# Balloon Data and Planetary Temperature Profiles

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AHAC
23 June 2011

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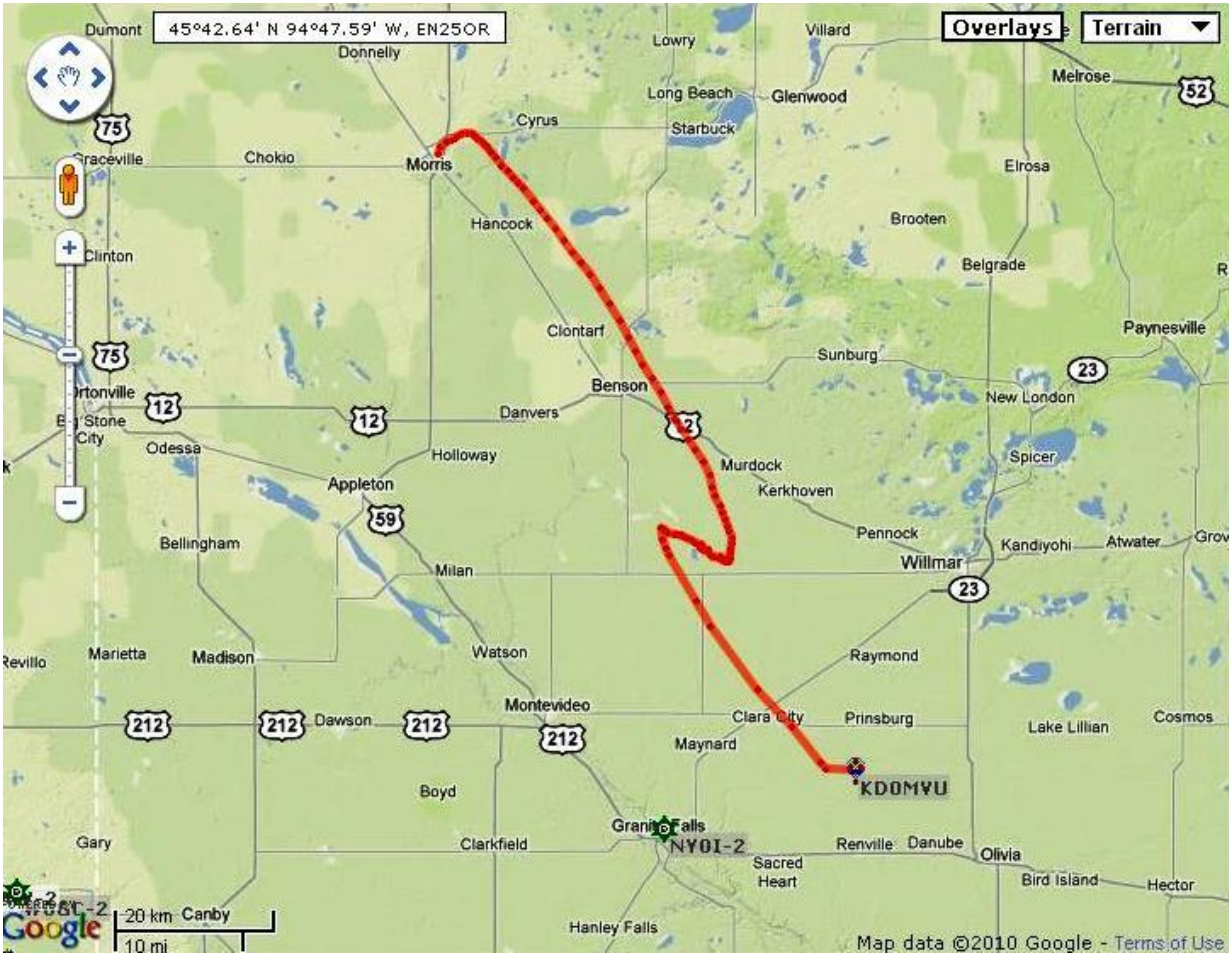
# Outline

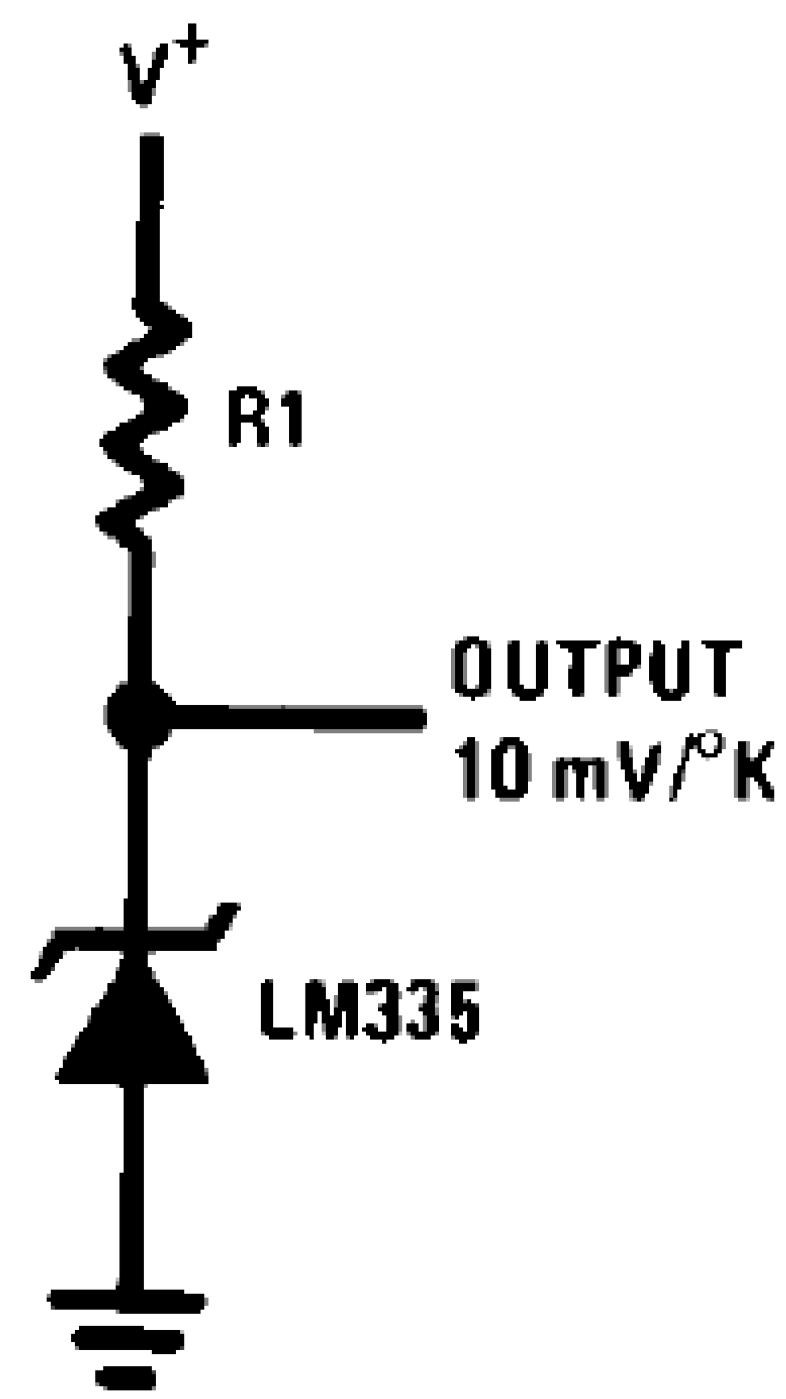
- Launch information
- Temperature measurement
- Earth’s atmosphere
- Atmospheric stability
- Solar system bodies with solid surfaces and substantial atmospheres
- Lab ideas


