An Observational Paradigm for Monitoring the Fate and Transport of an Effluent Plume

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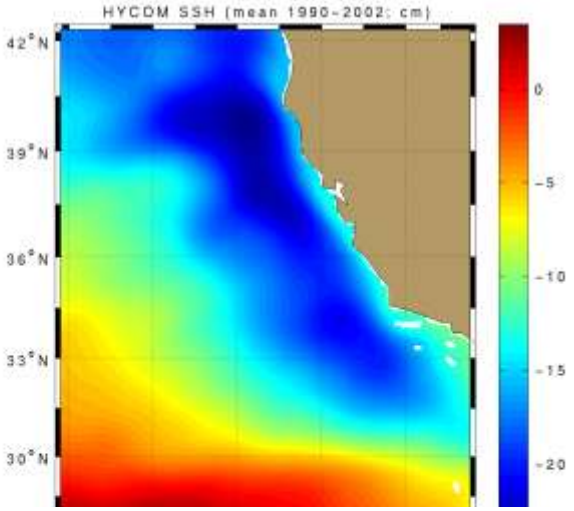
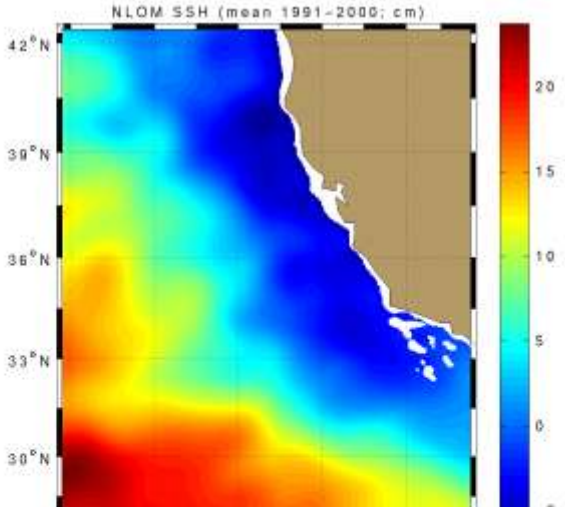
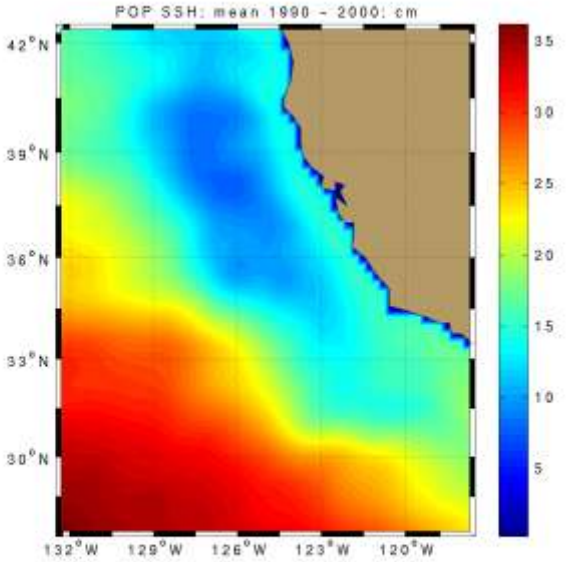
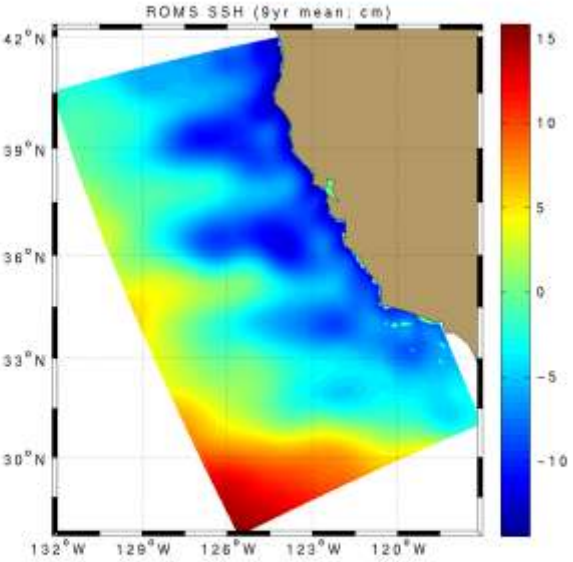
Why talk about observations at a modeling workshop?

Sea level (10 year mean) from four ocean models.





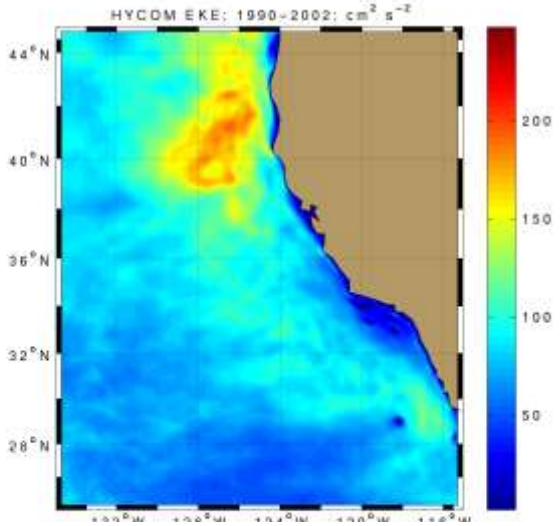


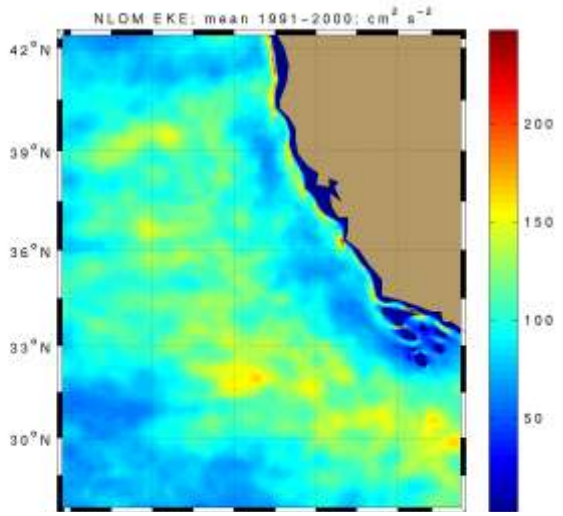


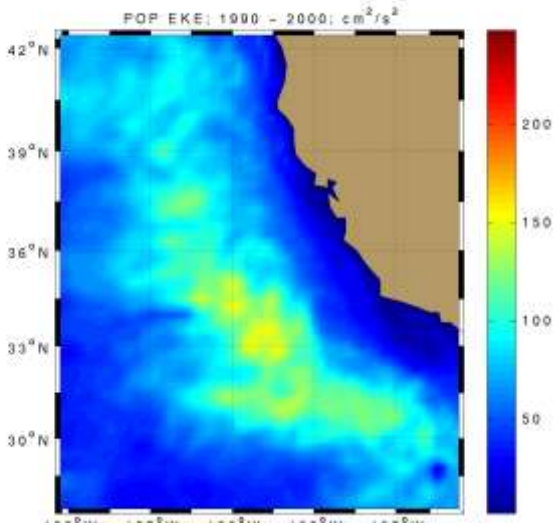
Which model do you pick to study fisheries in CCS?

