A Data-Assimilative, Physical-Biological Model for the Coastal Gulf of Alaska

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Motivation

"Coastal Ocean Observing and Forecasting Systems"

Data assimilation of physical observations

- Do more reliable ocean circulation estimates lead to more reliable ecosystem predictions?

Observation impact calculations

- Which observational datasets contribute most to corrections made to physics and biology?

Control vector impact calculations

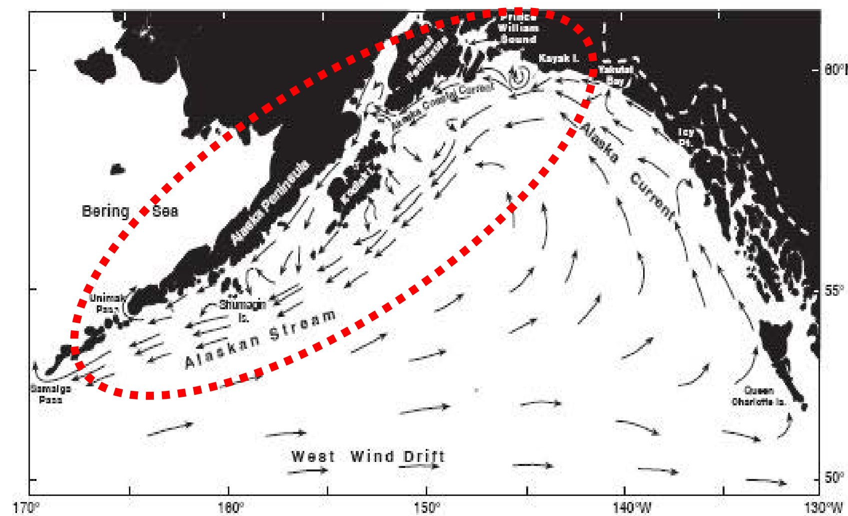
- Which model corrections contribute most to corrections made to physics and biology?

CGOA: Physical and Biological Properties

Physical Variability

- Downwelling-favorable winds
  (Stabeno et al., 2004)
- AS intrinsic mesoscale variability
  (Combes and Di Lorenzo, 2007)
- Anticyclonic (Yakutat) eddies
  (Okkonen et al., 2003)

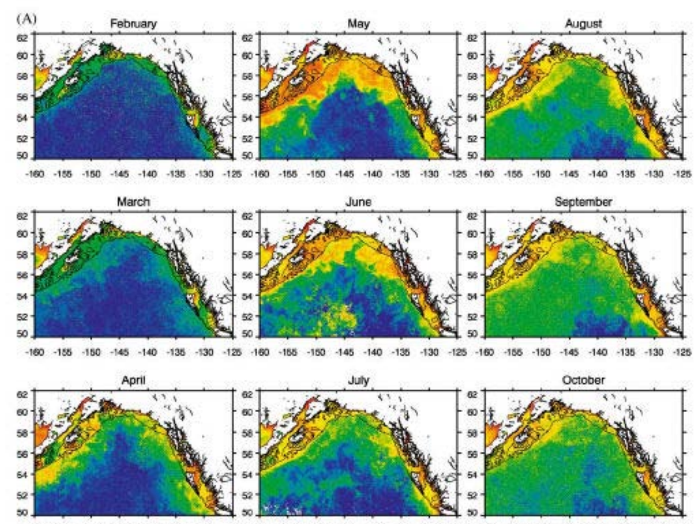
860 P.J. Stabeno et al. / Continental Shelf Research 24 (2004) 859–897



Biological Variability

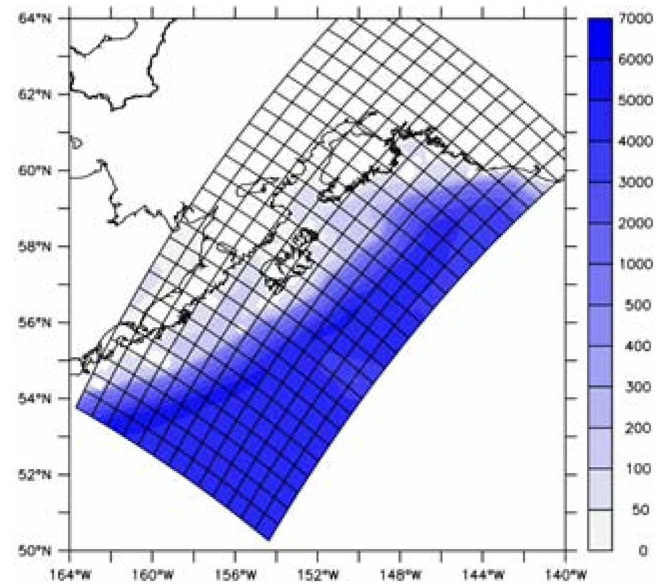
- CGOA shelf: highly productive
- Subarctic Gyre: HNLC region
  (Lam et al., 2006)
- Iron limitation on phytoplankton
  (Strom et al., 2006)

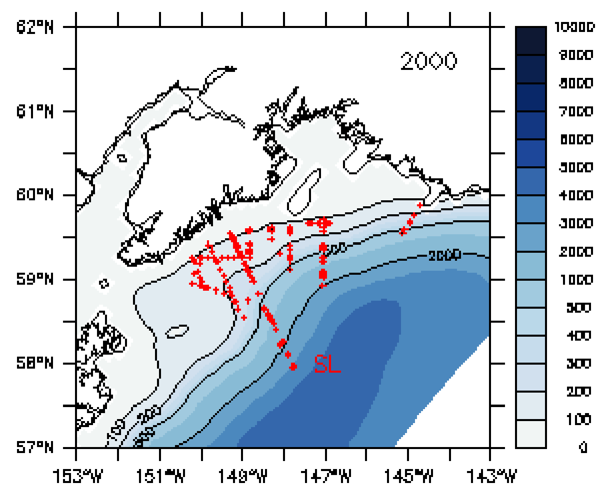
P.J. Brickley, A.C. Thomas / Deep-Sea Research II 51 (2004) 229–245



