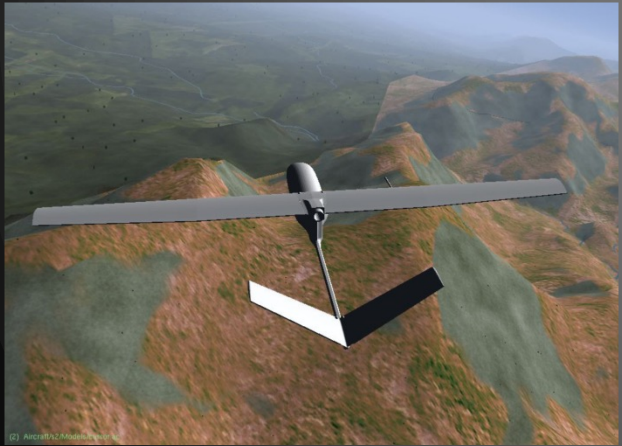
SUSTAINED IN SITU EXPLORATION OF THE HABITABILITY OF VENUS' CLOUDS



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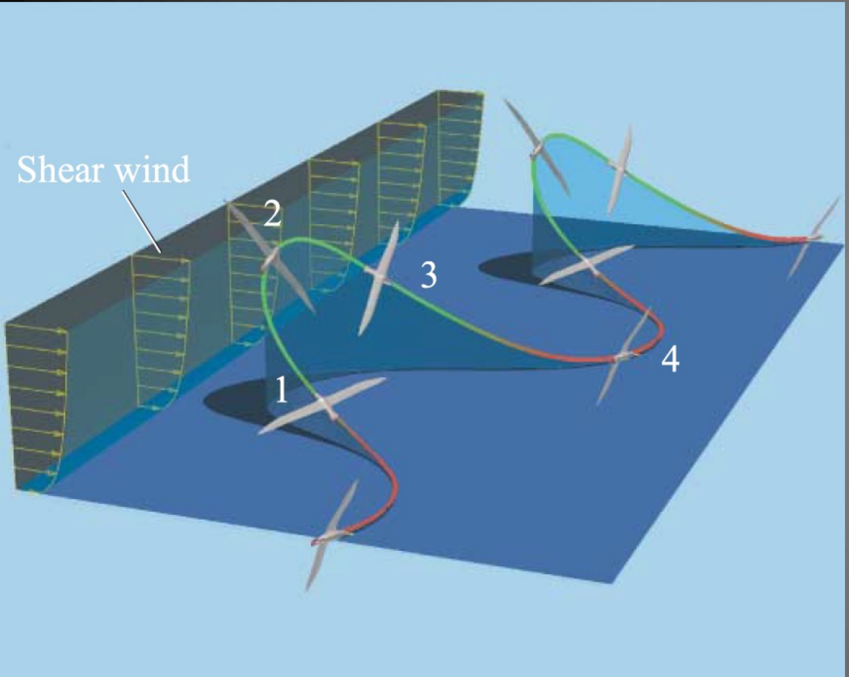
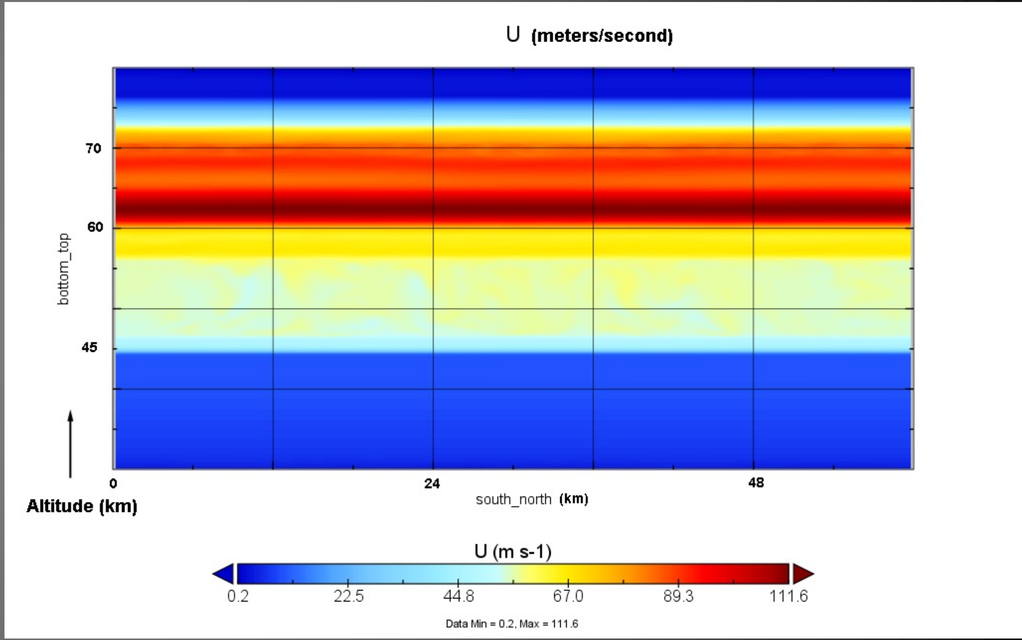
Venera-D: Venus Cloud Habitability System Workshop Nov 29-Dec 3 2021