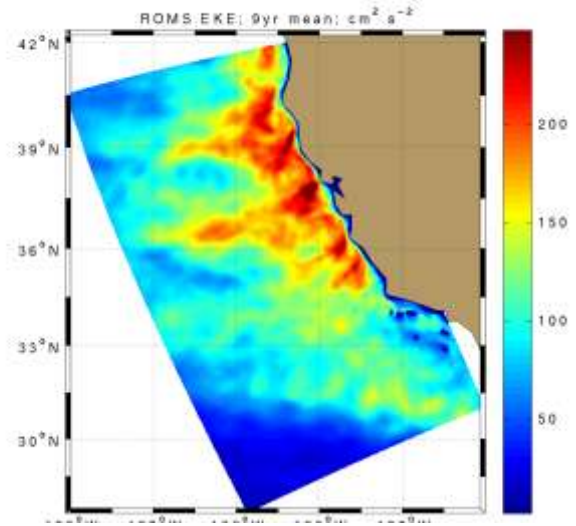
Figs from Centurioni et al. 2008

Eddy Kinetic Energy (10 year mean) from four models.









Which model do you pick to study fisheries in CCS?

Figs from Centurioni et al. 2008

Observations are a necessary component of model based studies and applications.

Fate and Transport is an important aspect of regional operational models.

- oil
- effluent
- ballast water
- search and rescue

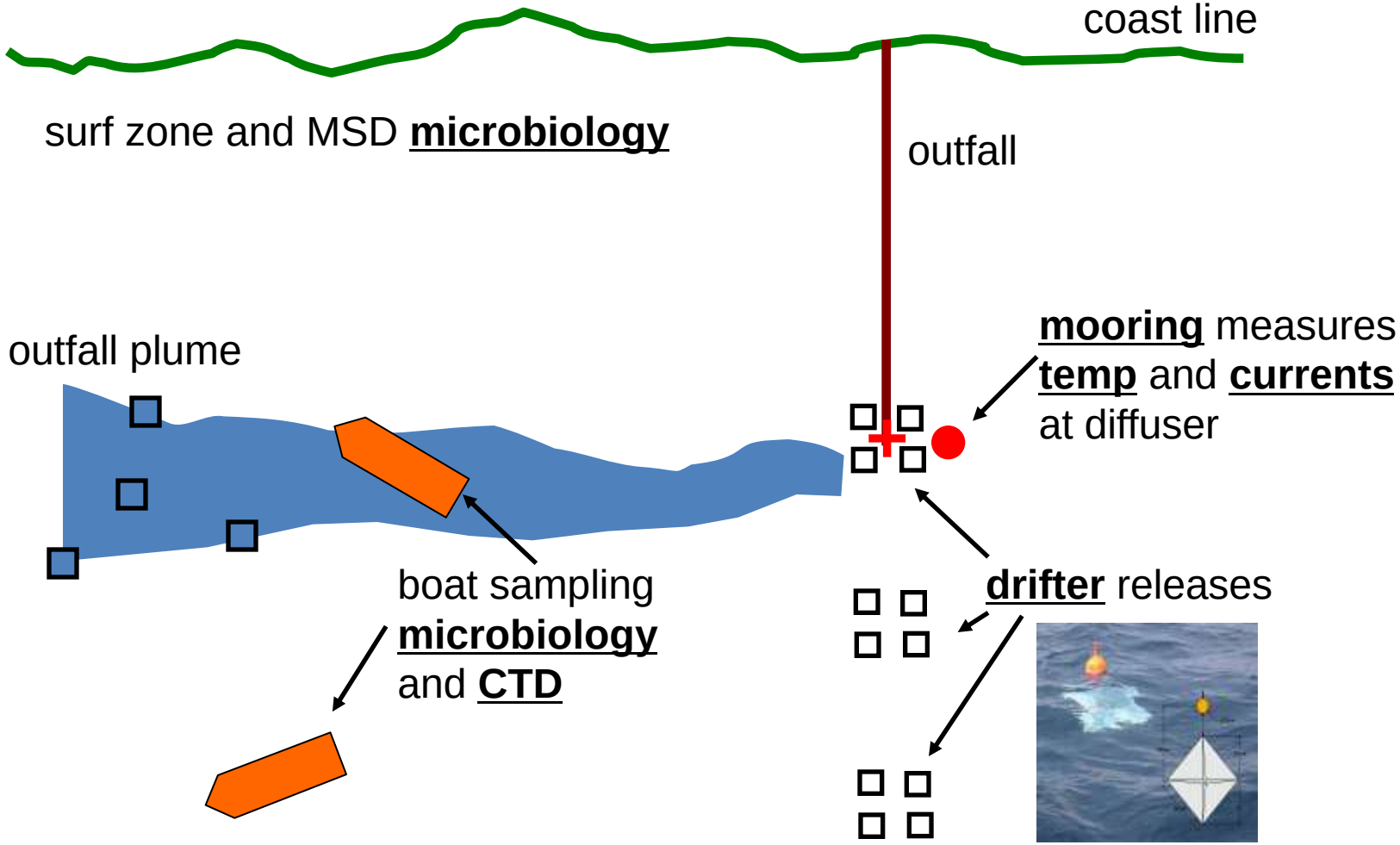
An Observational Paradigm for Monitoring the Fate and Transport of an Effluent Plume

Goal #1:
Observe pathways of a wastewater plume and plume composition along path.

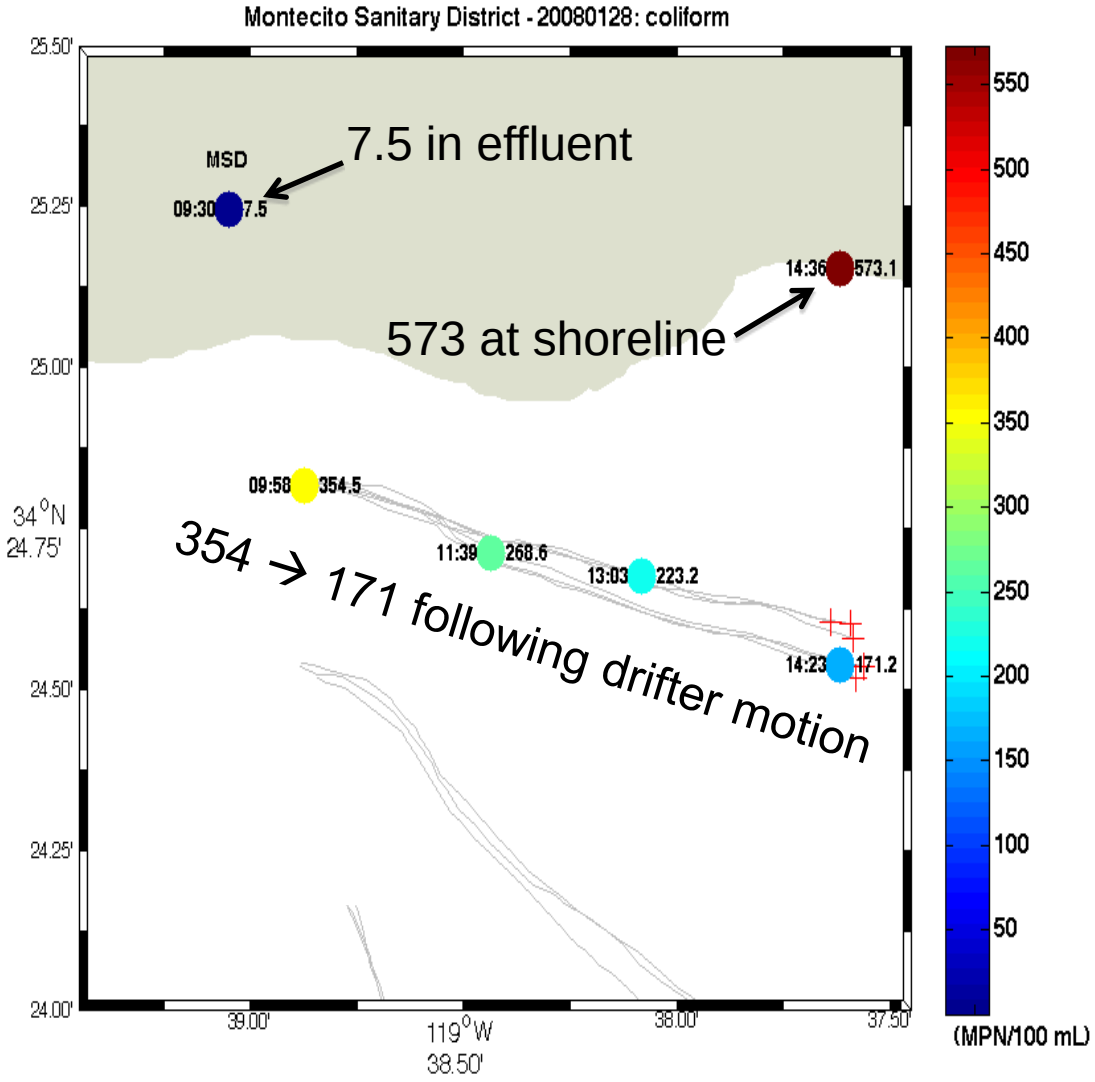
Goal #2:
Determine if/how effluent plume contributes to poor water quality at shoreline.