CGOA: Coupled Physical-Biological Model

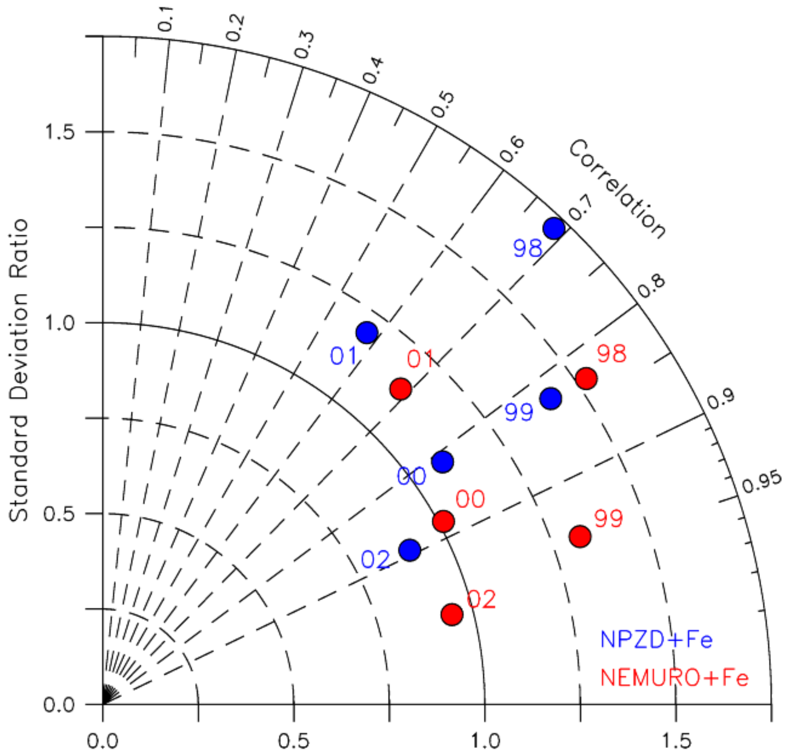
- **ROMS ocean model**
  - ~10 km horizontal resolution
  - 42 terrain-following vertical levels
- **Boundary/initial conditions**
  - Northeast Pacific (NEP) ROMS
  - (Curchitser et al., 2005)
- **Surface and river forcing**
  - CORE2 (Large and Yeager, 2008)
  - Freshwater line source (Royer, 1982)
- **Ecosystem model**
  - 4-Comp. NPZD (Powell et al., 2006)
  - Iron limitation (Fiechter et al., 2009)



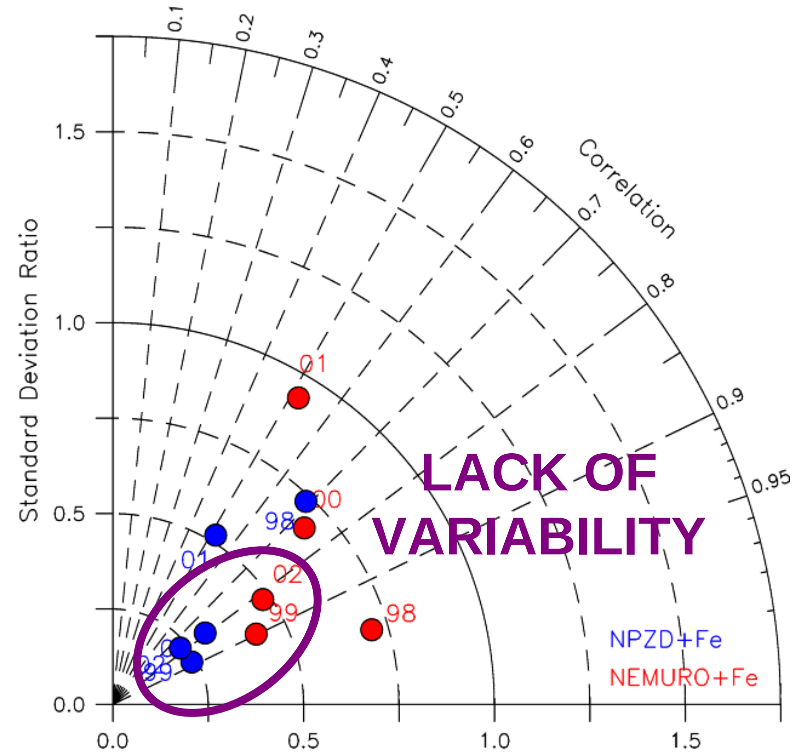


CGOA: Interannual Variability (1998-2002)

Taylor diagrams with respect to SeaWiFS Chlorophyll
(No data assimilation)



CGOA Shelf (<500m depth)

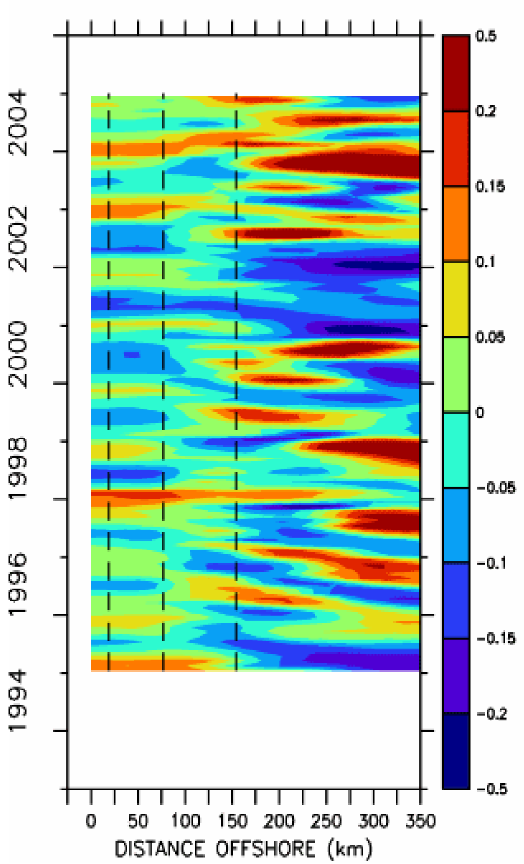


CGOA Basin (>500m depth)

