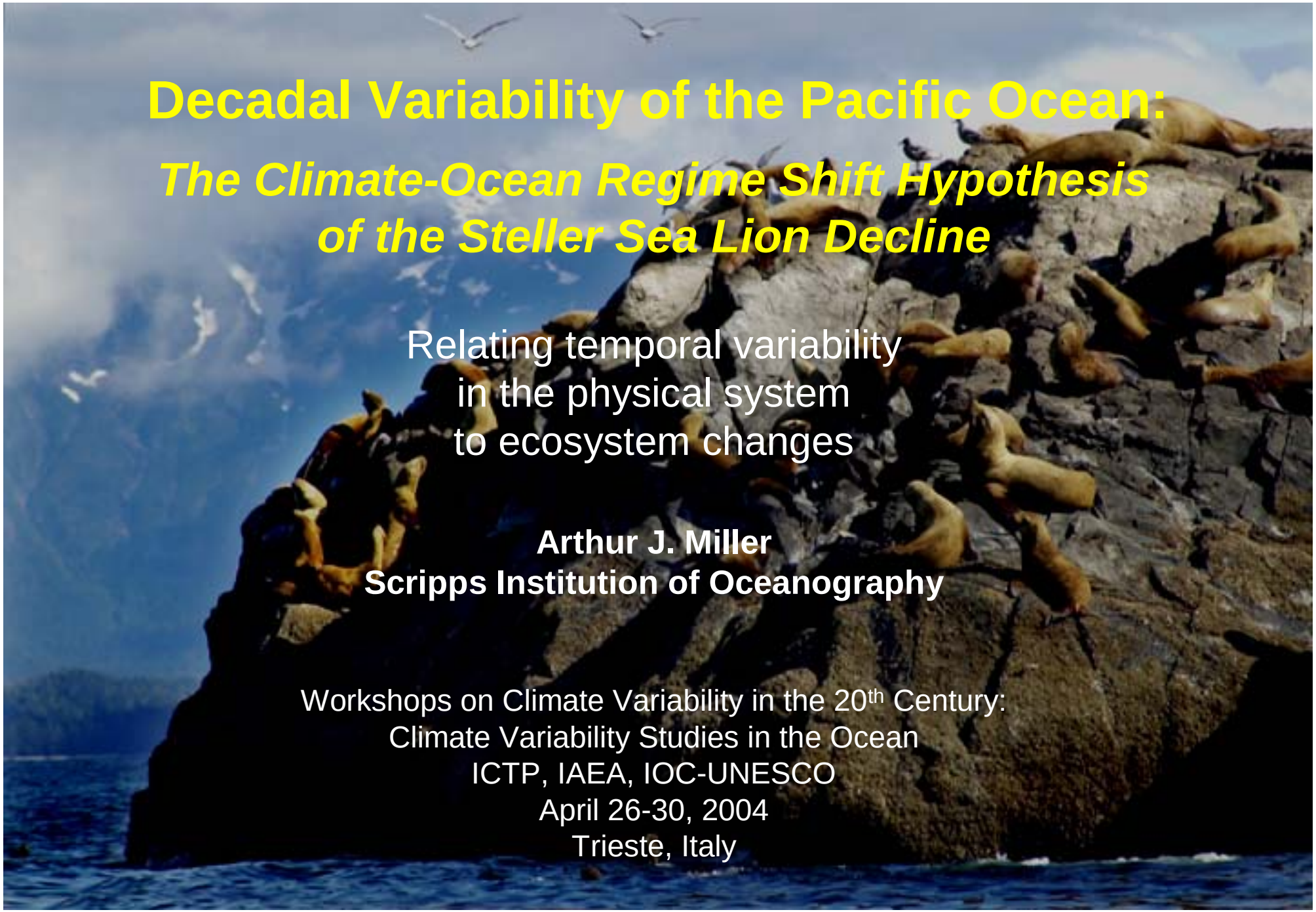


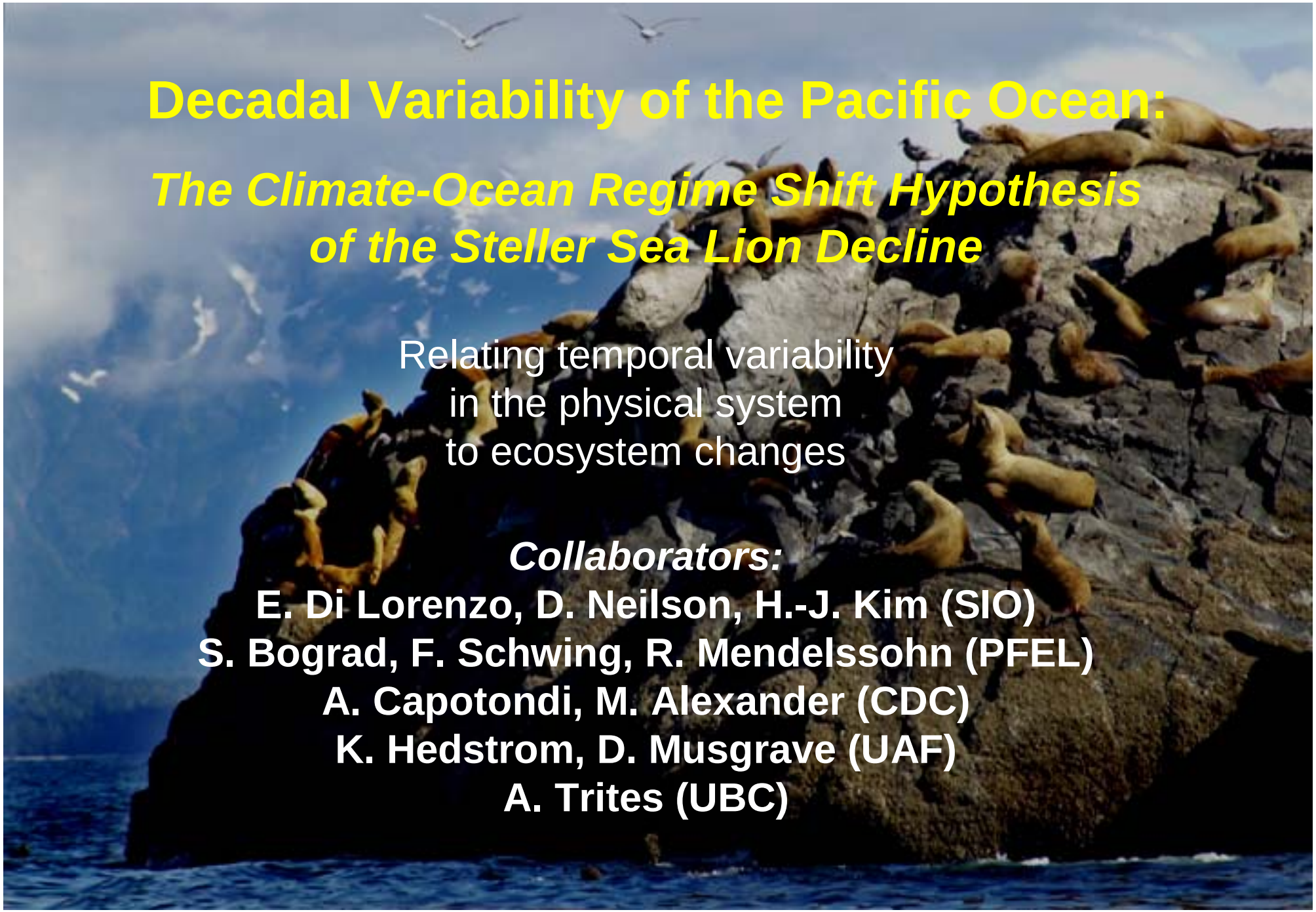
Decadal Variability of the Pacific Ocean:

The Climate-Ocean Regime Shift Hypothesis of the Steller Sea Lion Decline

Relating temporal variability
in the physical system
to ecosystem changes

Arthur J. Miller
Scripps Institution of Oceanography

Workshops on Climate Variability in the 20th Century:
Climate Variability Studies in the Ocean
ICTP, IAEA, IOC-UNESCO
April 26-30, 2004
Trieste, Italy



Decadal Variability of the Pacific Ocean:

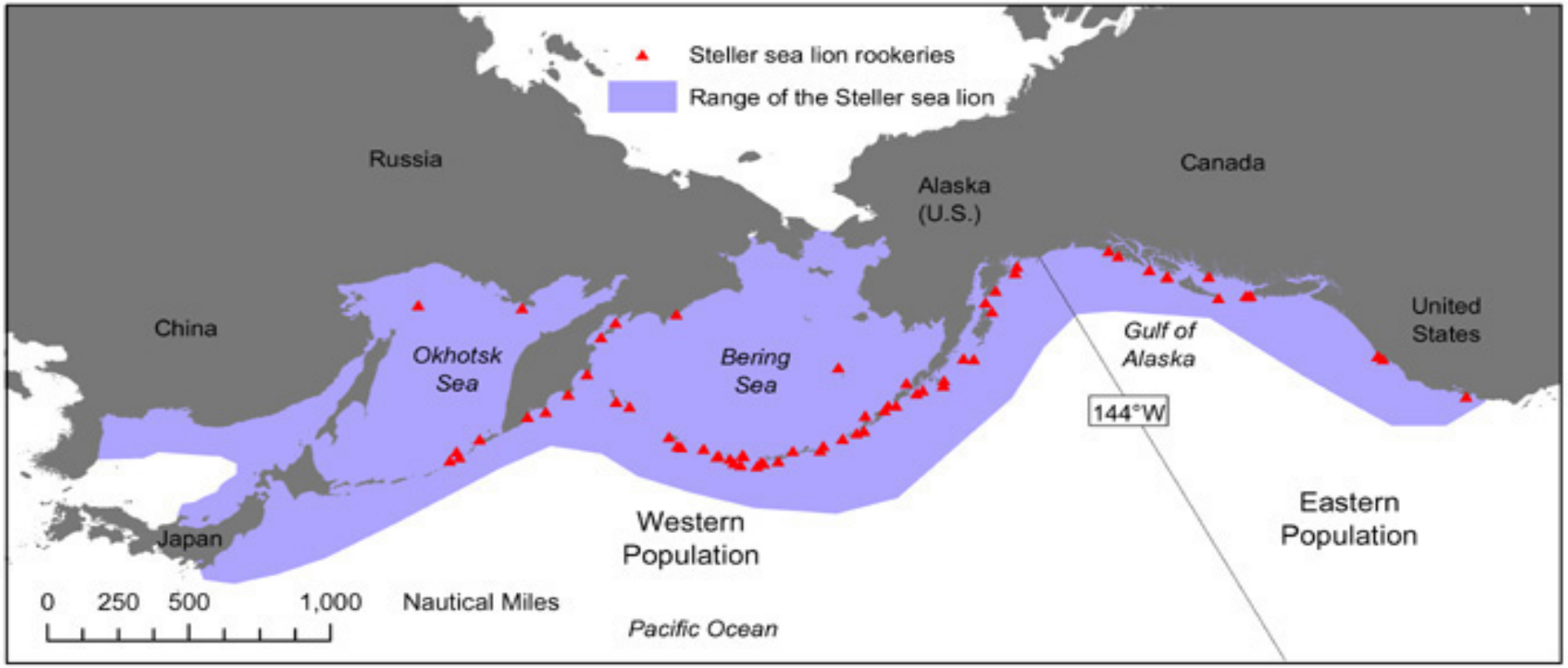
The Climate-Ocean Regime Shift Hypothesis of the Steller Sea Lion Decline

Relating temporal variability
in the physical system
to ecosystem changes

Collaborators:

E. Di Lorenzo, D. Neilson, H.-J. Kim (SIO)
S. Bograd, F. Schwing, R. Mendelssohn (PFEL)
A. Capotondi, M. Alexander (CDC)
K. Hedstrom, D. Musgrave (UAF)
A. Trites (UBC)

