# Eddies in the Gulf of Alaska

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# Outline

- Background
- Interannual variability
  - Eddy Kinetic Energy
  - Propagation patterns
- Influence of eddies on ecosystem
  - Nutrients
  - Chlorophyll/Phytoplankton
  - Zooplankton
  - Larval fish
- Summary/Conclusions



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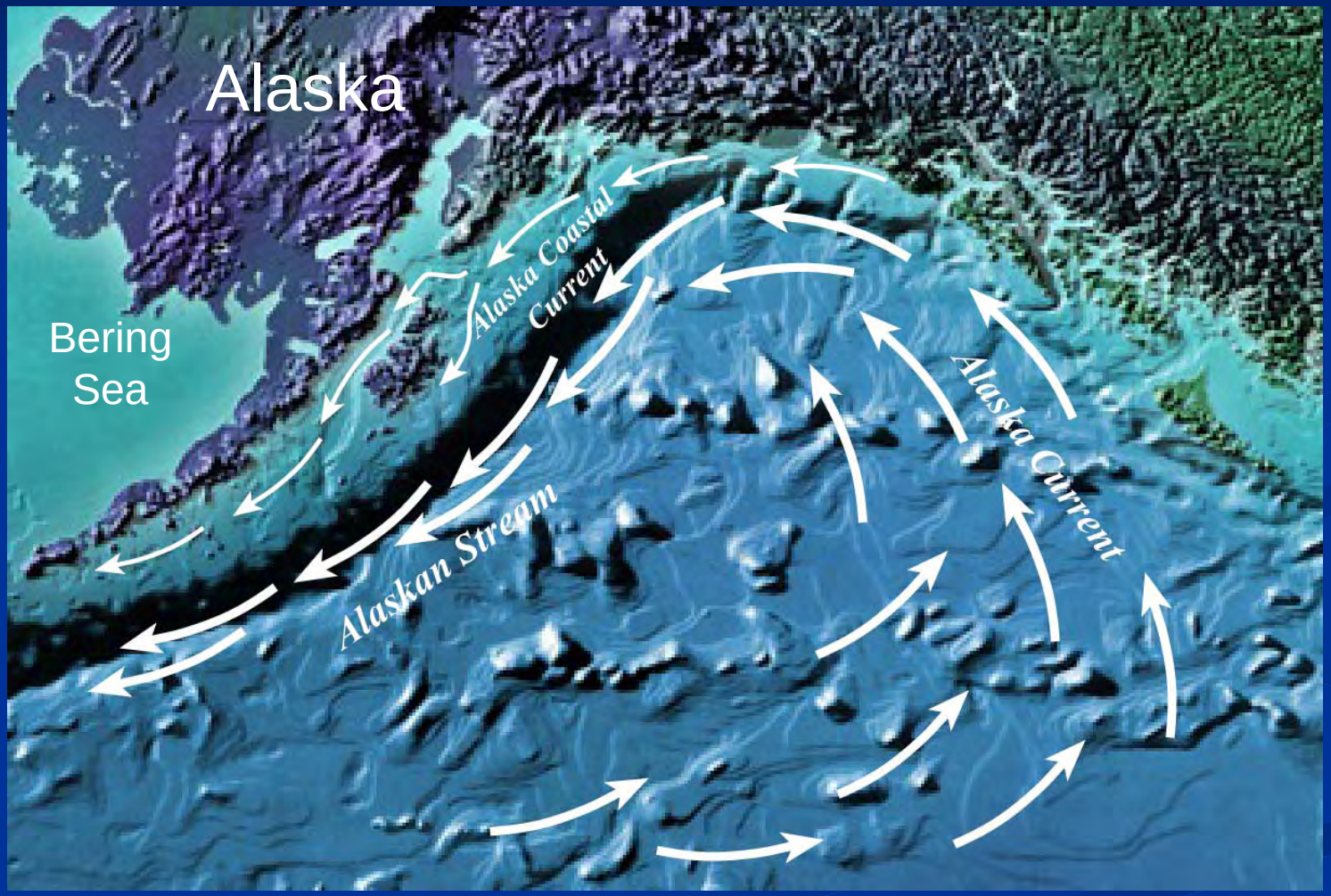
# Gulf of Alaska Circulation



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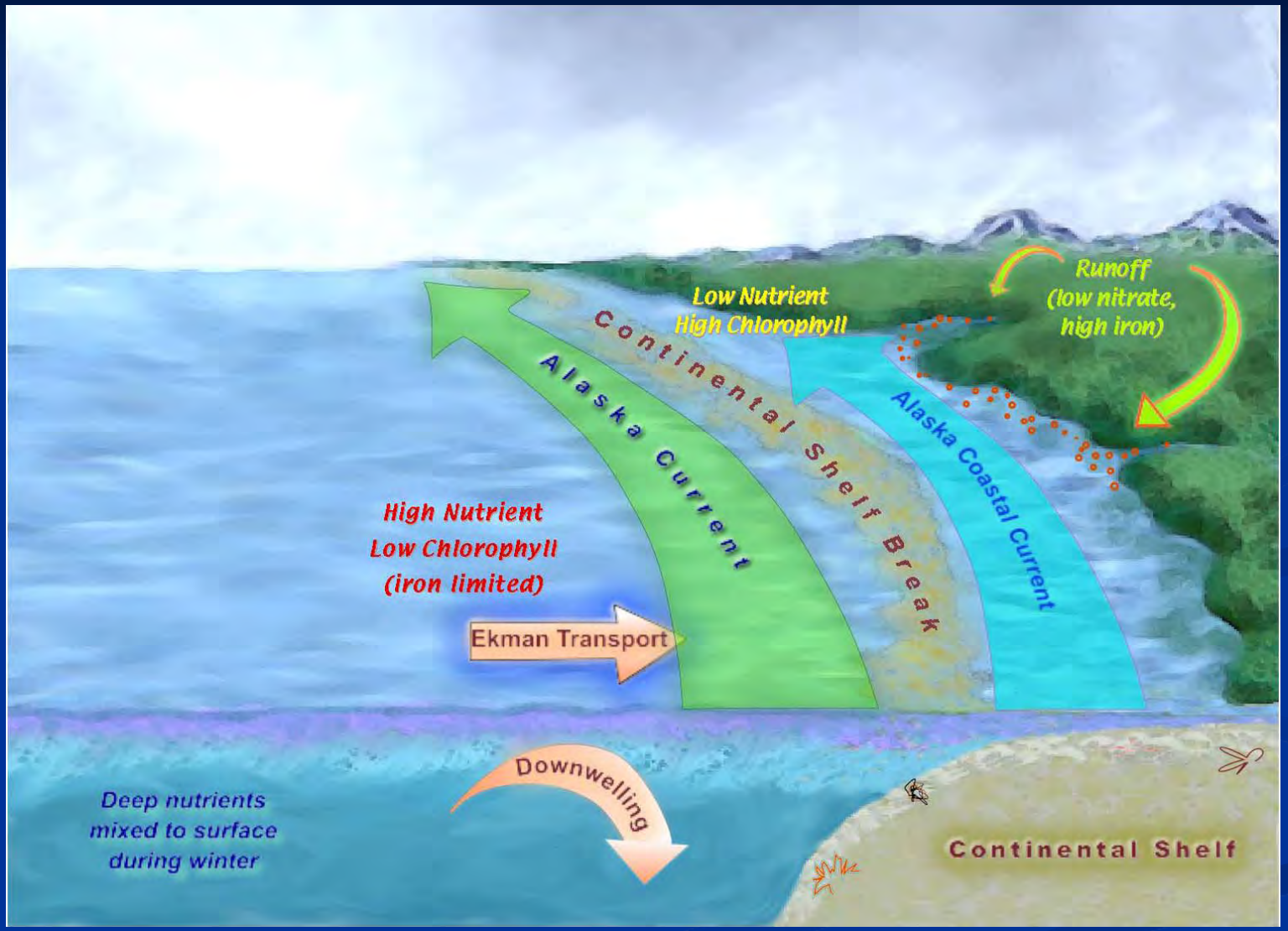
# Nutrient Limitation in the GOA



