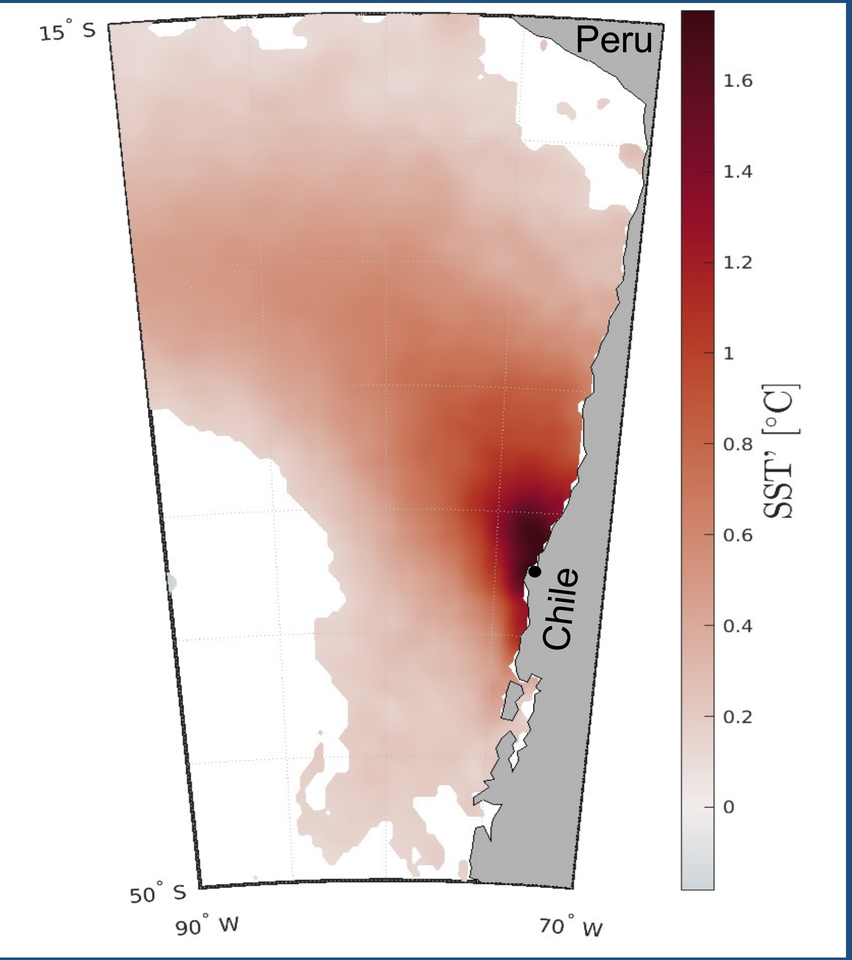
Dominant contributors to mixed layer temperature changes during summer marine heat waves in the Chile-Peru Current System

Kylene Cooley[1]
Melanie R. Fewings[1] (presenting)
James Lerczak[1]
Larry O'Neill[1]
Kevin Brown[2]

[1] College of Earth, Ocean, and Atmospheric Sciences, Oregon State University

[2] College of Pharmacy and School of Chemical, Biological, and Environmental Engineering, OSU

