Climate on the planet Mars

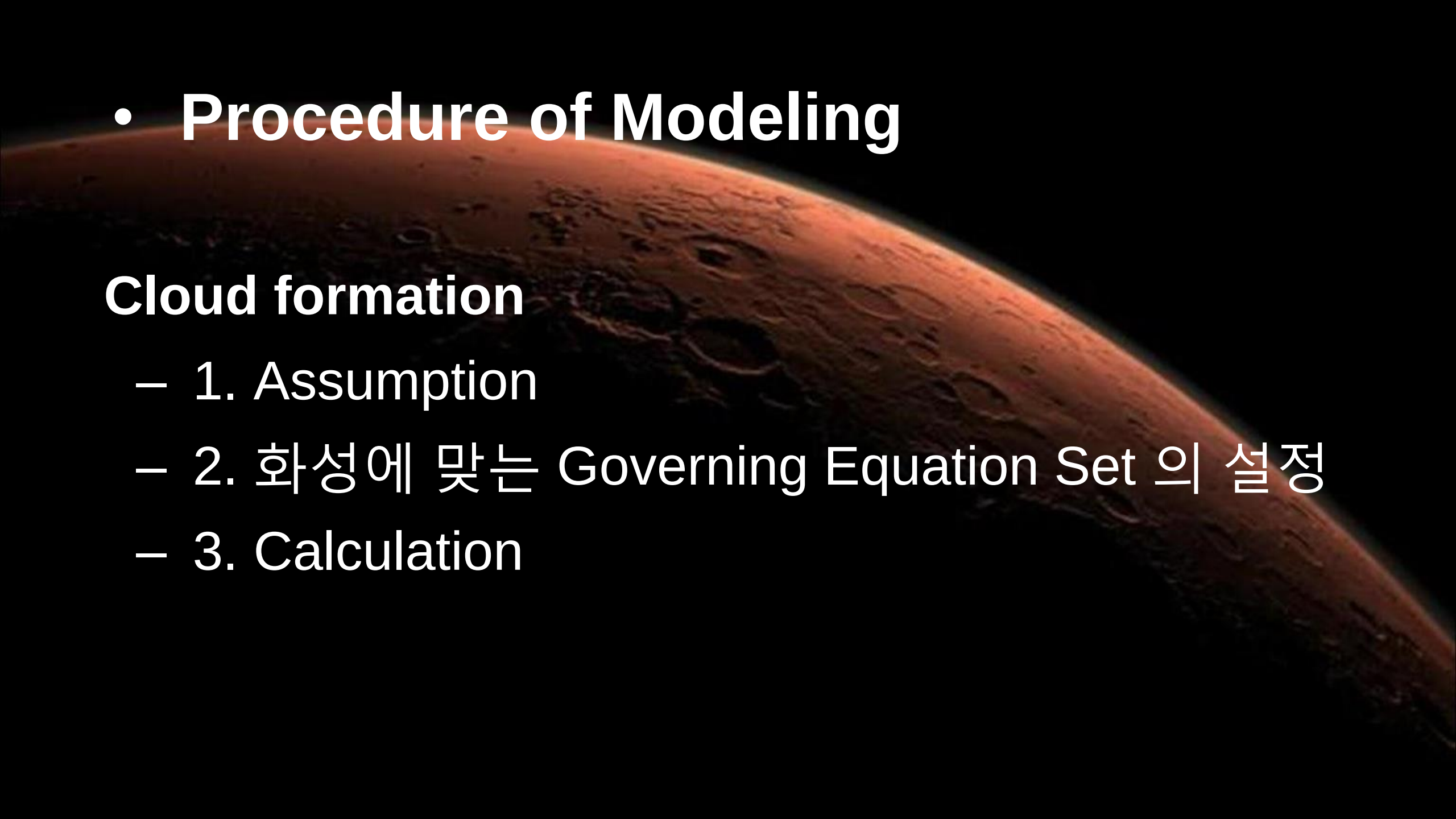
화성에서의 이산화탄소 구름 생성과 강설(snowfall) 에 대하여

2010-11052 최 유 성
2010-11105 정 성 하
2011-10978 이 장 호
2011-10974 육 심 찬
2011-10964 박 은 영

Contents

- **Abstract**

화성은 지구와 다른 기후 환경을 가지고 있다.
그러나 화성에서도 구름이 생기고 눈이 내린다.
따라서 화성에서 일어나는 기상현상에 대한 논의가
지구의 기상현상 이해의 확장에 도움이 되며
화성 탐사나 Teraforming의 연구에도 많은 도움이
될 것이라 생각하여 이번 연구를 시작하게 되었다.



- **Procedure of Modeling**

Cloud formation

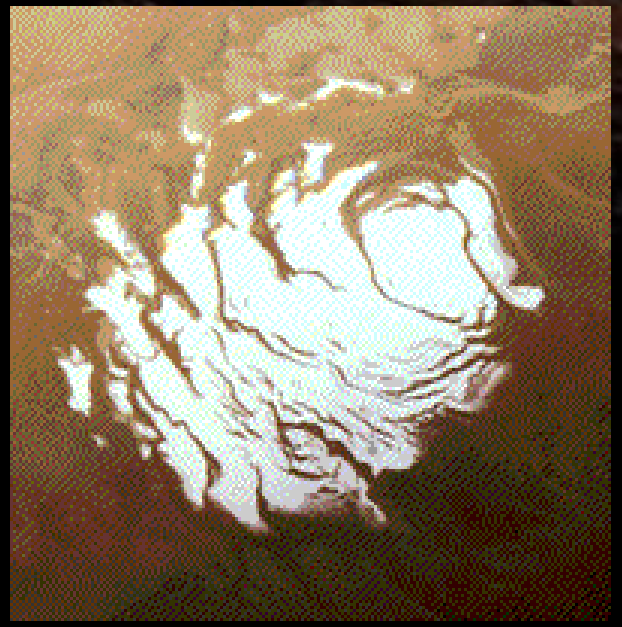
- 1. Assumption
- 2. 화성에 맞는 Governing Equation Set 의 설정
- 3. Calculation

Characteristics of Mars

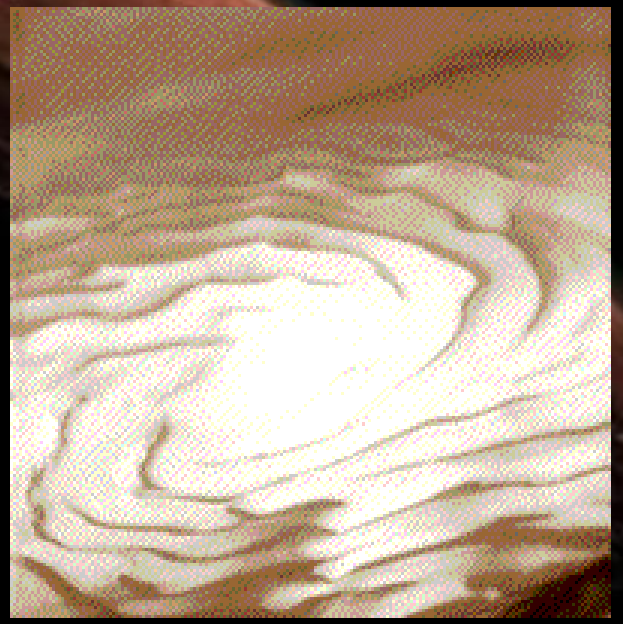
• Martian Climate & Global CO_2 cycle

- The central characteristic of the present Martian climate is the global CO2 cycle
- Temperatures in the polar regions during the long winter season fall to the extent that the tenuous CO2 atmosphere itself is deposited on the surface, forming the seasonal caps and significantly altering the global atmospheric pressure.

