EnVision

Science Study Team

System Engineering Working Group

ESA Study Team

/ work in progress /

EnVision:
ESA M5 candidate mission to Venus

UNDERSTANDING WHY OUR CLOSEST NEIGHBOUR IS SO DIFFERENT

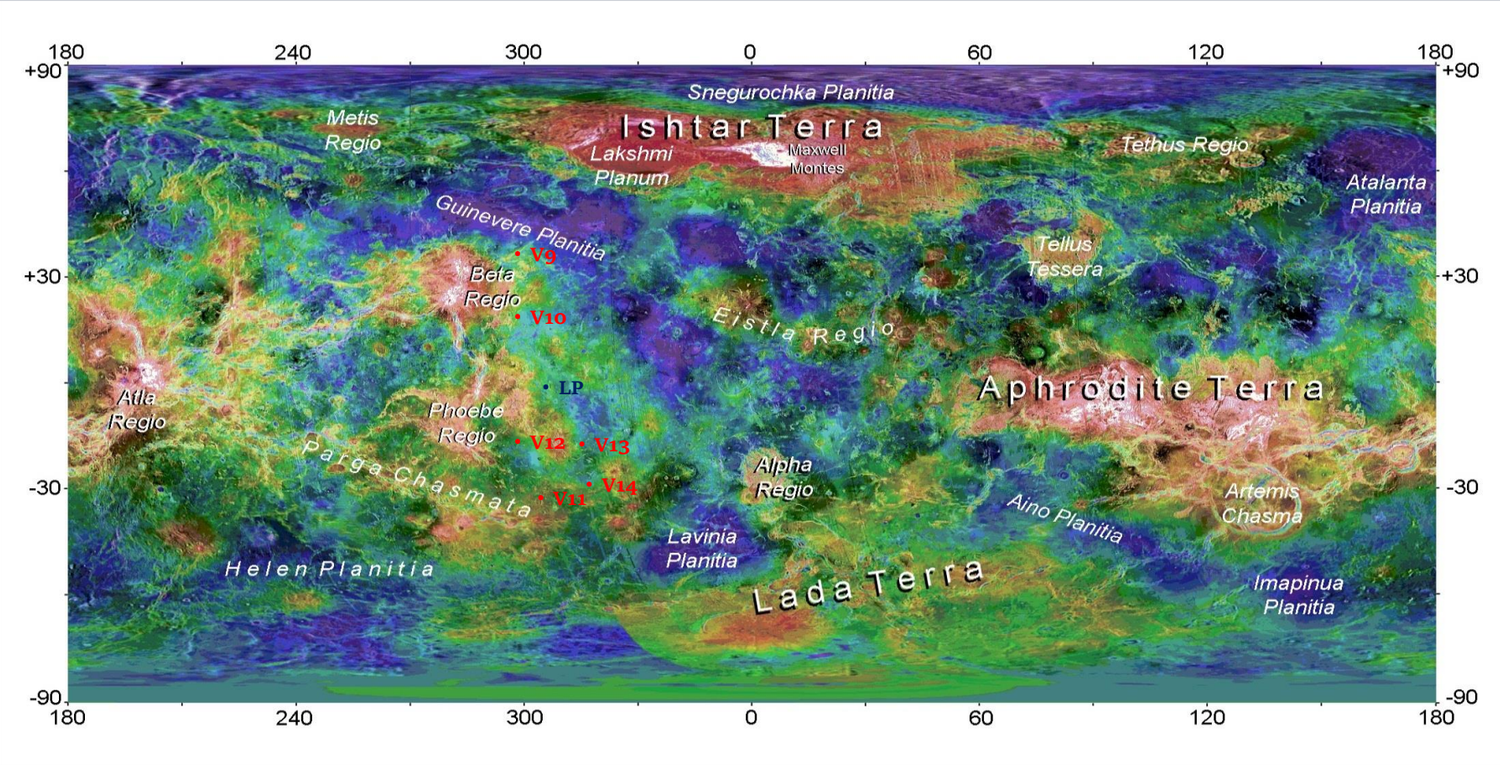
Venus surface

- **Global map**
  - *80% basalt lowlands*
  - *20% tesserae*
  - *unimodal surface height distribution*

- **Rare impact craters with random distribution over the planet**
  ⇒ no Earth-like plate tectonics
  ⇒ relatively young surface (< 1 By)

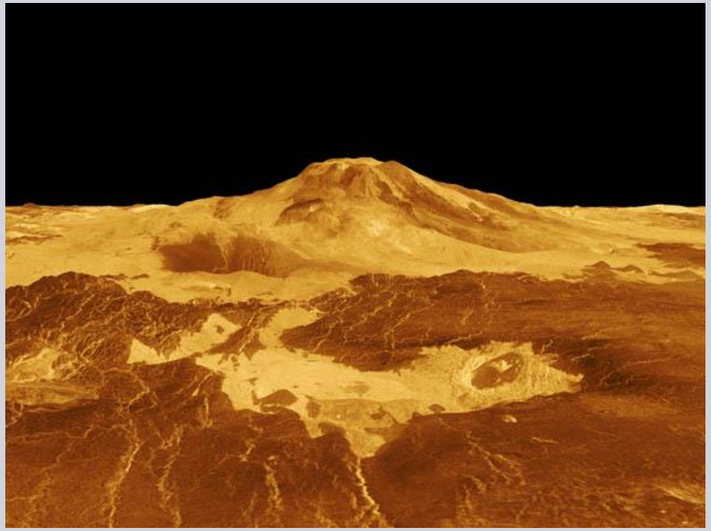
- **Very slow weathering**

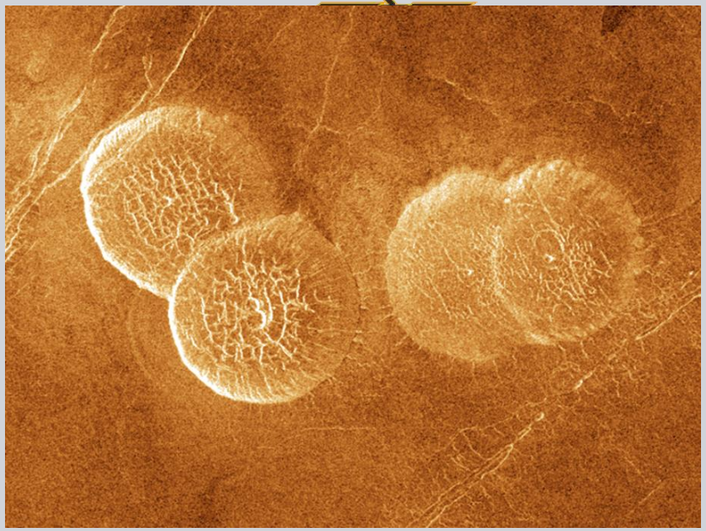
- **Ancient ocean influenced the morphology and geochemistry of the planet ?**

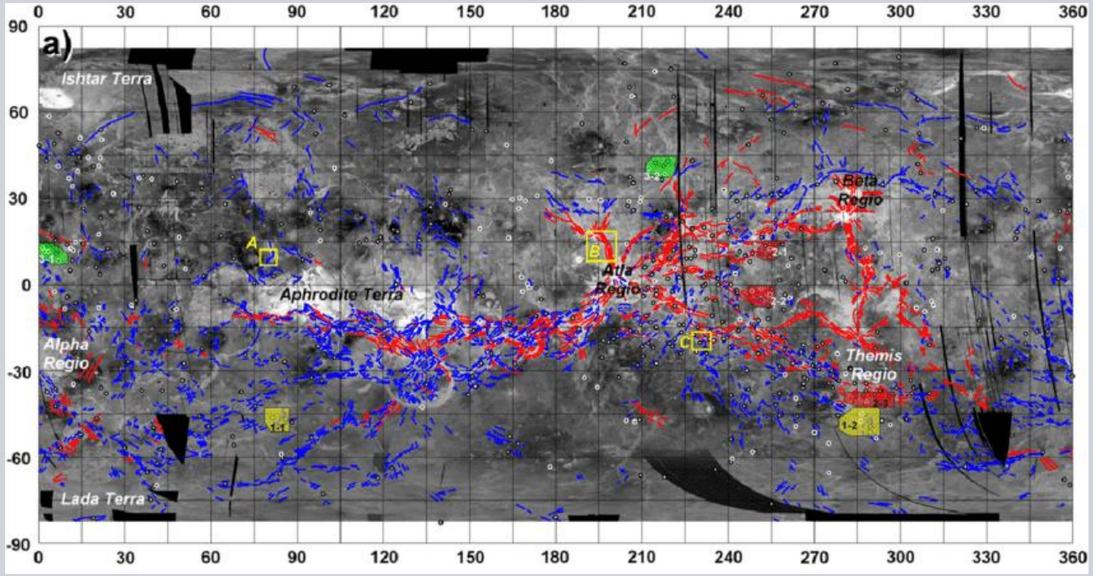


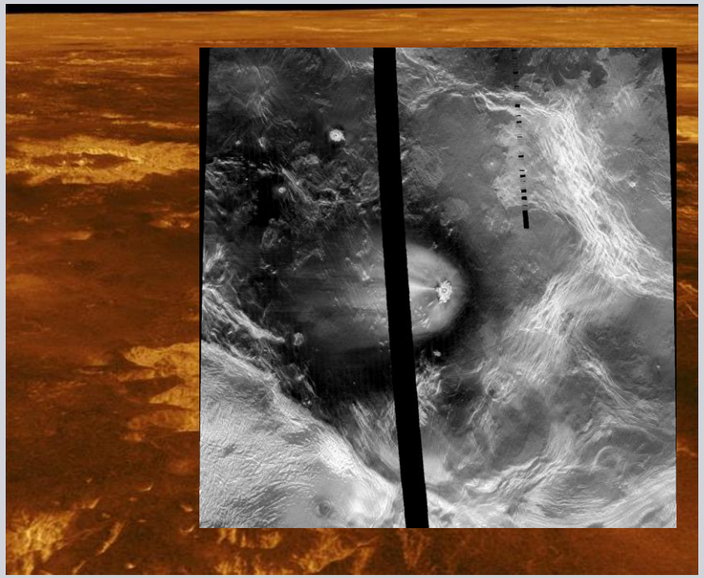
Surface features

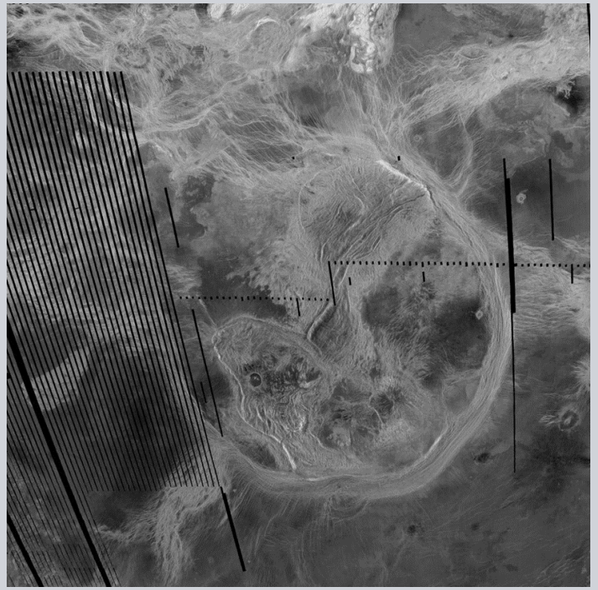
- Different kinds of volcanoes
- Coronae
- Impact craters
- Aeolian features
- Rift zones