Dynamic Soaring in the Atmosphere of Venus

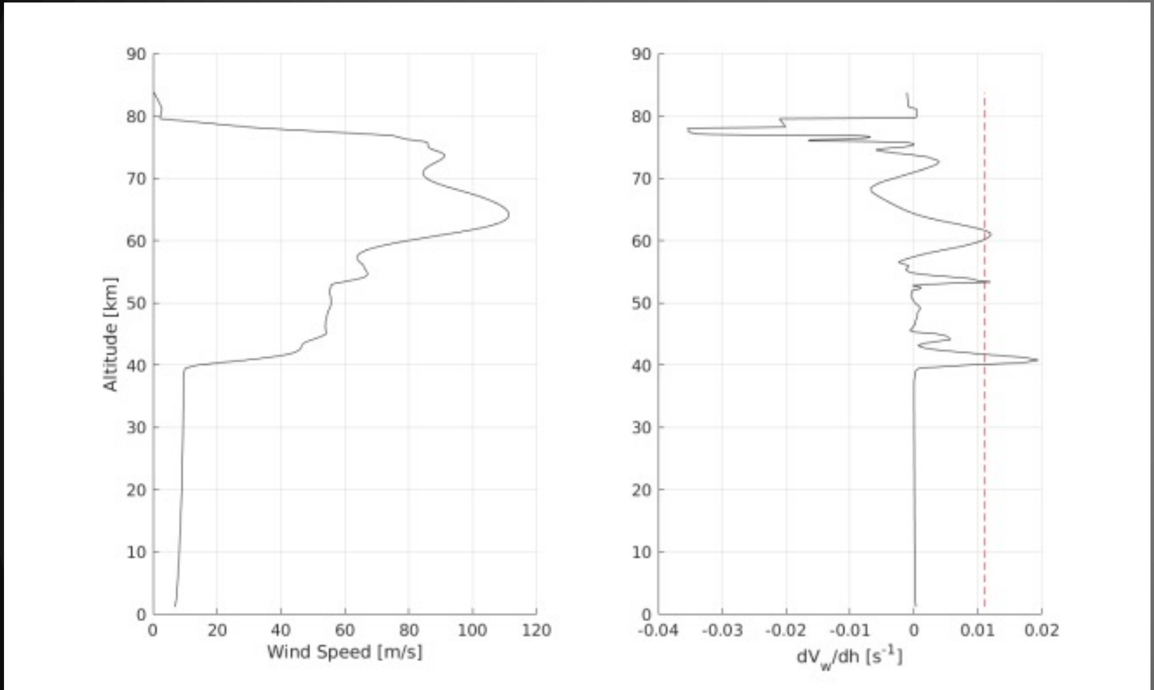


Dipping into and out of a shear layer near the surface allows albatrosses to cross the oceans with very little energy expenditure



Venus zonal winds as a function of altitude at midnight at the equator from IPSL GCM (Lebonnois et al.). Persistent vertical shear at ~60 and ~70 km.

