# FWFC – INTRODUCTORY METEOROLOGY - PART ONE

# MOISTURE IN THE ATMOSPHERE

# MOISTURE IN THE ATMOSPHERE

What is weather?

The state of the atmosphere - temperature, pressure, clouds, precipitation, etc....

What is climate?

Average weather (30 year average)

Difference between weather and climate?

Climate is what you expect, weather is what you get

# MOISTURE IN THE ATMOSPHERE

What drives the weather?

- heat imbalance
- simply put, weather is heat on the move
- the atmosphere  is a heart engine

How does heat move in the atmosphere?

- conduction
- convection
- radiation
- states of water

# EFFECTS OF PHASE CHANGES ON LATENT HEAT

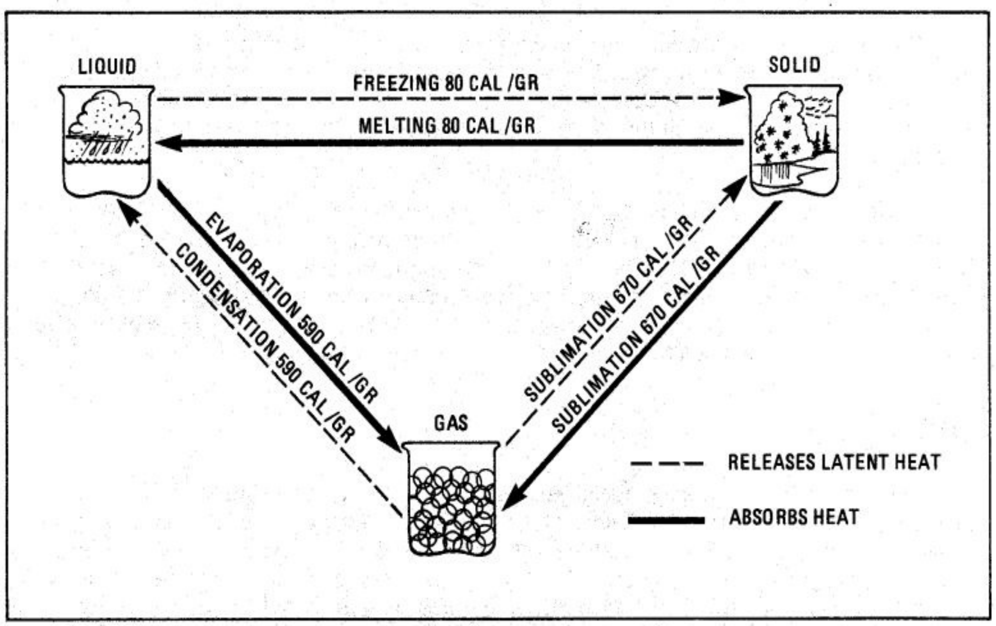


Figure 1-2 Change of State

The amount of latent heat released depends on the moisture content of the air (i.e. gm/cu. metre)

# MOISTURE CONTENT

Have you heard the following?

- When air (at a given temperature) is holding all all the water vapour it can, it is said to be saturated
- The air does not have a holding capacity for water vapor. The atmosphere is a mixture of gases. While saturation (which involves bonds between different molecules) is a real phenomenon in liquids it does not describe the interaction of atmospheric constituents

# SATURATION

- Water molecules switch constantly between phases
  - If more molecules are leaving a surface than arriving – evaporation
  - if more arrive than leave - condensation

  It is these relative flows of molecules which determine whether a cloud forms or evaporates

- The rate at which vapor molecules arrive at a surface of liquid or solid depends upon the vapor pressure

- The rate at which vapor molecules leave the surface depends upon the characteristics of the surface.
  The number escaping varies with:
  - the phases involved (easier from liquid than solid)
  - the shape of the boundary (easier from highly curved (small) drops or ice crystals (convex)
  - the purity of the boundary (foreign substances interfere)
  - the temperature of the boundary (at higher temperatures the molecules have more energy and can more readily escape)

# CONDENSATION NUCLEI (CN)

- CNs are particles required for condensation to occur
- main sources - sea salt, dust, pollutants
- in areas of excessive CNs nuclei (over ocean, near cities) condensation can occur before saturation is reached

# SATURATION

- The air always contains sub microscopic drops, but as evaporation exceeds condensation, the drops last for long

- As air is cooled, the evaporation rate decreases more rapidly than does the condensation rate. It is the dew point temperature where the evaporation is less than the condensation and a droplet can grow into a cloud drop

# WATER VAPOUR CONTENT VARIES WITH TEMPERATURE

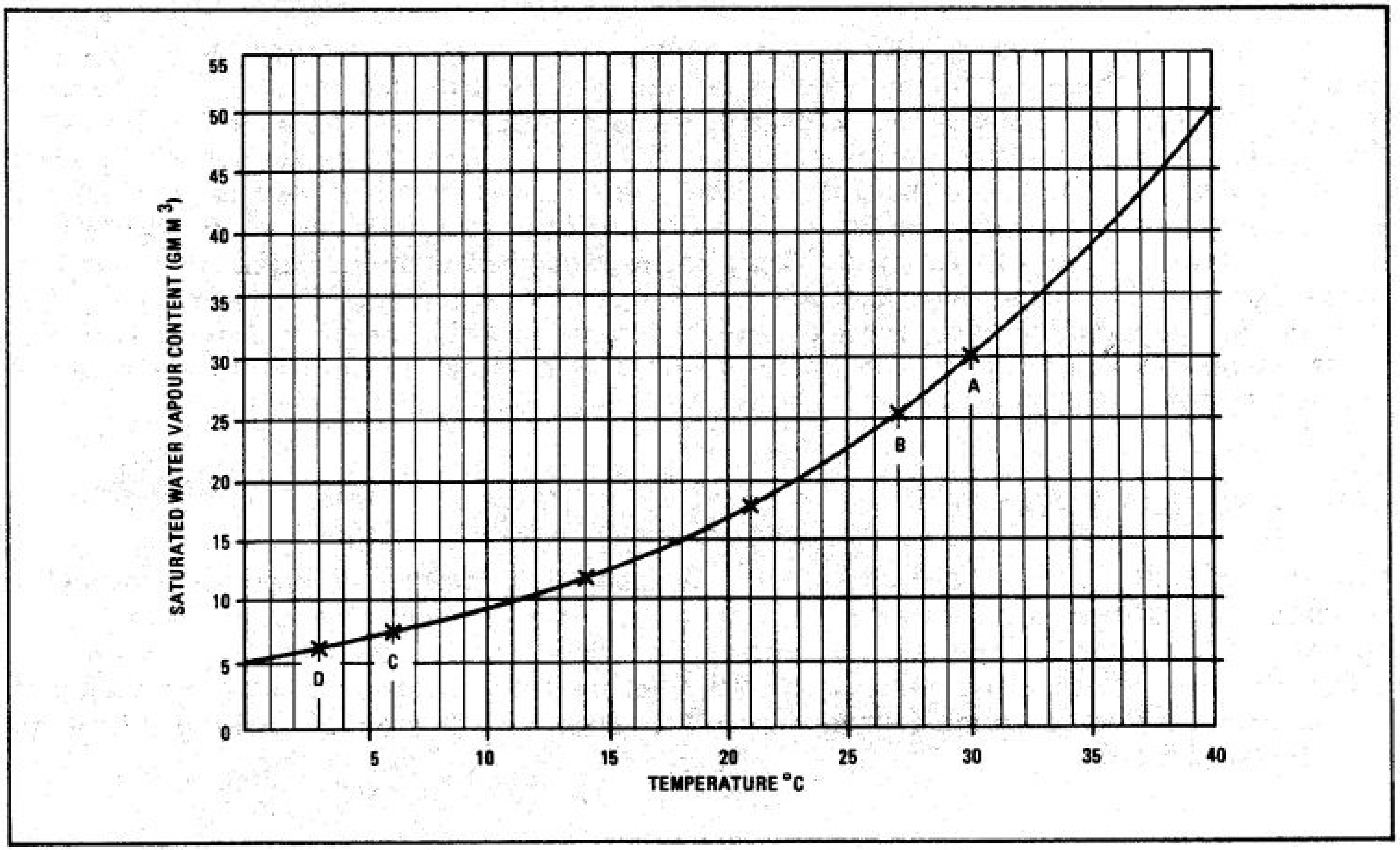



Figure 1-3 Variation of Saturated Water Vapour Content with Temperature

# VARIATIONS IN WATER VAPOUR EFFECTS THE WEATHER

- Cooled saturated warm air will yield more liquid water than cooled saturated cold air
- More liquid released means more latent heat released
- Dynamic weather (severe thunderstorms, hurricanes) are driven by latent heat release

# DEW POINT TEMPERATURE

- Dew point temperature - the temperature at a given pressure to which air must be cooled to cause saturation
- the spread between the air temperature and the dew point temperature is a direct measure of how close the air is to saturation
- the ‘warmer’ the dew point temperature the greater the moisture content

  i.e. 10°/9°; 18°/18°; 29°/21°
- Dew point temperatures are conserved

# RELATIVE HUMIDITY ( RH )

- compares the amount of water vapour in the air to the amount it could hold (expressed as % )

$$RH = \frac{\text{amount of water vapour in air}}{\text{amount of water vapour if saturated}} \times 100$$

- the relative humidity does not give a direct measure of the water content of the atmosphere

# RELATIVE HUMIDITY

Anywhere along the curve the RH = 100% but The water content changes as the air heats

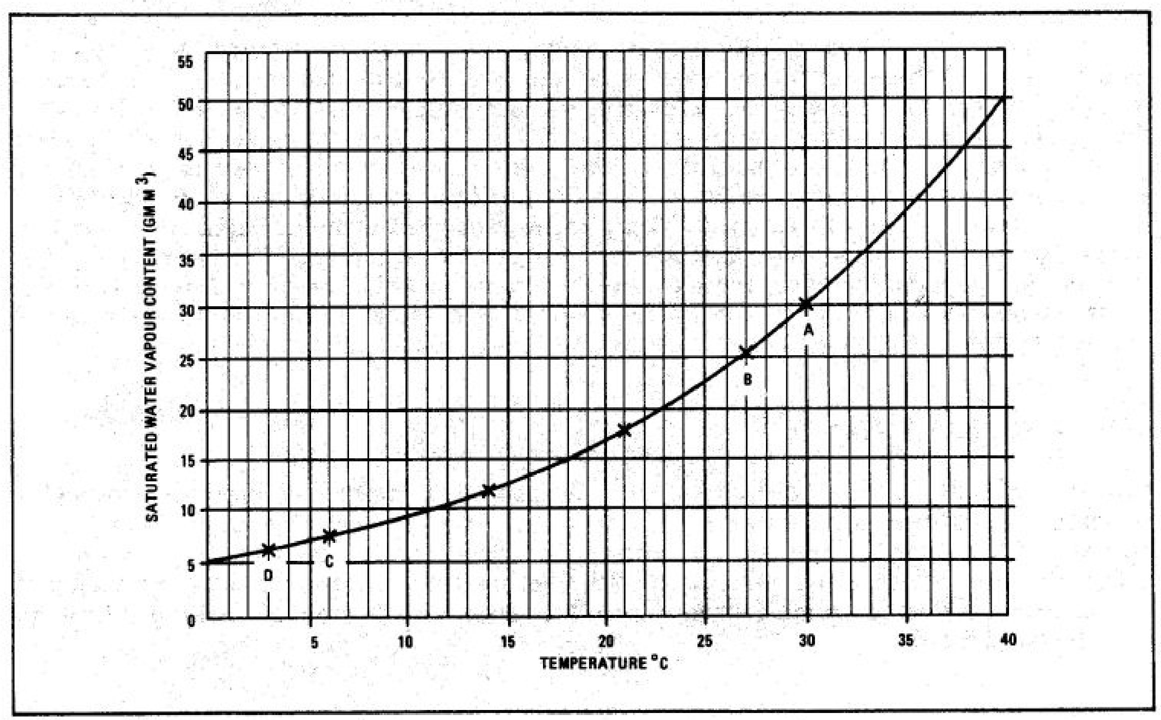
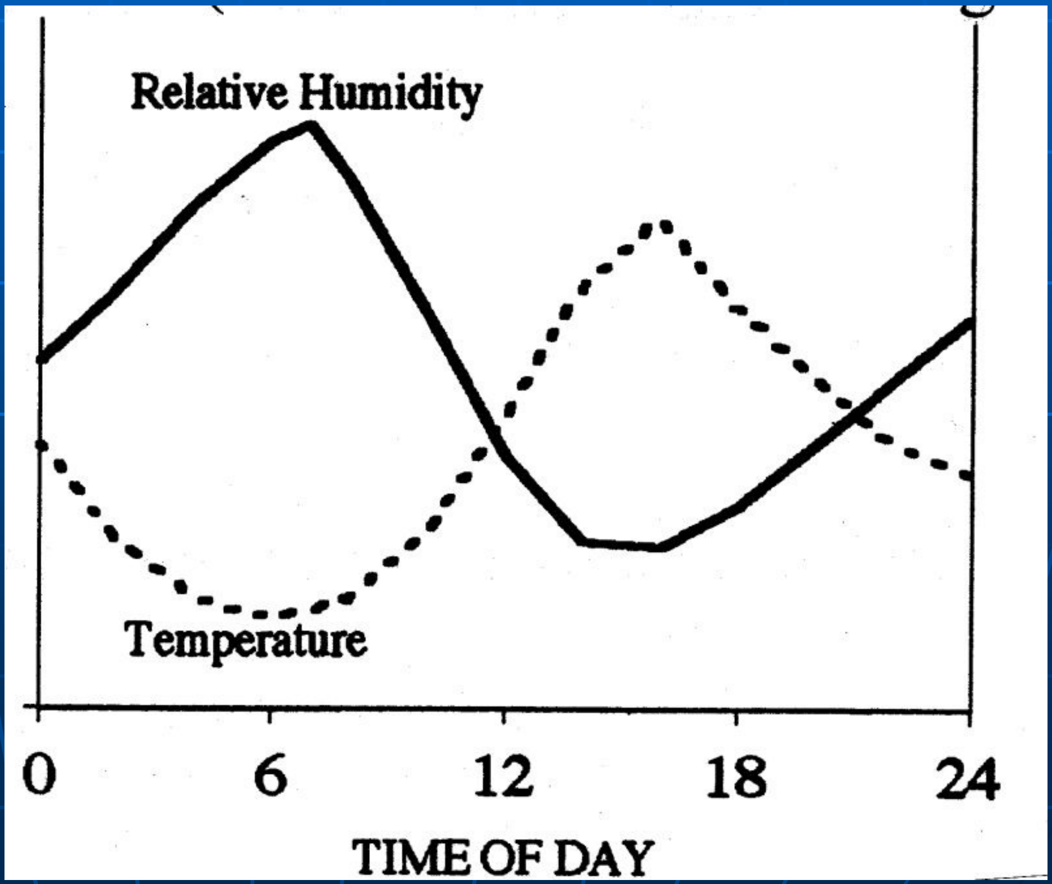



Figure 1-3 Variation of Saturated Water Vapour Content with Temperature

# DIURNAL VARIATION OF THE RELATIVE HUMIDITY

RH changes but actual moisture content does not!



