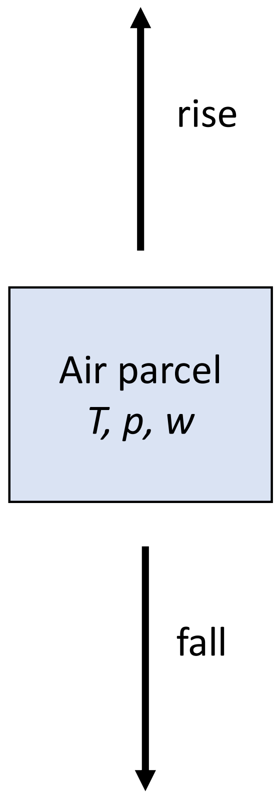
Physics and Chemistry of the Atmosphere

Assignment 1 - Introduction

Information

- Assignment can be found on Moodle
- Groups of 2 people maximum
- Submit solutions on Moodle
  - PDFs (handwritten solutions must be scanned)
  - Python file
- Provide details of your calculations for all answers
- Grading: (total points / total possible points) x 5 + 1
- **Due date: Friday, 07.03.2025 23:59**

Recap: concept of an air parcel



Surrounding air:
T, p, w

Simplifying assumptions:

- No heat (i.e. energy) exchange with the environment → *adiabatic*
- Surrounding air is still (i.e. fixed temperature gradient)

Diabatic vs. Adiabatic Processes

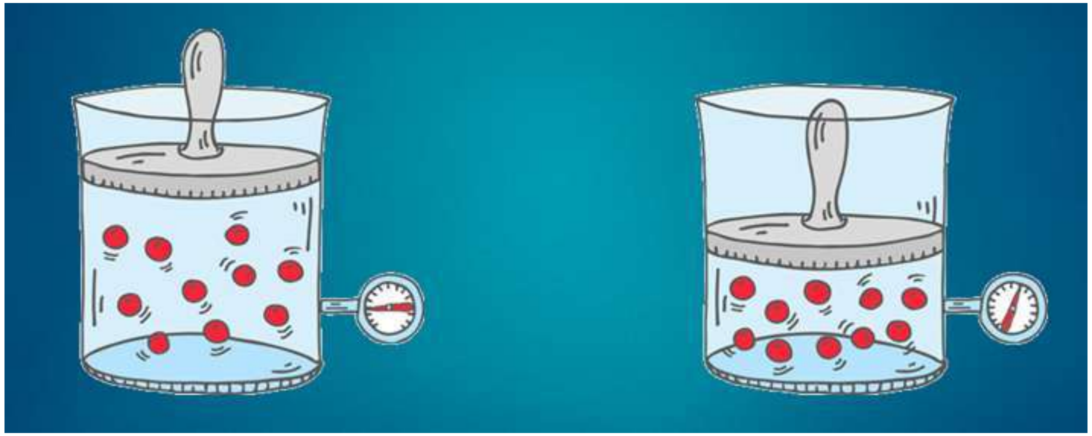
Diabatic process: Direct heat exchange with the environment.

Example: heat exchange between air and surface

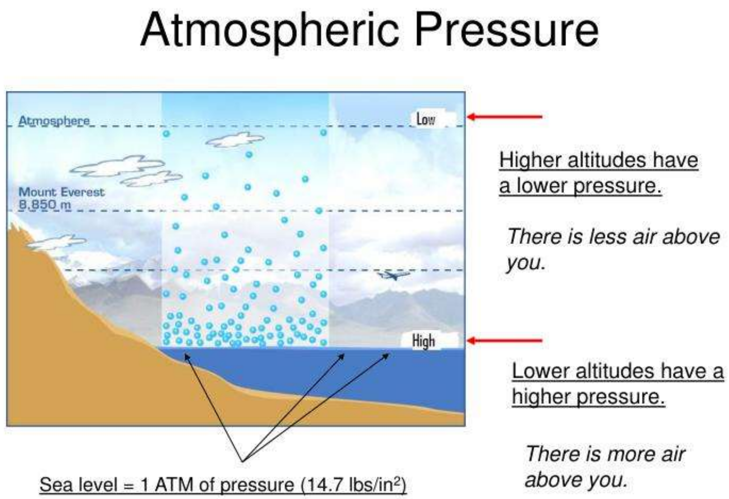
Diabatic vs. Adiabatic Processes

Adiabatic process: No heat exchange with the environment.

- *Heating due to compression*
- *Cooling due to expansion*



https://www.air-compressor-guide.com/articles/water-in-compressed-air-calculations



https://www.inspiritvr.com/air-pressure-at-mount-everest-study-guide/

Recap: thermodynamics

1st law of thermodynamics:

$$dq = c_p\, dT - \frac{1}{\rho} dp;$$

$[q] = \mathrm{J\,kg^{-1}}$
$[T] = \mathrm{K}$
$c_p = 1004 \mathrm{J\,kg^{-1}K^{-1}}$

work

change in internal energy

heat exchange

Adiabatic: no heat exchange

$$0 = c_p\, dT - \frac{1}{\rho} dp;$$

Change in temperature goes along with change in pressure

Recap: potential temperature

Potential temperature:
Temperature an air parcel would have when adiabatically brought to sea level (1000 hPa).

$$\theta = T\left(\frac{p_0}{p}\right)^{R/c_p}$$

$R \approx 287\ \mathrm{J\ kg^{-1}\ K^{-1}}$
$c_p \approx 1000\ \mathrm{J\ kg^{-1}\ K^{-1}}$

-> can also be read from skewT-logP diagram!

