Chapter 3:Observed Global Circulation

Main Objective

At the end of this chapter, students will expect to understanding the following concepts:

- **Global wind pattern and pressure system**
- **Forces to move air mass**
- **Semi-permanent cyclone and anti cyclone pressure**
- **Over view of general circulation models(GCM)**

Chapter 3:Observed Global Circulation

3.1 **Global wind pattern and Global surface pressure**

Air Movement.

Wind is the movement of air caused by differences in air pressure

The greater the difference, the faster the wind moves

Wind – horizontal movement of air horizontal movement of air

Air moves from locations of high pressure to locations of low air moves from locations of high pressure to locations of low pressure

Global Winds are grouped in to easterly(in low and high latitude) and westerly (in mid latitude) and Easterly winds in the tropics are called trade winds.

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Surface wind patterns

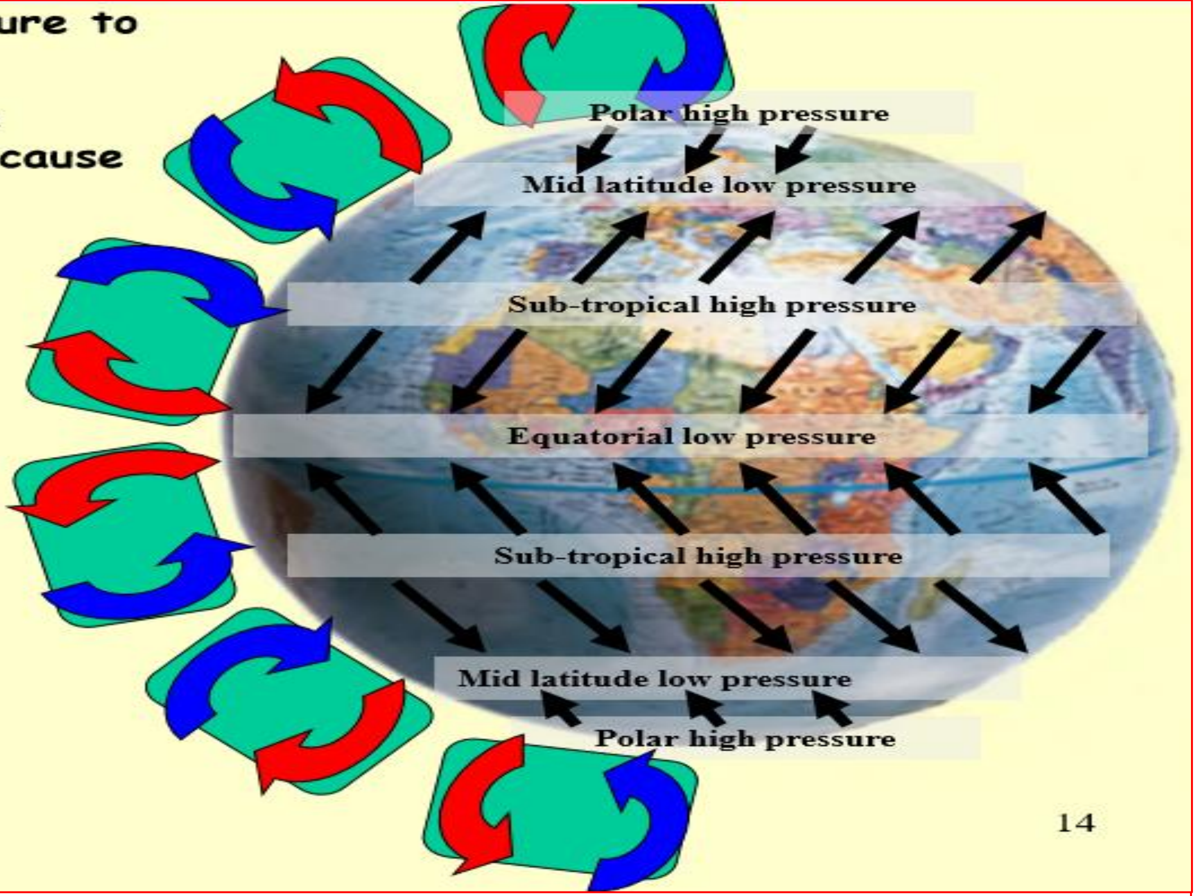
Winds always blow from high pressure to low pressure.

They are deflected because of the Coriolis Force which come about because of the rotation of the earth.

Winds in Northern Hemisphere are deflected to the right.

Winds in the southern hemisphere are deflected to the left.

These wind belts shift seasonally. (See next section)



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Trade wind

IN THE NORTHERN HEMISPHERE:

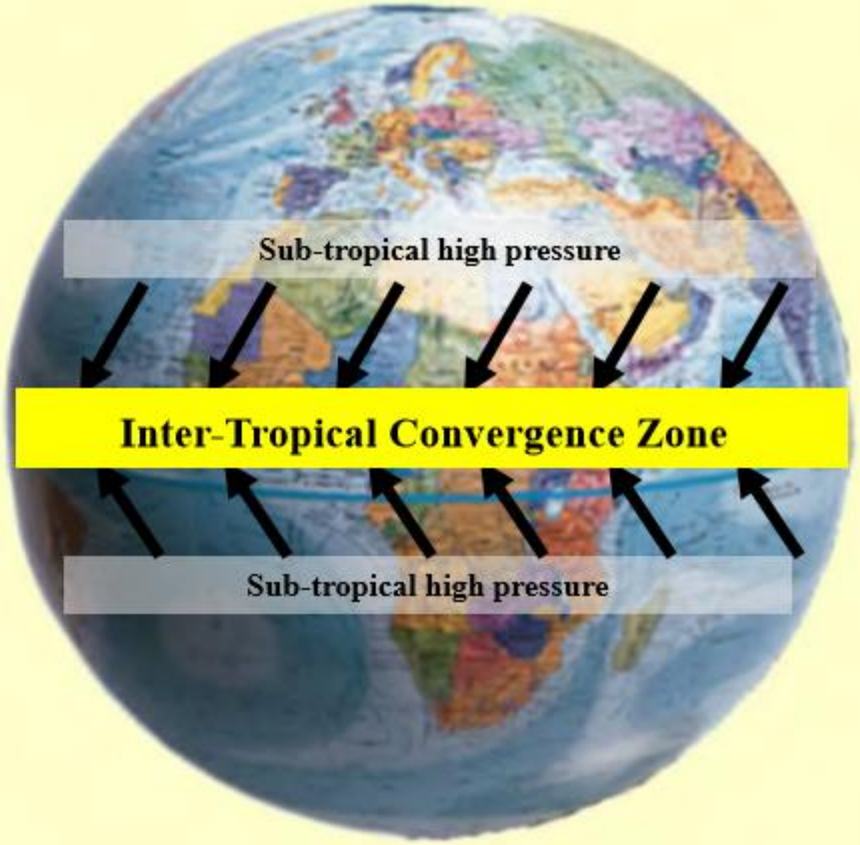
The winds that blow to the equatorial low pressure belt are called the North East Trade Winds

IN THE SOUTHERN HEMISPHERE:

The winds that blow to the equatorial low pressure belt are called the South East Trade Winds

The line along which they converge (meet) is called the INTER-TROPICAL CONVERGENCE ZONE.

This is often abbreviated to ITCZ



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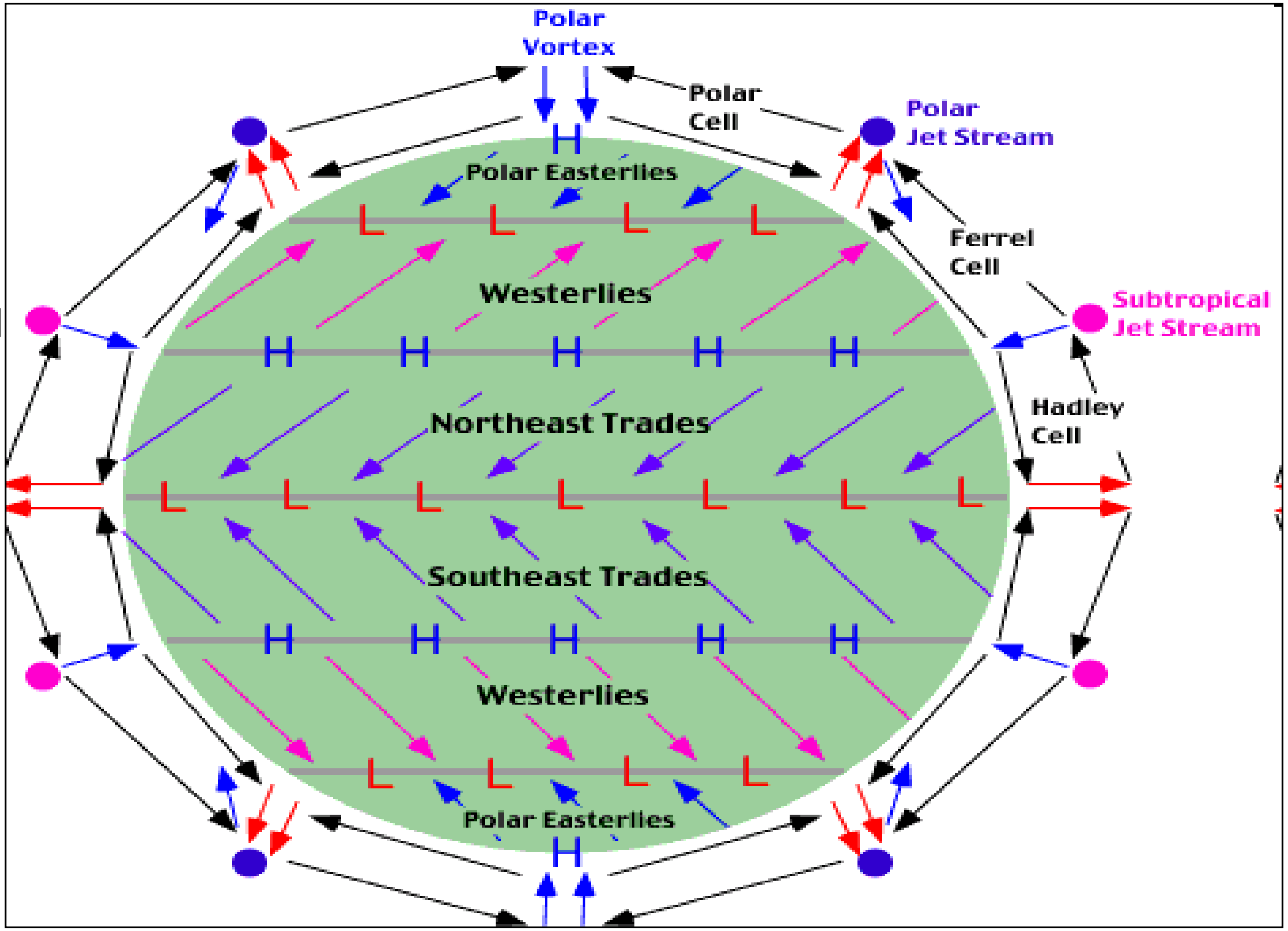
Prominent surface global wind systems include
Mid-latitude westerly winds
and the easterly Trade winds
which originate in the subtropical high pressure belt and
converge in the Inter-Tropical Convergence Zone (ITCZ)



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Winds around lows converge (come together) and circulate cyclonically — counterclockwise in the N. Hemisphere, and clockwise in the S. Hemisphere.

Winds around highs diverge (spread out) and rotate anticy clonically — clockwise in the N. Hemisphere, and counterclockwise in the S. Hemisphere.

The cyclones are regions of bad weather (clouds, rain, high humidity, strong winds) and fronts.

