Production on the Gulf of Alaska Shelf: spatial-temporal expansion of GLOBEC field measurements using an ecosystem model embedded in a circulation model

Effects of iron and circulation on the nitrate cycle and primary production (2001 – 2003)

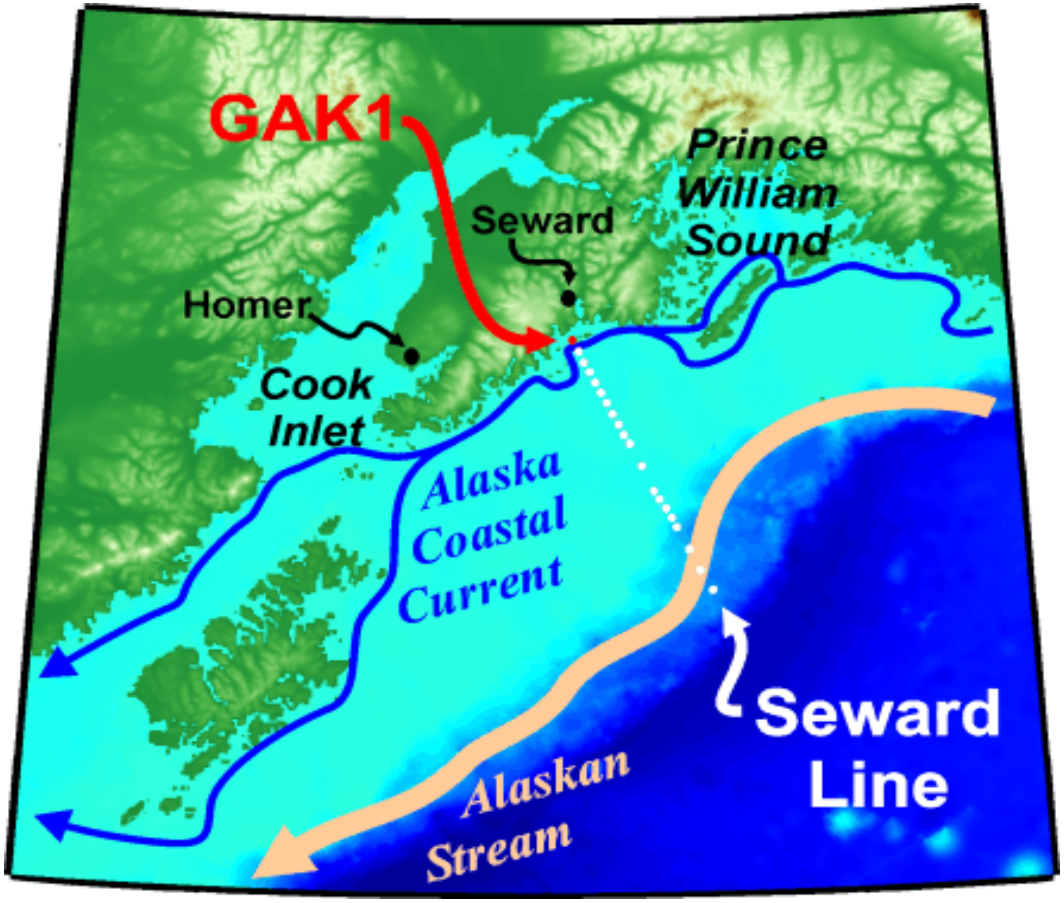
Kenneth O. Coyle, Sarah Hinckley, Wei Cheng, Georgina Gibson, Albert Hermann, Kate Hedstrom

Assistance From:
Liz Dobbins
ARSC Support Staff

Funding Agencies:
North Pacific Research Board
National Science Foundation

Computer Resources from:
Arctic Regional
Supercomputing Center

GLOBEC Study



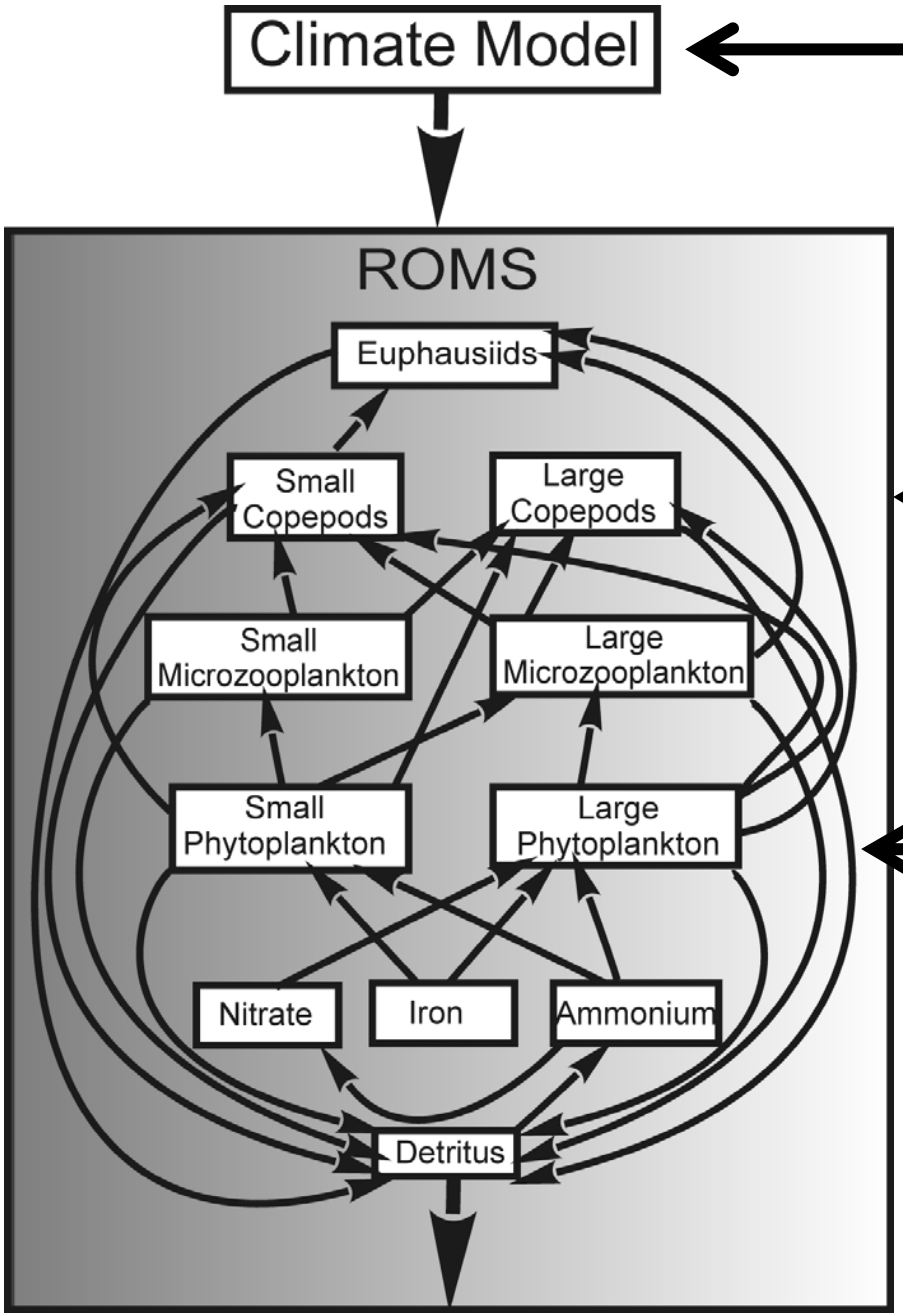
Goal: Elucidate mechanisms linking oceanography and ecosystem response to climate forcing on the northern Gulf of Alaska Shelf.

Reality: Support for a single line of stations with 6 collections per year (1998 – 2004) for observations.

Tool: ROMS numerical model with ecosystem component calibrated using observations from the Seward Line.

Complications: Complex system of currents resulting in a varying mix of oceanic and neritic communities in space and time.

- **Ocean Environment (LCHN)**: Low Chlorophyll, high nutrient, small cell, iron limited.
- **Coastal Environment**: Intense spring blooms, nitrate limiting in summer, large cells (diatoms)
- **At any point in space and time**: the observations are the result of varying mixes of coastal and oceanic communities.

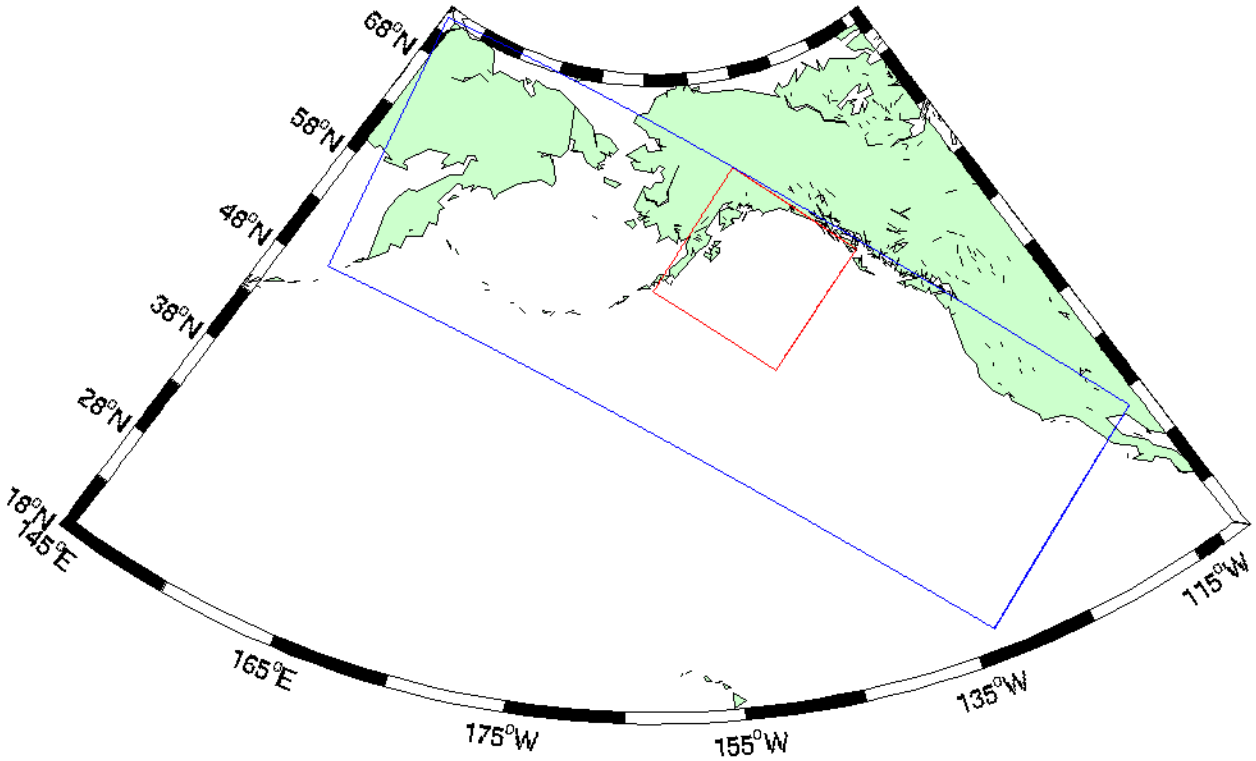


System is forced by output from the CCSM (Community Climate System Model) climate models.

