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A Review of Surface Heat Flow Estimates on Venus

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I) INTRODUCTION:

On **Earth** the surface heat flow is well known to be **87 mW m^{-2}** [1] due to the in-situ determination in thousands of different locations and is dominated by the three main heat transport mechanisms: thermal conductivity, plate-tectonics and hot-spot-volcanism, as two different forms of heat convection. On Venus the amount of heat loss is not known, because no measurements have taken place up to now. Thus only some different estimates exist in literature with quite different results. The purpose of this paper is to review these models and their results regarding the mean heat loss and to compare them to an estimation model based on the heat capacities of possible Venusian heat transport mechanisms.

II) DESCRIPTION OF THE MODELS:

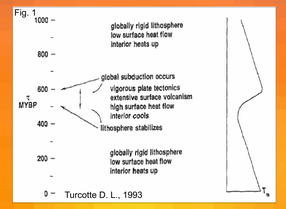
A) GLOBAL SCALINGS FROM EARTH TO VENUS:

Equation **(1)** implies the assumptions of **equal** mechanisms of interior heat transport, thermal structure, heat production rate, composition, etc.

$$q_{Venus} = 0.815\, q_{Earth} \quad (1)$$

Based on equation **(1)** (with q_{Venus} and q_{Earth} as the mean heat flows of the planets and 0.815 as the mass ratio between Earth and Venus) Solomon S. C. and Head J. W., 1982 [2] and Turcotte D. L., 1995 [3] have estimated the global mean surface heat loss on Venus to be **78 mW m^{-2}** and **63 mW m^{-2}**, respectively.

B) CATASTROPHIC/EPISODIC RESURFACING MODEL:



The catastrophic resurfacing model given by Turcotte D. L., 1993 [4] assumes a strong time-dependent heat loss with periodes (with a duration of ~ 150 Myr) of extensive heat loss due to plate-tectonics and/or hot-spot-volcanism. Thereby the last (global) event is assumed to have occurred about 500 Myr ago, whereby this value is due to the estimated age of the surface given by the crater distribution. Since the last resurfacing event only thermal conductivity in this model is responsible for the surface heat loss. Thus the present surface heat flow can be estimated according to equation **(2)** (with k as the thermal conductivity, κ as the thermal diffusivity, T_m and T_s as the mean mantle and surface temperatures respectively and t as the time since the lithosphere was stabilized: the mean surface age) and resulted in an amount of heat loss of about **11 mW m^{-2}**.

$$q_{Venus} \quad \frac{k(T_m \quad T_s)}{(\quad t)^{1/2}} \quad (2)$$

In our present understanding this value seems to be too low, because it is lower than the two measurements on the Lunar surface (14 mW m^{-2} and 21 mW m^{-2}) and consequently would rule out any recent volcanic activities.

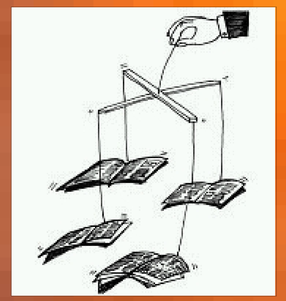
C) PARAMETERIZED CONVECTION MODELS:

-) Phillips R. J. and Malin M. C., 1983 [5]: a model with no core heat component and with a chondritic heat source; resulted in an amount of **~ 50 mW m^{-2}**

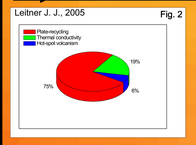
-) Arkani-Hamed J. and Toksöz M. N., 1984 [6]: various model calculations with the assumptions that 90 % of the heat-producing elements are concentrated in the outer 120 km of the planet, with a constant density regime, without mantle phase transitions and that the surface temperature has not undergone any changes up to the present; resulted in amouts between **42 and 80 mW m^{-2}**

-) Solomatov V. N. and Moresi L. N., 1996 [7]: a first result was achieved by a model with constant viscosity conditions (no stagnant lid); resulted in **50 mW m^{-2}**

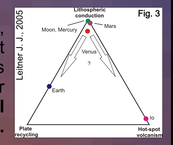
-) Solomatov V. N. and Moresi L. N., 1996 [7]: a second result was given by a model, where the constant viscosity regime is switched to a stagnant lid regime about 0.6 Gyr ago (after the switch the surface flux and lithospheric thickening are purely controlled by diffusion cooling of the lithosphere); **~ 15 mW m^{-2}**

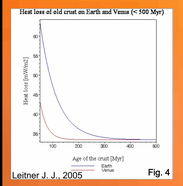


D) CAPACITIES OF THE HEAT TRANSPORT MECHANISMS:



On Earth the proportions of the three main heat transport mechanisms are well known (figure 2) in contrast to Venus (figure 3), where one of the greatest open questions is wether plate-tectonics or hot-spot-volcanism was responsible for past resurfacing and heat loss. Nevertheless, since Magellan it is widely accepted that plate-teconics is not operative on Venus at present, an observation which is in a good agreement with the calculation of the possiblel plate-teconical driving forces under terrestrial [1] and Venusian conditions given in Leitner J. J. and Firneis M. G., 2005a [8]. **Thus on Venus presently only thermal conductivity and an equivalent to terrestrial hot-spot-volcanism (Corona-volcanism) can contribute to the total heat loss.**





In figure 4 (Leitner J. J and Firneis M. G., 2005b [9]) for a 500 Myr old Venusian crust the proportion due to **thermal conductivity** to the total heat loss of **~ 33.5 mW m^{-2}** is shown (a result which agrees well with an other estimation of 37.7 mW m^{-2} published in [3]).

If Venusian Corona structures pose the equivalent to terrestrial hot-spots and in this manner the surface manifestation of a mantle plume then the contribution to mean surface heat loss due to Coronae (and their subtypes: Arachnoids and Novae) can be estimated by equation **(3)**, with ρ and c_p as the density and the specific heat of the volcanic material, H_f as the fusion heat of the magma, ΔT as the temperature difference between the eruption temp. and the surface temp., dV/dT as the volumetric flux of magma with time and n_W as a weight-factor for all presumably active plume-induced structures at present (Leitner J.J., 2005, [10]). Thus **Corona-volcanism** contribute: **6 ± 1.4 mW m^{-2}**.

$$q_{Coronae} \quad n_W \quad (c_P \quad T \quad H_f)\frac{dV}{dt} \quad (3)$$

III) SUMMARY OF THE RESULTS:

Global scaling models: 63 and 78 mW m^{-2}

Catastrophic/episodic resurfacing models: 11 mW m^{-2}

Parameterized convection models: between 15 and 80 mW m^{-2}

stagnant lid model: 15 mW m^{-2}

non-stagnant lid model: 50 mW m^{-2}

Capacities of the heat transport mechanisms: 39.5 ± 1.4 mW m^{-2}

IV) DISCUSSION:

In contrast to the values given by the global scaling models and the catastrophic model, which are too high (and not consistent with the observed geology) and too low respectively (because they would rule out any tectonic or volcanic activity), the results due to a consideration of the transport capacities of the separate mechanisms seem to be a reasonable estimation of the global mean surface heat loss on Venus at present and in a good agreement with the observed surface features.

V) REFERENCES:

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VI) ACKNOWLEDGEMENTS:

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