**Richard Ghail**
Lead Scientist, *Royal Holloway*

**Colin Wilson**
Science Investigation Lead, *Oxford*

**Thomas Widemann**
Programme Manager, *Paris Obs.*

**Thomas Voirin**
EnVision Study Manager, *ESA*

**Dmitri Titov**
EnVision Study Scientist, *ESA*

**Adriana O'Campo**
NASA Lead for EnVision

**Philippa Mason**
VenSAR, *Imperial College London*

**Lorenzo Bruzzone**
Radar Sounder, *University of Trento*

**Jörn Helbert**
VenSpec-M, *DLR, Berlin*

**Robbie Herrick**
VenSAR, *ASF, Fairbanks*

**Caroline Dumoulin**
Radio Science, *LPG Nantes*

**Ann-Carine Vandaele**
VenSpec-H, *Aeronomie, Bruxelles*

**Geoff Burbidge**
VenSAR, *Airbus, Portsmouth*

**Pascal Rosenblatt**
Radio Science, *Laboratoire Géoazur*

**Emmanuel Marcq**
VenSpec-U, *LATMOS, Versailles*

# EnVision

## Europe's revolutionary new mission to Venus


UNDERSTANDING WHY OUR CLOSEST NEIGHBOUR IS SO DIFFERENT

# Science focussed on four themes

1. **Activity** – *How geologically active is Venus today?*
2. **History** – *How has Venus evolved through time?*
3. **Climate** – *How has Venus' atmosphere been determined by its geological activity?*

EnVision aims to understand

**Venus from its clouds to the core**

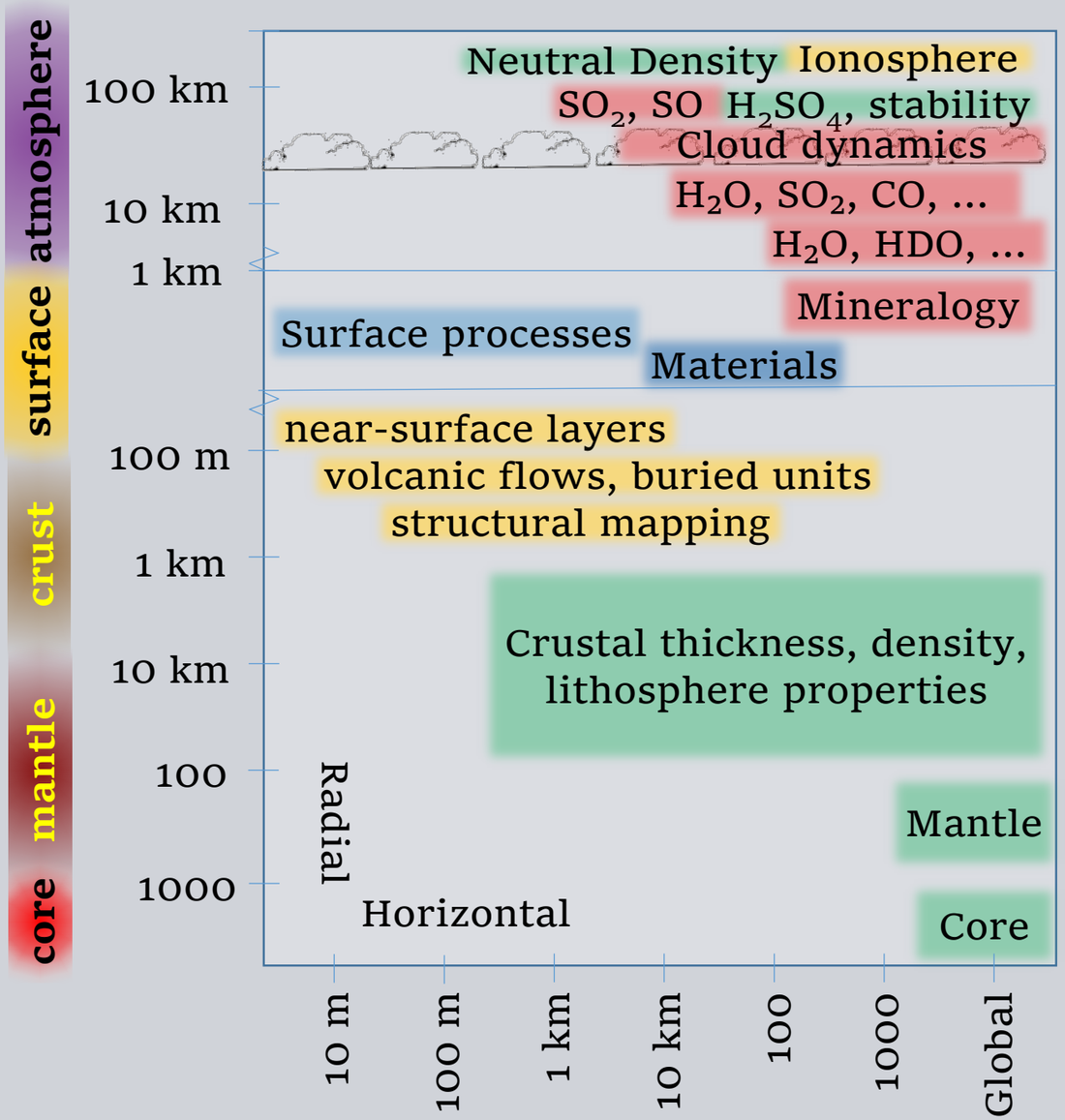
and so discover why Venus is so different to Earth

VenSpec

VenSAR

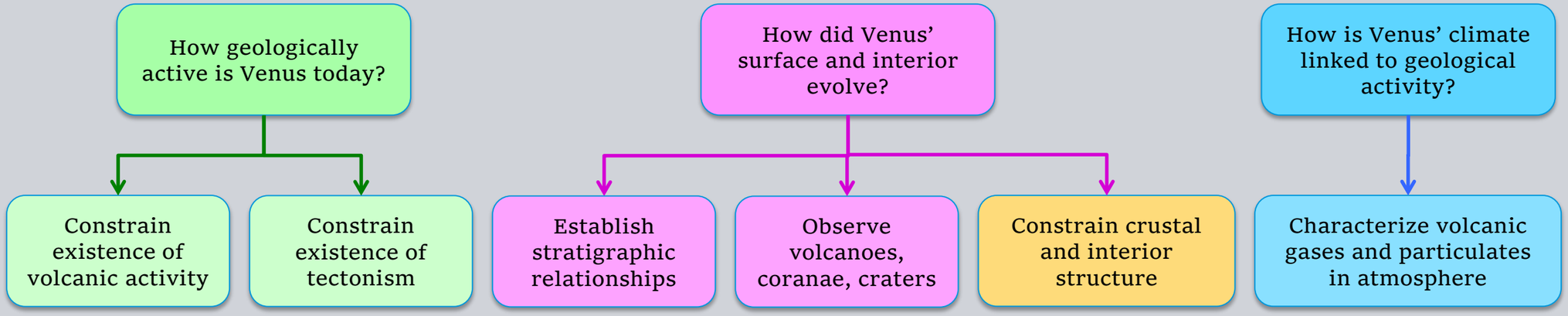
Subsurface Sounder

Radio Science




# Science requirements

UNDERSTANDING WHY OUR CLOSEST NEIGHBOUR IS SO DIFFERENT




| | | | |
|---|---|---|---|
| 4 cycles | 50% coverage | Nested approach | **20% coverage** |
| > 2 cycles | 100% coverage | **ROIs** | 2% coverage |
| 4 cycles | periapsis at <300 km | | 0.2% coverage |

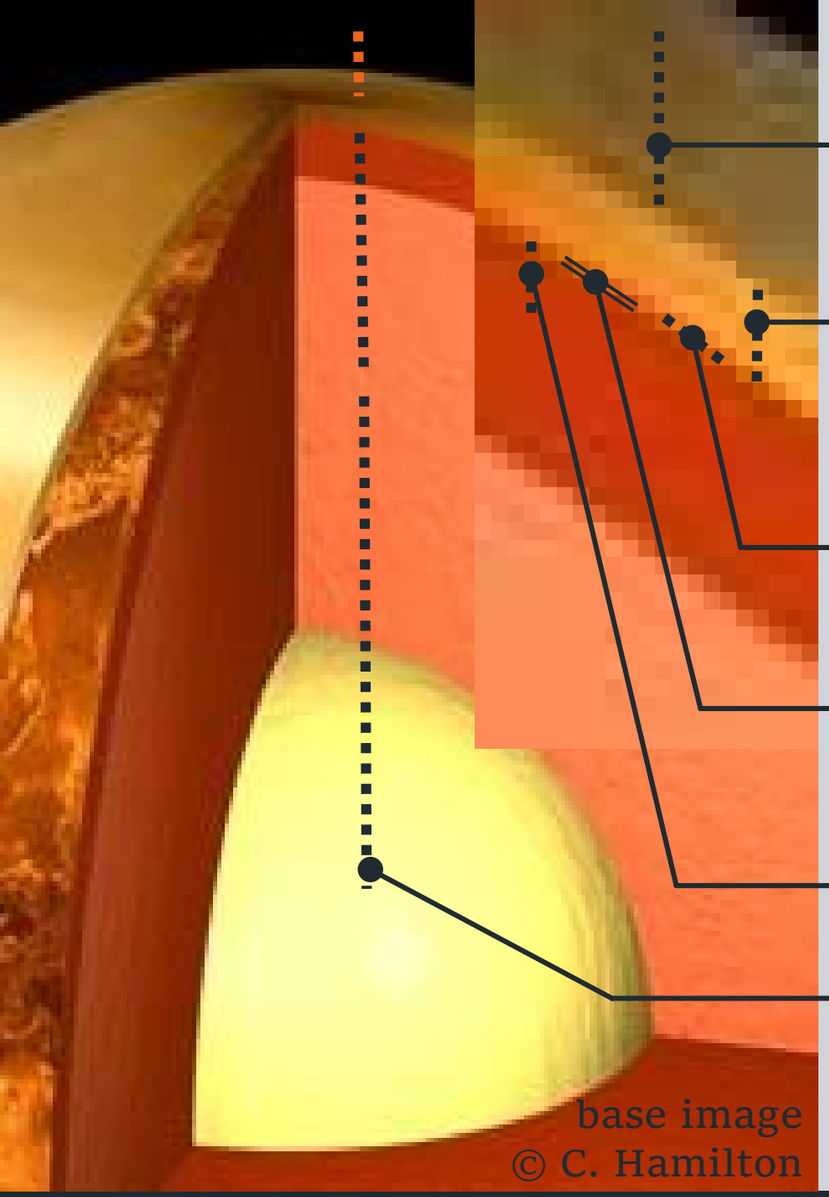
| | | | | |
|---|---|---|---|---|
| Thermal Emissions 1 K | $k_2$ ± 0.01 | ≤ 50 m resolution | topography | Troposphere gas 1% |
| cm-scale changes | Spin rate ± $3.10^{-6}$ | ≤ 10 m resolution | mineralogy | Mesosphere gas 10% |
| Volcanic gases $H_2O$, SO, $SO_2$ | Spin axis ±10 cm | ≤ 2 m resolution | Subsurface layering | |

| | | |
|---|---|---|
| 2.6 years science | Frozen eccentricity orbit 220-470 km | **Data return 240 Tbits** |
| | Orbit prediction 300 m / 10 s within 2 weeks | |
| | 35 m DSA (10 hours daily) | |

| | | | | |
|---|---|---|---|---|
| Radiometry | SAR, 1 m | VenSpec-M IR Thermal emissivity | | RSE |
| SAR, 30 m | SAR, 6 m | VenSpec-U | VenSpec-M | |
| InSAR | Polarimetry, 30 m | VenSpec-H | | SRS |