Recap: moisture in the atmoshpere

Mixing ratio:

$$w = \frac{m_v}{m_d}$$

m_v: mass of water vapor in the air [kg] or [g]

m_d: mass of dry air [kg]

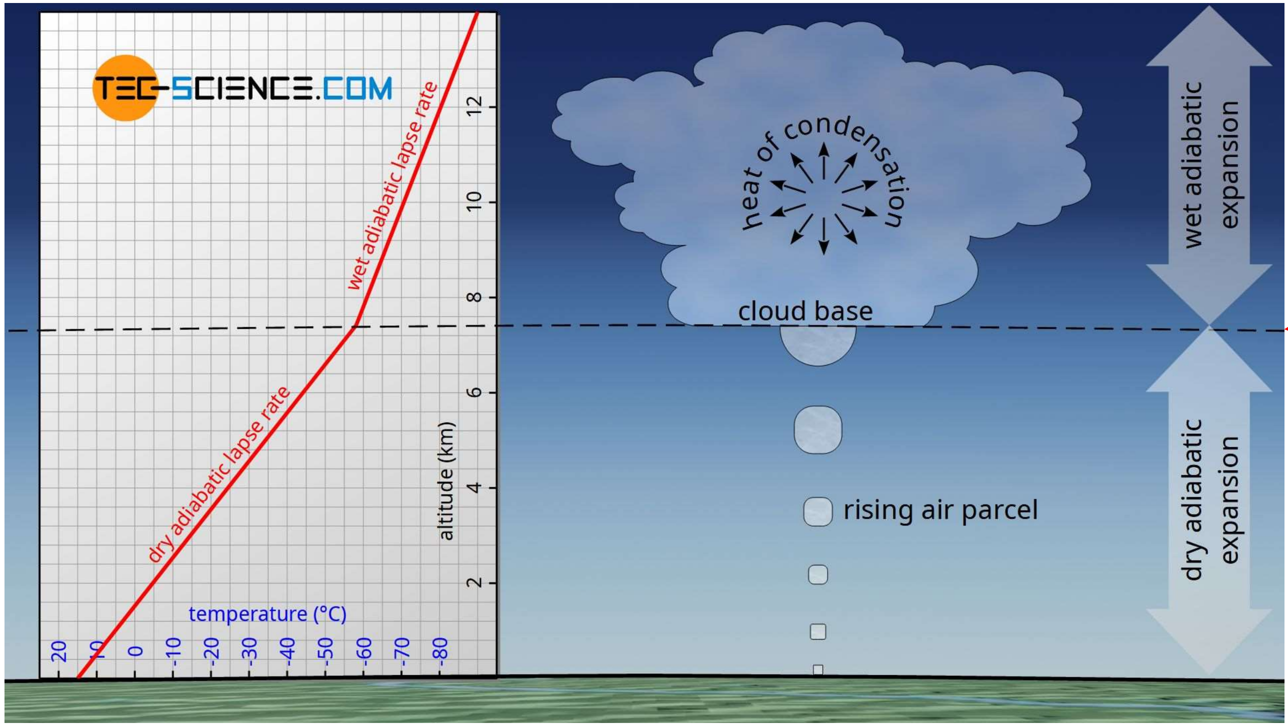
Saturation: The maximum amount of water vapor an air parcel can contain at a specific temperature and pressure.

Relative humidity:

$$RH = \frac{w}{w_s} * 100\%$$

w_s: saturated mixing ratio [kg/kg] or [g/kg]

Adiabatic lapse rates



https://www.tec-science.com/mechanics/gases-and-liquids/barometric-formula-for-an-adiabatic-atmosphere/

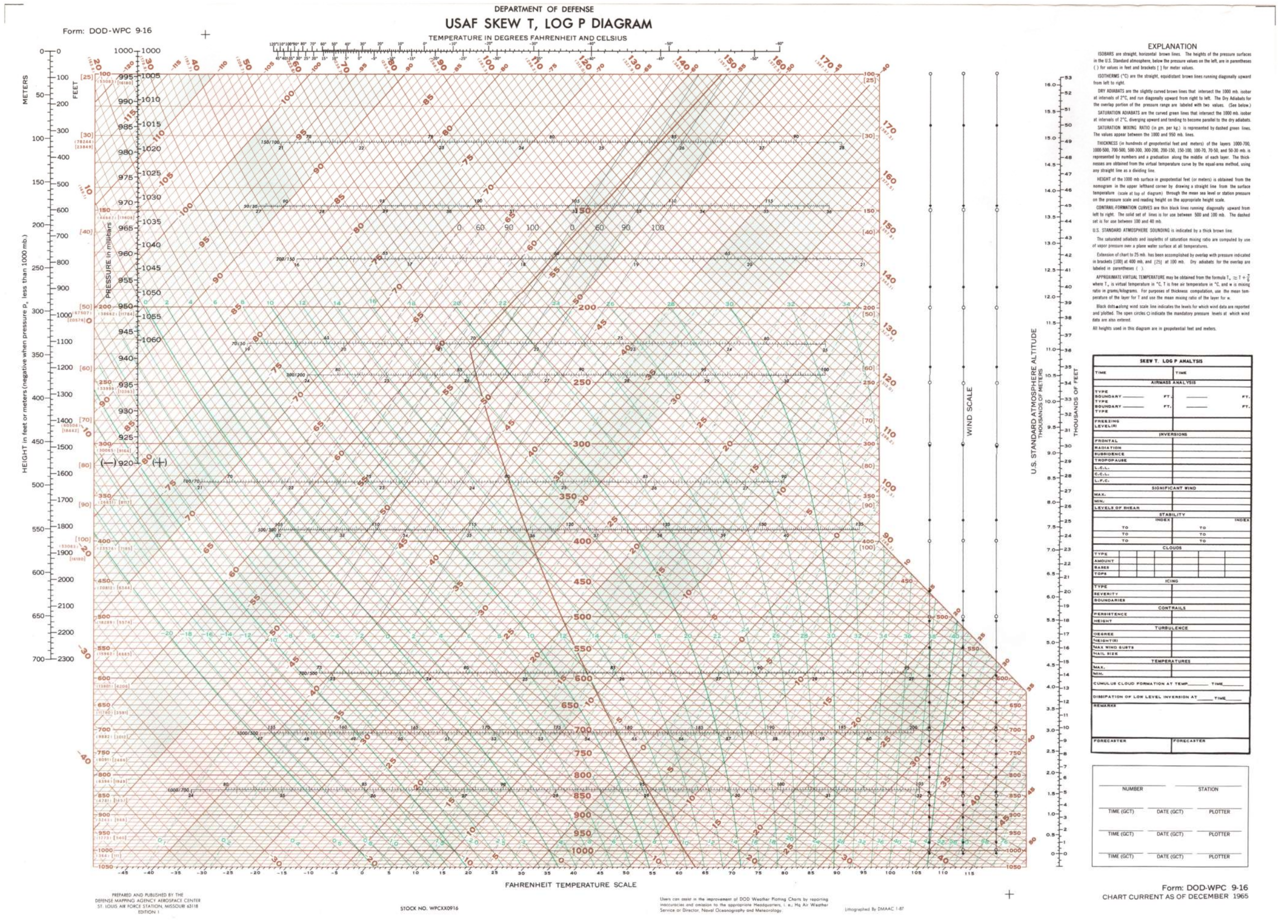
Lifting Condensation Level (LCL)

- Air is saturated.
- Further lifting of air parcel results in condensation (i.e. cloud forming).
- Condensation releases energy, that reduces the temperature gradient.

