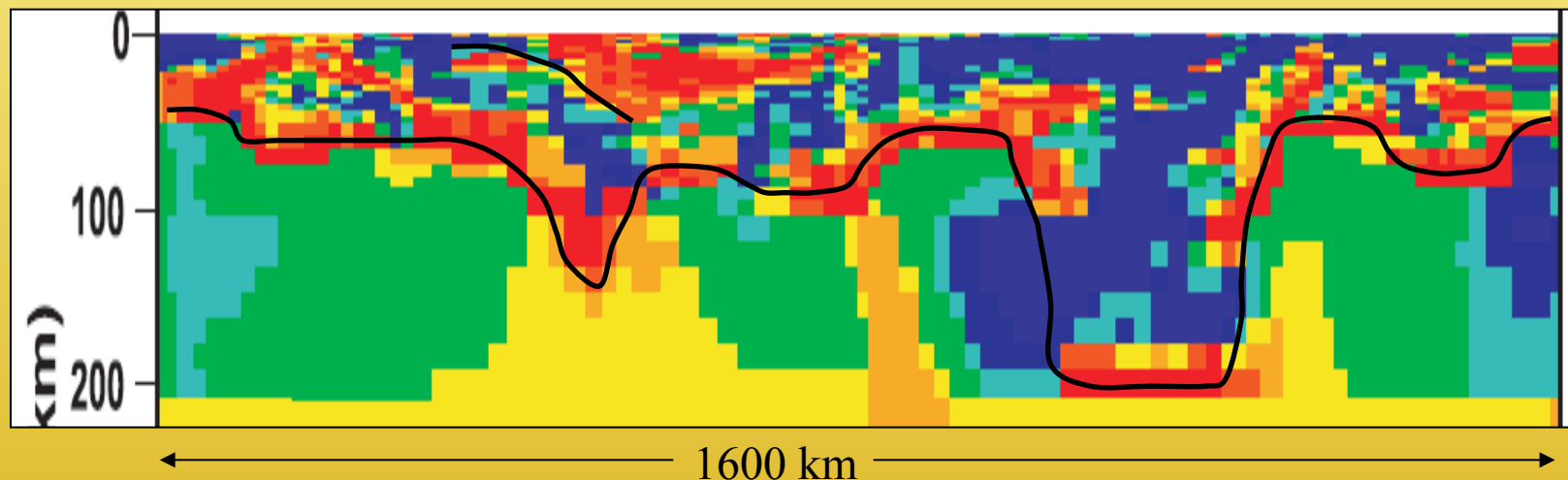


Aerial Electromagnetic Sounding of the Lithosphere of Venus

VEXAG Open Mike 10/28/09

Robert E. Grimm, Southwest Research Institute



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

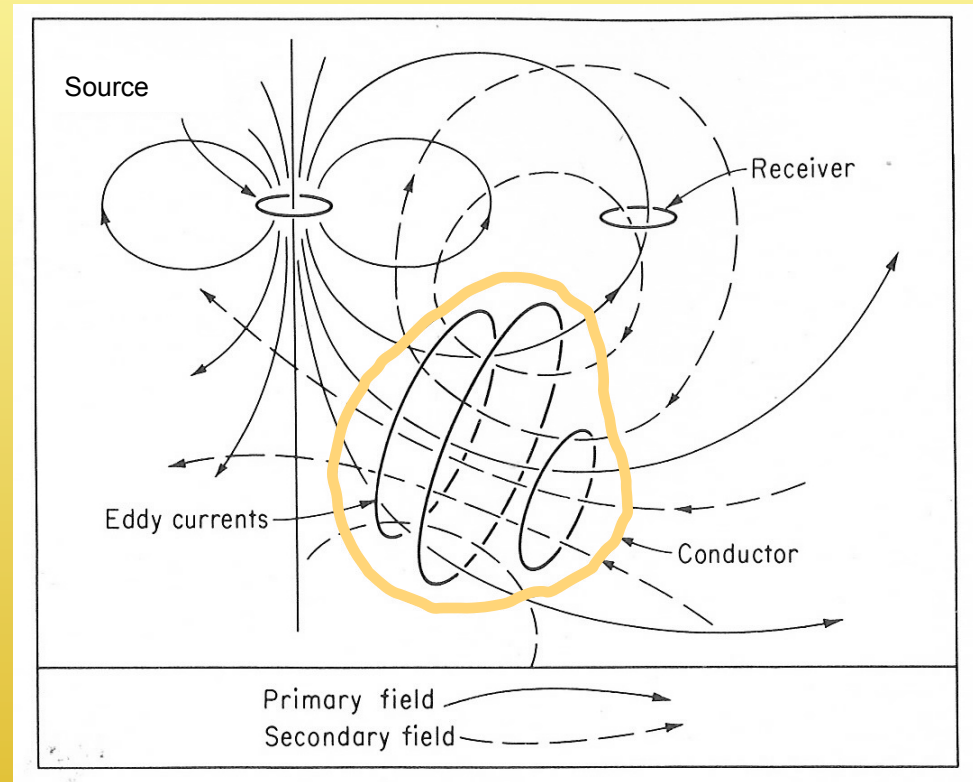
Measure the thickness of the thermal lithosphere