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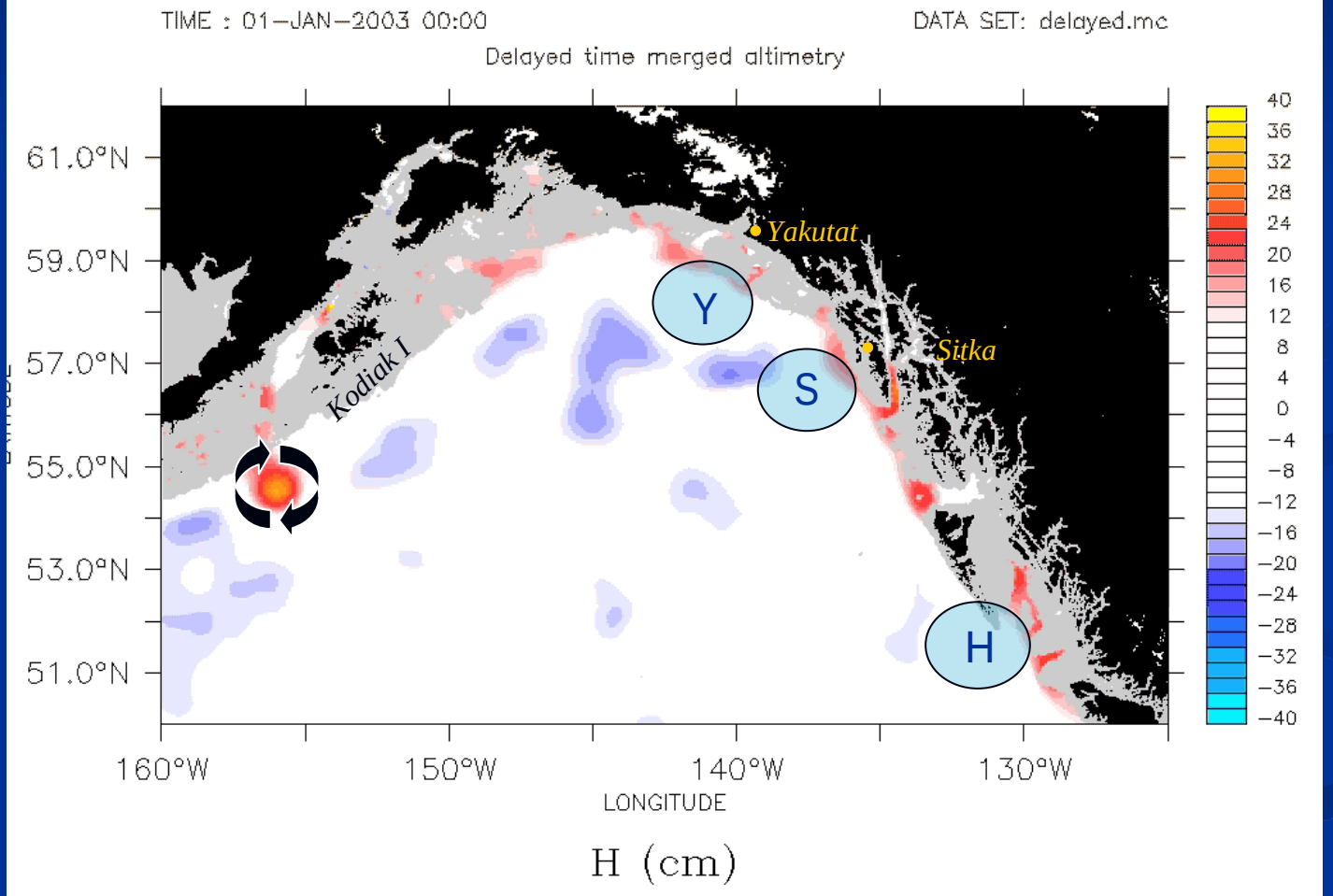
# Movie – sea surface height

= Formation regions (Yakutat, Sitka, Haida)



