J2.3 OCEANIC BIOLOGICAL RESPONSE TO A TYPHOON

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1. INTRODUCTION

Typhoon landfall may devastate the economy and cause human lives. Yet typhoon may also enhance other form of life - the primary biological productivity in the ocean. Ocean productivity affects not only the local fishery, but also the uptake of carbon dioxide, an important greenhouse gas, and a major cause of natural and manmade climate changes.

Documenting the biological response to the passages of typhoons using ships with prescribed tracks, or using moored buoys with fixed location, is difficult because of the transient and severe nature of the typhoons. Two spaceborne microwave sensors, QuikSCAT and the Tropical Rain Measuring Mission (TRMM) Microwave Imager (TMI) allow us to measure ocean surface wind vectors [Liu, 2002], and sea surface temperature (SST) [Wentz et al., 2000] under the cloud cover of typhoons, day and night. The Sea Viewing Wide-Field-of-View Sensor (SeaWifs) shows us the biological activities through ocean color [O'Reilly et al., 1998], after the typhoon passage. Together the three sensors reveal the fertilization of the sea by Typhoon Kai-Tak; such revelation may have significant implication to our understanding of the global carbon cycle and climate changes.

2. THE PARADOX

In the subtropical gyres of world's oceans, the circulation is anticyclonic (clockwise in the Northern Hemisphere), which results in surface convergence and downwelling. The circulation does not favor the supply of nutrients from below. There has been intense search for new sources of external nutrient supply that contributes to sustaining the primary production in the surface waters, where there is abundant light for photosynthesis. The suggestions range from mesoscale eddies [McGillicuddy et al., 1998] to Rossby waves [Uz et al., 2001]. The vertical pumping of nutrient by transient tropical cyclones, with its intense wind vorticity, has been speculated as a possibility, but undocumented by observations.

3. OBSERVATIONS

QuikSCAT observed typhoon Kai-Tak lingering for several days in the northern part of South China Sea (SCS) between 5th to 8th July 2000. There is a sharp increase of Ekman pumping velocity, (the vertical velocity resulted from wind induced surface convergence and uplifting of the thermocline) computed from QuikSCAT winds, during the passage of Kai-Tak (Fig. 1a). The sea surface temperature dropped from 30°C before the typhoon to 22°C the day after the typhoon departure, a drastic 8°C drop as revealed by TMI in Fig. 1b. SeaWifs showed 300 time increases (from 0.1 to 30 mg/m^3) in chlorophyll-a (indicating biological activities) within a few days (Fig. 1c).

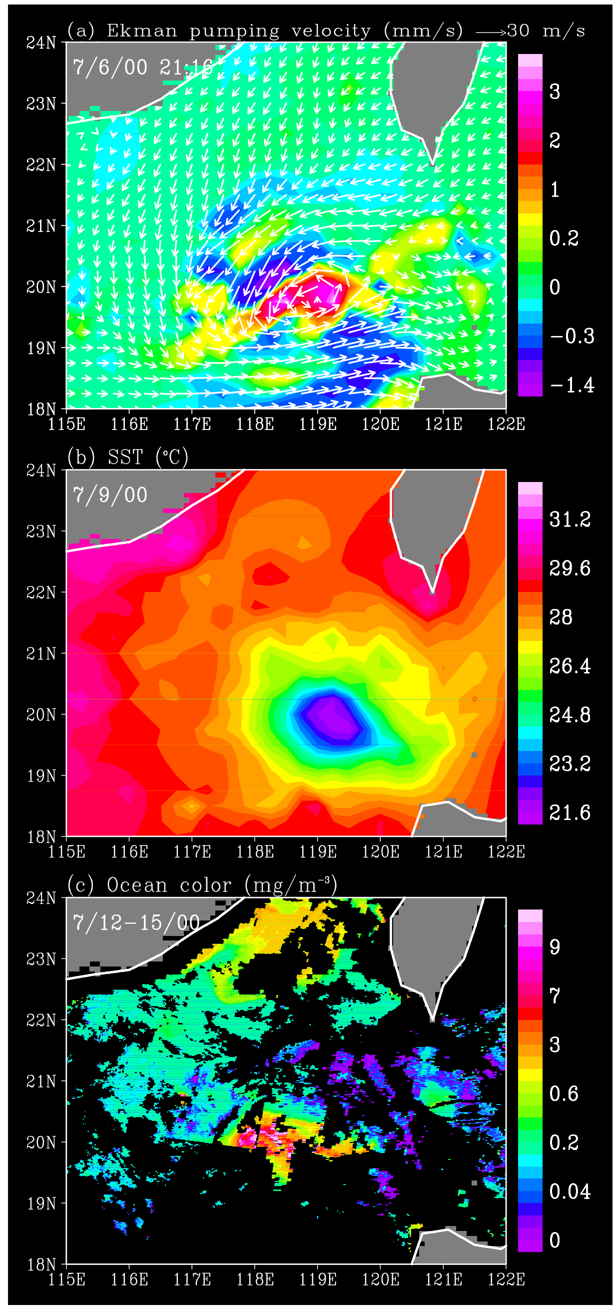

Figure 1: The effects of Typhoon Kai-Tak as, (a) wind vector (white arrows) superimposed on the color image of Ekman pumping velocity on July 8, 2000; (b) sea surface temperature observed by TMI on July 9, 2000; and (c)composite map of

ocean color observed by SeaWifs July 12-15, 2000.

4. THE CARBON IMPLICATION

Fig. 2 shows that the temperature depression and the phytoplankton bloom, as indicated by the increase of chlorophyll-a, were evident for a month after the passage of the typhoon. The corresponding primary production integrated over the depth of the ocean (IPP) was estimated by applying the observed chlorophyll-a concentration and SST in a model by Behrenfeld and Falkowski [1997]. The value increases from approximately 0.3 to 3 grams of carbon per square meter per day (Fig. 2). Integrated over the period (12 July to 16 August) and the area of the biological bloom, the Kai-Tak passage was found to generate 2-4% of the annual new production in SCS. This is a low estimate because the primary production from July 6-12, the period immediately after the typhoon passage, was not included; there was insufficient cloud-free SeaWifs data for this period.

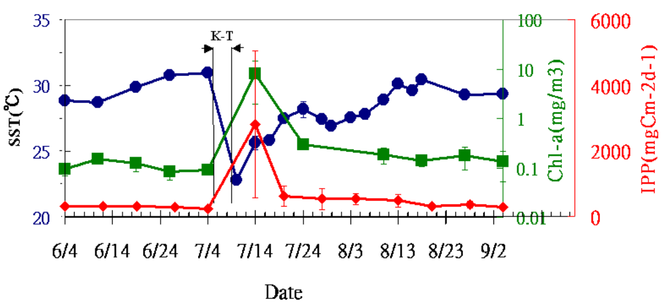

Figure 2: Changes in SST (blue), Chlorophyll-a (green,log scale), and IPP (red), before and after Kai-Tak's passage (5-8 July).

5. DISCUSSION

Many stronger typhoons traverse the SCS each year, and even weaker typhoons could have pumped up significant nutrient; the contribution of typhoon to biology and carbon cycle cannot be ignored. This observation of strong episodic nutrient injection through wind-induced vertical mixing and Ekman pumping may help to resolve the old controversy of nutrient supply in sustaining the amount new production in oligotropic (nutient-poor) oceans. The results also demonstrate the science / application synergy among the three spaceborne sensors of the National Aeronautics and Space Administration.

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