Aerial Electromagnetic Sounding of the Lithosphere of Venus

VEXAG Open Mike 10/28/09

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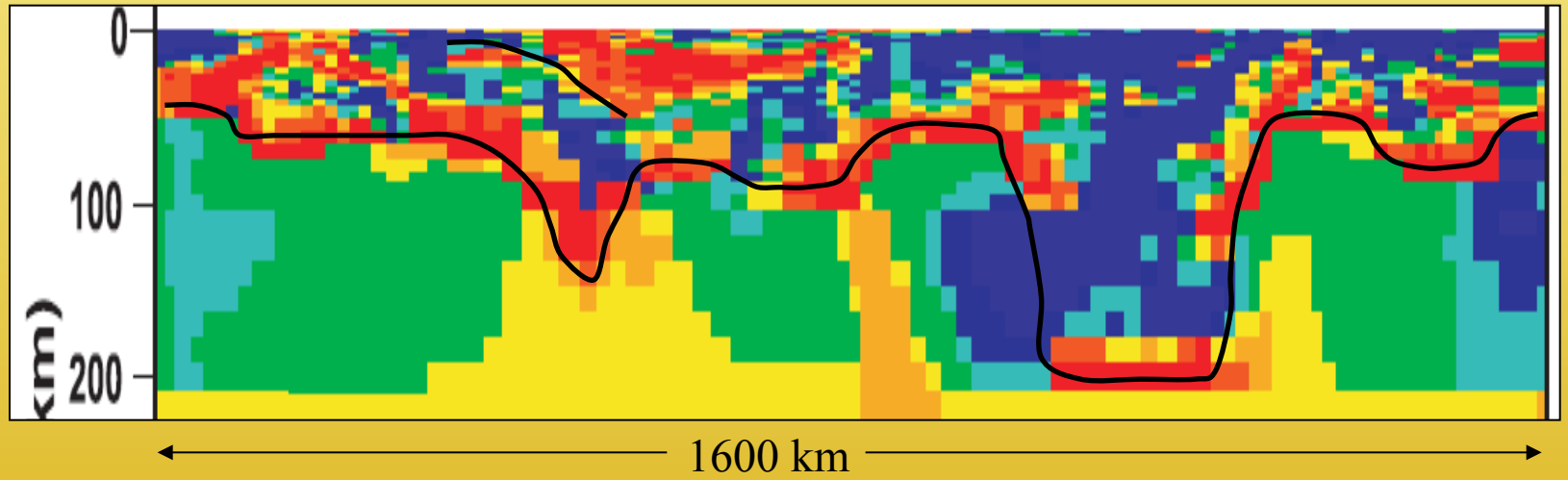


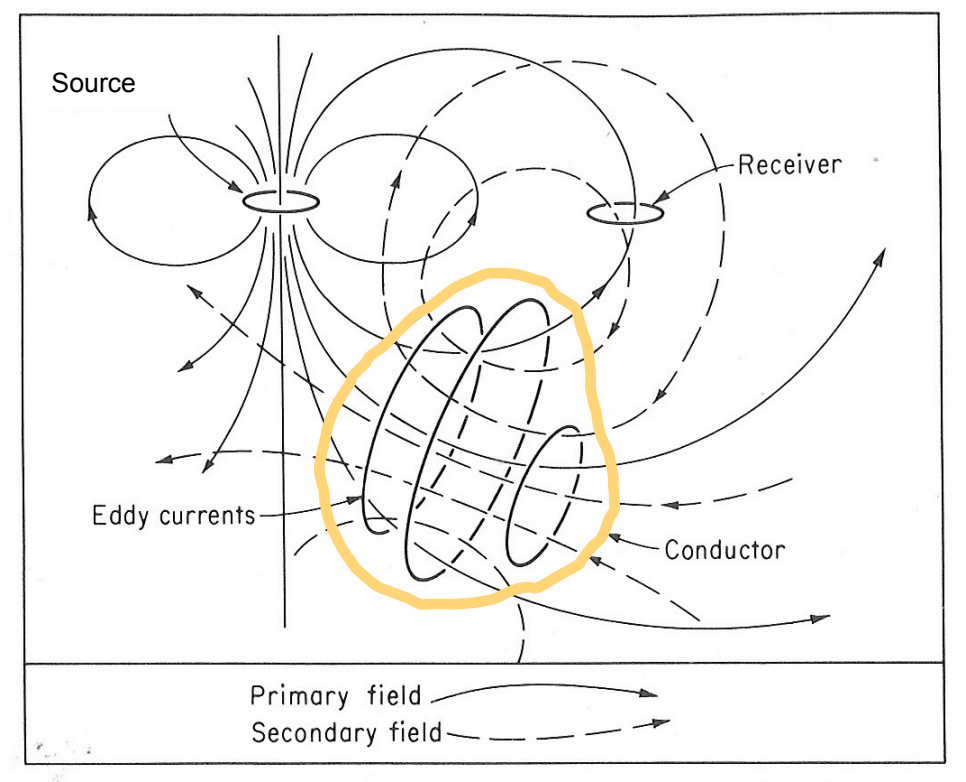
How does Venus lose its heat, and what are the implications for tectonics and volcanism?

