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Anomalous wind triggered the largest phytoplankton bloom in the oligotrophic North Pacific Subtropical Gyre

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In summer 2010, a massive bloom appeared in the middle (16–25°N, 160–200°E) of the North Pacific Subtropical Gyre (NPSG) creating a spectacular oasis in the middle of the largest oceanic desert on Earth. Peaked in June 2010 covering over two million km^2 in space, this phytoplankton bloom is the largest ever recorded by ocean color satellites in the NPSG over the period from 1997 to 2013. The initiation and mechanisms sustaining the massive bloom were due to atmospheric and oceanic anomalies. Over the north (25–30°N) of the bloom, strong anticyclonic winds warmed sea surface temperature (SST) via Ekman convergence. Subsequently, anomalous westward ocean currents were generated by SST meridional gradients between 19°N and 25°N, producing strong velocity shear that caused large number of mesoscale (100-km in order) cyclonic eddies in the bloom region. The ratio of cyclonic to anticyclonic eddies of 2.7 in summer 2010 is the highest over the 16-year study period. As a result of the large eddy-number differences, eddy-eddy interactions were strong and induced submesoscale (smaller than 100 km) vertical pumping as observed in the *in-situ* ocean profiles. The signature of vertical pumping was also presented in the *in-situ* measurements of chlorophyll and nutrients, which show higher concentrations in 2010 than other years.

Ocean eddies are abundant in the North Pacific Subtropical Gyre (NPSG)[1–3]. They typically move westward at a speed of about 0.1 m/s[2,4,5], forming high spatial variability in sea surface height (SSH) which is similar to that of linear Rossby waves[4]. The nonlinear ocean eddies are stronger in spring and summer[1] and in years when background sea surface temperature (SST) front is strong[3]. During the strong SST front periods, vertical shear between the eastward-flowing Subtropical Countercurrent (STCC) and the westward-flowing North Equatorial Current (NEC) increased, inducing baroclinic instability that is the essential ingredient for eddies to grow[3]. The eddy variability associated with the Hawaii Lee Countercurrent (HLCC) is also determined by the vertical-shear-induced baroclinic instability on the seasonal[6] and interannual-to-decadal[7] time scales.

Eddies play a significant role in influencing the marine environments in the NPSG. The eddy-induced meridional heat transport on subsurface can exist along the subtropical SST fronts[8]. The "cusp-shaped" SST fronts induced by the ocean eddies can be found during spring, forming warm and cold SST tongues[5].

Chlorophyll (CHL) concentrations are generally low in the NPSG because of nutrient limitation[9]. Seasonally, the CHL concentration is the lowest in summer with a climatological value smaller than 0.06 mg/m^3 due mainly to a constrained in mixing of essential nutrients to the sunlit layer[10] and phytoplankton lowering the production of CHL in response to high light in the shallower mixed layer[11,12]. Although deprived of nutrients in summer, phytoplankton blooms have been reported in the NPSG with most of the blooms located in the eastern part of the NPSG and closed to the Hawaiian Islands[13–17]. Interestingly, most of these blooms occur almost annually[14]. In contrast, blooms are rarely reported in the western NPSG with the exception of a large bloom (about 2000-km long) reported in 2003[18].

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