

VENUS CLIMATE STABILITY AND VOLCANIC RESURFACING

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The climate of Venus is to a large degree controlled by the radiative properties of its massive atmosphere. In addition, outgassing due to volcanic activity, exospheric escape processes, and surface/atmosphere interactions may all be important in moderating the abundances of atmospheric CO₂ and other volatiles. Before the return of detailed radar images of Venus' surface by the Magellan spacecraft, estimates of the magnitude of volcanic source terms were relatively unconstrained. Recent work on the interpretation of the impact cratering record as revealed by Magellan, however, have placed some plausible limits on the magnitude of the volcanic flux [1][2][3]. In addition, the high temperatures and pressures at the surface of Venus have led to the suggestion that heterogeneous reactions between surface minerals and the atmosphere may play an important role in buffering CO₂ and other volatiles [4]. For example, Fegley and Treiman [5] have shown that the surface temperature and pressure on Venus coincide approximately with the P-T equilibrium of the calcite-wollastonite mineral reaction. If this is the case, perturbations to the atmospheric inventory of radiatively active species, caused by volcanic eruptions, may have a significant impact on the climate of Venus and upon the stability of the greenhouse effect. For example, it appears that a small increase in atmospheric CO₂ would increase the magnitude of the greenhouse effect, and at the same time shift the calcite-wollastonite mineral equilibrium to one of both a higher temperature and pressure. In this way, the buffering effect of the surface mineral equilibrium can produce an important feedback on the greenhouse effect.

We have developed an evolutionary climate model for Venus using a systems approach that emphasizes feedbacks between elements in the climate system. Modules for atmospheric radiative transfer, surface/atmosphere interactions, tropospheric chemistry, and exospheric escape processes have so far been developed. Climate feedback loops result from interconnections between modules, in the form of the environmental parameters pressure, temperature, and atmospheric mixing ratios. The radiative transfer module has been implemented by using Rosseland mean opacities in a one dimensional grey radiative-convective model. The model has been solved for the static (time independent) case to determine climate equilibrium points. The dynamics of the model have also been explored by employing reaction/diffusion kinetics for possible surface atmosphere heterogeneous reactions over geologic timescales. It was found that under current conditions, the model predicts that the climate of Venus is at or near an unstable equilibrium point. Without sources, the surface/atmosphere system spontaneously evolves to a cooler, lower pressure state. Assuming that surface carbon and sulfur reservoirs are active, a single volcanic event involving an eruption approximately the size that created the Deccan traps on Earth is sufficient to precipitate a climate catastrophe towards a state of higher surface pressure and temperature. Finally, the effects of constant rate volcanism and corresponding exsolution of volatiles on the stability of the climate model were also explored. Average terrestrial lava abundances of about 200 ppm were assumed for SO₂, and a lower limit of 50 ppm was considered for H₂O. The exospheric escape of H₂O was modeled as a diffusion limited process in which the escape rate is uniquely determined by the abundance and a time constant. Current estimates of hydrogen escape rates place the time constant against escape at about 160 m.y. [6]. By including the constant source and exospheric escape terms in the dynamics of the model, we determined that an injection rate of 3×10^{13} g each of H₂O and SO₂ per year would be sufficient to keep the

current climate in a steady state close to the present point of unstable equilibrium. Using the assumption of volatile abundances described above, this amounts to an upper bound on the yearly volcanic flux of about 18 km^3 , approximately the rate associated with the formation of large igneous provinces on the earth.

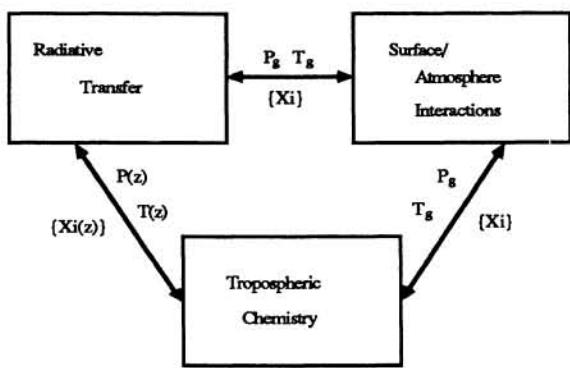


Figure 1. Climate Model Summary.

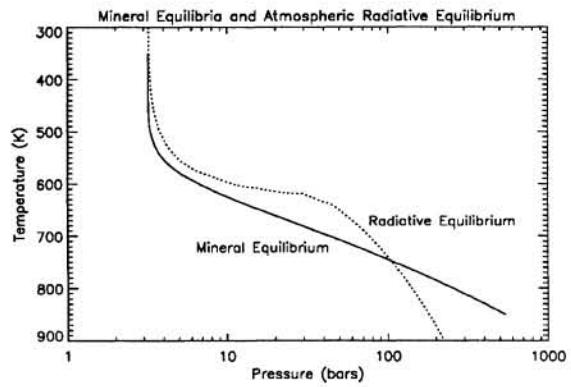


Figure 2. Mineral equilibria and radiative equilibrium curves for surface pressures and temperatures.

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