THIRTY YEARS OF MASS BALANCE AND CLIMATE RECORDS ON HINTEREISFERNER: A BASIS FOR MODELLING

(Abstract)

by

M. Kuhn
(Institut für Meteorologie und Geophysik, Universität Innsbruck, Schöpfstrasse 41, A-6020 Innsbruck, Austria)

The effect of the present-day climate on a typical Alpine valley glacier is demonstrated on the 30-a record of mass balance of Hintereisferner. The balances of 1952-53 to 1981-82 were determined by the direct glaciological method, occasionally checked by geodetic volume comparison. The series includes three negative and two positive extremes, the first 15 a being predominantly negative. Specific balances for 100 m altitude zones have been established for all years except two. These records are supplemented by climatic data from a nearby valley station, and, since 1969, by temperature records taken at the equilibrium line and at the glacier front. Based on these and other records, a model is developed that describes the altitudinal and temporal development of mass and energy balance using temperature and precipitation. The performance of this model is tested for various climates.

SENSITIVITY OF AN ICE-SHEET MODEL TO ATMOSPHERIC VARIABLES

(Abstract)

by

Tamara Shapiro Ledley*
(Department of Meteorology and Physical Oceanography, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139, U.S.A.)

Recent studies of long-term climate variations which have employed zonally-averaged ice-sheet models and an equilibrium-line net-budget parameterization (Oerlemans and Bienfait 1981, Pollard 1982) have been able to reproduce many of the complete deglaciations and reinitiations of the northern-hemisphere ice sheets found in the geologic record. However, when the equilibrium-line net-budget parameterization is replaced with an energy-balance equation designed to compute the temperature and ablation at the ice surface, the reinitiation of a zonally-averaged ice sheet is much more difficult than previously indicated.

In order to investigate what magnitude changes in air temperature and surface albedo are necessary to initiate ice-sheet growth, an energy-balance net-budget parameterization, in which these terms are varied, is applied to a zonally-averaged ice sheet that is initiated with either ice-free conditions (low summer surface albedo of 0.16) or with a 10 m-thick ice field (high-surface albedo ranging from 0.7 to 0.8).

The energy-balance net-budget parameterization is made up of two parts: the accumulation rate and the ablation rate. The accumulation rate is parameterized as follows:

$$S_n = P_r * r_a * F_y * e_s/e_{si}$$

where P_r is the present precipitation rate, r_a is the ratio of the density of water to ice, F_y is the fraction of precipitation that falls as snow, and e_s/e_{si} is the ratio of the saturation vapor pressure at the surface air temperature to that at the present surface air temperature. The ablation rate is derived from a surface-energy balance equation of the form:

$$F_P + F_s + (1-a)\, F_{sw} + F_{lw} + F_{ir} = 0$$

where F_P is the latent heat flux, F_s is the sensible heat flux, a is the surface albedo, F_{sw} is the short-wave radiation available at the surface, F_{lw} is the long-wave radiation from the atmosphere, and F_{ir} is the long-wave radiation from the surface. The

*Present address: Department of Space Physics and Astronomy, Rice University, PO Box 1892, Houston, Texas 77251, USA

https://doi.org/10.3189/S0260305500003840 Published online by Cambridge University Press

accumulation and ablation rates are computed at approximately two-week time steps through the seasonal cycle and then summed over the year to obtain the annual net budget.

Using this net-budget parameterization and a solar insolation regime at 120 ka BP, preliminary experiments were performed.

First the ice-sheet model was initiated with ice-free conditions. In this case it was found that a drop in mean air temperature in all seasons of between 20 and 25 K was required to initiate an ice sheet. This is a very large mean temperature change; however, it must be viewed with caution for two reasons. First, the reduction of the mean annual temperature is probably not climatically realistic. In the model there is a decrease the in winter snowfall due to its dependence on saturation vapor pressure, despite the cooling. Second, there are computational constraints in defining the surface albedo that are presently part of the model which may enhance the difficulty in initiating an ice sheet.

