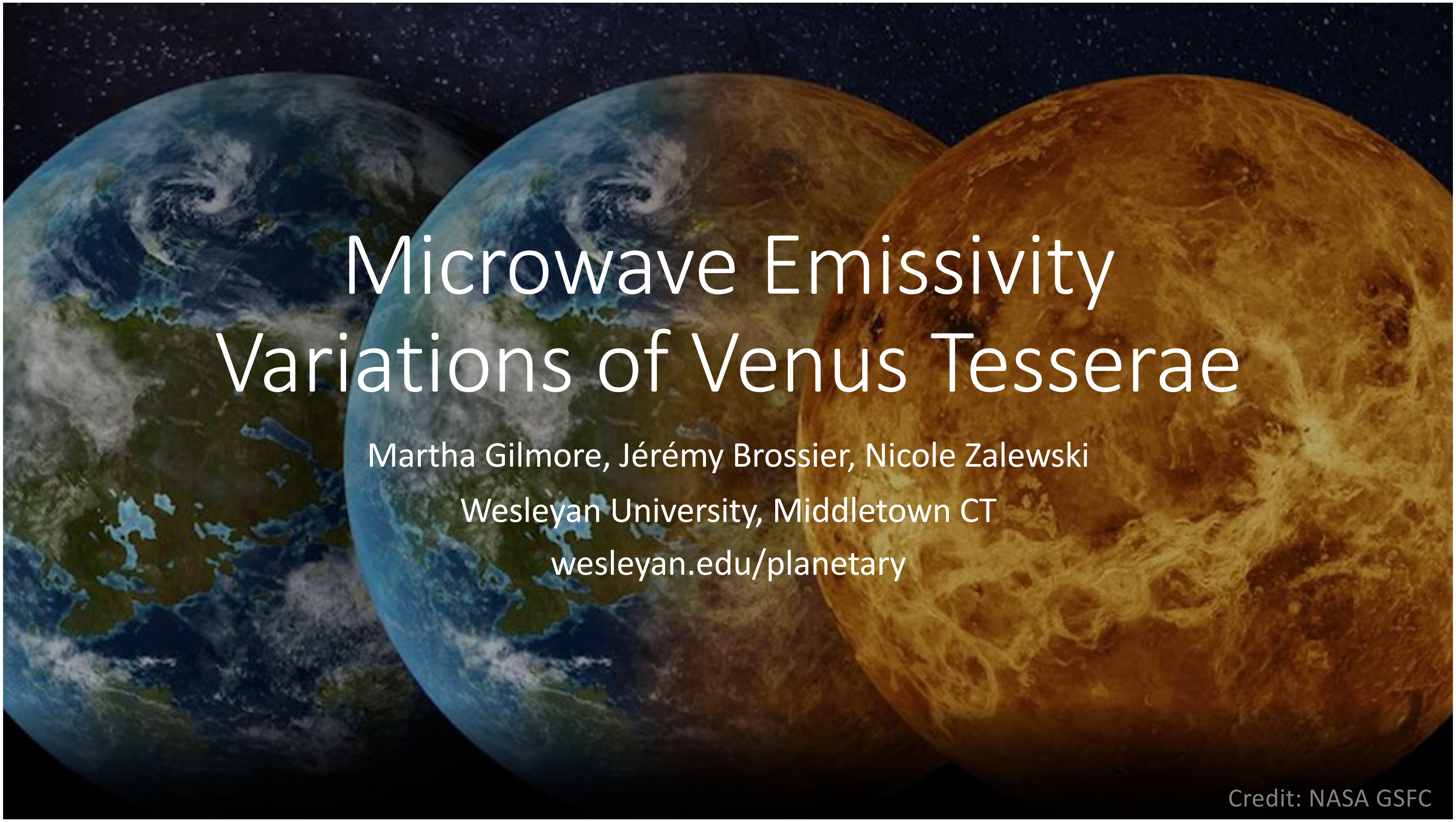
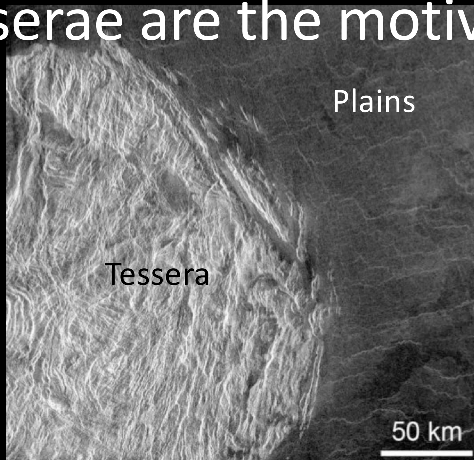


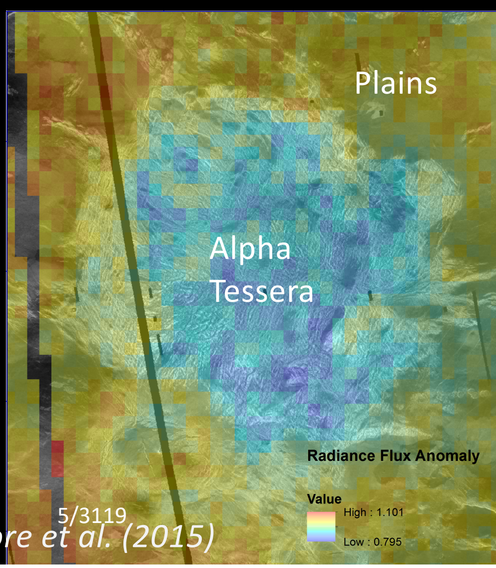
Microwave Emissivity Variations of Venus Tesserae

Martha Gilmore, Jérémy Brossier, Nicole Zalewski
Wesleyan University, Middletown CT
wesleyan.edu/planetary

