VALIDATING ROMS-BEC FOR ANTHROPOGENIC NUTRIENT APPLICATIONS

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On Behalf of Colleagues From

How Uncertain Are Our Model Findings?

Applications of ROMS-BEC has the potential to support decisions on nutrient management

…with billion-dollar implications

*Managers need **clear communication on model uncertainty** to use it for decision support*

Two Parts of Model Validation

Testing, sensitivity analysis of model parameters

Curtis covered last week, and we presented some again this morning

Model performance assessment

Curtis covered our west coast work last week

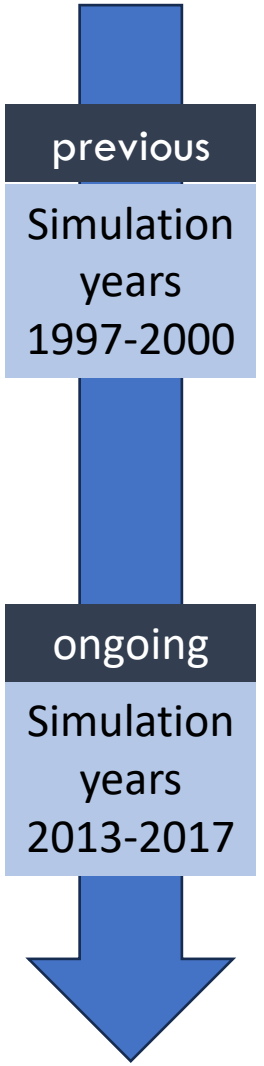
Bight-focused work covered in this talk

Goal of This Talk

- To summarize our previous approach to performance assessment in the Bight

  Overview of detailed information found in the *Kessouri et al 2021 Journal of Advances in Modeling Earth Systems* [doi.org/10.1029/2020MS002296](doi.org/10.1029/2020MS002296)

- Highlight ongoing work that expands on this approach with…
  - Recent time-period
  - New data types



PERFORMANCE ASSESSMENT: OUR APPROACH FEATURED TWO MAJOR COMPONENTS

1. Qualitative synthesis of what model tells us about ecosystem function and whether those ideas have scientific consensus in the published literature

2. Quantitative comparison of model predictions against observations of state and rates of physics, biogeochemistry, and plankton

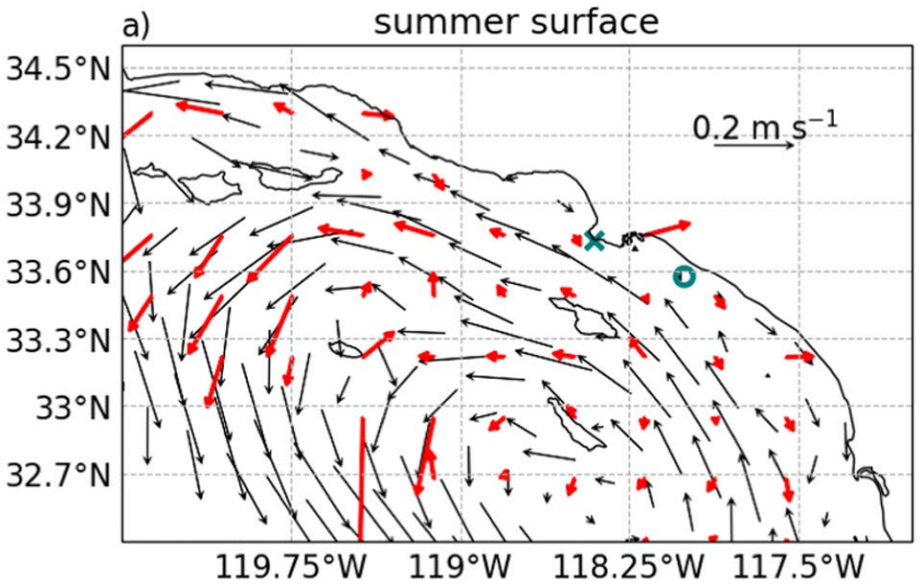
"does model give us the right answer for the right reason?"

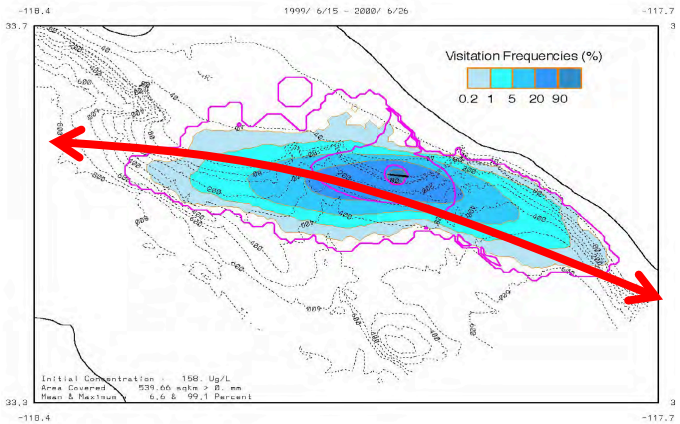
Qualitative Synthesis Compared model to published literature

Ocean physics

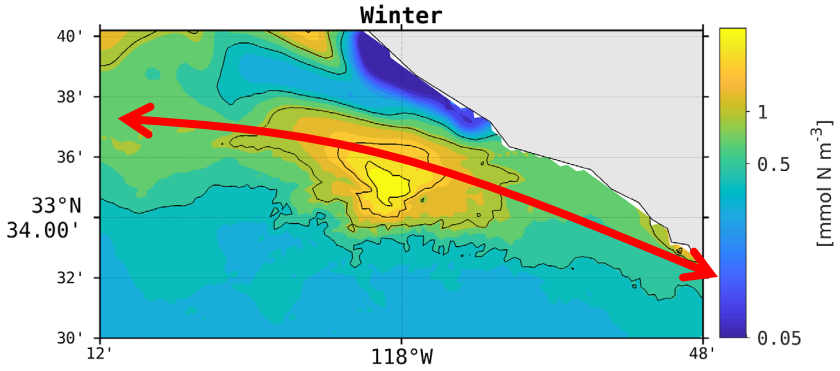
- Ocean circulation features (upwelling, currents, fronts, jets, eddies and tides, etc.)
- Mechanistic controls on vertical mixing, including around outfall pipes

Simulated (black) currents variability, intensity and direction match **observed data (red)**





Observed visitation frequencies of OC San outfall plume in 1999 (Tetra Tech 2002)



Simulated ammonium concentration from OC San outfall plume in 1999

Qualitative Synthesis Compared model to published literature

Ocean physics

- Ocean circulation features (upwelling, currents, fronts, jets, eddies and tides, etc.)
- Mechanistic controls on mixed layer depth, including around outfall pipes

Controls on nutrient transport and seasonal and interannual patterns in primary production

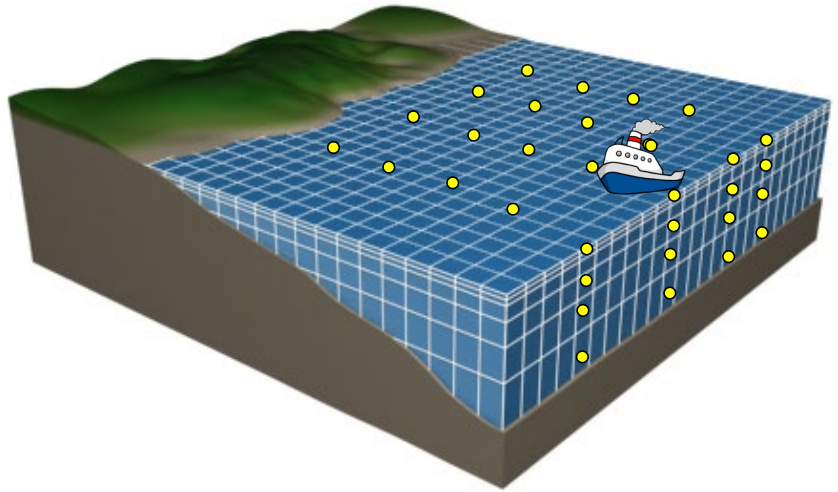
- Spatial gradients and seasonality in dissolved nitrogen
- Magnitude of phytoplankton blooms and what is controlling them (light, nutrients, etc.)