Steller Sea Lion Population Distributions



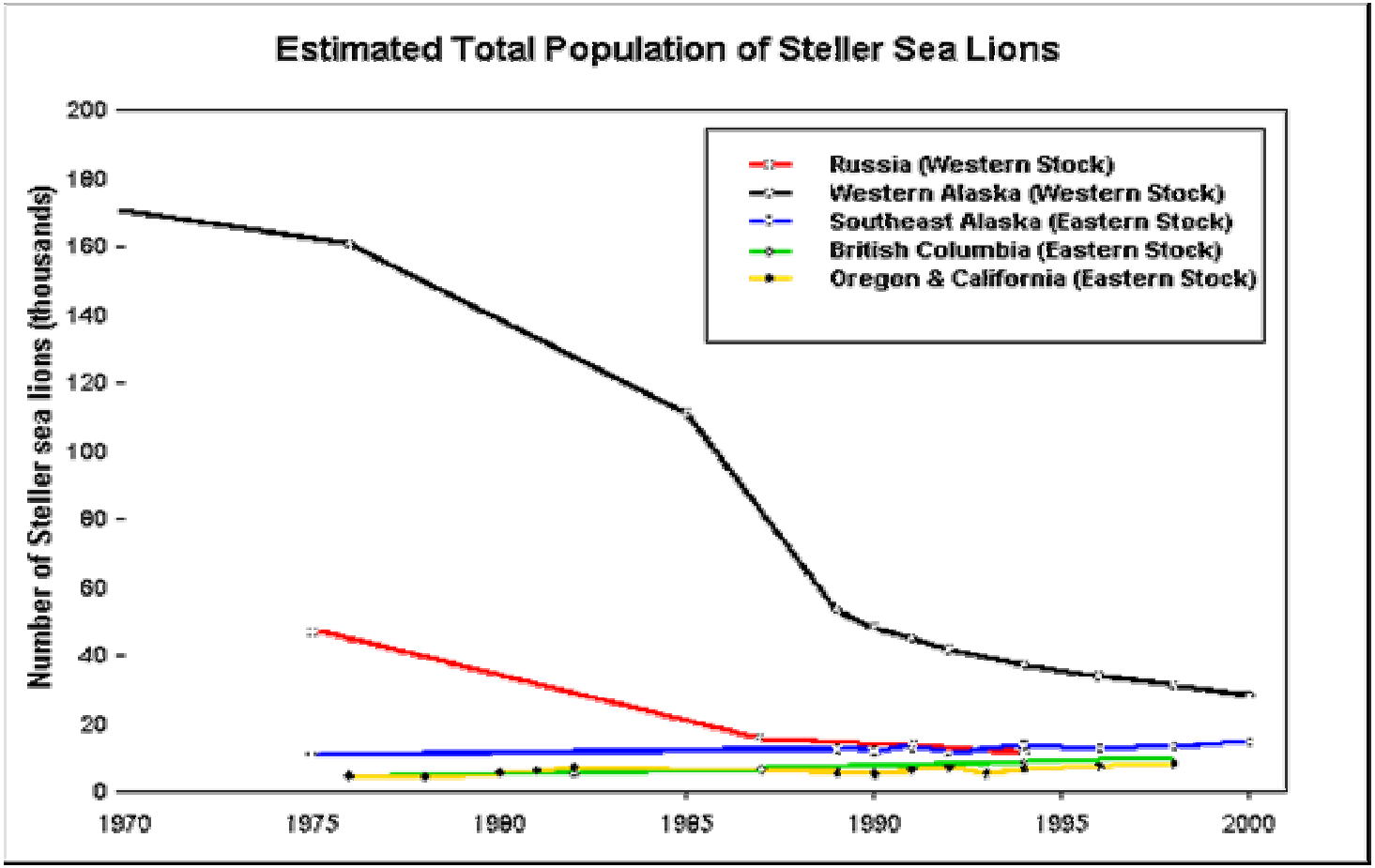
NMFS

Ugamek Island Photos of Hauled-Out Steller Sea Lions

1969 **1979** **1986**

NMFS

SSL population declines since 1976-77 Climate Shift:
Western Gulf of Alaska population dropped
Eastern Gulf of Alaska population was stable



NMFS

Basic Issues in SSL Decline

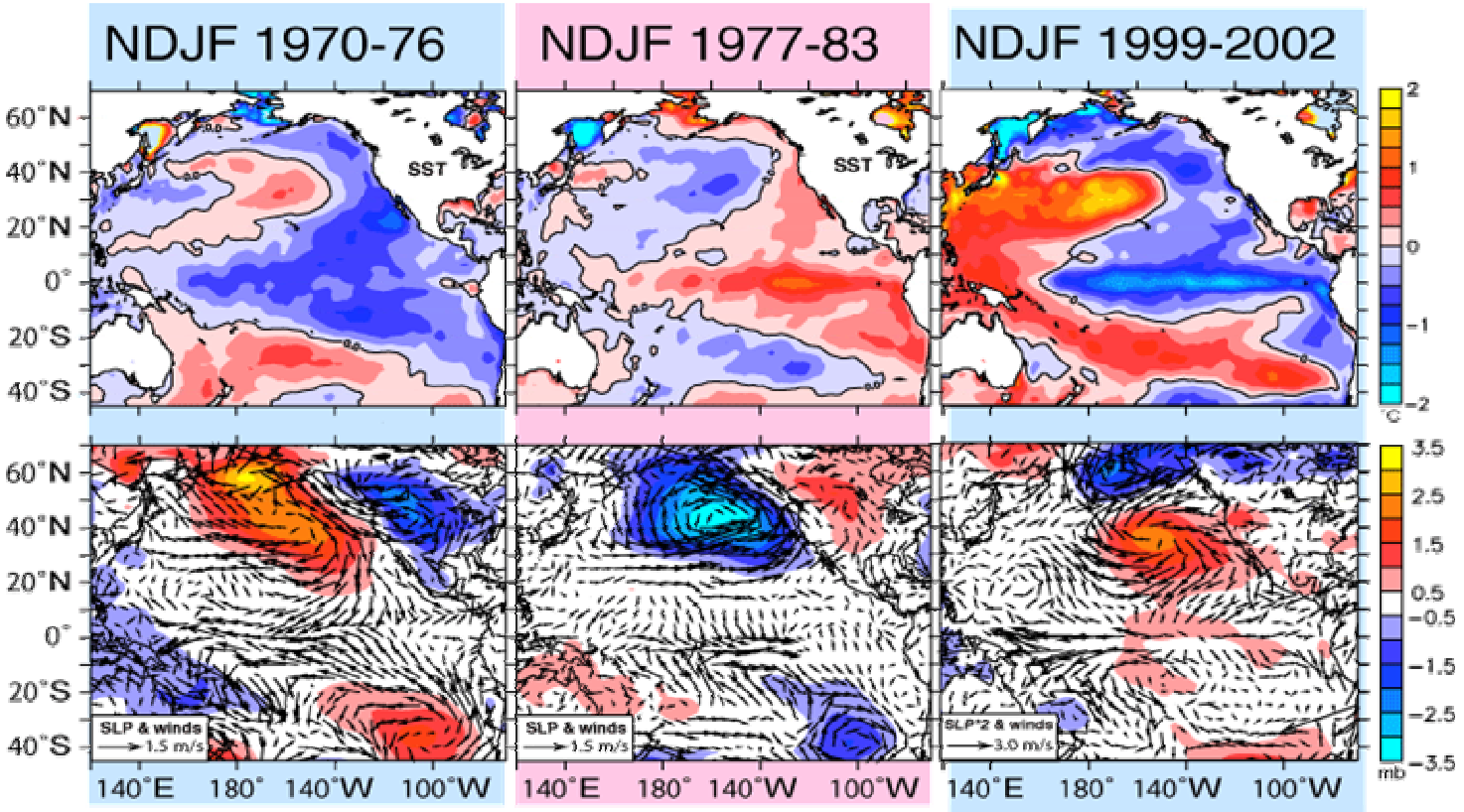
- Temporal change:
  - Decline after mid-1970’s
- Spatial asymmetry:
  - Decline in western Gulf of Alaska
  - Stable populations in eastern Gulf

(Trites, 2004)

Of course, there are some other "less appealing" theories…..

Overfishing of Favorite Forage…Disease…Pollution…
…Shot by Fishermen….Increased Predation:

North Pacific Regime Shifts: State Changes in Forcing



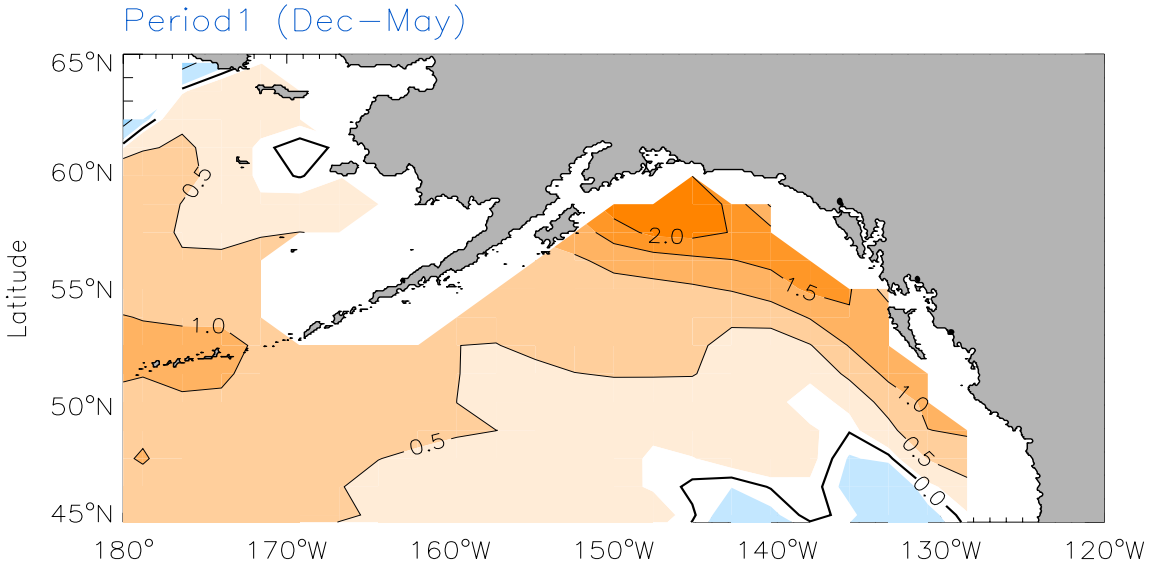
SSTA

SLPA, WindA

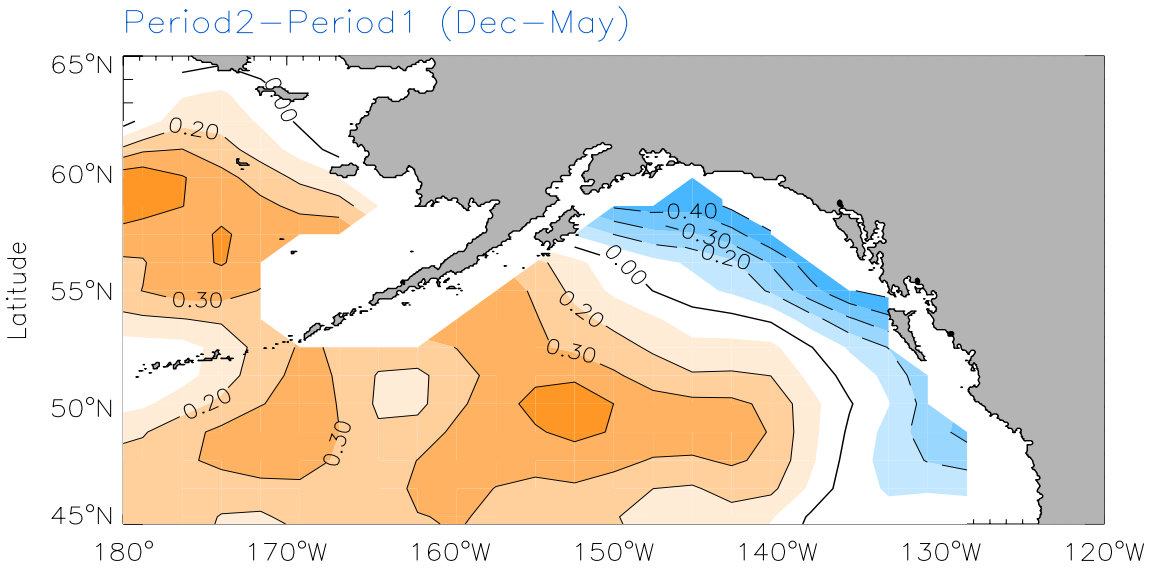
"cool" "warm" "cool?"