45°42.64' N 94°47.59' W, EN25OR
Overlays
Terrain
Dumont
Donnelly
Lowry
Villard
Melrose
Long Beach
Glenwood
Starbuck
Cyrus
Graceville
Chokio
Morris
Elrosa
Hancock
Brooten
Clinton
Belgrade
Clontarf
Paynesville
Sunburg
Benson
New London
Ortonville
Big Stone City
Danvers
Odessa
Holloway
Murdock
Spicer
Appleton
Kerkhoven
Bellingham
Pennock
Kandiyohi
Atwater
Willmar
Milan
Marietta
Madison
Watson
Raymond
Montevideo
Dawson
Clara City
Prinsburg
Lake Lillian
Cosmos
Maynard
KD0MVU
Boyd
Granite Falls
NY0I-2
Gary
Clarkfield
Renville
Danube
Olivia
Sacred Heart
Bird Island
Hector
20 km
Canby
10 mi
Hanley Falls
Map data ©2010 Google - Terms of Use

# Temperature Circuit

R1 2KΩ

Basic Temperature Sensor




TL/H/5698-2

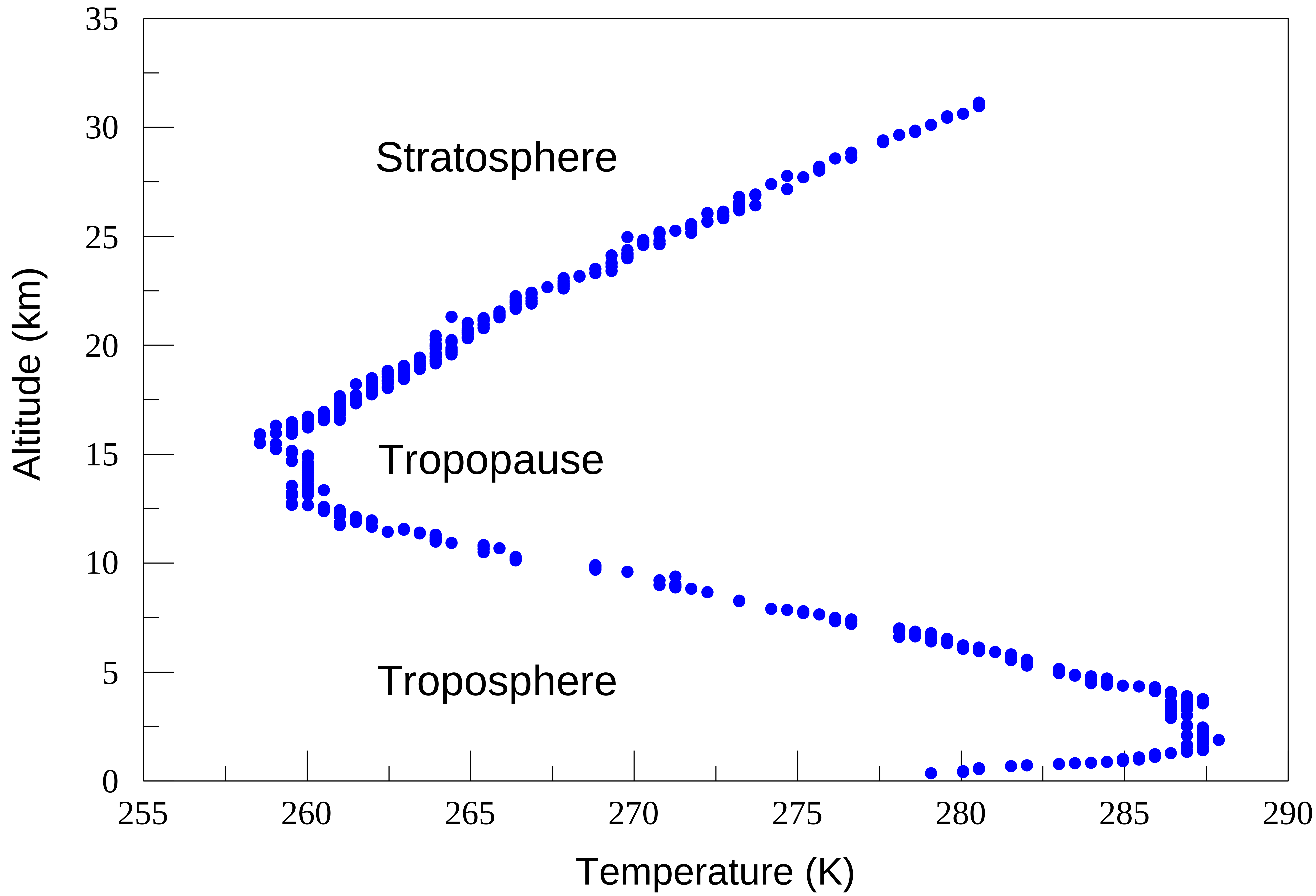
| DeviceId | Timestamp | A1 | A2 | A3 | A4 | A5 | A18 |
|---|---|---|---|---|---|---|---|
| 30 | 11/6/2010 8:52 | 553 | 874 | 571 | 585 | 855 | 351 |
| 30 | 11/6/2010 8:52 | 540 | 867 | 573 | 584 | 851 | 412 |
| 30 | 11/6/2010 8:52 | 534 | 865 | 573 | 585 | 849 | 451 |
| 30 | 11/6/2010 8:52 | 503 | 856 | 574 | 585 | 854 | 552 |
| 30 | 11/6/2010 8:52 | 497 | 853 | 574 | 586 | 855 | 588 |
| 30 | 11/6/2010 8:53 | 476 | 843 | 576 | 585 | 850 | 684 |
| 30 | 11/6/2010 8:53 | 473 | 841 | 577 | 586 | 849 | 715 |
| 30 | 11/6/2010 8:53 | 451 | 835 | 579 | 586 | 850 | 783 |
| 30 | 11/6/2010 8:53 | 434 | 832 | 580 | 587 | 854 | 809 |

A18 Altitude from GPS position

A3 Digitized External Temperature

$$T(K) = T(V) * 5/1023 * 100$$

# Altitude versus Temperature
# 6 November 2010



Troposphere

normally heated from the bottom

near surface - inversion

8:52 am, 6 November 10

measured environmental

lapse rate (ELR) 3.2 K $km^{-1}$

average ELR

~ 6.4 K $km^{-1}$

Tropopause

lapse rate ~0 K $km^{-1}$

Stratosphere

temperature gradient +1.5 K $km^{-1}$

heating due to solar ultraviolet radiation

photo-dissociation of $O_3$

# Atmospheric Stability in the Troposphere

Rising air bubbles cool.

If the bubble cools faster than the surrounding air it will sink back down and be stable

If the bubble cools more slowly than the surrounding air it will continue to rise.

These temperature changes are indicated by the lapse rates.