Circulation simulation is provided by ROMS (Reagional Ocean Modeling System; shaded area)

Box diagram of the Gulf of Alaska ecosystem model embedded in the ROMS circulation model

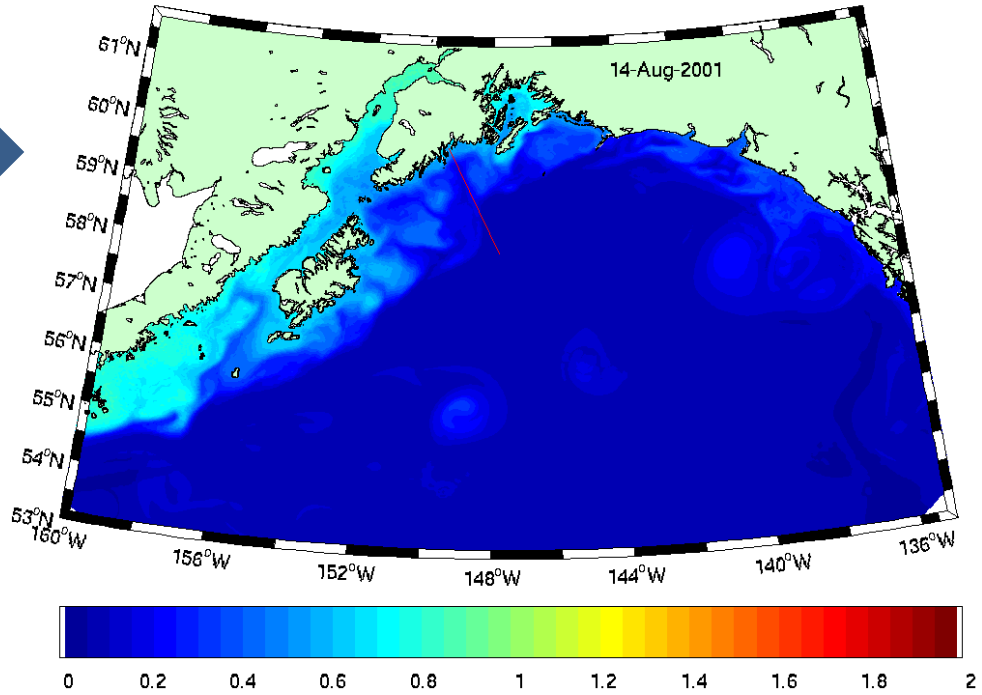
The model is run on the NEP grid (blue, 10 km resolution) to get boundary conditions and on the CGOA grid (red, 3 km resolution) to model the coastal Gulf of Alaska



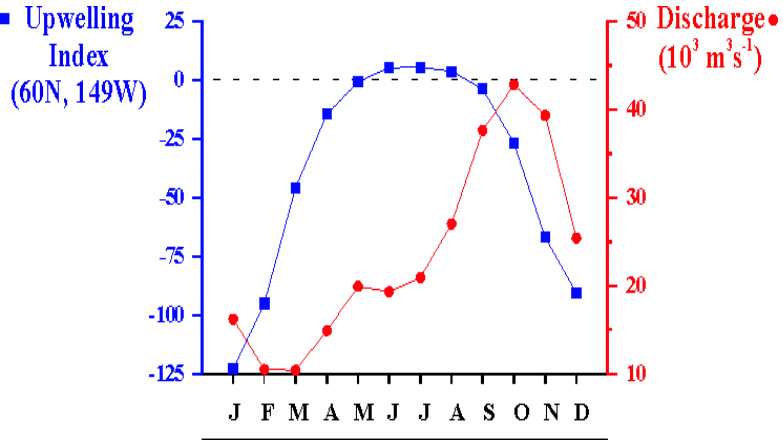
Dissolved Iron (nM) on the Northern Gulf of Alaska Shelf