Measure the thickness of the thermal lithosphere

Predictions: Mobile Lid ~100 km, Stagnant Lid ~500 km

EM Sounding

Grant and West, 1968



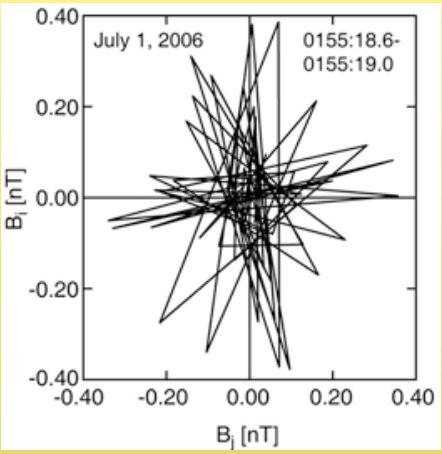
- Determines electrical structure from inductive response to natural or artificial sources.
- **Skin Depth (km) = $0.5\sqrt{\rho/f} = 0.5\sqrt{T/\sigma}$**

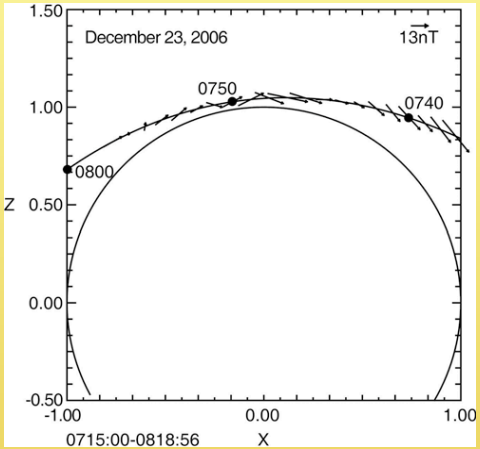
  f = freq, Hz; T = period, s

  ρ = resistivity, Ω-m; σ = conductivity, S/m
- Very dry (resistive) extraterrestrial lithospheres raise frequency that can penetrate to a specified depth: simplifies measurements and improves SNR.

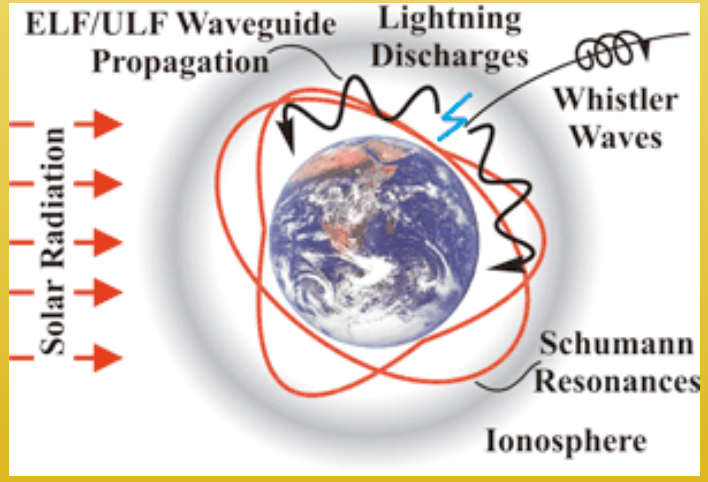
What is Measured?

- *Lightning confirmed by VEX.* Whistlers consistent with energy refracted vertically as it enters ionosphere from below. Extrapolated rate ~20% Earth's. (*Russell et al.*, 2008).





