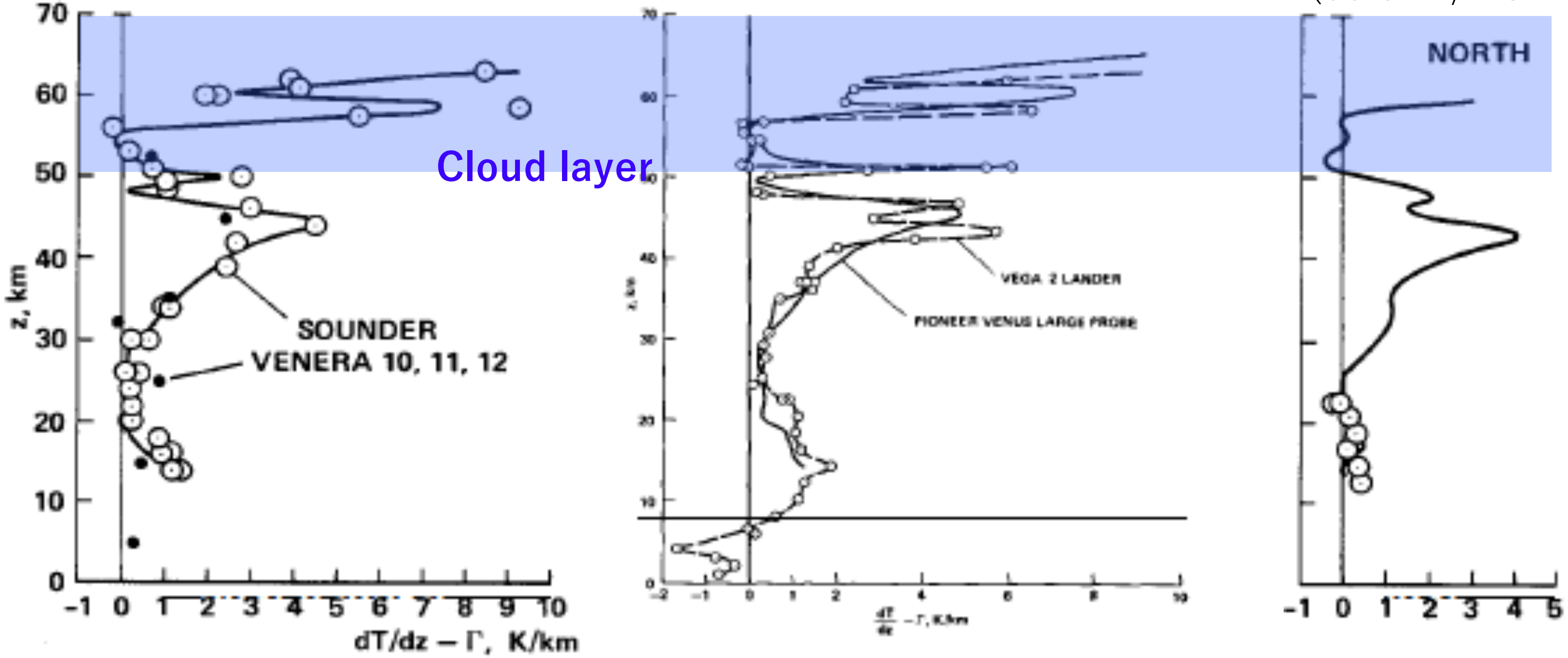
Thermal structure of the Venusian atmosphere from the sub-cloud region to the mesosphere as observed by radio occultation

○Hiroki Ando (hando@cc.kyoto-su.ac.jp), Takeshi Imamura, Silvia Tellmann, Martin Pätzold, Bernd Häusler, Norihiko Sugimoto, Masahiro Takagi, Hideo Sagawa, Yoshihisa Matsuda, Sanjay Limaye, Raj Kumar Choudhary and Maria Antonita

Previous in-situ measurements

PVO probe, Venera landers (Equatorial region)

PVO north probe
(59.3˚N, 4.8˚E)

