Thinking Big and Small: Coastal-Open Ocean Exchanges in the California Current Upwelling System

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- **Thinking Big**: connections to the broader Northeast Pacific
- **Thinking Small**: filaments, mesoscale, submesoscale
- **Historical data rescue**

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NOAA Climate Observations and Monitoring Program
NOAA COM/MAPP/CSI Programs
NASA Ocean Vector Winds Science Team
NASA Ocean Surface Topography Science Team

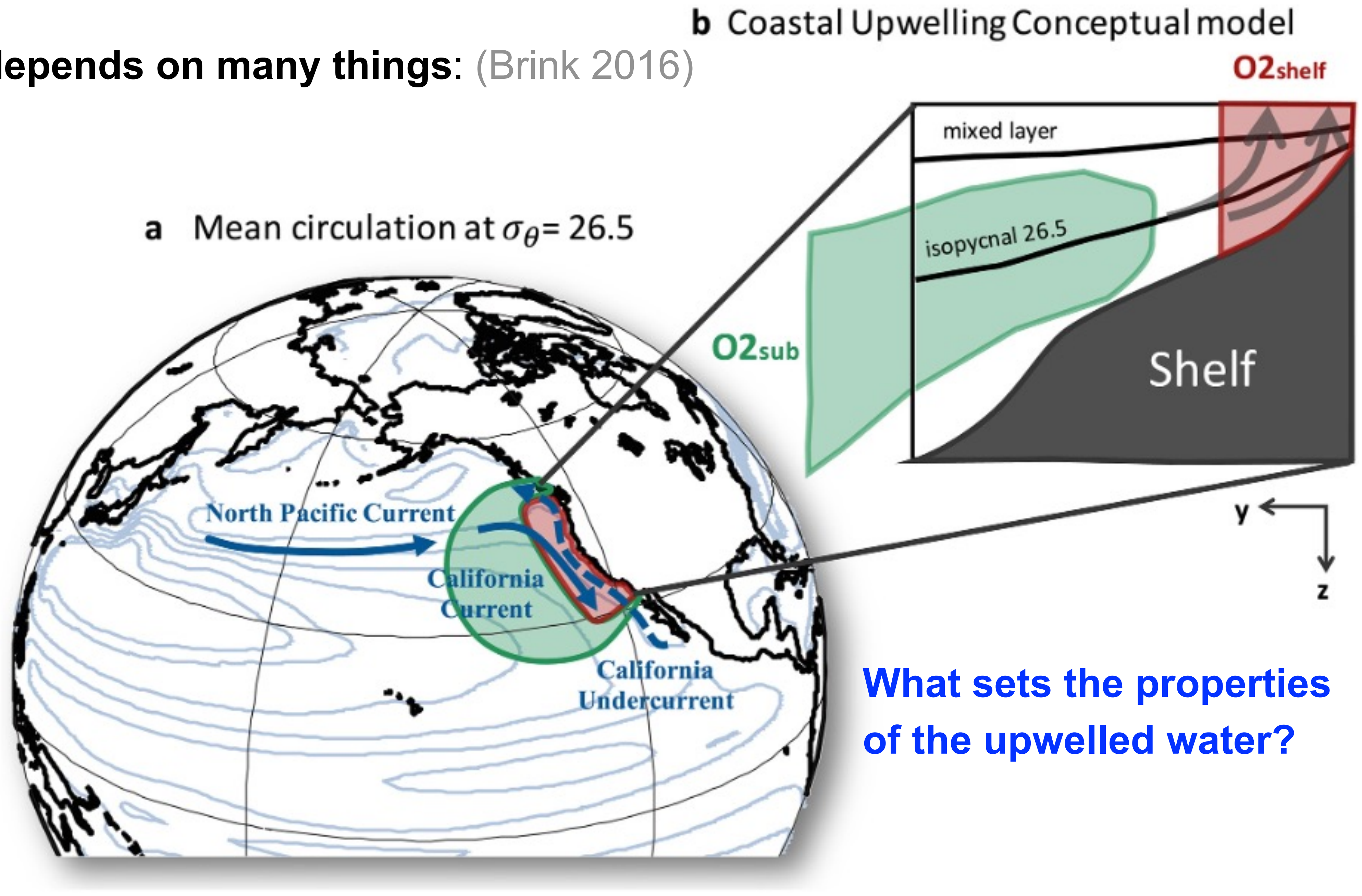
The California Current Upwelling System: Background

- California Current System (CCS) supports important ecosystems and fisheries: $100Ms/year (Hickey 1979, Checkley and Barth 2009, Chavez and Messié 2009, many others…)

- Northern, Central, and Southern CCS and Southern California Bight are dynamically distinct regions (there is not "a CCS") (e.g., Hickey and Banas 2008)

- **Cross-shelf exchange by upwelling and downwelling depends on many things**: (Brink 2016)
  - stratification (Lentz and Chapman 2004)
  - source water depth (links to undercurrent)
  - alongshelf pressure gradients (McCabe et al. 2015)
  - variations in shelf width (Pringle 2002)
  - local and remote wind forcing (Battisti and Hickey 1984)
  - wind stress curl (Castelao and Luo 2018)

- **Here, focus on Northern California Current System** but note other observing programs:
  - CALCOFI
  - CCE-LTER
  - Trinidad Head
  - California Underwater Glider Network
  - Ocean Networks Canada
  - IMECOCAL