Observational Plan:

Weekly (once per week) sampling for 1 year off Santa Barbara (CA) coast.



Observations of total coliform following drifter motion.



Concentrations decrease moving away from source.

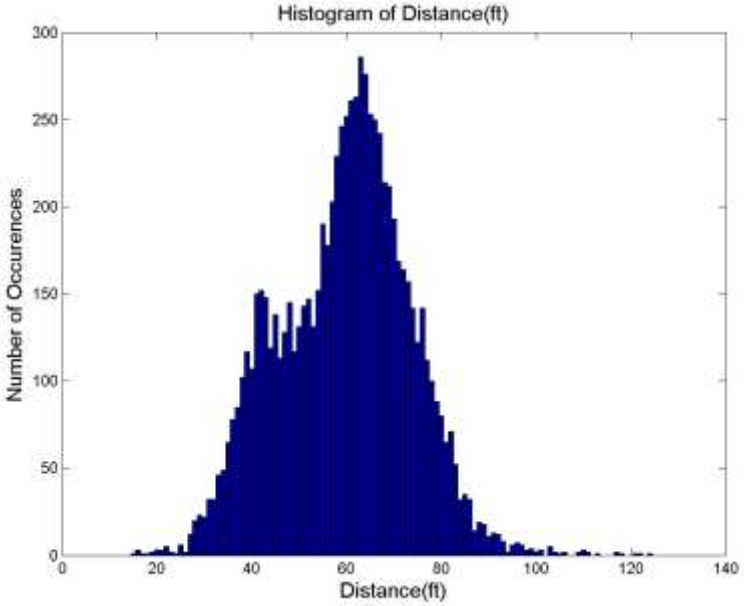
Disconnect between effluent (7) and ocean water sampled above diffuser (354).

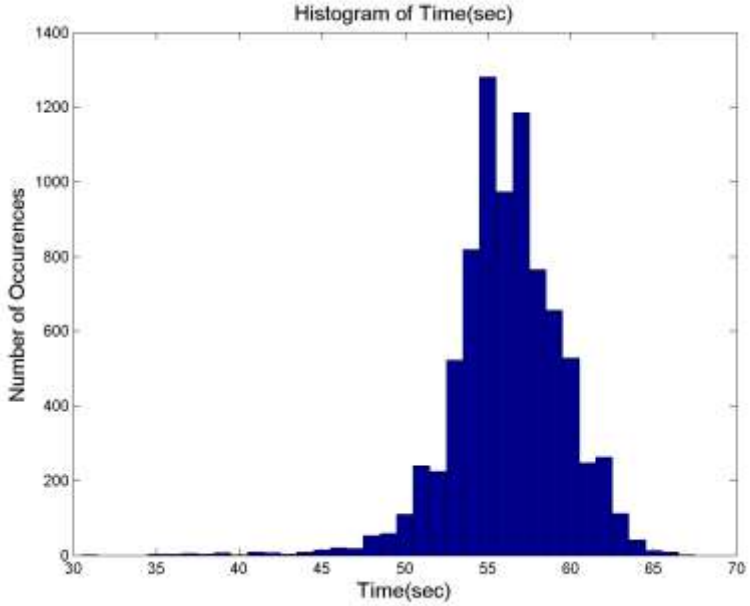
Disconnect between shoreline (573) and all other samples (< 354).

Conclusions: coliform source presumably upstream of diffuser; effluent not reaching shoreline locally.

Step 1: Determine distance and time of plume to surface.

Moored T-S and current info, effluent discharge characteristics, and plume model.

