# Spatial-temporal patterns of residence-time, transport and connectivity among near-shore marine reserves on the Oregon shelf from particle-tracking using inputs from multiple physical models

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## Roadmap

Brief Motivation

Metrics

Examples

Conclusions/Summary

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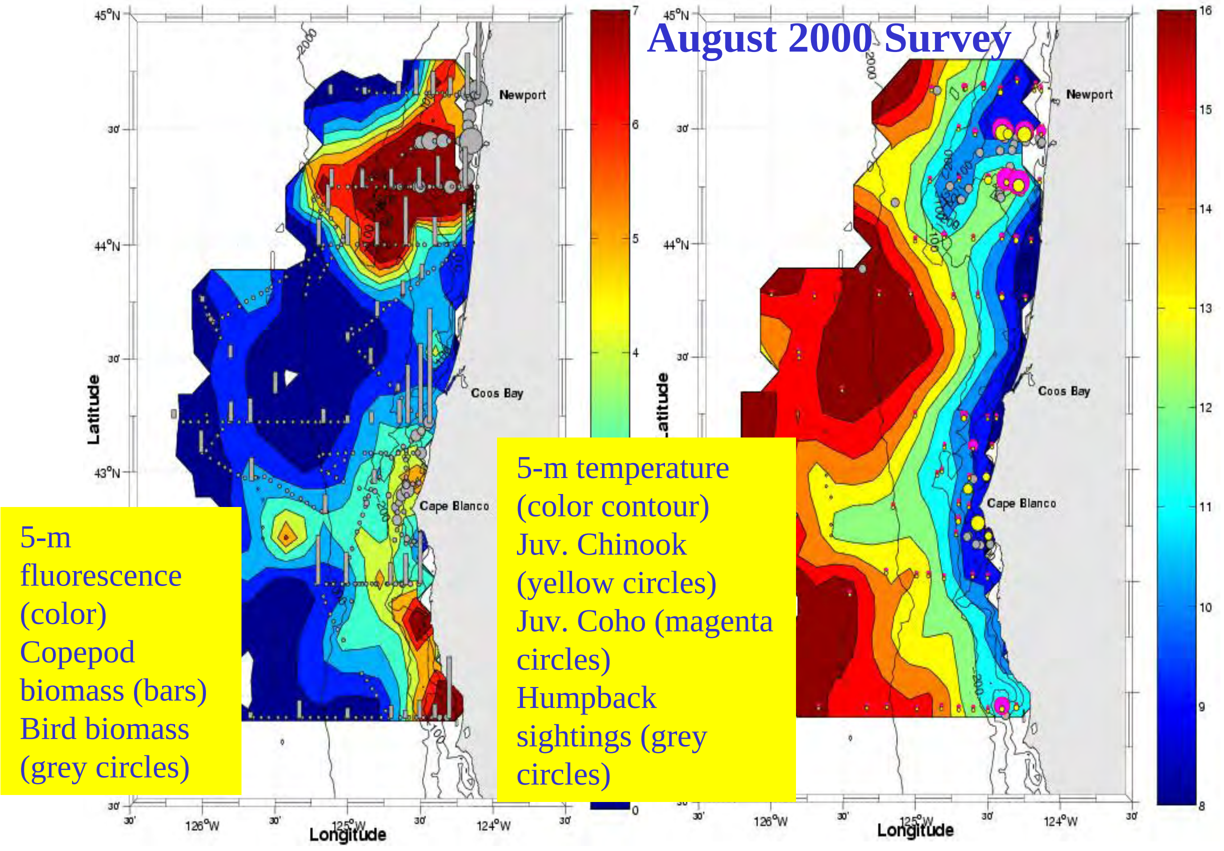
# Mesoscale Structures in Shelf Systems

- 10's to 100's of kilometers
- Persistence of weeks to months
- Associated biological structures on similar spatial and temporal scales
- Types: upwelling fronts, river plume fronts, shelf break fronts, eddies



August 2000 Survey

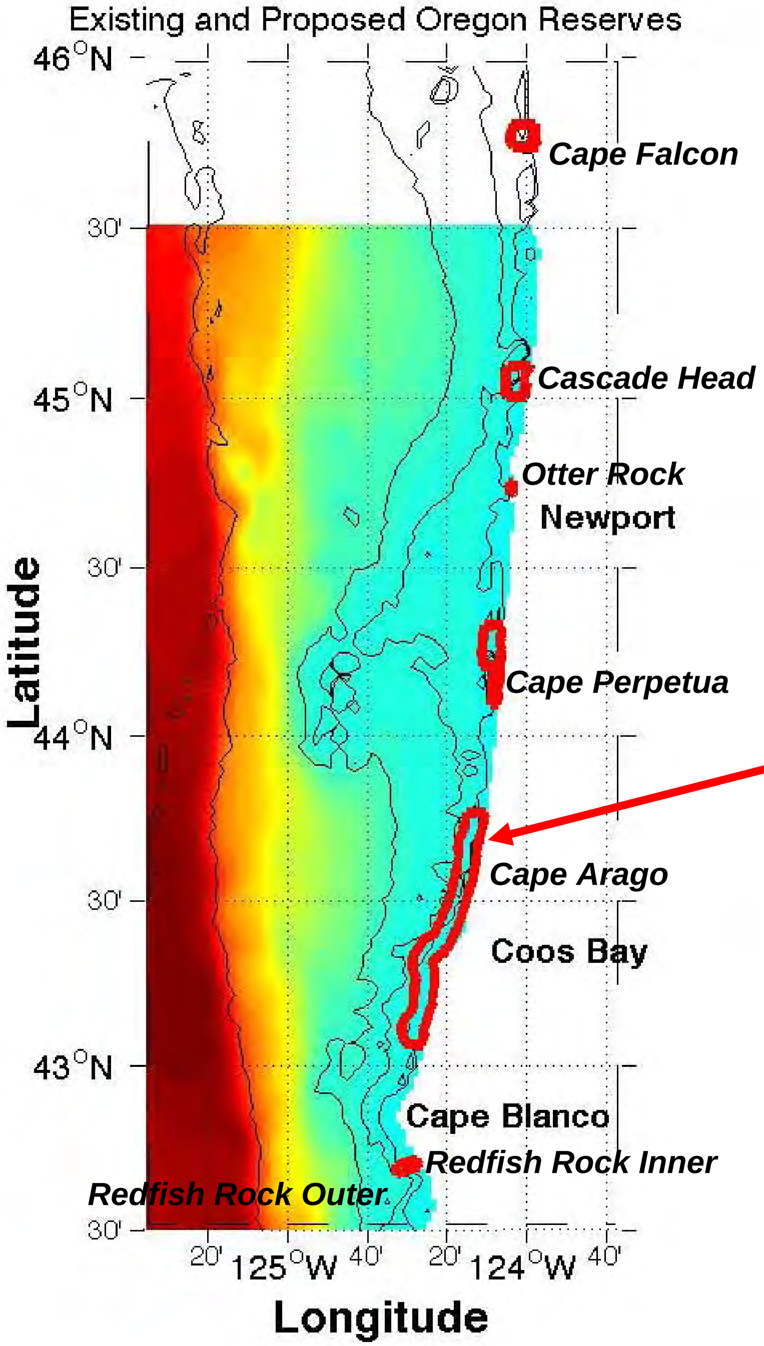
5-m fluorescence (color)
Copepod biomass (bars)
Bird biomass (grey circles)