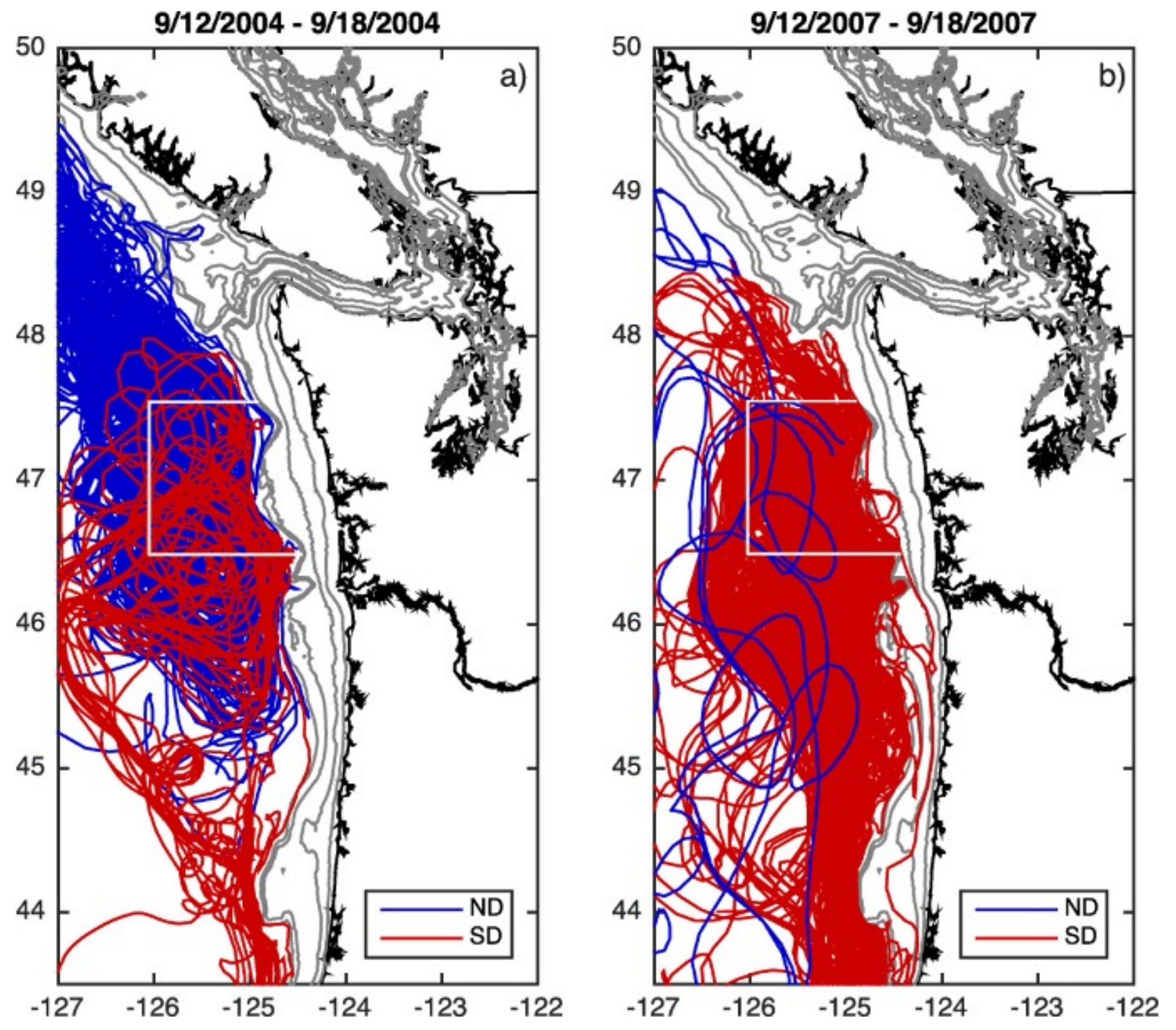


What sets the properties of the upwelled water?

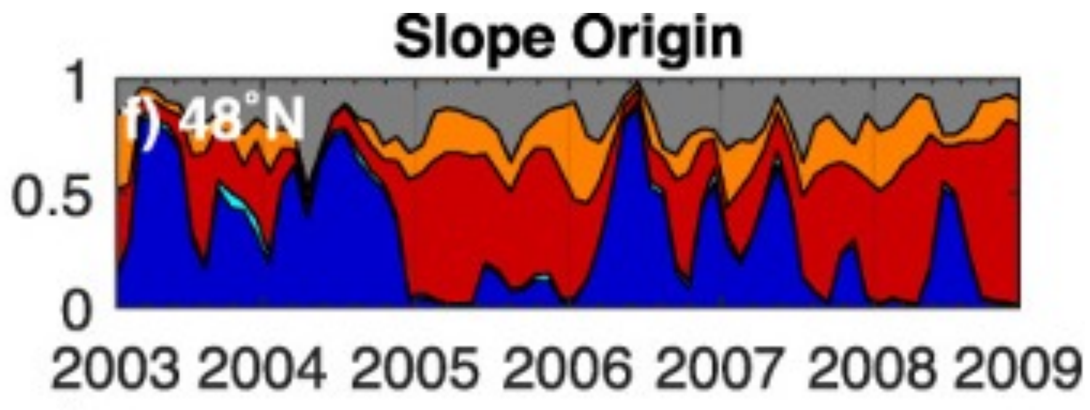
Pozo Buil et al. 2017

Thinking Big: connections between the NCCS and broader Northeast Pacific

- Cascadia model (see LiveOcean): 1.5-km horizontal resolution
- Model shows strong **seasonal**, **interannual** and **along-coast variations** in whether slope **waters come from the north or south**, with major impacts on shelf water properties (e.g., 'subarctic invasion' of 2002, Huyer et al. 2007)
- Need for observations to test model predictions of **transport pathways** and their **interannual variability** and understand **coastal to open ocean exchange** in the context of these **large along-coast excursions**



