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Upper Ocean Thermal Response to Strong Autumnal Forcing of the Northeast Pacific

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ABSTRACT

CASID free-drifting thermistor chain buoys that utilized Service ARGOS positioning and data collection were deployed in the northeast Pacific Ocean in the vicinity of OWS-P in late autumn in both 1980 and 1981 as part of the Storm Transfer and Response Experiment (STREX). It is argued that because of the large drag on their 120–125 m lines, CASID buoy drift is tightly coupled to currents. The response function of buoy motion and line shape to a two-dimensional current profile is determined, and an inversion technique is developed to infer relative flow past the buoy. In the mixed layer 6 cm s^{-1} errors in the inferred horizontal flow are acceptable, because advective temperature changes in the drifting CASID frame of reference are small. They are not acceptable in the thermocline where advection is large. These advective effects are removed from observed subinertial thermal evolution and the result compared to the effects of vertical heat redistribution processes and of surface heat flux, estimated from STREX synoptic analyses of air-sea interaction parameters.

A number of processes are responsible for the late autumn mixed-layer temperature change over both 50 days and a 1–2 day storm period. A 50-day SST change of −13.2°C following the mixed-layer flow and averaged over a three-buoy array is due to surface cooling (−0.04°C), entrainment (−1.1°C, of which −0.8°C is due to mixed layer deepening), and vertical mixing or diffusion (−1.5°C). Of the latter, −1.4°C occurs episodically in response to some, but not all storms, and the resulting thermocline heating appears clearly in a composite of twenty cooling/mixing events. The SST cooling and the distinctive heating pattern in the seasonal thermocline imply vertical diffusivities greater than 10×10^{-4} m^2 s^{-1} at the base of the mixed layer and about 4×10^{-4} m^2 s^{-1} in the lower two-thirds of the thermocline. When such enhanced diffusion is accounted for, the imbalance in the mixed layer heat budget (−0.2 ± 0.8°C) is well within measurement uncertainty. Enhanced diffusion is even more important in the 1–2 day episodic

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cooling response to a storm. Averaged over nine such events, it accounts for 63% of the −0.41°C of SST cooling at a CASID buoy. Only about 10% and 13% of the cooling is due to surface cooling and entrainment, respectively. Thus the mixed-layer heat budget imbalance on this time scale is only −0.06 (±0.10)°C. Over two to ten days there can be substantial horizontal advective heating or cooling, but these periods average to a small net effect on SST and do not appear to be necessarily associated with episodic cooling.

The sub-mixed layer estimates of subinertial flow and of temperature gradients indicate that most of the heat mixed vertically into the thermocline during episodic cooling is advected to the south and east. In both 1980 and 1981 the rate of change in heat content of the upper 120 m was about -140 W m^{-2}, of which about -50 W m^{-2} was due to this flow. The processes of surface cooling, vertical advection and diffusion, and mixed layer advection each tend to cool too, but only at rates less than about 20 W m^{-2}. Over 50 days of late autumn in both 1980 and 1981, the heat budget of 120 m has an imbalance of about $-20 \pm 36 \text{ W m}^{-2}$.

A striking 50–200 km horizontal variability appears in the upper ocean response to a single storm. For two to four inertial periods following the onset of the storm, the magnitude of the inertial shear and low-frequency currents show a marked correspondence with the inferred strength of episodic SST cooling due to enhanced vertical diffusion. This correlation suggests a link between cooling and ocean dynamics, with strong vertical mixing between the thermocline and mixed layer receiving its energy locally from supercritical storm-driven currents. These currents depend largely on the preexisting current field whose horizontal scale determines the scale of episodic cooling. No such correspondence is found with either mixed layer depth, mixed layer deepening, the surface heat flux, or the surface wind forcing.

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