5-m temperature (color contour)
Juv. Chinook (yellow circles)
Juv. Coho (magenta circles)
Humpback sightings (grey circles)

From Batchelder et al. (2002)

# Marine Spatial Planning in Oregon

Six existing reserves and one proposed reserve.



Proposed Reserve

# What is the connectivity among these reserves?

What factors influence connectivity?

Marine connectivity is influenced by many physical and ecological factors.

- Advection
- Diffusion
- Predation/Mortality
- Food resources
- Habitat
- Season
- Species of interest
- Pelagic larval duration
- Temperature
- Behavior
- Size and configuration of reserve habitat

How do we measure (estimate) connectivity?

Direct observation is exceedingly difficult. Source-destination relationships are particularly difficult to observe in the sea.

Instead, we use high-resolution biophysical models to examine the effects of spatial and temporal environmental variability and life history on patterns of dispersal and retention.

# 4 MODELS USED HERE

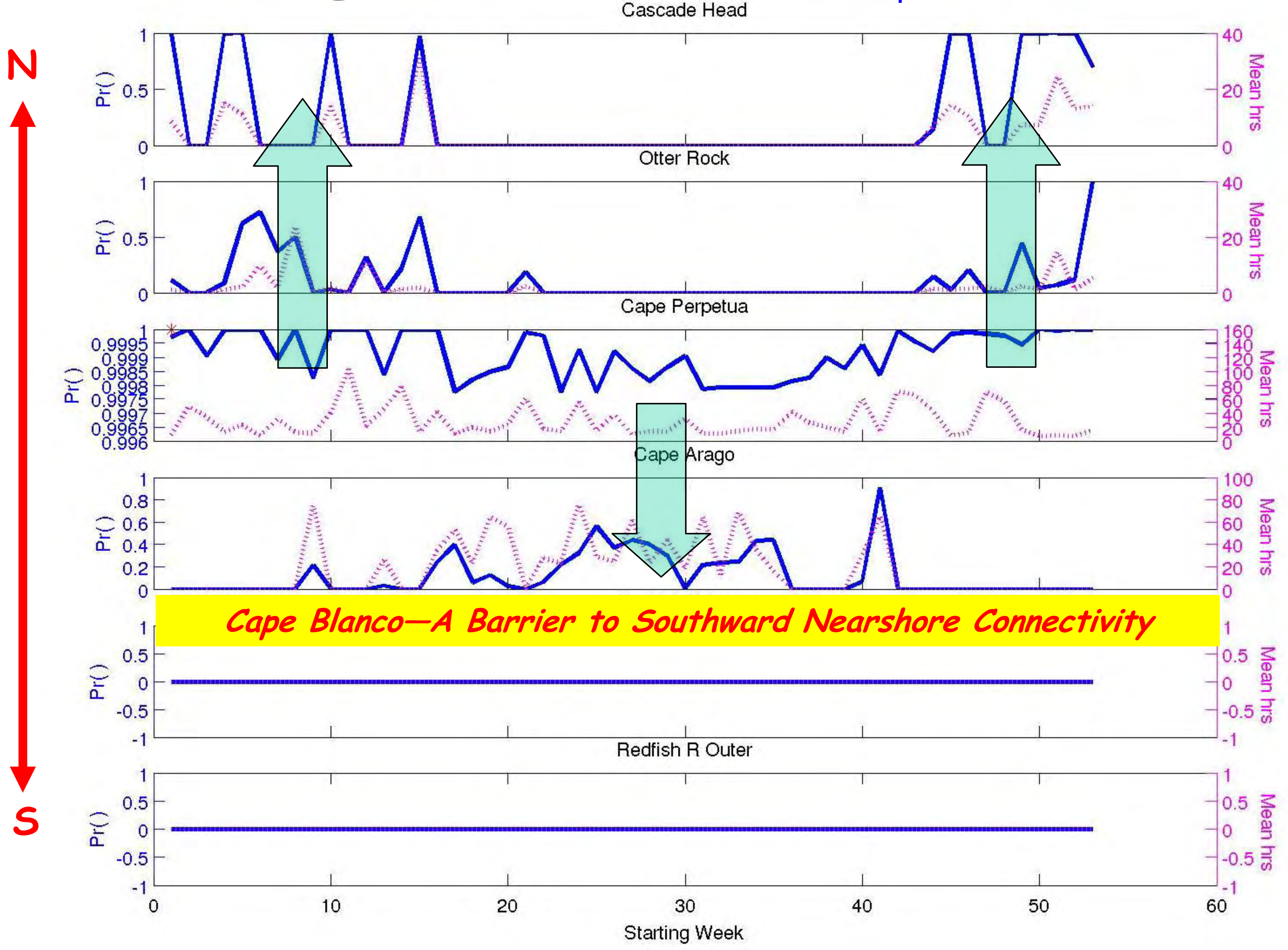
- **RCCS:** Small domain; **1 km**; COAMPS wind forcing; blended product using 9-27 km resolution, but mostly 9 km; no tides; IC/BCs from NEP; **2002**; Daily avg fields (Curchitser)
- **NEP:** Larger domain; **10 km**; 6 hr T42 CORE wind and surface fluxes; no tides; IC/BCs from CCSM-POP hindcast model; **1958-2004**; Daily avg fields (Curchitser)
- **RTOFS:** No.Cal.-OR; **3 km**; NAM (9 km) winds and sfc flux; climatological BCs and data assimilation; 8/2010-2011; Daily avg fields (Kurapov)
- **Osborne:** No.Cal.-OR; **1 km**; daily avg COAMPS winds; bulk fluxes computed from NCEP/NCAR variables; **8 tidal constituents** (M2,S2,K2,N2,K1,P1,O1,Q1) from a harmonic of SSH and depth avg current from a barotropic tidal model; IC/BCs from larger domain models; Apr-Aug for **2002** and 2011; Hourly snapshots (Osborne)

# COMPARISONS

- 2002: RCCS (1 km) metrics of short PLD connectivity of Oregon marine reserves
- 2002: RCCS (1 km) vs. NEP (10 km)
  - Effect of model resolution on retention (residence) time
- 2002: Osborne (1 km w/o tides) vs. RCCS (1 km)
  - Two different 1 km models
- 2002: Osborne (1 km w/ tides) vs. Osborne (1 km w/o tides)
  - Identical models, except for tidal forcing
- 2002: Osborne model results comparing different depths
- 2011: RTOFS (3 km) vs. Osborne (1 km w/o tides)
  - Effect of model resolution.