Peterson and Schwing, 2003

Observed Changes in Ekman pumping

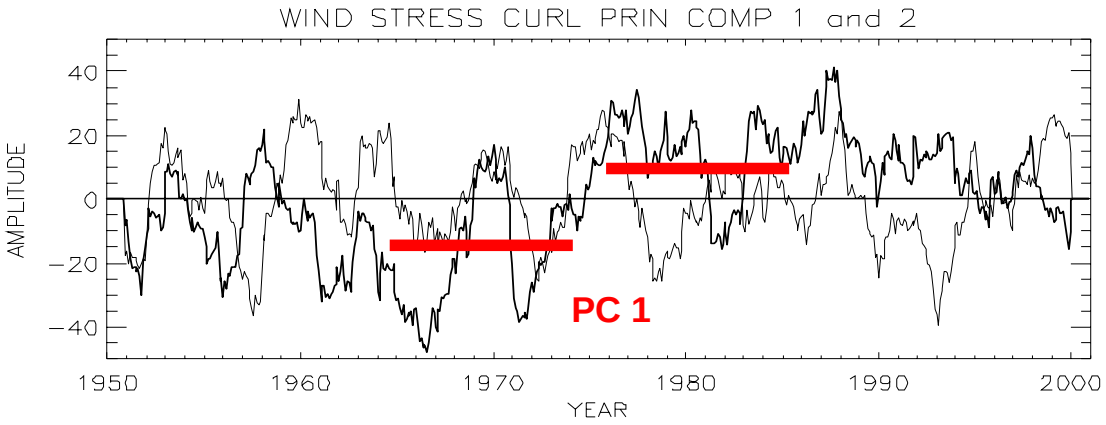


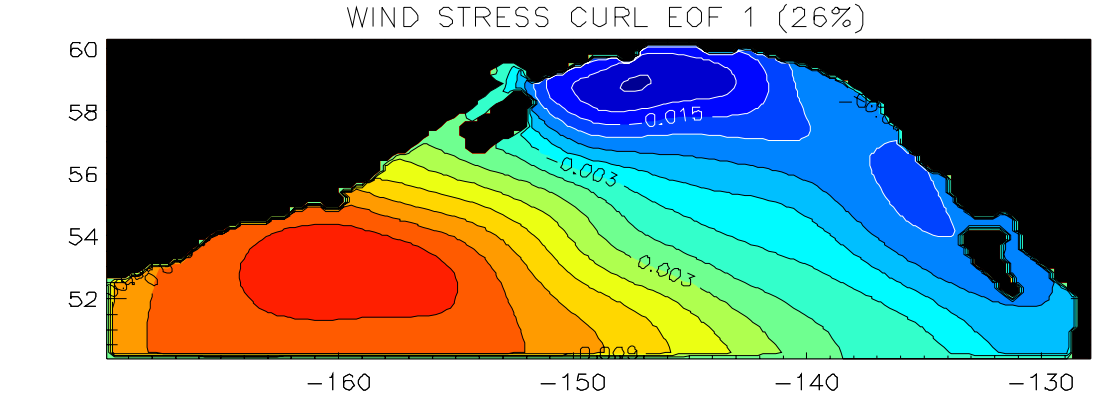
Pre-shift mean conditions 1960-75 Dec-May

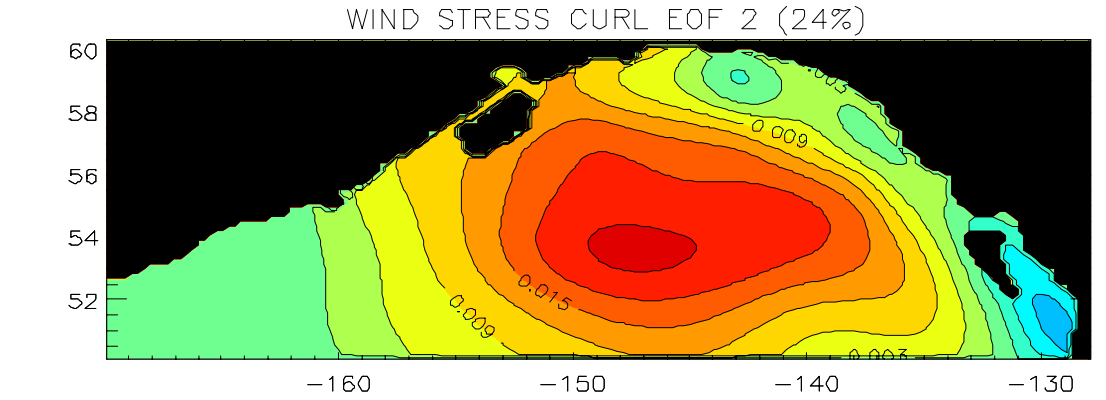


Change after shift (1977-97) -(1960-75)

Capotondi, Alexander, Deser and Miller (JPO, *sub judice*)



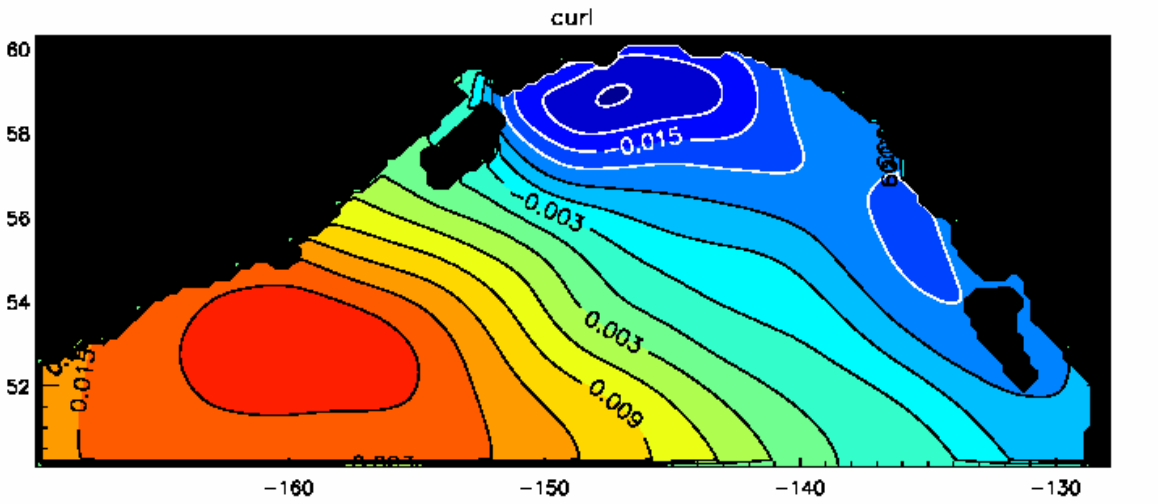




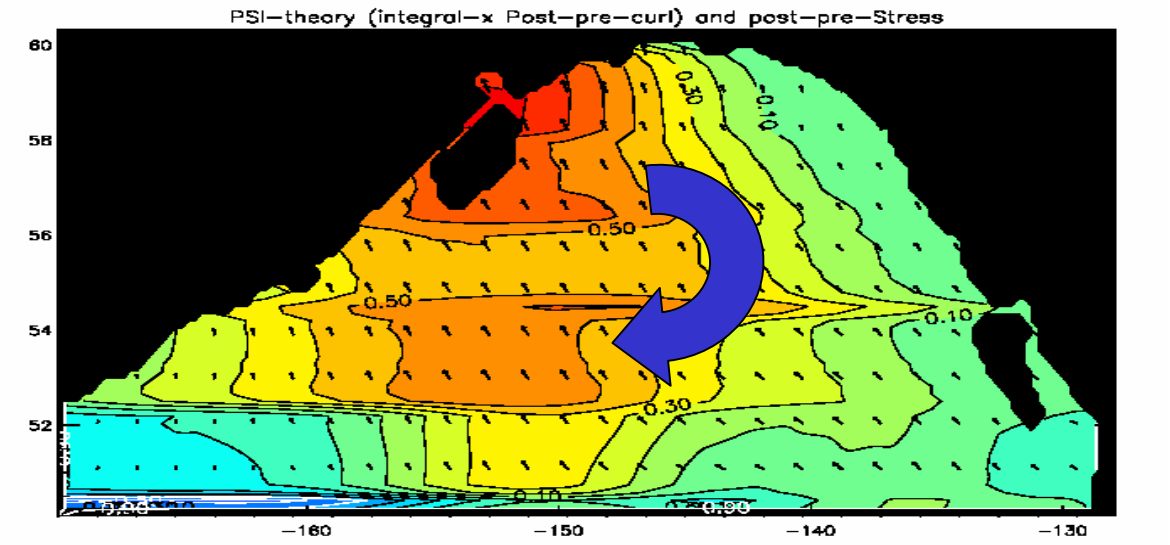
EOF Analysis of
Wind Stress Curl
also reveals the
basic decadal pattern
of the
Aleutian Low variations

Miller, Di Lorenzo et al.
(GRL, *sub judice)*

Climate shift in wind-stress curl



Theoretical streamfunction response



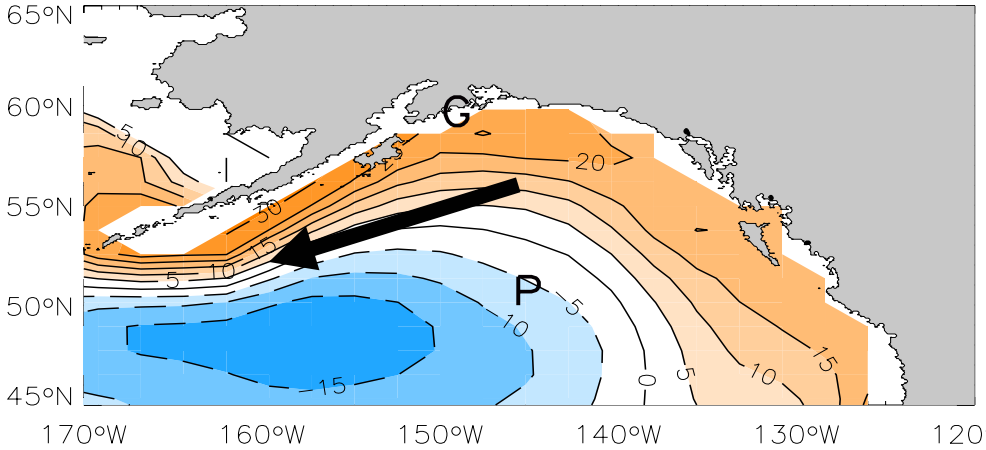
Theoretical solution
(steady state)
to wind-stress curl forcing
yields a ***weakening*** of
the Alaskan Stream……
…but this assumes Rossby
waves equilibrate the western
bouindary currents.

Cummins and Lagerloef (2003)
show that Rossby waves
are not important in open-ocean
interannual/decadal variability.

(Models suggests topographic
Rossby waves along shelf-slope
may be important in establishing
WBC response.)

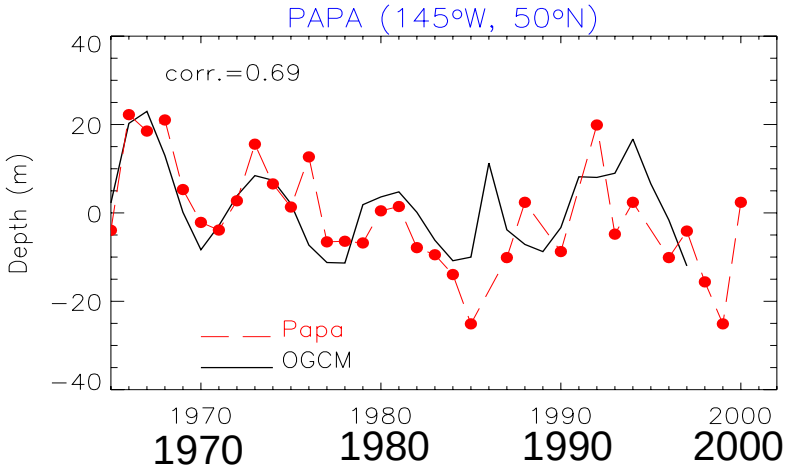
Capotondi, Alexander, Deser, and Miller (JPO, sub judice)

Coarse Resolution Model Pycnocline ($26.4\sigma_\theta$) depth changes Period2 (1977-97) – Period1 (1964-75)

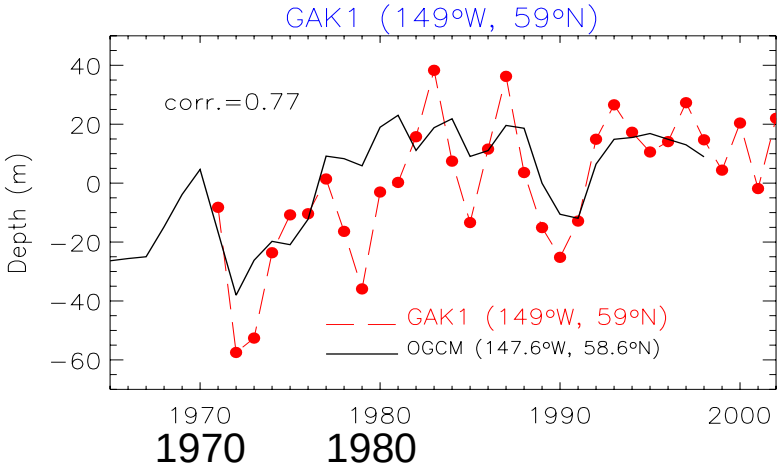


Strengthened Alaskan Stream!