# Science requirements flow down

UNDERSTANDING WHY OUR CLOSEST NEIGHBOUR IS SO DIFFERENT




**VenSpec-U**
Mapping SO, $SO_2$ and UV absorber at cloud top. 210–240 nm (@ 0·2 nm), 190–380 nm (@ 2 nm), ~10 km spatial resolution

**VenSpec-H**
Mapping of near surface atmosphere $H_2O$, HDO at 0–15 km @1·08–1·2 μm, $H_2O$, HDO, OCS, $SO_2$ at 30–40 km @ 2·44–2·47 μm, ~100 km spatial resolution

**VenSpec-M**
Mapping mineralogy by surface emission at 6 channels 0·82–1·2 μm at <50 km resolution

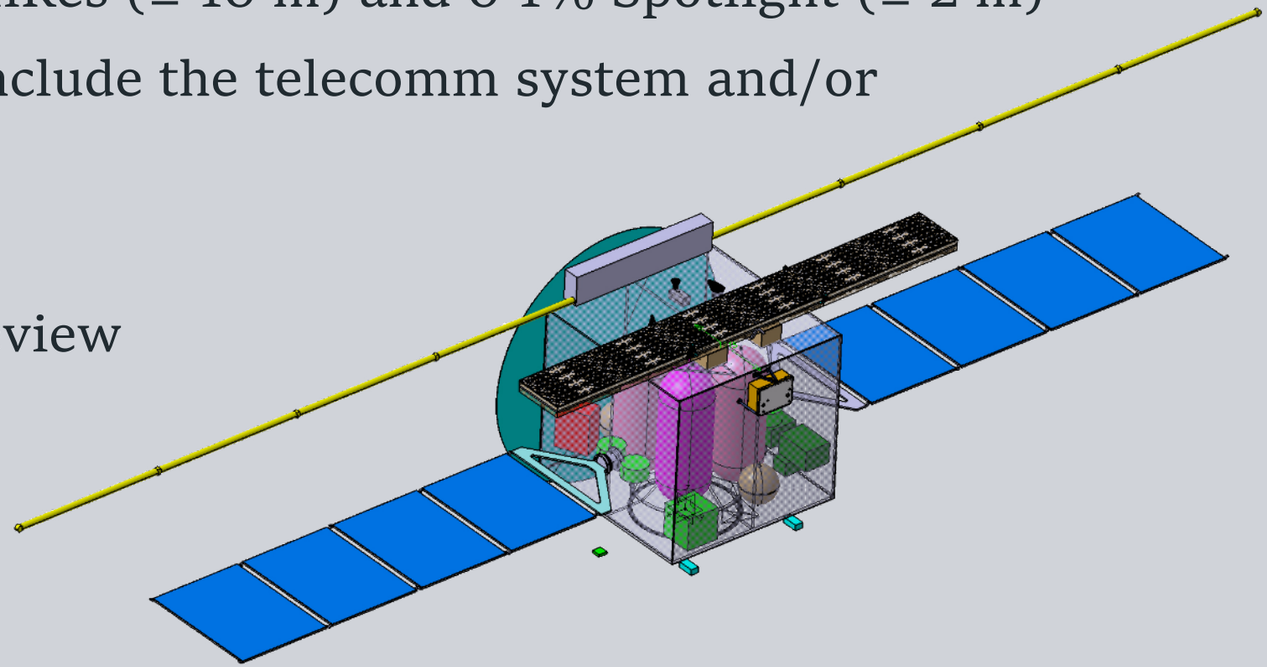
**VenSAR**
Surface morphology, 1–50 m, polarimetry, cm changes by DInSAR @ 3·2 GHz, 5 × 38 km radiometry at 1 K precision,

**SRS**
Subsurface radar down to 1000 m depth and ~10 m resolution @ TBD MHz

**Radio Science**
Two-way mapping, radio occultations, gravity field, $k_2$ love number

# Detecting past and present geological activity

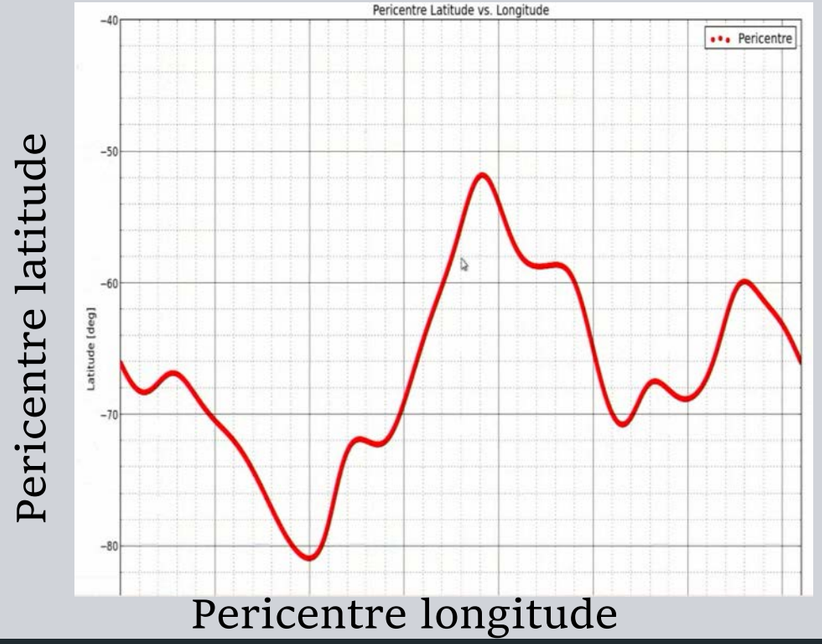
- ESA's Concurrent Design Facility baseline study successfully achieved the mission targets within the design to cost envelope
- Baseline mission is 2032 launch, chemical propulsion with aerobraking (12 to 24 months)
- Mission start in June 2035, with a ≥ 4 cycle science duration (2.66 Earth years)
- ≥ 240 Tbit data return in 4-cycles, with >60% IR and sounder coverage, >15% InSAR and polarimetry (at ≤50 m resolution), and 2% HiRes (≤ 10 m) and 0·1% Spotlight (≤ 2 m)
- NASA contributions are under review; may include the telecomm system and/or
  - VenSAR front end with UK back end, or
  - Complete SAR instrument
- EnVision passed the Mission Development Review and is now starting Phase A study
- Two parallel industrial studies from June 2019 to Q2 2021 ahead of final down-selection in Sep 2021

