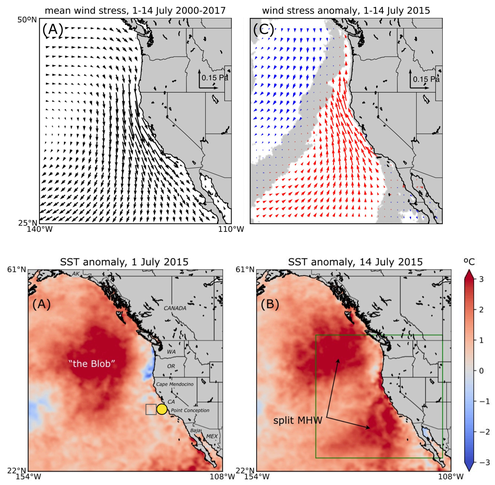
Seasonality in the Ocean Warming Response to Wind Relaxations off the Western United States

Melanie R. Fewings[1], Kevin S. Brown[2], and Carlos Moffat[3]

[1]melanie.fewings@oregonstate.edu, College of Earth, Ocean, and Atmospheric Sciences, Oregon State University
[2]Department of Pharmaceutical Sciences and School of Chemical, Biological, and Environmental Engineering, Oregon State University; [3]School of Marine Science and Policy, University of Delaware

Background and motivation

- During 2014–2016, marine heat waves (MHWs) in the northeast Pacific caused major economic and ecological damage[1,2,3,4].
- In July 2015, the large-scale MHW split into two parts. An unusually persistent weak wind event ('relaxation') determined the region of enhanced sea-surface temperature (SST) off California[5].



Fewings and Brown, 2019

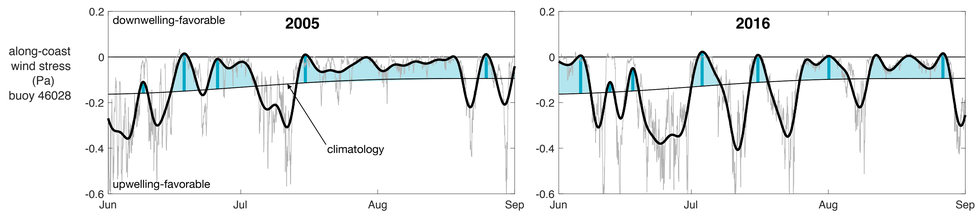
- While SST warmed off California in July 2015, the net air-sea heat flux anomalies were small due to increased cloudiness. The residual in the ocean surface mixed layer heat budget had a similar pattern to the wind stress anomaly[5].
- Here, we investigate whether the same relationships between SST, wind stress, and air-sea heat flux anomalies hold for other wind relaxations in summer 1992–2017.

Data and Methods

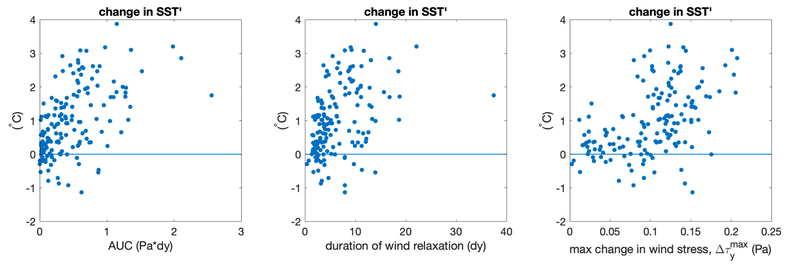
- **SST**: GHRSST L4 Canada Meteorological Center (CMC) v2.0, daily, 0.2° lat-lon grid
- **Wind stress**: NOAA NDBC buoys, 1992–2017, hourly, stress estimated using COARE v3.5
- **Sensible and latent air-sea fluxes** and matching SST: SeaFlux, 3-hourly, 0.25° grid
- **Shortwave and longwave** radiative fluxes: CERES (Clouds and the Earth's Radiant Energy System), daily average, 1° grid
- **Anomalies:**
  - relative to 2000–2017 climatologies
  - *SST'* = SST anomaly
  - Q_{net}' = net air-sea heat flux anomaly
- **Ocean surface mixed layer heat budget:**
  - R = residual
  - climatological mixed layer depth h_{ML} = 20 m

$$SST'(t_f) - SST'(t_i) = \Delta SST' = \int_{t_i}^{t_f} \frac{Q'_{net}}{\rho_0 c_p h_{ML}}\, dt + \int_{t_i}^{t_f} R\, dt$$

Wind relaxations and warming SST

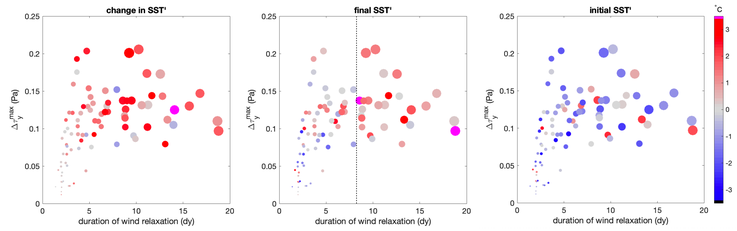


We define wind relaxation as when the 5-day low-pass filtered wind stress (thick line) is above the climatology. AUC (blue shading) is the area between the lf wind stress and climatology. Thin line shows hourly data.