Stone et al. 2017



BLUE = waters from the north (colder, fresher)*

RED = waters from the south (warmer, saltier)

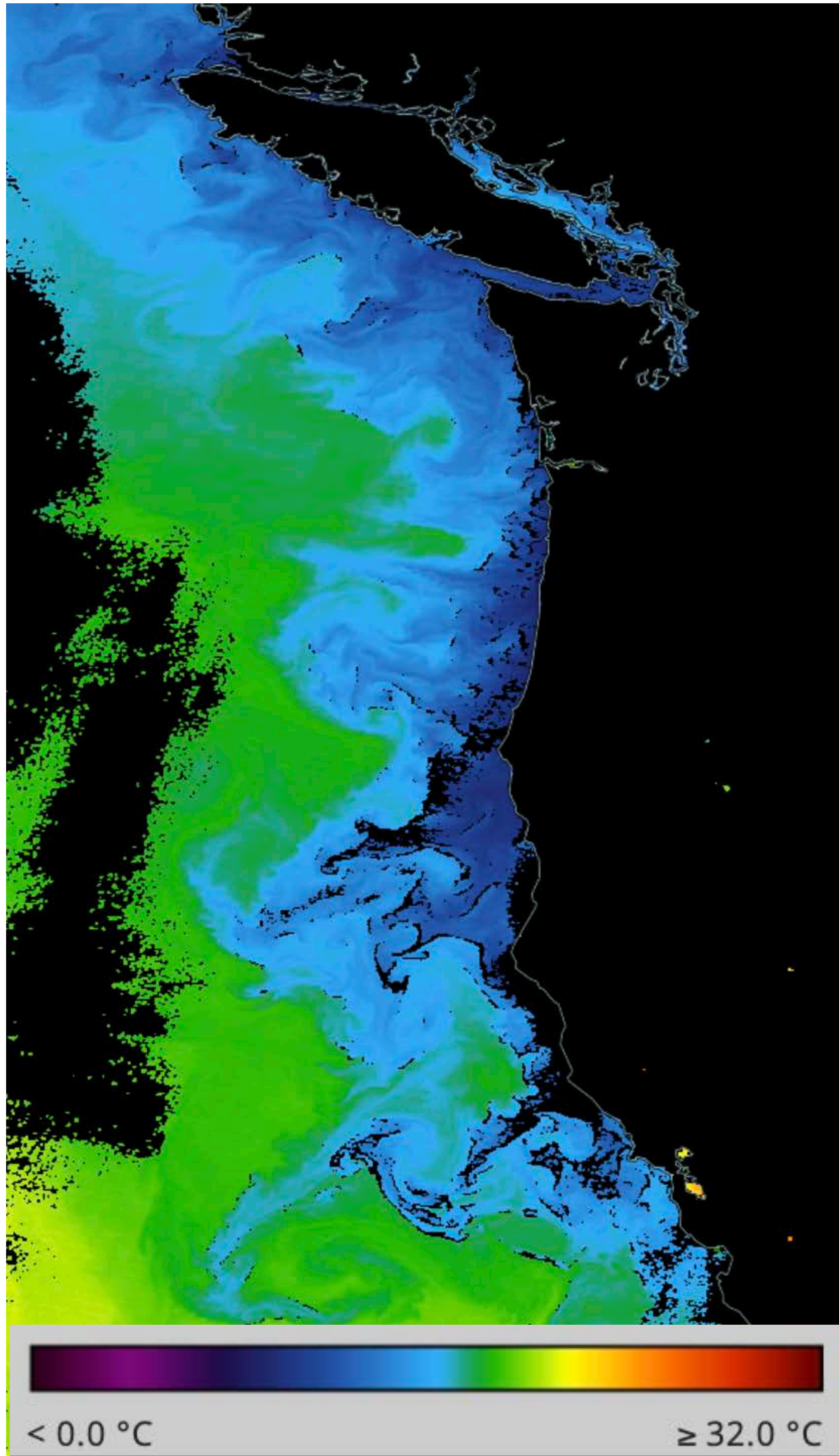
*associated with lipid-rich copepods, good for salmon (Peterson et al. 2017)

Thinking Small: filaments, mesoscale, & submesoscale

- **filaments and submesoscale:**
  - "The upwelling front" is not really 2-D
  - What are the **dynamics and fate of filaments of recently upwelled water**?
  - Need for submesoscale-resolving **subsurface observations** of upwelling filaments and their **frontal evolution & restratification** (e.g., Johnson 2020a, 2020b)

- **mesoscale and submesoscale eddies:**
  - models indicate **eddy-driven offshore transport** of nutrients and fixed carbon **reduces biological production** in EBUS (Gruber et al. 2011, Nagai et al. 2015)
  - models indicate **submesoscale currents reduce productivity** near coast (Kessouri et al. 2020)
  - need subsurface observations to test these model predictions

satellite sea-surface temperature
Sep 10, 2022 (Suomi NPP/VIIRS)



To understand our changing climate, we need **long time series** (decades)

- Changing climate → we want to identify trends, anomalies, extreme events
  - MHWs, including El Niños
  - subarctic invasions
  - droughts
  - unusual precipitation and river inputs

- For reliable identification of anomalies and extreme events, we need **robust climatologies**
  - require long time series = **many decades** (convention is 30 years)
  - much greater than the length of a single typical project
  - agencies can support, e.g. NSF Long-Term Ecological Research Network, Ocean Observatories Initiative

