A Biocomplexity Project
Flow, Fish and Fishing

A Coastal Environmental
Quality Initiative (CEQI)

Simulated Coastal Connectivity in the Southern California Bight (SCB)

Satoshi Mitarai, Dave Siegel, James Watson (UCSB)
Charles Dong & Jim McWilliams (UCLA)

Background

- Circulation models can be used to assess connectivity

  Assume larval time course & behavior

  Physics drives the rest

- Circulation models are getting better

  Validated with observations

- Future direction is data assimilation

  Ocean observatory & data driven models

- We are at the first step

Coastal (Physical) Connectivity

Sample population dynamics model

of adults at x in year n+1 = # of survivors at x in year n + # of recruits to x from everywhere

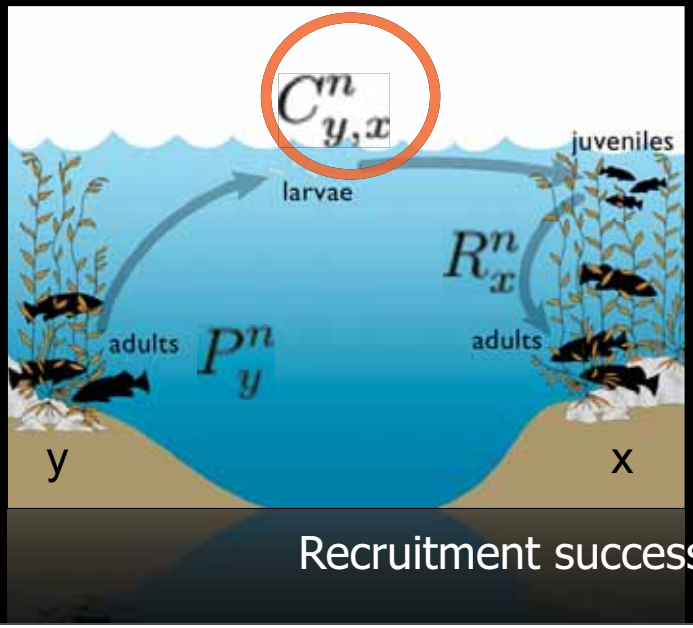
$$A_x^{n+1} = (1 - M)A_x^n + R_x^n \left(\int P_y^n C_{y,x}^n \right)$$

Natural mortality

Coastal connectivity

Fraction of water parcels transported to x

# of larvae produced at y



Recruitment success (%)

General Circulation Patterns in SCB

- Wind sheltering creates mean recirculation

Surface-Circulation Cartoon

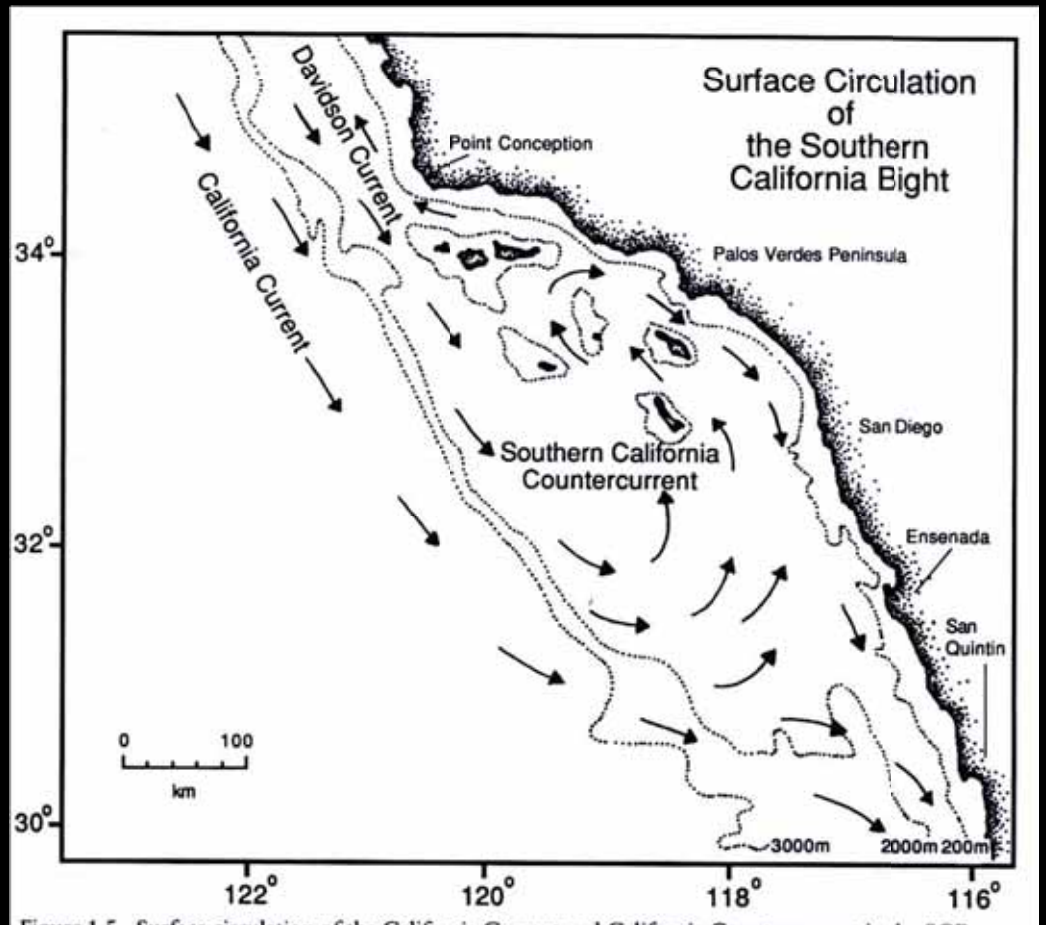


Figure 1.5. Surface circulation of the California Current and California Countercurrent in the SCB.

Environmental Impact Report, SLC, CA

6 synoptic views of circulation in SCB

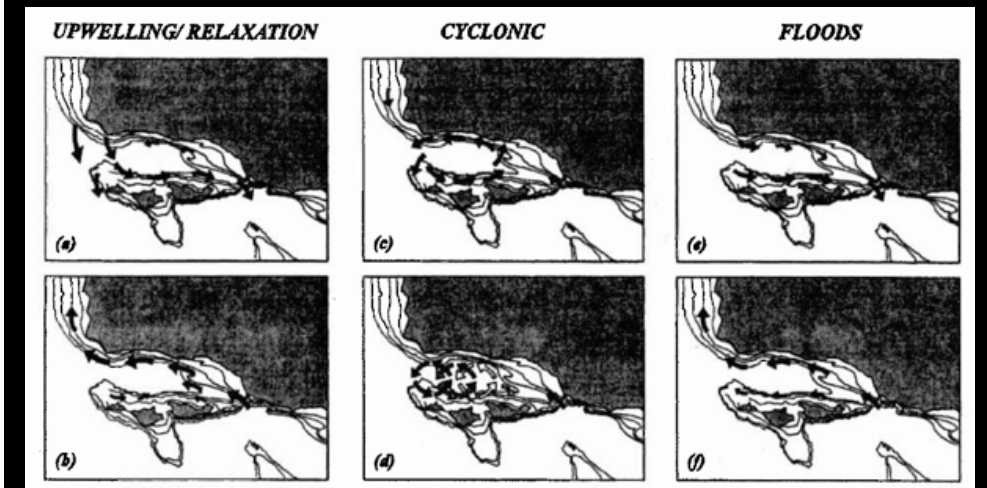


Figure 10. Schematic diagram of the six synoptic views of circulation in the Santa Barbara Channel. (a) Upwelling, (b) Relaxation, (c) Cyclonic, (d) Propagating Cyclones, (e) Flood East, and (f) Flood West.

Dever et al. (1991)

Questions

- Is connectivity spatially heterogeneous?

  Complex topography (islands & headlands)

  If heterogeneous,...

  - Are there strong sources or destinations?
  - Persistent season to season?
  - Interannual variability?