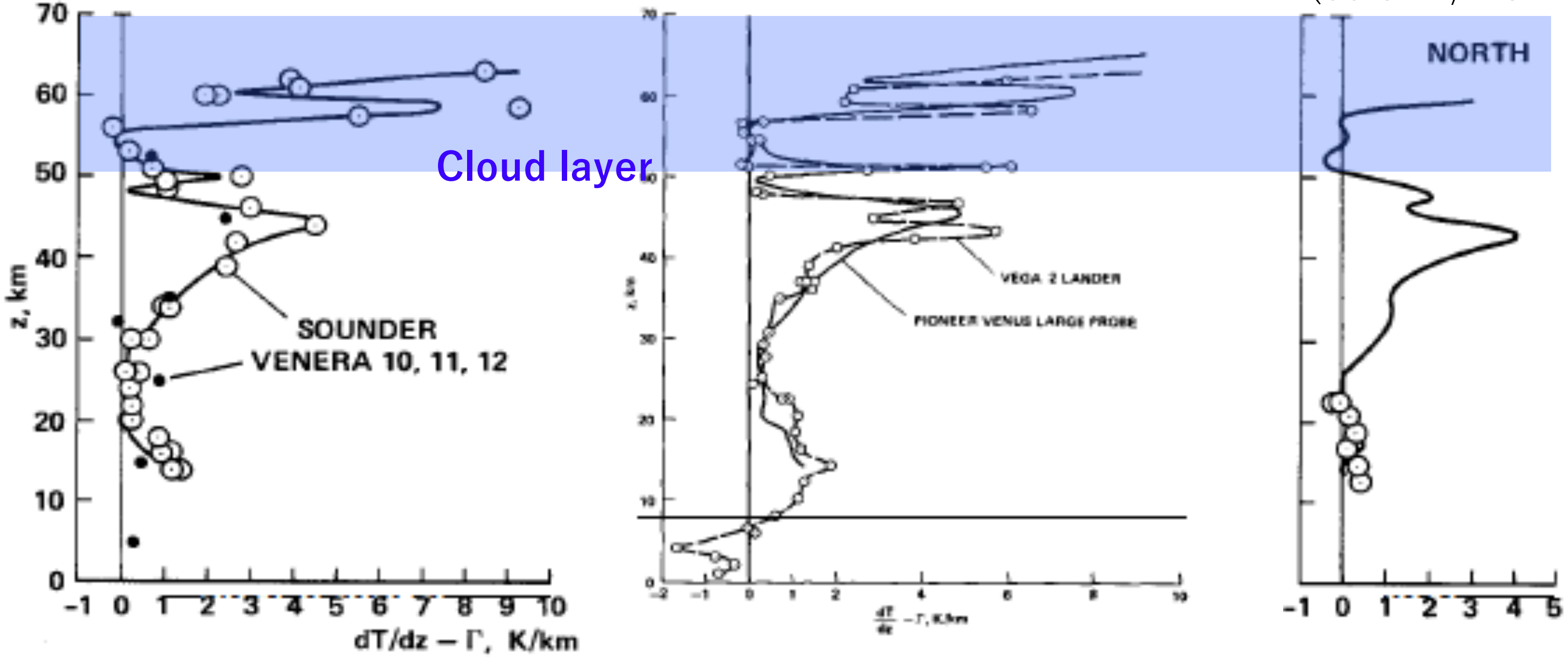


- A few in-situ measurements have been conducted to obtain the vertical temperature and static stability distributions near the equator and 60˚N.
- There is a low-stability layer at 50–55 km altitudes, a moderately stable one below 50 km altitude and highly stable one above 55 km altitude.

Previous in-situ measurements

PVO probe, Venera landers (Equatorial region)

PVO north probe (59.3˚N, 4.8˚E)

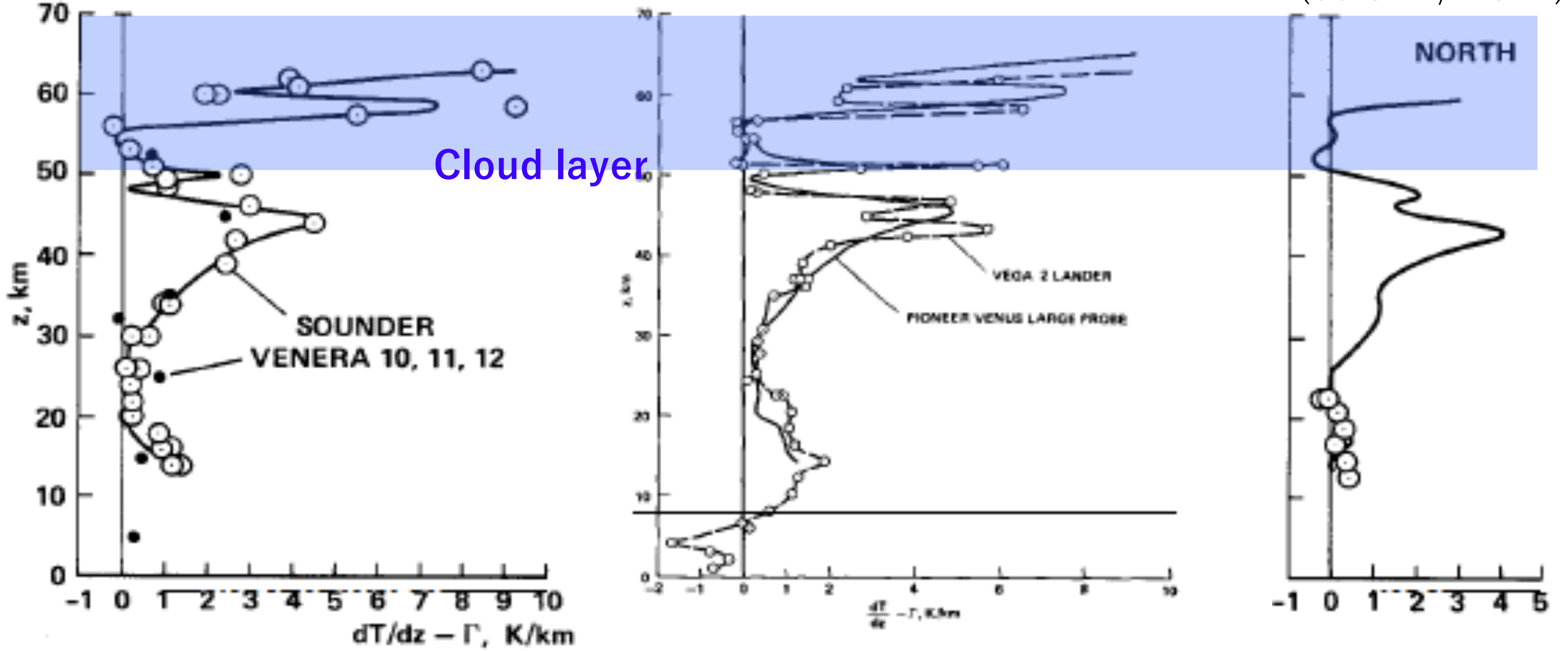


- The number of data is so small that there is little statistical significance.
- The observed region has been limited in low-latitudes and 60˚N. There are no observations in high-latitudes.