NEMURO+Fe (16 components) NPZD+Fe (6 components)

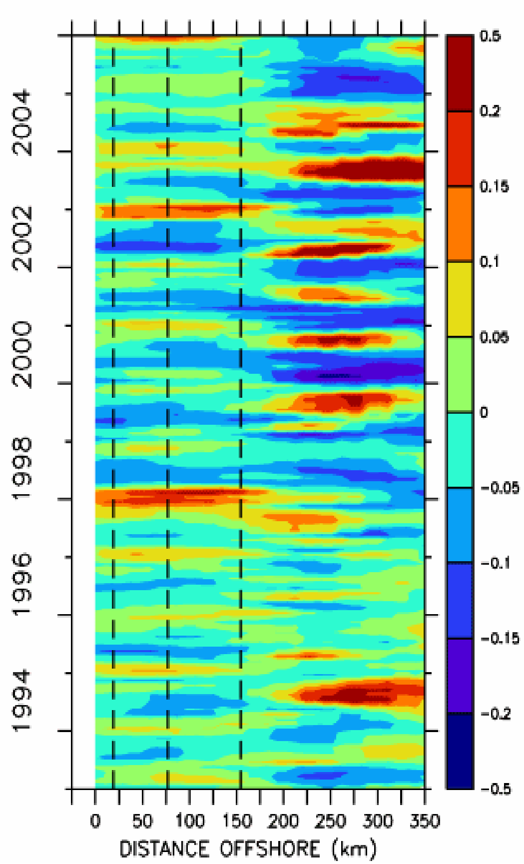
CGOA: GAK Line Sea Surface Height (1995-2004)

