Apr 5th, 10:30 AM - 10:45 AM

Patterns and variability in ocean acidification conditions in Puget Sound and the Strait of Juan de Fuca

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Newton, J. A. (Jan A.); Alin, Simone; Curry, Beth; Sutton, Adrienne J.; Mickett, John; Feely, Richard A.; Lebrec, Marine; Greeley, Dana; Ruef, Wendi; Fassbender, Andrea; and Klinger, Terrie, "Patterns and variability in ocean acidification conditions in Puget Sound and the Strait of Juan de Fuca" (2018). *Salish Sea Ecosystem Conference*. 148.
https://cedar.wwu.edu/ssec/2018ssec/allsessions/148

Speaker
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Patterns and variability in ocean acidification conditions in Puget Sound and the Strait of Juan de Fuca

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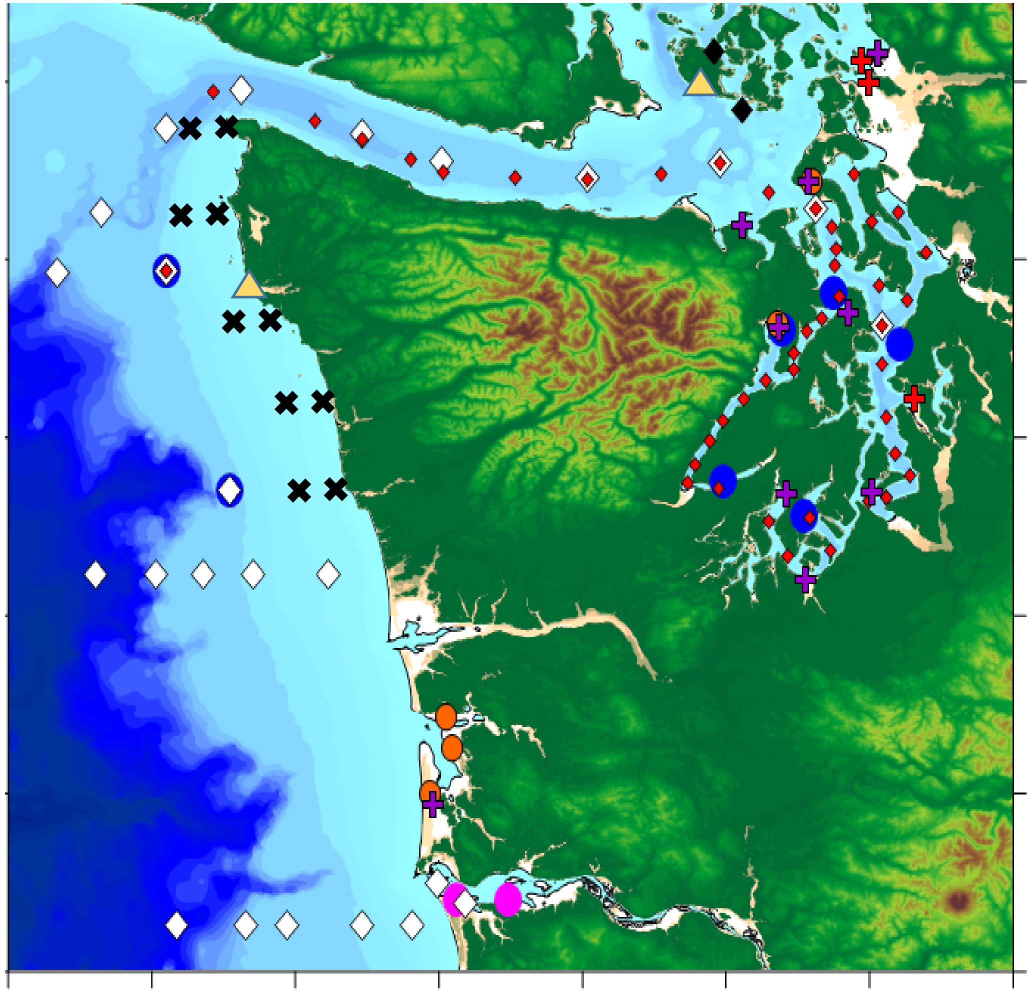
WOAC — WASHINGTON OCEAN ACIDIFICATION CENTER