Goal of This Talk

- Assess connectivity via advection of water parcels

  Using realistic ROMS simulations

- Methods: two steps

  1. Determine dispersal kernels

     Expected dispersal patterns from a single site

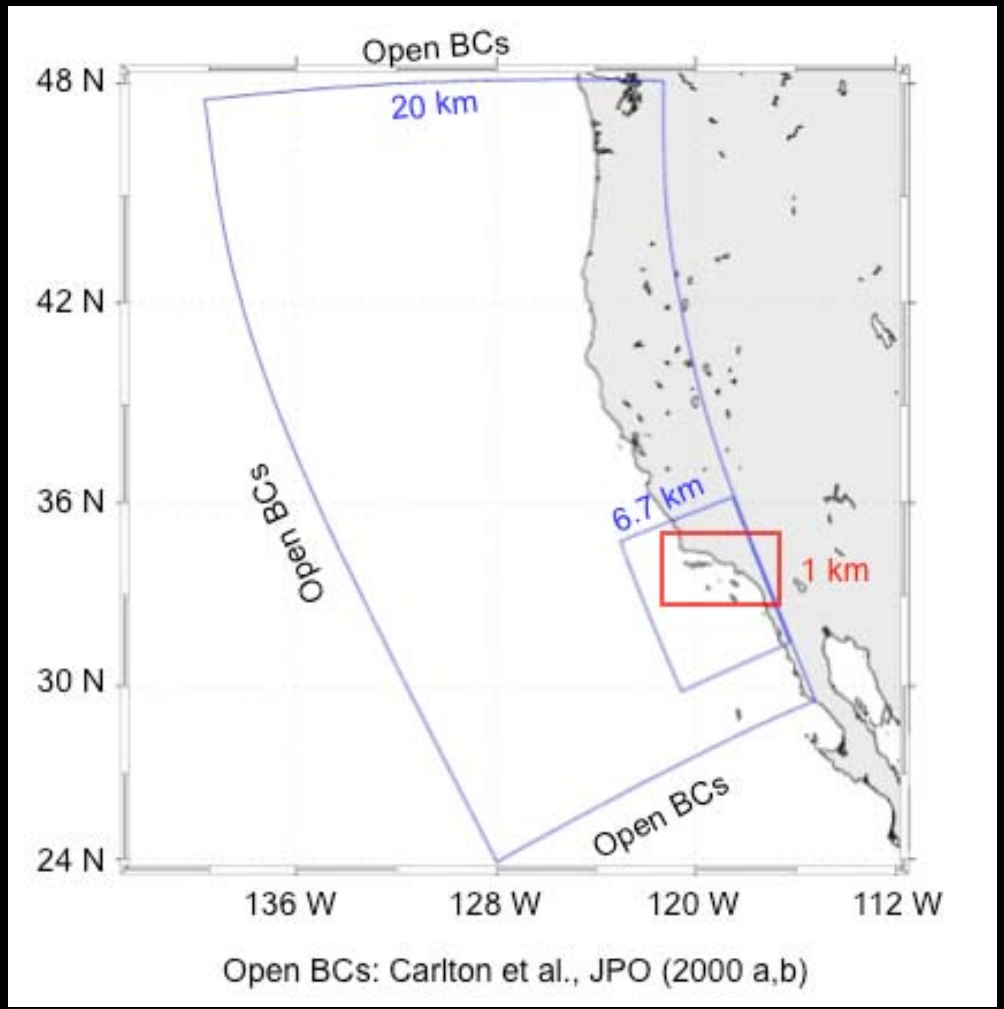
  2. Assess coastal connectivity

     For several specific species

ROMS Simulations

- Driven by realistic winds & BCs

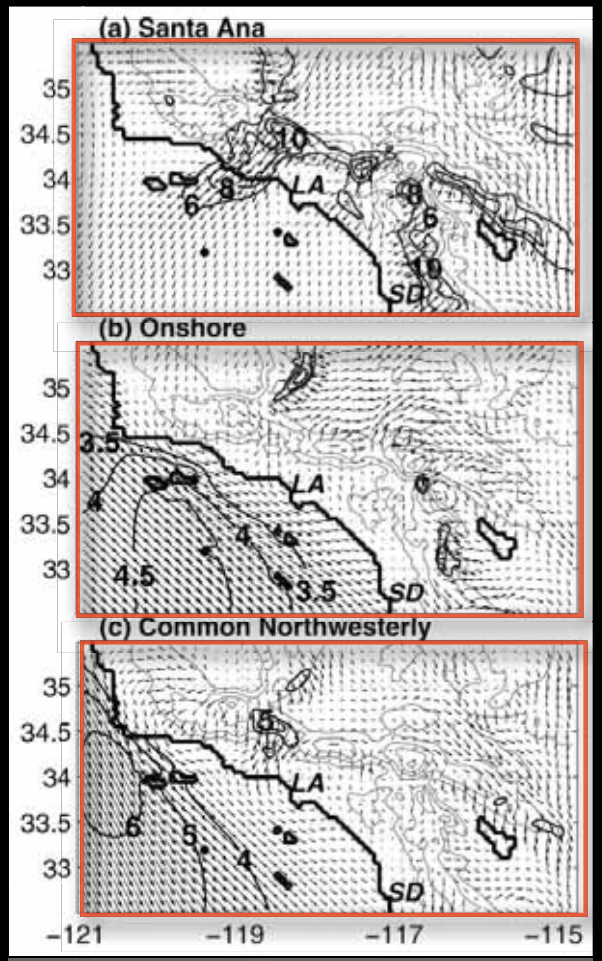
Domain configuration



Dong & McWilliams, Cont. Shelf Res. (2007)

Wind forcing

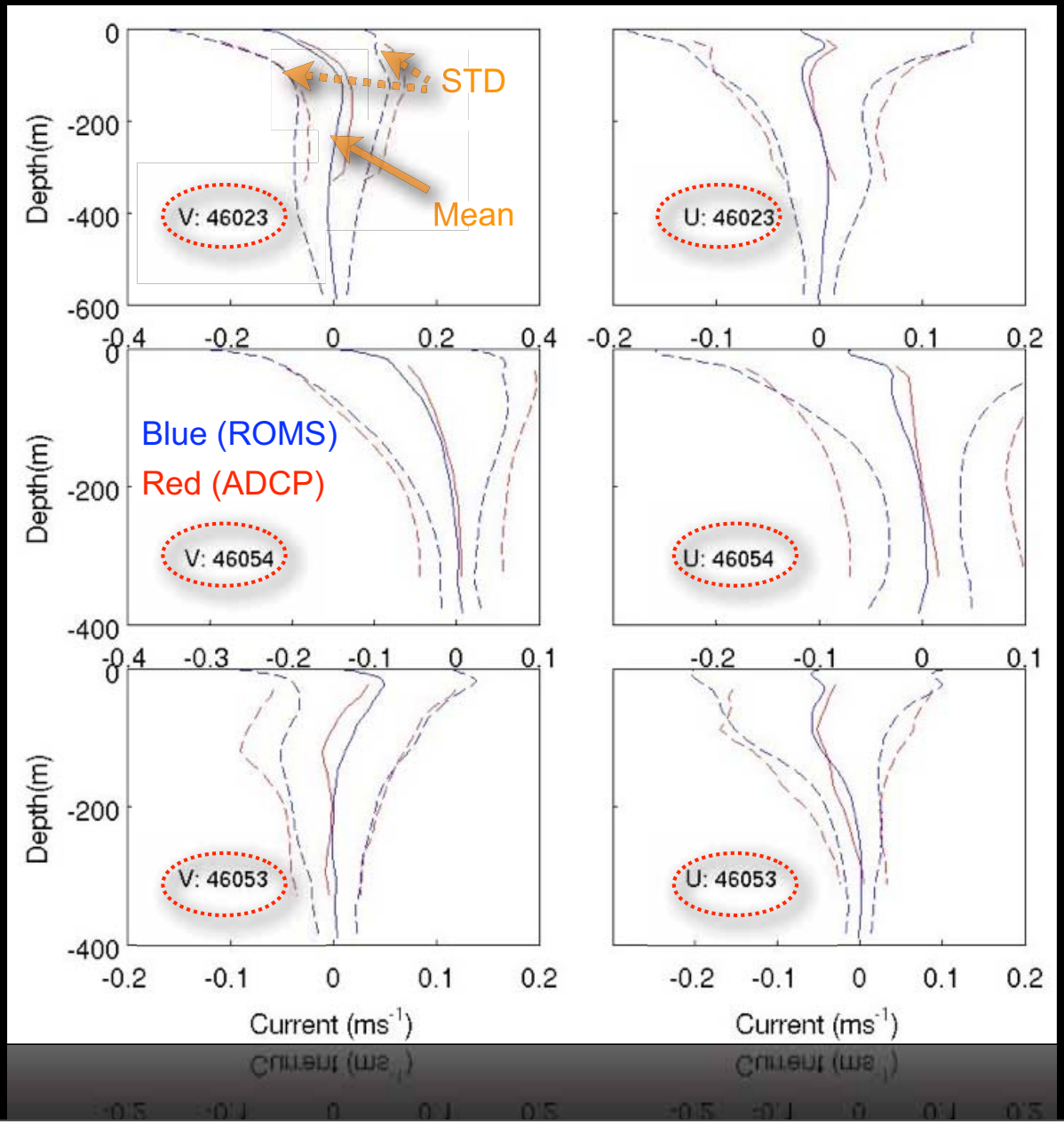
Realistic wind simulations
(MM5 simulations, 18, 6, 2 km)



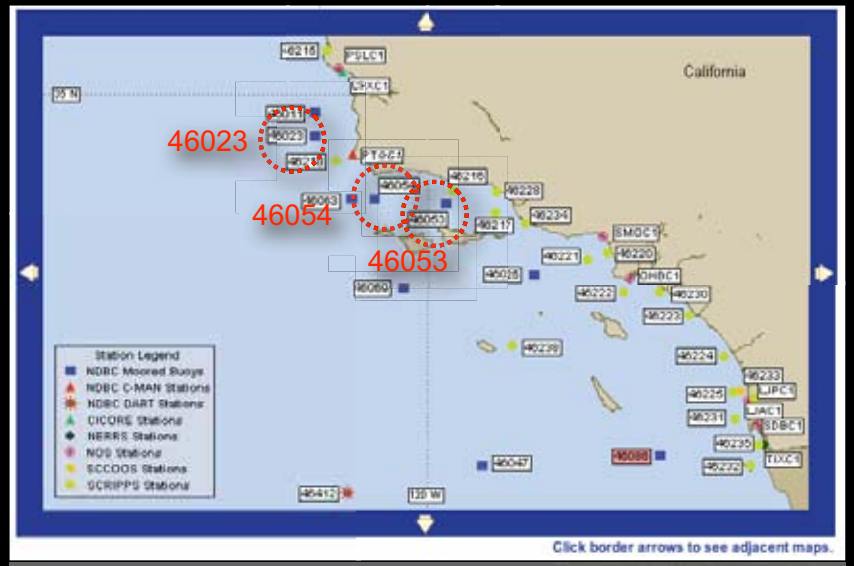
Conil & Hall (2006)