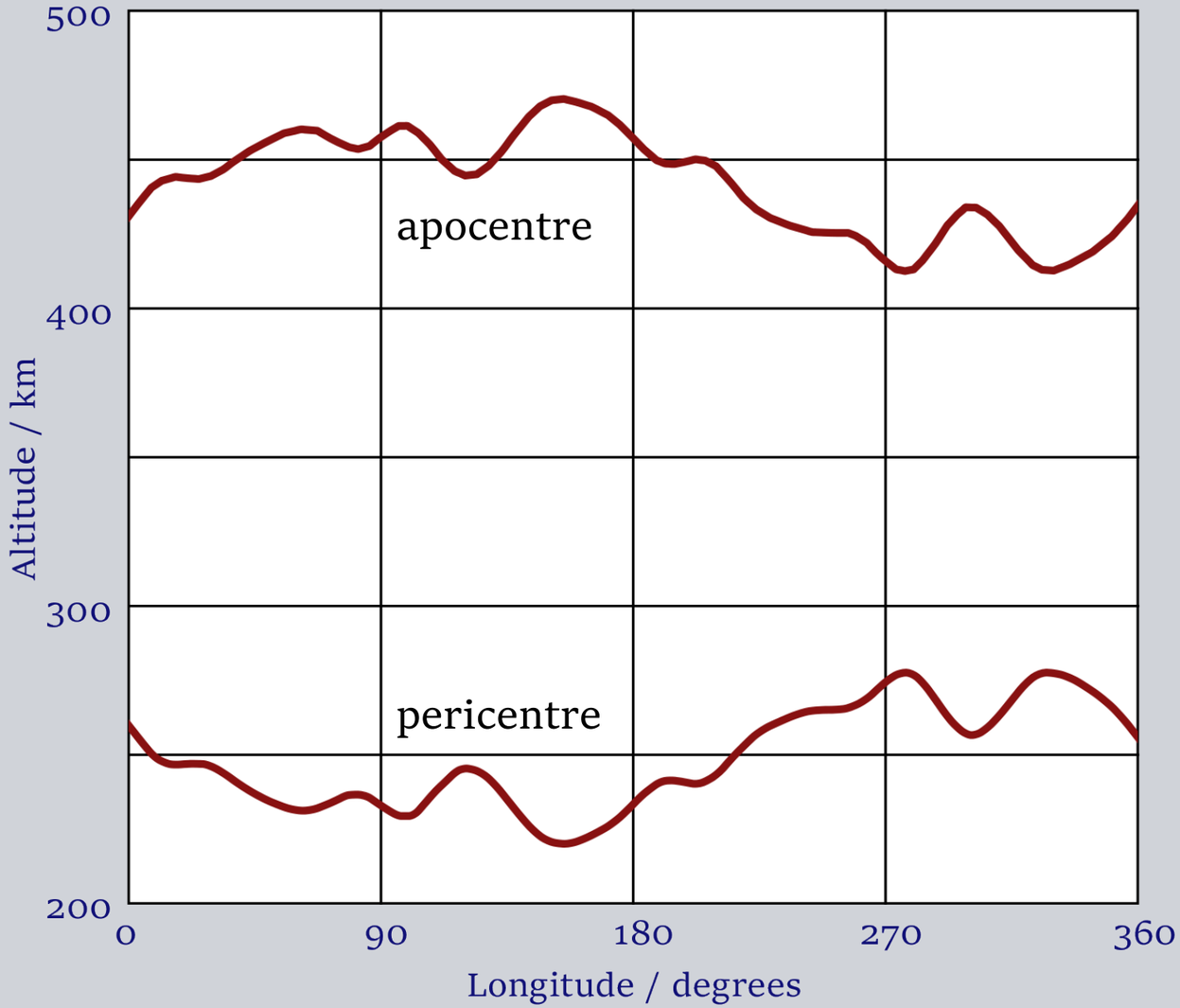


# Current status

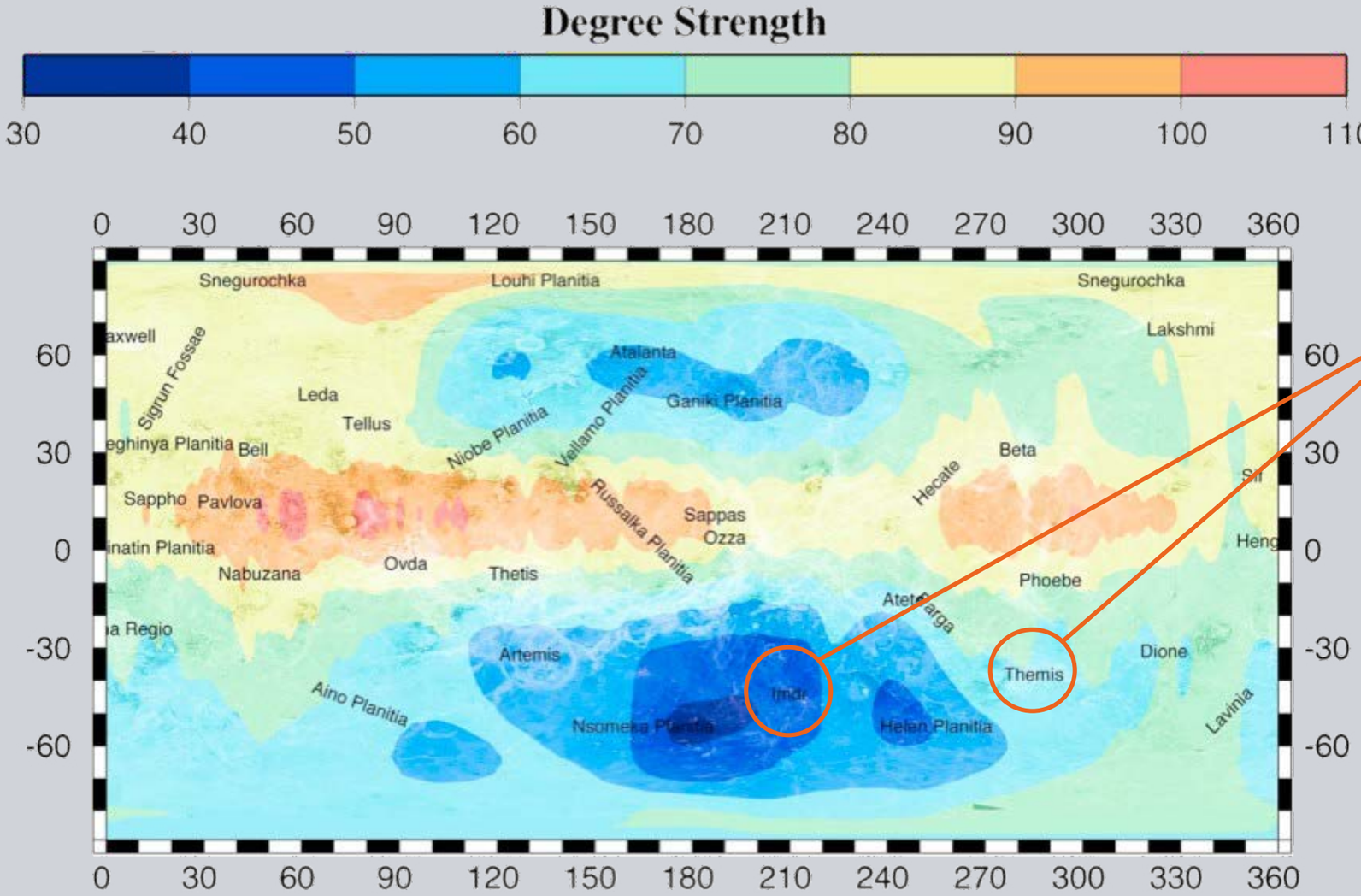
Frozen eccentricity orbit reduces propellant consumption, but leads to:

- Limitation on maximum accessible incident angle at highest altitudes
- Rapid changes in altitude over equator are problematic for beam/image convergence
- Non-uniform degree strength gravity field




# Science orbit




Anderson & Smrekar, 2006

Possible Active Hot spots

- Variable degree strength gravity field from 70 to 150
- Highest in the low-resolution areas of Magellan in the southern hemisphere

# Radio Science experiment and VenSAR geodesy

## Radio Science & Geodesy

- *Gravity experiment*

  Shallow and deep interior structure, thermal and tectonic evolution of the planet

- *Radio-occultation*

  Temperature and pressure profiles in the troposphere, Total Electron Count (TEC) profiles in the ionosphere, monitoring of $H_2SO_4$ vapour at cloudbase

- *Precise Orbit Determination*

  Improved InSAR from <100 m orbit knowledge

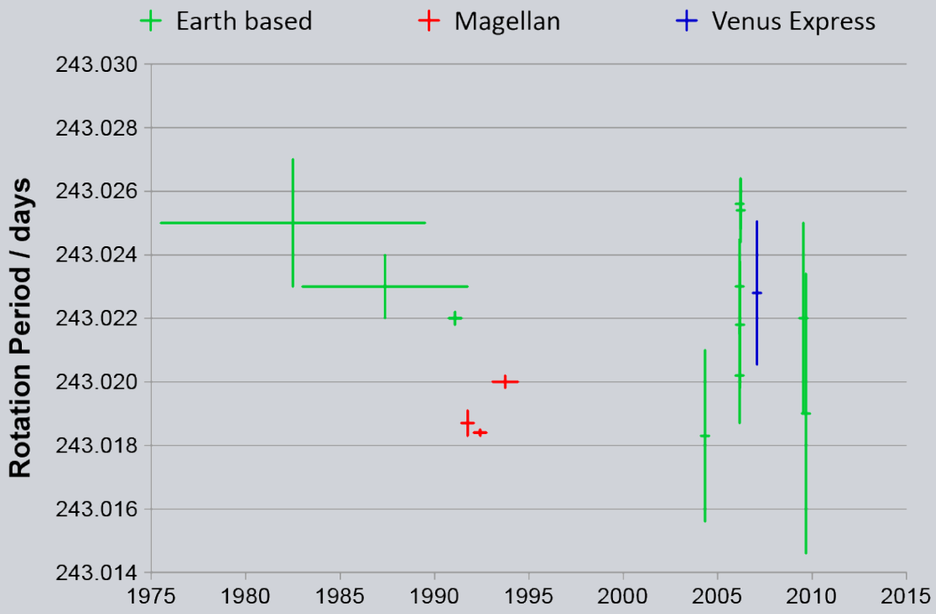
## VenSAR Geodesy Measurements

- *Planetary ephemerides*

  Spin axis wobble, improved GR, GM and $J_2$

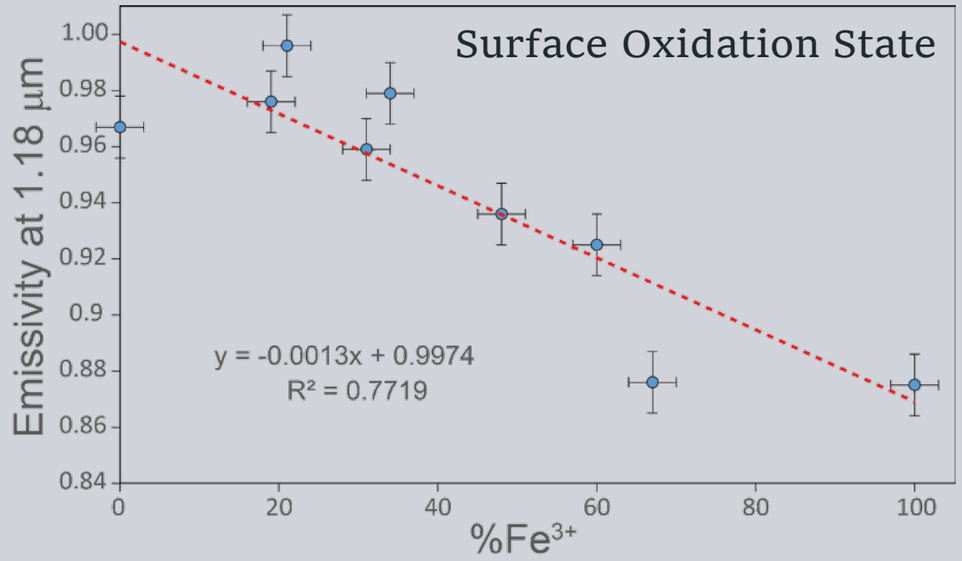
- *Length of Day*

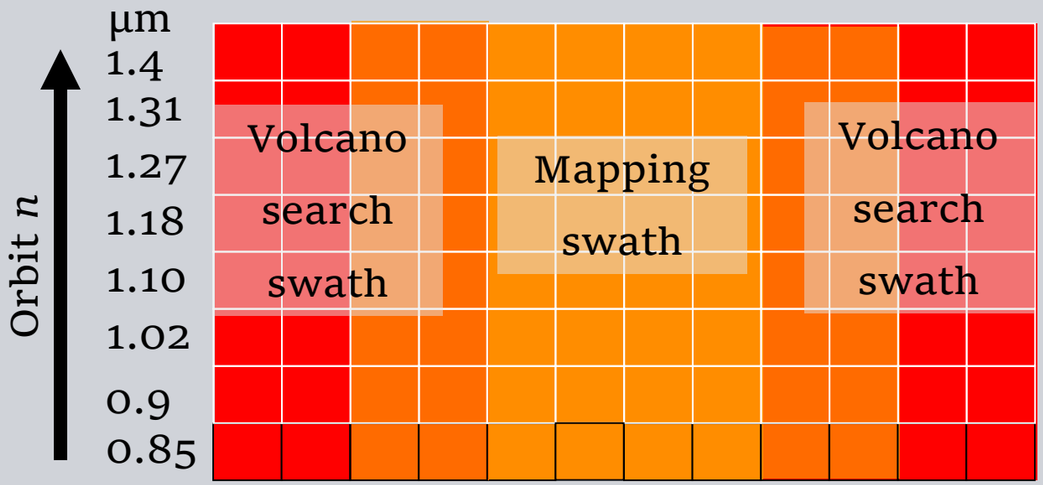
  Measure and understand variability in spin rate




