Development of Multiparameter Mesoscale Eddy Products for Operational Use

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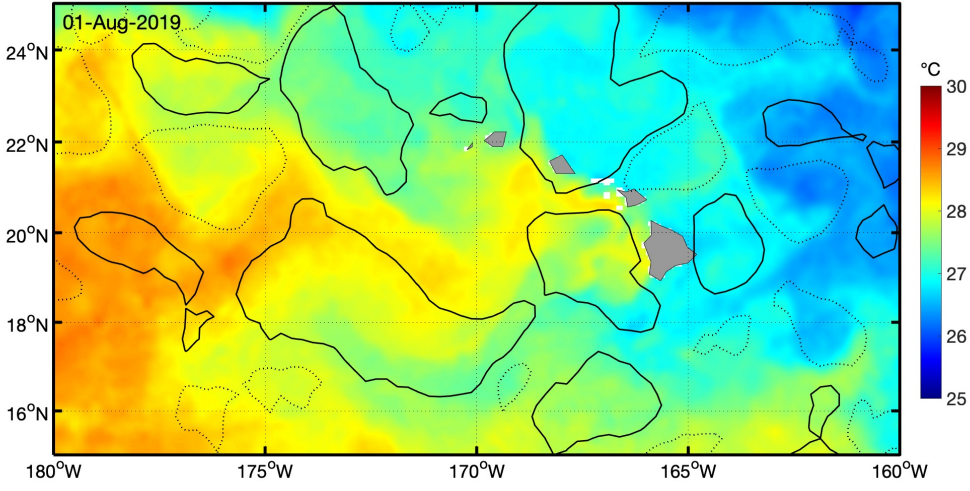
OSTST Meeting

November 2, 2022

Motivation

- Develop an eddy tracking system based on the NOAA RADS gridded SLA and geostrophic current product
- Leverage multiple satellite observations (SST, SSS, Ocean Color Chl-a)
- Create a system that is user friendly that does not require tracking down additional products
- Create a system to classify eddies using available variables in a multiparameter analysis



Geo-polar SST (°C) overlaid with cyclonic (dashed) and anticyclonic (solid) eddy contours in the Pacific Ocean surrounding the Hawaiian Islands.

Background – The California Current

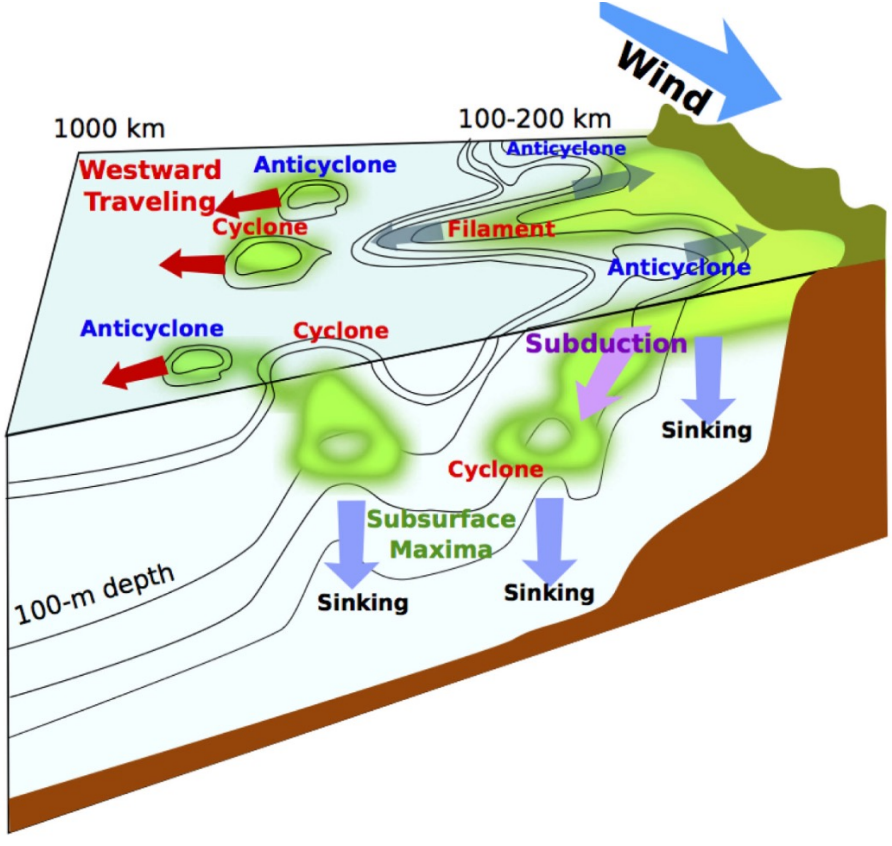


Figure 15. Schematic diagram summarizing the dynamics of offshore transport of organic carbon in the California Current System as diagnosed by our model simulation. After being formed in the upwelled waters, a substantial fraction of the organic matter is transported offshore, first by filaments that protrude across the coastal upwelling front, which tends to act as a barrier for offshore transport. Much of the organic matter is subducted at the fronts associated with the filaments. From there, the organic matter is readily transported further offshore by westward propagating eddies, which form at an offshore distance of about 100–200 km. Most of the initial offshore transport in summer occurs by cyclonic eddies, largely reflecting their generation at the tip of the filaments. The organic carbon in the cyclonic eddies is then stirred and entrained also into anticyclonic eddies, which travel west as well. The eddy fluxes dominate the transport in the region 200–800 km from the shore.

- Cross-shelf transport of organic matter and biogeochemical/biophysical properties by mesoscale eddies is a critical part of biogeochemical and biophysical cycling in the California Current System

- Tracking these eddies and their biophysical properties can provide a valuable tool for ecosystem, water quality, biophysical, and biogeochemical studies, among others.

Nagai et al., (2015)

Overview of Eddy Tracking

Overview of Eddy Tracking

- Inputs:
  - NOAA Radar Altimetry Database System (RADS) NRT Altimetry 0.25° x 0.25° daily grids (Sea Level Anomalies (SLA), U, V)
  - NOAA Geo-Polar Blended NRT L4 Analysis 5 km daily grids (night SST)
  - NOAA MSL12 NRT VIIRS multi-sensor ocean color DINEOF gap-filled analysis 9 km daily grids (Chl-a)
  - SMAP JPL V5.0 interpolated 0.25° x 0.25° daily grids (SSS)
- Uses a closed-contour eddy tracking method adapted from Chaigneau et al. (2008, 2009) and Pegliasco et al., (2015)
- Trajectories considered valid if eddy tracking run for 100+ days, calculated using a cost-function:

$$CF_{e_{1,}e_2} = \sqrt{\left(\frac{\Delta R - \overline{\Delta R}}{\sigma_{\Delta R}}\right)^2 + \left(\frac{\Delta A - \overline{\Delta A}}{\sigma_{\Delta A}}\right)^2 + \left(\frac{\Delta EKE - \overline{\Delta EKE}}{\sigma_{\Delta EKE}}\right)^2}$$

- Threshold free but a threshold can be applied if desired
- Available from August 2019-present
- Observation based in entirety, does not require model input

