Abstract #1934: ATMOSPHERIC WINDOWS TO IMAGE THE SURFACE FROM BENEATH THE CLOUD DECK ON THE NIGHT SIDE OF VENUS

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INTRODUCTION

Recent orbital and flyby mission efforts to study the surface have concentrated on atmospheric windows in the near-infrared. Here, we investigate how placing an instrument beneath the cloud deck (e.g., on a balloon) alters those spectral windows capable of viewing the surface and the spatial resolution of the imaging data that could be collected.

Orbital Windows: 0.85, 0.9, 1.0, 1.1, & 1.18 μm [1, 2]
Orbital Footprint: 50 – 100 km [3, 4]
Wavelengths investigated: 0.7 – 250 μm

MODELING METHODS

Surface Viewing Atmospheric Windows

Any wavelength at which ≥50% of signal measured at the sensor comes from the surface.

$$I_{total}(s) \geq \frac{1}{2} \times I_{Sur}(s) \quad \text{or} \quad I_{Sur}(s) \geq I_{Atmo}(s)$$

We used the radiative transfer equation to determine signal strengths. Absorption and scattering coefficients come from [5]. Temperature values for the surface and atmosphere come from [6].

$$I_\lambda(s) = \left[I_{Sur}(0) \exp[-\int_0^s k_\lambda(s')ds'] \right] + \left[\int_0^s k_\lambda(s')\, B_{\lambda(T(s'))} \exp\left[-\int_{s'}^s k_\lambda(s'')ds'' \right] ds' \right]$$

Scattering Footprint

Based on a path integral approach from [7].

$$w^2 = \left(\frac{1}{2}\right)\left(\frac{2a}{3S} + \frac{16\alpha}{bS^3}\right)^{-1}$$

Where w is the scattering footprint, a the absorption coefficients, b the scattering coefficients, S the path length, and α is a function of the mean square scattering angle ($\frac{1}{2<\theta>^2}$) [7].

Assumptions

- Nadir viewing angle
- Thermodynamic equilibrium
- Constant surface emissivities
- Lambertian surface
- Plane-parallel and homogenous slab layers
- Rayleigh scattering only

Parameters Explored

- Surface elevation: 0, 3, & 11 km
- Surface emissivity: 0.7, 0.86, 0.95, & 1.0
- Sensor altitude: 10, 20, 30, 40, & 50 km
- Regional Temperature Variation: $\pm 20\ K$

EXAMPLE TARGETS

We investigated windows and footprints for two particular locations to examine different example parameter sets: Ishtar Terra and Ganiki Chasma (Figure 2). Locations like these have been identified as potential high priority targets for study [8].

- Ishtar Terra
  - Why? – possible continental-like crust; major science objective [8].
  - Surface elevation: 3 – 11 km
  - Assumed emissivity: 0.7 – 0.85
- Ganiki Chasma
  - Why? – possible active volcanism [9]; also major science objective [8].
  - Surface elevation: -2 – 2 km
  - Assumed emissivity: 0.90 – 0.95

