Zooplankton anomalies in the California Current before & during the warm ocean conditions of 2005

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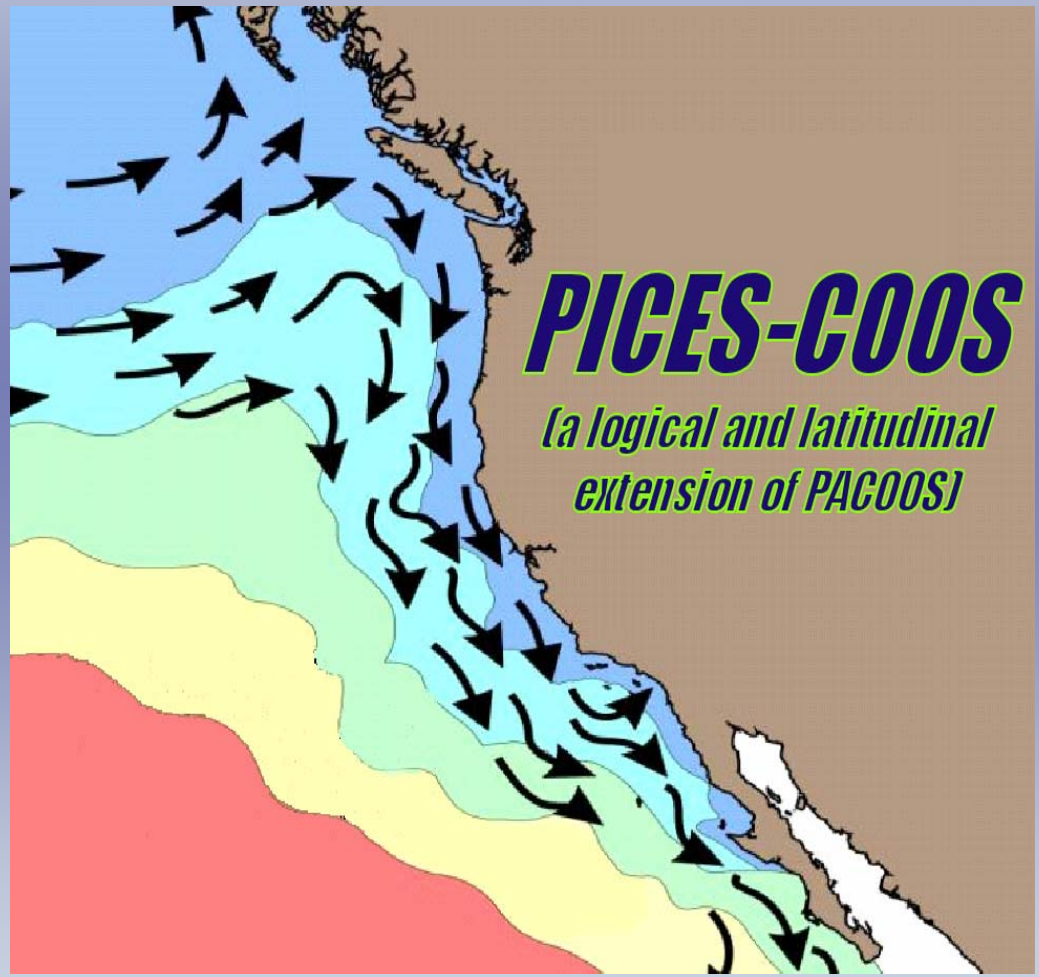


Background to 2005: (an unusual year in the CCS, difficult for many resident species)

In spring and early summer of 2005, the northern California Current System had:

- **Anomalously warm temperature**
- **Very late spring transition to upwelling**
- **Low phytoplankton biomass**
- **Very poor reproduction & survival of plantivorous seabirds & mammals**
- **Poor growth, survival, recruitment of many fish species**

Do anomalies of CCS zooplankton (biomass and/or composition) help connect these observations?

‘Foreground’ Questions

- **What happened to CCS zooplankton during (and before) 2005?**
  - **Changes in total biomass**
  - **Changes in community composition & zoogeography**
- **When did the 2005 CCS anomalies ‘begin’?**
  - **Breakdown of the post-1999 ‘cool regime’**
  - **Sequence within 2005**
- **How much of the CCS was affected in 2005? Where were the effects strongest?**
  - **Sign & magnitude of between-region correlations**

‘Underlying’ Questions (answers perhaps applicable to other systems and ‘events’):

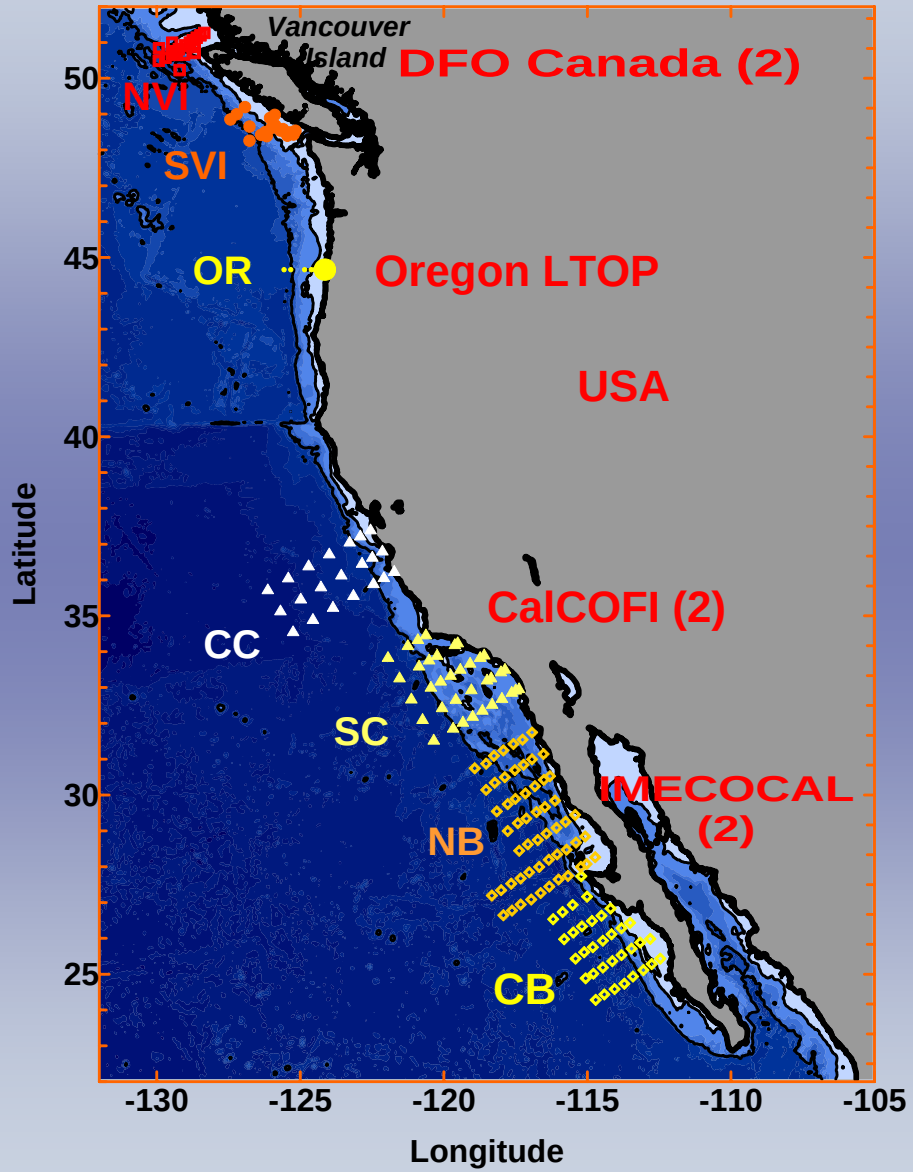
- **How steeply does zooplankton ‘similarity’ break down with increasing separation in space and time (scales of alongshore correlation)**

