REMOTE SENSING OF SEA SURFACE FEATURES: IMPLICATIONS OF FISHERIES IN NORTH PACIFIC OCEAN

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ABSTRACT:

The use of remote sensing methods to examine physical oceanography is becoming increasingly important within marine fisheries oceanography. This paper mainly discussed the surface sea conditions, using the indicators of SST and Chlorophyll-a that conduced to the production of Ommastrephes bartrami which is the second important fish in the North Pacific Ocean, which is the main catch of China because of its large amount and important value in economy. We illustrate approaches to use these data to construct indicators that describe aspects of ecosystem dynamics in the North Pacific. Specifically, sea surface temperature data to develop indices of biologically important ocean features and ocean colour data to describe the temporal chlorophyll dynamics of the North Pacific Ocean. The changes during the research span in the North Pacific based on these indices are discussed.

1. INTRODUCTION

The Pacific Ocean is the largest of the Earth's oceanic divisions. The equator subdivides it into the North Pacific Ocean and South Pacific. The North Pacific Ocean.is rich in fishery resources, especially in the Oyashio and Kuroshio extension zone. Extensive Kuroshio-Oyashio transition zone is formed in the western North Pacific Ocean as the result of widely mixing of the two water masses and it becomes one of the most high-yield oceanic fisheries in the world (Pravakar Mishra et al., 2001). Ommastrephes bartrami is an oceanic squid occurring worldwide in subtropical and temperate oceanic waters. With the sharp decline in abundance of Japanese common squid (Todarodes pacificus) in the early 1970s, O.bartrameii became the target of fishery in the North Pacific in 1974. This species has a one-year life span and performs an extensive seasonal north-south migration. To explore the marine environment of fisheries, many research were carried out using the remote sensing techniques.

Satellite remotely sensed oceanographic data provide reliable global ocean coverage of sea surface temperature, sea surface height, surface winds, and ocean colour, with relatively high spatial and temporal resolution. High resolution satellite Sea Surface Temperature (SST) maps were one of the first external ocean products fishermen are often willing to use. SST maps provide useful information on mesoscale ocean flow field (fronts, eddies), position of the main current systems and regions of upwellings. The SST changes primarily have important biological implications for hospitable/inhospitable conditions for many organisms including species of plankton, seagrasses, shellfish, fish and mammals.

Ocean colour provides in an indirect way a measurement of phytoplankton concentration. As phytoplankton is the primary food and energy source for the ocean ecosystem, fishermen find good fishing spots in areas rich in phytoplankton (H.U.Solanki et al., 2001). Satellite ocean colour maps (e.g. SEAWIFS) became routinely available. Ocean colour provides in an indirect way a measurement of phytoplankton concentration. As phytoplankton is the primary food and energy source for the ocean ecosystem, fishermen find good fishing spots in areas rich in phytoplankton. Satellite ocean colour remote sensing has improved our capability of pigment concentrations over wide areas.

2. MATERIALS AND METHODS

2.1 Data

NOAA has been flying satellites that carry AVHRR sensors since 1978. At any one time there are two operational satellites carrying AVHRR sensors, one passing overhead in the early morning, around 2:30 AM, and in the early afternoon, about 2:30 PM; and the other in mid-morning, about 6:30 AM, and late afternoon, about 6:30 PM. Since the 1980s satellites have been increasingly utilized to measure SST and have provided an enormous leap in our ability to view the spatial and temporal variation in SST. Satellite measurements of SST are far more consistent and, in some cases, accurate than the in situ temperature measurements.

Remotely sensed infrared SST images were obtained from NOAA/AVHRR global level 3 products. The satellite measurement is made by sensing the ocean radiation in two or more wavelengths in the infrared part of the electromagnetic spectrum or other parts of the spectrum which can then be empirically related to SST. These wavelengths are chosen because they are, within the peak of the blackbody radiation expected from the earth, and able to transmit well through the atmosphere. Images were at a spatial resolution of 9 km×9 km, and a temporal resolution of one day. The images used in this study covered the period 1995 to 2001.

From September 1997 to present, chlorophyll *a* data collected by the Sea-viewing Wide Field-of-view Sensor (SeaWiFS) instrument on board the Seastar spacecraft were used. The data

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calibration, processing, and validation program calibrates the SeaWiFS data; develops the mathematical procedures (algorithms) for operational atmospheric correction and for derived data; and validates the accuracy of the derived products, such as the concentration of chlorophyll a.

