Title: Analysis of the spatial and temporal variability of DMS in the East China Sea

LI Si-yu and SUN Qun

(College of Marine and Environmental Sciences, Tianjin University of Science and Technology, Tianjin 300457, China)

1.Aim:

Based on the Generalized Additive Mixed Model (GAMM) of the East China Sea, the spatial and temporal characteristics of DMS in the East China Sea are analyzed by using long-term high-resolution chlorophyll-a (Chl-a) and sea surface temperature (SST) satellite observations to obtain the surface DMS concentration data in the East China Sea from 1998 to 2020.

2.Methods:

The calculation model of DMS concentration was based on SST and local calibration chlorophyll-a v5.0 (LMC v5.0) data to obtain sea surface DMS results, where SST data were obtained from NOAA National Climatic Data Center (NCDC, http://www.ncdc.noaa.gov/oisst/). The SST data were obtained from the AVHRR (Advanced Very High Resolution Radiometer) Optimal Interpolation Day-by-Day OISST v2.1 data with a horizontal spatial resolution of 1/4°, and the daily average SST data set for 1998-2020 was processed.

Chl-a data were obtained using the OCCCI v5.0 (Ocean Color Climate Change Initiative version 5.0) remote sensing chlorophyll data provided by the European Space Agency (ESA https://climate.esa.int/en/projects/ocean-colour/). The Chl-a and Rrs560 data were extracted from the study area, and the daily mean LMC v5.0 dataset was obtained for the period 1998-2020 with a horizontal spatial resolution of 4 km×4 km according to the local Chl-a concentration data correction method in the East China Sea. the LMC v5.0 dataset was divided by a 1/4° grid to be consistent with the SST dataset.

The DMS concentration is set as the response variable and other parameters (e.g., longitude, latitude, month, SST and Chl-a) are set as explanatory variables:

$$\ln(DMS) = \alpha + e_i + s(Lon, Lat) + s(\ln(Chl - a)) + s(SST) + s(Month) \qquad (1)$$

Where: α is the grand mean, e_i is the random intercept, s(.) is a one-dimensional nonlinear function based on the thin-slab regression spline, and is the residual of the model.

Since cloud cover or other errors can lead to missing remote sensing data, the empirical orthogonal function interpolation (DINEOF) method is used to reconstruct the missing regions by constructing an empirical interpolation model based on the long time series observation dataset. DINEOF was used to complement the missing values in the East China Sea surface daily average LMC v5.0 and SST datasets from 1998 to 2020, and the reconstructed daily average of LMC v5.0 and SST datasets for 23 years (1998-2020) were obtained, and then brought into the GAMM model to hindcast the DMS concentration in the East China Sea.

In this paper, the model was externally validated using the 2015 East China Sea DMS measured data (Fig. 1). The external validation correlation coefficient was 0.65 ($p<0.05$). The standard deviations of measured and simulated DMS were 0.43 and 0.76 nmol/L, respectively, and the root mean square error of model and measured DMS was 0.59 nmol/L. This indicates that the model can better hindcast the surface seawater DMS concentration in the East China Sea.

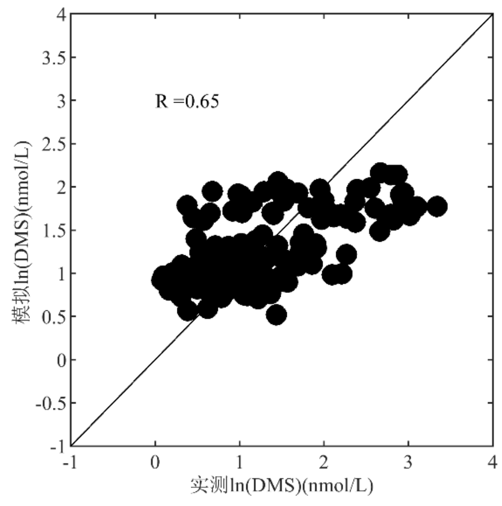

Fig. 1 GAMM external validation of ECS

3.Result:

The annual mean value of DMS concentration in surface seawater in the East China Sea was 2.67 nmol/L, which was higher than the global mean DMS concentration in surface seawater, showing a distribution characteristic of gradual decrease from coastal to offshore (Fig. 2a). The standard deviation contour also shows a similar distribution, with the standard deviation of DMS in coastal waters being higher, up to 0.5 nmol/L, and decreasing to 0.1 nmol/L in the middle of the outer shelf, indicating that the nearshore DMS concentration in the East China Sea is more variable compared to the outer sea.

