Venus' Radar-Bright Highlands: Different Causes At Low- and High-Latitudes

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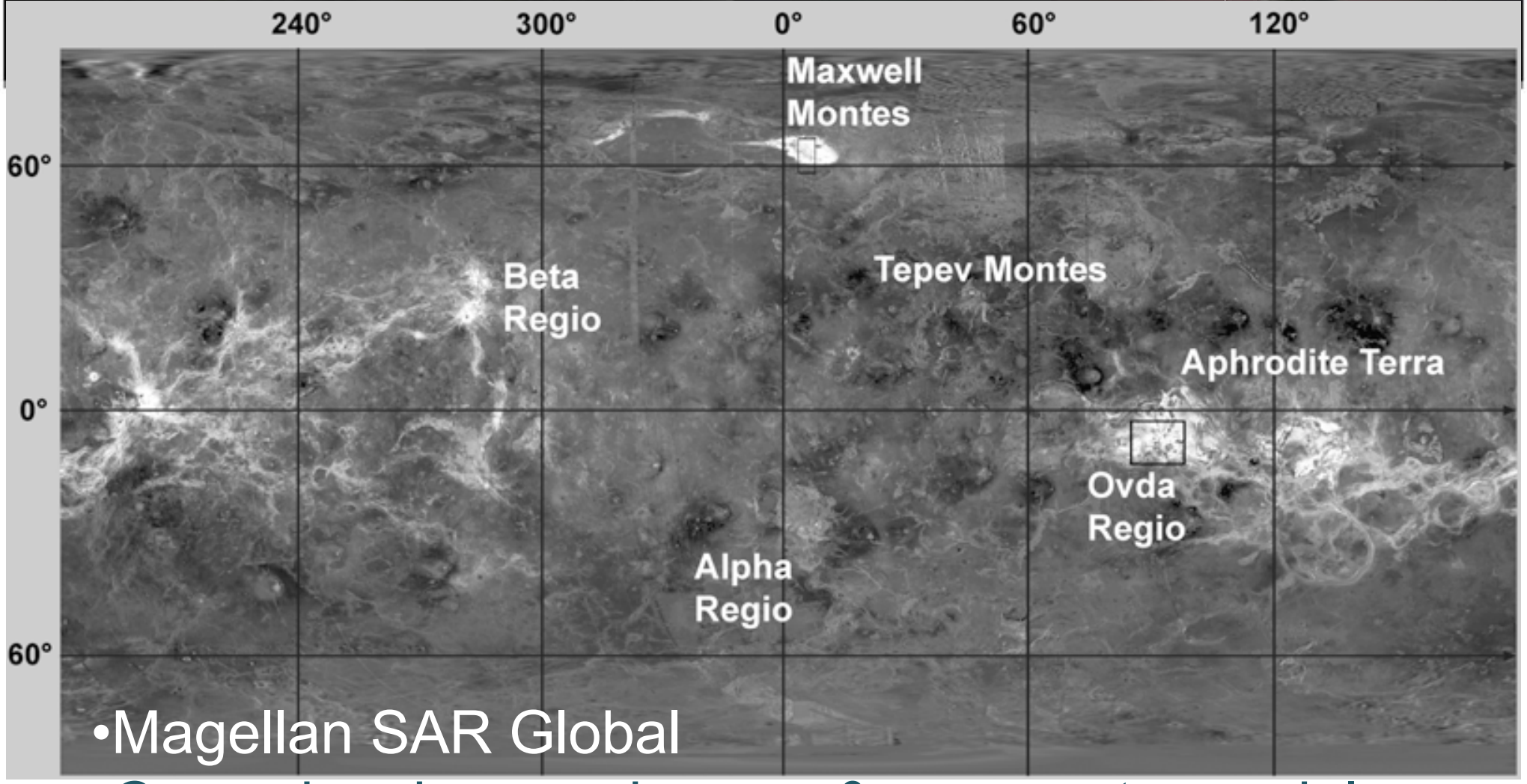
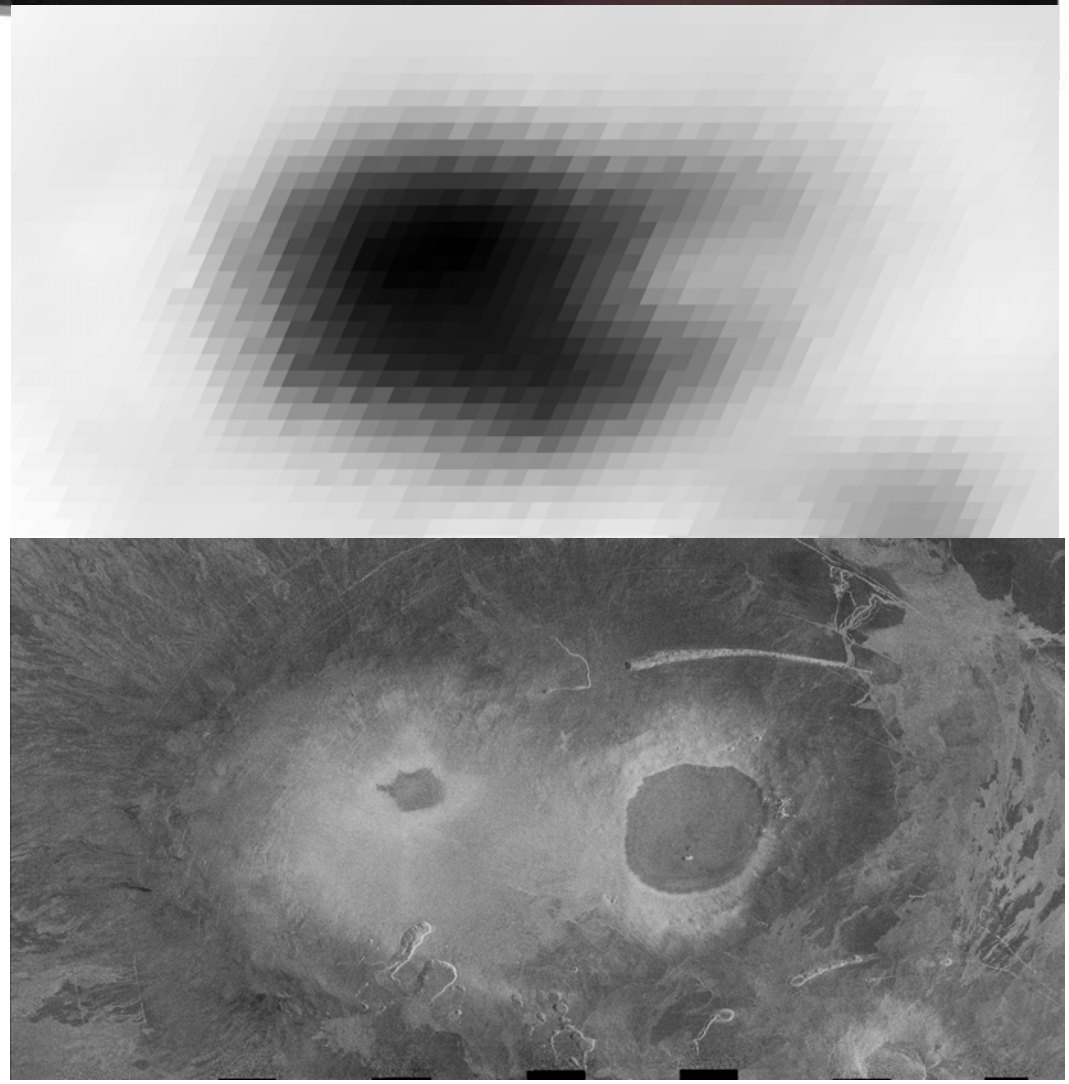
Anomalous High Radar Backscatter in Venus' Highlands



