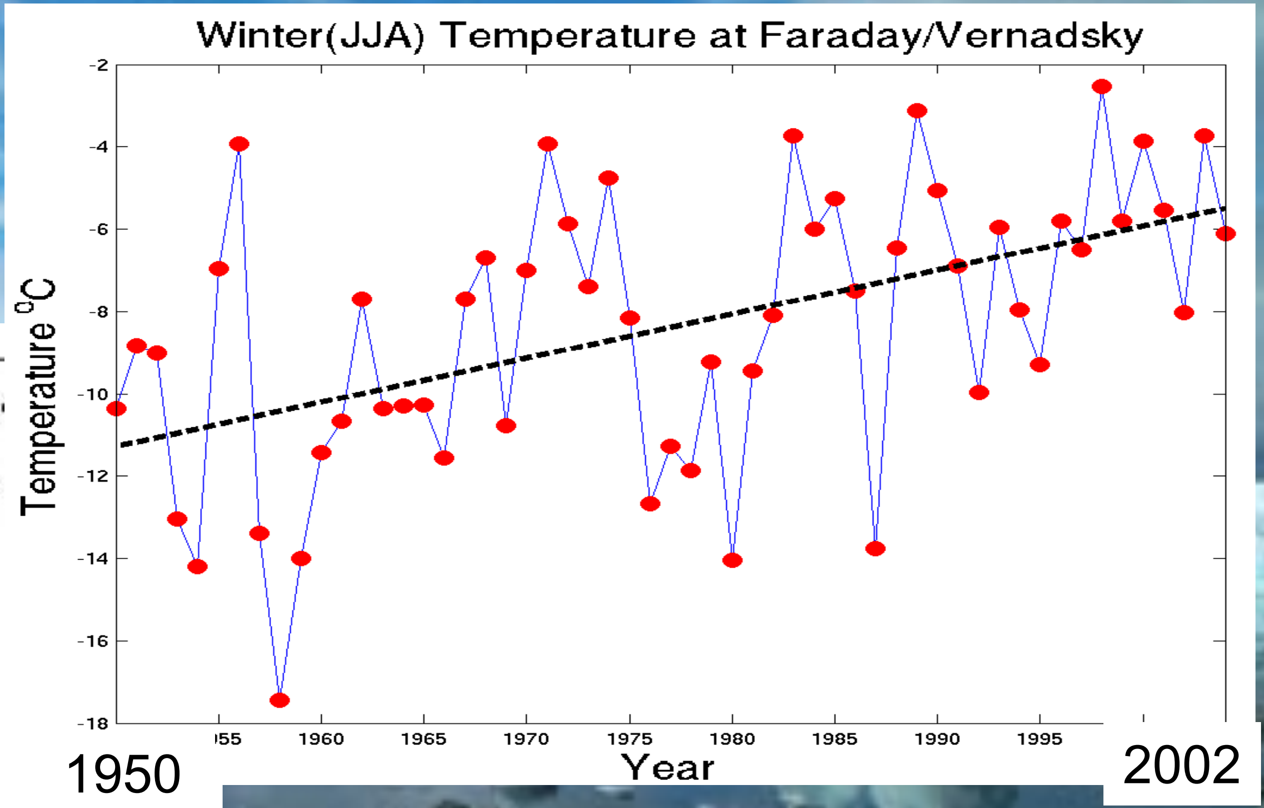
US Southern Ocean GLOBEC Program: 2001 -2002

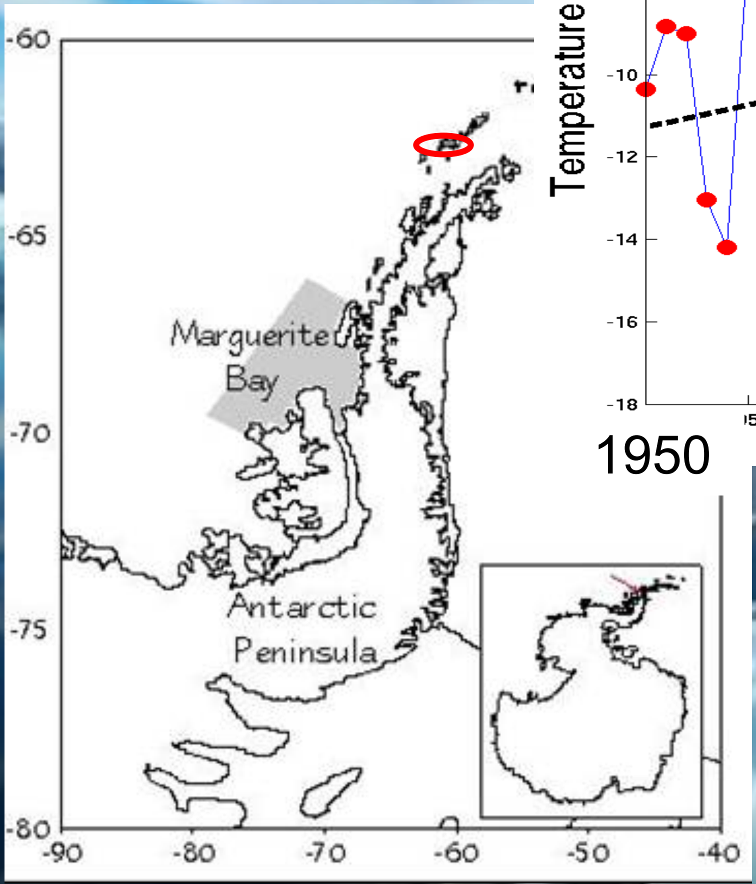
- Investigated the physical and biological factors that influence the growth, recruitment, and overwintering survival of Antarctic krill and their predators in the vicinity of Marguerite Bay, west of the Antarctic Peninsula.
- Extensive field program during austral fall and winter 2001 & 2002



Larval krill survival is attributed to the annual presence of an early forming and long-lasting ice cover, which provides a dependable food source and protection for larval krill.

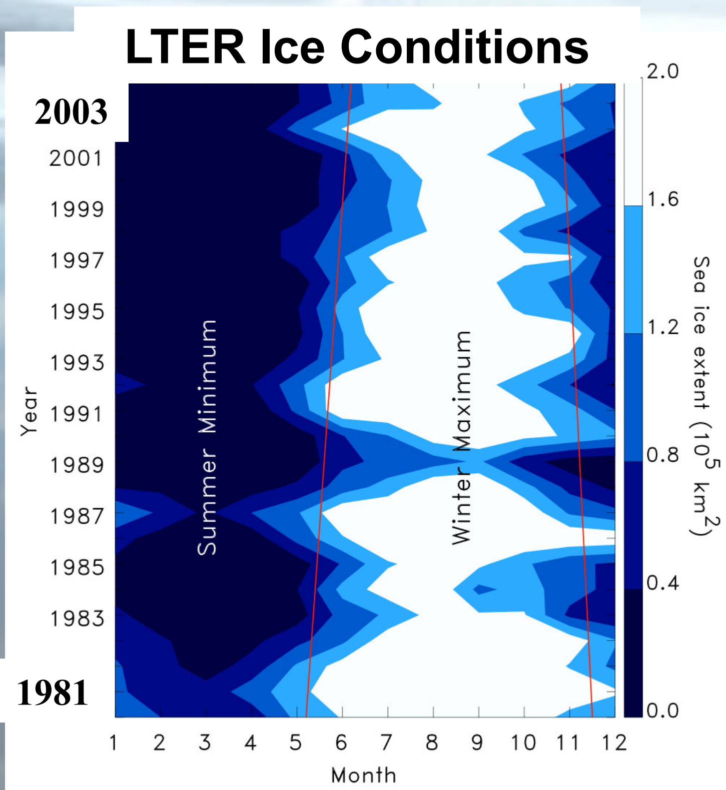
Winter Increase in Air Temperature : 1950 - 2002