Credit: NASA GSFC

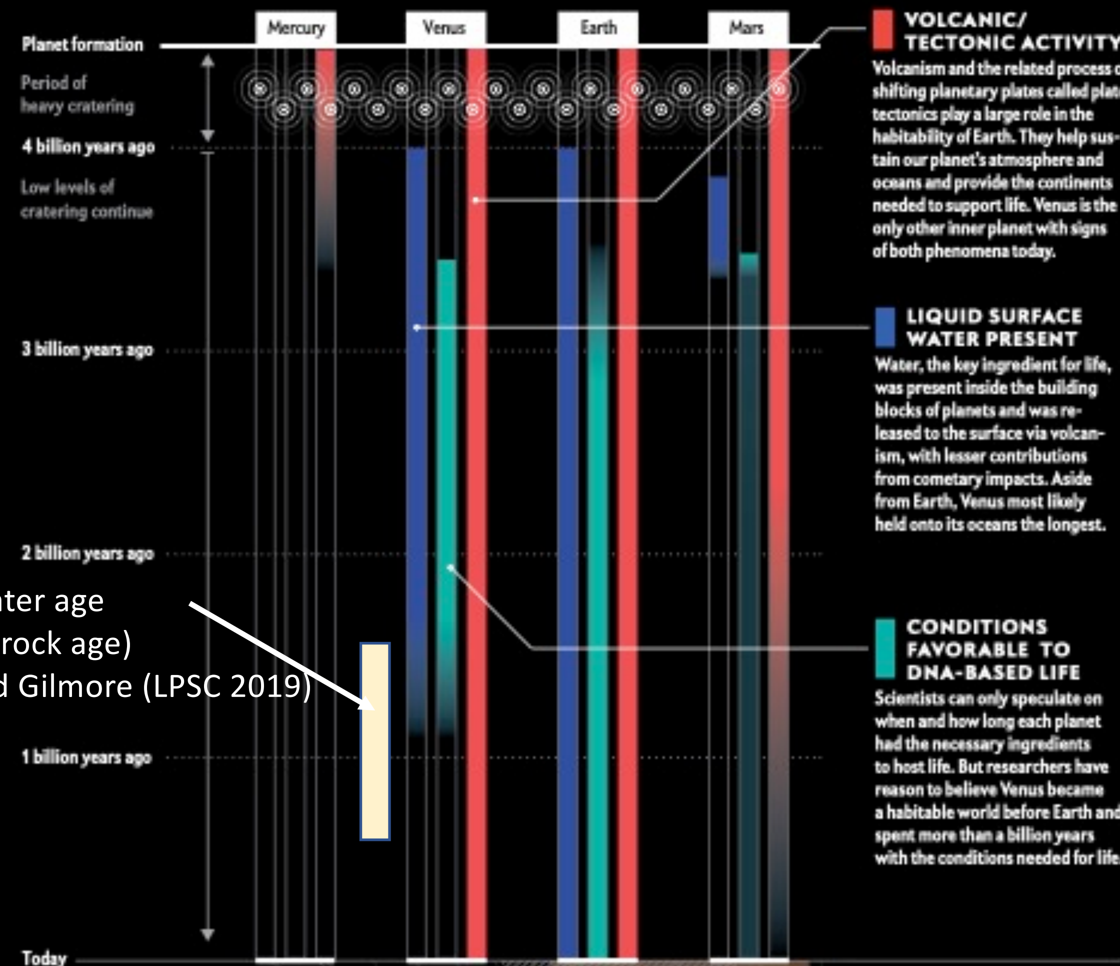
Tesserae are the motivation





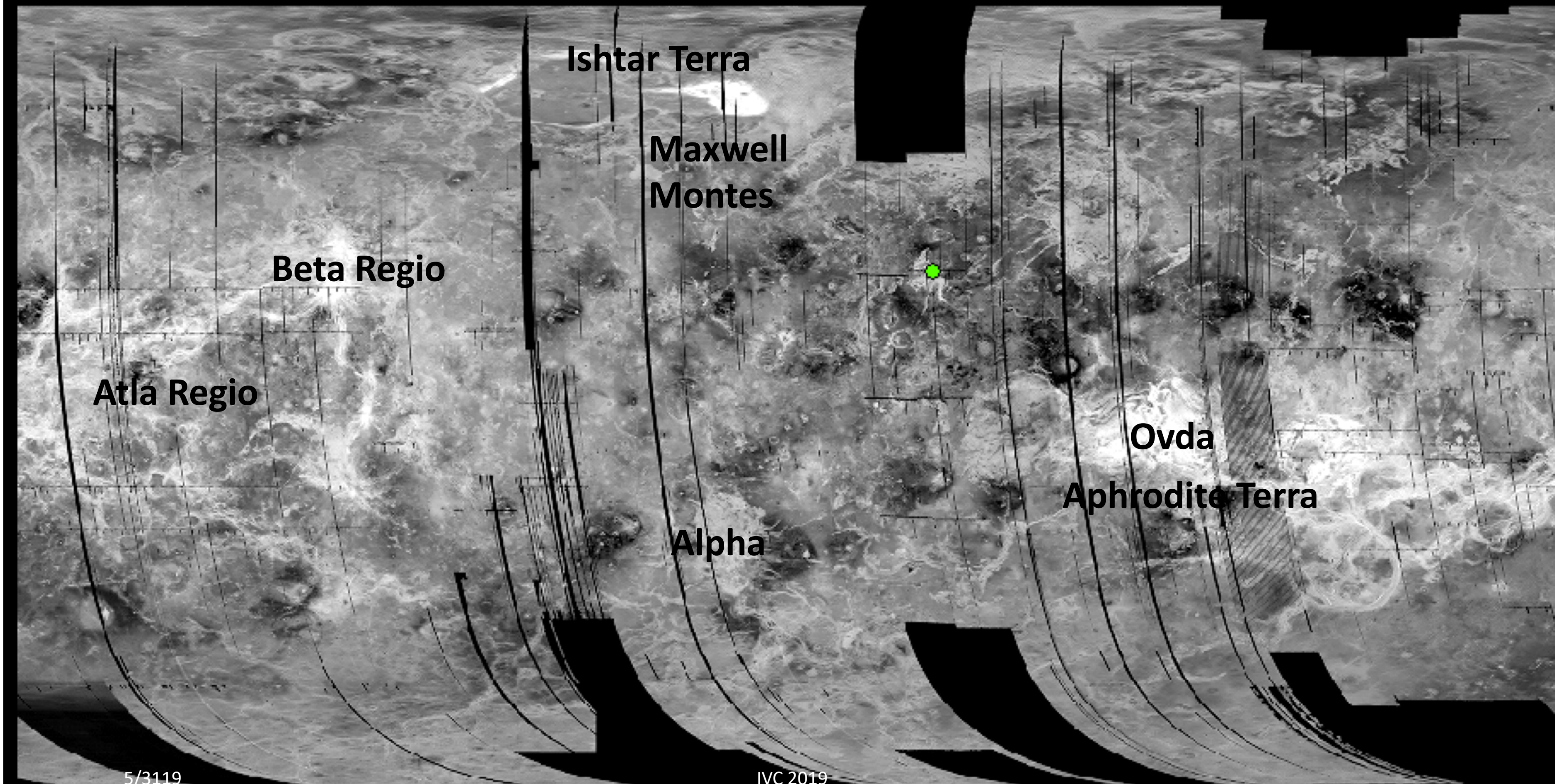
Gilmore et al. (2015)

Tessera Crater age
(minimum rock age)
Perkins and Gilmore (LPSC 2019)

