Global climate changes have led to remarkable environmental changes in the Arctic. On the other hand, Dimethyl sulphide (DMS) emission in Arctic Ocean plays an important role for the global warming. The ice cover as the special feature of Arctic Ocean has significant effect on regulation of the large distribution of phytoplankton production. Chlorophyll-a (CHL), as the primary production of phytoplankton, has its strong relationship with DMS derived aerosol in the ocean surface. This paper will describe the physical and phytoplankton data (based on the past 5 years SeaWiFS satellite data recorded 1998-2002) in the Barents Sea region (30-35°E and 70-80°N). The relationship between temperatures, photosynthetic available irradiance (PAR), cloud cover, ice cover and CHL were also analysed. The field data was based on the three Cruises gathered biological and physical measurement on vertical potential density, temperature, salinity, CHL as well as sulphur compounds. The field data is compared with the satellite data within the study region and the good agreement was achieved before calibrating parameters of the developed DMS model using Genetic Algorithm. The significant inter-annual variation of CHL leads significant inter-annual production of DMS in this study region. The DMSPd field data is used for further DMS calibration. We finally applied the CSIRO GCM forcings to the calibrated DMS model to predict sea-to-air flux of DMS for enhanced greenhouse conditions (from 1xCO2 to 3xCO2) in the zonal 70°- 80°N global belt.
Introduction

Dimethyl sulphide (DMS) is the main sulphur released during the decay of ocean biota (Lovelock et al [1]). Aerosols formed from the conversion of DMS can exert a climate cooling effect by scattering and absorbing solar radiation and promoting the formation of cloud condensation nuclei (CCN) and hence increase the albedo of clouds, reflecting more solar radiation back to space, thus change the climate (Charlson et al [2]). The main source of DMS is the dimethyl sulphonylpropionate (DMSP) (Kiene and Bates [3]). As Arctic Ocean is mostly covered by ice, the ice algae have high DMSP content when there is a high salinity and low temperature associated Kirst et al [4]. High biomass of *Phaeocystis sp.* and *Emiliania huxleyi*, known to occur in Arctic Ocean, could lead to subsequent production of large quantities of DMS, just as ice-algal communities are likely to be an important source of DMS for Arctic Ocean (Bouillon et al [5]). As most Arctic Ocean is covered by ice, the steady decreasing rate of ice cover would give rise to a stratified and nutrient-rich euphotic zone, which supports pronounced spring bloom in the area (Olli et al [6]). Ice melting phenomenon also affects the sea levels and ocean circulations, hence it has significant impact on global climate.

Here we investigate the impact of simulated climate change on the DMS in the year 1998 to 2002 based on the calibrated satellite data (CHL) in the same study region and then apply the CSIRO GCM forcings to the calibrated DMS model to predict sea-to-air flux of DMS for enhanced greenhouse conditions (from 1xCO2 to 3xCO2) in the zonal 70- 80°N global belt.

Model, Calibrations and Results

1 The DMS model and calibrations

The DMS model was firstly introduced by Gabric et al [7] which was adapted the ecological structure of the nitrogen-based plankton community model of (Moloney et al., [8]). The model was a depth averaged model and was developed and used for sub-Antarctic southern ocean modelling (Gabric et al [9],[10]). The DMS model is divided to two sub-models: A PZN sub-model uses following equations:

\[
\frac{dP}{dt} = k_{23} \left( \frac{N}{N + k_{24}} \right)P - k_1 PZ
\]  
(1)

\[
\frac{dZ}{dt} = k_4 (1 - k_{20}) PZ - k_{19} Z
\]  
(2)

\[
\frac{dN}{dt} = k_4 k_{20} PZ + k_{19} Z - k_{23} \left( \frac{N}{N + k_{24}} \right)P
\]  
(3)
where P is the phytoplankton (CHL), Z is the zooplankton, N is the nitrogen (as nitrate). The surphur sub-model is described by the following equations:

$$\frac{\partial DMSP}{\partial t} = k_5 P + k_{21} Z - k_{27} DMSP - k_{31} DMSP$$  

(4)

$$\frac{\partial DMS}{\partial t} = k_6 P + k_{27} DMSP - k_{28} DMS - k_{30} DMS$$  

(5)

Parameters $k_i$ (1 < i < 31) are listed in Gabric et al. 1993.

