Venus Climate Flagship

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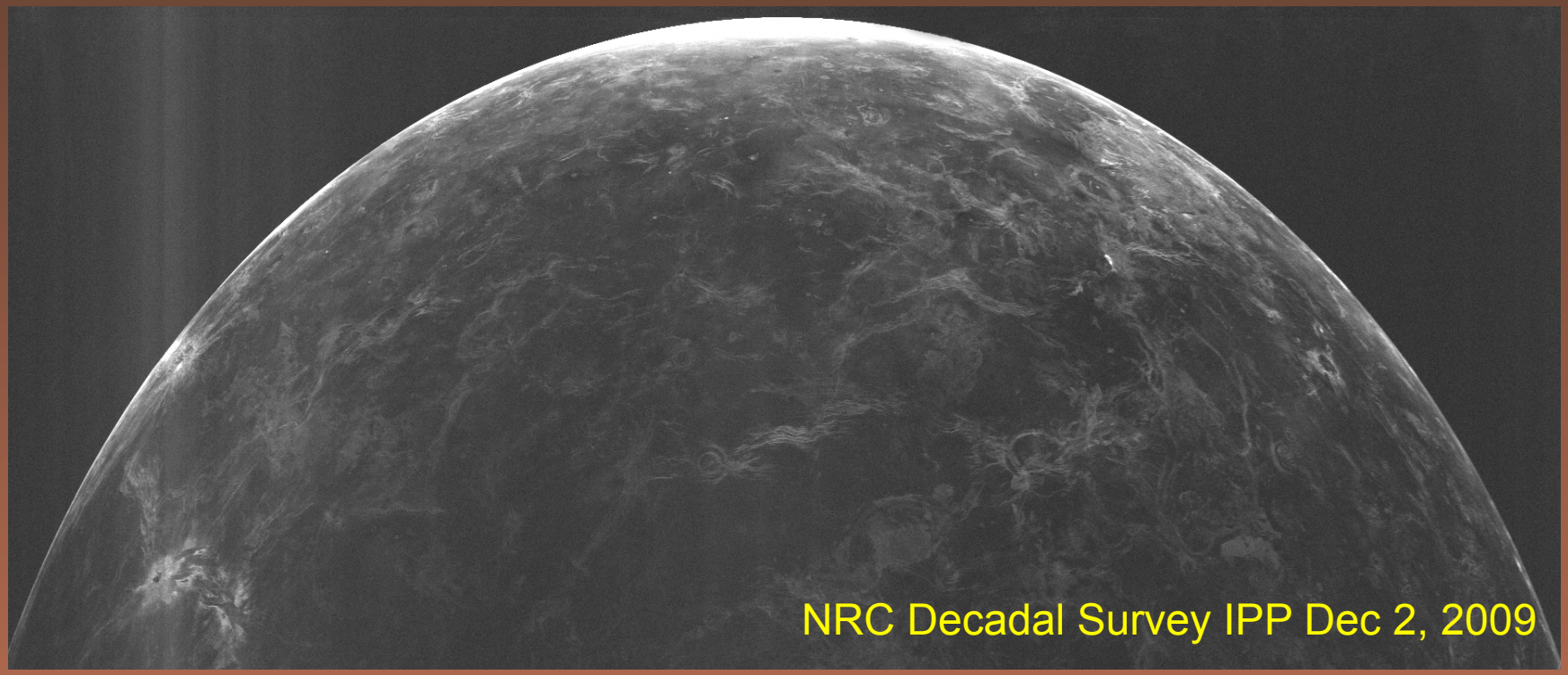


NRC Decadal Survey IPP Dec 2, 2009

VCF Science Objectives

- Distinguish between theories of Venus' atmospheric origins and how it evolved differently from Earth's
- Reveal the tectonic and volcanic evolution of Venus and its link to climate
- Determine the interplay between photochemistry, clouds, atmospheric circulation and the greenhouse effect
- Investigate processes that have been suggested as critical in driving Venus' atmosphere superrotation
- Examine surface/atmosphere chemical cycles that influence climate
- Explore the geology & geochemistry at one location, obtaining ground truth for understanding geologic history