Previous in-situ measurements

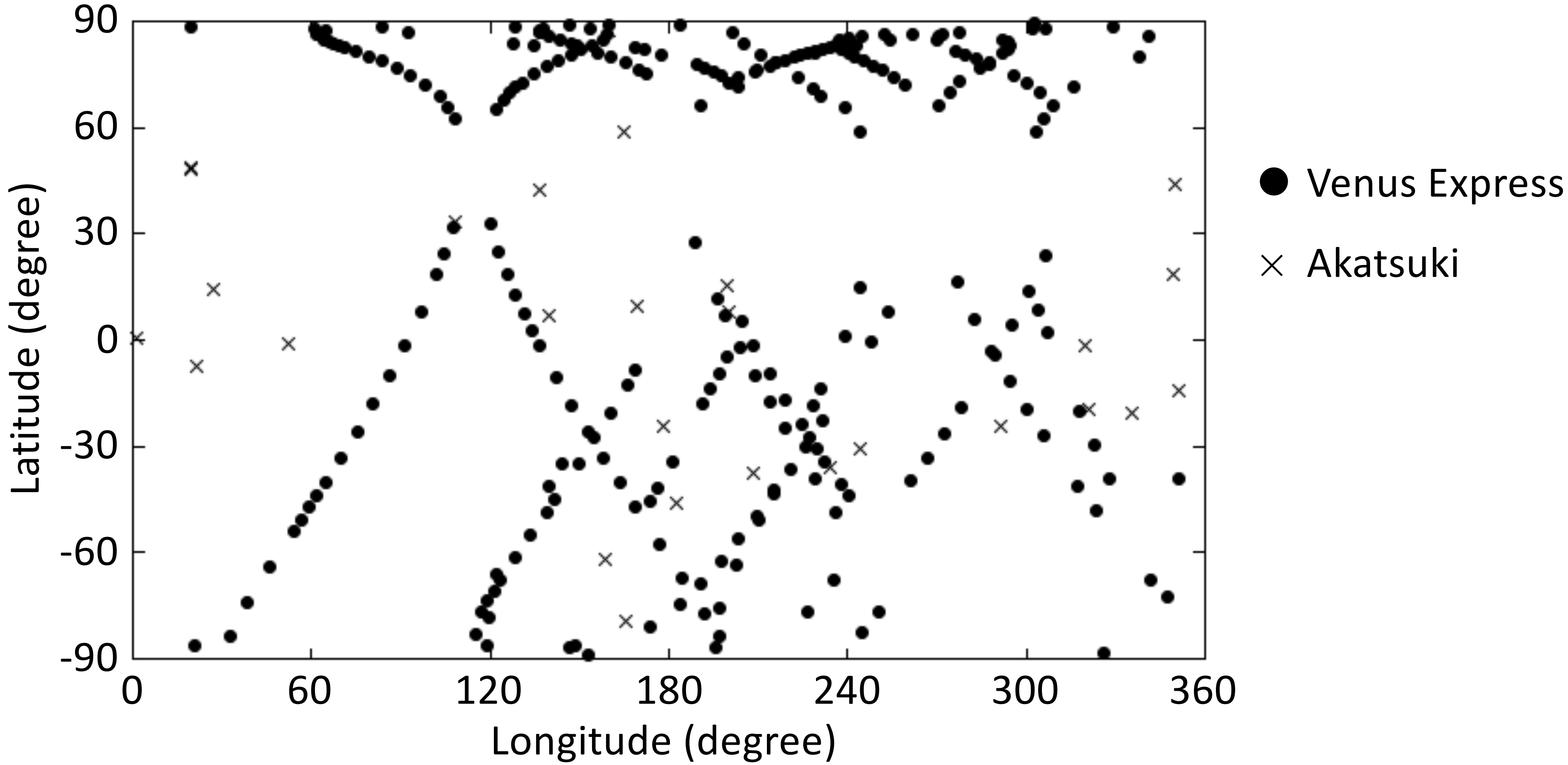
PVO probe, Venera landers (Equatorial region)

PVO north probe
(59.3˚N, 4.8˚E)