NANOOS

OAP — OCEAN ACIDIFICATION PROGRAM

WOAC strategies for assessing Washington's waters

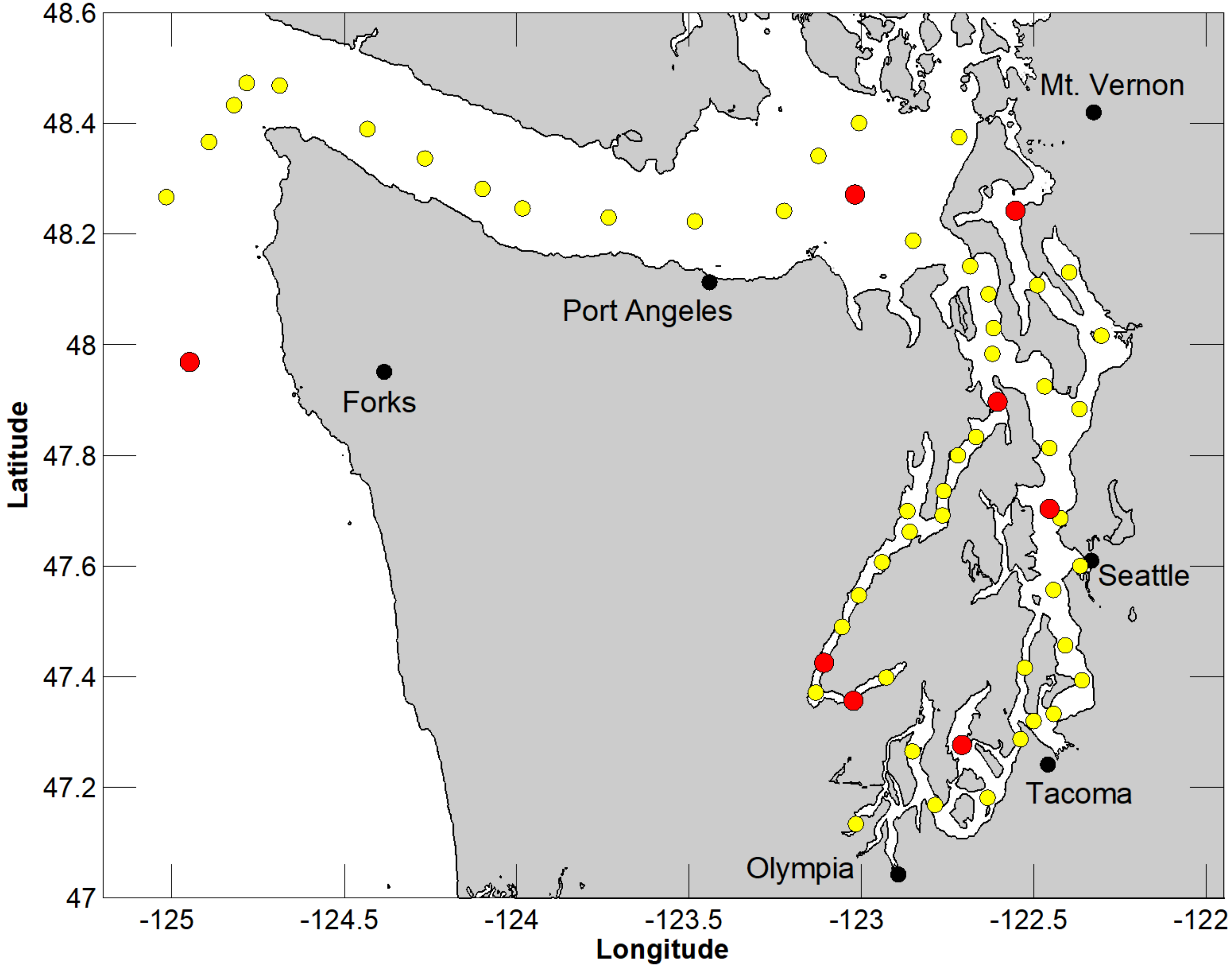


Utilize:

- Both **chemistry** (DIC, TA) and **biology** measurements
- Both **temporal** trends (buoys) & **spatial** coverage (surveys)
- **Leverage** from existing networks

Map: Greeley; Photos: Vander Giessen & USA Today

Cruises: Addressing spatial variation & biology

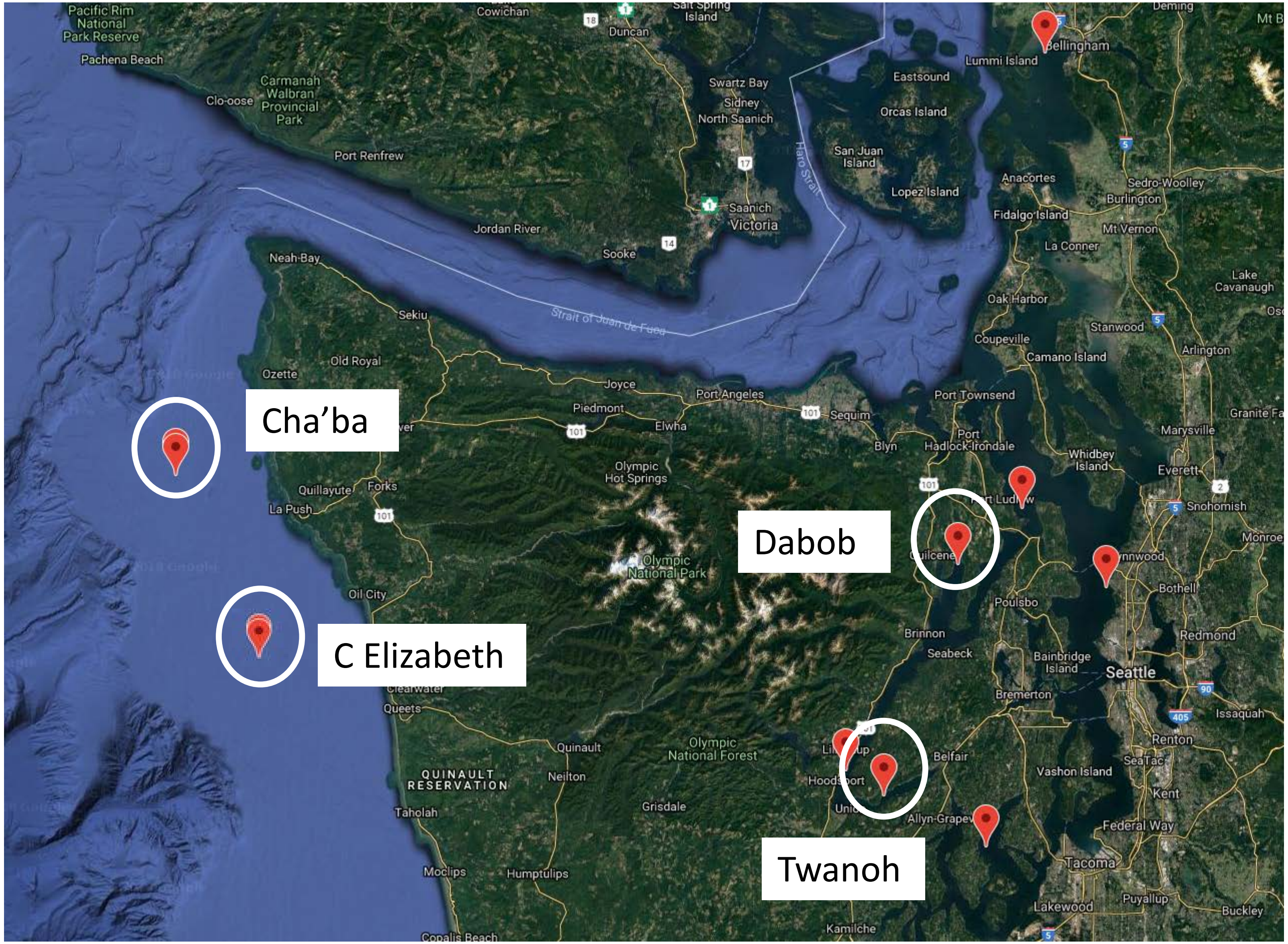


- Water quality
- Carbon variables
- At red stations:
  phytoplankton,
  microzooplankton,
  macrozooplankton

- Seasonal sampling (3x/year)

