Data analysis of Mars orbiters:

Rederivation of MGS radio occultation's temperature with the consideration of CO_2 condensation in the Martian atmosphere

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Noguchi et al. [2014, JGR]:
Estimation of changes in the composition of the Martian atmosphere caused by CO2 condensation from GRS Ar measurements and its application to the rederivation of MGS radio occultation measurements

Summary

- Martian atmospheric composition:

  CO_2 and other gases (N_2, Ar, etc…)
- Radio occultation, which can probe temperature profiles, needs the information of composition rate
- Problem: CO_2 condensation at polar night causes change of composition rate (CO_2 depletion and other non-condensation species' increase) , which affects radio occultation measurements
- But no observation of the seasonal change of (all the) composition rate available
- We show
  - how to estimate the change of composition rate and
  - Radio occultation rederivation using the estimated rate

Martian (neutral) atmosphere

- Composition

→Observed by Viking lander (1970's)

Main species : **CO_2 95%**

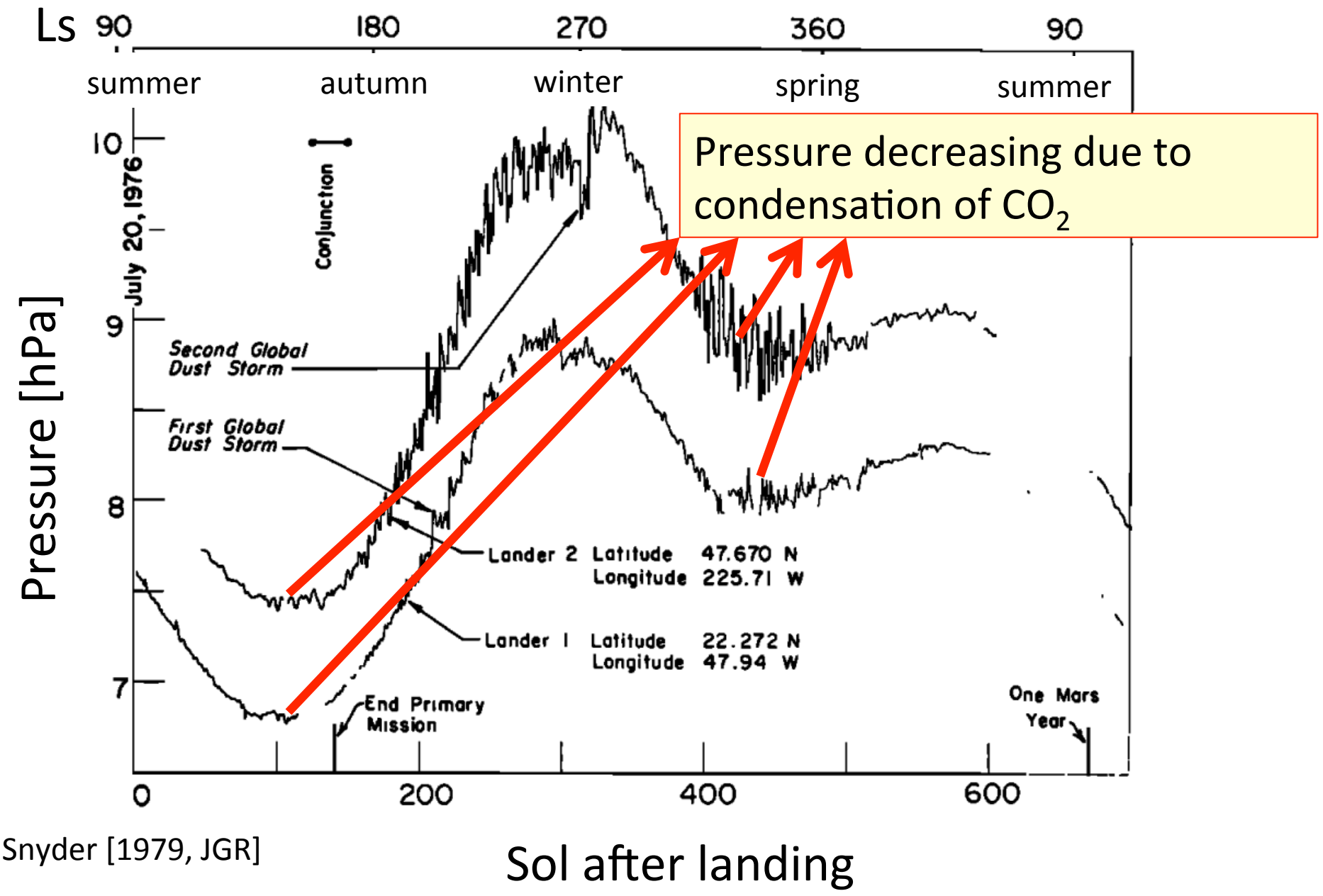
Other main species: **N_2 2.7 %**, **Ar 1.6%**