These data were delivered as a 9-km pixel resolution product. This product is derived from the raw measured wavelength bands using the SeaWiFS algorithm, and distributed as version 4. Here we use level 3 standard mapped images of 8 days composition, which are projections of the GAC data onto a global, equal-angle grid ($2\pi/2048$).

2.2 Methods

In this paper, we take out the SST, chlo-a data in the research area from the overall data. We use many statistics, such as mean, standard devivation(SD) and coefficient of variability(CV) to explore the sea surface characteristics in the North Pacific Ocean. The yearly change of surface condition is not studied, because this change is random and not easy to get. The monthly and seasonal change is periodical and observational. So the variables of SD and CV are calculated as the following equation：

$$SD=\sqrt{\frac{\sum(x-\bar{x})^2}{N-1}} \qquad (1)$$

$$CV=\frac{SD}{\bar{x}}*100\% \qquad (2)$$

where $\bar{x}$ =the mean value
N=the overall observation number

There is some statistical difference between the variable of SD and CV. The variable of SD indicates the changes to the mean and measures the absolute change. While the variable of CV is a comparative one and it remove the changes caused by different mean, so it can indicate the comparative degree of change.

Programs were written in C++ language to extract, analysis and display image data within the region defined above. Cloud cover is the primary limitation of these data, temporal averaging can provide increased spatial coverage at the expense of temporal resolution. We composed the images by 8 days to reduce the none data in the images. The 8 days time span is temporal resolution of the ocean colour data we had gathered. SST image data was composed to new datasets of 8 days and yield data was also gathered together in 8 sequential days. Equation 3 shows the processing way.

$$TM_k(x,y)=\frac{\sum_{i=1}^{n}T_i^k(x,y)\times D_i^k(x,y)}{\sum_{i=1}^{n}D_i^k(x,y)} \qquad (3)$$

where $TM_k(x,y)$ =the average sea surface temperature value of the pixel (x,y) by k months
n= the pixel number within the time span
$T_i^k(x,y)$ =the sea surface temperature value of the pixel (x,y) in the image i
$D_i^k(x,y)$ =the number of days within the time span

3. RUSULTS AND DISCUSSION

The surface condition of North Pacific Ocean was dynamical and especially influenced by the currents. The surface circulation of Pacific waters is generally clockwise in the Northern Hemisphere (the North Pacific Gyre). The North Equatorial Current, driven westward along latitude 15°N by the trade winds, turns north near the Philippines to become the warm Japan or Kuroshio Current. Turning eastward at about 45°N, the Kuroshio forks and some waters move northward as the Aleutian Current, while the rest turn southward to rejoin the North Equatorial Current.

Figure 1-A shows the spatial distribution of the averaged SST map composed by 1995-2001 in the North Pacific Ocean. SST in the North Pacific vary from freezing in the poleward areas to about 30 C near the equator. Poleward of the temperate latitudes salinity is also low, because little evaporation of seawater takes place in these frigid areas. The warm pool can be easy found in the filed of 110°-160°E，10°-20°N having the averaged one higher than 28℃，about 5℃ higher than the east part. SSTs above 26.5 °C are generally favorable for the formation and sustaining of tropical cyclones. Generally the higher the SST, the stronger the storm.

The SST SD map in the transition zone is the highest in Kuroshio and Oyashio currents for the reason of mixture of the two currents and more than 5℃.the lowest in the low latitude,less than 2℃. As a whole , the spatial pattern of SD is higher in East-North region and lower in South-East region. The SST CV map (Fig. 1-C) shows no west-east extend changes as SST CV maps. The highest region is the extend of Extension and higher lotitude regions and seacoast. So the ocean current is the major factor that influence the distribution of SST and chlo-a.

From all the maps of different SST variables, an apparent tongue can be found along Japanese and Russian boundary. The front of Oyashio occurs at this place near 41˚N, where the surface temperature tongue shows. Highest population densities of O. bartrami was found along the subarctic frontal zone during July-December(Wang Wen-yu, Shao Quan-qin, 2005). The separation point for the Kuroshio is reached 35˚N. It defines the transition from the Kuroshio proper to the Kuroshio Extension. Flow in the Extension is basically eastward, but the injection of a strong jet into the relatively quiescent open Pacific environment causes strong instability.