# ATMOSPHERIC HEATING

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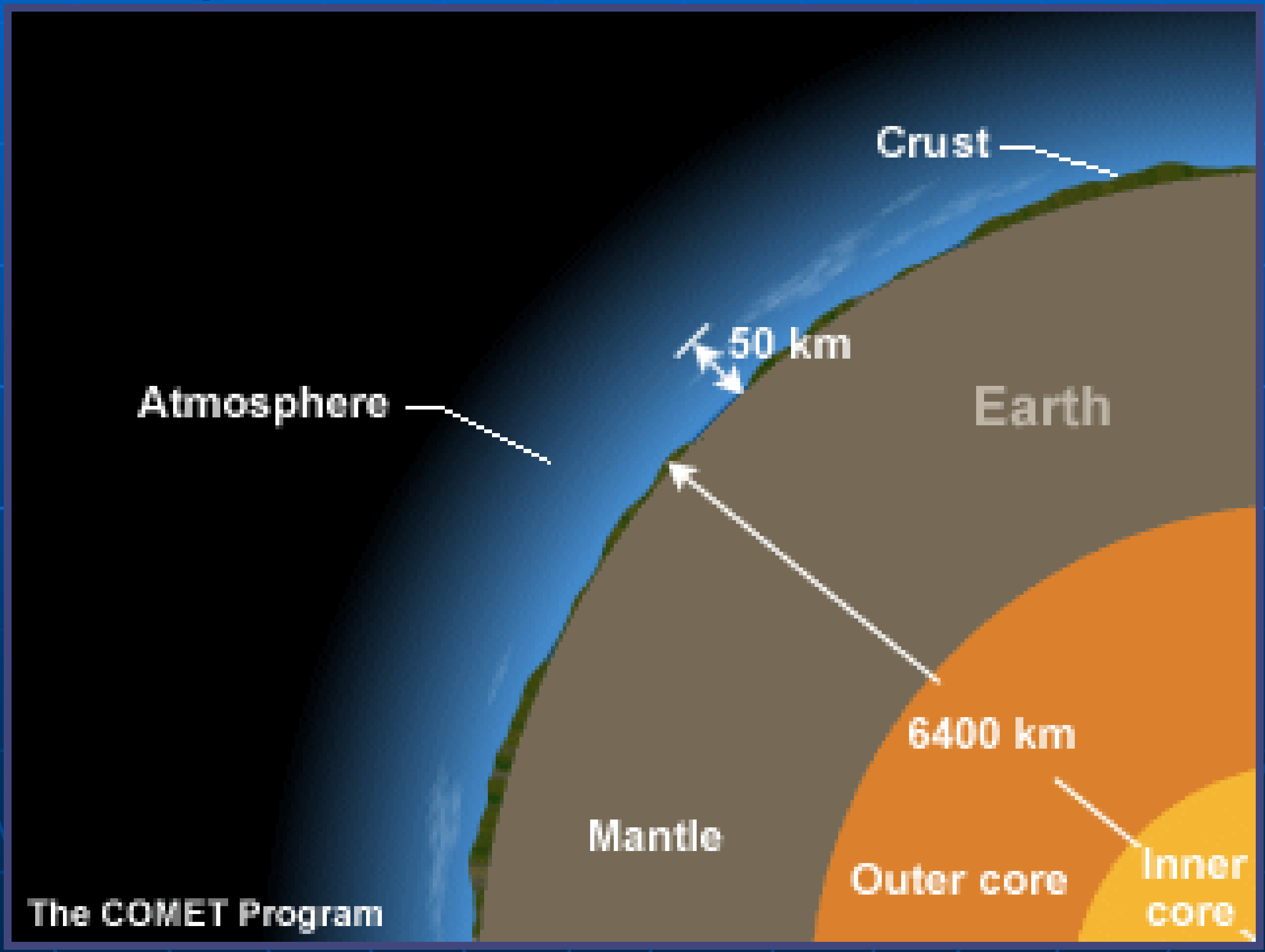
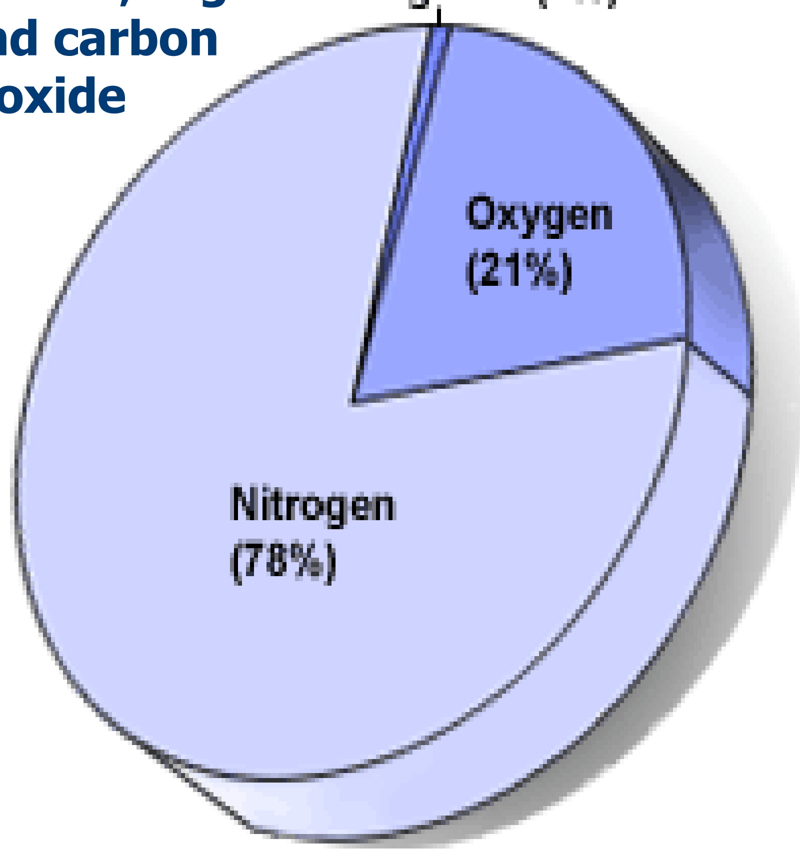
# ATMOSPHERIC HEATING

Life’s thin layer



# THE ATMOSPHERE



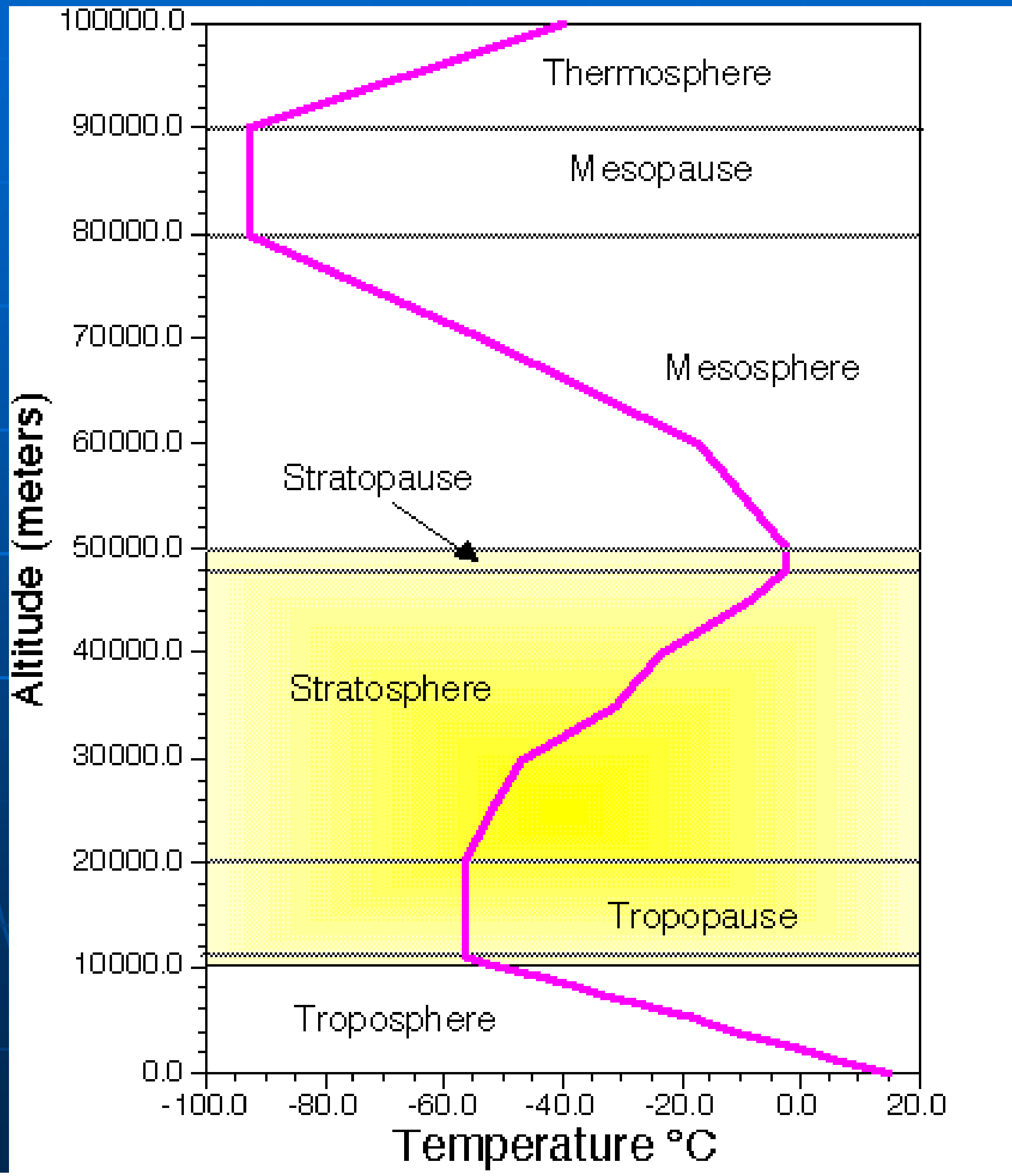

Proportional volume of gases composing dry air.
Nitrogen and oxygen obviously dominate.

The COMET Program

# PRINCIPLE PROPERTIES OF THE ATMOSPHERE

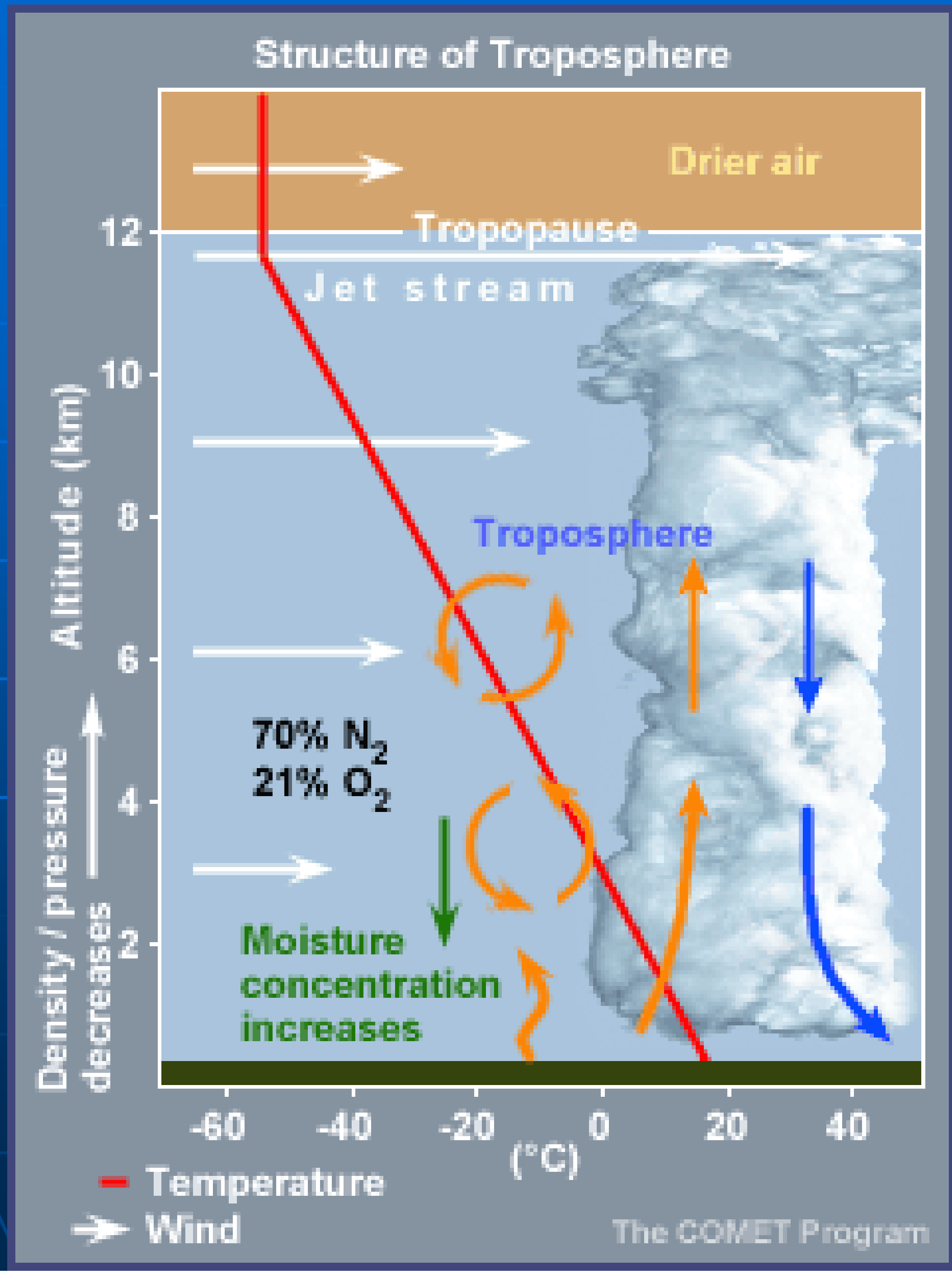
- mobility
- expansion (temperature decreases)
- compression (temperature increases)

# LAYERS OF THE ATMOSPHERE



# TROPOSPHERE

- average depth - 11 km (varies 8 km at poles to 17 km at equator
- known as weather layer due to the presence of water vapour and large-scale vertical currents
- temperature decreases with height



Structure of Troposphere
Drier air
Tropopause
Jet stream
Troposphere
70% $N_2$
21% $O_2$
Moisture concentration increases
Altitude (km)
Density / pressure decreases
12
10
8
6
4
2
-60
-40
-20
0
20
40
(°C)
Temperature
Wind
The COMET Program

# STRATOSPHERE

- Layer above troposphere – top is about 45,000 metres
- Temperature remains constant then increases with height – ozone absorption
- Nacreous clouds

