POTENTIAL EFFECT OF NUCLEAR WAR SMOKEFALL ON SEA ICE

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Abstract. A large nuclear war could produce massive quantities of smoke from burning cities and industries. A portion of this smoke would fall out on Arctic sea ice, thus lowering its albedo and potentially increasing the solar energy absorbed by the ice and the snow that covers it. We use a one-dimensional thermodynamic sea ice model to examine the effect of 'smokefall' on the seasonal variation of sea ice. In particular, we test the sensitivity of the model results to the time of year, duration, and latitude of smokefall.

Sea ice thickness variations and the period of summer ice-free conditions are sensitive to the season of smokefall. The largest sea ice perturbations are generated by smokefall in spring. In this case the period of ice-free conditions during the summer can increase by 2 – 3.5 months between 67.5° N and 82.5° N. In any given season, the annual cycle of sea ice is not very sensitive to the duration of smokefall. The equilibrium annual cycle of sea ice variation is restored within a few years of smokefall when the smoke is flushed out of the ice/snow system.

Since the sea ice model used here is not a comprehensive global climate model, it is difficult to predict the mid-latitude climate effects of the massive, but temporary, Arctic sea ice changes. However, our results suggest that future global climate model simulations of the effects of nuclear war smoke include interactive sea ice calculations.

1. Introduction

It has been suggested that massive amounts of smoke produced in a large scale nuclear war could create severe atmospheric and environmental effects over widespread areas, the so-called 'nuclear winter' (Crutzen and Birks, 1982; Turco et al., 1983; see NRC, 1985 for a review). The potential climatic effects of large amounts of smoke in the atmosphere have been investigated by researchers using increasingly sophisticated global climate models, ranging from one-dimensional (1-D) vertical globally-averaged models (Turco et al., 1983), to 3-D circulation models with specified immobile smoke (Covey et al., 1984; Thompson et al., 1984), to the current generation of models which allow smoke to be transported with the winds (MacCracken and Walton, 1985; Aleksandrov, 1985; Haberle et al., 1985; Thompson, 1985; Malone et al., 1985).

These modeling investigations have concentrated on the effects of smoke in the atmosphere within the first few weeks or months after nuclear war fires. A future generation of comprehensive climate simulations will probably extend the examination of smoke

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effects to consider medium term implications for climate of the large short term perturbations and the effects of lingering smoke and dust (time scales of 6 months to a few years). One such study has already been done by Robock (1984) using a simplified energy balance model. He concluded that the effect of smoke on global climate could persist for several years, even after the removal of smoke from the atmosphere, due to feedbacks that extend climatic ‘memory’ at high latitudes.

The purpose of this paper is to examine the importance of a potential direct influence on medium term climate that might occur after smoke has been removed from the atmosphere and deposited on sea ice. The deposition of smoke at the surface we will term ‘smokefall’.

Warren and Wiscombe (1985) suggest that the smokefall following a nuclear war could cause a continuing climate disruption by lowering the albedo of snow and sea ice surfaces for several years. Warren and Wiscombe then go on to compute the spectrally averaged new and old snow albedos as a function of the weight fraction of smoke in the snow using a radiative-transfer model for snow to obtain snow spectral albedo, and an atmospheric radiation model to obtain the solar spectrum for the subarctic-summer standard atmosphere. Their results will be used in this study.

There are several important reasons for examining the effect of nuclear war smokefall on the time variation of sea ice: (1) The horizontal thermal gradients at the winter ice-ocean boundary are among the largest on the surface of the Earth. Such thermal gradients (representing diabatic heating gradients) can influence synoptic circulation systems and perhaps planetary scale circulations (Herman and Johnson, 1978; Walsh and Johnson, 1979; Cavalieri and Parkinson, 1981). (2) Ice cover variations can produce large changes in heat and moisture flux at the surface. Sea ice, particularly ice greater than 1 m thick, has a strong insulating effect on the ocean surface. An area of open ocean can transmit 100 times more heat to the atmosphere in winter than an equal area of sea ice. Effective insulation can make the surface of thick ice more than 40 °C colder than the surface water. Such cold surface temperatures produce a low level temperature inversion that inhibits mixing to higher levels in the atmosphere. (3) The albedo difference between sea ice and open ocean is large, thus during the half-year of high insolation the nature of the surface has a large effect on the amount of solar energy absorbed at the surface and whether the energy is stored or made immediately available to the atmosphere. In summer open ocean areas store energy that can be used to delay ice formation in autumn or decrease maximum ice thickness in winter. These effects may cause large scale, medium term changes in climate that can be enhanced through feedbacks between the atmosphere, ocean, land, and cryosphere. Therefore, it is important to examine the effect of smokefall resulting from nuclear war on sea ice variations.

2. The Model

2.1. The Sea Ice Model

The sea ice model used here is that described in Ledley (1985a, 1985b) and is based on