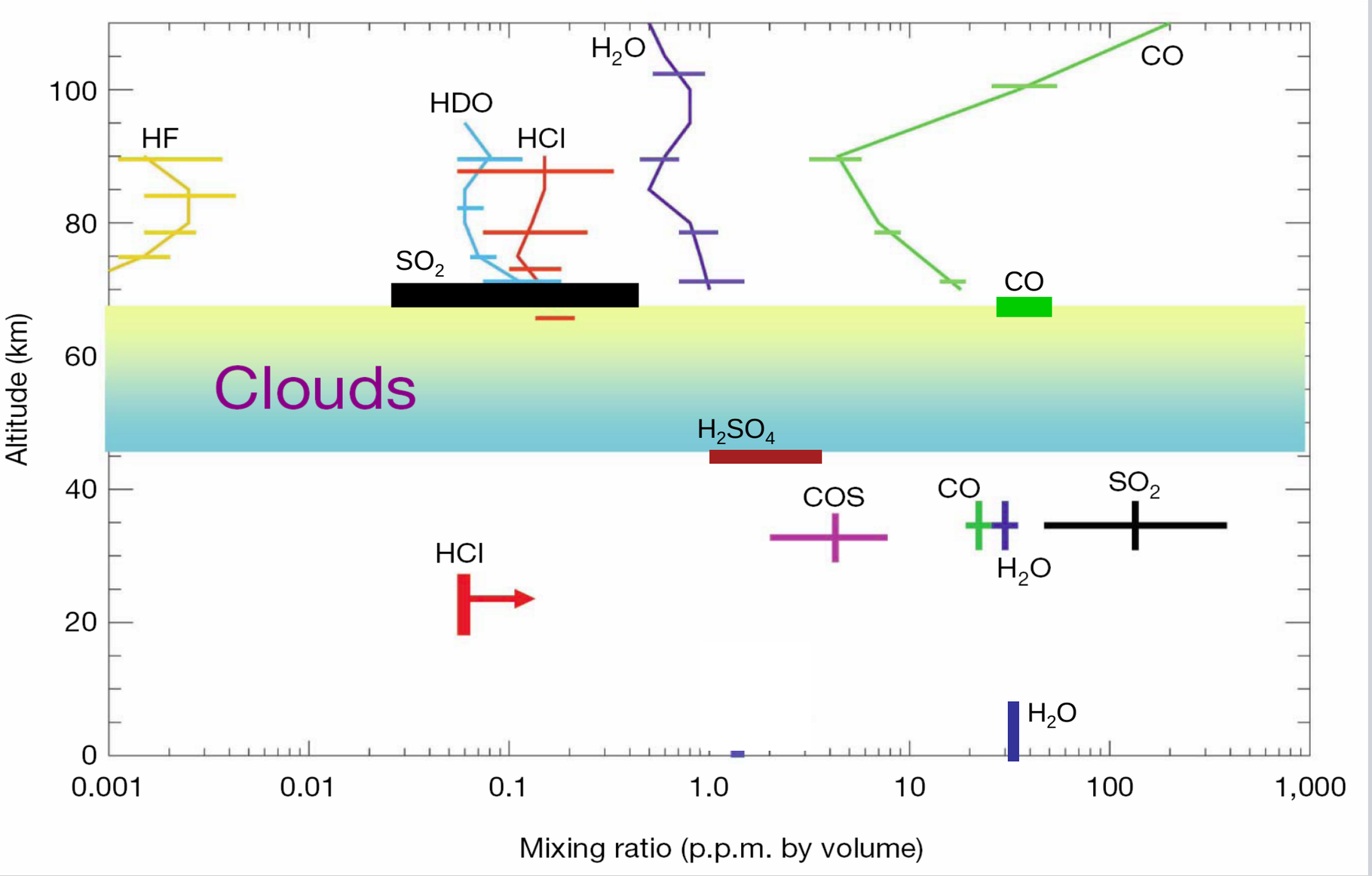


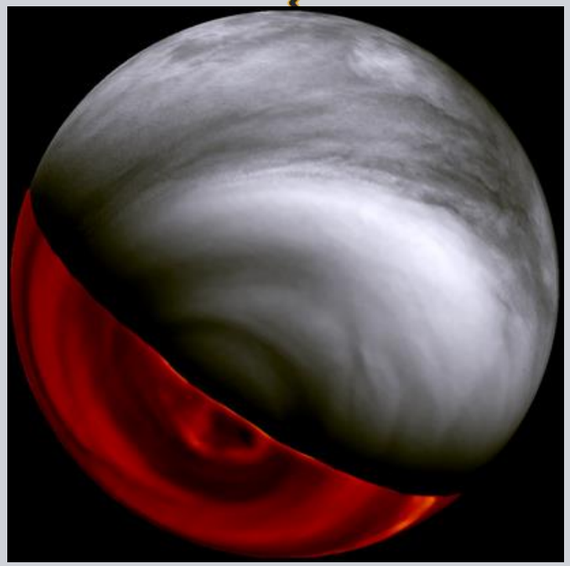






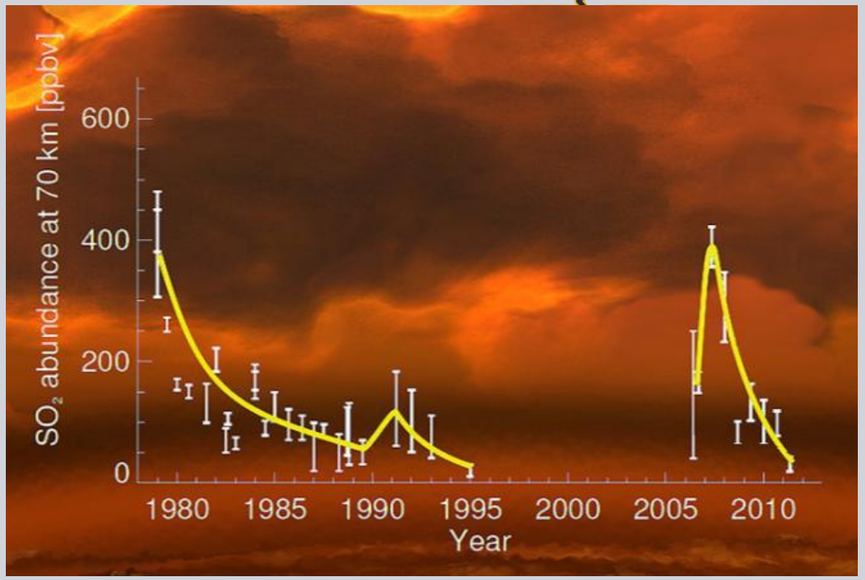
Venus atmosphere

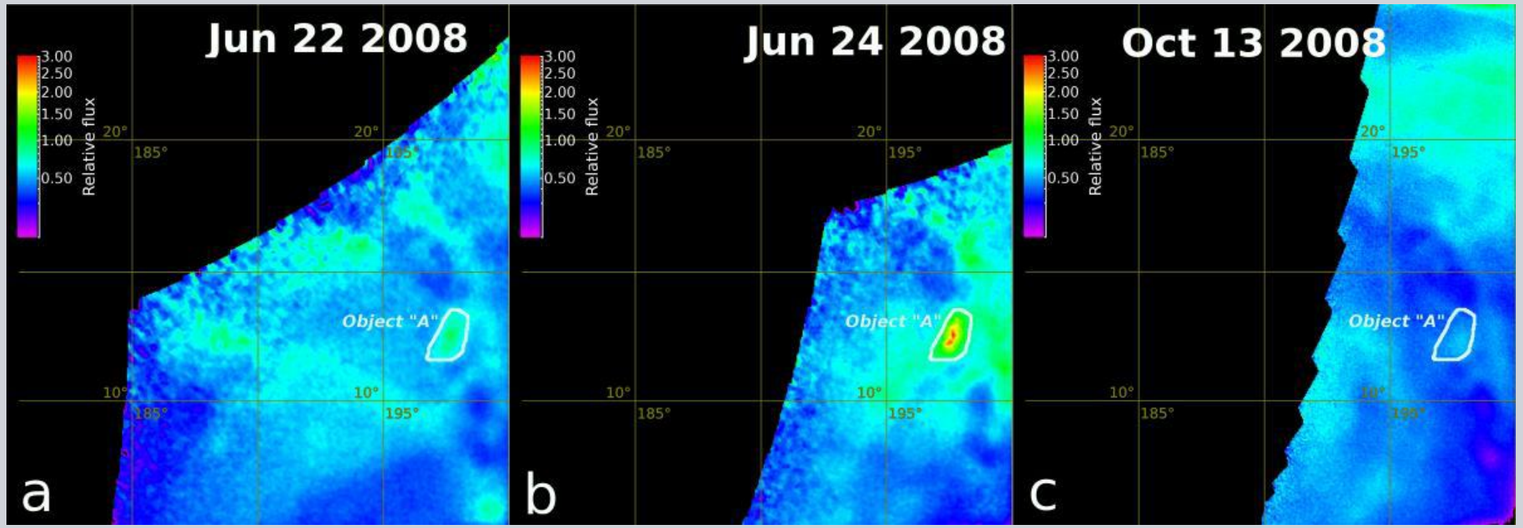


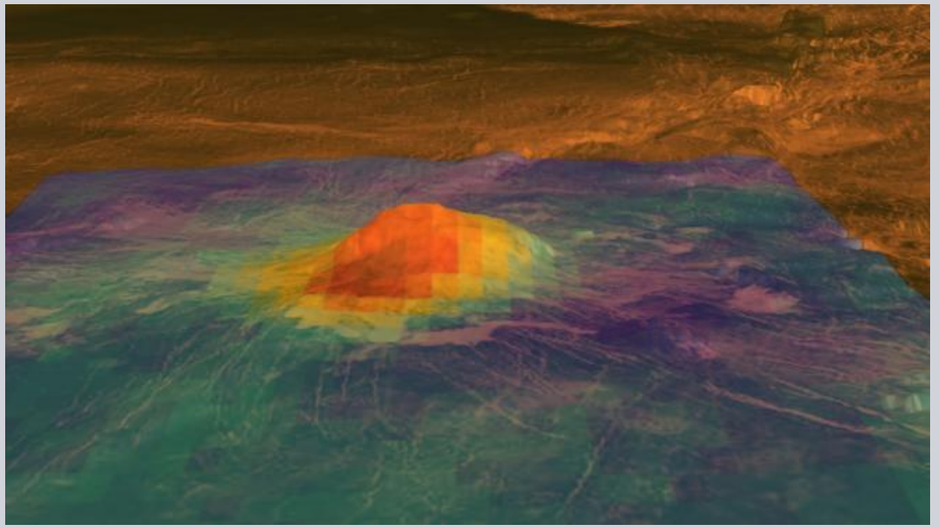


Hints at active volcanism

- *Episodic variations of mesospheric SO_2*
- *High emissivity near hotspot volcanoes: unweathered lava?*
- *Temporal changes in thermal emission from surface: a volcanic eruption caught in the act?*