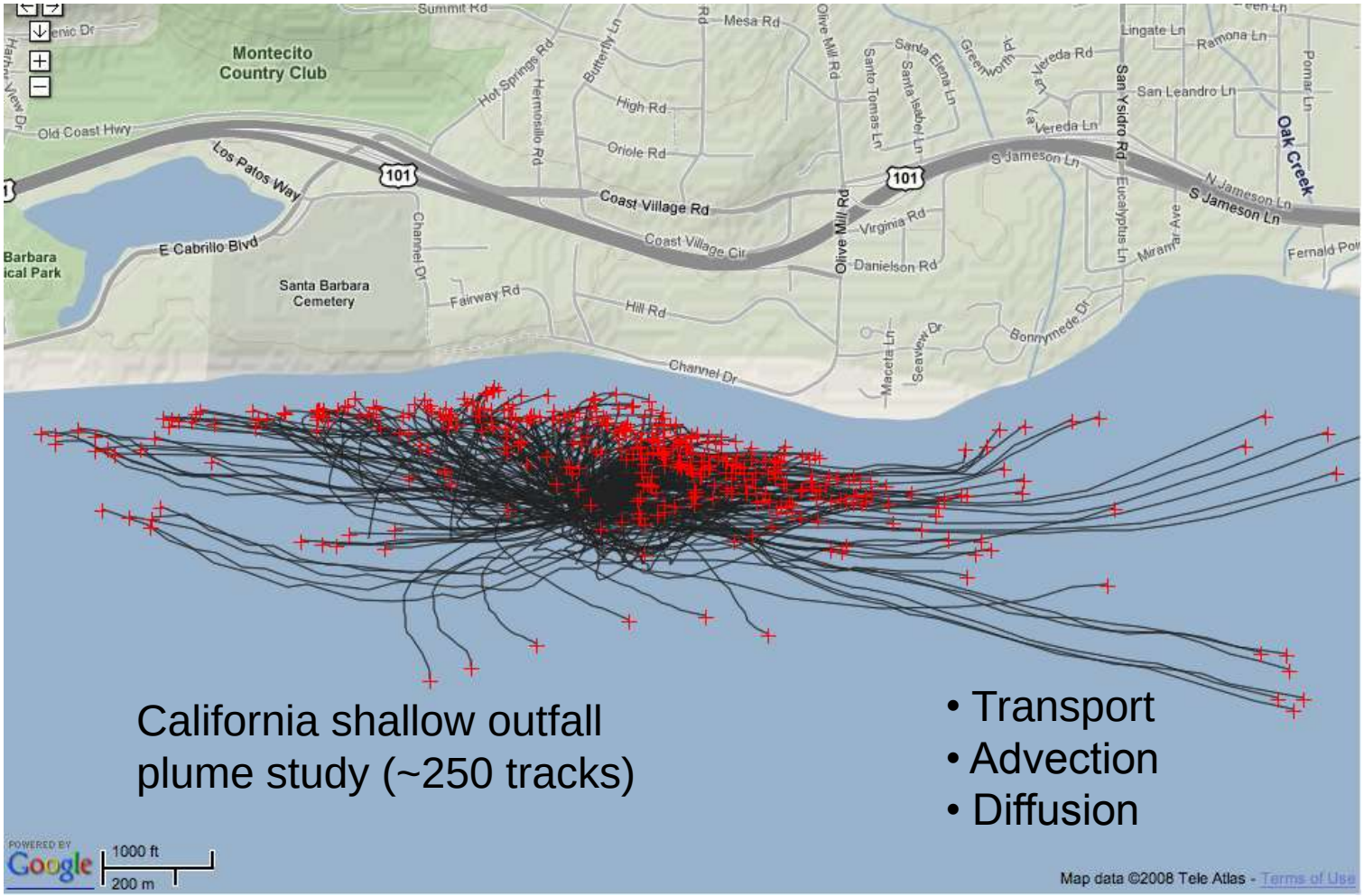




- Distance from diffuser where plume reaches the surface is 59.56 ft, with a std of 13.855 ft.
- Time for plume to surface is 56.2 sec, with a std of 3.3 sec.
- Plume reaches surface in all realizations.

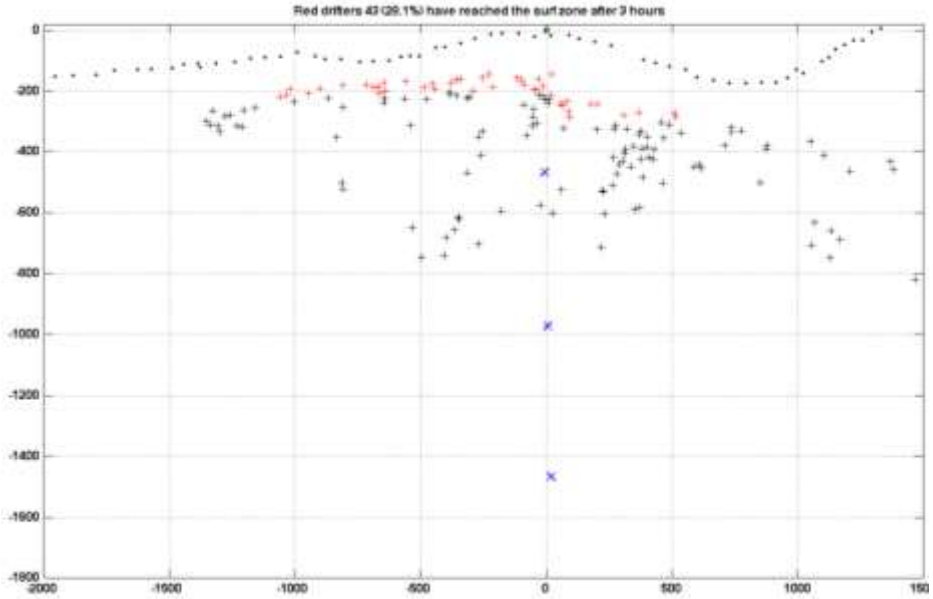
Step 2: Water following drifters to track surface plume.

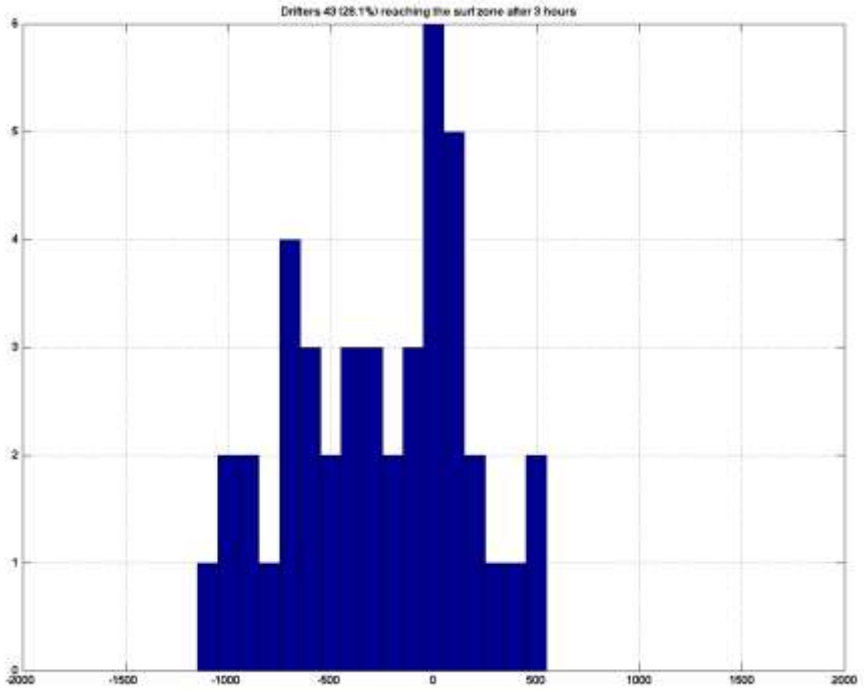
Observations of advection and (horizontal) diffusion of plume waters as they move from the diffuser.



Step 2 (continued):

Distribution of along coast location where tagged effluent plume reaches surf zone within 3 hours of discharge.





- after 3 hours drifters reach the “surf zone” within ~1000 m alongshore
- after 3 hours there are more “surf zone” encounters upcoast
- bathymetry is relatively coarse for this application

