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DELINEATION OF MESO SCALE FEATURES IN THE KUROSHIO-OYASHIO TRANSITION REGION AND FISH MIGRATION ROUTES USING SATELLITE DATA OFF JAPAN

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ABSTRACT: Kuroshio warm-core rings (KWCR) are invariably formed from the intensification of Kuroshio Extension transport heat, salt and biomass from lower to higher latitudes. The distribution pattern of these rings and other meso-scale features such as eddies, cold and warm streamers in Kuroshio-Oyashio transition region and their interaction results in the occurrence and migration of potential fisheries zones (PFZ). Past studies have shown that formation of fishery grounds and their migration attribute to warm and cold streamers entrained along the periphery of warm-core rings. In this paper combining NOAA-AVHRR, ADEOS/OCTS data and sea truth observations, we describe different meso-scale features and their interactions with surrounding water through local advection and streamer activities as well as how fish species utilize different range of temperatures and phytoplankton blooming areas for their migration. It is noteworthy that sardine schools use the warm streamers for their migration towards north from Kuroshio Extension to warm-core rings and from the warm-core rings to the coastal waters within a specific range of thermal and chlorophyll signature. Similarly, skipjack moves in a range of temperature (20.5 - 23.0°C) and pigment concentration (0.12 – 0.16 μg/l) in the Kuroshio region. The movement of fishing grounds associated with the warm-core rings and warm streamers are also discussed. It is concluded that the satellite information provides a space/time overview of different oceanographic features can profitably be utilized in delineating PFZ and increases our understanding how they are continually interacting.

1. INTRODUCTION:

Along the east coast off Japan the warm and nutrient depleted current Kuroshio, from the South Pacific and the cold and nutrient rich current Oyashio flowing along the Kuril Islands meet with each other and the confluence region is known as "Kuroshio-Oyashio transitional region". Their physical and biological importance is well investigated in the past by various researchers (Kawai, 1972; Kawai and Saitoh, 1986; Kawamura et. al, 1986). Meso-scale features such as warm-core and cold-core rings, eddies and warm and cold streamers, the byproducts of these two major currents invariably present at any time of the year and in association with Kuroshio Extension (KE), they transport heat, salt and subtropical species of plankton and fish larvae from north to south (Sugimoto and Tameishi, 1992). As a result of which, the Kuroshio -Oyashio confluence region supports rich ecosystems and fisheries. It is well known that the physical and bio-chemical properties such as sea surface temperature (SST) and chlorophyll (index of phytoplankton) can be profitably utilized through remote sensing techniques to detect the potential fisheries grounds and exploit the resources (Solanki *et al*., 2000). As fish can spawn, feed and migrate only within an allowable range of temperature and color (chlorophyll), hence, understanding the interaction different physical phenomenon such as streamers and eddies through satellite data can provide us a space and time overview as well as enable us to delineate the fish migration route and potential fisheries zones (Tameishi *et al.* 2000).

In this paper the physical and biological characteristics of a warm-core ring and streamer and their importance in the migration of some fish species are reviewed using survey and satellite based data.

2. IMPORTANCE OF WARM-CORE RING AND STREAMERS:

Warm-core, anticyclonic rings are usually formed from the meandering boundary current extensions are generally similar globally (Olson, 1991). The meanders of Kuroshio Extension (KE) at 144° and 150°E pinch off warm-core rings. On an average 2 to 3 rings are shaded in the Tohoku area are observed in between 1993 to 1998. Mishra and