- Pressure

→less than 1/100 of Earth

Large seasonal change (20-30%) caused by condensation of CO_2 in polar nights

Drastic pressure change by CO_2 condensation

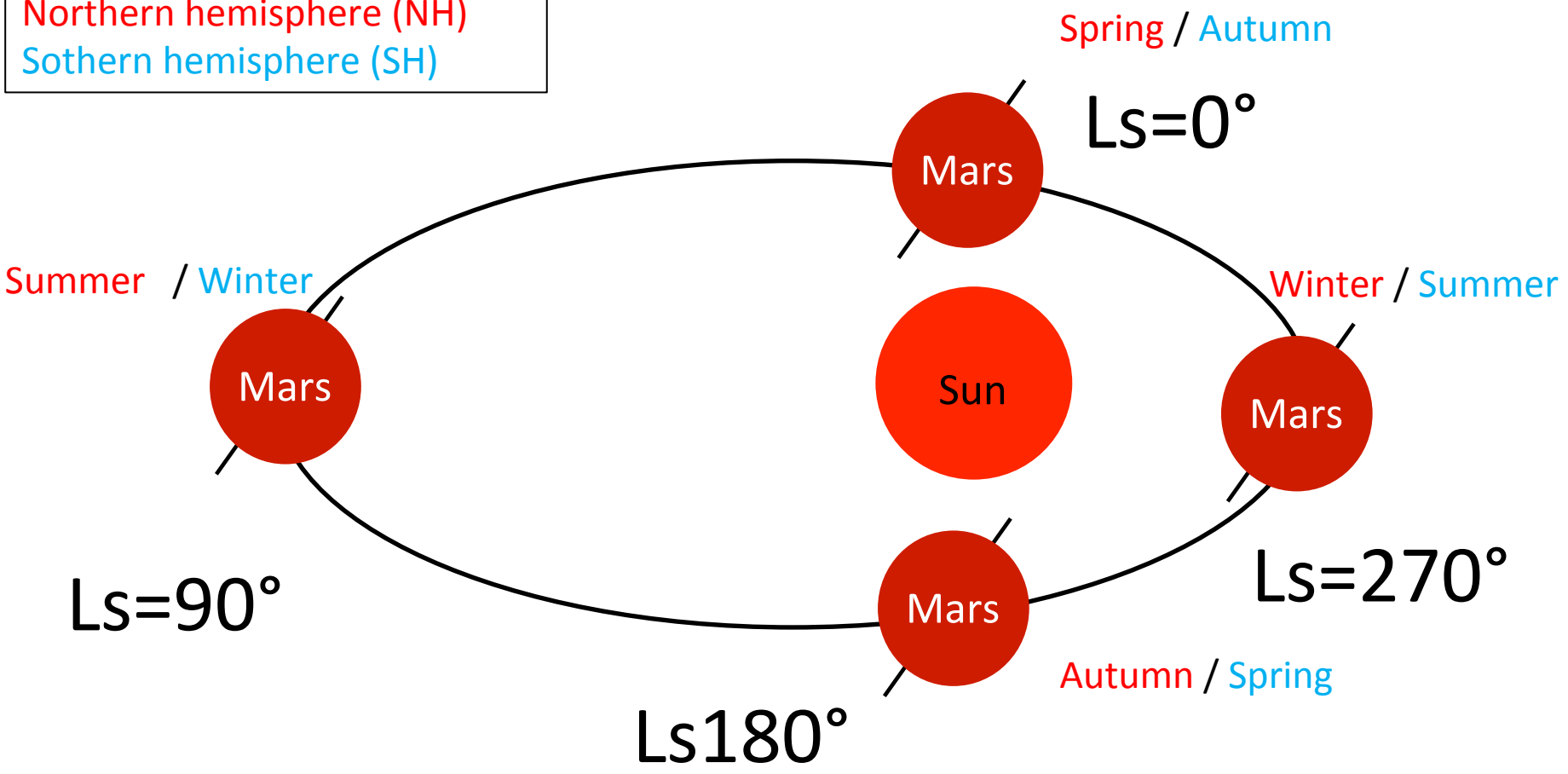


Snyder [1979, JGR]