Composite SST anomaly
over 37 extreme warm events in 1980-2019



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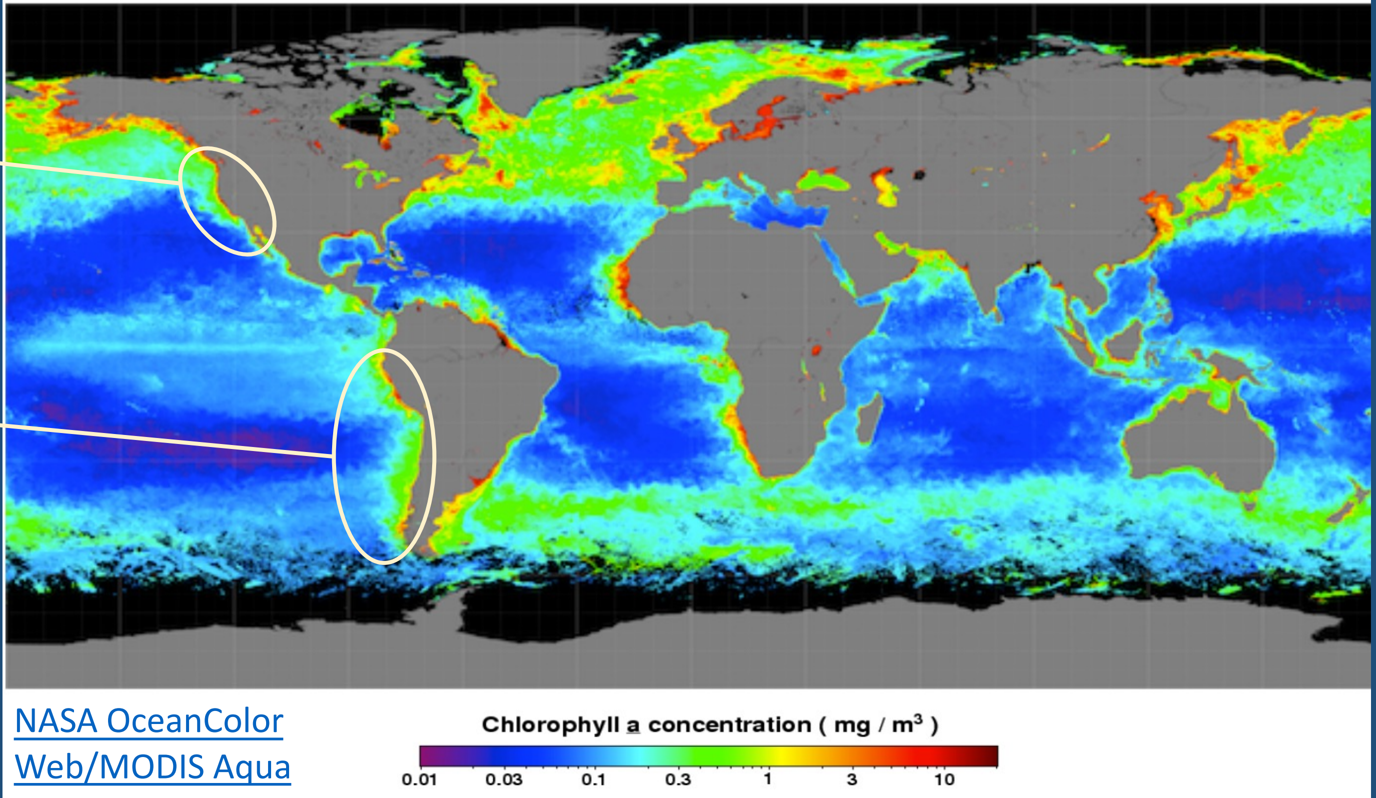
Eastern Boundary Upwelling Systems:
Highly productive, yet sensitive to warm water anomalies (marine heat waves)

California Current System (CCS)
(our previous and ongoing work)

Chile-Peru Current System (CPCS)

2007:
$\sim 7.5 \times 10^6$ t
of anchoveta landed
(Montecino and Lange 2009)



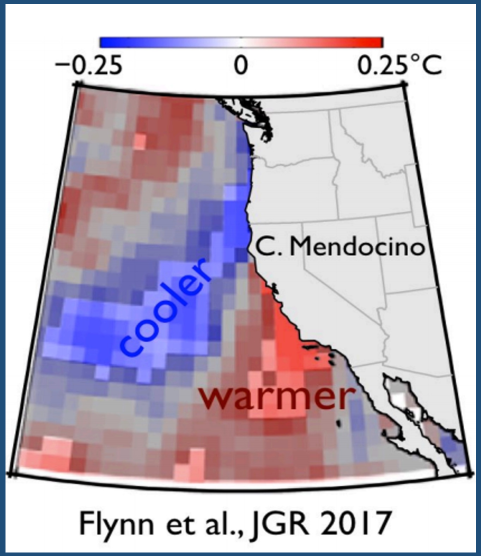
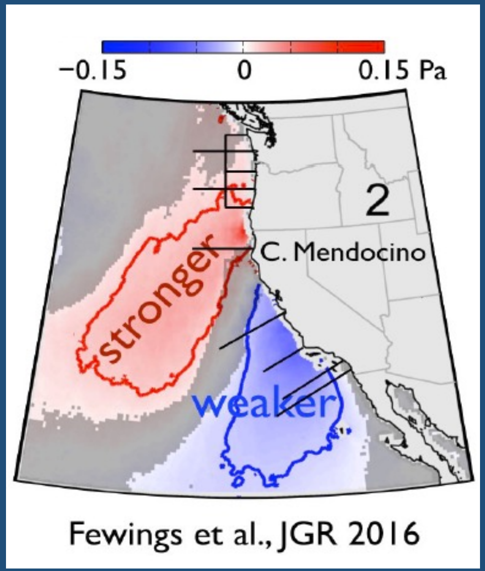
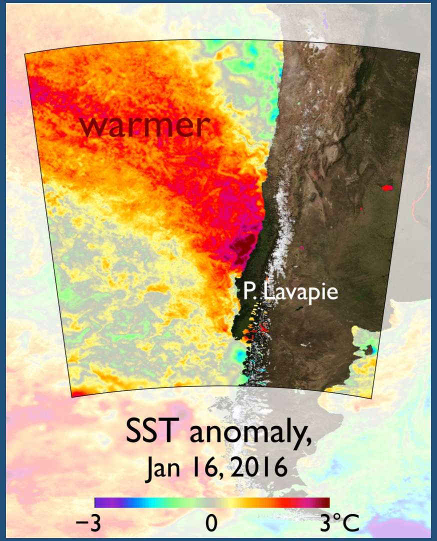
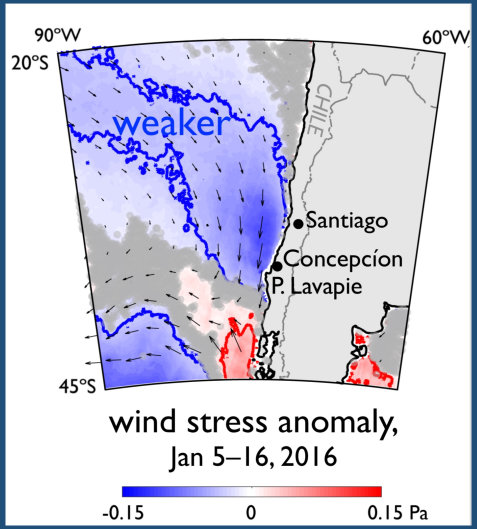
NASA OceanColor Web/MODIS Aqua