The anticyclones are regions of good weather (clear skies or fair-weather clouds, no precipitation, dry air, and light winds).

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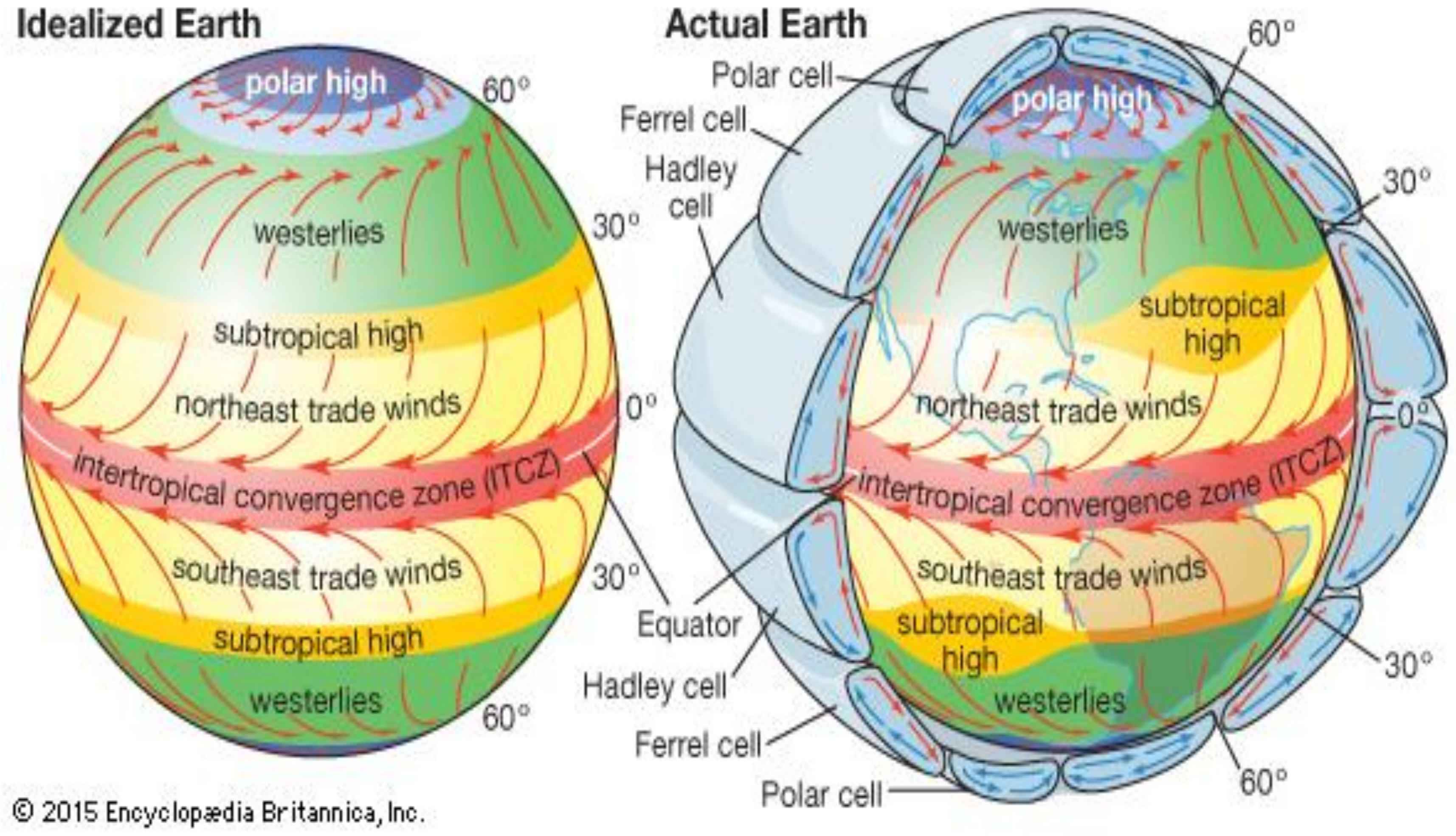
compare



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Wind is named based on the direction from which it originated

TIME SCALES TO CIRCLE THE EARTH IN THE MEAN ZONAL WIND

NAME OF WIND	TYPICAL WIND SPEED	TYPICAL TIME TO CIRCLE EARTH
TRADE WINDS NEAR SURFACE	<<10 m/s	>one month
WESTERLIES NEAR SURFACE	<10 m/s	>one month
SUBTROPICAL JET-SUMMER	10 m/s	33 days (45^{o}lat)
SUBTROPICAL JET-WINTER	40 m/s	8 days (45^{o}lat)

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Forces driving atmospheric motion

Four forces forces affect the direction and speed of air (wind) as it affect the direction and speed of air (wind) as it moves throughout the atmosphere:

1`. Gravitational force G

2. Pressure gradient force

3. Coriolis force

4. Friction force

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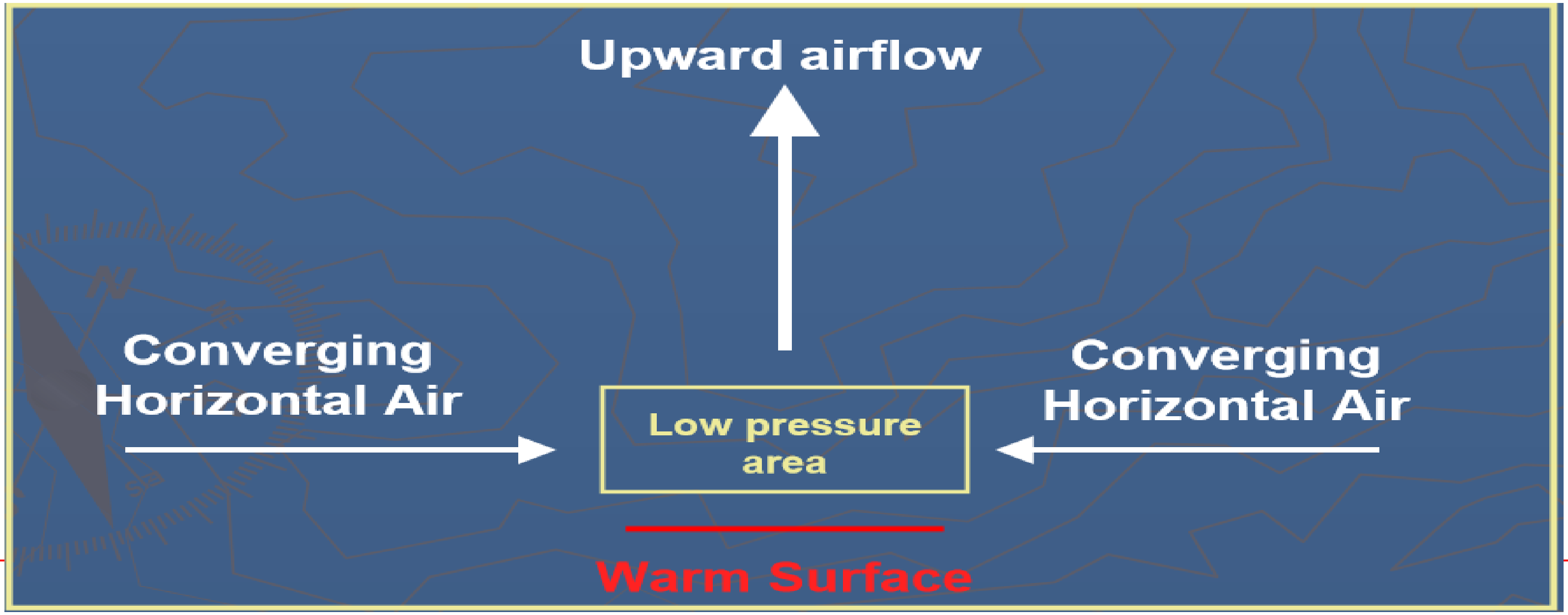
Pressure Gradient Force: air moves from high pressure regions to low pressure

Variations in air pressure are caused by uneven heating of the earth's surface

Warm surfaces encourage upward vertical motion



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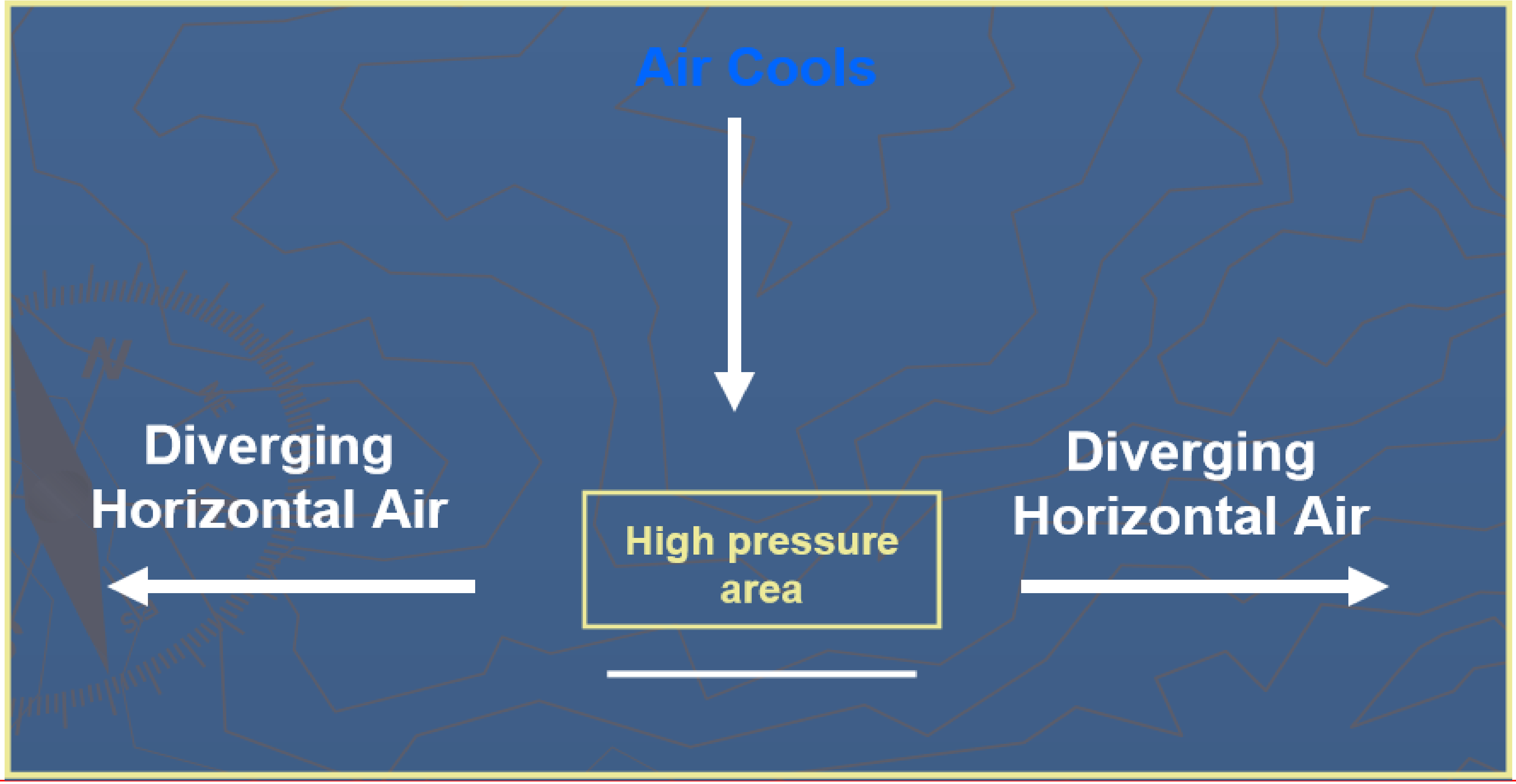
As air molecules cool, they condense and decend towards the surface



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Coriolis Force: air flow is deflected from a straight path by the rotation of the earth.