Simulated Iron Aug 14

Upper 30 m



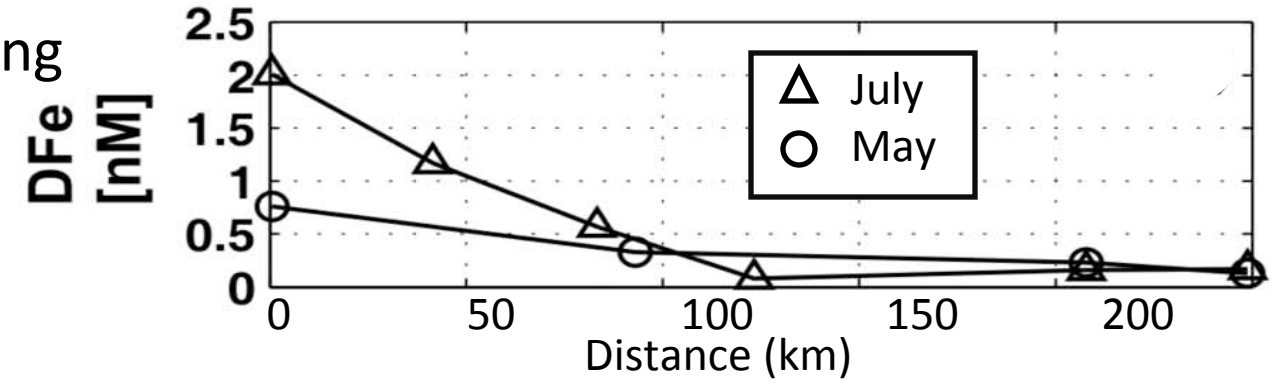
From Weingartner et al. 2002



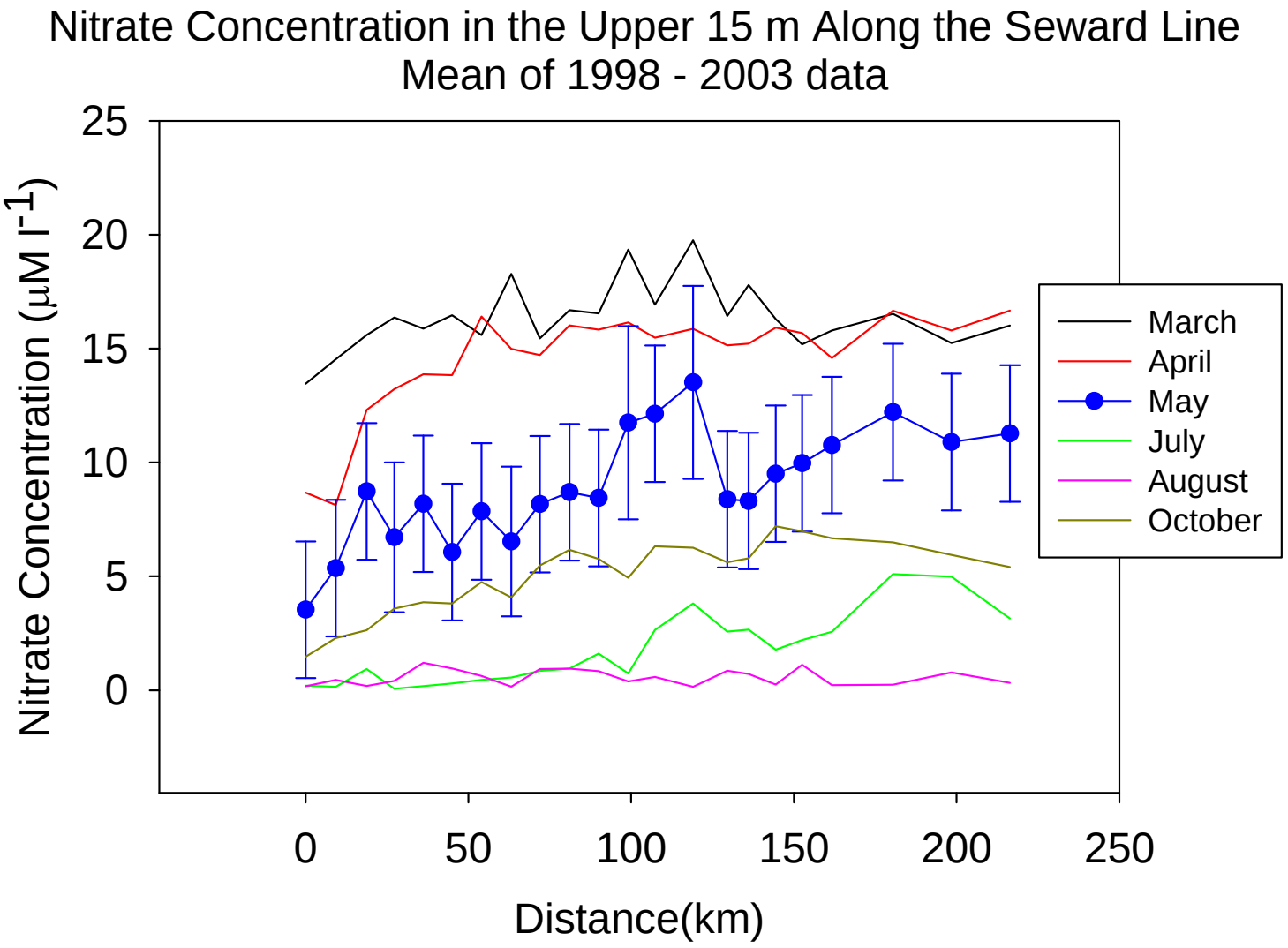
Measured Iron along Seward Line,

Upper 30 m

From: Wu et al., 2009

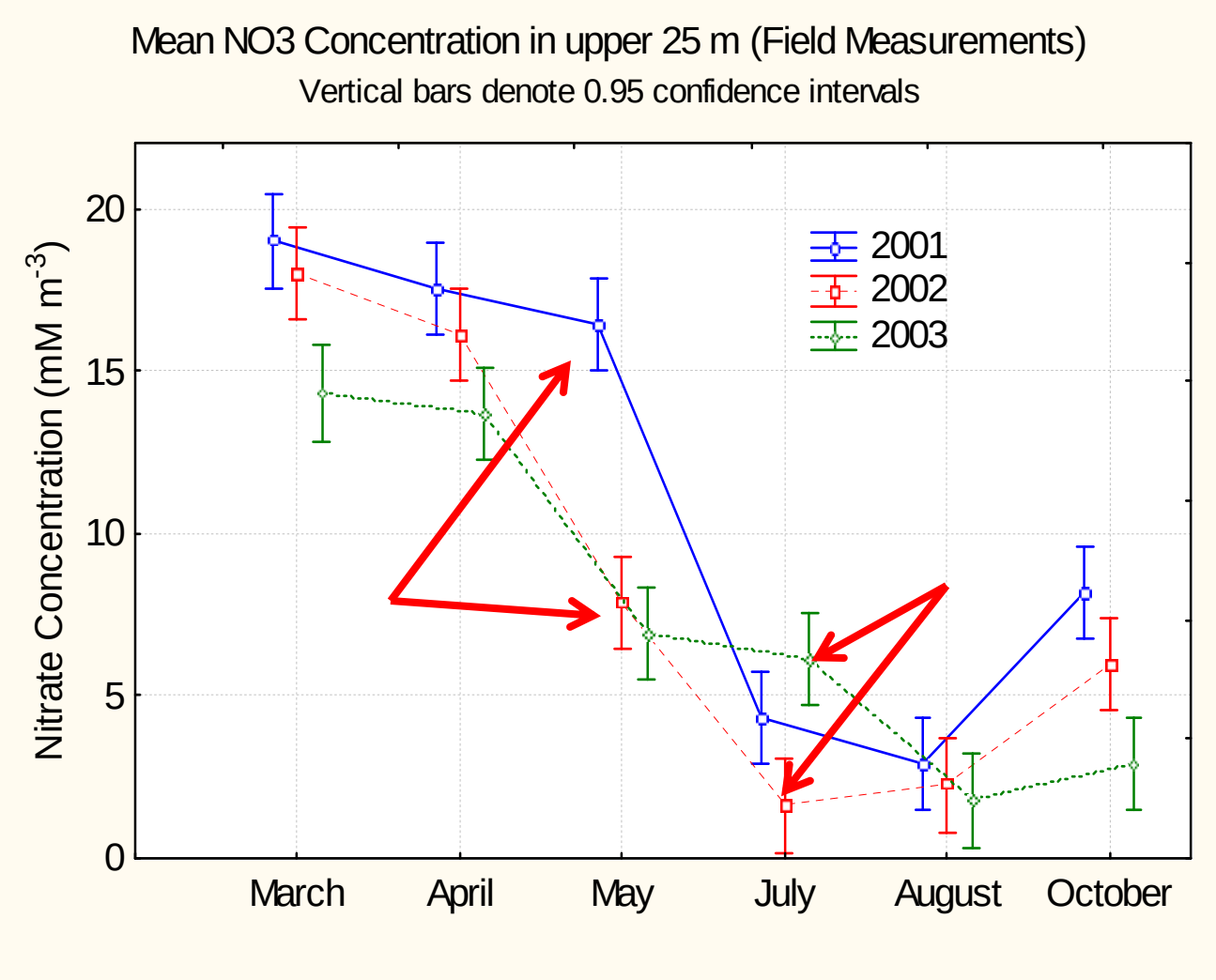


Seasonal Nitrate Cycle Summarized

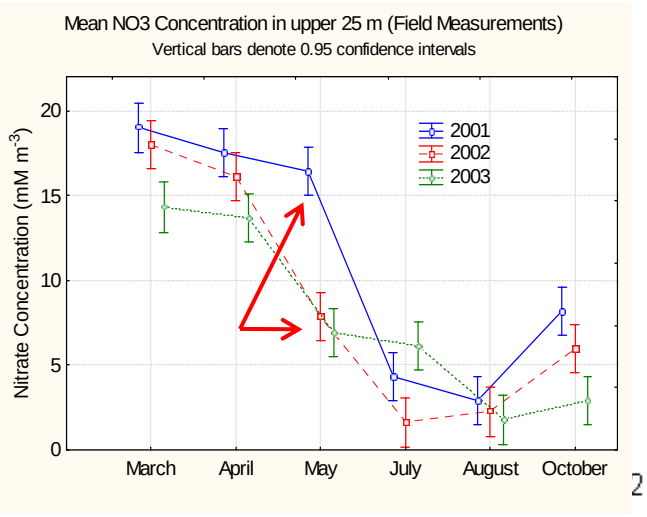


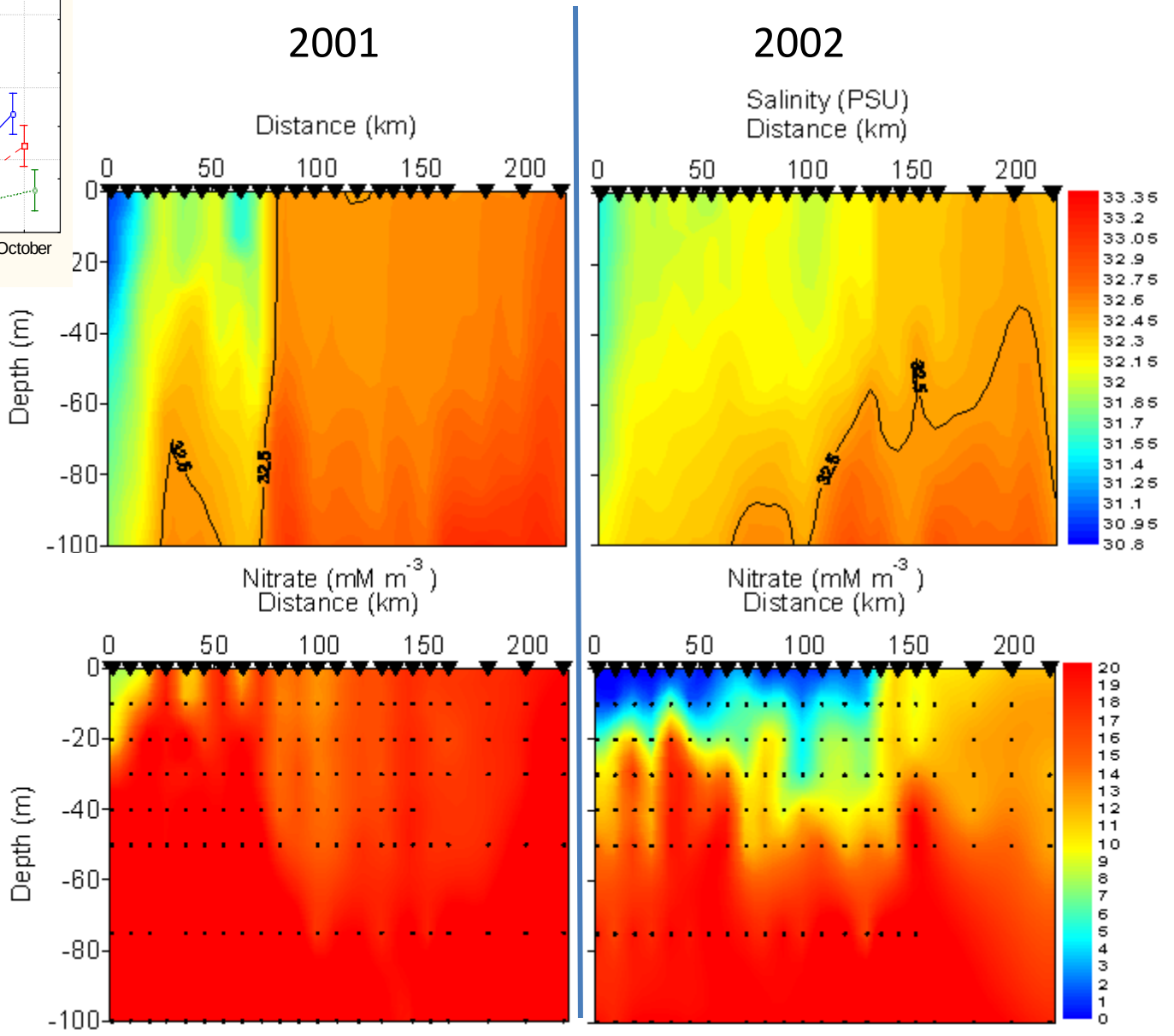
Error bars indicate 95% confidence intervals

Interannual Differences between nitrate utilization (2001 – 2002 & 2002 – 2003)



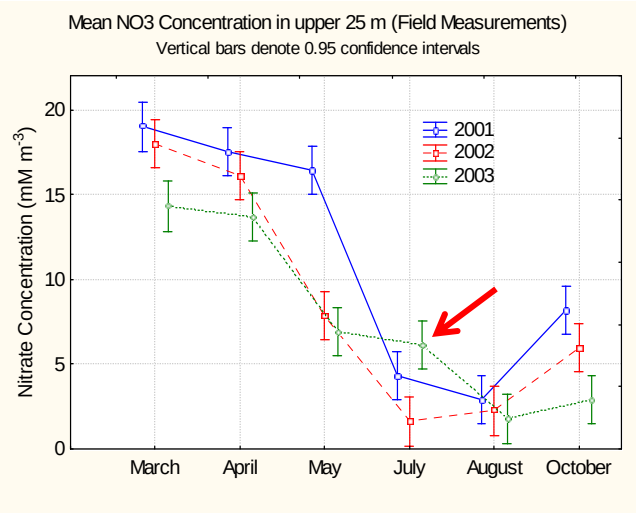
Seward Line Nitrate Concentration and Salinity in May



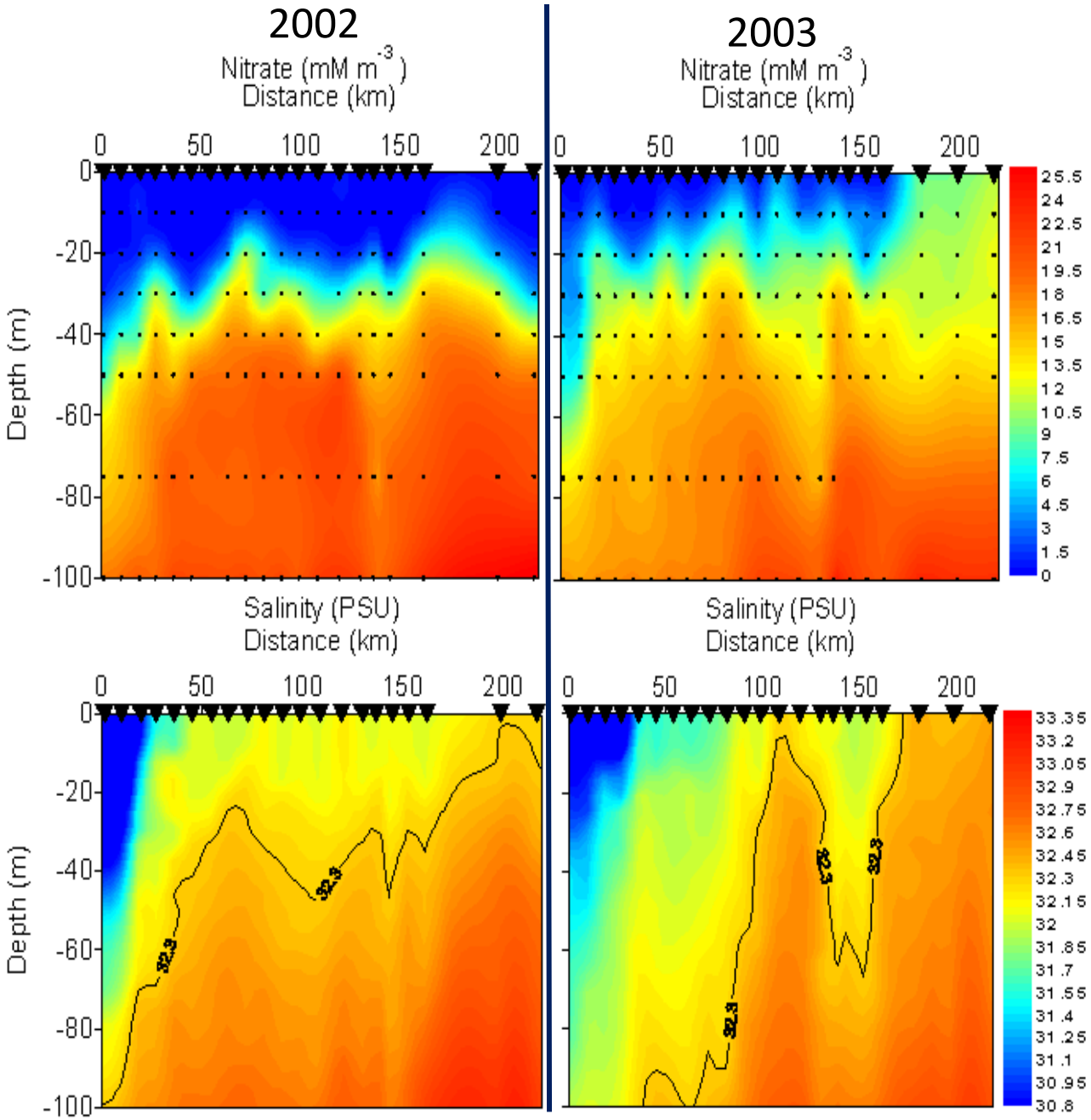


- 2001: Oceanic water advected into km 75.
- 2001: Little nitrate draw down into km 25.
- 2002: coastal water mixed across the surface to km 125.
- 2002: Nitrate near zero in surface water out to km 75.