RESULTS

Surface Viewing Atmospheric Windows

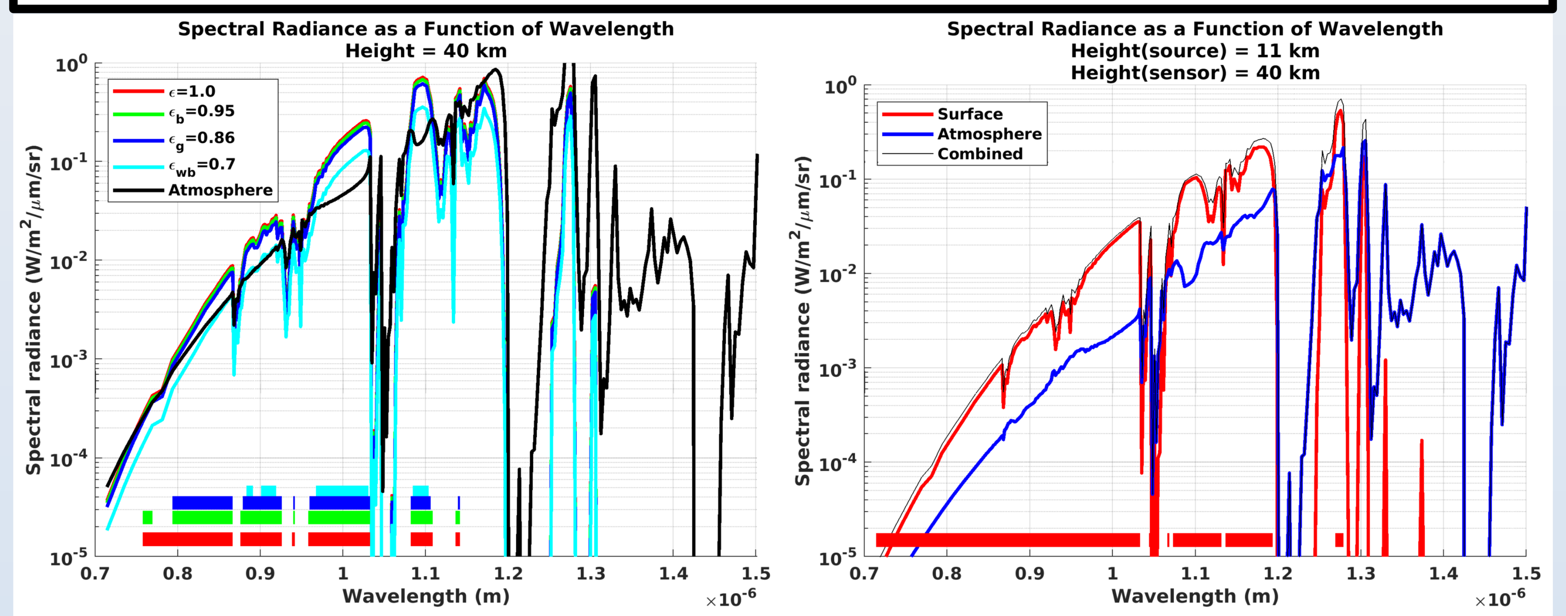
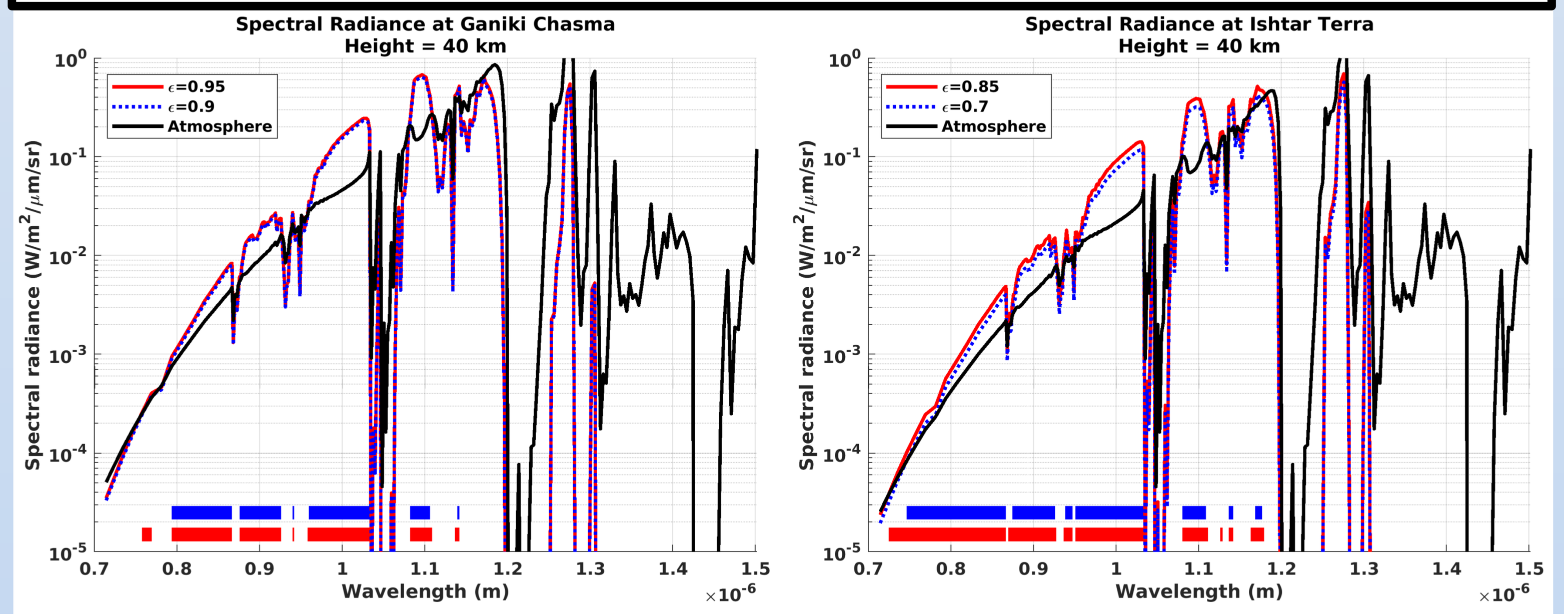