Sugimoto (2000) studied the formation processes, evolution and biology of a Kuroshio warm-core ring that was formed in the early part of 1993. Some of the results pertaining to this study in order to understand various mesoscale processes are described. Figure 1 is a thermal image showing the typical development of the warm-core ring 93A. After separation from the main current, this ring was drifted to the transitional region and was oscillating in between the mean Kuroshio and Oyashio current. Seasonal fluctuations in the movement of ring was observed and well correlated with the intensification of Oyashio current system. Usually, the ring core moved to the maximal south and north in spring and autumn, on intra-annual basis whereas on inter-annual basis, there was a cumulative northward movement. The core temperature data at 200m revealed that in May-June months interaction with Kuroshio Extension resulted in lifting in core temperature, whereas in winter, core temperature, salinity and ring diameter decreased due to wintertime cooling. It was concluded that warm streamer intrusion at regular intervals playing a dominant role in deciding the ring life. This type observation was found to be inconsistent with earlier reported literature for Kuroshio warm-core rings

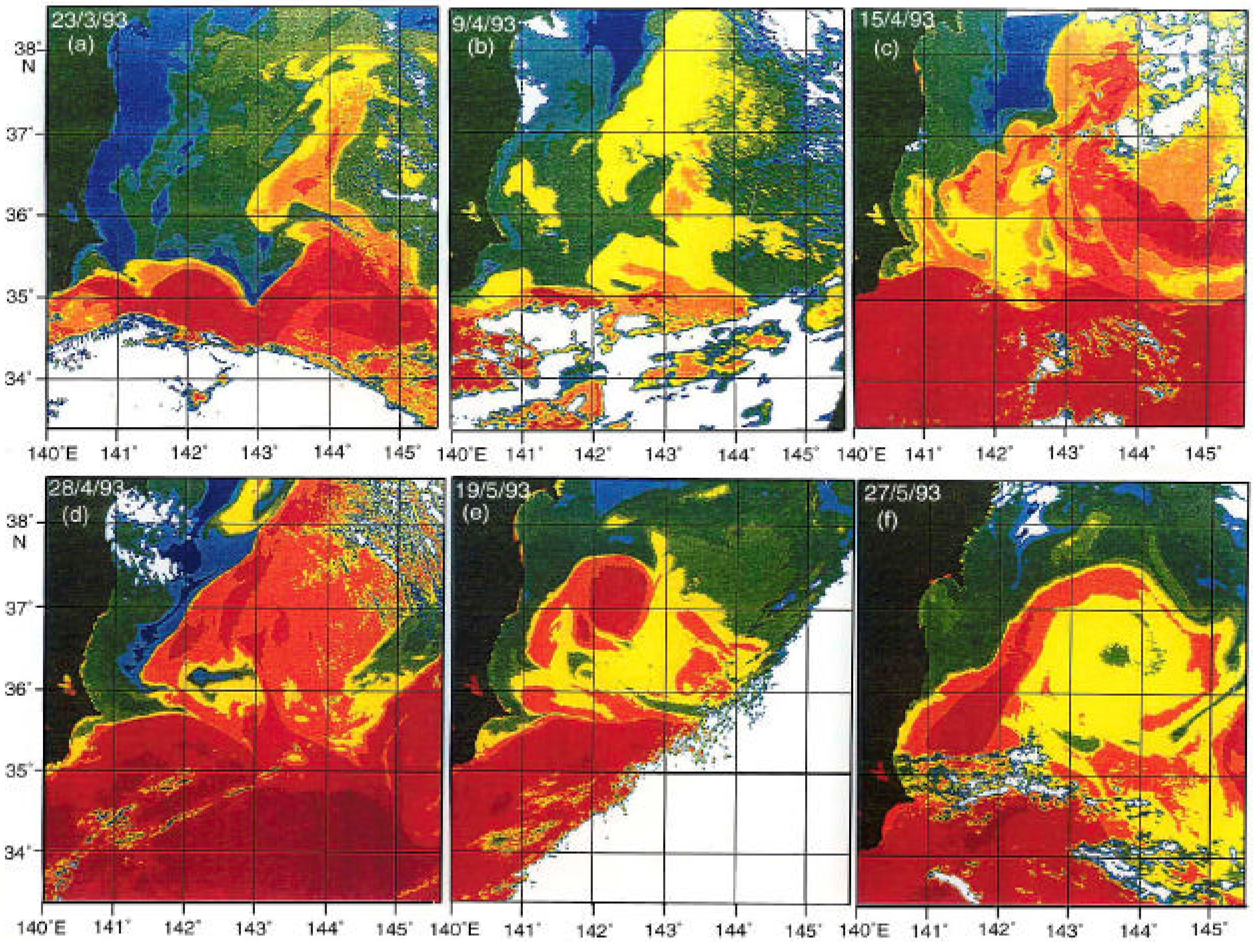

Figure1.NOAA-AVHRR thermal images showing the formation process of ring.