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

EM Sounding

Grant and West, 1968

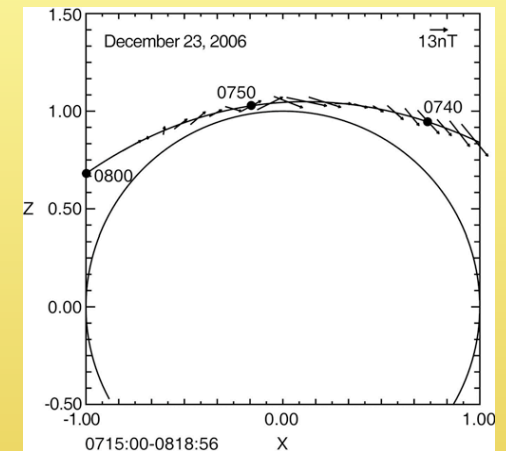
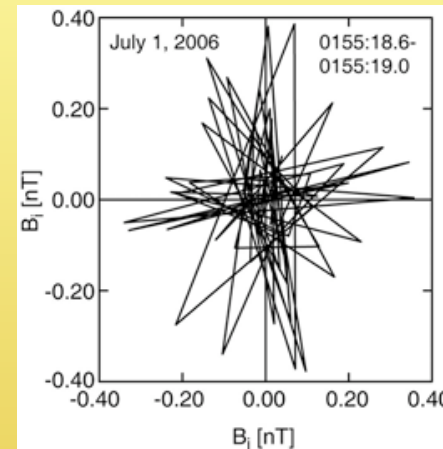
- Determines electrical structure from inductive response to natural or artificial sources.
- **Skin Depth (km) = $0.5 \sqrt{\rho/f} = 0.5 \sqrt{T/\sigma}$**
f = freq, Hz; T = period, s
 ρ = resistivity, $\Omega\text{-m}$; σ = conductivity, S/m



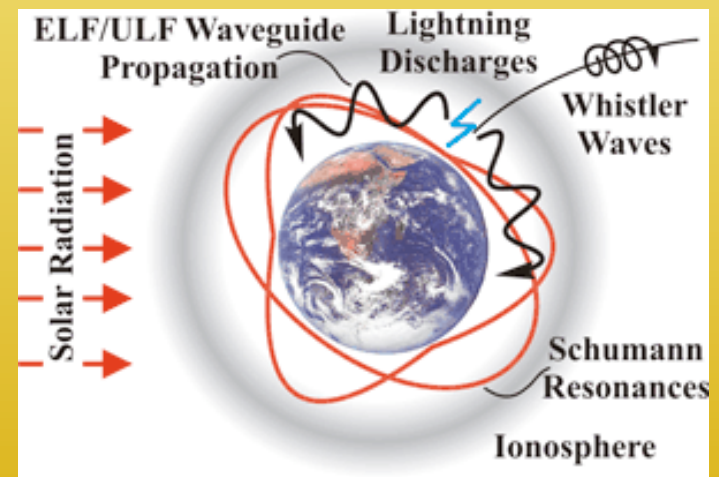
- Very dry (resistive) extraterrestrial lithospheres raise frequency that can penetrate to a specified depth: simplifies measurements and improves SNR.