Figure 1. Top left: Effect of emissivity on potential windows. Top right: Effect of surface elevation for an emissivity of 1. The above figures demonstrate the important parameters in determining surface viewing atmospheric windows.
Bottom left: Ganiki Chasma at 0 km elevation. Bottom right: Ishtar Terra at 3 km elevation. The below figures present two example targets and the combined effects of varying surface elevation and surface emissivity.
Bars at the bottom of each figure highlight wavelengths that meet our window criterion.



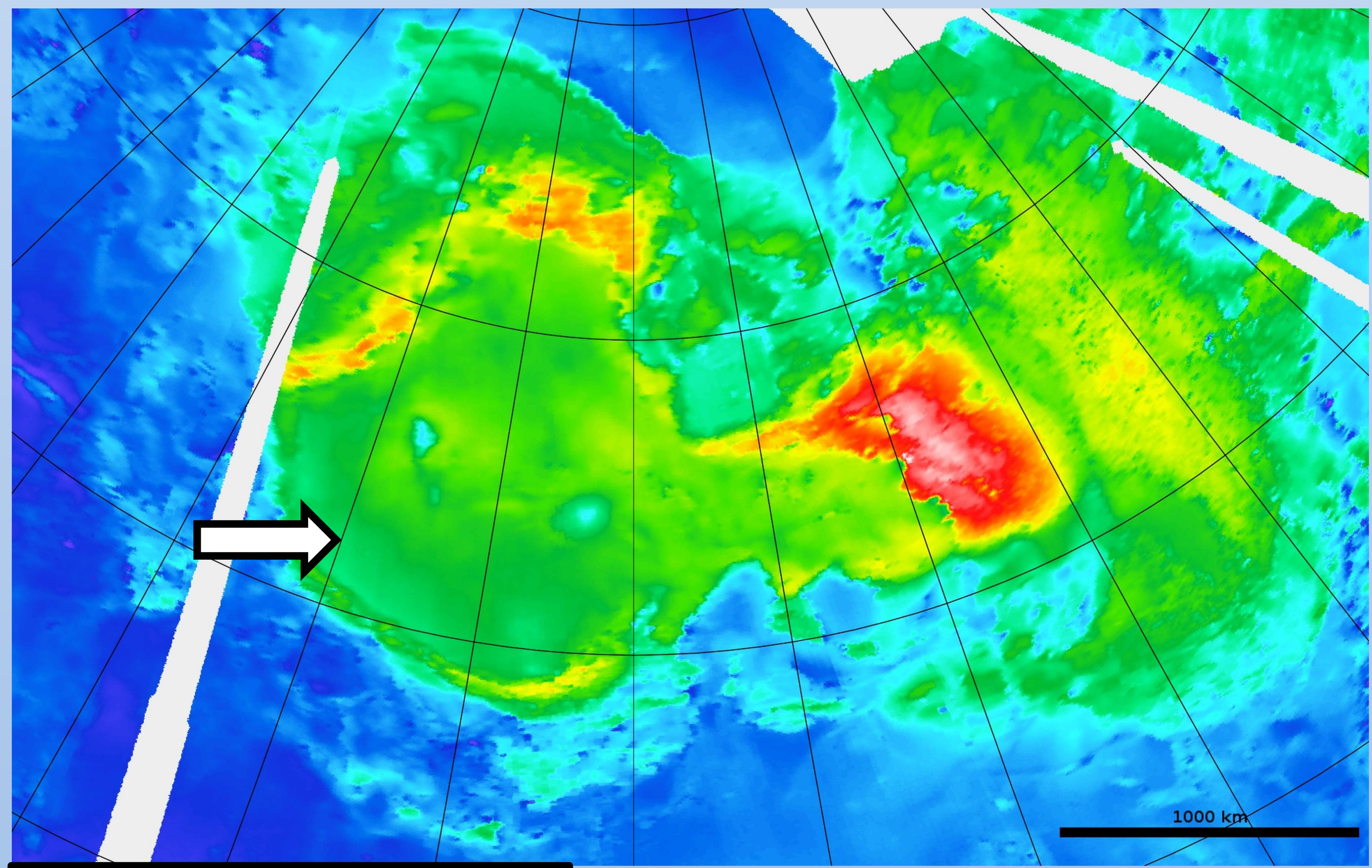