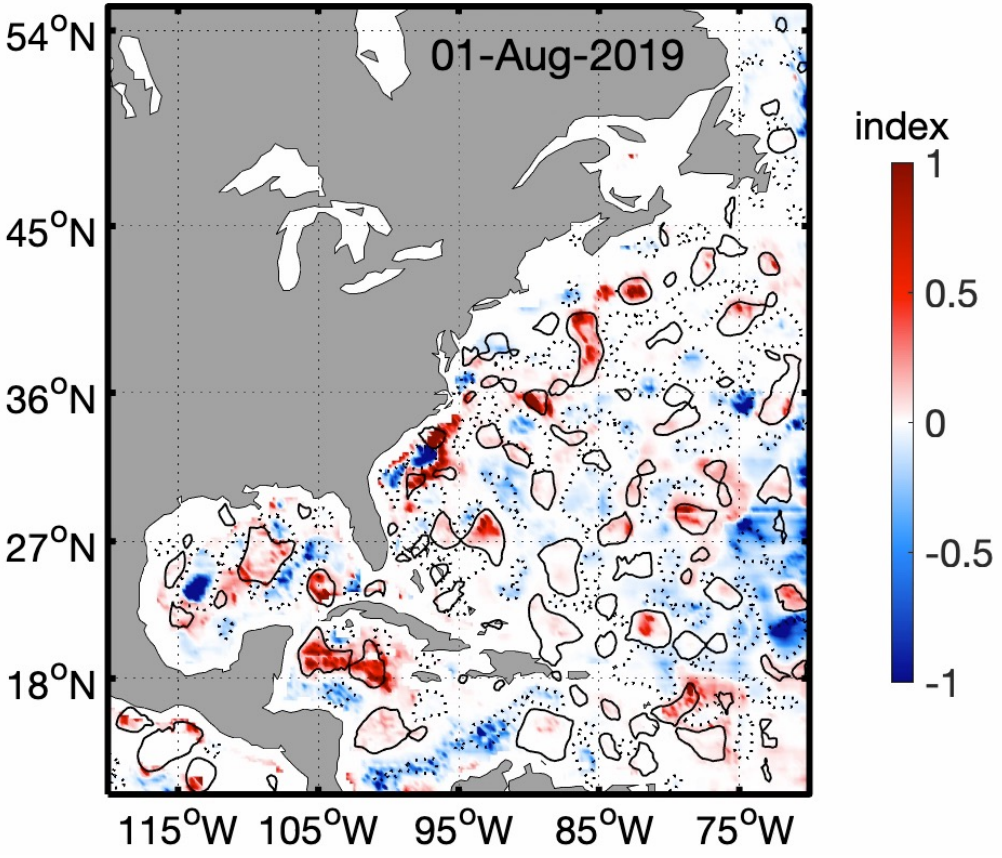
Multiparameter Eddy Significance Index

Multiparameter Eddy Significance Index (MESI)

Normalized index of multiparameter eddy variability that describes the potential impact of a given eddy on mixed layer dynamics and nutrient pumping

$$MESI = Z_{SLA} * abs(Z_{SST}) * abs(Z_{SSS}) * abs(Z_{Chla}) * abs(\log_{10}(Z_{EKE}))$$

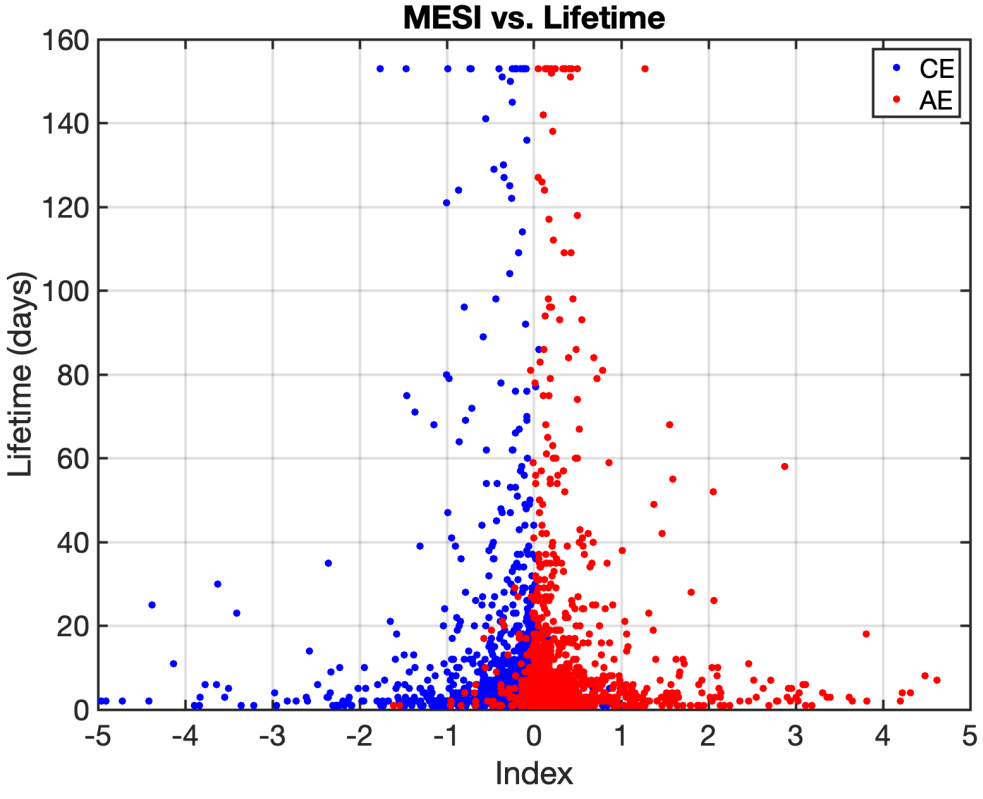
$$Z_{var} = \frac{var - \overline{var}}{\sigma_{var}}$$



Roman-Stork et al. (In Review)

Why threshold free?

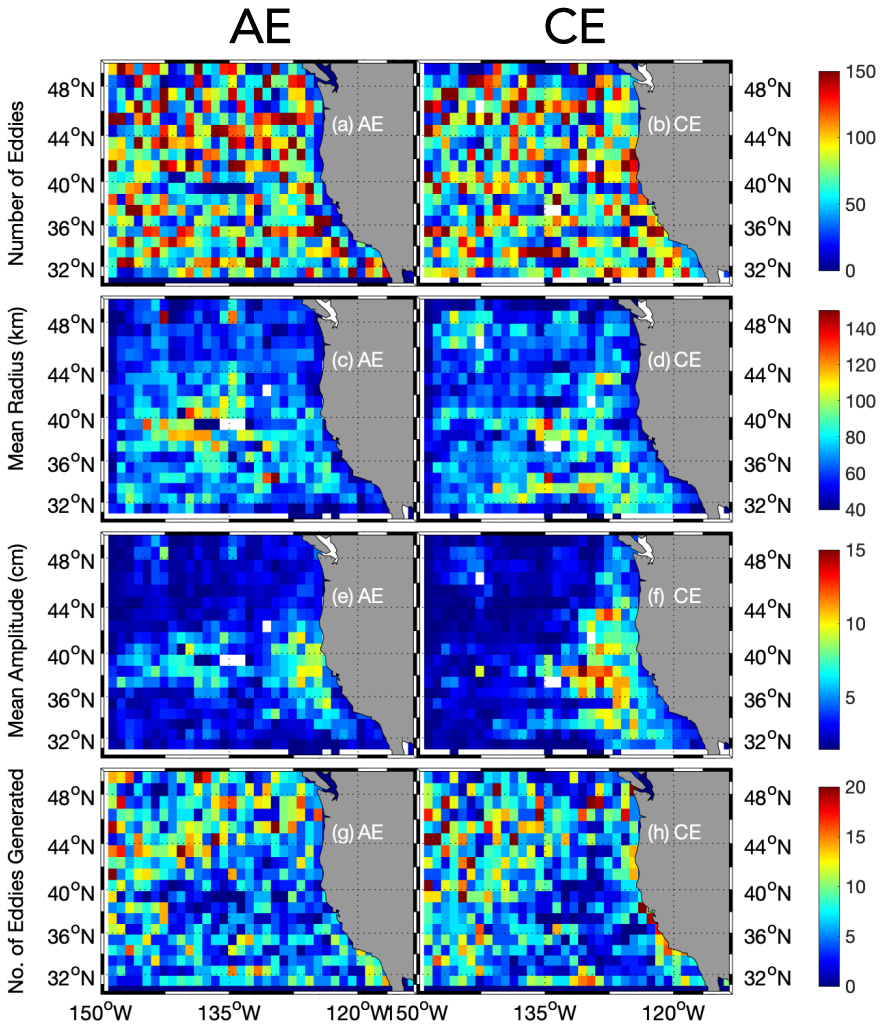
- Our system keeps transient eddies filtered out by other eddy tracking systems:
  - Important for air-sea interactions, local weather → feeds back into oceanic systems
  - Play a role in ocean circulation
  - Still impact upper ocean processes and ecosystem dynamics
  - Impact nutrient cycling and water quality
  - Does result in some false eddies
  - Thresholds can easily be imposed by end users