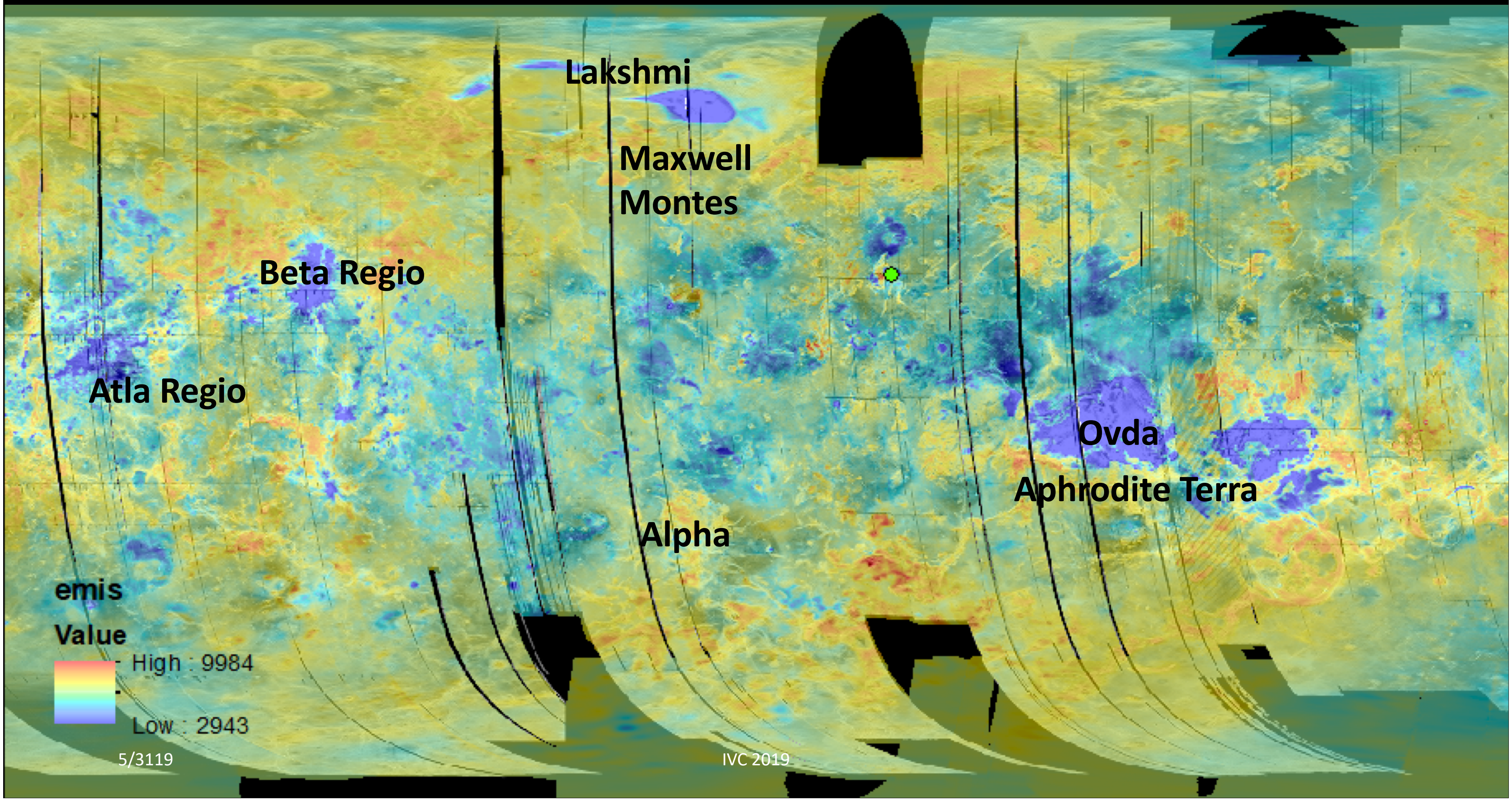


Graphic by Tiffany Farrant-Gonzalez, Dyar et al. Sci. Am. Feb 2019

Magellan Synthetic Aperture Radar (SAR), 12.6 cm, 2.385 GHz, 75 m/pixel | f (incidence angle, roughness, electrical properties)

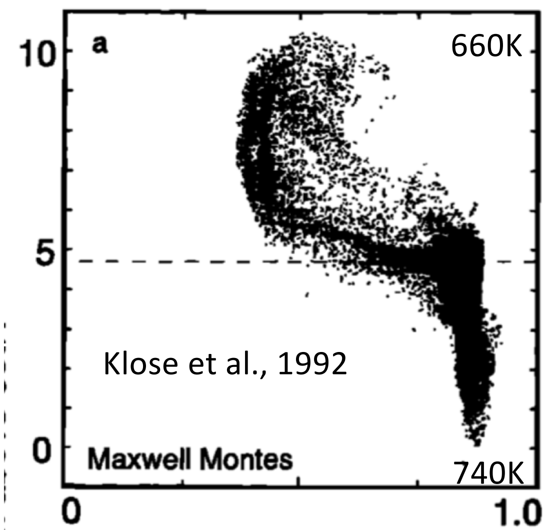


Magellan Microwave Derived Emissivity (from passive radiometer) ~4.5 km/pixel | f (T) which is f (altitude)

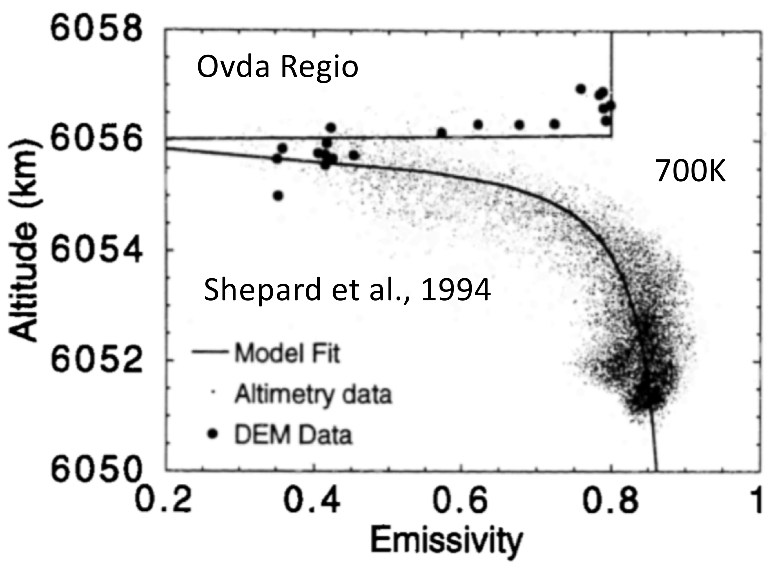


Most everyone agrees: Something on the mountaintops has a higher dielectric constant than the lowlands (*Pettengill et al., 1988 and subsequent papers*). But what?
Can we use this difference to say something about the composition of the rocks? The atmosphere? (ala *Treiman et al., 2016*)

Lots of work by lots of people → two primary models based on emissivity data

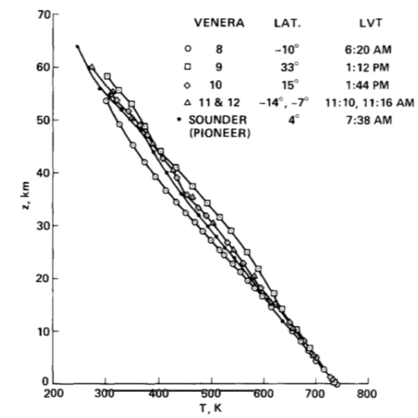


Change with altitude then steady (Semiconductor)



Sharp drop and then return with altitude (Ferroelectric)