# Radio Science experiment and VenSAR geodesy

UNDERSTANDING WHY OUR CLOSEST NEIGHBOUR IS SO DIFFERENT



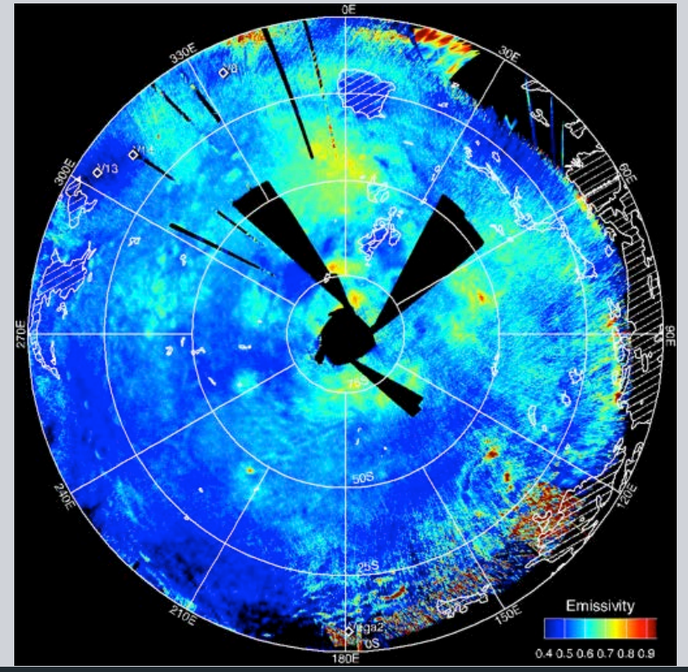

Spatial oversampling provides for mapping and confirmation of detected eruptions

VenSpec-M is a multi-spectral imager designed to:

- Map surface composition on a global scale
- Monitor for volcanic activity
- Map near surface water vapour abundance

Pioneered by VIRTIS on Venus Express, VenSpec-M greatly improves sensitivity and spectral and spatial coverage:

- 14 spectral bands cover all five surface windows
- Oversampling at 10 km spatial resolution
- High signal to noise ratio




VIRTIS on Venus Express mapped the hot surface at 1 µm using emissivity data

# VenSpec-M: IR imaging



EnVision
UNDERSTANDING WHY OUR CLOSEST NEIGHBOUR IS SO DIFFERENT

VenSpec-H is a high resolution infrared spectrometer designed to:

- Measure $H_2O$ and HDO contents in the lower Venus atmosphere
- Probe $H_2O$, CO, OCS, $SO_2$ at the 30-40 km

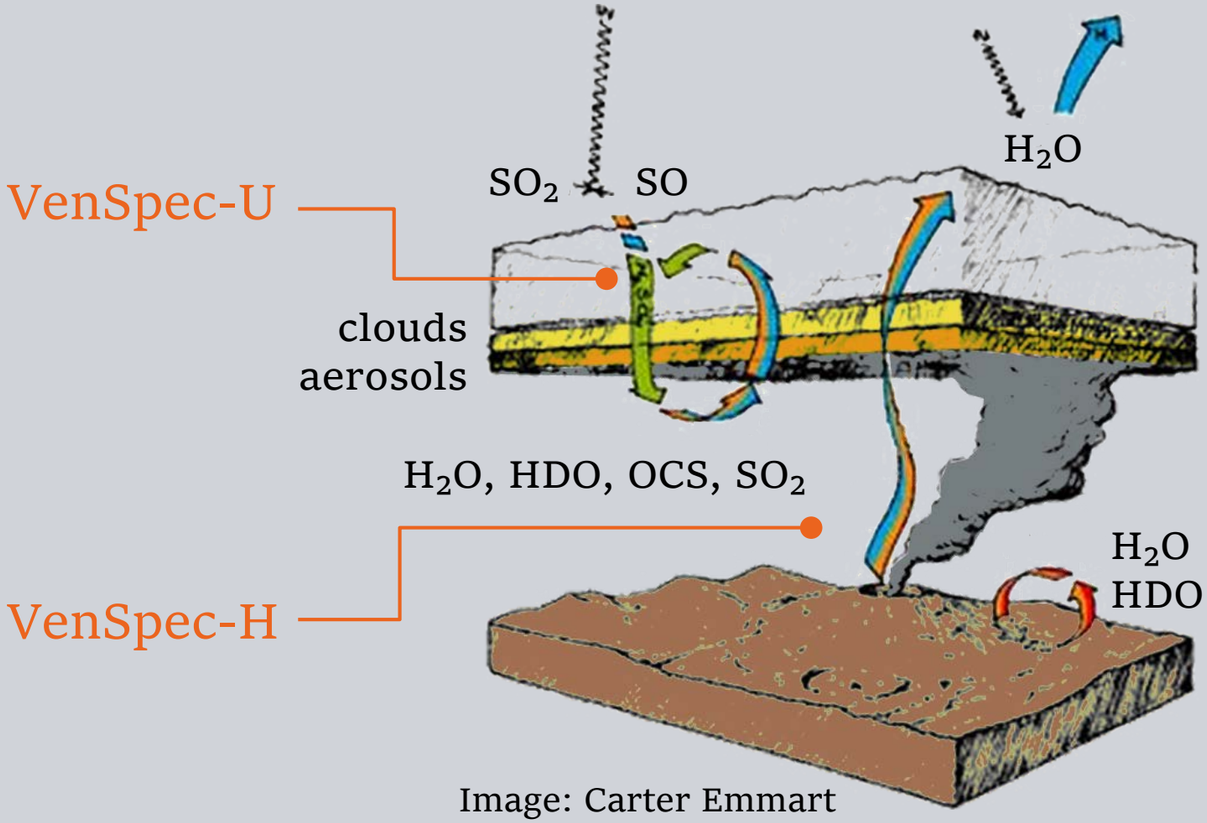
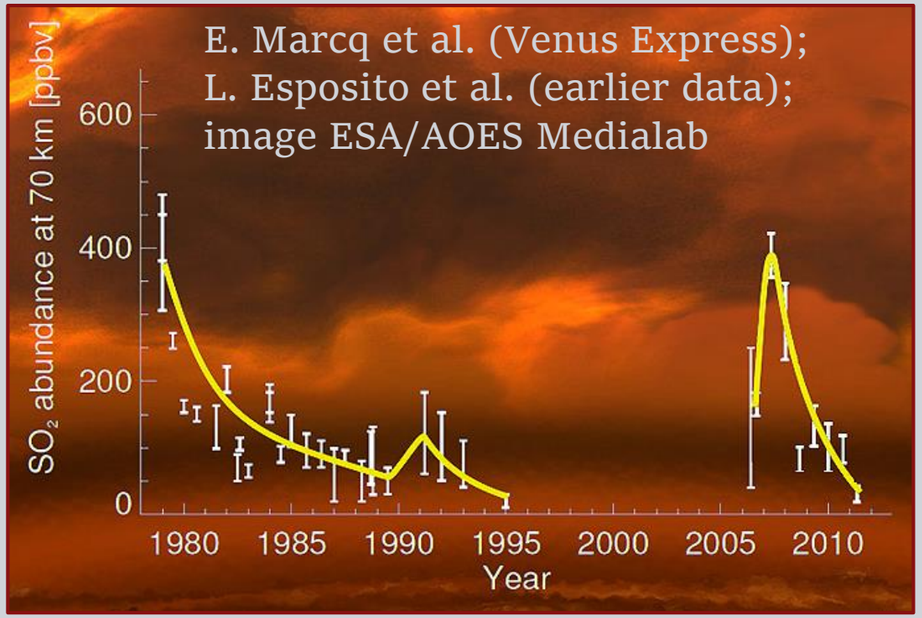



Image: Carter Emmart

VenSpec-U is an ultraviolet spectrometer designed to:

- Map mesospheric variability of SO and $SO_2$, cloud and aerosol properties
- Distinguish atmospheric circulatory change from volcanic emissions