Patterns in oxygen and pH

- Trends in surface and subsurface O_2 and pH and inshore versus offshore gradients

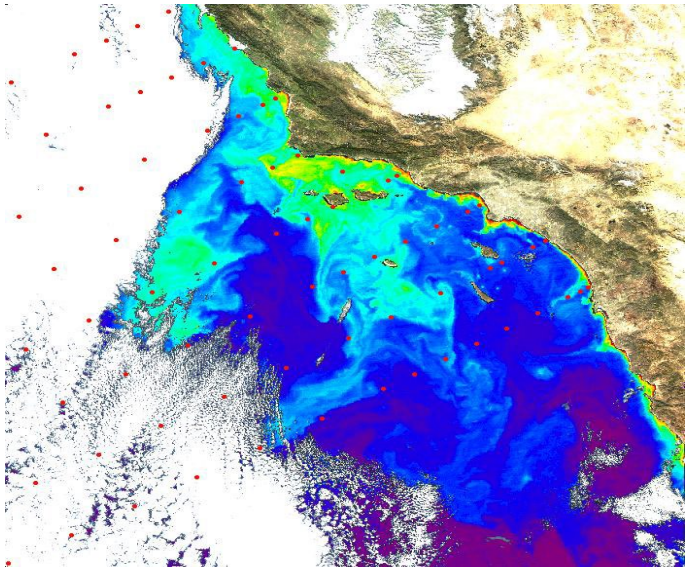
Approach for Quantitative Comparisons

- Data sources
- State and rate variables
- Spatial and temporal gradients of comparison
- For each comparison of predicted versus observed, judge performance



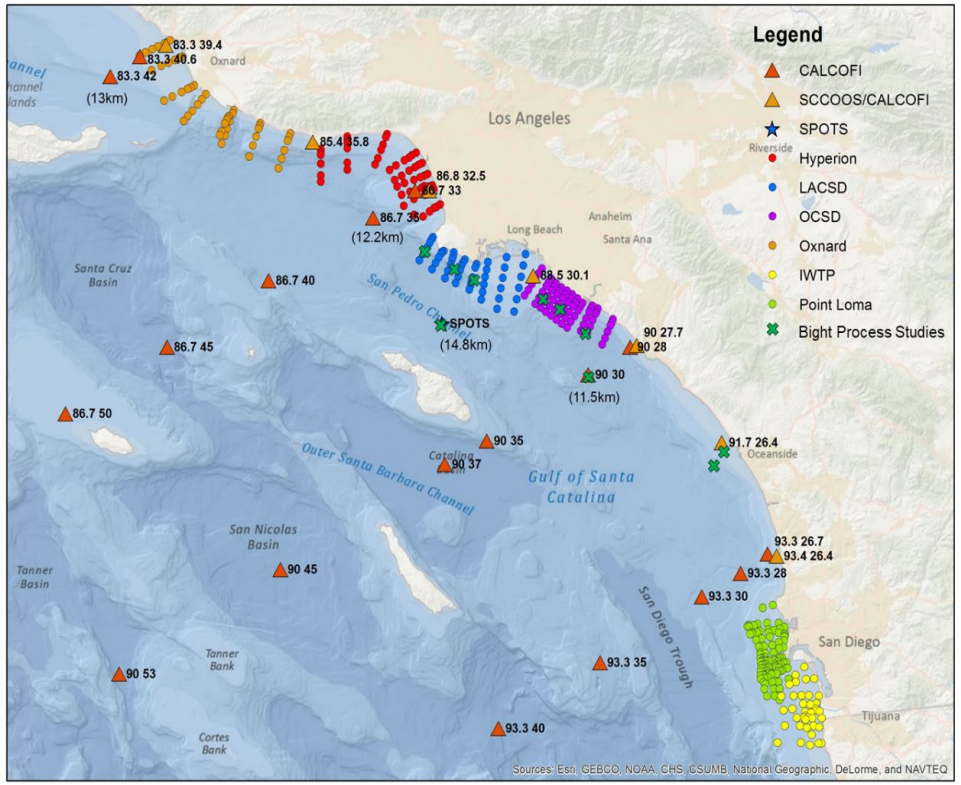
THREE SOURCES OF DATA FOR QUANTITATIVE ASSESSMENT

REMOTE SENSING



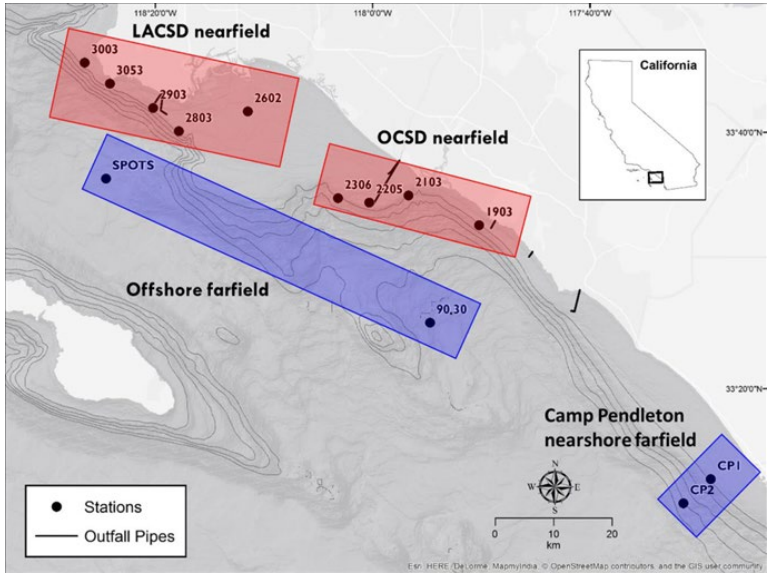
https://oceancolor.gsfc.nasa.gov/SeaWiFS/

QUARTERLY CTD SURVEYS



Schiff, K., et al., 2016. Southern California bight regional monitoring. doi.org/10.1007/s00267-001-2628-9.

SPECIAL STUDIES (BIGHT REGIONAL MONITORING PROGRAM)



E.g. Sampling stations for process studies to measure nitrogen transformations

From McLaughlin et al. 2021 doi.org/10.1525/elementa.2020.00145

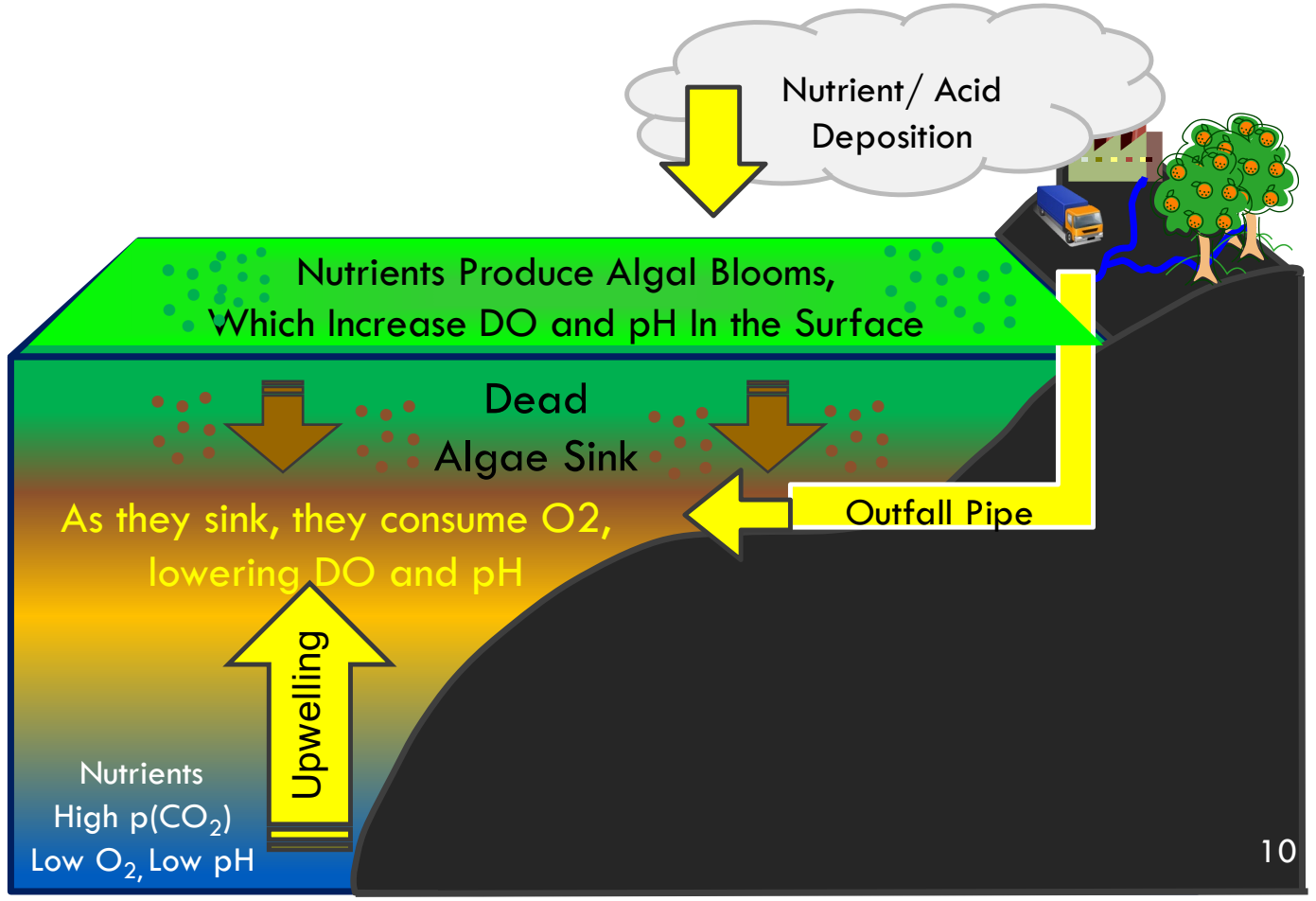
Four Categories of Ocean Variables of Interest

Ocean physics

Nutrients (nitrogen is the limiting nutrient)

Phytoplankton

Oxygen & Carbonate System (e.g., pH, omega aragonite)