ROMS Validations

ROMS vs NDBC ADCP



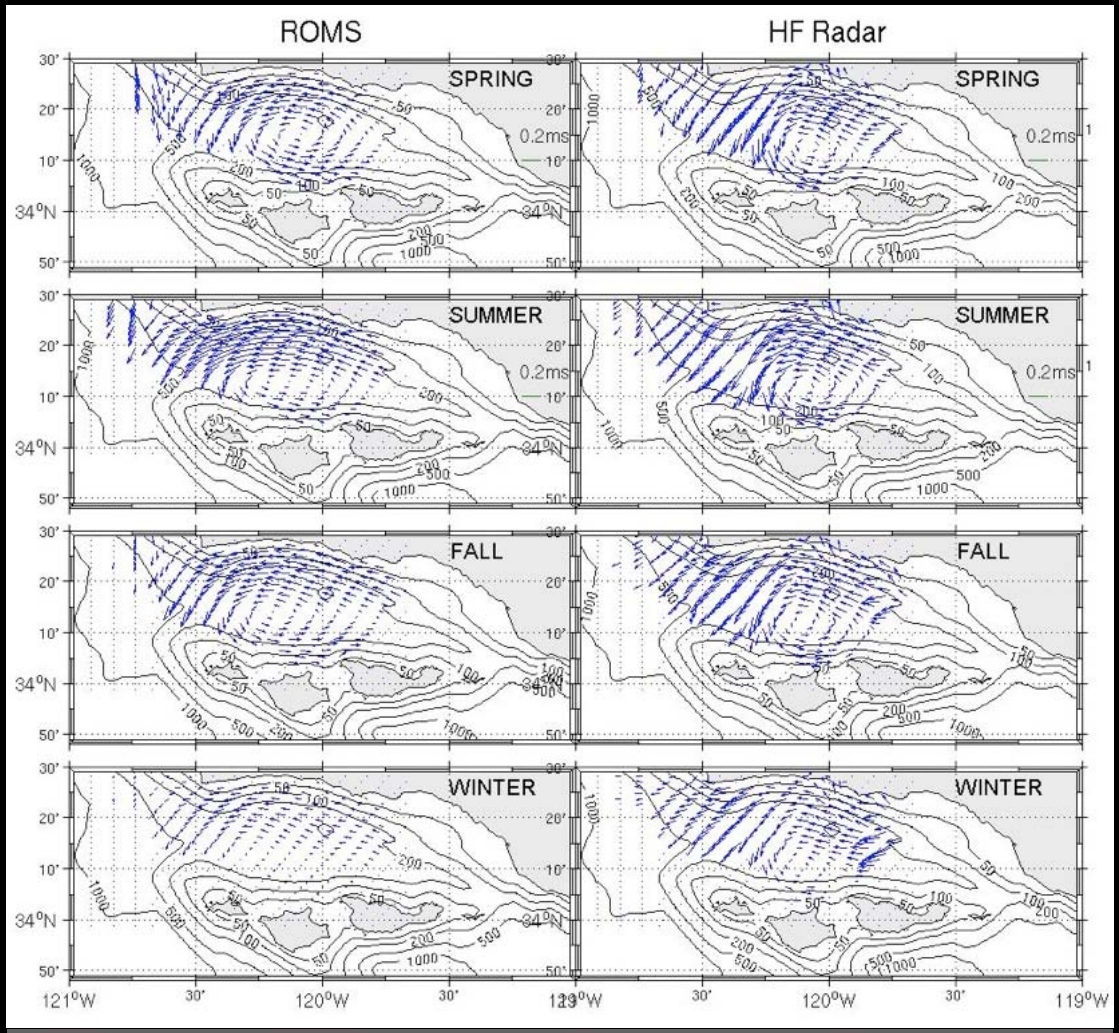
NDBC Station Map



C. Dong, E. Icida and J. McWilliams "Circulation and Multiple-Scale Variability in the Southern California Bight" (2008)

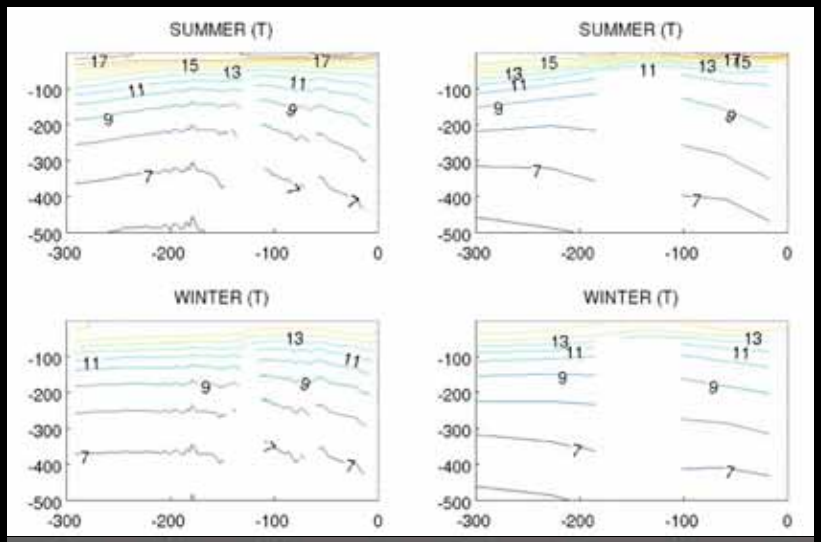
ROMS Validations

ROMS vs HF radar

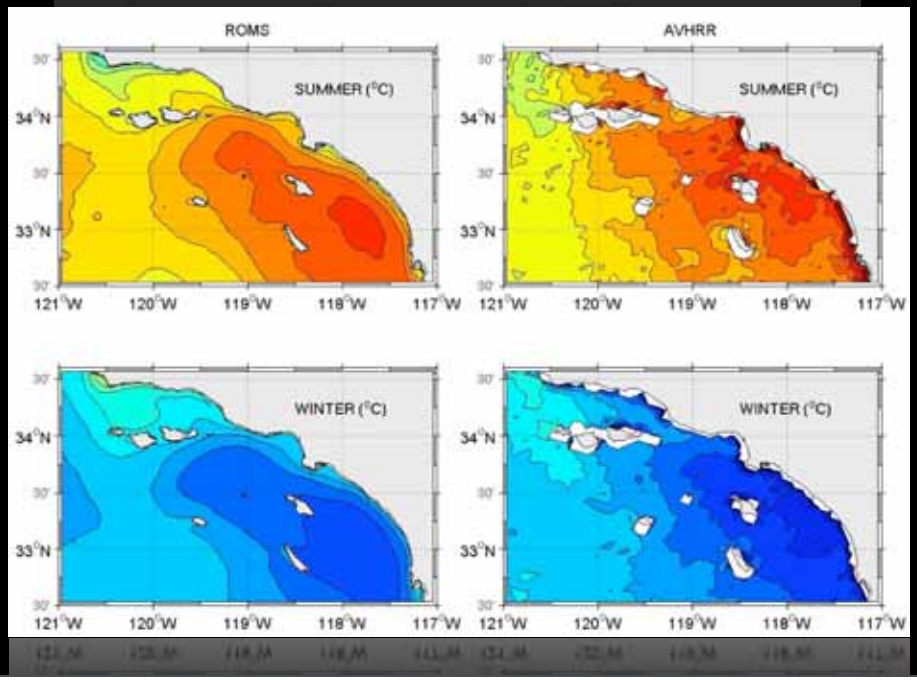


C. Dong, E. Icida and J. McWilliams "Circulation and Multiple-Scale Variability in the Southern California Bight" (2008)

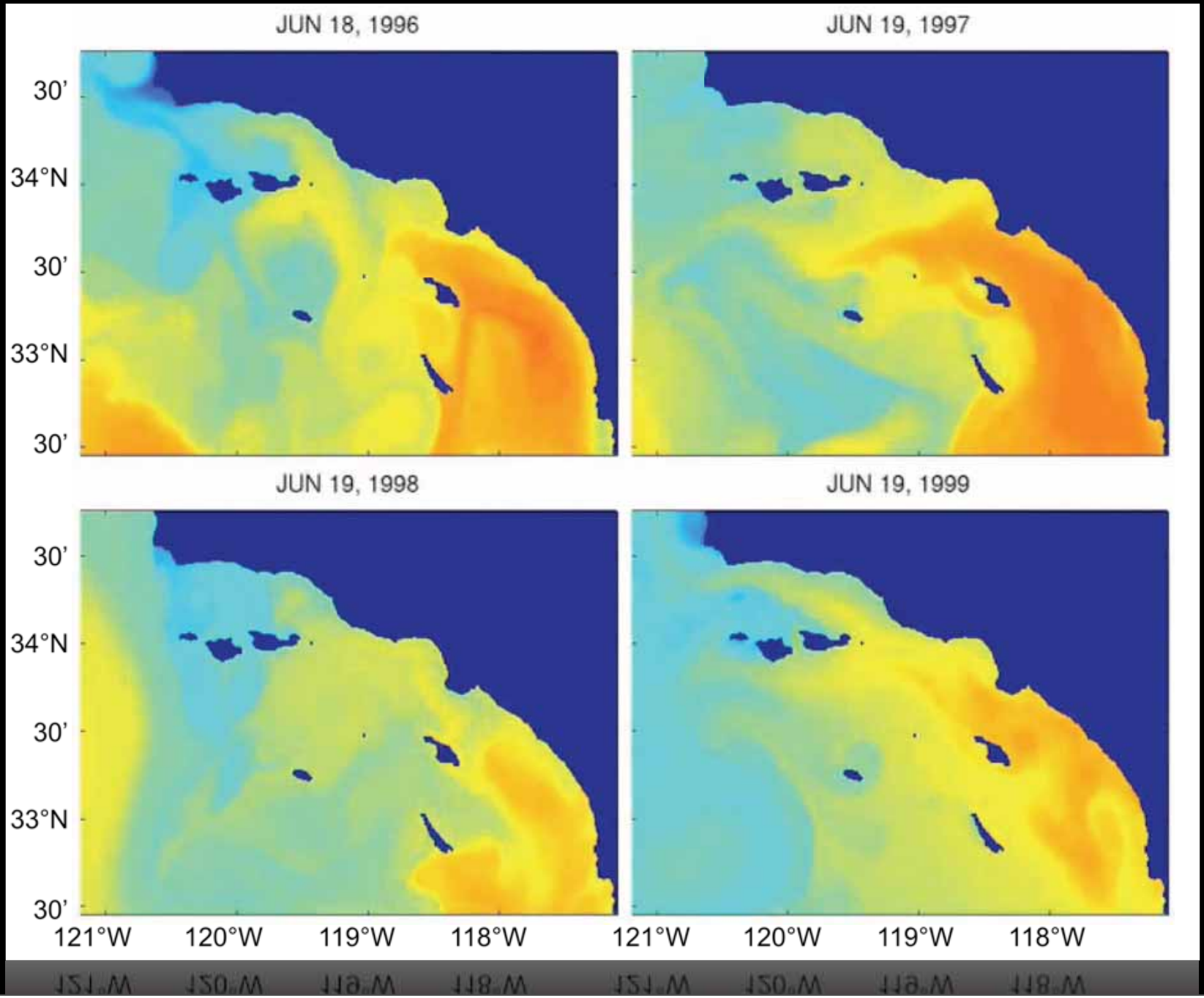
ROMS vs CalCOFI



ROMS vs AVHRR



A Sample Movie (SST)