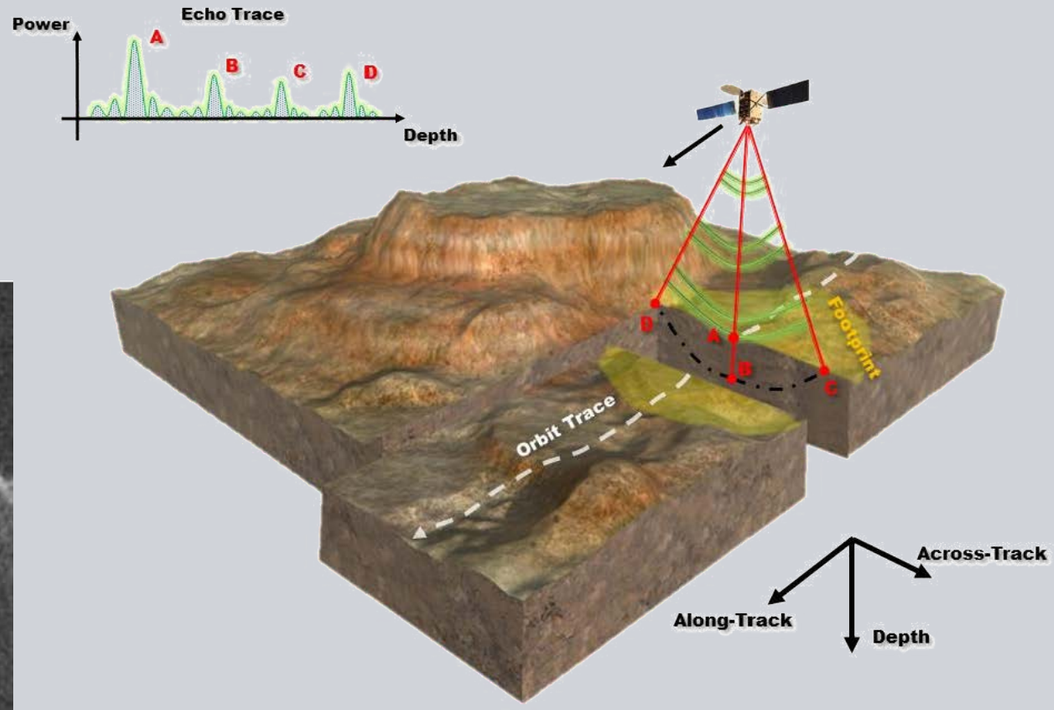



# VenSpec-H, -U: IR and UV spectroscopy

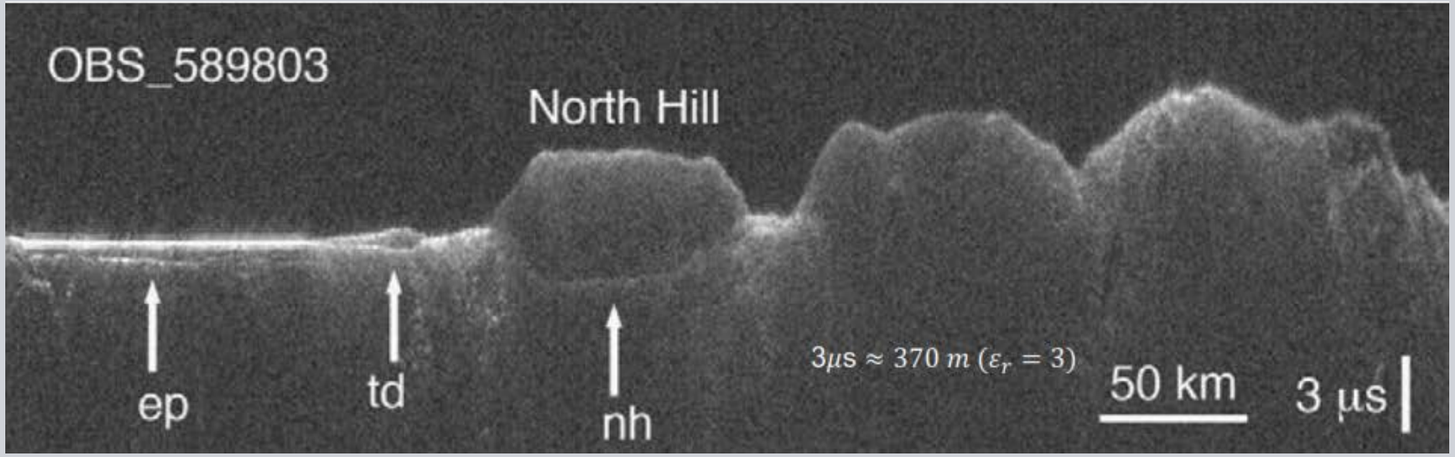
UNDERSTANDING WHY OUR CLOSEST NEIGHBOUR IS SO DIFFERENT

The Subsurface Radar Sounder will acquire information on the shallow Venus subsurface to:

- Characterize different stratigraphic and structural patterns in the subsurface
- Map the vertical structure of geological units by exploring the subsurface properties of tessera, plains, lava flows, impact ejecta and other materials
- Detect subsurface structures that are not directly linked with surface, e.g. stealth coronae




Portion of western Medusae Fossae Formation, a low-density pyroclastic deposit spanning across the crustal dichotomy on Mars
**td**: Thin deposit (50–100 m) **nh**: North Hill deposit (~580 m)
**ep**: Plains reflectors under Elysium Planitia [Carter et al. 2009]




# Subsurface Radar Sounder




UNDERSTANDING WHY OUR CLOSEST NEIGHBOUR IS SO DIFFERENT

## VenSAR requirements:

- 30-50 m resolution observations
  - ~20% of planet observed ≥ 3 times with same geometry
  - Full raw (SLC) data for DiffInSAR
  - Polarimetry
  - Topography from stereo and/or interferometry
- 6-10 m high res imagery
- 1-2 m resolution spotlight imagery
- Radiometry

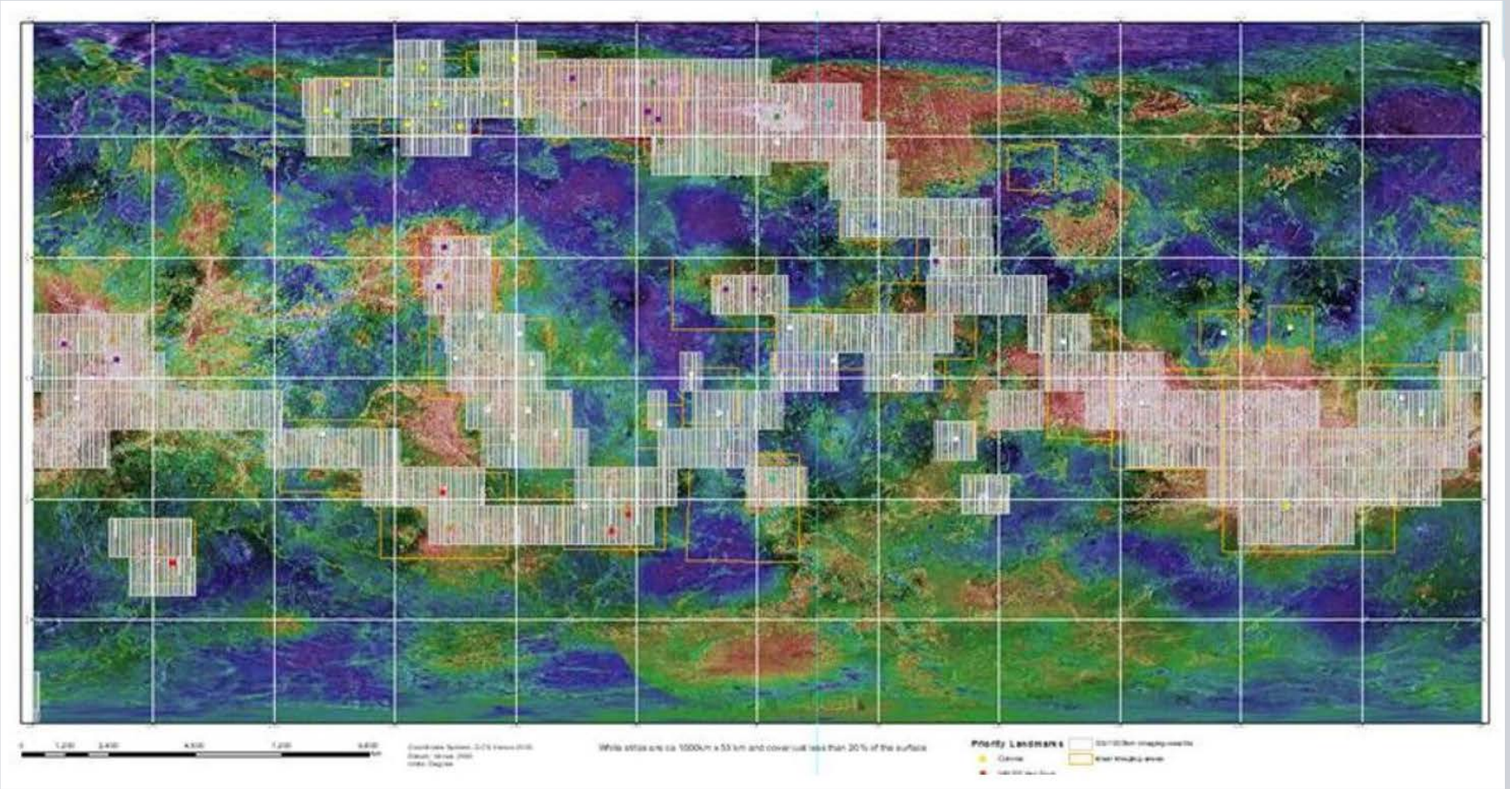
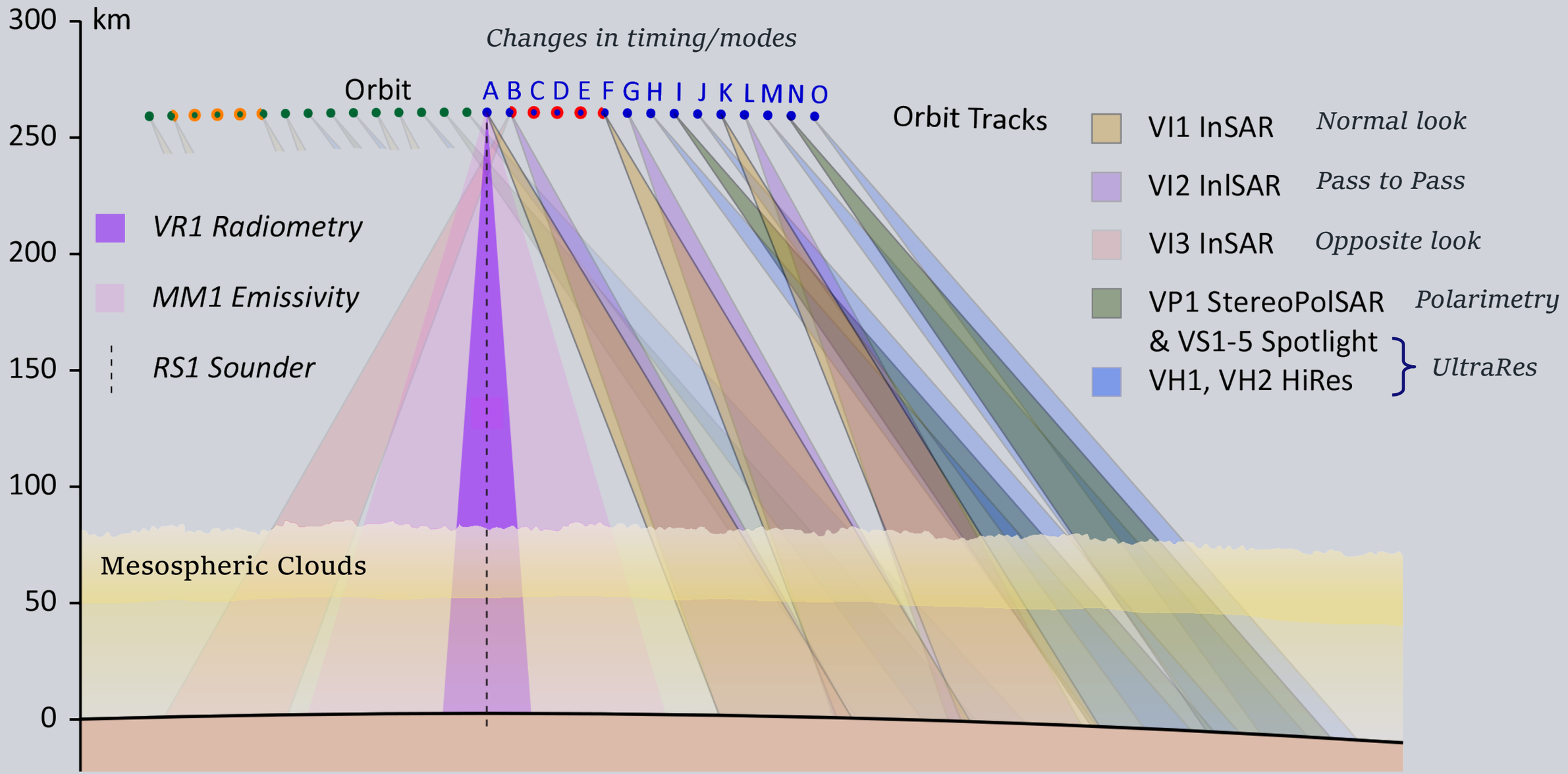


Illustration of possible target region of 20% coverage for repeated observations at ~ 30-50 m resolution.
To include representative sample of all terrain types.