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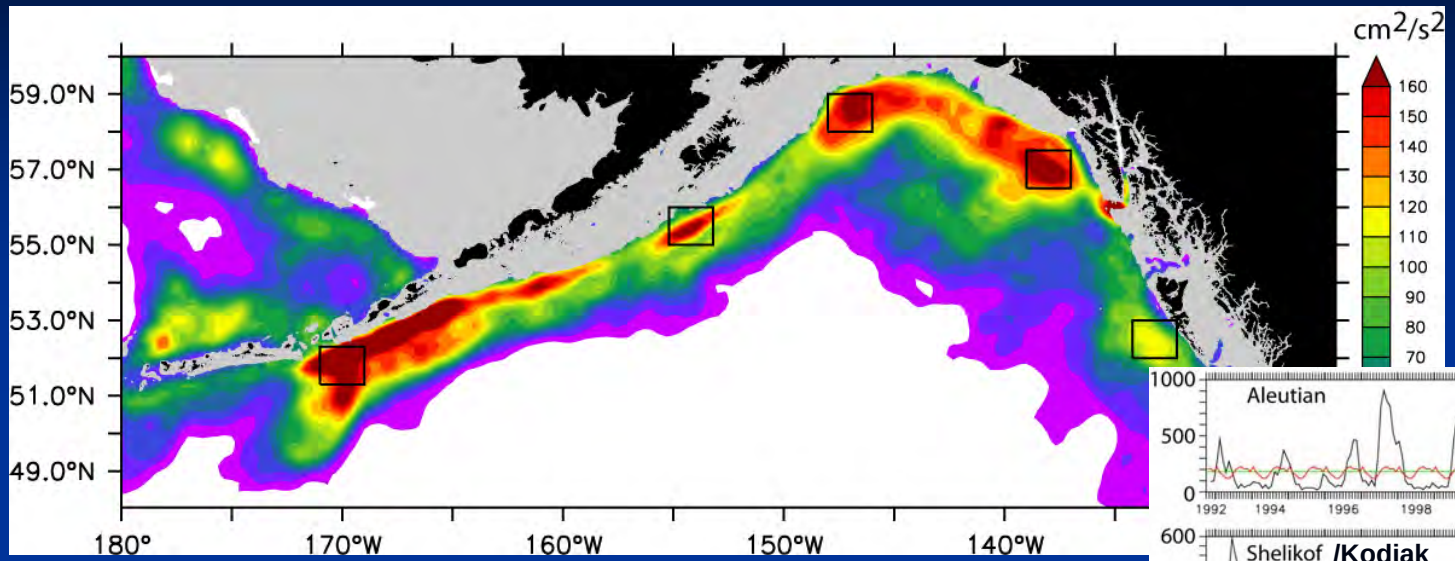
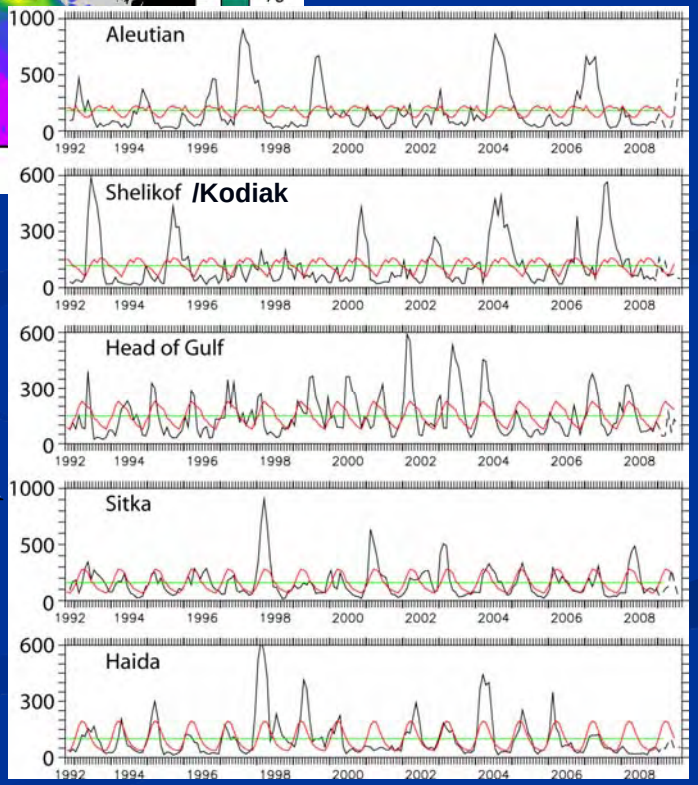
# Variability – Eddy Kinetic Energy




- Formation regions/ Translation pathways
- Seasonality (strong seasonal cycle in east, weaker in west)
- 1998 El Niño (Haida and Sitka eddies)



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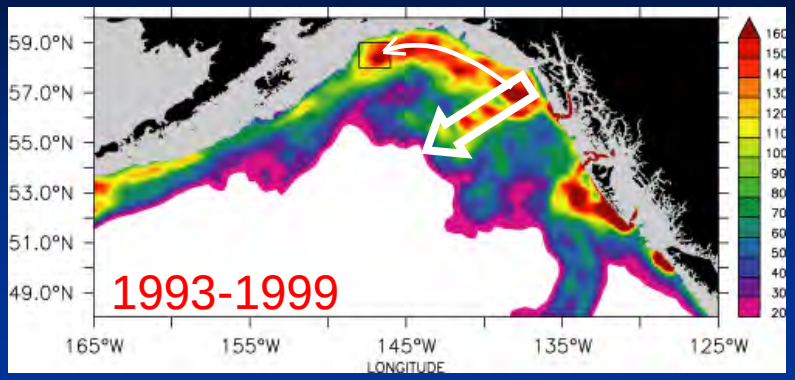
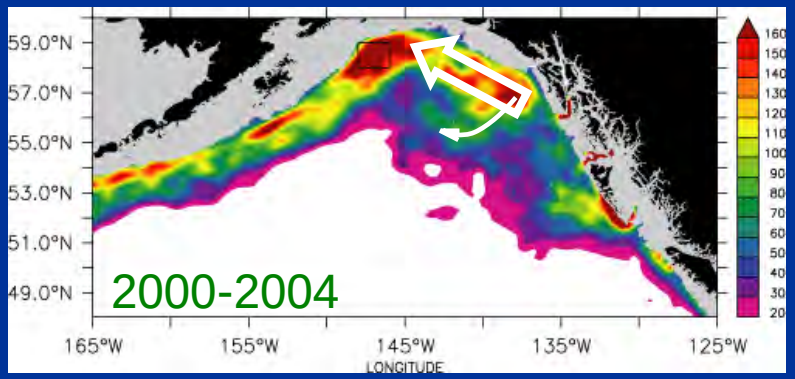
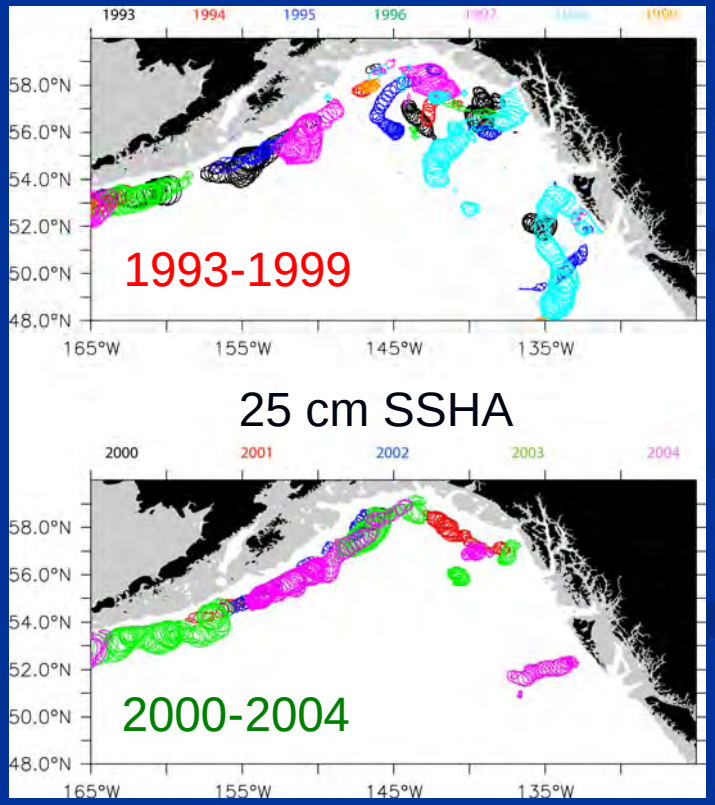
# Variability – Eddy Pathways




