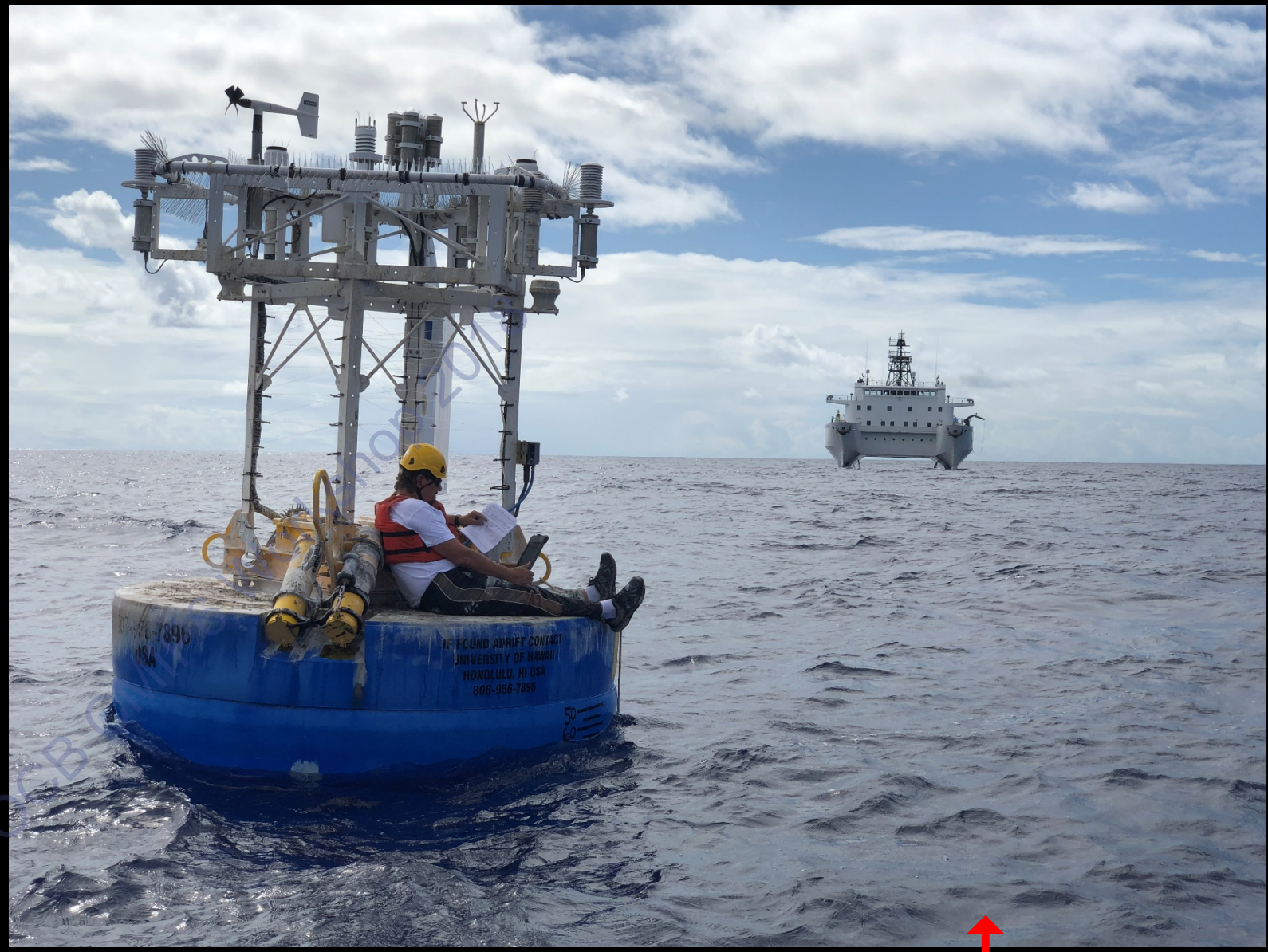
Magnitude and timing of ocean carbon uptake variability constrained by seawater pCO_2 time series observations