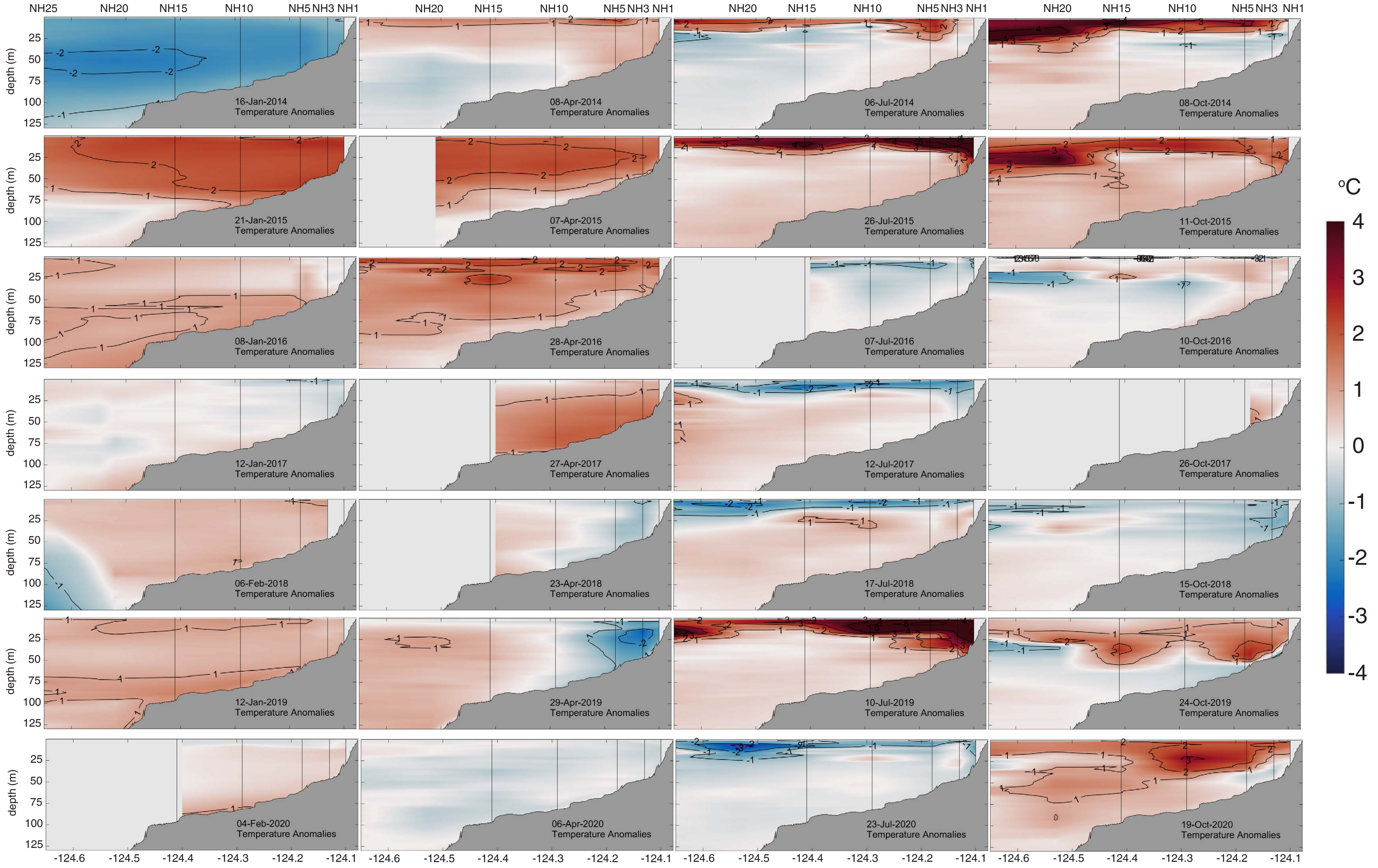
- What can we do while we wait to build up new 30-yr long time series?
  RESCUE HISTORICAL OBSERVATIONS!
  3 examples from our lab