**1993-1999:**

- Weaker gyre circulation
- More eddy propagation into basin; less propagation along slope




**2000-2004:**

- Stronger gyre circulation (Volkov & van Aken, 2005)
- More eddy propagation along slope



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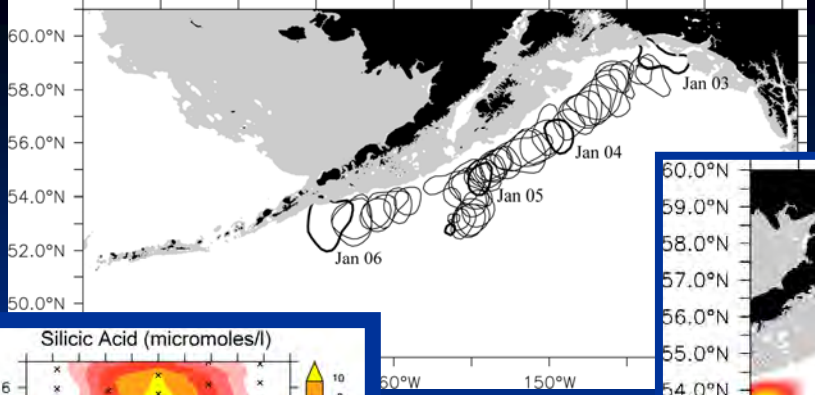
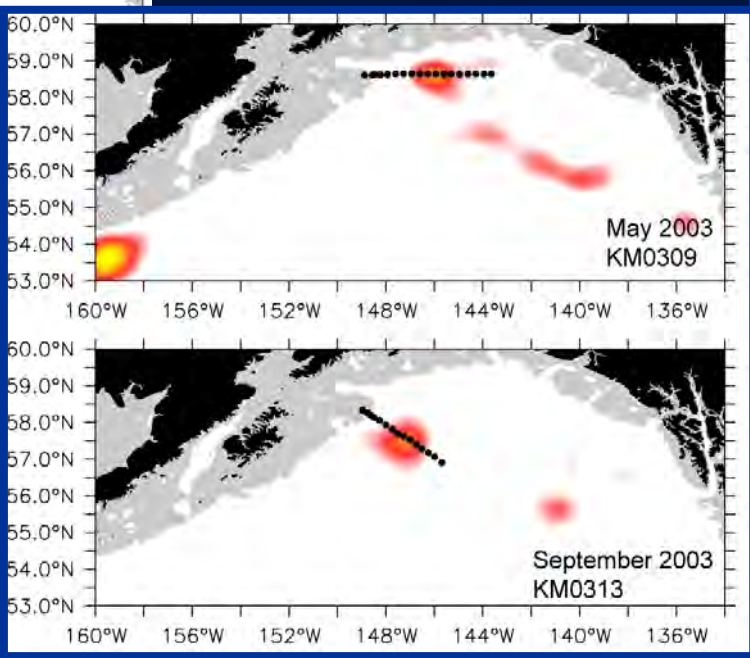
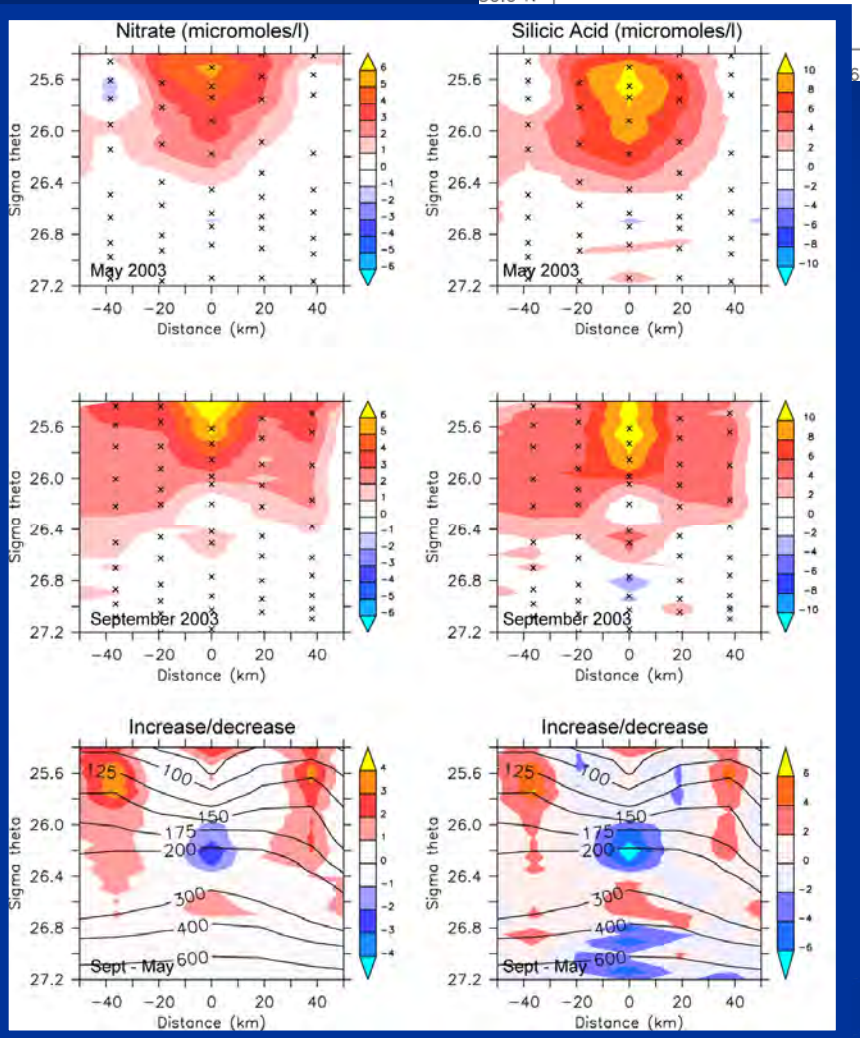
# Nutrients




- Positive nitrate and silicate anomalies
- From May to Sept, nitrate anomalies increase in eddy ring
  - due to remineralization?
  - High remineralization from excess production in eddy ring?



