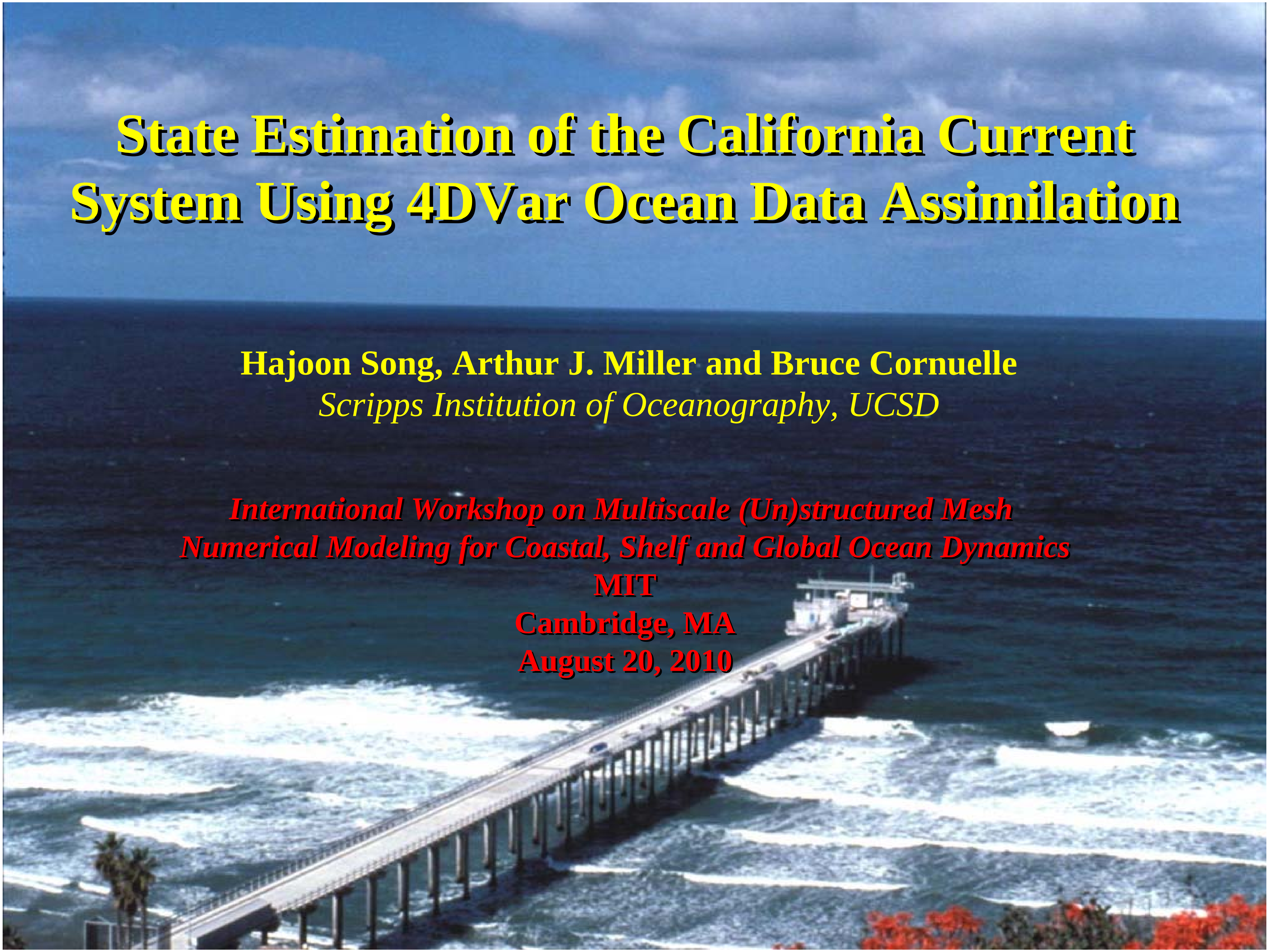


State Estimation of the California Current System Using 4DVar Ocean Data Assimilation

Hajoon Song, Arthur J. Miller and Bruce Cornuelle
Scripps Institution of Oceanography, UCSD

International Workshop on Multiscale (Un)structured Mesh Numerical Modeling for Coastal, Shelf and Global Ocean Dynamics

MIT

Cambridge, MA

August 20, 2010

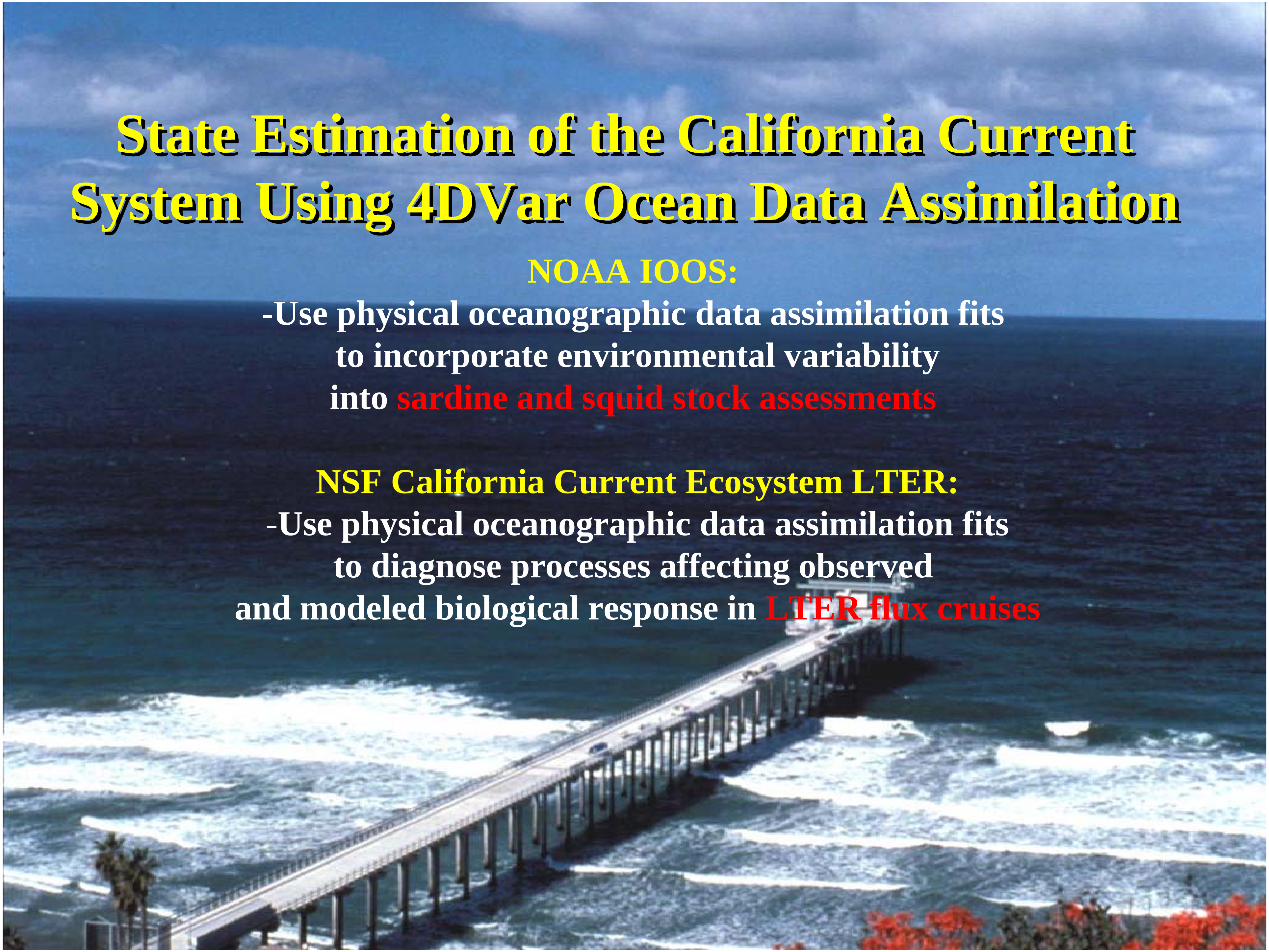
State Estimation of the California Current System Using 4DVar Ocean Data Assimilation

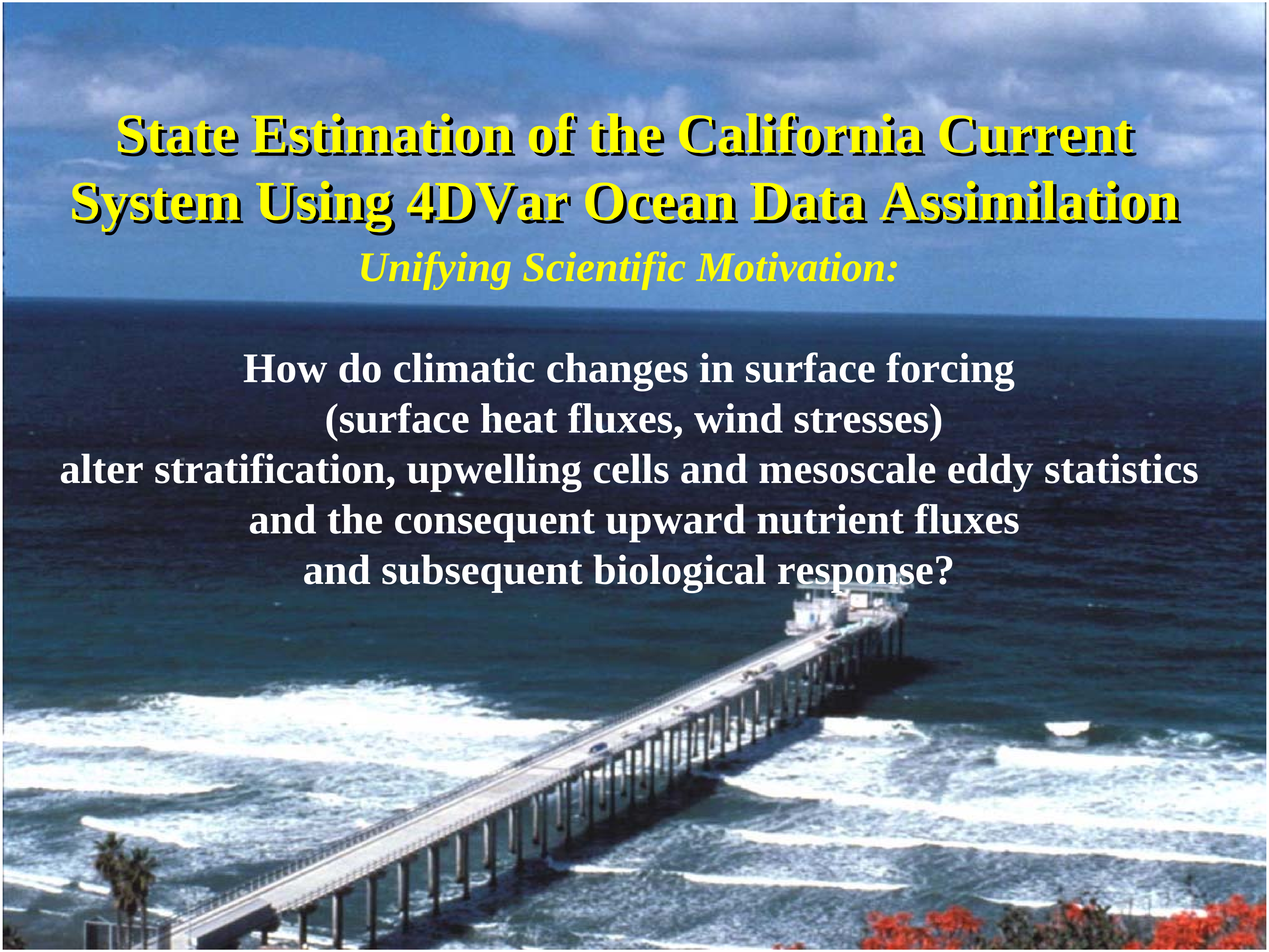
NOAA IOOS:

-Use physical oceanographic data assimilation fits to incorporate environmental variability into sardine and squid stock assessments

NSF California Current Ecosystem LTER:

-Use physical oceanographic data assimilation fits to diagnose processes affecting observed and modeled biological response in LTER flux cruises

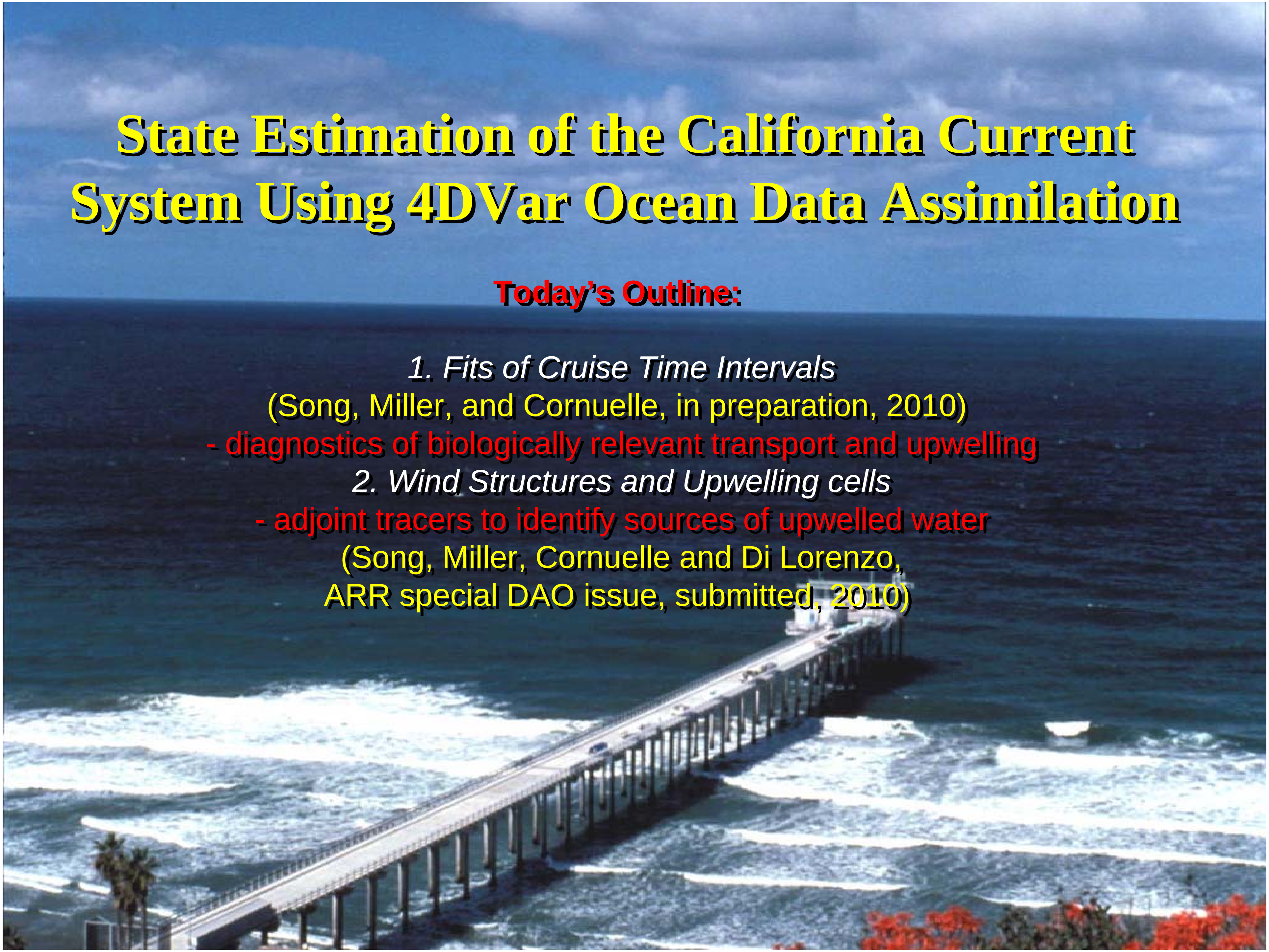




State Estimation of the California Current System Using 4DVar Ocean Data Assimilation

Unifying Scientific Motivation:

**How do climatic changes in surface forcing
(surface heat fluxes, wind stresses)
alter stratification, upwelling cells and mesoscale eddy statistics
and the consequent upward nutrient fluxes
and subsequent biological response?**


State Estimation of the California Current System Using 4DVar Ocean Data Assimilation
Today's Outline:
1. Fits of Cruise Time Intervals
(Song, Miller, and Cornuelle, in preparation, 2010)
- diagnostics of biologically relevant transport and upwelling
2. Wind Structures and Upwelling cells
- adjoint tracers to identify sources of upwelled water
(Song, Miller, Cornuelle and Di Lorenzo,
ARR special DAO issue, submitted, 2010)

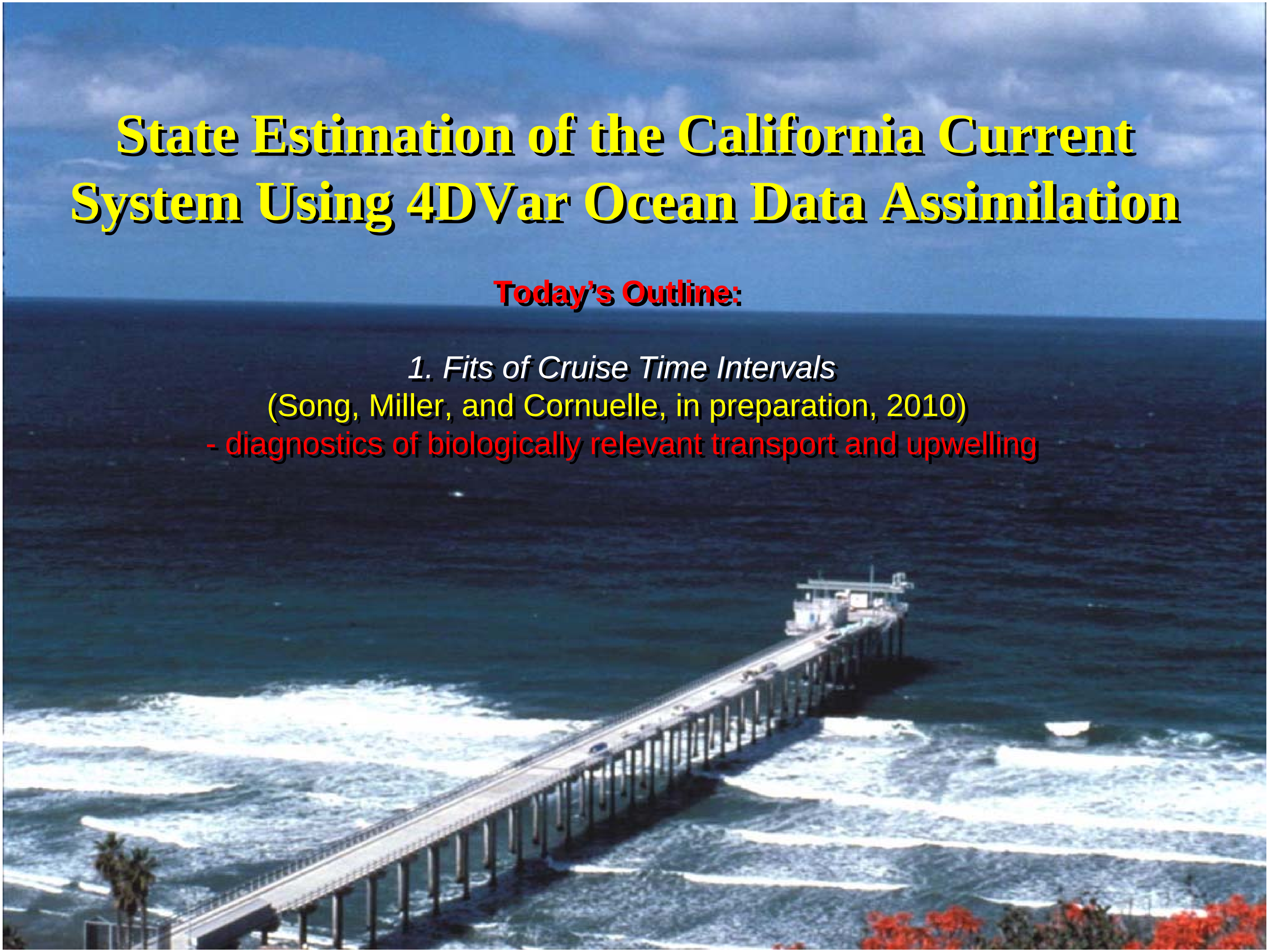
State Estimation of the California Current System Using 4DVar Ocean Data Assimilation

Today's Outline:

1. Fits of Cruise Time Intervals

(Song, Miller, and Cornuelle, in preparation, 2010)

- diagnostics of biologically relevant transport and upwelling



Ocean 4DVAR Data Assimilation

- Building the ocean states that are close to the observations as well as dynamically consistent.
- Effort to build the ocean states for 7 consecutive years (2002 ~ 2008) of April over the California Current System.
- Completed 5 years of April (2002, 2003, 2006, 2007, 2008).