A. Seiff *et al.* 1985

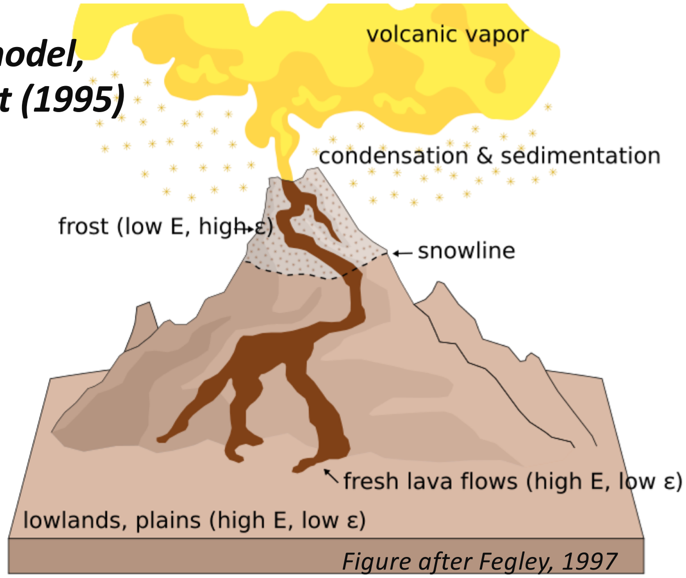


ure 1-1. Temperature Data Transmitted by the Descent Capsules of Venera 8 Through 12 and the Pioneer Venus Sounder Probe

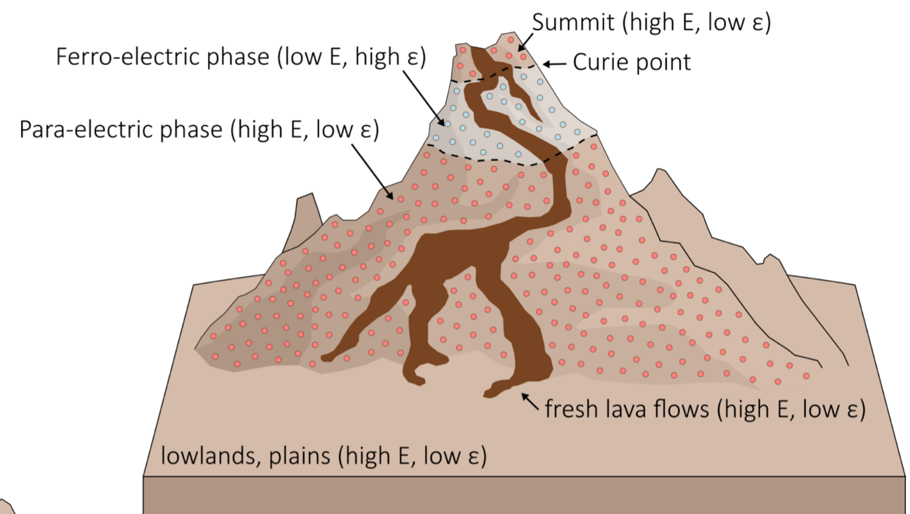
All depends on Seiff!

Temp/altitude of change = f(composition)
Magnitude of change= f(volume of high dielectric)

Frost model, Brackett (1995)



Ferroelectric model (e.g., Shepard, 1994)

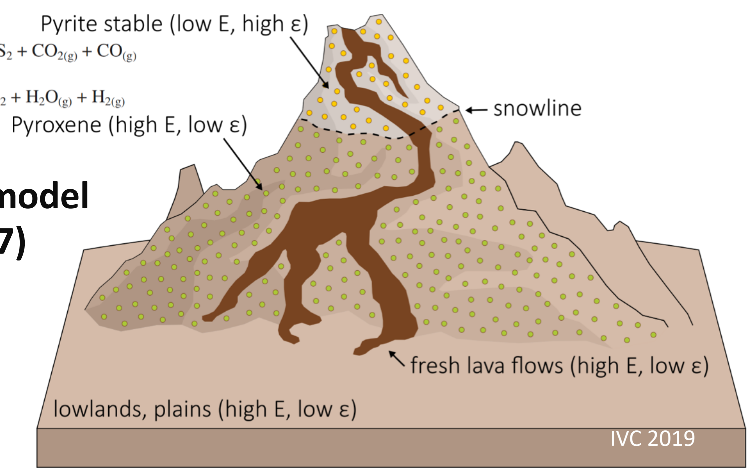


FeO (in minerals) + $2COS_{(g)} \rightarrow FeS_2 + CO_{2(g)} + CO_{(g)}$

FeO (in minerals) + $2H_2S_{(g)} \rightarrow FeS_2 + H_2O_{(g)} + H_{2(g)}$

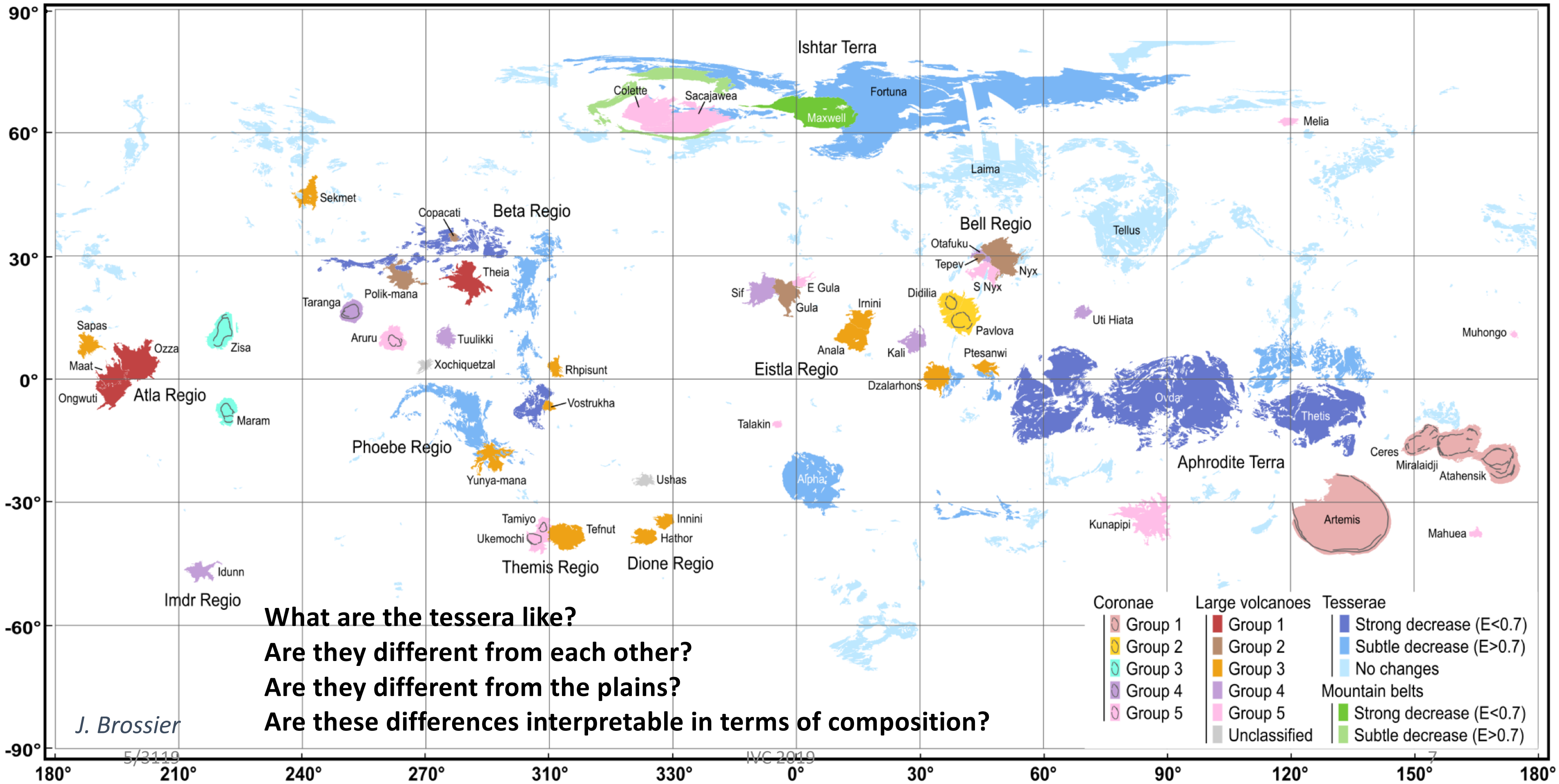
Zolotov 2018

Semiconductor model (e.g., Fegley 1997)