# MESOSPHERE

- Located above the stratosphere
- Noctilucent clouds

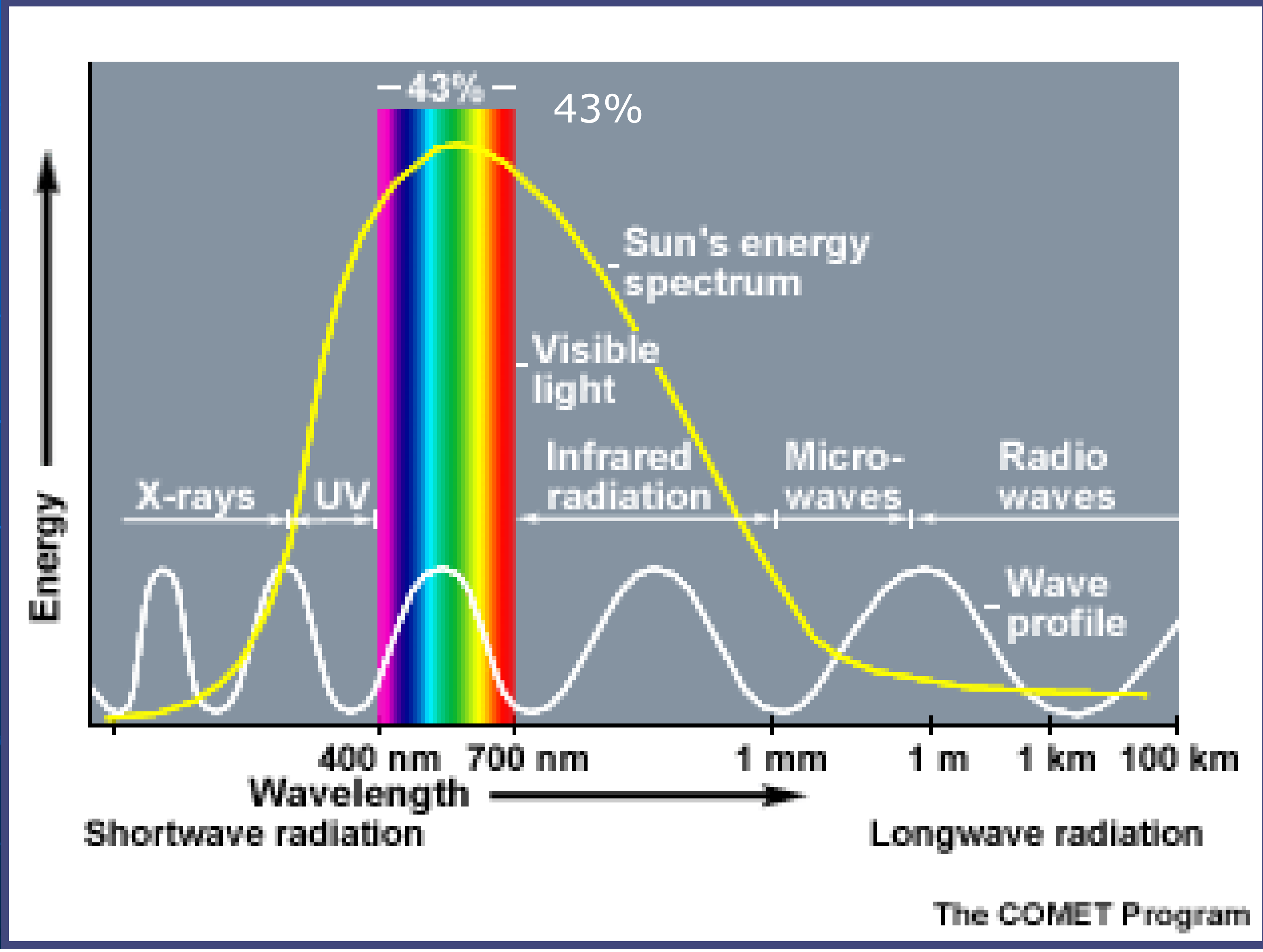
# LAYERS ABOVE

- Thermosphere – extends to about 600+ km above surface
  Space station and shuttles operate near the top of this layer
- Exosphere - atmospheric gases escape into space
  Upper boundary is around 10,000 km

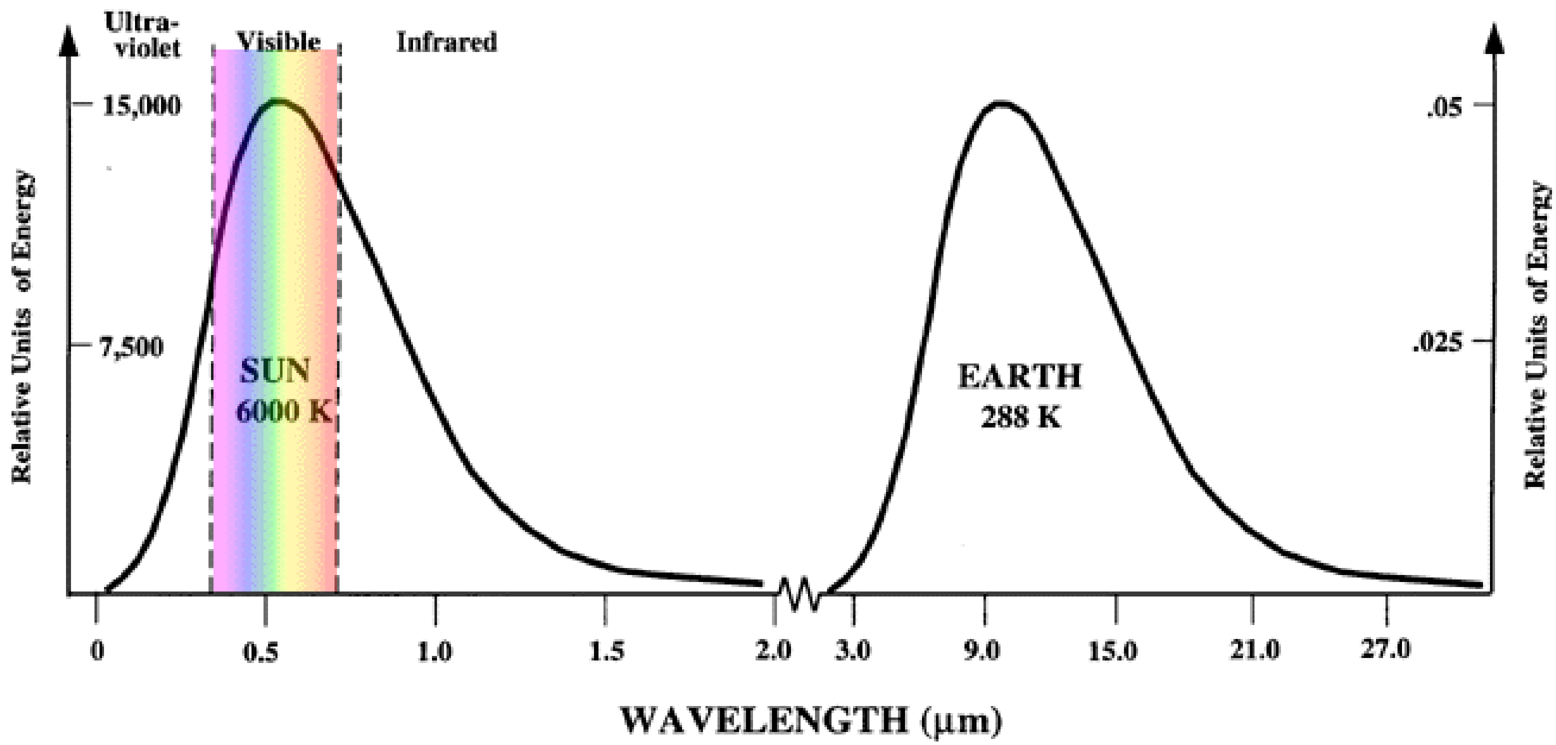
# HEATING BY RADIATION

- all matter radiates energy in the form of electromagnetic waves
- the hotter the substance - the greater the energy radiated and the shorter the wavelength

# SOLAR RADIATION

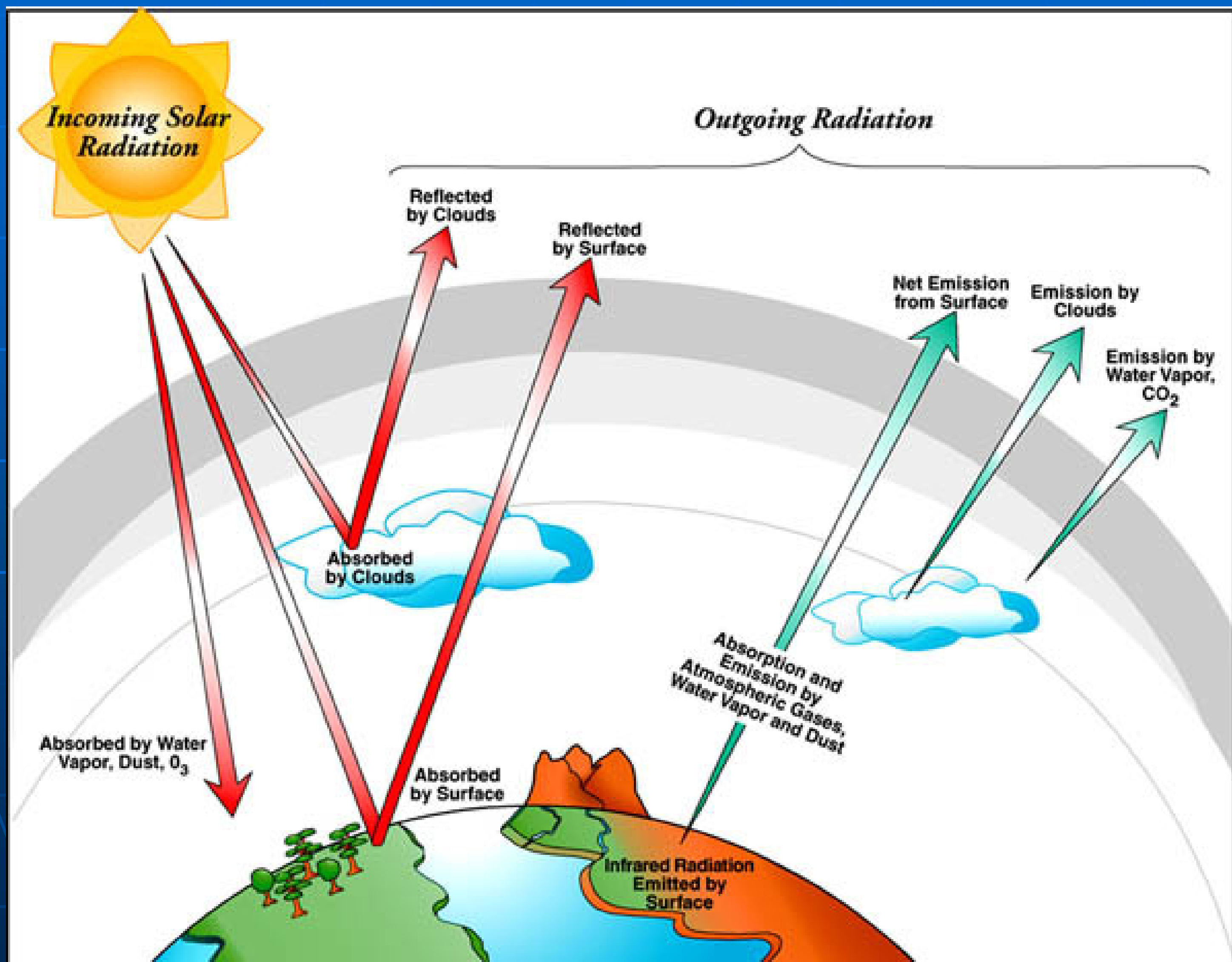


# SOLAR AND TERRESTRIAL RADIATION




Comparison of the emission spectra of the sun and the earth. Note the huge disparity in the amount of energy emitted by the sun (left-hand scale) and the earth (right-hand scale).

# RADIATION BALANCE



# ANGLE OF INCIDENCE AND REFLECTION

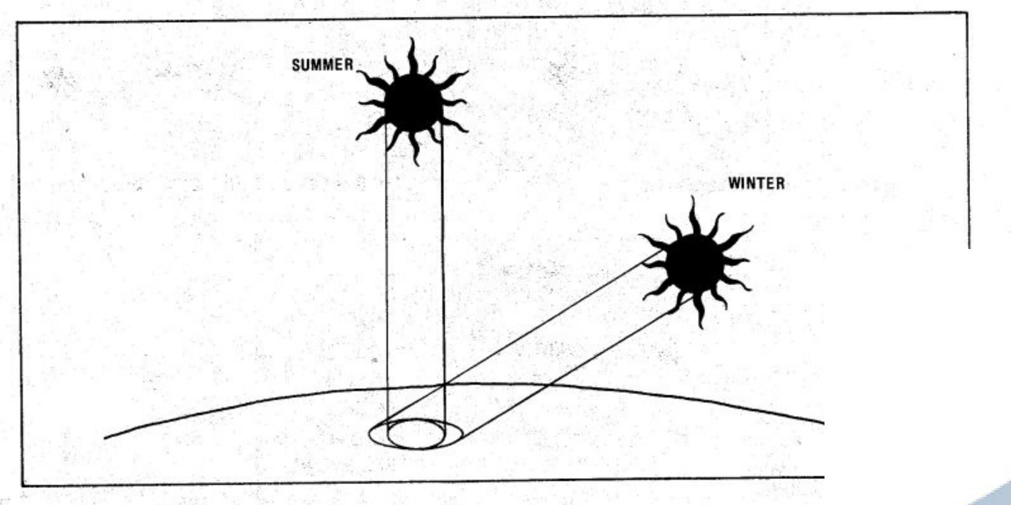
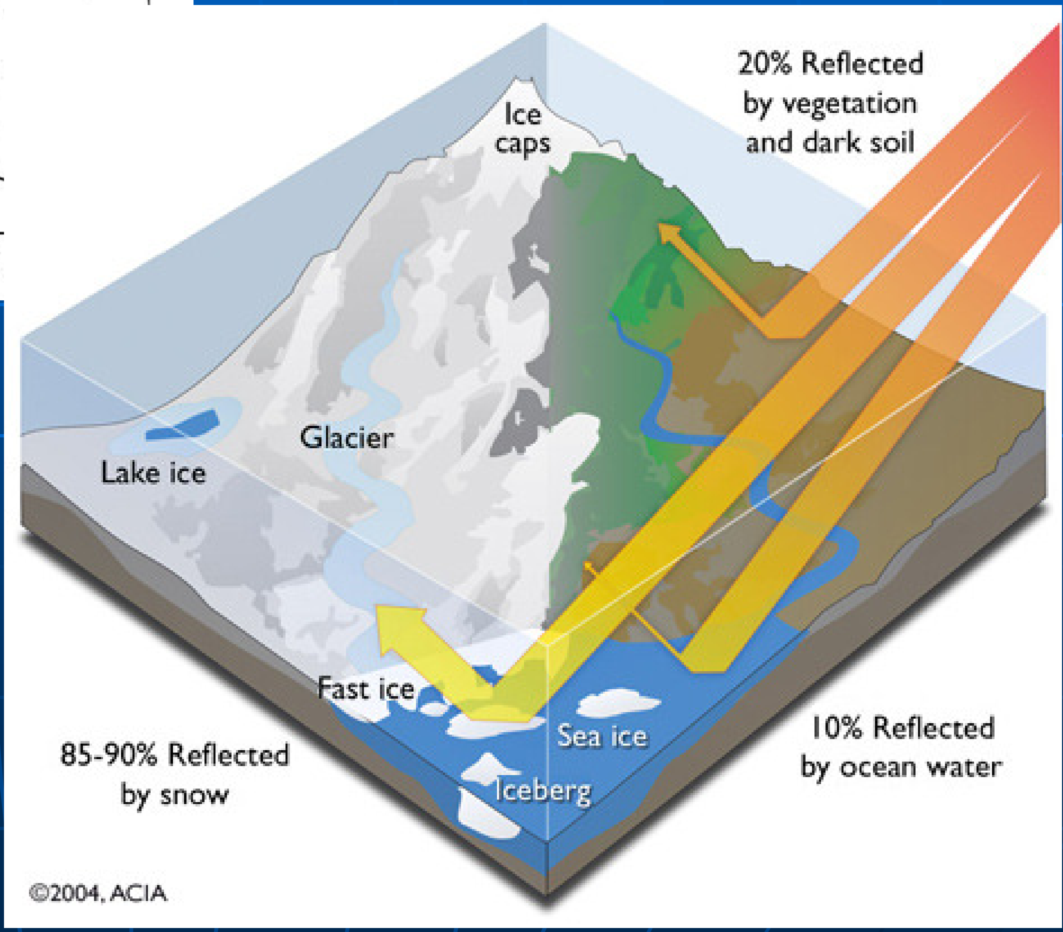
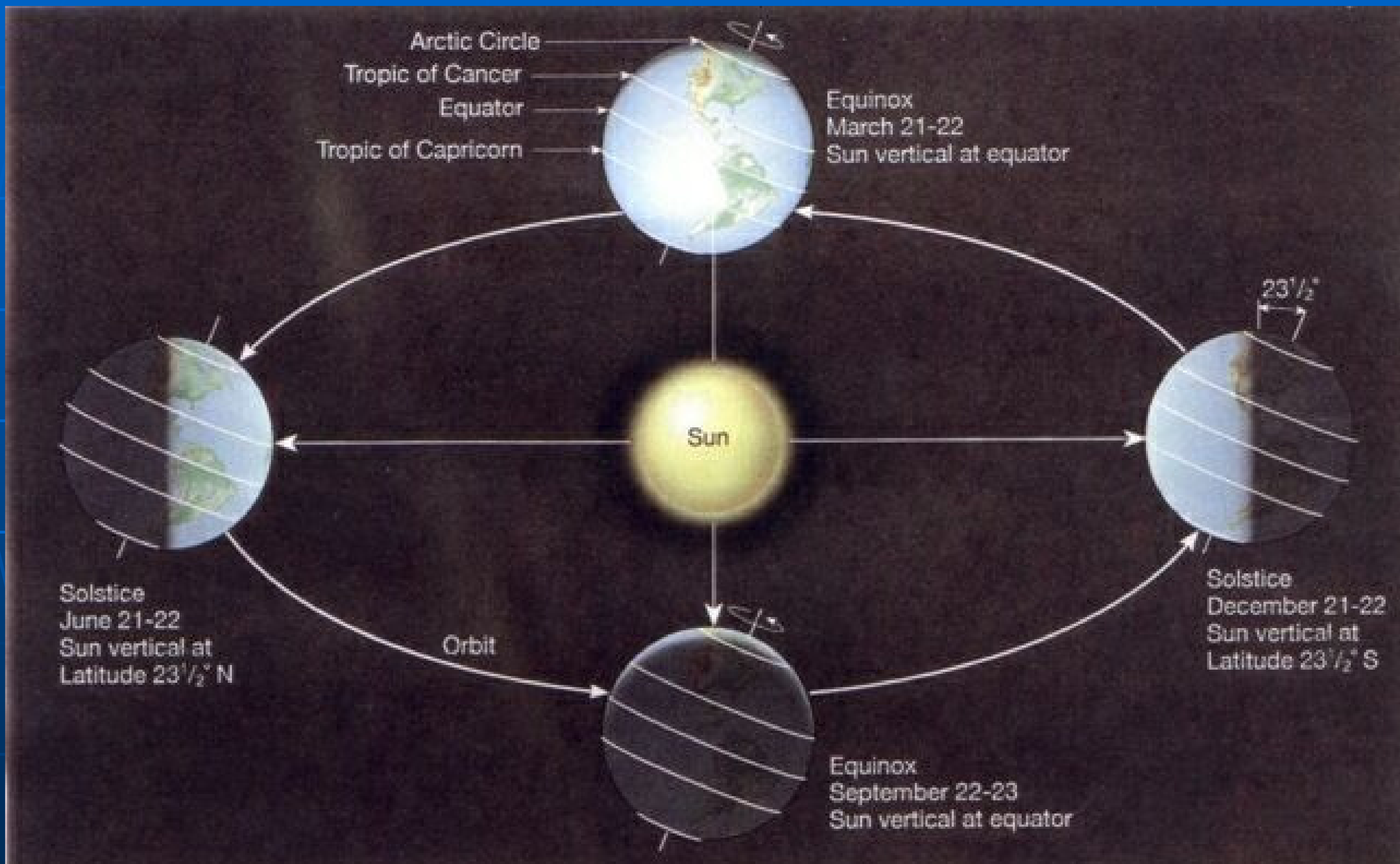



