Large-scale time and space patterns of chlorophyll phenology in the California Current

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Rationale / Goals

Variability in chlorophyll phenology potentially link shifts in seasonality in physical forcing and the base of the trophic system.....

Strong interannual anomalies in CHL in California Current are well documented – Do these result from changes in overall annual mean, amplitude or shifts in phase (phenology)?

Quantify interannual variability in SPATIAL GEOGRAPHY of CHL phenology

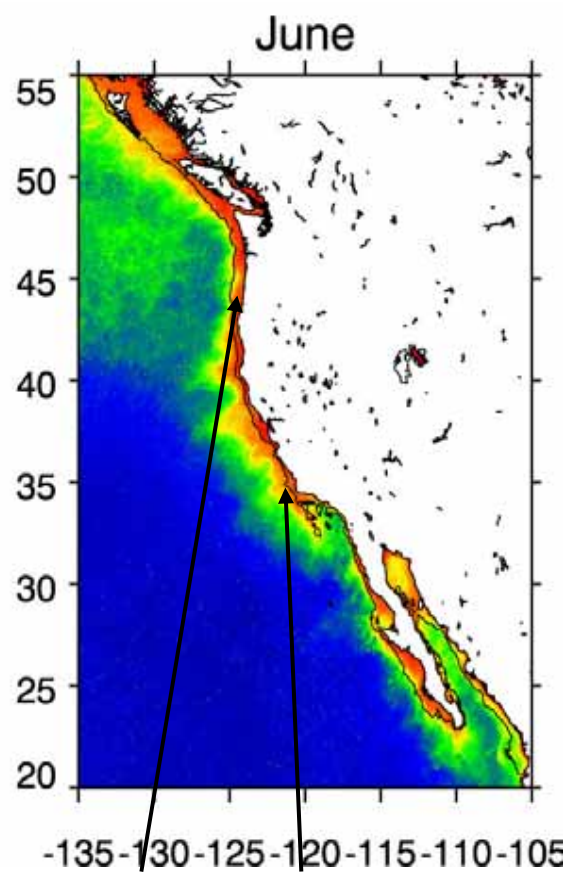
Background

CHL Time/Space patterns in the California Current

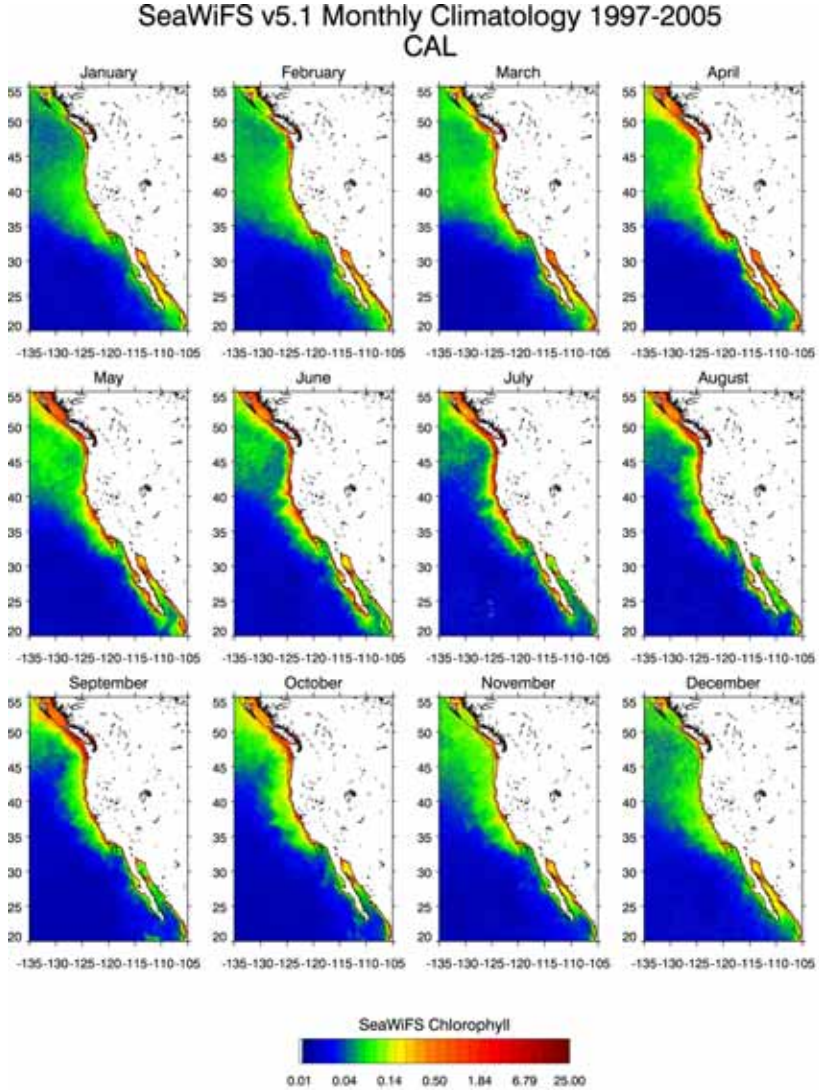
- Elevated concentrations along the coast
  - – equatorward (upwelling) winds
- Latitudinal progression in wind forcing seasonal cycle
  - – year-round at low latitudes
  - – only in summer at higher latitudes
  - - shorter & weaker summer upwelling at highest latitudes