Step 3: Verify plume tracking

CTD casts following plume

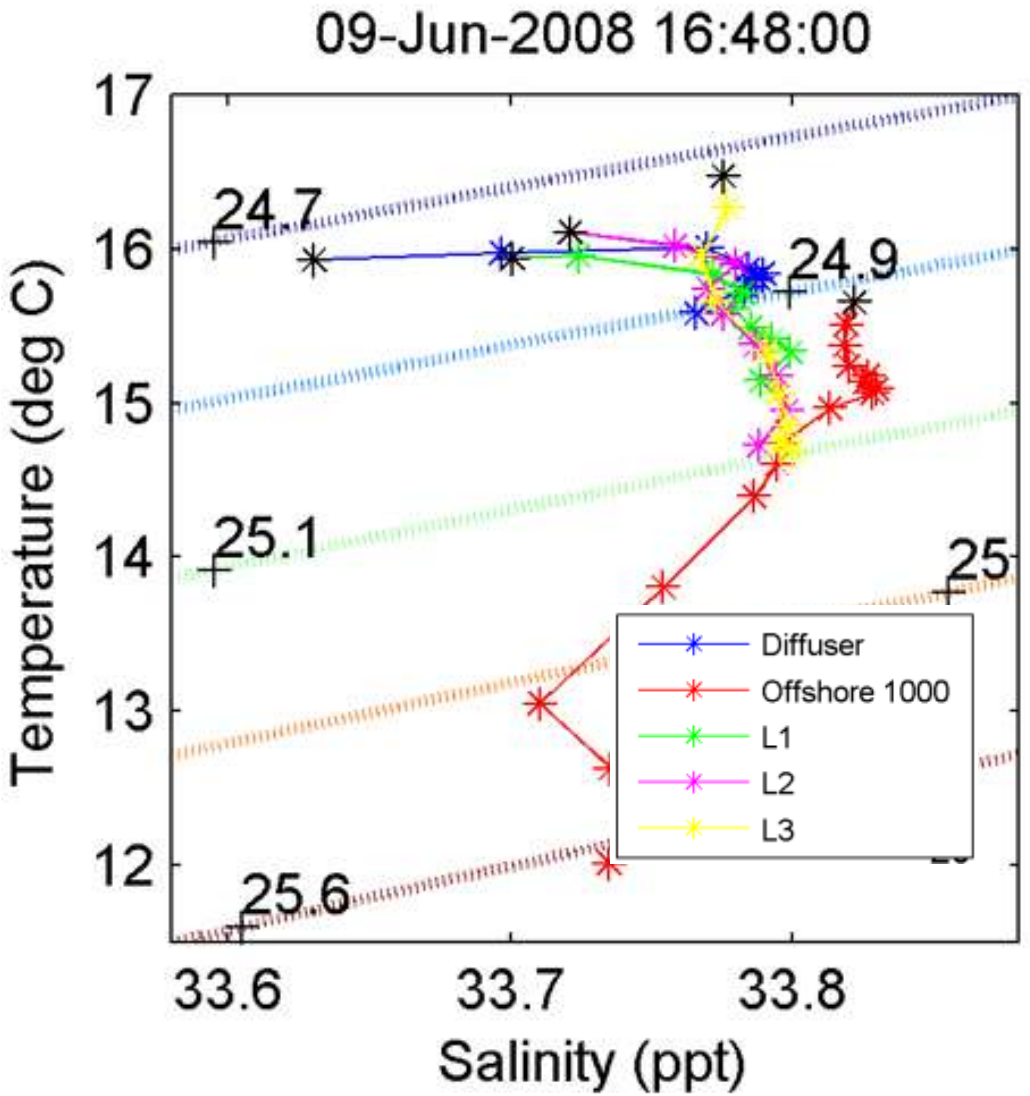
1. S(offshore1000,1 m) = 33.82 ppm

2. S(diffuser,1 m) = 33.63 ppm
   Presumed plume signal

3. S(Lagrangian1,1 m) = 33.70 ppm
   Mixing w/ ocean increases S.

4. S(Lagrangian2,1 m) = 33.73 ppm
   More mixing further increases S.

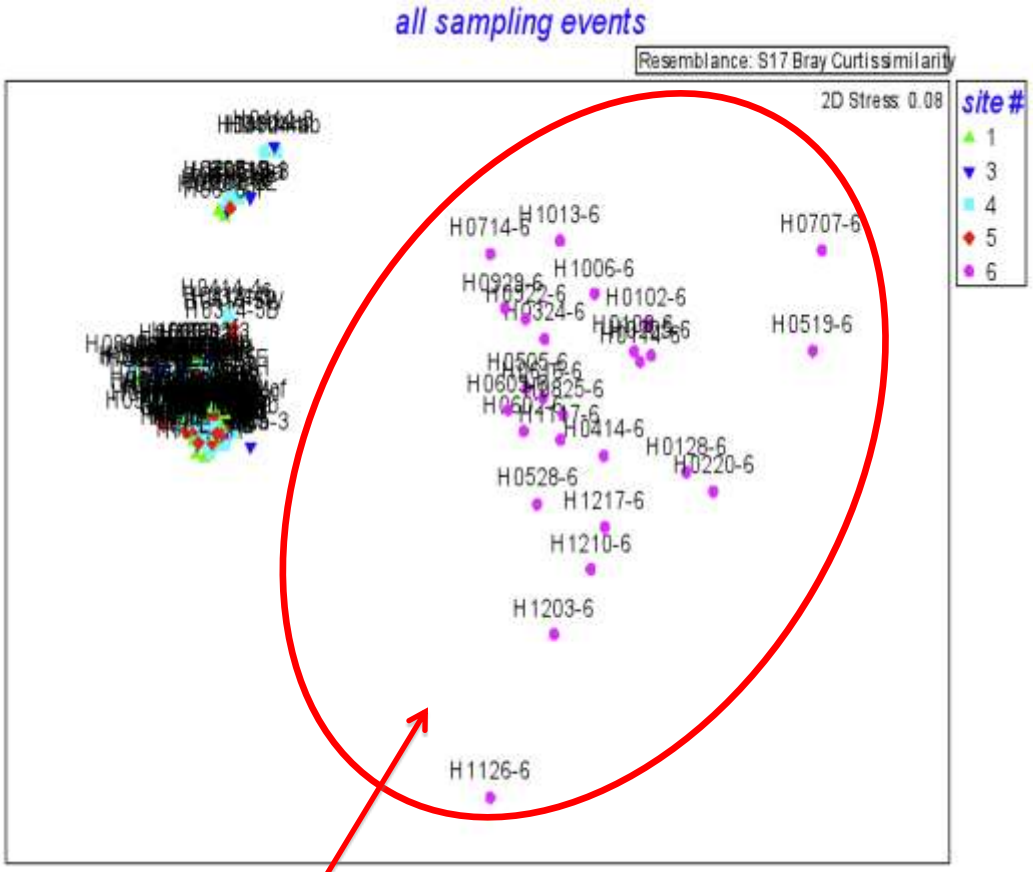
5. S(Lagrangian3,1 m) = 33.78 ppm
   More mixing, greater S.



Salinity Signal at Diffuser and Following Drifters
Salinity increases toward background value with mixing.

Step 4: Water sampling for plume microbiology/chemistry

Water sampling following plume (w/ CTD casts)



Site 6 = Effluent

Multi-dimensional scaling (MDS) plot of all samples grouped by site from the 26 selected sampling events for DNA-based TRFLP analysis.

Effluent samples are variable in time and distinct from ocean samples.

Step 4 (continued): Plume microbiology/chemistry

Water sampling following plume (w/ CTD casts)

	Overall	Offshore1000[a]	Diffuser[b]	Lagrangians[c]	Shoreline[a,b,c,d]	Effluent[d]
Average	1.9	0.4	1.6	0.7	8.4	0.5
SD	6.8	2.0	3.9	2.6	15.3	1.0
SE	0.4	0.3	0.5	0.2	2.2	0.1
Min	0	0	0	0	0	0
Max	80.8	10	15.1	10	80.8	5.2
# samples	344	50	52	142	50	50

E. coli summary statistics by sampling location showing **values at shoreline are much larger than at other sampling locations**.