Research questions

1. Is the area of anomalous warming for historical extreme warm SST anomalies in the CPCS similar in shape and location to the January 2016 warm event?

2. Could the net surface heat flux anomaly account for most of the anomalous warming?

3. If not, does the anomalous warming pattern coincide with a weak wind stress anomaly as in wind relaxations in the CCS?

	SST anomaly	Wind stress anomaly
Typical CCS southern wind relaxation		
Jan 2016 event in CPCS		

Chile-Peru Current System — Research Questions — SST' Event Patterns — Mixed-Layer Anomaly Heat Budget — Wind Stress Magnitude Anomaly

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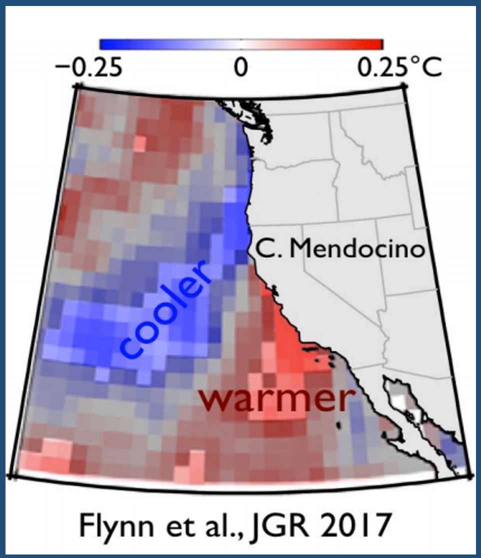
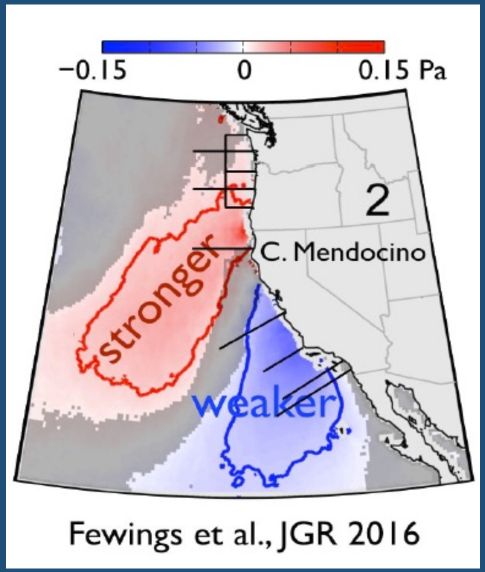
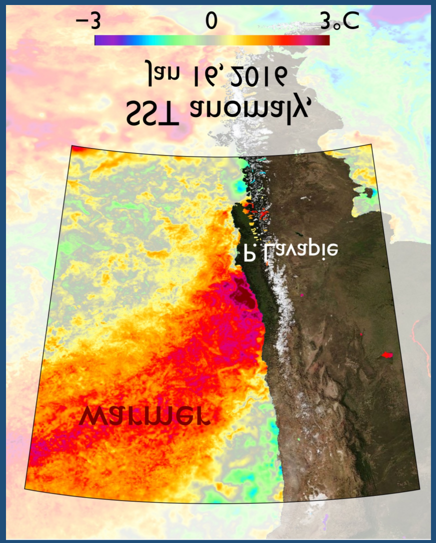
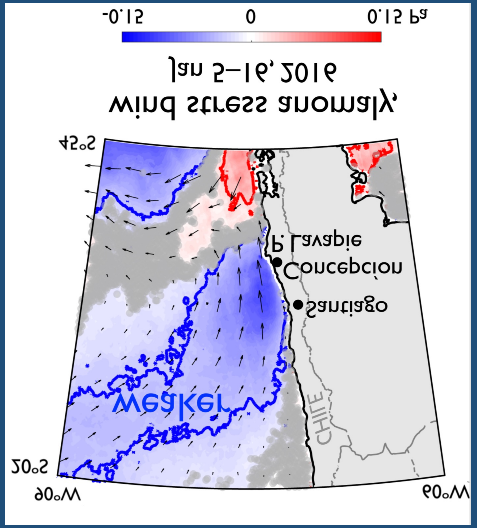
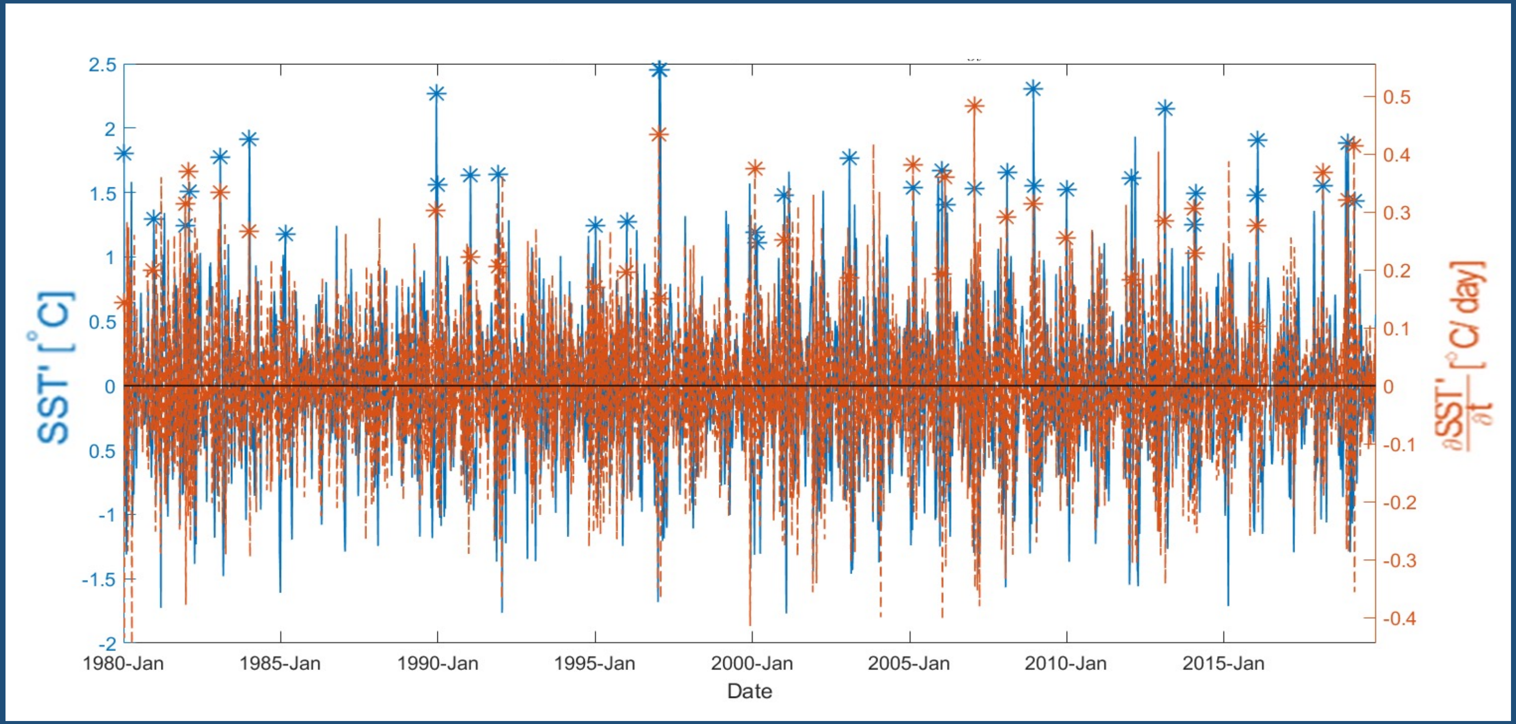
Typical CCS southern wind relaxation		
Jan 2016 event in CPCS		