Environmental lapse rate (ELR)

measured $|\Delta T/\Delta z|$

Dry adiabatic lapse rate (DALR)

9.76 K $km^{-1}$

Saturated adiabatic lapse rate (SALR)

minimum ~ 4 K $km^{-1}$

# DALR Derivation

| | |
|---|---|
| First Law of Thermodynamics | $dQ = dU + \delta W$ <br> $= nc_v dT + PdV$ |
| Ideal Gas Law | $pV = nRT$ <br> $Vdp + pdV = nRdT$ |
| $R = c_p - c_v$ | $dQ = nc_v dT + nRdT - Vdp$ <br> $= nc_p dT - Vdp$ |

Adiabatic ($dQ = 0$)    $nc_p dT = Vdp$

Molecular mass per mole = $m_m$

$C_p = c_p/m_m$

$\rho = n\, m_m/V$

$dT/dp = V\, m_m / (nc_p m_m)$

$= 1/(C_p\, \rho)$

| | |
|---|---|
| Hydrostatic Equilibrium | $dp = -g\rho\, dz$ |
| | $dT/(-g\rho dz) = 1/(C_p\, \rho)$ |
| so | |
| The DALR | $dT/dz = \lvert -g/ C_p \rvert$ |

$g_{\oplus} = 9.80\ \text{m s}^{-2}$

$C_{p\ \oplus} = 1004\ \text{J Kg}^{-1}\ \text{K}^{-1}$

$DALR_{\oplus} = 9.76\ \text{K km}^{-1}$

SALR lower due to the release of the latent heat of condensation (minimum ~ 4 K $km^{-1}$)