Figure 2-5 Angle of Incidence



# ASTRONOMICAL SETTING



# MARITIME EFFECTS

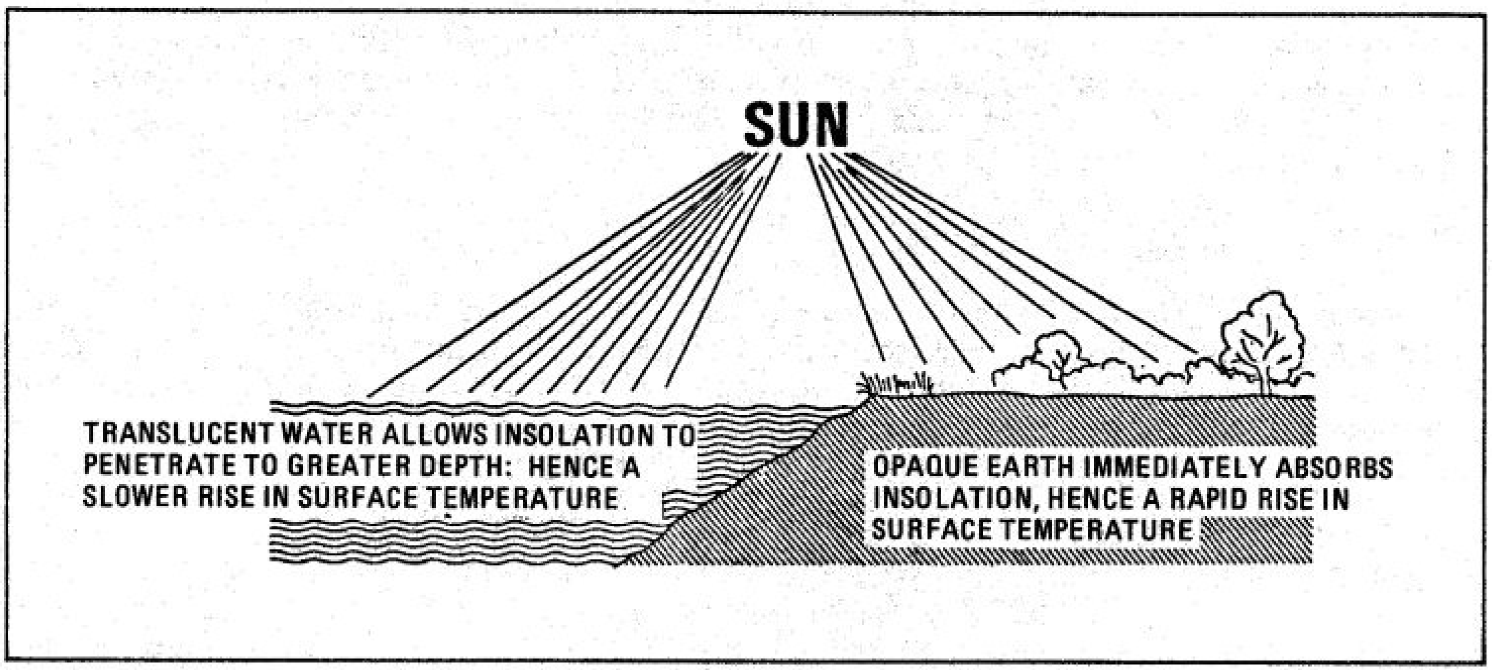



Figure 2-8 Heating of Land and Water Surfaces

**Small diurnal and seasonal temperature changes**

**Large diurnal and seasonal temperature changes**

# HEATING THROUGH CONDUCTION

- when two bodies touch, heat flows (warm to cold)
- air touching the earth's surface is heated (or cooled) by conduction
- air is a poor conductor so any heat gain tends to remain confined to a shallow surface layer

# ABSORPTION OF TERRESTRIAL RADIATION

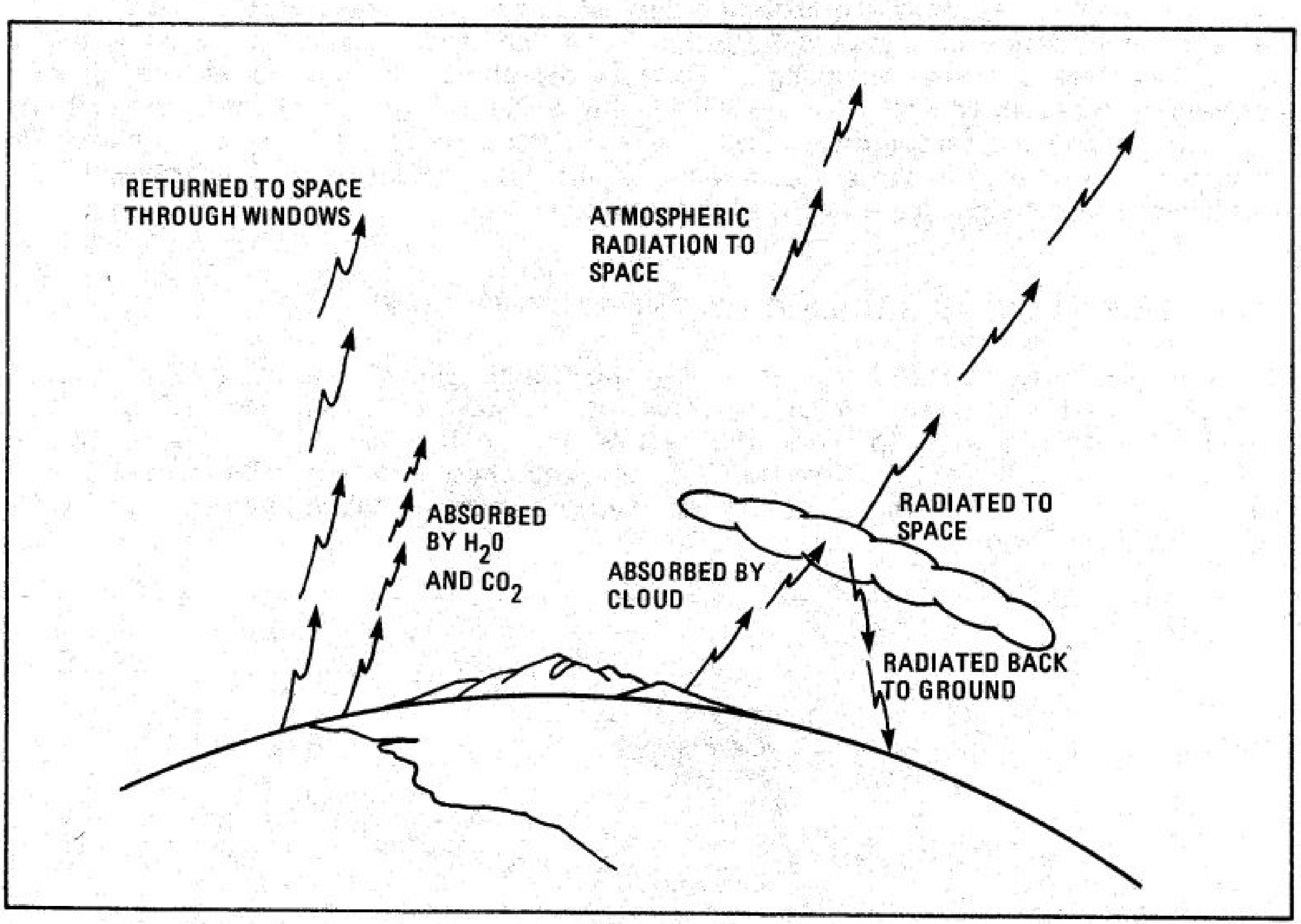
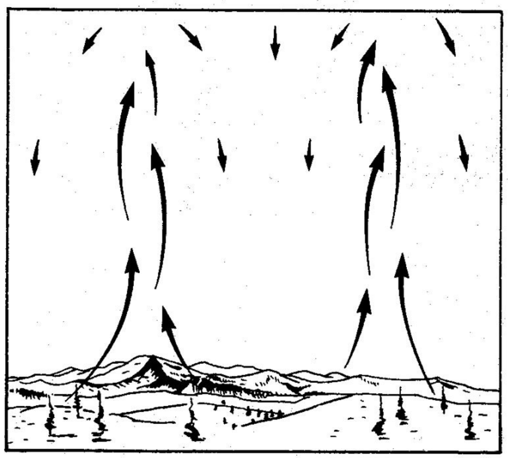



Figure 2-4 Terrestrial Radiation

# HOW IS THE TROPOSPHERE HEATED?

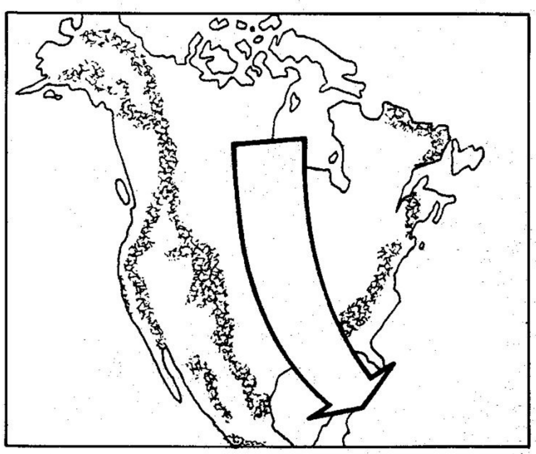
- Conduction
- Absorption of outgoing terrestrial radiation