Model

- Regional Ocean Modeling System (ROMS)
- Using 4-dimensional variational method.
  - Adjusting initial condition
  - Adjusting surface forcing
  - Adjusting open boundary conditions
- One month assimilation window
- Prior state vector from 2-week CCS fits of Broquet et al. (2009)

Observations

- AVHRR – Infrared SST
- Along track sea surface height anomaly from AVISO
- Temperature - Salinity profiles from
  - CalCOFI cruise
  - Argo
  - LTER
  - Glider

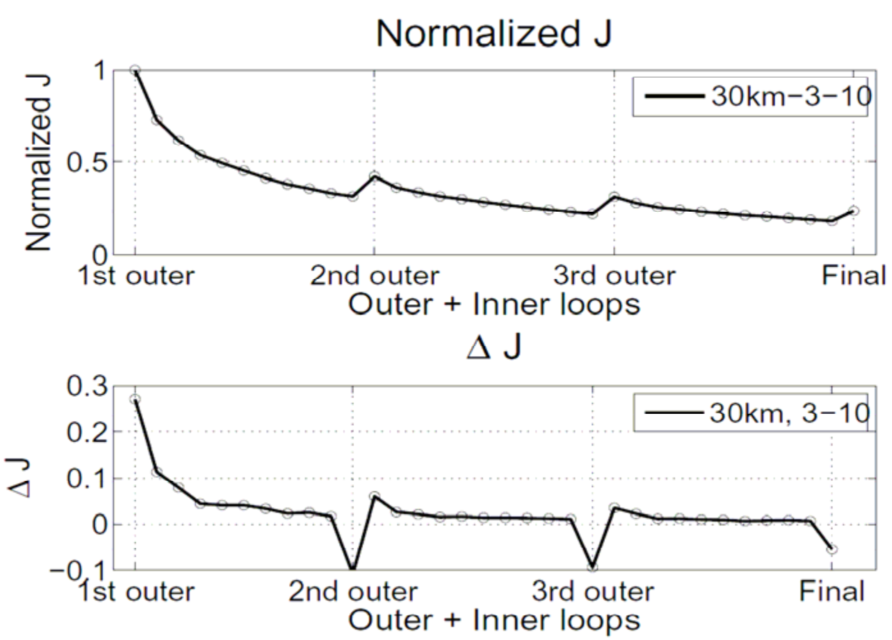
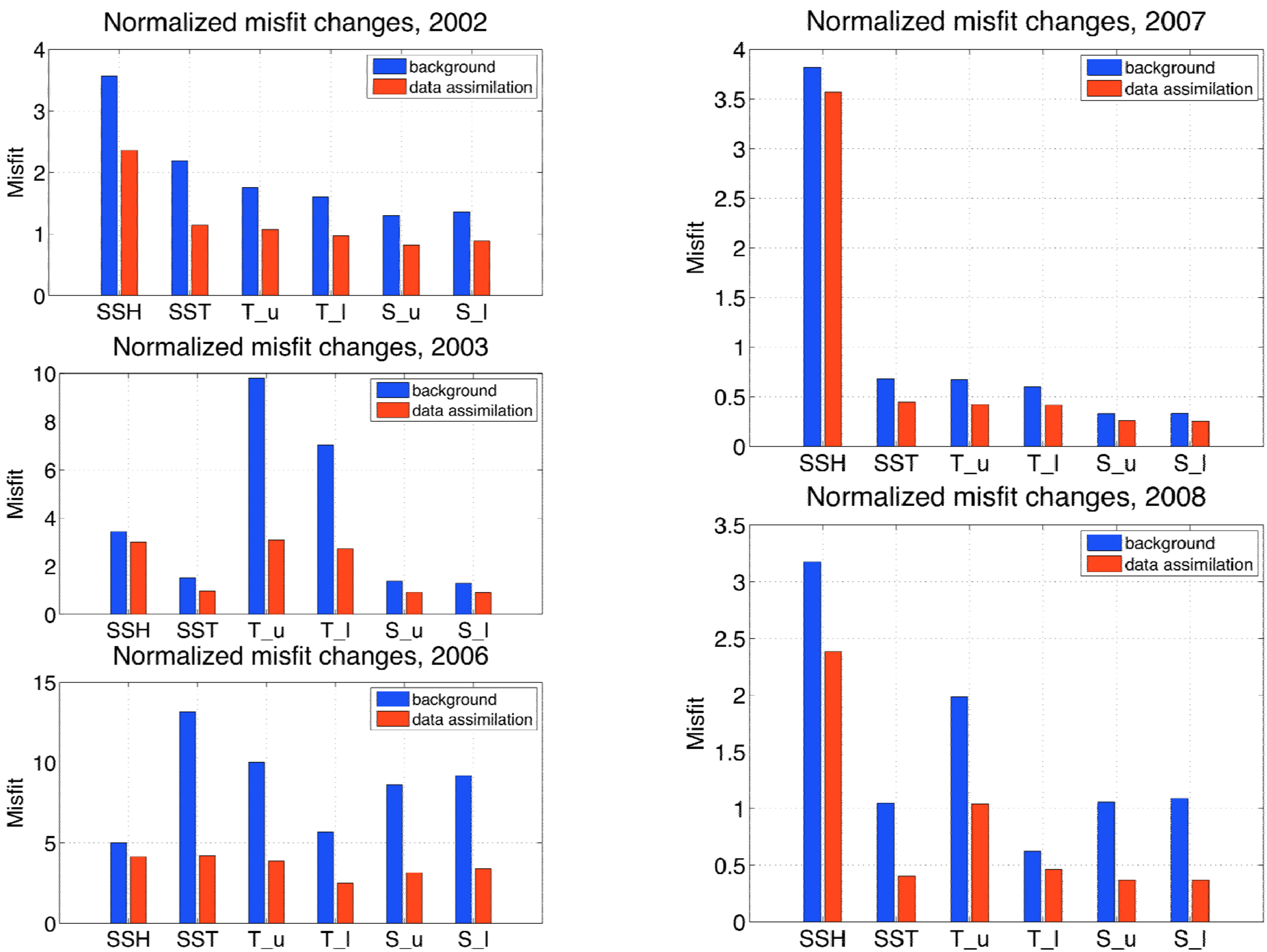
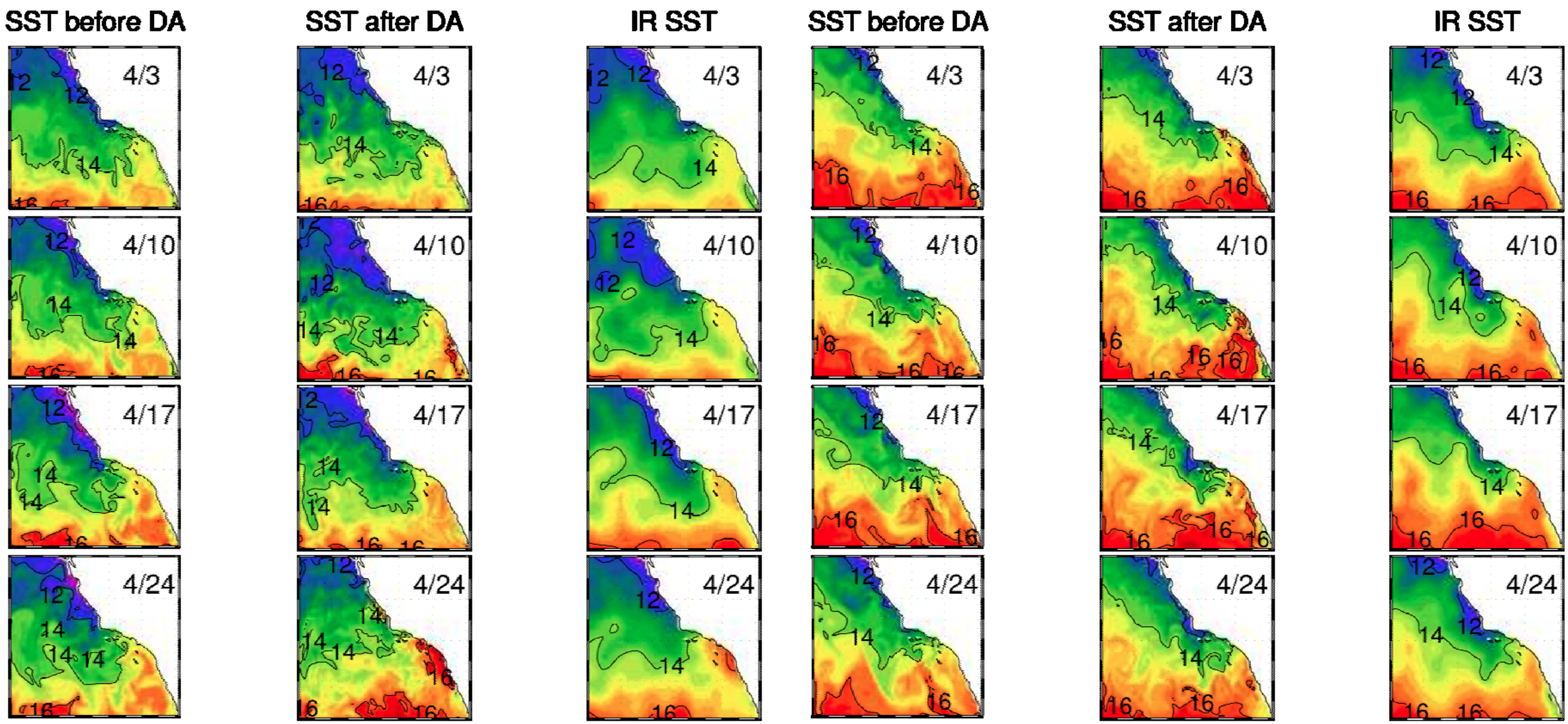


FIGURE 1. Normalized cost function at each loop during 2 months.



Normalized misfit changes, 2002
Normalized misfit changes, 2003
Normalized misfit changes, 2006
Normalized misfit changes, 2007
Normalized misfit changes, 2008
Misfit
background
data assimilation
SSH
SST
T_u
T_l
S_u
S_l

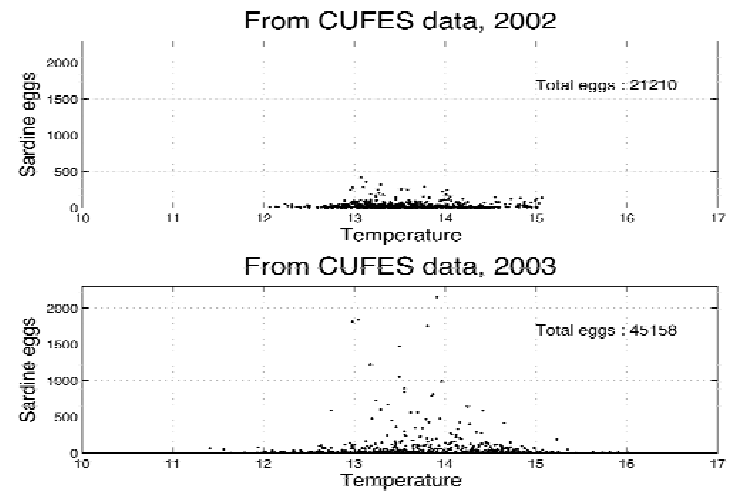
Applications – Hindcasts of 2 key years in sardine spawning: 2002 and 2003