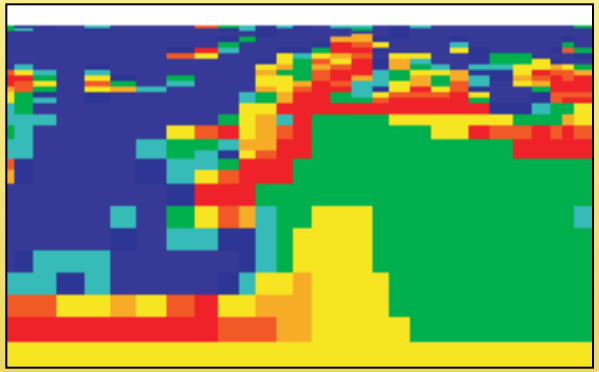
- *Lowest lightning frequencies suitable for lithospheric sounding.*
  - Schumann resonances = global interference patterns, 10-30 Hz.
- *Measure E- and B-fields for complete single-station sounding.*
  - Magnetotelluric and wave-tilt methods.
  - Aerial measurement analogous to terrestrial exploration at 1-20 kHz.

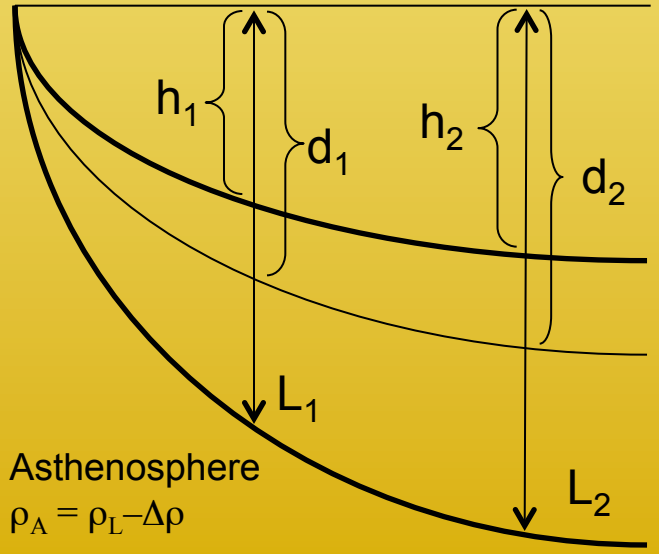


Multiple Measurement Locations

- Comparing measurements at 2 or more locations allows testing of principal hypotheses for lithospheric structure, *independent of conductivity-temperature modeling*.
  - Let maximum penetration depth = d(x,f).
  - Assume T(d) = const and dT/dz = const.

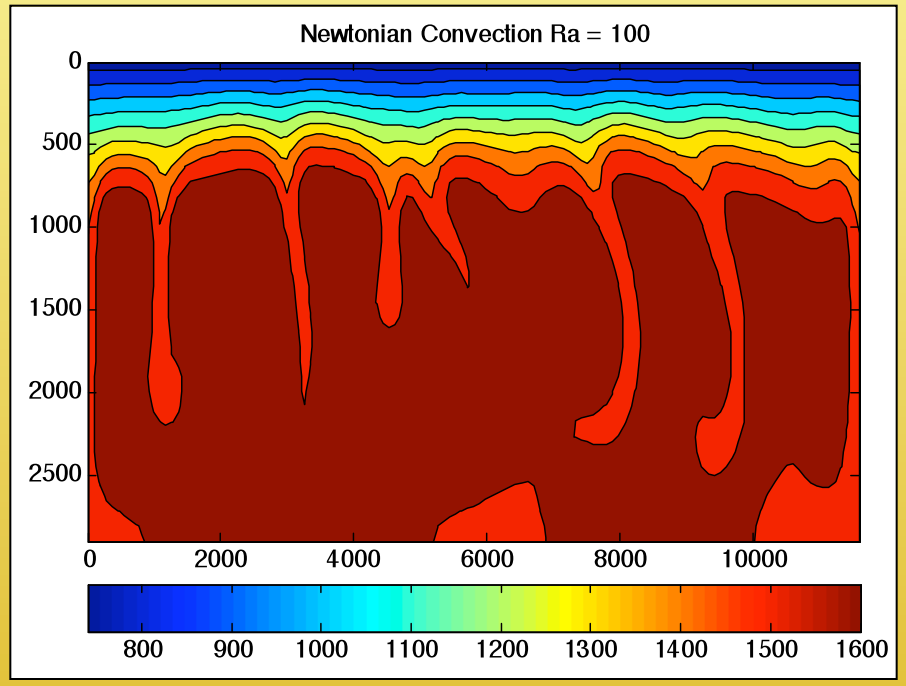
  $\rightarrow L_2/L_1 = d_2/d_1$
  - Isostatic $L_2 - L_1 = (h_2 - h_1)\rho_L/\Delta\rho$
  - Uniquely determine L_1, L_2
    - Select lowlands/rolling plains.