INDICATORS OF OCEAN STATE & RATE

Ocean Physics

- Temperature

Nutrients

- Nitrate
- Ammonium
- Nitrification
- Nitrate uptake
- Ammonium uptake

Plankton

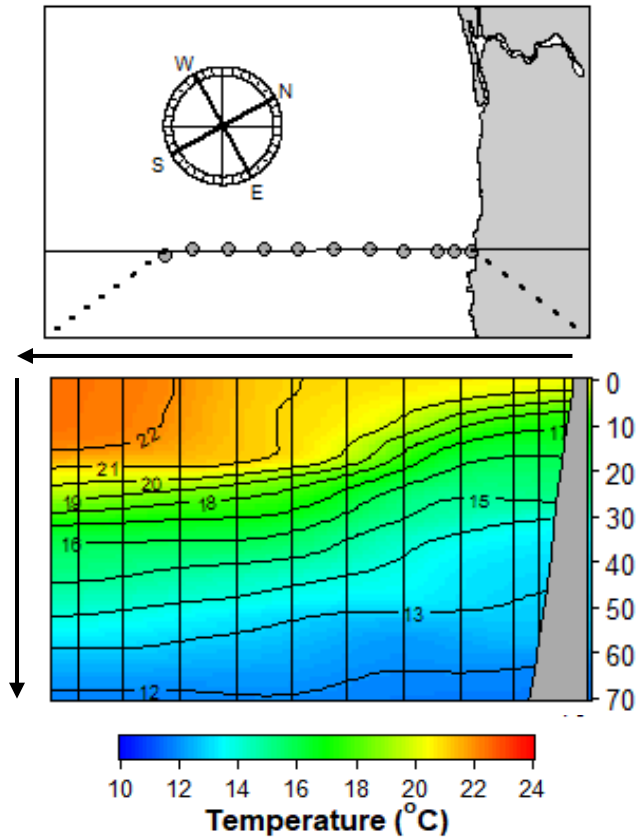
- Chlorophyll-a
- Primary production
- Phytoplankton growth
- Zooplankton grazing

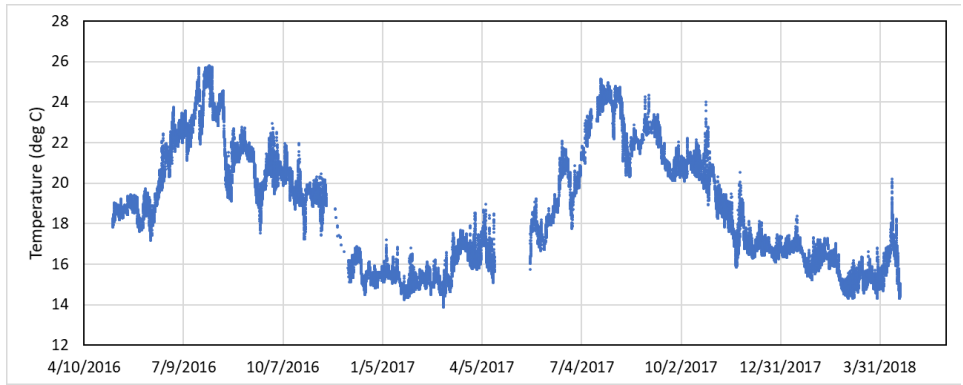
Oxygen & carbonate cycling

- Dissolved oxygen
- pH
- Omega aragonite

Agreement to Prioritize Data-Model Comparisons on these Scales

- Vertical
  - Algal blooms at the surface
  - Declining oxygen and pH at depth
- Plume scale
  - Plume "tracers" are intensified near point sources
- Monthly to seasonal to interannual time-scales
  - Well mixed water column in winter; stratification in summer
  - Interannual climate states (e.g. El Nino, warming etc.)
- Alongshore and cross-shore
  - Primary production is consistently elevated inshore and greatest near locations of nutrient inputs
- Events

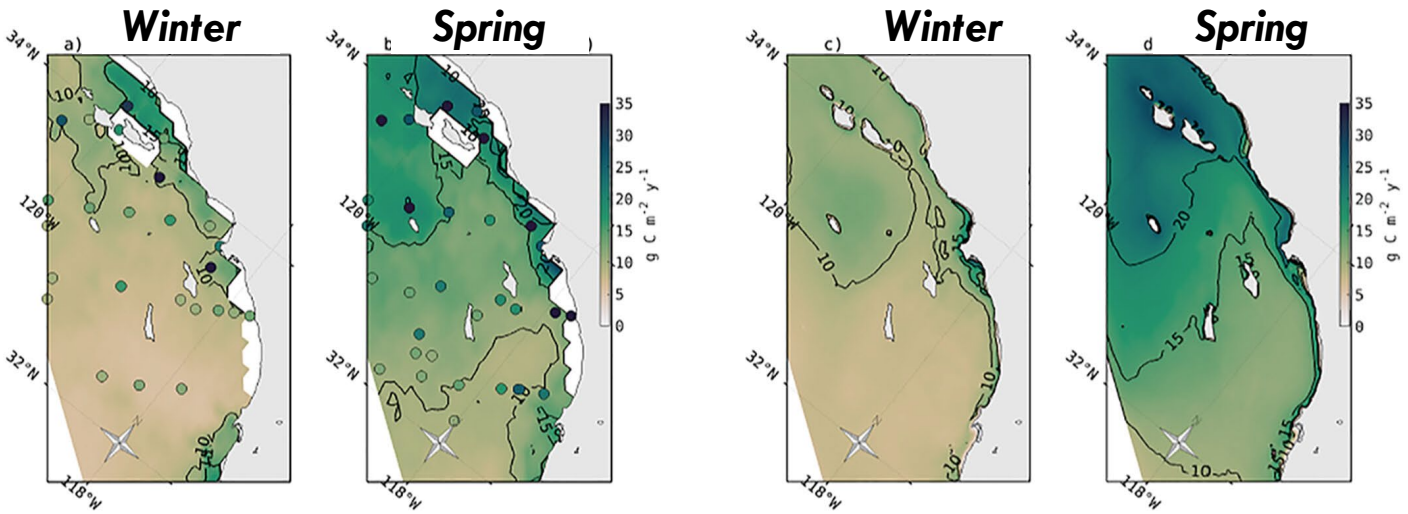


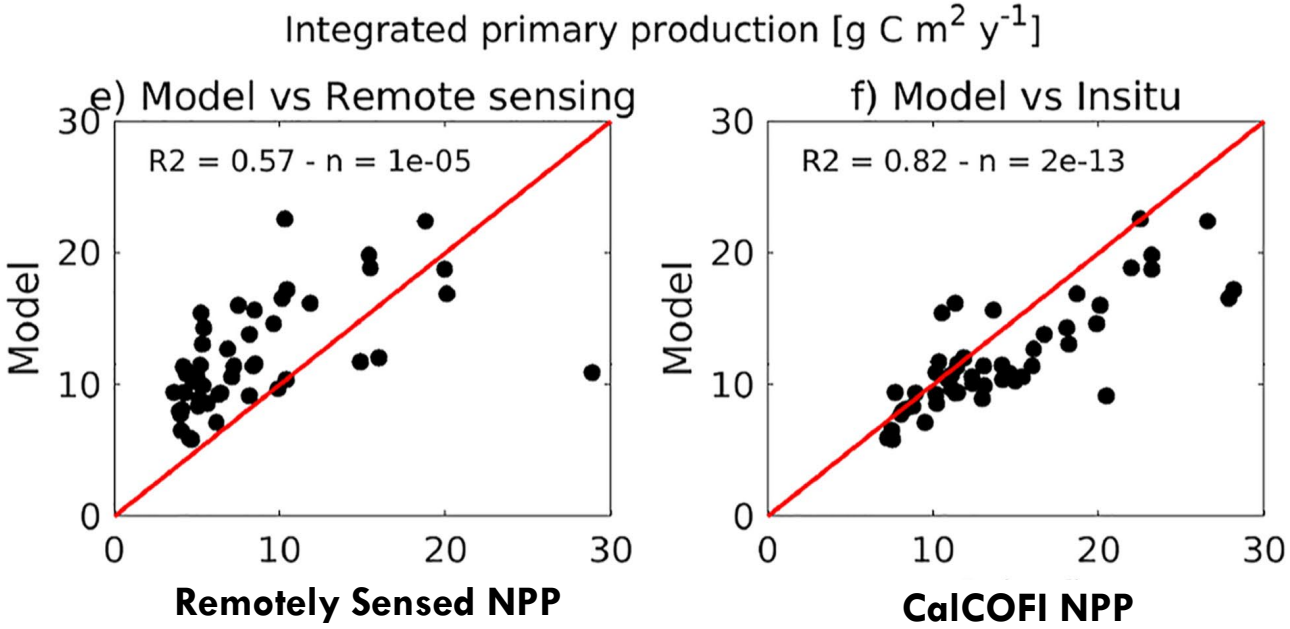


USED REMOTE SENSING AND CALCOFI DATA TO LOOK AT HORIZONTAL GRADIENTS IN NET PRIMARY PRODUCTION RATES (NPP)