Roman-Stork et al. (In Review)

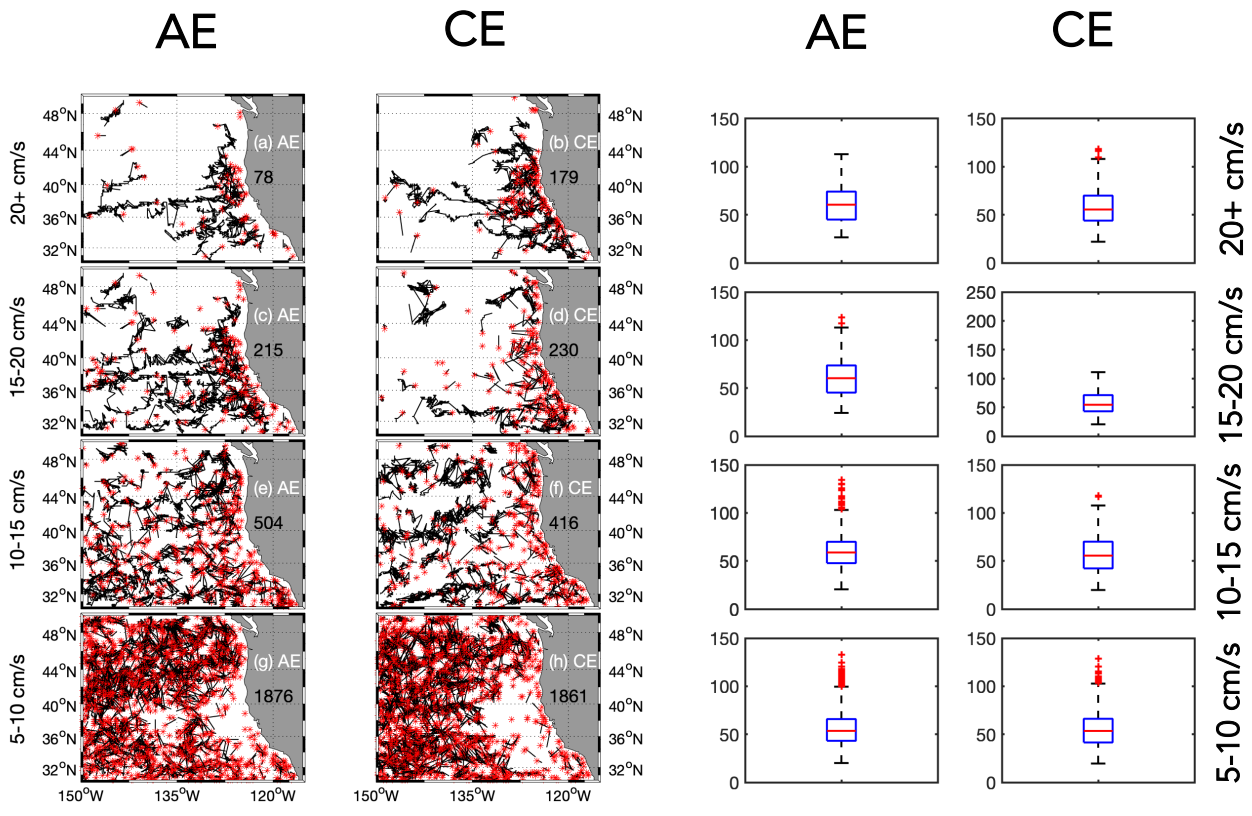
Eddy Characteristics in the California Current System

Eddy Characteristics



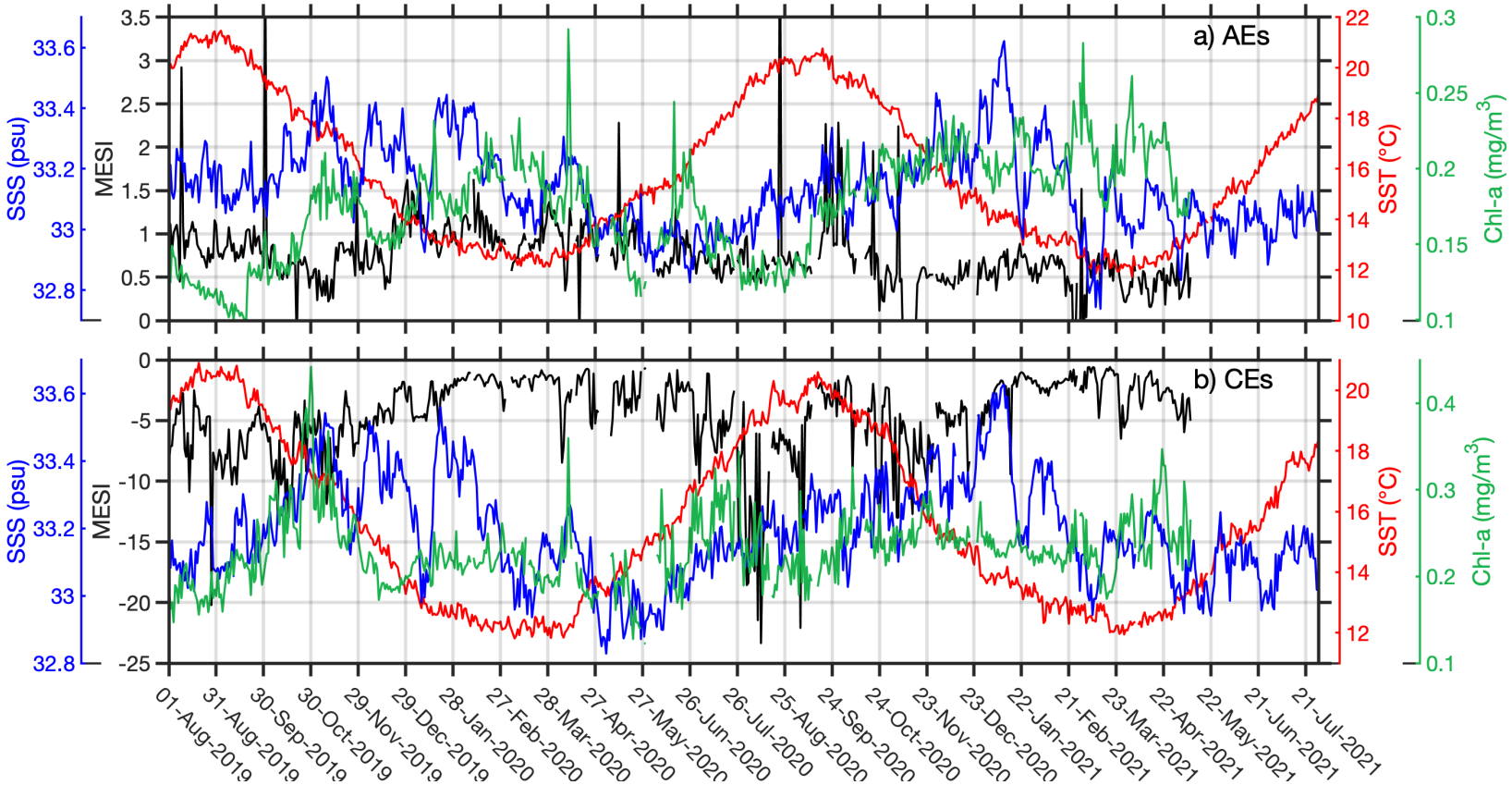
- Eddy characteristics for August 1, 2019 – August 1, 2021
- Eddies sorted into anticyclonic (AE) and cyclonic (CE) eddies
- Resulting eddy characteristics shown in 1° bins (4 grid points per bin)
- Distribution of characteristics highlights regional differences (Radius, No. of eddies generated) and location of California Current (Amplitude)
- End users do not need to download and compare multiple datasets
- Consistent with literature