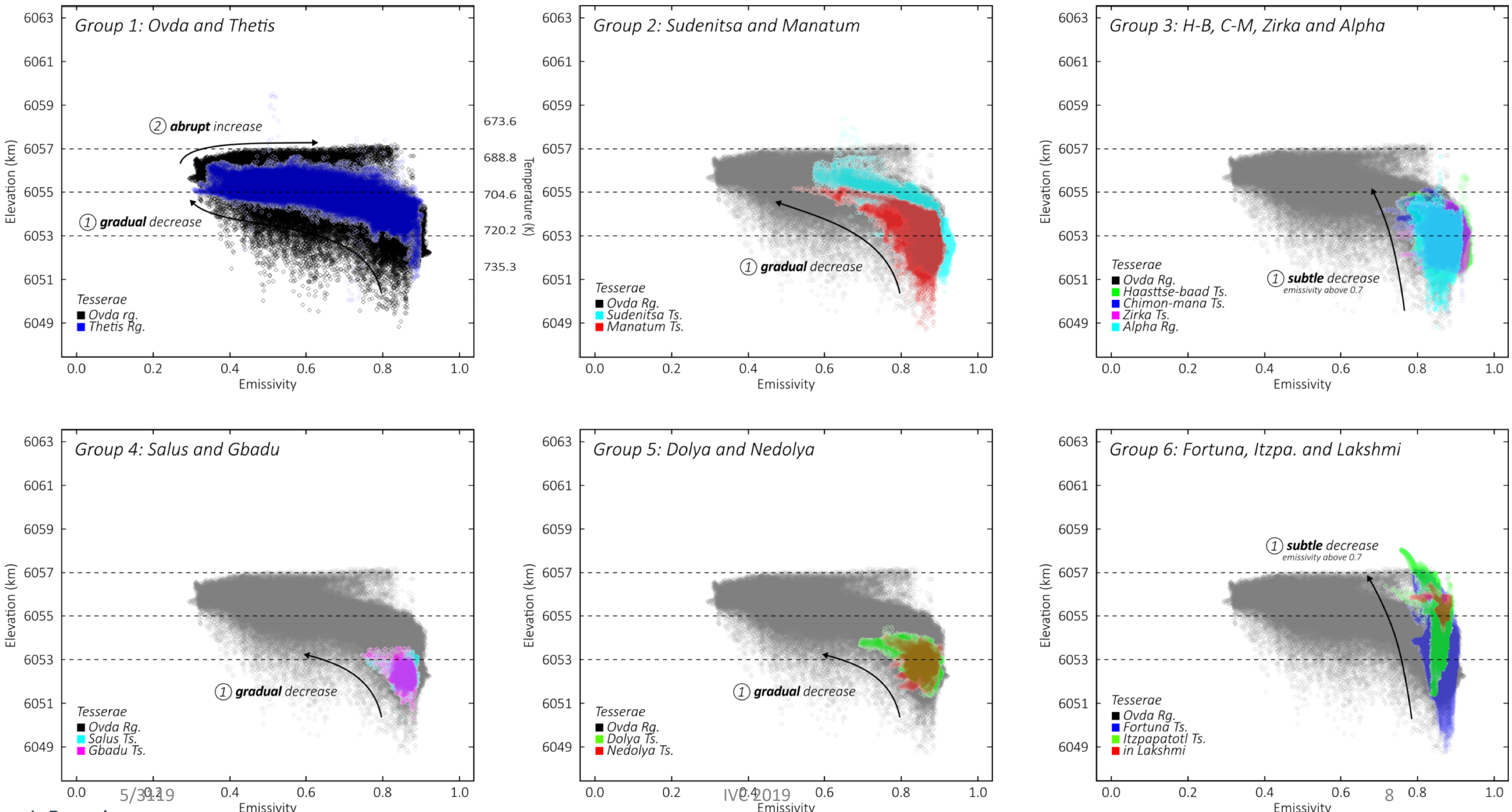


J. Brossier

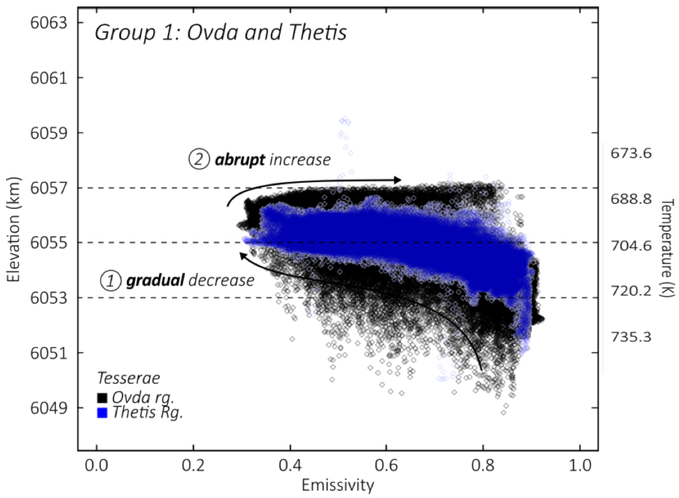
Gilmore group: Look at the radar emissivity of everything tall(ish) on Venus. See Brossier et al poster this conf

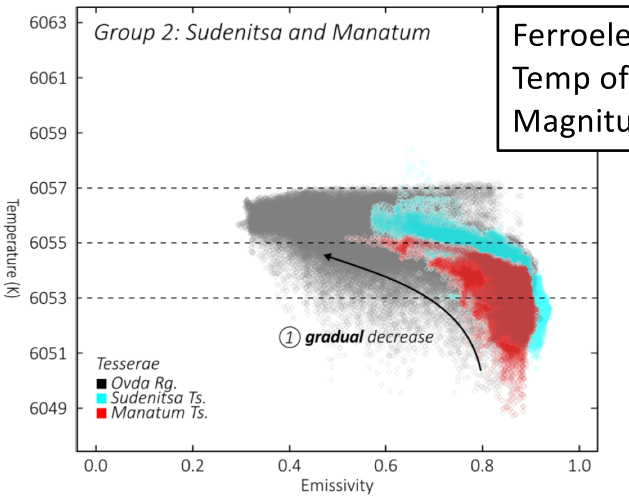


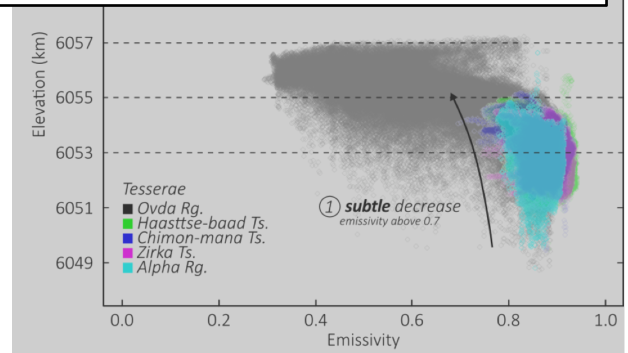
What are the tessera like?
Are they different from each other?
Are they different from the plains?
Are these differences interpretable in terms of composition?