Introduction

CHL seasonality & anomalies in the California Current



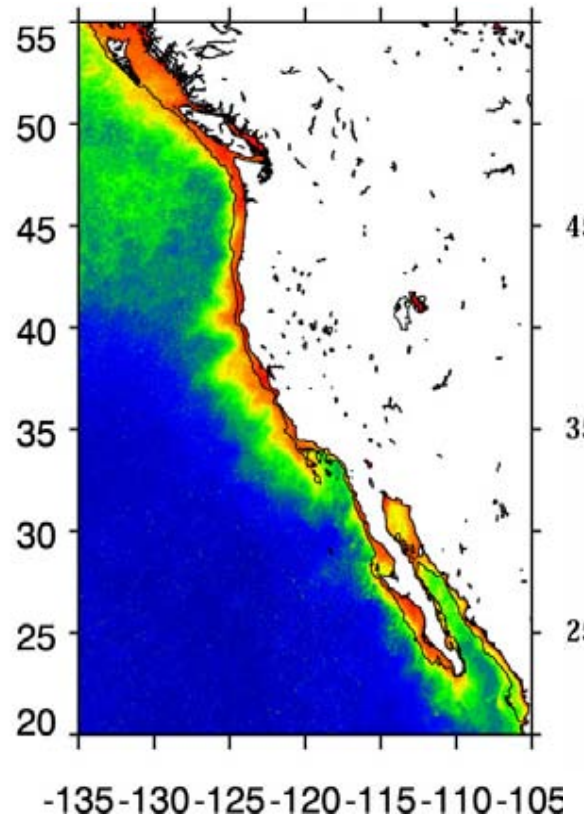
100 km wide
cross-shelf mean



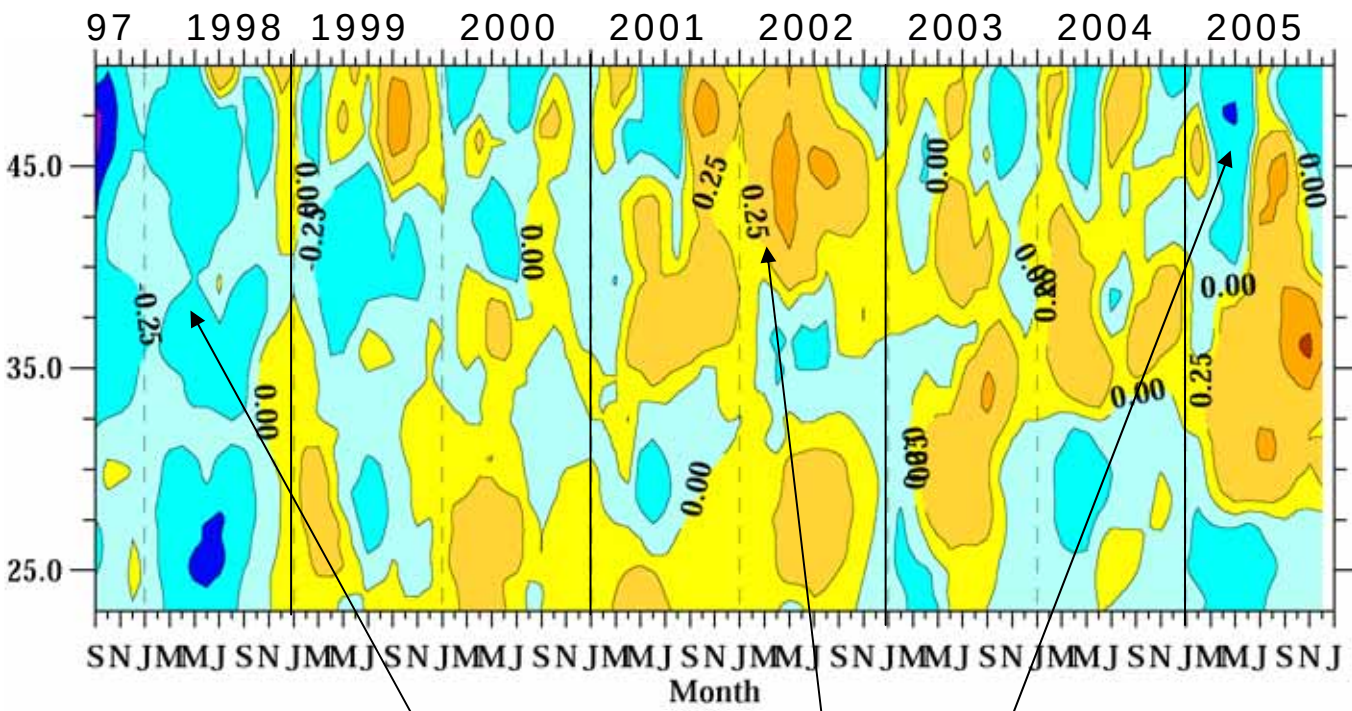
Climatological Seasonal Cycle

Introduction

CHL seasonality & anomalies in the California Current



Monthly averaged, 100km wide coastal means

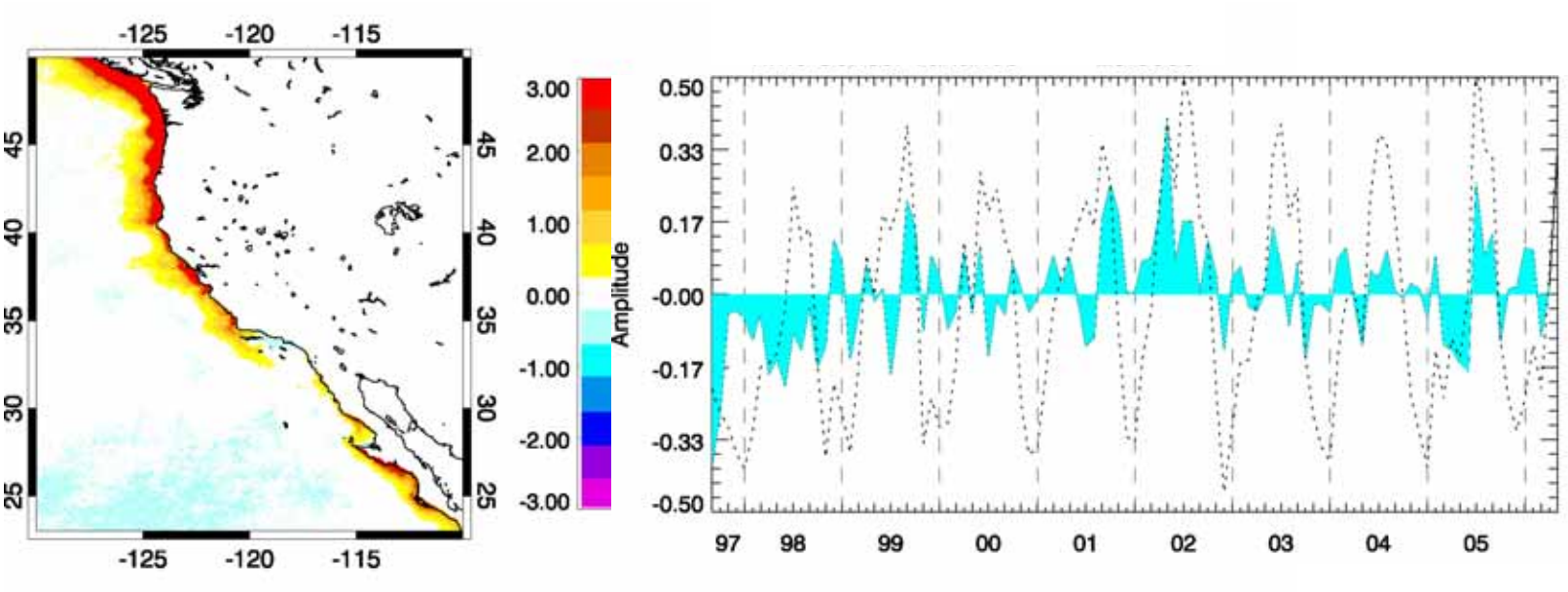


Anomalies: 97-98 El Nino, 2002 subarctic intrusion, 2005 delayed upwelling

Introduction

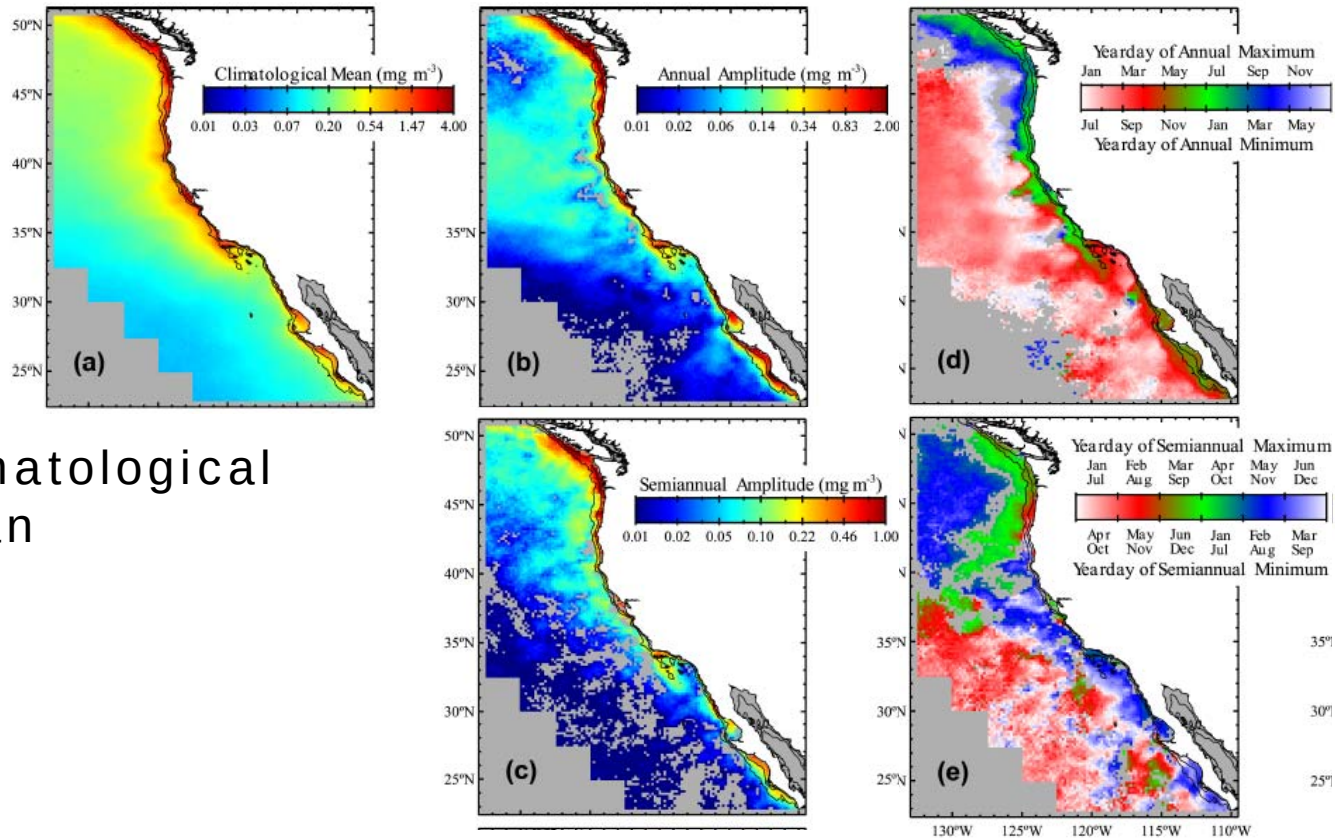
CHL anomalies in the California Current

EOF decomposition of monthly timeseries



Mode 1: ~20% of total variance

Seasonal Cycles: climatology



Climatological Mean

Annual