ROMS Simulations Summary

- Show excellent agreement with observations

  Not only mean, but also variations

- Seasonal & interannual variability is captured well

  Integrated 1996 – 2003

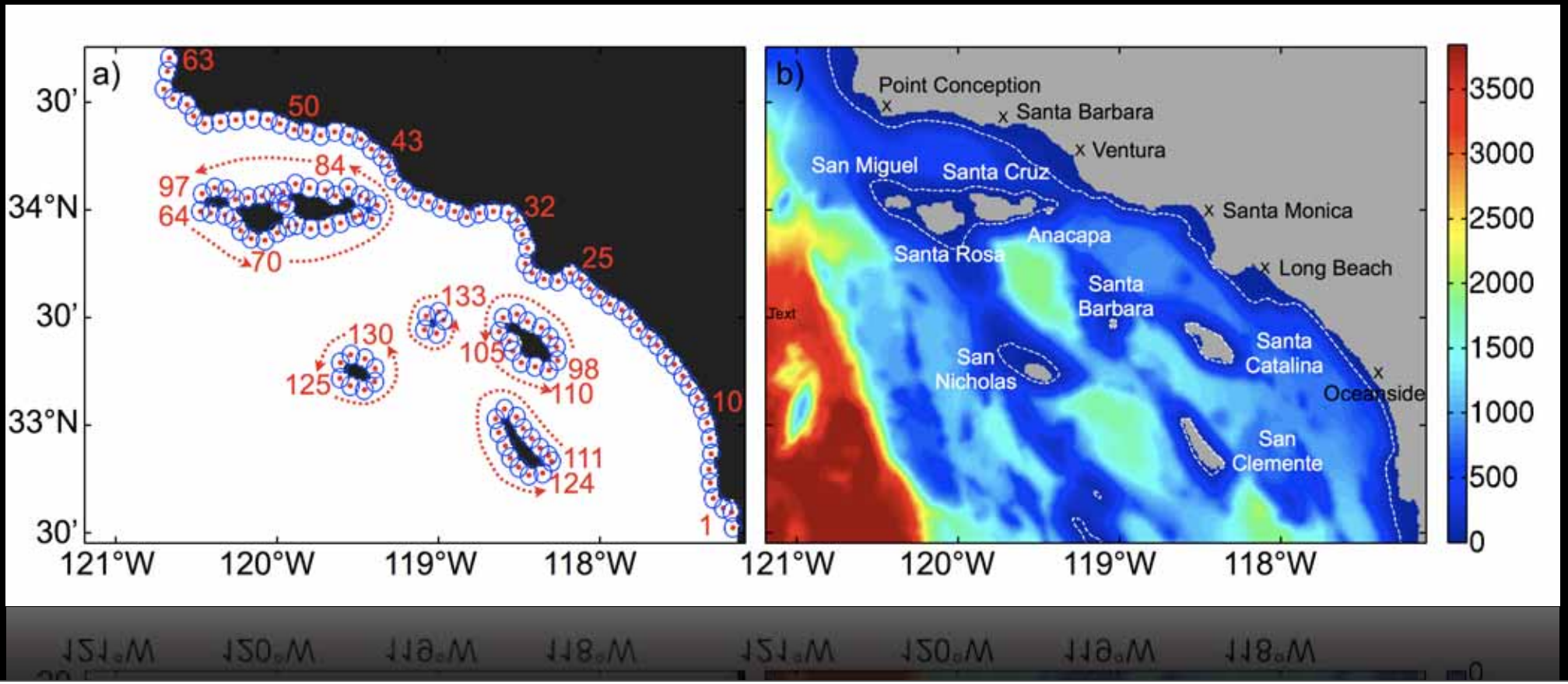
  Including strong El Niño & La Niña

Lagrangian PDF Methods

- Describe expected dispersal patterns from single site

  By releasing many (~ million) particles each site

  Dispersal kernels = expected dispersal from a site



Lagrangian Particle Tracking

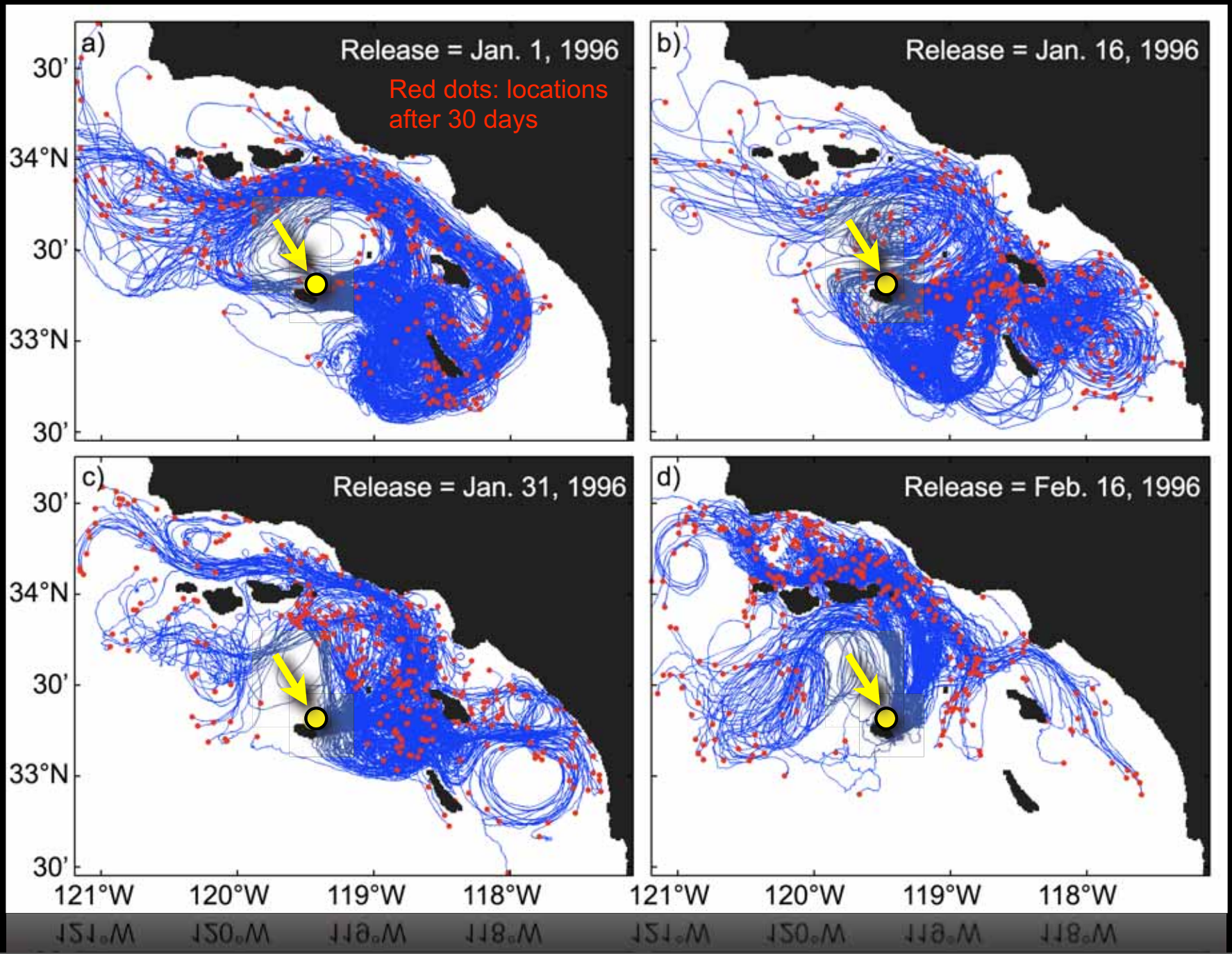
- Released every 1 km, every 6 hours
- From Jan. 1, 1996 thru Dec. 31, 1999

  Including strong El Niño & La Niña
- Passively transported by simulated currents

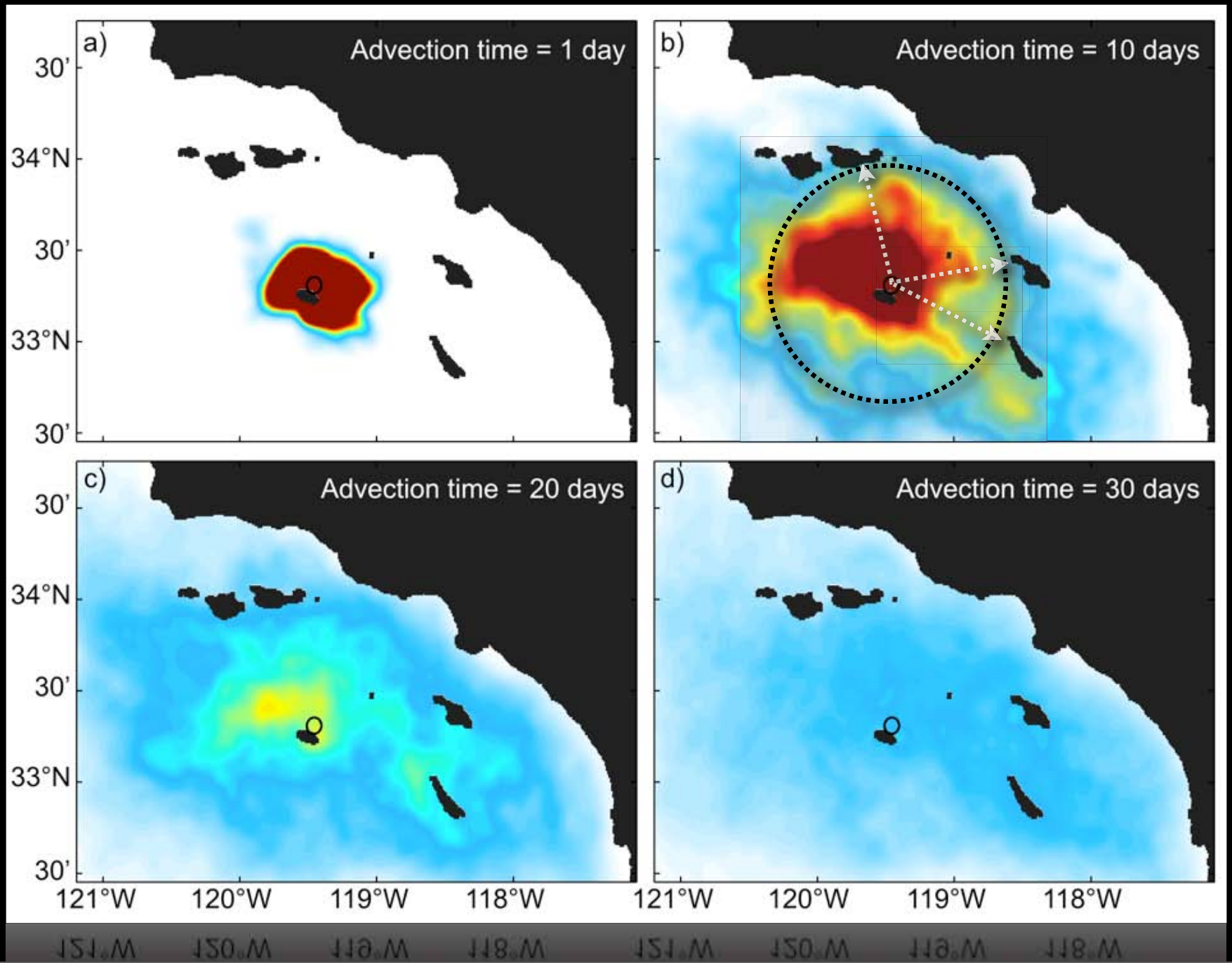
  Mostly stay near surface

  No behavior (future work)