- **Time lags for onset and recovery (‘ecological inertia’)**

Data sources:

Zooplankton time series from 4 monitoring programs in 7 ‘regions’

- Canada:
  - N. Vancouver Island (NVI)
  - S. Vancouver Island (SVI)
- Oregon:
  - Newport Line LTOP (OR)
- CalCOFI:
  - Central California (CC)
  - Southern Califonria (SC)
- IMECOCAL:
  - Northern Baja (NB)
  - Central Baja (CB)



Similarities & differences in zooplankton methodologies

Program	Sampling interval	Samples per survey	Spatial replicates
Canada DFO	Vertical bongo,0.2 mm mesh	~Seasonal (3-6 per year)	10-20
Oregon NMFS	Vertical bongo,0.2 mm mesh	Biweekly	“few”
CalCOFI	Oblique bongo, 0.5 mm mesh	Seasonal (2 or 4 per year)	“many”
IMECOCAL	Oblique bongo, 0.5 mm mesh	Seasonal (4 per year)	“many”

Nevertheless, a good shared basis for quantitative comparison!

- **All programs compare ratios of within-survey means (of many samples) to long term regional climatologies (also based on many samples)**
- **The outputs are annual time series of log-scale anomalies**
- **Show changes in relative amount (2x more, 3x less, ….) AND**
- **Filter out seasonal cycle, spatial patchiness**

Added benefit:

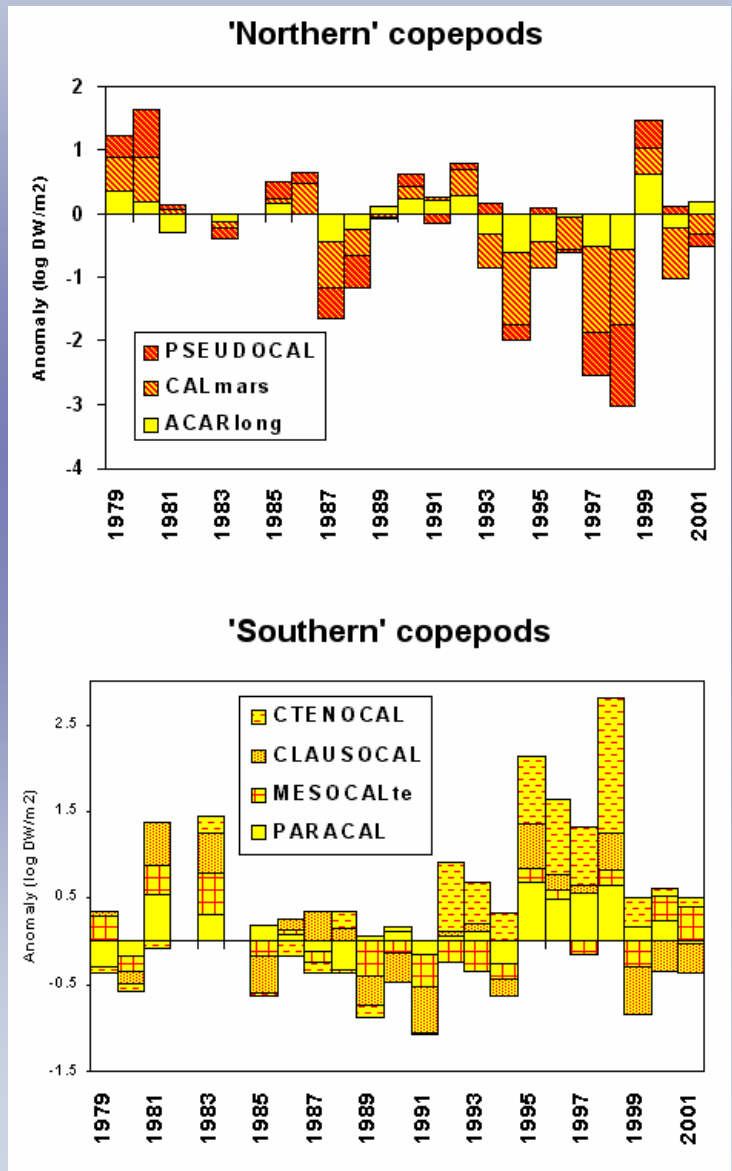
- **Log-scale anomalies A_t also filter out any sampling biases (c) that are shared by both data B_t and climatology $\overline{B}$**

$$A_t = \log\left(\frac{cB_t}{c\overline{B}}\right)$$

$$= \log(B_t) - \log(\overline{B}) + \log(c) - \log(c)$$

Useful tool: Averaging of anomalies within species assemblages

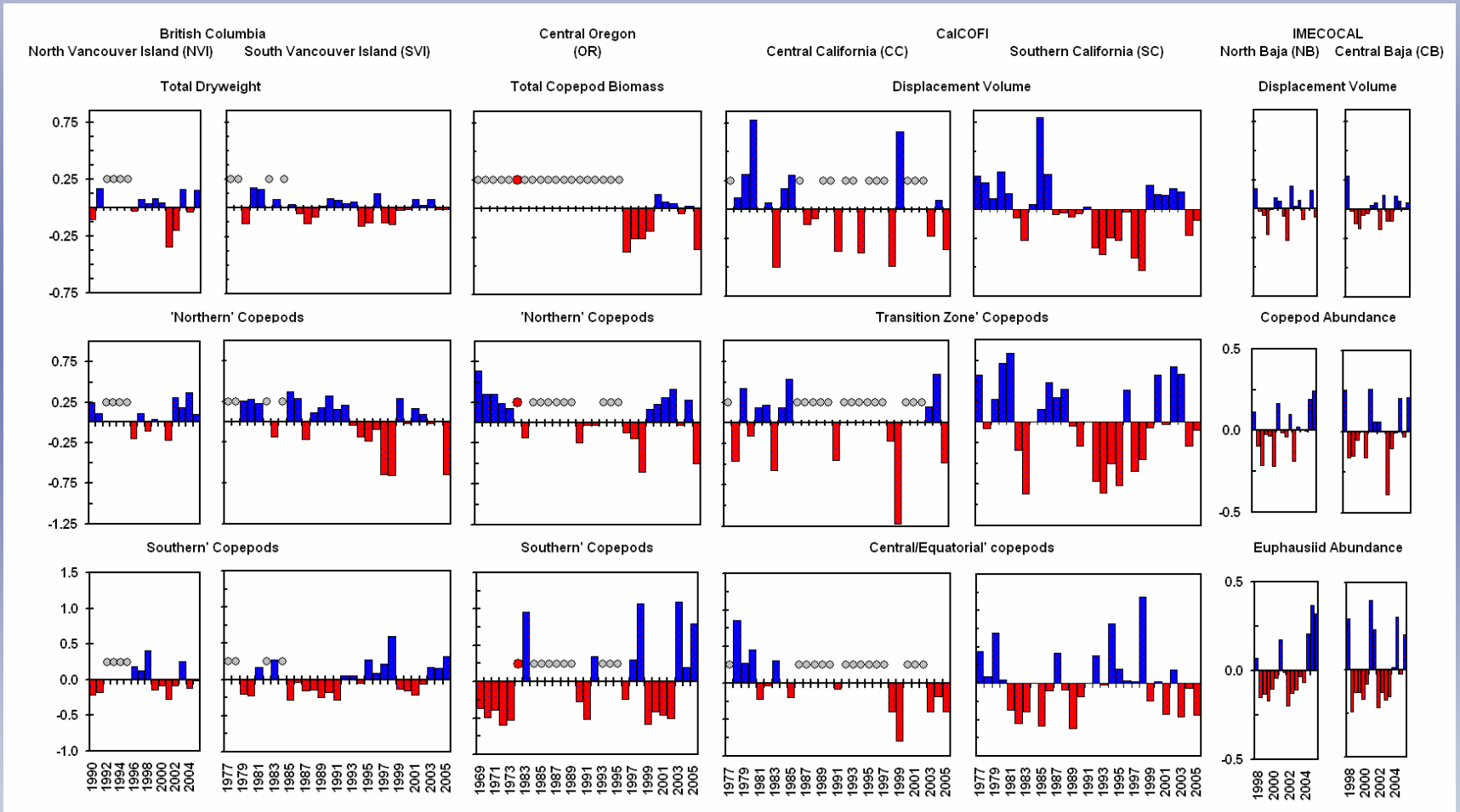
- Further reduces noise
- Often a stronger signal than Δ(total biomass)
- Invites comparisons with information about zoogeography and community ecology
- Especially useful for understanding effects of changing current patterns