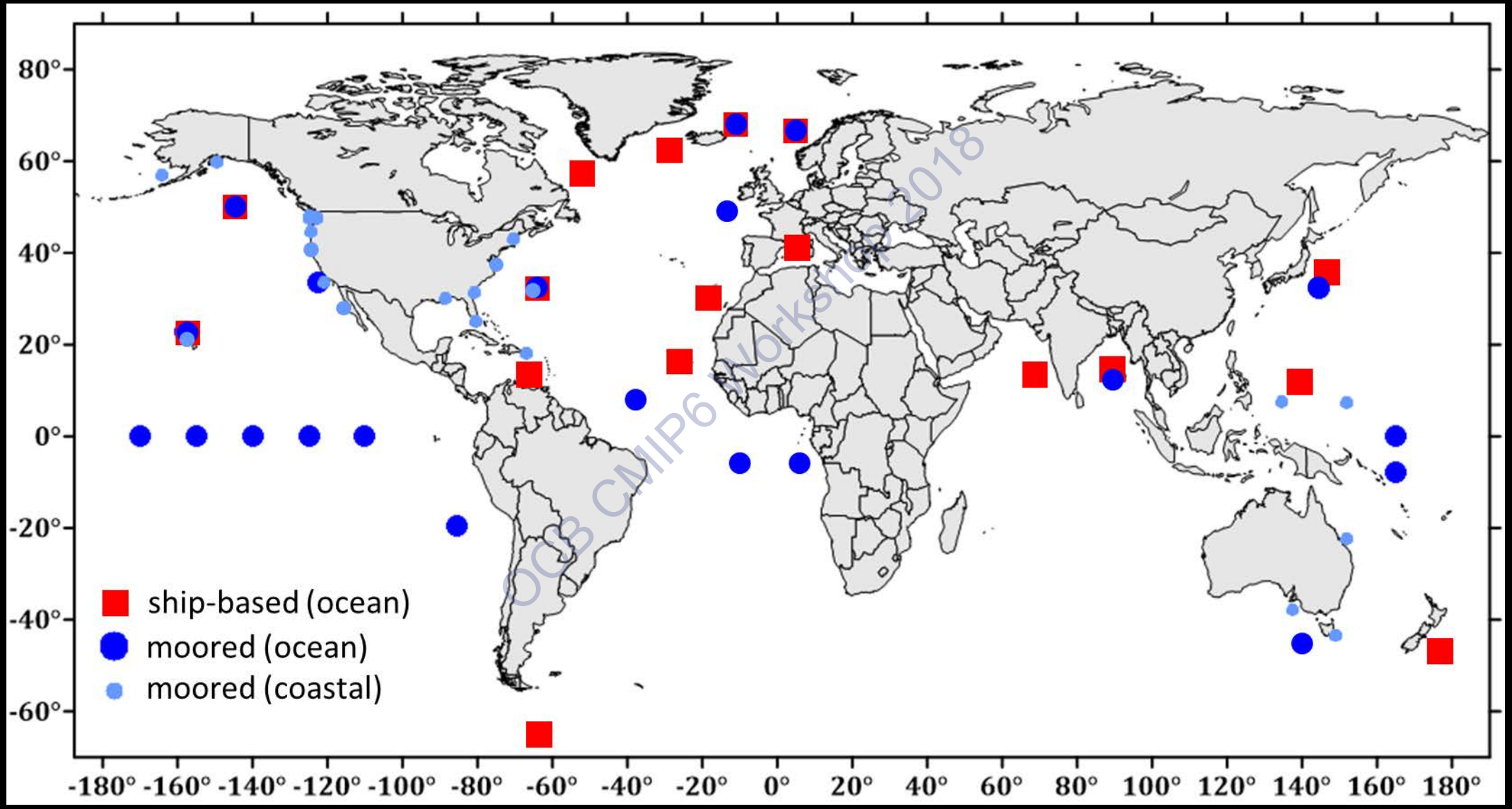


PMEL CARBON PROGRAM

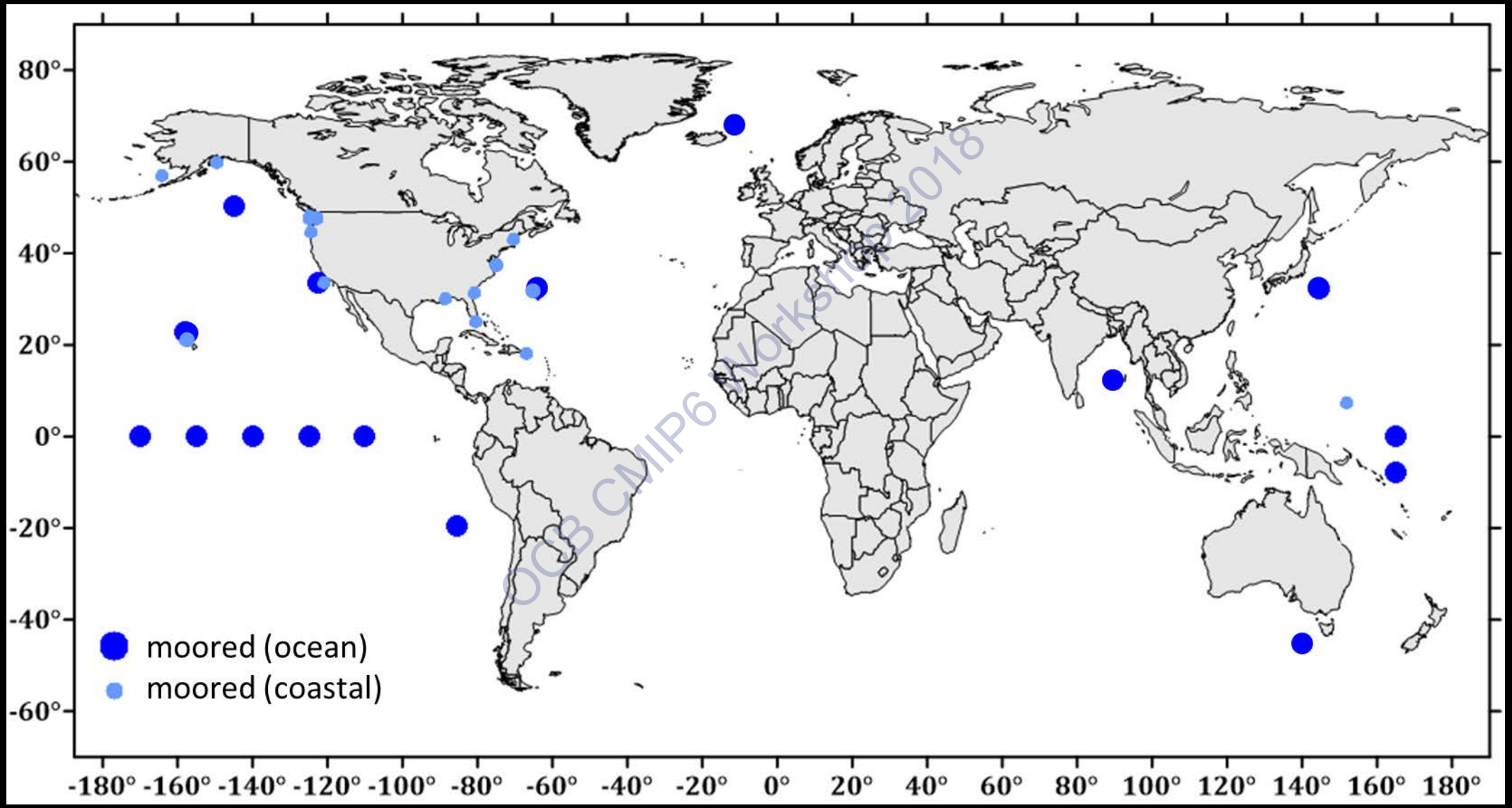
Adrienne Sutton, NOAA Pacific Marine Environmental Laboratory, Seattle, WA and 30+ collaborators, e.g.

Synthesis and intercomparison of ocean carbon uptake in CMIP6 models Working Group and Workshop, 8 December 2018

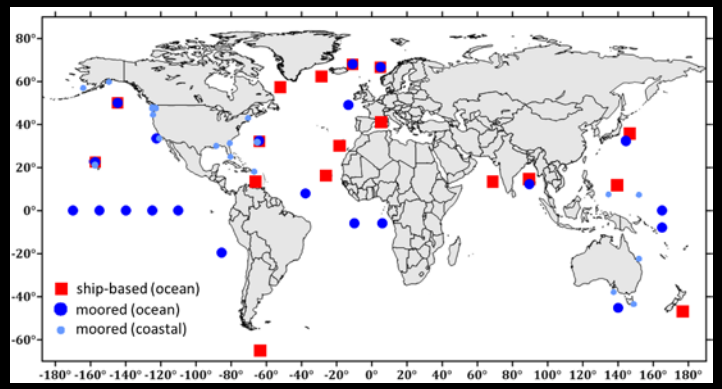
Surface ocean carbon time-series



NOAA surface ocean moored pCO_2 time-series



Opportunities for connection to modeling



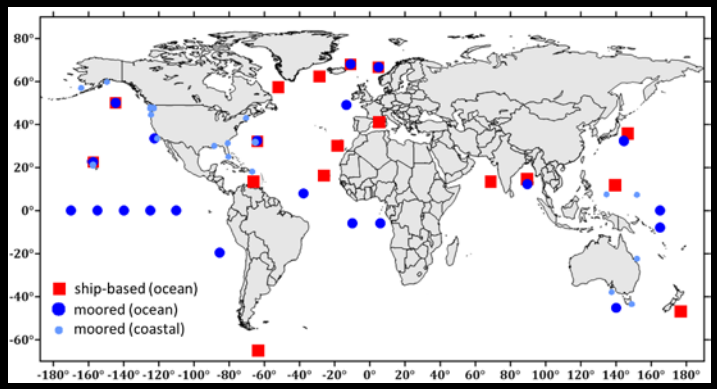
Compare observation vs model constraint of ocean's [local] intrinsic variability of CO_2 flux.

- What is true intrinsic variability versus model spread/uncertainty?