# RCCS-2002 CONNECTIVITY

17724 particles released from CP



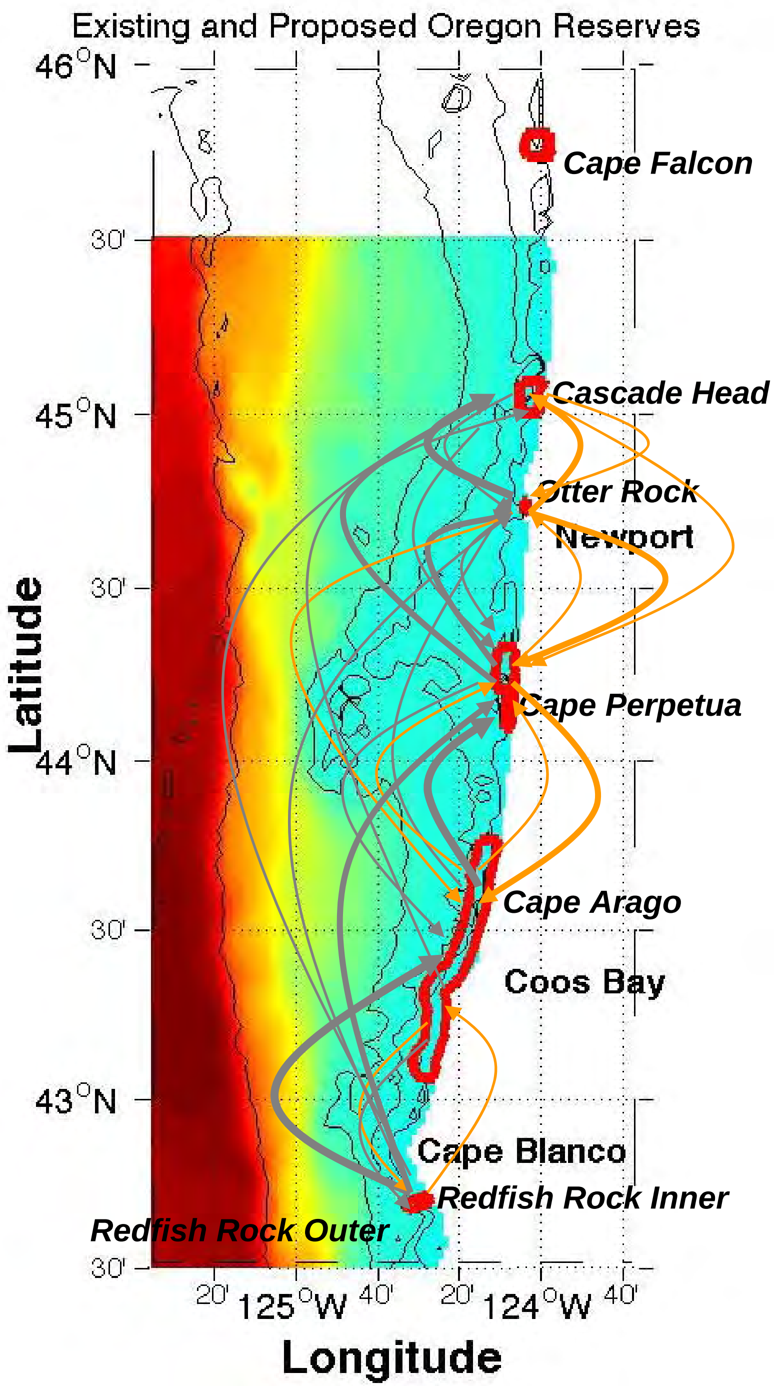
**Cape Blanco—A Barrier to Southward Nearshore Connectivity**

# Oregon Shelf Marine Connectivity

*Shown: Connectivity (% of released particles) reaching another reserve.*

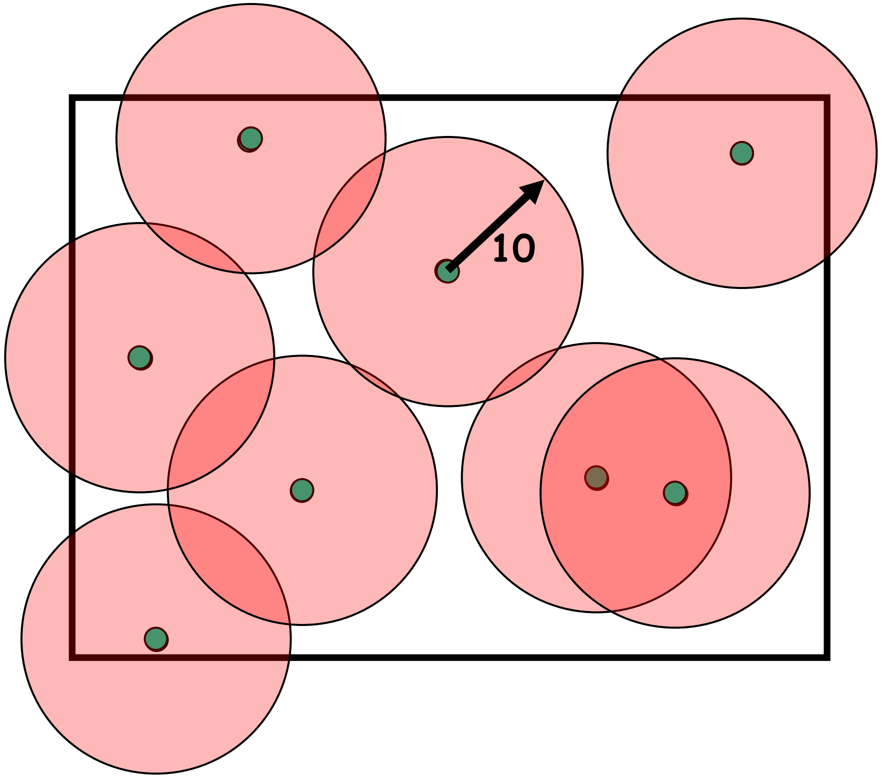
| *Period* | *1-10%* | *10-40%* | *>40%* |
|---|---|---|---|
| *Downwelling* | ← | ← | ← |
| *Upwelling* | ← | ← | ← |