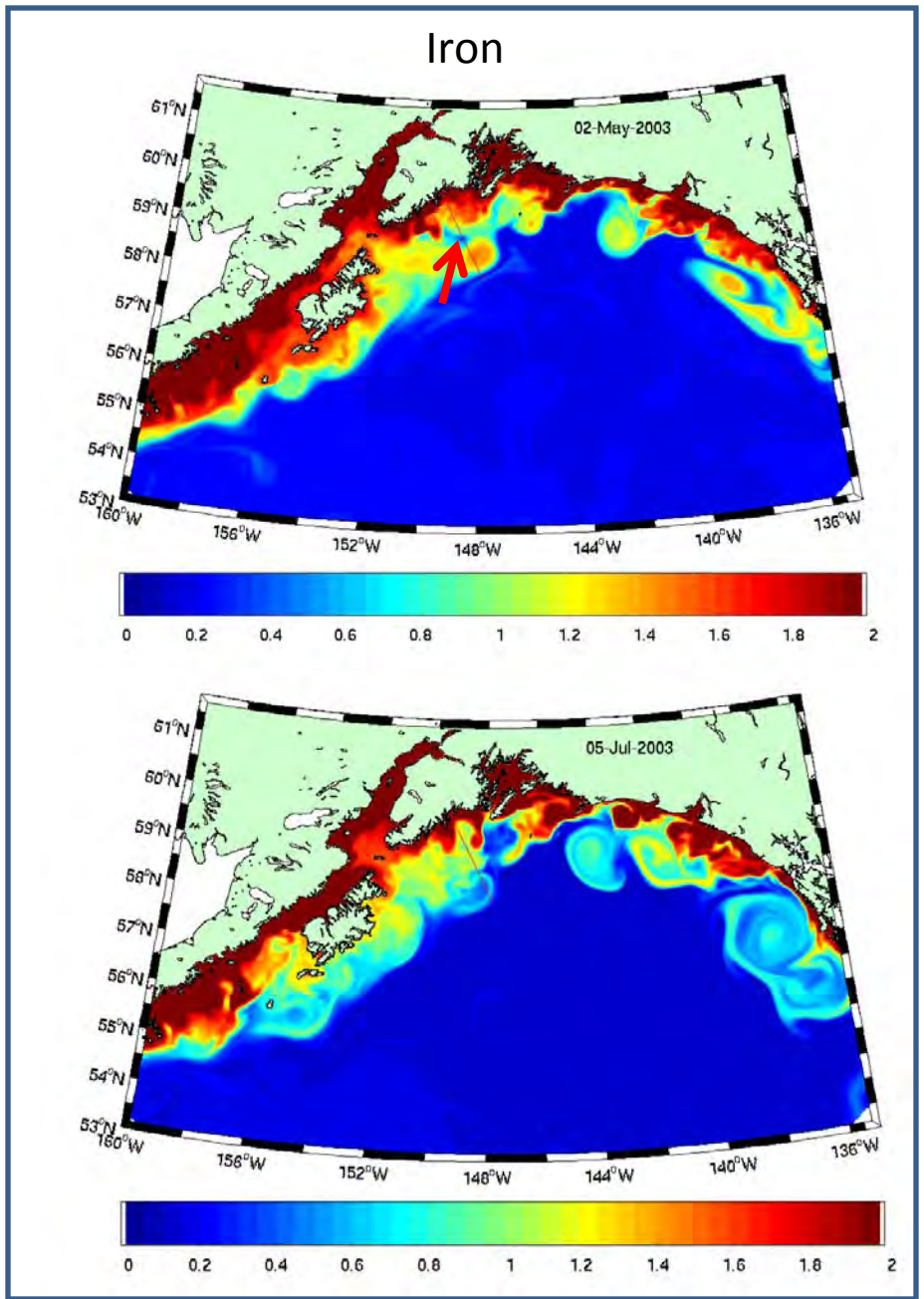
Seward Line Nitrate Concentration and Salinity in July

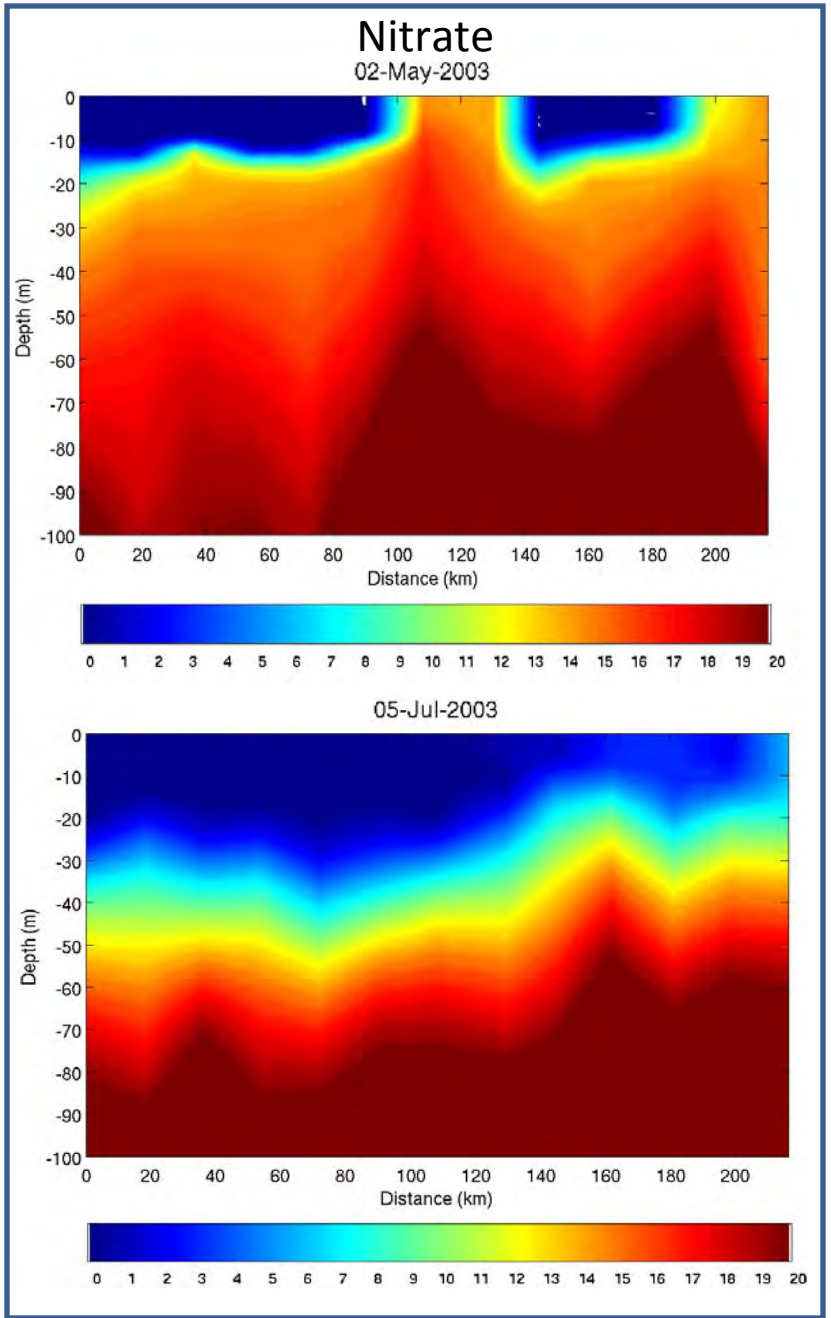


- 2002: Nitrate gone from upper water column along entire line.
- 2003: Nitrate present in surface and surface on outer and middle line.
- 2002: coastal water mixed across the surface to the end of the line.
- 2003: oceanic water near surface into km 100.