Presentation of Results:

- **Anomaly time series for:**
  - **Total biomass (weight or displacement volume)**
  - **‘Resident’ copepod assemblage**
  - **‘Intruder’ copepod assemblage (from south & offshore)**
- **Similarities among time series (zooplankton indices) and among years from multivariate MDS ordination**
- **Link to CCS temperature (not in the MDS)**
- **Detailed within-2005 chronology (Oregon), and persistence of zooplankton vs physical anomalies**

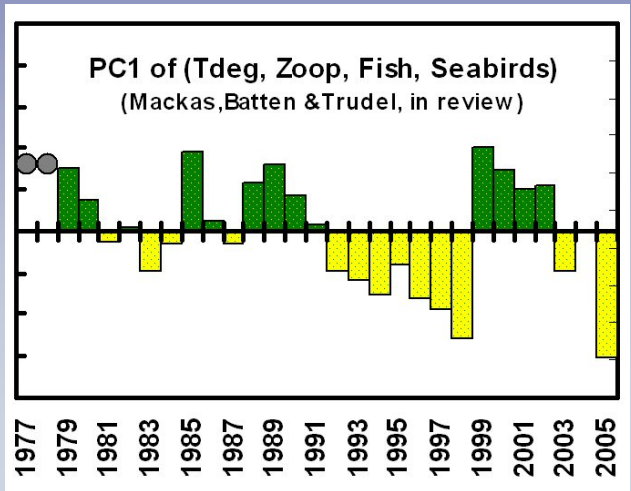
Overview: anomalies from all 7 regions
(details by region to follow but note relative amplitudes)

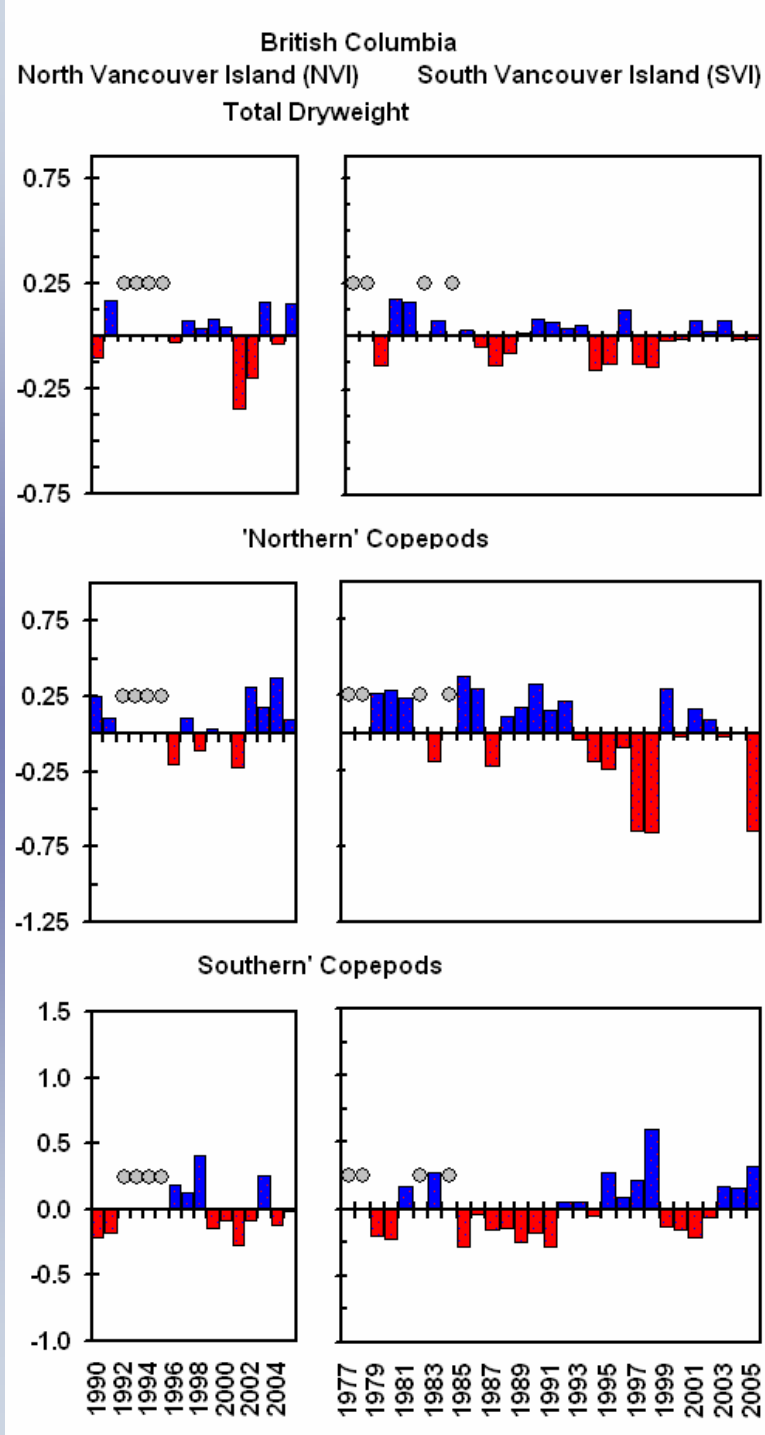


(smaller) (larger) (smaller)

Anomaly time series by region: BC

- Total biomass & resident ‘northern’ species high in 1980s, low in 1990s, high 1999-2002, low 2004-05
- ‘Southern’ species the opposite
- Zooplankton share signal with physics & fish?