Time on Mars

Sol: One day on Mars (≒24 hours)
MY（Mars Year）: Year on Mars (≒2 Earth years)
Ls（Solar Longitude）: Seasons of Mars

Northern hemisphere (NH)
Sothern hemisphere (SH)

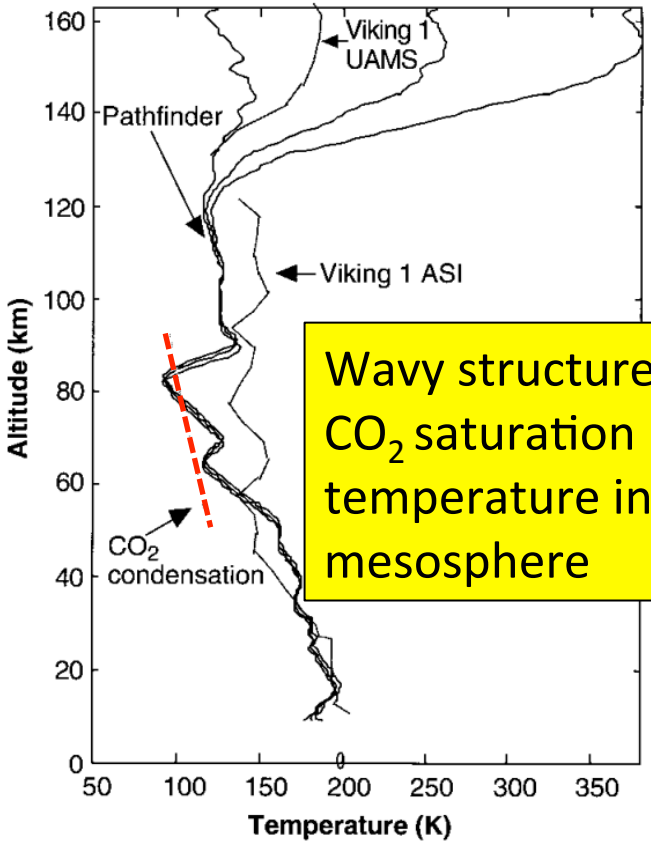


Elliptical orbit→Seasons in the SH are more extreme (i.e., hotter summer and colder winter) in the NH.

Condensation of CO_2 in the Martian atmosphere

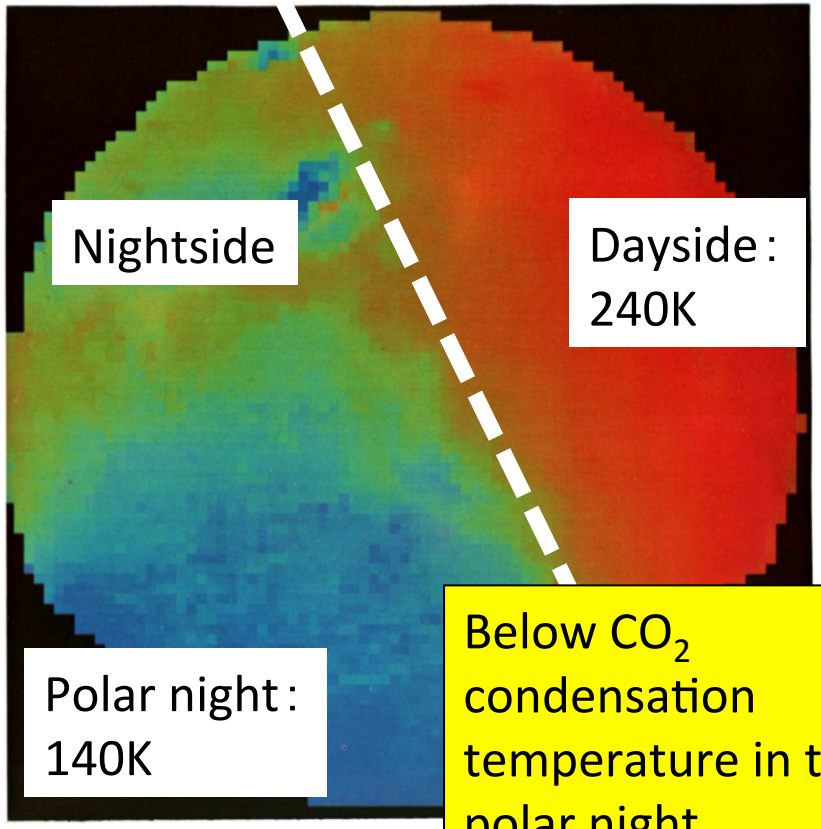
Frequently observed in the mesosphere and polar nights