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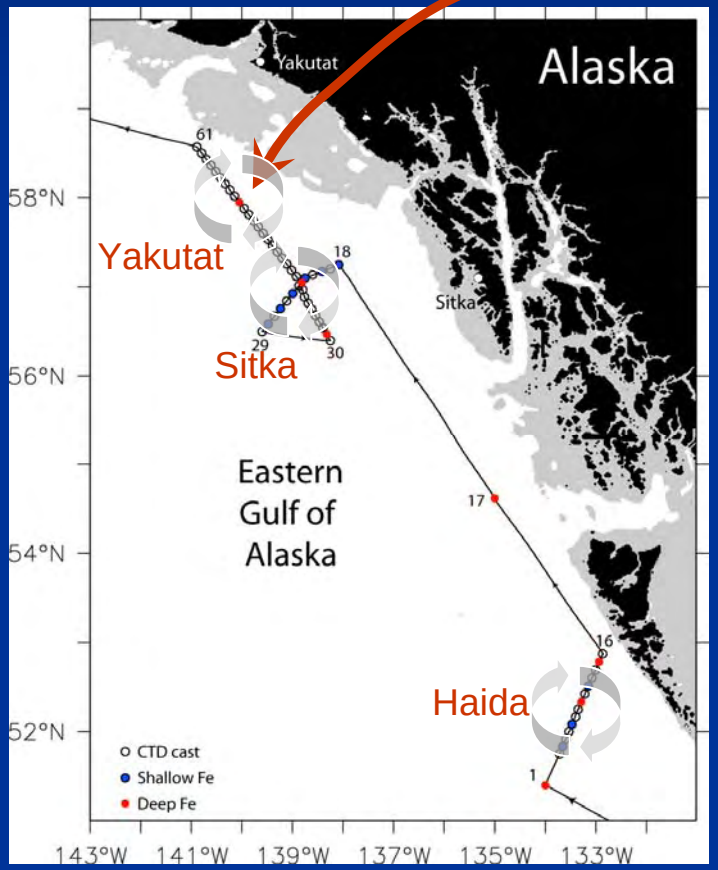
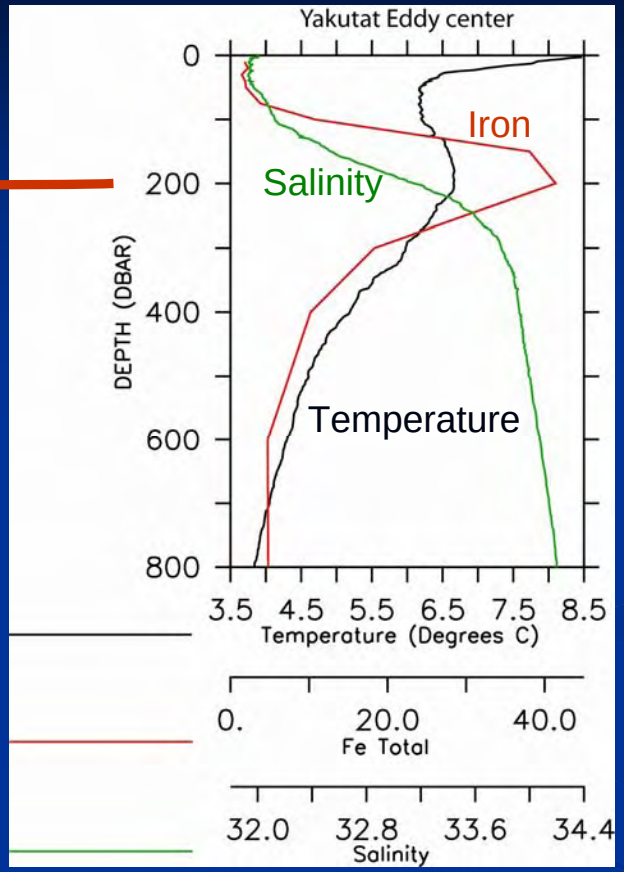
# Temperature inversion and Fe

- 2005 Yakutat Eddy observed soon after formation




- Iron maximum at 200m coincident with temperature inversion
- Eddies may be instrumental in carrying iron off-shelf