4 Seasons of the Mars



North polar cap during winter



South polar cap during winter

- # Snowfall at the Mars

Snow on Mars: NASA Spacecraft Spots 'Dry Ice' Snowflakes

by SPACE.com Staff | September 14, 2012 07:30am ET

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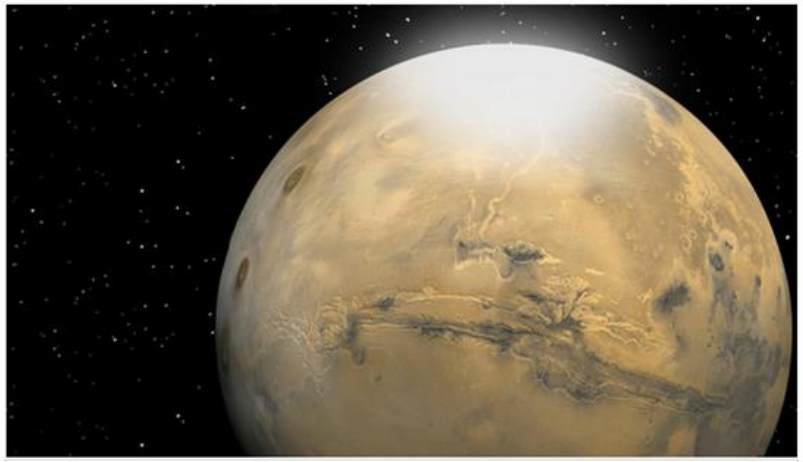


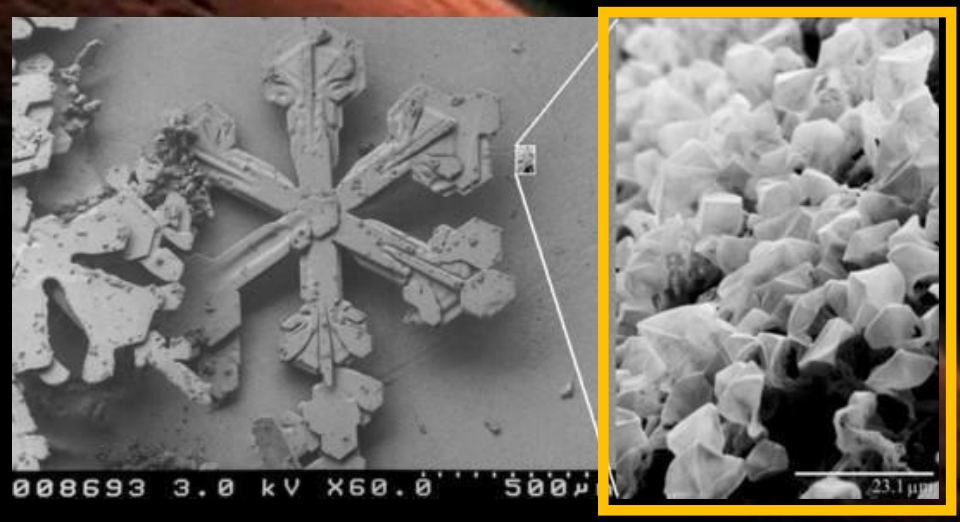
Researchers have calculated that carbon dioxide snow particles on Mars are roughly the size of a human red blood cell. Martian snow is depicted in this artist's rendering as a mist or fog that eventually settles to the surface.

Credit: NASA, Christine Daniloff/MIT News

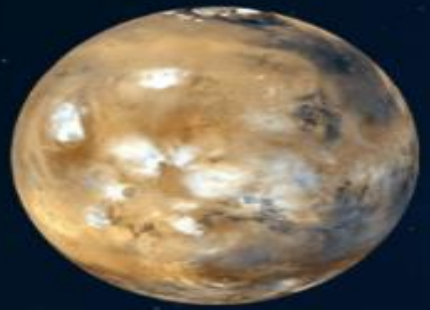
View full size image

A spacecraft orbiting Mars has detected carbon dioxide snow falling on the Red Planet, making Mars the only body in the solar system known to host this weird weather phenomenon.

The snow on Mars fell from clouds around the planet's south pole during the Martian winter spanning 2006 and 2007, with scientists discovering it only after sifting through observations by NASA's Mars Reconnaissance Orbiter



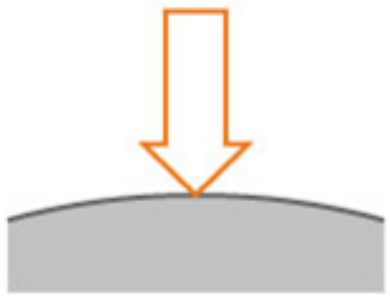
이산화탄소 눈 결정모양



Comparison with the Earth

	Earth	Mars
Average Distance from Sun	93 million miles	142 million miles
Average Speed in Orbiting Sun	18.5 miles per second	14.5 miles per second
Diameter	7,926 miles	4,220 miles
Tilt of Axis	23.5 degrees	25 degrees
Length of Year	365.25 Days	687 Earth Days
Length of Day	23 hours 56 minutes	24 hours 37 minutes
Gravity	2.66 times that of Mars	0.375 that of Earth
Temperature	Average 57 degrees F	Average -81 degrees F
Atmosphere	nitrogen, oxygen, argon, others	mostly carbon dioxide, some water vapor

• Gravity



Surface Gravity

The gravitational acceleration experienced at a planet's surface

About 38% that of Earth

Mars:	**Earth:**
3.71 meters per second squared	9.80665 meters per second squared
or	*or*
12.2 feet per second squared	32.174 feet per second squared

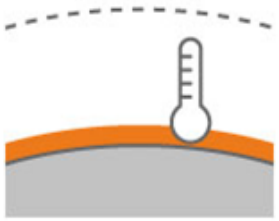
Escape Velocity

The speed an object needs to break free from the gravitational attraction of a planet, moon, or other body without further propulsion

About 45% that of Earth

Mars:	**Earth:**
18,108 kilometers per hour (5.03 km/second)	40,284 kilometers per hour (11.19 km/second)
or	*or*
11,252 miles per hour	25,030 miles per hour

• Temperature



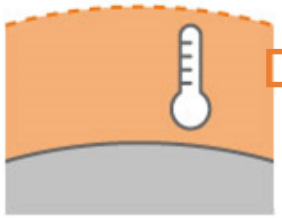
Temperature of the Surface (Typical Minimum/Maximum)

How hot or cold the surface varies between day and night and among seasons

Mars is colder than Earth because it is farther from the Sun.