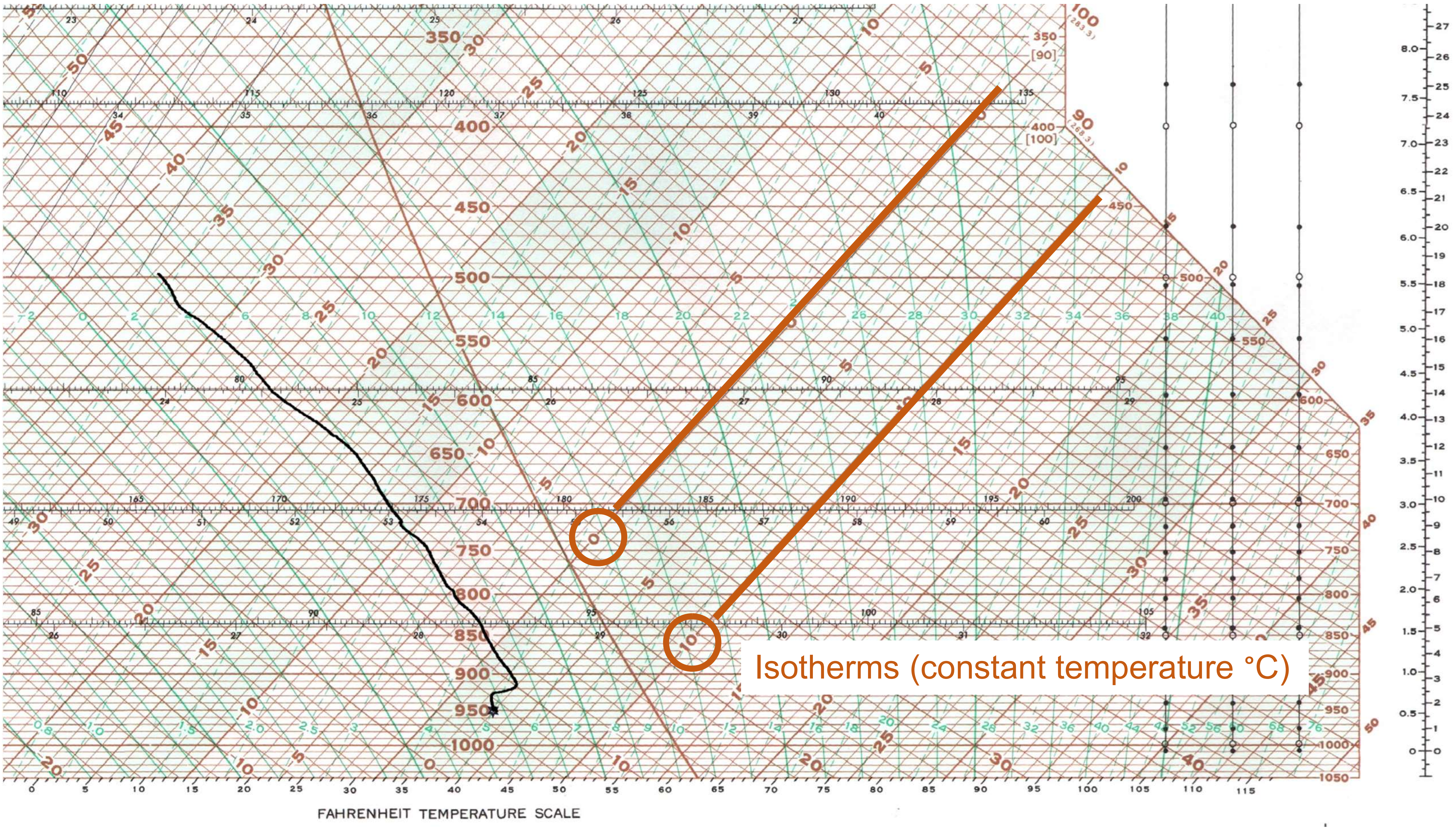
Wet/dry adiabatic lapse rate:
Temperature change of a lifted air parcel [°C/m]