How do we identify extreme warm anomaly events?

Identified events and maximum anomalous warming immediately preceding events

Datasets:

- ERA5 daily 0.25-degree reanalysis
    - SST
    - Zonal and meridional wind stress
    - Components of net surface heat flux
- Holte et al. 2017 Argo float mixed-layer depth climatology



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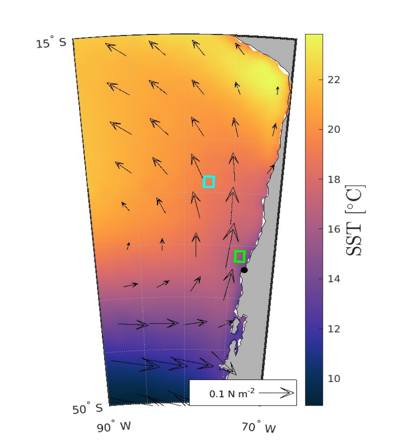


Bandpass filter 10 days to six months

Chile-Peru Current System

Research Questions

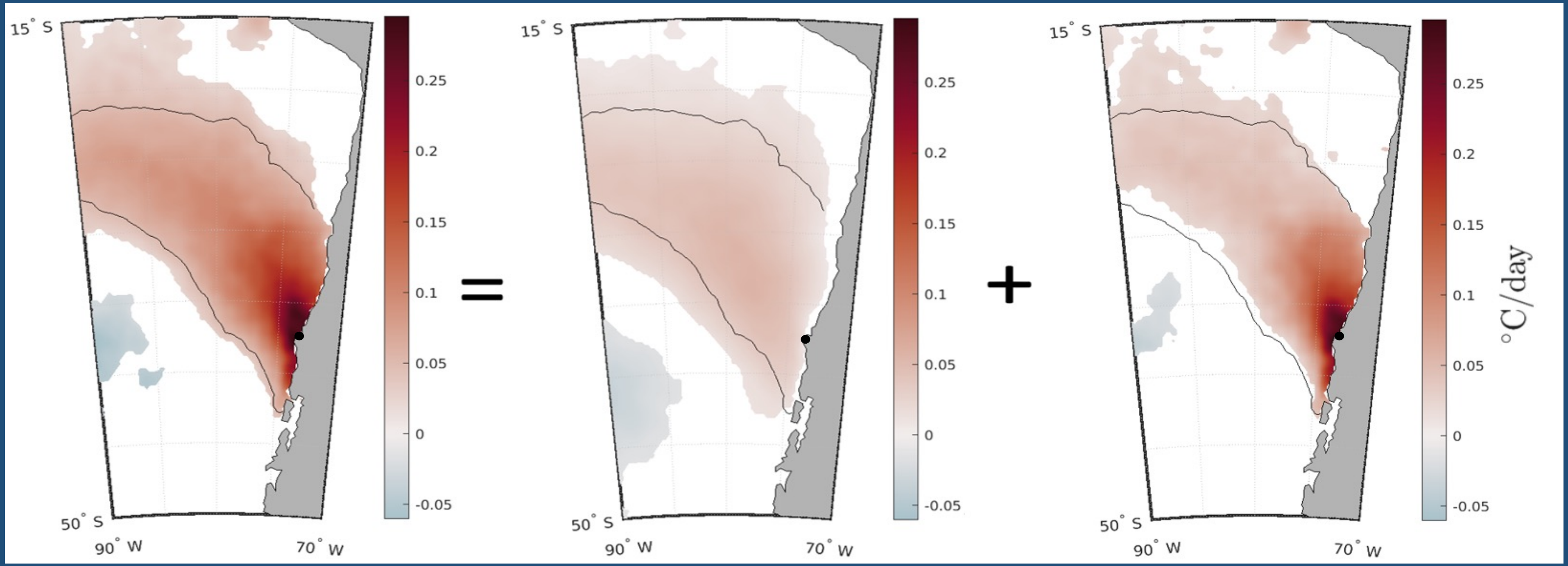
SST' Event Patterns

Mixed-Layer Anomaly Heat Budget

Wind Stress Magnitude Anomaly

The net surface heat flux anomaly cannot explain the anomalous warming

- The **residual** in the anomaly heat budget is larger than the surface heat flux anomaly term



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$$\partial SST'/\partial t \quad = \quad Q'_{net}/\rho_w c_p h_0 \quad + \quad R$$

Chile-Peru Current System

Research Questions

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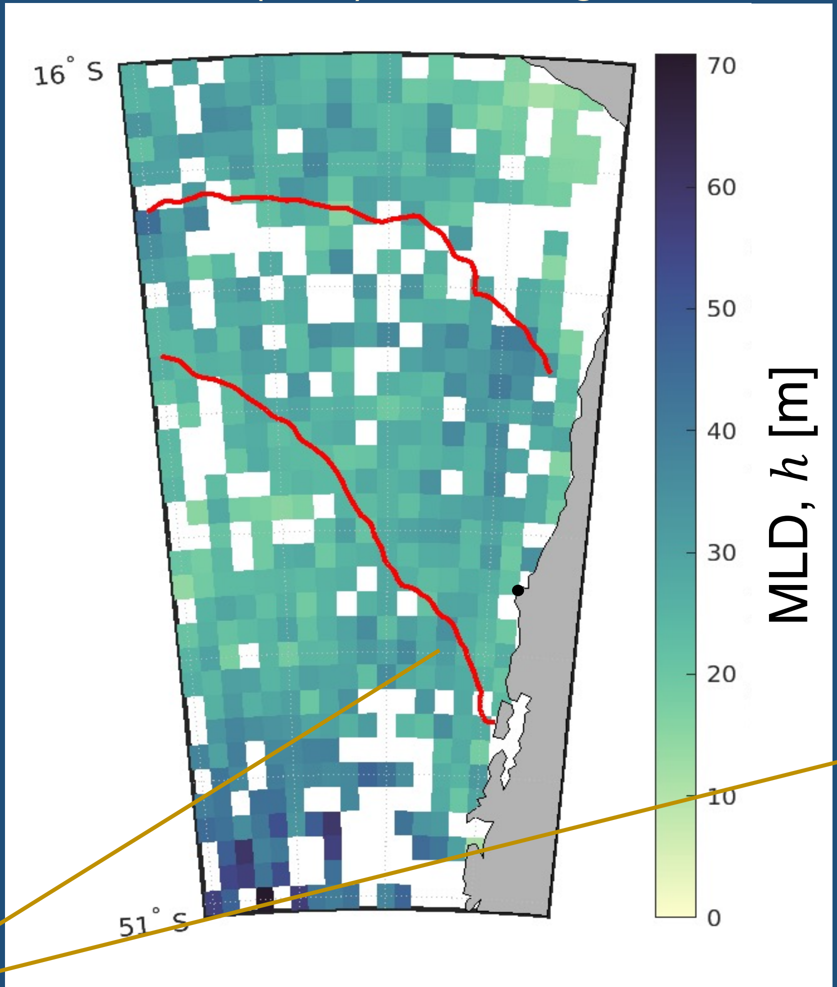
If we allow the MLD to differ from climatology, could air-sea heat flux explain the residual?