- Are models underestimating seasonal-decadal variability in ΔpCO_2? If so, why?
- How does variability impact detection/attribution of anthropogenic trends in CO_2 uptake?

Modeling community needs (I think…):

- easy, timely access to standardized climate-quality data
- winter measurements
- co-located oceanic and atmospheric observations
- ability to resolve variability of mesoscale eddies and boundary systems
- variability in carbon uptake and impact on trend detection/attribution

Opportunities for connection to modeling



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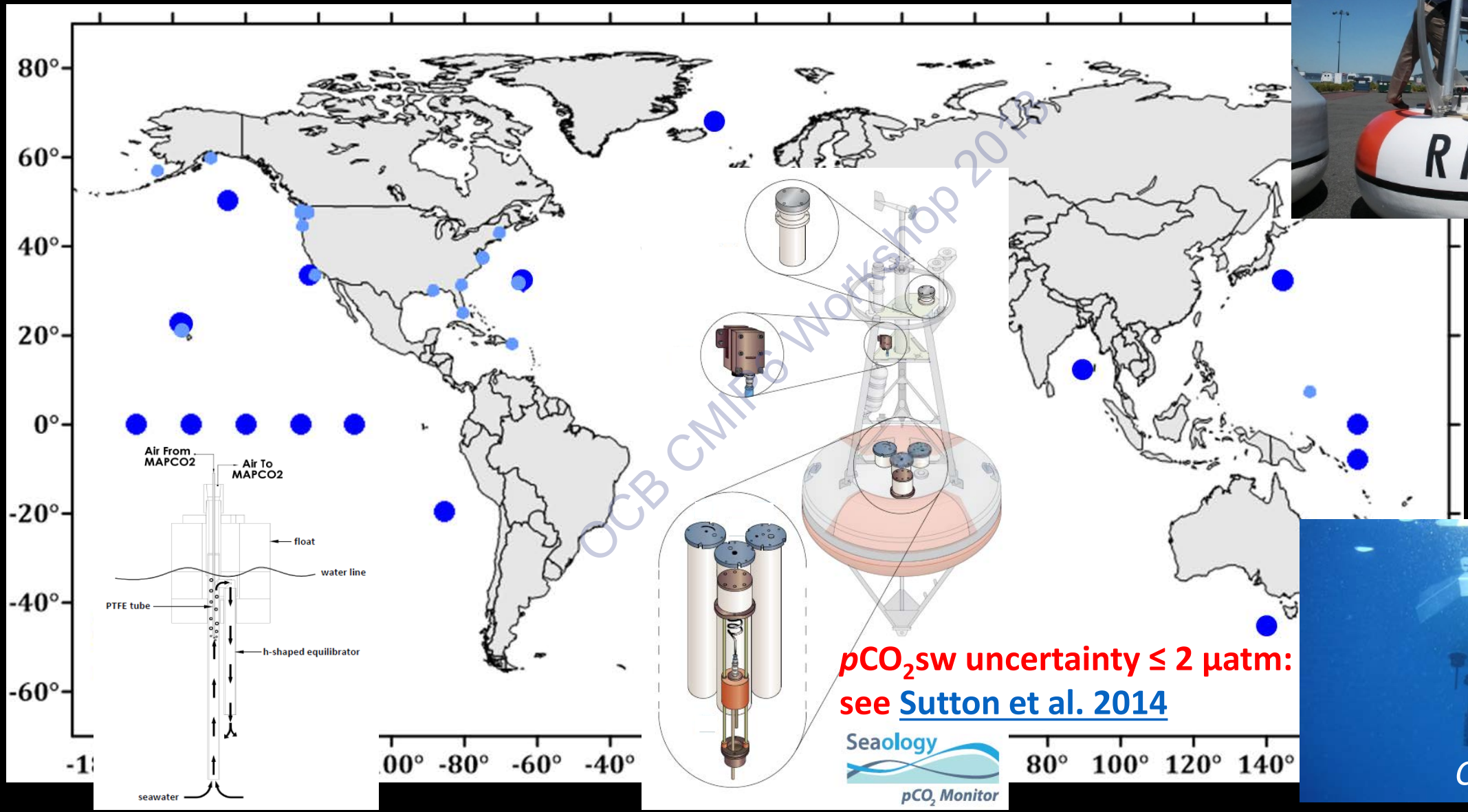
Observing needs:

- use answers to the above to identify priority areas to fill observing gaps, inform development of new process studies, etc.

Modeling needs: easy, timely access to standardized climate-quality data



pCO_2sw uncertainty ≤ 2 µatm:
see Sutton et al. 2014

Modeling needs: easy, timely access to standardized climate-quality data

Data quality

Moored pCO_2 system similar to underway methodology
Calibrated with reference gas in situ
Published SOPs
Lab and field verified uncertainty of ±2 µatm

Data access

Via SOCAT
Via individual time series at
www.nodc.noaa.gov/ocads/oceans/Moorings/ndp097.html
or *https://doi.org/10.5194/essd-11-421-2019*

new time-series data product

https://www.pmel.noaa.gov/co2/timeseries/PAPA.txt

```
#
# Please reference these data as
#
#    Sutton, A.J. et al. [2018 ESSD paper]
#
# ----------------------------------------------------------------------
# VARIABLES AND METHODOLOGY
#
# datetime_utc: Date and time of measurement in UTC (YYYY-MM-DD HH:MM)
# SST: Sea surface temperature at 0.5m depth (degrees C); uncertainty <0.01
# SSS: Sea surface salinity at 0.5m depth; uncertainty <0.05
# pCO2_sw: seawater pCO2 at <0.5m depth (µatm); uncertainty <2
# pCO2_air: air pCO2 at 0.5-1m height (µatm); uncertainty <1
# xCO2_air: air xCO2 at 0.5-1m height (µmol mol-1); uncertainty <0.02
# pH_sw: seawater pH at 0.5m depth; uncertainty <0.02
#
# Data quality control flags:
# NaN represents missing or bad data
#
# Original deployment-level metadata available at:
# https://www.nodc.noaa.gov/ocads/data/0100074.xml
#
# Original deployment-level data and data quality flags available at:
# https://www.nodc.noaa.gov/ocads/oceans/Moorings/Papa_145W_50N.html
#
# Methodology citations:
# Sutton, A. J., Sabine, C. L., Maenner-Jones, S.,
# Lawrence-Slavas, N., Meinig, C., Feely, R. A., Mathis, J. T.,
# Musielewicz, S., Bott, R., McLain, P. D., Fought, H. J., and Kozyr, A.:
# A high-frequency atmospheric and seawater pCO2 data set from 14 open-
# ocean sites using a moored autonomous system, Earth Syst. Sci. Data, 6,
# 353-366, https://doi.org/10.5194/essd-6-353-2014, 2014.
#
# Sutton, A.J. et al. [2018 ESSD paper]
#
# ----------------------------------------------------------------------
datetime_utc    SST     SSS     pCO2_sw pCO2_air        xCO2_air        pH_sw
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2007-06-08 01:04        7.058   32.508  366     381.6   387.0   8.086
2007-06-08 01:34        7.054   32.508  366     381.8   387.2   NaN
2007-06-08 02:04        7.073   32.516  366.2   381.9   387.4   NaN
2007-06-08 02:34        7.066   32.516  366.4   382.1   387.6   NaN
2007-06-08 03:04        7.085   32.525  366.5   382.4   388.0   NaN
2007-06-08 03:34        7.081   32.525  366.3   382.5   388.1   NaN
2007-06-08 04:04        7.068   32.532  366.3   382.5   388.1   8.084
2007-06-08 04:34        7.080   32.532  366.7   382.5   388.2   NaN
2007-06-08 05:04        7.063   32.539  366.4   382.5   388.3   NaN
```
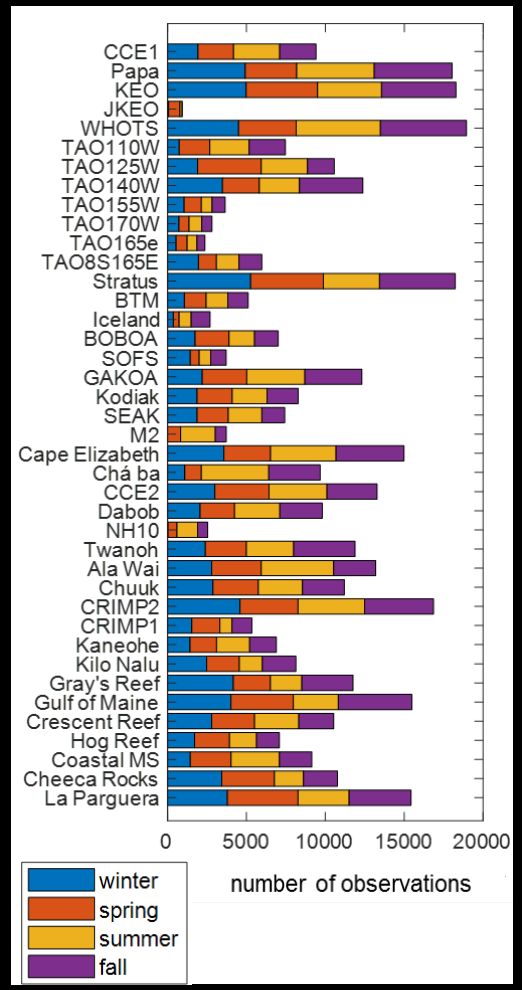
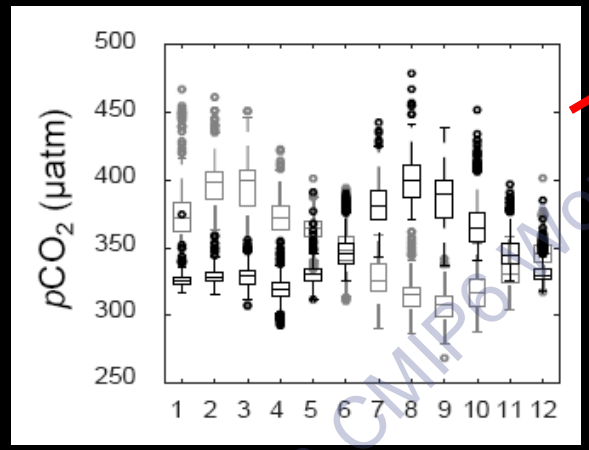
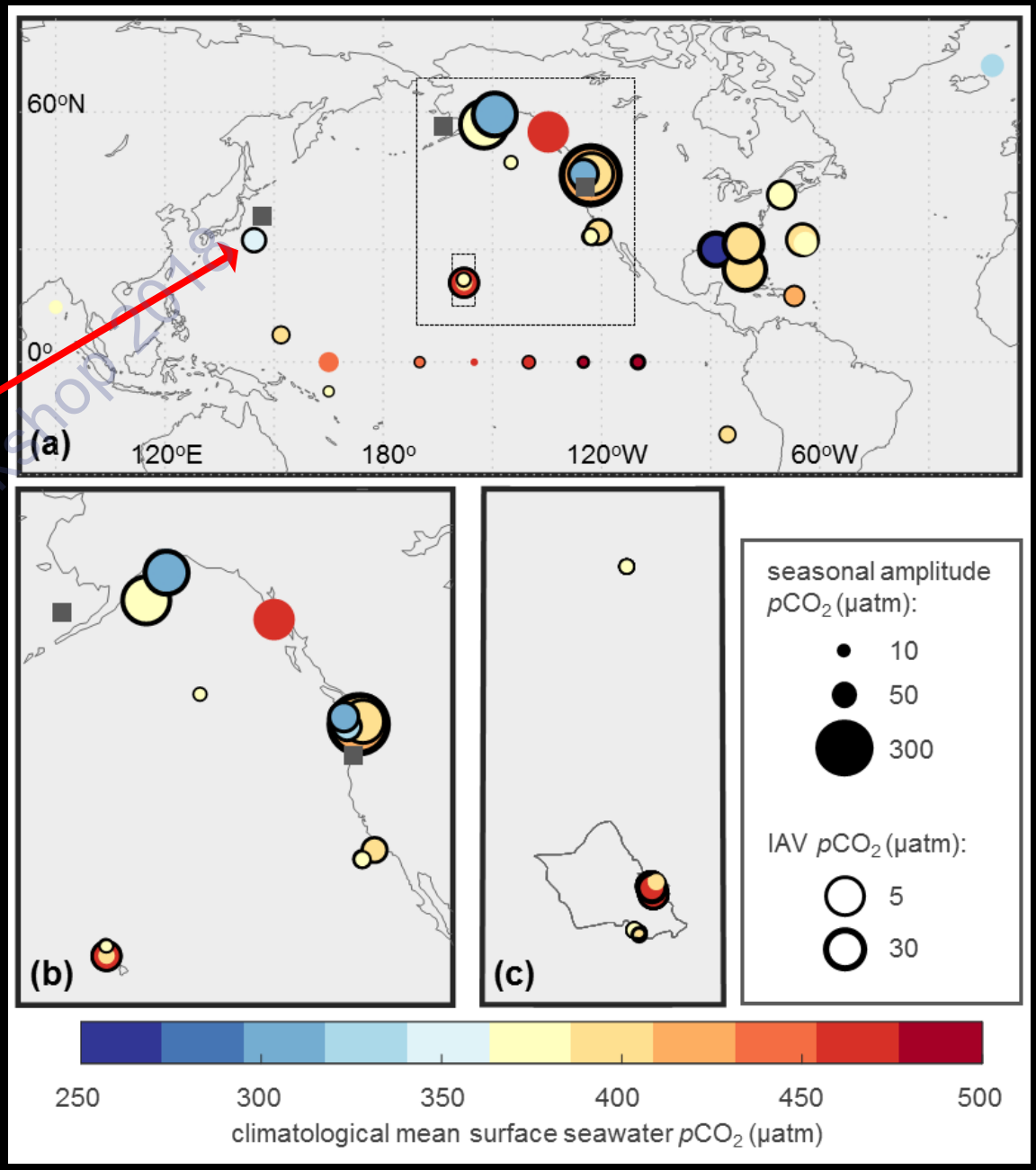