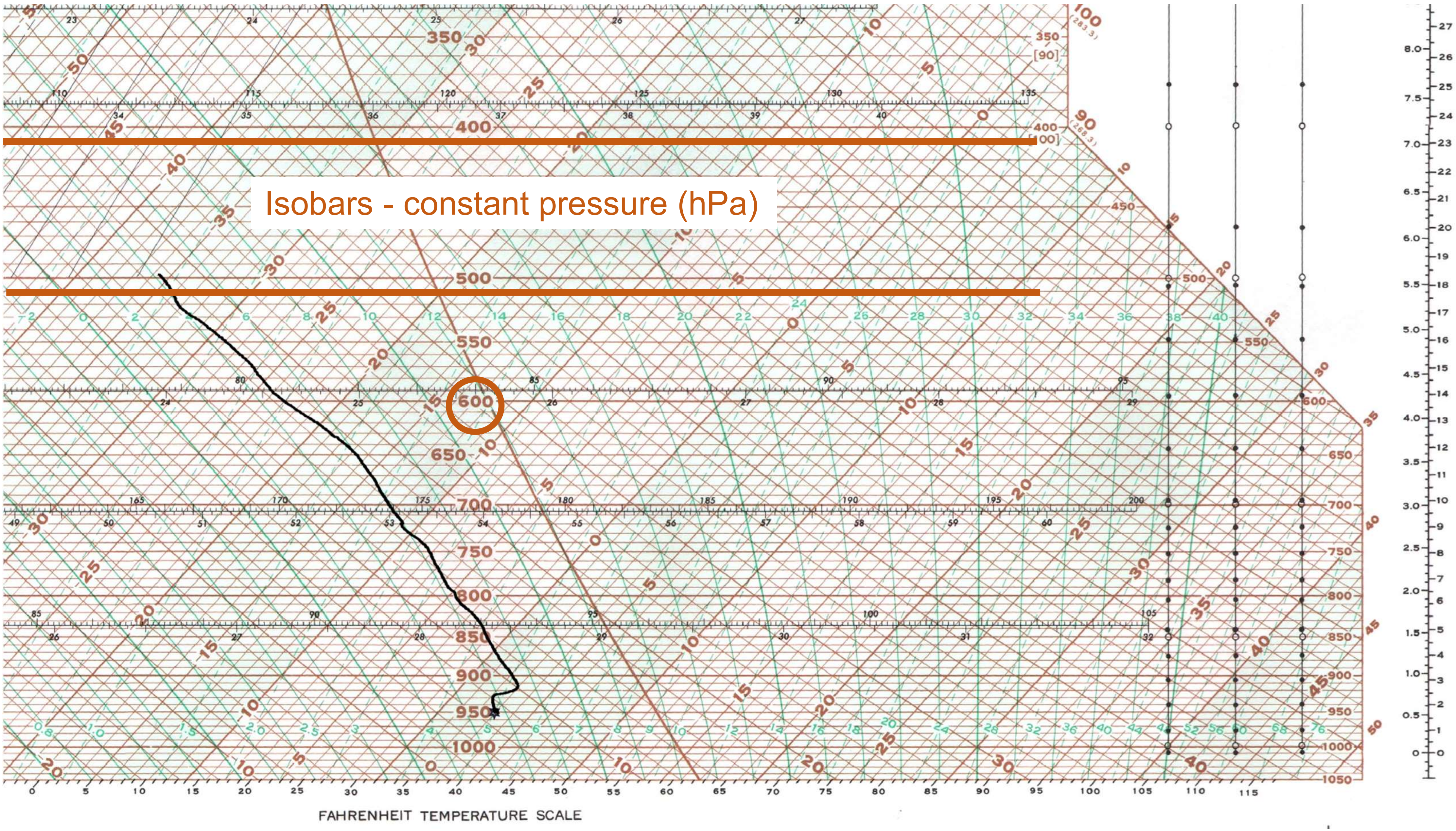
Environmental lapse rate:
Temperature change of environment with altitude [°C/m]