Mars:
-284 to 86° Fahrenheit
-140 to 30° Celsius

Earth:
-126 to 136° Fahrenheit
-88 to 58° Celsius

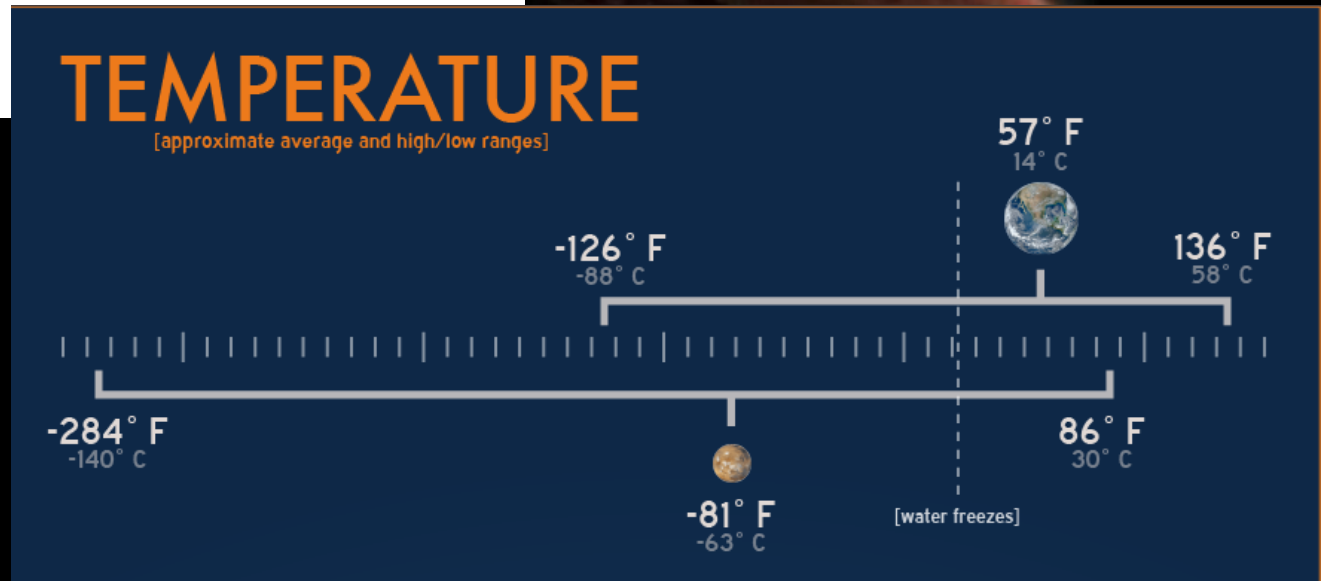


Average Temperature of the Atmosphere

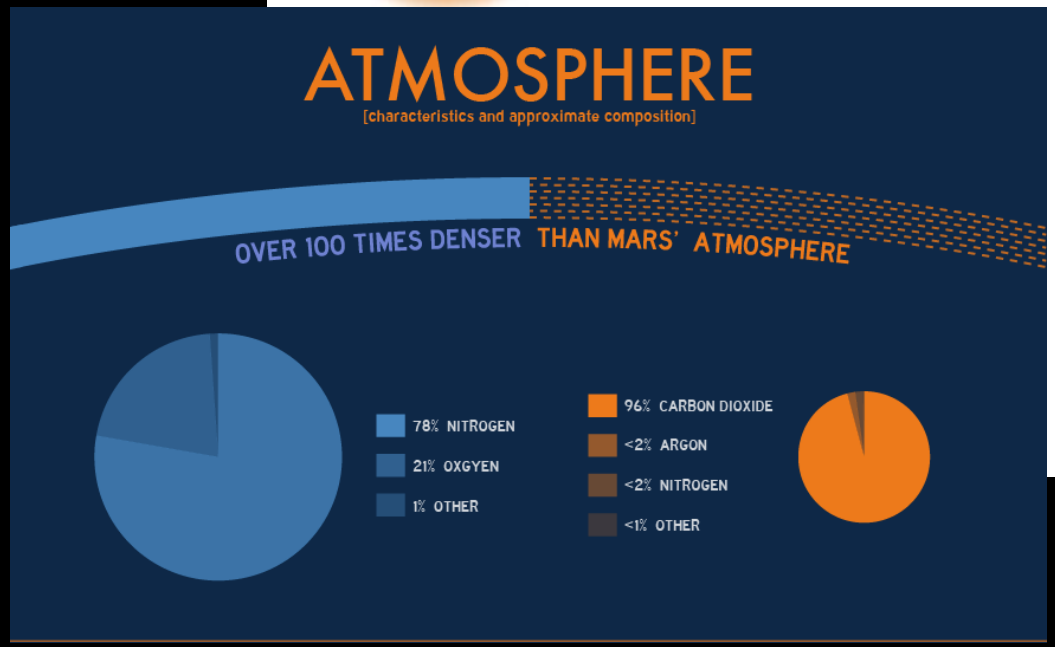
Measurement of how hot or cool the atmosphere is at different altitudes (heights relative to the surface)

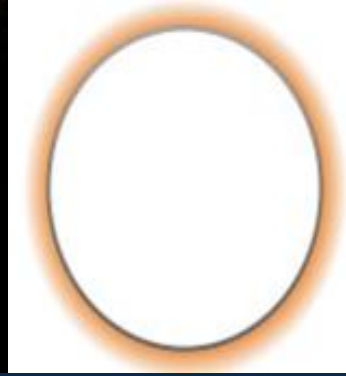
Mars:
-81° Fahrenheit
-63° Celsius
210 Kelvin

Earth:
59° Fahrenheit
15° Celsius
288 Kelvin



• Composition





Composition of the Atmosphere

The chemical materials that make up the layers of gases surrounding a planet or moon, which are held in place by the object's gravity

Mars' atmosphere is 100 times less dense than Earth's

Mars:	**Earth:**
Main Gases:	Main Gases:
96% Carbon Dioxide (CO_2)*	78.09% Nitrogen (N_2)
1.93% Argon (Ar)**	20.95% Oxygen (O_2)
1.89% Nitrogen (N_2)	0.93% Argon (Ar)
0.145% Oxygen (O_2)	0.039% Carbon Dioxide (CO_2)
<0.01% Carbon Monoxide (CO)	

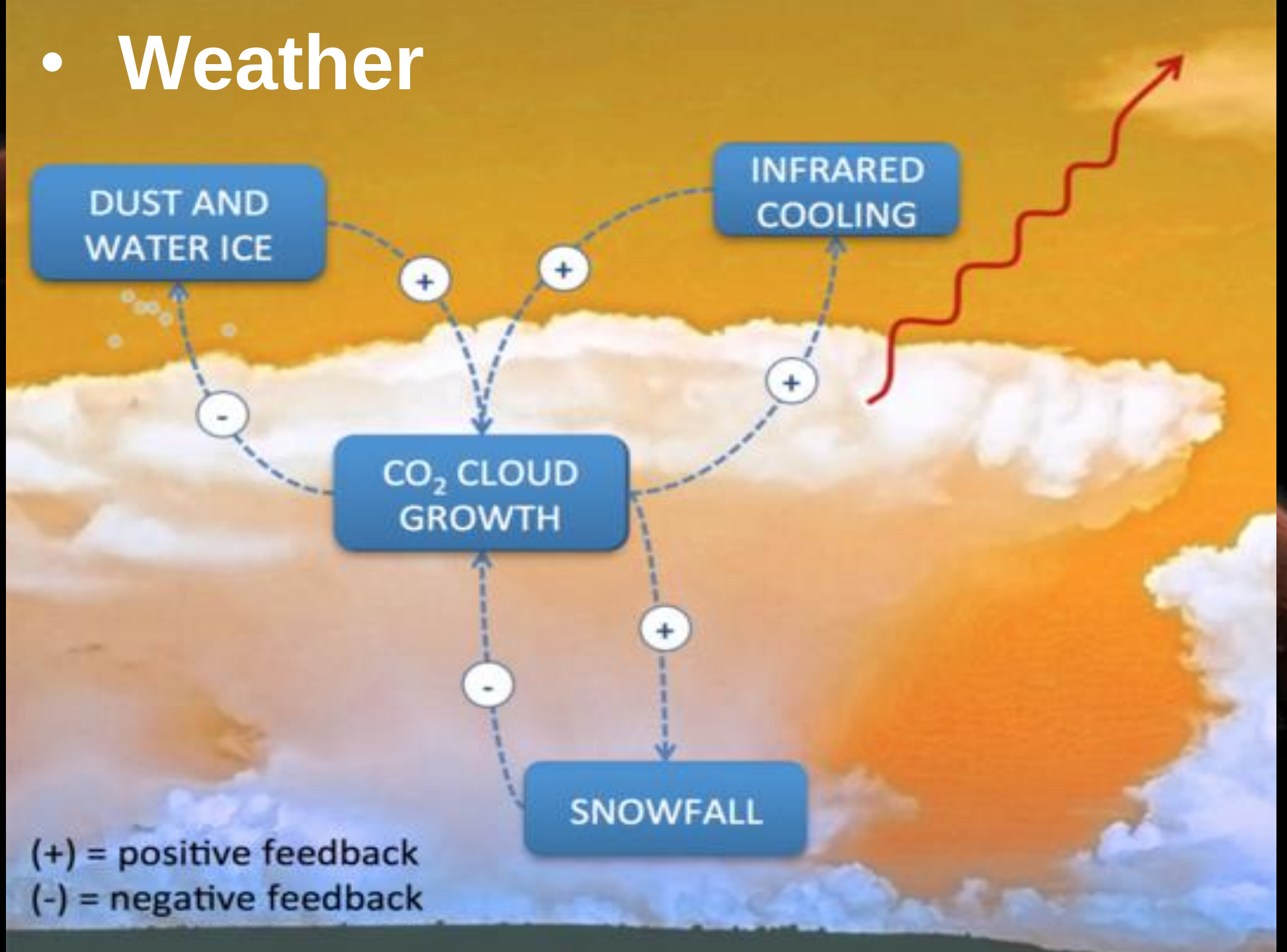
Both planets also have other gases in very small amounts (trace gases).

Did you know...?

**Carbon dioxide is used for carbonation in beverages. Frozen carbon dioxide is "dry ice."*

***Argon is used to make blue "neon lights."*

- **Weather**


DUST AND WATER ICE
INFRARED COOLING
CO_2 CLOUD GROWTH
SNOWFALL
+
+
+
+
-
-
(+) = positive feedback
(-) = negative feedback


CO2 Cloud

- Assumption

1) 태양과 화성과의 거리는 변하지 않는다.
2) 화성은 세차운동을 하지 않는다.
3) 화성의 먼지 폭풍에 대한 효과는 무시한다.
4) Dry adiabatic air (대기는 건조단열적으로 상승)
5) CO2 cloud의 ice crystal은 구형으로 생긴다.
6) Homogeneous CO2 atmosphere
7) 대기의 총 두께 ~ 70Km
8) 대기를 이상기체로 가정한다.
9) Hydrostatic Assumption
10) 먼지폭풍으로 인해 CCN이 충분히 공급된다.