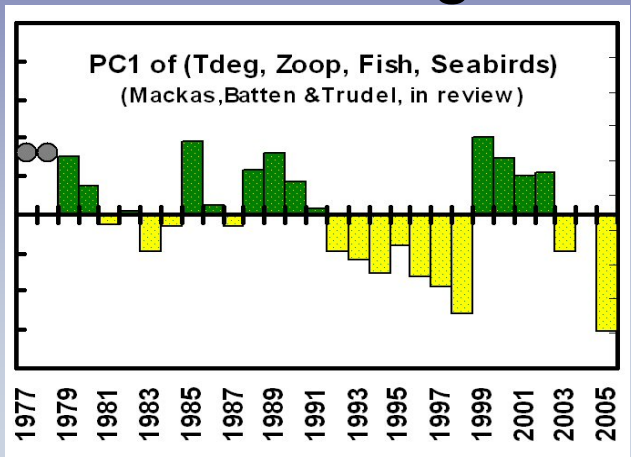


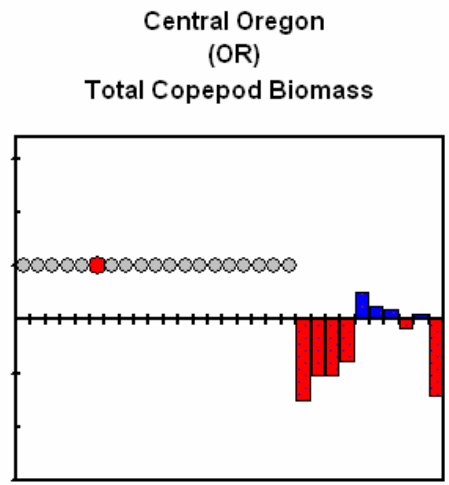


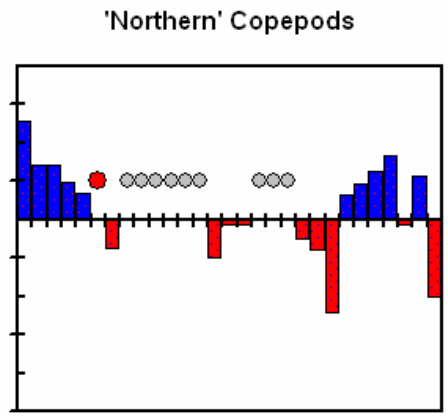
Anomaly time series by region: OR

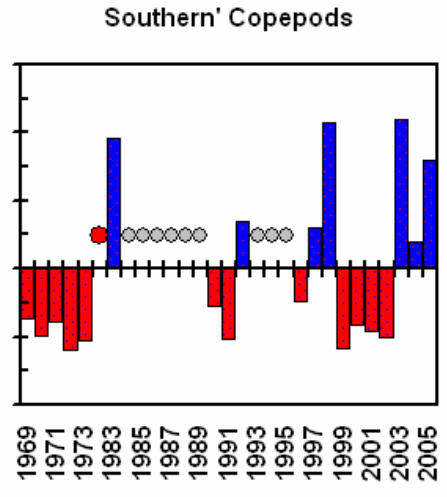
Same story as BC:

- **Total biomass & resident 'northern' species high in 1970s, low in 1990s, high 1999-2002, low 2004-05**
- **'Southern' species the opposite**
- **Same shared signal??**





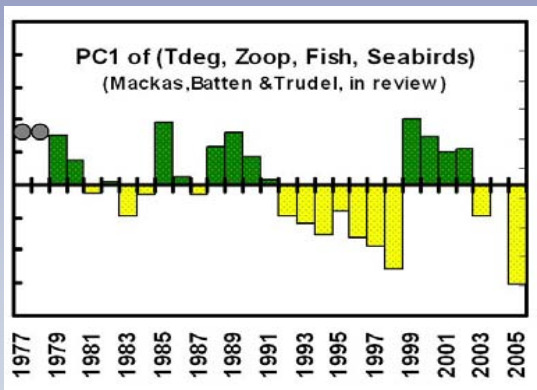


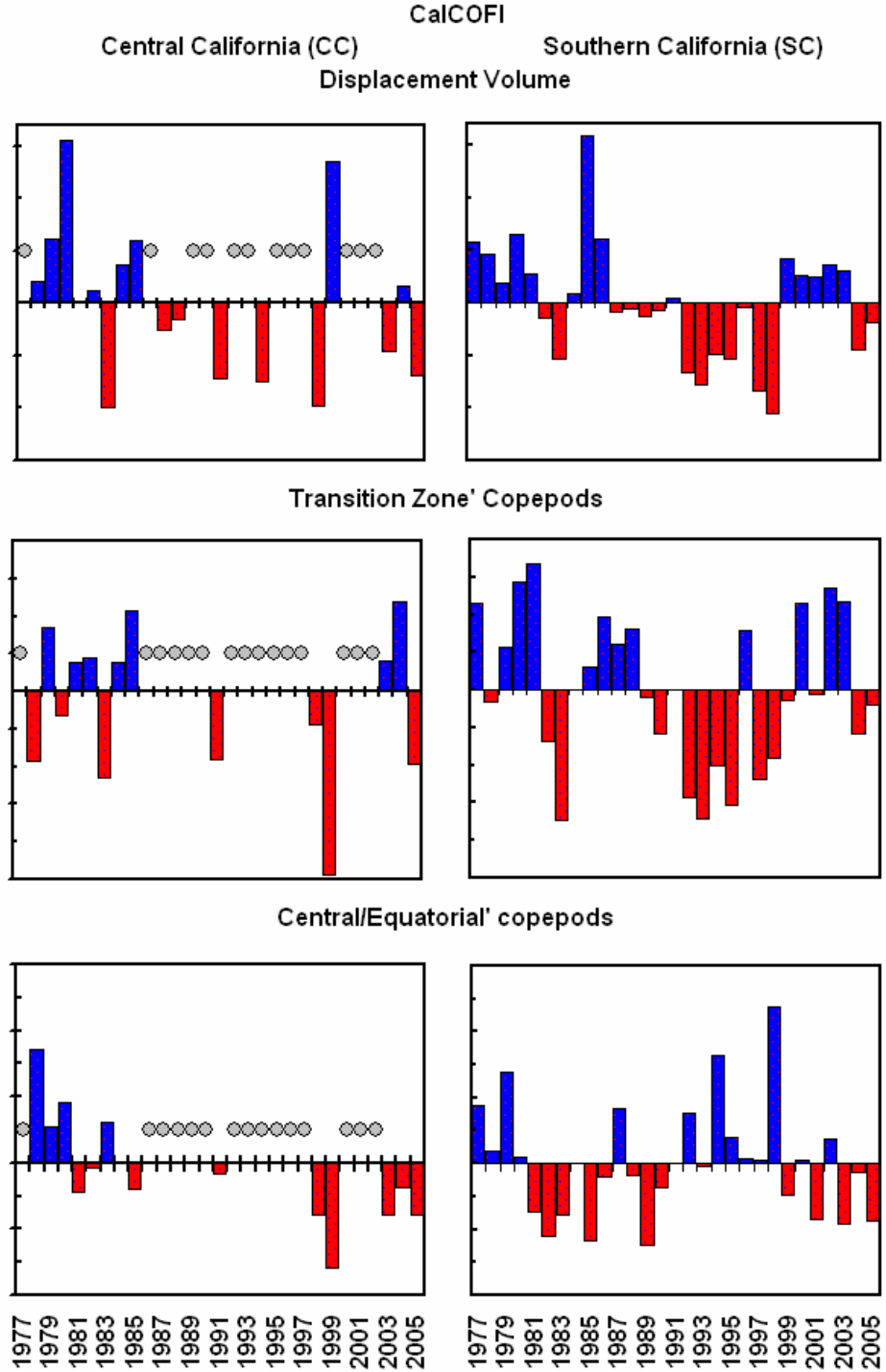


Anomaly time series by region: CalCOFI

Similar (but not identical) story to BC & OR:

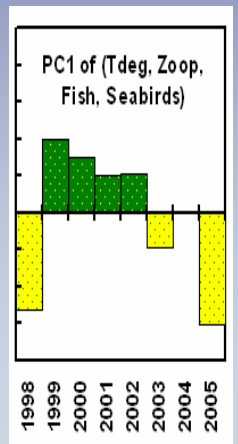
- **Total biomass & 'Transition Zone' species high 1970-mid80s, low in 1990s, high 1999-2002, low 2004-05**
- **'Cental/Equatorial' species often the opposite, but in 2004-05 were also low**

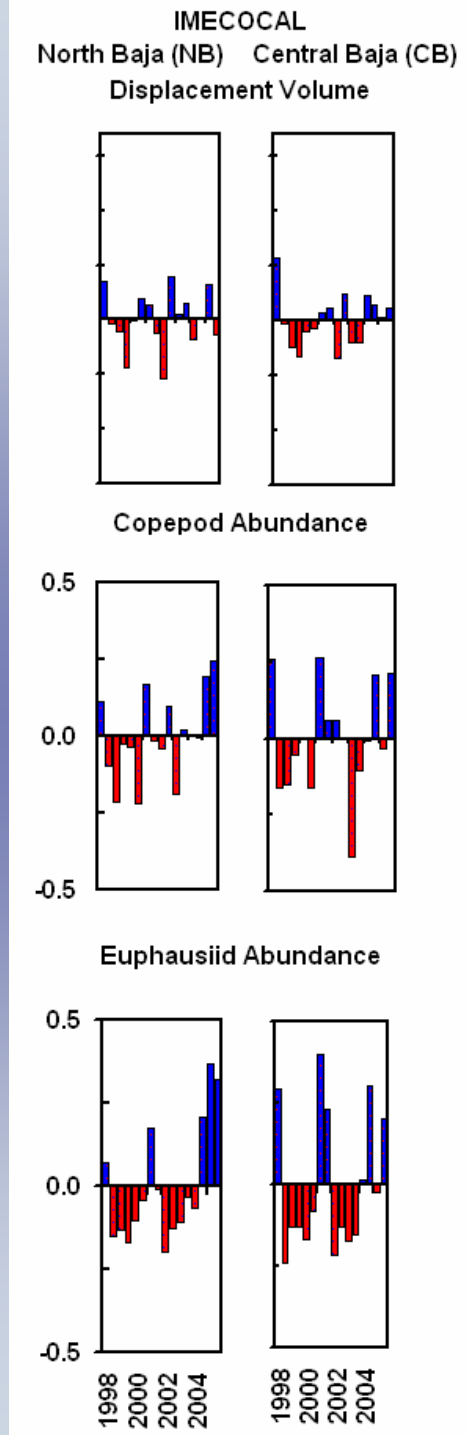




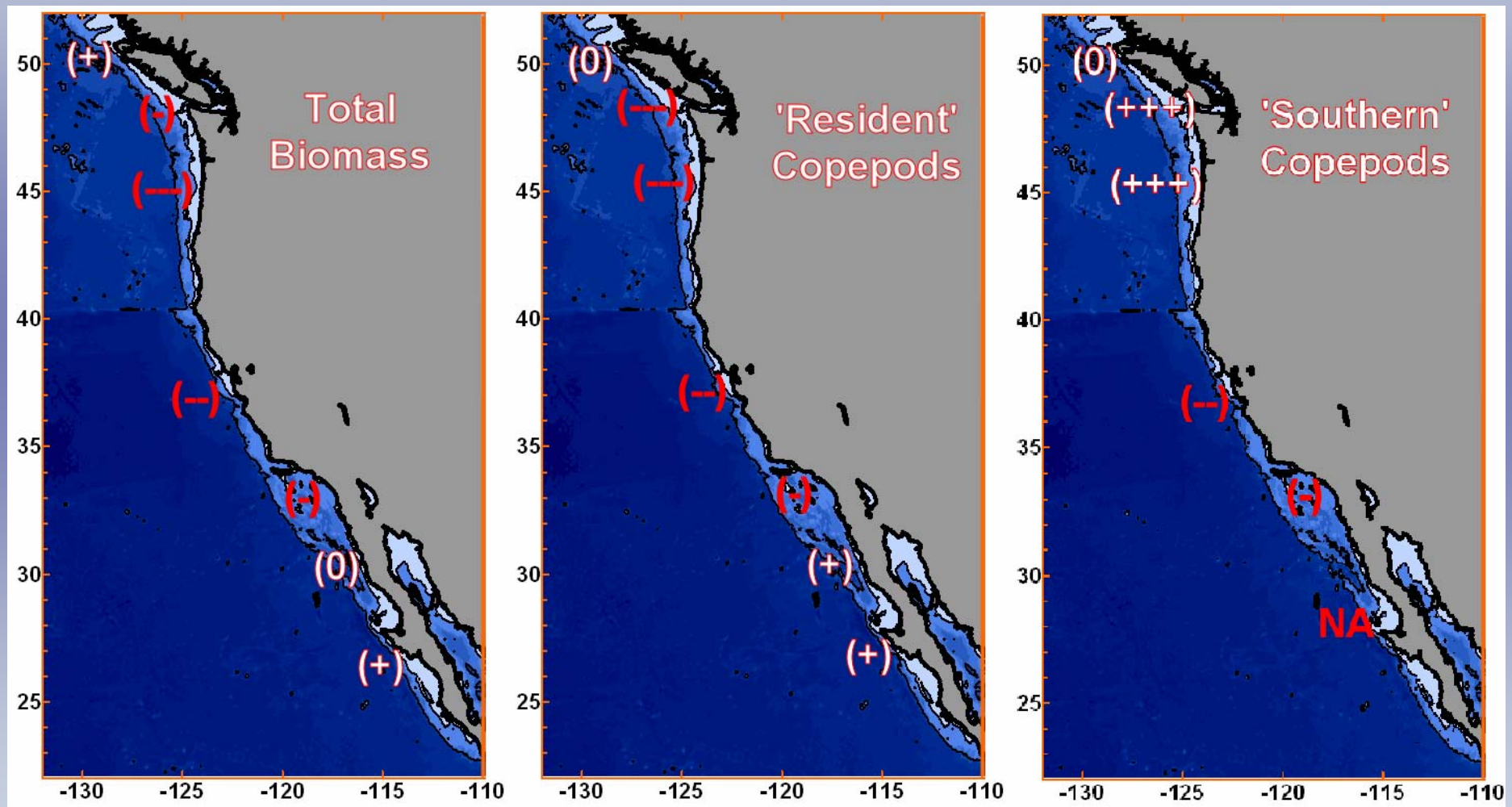
Anomaly time series by region: IMECOCAL

- Shorter time series (1998-present)
- Since 1998, Baja zooplankton have varied out-of-phase with other regions in the CCS (not true for early years of CalCOFI coverage off Baja)
- Total biomass & abundance low 1999-2002, higher 2004-05
- Share signal of northern CCS?