Pathfinder's decent



Wavy structures with CO_2 saturation temperature in the mesosphere

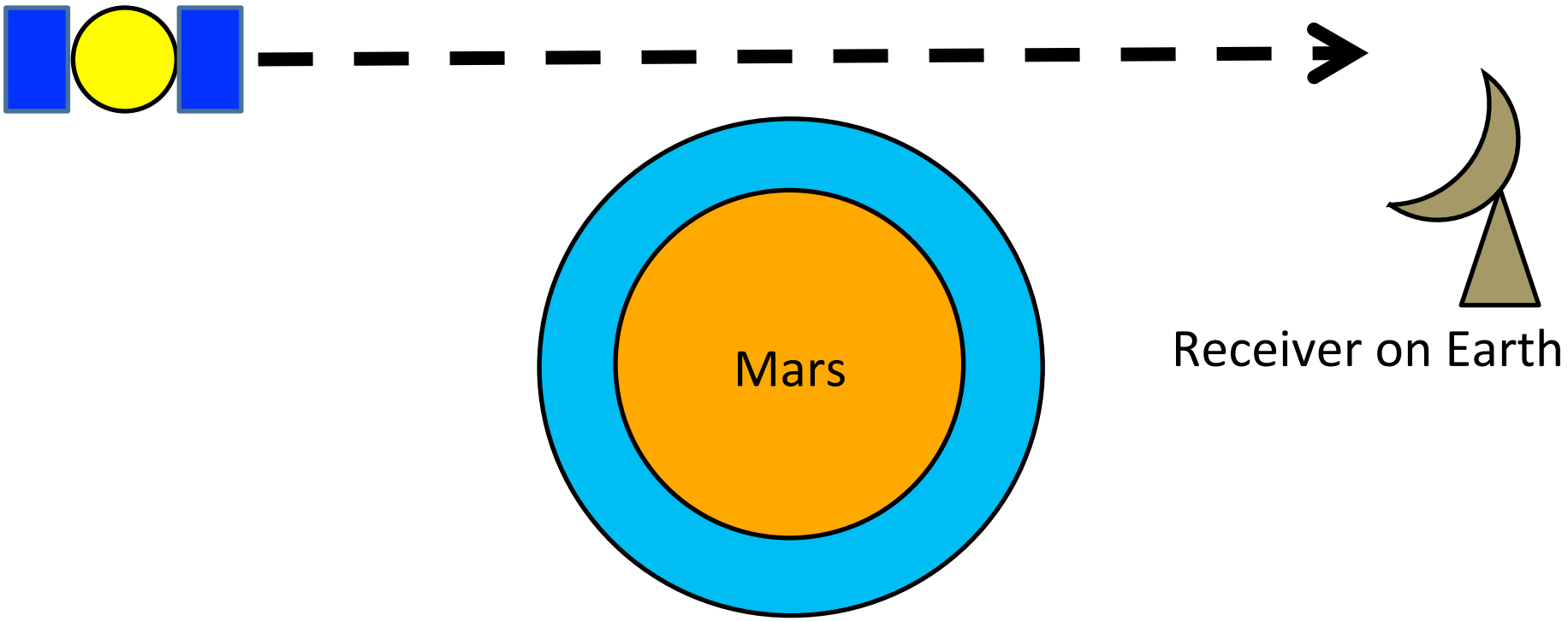
IR obs. (20um) by Viking orbiter



Below CO_2 condensation temperature in the polar night

Radio occultation (RO) measurement

- Probes temperature profiles (T precision<1K, alt. resolution<1km）
- Utilizes radio waves transmitted from spacecraft to receiver on Earth, which pass through planetary atmosphere
- Records radio waves‘ frequency changes according to vertical distribution of atmospheric refractivity
- Provides refractivity → number density of air → temperature