Historical data use in our lab (i): Newport Hydrographic Line

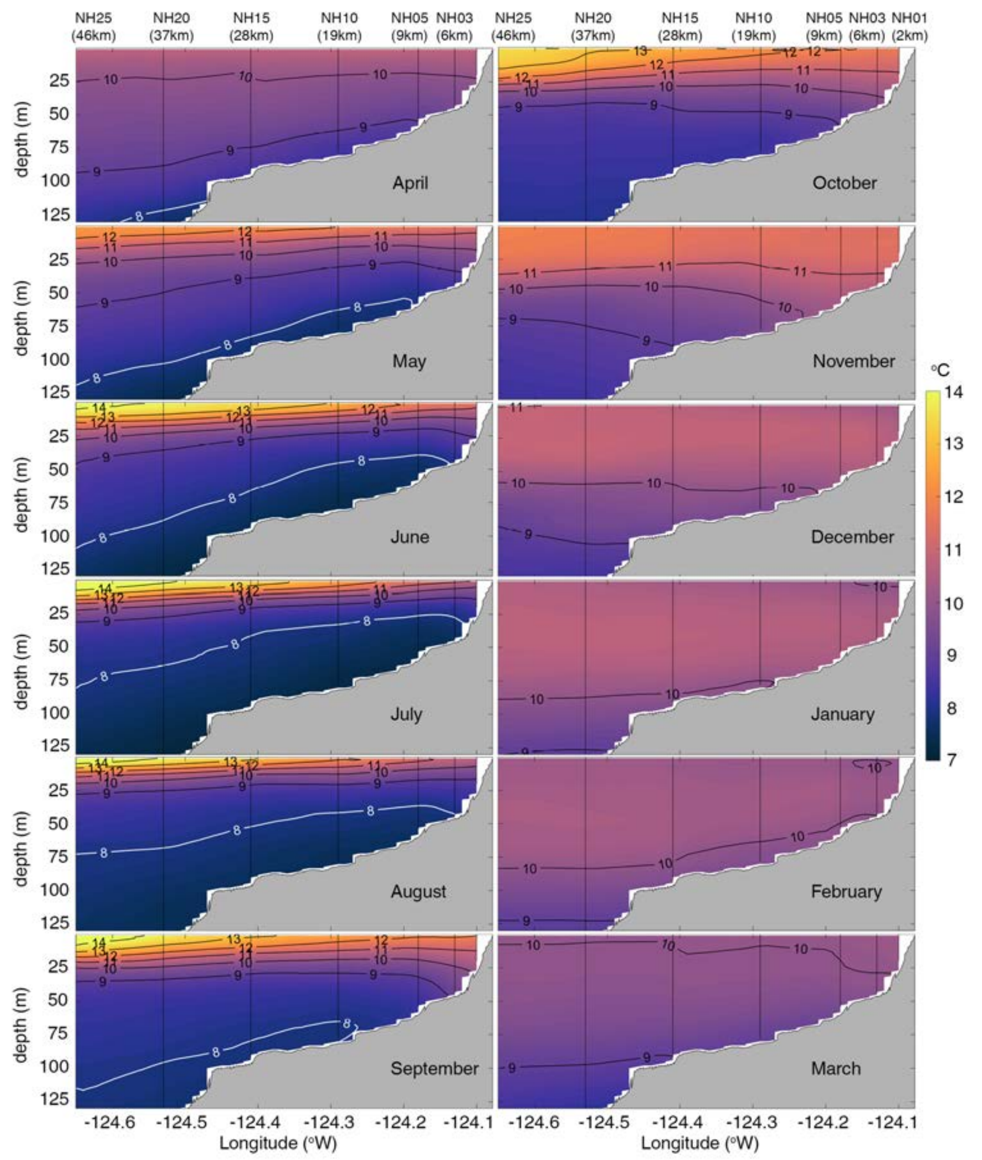
- Newport Hydrographic Line shipboard CTD sections (Risien et al. 2022)
- Ongoing work on salinity vs. temperature influences on stratification
- Robust **subsurface temperature anomalies.** What role does cross-shelf exchange play?

January April July October

2014
2015
2016
2017
2018
2019
2020



monthly mean **temperature**



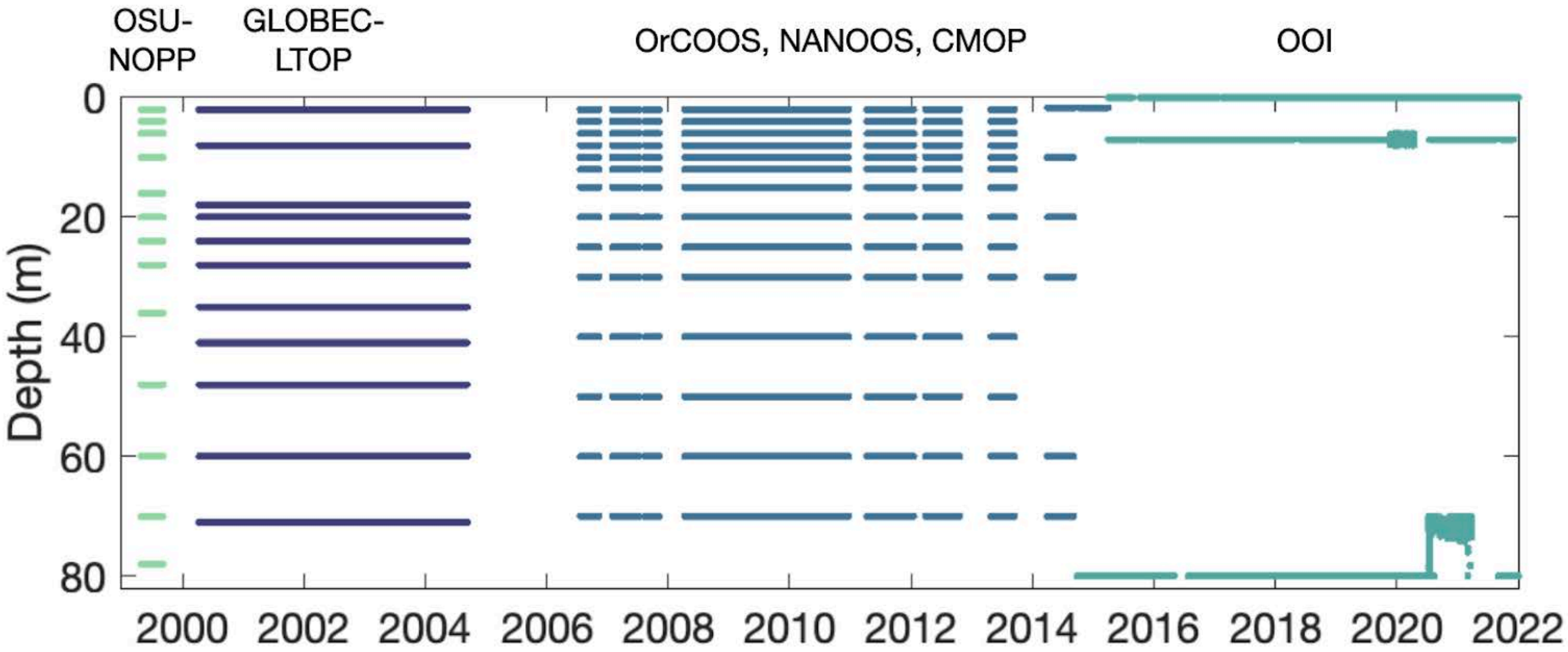
>550 cross-shelf shipboard transects ~biweekly 1997–present!