- Magellan SAR Global
- Cause has been unknown, & very controversial.
- Equatorial highlands are different from Maxwell.

What We Did: Elevation & Radar Properties

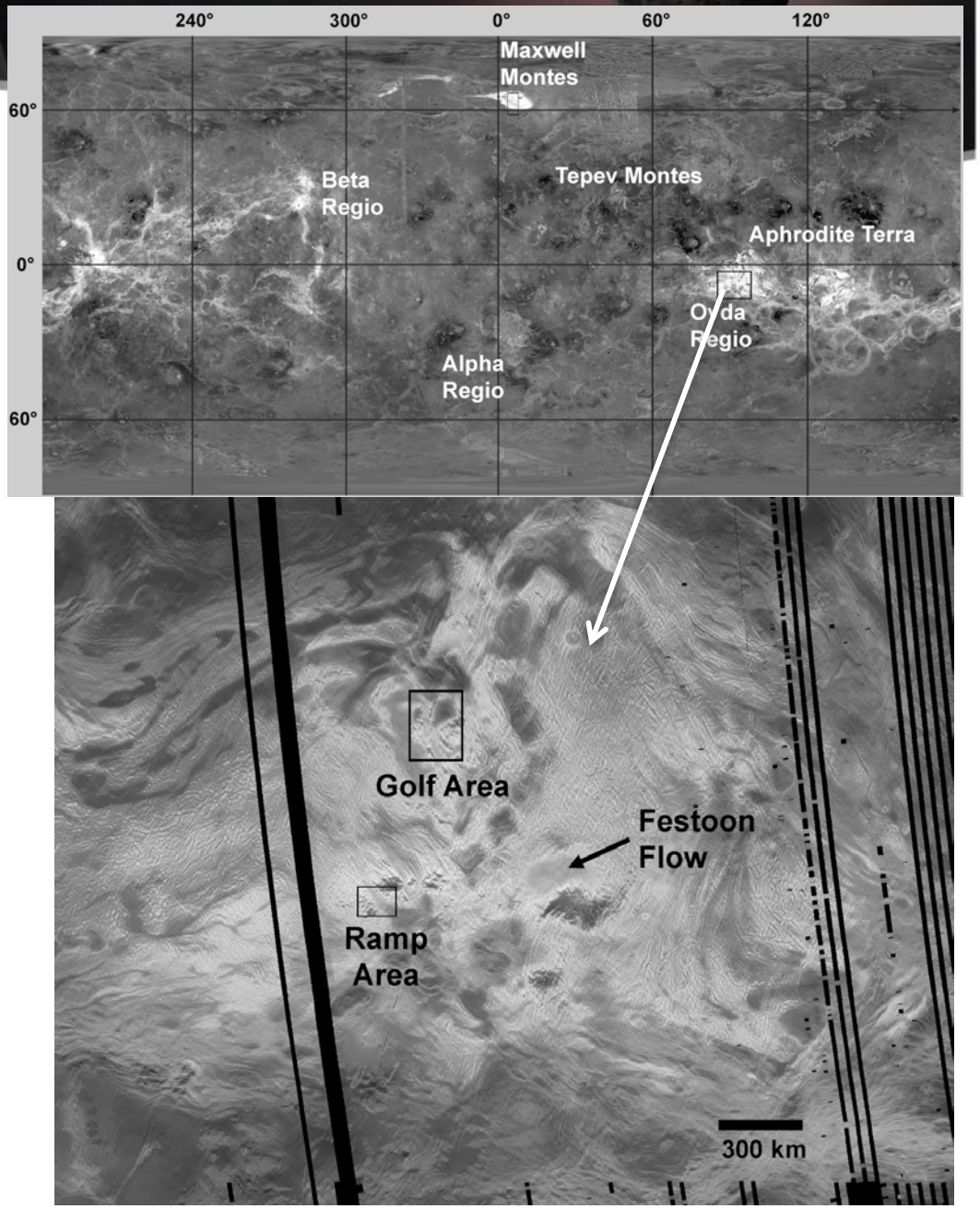
- Earlier work (Klose, 1992; Arvidson, 1994) used Magellan passive emissivity and radar altimetry
  - Pixel size > 10 km
- Higher spatial resolution by using stereoaltimetry and SAR backscatter coefficient.
  - SAR backscatter from FMIDR images, ~75 m/pixel.
  - Stereoaltimetry from Herrick et al. (2012), cycle 1 and cycle 3 left-looking SAR, draped on altimetry. ~1 km/pixel.