What is Measured?

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

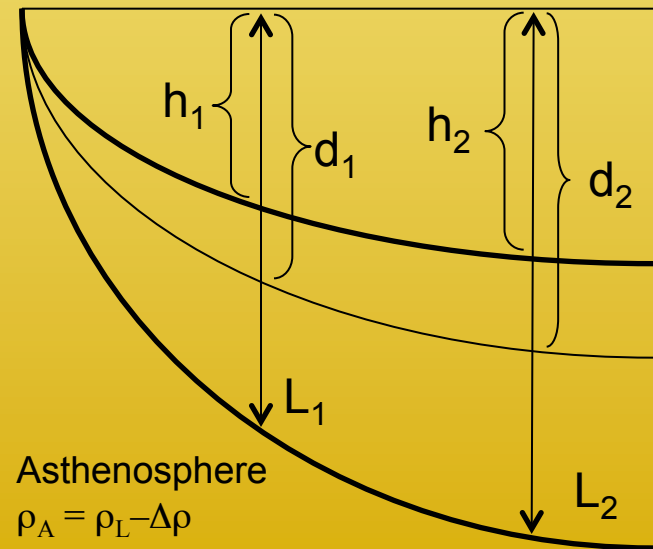
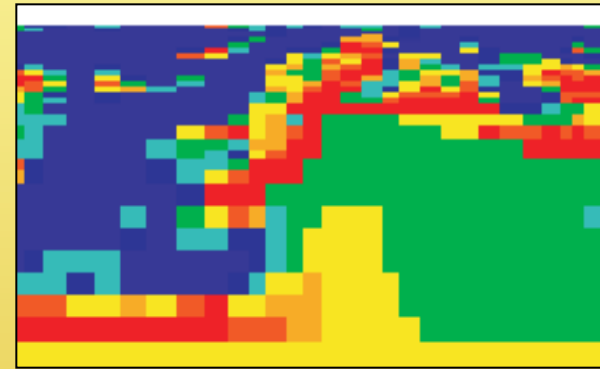


- *Lowest lightning frequencies suitable for lithospheric sounding.*
 - Schumann resonances = global interference patterns, 10-30 Hz.
- *Measure E- and B-fields for complete single-station sounding.*
 - Magnetotelluric and wave-tilt methods.
 - Aerial measurement analogous to terrestrial exploration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