Model vs. Obs PAPA



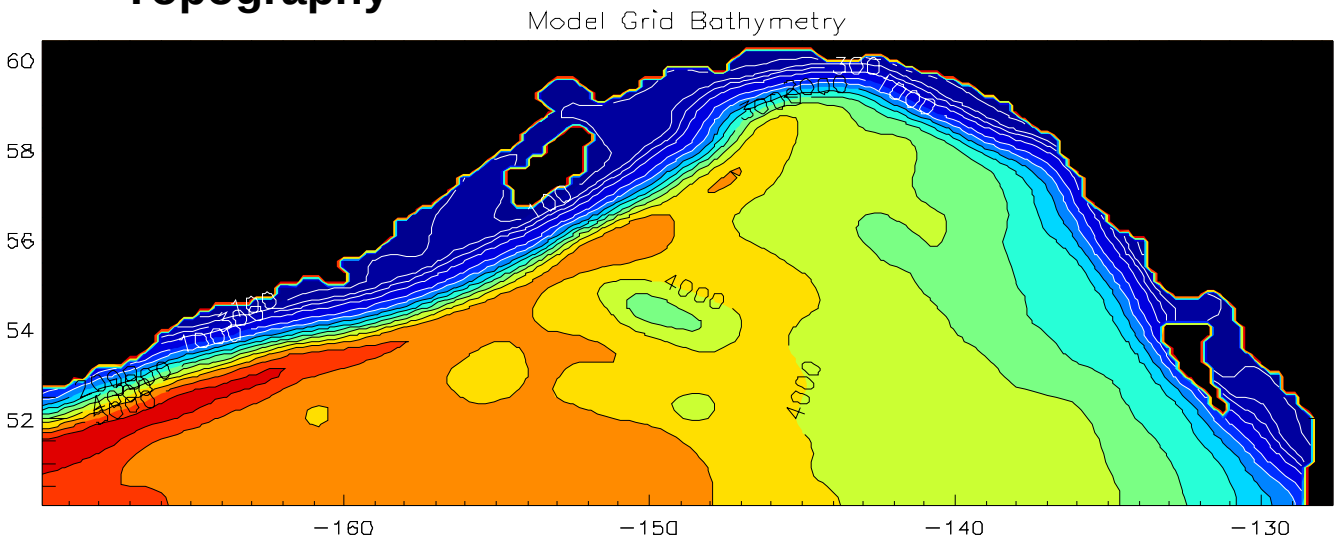
Model vs. Obs GAK



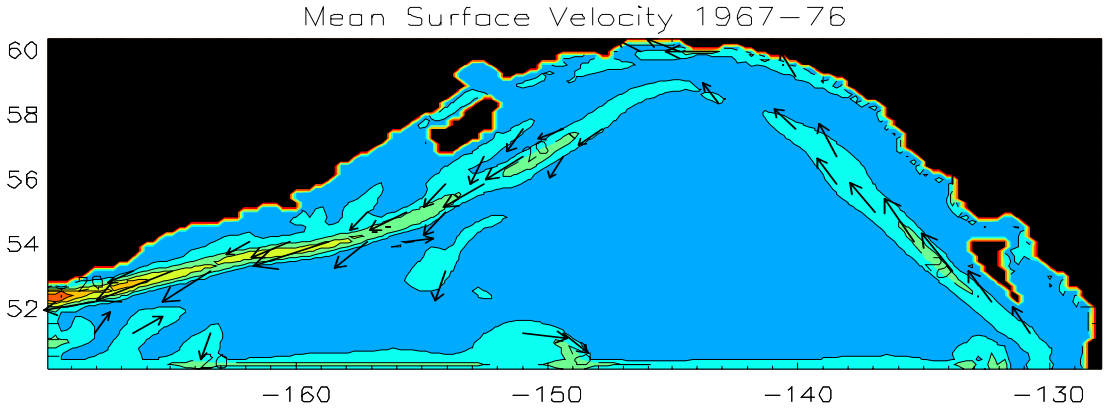
Eddy Permitting Primitive Equation Model Hindcast
Regional Ocean Modeling System (ROMS)

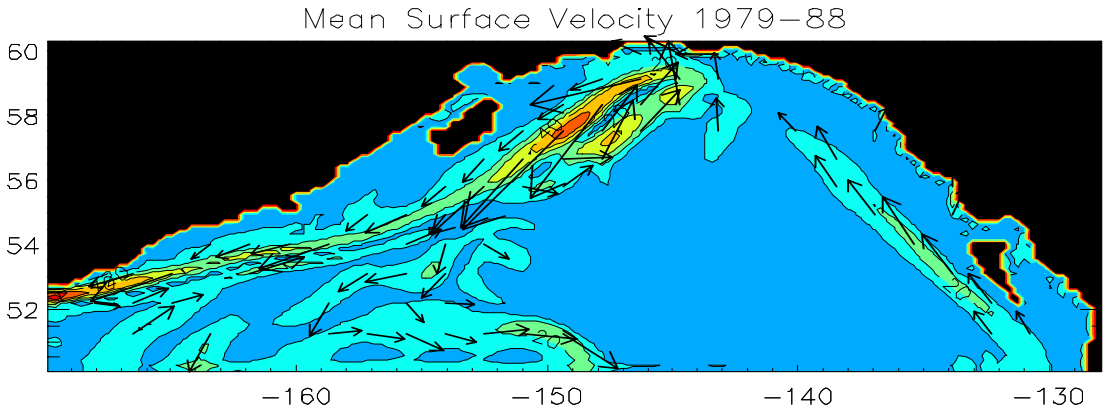
1950-1999 NCEP Winds
16km resolution
Relaxation to climatological SST, BC's, SSS

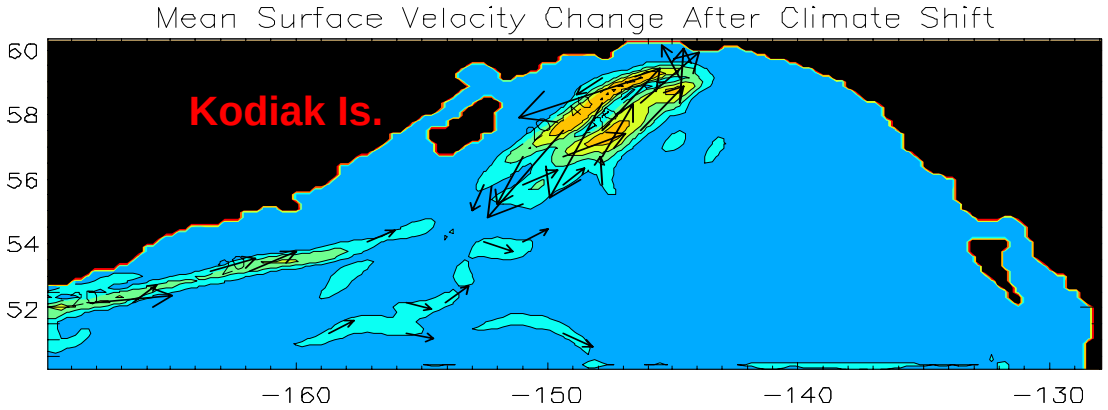
Topography



Miller. Di Lorenzo, et al. (GRL, *sub judice*)







Eddy-Permitting Model Eddy Surface Currents

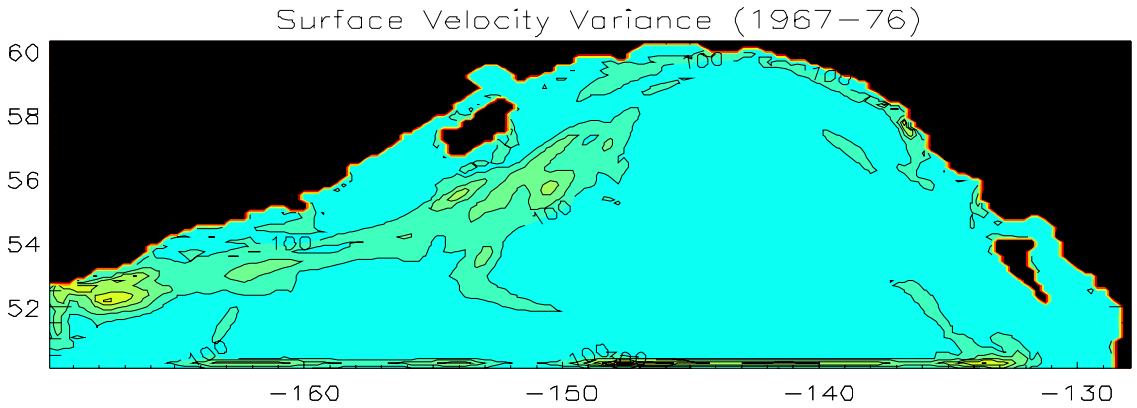
Before 76-77 Shift

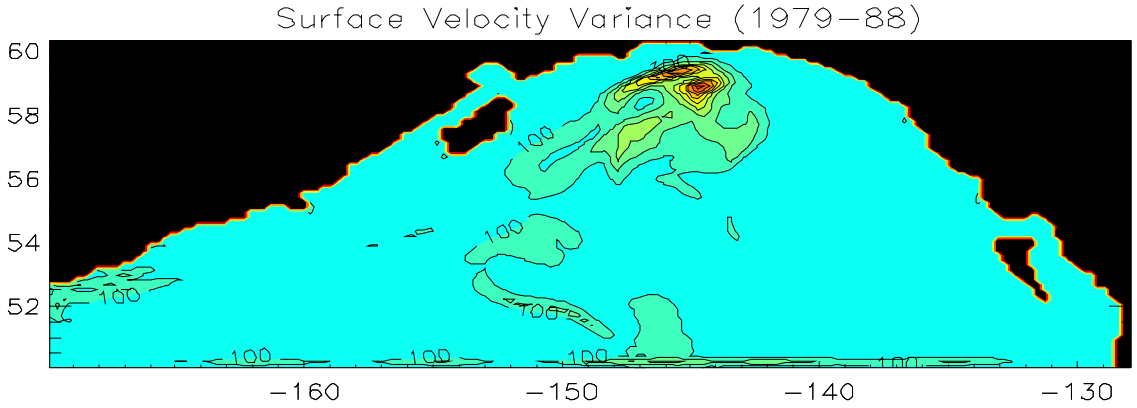
After 76-77 Shift

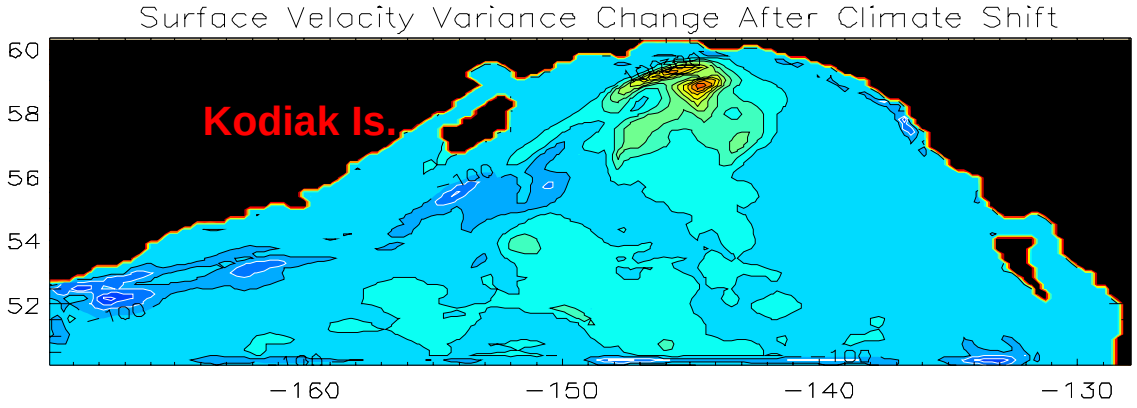
Difference

- Stronger Stream north of Kodiak
- Weaker Stream southwards

Miller, Di Lorenzo, et al. (GRL, *sub judice*)