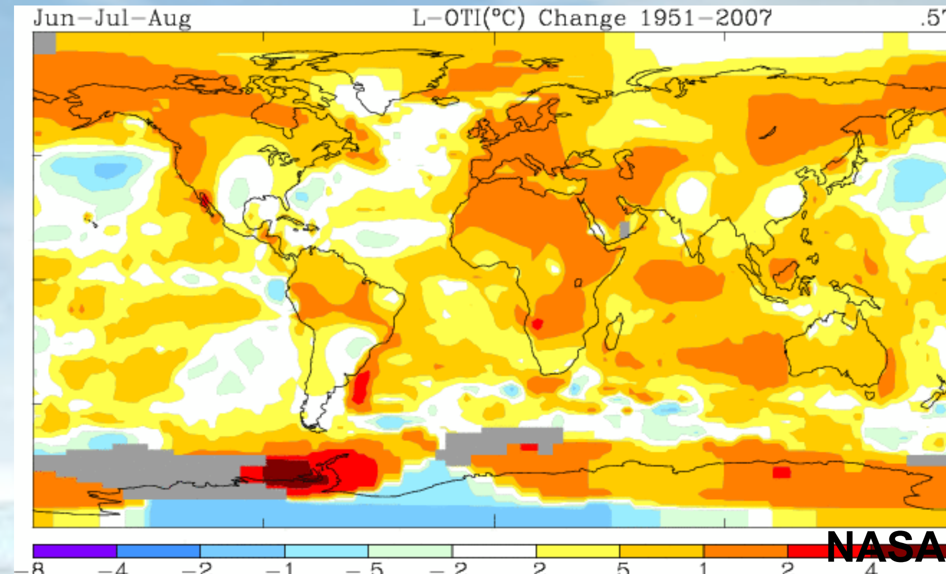




Western Antarctic Peninsula & Bellingshausen Sea

Winter temperatures warming faster than any other area on the planet: 5.8ºC between1950-2005.