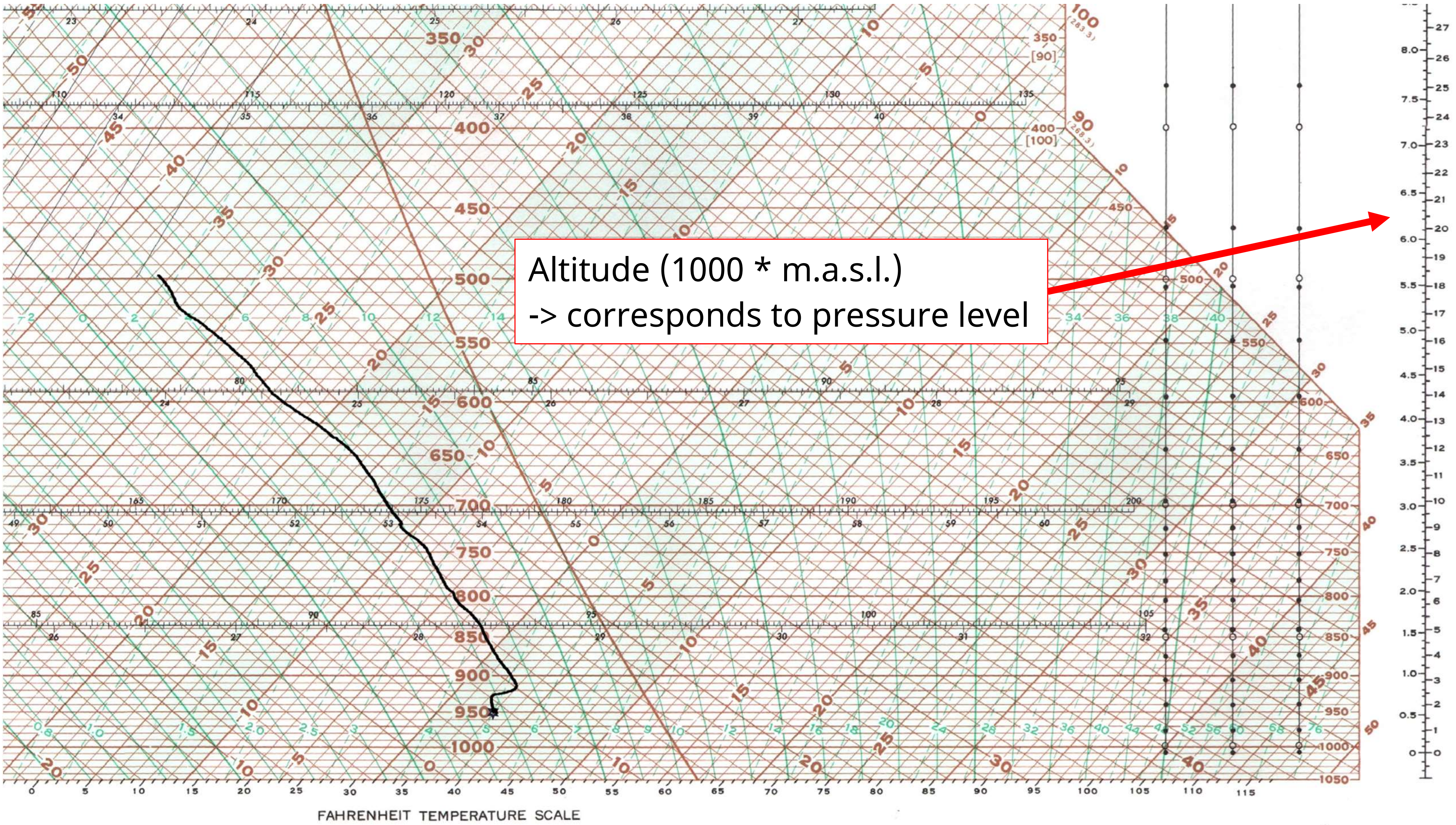
Task 1: Skew T ln p diagram

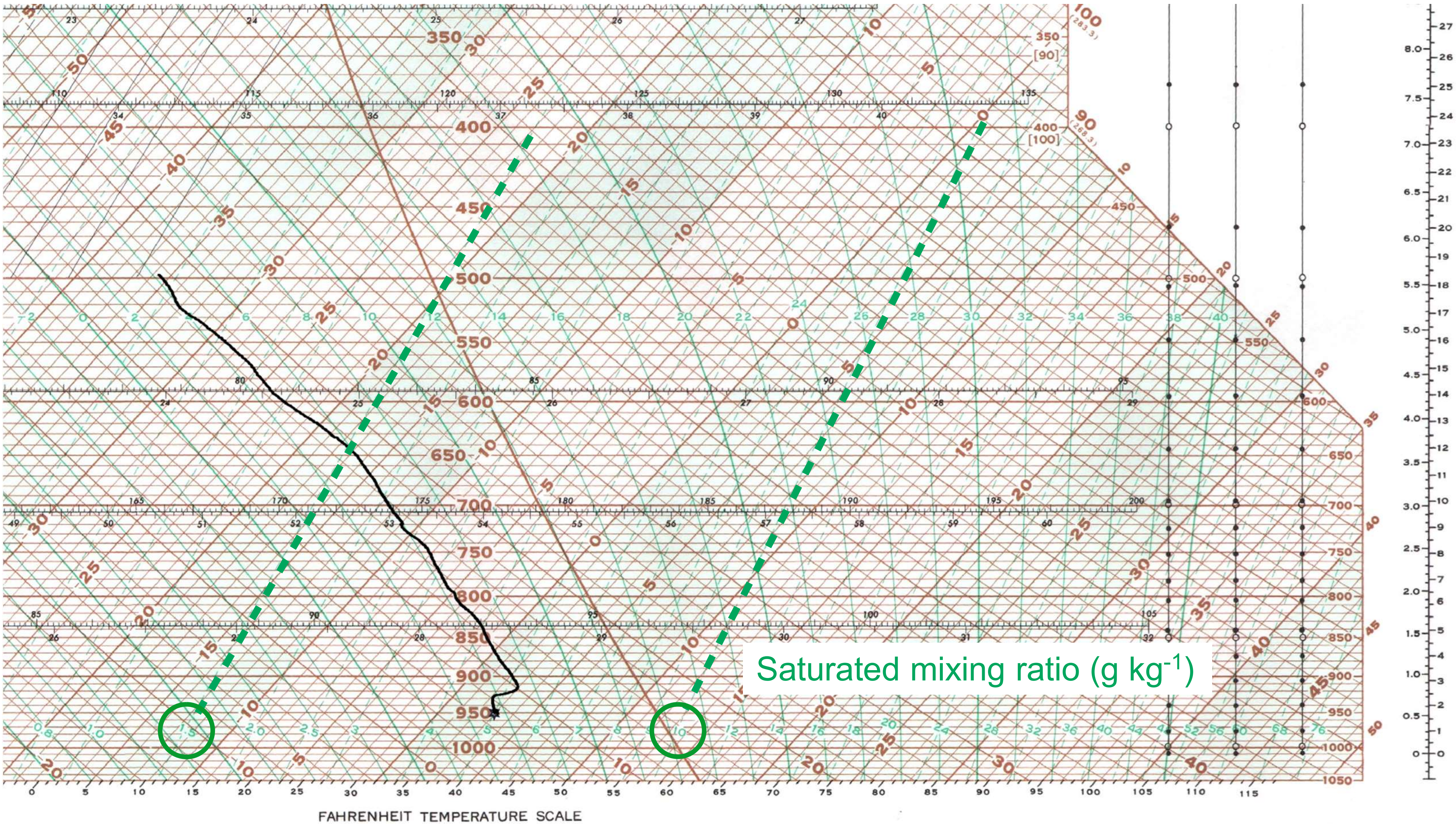


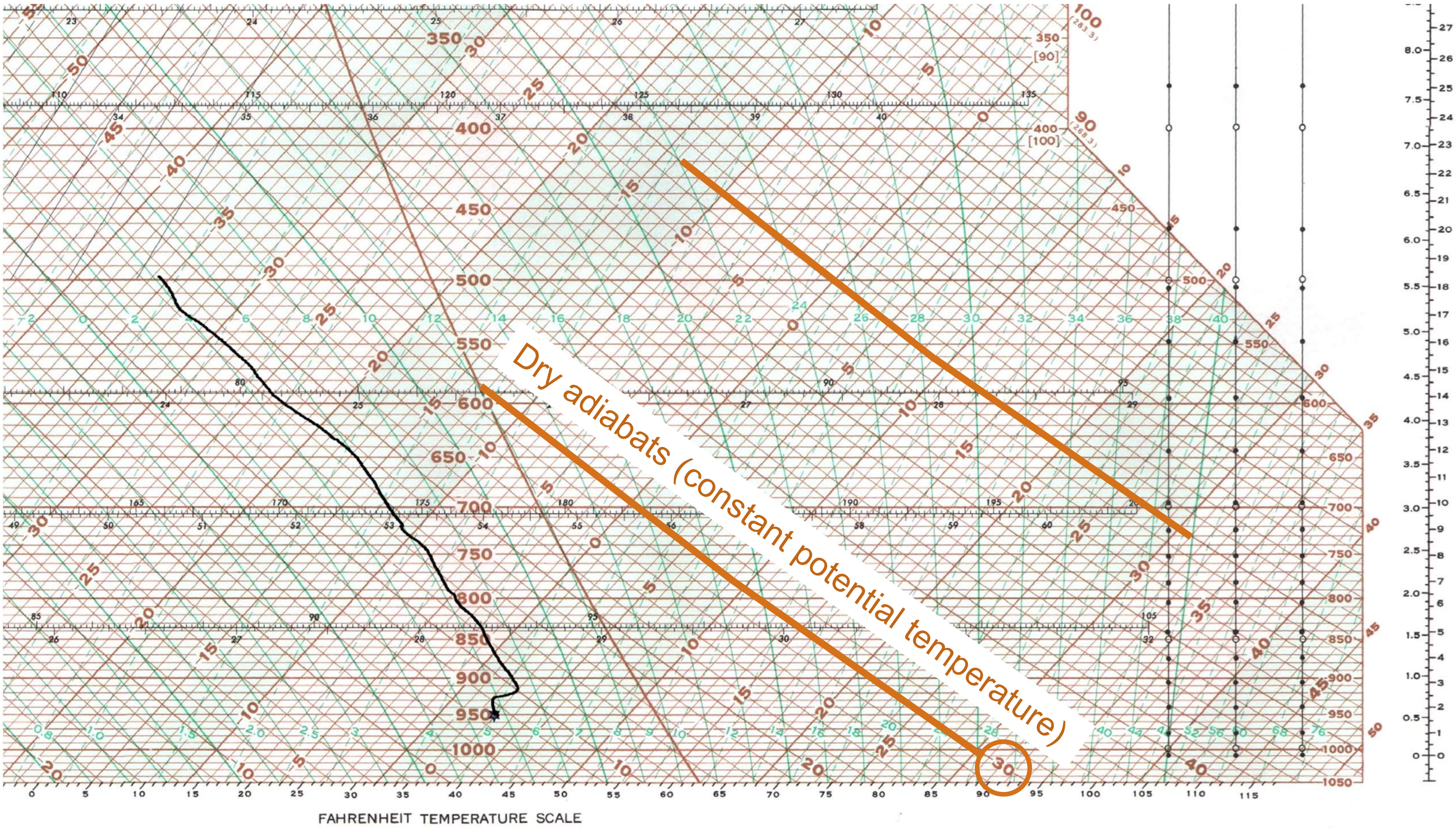
WEATHERGRAPHICS.COM

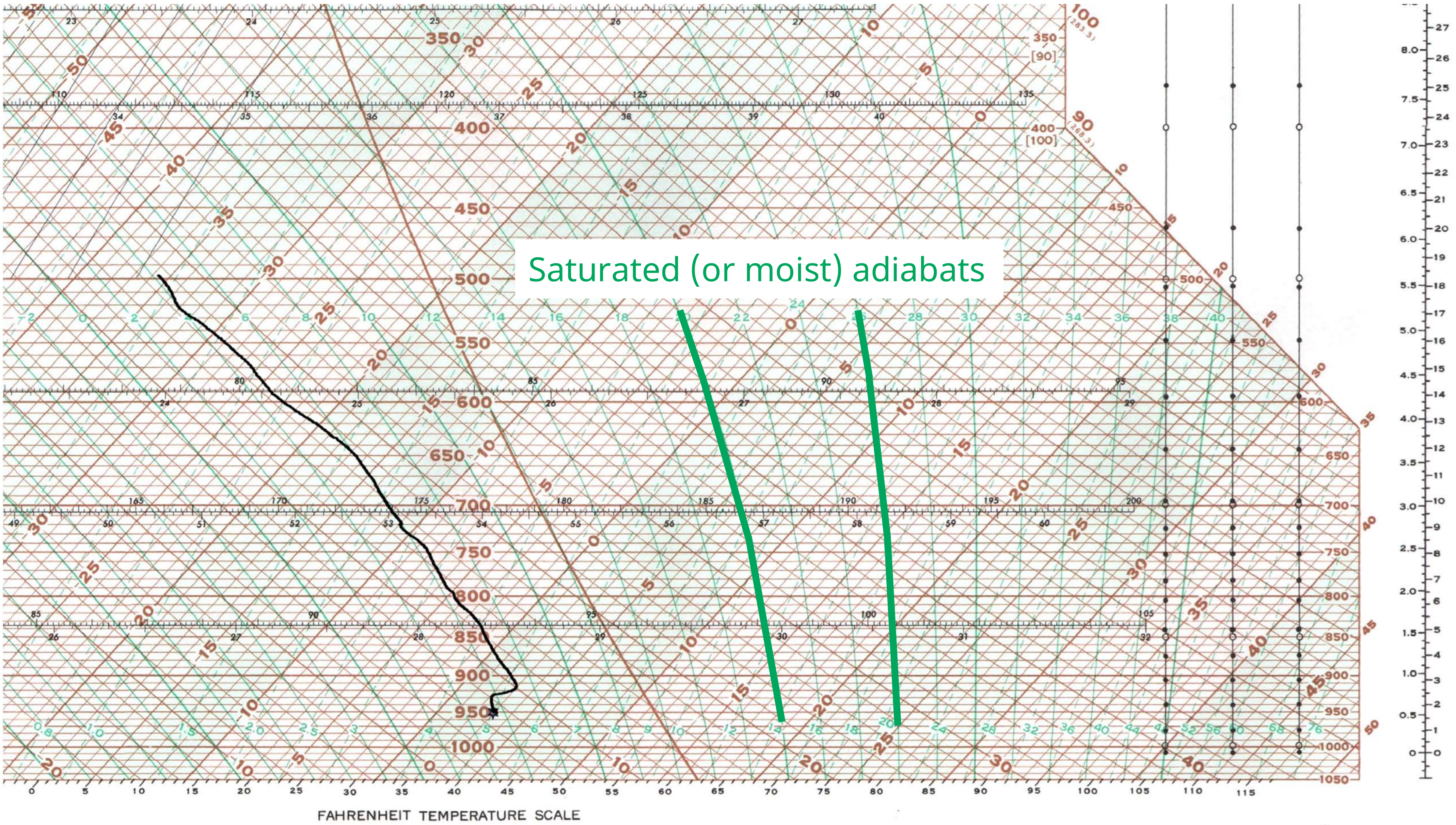

Isotherms (constant temperature °C)
FAHRENHEIT TEMPERATURE SCALE