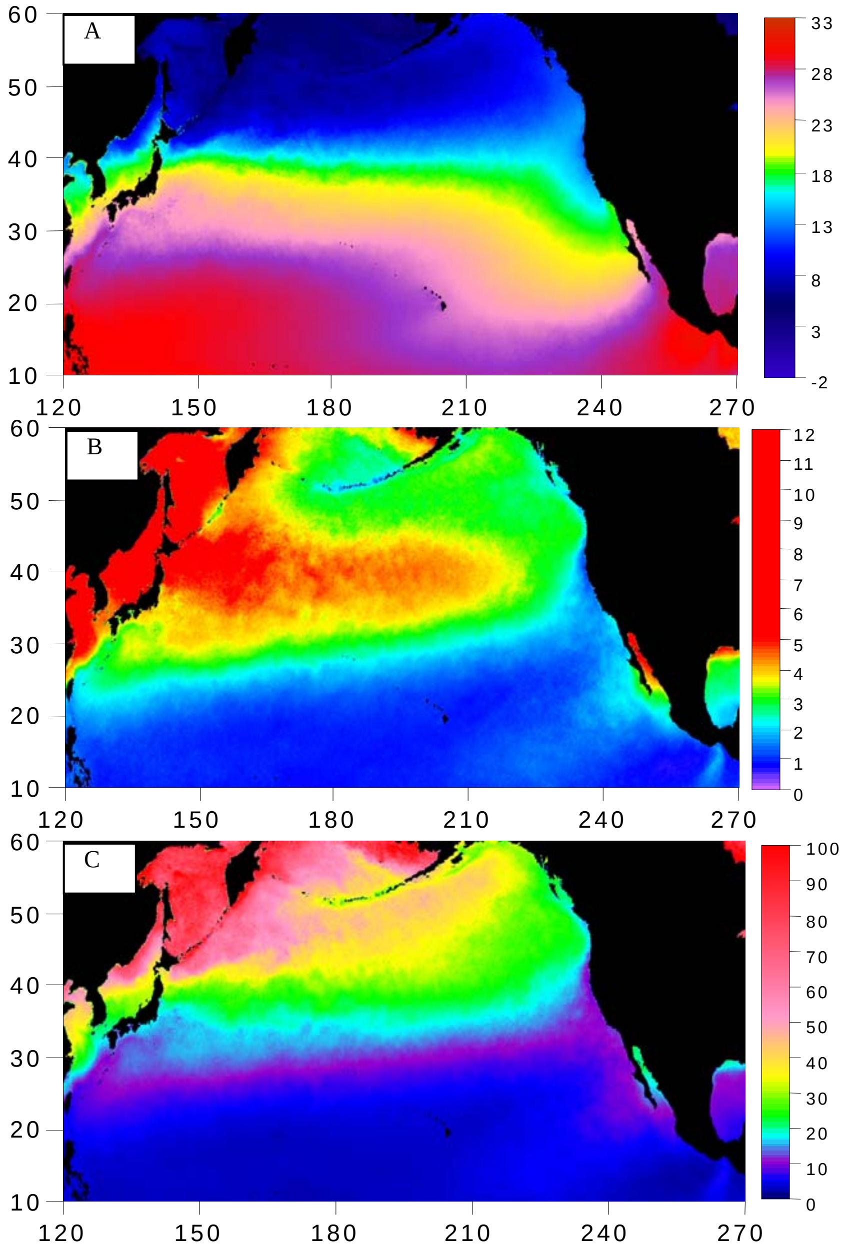

Figure 1. The Basal Characters of the North Pacific SST Field(A：The Distribution Map of SST Mean，B：The Distribution Map of SST Standard Deviation，C：The Distribution Map of SST Coefficient Variance)

.Figure 2-A shows the spatial distribution of chlorophyll-a mean concentration in the North Pacific Ocean. The lowest chlorophyll-a concentration is located in the warm pool of North Pacific. The higer the latitude and the higer chlorophyll-a concentration can be found. And the highest productive area is found near the coast as the coastal waters is polluted by land-carriage materials and forms the different waters to the open oceanic waters.The chlorophyll-a concentration in the sea area where Kuroshio or black (i.e. unproductive) current flows into, is lower than 0.25mg/m^3, while the chlo-a concentration in the sea area where the Oyashio or parent current(i.e. productive) flows into, is commonly higher than 0.5mg/m^3. In the transition zone, the chlo-a concentration is between 0.25-0.5mg/m^3. Along the transition zone, the southern edge of the Oyashio and the northern edge of the Kuroshio maintain their own frontal systems.