Modeling needs: winter measurements

Temporal variability [local] of air-sea CO_2 flux from 3-hourly measurements of air (~1m height) and sea surface pCO_2 (~0.5m depth)



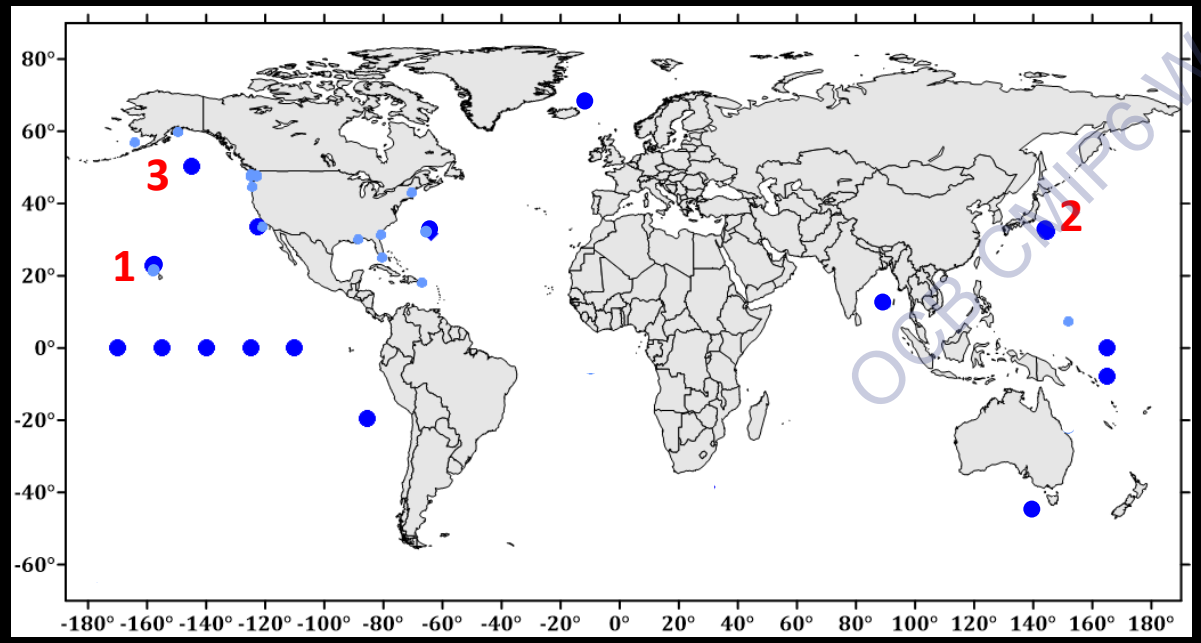


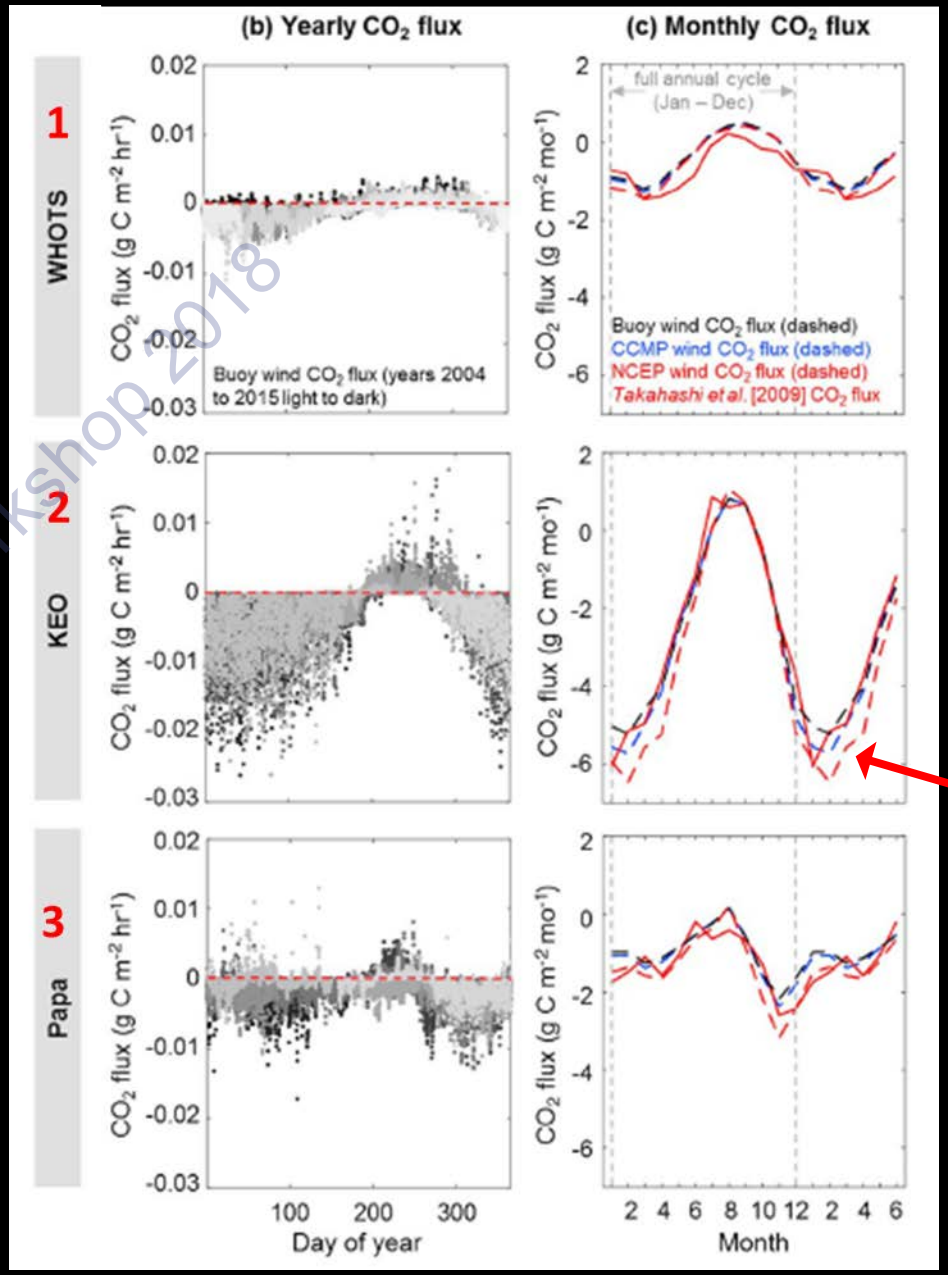


Sutton et al. 2019

Modeling needs: co-located oceanic and atmospheric observations

Most open ocean buoys have measurements of oceanic and atmospheric parameters, including those for calculating both air-sea heat and CO_2 fluxes

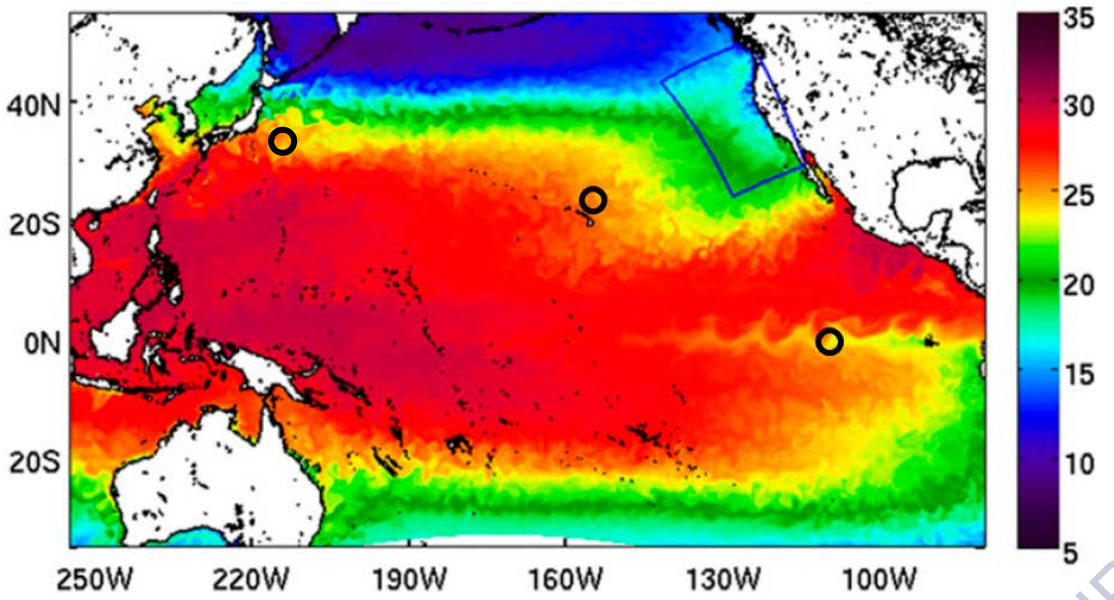


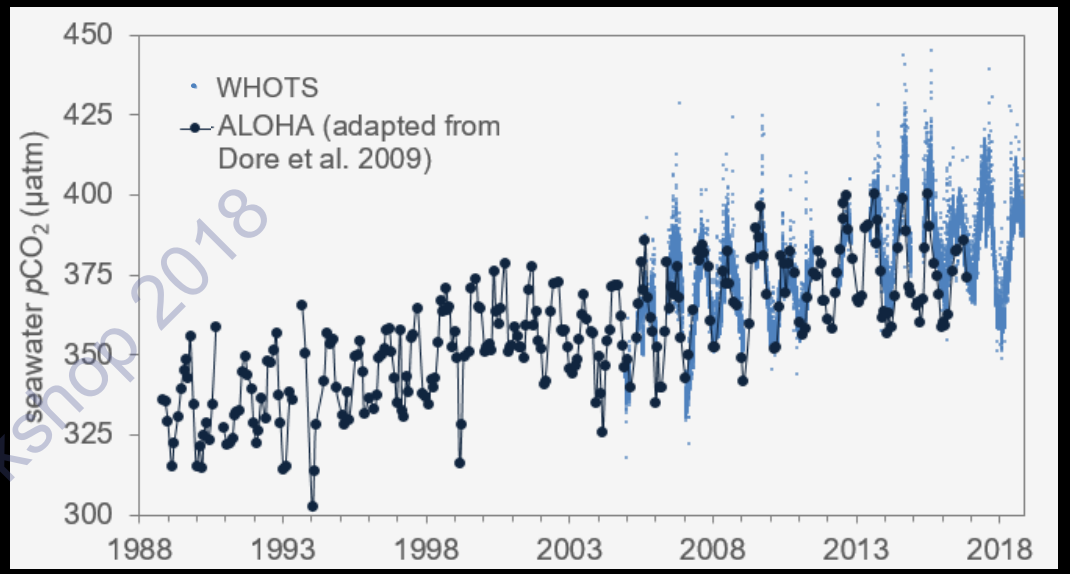


Sutton et al. 2017

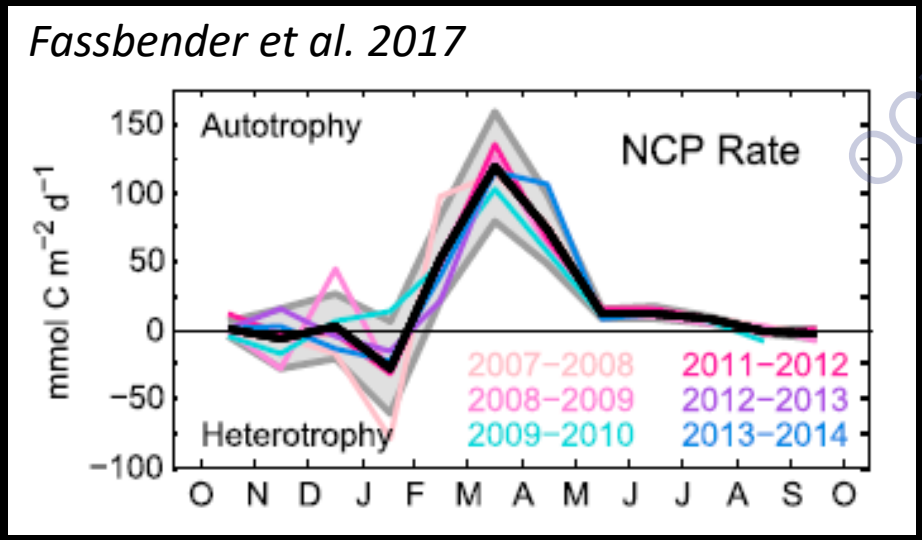
Modeling needs: resolve mesoscale eddies, boundary systems