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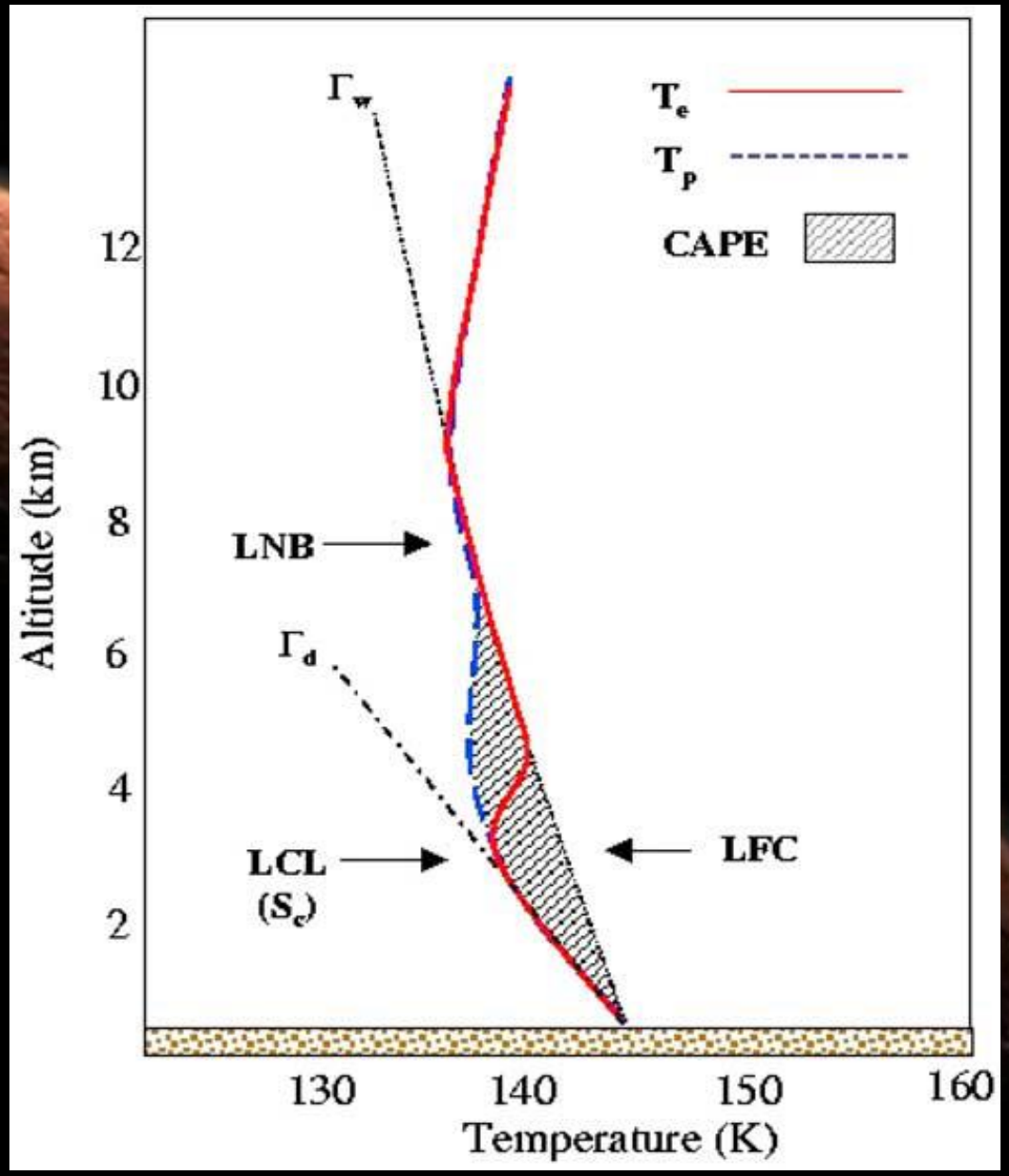
Conceptual Figure

convectional cloud 생성 시나리오

- condensation begins. (LCL)
- When the parcel temperature is higher than the back ground environment temperature free convection can occur (LFC).
- The parcel will continue to rise due to buoyancy until its temperature is again equal to the environment temperature (LNB)



• Calculation

At surface T= 249.5K
Gravitational Acceleration = 2.69 m/s^2
Density of solid dry ice = 1560kgm^-3
Latent heat of sublimation at 121K, 613KJkg^-1

Saturation vapor pressure of carbon dioxide (empirical)

$$\ln e_{si} = \frac{\Delta H}{RT} + 23.8(\ln torr)$$

$$\Delta \mathrm{H} = 6.5 \mathrm{kcal/mole}$$

(Bryson et al., 109)
Vapor pressure e = p

$$\mathrm{r} = \frac{e}{e_{si}}$$

- Calculation

Dew point T$-T_{frost} = -R_v T T_{frost} \ln r$

$$T_{frost} = 236.2K$$

Lifting condensation level

$$\frac{T - T_{frost}}{T T_{frost}} = \frac{\frac{\gamma}{\gamma - 1}}{\frac{l_v}{R_v}} \ln \frac{T_{lcl}}{T} + \left(\frac{1}{T_{lcl}} - \frac{1}{T}\right)$$

$$T_{lcl} = 167.6K$$

• Calculation

Dew point & Dry Lapse rate

$$\Gamma_{frost} = -\frac{dT_{frost}}{dz} = \frac{g}{\epsilon l_v}\frac{T_{frost}^2}{T}$$

Dew point lapse rate = 1.346*10^-3 K/km

Dry lapse rate = 5.27 K/km

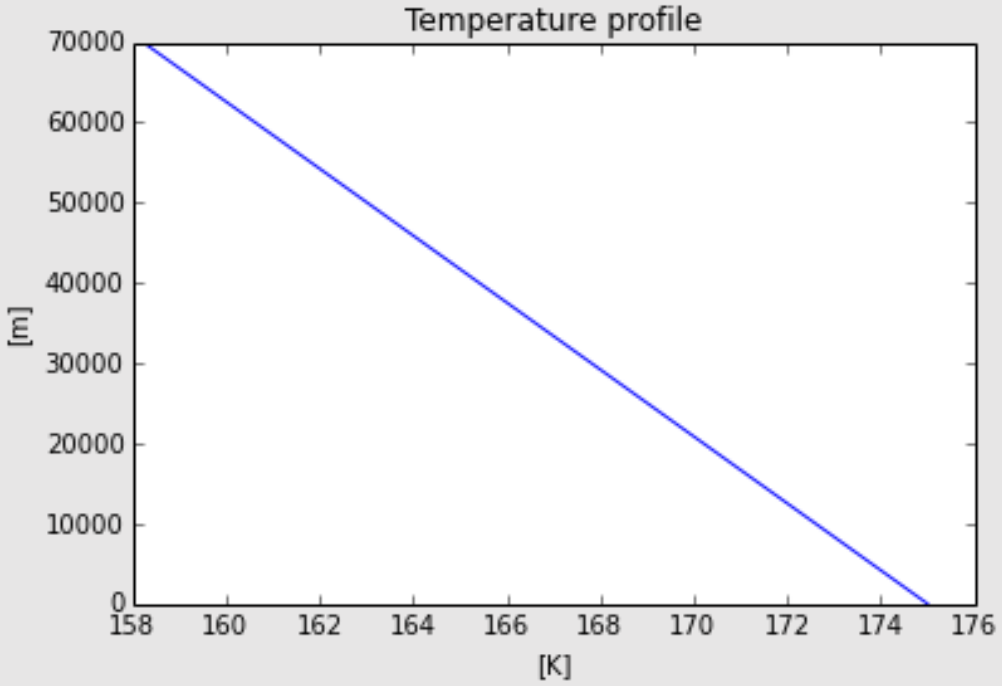
$$z_{lcl} - z_0 = \frac{T_0 - T_{frost,0}}{\Gamma_d - \Gamma_{frost}}$$