# Stability

Absolute stability

ELR < SALR

Conditional instability

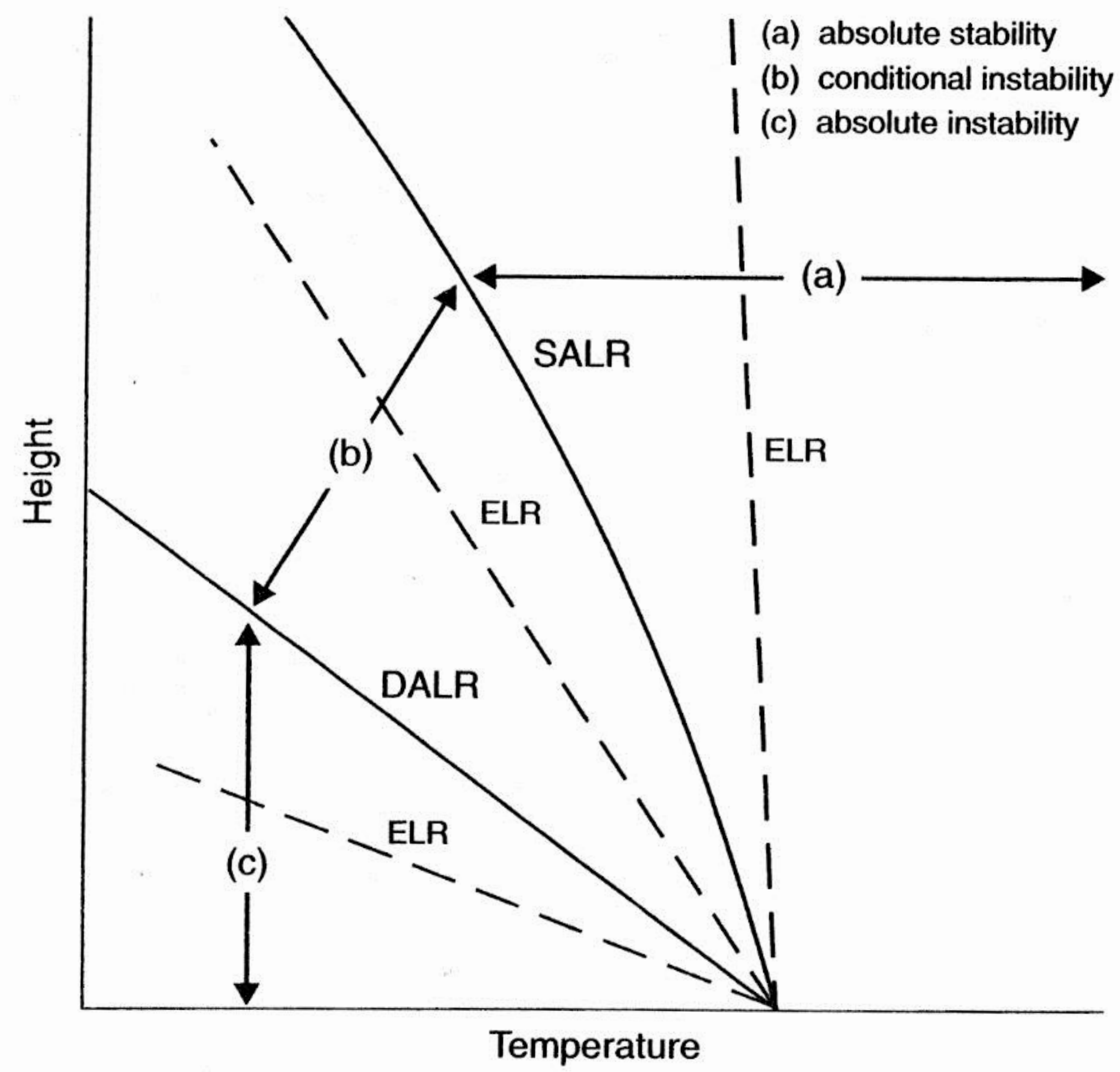
SALR<ELR<DALR

Absolute instability

ELR>DALR

6 Nov 10 launch

ELR = 3.2 K $km^{-1}$



# Solar System Bodies with Solid Surfaces and Substantial Atmospheres

## Atmospheric Constituents

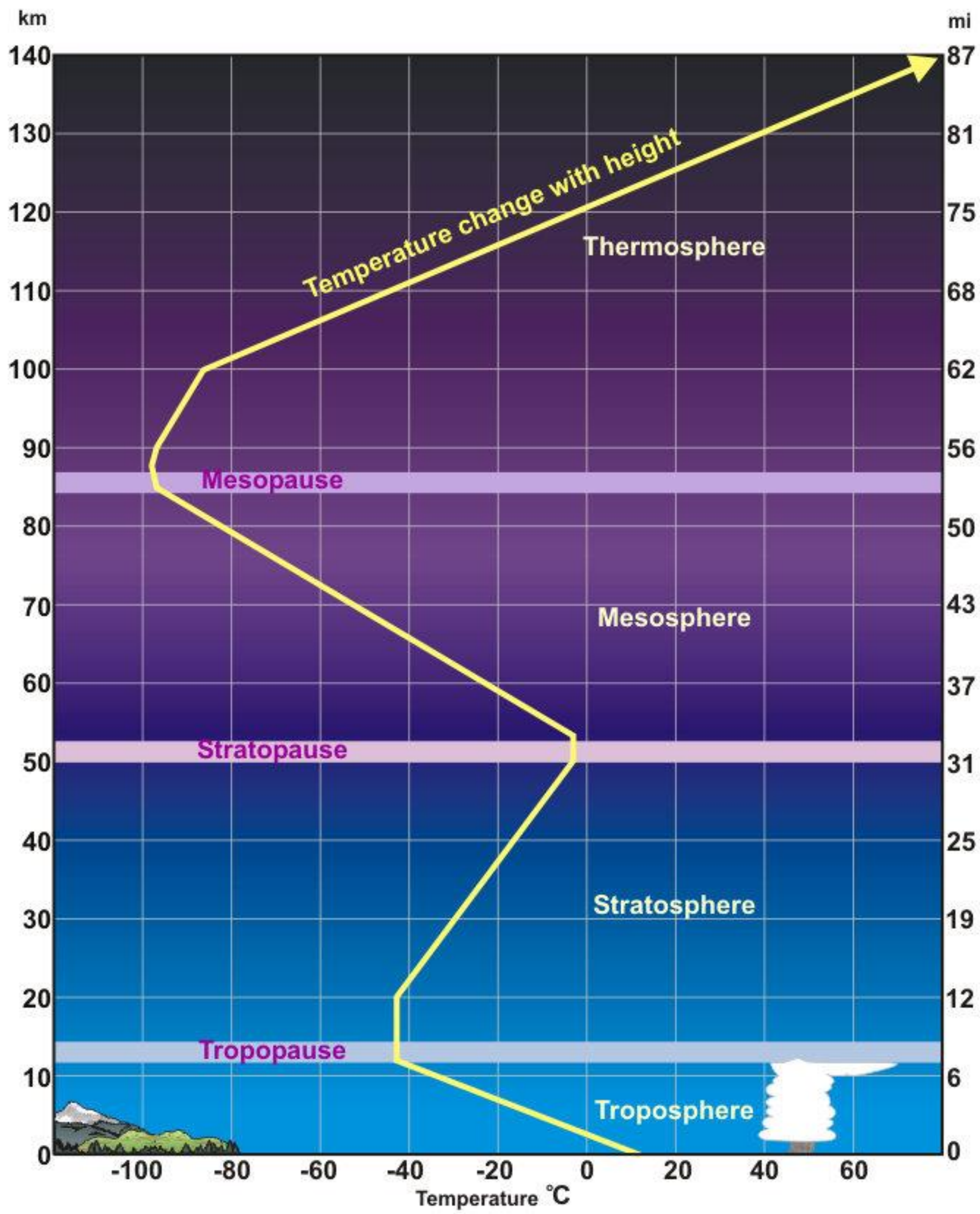
| | | | |
|---|---|---|---|
| Earth | 78% $N_2$ | 21% $O_2$ | |
| Venus | 96.5% $CO_2$ | 3.5% $N_2$ | |
| Mars | 95.3% $CO_2$ | 2.7% $N_2$ | 1.6% Ar |
| Titan | 90-97% $N_2$ | 0-6% Ar | 0.5-4% $CH_4$ |

Atmospheric Pressures

| | |
|---|---|
| Earth | 1010 hPa |
| Venus | 9.2 MPa |
| Mars | 6 hPa |
| Titan | 1500 hPa |