The reason for the difficulty in initiating the growth of an ice sheet from ice-free conditions is that low summer albedos associated with these conditions increase the amount of absorbed solar radiation to such an extent that any modest decrease in air temperature is overwhelmed resulting in complete snow/ice ablation.

In order to examine how important the surface albedo is to the inititiation of an ice sheet a few experiments were performed which were initiated with a ten meter ice field with a surface albedo ranging from 0.7 to 0.8. In the case when the snow/ice surface albedo was set to 0.8 a reduction in mean air temperature of only 3 K produced ice-sheet growth with about 350 m of ice accumulating at 72.5°N after 5 ka. This was the only case in these preliminary experiments which produced ice-sheet growth. In the cases where the snow/ice surface albedo was set to 0.8 and 0.75 and the mean air temperature was decreased 2.5 and 3 K respectively the 10 m-ice field melted away slowly with a residual ice field, present after 1 ka, completely disappearing after 5 ka. In other experiments in which the snow/ice surface albedo was set to 0.8 and mean air temperature was decreased 2 K, and in which the snow/ice surface albedo was set to 0.7 and mean air temperature was decreased 2.25, 3 and 4 K, the 10 m-ice field melted away within the first thousand years.

Despite the fact that these results are preliminary and must be viewed with caution, the magnitude of the difference between the reduction in mean air temperature required to initiate ice-sheet growth when an initial ice field is assumed compared to when ice-free conditions are assumed is quite large. This suggests the critical importance of the summer surface albedo in determining ice-sheet initiation.

In conclusion, these results suggest that there is great difficulty in making the transition from interglacial to glacial conditions using zonally-averaged conditions, and that making that transition requires the crossing of a climatic threshold in which ice and snow accumulation in the winter season, and thus high surface albedo, can be maintained through the summer season.

REFERENCES

Oerlemans J, Bienfait J M 1981 Linking ice sheet evolution to Milankovitch radiation variations: a model simulation of the global ice volume record. *In Soleil et climat. Journées d'études internationales. Toulouse...1980.* Toulouse, Centre National d'Études Spatiales: 357-368

Pollard D 1982 A simple ice sheet model yields realistic 100 kyr glacial cycles. *Nature* 296(5855): 334-338

THE PREDICTABILITY OF GLACIATION CYCLES

(Abstract)

by

H. Le Treut

(Laboratoire de Météorologie Dynamique, 24 rue Lhomond, 75231 Paris Cedex 05, France)

and M. Ghil

(Courant Institute of Mathematical Sciences, New York University, 251 Mercer Street, New York, New York 10012, U.S.A.)

We consider a nonlinear climatic oscillator, which includes radiation balance, oceanic thermal inertia, a highly simplified hydrological cycle, the mass balance and the plastic flow of ice sheets, and the elasticity of the Earth's lithosphere and the viscosity of its mantle, as well as their various interactions. The study of the unforced behaviour of the system (Källén and others 1979, Ghil and Le Treut 1981, Ghil and Ravantzis in press) has shown the existence of a self-sustained periodic oscillation with amplitude of a few degrees Celsius, in the absence of any periodic forcing. The free period of the oscillator, depending on model parameters, lies roughly between 5 and 15 ka.

The forced oscillations of this climatic oscillator is studied next (Le Treut and Ghil 1983, Ghil in press): the model is subjected to forcing at the astronomical periodicities of precession 19 and 23 ka, obliquity 41 ka, and eccentricity 100 and 400 ka. The forcing is assumed to act on the climatic system by variations in mean annual isolation, in the case of eccentricity, as well as by its effects on the ice-mass balance through the nonlinear precipitation-temperature feedback.

The effects investigated cause only small changes in ice-mass V and global temperature T when self-sustained oscillations are absent. In their presence, a nonlinear resonant response to the forcing leads to large changes in T and V. The systematic study of the Fourier power spectrum for various conditions of forcing gives an insight into the dynamics of the model. For low values of forcing, the response is at the frequency of the free oscillation, at the frequency of the forcing and at combination tones of these.

For higher values of the forcing, due to the mechanism of frequency locking (entrainment), the