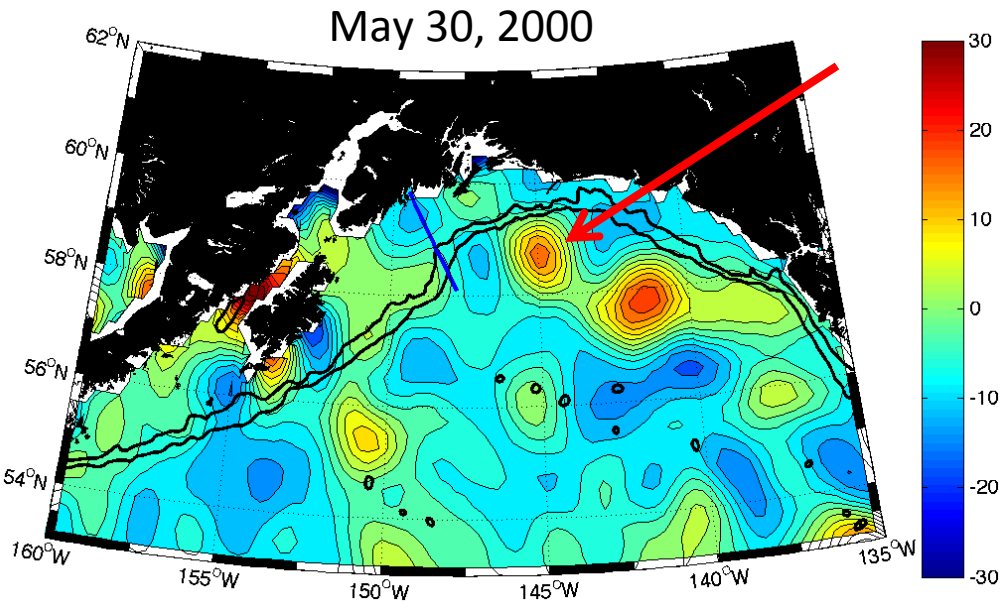


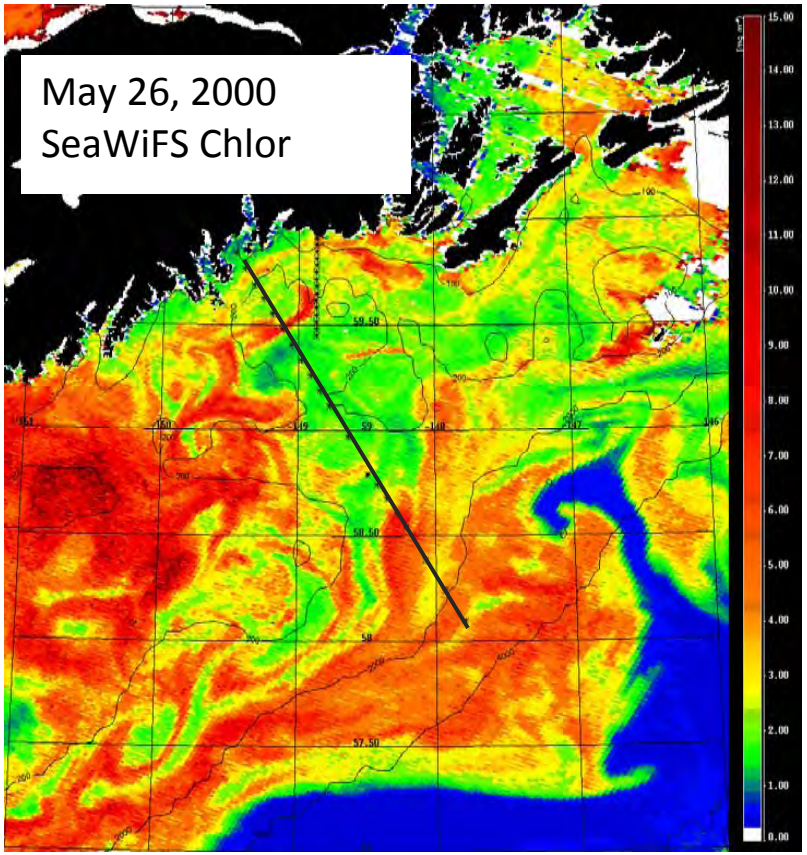
Simulated mean iron concentration in the upper 30 m and simulated nitrate sections along the Seward Line (arrow indicates iron poor water on shelf



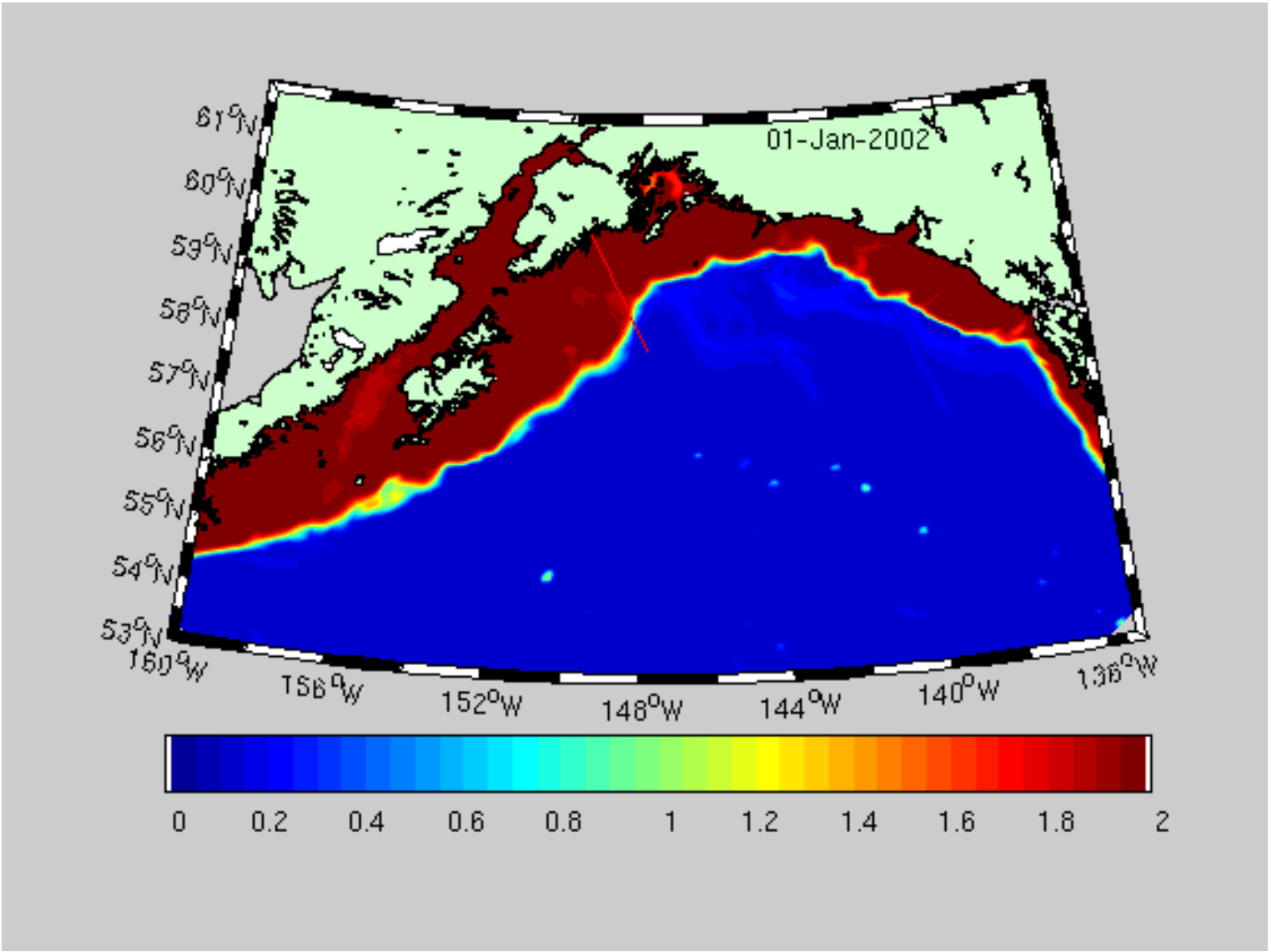


Satellite altimetry data showing an eddy near the Seward Line in May 2000; SeaWiFS chlorophyll data