Eddy Trajectories



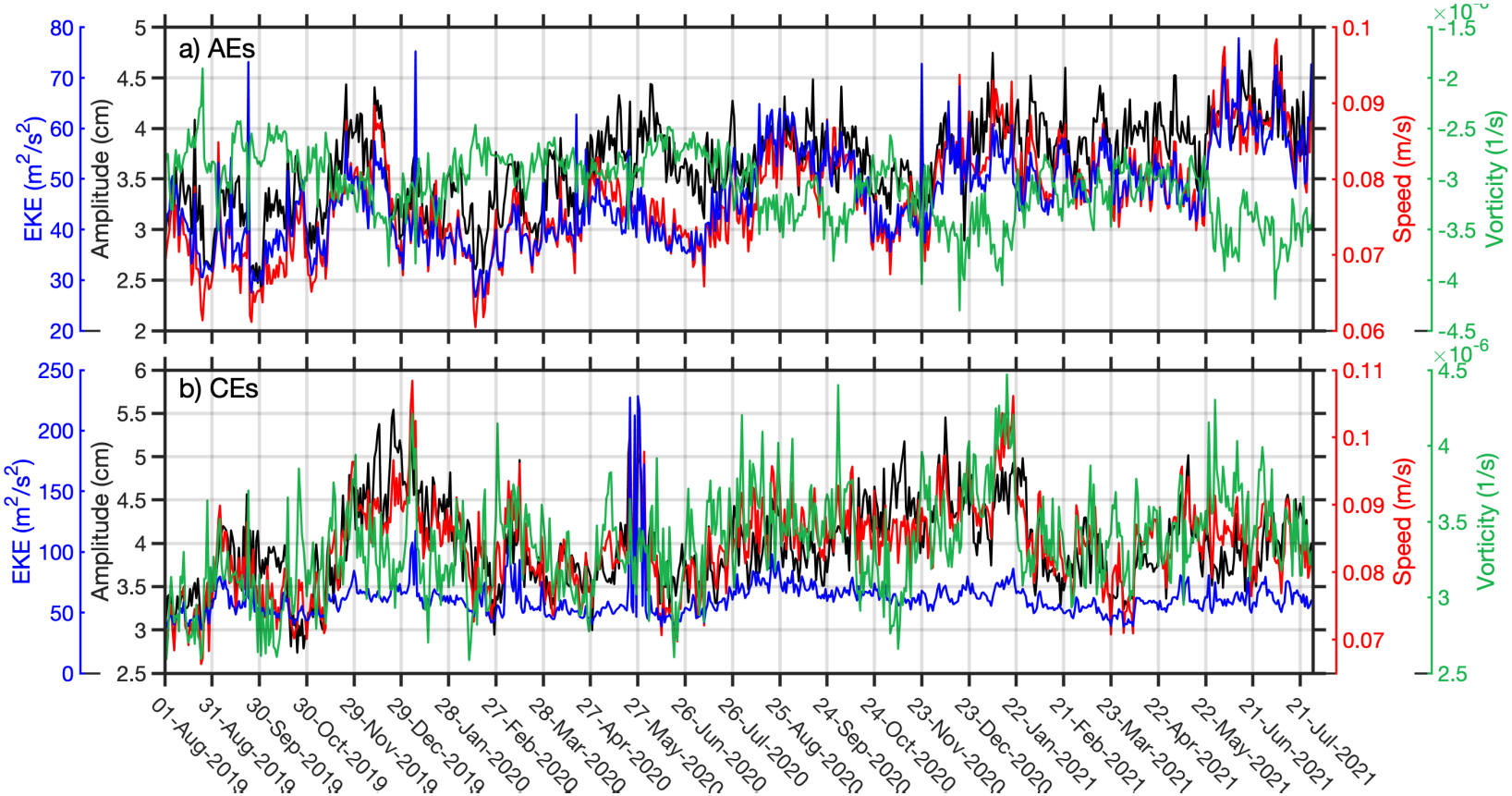
- Eddy trajectories plotted in bins based on eddy speed (5-10 cm/s, 10-15 cm/s, 15-20 cm/s, and 20+ cm/s)
- **Numbers in black** indicate number of eddies shown in the category
- Red stars are point of eddy genesis, **black lines are** the trajectories
- **Box plots** show corresponding distribution of eddy radii (km) in each category
- Trajectories and related statistics can be filtered and analyzed according to any parameter

Eddy Characteristics



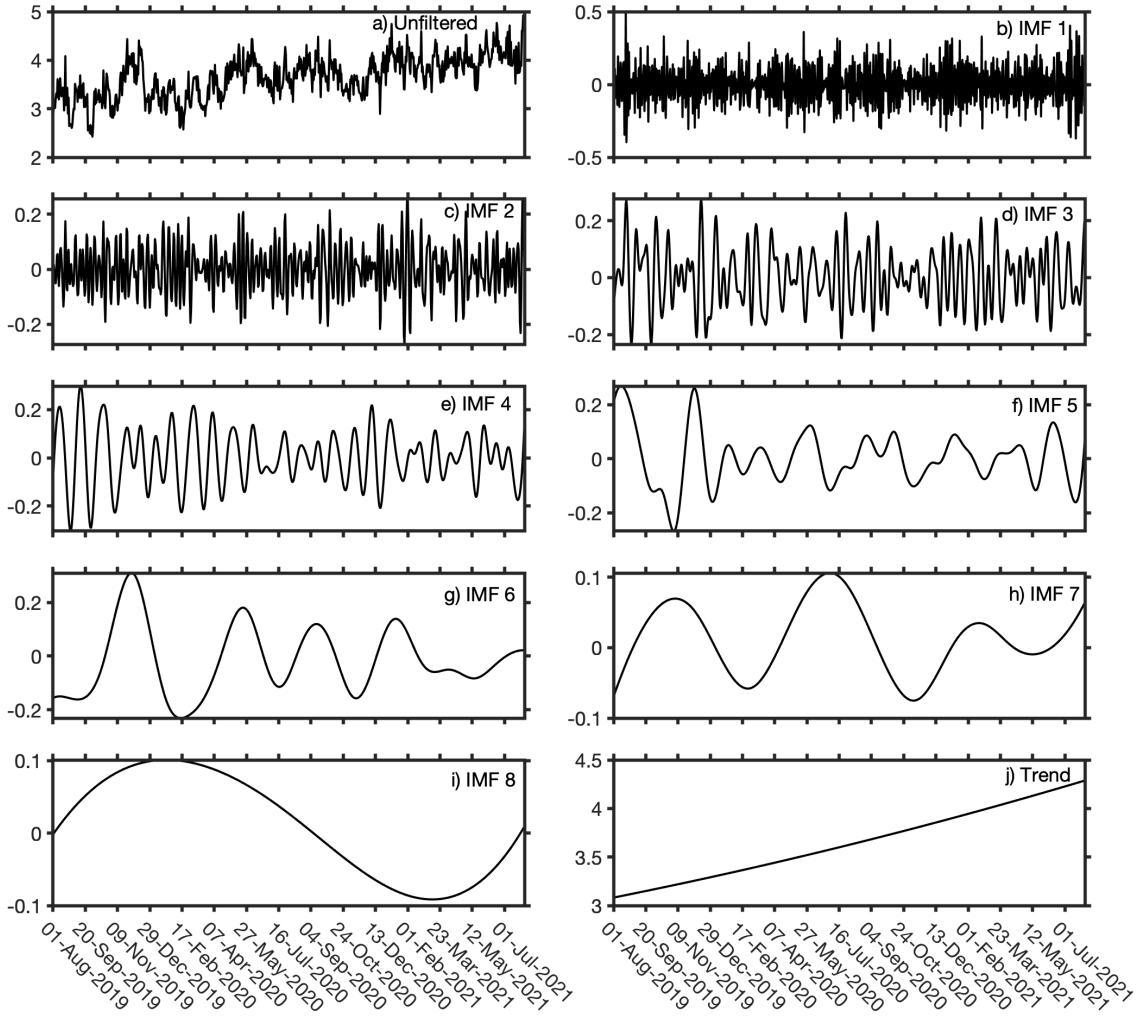
Daily time series of **mean MESI**, mean SSS (psu), mean SST (°C), and mean Chl-a (mg/m^3) averaged across the research area (210-260°W, 10-55°N) for a) AEs and b) CEs from August 1, 2019-August 1, 2021.

