FLOW INSTABILITIES IN VENUS CLOUDS EXPLORED BY AKATSUKI RADIO SCIENCE EXPERIMENT. A. Bhattacharya[1], V. Sheel[2], J. P. Pabari[2], T. Imamura[3] and K. McGouldrick[4], [1]SVNIT Surat, India, ananyo0806@gmail.com, [2]PRL Ahmedabad, India, [3]Graduate Institute of Frontier Sciences, University of Tokyo, Japan and [4]LASP, CU Boulder, US.

Introduction: Planetary atmosphere of Venus undergoes strong zonal circulation consisting of high speed winds around the cloud region i.e. 48-70 Km. The atmospheric circulation patterns in the middle cloud region i.e. 50-56 Km shows strong convective activity. Thus, the interaction between the mean zonal circulation and vertical motion due to convective activity can give rise to shear flow instabilities leading to formation of Kelvin-Helmholtz billows in the cloud region.

Measurements from radio occultation experiments from various Venus orbiters have been utilized to study the thermal structure of the atmosphere. Akatsuki radio science experiment derived temperature profiles and in-situ measurement of zonal wind speeds from Pioneer Venus probes are utilized to study the possibility of shear flow instability. Computation of Richardson's number yields low magnitudes in the cloud region indicating multiple instances of occurrence of shear flow instabilities due to interaction flow interactions.

Radio occultation: In this method, the orbiter transmits radio wave signals to a Earth based tracking station and in the process, it passes through the atmosphere of the planet. The propagation of radio waves through the atmosphere is then processed to retrieve the properties of ionosphere and neutral atmosphere. Radio occultation experiments onboard Venus orbiters have studied thermal structure, composition, small scale disturbances and characteristics of internal gravity waves and saturation characteristics.

Method: JAXA Data ARchive and Transmission System (DARTS) has data from 34 radio occultation experiments performed by Akatsuki. Level 4 data from Akatsuki radio science experiment [1] is used to compute static stability and Brunt-Vaisala (BV) frequency equation (1) by incorporating adiabatic lapse rate values from Venus International Reference Atmosphere (VIRA) [2]. The wind speeds are calculated using an analytic formula [3] from the in-situ measurements of Pioneer Venus probes. Further, the wind speed inputs are then corrected for latitudinal variation [4].

The necessary condition for occurrence of KH instability is expressed in terms of Richardson's number, Ri using equation (2). KH instability occurs if the magnitude of Ri is less than or equal to 0.25. However, it is to be noted that it is a necessary but not a sufficient criterion. We have only considered the non-negative values of Ri, as negative values indicate presence of static instability. Ri has been previously utilized in radiative-dynamical models for Venus clouds [5] to study mixing processes in unstable and turbulent atmosphere. Our computations for Ri yield values varying by large order of magnitude from one another, therefore to incorporate the range of absolute values we define a term Z as expressed in equation (3) such that KH instability occurs when Z is less than zero.

$$N^2 = \frac{g}{T} S \tag{1}$$

$$Ri = \frac{g}{T} \frac{S}{(\frac{du}{dh})^2} \tag{2}$$

$$Z = log_{10}\left(\frac{Ri}{0.25}\right) \tag{3}$$

Where N^2 is square of BV frequency, g is acceleration due to gravity, S is static stability, T is the temperature, u is the zonal speed, h is length along vertical direction and Ri is Richardson's number.

Results: Figure 1 depicts the combined magnitude of N^2 vs. altitude for all the 34 radio occultation experiments. It can be seen that the atmosphere has a quasi-neutral stability in the 50-55 km region, due to the static stability earlier reported [6] and a comparison with previous radio occultation measurements. The relatively larger magnitudes of N^2 could be attributed to intense convective activity and noise in the measurement. Negative values of N^2 in figure 1 indicate static instability in the clouds.

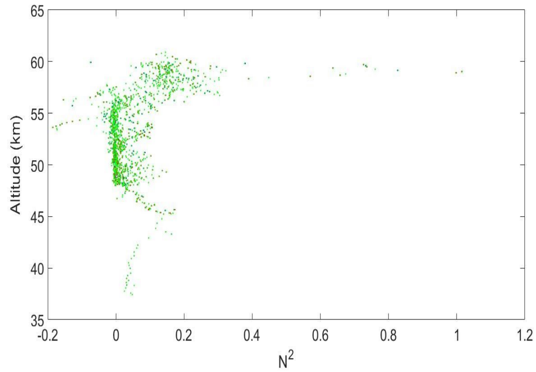

Figure 1. N^2 vs. Altitude (km) for shear flow instability

On the other hand, computations of parameter Z indicate that there are multiple occurrences where the Richardson's number is less than the critical value implying high possibilities of development of Kelvin Helmholtz billows in the cloud region. We show an example of variation of parameter Z along the altitude in figure 2. The value of Z is due to the quasi-neutral state of the cloud region which yields a lower magnitude of Ri. Another factor is the strong wind shear due to the super-rotation process occurring throughout the cloud region.

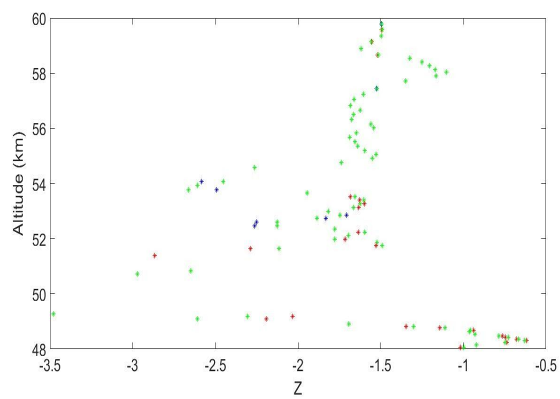

Figure 2. Z vs. Altitude (Km) in cloud region

Discussion: From equations (1) and (2), it can be seen that computations of Richardon's number are sensitive to static stability, temperature and wind speed measurements. Thus, input data from peer-reviewed works are used for the computation.

The interaction of zonal wind with convective activity in the cloud region is of great interest in order to study the dynamical process of Venusian atmosphere. Breaking of the KH billows can be expected to be a source of generation of turbulent flow in the cloud leading and thus, playing a role in atmospheric transport of momentum and energy. Furthermore, KH instability is one of the saturation mechanisms for internal gravity waves.

Lastly, the phenomenon of the atmospheric lightning process is yet to be fully understood. Convection has been the driving force for charge separation mechanisms on Earth. The role of zonal circulation and convective activity into possible charge separation mechanisms has not been explored in case of Venus. Charge separation due to transport of large sized ice particles has been discussed earlier [7]. Further work will explore the characteristics of flow instability and their role in various atmospheric processes on Venus.

References:

[1] Murakami S. et al. (2018) *NASA Planetary Data System*. [2] Seiff A. et al. (1985) *Adv. Space Res., 5,* 11, 3-58. [3] Schubert G. and Walterscheid R. L. (1984) *J. Atmos Sci.,* 41, 1202-1213. [4] Young R. E. et al. (1984) *J. Atmos. Sci.,* 41, 15. [5] Ando H. et al. (2020) *Sci. Rep.,* 10, 3448. [6] Ando H. et al. (2020) *Sci. Rep.,* 10, 3448. [7] McGouldrick K. et al. (2011) *PSS,* 59, 934-941.