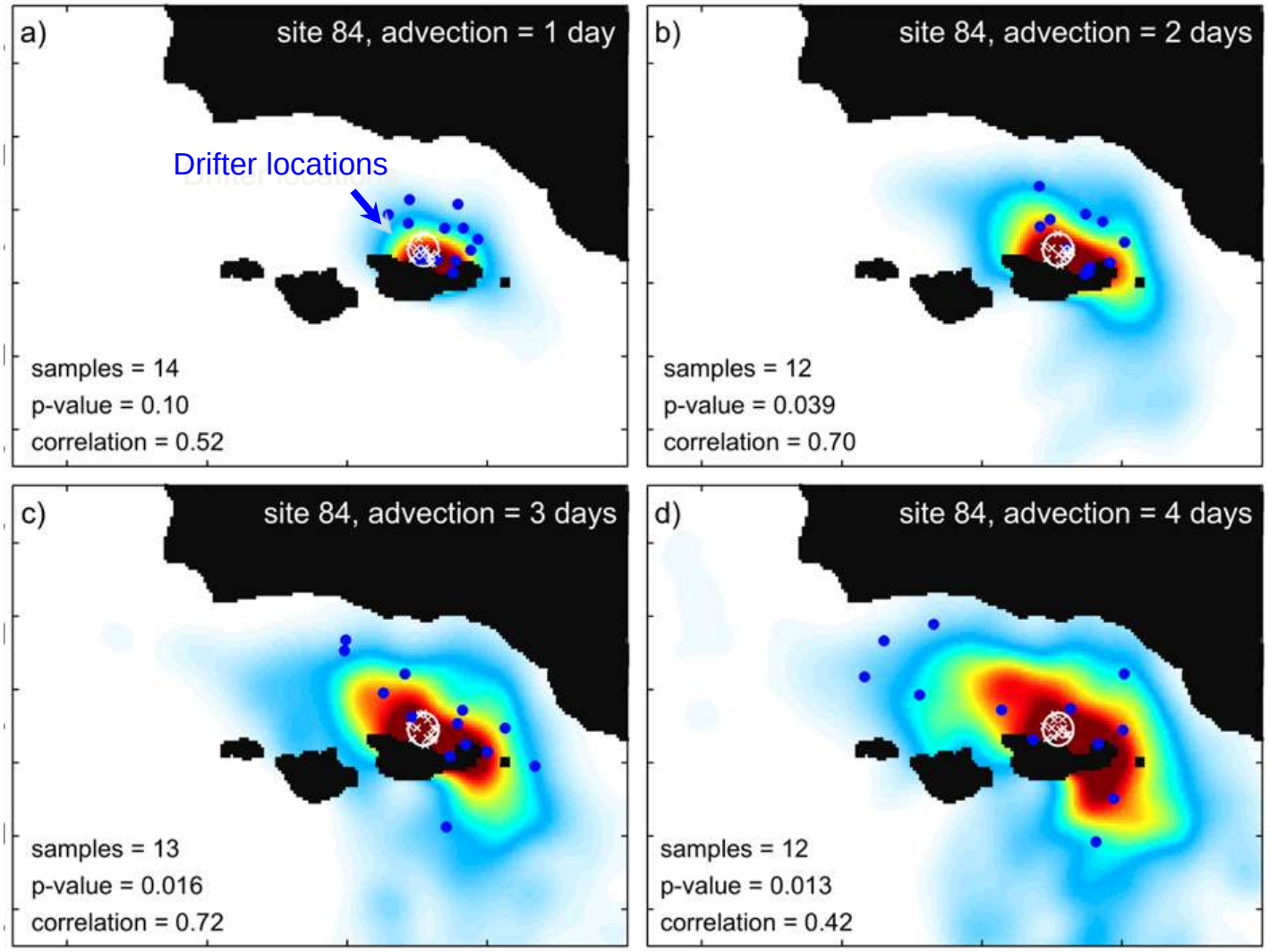
This sort of analysis is performed with:

- nutrients
- FIB (univariate data)
- DNA via TRFLP (O(100) OTUs)
- DNA via PhyloChip (O(1000) OTUs)

Conclusions

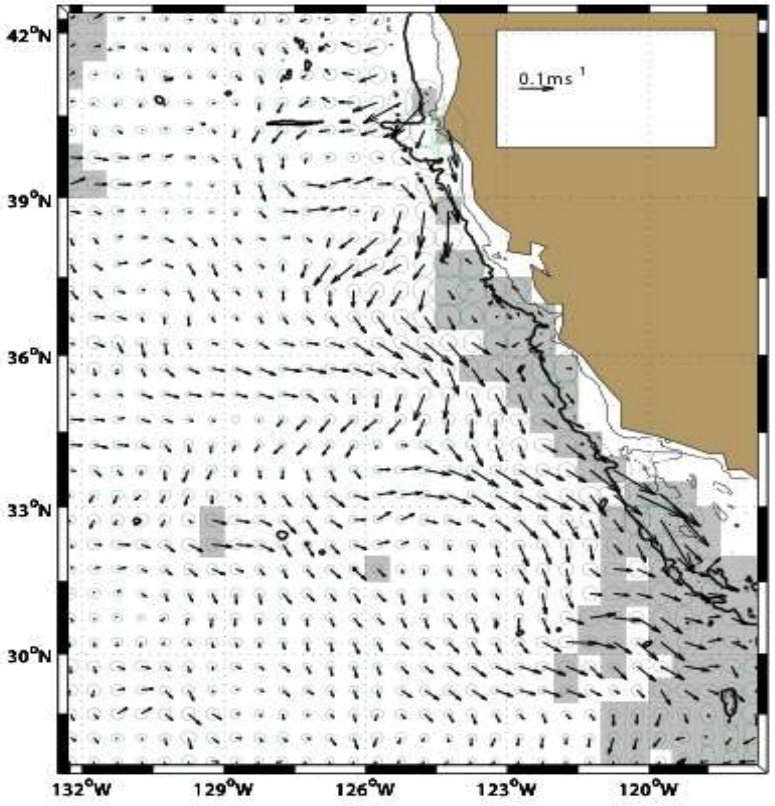
- Observations - necessary component of model studies and applications.
- Novel experimental design for observing dilution and transport.
- Microbial communities within effluent are highly variable in time.
- Treated effluent reaches the surf zone along ~3 km span of shoreline.
- No apparent relationship between bacterial concentrations in effluent and sampled in ankle-deep water at the shoreline.
- Effluent fertilizes the near-shore environment with elevated concentrations of Nitrate+Nitrite and Phosphate.
- The highly diverse set of OTUs distinguishable through PhyloChip analysis provide a much improved mechanism for identifying effluent.