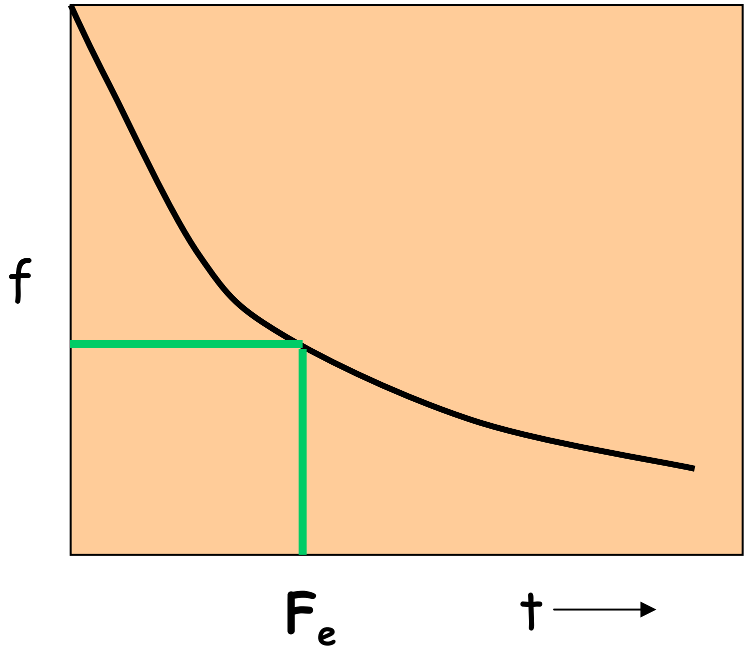
Alongshore connectivity is highly seasonal; upwelling periods have high N→S connectivity; downwelling periods have high S→N connectivity. Alongshore connectivity is greater during winter downwelling. Cape Blanco is a barrier to connectivity, esp. in summer. Larger reserves are more connected than small reserves.



# Retention (E-flushing) Time ($F_e$)

- select a distance (r) or control volume; here r=10 km
- track fraction (f) of particles remaining within r of the initial location as function of time (t)
- note time when f declines to < 1/e (~0.368)

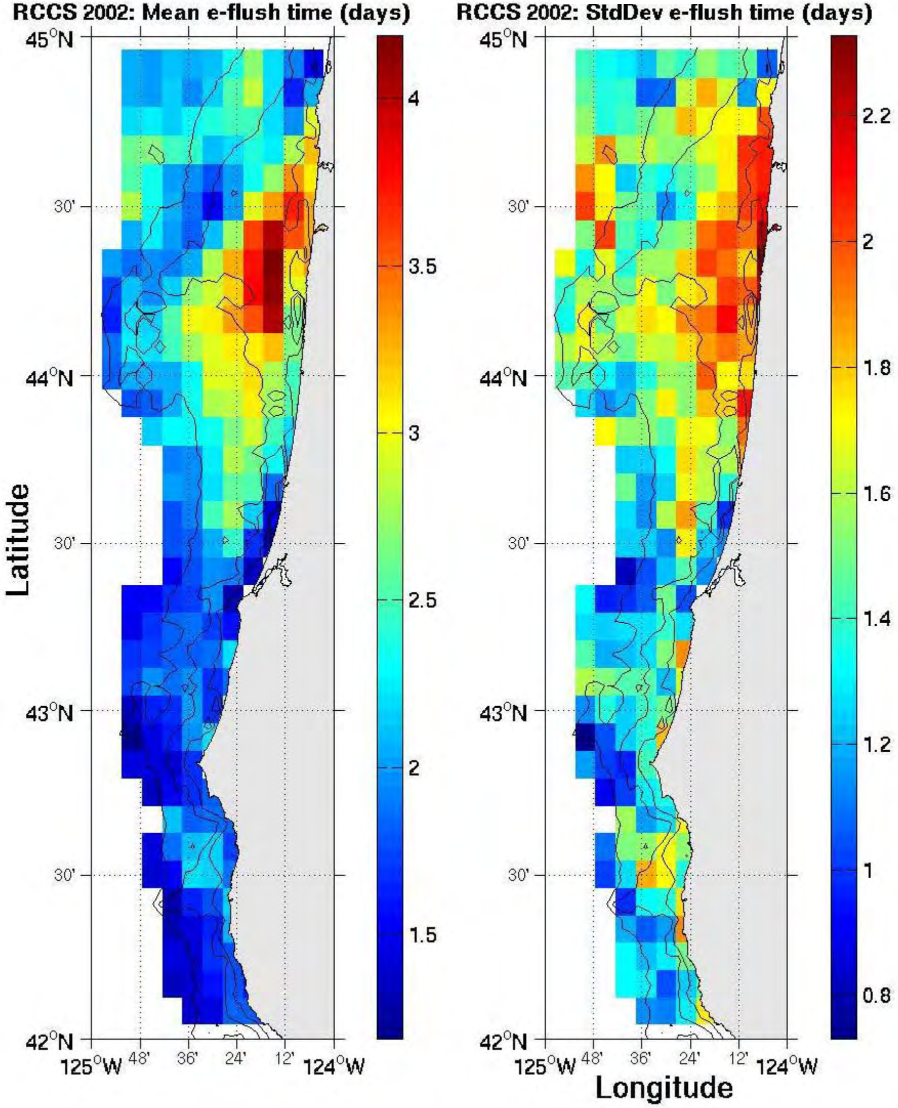




# spatial pattern of e-flush

**Longest flush time and greatest variability in inner Heceta Bank Region**

These results are based on statistics from 50K particles per release. A new release every 7d during 2002. 'Individuals' advected 3D, meaning they changed depth with vertical velocities. Time step for particle tracking=1hr.