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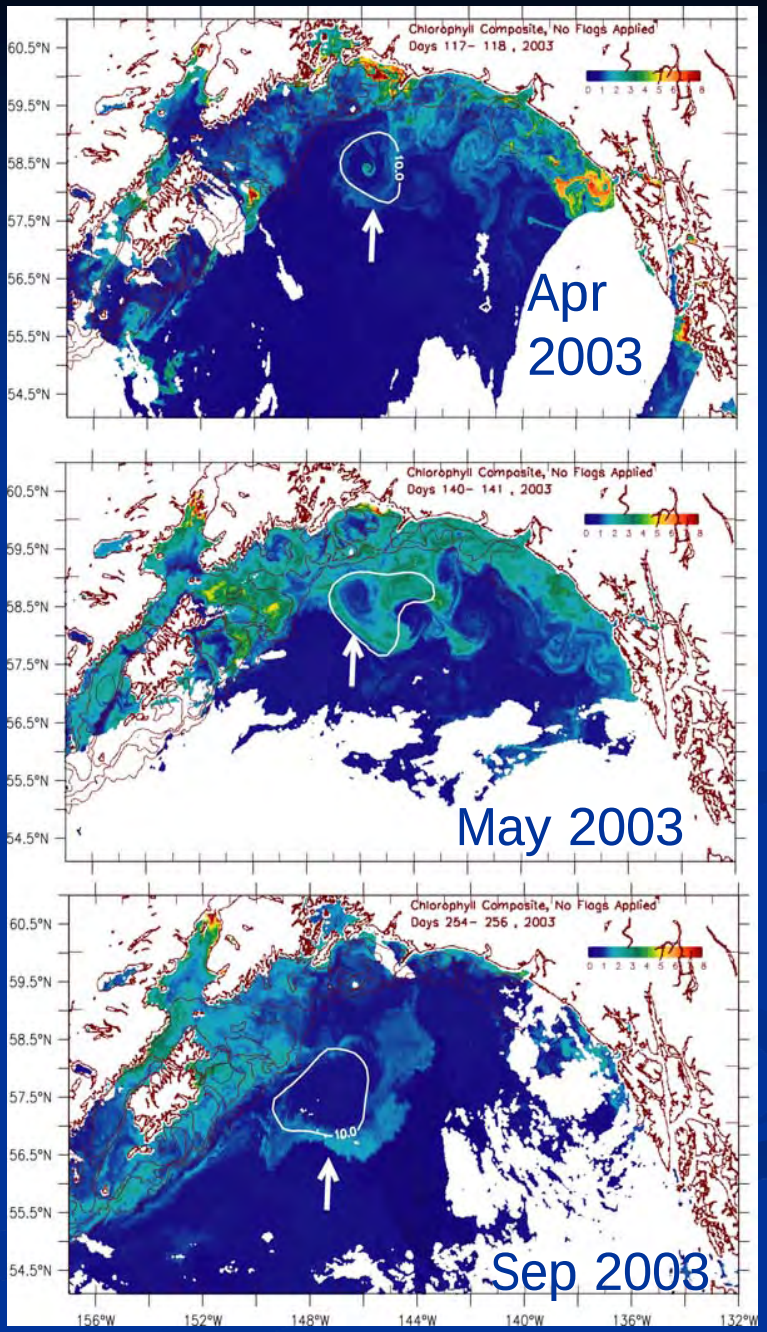
# Chlorophyll

Influence of eddies on chlorophyll (phytoplankton) distributions may be due to:

- Advection of coastal chlorophyll into basin
- Vertical processes within the eddy supplying macronutrients and/or iron to euphotic zone.



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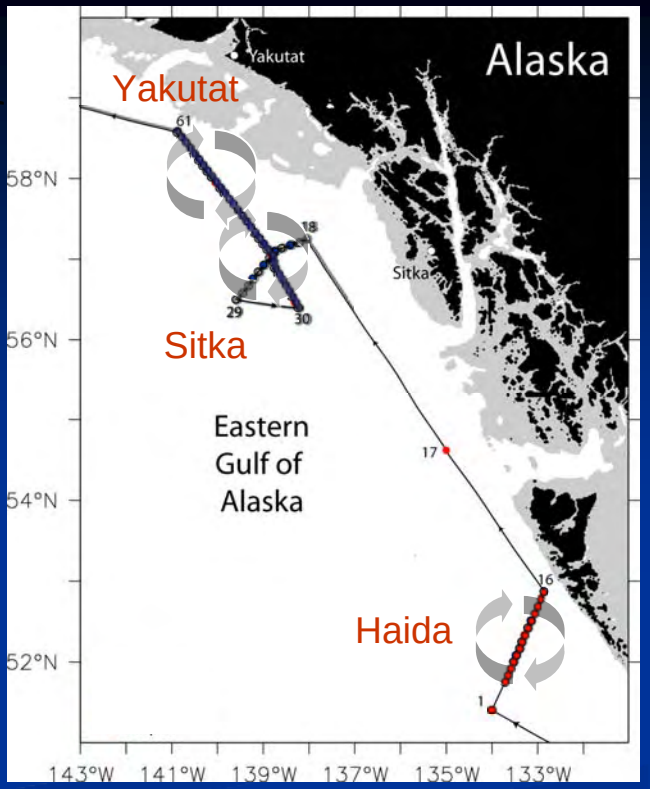
# Zooplankton & Phytoplankton

Offshore-SW Eddy Center Onshore-NE

Zooplankton sampling across Haida Eddy (SW-NE)




- Zooplankton assemblages significantly different between Haida and Sitka eddies (mostly due to higher abundances in Sitka eddy)
- No significant differences between zooplankton assemblages at edge and center stations



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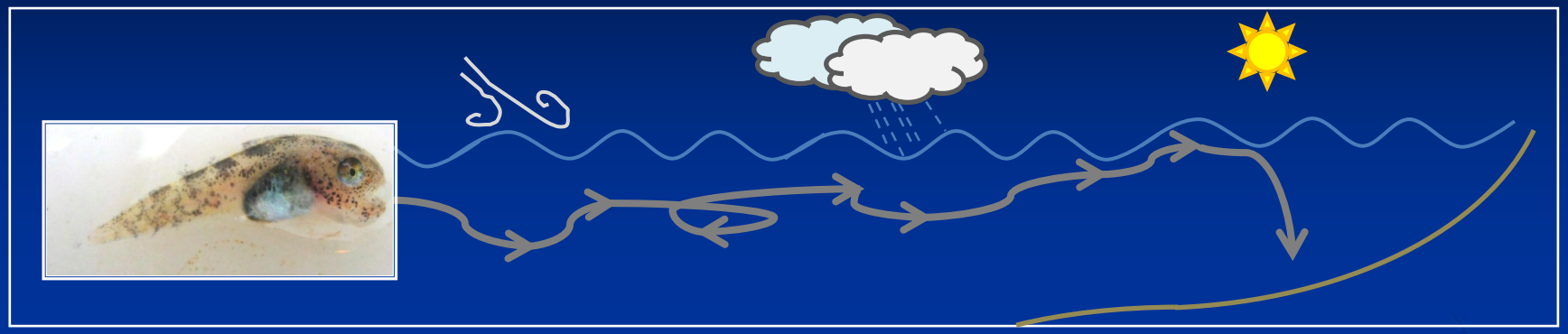
# Influence of eddies on larval fish



- Valuable fisheries in the Gulf of Alaska include
  - Deep-water spawners (Pacific halibut)
  - Shelf spawners (Walleye pollock, Pacific cod)
- Larval dispersal influences growth, survival, and recruitment
- Eddies may impact dispersal trajectories (and/or other conditions necessary for growth/survival)



