Visualize Venus
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I use 3D visualization of radar and altimetry data for research and teaching aimed at understanding evolution of Venus, the major surface processes, and related geodynamical processes—in short, how Earth's sister planet gets rid of heat, currently, and how she had done so through time. 3D images are constructed using data from NASA's Magellan Mission. For a limited portion of the planet true stereo images (red-blue anaglyphs) can be constructed using different cycle radar data with varied illumination direction (e.g., Plaut 1993); for the rest of the planet we can construct synthetic stereo images (Kirk et al. 1992), which are lower resolution, yet cover immense areas of the planet allowing one essentially endless, free, helicopter time in this fantastic terrestrial world.

Venus is about the same size and density as Earth, was formed at the same time (a Thursday afternoon some 4.6 billion years ago), and resides at a similar distance from the Sun. And like Earth, Venus cools over time—that is, internal heat must escape. So the big question is: how does Venus cool—how does she get rid of her heat? Since Venus is devoid of water, sediments, and life (at least as far as we know), which on Earth mask evidence of heat escape processes, the cooling process should be evident. Earth currently cools through plate tectonic processes; Magellan mission data clearly indicate that Venus does not! Like many siblings, Venus followed a very different evolutionary path than Earth; the fun is to try and understand the path and contributing processes. But after more than ten years of study using data from NASA's Magellan orbiter mission Venus still holds many of her secrets, including the age of her crust and surface features, and the processes by which the majority of heat escapes to the surface.

Venus' current physical environment is also very different from Earth's current physical environment; Venus is hot (~500 °C), ultra dry (inside and out!), acidic, hosts surfaces of endless basalt and no granite so far as we know, and her CO_2-rich atmosphere has a density similar to Earth's oceans (~100 bars at the surface!). Thus Venus presents a wonderful playground for geological research—it is a rheological and tectonic laboratory beyond imagination. Venus also presents a wonderful playground for science talks at all levels of discovery.

Synthetic stereo radar images are not only the single most critical research tool for our work, they are also the single most exciting communication and teaching tool. From a research standpoint, synthetic stereo anaglyphs allow us to merge data constraints from radar backscatter (which basically indicates surface roughness and/or surface orientation) with topographic relief. Thanks to the NASA Magellan mission, and basic off the shelf software (and a talented graduate student who wrote nifty macros) we can produce stereo or synthetic stereo images for ninety-eight percent of Venus' incredible surface. Images are constructed using Magellan SAR (Synthetic Aperture Radar) data (available at NASA's PDS MAP-A-PLANET web site: http://pdsmaps.wr.usgs.gov/maps.html), and Magellan altimetry data. We now have at UMD the entire planet in synthetic stereo imagery (about 60 plus gigabytes of imagery). From a talk/presentation/teaching standpoint these images provide the single most critical aspect for talks at all levels, and with a wide range of goals. Stereo radar imagery allows the audience to directly participate in the discovery of Venus processes. Fundamentally every time I give a talk or lecture I hope to have the audience come away with a better understand of the scientific

process, information or a story about some particular topic or region, and most important perhaps, the joy of discovery or of understanding the beauty of logical thought. Visual images provide a wonderful tool toward achieving these goals.

Puzzling about Venus evolution, Venus tectonics, Venus volcanism, how Venus might work are fantastic topics because we know so very little; perhaps it this general lack of knowledge that allows essentially all people the freedom to explore and discover processes that might have contributed to this planet's evolution. (One can hardly get down on his/herself or others for not knowing what this foreign planet is like, or how it works). As the audience, young to old, 'educated' or not, dons the fashionable red-blue glasses, they are transported to an imaginative world of discovery; they see 3D pictures that are recognizable, yet fantastic—almost magical. With a few ground rules of radar, chemistry, physics, and geology, dependent on audience expertise (or perceived expertise!) and goals of the particular talk, the audience immediately becomes explorers. Donning red-blue 3-D glasses, we can all digitally 'fly' above the surface and gaze down to the remarkable landscapes below. Flights reveal incredible views of surface folds, cracks, faults, fractures, lava flows, and impact craters that dwarf any such features on Earth. The patterns and interaction of features tell stories, and beg questions. Long, periodic ribbon-like ridges and troughs preserve a record of an ancient time when there was thin crust everywhere. Thin global crust led to increased volcanic activity and surface temperatures of roughly 1000 K (1340° Fahrenheit), insulated by thick volcanic greenhouse gases. Deep mantle plumes likely rose and interacted with the surface leaving evidence of their calling as well as evidence of thin, globally extensive crust. As Venus cooled internally over time, the crust thickened, thereby decreasing the levels of volcanism and greenhouse gases, leading as well to cooler surface conditions. Deep mantle plumes that rose to interact with this surface left a very different signature.

Once given a problem (or allowed to discover one on their own) the audience is off and running. The audience makes the observations, either guided or not (again, dependent in-part on overarching goals), and begins to assemble stories of how the scenes they observe came to be. All scientists that I know love their work because of the joy of discovery—facts mean little, discovery is everything. Visualizations, and 3D visualizations in particular, allow an audience to feel directly part of the discovery. Synthetic stereo radar images transport the audience (comfortably) to Venus hot, dry, acidic, high-pressure surface. The landscape is familiar enough to allow them to ask question, make critical observations, and assembly sequences of events, yet it is foreign enough to allow them complete freedom from preconceptions, and even their own egos. Curiously most of my talks bring the audience back to thinking about the earth, and how it works as a planet, and thus just as travels to other lands cause us to reflect on our world, forays to Venus cause students and the general public to see their own planet in a new light. I am convinced that the magic of Venus results from the visual images because people can immediately interact with the data sets, bringing their own experience (and questions and observations) to the table; they are an integral part of the exploration process; for my money, this is how we all really learn, and get excited about new worlds. Without visualization Venus research, and communication of Venus research would be a cold, dry, world with little atmosphere.