- First samples 2008
- WOAC >2014

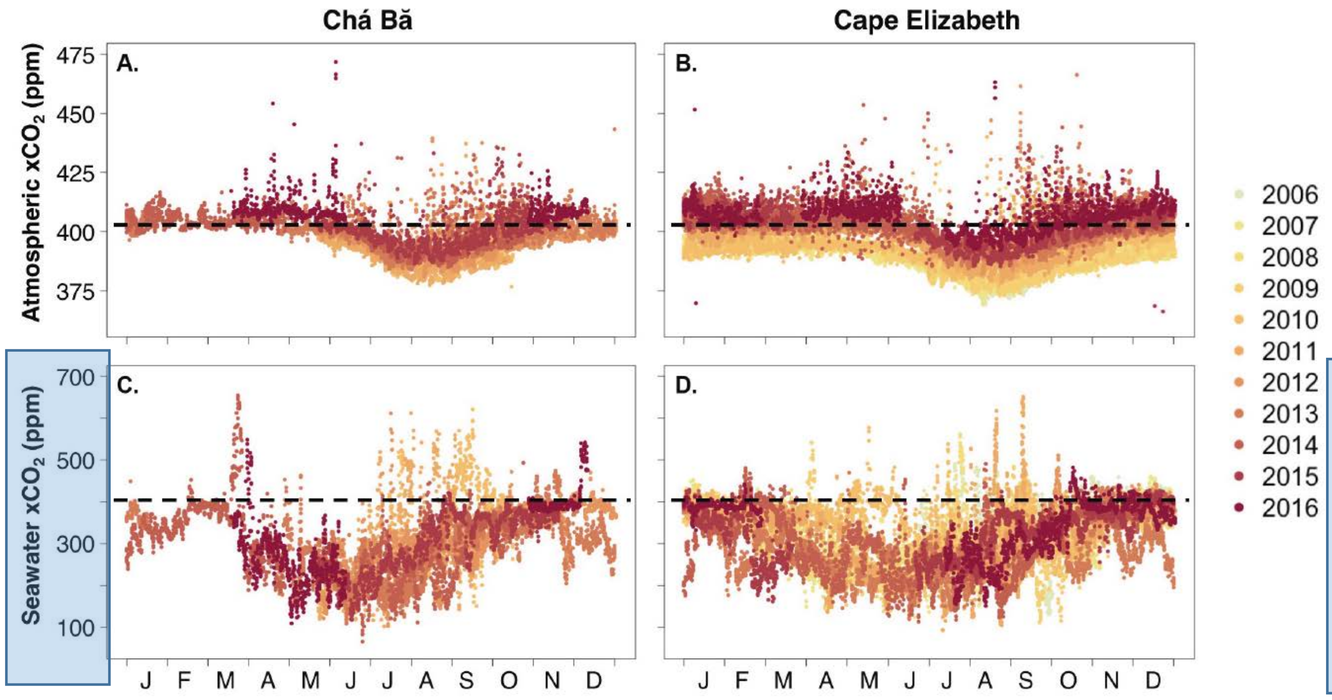
Moorings: Addressing temporal variation & drivers

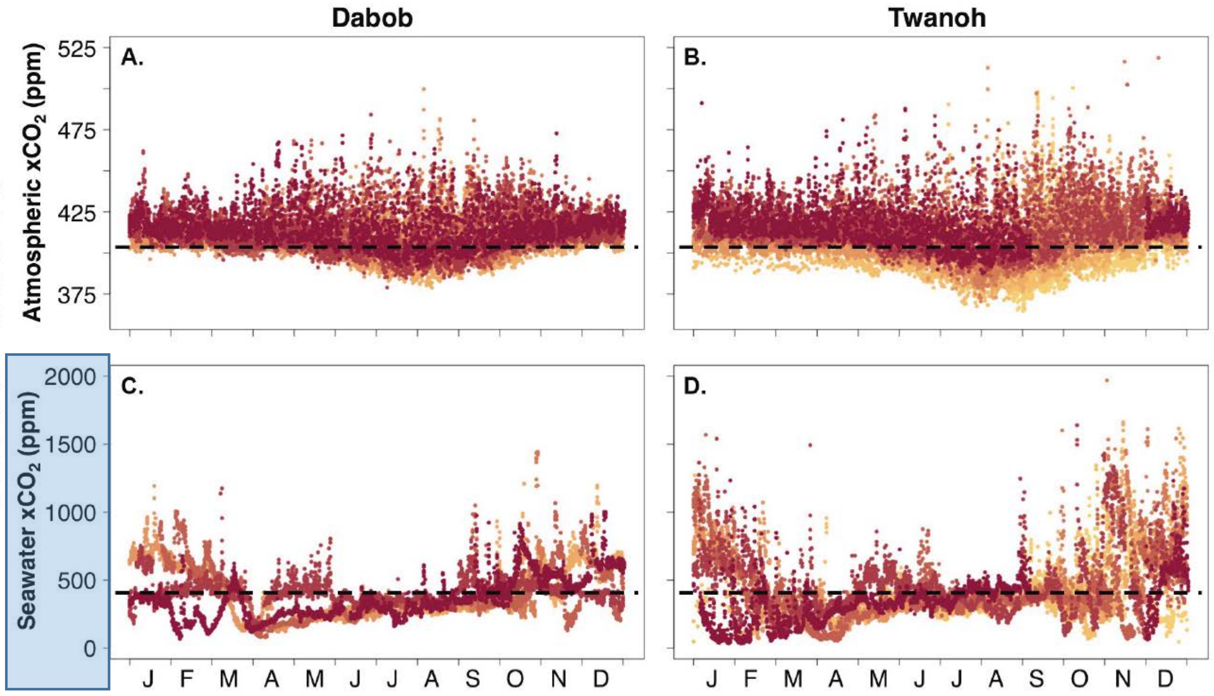


- Water quality
- Carbon variables
- High-frequency sampling (>1x/day)
- First data 2006 (CE); 2009 (Tw)

Mooring analyses: Coast versus Hood Canal

- **Magnitude of variation is different**
  - Range: **151-482** versus **34-1233** *(C Eliz vs. Twanoh, 2016)*
  - St Dev: **64** versus **200** *(C Eliz vs. Twanoh, years 2009-2015)*

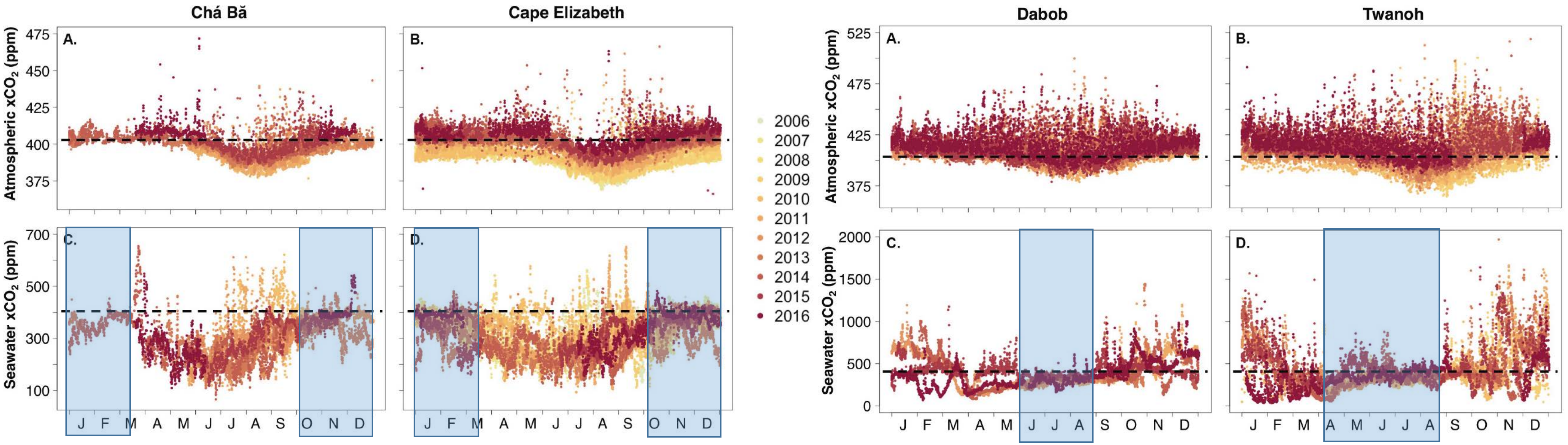




Alin et al., 2017, 2016 PSEMP

Mooring analyses: Coast versus Hood Canal

- **Seasonal pattern of variation is different:**
  - Coast highest variation **during summer**: associated with upwelling
  - Hood Canal highest variation **during winter**: associated with mixing/storms