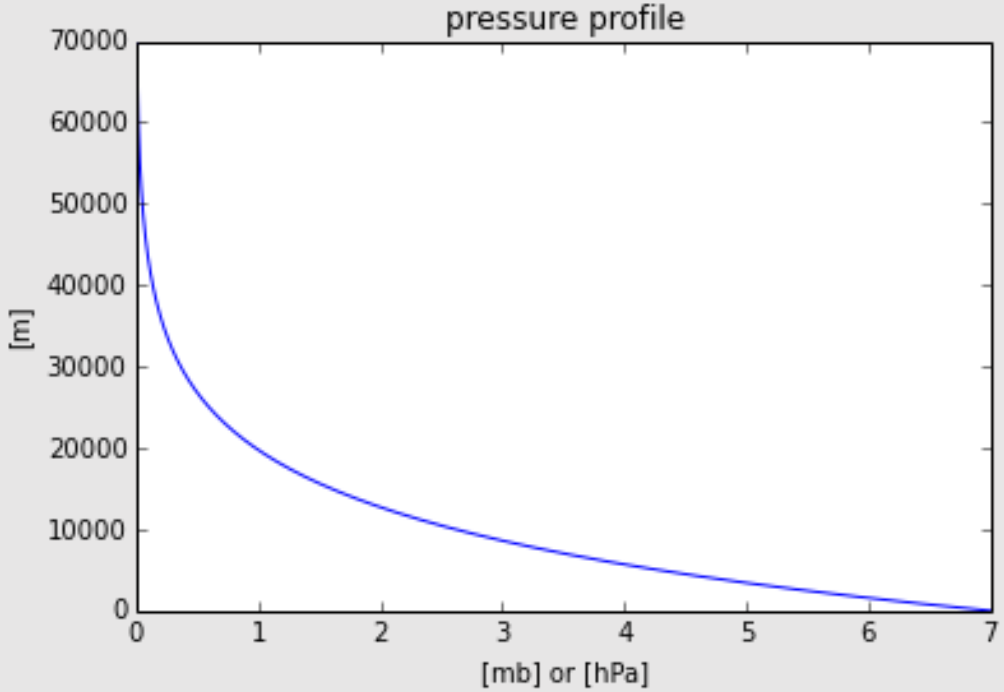
$$z_{lcl} = 3.39km$$

$$\text{Environmental height at } T_{lcl} = 26km$$

Graphical Analysis

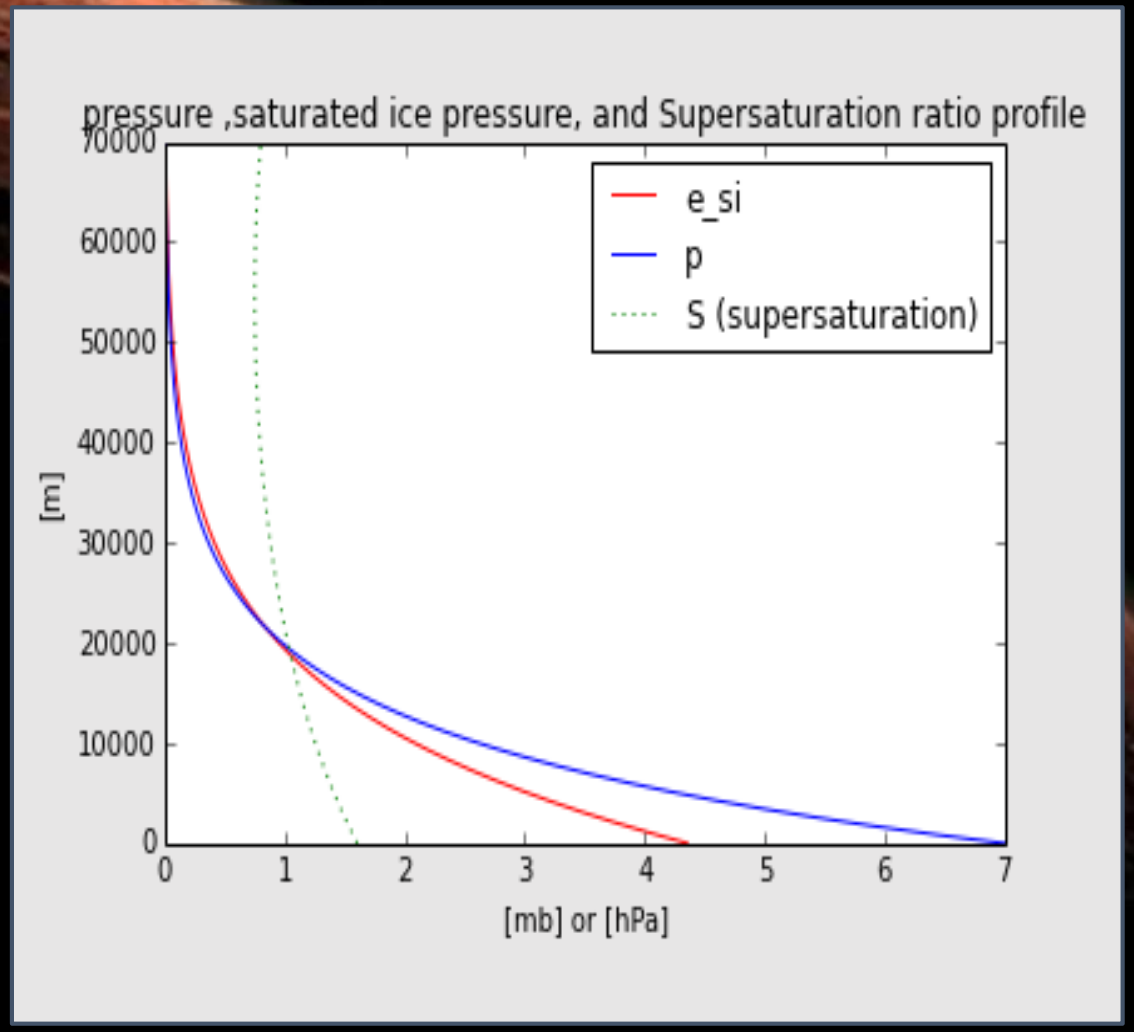
모델 계산의 용의성을 위해 고도에따라 온도는 선형적으로 감소, 대기의 압력은 hydrostatic equation에 따라 지수적으로 감소하는 모델을 사용.





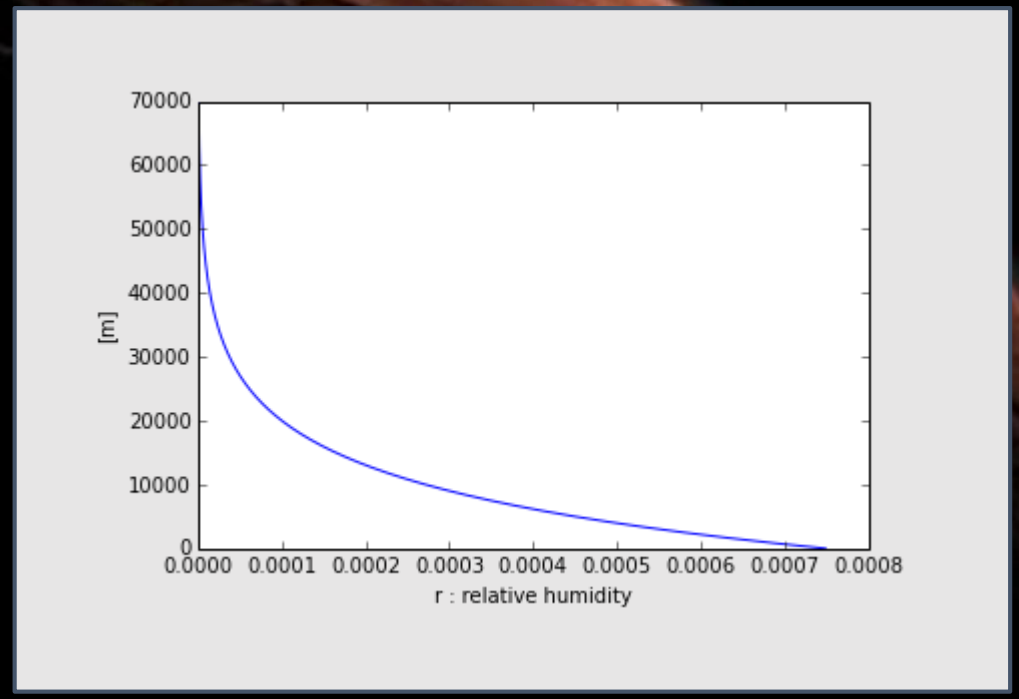
Graphical Analysis

- surface Temperature = 175K (극지방 지표면 온도)
- 계산 결과에 따르면, 고도 20~30Km 사이까지 과포화.
- 화성의 양 극에 극관이 생김.
- 만약 구름이 있다면 구름은 25Km 정도가 넘으면 승화 과정을 통해 소멸.