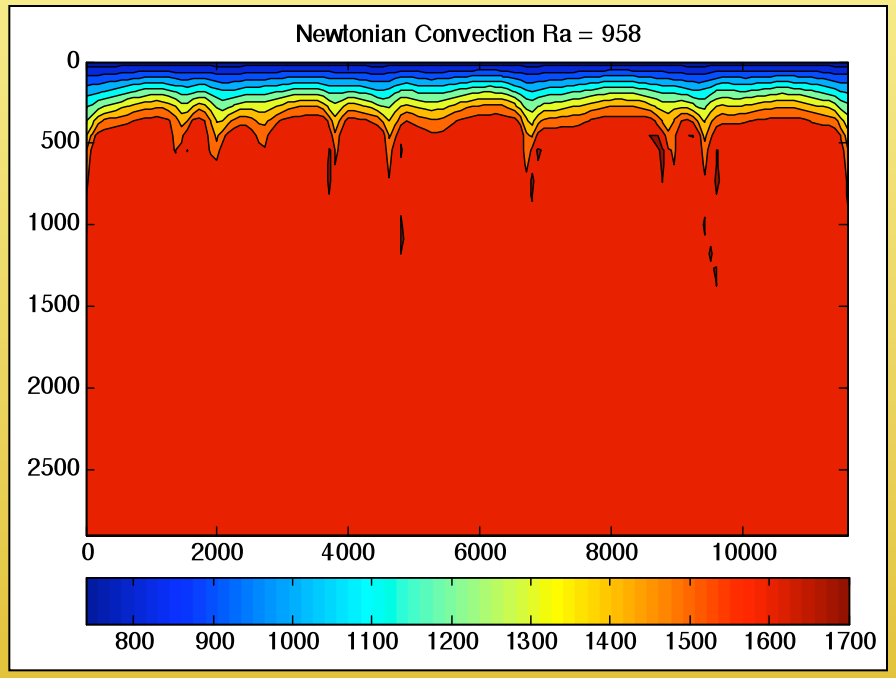




Model Demonstration

- Newtonian viscous CITCOM models (Moresi and Solomatov, *Phys. Fluids*, 1995) by Amy Barr, SwRI.