CalCOFI data**, superimposed on maps of **remotely sensed NPP

Maps of Modeled NPP

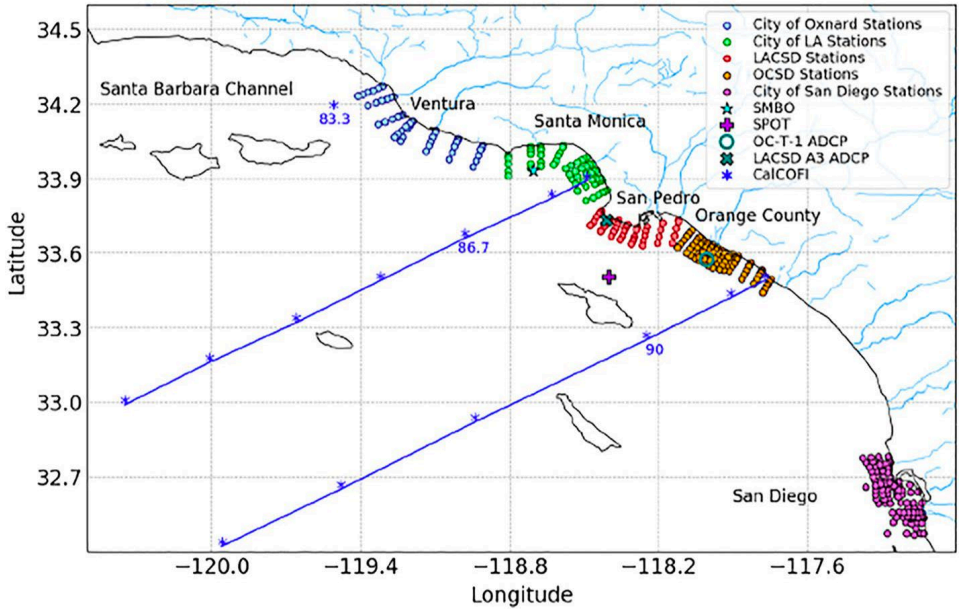


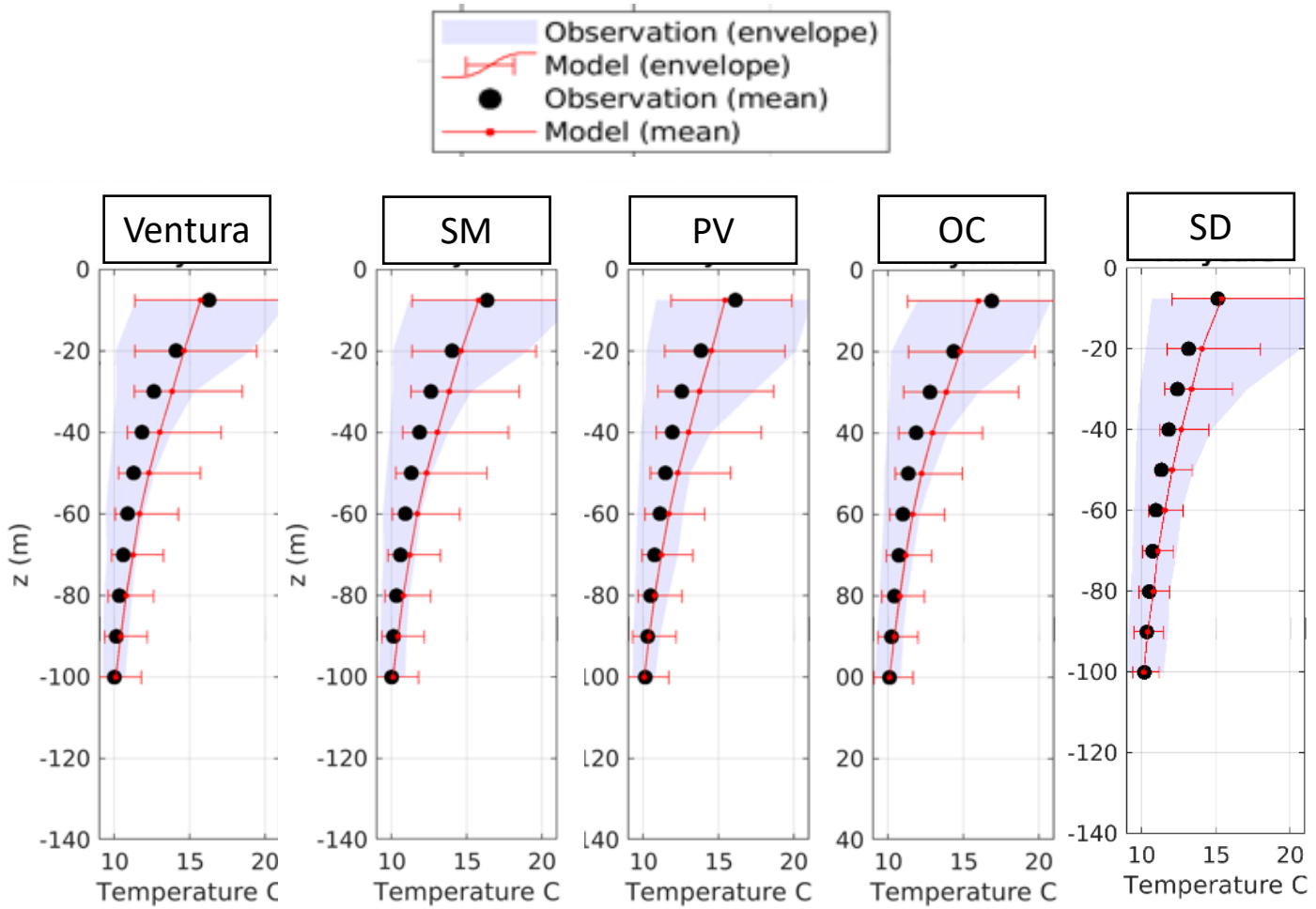


To look at Vertical Profiles, We developed a Methodology for Quantifying Performance from Quarterly Survey Data

We extracted the model and processed the statistical analysis by subregion

Geographical view at the monitoring subregional stations





For Each Profile, We calculated Six metrics that Scores Performance

Correlation : shape of the profile

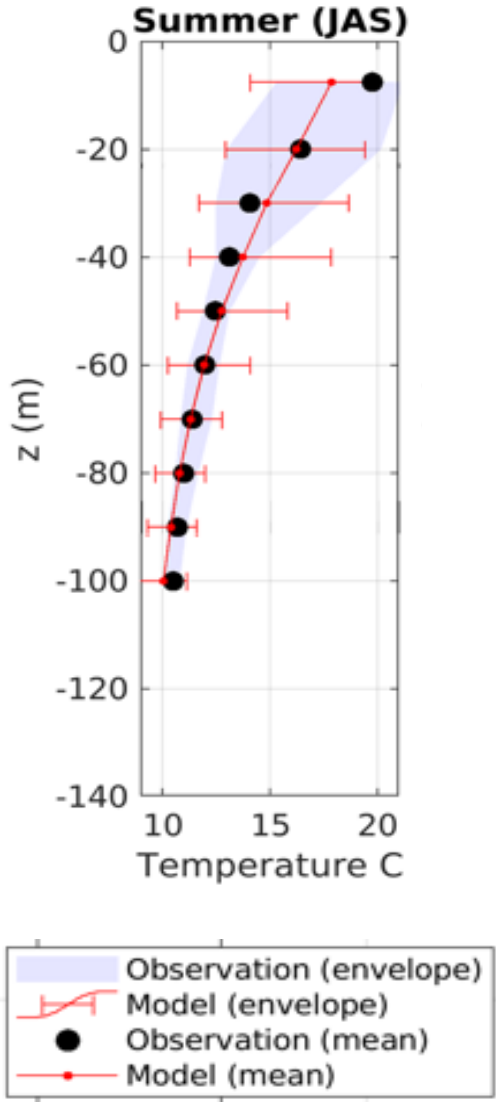
Cost function : goodness of the fit

Ratio of standard deviations : departure from the mean

Percentage bias: under/over estimation

H: t-test of the mean

Nash-Sutcliffe (model Eff.): ratio of model error to data variability



And We Used An Objective Means to Score the Performance

Remember the color-coded scoring, because you will see it later

Statistic	**E**xcellent	**G**ood	**R**easonable	**P**oor
Cost Function	<1	1-2	2-5	>5
Nash Sutcliff Model Efficiency	>0.65	0.65-0.5	0.5-0.2	<0.2
Percentage Bias	<|0.1|	|0.1-0.2|	|0.2-0.4|	>|0.4|
H	0			1
Correlation Coefficient	1-0.9	0.9-0.8	0.8-0.6	<0.6
Ratio of standard deviations	1-0.9, 1-1.1	0.9-0.8, 1.1-1.2	0.8-0.6, 1.2-1.4	<0.6, >1.4

Based on the work of Allen et al., 2007 https://doi.org/10.1016/j.jmarsys.2007.01.005

PERFORMANCE ACROSS STATE VARIABLES

We looked at annual average, subregional and seasonal scales to assess performance

E: Excellent	G: Good	R: Reasonable	P: Poor

Performance by State Variable (1997-2000)					
	Temperature	NH4	Chl-a	O2	pH
Correlation	E	G	E	E	E
Bias	E	E	R	E	G
Deviation ratio	E	G	E	E	R
Cost function	E	G	E	E	E
Nash Sutcliffe function	E	R	E	E	G
H	E	G	G	E	G

Overall, the model typically scored excellent to good on annual time scales

Variability in performance of individual state variables

PERFORMANCE ACROSS STATE VARIABLES

State variables that received extra attention and discussion…

- pH
- Ammonium
- Chlorophyll-a

In each case, we investigated to understand the problem.