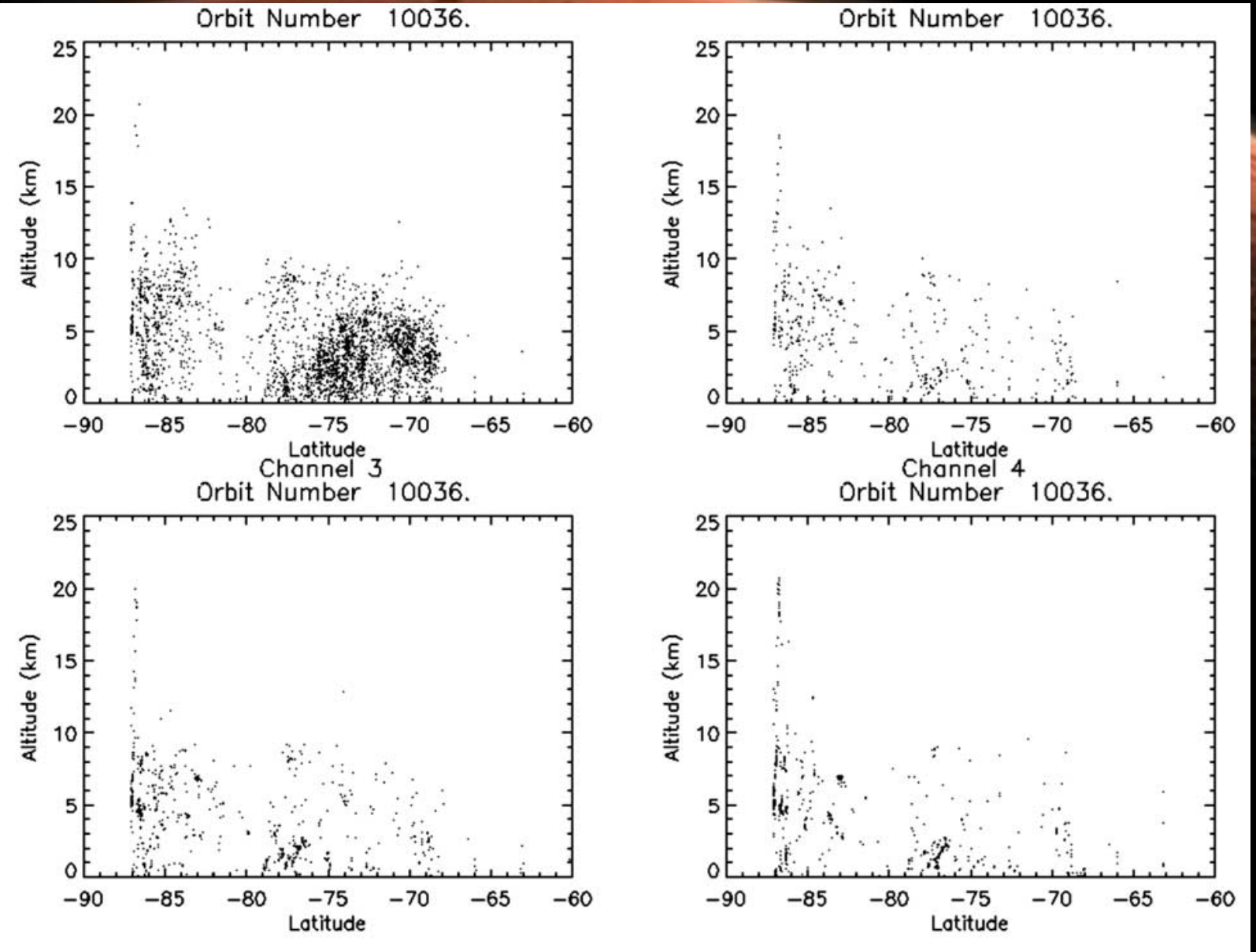


Graphical Analysis

초기 온도가 화성의 평균 온도인 240K 에서는 구름이 생성되기 힘들다.
r : 0.0001 ~ 0.0075
즉, 온도가 충분히 낮을 때 구름이 생성 된다.



Graphical Analysis

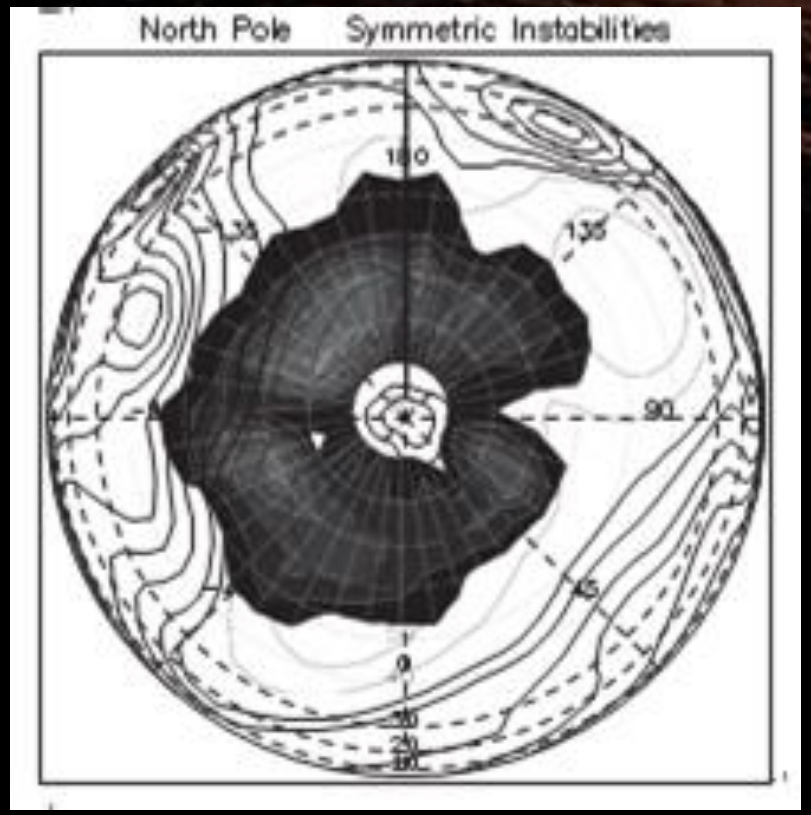


- Mars Orbiter Laser Altimeter (MOLA)를 이용한 관측.
- 남반구 극지방 겨울의 구름 echo 데이터.
- 지표에서 20Km까지 다양하게 분포.