Semi-annual

Annual and semiannual harmonics

from Legaard and Thomas, JGR, 2006

Data and Methods

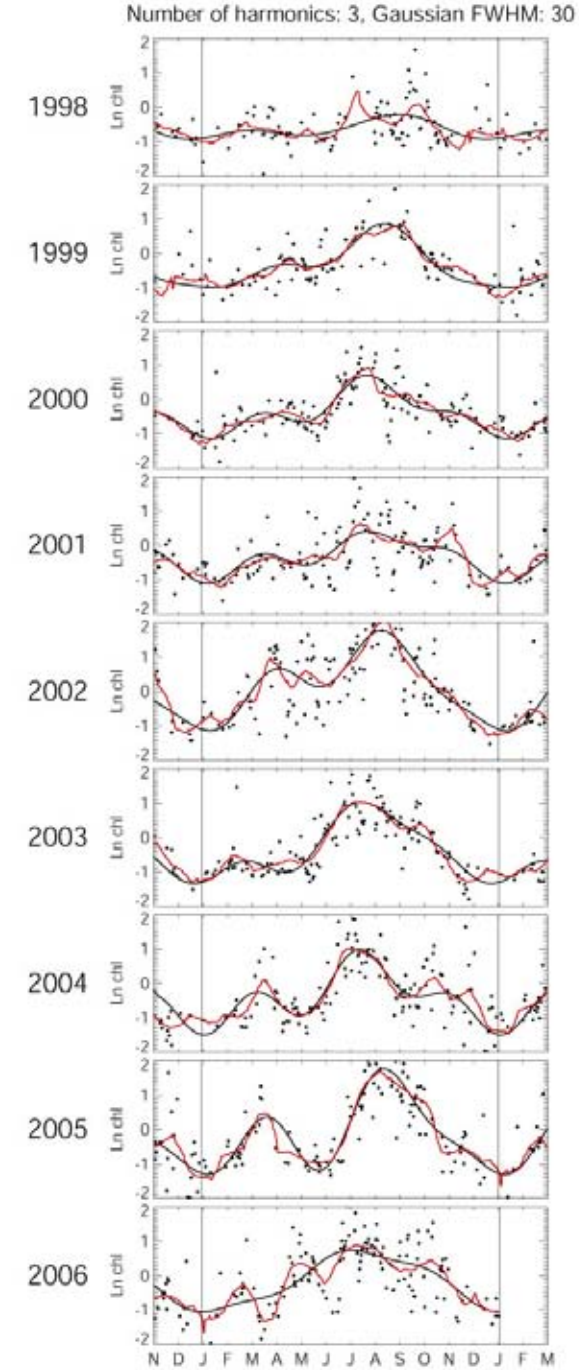
9 years of SeaWiFS ocean color data – 1998 - 2006

- [CHL] over the California Current System
- DAILY data, remapped to common projection
- 4km spatial resolution, log transformed [chl]

Gappy time series at each location ..... phenology

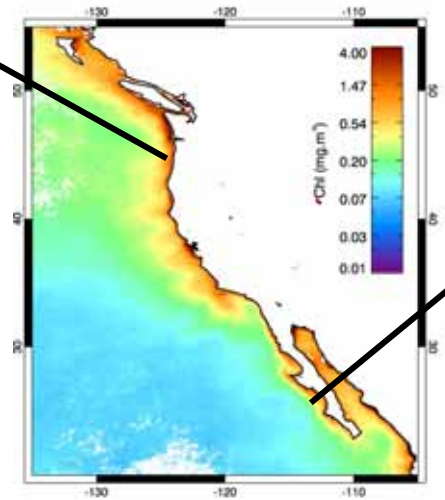
- each year treated separately
- 12 months of data + 2 months either side
- MODEL 16 month time series with 1st 3 harmonics
  - ANNUAL, SEMI-annual and TRI-annual
  - each year : Mean + 3[Amp & Phase] .... at every location
  - *+ residuals ... more later on these*