Tepev Mons, ~200 Km across

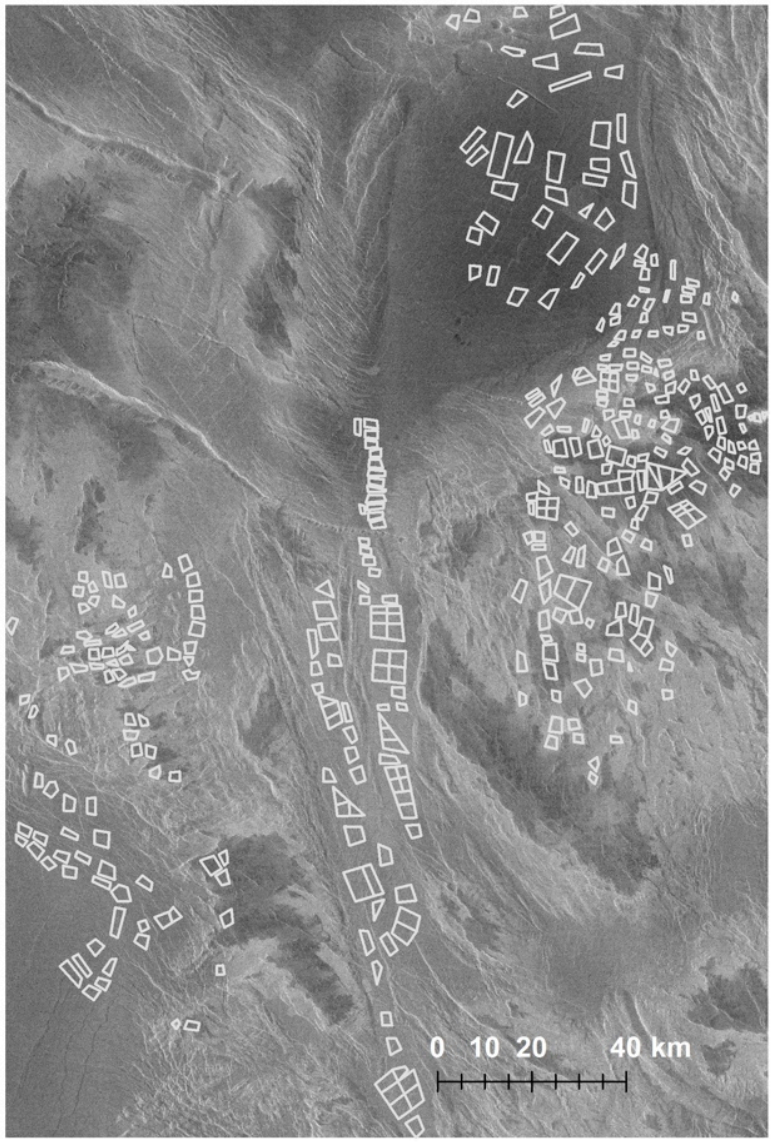
Ovda Regio – Dark Mountaintops

- Gradual increase in SAR backscatter going uphill.
  - Crosses geologic structures
- Sudden change from SAR-bright to SAR-dark at highest elevations
  - Also seen in emissivity
- SAR backscatter also affected by surface roughness