GAK Line



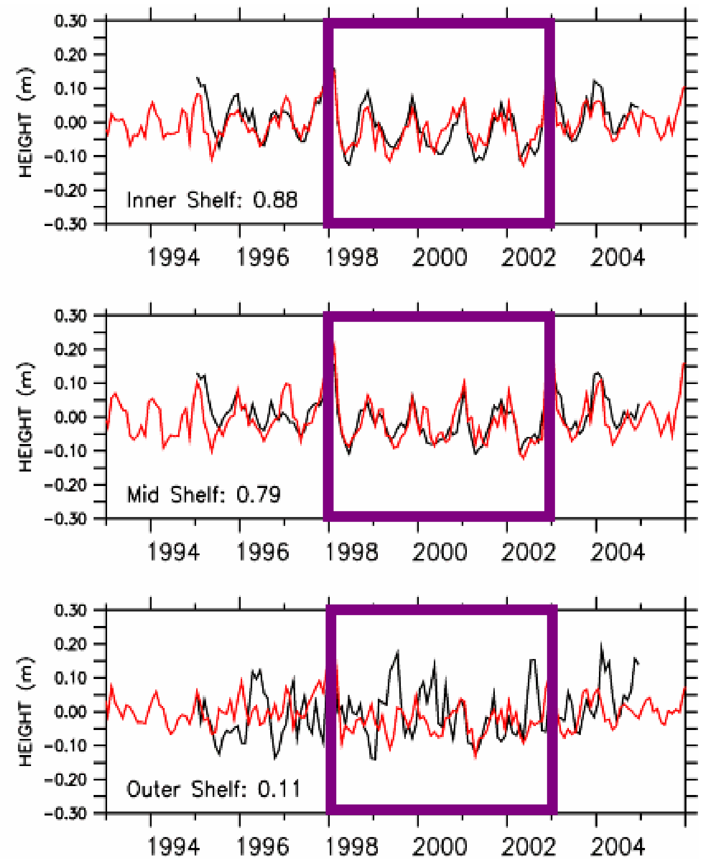
ROMS

GAK Line



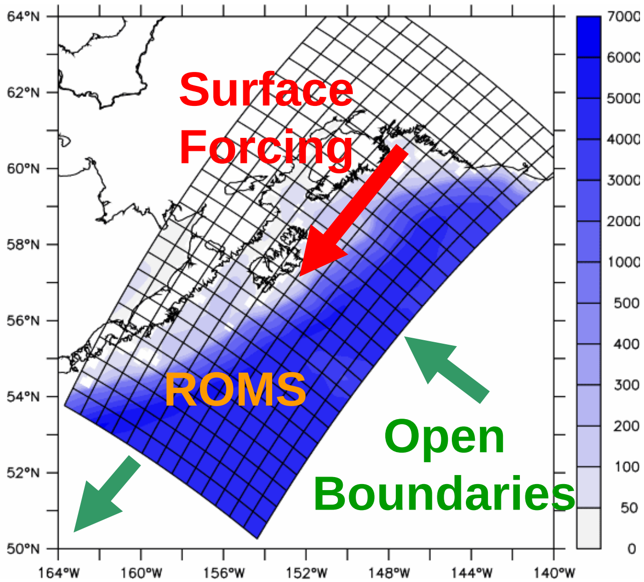
AVISO

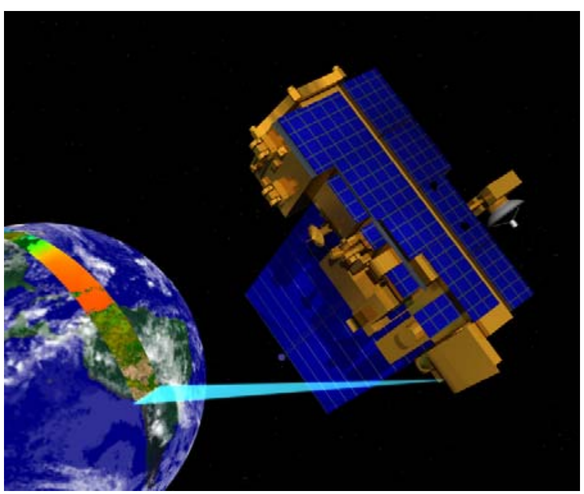
GAK Stations



ROMS vs. AVISO

Strong Constraint Variational Data Assimilation

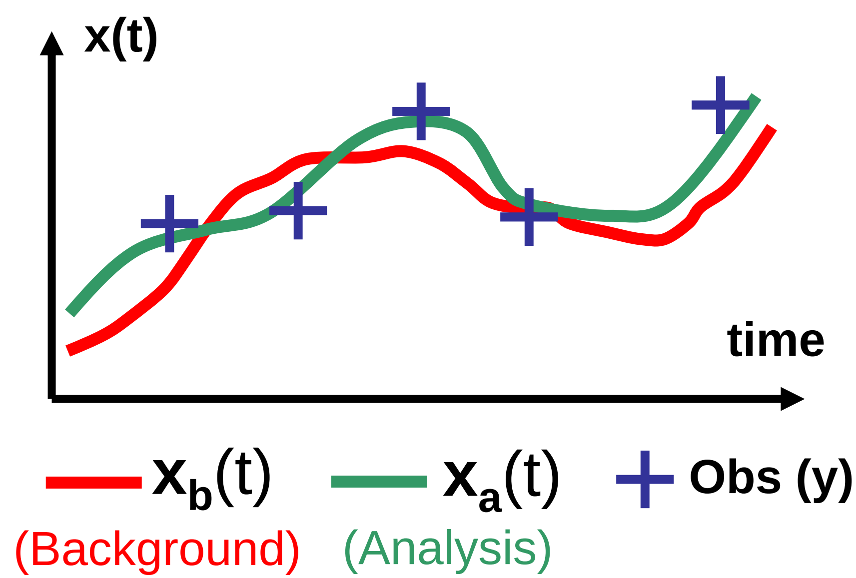




Model solution depends on:

- Initial condition: x(0)
- Surface forcing: $f_b(t)$
- Boundary conditions: $b_b(t)$

(• Model error if weak constraint)



Strong Constraint Variational Data Assimilation

The objective of the strong constraint incremental 4-dimensional variational (I4DVAR) approach is to find the increments to the initial condition (δx), boundary conditions (ε_b), and surface forcing (ε_f), that minimize the cost function (J) given by:

$$\mathbf{J = 1/2\ z^T D^{-1} z + 1/2\ (Gz\text{-}d)^T R^{-1} (Gz\text{-}d) = J_b + J_o}$$