SST warms during wind relaxations. How? Below, we consider a simple heat budget for the ocean surface mixed layer offshore from buoy 46028.

Only unusually long wind relaxations result in warm SST anomalies



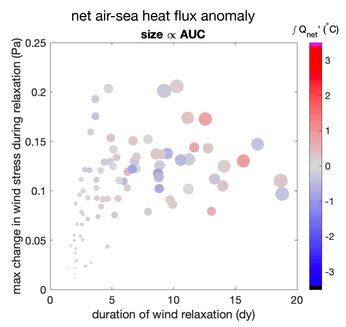
SST generally warms during wind relaxations.

However, only long **duration** relaxations consistently show a warm SST anomaly at the end of the relaxation.

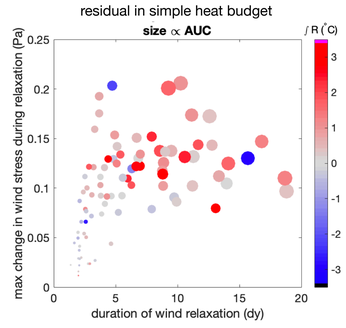
This is because the SST' at the onset of relaxation is typically cold, due to wind intensification that precedes relaxation[6].

Typical wind relaxations (< 8 days) do not increase SST enough to overcome a preexisting cold anomaly caused by a wind intensification that precedes the relaxation. The wind relaxations off California are generally the final stage of a 3-stage series of wind events: relaxation off Oregon, then wind intensification off California, then wind relaxation off California[8].

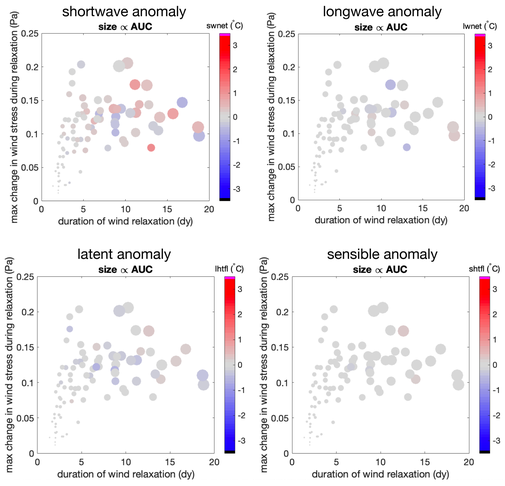
How does the air-sea heat flux change during wind relaxations off California in summer?



The air-sea heat flux anomalies are fairly small. (Heat flux is shown as equivalent change in mixed layer temperature.)



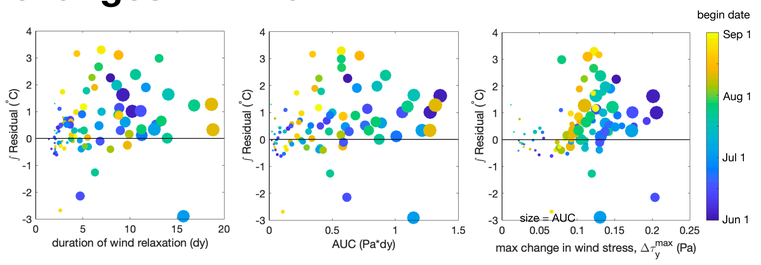
The residual in this simple heat budget is large. Changes in air-sea heat flux cannot explain the SST changes during wind relaxations.



Positive indicates anomalous ocean warming, or less than climatological cooling.

The dominant contributor to the air-sea heat flux anomaly is shortwave radiation, followed by latent heat flux anomaly.

Relationship of the residual warming to changes in wind



The residual in our simple heat budget, i.e. the amount of unexplained ocean warming, is not related to the duration of the wind relaxation event or the total wind stress deficit (AUC), but is related to the maximum change in wind stress, consistent with wind-driven vertical mixing (~u^3) being important. The response is stronger in late summer, consistent with stronger stratification (larger change in entrainment) and surface heating as the ML shoals.

References

1) Bond, Cronin, Freeland, Mantua. 2015. *Geophysical Research Letters* 42.
2) Peterson, W., Fisher, Strub, Du, Risien, J. Peterson, Shaw 2017. *J. Geophys. Res.* 122(9).
3) McCabe, Hickey, Kudela, Lefebvre, Adams, Bill, Gulland, Thomson, Cochlan, Trainer 2016. *Geophys. Res. Lett.* 43(19).
4) Gentemann, Fewings, García-Reyes. 2017. *Geophys. Res. Lett.* 44.
5) Fewings and Brown. 2019. *Frontiers in Marine Science*, 6.
6) Flynn, Fewings, Gotschalk, Lombardo. 2017. *J. Geophys. Res.* 122.
7) Fewings. 2017. *Monthly Weather Review* 145.
8) Fewings, Washburn, Dorman, Gotschalk, Lombardo. *J. Geophys. Res.* 121.

Acknowledgments

This work was funded by NASA Ocean Vector Winds Science Team grant 80NSSC18K1611.