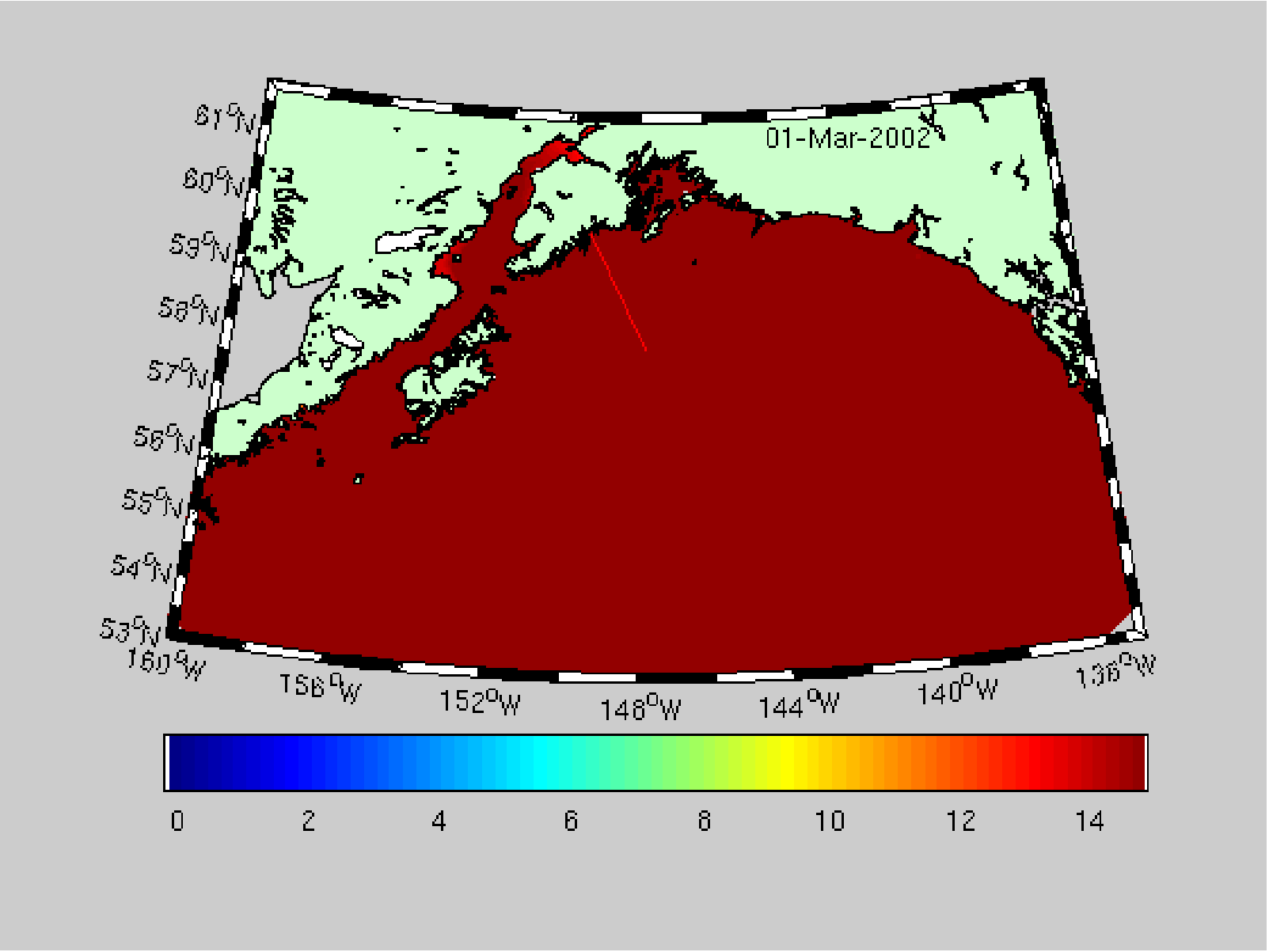




Mean Iron Concentration (nM) in the upper 30 m

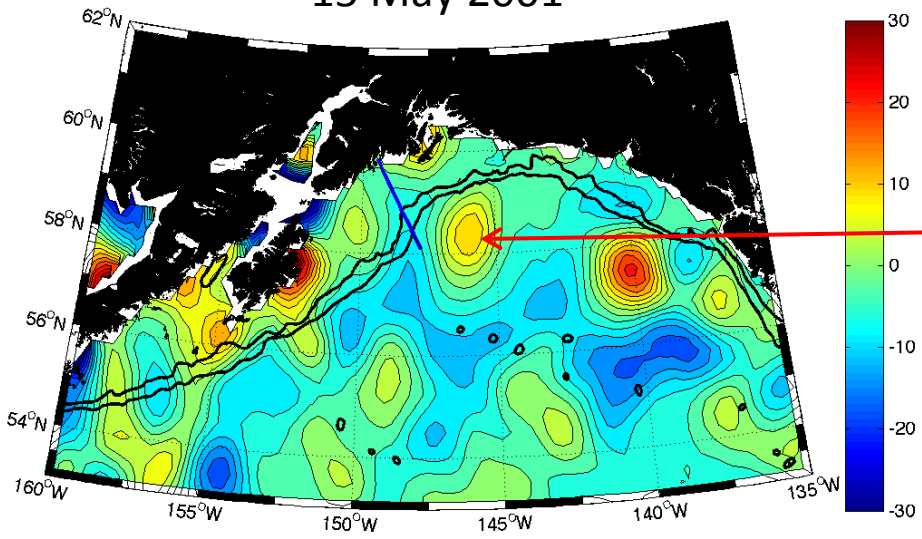


Mean Nitrate Concentration (μM) in the upper 25 m

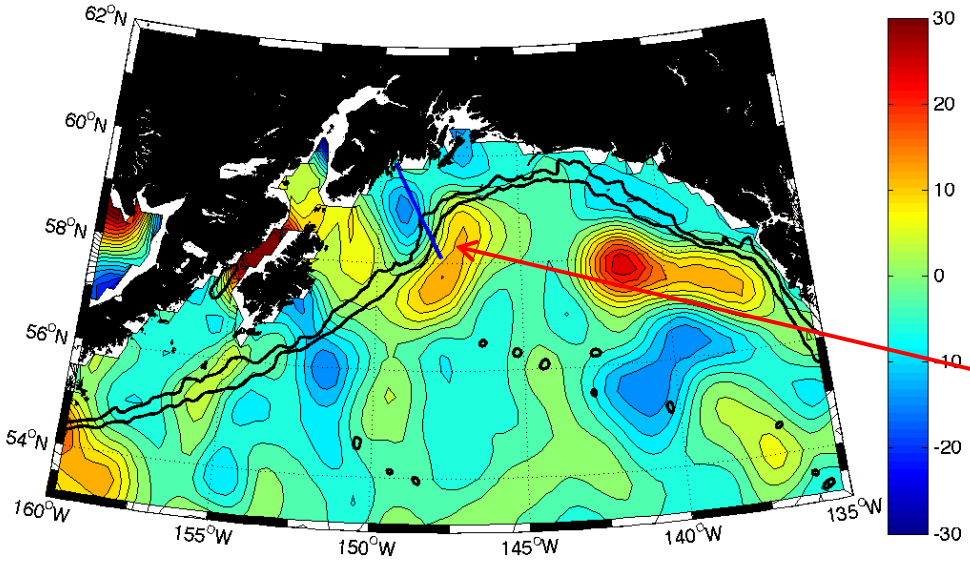


Satellite altimetry data May and July 2001.

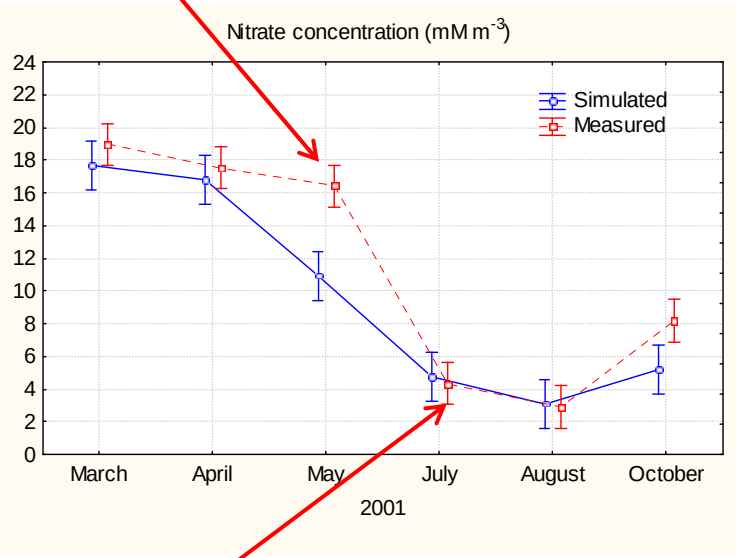
15 May 2001



30 June 2001



Eddy to the east of the Seward Line

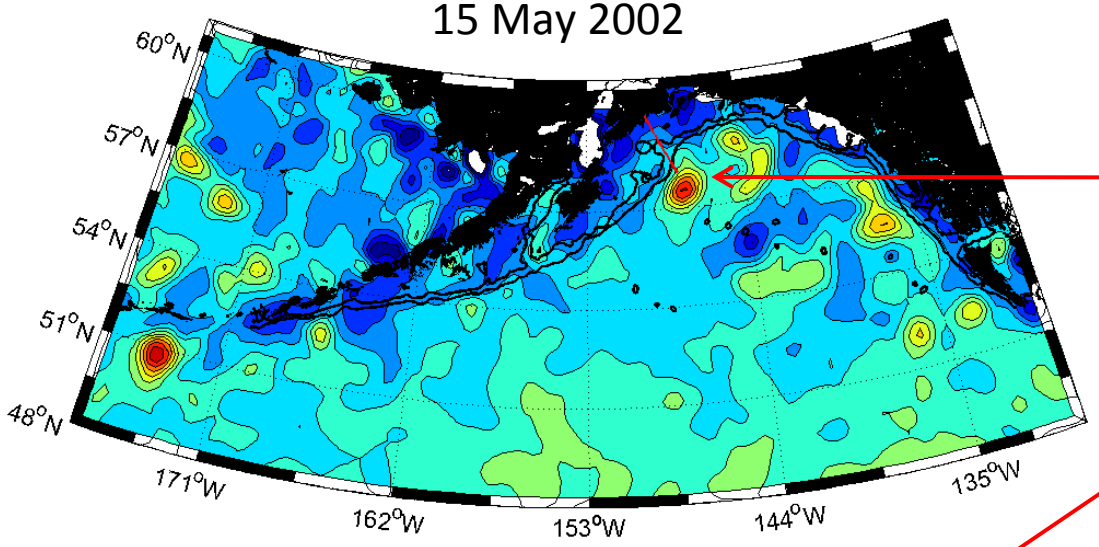


Eddy crossing the Seward Line

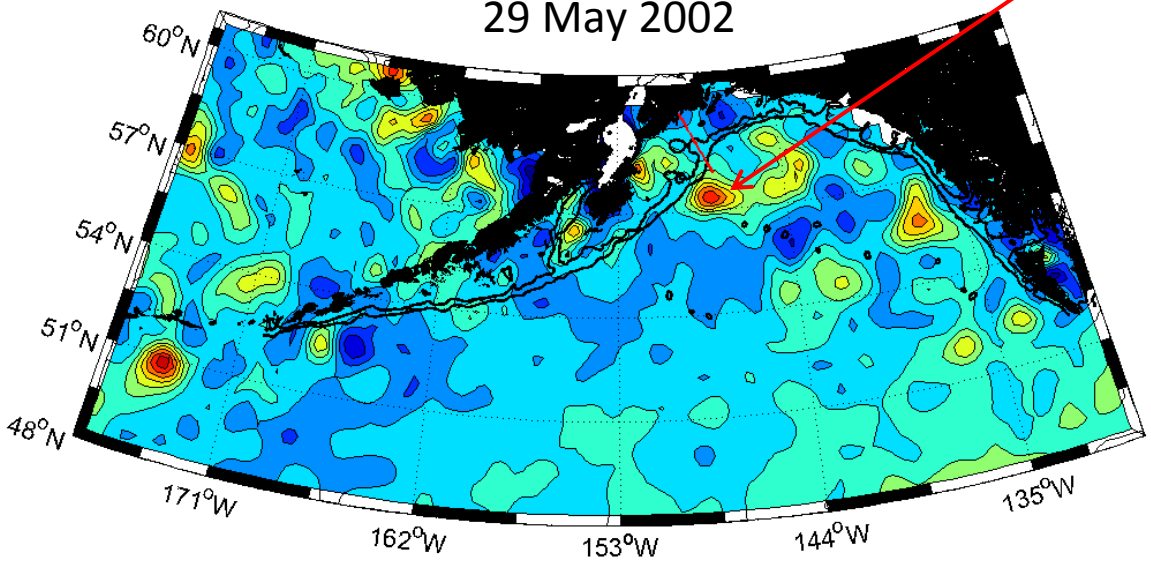
Satellite altimetry data in May 2002.

Plots provided by Markus Janout

15 May 2002

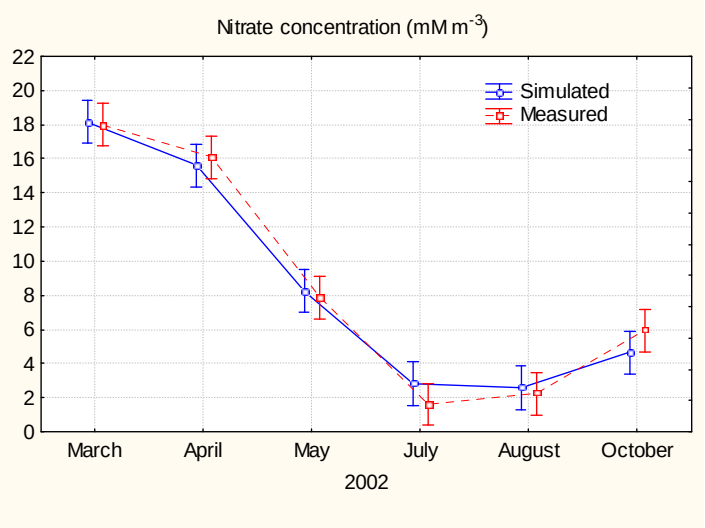


29 May 2002

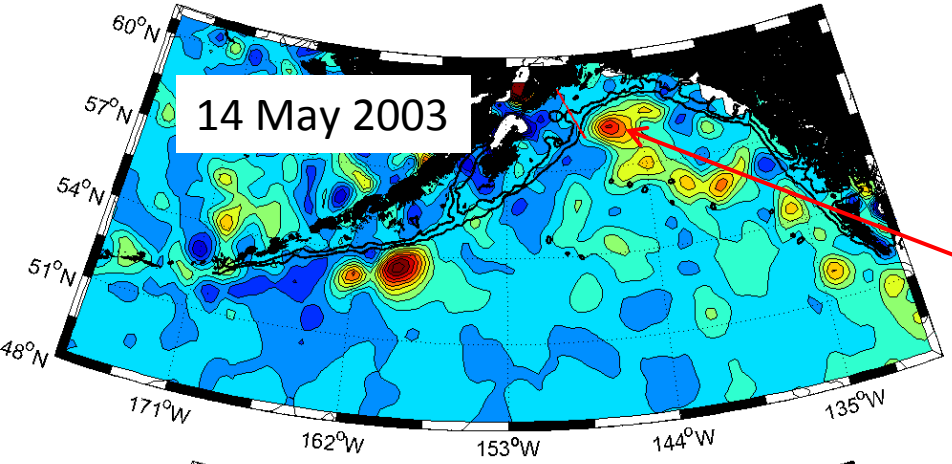


Eddy off the Seward Line potentially moving coastal water offshore.