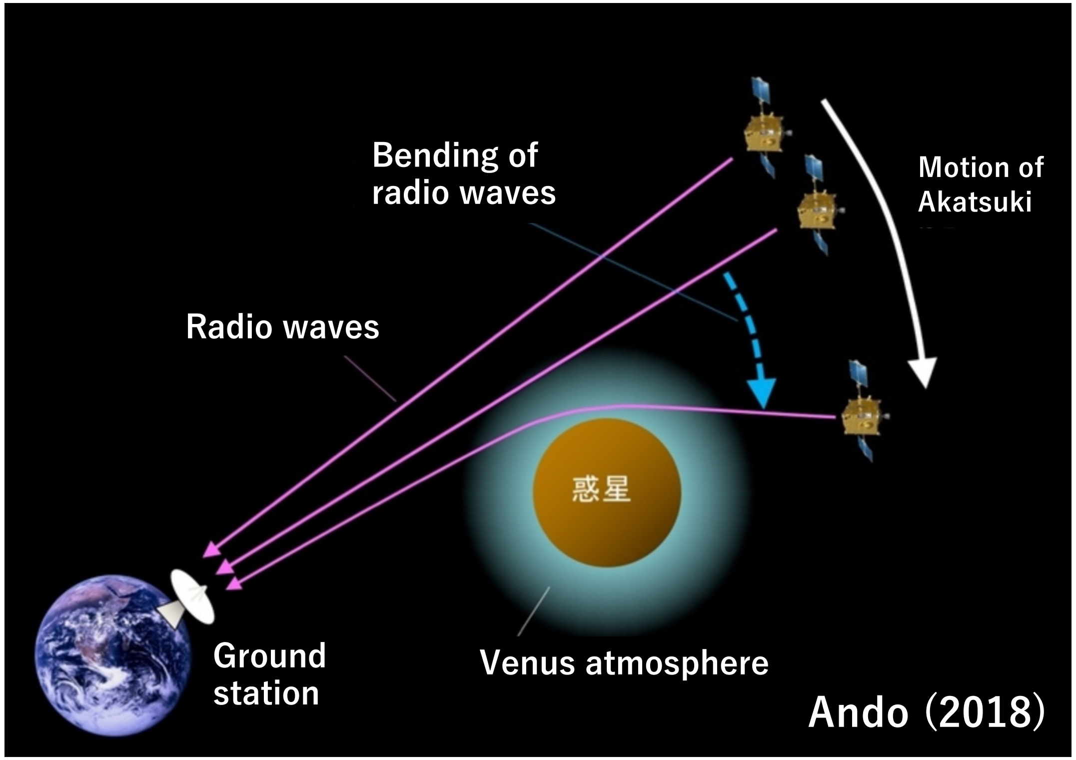
- We analyzed the radio occultation data in Venus Express (polar orbit) and Akatsuki (equatorial orbit) missions and showed **the mean temperature and static stability distributions at 40–85 km altitudes globally**.

Data point distribution



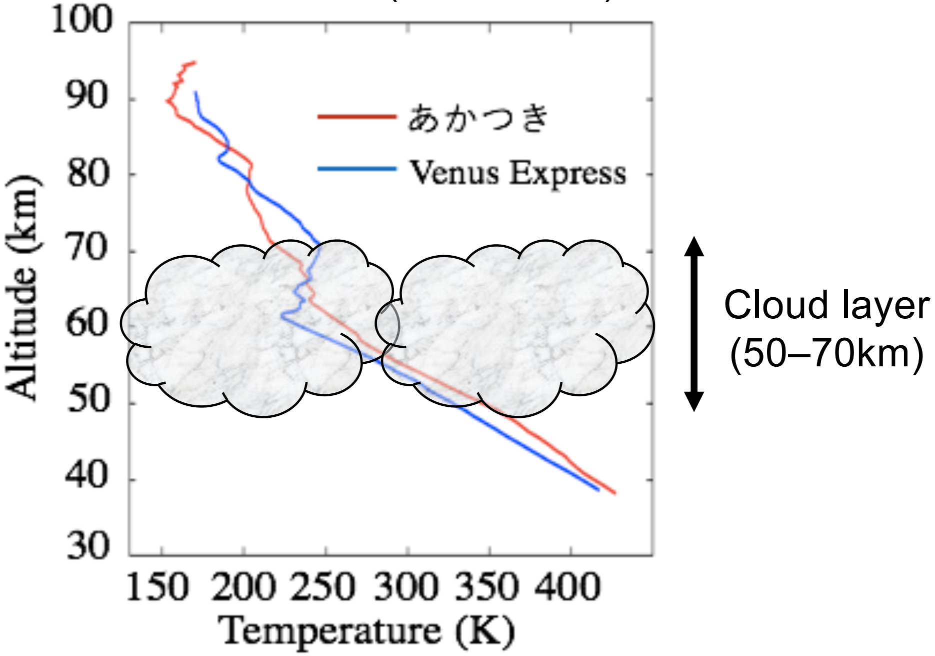
What is radio occultation?

- Radio waves are transmitted from the spacecraft, refracted in the planetary atmosphere, and received at a ground station.
- From the temporal variation of the received frequency (doppler shift), a vertical temperature profile is retrieved.
- From the temporal variation of the received signal power, a vertical profile of H_2SO_4 vapor mixing ratio can be also retrieved.

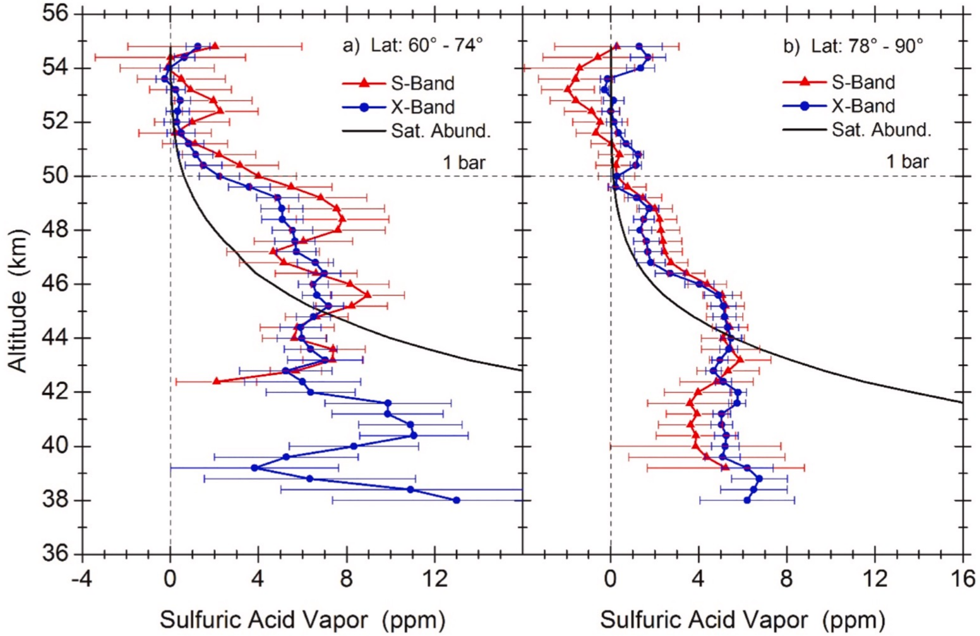


Examples of temperature and H_2SO_4 vapor mixing ratio profiles obtained by radio occultation