Science Themes

I. Activity – *How geologically active is Venus today?*

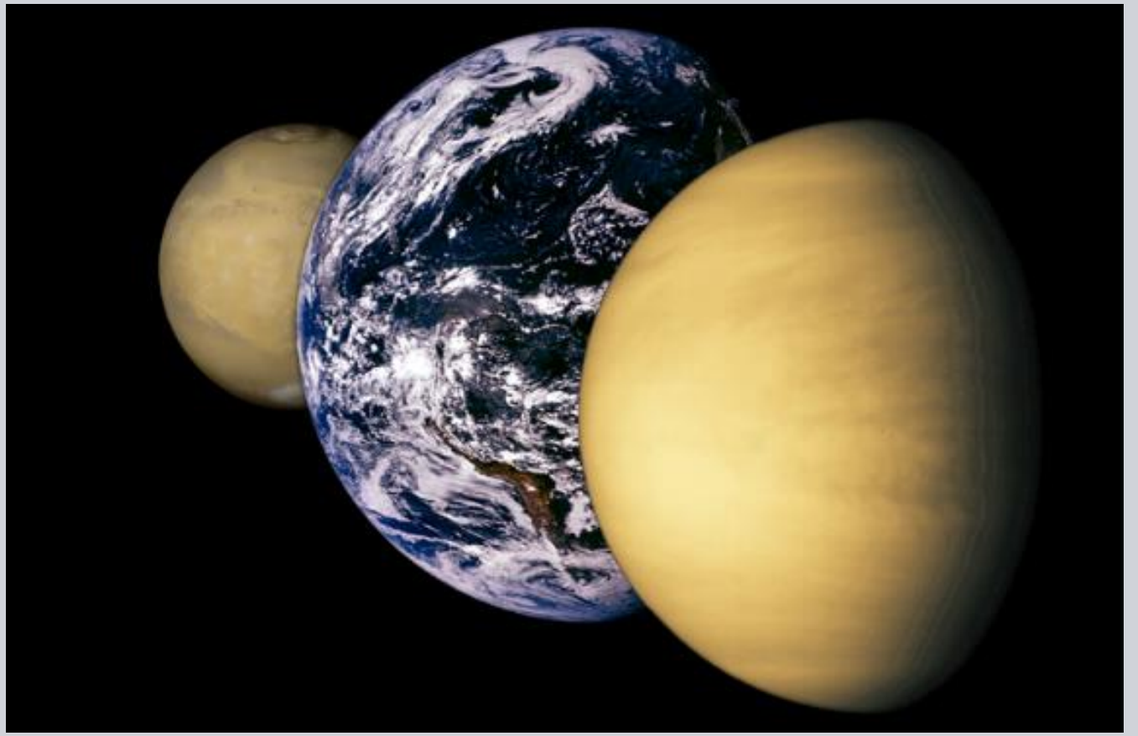
II. History – *How has Venus evolved through time?*

III. 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



I. How active is Venus today ?

Science objectives

Volcanic activity

Tectonic activity

Landscape changes

Nature of radar-bright highlands

Spatial (~100 km) and temporal (hours – years) **variations of T_{surf}** in volcanically active regions

Reconnaissance scale:
Changes in surface morphology (30 m resolution) on selected targets: EV-MGN and EV-EV comparison

Exploration scale:
Changes in surface morphology (10-5 m resolution) on selected targets

Spatial and temporal variations of volcanic gases
(1) near-surface H_2O, (2) SO_2 and H_2O at the cloud top (3) H_2SO_4 at 60-45 km (~ 1 ppm accuracy)

Surface topography to characterize volcanic and gravity driven processes

II. How has Venus evolved ?

Science objectives

Origin of plains and tesserae

Characterization of volcanic and tectonic features

Crust and lithosphere

Interior structure

Mapping geological units

Relative dating based on impact craters and geomorphology

Regional imagery of representative 10-20% of the surface (1500x1500 km @ 30 m/px)

High-resolution nested imagery at 5-10 m resolution at targeted sites

Determine surface composition by mapping near-IR and microwave emissivity

Constrain surface physical properties using radar polarimetry and emissivity

Search for subsurface boundaries within the top 1 km of crust

Map thickness of crust & lithosphere through improved gravity mapping with resolution < 200 km

Constrain interior structure through gravity & spin vector observations

III. What made Venus climate so hostile ?

Science objectives

Variability of tropospheric and mesospheric gases and its link to volcanism

Variability of cloud particulates and its link to volcanism

Surface-atmosphere chemical interactions

Spatial and temporal variations of minor species in the troposphere with tbd sensitivity and their variations on time scales from hours to years and spatial scales of <100 km

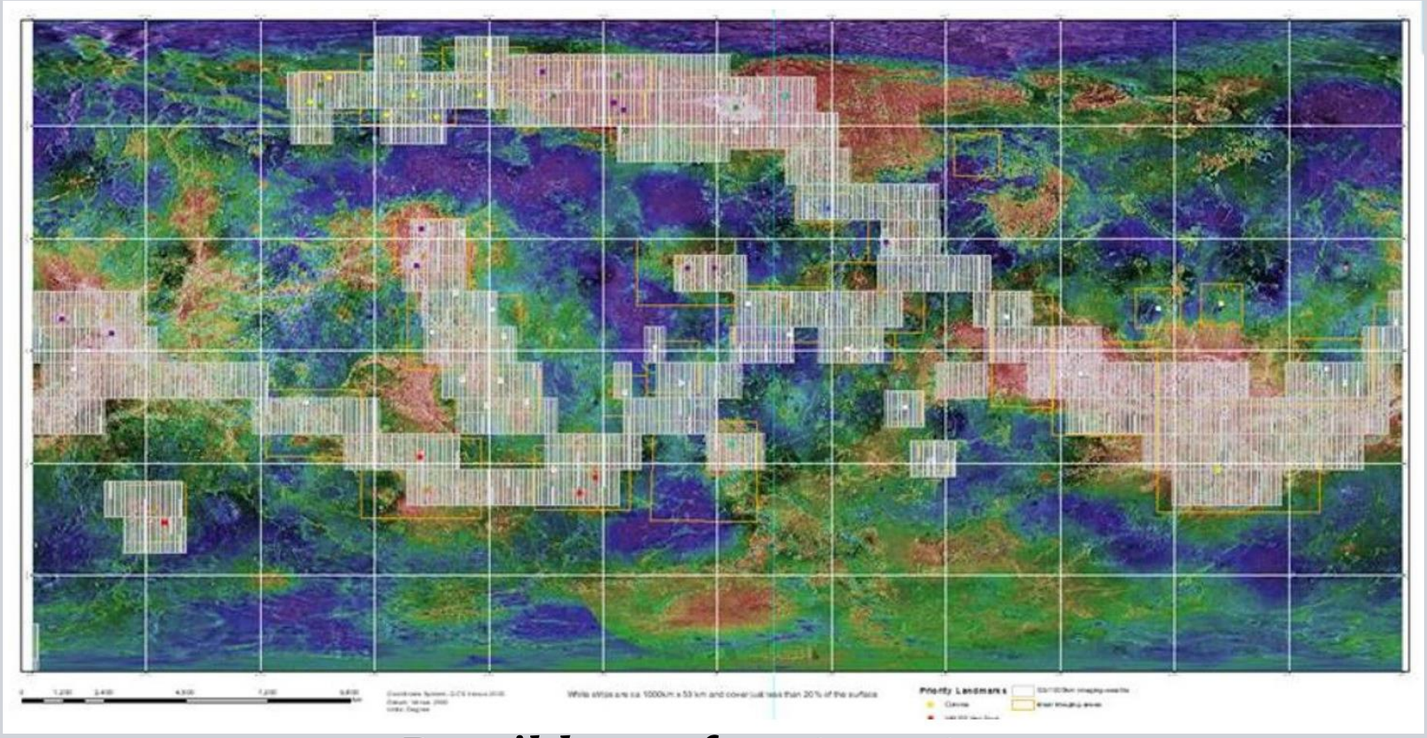
Vertically integrated total cloud opacity, cloud properties and their variations on time scales from hours to years and spatial resolution of ~ 100 km (tbc)

Spatial and temporal variations of key trace gases at the cloud top (65-75 km) with tbd sensitivity on timescales from hours to years and spatial resolution from 50 to 3 km

Cloud top properties and their variations on time scales from hours to years with spatial resolution from 50 to 1 km, including spatial distribution of the unknown UV absorber

SAR (Synthetic Aperture Radar)

- ***recconnaisance*** **observations with 30 m resolution**
  - *~20% of the surface (repeated)*
  - *polarimetry*
  - *Radiometry*
  - *stereo and interferometry*
  - *altimetry*
- ***exploration*** **imagery at 5 m (spotlight) to 10 m (stripmap) resolution and 20 km swath**
- **cm-scale deformation (in work)**



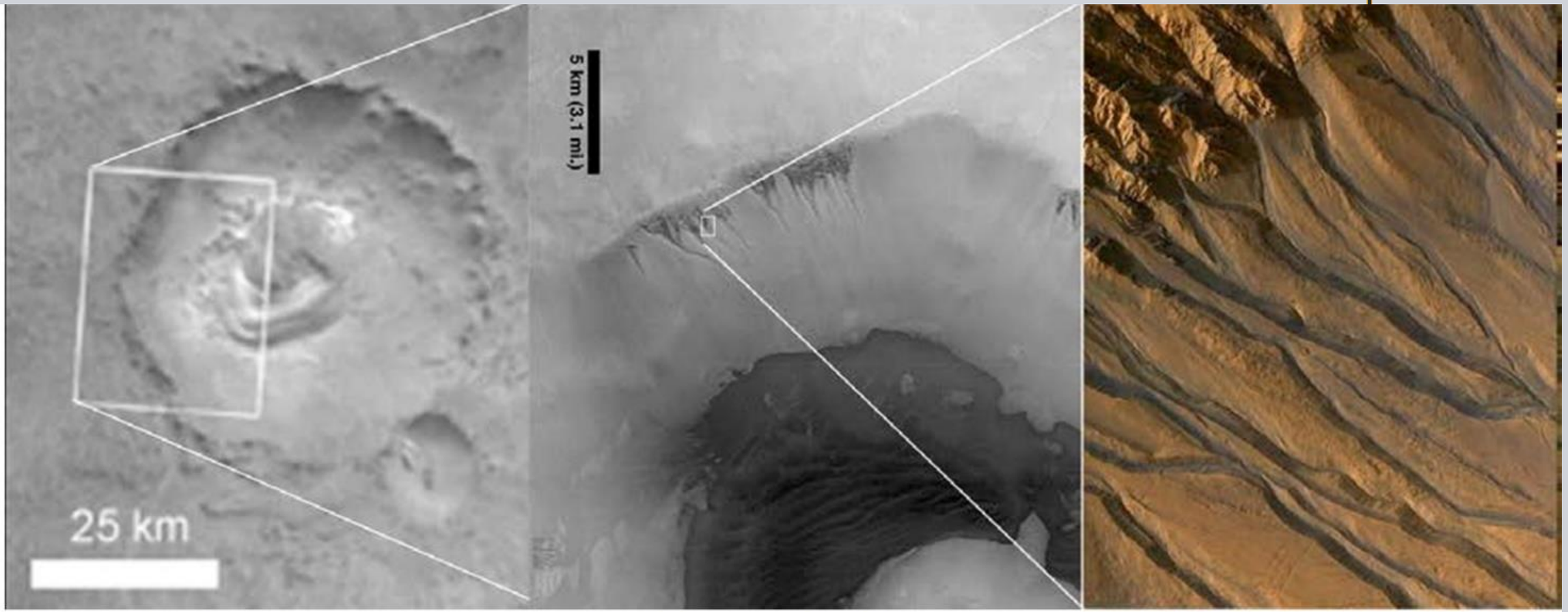
Possible surface targets

SAR imaging hierarchy

Targets for EnVision SAR observation

	Global	Regional	Reconnaissance	Exploration
Feature size	10,000 m	1000 m	**100 m**	**10 m**
Envision spatial resolution	50 km	1 km	30 m	5-10 m
Envision coverage (% global)	use Magellan	use Magellan	**20%**	**2%**
EnVision coverage (km²)	use Magellan	use Magellan	**92,000,000 km²**	**9,200,000 km²**
Geomorphological features:				
Structures	Terra "continents"; planitiae; tesserae		chasmata, dorsa	folds, graben
Volcanic features	Volcanic rises (Regiones)		volcanic edifices	lava flows
Sediments	"Featureless" plains		parabolas, haloes	Landslides

SAR “nesting” approach: a Martian lesson



Viking: 150 m / pixel
[*equivalent to Magellan*]

MGS: 20 m / pixel (MGS)