# OTHER WAYS OF TRANSPORTING AND HEATING THE TROPOSPHERE

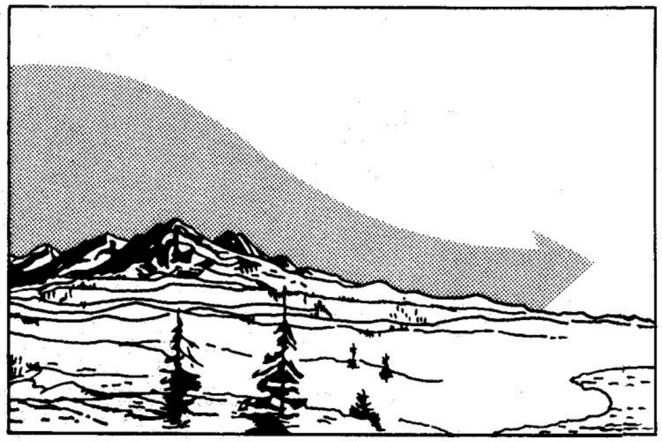


CONVECTION

TURBULENT MIXING



ADVECTION



COMPRESSION

# ATMOSPHERIC COOLING

# LAPSE RATES

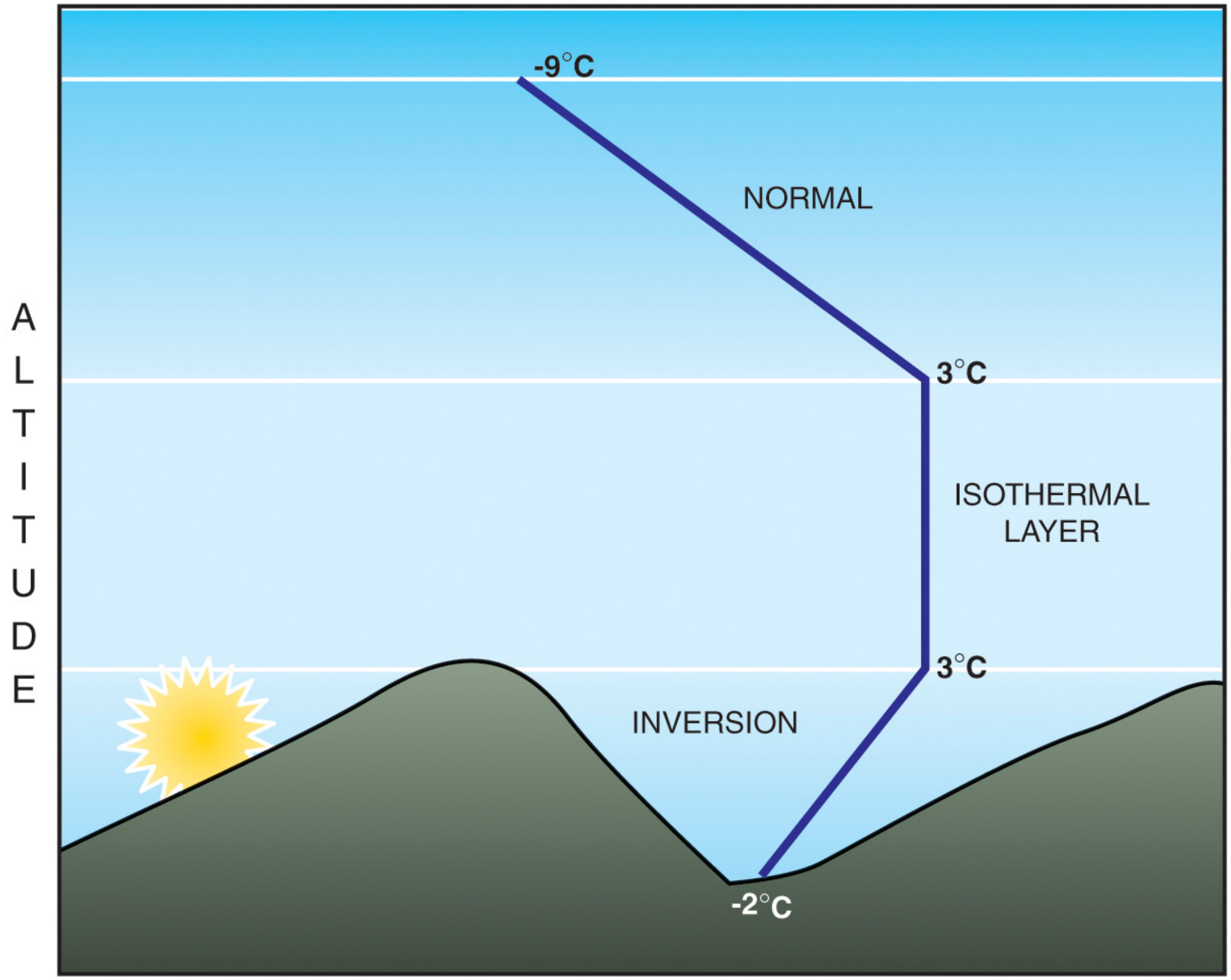
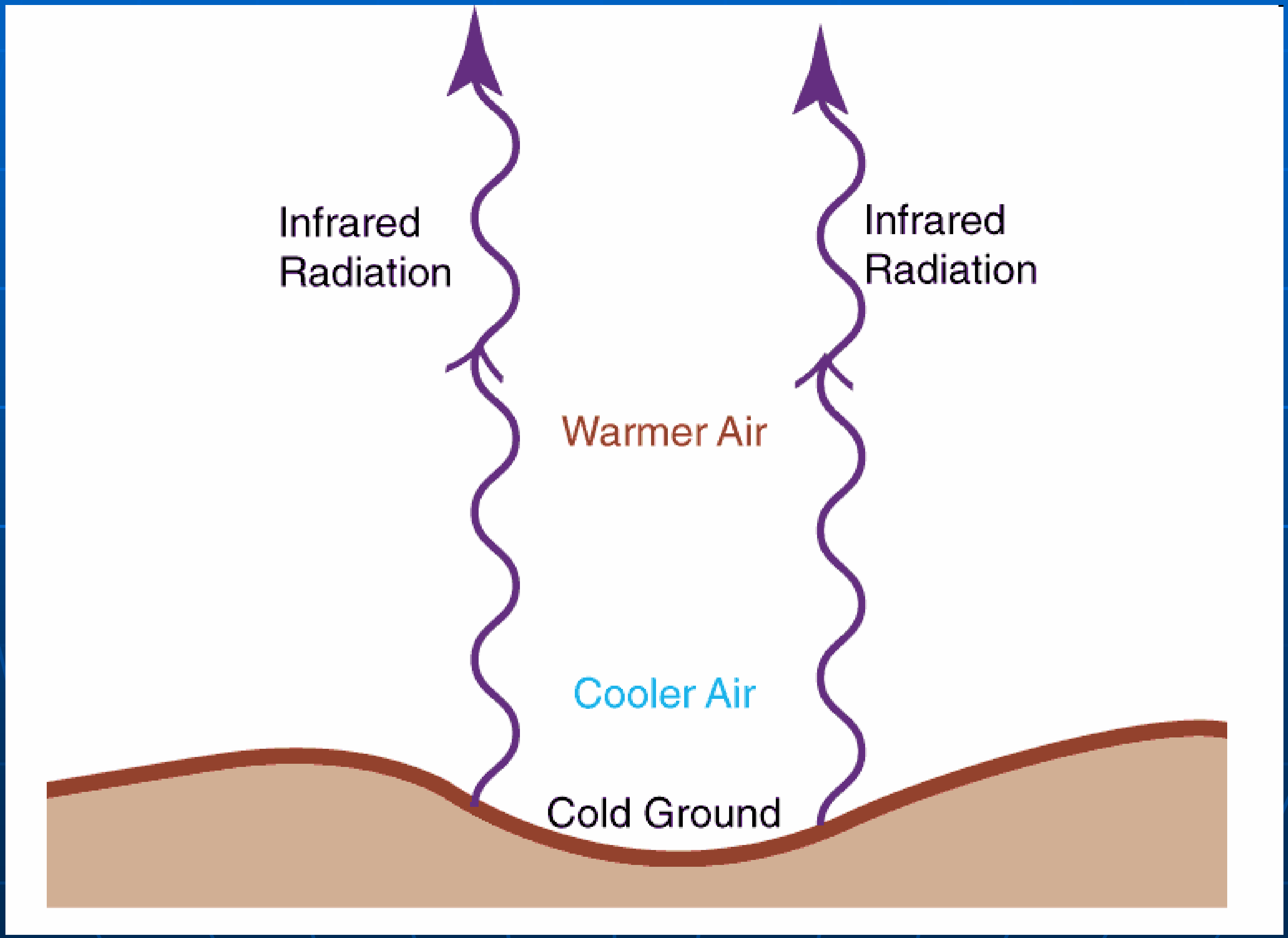



Fig. 1-7 - Different lapse rates of the atmosphere

# NOCTURNAL RADIATIONAL COOLING



# NOCTURNAL INVERSION

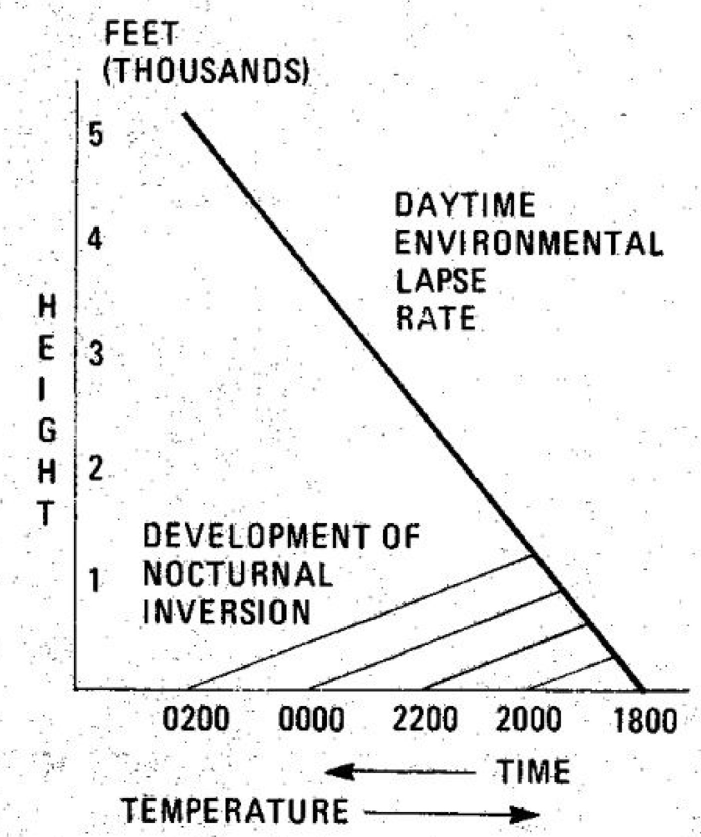
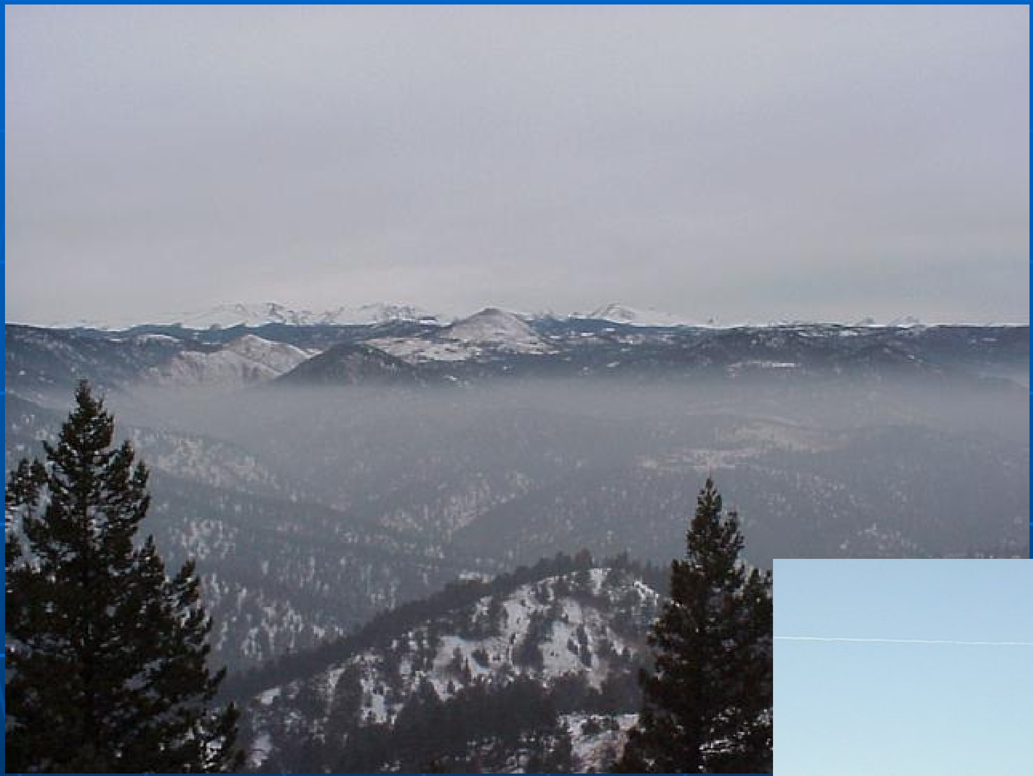



Figure 3-3 Development of a Nocturnal Inversion

# SMOKE UNDER AN INVERSION



# FACTORS AFFECTING COOLING

- Wind
- Cloud
- Topography
- Maritime

# WIND EFFECT

Wind weakens the inversion due to vertical mixing

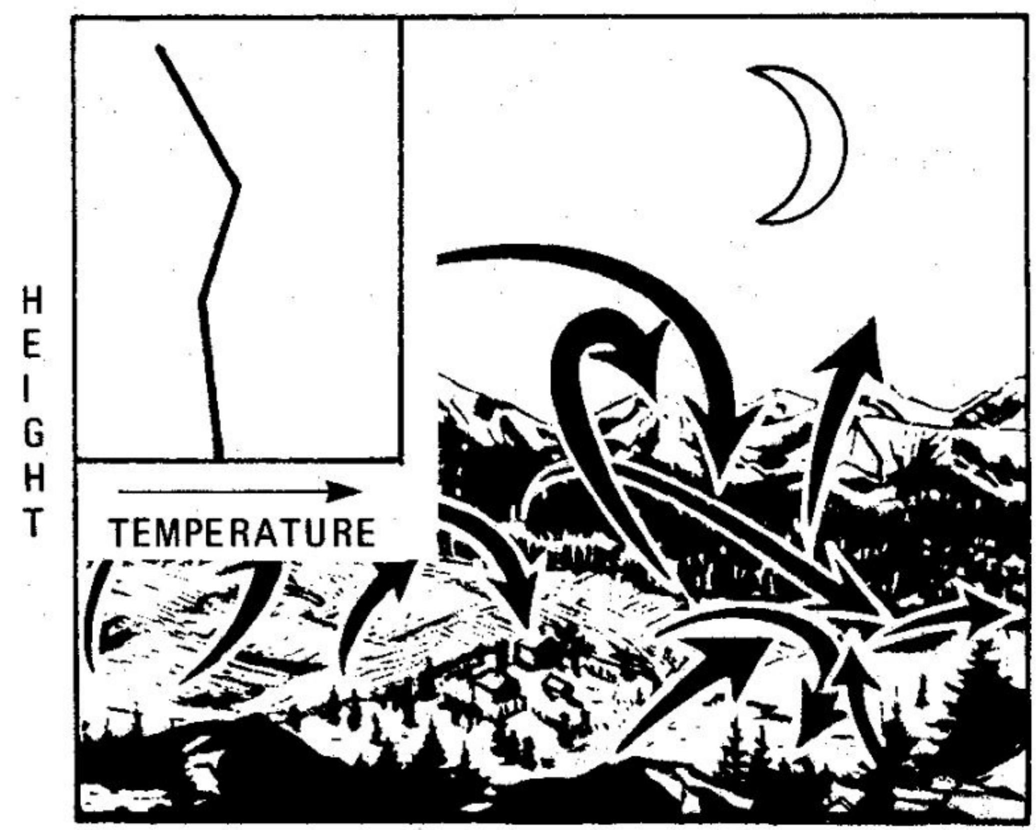
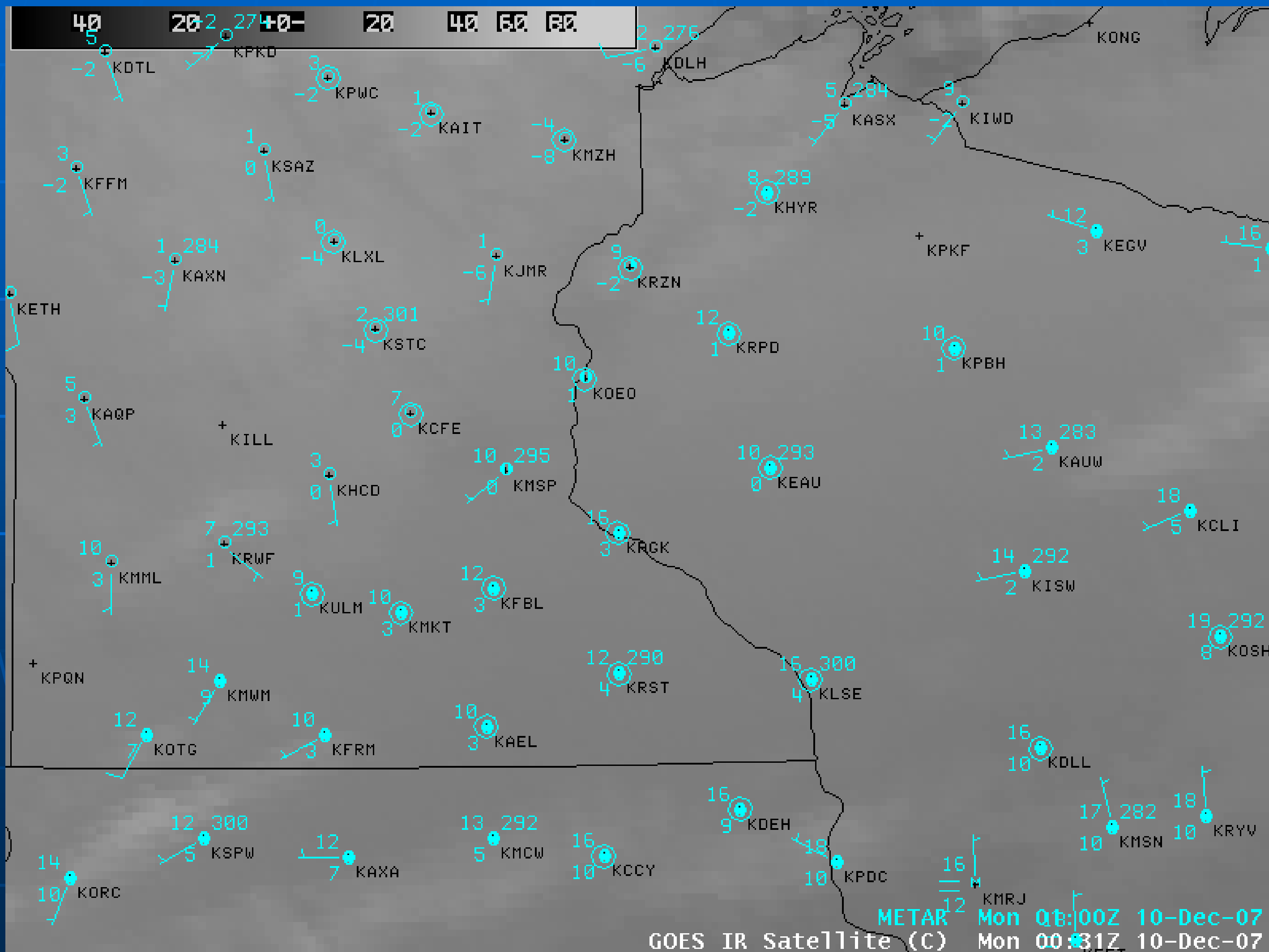