Eddy Characteristics



Daily time series of **eddy amplitude** (cm), mean EKE (m^2/s^2), mean speed (m/s), and mean vorticity (1/s) averaged across the research area (210-260°W, 10-55°N) for a) AEs and b) CEs from August 1, 2019-August 1, 2021.

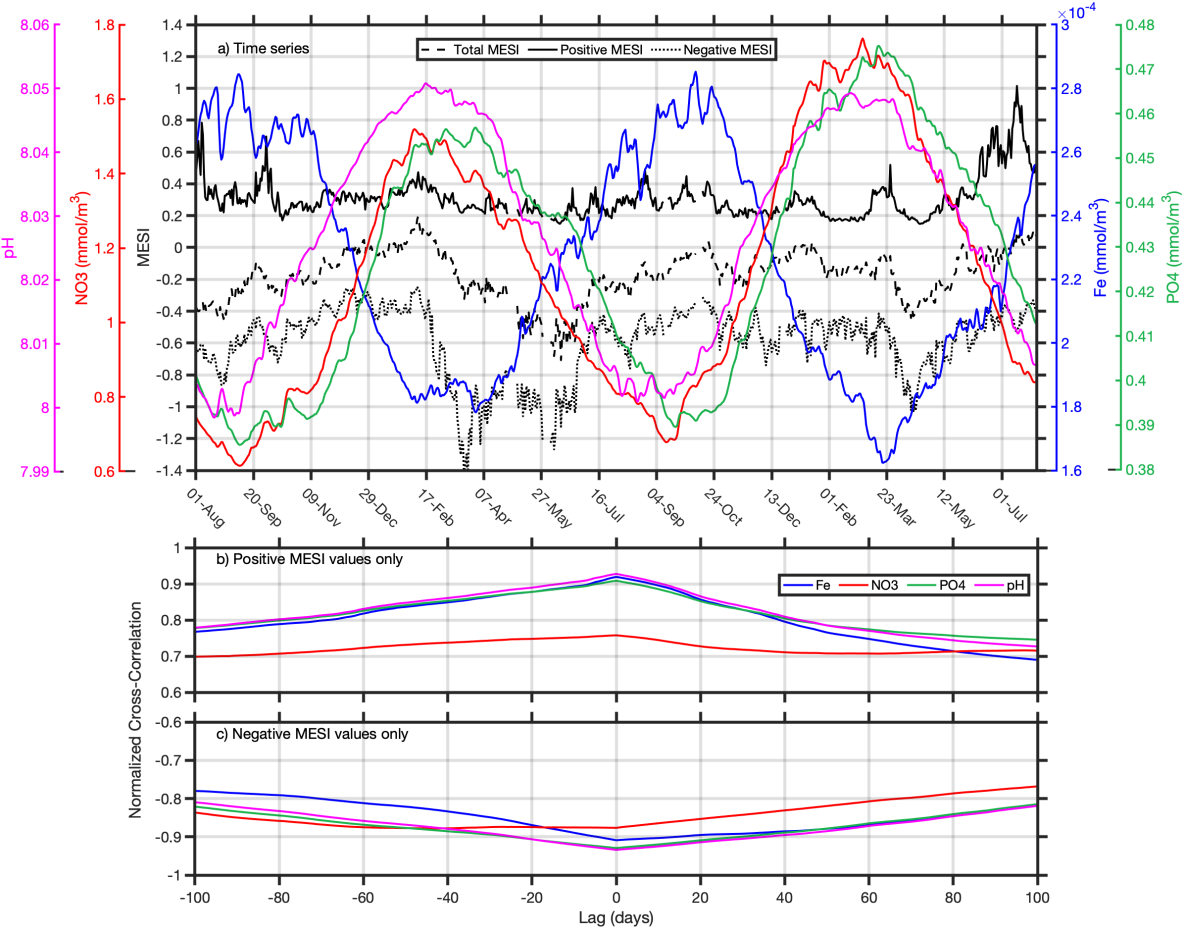
Eddy Characteristics



- Ensemble Empirical Mode Decomposition (EEMD) analysis of daily anticyclonic eddy time series of amplitude (cm), separated into individual intrinsic mode functions (IMFs; b-i)), the original time series (a), and the remaining trend (j).
- Can identify dominant modes of periodicity within the eddy time series (seasonal, intraseasonal, etc.)
- Significant overall trend → increase of almost 1.5 cm in just 2 years in the California Current System