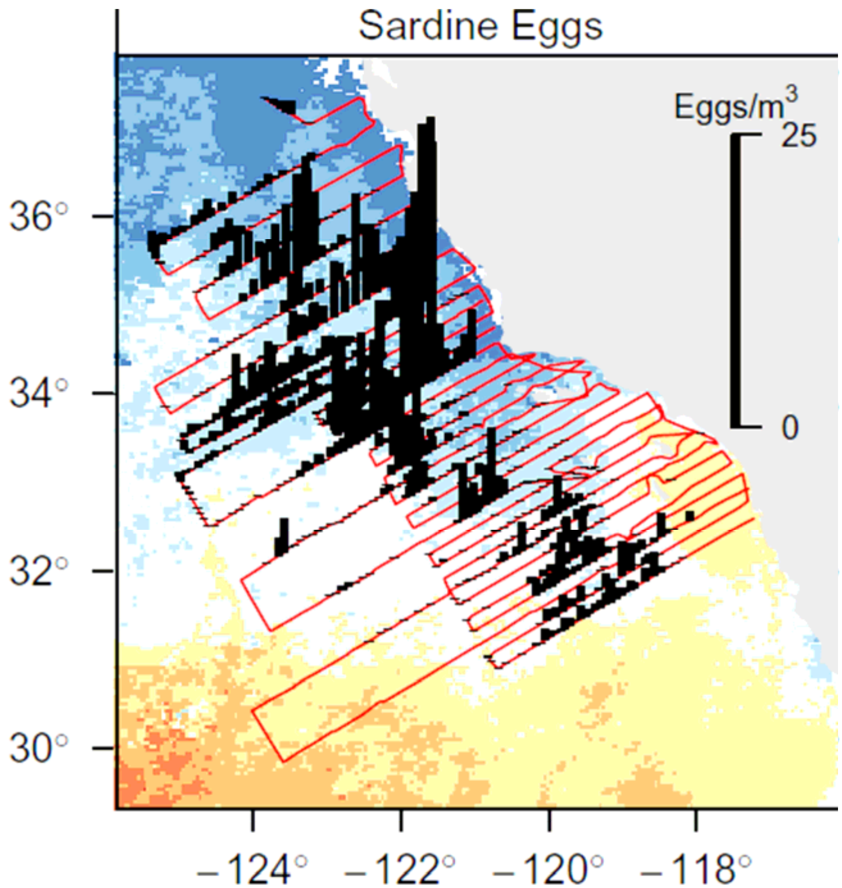


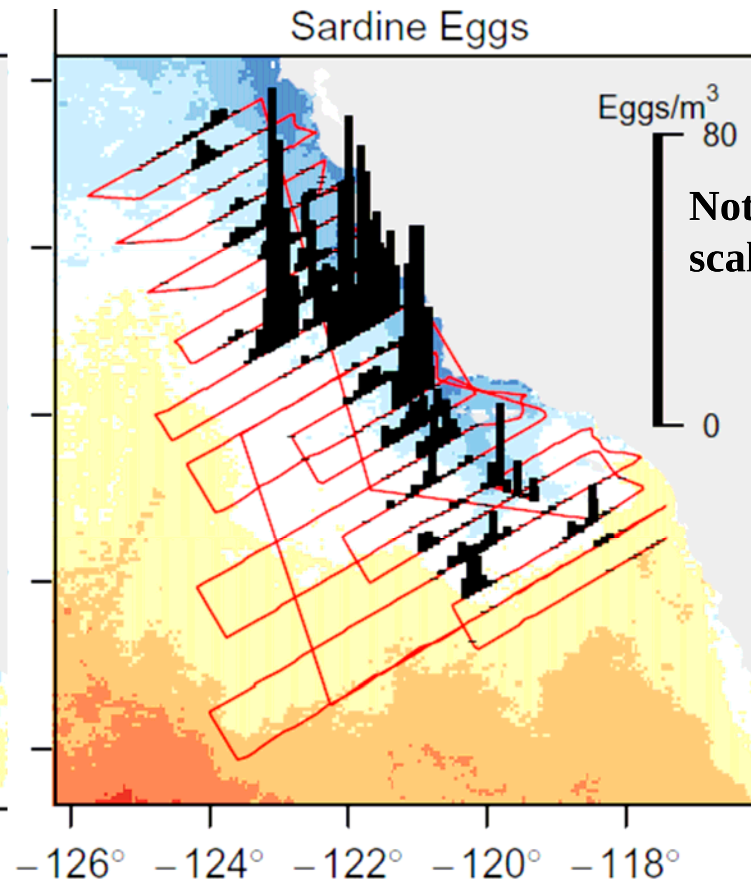
SST, 2002 April, cooler
Fewer eggs, over large area

SST, 2003 April, warmer
More eggs, close to coast

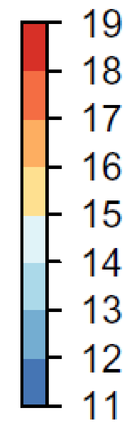
Sardine Egg Distribution: April 2002 vs. 2003







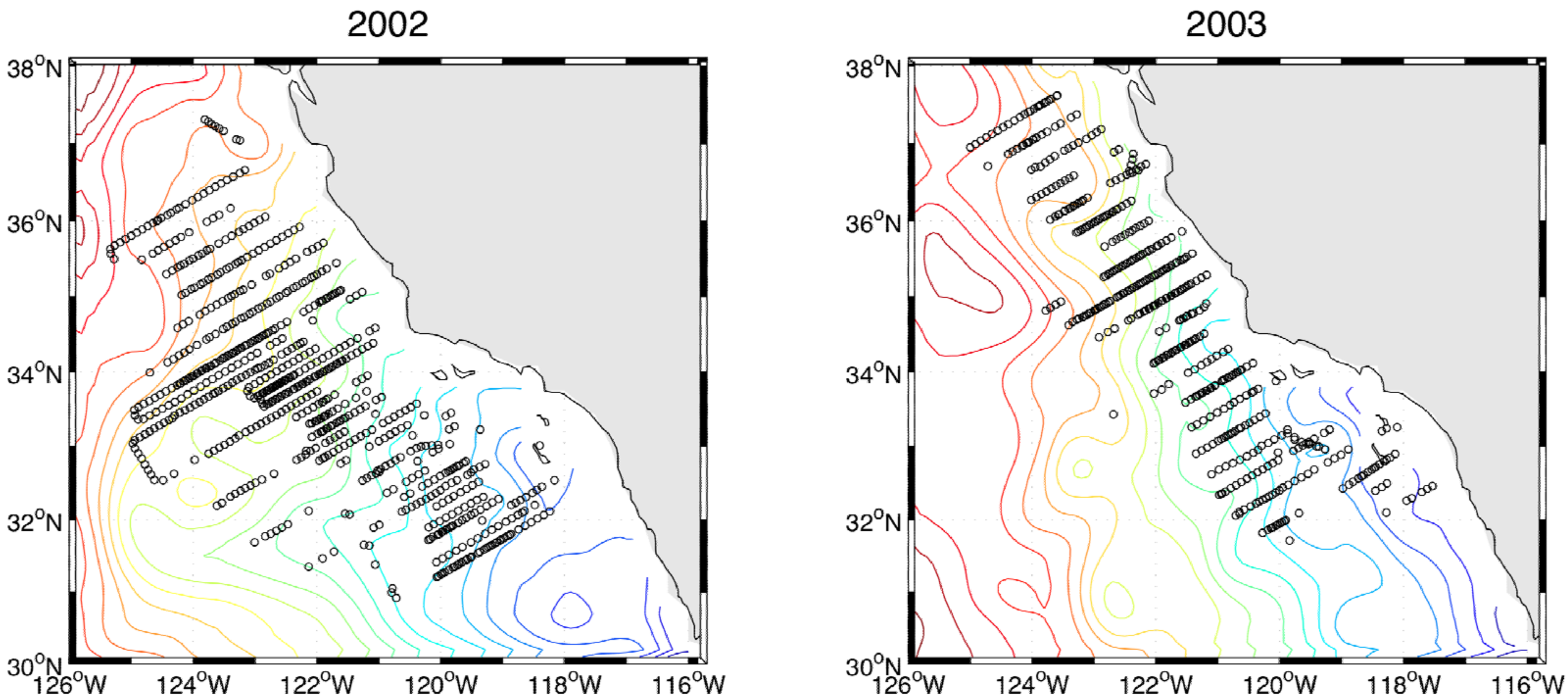
Note: egg scale differs



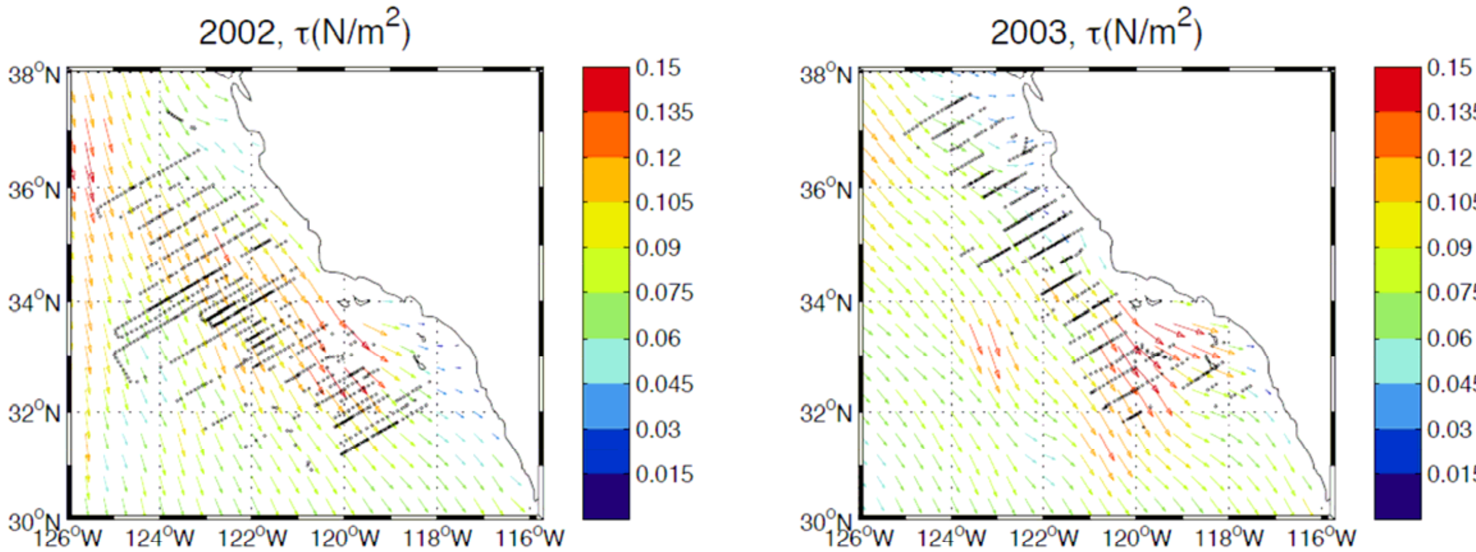
Diagnostics of the Fits:

Streamfunction indicates offshore flow in 2002,

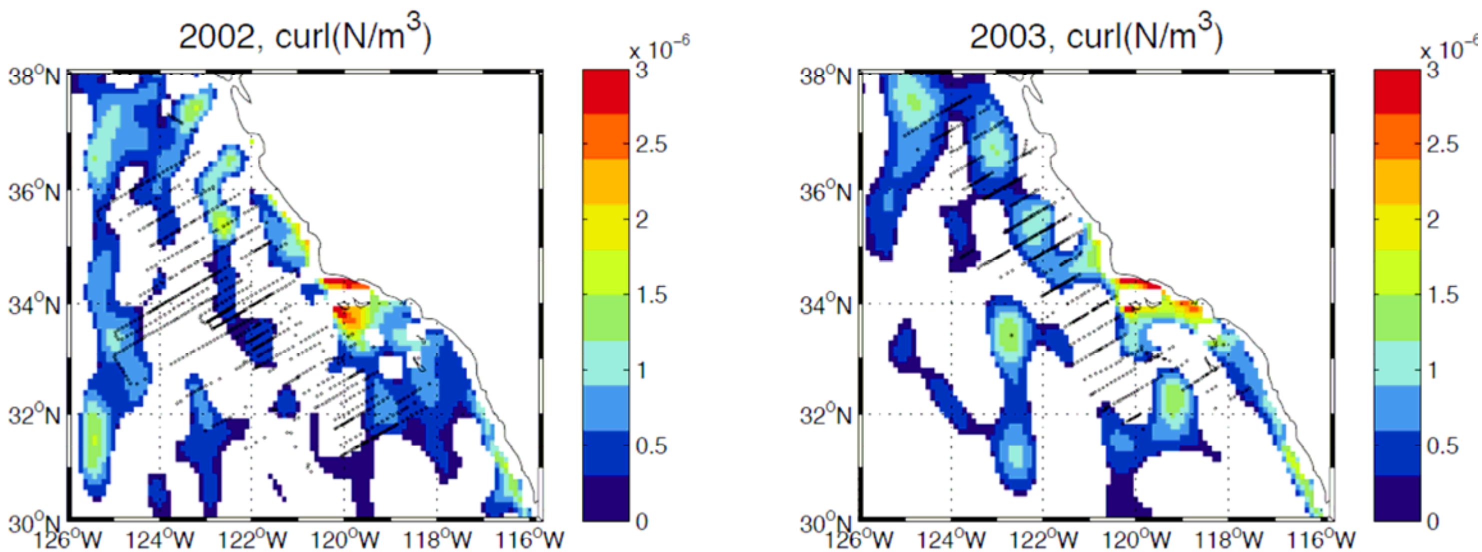
stronger alongshore flow in 2003



Winds were stronger in 2002: offshore transport
Wind stress curl similar for both years



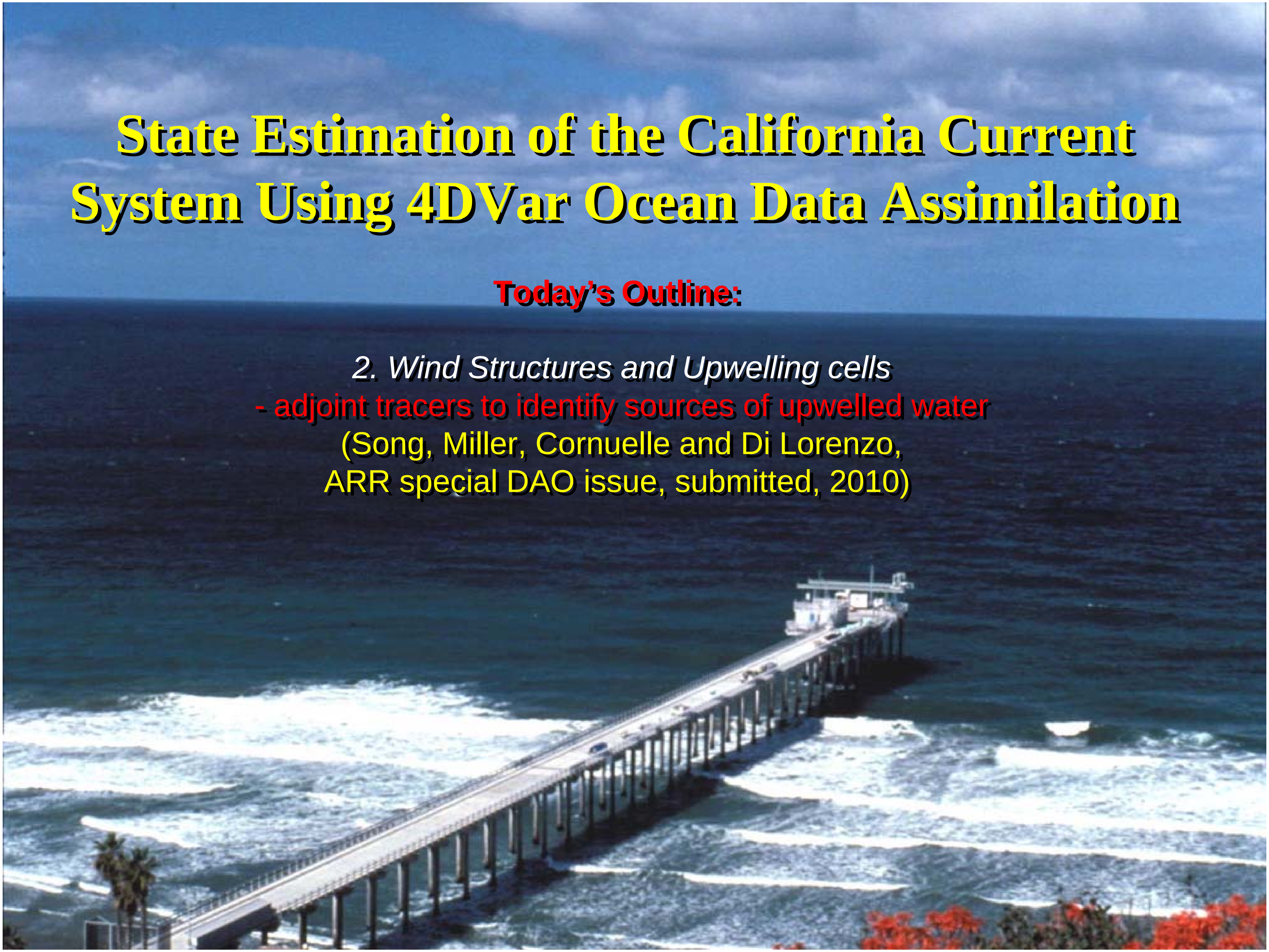
Currently, diagnosing source waters of upwelling in the eddy fields….



State Estimation of the California Current System Using 4DVar Ocean Data Assimilation

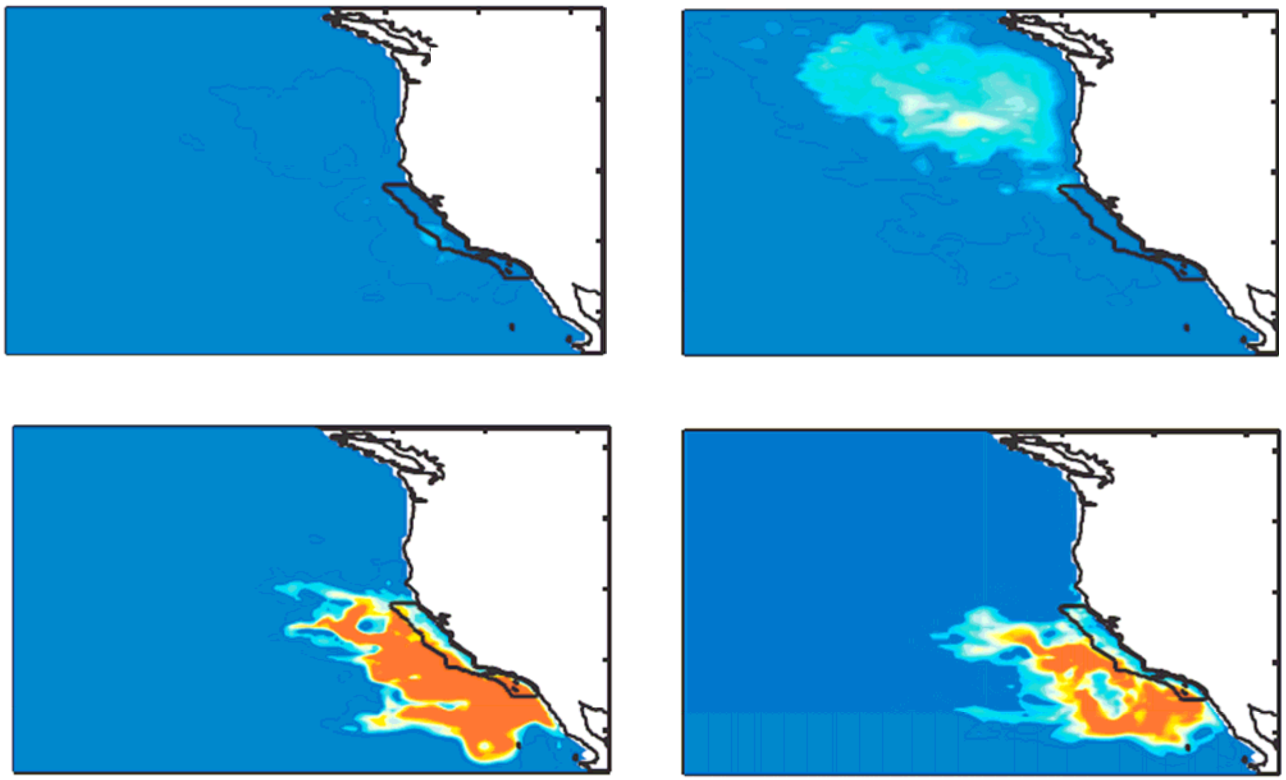
Today's Outline:

2. Wind Structures and Upwelling cells
- adjoint tracers to identify sources of upwelled water
(Song, Miller, Cornuelle and Di Lorenzo,
ARR special DAO issue, submitted, 2010)



Adjoint *backward* runs of passive tracer in upwelling zone: Weaker upwelling winds cause shallower coastal upwelling cell (Chhak and Di Lorenzo, 2007)