Molemaker et al. 2015

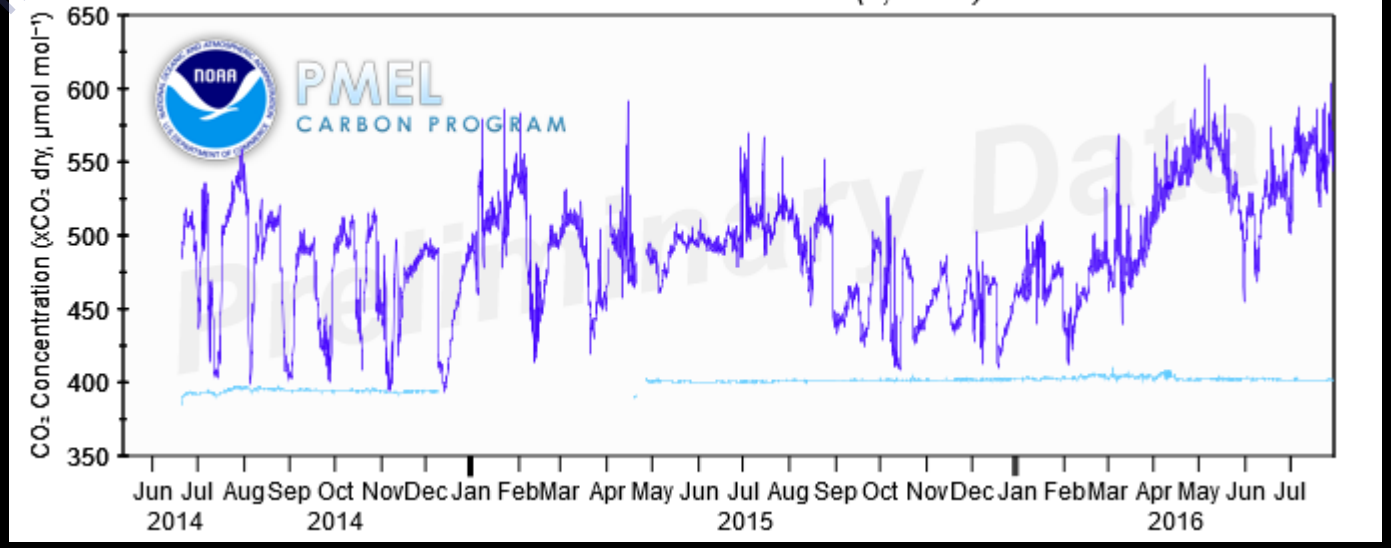




Fassbender et al. 2017



CO_2 Concentration at TAO (0,110W)

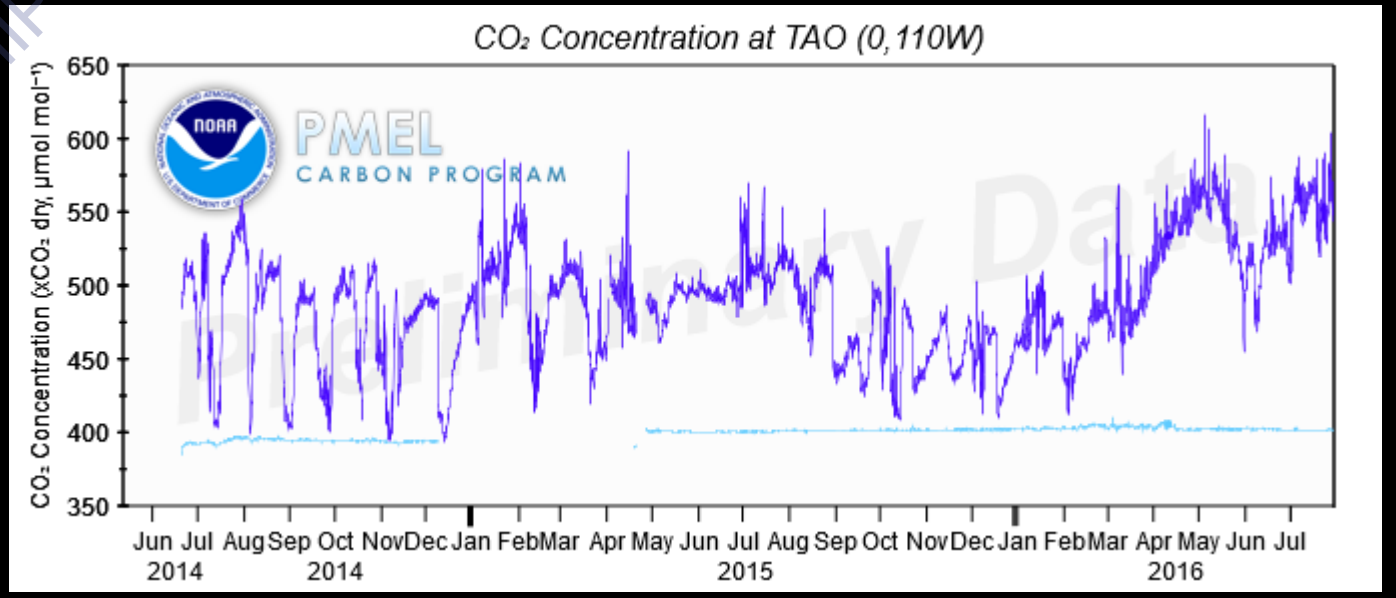


Modeling needs: resolve mesoscale eddies, boundary systems

from K. Donohue

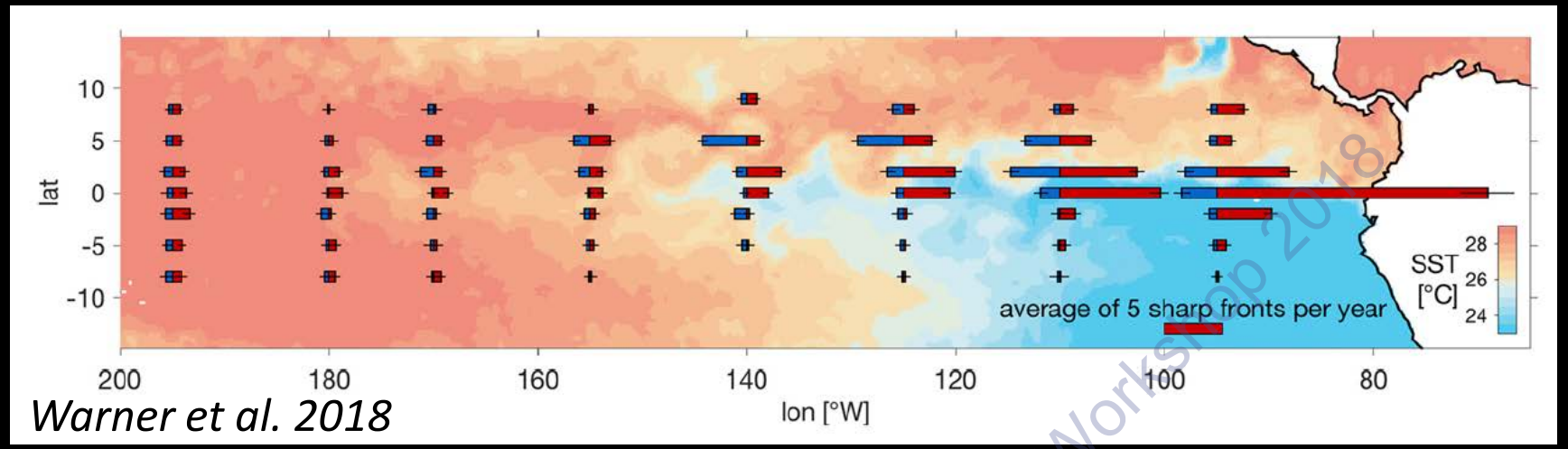
from manuscript in prep

from manuscript in prep



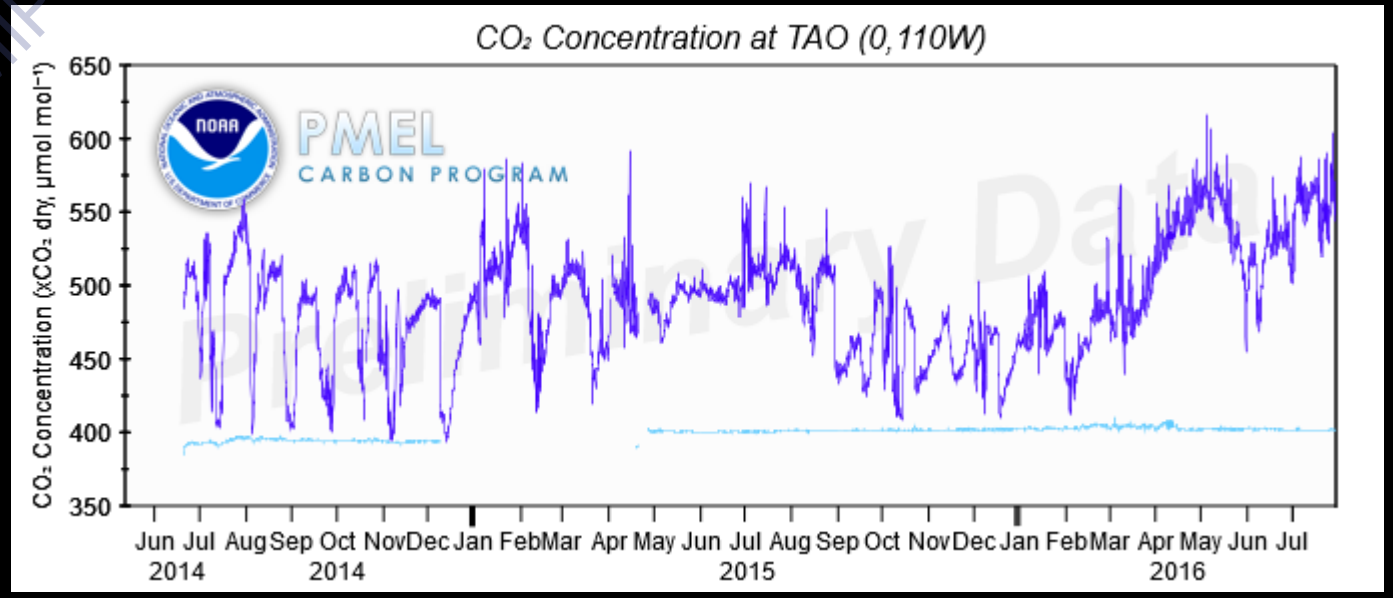
Saildrones observed abrupt fronts with SST, SSS, pCO_2 changes as large as 1°C, 0.3, 75 µatm, respectively, in less than 1 km