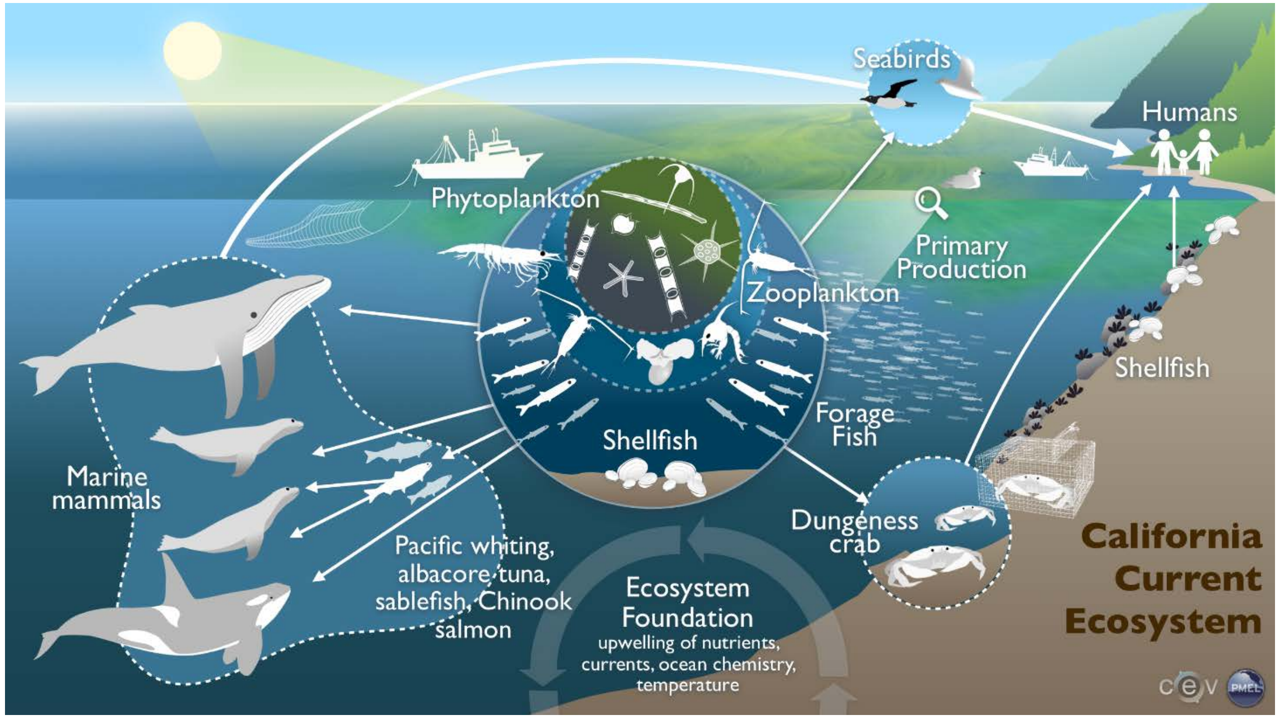
Though comparing summers alone, Twanoh range is ~200 ppm larger than at C Eliz

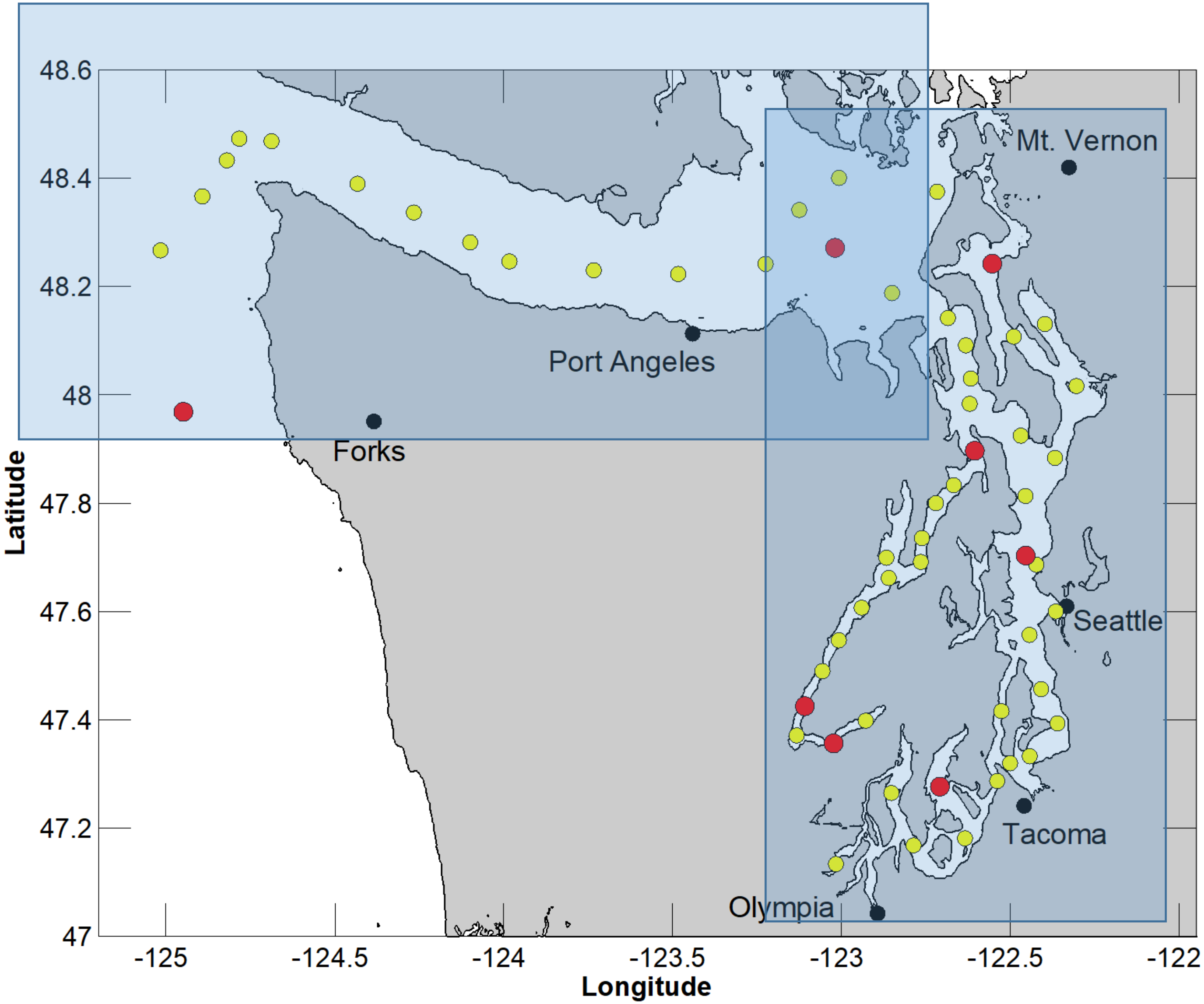
Alin et al., 2017 PSEMP

High-temporal resolution observations summary:

- Range of variation in xCO_2 is higher within Hood Canal than off coast
- Seasonal pattern of highest variability differs between locations

- What does this imply for organisms ?