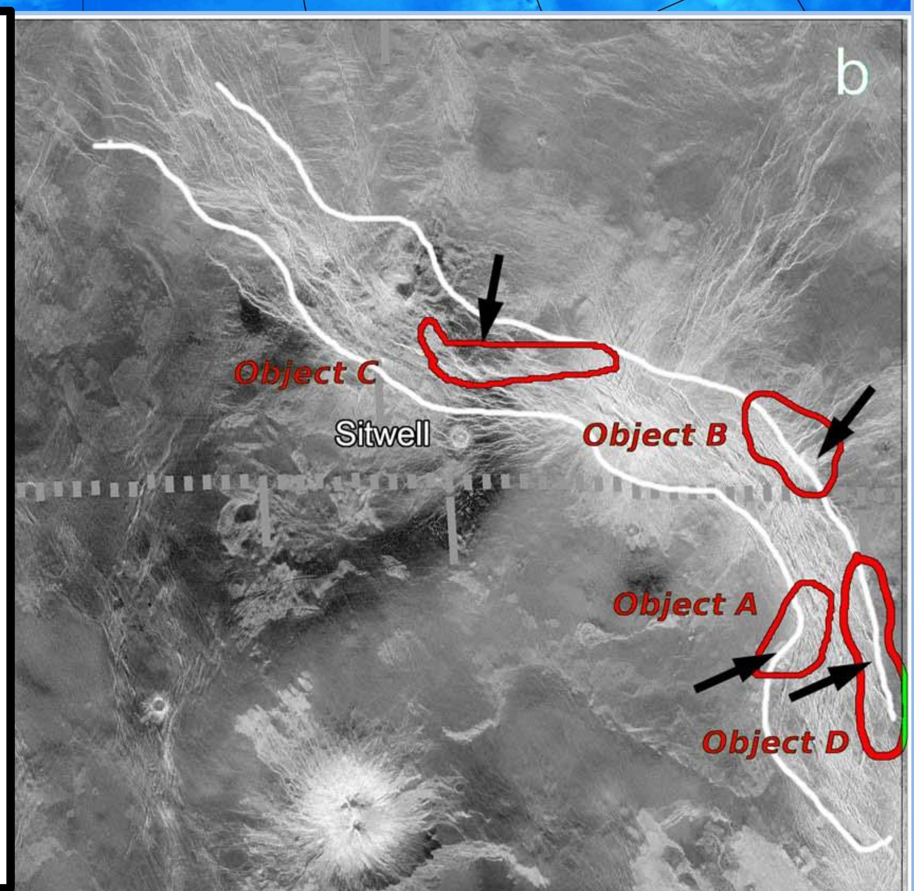


Figure 2. Above: Colorized topographic map of the Ishtar Terra region taken from JMARS. Most of Ishtar Terra is >3 km above mean planetary radius (MPR), and Maxwell Montes is the highest point on the planet at 11 km above MPR. The arrow corresponds to the region from which representative elevation values were taken.
Right: image taken from [9] showing possible cooling lavas in Ganiki Chasma (AKA Ganis Chasma). Red outlines mark locations of persistent bright spots located using the Venus Monitoring Camera.



