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An Operational Model of Iceberg Drift

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A new iceberg drift, deterioration and calving model has been under development at the Canadian Ice Service (CIS). The model includes several new features, including the utilization of detailed environmental forcing input, and a robust implicit numerical solution method. In particular, the vertical distribution of water current is incorporated in calculations of water drag force on the iceberg keel. The model is also the first to include treatment of calving, prediction of calved ice piece size distribution and deterioration, as well as the drift of calved pieces. This paper gives a description of the drift model formulation as well as verification tests that include comparisons of model predictions with field observations. Additionally, the paper presents the outcome of a parametric study aimed at examining the sensitivity of iceberg drift to input parameters and environmental forcing.

INTRODUCTION

The Canadian Ice Service (CIS) has been developing a new operational model to forecast iceberg drift and deterioration over the Grand Banks region. Offshore developments in that region have led to increasing demands for reliable iceberg drift forecast, and new forecast output concerning, for example, calving and small ice mass populations. The new CIS model deals with the dynamics and drift of icebergs, as well as the deterioration of the icebergs due to various thermal processes and calving. The model also keeps track of calving events, size distributions of the calved bergy bits, and their melt and drift. The calving and deterioration aspects of the model have been presented in the papers of Savage et al. (2000, 2001) and Savage (2002). The present paper focuses on iceberg drift. Particularly examined are the impact of input parameters and environmental forcing on the predicted tracks of icebergs.

Drift of icebergs is modeled by considering the various forces that act on each iceberg, and solving the linear momentum equations. There have been several models that address dynamics of iceberg drift such as El-Tahan et al. (1983), Banke and Smith (1984), Murphy and Anderson (1986), and Bigg et al. (1997). The present drift model builds on such models and incorporates several new features, including a more detailed environmental forcing input. For example, water drag forces are calculated using water current values at 10-m vertical intervals. A detailed description of keel geometry was then needed. Consequently, a parameterization of keel geometry is included in the model, which relates keel areas at 10-m depth intervals to the waterline length of the iceberg. Barker et al. (2004) give details of the analysis of iceberg geometry.

In the present investigation, the role of several input parameters and scenarios of environmental forcing are examined by comparing predicted iceberg tracks to measurements. The observations of Smith and Donaldson (1987) are used here since they are the most reliable and complete dataset available to date. Tests examined the role of water and air drag coefficients, water current input, wind waves, wind drag force, and waterline length of the iceberg. Tests of water current input included a number of cases using values of water current at various depths and average values. In addition, several scenarios of free drift were examined.

The influence of input parameters and variables was established by comparing predicted tracks to observations. Visual inspection of the tracks as well as quantified comparisons were done based on distances between iceberg locations at the end of certain track segments. The conclusions summarize the relative significance of the various parameters and variables. They also establish a basis to guide the choice of environmental forcing and the appropriate procedures for operational use of the model.

GOVERNING EQUATIONS

The equations of the balance of linear momentum which govern the drift of an iceberg can be expressed as:

$$m\left(\frac{d\vec{V}}{dt}+\vec{f}\times\vec{V}\right)=\vec{F}_a+\vec{F}_w+\vec{F}_r+\vec{F}_p+\vec{F}_{am} \qquad (1)$$

where m and $\vec{V}$ are the mass and velocity of the iceberg, respectively, and $\vec{f}$ is Coriolis force parameter. The terms on the right-hand side of Eq. 1 represent the forces due to air drag, water drag, wave radiation stress, water pressure gradient and added mass, respectively. Equations describing those forces are given below.

The force due to air drag $\vec{F}_a$, is given by:

$$\vec{F}_a=\frac{1}{2}\rho_a C_a A_a|\vec{V}_a|\vec{V}_a \qquad (2)$$

where ρ_a is air density, C_a is air drag coefficient, A_a is cross-sectional sail area and $\vec{V}_a$ is wind velocity. Since iceberg velocity

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