Satellite altimeters can measure the sea-surface dynamic topography down to the oceanic mesoscale, but the information on the temporal mean topography is lost in the altimeter data processing. The sea-surface velocity may be divided into the temporal mean velocity and velocity anomaly. Velocity anomaly can be derived from sea-surface dynamic topography anomaly obtained from altimeter data with geostrophic approximation. The temporal mean velocity can be recovered by combining in situ surface velocities estimated from trajectories of surface drifting buoys (hereafter, drifter) with velocity anomalies, as follows: at a point where a drifter measured the surface velocity, the temporal mean velocity can be estimated by subtracting the altimeter-derived velocity anomaly at that time from the drifter-measured instantaneous surface velocity (Fig. 1: Uchida and Imawaki, 2003). Sum of thus obtained mean and anomalies from altimeter data gives us a time series of the instantaneous velocity field.

The method is applied to the surface flow field of the North Pacific, using TOPEX/POSEIDON and ERS-1/2 altimeter data (CLS gridded data; Fig. 2, and WOCE-TOGA surface drifter data (Fig. 3) obtained from October 1992 through August 2001. The temporal mean velocity is estimated with a resolution of quarter-degrees in both latitude and longitude.

Fig. 1 Conceptual view of estimating the mean velocity $\bar{V}$ by combining altimeter-derived velocity anomaly $V''_{cl}(x,y)$ and drifter-derived instantaneous velocity $V_0(x,y,t)$. If you have the drifter-measured velocity $V_0$ at some point $x$ at some time $t$, you can estimate the mean velocity $\bar{V}(x,y)$ at that point, by combining altimeter-derived anomaly $V''_{cl}$ of sea-surface geostrophic velocity at that point at that time.

The obtained mean velocity field (Figs. 4-7) clearly shows the general pattern of the North Pacific Subtropical Gyre, the Hawaiian Lee Current (the eastward current), the Alaskan Stream (the narrow southwestward-flow) along the Alaska Peninsula, etc. Instantaneous velocities estimated by summing up the temporal mean velocity and anomalies, every ten days during the eight-year period of 1993-2000 (Imawaki et al., 2003). The instantaneous flow field (Fig. 8) shows energetic variability of the Kuroshio Extension vividly, as shown by the animation. One of the interesting features is that the temporal mean Kuroshio Extension almost disappears just before the Shatsky Rise (at about 155°E, 10°N), although the instantaneous Kuroshio Extension continues to flow down to the Emperor Seamounts (at about 170°E).

Fig. 5 Mean velocity field for the Japan Sea. The Tsushima Warm Current, East Korean Warm Current, Tsugaru Warm Current and Soya Warm Current are clearly seen.