Toward predicting the spatial pattern of mid-latitude marine heat waves based on the imprinting of regional wind anomalies

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SST anomaly July 1, 2015

SST anomaly July 14, 2015

GHRSSST L4 MUR

-3 0 3°C
The prevailing winds in summer are driven by the North Pacific High and Aleutian Low pressure systems.

Halliwell and Allen, JGR 1987; Figures from Fewings et al., JGR 2016
In 2014-2016, persistent ridging caused a large-scale marine heat wave (Bond et al., 2015 and others).

The heat wave was worse in the southern half of the California Current System.

*Figure 1.* Monthly SST anomalies, relative to the 2002–2012 climatology. White indicates anomalies <1 SD for that location and month. The SD varies from 0.34 to 1.97°C over the study area. In the panel with ‘no data’, red dots indicate, from top to bottom, Newport; Cape Blanco; Cape Mendocino; Monterey; and Santa Barbara.

The dominant wind variability along the coast in summer is a dipole

Wind and SST anomalies in “southern relaxation” phase have similar spatial structure to southern half of split Blob

Figure 6. Evolution of wind stress anomalies for the composite wind relaxation event, based on 67 events during May–August 2000–2009. The number in each panel indicates time in days relative to the onset of wind relaxation at the Pt. Conception buoys ([dy]0). Color indicates the wind stress anomaly in the direction of the mean wind stress at each point (Figure 1). Blue indicates weaker than the mean upwelling-favorable wind stress, and/or downwelling-favorable wind stress. Red indicates the upwelling-favorable wind stress is stronger than the mean in Figure 1. Red and blue contours indicate a wind stress anomaly of ±0.03 Pa. The cross-mean component of the wind stress anomalies is weak (not shown). Grey indicates the anomaly is not wind stress anomaly during southern relaxation (stage 3).

Fewings et al., JGR 2016, Fewings MWR 2017

Change in SST during relaxation

Flynn, 2016
Flynn et al., JGR 2017
Could unusual persistence of the southern relaxation phase of the dipole explain the "Split Blob"?
In July 2015, winds in the southern California Current System WERE in a persistent relaxation state.

We extended Hilbert EOF 1 of along-coast wind velocity to 2015 using OceanSAT, RapidSCAT, and ASCAT-A satellite winds.

(Fewings, MWR 2017)

2009:

2015:

more persistent relaxations (red)
The anomaly in wind stress during July 1-14, 2015 does show a large-scale wind relaxation.
The air-sea heat flux anomaly does NOT explain the SST anomaly during the split Blob of 2015 (or typical wind relaxations; Flynn et al., JGR 2017)

The surface mixed layer anomaly heat budget:

\[
\int_{\text{Jul 1}}^{\text{Jul 14}} R \, dt = (SST'_{\text{Jul 14}} - SST'_{\text{Jul 1}}) - \int_{\text{Jul 1}}^{\text{Jul 14}} \frac{Q_{\text{net}}}{\rho c_p h} \, dt
\]

| change in SST anomaly, 1–14 July 2015 | net air-sea heat flux anomaly, 1–14 July 2015 | residual in 1-D heat budget = (a) - (b) |

OAFlux air-sea heat flux anomaly is near zero or the wrong sign to explain observed increase in SST. We hypothesize changes in vertical mixing and entrainment cause the SST anomalies.
We suggest the spatial structure of NE Pacific marine heat waves will be predictable even if the timing is not: a split Blob.
Conclusions

• The “split Blob” spatial structure of the MHW = large-scale MHW + regional dipole SST anomaly from persistent “southern” wind relaxation

• Persistent ridging causes large-scale MHW
• Persistent ridging causes regional “southern” wind relaxation
• Southern wind relaxation causes dipole SST anomaly
• The sum of SST anomalies is a split Blob.

• Wind stress (and curl) anomalies, but NOT surface heat flux anomalies, explain the stronger SST anomalies in the southern CCS.

• This implies mixed layer depth changes and entrainment cause the dipole SST anomaly

• This suggests the “split Blob” spatial structure will also occur in future MHW in the NE Pacific