Summary #1: signs and amplitudes of 2005 zooplankton anomalies



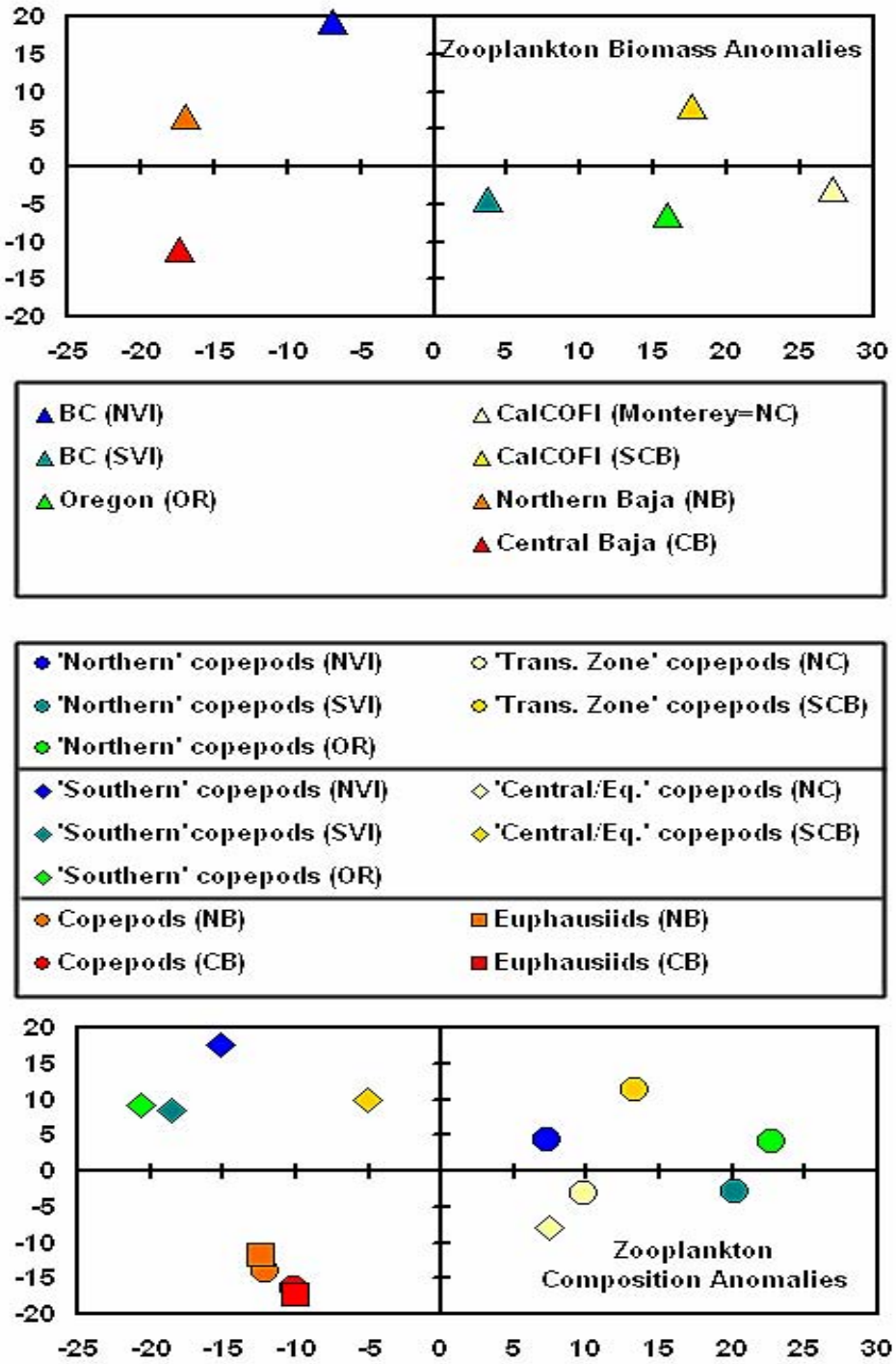
Comparisons among variables

'Metric Multidimensional Scaling' ordination:

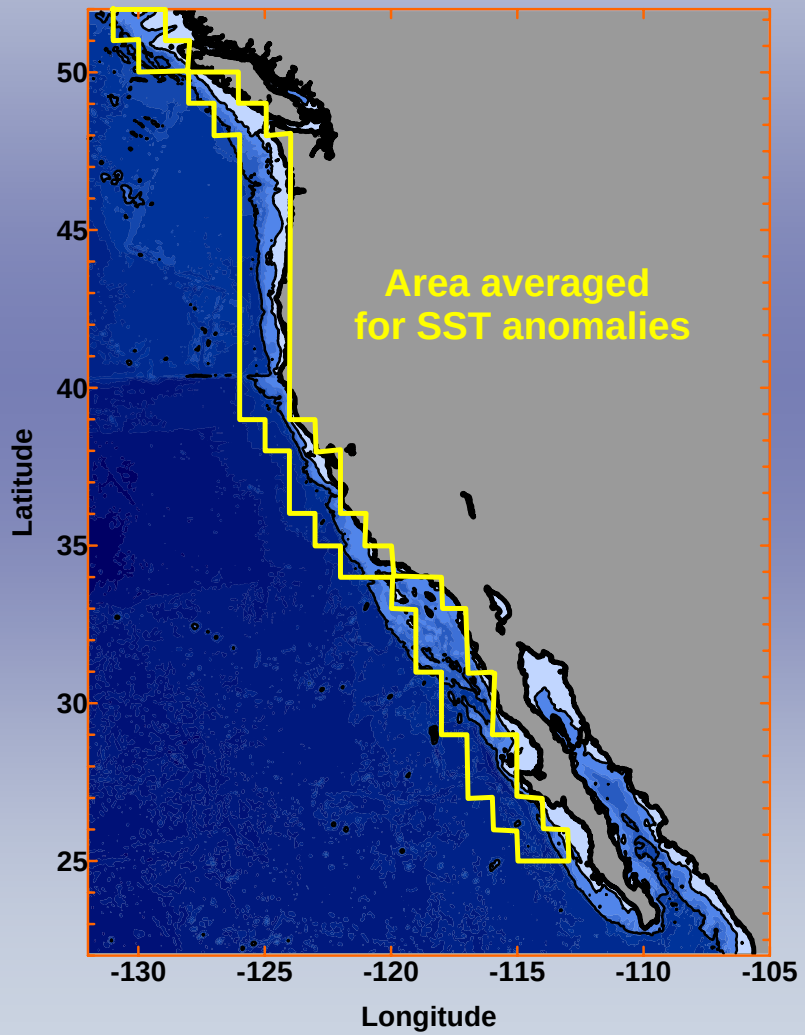
- Each time series a data point
- 'Close together' means time series are similar
- 'Far from origin' = accounts for bigger fraction of variability