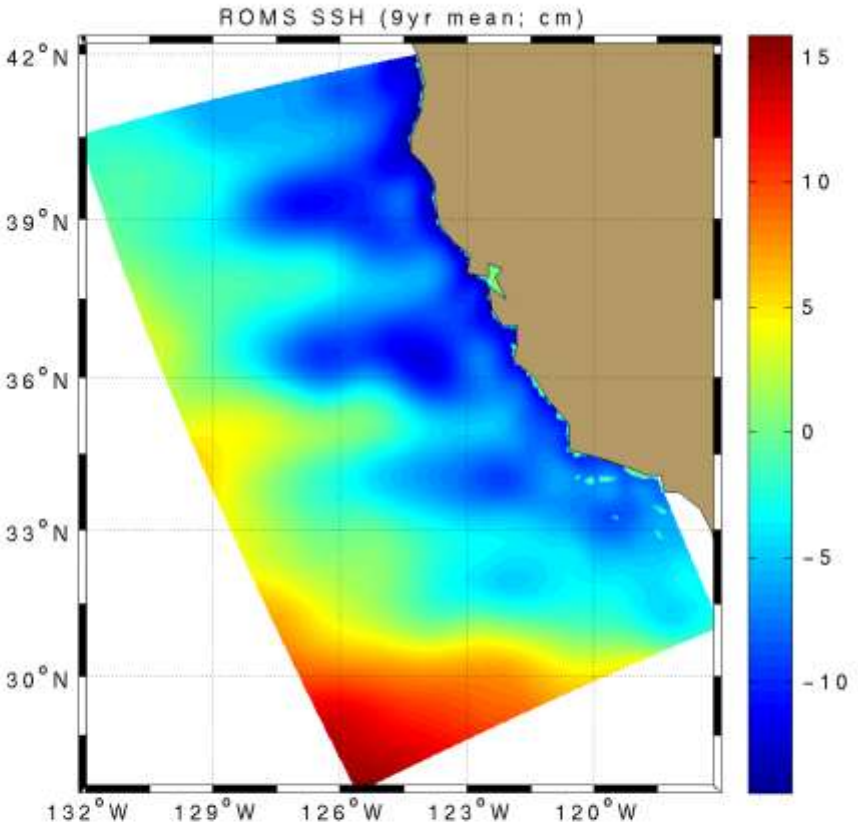
Modeled Lagrangian PDFs and observations indicate good qualitative agreement for a single release site and 4 advection times.



