EXPLORATION TARGETS IN THE LOWER ATMOSPHERE OF VENUS. Sanjay S. Limaye[1], Lori S. Glaze[2], James A. Cutts[3], Colin F. Wilson[4], Helen F. Parish[5], G. Schubert[5], Kevin H. Baines[1,3], Curt Covey[6], Thomas Widemann[7], [1]University of Wisconsin, 1225 W. Dayton St., Madison, WI 53726, SanjayL@ssec.wisc.edu, [2]NASA/GSFC, Greenbelt, MD, [3]Jet Propulsion Laboratory, Pasadena, CA, [4]Oxford University, Oxford, UK, [5]University of California, Los Angeles, CA, [6]Lawrence Livermore National Laboratory, Livermore, CA, [7]Paris-Meudon Observatory, Meudon, France

Measurements made from the VeGa 1 lander during its descent to the surface in June 1985 are the last measurements made in the lower atmosphere of Venus and on the surface of Venus. Since then, much progress has been made in the numerical modeling of the global circulation of Venus, but the different models still cannot agree on the mechanisms or the processes responsible for the maintenance of the su-perrotation of the atmosphere (Lebonnois et al., 2013). Understanding the exchange of angular mo-mentum between the atmosphere and the solid planet is one key measurement not yet made, and sustained meteorological measurements around the level of the peak density of kinetic energy (~ 20 km altitude) in equatorial latitudes are needed.

Session: This topic is intended for the session “Within the Atmosphere”. The focus is on exploration targets in the altitude range surface to 45 km. The primary VEXAG Goal addressed is I.B (Processes that control climate), and also relevant for II.A (How is Venus releasing its heat?) and III.B (surface-atmosphere interaction).

Target: The target region is from the base of the cloud layer to the surface, with emphasis on equatorial, mid and polar latitude samples. Due to increasing temperatures found in the Venus atmosphere below the base of the cloud layer, not much attention has been paid to sustained measurements in the 0-50 km region. At 50 km the ambient temperature is about 347K at about 1 bar pressure. At increasing pressures to- wards the surface the temperature rises at about 8 K per km, stressing electronics, instrumentation and platform operations at those altitudes. It is quite possible, and actually desirable that the platform may need to make periodic vertical excursions for long term survival for tackling thermal conditions, but large excursions in pressure may also pose chal- lenges for the platform capabilities. Phase change balloons have been considered in Japan and by JPL in recent years, and a metallic bellows based “balloon” has been considered for the Venus Mobile Explorer (VME) studied for the recent Planetary Science Decadal Survey [2].

Science Goal(s): The main scientific question is what atmospheric processes are responsible for the peaks of the angular momentum and kinetic energy density which occur in a rather narrow layer centered at about 20 km in low latitudes. The previous Venera and Pioneer Probe measure- ments represent the only hard information about the conditions in the atmosphere below the clouds. Presence of some aerosols has been suggested, but not much is known about their source, nature and physi- cal/chemical properties. It is known that the temperature lapse rate is very close to being adiabatic, suggesting that the atmosphere is well mixed and thus strong vertical motions may be encountered. The north probe vertical profile does not show the momentum and kinetic energy peak, suggesting latitude dependence.

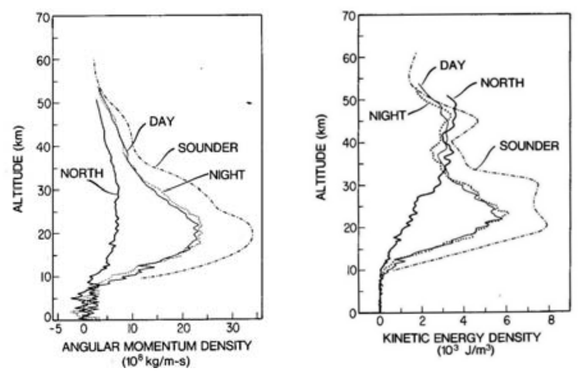

Figure 1. Angular momentum (left) and kinetic energy (right) per unit volume from the zonal speed of the Pioneer probes and ambient atmospheric density (Schubert et al., 1980) for the North (60.2° N), Day (31.3° S), Sounder (4.0° N), and the Night (27.4° S) Probe locations [3].