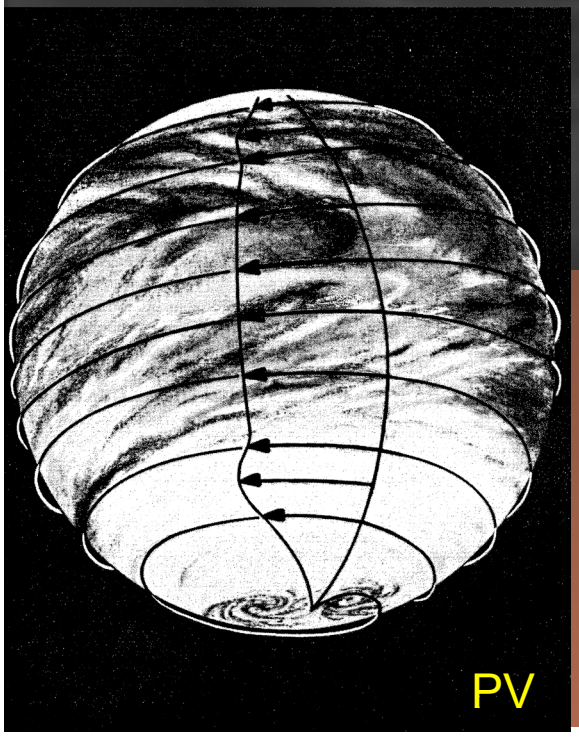
VCF Mission Architecture

- Orbiter with radar imaging, altimetry, near-IR spectroscopic imaging
- Balloon with atmospheric structure, tracking, and GCMS
- Lander with LIBS/Raman, imaging, gamma ray spectroscopy.
- Landing on plains or gentle slope of a volcano
- Orbiter, balloon, lander stacked for delivery by one Atlas V launch vehicle

South polar vortex

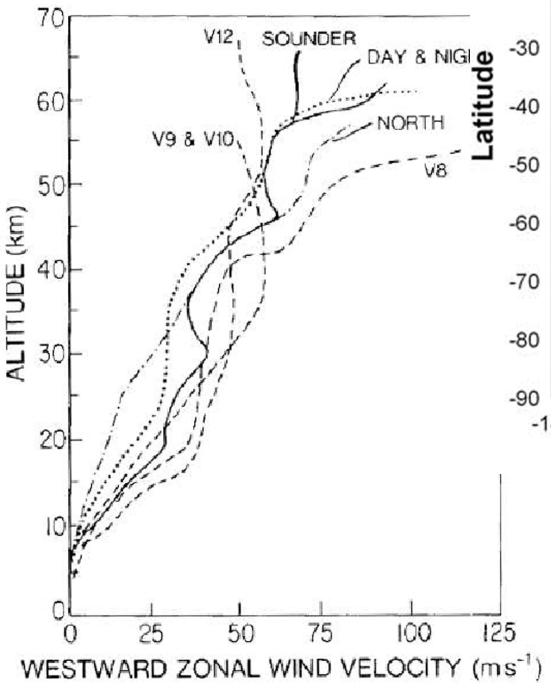
Why does the atmosphere superrotate?