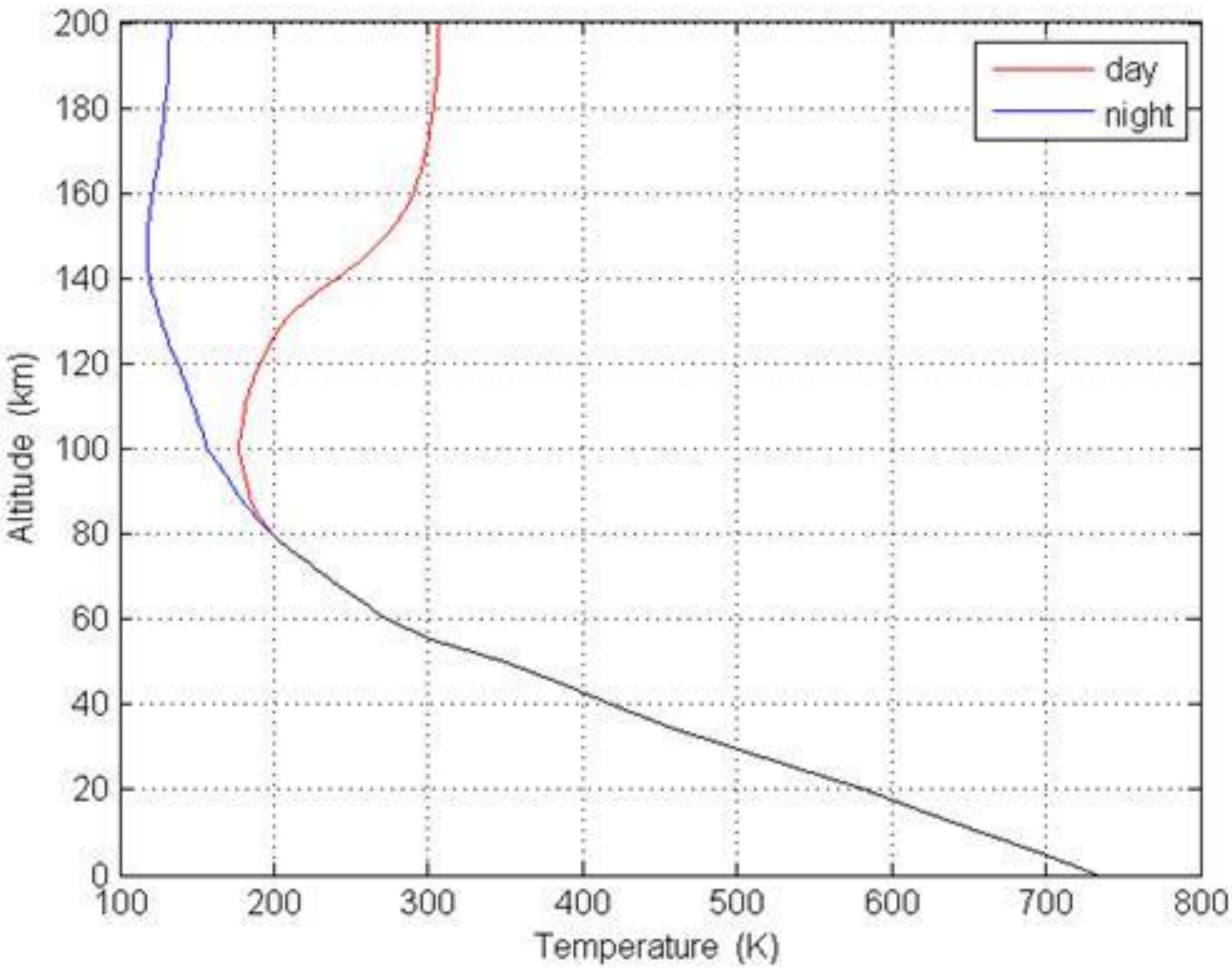
# Earth
# Altitude versus Temperature

http://www.srh.noaa.gov/srh/jetstream/atmos/atmprofile.htm



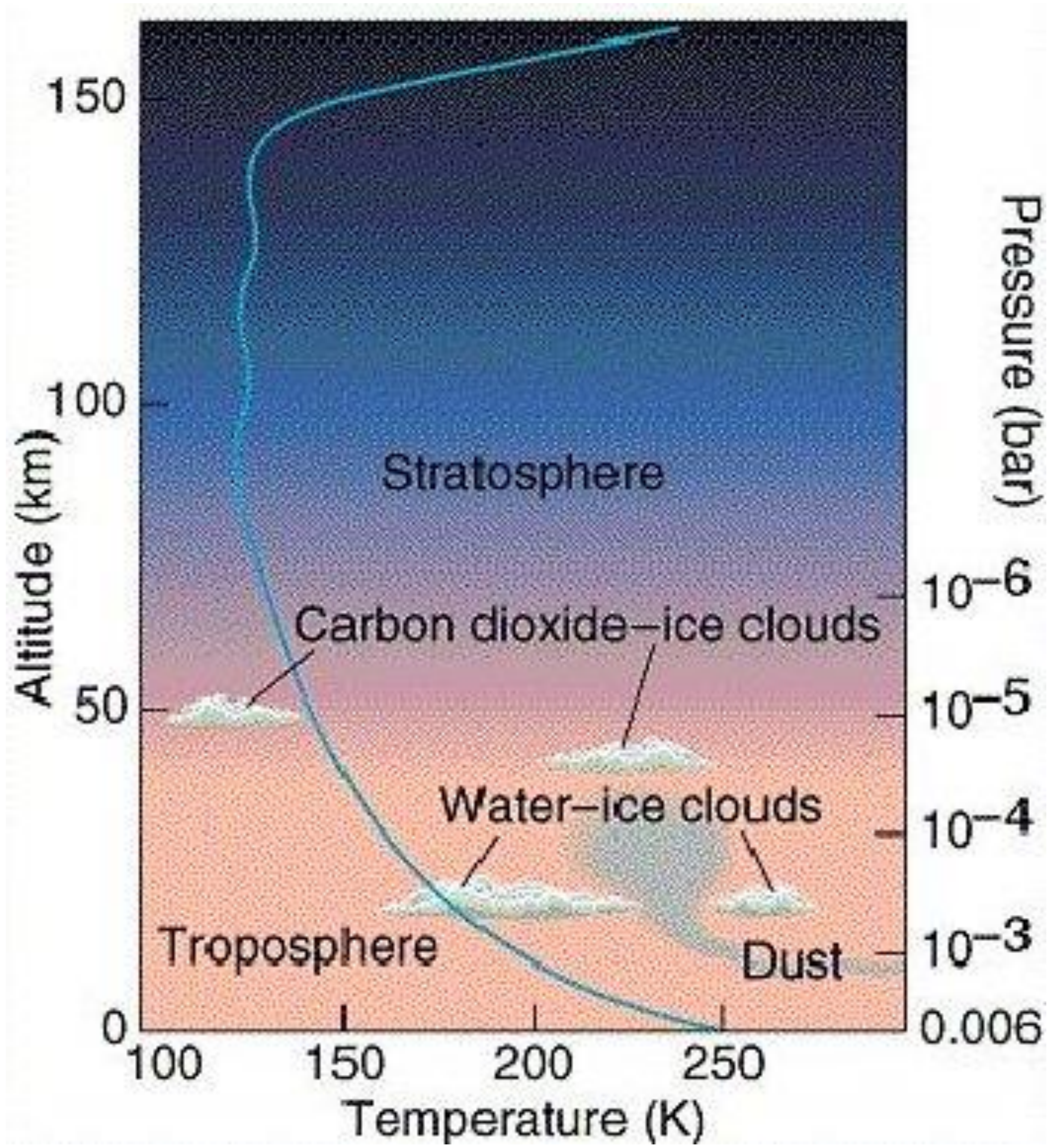
# Venus
# Altitude versus Temperature

Belgian Institue for Space Aeronomy

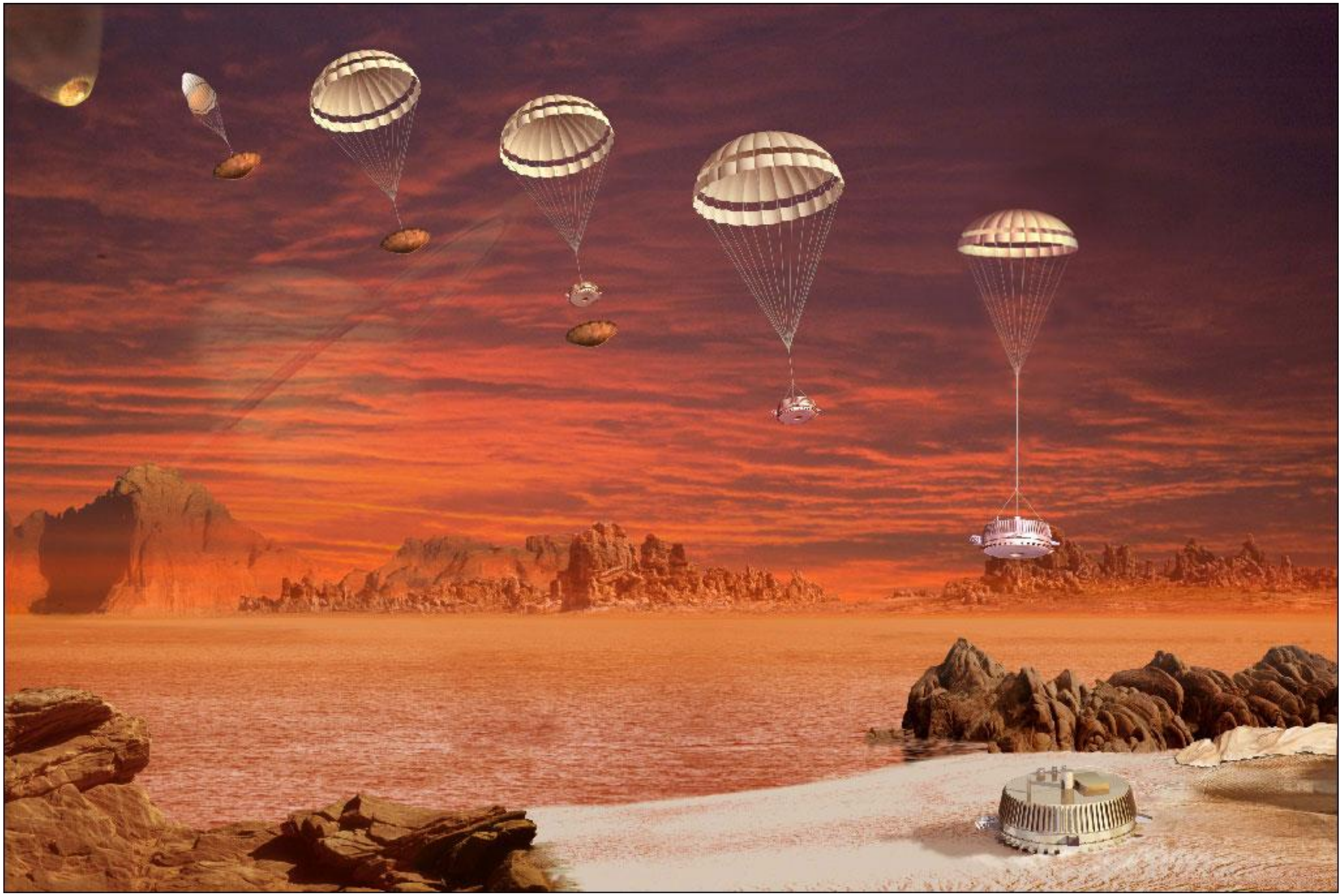


# Mars
# Altitude versus Temperature

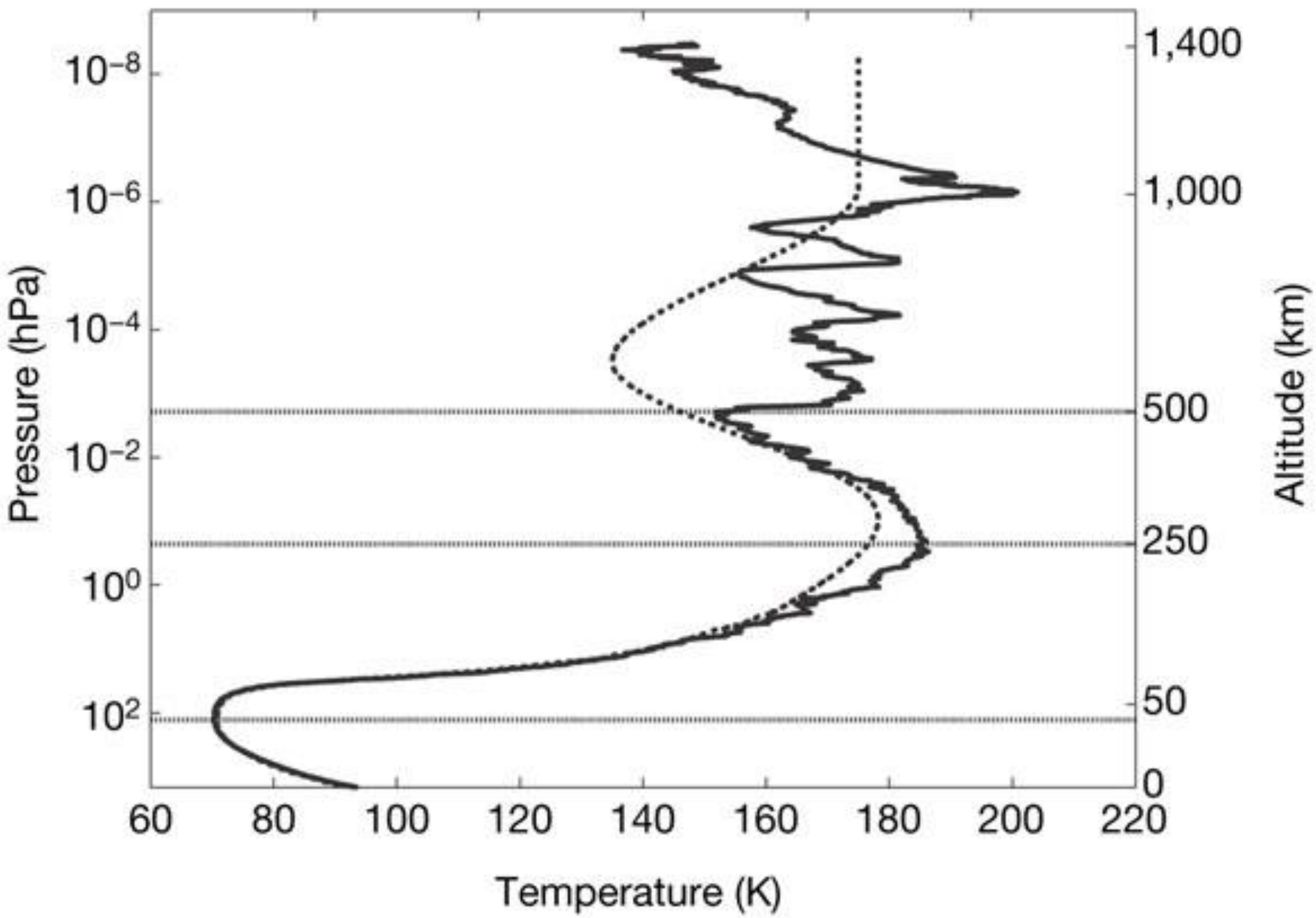