From the SD map of chlorophyll-a(Fig. 2-B), the spatial pattern of east-north to south-west extension can also be found. And this spatial trend is overall the same in cholophyll-a maps. The crests of Kuroshio in the North West Pacific are obvious in this map. From the CV map of chlorophyll-a(Fig. 2-C), the higher CV value(>80) can be found in the region of Oyashio and Korushio extension zone. Fingure 2-C shows the proctive characteristics of Oyashio and Korushio Zone as a whole.

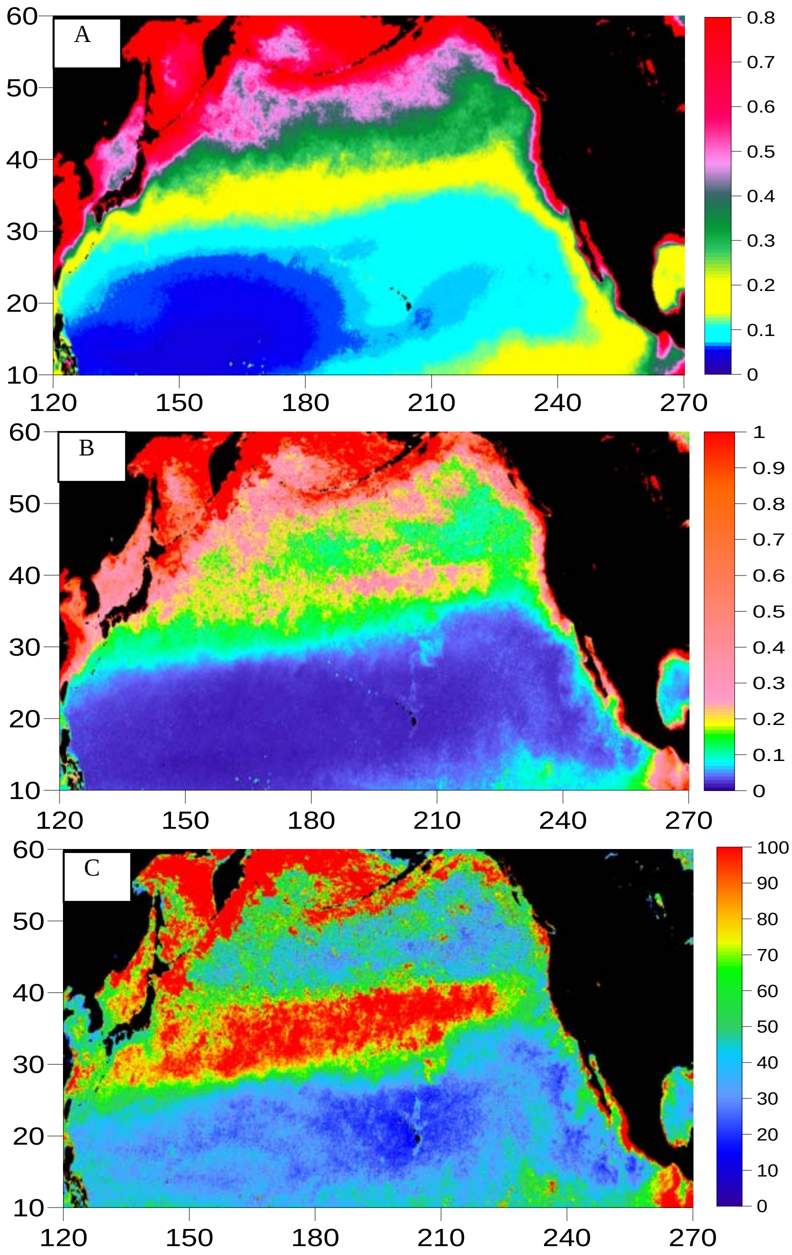

Figure 2 The Basal Characters of the North Pacific Chlo-a Field(A：The Distribution Map of Chlo-a Mean，B：The Distribution Map of Chlo-a Standard Deviation，C：The Distribution Map of Chlo-a Coefficient Variance)

More surface characteristics can been found on chlorophyll a maps than SST maps. So more work was carried out to explore the sea conditions from chlorophyll a datasets. From the SeaWiFS ocean color satellite remote sensing images, a Chlorophyll font can be easily between the low chlorophyll subtropical gyres and the high chlorophyll subarctic gyres. Thetransition zone chlorophyll front is a dynamic global feature defining migration and forage habitat for marine resources. It is a zone of surface convergence where cool, vertically mixed, high chlorophyll, surface water on the north side sinks beneathwarm, stratified, low chlorophyll water on the south side(Polovina etc. 2001).