Deflection increases north and south of the poles

No deflection at the equator

Deflection causes air motion to curve to the right in the N Hem

Deflection causes air motion to curve to the left left in the in the S Hem

Frictional force: drag (backward force) on wind as it moves over the earth's surface

Extends to and elevation of about 500m

Decreases with increasing elevation

Gravity: pulls atmosphere toward earth creating air pressure

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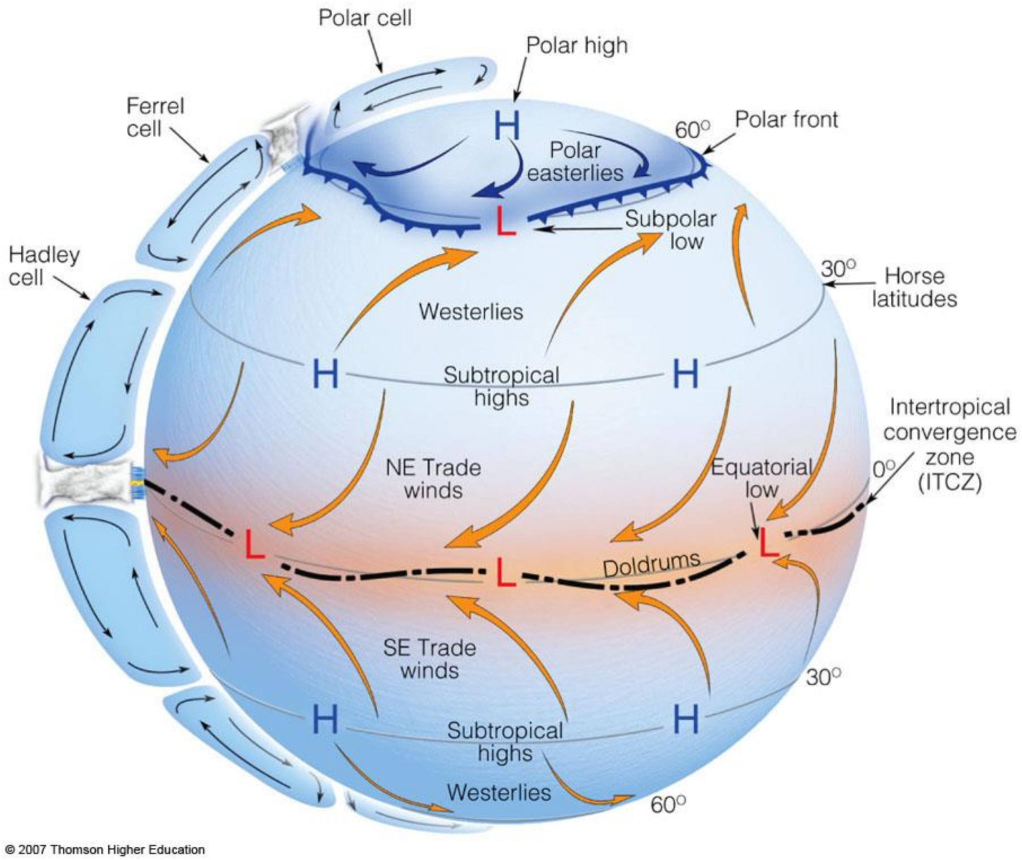
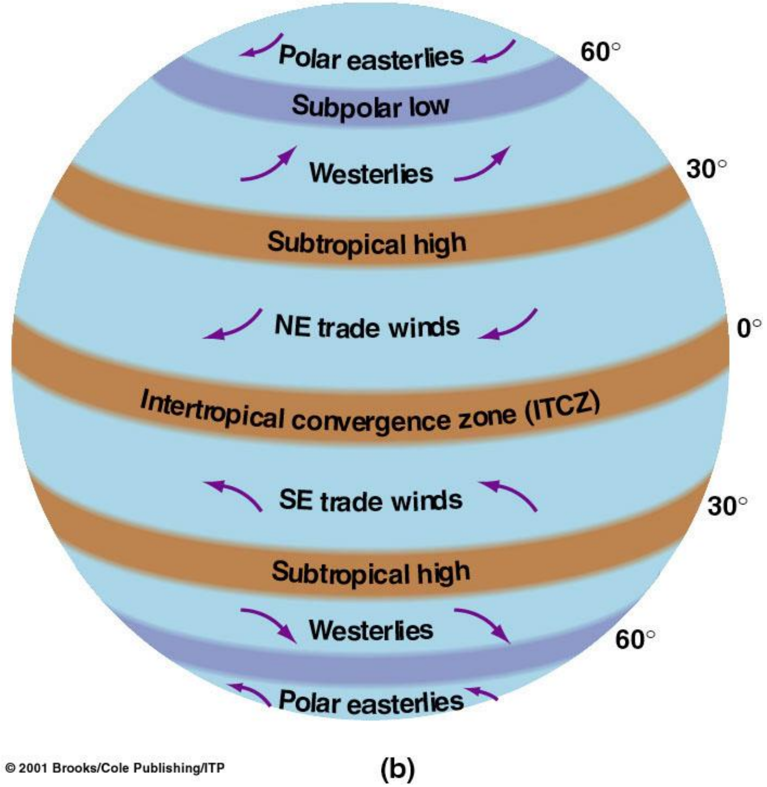
The global permanent pressure systems:





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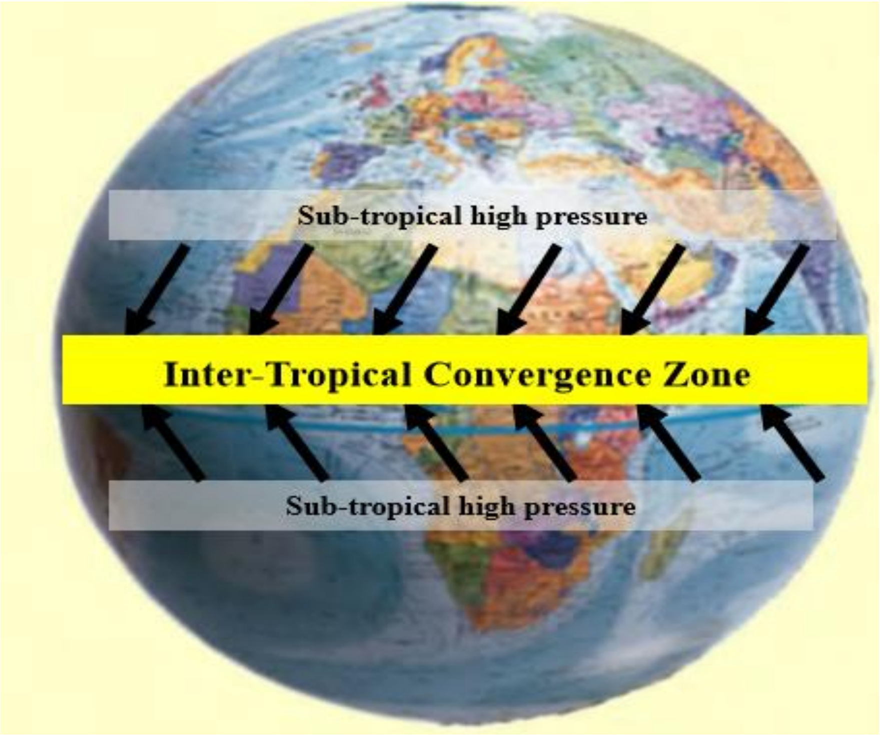
1. ITCZ (Intertropical Convergence Zone)/Doldrums is hot and humid, with low pressure, strong upward air motion, heavy convective (thunderstorm) precipitation, and light to calm wind.

The line along which they converge (meet) is called the INTERTROPICAL CONVERGENCE ZONE. IN THE NORTHERN HEMISPHERE: The winds that blow to the equatorial low pressure belt are called the North East Trade Winds

IN THE SOUTHERN HEMISPHERE: The winds that blow to the equatorial low pressure belt are called the South East Trade Winds



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In December, the zone of maximum insolation (solar energy) is south of the Equator. This means that the wind belts shift southwards.
By contrast, in June, the zone of maximum insolation is well to the north of the Equator. This means that the wind belts shift northwards.

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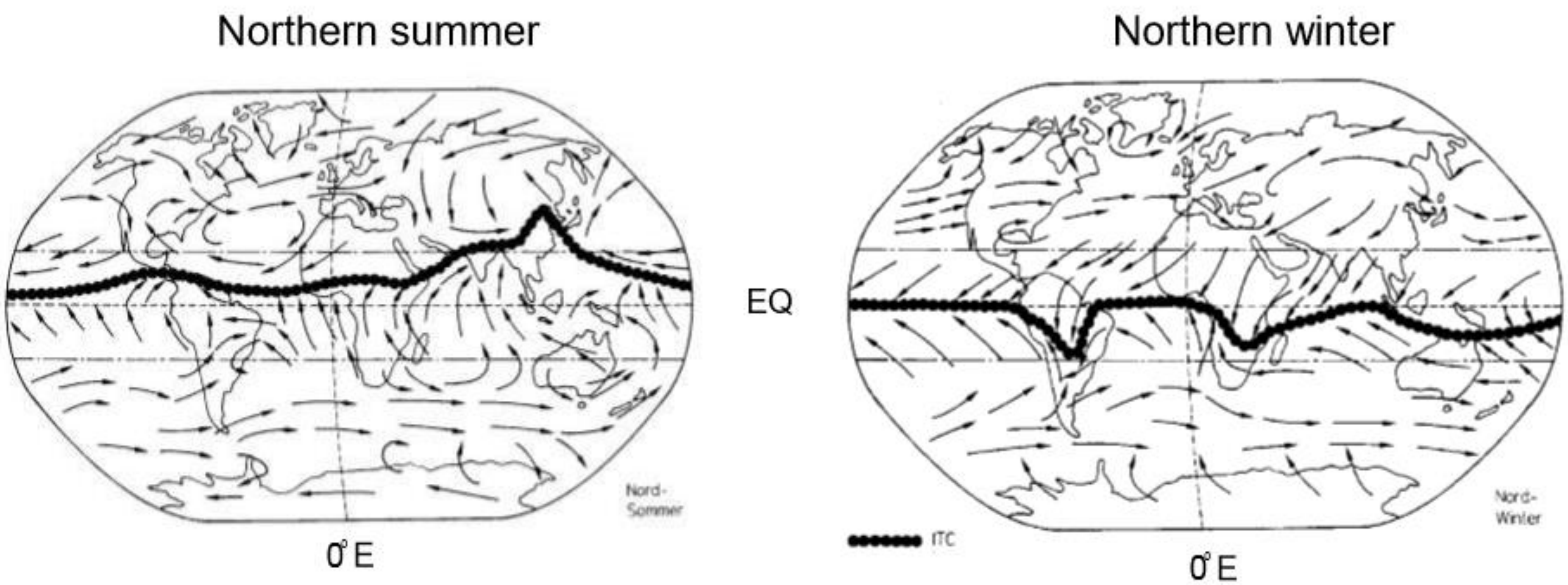
How to cause ITCZ to generate general circulation?