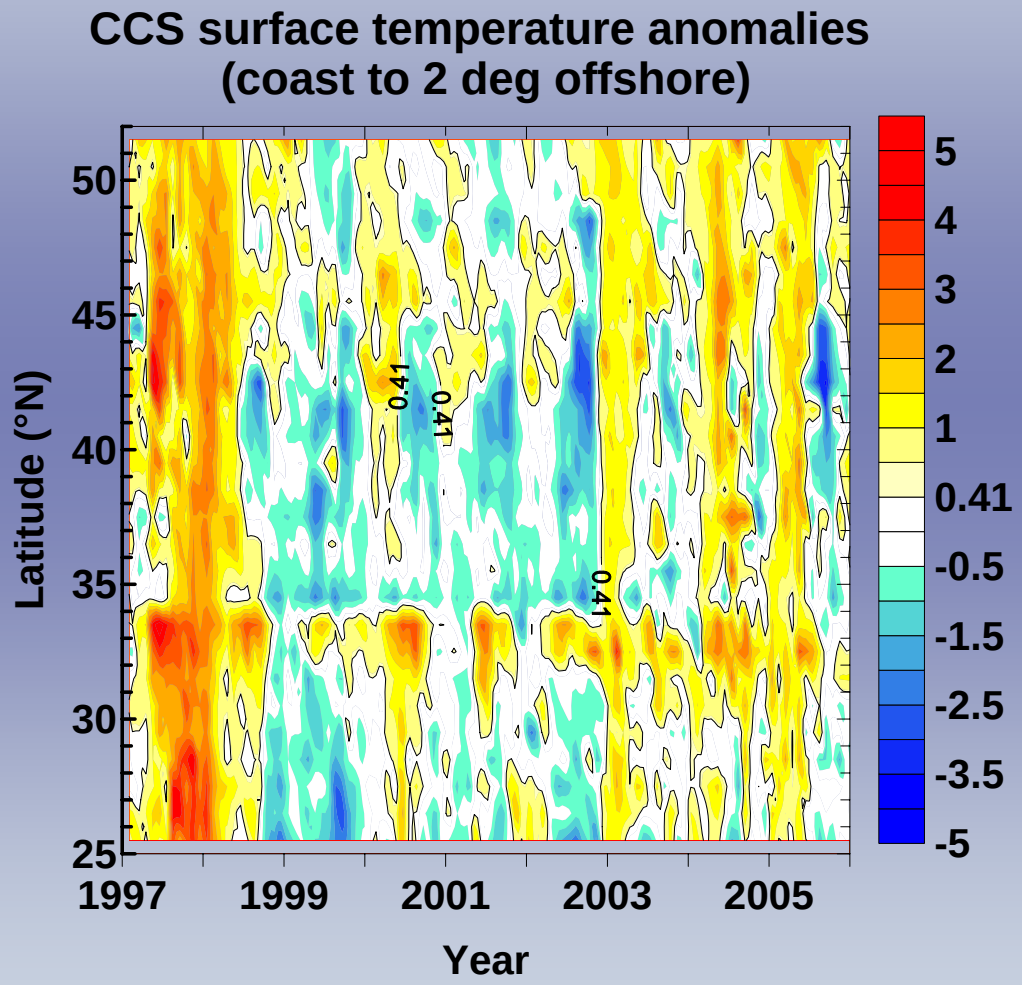
Temperature data not included BUT

- Left ~ "positive when northern CCS is warm"
- Right = "positive when northern CCS is cool"



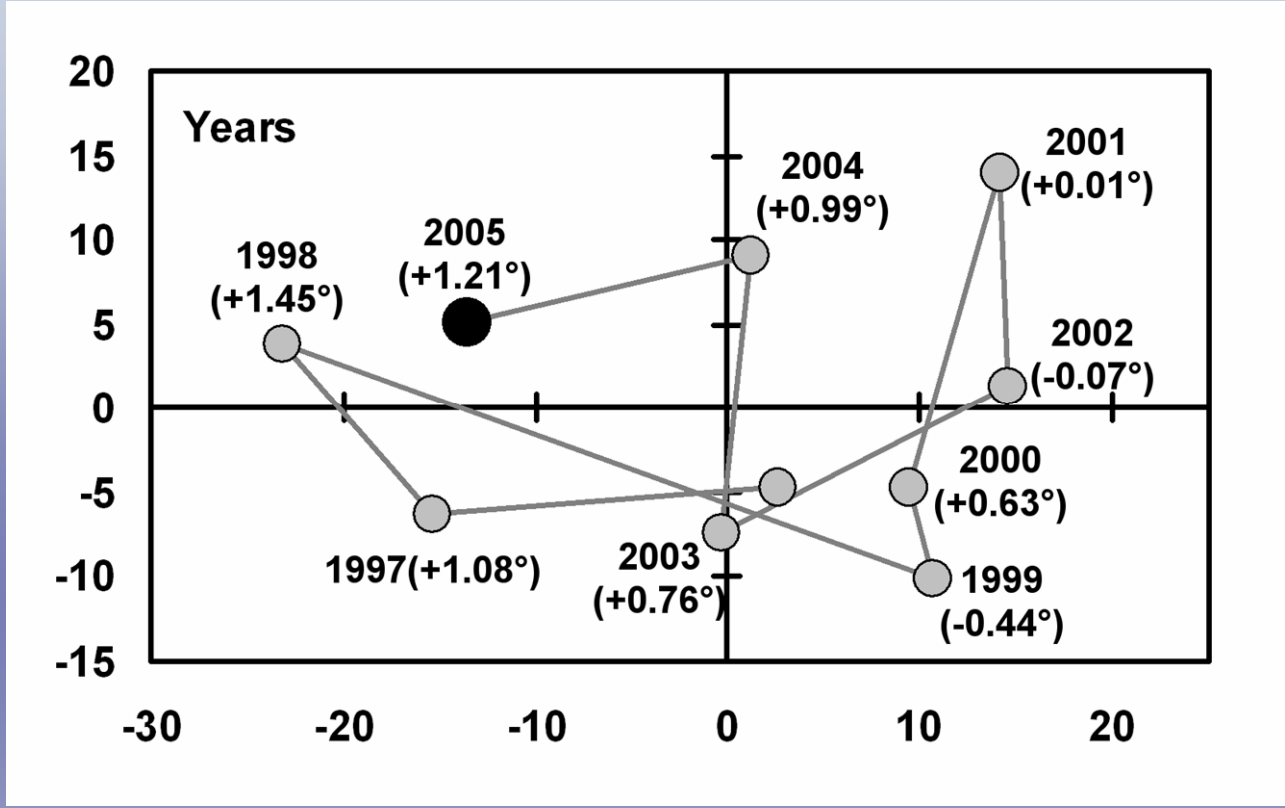
Strong covariance of zooplankton & CCS temperature anomalies





from http://www.pfeg.noaa.gov
1945-1989 COADS climatology

Sign & amplitude comparisons among years



- Each year a data point, ‘close together’ means years are similar, ‘farther from origin’ means bigger signal
- 2005 was most like 1997 & 1998, least like 1999-2002 (1996, 2003 & 2004 were intermediate)
- Left ≈ “northern CCS is warm”
- Right ≈ “northern CCS is cool”