The seasonal variation curves of DMS concentration in the East China Sea were obtained by averaging the daily average DMS concentration data of the East China Sea surface seawater from the GAMM model hindcasts month by month (Fig. 2b). The seasonal variation of DMS in the East China Sea showed a bimodal distribution, with the two highest values in May and November, respectively. The DMS concentration in the surface seawater of the East China Sea increased from February to May and from September to November, with the largest increase from March to April, averaging 1.28 nmol/L, and the largest decrease from July to August, averaging 1.03 nmol/L.

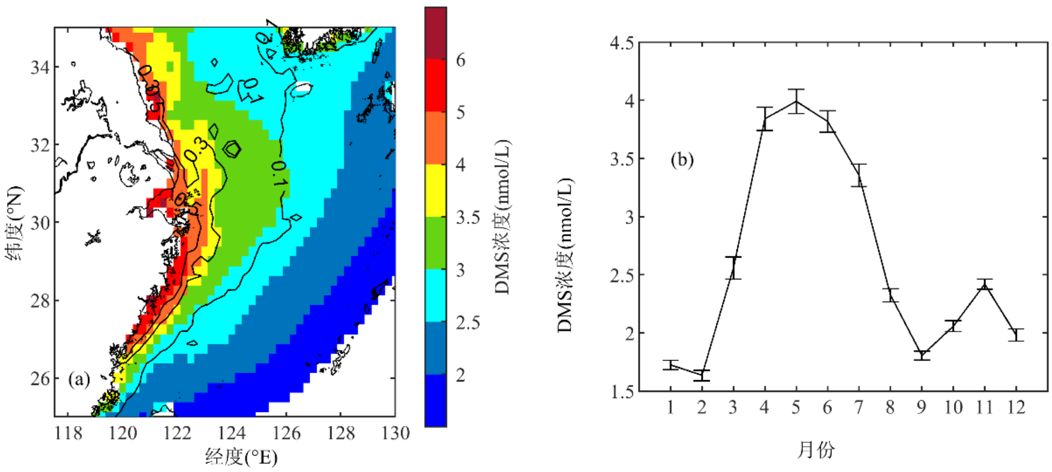

Fig. 2 (a) Distributions of annual average DMS concentration in the ECS, and the contour line indicates the standard deviation of the 22-year monthly mean DMS concentration; (b)Seasonal variations of DMS concentration

From Fig 3a, it can be seen that the anomalous values of DMS concentration in the East China Sea from 1998 to 2020 range from -0.07 to 0.09 nmol/L, with obvious interannual variation. The anomalous values of DMS concentration between 1998 and 2010 are mostly positive anomalies, and the maximum positive anomaly value appears in 2002, which is as high as 0.09 nmol/L, indicating that the DMS concentration in the East China Sea shows an increasing The maximum positive anomaly value occurred in 2002, which was as high as 0.09 nmol/L, indicating that the DMS concentration in the East

China Sea showed an increasing trend, while from 2011 until 2020, the DMS anomalies were all negative, and reached the maximum negative anomaly value in 2018, indicating that the DMS concentration in the East China Sea showed a decreasing interannual trend. The standard deviation can well reflect the interannual variability. Fig 2a shows that the standard deviation contour of DMS concentration in the East China Sea surface water is dense in the nearshore and sparse in the outer sea, and the standard deviation in the nearshore (higher than 0.5) is larger than that in the outer sea (less than 0.1), therefore, the interannual variability of DMS in the East China Sea surface water has obvious spatial distribution characteristics, with large interannual variability in the nearshore and gentle interannual variability in the outer sea.