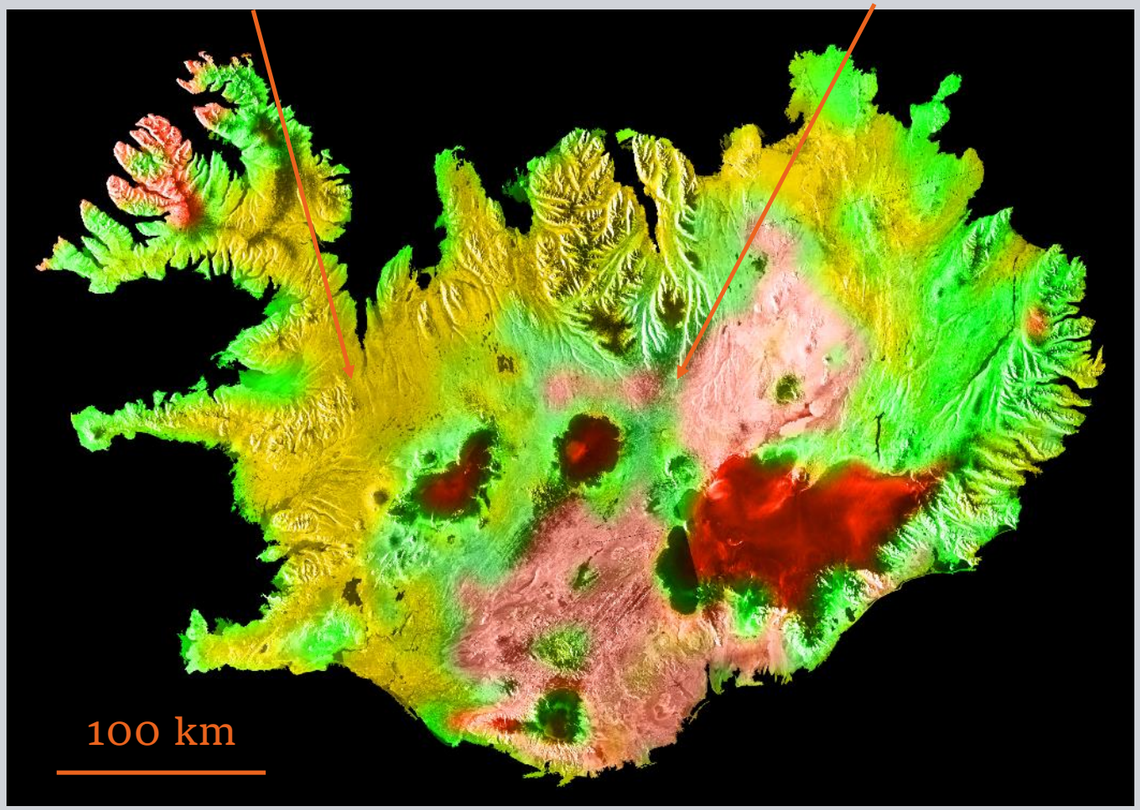
MRO: 1 m / pixel

Reconnaissance scale (10^3 km @ 50m/px)

SAR emissivity

Weathered basalt
[*low permittivity*]

Fresh basalt
[*high permittivity*]

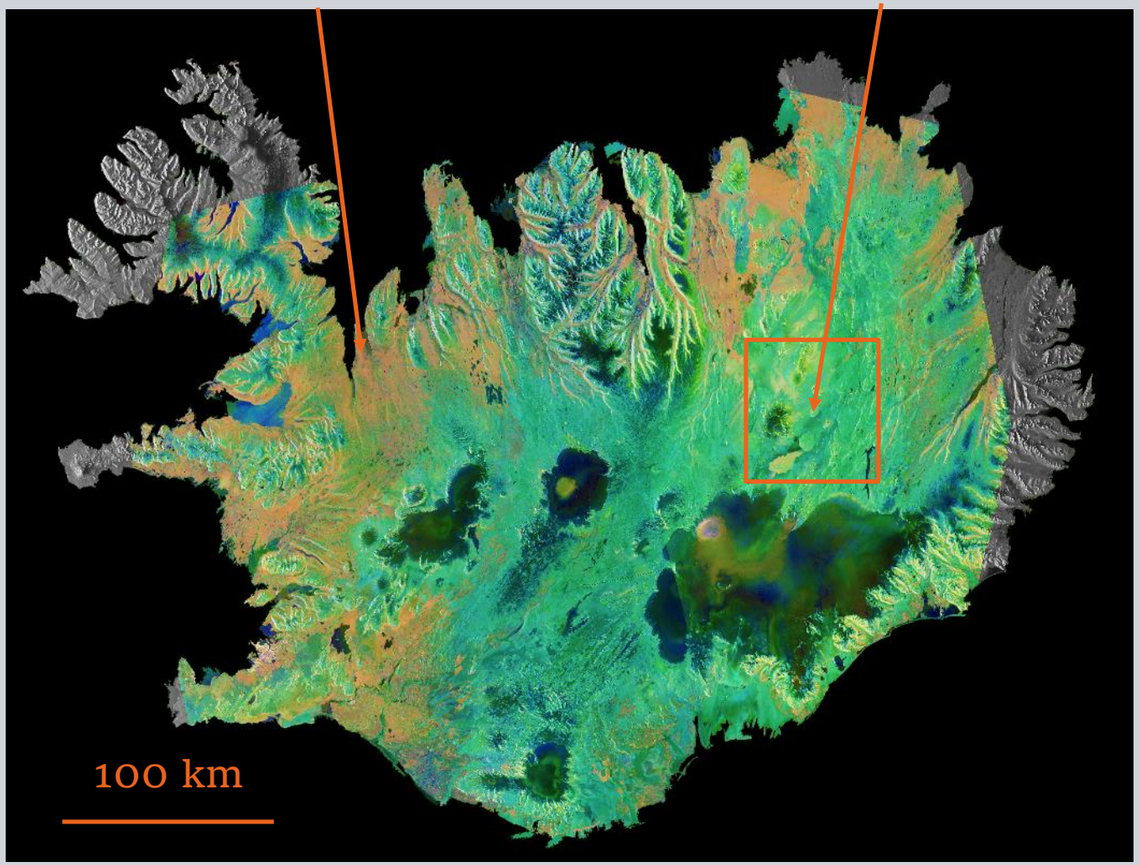


Simulated colour-coded emissivity [*relative permittivity*]

SAR polarimetry

Granular material
[*weathered lavas, soils*]

Rough bare rock
[*aa lava, boulders*]



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

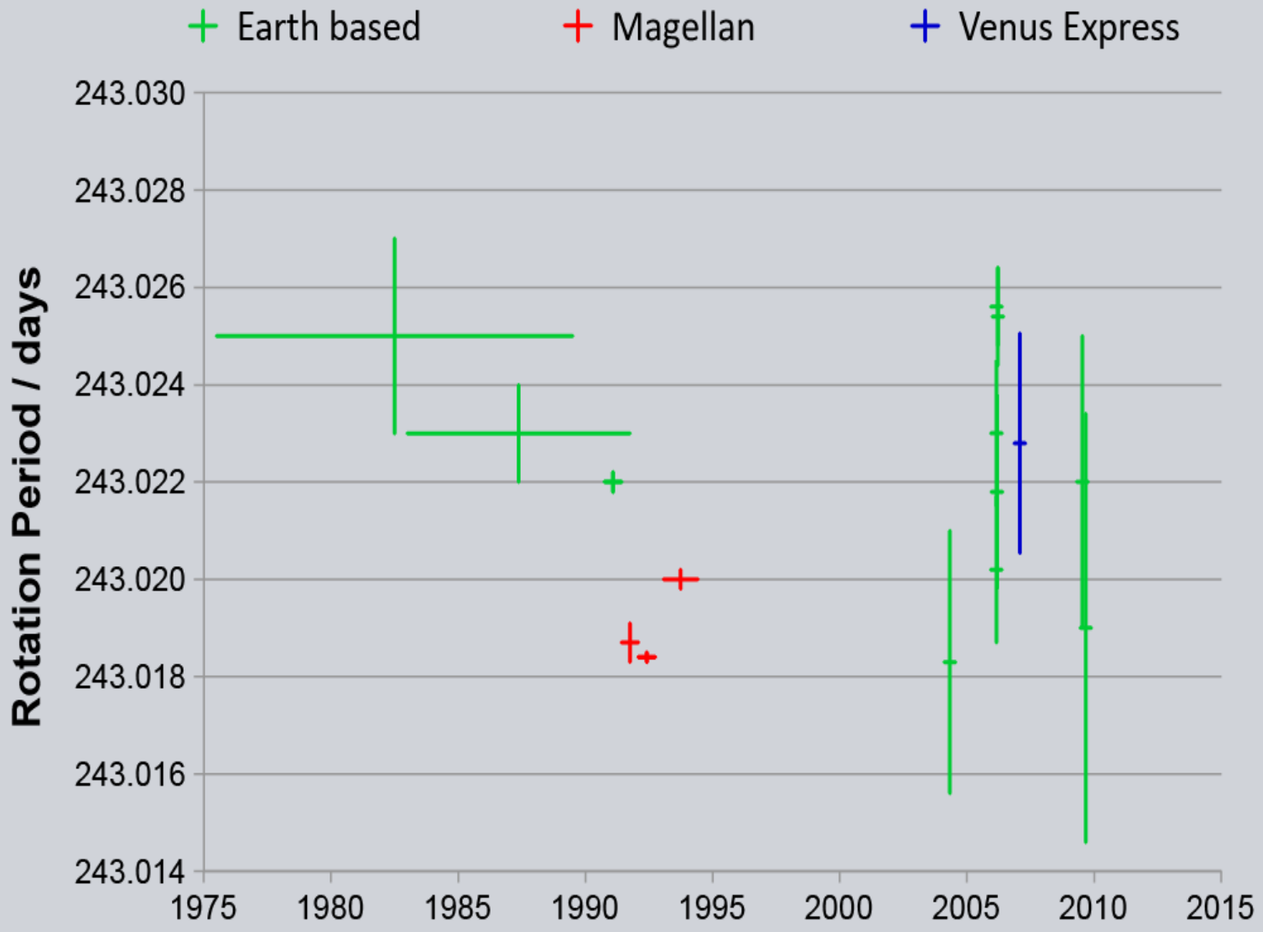
VenSAR Geodesy

- **Planetary ephemerides**

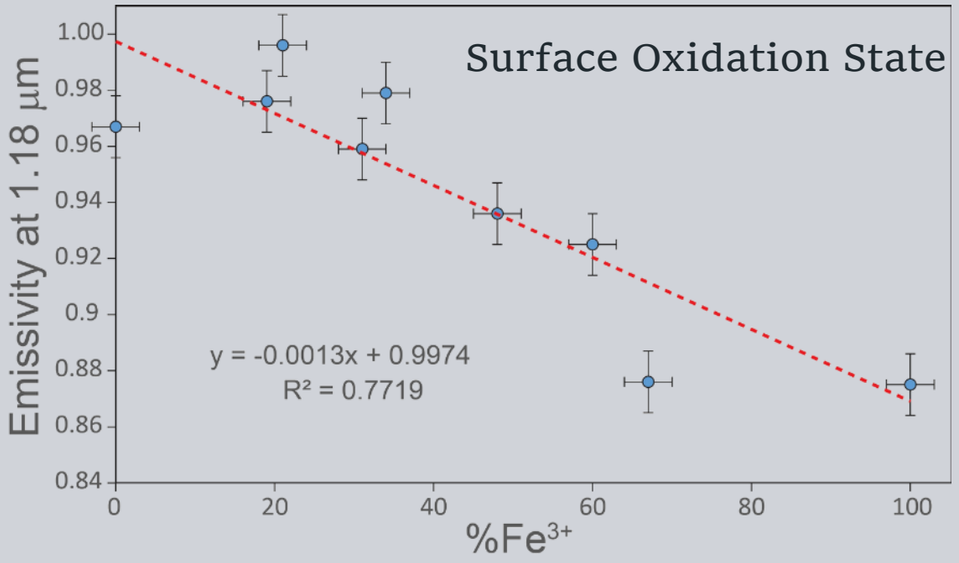
  Spin axis wobble, improved GR, GM and J_2