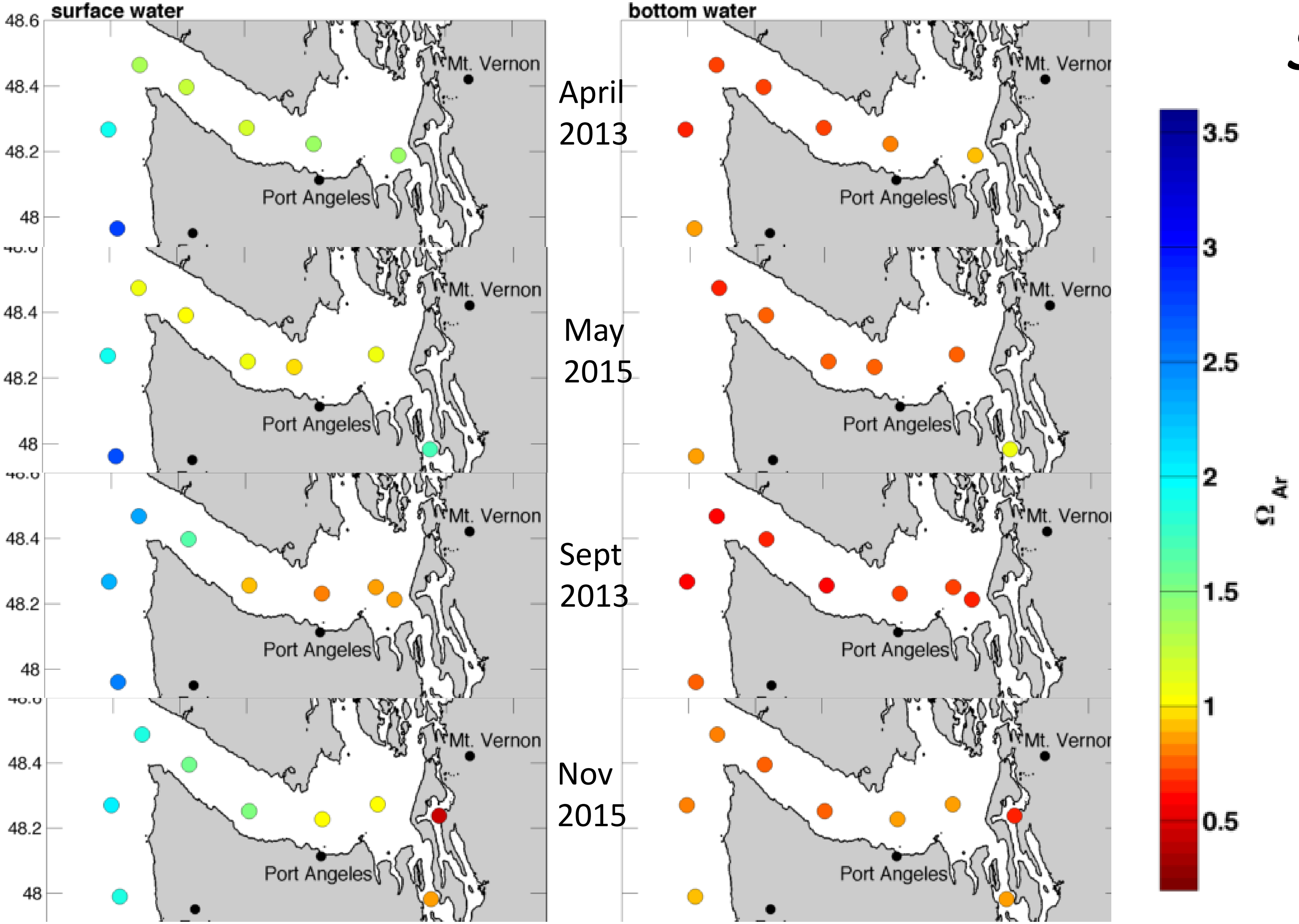


Cruise analyses:

Depth analysis:
Top 5-meter layer &
Bottom 10-meter layer

Spatial analysis:
coast-strait, basins

Mostly PRISM,
NANOOS, WOAC
cruises 2008-2017
n=22



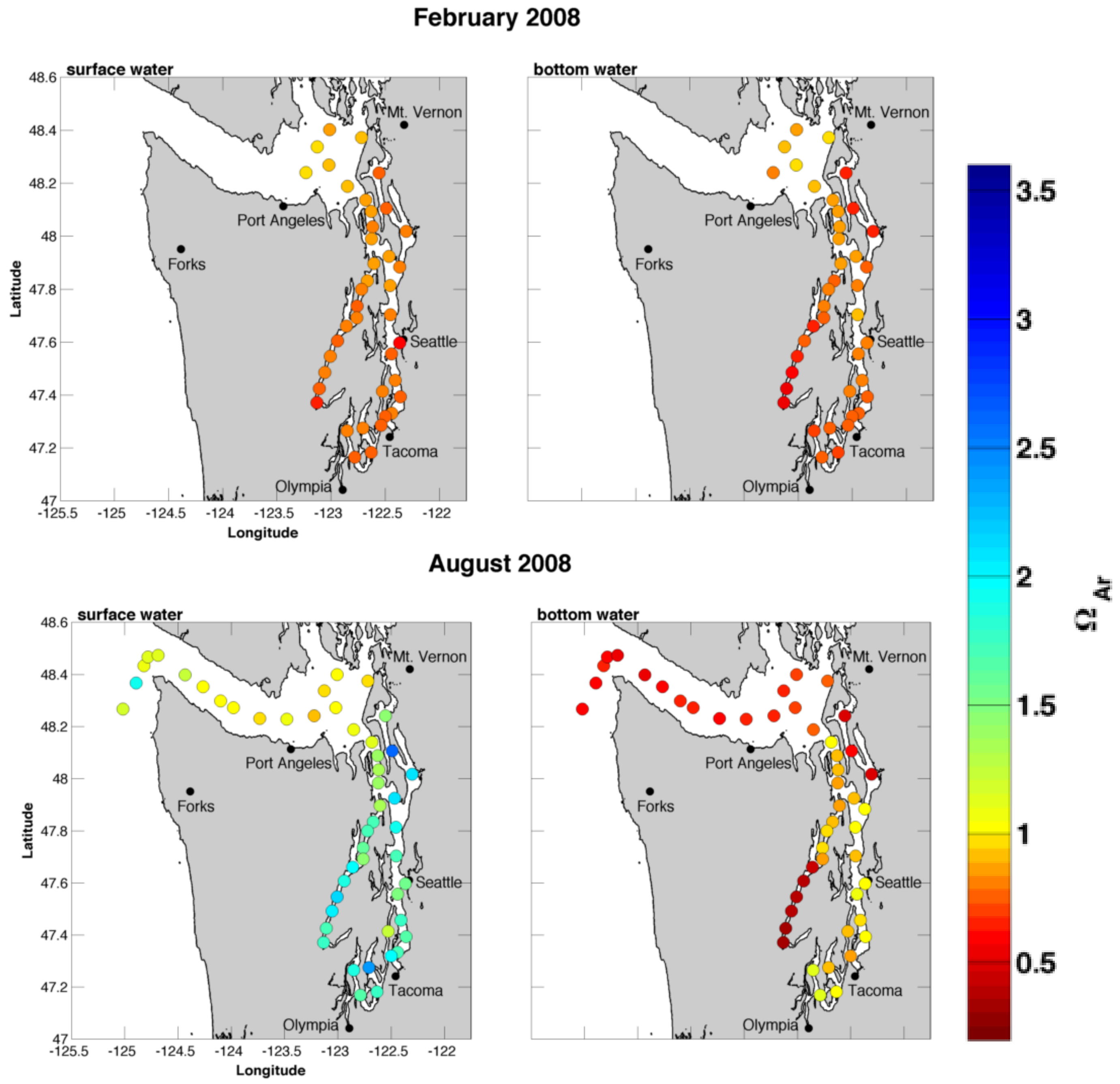
Strait to Coast

Surface top 5 m:

- Gradient of increasing omega toward the coast

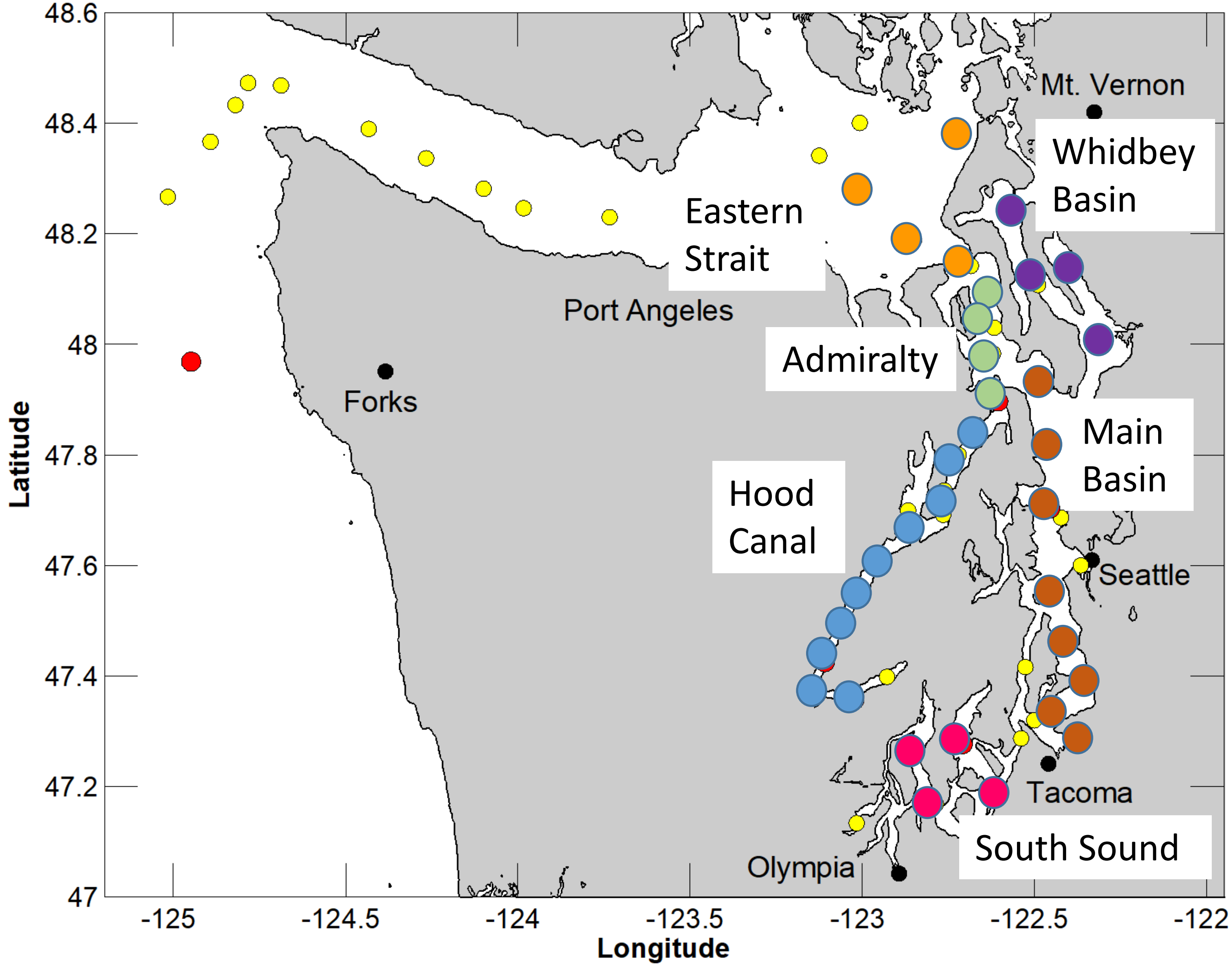
Bottom 10 m:

- Deep waters consistently low omega



Salish Sea: what we learned from the first OA cruises

- Homogeneity between depths in winter
- In summer:
  - strong depth differences
  - moderate basin differences



New analysis of season, basin, and depth

For:
Top 5 meter layer &
Bottom 10 meter layer

computed average Ω_{arag} for seasonal cruises:

Feb, Nov cruises
2008-2016 (n=1-2/mo)

April, July, Sept cruises
2014-2017 (n=3-4/mo)

Puget Sound inflow/outflow waters

	Feb	April	July	Sept	Nov	
Eastern	0.92	1.2	1.2	0.95	0.80	surface
Strait	0.94	1.2	1.0	0.79	0.77	deep

Omega Aragonite
>2-2.5
>1.5-2
>1-1.5
>.75-1
>0.5-.75
0-0.5

Surface waters

	Feb	April	July	Sept	Nov	
Eastern Strait	0.92	1.2	1.2	0.95	0.80	surface
	0.94	1.2	1.0	0.79	0.77	deep
Whidbey Basin	0.77	1.7	2.0	1.6		surface
Main Basin	0.79	1.3	1.8	1.4		surface
South Sound	0.78	1.3	1.6	1.3		surface
Hood Canal	0.79	2.2	2.1	1.3	0.49	surface