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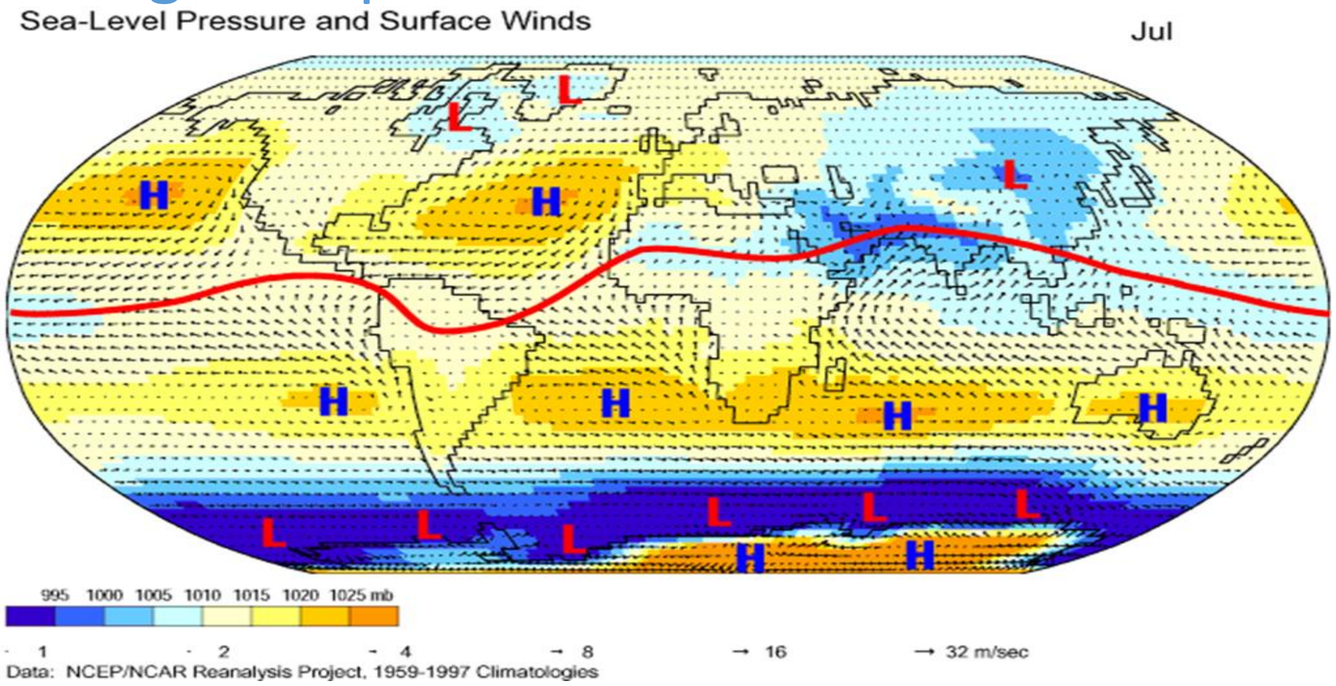
Seasonal migration of ITCZ

In January, the ITCZ zone is found south of the equator

During this time period, the Southern Hemisphere is tilted towards the Sun and receives higher inputs of shortwave radiation



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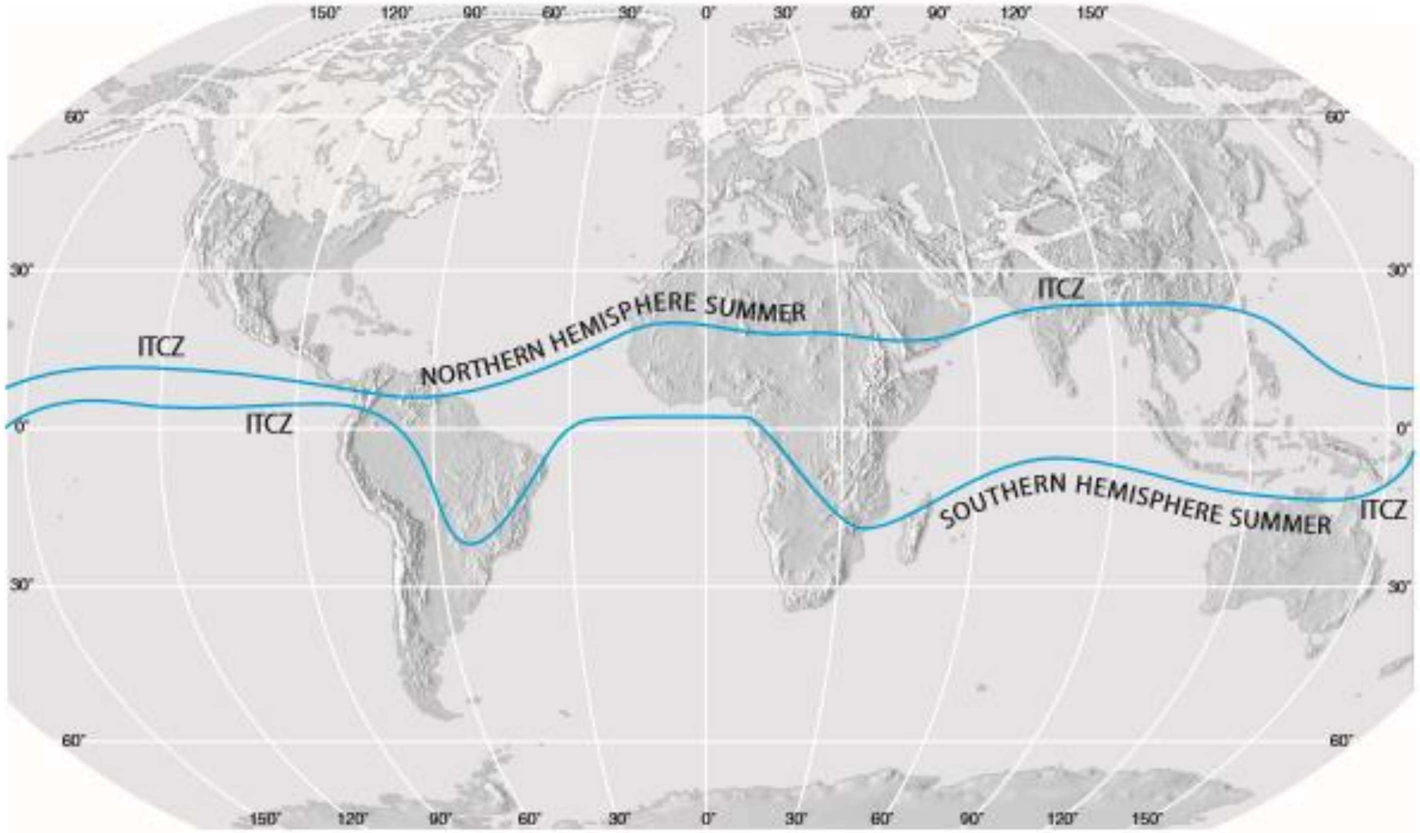
Migration of ITCZ b/n 10 to 20^0 latitudes away from the equator in most location.



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During July, the ITCZ is generally found north of the equator.

This shift in position occurs because the altitude of the Sun is now higher in the Northern Hemisphere

The more intense July Sun causes land areas of Northern Africa and Asia rapidly warm creating the Asiatic Low which becomes part of the ITCZ.

In the winter months, the ITCZ is pushed south by the development of an intense high pressure system over central Asia.

The extreme movement of the ITCZ in this part of the world also helps to intensify the development of a regional winds system called the Asian monsoon.

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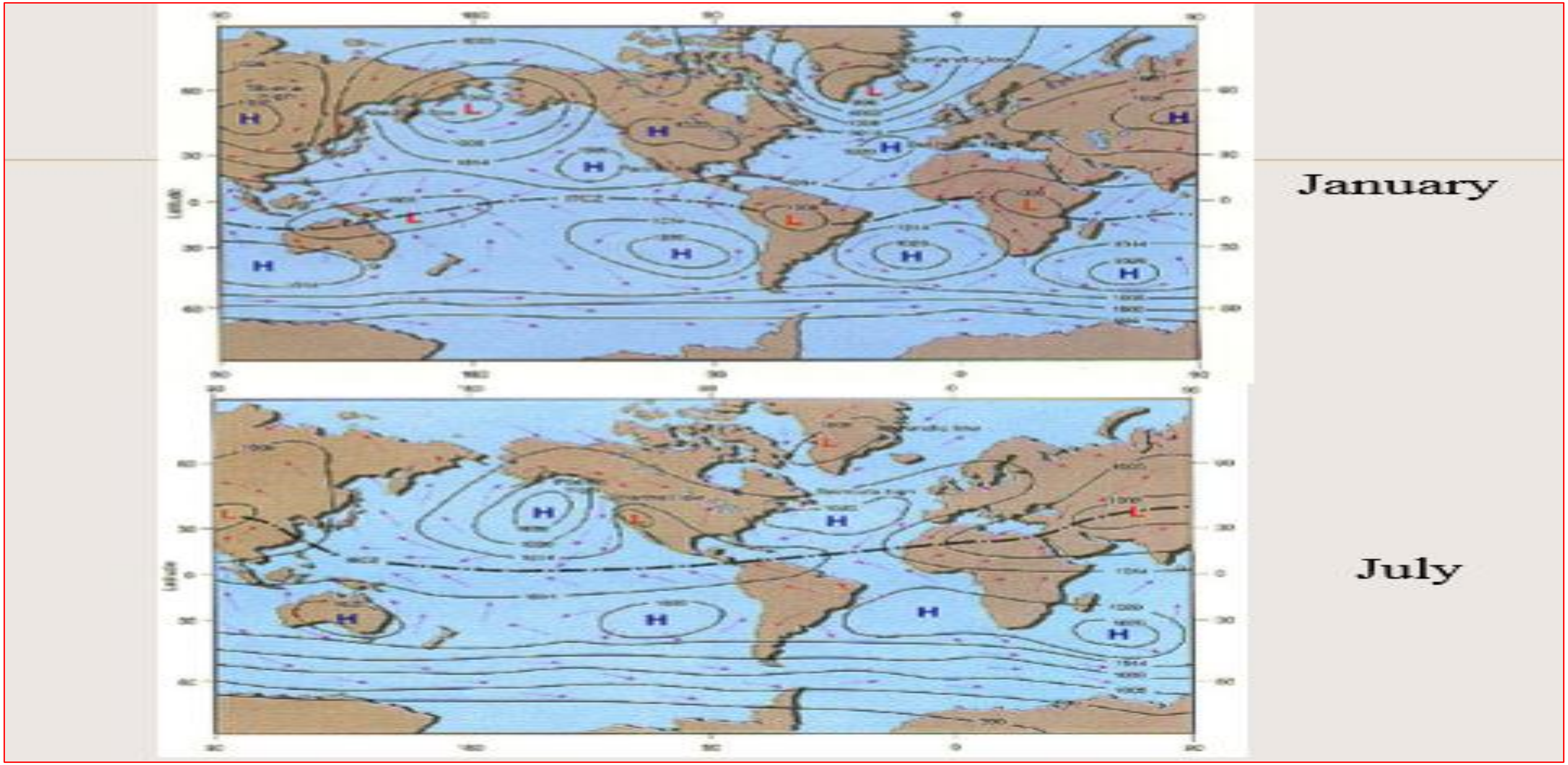