http://astronomy.nmsu.edu/tharriso/ast105/Mars.html



# Huygen's descent to the surface of Titan
# 14 January 2005



# Titan
# Altitude versus Temperature



# Stratospheric Temperature Increase in Titan's Atmosphere

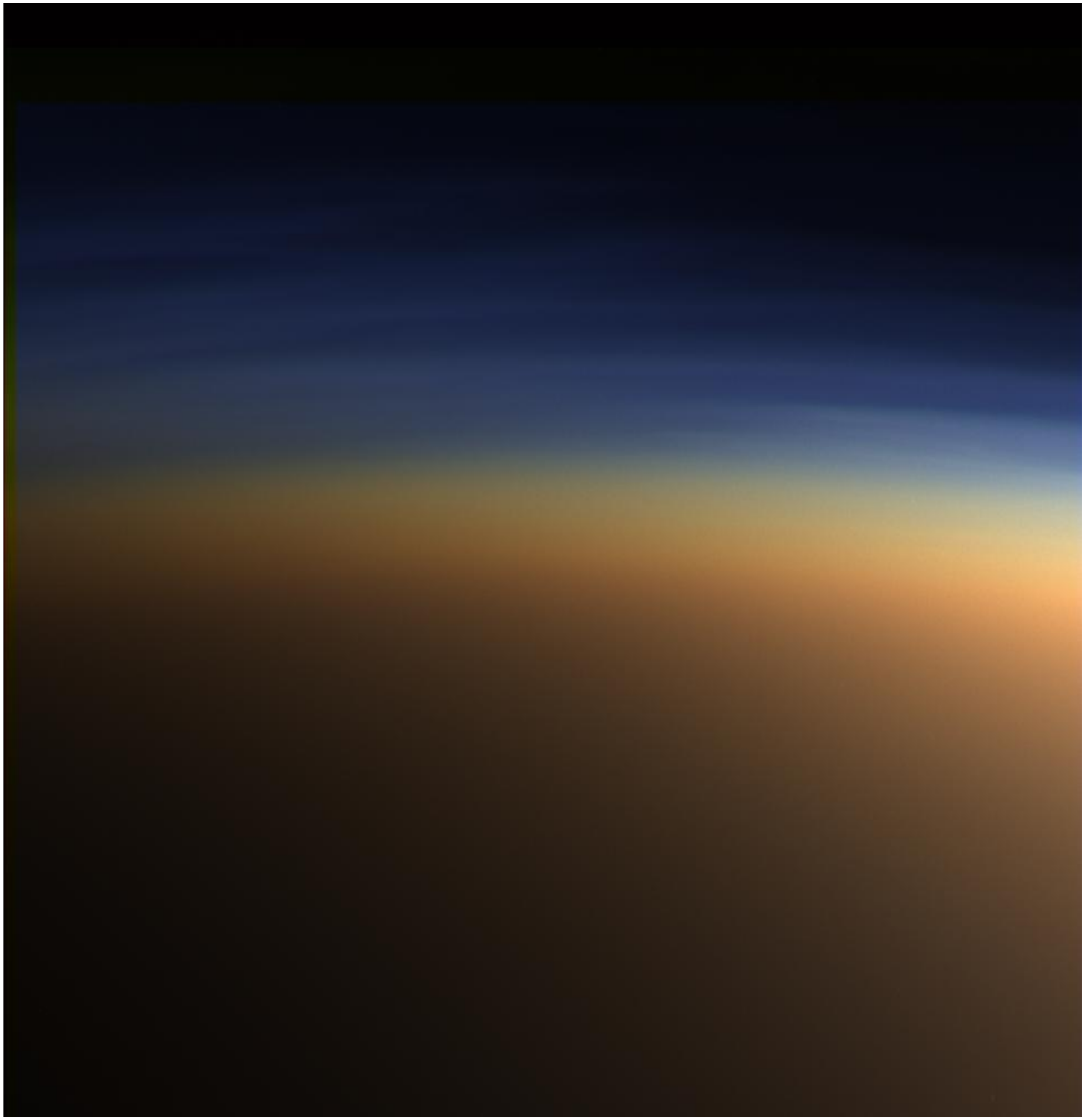
Heating due to solar ultraviolet radiation

photo-dissociation of $CH_4$.

