*Climate Change Research: Evaluation and Policy Implications*
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# LAND ICE AND SEA LEVEL CHANGE

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in co-operation with the University of Amsterdam and the Free University (Amsterdam)

sponsored by
- Dutch National Research Programme on Global Air Pollution and Climate Change
- Netherlands Organization for Scientific Research (NWO)
- Netherlands Antarctic Research Programme
- European Commission (ENVIRONMENT)

**Abstract**

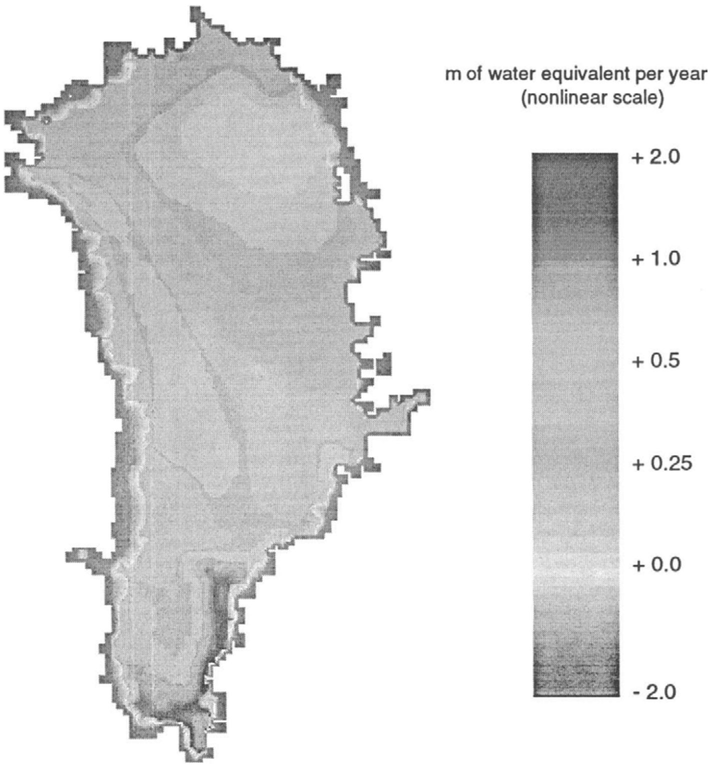
Sea-level change is an important issue in the greenhouse problem. All workers agree that predictions made so far have a high degree of uncertainty. Comparable contributions to this uncertainty come from limited knowledge of future emissions of greenhouse gases, different opinions concerning the response of the climate system, and inadequate knowledge of the sensitivity of land ice to climate change.

The goal of this project is to improve estimates of the contribution of land ice masses to sea-level change in the coming 150 years.

## MASS BALANCE OF THE GREENLAND ICE SHEET

The mass balance of the Greenland ice sheet has been studied with an energy balance model. The mass balance is generated from climatological input. Data from several field experiments have been used to improve the parameterization of energy transfers between atmosphere and surface. The grid resolution is 20 km.
The picture below shows the calculated surface mass balance for the "reference case". Sensitivity tests reveal that

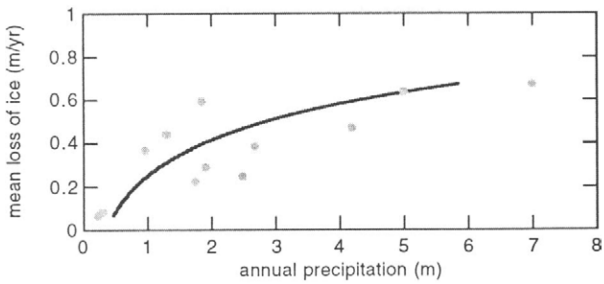
a 1K warming implies a 0.30 mm/year sea-level rise
a 1K warming (+ dP) implies a 0.21 mm/year sea-level rise
a 10% increase in cloudiness implies a 0.02 mm/yr sea-level drop
a 0.02 decrease in albedo implies a 0.17 mm/year sea-level rise
[dP is a change in precipitation in proportion to saturation vapour pressure]