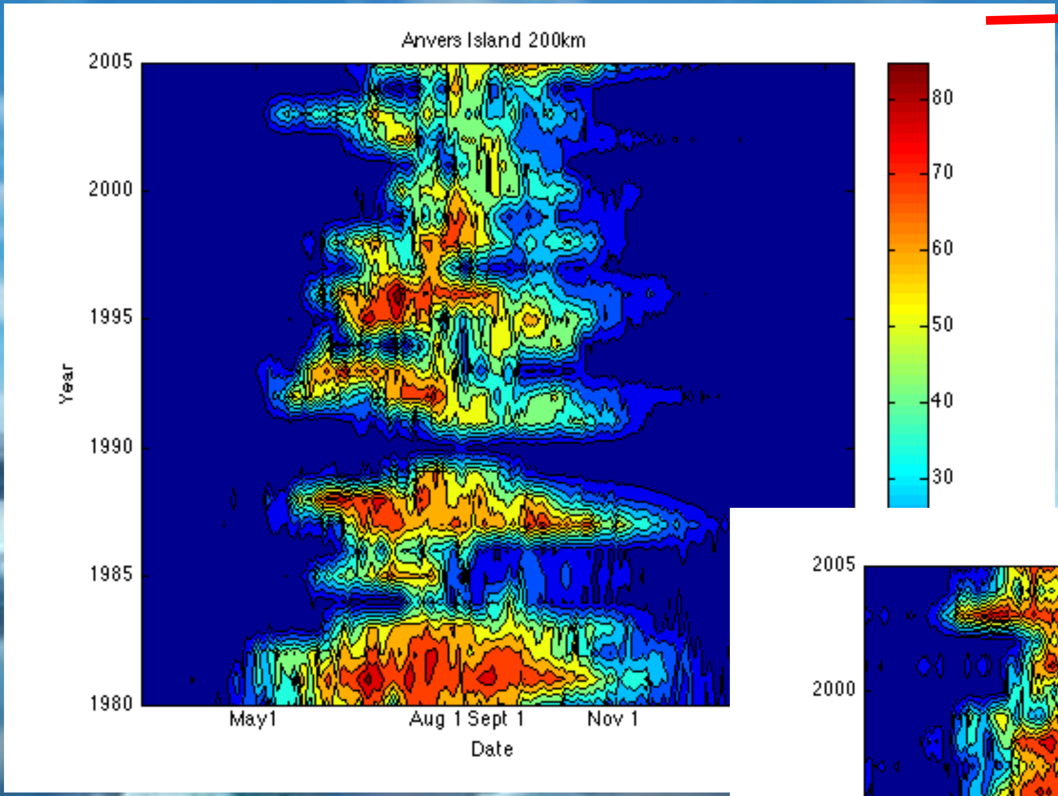


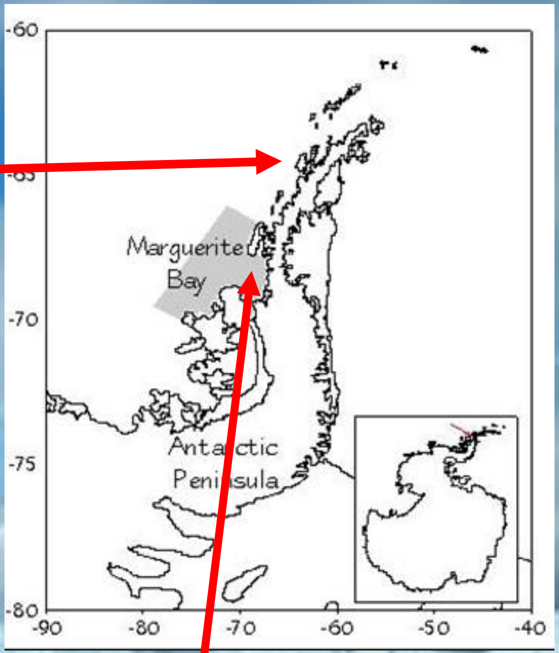


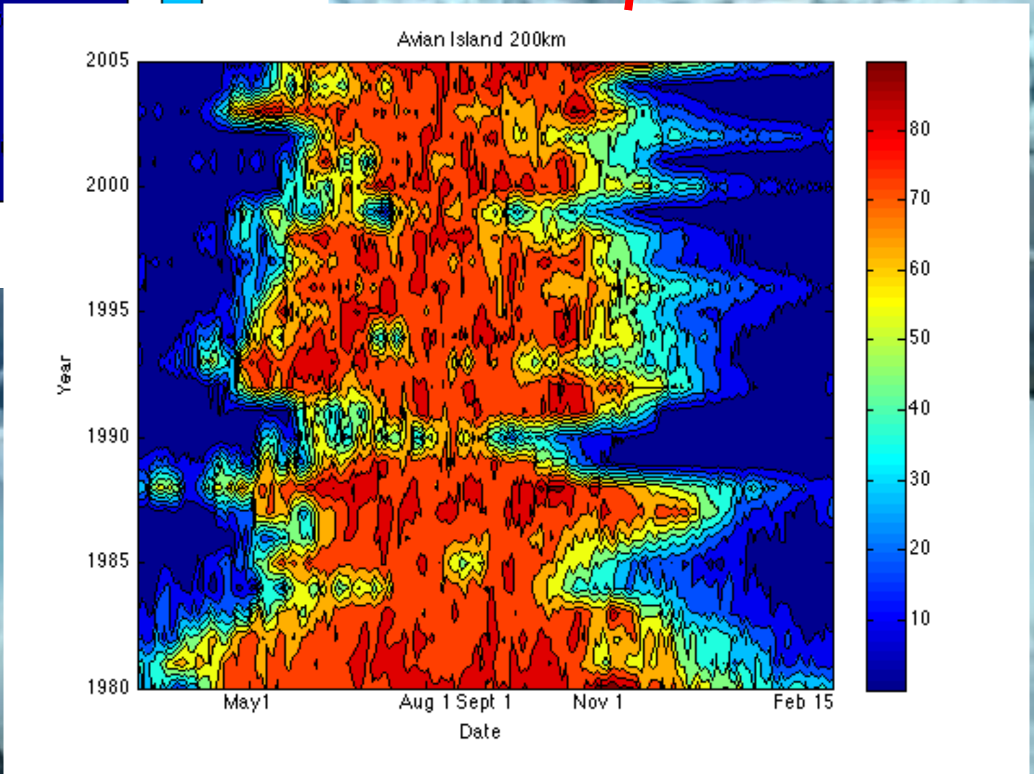
- **Sea ice retreating 31 days earlier in spring**
- **Advancing 54 days later in fall**
- **Related to a shift towards positive values of the Southern Annual Mode since the 1990s**

(Stammerjohn et al. 2008)

Ice Concentration and Duration 1980 - 2005



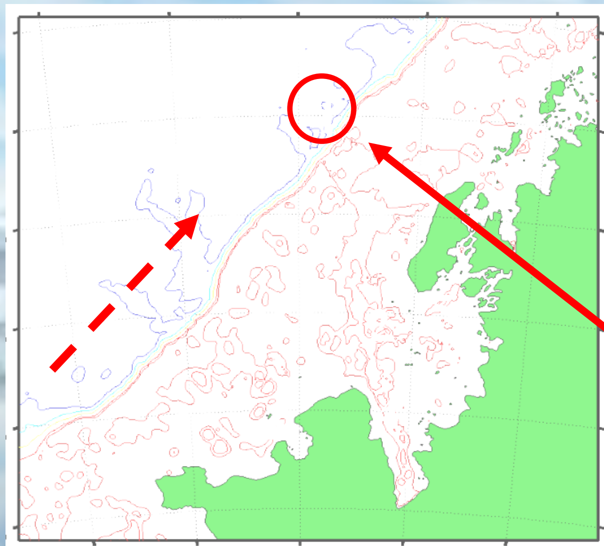




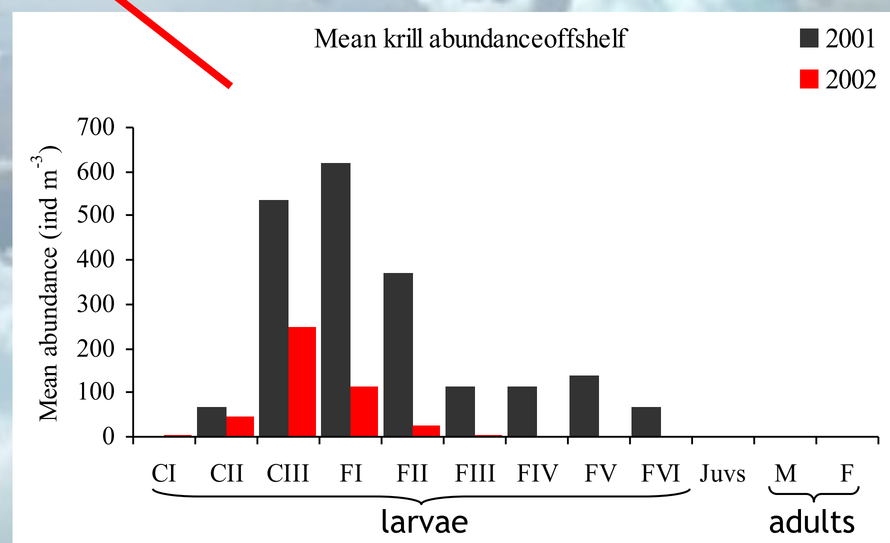
Erik Chapman

High Larval Densities in 2001 and High Recruitment to Juvenile Stage in 2002

(Daly 2004)



- **2001: larvae very abundant, up to 132 ind m^{-3}**
- **2002: fewer larvae, large recruitment of juvenile krill**



Southern Ocean GLOBEC: Sea Ice Duration & Extent:

Winter Sea Ice extent was similar in 2001 and 2002

Fall 2001:

- Lower ice coverage during summer
- Sea ice formed later (June/July)

Fall 2002:

- South Marguerite Bay covered by ice throughout the year
- Sea ice formed earlier (May)