D = Background error covariance matrix

G = Tangent linear model sampled by **H**

R = Observation error covariance matrix

d = $\mathbf{y - H(x_b)}$ = Innovation vector

z = $(\delta x(0), \varepsilon_b(t), \varepsilon_f(t))^T$ = Increments vector

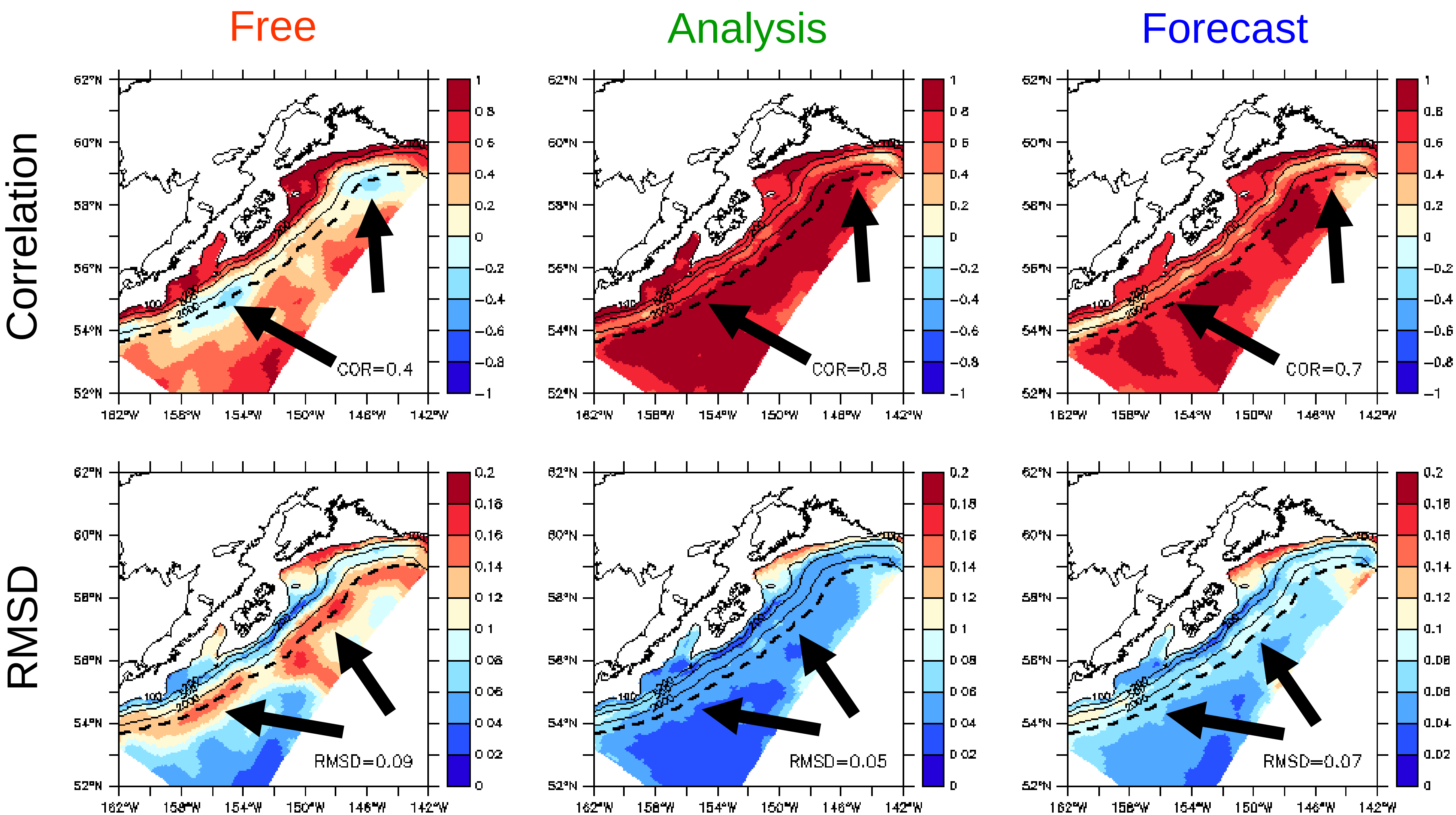
I4D-VAR Data Assimilation for CGOA

- **ROMS with NPZDFe, 7-day assimilation cycle**
- **Univariate background error covariances (D)**
  - Isotropic, homogeneous correlations (50 km horiz., 30 m vert.)
  - Surface forcing: 300 km for wind stress, 100 km for T/S fluxes
  - Standard deviations based on non-assimilated 5-year run
- **Observations sources and standard deviations (R)**
  - AVISO 7-Day ADT, Pathfinder 7-Day SST, GLOBEC *in situ* T/S
  - MDT = 2 cm; T = 0.25 C (sat), 0.1 C (in situ); S = 0.1
- **Cases**
  - “Free”: no data assimilation
  - “Analysis”: data assimilation up to and during current cycle
  - “Forecast”: data assimilation up to previous cycle

CGOA Sea Surface Height, 1998-2002

Model-Data correlations and RMS differences (ROMS-AVISO)

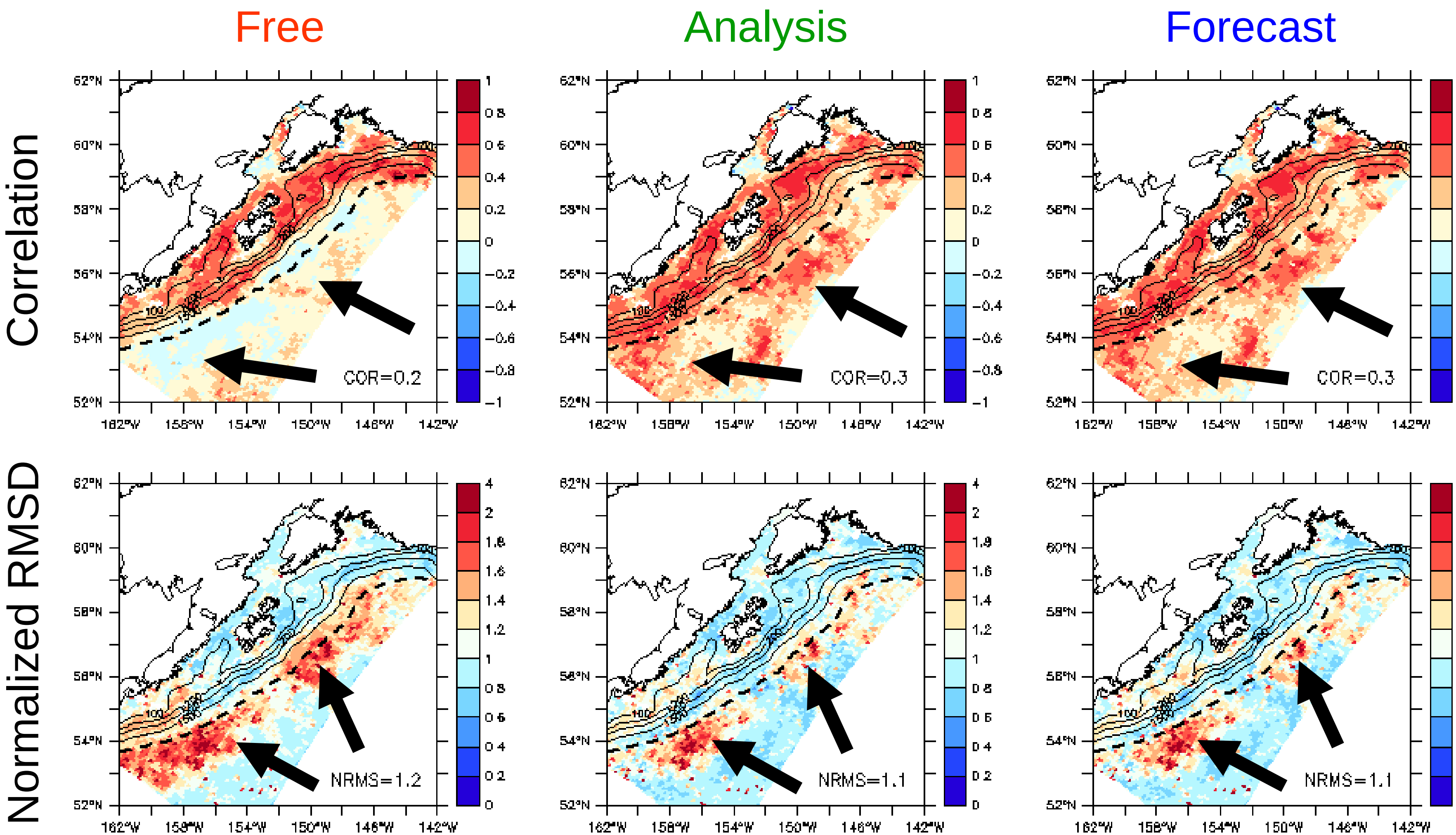
(Assimilated datasets: AVISO ADT, Pathfinder SST, GLOBEC T/S)