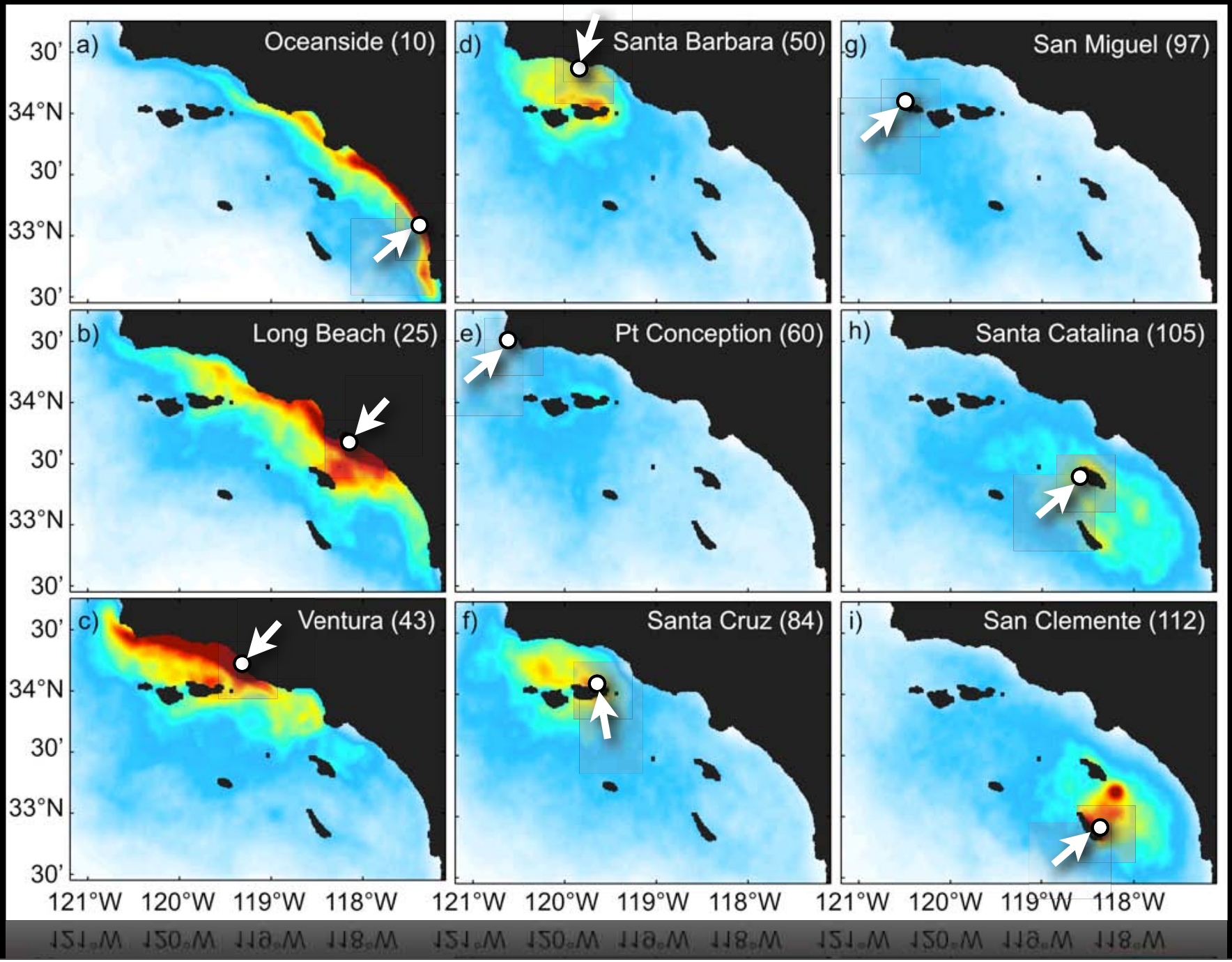
30-day Trajectories From San Nicholas



Dispersal Kernel from San Nicholas

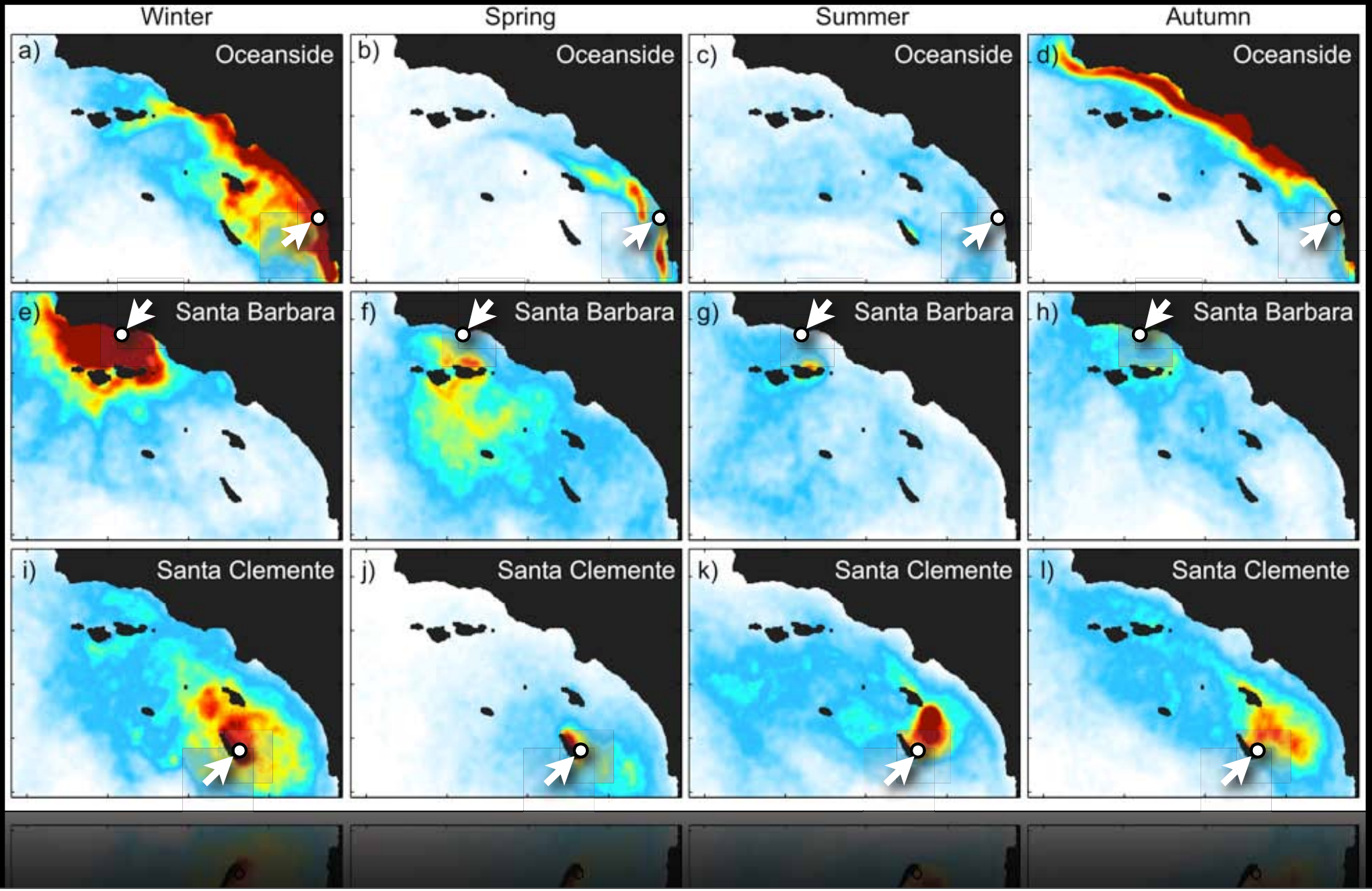


Kernels From Different Sites (30 d)



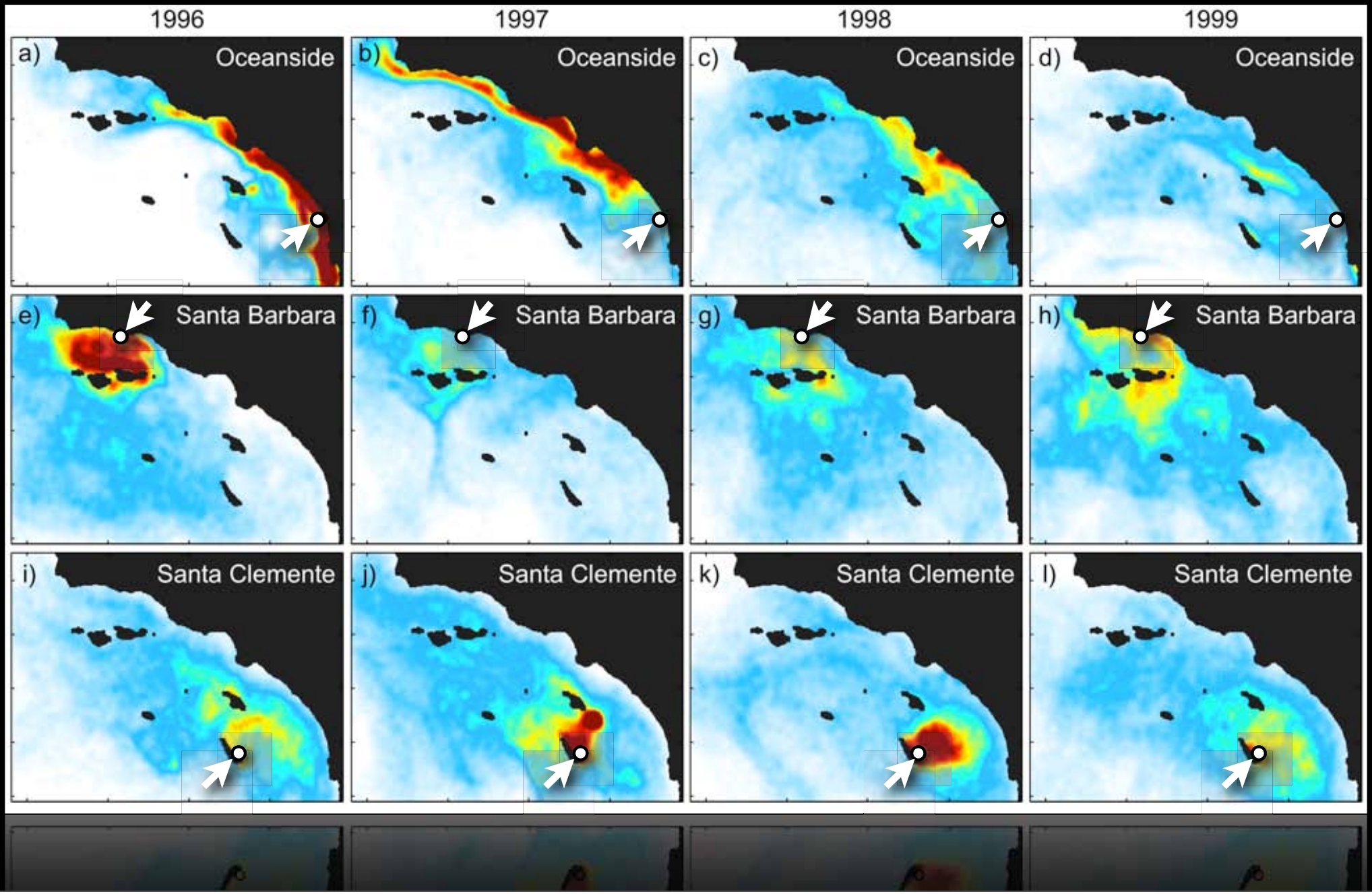
Seasonal Variability

Advection time = 30 days



Interannual Variability

Advection time = 30 days



Dispersal Kernels in SCB

- Spread out in the entire Bight within 30 days or so
- Show strong position-dependence

  Poleward transport, retention in Channel & near San Clemente Island
- Strong seasonal & interannual variability