Data Example

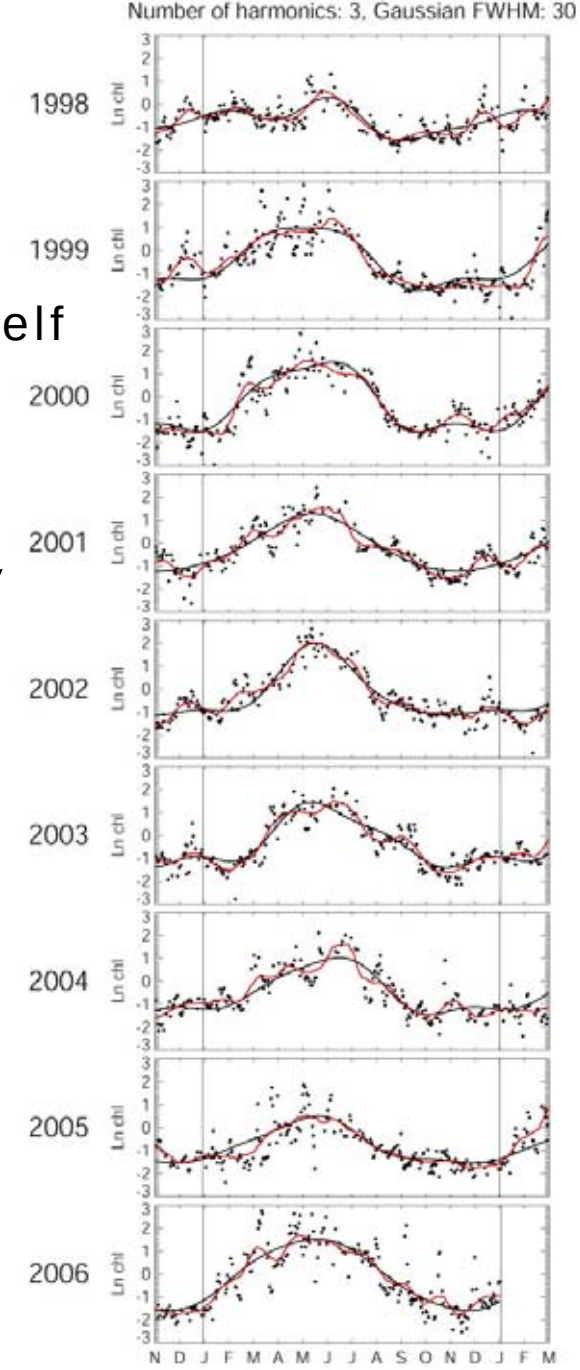


Oregon shelf

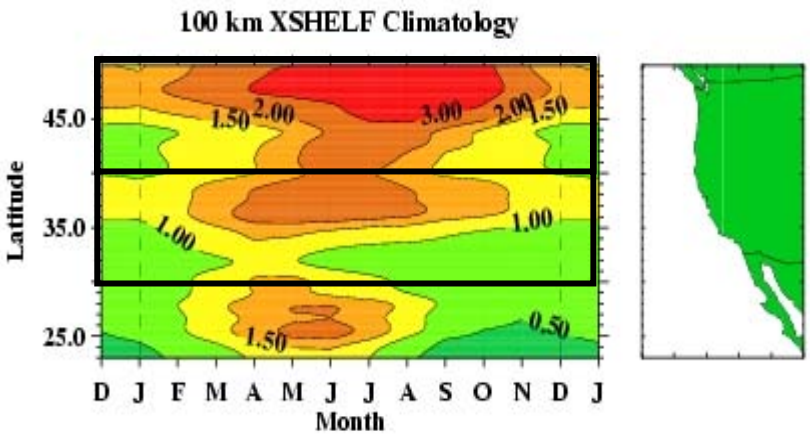
Baja shelf



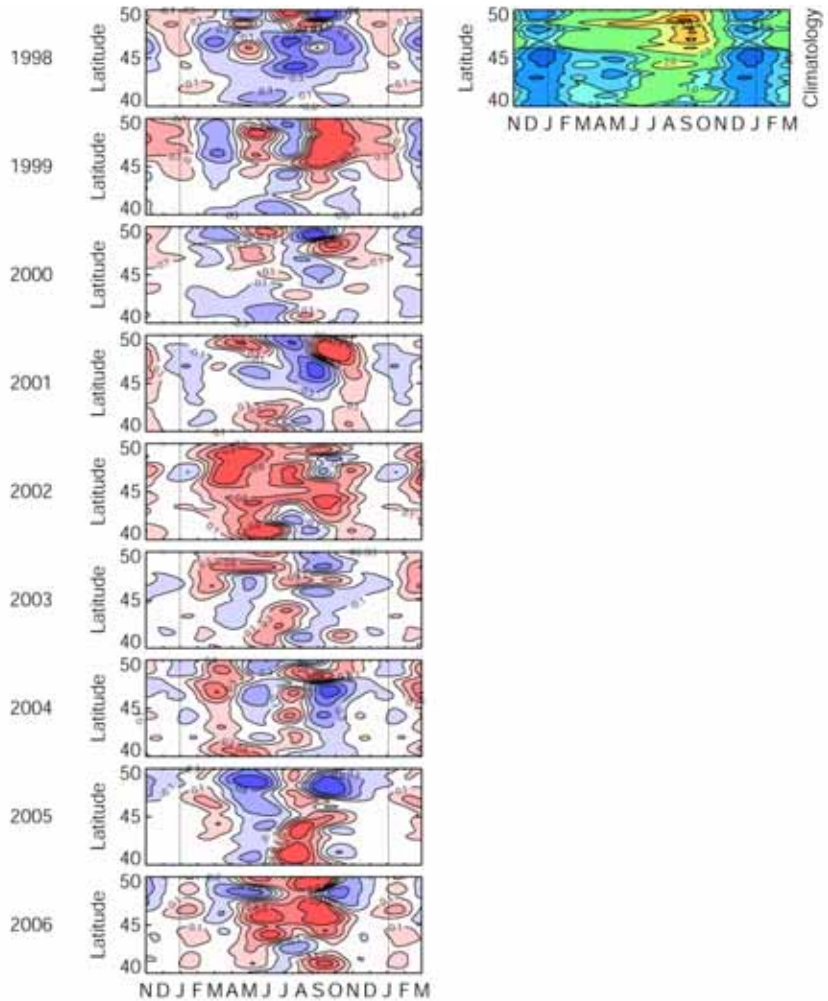
- Original data
- fit 3 harmonics
- filter (gaussian: 30 day FWHM)