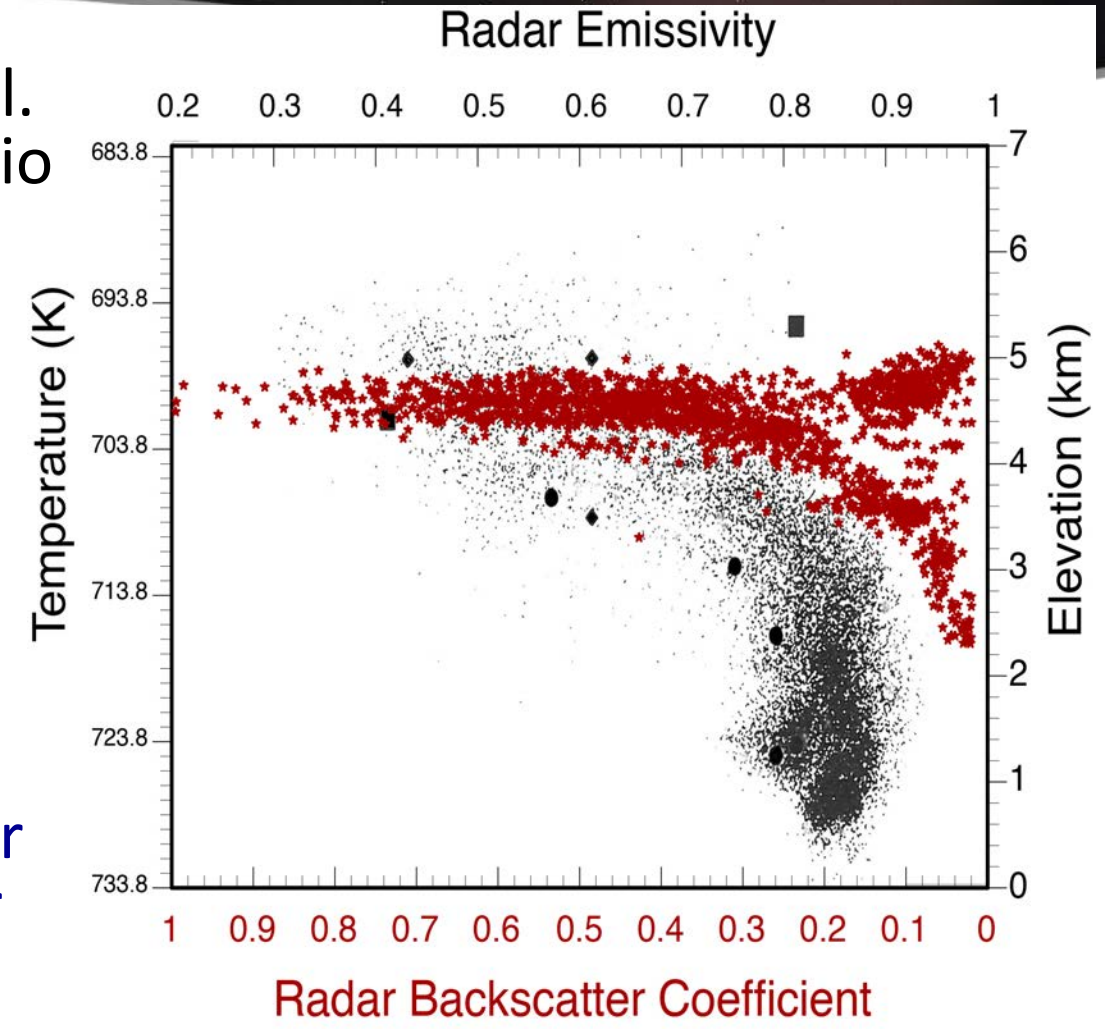
Ovda Regio – ‘Golf’ Area

- Deep hole (top right) to heights (mid–right & left).
- Polygons selected for constant elevation and SAR backscatter.
- Roughness elements avoided.