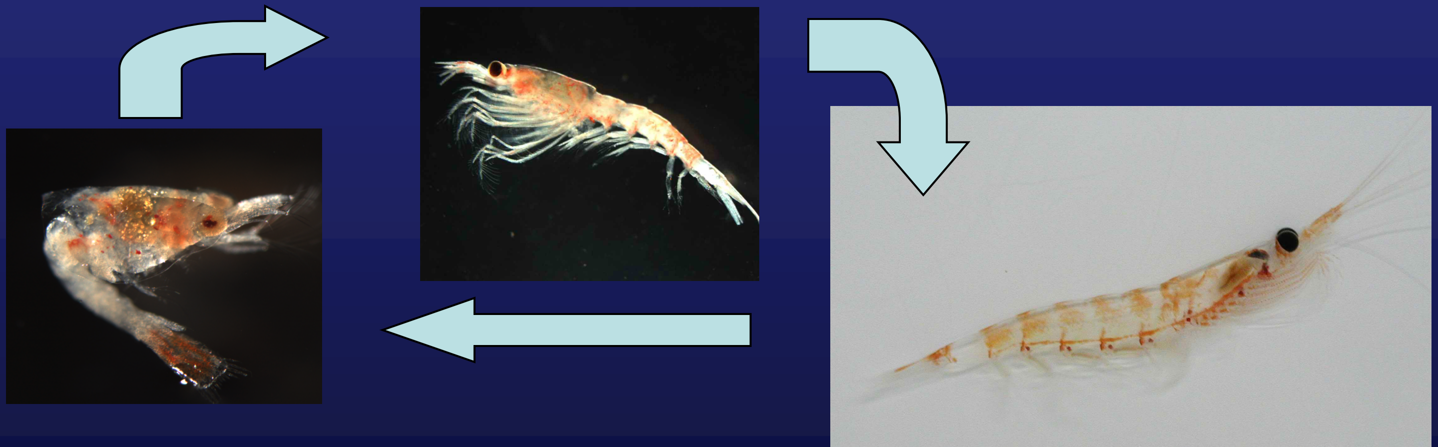
Role of Phytoplankton

- Females require above average chl to support reproduction (1-5 mg chl m^{-3}) (Ross & Quetin, 1986) and sustain multiple spawning (>0.5 mg chl m^{-3}) (Nicol et al., 1995).

- First-feeding larvae need food to survive

- Enhanced food availability allows larvae to achieve faster growth rates, thereby obtaining a larger size and better condition to survive starvation overwinter (Daly, 2004).

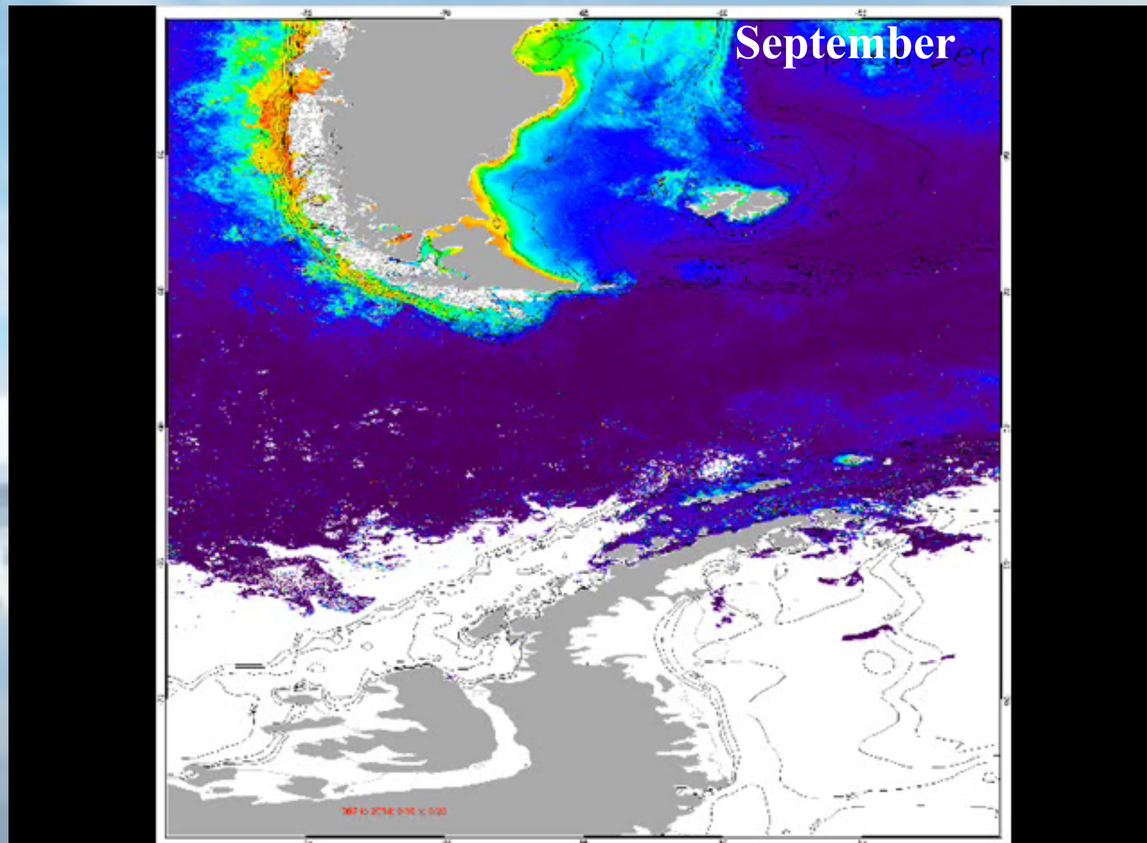
- **Thus, knowledge about differences in the timing, extent, and evolution of phytoplankton blooms is important for understanding interannual variability in krill recruitment.**