If it was modeling bias (e.g. incorrect inputs), then we corrected and reran model before we published

In multiple cases, it was a field data quality issue

EXAMPLES OF DATA QUALITY ISSUES AND APPROACH TO FIX IT

Chlorophyll-a

- Data sets from 2 decades ago had calibration issues

Solution: After 2009, community worked on intercalibration & upgrades to sensor technology

pH

- potentiometric has poor precision (± 0.4), so our chemists advised us not to trust its use in an assessment

Solution: invest in new high quality bottle data (± 0.05)

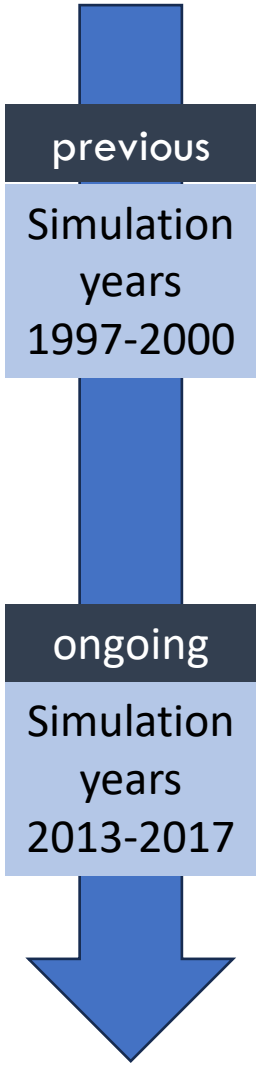
Goal of This Talk

- Provide a summary of our previous approach to performance assessment in the Bight

Overview of detailed information found in the Kessouri et al. JAMES 2021 paper

doi.org/10.1029/2020MS002296

- Highlight ongoing work that expands on this approach with…
  - Recent time-period
  - New data types



Approach to Ongoing Performance Assessment

Repeat "Core set" of Analyses on recent time period (2013-2017) as a check on overall performance

- Quarterly data to look at seasonal, subregional and vertical gradients

New Improved Data Types, Spatial and Temporal Scales of interest

- **E.g., New** high quality **pH data** set
- **E.g., Time series** to look at events on seasonal, interannual/decadal timescales

OVERALL, PERFORMANCE IS AS GOOD OR BETTER THAN PREVIOUS ACROSS ALL VARIABLES

EXAMPLE CHLOROPHYLL-A ACROSS SUBREGIONS

1997-2000 PERFORMANCE ASSESSMENT

	Ventura	Santa Monica	Palos Verdes	Orange County	San Diego
Correlation	E	E	E	E	E
Bias	E	E	P	P	P
Deviation ratio	R	R	E	P	P
Cost function	E	E	E	E	G
Nash Sutcliffe function	G	E	E	G	P
H	E	E	E	P	P

Empirical estimation from fluorescence

2013-17 PERFORMANCE ASSESSMENT (PRELIMINARY)

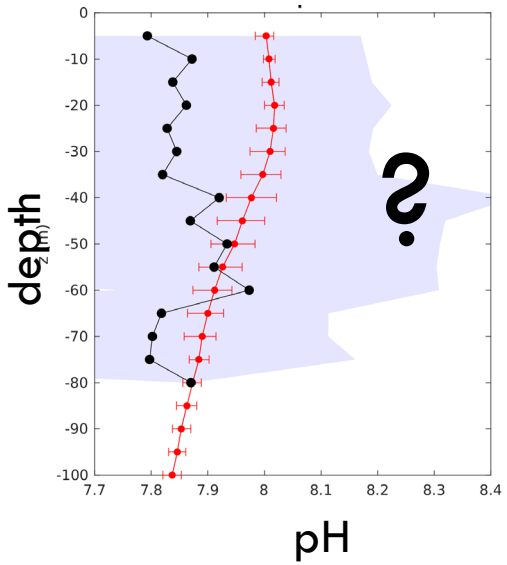
Ventura	Santa Monica	Palos Verdes	Orange County	San Diego
G	G	E	R	E
R	R	R	G	R
E	E	G	G	E
E	E	E	E	E
E	E	G	E	E
E	E	E	E	E

Method based on voltage

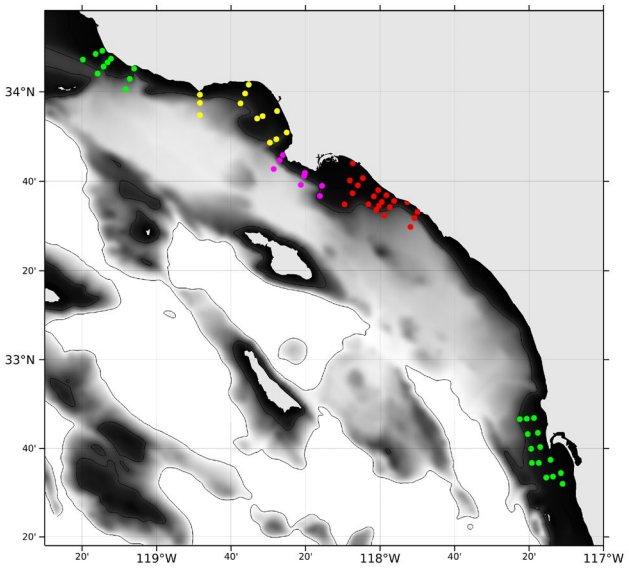
E: Excellent	G: Good	R: Reasonable	P: Poor

NEW pH DATA SET PROVIDED OPPORTUNITY TO REASSESS PERFORMANCE USING HIGH QUALITY BOTTLE DATA

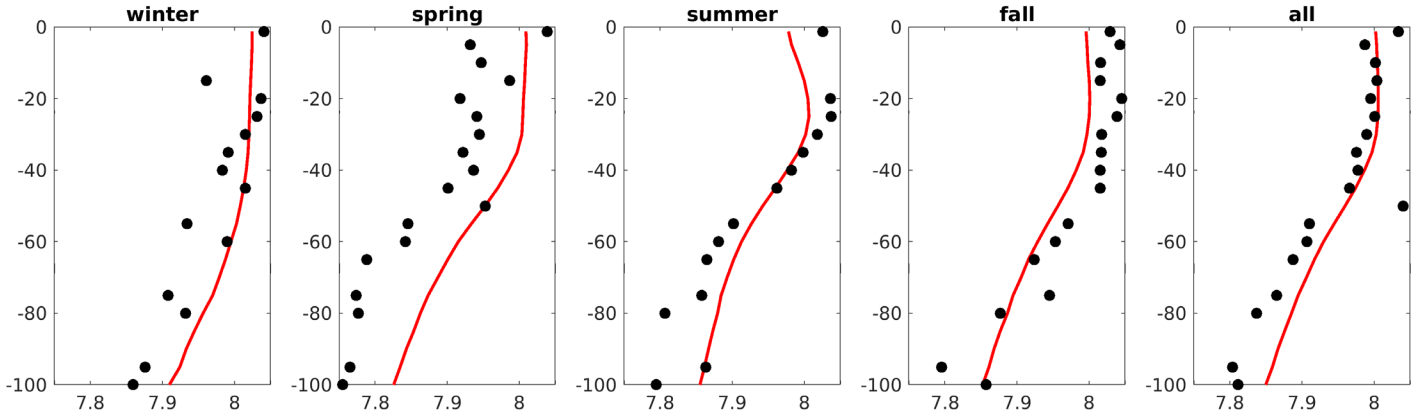
Reminder: Previously, we used potentiometric profiles, with large measurement error (+/- 0.4)



New pH monitoring data



Now, with new bottle data observations, we can assess performance across regions and seasons