Ando et al. (2015; 2018)

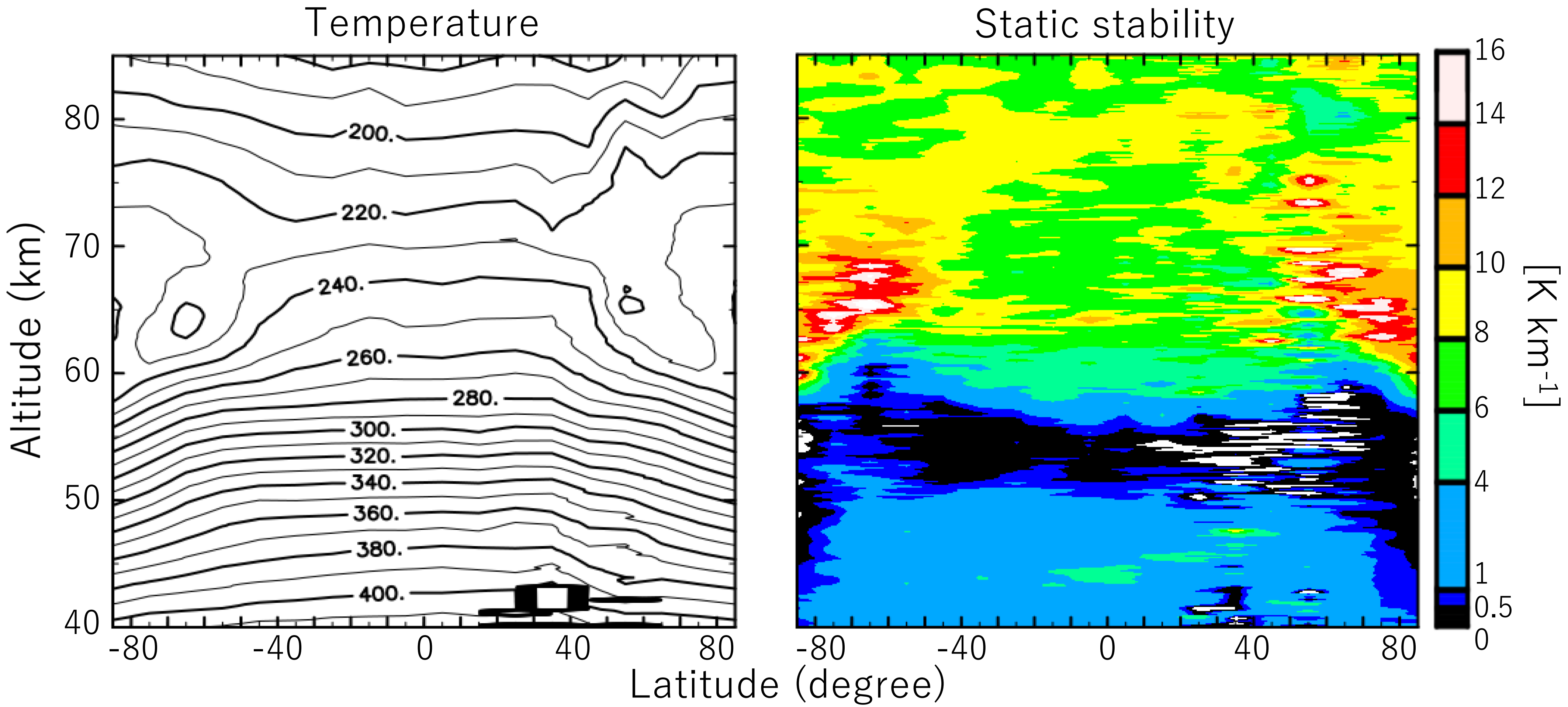


Oschlisniok et al. (2021) & Ando et al. (in prep.)