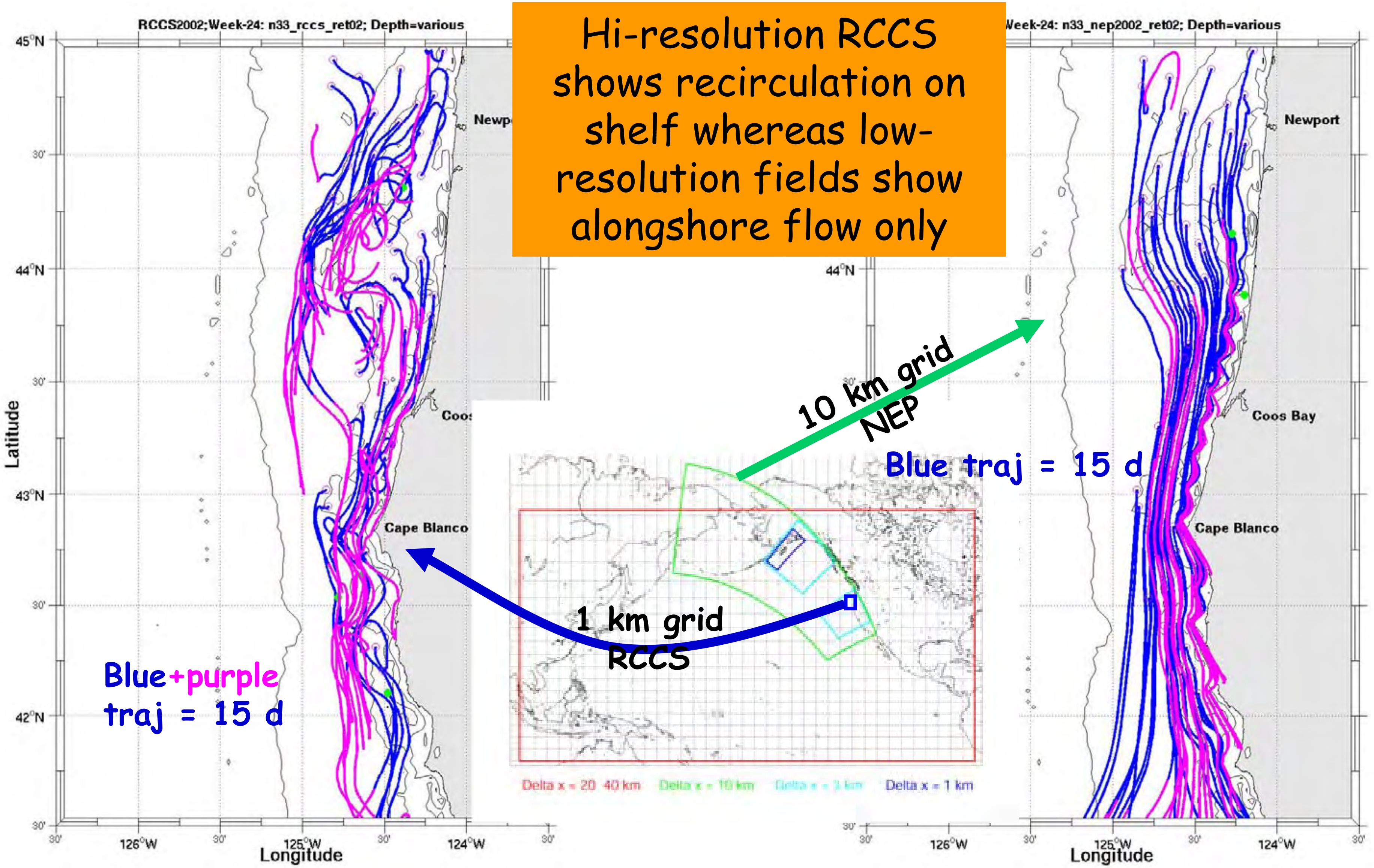


Mean

StdDev

# Comparison of 1 km and 10 km grids

12 Jun 2002



Hi-resolution RCCS shows recirculation on shelf whereas low-resolution fields show alongshore flow only