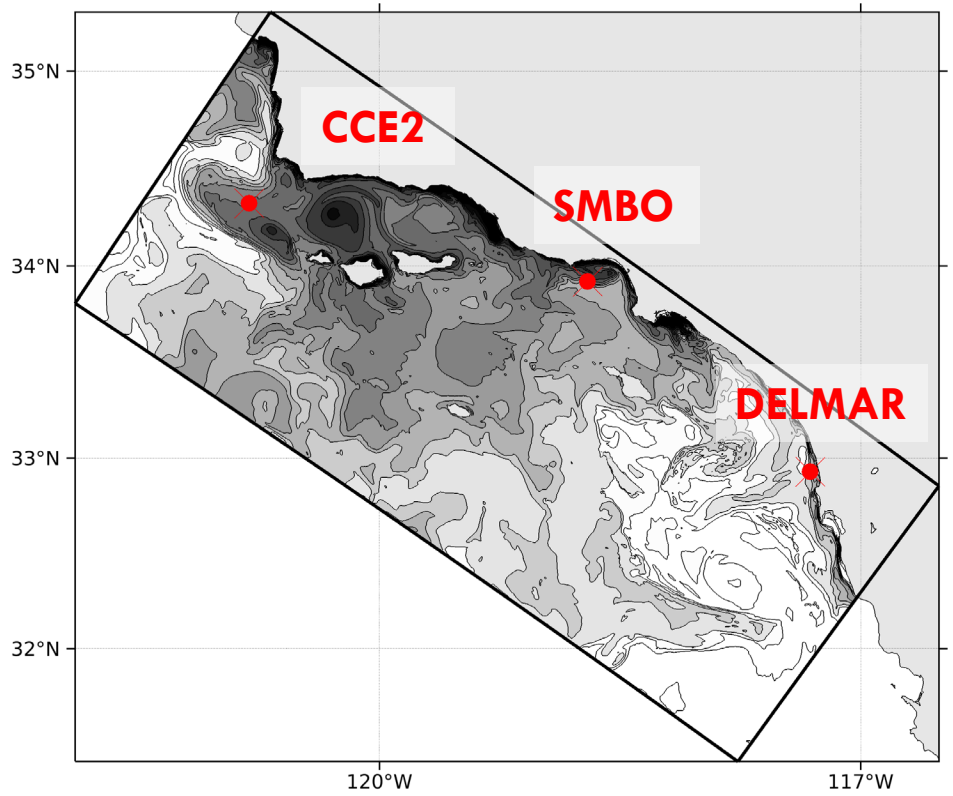
Measurement error = +/- 0.05

Observations in black
Model in red

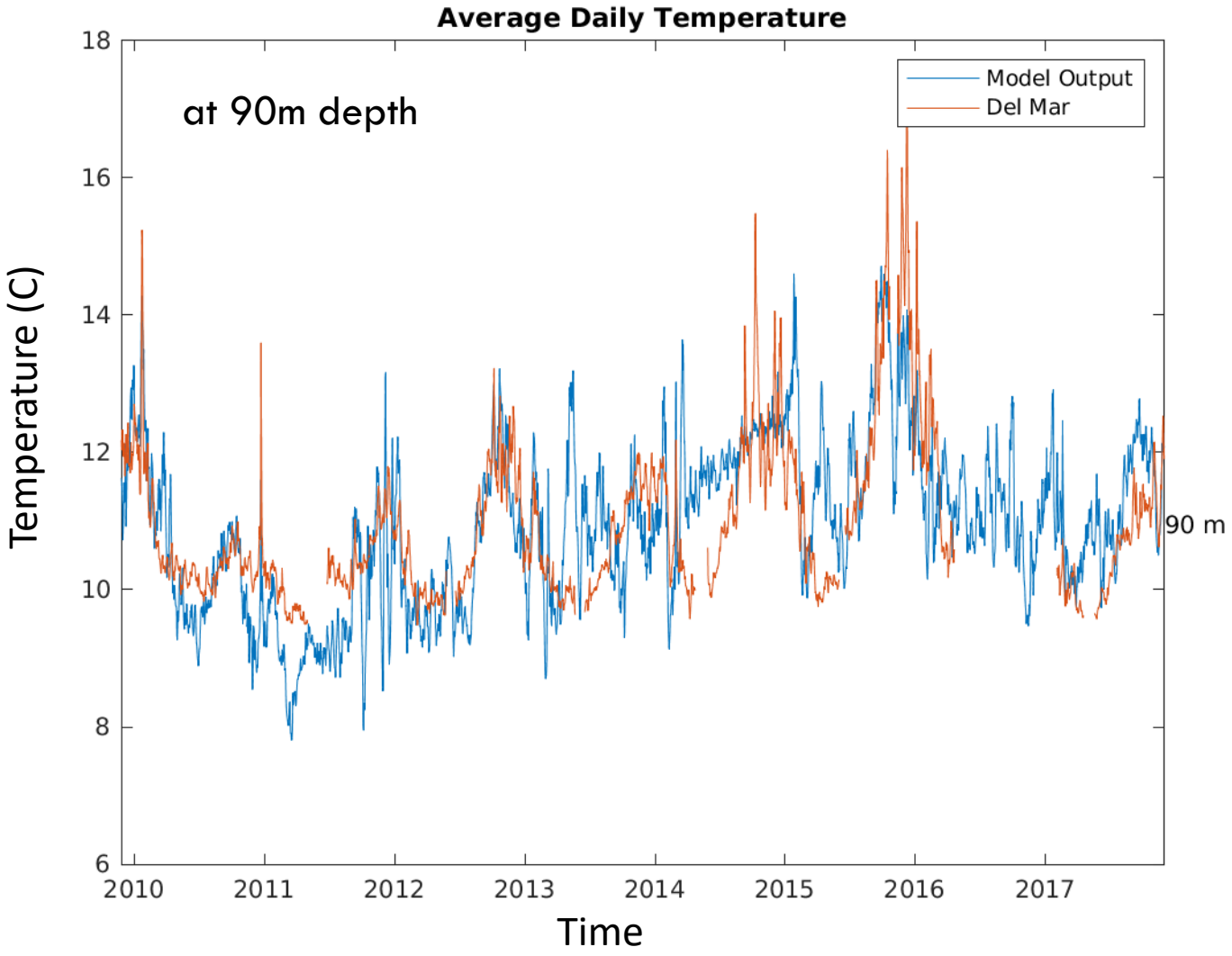
We have Two Types of time Series Data

- Moored sensors
  - We have three that are suitable for analysis
  - We are discussing performance criteria for these with partners

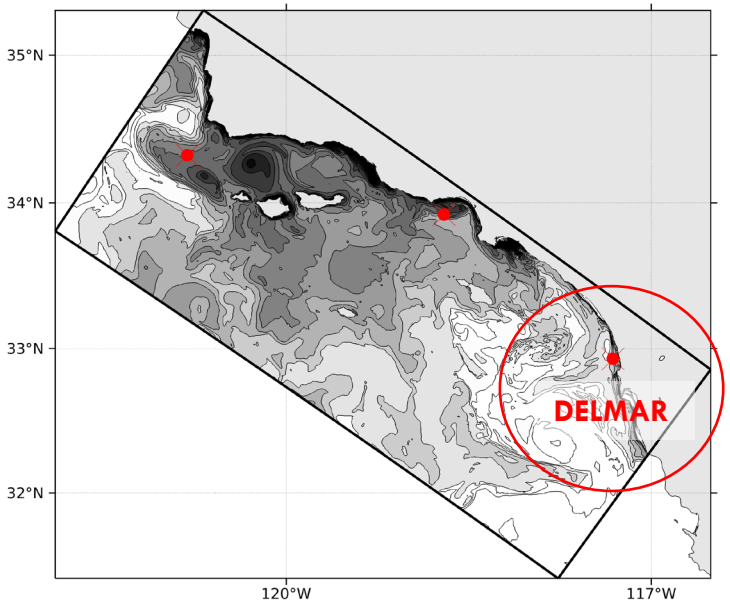
- Quarterly data over 20 years



EXAMPLE OF MOORED SENSOR TIME SERIES COMPARISONS



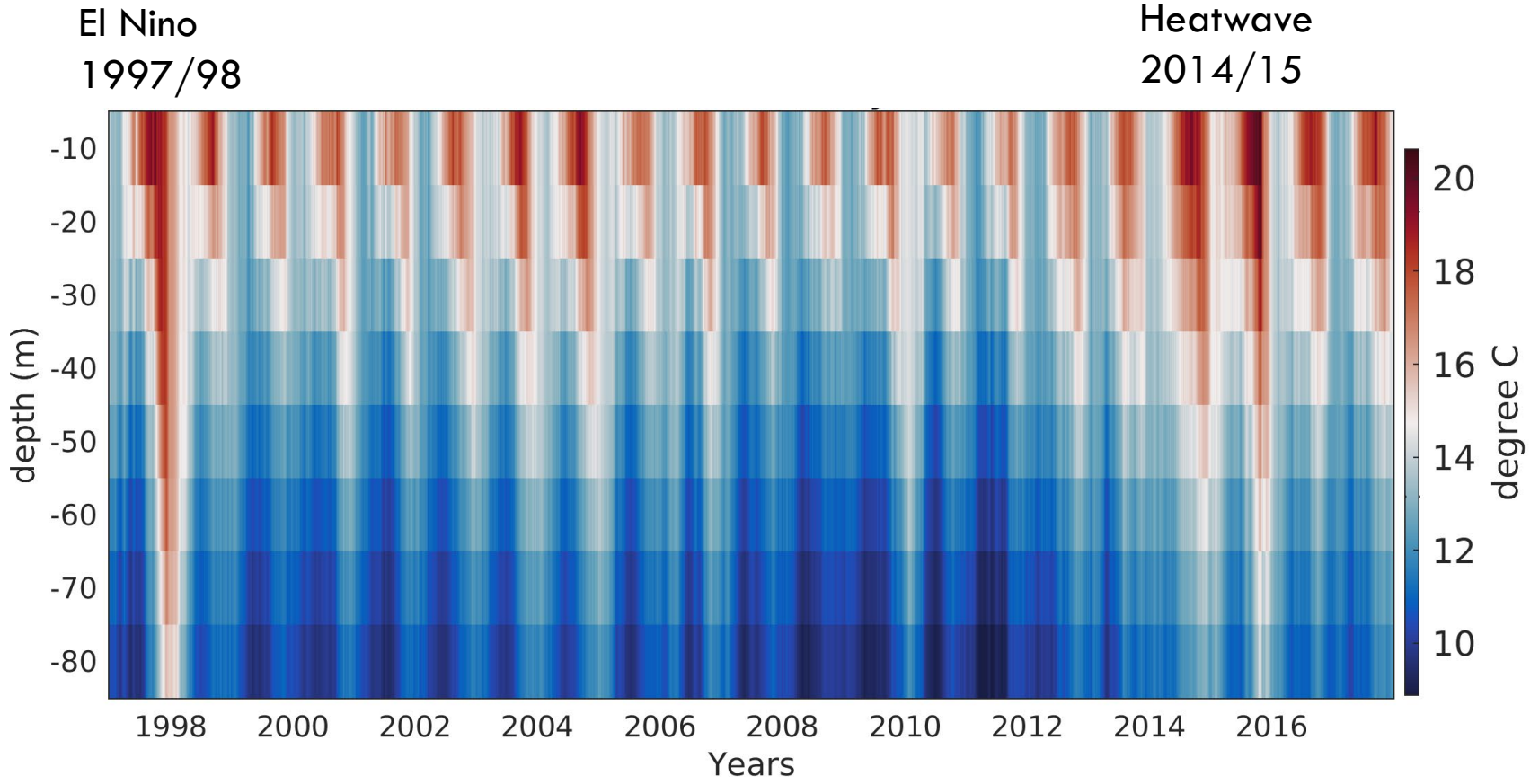
[Work in progress….We are discussing performance criteria and scoring for these comparisons]



WITH 20 YEARS OF MODEL SIMULATIONS, WE CAN LOOK AT PERFORMANCE OF MODEL IN CAPTURING INTERANNUAL CLIMATE STATES AND "EVENTS"

Qualitative validation:

Modeled temperature, averaged Bightwide: Is the capturing recently documented climate events?