Discussion: The VME study identified several technology development needs and other concepts for the lower atmosphere mobile platforms will also have comparable needs. Investments in such development are needed before any sustained measurements from a capable floating or flying platform can be made below 50 km altitude.

The question of super-rotation of the atmosphere has been a mystery since its discovery more than half a century ago. Exchange of angular momentum between the surface and the atmosphere is a key process about which little is known, but the recent reports of rotation rate of Venus [4] and theoretical and numerical analysis suggests that such exchange can be very significant [5]. Measurements of the atmospheric conditions in the lower atmosphere and use of numerical circulation models are needed to understanding the atmospheric superrotation, its origins and the planet's spin evolution when more knowledge of the lower atmosphere circulation and nature of turbulence is obtained.

Significant technology development	~TRL	Notes	Development duration
Bellows system	3	Inflation system, valves, materials, reliability. Model of the bellows concept created. Specific technologies listed below.	24 months
Bellows system testing	4	No large scale Venus environmental test chamber.	18 months
Bellows system Integration	5	Integration of the large bellows system, high pressure tank and related separation mechanisms around the instrument pressure vessel may require specialized approaches and equipment	12 months
High temp/press gondola tank separation system	4	Mechanisms will need to operate in the high temperature and pressure environment.	24 months
Laser raman/LIBS instrument and window.	4	Requires the ability to focus over a selected range. Need to control heat flow through the window.	12 months
High Temperature and pressure testing with CO_2 of very large subsystems.	3 to 6	Technology available but requires large investment to develop facilities.	12 months
Accompanying technology development			
Materials optimizations			
A. Optimization of bellows materials.	5	Prototype used stainless steel with a wall thickness of 0.18 mm. Material thickness; plastic/elastic deformations and other optimizations will be part of the technology trades.	12 months
B. Optimization of the primary structures materials.	6	Metal matrix and other materials could reduce mass. Coated high temperature composites for some structures like the tank are possible.	N/A TRL ≥ 6
C. Thermal gradient during inflation.	6	The effects of local cooling by helium at the bellows' intake and other effects during inflation could add thermal stresses to the bellows wall.	N/A TRL ≥ 6
Bellows performance over Venus pressures.	4	Identify materials that can maintain pressure throughout bellows operation.	18 months
Pressure regulator and release valves	4	Identify materials that can maintain pressure throughout bellows operation.	18 months
Mechanism operation over temperature and pressure.	4	The design has multiple load bearing bolt and umbilical cuts at Venus surface temperature and pressure.	24 months
Carbon Phenolic material verification and availability	9	Depending on use of existing stocks before this mission, new manufacturing and qualification processes need to be recertified. Flying a Pioneer-Venus size probe before VME is assumed so the Rayon to Carbon Phenolic process is assumed to be qualified.	N/A TRL ≥ 6

Figure 2. Technology development needs identified by the VME concept study team (Table 13, [2]).

Required Measurements: The primary measurement needed is of the magnitude and direction of the ambient circulation. Frequent measurements are nec- essary (at least over short intervals) to get some idea of the strength of small scale turbulence. The measure- ments are needed for a sustained duration (as long as practical) to get some idea of the larger scale waves in the lower atmosphere of Venus. Proximity to the sur- face will of course present opportunities for surface imaging if the data rates can support it. Following measurements should be considered:

1) Measurement of the magnitude and direction of the horizontal drift of the floating platform and vertical motions, preferably by an on- board capability or with the ground and orbiter Doppler methods
2) Atmospheric temperature and pressure, and
3) Net flux of radiation and solar flux.

The VMC concept studied the bellows based balloon in the context of landed operations and identified Technology development needs (Figure 2). For the purpose of the atmospheric measurements this is not required, and the exclusion of landed operations may enable a somewhat less challenging deployment. Data communication can be through an orbiter relay or a higher level flying/floating platform.

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