Data flowchart

Time series of frequency changes of radio waves

Abel transform

Vertical profile of refractivity μ

Electron number density

$$\mu - 1 = \sum \kappa_i n_i$$

Using composition rate!

Vertical profile of air number density N

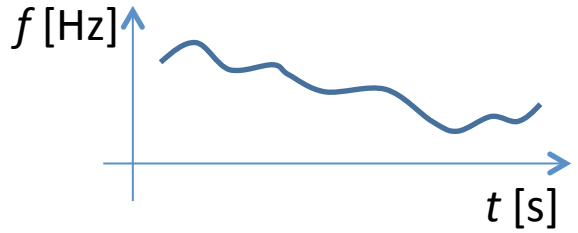
Hydrostatic equilibrium

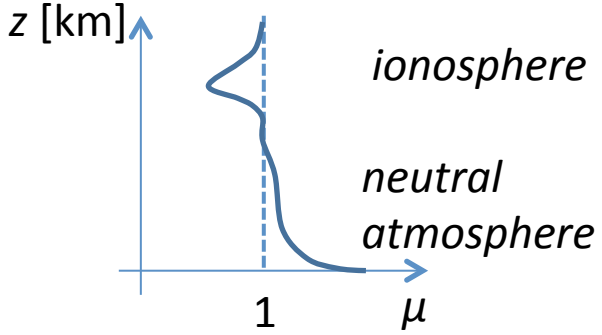
Using composition rate!

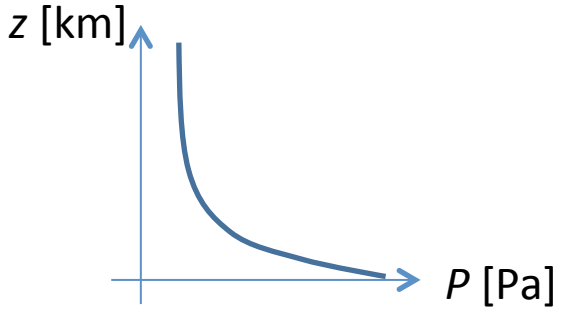
Vertical profile of pressure P

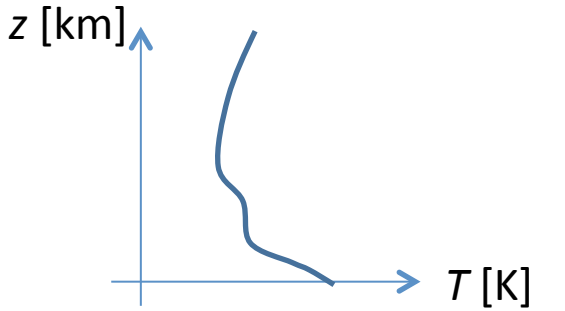
ideal gas law

Vertical profile of temperature T









Temperature retrieval by RO

Needs atmospheric composition ratio when

1. Converting refractivity μ to number density of air n

   → $\mu - 1 = \sum \kappa_i n_i$ κ: factors specific for gases

2. Using mean molecular weight to retrieve temperature from number density, assuming hydrostatic equilibrium

→However, previous studies did not consider the change of atmospheric composition ratio caused by CO_2 condensation

Purpose of study

This study

- Estimates the change of composition rate including CO_2
- Rederives the MGS RO temperature to discuss CO_2 condensation (saturation) and vertical distribution of mixing ratio

  - About 70 profiles of MGS-RO in the southern polar night region, where the effect of CO2 condensation is strongest.

Method: estimation of seasonal change of composition rate

- Main three constituents: CO_2, Ar, N_2
- Only Ar 's mixing ratio can be available from observations (Gamma Ray Spectrometer of Mars Odyssey [Sprague et al., 2012])

→how to obtain N_2 and CO_2?