SeaWiFS Chlorophyll climatology 1997-2004

Marrari et al. 2006, 2008

Images represent 2 week intervals from September to April



Marina Marrari

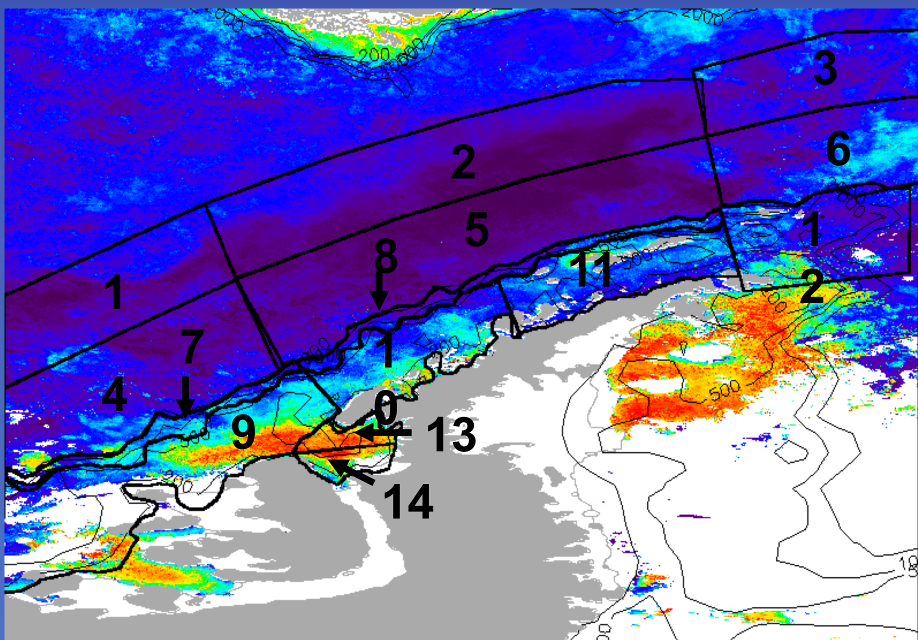
Chunamin Hu

USF

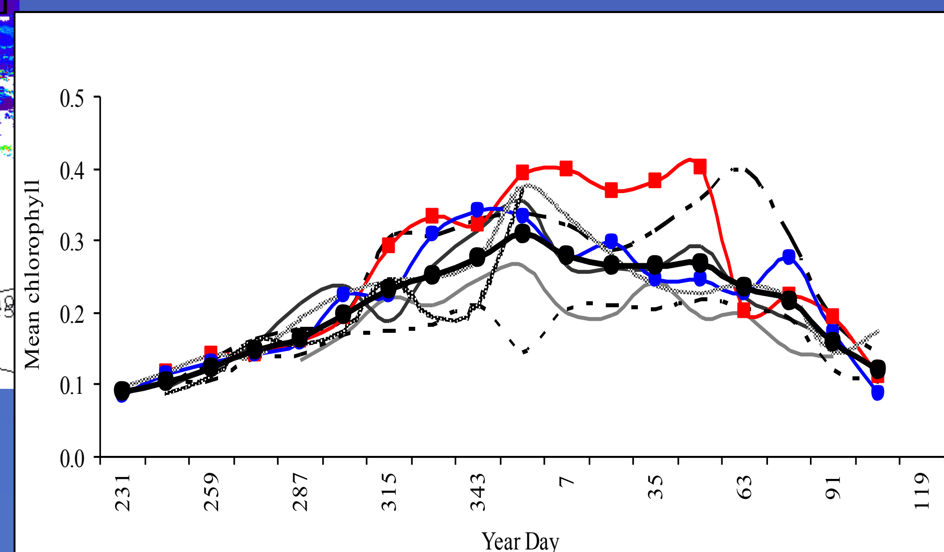
1. First elevated chl concentrations in October in the Bellingshausen Sea, and along the shelf-break
2. Blooms progress onshelf into Marguerite Bay and persist until April
3. In the northern Peninsula blooms move to coastal areas, but concentrations were relatively lower during our study period.

CHLOROPHYLL DYNAMICS (Marrari et al. 2008)

- In order to investigate differences in the timing and evolution of blooms, study area divided in 13 sub-regions.
- Generated time series of mean chlorophyll in each sub-region from 1997 until 2004.



Red – 2001
Blue – 2002
Black - Climatology



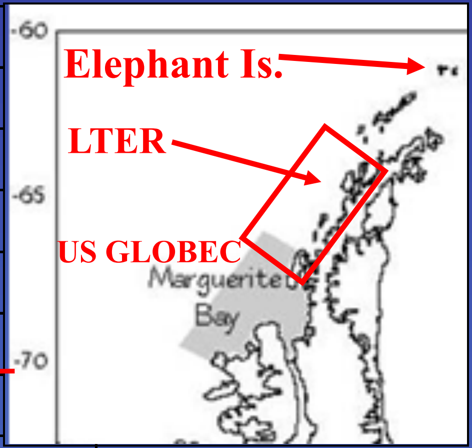
25 Years of *E. superba* Recruitment Data

Year Spawned	R_1	Location
1979-1980	0.559	Elephant Island*
1980-1981	**0.757**	Elephant Island*
1981-1982	0.470	Elephant Island*
1987-1988	0.651	Elephant Island*
1994-1995	0.639	Elephant Island*
1999-2000	0.573	Elephant Island*
2000-2001	**0.748**	LTER/Marguerite Bay[+]
2000-2001	0.000	Elephant Island*
*Siegel et al, 2002, [+]Siegel et al. 2003		