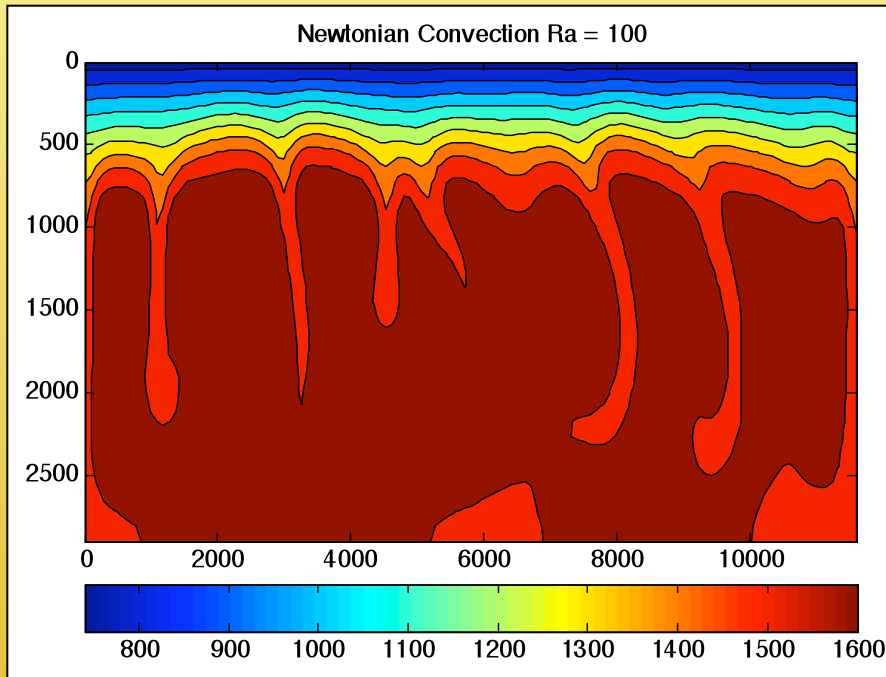
Multiple Measurement Locations

- 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 $T(d) = \text{const}$ and $dT/dz = \text{const}$.
 - $L_2/L_1 = d_2/d_1$
 - 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.

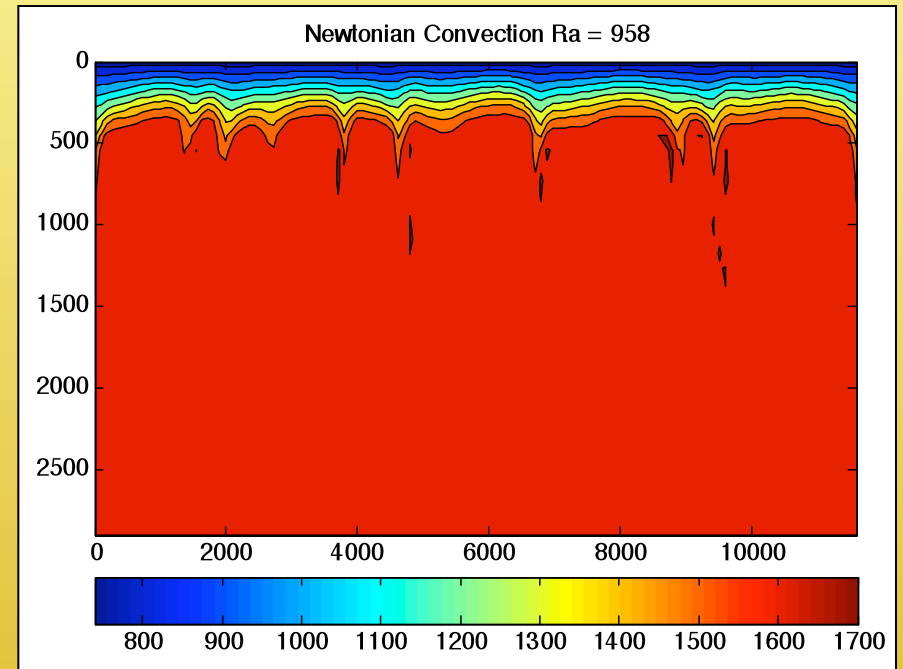


Heat Flow = 7.4 mW/m²

Mean Conductive Lid Thickness = 750 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.