CGOA Surface Chlorophyll, 1998-2002

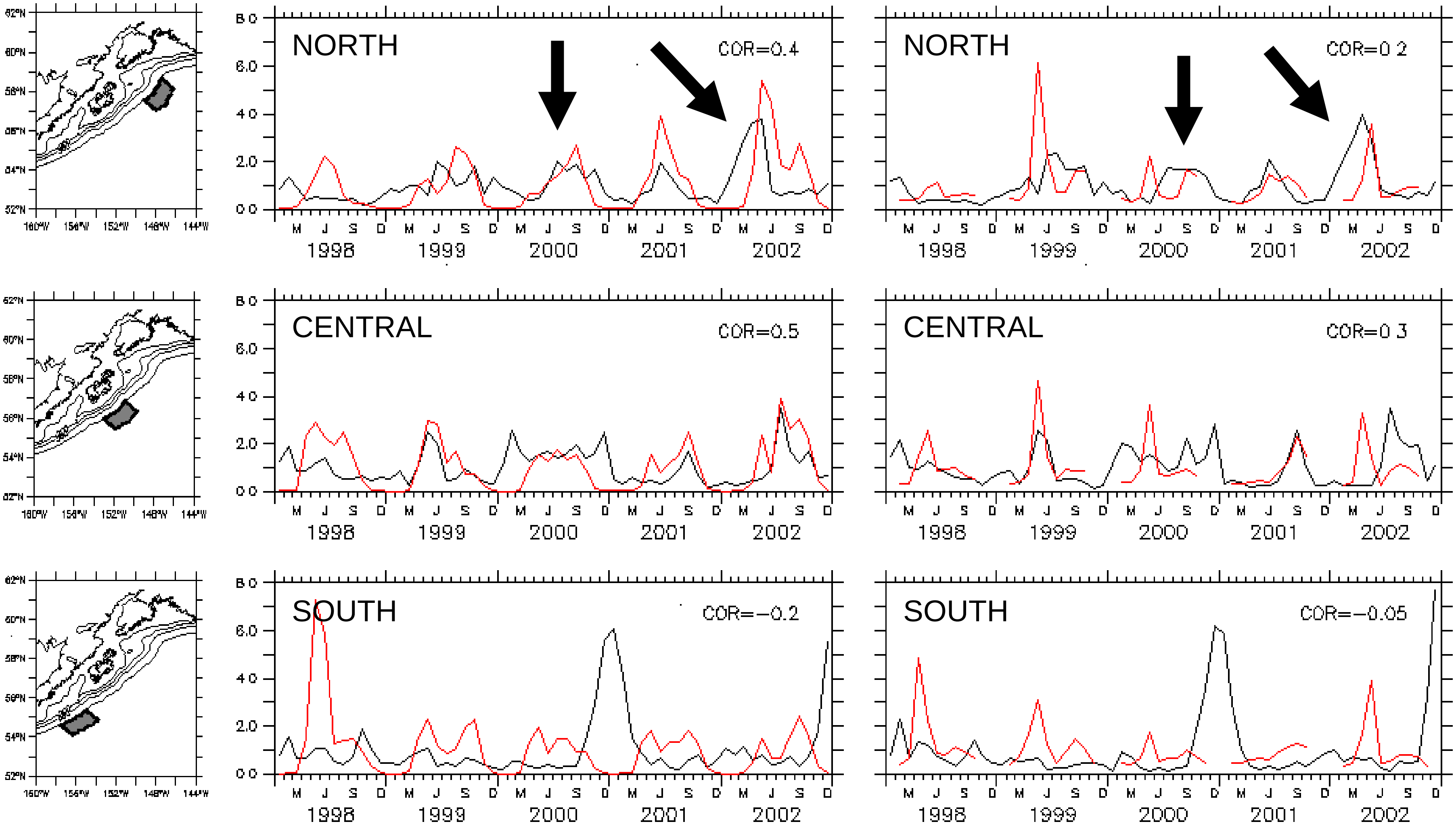
Model-Data correlations and RMS differences (NPZDFe-SeaWiFS)

(Assimilated datasets: AVISO ADT, Pathfinder SST, GLOBEC T/S)



CGOA Ecosystem Response to Mesoscale Variability

Model Analysis (EKE, Chl) Observations (EKE, Chl)



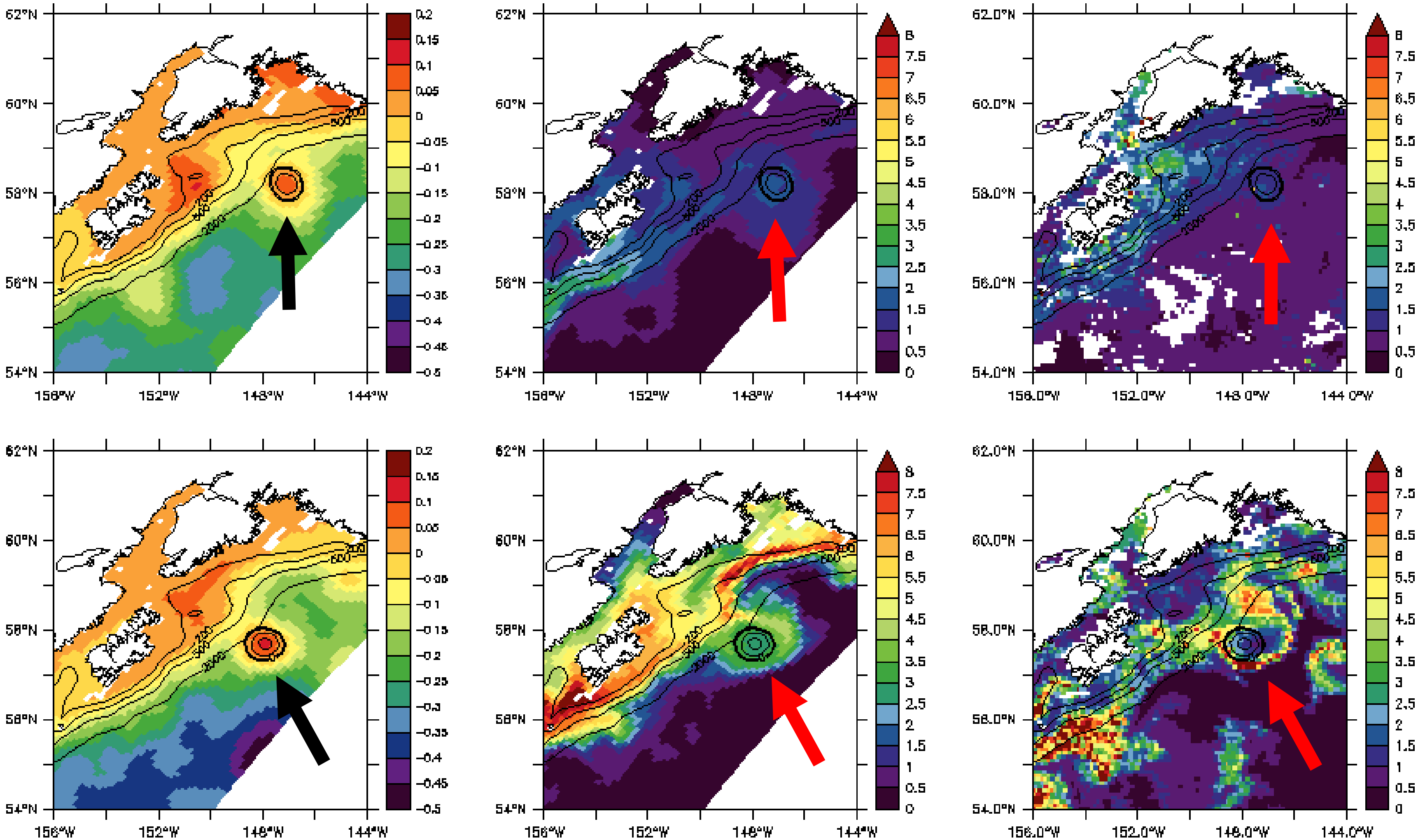
CGOA Ecosystem Response to Mesoscale Variability