6 years

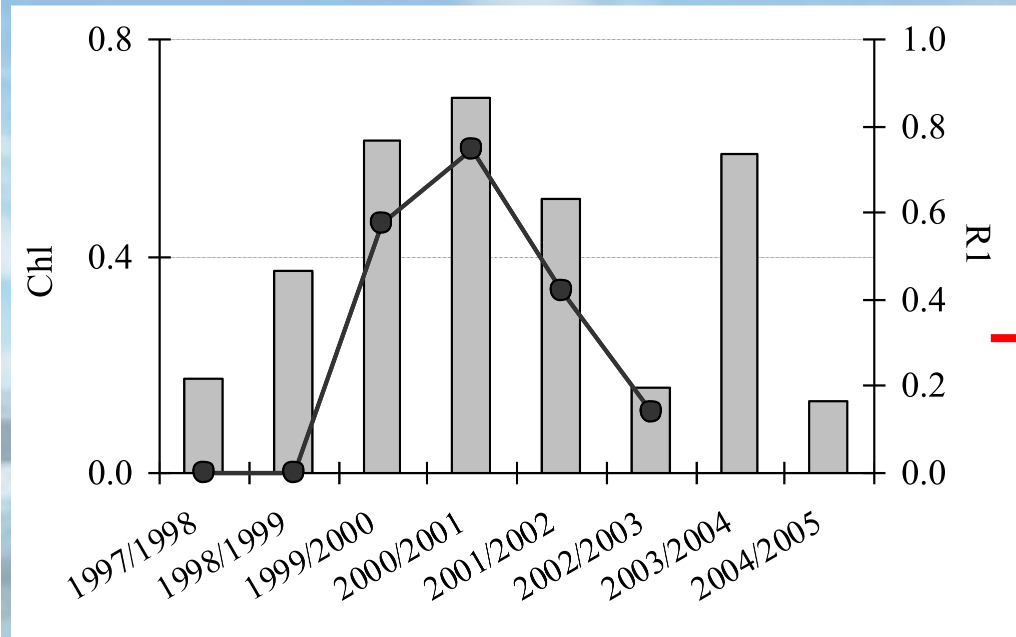
7 years

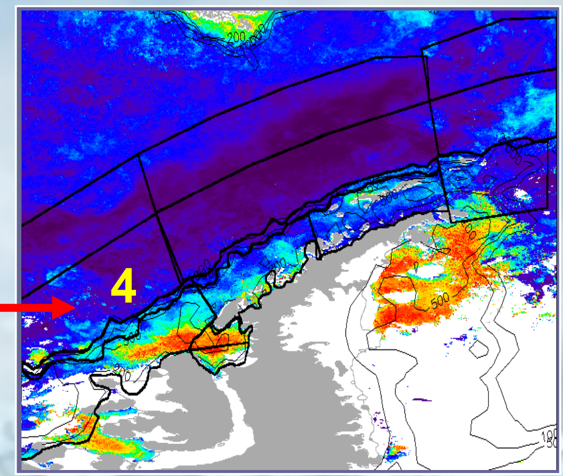
5-6 years



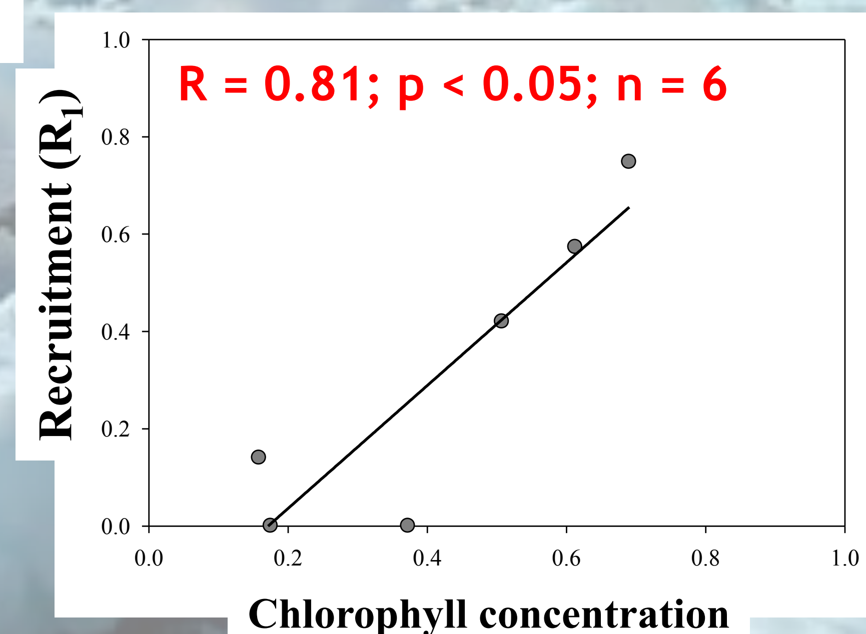
- R_1 is percent of recruited juveniles (year 1) relative to total number of krill > 20 mm
- Since 1977, only <u>five</u> high recruitment (R_1 > 0.5) events
- 1980/81 and 2000/01 had largest recruitment events
- Since 1982, about 5-7 years between successful recruitments
- Krill live about 6-7 years

Chlorophyll vs. Krill Recruitment





Grey bars: Chl, black circles: R_1



Chl^{SWF} in the Bellingshausen Sea during Nov

vs.

R_1 of *E. superba* in the WAP

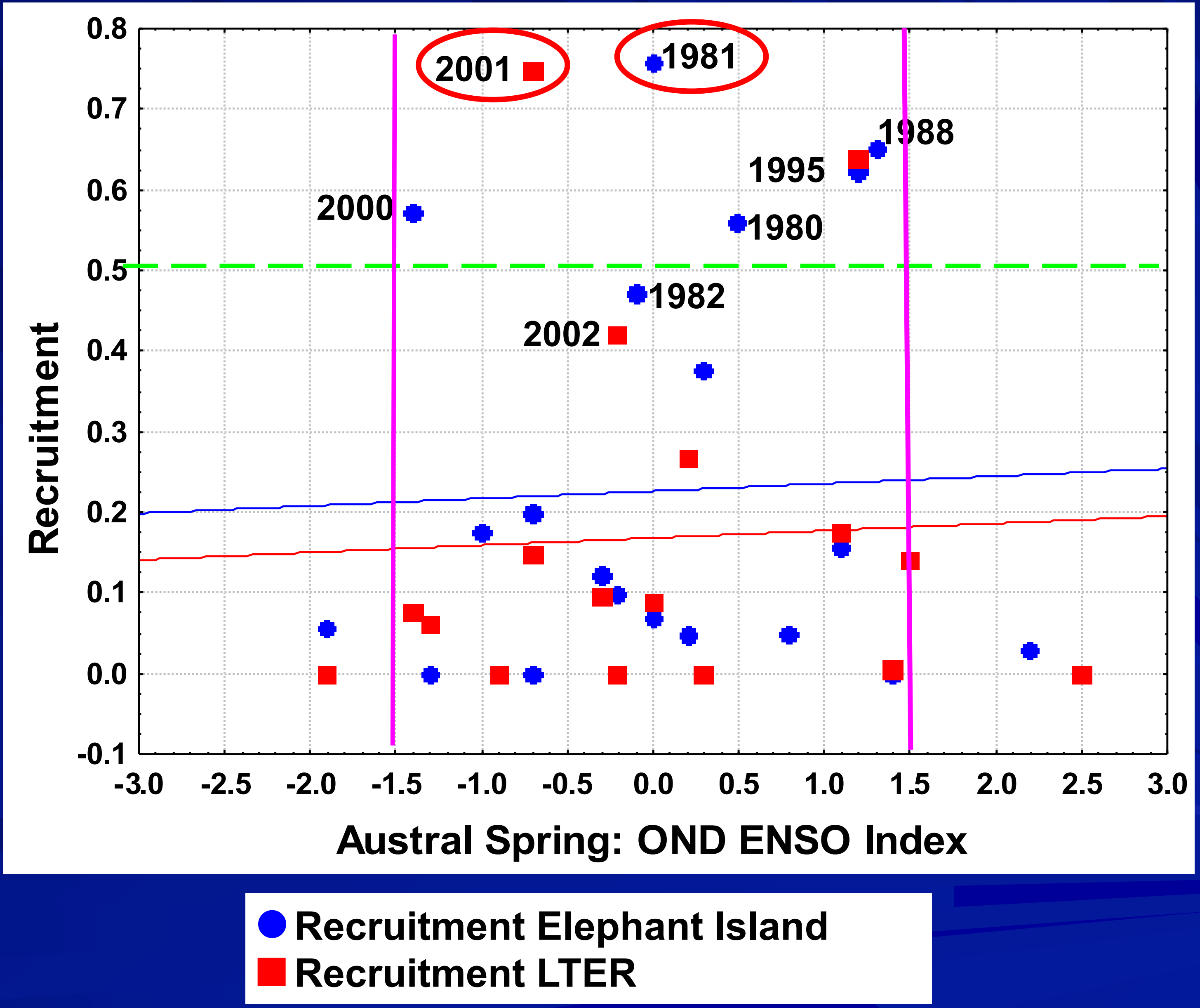
Oceanic Niño Indices (NOAA) vs Krill Recruitment