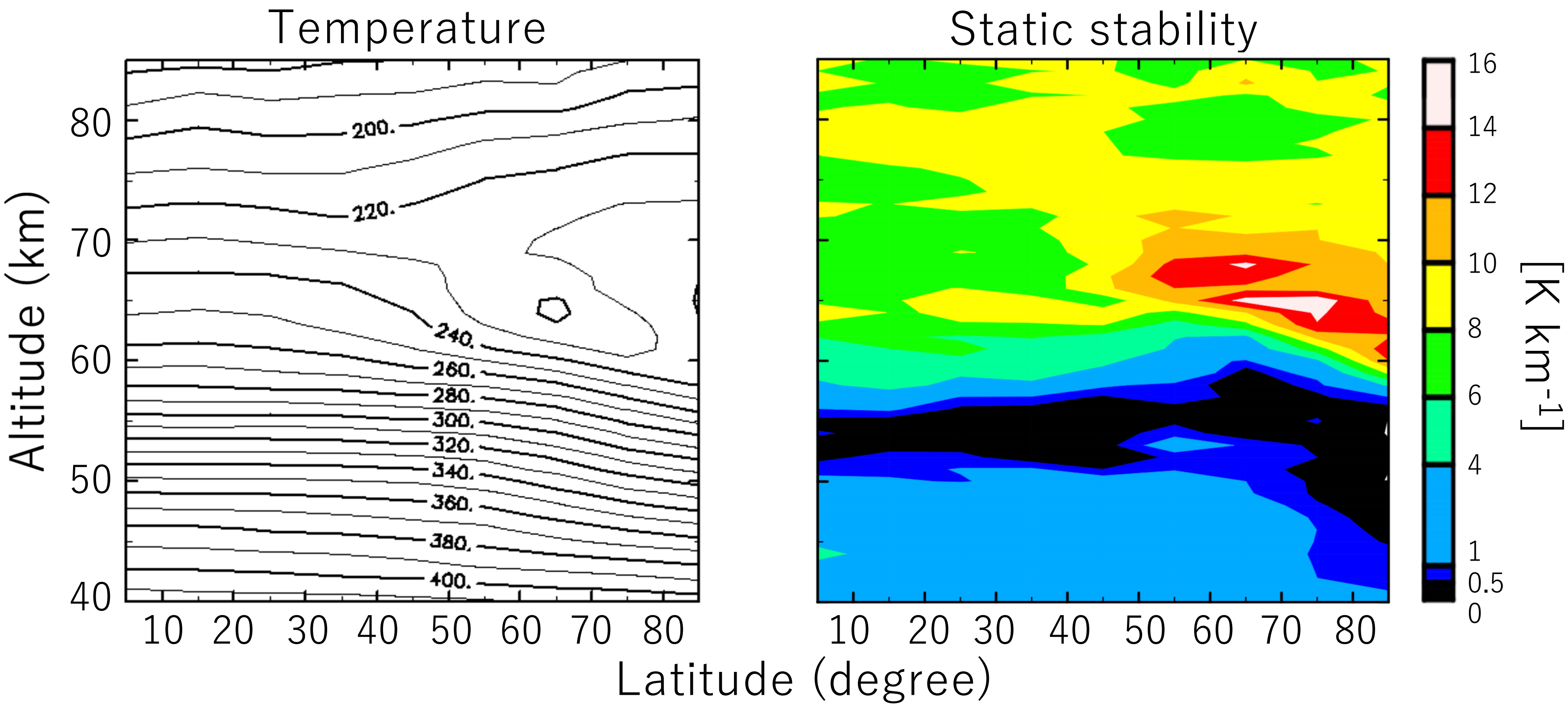


- We can retrieve a vertical temperature profile from the sub-cloud region to the mesosphere (40–90 km altitudes).
- We can also retrieve a vertical profile of H_2SO_4 vapor mixing ratio from the lower cloud layer down to the sub-cloud region (40–55 km).

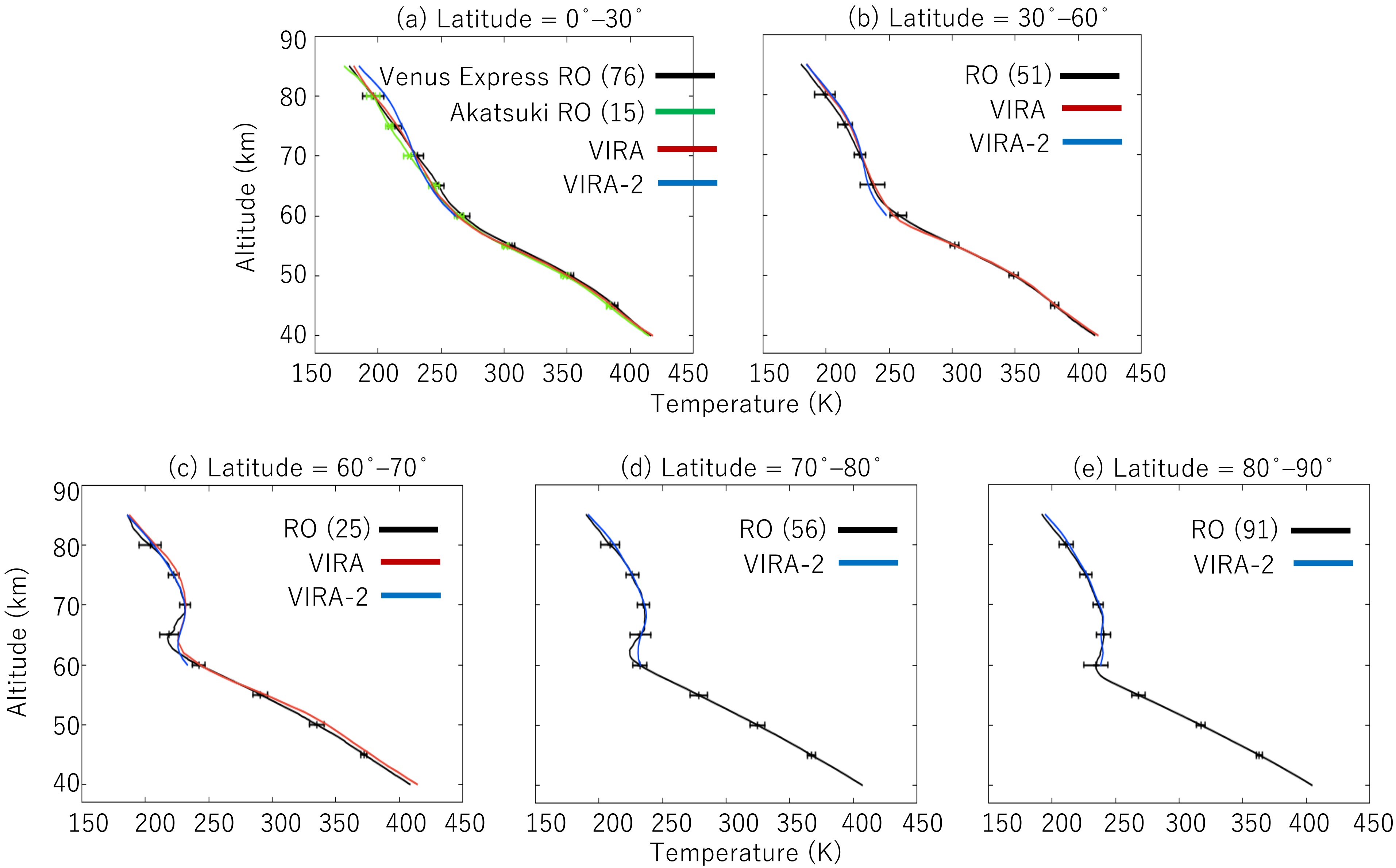
Latitude-height distributions of temperature and static stability