Eddy-Permitting Model Eddy Surface Currents

Before 76-77 Shift

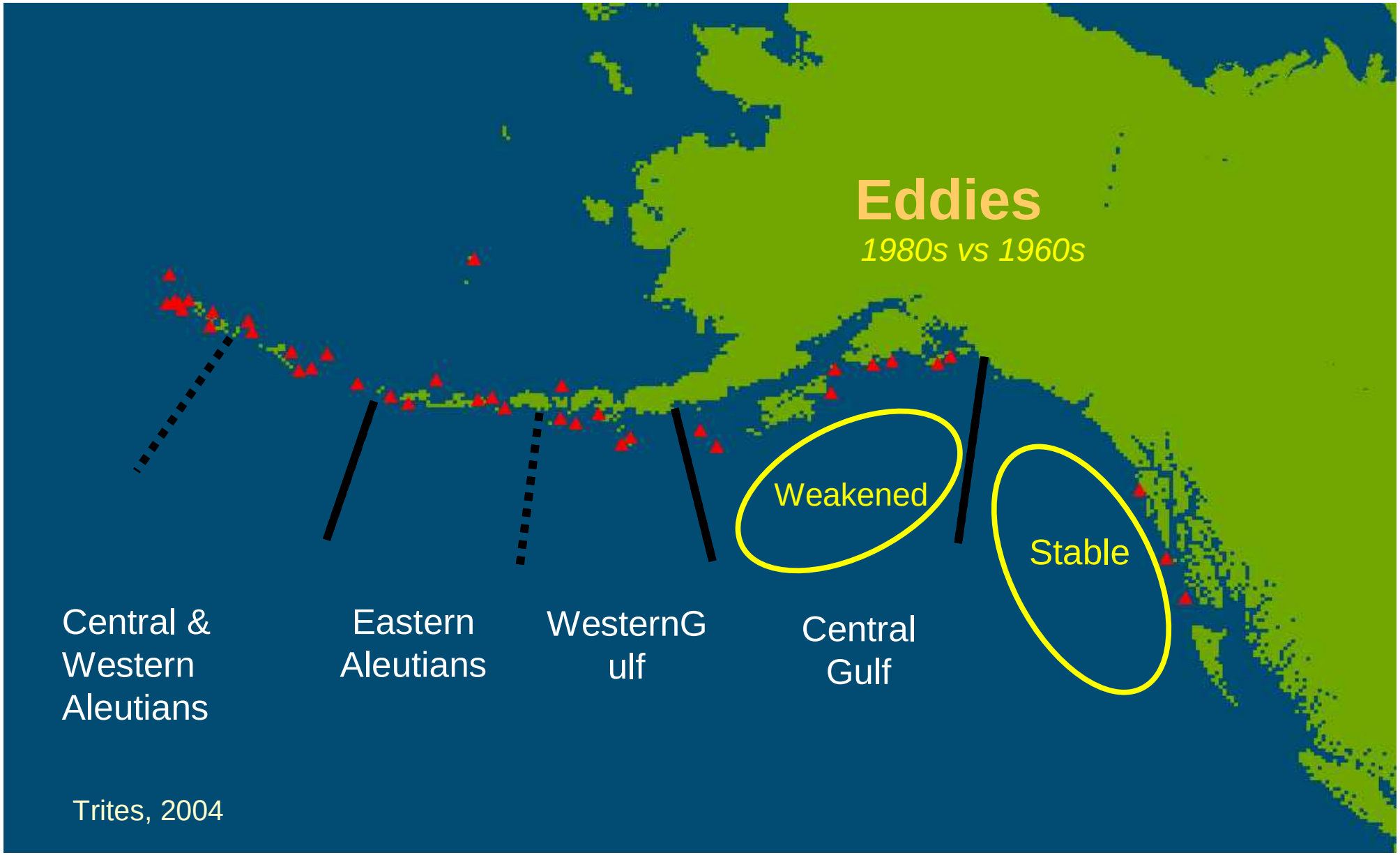
After 76-77 Shift

Difference

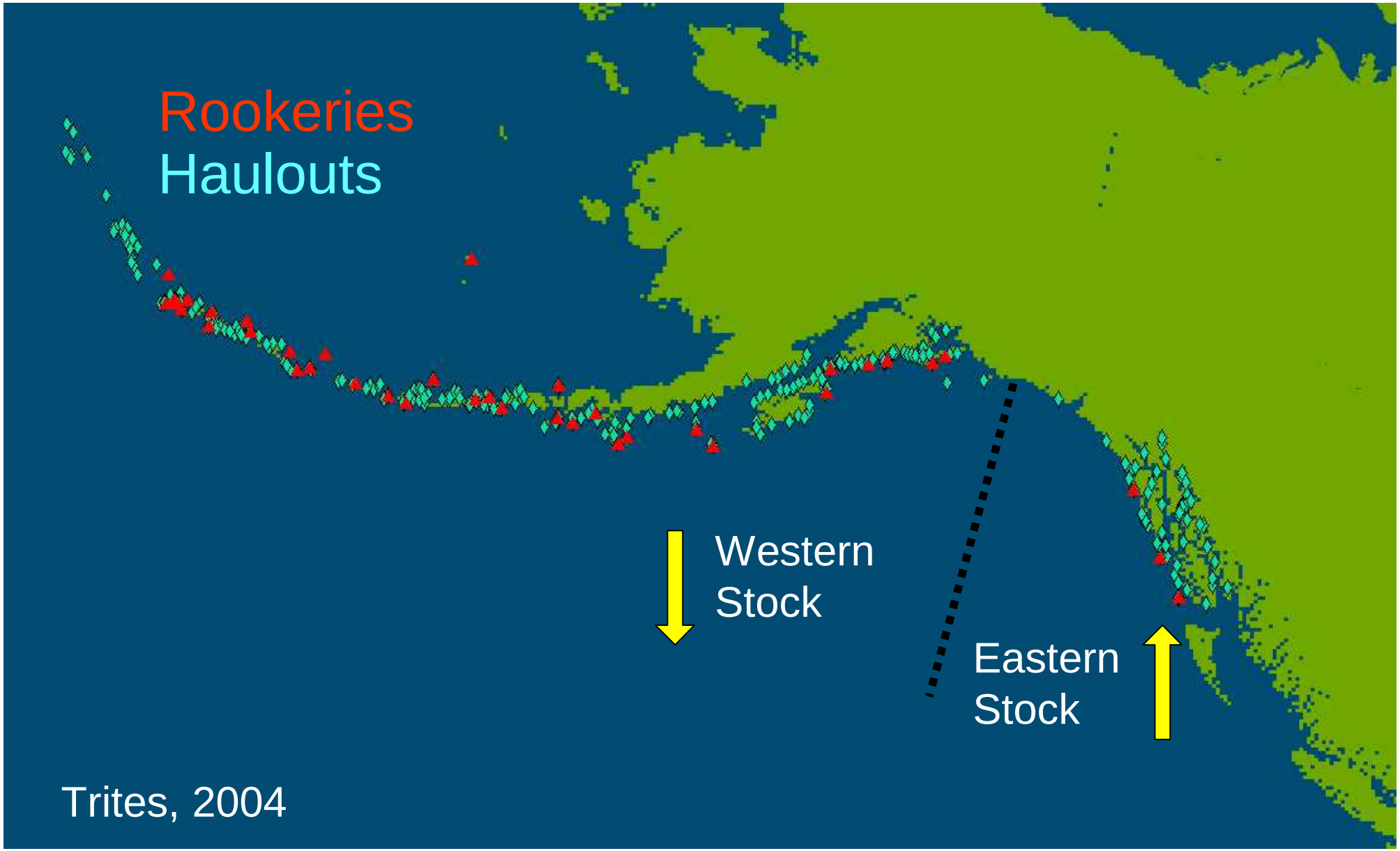
- **More eddies north of Kodiak**
- **Fewer eddies southwards**

Miller, Di Lorenzo, et al. (GRL, *sub judice*)

Regional Differences



Steller Sea Lion Biogeography




Preferred Species
herring, sandlance, capelin, smelts, salmon, flatfish, cod, pollock, rockfish, Atka mackerel, octopus, squid
Trites, 2004