EI: $R^2 = 0.017$

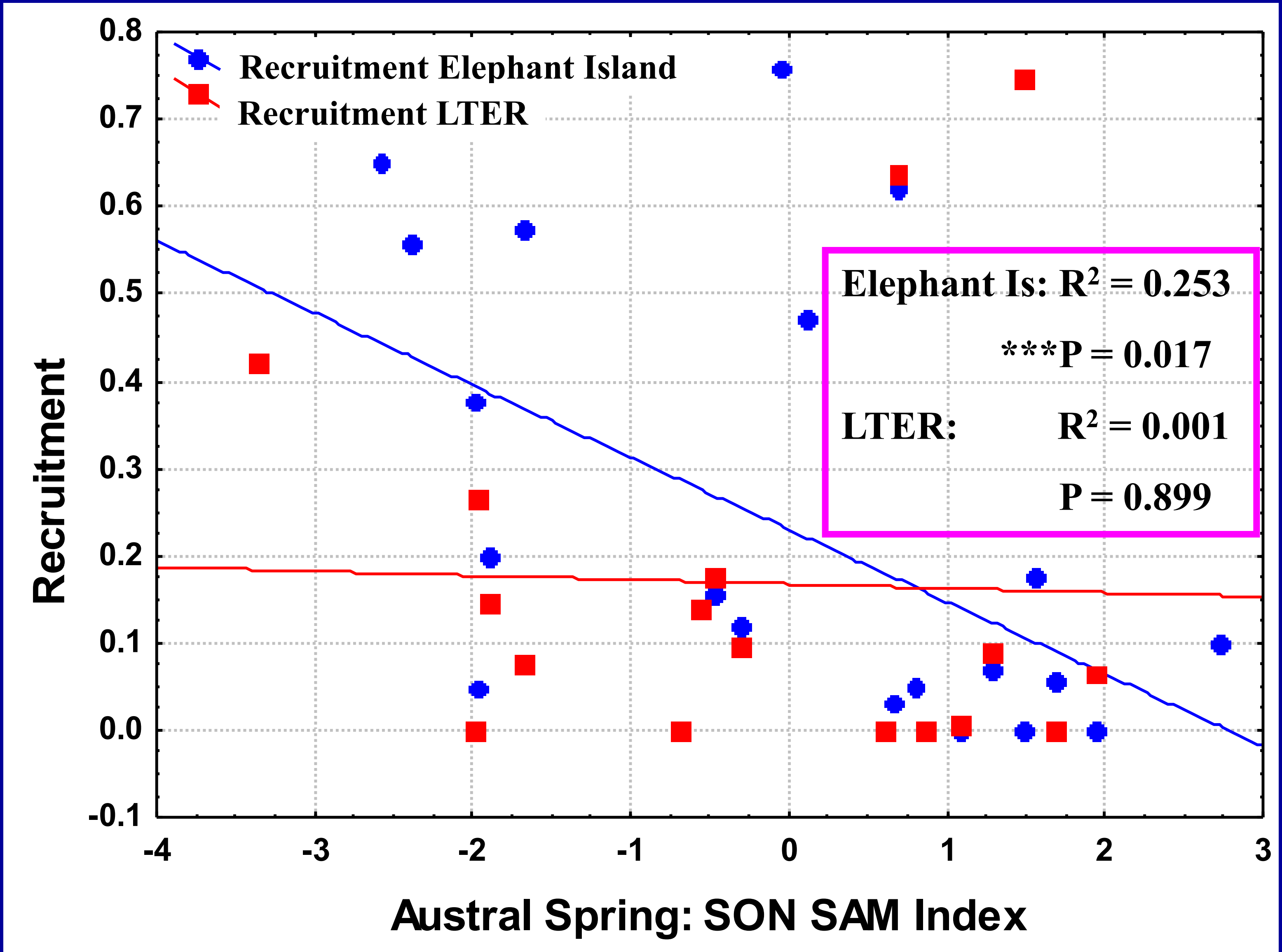
$P = 0.854$

LTER: $R^2 = 0.002$

$P = 0.858$

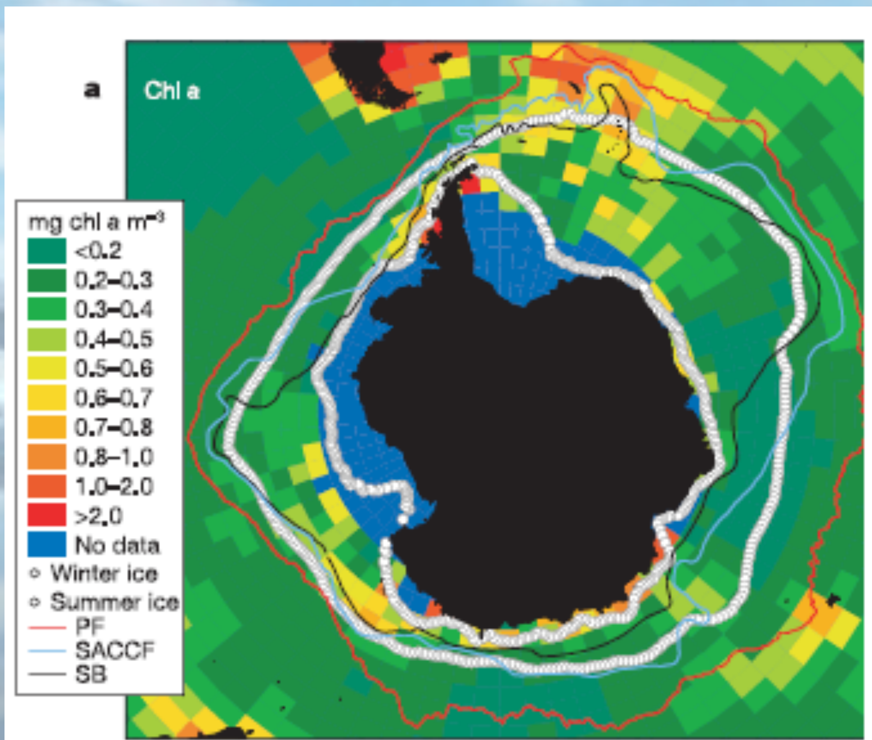


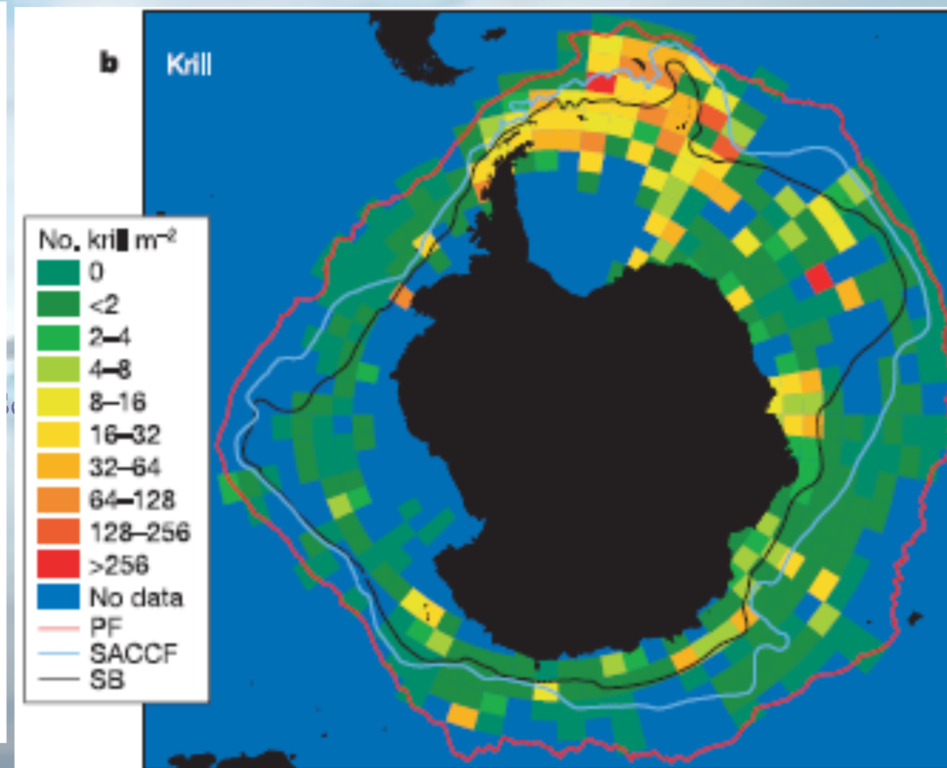
Spring Southern Annular Mode Indices vs Recruitment