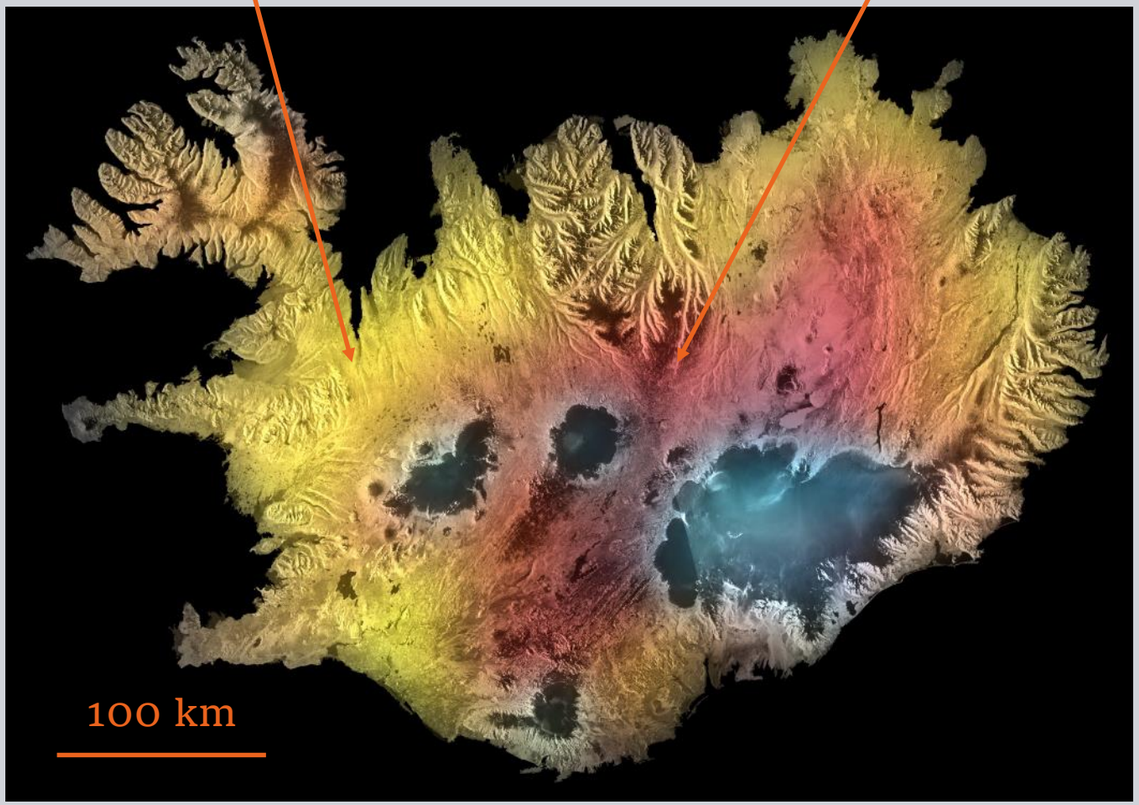

# Science operations

UNDERSTANDING WHY OUR CLOSEST NEIGHBOUR IS SO DIFFERENT

# VenSpec-M emission maps

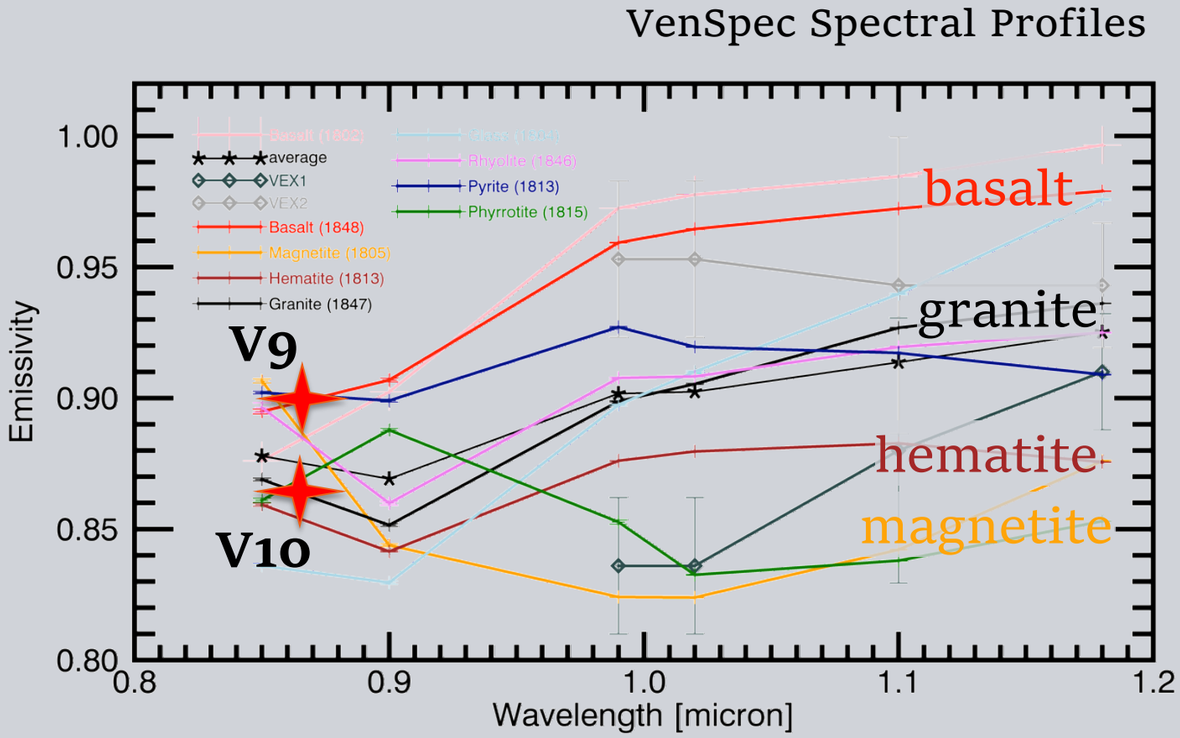
Weathered basalt
[*hematite-rich*]

Fresh basalt
[*magnetite-rich*]




Simulated 3-band [*1·1, 1·02, 0·9 μm RGB*] VenSpec-M on VenSAR image

# VenSpec-M emission spectra



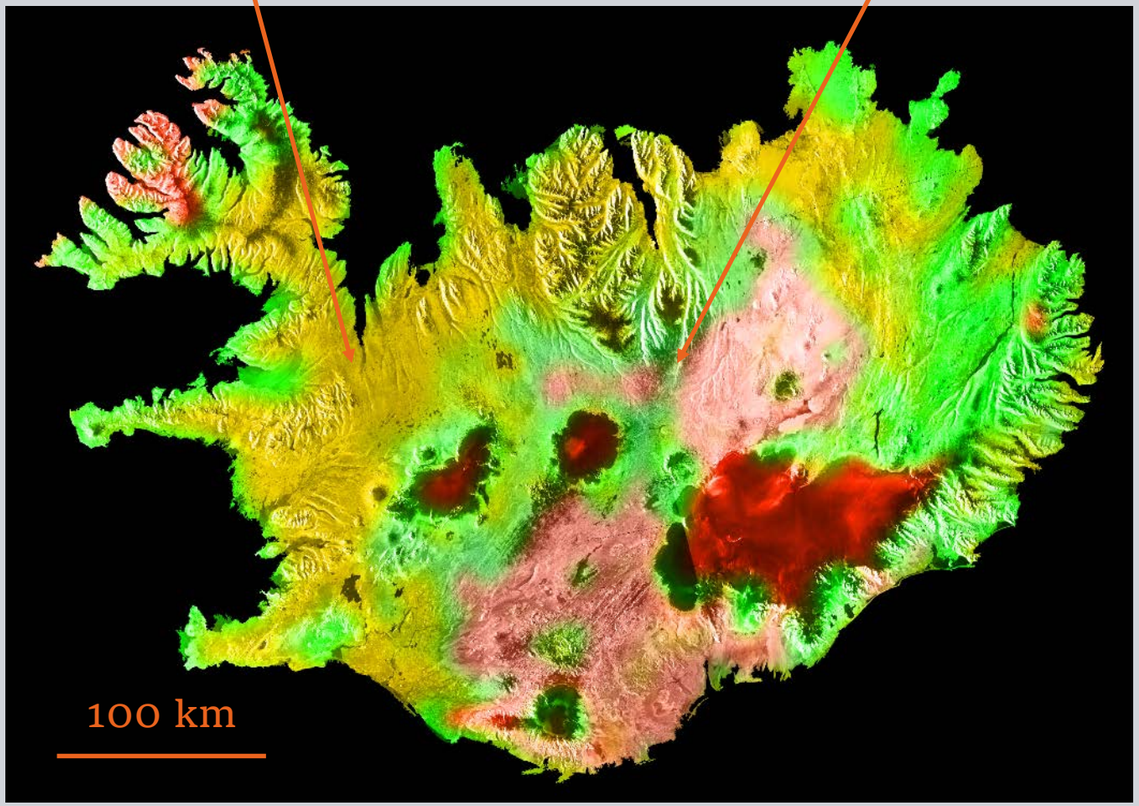

# Global scale ( $10^2$ - $10^4$ km scale )

UNDERSTANDING WHY OUR CLOSEST NEIGHBOUR IS SO DIFFERENT

## SAR emissivity

Weathered basalt
[*low permittivity*]

Fresh basalt
[*high permittivity*]