  Responding to wind

Connectivity for Particular Species

- Given spawning season & PLD

  Rockfish: winter – spring, PLD ~ 100 d

  Kelp bass: spring – fall, PLD ~ 30 d

- Assume homogeneous larval production

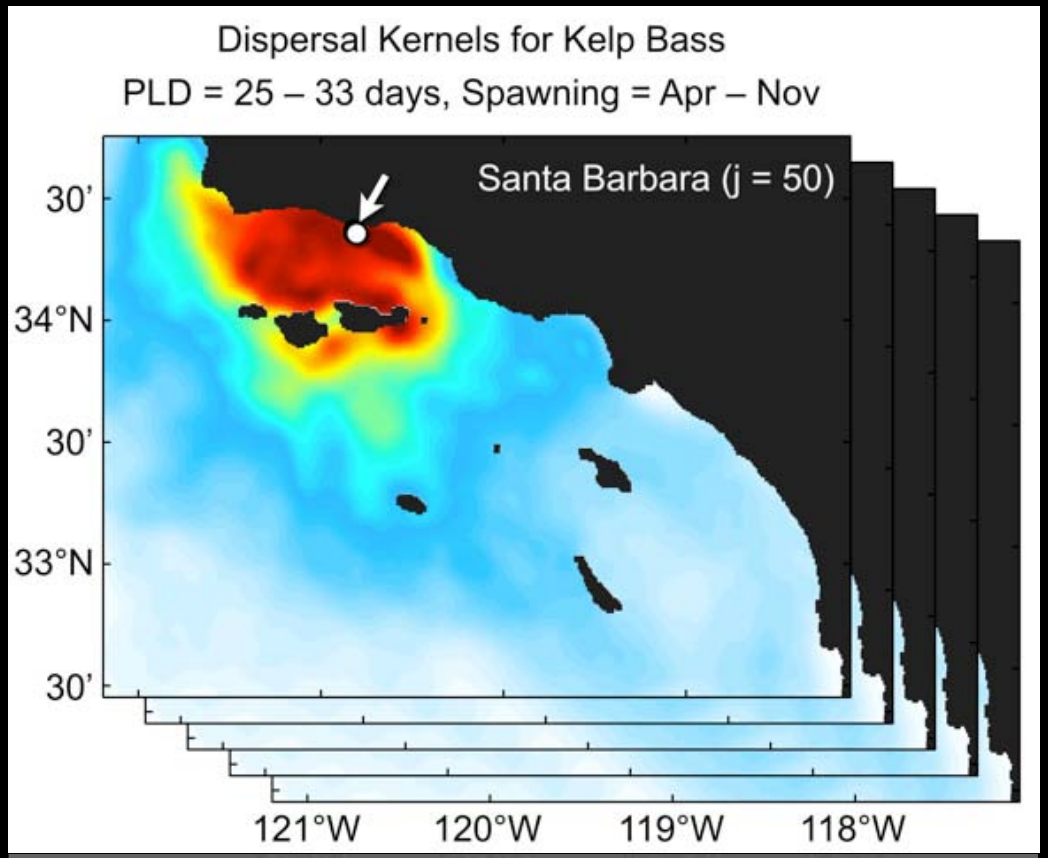
  Connectivity via advection of water parcels

species	latin name	range	spawning season	PLD range	Best guess
Lingcod	*Ophiodon elongatus*	AK to baja	nov-april	30-120	30
kelpbass	*Paralabrax clathratus*	WA to Baja	april-nov	25-33	28
Cabezon	*Scorpaenichthys marmoratus*	AK to baja	oct-mar	90-120	105
Black rockfish	*Sebastes melanops*	AK to huntingtion beach	jan-may	60-180	110
canary rockfish	*Sebastes pinniger*	AK to baja	dec-april	60-120	116
red abalone	*Haliotis rufescens*	OR to baja	year-round	3-12	7
red sea urchin	*Strongylocentrotus franciscanus*	AK to baja	generally winter, but ap	40-60	42

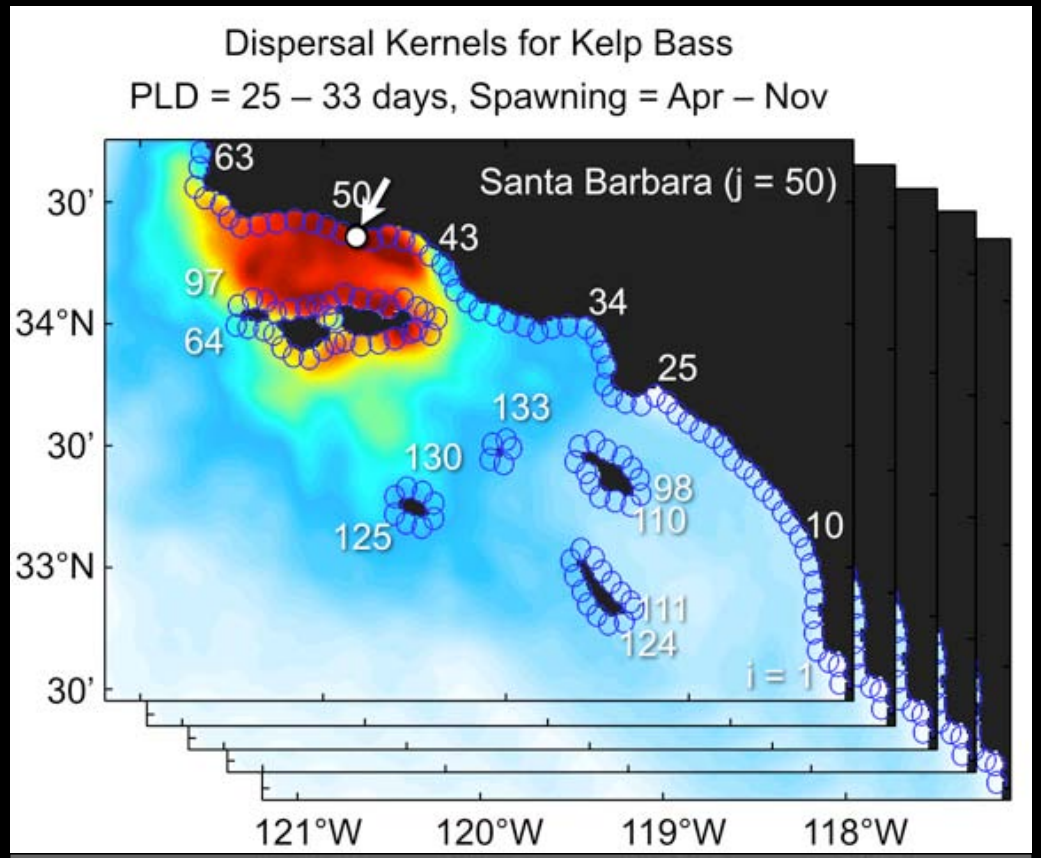
Coastal Connectivity

- Can be deduced from dispersal kernels

1. Obtain dispersal kernels for a particular species from each source site



2. Evaluate dispersal kernels at all sites



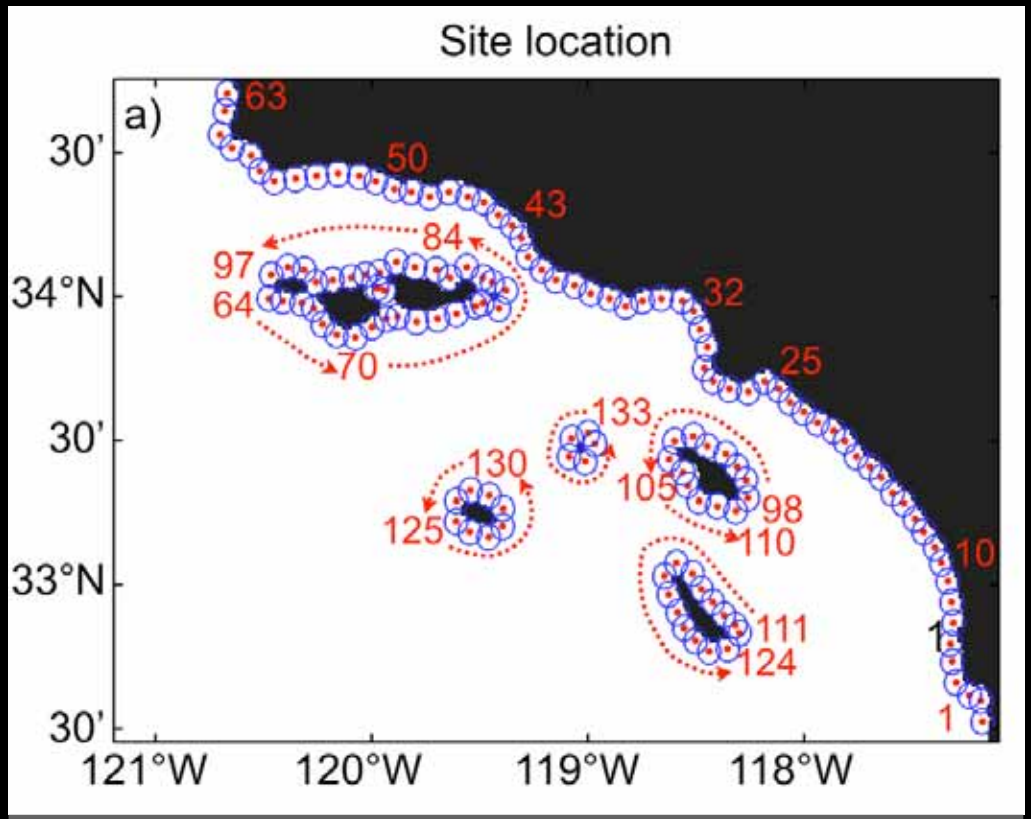
137 x 137 site connectivity matrix

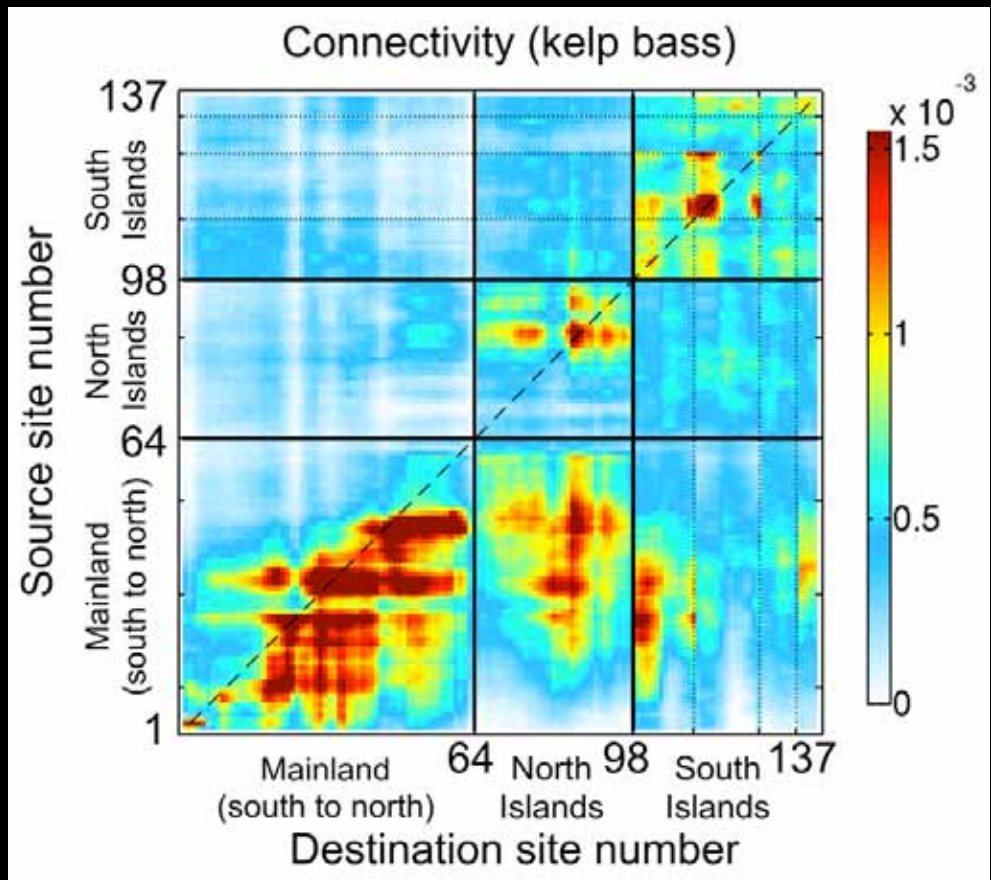
Connectivity Matrix (Kelp Bass)