- **Length of Day**

  Measure and understand variability in spin rate



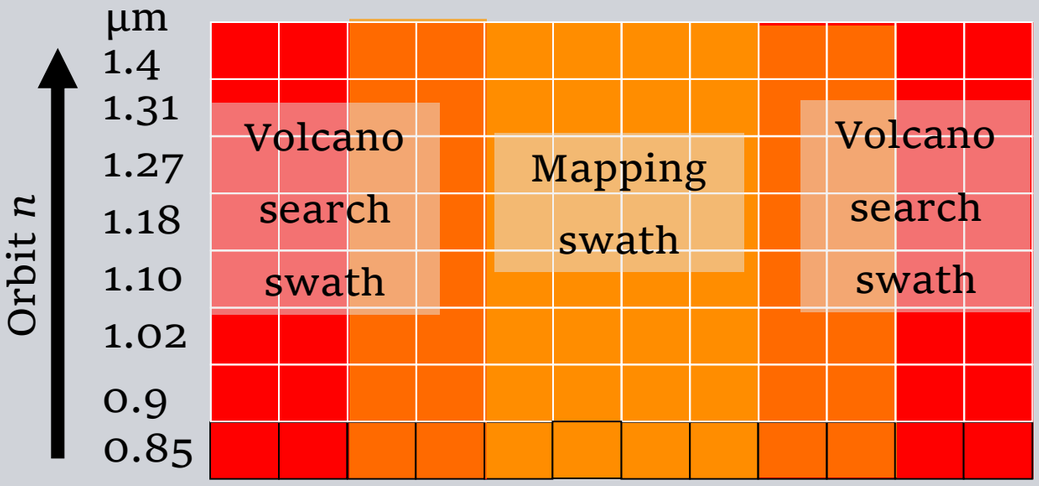
VenSpec-M
surface imaging in the near-IR spectral “windows”



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

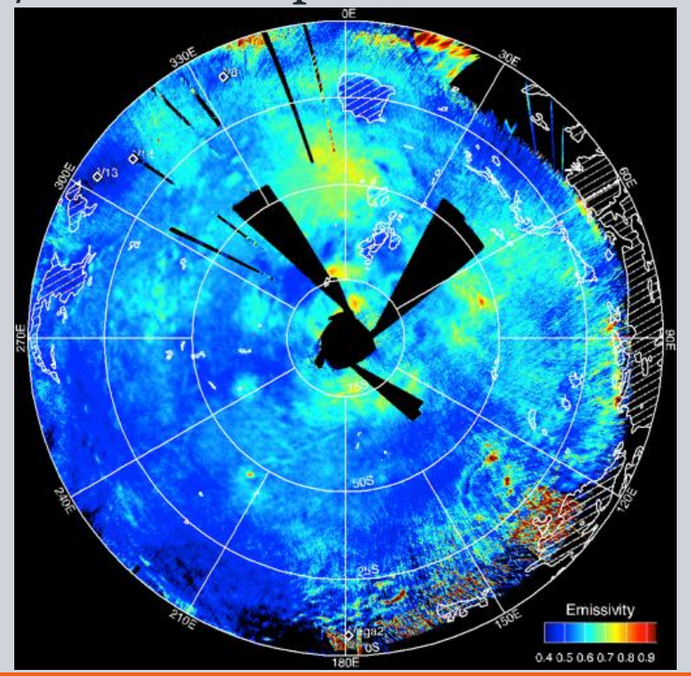
- *map **surface composition** on a global scale*
- *monitor for **volcanic activity/ weathering***
- *map **water vapour abundance** near the surface*

VenSpec-M will greatly improve sensitivity and spectral and spatial coverage wrt VIRTIS/ Venus EXpress:



Spatial oversampling provides for mapping and confirmation of detected eruptions

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



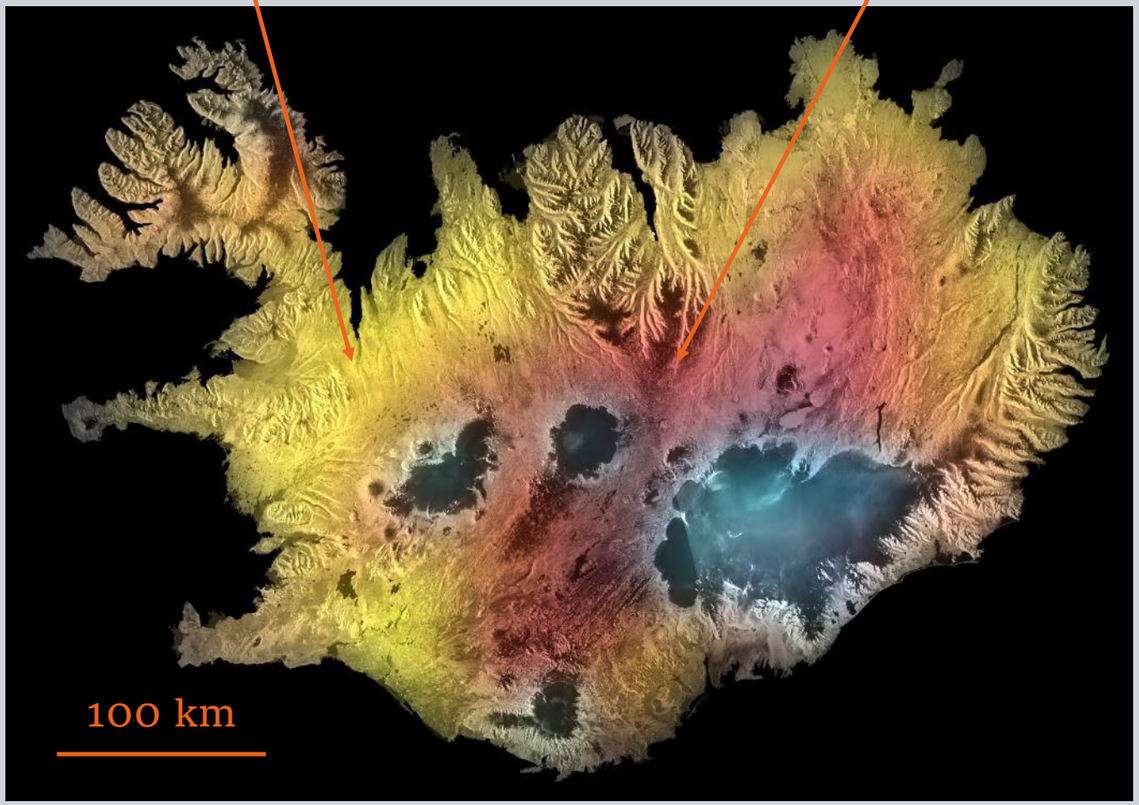
VIRTIS on Venus Express mapped the surface emissivity at 1 µm

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

VenSpec-M emission maps

Weathered basalt [*hematite-rich*]

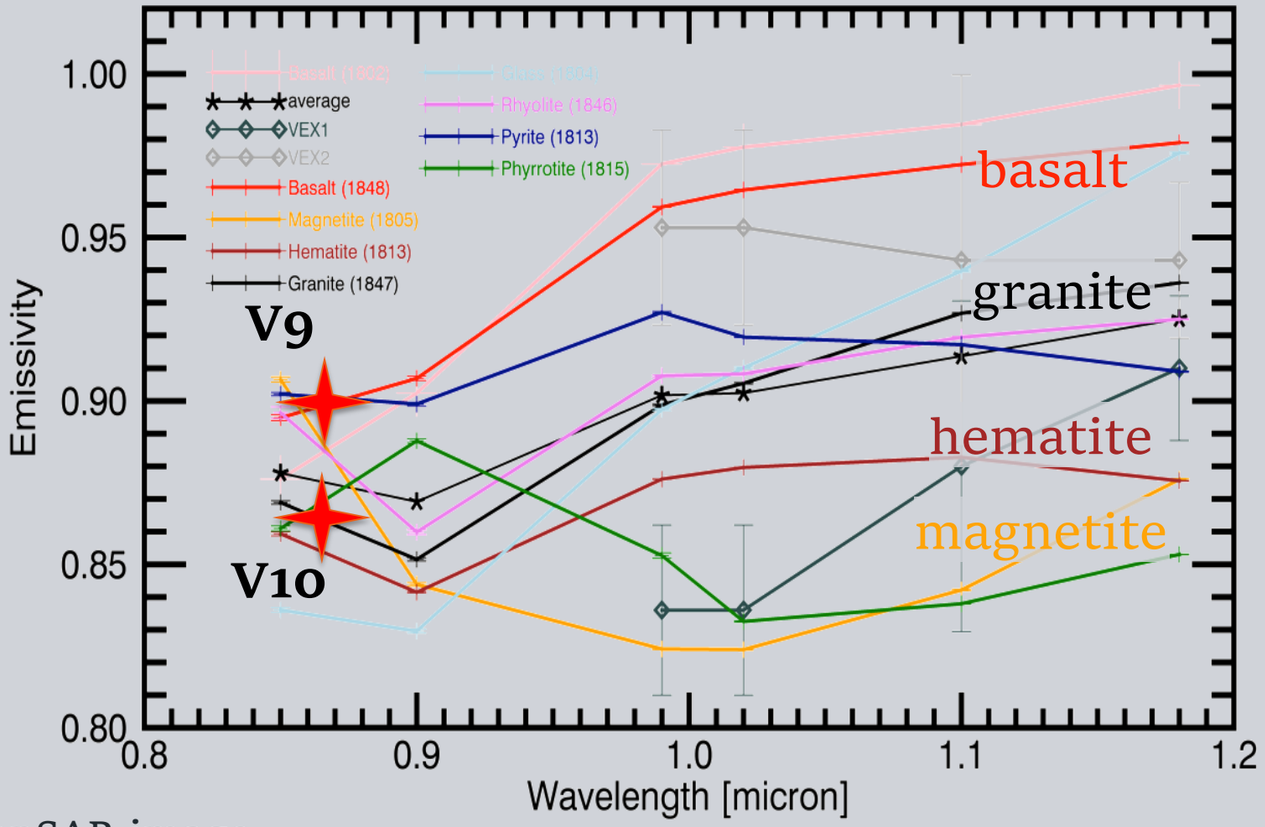
Fresh basalt [*magnetite-rich*]