Figure 3-5 Effect of Wind

# CLOUD EFFECT
# BLACK STRATUS



# TOPOGRAPHICAL EFFECT

Cold air drains causing the inversion to strengthen and deepen

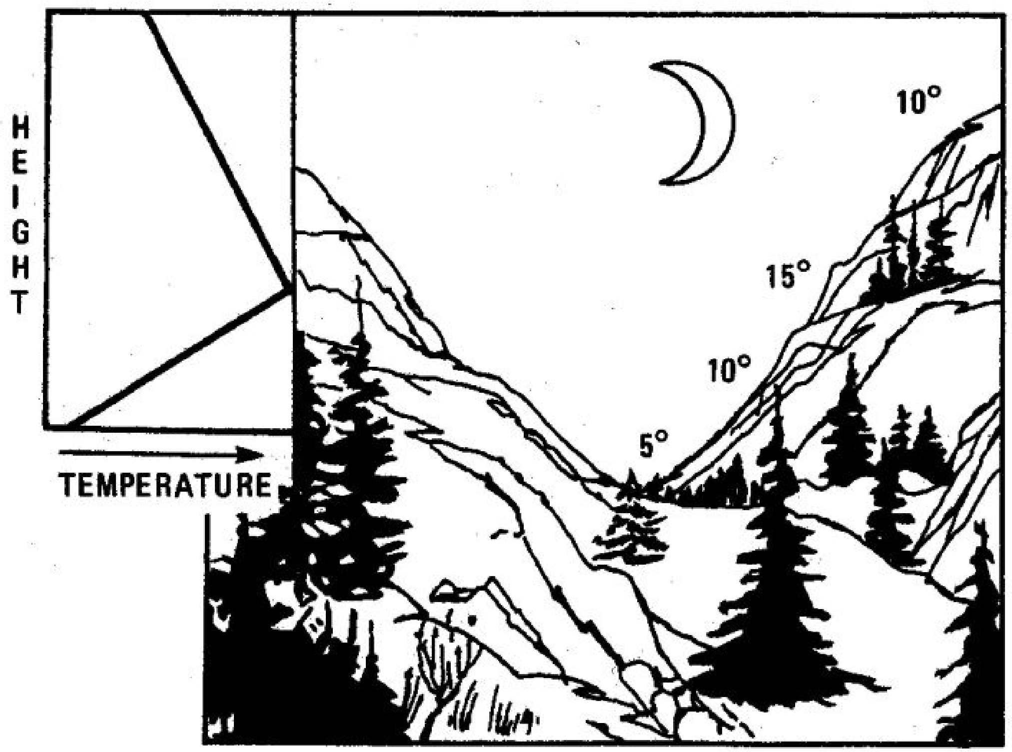
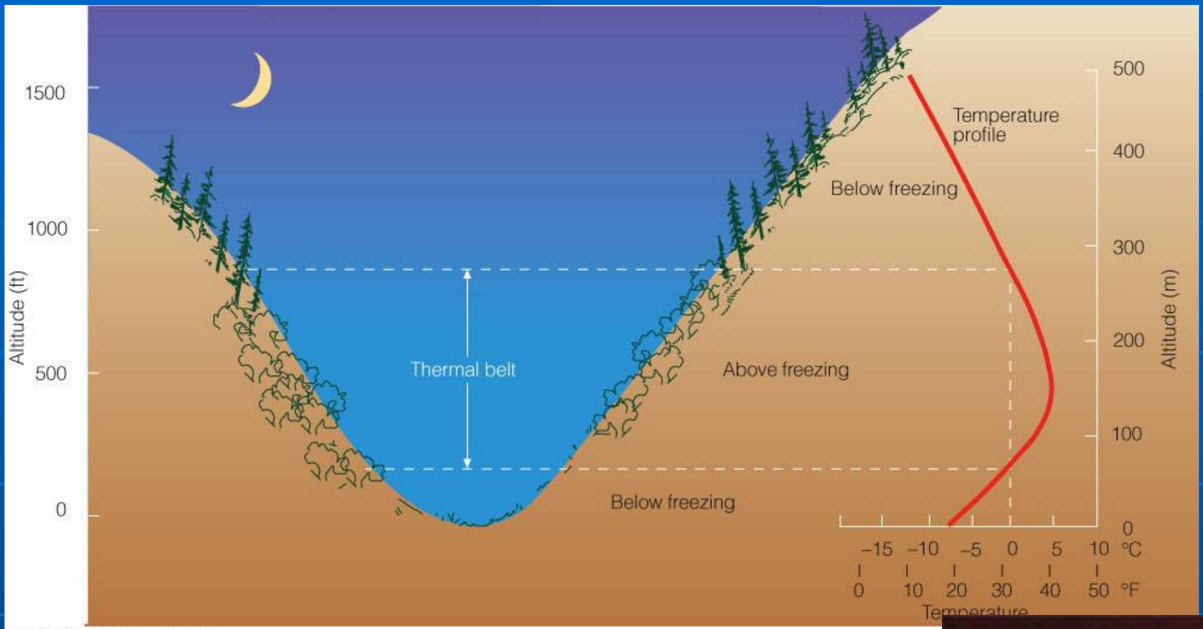



Figure 3-7 Drainage Effect

Top of the inversion

# THERMAL BELT






# MARITIME EFFECT

Inversion is weakened or even non-existent over water due to convective mixing

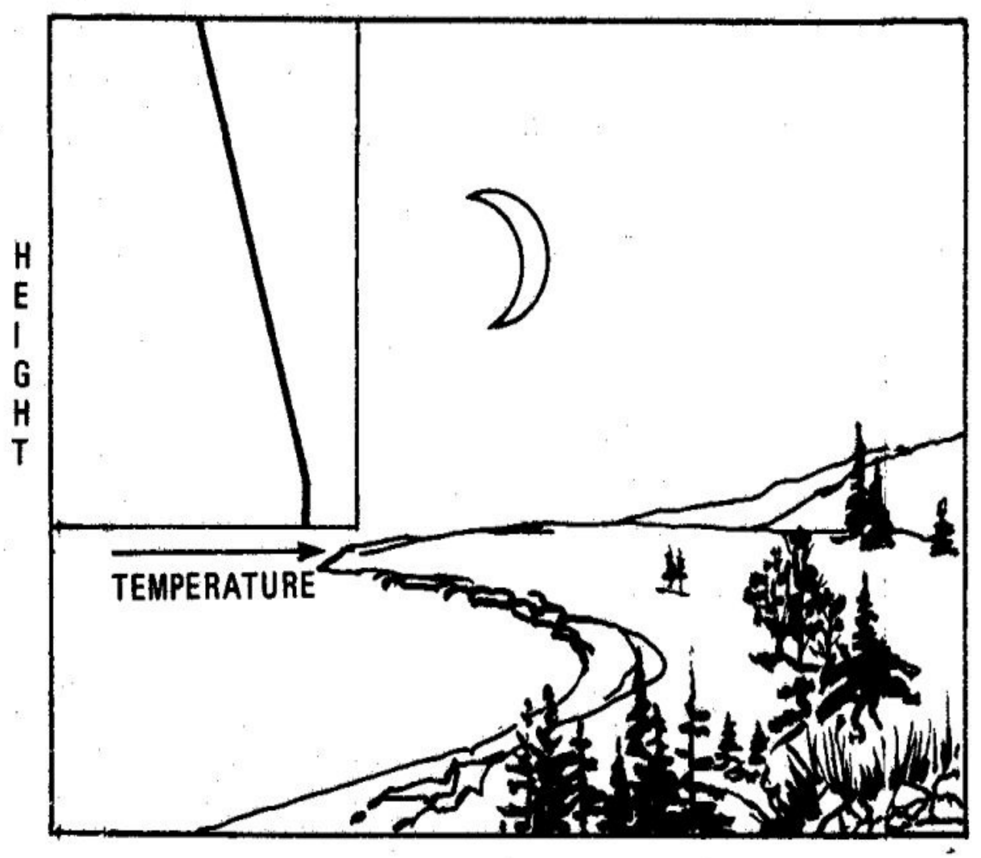
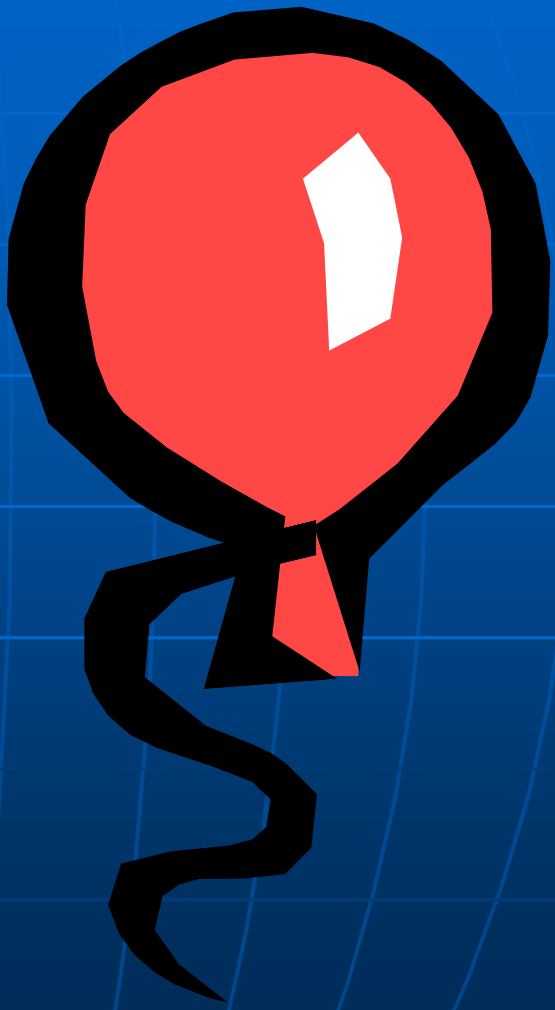



Figure 3-8 Maritime Effect

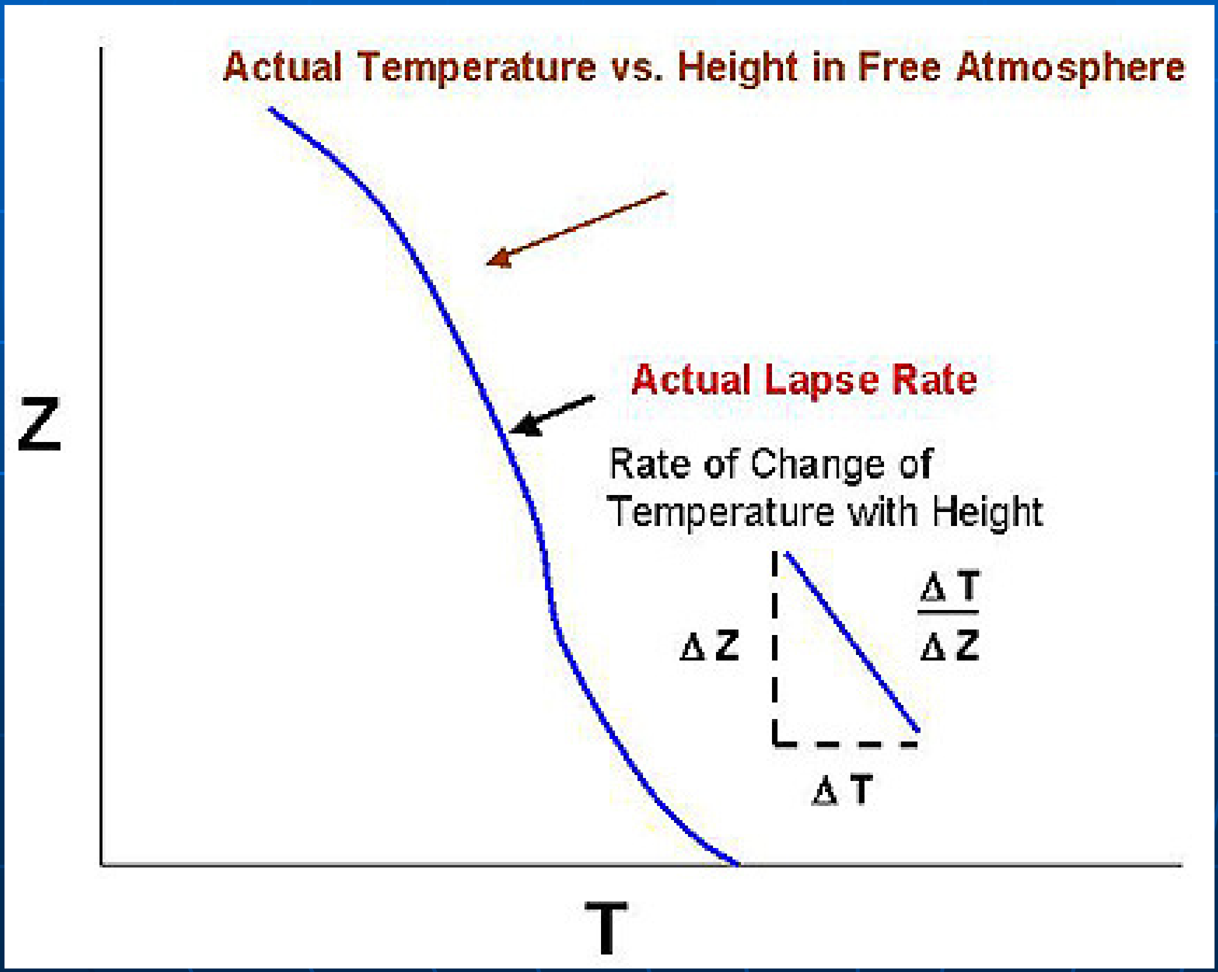
# ADIABATIC PROCESSES

- ‘Sealed bubble’ where heat is neither added or removed
- Temperature change is a result of expansion or contraction only



# ENVIRONMENTAL LAPSE RATE (ELR)

- The actual vertical temperature curve




The ELR is changes in time

# ADIABATIC LAPSE RATES

- Dry Adiabatic Lapse Rate (DALR)
  - non–saturated air
  - 3°C/1000 ft (10°C/1000 m)

- Saturated Adiabatic Lapse Rate (SALR)
  - Saturated air
  - 1.5°C/1000 ft (6°C/1000 m)

# VERTICAL MOTION OF DRY AIR

- Dry air means 'air that is not saturated'