Historical data use in our lab (ii): NH-10 moorings

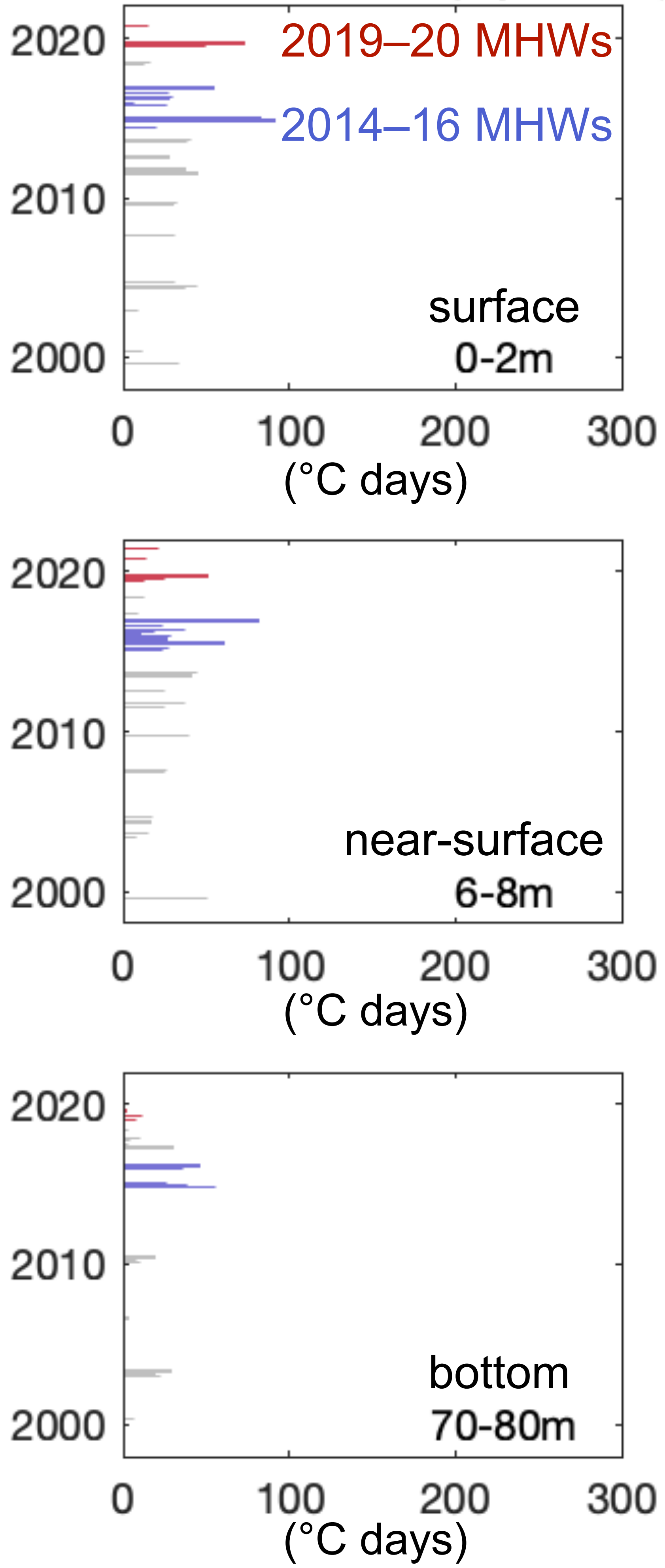
- NH-10 mooring site on the 80-m isobath off Newport, Oregon:
  - 6 programs culminating in OOI Endurance Oregon Shelf mooring
  - We concatenated into a 24-yr time series (Risien et al. 2023)

- Enables calculation of robust seasonal climatologies and anomalies

- Enables assessment of **subsurface** marine heat waves (MHWs):
  - Cumulative intensity of MHWs has increased over the 24 years (Cervantes et al., *in preparation*)
  - Surface, near-surface, and bottom MHWs all differ → satellite observations not enough
  - What is the role of coastal-open ocean exchange in these MHWs?