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

VenSpec-M emission spectra

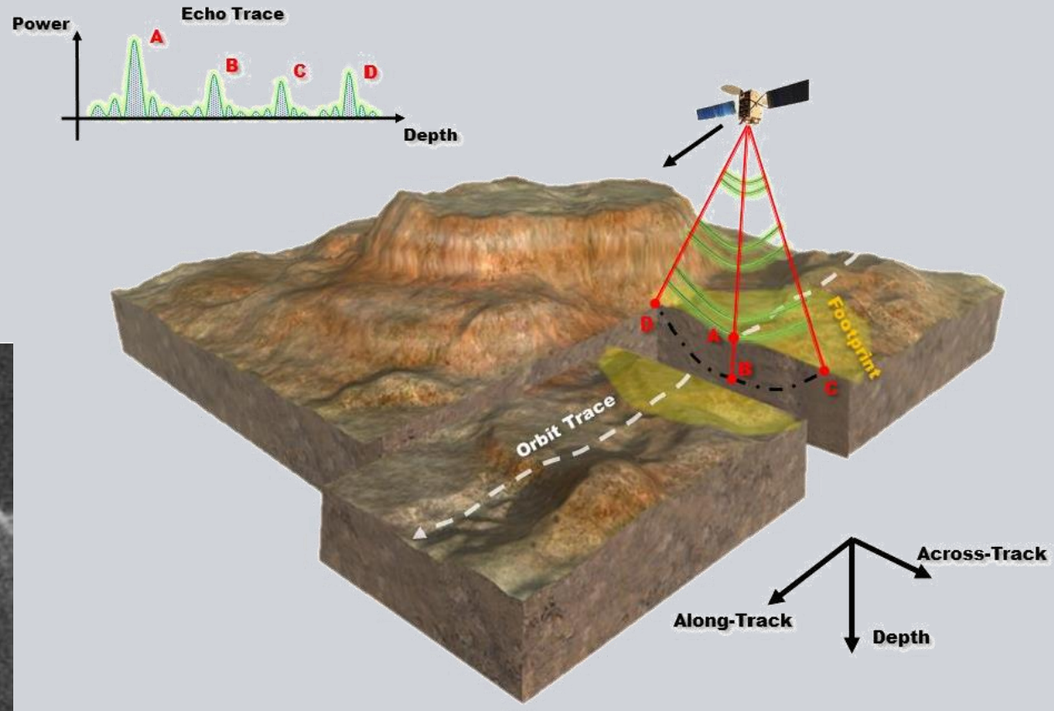
VenSpec-M Spectra of minerals



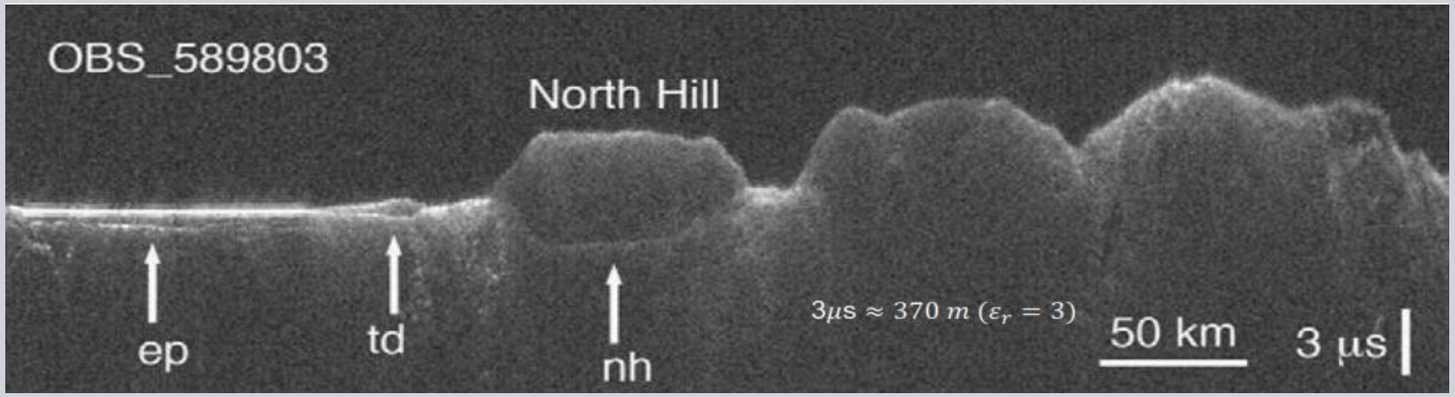
Subsurface Radar Sounder

The **Subsurface Radar Sounder** will acquire information on the shallow Venus subsurface down to 1000 m with vertical resolution of ~10 m 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*

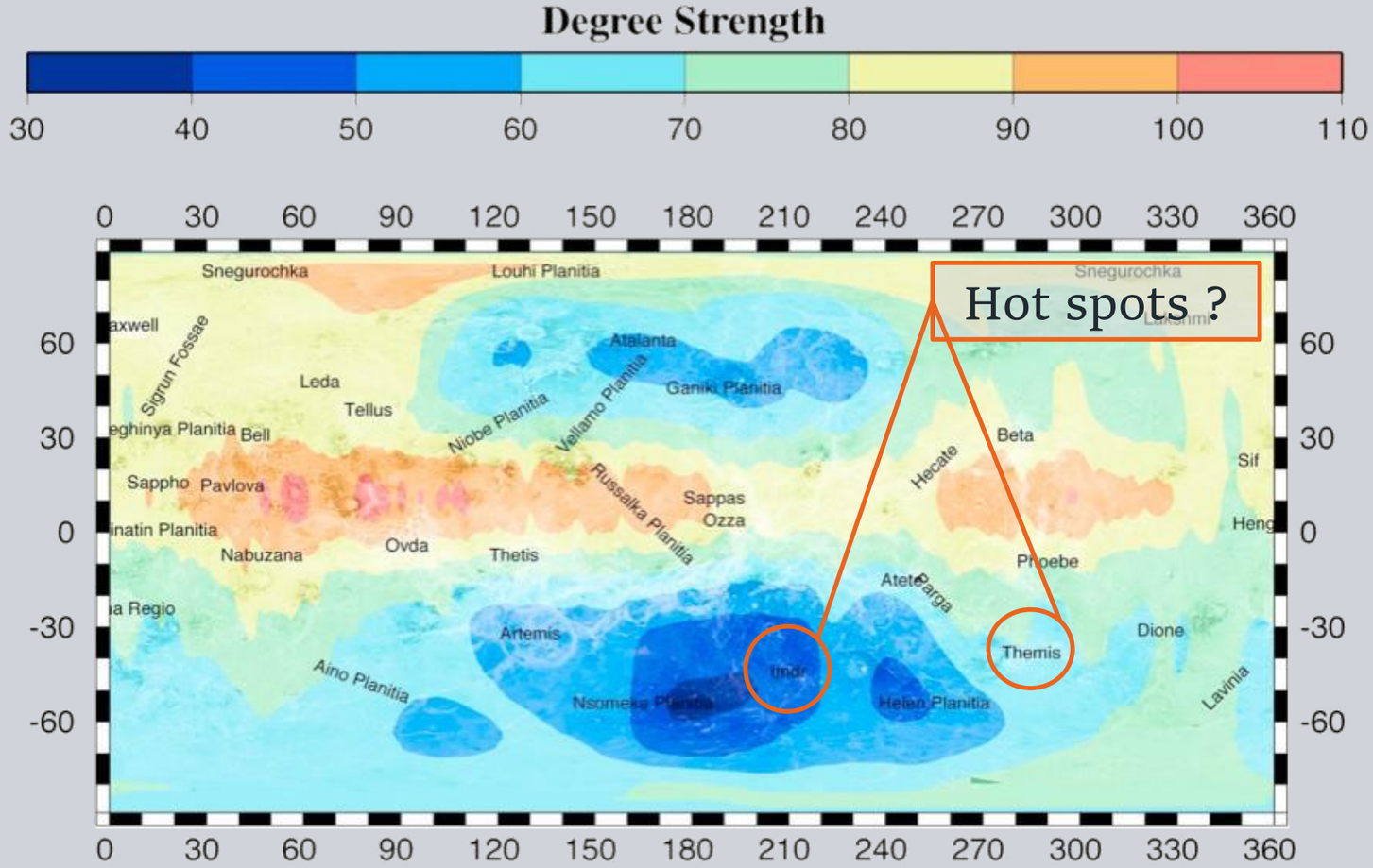


Portion of western Medusae Fossae Formation, Mars, a low-density pyroclastic deposit spanning across the crustal dichotomy on Mars
td: Thin deposit (50–100 m) **nh**: North Hill deposit (~580 m)
ep: Plains reflectors under Elysium Planitia [Carter et al. 2009]



Radio Science experiment

- **Gravity experiment**
  - gravity field at < 200 km resolution
- **Radio occultation experiment**
  - temperature profiles in the mesosphere
  - H_2SO_4 vapour and liquid phase abundance at 60-45 km



Anderson & Smrekar, 2006

VenSpec -H, -U: IR and UV spectroscopy

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

- ***H_2O and HDO*** *in the lower atmosphere*
- ***H_2O, CO, OCS, SO_2*** *at the 30-40 km*

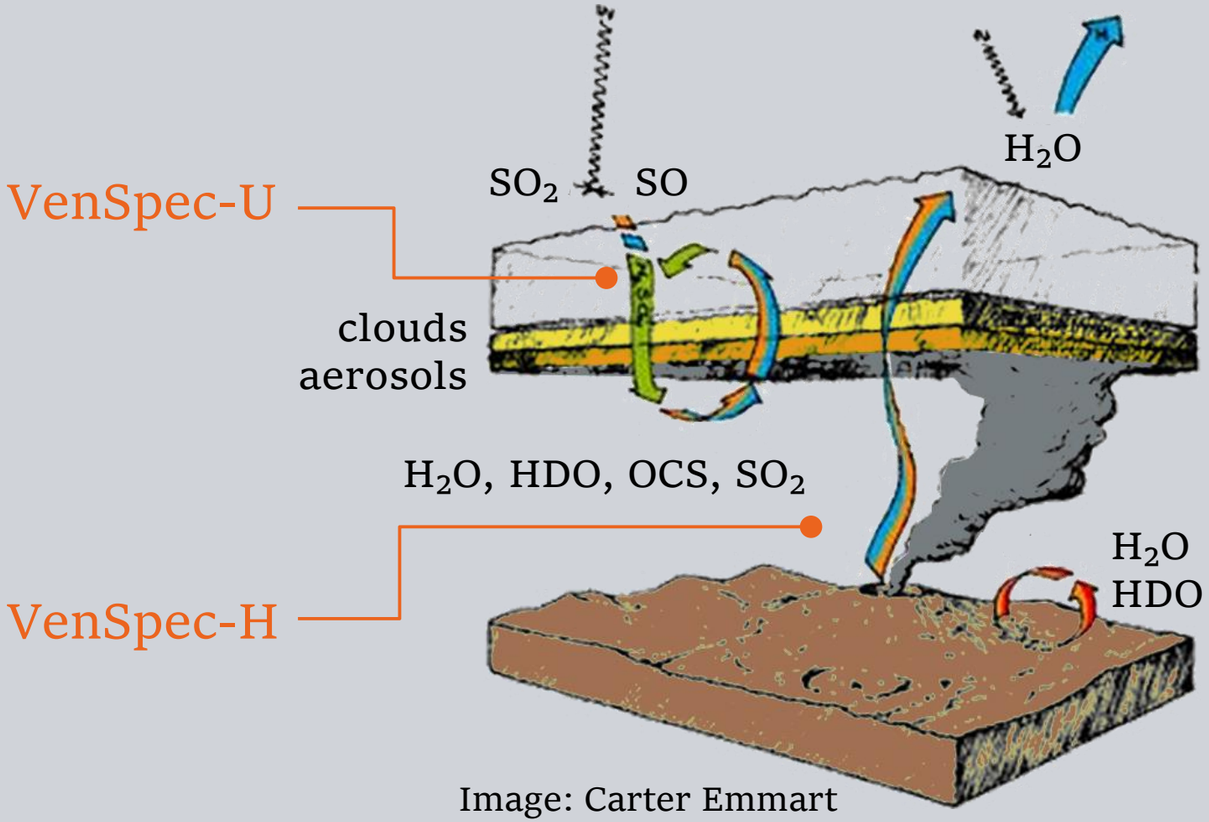
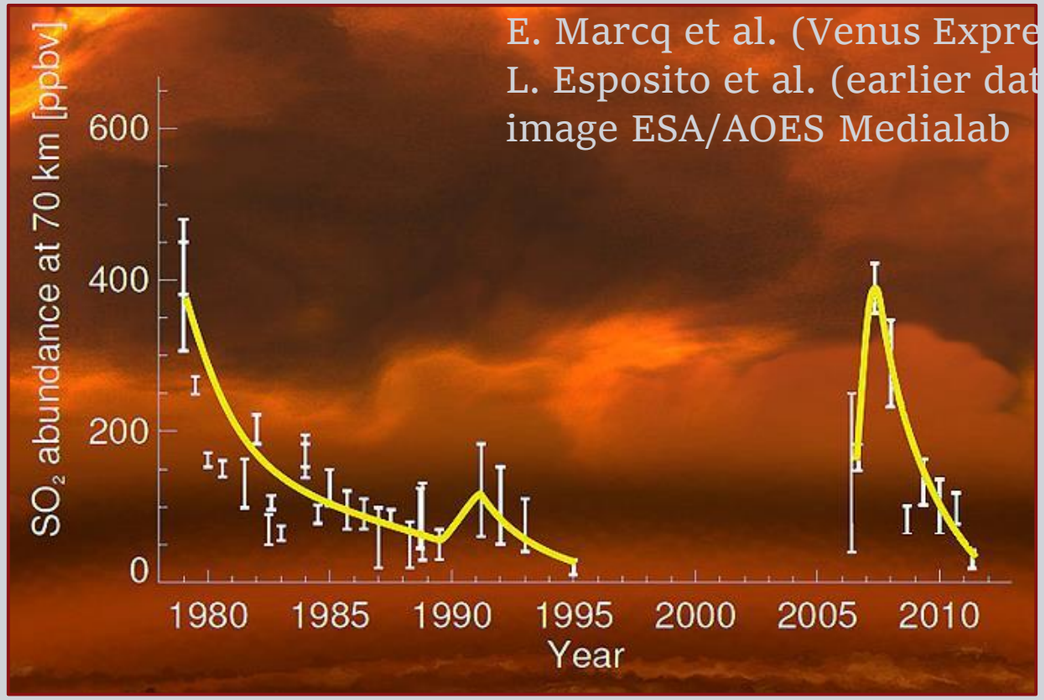