- Ascent – air will cool at the DALR
- Descent – air will warm at the DALR

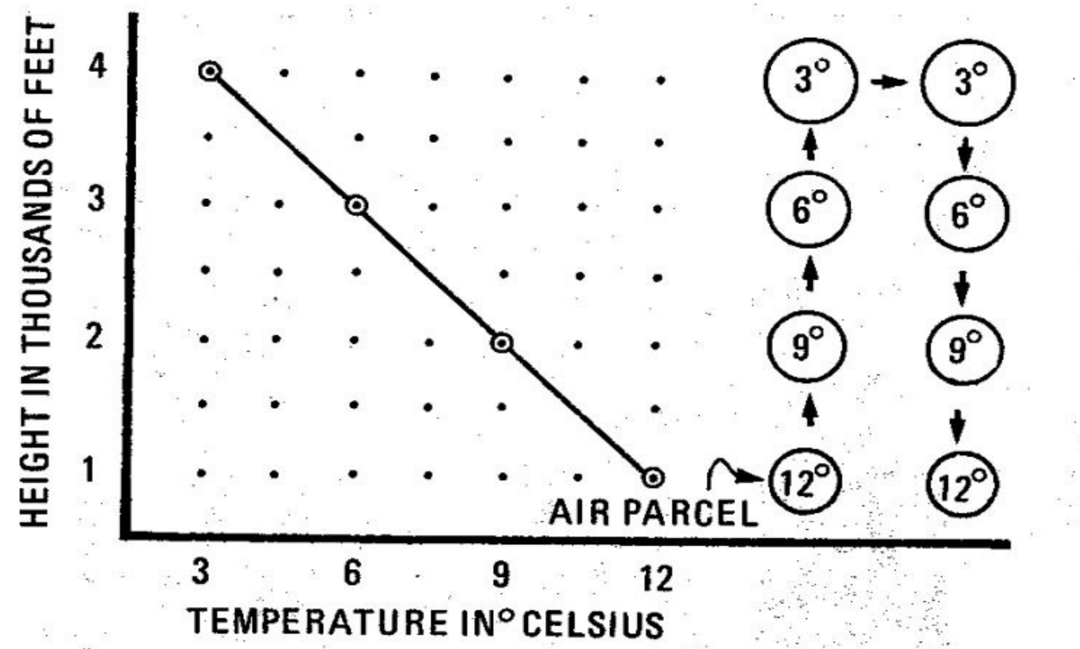



Figure 3-10 Dry Adiabatic Lapse Rate

# VERTICAL MOTION OF MOIST AIR

- Moist air means 'air that is saturated'
- Ascent – air will cool at the SALR
- Descent – air will warm at the DALR

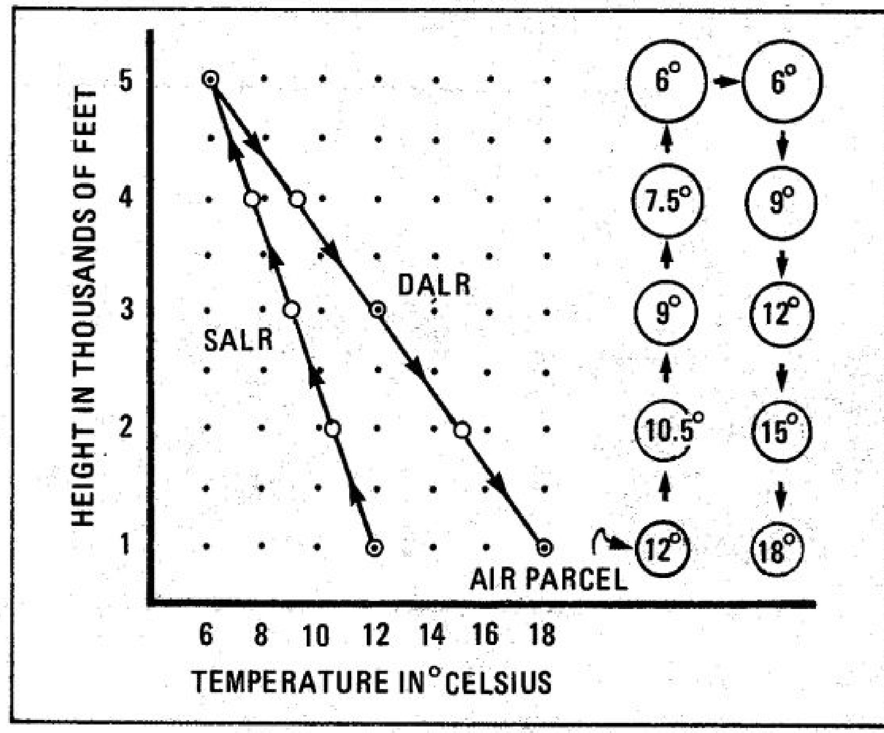



Figure 3-12 Ascending and Descending Moist Air

# REAL LIFE

- In real life both the ‘dry’ and ‘moist’ ascent needs to be taken into consideration!

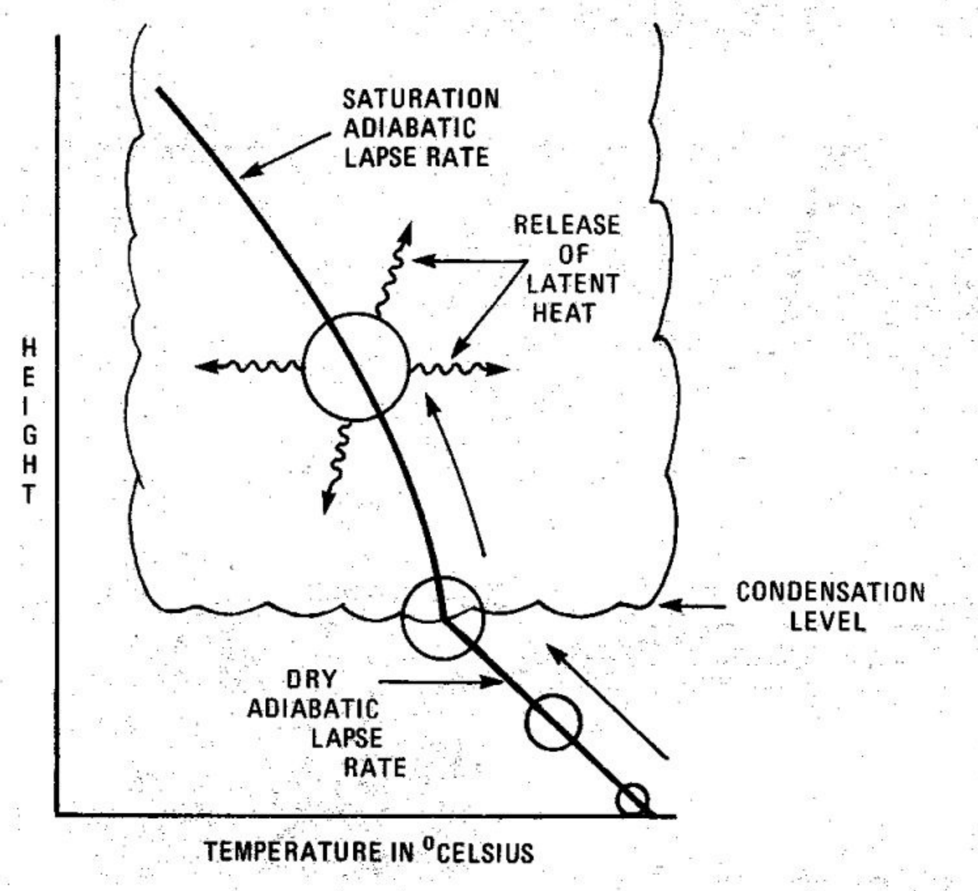
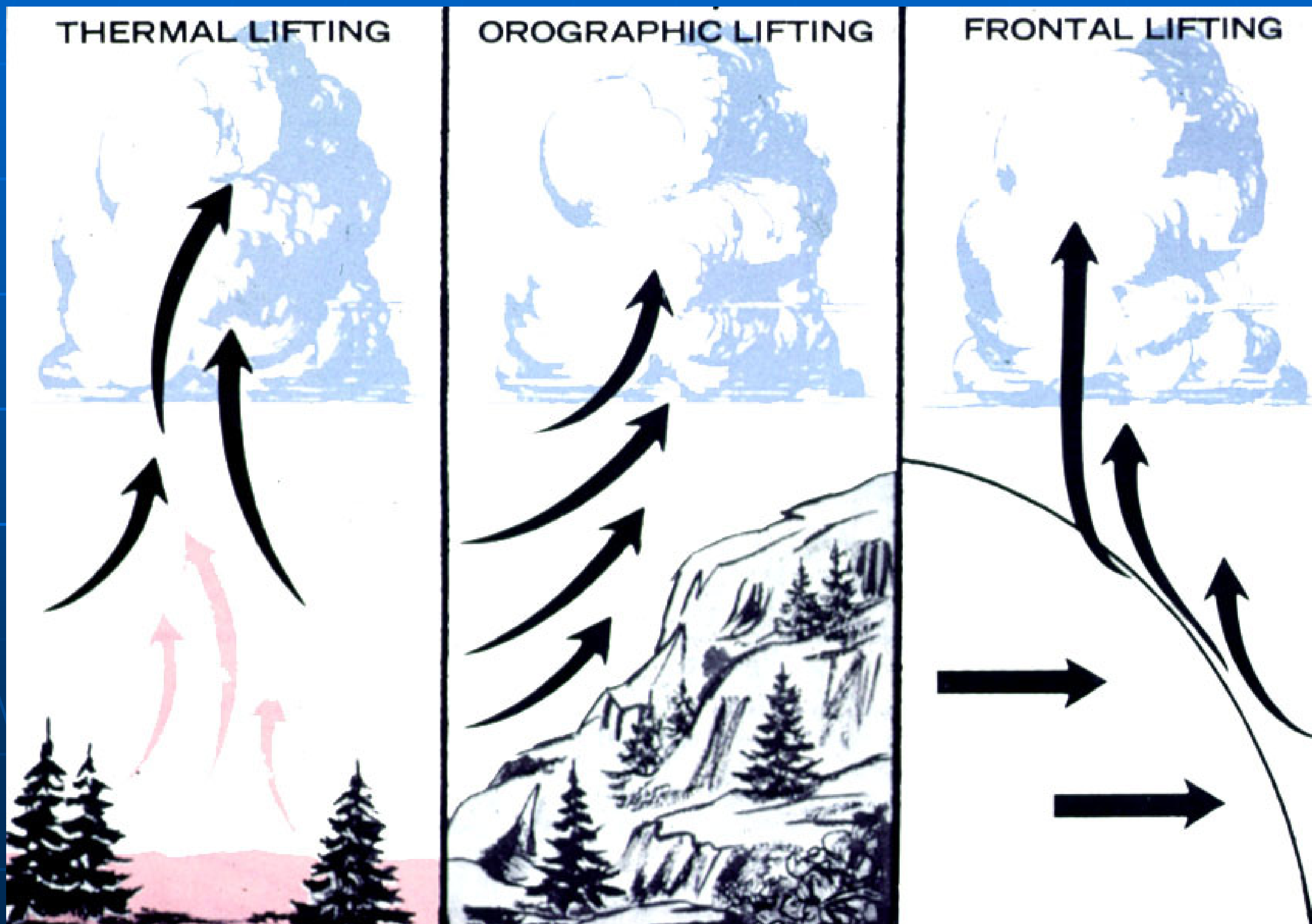



Figure 3-11 Adiabatic Lapse Rate (SALR)

# TYPES OF ATMOSPHERIC COOLING

- Expansion cooling
  - Orographic and upslope lift
  - Mechanical turbulence
  - Convection
  - Convergence
  - Large-scale lift
- Other ways
  - Evaporation
  - Advection

# OROGRAPHIC, CONVECTIVE AND FRONTAL LIFT



# MECHANICAL TURBULENCE

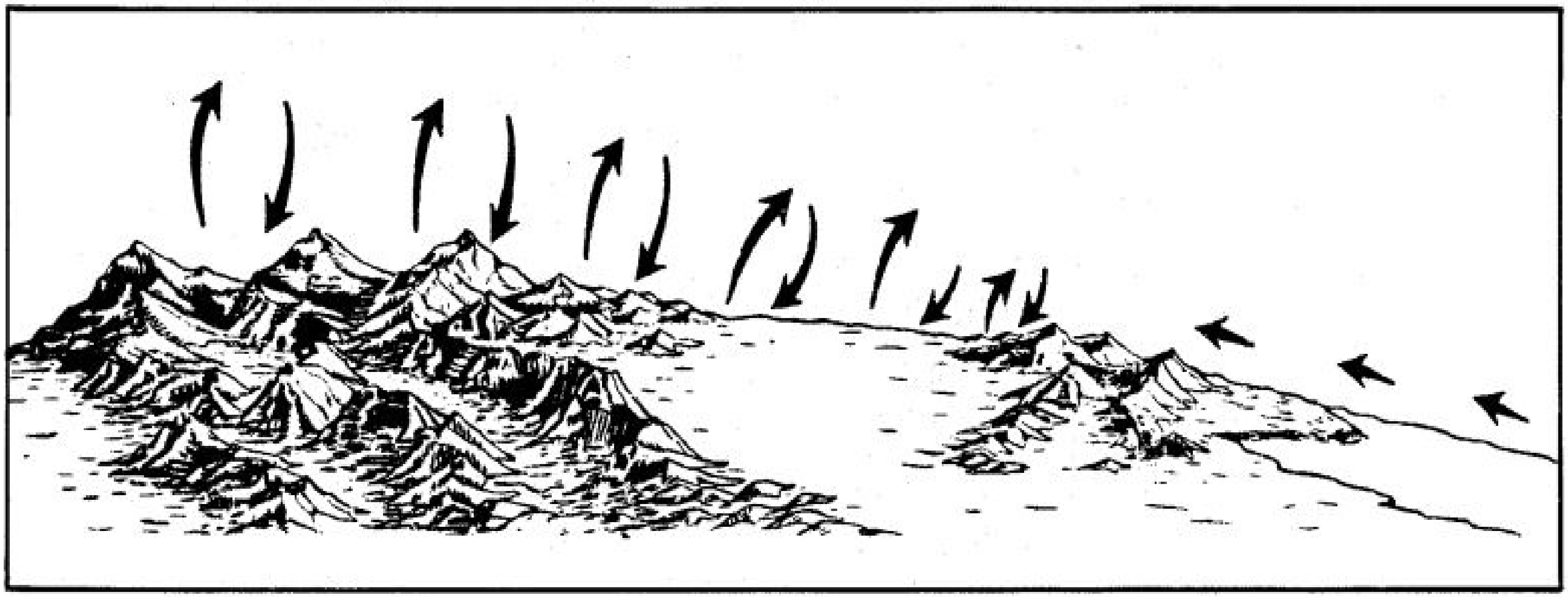
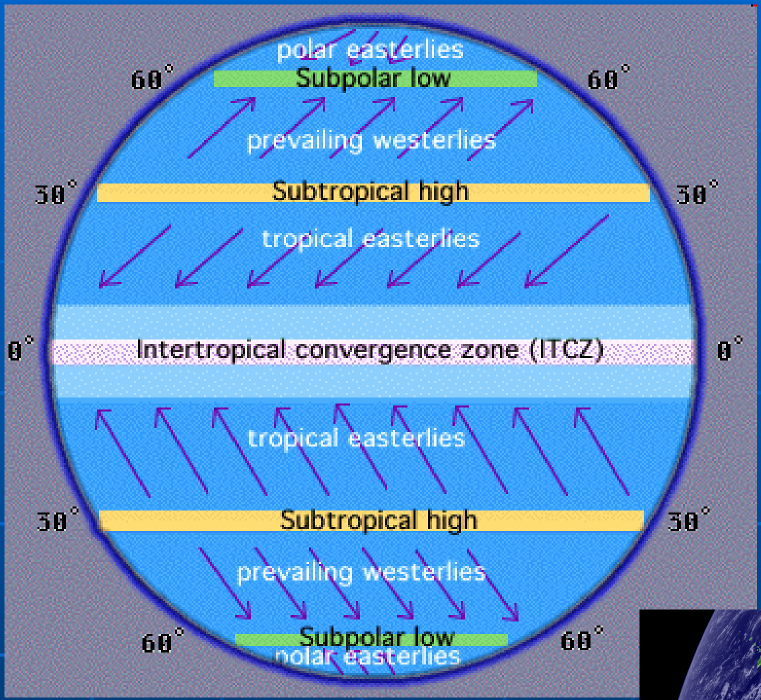
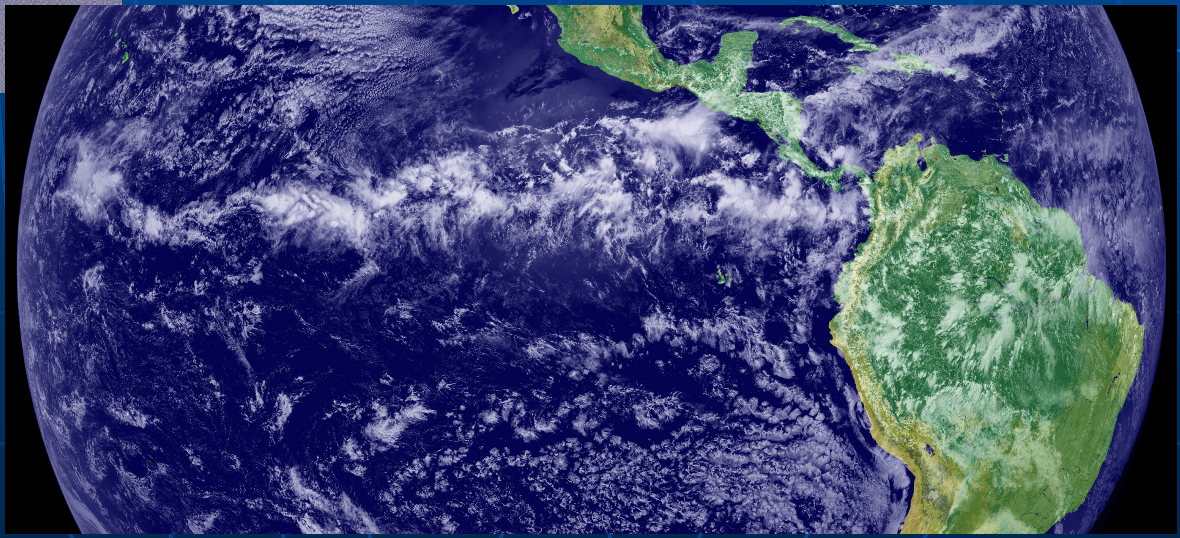