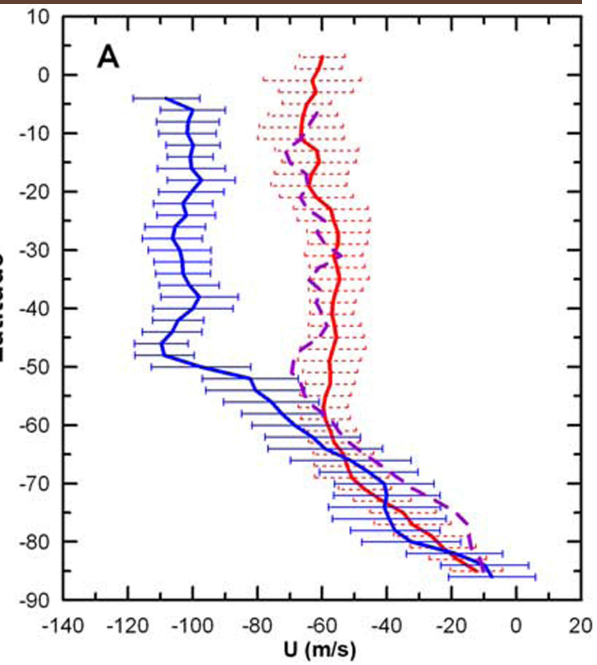
Probes: Winds decrease with altitude



PV

VEX



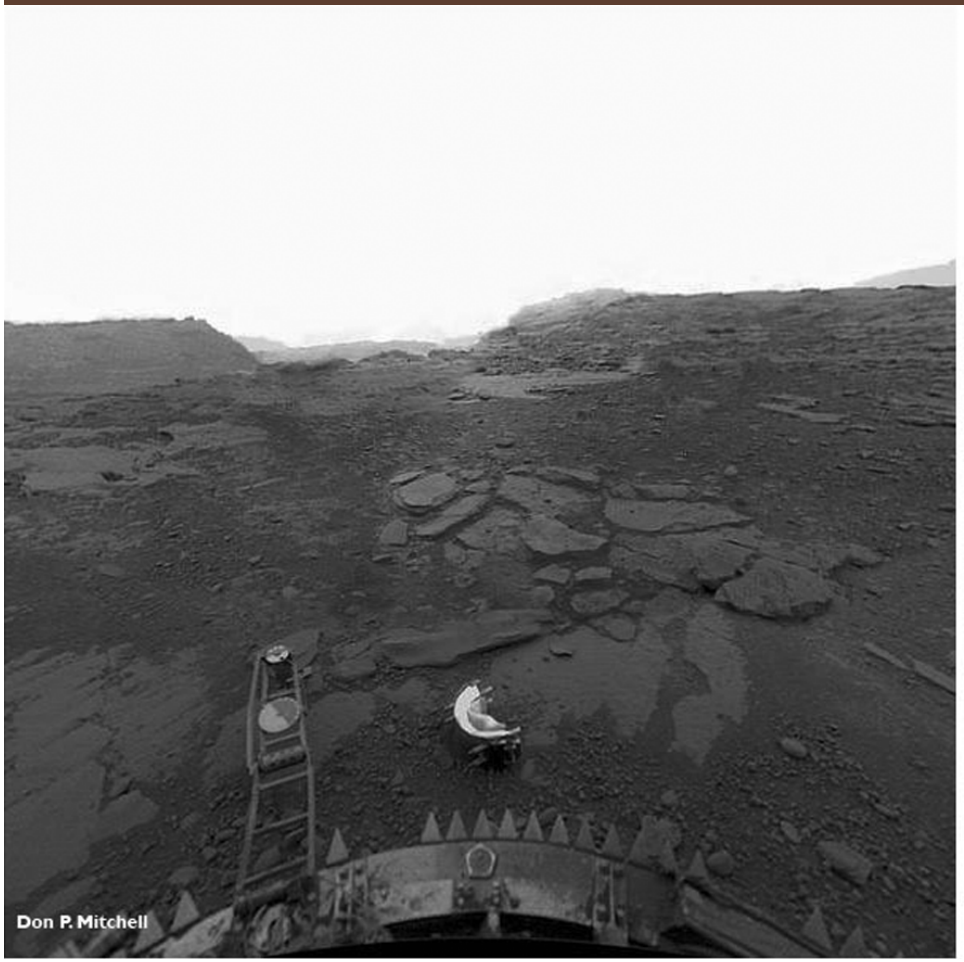


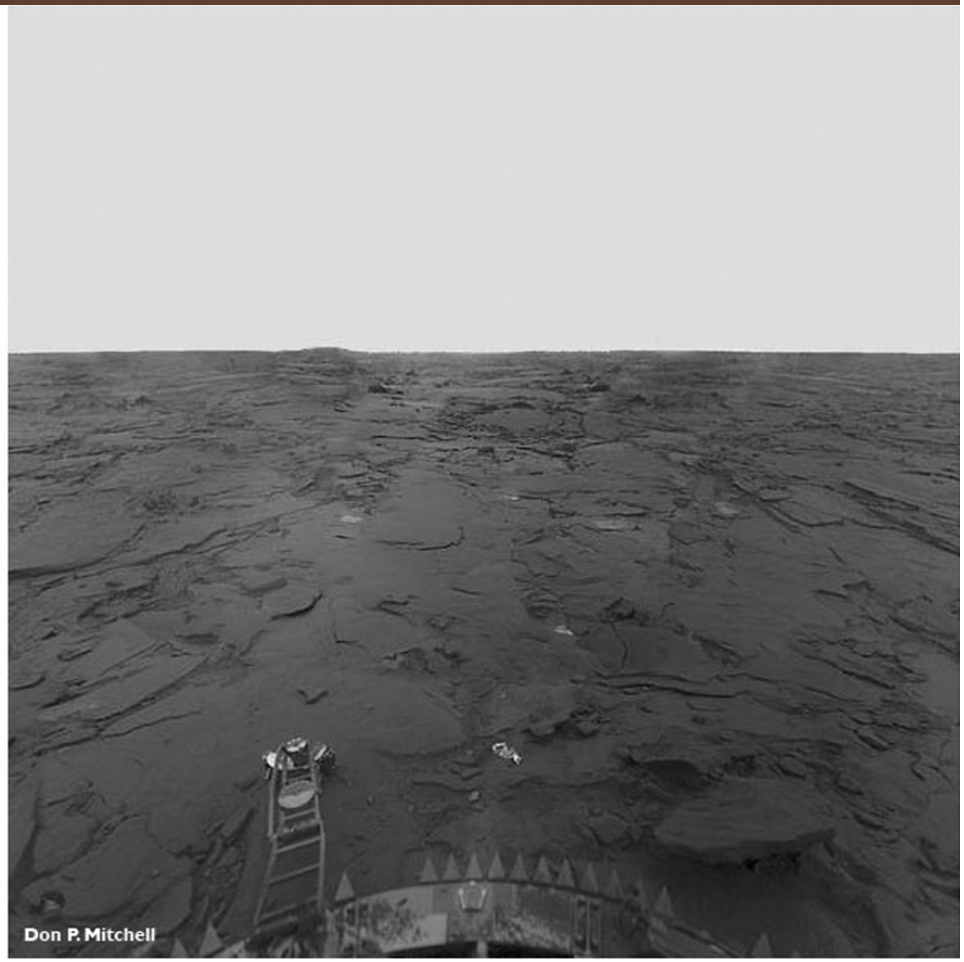
VEX East-west winds, decreasing at the poles