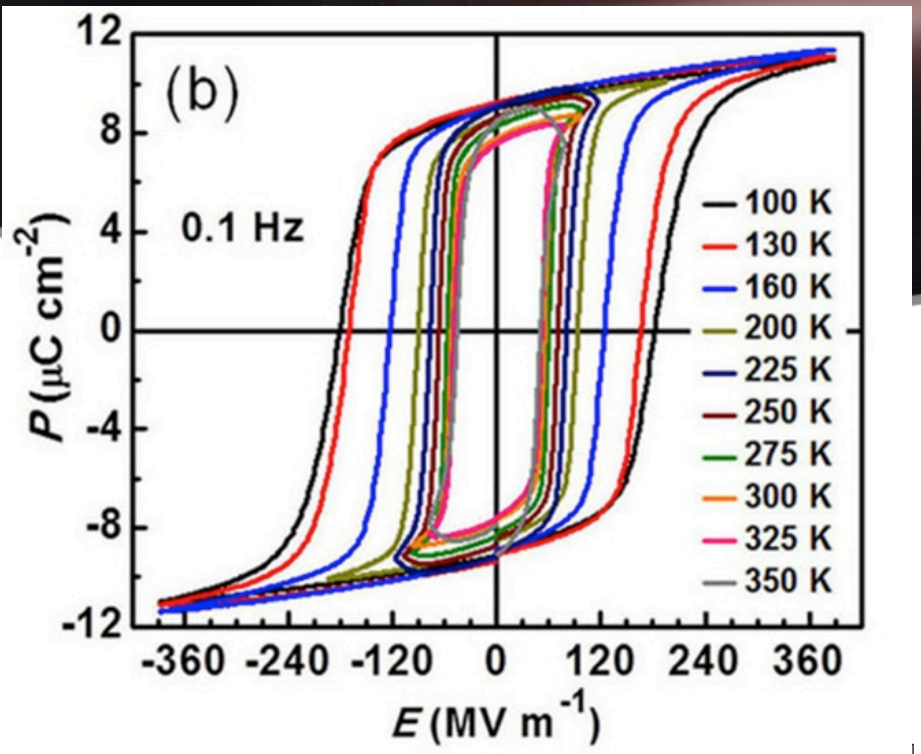
Ovda Regio – Radar & Elevation

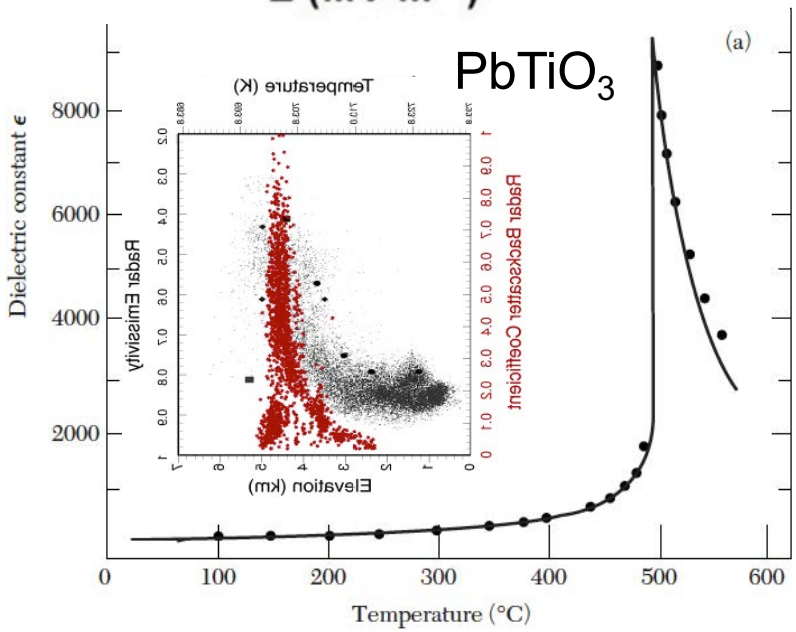
- Earlier work (Arvidson et al. 1994), for whole Ovda Regio at ~10 km/px
  - Magellan altimetry
  - Magellan emissivity
- Our work, small areas, at high spatial resolution (~1 km/px)
  - Magellan SAR-stereo DEM
  - Magellan SAR backscatter
- VERY sharp change in radar properties (permittivity, or dielectric constant) at ~700 K (~4.6 km elevation)



Why such weird radar response?

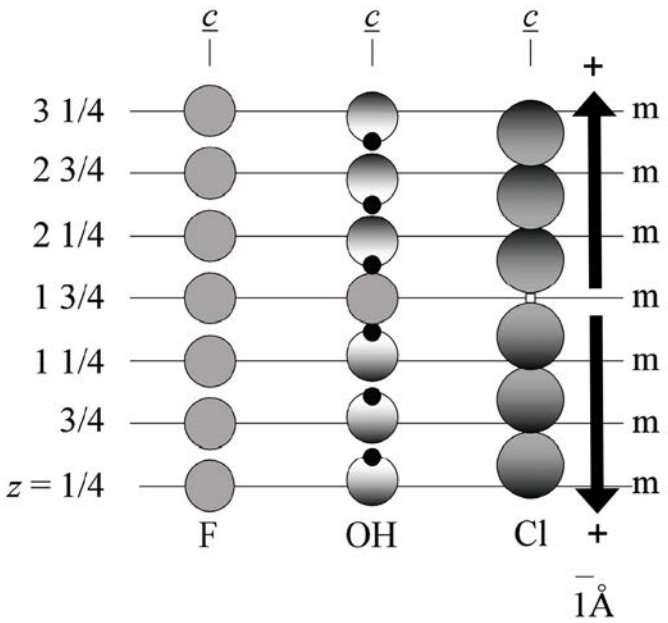
- This pattern is consistent with a **ferro-electric** substance (Arvidson et al. 1994; Shepard et al. 1994).
  - Have a persistent electrical dipole that can be reversed with an applied electric field.
  - Above a critical temperature, the dipole vanishes
  - Just below the critical temperature, the dielectric constant appears huge
- **Nearly all known ferroelectrics do not occur in nature**, and would require unusual geochemistry
  - $Pb(Ba,Sr)TiO_3$ (a perovskite)
  - $Pb_2Bi(Ta,Nb)O_6$ (a pyrochlore)
  - $Na(Nb,Ta)O_3$ (a perovskite)



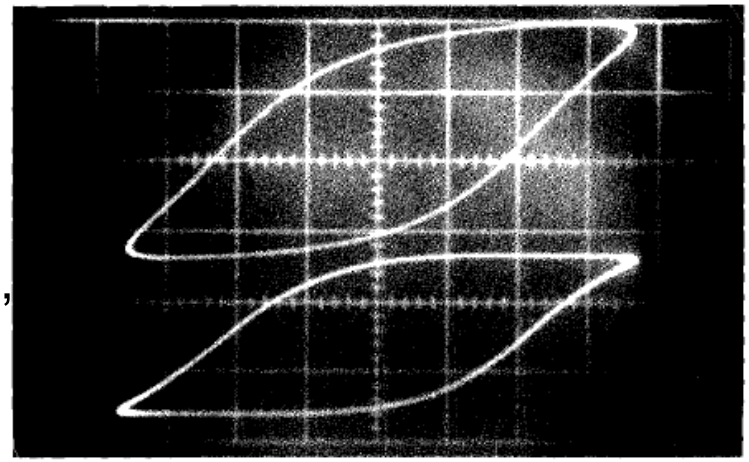


EXCEPT -- Chlorapatite !