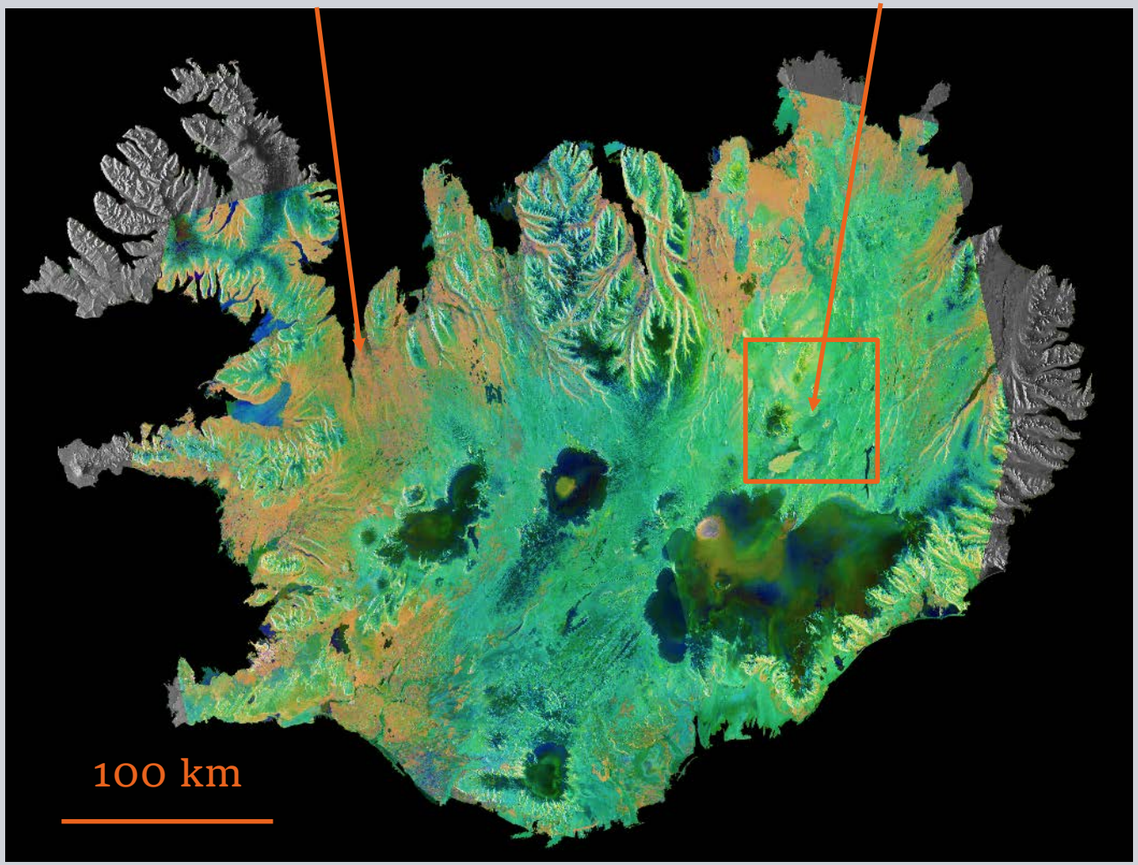



Simulated colour-coded emissivity [*relative permittivity*]

## SAR polarimetry

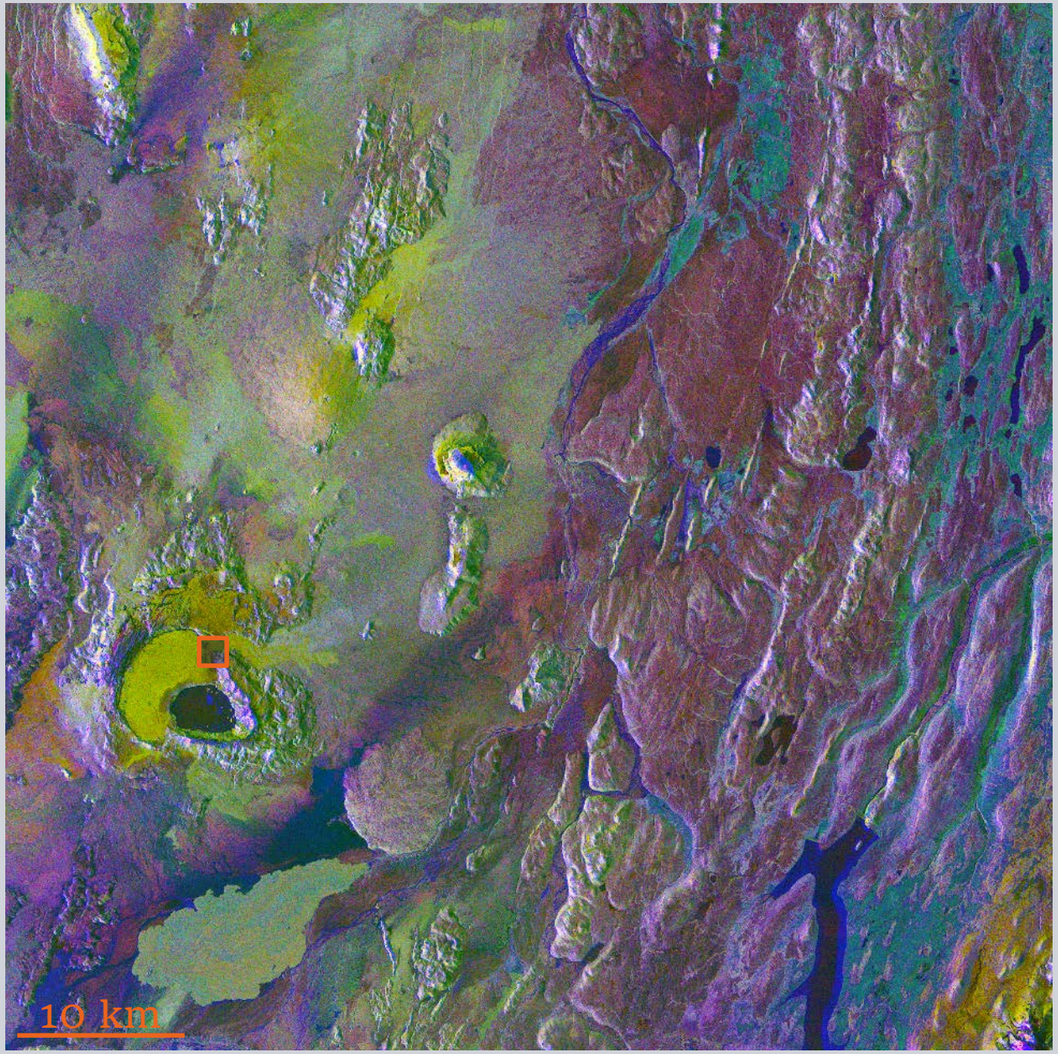
Granular material
[*weathered lavas, soils*]

Rough bare rock
[*aa lava, boulders*]