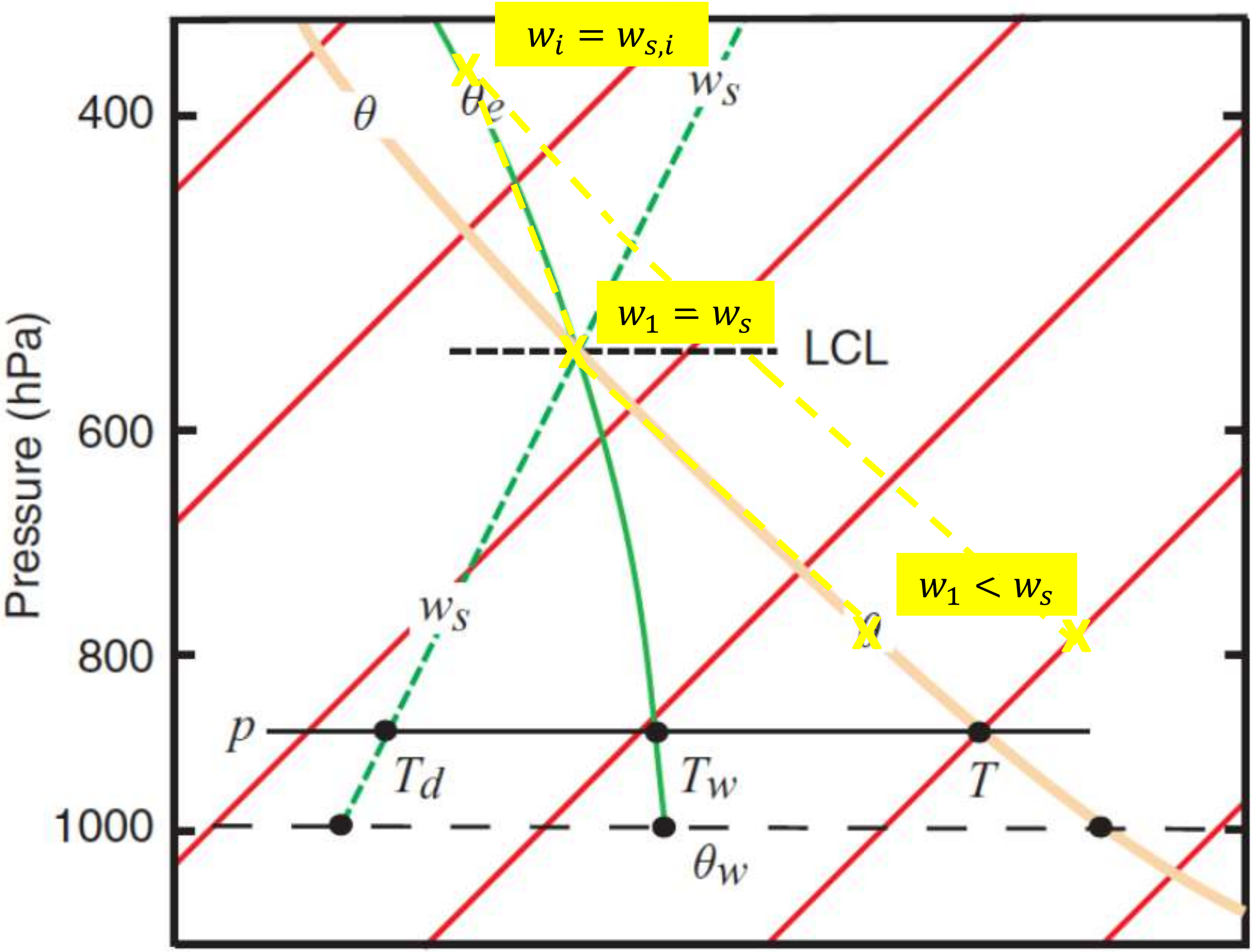

Isobars - constant pressure (hPa)
350
400
450
500
550
600
650
700
750
800
850
900
950
1000
1050
FAHRENHEIT TEMPERATURE SCALE


Altitude (1000 * m.a.s.l.)
-> corresponds to pressure level
FAHRENHEIT TEMPERATURE SCALE


Saturated mixing ratio (g kg-1)
FAHRENHEIT TEMPERATURE SCALE


Dry adiabats (constant potential temperature)
FAHRENHEIT TEMPERATURE SCALE


Saturated (or moist) adiabats
FAHRENHEIT TEMPERATURE SCALE



Θ: potential temperature
T: temperature
T_w: wet bulb temperature
T_d: dew point temperature
w_s: saturated mixing ratio
LCL: lifting condensation level