Negative PDO Phase | **Positive PDO Phase**



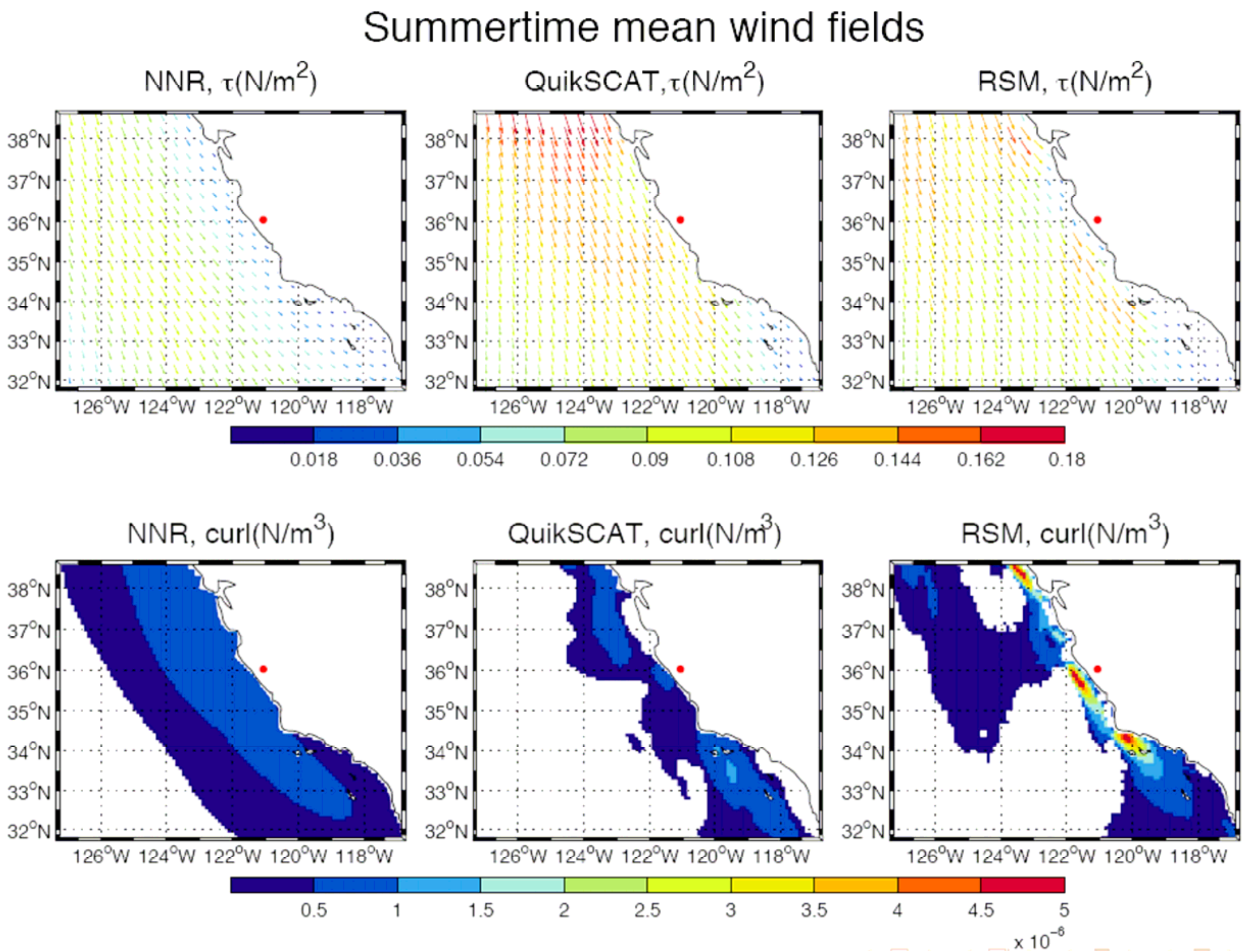
Surface layer transport into coastal upwelling zone

Mid-depth (150m) transport into coastal upwelling zone

More nutrient flux to surface | **Less nutrient flux to surface**

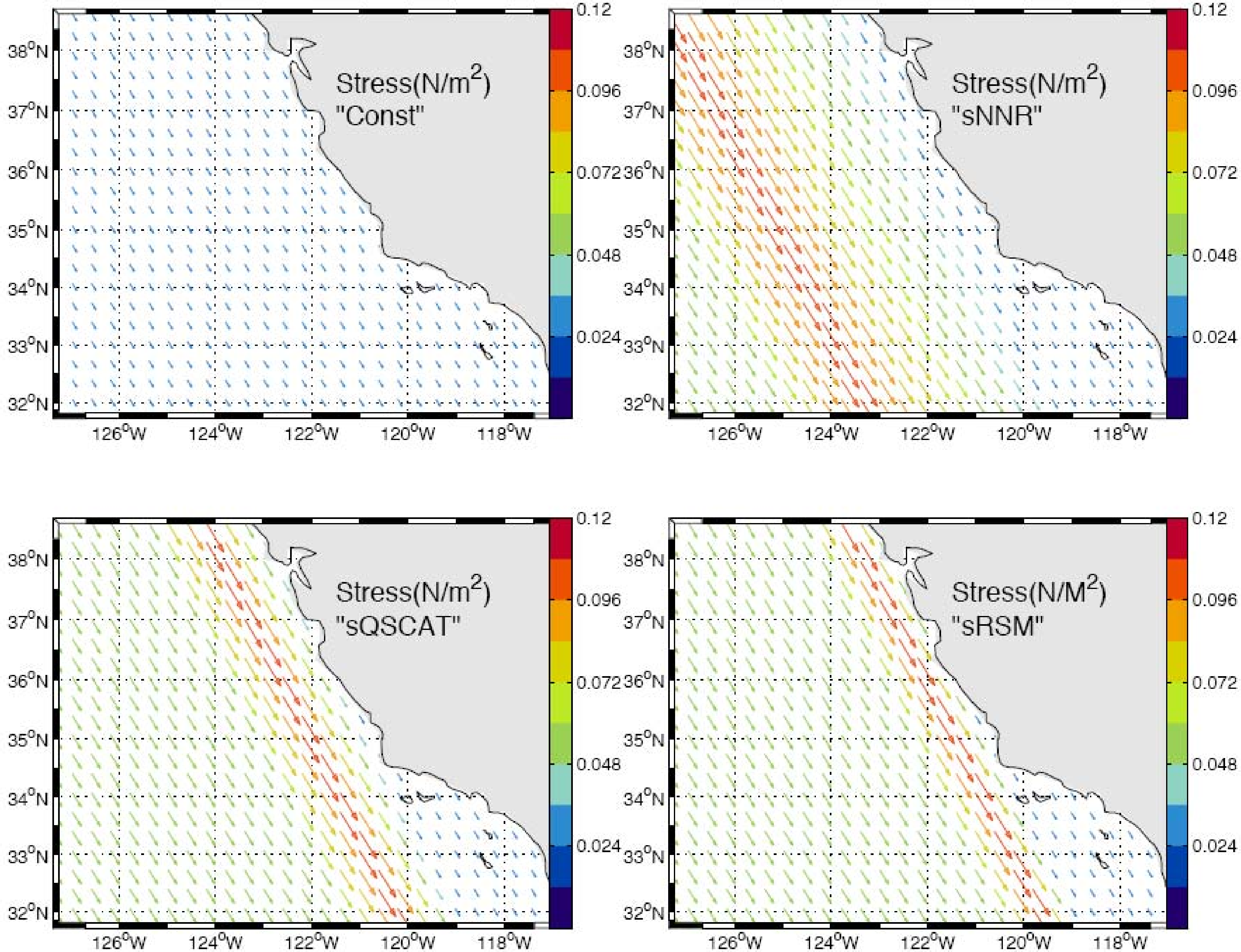
How does the structure of the wind forcing affect the source of upwelled waters?

(Song, Miller, Cornuelle, and Di Lorenzo, 2010, in prep.)



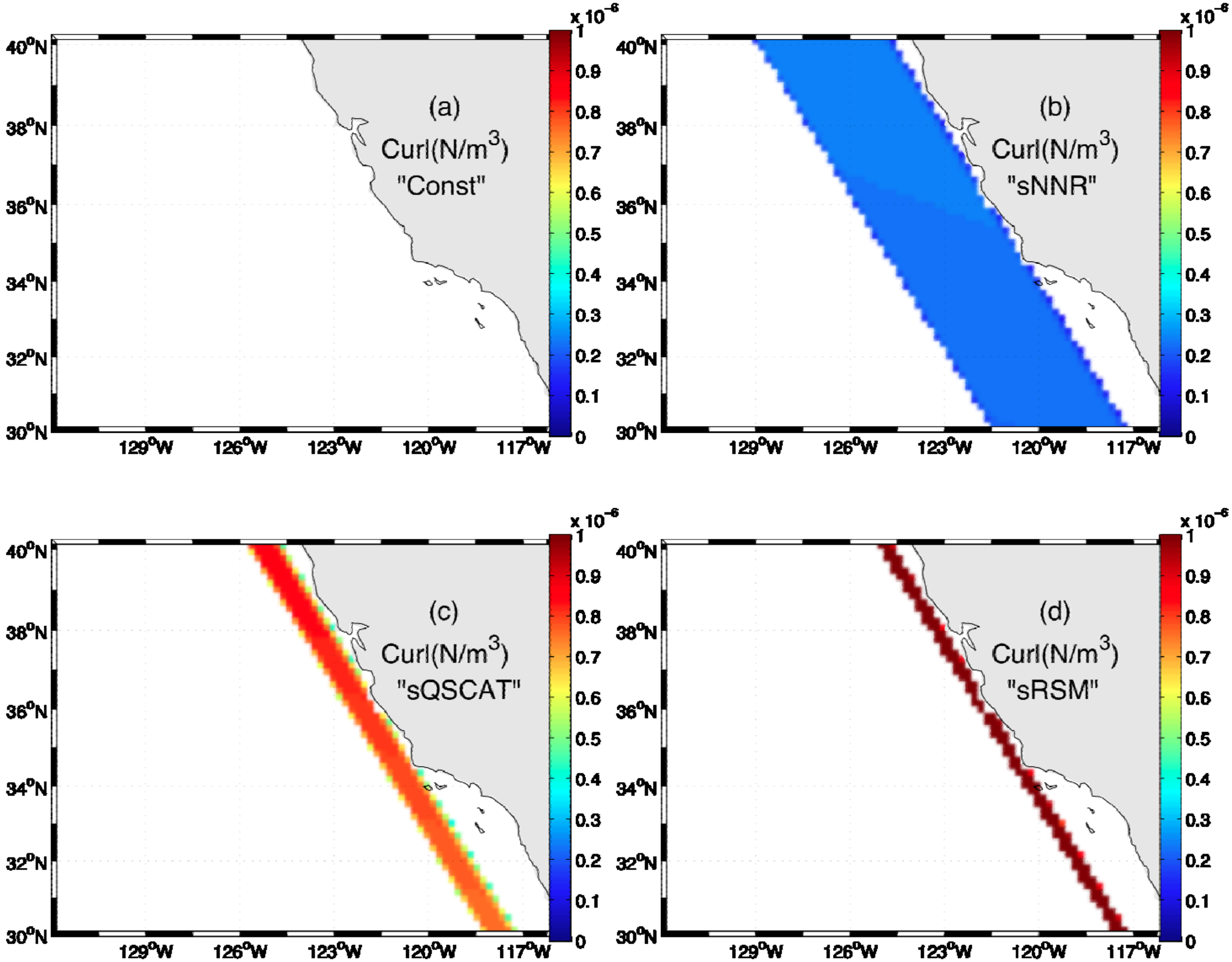
Consider idealized wind forcings representing typical datasets

(Song, Miller, Cornuelle, and Di Lorenzo, 2010, in prep.)