No. With the assumption
$R = 0$,
the best-fit MLD from linear regression is more than **5x smaller** than observed summer mean MLD

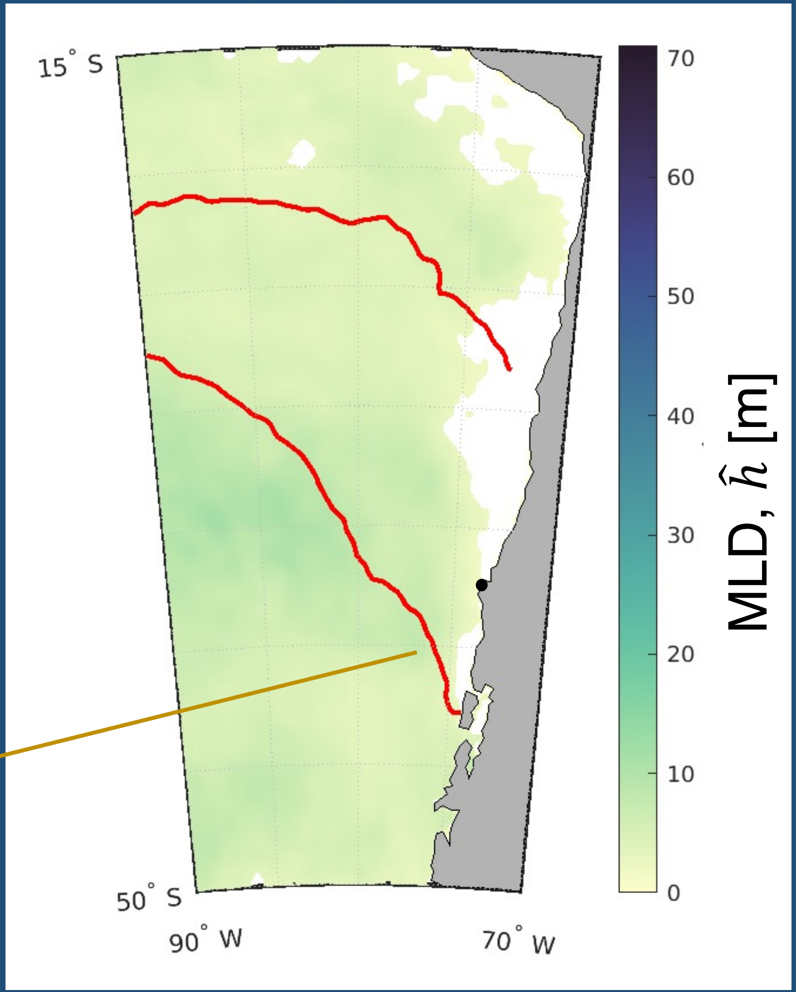
Red line is
$\partial SST'/\partial t = 0.05\ °\mathrm{C\ day}^{-1}$
contour

Summer (DJF) climatological MLD



Average of Holte, et al. 2017 Argo climatology for Dec, Jan, Feb

Linearly regressed MLD



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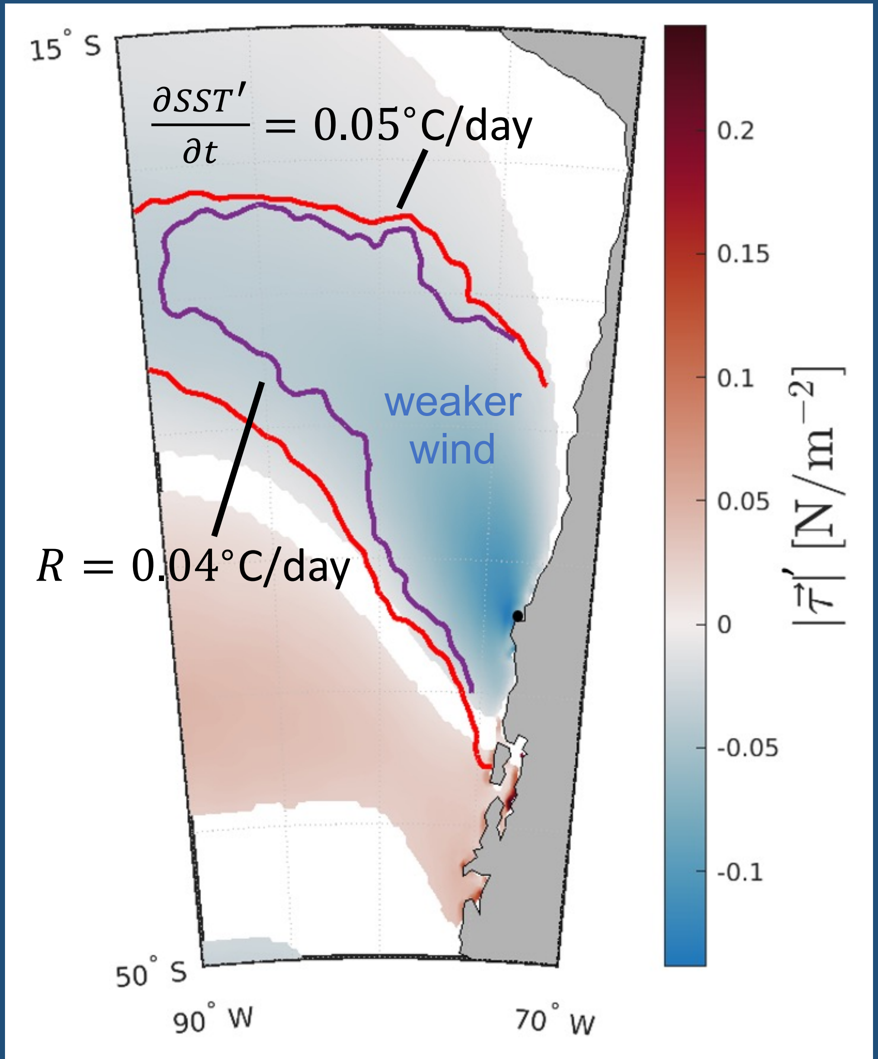
Composite wind stress magnitude anomaly indicates weakened wind stress in warming area