Applications of Eddy Tracking

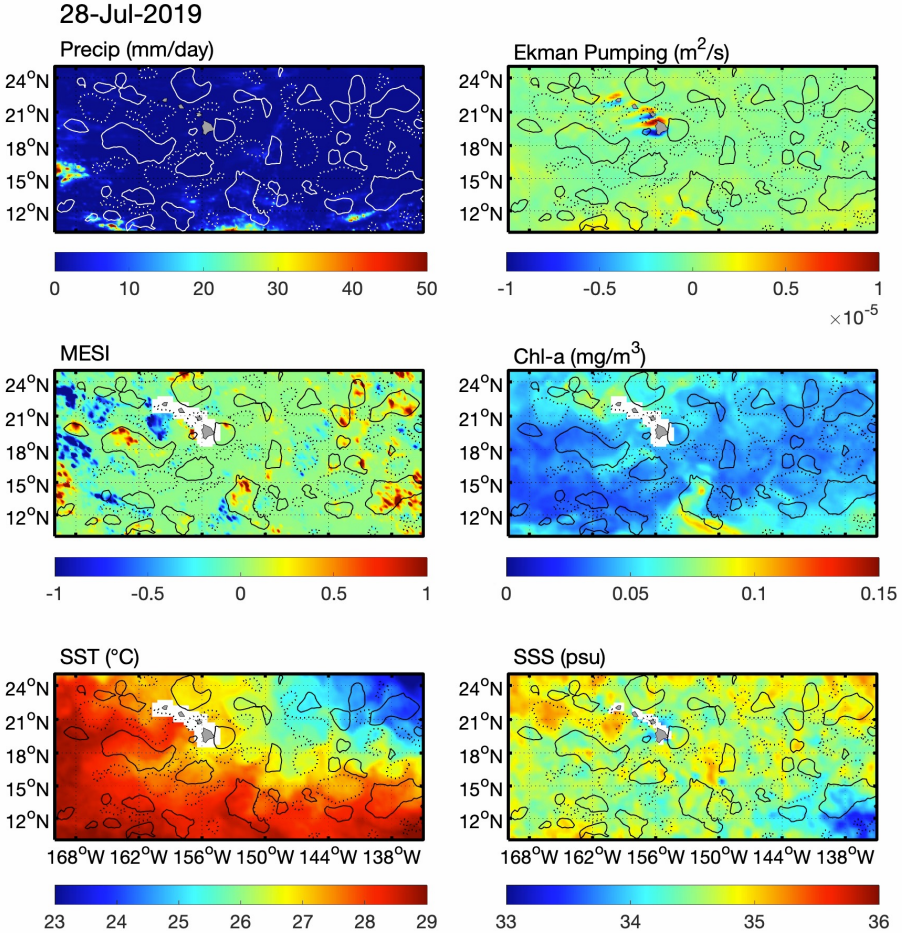
Applications of Eddy Tracking



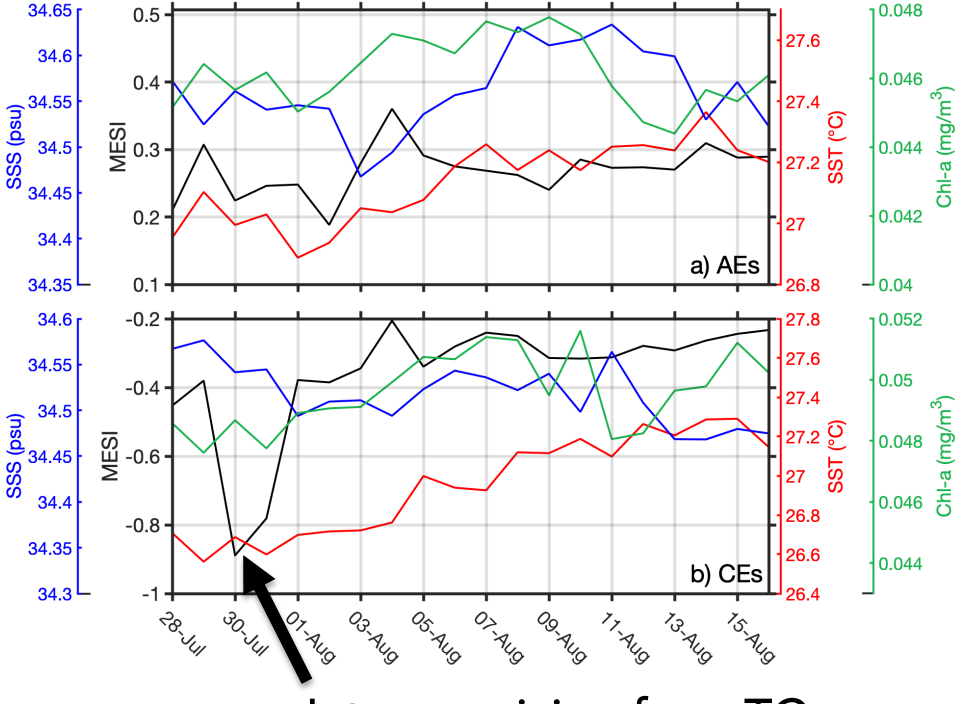
- Up to 95% cross-correlation with no lag between MESI and BGC variables for the California Current System
- Nitrate has the lowest correlation through time of all the BGC variables tested
- Suggests that MESI can be used as a NRT indicator of biogeochemical activity and can be used to monitor systems using observations rather than model output
- Total and negative MESI values (CEs) vary more closely with BGC variables than positive MESI values (AEs)
  - Consistent with eddy activity in California Current System

Roman-Stork et al. (In Review)

Applications of Eddy Tracking



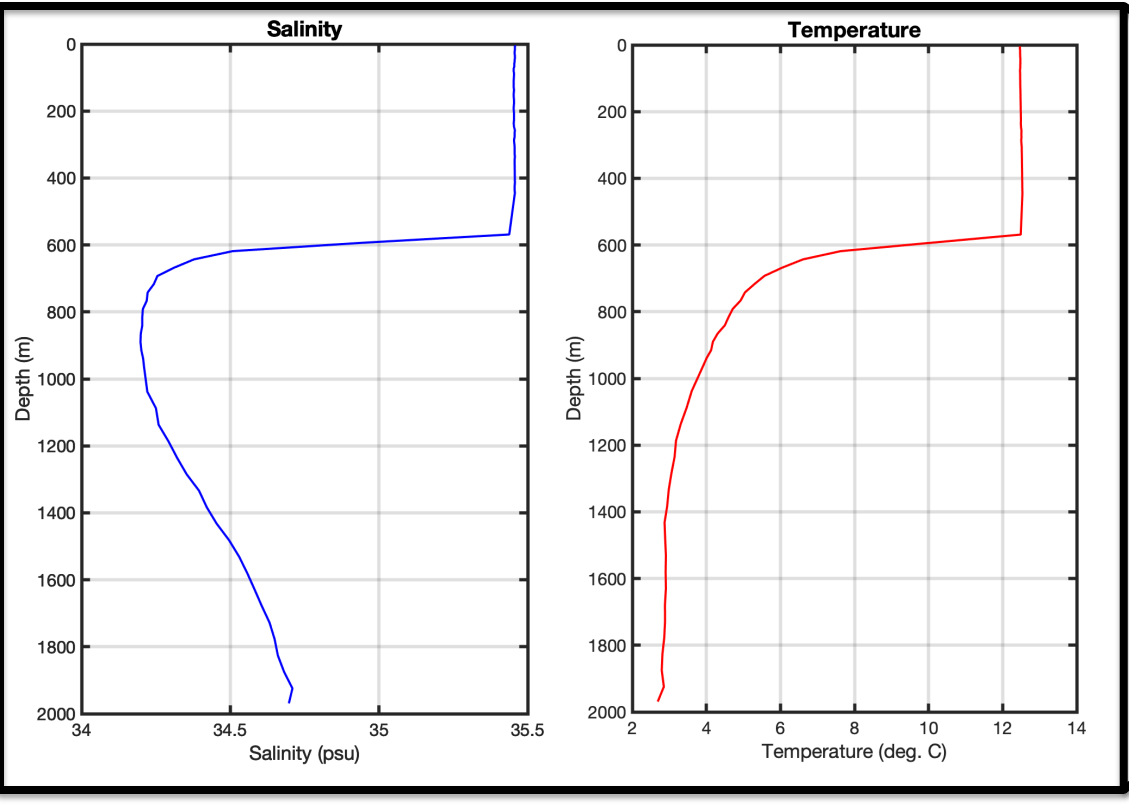
- Hurricane Erick near the Hawaiian Islands (July 30-August 5, 2019)
- (Left): Satellite observations and eddy contours
- (Right): Time series of mean eddy properties