Propulsionless Flight in Venus' Atmosphere

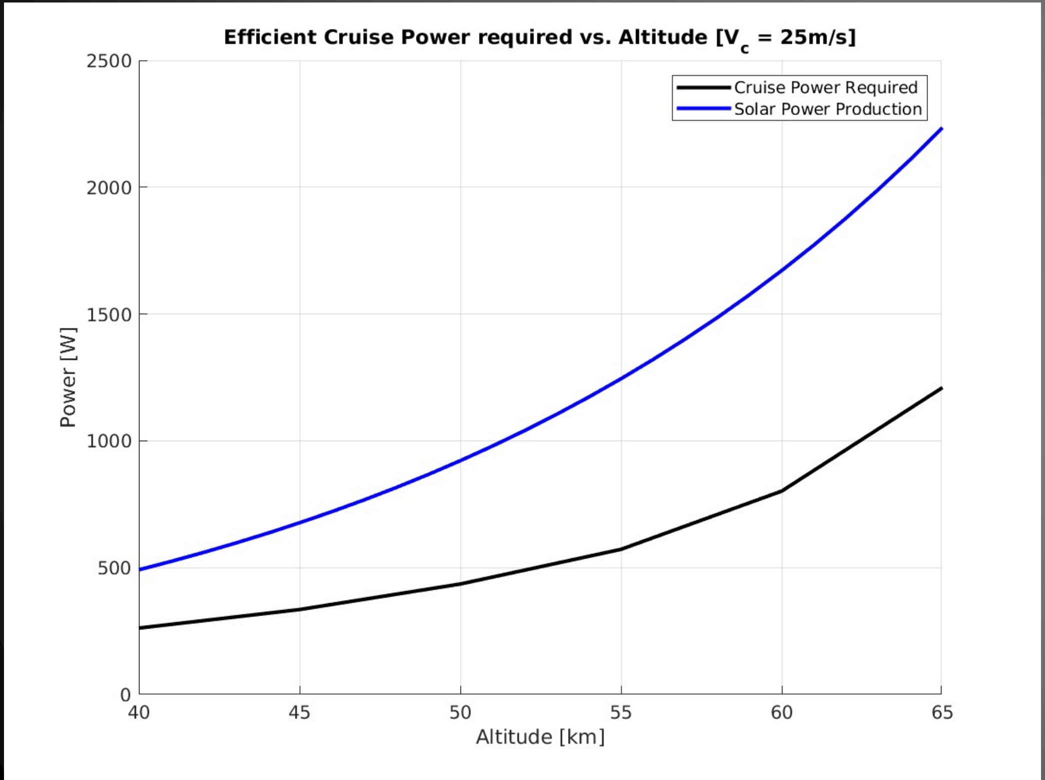


Vertical slice of horizontal winds (left) and wind shear (right) from IPSL Venus GCM at the equator at midnight.

The vertical red line depicts where dynamical soaring is possible with a glider with CL/CD = 50.

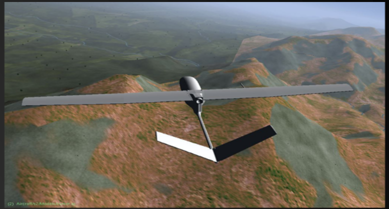
Venus designed aircraft has Cl/CD ~70.

Solar Power



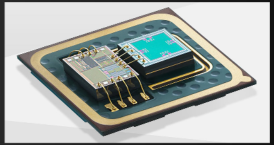
- Venus dynamic soaring aircraft flies with the wind, encountering 2.5 days of sunlight, 2.5 days of darkness.
- Blue line shows available solar energy vs. altitude from radiative transfer calculations and solar cell efficiency.
- Black line shows the energy required if cruise power were used instead of dynamic soaring.
- With 2.6 kg Li-ion batteries, the amount day and night averaged available power is 110 W continuous.
- Assumes 80% of the 5.35 m2 available surface is accommodates solar cells.