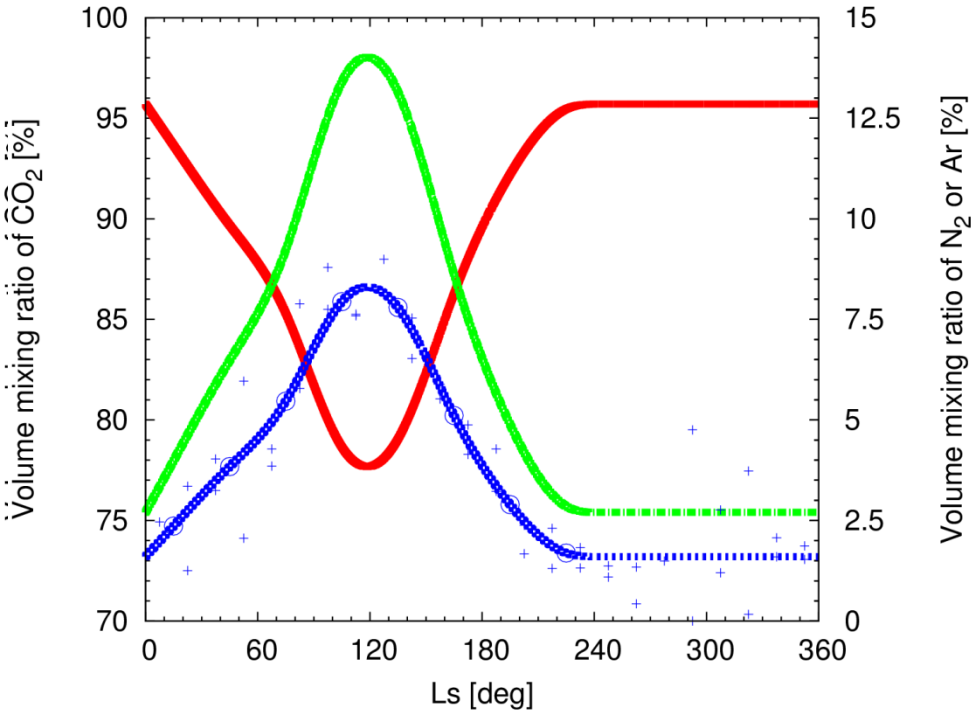
- N_2 : Ratio of Ar and N2 (2.7% : 1.6%) should be kept because N_2 and Ar do not condensate.

  N_2=2.7/1.6 Ar

- CO_2=100 -（N_2+Ar）[%]

→Empirical model of seasonal changes of the three gases' mixing ratio obtained!

Note: Constant vertical profiles assumed in this step (We will discuss this point later).