Harmonic model : original data comparison



Climatological data

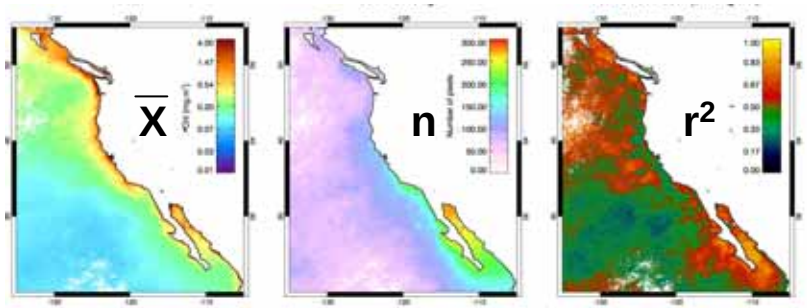


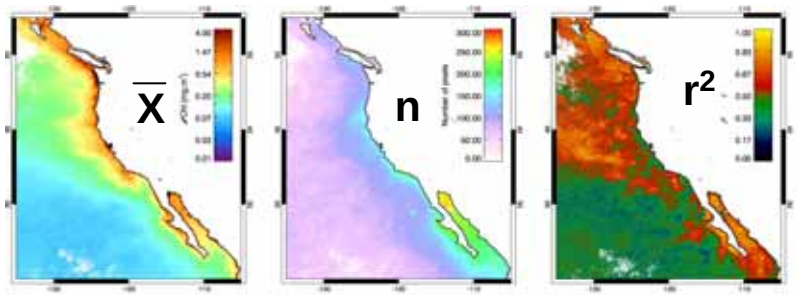
Harmonic model

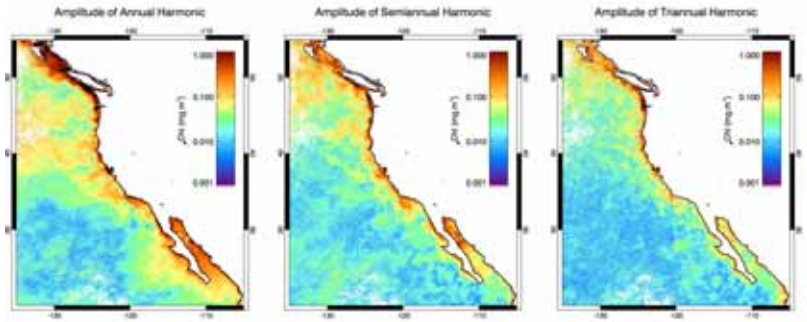
Geography of Phenology

1998

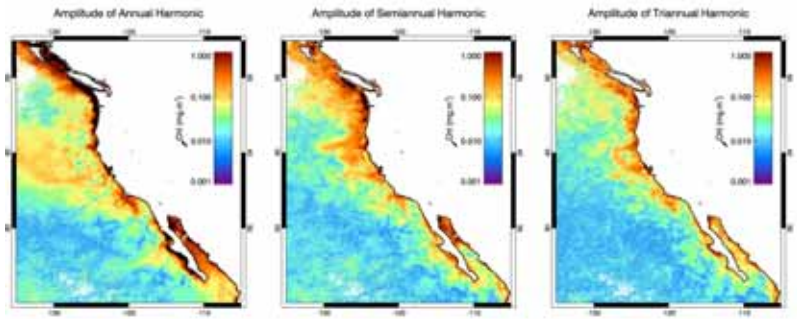
2002

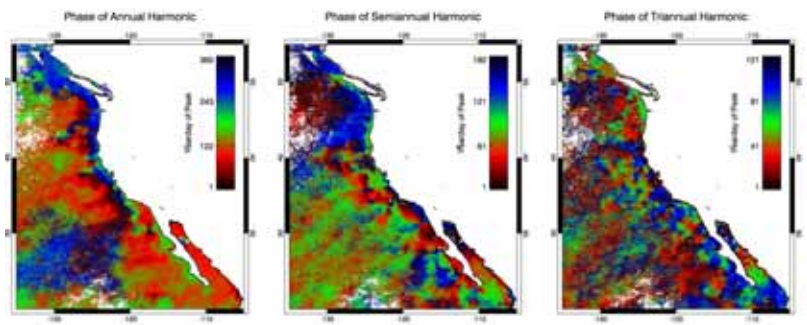




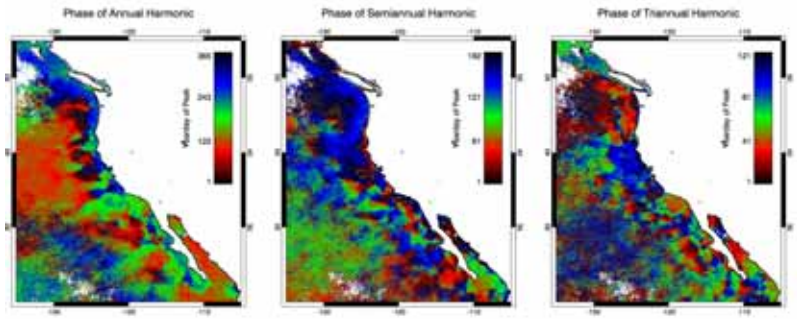


amplitudes





phases



annual

semi annual

tri annual

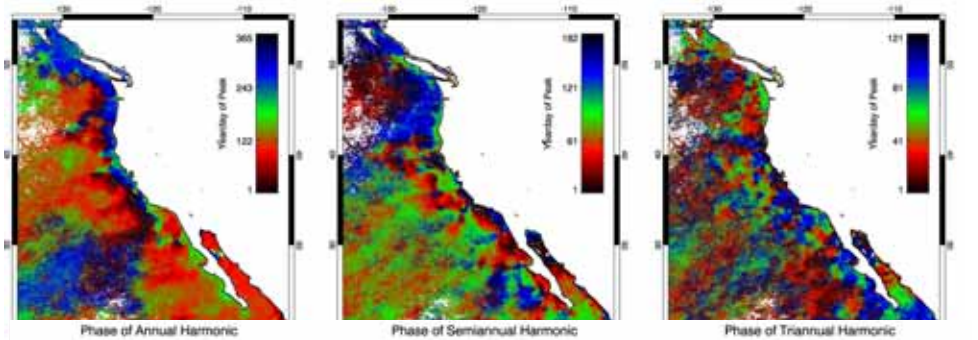
annual

semi annual

tri annual

Variability in Phases

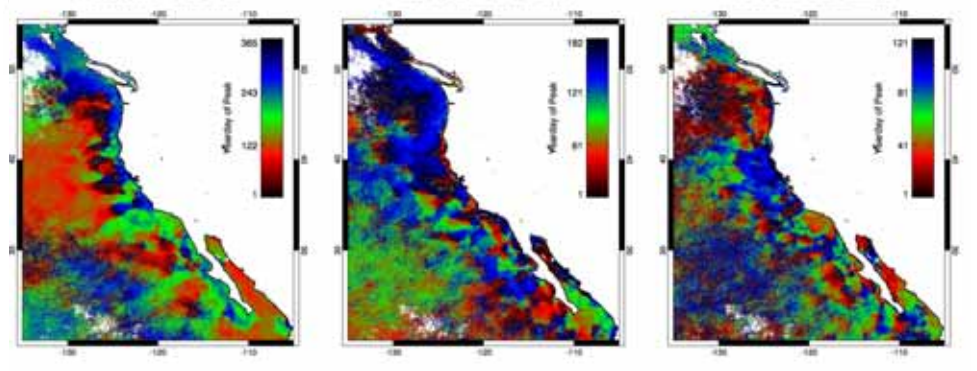
1998



El Nino period

negative chl anomalies

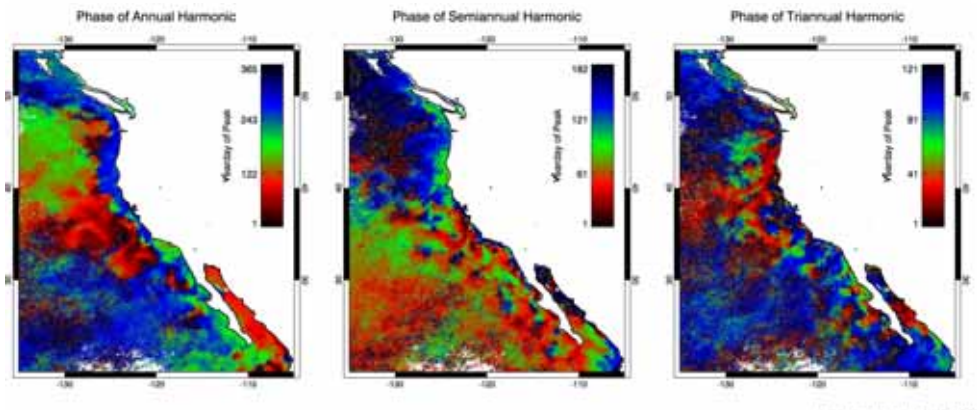
2002



Subarctic intrusion period

positive chl anomalies

2005



delayed upwelling year

negative chl anomalies (early)

Annual semi-annual tri-annual

Time / Space Similarity in Phases

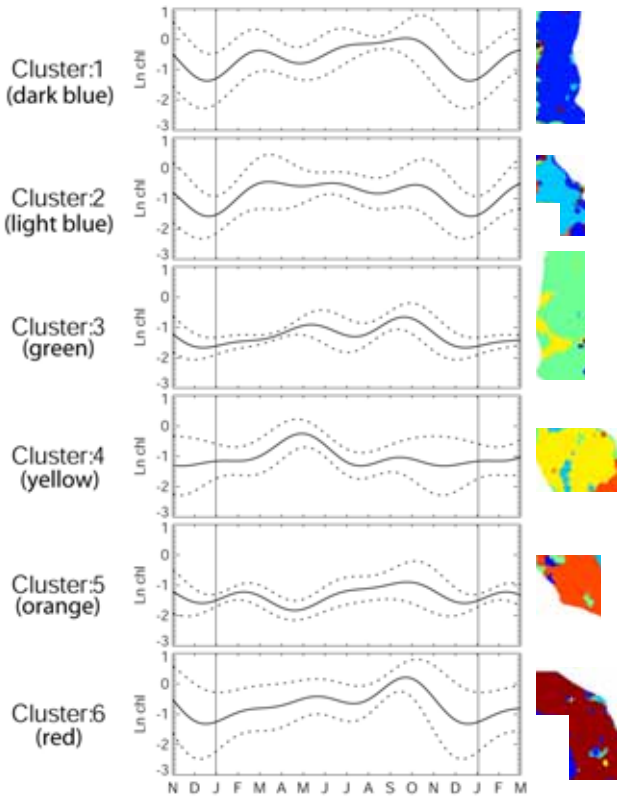
multivariate analysis of **phase** components

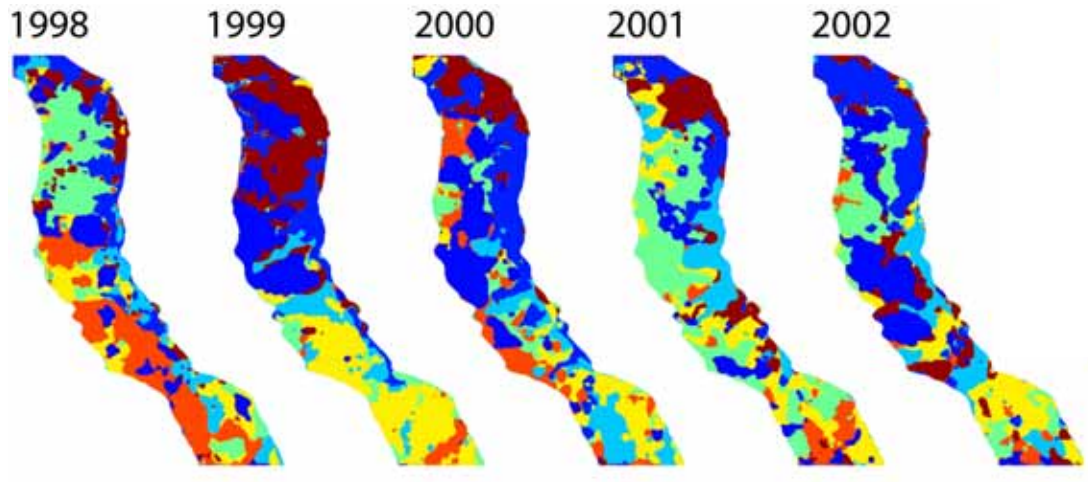
9 years of data, all locations

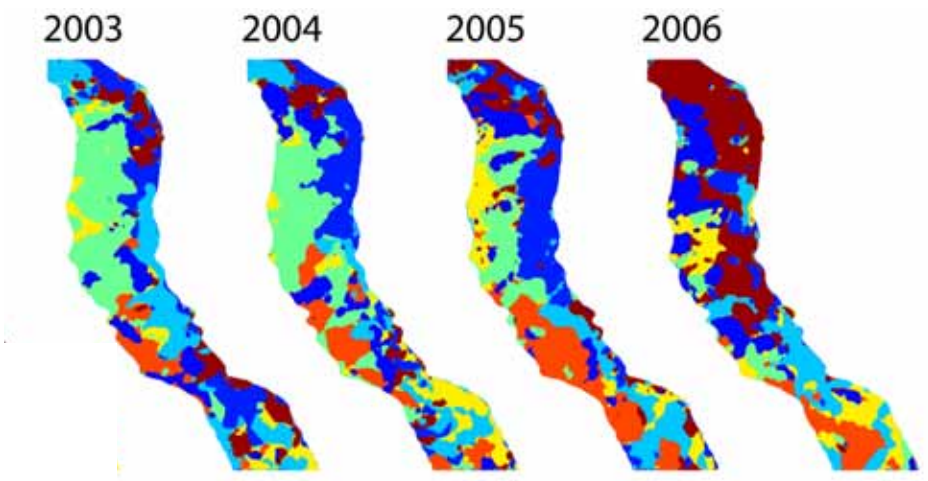
k-means cluster analysis

6 groups:

MAP EACH YEAR





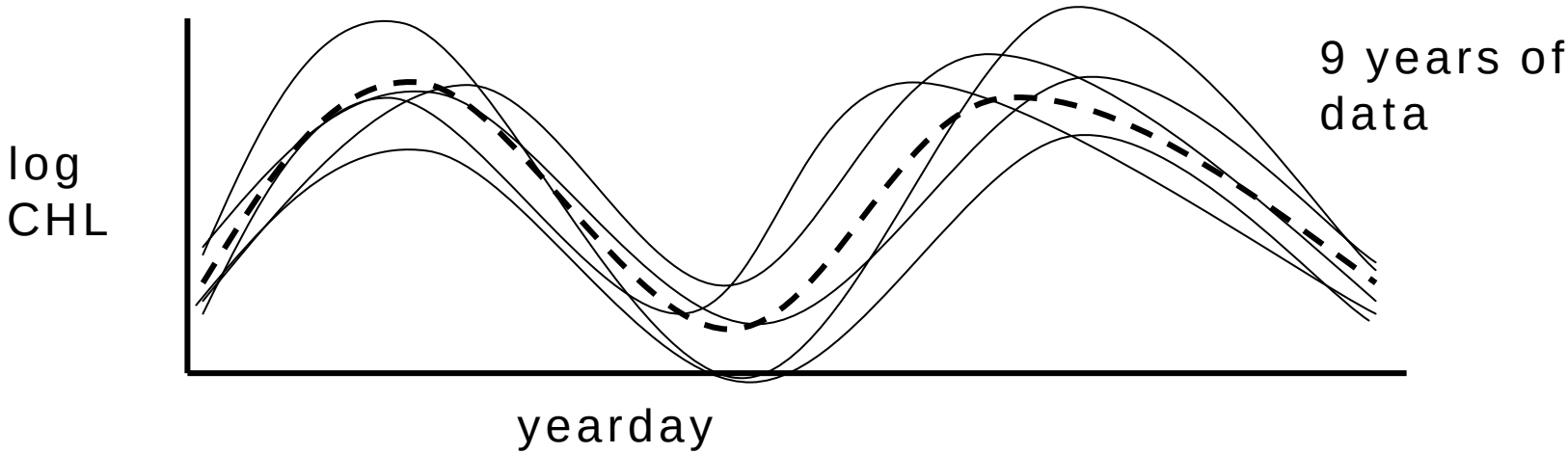


Total location-specific CHL Variance =

Shifts in overall annual mean

Shifts in harmonic amplitudes

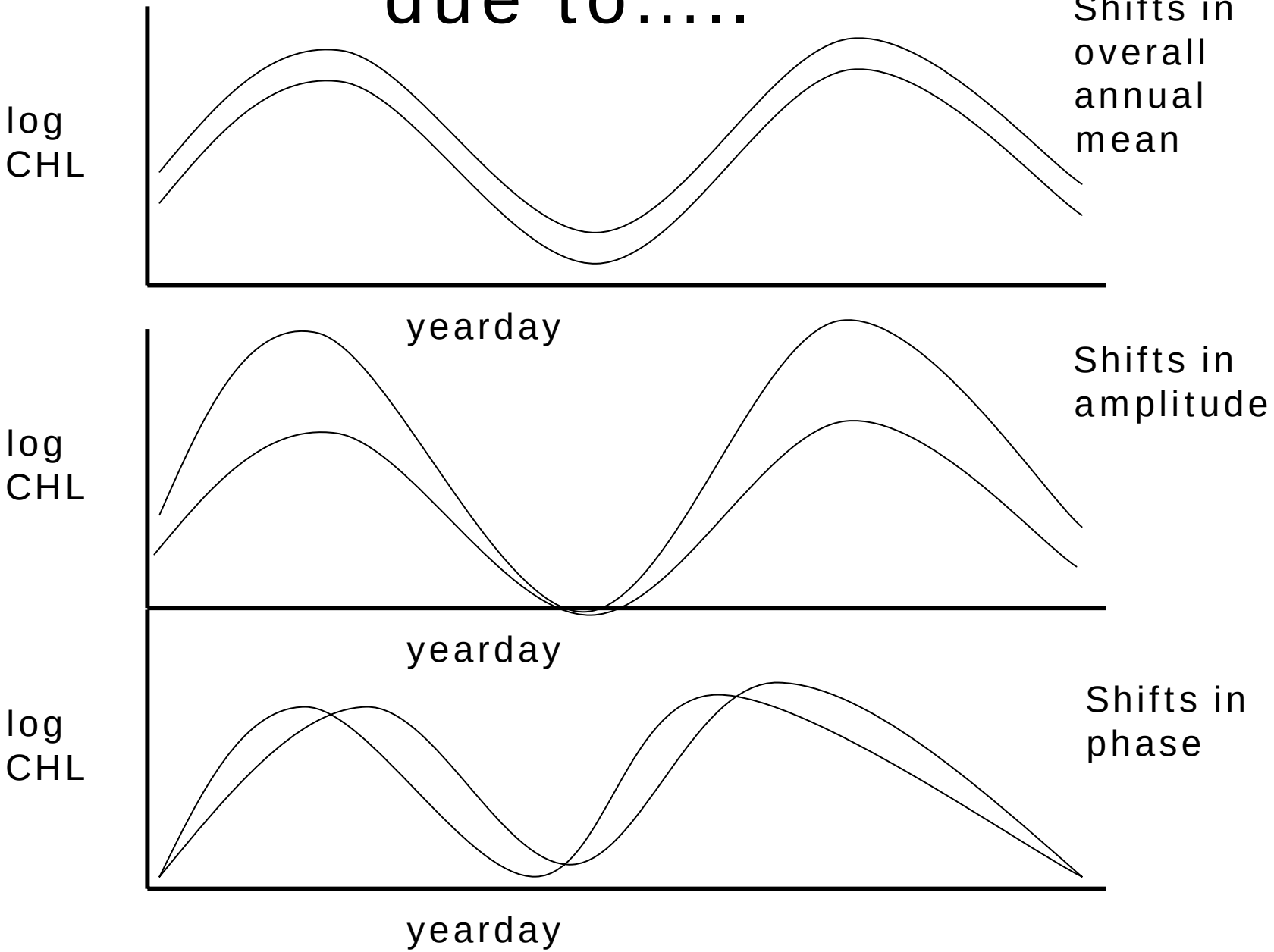
Shifts in harmonic phases



Variability metrics:

- For any 1 year- summed difference from climatology over 365 days
- For all 9 years- summed variance over 365 days

Total Interannual CHL Variance due to.....



Interannual Variability in Pattern

Annual Mean Component:

1998 & 2006 Central Calif

2002 Pacific NW

Amplitude of 3 Harmonics Component:

Most years – Pacific NW shelf edge notably 1998, 1999, 2002, 2005

2002, 04, 05 offshore Central Cal.