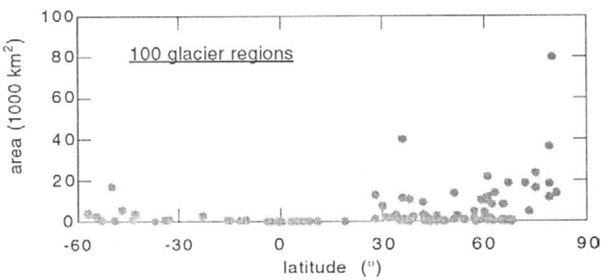

**Conclusion:**
Greenland ice sheet, +1K: 0.21 mm/year sea-level RISE (*best estimate*)

## GLACIERS AND SMALL ICE CAPS

A model has been designed that simulates mass balance profiles on glaciers. It has been tested on 12 glaciers for which good observations exist. After careful calibration a large number of sensitivity tests have been carried out. There appears to be a significant correlation between glacier sensitivity and precipitation regime. The figure below shows the result for an experiment with uniform 1K warming and an increase in precipitation proportional to saturation vapour pressure of the air. The mean loss of ice, averaged over the entire glacier, is shown for the 12 glaciers studied.




Extrapolation of this result to all glaciers and small ice caps outside Greenland and Antarctica yields a sea-level rise of 0.46 mm/yr for a uniform 1K warming (this includes increasing precipitation). This is about half the value of the 1.2 ± 0.6 mm/yr used in IPCC-1990.
The difference is due to an earlier overestimation of glacier sensitivity in the dry subpolar regions, where a large amount of glaciers and small ice caps are located (see below).

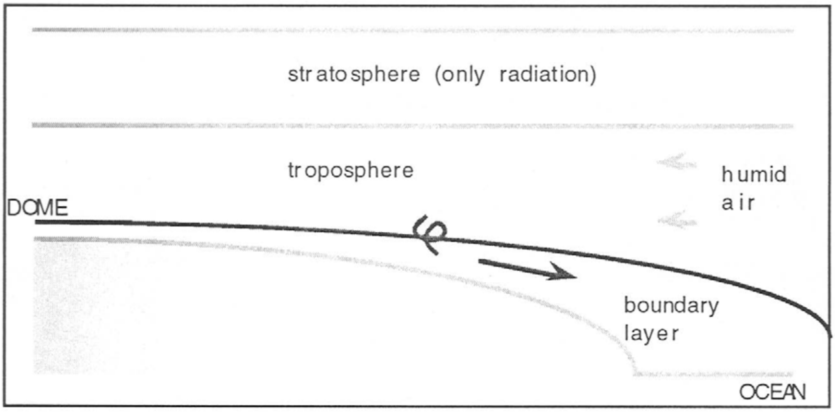



**Conclusion:**
Glaciers and ice caps, +1K: 0.46 mm/year sea-level RISE (*best estimate*)

## SNOW ACCUMULATION ON THE ANTARCTIC ICE SHEET

A simple meteorological model has been developed to simulate the temperature and precipitation distribution over the Antarctic continent. The model is two-dimensional (vertical plane, see figure below), and has 4 layers: stratosphere, troposphere, boundary layer and surface of the ice sheet. It has a detailed radiation scheme for short and long wave radiation.

The katabatic outflow is explicitly calculated and drives the circulation over the ice sheet. The boundary layer has two shear zones: one at the ice sheet surface and one at the top of the boundary layer, where significant entrainment takes place. Boundary layer depth is a prognostic variable.




Moisture is brought to the ice sheet by the return flow in the free troposphere. Precipitation occurs because of cooling of the air (due to uplift and a negative radiation balance). The moisture budget at the surface has four contributions:

- precipitation
- riming
- evaporation
- divergence of snow drift

When run with appropriate boundary conditions (annual mean insolation and temperature at the ocean boundary), the model gives a satisfactory simulation of the meridional profiles of temperature and accumulation on the Antarctic ice sheet (annual mean state).
In case of a warmer climate, snow accumulation increases because the "moisture pump" intensifies. The increase is partly compensated by larger evaporation on the steep slopes of the ice sheet, however. For a uniform 1K warming, the model predicts an increase in snow accumulation that is equivalent to a 0.27 mm/year sea-level drop.

**Conclusion:**
Antarctic ice sheet, +1K: 0.27 mm/year sea-level DROP (*best estimate*)

**PAPERS FROM THIS PROJECT (printed or accepted, status November 1994)**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About 12 additional papers have been submitted