2005 zooplankton anomalies persisted longer than ‘ocean’ anomalies

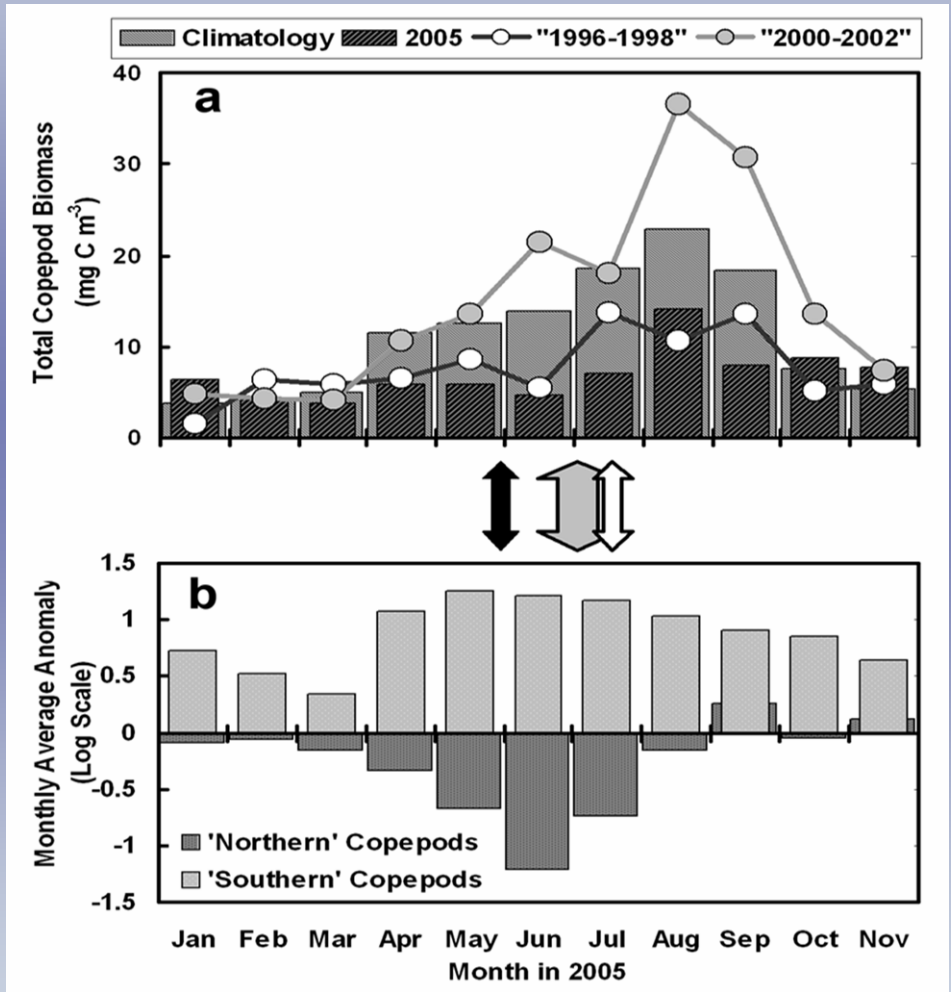
Total biomass remained low throughout 2005 (relative to climatology, to ‘cool’ years, and ‘warm’ years)

vs.

Timing of ‘return to normal’ for upwelling (black), Chl *a* (grey), SST (white)

vs.

‘Southern’ copepods remained abundant all year, ‘northern’ copepods recovered by autumn



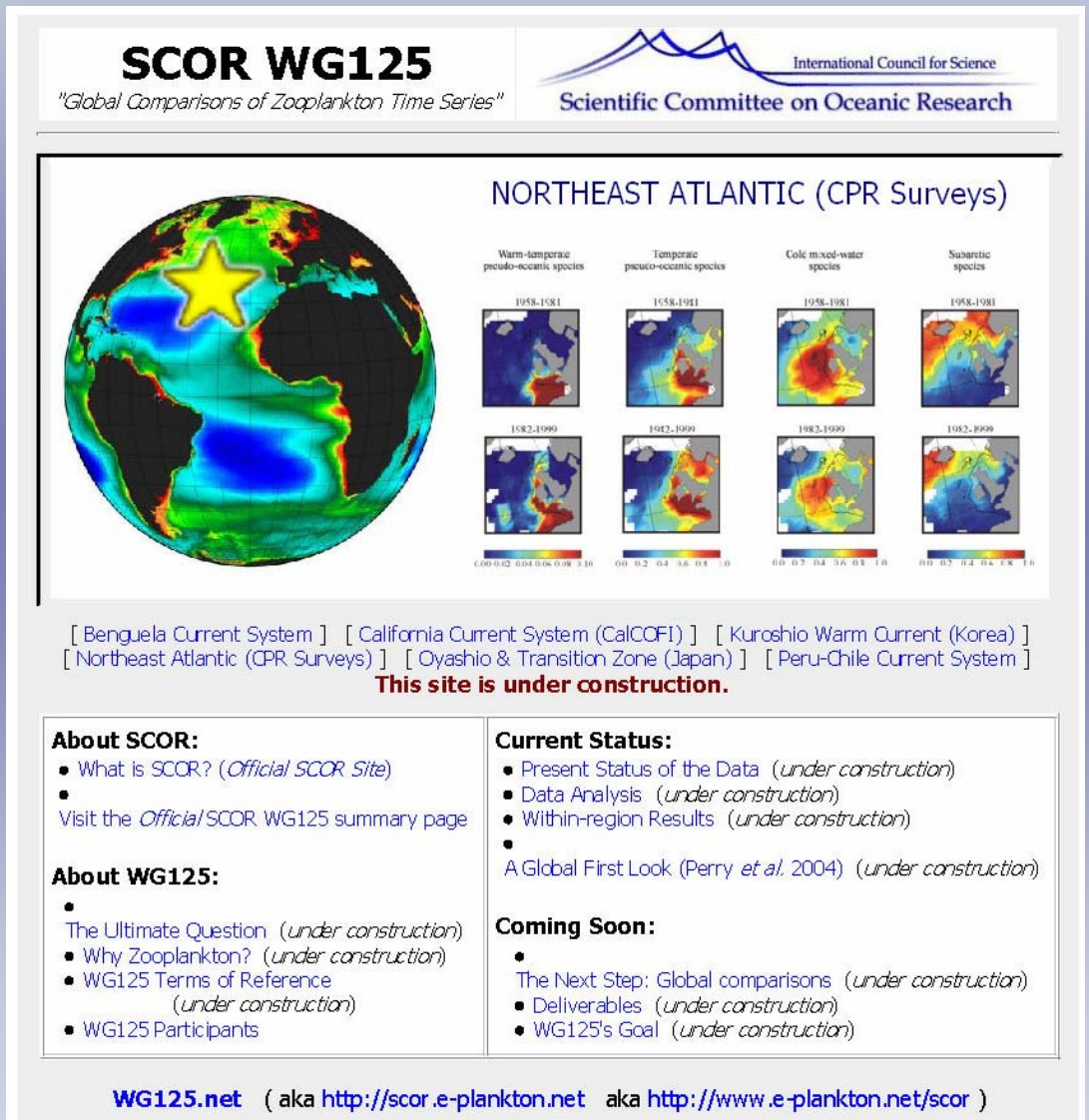
Summary of 2005 events ('Foreground' questions)

- **Much of the CCS had lower-than-normal total zooplankton biomass, plus low abundance & biomass of 'resident' taxa**
- **Zooplankton anomalies persisted to end of 2005 or early 2006**
- **Response was strongest in northern CCS, (roughly Monterey-Columbia River)**
- **Response was weak or reversed off Mexico & off Northen Vancouver Island**

Spatial coherence & persistence of anomalies

- **Our comparison of zooplankton time series spans an entire boundary current LME (~2800 km)**
- **At separations under ~ 700 km, same species change, in same direction, and in same years (regional zooplankton are “singing in chorus”)**
- **At separations ~1000-1500 km, modes of change begin to differ strongly (which species), but still agree on sign and timing of changes (zooplankton are “singing in harmony”)**
- **Correlations weaken and/or flip sign at the N and S ends of the CCS (zooplankton are starting to “sing different songs”)**
- **CCS zooplankton anomalies ‘filter’ environmental forcing (‘redder’ spectrum, lagged onset, persistence & ‘ecological inertia’)**

COMING SOON: Global comparisons of zooplankton time series



Members from PICES:

- **Mackas (co-chair)**
- **H. Batchelder**
- **D. Checkley**
- **S. Chiba**
- **Y.-S. Kang**
- **M. Ohman**

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