3. BIOLOGICAL CHARACTERISTICS OF WARM-CORE RINGS AND STREAMERS:

Our analysis of long-term data on variation of chlorophyll pigments in the ring core, Kuroshio and Oyashio water column clearly indicate conditions of spring and autumn blooming in the Oyashio and core water to different levels. The Oyashio water observed to be five times more productive than core waters. At the initial stage the chlorophyll concentration in the core and Kuroshio water at almost same level, however, drastic changes take place, when the core is emplaced in the Oyashio region due to cold streamer intrusion affecting in reduction of salinity and increasing the chlorophyll content. The effect of warm and cold streamer intrusion on warm-core ring and the blooming conditions were also observed in OCTS images (Ingake and Saitoh, 1998 and Saitoh *et al*., 1998). The available ADEOS-OCTS images for a warm-core ring showed that Chlorophyll concentration was less during April to May'97 and become June'97 and exceeded to 2 mg/m^3 on 3rd May 1997. Warm and cold streamers of Kuroshio and Oyashio origin respectively were usually observed during late-April and mid-May encompassing the ring. The chlorophyll concentration varied from 5-10 and 0.6 mg/m3 for cold and warm streamers respectively. Another point to note is that occurrence of spring bloom along the periphery of the warm-core rings might be playing an important role in deciding fishery grounds.