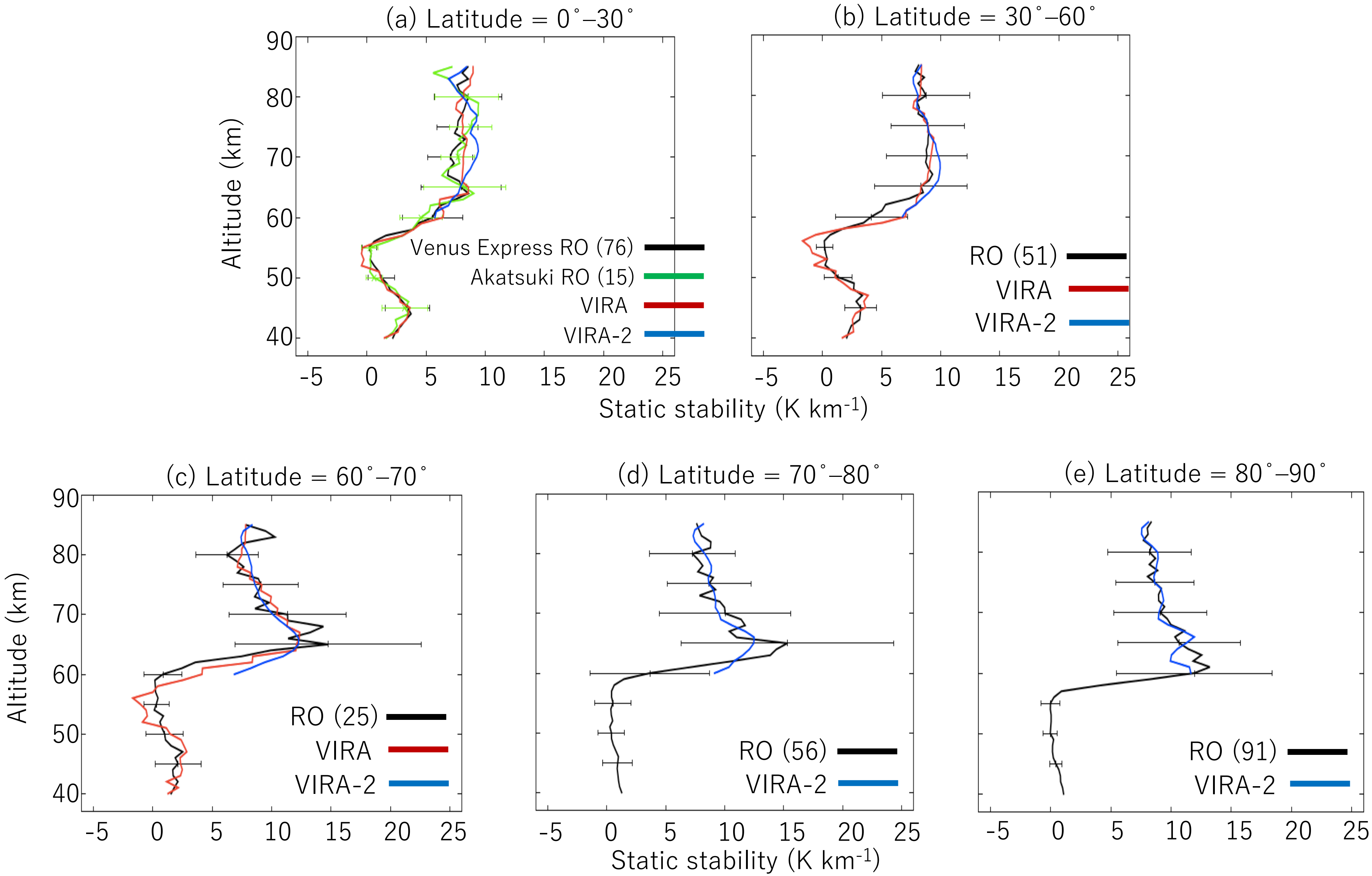
Latitude-height distributions of temperature and static stability



- In low- and mid-latitudes, the static stability distributions are qualitatively consistent with the previous in-situ measurements.
- In high-latitudes, on the other hand, the low-stability layer extends down to the sub-cloud region. This has not been shown in any previous measurements.