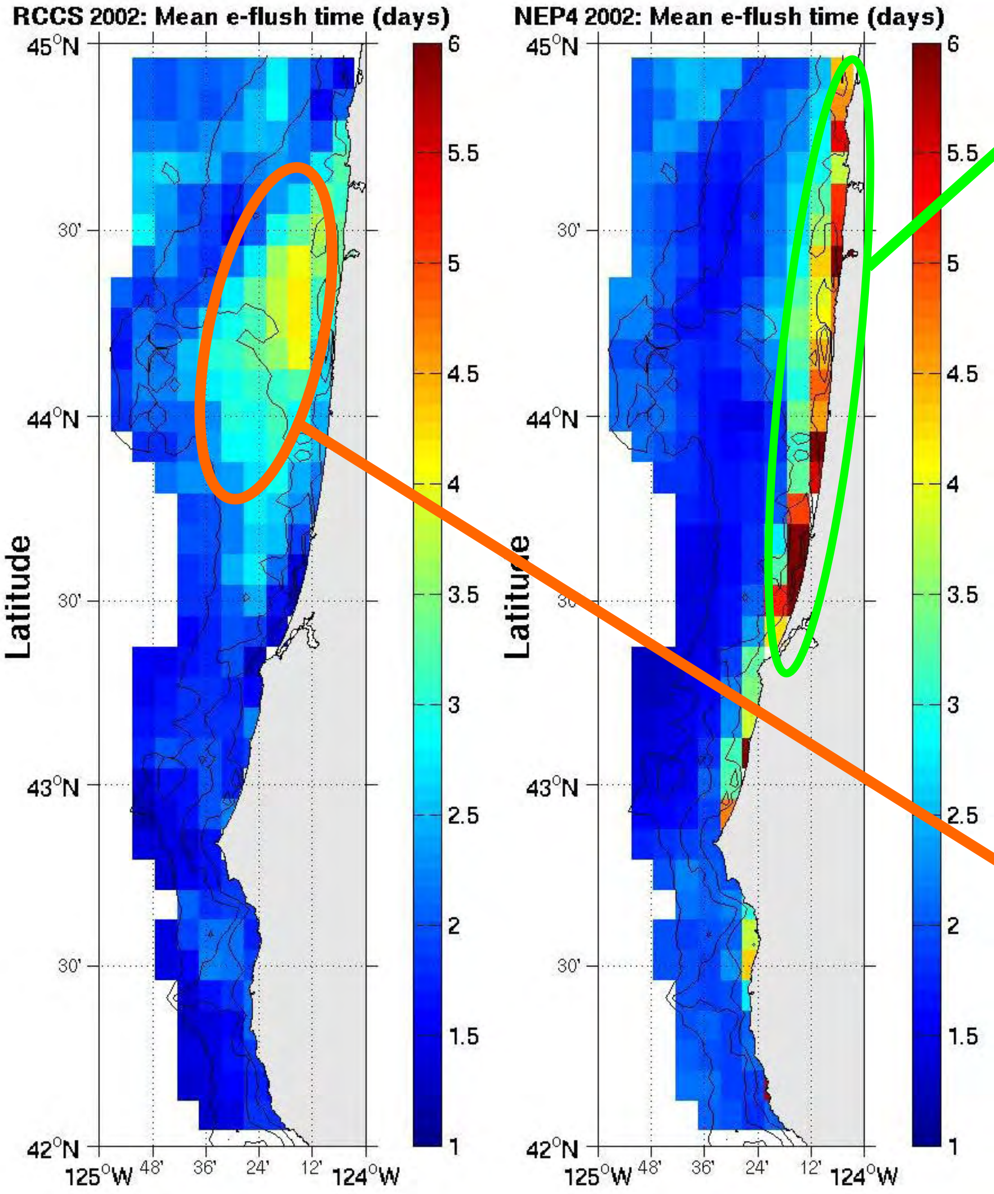
10 km grid NEP

Blue traj = 15 d

1 km grid RCCS

Blue+purple traj = 15 d

# Comparison of 1 km and 10 km grids

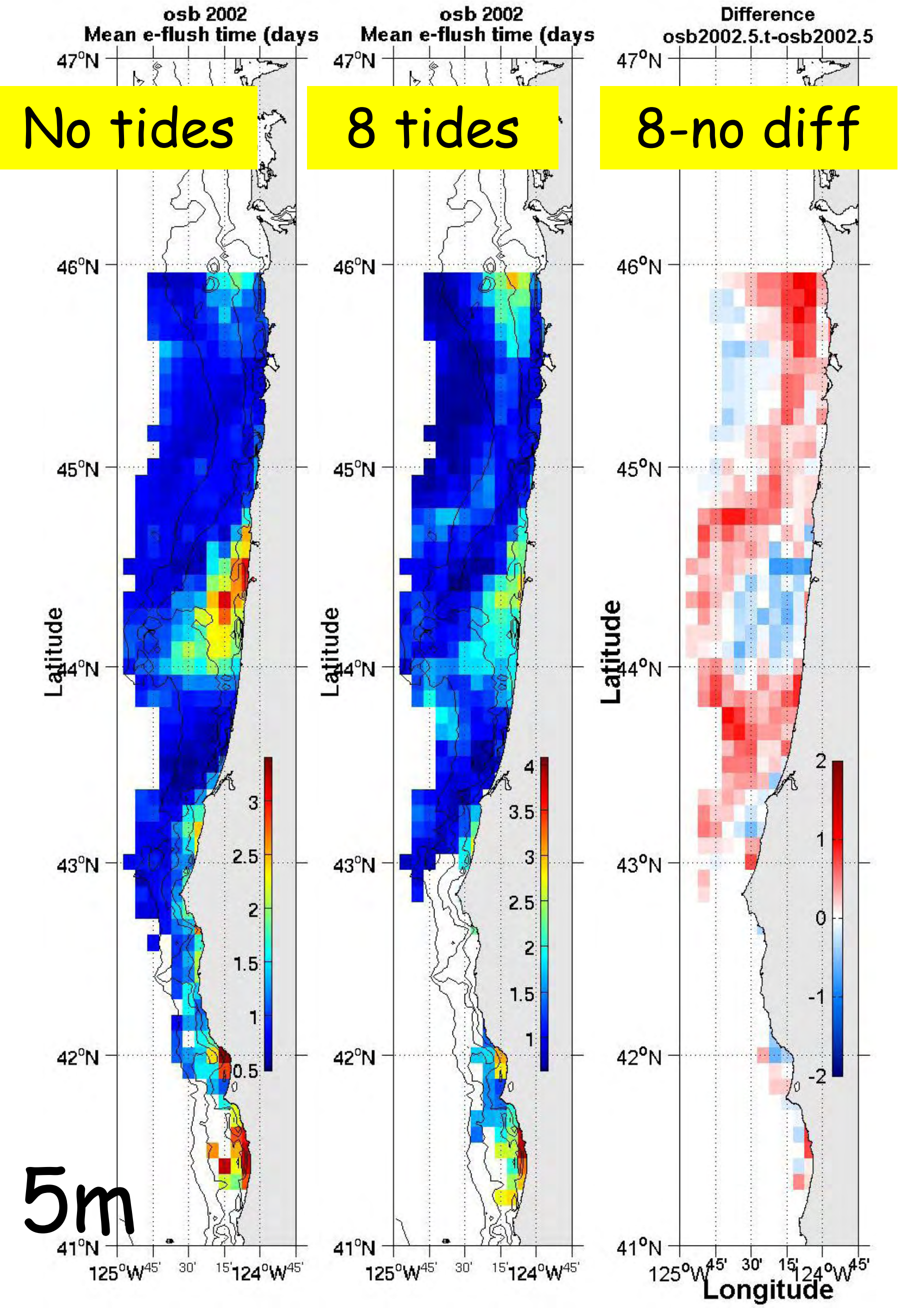


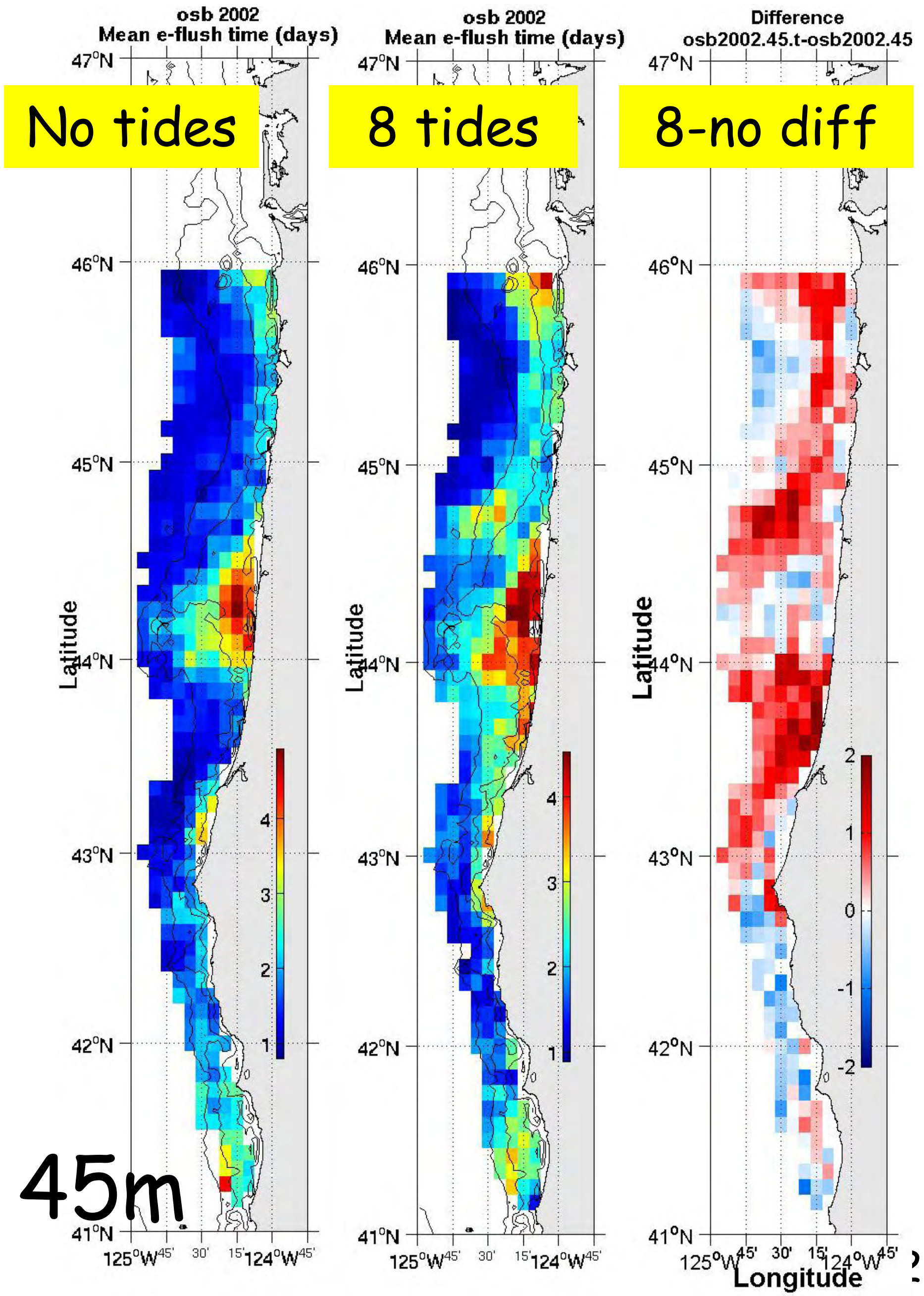
NEP 10 km simulation shows greatest e-flush times nearshore, likely due to boundary effects