Gulf of Alaska trawl catches

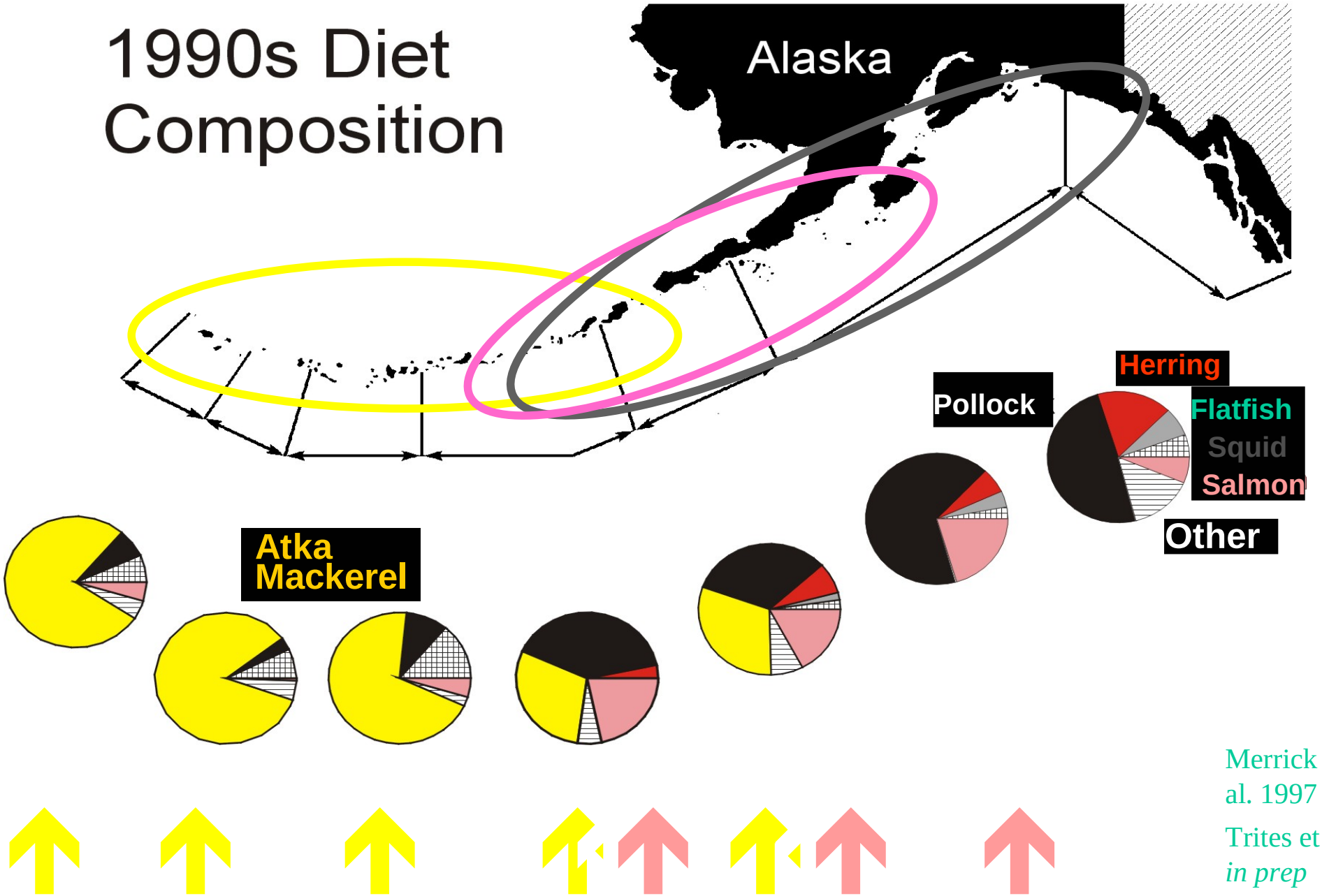
1960’s

1970’s

1980’s

Trites, 2004

1990s Diet Composition



Merrick et al. 1997

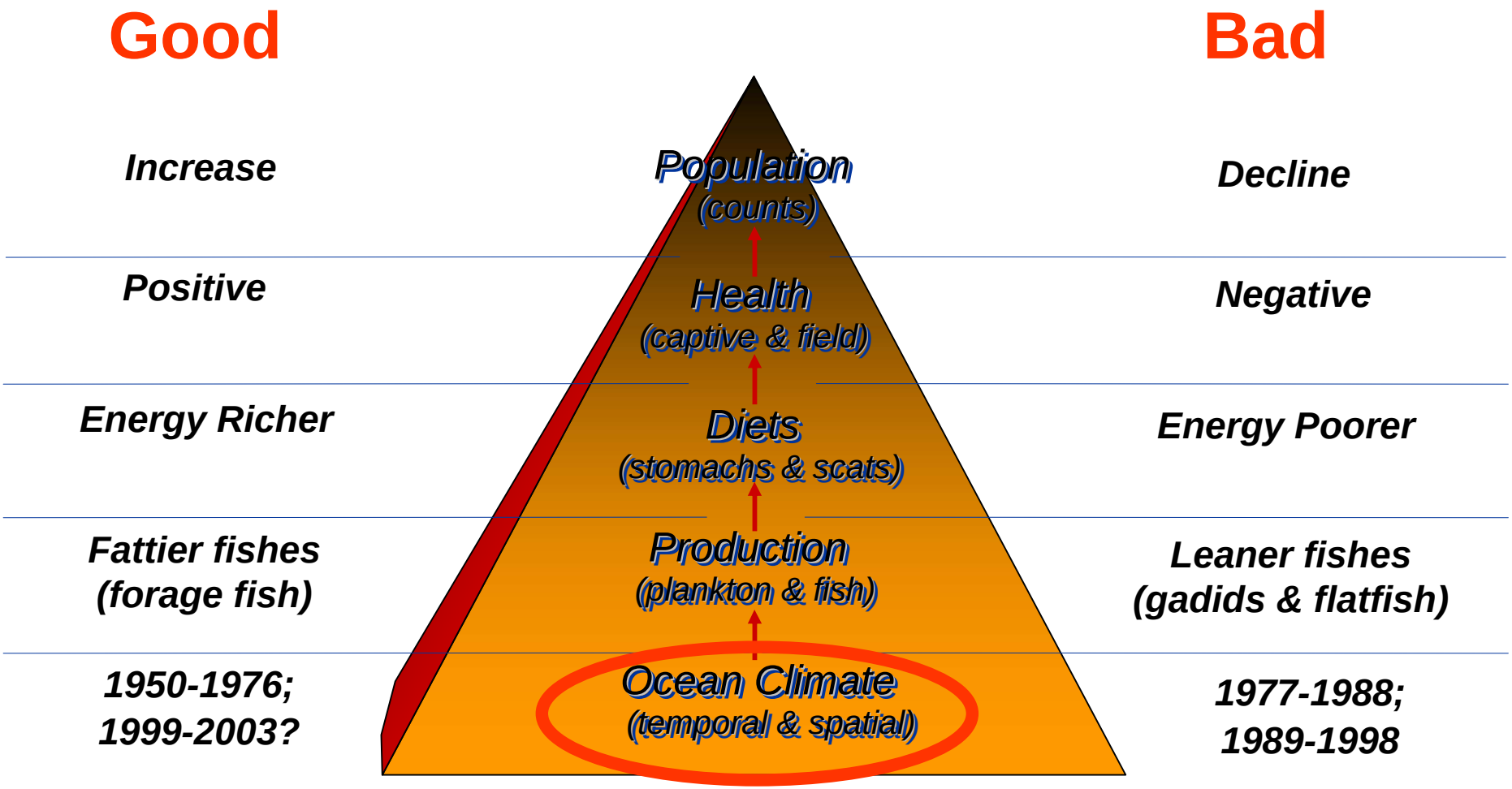
Trites et al. *in prep*

Trites, 2004

Juveniles

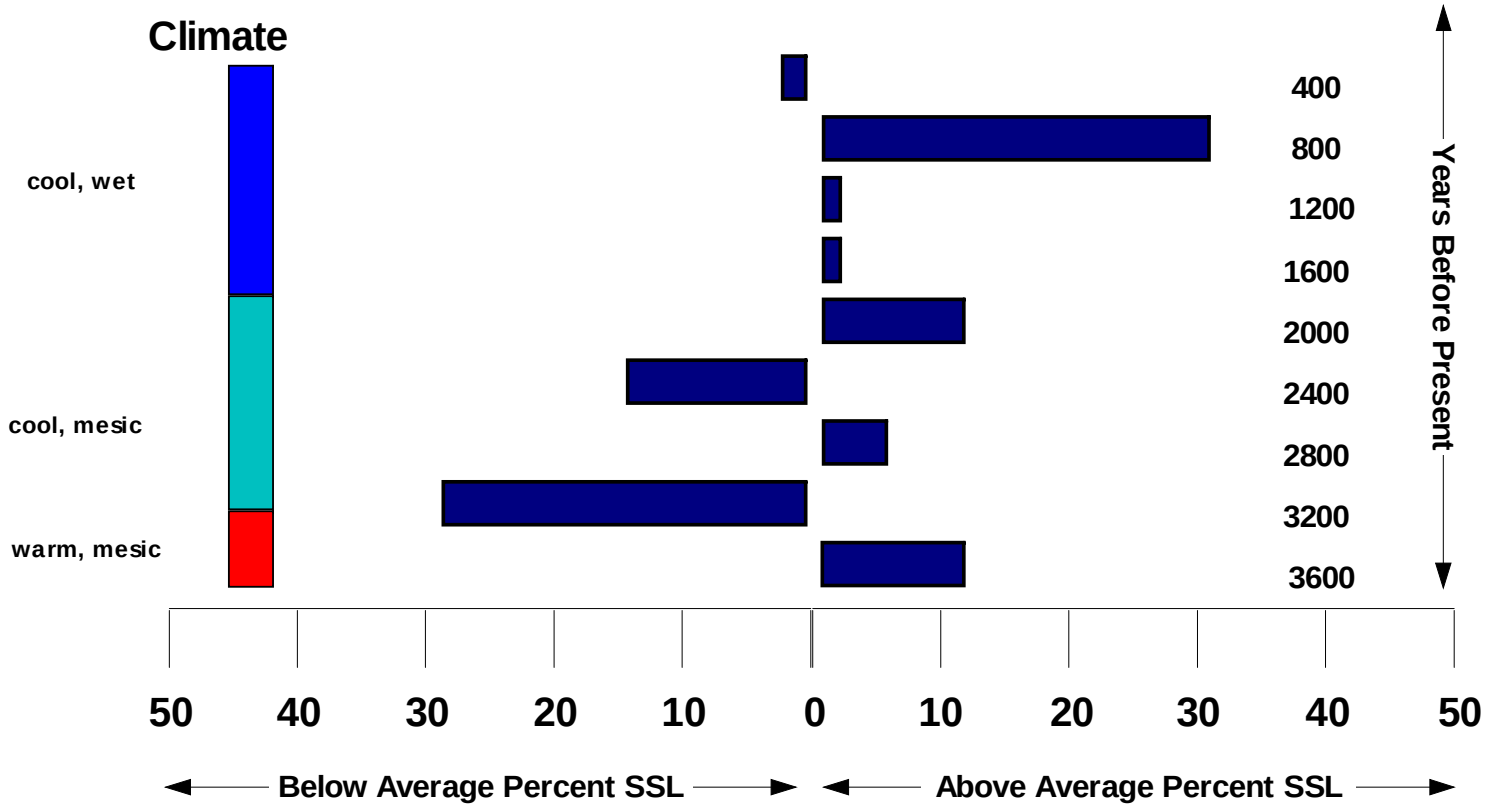
- Energetically living on the edge
- Low energy prey may lead to stunted growth, delayed age at first birth & increased risk of disease and predation

Why Did They Decline?



Trites, 2004

Long-Term Evidence of Climate Forcing Relative Abundance of SSL based on Archaeological Data



Maschner et al.

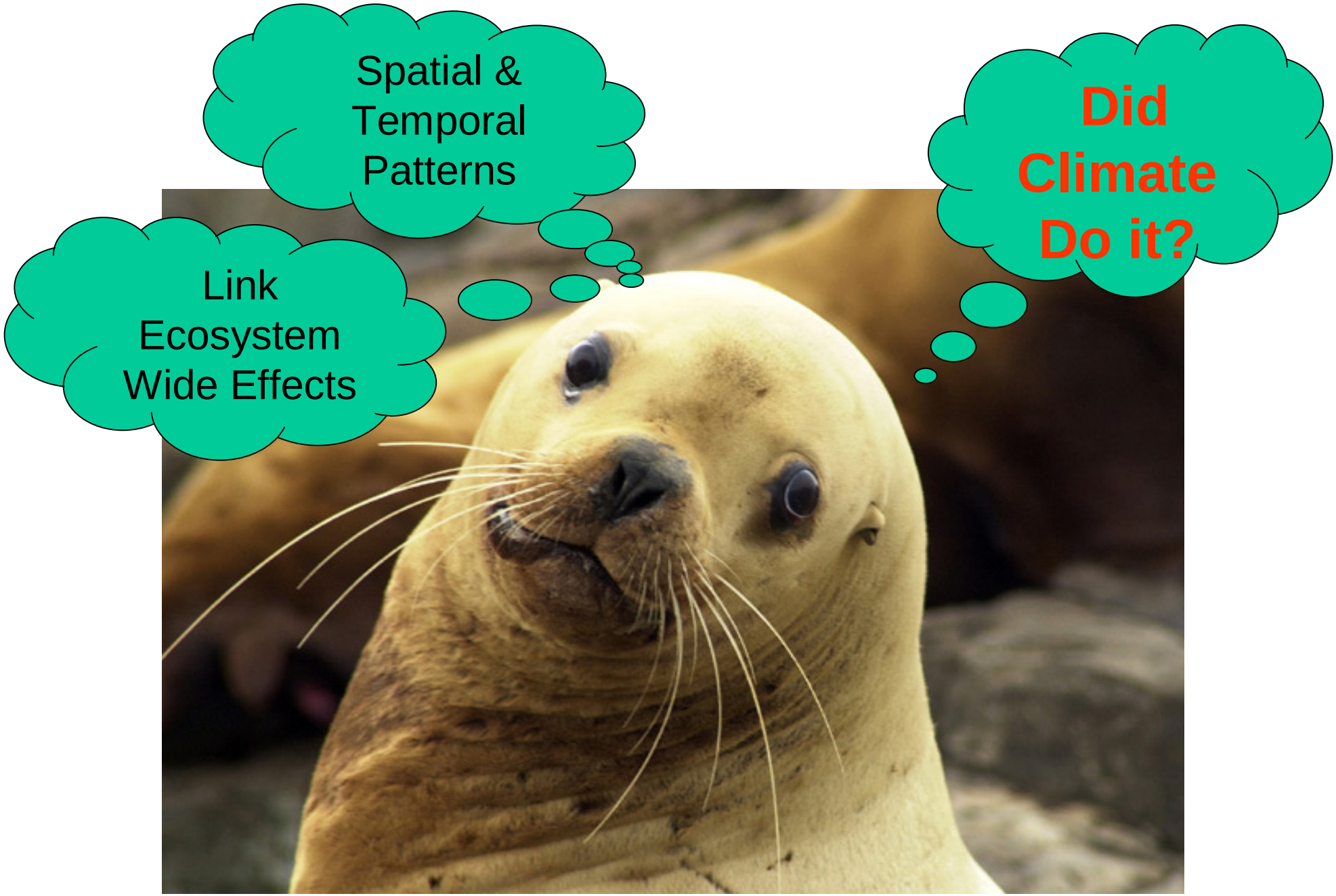
NOAA-CIFAR Synthesis Paper Highlights

Title: **The Climate-Ocean Regime Shift Hypothesis of the Steller Sea Lion Decline**
Forum: *Fisheries Oceanography,* in preparation
Authors: Trites, Miller, Maschner and 17 co-authors

Thesis: Spatial and temporal variations in the ocean climate system are creating adaptive opportunities for high trophic levels which is the underlying mechanism for the decline of the Steller sea lion populations in the western Gulf of Alaska.

Important results:

Temporal issue - 1970s to 1990s changes
Spatial issue - East vs west asymmetry in Gulf of Alaska
Biogeographic transition point at 170W
Basin-scale climate changes have regionally sensitive impacts
Upscaling from local complexities to broadscale regularities
Eddy variance changes in western Gulf


Spatial & Temporal Patterns
Did Climate Do it?
Link Ecosystem Wide Effects

Some Outstanding Questions

The Climate-Ocean Regime Shift Hypothesis of the Steller Sea Lion Decline

What mechanisms control the restructuring of the ecosystem by climate, especially concerning fish?

How do human activities and ecosystem interactions work with variable climate forcing to alter Steller sea lion populations?

Do Steller sea lions feed in eddies?

What can be said about changes in sub-surface conditions?

How does vertical mixing vary in space and time?

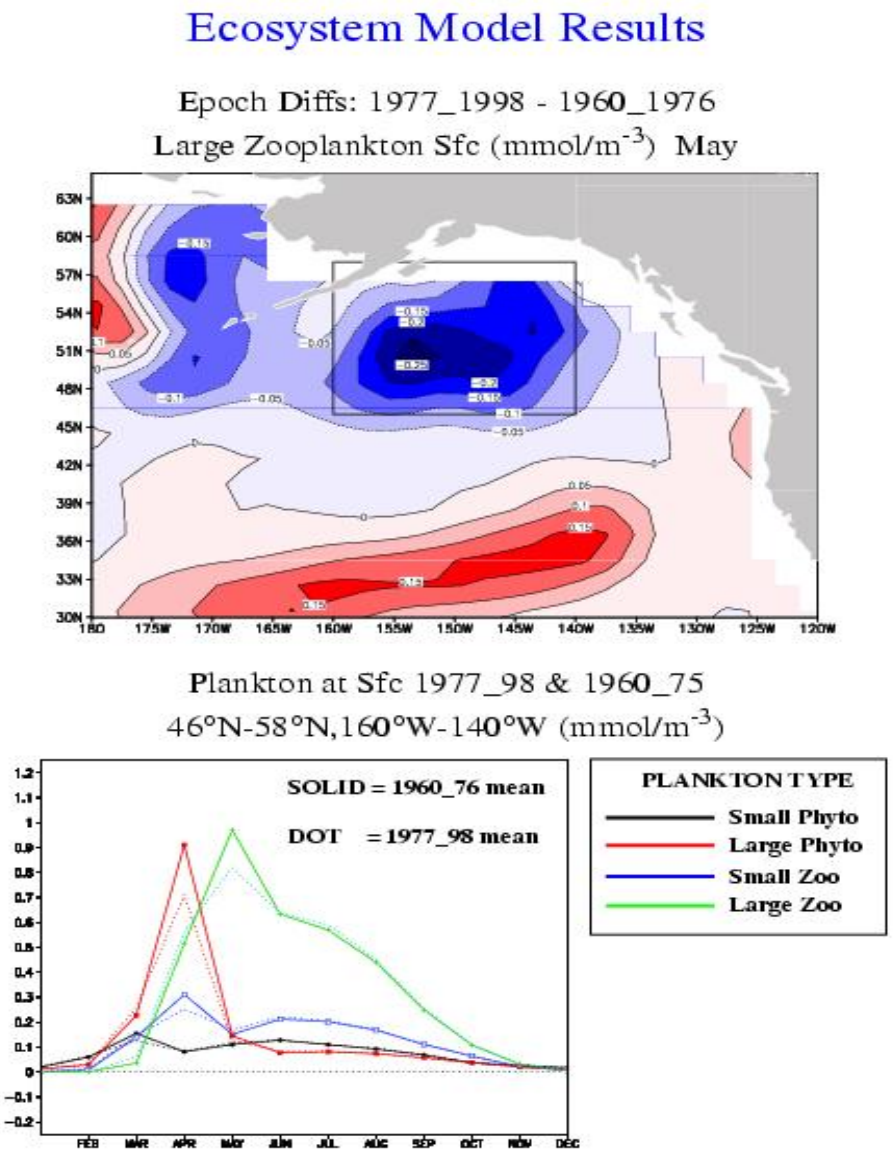
What other regime shifts may have occurred?


Thanks to ICTP!