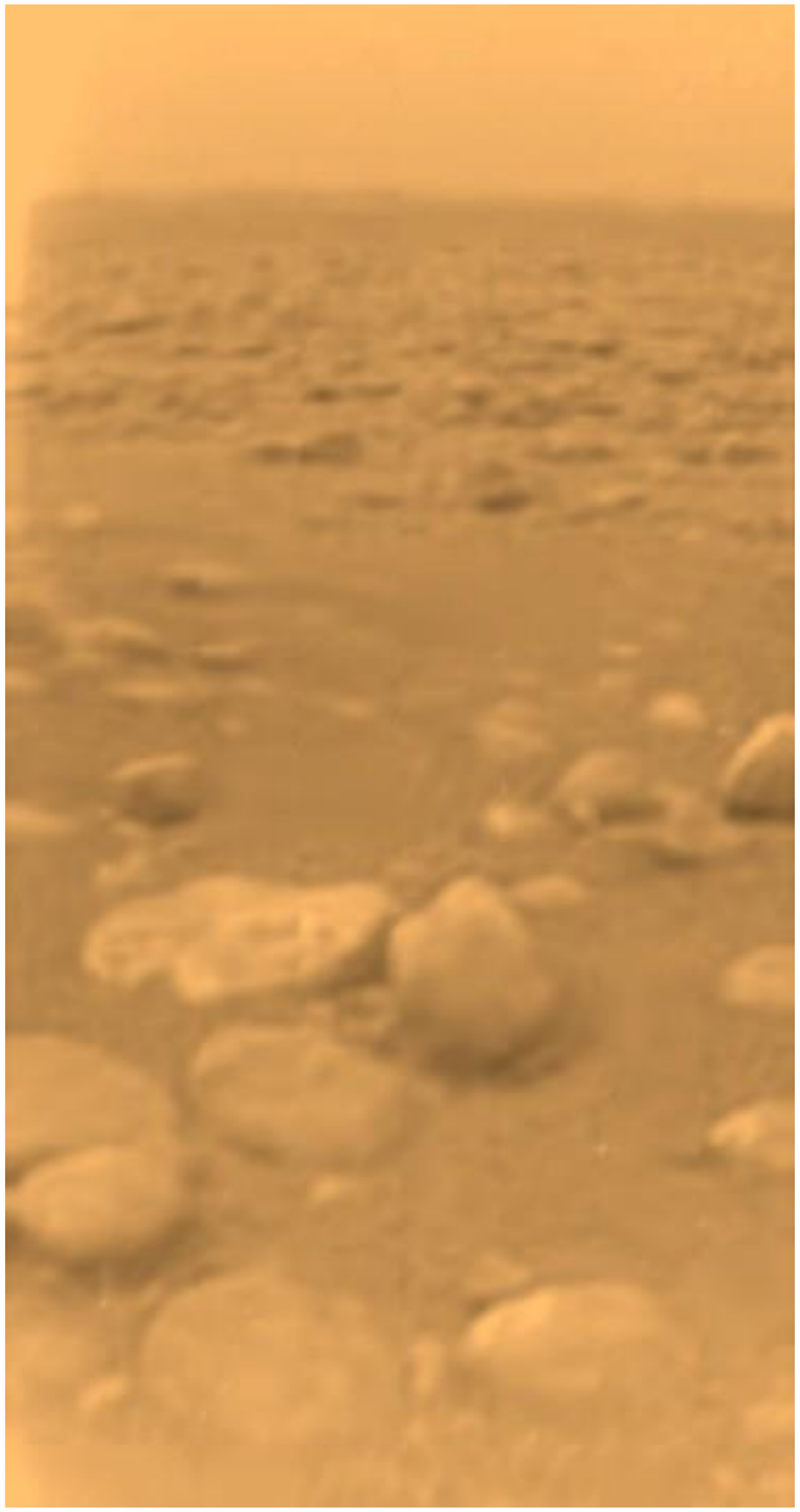
Chemical reaction produce hydrocarbon-nitrile aerosols known as tholins, for example $(C_{11}N_4H_{14})n$.