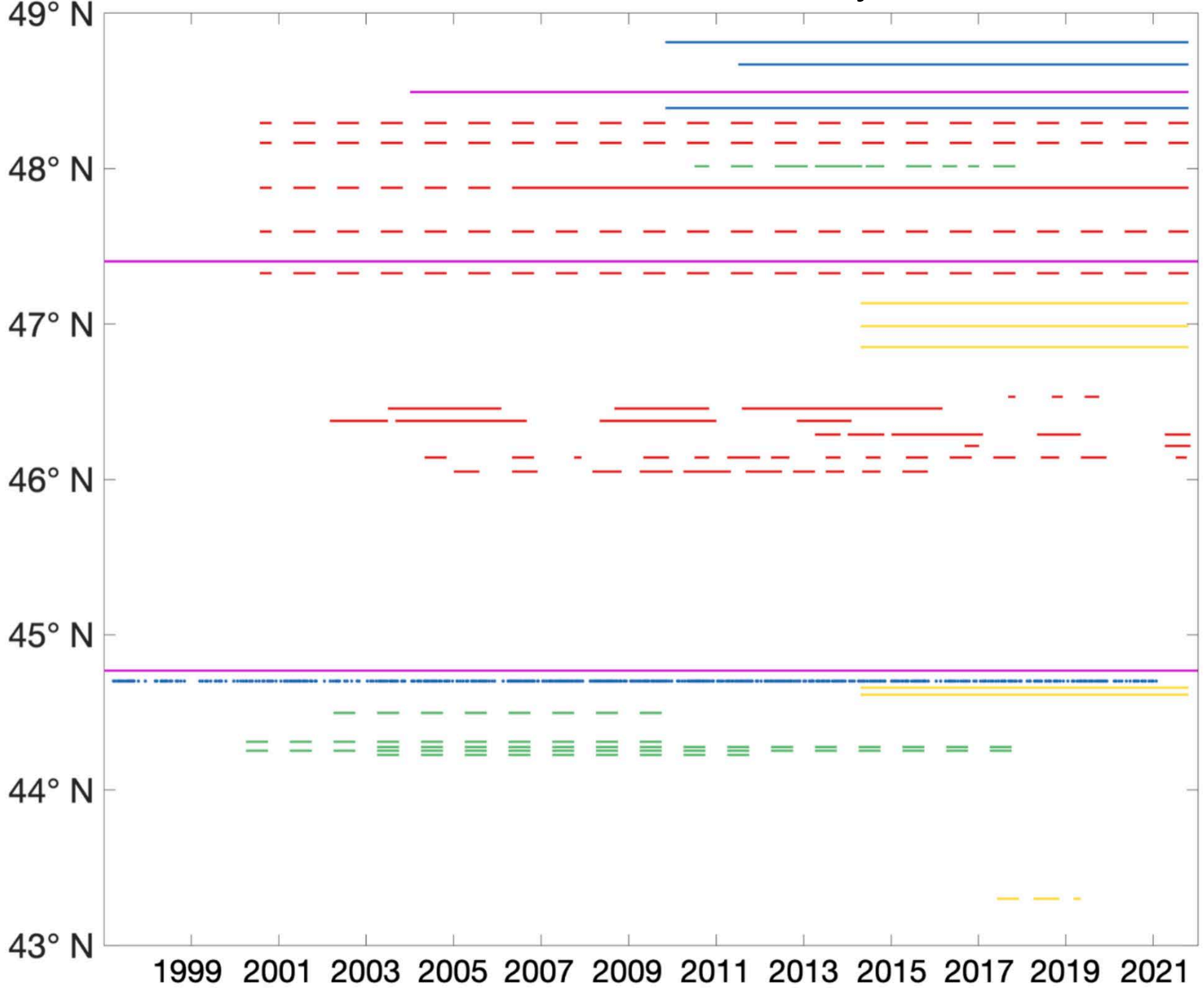
MHW Cumulative Intensity

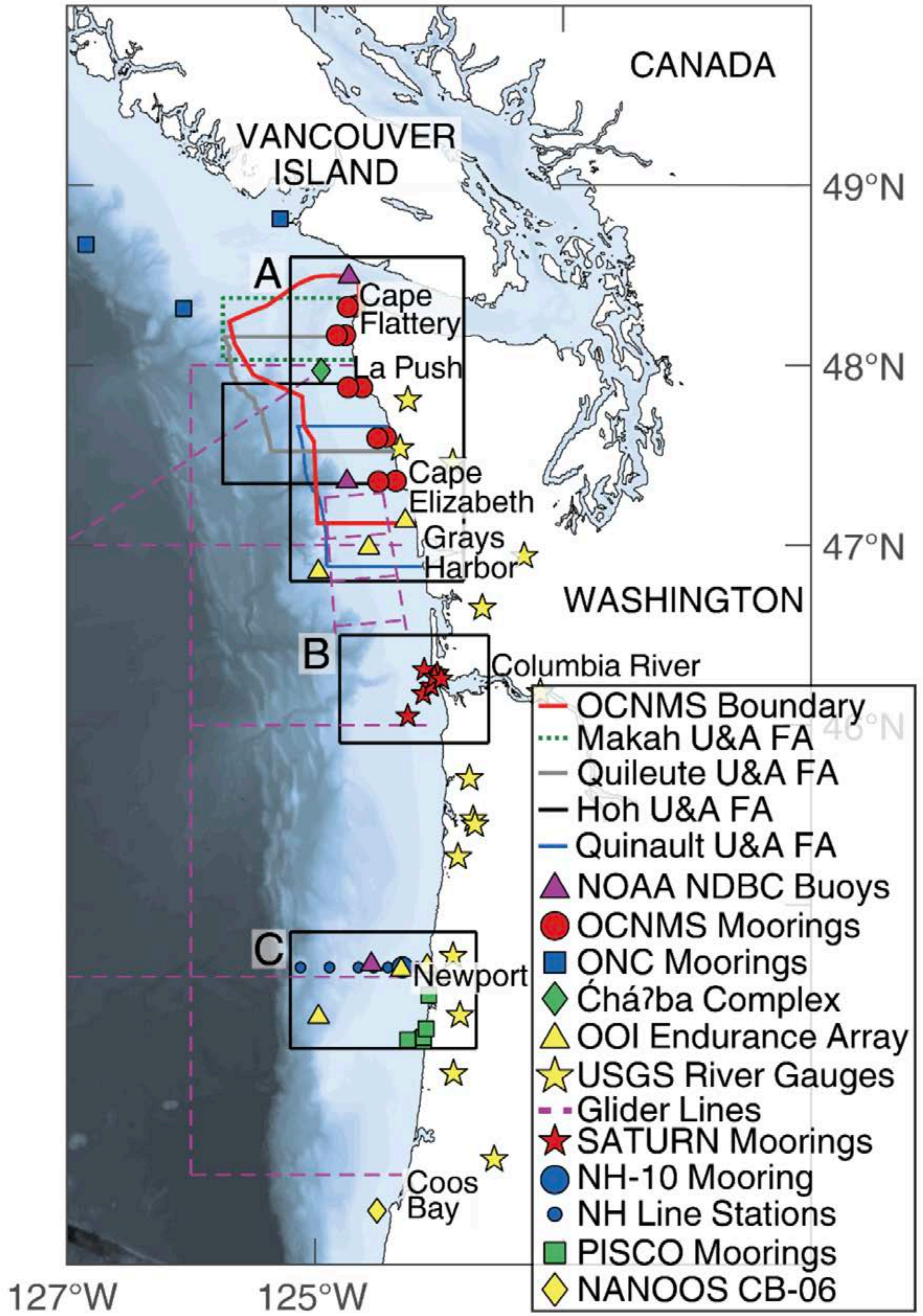


Historical data use in our lab (iii): Olympic Coast National Marine Sanctuary

- NOAA-funded project: Variability of subsurface water masses in the OCNMS
  - 23+ years of mooring data at OCNMS: T, S, velocity, DO: updated climatologies, anomalies
  - Relation to conditions on Newport Hydrographic Line?
  - What is the influence of cross-shelf exchange on anomalies at OCNMS?

timeline of data availability





Figures by
Brandy Cervantes

Conclusions and recommendations

- Thinking BIGGER and SMALLER: high-resolution models and relatively sparse observations show that
  - Models have outpaced observations
  - Need to observe bigger scales: **along-coast transport affects water masses exchanged** from coastal to open ocean
  - Need to observe smaller scales: submesoscale-resolving subsurface observations of filaments of upwelled water

- For **climate records**:
  - We need more **long-term** data sets of **subsurface observations**
  - We need more comprehensive observations **where Argo floats don't go**: continental shelf and slope regions

- We need to **rescue historical data sets**
  - Funding agencies could each have an in-house effort for historical data rescue (USGS has had this)
  - Funding agencies could provide personnel to support getting new observations into archives like NCEI, rather than expecting PIs to provide personnel time as part of the project. This would be more consistent and efficient and let PIs and scientists concentrate on writing the papers.