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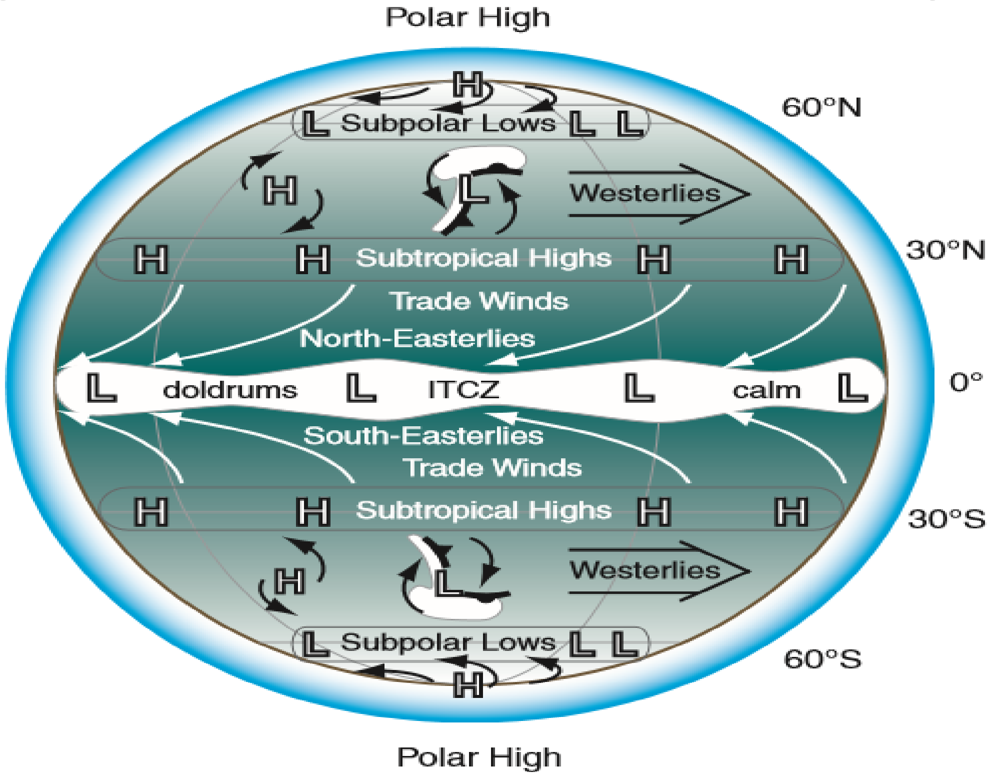
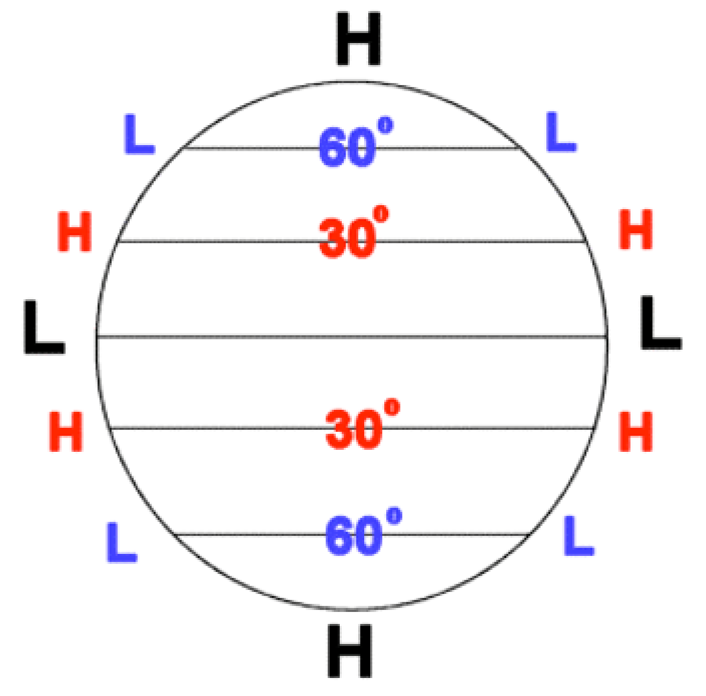
Subtropical High Pressure Belts(the horse latitudes) – poleward of the Hadley cell, air descends and surface pressures are high (at about 30 degrees latitude) A number of large surface anticyclones are formed





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In these belts are hot, dry, cloud-free air descending from higher in the troposphere. On land, many of the world's deserts are near these latitudes.

Near 60° latitude are belts of low surface pressure called subpolar lows. Along these belts are light to calm winds, upward air motion, clouds, cool temperatures, and precipitation

Near each pole is a climatological region of high pressure called a polar high.

In these regions are often clear skies, cold dry descending air, light winds, and little snowfall.

Between each polar high (at 90°) and the subpolar low (at 60°) is a belt of weak easterly winds, called the polar easterlies.

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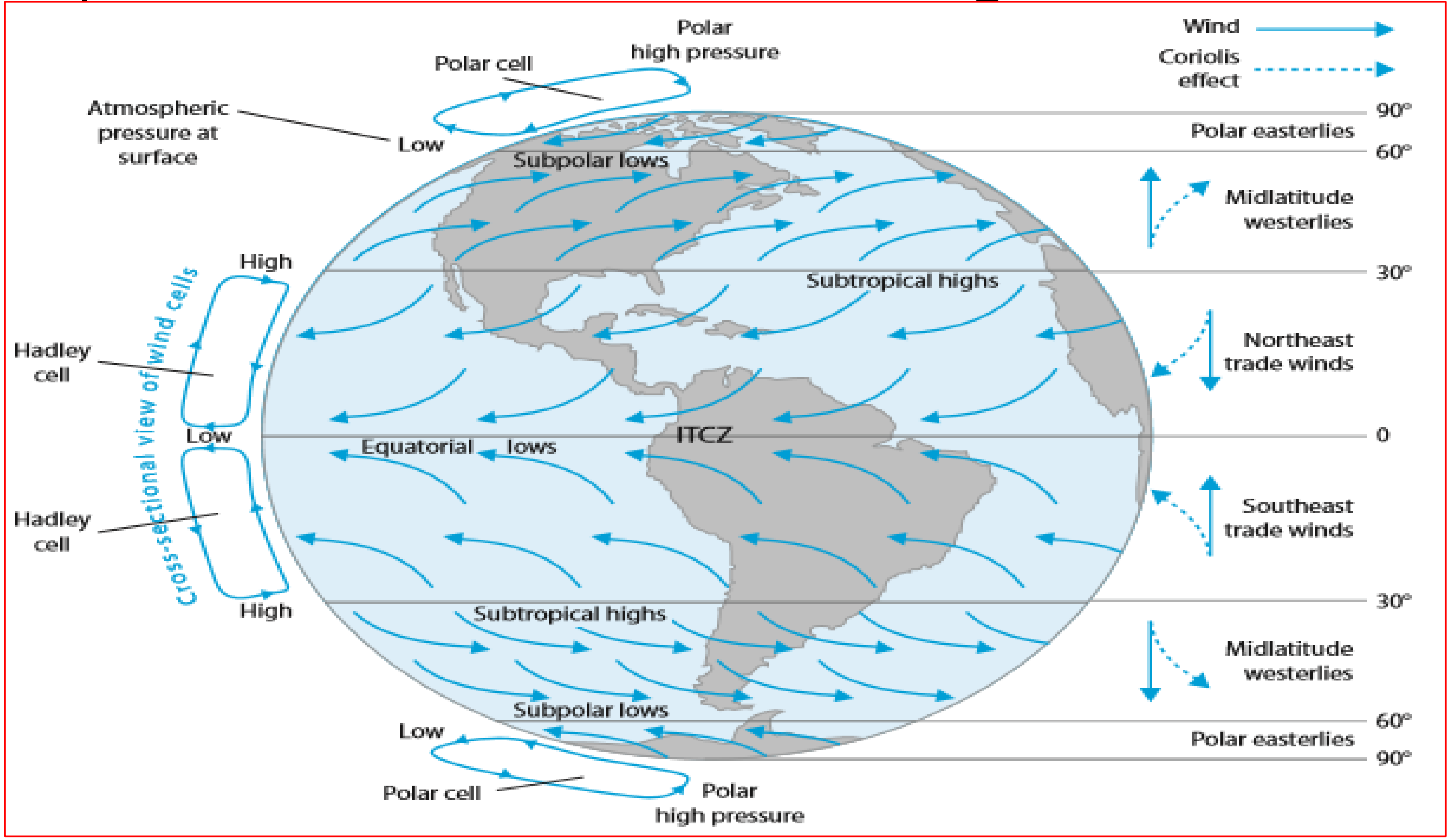
Summary of pressure and wind belts three-cell general circulation



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3.3 Actual global surface circulation

Why does the pattern look somewhat different from the three cell model?

These differences are caused primarily by two factors

1.The Earth's surface is not composed of uniform materials.

The two surface materials that dominate are water and land.

These two materials behave differently in terms of heating and cooling causing latitudinal pressure zones to be less uniform.

2. The second factor influencing actual circulation patterns is elevation

Elevation tends to cause pressure centers to become intensified when altitude is increased. This is especially true for high pressure systems.

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The General Circulation and Precipitation Patterns

- Converging surface flows:

Low surface pressure

Uprising air

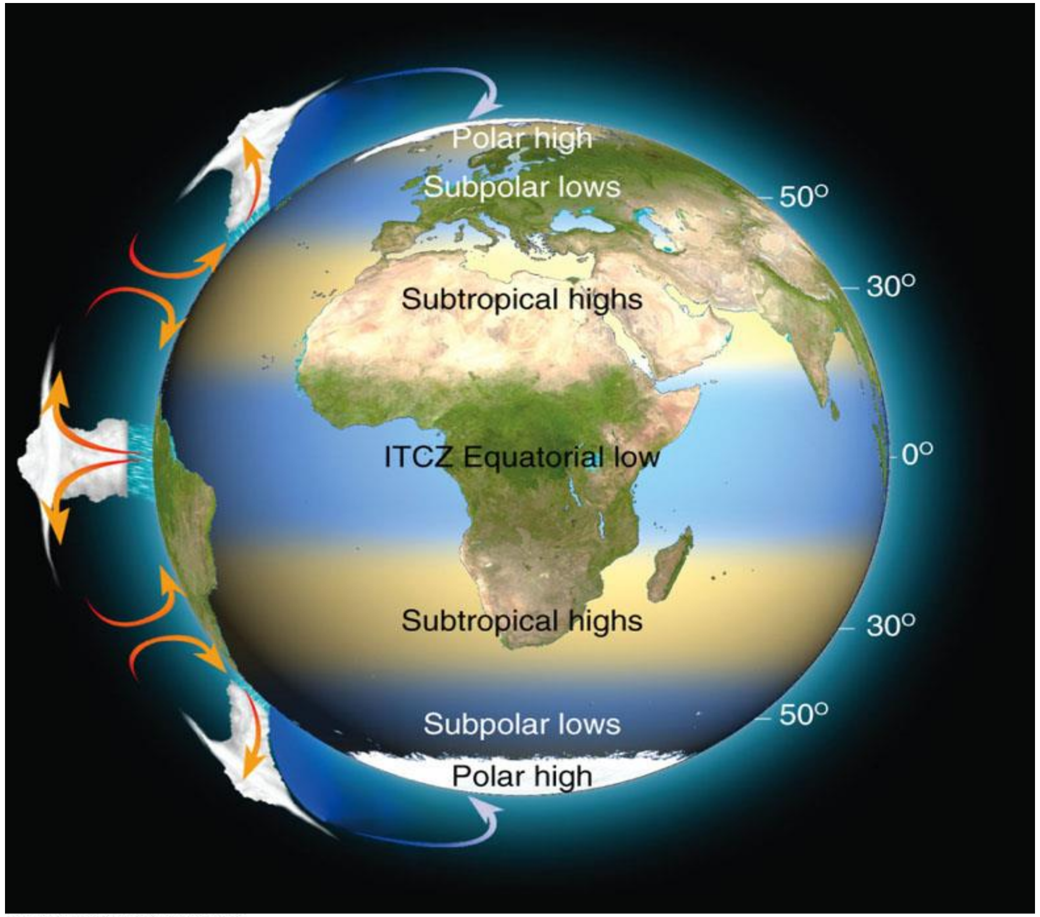
Heavy precipitation

- Diverging surface flows:

High surface pressure

Sinking air

Dry climate



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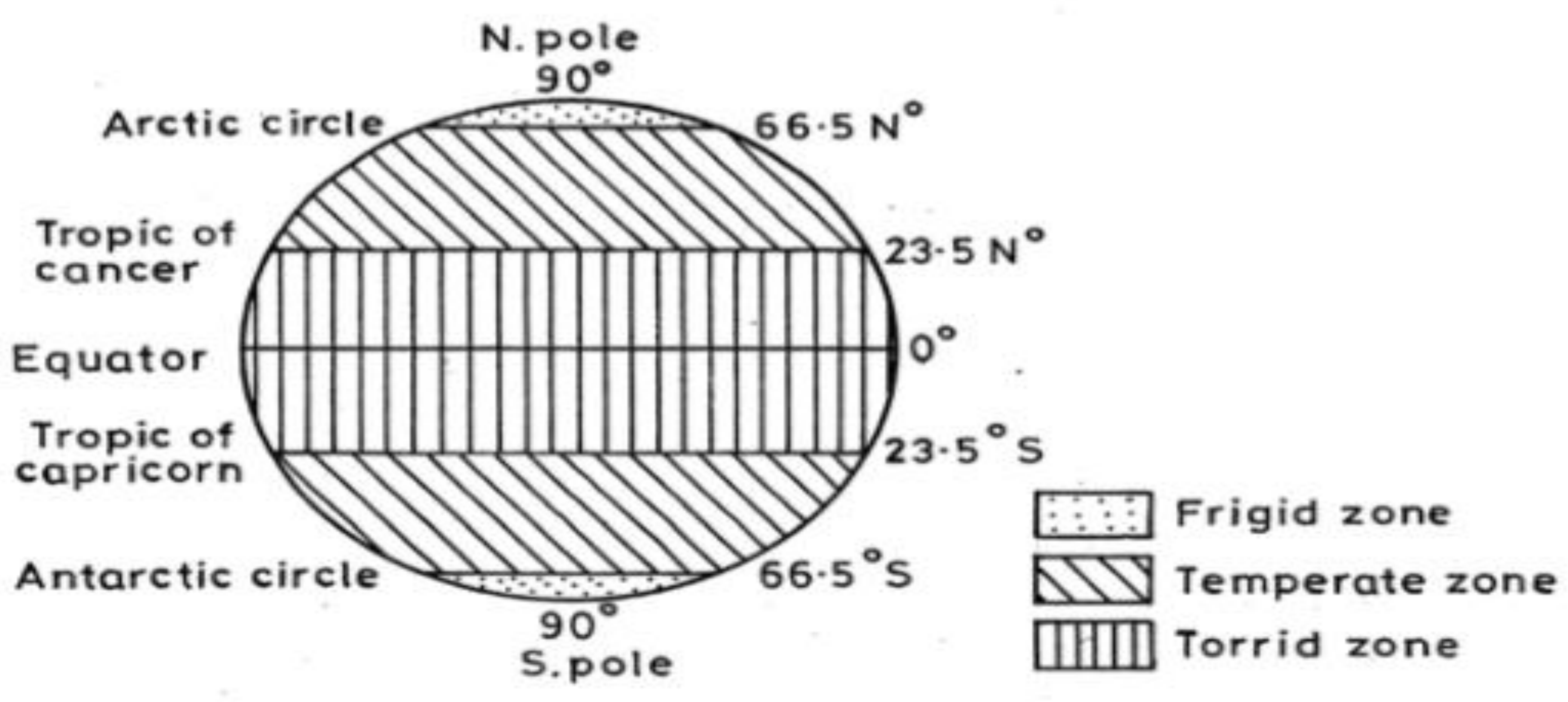
Climate zones of Earth based on temperature

Torrid zone, Temperate zone and Frigid zone;



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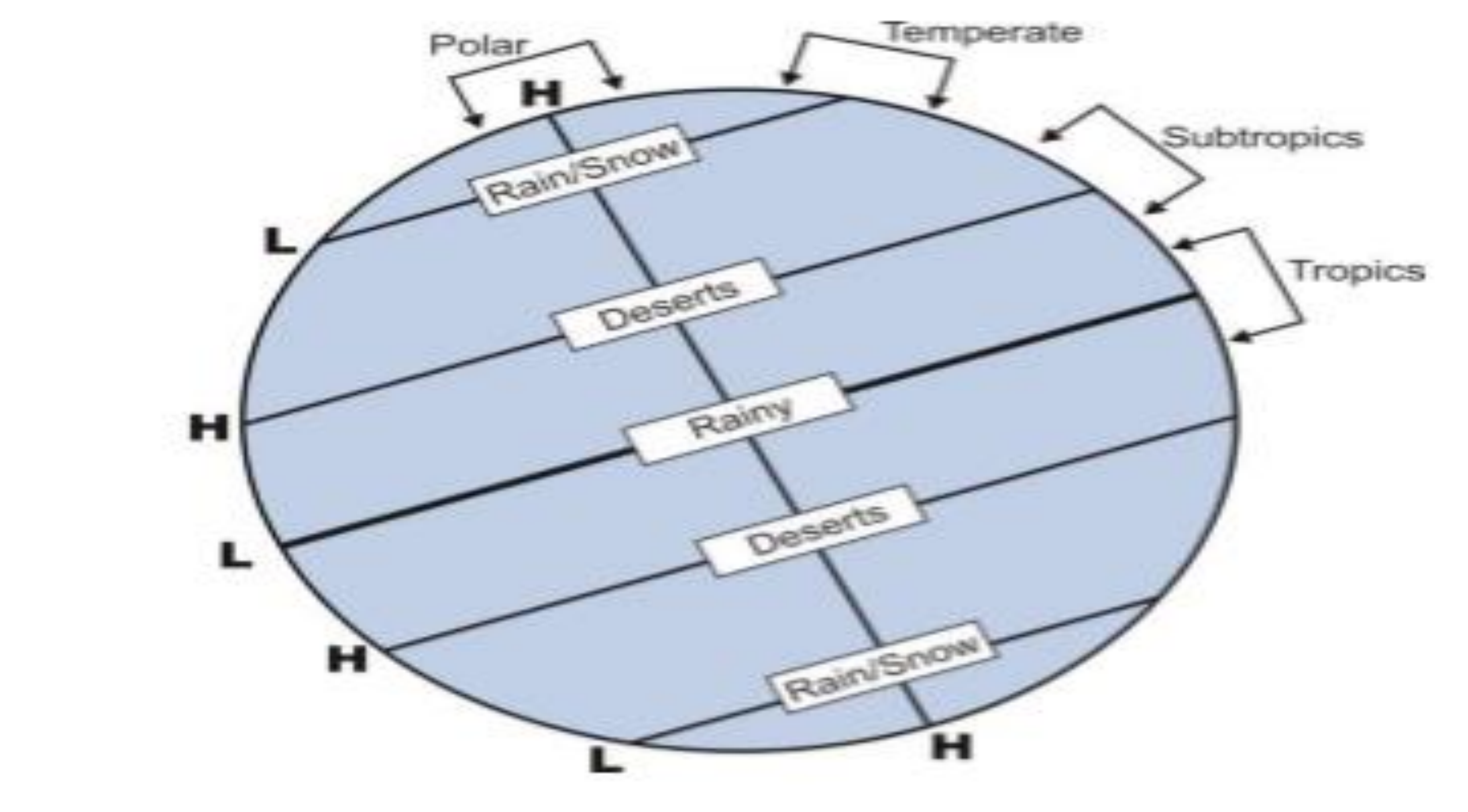
Climate zone based on rainfall



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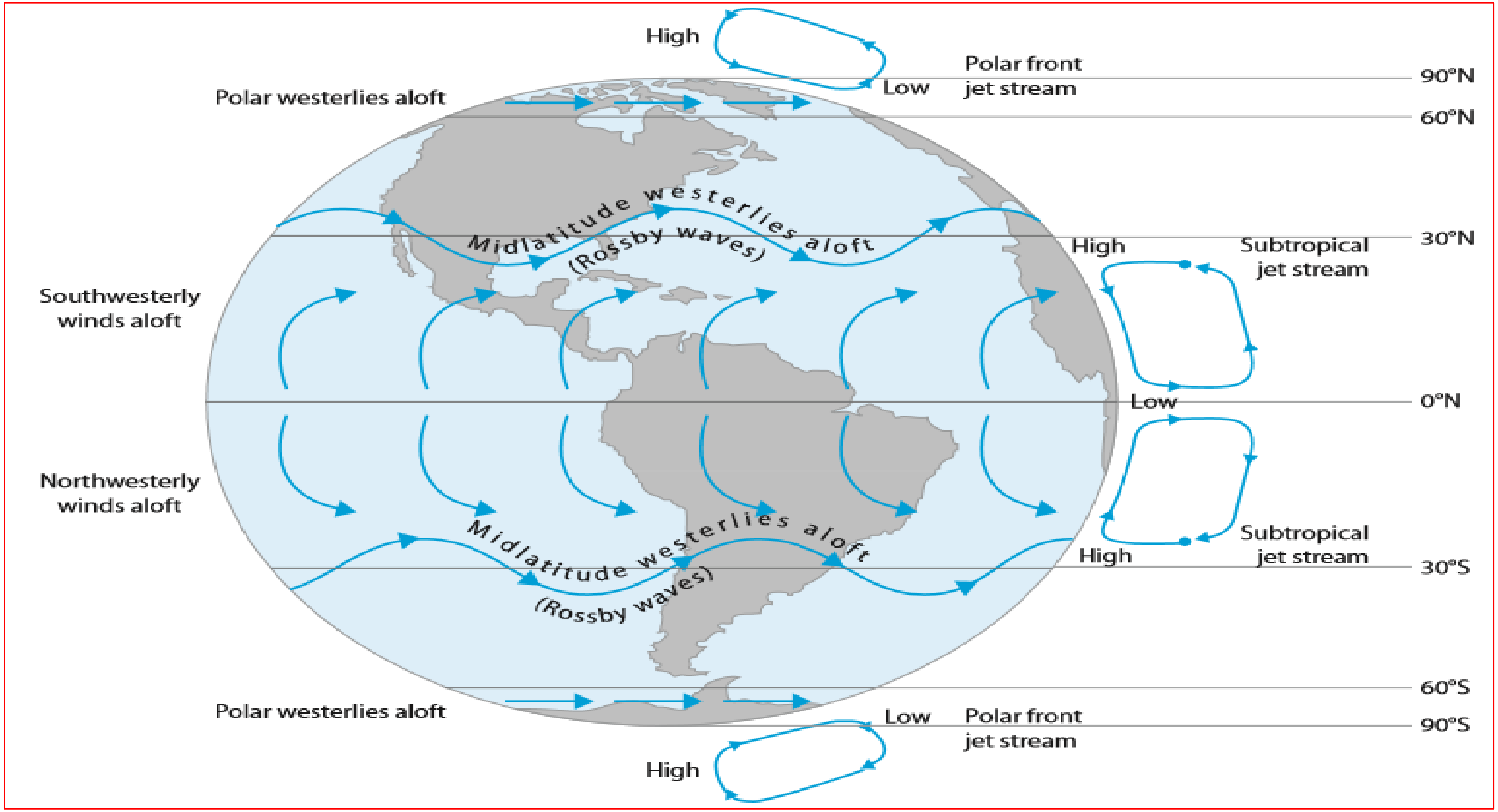