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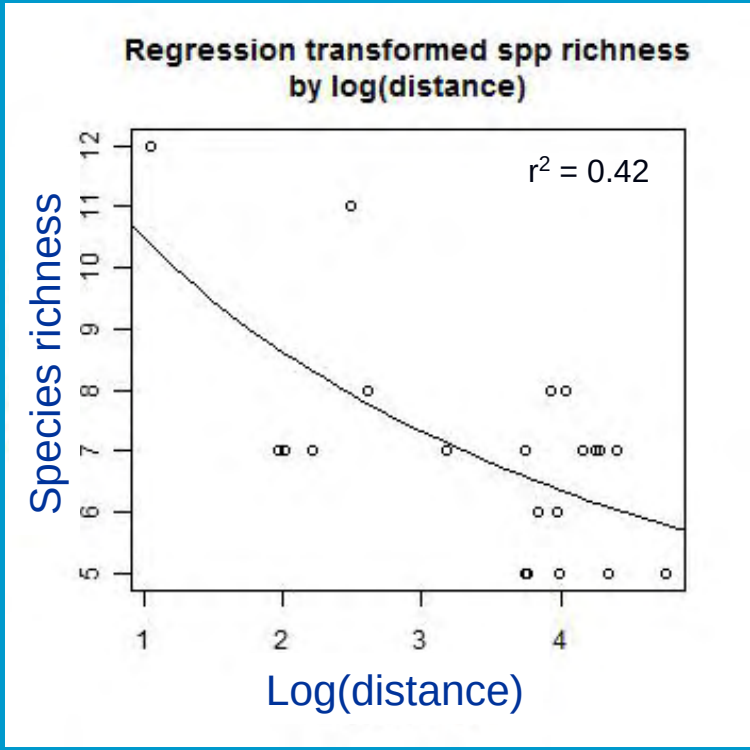
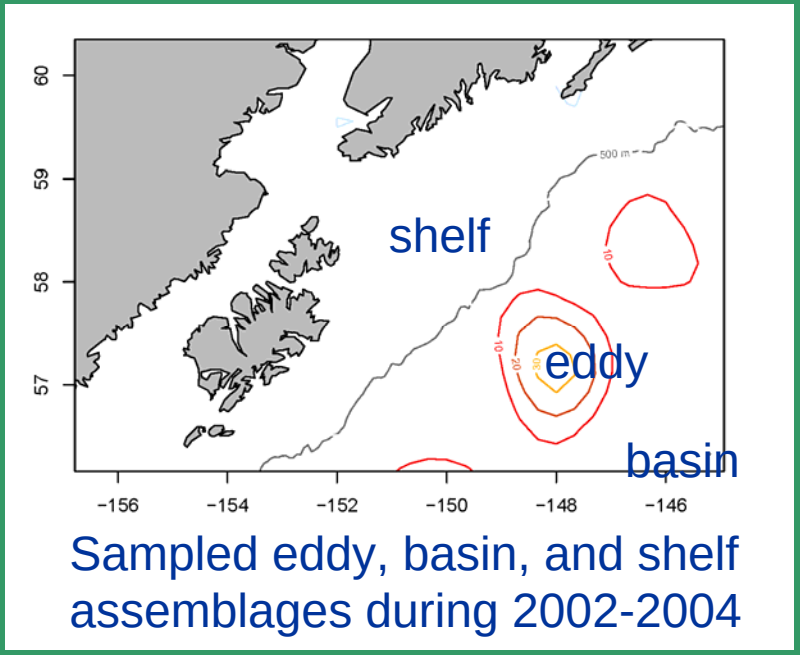
# Larval fish in eddies

- Young eddies in Eastern GOA
  - Species richness increases from eddy edge towards center




Sampled eddy, basin, and shelf assemblages during 2002-2004

- Older eddies in Western GOA
  - Larval assemblages within eddy are different from neighboring basin and shelf assemblages
  - Gradients in species richness across eddies (sometimes positive, sometimes negative)



*Atwood et al., submitted*

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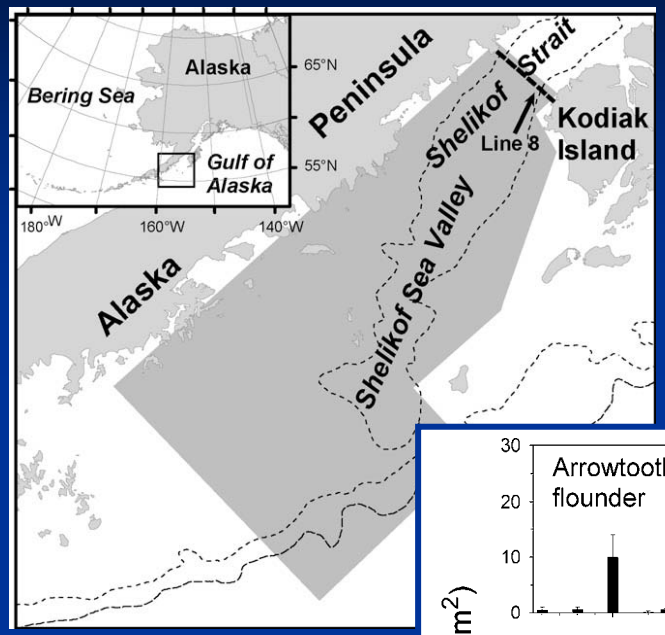
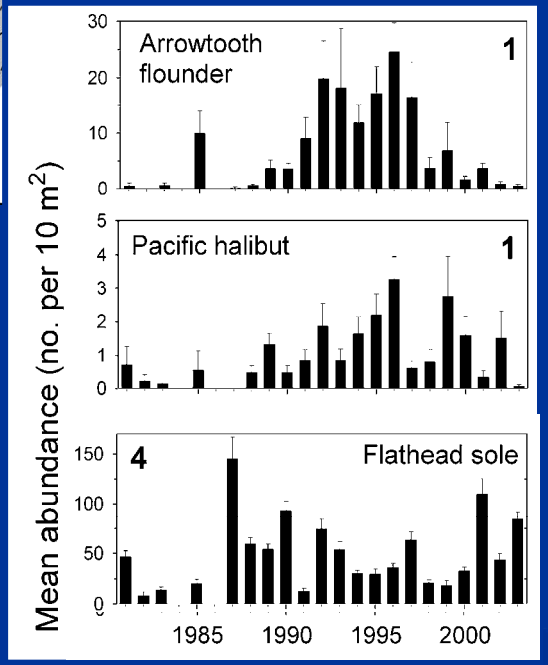
# Interannual variability in larval fish




Mean abundance of larval fish species. From Doyle et al 2009.