Flexible Science Payloads



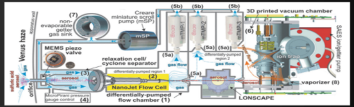
Configuration Core Science Payload (250 mg, 500 mW,) plus one or two major instruments (10 kg, 30 W).

Core Science Payload



Solid State Pressure, Temperature and 3D acceleration sensors (100 mg, 100 mW).

12 MEMS gas composition sensors for measurements of specific gases at ppb concentrations. (10 mg/10 mW each)

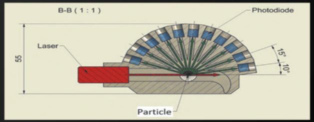


Major Science Instruments

Venus Aerosol Mass Spectrometer (Baines et al. 2020)

Aerosol Polarizing Nephelometer (Renard et al. 2020)

Venus Life Detection Microscope (Sasaki et al. 2019)



Two Science-Targeted Missions

Venus Aerosol Explorer (VAE)

Core payload (P,T, acceleration, MEMS composition sensors) plus Aerosol Mass Spectrometer (9 kg, 30 W average) (Baines et al. 2021).

Aerosols and gases are separated with a cyclone system, and mass spectroscopy is performed on each independently. The simultaneous measurements of the composition of trace gases and aerosols with ppt sensitivity over space and time will completely specify the chemical environment of Venus' clouds

Venus Life Explorer Aircraft (VLEA)

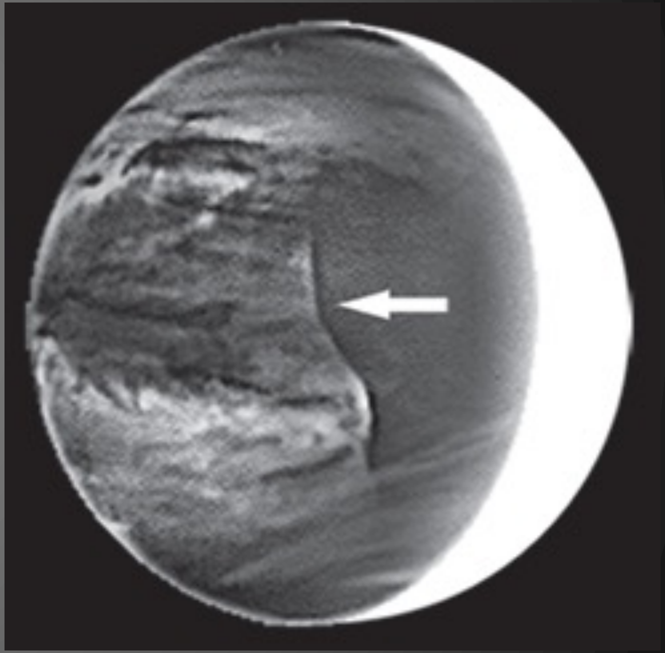
Core payload (P,T, acceleration, MEMS composition sensors) plus Venus Life Microscope (2 kg, 10 W) (Sasaki et al. 2019). Fluorescence of aerosol contents during a series of dye applications to determine composition of organics. The origin (biologic or abiotic) is determined unequivocally.

Low water activity in Venus' Clouds: How significant is this limitation for life?

- Life does not exist on Earth for $a_w < 0.6$
- However, that may be because on Earth life never had to solve that problem (at least at large scales).
- The increase in metabolic energy required goes as $\log(a_w)$. Brillion, L., *Science and Information Theory*, 2^{nd} edition, Dover, 1961.
- Assuming that low water activity was just another evolutionary problem that Venus life had to solve, the additional metabolic energy required for life to function at $a_w = 0.02$ is 1.5x the amount of energy required for life to live at $a_w = 0.6$

Conclusions

- Dynamic Soaring in Venus’ atmosphere supports weeks or months long in situ investigations of Venus’ clouds.
- Dynamic Soaring aircraft can provide 110 W of continuous power for navigation, operations, communications, and science instruments
- Unlike other aerial platforms, dynamic soaring aircraft can navigate to regions of interest.



https://www.youtube.com/watch?v=b99gNhfz_bo