SAM indices: Byrd Meteorology Polar Group

Summer Mean Density of Krill and Chlorophyll Correlated at Circumpolar Scale





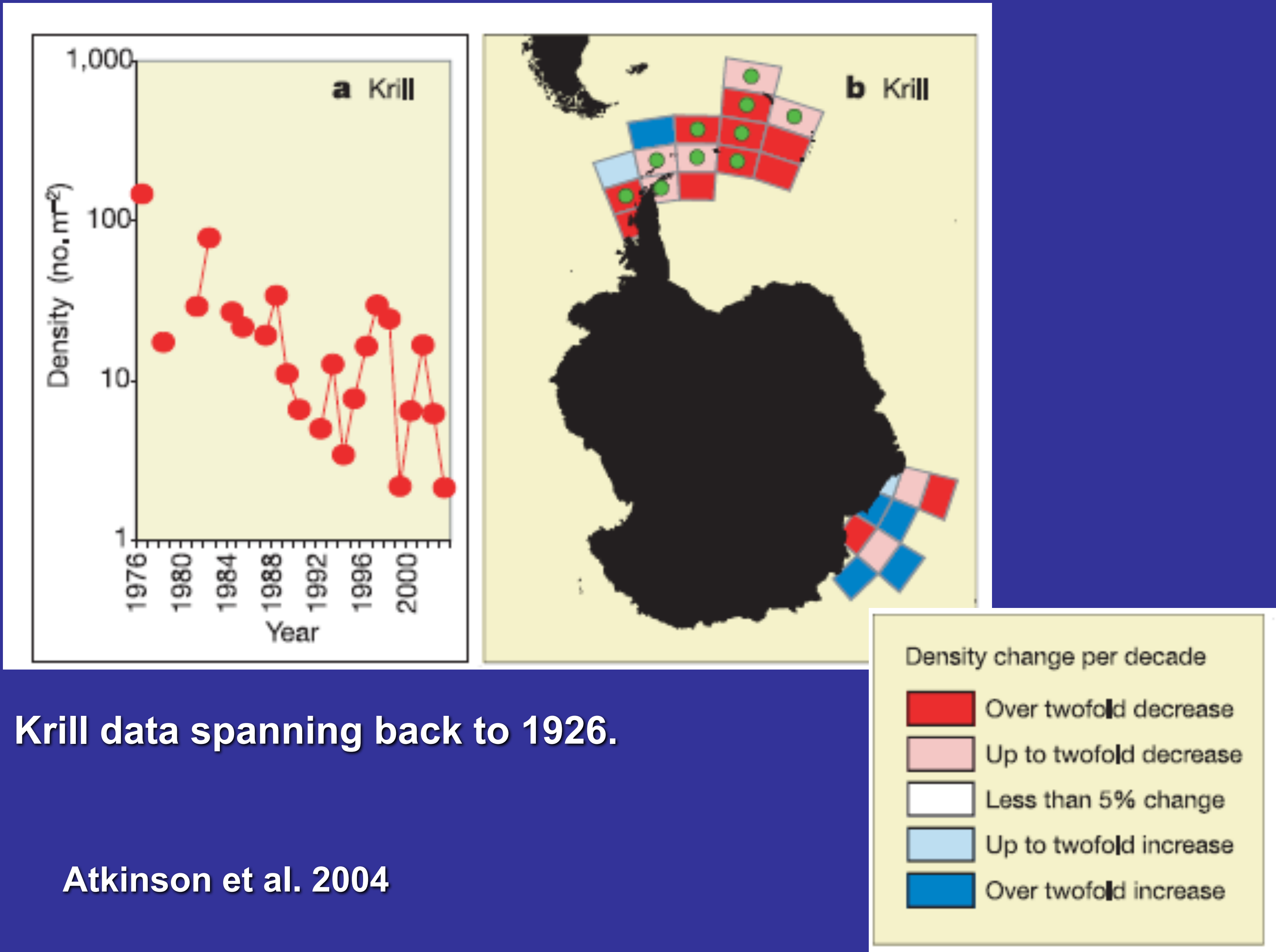
SeaWiFS Chlorophyll

Krill Abundance

R^2 = 0.051 p = 0.017

Atkinson et al. (2004)

Decrease in Krill Abundance: 1976 to 2003



Krill data spanning back to 1926.

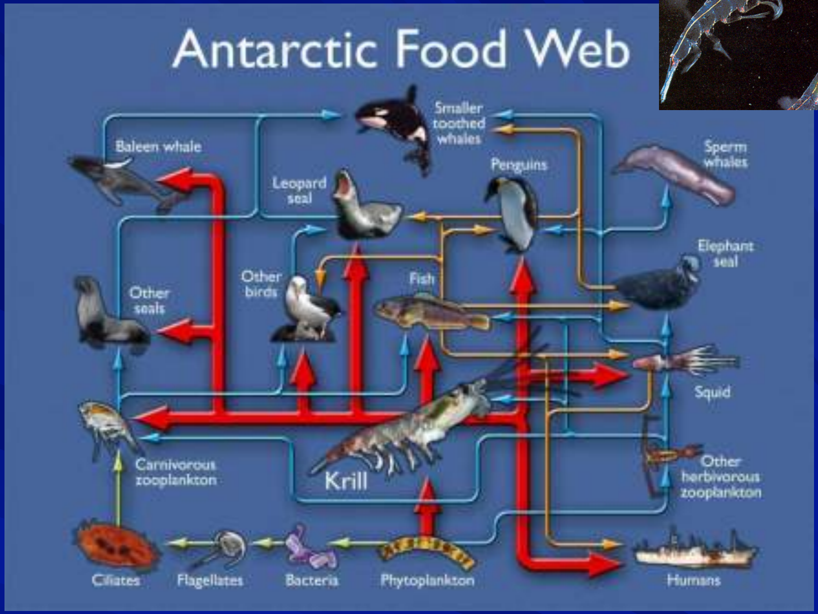
Atkinson et al. 2004

GLOBEC Synthesis & Modeling Phase: End-to-End Food Web Models for Georges Bank, NE Pacific, and Southern Ocean

Goals

- Comparative analysis of physical and biological processes between regions

- Develop diagnostic measures to evaluate affects of climate variability and fishing pressure

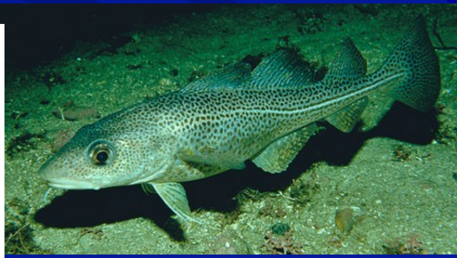


Potential outcomes

- Transition results for ecosystem-based fisheries management

- Food web budgets for global carbon models

Coho salmon
NE Pacific



Atlantic cod
Georges Bank