More on
Clouds of Mars

• Clouds of North & South Pole

✓ 대기의 불안정도 비교

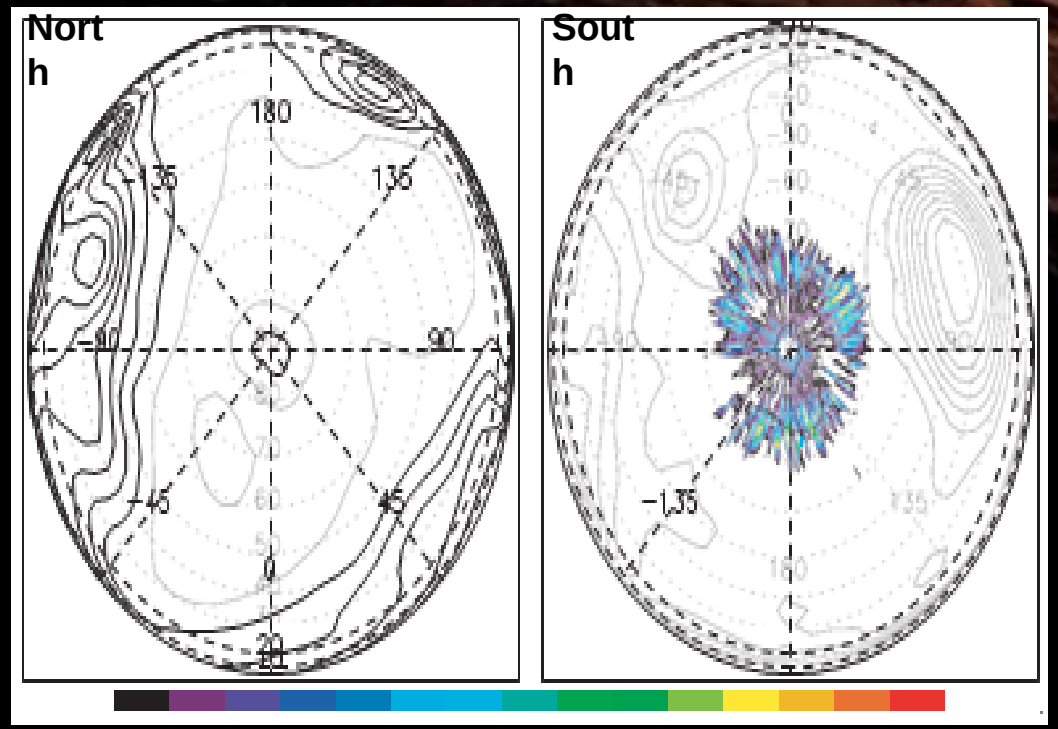


North Pole

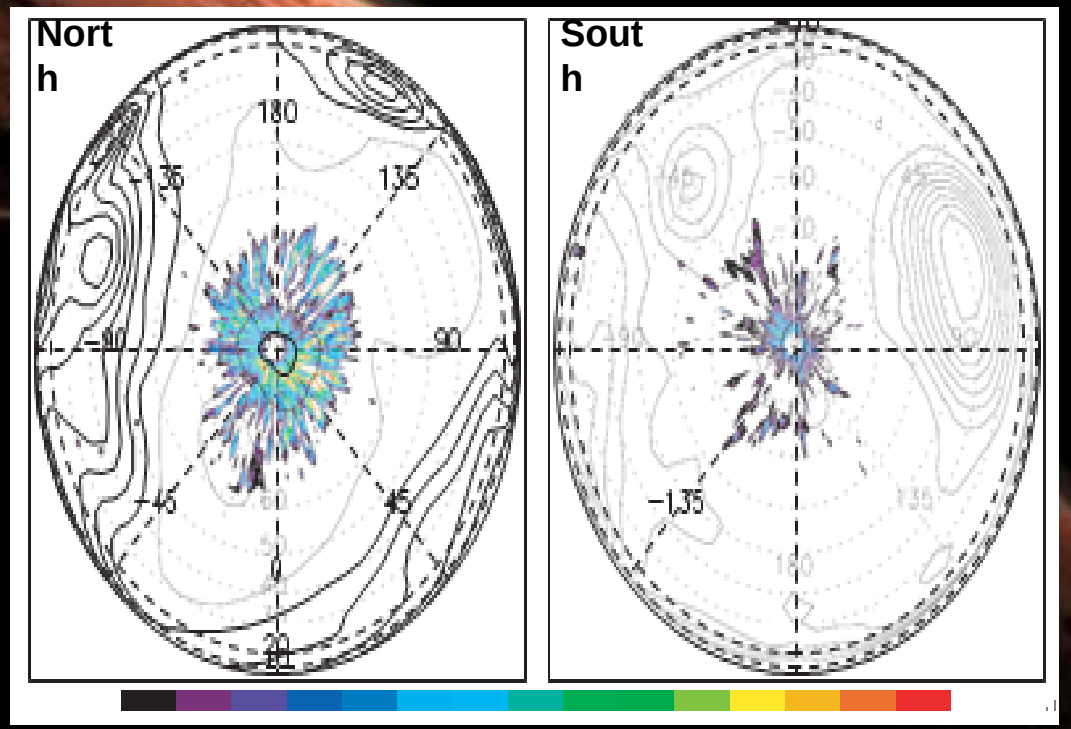
South Pole

• Clouds of North & South Pole

✓ 대기의 불안정도에 따른 구름형성 차이



Ch 1 Cloud



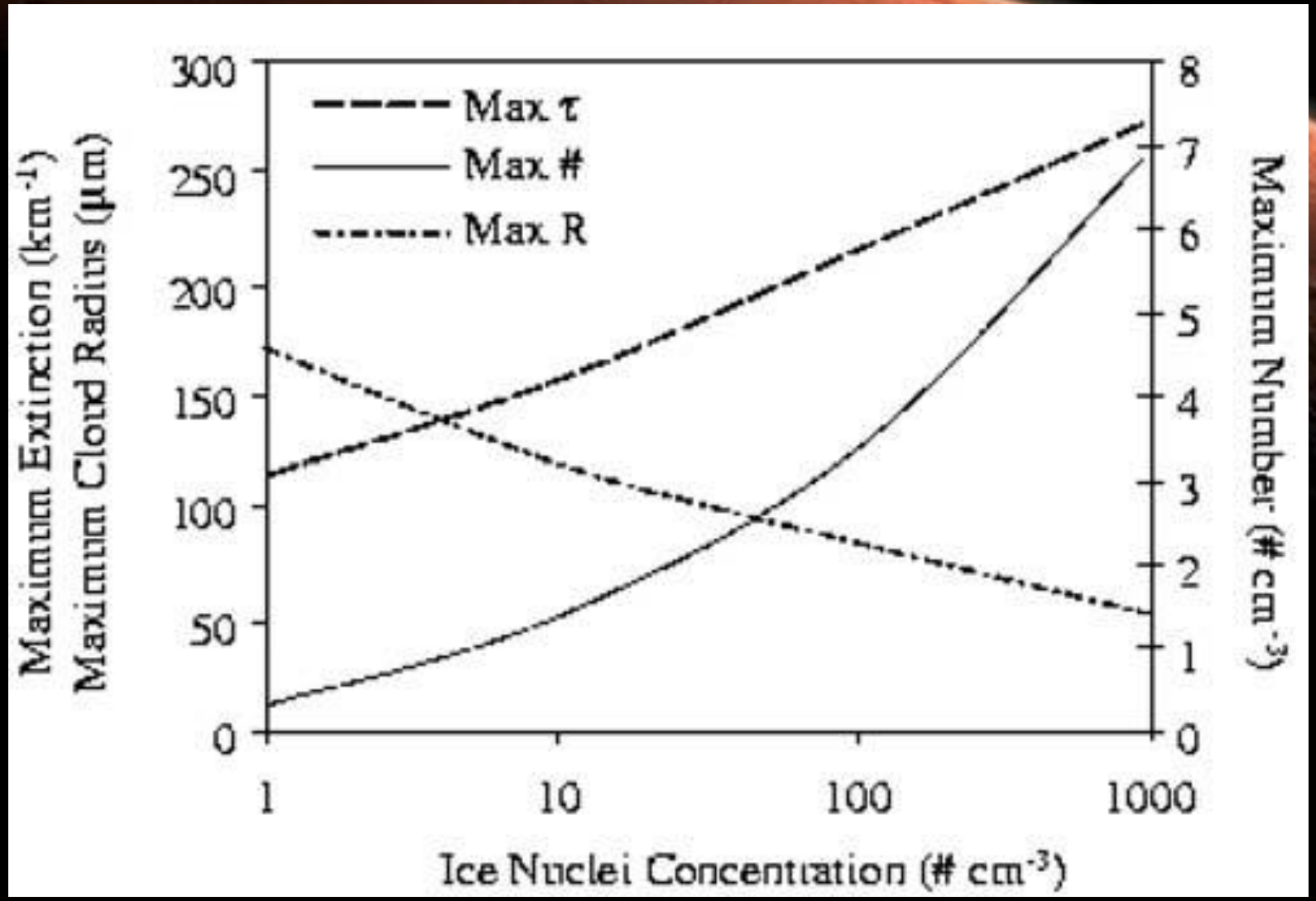
Ch 4 Cloud

Conditions for growing of ice crystal

- ✓ **Updraft wind**
  상승 기류에 의한 공기의 냉각과 잠열 방출로 얼음 입자들이 지속적으로 성장

- ✓ **Concentration of IN (Ice Nuclei)**
  충분한 수의 IN이 없으면 deposition이 일어나기 매우 어려움.
  그러나 IN이 너무 많으면 입자의 크기가 작아져 Snowfall이 일어나지 않을 수 있음.