PLD = 25 – 33 d, Spawning = Apr – Nov

- Connectivity is heterogeneous & asymmetric

Strong transport from mainland to Islands



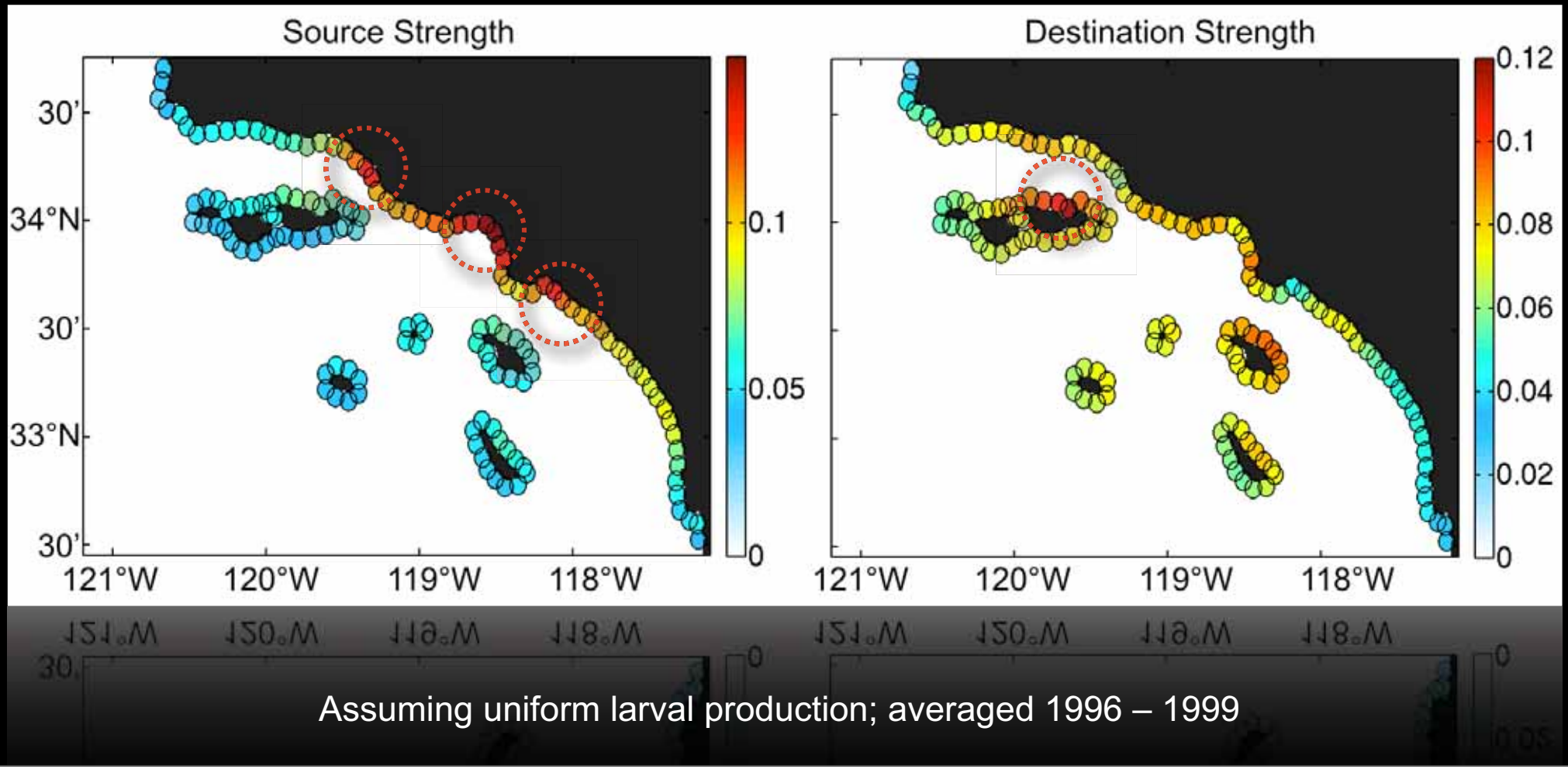


Assuming uniform larval production; averaged 1996 – 1999

Strong Source & Destination (Kelp Bass)