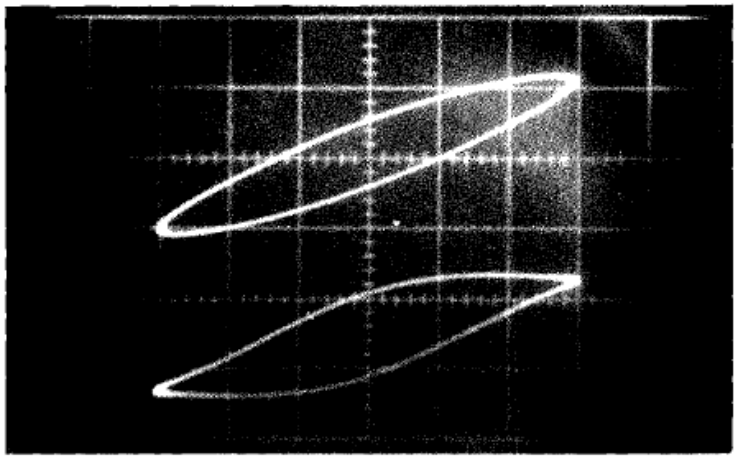
- **<u>Only</u> ferro-electric rock-forming mineral (that we have discovered)**.
- Cl atoms are offset from symmetry (mirror) planes in apatite structure; they are too big.
- Offsets give domains of persistent electrical dipoles.



298 K (Rausch, 1976)



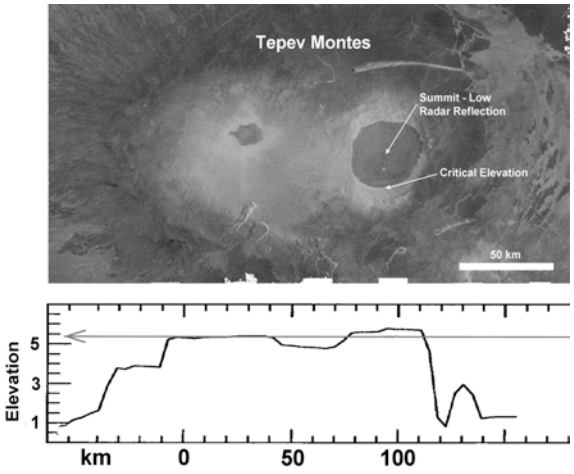
373 K



Ferroelectric to at least 675 K; transition estimated at 675 – 775 K, maybe 695±4 K.

Is Chlorapatite Reasonable?

- By analogy with Earth, Venus basalts likely contain enough phosphorus produce a few % apatite, which is sufficient.
- Igneous apatite (on Earth) is primarily fluor-apatite. If so on Venus, then Cl-apatite could form by reaction with atmosphere.
  - Perhaps why some tall volcanoes do not show the ferro-electric radar signature.
- Need high-temperature electrical data!!