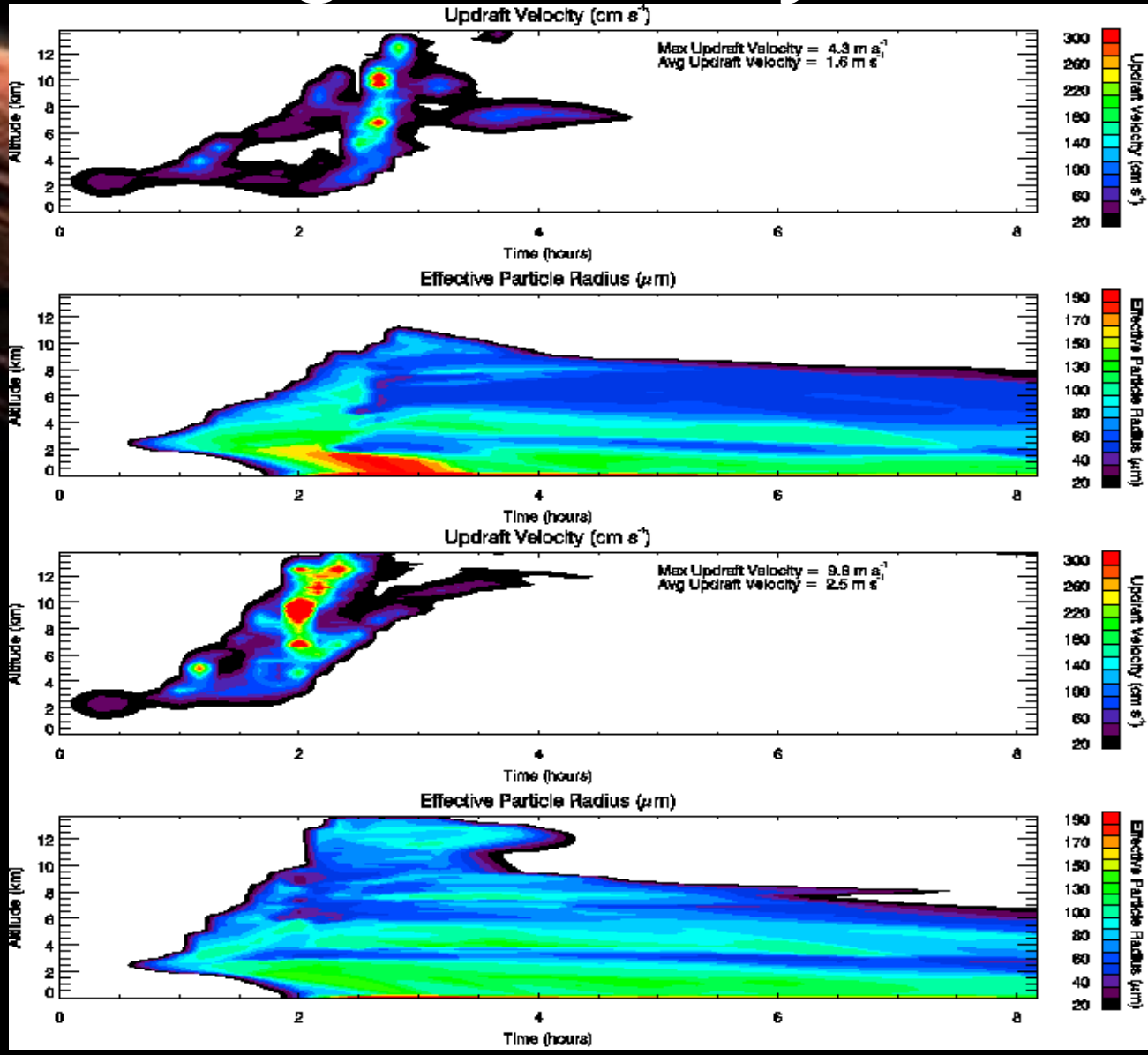
Conditions for growing of ice crystal



- IN이 농도가 낮으면 입자의 반지름은 크지만 농도가 매우 적음
- 반면, IN 농도가 높으면 입자의 반지름은 작지만 농도가 커짐

Conditions for for growing of ice crystal

- Updraft wind에 따라 ice particle이 생성됨
- Updraft wind가 상대적으로 빠른 경우 구름이 더 높이 올라가고 전체적인 입자의 크기가 고도에 따라 고르게 분포.



결과 및 고찰

Result & Discussion

조사를 통해 화성의 특징과 구름 생성과 강설의 조건을 알아보았다.
모델링을 통해 구름의 생성과 소멸 고도를 조사해 보았다.

-> 화성의 구름은 20 ~ 30Km 까지 연직적으로 존재할 수 있다.
-> 온도가 충분히 낮은 극지방의 밤에 구름이 잘 생성된다.
-> 입자의 성장은 updraft wind와 IN의 농도에 영향을 받는다.
->

Reference

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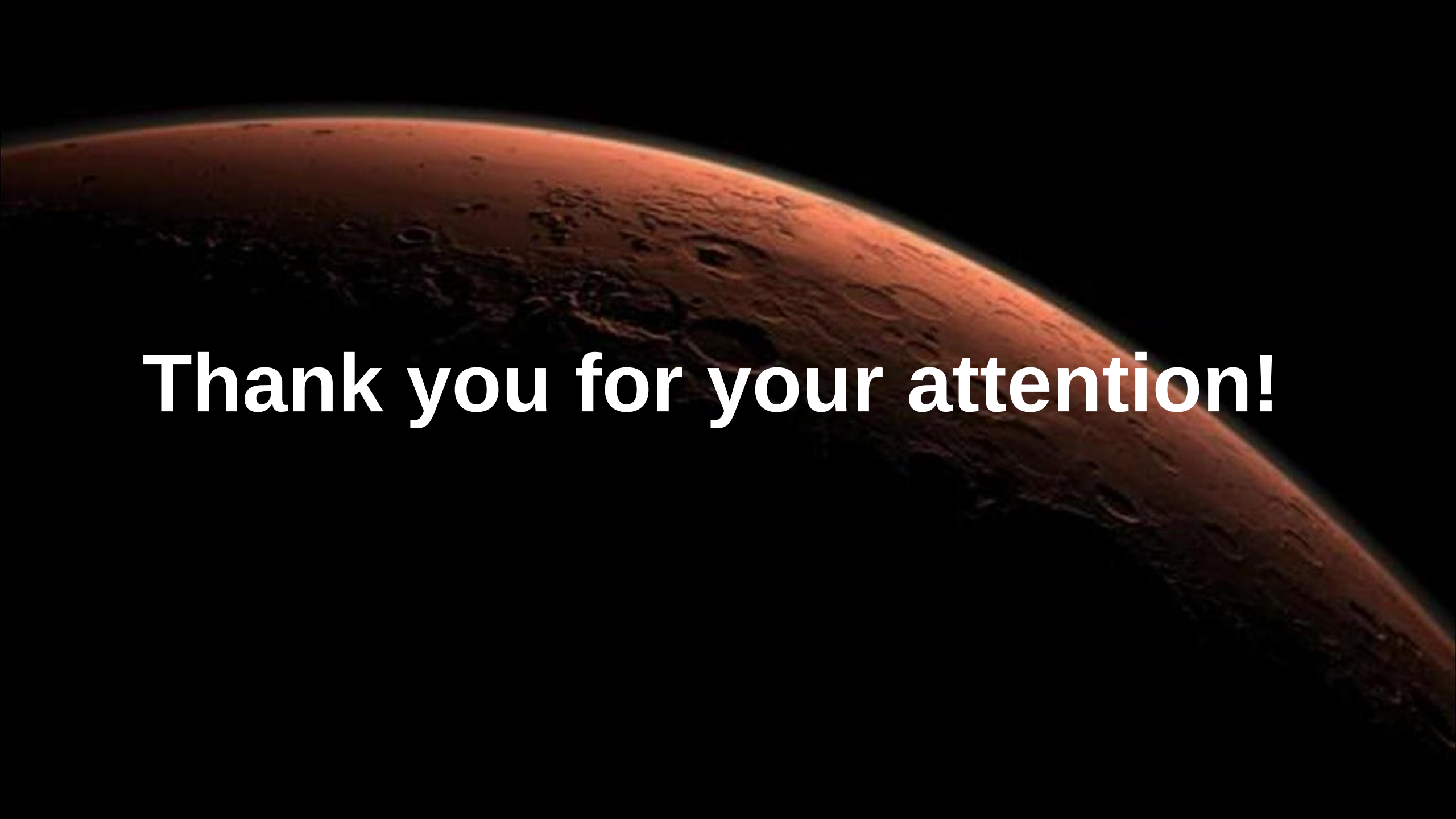
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