RESULTS

Scattering Footprint

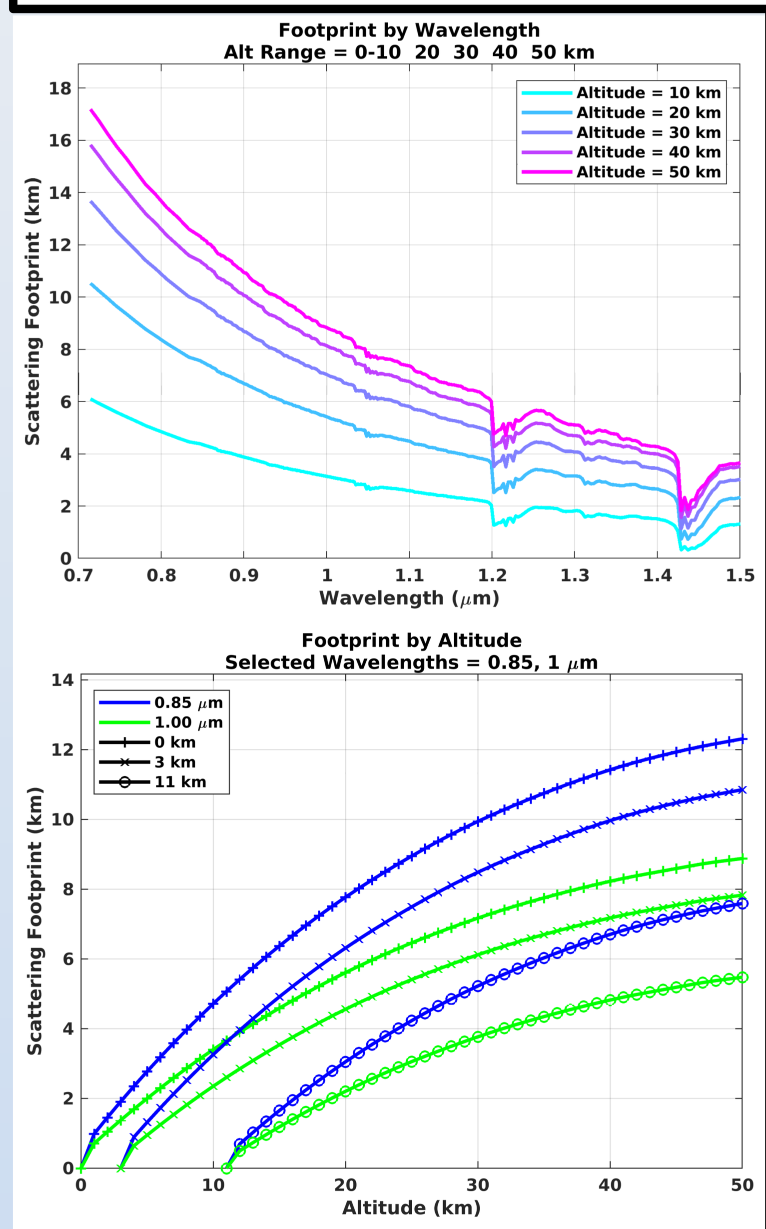


Figure 3. Top: Wavelength vs. scattering footprint for various sensor altitudes. The footprint size exponentially decreases with sensor altitude. The step functions in scattering footprint at ~1.2 and 1.42 μm are caused by spikes in the CO2 absorption coefficients at these wavelengths. These correlate with large drops in signal shown in the plots of Figure 1.

Bottom: Altitude vs. scattering footprint for various surface elevations. Increasing surface elevation significantly reduces the scattering footprint. The scattering footprint for system altitudes of 40 to 50 km equals or exceeds 5 km, making the Magellan Gridded Topographic Data Record sufficient to remove the effect of surface elevation from the observed emissivity.

TAKE AWAY

- Important parameters for surface viewing atmospheric windows
  - Surface elevation (higher, better SNR)
  - Surface emissivity (lower, fewer windows, worse SNR)
- Unimportant parameters for windows
  - Regional temperature variation
  - Sensor altitude
- Important parameters for footprint
  - Wavelength (longer, smaller footprint)
    - At 1 μm, there is approximately a 1 order of magnitude improvement over the orbital footprint.
  - Surface elevation (higher, smaller footprint)
  - Sensor altitude (lower, smaller footprint)
- Thicker atmosphere at low altitudes causes larger portion of extinction and scattering. Higher surface elevation results in better SNR, more surface viewing atmospheric windows, and a smaller scattering footprint.
- Identified windows are essentially expanded versions of satellite windows, plus a window at ~1.27 μm for elevated surfaces. This additional window is normally blocked by O2 airglow at ~95 km [2]. These provide the ability to improve spectral and/or spatial resolution, and to reduce measurement error.

REFERENCES

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