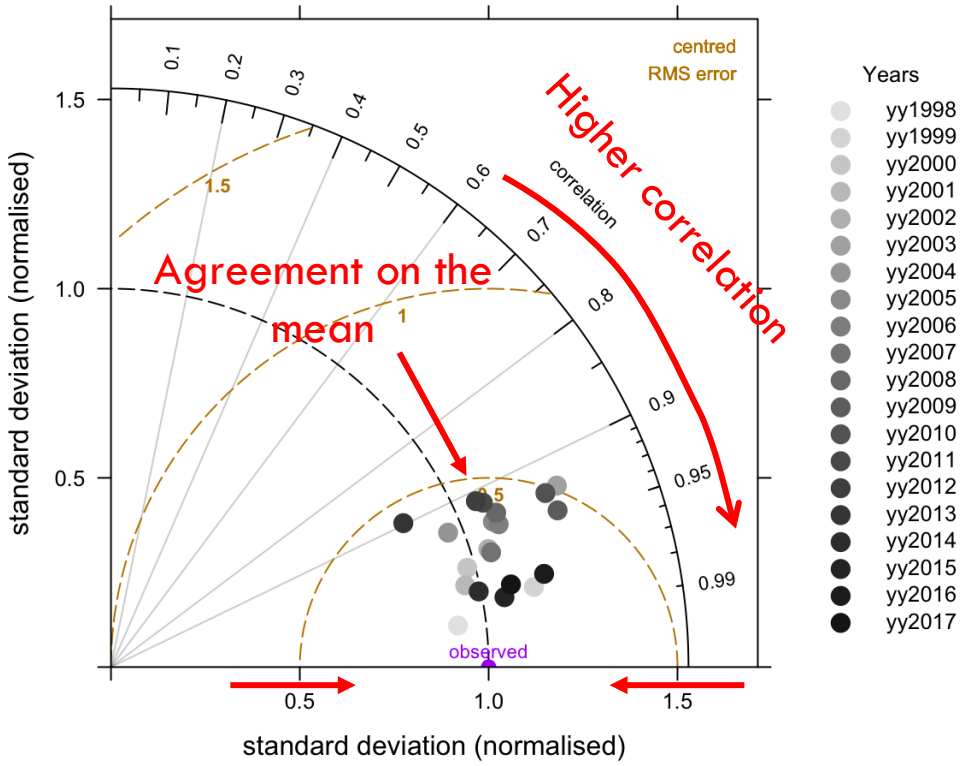


WITH 20 YEARS OF QUARTERLY DATA, WE CAN ASSESS HOW MODEL CAPTURES DIFFERENT OCEAN CLIMATE STATES IN OBSERVED VERTICAL GRADIENTS

Quantitative validation:
Preliminary synthesis on model performance assessment across two decades shows that the model is overall performing well on every single year

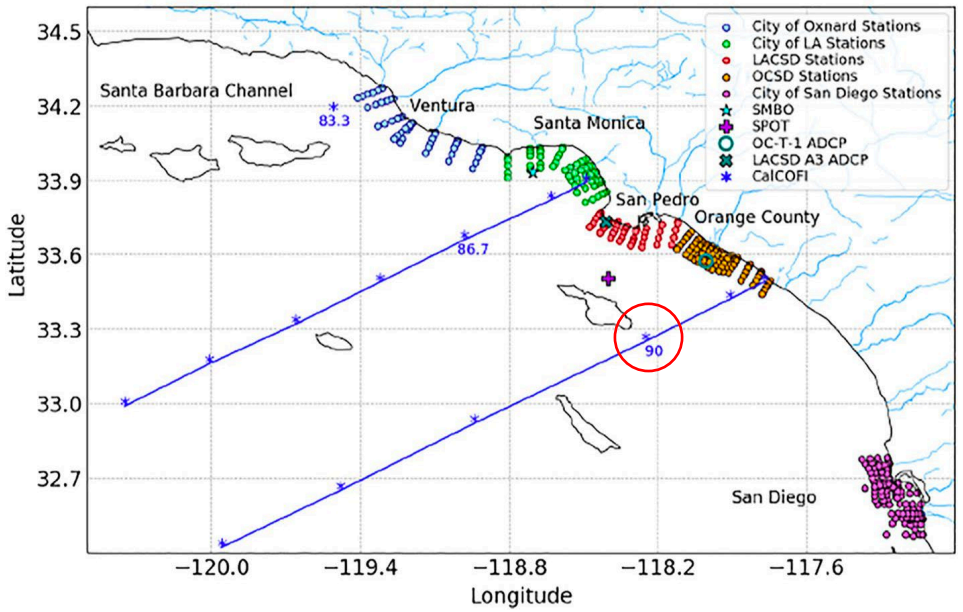
Results are equivalent for oxygen

Temperature

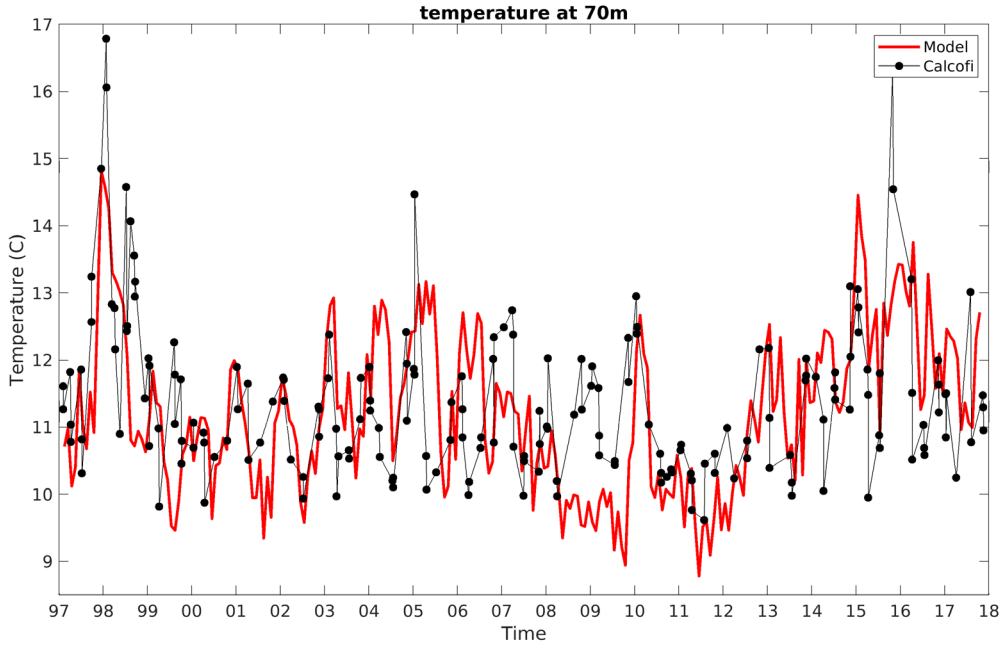


Agreement on the variability

WE CONTINUE TO MINE QUARTERLY DATA TO LOOK AT TIME SERIES AT STATIONS OF INTEREST



Example: Offshore Line #90



Profile Metric Scoring	Station 90
Correlation (0.98)	E
Bias (0.04)	E
Deviation ratio (1.05)	E
H (0)	E

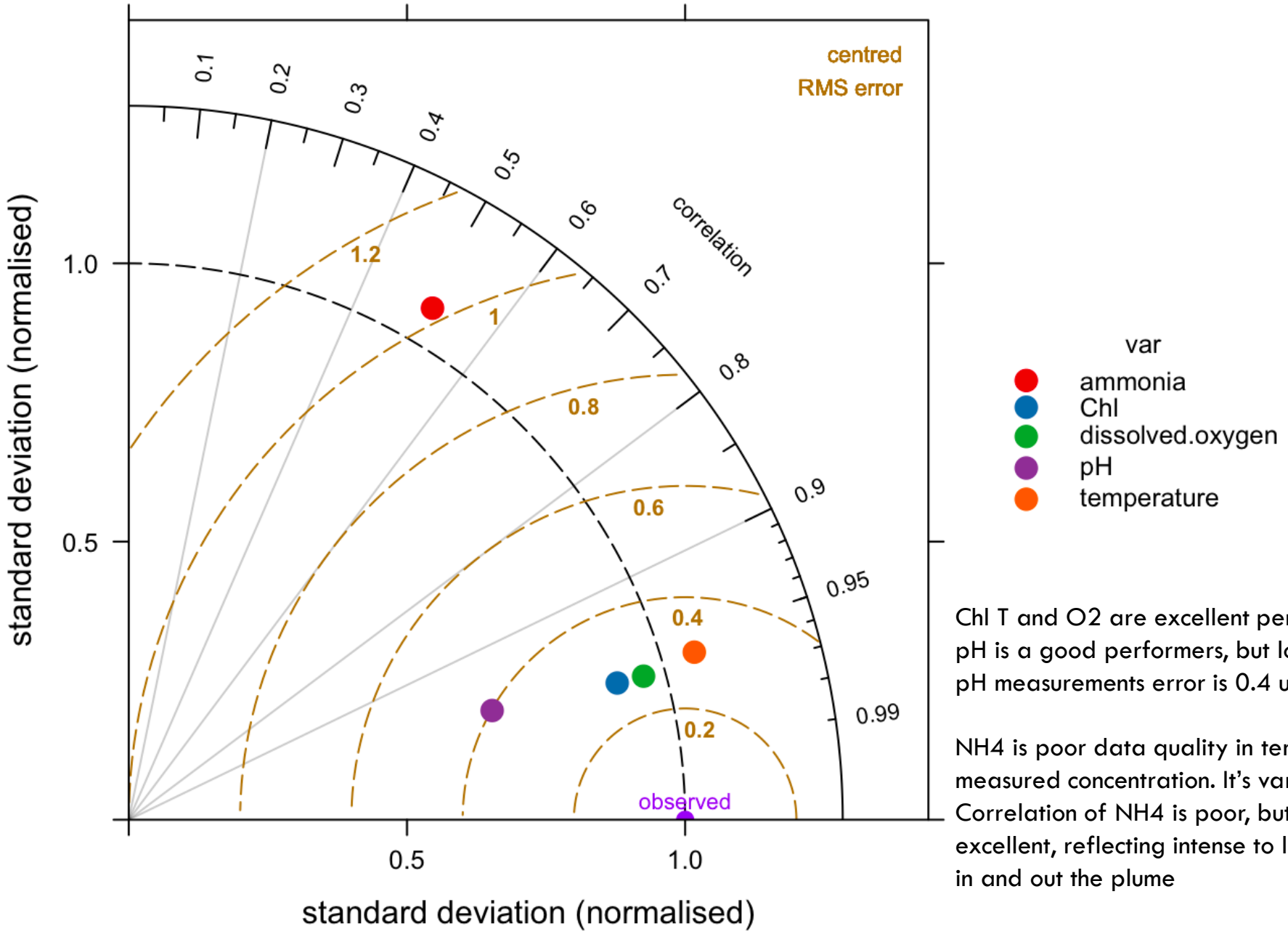
Next Steps

- With partners, develop quality assurance screens and clean up procedures to use field data for performance assessment
- Identify key graphics of most interest (to Panel or to stakeholders)
- Decide on appropriate documentation

QUESTIONS? COMMENTS? FEEDBACK?