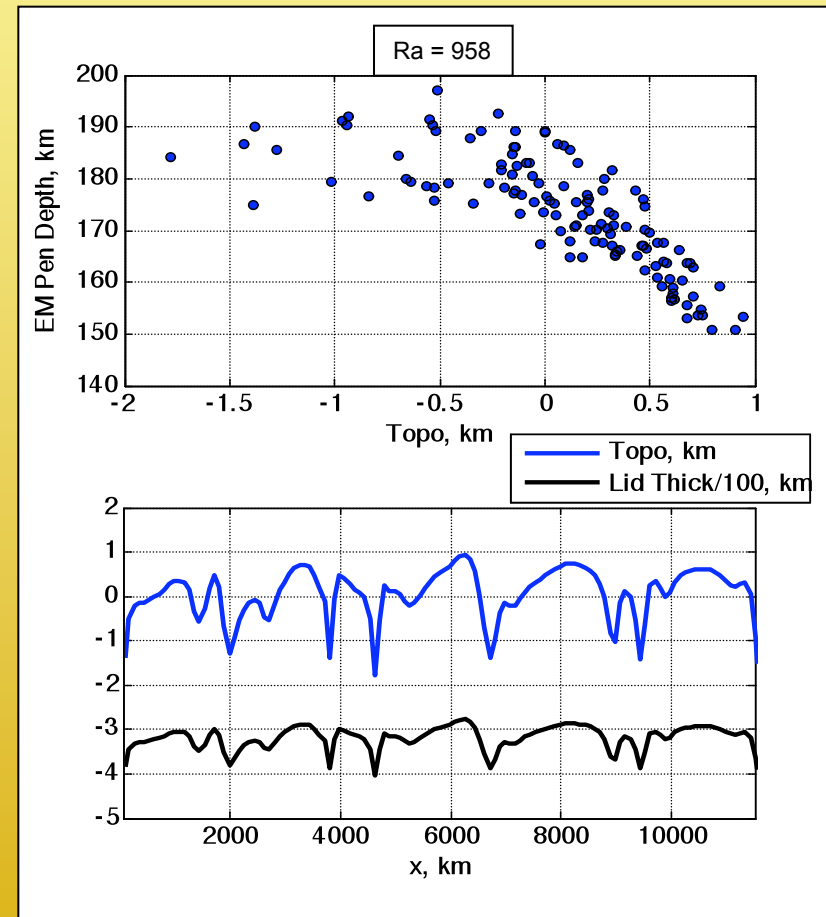
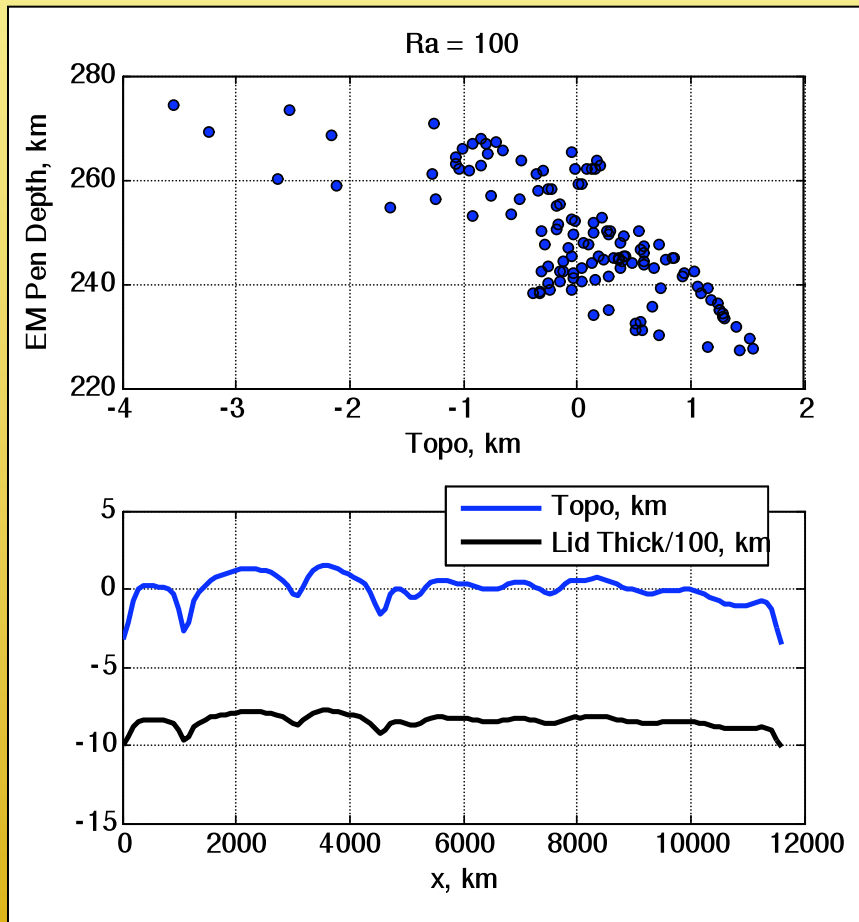


Heat Flow = 13 mW/m²

Mean Conductive Lid Thickness = 450 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.