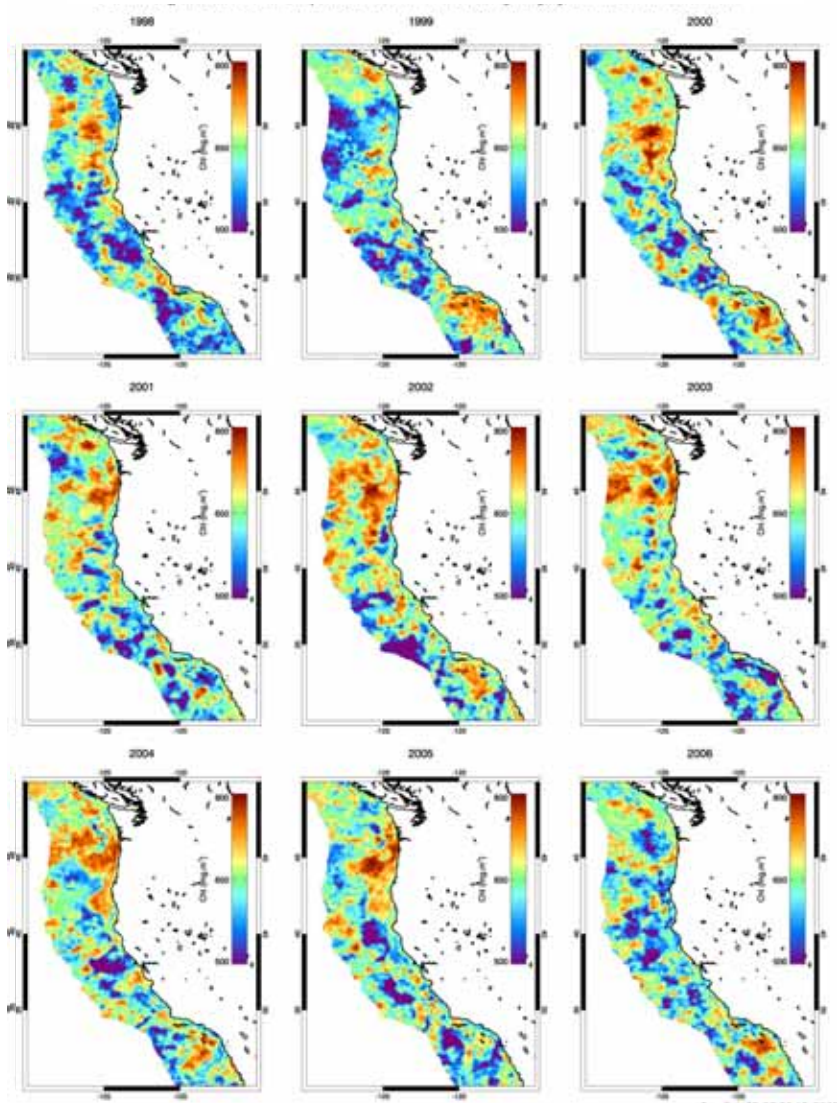
Phase of 3 Harmonics Component:

Most years – Pacific NW, especially off Oregon (weak in 1999, 2006)

SoCal Bight (weak in 1998, 2001)

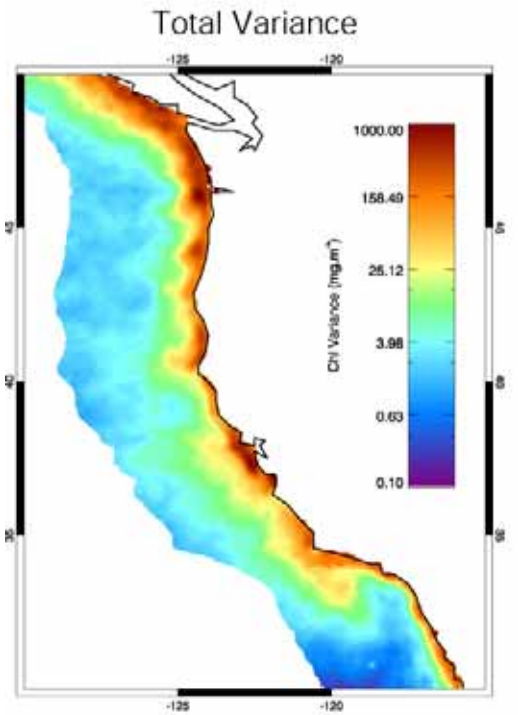
$$\sum_{\text{day } 1}^{365} \Delta \text{from climatology}$$

Changes in Phase



Interannual Variability

9 years



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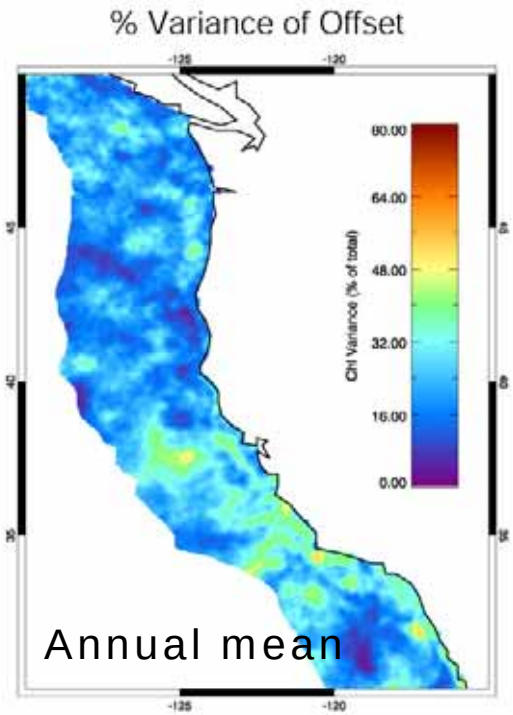

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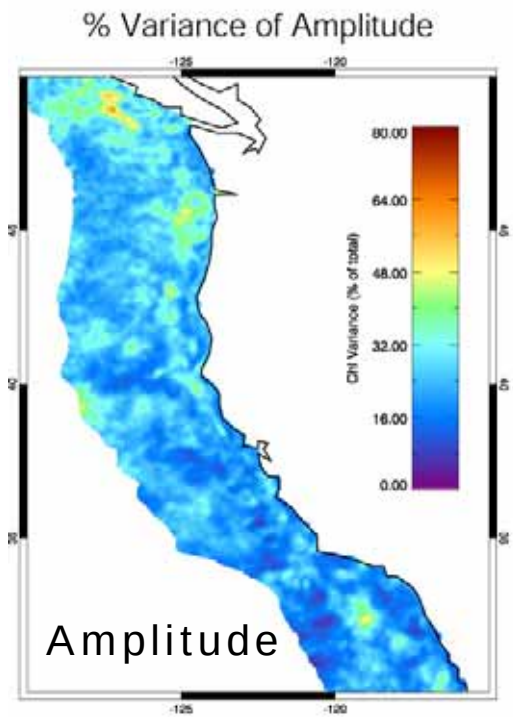

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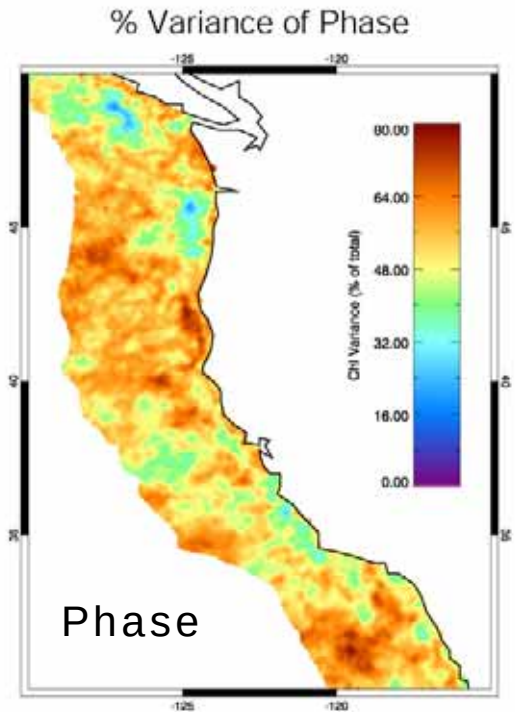
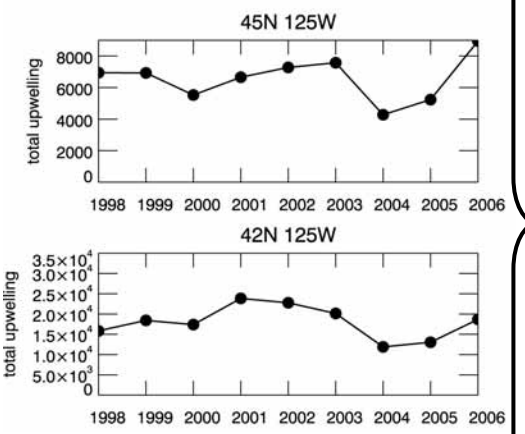