Modeling needs: resolve mesoscale eddies, boundary systems



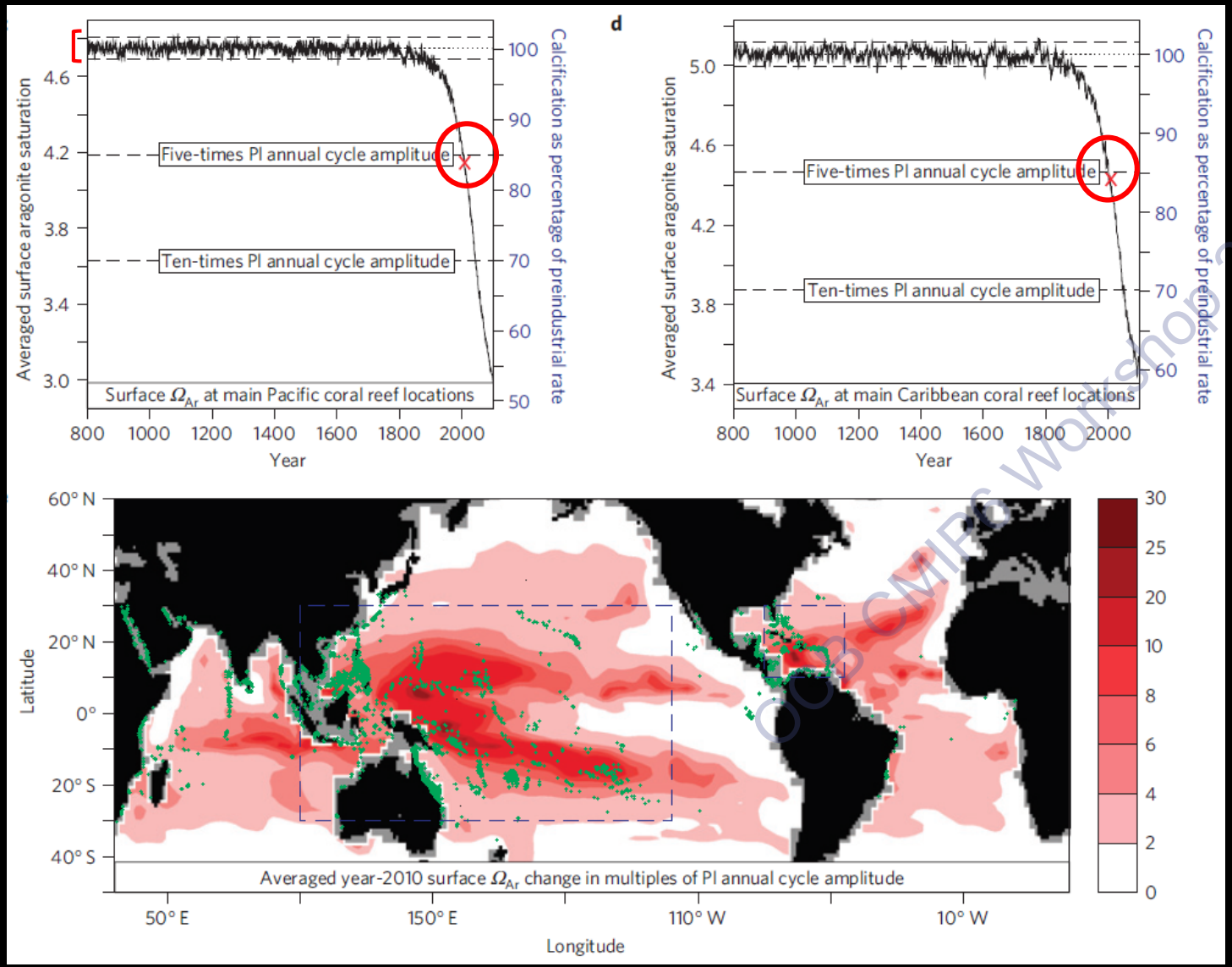
Warner et al. 2018

What is the census of eddies, fronts, etc. and how do small scale features impact CO_2 uptake?

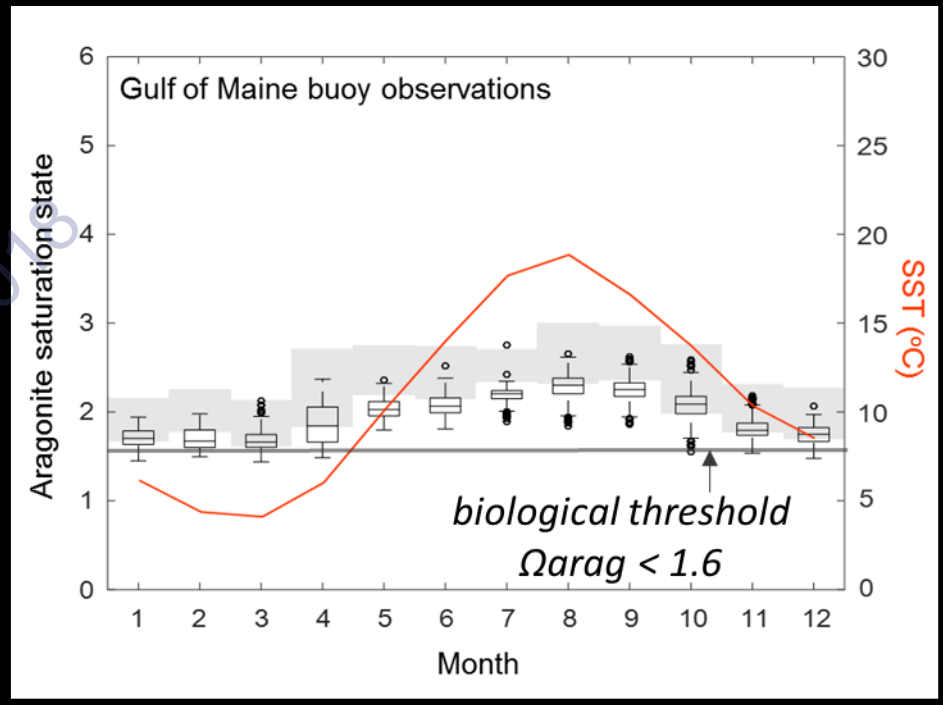


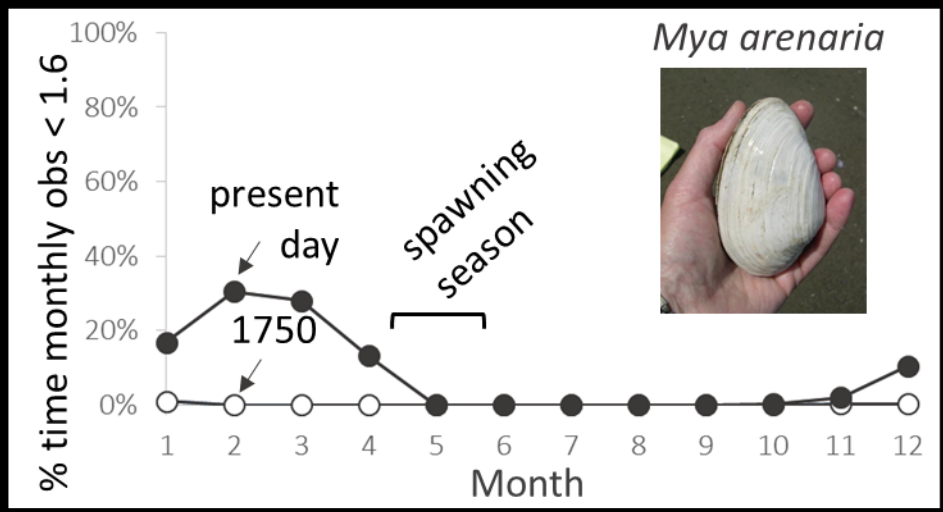
Modeling needs: variability impact on trend detection/attribution