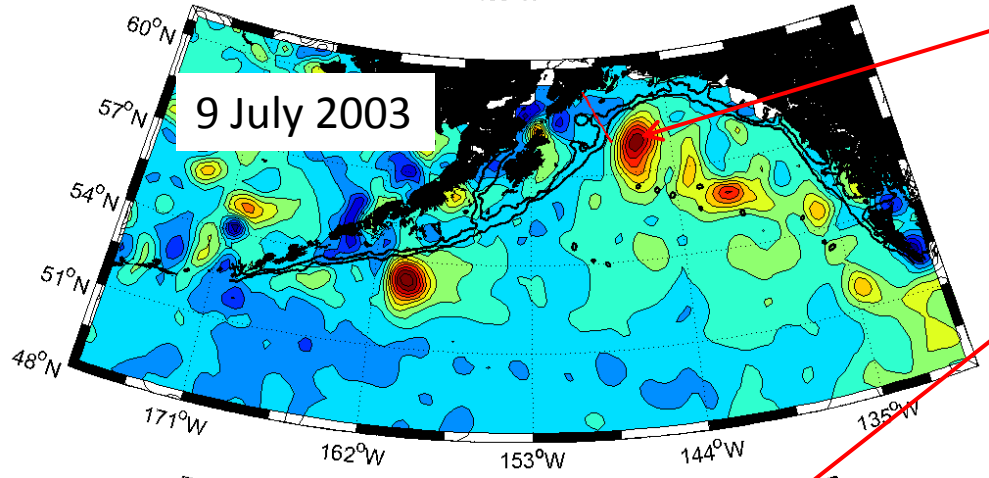
Eddy west of the Seward Line potentially moving coastal water offshore.



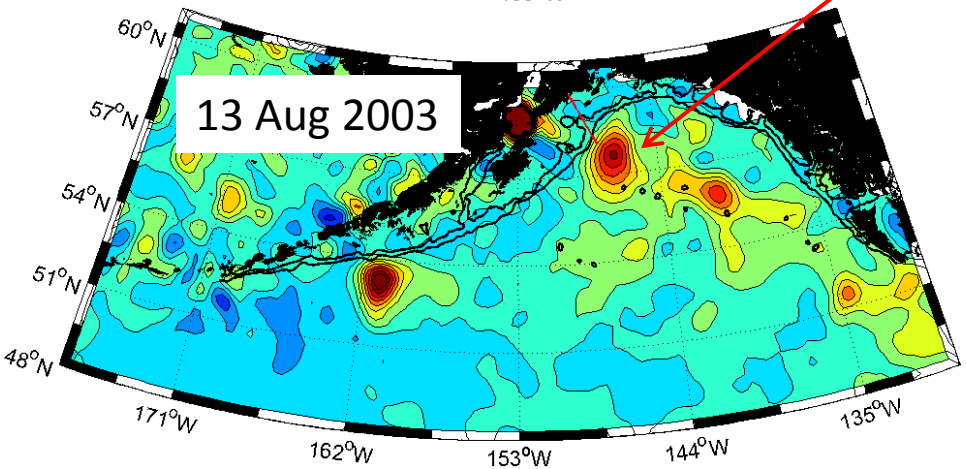
Satellite altimetry data May, July & August 2003.