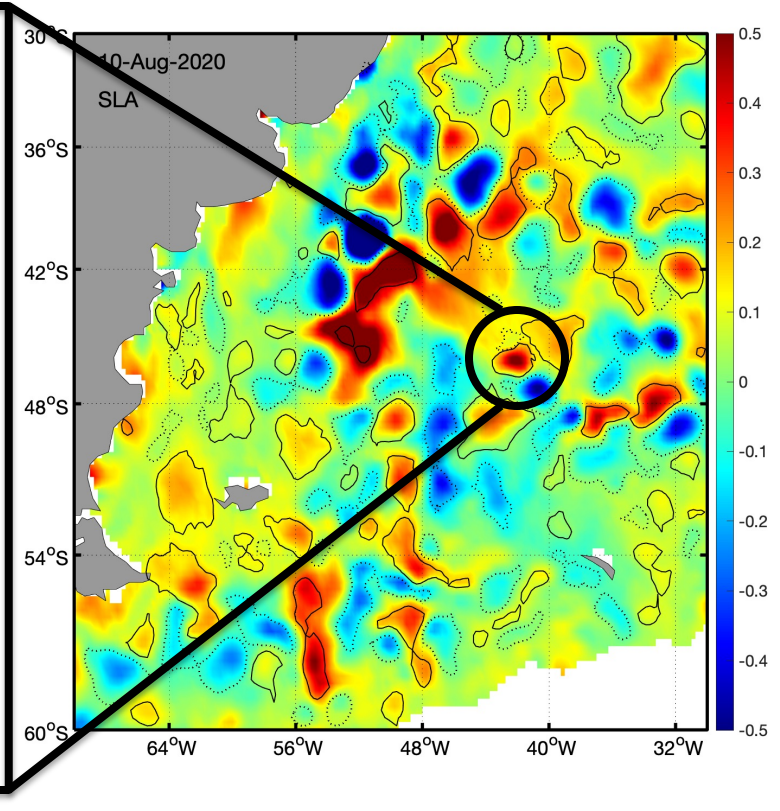


Applications of Eddy Tracking

Argo Profiles

Eddy Field – NOAA RADS SLA





Flagged Argo profiles and corresponding eddy in SLA (m) with eddy contours

Summary


NOAA
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
U.S. DEPARTMENT OF COMMERCE


GLOBAL SCIENCE & TECHNOLOGY, INC.


CoastWatch.
noaa.gov


NOAA
Laboratory for Satellite Altimetry
NOAA·NESDIS·STAR

Summary

- Multiparameter eddy tracking allows for user-friendly analysis of NRT eddies in the California Current System and beyond
- MESI can be used in concert with eddy tracking to rapidly identify eddies that may have strong biogeochemical and biophysical impacts, with applications across numerous fields of oceanography for both operational uses and research
- Multiparameter eddy tracking is presently an experimental regional product for NOAA CoastWatch, but will soon be global
- Experimental version using ADT instead of SLA also in development
- Exploring Argo QC for OHC calculations with NOAA NCEI

Questions?

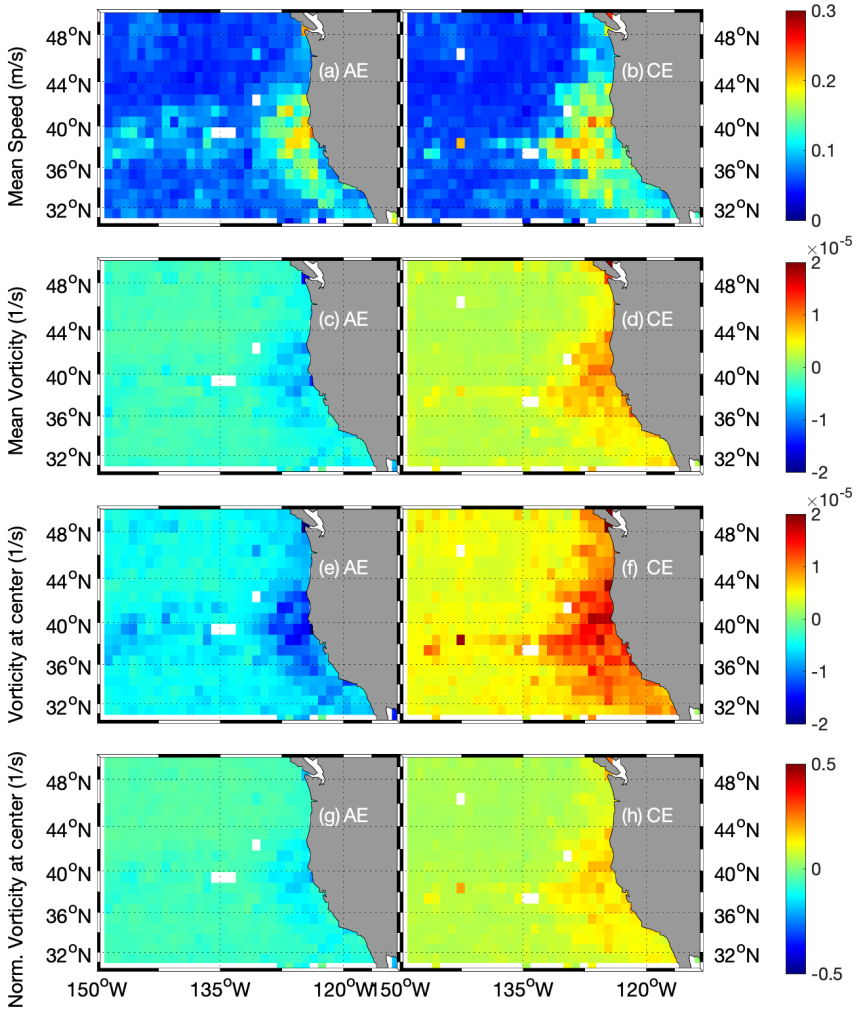
Email Heather Roman-Stork: heather.roman-stork@noaa.gov

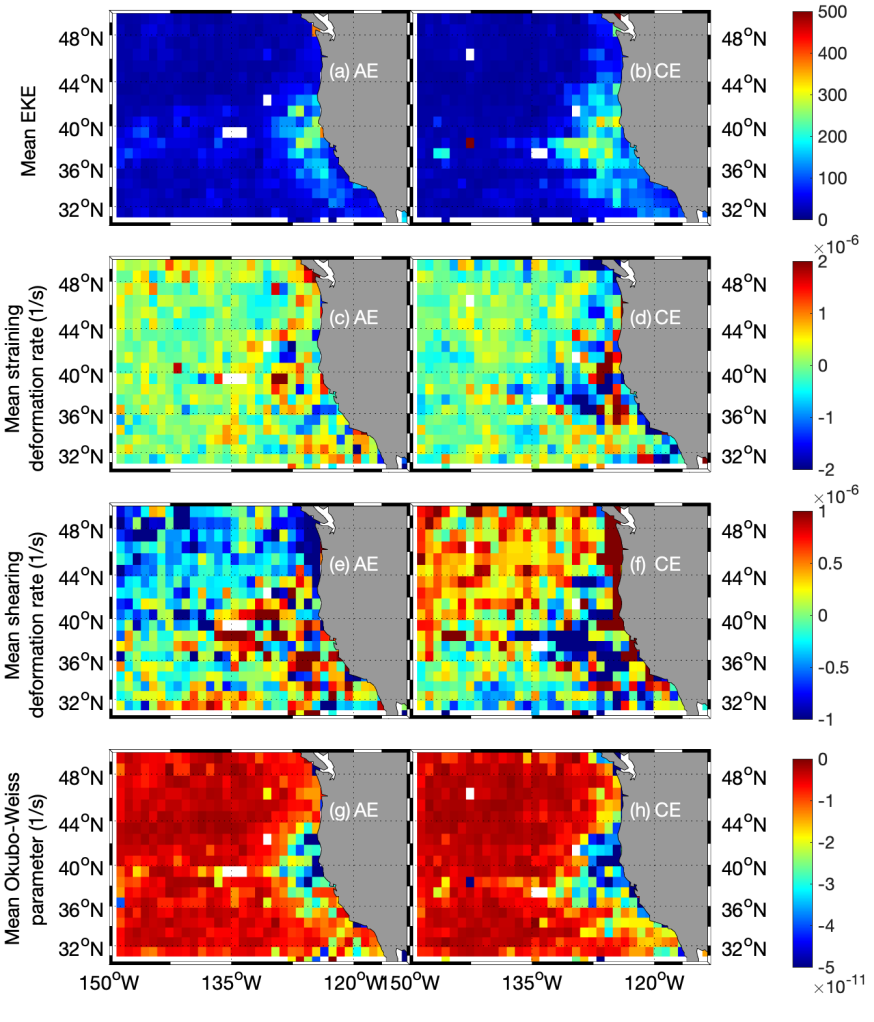
Extra Slides

Variables Tracked

- Date/time
- Overall eddy coordinates
- Observation number
- Eddy trajectory
- Eddy contours
- Eddy area
- Amplitude
- Radius
- Mean speed
- Mean vorticity
- Vorticity at center
- Normalized vorticity at center
- Mean EKE
- Mean straining deformation rate
- Mean shearing deformation rate
- Mean Okubo-Weiss parameter
- U inside eddy
- V inside eddy
- Mean SST
- Mean SSS
- Mean Ocean Color Chl-a
- Mean MESI