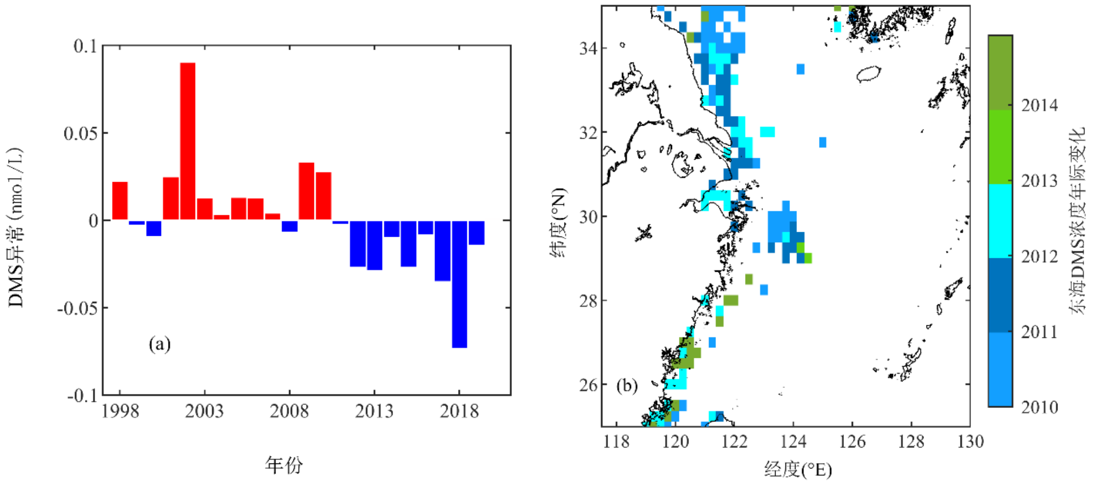

Fig. 3 (a)Anomaly inter-annual variation of DMS in the ECS; (b)Interannual change trend of DMS anomaly in the ECS

Based on the above, the interannual variability of DMS concentration in the East China Sea was found to be spatially significant, and the cumulative distance level method was used to find out the abrupt change in the interannual variability of DMS concentration at each grid point in the study area and to determine whether the abrupt change was significant. From Fig. 3(b), 4 it can be seen that the interannual variability of DMS in the East China Sea nearshore seawater showed a significant increase followed by a decrease, with the DMS anomalies ranging from -0.78 to 0.98 nmol/L, and the abrupt change years were between 2010 and 2014. The interannual variation of DMS in the rest of the East China Sea is mild, with DMS anomalies ranging from -0.09 to 0.11 nmol/L.

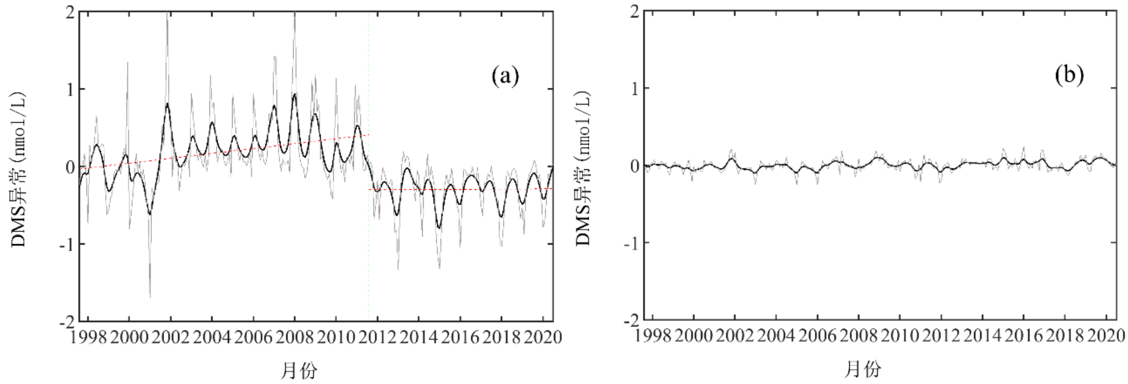

Fig. 4 (a) Inter-annual variation of DMS in the ECS nearshore; (b) Inter-annual variation of DMS in the ECS offshore

4.Perspectives in future:

In order to have a more in-depth analysis of the spatial and temporal variation characteristics of DMS in the East China Sea and the influence processes, the GAMM model will be further improved by adding environmental factors and using scenarios to predict future DMS concentrations in the future.