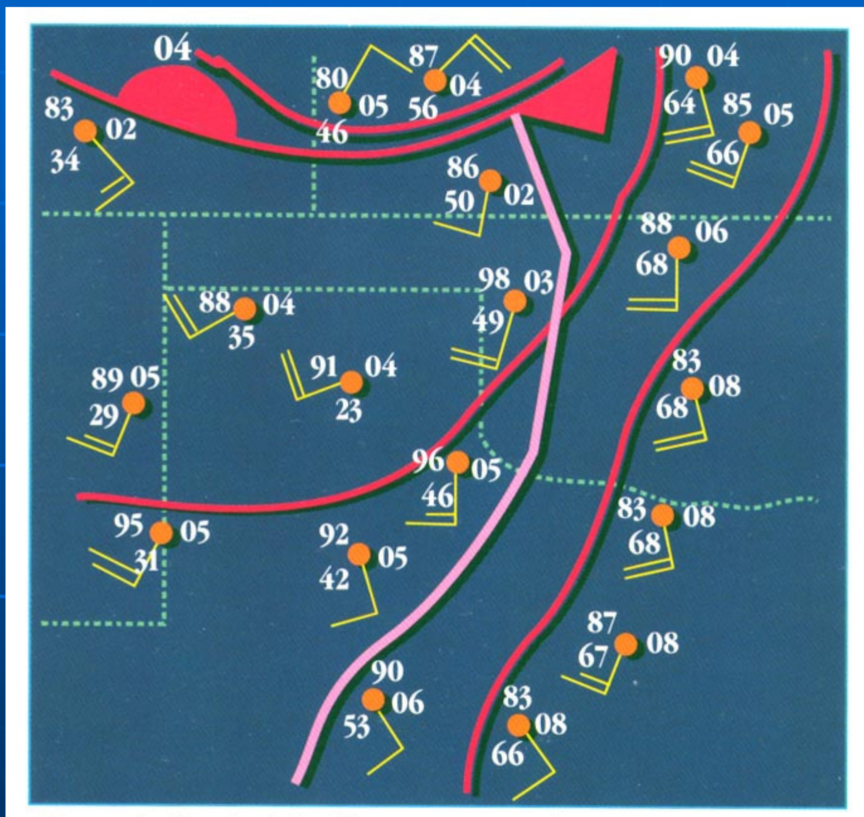
Figure 3-14 Mechanical Mixing

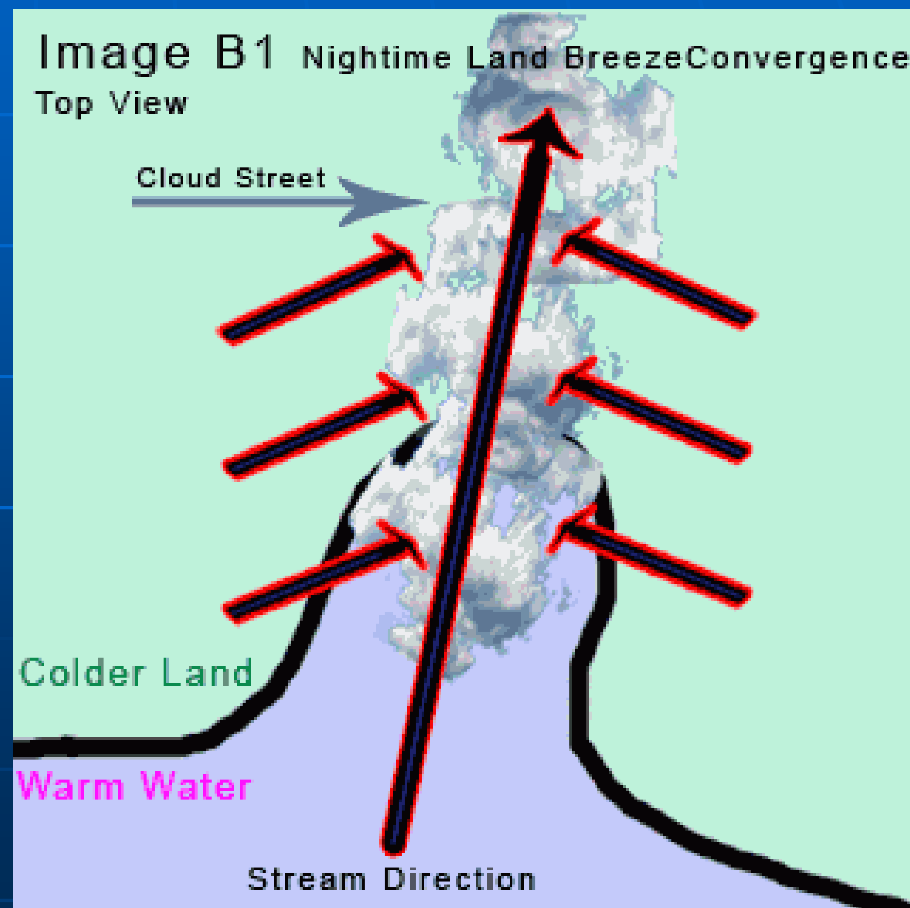
# LARGE SCALE CONVERGENCE



# SMALL-SCALE CONVERGENCE





# LARGE-SCALE ASCENT

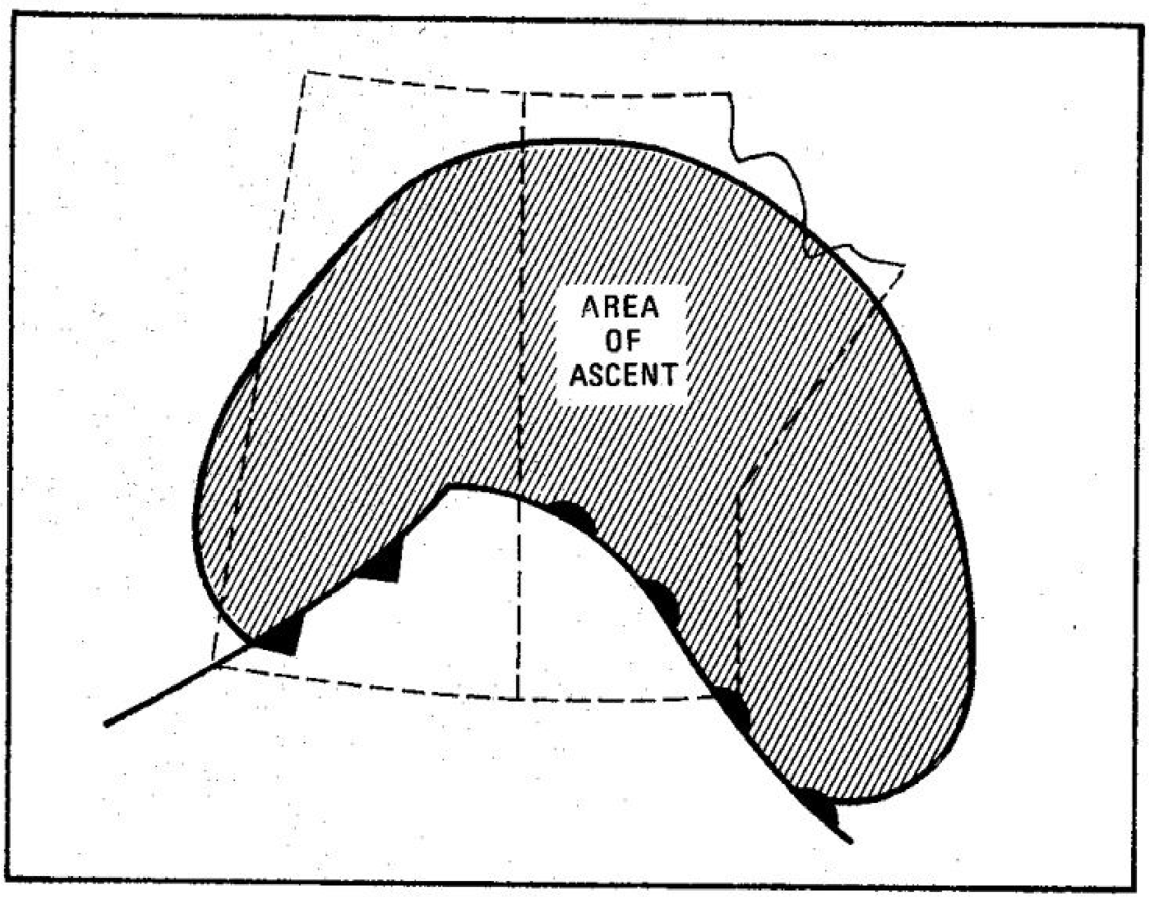
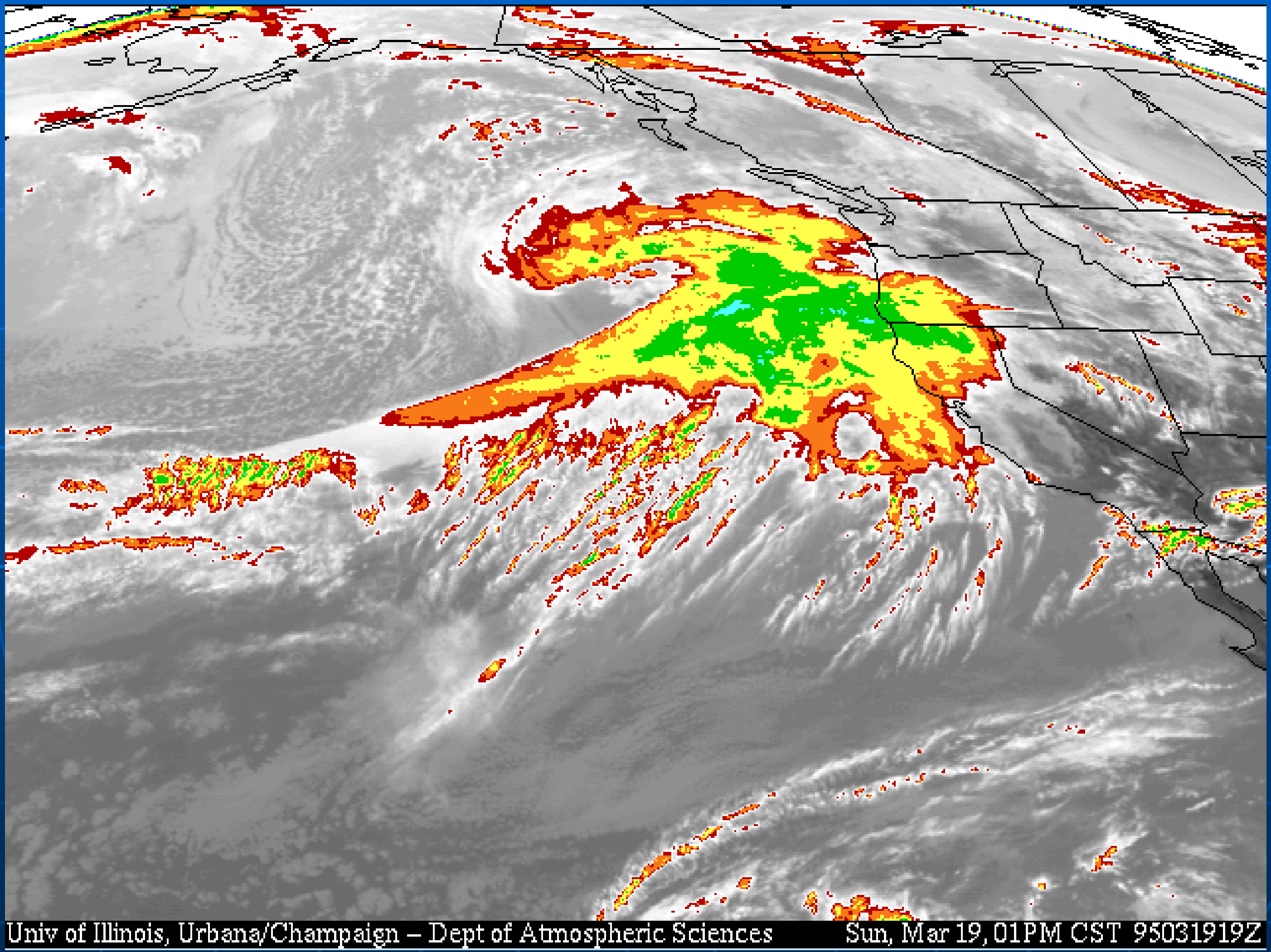



Figure 3-18 Frontal Ascent

# LARGE-SCALE ASCENT



# EVAPORATION COOLING

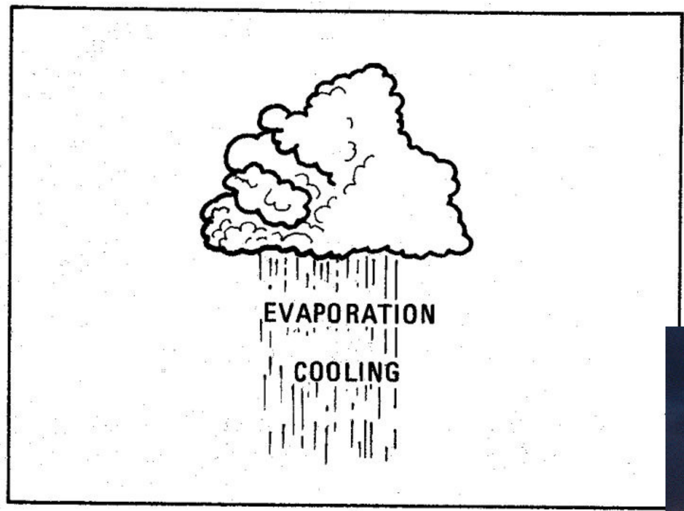



Figure 3-16 Evaporation Cooling

# WARM AIR ADVECTION

- Warm air advection – warm air moving horizontally over a cold surface

# STABILITY AND WEATHER

# TIME FOR A BREAK