Tholins generate the orange color of Titan's atmosphere

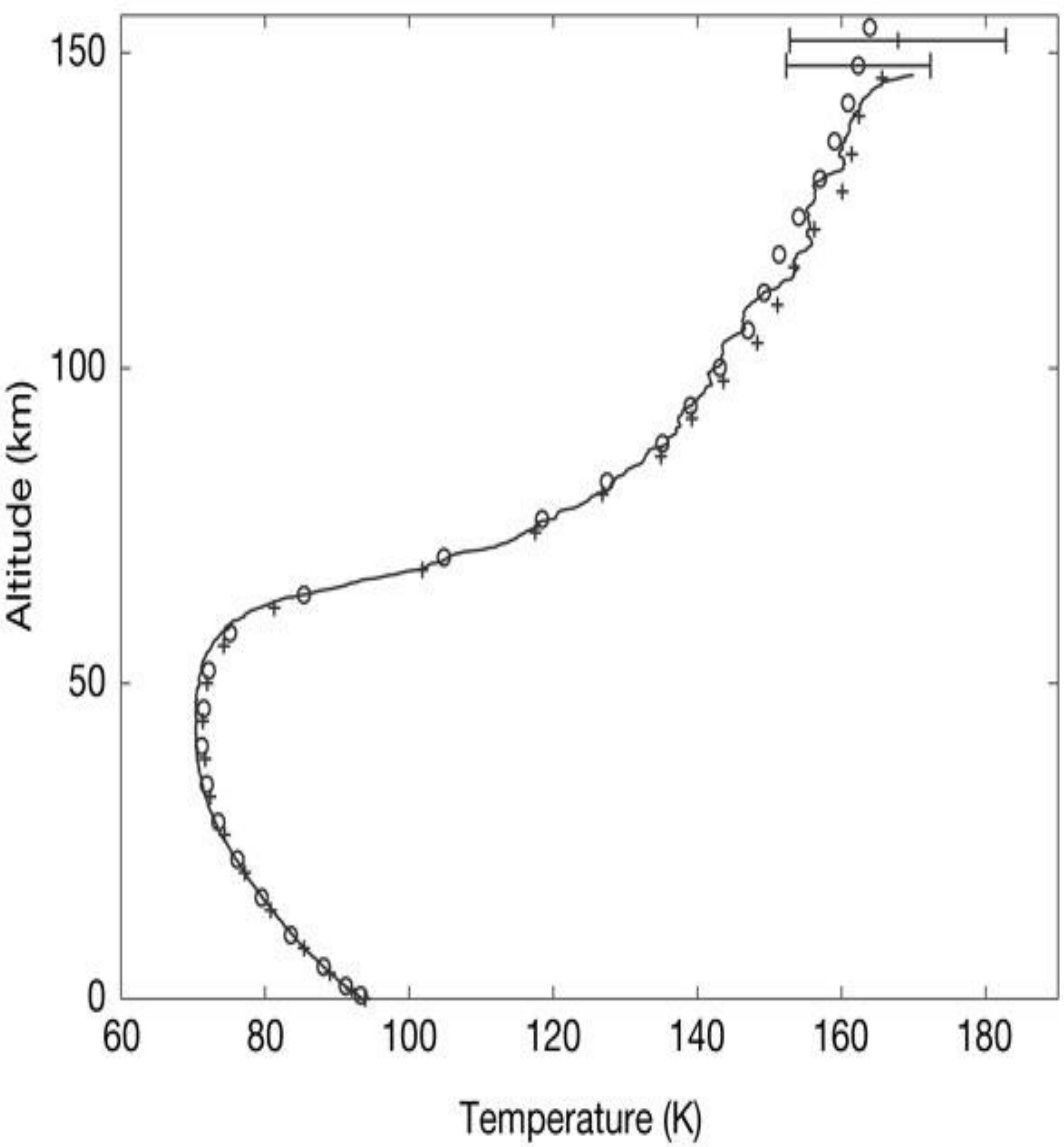
# Titan’s Atmosphere

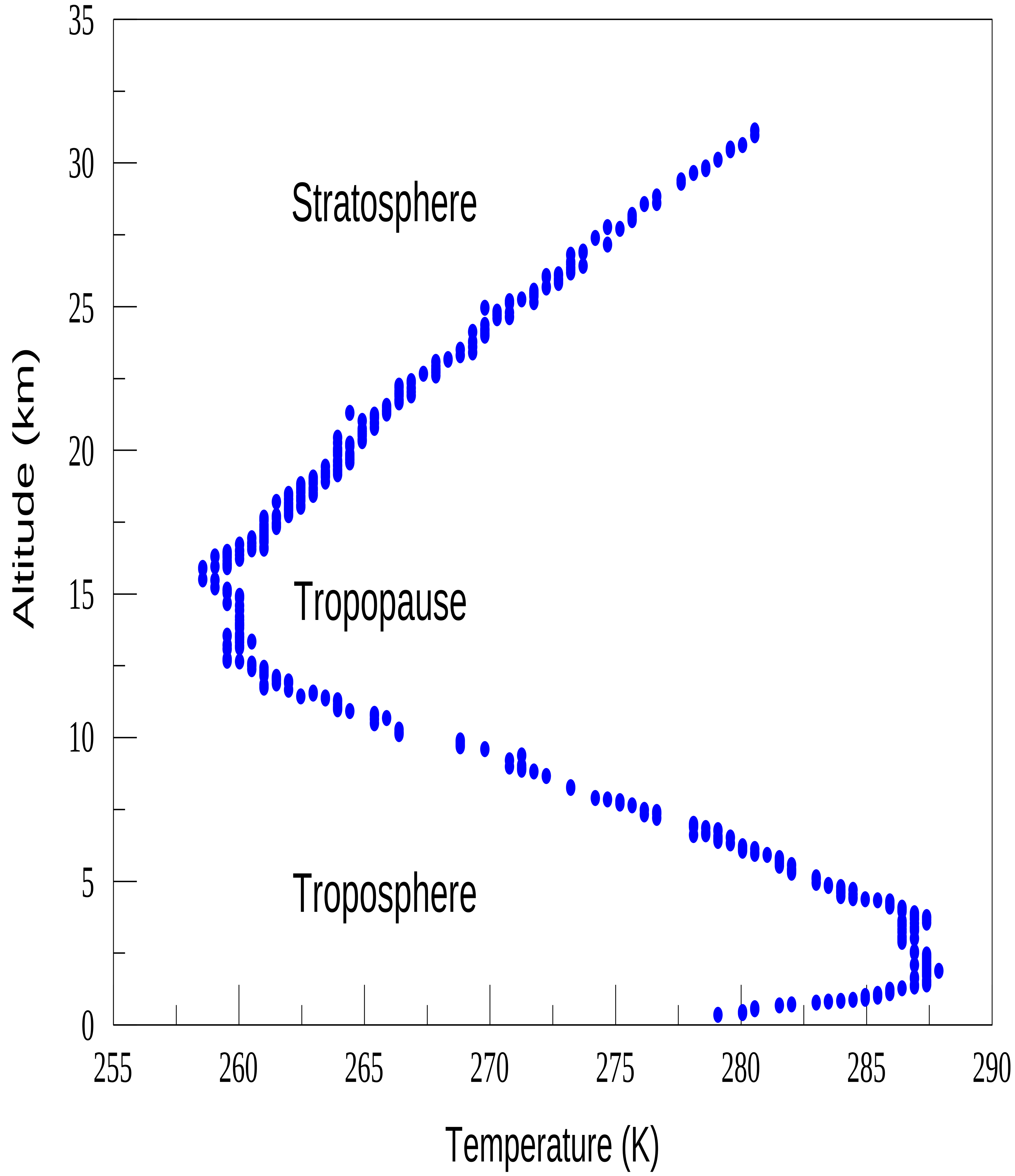


# Titan’s Surface



# Temperature profiles for the lower atmospheres of Titan and the Earth



$ELR_{Titan}$ < 0.85 K $km^{-1}$ near the surface

$g_{Titan}$ = 1.36 m $s^{-2}$

$C_{p\ Titan}$ = 1044 J $Kg^{-1}$ $K^{-1}$

$DALR_{Titan}$ = 1.30 K $km^{-1}$

SALR =? Methane saturation not water

# Lab Activities

- Temperature measurement and calibration
- Temperature structure of the Earth's atmosphere
  - Lapse rates
  - Stability
- Temperature structure of Titan's atmosphere
  - Lapse rates
- Physical and chemical processes

# References


- Briggs, D., Smithson, P., Addison, K., and Atkinson, K, ***Fundamentals of the Physical Environment, Second edition,*** Routledge Publishing, New York, NY, 1997.
- M. Fulchignoni, et al. *Nature* **438**, 785-791 (8 December 2005) ***In situ*** **measurements of the physical characteristics of Titan's environment**
- **European Space Agency: Titan images**
- http://pds-atmospheres.nmsu.edu/education_and_outreach/encyclopedia/adiabatic_lapse_rate.htm The Planetary Atmosphere Data Node [cited 23 May 2011]
- Lucy-Ann McFadden, Paul R. Weissman and Torrence V. Johnson, Editors, ***Encyclopedia of the Solar System***, Academic Press, Boston, MA, 2007, Chapters 7, 9, 15, and 25
- NSF CCLI Balloon Workshop, Taylor University, 29 – 30 July, 2009, Reference documents and references therein