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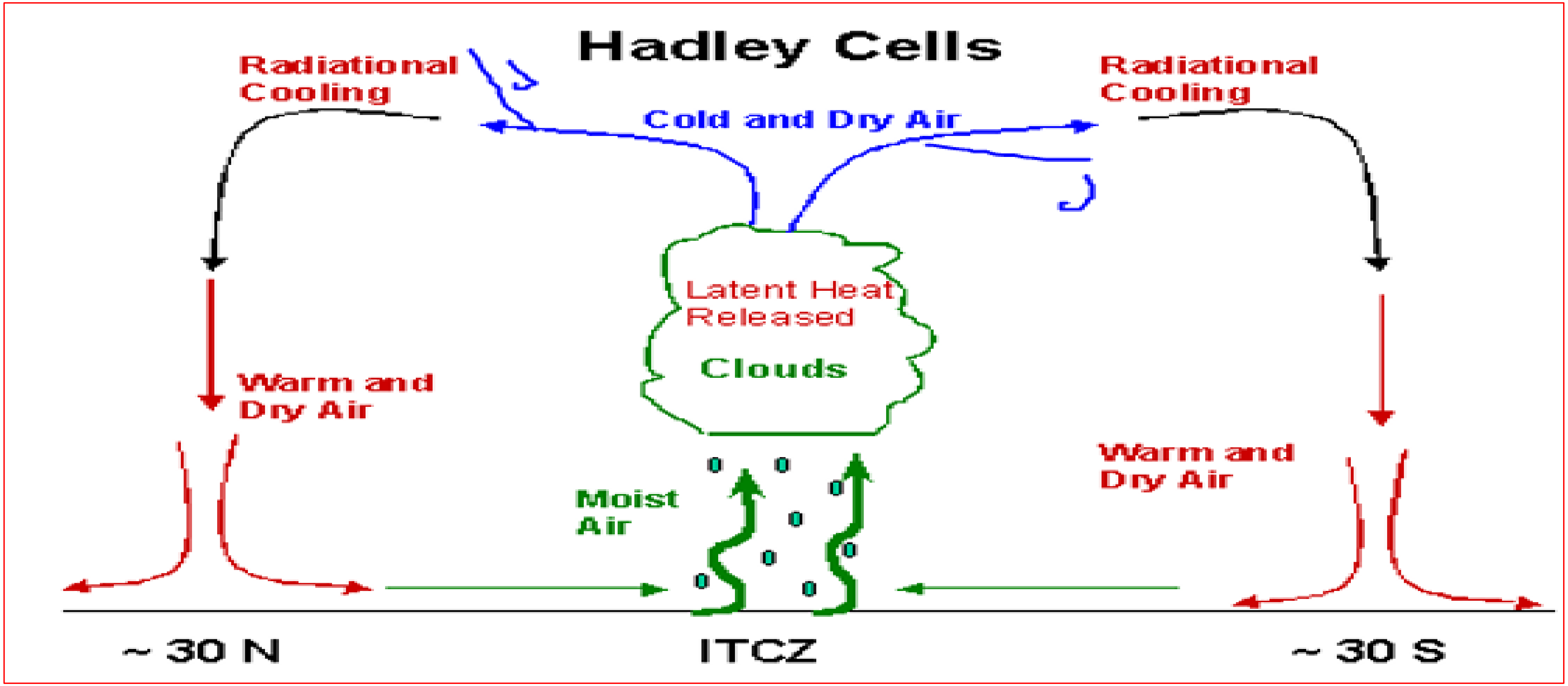

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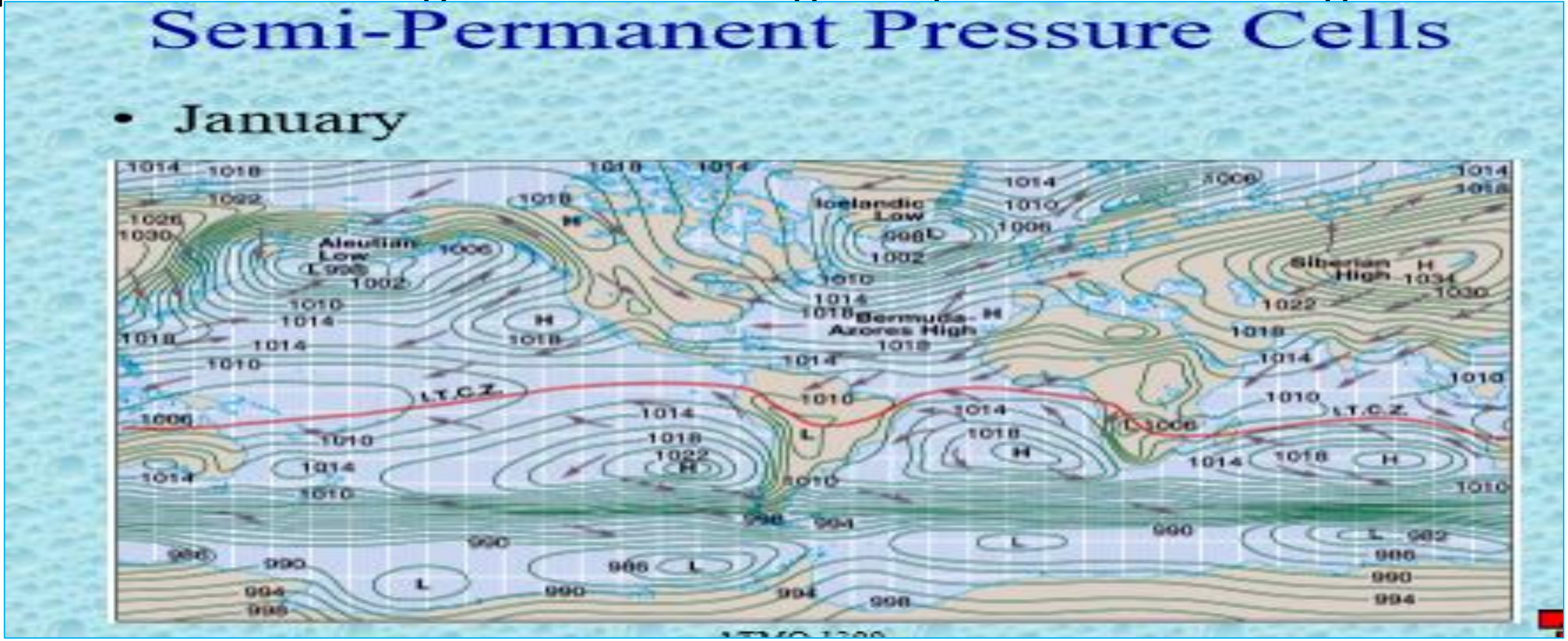
Semi- Persistent features of the atmospheric circulation

Features Semi-permanent cyclones and anticyclones areas of high/low pressure that undergo seasonal changes in position and strength.



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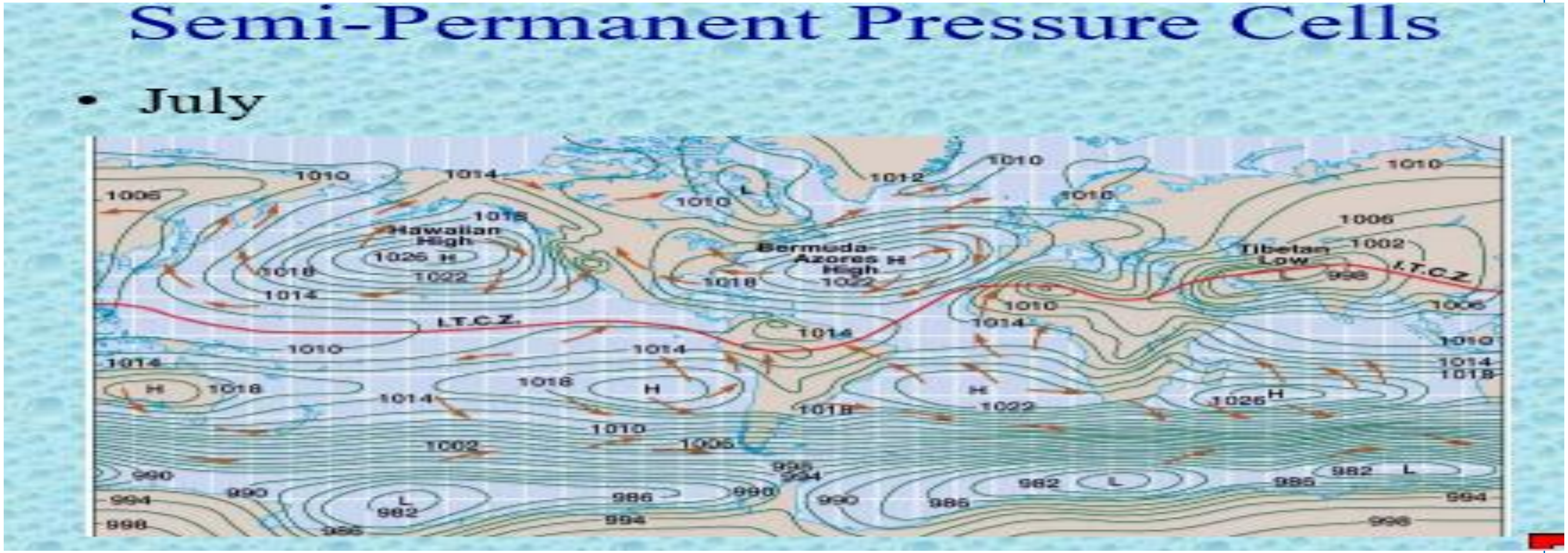
The pressure feature in the northern hemisphere in January are

Aleutian low, Iceland low, Bermuda high, Siberia high



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The major surface based semi-permanent high pressure cells located near 30^0 latitude are:

- The Bermuda or Azores high in northern atlantic ocean
- The Hawaiian high in the northern pacific ocean.

Southern hemisphere subtropical anticyclone include:

- The south pacific high,
- The south Atlantic high
- The Indian ocean high.

Subtropical High-Pressure Belts features are caused by Hadley cell circulation

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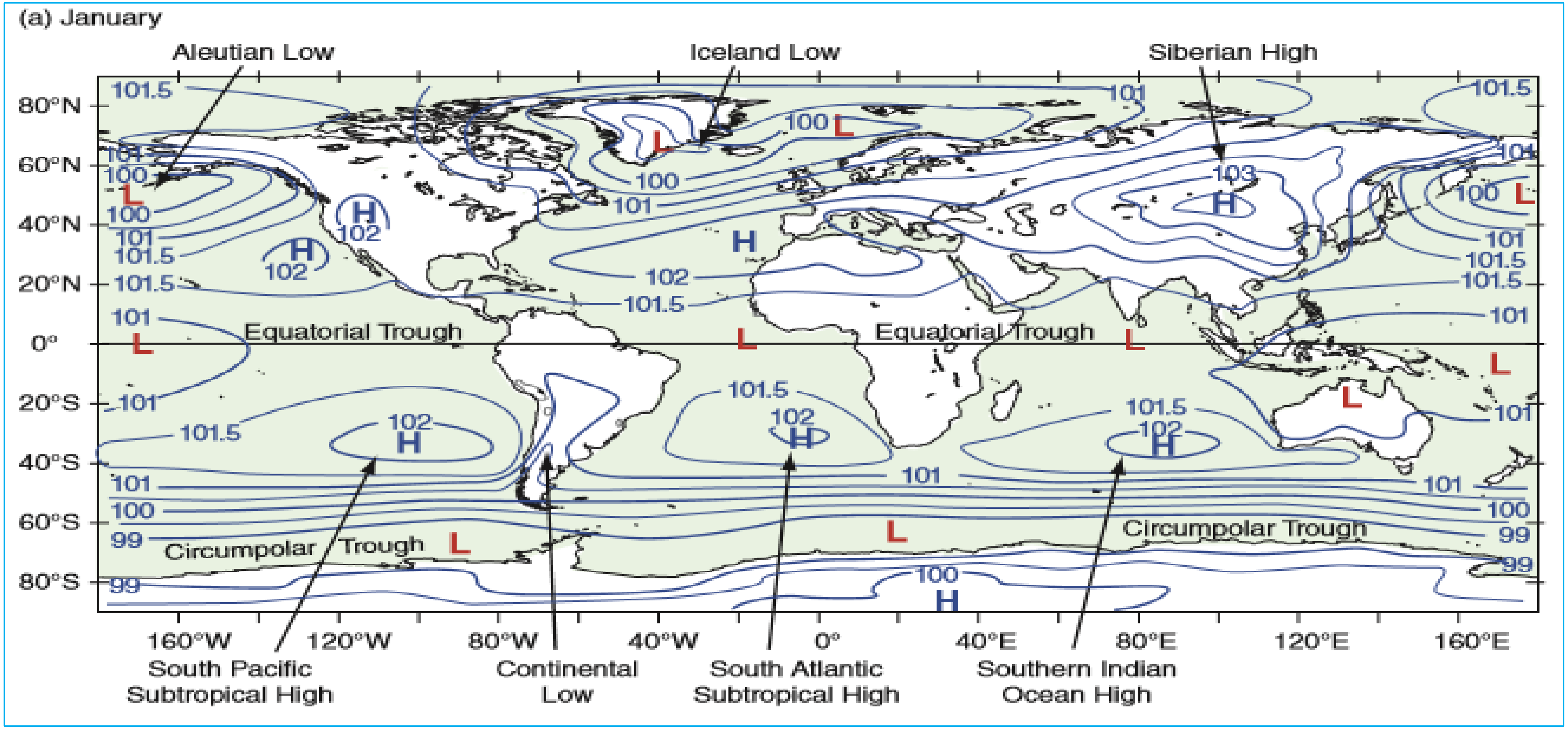
During January (North)