Group 1: Ovda and Thetis
2 abrupt increase
1 gradual decrease
Tesserae
Ovda rg.
Thetis Rg.
Elevation (km)
Emissivity
Temperature (K)
673.6
688.8
704.6
720.2
735.3
Group 2: Sudenitsa and Manatum
1 gradual decrease
Tesserae
Ovda Rg.
Sudenitsa Ts.
Manatum Ts.
Group 3: H-B, C-M, Zirka and Alpha
1 subtle decrease
emissivity above 0.7
Tesserae
Ovda Rg.
Haasttse-baad Ts.
Chimon-mana Ts.
Zirka Ts.
Alpha Rg.
Group 4: Salus and Gbadu
1 gradual decrease
Tesserae
Ovda Rg.
Salus Ts.
Gbadu Ts.
Group 5: Dolya and Nedolya
1 gradual decrease
Tesserae
Ovda Rg.
Dolya Ts.
Nedolya Ts.
Group 6: Fortuna, Itzpa. and Lakshmi
1 subtle decrease
emissivity above 0.7
Tesserae
Ovda Rg.
Fortuna Ts.
Itzpapatotl Ts.
in Lakshmi

J. Brossier

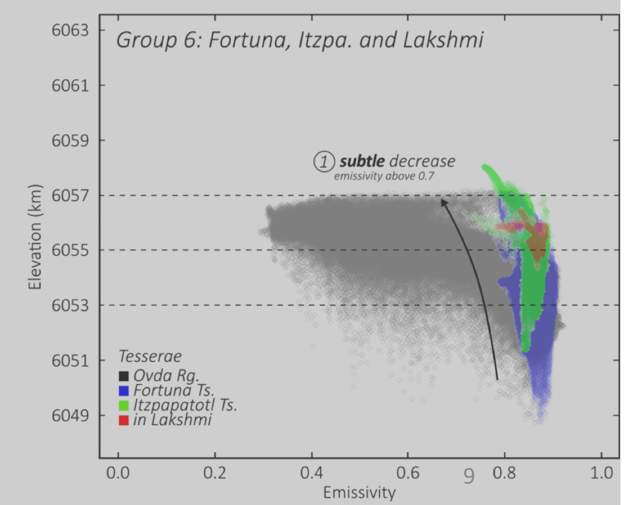






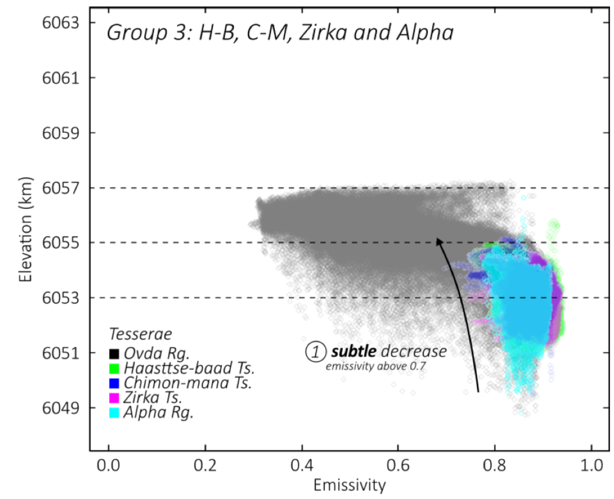
Ferroelectrics:
Temp of peak = f(composition)
Magnitude of peak = f(volume of high dielectric)

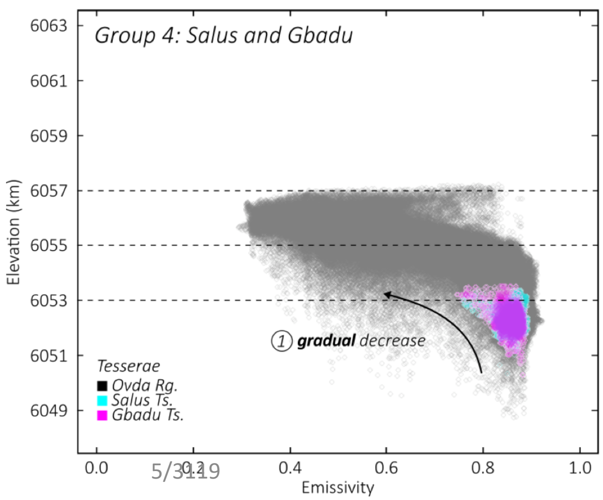
- Ovda has largest emissivity excursion signature @ ~6056 km/705K. Gradual decrease and abrupt increase consistent with ferroelectrics (*Shepard et al., 1994; Treiman et al. 2016*). Thetis is the same, but less tall.
- Sudenista and Manatum similar shape. Sudenitsa has lower amounts of same minerals as Ovda.

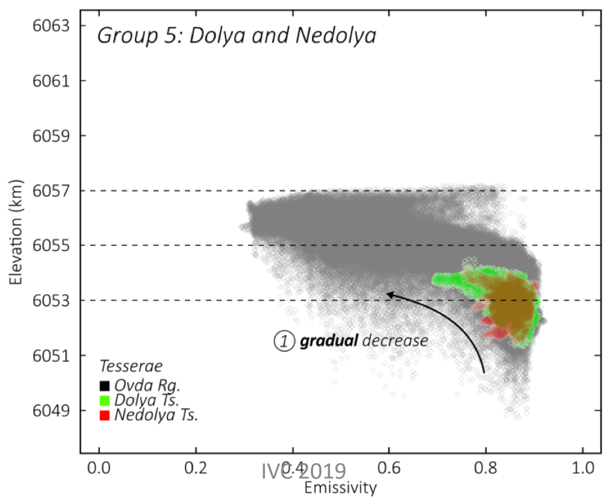


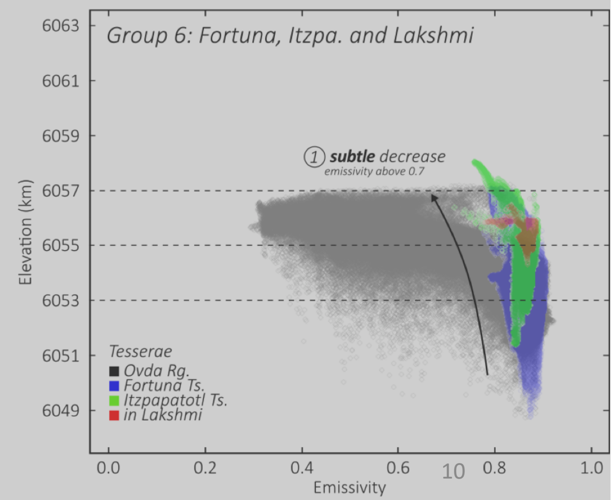
- Two sets of neighbors have emissivity anomalies @ 2-3 km (~720-730K) below Ovda, consistent with a different mineralogy.