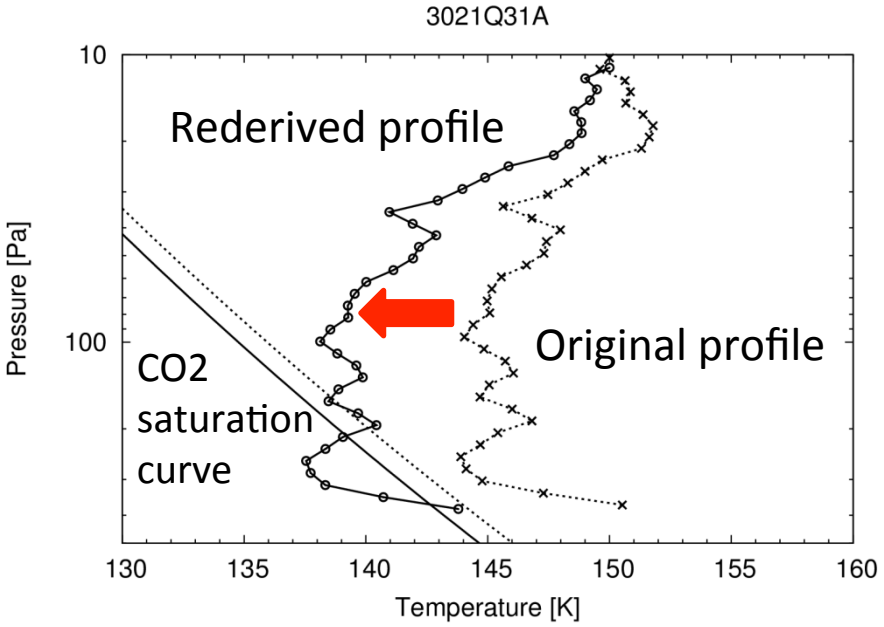


Results

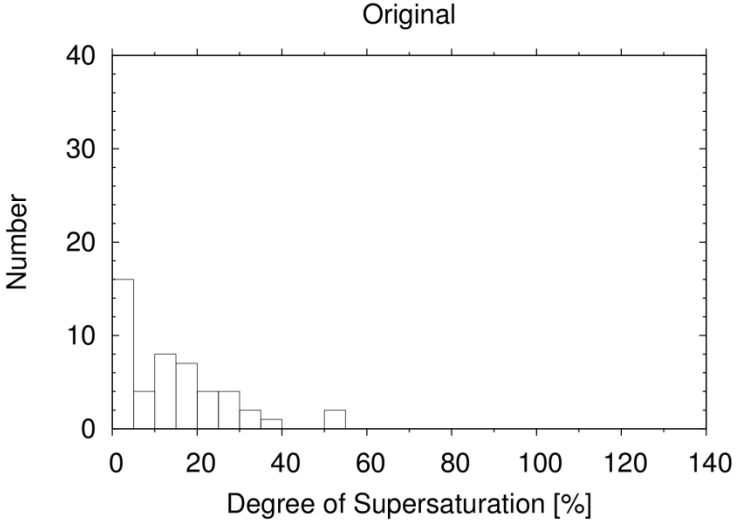
- Rederived temperature of MGS-RO utilizing the newly estimated composition rate

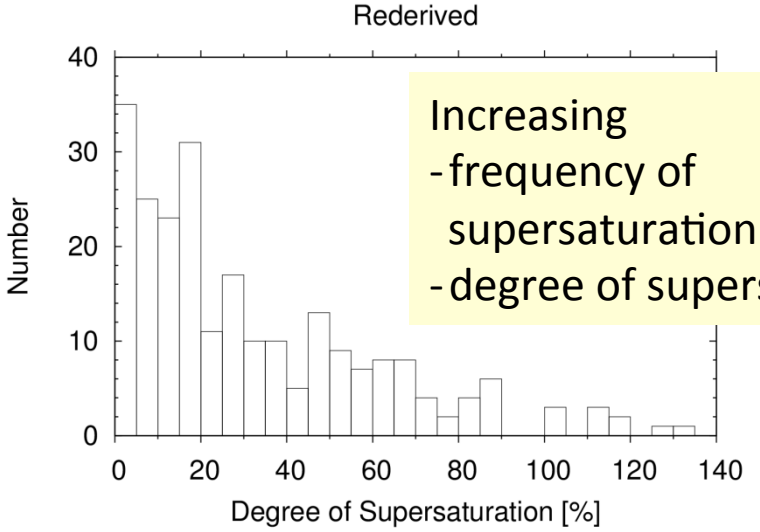
  Sample: Rederivation with 78% CO_2

- Overestimation of temperature without consideration of CO_2 condensation



- We utilize the updated MGS-RO temperature and pressure data to calculate the degree of CO_2 supersaturation