Image: Carter Emmart

VenSpec-U is an ultraviolet spectrometer designed to:

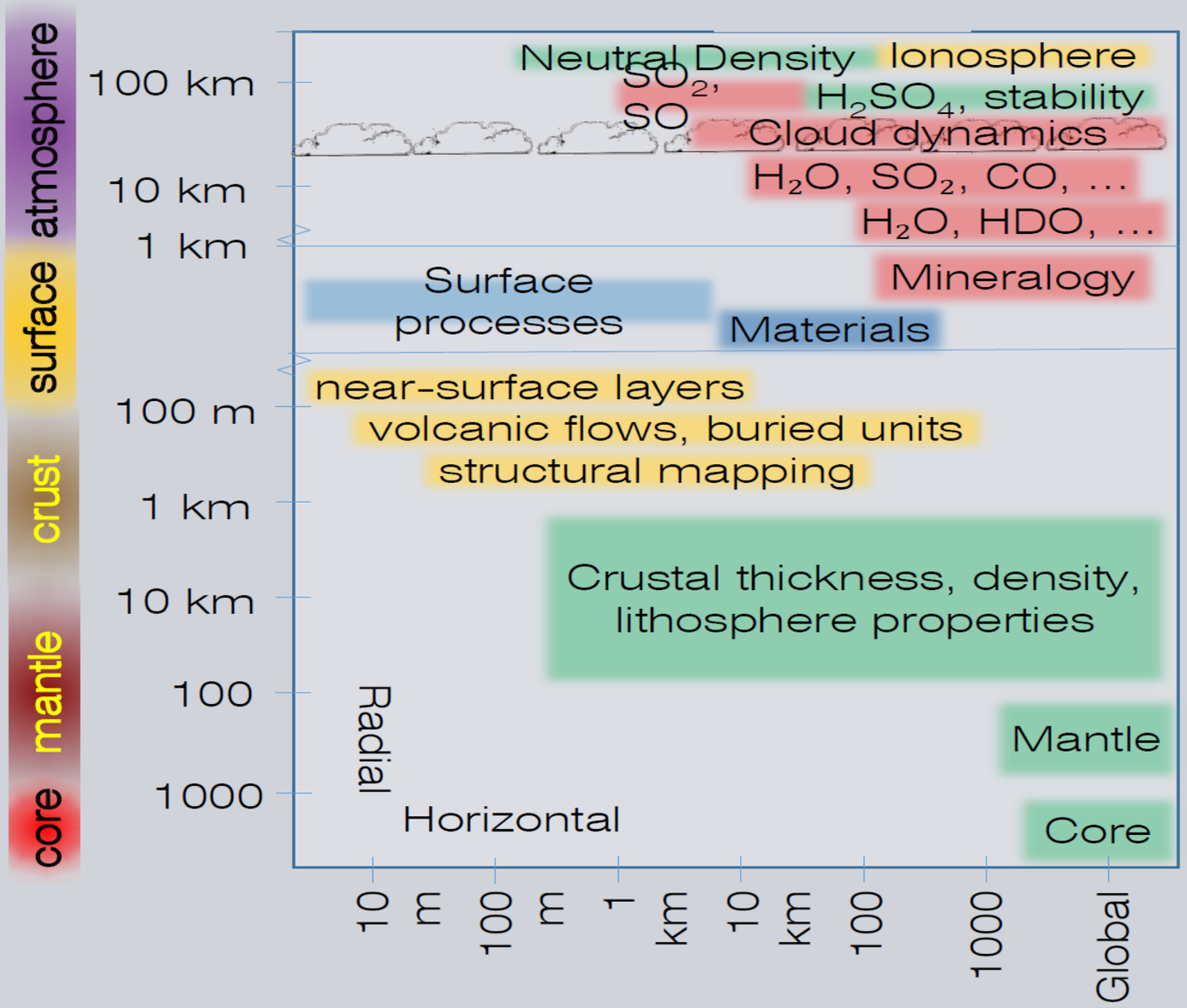
- *mesospheric variability of* ***SO and SO_2, cloud and aerosol properties***
- *distinguish atmospheric dynamics change from volcanic emissions*



Key principles of EnVision observations

- **Nested SAR imaging is essential for understanding context and global significance**
- **Combination of interior, surface, and atmospheric data (co-located and sometimes simultaneous observations) is key to understanding processes and cycles**
- **Careful selection of Regions of Interest – a representative set of surface targets (targeted mission)**
- **Repeated observations over at least 2 Venus sidereal days (cycles)**

Synergy of EnVision payload: a summary



VenSpec

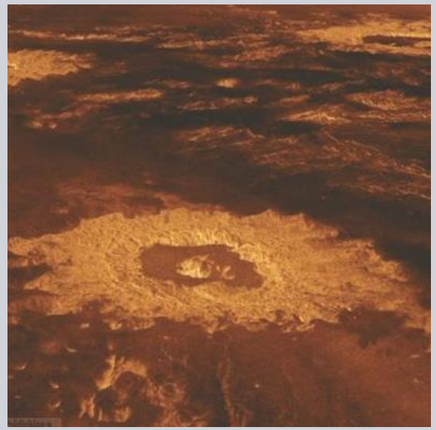
VenSAR

Subsurface Sounder

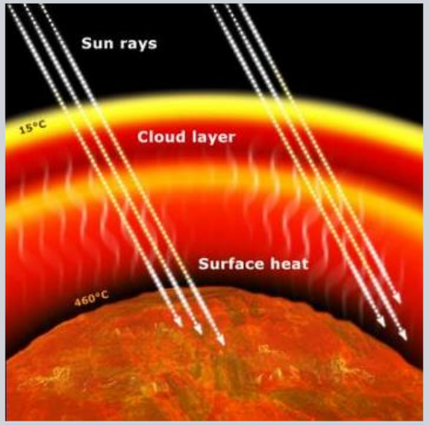
Radio Science

Comparative planetology

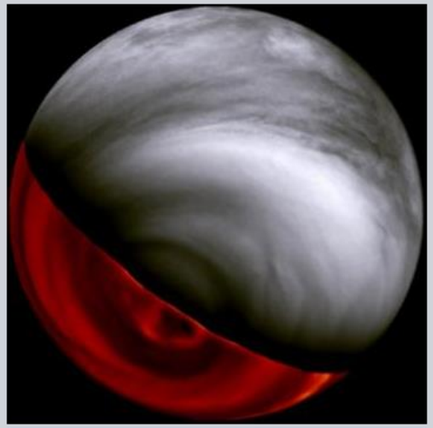
Comparing geophysical processes on Earth, Venus, Mars, Titan



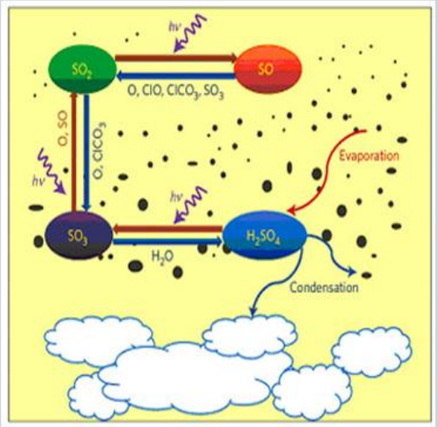
Impact craters & modification



Radiative Balance, Greenhouse effect

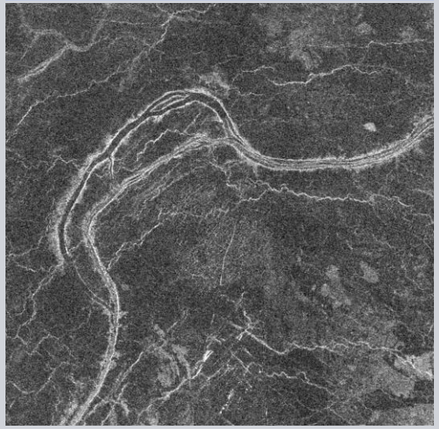


Atmospheric dynamics, weather, turbulence



Atmospheric chemistry, clouds

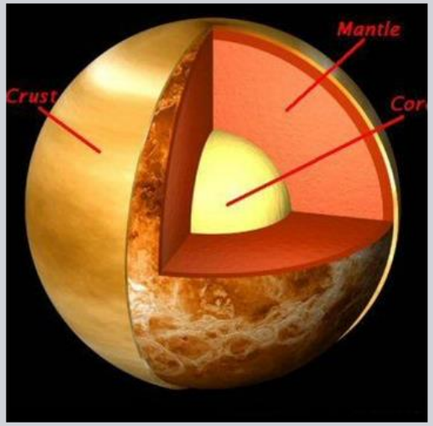
Atmospheric electricity, lightning



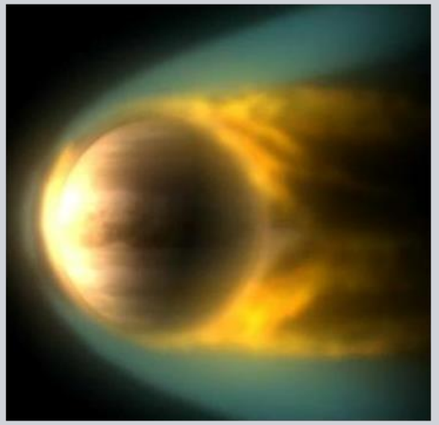
Meandering flow channels

Sand and dust transport, weathering

Volcanism, tectonism, exchange with atmosphere



Interior structure and its evolution

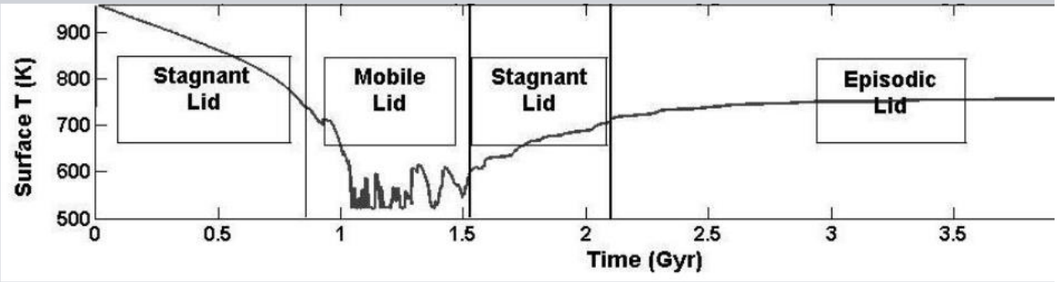


Exchanges with space Solar wind & magnetosphere

Planetary Evolution

What is Venus:
a “failed Earth”? A proto-Earth?