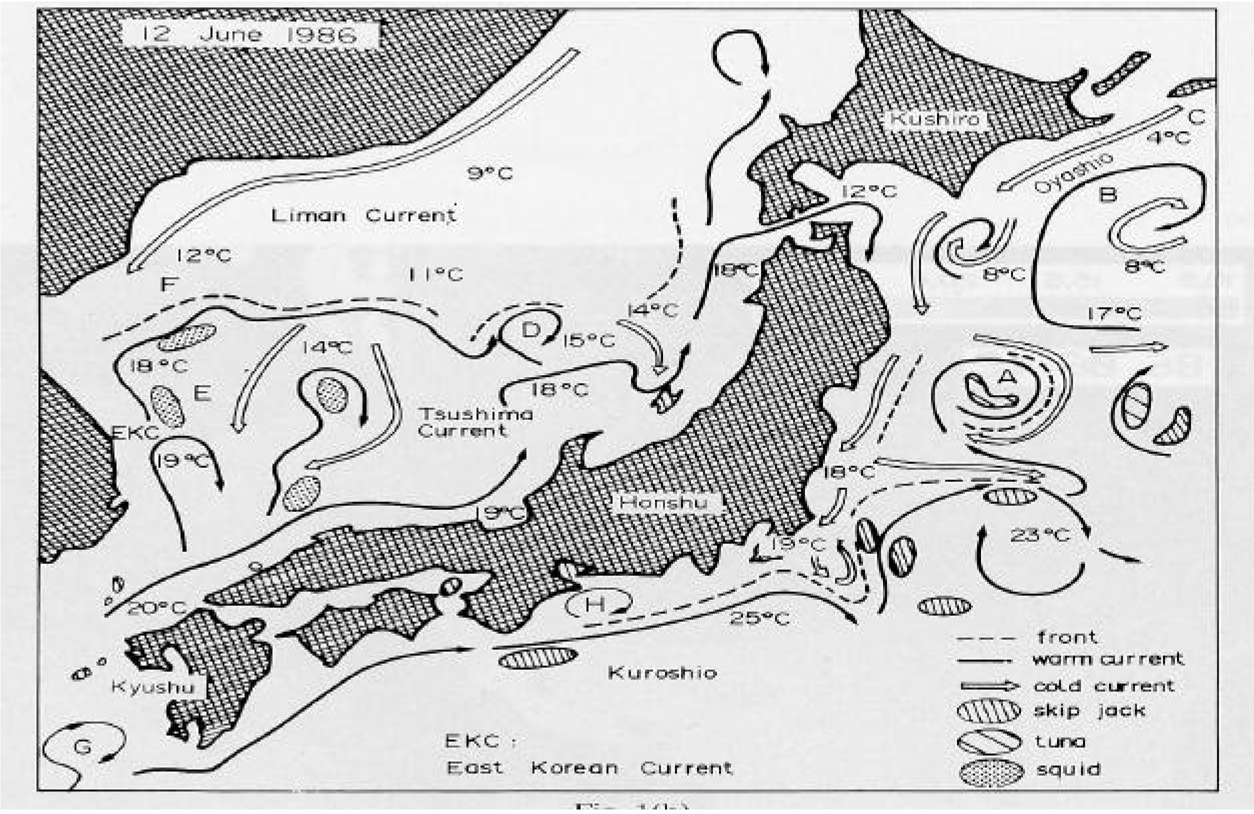

Figure 2. A schematic representation horizontal structures of SST, with fishing grounds in and around of WCR (after, Sugimoto and Tameishi, 1992).

4.SATELLITE-BASED OBSEVATIONS:

It has been observed that some important migratory fishes, e.g., sardines, squids, bluefin tuna and mackerels approach to near shore of Sanriku following a favorable temperature and phytoplakton. Figure 2 shows a schematic diagram of the region as observed by Sugimoto and Tameishi (1992). Based on their classifications, it is observed that the fishing ground of bluefin tuna (*Thunnus thynnus*) was formed when the ring-core sea-surface temperature was around 19°C. Sugimoto and Tameishi (1992) observed that mackerel (*Scomber japonicus*) was found in the head of the cold streamer of Oyashio. Flying squid and skipjack fishing grounds were found at the periphery of warm-core rings because of higher chlorophyll presence. Saitoh *et al.* (1986) observed that Pacific saury (*Coloabis saira*) migrated from north along the cold streamer.

Sardine schools found to be distributed in the warm streamer (Tameishi *et al.*, 1996). Warm streamer acts as the migration route for sardine schools to northward and from offshore to near shore. This is initiated under favorable conditioning of temperature and phytoplankton biomass and confirmed with the OCTS images. The most favorable temperature and chlorophyll range for skipjack corresponded to 20.5-23.0 ° C and 0.12-0.16 µg/l in Kuroshio. The fishing ground of skipjack (*Katsuwonus pelamis*) usually formed near the Kuroshio front when the SST was 22-23°C and move along the warm streamer. Figure-3 is ADEO S/OCTS thermal and color imagery with fishing grounds of skipjack shown on it. The skipjack fishing grounds were concentrated at red spots, which correspond to the water of both favorable temperature and color in the Kuroshio waters (Tameishi *et al.*, 2000).