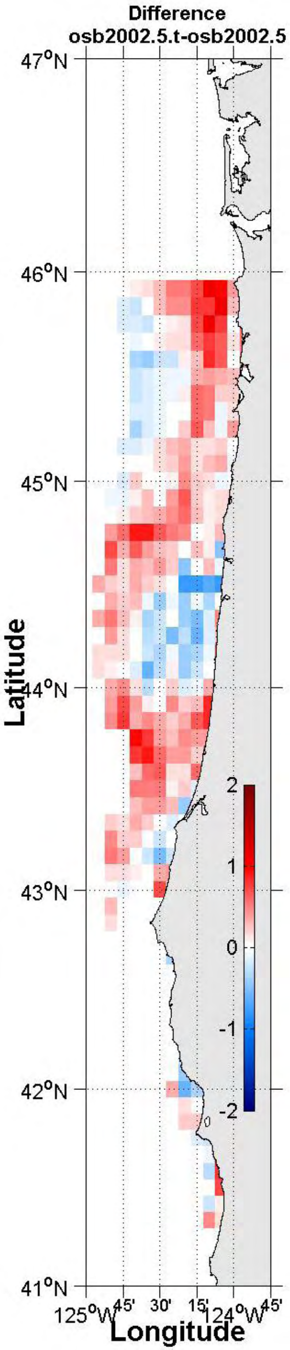
RCCS 1 km simulation shows greatest e-flush times near center of Heceta Bank—not immediately adjacent to shore; does a better job resolving coastal upwelling

Osborne-2002 (Apr-Aug)

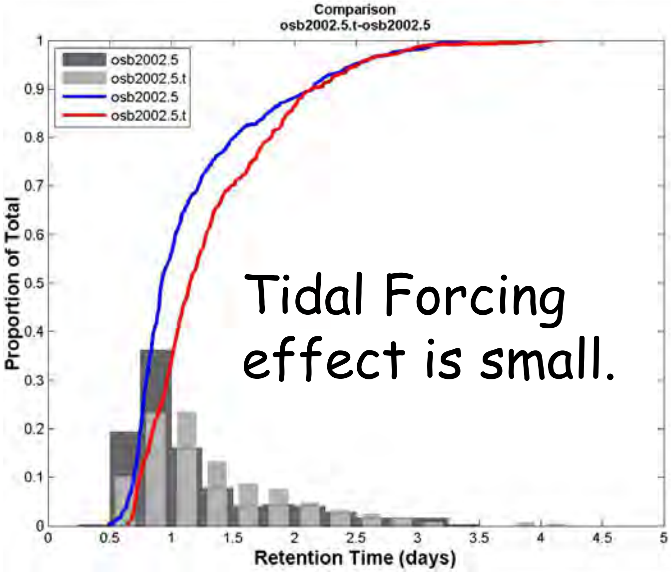
# Does tidal forcing matter for connectivity?