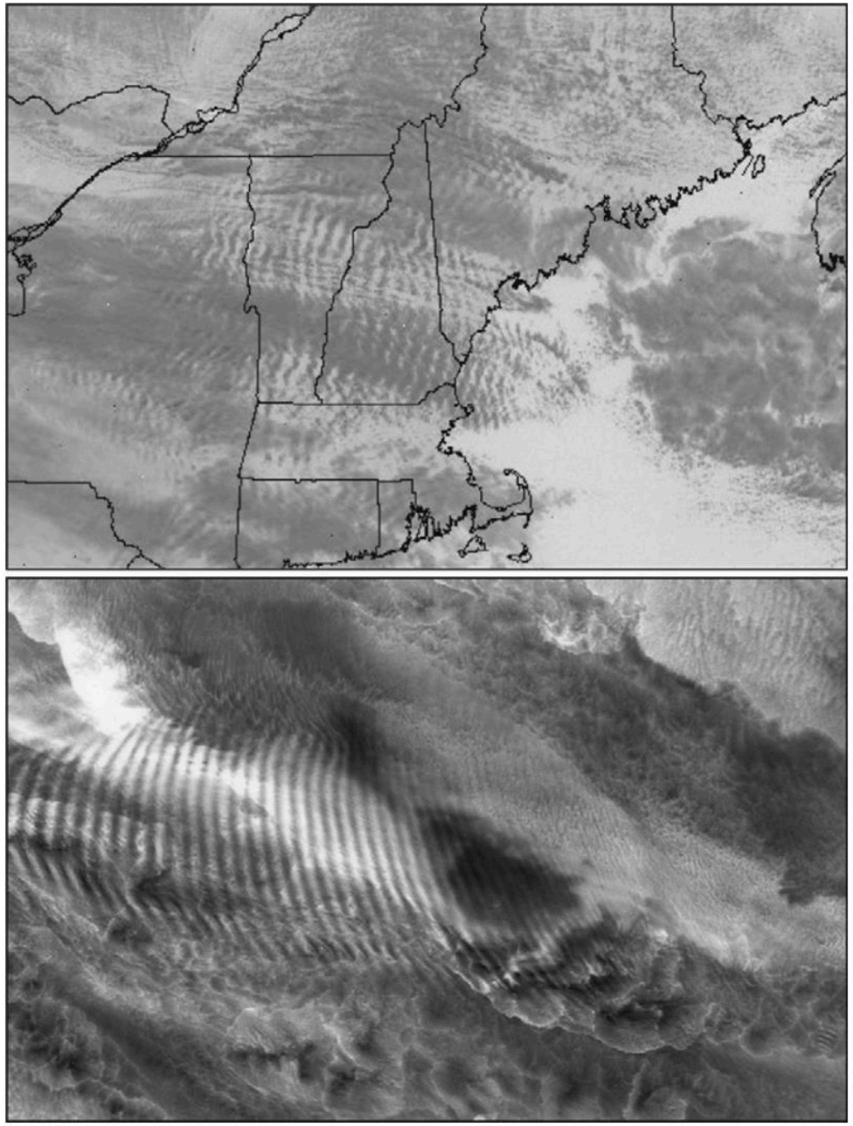
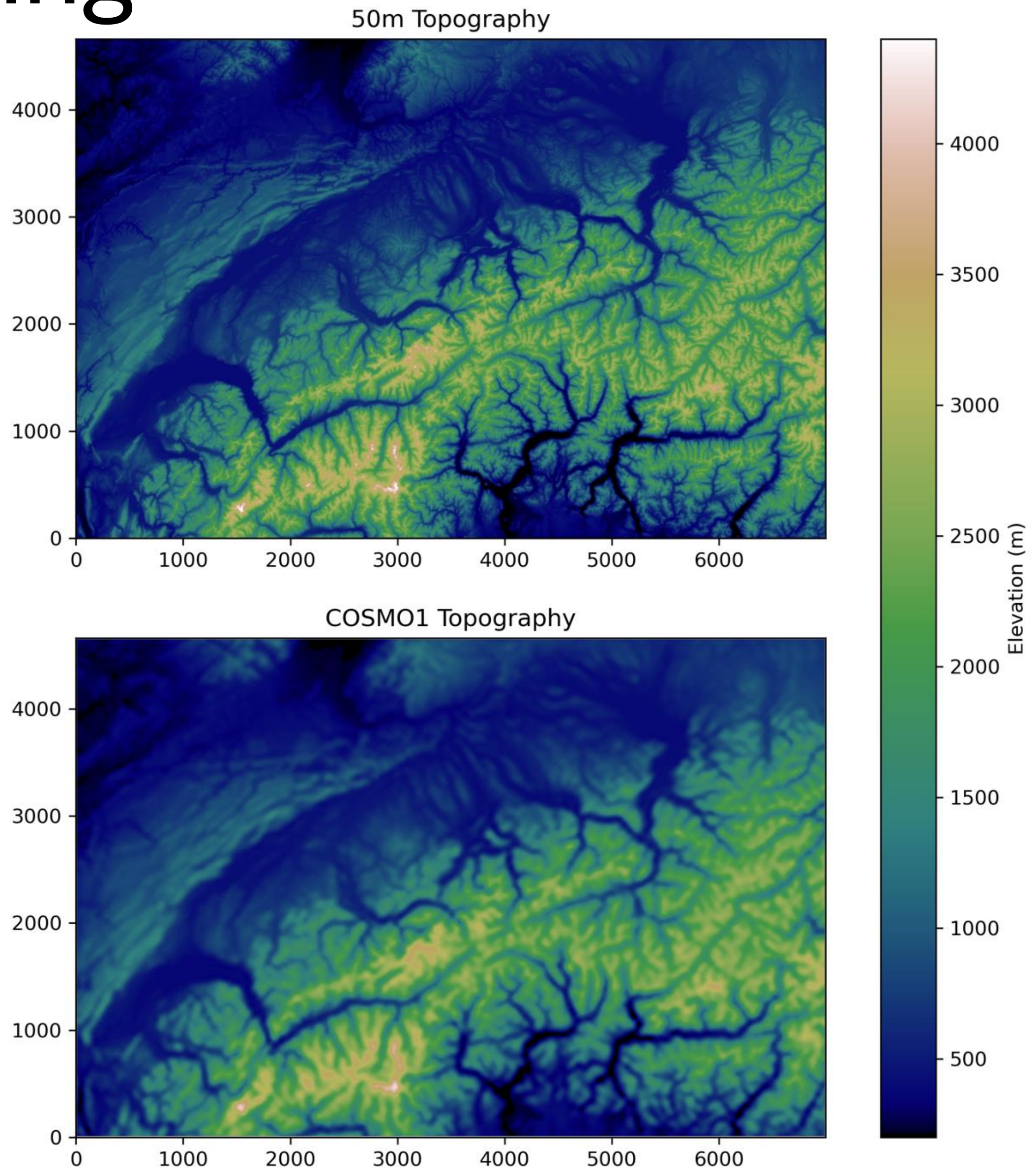


Fig. 3.14 Gravity waves, as revealed by cloud patterns. The upper photograph, based on NOAA GOES 8 visible satellite imagery, shows a wave pattern in west to east (right to left) airflow over the north–south-oriented mountain ranges of the Appalachians in the northeastern United States. The waves are transverse to the flow and their hori-


Zane Merva

Problem 2: Basic Downscaling

- Data from (old) Swiss weather model, COSMO1
  - Data for 11.03.2021 01:00
  - Model resolution of 1.1 km
- Digital Elevation Model (DEM) of Switzerland with 50m resolution
- Goal: High resolution maps of temperature and pressure



Basic Downscaling