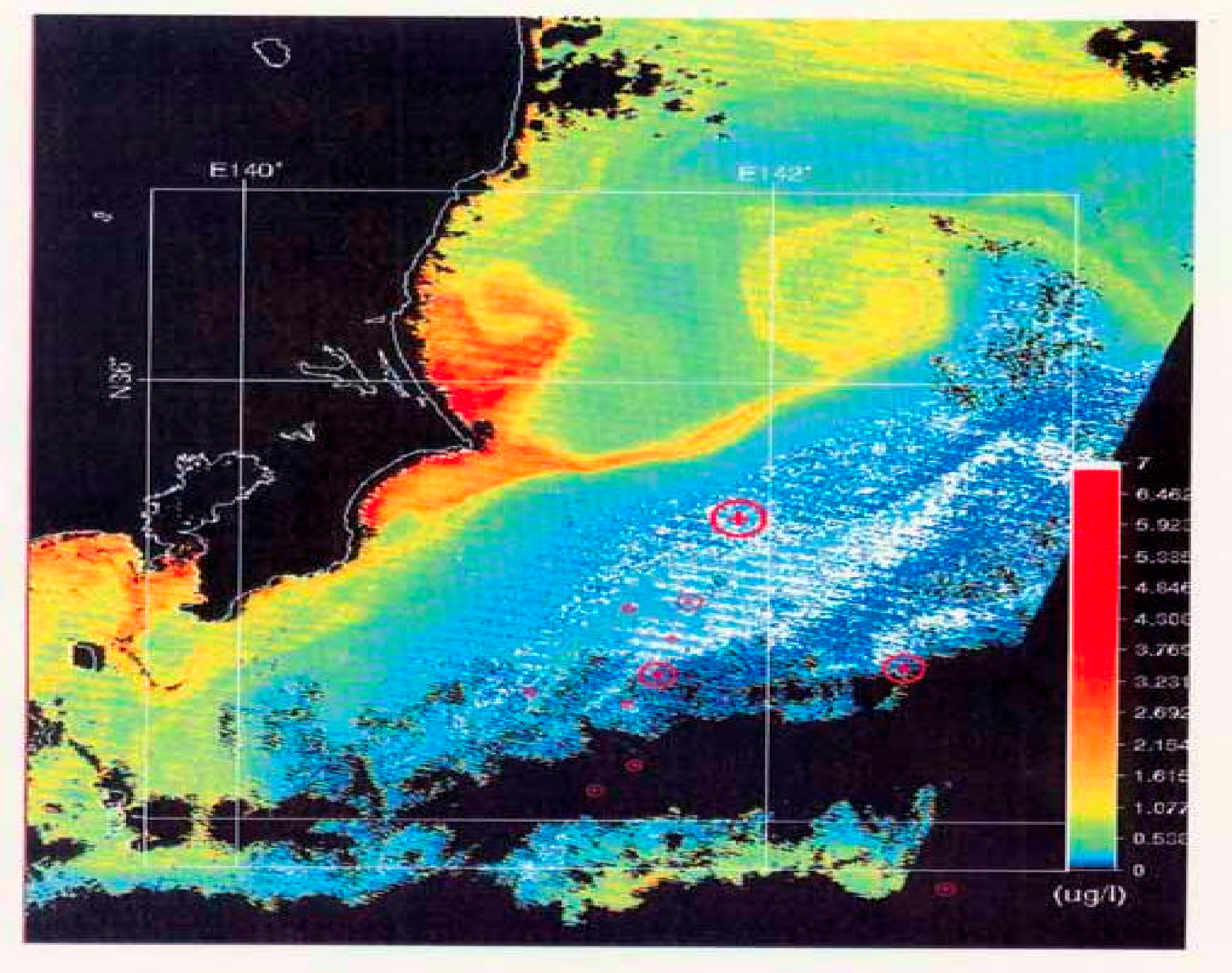

Figure 3. OCTS image with fishing grounds of Skipjack shown in red circles

5. CONCLUSION:

Warm-core rings that are formed from the Kuroshio extensions usually move northeastward and oscillate in the Kuroshio-Oyashio transition region and finally decay. During their lifetime, they interact with warm and cold streamers and create in forming potential fisheries grounds. Bluefin tuna and yellowfin tuna use the warm core ring and warm streamers for their northward migration. Flying squids grounds are found in the inside of the warm-core ring, whereas Pacific saury and mackerel migrate southward using the cold streamers surrounding warm core rings. Warm streamers are found to provide better conditions for Sardine schools for their northward migration. Importantly, the development of warm streamers allows sardines to migrate from offshore waters to coastal water and thereafter northward in search of food.

In this study, fish migration route and formation of fishing grounds were made based on composite images of sea surface temperature, color and sea truth data are found to be a suitable approach for effective interpretation, measurement of the enhanced biological production.

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