In the North Pacific, the front is seasonally migrates north and south. The Chlo-a isoline of 0.2 mg/m^3 seems to be a good indicator of Chlo-a front in the yearly or monthly average map. Figure 3 shows the change of chlo-a front average position from year of 1998 to 2001 respectively. The transition zone chlorophyll front exhibited considerable meandering and greater monthly latitudinal movement in 1998. While the transition zone chlorophyll front remained between about 30°N and 40°N latitude showing very little meandering in 1999,2000,2001 during the same period. The position and dynamics of the front varied substantially between the 1998 El Niño and the 1999 La Niña(Polovina etc. 2001). Our result also seems to explain the 1998 El Niño and the 1999 La Niña event

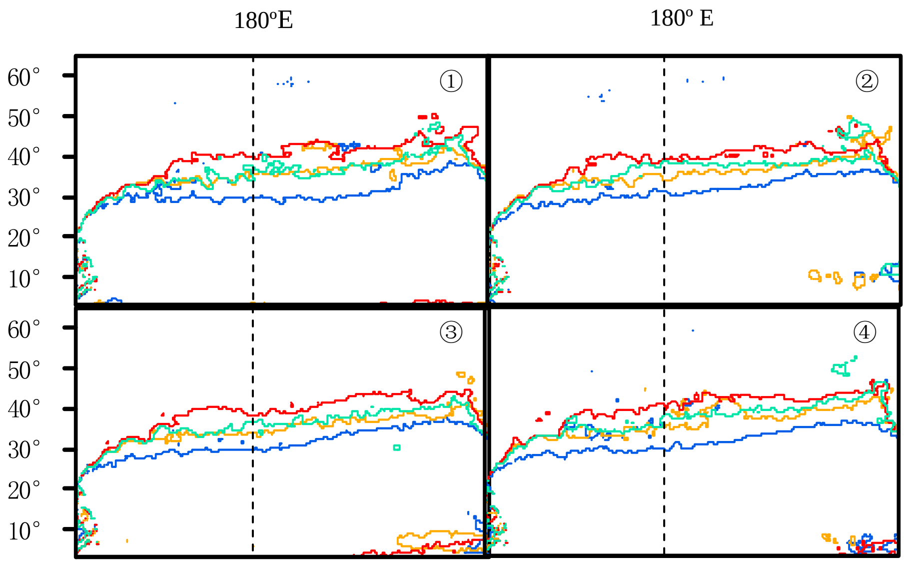

Figure 3 The Migration of Chlorophyll a Front in North Pacific（①-④presents the migration route of Chlorophyll a Front from 1998 to 2001 respectively; the blue line represents the average location of Chlorophyll a Front from January to March; the yellow line represents the average location of Chlorophyll a Front from April to June, the red line represents the average location of Chlorophyll a Front from July to September, the green line represents the average location of Chlorophyll a Front from October to December）

4. CONCLUSIONS

In this paper, time series remote sensing data of SST and ocean colour are gathered and composed. And GIS is adopted to map and analyze spatial-temporal characters of North Pacific Ocean especially the fishing ground in the Kuroshio Extension and Kuroshio-Oyashio transition regions. SST and ocean colour images are used to be a suitable approach for effective interpretation of the marine environment.

The satellite measured data provides both a synoptic view of the ocean and a high frequency of repeat views, allowing the examination of basin-wide upper ocean dynamics not possible with ships or buoys. However, there are several difficulties with satellite based absolute measurements. First, in infrared remote sensing methodology the radiation emanates from the top "skin" of the ocean, approximately the top 0.01 mm or less. It is somewhat difficult to compare to measurements from buoys or shipboard methods. Secondly, the satellite cannot look through clouds, creating a "fair weather bias" in the long term trends of SST. Further research on the mechanism of fishing ground should be carried out collecting more information on deeper water such as temperature, salinity and chlorophyll.

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