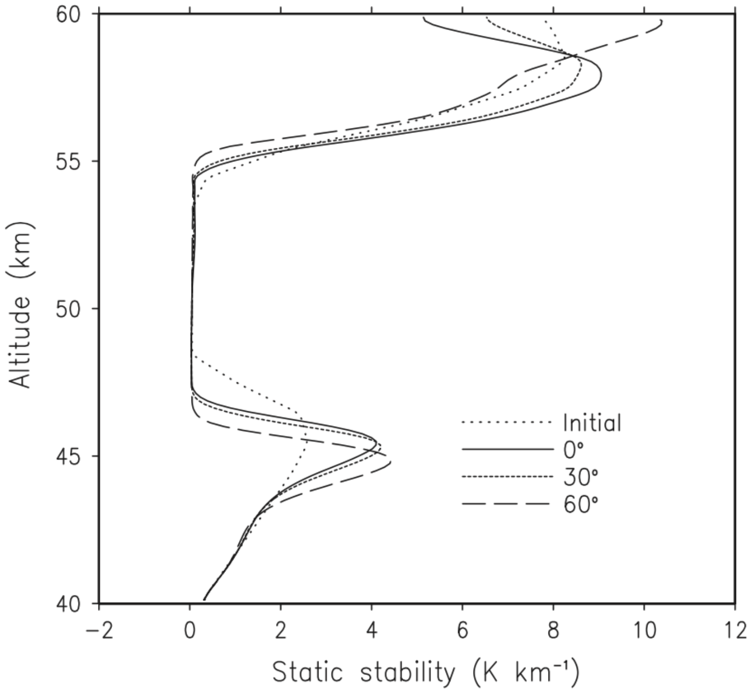
(a) Latitude = 0°–30°
Venus Express RO (76)
Akatsuki RO (15)
VIRA
VIRA-2
(b) Latitude = 30°–60°
RO (51)
VIRA
VIRA-2
(c) Latitude = 60°–70°
RO (25)
VIRA
VIRA-2
(d) Latitude = 70°–80°
RO (56)
VIRA-2
(e) Latitude = 80°–90°
RO (91)
VIRA-2
Altitude (km)
Temperature (K)
90
80
70
60
50
40
150
200
250
300
350
400
450



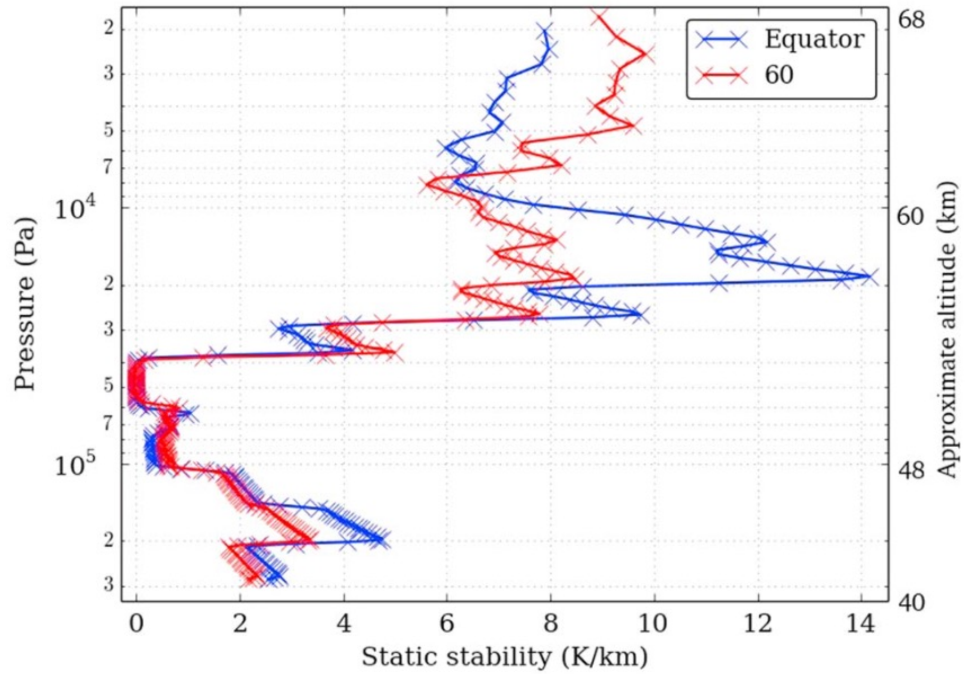
(a) Latitude = 0˚–30˚
(b) Latitude = 30˚–60˚
(c) Latitude = 60˚–70˚
(d) Latitude = 70˚–80˚
(e) Latitude = 80˚–90˚
Altitude (km)
Static stability (K km-1)
Venus Express RO (76)
Akatsuki RO (15)
VIRA
VIRA-2
RO (51)
RO (25)
RO (56)
RO (91)

Discussion

Imamura et al. (2014)



Lefevre et al. (2017)



- Imamura et al. (2014) and Lefevere et al. (2017) conducted the numerical simulations to investigate the convective motion in the cloud layer. They found that the latitudinal variation of the depth of low-stability layer is ~1 km.
- This suggests that the latitudinal variation of the depth of low-stability layer cannot be explained in terms of the radiation processes. Should we consider dynamical processes such as mean meridional circulation and disturbances?

Summary

- We analyzed radio occultation data obtained in Venus Express and Akatsuki missions and showed the mean thermal structure (temperature and static stability).
- In low- and mid-latitudes, the static stability distributions are qualitatively consistent with the previous in-situ measurements. In high-latitudes, the deep low-stability layer extends down to the sub-cloud region (~42 km altitude). This feature has not been clarified in any previous measurements.
- The paper about this study has been published by Scientific Reports (Ando et al., 2020). In addition, we are theoretically investigating how the thermal structure clarified by the radio occultation measurements is created and maintained by using Venus GCM (we will submit our paper about this theoretical study soon).