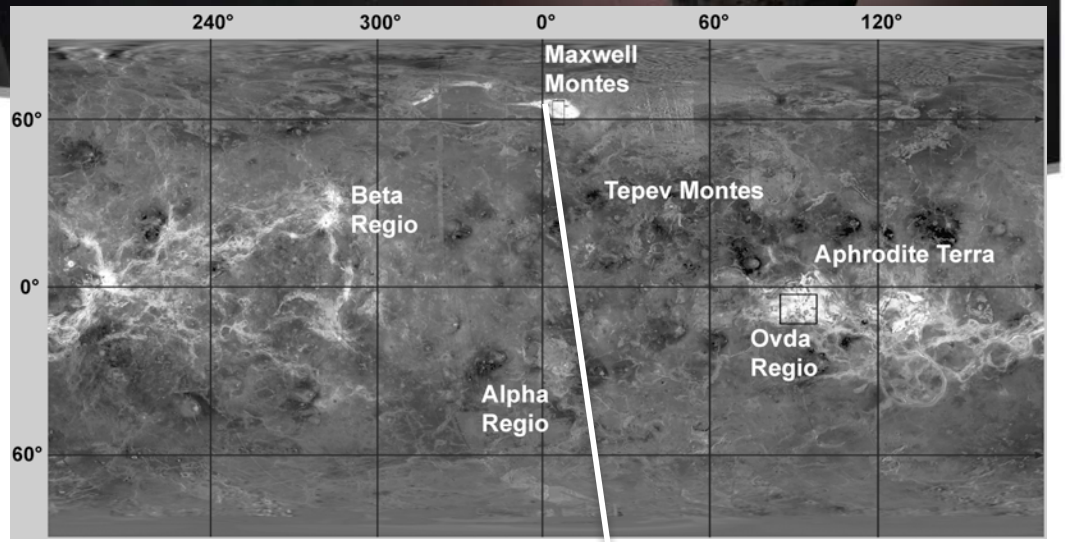


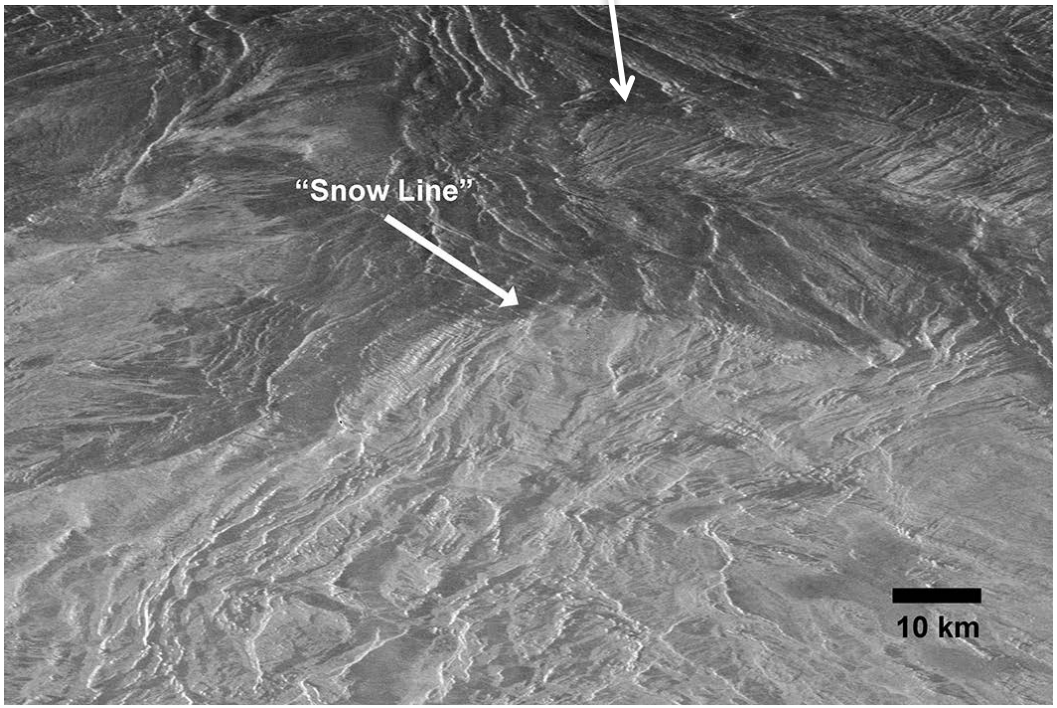
Tepev Mons
5 km tall

Maat Mons
8 km tall

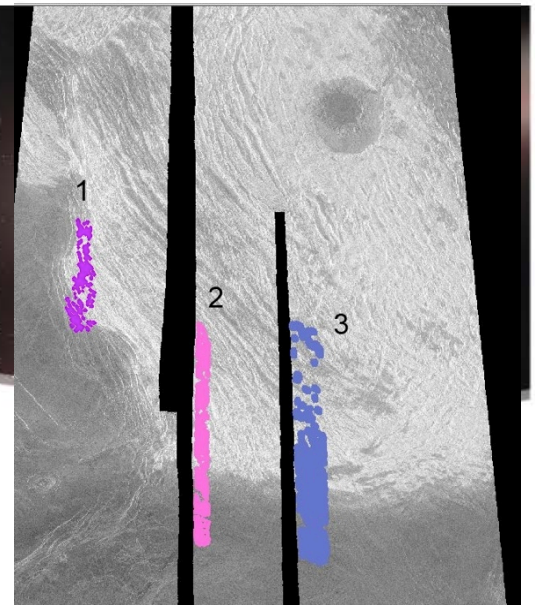
Maxwell Montes – 'Snow' Line

- Sharp increase in SAR backscatter going uphill – "snow line.'
  - Crosses geologic structures
  - SAR backscatter also affected by surface roughness
- Atmosphere deposit or T-dependent weathering product?