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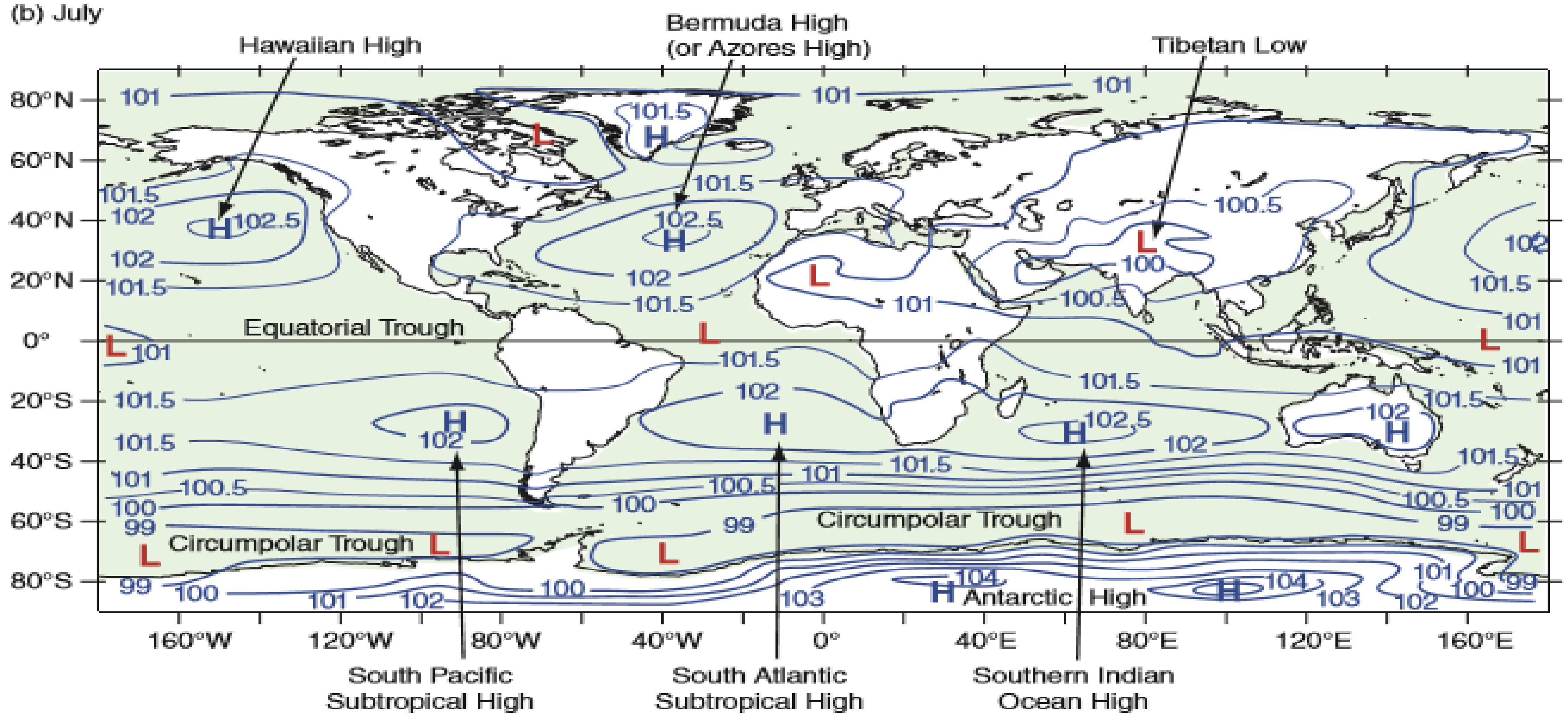
During july



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3.5 Climate Models (General Circulation Models)

To include the full three-dimensional aspect of climate, including the calculation of the dynamical transports, requires solving numerically:

- energy,
- momentum,
- Mass and
- water vapour conservation equations

General Circulation Models (GCMs) were originally adapted from weather forecasting models.

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Uses of GCMs

1. To understand the current atmospheric circulation (i.e. atmospheric dynamics and physics)

2. To provide short term weather forecasts.

3. To estimate the impact of initial ground or ocean conditions on monthly and seasonal weather.

4. To simulate past climates, so as to improve our understanding of the earth's climate system.

5. To estimate future climate changes resulting from natural or anthropogenic processes.

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GCMs need to solve a set of fundamental equations in order to obtain values for the wind, temperature, moisture and pressure at each location in the earth's atmosphere

1. Conservation of momentum (F=ma)

West wind:

$$\frac{\partial u}{\partial t} = -\underbrace{\left(u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} + w\frac{\partial u}{\partial z}\right)}_{\text{Advection of momentum}} - \underbrace{\frac{1}{\rho}\frac{\partial P}{\partial x}}_{\text{Pressure gradient}} - \overbrace{fv}^{\text{Rotation effect}} - \text{Friction}$$

South wind:

$$\frac{\partial v}{\partial t} = -\left(u\frac{\partial v}{\partial x} + v\frac{\partial v}{\partial y} + w\frac{\partial v}{\partial z}\right) - \frac{1}{\rho}\frac{\partial P}{\partial y} + fu - \text{Friction}$$

Vertical wind:

$$\frac{\partial w}{\partial t} = -\left(u\frac{\partial w}{\partial x} + v\frac{\partial w}{\partial y} + w\frac{\partial w}{\partial z}\right) - \frac{1}{\rho}\frac{\partial P}{\partial z} - g - \text{Rot} - \text{Fric}$$

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2. Conservation of mass:

Density (ρ): $$\frac{\partial \rho}{\partial t} = -\left(\frac{\partial \rho u}{\partial x} + \frac{\partial \rho v}{\partial y} + \frac{\partial \rho w}{\partial z}\right)$$

Mass flux divergence

3. Conservation of energy:

Temperature (T):

$$\frac{\partial T}{\partial t} = -\frac{c}{\rho}\left(u\frac{\partial T}{\partial x} + v\frac{\partial T}{\partial y} + w\frac{\partial T}{\partial z}\right) + \text{Net Rad. (SW+LW)} +$$

$$+\text{Sensible heat from surface} + \text{Latent heat } \left(-L\frac{\partial q}{\partial T}\right)$$

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4. Conservation of moisture:

Specific Humidity (q):

$$\frac{\partial q}{\partial t} = -\left(u\frac{\partial q}{\partial x} + v\frac{\partial q}{\partial y} + w\frac{\partial q}{\partial z}\right) + \text{Evap.} - \text{Precip.}$$

5. Equation of state:

Pressure (P): $P = \rho RT$ R=dry air gas constant

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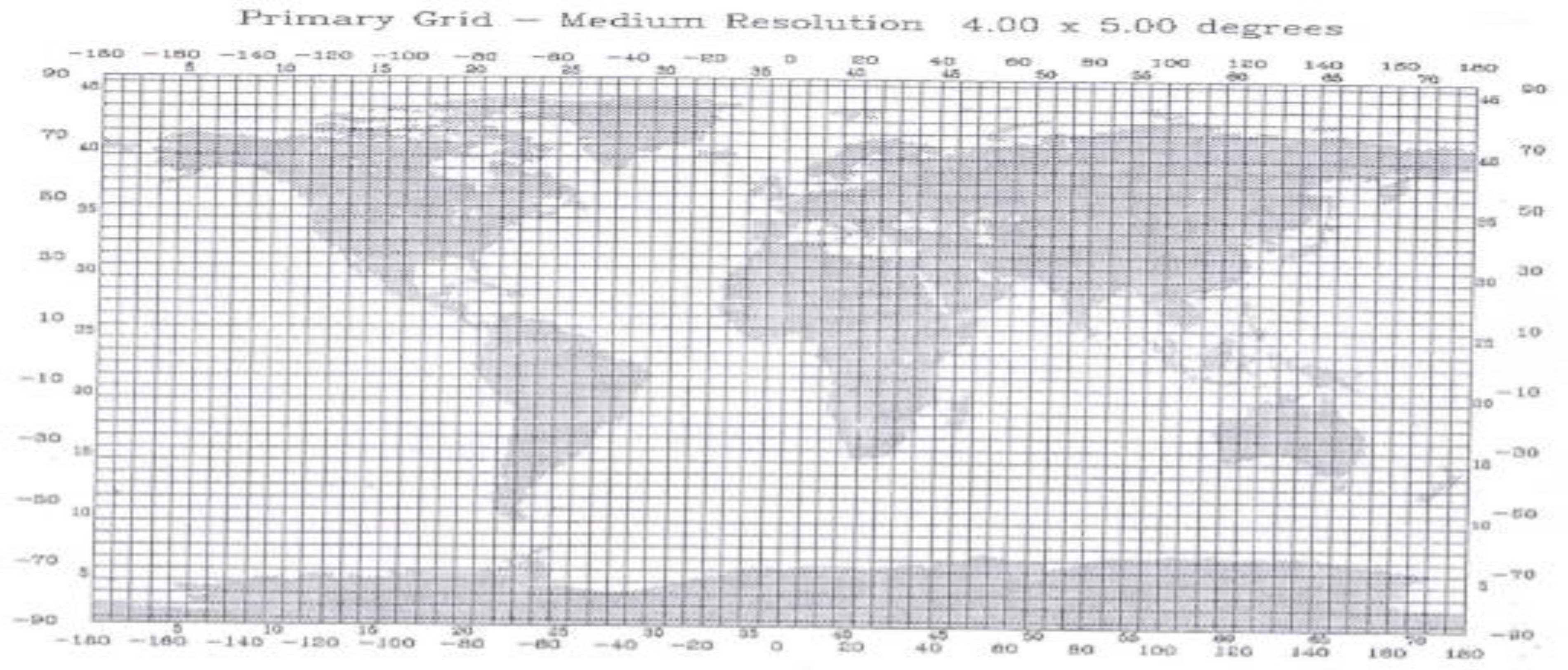
This set of nonlinear partial differential equations cannot be solved analytically, and therefore has to be solved numerically, with finite time steps and grid boxes.



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Next Chapter: 4