PLD = 25 – 33 d, Spawning = Apr – Nov

- Source: Long beach, Santa Monica, Venture
- Destination: Chinese Harbor

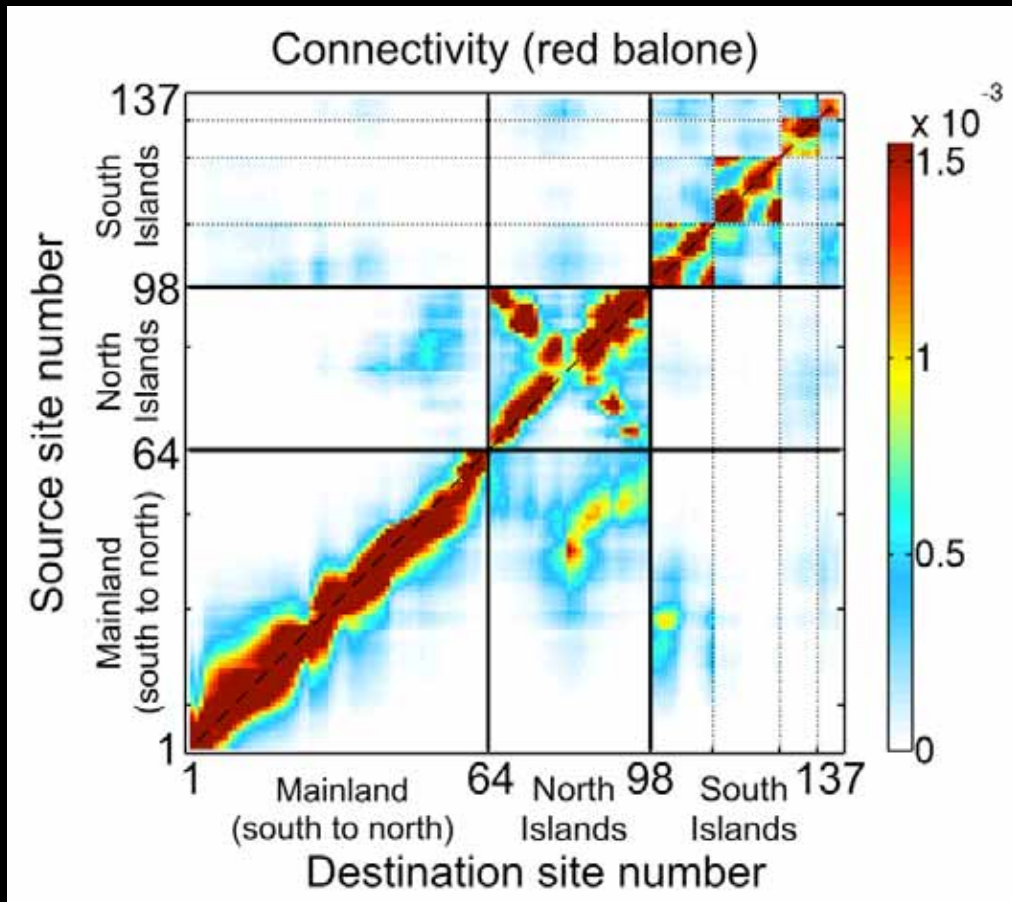


Assuming uniform larval production; averaged 1996 – 1999

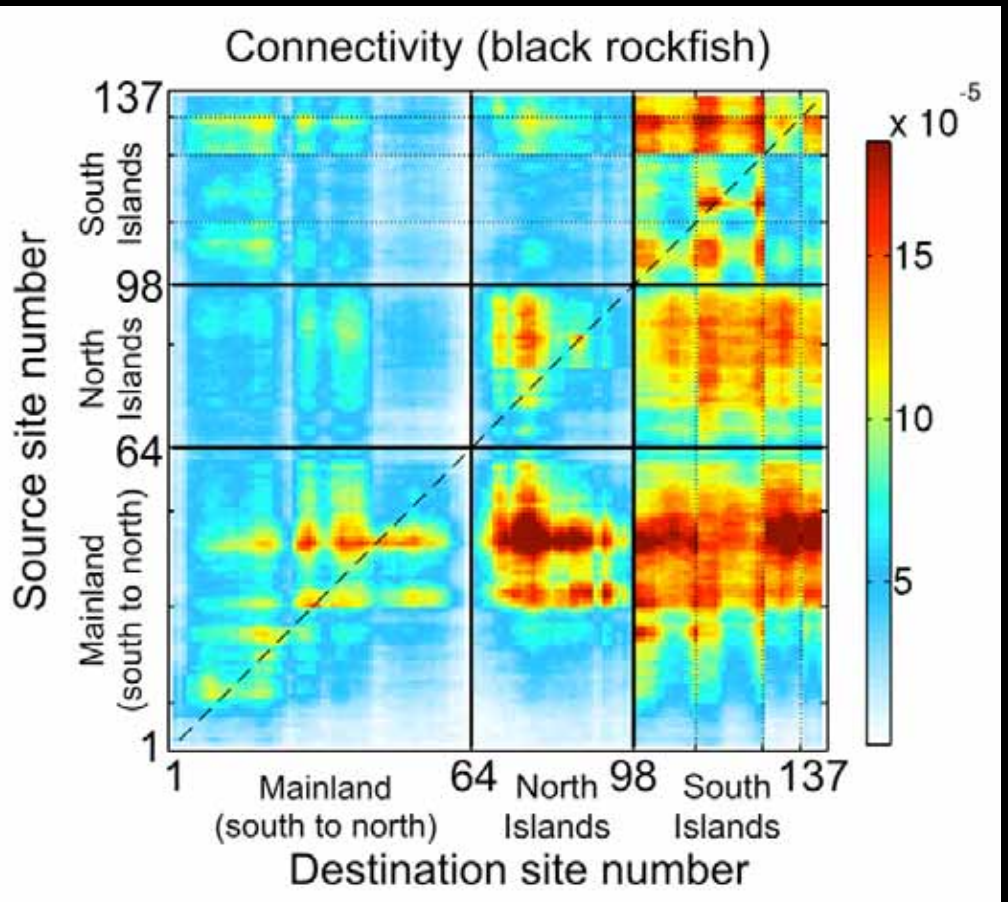
Red Abalone & Black Rockfish

- Connectivity depends on species

PLD = 3 – 12 days, all year around



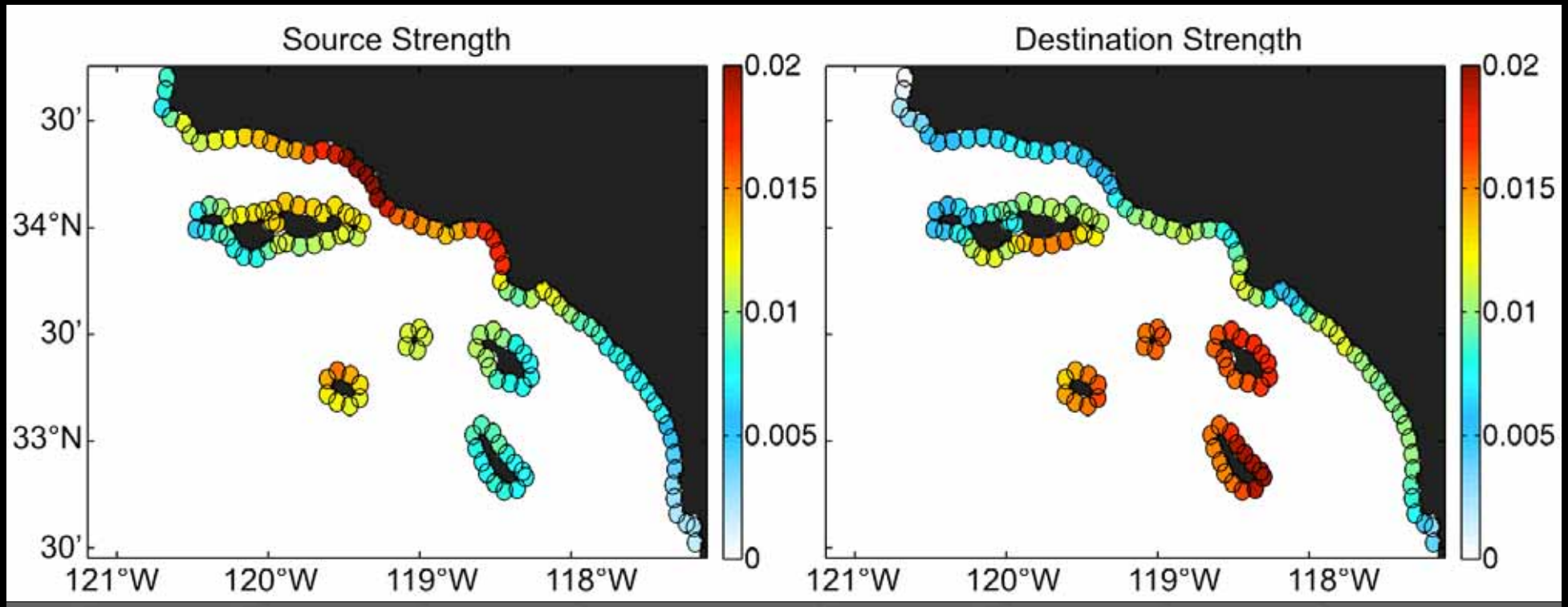
PLD = 60 – 120 days, Jan – May



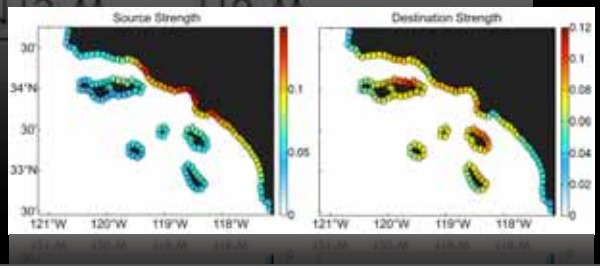
Strong Source & Destination (Rockfish)

PLD = 60 – 120 d, Spawning = Jan – May

- Source: Northern Mainland, Santa Cruz, San Nicholas
- Destination: All Southern Islands



Different from Kelp bass



Is connectivity persistent?

- Dispersal kernels describe the expected connectivity
- How does realization (not expected) look like?

  Similar to expected connectivity?

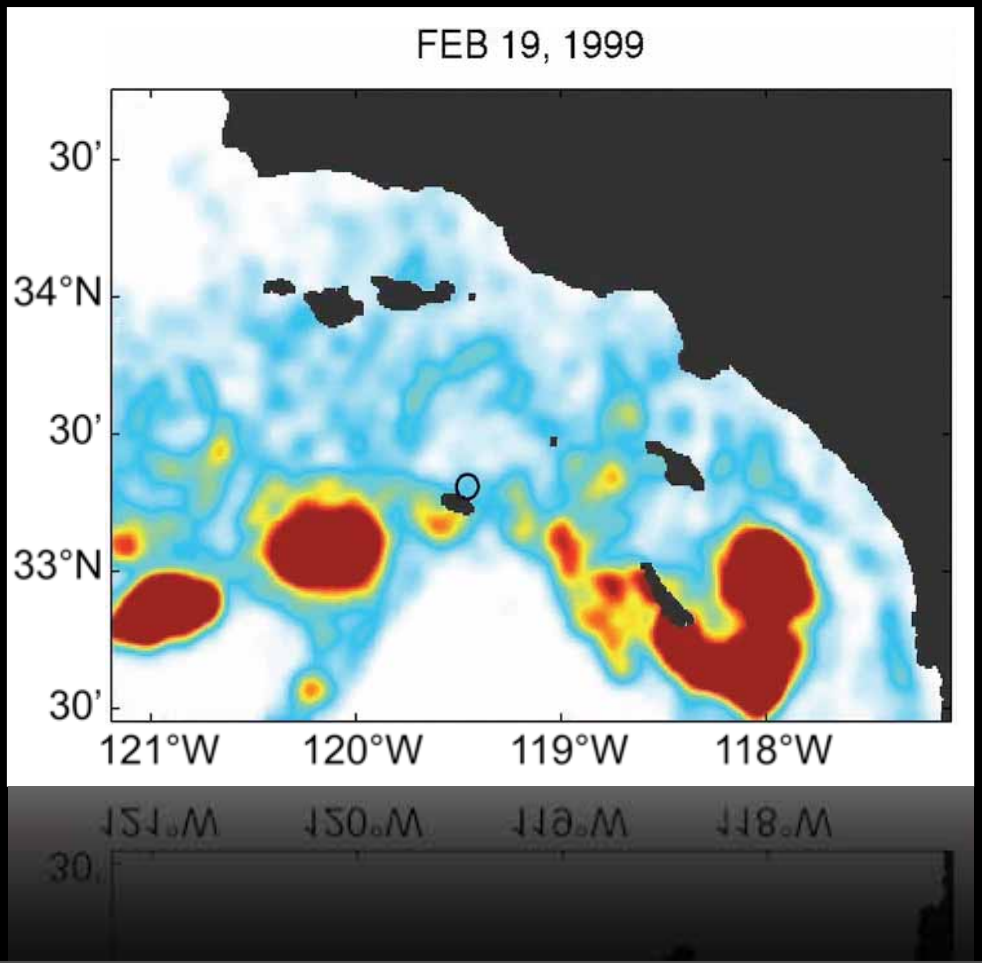
  Persistent season to season?

Realizations (Not Expectations)

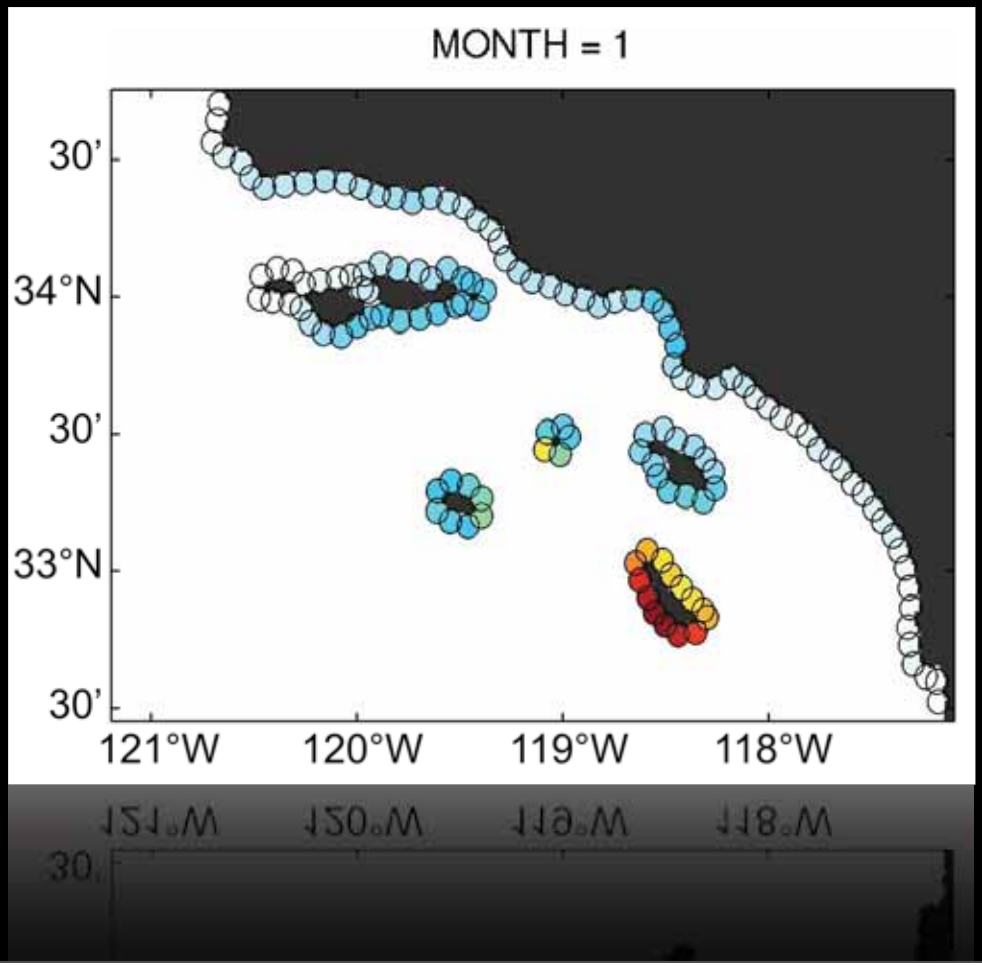
- Connectivity is not persistent month to month

  Very different from mean

Release = 1/1/96 – 1/31/96, San Nicholas



Monthly destination from San Nicholas



Summary

- Connectivity is heterogeneous & asymmetric

  Reflecting flow features in SCB

- Connectivity is different for different species

  Strong source & destination locations change

- Connectivity is not persistent season to season

  Intrinsic variability to eddy motions

- Strong interannual variability

Mitarai, Siegel, Watson, Dong & McWilliams, to be submitted to JGR

Future Work

- Comparison with available observations

  Drifters, population genetics, microchemistry, recruit data

- Assess fish life history

  Ontogenetic behaviors, larval food availability, etc.

- More simulation years & bigger domain

  Requires time & computational resources

- Integrate this frame work into SCCOOS