Eddy Characteristics





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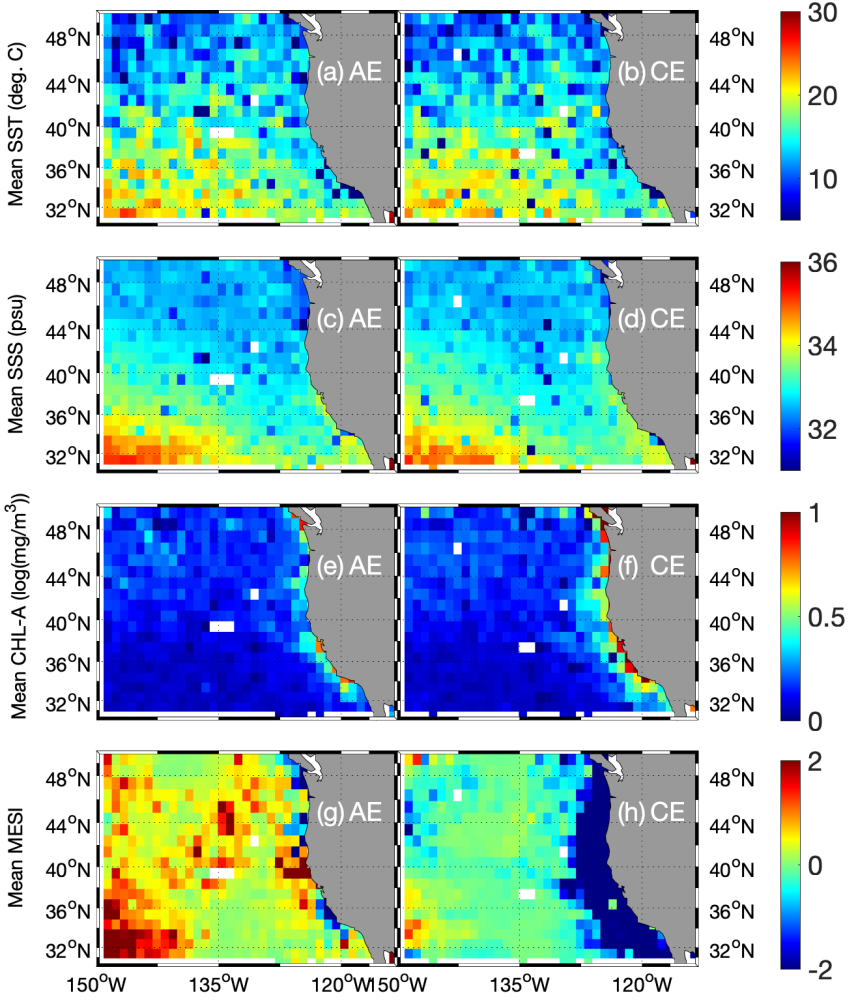
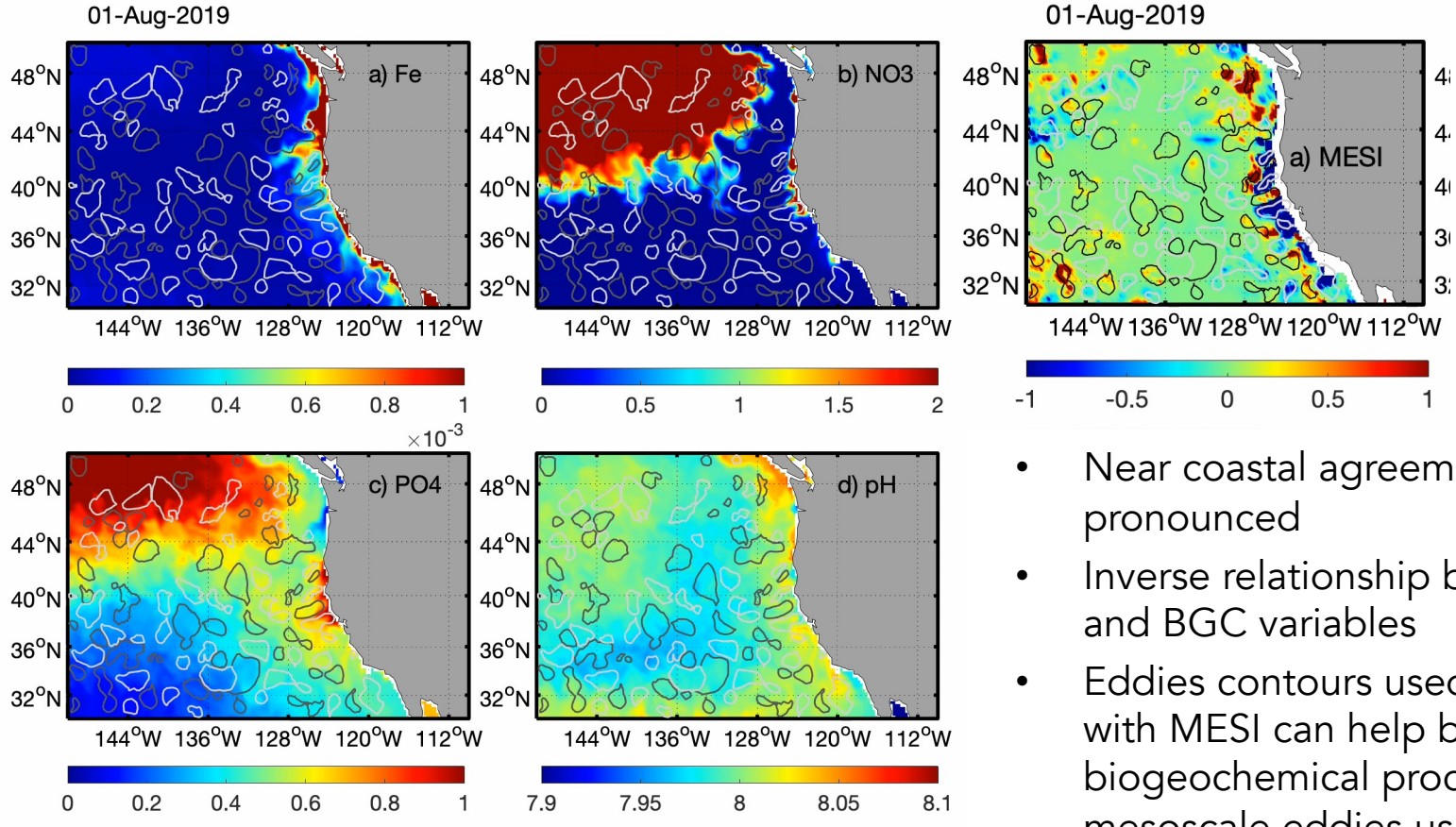


- Multiparameter eddy characteristics
- Leverages observations from multiple satellite observations and multiple satellite data products
- Characteristics easily divided by circulation type
- End users do not need to download multiple datasets

Applications of Eddy Tracking



- Near coastal agreement most pronounced
- Inverse relationship between MESI and BGC variables
- Eddies contours used in conjunction with MESI can help better understand biogeochemical processes in mesoscale eddies using satellite observations and eddy tracking