Fayçal Kessouri faycalk@sccwrp.org

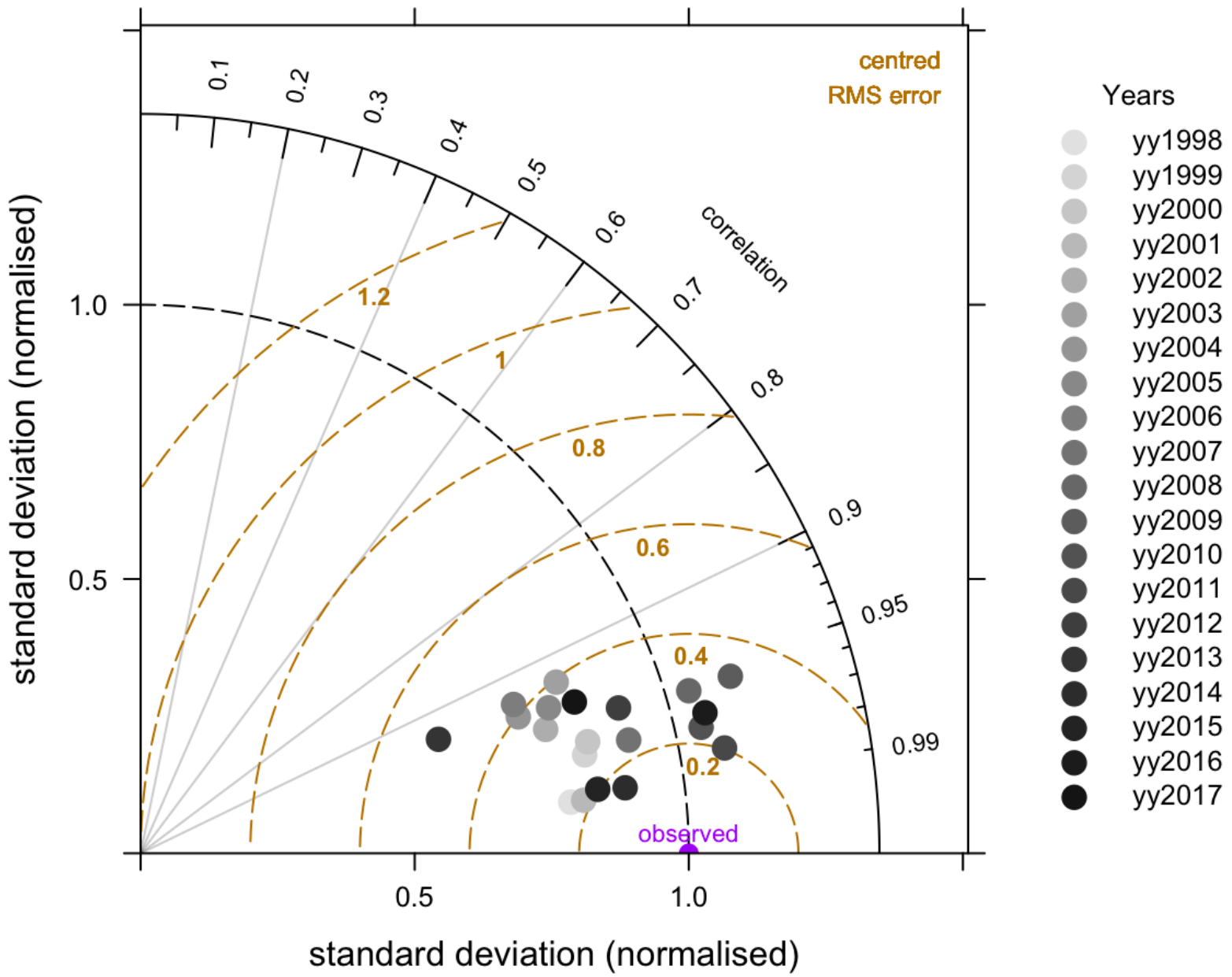
Pocket slides



Chl T and O2 are excellent performers
pH is a good performers, but low confidence because pH measurements error is 0.4 units

NH4 is poor data quality in term of absolute measured concentration. It's variability can be useful. Correlation of NH4 is poor, but its variability is excellent, reflecting intense to low gradients captures in and out the plume

Dissolved Oxygen



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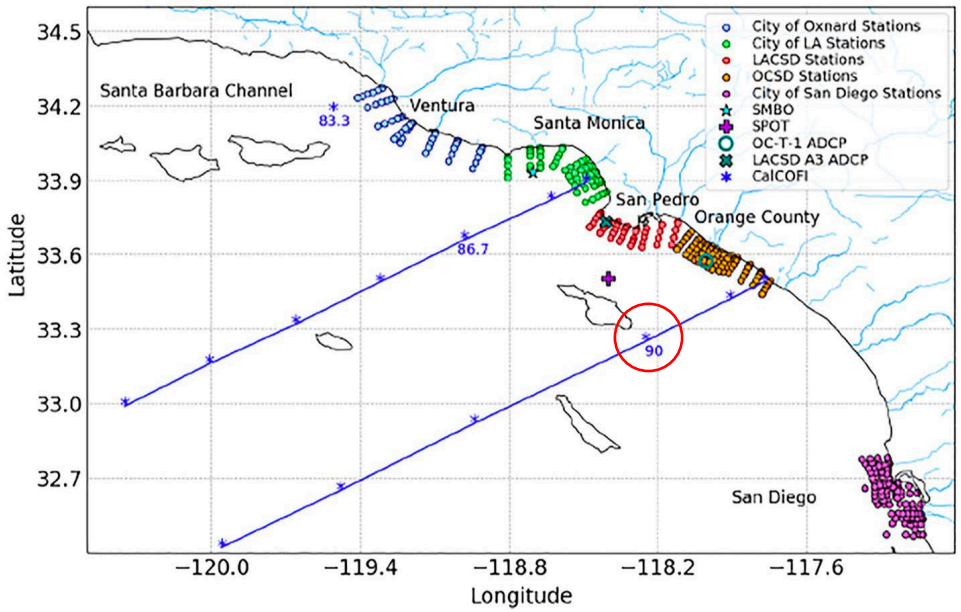

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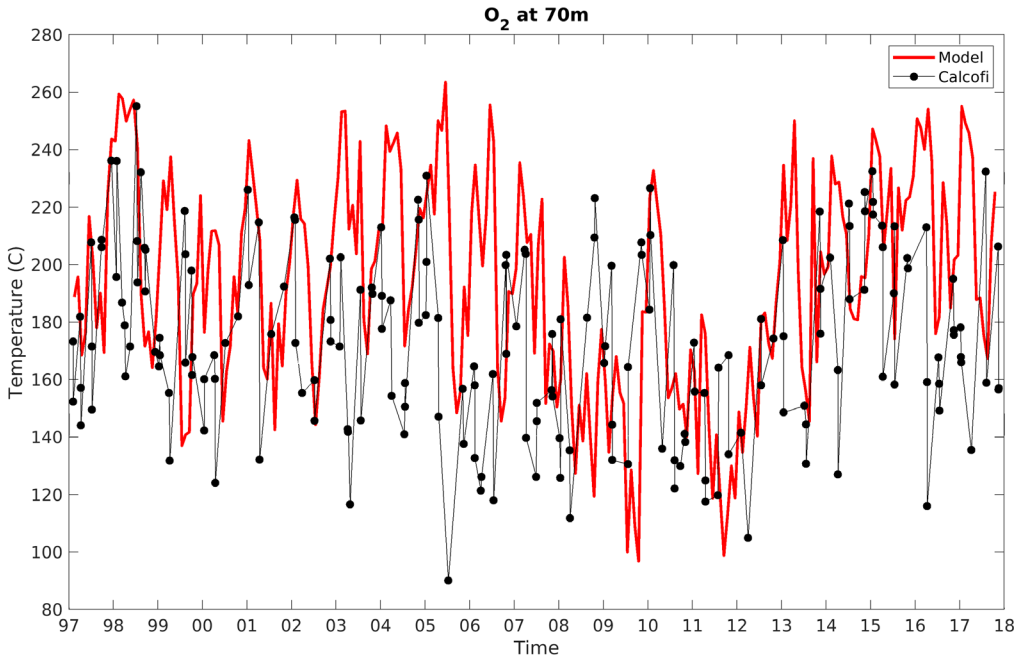

Profile Metric Scoring	Station 90
Correlation ()	E
Bias ()	E
Deviation ratio ()	E
H ()	E