Timing of Yakutat/Sitka anticyclonic eddies in Northern CGOA

SSH Analysis | Chl Analysis | Chl Observations

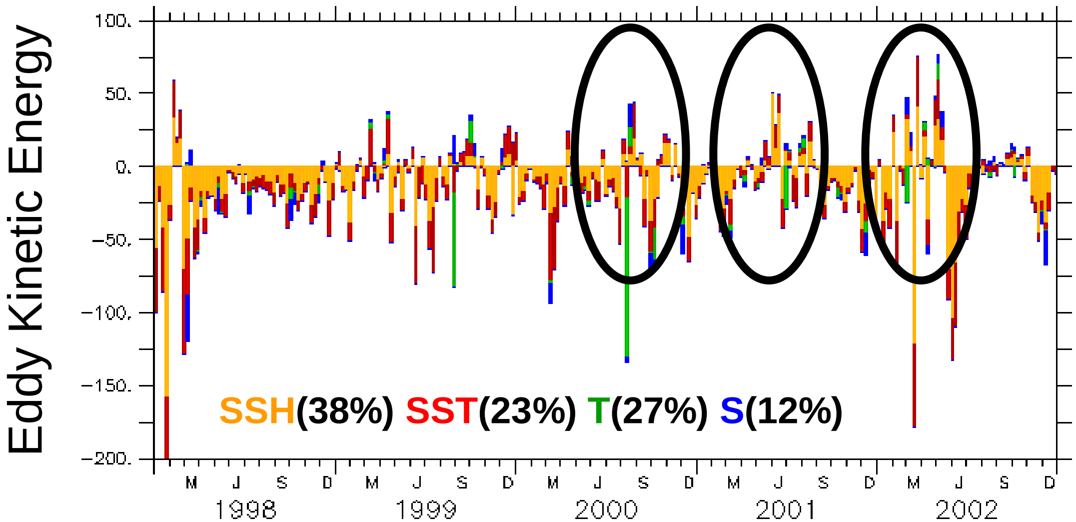
SEP 2000

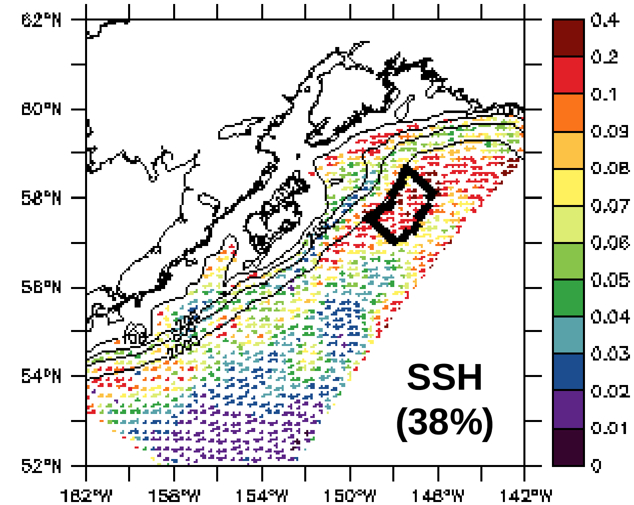
MAY 2002

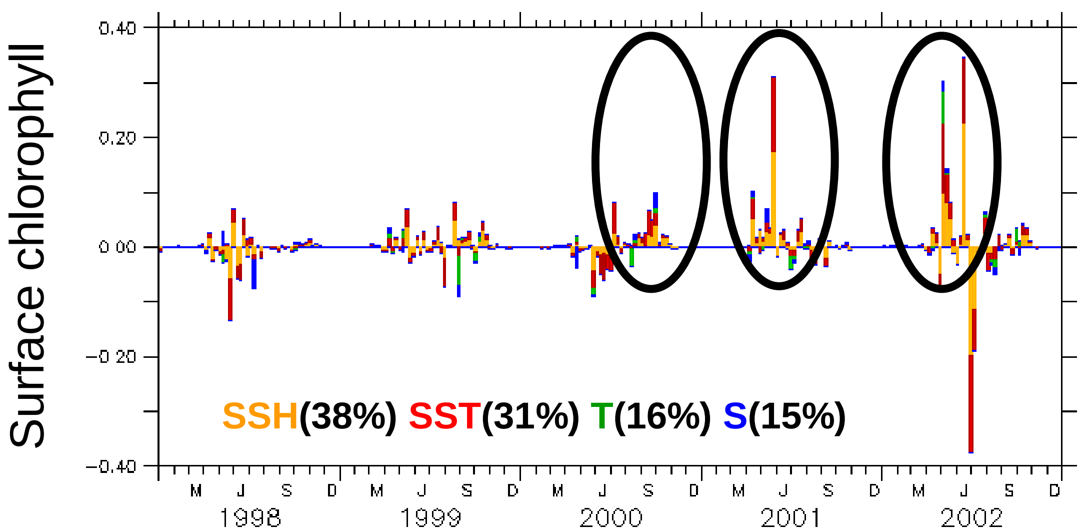


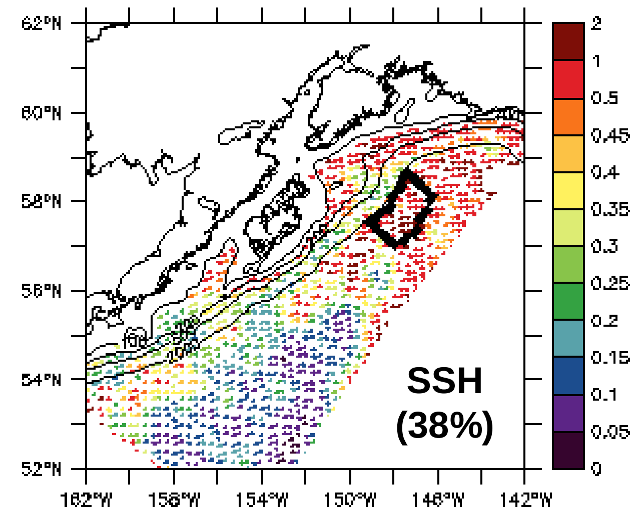
Observation Impact in Northern CGOA

Assimilation of satellite SSH and SST, and *in situ* T and S



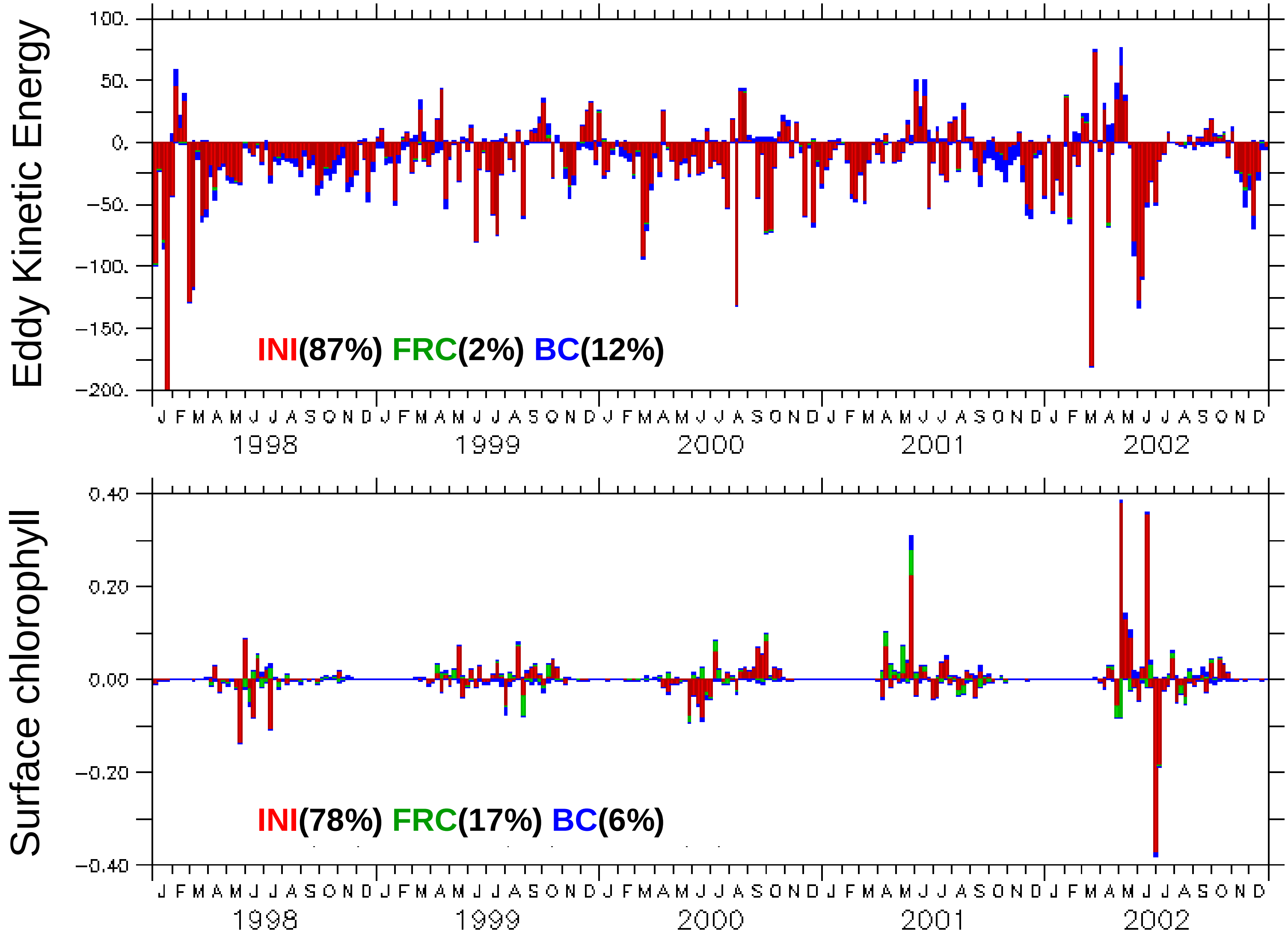






Control Vector Impact in Northern CGOA

Adjustments to initial conditions, surface forcing, and boundaries



Summary (1)

Data assimilation of physical observations

- Data assimilation yields more reliable ocean circulation estimates, leading to improved ecosystem predictions

Observation impact calculations

- Corrections to physical and biological processes occurs primarily from assimilation of satellite SSH observations

Control vector impact calculations

- Correction to physical and biological processes occurs primarily from adjustments to model initial conditions

Summary (2)

Data assimilation of physical observations

- Ecosystem forecasting ability on weekly timescales without assimilation of biological observations

Observation impact calculations

- Assessment and optimization of ocean observing system design (data redundancy, in situ vs. satellite)

Control vector impact calculations

- Errors in ocean circulation initial conditions are primary source of uncertainties in ecosystem model forecasts