Model calibration proceeded in two stages, with the PZN sub-model parameters estimated first, followed by the sulphur sub-model parameters. Parametric estimation for the calibration was done using a Genetic Algorithm (GA) which is an non-derivative based optimization technique that mimics natural evolution [11]. The PZN sub-model parameters were calibrated against satellite CHL data derived from five years of SeaWiFS (8-day) Standard Mapped Images. Optimization used a chi-square statistics.

2. Results

Mixed layer depth (MLD) is critical to phytoplankton growth and hence the DMS production rate (Gabric et al., 2003). In the study region, the mean MLD (Figure 1 (left)) is shallow in summer and deeper in winter. Ice cover stayed high in first 5 months decreased to a minimum in August (Figure1 (right)). From September, ice cover increased again.

![Figure 1: Monthly mean MLD, and ice cover in the study region.](image)

The period of CHL bloom generally initiated in the early April, gradually increased to its peak around end of April or early May, then decreased from middle of the May or
June. From the middle of June to late September, CHL appeared lower until it disappeared by the end of September [12]. There was a second smaller bloom in September due to the shallower MLD and increased wind speed.

The DMS concentrations were low in winter. The maximum DMS concentrations were in middle of July. The spring blooms of phytoplankton (CHL peaks) were a few days ahead of DMS first blooms in May. CHL blooms shifted from 17\textsuperscript{th} May to 5\textsuperscript{th} May during the 5 years. This is due to the increased SST and the earlier ice melting. The time lags between the CHL blooms and DMS peak blooms are increased from 45 days to 68 days in the 5 years. It is interesting to see that year 1998 had its DMS first blooms in spring a few days before CHL bloom while in other years, DMS had its first bloom a few days after the CHL spring bloom. The reason could be that the higher ice cover in year 1998 in south part of the study region could generate more and earlier DMS from the ice algal when ice started melting in spring. There is a small autumn bloom for both CHL and DMS in late September.

The DMS flux is calculated in the ice-free water. It is clear that the year 2002 was the most DMS emission year and year 1999 was the least DMS emission year. The high inter-annual variability of DMS flux could be caused by high inter-annual variability of CHL as well as the wind speed and SST records. There were two blooms in the DMS flux cycles. The double peak (two blooms) could be caused by the combined effects of changes in wind speed, SST and MLD on the DMS flux (Gabirc et al [13]).

The transit climate data from GCM simulations for the period of 1960-1970 (pre-industry level: 1xCO2) and 2078-2086 (tripled equivalent CO2: 3xCO2) were obtained in the zonal 70\degree-80\degree N. From the pre-industry level (1xCO2) to tripled equivalent CO2: 3xCO2, the following changes in zonal 70\degree-80\degree N would be possibly made according to our model results: SST is expected to increase 1\degree C overall; Ice cover would be reduced greatly within next 80 years especially during August to October (reduce up to 61%), although a slightly increasing ice cover could occur in spring and early summer (increase up to 4\% during April to June) (Figure 2 (a)). MLD could decrease 6.5m on average. We can conclude that the significant decrease of ice cover and increase of SST are the main reason of increasing DMS flux to more than 100\% by year 2086. This significant change in the northern belt would cause large impact on global warming.
Conclusion

Both satellite data and field data sets were used to calibrate a regional DMS production model. Significant inter-annual CHL variation leads to significant DMS inter-annual variability in the study region. The GCM-simulated physical forcings for the 70–80°N band of decreasing sea-ice coverage, significant increasing of the SST and a decreasing MLD are the main causes of a simulated annual DMS flux increase of more than 100% by the time of year 2080. Such a large change would have a great impact on the Arctic energy budget and may offset the effects of anthropogenic warming that are amplified at Arctic Ocean.

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