Possible dominant processes:

- Reduced entrainment (and Ekman pumping?)
- Mixed-layer shoaling



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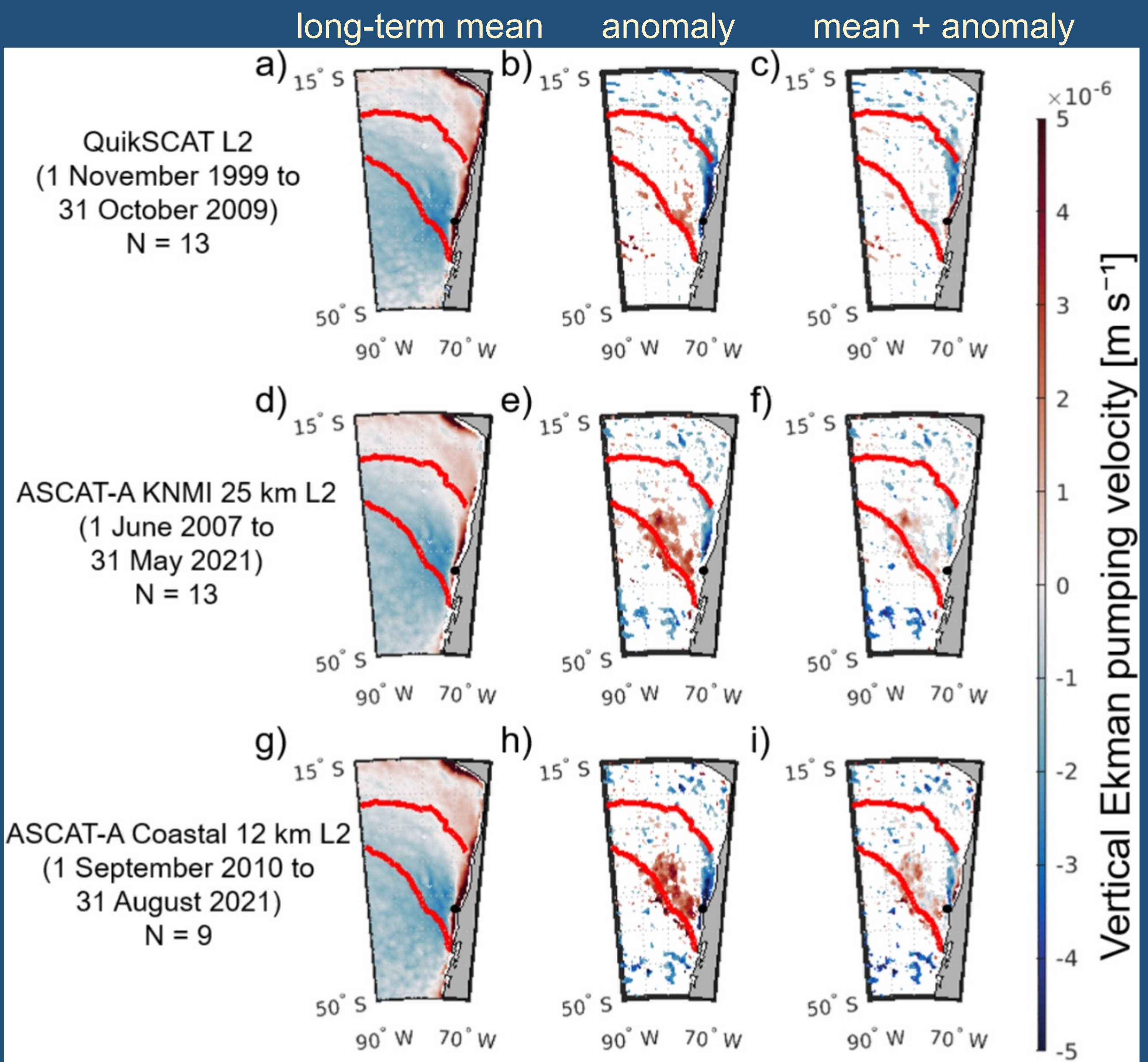
Chile-Peru Current System — Research Questions — SST' Event Patterns — Mixed-Layer Anomaly Heat Budget — Wind Stress Magnitude Anomaly