Sutton et al. 2016



Friedrich et al. 2012

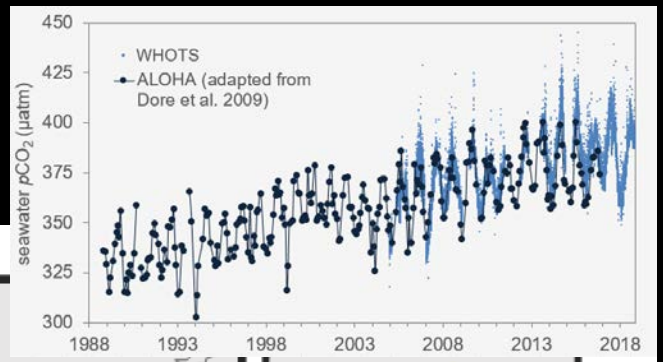


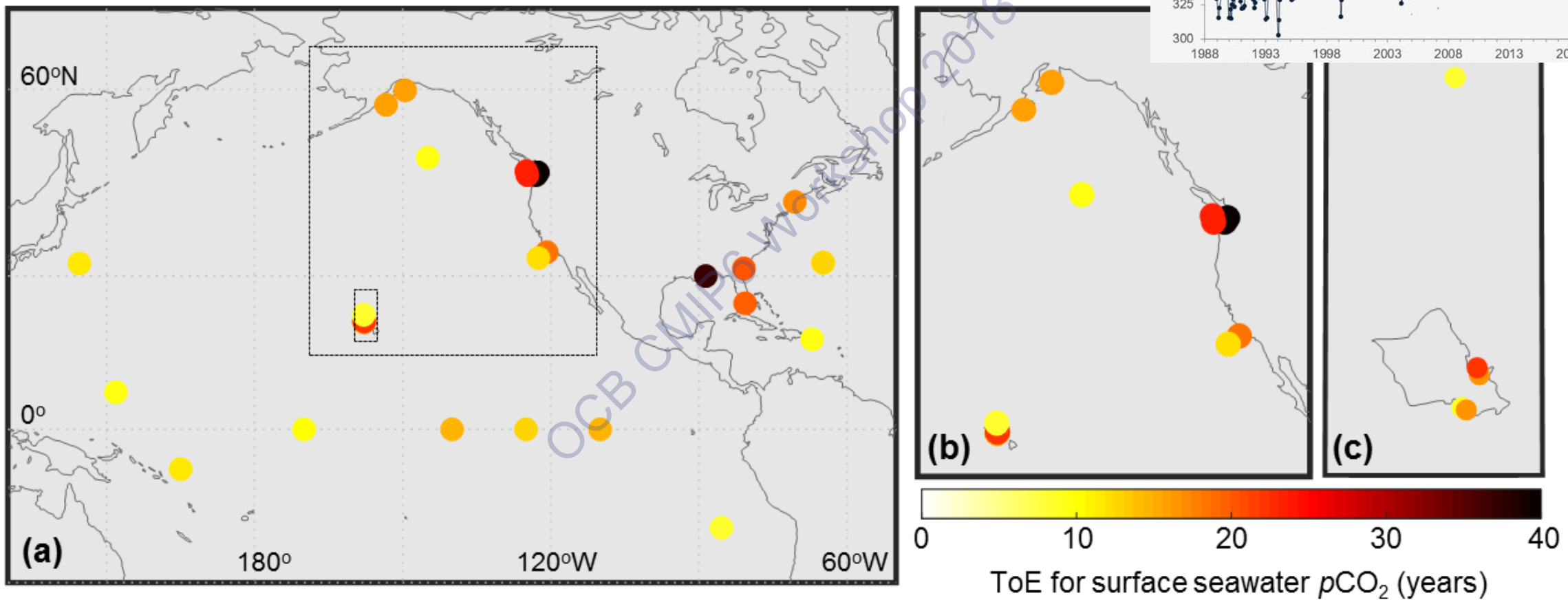


Modeling needs: variability impact on trend detection/attribution

method of Tiao et al. 1990; Weatherhead et al. 1998:

$$ToE = \left(\frac{3.3\sigma_N}{|\omega_0|} \sqrt{\frac{1+\emptyset}{1-\emptyset}} \right)^{2/3}$$





Sutton et al. 2019

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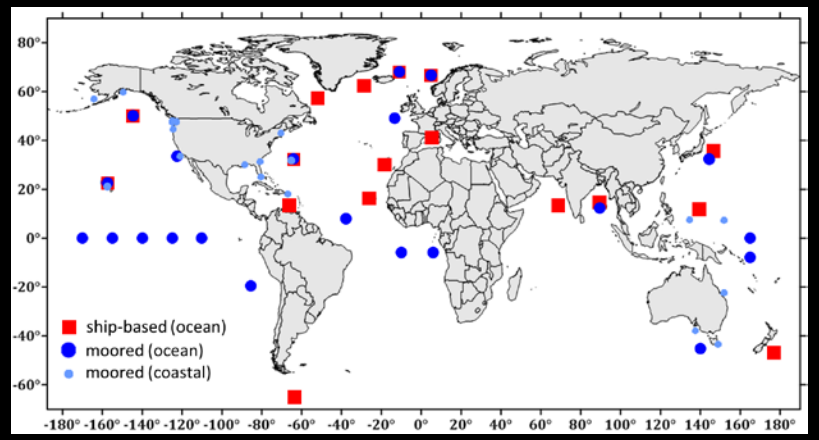

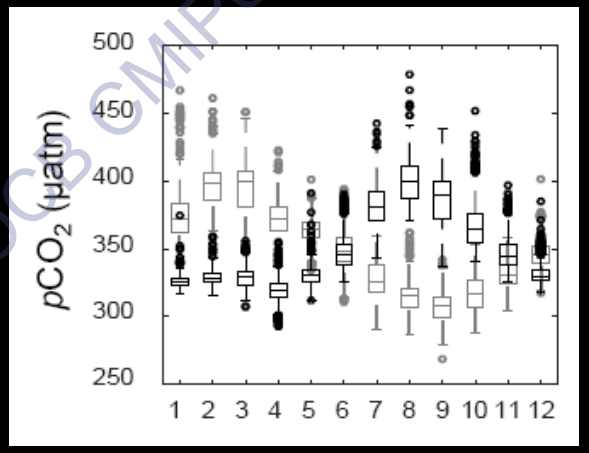

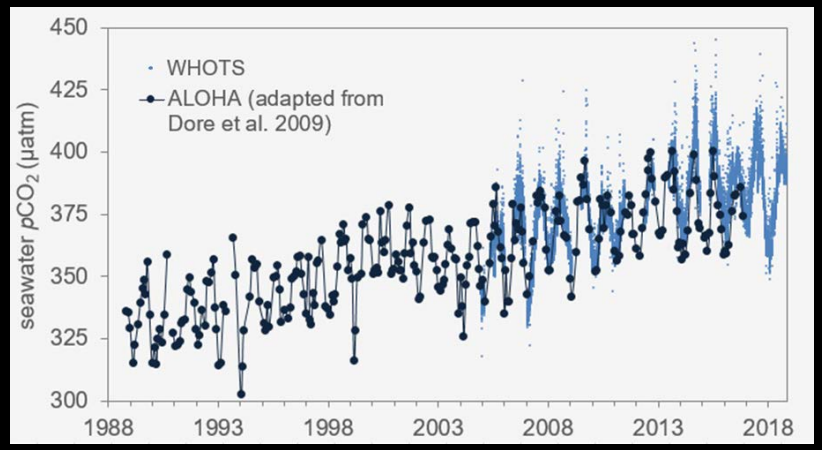

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