- Doyle et al 2009 found that late spring larval abundance of deepwater spawners is influenced by:
  - Along-shore winds (+)
  - Freshwater runoff (-)
  - SST
  - Flow down Shelikof Strait (+)



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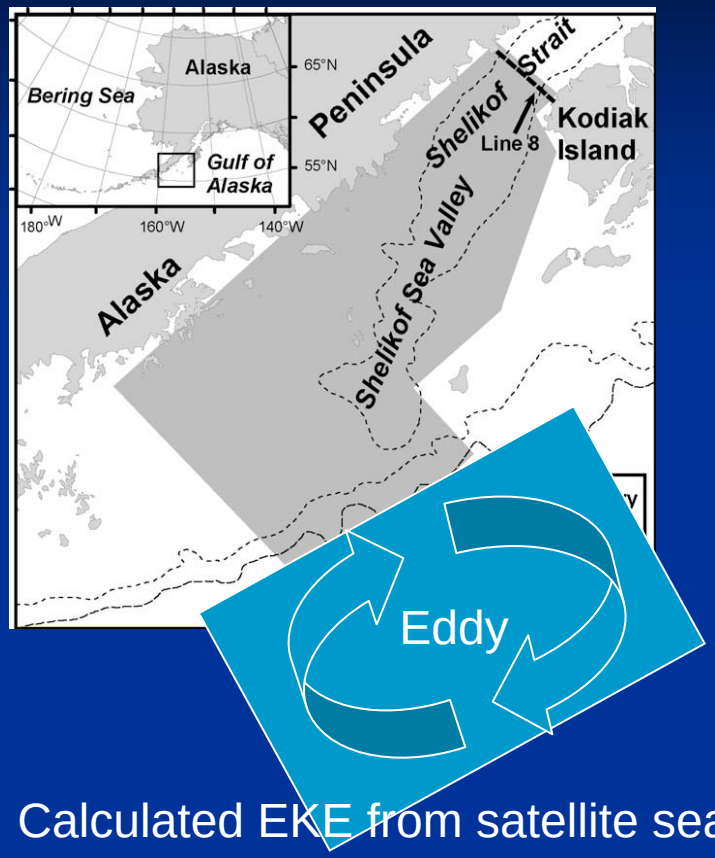
# Interannual variability in larval fish




Calculated EKE from satellite sea surface height anomalies in region offshore of larval sampling region as an index of eddy activity.

- Late spring abundance of deepwater spawners is influenced by:
  - Along-shore winds (+)
  - Freshwater runoff (-)
  - SST
  - Flow down Shelikof Strait (+)
  - Eddy Kinetic Energy (-)



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# Summary

- Variability
  - Strong seasonal cycle in east, weaker in western GOA
  - Interannual variability has different character in different regions
- Physical/Chemical signature
  - Fresh, shelf derived water carried into interior of basin in shallow core
  - Anomalous heat and salinity carried into the basin in subsurface core
  - Excess nitrate, silicate, and phosphate carried into the basin in subsurface core
  - Coincident temperature inversion and iron maximum in young eddy



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# Summary

- Eddies influence ecosystem in the Gulf of Alaska
  - Phytoplankton
    - High chlorophyll at center and edges
  - Zooplankton
    - Species assemblages differ in young Haida and Sitka eddies
  - Larval fish
    - High species richness at center of young eddies
    - Larval assemblages differ between eddy, basin, and shelf
    - Deepwater spawner abundance negatively influenced by eddies near Kodiak



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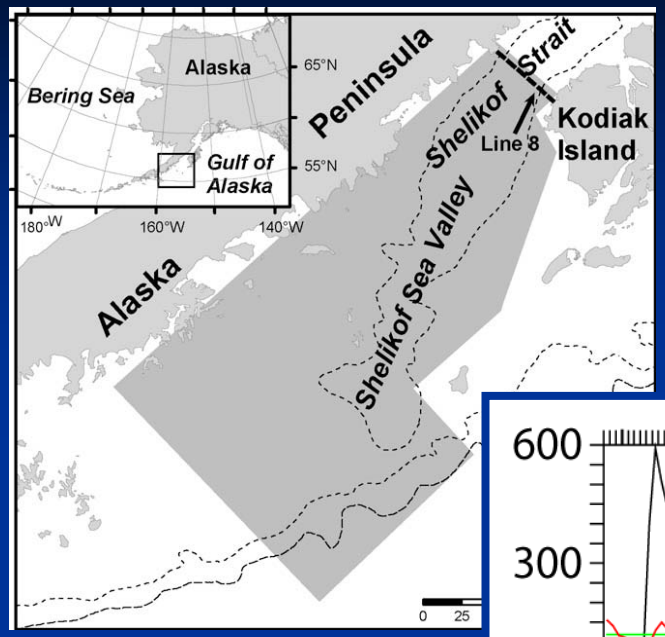
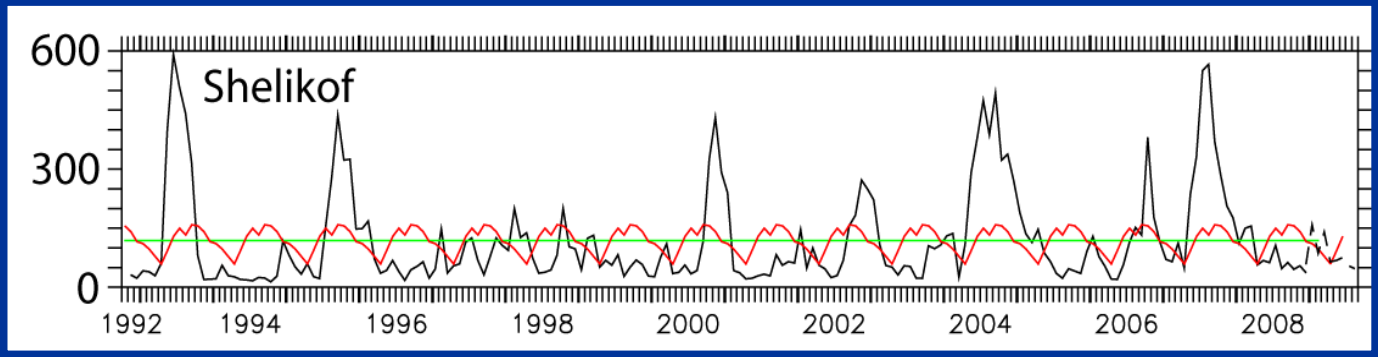
# Predictability?




Eddy Kinetic Energy




- Given the weaker eddy activity near Shelikof Strait in the last 2 years (2008 – 2009), we would expect increased abundance of larval deepwater spawners (Arrowtooth flounder, Pacific halibut, Flathead sole)



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# Thank you



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