Physical-Biological Ocean Hindcast
(Chai et al. model)

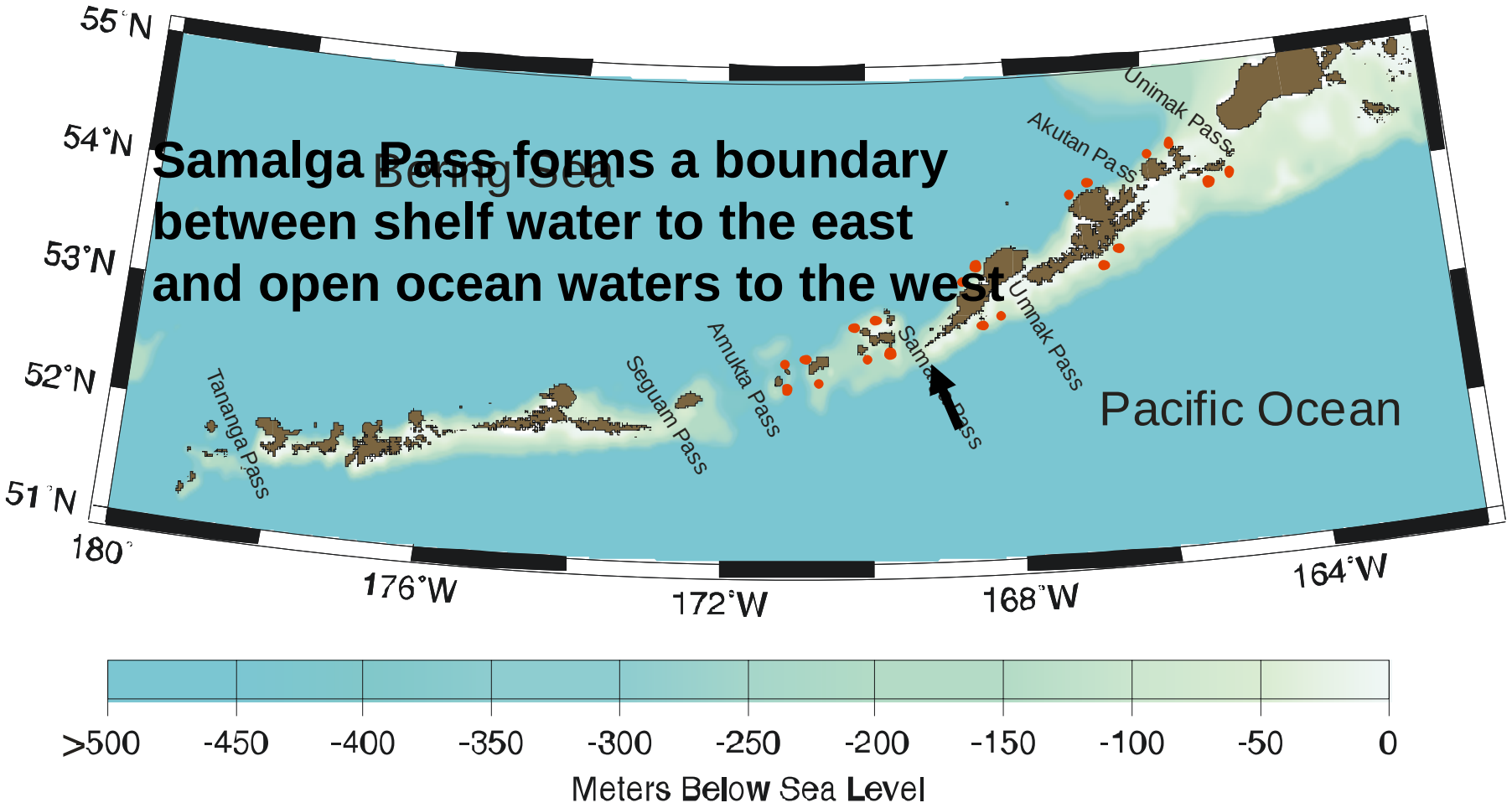
Decrease in large zooplankton
(and large phyto, small zoo) after the 1976-77 shift…

…But occurs only during spring bloom



Alexander et al.

Locations of Passes sampled May-June 2002



Samalga Pass forms a boundary between shelf water to the east and open ocean waters to the west

Coyle et al.

Surface Salinity along Aleutian Islands

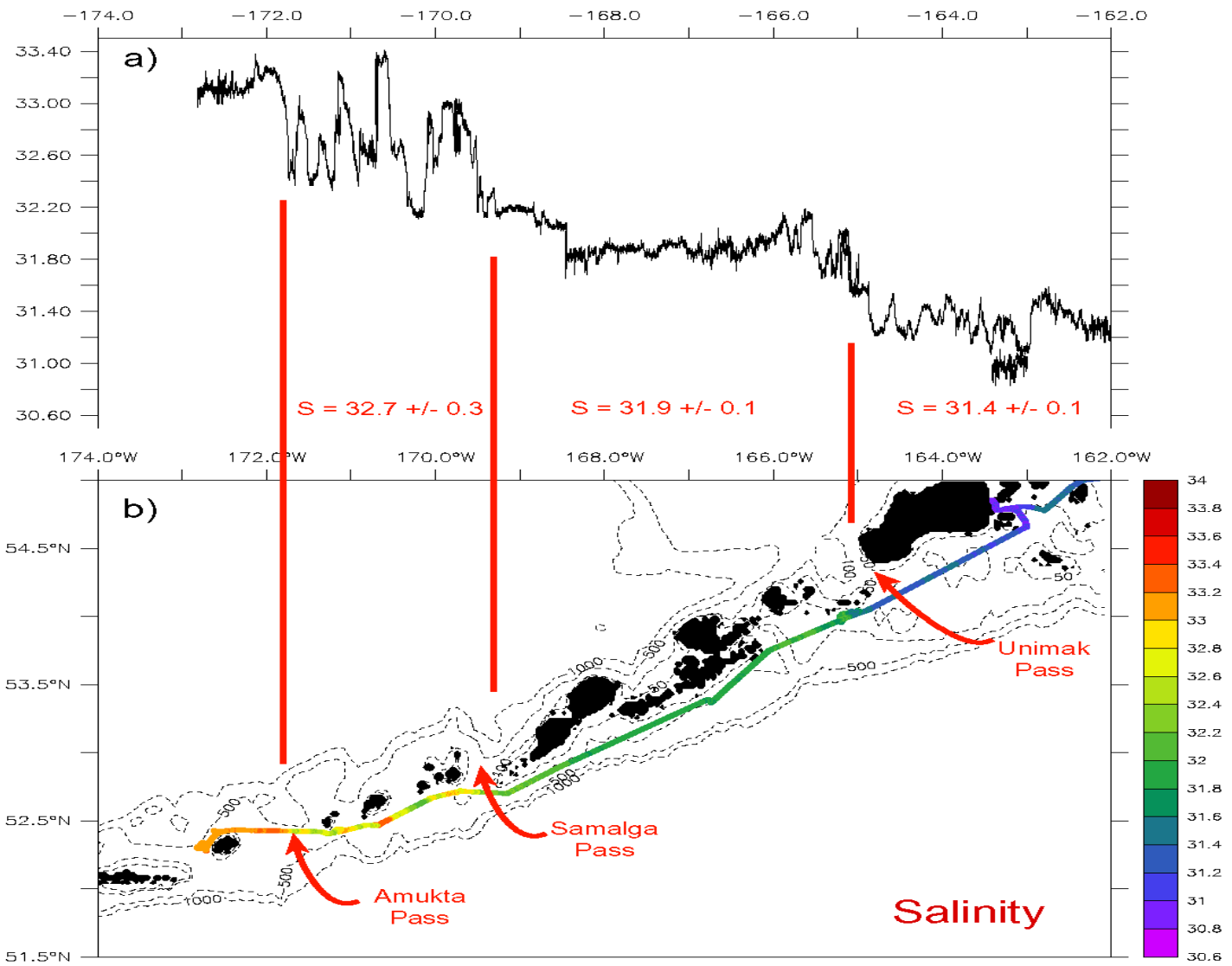


Figure 3. Underway sea surface salinity (psu) during 2001 cruise. a) salinity plotted against latitude. b) salinity represented by colored line on map. Average salnity in the regions east of Unimak Pass, between Unimak and Samalga Passes, and between Samalga Pass and Amukta Pass are noted.

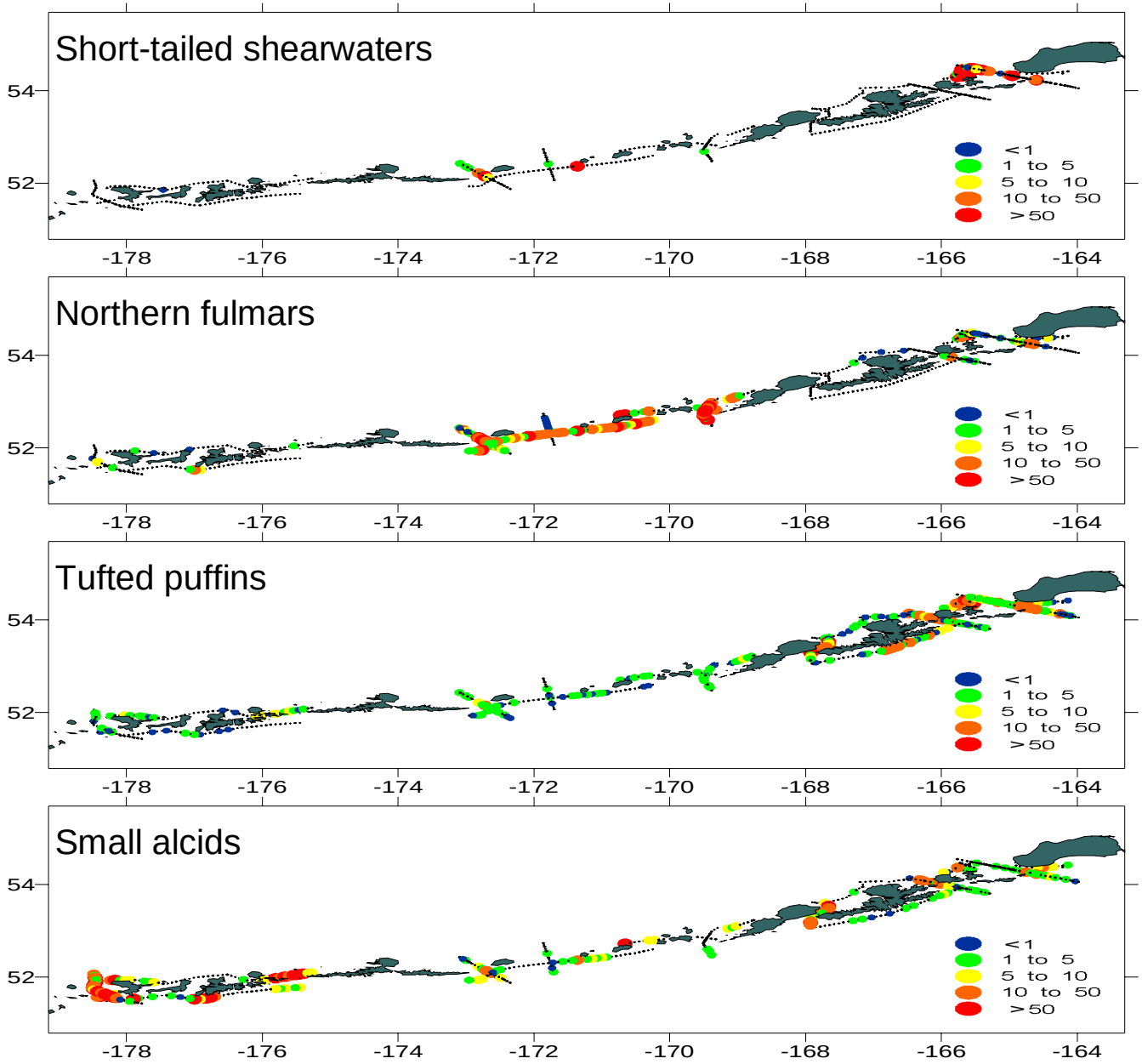
East of Samalga Pass, ACC has strong influence

West of Samalga Pass, Alaska Stream has strong influence

Ladd et al. (2004)