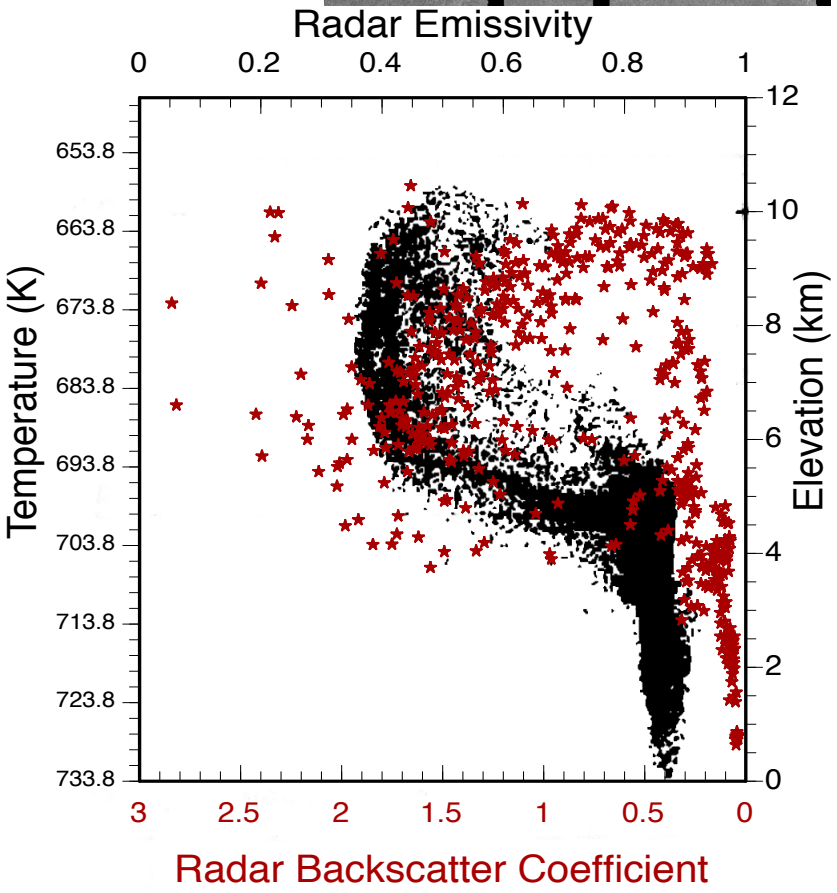




Maxwell Montes – ‘Snow’ Line

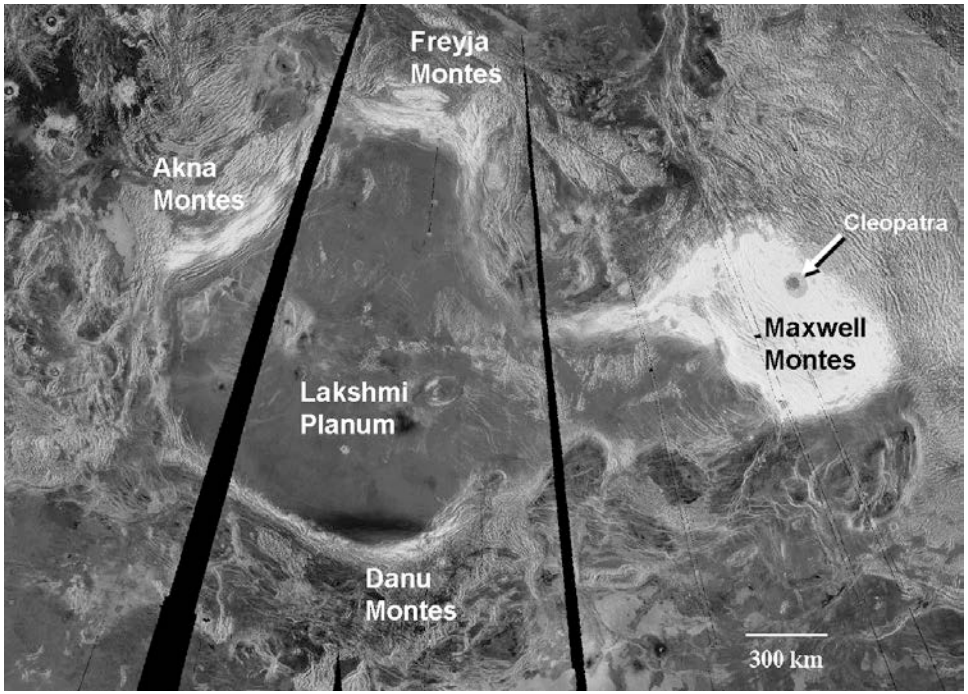


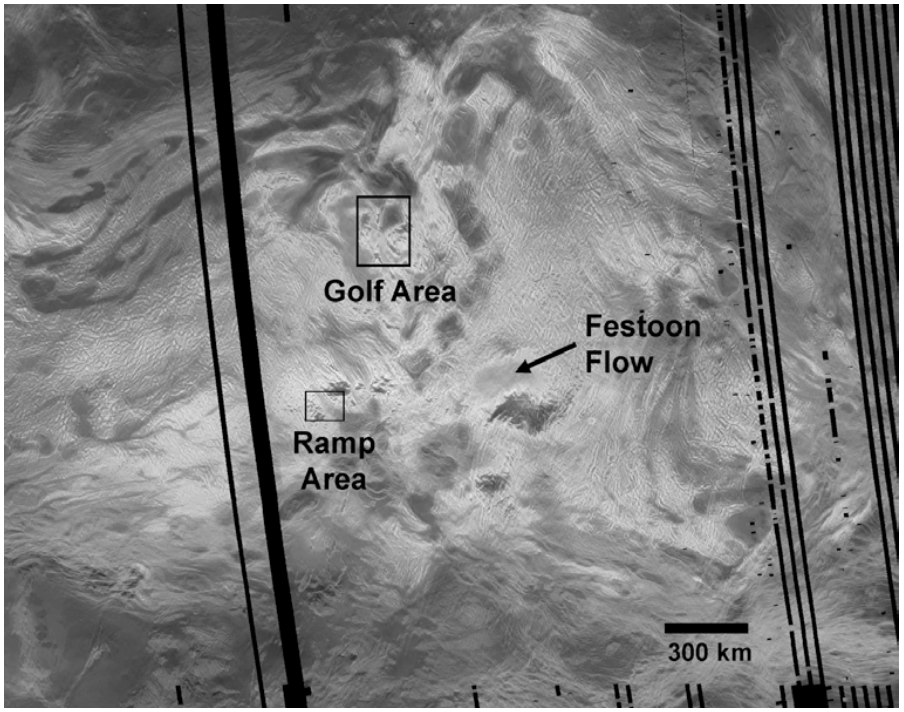
- ‘Snow Line’ fairly sharp in SAR, but many areas of lower SAR backscatter at high elevations.
  - Slope dependence?
- Generally similar to Magellan emissivity & altimetry
- Decrease in SAR backscatter at highest elevations is real (see image), but barely apparent in emissivity.
- Low values for SAR backscatter may be inconsistent with simple elevation-dependent ‘snow-line.’
  - Problems with stereo-DEM!



Conclusions – High SAR Backscatter

- Equatorial highlands – pattern is consistent with a **ferroelectric** (chlorapatite) – time dependent production.
- Maxwell is more-or-less consistent with surface-atmosphere reaction product - **not a ferroelectric**.
- *Unknown why Maxwell and equatorial highlands are different.*





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