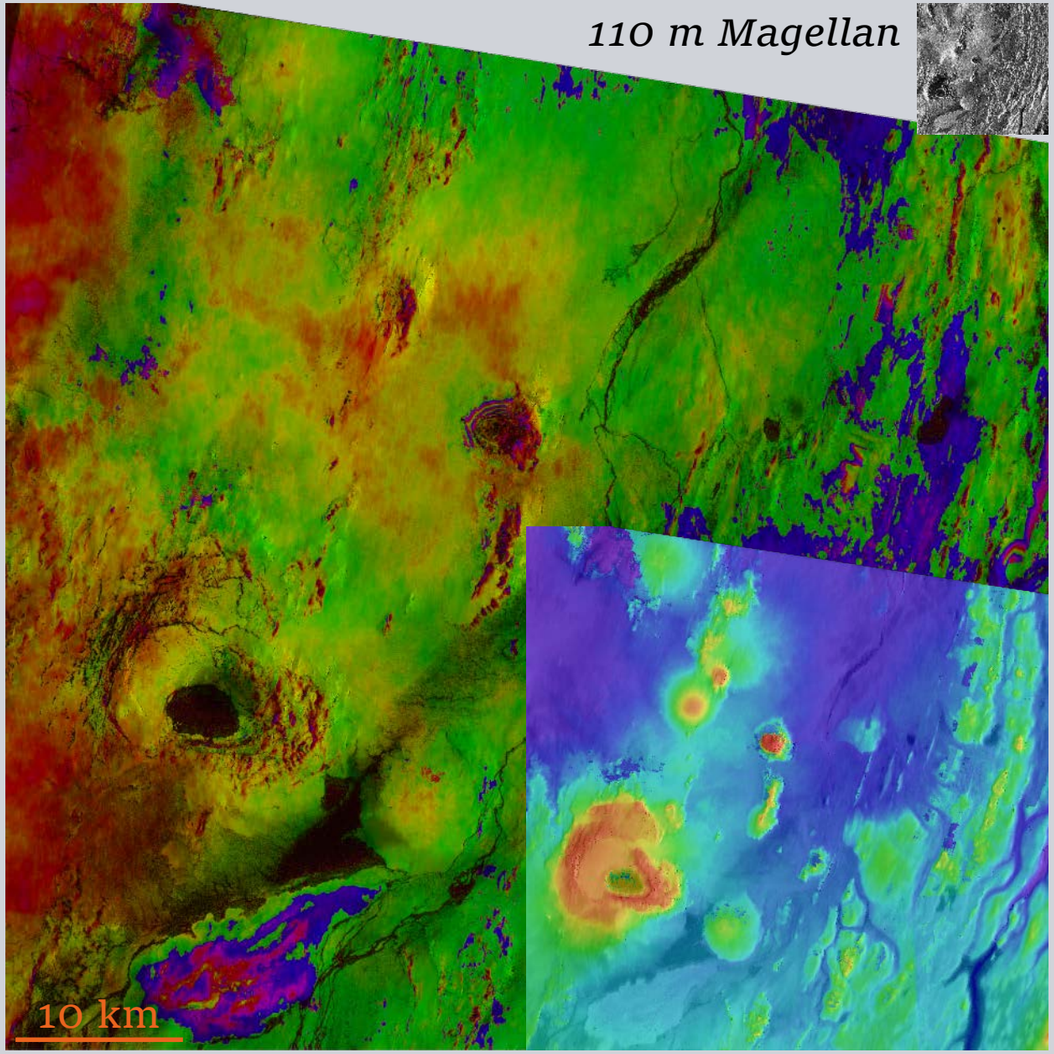



Simulated polarimetric [*VH-VV-HH RGB*] PolSAR

# Reconnaissance ( $10^{-1}$ - $10^{3}$ km) scale

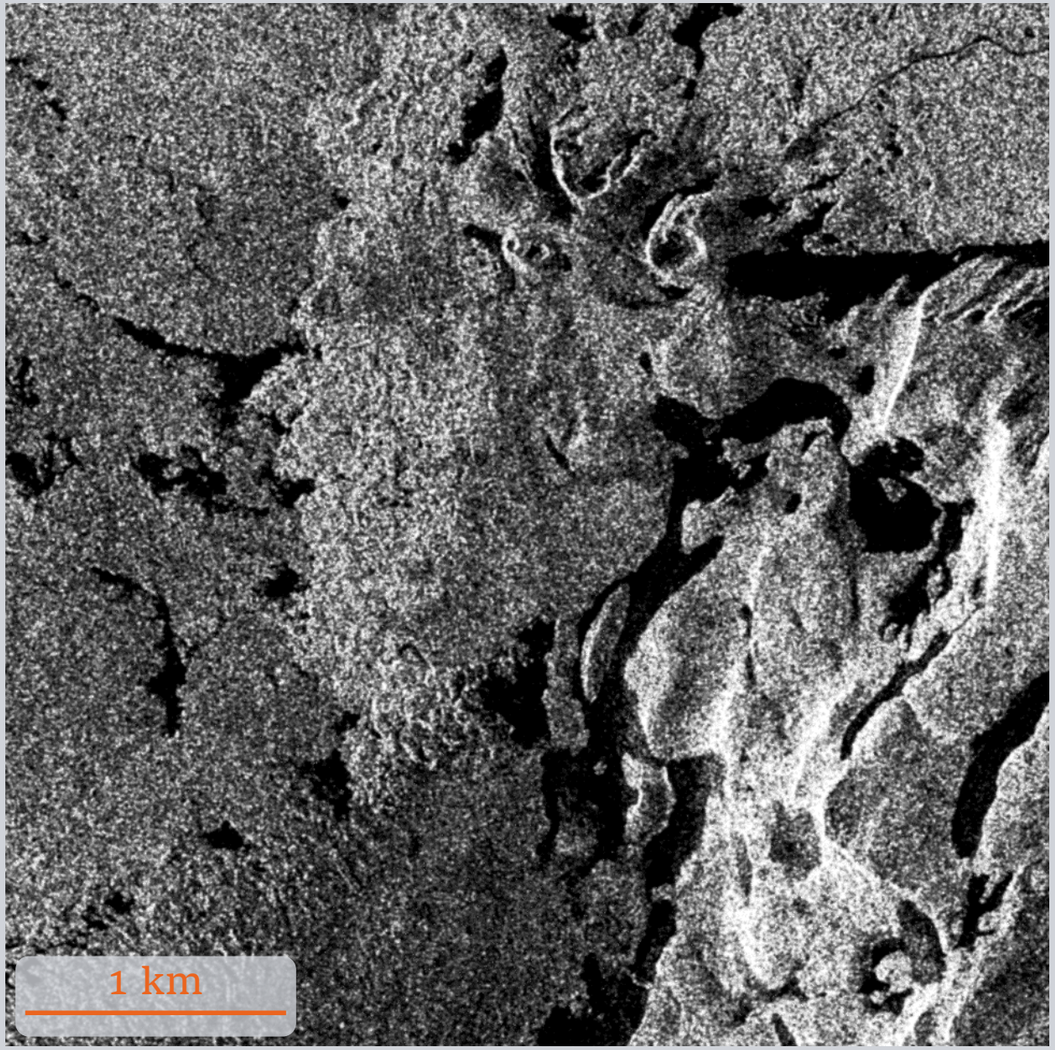



30 m Polarimetric 53-km scanSAR swath



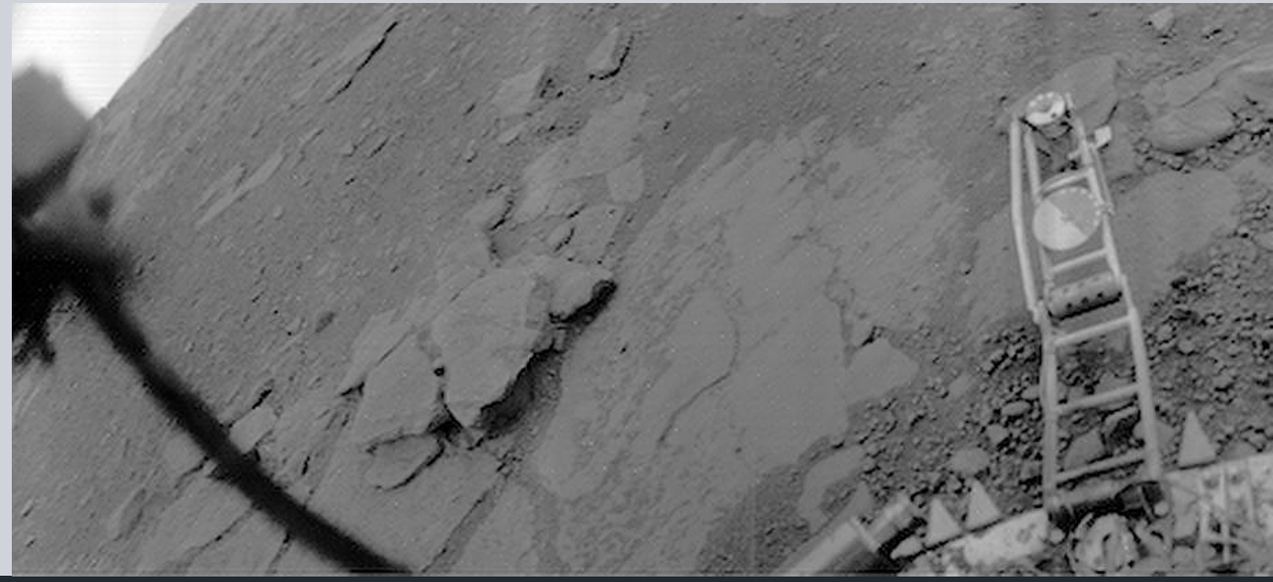

30 m DInSAR with 60 m derived DEM

# Reconnaissance ( $10^{-1}$ - $10^{3}$ km) scale




2 m UltraRes 30-km wide stripmap swath

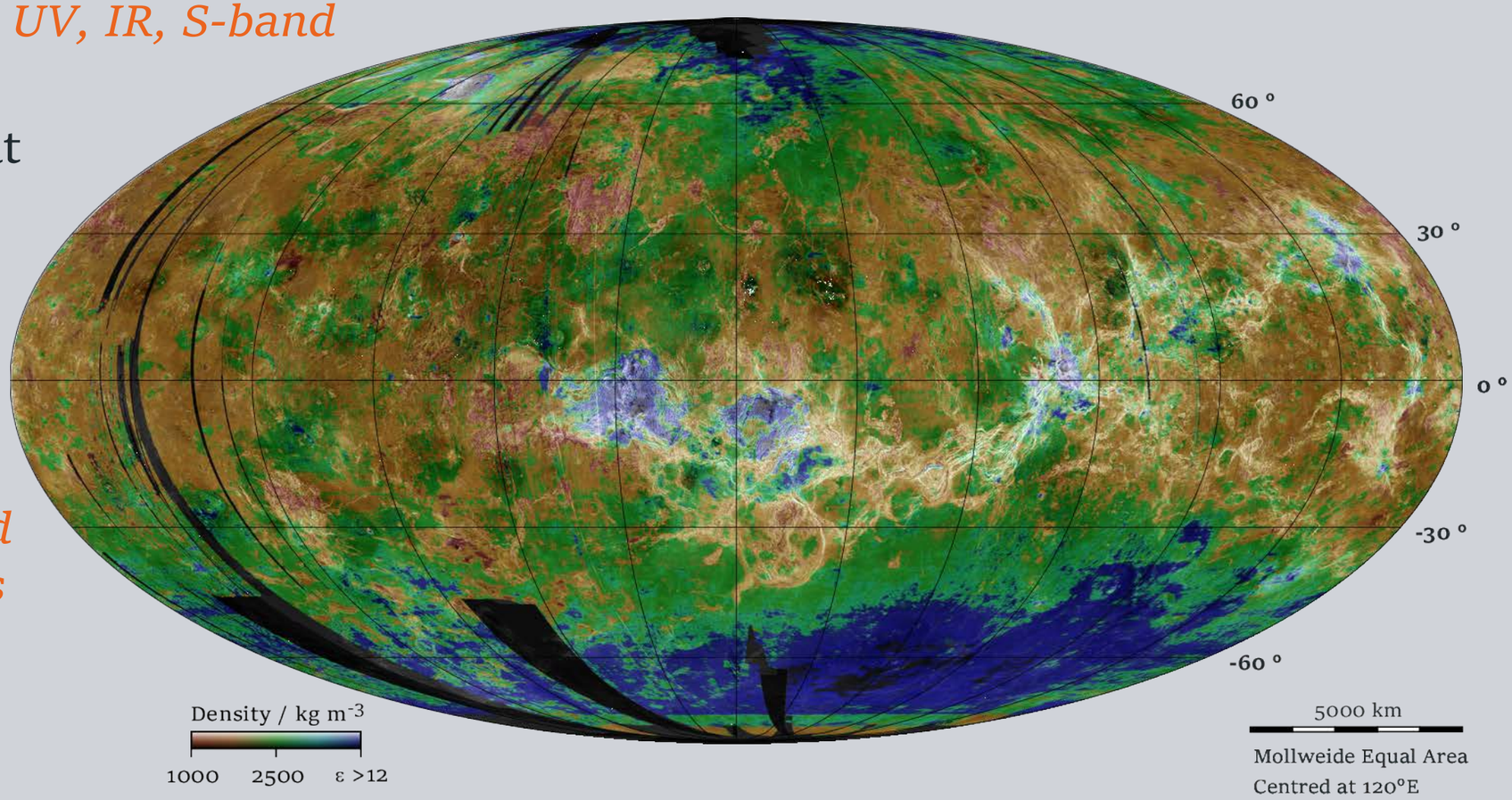
- Reaching ≤10 m resolution used for selected targets, including Venera landing sites
- Nested data are essential for understanding context and global significance
- The combination of interior, surface, and atmospheric data is key to understanding processes and cycles



# High-res (1 – 10 m resolution) imagery

# Holistic nested data

- To really learn about Venus, we need to use all the available types of data that can be acquired from orbit
  - *EnVision delivers gravity, UV, IR, S-band and sounding radar*
- We need to link observations at all scales
  - *EnVision delivers nested data from global to 1 m*
- We need to understand change
  - *EnVision delivers repeated observations over 4 Venus days (32 months) with IR and InSAR*




# EnVision the future of Venus exploration

UNDERSTANDING WHY OUR CLOSEST NEIGHBOUR IS SO DIFFERENT

# EnVision warmly invites your participation and support.

More information: www.envisionvenus.eu

Lead proposer: Richard Ghail (Royal Holloway)

Deputy Leads: Colin Wilson (Oxford U) &
Thomas Widemann (Paris Obs)