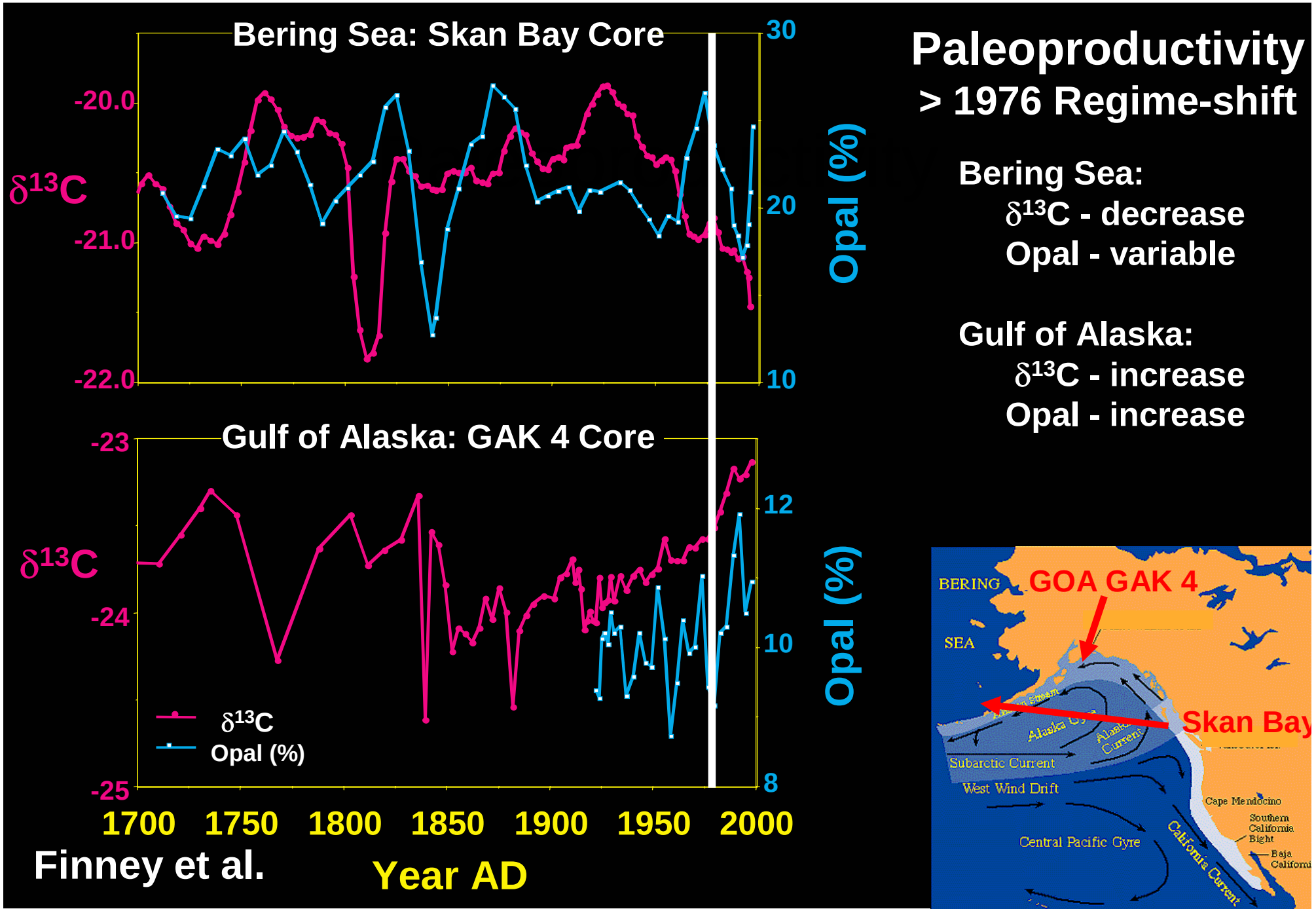
Seabirds Reflect Biogeographical Boundaries

West of Samalga Pass: Fulmars and Auklets (open ocean food web) dominant



East of Samalga Pass Shearwaters and Puffins (coastal food web) dominant

Jahncke et al.

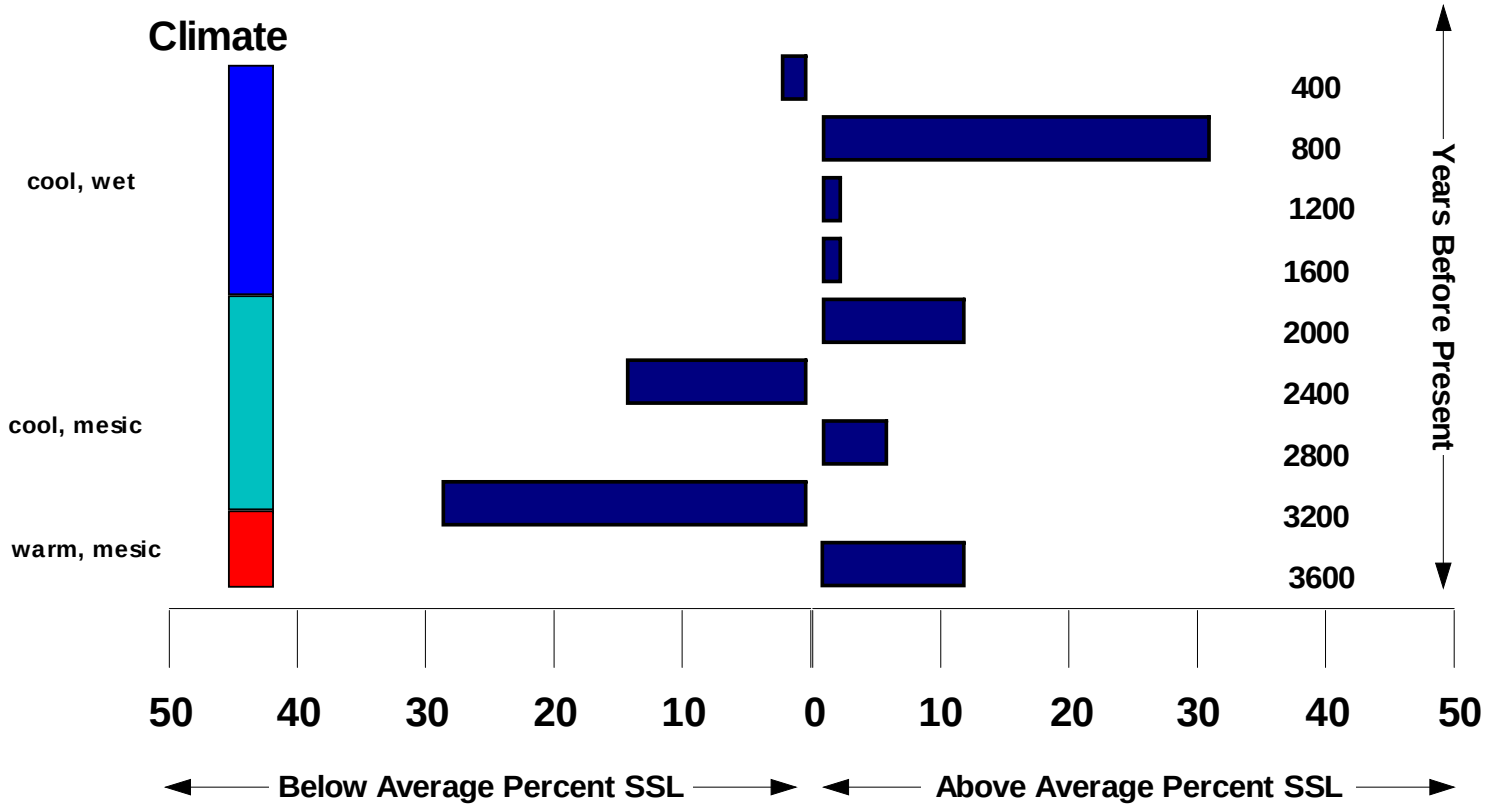


Paleoproductivity
> 1976 Regime-shift

Bering Sea:
- $\delta^{13}C$ - decrease
- Opal - variable

Gulf of Alaska:
- $\delta^{13}C$ - increase
- Opal - increase

Relative Abundance of SSL based on Archaeological Data



Maschner et al.

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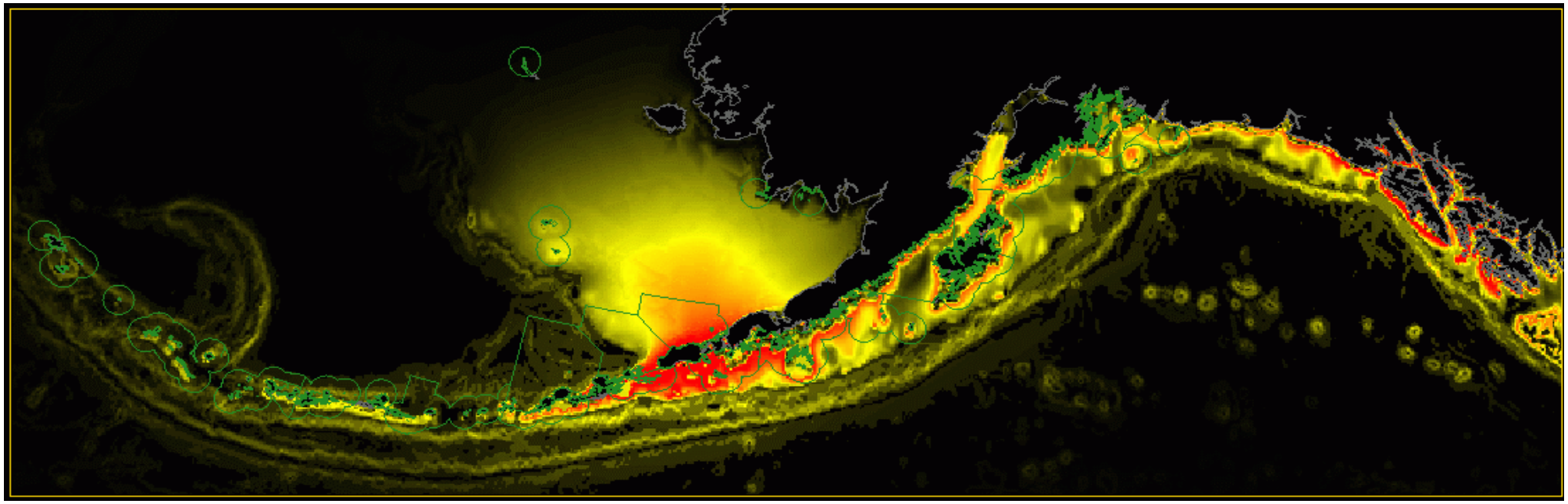
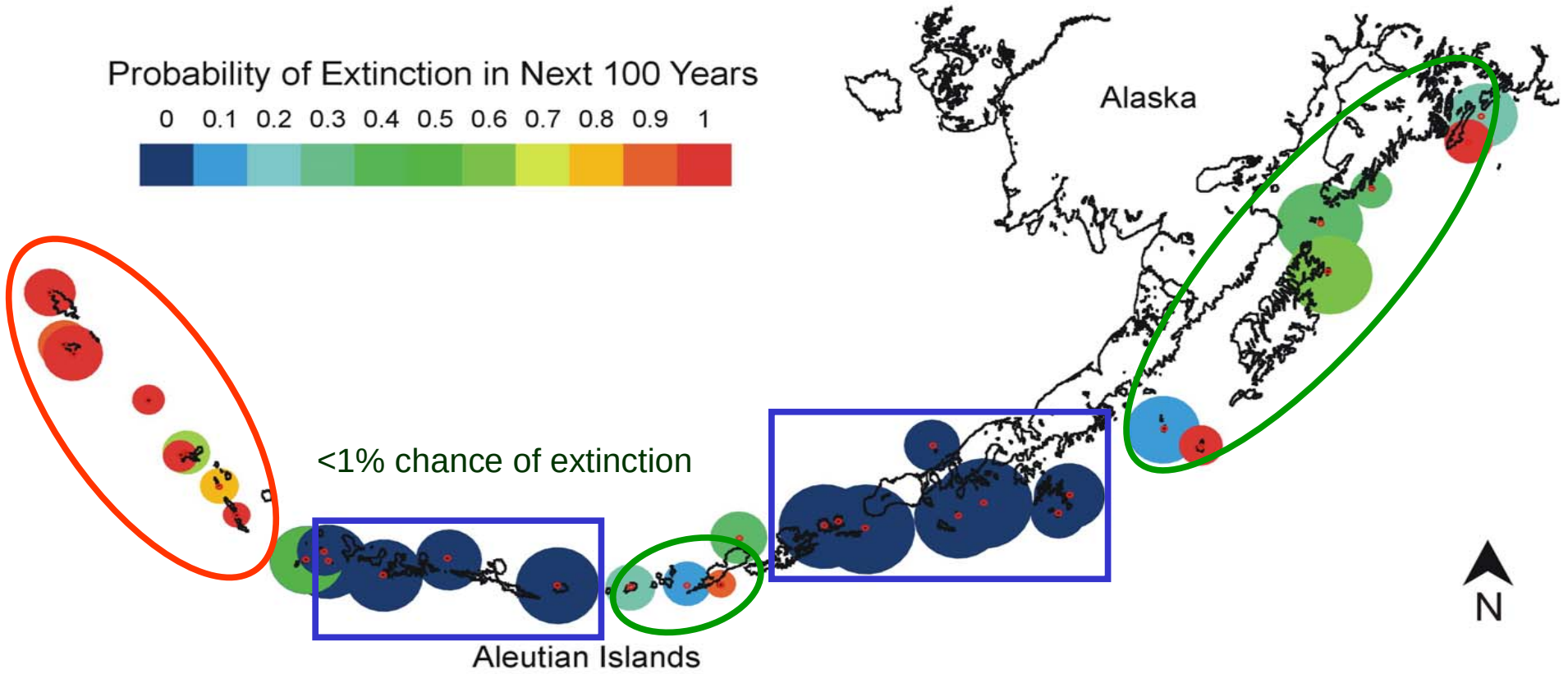
Regional Foraging Habitat

Winter



Gregr & Trites *in prep*

Regional Population Trends



Winship & Trites (in prep)