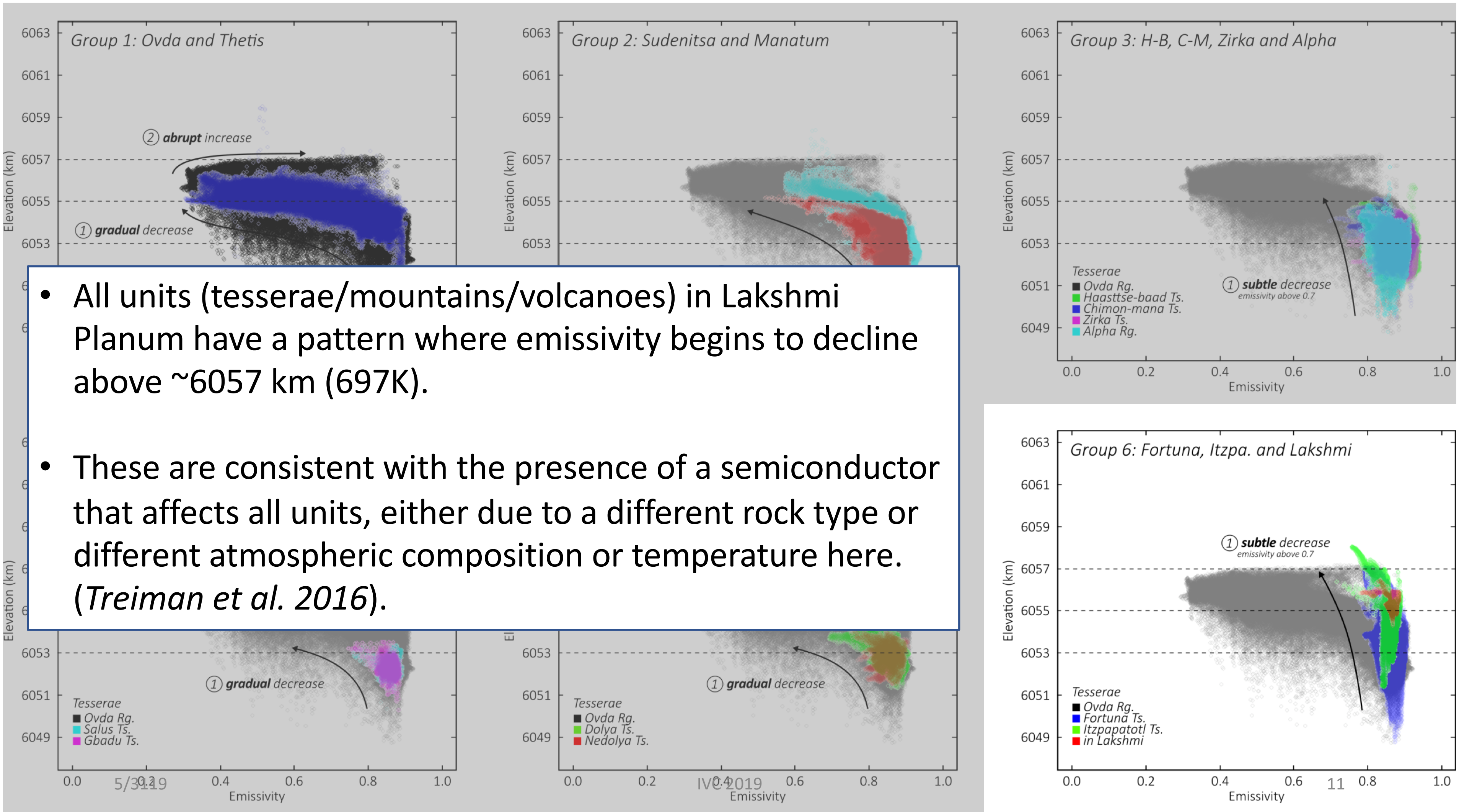
- Four other tesserae, including Alpha, are tall enough to go through this emissivity transition, but do not, suggesting a different mineralogy than the others.