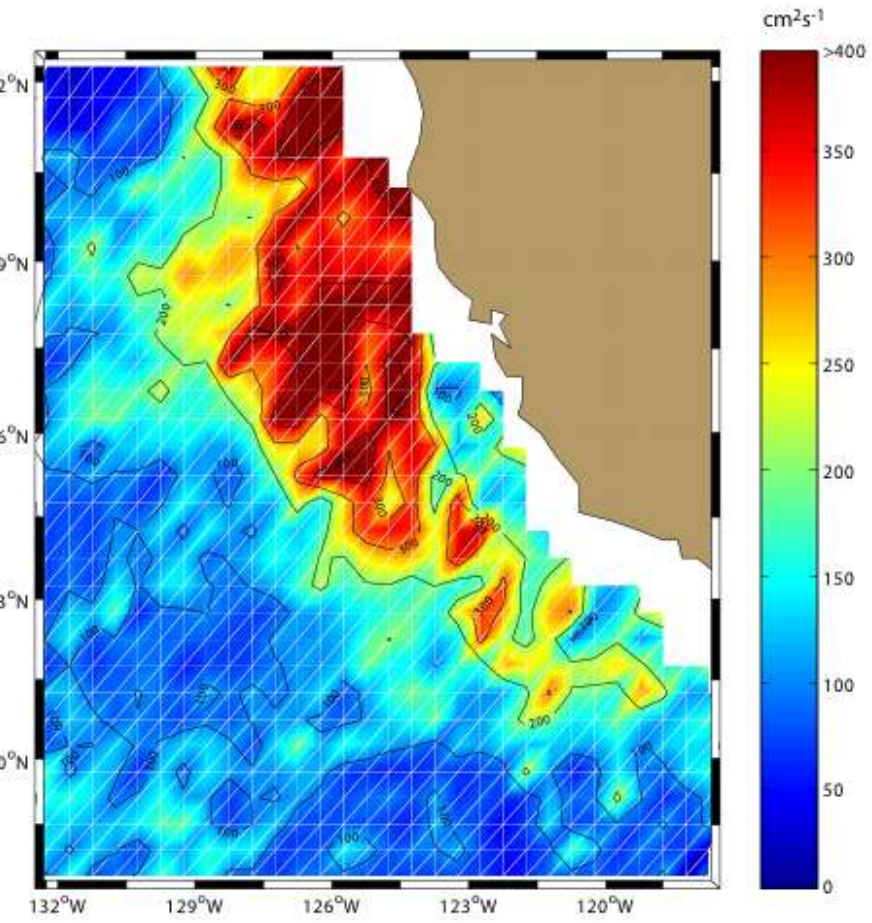
Ohlmann and Mitarai, in review GRL

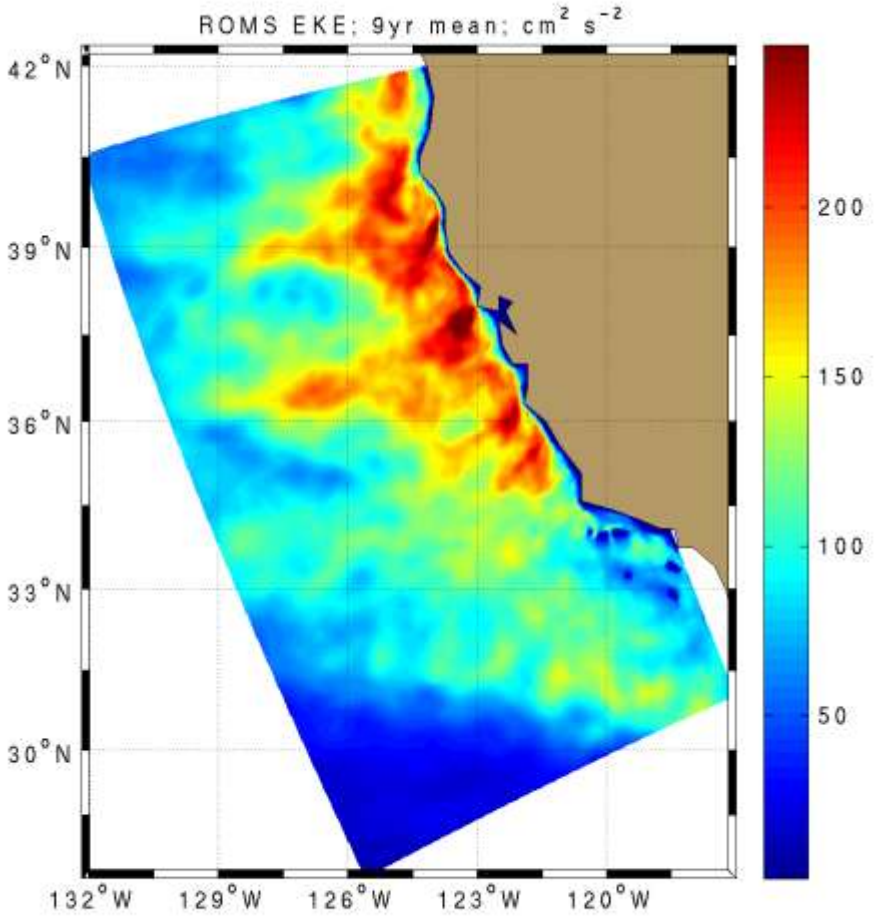
Drifter 15m velocity and ROMS sea level



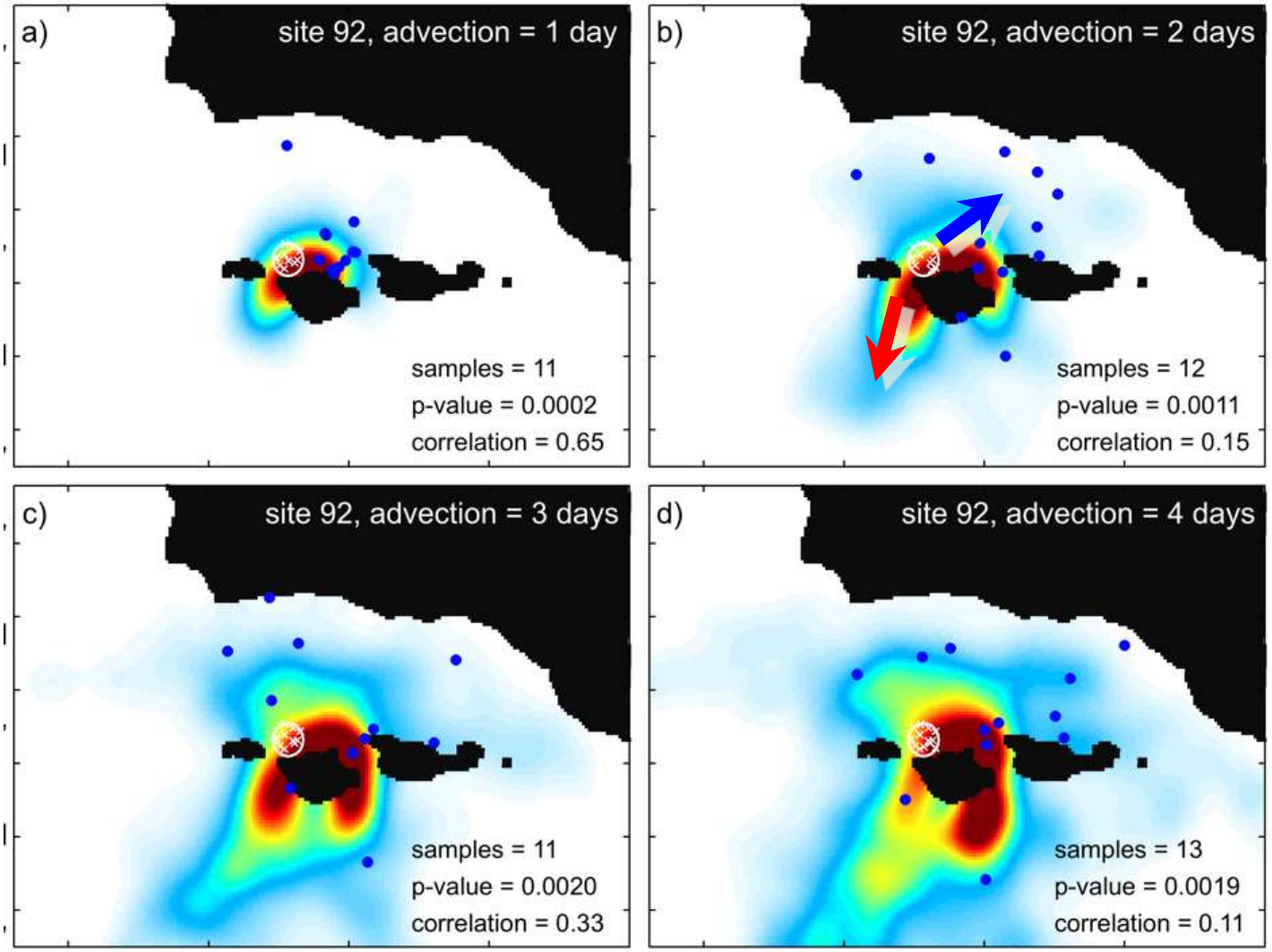


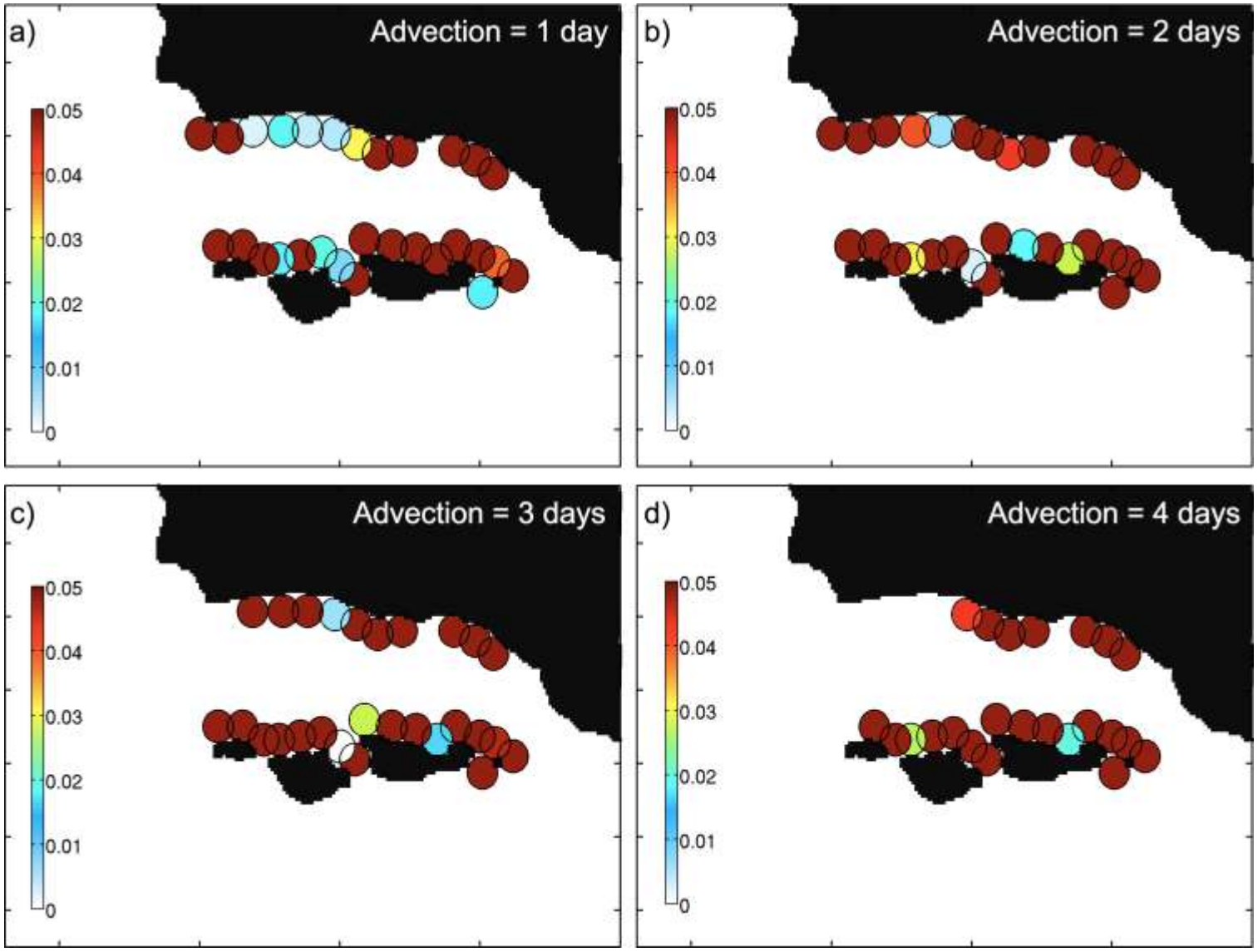
ROMS/Drifter eddy energy comparison





Poor model-data agreement when a different release site is considered.




a)
Advection = 1 day
b)
Advection = 2 days
c)
Advection = 3 days
d)
Advection = 4 days
0.05
0.04
0.03
0.02
0.01
0