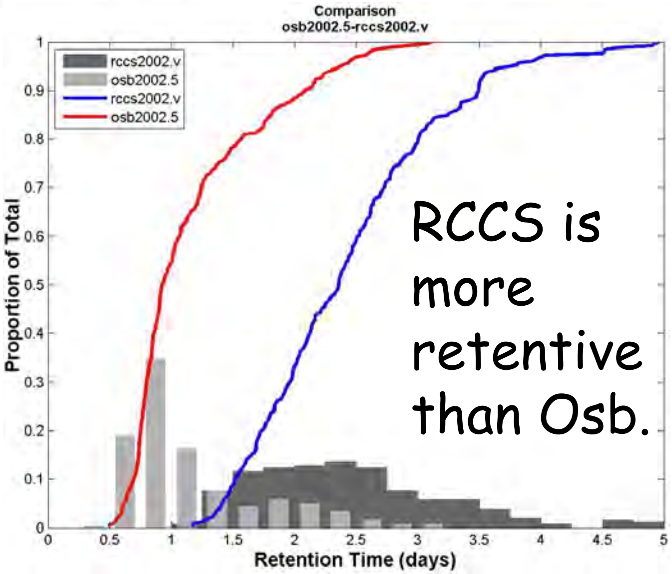




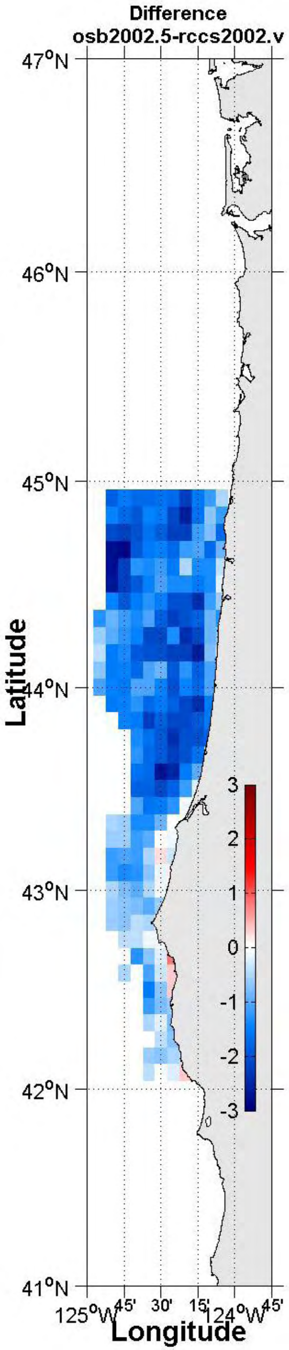
# Effect of tides is less than the effect of model or different forcing (at least for OR).



Tidal Forcing effect is small.



RCCS is more retentive than Osb.



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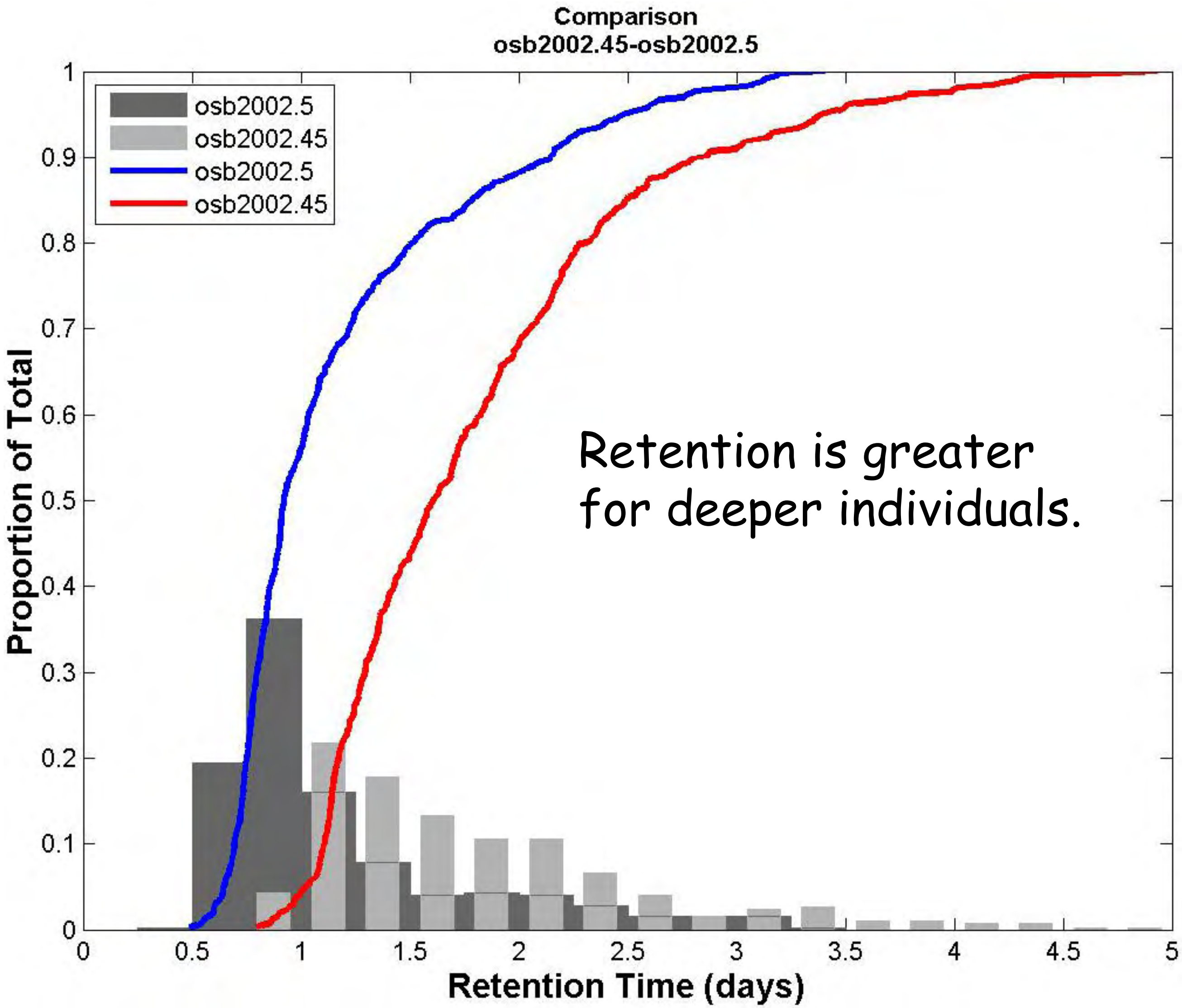
# Effect of Individual Depth



Retention is greater for deeper individuals.

# Summary and Conclusions I

- Connectivity is impacted by multiple physical and biological processes. Important among these are depth of individuals, duration of pelagic stages, and seasonality of reproduction. Interactions of these are significant.
- Oregon MR nearshore connectivities are strongly seasonal and asymmetrical (higher connectivity in winter/downwelling than summer/upwelling).
- Coarse model resolution in shallow nearshore regions do not allow adequate consideration of the small-scale shelf processes that control transport and retention.
- On the wind-forced Oregon shelf, tidal forcing alters retention times, BUT the effect is minor when compared to other potential changes, like depth and individual behavior. Tides may matter more in other systems.

# Summary and Conclusions II

- Retention (residence time) is greater for deeper individuals. Effects of depth on transport and connectivity is less clear because colder temperatures at depth that prolong the duration of pelagic life stages may compensate for the slower transports.
- Tidal forcing has a greater impact on transport of deeper individuals than shallower individuals.
- Climate change will alter shelf circulation and temperature (temporally and spatially). Analysis of transport, connectivity, and residence time metrics will enable prediction of impacts on marine populations and the efficacy of marine reserve networks.

# Special Thanks to:

- Enrique Curchitser (Rutgers) for providing the NEP and RCCS ROMS simulations.
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