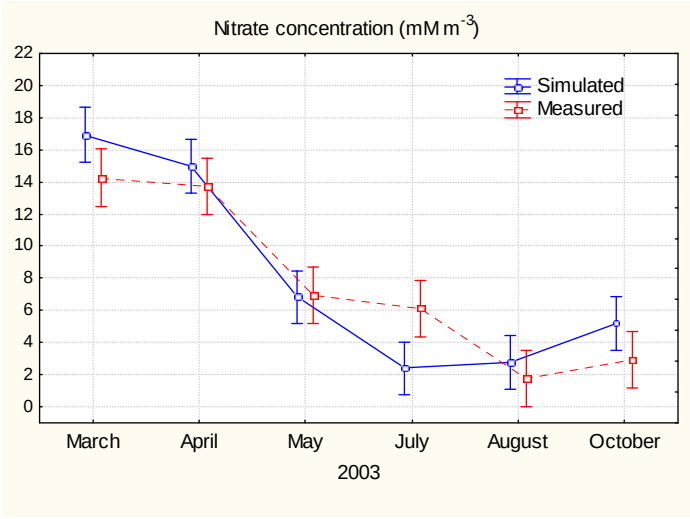


Eddy to the east of the Seward Line



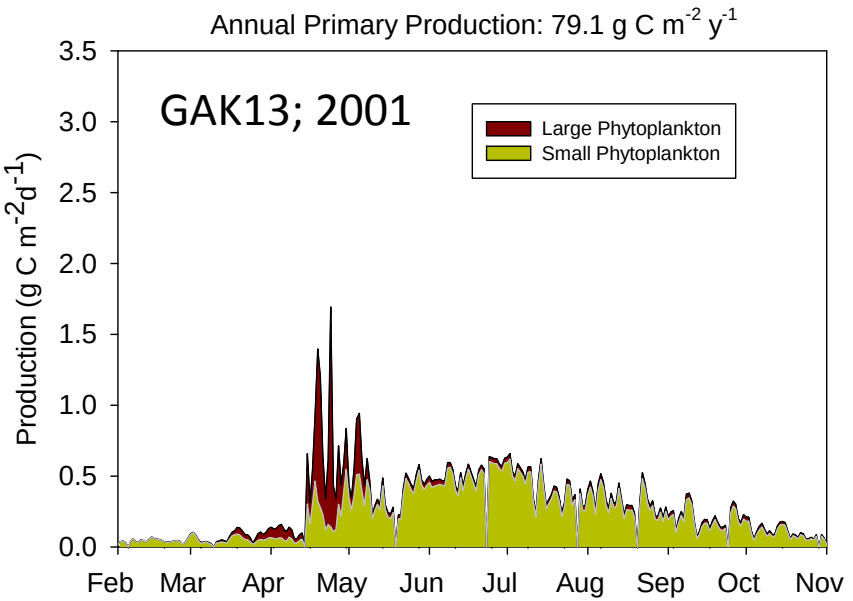
Eddy crossing the Seward Line



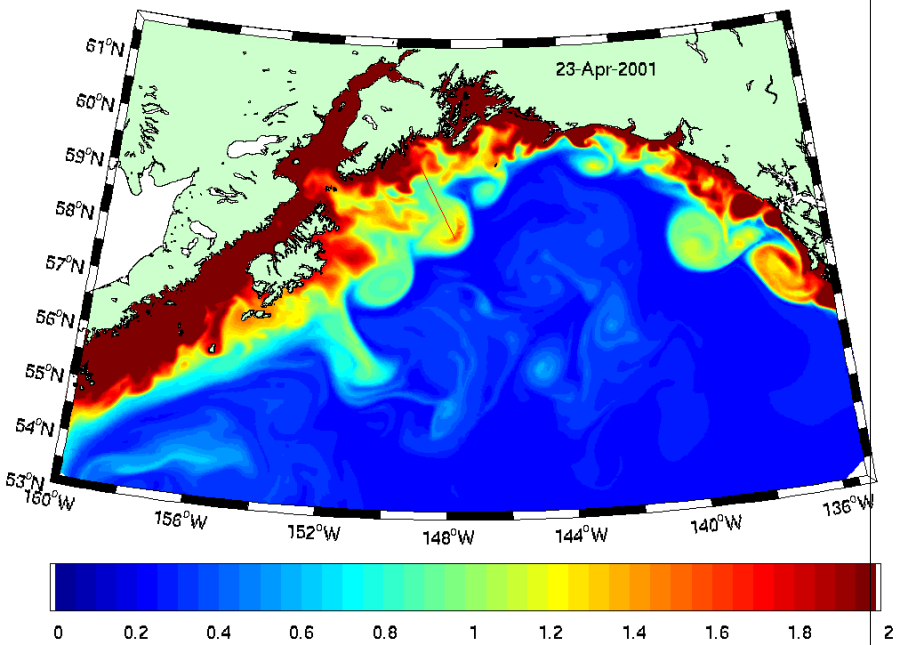


Simulated Primary and Mean Iron Concentration (nM) in the upper 30 m

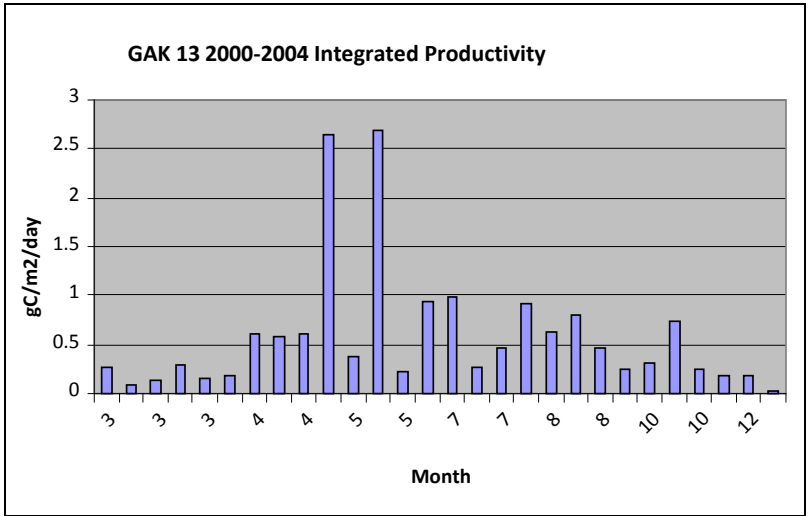
Simulated Primary Production



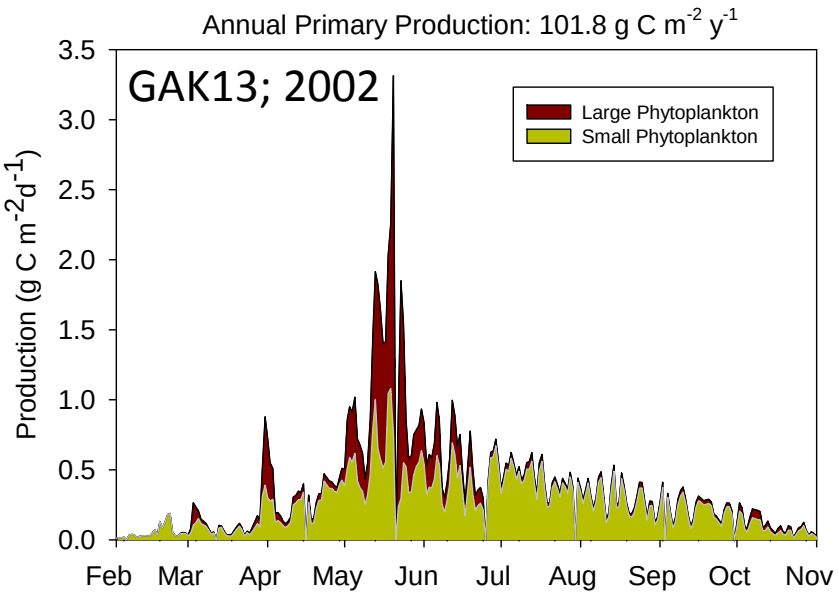
Simulated Iron Concentration

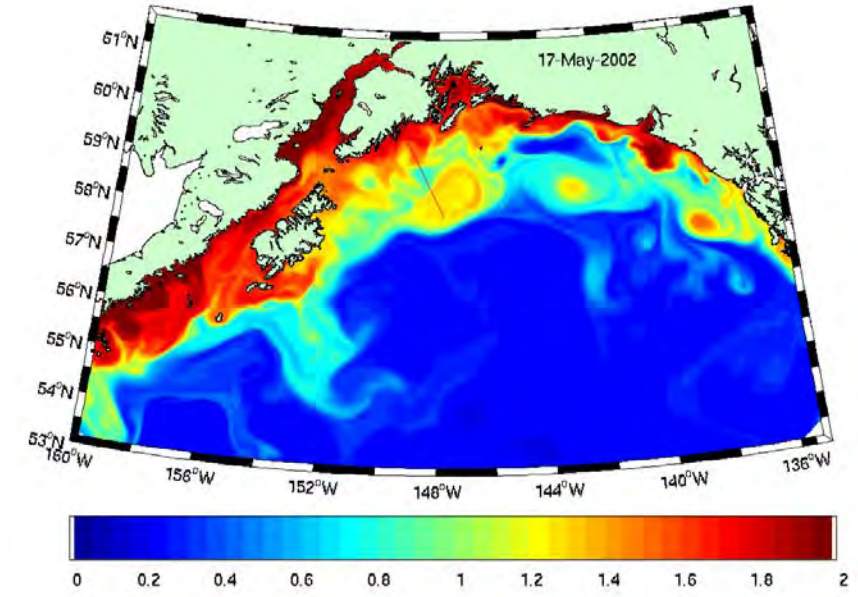


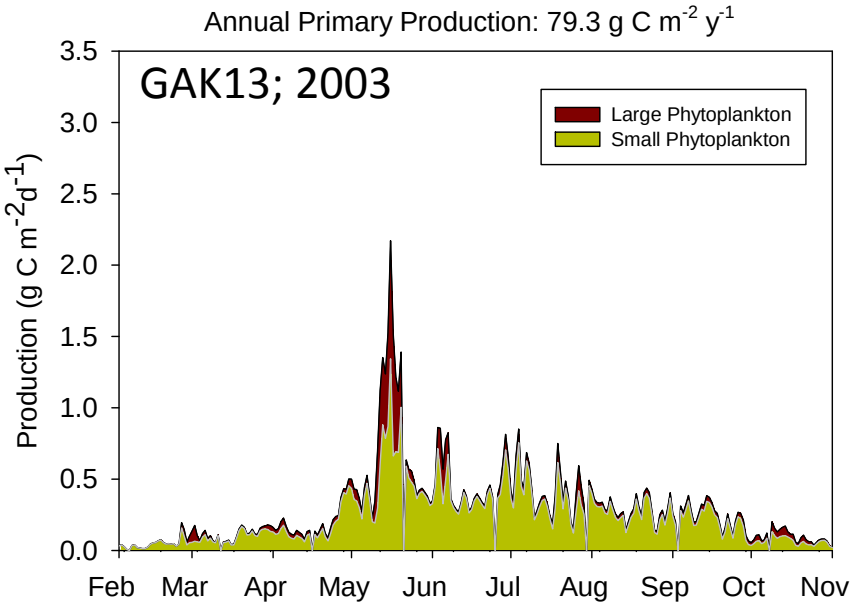
Measured primary production for 2000 to 2004 at the outer end of the Seward Line by month (slide from Whitledge)

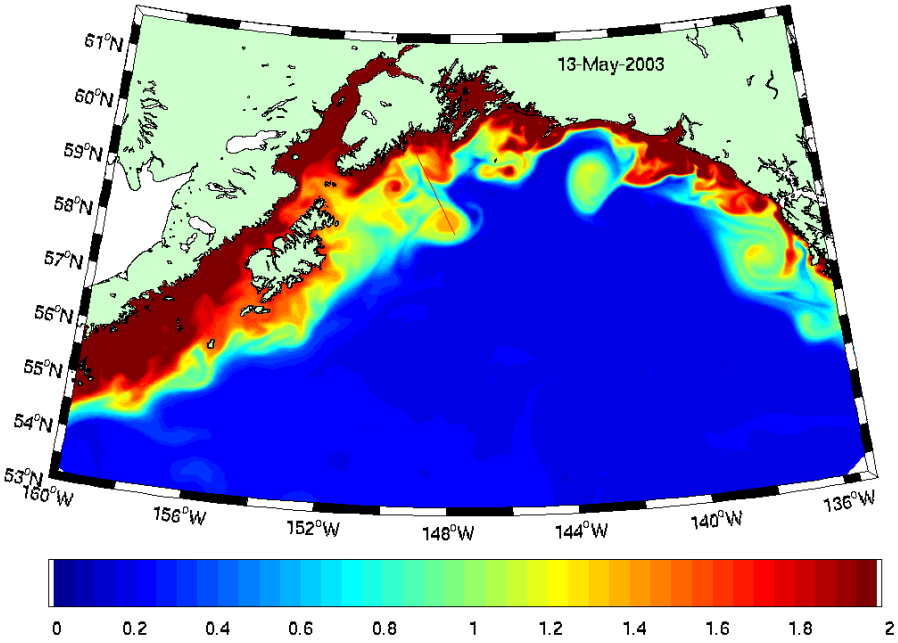


Simulated Primary and Mean Iron Concentration (nM) in the upper 30 m



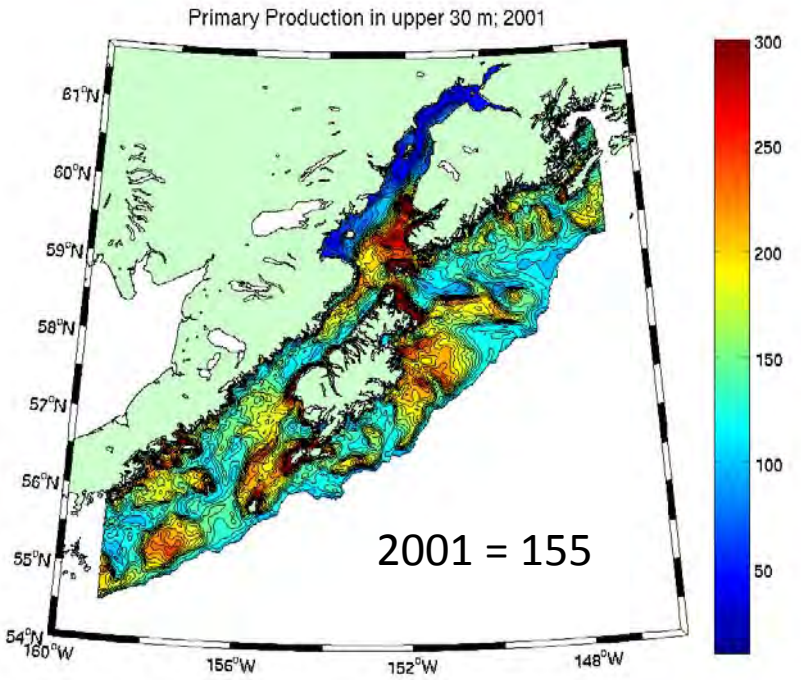


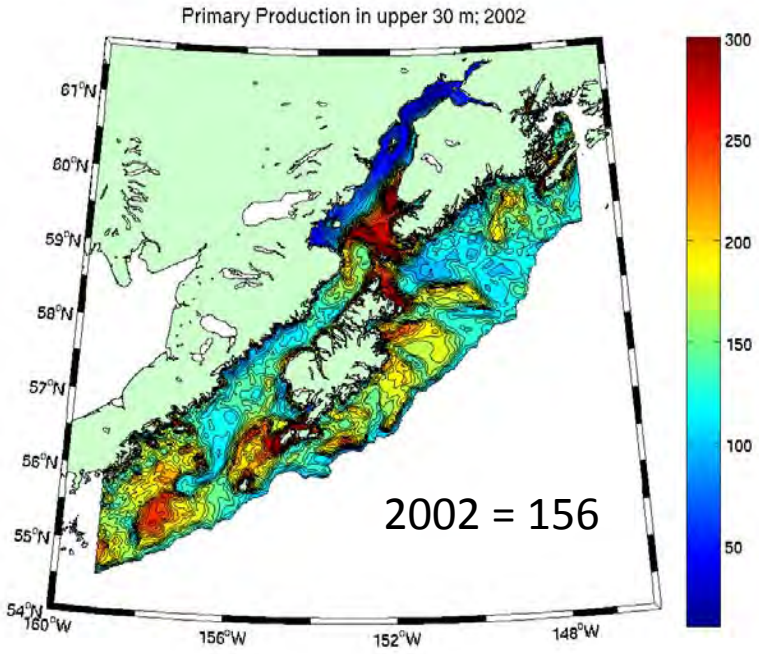


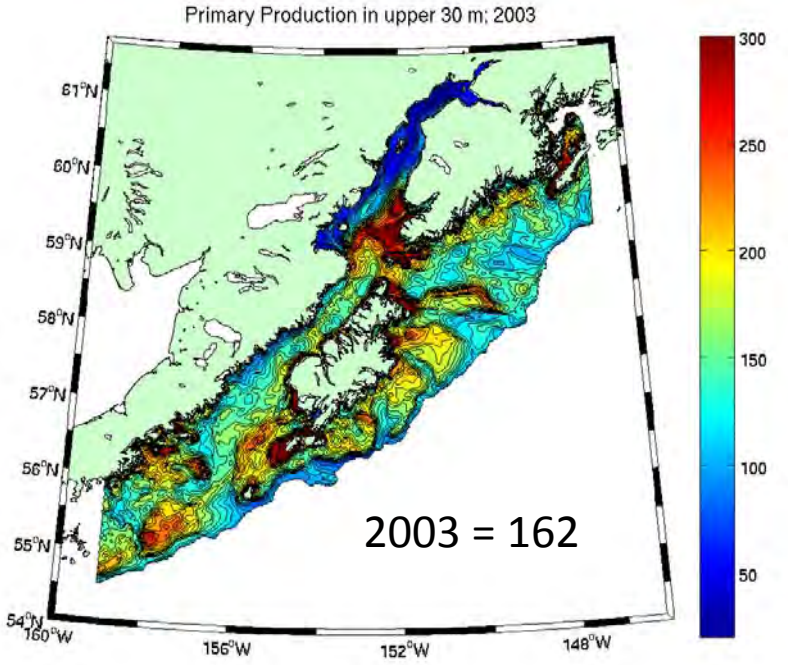


Western Shelf Region, simulated annual production (g C m^{-2} y^{-1}) on the shelf:
(bottom depth < 300 m)

Literature values: 100-300 (Sambrotto and Lorenzen, 1987)







Summary

1)Iron is critical to simulating the GOA shelf ecosystem. Iron must be added with freshwater to get a production cycle similar to observations.

2)The forcing files must capture the annual cycle of freshwater runoff.

3)The timing and intensity of the spring bloom on the GOA shelf is highly influenced by circulation features (eddies and meanders) moving iron-poor oceanic and iron-rich eddy water westward along the outer shelf and shelf break.

4)Simulations of the seasonal production cycle can be improved if the forcing files can be refined to more accurately simulate the location and intensity of eddies and meanders affecting cross-shelf circulation.

5)Production

Between the Shumagins and PWS: about 155 - 165 g C m^{-2} y^{-1}
Lower Cook Inlet: up to 300 g C m^{-2} y^{-1}
Portlock Bank – Kodiak: up to 300 g C m^{-2} y^{-1}