Omega Aragonite	
>2-2.5	blue
>1.5-2	green
>1-1.5	yellow
>.75-1	orange
>0.5-.75	red
0-0.5	dark red

Hood Canal is very different

	Feb	April	July	Sept	Nov	
Eastern	0.92	1.2	1.2	0.95	0.80	surface
Strait	0.94	1.2	1.0	0.79	0.77	deep

Omega Aragonite	
>2-2.5	
>1.5-2	
>1-1.5	
>.75-1	
>0.5-.75	
0-0.5	

	Feb	April	July	Sept	Nov	
Hood	0.79	2.2	2.1	1.3	0.49	surface
Canal	0.69	0.48	0.60	0.72	0.68	deep

Whidbey is similar and different from Hood

	Feb	April	July	Sept	Nov	
Eastern	0.92	1.2	1.2	0.95	0.80	surface
Strait	0.94	1.2	1.0	0.79	0.77	deep
Whidbey	0.77	1.7	2.0	1.6		surface
Basin	0.63	0.65	0.62	0.83		deep
Hood	0.79	2.2	2.1	1.3	0.49	surface
Canal	0.69	0.48	0.60	0.72	0.68	deep

Omega Aragonite

>2-2.5	
>1.5-2	
>1-1.5	
>.75-1	
>0.5-.75	
0-0.5	

South Sound deep conditions better; surface worse

		Feb	April	July	Sept	Nov	
Eastern Strait		0.92	1.2	1.2	0.95	0.80	surface
		0.94	1.2	1.0	0.79	0.77	deep
Whidbey Basin		0.77	1.7	2.0	1.6		surface
		0.63	0.65	0.62	0.83		deep
South Sound		0.78	1.3	1.6	1.3		surface
		0.72	0.83	1.4	1.0		deep
Hood Canal		0.79	2.2	2.1	1.3	0.49	surface
		0.69	0.48	0.60	0.72	0.68	deep

Omega Aragonite

>2-2.5	
>1.5-2	
>1-1.5	
>.75-1	
>0.5-.75	
0-0.5	

Main Basin similar to South; except at depth

		Feb	April	July	Sept	Nov	
Eastern Strait		0.92	1.2	1.2	0.95	0.80	surface
		0.94	1.2	1.0	0.79	0.77	deep
Whidbey Basin		0.77	1.7	2.0	1.6		surface
		0.63	0.65	0.62	0.83		deep
Main Basin		0.79	1.3	1.8	1.4		surface
		0.80	0.81	0.97	0.90		deep
South Sound		0.78	1.3	1.6	1.3		surface
		0.72	0.83	1.4	1.0		deep
Hood Canal		0.79	2.2	2.1	1.3	0.49	surface
		0.69	0.48	0.60	0.72	0.68	deep

Omega Aragonite

>2-2.5	
>1.5-2	
>1-1.5	
>.75-1	
>0.5-.75	
0-0.5	

Even proximal areas differ

	Feb	April	July	Sept	Nov	
Eastern	0.92	1.2	1.2	0.95	0.80	surface
Strait	0.94	1.2	1.0	0.79	0.77	deep
Admiralty	0.84	1.2	1.7	1.2	0.85	surface
Inlet	0.86	1.1	1.1	0.90	0.78	deep
Main	0.79	1.3	1.8	1.4		surface
Basin	0.80	0.81	0.97	0.90		deep

Omega Aragonite
>2-2.5
>1.5-2
>1-1.5
>.75-1
>0.5-.75
0-0.5

Differences between basins

		Feb	April	July	Sept	Nov	
Eastern Strait		0.92	1.2	1.2	0.95	0.80	surface
		0.94	1.2	1.0	0.79	0.77	deep
Whidbey Basin		0.77	1.7	2.0	1.6		surface
		0.63	0.65	0.62	0.83		deep
Main Basin		0.79	1.3	1.8	1.4		surface
		0.80	0.81	0.97	0.90		deep
South Sound		0.78	1.3	1.6	1.3		surface
		0.72	0.83	1.4	1.0		deep
Hood Canal		0.79	2.2	2.1	1.3	0.49	surface
		0.69	0.48	0.60	0.72	0.68	deep

Omega Aragonite

Omega Aragonite	
>2-2.5	blue
>1.5-2	green
>1-1.5	yellow
>.75-1	orange
>0.5-.75	red
0-0.5	dark red