- ***Was Venus habitable before developing a runaway greenhouse effect?***
- ***Or did the water escape during steam atmosphere phase, before it ever condensed?***
- ***Planetary evolution depends sensitively on tectonic regime***



Divergent Climate Histories

Close to Sun → warmer
H_2O evaporates
Positive feedback
Runaway greenhouse

H_2O dissociates
H lost to space
O lost to space and surface

Thick secondary CO_2 atmosphere

Surface H_2O removes CO_2 from atmosphere

Oxygen accumulates in atmosphere

Short term variations from orbit variation and other extreme events

Plate tectonics starts stabilizing CO_2 cycle

Greenhouse warming
Liquid H_2O at surface

Smaller planet → escape easier
Far from Sun → colder
Early thick atmosphere lost up & down

Subsequent oscillations in orbital elements affect atmosphere on 10^4-10^6 year timescales

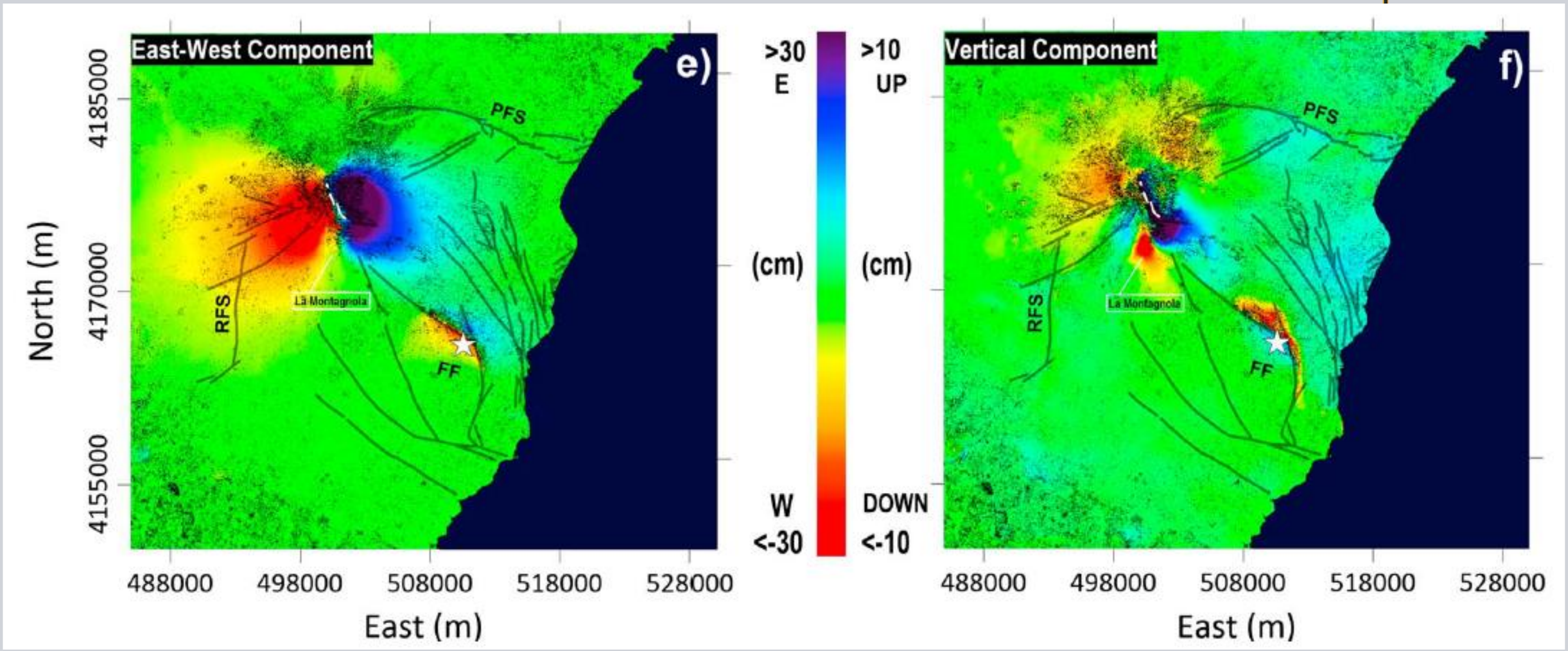
Uniting the community

- **EnVision website https://envisionvenus.eu/**

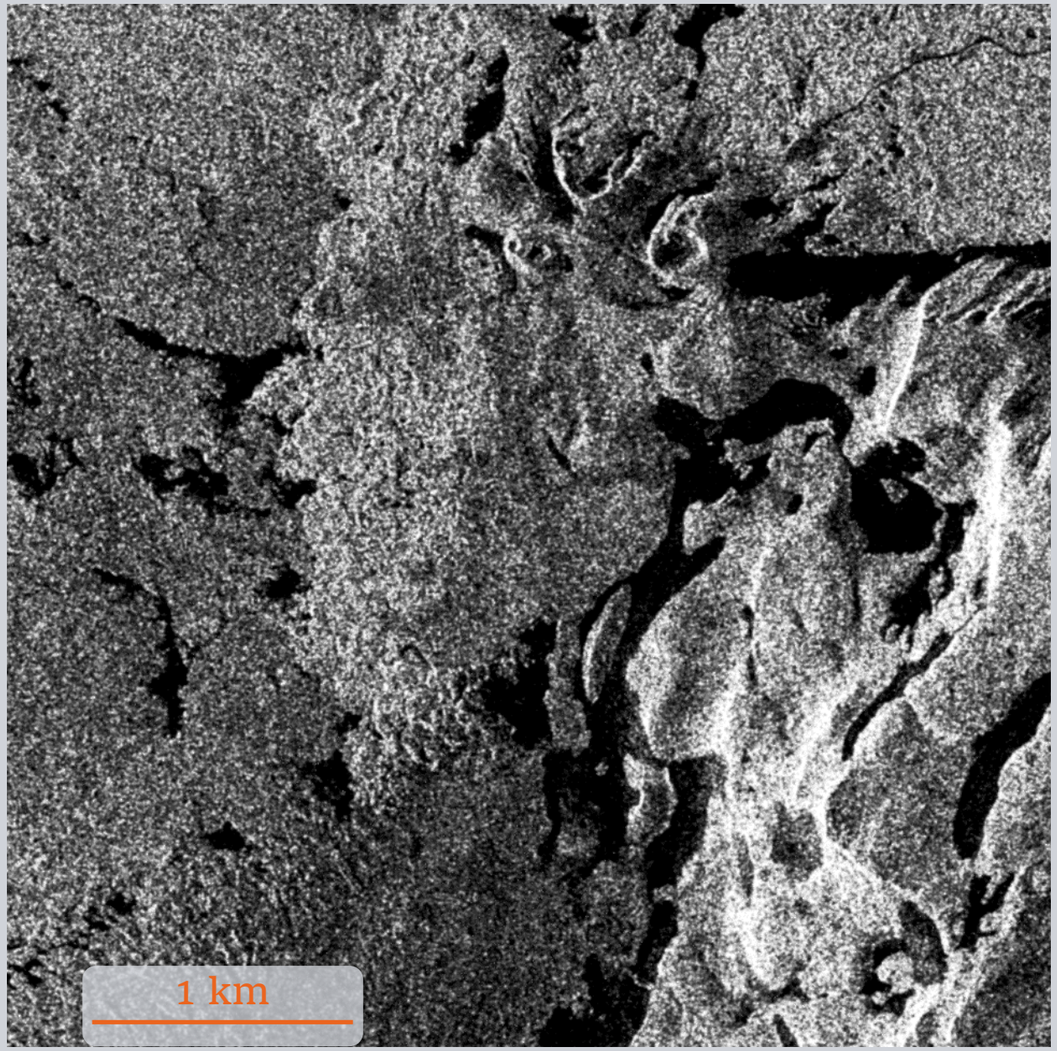
- **EnVision science conference: Paris, 12-14 February, 2020**

Thank you !

SAR cm-scale changes: a Terrestrial lesson

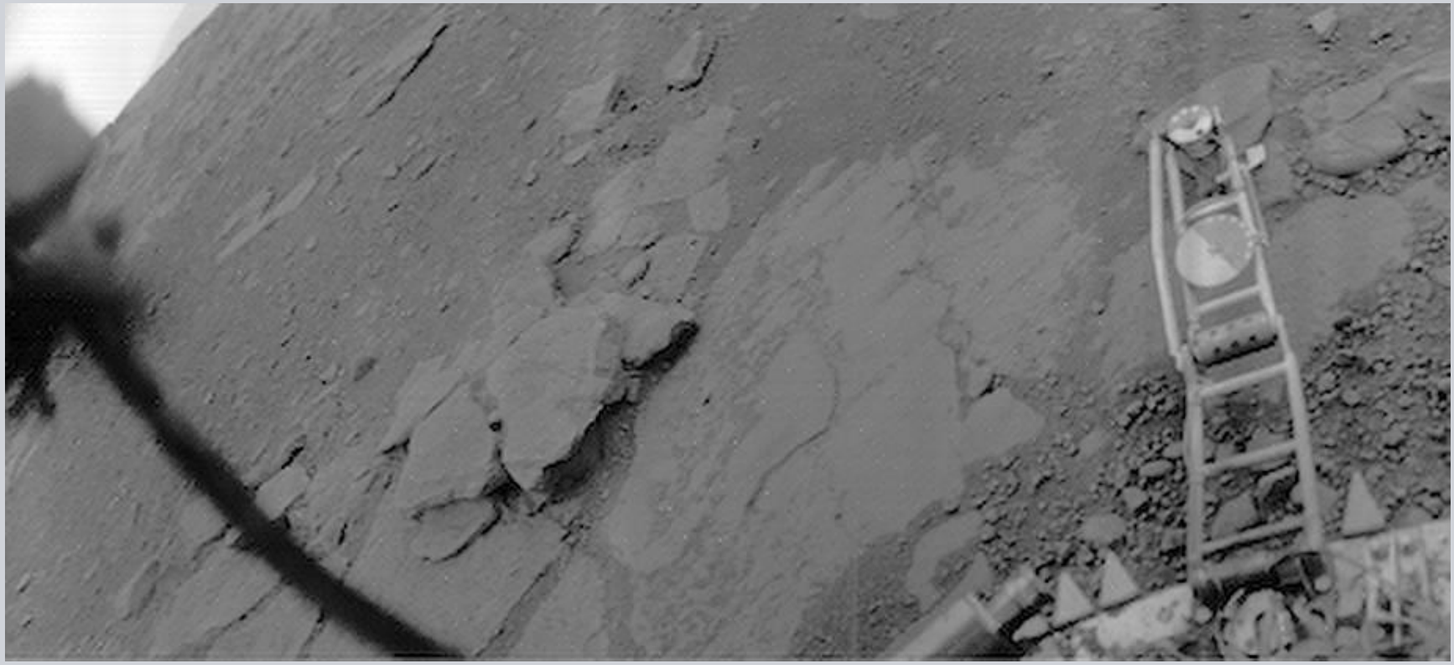


Exploration and “spotlight” scales
(10-100 km @ 5-10 m/px)



2 m UltraRes 30-km wide stripmap swath

- ≤10 m resolution will be used for selected targets, including Venera landing sites



SAR science operations