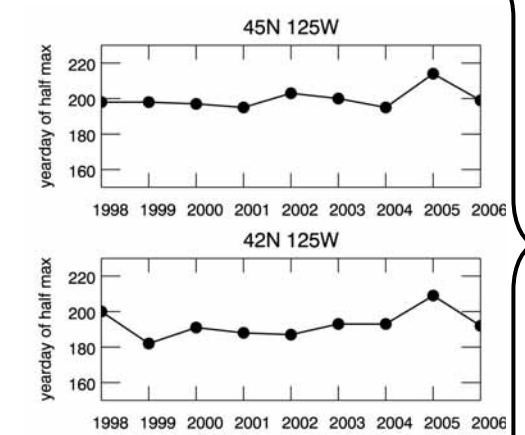
$$\sum_{\text{day 1}}^{365} \text{Variance}$$

Regional Specifics

40-45ºN cross-shelf (100km) mean

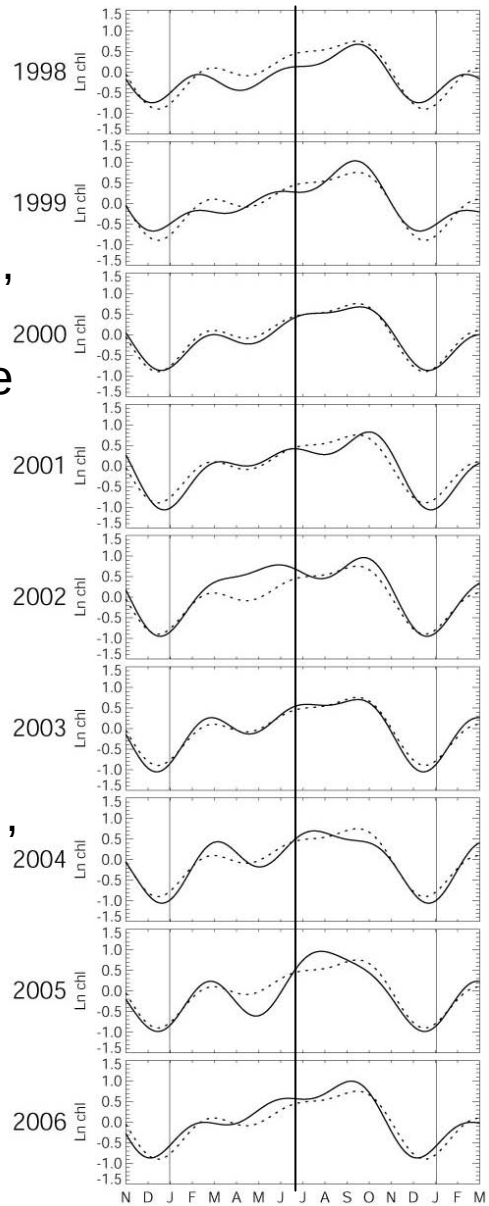


Upwelling, summer magnitude

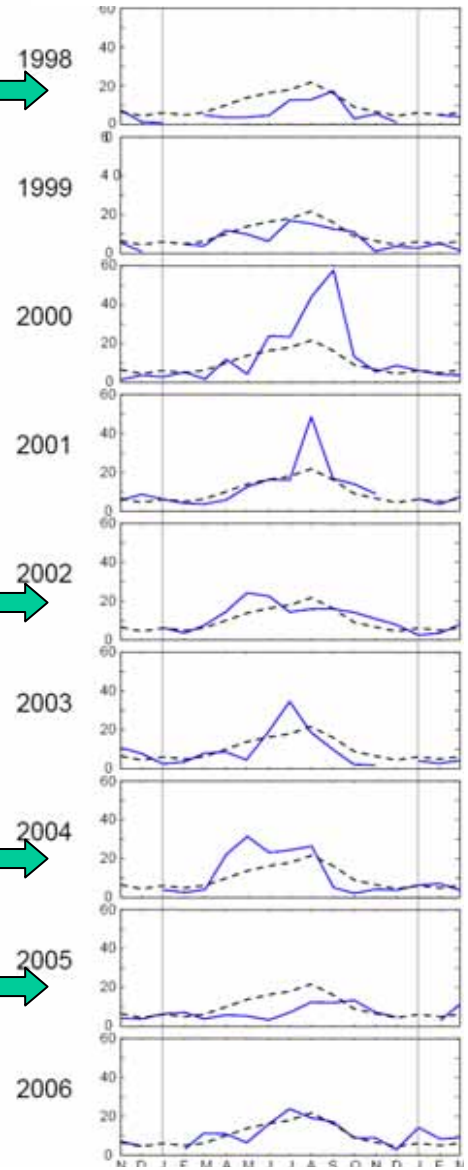


Upwelling, relative timing

CHLOROPHYLL



Oregon Shelf Copepod biomass

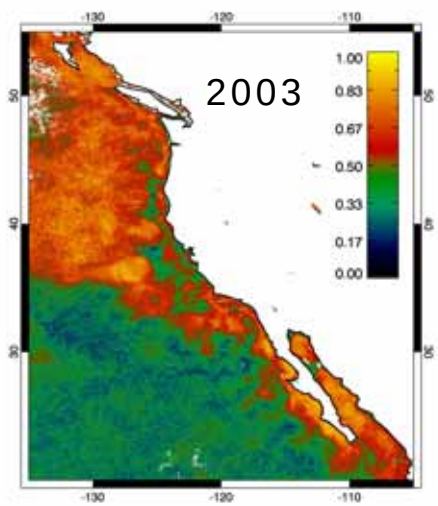


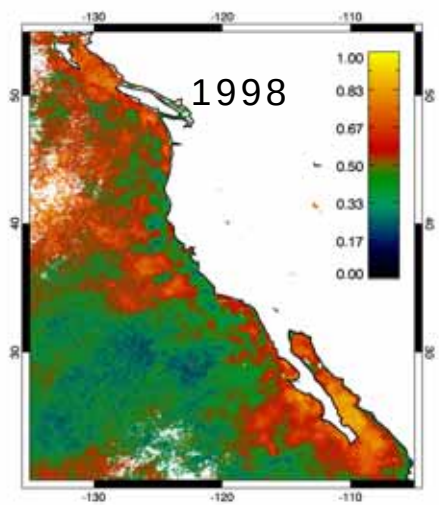
from Julie Keister, OSU

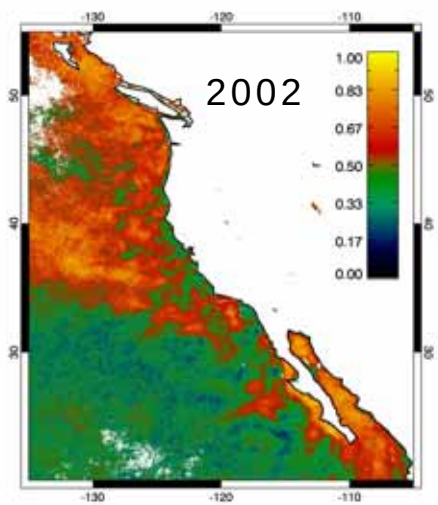
Mesoscale Variability

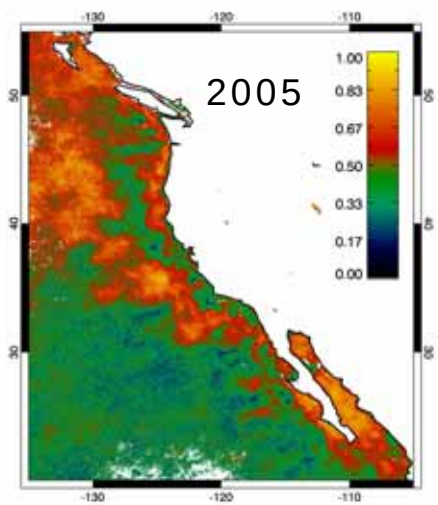
r^2 value: data fit to 1st 3 harmonics

LOW values = poor fit = strong mesoscale variability









Summary

- 9 years of satellite color data provide SPACE PATTERN quantifying chl phenology
- Allow examination of both interannual differences and integrated maps of interannual variability
- Grouping of time/space locations of similar PHASE allow quantification of regionality and interannual changes in regionality
  - patterns consistent with interannual differences in forcing
- Separate interannual variability into components resulting from changes in 1) annual mean 2) amplitude of cycles and 3) phase shifts in cycles
- Phase shifts dominate variance in most regions... weaker in Columbia River plume region
- Maps provide a new view of California Current regionality and biogeographic provinces.... And their interannual variability

Acknowledgements

NSF & US GLOBEC PROGRAM