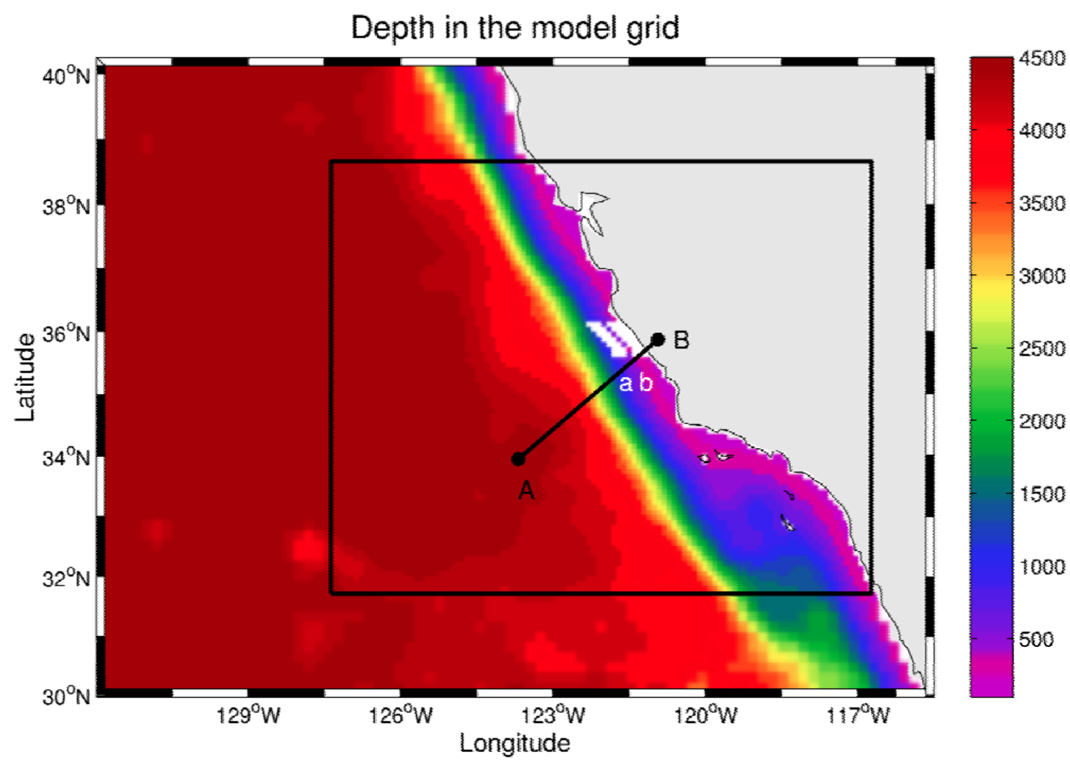
Consider idealized wind forcings representing typical datasets

(Song, Miller, Cornuelle, and Di Lorenzo, 2010, in prep.)

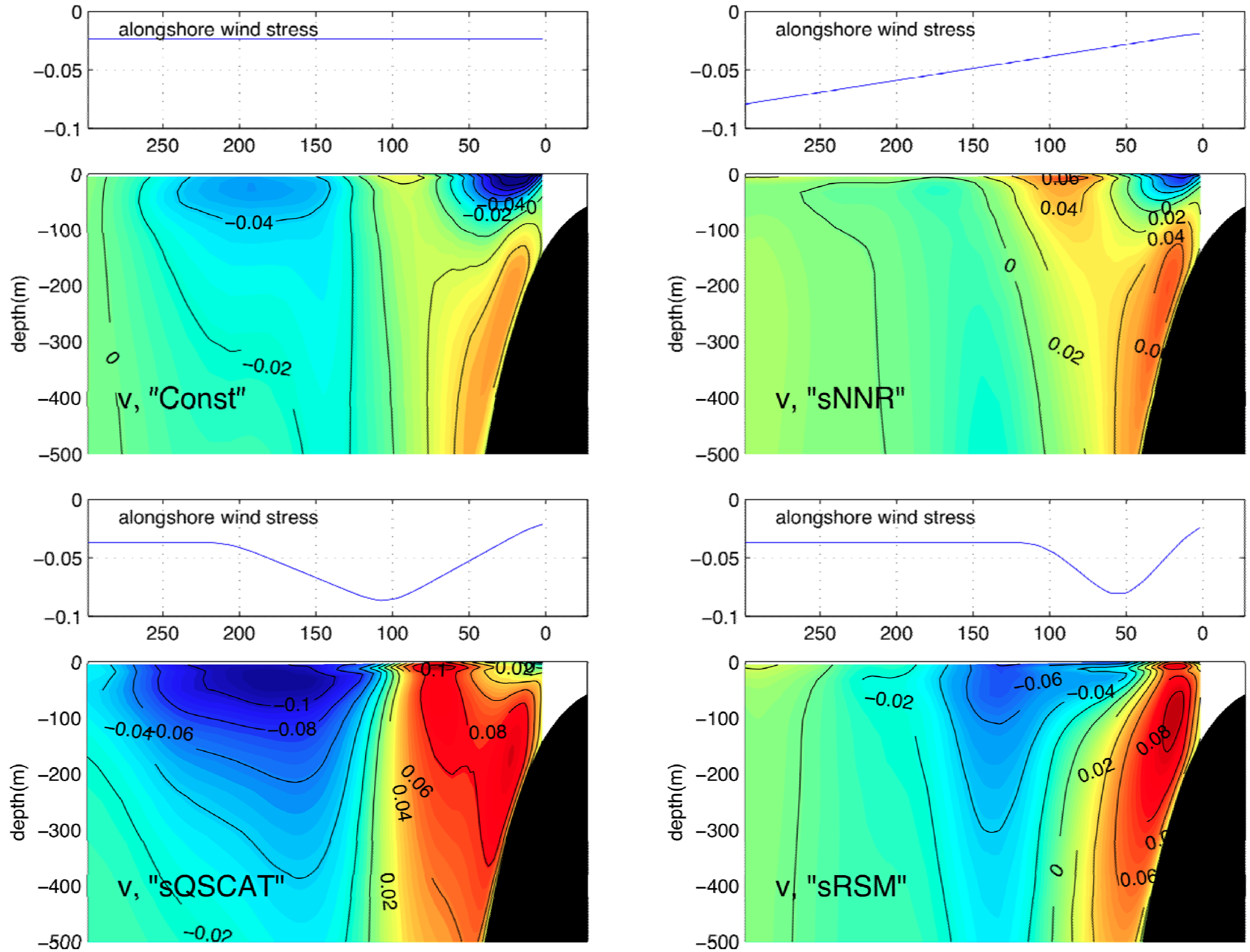


Model domain and settings

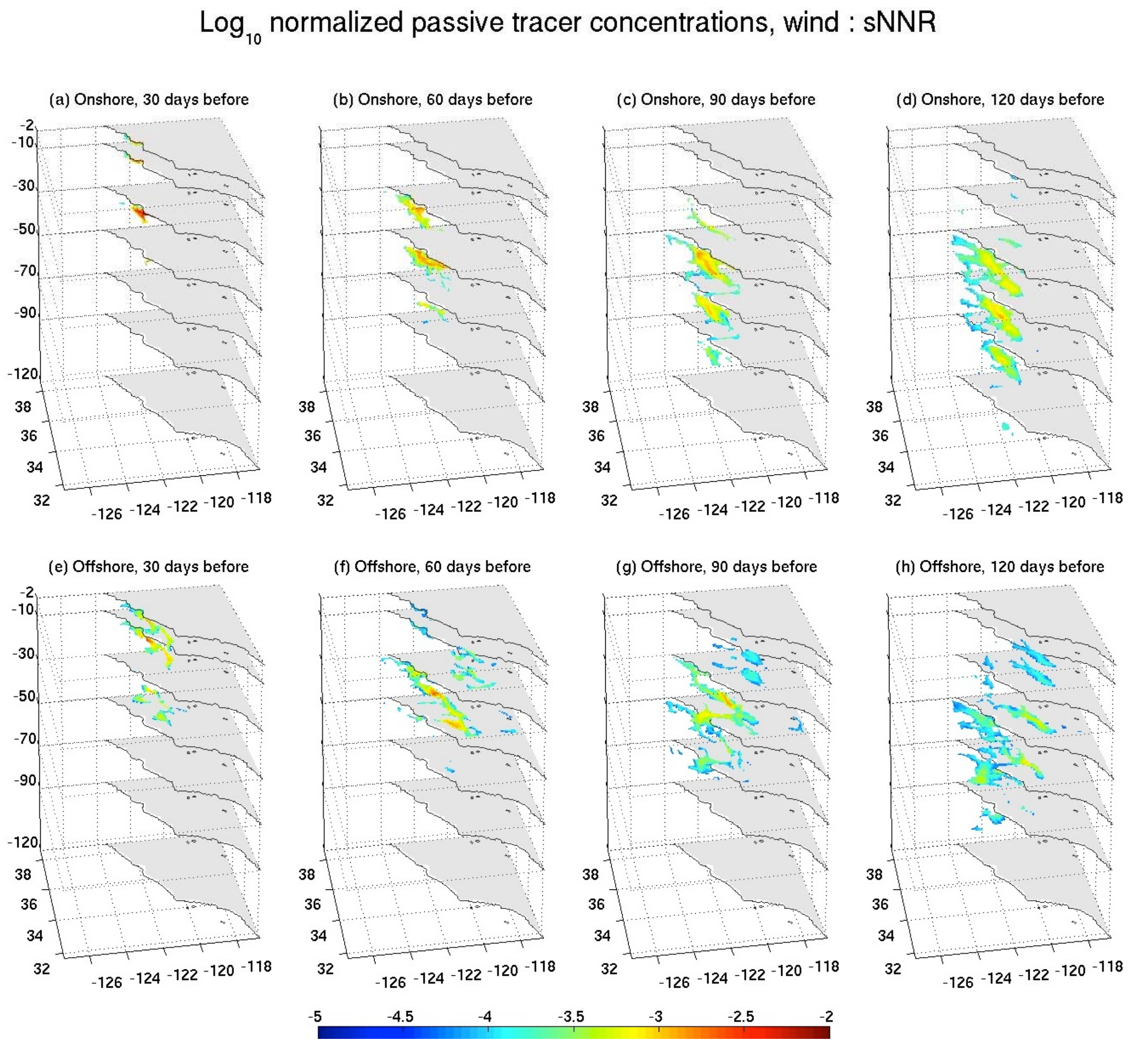
- 6-year simulation and the last 5 years were considered.
- Passive tracers at white areas from the surface down to 10m
- 4 months of adjoint run during the upwelling season at each year