Heat Flow = 7.4 mW/m^2

Mean Conductive Lid Thickness = 750 km

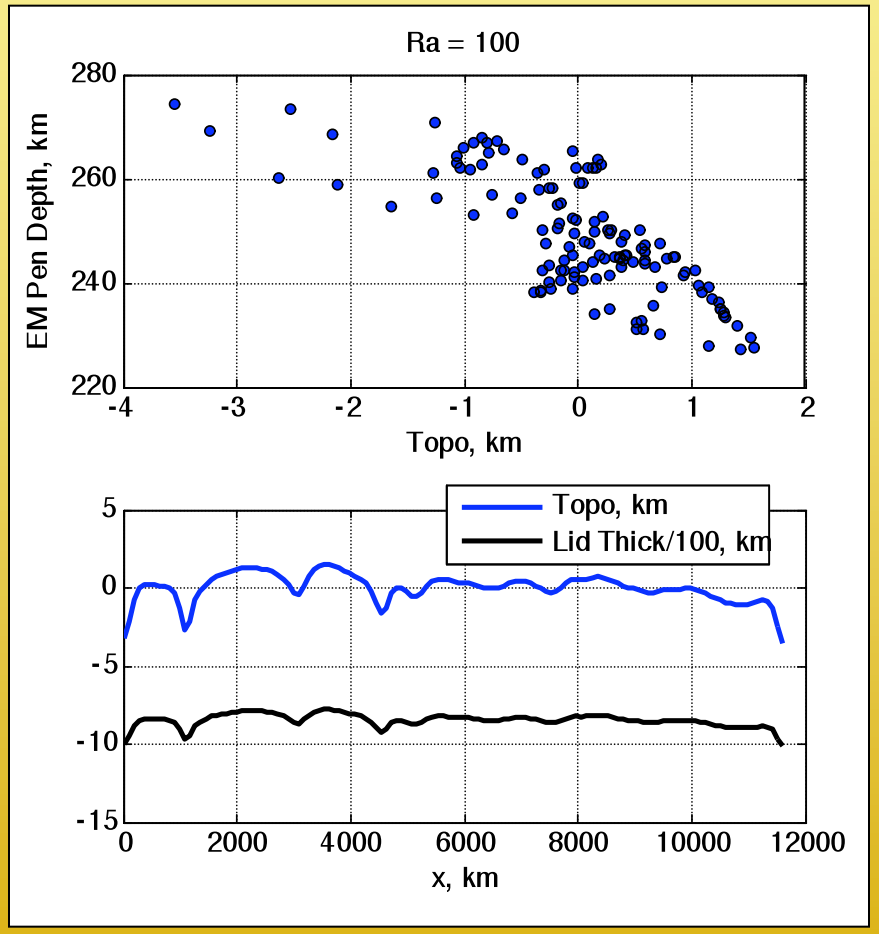
Heat Flow = 13 mW/m^2

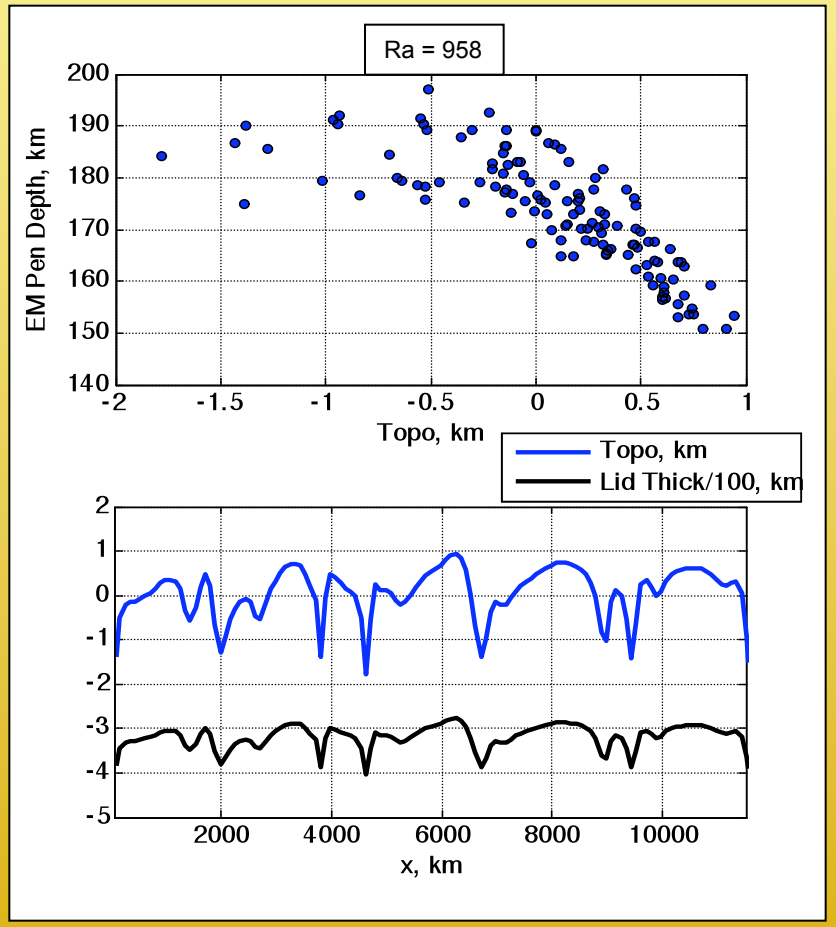
Mean Conductive Lid Thickness = 450 km

- Forward model EM response, convert to depth of penetration.
  - Does not depend on conductivity-temp assumptions as long as penetration depths 10s-100s km.

Model Demo, 2

- Single parameter $\rho/\Delta\rho \approx 50$.





EM-Derived Mean Lid Thickness = 900 km (target 750)

EM-Derived Mean Lid Thickness = 340 km (target 450)

Summary

- EM sounding is an efficient way to probe the interior of Venus from tens to hundreds of kilometers.
  - Deep penetration of global Schumann resonances enabled by paucity of water in lithosphere.
  - Noncontacting electrical measurements, single platform: well-suited to balloon.
- Directly assess lithospheric thickness
  - Enabled by correlation between EM penetration depth and thermal-isostatic topography using global aerial mobility.
- Additional properties of interior derived using laboratory conductivity-temperature data.
  - Crustal thickness, mantle temperature and water content.