Is there evidence for climate change at the surface?

Processed Venera 13 panorama

Weathered rock may hold the chemical clues

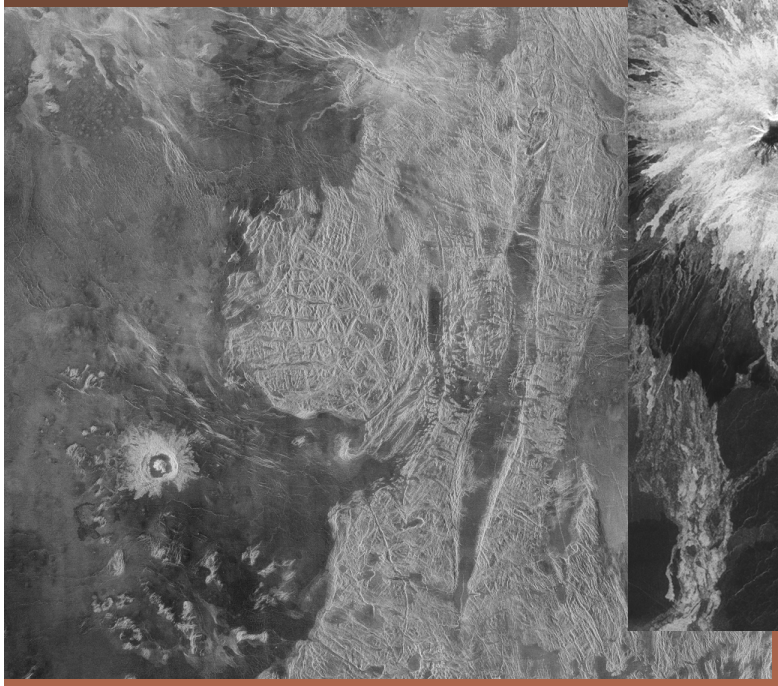




Is Venus Geologically Active?