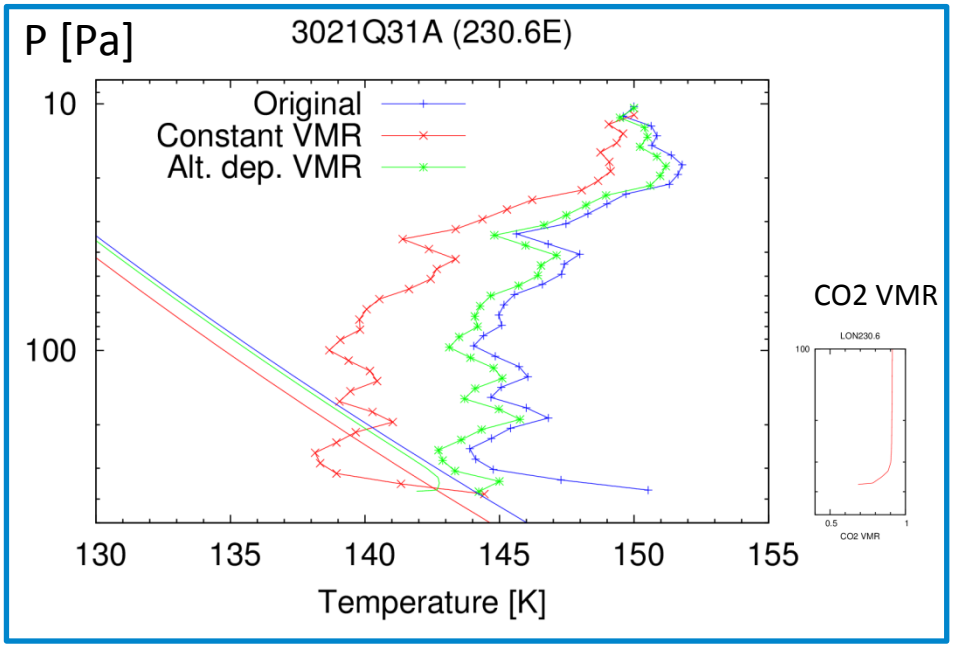
Increasing
- frequency of supersaturation and
- degree of supersaturation

Discussion: vertical profiles of gases

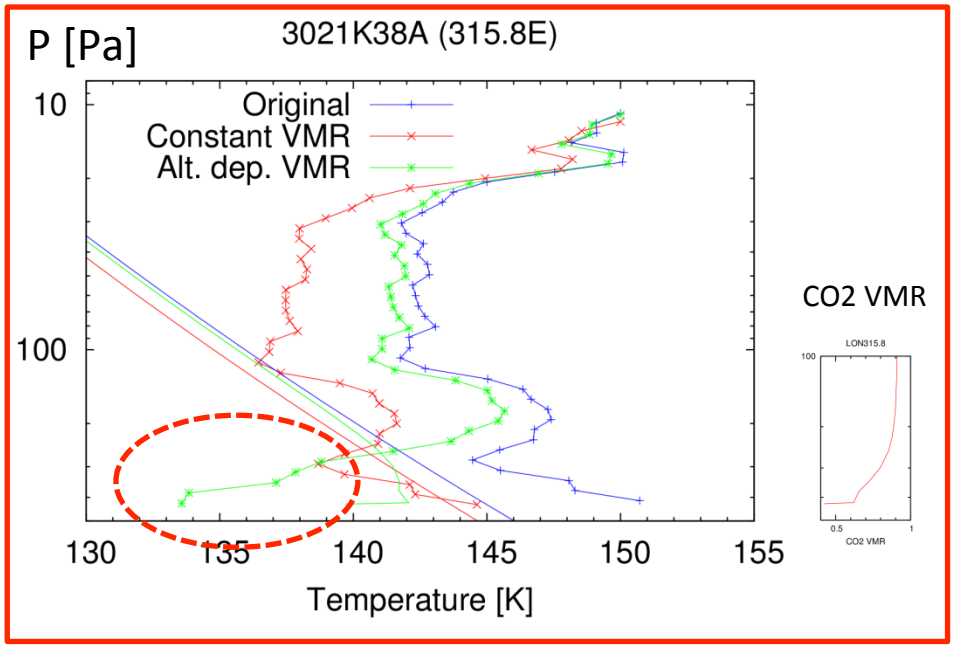
Problem: there is no direct measurements of vertical structures of atmospheric composition during CO2 condensation in polar nights.

Results when applying vertical distribution of MCD Ar for MGS-RO rederivation:

Result rederived looks realistic…



Looks unrealistic…



- Needs good estimation of vertical profiles (especially in the lower layer)
- Other way around, we might be able to obtain the information on the mixing ratio if we adjust temperature to CO2 saturation temperature (or 35% supersaturation temperature) → future work!

Conclusion

- We rederive MGS-RO temperature and pressure profiles with the consideration of CO_2 condensation in the Martian atmosphere
- Overestimation of RO temperature occurs if we do not consider CO_2 condensation
- Uncertainty of the vertical profiles of the constituents causes large errors of temperature

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