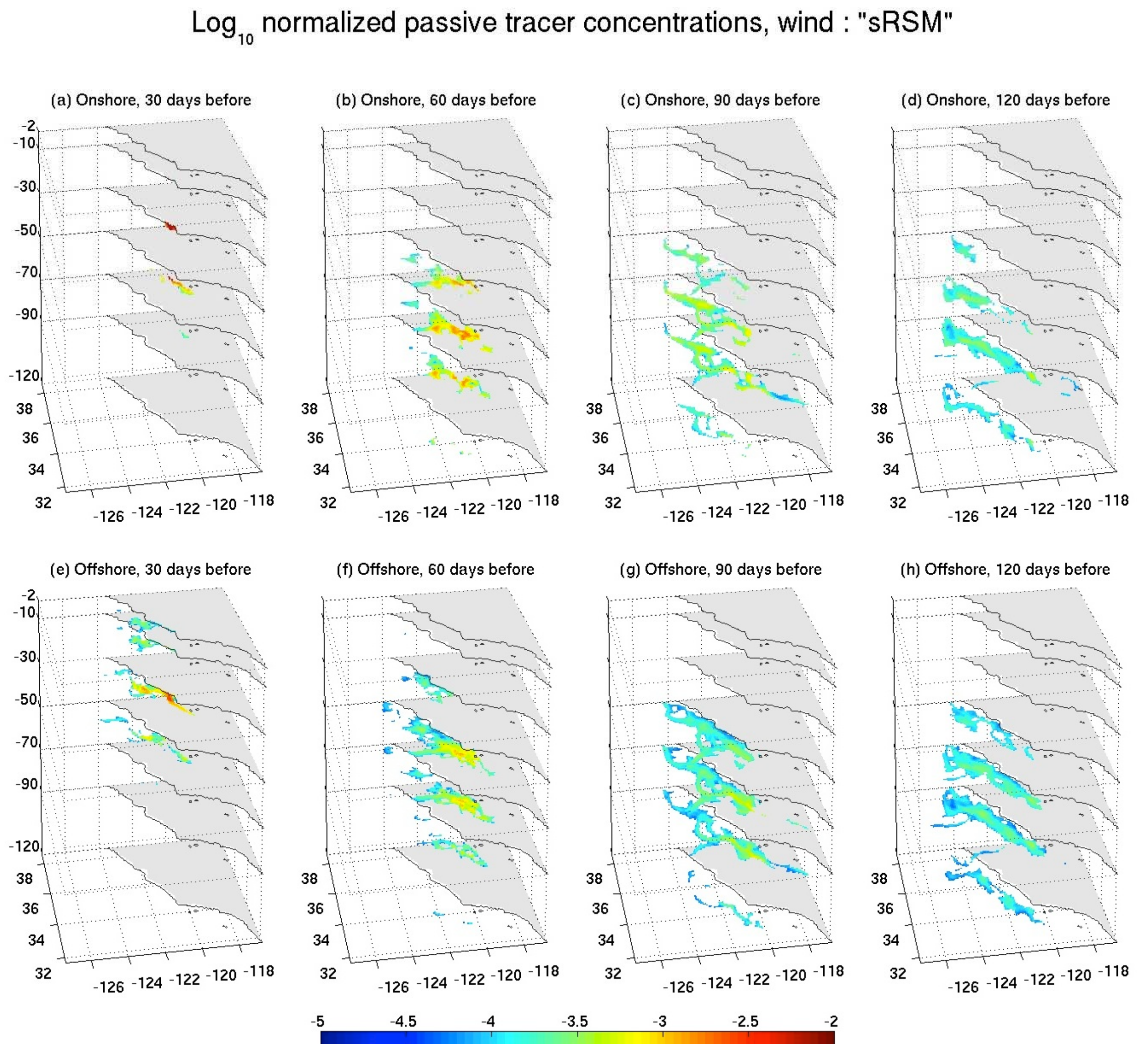
Alongshore currents



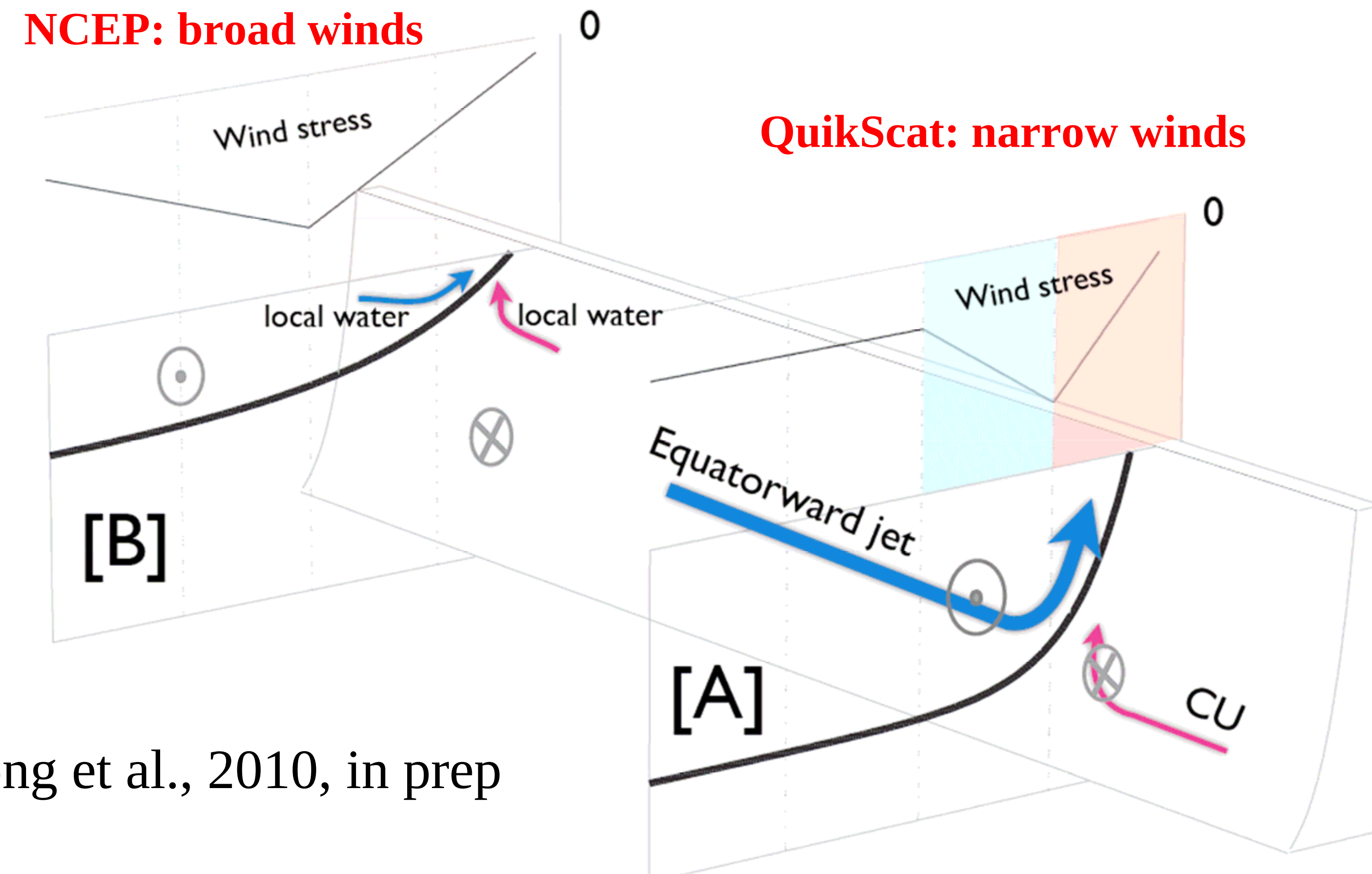
Pseudo NCEP/NCAR wind case



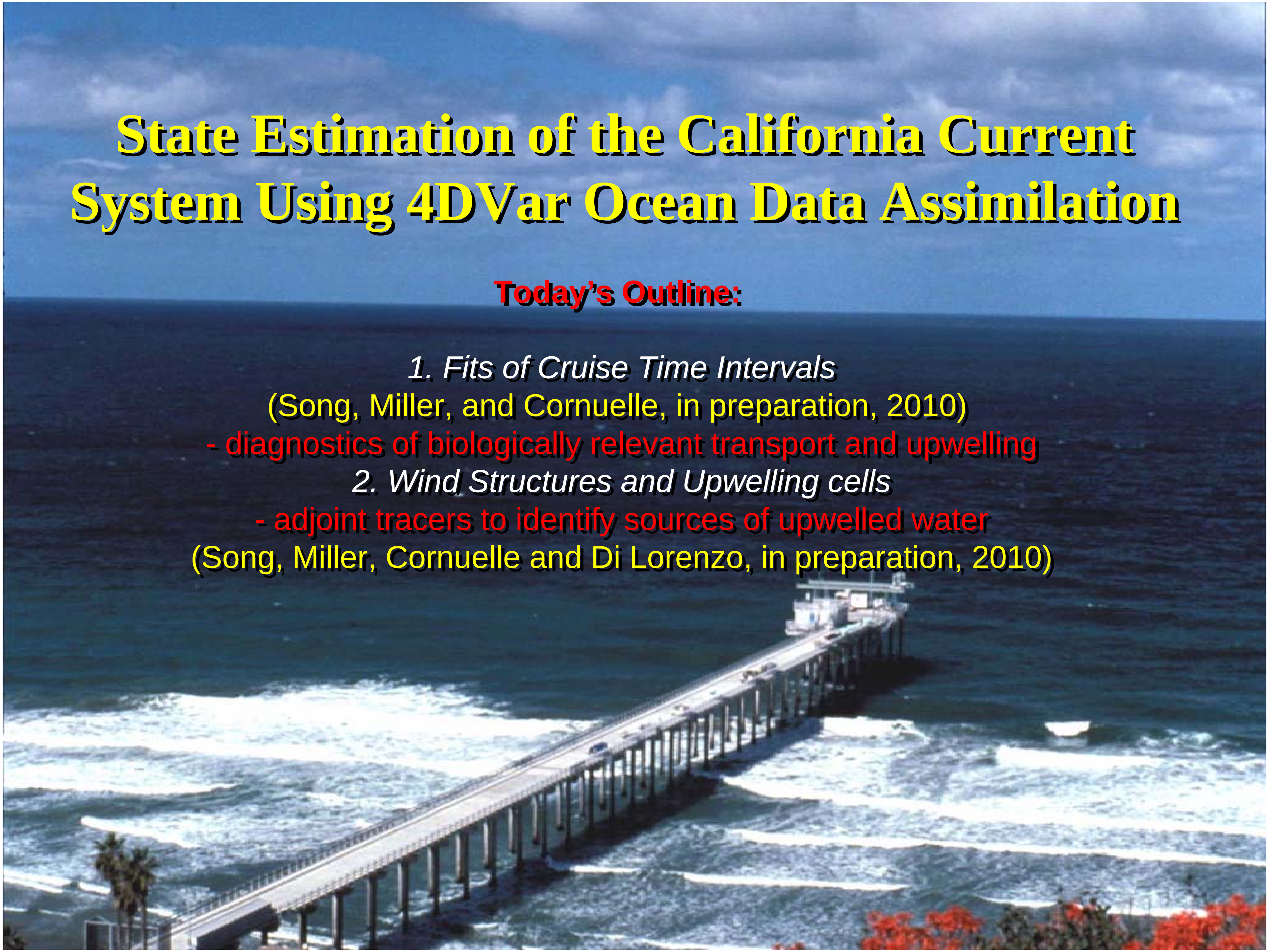
Pseudo RSM wind case



Schematic Summary: Higher resolution wind forcing →
Stronger wind stress and wind stress curl near the coast →
Altered upwelling cells entrain water from the Cal Current and deeper from the Undercurrent



Song et al., 2010, in prep



State Estimation of the California Current System Using 4DVar Ocean Data Assimilation

Today's Outline:

1. Fits of Cruise Time Intervals
(Song, Miller, and Cornuelle, in preparation, 2010)
- diagnostics of biologically relevant transport and upwelling

2. Wind Structures and Upwelling cells
- adjoint tracers to identify sources of upwelled water
(Song, Miller, Cornuelle and Di Lorenzo, in preparation, 2010)


IMUM
International Workshop on Multiscale (Un)structured Mesh
Numerical Modeling for Coastal, Shelf and Global Ocean Dynamics
Thanks!