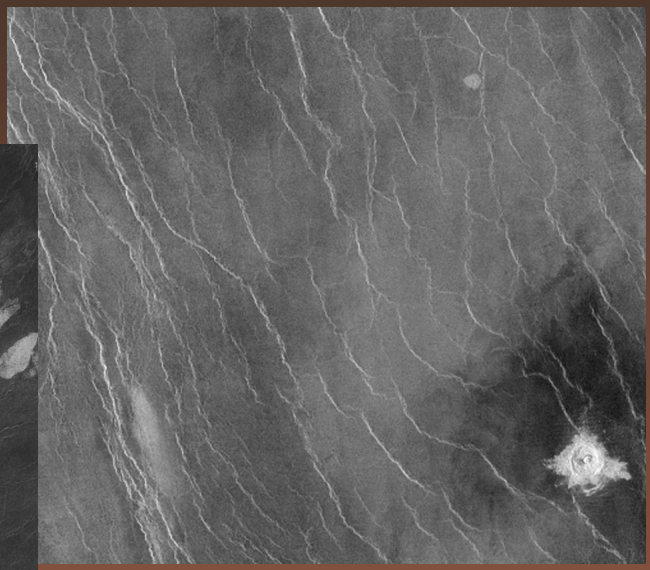
Magellan saw young volcanic features

Tessera

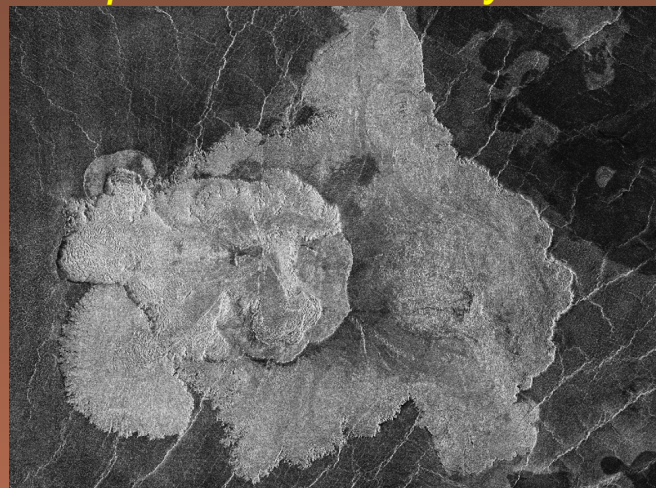


Volcanoes

Plains



Compositional Diversity



VCF Straw Man Payload

Platform	Instrument	Investigation	Measurement
Orbiter	SAR/Radar altimetry	regional imaging & global topography	10X Magellan horiz & vertical
	VIS-IR imaging spectrometer	composition, clouds, surface emissivity	Optimized atm & surface
	VIS-IR camera	clouds & winds	Optimized for wind speeds
Lander	Descent camera	nested images, compare to SAR	100 m to 10 cm/pixel
	Neutral Mass Spectrometer	noble gases, isotopes, composition	Precision noble & light elements
	Atmospheric Structure	P, T, winds, stability	Rapid P,T, accel. on descent
	Spectrometer	radiation balance & composition	Up & down solar & IR flux
	Panoramic camera	geologic history & mineralogy	High res multi-color panorama
	LIBS/Raman spectrometer	elements and mineralogy	Several locations near lander
	Gamma ray spectrometer	bulk element composition	Average of 1 m^3 under lander
	Microscope	mineral texture	Mineral formation & alteration
Balloon	Tracking	winds, thermal tides, and super-rotation	4 circumnavigations
	Atmospheric Structure	P, T	Over local time and latitude
	Accelerometer	vertical winds & turbulence	Convective instabilities
	Nephelometer	cloud particle size & composition	Composition with height
	Radiometer	atmospheric energy balance	Up & down solar & IR flux
	GCMS	cloud & atmosphere composition	Cloud & photochemistry

VCF Science Performance

MAJOR OPEN SCIENTIFIC QUESTIONS ABOUT VENUS	VENUS FLAGSHIP MISSION			VENUS CLIMATE FLAGSHIP		
	Orbiter	Landers	Balloons	Orbiter	Lander	Balloon
VENUS ATMOSPHERE						
How did Venus evolve to become so different from Earth?						
Was Venus ever habitable, and for how long?						
Did Venus lose a primary atmosphere due to impacts or loss to space?						
What drives Venus' atmospheric superrotation?						
How do geologic activity and chemical cycles affect the clouds and climate?						
How are atmospheric gases lost to space?						
VENUS GEOLOGY						
What is the volcanic and tectonic resurfacing history of Venus?						
How were the heavily deformed highlands made?						
How active is Venus geologically?						
Did Venus ever have plate tectonics and if so, when did it cease?						
How are geology and climate connected on Venus?						
What has been the role of water and other volatiles in Venus geology?						
VENUS INTERIOR STRUCTURE						
Does Venus have Earth-like continents?						
What are the chemical, physical, and thermal conditions of the interior?						
How does mantle convection work on Venus?						
What is the size and physical state of the core?						
What is the structure of the Venus lithosphere?						
How have water and other volatiles affected Venus' interior evolution?						
VENUS GEOCHEMISTRY						
Was there ever an ocean on Venus, and if so, when and how did it disappear?						
What caused the resufacing of Venus over the past billion years?						
What is the nature of chemical interactions between surface and atmosphere?						
What are the tectonic forces behind Venus' volcanism?						
How were the rocks and soils of Venus formed?						
What do chemical differences of terrains say about the evolution of Venus?						

WAG Costs*

From Table 3.1 of the STDT final report, the Team X study of the flagship showed

Orbiter $0.41B
Balloon $0.3B
Lander $0.89B

Total $1.59B

However, the tallest technological pole - sample handling - has been removed from the mission design, and the SAR/ altimeter (and hence orbiter) is much smaller. If these things save $150M, adding an Atlas V for $250M yields a total cost of $1.7B.

*mileage may vary

VCF Summary

- Highest priority VEXAG science goals can be met with a mission that focuses on climate.
- A mission that simultaneously deploys an orbiter, lander and balloon is the most cost-effective means for studying the climate system – atmosphere, clouds, surface.
- Such a mission, Venus Climate Flagship, could be flown for $1.7B