Wind stress curl anomalies could contribute to warming

near the coast:
suppressed curl-driven upwelling
(less Ekman suction)
could lead to less outcropping
of colder isotherms
during extreme warm events

offshore: reduced Ekman pumping
could lead to ML shoaling
during extreme warm events

red = upward
blue = downward
Ekman pumping velocity
or anomaly



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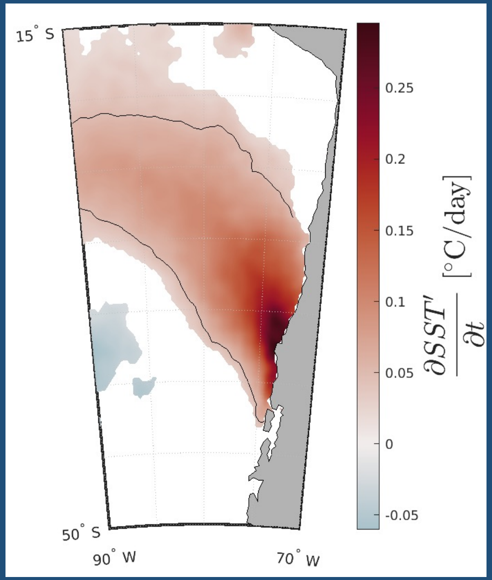
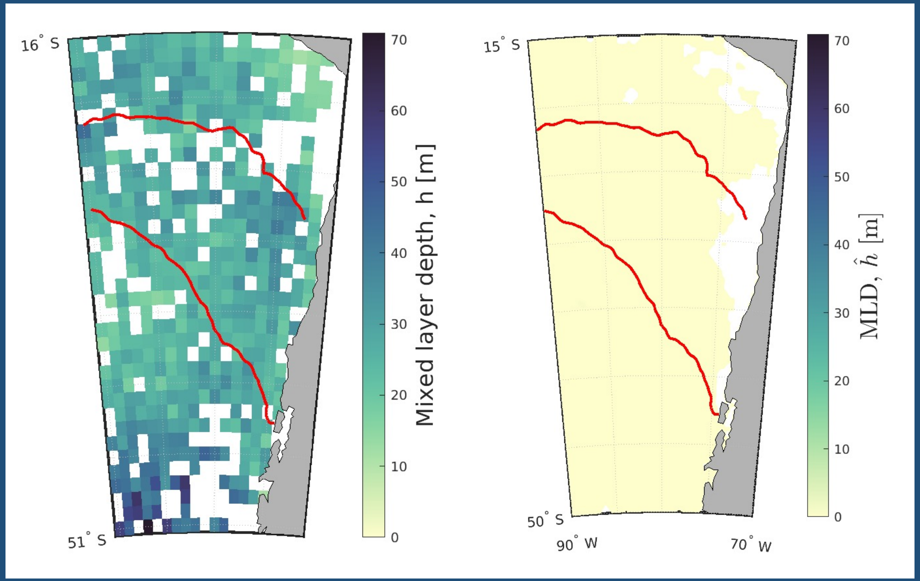
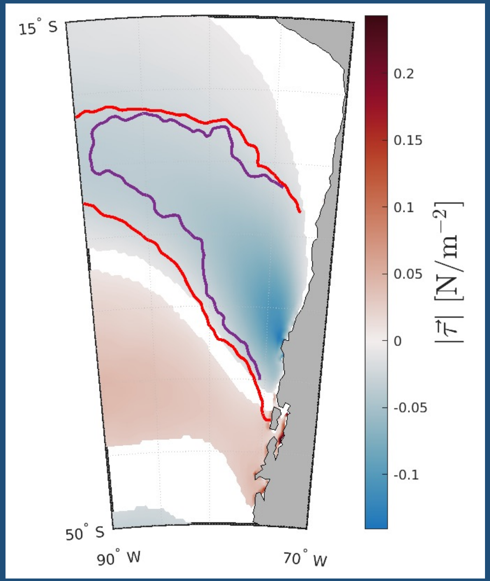
Summary







SST anomaly event pattern and anomalous warming pattern

Summer (DJF) MLD

> linear regression MLD

- $\frac{Q'_{net}}{\rho_w c_p h_0} \not\approx \frac{\partial SST'}{\partial t}$

R was large where $|\vec{\tau}|' < 0$

- reduced vertical mixing
- reduced Ekman pumping
- mixed-layer shoaling?

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Acknowledgments: This research was funded by NASA Ocean Vector Winds Science Team grant number 80NSSC18K1611 to Melanie Fewings.