- A paradox: we have both **not enough data** to understand the changing climate and **more data** than we can fully exploit
  - There's already lots of data available to be analyzed!
  - We **need people time** funded to analyze existing data
  - We need more **grad student and postdoc funding** (fellowships?), perhaps targeted at underrepresented groups

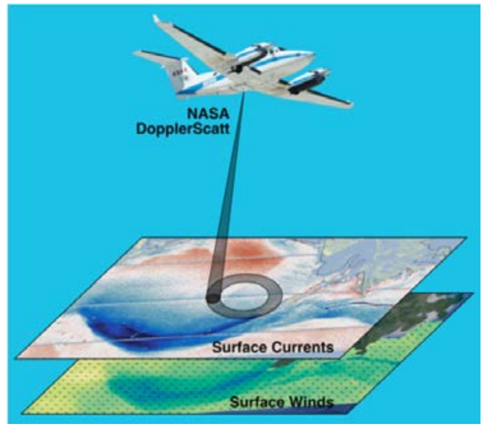
Looking to the future: global measurements of surface currents from space

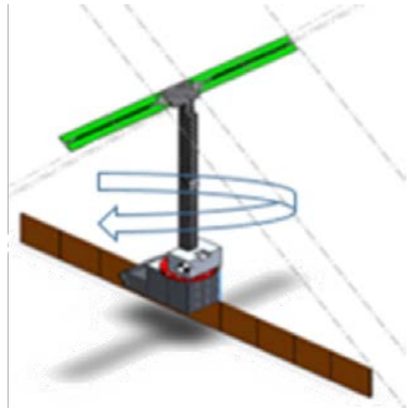
A NASA Earth System Explorers (ESE) Mission concept

ODYSEA (Ocean DYnamics and Surface Exchange with the Atmosphere)

HOW

- Achieving simultaneous measurements of vector winds & currents at 5-km data postings using a single Ka-band radar instrument.
- Building on NASA technological heritage of scatterometry (e.g., QuikSCAT) & DopplerScatt (mature airborne sensor, being used in NASA EVS-3 Mission S-MODE).





Mission details

Swath width: 1700 km	Orbit: sun-sync, 587 km	~90% global coverage daily (2x/day in many places)
NRT winds/currents (<3/6 hour latency)	Partner organizations: JPL, Ball, CNES, NOAA, DoD	Science Team: US and French institutions

PI: Prof. Sarah Gille
Scripps Institution of Oceanography

ODYSEA (and present) **capabilities for global vector winds & currents**

	Resolution	**Sampling**	**Coastal Sampling**
Vector winds	5 km (~20 km)	< daily (< daily)	~3 km from coast (~10-25 km)
Vector surface currents	5 km (~200 km)	~daily (~weekly)	~3 km from coast (~30 km)

*ODYSEA is relevant to Tuesday's panel breakout session on "Upper ocean sub-mesoscale (<200km) processes and climate system connections"

https://odysea.ucsd.edu/