511 Project Proposal: Modelling Air-sea-ice feedbacks in DMS production in an Arctic environment

The trace gas dimethylsulfide (DMS) is a biogenic sulphur gas produced by several species of phytoplankton in the open ocean. Once produced, this volatile gas is emitted into the atmosphere, where it is oxidized to form non-seasalt sulphate and methane-sulfonic acid. A seminal 1987 paper by Charleson et al proposed a feedback loop between the production of dimethylsulfide and regional climate. In this theory, called the CLAW hypothesis, the oxidation products of DMS in the atmosphere form cloud condensation nuclei (CCN), which act as precursors to clouds, which in turn increase planetary albedo, cooling the Earth. This temperature decrease will then have effects on primary productivity [1]. The implication of this scheme is that the biological activity of primary producers exerts a control on climate.

Since the publication of the CLAW hypothesis, the idea of a phytoplankton-mediated biological climate control has provided the motivation for the study of the mechanisms of production of DMS, as well an investigation of the climactic effects of its oxidation products, in the international community. Understanding the production of DMS and its effects is, however, a complicated question. The drivers of DMS production are only partially understood, and, because of the significant challenges inherent in measuring DMS in the field, in-situ measurements of DMS remain relatively sparse in the world ocean. For this exercise, I would like to create a seasonal (1-month resolution) model that uses DMS as a state variable to investigate feedbacks between DMS, cloud cover, and sea-ice cover in the Canadian Arctic. I am choosing to focus on the Canadian Arctic for two reasons: firstly, because the Arctic is the site of my recent field expedition, and I have unpublished DMS data that can be used to inform the state variable, and secondly, because the presence of sea-ice in the Arctic has been demonstrated to have important effects on the ecosystem and its DMS production by, for example, Levasseur et al’s 2013 measurements of extremely high DMS produced by under-ice diatoms [2].

Such a model will necessarily be an oversimplification of the dynamics at play, and, in many cases, I may not have meaningful data to input into the parameters. In the following paragraphs, I would like to sketch out both the understood factors in the DMS-climate feedback cycle, and the scheme for my proposed simplified model, potential data sources, and the methodology I aim to use.

1. DMS cycle
2. My simplified model

Figure 1b shows my proposed simplified model, which has six variables: primary productivity, seawater DMS concentration, sea-ice concentration, under-ice diatom population, under-ice DMS, and cloud cover, as well as two intermediate variables, DMS flux and albedo. These variables are dependent on each other, as well as on a suite of weather parameters. Here, I aim to summarize the interdependencies.

1. **DMS** In this highly simplified model, DMS is solely dependent on primary productivity – the seawater sulphur cycle is not parametrized.

Base data source: Jarnikova 2015, unpublished data, averaged, as well as other potential .

1. **Cloud cover** Cloud cover is dependent on DMS cconcentration and wind speed, which determines flux of DMS to atmosphere.

Base data source: Schweiger 2004, a seasonally-averaged

1. Methodology

Numerically - I aim to approach the construction of this model from the point of view of a set of interdependent ordinary differential equations that are also dependent on a limited suite of weather data.

Schweiger, A.J. (2004) Changes in seasonal cloud cover over the Arctic seas from satellite and surface observations, Geophysical Research Letters, Vol. 31, L2207, doi:10.1029/2004GL020067, 2004.