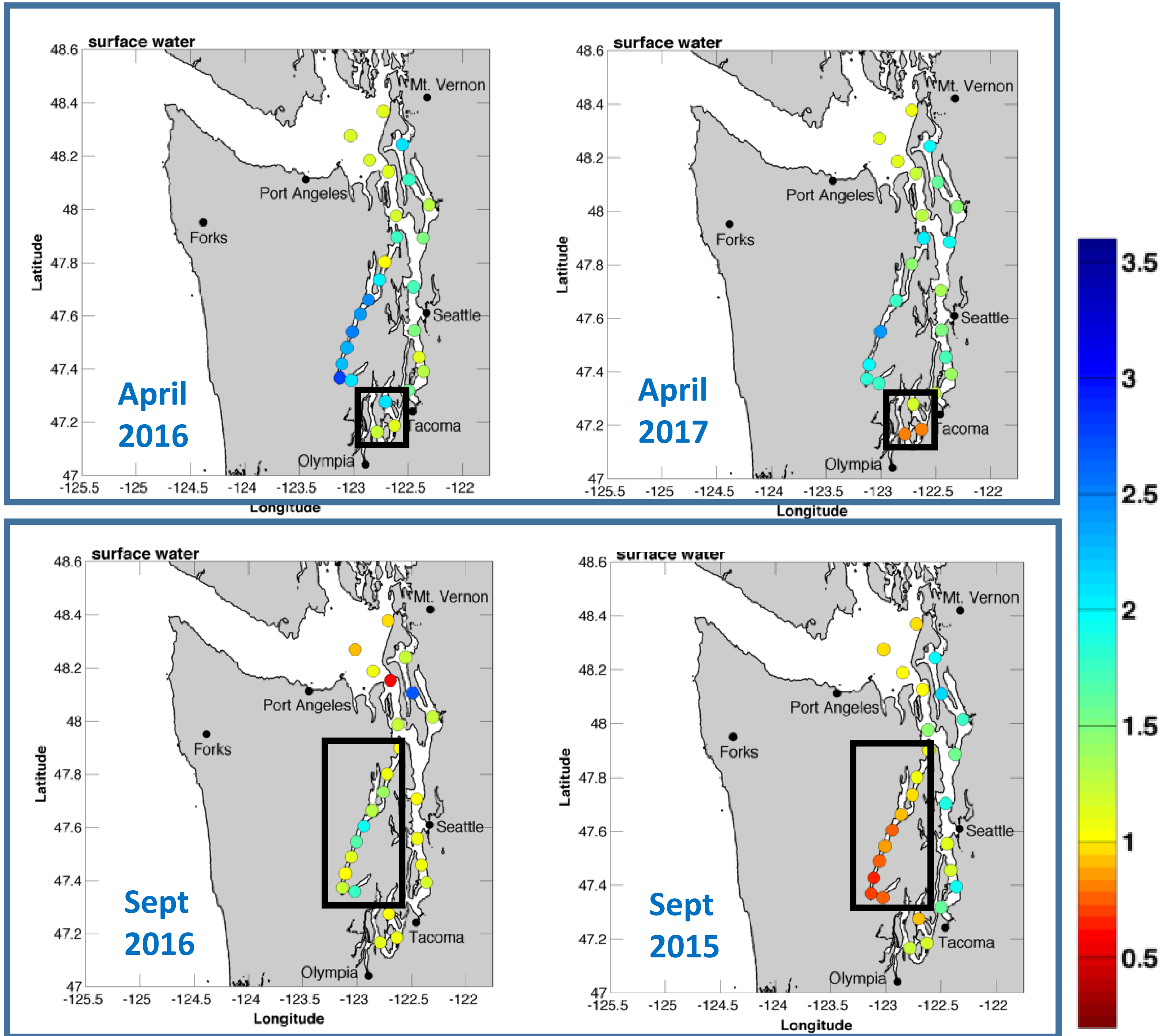
Differences between surface and deep

3.0 or greater
1.1 or less

	Feb	April	July	Sept	Nov	
Eastern Strait	**1.0**	**1.0**	**1.2**	**1.2**	**1.0**	surface/deep
Whidbey Basin	**1.2**	**2.6**	**3.2**	**2.0**		surface/deep
Main Basin	**1.0**	**1.7**	**1.9**	**1.6**		surface/deep
South Sound	**1.1**	**1.6**	**1.2**	**1.2**		surface/deep
Hood Canal	**1.1**	**4.6**	**3.6**	**1.9**	**0.72**	surface/deep

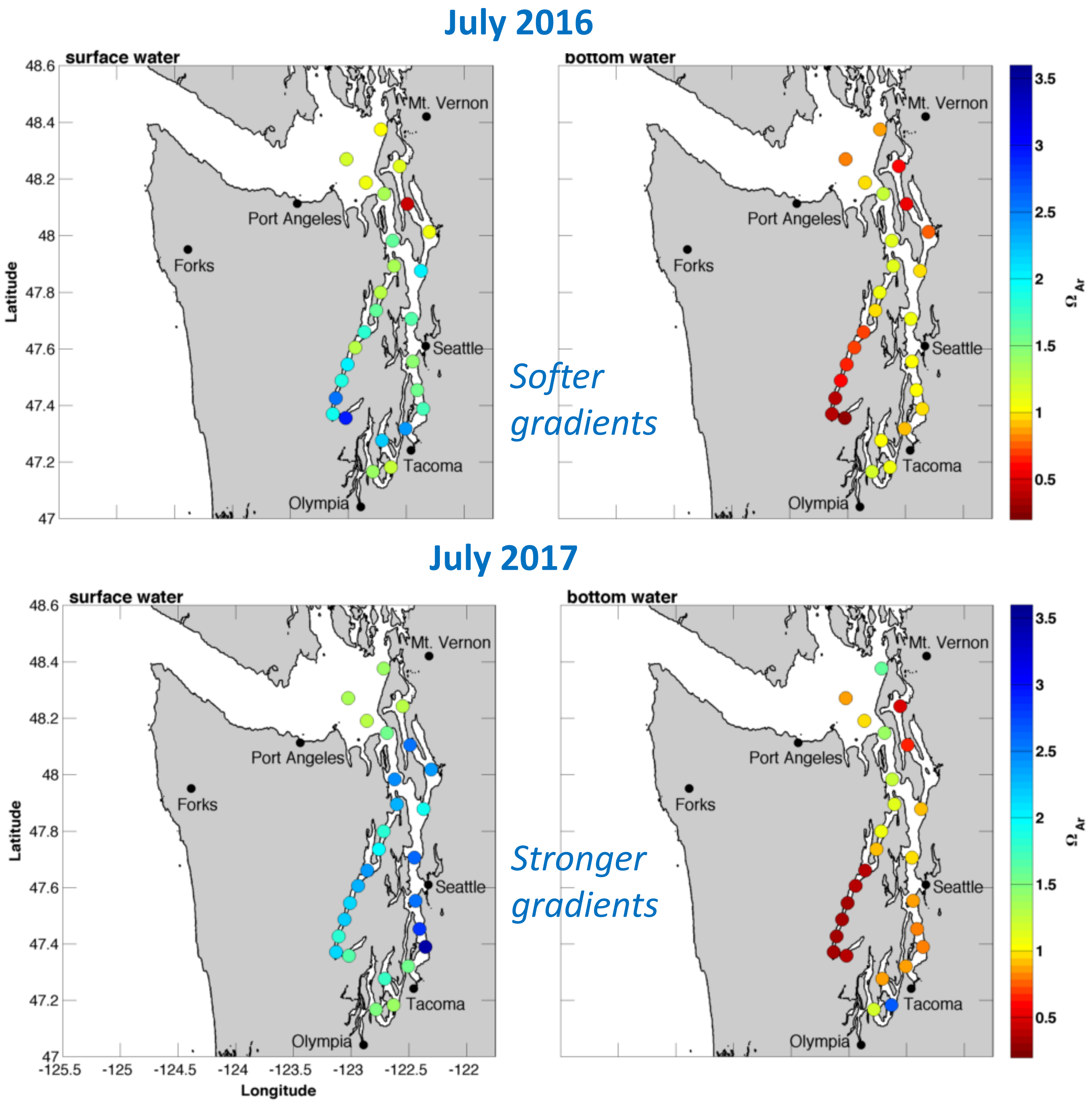
Variation, in summary

- **Depth**: In general, deep omega < surface omega
  - Except for fall in Hood C where surface omega < deep omega
    - Timing varies and is linked to density-driven flushing
  - Except for well mixed times/areas
    - Generally fall-spring, though timing varies by basin
- **Basin**: In general, Hood C and Whidbey B have lowest omega
- **Season**: In general, it depends!
- **Interannual** variation is also a factor



Interannual variation is not trivial

- Late or early seasonal flushing, with uplift of low omega waters, and differences in density gradients driving flushing dynamics may contribute to interannual differences.



Interannual variation is not trivial

- Differences in climate variables, such as solar radiation fueling production/respiration or streamflow fueling stratification, may also contribute to interannual variation.

Conclusions

- Variation in omega aragonite over depth, between basins, and among seasons is large in WA waters, particularly so in the Salish Sea.

- Coastal and localized upwelling, basin water renewal dynamics, bloom/respiration strength and timing, and stratficiation/mixing all play a major roles.

- Biological exposure to low omega varies substantially over all scales. Experimental design and biological impact assessments must account for this variable exposure.