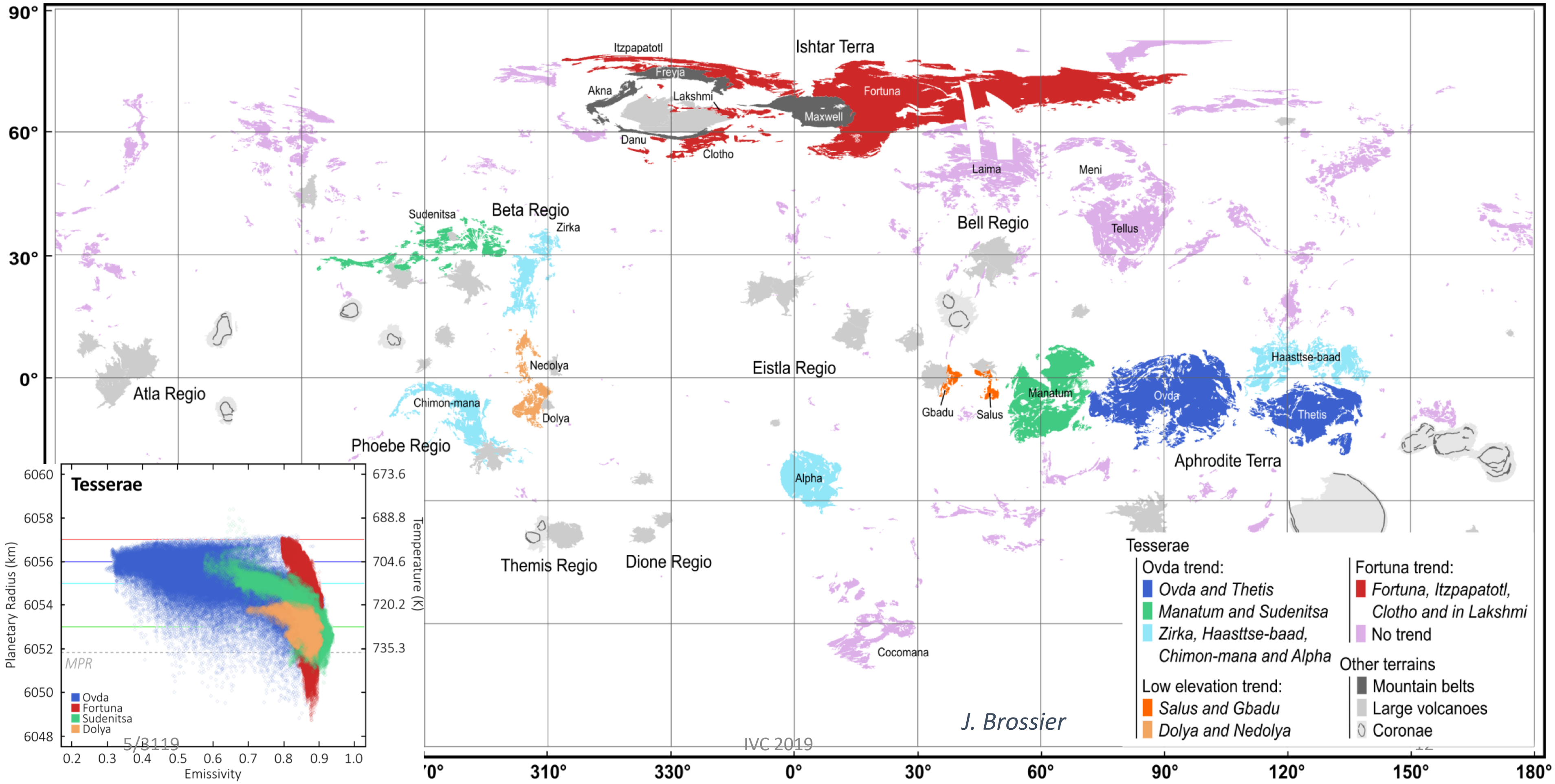




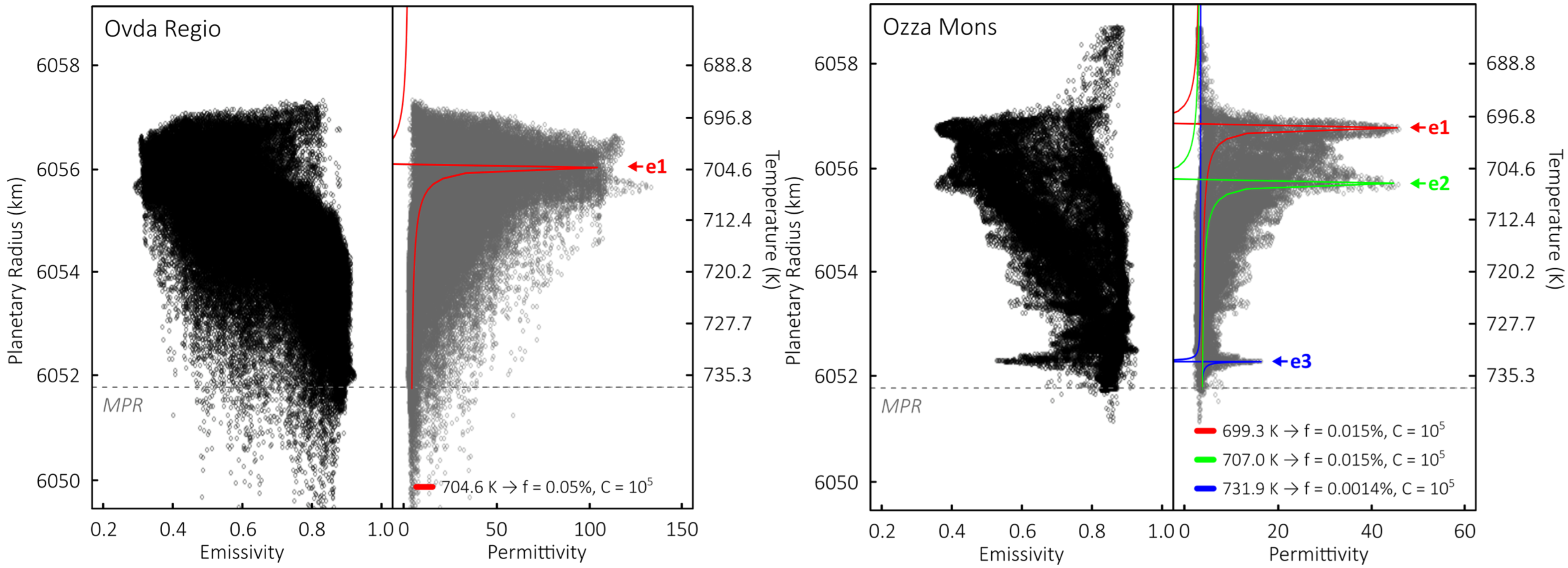


- All units (tesserae/mountains/volcanoes) in Lakshmi Planum have a pattern where emissivity begins to decline above ~6057 km (697K).
- These are consistent with the presence of a semiconductor that affects all units, either due to a different rock type or different atmospheric composition or temperature here. (*Treiman et al. 2016*).

Radar Emissivity Classes for Venus Tesserae



Emissivity to permittivity conversion after Campbell (1995) f(incidence angle, roughness)
Ferroelectric model after Shepard et al. (1994) for mineral with C = Curie constant, f = volume



Tessera has ~4X more ferroelectric than this volcano. Range of temperatures = different minerals of different compositions of same mineral. Similar excursions at ~700K in both terrains suggests common mineral.
We like apatite because it is ubiquitous and changeable. $Ca_5(PO_4)_3(Cl, F, OH)$, Chlorapatite is ferroelectric potentially formed by reaction of apatite to Venus Cl-rich atmosphere (*Treiman et al., 2016*).

Not exhaustive list of ferroelectrics at Venus T

Compound	Formula	Curie temp
Potassium Niobate	$KNbO_3$	708
Lutecium chromate	$LuCrO_3$	713
Cadmium iron niobate	$Cd(Fe_{0.5}\,Nb_{0.5})O_3$	723
Potassium lithium niobate	$K3Li_2Nb_5O_{15}$	703
Lead bismuth tantalate	Pb_2BiTaO_6	693
Strontium bismuth niobate	SrBi2Nb2O9	713
Lead bismuth tantalate	$PbBi_2Ta_2O_9$	703
Perovskite	$K(Ta,Nb)O_3$	0-760
Pyrochlore	$Pb_2Bi(Ta,Nb)O_6$	690-745
Leushite	Na(Nb,Ta)O3	?
Apatite	$Ca_5\,(PO_4)_3\,Cl$	675-775

Subarro 1960, Treiman et al., 2016,
Shepard et al., 1994 (and refs therein)

We hypothesize that exposed grains of fluorapatite ($Ca_5(PO_4)_3F$), the more common apatite in igneous rocks on Earth, will convert to chlorapatite ($Ca_5(PO_4)_3Cl$), a ferroelectric mineral at Venus temperatures.

Differences in excursion elevations are due to differences in the composition of apatite, where OH- can occupy the Cl- or F- site, or large cations, including rare earth elements, may substitute for Ca.

BIG LEAP HERE

Phosphates are more abundant in felsic rocks, which have more incompatible elements, including P_2O_5, relative to basalts. This is also true of the more obscure candidates for the ferroelectric transition that comprise incompatible elements combining with an atmospheric component (S, Cl, F).

Thus, the confirmation of a candidate incompatible-rich phase for high elevation tessera material supports their interpretation as being more chemically evolved than the plains.

Conclusions

- Most tesserae undergo a reduction in radar emissivity at high elevations, indicating the presence of high dielectric minerals.
  - The elevation varies a function of location in 6 classes:
  - Ovda has largest signature @ ~6056 km/705K. Sudenista and Manatum have lower amounts of same minerals as Ovda.
  - Two sets of neighbors have emissivity anomalies @ 2-3 km (~720-730K) below Ovda, consistent with a different mineralogy. Four other tesserae, including Alpha, are tall enough to go through this transition, but do not.
  - These tesserae are consistent with the presence of ferroelectric minerals common on Venus (they are also in the volcanoes and coronae)
  - **Tesserae have more dielectric minerals than the plains consistent with more evolved compositions.**
- All units (tesserae/mountains/volcanoes) in Lakshmi Planum have a pattern where emissivity begins to decline above ~6057 km (697K).
  - These are consistent with the presence of a semiconductor that affects all units, either due to a different rock type **or different atmospheric composition or temperature here.**